DOE/ER-0495T

DOE/ER-0495T
Dist. Category 402

Identification, Recommendation, and Justification of Potential Locales for ARM Sites

April 1991

U.S. Department of Energy
Office of Energy Research
Office of Health and Environmental Research
Atmospheric and Climate Research Division
Washington, D.C. 20585

Atmospheric Radiation Measurement

DOE/ER-0495T
Dist. Category 402

Identification, Recommendation, and Justification of Potential Locales for ARM Sites

April 1991

U.S. Department of Energy
Office of Energy Research
Office of Health and Environmental Research
Atmospheric and Climate Research Division
Washington, D.C. 20585

ARM
Atmospheric Radiation Measurement

Foreword

The Atmospheric Radiation Measurement (ARM) Program is a major component of the Department of Energy's Global Change research. This research is coordinated by the Committee on Earth and Environmental Sciences (CEES) of the Federal Coordinating Council for Science Engineering and Technology (FCCSET). ARM was initiated in FY 1990 in response to the emerging concensus that the "role of clouds" was the principal scientific uncertainty in climate change prediction. ARM is a field and modeling program and is based on the various model intercomparison studies that the Department has supported over the years, such as the study on the intercomparison of general circulation models (GCMs) and the Earth Radiation Budget led by Robert Cess; the program for climate model diagnosis and intercomparison led by Lawrence Gates; and the Intercomparison of Radiation Codes used in Climate Models (ICRCCM) cosponsored by DOE, the World Meteorological Organization and the International Radiation Commission.

This report is an account of a study that was undertaken within the ARM Program to examine locations suitable for establishing and maintaining experimental sites that meet the objectives of ARM and to recommend an ordered set of locales in which to locate sites, thereby creating the framework for site selection. Selection of specific ARM sites will come from further analysis based on the principles established in this report. The results of the study have been reviewed by several entities within the ARM Program and DOE, as well as leading scientists in the meteorological and atmospheric radiation community. This report incorporates the many helpful comments and suggested changes received from these reviews.

Ari Patrinos, Director
Atmospheric and Climate Research Division

Contents

Appendixes

Figures and Tables

Figures

Tables

Introduction

Introduction

The Atmospheric Radiation Measurement (ARM) Program is a major new research program initiated by the U.S. Department of Energy (DOE) to obtain improved understanding and quantitative description of radiative and cloud processes in the Earth's atmosphere. This program is a direct continuation of DOE's decade-long effort to improve General Circulation Models (GCMs) and related models for providing reliable simulations of regional and long-term climate change in response to increasing atmospheric concentrations of greenhouse gases. As outlined in the ARM Program Plan (DOE 1990), the objective of ARM will be achieved by measuring short- and long-wavelength radiation along with the physical and meteorological quantities that control this radiation, by simulating these measured quantities with numerical models, by comparing the measurements with the output of the models, and by refining both models and measurement procedures. Because of the dominant influence of clouds on both shortwave and longwave radiation (e.g., Cess et al. 1990; Ramanathan et al. 1989), the ARM Program will place particular emphasis on development of improved descriptions of cloud formation, maintenance, and dissipation, and of interaction of radiation with clouds.

To meet ARM's objectives, it will be necessary to make measurements under a wide variety of atmospheric and surface conditions. Four to six measurement sites, maintained for a period of up to a decade, will be required to verify the atmospheric models under a range of atmospheric and surface conditions. In addition, because such a limited set of primary sites will miss some special, but important, conditions, measurement campaigns of shorter duration have been recommended at additional locations as necessary. Until now, however, critical examination of the exact number of sites required and identification of the specific geographical regions, or locales, where such sites should be located has not been undertaken. This report describes an examination of the number and location of sites that are required to meet the ARM objectives. It also presents a recommended set of locales in which to establish ARM sites, ordered according to their scientific benefit in meeting the ARM objectives.

To meet ARM's objectives, measurements must be made under a wide variety of atmospheric and surface conditions.

The procedure for this examination and the resulting list of recommended locales began with a facilitated planning meeting that took place in La Jolla, California, in July 1990. During that meeting, the ARM Site Selection Team and the ARM Management Team developed a procedure for recommending potential locales for ARM sites. That procedure provided for the selection of a Locale Recommendation Team, which was formed shortly thereafter and met at Brookhaven National Laboratory in September 1990. The Locale Recommendation Team consisted of several Criteria Examination Teams (CETs) and an Evaluation Team. The CETs were given the responsibility to evaluate potential locales according to specific attributes: climate, atmospheric properties, surface properties and surface fluxes, logistical considerations, and synergism with other programs. The results of the CETs were then given to the Evaluation Team, who arrived at a recommended list of locales for ARM sites. A preliminary report of the results was prepared and distributed to the ARM Science Team for review. In November 1990, the Locale Recommendation Team met with members of the ARM Science Team in Las Vegas, Nevada, to receive comments and suggestions from that review. A subsequent revised version of the report was then distributed to members of the Science Team and other prominent atmospheric scientists for review. This final version of the report embodies the changes resulting from those suggestions.

In examining locations for ARM sites, an important distinction was made between "sites" and "locales." A site is defined as the location of a future ARM measurement facility; a locale is defined as a contiguous geographical region with generally homogeneous climatic and surface properties (or some other unifying attribute) within which an ARM site could be established. The current study is concerned only with recommending a set of locales; later a suitable site within each locale will be chosen at which to locate the ARM facility. An underlying premise of this process is that locales can be selected primarily on the basis of their utility in meeting the scientific objectives of ARM and on broad logistical considerations, whereas the actual location of a site within a locale might be based on specific logistical and operational considerations (with the proviso that the immediate region surrounding each site be suitably representative and homogeneous). This procedure is viewed as ensuring that both scientific and practical considerations will be addressed in selecting the set of ARM sites.

The Locale Recommendation Team was charged with recommending a set of locales that collectively exhibit the range of attributes needed to meet the ARM objectives. Additionally, the team was to consider potential logistical constraints and the potential for interactions with other atmospheric and oceanic research programs that could enhance the ability of the ARM Program to meet its objectives. Because of budgetary considerations, the number of ARM sites considered should be kept to a minimum.

The recommended set of locales developed by the procedure described here and presented in this report should be considered as an entity; elimination of one or another of the locales would qualitatively diminish the domain of attributes that can be studied and thus would compromise the ability of ARM to meet its objectives. Furthermore, if one site were eliminated, the optimal locations of the remaining sites might very well be different from those recommended here. However, since each successive locale is considered in the context of the previously recommended locales, eliminating or changing a given locale would not change the recommendations of locales higher on the list.

Because of the evolving nature of the ARM Program, complete and precise information pertinent to the complement of projects to be conducted at ARM sites was not available at the time of this study. Consequently, the Locale Recommendation Team relied on available information in arriving at its recommendations. As input to the scientific issues to be examined, the team relied on the draft Site Mission document (Version 1.0, September 8, 1990) and on experiments that were discussed in a series of meetings with groups of leading scientists from the atmospheric radiation, meteorology, and general circulation modeling communities (denoted here as "surrogate science team meetings").

In principle, further analysis and critical review by scientists and others involved in the ARM Program might lead to refinements of the current recommendations. However, because of the large input that ARM has received from the scientific community concerning the issues and processes to be addressed by ARM experiments, it was the judgment of the Locale Recommendation Team that the locale selection process could proceed with confidence that the choice of an optimum set of locales would not be substantially altered as ARM experiments became more precisely defined.

The conclusions of this study are included in the next section of this report, followed by a description of the criteria for selecting locales for ARM sites, a discussion of the procedure for locale recommendation that was formulated at the meeting in La Jolla, and a description of the application of that procedure. The recommended set of primary and supplementary ARM locales is then presented, followed by references. Details of the procedure described in this report can be found in the appendixes. Appendix A details the locale recommendation procedure formulated at the La Jolla meeting. Appendixes B, C, D, E, and F contain the reports from the CETs on climate, atmospheric properties, surface properties and fluxes, logistical considerations, and programs with synergistic potential with ARM. A list of participants in the locale recommendation procedure appears after the appendixes followed by definitions of acronyms and abbreviations used in this report.

Conclusions

Conclusions

The process reported here has constituted a systematic examination of the attributes governing the transfer of radiation in the atmosphere, and of the values of these attributes in all the climatologically significant categories of locales globally. This process has led to a recommendation of a set of locales in which to establish ARM sites. The process also has provided a framework by which to assess the ability of such a set of locales to span the pertinent attributes and thereby achieve the objective for selection of a set of sites for ARM measurements, namely that this set of sites collectively experience with appreciable frequency the key phenomena controlling the transfer of radiation in the atmosphere. In the view of the Locale Recommendation Team, this objective is largely achieved with the set of five recommended primary locales, namely that the recommended set of primary locales spans much of the range of attributes that are dominant with respect to the models of clouds and their influence on atmospheric radiation. It is the view of the team as well that if an ARM site cannot be established in any one of these locales, or an equivalent alternative, then adequate coverage of radiatively important attributes will not be achieved by the remaining set of locales. This, in turn, would seriously compromise the ability of the ARM Program to achieve its stated objectives.

In addition, there was agreement that sufficient differences exist between the recommended primary locale categories and other radiatively or climatically important locale categories to require a short-duration occupancy of certain supplementary locales to assess the ability of the primary sites to adequately capture and describe the key phenomena controlling the transfer of radiation in the atmosphere.

The recommended primary and supplementary locales and the principal attributes leading to the recommendation of these locales are described in Table 1.

A concern noted by the Locale Recommendation Team is that because of the logistical difficulties associated with some of the recommended locales, especially the Gulf Stream locale, alternatives to these locales must continue to be considered. For the Gulf Stream locale more than one alternative locale (one for clouds, another for fluxes, etc.) may be required to adequately observe these phenomena elsewhere. On the other hand, rather than deal with multiple alternatives, it may be preferable to use a campaign approach, rather than long-term site occupancy, to obtain the necessary data at the Gulf Stream locale.

If for reasons such as these, or for other logistic or synergistic considerations, it becomes necessary at any time to amend the set of primary locales for ARM sites, it is emphasized that changes should not be made arbitrarily. Rather, a framework and methodology developed in this study and described in this report should be employed in considering any such changes in locales for ARM sites from the set recommended here. The attributes of the locale being eliminated should be considered, and it should be established that these attributes are adequately represented in the replacement locale or locales.

The process reported here has led to a recommendation of a set of locales for ARM sites.

The recommended set of supplementary locales is not to be construed as an exhaustive or final list. In particular, the review of the set of recommended locales by the Science Team noted that, because of the intense orography coupled with the land-ocean boundary, the single locale specifically recommended for testing the ability of models to treat geographical inhomogeneities (the Northwest U.S.-Southwest Canada Coast locale) might actually be an overly severe test of models, at least as an initial intentionally heterogeneous locale. The possibility of less intense orography was suggested, perhaps by examining coastal effects at lower latitude on the west coast of the United States. A study at such lower latitude may be desirable also because of synergism by proximity to the primary ARM site in the Eastern Pacific Ocean. Alternatively, it was suggested that locales might better be chosen to incorporate heterogeneities one at a time. Suggested possible locales included the eastern slope of the U.S. Rockies and coastal areas adjacent to the southeastern U. S. coastal plains.

Table 1. Recommended Primary and Supplementary Locales

Primary Locales: Five locales were recommended as primary locales:

1. Southern U.S. Great Plains	Logistics; synergism; wide variety of cloud types; wide range of temperature and specific humidity; large annual, synoptic, and diurnal variation
2. Tropical Western Pacific Ocean	Deep tropical convection; cirrus; interannual variability in sea surface temperature; high sea surface temperature; high specific humidity
3. Eastern North Pacific Ocean or Eastern North Atlantic Ocean	Marine stratus; transition between marine stratus and broken cloud; aerosol influences
4. North Slope of Alaska	Large seasonal variation in surface properties; distinct surface properties from previous locales
5. Gulf Stream off Eastern North America, extending eastward	Extreme values and variation in surface heat fluxes; marine stratus; altostratus; mature cyclonic storms; genesis region for cumulonimbus and widespread layered clouds associated with large synoptic storms

Supplementary Locales: Four locales were recommended as supplementary locales:

1. Central Australia or Sonoran Desert	High temperatures; low specific humidities; frequent totally clear sky
2. Northwest U.S.-Southwest Canada Coast	Coastal and orographic inhomogeneity; marine stratus and nimbostratus
3. Amazon Basin or Congo Basin	Deep convection; large latent heat fluxes; high specific humidity; large seasonal variation in rainfall
4. Beaufort Sea, Bering Sea, or Greenland Sea	Sea ice; sea-ice edge; fog and marine stratus

Additional supplementary locales were suggested in the review of this document as valuable in permitting examination of specific processes or phenomena not captured in the recommended set of primary and supplementary locales. The Southern Circumpolar Ocean exhibits high frequencies of marine stratus clouds and very low aerosol concentrations, in contrast to the Eastern North Pacific and Eastern North Atlantic locales, permitting isolation of aerosol influences on cloud microphysical and radiative properties.

A supplementary locale in the Central Equatorial Pacific, in conjunction with the locale in the Tropical Western Pacific, would permit examining processes linking the warm pool with water vapor and cloud transport by the equatorial easterlies (Walker Cell) and trade winds (Hadley Cell). The necessity of establishing supplementary ARM sites in these locales will have to be resolved as experience is gained in the early years of the program.

Criteria for Locale Selection

Criteria for Locale Selection

The criteria for locale selection evolved during the planning stages of the ARM Program and from meetings of the surrogate science teams, the Site Selection Team and the ARM Management Team. The criteria derive from the ARM scientific objectives and operational considerations as initially outlined in the ARM Program Plan (DOE 1990). They were formulated at the July 1990 meeting in La Jolla and stem directly from the scientific objective of the ARM Program: "to characterize empirically the radiative processes in the Earth's atmosphere with improved resolution and accuracy . . . to better identify the best approaches to improved parameterizations of radiative transfer effects."

This section of the report describes the process that was used to formulate the criteria for locale selection. First, the ARM objectives and issues identified during the process are outlined, followed by a discussion of the requirements and guidelines that led to the development of the criteria. Finally, the criteria for selecting the first and subsequent locales and the scientific and nonscientific attributes that apply to those criteria are described, followed by a discussion of the classes of attributes to be evaluated by the Criteria Examination Teams (CETs).

Meeting ARM Objectives

To meet the ARM objective of characterizing and parameterizing relevant atmospheric and radiation processes, the set of locales for ARM sites must be capable of allowing measurements to be made of the key processes that are simulated in GCMs and related models. This approach relieves any requirement of conducting ARM measurements at all climatically significant locations, replacing it with a much less stringent requirement, namely that ARM conduct measurements at a set of sites that will collectively experience, with appreciable frequency, the key phenomena controlling the transfer of radiation in the atmosphere.

To identify these key phenomena and ascertain whether they will be adequately experienced at the ARM sites, two classes of objectives must be considered within the overall objective of the ARM Program:

> **Class 1.** Relate observed instantaneous radiative properties of the atmosphere (spectrally resolved and as a function of position and time) to the then present atmospheric temperature and composition (specifically including water vapor and clouds) and surface radiative properties, both as functions of position, and develop parameterizations for these relationships.

> **Class 2.** Develop parameterizations to describe atmospheric composition (again specifically including water vapor and clouds) and surface properties governing atmospheric radiation in terms of relevant prognostic variables, with the objective of incorporating these parameterizations into general circulation models and related models.

Criteria for locale selection derive from ARM scientific objectives and operational considerations.

The following example illustrates why the criteria for locale selection must address both classes of objectives. To describe how clouds interact with radiation, it would be sufficient to ensure that the number and distribution of ARM sites is broad enough to conduct measurements on all climatologically important cloud types. However, a given cloud type can form or dissipate by more than one process. For example, stratus is formed by lifting and cooling in the warm sector of extratropical storms, as is characteristic of continental stratus, and also by vertical mixing of moisture from the ocean surface throughout the planetary boundary layer, as is characteristic of marine stratus. Therefore, to achieve Class 2 objectives, measurements must be conducted at both types of locales. Similarly, in order to evaluate the accuracy of cloud models, ARM sites must individually and collectively span a wide range of the attributes that govern the formation, persistence, dissipation, distribution, and macrophysical and microphysical properties of clouds.

Both Class 1 and Class 2 objectives were considered in formulating the criteria for recommending potential locales. In addition to ensuring that the set of ARM sites would meet these objectives, several issues were addressed that are expected to permit the objectives to be met. These issues are outlined in the following subsection.

Issues Influencing the Choice of Locales

During the site selection process, many issues pertinent to choosing locales for ARM sites were identified. These issues, which influenced the criteria identified for locale selection, are described here and summarized in Table 2.

- The issue of sampling the climatologically most important regions versus sampling a wide range (perhaps extreme) of climatic conditions. It is desirable to examine the maximum range of variables such as temperature, water content, and aerosol loading, to establish confidence in model parameterizations. This would suggest locating ARM sites in regions that cover a wide range of values of such variables. On the other hand, it has been proposed that ARM sites should be located in the most radiatively important climatic regions of the Earth, since understanding the physical processes governing these regions will be of the greatest value in enhancing confidence in climate models. Although such regions might not experience the full range of values for key variables desired for testing the numerical algorithms within GCMs, they would provide a testbed of data with which the overall performance of the GCMs could be evaluated.
- The issue of regions of unusual or unique climatic importance. It may be desirable to locate ARM sites in regions that are not radiatively important, but which indirectly exert a strong influence on atmospheric radiation processes because of a particular intense, localized climatic process. For example, convective storms in the tropical Pacific transfer a substantial amount of water vapor to the upper atmosphere. Such regions may not present a wide range of attributes nor be the most radiatively important climatic regions. However, such unique features must be accurately simulated in order to fully describe the Earth's atmosphere.
- The issue of homogeneity versus heterogeneity. Homogeneity in the context of this report refers to a variety of attributes within a locale. A locale may be homogeneous in one attribute (e.g., topography) but heterogeneous in another (e.g., precipitation or temperature). This homogeneity is very much a function of scale; within the context of this activity, the scale on which homogeneity is characterized is that appropriate to present and near-term GCM grid-scale, i.e., roughly 200 km. Homogeneity of a locale is desirable for initial attempts to relate radiative properties to atmospheric composition and surface properties. A spatially homogeneous terrain more closely approximates a one-dimensional system, suitable for testing GCMs operating in a single-column mode and for examining the relation between spatial and temporal variability. Heterogeneity is desired because much of the planet is heterogeneous, necessitating treatment of heterogeneous situations in models with consequent testing of those models.
- The opportunity for cooperation between the ARM Program and other programs with similar objectives ("synergism"), thereby enhancing ARM capabilities, and perhaps reducing costs,

versus locating ARM sites at locations that are optimum in meeting ARM's scientific objectives.

- The importance of logistical considerations. To what extent should scientific objectives be compromised by considerations of logistical feasibility or cost?
- The issue of resources and costs associated with establishing and operating a relatively large number of sites versus gaining enhanced capabilities at fewer sites. For a given budget, what number of sites maximizes the scientific benefits?

Site Requirements

Taking into account both the ARM objectives and the issues outlined in the preceding sections, the participants at the La Jolla meeting identified the following site selection requirements upon which to base their criteria for locale selection:

- The need for a set of sites that represent or span climatologically important regions.
- The need to sample a wide range of atmospheric and surface conditions in order to examine model performance under such a wide range of conditions.
- The need for ARM measurements to be logistically feasible at the site.

Guidelines for Influencing Locale Selection

Once the site selection requirements were identified, it was possible to establish the following guidelines for recommending locales:

- Identify domains of "attributes" that must be spanned by selected ARM sites. Important domains of attributes include climate, terrain, orographic features, etc.
- Identify candidate locales for ARM sites and examine the values of pertinent attributes at each.

Table 2. Summary of Issues Influencing Locale Selection

Selection Issues	Rationale
Climatologically Representative	GCMs must simulate key regions of climatological significance.
Large Range of Attributes	Allows testing conditions over which GCMs perform well.
Radiatively Important	GCMs must do well with those regions that dominate the radiation budget.
Unique Processes	Certain locale features have widespread effect on atmosphere (e.g., deep tropical convection).
Homogeneous	Allows resolution by GCM grids, except when locales are selected for key subgrid processes.
Cooperation Possible	Benefit from work done by other scientific programs.
Logistics	Evaluate accessibility of site versus other benefits.
Resources	Evaluate cost of accessing site versus other benefits.

- Select a minimal set of locales that sufficiently spans domains of radiation-influencing attributes.

Criteria for Recommending Potential Locales

On the basis of the requirements and guidelines outlined in the preceding subsections, locale selection principles were established that led to an ordered set of criteria for selecting the first and subsequent locales. Although meeting the scientific objectives of ARM was the highest priority for establishing the criteria for locale selection, the need for the logistical feasibility of establishing an ARM site also was given major consideration. Logistical feasibility will be particularly important for the first site because there will be a high expectation for it to establish the capability of ARM to achieve its measurement and scientific objectives. The selection principles that led to the criteria are as follows:

- The set of locales should stress models describing radiation transfer in the atmosphere and atmospheric properties influencing such radiation transfer by spanning, as greatly as possible, the domain of radiation-influencing attributes. (These attributes are outlined in the following subsection.)
- The climatological and surface-property attributes of each locale should be homogeneous within the locale, except when a locale is intentionally chosen to be inhomogeneous to permit testing of the ability of models to treat atmospheric processes influenced by geographic inhomogeneities.
- The logistics of establishing and operating an ARM site within a locale should be favorable or at least tractable.
- Insofar as possible, locales should be selected so as to maximize opportunities for cooperation between the ARM Program and other programs with similar objectives.
- Subject to the above, the set should be as small as possible, consistent also with the need to establish the widespread applicability of the models.

Based on these principles, the criteria for selecting the first and subsequent locales were identified.

Selection of the first locale should be based on the following ordered criteria:

a. logistical favorability

b. the climatic and geographical homogeneity of the locale

c. synergism with programs conducted by entities other than ARM that might be gained by establishing an ARM site in the locale

d. the ability of the locale to stress ARM models by exhibiting a wide variability temporally in properties influencing the transfer of radiation in the atmosphere.

Selection of the second and subsequent locales should be based on the following ordered criteria:

a. the ability of the locale to stress ARM models

b. the climatic and geographical homogeneity

c. programmatic synergism

d. logistical favorability.

This ordering of criteria is depicted schematically in Figure 1.

Recommend Locale 1:

Priority

- Favorable logistics
- Homogeneity of geographical and climatological properties
- Synergism with other programs
- Stress the models

Recommend Locale *i*, *i* = 2 . . . *n*

Priority

- In combination with locales 1 to (i - 1) stress the models
- Homogeneity of geographical and climatological properties
- Synergism with other programs
- Favorable logistics

Figure 1. Priorities for Recommending Locales

Attributes to be Considered when Recommending ARM Sites

In addition to formulating the criteria for recommending locales, the participants at the La Jolla meeting developed a general list of attributes relevant to the selection of ARM sites. The attributes were distinguished as scientific (i.e., pertaining to the scientific objectives of ARM) and nonscientific (e.g., pertaining to the ability to conduct the measurements or the ease with which the objectives could be achieved). These attributes, which were based on the ARM Program Plan and discussions with the ARM Management Team and surrogate science team members, were to be examined for each locale. The following were identified as classes of attributes pertinent to the site selection process:

Classes of Scientific Attributes Governing Site Selection

- Climate: cloud frequency (predominantly clear, predominantly cloudy), cloud type (cirrus, stratus, cumulus, etc.), fog frequency, precipitation amount and frequency, mean temperature, temperature range, seasonality . . .
- Meteorology: synoptic scale processes; mesoscale processes; role of the locale in global atmospheric circulation. . .
- Surface flux properties

- Concentrations and variability of water vapor, ozone, natural and anthropogenic trace gases and aerosols
- Surface properties: ocean/land, forest, low-vegetation, desert, snow/ice . . . ; homogeneous/heterogeneous
- Terrain: level, mountainous . . . ; homogeneous/heterogeneous
- Continentality: mid-continent, continental margin, ocean
- Altitude
- Latitude.

Nonscientific Attributes Governing Site Selection

- Logistics: pertaining to the ability of establishing ARM sites and conducting ARM measurements at locations within the locale.
- Synergistic: pertaining to the opportunity for the ARM Program and other atmospheric or oceanographic research programs to maximize use of resources. ARM sites could be located where other projects are being conducted or are expected to be conducted, thereby permitting ARM to take advantage of measurements performed by such other programs and/or facilities maintained by such other programs.

Based on these classifications, the attributes pertinent to locale selection were organized into the following classes:

- Climate
- Atmospheric properties
- Surface properties
- Surface energy fluxes
- Logistical considerations
- Synergism with other programs.

ARM
Atmospheric Radiation Measurement

Formulation of Locale Recommendation Procedure

Formulation of Locale Recommendation Procedure

On the basis of the criteria outlined in the preceding section, a procedure was formulated at the La Jolla meeting for selecting a set of appropriate locales. This procedure, including the sequence of steps, guidelines, subtasks assigned to the CETs, and the Evaluation Team procedure, is outlined here and detailed in Appendix A.

Sequence of Steps

The procedure for recommending appropriate locales for ARM sites consisted of the following sequence of steps:

1. Identify the domain of attributes that must be spanned by ARM sites, based upon information provided by the ARM Program Plan, the ARM Site Mission, and input from leading scientists from the atmospheric radiation, meteorology, and general circulation modeling communities.
2. Identify candidate locales for ARM sites.
3. Examine the values of the pertinent attributes of these locales with respect to the scientific requirements of the ARM experiments.
4. Identify logistical constraints that might preclude conducting ARM measurements in candidate locales or impose major logistical hurdles.
5. Identify other atmospheric or oceanographic research in the candidate locales that might provide synergistic benefits.
6. Recommend a set of locales that will best satisfy the scientific goals of ARM, taking into account the ordered selection criteria and budgetary constraints.
7. Submit the recommended set of locales, including the recommendation procedures and the justifications for the recommendations, for review by the ARM Science Team and the broader scientific community.
8. Consider suggested revisions to the procedures and revise the recommendations as appropriate.

The procedure specified that the attributes of the candidate locales should be examined by categories of attributes and noted that this could be done in parallel by the CETs assigned to the classes of attributes.

A procedure was formulated for selecting a set of appropriate locales.

Guidelines for Criteria Examination Teams

To assure that the recommended locales would meet the ARM requirements with respect to each of the attribute classes identified above, guidelines were developed for the CETs charged with examining the attribute classes. The guidelines encompassed the objective, scope, input, output and approach to be used by the CETs during their examinations. Those guidelines were as follows:

Objective:

- The teams were to evaluate the ability of single locales, and of sets of locales, to meet the ARM site requirements of model stress and homogeneity.

Scope:

- The teams were to consider only the attributes within the scope of their team. They were to use the supplied initial list of potential locales but could request that other locales be added to this list if they found it incomplete.

Input:

- During their examination of the potential locales, the teams were to use the ARM Site Mission and expertise from the scientific community as required.

Output:

- The teams were to recommend one or more candidate ranked-ordered subsets of approximately six locales which best met the ARM Site Mission with respect to the special area the team was considering.
- The CETs were to discuss how well each potential locale met the criteria set by the team.
- The teams were to discuss the criteria used in evaluating the potential locales and in forming the subsets of locales.

Approach:

- Each team was to evaluate the ability of measurements conducted within each of the potential locales to stress models with respect to the appropriate set of attributes for that team.
- Teams assigned to evaluate the climatology and surface properties attributes were to assess the homogeneity of each potential locale, except for locales designated as intentionally inhomogeneous.
- Each team was to construct candidate subsets of locales which covered the range of the appropriate set of attributes.

Subtasks for Criteria Examination Teams

After identifying the guidelines for the CETs, an ordered set of subtasks was established. Those subtasks were as follows:

1. Obtain the necessary input.
2. Determine what criteria the team would use in evaluating the potential locales.
3. Determine what criteria the team would use in forming the subsets of locales.
4. Obtain the information necessary to perform the desired evaluations.
5. Examine and evaluate the potential locales by the criteria determined above.
6. Assess the total list of potential locales to determine if it covered the range of appropriate criteria and, if it did not, suggest additional locales to be added to the list and go back to subtasks (4) and (5) above if necessary.
7. Group subsets of potential locales according to the criteria established above.

Evaluation Team Procedure

After completing the procedure described above, the CETs charged with scientific attributes were to report on one or more sets of locales which collectively would satisfy the requirements from the perspective of their attribute classes. These recommended candidate sets of locales were to be transmitted to the Evaluation Team, which was charged with identifying a single set of locales that would satisfy the requirements of all the CETs, and which further would satisfy logistical requirements and maximize the opportunity for synergistic interaction with other programs. If necessary, the Evaluation Team was to meet with the CETs to examine alternative sets of locales that might better satisfy the requirements of the teams. As a result of this procedure, the Evaluation Team was to recommend a single set of locales, including alternatives, where such alternatives were equivalent.

ARM
Atmospheric Radiation Measurement

Application of the Locale Recommendation Procedure

Application of the Locale Recommendation Procedure

This section describes how the locale recommendation procedure was applied to identify a set of locales that best satisfies the objectives of the ARM Program. The section is organized according to the steps outlined in Section 3. The input from the Science Team review (Step 7) and the revisions made as a result of that review (Step 8) are incorporated, as appropriate, in the discussion of Step 6, Recommending a Set of Locales.

Identifying the Domain of Attributes

The first step in applying the procedure for locale selection was to identify the domain of attributes that must be spanned by the ARM sites. The original list of scientific attributes pertinent to locale selection included climate, atmospheric properties, surface properties, and surface energy fluxes. However, the CETs formed to examine the attributes for surface properties and surface energy fluxes were ultimately merged because of the similarities between the criteria that had been developed by those two teams. In addition to the CETs assigned to examine the scientific attributes, CETs were formed to examine two classes of nonscientific attributes: logistical considerations and synergism with other programs. Each of the CETs prepared detailed reports. These reports comprise Appendixes B through F.

Identifying Candidate Locales

The second step of the procedure was to develop a list of locales to be considered by the various CETs. The Climate CET compiled an initial list of locale categories (e.g., tundra, equatorial rainforest) by considering major regions of the world that are climatically homogeneous. The starting point for developing this list was the system of climate classification developed by Köppen and modified by Trewartha (Trewartha and Horn 1980). The Köppen system was selected because vegetation and terrain are included with temperature, precipitation and seasonality among the classification criteria. Details are provided in the Climate CET, Appendix B.

The locale categories identified in this process are grouped according to land locales and ocean locales. They are briefly described below, along with the major world regions that fall within each category (except some ocean categories). Note that these descriptions are general; they are intended to elicit a sense of the character of each category, not to delineate boundaries with precision. Some frequently used terms include the following:

- Equatorial: Approximately ± 5° N and S
- Tropical: Approximately ± 23.5° N and S (includes Equatorial zone)

The first step was to identify the domain of attributes that must be spanned by ARM sites.

- Subtropical: 23.5° to approximately 35° N and S
- Midlatitude: Approximately 35° to 50° N and S
- High latitude: 50° to approximately 66.5° N and S
- Polar: Poleward of 66.5°N and S
- Temperate: Subtropical and midlatitude, without extremes of temperature or aridity
- Continental: Interior of continents, exhibiting seasonal extremes minimally moderated by marine influence

Locale Category Descriptions: Land Locales

Equatorial Rainforest. Temperatures average near 27°C year-round; heavy rainfall (> 2000 mm/yr) but some seasonal variation; intense convective storms; region of true selva (equatorial rainforest). (Amazon River basin; Congo River basin; insular Southeast Asia).

Tropical Monsoon Region. High temperatures year-round; strong seasonal variation in precipitation with marked rainy season at high sun; for this evaluation includes both true monsoon areas (windward margins of continent) and narrow leeward margins with heavy orographic precipitation, a more pronounced dry season and somewhat greater annual temperature extremes. (Southern India, west coast of southeast Asia; northern Australia; northeast coast of South America; Sierra Leone and Liberia).

Continental Deserts/Arid Regions. Continental interiors dominated alternately by tropical and polar continental air masses; shut off by mountains from maritime air mass sources; extreme annual temperature variation; includes both midlatitude and subtropical desert areas. (Southwest U.S., northern Mexico; central Australia; central Sahara; Arabian peninsula; Gobi Desert; Kalahari Desert).

Subtropical Grasslands. Semiarid steppe/prairie; high annual maximum temperatures; dominated by tropical continental air masses with occasional incursions from polar source regions; flat to slightly rolling terrain; natural grassland vegetation or savannah due to scant precipitation. (West/central U.S.; Pampas (Argentina, Uruguay); South Africa and Botswana; outer margins of central Australian desert).

Subtropical with Winter Rainy Season. ("Mediterranean"). Narrow coastal strips west of the subtropical grasslands, backed on the east by mountains; hot, dry summers, cool rainy winters; subject to strong, hot, dry mountain winds (Santa Ana, mistral, bora); scrubby vegetation. (Southern California; central Chile; coastal margins of Mediterranean basin; southern tip of Africa; southwest Australian coast).

Midlatitude Continental Prairies. Poleward continuation of subtropical grasslands; continental air masses dominate; may be hot in summer but winters very cold; scant precipitation mainly in early summer; extended periods of snow cover (60-130 days per year). (North-central U.S., south-central Canada; Soviet Union north of Caspian Sea; eastern margin of Gobi desert).

Temperate East Coastal Plains. Midlatitude; seasonal temperature variation due to alternating influence of tropical maritime and polar air masses, but muted by marine location; adequate precipitation in all seasons; inland from immediate coast (not intentionally heterogeneous); generally flat; native vegetation ranges from temperate rainforest poleward to summer deciduous forest. (Southeast U.S.; Uruguay and northeastern Argentina; southeastern China and southern

Japan; eastern Australia; small areas in eastern South Africa).

Midlatitude Humid Continental Plains. Strong continental effects, with cold winters and hot, humid summers; most precipitation comes in summer, from both cyclonic and convective storms, but winter has a higher proportion of cloudiness; snow cover averages 30-60 total days; major agricultural areas (cropland), though the natural vegetation is deciduous forest (except for the "Prairie Wedge" in North America). (Midwest U.S.; northern margins of the Black Sea and east-central Soviet Union; North China Plain).

Wet Temperate West Coastal. Midlatitude coastal areas, windward sides of continents; marine influence moderates temperature range; precipitation throughout year also has orographic component. (Northwestern U.S., southwestern Canada; south-central Chile; northwest Europe).

Leeward Slope of Mountain Range. Complex terrain, temperature altitudinally dependent; orographically induced lack of precipitation (rainshadows). (Eastern slope of the Rockies; western Ethiopia and Kenya).

High Latitude Continental Boreal Forest. Source region of continental polar air masses; extreme annual temperature range with short, cool summers; slight precipitation from cyclonic storms but evaporation is small; dense but short needleleaf forest, relatively flat terrain. (Central Canada; north-central Soviet Union (Siberia)).

Tundra. Region of the so-called "arctic front," marked by intense east-moving cyclonic storms and shifting polar front; average temperature of warmest month is above freezing but below 10°C; temperature range more moderate than that of continental interior; persistent cloud cover; treeless vegetation includes grasses, sedges, lichens, some willow shrubs. (Northern Canada and north slope of Alaska; northern Siberia; northern Scandinavian peninsula).

High Latitude Ice Plateau. No monthly temperature average over freezing; strong temperature inversions may occur over the ice; plateau consists of glacial ice several thousand feet thick in the form of a broadly sloping dome (margins may be marked by steep slopes or areas of considerable local relief). (Greenland; Antarctica).

Lake Effect Region. Areas near large lakes, inland seas, especially the windward margins; "marine" effects such as increased precipitation. (U.S. Great Lakes; Lake Titicaca; Caspian Sea; Aral Sea; Lake Victoria).

Highland Plateau. Relatively flat but high altitude; climatically distinct from lower regions at same latitude; dry (isolated from marine air masses). (Utah; Bolivia; northern Ethiopia; Tibet).

Locale Category Descriptions: Ocean Locales

Equatorial/Tropical Oceans. Region of westward-flowing warm equatorial currents; Intertropical Convergence Zone; beginning of Hadley cells; marked by high evaporation with consequently heavy rainfall and large amounts of moisture in the atmosphere; global maximum of atmospheric water vapor content.

Tropical Cyclone Spawning Areas. Regions of poleward extent of the Intertropical Convergence Zone, about 10-15° N and S, especially along eastern and western margins near continents.

Central Gyres. Subtropical central oceans; regions of atmospheric high pressure cells with little precipitation; characterized by high salinity and fairly warm temperatures; areally the dominant feature of ocean circulation; relatively uniform over large regions; principal climate drivers for the midlatitude continents.

Western Boundary Currents. Subtropical to midlatitude; poleward turn of warm equatorial currents; currents tend to be compressed, long, narrow, not much surface area; considerable cloudiness; much warmer than land areas immediately to west, especially in winter; maximum latent heat input to atmosphere. (Gulf Stream; Brazil Current; Kuroshio Current; Agulhas Current; East Australian Current).

Eastern Boundary Currents. Subtropical latitudes; slightly equatorward in the southern hemisphere, northward to about 35°N in the eastern North Pacific; region of stratus development due to weak upwelling of cold currents as they turn along the continents toward the equator; dry, especially in the southern hemisphere, where annual precipitation averages less than 100 mm. (California Current; Peru (Humboldt) Current; Canaries Current, Benguela Current).

Eastern Margins of the Gyres. Transitional areas between the central gyres and the cold eastern boundary currents; slow equatorward drift; regions of stratocumulus (transition to marine stratus along the boundary currents).

Mediterranean Seas. A true (salt-water) sea completely enclosed by land; large enough to be "oceanic" but restricted ocean dynamics; no central gyre or well-developed boundary currents; semi-arid climate with hot, dry summers, rainy winters; climate less marine, more influenced by adjacent land climate than open ocean areas. (Mediterranean Sea).

High Latitude Ice-Free Seas. General category including seas with differing characteristics; Norwegian Sea is ice free due to warming by the North Atlantic Drift; scene of considerable heat exchange between atmosphere and ocean; Circumpolar Southern Ocean is the connecting area for all world's oceans (only free exchange on globe); energetic, region of strong atmospheric frontal activity.

High Latitude Ocean Ice Edge. The Marginal Ice Zone; possibly the most important category from a climatic point of view due to pronounced positive feedback conditions; however, very difficult logistically to monitor. (Greenland Sea; Bering Sea; Chukchi Sea; Ross Sea).

Semi-Enclosed Seas. Detached from open oceans by island chains, limiting water exchange; limited ocean dynamics; smaller size amplifies changes in adjacent ocean conditions, more apparent atmospheric feedback effects.

Inland Water Bodies. General category of freshwater or brackish water bodies lacking ocean characteristics but large enough to affect climate over adjacent land areas; water budget is sensitive to river flow. (Great Lakes; Lake Titicaca; Black Sea, Baltic Sea; Lake Victoria).

Once the climatologically significant locale categories were identified, several locales were identified for each category, taking terrain, surface cover (e.g., natural vegetation, crops, ice) and patterns of air masses, winds and ocean currents into account to focus on distinct areas within the broader regions.

Finally, the list of potential locales identified by this process was shortened to a list of candidate locales which were to be evaluated by the CETs to determine their suitability in meeting the ARM objectives. Candidate locales were selected for detailed examination on the basis of meeting one or more of the following criteria:

- Highly representative of the category
- Homogeneous in geographic attributes such as terrain
- Favorable logistic and/or synergistic attributes
- Of unique or particular pertinence to research goals of ARM.

This set of categories was selected to span a broad range of climatic and geographic regimes. In selecting the candidate locales, it was deemed preferable to suggest multiple, approximately equivalent locales within categories of greatest potential interest to ARM, rather than to select one locale from every category. By keeping the list of candidate locales down to a workable size, the CETs could devote their attention to applying detailed criteria, including logistic and synergistic considerations, to the locales of greatest scientific merit. Therefore, based on initial prioritization some categories were not represented in the final list. The locale categories and potential and candidate locales within these categories, are given in Table 3; candidate locales are indicated by check marks (✓).

The initial roster of potential and candidate locales was circulated to the ARM Management Team and to members of the Locale Recommendation Team. This list was also reviewed by the members of the Science Team in their review of a draft version of this report. It was explicitly noted that additional locale categories and/or candidate locales could be added to the list at any time. Locales which were subsequently added to the original list are also included in Table 3. All locales were then subjected to examination by each CET. The approximate locations of the candidate locales are shown in Figures 2 through 4. The illustrated locale boundaries should not be taken as absolute; the attributes of each locale are more critical to this decision process than are precise locations. Two candidate locales do not appear on the maps: the Antarctic Plateau, which is the ice-covered heart of the continent and does not include the mountainous areas; and the Circumpolar Southern Ocean, which stretches from the edge of the continent to approximately 45°S latitude.

Evaluation Criteria Used by Criteria Examination Teams

The list of candidate locales, as amended, was examined in detail by each CET. Each team determined the criteria it would use to evaluate the sites relative to its specific area of responsibility. Each of the CETs examining scientific criteria was directed to select one or more sets of locales that would stress the models by spanning a wide range of conditions that affect radiation and clouds. The criteria developed by the CETs are summarized here and detailed in Appendixes B through F. Since atmospheric processes are viewed as the key set of processes that must be captured by the ARM sites, the criteria of the Atmospheric Properties CET are presented in considerable detail.

Table 3. Locales Considered and Selected for Evaluation by CETs, Listed by Locale Category[a,b]

LAND LOCALES

The number of land locales identified for consideration was 42, and the number selected for detailed for examination, indicated by ✓, was 17.

Temperate East Coastal Plains
- ✓ Mid-Atlantic U.S.
- ✓ Southeast U.S. Coastal Plain
- Southeast Canadian Coast
- Southeast Coast of China (South of Yellow River; Shanghai to Canton)
- Southeast Australian Coast
- Gulf Coastal Plain of Southeast U.S. (Florida Panhandle to Louisiana, South of Birmingham to Memphis)

Subtropical Grasslands
- ✓ Southern U. S. Great Plains
- The Pampas (Argentina, Uruguay)

Table 3. (contd.)

Midlatitude Continental Prairies
- ✓ Northern U. S. Great Plains

Midlatitude Humid Continental Plains
- ✓ Midwest U.S. North of Ohio River
- North China Plain
- Lower Danube Valley/North Rim of Black Sea

High Latitude Continental Boreal Forest
- ✓ West Siberian Boreal Forest
- ✓ Canadian Boreal Forest

Equatorial Rainforest
- ✓ Amazon Basin
- ✓ Congo Basin

Tropical Monsoon Region
- ✓ Southern Indian subcontinent
- Southeast Asia
- Northern Australia
- Eastern South America from Orinoco to 15°S

Continental Deserts/Arid Regions
- ✓ Sonoran Desert (Southwest U. S. Northern Mexico)
- ✓ Central Australia
- Sandy, flat Sahara
- Arabian Peninsula
- Gobi Desert (Mongolia)
- Kalahari Desert (South Africa)

High Latitude Ice Plateau
- ✓ Greenland Plateau
- ✓ Antarctic Plateau

Tundra
- ✓ North Slope of Alaska (inland from coast)
- Northern Canada
- Northern Siberia

Leeward Slope of Mountain Range (IH)
- ✓ Eastern Slope of U. S. Rockies

Wet Temperate West Coastal (IH)
- ✓ Northwest U.S/Southwest Canada
- South central Chile
- Northwest European coast

Subtropical with Winter Rainy Season ("Mediterranean") (IH)
- Coastal Morocco
- Southwest Australian Coast
- California south of Los Angeles

Table 3. (contd.)

- Central Iberian Plateau
- Central Chile (IH)

Lake Effect Region (IH)
- Great Lakes Area North America

Highland Plateau
- Tibetan Plateau (North of Himalayas)

OCEAN LOCALES

The number of ocean locales identified for consideration was 33, and the number selected for detailed examination, indicated by ✓, was 14.

Central Gyres
- ✓ Sargasso Sea (North Atlantic)
- ✓ Central North Pacific
- South Central Pacific

Equatorial-Tropical Oceans
- ✓ Tropical Western Pacific Ocean
- ✓ Tropical Atlantic
- Tropical Western Indian Ocean

High Latitude Ice-Free Seas
- ✓ Circumpolar Southern Ocean
- ✓ Norwegian Sea

High Latitude Ocean/Ice Edge (IH)
- ✓ Greenland Sea
- ✓ Bering Sea
- ✓ Beaufort Sea (North of Alaska)
- Chukchi Sea (North of Bering Straits)
- Antarctic Ice Shelf

Western Boundary Currents (IH)
- ✓ Gulf Stream off Eastern North America
- Kuroshio current East of Japan

Eastern Boundary Currents
- ✓ Eastern North Pacific (28-40°N, 120-130°W)
- ✓ Eastern South Pacific
- Eastern South Atlantic

Eastern Margins of the Gyres
- ✓ Eastern North Atlantic—Azores to Africa (35-38°N, 20-35°W)

Tropical Cyclone Spawning Areas
- Southeastern North Pacific, off Mexico
- Southeastern North Atlantic
- Western North Pacific near Philippines

Western South Pacific near Australia
Southern Indian Ocean
Northern Indian Ocean

Mediterranean Seas
Mediterranean Sea

Semi-Enclosed Seas
✓ Australia-Indonesia Semi-Enclosed Sea
Gulf of Mexico
Caribbean Sea
South China Sea

Inland Water Bodies
Great Lakes
Black Sea
Baltic Sea

(a) The total number of locales identified for consideration was 75, and the number of locales selected for detailed examination, indicated by ✓, was 31.

(b) (IH) denotes locale categories that have been selected as intentionally heterogeneous to permit testing of the ability of models to treat this heterogeneity.

