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

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Validation of Satellite-Derived SLW Cloud Properties

How do satellite retrievals of Tcld, Re, LWP correspond to aircraft icing?

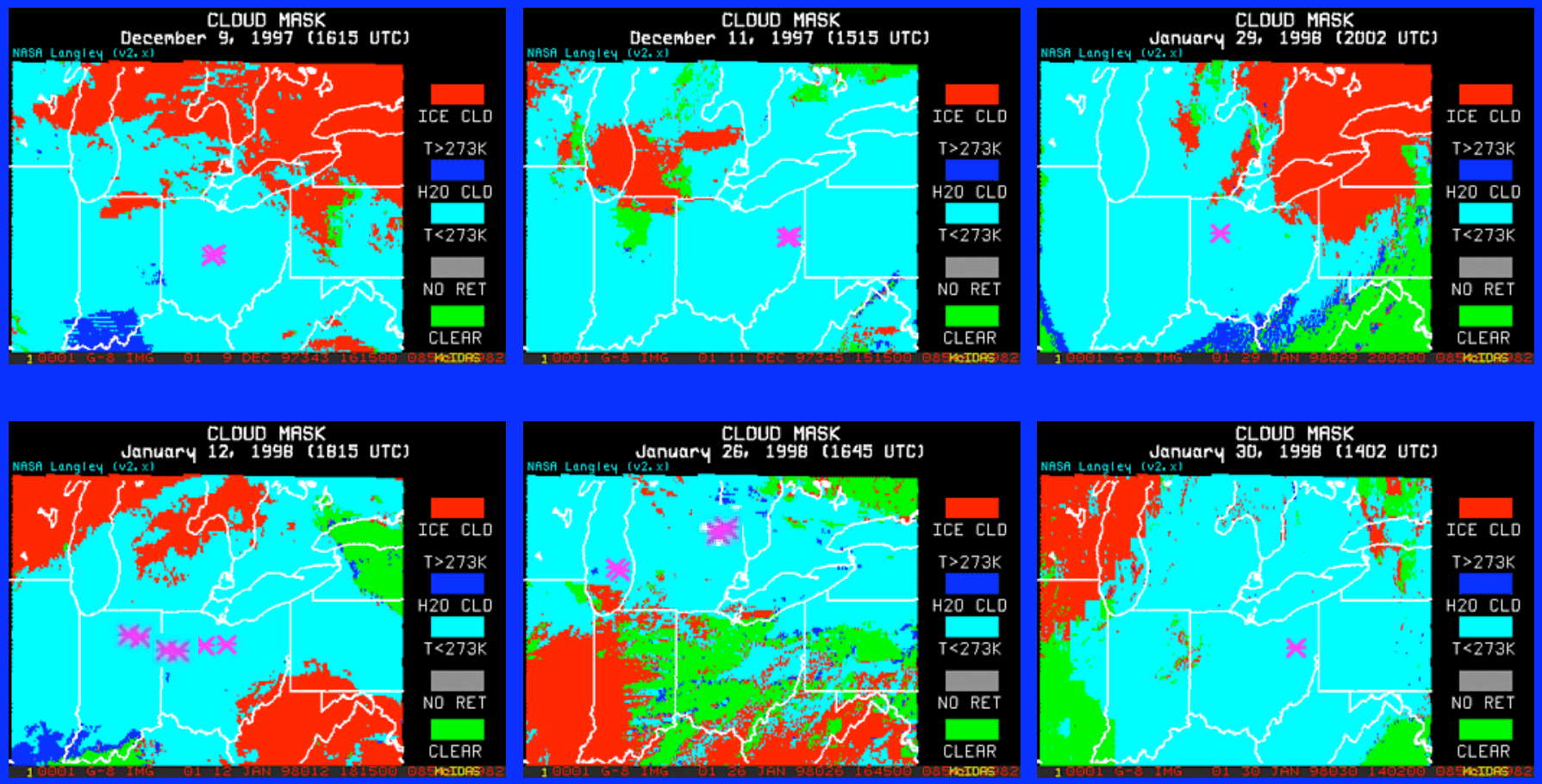
•Correlate with measurements from icing research aircraft (NASA GRC)

- 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)



× - denotes Twin Otter cloud top penetrations

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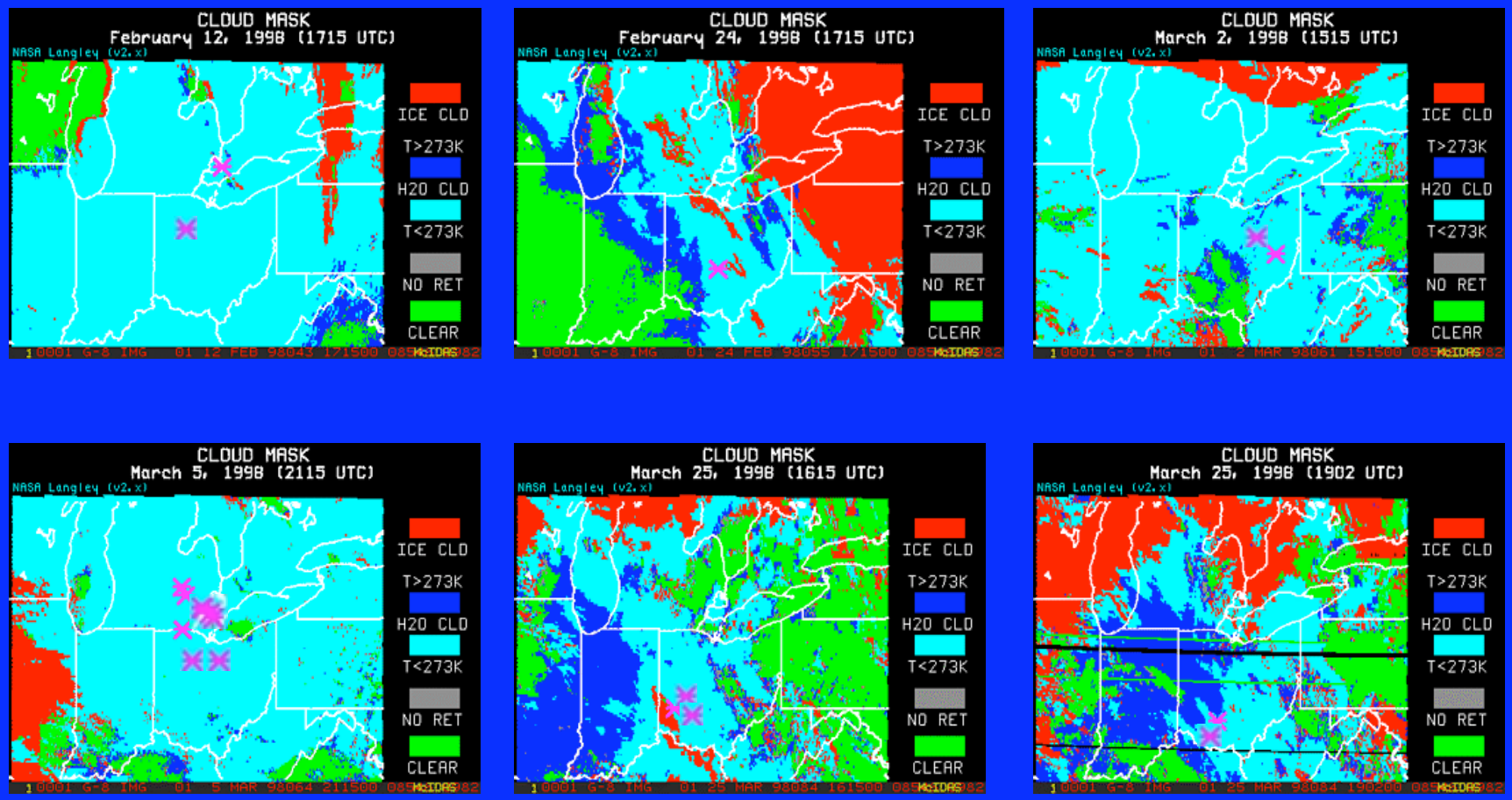
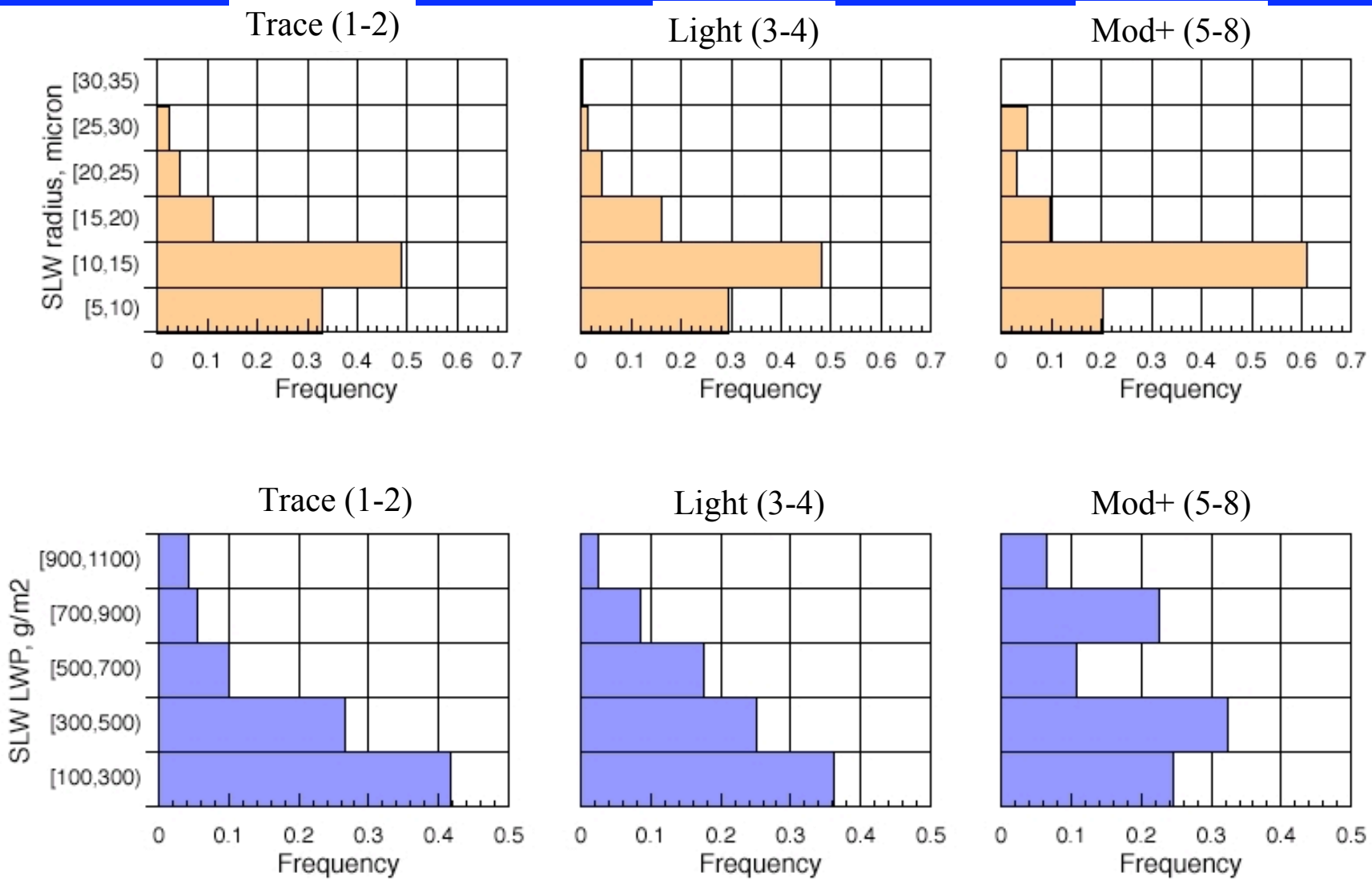


× - denotes Twin Otter cloud top penetrations

GOES SLW vs. PIREPS Icing

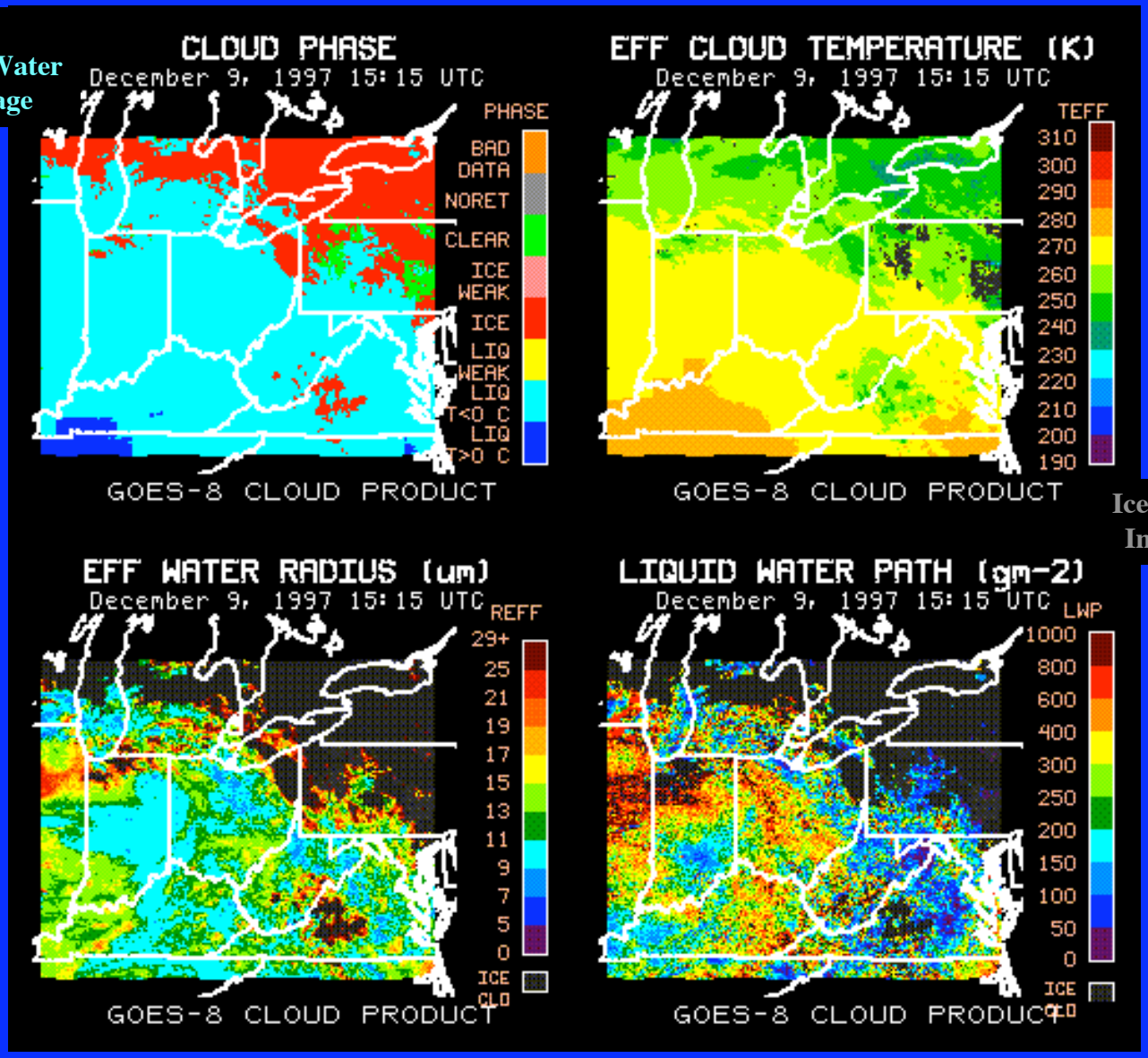
Compared to Positive icing PIREPS and provided there were no overcast ice clouds, LaRC GOES technique detected SLW 98% of the time (Smith et al., 2000)

Comparison of GOES Cloud Properties with PIREPS Icing Intensity
N=7800 (Jan-March, 2003)



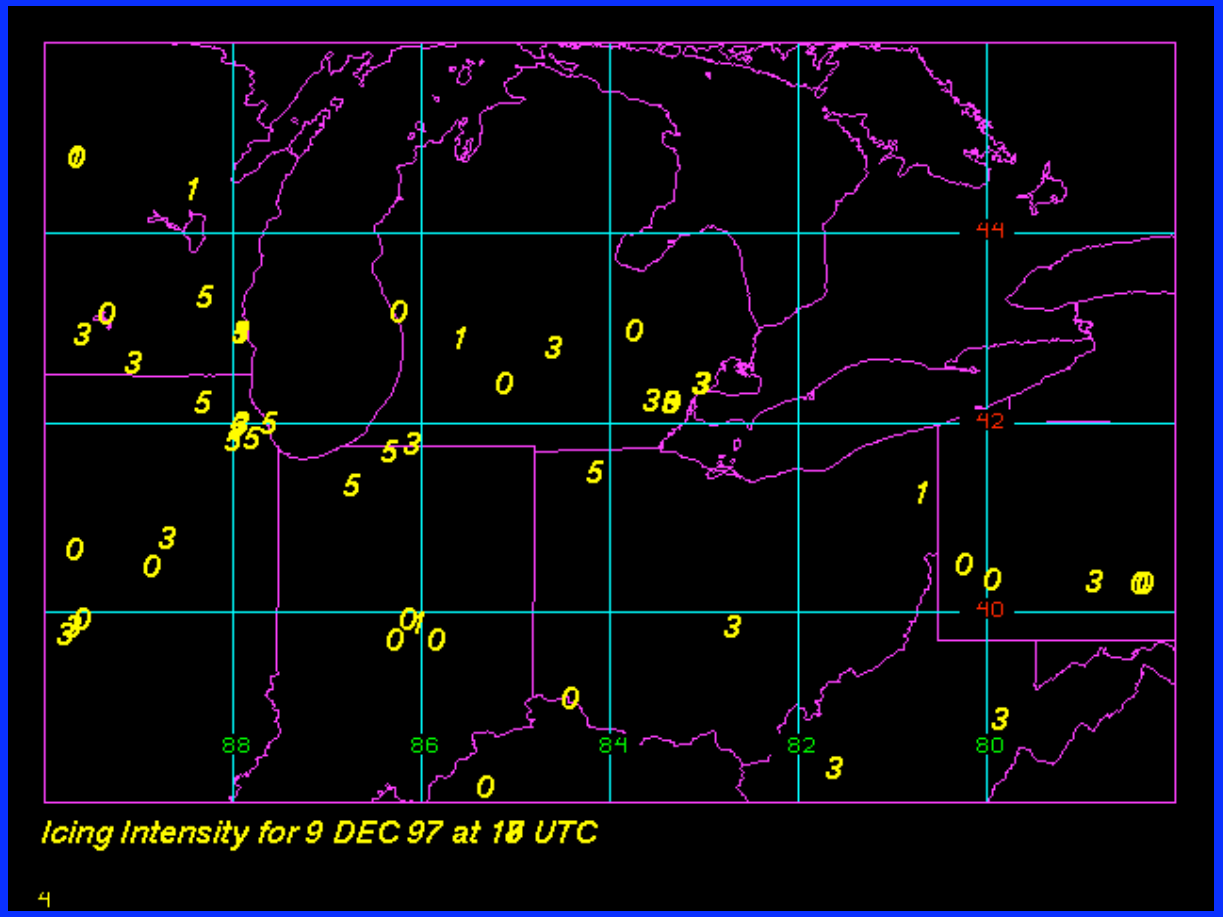
GOES-Derived Cloud Properties (Dec. 9, 1997)

