4.2 SUPERCOOLED LIQUID WATER CLOUD PROPERTIES DERIVED FROM GOES: COMPARISONS WITH IN-SITU AIRCRAFT MEASUREMENTS

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1. INTRODUCTION

The existence of super-cooled liquid water (SLW) in clouds is of concern to the general aviation community since it can freeze on contact with aircraft and adversely affect the aircraft's performance. Icing on the airframe can increase drag, decrease lift and cause control problems. Several factors determine the degree with which SLW will freeze and affect an aircraft's performance including the type and weight of the aircraft, the duration of exposure to SLW and the accretion rate of ice on the airframe. The severity of ice accretion is sensitive to temperature, the liquid water content and the drop size distribution (Rasmussen et al., 1992). Much attention has been given to improving the detection and forecasting of aircraft icing over the past decade. A number of temperature and humidity based diagnostic algorithms have been incorporated with numerical weather prediction models to produce icing forecast products over the United States (Schultz and Politovitch, 1992; Forbes et al. 1993). An intercomparison of in-flight icing algorithms was recently conducted by Thompson et al., 1997 and Brown et al., 1997. Those studies revealed that temperature and humidity based algorithms significantly over-predict the area coverage of SLW clouds. Thompson and Bullock (1997) showed that satellite data can be used to reduce the predicted spatial extent of SLW by excluding areas where the satellite-derived cloud top temperature is above freezing. Satellite data can also be used to detect SLW directly since it is often found to accumulate in the top several hundred meters of cloud layers (Rauber and Tokay, 1991). Recent advances in geostationary satellite sensors now permit us to derive cloud optical depth, particle size, phase and water path in near real-time. Ellrod (1996) and Ellrod and Nelson (1996) have shown the potential for using geostationary satellite data to detect SLW clouds. In this paper, we apply a technique to identify SLW clouds and derive the cloud optical properties from geostationary satellite data. Smith et al., 2000 demonstrated a favorable comparison of this technique to positive Pilot reports of icing. In this paper, the satellite retrievals are co-located and compared with in-situ aircraft measurements of cloud microphysical properties made over a three month period from the NASA Glenn Twin Otter This work is being done in an effort to further validate the satellite retrievals and to explore the potential for determining icing severity from real-time operational satellite data based on the extent to which the aircraft data are able to indicate icing severity.

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2. DATA AND METHODOLOGY

A suite of algorithms have been developed to derive pixel level cloud properties for the Clouds and Earth's Radiant Energy System (CERES) project (Minnis et al. 1995; 1998, 1999 and Arduini et al. 1999). These algorithms have been adapted and are being applied to Geostationary Operational Environment Satellite (GOES-8) data over the United States for the Atmospheric Radiation Measurement (ARM) program. Cloud properties are determined by matching radiance observations at 0.63, 3.9, 10.8 and 12.0 µm at a nominal 4 km resolution to parameterizations of model calculations of cloud emittance and reflectance for a wide range of water droplet and ice particle sizes (Minnis et al, 1998). Additionally, a robust cloud mask has been developed to exploit the multi-spectral information now available on operational satellites. Accurate maps of clear-sky surface albedo and emissivity have been developed (Smith et al. 1999, Sun-Mack et al, 1999) and are crucial to both the cloud identification and the cloud retrievals. The atmospheric contribution to the satellite radiances is separated from the cloud contribution. Atmospheric optical depths are calculated for the GOES-8 wavelengths following the method of Kratz (1995) and utilizing temperature and humidity profiles obtained from 3-hourly Rapid Update Cycle (RUC) operational analyses. Calibration of the 0.63 -µm channel is performed and follows the method of Nguyen et al. (2001). Nominal calibrations for the other channels are employed. These algorithms are running operationally at 30-minute resolution since early to derive cloud and radiation parameters from GOES-8 data taken over the southern great plains (SGP) of the USA for the ARM program (see http://angler.larc.nasa.gov/armsgp for examples of the cloud products). In this study we apply the technique to GOES data over the Ohio valley at times coincident with NASA Glen Twin Otter flights.

2.1 Determination of SLW

In the satellite analyses presented here, clouds determined to be composed of water droplets with temperatures below 273K are denoted as SLW and indicate the potential for aircraft icing. The methos is desribed in more detail in Smith et al., 2000.

3. RESULTS

There were at least 17 Twin Otter flights that penetrated SLW clouds during the period of Jan 17 thru March 30, 2001. Satellite analyses have been performed for 8 of these flights at the time of this writing. Figure 1 depicts cloud phase derived from the GOES data over a large region encompassing the Ohio valley and the location of the aircraft flights. Large areas of SLW were identified in the satellite retrievals for all the days. On a few of the days, cirrus clouds were present above the aircraft. Table 1 list the mean cloud microphysical properties and cloud temperature derived from the satellite data in a region approximately 3600 square miles encompassing the aircraft flights. Cloud optical depths ranged from about 10 to 40. Liquid water paths were found to range from 70 to 260 g/m**2 and the water droplet effective radii generally ranged from 8 to 12 um with a mean value of 17 um found on March 21. It's like we have misidentified some cirrus edge pixels in this region as SLW. a day in which there was significant cirrus aloft. The cloud temperatures were generally 260 to 266 K.