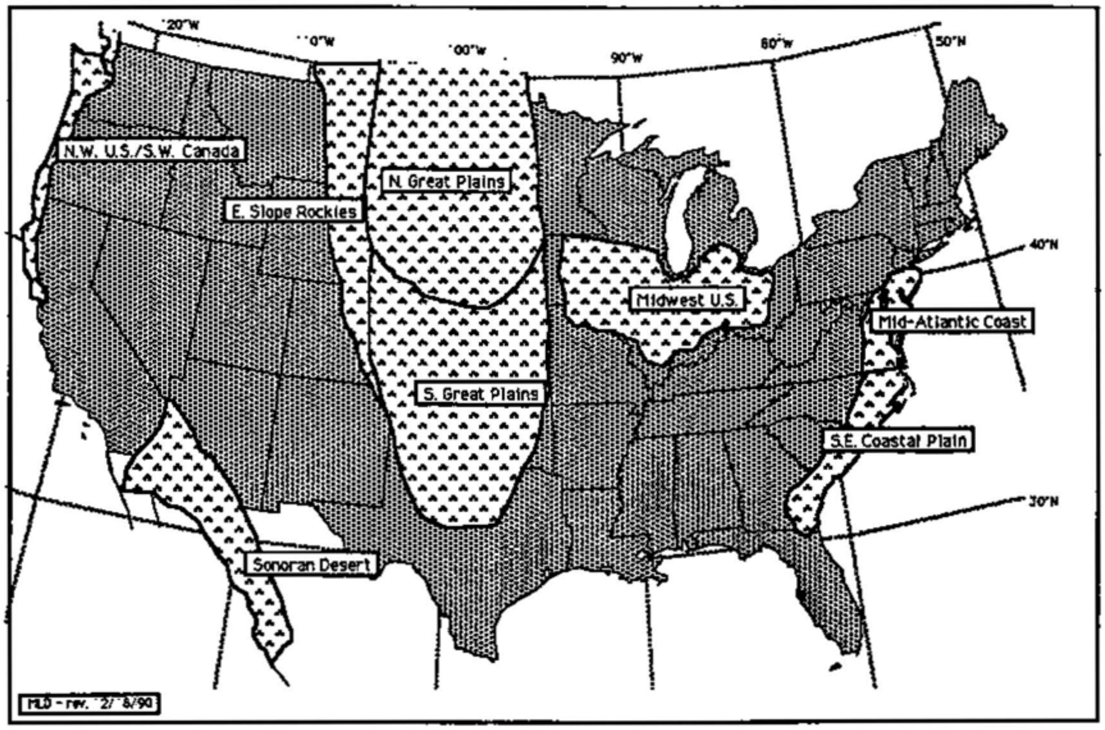

Figure 2. Locales in the Contiguous U.S. and Vicinity Selected by the Criteria Examination Team

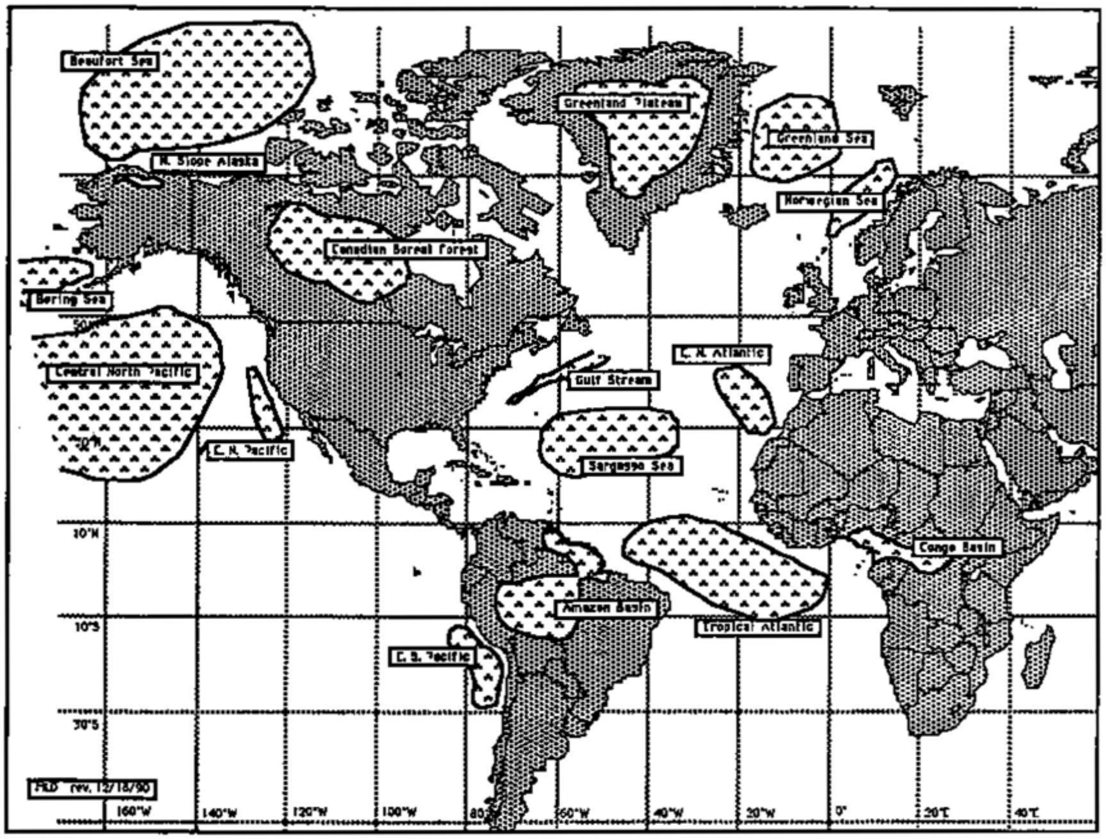

Figure 3. Locales in the Western Hemisphere (Except Contiguous U.S.) and Oceans Selected by the Criteria Examination Team

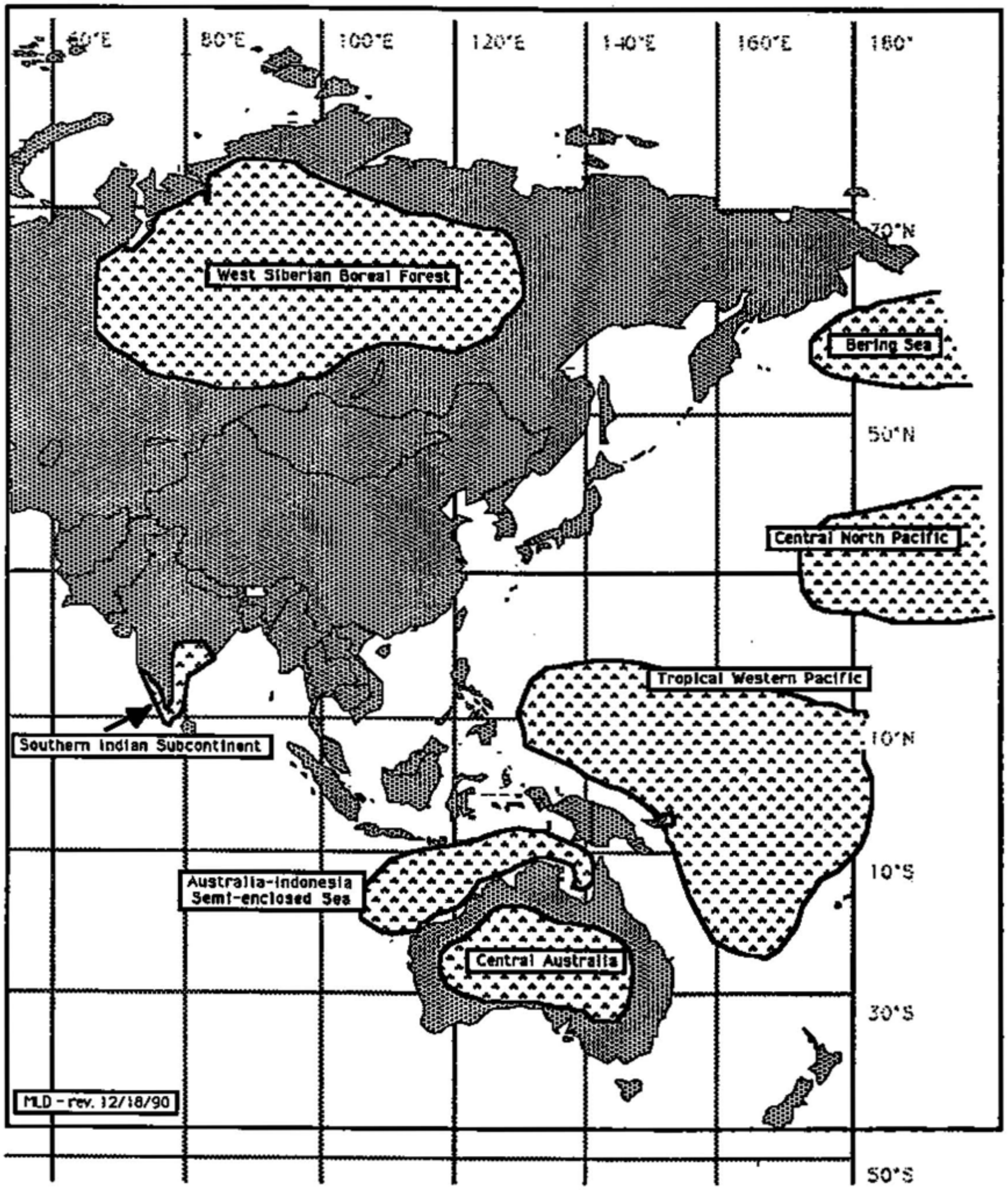

Figure 4. Locales in Asia and Western Pacific Selected by the Criteria Examination Team

Examining the Values of the Pertinent Attributes

The third step in the procedure was to examine the values of the pertinent attributes of these locales with respect to the scientific requirements of the ARM experiments. The following subsection contains a discussion of the criteria developed by the Atmospheric Properties CET (see Appendix C for details). A detailed discussion of the criteria that were developed by the Surface Properties and Surface Fluxes CET is not provided here but can be found in Appendix D.

Criteria Developed by the Atmospheric Properties Criteria Examination Team

As noted in the ARM Program Plan (DOE 1990), an accurate treatment of clouds within GCMs and related models is essential for a realistic simulation of climate. The decision was therefore made to make locale selection dependent primarily on cloud factors, with other factors being secondary in their role in the site selection process. The other factors considered included temperature, the moisture content of the atmosphere, aerosol loading, and haze.

A number of cloud categories were considered in order to define the criteria by which the locales would be selected. Among the categories considered were the aspect ratio of clouds (having the advantage of being a continuous number describing cloud shape, but impractical in terms of evaluation from surface observations), cloud height (low, medium and high) and definition by cloud type. Of these possible categories, cloud type was selected as a result of clearly defining key cloud species within GCMs and related models, and because cloud type is frequently an indicator of a specific formation mechanism that needs to be taken into account within the models.

The following cloud types were identified as having the greatest impact on the radiation budget of the atmosphere:

- Marine stratus (MSt): associated with the mixing of water vapor through the boundary layer in the absence of conditional instability; presently poorly treated in GCMs and related models, yet widespread in many regions of the world's ocean.
- Continental stratus and altostratus (As): associated with warm fronts in extratropical cyclones, and having a sufficiently widespread area to allow resolution by existing GCM grids.
- Cirrus (Ci): ice clouds formed by a variety of mechanisms; common over many locations; play a major role in the IR planetary radiative balance.
- Cumulonimbus (Cb): deep convective systems associated with instabilities in the thermal structure of the atmosphere; play a major role in exchange processes between the lower and upper atmosphere; treated in a parameterized manner in GCMs and related models as a result of having a horizontal extent much smaller than GCM grids.
- Cumulus (Cu): convective clouds formed without significant vertical development; associated with boundary layer heating driving convective eddies; frequent in the tropics, as well as post cold frontal clouds in the extratropics.
- Totally clear sky conditions: included as the simplest test of radiation models.

Three major locale selection criteria were identified by the Atmospheric Properties CET: frequency of occurrence of each cloud type and totally clear sky; temperature extremes; and water vapor. Each is discussed below.

The first criterion for locale selection was based on the frequency of occurrence (f) of each cloud type and of totally clear sky. A representative frequency within the locale of between 40 and 70% (temporally) for each cloud type was required to ensure that the formation and dissipation processes likely would be observed. In addition, this range allows a moderate probability that clear-sky conditions also would be observed at the candidate locales.

Two situations required relaxing the 40 to 70% frequency requirement. The first situation results from the observation that the frequency of occurrence of tropical Cb's is only about 25%. The criterion used for the occurrence of Cb was therefore defined to be a summer frequency of occurrence of $\geq 10\%$. The second situation involves clear skies. Since modeling totally clear sky conditions is relatively simple, it was decided that fewer such cases would be necessary. Therefore, the occurrence frequency criterion for totally clear sky was also $f \geq 10\%$.

Temperature extremes formed the second criterion for locale selection. This is necessary in order to stress radiation models (e.g., testing of models of the water vapor absorption continuum). Locales with large seasonal cycles ($T_{summer} - T_{winter} \geq 20K$) or exceptionally warm temperatures ($T \geq 300K$) were favored. A large seasonal cycle in temperature was ensured by selecting at least one midlatitude midcontinental locale.

The third criterion adopted was associated with water vapor. Locales with extremely high specific humidity ($q \geq 16$ g/kg), or large seasonal variations ($q_{summer} - q_{winter} \geq 6$ g/kg) were sought in order to stress radiation and cloud models, since high specific humidity accentuates the water vapor continuum, which is a large uncertainty in the clear-sky infrared radiation balance. Strong seasonal variations stress radiation parameterizations and the prediction of clouds.

Other, less quantitative criteria were also used. It was recognized that haze and dust can have a significant radiative influence. In selecting some of the locales, the probable existence of haze or dust under some conditions has been considered but could not be quantified during the preparation of this report.

Identifying Logistical Constraints

The fourth step of the procedure was to identify logistical constraints that might preclude conducting ARM measurements in candidate locales or impose major logistical hurdles. The analysis of the Logistics CET consisted of an evaluation of factors that are considered operational. These factors (e.g., access, services, and impacts) are those that would affect the transportation, support, and maintenance of personnel and equipment at CART sites. A detailed discussion of the logistical considerations pertinent to ARM measurements and examination of candidate locales are contained in Appendix E.

Identifying Programs Synergistic to ARM

The fifth step of the procedure was to identify other atmospheric or oceanographic research in the candidate locales that might provide synergistic benefits to ARM. A list of synergistic activities by programs other than ARM was developed after canvassing the atmospheric radiation and meteorological communities as well as from a large number of inquiries among the pertinent federal and international agencies. The list of these potentially synergistic activities and an analysis of the synergistic activities in each of the candidate locales are presented in Appendix F.

the objective of stressing models which describe cloud formation, persistence, dissipation, altitude distribution, and type explicitly requires variability in such site attributes as surface latent and sensible heat fluxes. Thus in addition to meeting the objective of variability in cloud type, it was necessary also to meet the objective of variability of surface heat flux components.

Application of Locale Selection Procedure by the Evaluation Team

In its deliberations, the Evaluation Team relied heavily on the information and recommendations provided by the CETs addressing scientific attributes, as summarized in Appendixes B, C, and D. The following is a summary of the sequence of steps taken by the team as it carried out the procedure specified at the La Jolla meeting. The results of this process are also summarized in Table 4, which indicates whether a given locale was recommended as a primary or secondary locale, was considered an alternative to one of the recommended locales, or was eliminated from consideration:

1. The Evaluation Team identified all candidate locales (denoted in Table 3 by ✓) that appeared in any of the sets of locales generated by the Atmospheric Properties CET and the combined Surface Properties and Surface Flux CETs. The remaining locales (those that were not retained by at least one CET) were eliminated from further consideration as primary locales for ARM sites. This elimination was provisional, it being understood that at some future stage of the recommendation process, the eliminated locales might be considered as alternatives to locales that had been retained. Of the original 31 candidate locales, 8 were eliminated at this stage, leaving 23 for further consideration.

In general, elimination of locales at this stage reflected the fact that eliminated locales exhibited a lesser range of pertinent attributes than did retained locales. For example, the Southeast U. S. Coastal Plain exhibits a smaller seasonal range of both temperature and specific humidity than does the Mid-Atlantic U. S. Coastal Plain, while exhibiting comparable frequencies of the several cloud types. The tropical Atlantic exhibits lesser maximum sea surface temperatures and lesser amounts of deep convection than does the Tropical Western Pacific.

Table 4. Results of Evaluations of Candidate Locales

This table lists all locales that were considered by the CETs as candidate locales for ARM sites and indicates, by locale, whether that locale was recommended as a primary or supplementary locale, is considered an alternative to one of the recommended locales, or was eliminated from consideration. The numbers in the columns denote the step, N, of the Evaluation Team procedure at which the recommendation was made, as follows:

Column I	Locale identified as possible alternative in step N
Column II	Locale selected as a primary locale in step N
Column III	Locale selected as a supplementary locale in step N
Column IV	Locale eliminated (provisionally) in step N

Certain locales, which were provisionally eliminated from consideration at a given step of the procedure, were subsequently reconsidered; this is indicated by a locale having multiple entries in the table.

Table 4. (contd.)

	Column			
	I	II	III	IV
LAND LOCALES				
Temperate East Coastal Plains				
Mid-Atlantic U.S.	8			9
Southeast U.S. coastal plain				1
Subtropical Grasslands				
Southern U. S. Great Plains		4		
Midlatitude Continental Prairies				
Northern U. S. Great Plains				4
Midlatitude Humid Continental Plains				
Midwest U.S. north of Ohio River				4
High Latitude Continental Boreal Forest				
West Siberian boreal forest				1
Canadian boreal forest				1
Equatorial Rainforest				
Amazon basin	6		9	
Congo basin	6		9	
Tropical Monsoon Region				
Southern Indian subcontinent				1
Continental Deserts/Arid Regions				
Sonoran Desert (SW U. S. -Northern Mex.)			9	
Central Australia			9	
High Latitude Ice Plateau				
Greenland Plateau	7			9
Antarctic Plateau	7			9
Tundra				
North slope of Alaska (inland from coast)		7		
Leeward Slope of Mountain Range (IH)				
Eastern slope of U. S. Rockies				1
Wet Temperate West Coastal (IH)				
Northwest U.S./Southwest Canada			9	
OCEAN LOCALES				
Central Gyres				
Sargasso Sea (N. Atlantic)	7			9
Central North Pacific				1
Equatorial/Tropical Oceans				
Tropical Western Pacific Ocean		5		
Tropical Atlantic				1

Table 4. (contd.)

	Column I	Column II	Column III	Column IV
High Latitude Ice-Free Seas				
Circumpolar Southern Ocean	7			9
Norwegian Sea	7			9
High Latitude Ocean/Ice Edge (IH)				
Greenland Sea			9	
Bering Sea			9	
Beaufort Sea (North of Alaska)			9	
Western Boundary Currents (IH)				
Gulf Stream off eastern N. America	6	8		
Eastern Boundary Currents				
Eastern North Pacific (28-40°N, 120-130°W		6		
Eastern South Pacific				1
Eastern Margins of the Gyres				
Azores to Africa (35-38°N, 20-35°W)		6		
Semi-Enclosed Seas				
Australia-Indonesia Semi-Enclosed Sea				5

The eight locales eliminated from consideration at this time were as follows:

Southeast U.S. Coastal Plain
West Siberian Boreal Forest
Canadian Boreal Forest
Southern Indian subcontinent
Eastern slope of U. S. Rockies
Central North Pacific
Tropical Atlantic
Eastern South Pacific

2. The Evaluation Team distinguished among primary, supplementary, and campaign locales as identified by the Atmospheric Properties CET and as summarized in Appendix C. The following are the locales recommended as primary locales by the Atmospheric Properties CET together with a brief indication of the reasons for these recommendations:

Midwest U.S.	High frequency of a variety of cloud types. High seasonal variability in temperature and specific humidity. High variability of aerosols.
Eastern North Pacific	High frequency of marine stratus. High variability of aerosols.
Tropical Western	High frequency of deep Cb and Cu. Extreme high values of temperature and specific humidity. Region includes Southern Oscillation and associated phenomena.
Gulf Stream off Eastern North America	Frequent mature cyclonic storms. Extensive cumulus activity.

The Evaluation Team distinguished between primary and campaign locales as given by the combined Surface Properties and Surface Flux CETs and as summarized in Appendix D. The following are the locales recommended as primary locales by the combined Surface Properties and Surface Flux CETs together with a brief indication of the reasons for these recommendations.

Midwest U.S. or Northern U.S. Great Plains	Wide range of seasonal variations in surface cover and fluxes.
North Slope of Alaska	Large range of seasonal changes.
Amazon Basin or Congo Basin	Extreme water vapor flux and precipitation; well-defined forest cover.
Tropical Western Pacific Ocean	Extremely high sea-surface temperature over large area.
Greenland Sea or Bering Sea	Large range of surface albedo and surface fluxes associated with intermittent ice cover.
Gulf Stream off Eastern North America	Large range of surface latent and sensible heat fluxes.

3. The Evaluation Team grouped locales into sets exhibiting highly similar attributes, denoted as "close-equivalence" sets. The identification of locales with similar scientific attributes was seen as allowing recommendation of one locale or another, thereby permitting the ultimate recommendation or decision to be based on nonscientific considerations such as logistics or synergism.

For example, as discussed in Appendixes B, C, and D, the Midwest U.S. and Northern and Southern U.S. Great Plains locales are all highly continental, exhibiting large seasonal variations in temperature, specific humidity, precipitation amount, surface latent heat fluxes, and surface cover, the latter especially enhanced by the seasonality of snow cover and of the growing cycle of vegetation. All three locales exhibit comparable cloud type frequencies. The similarity in seasonality in precipitation and temperature of the Midwest and Southern Great Plains locales is illustrated in Figure 5. Although the Northern Great Plains locale exhibits a somewhat lower temperature profile and a substantially lower precipitation profile, the overall attributes of this locale were judged to be sufficiently close to those of the Midwest U.S. and Northern and Southern U.S. Great Plains locales as to permit the three locales to be grouped together.

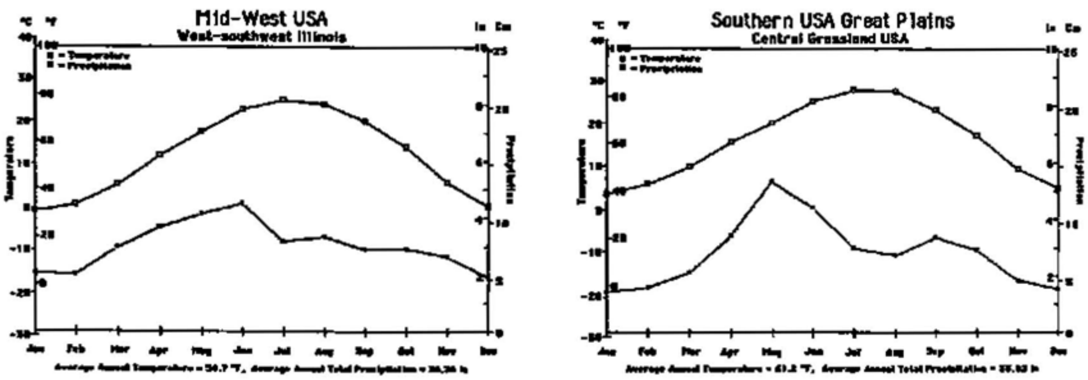

Figure 5. Comparison of the Temperature and Precipitation Profiles of the Midwest U. S. and Southern U. S. Great Plains Locales.

The close-equivalence sets that were identified are listed here:

(a)	Midwest U.S.	Southern U.S. Great Plains	Northern U.S. Great Plains
(b)	Tropical Western Pacific Ocean	Australia Indonesia Semi-enclosed Sea	
(c)	Eastern North Pacific	Eastern North Atlantic (Azores to Africa)	
(d)	Canadian Boreal Forest	Siberian Boreal Forest	
(e)	Sonoran Desert	Central Australia	
(f)	Greenland Plateau	Antarctic Plateau	
(g)	Amazon Basin	Congo Basin	
(h)	Greenland Sea	Bering Sea	Beaufort Sea

4. The Evaluation Team recommended the Southern U. S. Great Plains as the first primary locale and eliminated Midwest U.S. and Northern U. S. Great Plains as candidate locales for primary sites.

Rationale: All three locales exhibit favorable logistics; high geographical homogeneity; a wide variety of cloud types; and large intra-annual variability of surface flux properties and weather, including cloud types, temperature, and specific humidity. A mid-continental locale was also favored by the expected sensitivity of mid-continental locations to climate change and the consequent desire to obtain data for testing climate models at such a location. Initially the Evaluation Team had recommended the Midwest U. S. locale, on the basis of greater variability in surface fluxes and pollutant aerosol concentrations. However it was emphasized that if synergistic potential or logistical considerations were found tor strongly favor a site in one of the Great Plains locales, the effect of selecting one of these alternatives would be slight from a scientific perspective.

Based on discussions at the Science Team meeting, the recommendation for the first locale was changed to the Southern Great Plains Locale, largely because this locale additionally affords the opportunity for synergistic activity with other ongoing and planned meteorological projects and facilities. A key facility is the network of wind profiling stations that will be installed in this area as part of the planned National Oceanic and Atmospheric Administration (NOAA) Wind Profiler Demonstration Network; the locations of these stations are indicated in Figure 6. The high density of vertical atmospheric structure data from this network will be of paramount importance to a number of ARM experiments, specifically including those constructing or using four-dimensional data sets. Another pertinent project is the Global Energy and Water Cycle Experiment (GEWEX). Also the Southern U.S Great Plains, being at lower latitude than the other locales, is situated somewhat more favorably to the orbit of the TRMM satellite, which is expected to provide valuable measurements of key physical and radiative variables.

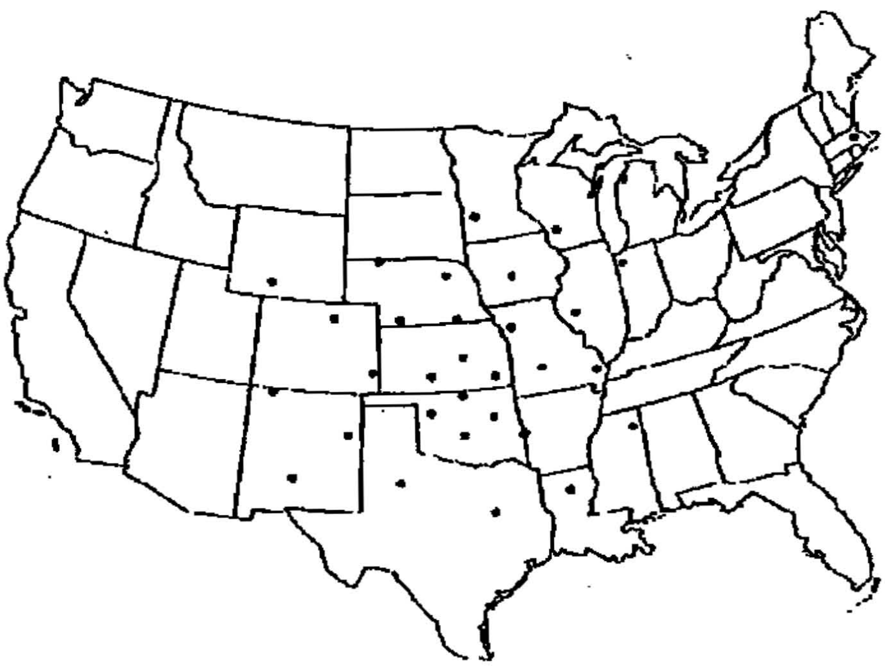

Figure 6. Locations of Stations for Planned NOAA Wind Profiler Demonstration Network.

Alternatives: Both the Midwest U.S. and the Northern Great Plains are close alternatives to the Southern Great Plains. The Midwest locale experiences more variability in aerosol loading than the Great Plains locales (favoring Midwest); Northern Great Plains locale has greater probability of experiencing snow cover (favoring Northern Great Plains). Although the three locales differ climatologically and geographically in some respects, all present a considerable variety of cloud types and a wide annual range of temperature, precipitation and surface flux properties. Therefore, even if synergistic potential or logistical considerations beyond those already noted are subsequently found that would strongly favor a site in the Midwest U.S. or the Northern Great Plains, the effect of selecting one of these alternatives would remain slight from a scientific perspective.

Cumulative Record: 1 primary locale recommended, 10 locales eliminated.

5. The Evaluation Team recommended the Tropical Western Pacific Ocean (TWPO) as the second primary locale.

Rationale: The Tropical Western Pacific Ocean (TWPO) is the best locale for observing cumulonimbus clouds and is excellent for observing fair weather cumulus clouds. Although cumulonimbus clouds are fairly prevalent at the previously-selected primary locale (Southern U.S. Great Plains), they arise from different mechanisms, such as surface heating, frontal boundaries, and traveling disturbances generally absent in the TWPO, and exhibit different drop size distributions. Similarly, fair weather cumulus clouds are widespread over the surface of the Earth, and are thus important for the ARM Program, but they are not present with great frequency at the Southern U.S. Great Plains locale and again arise from different formation mechanisms. The TWPO locale experiences extreme high temperature and specific humidity for an ocean locale. The TWPO is the only candidate locale in which the El Niño - Southern Oscillation and related phenomena can be observed.

This locale is essential for several experiments that have been proposed for the ARM Program, e.g., the examination of anomalous infrared absorption at high-sea surface temperature (Raval and Ramanathan 1989) and examination of the influence of deep convection on the transport of water vapor to the high troposphere and on cirrus cloud distribution over the ocean (Draft Site Mission).

Alternatives: At the Science Team meeting the Australia-Indonesia Semi-enclosed Sea (AISS) was proposed as a near-equivalent alternative to the Tropical Western Pacific Ocean, largely on the basis of the logistical and synergistic advantages afforded by existing programs conducted in the vicinity of Darwin, Australia.

In view of the suggestion of the AISS locale, the relative merits of the AISS and the TWPO toward meeting ARM objectives were examined in some detail following the Science Team meeting. Essentially the climate of the AISS is more monsoonal and less truly tropical than that of the TWPO. During June, July and August (JJA) deep convection is uncommon, with cumulonimbus clouds observed only 5% of the time. Fair-weather cumulus clouds are most common during JJA. During December, January and February (DJF) a monsoon circulation is established, with cumulonimbus clouds observed 15% of the time. However even this is considerablyl less than at the TWPO (20%). The longwave cloud radiative forcing (CRF) at the AISS exceeds 80 W/m^2 during DJF, which is nearly as high as anywhere in the tropics, but during JJA the longwave CRF is less than 20 W/m^2. The precipitation patterns in the two locales are very different, with Darwin receiving almost all of its precipitation within a two-month period (January and February), in contrast to the TWPO, which has a relatively uniform precipitation pattern over the year.

Table 5 compares seasonal cloud frequencies, temperature, and water vapor for the two locales:

The strong seasonality at Darwin is illustrated by the cloud frequencies for cumulonimbus, cirrus,

Table 5. Comparison of Cloud Frequencies, Temperature, and Water Vapor for Darwin, Australia, and Tropical Western Pacific Ocean Locales

	Darwin		TWPO	
	DJF	JJA	DJF	JJA
Cloud Type Frequency				
Stratus	30	20	30	30
Cumulonimbus	15	5	20	25
Cirrus	60	30	70	65
Cirrus alone	3	3	0	0
Altostratus	60	30	70	65
Cumulus	45	50	45	45
Clear	0	5	0	0
Temperature (°C)	28	20	28	24
Water vapor (g/kg)	18	14	18	18

and altostratus, and by temperature and water vapor content.

A number of investigators expressed preference for the AISS locale explicitly because of the seasonality. Specifically mentioned were the ability to conduct a study at that locale to focus on the monsoonal break period, and the ability to stress models by taking advantage of the seasonal variability. However, concern was expressed that cloud forcing was different from that in the open ocean, being dominated by more complex flow patterns.

Further concerns were expressed that a substitution of the AISS locale for the TWPO might have the effect of losing the ability to capture certain key ARM objectives, specifically the study of deep tropical convection, with resultant transport of water vapor to the high troposphere, and of the possible dependence of this convection on widespread changes of sea-surface temperature. Since high ocean temperatures drive this convection, changes in sea surface temperature associated with El Niño cycles would be a unique means of studying this dependence. Such studies would require measurements over at least one and preferably two or more El Niño cycles; these cycles have a duration of approximately two years. This interannual variability is viewed as a close analog to climate change. Sea-surface radiative fluxes can change by as much as 50 to 60 W/m^2 over the El Niño cycle. Because of the unique attributes of the TWPO, if a primary ARM site were not established in this locale, it would be necessary to conduct extensive measurements in this locale on a supplementary basis.

Despite the numerous logistical advantages, and certain scientific attributes that would favor the AISS, it was the prevailing sense of the members of the Science Team that the issues initially favoring the TWPO strongly favored that locale over the AISS. For those reasons the TWPO remains the recommended choice for the second ARM locale.

In lieu of either the TWPO or the AISS, consideration might be given to tropical forest locales, either the Amazon Basin or the Congo Basin. These alternative locales provide opportunities to observe altostratus and large fair weather cumulus clouds, but neither is as good as the Tropical Western Pacific for observing cumulus clouds. Marine stratus are not present in the tropical forest locales, but these are captured at the Eastern Pacific Ocean Locale. The cumulonimbus clouds of the tropical forest locales do not reach the same vertical extent as those of the Tropical Western Pacific, and therefore do not afford the same opportunity as does that locale to observe the high altitude vertical transport of water vapor. Consequently these locales are viewed as inadequate substitutes for TWPO or AISS.

Cumulative Record: 2 primary locales recommended, 11 locales eliminated.

6. The Evaluation Team recommended the Eastern North Pacific Ocean or the Eastern North Atlantic Ocean as the third primary locale.

Each of the recommended ocean locales exhibits distinct radiative properties essential to ARM.

Rationale: The principal reason for selecting one or the other of these locales is the high frequency of low-level marine stratus clouds. Both the Eastern North Pacific and the Eastern North Atlantic locales exhibit a high frequency of low-level marine stratus, which is a key cloud type governing the global energy budget. Marine stratus clouds are less mixed with other cloud types in the Eastern North Pacific than at alternative locales; thus they can be observed in this locale in their purest form. This locale also experiences moderate latent heat fluxes and spans a range of conditions. Also, large variations in anthropogenic aerosols (from California) are expected for different synoptic situations, permitting the testing of aerosol influences on cloud optical properties. The region of the Eastern North Atlantic Ocean extending from the Azores to Africa also offers a variety of marine cloud types, including the transition from marine stratus to stratocumulus to fair-weather cumulus. In addition, this locale offers the potential for synergism with the First International Satellite Cloud Climatology Project (ISCCP) Regional Experiment (FIRE) Program. An ARM site in either of these locales would meet the requirements of an eastern ocean margin locale.

Formation and development of winter storms can be observed in the Eastern North Pacific Ocean locale. However, such storms can also be observed over the Midwest U.S. and formation processes are largely independent of surface properties, so the locale may not represent an incremental gain from this perspective.

Alternatives: There is no suitable alternative to this locale among the candidate locales. The clouds are the key to the selection of this particular locale. A suitable alternative must provide adequate opportunity to observe low-level marine stratus clouds. Alternative locales would in all likelihood be marine locales and, therefore, subject to many of the same criticisms as the Eastern North Pacific/Eastern North Atlantic locale itself. Thus, logistical considerations would seem to favor the originally selected locale over possible alternatives. If this locale were omitted from the set and not replaced by a suitable alternative, the remaining locales would not cover the full complement of radiatively significant clouds types.

From the surface property and surface flux perspectives, this locale is typical of mid-latitude ocean locales and would serve as a "generic mid-latitude ocean locale" in the absence of any other such locale. However, other mid-latitude ocean locales could serve equally well in this regard.

A possible alternative approach to establishing a locale that captures the marine stratus clouds of this locale is that of combining the Eastern North Pacific and the Northwest U.S./Southwest Canada Coast Locales. The Eastern North Pacific provides the ability to observe low-level marine stratus clouds over a homogeneous background. Surface homogeneity is lost by combining the two locales. Although it should be possible to observe optical properties and radiative effects of marine clouds from coastal sites, an ocean site is required to observe cloud formation and maintenance processes characteristic of the open ocean, because these can only be observed from an ocean site.

Comments: From an atmospheric perspective, both of the recommended ocean locales (Tropical Western Pacific Ocean; Eastern North Pacific/ Eastern North Atlantic) are essential, and there are no really good alternatives to such a pair. The locales provide the best opportunity to observe widespread—hence, important for the ARM program—types of marine clouds. Moreover, the locales are complementary in that the cloud types observable in one locale are not present with sufficient frequency to be readily observed in the other. If one of the recommended Pacific Ocean locales is for some reason not selected to host a site, then either the Gulf Stream off Eastern

N. America or the Sargasso Sea is considered essential in order to observe a full complement of radiatively significant cloud types.

Cumulative Record: 3 primary locales recommended, 1 identified as an alternative, 11 locales eliminated.

7. The Evaluation Team recommended North Slope of Alaska as the fourth primary locale.

Rationale: The North Slope of Alaska was selected because it experiences highly diverse atmospheric and surface properties, ranging from cold air temperatures and high albedo when covered with ice or snow and polar night at mid-winter to moist vegetation and low sun in summer. It also experiences a wide range in surface fluxes, although a wide range of surface fluxes can also be observed from previously recommended locales at the Southern U.S. Great Plains locale or its alternative albeit under different temperature conditions, etc . The North Slope locale is climatologically distinct in terms of latitude, and temperature. Together, the two land locales, the Southern U. S. Great Plains and the North Slope of Alaska, span a wide range of atmospheric, surface flux, and geographic conditions. The locale is situated in the region of largest probable climate feedbacks, relating surface temperature, surface albedo, evaporation and cloud cover; it is a polar atmospheric heat sink in winter. Compared to other high-latitude locales, the North Slope locale is logistically appealing.

Alternatives: The high-latitude ice plateau locales (Greenland, Antarctic) and the high-latitude ice-free sea locales (Circumpolar Southern Ocean or Norwegian Sea) locales are alternatives to the North Slope of Alaska. If the North Slope locale were eliminated from the set of ARM sites, the wide range of conditions (temperature, surface fluxes, etc.) spanned by this locale and the Southern U.S. Great Plains could be partially restored only by the inclusion of one of the listed alternatives.

Logistically, the North Slope is preferable to the alternatives, with the possible exception of the Antarctic Plateau. At the Science Team meeting, some investigators expressed preference for an Antarctic site, noting polar stratospheric ozone and low concentrations of southern hemisphere aerosol as possible reasons of preference. However, these views were not generally seen as compelling, especially in the context of the wide seasonal variability at the North Slope locale.

Cumulative Record: 4 primary locales recomended, 1 identified as an alternative, 11 locales eliminated.

8. The Evaluation Team recommended the Gulf Stream off eastern North America as the fifth primary locale.

Rationale: The Gulf Stream locale exhibits extreme ranges in magnitude of surface heat fluxes. Cold air outbreaks are extreme in magnitude, and air-water temperature differentials are greater here than anywhere else. This is the best locale for exercising surface boundary flux models under extreme conditions. The Gulf Stream locale is the best of the candidate locales for observing variability in surface energy fluxes, fair-weather cumulus cloud fields and mature storms, and it is a key locale for observing altostratus clouds.

This locale provides the best opportunity to observe extra-tropical deep cyclones. The processes best observed here—formation and maturation of marine cumulus clouds—are universal, but the Gulf Stream locale gives the highest "signal-to-noise ratio" for observing these processes involved. The Gulf Stream locale is the best place (because of their frequency) to observe mature synoptic storms. These are the only such cloud systems that might actually be resolved by a GCM, and hence offer the possibility of testing microphysics parameterizations without the usual difficulties associated with sub-grid variability. Convective activity during cold air outbreaks is interesting, but has less climatic significance because of its localized nature.

The vicinity of the Gulf Stream is a key locale for observing altostratus clouds and the formation and maturation of storms of tropical origin. Storms observed in the Pacific Ocean locales do not reach the maturity of those observed in the Atlantic Ocean. Further, the Gulf Stream off eastern North America is the site of extreme air-sea fluxes, especially during cold-air outbreaks from the North American continent during winter.

Alternatives: Because of the extreme difficulties in establishing and maintaining an ARM site in the Gulf Stream locale, the possibility of alternative locales must receive special consideration. More than one alternative locale (one for clouds, another for fluxes, etc.) may be required to adequately observe these phenomena elsewhere. On the other hand, rather than deal with multiple alternatives, it may be preferable to use a campaign approach to obtain the necessary data at the Gulf Stream locale.

The Mid-Atlantic Coastal Plain was considered as a possible alternative to the Gulf Stream off Eastern North America. From a logistical standpoint, the Mid-Atlantic Coastal Plain is greatly preferable to the Gulf Stream locale. This locale offers suitable, albeit inferior, frequency of altostratus, a primary cloud type for the Gulf Stream locale. However, a site in the Mid-Atlantic Coastal Plain would be complementary in many respects to the two previously selected primary land locales.

The choice of the Mid-Atlantic Coastal Plain as an alternative would greatly diminish the variability in surface energy flux distributions that would be accessed in comparison to the Gulf Stream locale. The high heat fluxes from ocean to atmosphere in the Gulf Stream Locale result from large air-sea temperature differences, dry air and strong winds. These are satisfied during cold-air outbreaks during winter. The large air-sea temperature differences are sustained by advection of warm water by the Gulf Stream, typically 18°C during winter. Similar meteorological conditions can be found over the Great Lakes in winter, but there the heat in the water is supplied only by summer warming, and this can soon be exhausted leading to freezing water temperatures and even the formation of ice.

A location somewhat east of the Gulf Stream (e.g., north of the Sargasso Sea locale) might prove equally suitable for cloud and cloud-radiation balance studies while better satisfying the constraint of surface homogeneity, but with loss of extreme values of surface fluxes.

Additional possible alternative locales to capture high surface latent heat fluxes include Southern India, after monsoonal rains, and rain forest, particularly at the start of the dry season. Irrigated central California may be another alternative locale, but irrigated areas have been discounted by considerations of homogeneity. Other areas may experience conditions of high heat fluxes on time scales of a day or so (e.g., the rice-growing areas of Southern Texas after the passage of a cold front or the Southern U.S. Great Plains or Midwest U.S. after a cold front passage is preceded by widespread rain).

Data presented in Appendix D compare latent and sensible heat fluxes at possible alternative land sites with those reported for the Gulf Stream locale for averaging times of a month. Much greater fluxes are found at the Gulf Stream locale. For the alternative land locales, significant variations in surface fluxes can be expected on time scales of an hour to days. For example, latent heat flux within the contiguous United States sometimes reaches peak values of 400 to 500 W/m^2 (compared with peak values over the Gulf Stream in excess of 1000 W/m^2). These peaks over the land are associated with the diurnal cycle of insolation, so over the period of a few hours large changes in fluxes can be expected over land. Even more rapid changes can result from sudden changes in surface moisture associated with rainfall. Over the ocean the diurnal modulation of the fluxes is very much smaller and, in the absence of ice, the latent heat flux is never limited by the availability of surface moisture. Consequently the time scales of changes in the turbulent fluxes over the ocean are those of meteorological features or advective changes in sea-surface temperature, i.e., many hours to weeks.

Cumulative Record: 5 primary locales recommended, 1 identified as an alternative, 11 locales eliminated.

9. The Evaluation Team selected a suite of locales, complementary to the set of primary locales, that are necessary in order to span the ranges of important attributes. The sites in these locales would be occupied

intermittently or on a campaign basis to provide additional measurements relevant to specific issues which cannot be adequately addressed at one or more of the primary sites.

Central Australia or Sonoran Desert

Rationale: The high temperatures and low specific humidities of the Central Australia or Sonoran desert locales permit substantial extension of the range of conditions over which models can be tested, especially clear-air radiative transfer models. The Central Australia locale is slightly favored because of its homogeneity and synergistic potential. The Sonoran Desert is favored because of its proximity and consequent logistic favorability.

Northwest U.S.—Southwest Canada Coast

Rationale: This locale is an intentionally heterogeneous locale for stressing cloud models in coastal-mountain orographic situations. Marine stratus clouds present at this locale exhibit very low droplet concentrations because of low pollutant concentrations.

Although the Science Team recognized the necessity of including intentionally heterogeneous locales in the set of supplementary locales in order to stress and test cloud and radiation models, concern was expressed that because of the intense orography, coupled with the land-ocean boundary, this locale might prove too difficult, at least as an initial intentionally heterogeneous locale. To overcome this concern, inclusion of a locale with less intense orography was suggested. One possibility would be to examine coastal effects on the west coast of the U. S., but at lower latitude where the orography is less intense. A study at such a lower latitude locale, might gain synergism by proximity to the primary ARM site in the Eastern Pacific Ocean.

Amazon Basin or Congo Basin

Rationale: This locale category is climatologically important, with moderate intra-annual variability and little interannual variability. Low interannual variability diminishes the need for long-term occupancy. However, the length of occupancy should be extended if predicted results based on models are not consistent with observations. In the event that continuous measurement activities cannot be maintained in the Tropical Western Pacific Ocean locale, then the tropical rain forest locales become important alternatives.

Beaufort Sea, Bering Sea, or Greenland Sea

Rationale: The Beaufort Sea, Bering Sea, or Greenland Sea are key locales for observing the ocean ice edge, which is important for studying changes in albedo and surface fluxes accompanying the growth and decay of sea ice, and the possible albedo compensation by the decay or growth of marine stratus clouds. While sea ice and stratus clouds interact differently with atmospheric radiation, they are frequently difficult to distinguish in remotely sensed images.

The Beaufort Sea locale is perhaps the most appealing logistically. It is frozen in winter and melts in summer providing ample opportunity for ice-edge studies. The proximity to the recommended North Slope of Alaska locale affords the opportunity for campaigns in conjunction with a site in that locale.

Cumulative Record: 5 primary locales recommended, 1 identified as an alternative; 4 supplementary locales identified, with 4 locales identified as alternatives; 17 locales eliminated.

Final Result

The results of the locale recommendation process are summarized here:

Primary Locales: Five locales, including one pair of alternatives, were recommended as primary locales:

1. Southern U.S. Great Plains
2. Tropical Western Pacific Ocean
3. Eastern North Pacific Ocean or Eastern North Atlantic Ocean
4. North Slope of Alaska
5. Gulf Stream off Eastern North America, extending eastward

The locations of these primary locales are shown in Figure 7.

Supplementary Locales: Four locales, including three sets of alternatives, were recommended as supplementary locales:

1. Central Australia or Sonoran Desert
2. Northwest U.S.-Southwest Canada Coast
3. Amazon Basin or Congo Basin
4. Beaufort Sea or Bering Sea or Greenland Sea

The locations of these supplementary locales are shown in Figure 8.

Of the initial 31 locales, 17 locales were eliminated from further consideration.

