Verification of WAFS Icing Products

20 April 2009

Prepared by the NOAA/ESRL/GSD Forecast Verification Section,
Earth System Research Laboratory

Outline of Discussion

- Motivation and Background
- Assessment Strategy
- CloudSat-based Icing Diagnostic
- Phase 1 Analysis
- Phase 2 Analysis
- Summary

Assessment Background

- Assess the WAFC Washington and WAFC London global icing products
- Understand performance with respect to operational decisions regarding oceanic flights
- Compare performance of automated grids to that of the SigWx Charts

Assessment Strategy

- Build icing diagnostic based on satellite product(s)

- Phase 1: Understand product in data rich CONUS region
  - Intercompare new icing diagnostic with PIREPs and CIP
  - Goal: build understanding of product for use in data poor areas
  - Study period: November 07 through January 08

- Phase 2: Extend to global domains
  - Apply new icing diagnostic to the data sparse domains
  - Intercompare with Washington and London grids; Sig Wx Charts
  - Study period: November 08 through January 09

CloudSat-based Icing Product (CLIP)

CloudSat

On-board instrument: CPR-Cloud Profiling Radar (94 GHz radar)

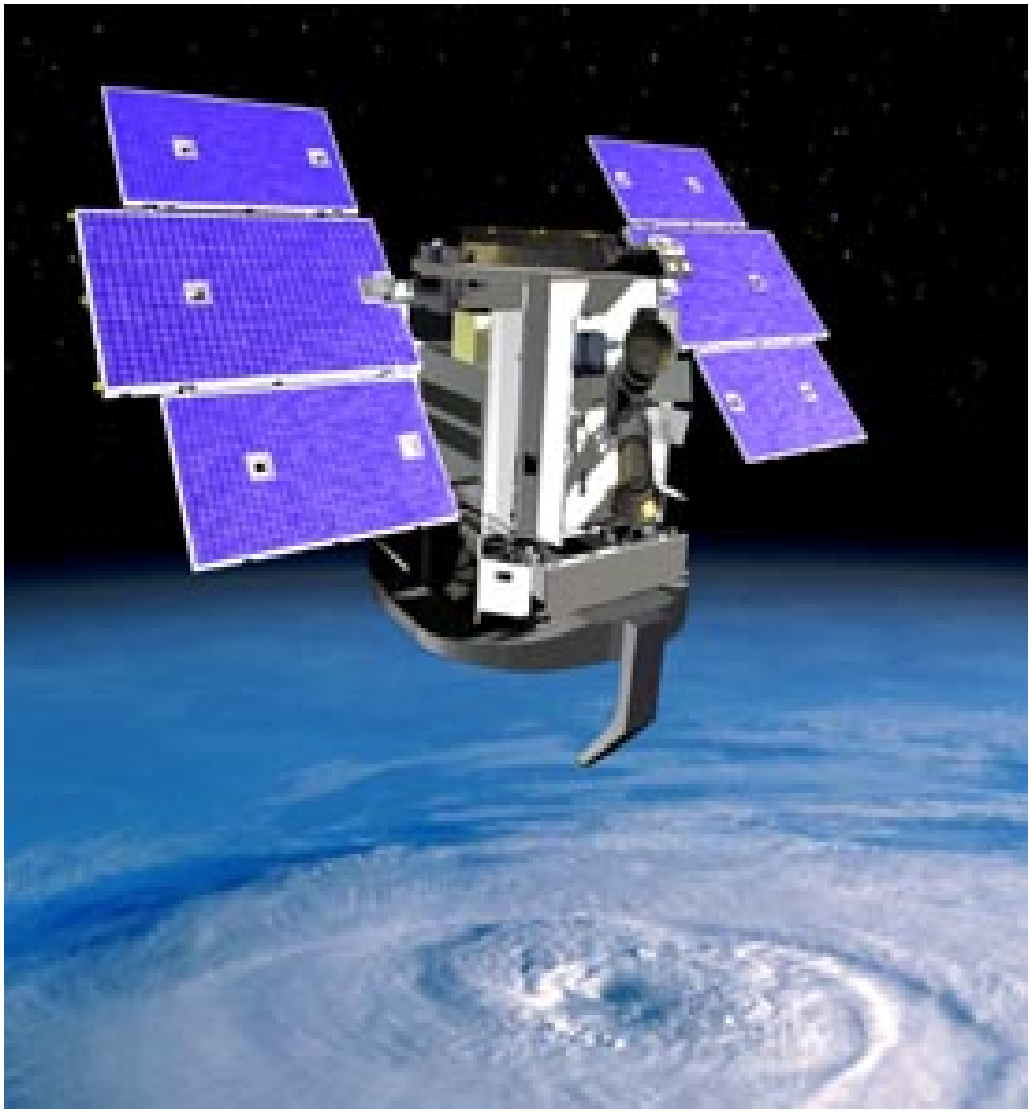
Objectives:

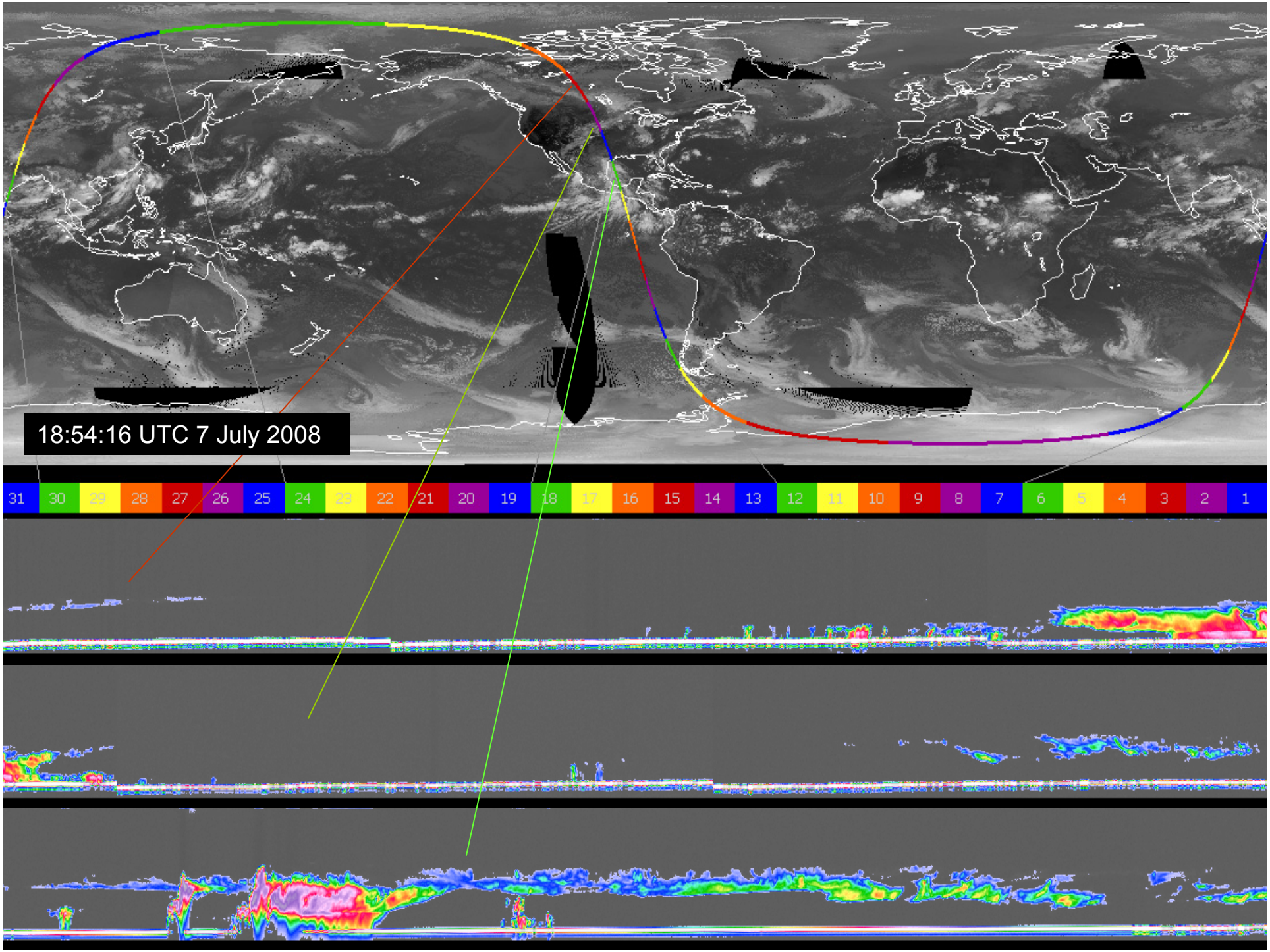
・Evaluate the representation of clouds in weather and climate prediction models.

・Evaluate the relationship between cloud liquid water and ice content and the radiative properties of clouds

・Evaluate cloud properties retrieved using existing satellite measurements and promote the development of new remote sensing methods for observing clouds.

・Contribute to an improved understanding of the indirect effect of aerosols on clouds by investigating the effect of aerosols on cloud formation.




18:54:16 UTC 7 July 2008
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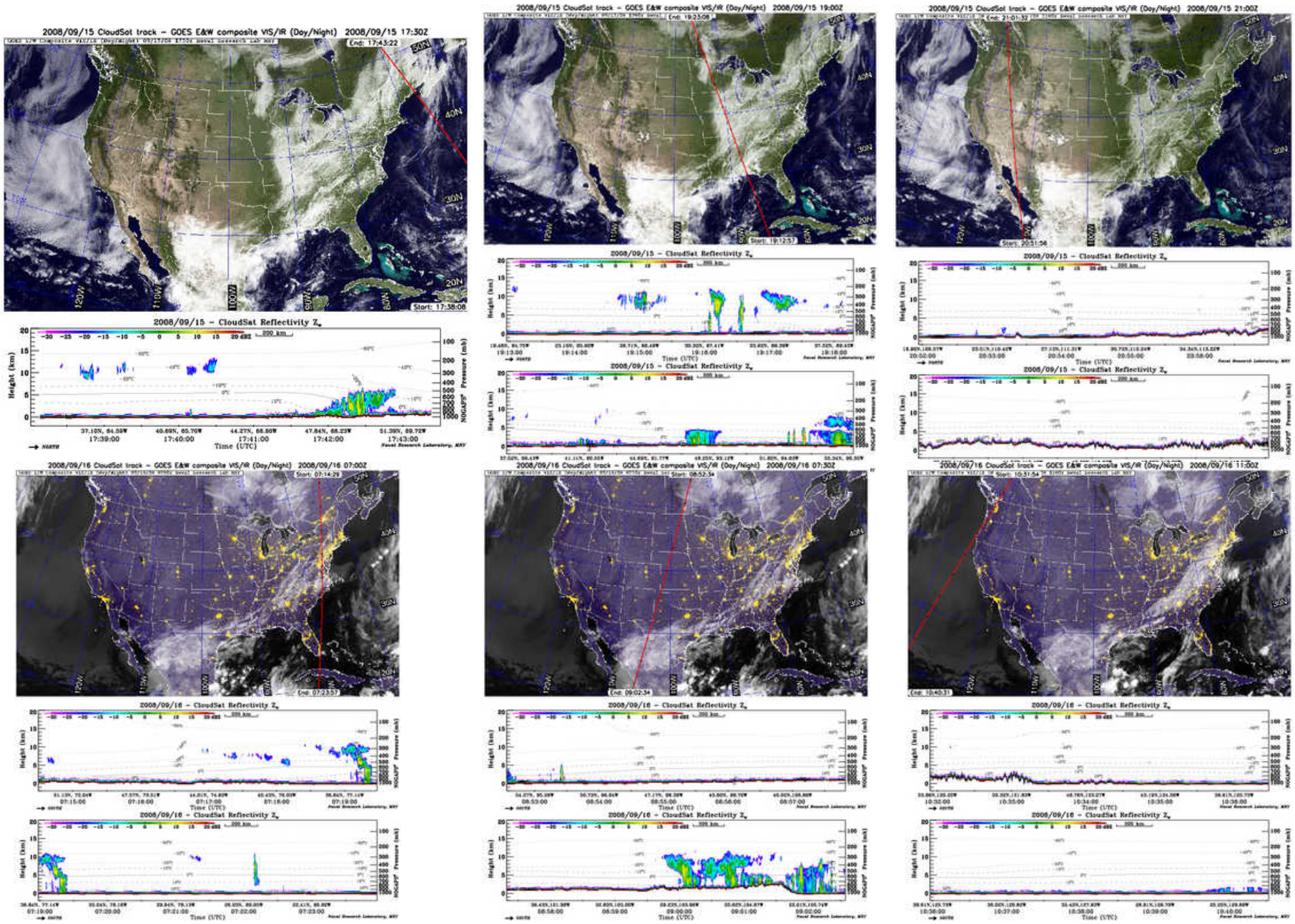
CloudSat Standard Data

- Radar Backscatter Profiles (reflectivity)
- → Cloud Geometrical Profile (shape and size)
- → Cloud Classification (types of cloud)
- Cloud Water Content (includes liquid and ice)
- Cloud Optical Depth (radiative property)
- Radar-Lidar Cloud Geometrical Profile
- Radar-Lidar Cloud Classification
- Fluxes and Heating Rates (indirect products?)

Typical CloudSat passes over CONUS domain



CLIP Methodology

Retrieval of icing conditions using CloudSat data:

1. Locate clouds using cloud geometric and reflectivity data (CloudSat)
2. Classify cloud types using cloud classification data (CloudSat)
3. Find vertical temperature distribution along CloudSat track (GFS)
4. Icing condition is defined according to cloud types:

Sc, St: area 0 — -10 degrees

As, Ac: area 0 — -20 degrees

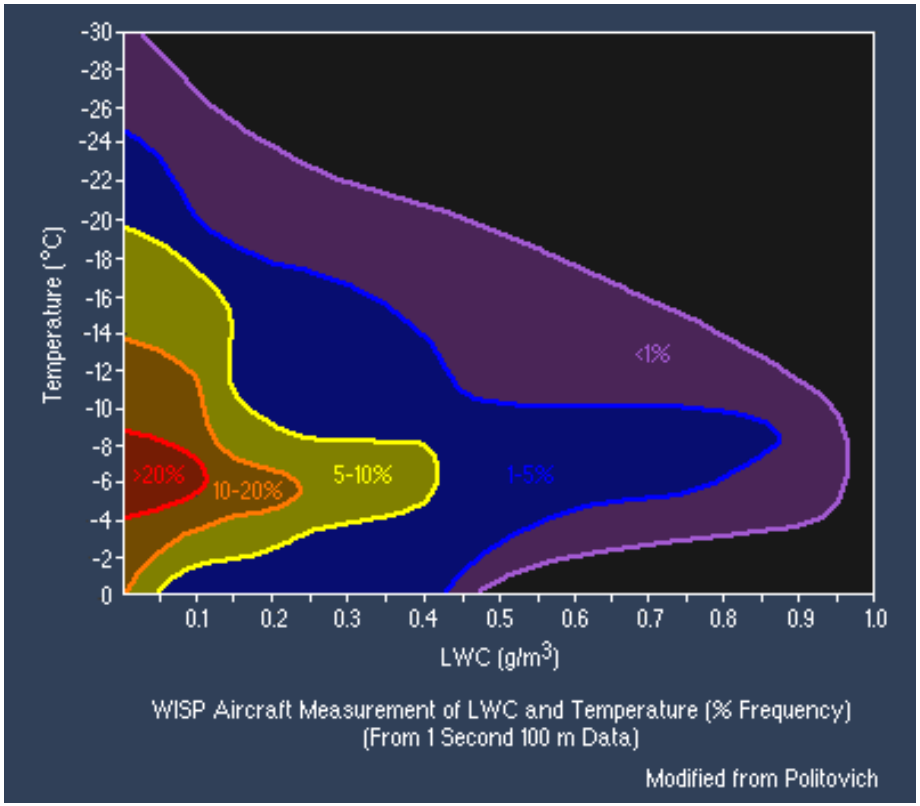
Cu, Ns, Deep convection: area 0 — -25 degrees

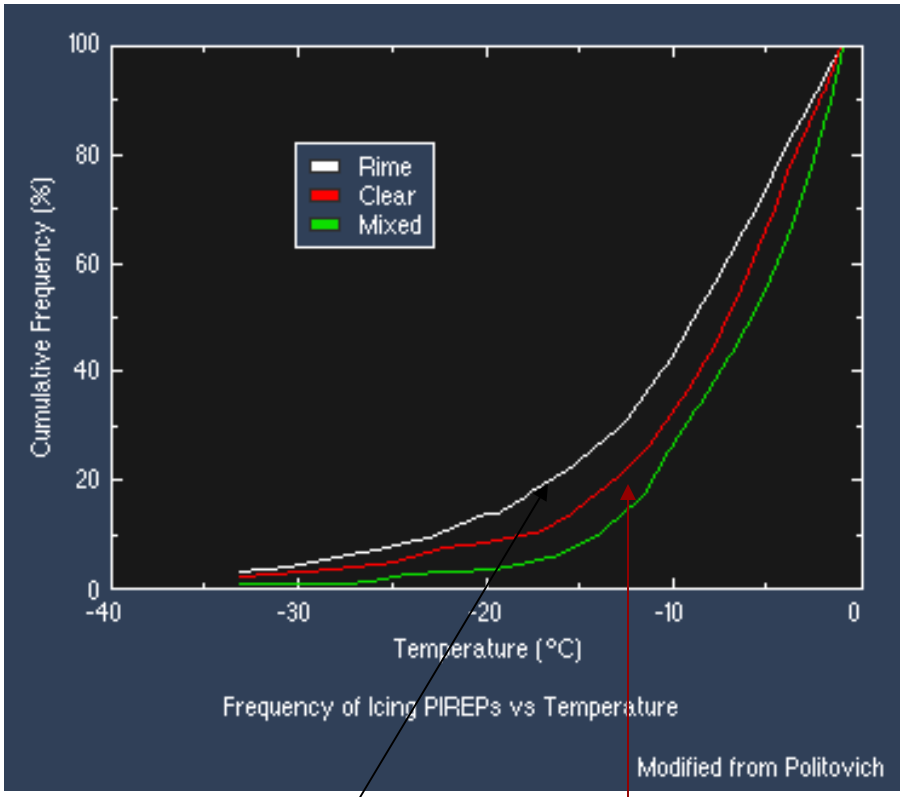
High clouds, Ci, Cs, Cc: no icing

[These thresholds are estimated based on the studies by Rauber and Tokay (1991); and Politovich (1996)]

