An Introduction to COMBLE-MIP

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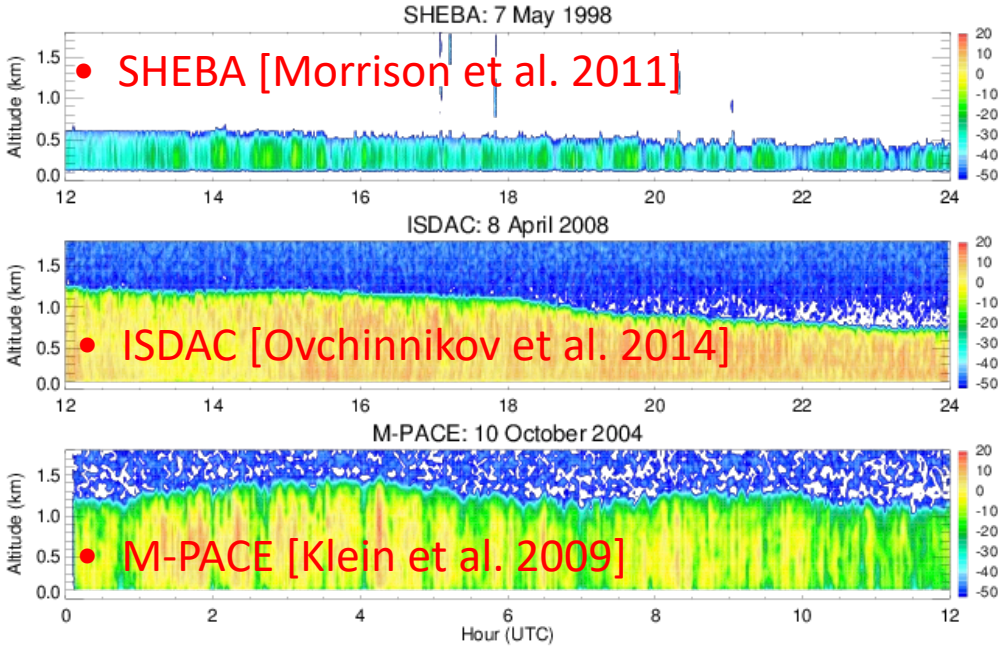
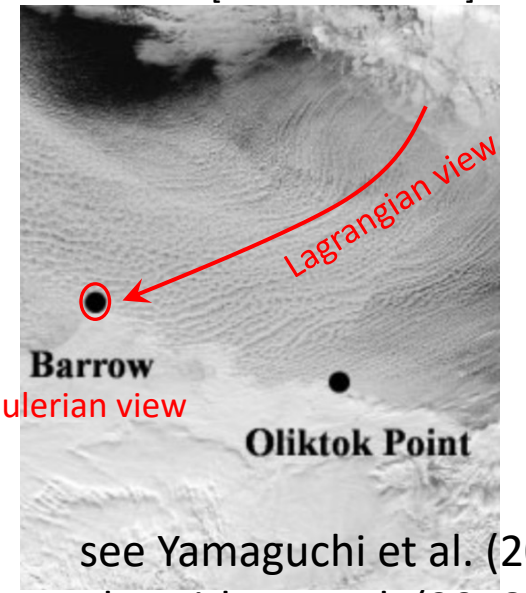
Vertically pointing mm-wavelength radar



