Overview of Satellite Retrievals During AIRS-II

P. Minnis[1], L. Nguyen[1], J. K. Ayers[1], D. A. Spangenberg[2], M. L. Nordeen[2], D. Phan[2] , R. Palikonda[2], J. Haggerty[3], and J. Murray[1]

[1] NASA Langley Research Center, Atmospheric Sciences, Hampton, VA

[2] Analytical Services and Materials, Inc, Hampton, VA

[3] NCAR, Boulder, CO

Satellite Data Analyses

- **All GOES-12 analyses have been updated (0.5 - 1 HR)**
  - **better scene classification**
  - **improved night-day transition**
  - **updated calibration (not much difference)**

- **Terra/Aqua MODIS & NOAA-16 being re-analyzed**
  - **new multilayer classification**

- **Data available on web,** http://angler.larc.nasa.gov/bangor/goes12.html
  - **raw imagery**
  - **product imagery with links to digital data**
  - **flight track overlay imager**
  - **Flight Matched with ascii files**
  - **Ground site matched with ascii files**

Methodology

- **Visible Infrared Solar-Infrared Split Window Technique (VISST)**
  - Daytime
  - 0.65, 3.9, 10.8, 12.0 μm channels
  - Utilizes parameterization of theoretical radiance calculations for 7 water and 9 ice crystal size distributions
  - Retrieves cloud optical properties by matching calculations to observations

- **Solar-Infrared Infrared Split Window Technique (SIST)**
  - Night
  - 3.9, 10.8, 12.0 μm channels (no 12-μm on GOES-12)
  - Minimum error, iterative regression method
  - Retrieves cloud optical properties by matching calculations to observations

Required Inputs

- Soundings from RUC-20
- Surface characterization from IGBP 10 minute map
- Uses CERES cloud mask algorithm
- Clear sky reflectance from CERES & GOES-based ocean model
- Satellite data GOES-12 (4-km), Terra & Aqua MODIS (1-km)
  - reanalyzed September/October 2005

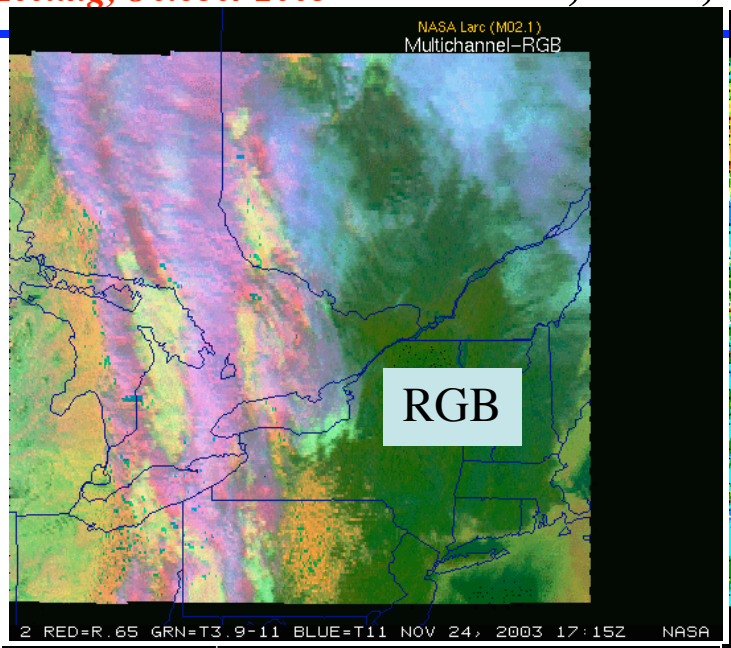
SATELLITE CLOUD PIXEL PROPERTIES

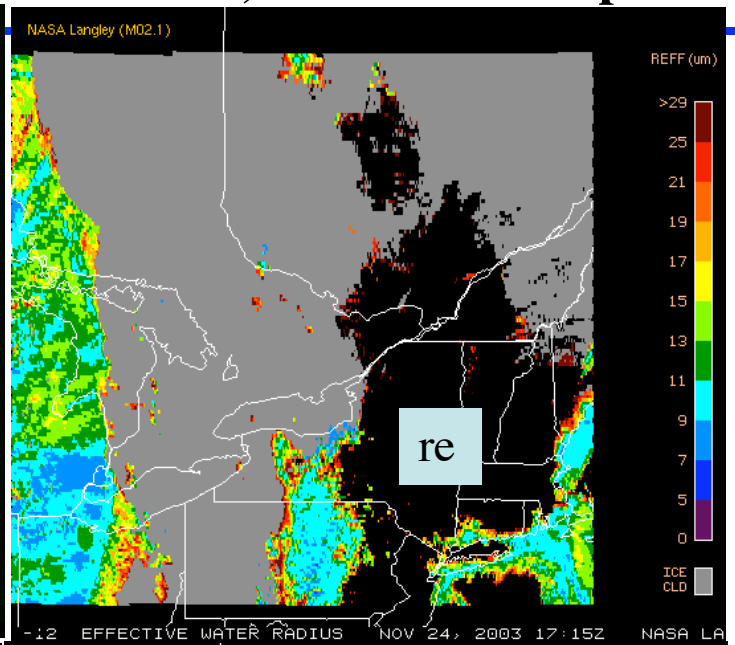
• CLEAR or CLOUDY	
• EFFECTIVE RADIATING TEMP	Tc
• EFFECTIVE HEIGHT, PRESSURE	Zc, pc
• TOP/BASE PRESSURE & HEIGHT	p_t, p_b, Z_t, Z_b
• THICKNESS	h
• PHASE (0 - 2)	P
• EMISSIVITY	ε
• WATER DROPLET EFFECTIVE RADIUS	re
• OPTICAL DEPTH	τ
• LIQUID WATER PATH	LWP
• ICE EFFECTIVE DIAMETER	De
• ICE WATER PATH	IWP
• ICING POTENTIAL, SEVERITY	IP

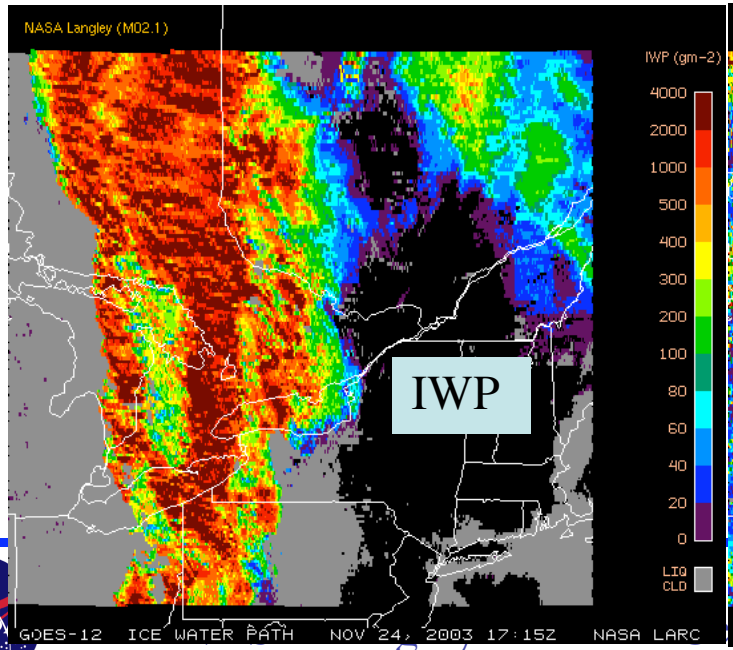
SATELLITE CLOUD PIXEL PROPERTIES & IMAGES

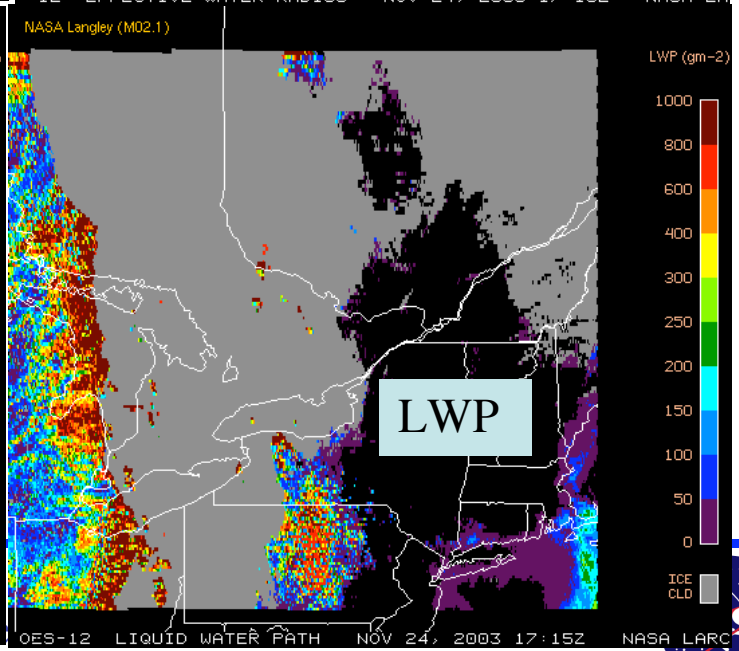
	IMAGE	PIXEL
• VISIBLE (0.65 μm)	X	X
• IR (10.8 μm)	X	X
• Solar IR (3.9 μm)	X	
• 13.3 μm	X	
• 6.7 μm	X	
• RGB	X	X
• T11 - T3.9 (T4-T2)	X	X
• T11 - T6.7 (T4-T3)	X	X
• T11 - T13 (T4-T6)	X	X