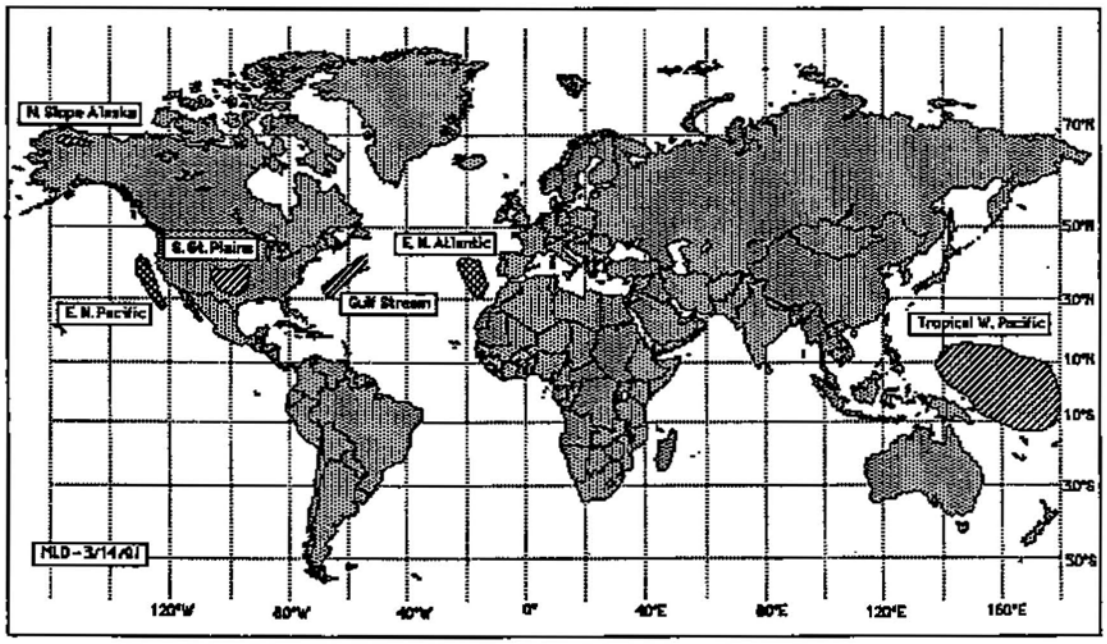

Figure 7. Recommended Primary Locales

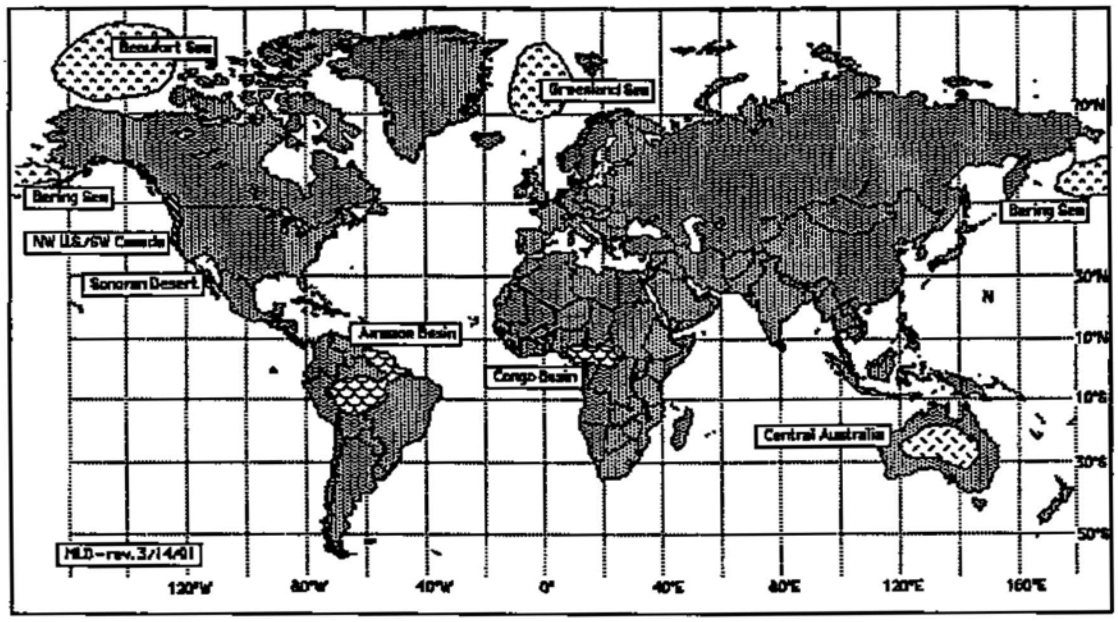

Figure 8. Recommended Supplementary Locales

Locale Recommendations

Locale Recommendations

The recommended set of primary ARM locales is presented here ordered according to the incremental scientific understanding expected to be gained by conducting ARM measurements at sites within these locales and by logistical considerations. The primary locales constitute a set that was selected to span the range of attributes that are dominant with respect to the models of clouds and their influence on atmospheric radiation. If any one of these locales is removed, the remaining locales do not provide adequate coverage of radiatively important attributes.

In the judgment of the Evaluation Team, in concurrence with the principles specified at the La Jolla meeting, it is important for logistical reasons that the first land locale be occupied and producing valid, high-quality data as soon as possible. The experience gained at this locales site will prove invaluable when subsequent sites are established. This principle clearly mandates the choice of the Southern U.S. Great Plains locale (or one of the two alternatives, Northern Great Plains or Midwest U.S.) for the initial ARM site.

Although logistical difficulties are associated with ocean locales, ocean sites are crucial to meeting ARM objectives. Therefore, a site in the second locale, the Tropical Western Pacific Ocean (TWPO), should be established as soon as feasible. The order of occupancy of the remaining sites does not appear to be so critical as that of the first two. As the ARM Program evolves, compelling reasons may appear for occupying the remaining sites in some order other than that proposed. It is the judgment of the Evaluation Team that the order in which primary sites 3 to 5 are occupied would not have a significant effect on the scientific objectives of the ARM Program.

In the discussion that follows the scientific justifications for establishing ARM sites are presented for the recommended primary and supplementary locales. Also presented are brief summaries of logistical considerations and of programs other than ARM which might afford the possibility of cooperative interaction with ARM. Logistical considerations are abstracted from the discussion presented in Appendix E, which presents a discussion for all locales examined in this study. Programs referred to in the discussions of synergistic considerations are described in more detail in Appendix F.

Primary locales were selected to span the range of attributes that are dominant in modeling clouds and their influence on atmospheric radiation.

Primary Locales

Sites in the primary locales will operate with a full complement of instrumentation required for carrying out the ARM measurements pertinent to the scientific objectives of the particular locale and will be occupied for an extended period of time, up to a decade.

1. Southern U.S. Great Plains

Key requirements for the first ARM locale include favorable logistics; high geographical homogeneity; a wide variety of cloud types; large intra-annual variability of surface flux properties and weather, including cloud types, temperature, and specific humidity. These requirements are met by the Midwest U. S., Northern Great Plains, and Southern Great Plains locales. Extratropical cyclones pass through all three areas in the fall-to-spring seasons, with resulting stratus, imbedded convective and cirrus clouds. The spring-and-summer seasons produce significant convective activity of both airmass-type thunderstorms and organized mesoscale convective systems. Cirrus clouds are common during winter within these locales. These locales also offer a wide range of temperature and specific humidity, including significant synoptic and diurnal variations. A mid-continental locale also was favored by the expected sensitivity of mid-continental locations to climate change and the consequent desire to obtain data for testing climate models at such a location. The Southern U.S. Great Plains locale was recommended as the first ARM locale because it additionally affords the opportunity for synergistic activity with other ongoing and planned meteorological projects and facilities.

Logistical Considerations

All three mid-continental U. S. locales are logistically favorable.

Synergism with Other Programs

The Southern U.S. Great Plains locale was recommended as the first choice over the Northern U.S. Plains and the Midwest U.S. largely because of the synergism that will be afforded to ARM resulting from the high density of wind profiling stations that will be installed in this area as part of the planned NOAA Wind Profiler Demonstration Network. The high density of vertical atmospheric structure data from this network will be of paramount importance to a number of ARM experiments.

There are several activities in other programs within the Southern U.S. Great Plains locale that might form the basis for synergistic collaboration with ARM. The National Severe Storms Laboratory at Norman, Oklahoma, maintains a network of research quality meteorological instrumentation including a variety of radars. This institution also conducts numerous specialized field projects in this vicinity. There is a Long Term Ecological Research (LTER) site (tall grass prairie; Konza Prairie Research Natural Area), located 10 km south of Manhattan, Kansas. This site was the location of field measurements under the First ISCCP Field Experiment (FIFE) conducted by the International Satellite Land Surface Climatology Project (ISLSCP). This locale is also the site of the First ISCCP Regional Experiment (FIRE) Cirrus IFO-II project, to be conducted in November and December 1991, in southern Kansas. Another pertinent project is the Global Energy and Water Cycle Experiment (GEWEX). Also the Southern U.S Great Plains, being at lower latitude than the other locales, is situated somewhat more favorably to the orbit of the Tropical Rainfall Measuring Mission (TRMM) satellite, which is expected to provide valuable measurements of key physical and radiative variables.

2. Tropical Western Pacific Ocean

Ocean locales are important for ARM both because of the large fraction of the Earth surface covered by oceans and because of the globally important cloud types and meteorological situations that are found only at ocean locations. Numerous experiments pertinent to ARM objectives and certain unique experiments of key importance to ARM objectives can be performed at the TWPO locale. The locale is characterized by a large pool of warm ocean water that is unique globally. Cumulonimbus clouds are frequent, with a resultant large flux of water to the high troposphere; this convective activity is thought to be highly sensitive to climate warming. Other cloud types are frequently observed, including fair-weather cumulus and altostratus associated with organized convective systems. Cirrus clouds also occur frequently as outflow from convective towers. Surface water-vapor concentrations are among the highest globally, permitting tests of anomalous water vapor absorption. There is large multi-year atmospheric variability (El Niño - Southern Oscillation events) relative to other ocean locales.

Logistical Considerations

The TWPO locale is extremely distant from the U.S. but is served by major airports. The locale is ice free and has several islands (some U.S. owned) that could be used as bases for operations. Staging areas with docks and other facilities are available in Australia and the Philippines. The U.S. military maintains bases on Kwajalein and other islands.

Synergism with Other Programs

As part of the World Ocean Circulation Experiment (WOCE), the Tropical Ocean-Global Atmosphere (TOGA)/Coupled Ocean Atmosphere Response Experiment (COARE) will be conducted in the TWPO over a several-year period. Some pilot studies were initiated in 1990. These will be extended to an enhanced monitoring network in the period 1991-1994. An intensive observational period is currently planned for fall of 1993.

The Australian Commonwealth Scientific and Industrial Research Organization (CSIRO) is conducting a satellite validation campaign starting in 1991 using shipboard radiometers and radiosoundings in the TWPO.

3. Eastern North Pacific or Eastern North Atlantic

Eastern ocean margins represent another prevalent and climatologically important cloud and meteorological situation that is quite distinct from that represented by the TWPO. Both the Eastern North Pacific and the Eastern North Atlantic locales exhibit a high frequency of low-level marine stratus, a key cloud type governing the global energy budget that persists for long periods of time over relatively large areas of the Earth. Although they can have a significant impact on radiative transfer and the Earth's heat budget, these clouds are poorly understood and inadequately treated in climate models.

Marine stratus clouds are less mixed with other cloud types in the Eastern North Pacific than at alternative locales; thus they can be observed in this locale in their purest form. They occur off the coast of southern California with a frequency of 55% in the wintertime and 70% in the summer. Transitions commonly occur between marine stratus and broken cloud conditions. Understanding the mechanisms and developing models for this transition are crucial to the simulation of climate change. Large variations in anthropogenic aerosols (from California) are expected for different synoptic situations.

The region of the Eastern North Atlantic Ocean extending from the Azores to Africa also offers a variety of marine cloud types, including the transition from marine stratus to stratocumulus to fair-weather cumulus. An ARM site in either of these locales would meet the requirements of an eastern ocean margin locale.

Logistical Considerations

For an ocean locale, the Eastern North Pacific Ocean affords substantial logistical advantages and synergistic possibilities. The locale is easily accessible and ice free. U.S. west coast staging areas are available, and islands exist that could be used as operational bases.

The Eastern North Atlantic Ocean locale is distant from the U.S. but is served by international airports in Portugal and Spain. Islands (foreign territory) are available for operational bases. Staging areas (Gibraltar, Lisbon) are available. The locale is ice free. International arrangements would be required.

Synergism with Other Programs

The WOCE Implementation Plan of March 1989 identified the time series stations PRS 2 and PRS 3 as a U.S. contribution to WOCE in the North Pacific. PRS 2 is located near Oahu, and PRS 3 will be located off the coast of California. These stations would form a pair across the eastern subtropical gyre in the North Pacific, and allow the development of an "index of circulation" for the gyre. PRS 3 also could be used to monitor the eastern boundary region of the North Pacific for transport estimates within the California Current. PRS 3 should be associated with the heat flux line P2 at 32° N and the current meter moorings PCM 2 off the California coast. The goal is for both stations to run monthly for ten years. The station off Oahu has been operating for two years, and establishment of a similar station in the California Current near 32° N to monitor the eastern rim of the gyre has been recommended. FIRE Phase I conducted a major field experiment to study marine stratocumulus clouds off the southwest coast of California in July 1987.

The Eastern North Atlantic Ocean locale offers the potential for cooperative interaction with the FIRE Program.

4. North Slope of Alaska

The North Slope of Alaska locale, in combination with the Southern U. S. Great Plains, encompasses a wide and highly diverse range of surface property attributes. This locale exhibits large seasonal variation in surface flux properties, more than competing locales in the deserts, tropical rain forests or northern boreal forests. The seasonal variation from snow-ice cover to vegetation in effect offers two climatological locales at one locale. The locale is well suited to modeling, exhibiting a gentle uniform slope without severe local inhomogeneities.

Logistical Considerations

Although weather conditions can be severe, this locale actually affords substantial logistical strengths. The Dalton Highway provides year-round access to Prudhoe Bay. There are daily year-round flights to Barrow and nearby population centers for logistical support and provision of supplies.

Synergism with Other Programs

A LTER Tundra site (Arctic Tundra Site) is located at Toolik Lake 260 miles north of Fairbanks, Alaska, in the northern foothills of the Brooks range. The LTER program is a National Science Foundation (NSF) funded, long-term ecological research program. DOE also supports this site and several others through the R4D project. One of these sites, Franklin Bluff is reported to have relatively uniform terrain and would be suitable as an ARM site. It is accessible by road year-round.

There is a NOAA Geophysical Monitoring for Climate Change (GMCC) Observatory at Barrow, Alaska. This is a logistically attractive site, but is close to the Arctic Ocean and is strongly influenced by it.

Another potential site is the University of Alaska site at Poker Flats. This is a taiga site roughly 40 miles north of Fairbanks. Facilities are available at this site. Previous radiation measurements have been made here as part of another DOE program.

5. Gulf Stream Off Eastern North America

The Gulf Stream off eastern North America exhibits frequent mature cyclonic storms, including occluded systems and large scale induced stratiform activity with a reduction in the frequency of embedded convection. In winter, stratus and altostratus each occur with a frequency of 50%. In summer, stratus occurs with a frequency of 30%, altostratus with a frequency of 45%. Such conditions provide tests of the treatments of widespread stratiform clouds in global-scale models. This is a genesis region for storms of various types, including cumulonimbus activity in cold air outbreaks and cyclogenesis with the proper synoptic conditions. Fair-weather cumulus clouds are also relatively common during the summer months. The proximity of this locale to the heavily populated east coast of the U.S. suggests a highly variable aerosol loading.

This locale greatly extends the range of surface energy fluxes over which models will be exercised. Cold air outbreaks are extreme in magnitude, and air-water temperature differentials are greater here than anywhere else. This is the best locale for exercising surface boundary flux models under extreme conditions.

Logistical Considerations

The locale is close to the U.S., and staging areas are available along the U.S. east coast. The locale is ice free but is logistically highly problematical because of high ocean currents and occasional severe storms. Some islands (Bahamas) are available in the southern area, but no islands are available in the northern areas. Mooring conditions (for buoys) would be difficult because of current speeds.

Because of the logistical difficulties associated with this locale, the Locale Recommendation Team felt that alternatives to this locale must continue to be considered. More than one alternative locale (one for clouds, another for fluxes, etc.) may be required to adequately observe these phenomena elsewhere. On the other hand, rather than deal with multiple alternatives, it may be preferable to use a campaign approach to obtain the necessary data at the Gulf Stream locale.

Synergism with Other Programs

There are a number of programs of other agencies that might afford synergism with an ARM site in the Gulf Stream Locale. The Atmosphere/Ocean Chemistry Experiment (AEROCE), a program whose goal is to characterize the chemical climatology over the North Atlantic Ocean, currently measures ozone, a wide range of chemical species in aerosols and precipitation and a number of tracers at Barbados, Bermuda, Canary Islands, and Ireland.

The Bermuda/Pacific Time Series Sites program which is part of Joint Global Ocean Flux Study (JGOFS) has established two open-ocean time-series sites, an Atlantic Site near Bermuda and a Pacific Site near Hawaii. The Bermuda site is located 80 km southeast of Bermuda and has been collecting data since October 1988.

Supplementary Locales

Sites in these locales are intended for intermittent or episodic occupation. Sites will be selected as required to address specific modeling needs that cannot be adequately addressed with measurements at the primary sites.

Supplementary locales are intended for intermittent or episodic occupation to address specific modeling needs.

1. Central Australia or Sonoran Desert

The high temperatures and low specific humidities of the Sonoran Desert or the Central Australian Desert permit substantial extension of the range of conditions over which infrared radiation transfer models can be tested. Totally clear sky is frequent, occurring at least 30% of the time in all seasons, enhancing the value of such studies in these locales.

Logistical Considerations

The Sonoran Desert locale, especially that portion within the United States, exhibits highly favorable logistical considerations. The Central Australia locale is extremely distant from the United States but has a major international airport. While some sites within this locale may have good local access, access to other sites is likely to be difficult. Local services are likely to be fair. The climate is hot, with occasional severe storms.

Synergism with Other Programs

A Global Baseline Surface Radiation Network (GBSRN) station is planned for the Central Australia locale. The CSIRO in Australia has a long history of research into atmospheric radiation, cloud physics, cloud radiation interaction and atmospheric radiative transfer modeling. In addition to the possibility of collaboration at the land sites, the CSIRO is mounting a satellite validation campaign starting in 1991 using shipboard radiometers and radiosoundings in the Western Tropical Pacific.

2. Northwest U.S.-Southwest Canada Coast

A campaign in the Northwest United States over several winter months would provide a test of the ability of circulation models to simulate the response of clouds to orographic inhomogeneity. This locale is very inhomogeneous and has abundant stratus/altostratus strongly modulated by the presence of a mountain range. Summertime stratus occurs with a frequency of 40% on the seaward side of the Cascade range and only 15% on the lee side. Wintertime nimbostratus also occurs significantly more frequently on the seaward slopes of the mountains. For these reasons, such a campaign should be considered by the ARM community.

Logistical Considerations

The locale is easily accessible. Sites within this locale are likely to have good local access. Access to sites within this locale would not be affected by weather (i.e., sites could be occupied and serviced all year). Sites in parts of this locale could possibly span international (U.S.-Canada) borders and may require special arrangements. A Canadian site should be accessible to U.S. investigators, but customs arrangements would be required for equipment. All services are likely to be available at sites within this locale. The climate is mild and damp; severe storms are infrequent.

Synergism with Other Programs

The University of Washington maintains an Atmospheric Sampling Site at Cheeka Peak, Washington. The Pacific Stratus Experiment has been conducted by NOAA and the University of Washington by aircraft and ship measurements off the Washington coast.

3. Amazon Basin or Congo Basin

A supplementary site placed in a tropical rain forest would be valuable for several reasons. Very deep convection occurs in this region almost daily. Surface latent heat fluxes are large and the specific humidity is often very high. Cloud and radiation models would be stressed in a number of ways. The accuracy of treatment of the water vapor continuum could be tested as well as radiative transfer in penetrating convective clouds. Smoke from biomass burning varies substantially, allowing tests of direct and indirect effects of this aerosol on radiative transfer and cloud microphysics. Seasonal variations in rainfall are large.

Logistical Considerations

The Amazon basin locale is remote from the United States but has a major international airport. Sites within this locale are unlikely to have good local access. Local services are likely to be poor. Climate is hot and humid. Language and cultural barriers may affect operations.

The Congo Basin locale is extremely distant from the United States. Sites within this locale are unlikely to have good local access. Local services are likely to be poor. Climate is hot and humid. Language and cultural barriers may affect operations.

Synergism with Other Programs

Of particular relevance to possible operation in the Amazon Basin are projects that are planned for the International Global Atmospheric Chemistry (IGAC) Programme on "Natural Variability and Anthropogenic Perturbations of Tropical Atmospheric Chemistry." These projects include the Biosphere-Atmosphere Trace Gas Exchange (BATGE) Program in the tropics, the goals of which are to determine the chemical fluxes and the factors that control these fluxes between representative tropical environments and the troposphere, and to develop the ability to predict the impact of these fluxes on both climate and land use changes. This program is in the planning stages and the exact location is not yet determined, but could be in the Amazon Basin.

The goals of the Deposition of Biogeochemically Important Trace Species (DEBITS) program are to determine the rates of deposition of biogeochemically important trace species and to identify factors that control these deposition fluxes. Initial activities are planned for southeast Asia, but expansion to other tropical locations is possible. The goals of a program entitled Impact of Tropical Biomass Burning on the World Atmosphere are to characterize the fluxes of chemically and radiatively important species from biomass burning into the global atmosphere, and to assess the consequences of biomass burning on the chemical and physical climate. A subprogram, the Biomass Burning Experiment (BIBEX) will conduct activities in the Amazon Basin over the next five to ten years and represents a potential candidate for interaction with ARM.

4. Beaufort, Bering, or Greenland Sea

The Beaufort, Bering and Greenland Seas contain the Arctic ice edge during the boreal winter and are characterized by open water covered by a thick blanket of fog and marine stratus during summer. A summer campaign would test the impact of snow and sea ice melt on surface reflectance and models of Arctic stratus formation. Aside from sea ice, the locales are homogeneous, considerably simplifying the measurement requirements.

Logistical Considerations

The Beaufort Sea locale is proximate to oil production activity at Prudhoe Bay; this could provide much logistical support. This locale is also proximate to the recommended North Slope of Alaska locale, permitting the possibility of conducting campaigns in conjunction with an ARM site in that locale.

The Bering Sea locale is distant from the United States. U.S.-owned islands may be available for operations. Staging areas in Alaska are available. International arrangements would be required if operations extended west beyond the U.S.-USSR convention line. The locale is in a marginal ice zone, but moorings would be relatively easy on the slope south of the ice edge.

The Greenland Sea locale is difficult to reach from the United States. Local services are poor. The climate is extremely cold with severe storms and high winds. Language and cultural barriers may affect operations.

Synergism with Other Programs

Programs with the potential for synergistic activities in these locales stem from the developing "Arctic Oceans Research Strategy" (1990) of the Interagency Arctic Research Policy Committee and includes the Interagency Western Arctic Program, which runs from 1990-1994 in the Bering, Chukchi, and Beaufort Seas and the Bering Strait.

References

References

Cess R. D. et al. 1990. "Intercomparison and Interpretation of Climate Feedback Processes in 19 Atmospheric General Circulation Models. J Geophys Res. 95: 16,601-16,615.

Ramanathan, V. et al. 1989. "Cloud-Radiative Forcing and Climate: Results from the Earth Radiation Budget Experiment." Science 243: 57-63.

Raval, A., and Ramanathan, V. 1989. "Observational Determination of the Greenhouse Effect." Nature 342: 758-61.

Trewartha, G., and L.H. Horn. 1980. *An Introduction to Climate.* McGraw-Hill, New York.

U.S. Department of Energy (DOE). February 1990. *Atmospheric Radiation Measurement Program Plan.* DOE/ER-0441, National Technical Information Service, Springfield, Virginia.

Appendixes

Appendix A

Locale Recommendation Procedure

This appendix outlines the procedure carried out by the Locale Recommendation Team, as developed by the Site Selection Team and the ARM Management Team at a facilitated planning meeting held in La Jolla, California, July 30 and 31, 1990. The objective of that meeting was to construct a procedure to recommend an ordered list of approximately six locales for ARM. Following are the definitions and principles used in developing the procedure:

- **Definition of "Locale"**

  A locale is a climatologically and geographically homogeneous region (except for locales that are intentionally heterogeneous, e.g., containing orographic features such as a mountain range or coast whose effects it is expressly intended to examine). Locales are reasonably compact and contiguous.

- **Principles Governing Locale Selection**

  The ensemble of selected locales should stress the models by spanning the domain of the radiation-influencing attributes.

  The climatological and surface attributes should be homogeneous within each of the locales—except when intentionally not so.

  Logistics and synergism with other programs should be considered.

Structure of Locale Recommendation Procedure

I. **Produce an initial list of candidate locales.** The La Jolla meeting specified that the initial list of candidate locales should be a reasonably comprehensive list of representative climatically and radiatively distinct regions. It was the view of the participants that the initial list need not be comprehensive since it would be circulated broadly to the CART community and the site selection team for review and with opportunity for additional candidate locales to be added.

The initial list of candidate locales should include representative climatically and radiatively distinct regions.

II. **Examine the candidate locales for suitability to ARM,** according to the sets of criteria discussed below. These evaluations can be undertaken simultaneously, by distinct teams (Criteria Examination Teams, CETs).

A. Climatological Stress

B. Surface Property Stress

C. Atmospheric Stress

D. Surface Energy Flux Stress

E. Climatological Homogeneity

F. Surface Property Homogeneity

G. Logistical Impacts

H. Synergism with other programs

The details of these examinations are discussed below.

Each of the CETs addressing the scientific criteria A through F will consider whether the total list of candidate locales that are being examined "spans" the space with respect to the attributes being examined. Should this not be the case, the CET will recommend additions or replacements to the list. Additional locales will then be considered by all the other CETs.

III. Evaluate and synthesize the reports from the CETs. A synthesizing procedure will evaluate the results of II. A through H above and will produce a list of scientifically ordered locales as well as a step by step scientific discussion and justification of the ordering of the list. The procedure is discussed below.

Tasks Within the Locale Recommendation Procedure

The CART locale recommendation procedure was divided into ten tasks. The first task must begin before any other can start and the last task cannot begin until all the others are complete, but the intermediate processes can proceed in parallel. The tasks are described here.

Task 1. Maintain list of candidate locales.

Objective:

To develop and maintain a list of locales which are potentially suitable for locating CART sites.

Output:

This task produces the initial list of candidate locales, which it forwards to tasks 2–9 to examine. Tasks 2–9 may propose changes to the list of candidate locales by suggesting additions or substitutions. Task 1 then provides the other tasks with the changes in the list of candidate locales.

Input:

This task is expected to make use of the following inputs in generating the list of candidate locales:

Input	Source
Site mission	ARM Program Office (Stokes)
Potential locales	Scientific Community Other Programs External Data Centers Site Selection Team

Task 2. Examine suitability of candidate locales to stress ARM models with respect to Climatic properties—CLIMATOLOGY TEAM

Objective:

To define the ranges of climatological conditions to characterize a particular locale. Of particular interest are those parameters which stress GCM models either through the extent of their ranges within a locale or by taking on extreme values. An integral part of this task is to assure that the suite of potential locales covers the necessary range of climatological conditions. The results of this process will be used in combination with the other characterizations to most efficiently assemble an ensemble of locales that fill the parameter space defined in the ARM goals.

Output:

A report detailing the suitabilityof each candidate locale for stressing models as a function of statistical properties of climatological variables. This will be based on a value ranking of grouped or ordered variables. An integral part of this task is to assure that the suite of potential locales covers the necessary range of climatological properties.

Input:

Proposed locales.

Climatological data from observation stations within the proposed locales.

Site mission.

Scientific community providing expertise as requested.

Scope:

This task will provide descriptive statistical data on the climatological data obtained for the proposed locales. The statistical data may include ranges of observations, means and estimators of variability that can be used to quantify the climatological properties being modeled. These analyses will form a part of the basis for determining the stress that will be imposed on the models.

Ordered Set of Steps:

a. Obtain a list of candidate locales, including their geographical boundaries or define boundaries.

b. Develop a set of generic model stress criteria that can be extracted from the descriptive numerical data for the candidate locales.

c. Order or group the climatological variables according to their relative importance to model stress evaluation.

d. Evaluate the range of extremes of the variables with respect to the model stress criteria and assign a model stress test suitability index (e.g., low, medium, high).

e. If candidate locales are insufficient for the above task, suggest new candidate locales based on climatological data.

Constraints:

Degree of specificity available for determining the model stress criteria.

Availability of climatological data.

Time available for the task.

Task 3. Examine suitability of candidate locales to stress ARM models with respect to Surface properties—SURFACE PROPERTIES TEAM

Objective:

To define the ranges of surface properties to characterize a particular locale. Of particular interest are those parameters which stress GCM models either through the extent of their ranges within a locale or by taking on extreme values. An integral part of this task is to assure that the suite of potential locales covers the necessary range of surface properties. The results of this process will be used in combination with the other characterizations to most efficiently assemble an ensemble of locales that fill the parameter space defined in the ARM goals.

Scope:

Surface properties whose variation have the greatest potential to stress the GCM models.

Output:

A report detailing the suitabilityof each candidate locale for stressing models as a function of statistical properties of surface variables. This will be based on a value ranking of grouped or ordered variables. An integral part of this task is to assure that the suite of potential locales covers the necessary range of surface properties.

Input:

Proposed locales.

Numerical data for each of the surface properties over the areas of potential locales and the geographic coordinates of the potential locales.

Site mission.

Scientific community providing expertise as requested.

Ordered Set of Steps:

a. Obtain a list of candidate locales, including their geographical boundaries or define boundaries.

b. Develop model stress criteria for surface properties.

c. Assemble data sets for each of the surface properties.

d. Compile a statistical characterization of the locale which should include, at least, areal and seasonal means, areal and seasonal ranges and extremes, description of variables in terms of areal variance, i.e., spatially lagged correlations and/or directional wave number spectra.

e. Evaluate the suite of potential locales to assure complete coverage of desired parameter ranges.

f. If candidate locales are insufficient for the above task, suggest new candidate locales based on surface properties data.

Constraints:

Degree of specificity available for determining the model stress criteria.

Availability of surface properties data.

Time available for the task.

Task 4. Examine suitability of candidate locales to stress ARM models with respect to atmospheric properties— ATMOSPHERIC PROPERTIES TEAM.

Objective:

To define the ranges of atmospheric properties to characterize a particular locale. Of particular interest are those parameters which stress GCM models either through the extent of their ranges within a locale or by taking on extreme values. An integral part of this task is to assure that the suite of potential locales covers the necessary range of atmospheric properties. The results of this process will be used in combination with the other characterizations to most efficiently assemble an ensemble of locales that fill the parameter space defined in the ARM goals.

Output:

A report detailing the suitability of each candidate locale for stressing models as a function of statistical properties of atmospheric variables. This will be based on a value ranking of grouped or ordered variables. An integral part of this task is the assurance that the suite of potential locales covers the necessary range of atmospheric properties.

Input:

Proposed locales.

Atmospheric data from observation stations within the proposed locales.

Site mission.

Scientific community providing expertise as requested.

Scope:

This task will provide descriptive statistical data on the atmospheric data obtained for the proposed locales. The statistical data may include ranges of observations, means and estimators of variability that can be used to quantify the atmospheric properties being modeled. These analyses will form a part of the basis for determining the stress that will be imposed on the models.

Ordered Set of Steps:

a. Obtain a list of candidate locales, including their geographical boundaries, or define boundaries.

b. Develop a set of generic model stress criteria that can be extracted from the descriptive numerical data for the candidate locales.

c. Order or group the atmospheric variables according to their relative importance to model stress evaluation.

d. Evaluate the range of extremes of the variables with respect to the model stress criteria and assign a model stress test suitability index (e.g., low, medium, high).

e. If candidate locales are insufficient for the above task, define new candidate locales based on atmospheric data.

Constraints:

Degree of specificity available for determining the model stress criteria.

Availability of atmospheric data.

Time available for the task.

Task 5. Examine suitability of candidate locales to stress ARM models with respect to surface energy flux properties—SURFACE ENERGY FLUX TEAM

Objective:

To evaluate selected surface energy fluxes averaged over candidate locales relative to the range of average flux values for ensembles of locales that are needed to effectively test large-scale models and their components used to simulate climate change for the ARM Program.

Scope:

Surface energy flux properties whose variation have the greatest potential to stress the GCM models.

Output:

A report detailing the suitability of each candidate locale for stressing models with respect to surface energy flux properties. This will be based on a value ranking of grouped or ordered variables. An integral part of this task is to assure that the suite of potential locales covers the necessary range of surface energy flux properties.

Input:

Proposed locales.

Site mission.

Temporally averaged meteorological data on precipitation, insolation and measures of latent and sensible heat flux representative of the locales. The averaging time could be as long as one month. Spatial averages of tens of kilometers would be acceptable.

Descriptions of the surface energy flux variables can be obtained from M. L. Wesely or R. L. Coulter of Argonne National Laboratory.

Textbooks such as W. Brutsaert's *Evaporation* can provide definitions and methods of computing the surface energy flux variables.

Ordered Set of Steps:

a. Obtain a list of candidate locales, including their boundaries, or define boundaries.

b. Develop model stress criteria.

c. Identify and classify, in order of relative importance, selected measures of surface energy fluxes in proposed locales and sets of locales.

d. Compute the relative measures of the selected surface energy terms. For sensible and latent heat fluxes over land, the potential evaporation could be used if data on the heat fluxes are not available. All terms could be normalized by division by insolation values.

e. Perform evaluation by selecting the likely extremes of the relative values (and insolation if that is the normalizing factor).

f. As necessary, analyze data to suggest new locales based on the relative surface energy flux values and supply information on any new locales to Task 1.

g. Supply information on grouping of measures, on mean measures for different locales, and on results of evaluation to evaluation team.

Constraints:

While data on latent and sensible heat fluxes over oceans might be available, such data over land might be insufficient and potential evaporation might have to be used instead. Locales provided by parallel internal functions to evaluate model stress requirements should be obtained before beginning the present evaluation.

Task 6. Examine climatic homogeneity of candidate locales—CLIMATOLOGY TEAM

Objective:

To assess homogeneity of candidate locales with respect to climate properties.

Scope:

Applies to attributes identified under climate properties; applies to each locale provided.

Output:

Evaluation/assessment of homogeneity of candidate locales with respect to listed climate properties.

Input:

Proposed locales.

Climate property data at many points within and perhaps near candidate locale.

Ordered Set of Steps:

a. Rank order importance of climate properties.

b. Identify climate properties for particular locale.

c. Evaluate proposed locale relative to spatial variability and gradient of each climate property.

d. Summarize climate property scores and identify climate properties with substantial and gross inhomogeneities.

Scale:

The following scale is to be used in steps c and d:

+ = minimal to slight inhomogeneities

0 = moderate inhomogeneities

- = substantial to gross inhomogeneities.

Comments:

1. The ensemble of proposed locales may by intent or design contain specified inhomogeneities.
2. It may be necessary to procure station records and/or source data to perform necessary calculations.

Task 7. Examine surface property homogeneity of candidate locales—SURFACE PROPERTIES TEAM

Objective:

To assess homogeneity of candidate locales with respect to surface properties.

Scope:

Applies to attributes identified under surface properties; applies to each locale provided.

Output:

Evaluation/assessment of homogeneity of candidate locales with respect to listed surface properties.

Input:

Proposed locales.

Surface property data at many points within and perhaps near candidate locale.

Ordered Set of Steps:

a. Rank order importance of surface properties.

b. Identify surface properties for particular locale.

c. Evaluate proposed locale relative to spatial variability and gradient of each surface property.

d. Summarize surface property scores and identify surface properties with substantial and gross inhomogeneities.

Scale:

The following scale is to be used in steps c and d:

+ = minimal to slight inhomogeneities

0 = moderate inhomogeneities

- = substantial to gross inhomogeneities.

Comments:

1. The ensemble of proposed locales may by intent or design contain specified inhomogeneities.
2. It may be necessary to procure station records and/or source data to perform necessary calculations.

Task 8. Examine logistical impacts of candidate locales—LOGISTICS TEAM

Objective:

The objective of this procedure is to evaluate the implications of logistical considerations on the selection of locales for CART operations. Logistics can represent assistance in ease of operation or complications that may make the operation more difficult or impossible.

Scope:

Locales that satisfy the scientific requirements for CART may be subject to environmental and logistical conditions that can assist or complicate operations. The logistical conditions may include such items as remoteness, national boundaries, suitability of operating environment, and availability of collateral data such as satellite data.

Output:

A description and assessment of the positive and negative logistical impacts on each proposed locale.

Comparison of locale logistical attributes with operational requirement.

Input:

Proposed locales.

Maps of relevant logistical elements (population distribution, national boundaries, satellite overpass patterns, terrain, and geophysical conditions).

Logistical, legal, and political constraints.

Lists of desirable locale attributes (information about candidate locales).

Operational requirements for performing ARM experiments (Site Mission).

Ordered Set of Steps:

a. Obtain a list of candidate locales, including their boundaries, or define boundaries.

b. Determine the relevant logistical parameters affecting a proposed locale.

c. Compare the logistical elements with requirements for CART operations.

d. Assess the logistical advantages and complications.

Constraints:

Constraints in this task will occur as a result of uncertainties in information that will be required from entities beyond the program. Such entities may be required to supply logistical support to ARM, such as platforms for offshore operations, access to foreign lands and border crossing, or collaborative participation by external countries and institutions.

Task 9. Examine synergism with other programs—SYNERGISM TEAM

Objective:

To identify programs other than ARM whose activities or facilities might lead to mutually beneficial coordinated activities with ARM.

Scope:

Programs in atmospheric science and related disciplines conducted within DOE, by other agencies of the federal government, by universities and the private sector, by research organizations in other countries, and by international programs. Includes land, ocean measurements; satellite measurement programs.

Facilities suitable for establishing ARM sites maintained by DOE, by other agencies of the federal government, by universities and the private sector, by research organizations in other countries, and by international programs.

Output:

A listing of major programs and facilities that may have synergistic potential with ARM.

A listing by locales, identifying programs and facilities with potential synergistic activities in the locales considered for examination in this project.

Input:

List of potential locales for ARM sites.

Suggestions from the research community of potential collaborative programs and facilities.

Descriptive information on pertinent programs and facilities.

Ordered Set of Steps:

a. Canvass the atmospheric radiation, meteorological, oceanographic communities and pertinent federal and non-U.S. agencies to identify activities and facilities in potential ARM locales that might afford the opportunity of synergistic collaboration with ARM.

b. Acquire information describing these activities and facilities.

c. Identify the locales to which these activities and facilities pertain.

d. Prepare listings of potentially synergistic programs and facilities, by program and by locale.

Constraints:

For many of the synergistic programs listed, activities are in the planning stages, and thus, any interaction with ARM will depend on the extent to which these programs are funded over the ARM operational time frame.

Comments:

For the ocean locales, development of an interaction with potentially synergistic oceanographic programs will be crucial to the establishment of ARM ocean sites and/or the conduct of ocean campaigns. Several major oceanography programs will be of interest to ARM in the future, including JGOFS, WOCE, and TOGA. It is recommended that ARM establish close contact with these programs to be in a position to take advantage of their field programs and to possibly influence the scientific direction of these programs during the planning process so that ARM needs can be met.

A similar situation pertains to the central Greenland and the Antarctic ice sheets locales. For the Antarctic, the principal Agency is the National Science Foundation and all activities must be coordinated through them. For the Arctic region, there is the Inter-Agency Arctic Research Policy Committee which may be helpful in locating appropriate sites and in identifying activities with which ARM could collaborate. Collaboration with these agencies and their ongoing programs will be essential for measurements in these locales.

Task 10. Rank and Recommend locales—EVALUATION TEAM

Objective:

To synthesize the results of the individual locale evaluation processes into a list of locales, in order of scientific priorities, recommended for siting considerations.

The list will be accompanied by a discussion of the logistical considerations which may have major impacts on eventual siting and by a discussion of the synergistic potential for interaction with other programs operating within the locale.

The resulting list and documentation will be suitable for review and modification by the Science Team, an independent peer review panel, the Program Office, and the Department of Energy.

Scope:

The scope of the task is limited to the synthesis of the reported results from the six CETs including their evaluations of the scientific value, logistical issues and potential for interactions with other programs for each candidate locale.

Output:

List of scientifically ordered locales.

Step-by-step scientific discussion and justification of the ordered list.

Recommended cutoff for the number of locales to be considered based on scientific grounds.

Discussion of the logistical considerations for each locale and a recommended course of action for meeting any major logistical constraints.

Input:

Note: all input data for this procedure are generated internally in the procedure.

Evaluations of locales based on the following scientific criteria:

- Atmospheric properties (ability to stress models).
- Surface properties (ability to stress models and homogeneity).
- Surface fluxes (ability to stress models).
- Climatological properties (ability to stress models and homogeneity).

Logistical evaluations of each locale.

Evaluation of the programmatic synergistic potential of each locale.

Ordered Set of Steps:

a. Identify and document the selection of the first locale based on the following ordered criteria:
   1. logistical considerations
   2. the two homogeneity criteria
   3. programmatic synergism
   4. the four stress criteria.
b. Identify and document the selection of each successive locale based on a combination of (and in order):
   1. the four stress criteria
   2. the two homogeneity criteria
   3. programmatic synergism.

   Note: The documentation of the selection should contain:
   1. an evaluation of the set of previous recommended locales with respect to the six guidelines for the scientific merit of the locales
   2. a set of goals derived from the evaluation used to guide the search for the next ordered entry
   3. a summary of the eventual selection's efficacy in meeting those goals and a comparison with alternative selections.
c. Identify a cutoff for the number of recommended locales based on a consideration and documentation of the incremental improvements that might be achieved by adding additional locales.
d. Review the list based on the evaluation of the logistical considerations.

   Identify any locale which may not be suitable for permanent occupation (approximately 5 years), for which the expense is deemed too large, for which staffing may offer major challenges, or other major logistical concerns.

For each so identified evaluate the ability to meet the scientific goals through:

campaigns

partial year occupancy

If alternative strategies for occupation are not available, identify any other locales which might be alternatives to the one of higher scientific priority.

Note: This discussion should follow the pattern of evaluating the role of the locale in meeting the scientific objectives, the extent to which the substitute meets them, and the consequences of the substitution for the remaining portions of the list.

Constraints:

Locales may only be the output of other procedures.

All evaluations with the exception of the logistical one must be available before the locales are ordered.

Apart from the identification of the first locale, logistical consideration will not be a factor in the ordering.

Comments:

This process is largely based on the scientific judgment of the staff responsible for executing the procedure. The key to success is the careful documentation of the process in a fashion suitable for review.

Appendix B

Climate

The tasks of the Climate Criteria Examination Team (CET) were 1) to assess the spatial homogeneity of a previously-defined group of candidate locales and 2) to develop one or more subsets ("ensembles") of these locales which together would stress current GCMs and radiation models by spanning a wide range of climate conditions.

A set of climate attributes was identified and used to characterize the candidate locales. Locales were then grouped according to criteria established for each attribute, and subsets of locales were identified that span the range of that attribute. To a large extent, locales within attribute groups can be considered interchange-able from the standpoint of climate; within groups, atmospheric and surface properties and logistical and synergistic considerations will determine specific recommendations.

Climate Attributes

Climate represents the average of atmospheric conditions over a time sufficiently long enough to establish statistical properties (mean values, variances, probabilities of extremes, etc.). Because specific atmospheric elements critical to the development of improved climate and radiation models (in particular patterns of cloud types and amounts) are treated in detail by the Atmospheric Properties CET, the Climate CET limited itself to considering only the most general aspects of climate, long-term global patterns of temperature and precipitation.

Global variations in temperature and precipitation are reflected in the following climatic attributes (listed in order of increasing complexity):

- Latitude
- Continentality
- Seasonality

Evaluation Criteria

Latitude

Latitude is not in itself an important criterion for ranking or selecting locales. However, since most basic climate elements, including insolation, temperature, precipitation, principal air masses and prevailing wind patterns, tend to be arranged in zones which run parallel to lines of latitude, it is a surrogate for many of these elements. Latitude can be divided into six categories which fall into 10 parallel global zones:

- Equatorial: ± 5° N, S
- Tropical: ± 23.5° N, S; includes Equatorial zone
- Subtropical: 23.5° to approximately 35° N and S
- Midlatitude: 35° to 50° N and S
- High latitude: 50° to approximately 66.5° N and S
- Polar: N, S of 66.5°

The original set of candidate locales was defined such that each locale fell within one of these zones. Each locale can be assigned to a latitudinal zone (with the understanding that the boundaries of neither the latitudinal zones nor the locales are precisely delineated), and within zones, each locale can be considered equivalent with regard to this attribute. Table 6 shows the latitudinal zone for each candidate locale; these are also summarized by zone in Table 7.

Important climate attributes were identified and used to characterize candidate locales.

