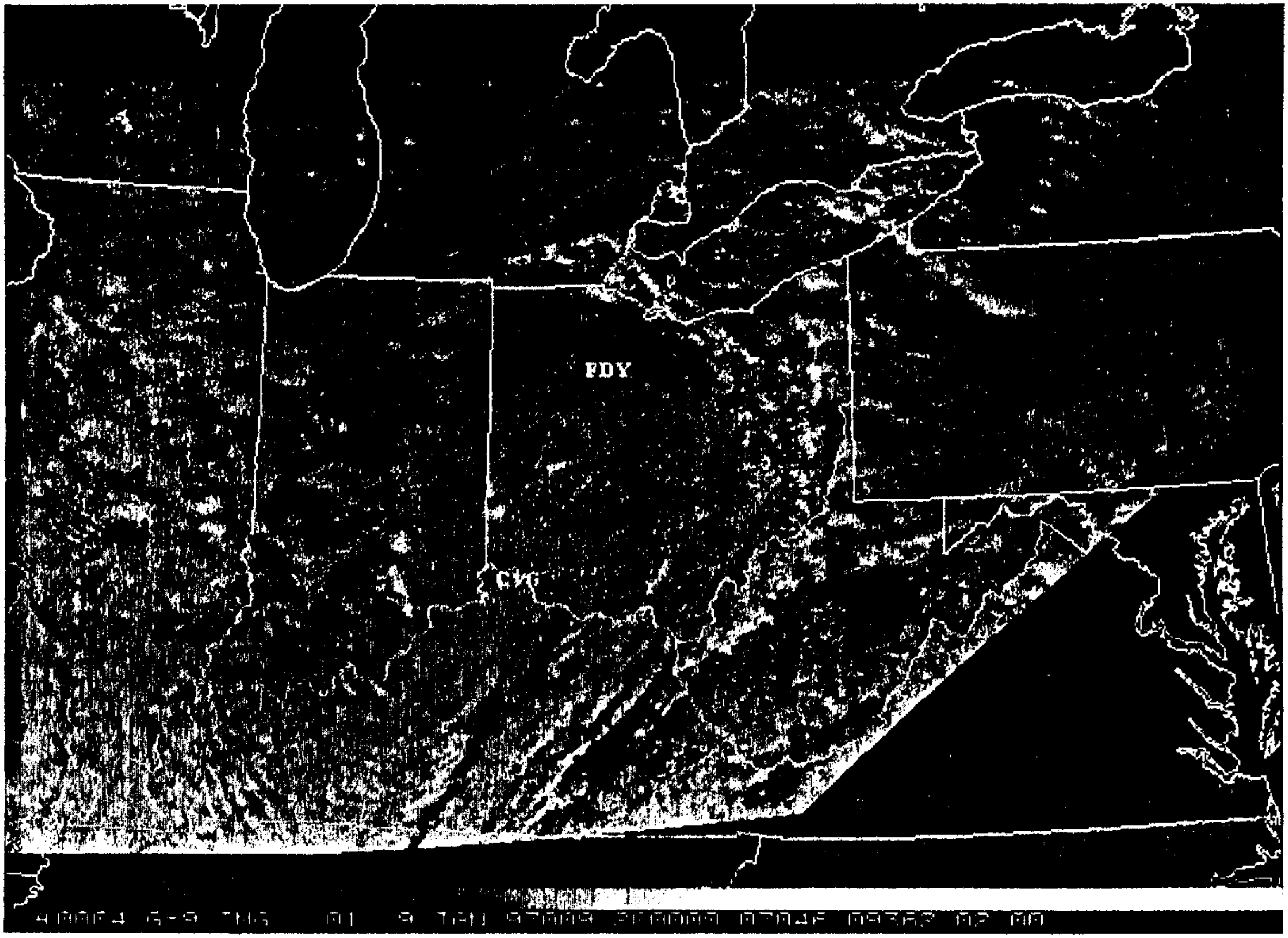
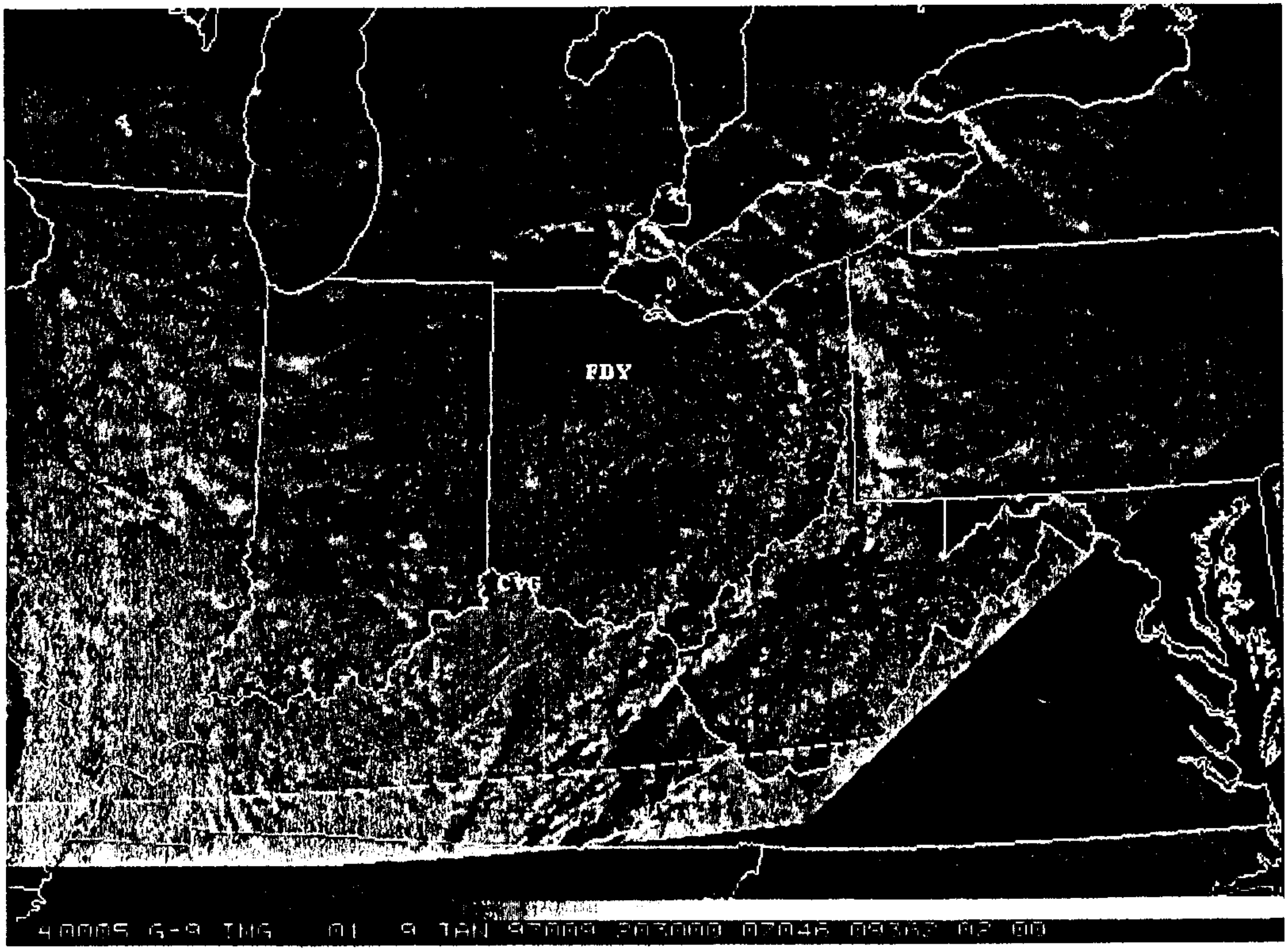
DCA97MA017

