Comparison of Super-Cooled Liquid Water Cloud Properties Derived from Satellite and Aircraft Measurements

William L. Smith, Jr., Patrick Minnis
*Atmospheric Sciences*
*NASA Langley Research Center, Hampton, VA*

B. Bernstein, F. McDonough
*NCAR/ RAP, Boulder CO*

Mandy Khaiyer
*AS&M, Inc., Hampton, VA*
Validation of Satellite-Derived SLW Cloud Properties

How do satellite retrievals of $T_{cld}$, $Re$, $LWP$ correspond to aircraft icing?

• Correlate with measurements from icing research aircraft (NASA GRC)
  – Winter 1998 NASA/FAA/NCAR Supercooled Large Droplet Research Project and compare satellite retrievals with:

• Correlate with PIREPS
  – 1998 Flight days
  – Jan 15 – Mar 30, 2003 (real-time runs to support Twin Otter flights)
GOES detects SLW for all 46 Twin Otter SLW cloud top penetrations (McDonough and Bernstein, 2000)

\[ \times \] - denotes Twin Otter cloud top penetrations
GOES detects SLW for all 46 Twin Otter SLW cloud top penetrations  
(McDonough and Bernstein, 2000)

- denotes Twin Otter cloud top penetrations
GOES SLW vs. PIREPS Icing

Compared to Positive icing PIREPS and provided there were no overcast ice clouds, LaRC GOES technique detected SLW 98% of the time (Smith et al., 2000)
Comparison of GOES Cloud Properties with PIREPS Icing Intensity
N=7800 (Jan-March, 2003)
GOES-Derived Cloud Properties (Dec. 9, 1997)

Cyan indicates Supercooled Liquid Water In Cloud Mask Image

Ice Cloud Properties In Grey not shown
PIREP Icing Intensity at 16-18 UTC Dec. 9, 1997
GOES-Derived Cloud Properties (March 5, 1998)

Cyan indicates Supercooled Liquid Water In Cloud Mask Image

Ice Cloud Properties In Grey not shown
PIREP Icing Intensity
at 17-19 UTC Mar. 5, 1998

Icing Intensity for 5 MAR 98 at 18 UTC.
GOES Droplet Radius
Satellite/Aircraft Comparison
March 5, 1998

[Graph showing data comparison with labels for MVR (um), LWC (g/m^3), Effective Radius (um), LWP (g/m^2).]
## PROTYPICAL ICING CATEGORIES

<table>
<thead>
<tr>
<th>Value</th>
<th>Criteria</th>
<th>Icing Intensity</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>clear or water cloud (w/Tcld &gt; 272 K or others) or ice cloud w/OD &lt; 8</td>
<td>no ice</td>
</tr>
<tr>
<td>1</td>
<td>ice cloud</td>
<td>indeterminate</td>
</tr>
<tr>
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</tr>
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<td>5</td>
<td>re &gt; 9 µm, LWP &gt; 400, Tcld &lt; 272 K</td>
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</tr>
<tr>
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GOES ICING
GOES Droplet Radius
Evelyth, Minn. King Air Crash
Oct 25, 2002 at 1645 UTC

**MODIS INFRARED**
10.8 μm

T_cld = -14 C
Z_cld = 4.1 km

**MODIS VISIBLE**
0.63 μm

3.9 – 10.8 μm BTD

Evelyth

NASA LaRC Cloud Phase
Evelyth, Minn. King Air Crash
Oct 25, 2002 at 1645 UTC

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10.8 μm

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GOES Water Droplet Effective Radius
Cloud Height Comparisons 1997-98

Twin Otter Icing Flights vs GOES Lapse Rate Method

$z_{topcld}$ = estimated height of all cloud in view

$zeffliq$ = estimated height of liquid clouds only
COMBINING GOES-EAST & WEST FOR CONUS DOMAIN

Proposed domain: 25°N - 50°N; 50°W - 130°W
EXPANSION PROCESS

• Focus on GOES-East (50°W - 105°W)
  - Develop ingest system for model & satellite input
  - Size the problem for computer processing
  - Provide products online (graphical & digital)
  - Make alterations for new channel (13.5 µm)

