Cloud Optical Depths and Liquid Water Paths at the NSA CART

J. C. Doran, J. C. Barnard, and S. Zhong
Pacific Northwest National Laboratory
Richland, Washington

C. J. Jakob
European Centre for Medium-Range Weather Forecasts
Reading, England

Introduction

As part of our efforts to characterize the cloud properties at the North Slope of Alaska (NSA) Cloud and Radiation Testbed (CART), we have used microwave radiometers (MWRs) and multi-filter rotating shadowband radiometers (MFRSRs) at Barrow (a coastal site) and Atqasuk (an inland site) to measure liquid water paths (LWPs) and cloud optical depths (τ) during the period June through September 1999. In addition to developing a climatology of cloud properties at the two sites, which will require the collection of data over several years, we are also interested in determining if there are significant differences in those properties between the sites, what features of the meteorology or surface conditions may account for those differences, and how well the European Centre for Medium-Range Weather Forecasts (ECMWF) model does in predicting the observed cloud properties. In this paper, we discuss our initial efforts to address these latter issues.

Data

The MWR data can be contaminated by water collecting on the instrument's window, and a sensor that sets a flag when this condition is encountered is not always reliable. As an alternative, we have used a filter routine provided by J. Liljegren (private communication) that uses both the LWP values and the variance of the water vapor path values to identify periods when the window is wet, and data collected during those times were removed. This procedure eliminated many but not all of the anomalously high LWP values in the data record. In particular, a small number of large and presumably erroneous LWP values remain and some care must be exercised in interpreting these data.

The MFRSR τ values were calculated either using a delta-Eddington approach or with the more exact code developed by Min (Min and Harrison 1996). In practice, the values obtained with the two approaches were very similar.

The MWRs and MFRSRs collect data at a nominal rate of one reading every 20 seconds, although the MWR rate is reduced somewhat when it is operating in its tip mode. For our comparisons between observations and the ECMWF predictions, we chose to group data in 3-hour blocks. For a mean wind speed of 6 ms^{-1}, which is representative of the winds in the Barrow area, this time corresponds to an advective length scale of approximately 65 km, which is comparable to the size of the ECMWF grid box closest to Barrow.

Analysis

Figure 1 shows a plot of predicted LWP values as a function of the observed LWP values. Although there is considerable scatter in the data, it is clear that the modeled values of the LWP generally fall below a 1:1 line that would represent a perfect prediction. No significant differences were found if different averaging periods (1 hour, 6 hours, or 24 hours) were used for the comparison.

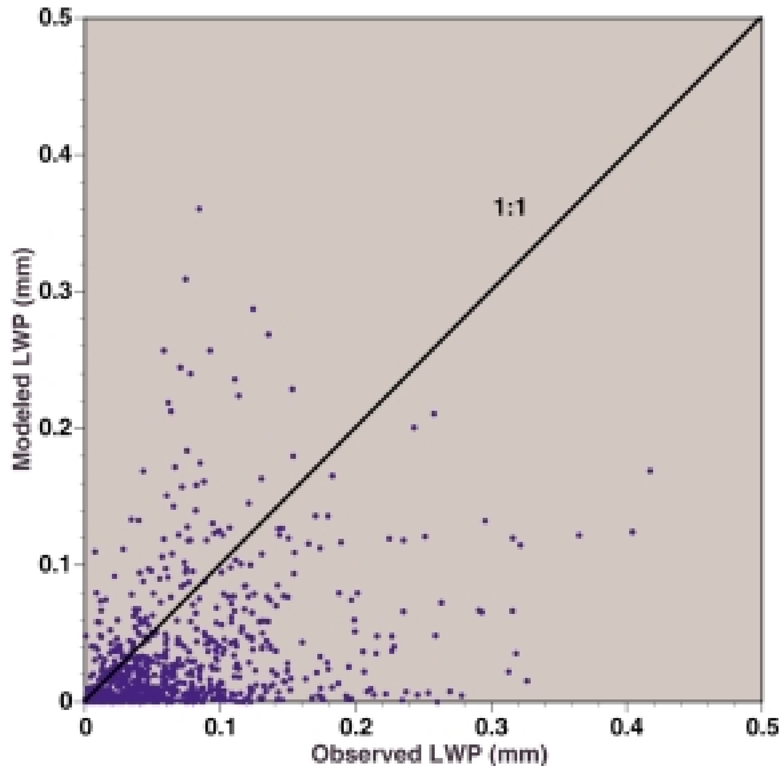

Figure 1. Comparison of modeled and observed LWPs at Barrow for June-September 1999. Each point represents a 3-hour block.