ATTACHMENTS_C
(1 - 11)

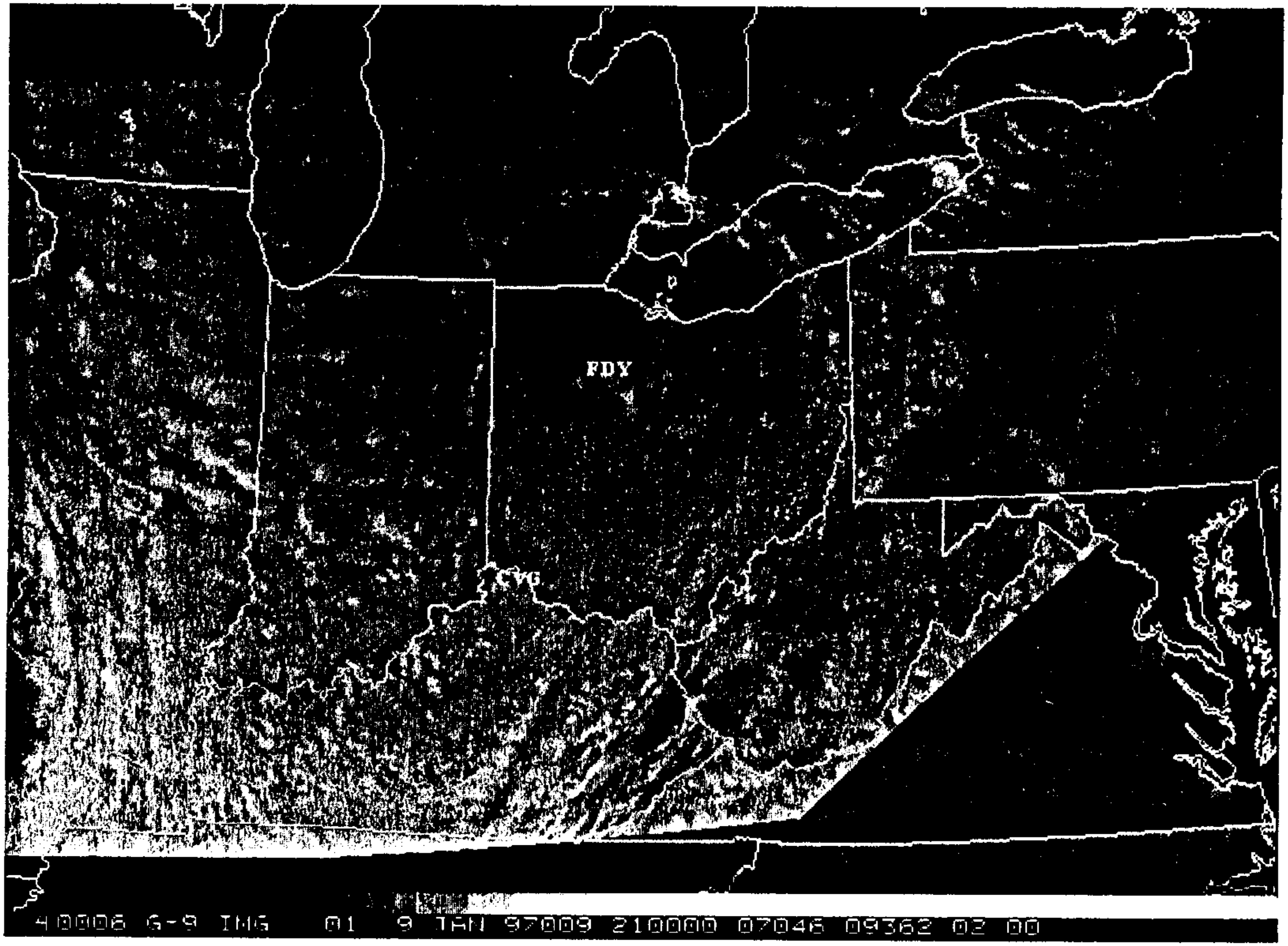
①



2

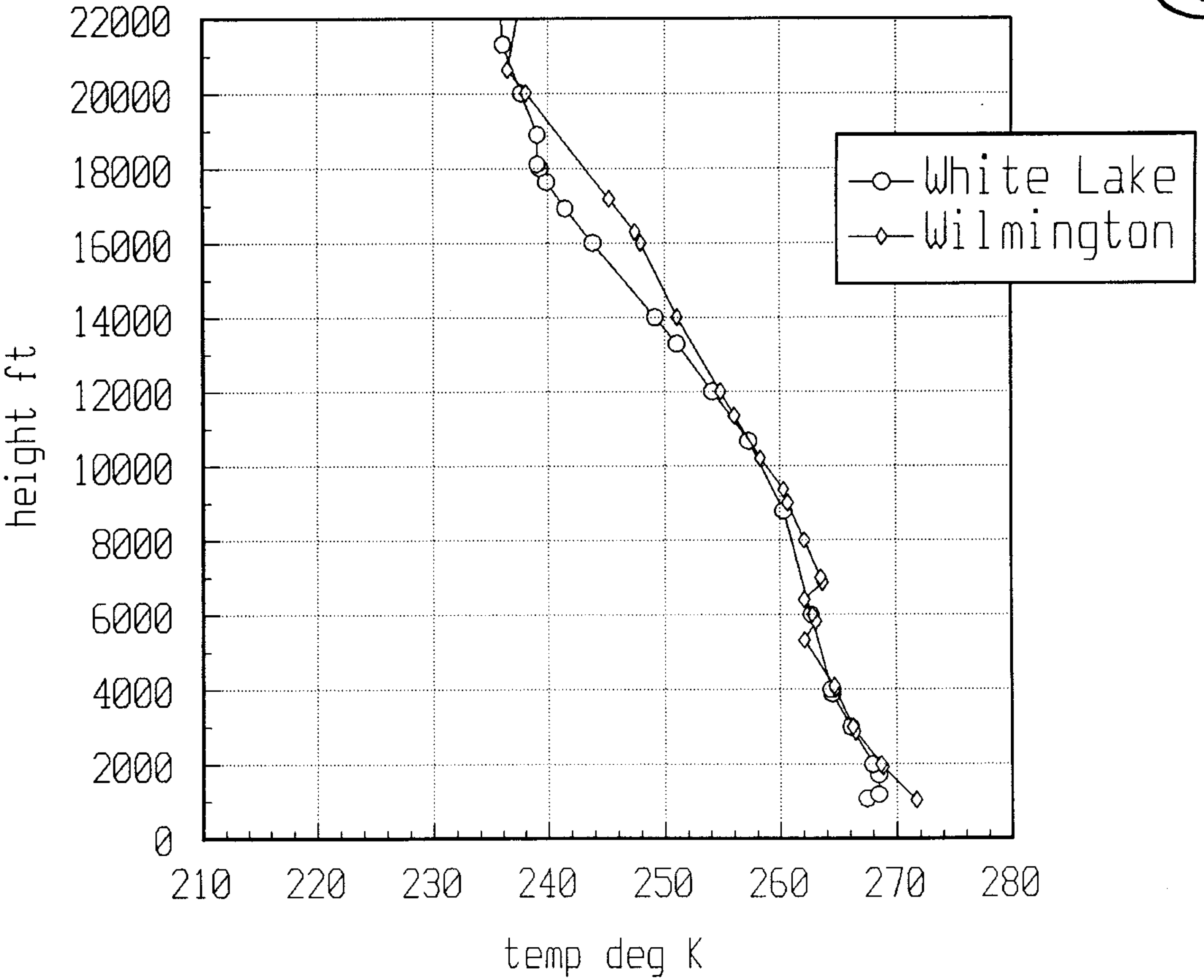


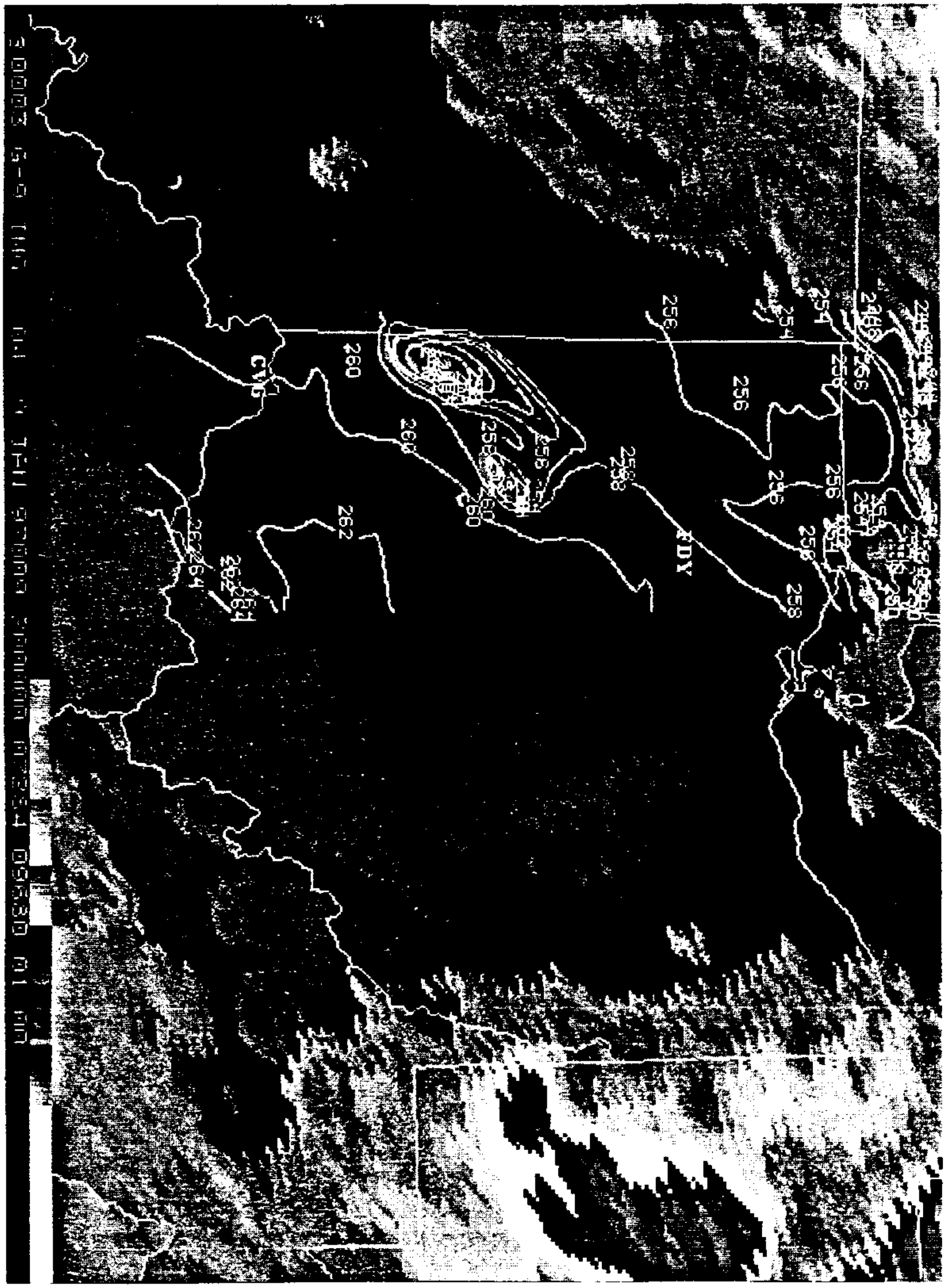
③



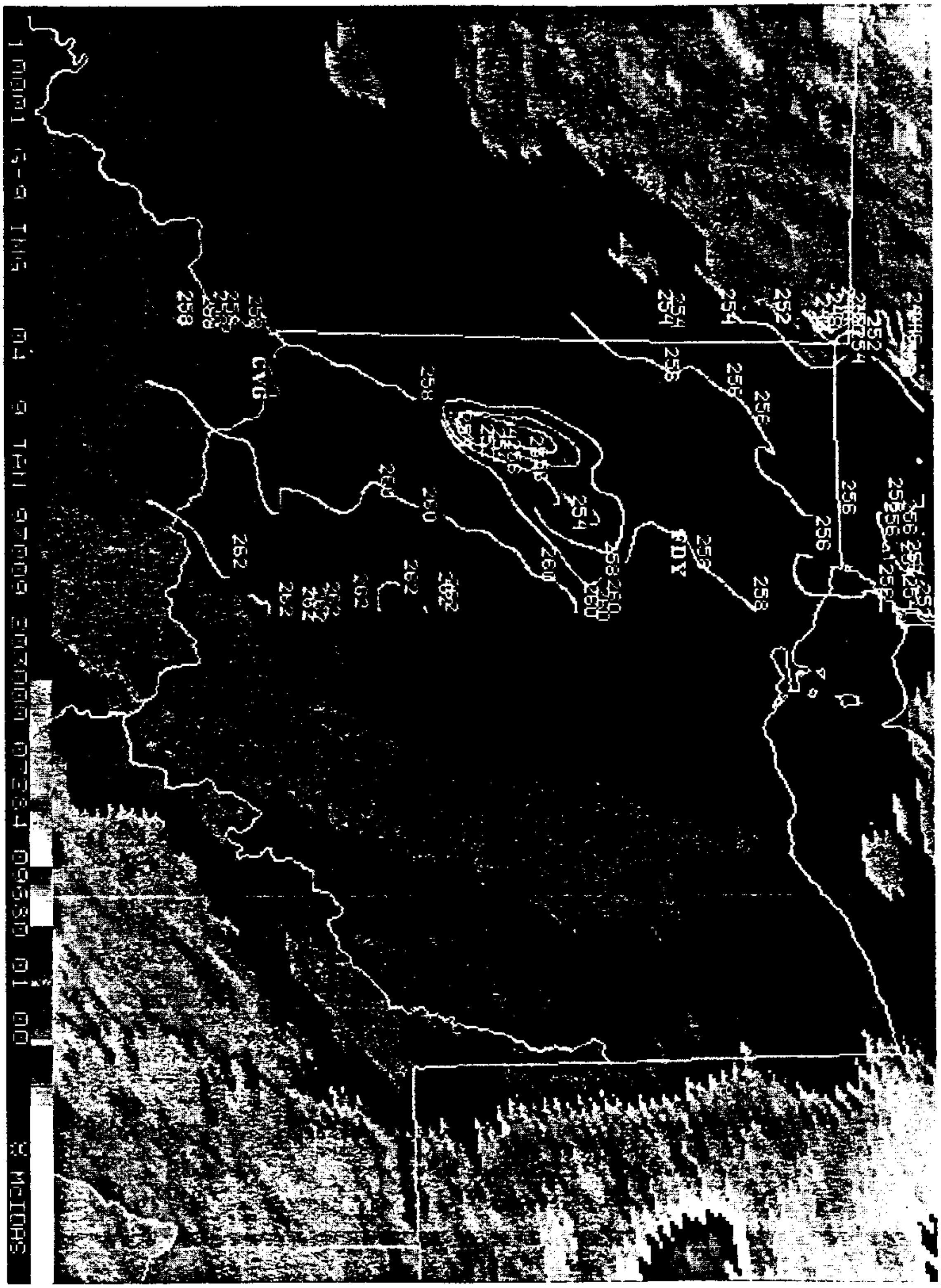