Cyan indicates
Supercooled Liquid Water
In Cloud Mask Image

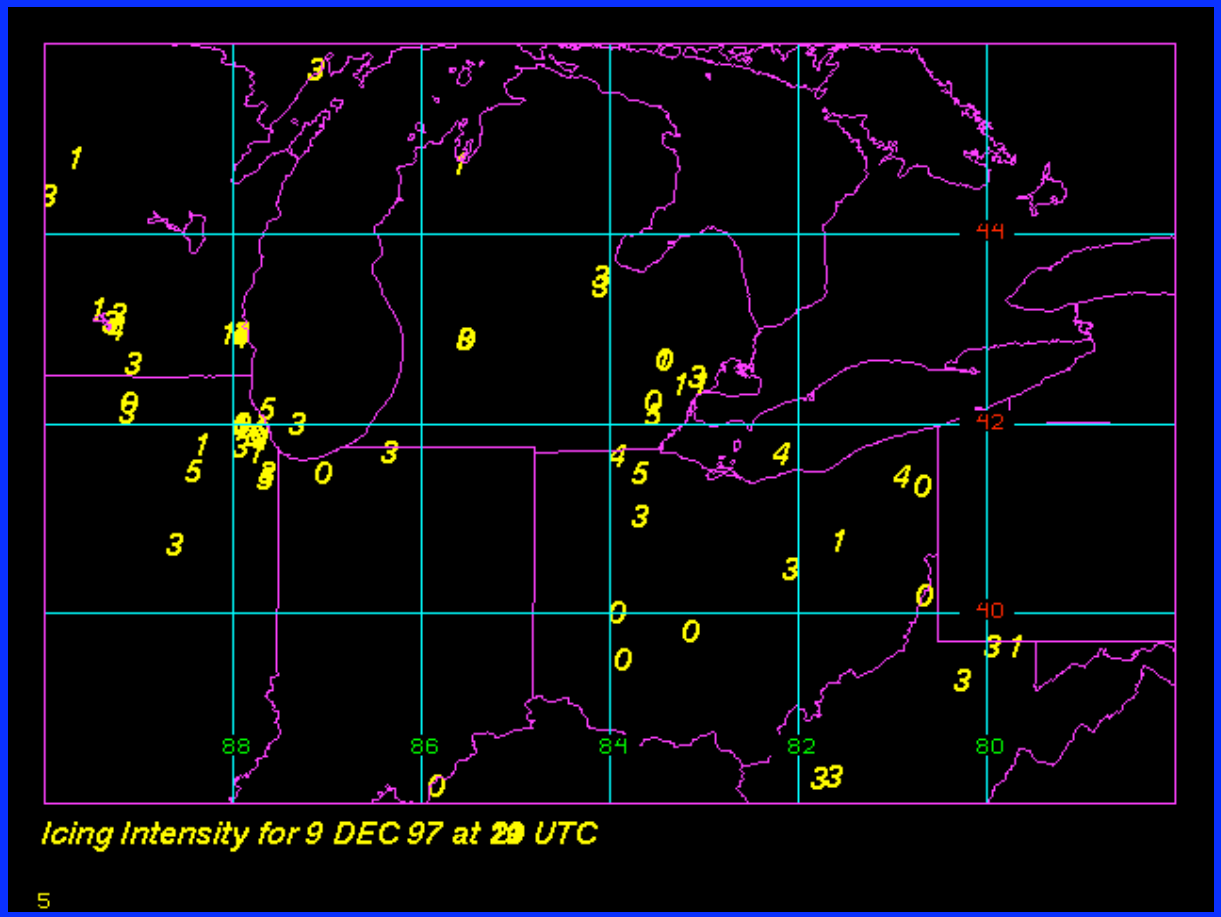


Ice Cloud Properties
In Grey not shown

PIREP Icing Intensity at 16-18 UTC Dec. 9, 1997



PIREP Icing Intensity
at 19-21 UTC Dec. 9, 1997



GOES-Derived Cloud Properties (March 5, 1998)

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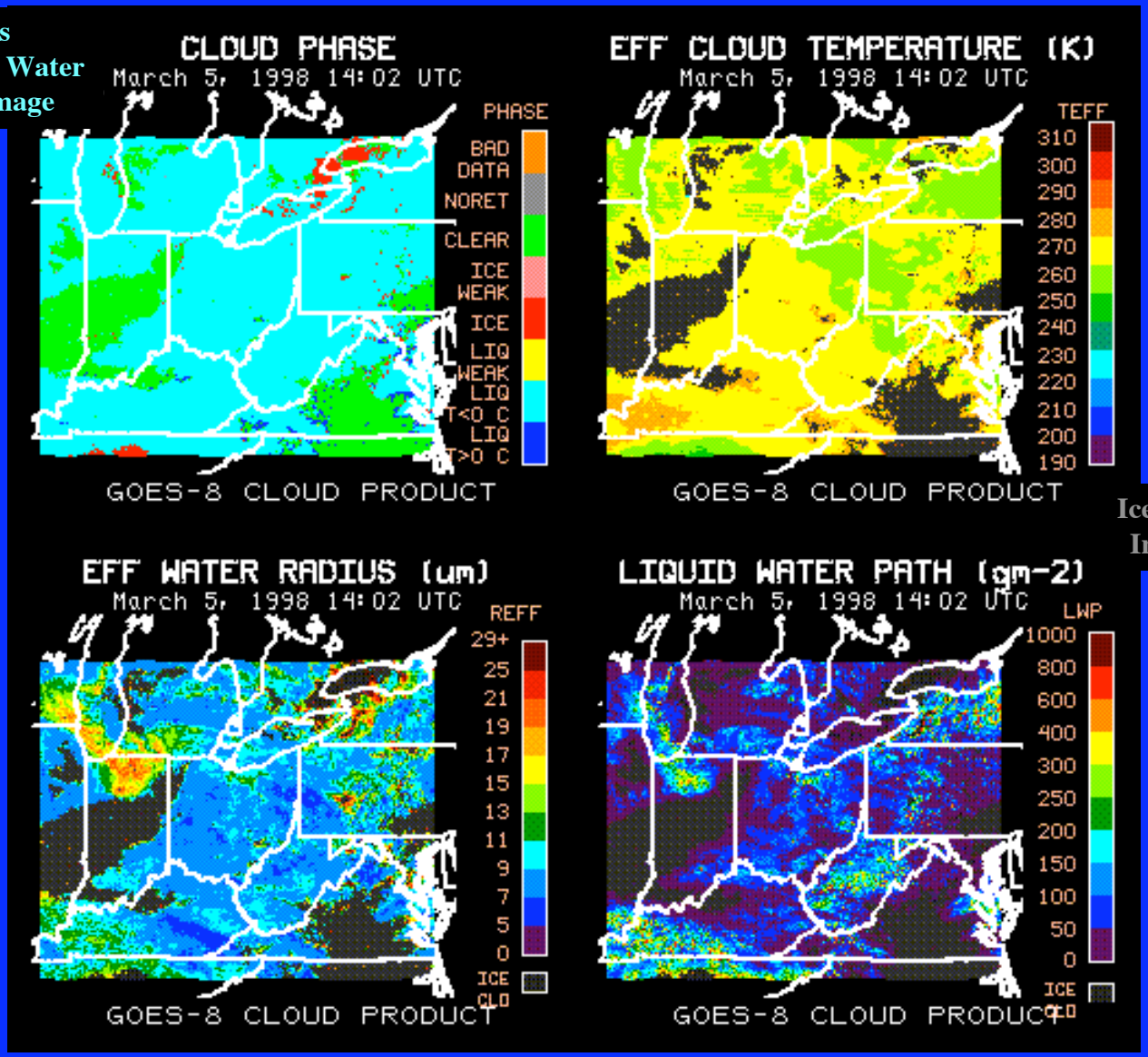

Ice Cloud Properties
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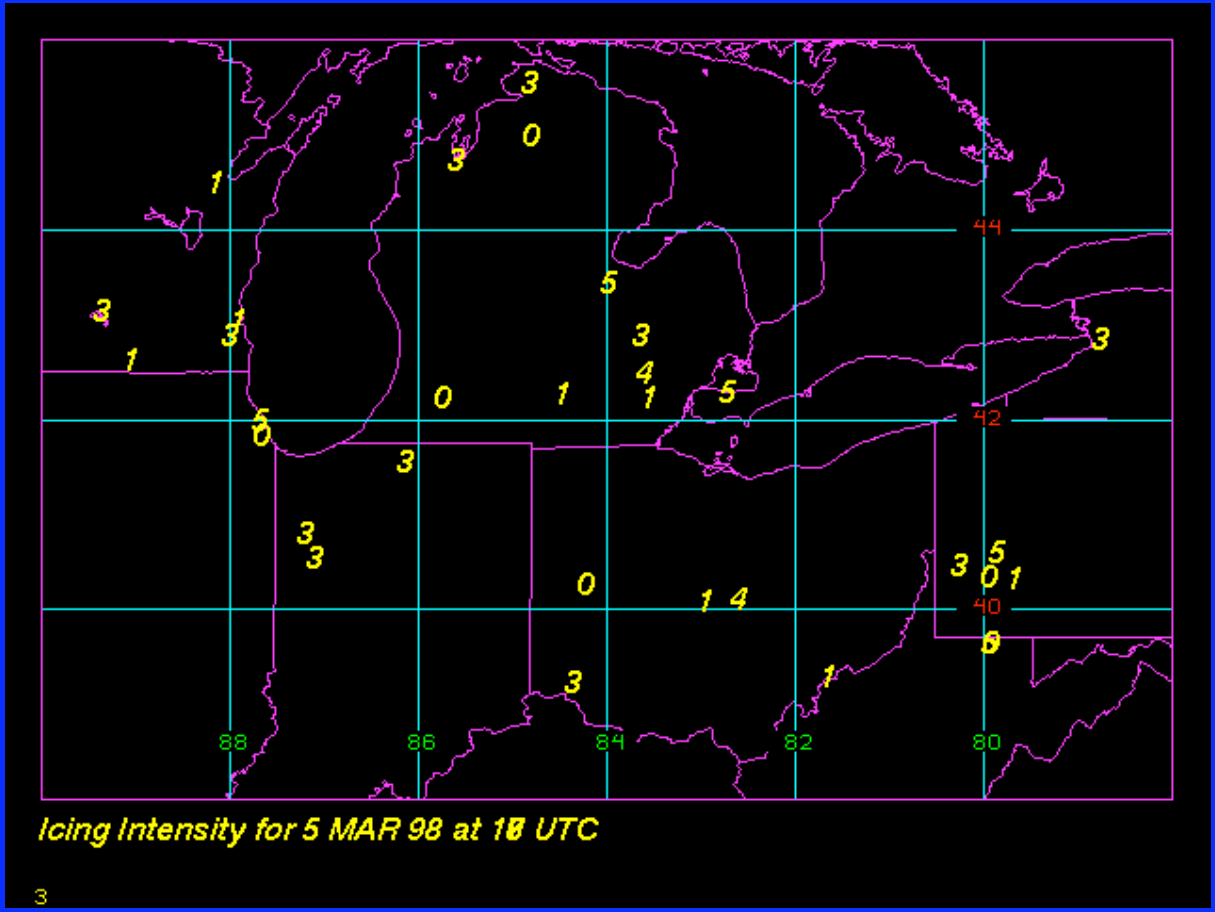
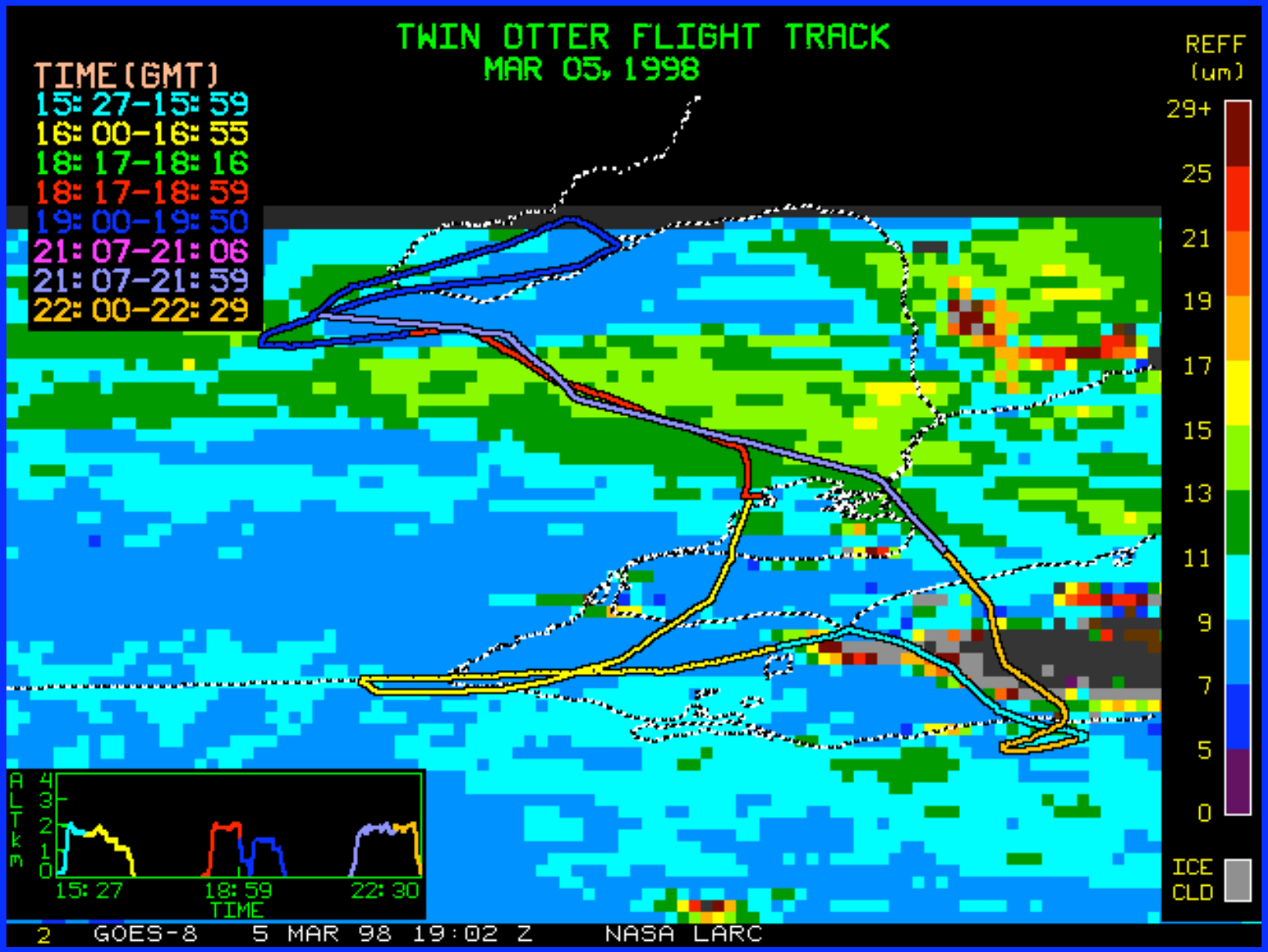
PIREP Icing Intensity
at 17-19 UTC Mar. 5, 1998



GOES Water Droplet Radius



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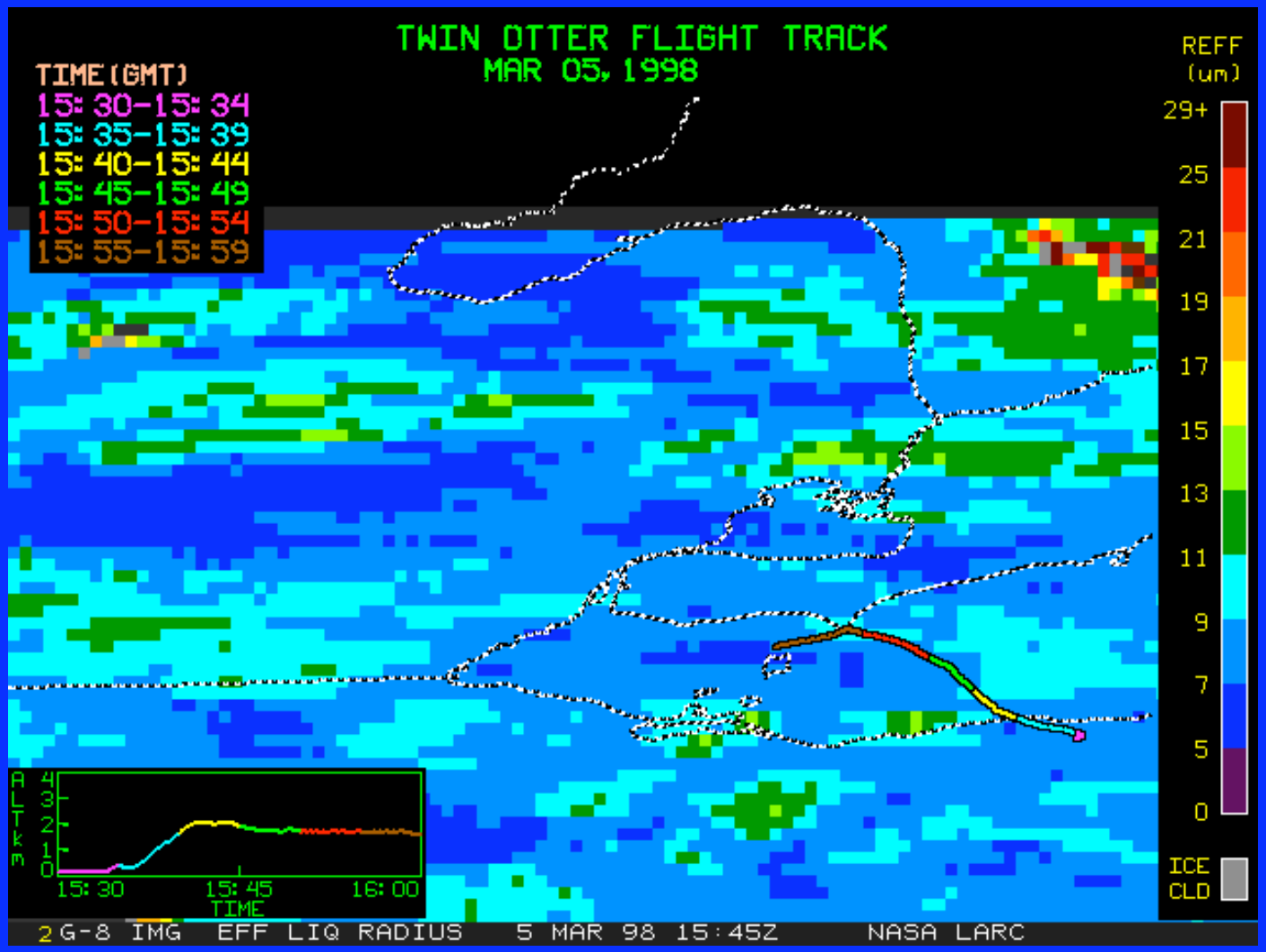
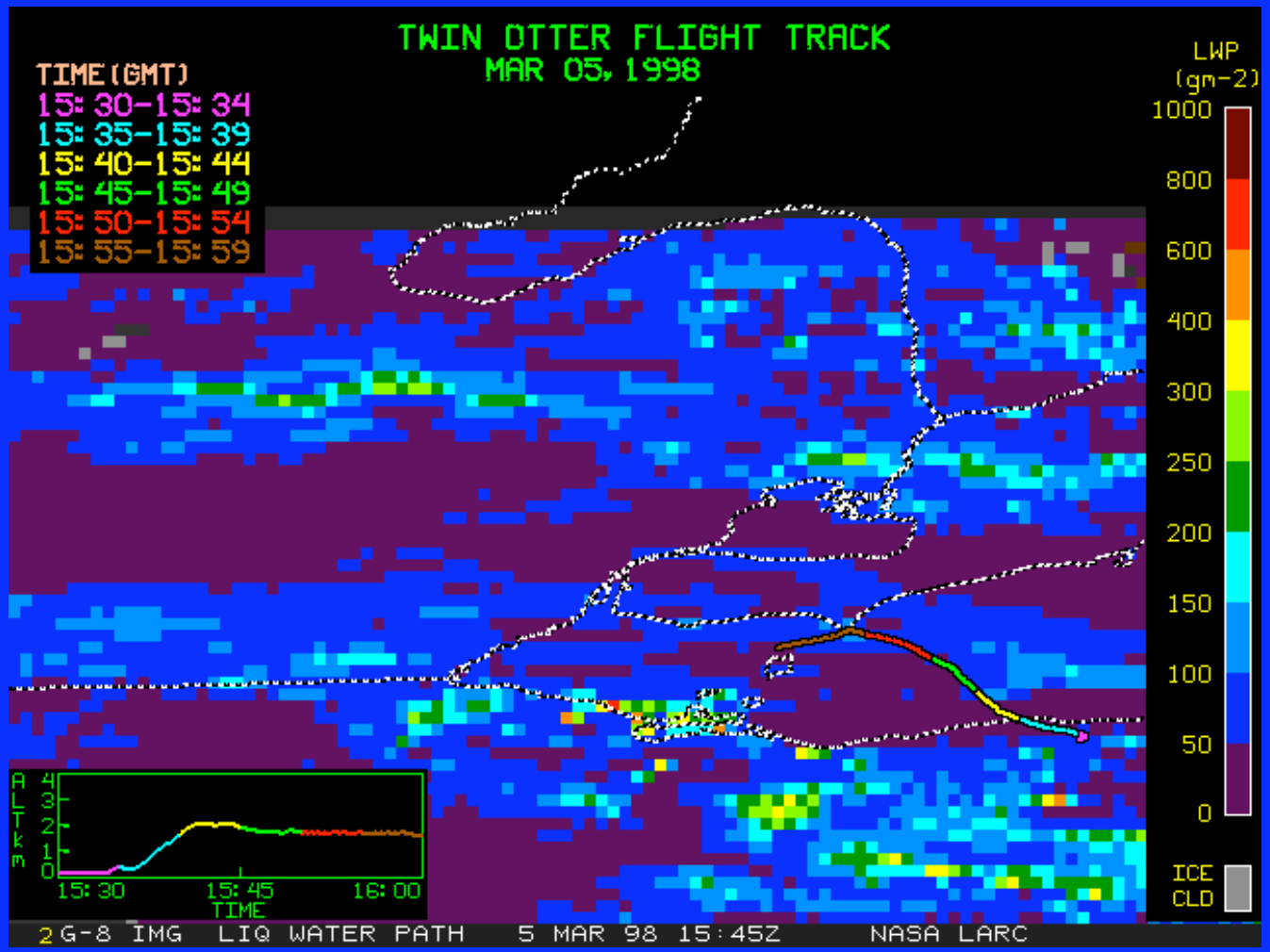
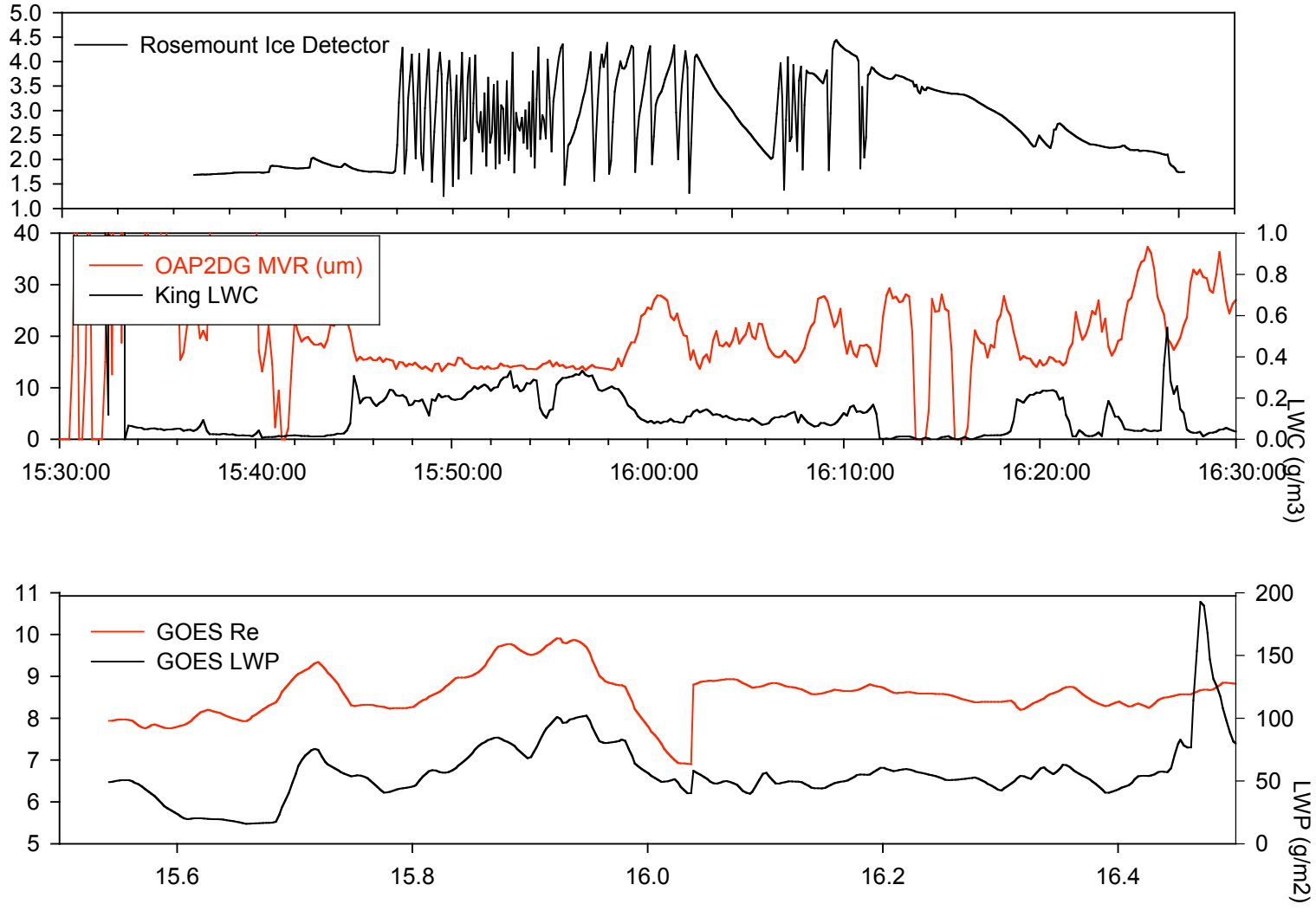


