P1.4 MT. WASHINGTON ICING SENSORS PROJECT (MWISP) CLOUD PARTICLE HABIT ANALYSIS

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1. INTRODUCTION

The April 1999 Mount Washington Icing Sensors Project (MWISP) was undertaken to improve the detection and prediction of aircraft icing (Henson and Anatta, 1999; Ryerson et. al., 2000). The Federal Aviation Administration (FAA) and the National Aeronautics and Space Administration (NASA) funded the project. It was directed by the National Center for Atmospheric Research (NCAR), the Mt. Washington Observatory (MWO), and the U.S. Army Cold Regions Research and Engineering Laboratory (CRREL). In total, 19 government, university, and industry agencies participated in MWISP.

Remote sensing measurements were taken with radiometers, X-, K-, and W-band radars; and a lidar—all located at the western base of Mt. Washington. Radiosondes were also launched from this location to support the project.

Probes were used to collect about 150 hours of ice crystal and cloud droplet imagery from the summit of Mt. Washington during MWISP. This paper will briefly review the initial problems with analyzing these data that was first reported by Schmitz et al. (2001). It will also discuss another new problem encountered and describe solutions to address all the problems. Finally, we will present preliminary results on the habit analysis of mixed-phase clouds from the MWISP probe data.

2. INSTRUMENTATION

Instrumentation used in classifying cloud ice crystal habits included two Optical Array Probes (OAP) by Particle Measuring Systems (PMS Inc., Boulder, CO). A Forward Scattering Spectrometer Probe (FSSP) was used to measure cloud droplet size distributions, which were used to determine liquid water content.

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The two OAP probes created images of cloud particles ranging from 0–800 microns to 0-6400 microns. The time between particles was also recorded by the OAP so that concentrations could be calculated. The OAP worked by recording the two-dimensional shadows of the cloud particles as they fall through the beam of a Helium Neon laser. The intensity of the shadow is also recorded and becomes an important part of our analysis.

3. PROCEDURES

Most of the analysis was completed with automated imagery analysis PMS OAP-2D processing software developed by Korolev and Sussman (2000). Manual analyses were done on a few subsets of data, characterized by different particle types, to verify the accuracy and usefulness of the software.

A single buffer of 2DC imagery is shown in Figure 1. These buffers usually contain less than a few seconds of data, but a number of particle images, when clouds are present.

Figure 1. Single 2DC gray image buffer from Schmitz et al. (2001)

Looking at a number of consecutive buffers, such as the one shown above, we did a manual analysis by identifying each individual shape. We randomly selected 10-seconds of buffers over 5-minute intervals for three different days, characterized by three different, predominant particle types (needle, dendrite, or sphere). We used techniques similar to those described in Korolev and Sussman (2000). Using the same methodology, we expected to get very similar results from the manual and automatic processes.

For the purpose of looking at cloud particles, the 2DC gray probe was used. It was able to detect particles with a diameter range of 0-

800 microns with a 12.5 micron resolution. Using the captured shadows of the cloud particles, the images were analyzed and recorded into one of four habit categories--sphere, needle, dendrite, or irregular.

The data output from the processing software came in two forms. The first was a graphical summary of the data, which included a graph of the concentrations of particles, the liquid water content, and the habit percentages. The other was in the form of ASCII data tables that could be generated for individual buffers. The tables include the time, the concentration in both the y and x direction of the image, the liquid water in both the y and x direction, as well as the fractional percentages of the four habits.

Initially there were inconsistencies between the manual and automatic techniques, but the revision of two problems in the software allowed for much better agreement. The first problem involved situations where a spherical-looking image had no shadow in its center.

Figure 2. Sample of spherical shadow problem

These holes in the cast shadows are caused by diffraction and are known as Poisson spots (Korolev et al., 1991 and 1999). Under the original specifications in the software, Figure 2 would probably be classified as an irregular, but it more likely should have been classified as a sphere. This problem was corrected by an updated method from Korolev, in which the Poisson spot is artificially shaded during the analysis.

The next problem was that software produced graphs of habit percentages that were not consistent with the numbers from the ASCII files that it generated. These numerical data were supposed to contain the underlying numbers for the plotted data. This problem is illustrated in Figures 3 and 4, below.

In Figure 3, irregulars are the dominant habit until after 19:00 UTC, when spheres form the majority of particles. Figure 4 is the reconstruction of similar data based on the ASCII table values. In this figure, irregulars are always dominant.

This problem was later corrected with a small modification provided by Korolev. With these problems corrected, we were finally also able to get more reasonable agreement between the tabular ASCII data and our manual samples.