④

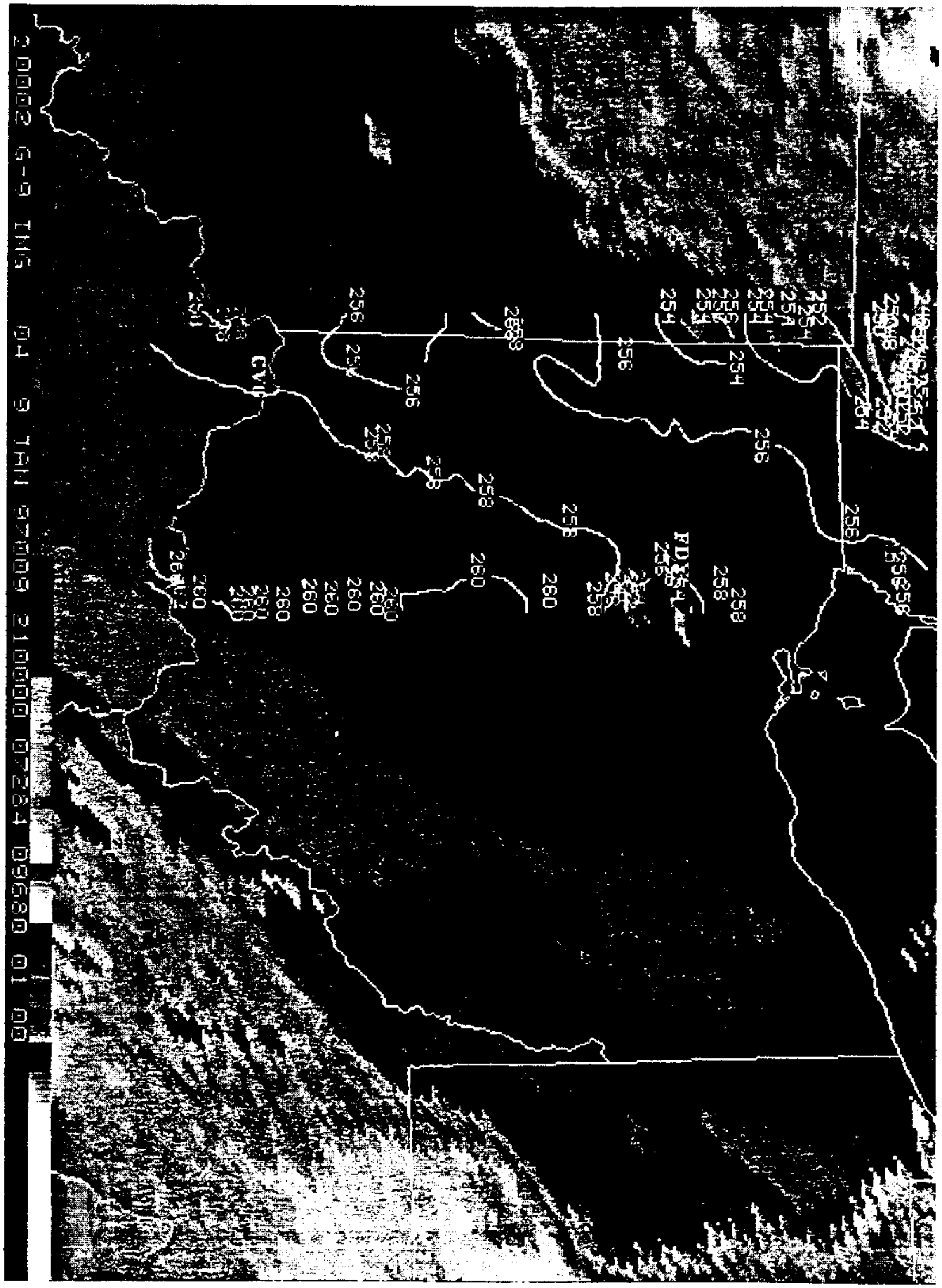
Upper Air Data 0000Z





⑤


10001 G-8 IMG 04 9 JAN 97009 083000 07284 09580 01 00 8 MCIDAS
CYG
FDY
252
254
256
258
260
262


20002 G-9 IMG 04 9 JAN 97009 210000 07284 09680 01 00
CVG
FDY
252
254
256
258
260

⑦

1.3

REMOTE SENSING OF AIRCRAFT ICING REGIONS USING GOES MULTISPECTRAL IMAGER DATA

Gary P. Ellrod*

Office of Research and Applications (NOAA/NESDIS)
Washington, DC

James P. Nelson, III —

Cooperative Institute for Meteorological Satellite Studies (CIMSS)
University of Wisconsin, Madison, WI —