GOES Liquid Water Path



Satellite/Aircraft Comparison
March 5, 1998



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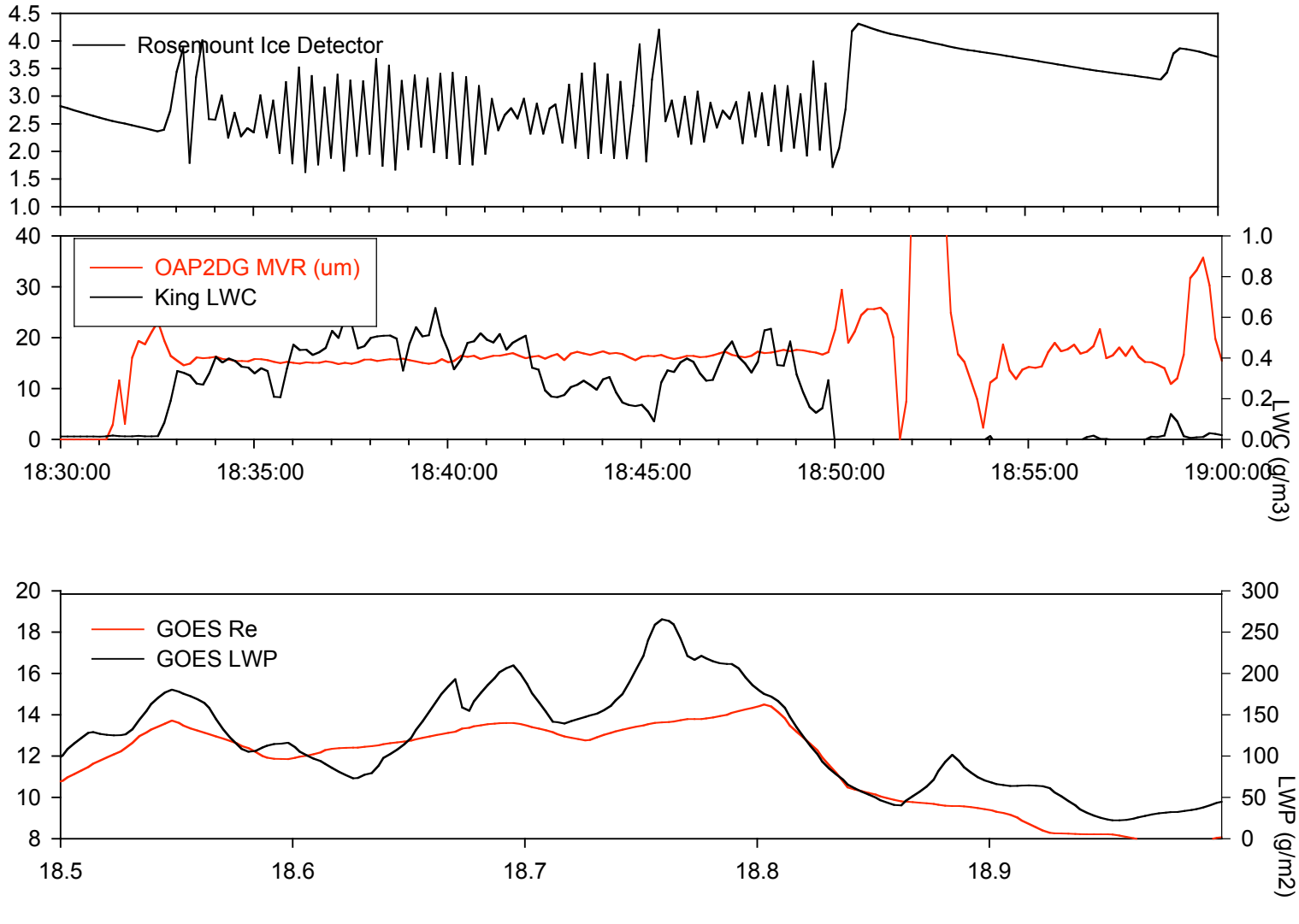

PROTOTYPE ICING CATEGORIES

value	Criteria			icing intensity
0	clear or water cloud (w/Tcld > 272 K or others) or ice cloud w/OD < 8			no ice
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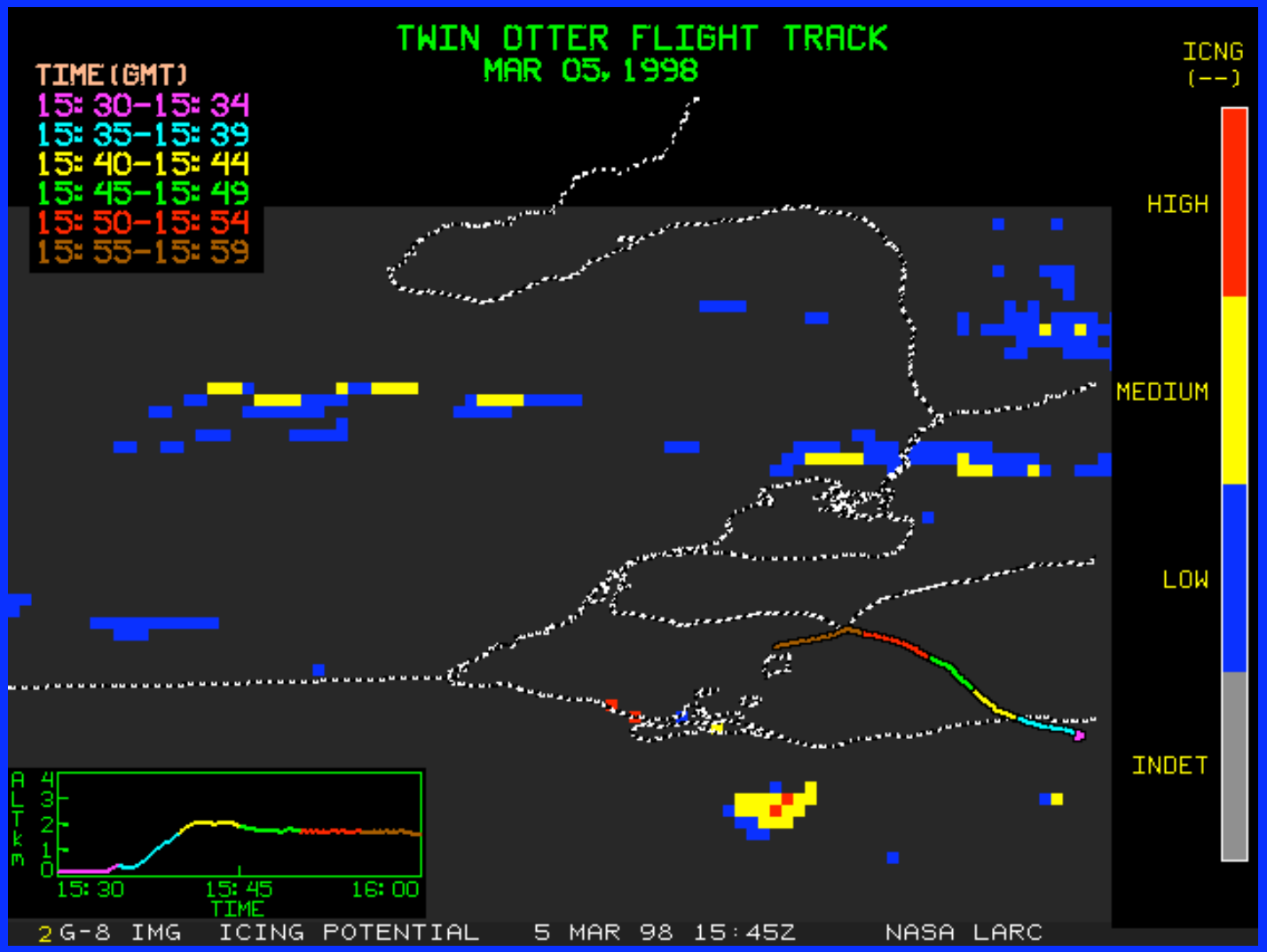
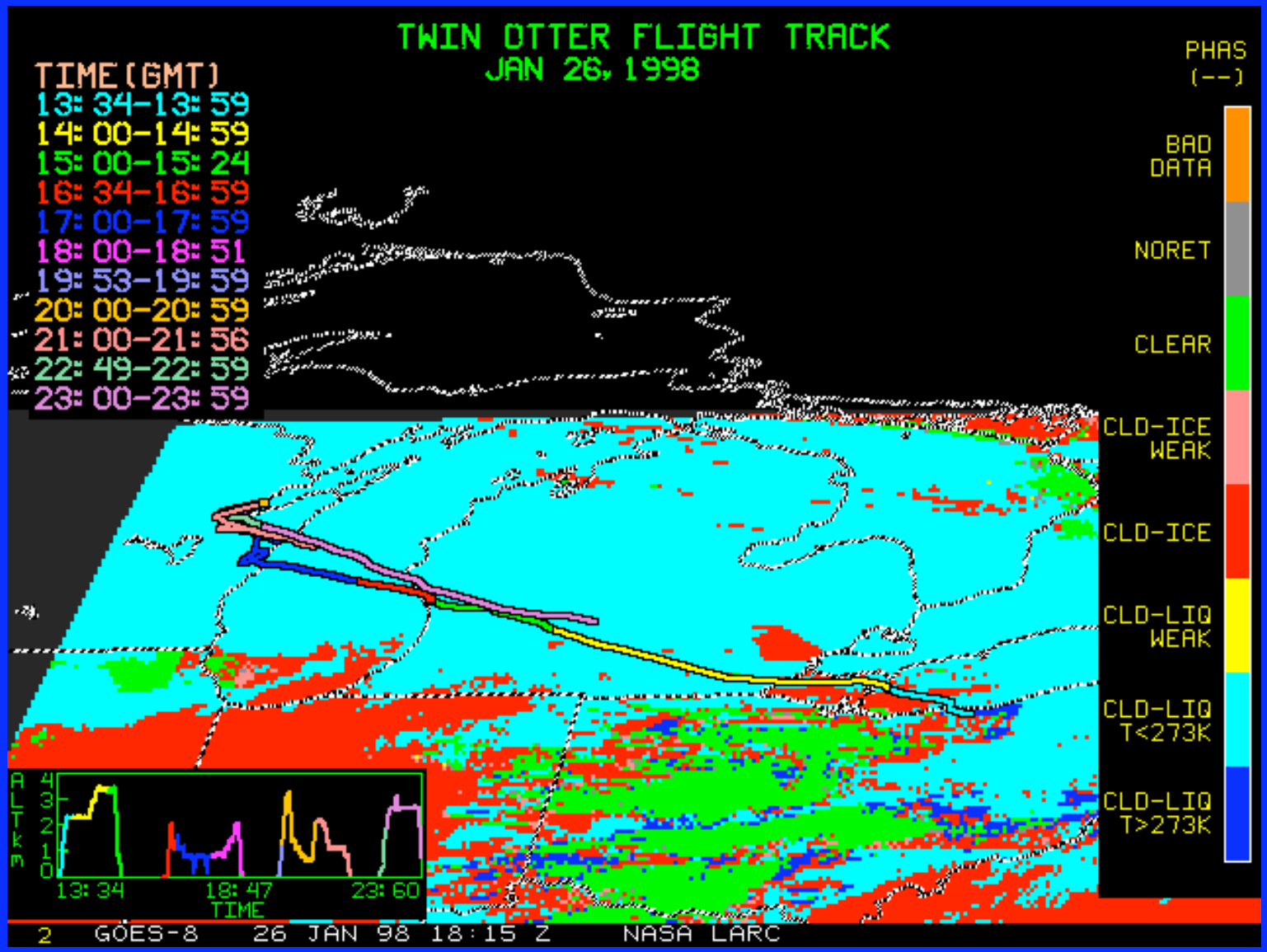
GOES ICING


TWIN OTTER FLIGHT TRACK
MAR 05, 1998
TIME(GMT)
15:30-15:34
15:35-15:39
15:40-15:44
15:45-15:49
15:50-15:54
15:55-15:59
ICNG
(--)
HIGH
MEDIUM
LOW
INDET
ALT km
4
3
2
1
0
15:30
15:45
16:00
TIME
2 G-8 IMG ICING POTENTIAL 5 MAR 98 15:45Z NASA LARC


