P1.29 COMPARISON OF CLOUD PROPERTIES AT A COASTAL AND INLAND SITE AT THE NORTH SLOPE OF ALASKA

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1. INTRODUCTION

The goal of the U.S. Department of Energy's Atmospheric Radiation Program (ARM) is to study the effects and interactions of sunlight, radiant energy, and clouds on temperatures, weather, and climate (Stokes and Schwartz 1994). As part of that effort, ARM has established three Cloud and Radiation Testbeds (CARTs) for conducting both long-term and intensive measurements of cloud properties, long- and shortwave radiation, meteorological variables, surface properties, etc. The measurements can be used to test, evaluate, and improve general circulation models (GCMs) used in climate studies. The North Slope of Alaska/ Adjacent Arctic Ocean (NSA/AAO) site is one of those CARTs, with its principal complement of instruments located at Barrow on the northern coast of Alaska at 71° 18 ' N, 156° 41 ' W. A more limited set of instruments has been installed at the village of Atqasuk (70° 28 ' N, 157° 24 ' W), approximately 100 km inland to the southwest.

Data from the ARM CARTs have been used to assess the performance of single column models (SCMs) and cloud resolving models (CRMs); these models, in turn, can be used to help test parameterizations to be used in GCMs. Because the size of a grid cell in a GCM may be on the order of 100 km or more, it is important to determine to what extent meteorological and radiometric observations made at Barrow or Atqasuk differ and how representative one or both sites are for the domain over which SCMs or CRMs are to be evaluated. During the warmer months of the year, one might expect significant differences in the cloud properties between inland and coastal regions of the NSA/AAO, depending on whether the prevailing synoptic flows are onshore or offshore. In the former case the upwind fetch for Barrow is over water or sea ice while the intervening fetch between Barrow and Atqasuk is over land and numerous small lakes; in the latter case the upwind fetch for both Barrow and Atqasuk is from mountainous areas and then over land and lakes.

We are conducting an ongoing study of selected cloud characteristics at Barrow and Atqasuk. We are examining the cloud optical depths and the liquid water paths at the two locations, and from these two quantities we can obtain the effective droplet radii for the clouds at each site. These are the crucial quantities needed to characterize the radiative properties of the cloud layers there (Leontyeva and Stamnes 1994). We wish to determine whether there are important differences in these cloud properties at the Barrow and Atqasuk sites, under what circumstances such differences will occur, what may be the causes for them, and whether these features can be captured by models such as that operated by the European Center for Medium-Range Weather Forecasting (ECMWF).

2. INSTRUMENTS AND DATA QUALITY

For the current analysis we use just the data from the microwave radiometers (MWRs) at each site to obtain values of the cloud liquid water paths (LWPs) during the warmer months of 1999 (June - September). The ARM MWR can obtain a value of the water vapor path (WVP) and the LWP every 20 to 30 seconds, depending on the operating mode of the instrument. Details of the MWR's characteristics and operating procedures are given in Liljegren (2000). The WVP and LWP values generated in the current standard ARM processing are based on a statistical retrieval technique and the Liebe and Layton (1987), Rosenkrantz (1993), and Grant (1957) absorption models.

There has been considerable controversy arising from comparisons of ARM MWR LWP values with aircraft-derived values obtained during the SHEBA (Curry et al. 2000) campaign, with ARM values of LWP being reported as much as a factor of two

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too large. The main difficulty appears to be associated with the particular values of absorption coefficients used for the liquid water retrievals. Han et al. (2001), using data from SHEBA, showed how the use of different radiation models could affect the retrieved values of LWP. The differences in the absorption coefficients among the models they investigated were small for temperatures above 273 K but became larger at temperatures below 273 K in which supercooled cloud water is found. They based their analysis on the measurements of Rosenberg (1972) and the more recent work of Liebe et al. (1991) and Rosenkrantz (1998). Lin et al. (2001) developed their own retrieval based on yet another microwave radiative transfer model and different liquid water and gas absorption coefficients. Their method produced a 47% reduction in the ARM LWP values for thin and moderate clouds. This appears to be roughly consistent with the findings of Han et al. (2001) but the use of a fixed ratio to compare retrieved LWP values can be misleading. We have examined the values generated by Han et al. in their reanalysis of the ARM data. We found that the ratio of their modified LWP values to the ARM values increases smoothly as the value of the ARM LWP increases, ranging from about 0.3 when the ARM LWP is 0.01 mm to nearly 0.9 for LWPs on the order 0.2 mm during June and July.