Nov 24, 2005, 1715 UTC, Product Examples





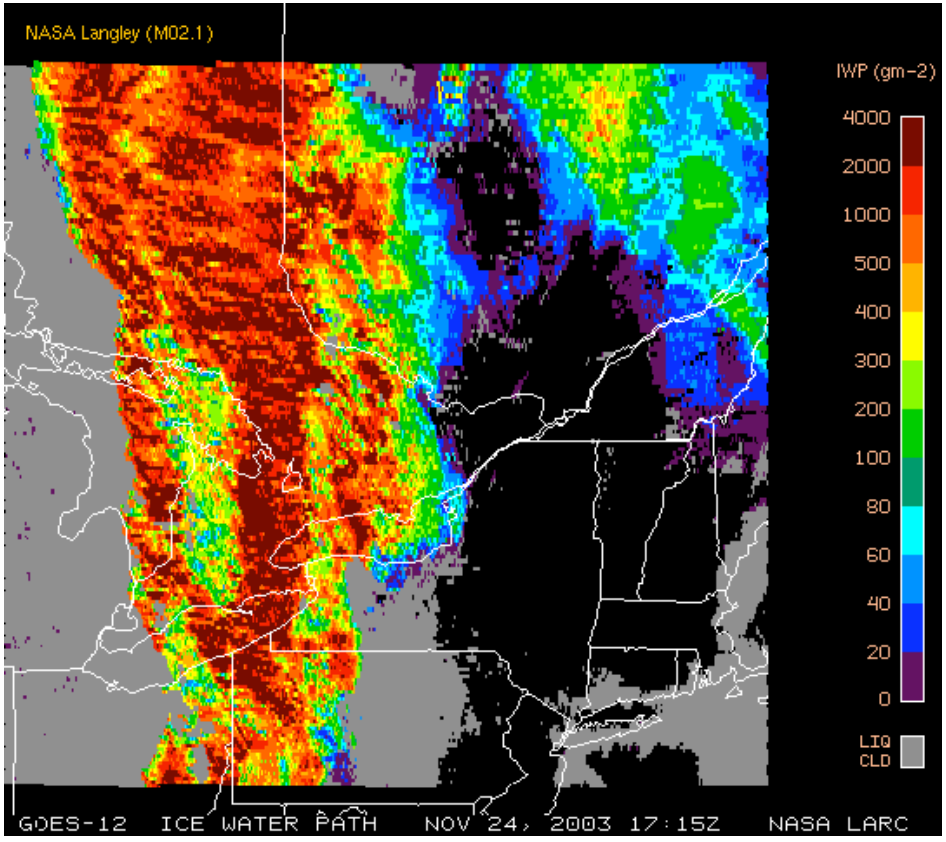




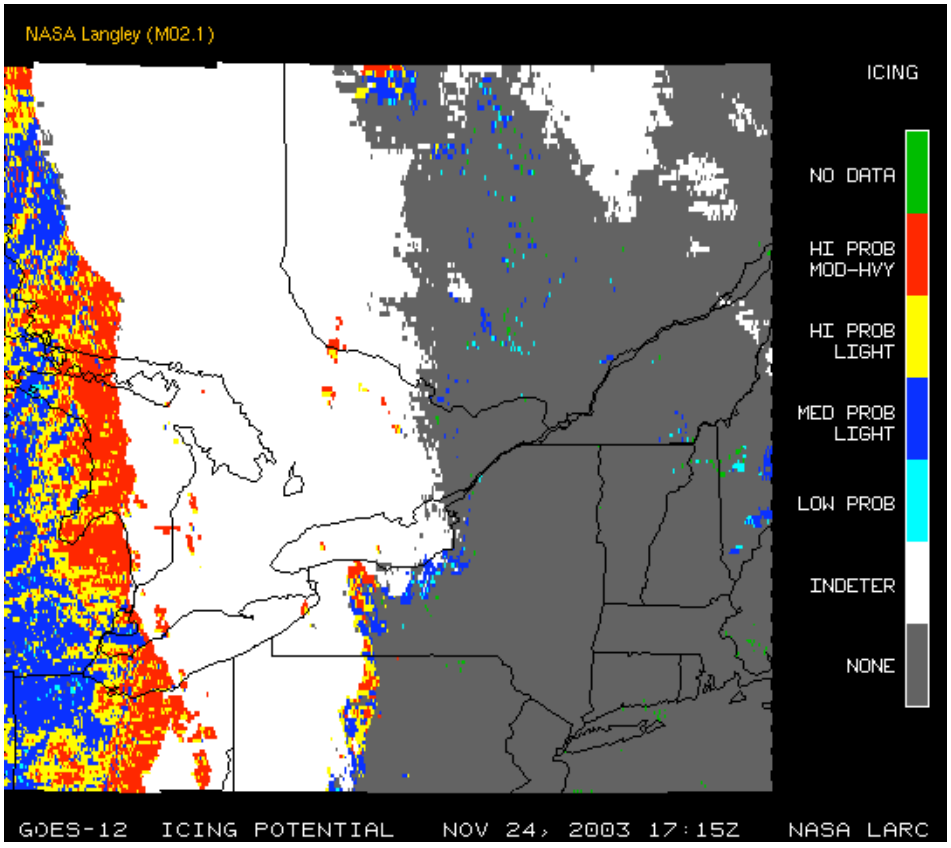
Nov 24, 2005, 1715 UTC

Converting Cloud Properties to Icing Diagnoses

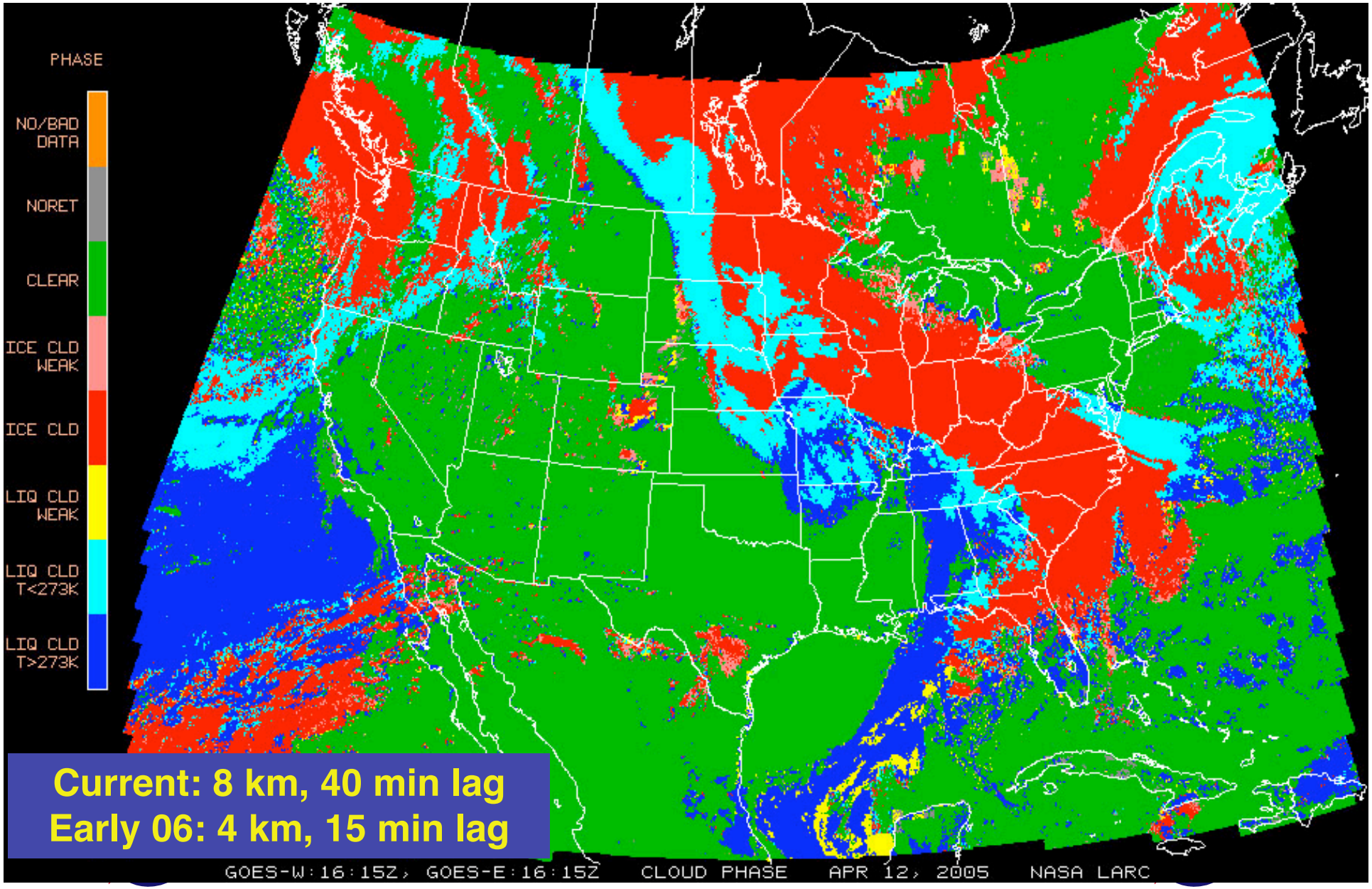
IWP



Combined Icing Probability/Severity



Algorithm running operationally every half hour over N. America
Merged G10/G12 Phase, 1615 UTC, 12 April 2005



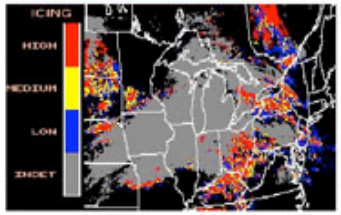
Current: 8 km, 40 min lag
Early 06: 4 km, 15 min lag

WWW-PM.LARC.NASA.GOV (Click ATReC/AIRS-II)

NASA Langley Flight Ops Center, Bangor Maine
Atlantic THORpex Regional Campaign
Alliance Icing Research Study II

[Home] [POCs] [Daily Schedule] [Mission Summaries] [Satellite Page] [Quicklook/Data]

- NASA ATReC/AIRSII Campaign Data Review Meeting, April 22, 2004
- ATReC Ops Plan
- THORPEX Science Plan
- AIRS-II Ops Plan
- AIRS-II Science Plan
- NASA Addendum to AIRS-II Science Plan



Icing intensity derived from GOES-8 Jan 28, 2003 20:15 UTC

The EUMETNET Composite Observing System (EUCOS) Program and THORPEX share a common goal of testing the hypothesis that the number and size of significant weather forecast errors over Europe and Eastern seaboard of the USA can be reduced by targeting extra observations over oceanic storm-tracks and other sensitive areas. The Atlantic-THORPEX Regional Campaign (ATReC) is being lead by EUCOS as a field campaign to make a significant contribution towards this common goal. THORPEX, as a Global Atmospheric Research Program (GARP), is an international research programme to accelerate improvements in the accuracy of 1 to 14-day weather forecasts for the benefit of society and the economy. The program builds upon ongoing advances within the basic-research and operational-forecasting communities, and will make progress by enhancing international collaboration between these communities and with users of forecast products. More information about THORPEX can be found on the THORPEX web site, www.mmm.ucar.edu/uswrp/programs/thorpex.html

The NASA Langley Research Center is participating in AIRS II to support the research activities of the NASA Aviation Safety Program (AvSP) and the NASA/NOAA/DOD Integrated Program Office (IPO). These Safety Program activities include ASAP - Advanced Satellite Aviation-weather Products (ASAP) and TAMDAR - Tropospheric Airborne Meteorological Data and Reporting. ASAP is a partnership with the FAA Aviation Weather Research Program (AWRP) to infuse current and next-generation satellite data and applications into FAA AWRP nowcasting products for aviation weather hazards including in-flight icing, convective weather, ceiling & visibility, turbulence and volcanic ash. The TAMDAR instrument was developed by NASA for commercial and private general aviation (GA) to extensively augment the MDCRS and AMDAR data stream and to increase weather awareness in the GA cockpit. The IPO supports the the NPOESS Atmospheric Sounder Testbed Project to develop the next generation of hyperspectral sounders that will fly on operational polar orbiting satellites. This research also supports GIFTS (the Geosynchronous Imaging Fourier Transform Spectrometer), a demonstration instrument for the development of the next generation of GOES (Geostationary Operational Environmental Satellite) sounders.