Table 6. Candidate Locale Climate Attributes

Locale	Latitude Zone	Continentality Index	Std. Dev. of k	Trewartha Group	Trewartha Type
Mid-Atlantic U.S. Coastal Plain	M	36.6	1.8	D	ca
Southeast U.S. Coastal Plain	S	31.2	3.1	C	f
Southern U.S. Great Plains	S	46.1	3	C	f
Northern U.S. Great Plains	M	54.3	3.4	D	ca,cb
West Siberian Boreal Forest	H	67	nd	E	-
Canadian Boreal Forest	H	66	nd	E	-
Southern Indian Subcontinent	T	-2	nd	A	m,w
Sonoran Desert SW U.S.; N Mex	S	40.4	3.1	B	W
Central Australia	S	38	nd	B	W h
Greenland Plateau	H	n/d		F	i
Antarctic Plateau	P	40	nd	F	i
N Slope of Alaska	H	42.6	1.8	F	t
E Slope Rockies U.S.	M	40.4	5	B	Sk
NW U.S.-SW Canada Coast	M	45.8	4.7	D	ca
Midwest U.S.	M	45.8	4.7	D	ca
Sargasso Sea (N. Atlantic)	S	n/a		C	n/a
Central North Pacific	M	n/a		C,D	n/a
Tropical W. Pacific Ocean	T,E	n/a		A	n/a
Tropical Atlantic	T,E	n/a		A	n/a
Circumpolar Southern Ocean	H	n/a		F	n/a
Norwegian Sea	H	n/a		D	n/a
Greenland Sea	H	n/a		F	n/a
Bering Sea	H	n/a		F	n/a
Gulf Stream off E. N. America	S,M	n/a		C,D	n/a
Eastern South Pacific	T	n/a		B	n/a
Eastern North Atlantic	S	n/a		B	n/a
Beaufort Sea	H	n/a		F	n/a
Australia-Indonesia Semi-Enclosed Sea	T	n/a		A	n/a

nd = no representative data available
n/a = not applicable

Latitude Zones:

E = Equatorial	M = Midlatitude
T = Tropical	H = High latitude
S = Subtropical	P = Polar

Table 7. Candidate Locales by Latitudinal Zone

Latitudinal Zone	Locale
Equatorial:	Amazon Basin
	Congo Basin
	Tropical W. Pacific Ocean (part)
	Tropical Atlantic (part)
Tropical:	Southern Indian subcontinent
	Tropical W. Pacific Ocean (part)
	Tropical Atlantic (part)
	Eastern South Pacific
	Australia-Indonesia Semi-Enclosed Sea
Subtropical:	Southeast U.S. Coastal Plain
	Southern U.S. Great Plains
	Sonoran Desert SW U.S., N. Mexico
	Sargasso Sea
	Eastern North Pacific
	Eastern North Atlantic
	Gulf Stream off Eastern North America (part)
Midlatitude:	Mid-Atlantic U.S. Coastal Plain
	Northern U.S. Great Plains
	E. Slope Rockies U.S.
	Midwest U.S.
	Gulf Stream off Eastern North America (part)
High latitude:	North Slope of Alaska
	West Siberian Boreal Forest
	Canadian Boreal Forest
	Greenland Plateau
	Circumpolar Southern Ocean
	Norwegian Sea
	Bering Sea
	Beaufort Sea
	Greenland Sea
Polar:	Antarctic Plateau

In order to stress the models with an ensemble of conditions, at least three locales should be selected, one from each of the most extreme latitudinal zones (equatorial or tropical and polar or high latitude) and one from the subtropics or midlatitudes. These choices would represent a wide range of values for many climate attributes, in particular insolation.

Continentality

Continentality is the degree to which a point on the earth's surface is subject to the influence of a land mass. Highly continental locales are characterized by considerable annual extremes in temperature as the continental land mass is heated during high sun and cools during low sun. Therefore, these locales will be located in the central portions of the large midlatitude continents, where seasonal shifts in prevailing air masses occur and incursions of marine air masses are extremely rare. Continentality thus represents both latitude and longitude, since a wide range of both are required to achieve extreme continental characteristics.

Continentality is usually measured by daily or annual range in temperature, with allowance for latitude. Several indices have been developed for assessing degree of continentality. Here we have chosen to use Conrad's equation (cited in Fisher et al.,1987):

$$k = \frac{1.7\,A}{\sin(\theta + 10)} - 14$$

where A is the difference between the mean temperature of the warmest and coldest month (°C) and θ is the latitude in degrees.

This index was chosen for pragmatic reasons: it is widely accepted and the data are more readily available than those required for other indices. By definition, ocean locales are not continental and are therefore unranked. [Ocean areas can be indexed in a similar manner, using an index of oceanicity such as that developed by Kerner (Landsberg 1958). However, such an index applies to island areas; here ocean locales are treated as uniform water areas, so measures of oceanicity do not apply.]

Because continentality is a matter of degree, selection of a value below which a locale is considered not to be continental is somewhat arbitrary. Here $k = 45$ is used as the cutoff; locales with an index of 45 or higher are classified as sufficiently continental to provide significant annual temperature extremes in order to exercise models. k was calculated for each locale based on available data. Because the great latitudinal and longitudinal extent of several of the candidate locales may induce considerable intra-locale spatial variability (inhomogeneity) of continentality, standard deviations were calculated as well where data from multiple stations were available. Conrad's k and associated spatial standard deviations for each locale are given in Table 6.

Noncontinental land locales fall into two groups according to the reason for lack of continental characteristics. The first of these includes locales on the continental margins in the mid- and high latitudes. These areas occur in the same latitudinal zones as the most highly continental locales, but the annual temperature variations associated with seasonal north/south shifts in the dominant air masses affecting these latitudes is muted by the encroachment of marine air masses. Proceeding outward from the continental interior, k decreases, dropping to near zero along the windward coasts.

A second category includes low and high latitude locales. These may exhibit some continentality, but fail to meet the criterion k value of 45 because they tend to be dominated over the year by a single type of air mass (tropical or polar). Continentality is defined primarily by seasonal swings in temperature, and in these locales the annual temperature ranges are not large. Continental characteristics in these regions are more marked in those locations associated with a midlatitude continent than in those where the continental interior lies near the equator. On the low-latitude margins of mid-latitude continents, continental effects are reflected in strong seasonal variations in precipitation more than in temperature. An important example of this situation is the marked seasonality of precipitation which occurs along the windward tropical and subtropical margins of Asia (monsoons). Because only one candidate locale fell clearly within this category, no attempt was made to develop a measure of continentality based on precipitation.

Continentality groupings for the land locales are shown in Table 8. Figure 9 shows approximate isolines of k for North America.

Because of the wide range of atmospheric conditions encompassed in the annual regime of a continental climate, it is recommended that the first locale chosen for a primary site should be highly continental. A noncontinental locale with minimal variation in temperature and precipitation should be selected second. Ideally this would be an ocean locale. However, if other considerations preclude the choice of an ocean locale for a primary site, the second site could be a windward coast in the extreme low or high latitudes, where continentality is minimal for a land location.

Seasonality

Seasonality refers to the cyclical, intra-annual variation of one or more climate elements. It is highly correlated with latitude and, as noted above, with the effects of continentality. Although seasonality correctly applies to any climate element, it is most often defined in terms of temperature and precipitation. Seasonality is a complex concept which cannot be characterized in a shorthand, quantitative way as is the case with continentality. Nonetheless, it is important to provide some consistent indicator of seasonality,

Table 8. Candidate Locales by Continentality Group

Continentality Group	Locale
Continental:	Southern U.S. Great Plains
($k \geq 45$)	Northern U.S. Great Plains
	West Siberian Boreal Forest
	Canadian Boreal Forest
	Midwest U.S.
Low/High latitude	Southern Indian Subcontinent
noncontinental:	Antarctic Plateau
	Amazon Basin
	Congo Basin
Continental margins:	Mid-Atlantic U.S. Coastal Plain
	Southeast U.S. Coastal Plain
	Southern Indian Subcontinent
	Sonoran Desert
	Central Australia
	North Slope of Alaska
	NW U.S. - SW Canada Coast

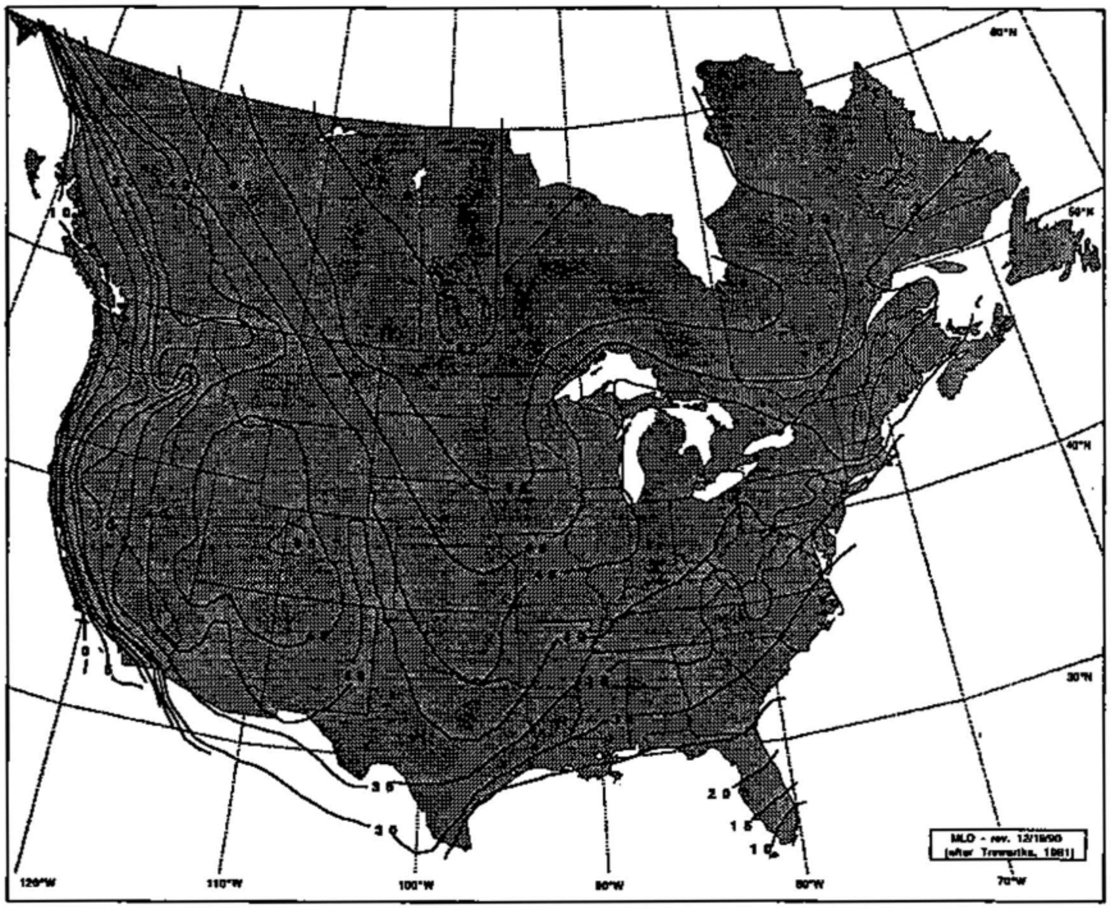

Figure 9. Isolines of Continentality

since a locale which exhibits strong seasonal variation in temperature or precipitation (or any other pertinent element, such as predominant cloud type) will stress the models far more than one with moderate or negligible seasonality.

The approach taken here is the use of a climate classification system which includes seasonal variation among its classification criteria. For this purpose we have chosen the system developed by Trewartha (Trewartha and Horn 1980), a modification of the well-known Köppen-Geiger system. Seasonality is captured in the Trewartha system in terms of the number of months with temperatures above or below criterion values and annual distribution of precipitation. Temperature is the basic criterion used to distinguish among groups, except for arid climates, group B, which are defined by the relationship between precipitation and temperature. Within each primary group, subtypes are defined. In the case of the primary groups (A, C-F), the secondary type is usually characterized by seasonal precipitation patterns. Details of the criteria used to define each category are given in Table 9. Note that although the names of Trewartha's climate groups do not necessarily coincide with those applied to latitudinal zones [above], they are in fact roughly equivalent.

Table 6 shows the assignment of each candidate locale according to its Trewartha climate group

Table 9. Trewartha Climate Classification System

System of climatic group and climatic types

Groups of climate	Types of climate	Pressure system and wind belt		Precipitation
		Summer	Winter	
A. Tropical humid	Ar, tropical wet	ITC, doldrums, equatorial westerlies	ITC, doldrums equatorial westerlies	Not over two dry months
	Aw, tropical wet-and-dry	ITC, doldrums, equatorial westerlies	Drier trades	High-sun wet (zenithal rains), low-sun dry
C. Subtropical	Cs, subtropical dry summer	Subtropical high (stable east side)	Westerlies	Summer drought, winter rain
	Cf, subtropical humid	Subtropical high (unstable west side)	Westerlies	Rain in all seasons
D. Temperate	Do, oceanic	Westerlies	Westerlies	Rain in all seasons
	Dc, continental	Westerlies	Westerlies and winter anticyclone	Rain in all seasons, accent on summer; winter snow cover
E. Boreal	E, boreal	Westerlies	Winter anticyclone and polar winds	Meager precipitation throughout year
F. Polar	Ft, tundra	Polar easterlies	Polar easterlies	Meager precipitation throughout year
	Fi, icecap	Polar easterlies	Polar easterlies	Meager precipitation throughout year
B. Dry	BS, semiarid (steppe)			
	BSh, (hot), tropical-subtropical	Subtropical high and dry trades	Subtropical high and dry trades	Short moist season
	BSk, (cold), temperate-boreal		Continental winter anticyclone	Meager rainfall, most in summer
	BW, arid (desert			
	BWh, (hot), tropical-subtropical	Subtropical high and dry trades	Subtropical high and dry trades	Constantly dry
	BWk, (cold), temperate-boreal		Continental winter anticyclone	Constantly dry

and type; Table 10 lists the locales by climate group. It can be seen that every primary group and most secondary types are spanned by the ensemble of all candidate locales. However, a wide variety of conditions can be studied by judicious sampling from these categories. A locale in the Dc type satisfies the need for a mid-latitude, strongly continental area with seasonality of precipitation as well as of temperature. An ocean locale in the A group represents an extremely homogeneous area in terms of both temperature and precipitation; an ocean locale in the C group, especially toward the more humid margin of the subtropical high, or a type Ar land locale would be possible but less desirable alternative choices.

Monthly Mean Temperature and Precipitation for Candidate Locales

Plots of surface temperature and precipitation were drawn for each candidate locale to indicate the variability that exists among them. Plots of surface temperature and precipitation were made available to the CETs at the beginning of the meeting for their use in the selection process and are given here in Figure 10.

The following pertains to the data used to depict the surface measurements of temperature and precipitation for the various locales:

1. **Mid-Atlantic U.S. Coastal Plain**

   The plot represents the average of 10 sites in the coastal Piedmont. Data taken from "Climate of the States," Vol.I, p.289.

2. **Southeast U.S. Coastal Plain**

   This plot represents the average of 7 sites in the southeast Piedmont. Data taken from "Climates of the States," Vol.I, p.78.

3. **Southern U.S. Great Plains**

   This diagram represents the average of 16 sites in the central to southern grasslands. Taken from "Climate of the States," Vol.II, p.833.

4. **Northern U.S. Great Plains. (High latitude-winter snow cover)**

   The plot represents the average of 15 sites in north central Montana. Data taken from "Climates of the States," Vol.II, p.751.

5. **Mid-West U.S.**

   The data for this plot represent 11 sites in west-southwest Illinois. It was obtained from "Climates of the States," Vol.I, p.97.

6. **Siberian Boreal Forest-USSR**

   The data are for Turukhansk, USSR. It was derived from the CD ROM World WeatherDisc.

7. **Canadian Boreal Forest-Canada**

   The plot was constructed from data of The Pas in Canada. It was derived from the CD ROM World WeatherDisc.

8. **Southern India Subcontinent-India**

   The diagram represents Mangalore, India and was produced from data taken from the CD ROM World WeatherDisc.

9. **Sonoran Desert-Southwest Arizona**

   The plot represents the average of 3 sites in southwest Arizona and was taken from "Climates of the States," Vol.II, p.511.

10. **Australian Desert**

    The data were for Wiluna, Australia and was derived from the CD ROM World WeatherDisc.

11. **Greenland**

    No data available for the Greenland Plateau. Two coastal sites were chosen to represent Greenland. Thule and Angmagssilik represent coastal extremes, one located along the northwest and the other along the southeast coast. Plots were made for each location using data from the CD ROM World WeatherDisc.

Table 10. Candidate Locales by Climate Group

Trewartha Climate Group	Locale
A	Southern Indian Subcontinent
	Amazon Basin
	Congo Basin
	Tropical W. Pacific Ocean
	Tropical Atlantic
	Australia-Indonesia Semi-Enclosed Sea
C	Southeast U.S. Coastal Plain
	Southern U.S. Great Plains
	Sargasso Sea
	Central North Pacific (part)
	Gulf Stream off E N. America (part)
D	Mid-Atlantic U.S. Coastal Plain
	Northern U.S. Great Plains
	NW U.S. - SW Canada Coast
	Midwest U.S.
	Central North Pacific (part)
	Norwegian Sea
	Gulf Stream off E N. America (part)
E	West Siberian Boreal Forest
	Canadian Boreal Forest
F	Greenland Plateau
	Antarctic Plateau
	N. Slope of Alaska
	Circumpolar Southern Ocean
	Greenland Sea
	Bering Sea
	Beaufort Sea
B	Sonoran Desert
	Central Australia
	E Slope Rockies U.S.
	Eastern South Pacific
	Eastern North Pacific
	Eastern North Atlantic

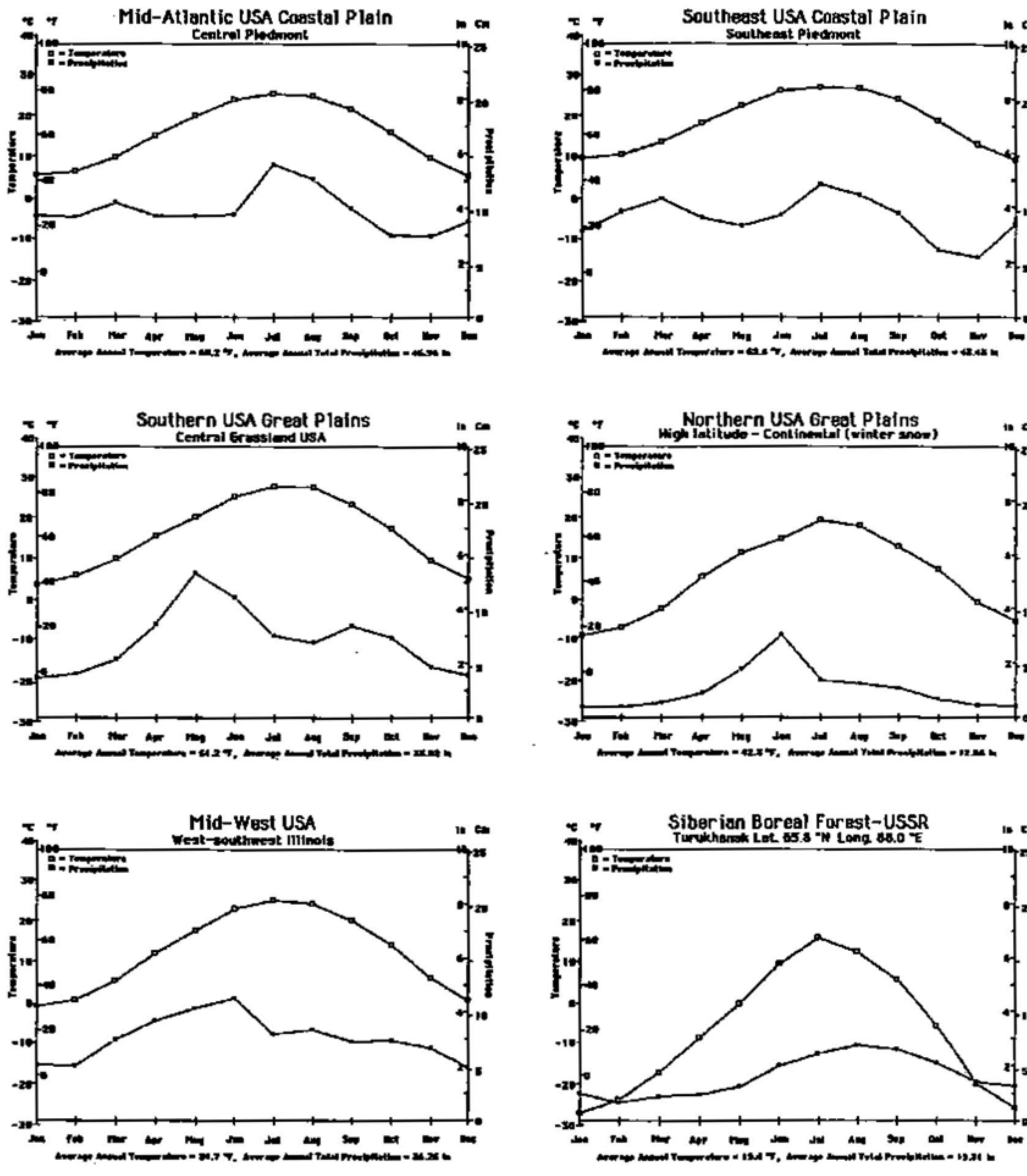

Figure 10. Annual Profiles of Surface Temperature and Precipitation for Candidate Locales

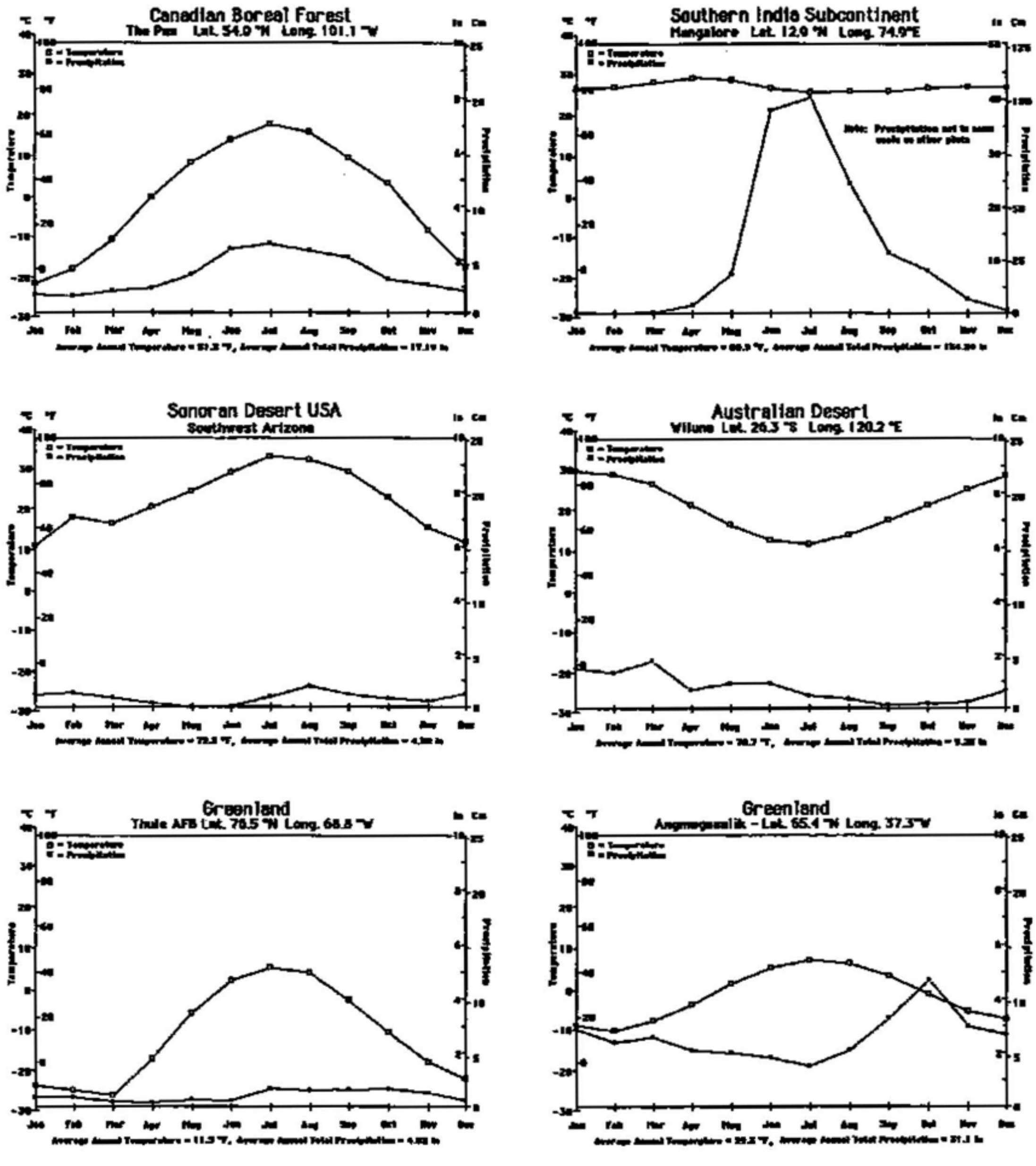

Figure 10. (contd.)

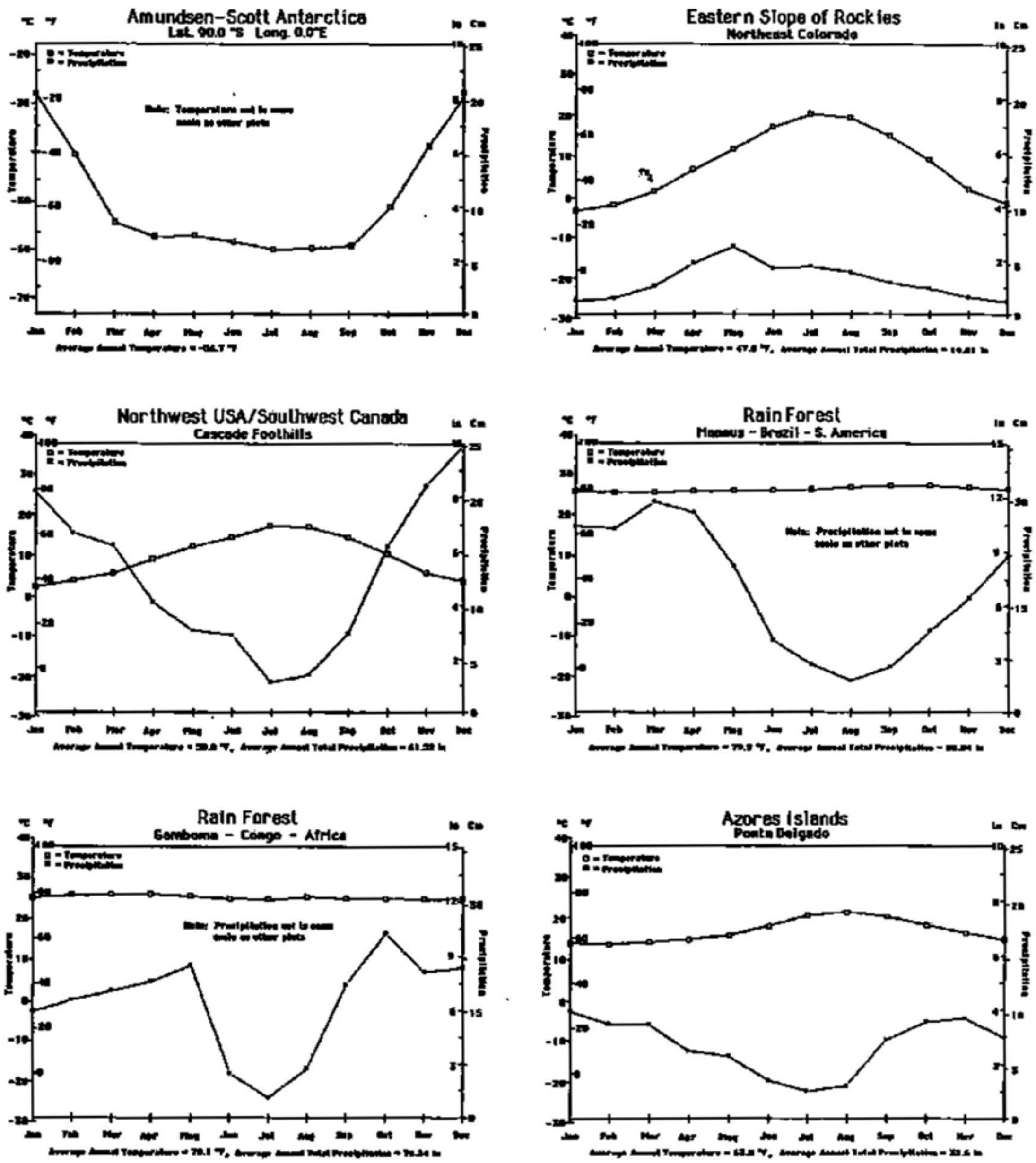

Figure 10. (contd.)

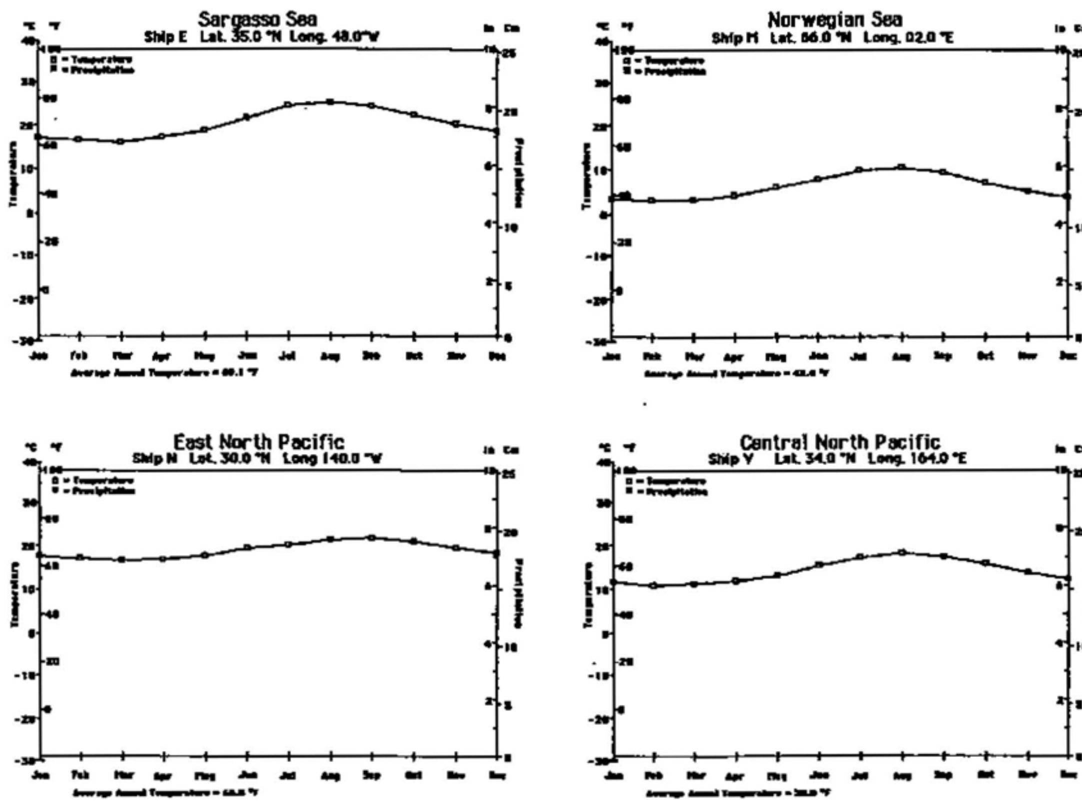

Figure 10. (contd.)

12. **Amundsen-Scott Station—South Pole**

    The data for this plot were taken from the CD ROM World WeatherDisc. The temperature scale was different from the other plots because of the extreme cold measurements. No precipitation measurements were plotted because the data for that station indicate only a trace.

13. **North Slope of Alaska**

    No long-term meteorological data could be found for the North Slope of Alaska. The data for this location were taken from the publication "Environmental Atlas of Alaska," University of Alaska, Hartman & Johnson, Institute of Water Resources, Fairbanks, AK. 1984 (see plates 24 and 30).

14. **Eastern Slope of the Rockies**

    The plot represents the average of 26 sites in the Colorado Drainage Basin. The data were taken from "Climate of the States," Vol.II, p.604.

15. **Northwest U.S./Southwest Canada**

    This plot represents the average of 17 sites in the East Olympic-Cascade Foothills. The data for the plot were taken from "Climates of the States," Vol.II, p.948.

16. **Rain Forest-South America-Brazil**

    The data for this plot were taken from the CD ROM World WeatherDisc for the site Manaua.

17. **Rain Forest-Africa-Congo**

    The data for this plot also were taken from the World WeatherDisc. They represent the site Gamboma.

18. **Azores Islands.**

    The data for this plot were derived from the CD ROM World WeatherDisc. They represent the site Ponta Delgado.

19. **Ocean Sites**

    The data for the ocean sites were taken from ship reports listed in the CD ROM World WeatherDisc. There are four ocean site plots: for the Sargasso Sea, the Norwegian Sea, the East North Pacific and the Central North Pacific.

Recommended Locales

Climatic attributes played a fundamental role in the nomination of candidate locales. In subsequent stages of the locale recommendation process, the more general climate attributes assumed a secondary position to the other scientific criteria used to propose the ensemble of ARM research sites. Climate classification systems and continentality indices are useful tools for characterizing locales, but they represent long-term averages, not specific atmospheric conditions. It is the opinion of this team that the attributes and criteria examined here should be used principally to support the findings of the other CETs and to resolve decisions as necessary. With that caveat in mind, the following locales are recommended:

Locale	Criteria	Comments
Northern U.S. Great Plains	• Mid-latitude • Continental • Seasonal temperature • Seasonal precipitation	Acceptable alternatives (in order): Midwest U.S. (less continental) Southern U.S. Great Plains (less continental, less temperature seasonality)
Tropical W. Pacific Ocean	• Equatorial/tropical • Homogeneous annual temperature • High evaporation	Accceptable alternatives (in order): Tropical Atlantic Gulf Stream (warmer S, E parts) (subtropical) Amazon or Congo Basin

This pair of locales spans the range of continentality by including both a highly continental and a non-continental locale. The Northern Great Plains locale presents seasonality of both temperature and precipitation, while the Tropical Western Pacific shows little seasonal variation in either characteristic.

The list does not span the range of latitudinal zones, however, in that polar/high latitude conditions are not included. The Northern Great Plains locale does have lengthy periods of incursions of arctic air masses during the winter, but the persistent extreme cold which characterizes polar regions is not represented. Also missing from this list is a hot, dry locale. In the interests of spanning a range of climatic regimes, we recommend that a locale be selected from each of these climatically and radiatively extreme groups. However, the climatic homogeneity of these "extreme" locales make them conducive to research in a campaign mode.

Recommendations for Additional/Future Work

It is the opinion of the Climatology CET that the principal contribution of this team occurred in the identification of locale categories and in the selection of potential and candidate locales. Locales which were suggested at the onset of the recommendation process were defined, described, and mapped in rough accordance with Trewartha climate types. However the concept of generalized climate attributes, separate from the specific aspects under consideration by other CETs, appears to have been of lesser utility in characterizing candidate locales in terms of ARM research requirements than the attributes considered by the other teams, in part because these attributes had been considered in the initial definition of the locale categories. Further, within the context of the locale selection process, these attributes did not lend themselves well to a rigorous, quantitative analysis for purposes of comparison and prioritization.

With due regard for the clarity of hindsight, we would, if a similar task were to be undertaken at some future time, recommend that:

- general climatological considerations be specifically addressed in a methodical way in the initial locale nomination process;
- specific climatological considerations be pooled with attributes examined by the other teams (atmospheric, geographic and surface flux properties).

A further concern was the severe time constraints within which the CETs were forced to work. In particular:

- Several locales, especially ocean and remote locales, were not adequately characterized due to the lack of time available to acquire the necessary data. In some cases, of course, little data would be available in any event. Nonetheless, some bias may have been injected due to an inability to compare, on the basis of quantitative scientific criteria, data-poor locales with the others.
- Lack of data also precluded addressing questions of intra-locale variability. Teams were usually limited to the use of averaged data and rarely had access to information on variance or to raw data from which such a measure could be calculated.
- Better methods could have been used in the criteria examination process. For example, several ideas were fielded for creating an ad hoc index of seasonality, but time constraints prevented their development and application. Also, the use of a Geographic Information System (GIS) to overlay the elements of importance to each team was suggested but precluded at this time.

It has been said that "the scale of observation creates the phenomenon." At the global scale with which the locale selection process began, the information available for this exercise may have been adequate (though not ideal). However, we recommend that both better data and better methods be applied as the site selection process continues. In particular, use of a GIS as an analytic tool is recommended in the selection of a site within a locale and in placement of instruments within a site.

Bibliography

Three preliminary ARM Guides have been prepared pertaining to North America, Kansas and the Oceans. These reports document the major climatological parameters available for those areas, and are available as BNL reports.

A comprehensive source for climatic data is the World WeatherDisc CD ROM, which contains a meteorological data base that encompasses stations around the world and includes 17 sets acquired from the archives of the National Climatic Data Center and the National Center for Atmospheric Research. Seven of the sets were accessed using software provided by the disc; the others were accessed using software created by members of the Information Team. The World Weather Disc (Version 2.0, 1990) was acquired from WeatherDisc Associates, Inc., Seattle, WA.

The following CD ROMs were used to provide added information to the CETs:

1. The World Atlas—a compilation of maps and information on geography, people, government, economy and communications. The Software Toolworks, Inc. Chatsworth, CA. 1989.
2. The World Factbook—this factbook contains 249 black-and-white map images and information gathered by the CIA on a number of statistics of each country involved. Quanta Press, Inc., St. Paul, MN, 1989.
3. The Northern Great Plains AVHRR—(Advanced Very High Resolution Radiometer) data set compiled from orbiting satellites covering the entire United States, southern Canada and northern Mexico. U.S. Department of the Interior, Eros Data Center, Jet Propulsion Laboratory, Pasadena, CA. 1987.

The following reference material was made available for use by the CETs:

1. Climates of the States, Vol. I & II—a practical reference containing basic climatological data for the United States. Water Information Center, Manhasset Isle, Port Washington, N.Y. 1974.
2. Landolt & Bornstein—New Series. Numerical data and functional relationships in science and technology. Springer-Verlag, New York 1984. The following volumes were available for reference:
   a. Meteorology-Climatology—Vol. 4c1 and 4c2.
   b. Meteorology-Dynamics of the Atmosphere-Vol. 4a.
   c. Meteorology-Properties of the Air-Vol. 4b.
   d. Oceanography-Vol. 3a, 3b and 3c.
   e. Geophysics-Solid Earth-Vol. 2a and 2b.
3. Climate, Present, Past and Future—Vol. I and II. H.H. Lamb. Barnes and Noble, 1972
4. Global Distribution of Total Cloud Cover and Cloud Type Amounts over Land and Global Distribution of Total Cloud Cover and Cloud Type Amounts over Ocean. U.S. Department of Energy, Office of Energy Research and the National Center for Atmospheric Research Boulder, CO. DOE/ER-046, NCAR/TN-317+STR, 1988 and DOE/ER/60085-HI, NCAR/TN-273+STR, 1986.
5. Atlas of Simultaneous Occurrences of Different Cloud Types over Land. Atmospheric Analysis and Prediction Center for Atmospheric Research. Boulder, CO., NCAR/TN-241+STR, 1984.
6. National Weather Charts for the Northern Hemisphere. U.S. Department of Commerce. Technical Paper No. 21, 1952.
7. Environmental Atlas of Alaska. University of Alaska, Hartman & Johnson, Institute of Water Resources, Fairbanks, AK. 1984.

8. The Marine Environment. American Geographical Society, Folio-18 Library of Congress Catalog Card No. Map 62-2, 1969.

9. World Survey of Climatology. Vol. II, Climates of North America, Bryson & Hare, Elsevier Scientific Publishing Company, New York, 1974.

10. Universal World Atlas. Rand McNally & Co., New York, 1987.

11. The Great Geographical Atlas. Rand McNally & Co., New York, 1982.

12. An Introduction to Climate. Trewartha & Horn, McGraw-Hill Book Comp., New York, 1980.

References

Fischer, G., H.H. Landolt and R. Bornstein. **1987**. Meteorology. in H.H. Landolt and R. Bornstein, eds., Numerical Data and Functional Relationships in Science and Technology, Vol. 4c Parts 1 and 2. Berlin and New York: Springer-Verlag.

Landsberg, H.E. 1958. Physical Climatology. DuBois, PA: Gray Print. Co.

Strahler, A. 1969. Physical Geography. New York: John Wiley and Sons, Inc.

Trewartha, G. 1961. The Earth's Problem Climates. Madison: University of Wisconsin Press.

Trewartha, G. and L.H. Horn. **1980**. An Introduction to Climate. New York: McGraw-Hill.

Climates of the States, Vol. I & II. 1974. Water Information Center, Manhasset Isle, Port Washington, N.Y.

Hartman, C.W., and P.R Johnson. 1984. Environmental Atlas of Alaska. University of Alaska, Institute of Water Resources, Fairbanks, AK. 1984.

The World Weather Disc. 1990. Version 2.0.

Appendix C

Atmospheric Properties

The goal of the Atmospheric Properties Criteria Examination Team (CET) was to examine the suitability of candidate locales to stress ARM models with respect to atmospheric properties. As noted in the ARM Program Plan (DOE 1990), an accurate treatment of clouds in GCMs is essential for a realistic simulation of climate. Therefore the decision was made to make locale selection dependent primarily on cloud factors, with other factors being secondary in their role in the site selection process. The other factors considered included temperature, the moisture content of the atmosphere, aerosol loading, and haze.

Criteria for Locale Selection

A number of cloud categories were considered in order to define the criteria by which the locales would be selected. Among the categories put forward were the aspect ratio of clouds (having the advantage of being a continuous number describing cloud shape, but impractical in terms of evaluation from surface observations), cloud height (low, medium and high) and cloud type. Of these possible categories, cloud type was selected as a result of clearly defining key cloud species within GCMs, and because cloud type is frequently an indicator of a specific formation mechanism that needs to be taken into account within the models. As a practical matter, climatological data are readily available describing the frequency of occurrence of a large number of cloud species.

The Atmospheric Properties CET identified the following cloud types as having a significant impact in defining the radiation budget of the atmosphere:

- Marine stratus (MSt): associated with the mixing of water vapor through the boundary layer in the absence of conditional instability; presently poorly treated in GCMs, yet widespread in many regions of the world's oceans.
- Continental stratus and altostratus (As): associated with warm fronts in extratropical cyclones and having a sufficiently widespread area to allow resolution by existing GCM grids.
- Cirrus (Ci): ice clouds formed by a variety of mechanisms; common over many locations; play a major role in the infrared planetary radiative balance.
- Cumulonimbus (Cb): deep convective systems associated with instabilities in the thermal structure of the atmosphere; play a major role in exchange processes between the lower and upper atmosphere; treated in a parameterized manner in GCMs as a result of having a horizontal extent much smaller than GCM grids.
- Cumulus (Cu): convective clouds formed without significant vertical development; associated with boundary layer heating driving convective eddies; frequent in the tropics, as well as post-cold frontal clouds in the extratropics.
- Totally clear sky conditions: included as the simplest test of radiation models.

Locales were selected primarily to assure that all climatically significant cloud types would be studied.

Locale selection was first based on the frequency of occurrence (f) of each cloud type and totally clear sky. This information was obtained from Warren et al. (1986, 1988) for both

December-January-February (DJF) and June-July-August (JJA) time periods. The frequency referred to here was derived from the number of times that a particular type was reported present at a given observing station between 0600 and 1800 LST, divided by the corresponding number of synoptic weather reports which contained information about that cloud. The assumption implicit in this method is that the frequency for a cloud obscured by lower clouds is the same regardless of whether the higher cloud can or cannot be seen. A representative frequency within the locale of between 40 and 70% for each cloud type was required to ensure that the formation and dissipation processes would likely be observed. In addition, this range allows a moderate probability that clear sky conditions also would be observed at the candidate locales. The resulting values for the original candidate locales are listed in Tables 11 and 12 and displayed in Figures 11 through 17. Locales added to the list subsequent to the Locale Recommendation Team meeting at Brookhaven National Laboratory are not included.

In order to assure that CART instrumentation can be used to measure the optical properties of cirrus clouds, it is necessary to consider locales with frequent occurrence of cirrus when there are no lower, obscuring clouds. The frequency of occurrence of cirriform clouds, Ci, when there are no other (NO) clouds, is given by

$$f(Ci|NO) = f(Ci)*f(NO|Ci)$$

where f(Ci) is the frequency of occurrence of cirrus for all conditions, and f(NO|Ci) is the (conditional) frequency of no other clouds occurring given the presence of cirrus. Values of f(Ci) came from Warren et al. (1986, 1988), and f(NO|Ci) came from Hahn et al. (1982,1984). Values of f(Ci|NO), are given in Tables 11 and 12 and shown in Figure 11. Values of f(Ci) are shown in Figure 17. A similar procedure was not followed for altostratus on the grounds that simultaneous stratus would often be associated with the same extratropical storm.

Two situations required relaxing the 40 to 70% frequency requirement. The first case results from the observation that the frequency of occurrence of tropical Cb's are of the order of only 25% (Figure 12). The criterion used for the occurrence of Cb was therefore defined to be a summer frequency of occurrence of ≥ 10%.

The second situation requiring that the frequency criterion be relaxed was for clear sky. In recognition of the relative simplicity of modeling totally clear sky conditions, it was felt that fewer such cases would be necessary. Therefore, the occurrence frequency criterion for totally clear sky was also f ≥10%.

Temperature extremes formed the second criterion for locale selection. This is necessary in order to stress radiation models (e.g., testing of the so-called "hot" absorption bands of CO_2). Locales with large seasonal cycles ($T_{summer} - T_{winter} \geq 20K$) or exceptionally warm temperatures ($T \geq 300K$) were favored. A large seasonal cycle in temperature was ensured by selecting at least one midlatitude midcontinental locale. The seasonal mean values on which the selections were based are shown in Figure 18, and are derived from the data of Oort (1983).

The third criterion adopted was associated with water vapor. Locales with extremely high absolute humidity ($q \geq 16$ g/kg), or large seasonal variations ($q_{summer} - q_{winter} \geq 6$ g/kg) were sought in order to stress radiation and cloud models, since high absolute humidity accentuates the water vapor continuum which is a large uncertainty in the clear-sky infrared radiation balance. Strong seasonal variations stress radiation parameterization and the prediction of clouds. The values on which the selection was based are shown in Figure 19, and are also derived from the data of Oort (1983).

Other less quantitative criteria were also used. It was recognized that haze and dust can have a significant radiative influence. In selecting some of the locales, the probable existence of haze or dust under some conditions has been considered but could not be quantified during the preparation of this report.