For our current analysis we have adjusted the original ARM LWP values by scaling them with the appropriate ratios determined from the Han et al. reanalysis results. It would be unwise to use this approach to analyze an individual cloud "event" with a duration of, e.g., a few minutes or tens of minutes, but errors associated with this correction procedure should be small for analyses extending over longer periods of time, such as weeks to months, as we are dealing with in this paper. Moreover, our interest is primarily on differences in cloud properties and not in absolute values at a single location, so that we believe the LWP values obtained from this adjustment technique are adequate for our present purposes.

Care must also be taken to identify and eliminate data collected during periods when the window on the MWR may be wet. A data flag to indicate a wet window condition was found to be unreliable and an alternative procedure developed by Liljegren (private communication) was used to eliminate bad data. The procedure identifies probable wet window conditions by monitoring the time series of both the WVP and LWP channels of the MWR; its use significantly reduces the number of anomalous spikes in the data series. Even with the use of this screening procedure, however, occasional values of LWP were obtained that appear implausible for most Arctic clouds (e.g., greater than 400 gm m^{-2}). Thus, in our analyses we prefer to use median, 25th, and 75th percentile values rather than mean values and standard deviations to describe the distributions of LWPs. Theses statistics are less sensitive to possible outliers and provide useful information on the positive skewness of the distribution.

3. RESULTS

Data from the MWR were analyzed for the period from June 1 through September 30, 1999 at both Barrow and Atqasuk. There were several extended periods of missing data and we thought it would be most appropriate to compare distributions of values only for time periods when both instruments were operating. (The data for one instrument were still included in the analysis if the other instrument was missing data for only a few hours.) In this way the inclusion of data from particularly cloudy or clear days at one site, when the instrument at the other site was not operating, would not bias the comparison.

Table 1 summarizes some of the statistical properties of the distributions for the whole period as well as for each of the four months. The distributions computed for the period as a whole were virtually identical at the two sites but there were substantial changes in the relative distributions over the course of the study period. The LWP values at both Barrow and Atqasuk increased noticeably from the early months to the later ones. In June the median LWP value at Barrow was only about 41% of that at Atqasuk but in September was about 21% higher than at Atqasuk.

As noted earlier, we anticipated that the cloud properties at the two sites might be sensitive to the direction of the prevailing winds. To study this possibility we used the output from the ECMWF model to estimate hourly wind directions at the 960 hPa level. Figure 1 shows the variation of the median LWPs at Barrow and Atqasuk as a

Table 1. Median, 25th percentile, and 75th percentile of liquid water paths (LWPs) at Barrow and Atqasuk. LWPs are in mm.

Site→	Barrow				Atqasuk			
Period ↓	median	25%	75%	# cases	median	25%	75%	#cases
June-September	0.035	0.011	0.075	2012	0.038	0.011	0.078	1932
June	0.013	0.005	0.039	447	0.032	0.009	0.067	410
July	0.025	0.008	0.061	565	0.023	0.008	0.065	543
August	0.052	0.024	0.097	422	0.050	0.025	0.098	419
September	0.052	0.026	0.090	578	0.043	0.015	0.090	560

function of the wind direction, where the wind direction data have been combined into 45° bins.

There are two maxima in the LWP values at each site, one for wind directions in the sector from 180° to 225° and a second in the sector from 315° to 360°. For winds from approximately 315° to 90° the median LWPs at Atqasuk were about the same as or larger than the median values at Barrow; for all other wind directions, the median values at Barrow were larger. Also shown in the figure are results from the ECMWF model, which we discuss below.