Website address: http://www-angler.larc.nasa.gov/bangor *Last Updated: Nov 10, 2003*
Responsible NASA Official: John Murray *(john.j.murray@nasa.gov)*
Website Curator: Louis Nguyen *(l.nguyen@nasa.gov)* Feedback on Langley Products and Services

ATReC/AIRS-II (Click Mission Summaries)

NASA Langley Flight Ops Center, Bangor Maine
Atlantic THORpex Regional Campaign
Alliance Icing Research Study II

[Home] [POCs] [Daily Schedule] [Mission Summaries] [Satellite Page] [Quicklook/Data]

Mission Op Summaries

Flight track overlay GOES-12 Images

1. November 19, 2003
2. November 24, 2003
3. November 25, 2003
4. November 26, 2003
5. November 28, 2003
6. November 28, 2003 - Citation Flight 2
7. November 30, 2003
8. December 01, 2003
9. December 02, 2003
10. December 03, 2003
11. December 03, 2003 - Citation Flight 2
12. December 04, 2003
13. December 05, 2003 - Citation Flight 1
14. December 05, 2003
15. December 08, 2003
16. December 10, 2003 - Citation Flight 1
17. December 10, 2003
18. December 11, 2003
19. December 12, 2003
20. December 13, 2003
21. December 14, 2003

Flight track overlay GOES-12 derived cloud product Images

1. November 19, 2003
2. November 24, 2003
3. November 25, 2003
4. November 26, 2003
5. November 28, 2003
6. November 30, 2003
7. December 01, 2003
8. December 04, 2003
9. December 05, 2003
10. December 11, 2003
11. December 12, 2003
12. December 13, 2003
13. December 14, 2003

Selected Twin Otter flight segments

14. November 11, 2003
15. November 25, 2003
16. December 10, 2003

Selected Canadian flight segments

17. February 06, 2004

Website address: http://www-angler.larc.nasa.gov/bangor *Last Updated: Nov 10, 2003*
Responsible NASA Official: John Murray *(john.j.murray@nasa.gov)*
Website Curator: Louis Nguyen *(l.nguyen@nasa.gov)* Feedback on Langley Products and Services

ATReC/AIRS-II Mission Summaries (November 30, 2003)

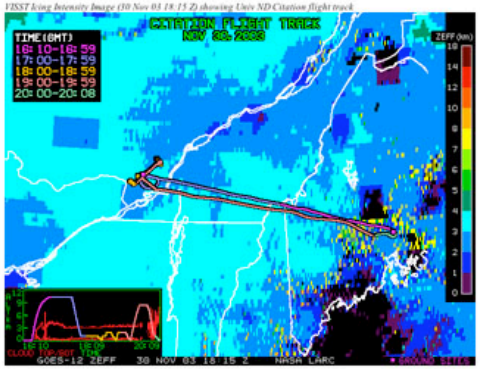
NASA Langley Flight Ops Center, Bangor Maine
Atlantic THORpex Regional Campaign
Alliance Icing Research Study II

[Home] [POCs] [Daily Schedule] [Mission Summaries] [Satellite Page] [Quicklook/Data]

VISST Cloud Product Summary for Nov 30, 2003

Mission Summary:
This flight was carried out in support of the AIRS2 program. The Citation took off from Bangor at 1624Z, arriving over Mirabel at 35,000 ft at about 1730Z. A spiral descent was made over the runway intersection down to 4,000 ft. Clouds were not encountered until about 7200 ft, where there was a layer about 1000 ft thick. The lower clouds had tops slightly above 4,000 ft, but variable. Several measurement passes were made along the runway at 4,000 ft going in and out of cloud along the way. In cloud, the Citation encountered light to moderate rime ice and liquid water contents of 0.1 to 0.4 g/m3. This was followed by a missed approach over the runway from 4,000 ft. The cloud extended down to slightly below 2,000 ft. This was followed by passes at 7,000 ft going west to east and missed approaches from 7,000 ft over the runway going east to west. This profile was carried out several times In general, the liquid water content was higher in the upper cloud layer, with larger mean values of the droplet sizes. There were a few ice crystals in both layers, but the clouds were composed primarily of water droplets. The clouds were well characterized by the measurements in the horizontal as well as the vertical.

VISST Icing Intensity Image (30 Nov 03 18:15 Z) showing Univ ND Citation flight track



Citation tracks on:
Cloud Phase
Droplet Radius
10.7 um BT
Eff. Cloud Height
Icing Intensity

UND Citation Flight Track overlayed on VISST Cloud Products

- JavaScript Loops:
  Icing Intensity, Cloud Phase, Droplet Radius, 10.7 um BT, Eff. Cloud Height
- Animated GIF Loop:
  Icing Intensity, Cloud Phase, Droplet Radius, 10.7 um BT, Eff. Cloud Height
- Icing Intensity Images:
  16:15, 16:45, 17:15, 17:45, 18:15, 18:45, 19:15, 19:45, 20:15
- Cloud Phase Images:
  16:15, 16:45, 17:15, 17:45, 18:15, 18:45, 19:15, 19:45, 20:15
- Droplet Radius Images:
  16:15, 16:45, 17:15, 17:45, 18:15, 18:45, 19:15, 19:45, 20:15
- 10.7 um Brightness Temperature Images:
  16:15, 16:45, 17:15, 17:45, 18:15, 18:45, 19:15, 19:45, 20:15
- Effective Cloud Height Images:
  16:15, 16:45, 17:15, 17:45, 18:15, 18:45, 19:15, 19:45, 20:15

VISST GOES-12 Derived Cloud Products

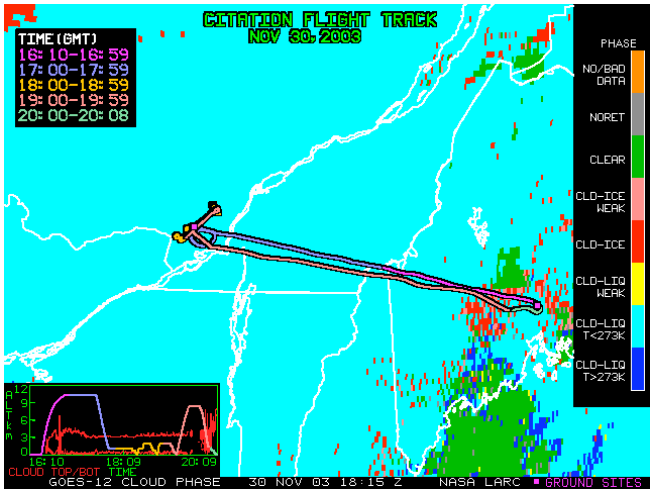
VISST GOES-12 Flight Track Matched Cloud Products

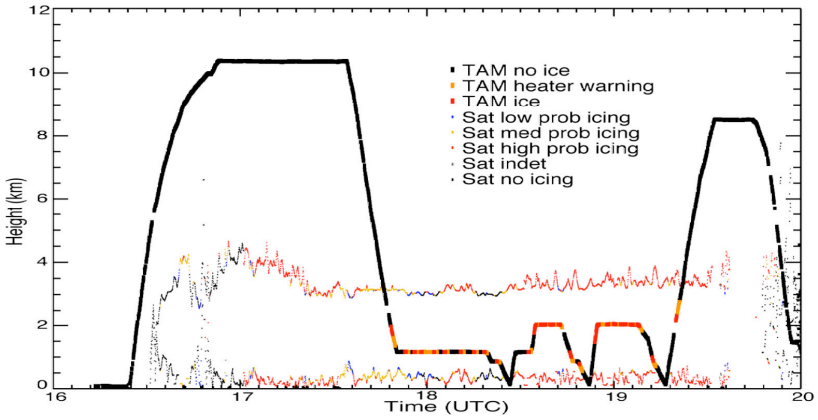
Aircraft Navigation Data:

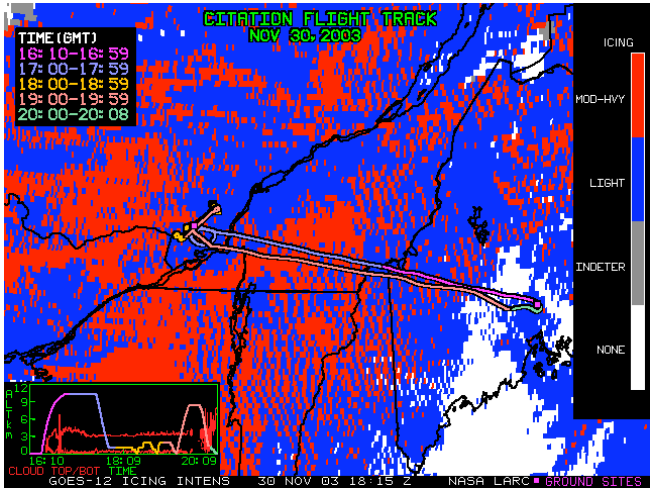
- Citation navigation and meteorological data written in NASA Ames format

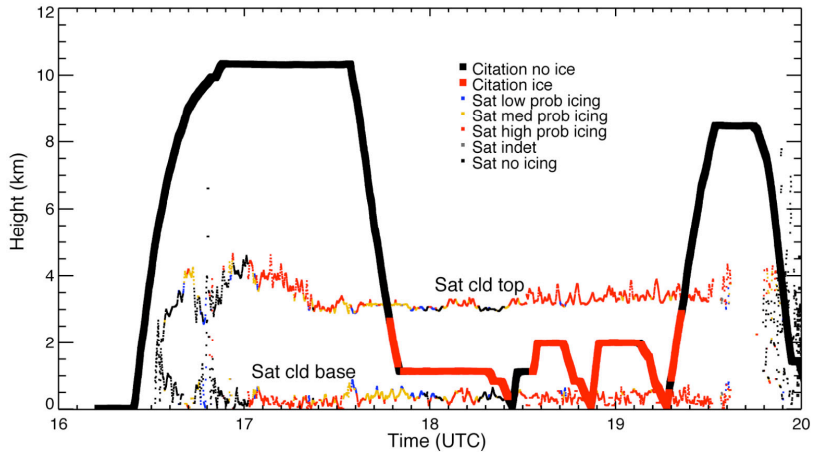
Website address: http://cwcwe-angler.larc.nasa.gov/bangor *Last Updated: Nov 10, 2003*
Responsible NASA Official: John Murray (john.j.murray@nasa.gov)
Website Curator: Louis Nguyen (l.nguyen@nasa.gov) *Feedback on Langley Products and Services*