Table 11. Frequency of Occurrence (%) of Cloud Types and Clear Skies by Locales

December/January/February

Locale	Stratus	Cb	Cirrus	P(no other|Ci)	f(Ci & clear)	Altostratus	Cumulus	Clear
Mid-Atlantic U.S. Coastal	40	10	50	50	25	30	5	10
Southeast U.S. Coastal	40	0	50	50	25	30	5	15
Southern U.S. Great Plains	30	0	60	65	39	25	0	20
Northern U.S. Great Plains	50	0	70	60	42	35	0	10
West Siberian Boreal Forest	50	5	60	70	42	30	0	20
Canadian Boreal Forest	35	0	60	50	30	50	0	10
Southern Indian subcontinent	30	5	40	60	24	25	15	25
Sonoran Desert SW U.S.;	15	0	60	60	36	30	5	20
Central Australia	20	5	30	30	9	30	20	35
Greenland Plateau	30	0	10	50	5	40	0	40
Antarctic Plateau	10	0	60	70	42	25	0	25
North Slope of Alaska	25	0	15	40	6	30	0	40
East Slope Rockies, U.S.	50	0	60	50	30	35	10	10
NW U.S.-SW Canada Coast	65	0	60	25	15	40	10	0
Midwest U.S.	35	0	50	55	27.5	25	0	15
Amazon Basin	75	10	35	15	5.25	65	20	5
Congo Basin	50	10	50	50	25	50	15	15
Sargasso Sea	30	10	40	5	2	50	40	1
Central North Pacific	40	10	30	5	1.5	50	35	1
Tropical W. Pacific	30	20	70	0	0	70	45	0
Tropical Atlantic	30	15	30	5	1.5	35	55	2
Circumpolar S. Ocean	70	5	40	15	6	50	10	0
Norwegian Sea	50	50	30	20	6	40	10	0
Greenland Sea	50	15	40	10	4	45	10	5
Bering Sea	65	10	20	20	4	30	10	2
Gulf Stream	50	10	35	20	7	50	30	1
Eastern S. Pacific	60	5	30	15	4.5	50	25	2
Eastern N. Pacific	55	5	35	10	3.5	45	20	5
Eastern North Atlantic	50	10	40	15	6	50	30	1

June/July/August

Locale	Stratus	Cb	Cirrus	P(no other|Ci)	f(Ci & clear)	Altostratus	Cumulus	Clear
Mid-Atlantic U.S. Coastal	40	0	60	30	18	30	15	10
Southeast U.S. Coastal	20	5	50	30	15	35	25	10
Southern U.S. Great Plains	15	15	55	30	17	30	30	10
Northern U.S. Great Plains	20	10	55	35	19	30	20	10
West Siberian Boreal Forest	20	20	50	35	18	30	15	5
Canadian Boreal Forest	40	5	65	20	13	50	30	0
Southern Indian subcontinent	50	10	65	10	7	55	15	0
Sonoran Desert SW U.S.;	10	15	50	20	10	40	20	20
Central Australia	15	0	20	60	12	30	5	45
Greenland Plateau	15	0	20	60	12	40	0	10
Antarctic Plateau	10	0	50	90	45	15	0	40
North Slope of Alaska	50	0	45	30	14	45	10	10
East Slope Rockies, U.S.	15	15	40	20	8	30	20	20
NW U.S.-SW Canada Coast	40	0	50	30	15	45	20	10
Midwest U.S.	20	10	60	40	24	40	20	10
Amazon Basin	30	5	25	25	6	40	30	15
Congo Basin	25	25	45	15	7	45	30	5
Sargasso Sea	15	15	25	10	3	35	60	0
Central North Pacific	25	15	40	5	2	50	50	0
Tropical W. Pacific	30	25	65	0	0	65	45	0
Tropical Atlantic	20	10	25	10	3	25	50	10
Circumpolar S. Ocean	70	0			0			
Norwegian Sea	60	20	40	20	8	45	5	0
Greenland Sea	75	5	40	15	6	40	5	0
Bering Sea	85	0	40	15	6	50	5	0
Gulf Stream	30	15	50	10	5	45	40	0
Eastern S. Pacific	70	10	20	15	3	40	20	0
Eastern N. Pacific	70	5	20	10	2	40	20	5
Eastern North Atlantic	40	0	25	20	5	40	40	0

Table 12. Statistics for Temperature (Celsius) and Humidity (g/kg) by Locales

December/January/February

Locale	<T> min	<T> max	<T>	Sigma (T)	<q> min	<q> max	<q>	Sigma (q)
Mid-Atlantic U.S. Coastal	2	7	4.5	5.5	6	8	7	2.5
Southeast U.S. Coastal	7	12	9.5	4.5	8	10	9	2
Southern U.S. Great Plains	2	12	7	5	2	5	3.5	1.5
Northern U.S. Great Plains			-5				2	
West Siberian Boreal Forest			-25				1	
Canadian Boreal Forest			-15				1	
Southern Indian subcontinent	20	28	24	2.5	8	16	12	2.5
Sonoran Desert SW U.S.;	15	20	17.5	3	4	8	6	2
Central Australia	25	30	27.5	3	7	14	10.5	2
Greenland Plateau			-20				1	
Antarctic Plateau			-25				0.1	
North Slope of Alaska			-25				0.2	
East Slope Rockies, U.S.			-5				2	
NW U.S.-SW Canada Coast			5				4	
Midwest U.S.			0				3	
Amazon Basin	25	30	27.5	2	16	18	17	2
Congo Basin	25	25	25	2	16	17	16.5	2.25
Sargasso Sea	18	22	20	3.5	10	14	12	2
Central North Pacific			15				8	
Tropical W. Pacific	25	30	27.5	2	16	19	17.5	1.5
Tropical Atlantic	25	25	25	2	16	18	17	2
Circumpolar S. Ocean			5				4	
Norwegian Sea			0				3	
Greenland Sea			-10				2	
Bering Sea			-10				2	
Gulf Stream			5				4	
Eastern S. Pacific	15	22	18.5	2.5	10	12	11	2
Eastern N. Pacific	15	20	17.5	3.5	6	10	8	2
Eastern North Atlantic	18	18	18	3.5	10	10	10	1.5

June/July/August

Locale	<T> min	<T> max	<T>	Sigma (T)	<q> min	<q> max	<q>	Sigma (q)
Mid-Atlantic U.S. Coastal	20	28	24	3	13	12	12.5	2
Southeast U.S. Coastal	25	27	26	2	12	14	13	2
Southern U.S. Great Plains	22	27	24.5	3	8	12	10	2
Northern U.S. Great Plains			20				8	
West Siberian Boreal Forest			10				6	
Canadian Boreal Forest			10				6	
Southern Indian subcontinent	25	25	25	2	18	20	19	2
Sonoran Desert SW U.S.;	20	28	24	3	8	14	11	2.25
Central Australia	15	20	17.5	2.5	1	6	3.5	1.5
Greenland Plateau			0				3	
Antarctic Plateau			-3.0				0	
North Slope of Alaska			5				4	
East Slope Rockies, U.S.			20				8	
NW U.S.-SW Canada Coast			15				7	
Midwest U.S.			22				10	
Amazon Basin	25	25	25	2	17	17	17	2
Congo Basin	20	25	22.5	2	14	17	15.5	2
Sargasso Sea	25	25	25	2	12	16	14	2.5
Central North Pacific			20				14	
Tropical W. Pacific	20	27	23.5	2	16	19	17.5	2
Tropical Atlantic	25	25	25	2	14	16	15	2
Circumpolar S. Ocean			0				2	
Norwegian Sea			10				6	
Greenland Sea			5				4	
Bering Sea			8				5	
Gulf Stream			20				12	
Eastern S. Pacific	15	20	17.5	3	7	11	9	1.5
Eastern N. Pacific	18	22	20	2.5	8	12	10	2.5
Eastern North Atlantic	22	22	22	3	12	12	12	2

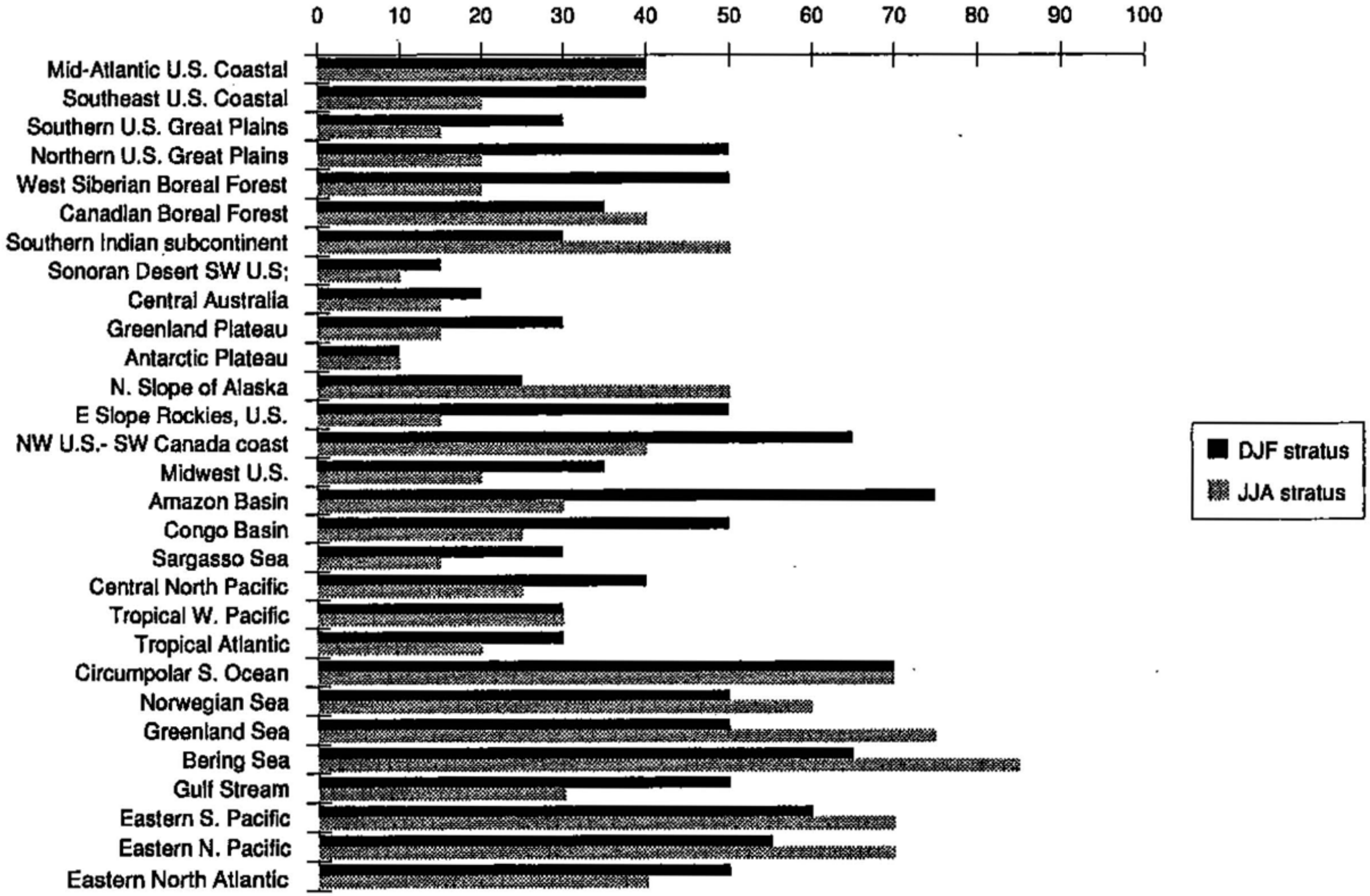

Figure 11. Frequency of Occurrence: Stratus

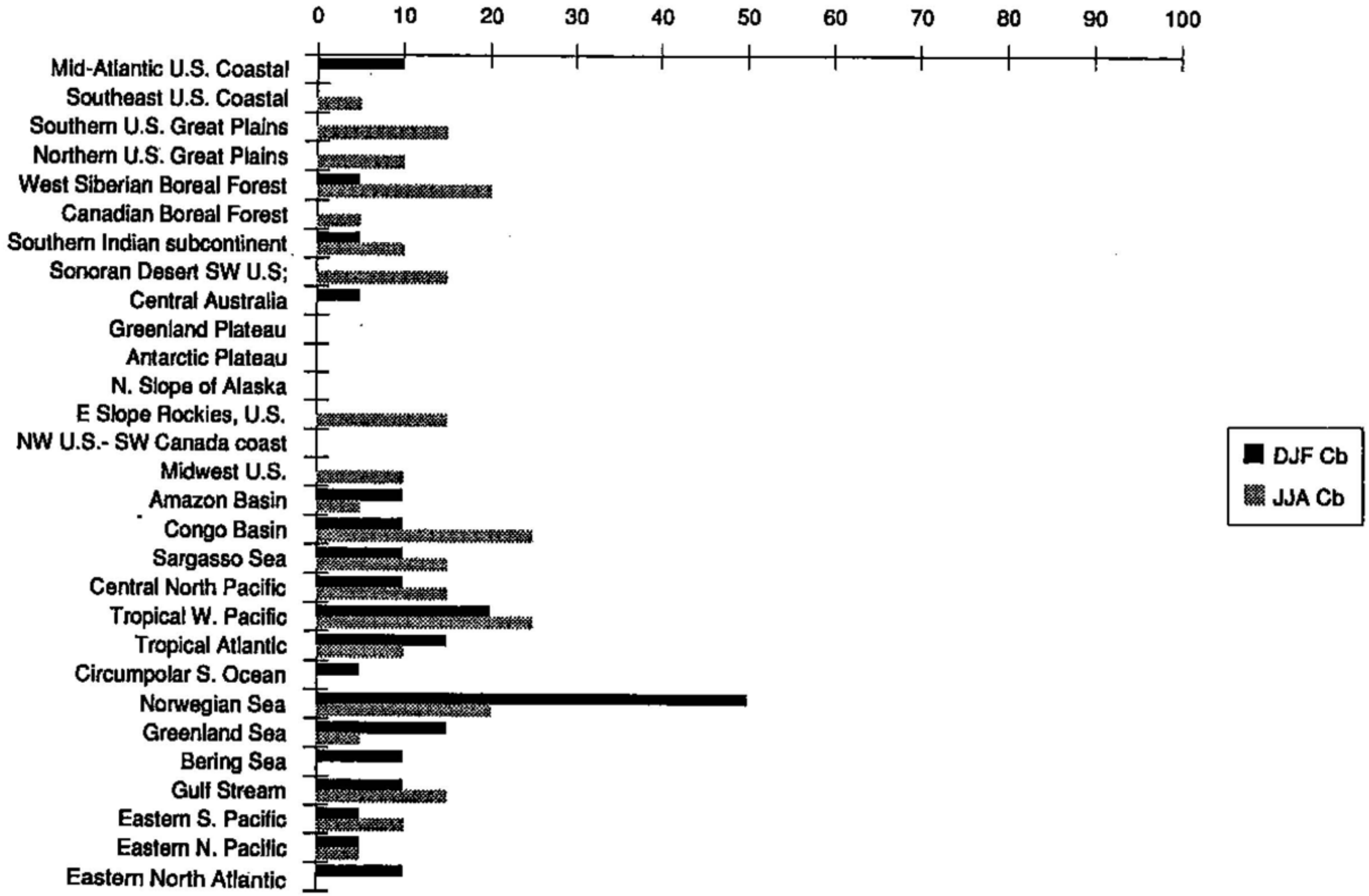

Figure 12. Frequency of Occurrence: Cumulonimbus

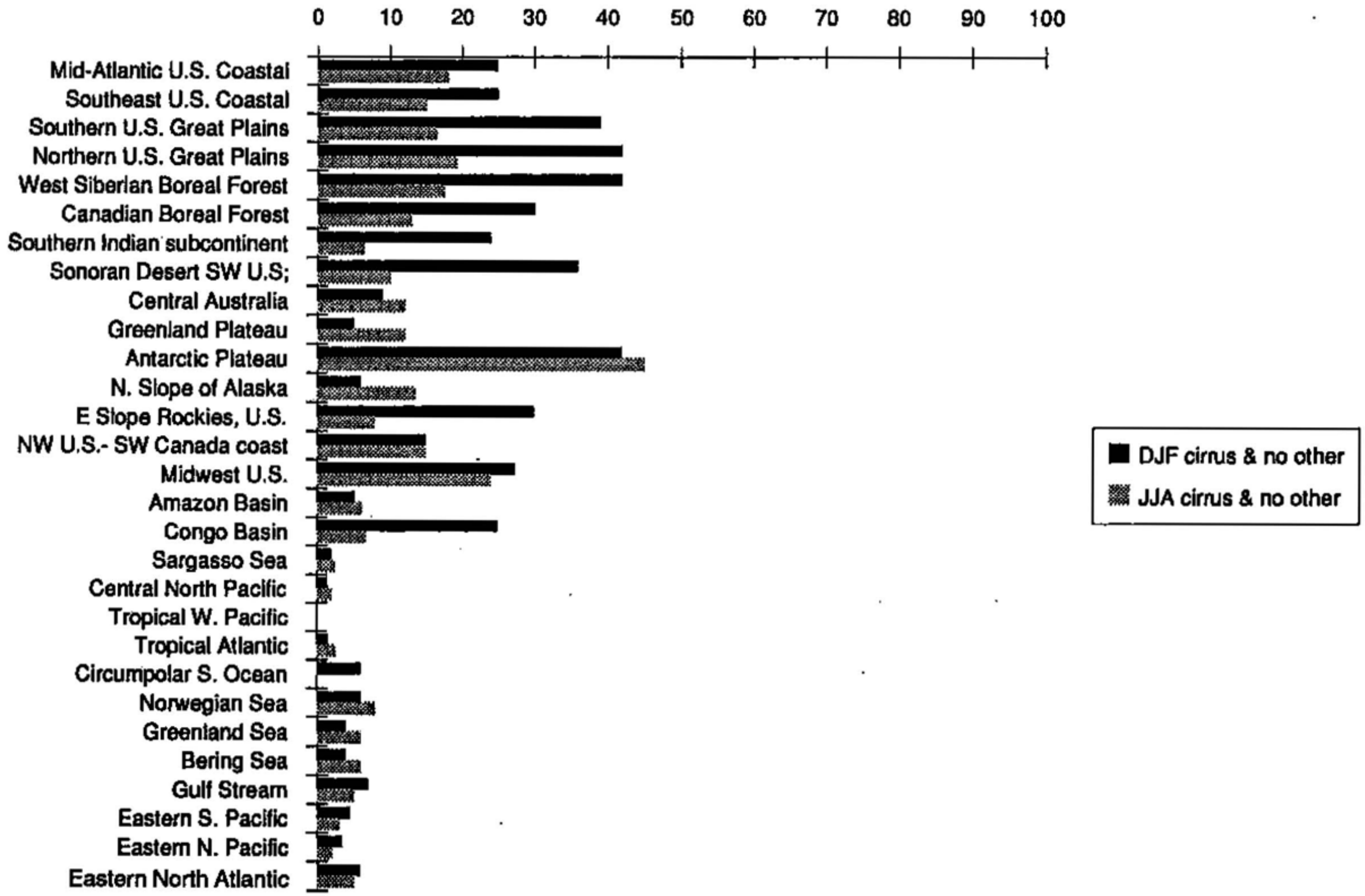

Figure 13. Frequency of Occurrence: Cirrus and No Other Clouds

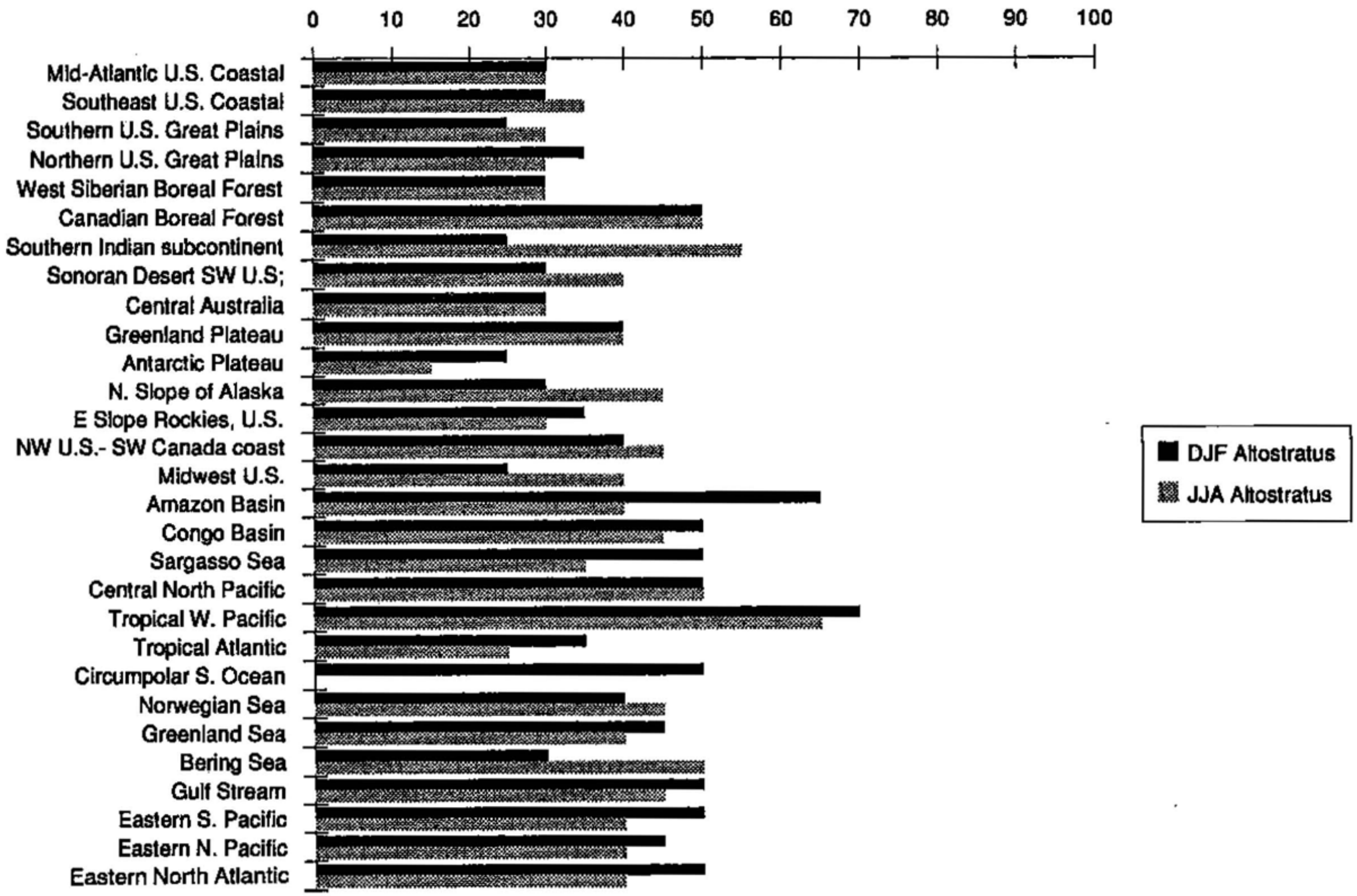

Figure 14. Frequency of Occurrence: Altostratus

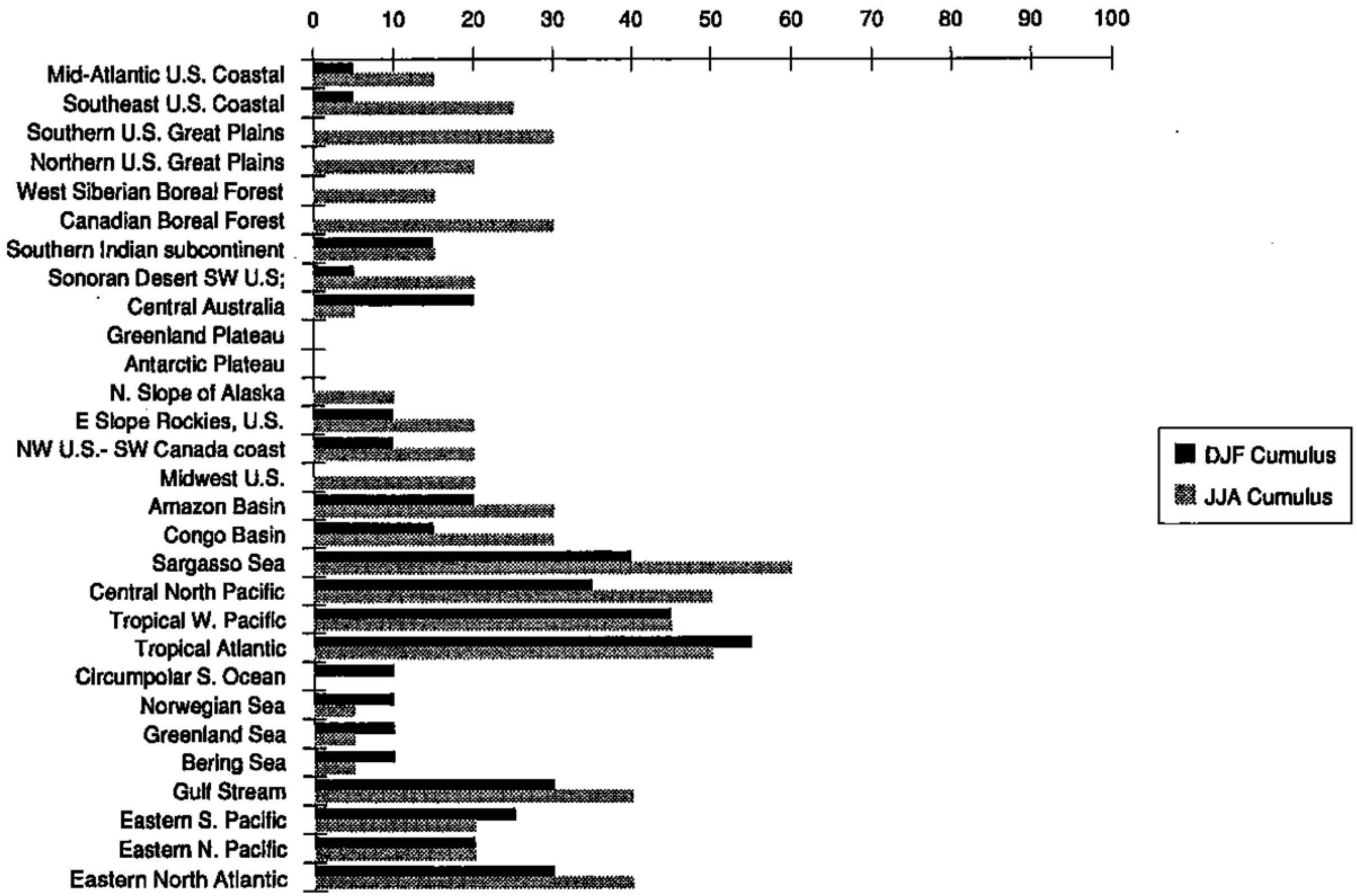

Figure 15. Frequency of Occurrence: Cumulus

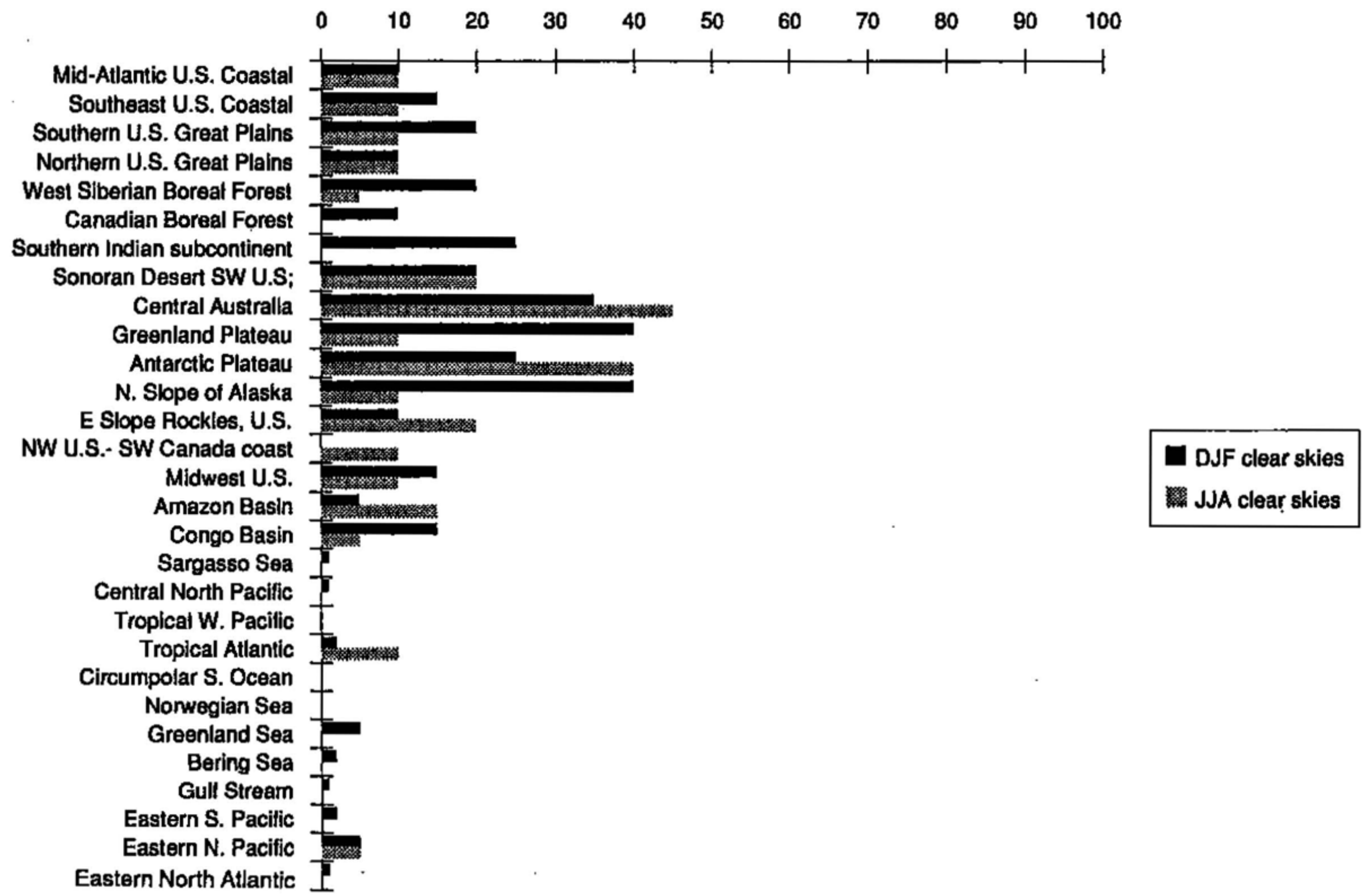

Figure 16. Frequency of Occurrence: Clear-Sky Conditions

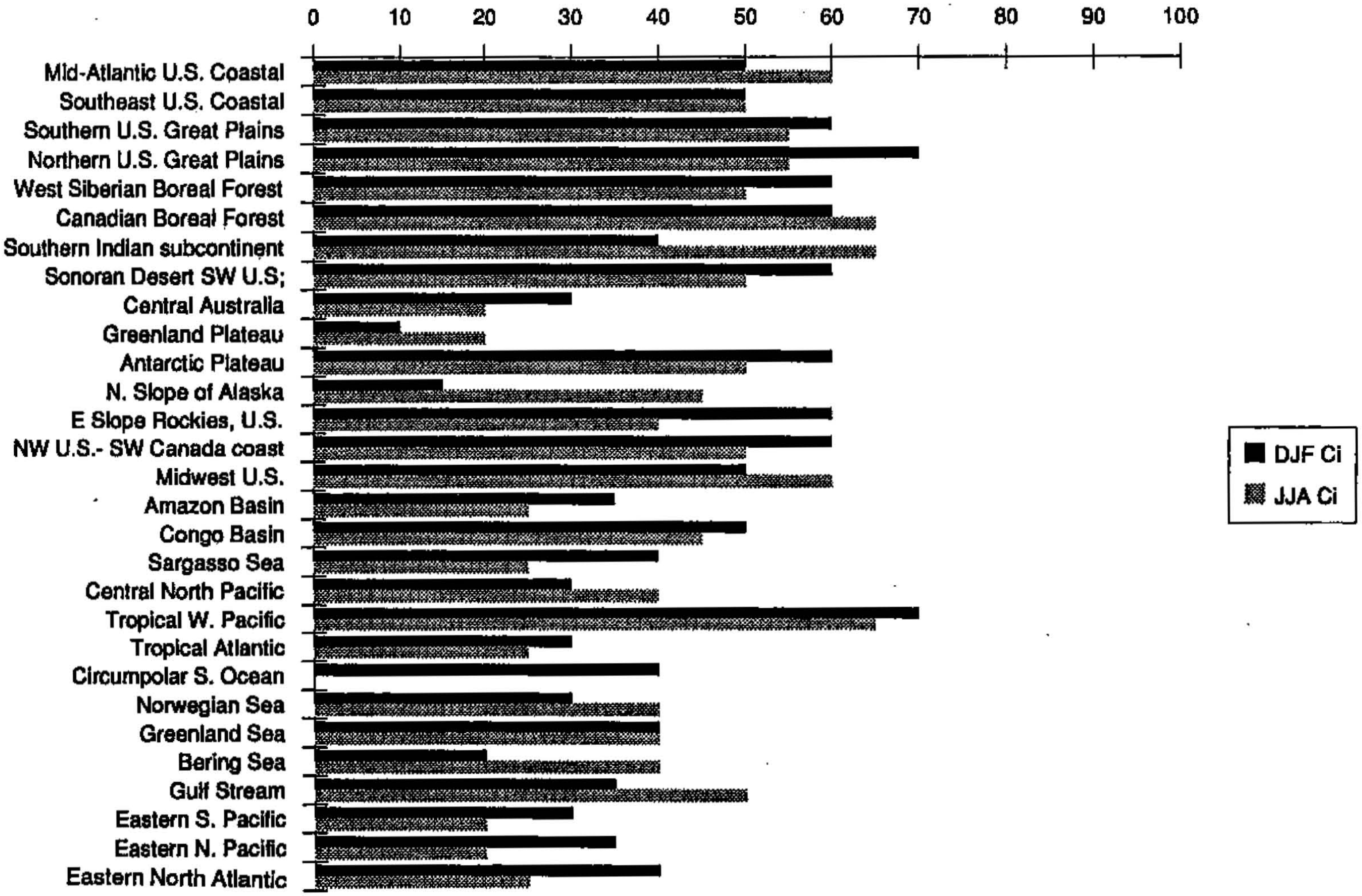

Figure 17. Frequency of Occurrence: Cirrus

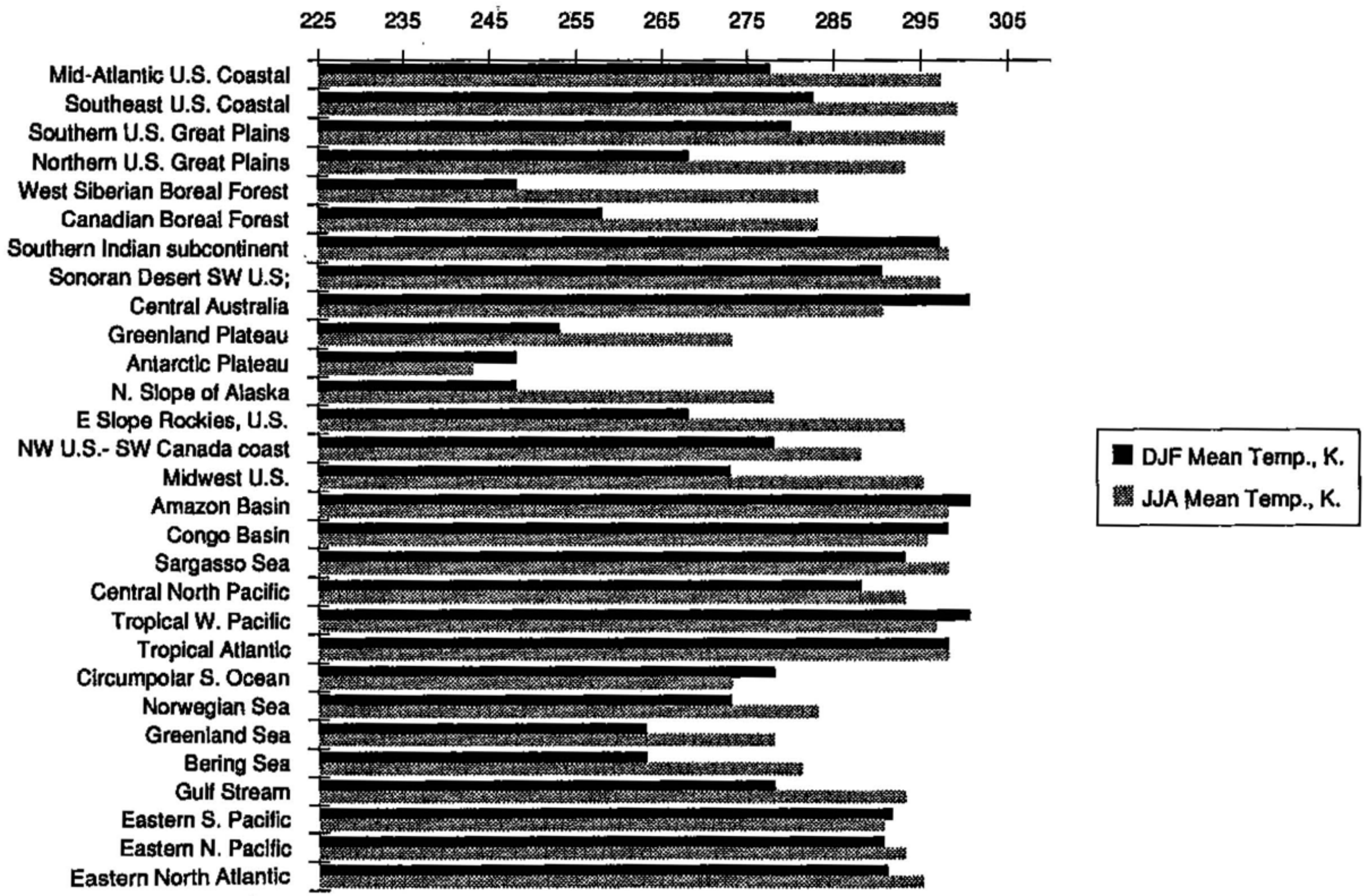

Figure 18. Mean Seasonal Values: Temperature

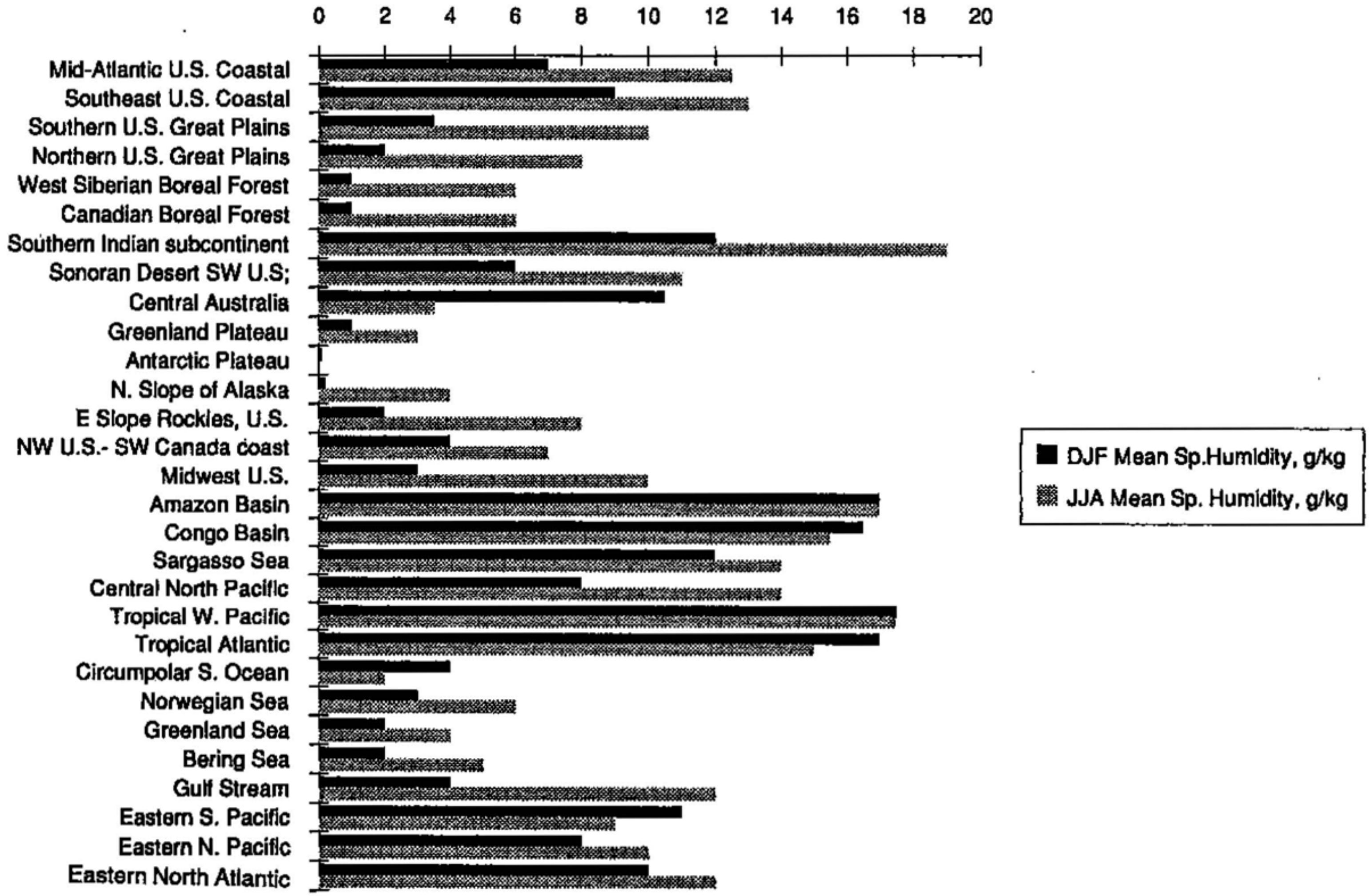

Figure 19. Mean Seasonal Values: Specific Humidity

Locale Selection

Three lists of locales are presented. The primary list gives those areas which are the preferred candidates from the perspective of strictly atmospheric processes. These areas present a variety of well-defined conditions that can stress models of radiation and clouds. In recognition of the fact that other considerations outside the scope of atmospheric processes will influence the final selection of locales, a list of alternative locales has been presented. While these alternative locales were not considered to be as favorable as the primary locales, they were judged to be acceptable alternatives. Finally, in consideration of the many specialized problems that may be addressed by ARM, a list of locales suited for short-term field campaigns has also been prepared.

The primary criterion for selection is that the locale be particularly suitable for at least one cloud type. If a locale was found to be appropriate for a particular type, but not uniquely so, other characteristics were considered for comparison with other locales. In some cases similar locales were equally appropriate for the same attributes and, hence, were nearly indistinguishable from the perspective of the Atmospheric Properties CET.

Tables 13 and 14 lists the primary locales selected by the Atmospheric Properties CET. The locales are listed in order of preference based on considerations presented below.

In selecting the first locale, an effort was made to ensure that the locale would provide conditions that would fully test, or stress, ARM models with respect to a variety of atmospheric properties. The recommended locale so selected is the U.S. Midwest, with both the Northern U.S. Great Plains and the Southern Great Plains being acceptable alternatives. On a seasonal basis these areas experience a wide variety of cloud types and amounts (Figures 11 through 16). Extratropical cyclones pass through all three areas in the fall to spring seasons, with resulting stratus, imbedded convective, and cirrus clouds. Spring to summer produce significant convective activity of both airmass type thunderstorms and organized mesoscale convective systems. Cirrus is also common during winter within these locales (Figure 13).

In addition to the cloud features, these three locales experience a wide range of temperature and absolute humidity. The widest variation is from winter to summer. Like most continental locations, there also can be significant synoptic and diurnal variations.

The Midwest locale was selected as the first choice over the Southern and Northern U.S. Plains based on secondary considerations, namely because it encompasses a large source region for anthropogenic aerosols and haze. Aerosols and haze particles can act as cloud condensation nuclei, thus influencing the microphysical and optical properties of clouds. They can also play a role in defining the radiative properties of the atmosphere.

The second locale selected is the Eastern North Pacific. This locale was selected primarily because of the relatively high probability of encountering marine stratus. These clouds persist for long periods of time over relatively large areas of the earth. Although they can have a significant impact on radiative transfer and the Earth's heat budget, they are presently poorly understood and inadequately treated in climate models. They occur off the coast of southern California with a frequency of 55% in the wintertime and 70% in the summer (Figure 11); such moderate frequencies suggest that a CART facility established in this locale would encounter numerous instances of transitions between marine stratus and broken cloud. Understanding the mechanisms and developing models for this transition are crucial to the simulation of climate change.

An additional factor for recommending the Eastern North Pacific locale as the second locale is the expectation that large variations in anthropogenic aerosols would be observed with different synoptic situations resulting in either offshore or onshore winds. The source for these aerosols would be the densely populated southern California region.

The frequent presence of cumulonimbus was a prime consideration in the selection of the Tropical Western Pacific as a primary locale. Deep convective clouds play an important role in the Earth's heat balance. They transfer moisture from the lower to the upper troposphere and lower stratosphere, where the cirrus anvils lose heat to space through IR transfer processes. These cold cirrus radiate heat to space less efficiently than the warmer low-level clouds. Cumulonimbus clouds occur with a typical frequency of 20% (Figure 12). The Tropical Western Pacific was ranked third, close behind the Eastern North Pacific locale, because of the smaller impact of cumulonimbus clouds and associated cirrus on the net planetary radiation balance, compared with marine stratus. However, it should be noted that convective activity is expected to respond much more sensitively to a climate warming than is the formation and maintenance of marine stratus.

Table 13. Primary Locales Selected by Atmospheric Properties CET

Primary Locales	Suitable Characteristics	Comments
Midwest U.S.	~~MSt.~~ , T, Cb, *q*, *Ci*, As, Aerosol, Cu, Clear	Good sample of a variety of clouds High seasonal variability in T & q. Good source of aerosols.
Eastern North Pacific	*MSt*, ~~T~~, ~~Cb~~, q, ~~Ci~~, As, *Aerosol*, ~~Cu~~, ~~Clear~~	Good for marine stratus and aerosol variability.
Tropical Western Pacific	~~MSt.~~, T, *Cb*, q, Ci, As, ~~Aerosol~~, *Cu*, ~~Clear~~	Good for deep Cb & Cu. Also extreme values of T & q. Region includes Southern Oscillation & associated phenomenon.
Gulf Stream off E.N. America	~~MSt.~~, ~~T~~, Cb, ~~q~~, Ci, *As*, Aerosol, Cu, ~~Clear~~	Mature cyclonic storms. Good cumulus activity.