Output from the ECMWF model were archived at one hour intervals at four sites in the Barrow-Atqasuk region. The gird points nearest Barrow and Atqasuk were centered on sites with latitude and longitude values of 71.05N, 156.8W and 70.48N, 157.5W, respectively. The model was reinitialized every 24 hours and forecast values from 12 to 36 hours after initializations were used for comparisons with the data.

From the LWP values predicted by the ECMWF model shown in Figure 1 it is evident that the model underpredicts the LWP values for all directions and at both sites. It does capture the local maximum in Barrow and Atqasuk LWP values in the 180°-225° sector, and it does predict somewhat higher values at Barrow than at Atqasuk, as was observed. It fails to capture the second local maximum in the 315°-360° sector, it shows virtually no difference between the median values at the two sites, and the underprediction is worse than for the 180°-225° sector. The simulated incoming shortwave radiation (not shown) is larger than the observed values, consistent with the smaller simulated values of LWP.

4. CONCLUSIONS

Noticeable differences are found in the liquid water paths of the clouds at Barrow and Atqasuk, and the differences are dependent on the direction of the prevailing wind. The ECMWF model was able to capture the first of the two maxima in the directional dependence of the LWP values but not the second. The median LWP values for the model simulated LWPs was only 47% of the observed values at both Barrow and Atqasuk for the June-September period, and the differences between the two sites were not reproduced.

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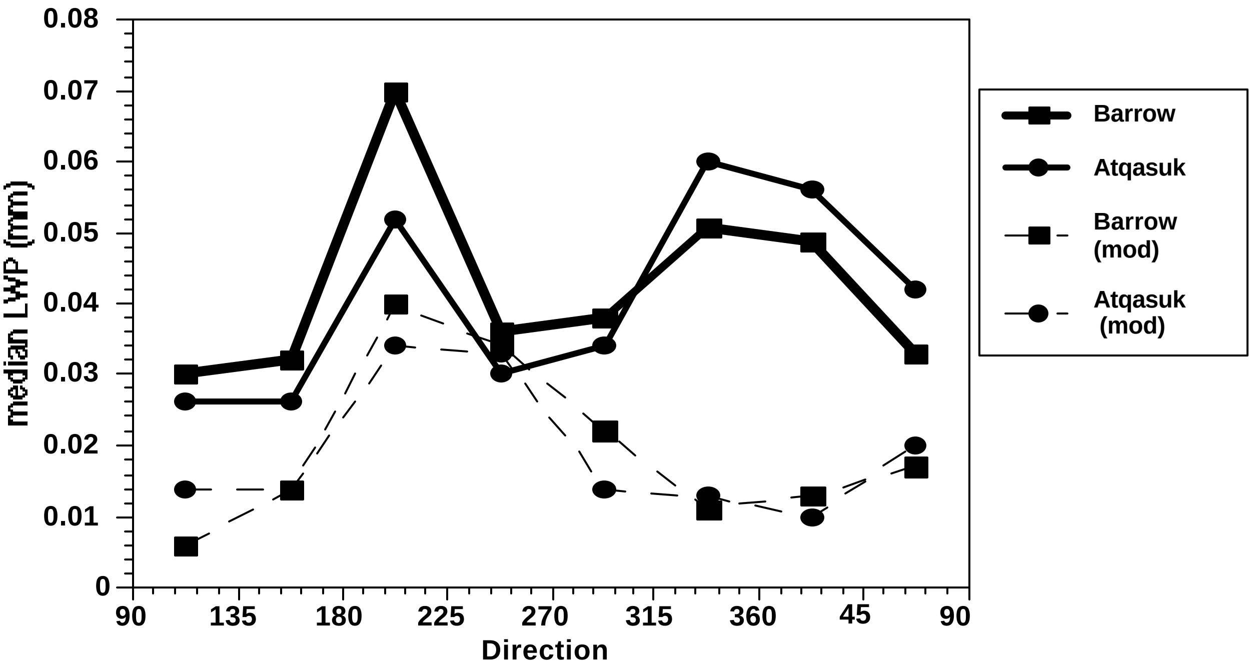

Figure 1. Variation of observed and modeled median liquid water paths at Barrow and Atqasuk with wind direction at 960 hPa. The solid lines are from observations; the dashed lines are from the ECMWF model

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