TWIN OTTER FLIGHT TRACK
JAN 26, 1998
TIME (GMT)
13:34-13:59
14:00-14:59
15:00-15:24
16:34-16:59
17:00-17:59
18:00-18:51
19:53-19:59
20:00-20:59
21:00-21:56
22:49-22:59
23:00-23:59
PHAS
(--)
BAD DATA
NORET
CLEAR
CLD-ICE WEAK
CLD-ICE
CLD-LIQ WEAK
CLD-LIQ T<273K
CLD-LIQ T>273K
ALT km
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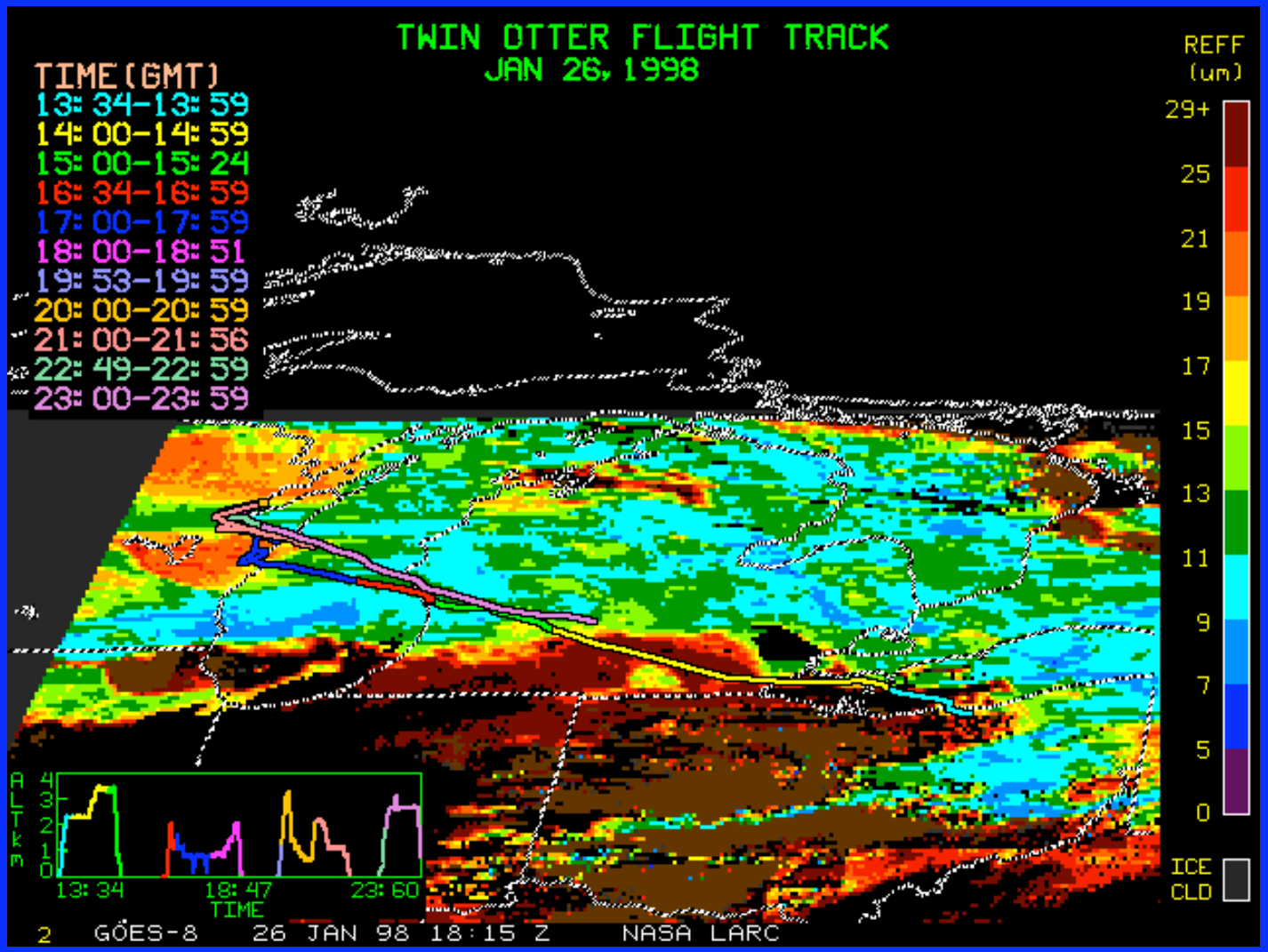
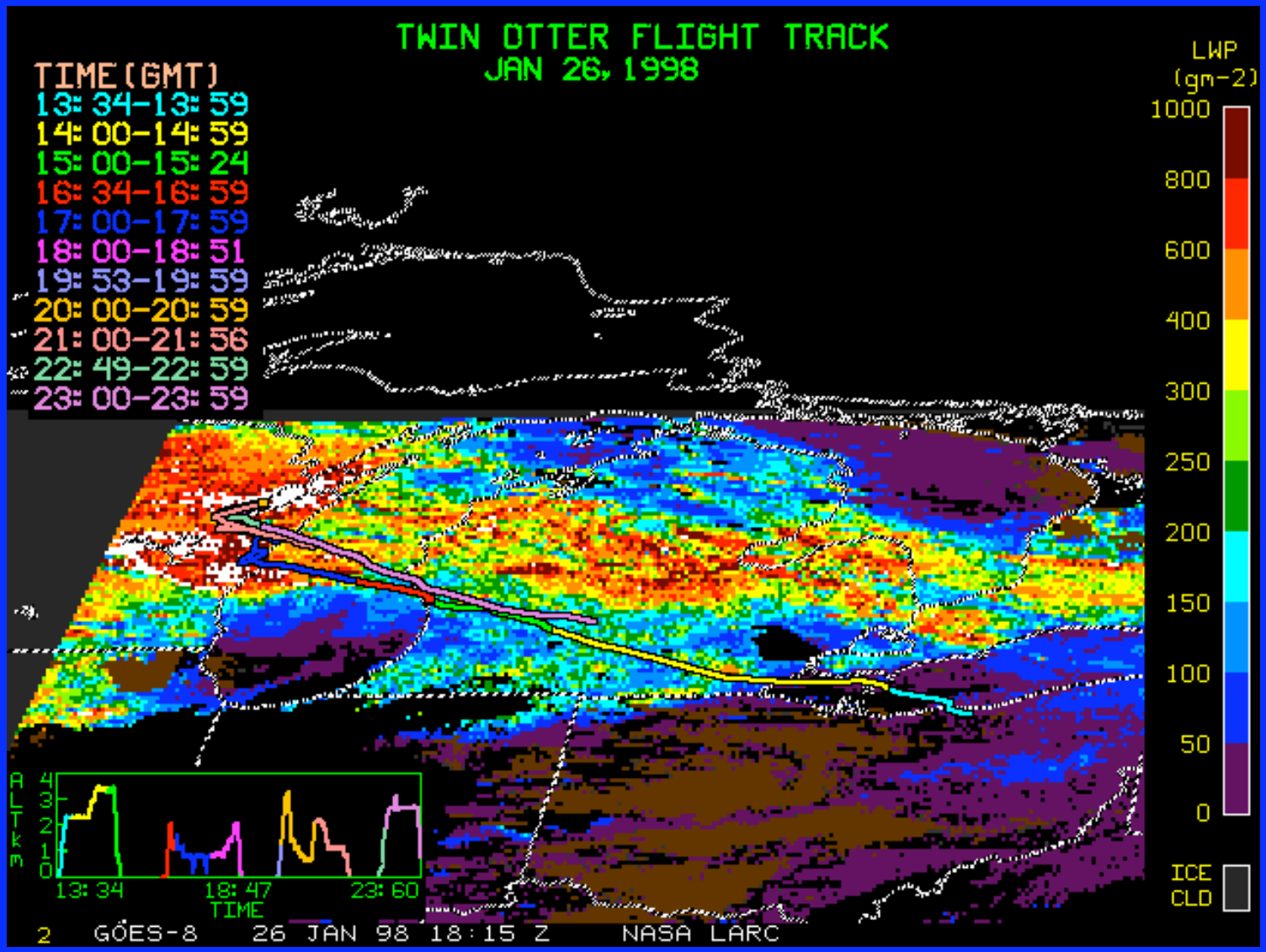
3
2
1
0
13:34
18:47
23:60
TIME
2 GOES-8 26 JAN 98 18:15 Z NASA LARC

GOES Droplet Radius



GOES LWP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JAN 26, 1998
TIME(GMT)
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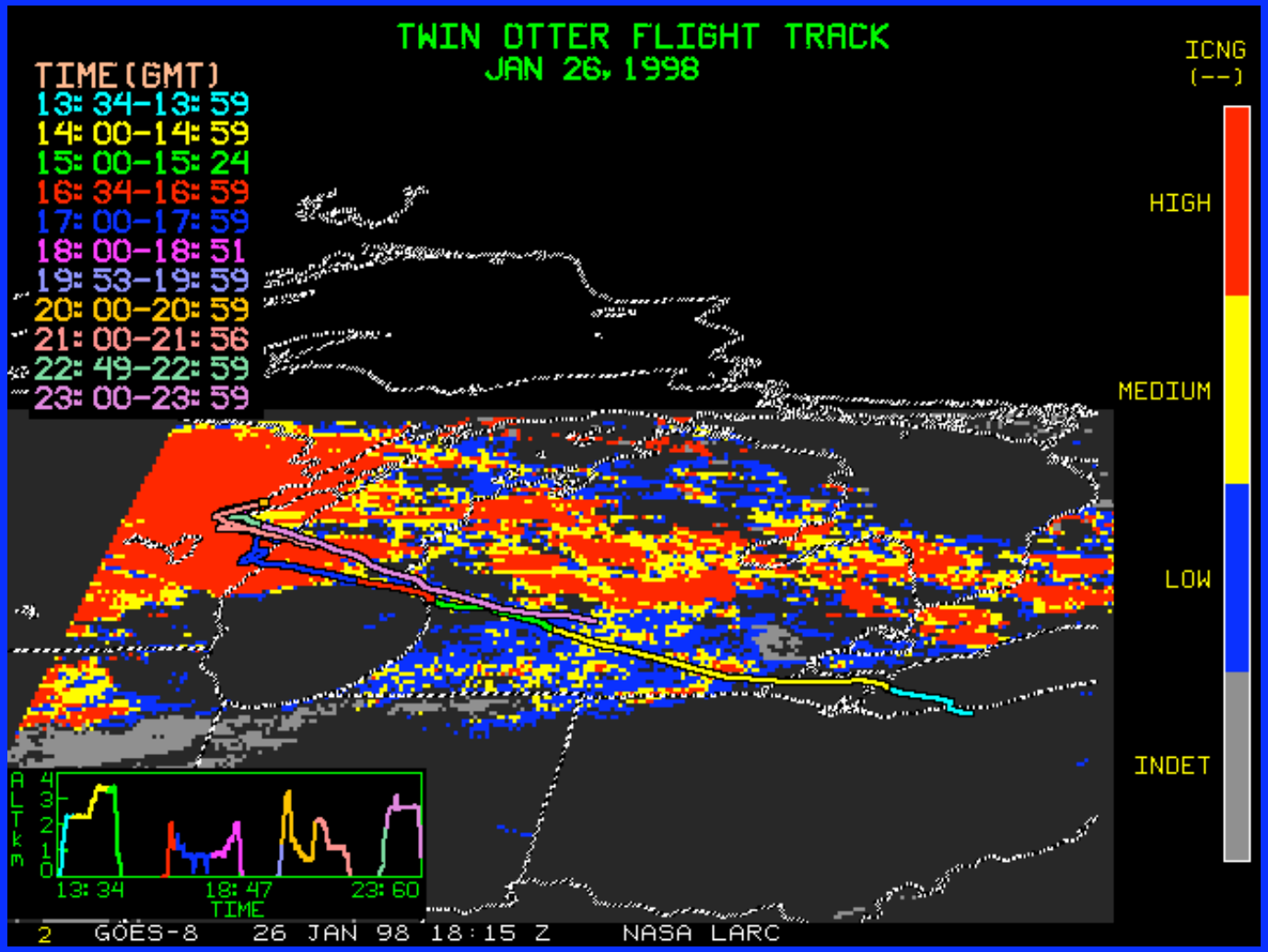
14:00-14:59
15:00-15:24
16:34-16:59
17:00-17:59
18:00-18:51
19:53-19:59
20:00-20:59
21:00-21:56
22:49-22:59
23:00-23:59
LWP
(gm-2)
1000
800
600
400
300
250
200
150
100
50
0
ICE
CLD
ALT km
4
3
2
1
0
13:34
18:47
23:60
TIME
2 GOES-8 26 JAN 98 18:15 Z NASA LARC

GOES ICING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JAN 26, 1998
TIME(GMT)
13:34-13:59
14:00-14:59
15:00-15:24
16:34-16:59
17:00-17:59
18:00-18:51
19:53-19:59
20:00-20:59
21:00-21:56
22:49-22:59
23:00-23:59
ICNG
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HIGH
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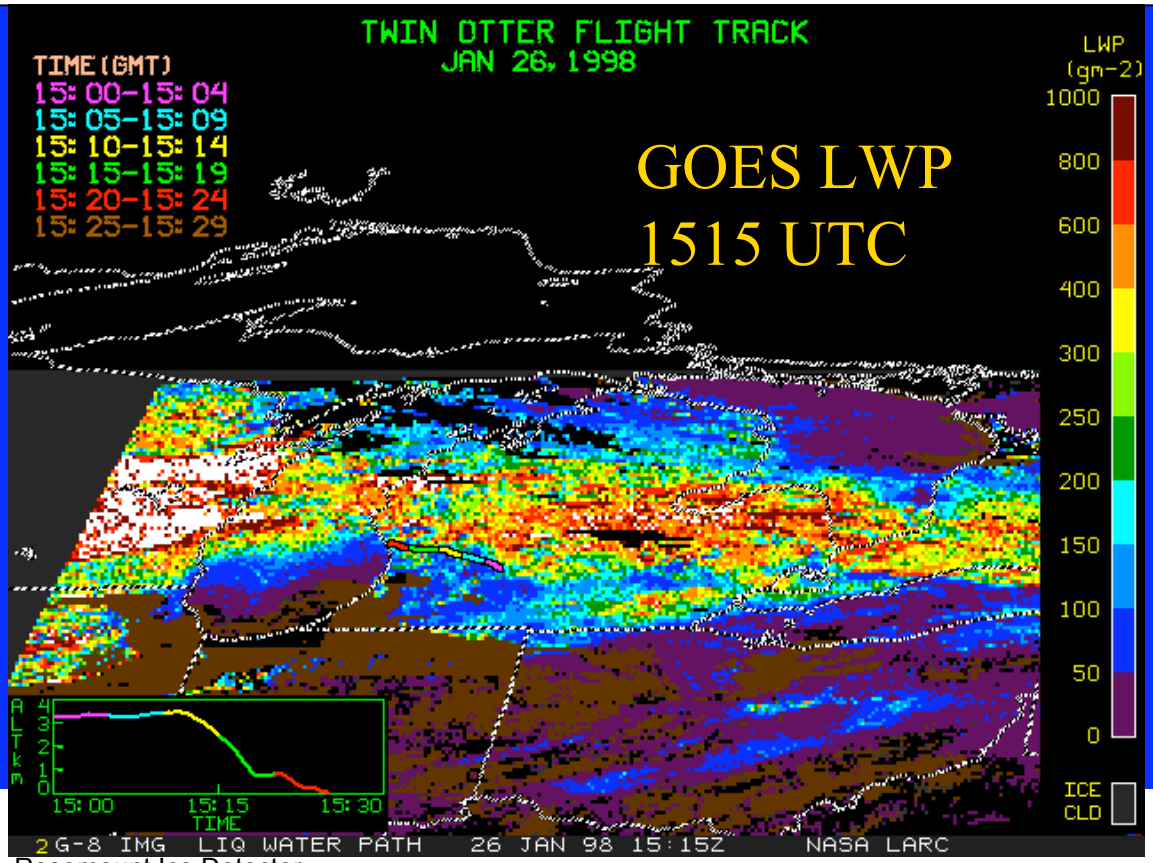
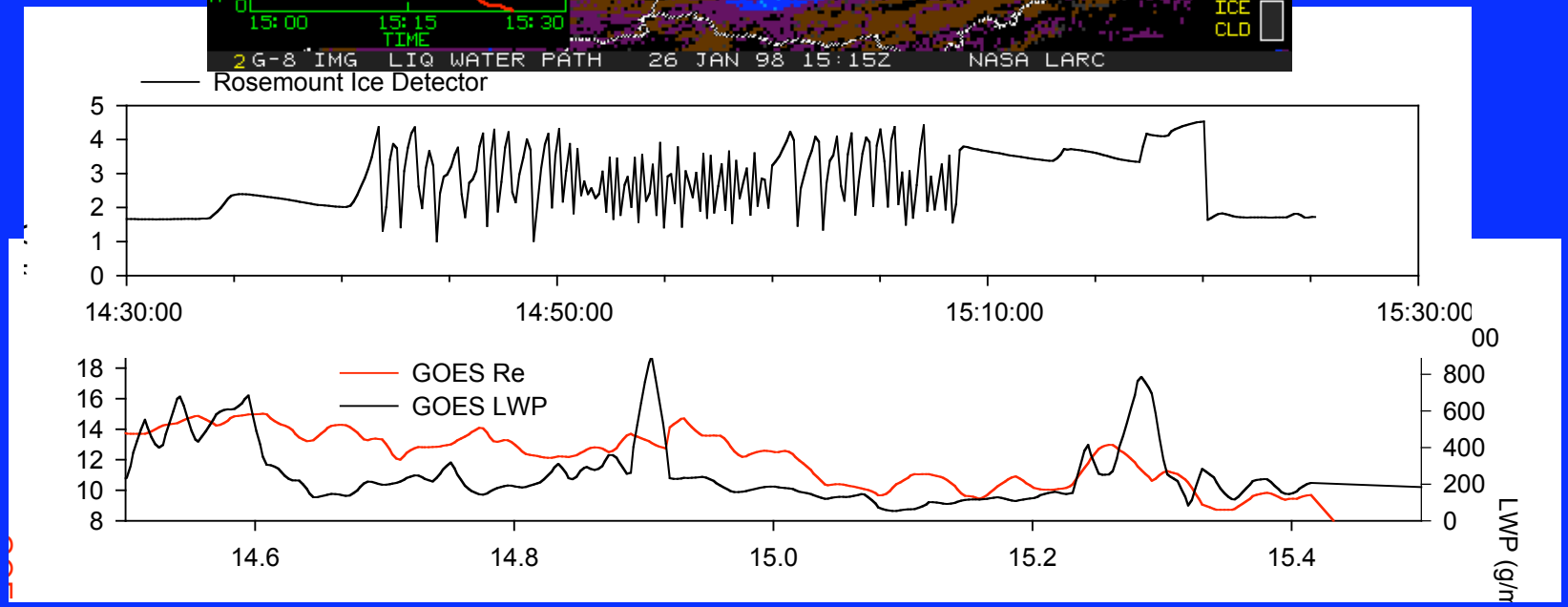
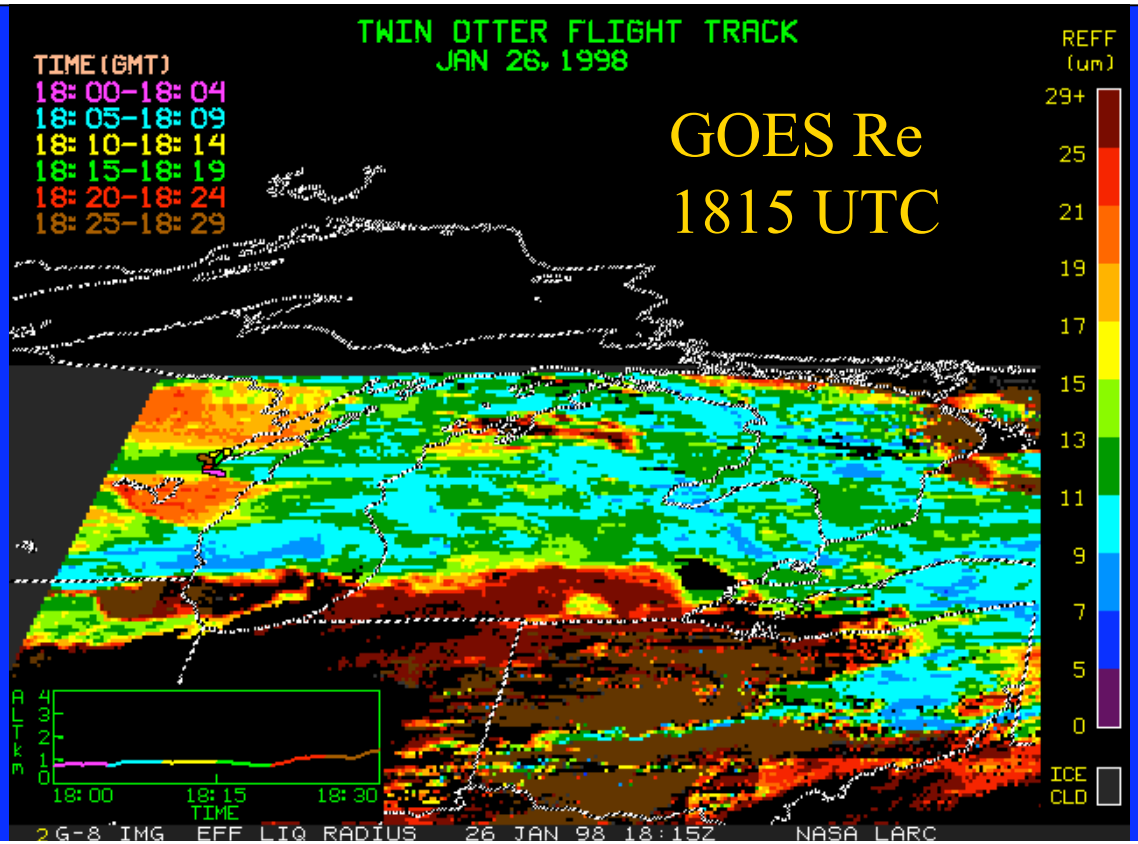
13:34
18:47
23:60
TIME
2 GOES-8 26 JAN 98 18:15 Z NASA LARC


TWIN OTTER FLIGHT TRACK
JAN 26, 1998
TIME(GMT)
15:00-15:04
15:05-15:09
15:10-15:14
15:15-15:19
15:20-15:24
15:25-15:29
GOES LWP
1515 UTC
LWP (gm-2)
1000
800
600
400
300
250
200
150
100
50
0
ICE CLD
ALT km
15:00
15:15
15:30
TIME
2G-8 IMG LIQ WATER PATH 26 JAN 98 15:15Z NASA LARC


Rosemount Ice Detector
5
4
3
2
1
0
14:30:00
14:50:00
15:10:00
15:30:00
GOES Re
GOES LWP
18
16
14
12
10
8
14.6
14.8
15.0
15.2
15.4
800
600
400
200
0
LWP (g/m