Case study

by Geerts (2008)





small cloud droplets

big cloud droplets

Literature review

1. Rauber and Tokay (1991 JAS): supercooled water exists at temperature < -30º.

2. Tabazadeh et al. (2002; PNAS): observed SWL near -40º in the atmosphere.

3. Rosenfeld and Woodley (2000 Nature): vigorous convective clouds can push supercooled water droplets to a -38° level.

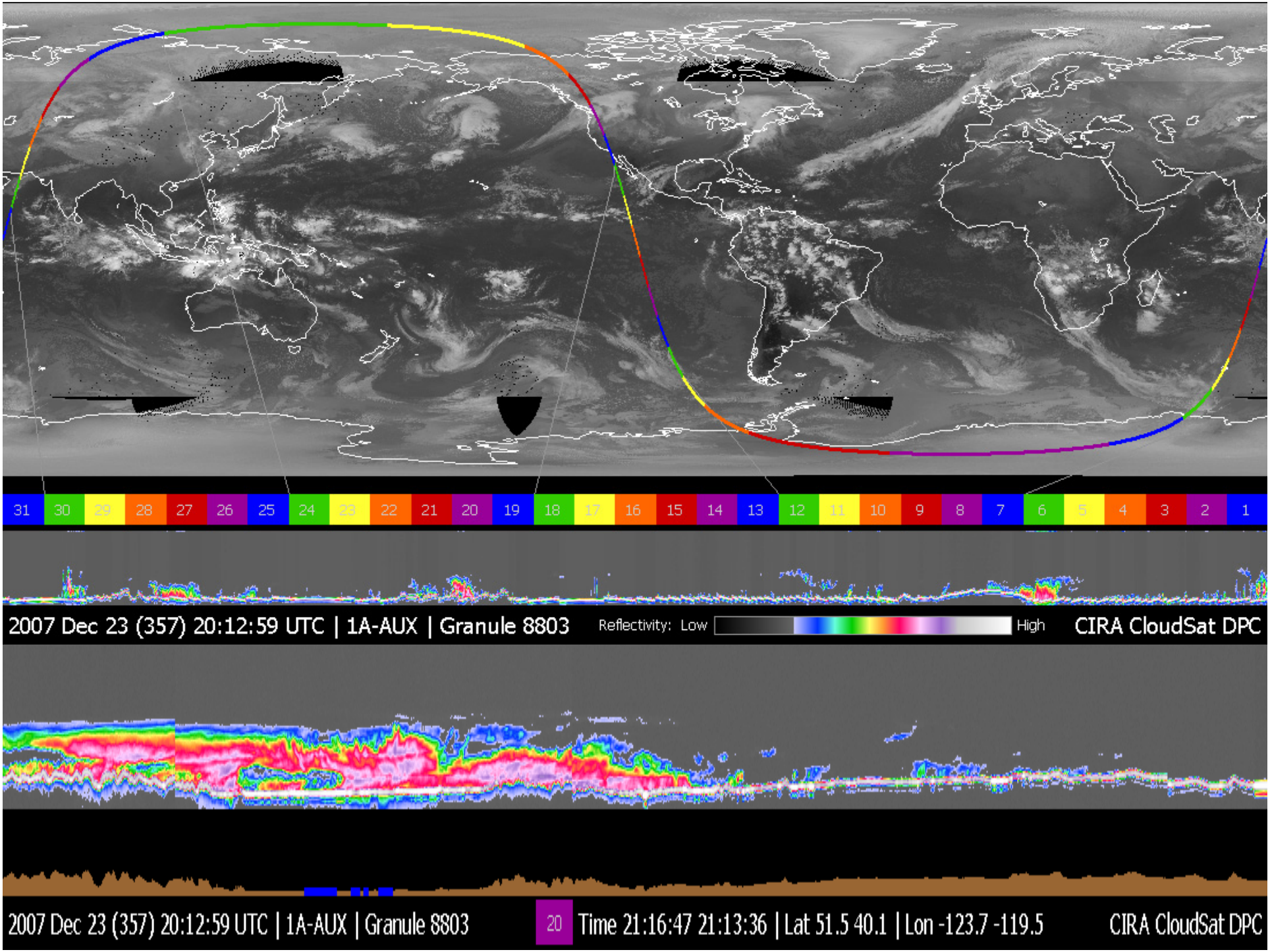
4. Heymsfield and Miloshevich (1989, 1993; JAS): the upper limit for existence of supercooled water should be around -40º.

Phase 1 Study

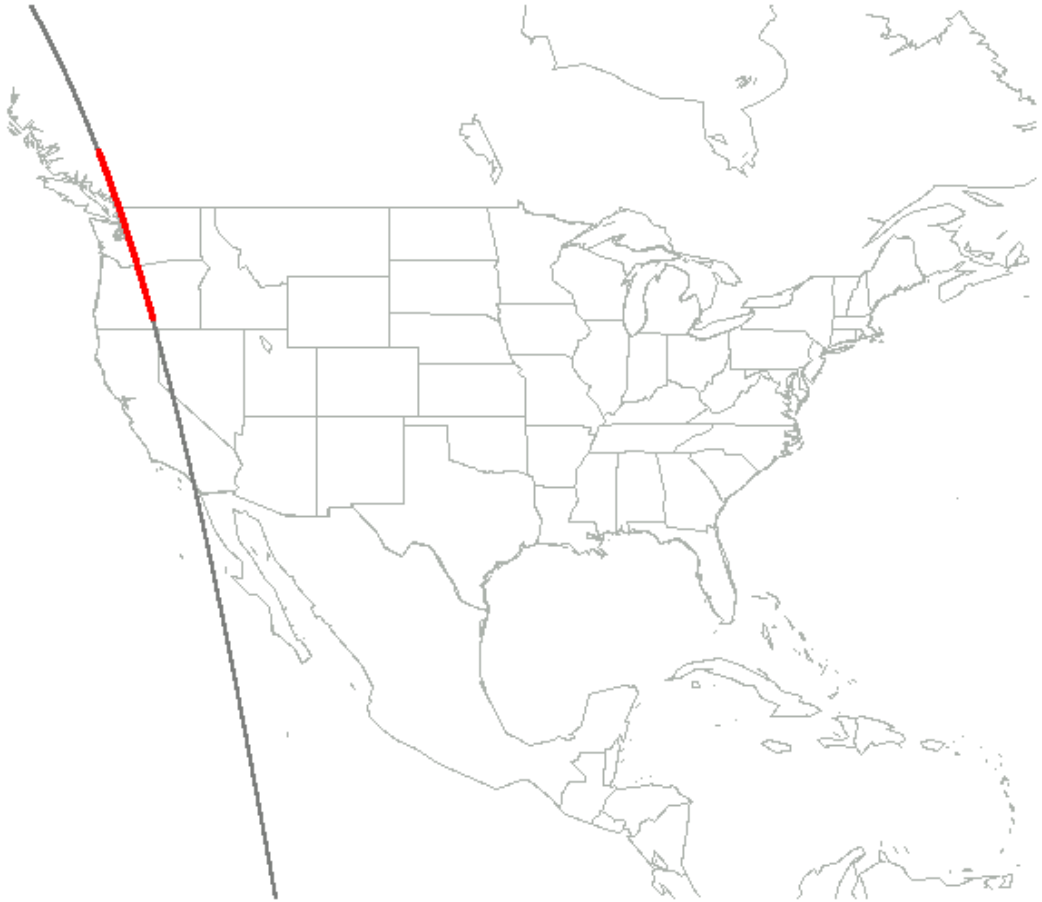
Case 1: Dec. 23 2007

Case 2: Jan. 10 2008

Case 3: Dec. 13 2007

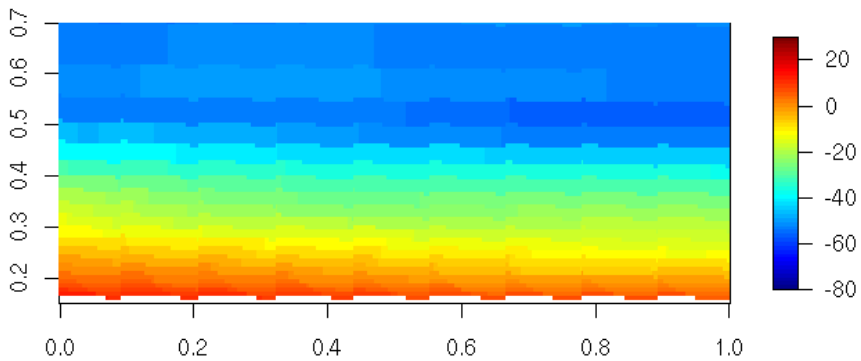

31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1
2007 Dec 23 (357) 20:12:59 UTC | 1A-AUX | Granule 8803
Reflectivity: Low
High
CIRA CloudSat DPC
2007 Dec 23 (357) 20:12:59 UTC | 1A-AUX | Granule 8803
20
Time 21:16:47 21:13:36 | Lat 51.5 40.1 | Lon -123.7 -119.5
CIRA CloudSat DPC

20071223

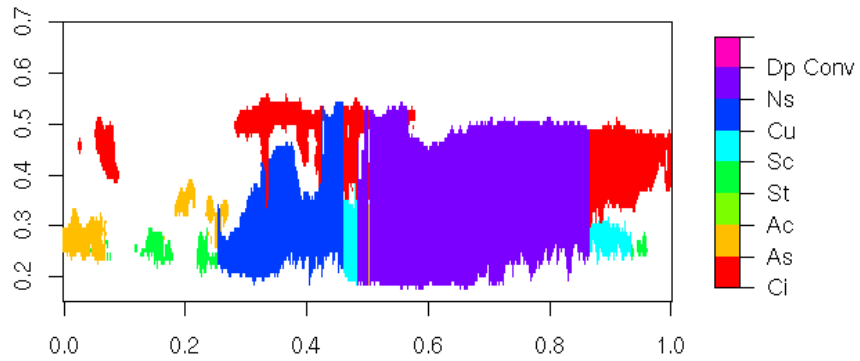


20071223

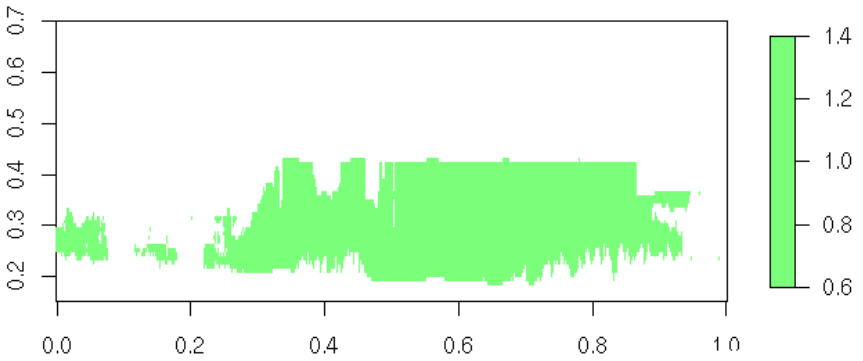
GFS Temperature



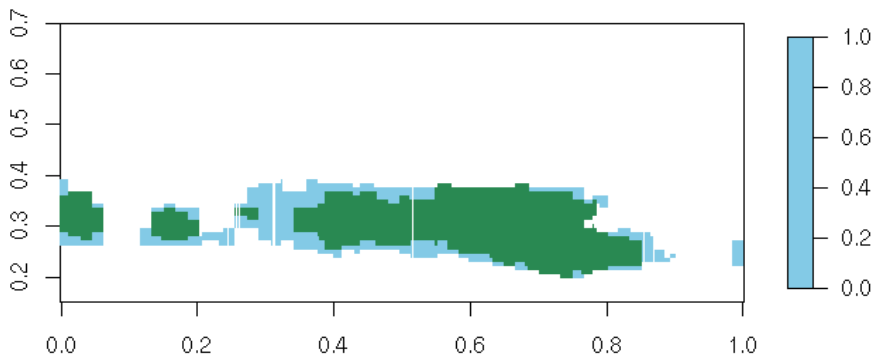
CloudSat Classification

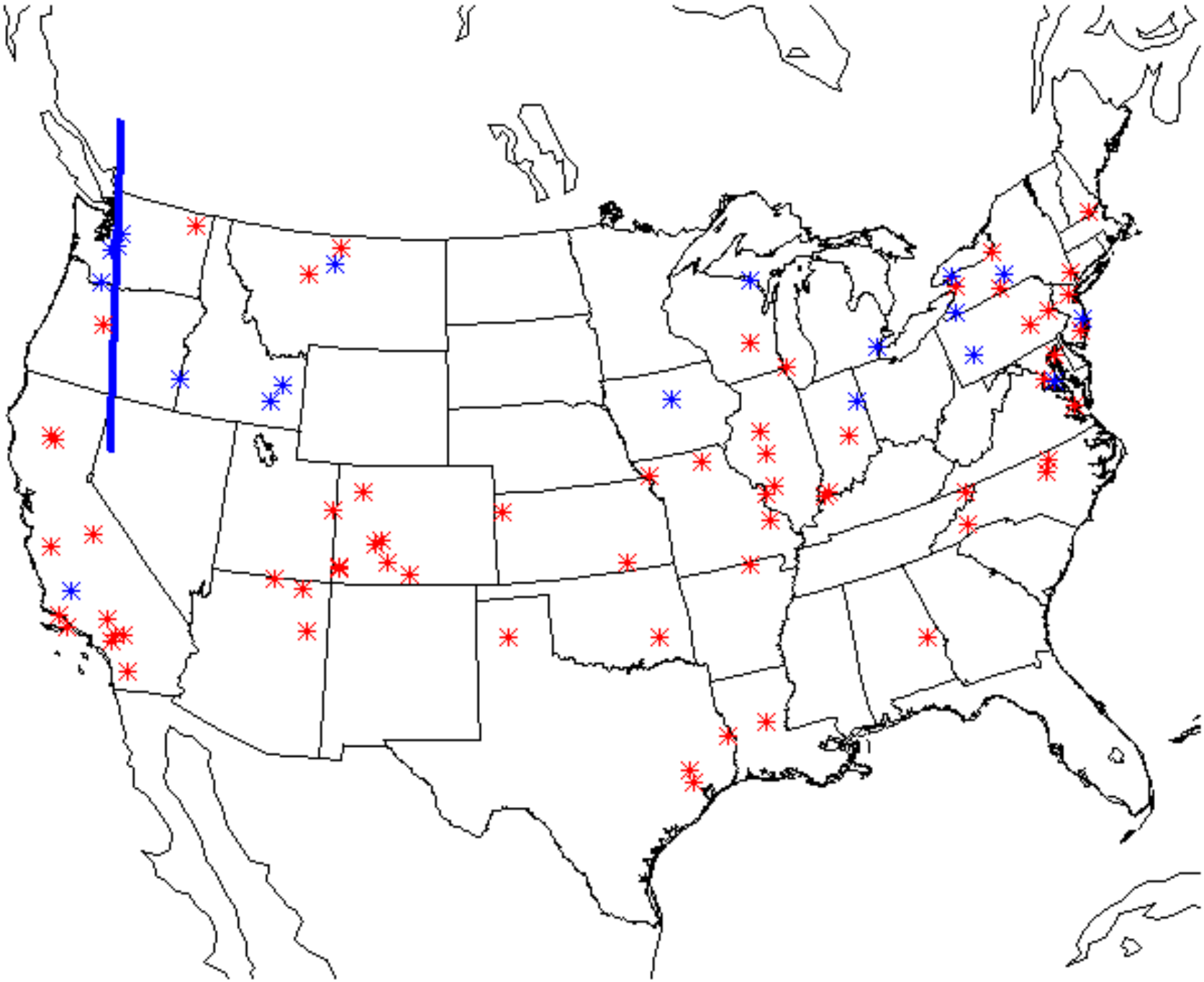


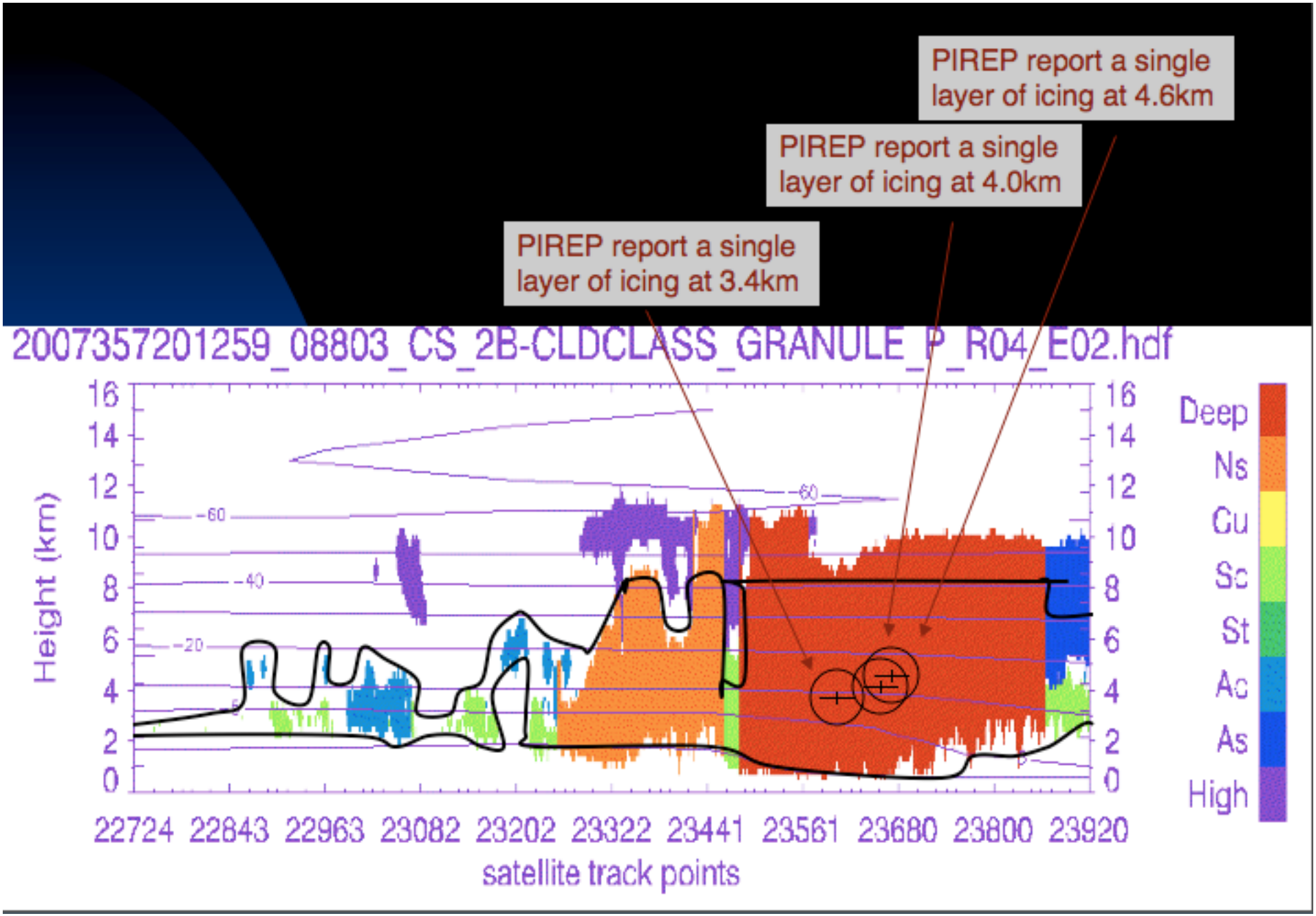
New Icing Diagnostic (CLIP)