Table 14. Alternative Locales Selected by Atmospheric Properties CET

Alternative Locales	Suitable Characteristics	Comments
S. or N. U.S. Great Plains	~~MSt.~~ , T, Cb, *q*, *Ci*, As, ~~Aerosol~~, ~~Cu~~, Clear	Possible substitutes for Midwest locale. Not as good for aerosols.
Mid Atlantic U.S.	~~MSt.~~, ~~T~~, ~~Cb~~, ~~q~~, Ci, As, Aerosol, ~~Cu~~, Clear	Possible substitute for Gulf Stream locale. Not as good for Cu or Cb.
Amazon or Congo Basin	~~MSt.~~, T, Cb, q, ~~Ci~~, As, Aerosol, Cu, Clear	Possible substitutes for Tropical W. Pacific. Not as good for Cu.

The Tropical Western Pacific has other attributes to recommend it as well. Large values of surface water vapor (Figure 19) and warm temperatures (Figure 18) are found in this locale; these extreme values are well suited to test the IR transfer models/modules. As a result of the Southern Oscillation a large year-to-year variability is often associated with temperatures in this locale. In addition, other cloud types are frequently observed, including fair-weather cumulus (f≈50%; Figure 15) and altostratus associated with organized convective systems. Cirrus also occur frequently (Figure 13) as outflow from convective towers. It should be noted that while the conditional probability of cirrus occurring with no other clouds (Figure 13) is modest, the absolute probability of cirrus occurring is relatively high (≈65 to 70%; Figure 17 and Table 11).

The first locale was chosen to study many cloud types under a wide variety of conditions. The fourth locale, the Gulf Stream off the East Coast of the U.S., was chosen for similar reasons, but with a different emphasis. The east coast of the U.S. experiences many mature cyclonic storms, including occluded systems. This implies more large-scale induced stratiform activity with a reduction in the frequency of imbedded convection. Winter stratus and altostratus each occur with a frequency of 50%. Summer stratus occurs with a frequency of 30%, altostratus with a frequency of 45%. Such conditions provide tests of the treatments of widespread stratiform clouds in global-scale models. A location somewhat east of the Gulf Stream might prove equally suitable while also satisfying the constraint of surface homogeneity.

The Gulf Stream locale also can be a genesis region for storms of various types, including cumulonimbus activity in cold air outbreaks and cyclogenesis with the proper synoptic conditions. Fair weather cumulus clouds also are relatively common during the summer months (Figure 15). The proximity of this locale to the heavily populated east coast of the U.S. suggests a highly variable aerosol loading.

In recognition of the logistical difficulties of instrumenting the Gulf Stream locale, the Mid-Atlantic Coastal region can be recommended as an acceptable alternative. This alternative locale is also suitable for the evaluation of models of stratiform cloud formation. The disadvantage of the Mid-Atlantic U.S Coastal locale is that it would not be expected to provide as good a sampling of fair weather cumulus or cumulonimbus clouds as the ocean locations. However, cumulus are well represented within the Tropical Western Pacific locale, and cumulonimbus are common at both the Tropical Western Pacific and Midwest U.S. locales. If the Gulf Stream locale is not selected as a long-term CART site, then it should be included as a campaign site (see below, Campaign Locales).

Two candidate locales are recommended as alternatives for the Tropical Western Pacific. Both the Amazon and Congo Basins feature similar warm, moist conditions with a relatively high frequency of occurrence for cumulonimbus (Figure 12). In addition to logistical advantages relative to the ocean locales (which are beyond the official purview of this CET) these locales have a fair representation of clear sky conditions (≈15%; Figure 16). Fair weather cumulus clouds are not as common in the Amazon and Congo as over the Tropical Western Pacific; this was why they were not a primary locale. Nevertheless, fair weather cumulus do occur at both the Amazon and Congo River Basins, as well as at the Midwest locale. Being land locales, it is expected that they might be operational for extended periods of time, and fair-weather cumulus could be adequately sampled. However, fair-weather cumulus occur much more frequently over the oceans. Marine cumulus typically have larger cloud droplets than continental cumulus, affecting both the cloud lifetime and optical properties. It is recommended that at least one of the ocean locales with frequent fair-weather cumulus be retained.

A locale that received considerable attention by the Atmospheric Properties CET was the Southern Indian Subcontinent. This locale was the only candidate associated with strong monsoon conditions. Although monsoons are not cloud types *per se*, they are climatically important phenomena which are recognized as a significant source of uncertainty in the numerical simulation of global as well as regional climate and climate change. No monsoon locales were recommended for study because the CART design does not address the important issues associated with monsoon development. These issues involve the mutual interaction between clouds and the atmospheric circulation on a variety of spatial scales. While this conclusion calls into question the CART design, which emphasizes cloud prediction given the atmospheric circulation, it is noteworthy that the monsoon clouds can be described by the cloud types sampled from the four chosen locales. The Tropical Western Pacific locale, in particular, shares much in common with the monsoon regions. The significant difference is the very complex orography of a monsoon locale, which is not an issue in the Tropical Western Pacific or in the other locales included in the primary list.

A second locale over which there was much deliberation was the Antarctic Plateau. While it experiences the most extreme temperatures of all the locales and has a negligible water content in its atmosphere, these same factors result in relatively simple situations to simulate with a radiation model. Clear skies are common, and the surface is relatively uniform. This locale is recommended only for campaign experiments in recognition of logistical difficulties associated with long-term occupation of the Antarctic Plateau.

A summary of the recommended locales and acceptable alternates is presented in Tables 13 and 14, where the following notation has been used to list the key characteristics: MSt = marine stratus, T = temperature, Cb = cumulonimbus, q = specific humidity, Ci = cirriform clouds in the absence of other clouds, As = altostratus, Cu = fair-weather cumulus, and Clear = clear sky conditions. Entries in *italics* indicate attributes that are favorable for the given locale. Entries in ~~strike-through characters~~ indicate attributes that are expected not to be found at the given locale.

Campaign Locales

A number of phenomena can be suggested which are of significant climatological interest but which do not require a full CART site for their study. To address such phenomena, it is strongly recommended that a series of campaigns be designed. Within the context of this report, campaigns are short-term, high-intensity experiments to 1) investigate a specific phenomenon, 2) evaluate properties with small temporal variability, or 3) collect data from locales where long-term programs are not feasible. The following experiments are given as a first list of such possible campaign strategies. A summary is presented in Table 15.

The Eastern North Atlantic and the Central North Pacific both offer a variety of cloud types, including the transition from marine stratus to stratocumulus to fair-weather cumulus. A critical understanding of these transitions is likely to follow from campaign experiments in either of these regions. Other members of the scientific community (e.g., the FIRE program's ASTEX experiment) have already initiated such studies in the Azores region.

The Bering Sea contains the arctic ice edge during the boreal winter and is covered by a thick blanket of fog and marine stratus during summer. A winter campaign experiment would test models of sea ice formation; a summer campaign would test models of snow and sea-ice melt and their impact on surface reflectance and models of arctic stratus formation. Aside from sea ice, the locale is homogeneous, considerably simplifying the measurement requirements.

Table 15. Campaign Locales Selected by Atmospheric Properties CET

Campaign Locales	Suitable Characteristics	Comments
Central North Pacific <u>or</u> Eastern North Atlantic	MSt. , ~~T~~, Cb, ~~q~~, Ci, As, ~~Aerosol~~, Cu, ~~Clear~~	Contain clouds in transition from MSt. to stratocumulus.
Bering Sea	MSt., ~~T~~, ~~Cb~~, ~~q~~, ~~Ci~~, As, ~~Aerosol~~, ~~Cu~~, ~~Clear~~	Good locale for studying sea-ice influences.
Gulf Stream	~~MSt.~~, ~~T~~, Cb, q, ~~Ci~~, As, ~~Aerosol~~, Cu, ~~Clear~~	Good locale for Cb, Cu.
Northwest U.S.	~~MSt.~~, ~~T~~, ~~Cb~~, q, Ci, As, ~~Aerosol~~, ~~Cu~~, ~~Clear~~	Intentionally inhomogeneous orography.
Antarctic Plateau	~~MSt.~~, *T*, ~~Cb~~, ~~q~~, Ci, As, ~~Aerosol~~, ~~Cu~~, ~~Clear~~	Good test locale for clear sky radiation.
Sonoran Desert SW U.S. <u>or</u> Central Australia	~~MSt.~~, T, ~~Cb~~, q, Ci, ~~As~~, Aerosol, ~~Cu~~, Clear	Dusty. High T and low q good for CO_2 'hot' bands studies.

If the Gulf Stream is not selected as a primary locale, it should be the focus of a campaign experiment. The strong wintertime air-sea interaction as continental air passes over the Gulf Stream generates considerable cumulus and cumulonimbus activity. This cloud formation process is not addressed specifically by the primary locales, but can be investigated on a campaign basis over a period of one to two months.

A campaign in the Northwest United States over several winter months would provide a test of the ability of circulation models to simulate the response of clouds to orographic inhomogeneity. This locale is very inhomogeneous and has abundant stratus/altostratus strongly modulated by the presence of a mountain range. Summertime stratus occurs with a frequency of 40% on the seaward side of the Cascade range and only 15% on the lee side. Wintertime nimbostratus also occurs significantly more frequently on the seaward slopes of the mountains. For these reasons, such a campaign should be considered by the ARM community.

An Antarctic campaign would provide a test of clear-sky radiation models at the coldest observed temperatures. Such conditions would highlight the absorption spectra of numerous anthropogenic and biogenic trace gases.

The Sonoran Desert or the Central Australian Desert are sufficiently hot and dry to permit the detection of the CO_2 hot bands. Totally clear sky is frequent, occurring at least 30% of the time in all seasons. These clear-sky conditions would be expected to enhance the value of studies in these locales.

The relative value of these campaigns is difficult to assess and should be addressed by the ARM Science Team. Other campaigns could easily have been recommended and probably will be by the Science Team. Flexibility in the selection of campaigns is highly recommended.

Concluding Notes

Although there was a limited amount of time to gather information, it is the view of the team that the conclusions reached by the analysis presented here, based largely on observed cloud frequencies, are likely to be sound and unlikely to change as additional information becomes available. Had more time been available, a quantitative assessment of the radiative impact of the various cloud types (both locally and globally) would have been performed, as well as an investigation of the sensitivity of the cloud types to climate change. Model simulations and satellite measurements of the planetary radiation balance would have proved useful in this regard. A more complete investigation of existing data at all locales would also have been desirable, in addition to developing more rigorous selection procedures based on such data.

Four primary locales may not be adequate to sample the great diversity of clouds observed in the earth's atmosphere. They probably will not provide examples of many features (e.g., tropical cyclones or orographic clouds). Also, the use of classical cloud types as criteria for locale selection is a simplification of the variety of cloud forms.

Despite these considerations, the Atmospheric Properties CET feels that the cloud types selected are characteristic of the predominant forms to be important for climate and climate change, and the four recommended locales sample a diversity of cloud types not explicitly considered in this study. There is no question that the extended occupation of sites in such locales will lead to substantial improvements in our ability to simulate clouds and their impact on radiation and climate.

References

Department of Energy. 1990. Atmospheric Radiation Measurement Program Plan . DOE/ ER-0441, Washington, D.C.

Hahn, C. J., S. G. Warren, J. London, R. B. Chervin, R. Jenne. 1982. Atlas of Simultaneous Occurrence of Different Cloud Types Over the Ocean. NCAR Technical Note NCAR/TN-201+STR, Boulder, CO.

Hahn, C. J., S. G. Warren, J. London, R. B. Chervin, R. Jenne. 1984. Atlas of Simultaneous Occurrence of Different Cloud Types over Land. NCAR Technical Note NCAR/TN-241+STR, Boulder, CO.

Oort, A. H. 1983. Global Atmospheric Circulation Statistics, NOAA Professional Paper 14, U.S. Department of Commerce, Rockville, MD.

Warren, S.G., C. J. Hahn, J. London, R. M. Chervin, R. L. Jenne. 1986. Global Distribution of Total Cloud Cover and Cloud Type Amounts Over Land. Office of Energy Research, U.S. Department of Energy, Washington, D.C.

Warren, S.G., C. J. Hahn, J. London, R. M. Chervin, R. L. Jenne. 1988. Global Distribution of

Appendix D

Surface Properties and Surface Fluxes

This appendix reports the recommendations provided by the CETs evaluating locales on the basis of surface properties and surface fluxes. The criteria used to discriminate among the candidate locales are discussed as well as the procedures followed. At the time of the team meeting in Brookhaven, much of the information required to make quantitative comparisons of locale characteristics was not available. Consequently, the locale selection is based on an examination of fewer attributes and less quantitative information than might be desired. Specific recommendations are given for additional studies that would permit a more quantitative evaluation.

Originally this team had consisted of two teams: one charged with examining surface properties, altitude, and terrain variability and charged with examining the surface fluxes. With the realization that surface properties largely determine sensible and latent heat fluxes, as well as surface albedo and emissivity (which clearly affect surface radiative fluxes), it became apparent that duplication of effort could be avoided by combining the two original teams into one. Furthermore, few direct (or indirect) measurements were found for determining the latent and sensible heat fluxes at each locale, so estimates of these quantities would have to be inferred from the surface variables. Thus, there would be a strong correlation between surface fluxes and surface type. The exception to this rule is that over ice-free oceans the surface properties are essentially uniform, but fluxes not necessarily so.

Two guiding principles were important in developing criteria for ranking the locales. First, it was necessary to find an ensemble of locales that sufficiently stressed the models in terms of their ability to simulate clouds and radiative transfer above various types of surfaces, and in diverse surface flux conditions. Second, it was recognized that it would be desirable to find locales in which the analysis of the observations and models would be simplified by virtue of the surface characteristics. For example, one might prefer locales where the surface surrounding an ARM site is homogeneous in all properties. One might then be justified in substituting temporal sampling of surface moisture for spatial sampling in a region surrounding the site. In model studies one could also be more justified in making the common assumption that within individual grid cells, the surface conditions were homogeneous. Thus, the criterion of surface homogeneity is an important consideration because the analysis and understanding of the ARM measurements and model simulations will be facilitated if the complicating issue of sub-grid scale variations can be avoided. It was recognized, however, that stressing models fully might require conditions of surface inhomogeneity, so in this sense our two guiding principles were somewhat in conflict. We generally decided that spatial homogeneity was more important.

The ensemble of locales must provide a diverse selection of surface properties.

Before the meeting, the team was unable to assemble a complete set of data describing all the surface attributes at each locale. In particular, detailed information of terrain and surface cover, natural vegetation types and crops, and the components of the surface fluxes were lacking. It is recommended that this information be obtained before the actual ARM sites are chosen. In lieu of better detailed surface information, the present locale recommendations are based on information derived from atlases, climatological compendia, some satellite data, and expert knowledge.

General Principles

General Considerations in Developing Selection Criteria

The ensemble of locales must be chosen carefully to provide a diverse selection of surface properties that will exercise models under a wide variety of conditions. For similar reasons, a locale in which surface conditions vary seasonally, or in response to different weather conditions generally will be preferred to locales where surface properties are invariant throughout the year. Within individual sites, however, spatial homogeneity is preferred because this facilitates analysis of the data and interpretation of the model simulations. In short, spatial homogeneity within individual locales is highly desirable, but temporal and inter-site uniformity in surface properties is not.

The team considered several different surface characteristics that might be important to the ARM scientific objectives. For land locales, surface properties that distinguish one locale from another include: altitude, terrain, soil type, vegetation type(s) and amount(s), land use, surface soil moisture, the extent and duration of snow and ice cover, and surface fluxes of radiation, sensible and latent heat. For ocean locales we considered the extent and duration of sea-ice and surface fluxes of radiation, sensible and latent heat.

For both land and ocean locales, there are other properties that can be used to characterize the surface. For example, the emissivity of the surface, the leaf area index, and the albedo (or more precisely, the spectral, bi-directional reflectance) are the characteristics actually used in many atmospheric models. Several different types of vegetation can give rise to the same surface albedo, so in this sense the radiation code of a model may be insensitive to certain differences in vegetation. However, the latent and sensible heat flux can be quite sensitive to the mix of vegetation. We concluded that where possible we should try to characterize each locale based on the more fundamental properties.

Terrain Homogeneity

Several scientific imperatives led to the decision to make surface homogeneity for individual sites the primary criterion within the scope of our team. First there are considerations having to do with making and interpreting measurements at ARM locales. In order to optimize the use of observational instruments, it is important that conditions not vary spatially within some domain of influence surrounding each site. One could then justifiably claim that any measurements made would be representative (at least statistically) of measurements one might make in a nearby location. Thus from a single location, one could more easily (and justifiably) interpolate between instruments and extrapolate to the surrounding area.

Another consideration having to do with the observational and instrument constraints is that according to the ARM Program Plan and the ARM Mission document, remote measurements from satellites will supplement the ARM site measurements. Satellite instruments may have a resolving power that typically varies from tens of meters to tens of kilometers. The interpretation of the data from these instruments is facilitated if the underlying surface is homogeneous within the smallest scales it resolves.

From the perspective of climate modelers, there are other reasons that surface homogeneity is desirable. It is well known that models contain simplifying assumptions that generally reduce the complexity of the physical system being modeled. The general rule in modeling is to begin with "idealized" conditions and proceed to the more complex. Because an objective of the ARM Program is to improve our understanding and modeling capabilities of clouds and radiation (especially as they are relevant to the global warming issue), the complexities introduced by relatively small-scale (less than 200 km) spatial variability are not of fundamental importance.

We believe that most of the uncertainties in clouds and radiation models arise for reasons other than surface inhomogeneities. Consequently, surface inhomogeneities complicate the issue without providing significant model verification capabilities. This is especially true of radiation codes.

In order to determine whether a locale could satisfy our criterion for surface homogeneity, we considered several factors. In particular we thought it important that the terrain be reasonably level and that the soil type and surface vegetation be uniform within a certain distance of each ARM site.

Quantifying these qualitative criteria proved difficult. The first question concerned determining the degree of spatial inhomogeneity that would be acceptable within various distances of the central measurement facility of each ARM site. Several different length scales were identified as being possibly important:

- the distance a ground-based radiation-measuring instrument located at the site "sees," (about 30 km)
- the lateral extent of a typical GCM grid-cell (200 to 500 km, but decreasing to about 100 km over the next decade)
- the typical domain of cloud models used to study cloud formation, maintenance, and dissipation processes (less than about 50 km)
- the "fetch" length that describes the distance required for some perturbation in clouds or other atmospheric variable caused by some inhomogeneity in surface properties to dissipate before reaching the region of the central site and ensure continuity between the planetary and surface boundary layers (variable, up to several hundred kilometers downwind of islands that create vortex wakes)
- the "footprint" of typical remote sensing instruments on satellites or aircraft that might be used in conjunction with the ARM program (usually much less than about 50 km).

From consideration of these length scales it was decided that it was important for the surface to be reasonably homogeneous out to a distance of 100 km of any potential ARM site. Unless at least one location within a locale met this criterion, the locale would be unacceptable. The higher the degree of homogeneity within the region and larger the fraction of area within the locale with acceptable homogeneity, the higher the locale would be ranked.

The next step was to quantify the degree of heterogeneity or terrain complexity that would be acceptable within the regions 200 km across. For most locales we wanted to avoid inhomogeneities that might be important in the cloud formation processes. Thus it was decided that variations in terrain should be small enough to rule out the creation of orographically induced cloud formations, such as lee wave clouds and drainage fogs or perturbations in the surface flux fields. These localized meteorological phenomena might be characteristic of a particular site but not of the category of locales it is supposed to represent. Irregularities in surface terrain that occur over less than a few tens of meters were not seen to be a problem as long as the irregularities were fairly uniform over 200 km. Thus a region strewn with boulders or a broad region of small sand dunes might be acceptable. Complex terrain with horizontal scales of a kilometer or more with slopes greater than about 1 in 100 were to be avoided. However, a uniform steeper slope that was constant in direction and magnitude over a 200-km region could be tolerated.

Quantifying the homogeneity of other surface properties was more difficult. We did not have available the satellite data that can be used to determine such properties as vegetation type, surface wetness, and soil type. Instead we drew on personal knowledge of the locales and certain general principles: crops often vary sharply over short distances with plowed fields interspersed with planted areas, and in regions requiring irrigation, wet fields interspersed with dry.

Criteria for Ensuring that Models will be Stressed

One goal in assembling a suite of sites is to obtain cloud and radiation data for different meteorological and surface conditions. Another is to test whether models can really capture the physics of cloud and radiation processes under a variety of conditions. Presumably the most difficult test is to attempt to simulate cloud and radiative processes under various extreme conditions. Thus, an important selection criterion is that sites be located in regions with strong differences in the properties that affect radiation and clouds.

In identifying which surface properties are most important in stressing models, it is convenient to consider separately radiative transfer models (which calculate radiative fluxes for a given atmospheric state) and cloud models (which prognostically calculate clouds and to some degree their radiative properties). The only surface properties that significantly affect radiation are the surface albedo (or more precisely, the spectral, bi-directional reflectance) and the surface emissivity. At an ARM site where the surface irradiance will be measured radiation models can be verified directly. Models respond to changes in the longwave flux, not directly to the surface emissivity, and variations in surface flux will occur whenever surface temperature changes. Radiation models will be stressed by surface temperature changes, and therefore it is not necessary to select locales based primarily on differences in surface emissivity. The same argument does not hold for albedo because large differences in upwelling shortwave radiation at the surface can be caused by differences in surface albedo. To stress radiation codes, the suite of locales should be located over a range of surface types with high and low albedos.

In contrast to radiation codes, prognostic cloud models may under some circumstances be very sensitive to various surface properties. Of primary importance are the absolute and relative amounts of sensible and latent heat fluxes which largely determine whether convective clouds will form. These fluxes, along with radiative fluxes, are also important in the formation, maintenance and dissipation of low-level stratus clouds and fog. In order to stress cloud models, it is therefore desirable that at different locales (or at different times) different mixtures of surface fluxes be found.

The absolute and relative amounts of surface sensible and latent heat flux are determined by several factors including the difference between ground temperature and surface air temperature, the relative humidity of the air, the ground wetness, the surface roughness, and vegetation type and amount. Ground wetness and surface roughness depend in part on land use, soil type, and vegetation. In so far as these variable surface properties affect latent and sensible heat flux, it is desirable to locate sites in regions where either temporal changes occur (e.g., crops in summer, barren in winter) or over different surface types.

Data Analysis

Prior to recommending a set of locales that best meet the criteria discussed above, the team collected information concerning the types of vegetation, surface albedo, altitude range and terrain, and surface fluxes for each of the candidate locales. This information is summarized here.

Vegetation Types

To a list of ten types of naturally occurring vegetation, derived from a simplified map of Natural Vegetation Regions of the World (an eleventh type—alpine tundra associated with highland areas—was discounted on grounds of likely orographic effects), two more were added: (artificially) irrigated cropland and cropland relying exclusively on naturally occurring precipitation. Scores (on a scale of 1 to 10) were allocated to each type by the team according to the criteria division described in the General Principle Secton of this appendix; these are given, together with a description of the vegetation types, in Table 16. The preferred subset of vegetation types consists of tundra, steppe and prairie grasslands, or naturally watered cropland (which were considered to have many equivalent characteristics within the scope of this Team) and tropical rain forest. If possible, dry deserts, icecaps and needle (boreal) forests would usefully augment the set. The distribution of vegetation types amongst the candidate locales is shown in Figure 20.

Table 16. Vegetation Types

Type	Map Classes	Equivalent Formation Classes	Score (1-10)
	Natural		
1	Equatorial and Tropical Rain Forest	1. Equatorial Rain Forest 2. Tropical Rain Forest	9
2	Temperate Rain Forest	4. Temperate Rain Forest (Laurel Forest)	5
3	Evergreen Hardwood Forest	7. Evergreen Hardwood Forest (Sclerophyll Forest)	1
4	Raingreen Forest, Woodland, Scrub, and Savanna	3. Monsoon Forest (Tropical Deciduous Forest) 8. Savanna Woodland 9. Thornbush and Tropical Scrub 10. Savanna	4
5	Steppe and Prairie Grasslands	14. Prairie 15. Steppe	9
6	Dry Desert and Semi-Desert	17. Dry Desert 11. Semi-Desert	8
7	Summer Green Deciduous Forest	5. Summer-Green Deciduous Forest	5
8	Needleleaf Forest	6. Neddleleaf Forest	6
9	Tundra (Arctic and Alpine)	16. Grassy Tundra 17. Cold Woodland 18. Arctic Fell-Field	9
10	Ice Caps and Glaciers		8
	Agricultural		
11	Artificially Irrigated		1
12	Naturally Watered		9

Surface Albedo

Global maps of monthly mean surface shortwave reflectance (or albedo) were used to determine the annual ranges of albedo at each locale. These data are derived from satellite measurements and form part of the ISCCP (International Satellite Cloud Climatology Project) database. The annual range was assumed to be characterized by the difference between the January and July values and these are shown in Figure 21. The locales that offer the greatest range of albedo are those which experience winter snow or ice cover, and these locales are generally preferred.

Altitude Range and Terrain

Contour maps were consulted to assess the topography of each locale. The detail of these maps was inadequate for anything more than coarse estimates, and these are shown in Figure 22, as the peak-to-peak range encountered in the entire area of the locale. It was not possible to estimate with any certainty either the vertical height excursions of less than 100 m (the contouring interval) or the smaller scale (kilometers to tens of kilometers) variations in the terrain (except those that were clearly mountainous). It was therefore decided that terrain homogeneity could not be used (perforce) as a criterion for distinguishing between the candidate locales, and the selection of this team rests on the assumption that within the chosen locales individual sites of uniform terrain can be found. This assumption must be tested as soon as more detailed information is available.

Surface Fluxes

Spatial homogeneity of surface energy fluxes was deemed necessary for all length scales considered in the Terrain Homogeneity Section above. Any discontinuity in the surface (e.g., roughness, temperature, vegetation, or moisture available for evapotranspiration) will perturb the surface boundary layer to a height of about 1/100X, X being the distance downstream of the discontinuity. Thus, in order to have continuity between the surface and planetary boundary layers, the surface must be uniform for about 100 km upstream.

For the land locales, homogeneity of the surface was identified as the most meaningful attribute which could be substituted for direct measurements of the spatial uniformity of the surface fluxes. Uniformity of terrain, vegetation, and available soil moisture will assure uniformity of the fluxes under given meteorological conditions. It seemed likely that within each candidate land locale (except those identified as intentionally heterogeneous) a site could be found that had sufficiently uniform terrain and vegetation for the required 100-km radius. Since the available data did not permit us to confirm this, we could not rank one locale more highly than any other based on the criterion for homogeneity. In general, areas with variable terrain, variable vegetation, irrigated crops, or significant bodies of water will likely have especially nonuniform soil moisture. This tendency is particularly true during periods of drought. An examination of the Palmer Hydrological Drought Index reveals that in any given year any U.S. locale, with the possible exception of the NW U.S. - SW Canada Coast, might experience drought conditions. Occupation of sites for several years would therefore be desirable.

All locales exhibit some diurnal and seasonal variations of the surface energy fluxes to stress the models. There are significant differences in the amount of energy available and in the distribution between sensible and latent heat fluxes (Bowen ratio) among the various locales. Annual average precipitation less pan evaporation (when available) was used to indicate the availability of surface moisture for evapotranspiration at each of the land locales. Monthly averages of insolation and precipitation were used to indicate the amount of energy available and the distribution between sensible and latent heat flux. (Periods of low precipitation result in higher Bowen ratios.) However, this information has to be weighed with consideration to snow cover at which times net radiation is small or even upward and both heat fluxes are small. January and July averages of net radiation and heat flux

09-11-90

VEGETATION TYPES

	Locale	1	2	3	4	5	6	7	8	9	10	11	12
LAND LOCALES	Mid-Atlantic U.S.Coastal Plain							✓					✓
	Southeast U.S. Coastal Plain		✓					✓					✓
	Southern U. S. Great Plains					✓						✓	✓
	Northern U. S. Great Plains					✓						✓	✓
	West Siberian Boreal Forest								✓				
	Canadian Boreal Forest								✓				
	Southern Indian subcontinent	✓	✓		✓							✓	✓
	Sonoran Desert SW U S; N Mex						✓						
	Central Australia						✓						
	Greenland Plateau										✓		
	Antarctic Plateau										✓		
	N Slope of Alaska									✓			
	E slope Rockies U. S.								✓				
	NW U.S-SW Canada Coast								✓				
	Midwest U.S.							✓					✓
	Amazon Basin	✓											
	Congo Basin	✓											
OCEAN LOCALES	Sargasso Sea (N. Atlantic)												
	Central North Pacific												
	Tropical W. Pacific Ocean												
	Tropical Atlantic												
	Circumpolar Southern Ocean												
	Norwegian Sea												
	Greenland Sea												
	Bering Sea												
	Gulf Stream off E. N. America												
	Eastern South Pacific												
	Eastern North Pacific												
	Eastern North Atlantic												

Figure 20. Distribution of Vegetation Types

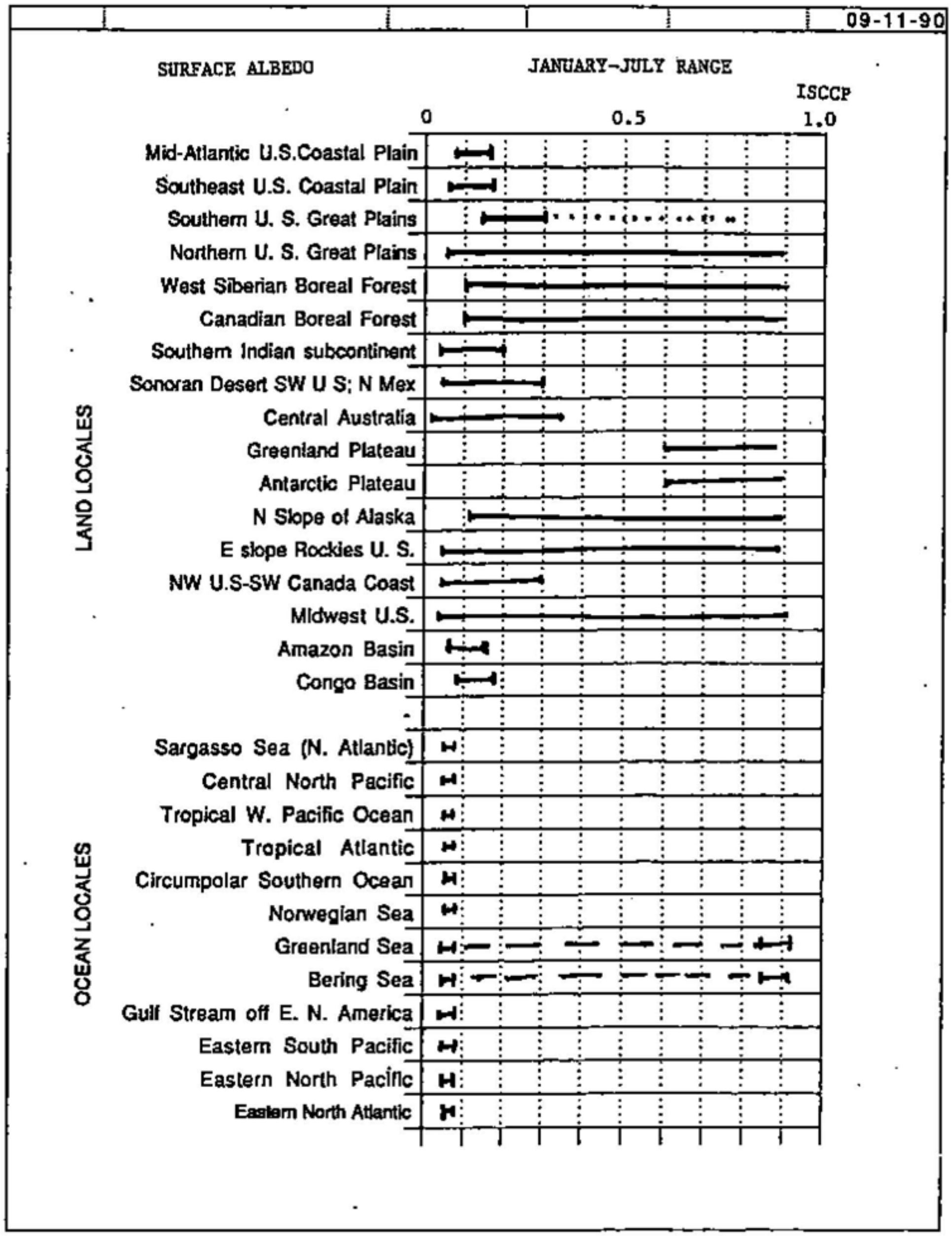

Figure 21. Range of Surface Albedo

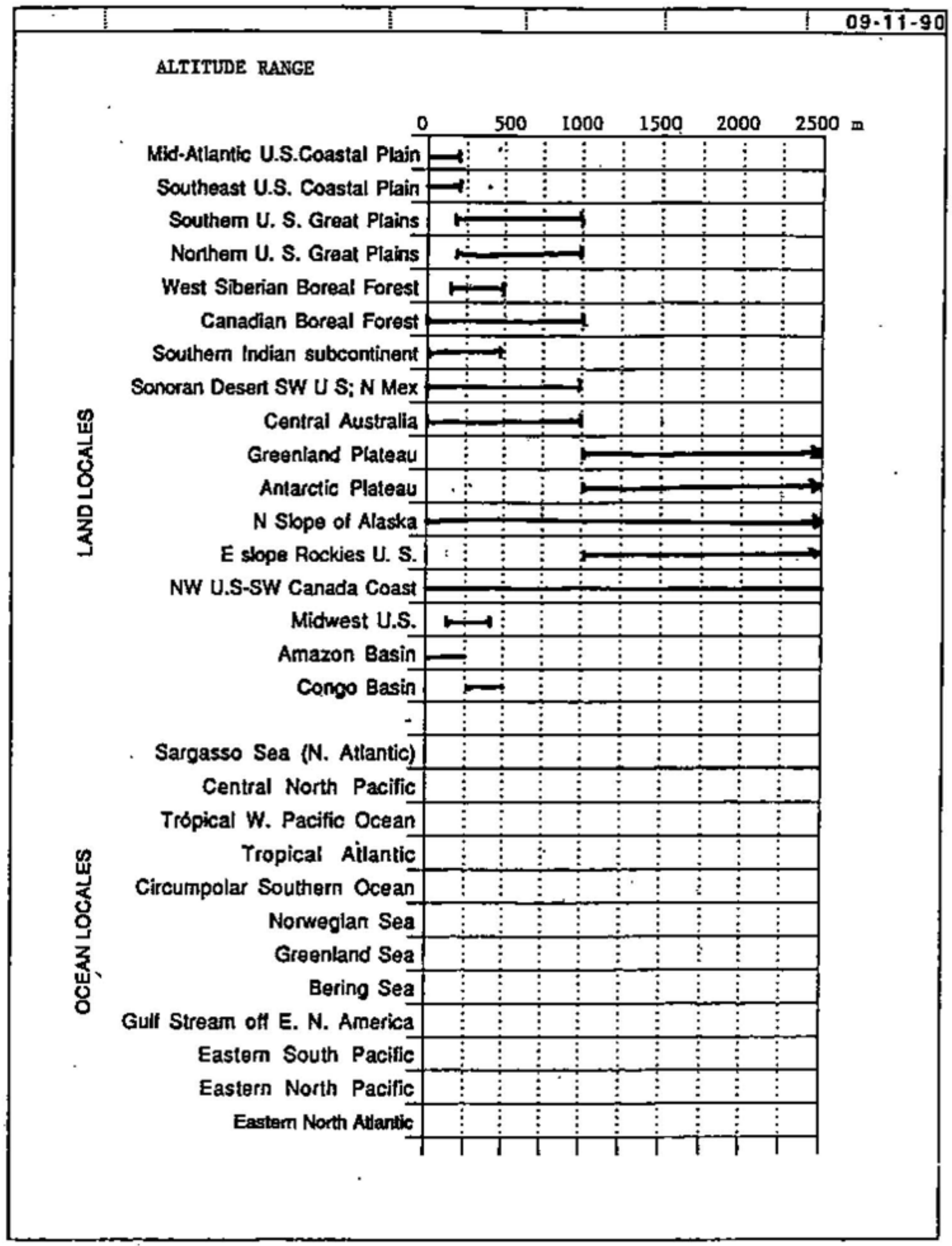

Figure 22. Altitude Range

and annual averages of evaporation were used to determine the ability of the ocean locales to stress the models. The results of some of these assessments are shown in Figures 23 to 26.

For some of the oceanic locales, estimates of averaged monthly components of the surface heat flux have been derived from compilations of meteorological observations from ships. Where

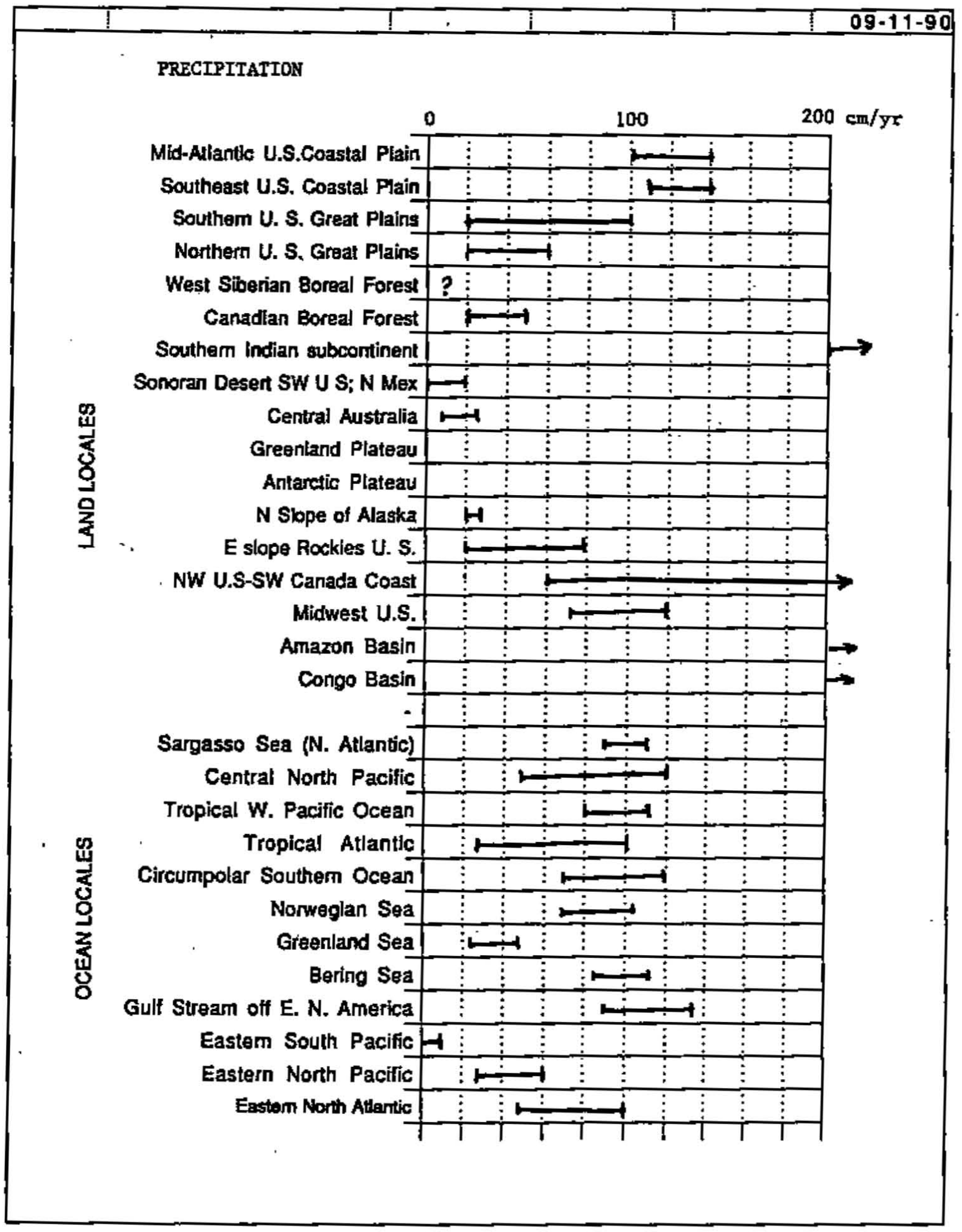

Figure 23. Precipitation

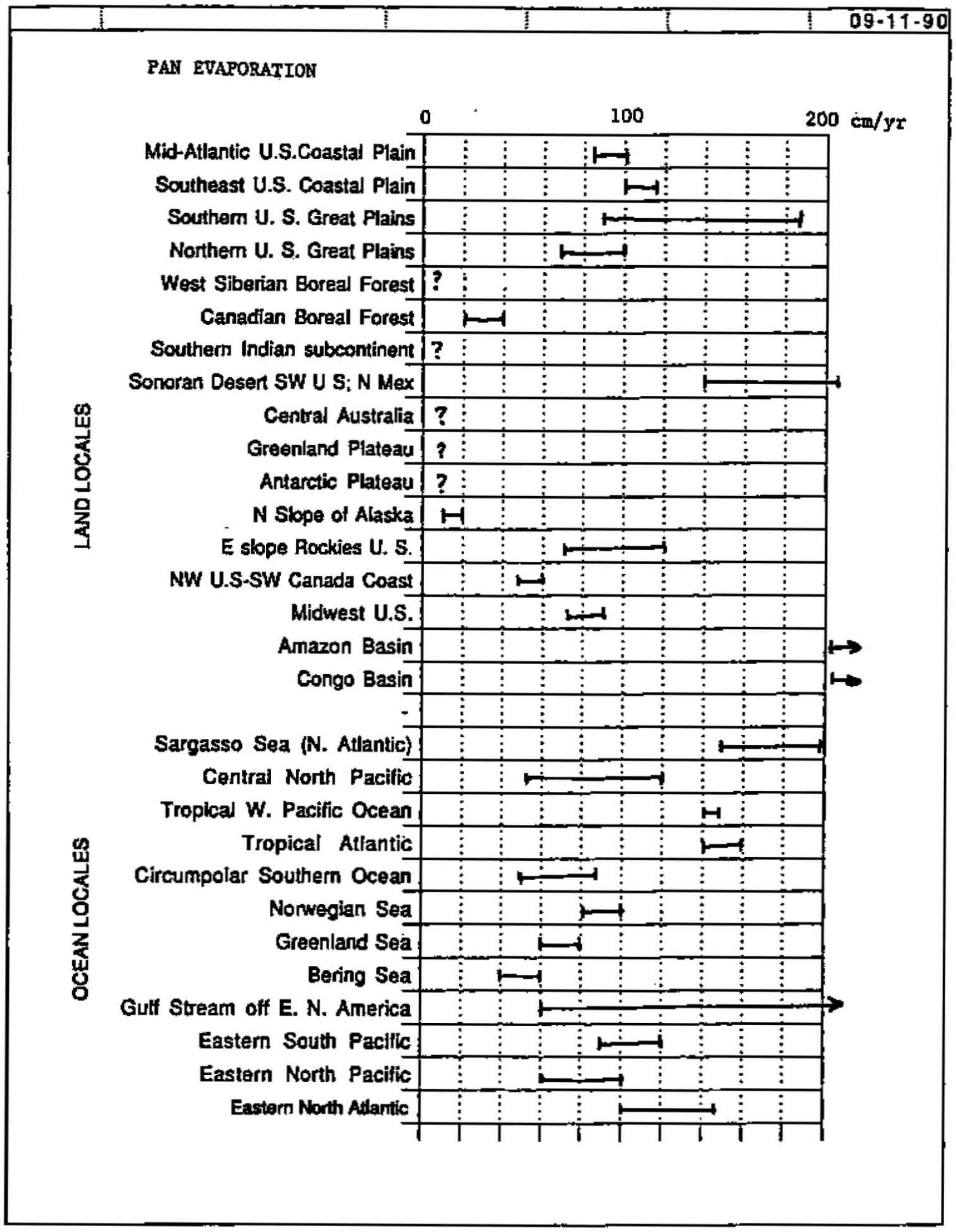

Figure 24. Pan Evaporation

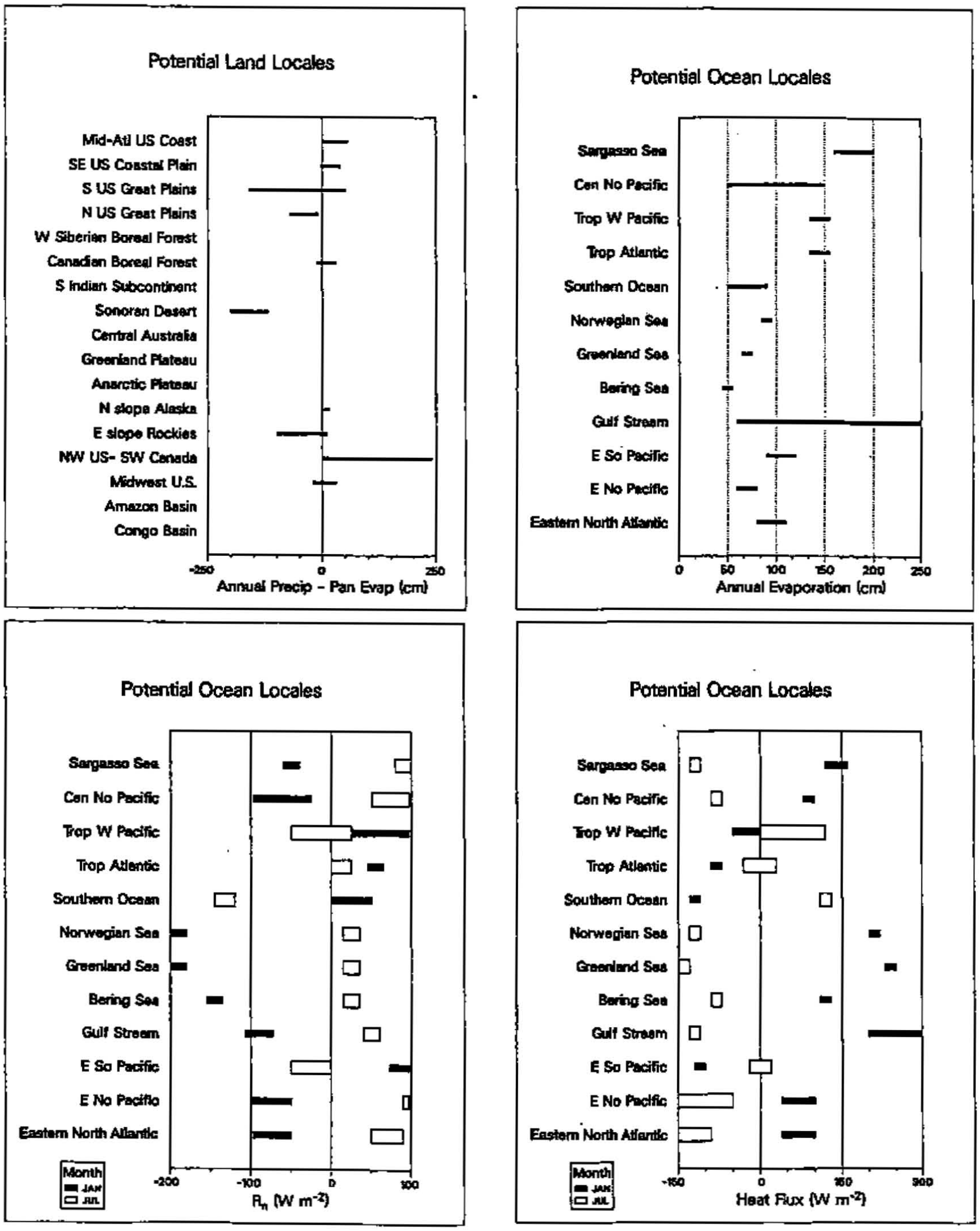

Figure 25. Land Locale: Annual Precipitation Minus Pan Evaporation
Ocean Locale: Annual Evaporation, January and July Radiation, and January and July Heat Flux

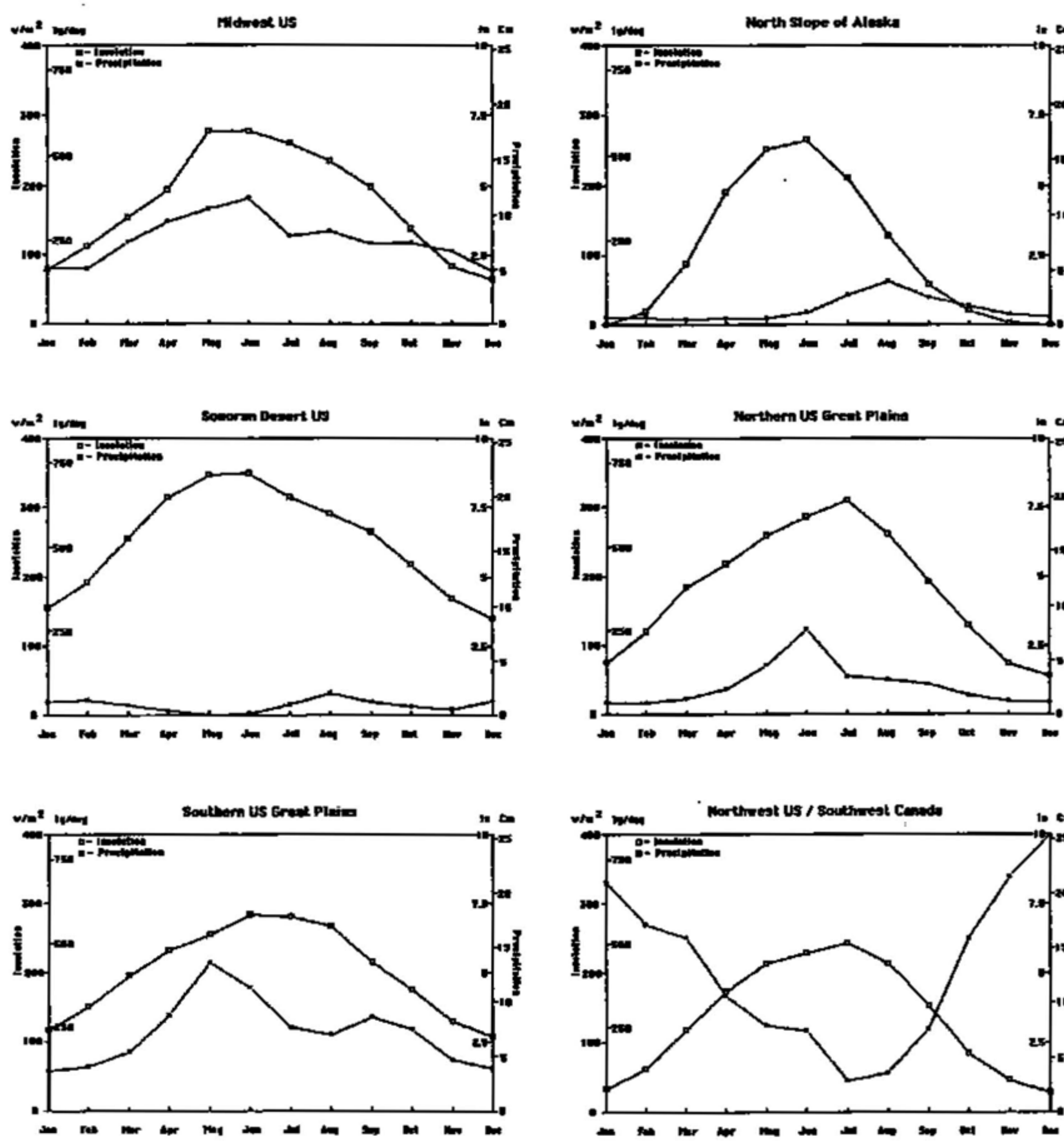

Figure 26. Annual cycles of Monthly Mean Insolation and Precipitation for North American Locales.