Figure 2 shows the median and the 25th and 75th percentile values for the predicted LWPs as a function of the observed values, which have been grouped into bins with median values at the points shown. The medians of the predicted values fall well below the 1:1 line, consistent with the behavior found in Figure 1. Note also that the 25th percentile value line is nearly horizontal, implying that the ECMWF model frequently predicts very little cloud water even when the observed values are relatively large.

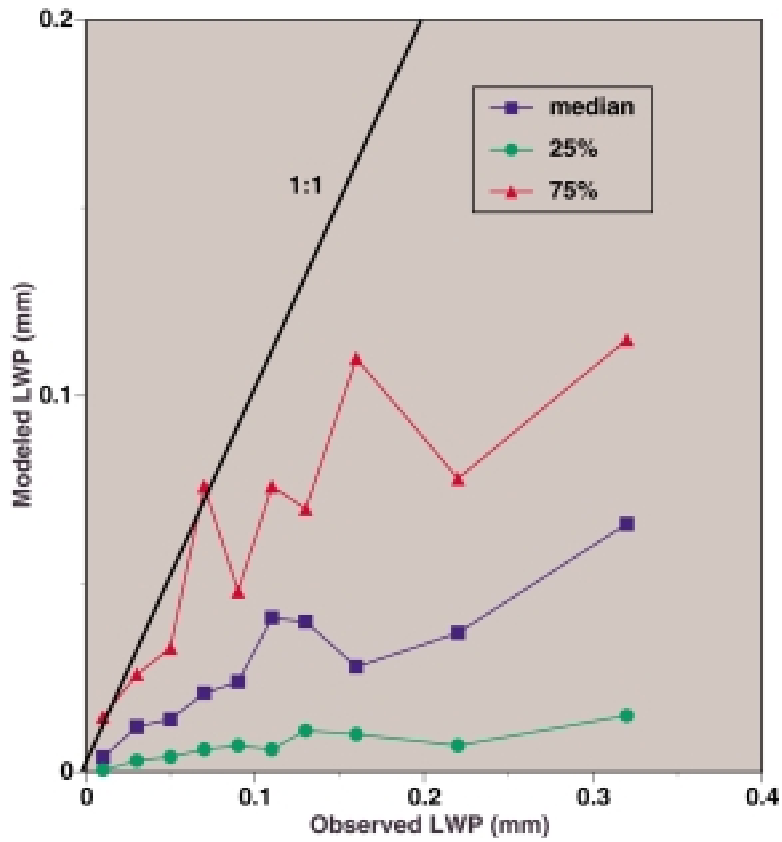

Figure 2. Distribution of modeled LWPs as a function of observed LWPs at Barrow.

Although τ is not a standard output of the ECMWF model, it can be estimated using the procedure described by Klein and Jakob (1999). Behavior similar to that shown for the LWPs is found when comparing model predictions with the observed τ values obtained from the MFRSR at Barrow, as shown in Figure 3. There are fewer data than for the LWPs because the latter can be measured day and night whereas τ can be reliably obtained only when the sun is 20° or more above the horizon. This condition is met for most of the day during June but for relatively few hours each day by September.

By combining hourly values of LWP and τ, it is possible to estimate the droplet effective radius of the clouds using the expression $r_{eff} = 1.5$ LWP/τ (Stephens 1978). Figure 4 shows a histogram of the distribution of effective radii at Barrow. The median value of 11.5 microns is reasonable, but a small number of outliers have values as large as 50 microns or more. Some of these outliers, but by no means all, have large values of LWP that may be associated with the difficulties associated with a wet window as described above. Many of the events occur in June, and we will need to examine the meteorological conditions during those times carefully to look for possible causes.