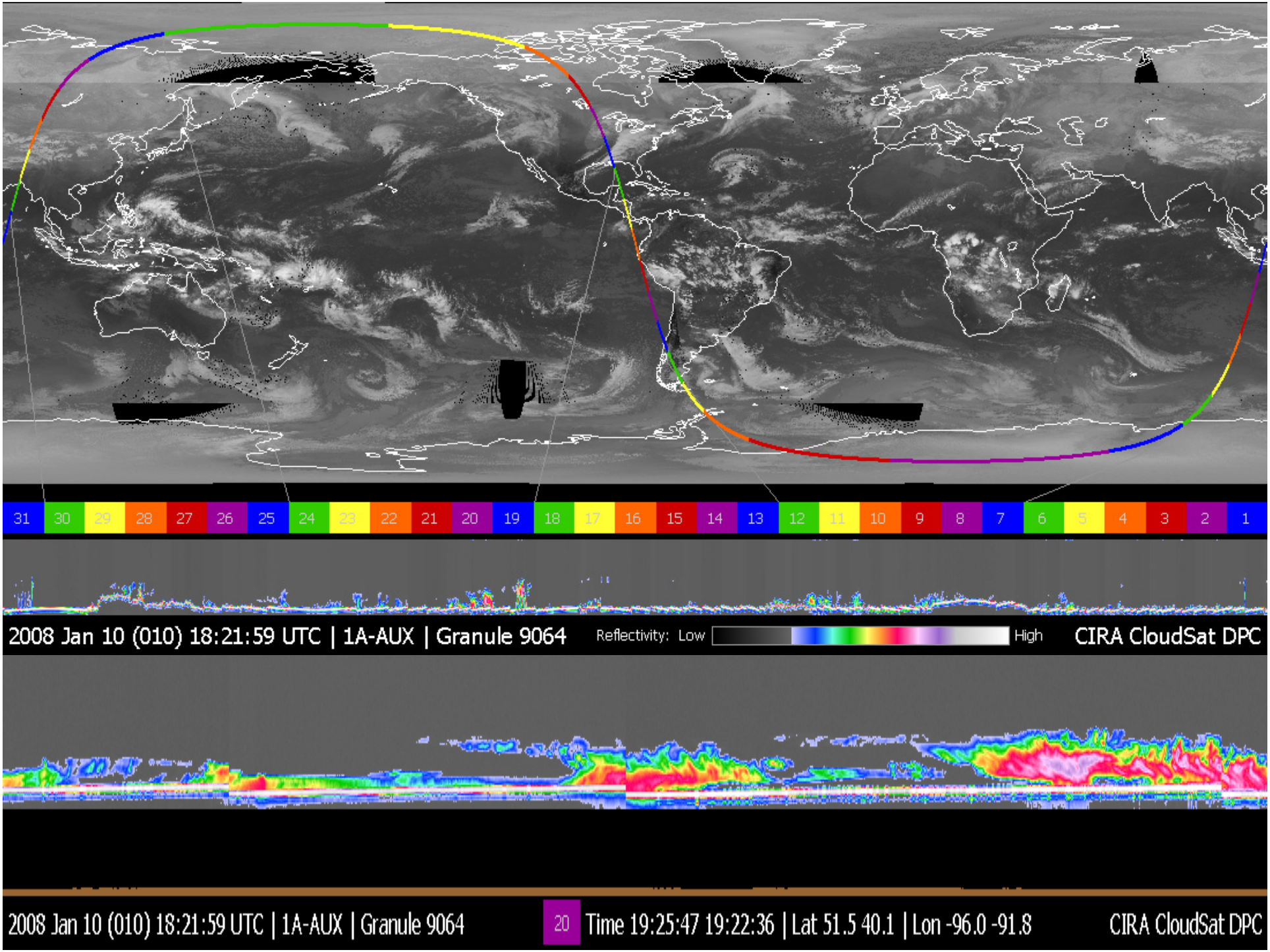


CONUS CIP






PIREP report a single layer of icing at 4.6km
PIREP report a single layer of icing at 4.0km
PIREP report a single layer of icing at 3.4km
2007357201259_08803_CS_2B-CLDCLASS_GRANULE_P_R04_E02.hdf
Height (km)
16
14
12
10
8
6
4
2
0
-60
-40
-20
60
22724 22843 22963 23082 23202 23322 23441 23561 23680 23800 23920
satellite track points
Deep
Ns
Cu
Sc
St
Ac
As
High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2008 Jan 10 (010) 18:21:59 UTC | 1A-AUX | Granule 9064
Reflectivity: Low
High
CIRA CloudSat DPC
2008 Jan 10 (010) 18:21:59 UTC | 1A-AUX | Granule 9064
20
Time 19:25:47 19:22:36 | Lat 51.5 40.1 | Lon -96.0 -91.8
CIRA CloudSat DPC

20080110

20080110

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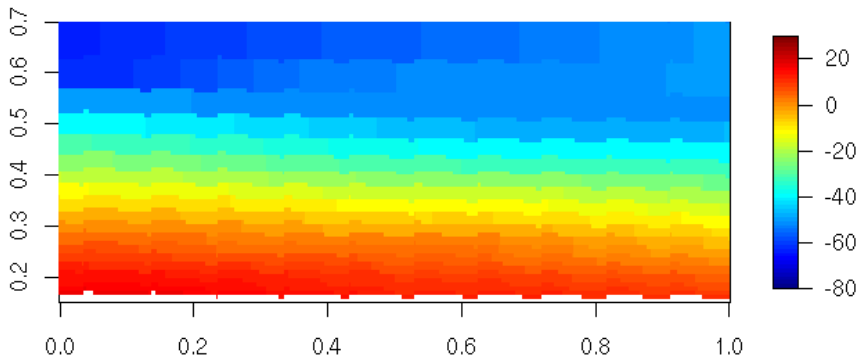
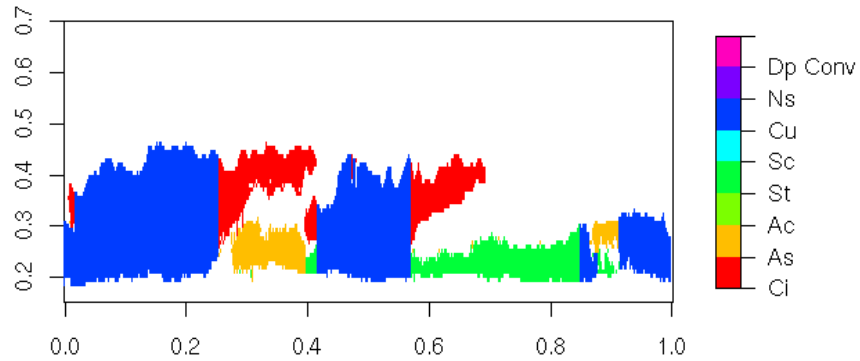


CloudSat Classification



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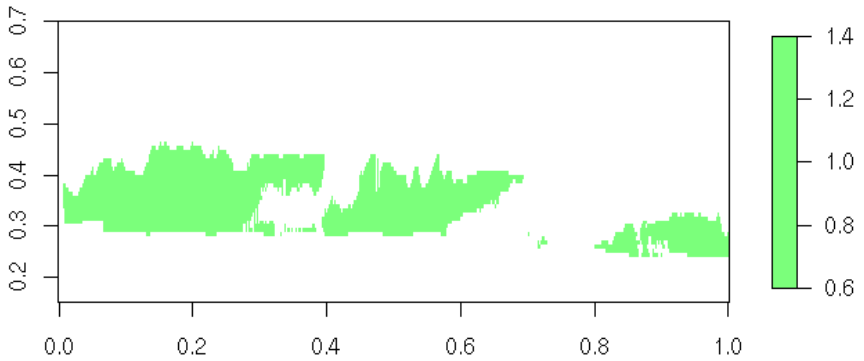
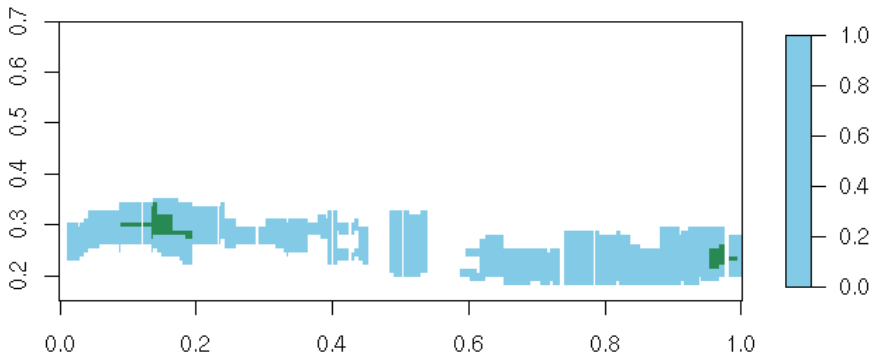
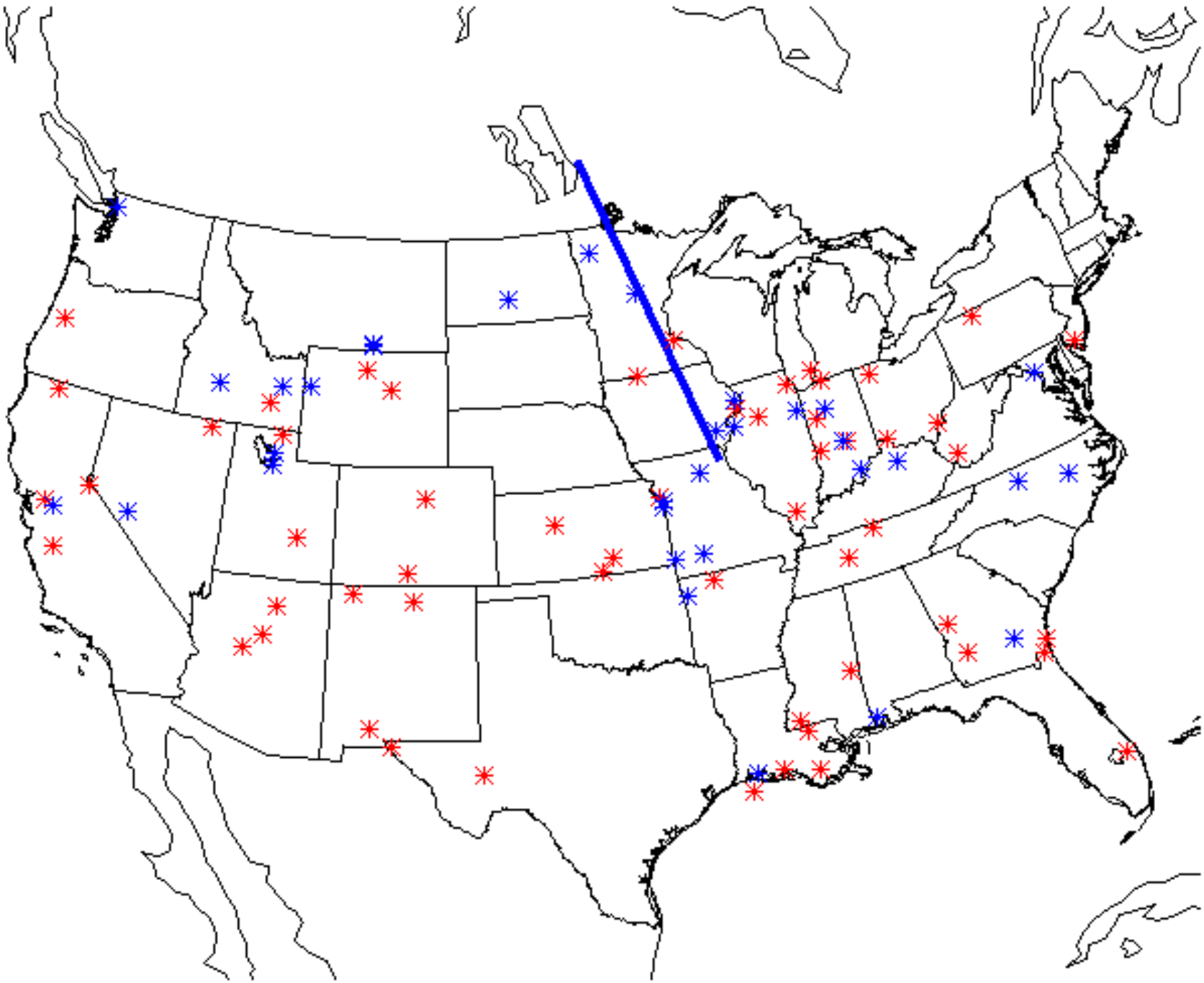
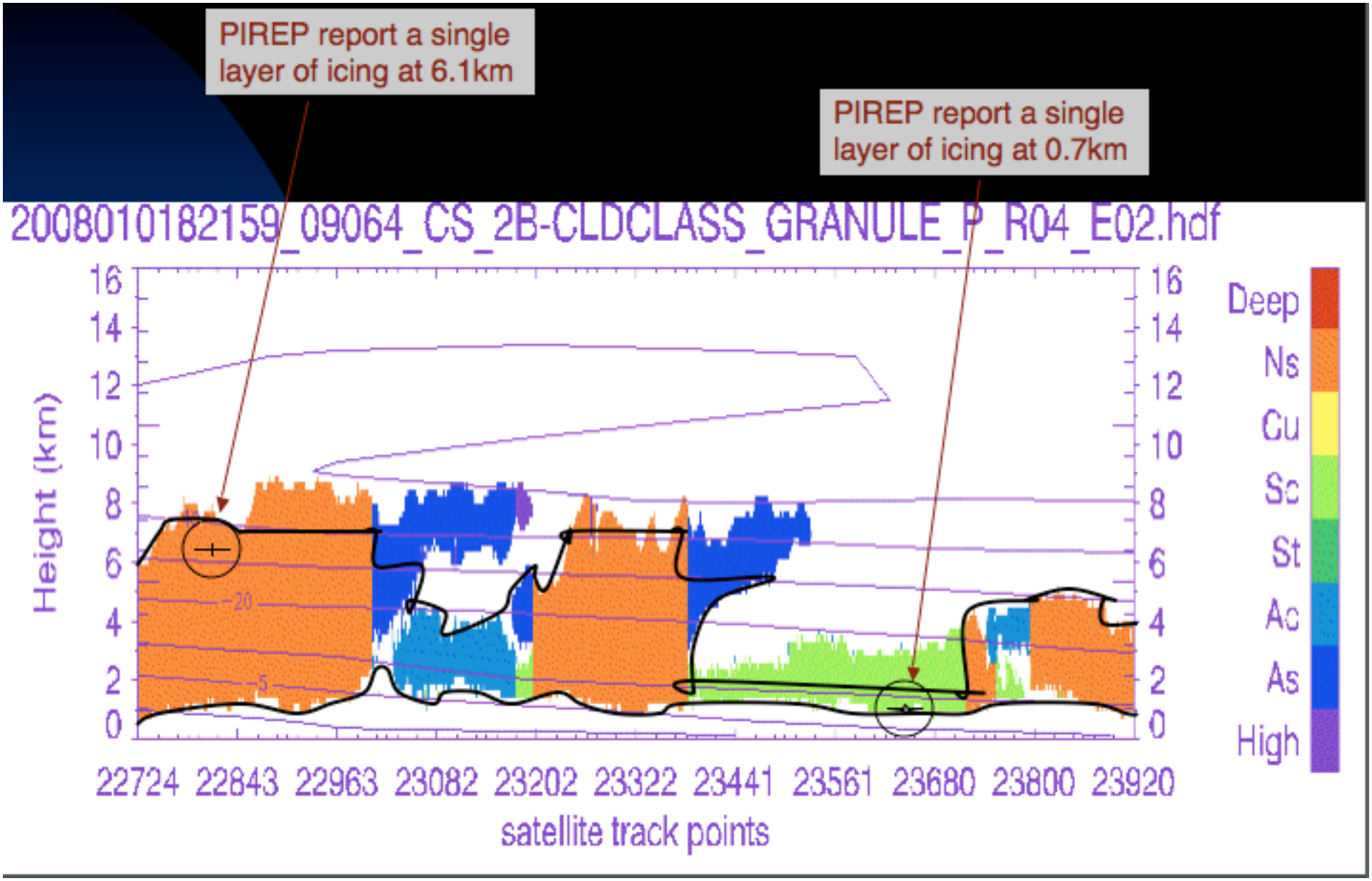