TWIN OTTER FLIGHT TRACK
JAN 26, 1998
TIME(GMT)
18:00-18:04
18:05-18:09
18:10-18:14
18:15-18:19
18:20-18:24
18:25-18:29
GOES Re
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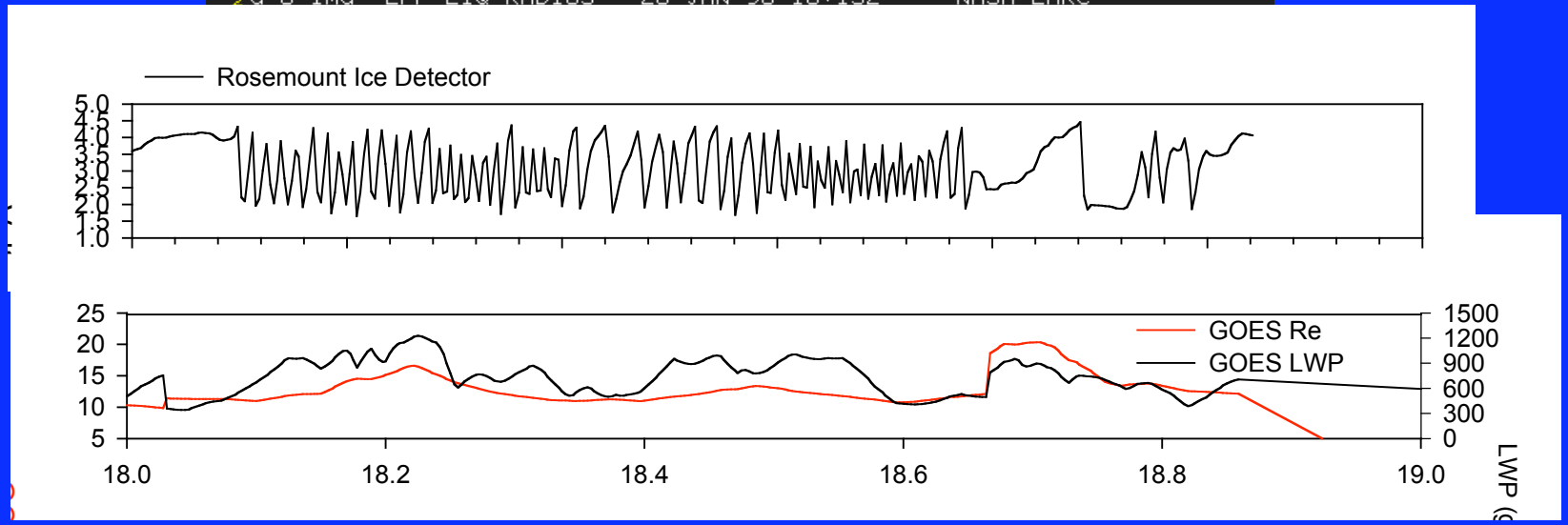
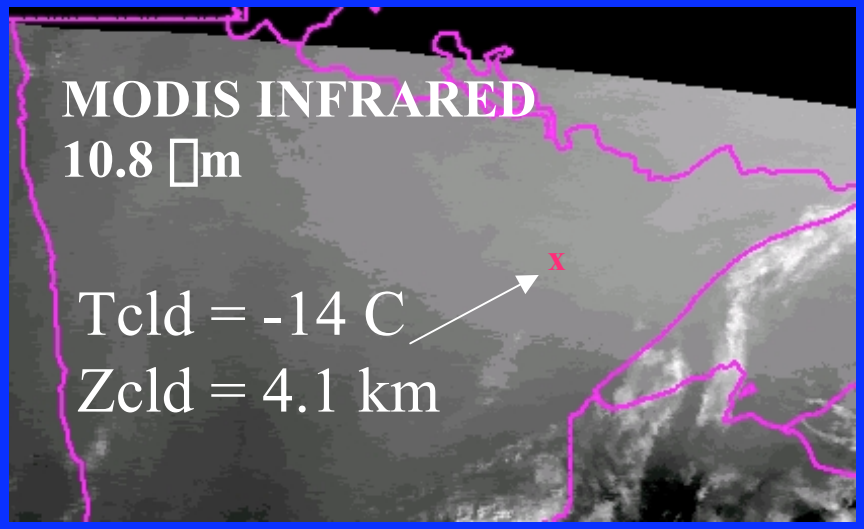
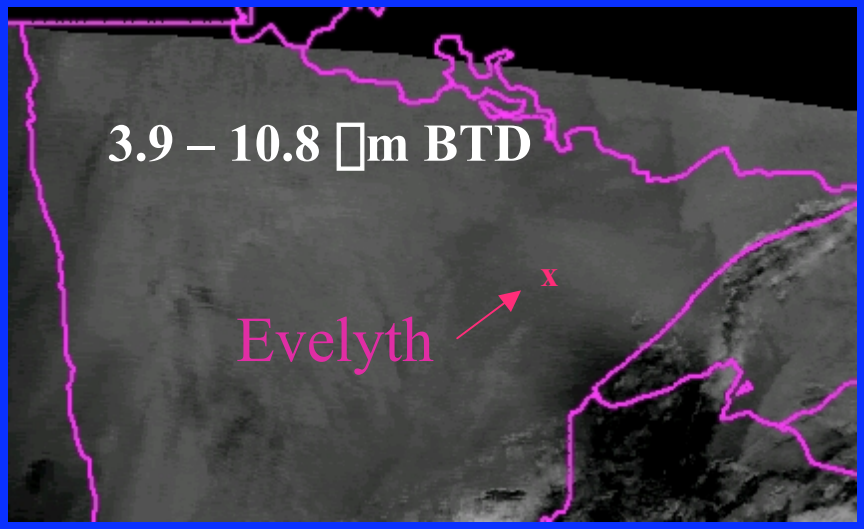
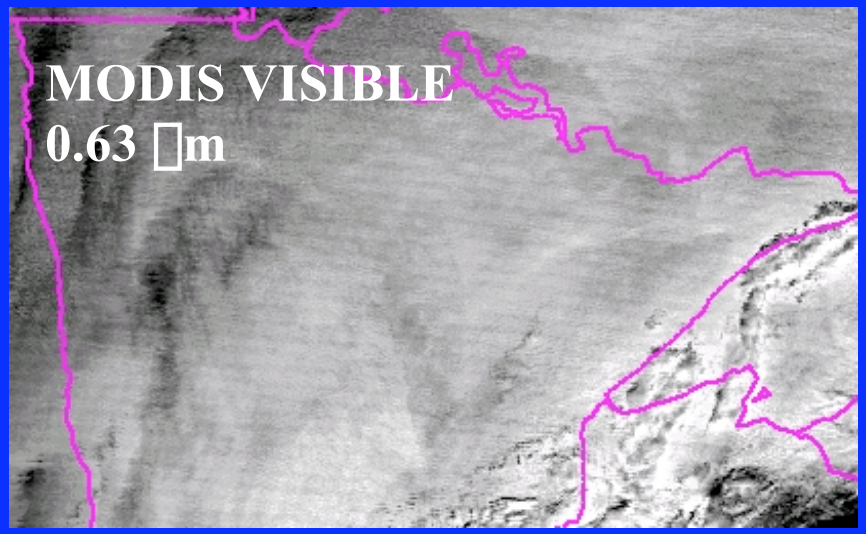
18:15
18:30
TIME
2 G-8 IMG EFF LIQ RADIUS 26 JAN 98 18:15Z NASA LARC

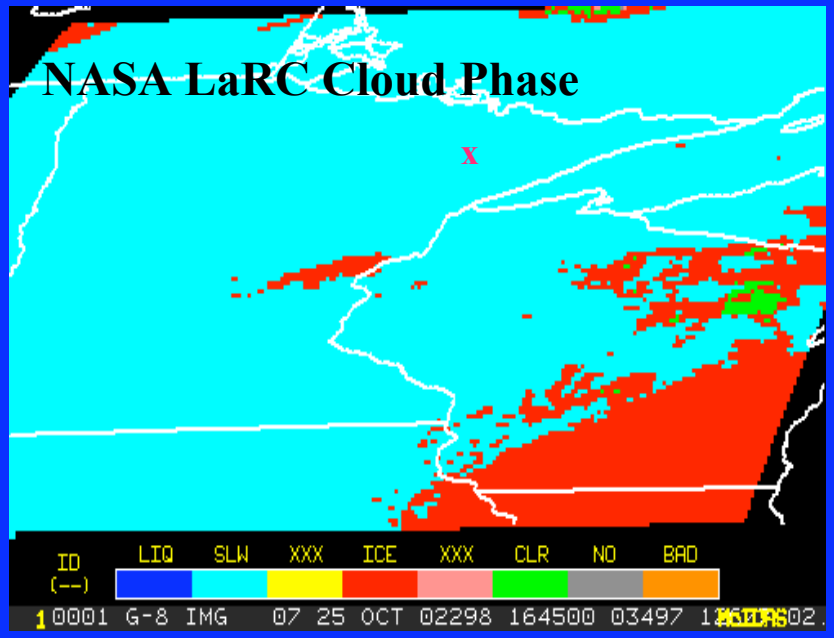

Rosemount Ice Detector
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
GOES Re
GOES LWP
25
20
15
10
5
1500
1200
900
600
300
0
18.0
18.2
18.4
18.6
18.8
19.0
LWP (g

Evelyth, Minn. King Air Crash
Oct 25, 2002 at 1645 UTC









Evelyth, Minn. King Air Crash
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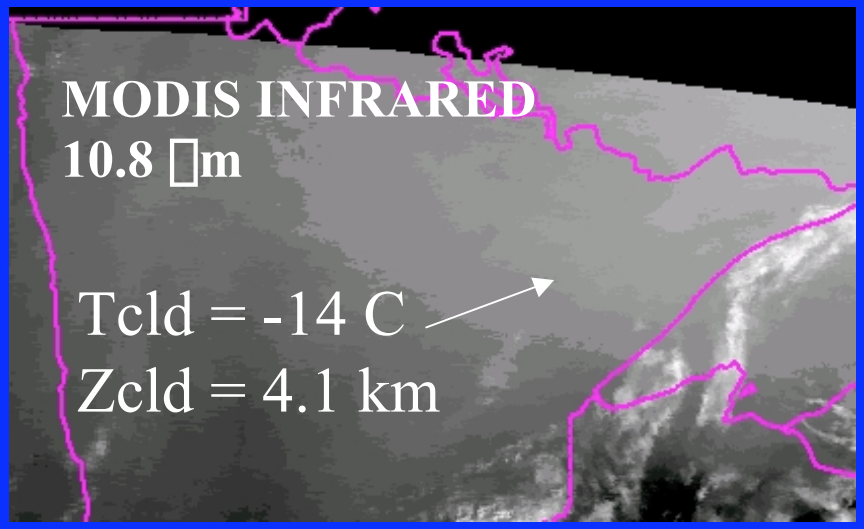
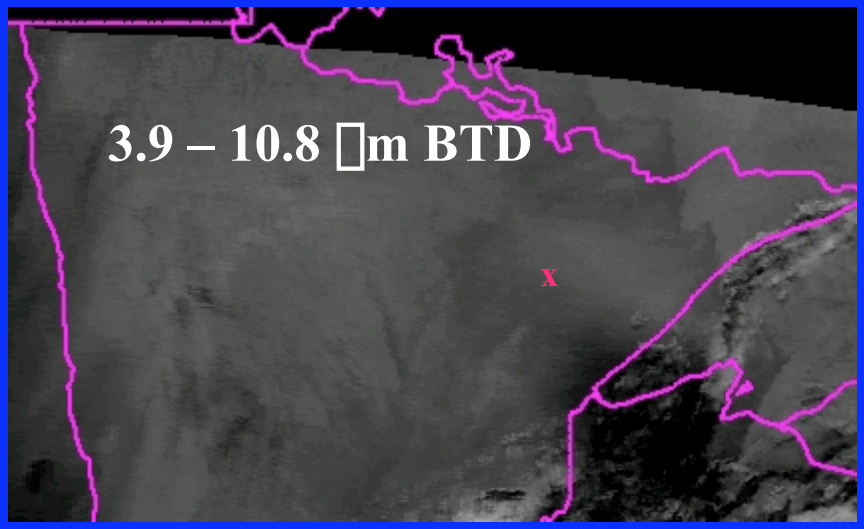
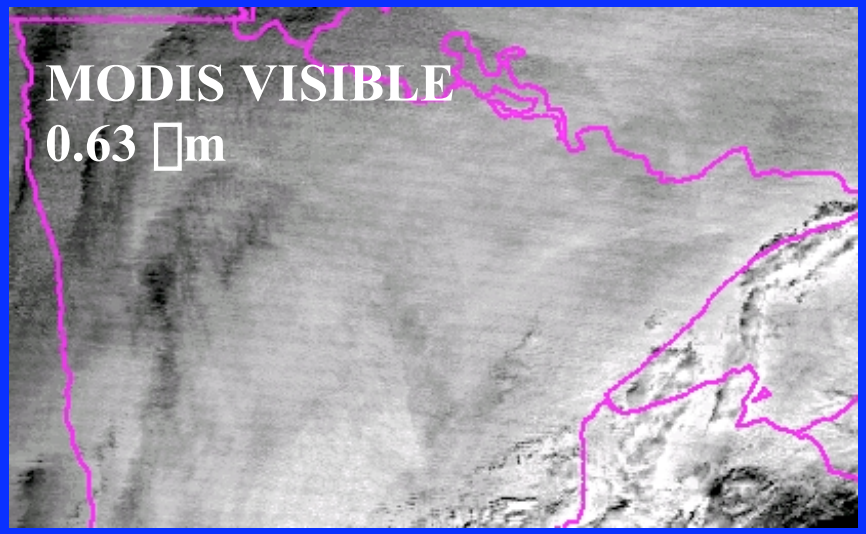
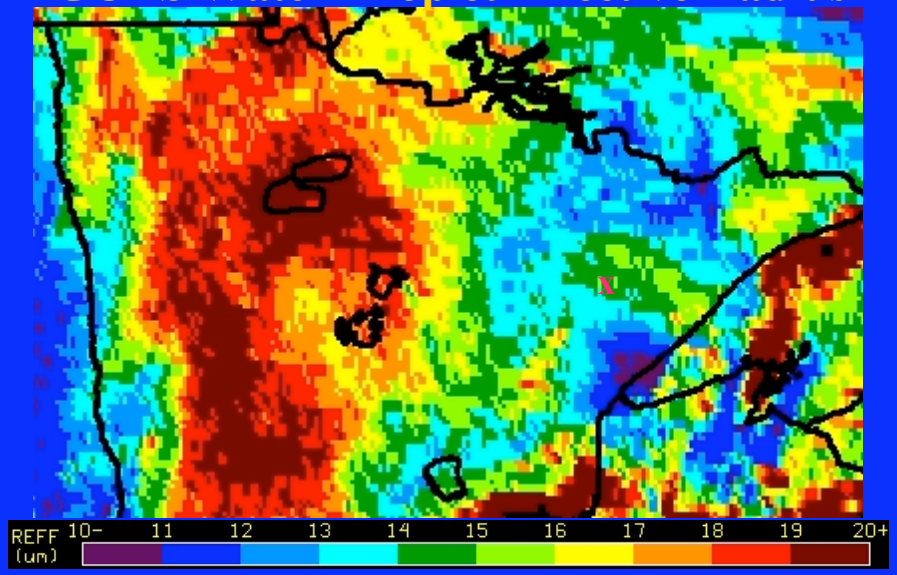






GOES Water Droplet Effective Radius

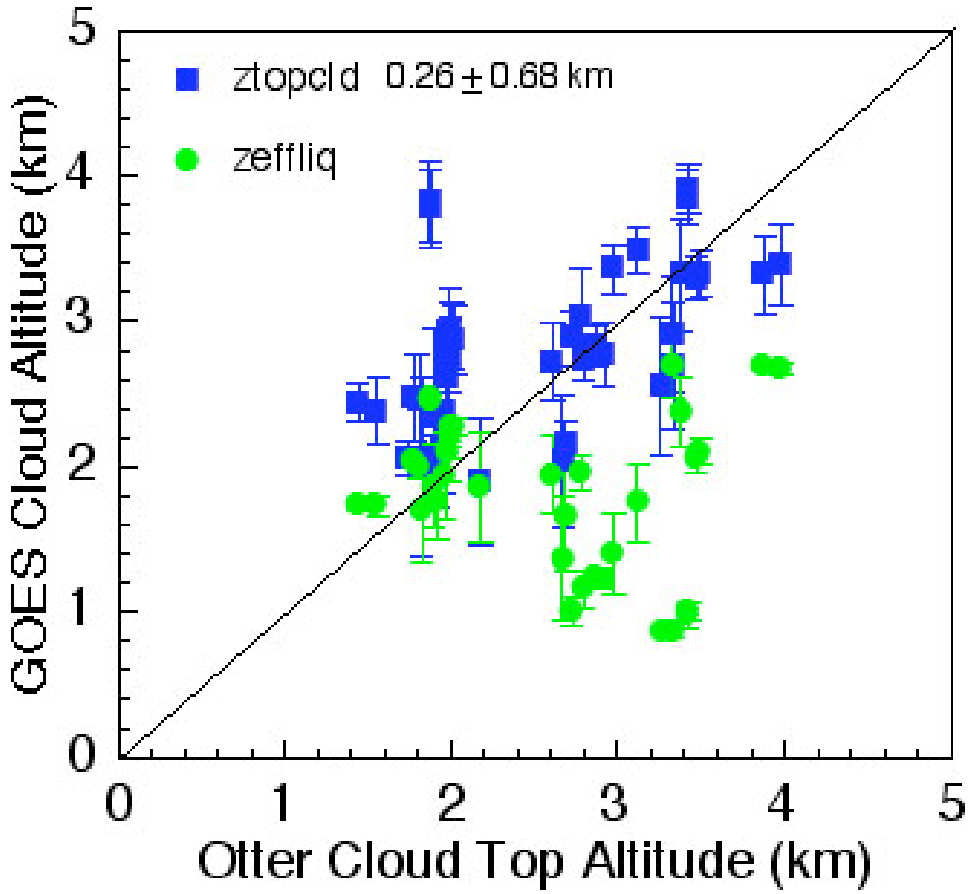


Cloud Height Comparisons 1997-98

Twin Otter Icing Flights vs GOES Lapse Rate Method

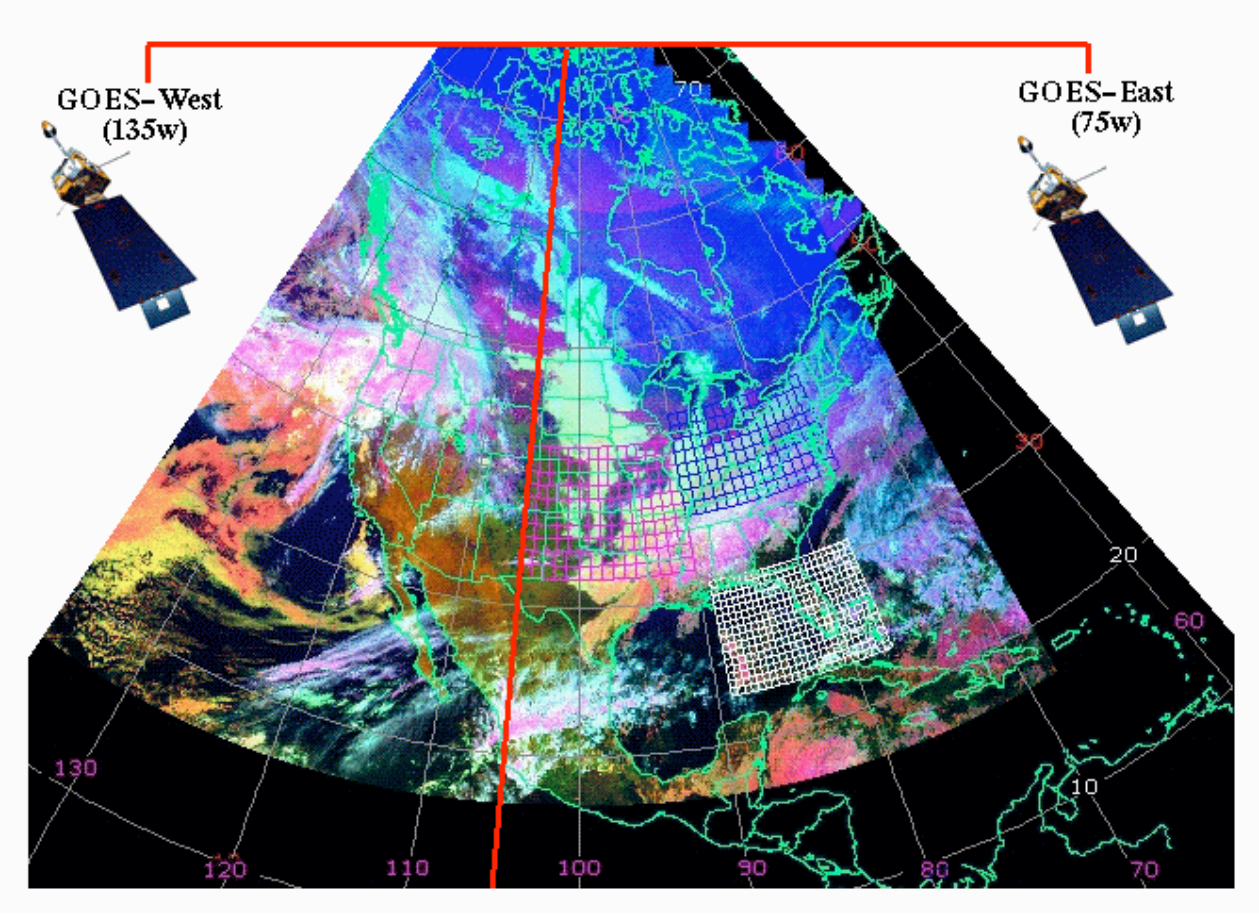
ztopcld = estimated height of all cloud in view