UND Citation Icing Flight on Nov 30, 2003



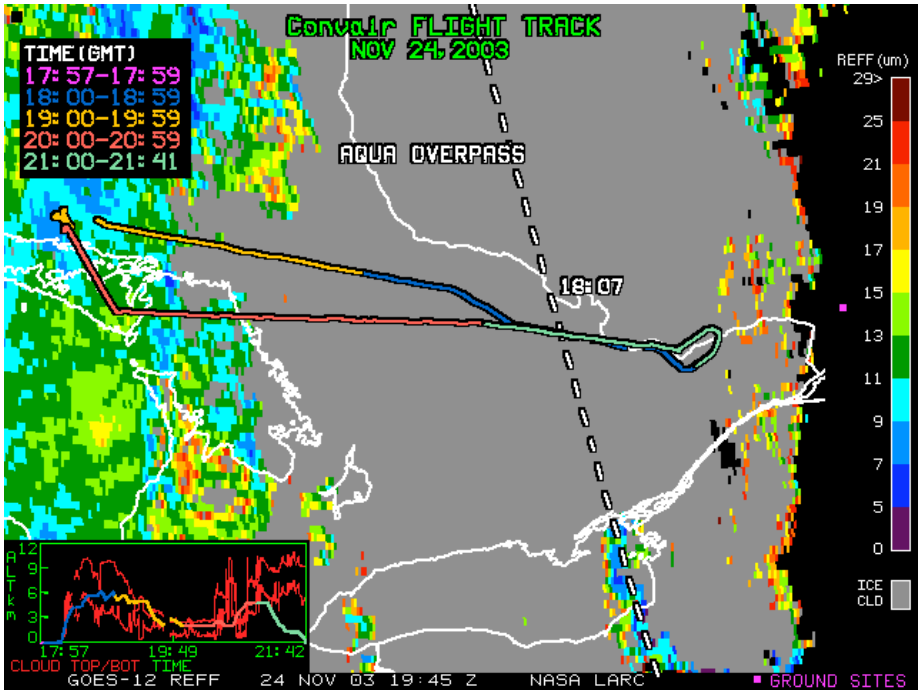


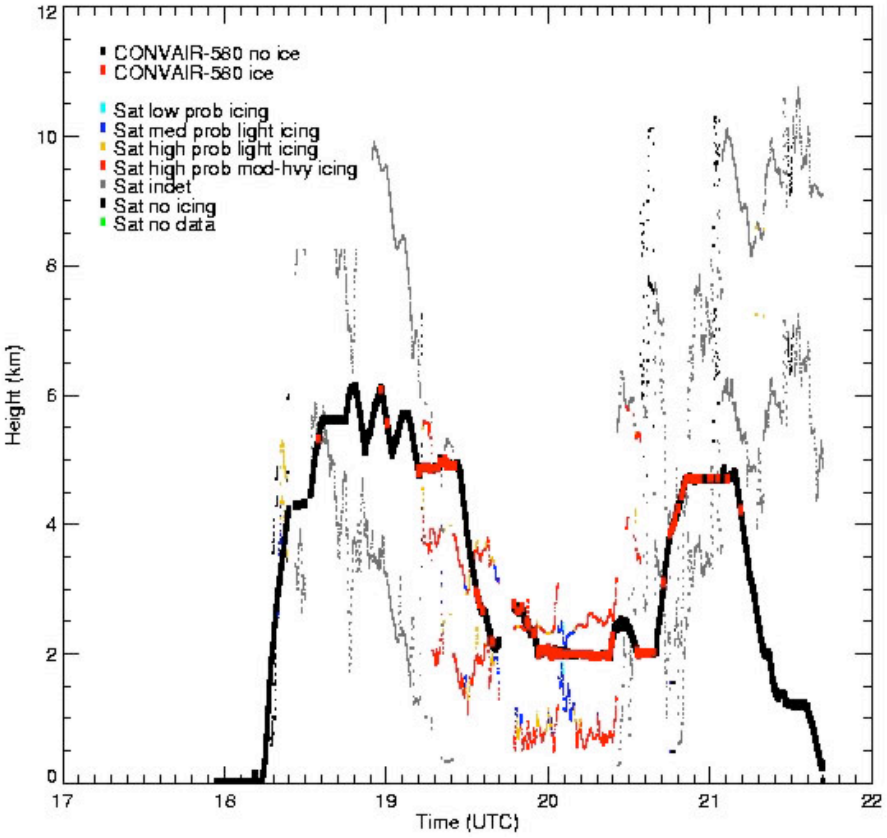




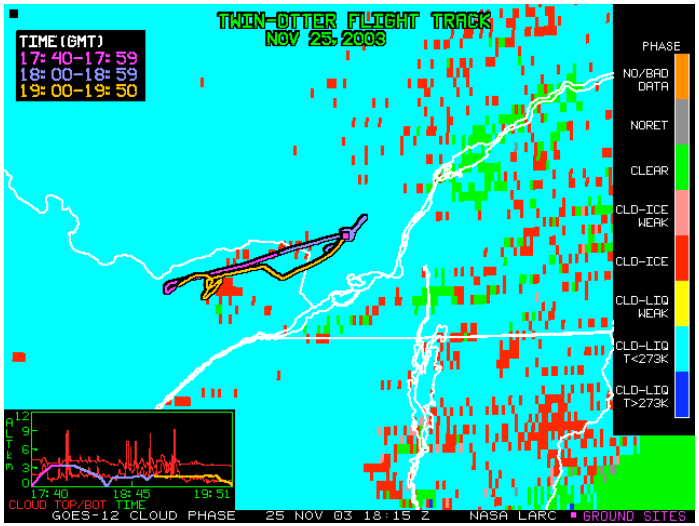
Convair Icing Flight on Nov 24, 2003

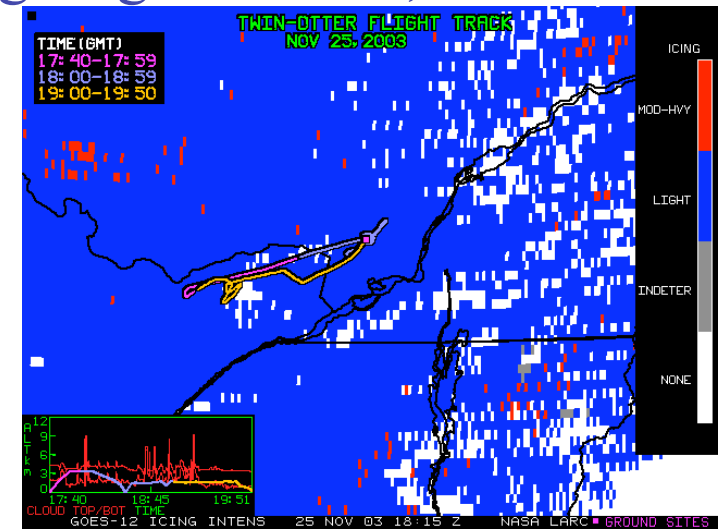
good case for icing & height

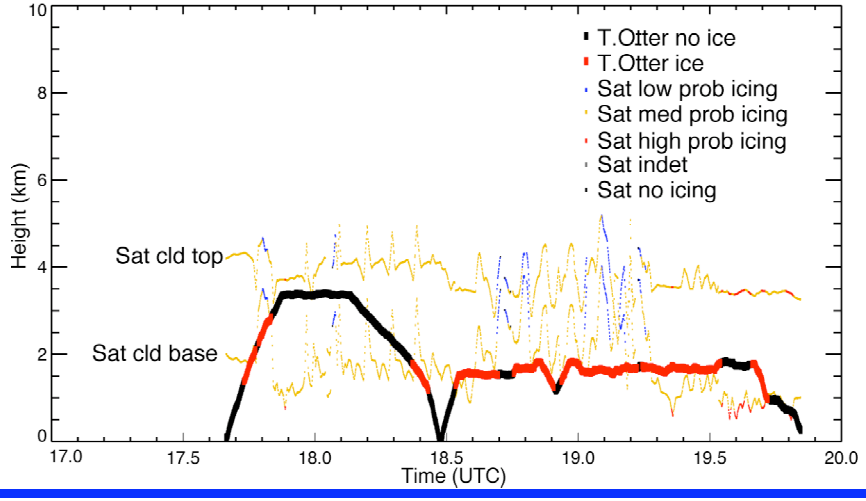




NASA Glenn Twin Otter Icing Flight Nov 25, 2004