CONUS CIP






PIREP report a single layer of icing at 6.1km
PIREP report a single layer of icing at 0.7km
2008010182159_09064_CS_2B-CLDCLASS_GRANULE_P_R04_E02.hdf
Height (km)
16
14
12
10
8
6
4
2
0
-20
-5
22724 22843 22963 23082 23202 23322 23441 23561 23680 23800 23920
satellite track points
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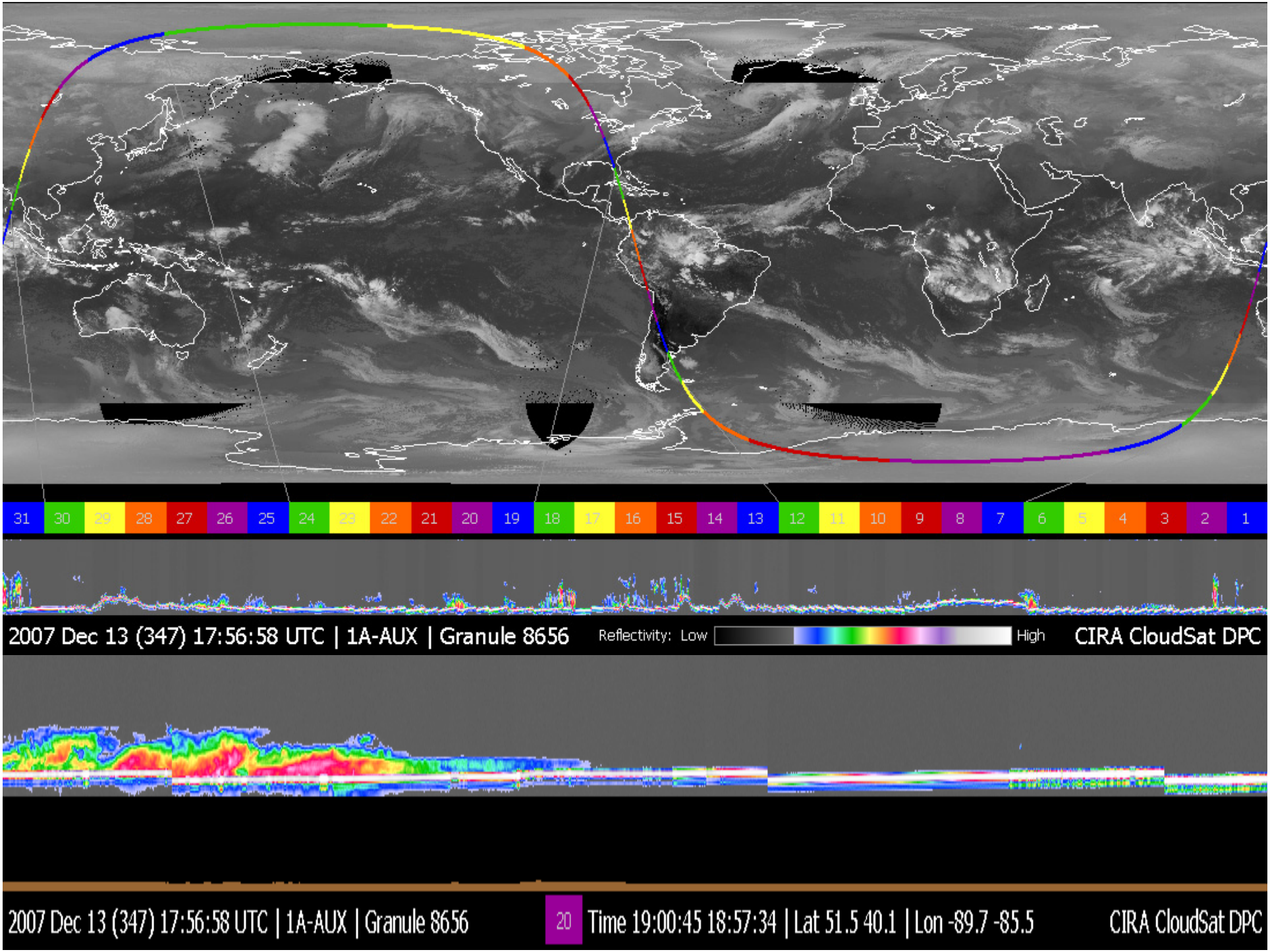
Ac
As
High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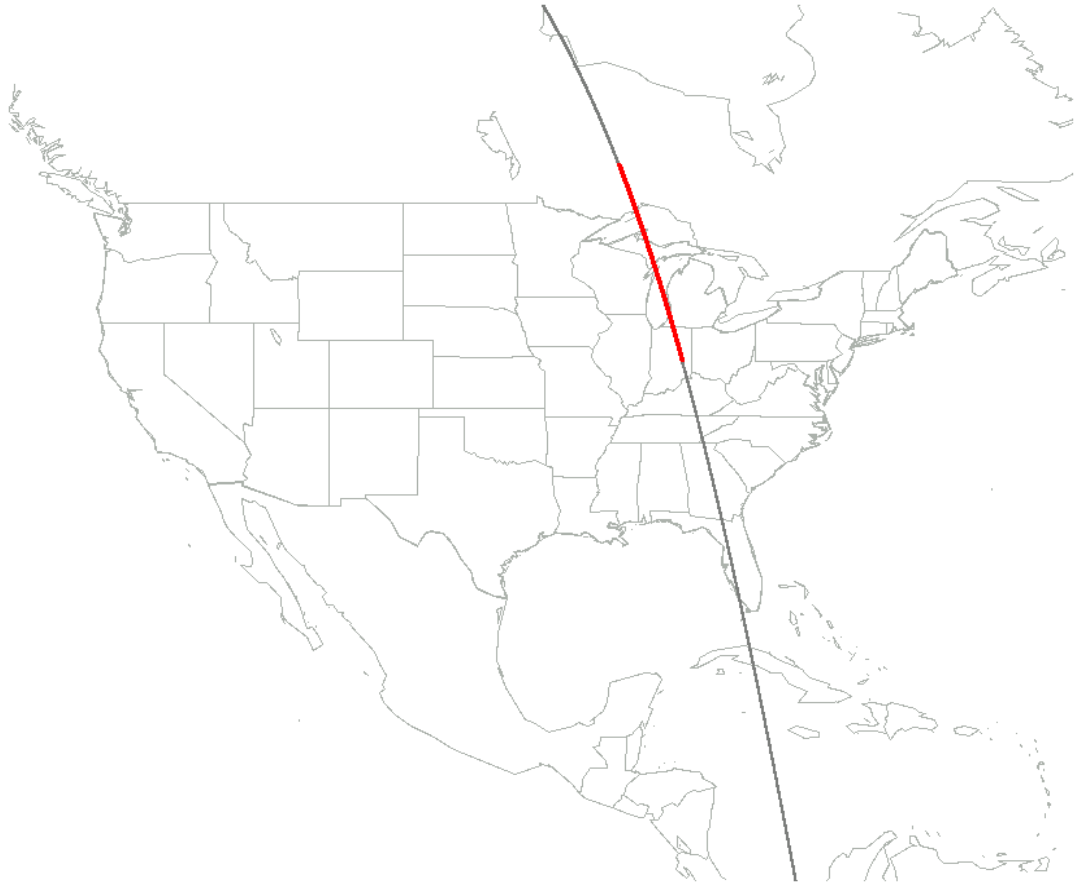
2007 Dec 13 (347) 17:56:58 UTC | 1A-AUX | Granule 8656
Reflectivity: Low
High
CIRA CloudSat DPC
2007 Dec 13 (347) 17:56:58 UTC | 1A-AUX | Granule 8656
20
Time 19:00:45 18:57:34 | Lat 51.5 40.1 | Lon -89.7 -85.5
CIRA CloudSat DPC

20071213



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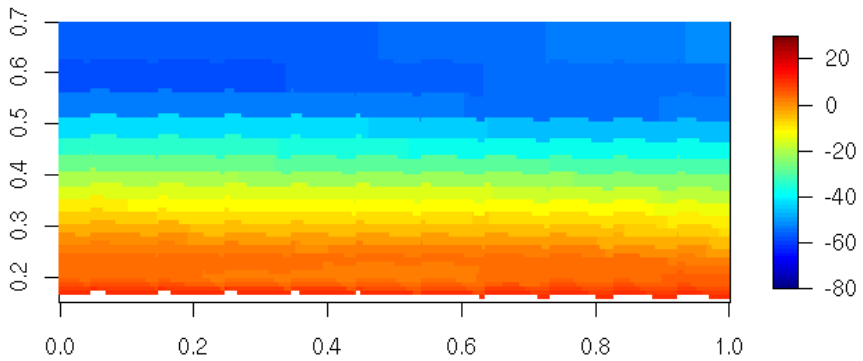
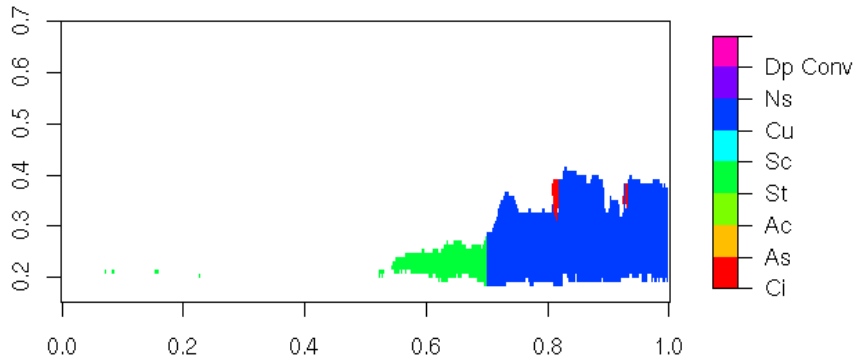


CloudSat Classification



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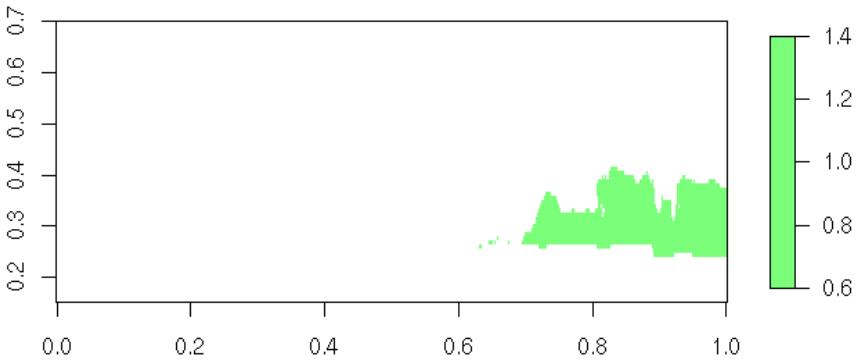

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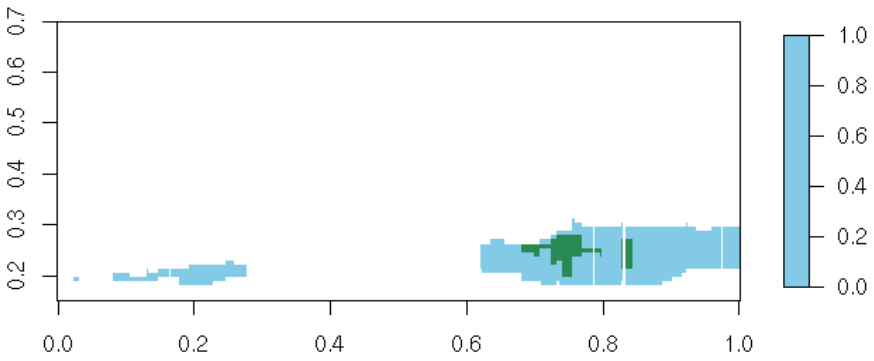

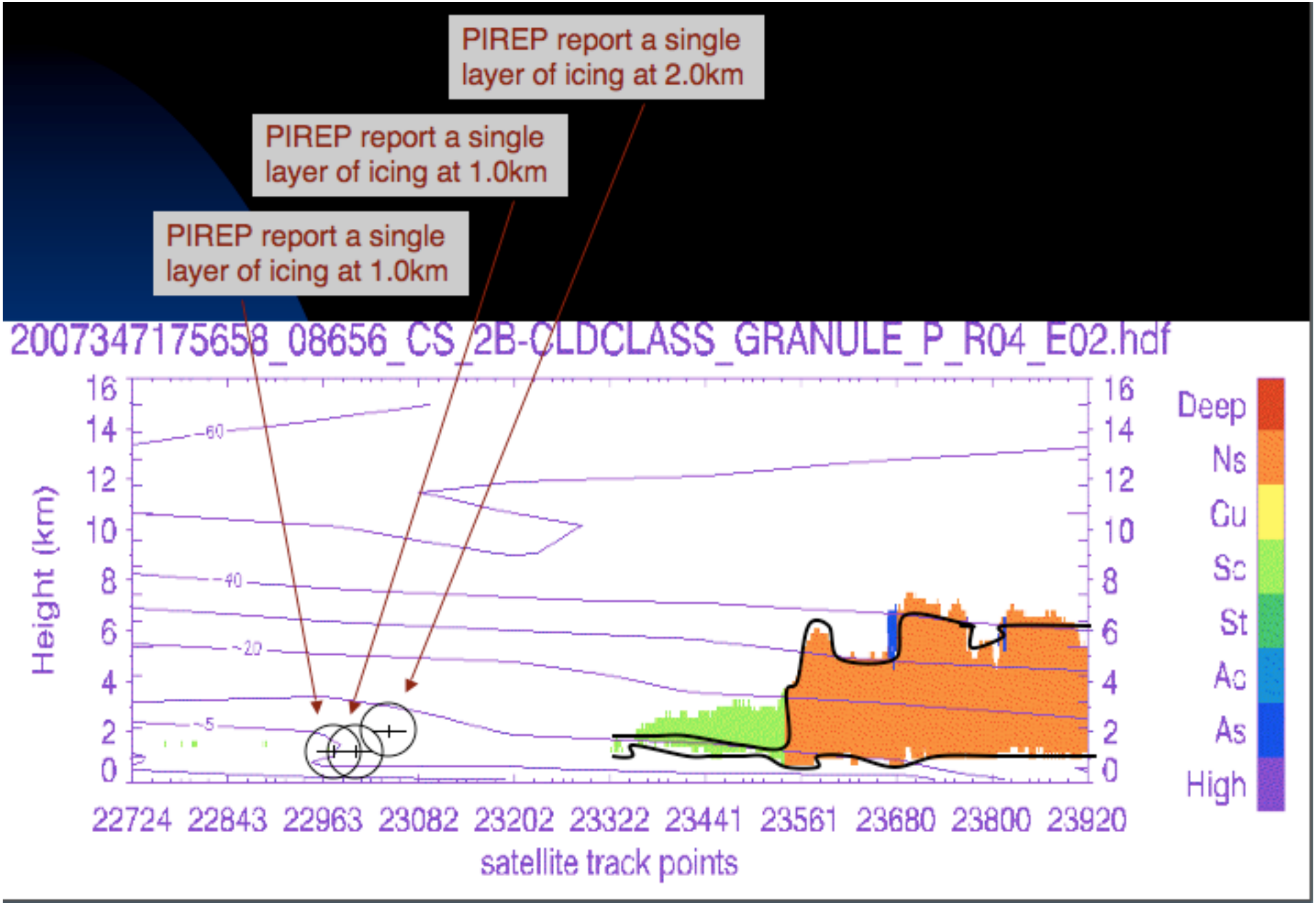
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2007347175658_08656_CS_2B-CLDCLASS_GRANULE_P_R04_E02.hdf
Height (km)
16
14
12
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8
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4
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-60
-40
-20
-5
22724 22843 22963 23082 23202 23322 23441 23561 23680 23800 23920
satellite track points
Deep
Ns
Cu
Sc
St
Ac
As
High

2x4 Contingency Table

CLIP

Fcst Grid	Yes	No (Clear)	No (Warm Cloud)	No (Cold Cloud)
Yes				
No				

Non-convective Clouds in the 10 to 20kft Layer

CloudSat

CIP	Y	NC	WC	CC
Y	37708	23217	4114	1003
N	16132	336367	6101	6789

Bias = CIP/CLIP = 1.23

Convective Clouds in the 10 to 20kft Layer

CloudSat

CIP	Y	NC	WC	CC
Y	46228	23217	5736	308
N	9248	336367	3553	1766

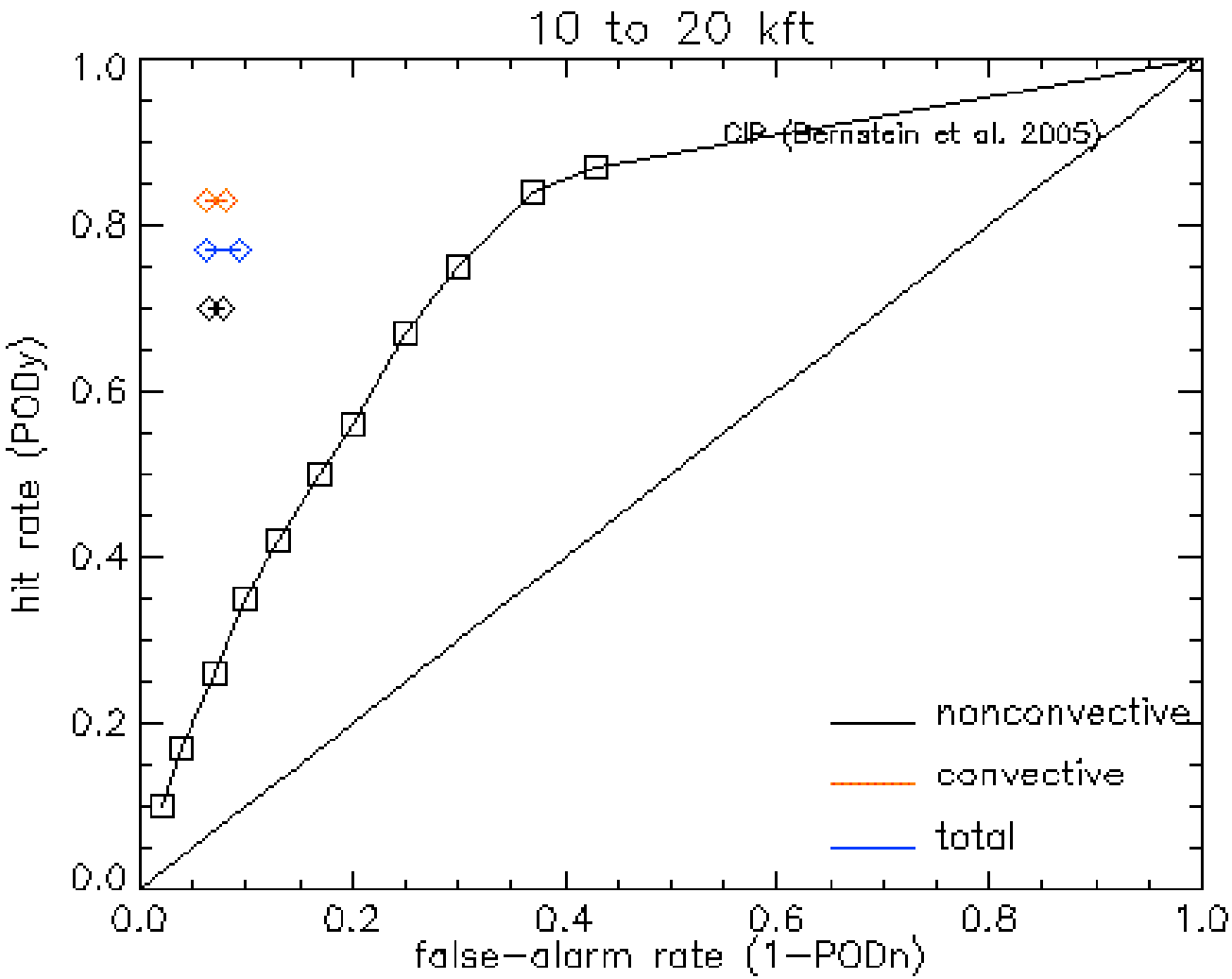
Bias = CIP/CLIP = 1.36

All Clouds in the 10 to 20kft Layer

CloudSat

CIP	Y	NC	WC	CC
Y	83936	23217	9850	1311
N	25380	336367	9654	8555

Comparison with Previous CIP Study



Phase 1 Summary: Understanding of CLIP

- Primary quantitative comparison to Current Icing Potential (CIP)
  - CIP is current operational grid diagnostic over CONUS
  - Strong agreement between CLIP and CIP for Phase 1 study

- PIREP case studies
  - Significant agreement
  - Disagreement example: CLIP diagnosed cloud, too warm

- Important details …
  - CLIP agreed most strongly at CIP Trace (~0.1) threshold
  - Little difference in agreement: coastal vs. continental
  - Vertical, horizontal windows in matching mechanics
    - Matched to horizontal and vertical scales in Phase 2
  - Primarily studied non-convective icing at mid-level

Phase 2 Discussion

- Background Information
  - Forecast descriptions (US, UK, SigWx)
    - Attributes, issuances
  - Matching mechanics
  - Stratifications

- Analysis
  - Comparison of US and UK grids
    - Qualitative cases
    - Quantitative
  - Comparison of grids to SigWx
  - Supplementary comparison of US grid/FIP in CONUS