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

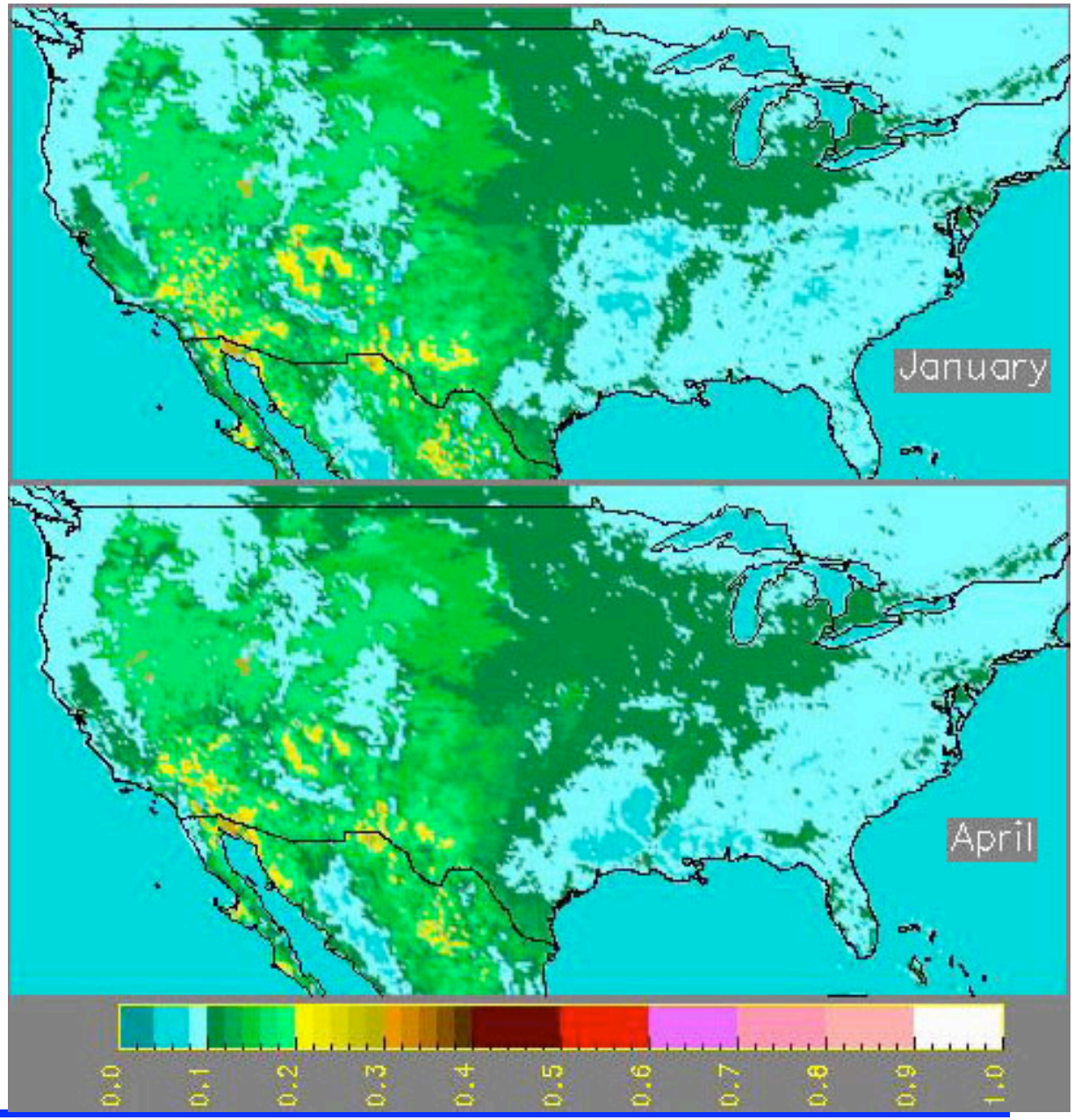
- **Focus on GOES-East (50°W - 105°W)**
  - **Develop ingest system for model & satellite input**
  - **Size the problem for computer processing**
  - **Provide products online (graphical & digital)**
  - **Make alterations for new channel (13.5 μm)**

- **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

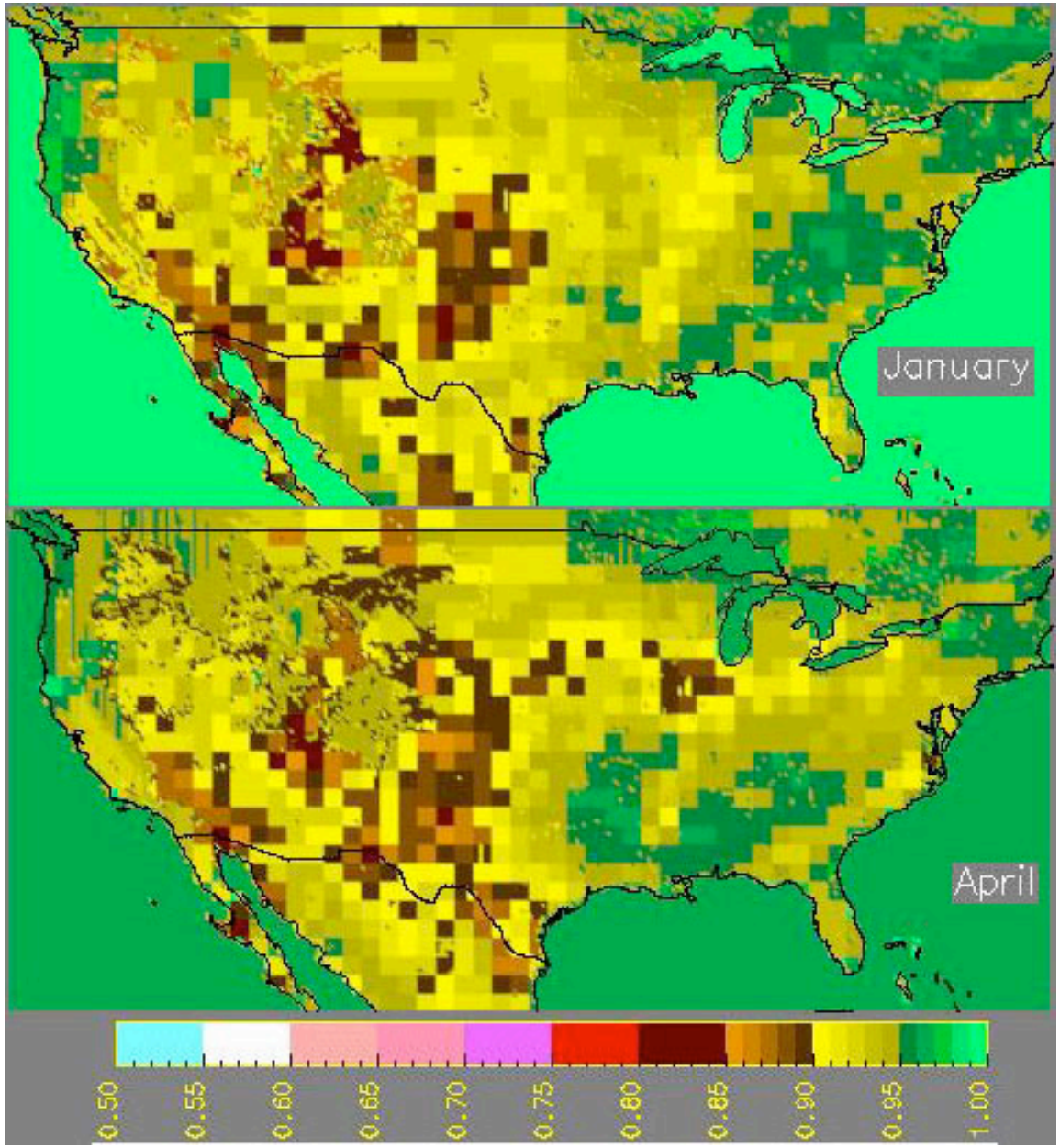
GOES Visible Channels Have Slightly Different Wavelengths Requiring Refinement for Future GOES Applications



Initial 3.7-μm Surface Emissivities for CONUS Cloud Analysis

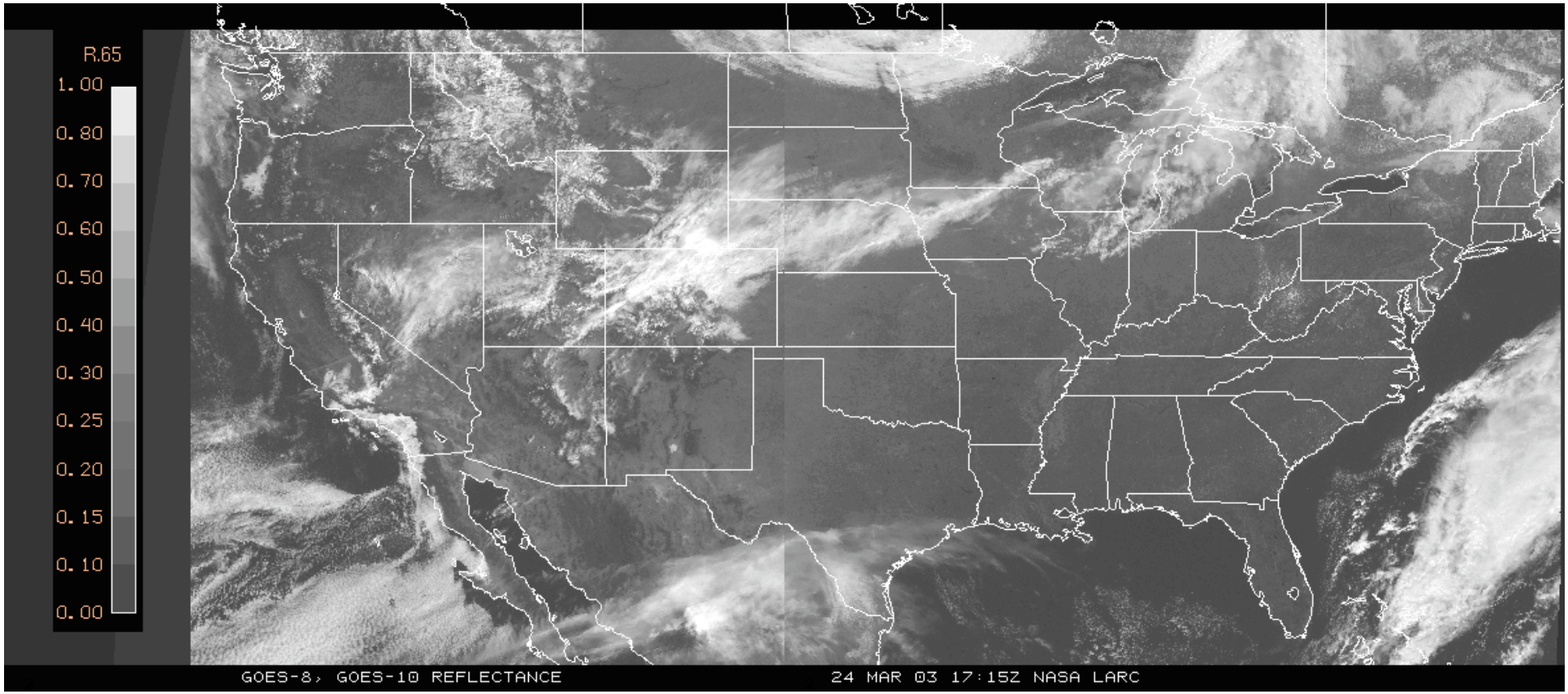
Derived From AVHRR Data by CERES Project

GOES Solar Infrared Channel Has Different Wavelength (3.9 μm) Requiring Refinement for Future GOES Applications



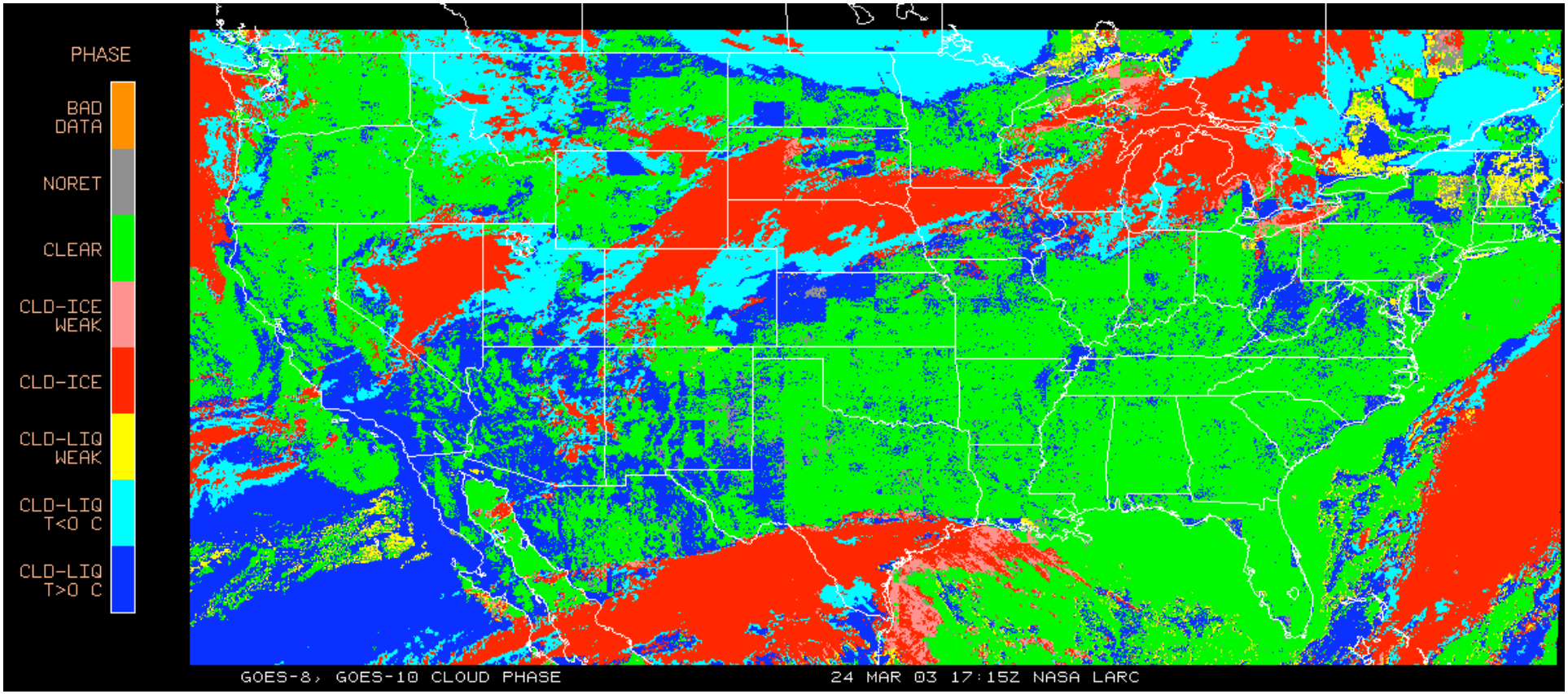
Combined GOES-8 & GOES-10 CONUS Imagery

Visible Channel, 24 March 2003, 1715 UTC



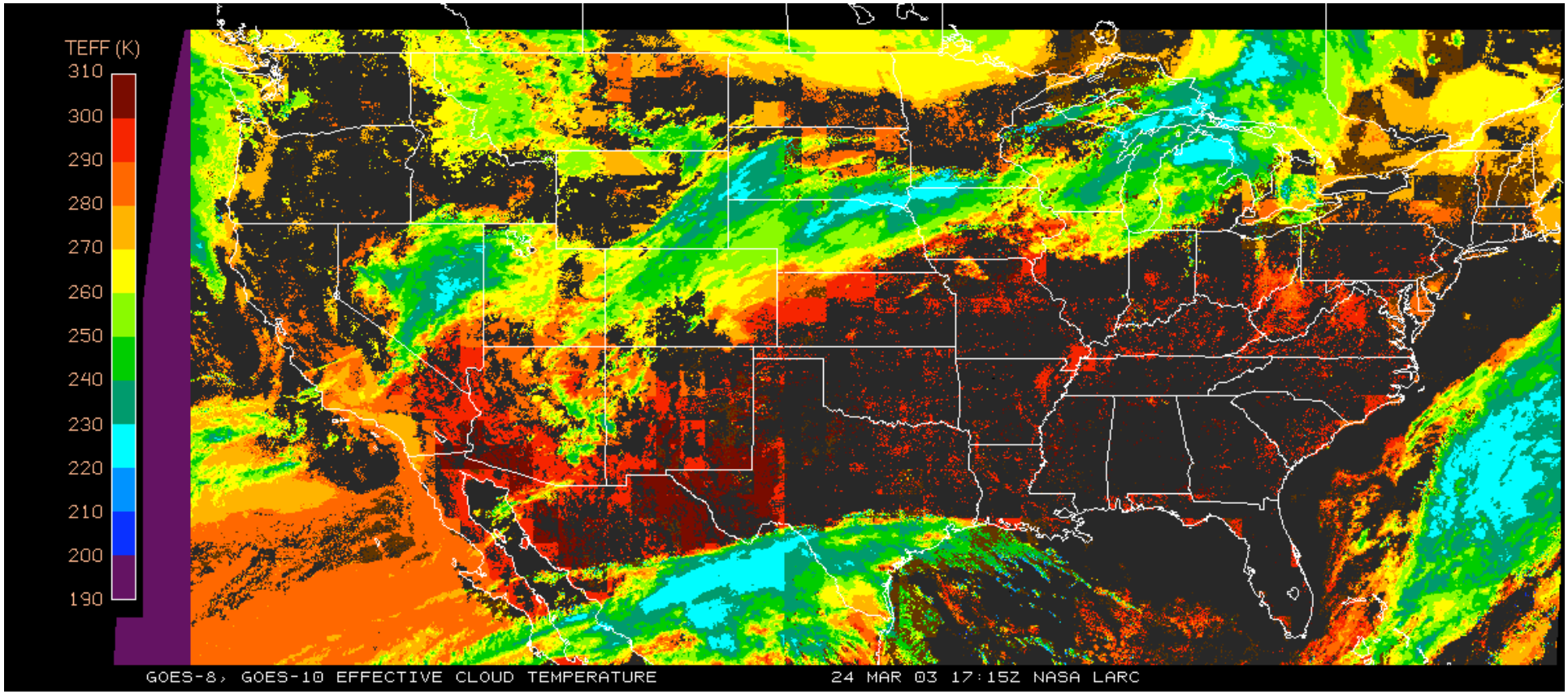
Combined GOES-8 & GOES-10 CONUS Cloud Mask