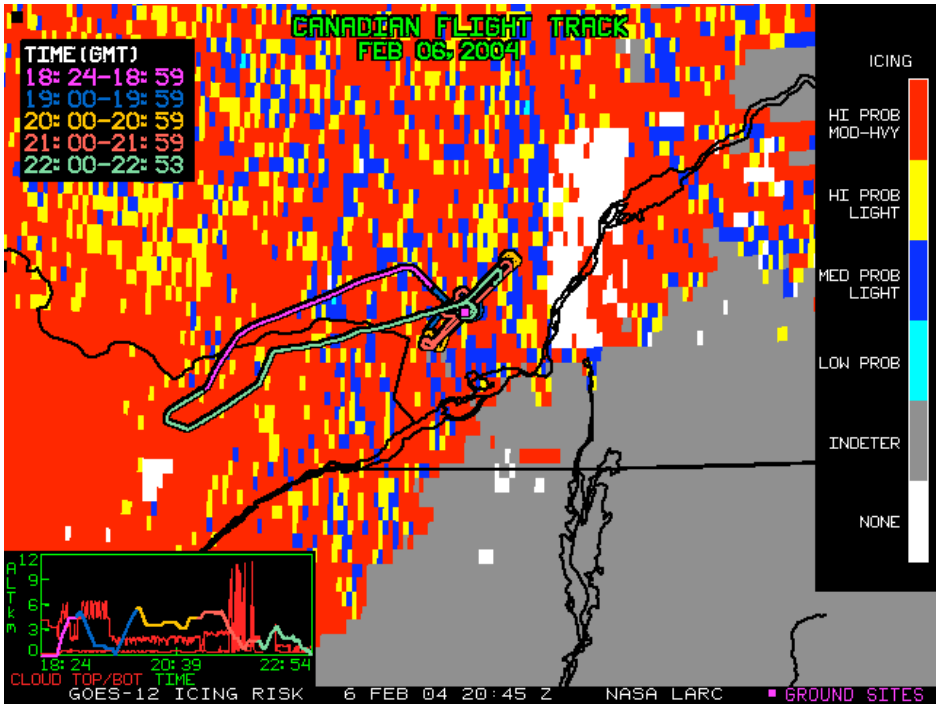


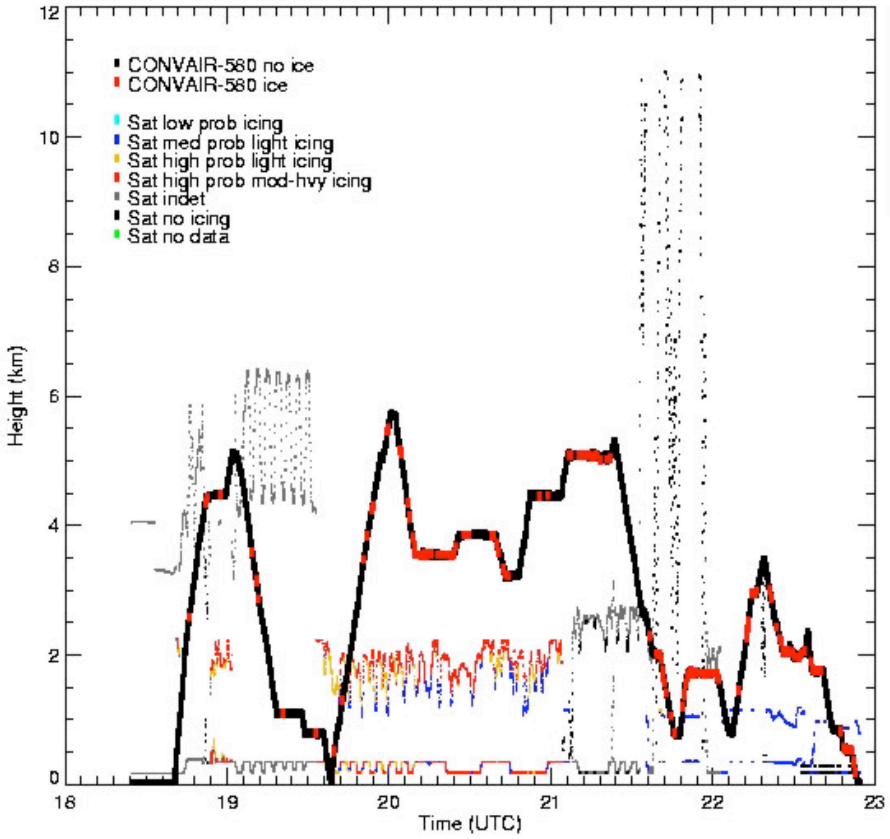




Convair Icing Flight on Feb 6, 2004

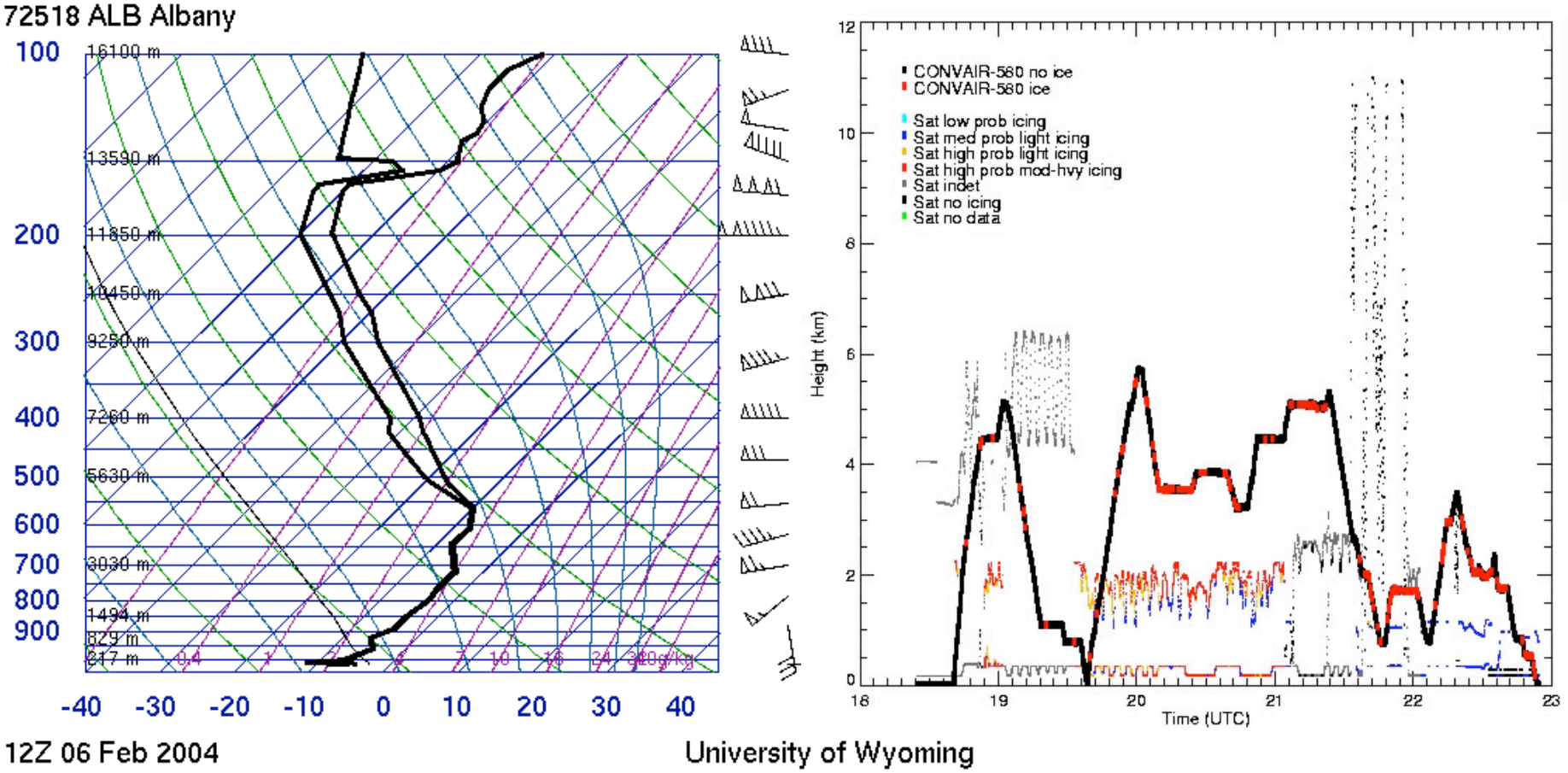
good case for icing, not height: sounding problem, T(z)





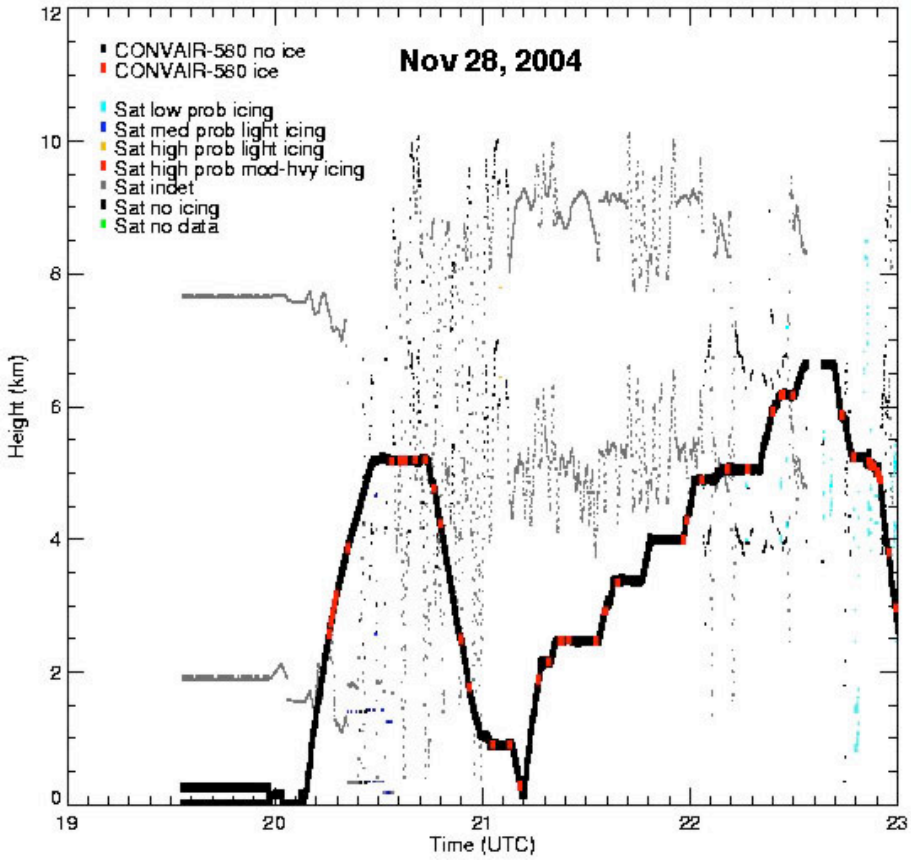
Convair Icing Flight on Feb 6, 2004

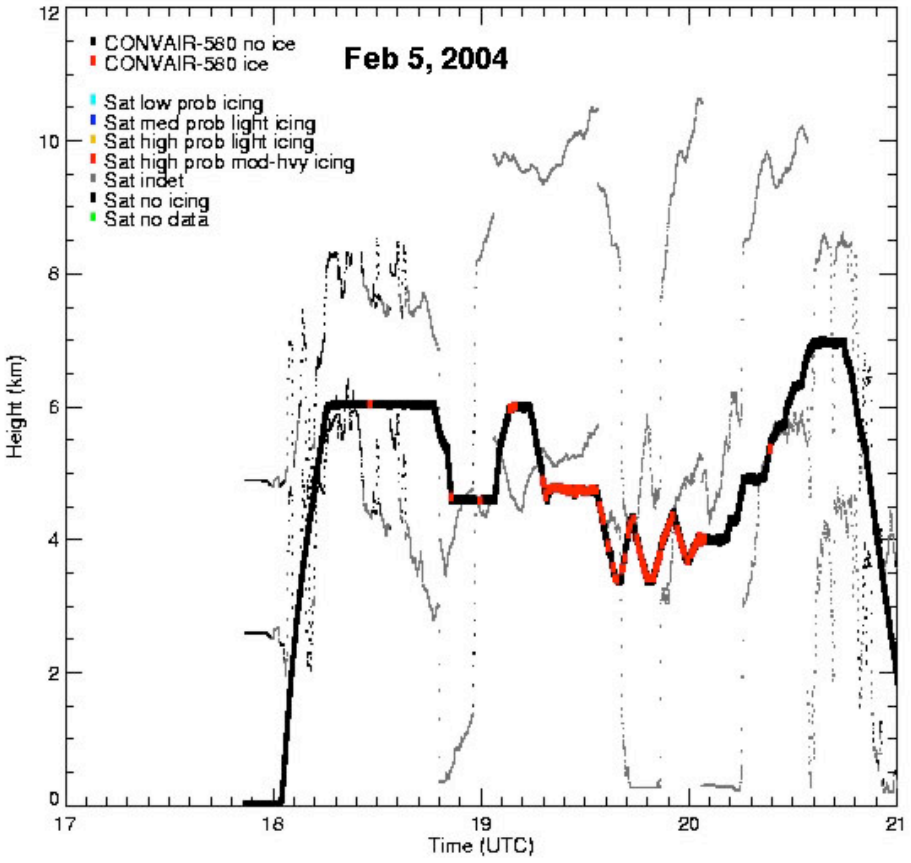
good case for icing, not height: sounding problem, T(z)