Phase 2
Background Information

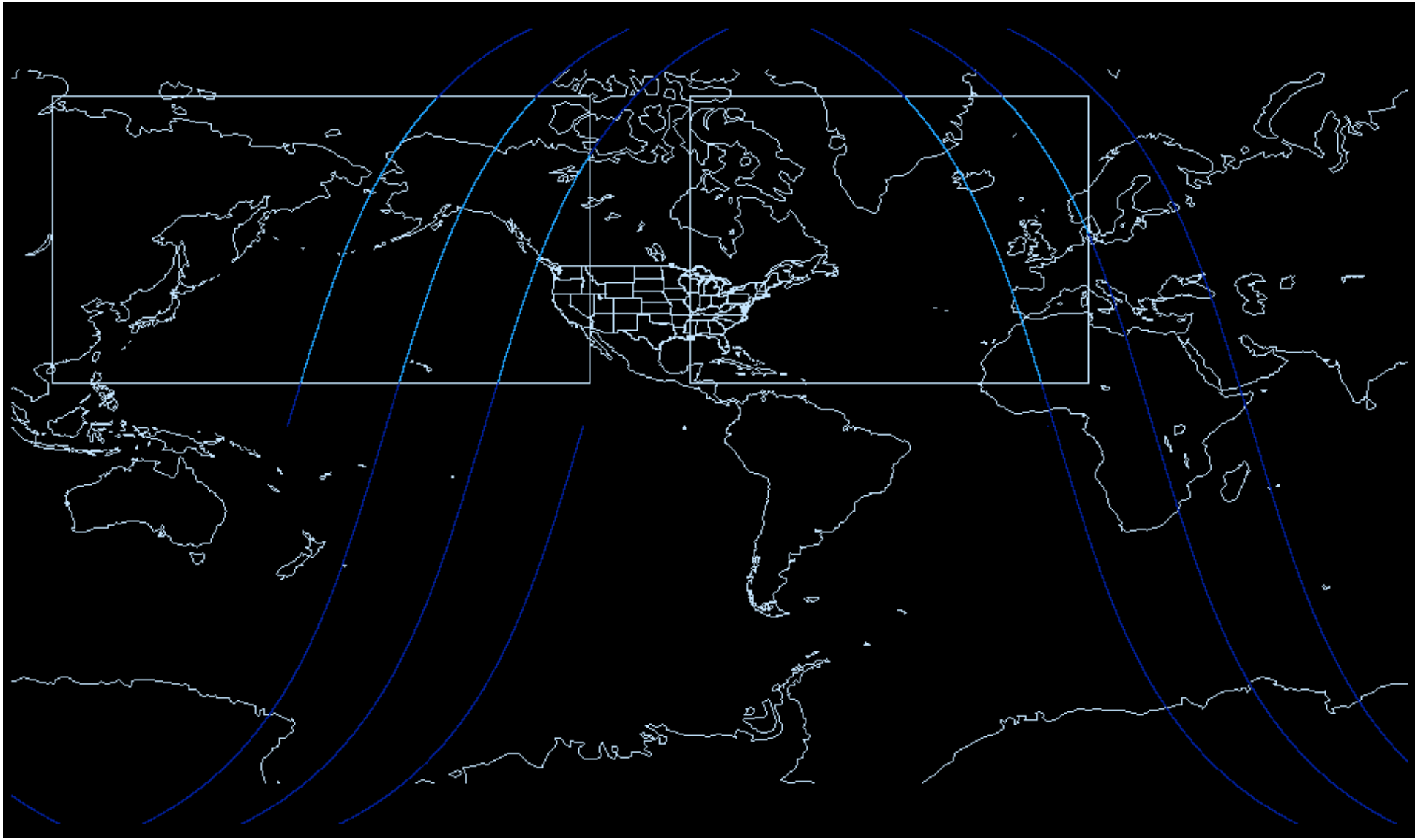
WAFS Gridded Forecasts

- Model-derived global forecasts
  - Washington (GFS)
  - London (UKMET)
- 3-hour time intervals
  - T+6, 9, 12, 15, 18, 21, 24, 27, 30, 33, and 36 hours
- Recommended use 1 hour 30 minutes before and after each time step
- Automatically updates and cancels the corresponding forecast issued six hours earlier

Phase 2 Analysis Stratifications

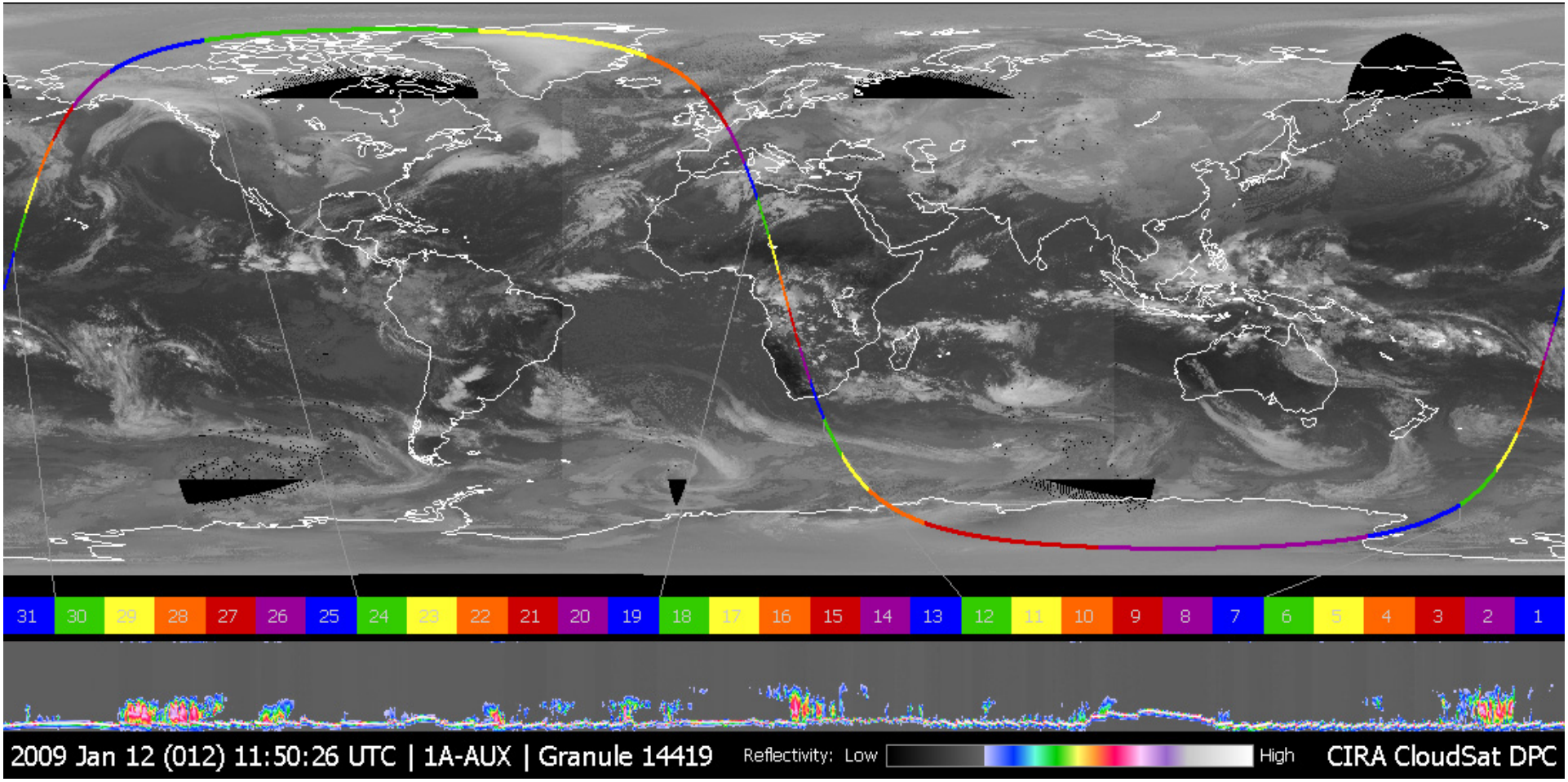
- Geographic domain
  - Global, N. Atlantic, N. Pacific
- Flight level
  - All, FL100, FL140
- Cloud type (as diagnosed by CloudSat)
  - All, Convective, Non-convective
- Algorithm threshold
  - 0.1, 0.3, and 0.5
- Lead time
  - All leads 6, 12, …, 36-h individually