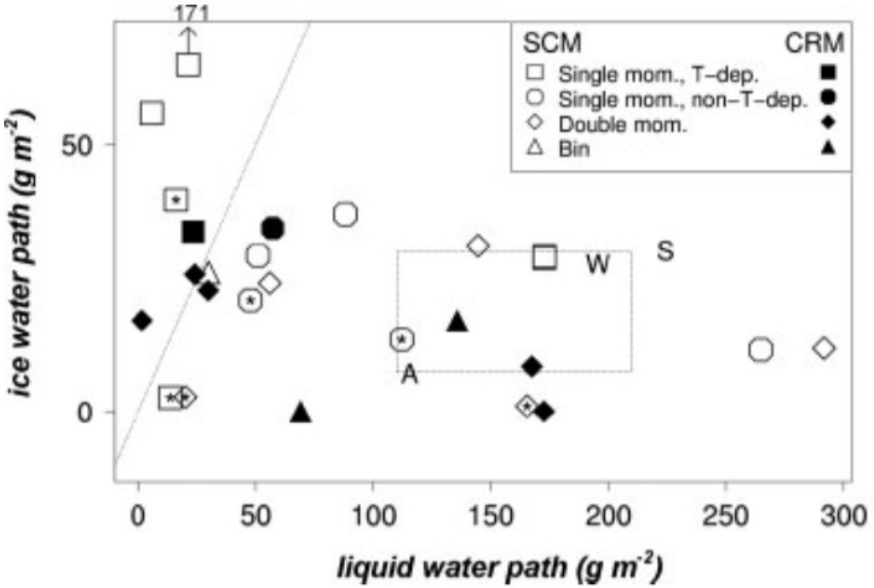
M-PACE [Klein et al. 2009]



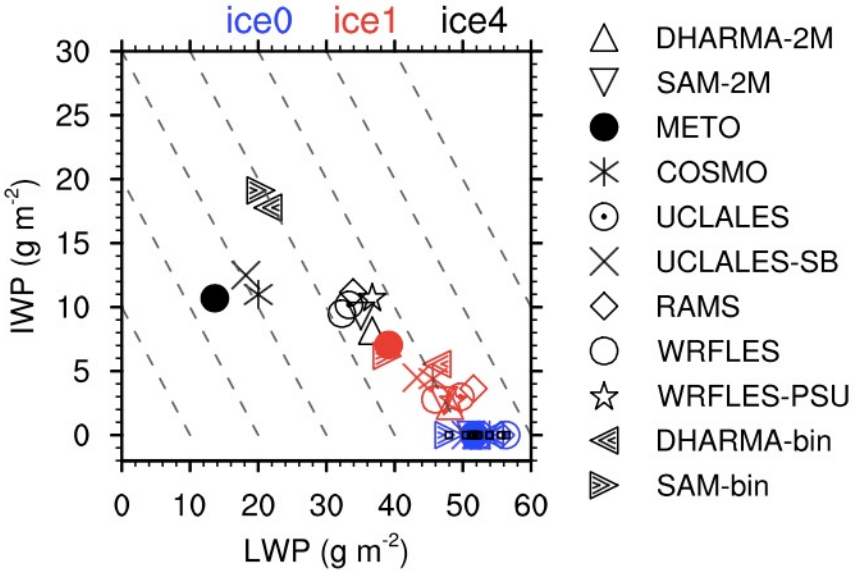
see Yamaguchi et al. (2015)
also Pithan et al. (2018)

Fridlind and Ackerman [Ch. 7 in *Mixed-Phase Clouds: Observations and Modeling*, Ed. C. Andronache, 2018]

Problem solved if N_i and habit are given (in LES)



Klein et al. (2009)



Ovchinnikov et al. (2009)

Case study set-up specifications	M-PACE	SHEBA	ISDAC	COMBLE	CONSTRAIN
nudged horizontal wind profile	Y	Y	Y	geostrophic	geostrophic
subsidence profile	Y	Y	Y	—	Y
sensible and latent heat fluxes	Y	Y	Y		
hygroscopic aerosol size distribution	Y	Y	Y	Y	fixed Nd
ice nucleating aerosol (somehow)	Y			Y	—
in-cloud ice number concentration		Y	Y		
ice properties (shape, capacitance, fall speed)			Y		
nudged temperature and water vapor			Y		
parameterized longwave radiative cooling			Y	—	
collision-coalescence turned off			Y		
set-up for SCM and LES	Y			Y	
quasi-Lagrangian following PBL trajectory				Y	Y

CONSTRAIN: de Roode et al. [JAMES 2019] following Field et al. [2014] cold-air outbreak case