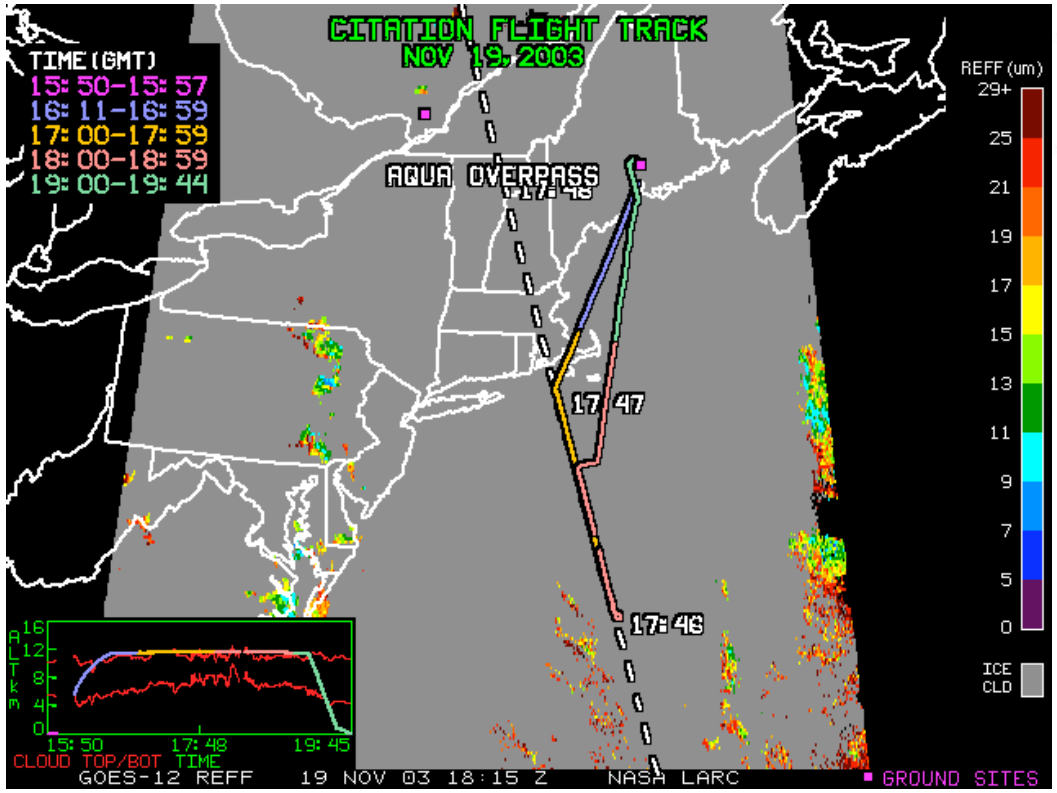
Convair Icing Flights

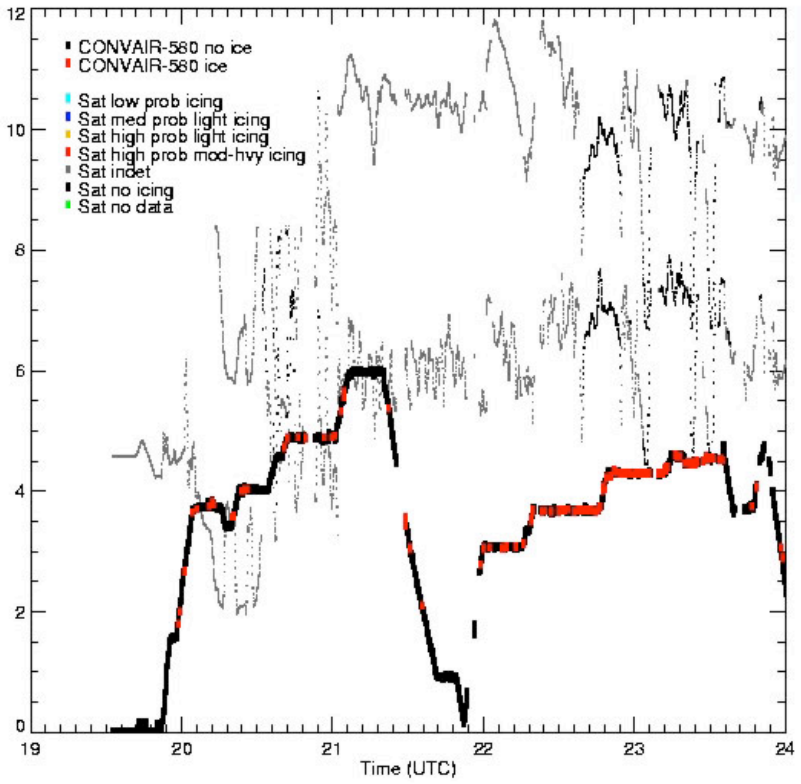
typical: ice cloud above, indeterminate from satellite



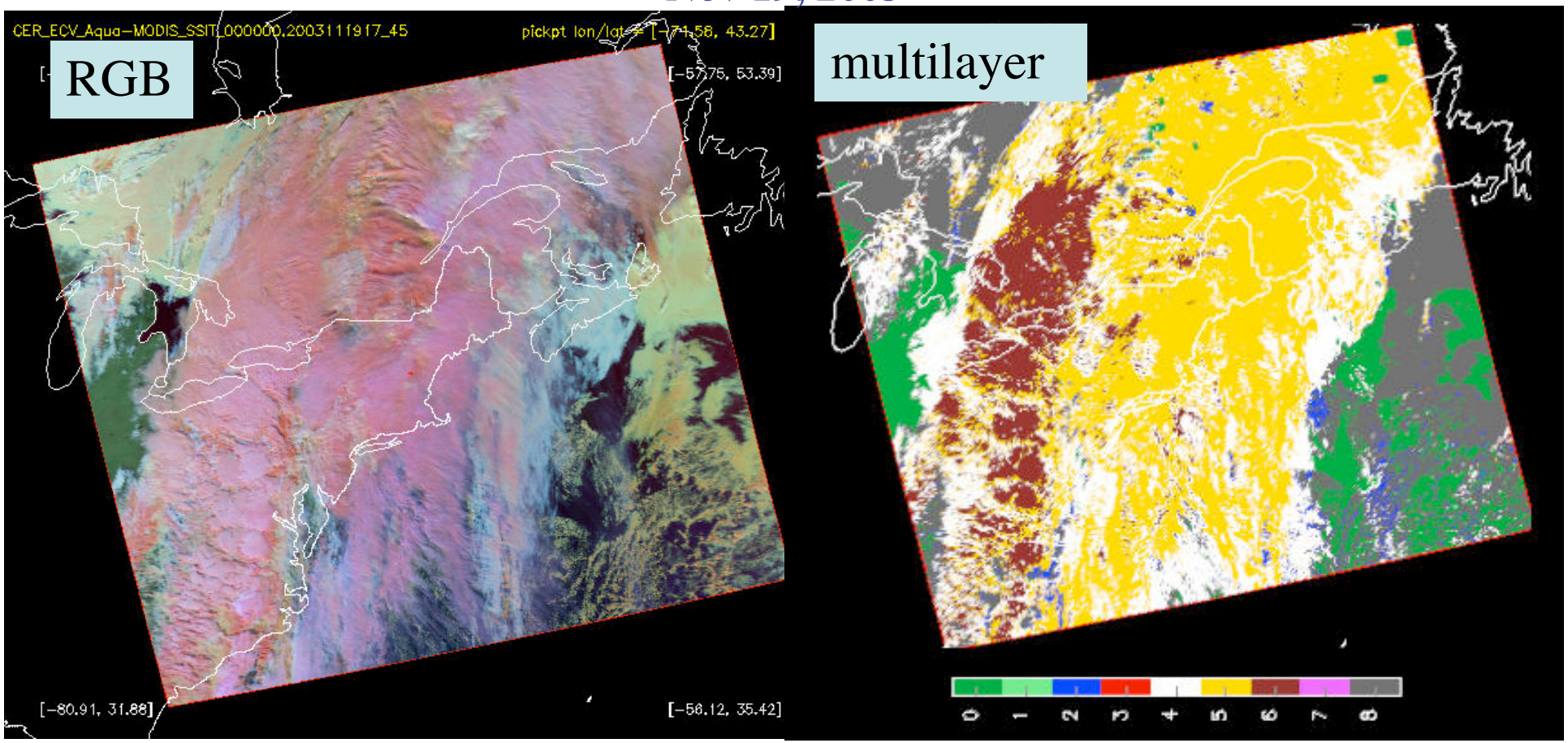


Ice Obscured Cases, Nov 19, 2003





Aqua MODIS Example
Nov 19, 2003



white: single ice; yellow: multi ice; brown: indeterminate ice; blue: multi water; gray: water

Ground Site Matched Products (updated)

www-pm.larc.nasa.gov (click Cloud Products and Satellite Imagery)

Cloud Products derived at Ground Site: Interactive tool to plot cloud products.