Domains

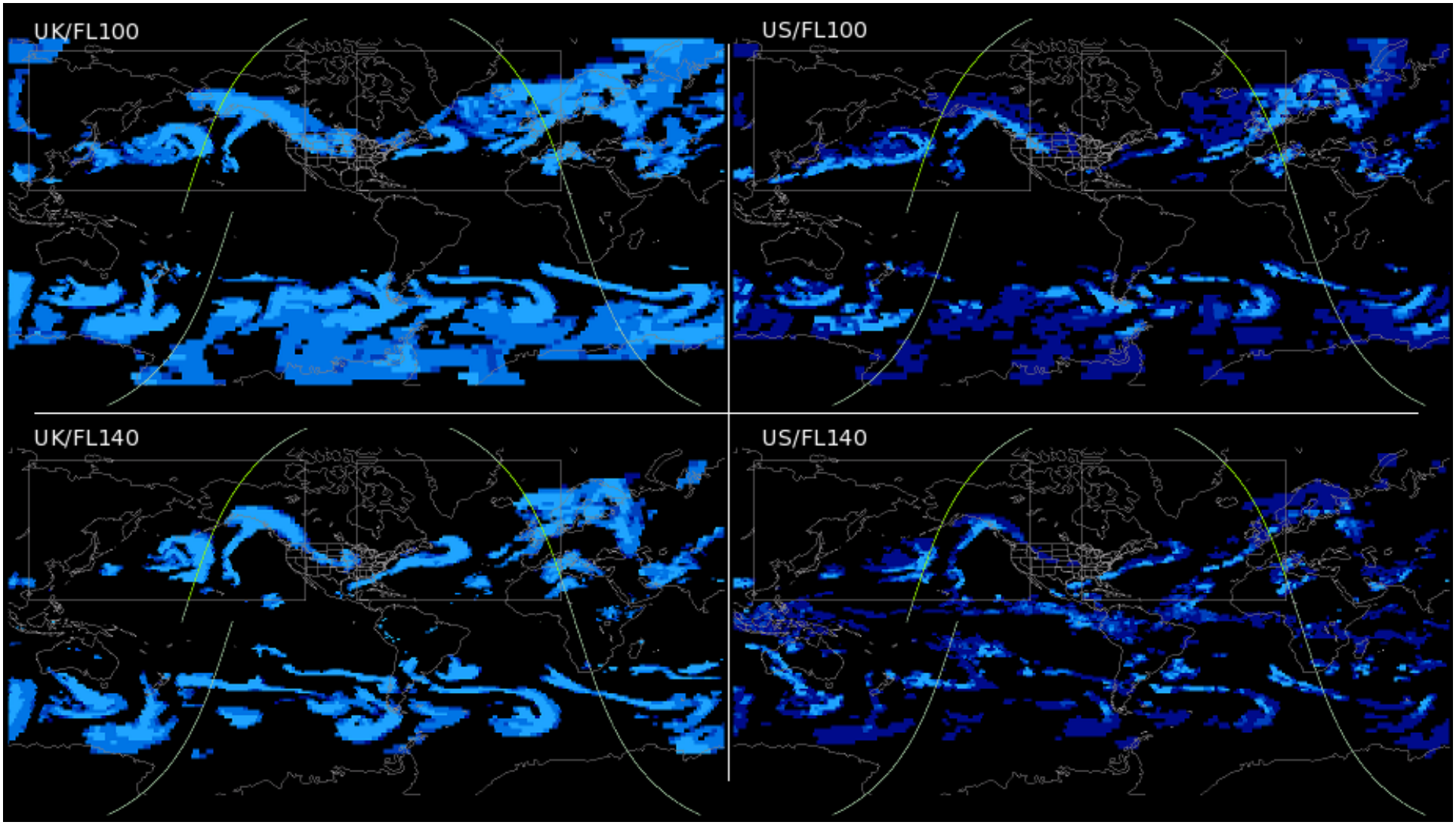


Phase 2 Analysis
Comparison of Global Icing Grids

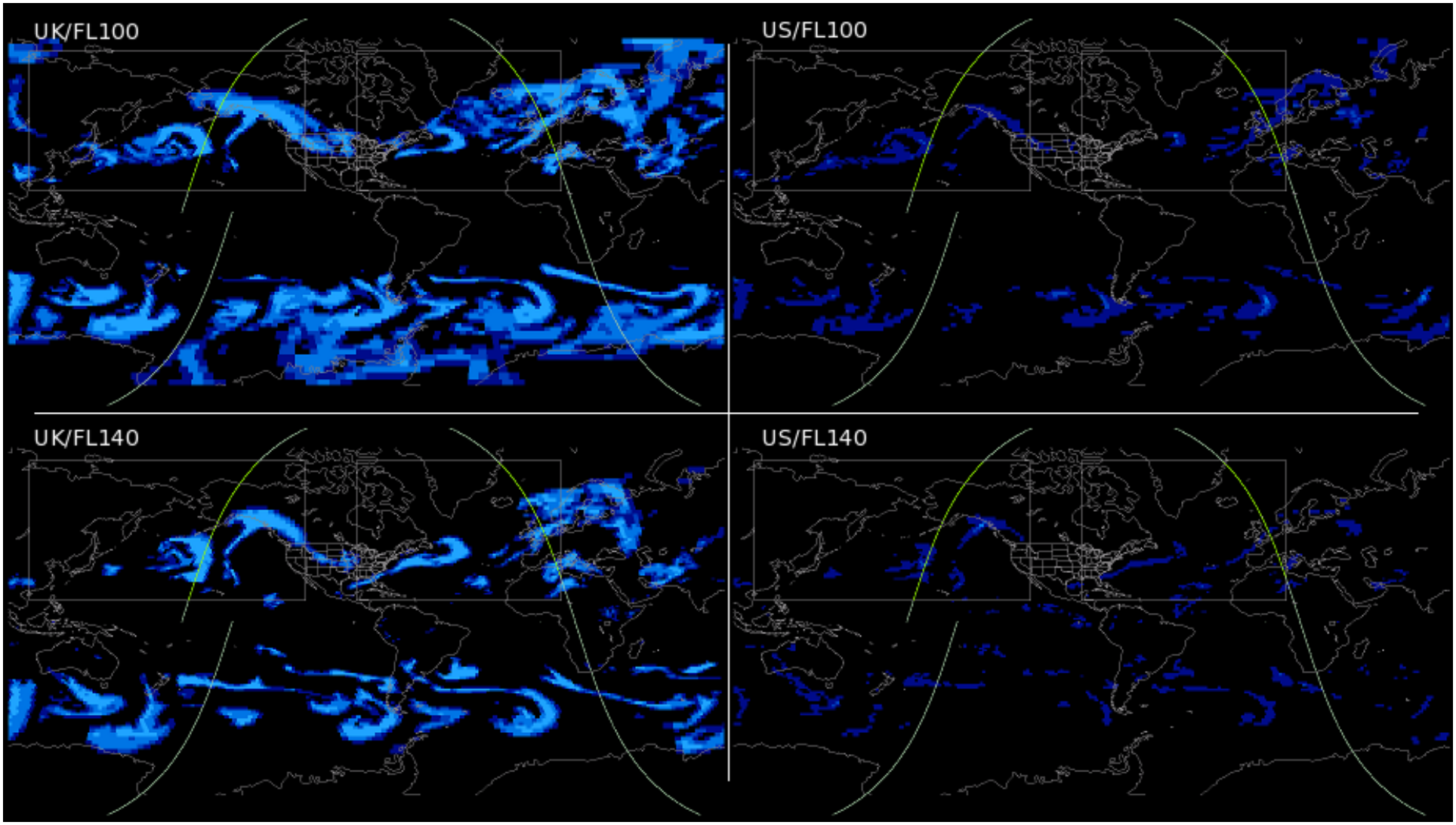
12 January 2009



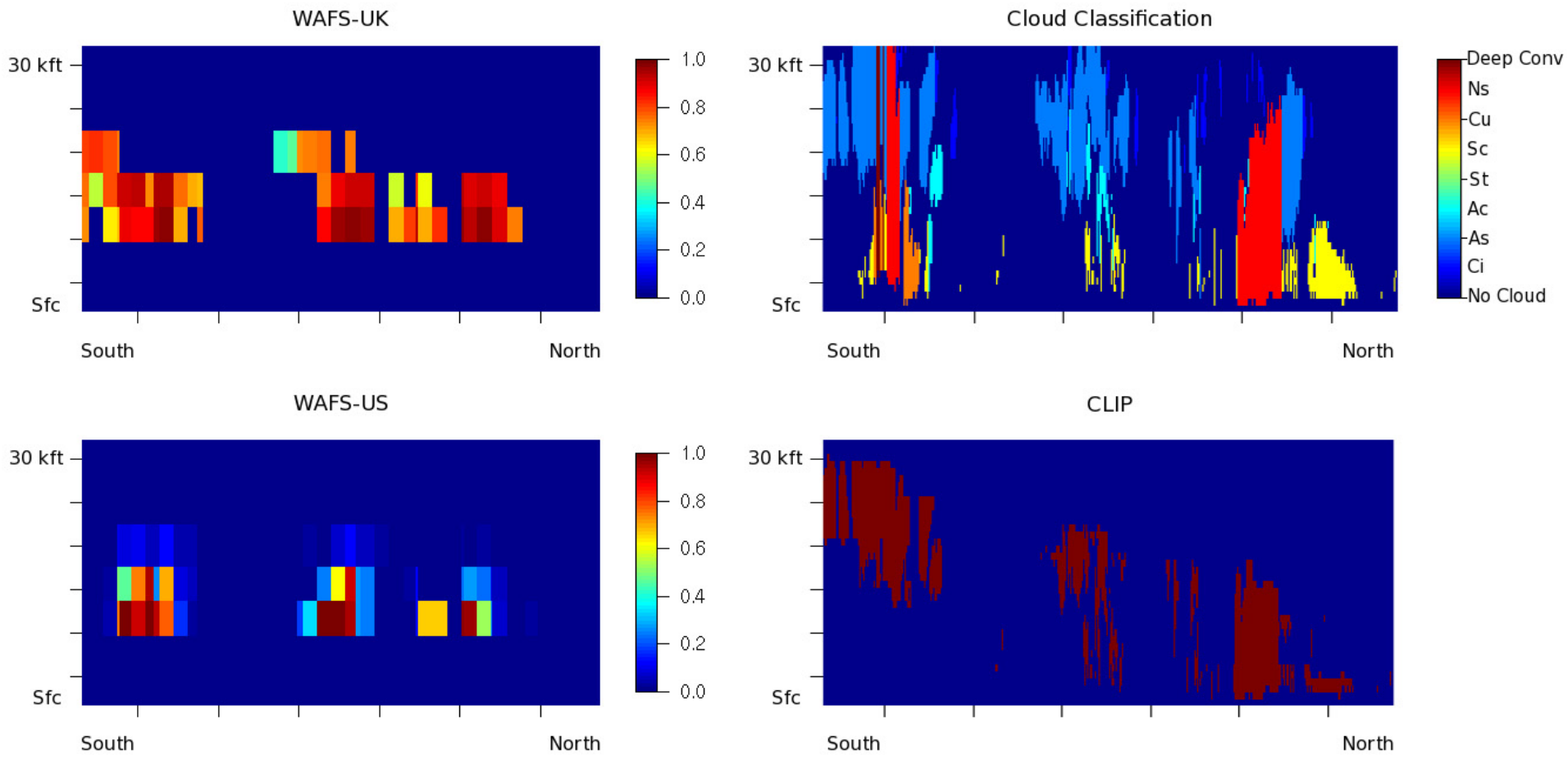
WAFS Maximum Icing



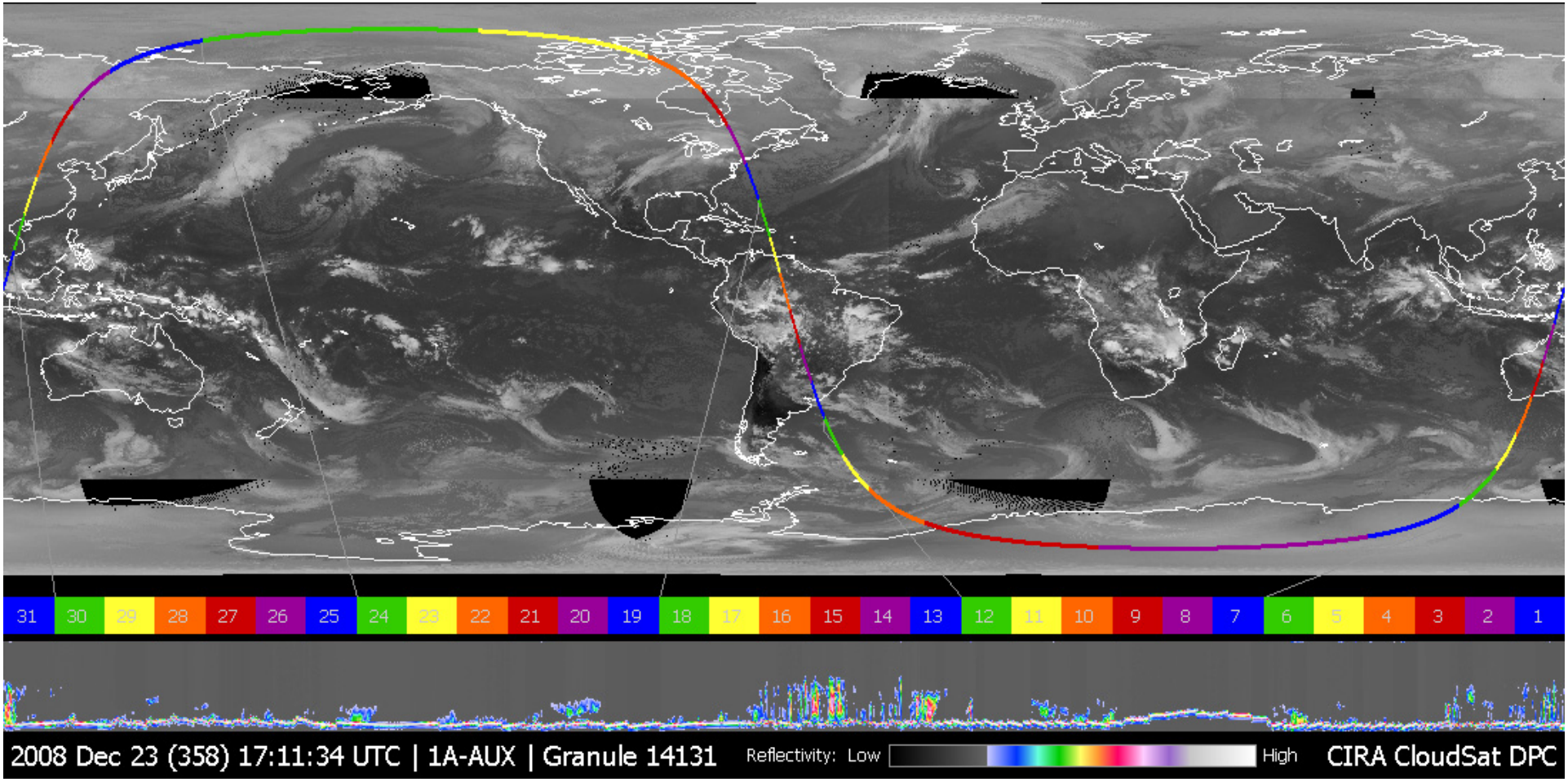
WAFS Mean Icing



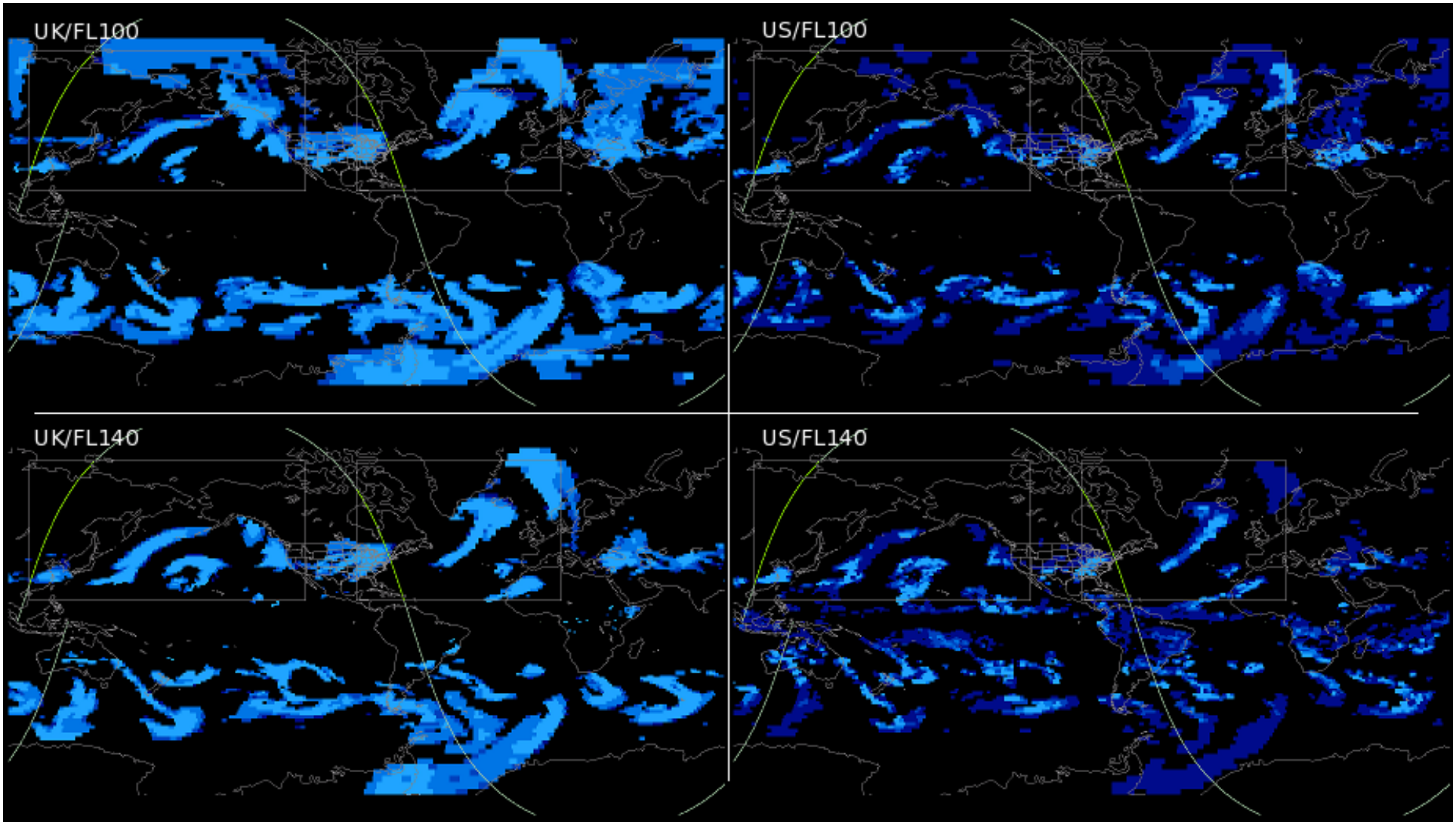
Vertical Cross Sections Along CloudSat Path in Atlantic Domain



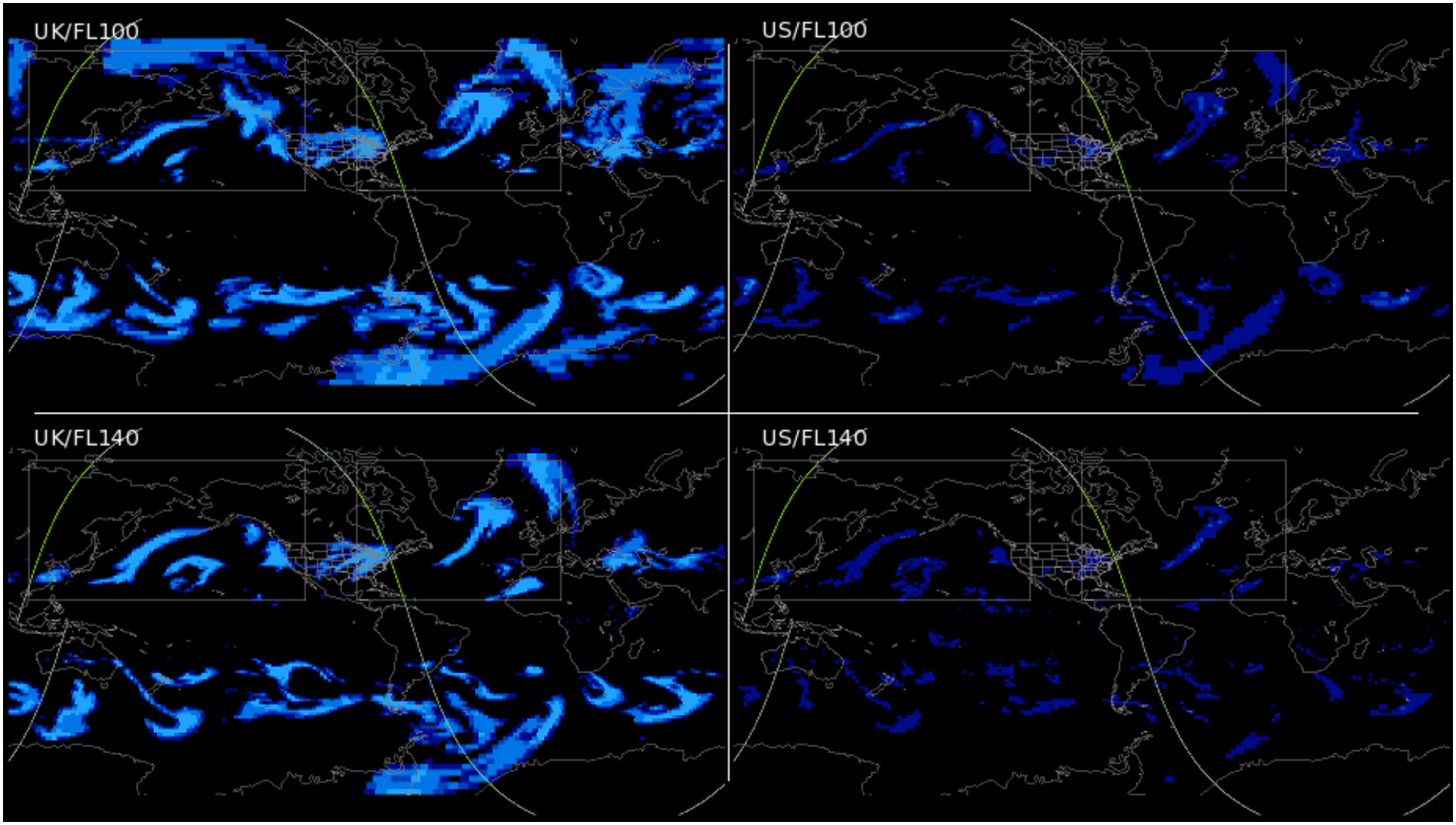
23 December 2008



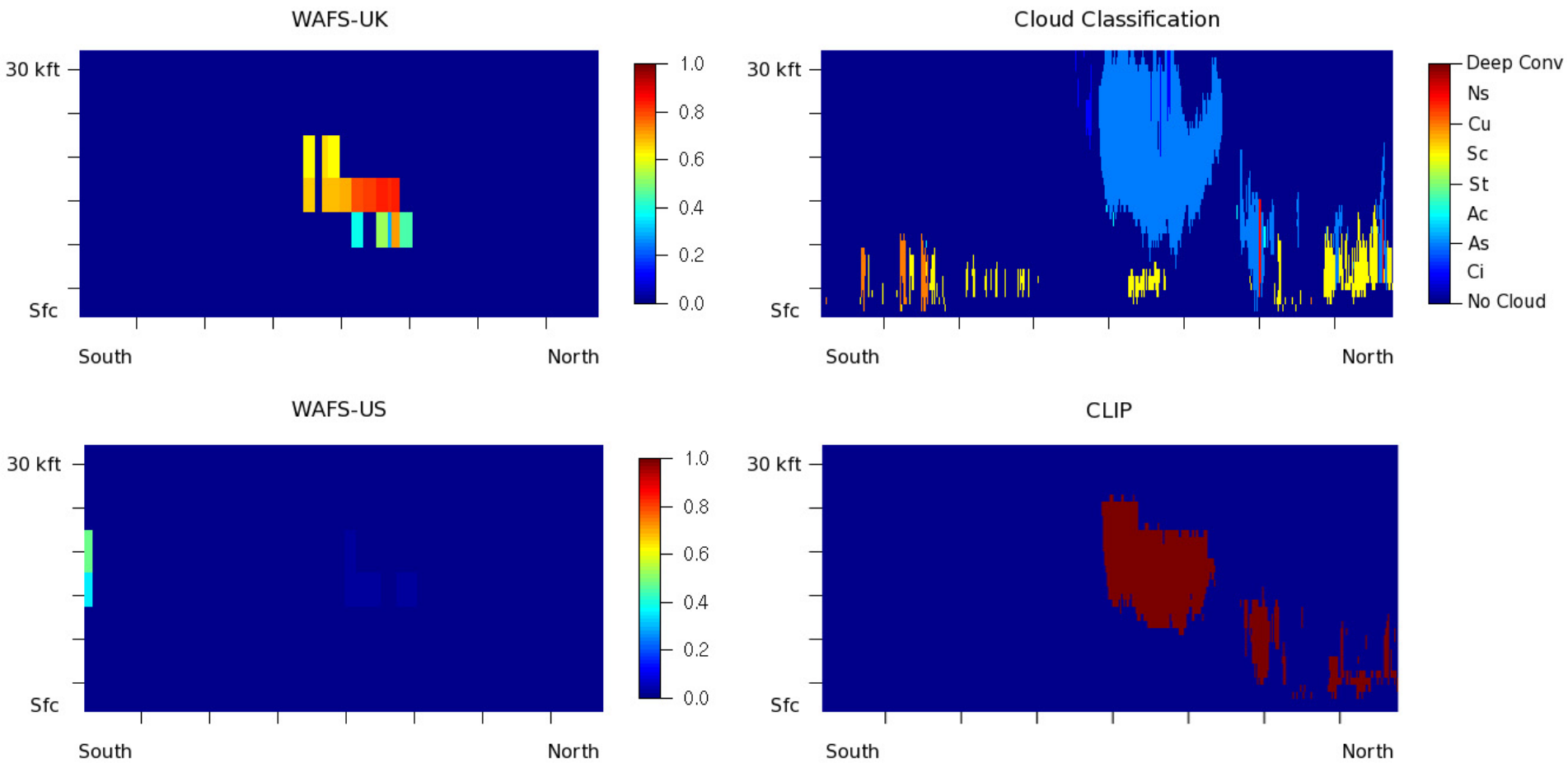
WAFS Maximum Icing



WAFS Mean Icing

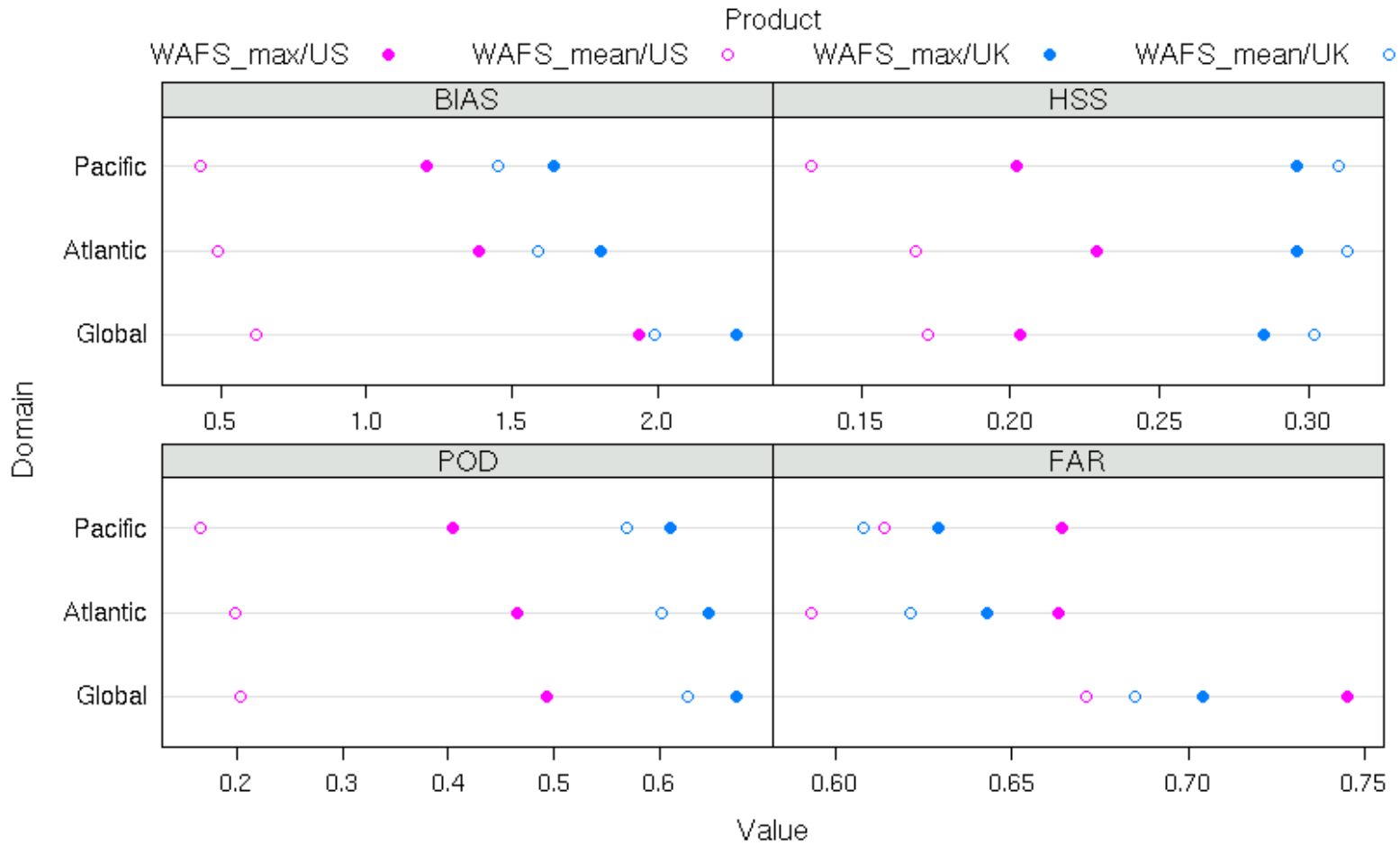


Vertical Cross Sections Along CloudSat Path in Atlantic Domain



Comparison of Performance: Geographic Domain

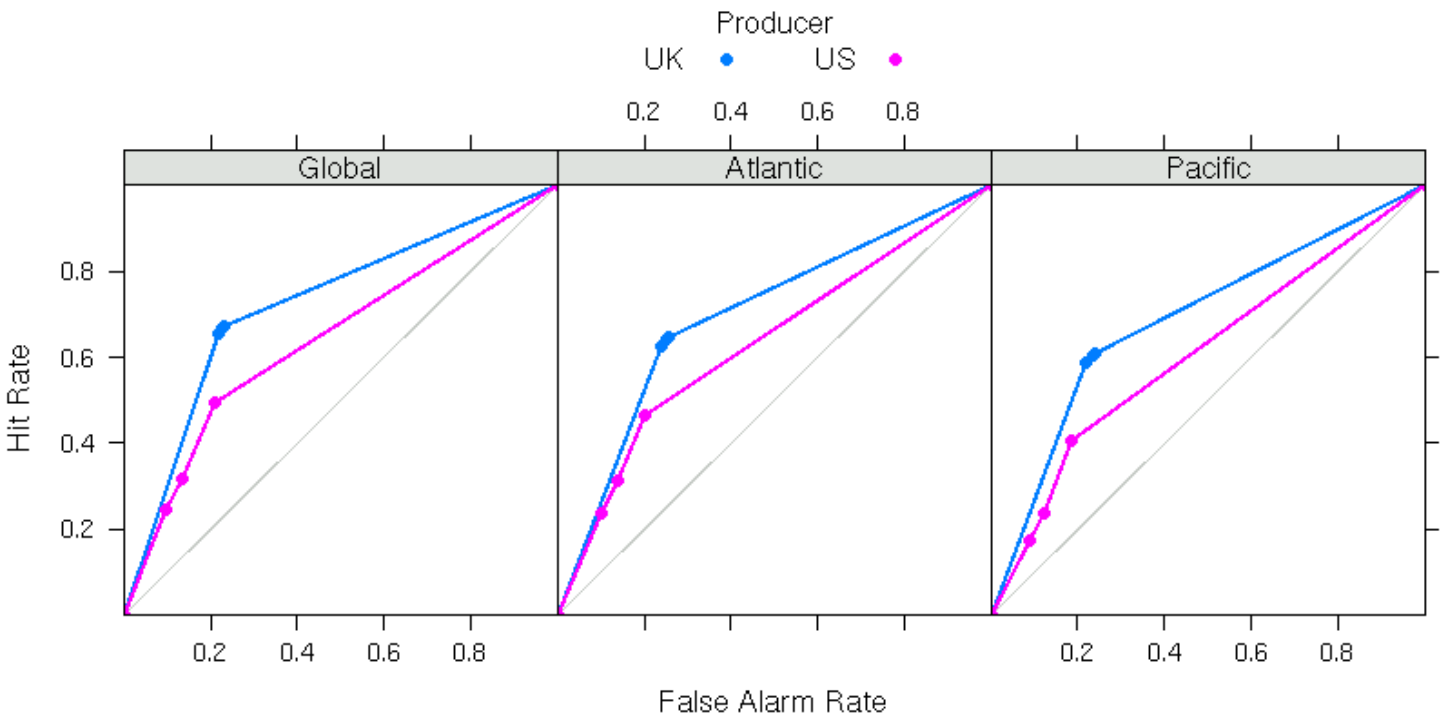
(Statistics for 0.1 threshold, all lead times, FL100/140, all cloud types)