1. INTRODUCTION

The advanced imagers on the GOES-8/9 spacecraft are providing five multi-spectral channels for observing clouds and surface features (Menzel and Purdom, 1994). The higher resolution, greater frequency, and additional channels compared to earlier satellites will improve our ability to detect weather hazards of interest to aviation. For example, several of these channels are useful in detecting conditions associated with the presence of aircraft icing (Ellrod, 1996). Efforts are underway to develop a product that effectively combines information from these imager channels to show areas where aircraft icing is a significant risk day or night (Ellrod, 1996; Vivekanandan, et. al, 1996). The purpose of this paper is to provide an update on progress in developing a GOES multi-channel icing image product within the National Environmental Satellite, Data and Information Service (NESDIS).

2. BACKGROUND

Aircraft icing is a serious hazard for many types of aircraft, especially light, fixed wing or rotary aircraft due to their relatively slow cruising speeds and limited altitude range. The crash of an ATR-72 commuter plane due to severe icing on 31 October, 1994 emphasized the significance of icing in aircraft operations. Meteorological conditions related to aircraft icing are well known (e.g., WMO 1954; Hansman, 1989; Schultz and Politovich, 1992). The most important ingredients are: (1) liquid phase clouds, (2) temperatures in the 0 to -20°C range, (3) large droplet diameters (>50μm), (4) weak upward motion to replenish the available supercooled water, (5) large liquid water contents, and (6) thick, extensive cloud systems resulting in long exposure to icing conditions during flight. Convection embedded within stratiform cloud systems can also lead to severe icing conditions. The role of cloud droplets of drizzle size (about 100μm diameter) is being viewed as very critical in light of investigations following the ATR-72 accident (Defer, 1996). These have been referred to as Supercooled Large Droplet (SLD) events.

3. APPLICATION OF GOES IMAGERY TO ICING DETECTION

Although infrared (IR) satellite imagery senses conditions at the tops of opaque clouds, it can be an effective remote sensing tool in icing detection, since supercooled water has been found to accumulate in the top several hundred meters of cloud layers (Rauber and Tokay, 1991; Defer, 1996). The standard longwave IR window channel (CH4-10.7μm) observes cloud top temperatures, as well as horizontal extent. The shortwave IR channel (CH2-3.9μm), when combined with CH4 IR, provides information on cloud phase at night, because differences in thermal emissivity result in distinctive brightness temperature differences between the two channels.

HEAT PAGE PRODUCT AVAIL
THIS WEEK

⑧

---

* Corresponding author's address: Room 601, NOAA Science Center, E/RA21, Washington, DC 20233 - E-mail: gellrod@nesdis.noaa.gov

---

fying
ely to
ld, VA,

K. Poli-
ing and
Vea. and

M.K.
he prox-
ST. Pre-
n
rican

super-

Veal,
aircraft.

nprove-
al United

1995:
art I:
on pro-

ck, 1996:
nosed

Center for
possible.
with figure
Donough
h for her

nce Foun-
sponse to
dministra-
The views
sarily rep-
ernment.

out for
reas in
. Chi-
lid for
l black
s of
Ps for

During daytime, CH2 has both thermal and reflected solar components. The latter results in a warming effect that is dependent on cloud phase (Curran and Wu, 1982), and to some extent, droplet size (Kleespies, 1995). Early evaluation has shown that severe icing in daytime often occurs in slightly cooler (2-3°C) areas embedded within liquid water clouds in CH2 imagery (Ellrod, 1996). It was hypothesized that this was a result of the presence of larger droplets necessary for heavy ice accumulations. Visible image brightness data (CH1-0.5μm) can be used to infer cloud thickness and phase, as well as horizontal extent. Unlike CH2 however, CH1 brightness data is not particularly sensitive to cloud droplet diameters.

4. INITIAL PRODUCT DEVELOPMENT

Digital IR brightness temperatures (T_b) and visible brightness counts (B) were collected from GOES-8 for about fifty reports of aircraft icing on thirteen days between December 16, 1994 and April 13, 1995. Based on data collected during this period, a decision tree was developed for day/night icing detection using channels 1, 2 and 4. At night, the shortwave IR T_b's are typically >2°C colder than the longwave IR in regions of water clouds. During the day, the CH4-CH2 T_b difference varies according to solar zenith angle (an effect of time of day and season). Figure 1 shows the relationship of T_b difference as a function of observed CH1 values of B. The plot also includes additional data collected from December 1995 to April 1996 from clouds identified as liquid stratiform, but with no confirming reports of icing.

Software was then developed to simultaneously process digital data from these channels to screen out areas not conducive to icing. Possible icing regions were color coded, while non-icing regions were indicated by the CH4 IR image data. A CH4 cloud top temperature range from -2 to -17°C was used. Preliminary results were encouraging, but there were numerous "false alarm" areas during the daytime due to thin cirrus and cold ground. Some areas where icing actually occurred were also inadvertently screened out.