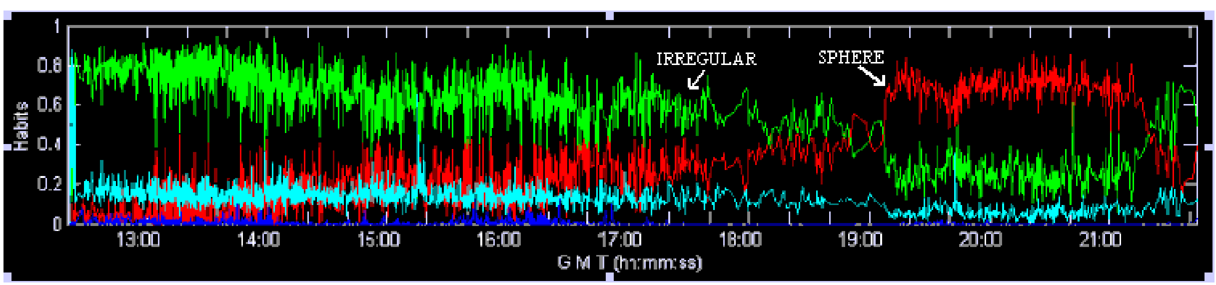

Figure 3. Graphical habit analysis for 14 April 1999 data created by PMS OAP-2D software. Time is linear.

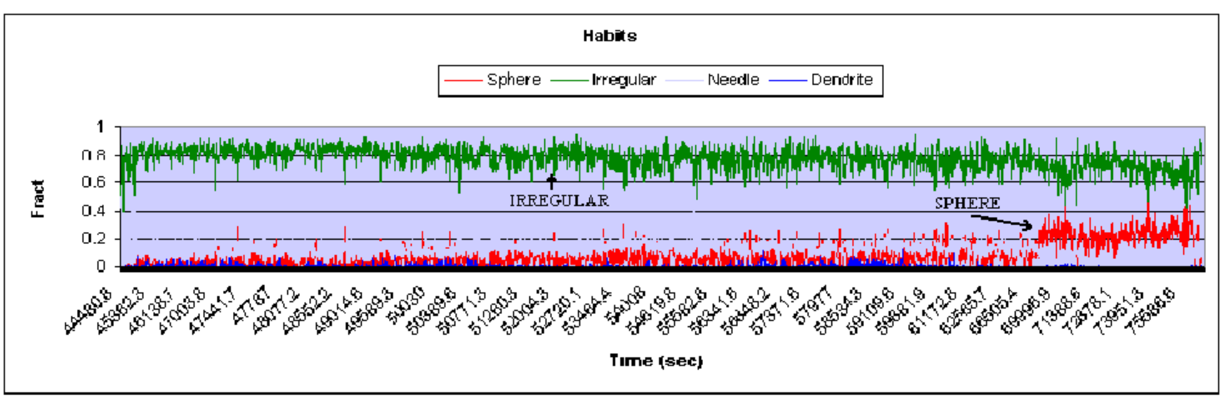

Figure 4. Graph constructed by using original ASCII numbers generated by the PMS OAP-2D software. The times are buffer times and the time scale is not linear, but the overall period is the same as Figure 3.

In order to get the manual or automated results from particle imagery, an intensity level must be specified. The intensity level is a way to specify how intensely the laser is shadowed. We used two intensity level thresholds. The first was 50%. For example, at this setting in Figure 2, only the two darkest shadows would be used in identifying the cloud particle. The second intensity threshold that we used was 25%. In this case, all three shadow colors would be used.

Korolev and Sussman (2000) suggested that the 50% intensity threshold should be used for most analyses. However, this setting presented a new problem when needles were the predominant habit. Manual analysis of these cases definitely showed that needles were the dominant habit, but using the 50% setting, the software classified most particles as irregular. If we changed the threshold to 25%, the software had needles as the predominant habit and the overall results were in much closer agreement to our manual results. Spheres on the other hand seem to agree better with the automatic results when the 50% setting was used. Percentages for dendrites didn't seem to change much with either setting. For these reasons during those cases with a high percentage of needles, we used the 25% threshold; otherwise, we used the 50% setting.

4. PRELIMINARY HABIT RESULTS

The corrected software has provided us with ASCII tabular data for each of the OAP observation periods on the summit of Mt. Washington. Because of our work in identifying and addressing problems, we are now confident in the OAP-2D analysis software and its output. We can now use the generated ASCII tabular data to do more detailed analyses.

Table 1 is a summary of the time periods for which we have processed cloud particle imagery data from the summit of Mt. Washington during MWISP. Several collection periods experienced some intermittent instrument problems, but these periods are easily identifiable from the records and those data will be filtered to yield useable results.

OAP cloud particle imagery was collected on 16 days during MWISP and we have thus far processed 10 of those days. For these days, the highest concentrations of particles were observed on 10 April 1999—vastly exceeding other days. The lowest were recorded on 24 April 1999. Data for 26 April 1999 was broken down into three periods because of limitations on the storage medium that was used to store the information.

Although irregulars predominate the overall statistics, there were usually times during most observation periods where some other habit seemed to prevail, as noted in the "Comment" column of Table 1. The habit data are also being stratified in 30 minute intervals to help other MWISP researchers correlate their remotely sensed measurements to particular cloud habits.

5. SUMMARY

During the 1999 MWISP cloud particle data was taken for various periods throughout the month using PMS OAP Gray Probes. We performed some detailed manual analyses at the outset of the project to serve as a baseline and check for the automatic analysis performed by the OAP software by Korolev and Sussman (2000).