Most notable difference in Global domain bias

Comparison of Performance: Geographic Domain

(Statistics for all lead times, FL100/140, all cloud types)

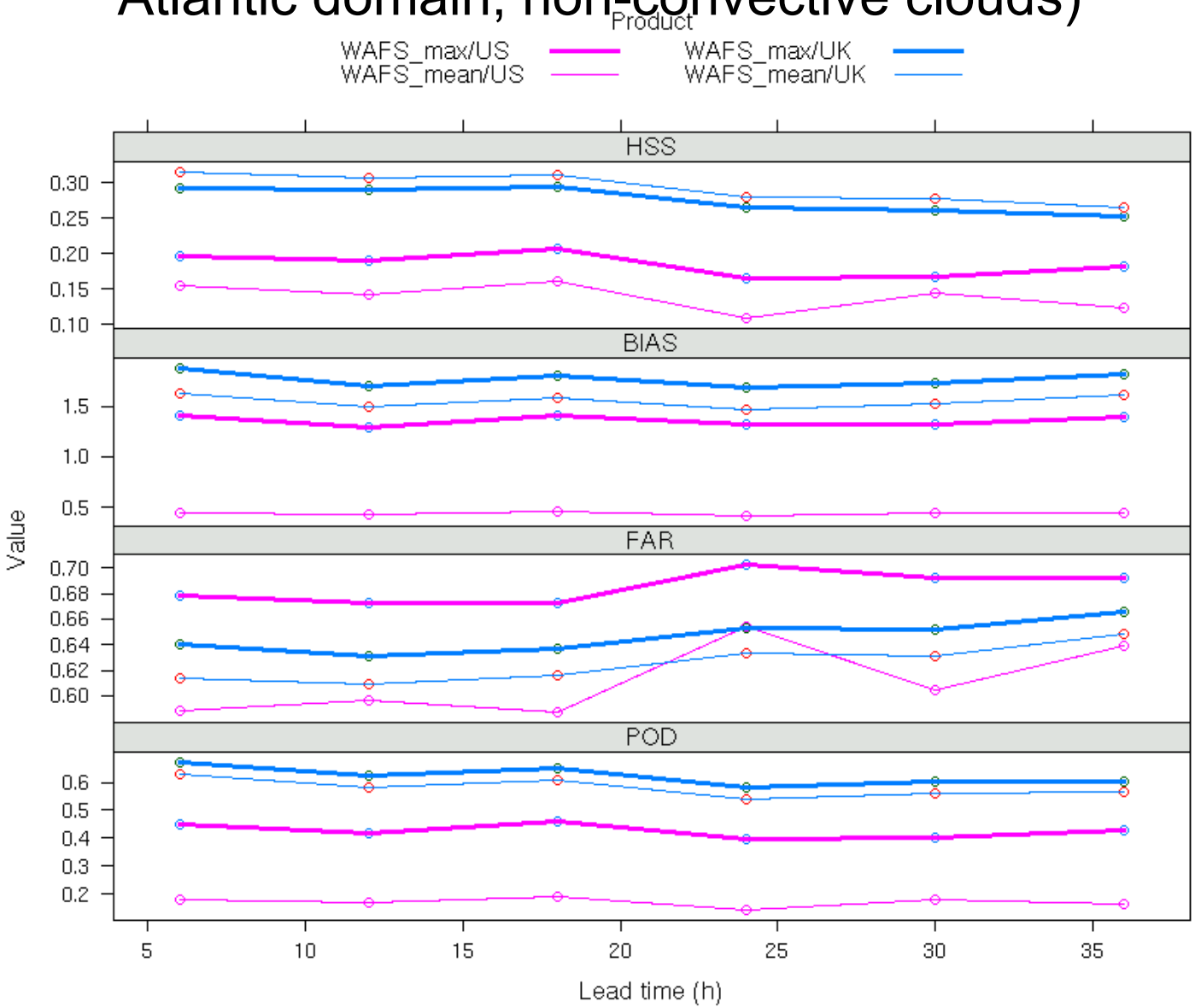


Thresholds: 0.1, 0.3, and 0.5

UK points clustered - little difference between thresholds

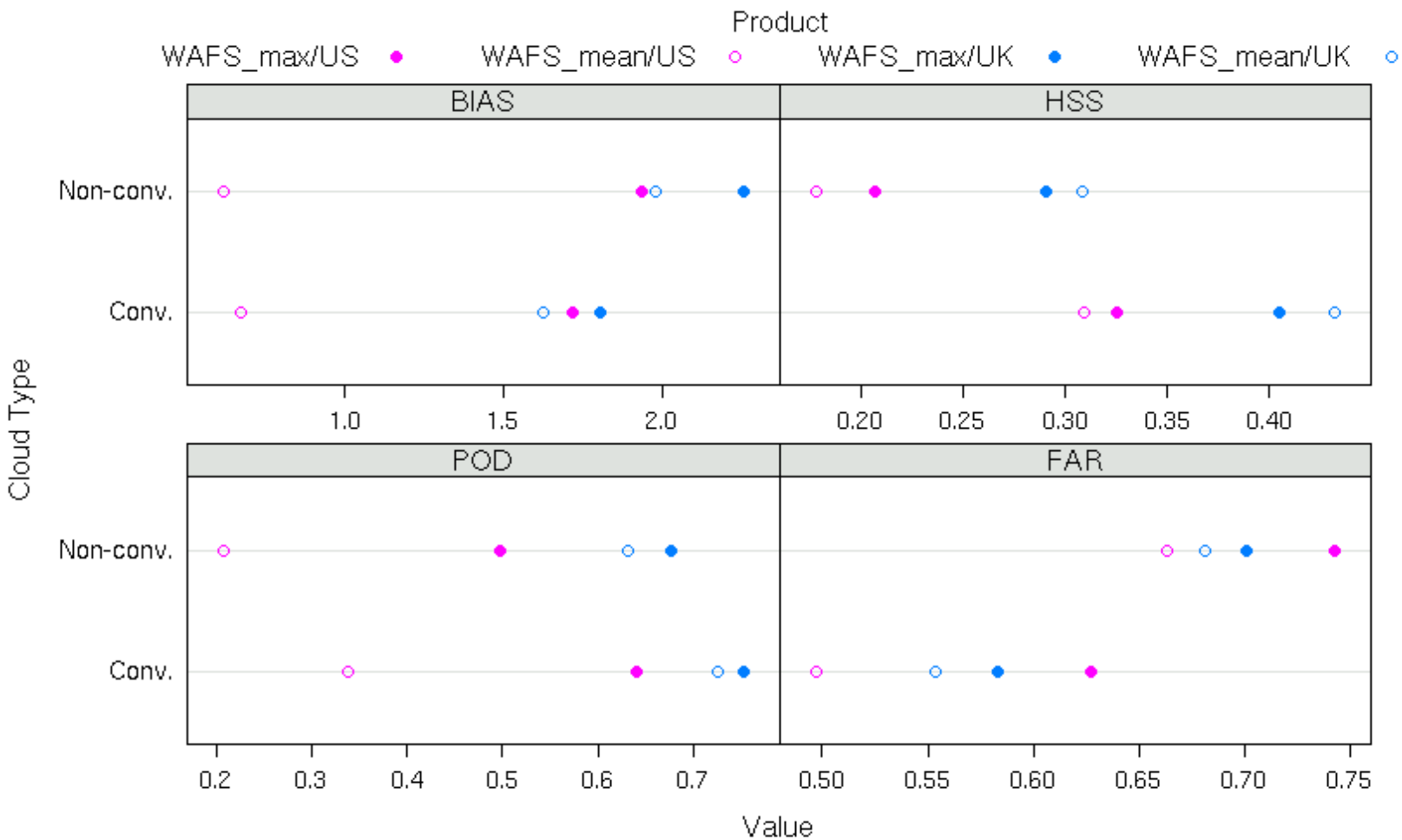
Comparison of Performance: Lead Time

(Statistics for 0.1 threshold, FL100/140, Atlantic domain, non-convective clouds)



Comparison of Performance: Cloud Type

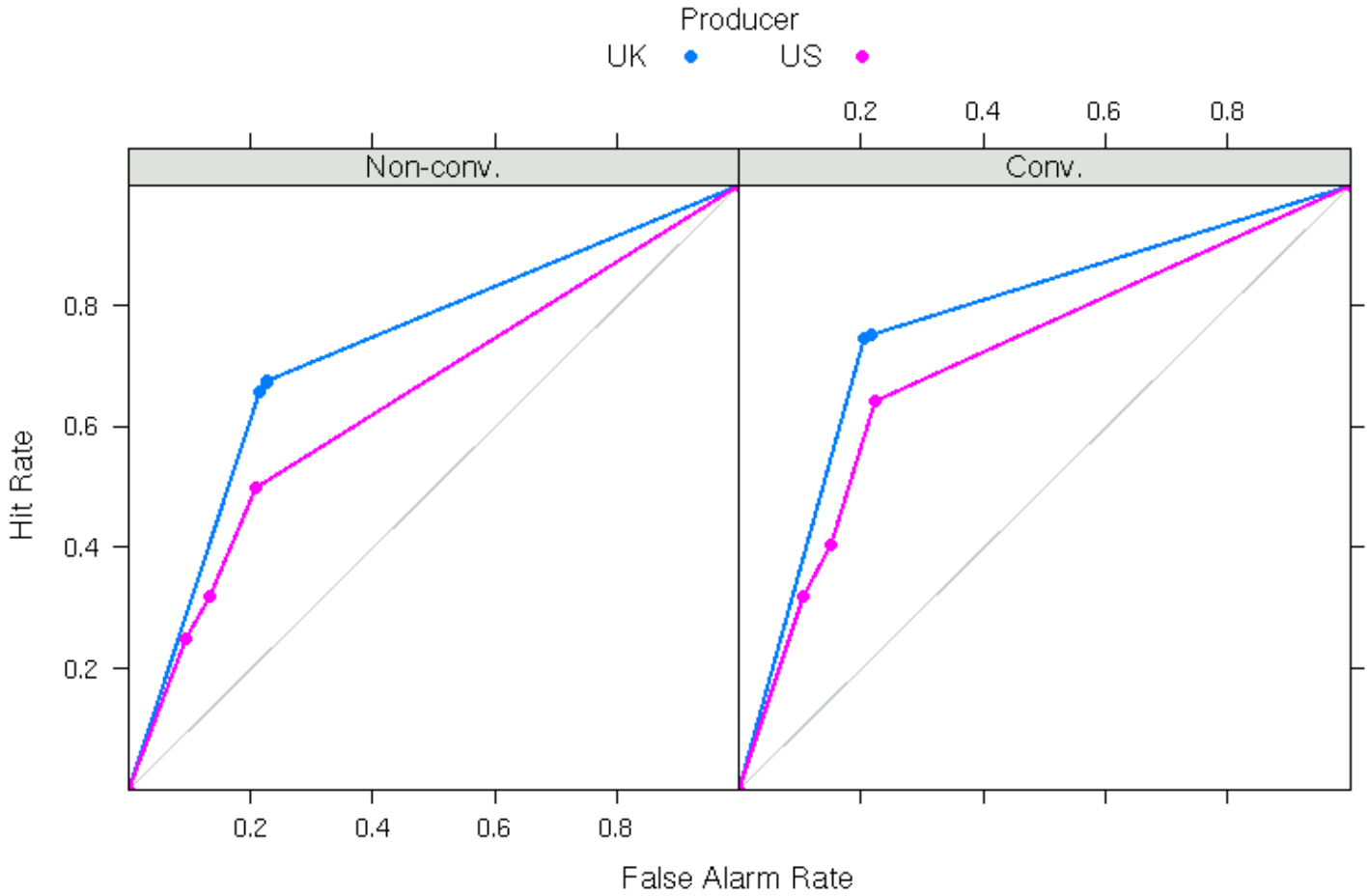
(Statistics for 0.1 threshold, FL100/140,
12- and 18-hr leads, Global domain)



Both algorithms perform better for convective icing

Comparison of Performance: Cloud Type

(FL100/140, 12- and 18-hr leads, Global domain)

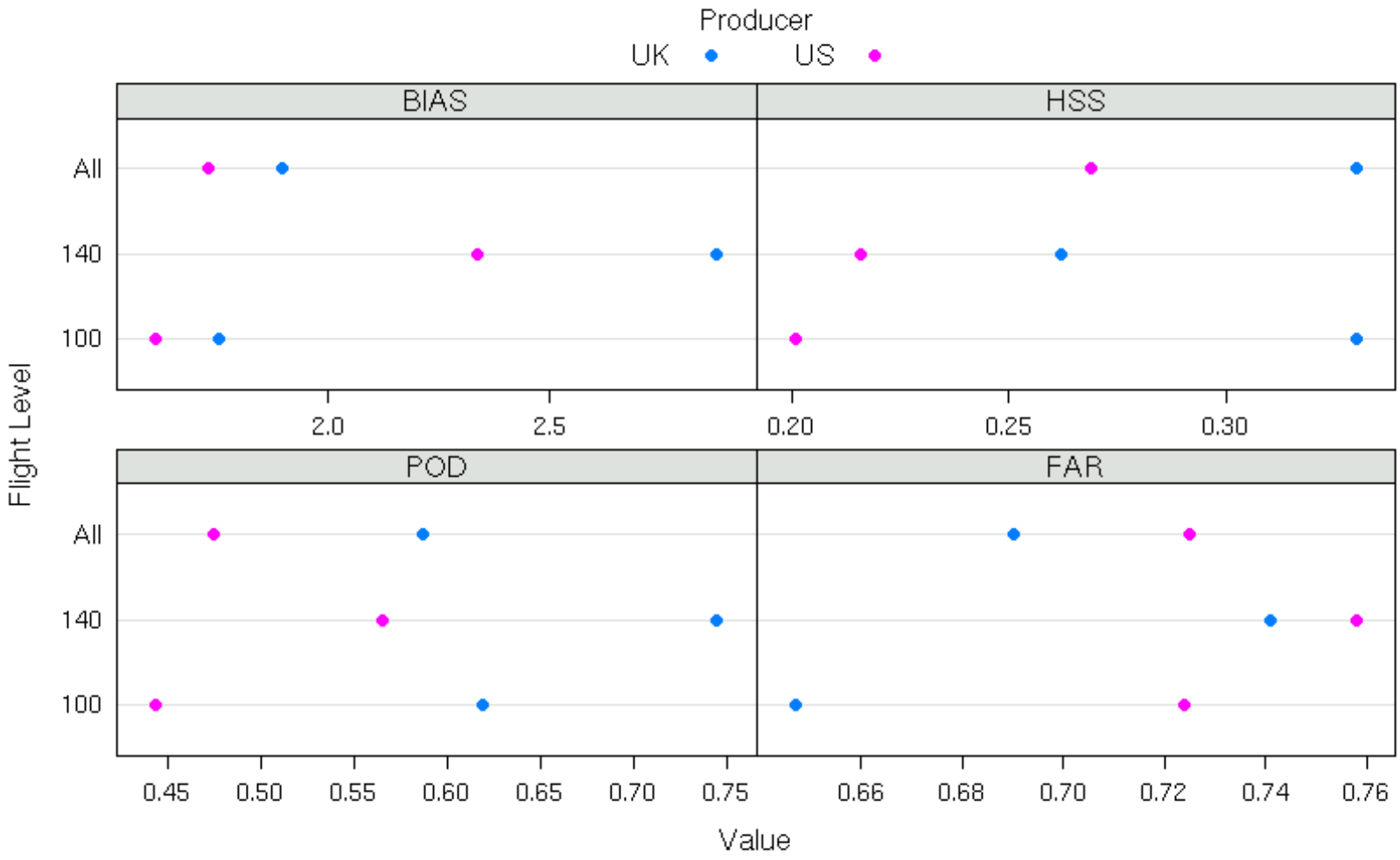


ROC Thresholds: 0.1, 0.3, and 0.5

Confirms algorithms perform better for convective icing

Comparison of Performance: Flight Level

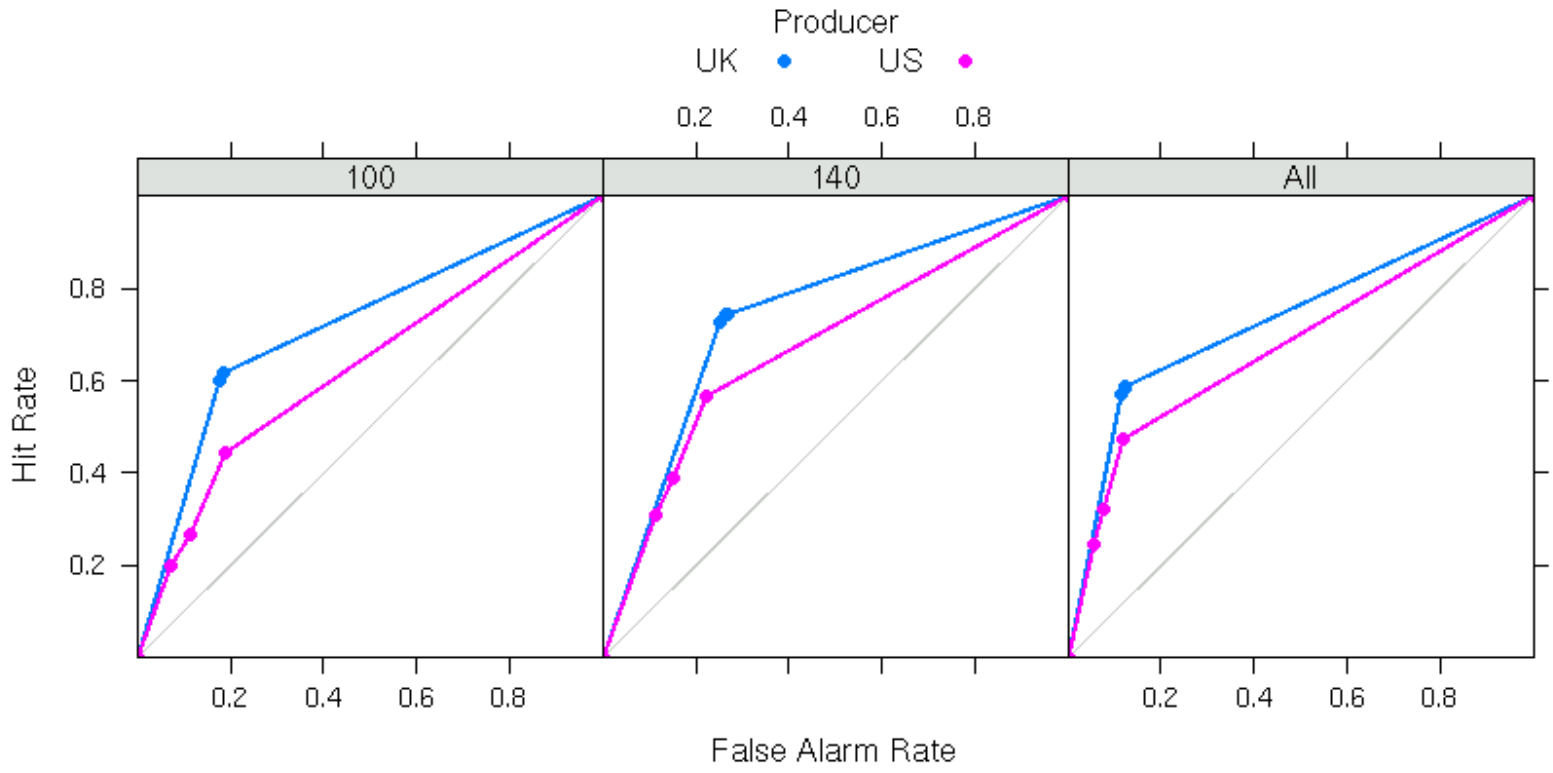
(Statistics for 0.1 threshold, 12- and 18-hr leads, Atlantic domain, non-convective clouds, max icing attribute)