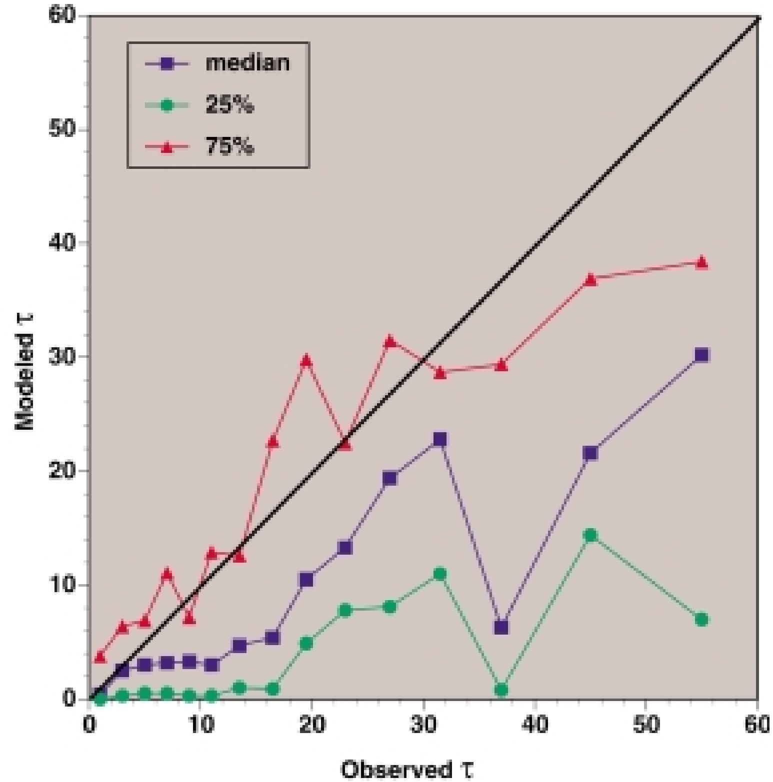

Figure 3. Distribution of modeled τ s as a function of observed τ s at Barrow.

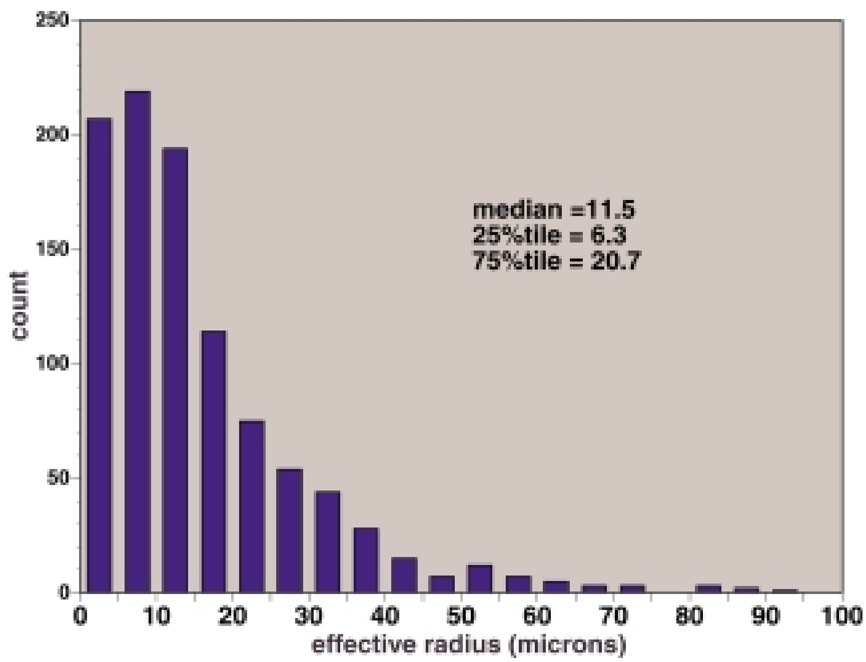

Figure 4. Distribution of droplet effective radii at Barrow.

The LWP distributions at Barrow and Atqasuk were surprisingly similar when calculated for the 4-month period of observations. A closer inspection, however, shows some interesting differences. Figure 5 shows histograms of the differences in LWP at Barrow and Atqasuk (Barrow-Atqasuk) for the months of June and August. During June, conditions favorable to the development of low clouds (<1 km) were more common than during other periods. Under those circumstances, there was a tendency for Atqasuk to have higher values of liquid water than Barrow, as seen in the upper left panel of the figure. In contrast, in August there is little obvious tendency for one site to have greater LWPs than the other when all cloudy periods are considered.