24 March 2003, 1715 UTC



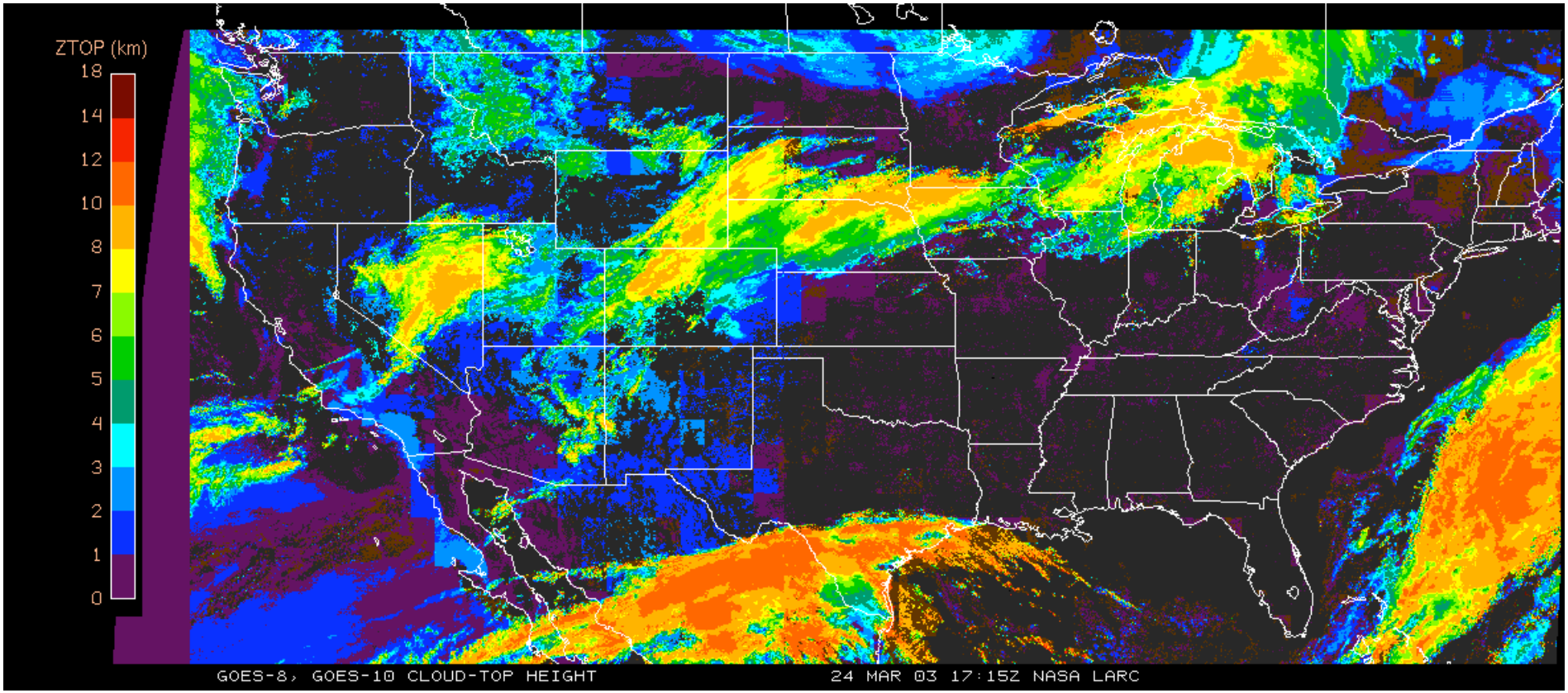
Combined GOES-8 & GOES-10 CONUS Cloud Temperature

24 March 2003, 1715 UTC



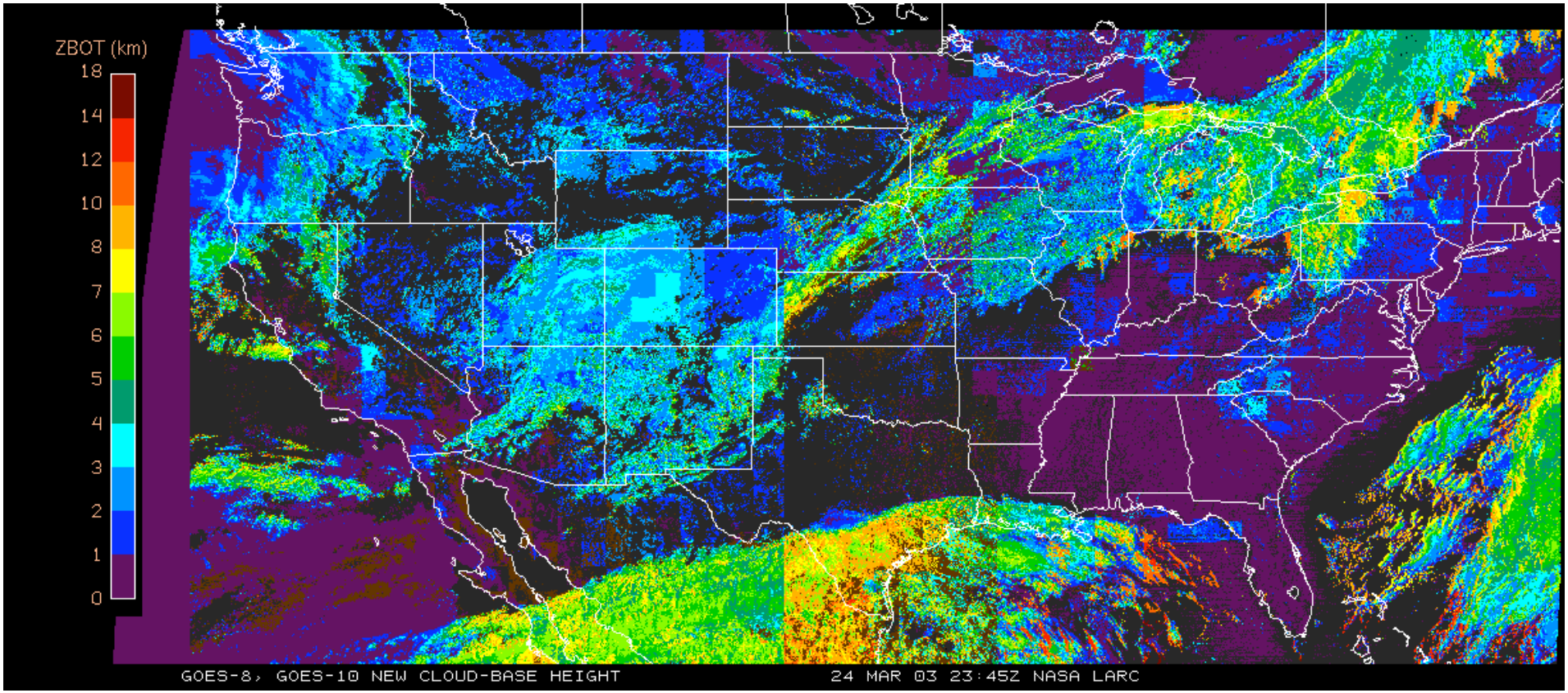
Combined GOES-8 & GOES-10 CONUS Cloud Top Altitude

24 March 2003, 1715 UTC



Combined GOES-8 & GOES-10 CONUS Cloud Base Altitude

24 March 2003, 1715 UTC



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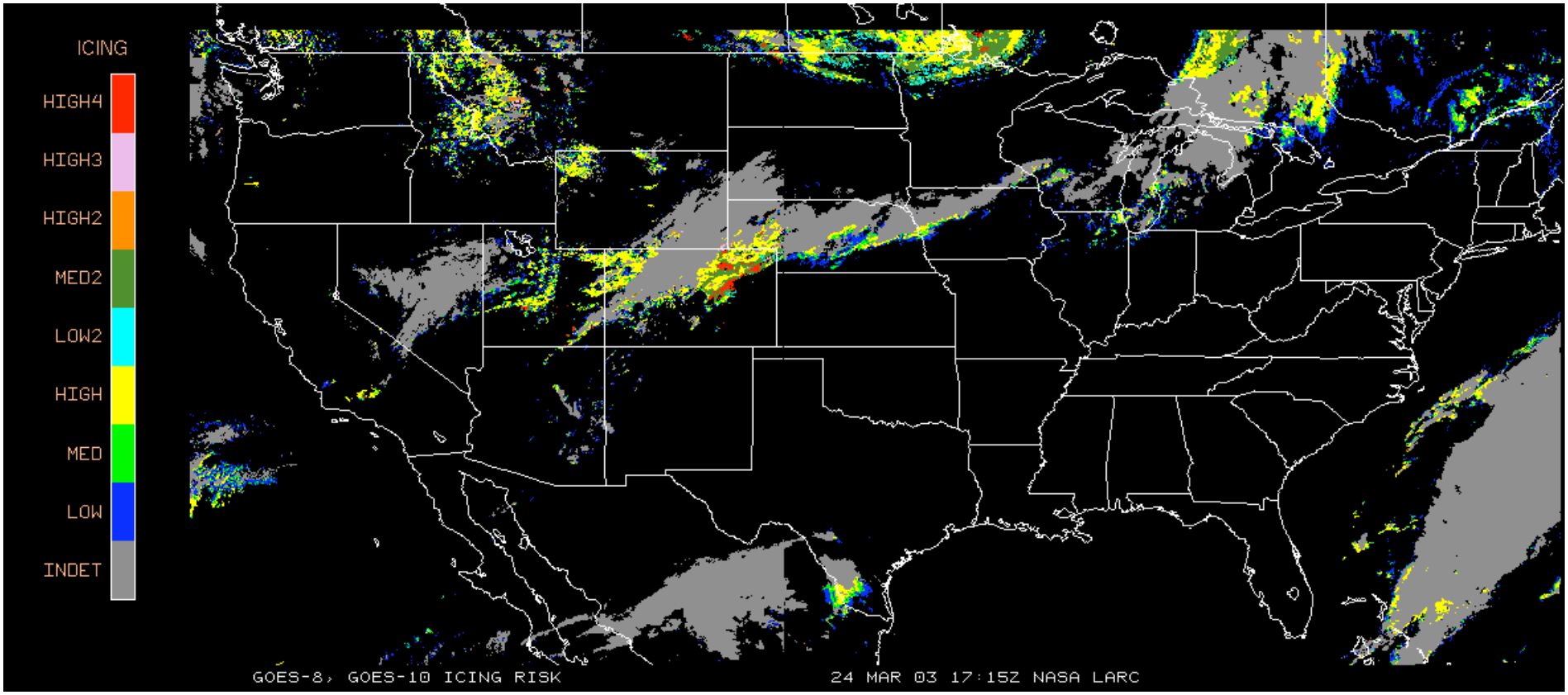
Combined GOES-8 & GOES-10 CONUS Icing Category

24 March 2003, 1715 UTC

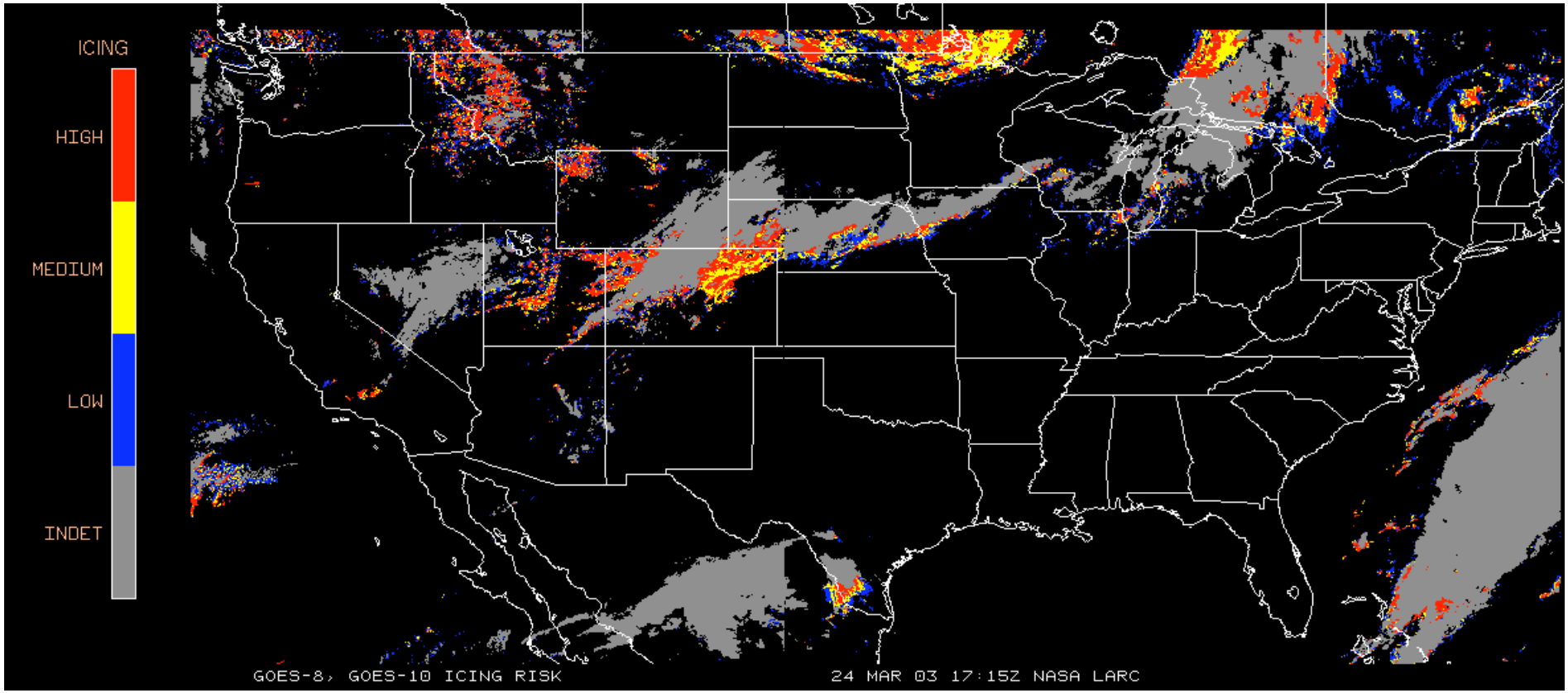
PROTOTYPE



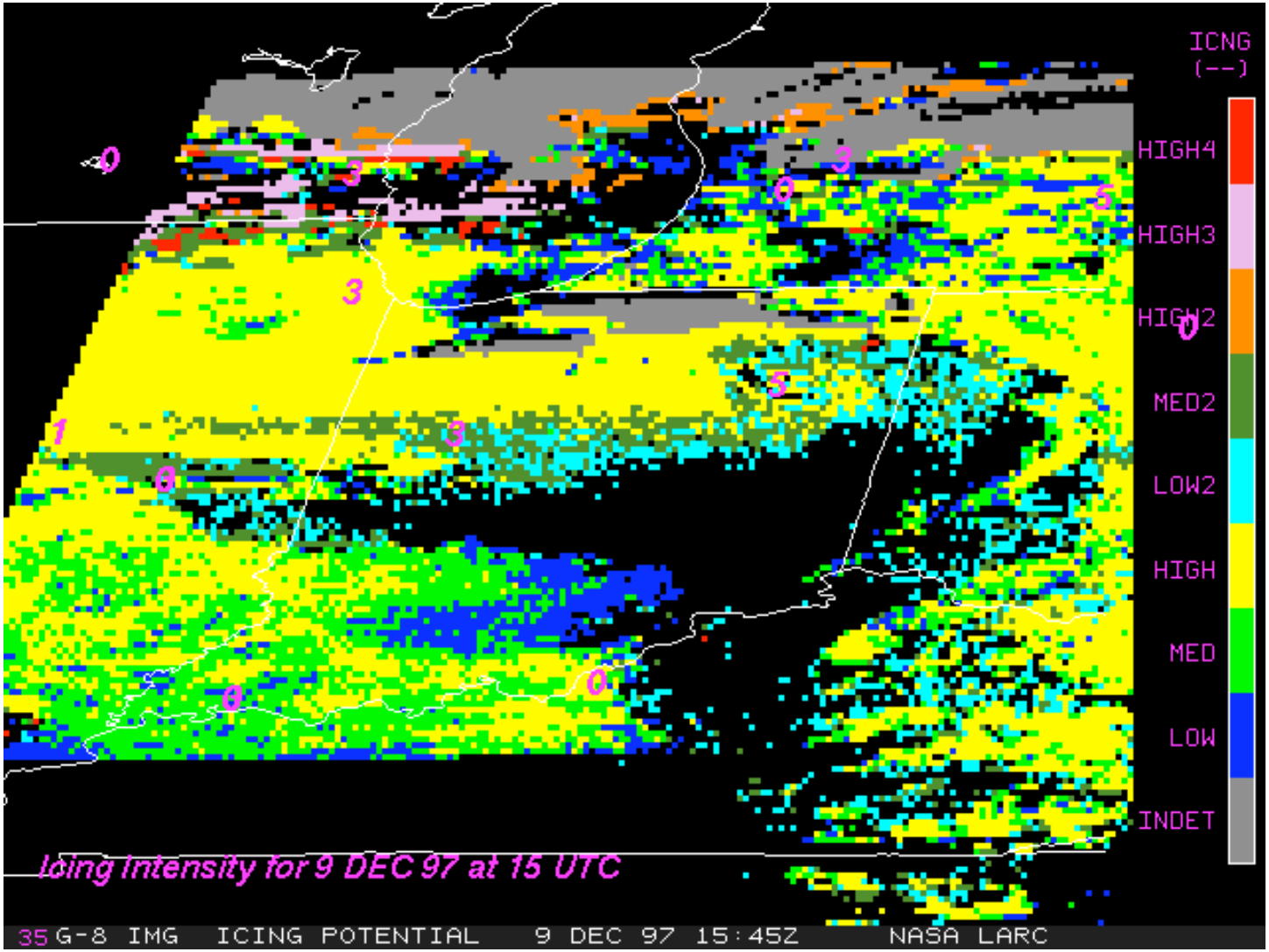
Combined GOES-8 & GOES-10 CONUS Icing Probability