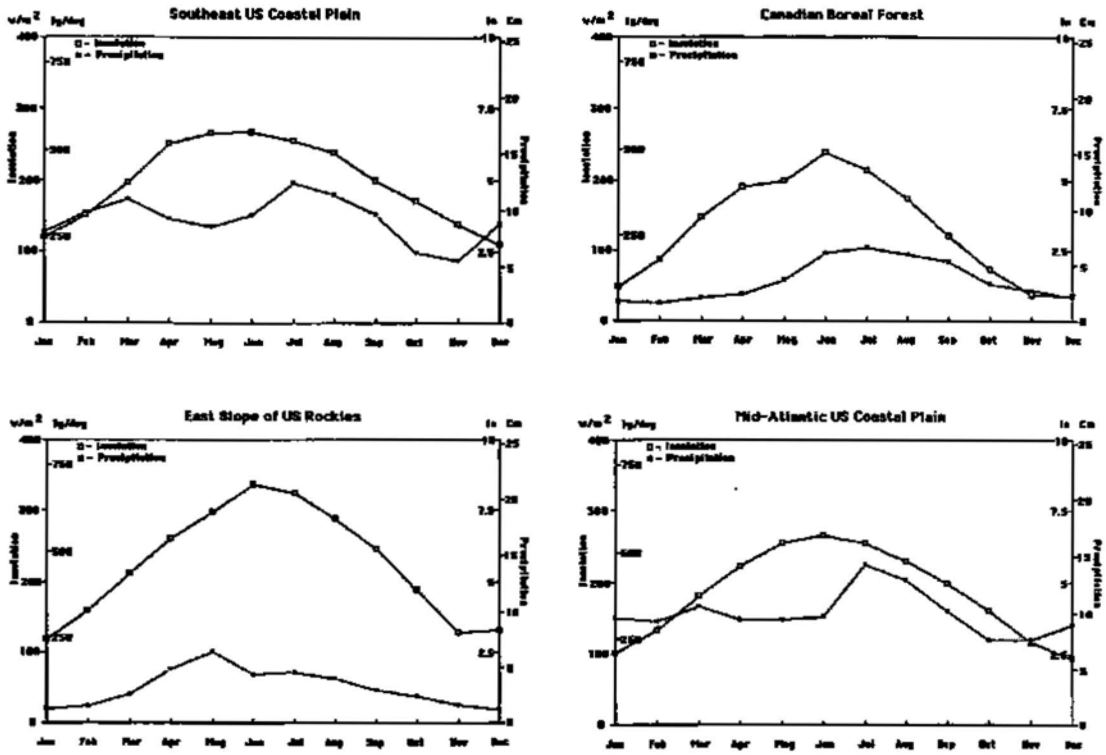

Figure 26. (contd.)

available, these were consulted. However, such information is usually available only with a relatively coarse resolution. The variations in sea-surface temperature, which can strongly modulate the turbulent (sensible and latent heat) fluxes and which cannot be so readily avoided in the site selection, may present some problems associated with spatial variabilities. On the other hand, short term temporal changes in surface fluxes at an ocean locale are much smaller than over land as the diurnal modulation of fluxes is very small over the ocean. A different measurement strategy may therefore be necessary over oceanic locales compared with that over terrestrial locales. There are no other significant features by which the ocean locales may be ranked for homogeneity other than the presence or absence of ice. In the case of the Marginal Ice Zone locales, this is an intentional nonhomogeneity.

Locale Selections

Locales were selected on the basis that about six would be instrumented. These are given in Table 17 and brief justifications are given below. It is recognized that for many reasons, mainly logistical, some locales may present significant difficulties for continuous site occupation over several years. This may be the case for all oceanic locales, and it is accepted that episodic occupation of ocean sites may be a necessary compromise, which, although not ideal, will not seriously jeopardize the ARM scientific goals. This is also true for the high-latitude land locale (North Slope of Alaska) where periodic occupation to sample the range of conditions around the year would probably be adequate.

Recommendations

The six primary locales are given in Table 17 and correspond to equatorial rain forest, steppe/prairie or naturally watered cropland, tundra, equatorial ocean, seasonally ice-covered ocean, and midlatitude ocean.

The first complementary locale (dry, subtropical desert) could also be considered a primary locale, especially for considerations of extreme surface flux conditions and for providing a very uniform surface over large distances.

Discussion

The land locales were selected to provide a range of surface types and surface fluxes with which to stress the GCMs, and with considerations given to the need to identify within each locale an area of uniform attributes at which to locate the ARM sites.

Of the primary land locales, the Midwest U.S. or the N. U.S. Great Plains were chosen as the first ARM site as offering easier logistics than the other locales. Either one of these locales presents the possibility of finding a site with sufficiently smooth terrain and uniform vegetative cover, although this is likely to be agricultural rather than natural. The seasonal changes would provide a wide spread of surface cover, ranging from bare earth to mature crops, and a full range of surface moisture conditions including the possibility of periods of extreme dryness during the several years of the ARM measurements. The presence of extensive seasonal snow cover, a certainty for the Northern Great Plains, would provide conditions of high surface albedo.

The tropical rain forests were selected to provide conditions of high latent heat fluxes (evaporation), rainfall, and insolation. On the scales of tens of kilometers and longer, large tracts of the surviving rain forests may provide adequately uniform vegetation. However, as the rain forests continue to be destroyed, such uniform areas will become fewer and the atmospheric burdens of the products of biomass burning may further complicate the measurements.

The tundra locale was chosen to provide further samples of land cover and colder conditions. In summer the tundra offers large expanses of uniform vegetative cover, quite distinct from those provided by the other locales, which is likely to be quite moist. In winter, however, a tundra site would provide extensive areas of uniform dry snow cover with high surface albedo, small heat fluxes and, at the winter solstice, conditions of the polar night.

Table 17. Locales Selected by Consideration of Surface Properties and Surface Fluxes

Primary Locales:		**Comments**
Land:	Midwest U.S. or Northern U.S. Great Plains	Good range of seasonal variations in surface cover and fluxes.
	North Slope of Alaska*	Large range of seasonal changes.
	Amazon Basin or Congo basin	Extreme water vapor flux conditions and precipitation, and well-defined forest cover.
Ocean:	Tropical W. Pacific Ocean*	Extreme sea-surface temperatures.
	Greenland Sea* or Bering Sea*	Large range of surface albedo and surface fluxes associated with ice cover.
	Gulf Stream off Eastern N. America	Large range of surface fluxes.
Alternative Primary Locales:		
Land:	Southern U.S. Great Plains	As alternative to midwest U.S. or N. Great Plain, less likely to offer reliable snow cover.
Ocean:	Tropical Atlantic*	As alternative to Tropical Pacific, but less extreme values experienced.
	Any mid- or high* latitude ocean locale	As alternative to Gulf Stream, would offer a range of conditions through the year, but with less extreme values.
Complementary Locales:		
	Central Australia*	Dry subtropical desert where surface fluxes not dominated by water; extreme surface type.
	W. Siberian Boreal Forest* or Canadian Boreal Forest*	Extensive, well defined forest cover, with seasonal snow cover.
	Greenland Plateau* or Antarctic Plateau*	Very uniform surface, very cold and very dry extreme conditions.
Alternative Complementary Locales:		
	Sonoran Desert*	As alternative to Central Australia—less uniform terrain.

* Locales suitable for episodic occupation.

The ocean sites were selected to provide a range of surface flux conditions with which to stress the GCMs. The downwelling solar radiation at the surface of the ocean is controlled by the solar zenith angle and atmospheric constituents, mainly cloud cover. The surface reflectance (albedo) is generally very small compared with land surfaces and apart from small changes (in the spatially averaged value) due to whitecapping, the albedo of the sea can be considered uniform over the length scales of interest (200 km). The main exception to this is when the sea-water freezes and becomes covered by ice and snow. The surface albedo may change from 6% (ice free) to 90%. The effect on the atmospheric radiation field is therefore profound. For this reason it is important to have an ocean ARM site at the ice-edge. Furthermore, the presence of sea-ice strongly modifies the turbulent air-sea exchanges, so an ocean site which experiences ice cover is required to provide measurements of the turbulent fluxes as the ice edge advances and retreats. A further, less dramatic, change in the ocean albedo can result from high burdens of near-surface suspended matter, including plankton, and these occur mainly within the areas influenced by the coast. From the surface fluxes viewpoint, the consequence of this change in albedo is small, compared with that due to ice, and need not be a consideration for locale selection.

The thermal emission from the sea surface, governed by the surface temperature and surface emissivity, peaks at the 10- to 13-mm spectral interval, which coincides with an atmospheric transmission window. The main absorber in this interval is water vapor which displays continuum absorption: this is poorly understood and its parameterization is a major uncertainty in numerical models of clear sky atmospheric radiation transfer. Yet in regions of high atmospheric water vapor burden, such as in equatorial regions, the continuum effect is an important factor in atmospheric water vapor absorption and thereby presents a possible positive feedback mechanism for climate change. Unlike land surfaces, the ocean has a high and uniform surface emissivity within the constraints of spatial variations in sea-surface temperature, thus provides a uniform background radiation field in which to make measurements of the water vapor continuum absorption. For this reason it is important to have an ocean ARM site in an equatorial ocean site.

The transfers of latent and sensible heat (the turbulent fluxes) are controlled by the local wind, atmospheric stability, relative humidity, air temperature, and by sea-surface temperature and show less diurnal variation than those over land. The evaporative (latent heat) flux provides the water vapor for the formation of marine clouds, and therefore an ARM ocean site which encompasses a wide range of flux values and meteorological conditions is necessary. This is likely to be a midlatitude or high latitude, ice-free locale. For much of the time over much of the ocean, the sea surface temperature lies generally within a few degrees of the air-temperature, so local variations in sea surface temperature, caused by ocean current structure, can cause large changes in the air-sea fluxes, possibly even changing their sign. Since sea surface temperature variability is a ubiquitous feature, some degree of variations in the sea-surface fluxes over length scales of the order of 100 km is to be expected. Nevertheless, in general this will be smaller than for terrestrial locales.

The recommendation of the Gulf Stream as a primary ocean locale is determined by the extreme surface fluxes that are experienced there, especially in winter (Figure 27). When cold, dry, continental air-masses are brought over the Gulf Stream by strong winds from the northwest, very large heat and moisture fluxes are generated at the sea-surface. Unlike conditions on land or inland waters, which become snow or ice covered in such meteorological conditions, thereby reducing the surface fluxes, the transport of warm water by the Gulf Stream maintains large air-sea temperature differences and large heat and moisture fluxes.

Table 18 compares latent and sensible heat fluxes (W/m^2) at possible alternative land sites, as monthly averages for the seasons shown, to those for the Gulf Stream locale. Clearly the Gulf Stream locale exhibits much greater values of these fluxes.

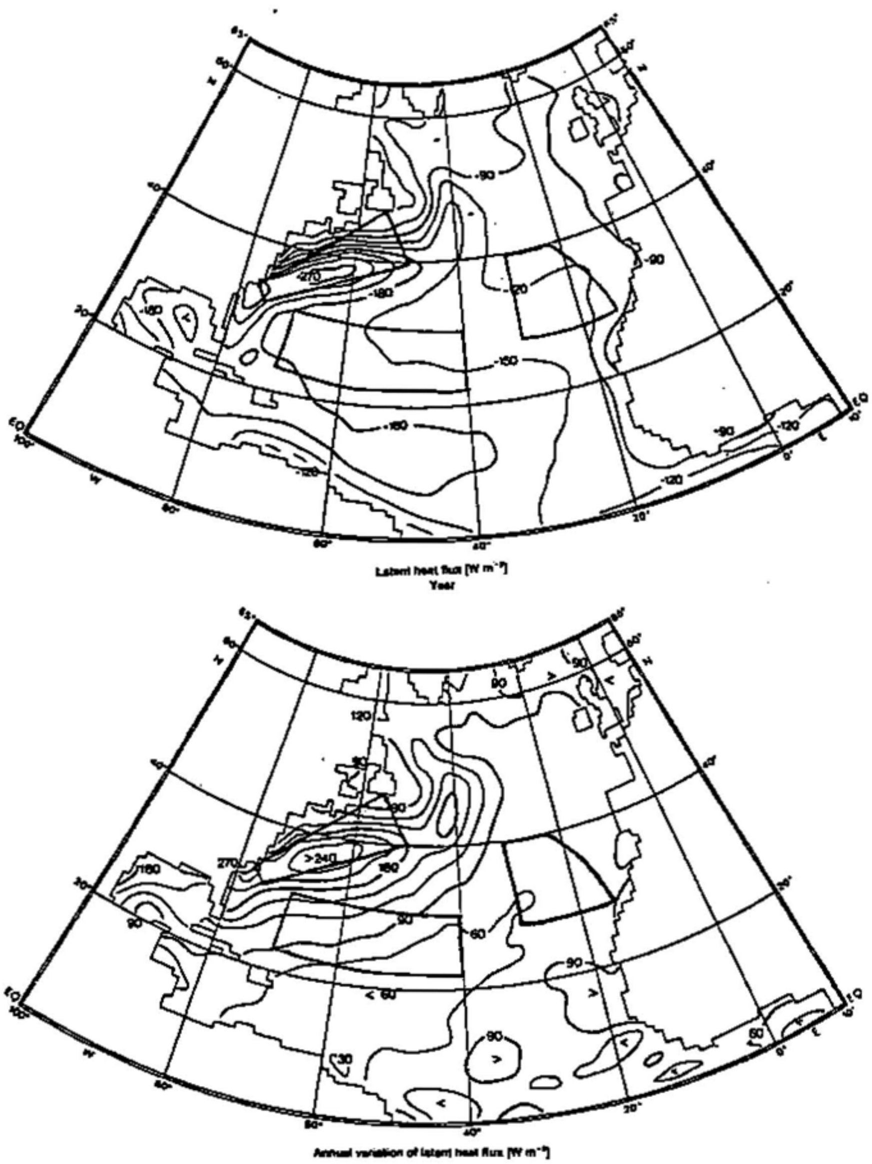

Figure 27. Latent Heat Fluxes from the Ocean to the Atmosphere (W/m²), shown as annual mean (top) and annual range, for the N. Atlantic Ocean. The boundaries of three locales are shown: the Gulf Stream, the Sargasso Sea, and the Eastern North Atlantic area. The extreme mean value and range found only in the Gulf Stream locale are apparent. (Isemer and Hasse 1987).

Table 18. Comparisons of Latent and Sensible Heat Fluxes (W/m^2)

Possible Alternative Land Sites		Latent	Sensible
San Antonio, Texas	- winter	120	50
Coastal Florida	- summer	145	20
Madison, Wisconsin	- summer	120	25
Lake Mead, Arizona	- early winter	240	50
For Comparison:			
Gulf Stream		390	100

Source: Sellers (1965)

Future Work

Locale Selection

Because of time constraints, quantitative estimates of several properties could not be made and the degree of homogeneity to be found within each locale was difficult to assess. It was also not possible to determine the degree to which surface inhomogeneity would complicate the measurement analysis and modeling processes. Furthermore the degree to which a model would be stressed by locating at different types of surfaces was not clear. Although the magnitude of boundary layer fluxes of latent and sensible heat can span a wide range, it is not generally known how sensitive cloud formation and growth are to these fluxes. One can argue that radiation codes can be tested without any knowledge of the latent and sensible heat fluxes, but most convective clouds and low lying marine stratus clouds are probably quite sensitive to these fluxes.

A more thorough analysis of data from AVHRR, Landsat, SPOT, and the Space Shuttle, could be beneficial in providing more quantitative information about surface homogeneity. For the U.S. sites, further information about surface type, terrain homogeneity, and land use could be obtained from the U.S. Geological Survey or the Department of Agriculture. If required, estimates of surface sensible and latent heat fluxes could be made (especially over oceans) based on temperature, humidity, and wind measurements using bulk aerodynamic parameterizations.

Site Selection

We expect from our brief study of limited data that most locales contain regions of sufficient extent and sufficient surface homogeneity to be acceptable as ARM sites. When site locations are selected within locales it will be imperative that the surface homogeneity issue be addressed again. A much more thorough and detailed study of the locales selected will be required in order to identify the areas that are most homogeneous and therefore most preferred as ARM site locations. As part of this analysis it would be valuable to determine what kind of inhomogeneities are most detrimental to ARM objectives and to ascertain what inhomogeneities can be tolerated.

Summary of Locale Properties

Although the recommendations of this team are contained in the Locale Selection Section, it is recognized that further evaluation and review of locales and potential site locations will be carried out in the coming months. As background for this continuing site selection process, we include brief summaries of the general characteristics of many of the candidate locales.

Midwest U.S. Most frequent haziness of any site; frequent synoptic air mass changes; deep convection usually associated with fronts and squall lines; frequent long periods of snow cover, but rarely all winter even on northern side. Great Lakes effects on N. side; hilly terrain to S. and SE. Large extent of flat cropland (generally corn & soybeans). Trees mostly deciduous and limited to river valleys except to S. and E. Many meteorologically simple sites. Surface moisture seasonally available, seasonal variability of precipitation and insolation.

Mid-Atlantic U.S. Coastal Plain. Terrain complexities: Atlantic coast, rise to piedmont, crop-forest mixtures on various spatial scales, Chesapeake; numerous rivers; snow cover rare; occasional haziness, particularly in summer. Surface moisture usually available, seasonal variability of precipitation and insolation.

S.E. U.S. Coastal Plain. Terrain complexities similar to Mid-Atlantic except that there is no large embayment; more large man-made lakes; extensive tree plantations (coniferous); snow cover very rare; haziness occasionally, frequently in summer. Surface moisture usually available, seasonal variability of precipitation and insolation.

Southern U.S. Great Plains. Hilly or mountainous regions on eastern side; irrigation may present homogeneity problems in parts of the western side; large relatively uniform areas, tend to be either wheat or grasslands; high probability of droughts; occasional widespread snow cover of several days duration; little forest coverage of any type except on eastern edge; E-W slope generally smooth and gradual. Surface moisture variable, seasonal variability of precipitation and insolation. (Possible synergism with severe storm research efforts.)

Northern U.S. Great Plains. Extensive natural lakes region on N.E. corner; several very large man-made lakes; extensive irrigation in parts of Nebraska; high frequency of droughts; except on fringes of region, forests limited to river edges; Black Hills in S. Dakota are a local inhomogeneity; Chinook winds down eastern slope of Rockies can lead to sudden, extensive drying and warming, particularly in winter. Frequent air mass changes, frequent intrusion of warm moist air in summer, terrain slope gradual and smooth. Snow cover more long-lasting than other U.S. regions but may disappear in a Chinook West. Surface moisture seasonally available, usually dry, seasonal variability of precipitation and insolation.

Siberian Boreal Forest. Appears not to have a great number of lakes, but does have extensive marshy regions; snow cover should be extensive and long-lasting. Surface moisture seasonally available, seasonal variability of precipitation and insolation.

Canadian Boreal Forest. Large number of lakes of various size; extensive, long-lasting snow cover. Surface moisture seasonally available, seasonal variability of precipitation and insolation.

Southern Indian Subcontinent. Monsoonal regimes lead to large variations in surface wetness and standing water; rice culture is associated with high percentage of water surface during part of year; arrival of monsoonal rains to different regions at different times can produce transitional inhomogeneities; mountains along SW coast; deep convection during part of the year.

Sonoran Desert. Considerable terrain variations in U.S. portion; infrequent thunderstorms during summer monsoon. Surface moisture rarely available, seasonal variability of insolation.

Central Australia. Large areas are highly homogeneous; very low moisture levels most of time. Possible synergism with CSIRO should be investigated. Surface moisture rarely available, seasonal variability of insolation.

Greenland Plateau. Highly homogeneous, but little investigated except for brief campaigns. Permanent ice/snow; high elevation, so little water vapor in atmospheric column. Seasonal variability of insolation. (Likely to be logistically difficult.)

Antarctic Plateau. Highly homogeneous; extreme surface stability during polar night; clearly logistical constraints make synergism mandatory; extreme dryness is interesting condition for model "unstressing"; extreme cold may severely impact instrument requirements. Always ice/snow covered, seasonal variability of insolation.

North Slope of Alaska. Seasonal variation from widespread ice/snow to widespread tundra swamps; possible extension to sea ice margin studies; arctic haze during winter. Surface moisture available, seasonal variability of insolation. Extensive homogeneous areas in northern part of foothills of Brooks range, especially towards coastal plain.

E. Slope Rockies U.S. In general can be simplified to 2-D heterogeneity because of approximate N-S uniformity; Chinook winds can produce rapid winter warming and melting; snow cover periodic; general dryness but occasional intrusion of Gulf air; surfaces generally dry. Surface moisture usually not available, seasonal variability of insolation.

NW U.S./S.W. Canada Pacific Coast. Difficult to reduce to two-dimensional inhomogeneity because of coastal ranges, river valleys, and sounds; generally quite wet with extensive coniferous forests; significant rain shadows E. of mountains. Surface moisture available, seasonal variability of precipitation and insolation.

Amazon Basin (Rain Forest). Widespread deep convection much of year; widespread uniform surface (at top of canopy), but slash and burn deforestation increasing; smoke from fires across large areas; a significant fraction of water vapor loading and subsequent precipitation appears to result from evaporation/transpiration from the Amazon Basin itself; seasonal precipitation mid to late summer related to seasonal displacement of intertropical convergence zone.

Congo Basin. Similar to Amazon but somewhat smaller in extent; a greater portion of the rain forest is elevated. Surface moisture available, seasonal variability of precipitation and insolation.

Sargasso Sea. Fair weather marine cumulus; moderate air-sea fluxes.

Central North Pacific. Widespread maritime stratus; intense extratropical storms; moderate air-sea fluxes.

Tropical W. Pacific Ocean. Frequent deep convection; typhoons possible N. of about 5° N. throughout year; numerous island chains, some of low elevation; water very warm; large latent heat flux.

Tropical Atlantic. Similar to W. Pacific except smaller and cooler; most islands are mountainous and thus exert considerable local effects

Circumpolar Southern Ocean. High winds at surface, extensive cloud cover.

Norwegian Sea. Several "fronts" always present in sea. Ice-free except for fjords and the like; strong extratropical cyclones; moderate air-sea fluxes.

Greenland Sea. Shifting sea ice margin, regions of high iceberg frequency. Studied in other programs.

Bering Sea. Sea ice margin generally further north, but extensive seasonal ice extending out from land. Persistent cloud cover.

Gulf Stream off N. America. Very sharp demarcation; frequent long-lasting eddies; frequent large variation in sea-air temperature differences as polar air is advected from the land; intense convection at times when moisture and sensible heat transfers are high.

Eastern S. Pacific. Upwelling can produce very cold water off S. American coast; widespread fog and stratus but almost no precipitation; El Niño periods can change conditions a great deal.

Eastern N. Pacific. Upwelling and marine stratus off California coast; periodic intrusion of smog/haze from Los Angeles basin.

Eastern N. Atlantic. Transitional Zone maritime stratus to fair weather stratocumulus. Moderate air-sea fluxes.

References

Brown, R. M. 1990. A preliminary ocean ARM guide for climatic evaluations. Brookhaven National Laboratory, Informal Report.

Ebensen, S. K., and V. Kushnir. **1981.** The heat budget of the global oceans: an atlas based on estimates from surface marine observations. Report 29 of the Climatic Research Institute. Oregon State University, Corvallis.

Hartman, C. W., and P.R. Johnson. **1984.** Environmental atlas of Alaska. University of Alaska, Institute of Water Resources, Fairbanks.

ISCCP. Seasonal, global maps of surface albedo.

Isemer, H.J., and L. Hasse. **1985.** Bunker climate atlas of the North Atlantic Ocean, Vol. 1: Observations. Springer-Verlag, New York.

Isemer, H.J., and L. Hasse. **1987.** Bunker climate atlas of the North Atlantic Ocean, Vol. 2: Air-sea interactions. Springer-Verlag, New York.

Kim, J., and S.B. Verma. **1990.** Components of surface energy balance in a termperate grassland ecosystem. *Boundary Layer Meteorology*, **51**, 401-417.

Rand McNally and Co., Universal World Atlas. Rand McNally and Co., New York.

Rand McNally and Co., **1982**. The Great Geographical Atlas. Rand McNally and Co., New York.

Sellers, W. D. 1965. Physical climatology. Univ. Chicago Press, Chicago.

Wendler, G., and F. Eaton. **1990.** Surface radiation budget at Barrow, Alaska. Theoretical and applied climatology, **41**, 107-115.

Appendix E

Logistical Considerations for Selection of CART Locales

The objective of the Logistics CET was to provide information to the Evaluation Team about logistical factors that might affect the selection of locales suitable for placement of CART sites. The Evaluation Team was charged with producing a list of locales in order of scientific priorities to be accompanied by a discussion of the logistical factors that may have major impacts on the eventual siting and by recommendations for action required to meet any major logistical constraints.

Before the formation of the Logistics CET, several logistical attributes were suggested for consideration. These included 1) satellite overpass patterns, 2) national boundaries, 3) population density, and 4) operational suitability. The Logistics CET refined these attributes somewhat. The team decided that "satellite overpass patterns" fell more under the category of collateral data and was not really a logistical factor. A special committee was formed to focus on examining the availability of satellite (and other collateral) data for CART and therefore is not discussed here. We considered that the general attribute labeled "operational suitability" would include attributes like "national boundaries" and "population density." Hence our analysis generally consists of an evaluation of factors that may be considered operational in nature. These factors (generalized in terms of access, services, ambiance, and impacts) are those that would affect the transportation, support, and maintenance of personnel and equipment at CART sites.

Activities of the CET

Each member of the Logistics CET contributed ideas about what constitutes "logistical considerations" and how these factors should be evaluated in terms of operating a CART site. A compilation and summary of the individual evaluations, made at the Brookhaven meeting of September 10 to 14, 1990, follows. Each locale is rated (subjectively) as having minimal logistical problems (+), moderate logistical problems (o), or major logistical problems (-). Specific factors that may have an impact on siting also are listed for each locale.

Meeting the ARM objective requires sites to be located in both land and ocean locales.

The ARM Program Plan (and the list of candidate locales) suggests that CART sites will be located in both land and oceanic locales. Ocean locales may be expected to be more difficult logistically than land locales. Access, for example, will generally be more difficult because it will be absolutely dependent on either ship or aircraft transportation. Similarly, the services that we anticipate will be required for operation of a CART site are also less likely to be available in ocean locales. Because, in these terms, the problems inherent in providing and supporting the measurement platforms needed by CART are fundamentally different in ocean and land locales, the ratings below were developed as relative rankings within the sets of land and ocean locales and were intended to be considered separately. For rough comparison of ocean and land locales, however, an ocean locale identified as having minimal logistical problems (+) would correspond to a land locale having moderate logistical problems (o). Ocean locales rated having moderate logistical difficulties (o) would thus correspond to land locales with major logistical difficulties (-). In any case, the specific logistical factors listed for each candidate locale (land and ocean) are based on an absolute evaluation and comments relevant to an ocean locale may be compared directly to those relevant to land locales.

It should be noted that working on the scale of "locale" rather than on the scale of "CART site" makes it difficult to be very specific about some logistical factors. In some cases, however, it is possible to identify potential sites within the specified locales and evaluate more specific logistical factors that might be relevant to those sites. The logistics CET recognizes that many logistical problems can be overcome with concerted effort, even in the most difficult of circumstances (e.g., we can put a man on the moon). Our approach here is to make assumptions regarding the logistical aspects of CART site operation and try to comment (in a general way) on relevant factors associated with the identified candidate locales.

General Assumptions

By definition, logistics refers to the procurement, supply, and maintenance of equipment, with the movement of personnel, and with the provision of facilities and services. In terms of a CART site we assume that the site must be constructed, operated over a period of years, and decommissioned. Each of these phases has logistical factors associated with it. For example, construction will require heavy equipment, construction materials, and a labor force, operation will entail occupation by site operators and investigators, and decommissioning will involve construction equipment and environmental restoration. Examples of more specific assumptions made when considering the land and ocean locales are listed below. Some of these assumptions are cast in terms of what may be expected from an "ideal" CART site (i.e., one without logistical problems).

Land Locales

- CART sites will be staffed by a full-time operations staff and visited frequently by investigators for various lengths of time.
- Both staff and investigators will require transportation to and from the locale and housing and support while at the site.
- Whenever possible, locally available services will be used in the construction, operation, and decommissioning phases.
- Investigators should be able to reach the locale by air (preferably commercial) from points within the United States.
- Within the locale, local infrastructure (i.e., roads, airfields, rivers) should be sufficient to allow transportation of material and personnel to the site.
- Within the range specified by scientific requirements, climatic conditions should be conducive to year-around occupation and operation of the site.
- Access should not be complicated by political factors (Visa requirements, work permits, etc.).
- Operation of a CART site will require substantial amounts (>250 kW) of electric power that must be generated locally or obtained from local utilities.

A discussion of logistical considerations for each of the potential land locales follows.

Temperate East Coastal Plains (marine influenced but inland)

Mid-Atlantic U.S. (+)

Locale is easily accessible. Sites within this locale are likely to have good local access. Access to sites within this locale would not be affected by weather (i.e., sites could be occupied and serviced all year). All services are likely to be available at sites within this locale. Climate is generally mild, although subject to occasional severe storms including hurricanes.

Southeast U.S. Coastal Plain (+)

Locale is easily accessible. Sites within this locale are likely to have good local access. Access to sites within this locale would not be affected by weather (i.e., sites could be occupied and serviced all year). All services are likely to be available at sites within this locale. Climate tends to warm and humid, subject to occasional severe storms including hurricanes.

Subtropical Grasslands

Southern U.S. Great Plains (+)

Locale is easily accessible. Sites within this locale are likely to have good local access. Access to sites within this locale would not be affected by weather (i.e., sites could be occupied and serviced all year). All services are likely to be available at sites within this locale. Climate tends to warm moderate, subject to occasional severe storms including tornados.

High Latitude, Mid-Continental (high to heavy seasonal snow cover)

Northern U.S. Great Plains (+)

Locale is easily accessible. Sites within this locale are likely to have good local access. Access to sites within this locale would not be affected by weather (i.e., sites could be occupied and serviced all year) although winter conditions can be difficult. Sites in parts of this locale could possibly span international (U.S.-Canada) border and may require special immigration arrangements. All services are likely to be available at sites within this locale.

Midlatitude Humid Continental Plains

Midwest U.S. (+)

Locale is easily accessible. Sites within this locale are likely to have good local access. Access to sites within this locale would not be affected by weather (i.e., sites could be occupied and serviced all year). All services are likely to be available at sites within this locale.

Mid-Continental, Flat Terrain, Boreal Forest

West Siberian Boreal Forest (-)

Locale is extremely distant from the United States and lacks a major international airport. It is unlikely that sites within this locale will have good local access. Visa problems are possible for most investigators. Access to sites within this locale may be seasonal and difficult to impossible during winter. Unlikely that local services within this locale would be adequate for site operations. Language and cultural barriers may affect operations.

Canadian Boreal Forest (o)

Lacking a major airport, this locale may be difficult to reach despite its proximity to the United States. Because the area is undeveloped, it is unlikely that sites within this locale would have good local access. Access to some sites within the locale may be difficult in winter. Canadian sites should be accessible to U.S. investigators, but customs arrangements would be required for equipment. Local services are likely to be minimally available at sites within this locale.

Tropical Monsoon Region (land)

Southern Indian Subcontinent (-)

Locale is extremely distant from the United States but does have a major international airport. While some sites within this locale may have good local access, access to other sites is likely to be difficult. Local services are likely to be fair to poor. Climate is hot and humid with prolonged rainy season and occasional severe storms. Language and cultural barriers may affect operations.

Continental Deserts/Arid Regions

Sonoran Desert; Southwest U.S.; North Mexico (o)

Locale is easily accessible. Much of the locale is undeveloped, however, and local access may range from good to bad. Access to sites within this locale would not be affected by weather (i.e., sites could be occupied and serviced all year). Sites in parts of this locale could possibly span international (U.S.-Mexico) border and may require special immigration arrangements. Mexican site should be accessible to U.S. investigators, but customs arrangements would be required for equipment. Availability of local services are likely to be good to fair in the United States and fair to poor in Mexico.

Central Australia (o)

Locale is extremely distant from the United States but does have a major international airport. While some sites within this locale may have good local access, access to other sites is likely to be difficult. Local services are likely to be fair. Climate is hot with occasional severe storms.

High Latitude Ice Plateau

Greenland Plateau (-)

Locale is difficult to reach from the United States. Local services are poor. Climate is extremely cold with severe storms and high winds. Language and cultural barriers may affect operations.

Antarctic Plateau (-)

Locale is extremely distant from the United States. Access by air may be seasonally limited. Local services are nonexistent. Climate is extremely cold with severe storms and high winds. Experience of existing Antarctic research programs can be drawn upon.

Tundra

North Slope of Alaska Inland from Coast (+)

Dalton Highway provides year-round access to Prudhoe Bay. There are daily flights to Barrow year-round. DOE currently operates three year-round stations on the north side of Brooks Range. There is a NOAA GMCC station at Barrow. There are population centers for logistical support and provision of supplies.

Leeward Slope of Mountain Range (IH)

Eastern Slope of Rockies U.S. (+)

Locale is easily accessible. Sites within this locale are likely to have good local access. Access to sites within this locale would not be affected by weather (i.e., sites could be occupied and serviced all year). All services are likely to be available at sites within this locale.

Wet Temperate West Coastal (IH)

NW U.S./SW Canada (+)

Locale is easily accessible. Sites within this locale are likely to have good local access. Access to sites within this locale would not be affected by weather (i.e., sites could be occupied and serviced all year). Sites in parts of this locale could possibly span international (U.S.-Canada) border and may require special immigration arrangements. Canadian site should be accessible to U.S. investigators, but customs arrangements would be required for equipment. All services are likely to be available at sites within this locale. Climate is mild and damp, severe storms are unlikely.

Tropical Rain Forest

Amazon Rain Forest (-)

Locale is remote from the United States but does have a major international airport. Sites within this locale are unlikely to have good local access. Local services are likely to be poor. Climate is hot and humid. Language and cultural barriers may affect operations.

African Rain Forest (-)

Locale is extremely distant from the United States. Sites within this locale are unlikely to have good local access. Local services are likely to be poor. Climate is hot and humid. Language and cultural barriers may affect operations.

Ocean Locales

CART sites located within ocean locales would likely be established and operated in ways different from land locales. Oceanic CART sites could be located on islands (in which case they may be operated in a manner similar to sites in land locales), or they could be based on oceanographic platforms (moored buoys, ships, drilling platforms, etc.) or they could combine both. In accordance with our general scheme of classification in terms of access, services, ambiance, and impacts the logistical problems involved with operating a site in an ocean locale may be classified into three areas, construction, operation/maintenance, and removal. As was the case for land locales, problems involving access, services, ambiance, and impacts are included with operation/maintenance.

Because they are permanent, stable, and relatively large, islands may offer attractive locations for CART sites. We recognize, of course, that islands may affect the local meteorological conditions so that some observations may not be representative of the ocean locale. In these cases it may be desirable to establish some remote stations on unmanned platforms in the surrounding waters. The islands themselves would still be valuable for staging and as bases for personnel. Islands large enough to have docks and an airfield would be especially desirable. The logistics CET considered the presence of islands a favorable attribute of the oceanic candidate locales.

Moored buoys may offer an alternative to islands for oceanic observations that might be affected by the presence of even small land areas. Buoys, and the instruments mounted on them, would require maintenance, regular visits made every six weeks to check and service instruments. Such visits are practical for moorings close to a base of operations where small vessels are available. More remote locations would require larger vessels, with concomitantly longer lead times (1 to 1.5 years) and expense. Locales that were amenable to buoy moorings are noted.

Because access to ocean locales must be by ship or aircraft, locales that are convenient to oceanographic staging areas are noted. Similarly, locales for which access and operation may be restricted by weather conditions, including ice, also are noted. We note that voice communication to all locales is good via International Maritime Satellite System (INMARSAT).

Central Gyres

Sargasso Sea (N. Atlantic) (+)

Locale is close to the United States and served by major international airports. Open ocean island (Bermuda) may be used as base of operations. Staging areas along the U.S. east coast are available. Locale is ice free but subject to occasional severe storms.

Central North Pacific (+)

Locale is distant from the continental United States but easily accessible from Hawaii. Islands in Hawaiian chain may be suitable for operational bases. West coast ports and Hawaii are available for staging. Locale is ice free but subject to occasional severe storms.

Equatorial Oceans

Tropical Western Pacific Ocean (o)

Locale is extremely distant from the United States but is served by major international airports. Locale is ice free and has numerous islands (some U.S. owned) that could be used as bases for operations. Staging areas with docks and other facilities are available in Australia and the Philippines.

Tropical Western Atlantic (o)

Locale is distant from the continental United States but served by major international airports. Islands (foreign owned) may be suitable for operational bases but international arrangements would be required. Ports in Brazil may be available for staging. Locale is ice free.

High Latitude, Ice-Free Seas

Circumpolar Southern Ocean (-)

Locale is extremely distant from the United States. Staging areas exist in Chile and the U.S. west coast. International arrangements would be required. Weather is bad, making oceanographic season short. Locale is ice free north of about 58°S. Moorings are difficult because of the weather and high current speeds. Some islands (foreign owned) are available for operations.

Norwegian Sea (o)

Locale is distant from the United States but served by major international airports. Islands (foreign owned) may be available for operations. Staging areas in Iceland and Norway are available but international arrangements would be required. Much of the locale is ice free most of the year but is subject to severe storms.

High Latitude Ocean—Ice Edge (IH)

Greenland Sea (o)

Locale is distant from the United States but served by major international airports. Islands (foreign owned) may be available for operations. Staging areas in Iceland and Norway are available but international arrangements would be required. Locale is in a marginal ice zone.

Bering Sea (o)

Locale is distant from the United States. Islands (U.S. owned) may be available for operations. Staging areas in Alaska are available. International arrangements would be required if operations extended west beyond U.S.-USSR convention line. Locale is in a marginal ice zone but moorings would be relatively easy on slope south of the ice edge.

Oceanic Western Boundary Current (IH)

Gulf Stream off eastern N. America (+)

Locale is close to the United States and served by major international airports. Staging areas along the U.S. east coast are available. Locale is ice free but subject to occasional severe storms. Some islands (Bahamas) available in southern area but no islands are available in northern areas. Mooring conditions would be difficult because of current speeds.

Eastern Ocean Margins

Eastern North Pacific (+)

Locale is easily accessible. The U.S. west coast staging areas are available. Large islands (Farallons, Catalina) could be used as operational bases. Locale is ice free.

Eastern South Pacific (o)

Locale is distant from the United States but served by major international airports. Islands (foreign owned) may be available for operations but international arrangements would be required. Staging areas are available on the west coast of the U.S. and in Peru. Difficult to obtain permission for oceanographic work near Peru and Ecuador. Locale is ice free.

Transitional Marine Climate

Eastern North Atlantic (o)

Locale is distant from the United States but served by international airports in Portugal and Spain. Islands (foreign owned) are available for operational bases. Staging areas (Gibraltar, Lisbon) are available. Locale is ice free. International arrangements would be required.

Appendix F

Programs with Synergistic Potential

This Appendix presents information on synergistic activities by programs other than ARM whose objectives or facilities might lead to mutually beneficial coordinated activities with ARM. The listing presented here results from canvassing the atmospheric radiation and meteorological communities as well as from a large number of inquiries among the pertinent federal and international agencies to identify activities in potential ARM locales that might afford the opportunity of synergistic collaboration with ARM. The category, locale, and a list of potential synergistic activities that were identified as of September 1990 are listed.

For many of the synergistic programs listed, activities are in the planning stages, and thus, any interaction with ARM will depend on the extent to which these programs are funded over the ARM operational time frame. For the "ocean locales," development of an interaction with potentially synergistic oceanographic programs will be crucial to the establishment of ARM ocean sites and/or the conduct of ocean campaigns. Several major oceanography programs will be of interest to ARM in the future, JGOFS, WOCE, and TOGA. It is recommended that ARM establish close contact with these programs to be in a position to take advantage of their field programs and to possibly influence the scientific direction of these programs during the planning process so that ARM needs can be met. A similar situation pertains to the Central Greenland and the Antarctic ice sheet locales. For the Antarctic, the principal Agency is the National Science Foundation and all activities must be coordinated through them. For the Arctic region there is the Inter-Agency Arctic Research Policy Committee which may be helpful in locating appropriate sites and in identifying activities with which ARM could collaborate. Collaboration with these agencies and their ongoing programs will be essential for measurements in these locales.

This Appendix presents information on synergistic activities according to two listings. First, a listing is given of major programs that have been identified as likely to have synergistic potential with ARM. Second, a listing is given by locales, identifying programs with synergistic activities in the locales considered for examination in this project.

Activities were identified in potential ARM locales that might afford the opportunity for synergistic collaboration.