A model bias in the predicted shortwave radiation was also found that is consistent with the biases found for LWP and τ. Figure 6 shows plots of the observed and modeled LWP and incoming shortwave radiation as a function of time. The thin lines are daily averages for the hours when the sun is above the horizon; the thick lines are 15-day running means. The underprediction of the LWP values is evident, as

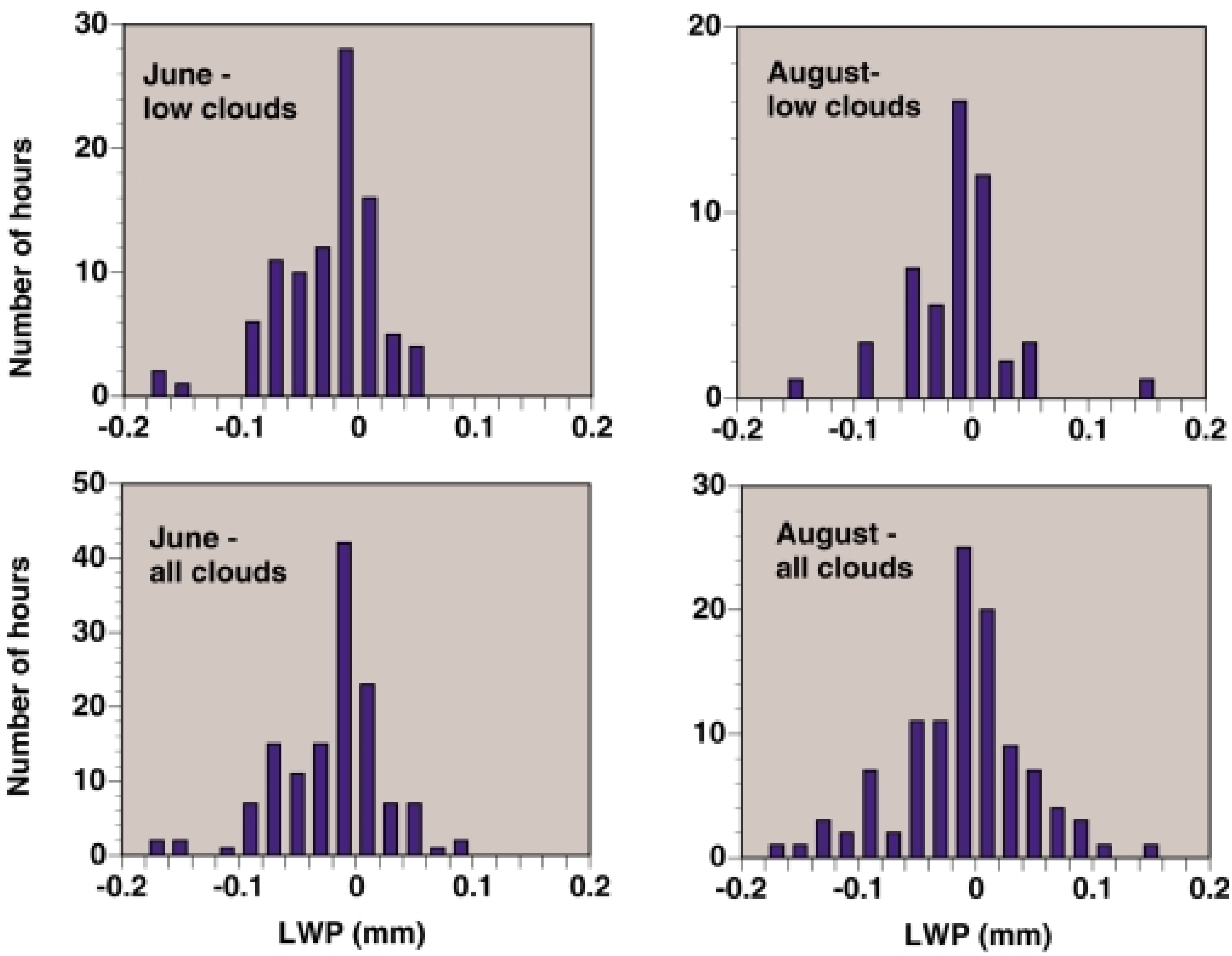

Figure 5. Differences in LWPs between Barrow and Atqasuk.