24 March 2003, 1715 UTC

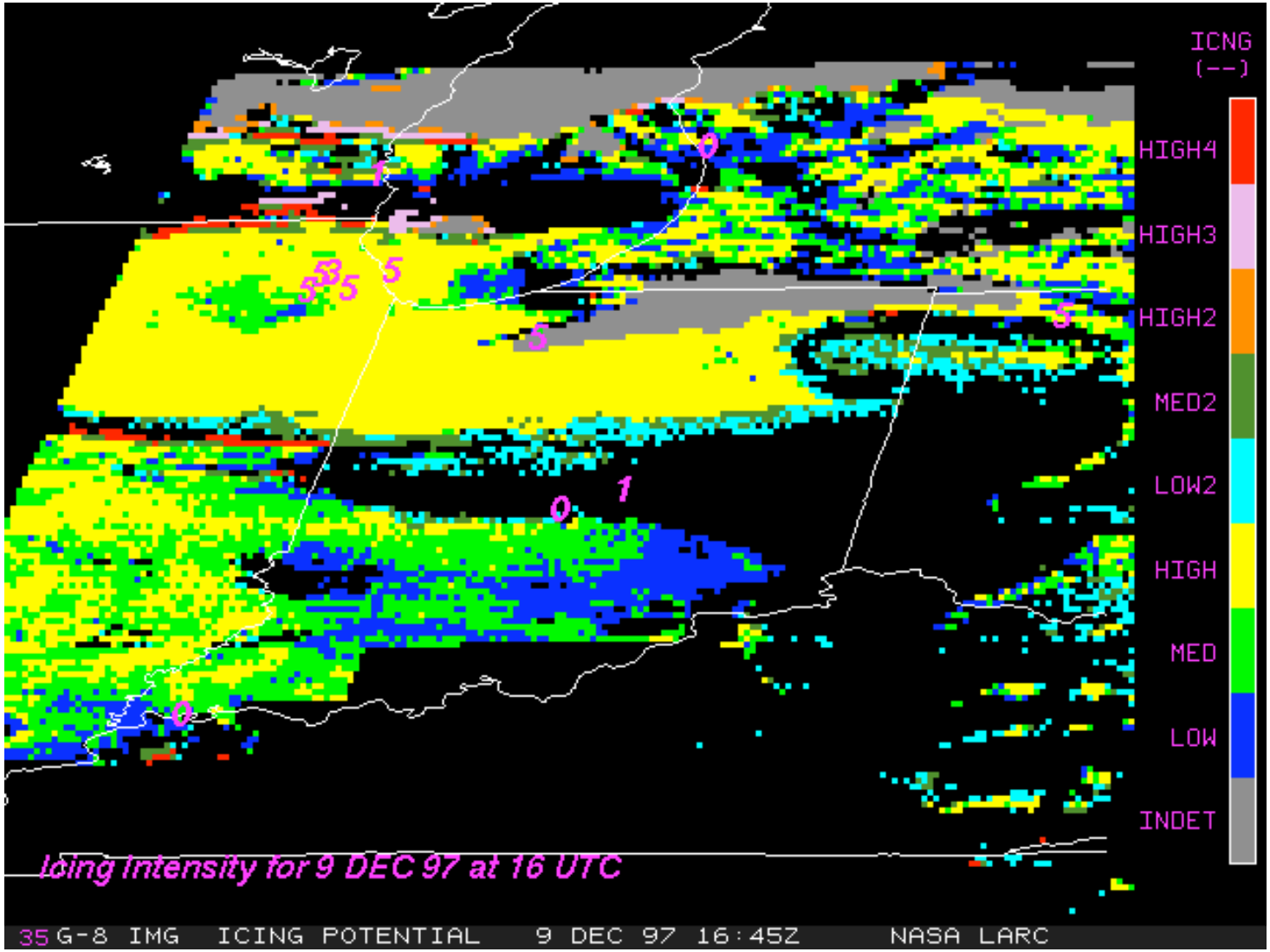
PROTOTYPE



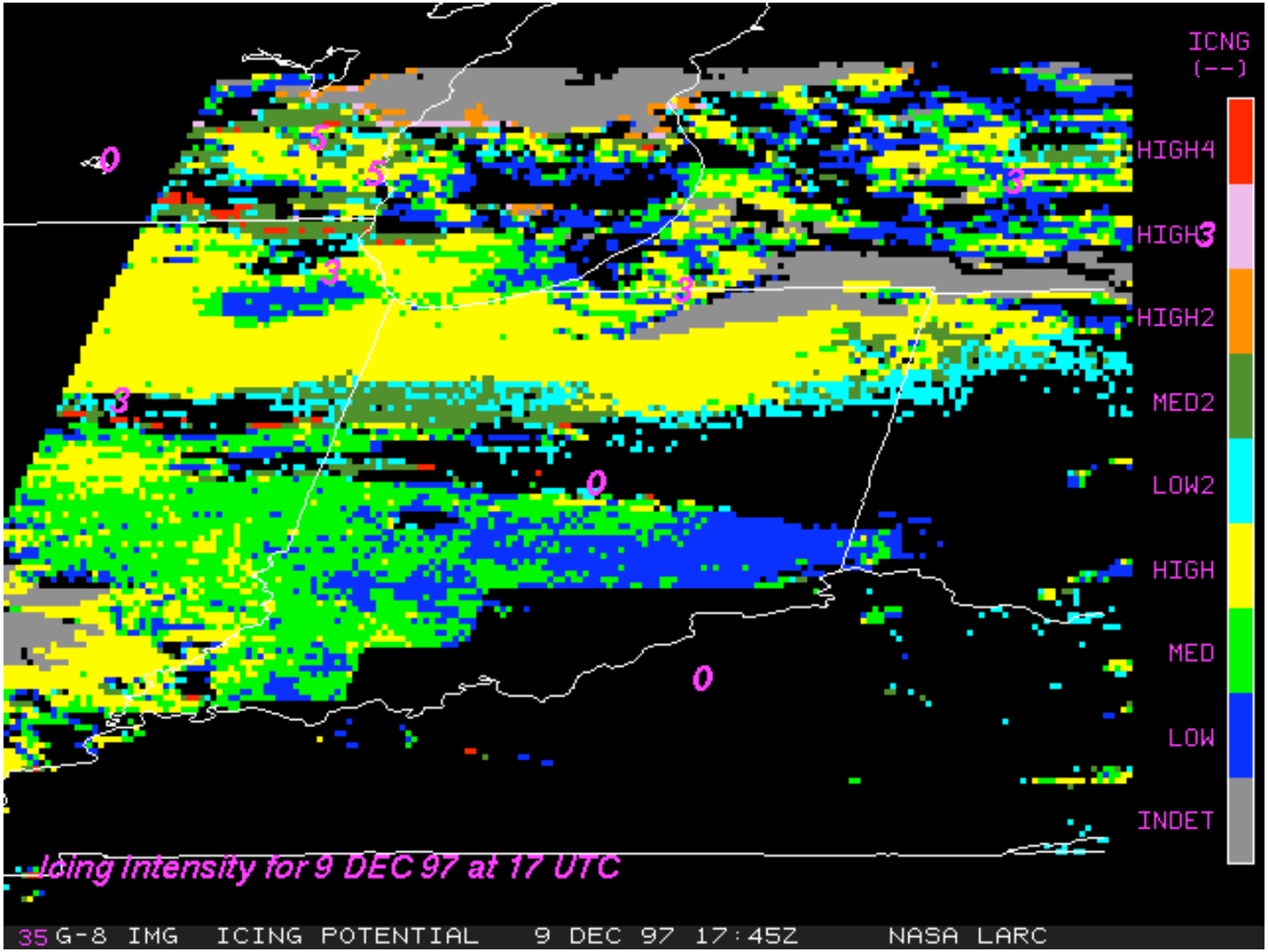
Comparison of Icing Categories With PIREPS, 9 Dec 1997, 1545 UTC



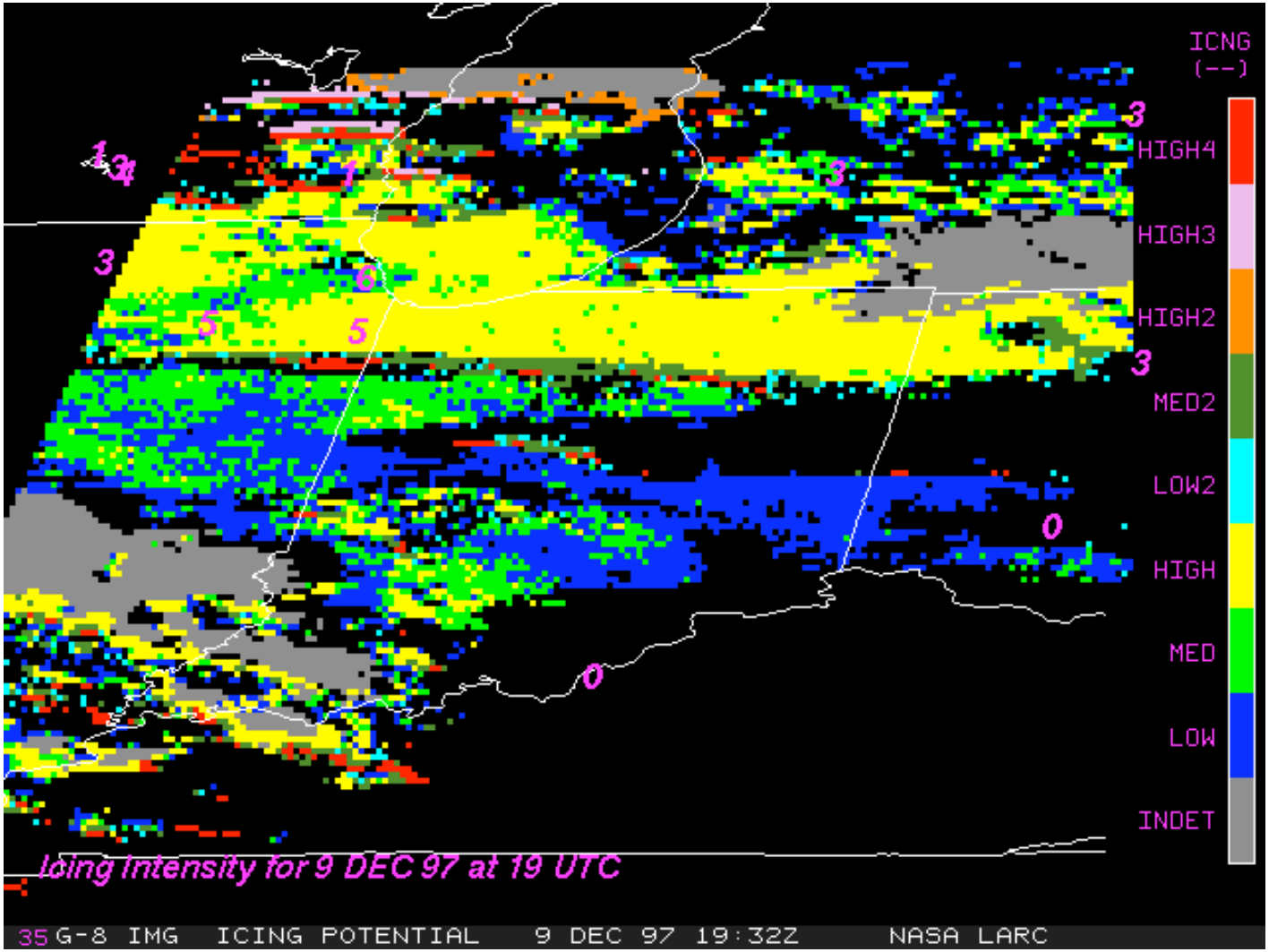
Comparison of Icing Categories With PIREPS, 9 Dec 1997, 1645 UTC



Comparison of Icing Categories With PIREPS, 9 Dec 1997, 1745 UTC



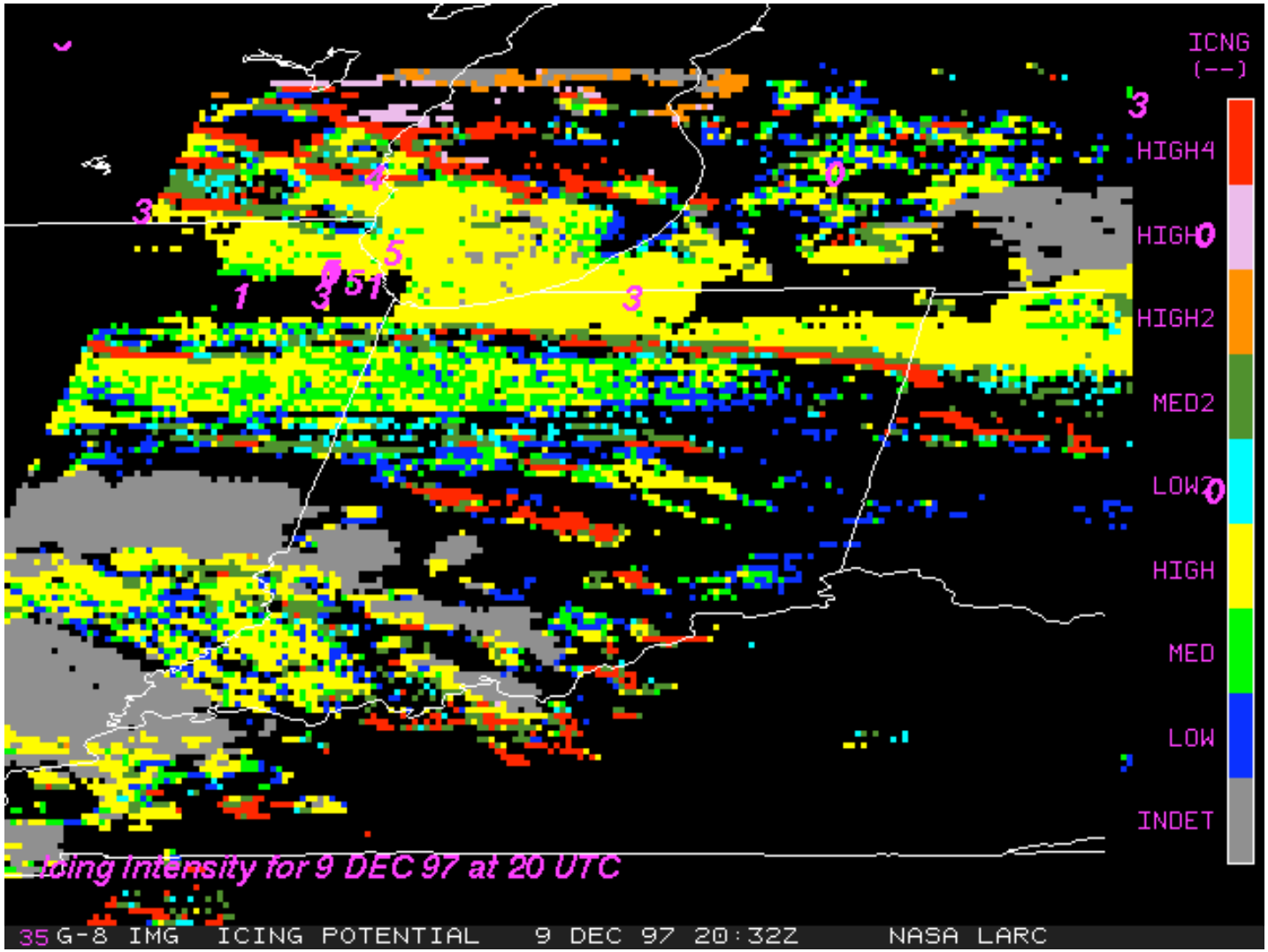
Comparison of Icing Categories With PIREPS, 9 Dec 1997, 1932 UTC



Comparison of Icing Categories With PIREPS, 9 Dec 1997, 2032 UTC

PIREP Icing generally corresponds to yellow (high):

LWP > 300 g/m^2
& 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**

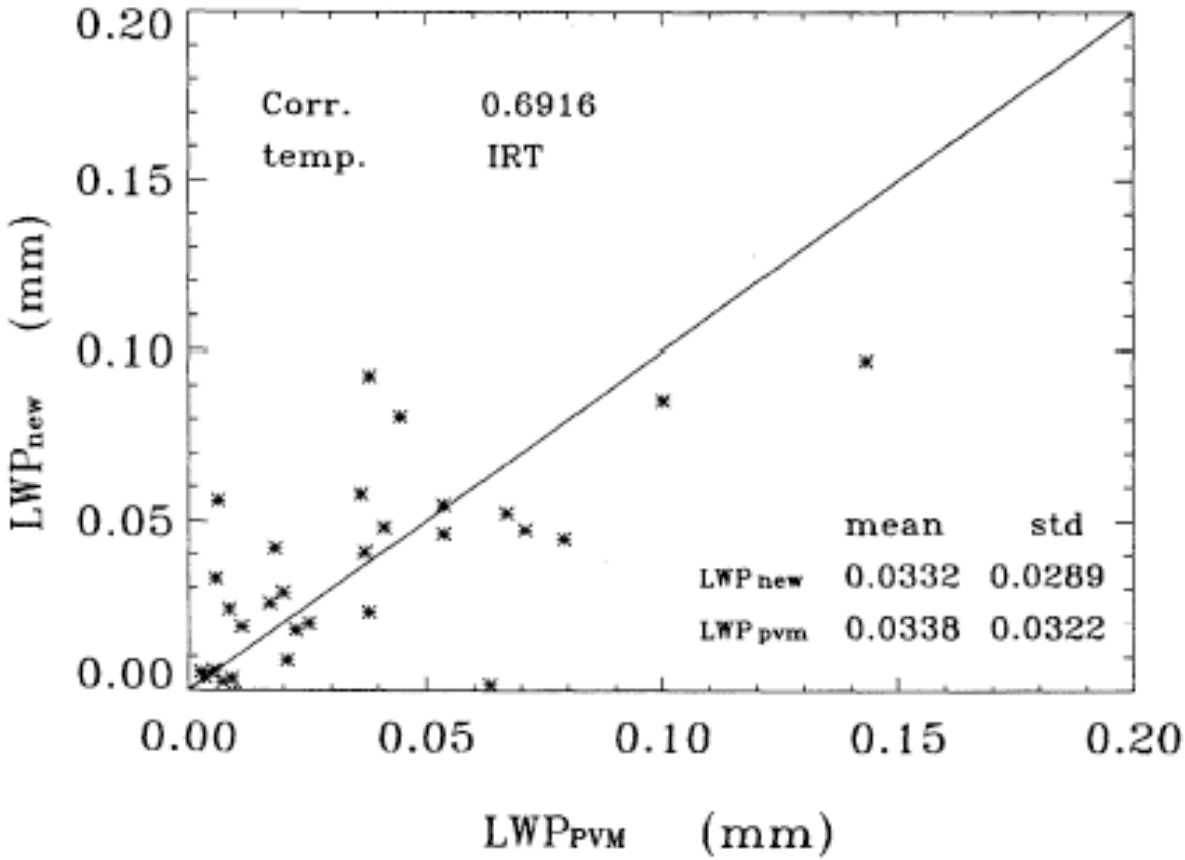
  - how far can we push infrared techniques?

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

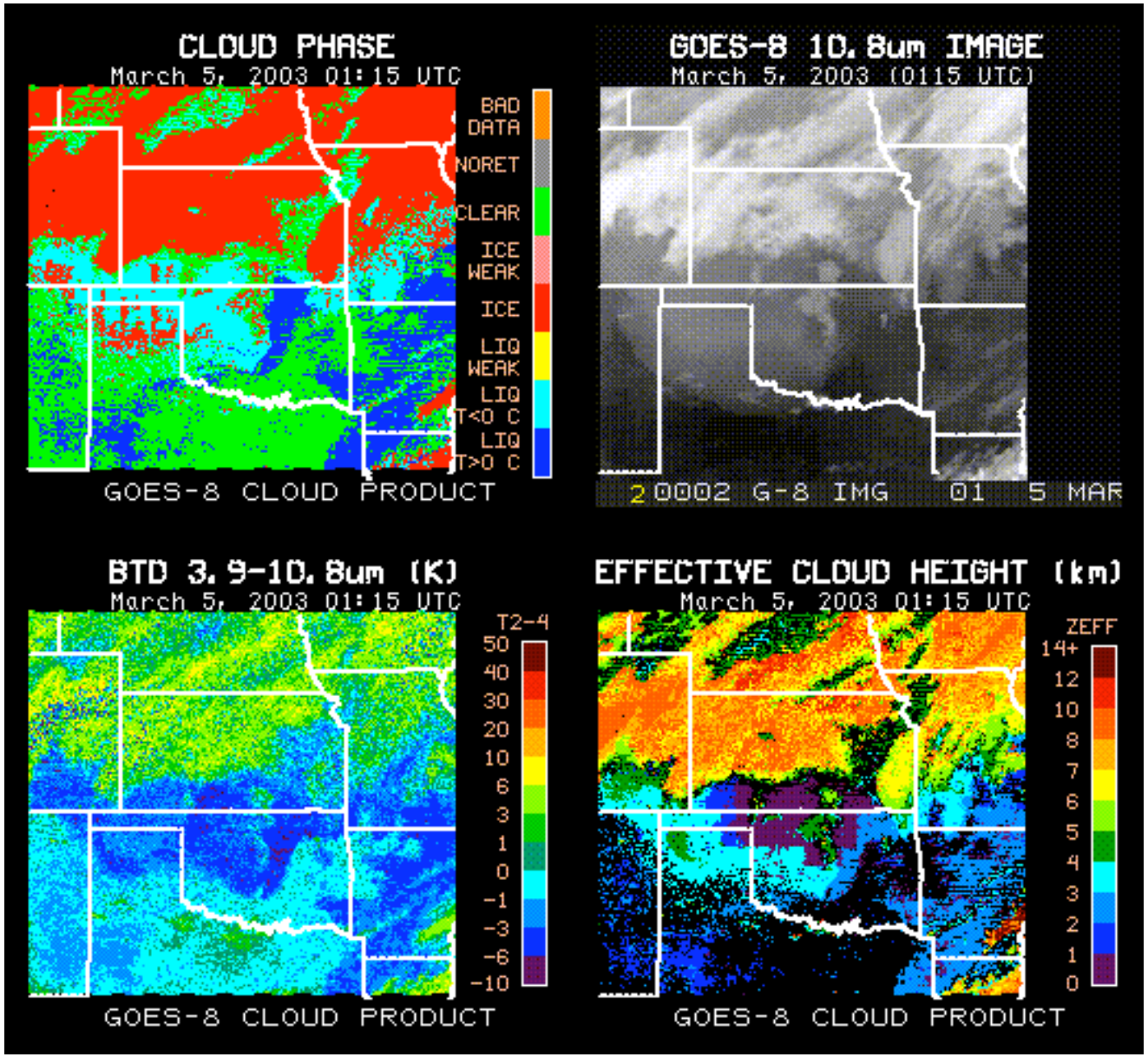
- **Integration of satellite results into comprehensive, operational icing product**

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**