4. CONCLUDING REMARKS

A technique for deriving cloud optical properties and, in particular, SLW, from high spatial and temporal resolution satellite data has been applied to GOES data over the Ohio valley. The results are being compared to aircraft measurements of SLW cloud microphysics. The analysis reported here is just the beginning. For the conference, we plan to have analyzed the aircraft microphysics data and plan to do a more thorough comparison of cloud properties derived from the satellite data along the flight track of the twin otter. Those data will be compared to the aircraft microphysics measurement as they have just recently become available. There were also about a half dozen flight days in January 2001 that will also be analyzed. The aircraft data are valuable to validating the satellite retrievals of SLW cloud properties. Of particular interest will be the comparison between the cloud microphysical properties derived from the aircraft data collected in-cloud and those properties derived from space

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	Optical Depth	LWP (g/m**2)	Droplet Radius (um)	Temperature (K)
Feb 23, 2001 (1445 UTC)	22	118	8.6	261
Feb 26, 2001 (1445 UTC)	38	182	7.7	263
Mar 02, 2001 (1445 UTC)	33	260	11.7	266
Mar 02, 2001 (1445 UTC)	24	135	9.1	267
Mar 07, 2001 (1445 UTC)	28	213	11.7	252
Mar 21, 2001 (1445 UTC)	10	102	16.9	262
Mar 27, 2001 (1445 UTC)	15	69	7.7	260
Mar 29, 2001 (1445 UTC)	26	204	11.6	261

Table 1. Cloud properties derived from GOES in the vicinity of the NASA GLEN Twin Otter for select cases

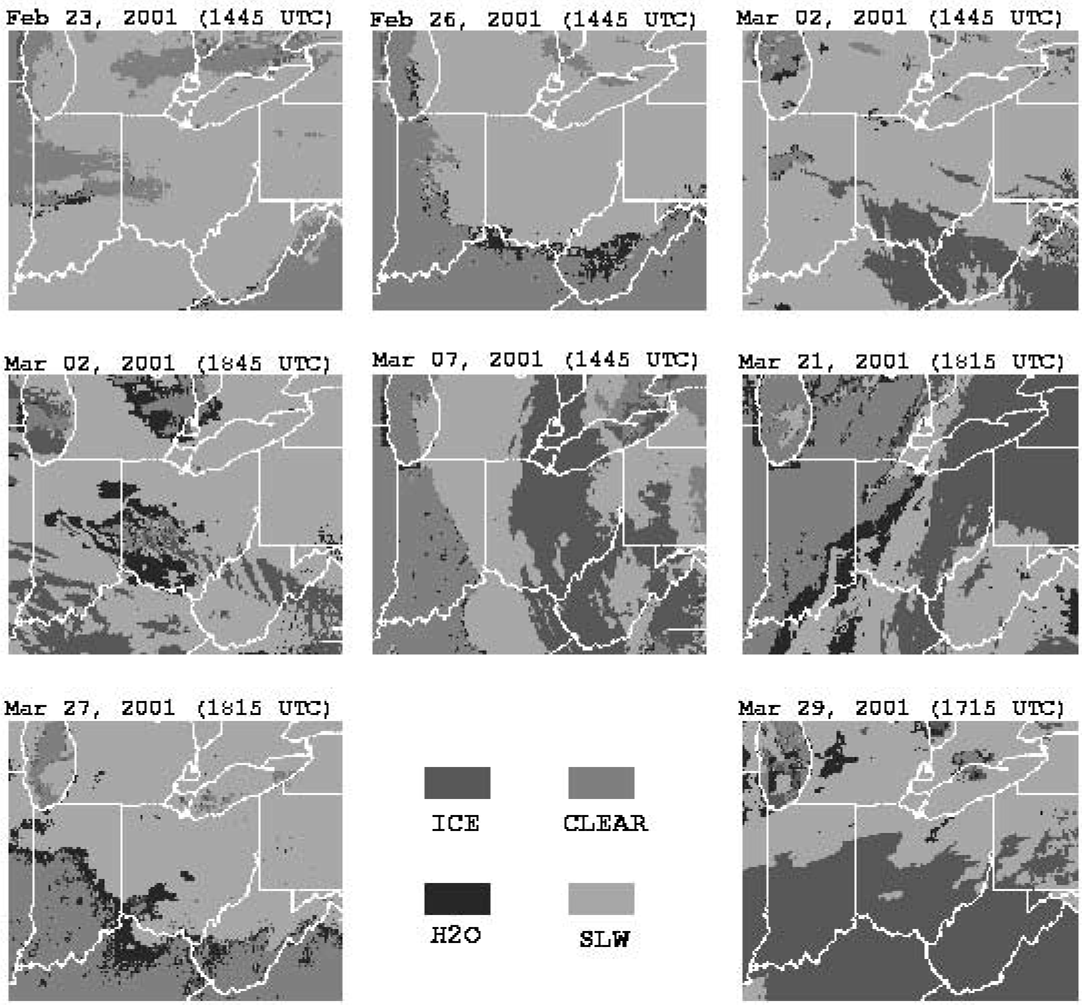

Figure 1. Cloud phase derived from GOES coincident with NASA Glen Twin Otter flights in SLW clouds.