5. RECENT PRODUCT IMPROVEMENTS

Some recent changes implemented in the software have resulted in noticeable improvements in the icing product. By raising the lower visible brightness threshold for day vs night conditions, the number of cold ground pixels incorrectly identified as conducive to icing was reduced. This problem is espec noticeable around sunrise. In addition, the slope the CH2-CH4 threshold was adjusted to that shown Figure 1. Table 1 summarizes the current algorith

The biggest improvement in the product was in t reduction of erroneous positive icing signatures caus by thin cirrus during daylight hours. The CH5 (12μm) has been used for many years to "cloud-clea regions of thin cirrus in various cloud climatolog projects or in sea surface temperature estimatio using Advanced Very High Resolution Radiomete (AVHRR) data onboard the NOAA polar orbitin satellite series. Data collected for GOES-8 during th winter of 1995-96 has shown that CH4 T_b's are usuall ≥2°C warmer than CH5 in daytime when thin cirrus is present (Figure 2). When liquid stratiform or convective clouds are present, T_b differences decrease and become <2°C between CH4 and CH5. Some data for cold ground or lake surfaces is also plotted to show that CH5 cannot be used to screen these types of scenes. The incorporation of CH5 in the icing product generation was completed in April 1996. As a result, there has been a significant reduction (but not a complete elimination) of bogus icing areas due to thin cirrus.

The GOES experimental icing product has been generated since the winter of 1995 on an HP-755 workstation at the NOAA Science Center in Camp Springs, Maryland. It now runs seven times per day, every 2 hours from 0815 to 2015 UTC, and requires about 10 sec of CPU time.

6. EXAMPLE: 12 APRIL 1996

A significant icing event occurred on the afternoon of 12 April 96 in the upper Midwest. Icing was observed in a narrow band from northern Wisconsin across south-central Minnesota, with a larger area of light to moderate rime icing in Iowa and eastern Nebraska. Moderate to locally severe mixed or clear icing was reported in the Minneapolis area by large commercial jetliners as well as general aviation aircraft. Figure 3 is the GOES multichannel icing risk product for 1915 UTC (1315 Central Standard Time). The uniform light gray area denotes possible icing. The narrow band across Minnesota and the broader area to the south relate well to pireps of moderate or greater icing. The whiter areas to the north and south show high, cold cirrus clouds. Some light snow or rain was occurring with multilayered clouds in central Minnesota and eastern South Dakota. A visible image at the same time (Figure 4) shows bright, smooth stratus clouds in the icing areas, whereas the cirrus clouds have more texture.

7. SUMMARY AND FUTURE WORK

A multichannel screening technique has been applied to GOES visible and infrared data to show areas of supercooled water clouds conducive to aircraft icing conditions. The recent addition of data from a longwave IR window channel (12μm) to eliminate thin cirrus, and other modifications, has resulted in an improved product that will be easier for aviation forecasters and other users to interpret. Some difficulties with false icing signatures due to cold ground still exist, particularly near sunrise and sunset. While it may not be possible to completely eliminate these, further work will attempt to reduce their impact. There will also be some experimentation with a two-level enhancement in an effort to identify possible areas of severe SLD icing situations. Verification is also needed, which will be a significant effort. The best approach may be to verify in the vicinity of large airports as suggested by Brown (1996), since pireps (positive or negative) are nearly always available.

8. REFERENCES

Brown, B., 1996: Verification of in-flight icing forecasts: Methods and issues. *FAA Intl. Conf. on Aircraft Icing*, Springfield, VA, May 6-8, 1996.

Curran, R. J. and M. Wu, 1982: Skylab near-infrared observations of clouds indicating supercooled liquid water droplets. *J. Atmos. Sci.*, 39, 635-647.

Defer, G., 1996: Post-Roselawn flight tests in icing conditions. *FAA Intl. Conf. on Aircraft Icing*, Springfield, Virginia, May 6-8, 1996.

Ellrod, G. P., 1996: The use of GOES-8 multispectral imagery for the detection of aircraft icing regions. *Preprint Volume, 8th Conf. on Satellite Meteorology and Oceanography*, January 28-February 2, 1996, Atlanta, Georgia, Amer. Meteor. Soc., Boston, 168-171.

Hansman, R. J., 1989: The influence of ice accretion physics on the forecasting of aircraft icing conditions. Preprint Volume, *3rd Intl. Conf. on the Aviation Weather System*, January 30-February 3, 1989, Anaheim, California, Amer. Meteor. Soc., Boston, 154-158.

Kleespies, T., 1995: The retrieval of marine stratiform cloud properties from multiple observations of varying solar illumination. *J. Appl. Meteor.*, 34, 1512-1524.

Menzel, W. P. and J. F. Purdom, 1994: Introducing GOES-I: The first of a new generation of Geostationary Operational Environmental Satellites. *Bull. Amer. Meteor. Soc.*, 75, 757-781.

Rauber R., and A. Tokay, 1991: An explanation for the existence of supercooled water at the top of cold clouds. *J. Atmos. Sci.*, 48, 1005-1023.

Schultz, P. and M. Politovich, 1992: Toward the improvement of aircraft-icing forecasts for the continental United States. *Weather and Forecasting*, 7, 491-500.

Vivekanandan, J., G. Thompson, and T. F. Lee, 1996: Aircraft icing detection using satellite data and weather forecast model results. *FAA Intl. Conf. on Aircraft Icing*, Springfield, VA, May 6-8, 1996.