- VISST - *Computed from pixel retrievals inside a 10 or 20km radius centered on the site.*

  ARM SGP | CRYSTAL-FACE | TWP Nauru | TWP Manus | TWP Darwin | ATReC Bangor | ATReC Montreal | SIRTA France | Chilbolton U.K | Cabauw Netherlands |

- LBTM - *Computed from 3x3 1/3 ° regions centered on the site.*

  SGP CART | TWP Nauru | TWP Manus | TWP Darwin

Click Montreal

NASA Langley Flight Ops Center, Bangor Maine
Atlantic THORpex Regional Campaign
Alliance Icing Research Study II

[Home] [POCs] [Daily Schedule] [Mission Summaries] [Satellite Page] [Quicklook/Data]

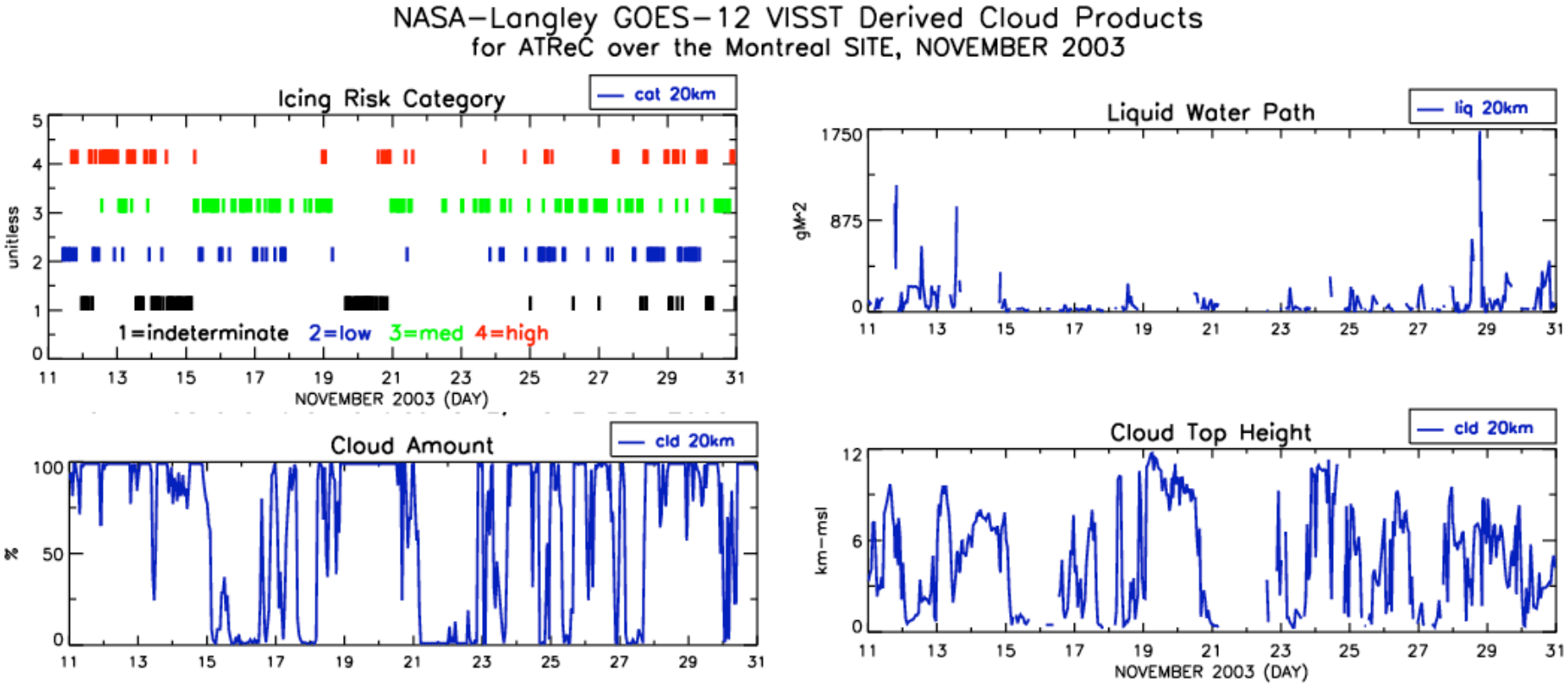
GOES-12 VISST Derived Cloud Products For ATReC Montreal Site

GOES-12 VISST derived Cloud Products are computed from the individual pixel retrievals from half hourly GOES-12 images.The cloud product means and standard deviations are computed from the pixels within both a **10 km (30 pixels)** and **20 km (110 pixels)** radius centered on the ATReC Montreal site.

Select up to 4 Cloud Products	Line 1 Select type / Radius	Line 2 *(optional)* Select type / Radius
Cloud Product 1	Type 20 km	Type 20 km
Cloud Product 2	Type 20 km	Type 20 km
Cloud Product 3	Type 20 km	Type 20 km
Cloud Product 4	Type 20 km	Type 20 km
2003 Dec Start day 01 End Day 30		Plot

Version 1.0: Nov 12, 2003

November 2003 VISST Ground Site Cloud Retrievals



Comparison of VISST & MWR Derived LWP at Mirabel, Quebec (Nov 30, 2003)

Haggerty et al., 2005

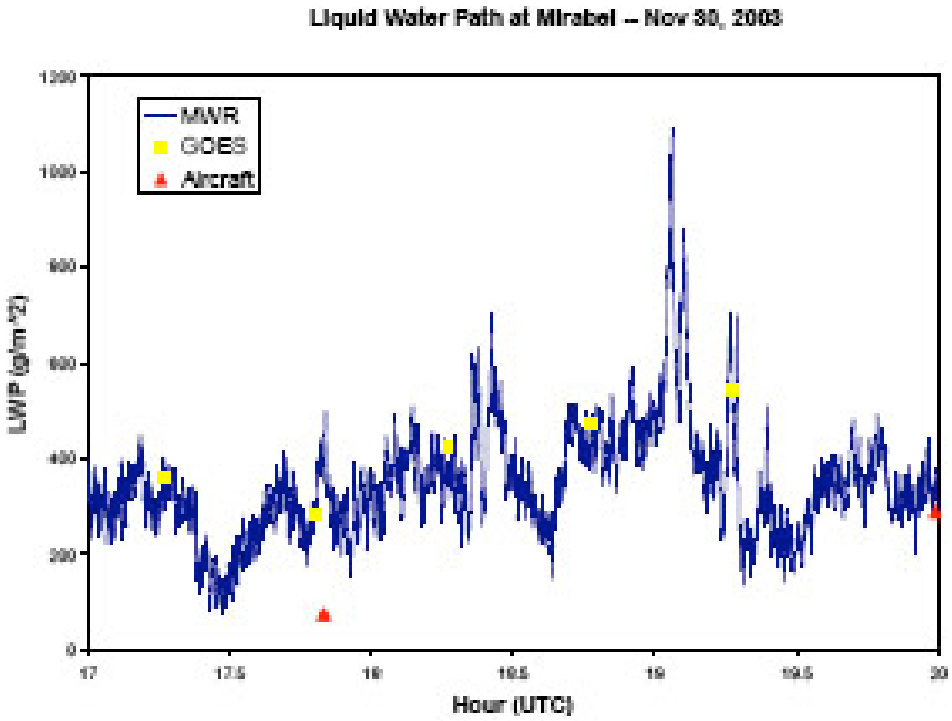
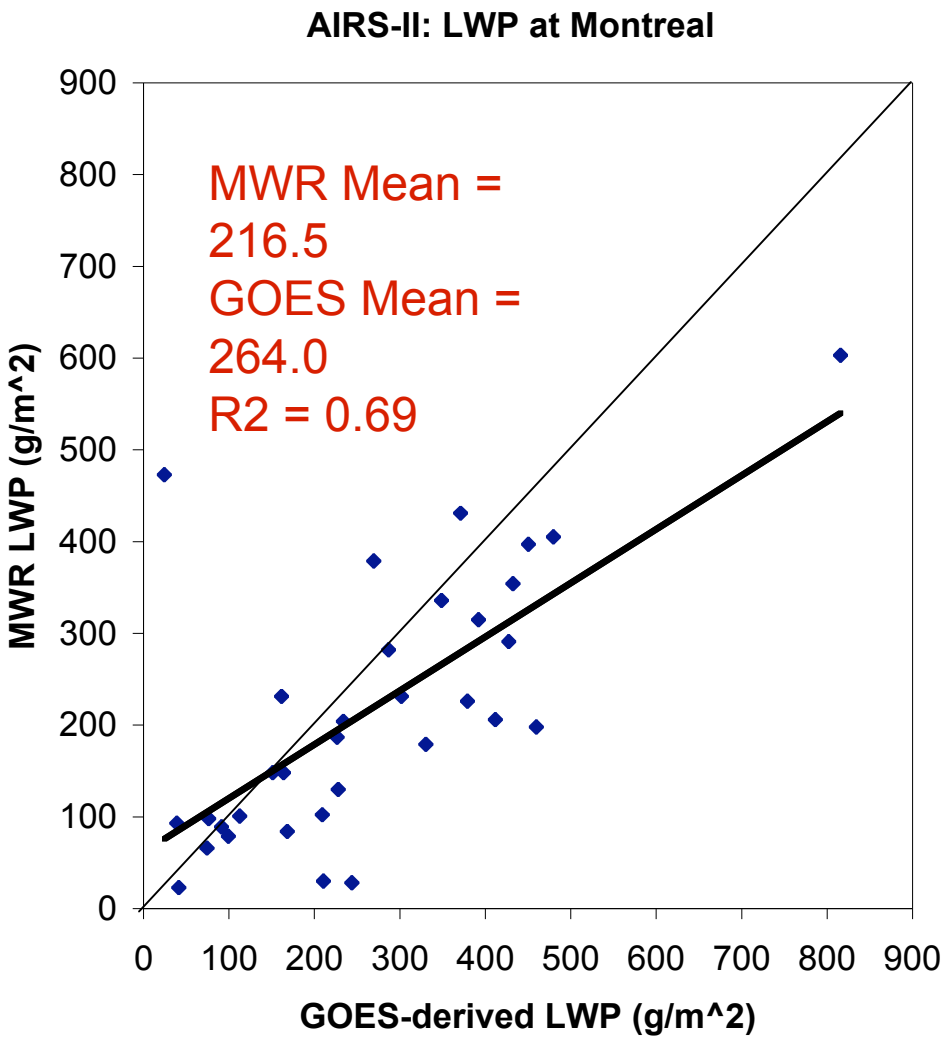