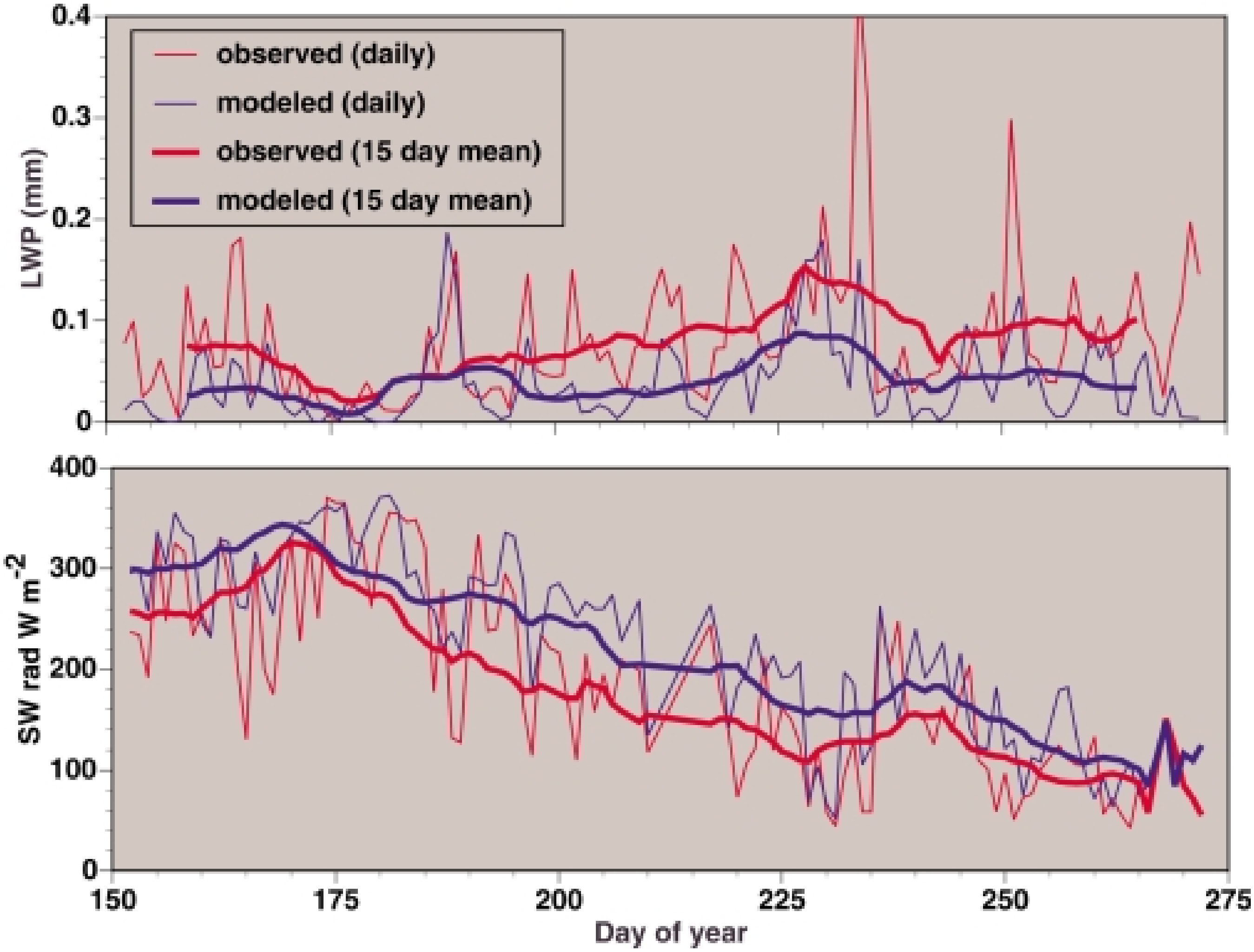

Figure 6. Liquid water path and downward shortwave flux at Barrow.

is the corresponding overprediction of the shortwave radiation. Note the period between days 175 and 180 when both the LWP and the shortwave radiation differences become small.

Summary

Comparisons of modeled and observed cloud optical depths and liquid water paths at Barrow show a tendency for the ECMWF to underpredict both τ and LWP, consistent with a tendency for the model to overpredict the incoming shortwave radiation. Relatively little difference between LWP differences at Barrow and Atqasuk were found, but there was tendency for Atqasuk to have larger LWP values early in the summer, when low level clouds were more common.

Acknowledgments

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References

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