• Focus on GOES-West (105°W - 135°W)
  - Intercalibrate east & west
  - Develop ingest system
  - Combine results with East for seamless product
Initial Clear-sky Visible (0.65 μm) Albedos for CONUS Cloud Analysis

Overhead Sun Values Derived From 1998 VIRS Data by CERES Project

GOES Visible Channels Have Slightly Different Wavelengths Requiring Refinement for Future GOES Applications
Initial 3.7-µm Surface Emissivities for CONUS Cloud Analysis

Derived From AVHRR Data by CERES Project

GOES Solar Infrared Channel Has Different Wavelength (3.9 µm) Requiring Refinement for Future GOES Applications
Combined GOES-8 & GOES-10 CONUS Imagery
Visible Channel, 24 March 2003, 1715 UTC
Combined GOES-8 & GOES-10 CONUS Cloud Mask
24 March 2003, 1715 UTC
Combined GOES-8 & GOES-10 CONUS Cloud Temperature

24 March 2003, 1715 UTC
Combined GOES-8 & GOES-10 CONUS Cloud Top Altitude

24 March 2003, 1715 UTC
Combined GOES-8 & GOES-10 CONUS Cloud Base Altitude
24 March 2003, 1715 UTC
## PROTOTYPE ICING CATEGORIES

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Combined GOES-8 & GOES-10 CONUS Icing Category

24 March 2003, 1715 UTC

PROTOTYPE
Combined GOES-8 & GOES-10 CONUS Icing Probability
24 March 2003, 1715 UTC

PROTOTYPE
Comparison of Icing Categories With PIREPS, 9 Dec 1997, 1545 UTC
Comparison of Icing Categories With PIREPS, 9 Dec 1997, 1645 UTC
Comparison of Icing Categories With PIREPS, 9 Dec 1997, 1745 UTC
Comparison of Icing Categories With PIREPS, 9 Dec 1997, 1932 UTC
Comparison of Icing Categories With PIREPS, 9 Dec 1997, 2032 UTC

PIREP Icing generally corresponds to yellow (high):
LWP > 300 g/m²
& re > 11 μm
SUMMARY

• Prototype system has been developed to produce icing products over CONUS every 15-30 minutes during daytime
  - icing intensity
  - cloud-top & base heights

• Initial validations appear promising
  - Much additional aircraft, radar, and model verification needed
    AIRS and previous experiments
CHALLENGES TO BE ADDRESSED

• Icing definition (probability, intensity)
  - objective definition, relate satellite parameters to icing

• Daytime validation, algorithm refinement
  - aircraft & surface measurements, cirrus contamination, input maps, backscatter angle bias

• Multilayer / high-cloud
  - what inferences can be made in obscured conditions?

• Nighttime/twilight algorithm refinement
  - how far can we push infrared techniques?

• Use of microwave data (DMSP, TRMM, AMSR) for ocean (single and multilayer)

• Integration of satellite results into comprehensive, operational icing product
COMPARISON OF IN SITU & MWR (Lin)
LWP, FIRE ACE 2000

Can apply microwave method over ocean to retrieve LWP & Tcld in both obscured (ice cloud) & unobscured conditions (DMSP, AMSR data)
Nighttime Analyses over Central USA March 5, 2003
LINKS

• Main homepage: www-pm.larc.nasa.gov
• R/T Imagery: www-angler.larc.nasa.gov/armsgp/g8usa.html
• R/T Products
  – ARM SGP: www-angler.larc.nasa.gov/armsgp/cldprod4.html
  – Midwest USA: www-angler.larc.nasa.gov/armsgp/cldprod4ohio.html
  – Florida: www-angler.larc.nasa.gov/crystal/cldprod4.html
  - CONUS Icing: under development

• Patrick Minnis: p.minnis@nasa.gov
• Bill Smith: william.l.smith@nasa.gov