WMO, 1954: Meteorological aspects of aircraft icing. *WMO Tech. Note No. 3*, WMO - No. 30.TP9, World Meteor. Org., Geneva, 18 pp.

Brightness Co
CH 1

Table 1
Thresholds/Ranges Used in GOES Icing Product

Test	Daytime	Nighttime
Cloud top temperature	-2 to -17°C	-2 to -17°C
Water vs Ice clouds T (Ch2) - T (Ch4)	> (0.16B - 6) (°K)	≤ -2.0°C
Day/Night	B ≥ 40 counts	B < 40 counts
Thin cirrus filter T (Ch4) - T (Ch5)	≥ 2°C	None

(10)

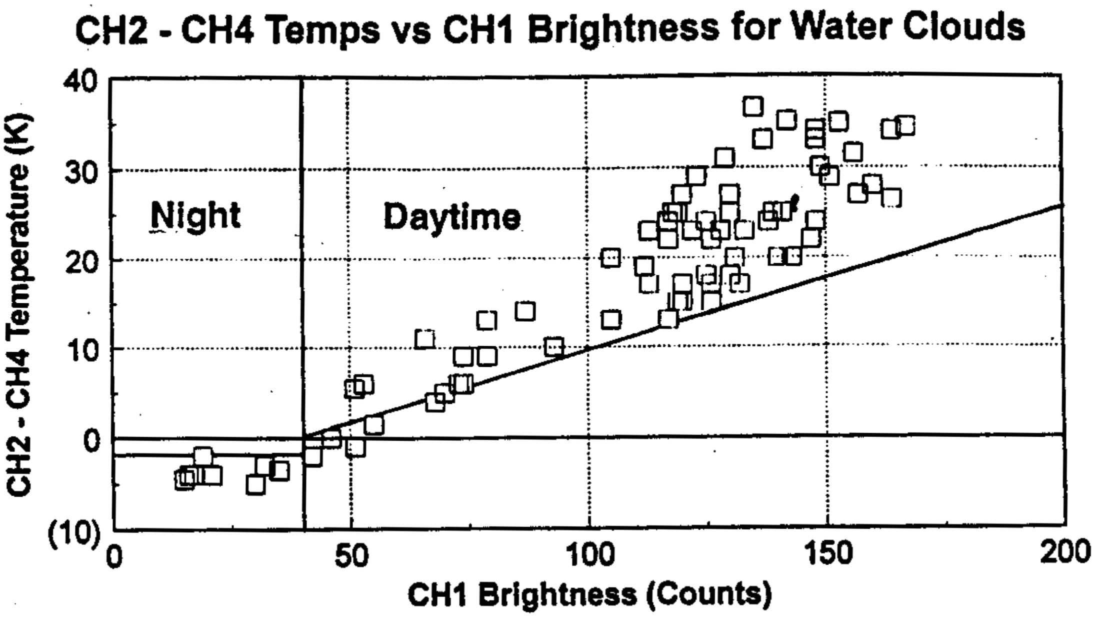


Figure 1. Plot of CH2 - CH4 T_b (°K) versus visible (CH1) brightness counts (based on a scale of 0 to 255 counts). Day/night separator is vertical line. Diagonal line for daytime, horizontal line for night are thresholds for water clouds versus ice clouds.

Figure 3. GOES multi-channel icing product image for 1915 UTC, 12 April 96. Uniform light gray shows icing risk area.

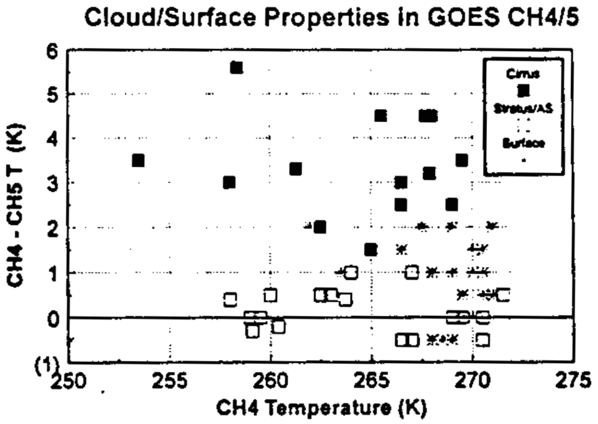


Figure 2. Scatter plot of CH4 - CH5 Tb (°K) versus CH4 T_b during daytime for thin cirrus clouds, opaque stratus or altostratus, and cloud-free ground or lake water.

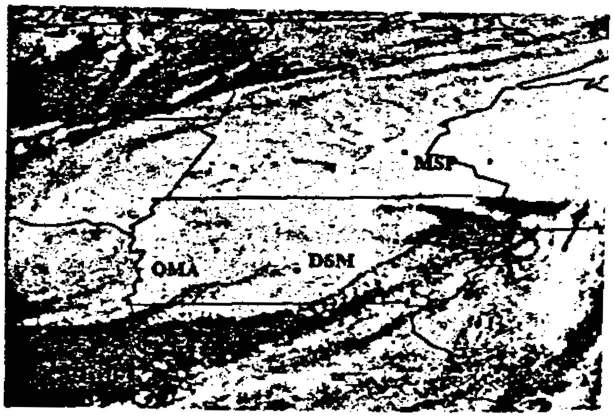


Figure 4. GOES-8 visible image at 1915 UTC, 12 April 96.