Although this step was very time-consuming, it proved extremely beneficial, since it revealed some problems that needed to be addressed to improve the accuracy of the automated analyses. The developers provided the necessary modifications and we recognized the importance of certain threshold intensity settings for some specific habits. We are now confident that the software can perform its stated task and generate meaningful results.

We are now using the data from the automated analyses to develop a complete picture of habit types found in mixed phase clouds during the MWISP field campaign. A summary (Table 1) of our preliminary findings was presented. More detailed results will be available at the conference.

6. ACKNOWLEDGMENT

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6. REFERENCES

Henson, R. and Anatta, 1999: Mt. Washington's wild weather sheds light on aircraft icing. *UCAR Quarterly*, Summer 1999, **24**, Univ. Corp. for Atmos. Res., 1-2.

Korolev, A.V., S.V. Kuznetsov, Yu E. Marakov, and S.V. Novikov, 1991: Evaluation of measurements of particle size and sample area from optical array probes. . *J. Atmos. Oceanic Technol.*, **8**, Amer. Meteo. Soc., 514-522.

Korolev, A.V., J.W. Strapp, and G.A. Isaac, 1998: Evaluation of the accuracy of PMS Optical Array Probes. *J. Atmos. Oceanic Technol.*, **15**, Amer. Meteo. Soc., 708-720.

Korolev, A.V., B. Sussman, 2000: A Technique for Habit Classification of Cloud Particles. *J. Atmos. Oceanic Technol.*, **17**, Amer. Meteo. Soc., 1048-1057.

Ryerson, C., M. Politovich, K. Rancourt, G. Koenig, R. Reinking and D. Miller, 2000: Overview of Mt. Washington Icing Sensors Project. American Institute of Aeronautics and Astronautics paper AIAA-2000-0488, Reston, VA, 10.

Schmitz W. G., J.P. Koermer, and C.C. Ryerson, 2001: Analysis of cloud ice crystal habits from the Mt. Washington Icing Sensors Project (MWISP), *11th Symposium on Meteorological Observations and Instrumentation*, Amer. Meteo. Soc., Albuquerque, NM, January 13-18, 242-244.

Day	Start time	End time	Mean	Sphere	Irregular	Needle	Dendrite	Comments
dd/mm/yy	(UTC)	(UTC)	Concentration	(% * con)/%	(% * con)/%	(% * con)/%	(% * con)/%	
			per liter	per liter	per liter	per liter	per liter	
3/4/99	22:33:48	29:33:50	NA	NA	NA	NA	NA	Many holes in data, but where
								good, a primarily dendrite case
7/4/99	1:48:17	16:54:14	NA	NA	NA	NA	NA	Good needle case after 13:40 UTC
10/4/99	12:00:26	0:09:40	42045.5	264.6 (.6%)	33473.9 (79.6%)	7644 (18.2%)	663 (1.6%)	Good needle case--whole period
14/4/99	12:21:20	21:45:34	2076	497.7 (24.0%)	1281 (61.7%)	284.8 (13.7%)	11.7 (0.6%)	Good sphere case, primarily after
								19:00 UTC
16/4/99	22:16:51	23:09:19	869.9	3.5 (0.4%)	414.4 (47.6%)	195.4 (22.5%)	256.5 (29.5%)	Dendrite and needle period
17/4/99	11:39:39	14:59:58	NA	NA	NA	NA	NA	Holes in data, but where good,
								many needles and dendrites
24/4/99	14:08:33	21:00:01	363.3	48 (13.2%)	277.6 (76.4%)	34.3 (9.4%)	3.4 (0.9%)	Mostly Irregular, but after 20:00 UTC,
								there are more dendrites
26/4/99a	11:34:20	16:23:45	8713.4	9.8 (0.1%)	5331.3 (61.2%)	2531.9 (29.1%)	840.7 (9.6%)	Good needle and dendrite case, es-
								pecially from 15:40 to 16:00 UTC
26/4/99b	16:27:17	17:24:28	7218.6	44.6 (0.6%)	6152.7 (85.2%)	856.3 (11.9%)	164.9 (2.3%)	Very good irregular period
26/4/99c	18:02:55	20:19:09	8530.6	58.8 (0.7%)	7372.1 (86.4%)	1046 (12.3%)	53.7 (0.6%)	Very good irregular period
27/4/99	10:43:23	18:02:17	3898.8	178.2 (4.6%)	2711.8 (69.6%)	966.3 (24.8%)	42.5 (1.1%)	Good needle case with some
								sphere's after 17:00 UTC
29/4/99	12:02:31	13:47:00	5686.3	14.8 (0.3%)	4065 (71.5%)	1570.1 (27.6%)	36.4 (0.6%)	Good needle case with very high
								fractions for the first min of the obs

Table 1. MWISP OAP cloud particle imagery and habit summary. Periods denoted with “NA” contain some data when the sensor was having problems and these problem periods need to be filtered before generating more meaningful statistics. Data for six additional days (13, 18-22 Sep 1999) also need to be processed.