Major Programs Likely to have Synergistic Potential with ARM

AEROCE (Atmosphere/Ocean Chemistry Experiment)

The goal of the program is to characterize the chemical climatology over the North Atlantic Ocean. Currently AEROCE measures ozone, a wide range of chemical species in aerosols and precipitation and a number of tracers (including ^{7}Be, ^{210}Pb, and ^{222}Rn) at four locations: Barbados (West Indies), Bermuda, Tenerife (Canary Islands), and Mace Head (Ireland).

ASTEX (Atlantic Stratocumulus Transition Experiment)

ASTEX is a major field program that is planned for summer 1992. It will be conducted from a base in the Azores and will consist of aircraft, island-based, ship-based, buoy and satellite platforms. The surface-based sensors will include a number of sensing systems, such as Doppler cloud radar, wind profiler, solar, passive microwave, rawindsonde, tethered balloon, and radiation instruments. The key question to be addressed by this program is:

What are the consequences for the atmosphere and ocean of the prevalent boundary-layer cloud type and amount, and how are the cloud type and amount selected.

Two major organizations will participate in ASTEX, FIRE (vide infra), and SARI (the Subduction Accelerated Research Initiative). The Office of Naval Research will serve as the lead agency for the ASTEX component of FIRE, under the direction of the Meteorological Research Program Office. Additional support will be provided by NSF, DOE, NOAA, and other DOD offices.

Bermuda/Pacific Time Series Sites

This program is part of JGOFS (vide infra). This program has established two open-ocean time-series sites, an Atlantic Site near Bermuda and a Pacific Site near Hawaii. The Bermuda site is located 80 km southeast of Bermuda and has been collecting data since October 1988. Planning is also underway for time series stations located in U.S. continental shelf/slope waters.

ECLIPS (Experimental Cloud Lidar Pilot Study)

The objectives of this program are to demonstrate the feasibility of obtaining a long-term climatology of cloud base and optical depth: to improve methods of satellite cloud retrieval, and; to obtain a data set of cloud optical properties complementary to the ISCCP (vide infra) data set.

FIRE (First ISCCP Regional Experiment)

FIRE is an ongoing multiagency program designed to promote the development of improved cloud and radiation parameterizations for use in climate models, and to provide for assessment and improvement of International Satellite Cloud Climatology Program (ISCCP) products. FIRE has been conducted in two phases. Phase I (1984–1989) has just been completed. Phase II (1989–1994) will focus on more detailed questions concerning the formation, maintenance, and dissipation of cirrus and marine stratocumulus cloud systems. NASA serves as the lead agency for FIRE.

FIRE Phase II Cirrus Studies

FIRE will conduct the FIRE Cirrus IFO-II in southern Kansas from November 13 to December 7, 1991. The primary objects of the study are the extended large-scale cirrus systems associated with the subtropical and midlatitude jet streams. The location coincides with the inner ring of the mesoscale NWS (National Weather Service) wind profiler network presently under construction by NOAA.

GBSRN (Global Baseline Surface Radiation Network)

Network to be established by the World Climate Research Programme (WCRP) to monitor long-term trends in radiation fluxes at the surface and to provide validation data for satellite determinations of surface radiation budget.

GEWEX (Global Energy and Water Cycle Experiment)

The Global Energy and Water Cycle Experiment is planned for 1995 to 2000. Its goals relate to characterization and modeling of the hydrological cycle so as to develop the ability to predict the variations of global and regional hydrological processes and water resources, in response to environmental change. Preliminary program information suggests they may initiate their experimental program in the south central U.S.

IGAC (International Global Atmospheric Chemistry Program)

This program is a core project of the International Geosphere-Biosphere Program (IGBP). The overall goal of IGAC is to measure, understand, and thereby predict changes now and over the next century in the global atmosphere with particular emphasis on changes affecting the oxidizing power of the atmosphere, the impact of atmospheric composition on climate, and the interactions of atmospheric chemistry with the biota. Six initial foci have been identified for IGAC: natural variability and anthropogenic perturbations of the marine atmosphere; natural variability and anthropogenic perturbations of tropical atmospheric chemistry; the role of polar regions in changing atmospheric composition; the role of boreal regions in changing atmospheric composition; global distributions, transformations trends, and modeling and international support activities.

Interagency Arctic Programs

Two interagency programs of potential interest to ARM are planned:

Interagency Western Arctic Program 1990–1994, Bering, Chukchi, Beaufort Seas, Bering Strait

Interagency Western Arctic Program 1992–1996,Canadian, Eurasian Basins.

ISCCP (International Satellite Cloud Climatology Program)

The basic objective of ISCCP is to collect and analyze radiance data sets from space-based sensor measurements to infer the global distribution of cloud radiative properties in order to improve the modeling of cloud effects on climate.

ISCCP has two components, operational and research. The operational component takes advantage of the global coverage provided by the current and planned international array of geostationary and polar-orbiting meteorological satellites to produce a five-year global satellite radiance and cloud data set. The main and most important characteristic of these data will be their globally uniform coverage of various indices of cloud cover. The research component of ISCCP will coordinate studies to validate the climatology, to improve cloud analysis algorithms, to improve modeling of cloud effects in climate models, and to investigate the role of clouds in the atmosphere's radiation budget and hydrological cycle. Validation will involve comparative measurements at a number of test areas selected as representative of major (or difficult) cloud types and meteorological conditions. Complimentary efforts within the framework of WCRP will promote the use of the resulting ISCCP data sets in climate research.

ISLSCP (International Satellite Land Surface Climatology Program)

The major objective of ISLSCP is to develop methodologies for deriving quantitative information concerning land surface climatological variables from satellite observations of the radiation reflected and emitted by the Earth.

JGOFS (Joint Ocean Global Flux Experiment)

The broad goal of this program is to improve our understanding of the processes controlling the cycling of carbon and related biogenic elements in the oceans. Various measurement programs are proposed for the next decade. The number of such activities will depend strongly on funding.

LITE (Lidar Technology Experiment)

NASA Office of Aeronautics and Space Technology (OAST)

The goal of this program is to probe the upper and lower regions of the atmosphere with optical elastic backscatter measurements from a space platform. The overall thrust is to provide data that will validate models of atmospheric properties related to the backscattering data, viz.,cloud top and planetary boundary layer heights, tropospheric and stratospheric aerosols and temperature and density from 10 to 40 km.

LTER (Long-Term Ecological Research Program)

NSF, Division of Biotic Systems and Resources

The main goal of this program is to study the ecological structure and processes in natural landscapes at temporal scales of a decade or longer. There are currently 15 sites located in the United States.

NSF OFFICE OF POLAR PROGRAMS

This office coordinates all U.S. activities at Antarctic sites.

PARKNET National Environmental Research Parks

DOE/OHER

The parks are located at six national laboratories with multidisciplinary staff on site. Ecological studies have been conducted in park areas for over 40 years.

BOREAS (Boreal Ecosystem-Atmosphere Study)

The goal of the study is to understand the interactions between the boreal forest biomes and the atmosphere in order to clarify their roles in global change. The study will be centered on two 20-by-20-km sites located at the ends of a 500-km transect within the boreal forest region of North America; the exact location has not yet been chosen. The program will run from 1990 to 1996.

STORM

The two primary goals of the National STORM program are to advance the fundamental understanding of precipitation and other mesoscale meteorological processes and their role in the hydrologic cycle and to improve the 0 to 48-hour prediction of precipitation and severe weather events.

STORM I (Field experiment under National STORM program)

This is a winter storm field experiment whose primary goal is to improve the understanding and prediction of winter storms, their associated weather, and the interactions of larger and smaller scales of motion. Some of the process studies involved with this particular core objective include solar and long-wave radiation at the meso-alpha scale (6 to 24 hours, 200 to 2000 km).

TOGA/COARE (The Tropical Ocean Global Atmosphere [TOGA] Coupled Ocean Atmosphere Response Experiment [COARE])

TOGA/COARE is an experiment planned for November 1992 to February 1993. The goals are to describe and understand the principal processes responsible for the coupling of ocean and atmosphere in the western Pacific warm pool system; the principal atmospheric processes that organize convection in the warm pool region; the oceanic response to combined buoyancy and wind stress forcing in the western Pacific warm pool region; the multiple scale interactions that extend the oceanic and atmospheric influence of the western Pacific warm pool system to other regions and vice versa.

WOCE (World Ocean Circulation Experiment)

WOCE is a major international study to understand the role of the ocean in climate. It is one of the largest oceanographic programs ever implemented, involving more than 50 countries around the world. It has been designed to provide, for the first time, a uniform and global data set on ocean circulation, heat transport, and air-sea fluxes and to foster the development of new ocean models for coupled ocean-atmosphere climate predictions.

WOCE is undertaking extensive field observations during the period 1990 to 1995. These include programs to calculate and validate air - sea fluxes globally by combining new satellite measurements with conventional ship meteorological observations; to observe the annual cycles of heat and fresh-water storage in the upper ocean; and to determine the three-dimensional ocean circulation from satellite altimetry, surface drifters, deep floats, current meter moorings, and a global set of hydrographic and tracer sections. A second goal of WOCE is to leave an effective ocean climate monitoring system in place following the WOCE field program.

WPDN (Wind Profiler Demonstration Network)

The National Oceanic and Atmospheric Administration (NOAA) of the U.S. Department of Commerce is establishing a 30-station Wind Profiler Demonstration Network in the central region of the United States. The configuration is shown in Figure 28 and in Table 19.

The Network will cover an area of approximately 1,500 by 1,500 km. The wind profiler is an unattended, highly sensitive Doppler radar that is designed to detect and process returns from the clear air. It makes an accurate vertical profile of the speed and direction of the wind in increments of 250 m from near the surface to an altitude of approximately 16 km. The wind profiler was developed by the Aeronomy Laboratory and the Wave Propagation Laboratory in NOAA's Environmental Research Laboratories.

The data from each system in the network will be transmitted via satellite to a central processing facility in Boulder, Colorado. There, the data from the individual sensors will be integrated into hourly reports for dissemination to the U.S. National Weather Service and other meteorological users.

The NOAA contact is Dr. Don Beran, Boulder, Colorado, (303) 497-6765. The contact at Unisys Corporation, the contractor that is manufacturing the units, is Edward Hudson, (516) 574-2674.

WSR88 (Weather Survey Radar 88)

The Weather Survey Radar 88 (WSR88) which has also been referred to as NEXRAD (for "next generation" radar) is a system of Doppler weather radars scheduled to replace the weather radars currently in use by the National Weather Service. The new radars were developed in a joint effort by the National Weather Service, the Federal Aviation Administration and the Air Force's Air Weather Service, to deploy an advanced radar with Doppler capability to provide a substantial increase in tornado warning lead time, improved detection of severe turbulence and wind shear and substantial reduction in the number of incorrect storm forecasts and false alarms. The radars will provide accurate, high-resolution data that gives detailed information on the structure, intensity, wind circulation, and movement of storms, as well as continuous computation and mapping of amounts of rainfall.

The WSR88 instruments will cover the continental United States, the southern tier of Alaska, Hawaii, and Puerto Rico, and overseas installations of the Air Force, Army, and Navy. Deployment is scheduled for the next decade.

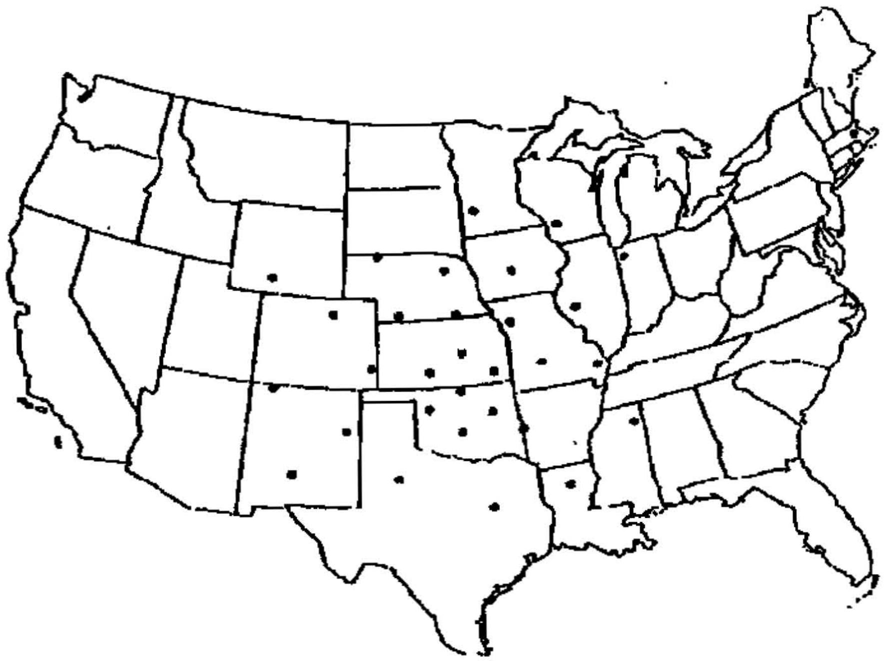

Figure 28. Locations of Wind Profiler Stations for Planned NOAA WPDN Network

Satellite Coverage for ARM

This section summarizes present and planned satellites making radiation and meteorological measurements pertinent to ARM.

TRMM

The Tropical Rainfall Measuring Mission (TRMM) satellite may be launched as early as 1994 as a joint Japan/U.S. mission. It will be launched in a low (350 km) circular Earth orbit with an inclination of 35° to the equator, providing coverage of the Inter-Tropical Convergence Zone (ITCZ), South America, Africa, Australia, and the southern regions of Japan and the U.S. The orbit is designed not to be sun-synchronous, so that samples may be taken throughout the diurnal cycle. The instrumentation will include two microwave radiometers, a cross-track scanning precipitation radar, and Advanced Very High Resolution Radiometer (AVHRR).

DMSP

The Defense Meteorological Satellite Program (DMSP) is currently operational, flying polar orbiting satellites at 835 km, 101.4-minute period (14.2 orbits per day), presently having two satellites (F8 and F9), one in morning orbit (0730 LST descending node) and one in a noon orbit (1200 LST descending node). The ascending times are dusk and midnight. The primary instrumentation is the Operational Linescan System (OLS) designed to gather visible and IR data from Earth scenes. The mission sensors of particular interest to ARM are the SSM/T on F8 and F9 and the SSM/I on F9, providing microwave data.

POES

The Polar Orbiting Environmental Satellites (POES) are currently operational, flying polar orbiting satellites at nominal 833 and 870 km altitudes, usually with one satellite crossing the Equator southbound at 0730 LST and the other crossing northbound at 1430 LST. The primary instrumentation is the AVHRR and the TIROS Operational Vertical Sounder (TOVS) consisting of the High Resolution Infrared Radiation Sounder (HIRS/2), the Stratospheric Sounding Unit (SSU), and the Microwave Sounding Unit (MSU).

Table 19. NOAA Wind Profiler Demonstration Network Site Locations

Nearby Town	State	Lat (N) ° ' "	Long (W) ° ' "	Elev ft
Platteville	CO	40 10 48	104 43 10	5000
Lathrop	MO	39 34 48	94 10 12	300
Fairbury	NE	40 06 00	97 20 24	1420
Hillsboro	KS	38 18 33	97 17 44	1465
White Sands MR	NM	32 24 22	106 20 57	4016
Haviland	KS	37 39 08	99 05 28	2125
Neodesha	KS	37 22 48	95 38 05	835
Lamont	OK	36 41 28	97 28 57	1005
Vici	OK	36 04 19	99 13 03	2125
Haskell	OK	35 48 28	95 46 54	695
Purcell	OK	34 58 47	97 31 07	1085
Conway	MO	37 31 24	92 42 09	1280
Slater	IA	41 54 03	93 41 57	1035
Neligh	NE	42 12 26	97 47 37	1720
Winchester	IL	39 39 22	90 28 48	557
Blue River	WI	43 13 18	90 31 54	740
Wolcott	IN	40 48 36	87 03 00	695
Bloomfield	MO	36 53 02	89 58 19	425
Maynard	MA	42 24 00	71 27 00	200
Wood Lake	MN	44 40 18	95 26 54	1045
DeQueen	AR	34 03 00	94 14 13	415
Okolona	MS	34 05 23	88 51 52	410
Winnfield	LA	31 53 50	92 46 57	305
Palestine	TX	31 46 45	95 42 48	455
Jayton	TX	33 01 00	100 58 48	2320
Tucumcari	NM	35 05 03	103 36 33	4070
Granada	CO	37 46 18	102 10 42	3790
McCook	NE	40 05 09	100 39 13	2625
Merriman	NE	42 54 20	101 41 41	3250
Medicine Bow	WY	41 54 09	106 11 09	6551
Aztec	NM	36 50 28	107 54 24	6240

GOES, GMS, METEOSAT

The U.S. Geostationary Operational Environmental Satellites, the Japanese Geostationary Meteorological Satellite (GMS) series, and the European METEOSAT series provide geostationary coverage of the earth from about 60°E to about 100°E (going westward), with the Russian GOMS satellite filling the hole. These satellites view a circular disk about 60° in radius, providing coverage from 50°S to 50°N in general and from 60°S to 60°N on station. The primary instrumentation in the U.S. satellites is the Visible and Infrared Spin-Scan Radiometer (VISSR) Atmospheric Sounder (VAS), providing as many as 48 images per day. Similar instruments are on the Japanese and European satellites. Only one of the normal two U.S. GOES satellites is now in orbit, but that should be corrected for most of the life of ARM.

Interaction of Satellite Coverage with ARM Locales

The DMSP and POES satellites cover all locales, with increasing density of coverage approaching the poles. The TRMM and GOES satellites do not provide such coverage. The locales not covered by GOES, GMS, or METEOSAT are: the North Slope of Alaska, the Bering Sea, most of the Canadian Boreal Forest, the Greenland Plateau, the Greenland Sea, the Norwegian Sea, and most of the West Siberian Boreal Forest. For TRMM, those locales as well as the following are not covered: much of the Central North Pacific, most of the Gulf Stream, much of the Eastern North Atlantic, the NW U.S./SW Canada, the Eastern Slope of the Rockies, the Northern Great Plains, the Midwest U.S, and much of the Southern Great Plains, the Mid-Atlantic Coast and much of the SE Coastal Plain, and parts of the Sonoran Desert.

Synergistic Activities in Locales Considered for Examination in This Project

Land Locales

Temperate East Coastal Plains (marine influence but inland)

Southeast U.S. Coastal Plain

PARKNET Site

Located at the Savannah River National Environmental Research Park.

Temperate East Coastal Plains (marine influence but inland)

Mid-Atlantic U.S.

No activities identified.

Subtropical Grasslands

Southern U.S. Great Plains

LTER Site

Tall grass prairie site (Konza Prairie Research Natural Area), 10 km south of Manhattan, Kansas. ISLSCP conducted field measurements here under FIFE in 1987 and 1989.

National Severe Storms Laboratory at Norman, Oklahoma

This institution may be a source of possible future collaboration with the ARM Program.

FIRE

Cirrus IFO-II to be conducted from November 13 to December 7, 1991, in southern Kansas.

High Latitude, Mid-Continental, Snow Cover

Northern U.S. Great Plains

No activities identified.

Midlatitude Humid Continental Plains

Midwest U.S.

Illinois State Water Survey

1. Network of 10 climate monitoring stations distributed over the state of Illinois.
2. Laboratory facilities at Champaign, Illinois.
3. Doppler radar at Willard airport.
4. Wind profilers and other meteorological facilities at Bondville, Illinois, south of Champaign. Some of these latter facilities are operated in collaboration with NOAA.

PARKNET Site

Fermilab National Environmental Research Park

STORM I-Field experiment under National STORM program

This is a winter field experiment whose primary goal is to improve the understanding and prediction of winter storms, their associated weather and the interactions with larger and smaller scales of motion. Some of the process studies involved with this particular core objective include solar and long-wave radiation at the Meso-alpha scale (6 to 24 hours, 200 to 2000 km). An exact location has not been chosen, but will be somewhere in the Midwest.

The National Oceanic and Atmospheric Administration (NOAA) of the U.S. Department of Commerce is establishing a 30-station Wind Profiler Demonstration Network in the Central region of the United States.

Mid-Continental, Flat Terrain, Boreal Forest

Canadian Boreal Forest

BOREAS

The goal of the study is to understand the interactions between the boreal forest biomes and the atmosphere in order to clarify their roles in global change. The study will be centered on two 20-by-20-km sites located at the ends of a 500-km transect within the boreal forest region of North America; the exact location has not yet been chosen. The program will run from 1990 to1996.

Mid-Continental, Flat Terrain, Boreal Forest

West Siberian Boreal Forest

No activities identified.

Tropical Rain Forest

Congo Basin

No activities identified.

Tropical Rain Forest

Amazon Basin

IGAC

Of particular relevance to this locale are projects that are planned for the IGAC program on "Natural Variability and Anthropogenic Perturbations of Tropical Atmospheric Chemistry." These projects include:

Biosphere-Atmosphere Trace Gas Exchange in the Topics (BATGE).

The goals of this program are to determine the fluxes and the factors that control these fluxes of chemical between representative tropical environments and the troposphere, and to develop the ability to predict the impact of these fluxes on both climate and land use changes. This program is in the planning stages and the exact location is not yet determined, but could be in the Amazon Basin.

Deposition of Biogeochemically Important Trace Species (DEBITS).

The goals of this program are to determine the rates of deposition of biogeochemically important trace species and to identify factors that control these deposition fluxes. Initial activities are planned for southeast Asia, but expansion to other tropical locations is possible.

Impact of Tropical Biomass Burning on the World Atmosphere.

The goals of this program are to characterize the fluxes of chemically and radiatively important species from biomass burning into the global atmosphere, and to assess the consequences of biomass burning on the chemical and physical climate.

A subprogram, the Biomass Burning Experiment (BIBEX) will conduct activities in the Amazon Basin over the next five to ten years and represents a potential candidate for interaction with ARM. A U.S. contact for the biomass burn project is:

Joel S. Levine
Atmospheric Sciences Div.
NASA Langley Research Center
Mail Stop 401b
Hampton, Virginia
Tel. (804) 864-5692

A more general contact for Amazon Basin work is:

Luiz Carlos B. Molion
Instituto de Pesquisas Espaciais
C. P. 515, 12.200
Sao Jose dos Campos - SP BRAZIL

Also the Amazon Project has measured surface radiative flux in the Amazon Basin. Contact Jim Tucker at NASA Langley for a U.S. representative.

Tropical Monsoon Region (land)

Southern Indian Subcontinent

The Division of International Programs, National Science Foundation has funded a project which involves collaboration between North Carolina State University and the Indian Institute of Technology, New Delhi. The first phase of the project was funded from 1983 to 1989. The project involved research on monsoon dynamics and air pollution. The second phase of the project started in March 1990 and is expected to continue for at least three years. The second phase is a study of the atmospheric boundary layer turbulence and dispersion processes in the tropics. The Indian Institute of Science, Bangalore, which is located in the southern peninsula, about 13°N latitude, participated in the first phase of the project.

Contact: Dr. Sethu Raman, North Carolina State University

Continental Deserts/Arid Regions

Central Australia

Possible Global Baseline Surface radiation network station. The Commonwealth Scientific and Industrial Research Organization (CSIRO) in Australia has a long history of research into atmospheric radiation, cloud physics, cloud radiation interaction, and atmospheric radiative transfer modeling. In addition to the possibility of collaboration at the land sites, the CSIRO is mounting a satellite validation campaign starting in 1991 using shipboard radiometers and radiosoundings in the Western Tropical Pacific.

Continental Deserts/Arid Regions

Sonoran Desert Southwest U.S.; Northern Mexico

LTER Site

Site at Jordana, 40 km north of Las Cruces, New Mexico.

PARKNET Site

Site at Los Alamos National Laboratory.

High Latitude Ice Plateau

Greenland Plateau

IGAC

The objective of the PASE (Polar Air-Snow Experiment) program is to establish the relationship between atmospheric composition and the chemical composition of ice in the central polar areas.

PASE is planning several field measurements at Summit in central Greenland as part of the GISPII and Greenland Ice Projects (GRIP). Project coordinating board will meet in September 1990.

Incoherent scatter radar facility at Sondre Stromfjord, Greenland.

High Latitude Ice Plateau

Antarctic Plateau

Amundsen Scott Research Station at South Pole reportedly have made recent radiation measurements of interest to ARM.

Possible Global Baseline Surface Radiation Network station at South Pole.

IGAC

The objective of the PASE (Polar Air-Snow Experiment) program is to establish the relationship between atmospheric composition and the chemical composition of ice in the central polar areas. This program is planning an experiment at Amundsen Scott Base in the Antarctic in 1991 for a full year. An additional experiment is planned for 1993 at Dome C, East Antarctica.

All U.S. activities at the Antarctic are coordinated through the NSF Polar Programs Office.

Contact: Peter Wilkniss at (202) 357-7894

Tundra

North Slope of Alaska (Inland from coast)

LTER Tundra Site (Arctic Tundra Site)

Located at Toolik Lake 360 miles north of Fairbanks, Alaska, in the northern foothills of the Brooks range. NSF-funded long-term ecological research program. DOE also supports this site and several others through the R4D project. One of these sites, Franklin Bluff is reported to have relatively uniform terrain, and would be suitable as an ARM site. It is accessible by road year-round.

NOAA GMCC Observatory at Barrow Alaska

This is a logistically attractive site, but is close to the Arctic Ocean and is strongly influenced by it.

University of Alaska Site at Poker Flats

This is a taiga site roughly 40 miles north of Fairbanks. Facilities are available at this site. Previous radiation measurements have been made here as part of a another DOE program.

Leeward Slope of Mountain Range

Eastern Slope of Rockies U.S.

Boulder Atmospheric Observatory (BAO)

LTER Grasslands Site-Central Plains Experimental Range east of Ft. Collins

Potential Global Baseline Surface Radiation Network Site

NOAA Wave Propagation Laboratory Activities

NCAR activities and facilities

SERI activities and facilities

University of Denver activities and facilities

University of Colorado activities and facilities

Colorado State University activities and facilities

Wet Temperate West Coastal

NW U.S./SW Canada

University of Washington Atmospheric Sampling Site, Cheeka Peak, Washington

Ocean Locales

Central Gyres

Sargasso Sea (N. Atlantic)

JGOFS

This program may be a source of possible future collaboration with the ARM Program.

WOCE

This program may be a source of possible future collaboration with the ARM Program.

Central Gyres

Central North Pacific

JGOFS

This program may be a source of possible future collaboration with the ARM Program.

WOCE

This program may be a source of possible future collaboration with the ARM Program.

Equatorial Oceans

Tropical Western Pacific Ocean

WOCE

This program may be a source of possible future collaboration with the ARM Program.

TOGA/COARE

This experiment will be conducted over a several year period starting with some pilot studies in 1990, extending to an enhanced monitoring network in the period 1991 to 1994. An intensive observational period is currently planned for the late fall 1992 (as of 1989, and later revised to fall 1993).

CSIRO

In Australia, CSIRO has a long history of research into atmospheric radiation, cloud physics, cloud radiation interaction and atmospheric radiative transfer modeling. In addition to the possibility of collaboration at the land sites, the CSIRO is mounting a satellite validation campaign starting in 1991 using shipboard radiometers and radiosoundings in the Western Tropical Pacific.

Equatorial Oceans

Tropical Atlantic

WOCE

This program may be a source of possible future collaboration with the ARM Program.

JGOFS

This program may be a source of possible future collaboration with the ARM Program.

Semi-Enclosed Seas

Australia-Indonesia Semi-Enclosed Sea

An extensive meteorological and radiation infrastructure is maintained in the vicinity of Darwin, Australia, including the following components:

Radar. At present, the C band 1.65° NOAA/TOGA radar is employed at Berrimah and operated continuously throughout the "wet" season. The NOAA/TOGA radar will be replaced during 1992 by a 1 degree beamwidth C band Doppler radar. Inclusion of a dual polarization capability on this radar is planned during 1993. This will involve the addition of an improved low sidelobe antenna suitable for dual polarization measurements, a ferrite switch for polarization control, and improved phase stability; and will be capable of Z_{DR}, Φ_{DP}, and $\rho_{HV}(0)$ measurements in addition to Doppler data collection. BMRC has a considerable amount of radar data processing software on a workstation to analyze the above radar data. The NCAR RDSS, SPRINT, CEDRIC, and ODAN packages are available for complete single and multiple Doppler analyses. In addition there exists a considerable amount of data suitable for single-Doppler and dual-Doppler synthesis.

Wind Profiler. A 50-MHz wind profiler will provide full wind data to approximately 25 km at up to 1.5-minute intervals. The profiler provides the three wind components. Plans include the inclusion of a 915-MHz profiler for monitoring winds in the PBL. Both profilers are possible sources of information on rainfall drop size distributions.

Raingauge Network and Disdrometer Measurements. The 26-element C scale tipping bucket raingauges employ onsite archiving and operate continuously throughout the period November to April inclusive. It is intended to develop an inner D-scale 25-element raingauge network with a 2-km spacing during 1991 to augment the current network. This network will provide detailed high resolution information on the scale measured directly with the TRMM 14 GHz radar. It will also provide a basis for adjustment of gauge-to-radar rainfall estimates.

The network will be deployed in alternate years in different locations (i.e., coastal and continental locations) to study the spatial characteristics of the two types of convective regimes, the relationship to radar derived precipitation fields and during the mission phase, the verification of the satellite derived rainfall estimates. During special observational programs the network will be deployed in an optimum location to measure rainfall from the system under study.

A Joss-Waldvogel disdrometer is also in operation continuously at Darwin during each wet season.

Automatic Weather Stations. A network of ten automatic weather stations (AWS) providing measurements of temperature, humidity, pressure, rainfall and windspeed and direction has been established primarily within 100 km of Darwin. This network is designed to provide meso-scale information on planetary boundary layer flow associated with the development of the convective activity. The units are portable, stand alone with onsite data archive. Data are available from five of these stations in real time at Darwin.

Anemograph Network. A network of six Woelfle anemographs surrounds the inner automatic weather station network. This network is intended to provide lower spatial and temporal resolution windflow information outside the primary mesoscale automatic weather station network. During ITEX, the network was placed on Bathurst and Melville Islands to provide information on the evolution of sea breeze circulations.

Radiation. The Bureau of Meteorology is installing a high-quality solar and IR surface radiation observation station in Darwin. The station will be part of a baseline radiation network being installed by the Bureau for the Australian region. The observations at Darwin will conform with the specifications for the Global Surface Radiation Network being established under the World Climate Research Programme.

Satellite Information. A full S band receiving facility is presently being established in Darwin for the direct reception of high resolution 6 hourly AVHRR data. One hourly S-VISSR GMS data are also archived routinely by the Bureau. The Bureau is establishing a link with the NASA WETNET, which will provide access to SSM/I data.

Rawinsonde Soundings. Rawinsonde soundings are undertaken every 12 hours and full wind soundings are undertaken every 6 hours. Up to three portable upper-air wind and temperature sounding units are available for special observing periods in joint BMRC/MCDM experiments.

Regional Forecast Centre, Darwin. The research station is maintained in cooperation with the Darwin Regional Forecast Office of the Bureau, which is a WMO Regional Meteorological Centre and produces analyses and forecasts for the tropical region extending from 40°S to 40°N and 90°E to 180°E.

Ancillary Observations. During special observational periods the standard network can be augmented by an additional portable rawinsonde unit and a full surface energy budget station. Additional automatic weather stations are also available.

High Latitude, Ice-Free Seas

Circumpolar Southern Ocean

JGOFS

This program may be a source of possible future collaboration with the ARM Program.

High Latitude, Ice-Free Seas

Norwegian Sea

JGOFS

This program may be a source of possible future collaboration with the ARM Program.

WOCE

This program may be a source of possible future collaboration with the ARM Program.

High Latitude Ocean—Ice Edge

Greenland Sea

The Joint Global Ocean Flux Study (JGOFS)

Interagency Eastern Arctic Program, 1988 to 1991, Greenland, Barents Seas, Fram Strait

U.S. Greenland Sea project, Iceland National Fisheries has cruises planned for this region.

High Latitude Ocean—Ice Edge

Bering Sea

Interagency Western Arctic Program

Programs in the Bering, Chukchi, and Beaufort Seas, and the Bering Strait, 1990 to 1994.

JGOFS

This program may be a source of possible future collaboration with the ARM Program.

WOCE

This program may be a source of possible future collaboration with the ARM Program.

Oceanic Western Boundary Currents

Gulf Stream Off Eastern N. America

AEROCE

The goal of the program is to characterize the chemical climatology over the North Atlantic Ocean. Currently AEROCE measures ozone, a wide range of chemical species in aerosols and precipitation and a number of tracers (including ^{7}Be, ^{210}Pb and ^{222}Rn) at four locations: Barbados (West Indies), Bermuda, Tenrife (Canary Islands) and Mace Head (Ireland).

Bermuda/Pacific Time Series Sites

This program is part of JGOFS. This program has established two open-ocean time-series sites, an Atlantic Site near Bermuda and a Pacific Site near Hawaii. The Bermuda site is located 80 km southeast of Bermuda and has been collecting data since October 1988.

JGOFS

This program may be a source of possible future collaboration with the ARM Program.

WOCE

This program may be a source of possible future collaboration with the ARM Program.

Eastern Ocean Margins

Eastern South Pacific

JGOFS

This program may be a source of possible future collaboration with the ARM Program.

WOCE

This program may be a source of possible future collaboration with the ARM Program.

Eastern Ocean Margins

Eastern North Pacific (28-40°N, 120-130°W)

JGOFS

This program may be a source of possible future collaboration with the ARM Program.

WOCE

The U.S. WOCE Implementation Plan of March 1989 identified the time series stations PRS 2 and PRS 3 as a U.S. contribution to WOCE in the North Pacific. PRS 2 is located near Oahu, and PRS 3 will be located off the coast of California. These stations would form a pair across the eastern subtropical gyre in the North Pacific, and allow the development of an "index of circulation" for the gyre. PRS 3 also could be used to monitor the eastern boundary region of the North Pacific for transport estimates within the California Current. PRS 3 should be associated with the heat flux line P2 at 32°N and the current meter moorings PCM 2 off the California coast. The goal is for both stations to run monthly for ten years. The station off Oahu has been operating for two years, and establishment of a similar station in the California Current near 32°N to monitor the eastern rim of the gyre is recommended.

Further information on the scientific aspects of time series stations may be obtained from the U.S. WOCE Office, Department of Oceanography, Texas A & M University, College Station , Texas 77843-3146 (telephone: [409] 845-1443, FAX: [409] 847-8879, electronic mail US.WOCE.Office/Omnet).

FIRE Phase I conducted a major field experiment to study marine stratocumulus clouds off the southwest coast of California in July 1987.

Transitional Marine Climate

Eastern North Atlantic

FIRE

The phase II Atlantic Stratocumulus Transition Experiment (ASTEX) will be conducted in spring or summer 1992. The program will be based in the Azores and will include, measurements by aircraft, ships, buoys, satellites, as well as in situ and remote sensing measurements from islands. Details can be found in the FIRE PHASE II Research Plan.

JGOFS

This program may be a source of possible future collaboration with the ARM Program.

WOCE

This program may be a source of possible future collaboration with the ARM Program.

Participants in Locale Recommendation Procedure

Participants in Locale Recommendation Procedure

Overall Project Leader

Stephen E. Schwartz

Participants in Development of Locale Recommendation Procedure

(La Jolla, California, July 30-31, 1990):

E. Baroni, ARM Program Administrator

S. Barr, Operations Team Leader

M. Dickerson, Modeling Team Leader

C. Flagg

G. Hendrey

A. Liebetrau

L. Newman

S. Schwartz, Site Selection Team Leader

G. Stokes, ARM Technical Director

J. Tichler

M. Wesely, Instrumentation Team Leader

Participants at Locale Recommendation Meeting

(Brookhaven National Laboratory, September 10-14, 1990)

K. Anderson
C. Berkowitz
H. Bernstein
R. Brown
M. Daum
P. Daum
P. Falkowski
C. Flagg
S. Ghan
R. Hart
G. Hendrey
M. Leach
B. Lesht
A. Liebetrau
B. Manowitz
P. Minnett
S. Schwartz
J. Shannon
K. Taylor
J. Tichler
C. Wirick

Membership of Teams Participating in Locale Recommendation Procedure

Climatology
O M. Daum
R. Brown

Surface Properties
O P. Minnett
G. Hendrey
J. Shannon
K. Taylor

Atmospheric Properties
O M. Leach
C. Berkowitz
S. Ghan

Surface Energy Flux
O R. Hart
P. Minnett
K. Taylor

Logistics
O W. Clements
G. Hendrey
B. Lesht
C. Flagg
C. Wirick
R. Hosker
K. P. Ellis

Synergism
O P. Daum
J. Tichler
D. Renne
R. Ellingson

Information Team
O R. Brown
H. Bernstein
M. Daum
K. Norden

Evaluation Team
O S. Schwartz
A. Liebetrau
K. Anderson
P. Falkowski
J. Tichler

O Denotes Team Leader

Addresses of Participants

Kevin Anderson
Pacific Northwest Laboratory
P.O. Box 999
Richland, WA 99352
(509) 375-2545
FAX: (509) 375-3641
E-Mail: D3E546@pnlg.pnl.gov

Eva Baroni
Pacific Northwest Laboratory
P.O. Box 999
Richland, WA 99352
(509) 375-3712
FAX: (509) 375-2698

Sumner Barr
Los Alamos National Laboratory
ESS-7, MS-D466
Box 1663
Los Alamos, NM 87544
(505) 665-2868
FAX: (505) 665-3687

Carl Berkowitz
Pacific Northwest Laboratory
P.O. Box 999
Richland, WA 99352
(509) 376-6460
FAX: (509) 376-5217

Herbert J. Bernstein
Oceanographic and Atmospheric Sciences Division
Building 051
Brookhaven National Laboratory
Upton, NY 11973
(516) 282-2261
FAX: (516) 282-3911
E-Mail: yaya@bnlux0.bnl.gov

Robert M. Brown
Oceanographic and Atmospheric Sciences Division
Building 051
Brookhaven National Laboratory
Upton, NY 11973
(516) 282-2260
FAX: (516) 282-3911

William E. Clements
Los Alamos National Laboratory
EES-5, MS-D466
P. O. Box 1663
Los Alamos, NM 87545
(505) 667-2637
FAX: (505) 665-0854
E-Mail: CLEMENTS@ESSDP1.LANL.GOV

Mary L. Daum
Analytical Sciences Division
Building 475
Brookhaven National Laboratory
Upton, NY 11973
(516) 282-2066
FAX: (516) 282-7867
E-Mail: DAUM@BNLCL6.bnl.gov

Peter H. Daum
Environmental Chemistry Division
Building 426
Brookhaven National Laboratory
Upton, NY 11973
(516) 282-7283
FAX: (516) 282-2887

Marvin Dickerson
Lawrence Livermore Laboratory
7000 East Avenue
Bldg. 1701, Room 141
Livermore, CA 94551
(415) 422-1806
FAX: (415) 422-5844

K. P. Ellis
Lawrence Livermore National Laboratory
P. O. Box 808, L-262
Livermore, CA 94550
(415) 294-5185
FAX: (415) 422-5844

Robert Ellingson
University of Maryland
College Park, MD 20770
(301) 405-5386
FAX: (301) 314-9482
E-Mail: bobe@meto.umd.edu

Paul G. Falkowski
Oceanographic and Atmospheric Sciences Division
Building 318
Brookhaven National Laboratory
Upton, NY 11973
(516) 282-2961
FAX: (516) 282-2060
E-Mail: falkowsk@bnlux0.bnl.gov

Charles N. Flagg
Oceanographic and Atmospheric Sciences Division
Building 318
Brookhaven National Laboratory
Upton, NY 11973
(516) 282-3128
FAX: (516) 282-2060

Steven J. Ghan
Pacific Northwest Laboratory
P.O. Box 999
Richland, WA 99352
(509) 376-3161
FAX: (509) 376-5217
E-Mail: s_ghan@nimbus.ascot.pnl.gov

Richard Hart
Argonne National Laboratory
9700 South Cass Avenue
Argonne, IL 60439
(708) 972-5839
FAX: (708) 972-5498

George R. Hendrey
Oceanographic and Atmospheric Sciences Division
Building 318
Brookhaven National Laboratory
Upton, NY 11973
(516) 282-3262
FAX: (516) 282-2060

Rayford P. Hosker, Jr.
National Oceanic and Atmospheric Administration
Environmental Research Laboratories
Atmospheric Turbulence and Diffusion Division
P. O. Box 2456
Oak Ridge, TN 37831
(615) 576-1248
FAX: (615) 576-1237

Martin J. Leach
Oceanographic and Atmospheric Sciences Division
Building 051
Brookhaven National Laboratory
Upton, NY 11973
(516) 282-3813
FAX: (516) 282-3911
E-Mail: LEACH@BNLCL6.bnl.gov

Barry Lesht
Environmental Research Division
Building 203
Argonne National Laboratory
Argonne, IL 60349
(708) 972-4208
FAX: (708) 972-5498
E-Mail: LESHT@ANLER.BITNET

Albert M. Liebetrau
Pacific Northwest Laboratory
P.O. Box 999
Richland, WA 99352
(509) 375-2694
FAX: (509) 375-3641
E-Mail: D39774@pnlg.pnl.gov

Bernard Manowitz
Environmental Chemistry Division
Building 051
Brookhaven National Laboratory
Upton, NY 11973
(516) 282-2458
FAX: (516) 282-3911

Peter Minnett
Oceanographic and Atmospheric Sciences Division
Building 318
Brookhaven National Laboratory
Upton, NY 11973
(516) 282-5983
FAX: (516) 282-2060

Leonard Newman
Environmental Chemistry Division
Building 426
Brookhaven National Laboratory
Upton, NY 11973
(516) 282-4467
FAX: (516) 282-2887

Kathy J. Norden
Oceanographic and Atmospheric Sciences Division
Building 051
Brookhaven National Laboratory
Upton, NY 11973
(516) 282-3832
FAX: (516) 282-3911
E-Mail: NORDEN@BNLCL6.bnl.gov

David Renne
Battelle Washington Operations
370 L'Enfant Promenade, Suite 900
901 D Street SW
Washington, DC 20024-2115
(202) 646-5254
FAX: (202) 646-5233

Stephen E. Schwartz
Environmental Chemistry Division
Building 426
Brookhaven National Laboratory
Upton, NY 11973
(516) 282-3100
FAX: (516) 282-2887
E-Mail: steves@bnlux0.bnl.gov

Jack Shannon
Argonne National Laboratory
Building 203
9700 South Cass Avenue
Argonne, IL 60439
(708) 972-5807
FAX: (708) 972-5498
E-Mail: SHANNON@ANLER.BITNET

Gerald M. Stokes
Pacific Northwest Laboratory
Mail Stop KI-74
P.O. Box 999
Richland, WA 99352
(509) 375-3816
FAX: (509) 375-2698
E-Mail: d38101@pnlg.pnl.gov

Karl E. Taylor
Lawrence Livermore National Laboratory
P.O. Box 808
Livermore, CA 94550
(415) 423-3623
FAX: (415) 422-7675
E-Mail: ktaylor@cirrus.llnl.gov

Joyce L. Tichler
Oceanographic and Atmospheric Sciences
Division
Building 051
Brookhaven National Laboratory
Upton, NY 11973
(516) 282-3801
FAX: (516) 282-3911
E-Mail: TICHLER@bnlcl6.bnl.gov

Marvin L. Wesely
Environmental Research Division
Argonne National Laboratory
Building 203
Argonne, IL 60349
(708) 972-5827
FAX: (708) 972-5498
E-Mail: WESELY@ANLER.BITNET

Creighton D. Wirick
Oceanographic and Atmospheric Sciences Division
Building 318
Brookhaven National Laboratory
Upton, NY 11973
(516) 282-3063
FAX: (516) 282-2060
E-Mail: wirick@bnlux0.bnl.gov

Acronyms and Abbreviations

Acronyms and Abbreviations

AEROCE	Atmosphere/Ocean Chemistry Experiment
AISS	Australia-Indonesia Semi-Enclosed Sea
ARM	Atmospheric Radiation Measurement
As	altostratus
ASTEX	Atlantic Stratocumulus Transition Experiment
AVHRR	Advanced Very High Resolution Radiometer
BAO	Boulder Atmospheric Observatory
BATGE	Biosphere-Atmosphere Trace Gas Exchange
BIBEX	Biomass Burning Experiment
BOREAS	Boreal Ecosystem-Atmosphere Study
CART	Clouds and Radiation Testbed
Cb	cumulonimbus
CET	Criteria Examination Teams
Ci	cirrus
COARE	Coupled Ocean Atmosphere Response Experiment
CRF	cloud radiative forcing
CSIRO	Commonwealth Scientific and Industrial Research Organization
Cu	cumulus
DEBITS	Deposition of Biogeochemically Important Trace Species
DJF	December, January, and February
DMSP	Defense Meteorological Satellite Program
DOE	Department of Energy
ECLIPS	Experimental Cloud Lidar Pilot Study
ENSO	El Niño - Southern Oscillation
f	frequency of occurrence
FIFE	First ISLSCP Field Experiment
FIRE	First ISCCP Regional Experiment
GBSRN	Global Baseline Surface Radiation Network
GCM	General Circulation Model
GEWEX	Global Energy and Water Cycle Experiment
GMCC	Geophysical Monitoring for Climate Change
GOES	Geostationary Operational Environmental Satellite
IGAC	International Global Atmospheric Chemistry

IH	intentionally heterogeneous
INMARSAT	International Maritime Satellite System
ISCCP	International Satellite Cloud Climatology Program
ISLSCP	International Satellite Land Surface Climatology Program
ITCZ	Inter-Tropical Convergence Zone
JGOFS	Joint Global Ocean Flux Study
JJA	June, July, and August
LITE	Lidar Technology Experiment
LTER	Long-Term Ecological Research
MSt	marine stratus
NOAA	National Oceanic and Atmospheric Administration
NSF	National Science Foundation
OAST	Office of Aeronautics and Space Technology
OLS	Operational Linescan System
POES	Polar Orbiting Environmental Satellites
SST	sea surface temperature
TOGA	Tropical Ocean - Global Atmosphere
TRMM	Tropical Rainfall Measuring Mission
TWPO	Tropical Western Pacific Ocean
VISSR	Visible and Infrared Spin Scan Radiometer
WOCE	World Ocean Circulation Experiment
WPDN	Wind Profiler Demonstration Network
WSR	Weather Survey Radar

* U.S. G.P.O.:1991-281-714-40079