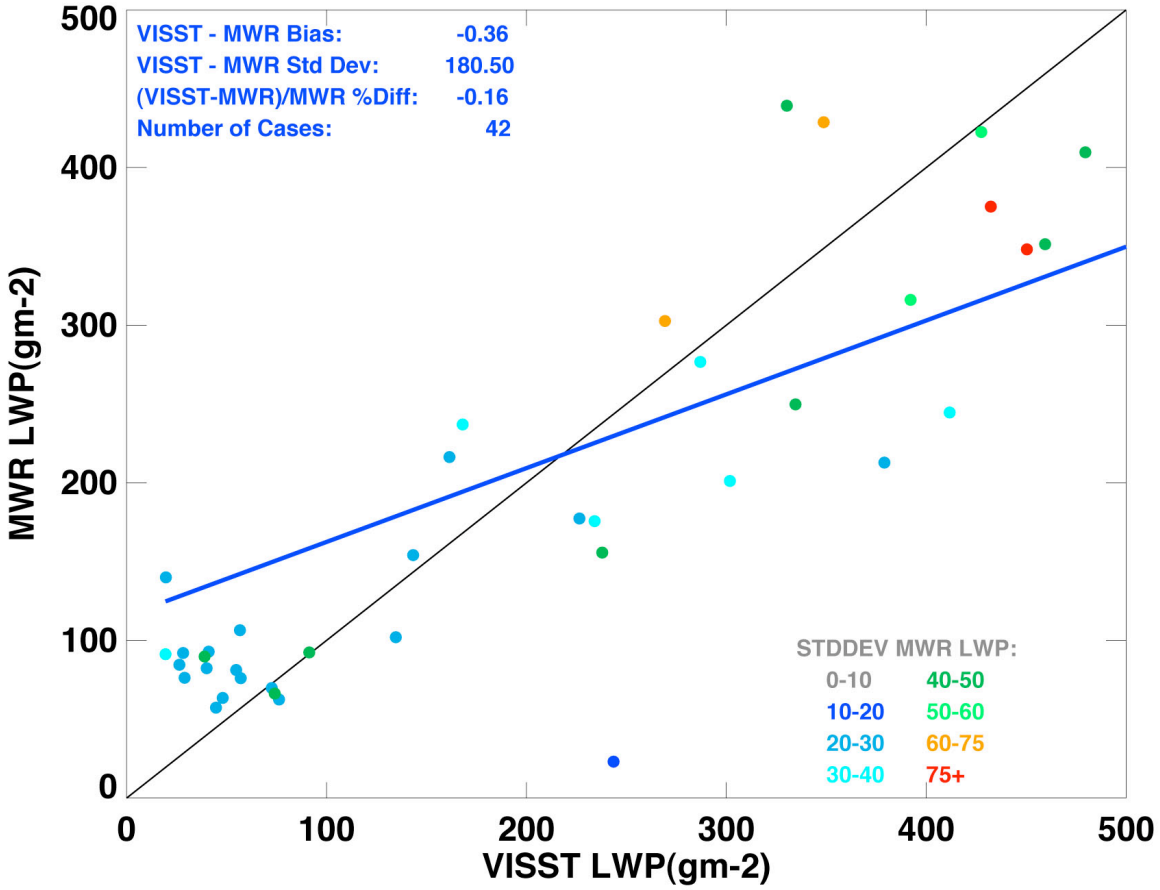
Figure 5: Liquid water path as estimated by a ground-based microwave radiometer (blue line), GOES satellite products (yellow symbols), and research aircraft (red symbols) on November 30, 2003 near Montreal, Canada.

Comparison of VISST & MWR Derived LWP at Mirabel, Quebec (Nov-Dec, 2003)

NCAR analysis, *Haggerty et al., 2005*

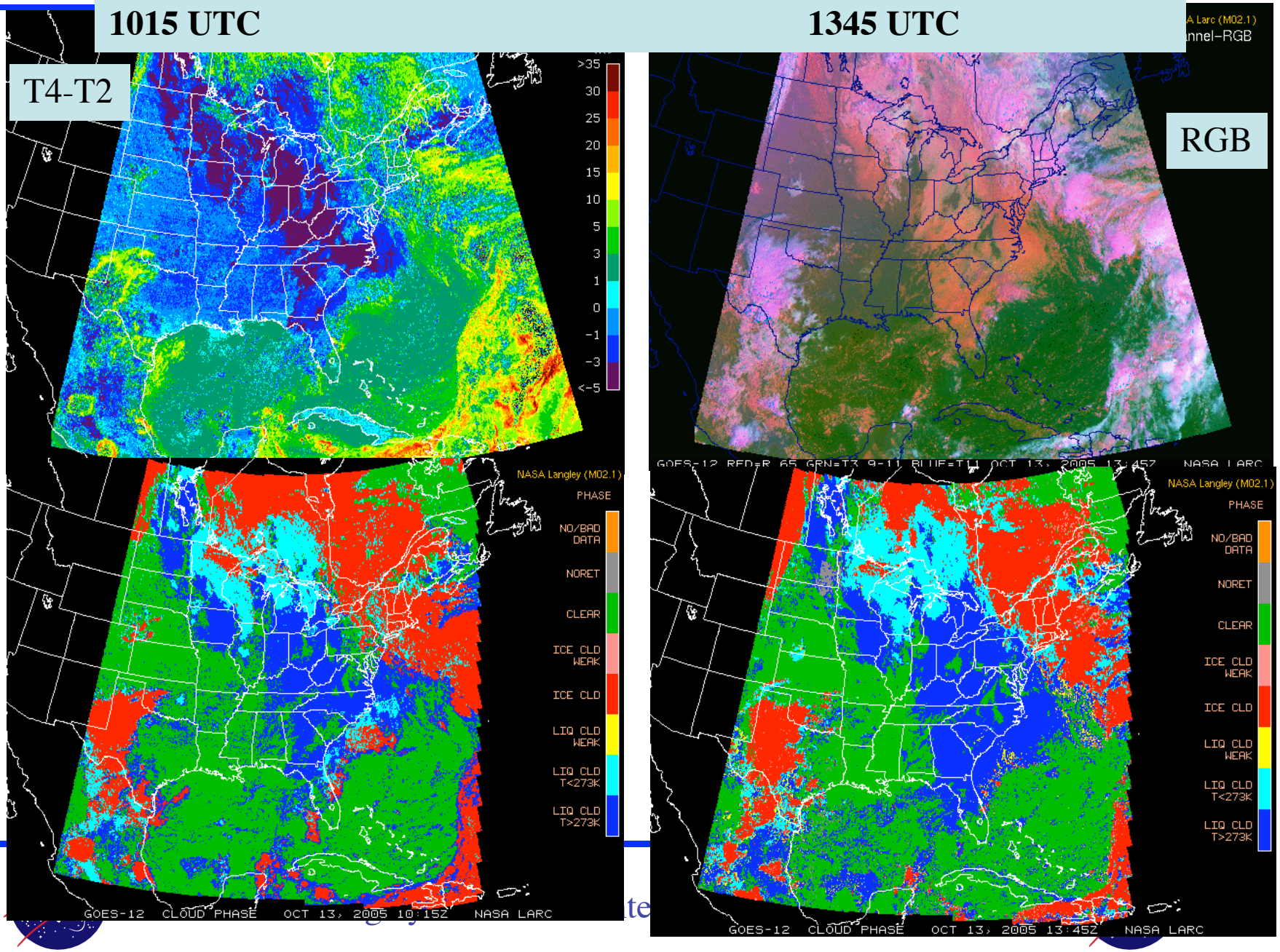


Comparison of VISST and MWR Derived LWP (Nov-Dec, 2003), not updated

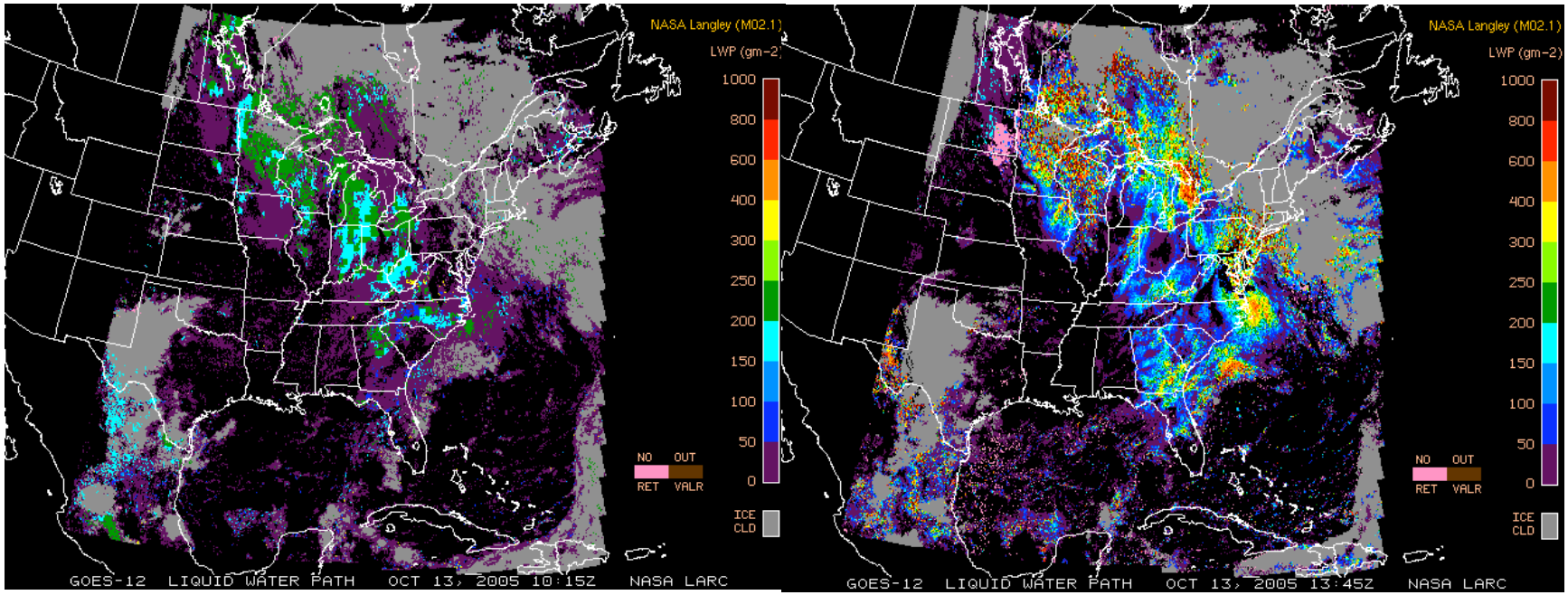


Night vs Day, GOES-12, 10/13/05, LWP

1015 UTC | **1345 UTC**



Night vs Day, GOES-12, 10/13/05, LWP



1015 UTC **1345 UTC**

Relative measures of LWP may help estimate nocturnal icing

miss larger LWP over southern Ont (large re), no 12 μm?

Conclusions

- Preliminary results show general agreement between GOES icing detection and in-situ aircraft observations when no high cloud above

- Additional studies are required for full validation
  - comparisons with in situ from all aircraft
  - radar retrievals of IWP, De, boundaries

The authors would like to thank the following for providing in-situ data: G. A. Isaac and the research teams of the Cloud Physics and Severe Weather Meteorology Division of the Meteorological Service of Canada, the Canadian National Research Council Convair-580, David Delene and Tony Grainger of the University of North Dakota, Tom Ratavsky of NASA Glenn Research Center, and Tim Schneider NOAA Environmental Technology Laboratory.

Future Work

- Reanalyze heights using RUC native format to provide better T(z)
  - Compare cloud boundary retrievals with sfc radar observations
- Conduct additional validation studies with surface and aircraft observations
- Complete analyses of multilayered clouds using MODIS data
  - use both mixed phase and multilayered cloud detections
- Perform comparisons with in situ and radar retrievals
- **Try to get ER-2 data linked to archive**