SHEBA

Rangno and Hobbs [JGR 2001]

contrast: COMBLE is *highly supercooled*

(b) Moderately Supercooled Stratiform Clouds (Tops –10° to –20°C)

TYPE IV

ice concentrations near or below ice nucleus concentrations; mostly pristine crystals

Small droplets at cloud top, possible ice, little or no precipitation

- Droplet concentrations > 100 cm^{-3}
- Maximum effective droplet radius < 10 μm
- Maximum threshold droplet diameter < 20 μm
- Ice concentrations nil or a few per liter

SHEBA
ISDAC

TYPE V

ice concentrations at or above ice nucleus concentrations due to fragmentation of crystals, freezing drops

M-PACE

Large droplets at cloud top, ice, precipitation

- Droplet concentrations typically < 100 cm^{-3}
- maximum effective radius > 10 μm
- Maximum threshold droplet diameter > 20 μm
- Ice concentrations 10-100 per liter

LES/SCM case studies

- pros
  - SCM is powerful basic test of ESM column physics (e.g., Neggers 2015)
  - convenient framework for model development (at least column physics)
  - can be used to tune model parameters (e.g., Williamson et al. 2013)
  - observation-derived cases highlight fundamental knowledge gaps (e.g., ice multiplication, mesoscale structure, CCN and INP budgets)
- challenges
  - how to choose? (statistically representative? extremes? ensemble?)
    - don't let the perfect be the enemy of the good?
    - confer about data quality and previous work, then take a vote
  - are SCM-based improvements borne out in free-running ESM?
    - must be paired with additional evaluation (e.g., light precipitation frequency during MICRE by Stanford et al. 2023)

Group activities on the GCSS/GASS model

- pros — done or in progress
  - reduced duplication of effort in setting up cases
  - valuable consensus-building & knowledge-sharing re cases & setup
  - can motivate and efficiently use dedicated efforts from observationalists
- cons
  - major effort from a lead organizer who is not specifically funded
  - overhead on every group to report specified results & file formats
- possible changes
  - introduce community code base (e.g., Python to convert outputs to unified format, apply forward simulators, plot results from models vs obs)
    - use DEPHY input/output community standards for LES/SCM specifications and output (https://www.lmd.jussieu.fr/~hourdin/Workshop1Dstd.html)
  - introduce use of ARM computing resources (ARM Workbench and Cumulus cluster)
  - emphasize a bare minimum package of runs & diagnostics (low-overhead option)
  - decrease emphasis on omnibus manuscripts?

Motivation for cold-sector mixed-phase cases

- scientific approach
  - objective not to converge LES models, but estimate impacts of specific process uncertainties
  - include processes most relevant to understanding climate model diversity
  - relevance extends to high-resolution global modeling (e.g., Sullivan and Voigt, 2021)
- science questions (Susannah Burrows, Xiaohong Liu, Johannes Mülmenstädt)
  - how accurately do aerosol need to be predicted for purposes of accurate cloud properties?
  - how INP-limited is the precipitation process, and how important is SIP?
  - how susceptible is rain occurrence to strong CCN seasonal cycles?
  - how important is spatial heterogeneity of aerosol on various scales?
  - would there be less precipitation in a warmer atmosphere?
- looking ahead
  - we don't have observations of the future, but SCM "fingerprint" may be valuable indicator of ESM diversity
  - LES sensitivity compared to SCM sensitivity an indicator of leading physics responsible (Sherwood et al. 2020)
  - could seek to use observations creatively in emergent constraints-ish approach?
  - pilot study contrasting DOE COMBLE and NASA ACTIVATE small ensembles was workshopped at the CFMIP/GASS meeting in Paris last month (contacts: Greg Cesana and Florian Tornow)

Today's agenda

- aerosol specification — Abbey Williams/UCSD
- aerosol-INP closure — Daniel Knopf/Stony Brook
- observational constraints — Florian Tornow/CU–NASA GISS
- COMBLE-MIP at the ARM Workbench — Max Grover/ANL
- preliminary results — Tim Juliano/NCAR
- discussion