Bias and FAR notably larger at FL140 for both algorithms

Comparison of Performance: Flight Level

(Statistics for 12- and 18-hr leads, Atlantic domain, non-convective clouds, max icing attribute)



ROC Thresholds: 0.1, 0.3, and 0.5

Confirms variation in performance by flight level

“Naïve Operational” Comparison

Atlantic domain, 0.1 threshold, FL100/140, 12- and 18-hr leads, max icing intensity, non-convective clouds

UK (fcst)

	Y	NC	WC	CC
Y	12367	15356	2940	3640
N	6684	54837	6430	3375

US (fcst)

	Y	NC	WC	CC
Y	8987	11576	3661	2251
N	10063	58617	5709	4764

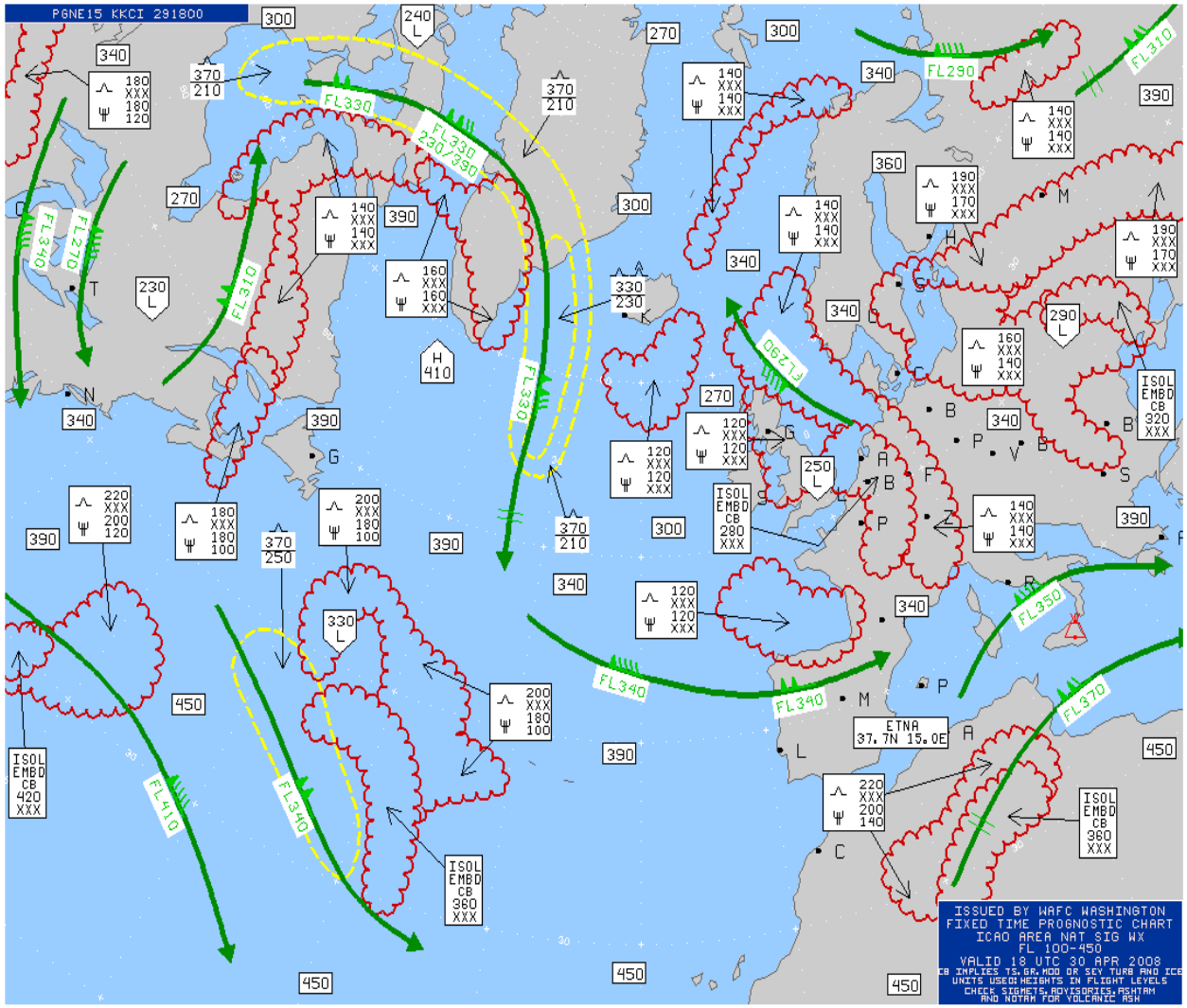
CloudSat (obs)

Phase 2 Analysis
Comparison of Global Icing Grids and SigWx Chart

WAFS Mid Level SIGWX

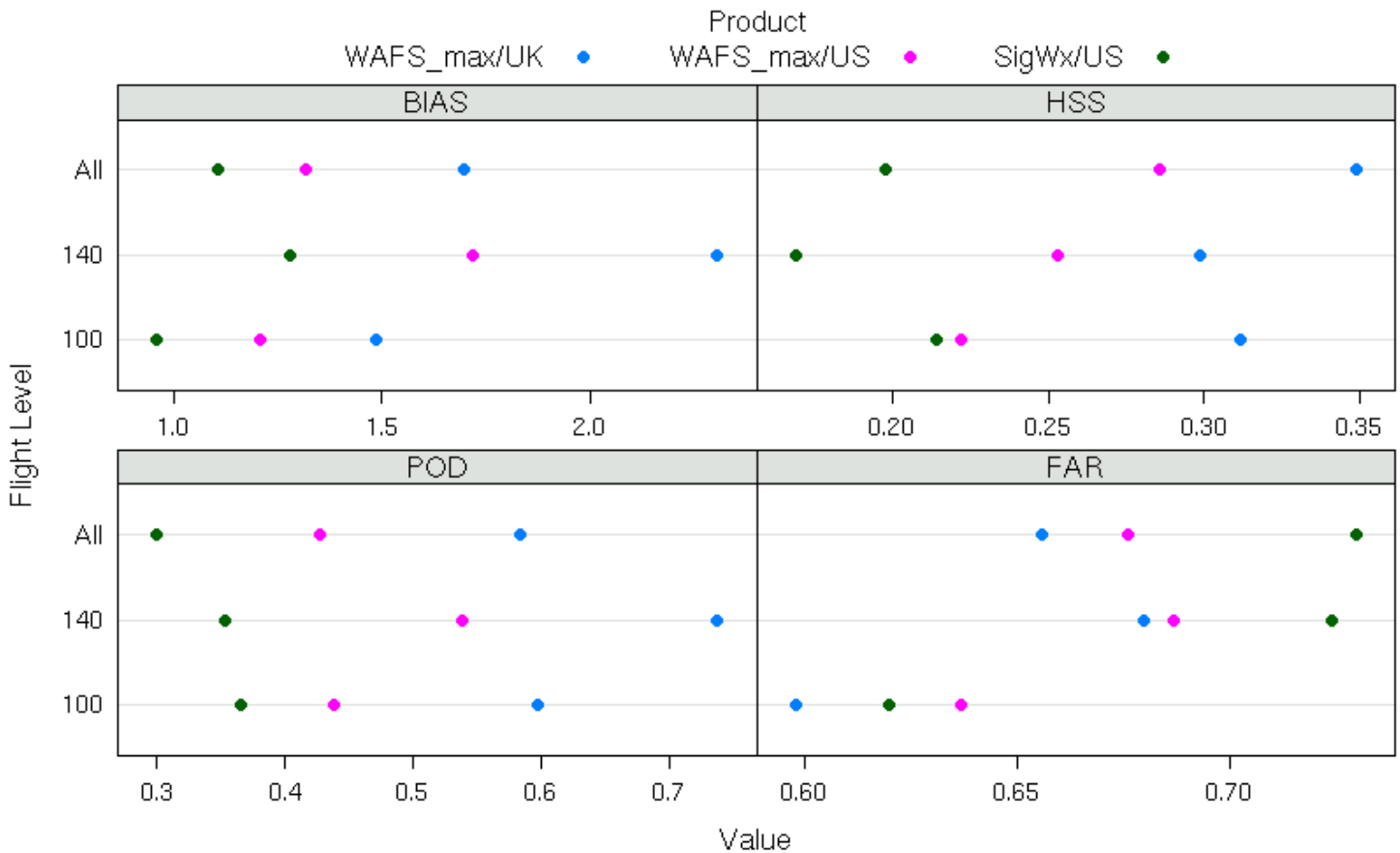
00z, 06z, 12z, 18z

- Thunderstorms/CB
- Tropical Cyclones
- Mod/Sev Turb (CAT or IC)
- Mod/Sev Icing
- Tropopause Heights
- Jetstreams (80kt and above depicted)
- Jet Depth
- Volcanic Eruptions
- Widespread Sand/Dust storms
- Release of Radioactive Materials



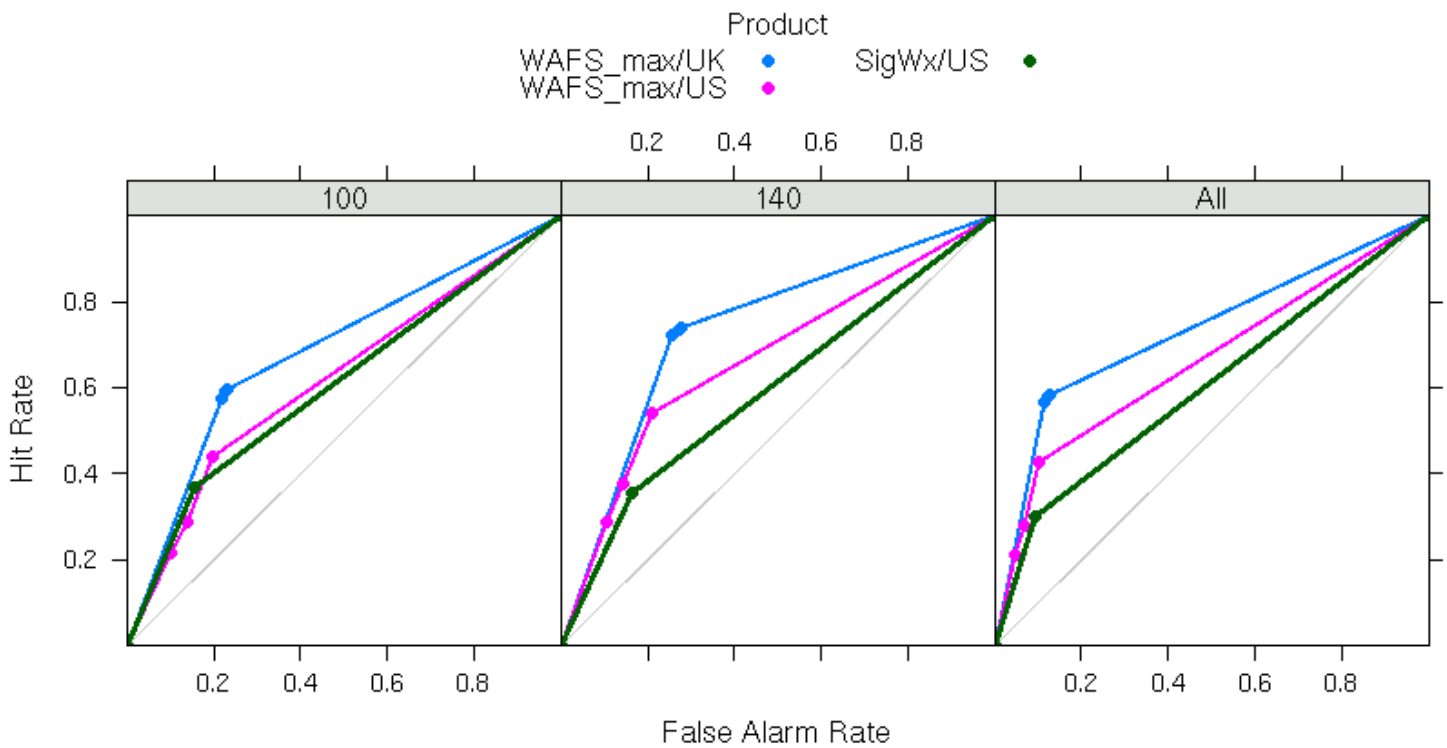
Comparison of Performance: SigWx Chart

(Statistics for 0.1 threshold, FL100/140, SigWx issuances/lead, Atlantic domain)



UK and US grids appear to outperform the SigWx icing product;
Note that SigWx doesn't forecast 'trace icing'

Comparison of Performance: SigWx Chart
(FL100/140, SigWx issuances/lead, Atlantic domain)

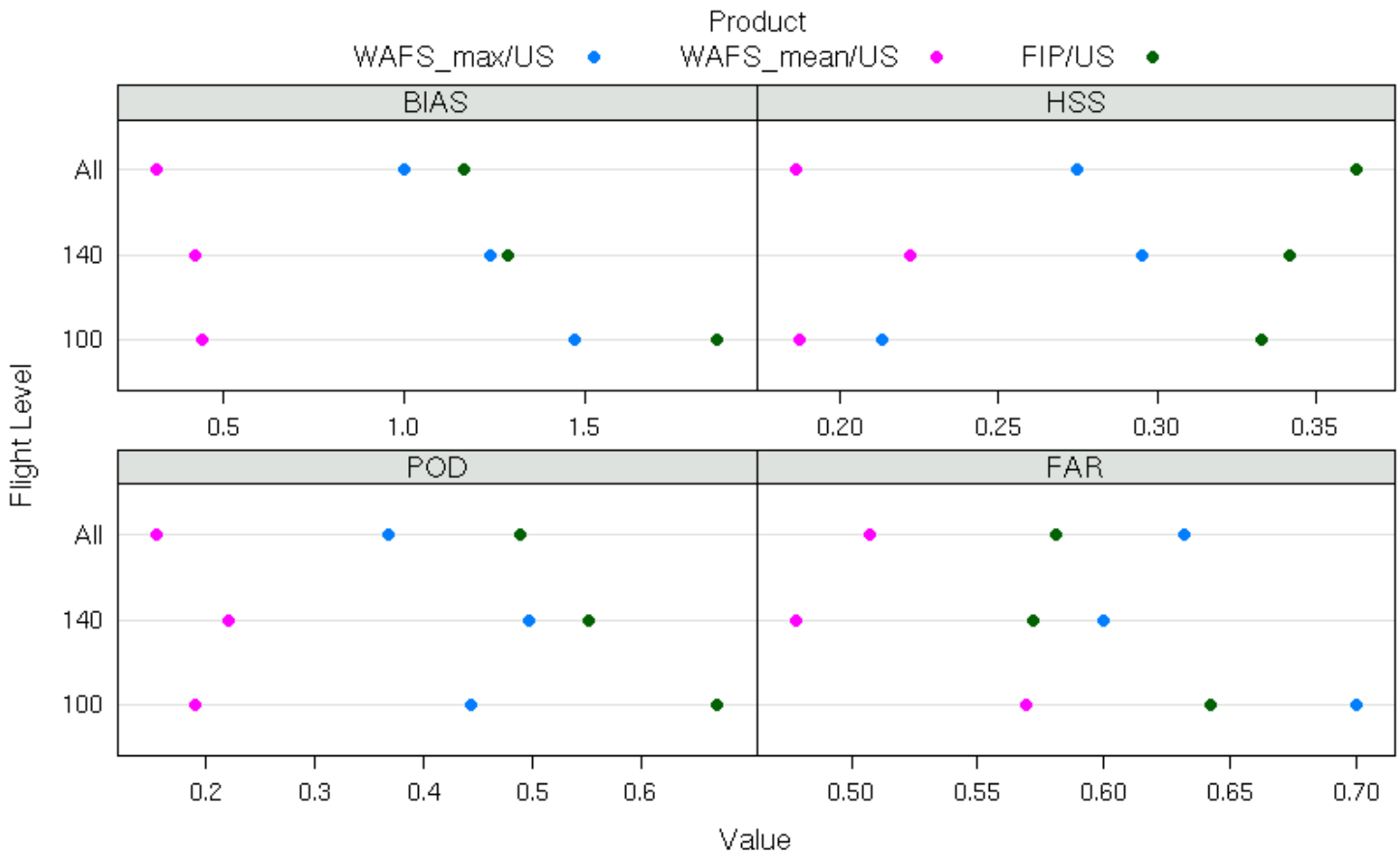


ROC Thresholds: 0.1, 0.3, and 0.5
Confirms algorithms seemingly outperform SigWx product

Phase 2 Analysis
Comparison of US Icing Grid and Forecast Icing Potential (FIP) over CONUS Domain

Diagnostic Comparison: Forecast Icing Potential (FIP)

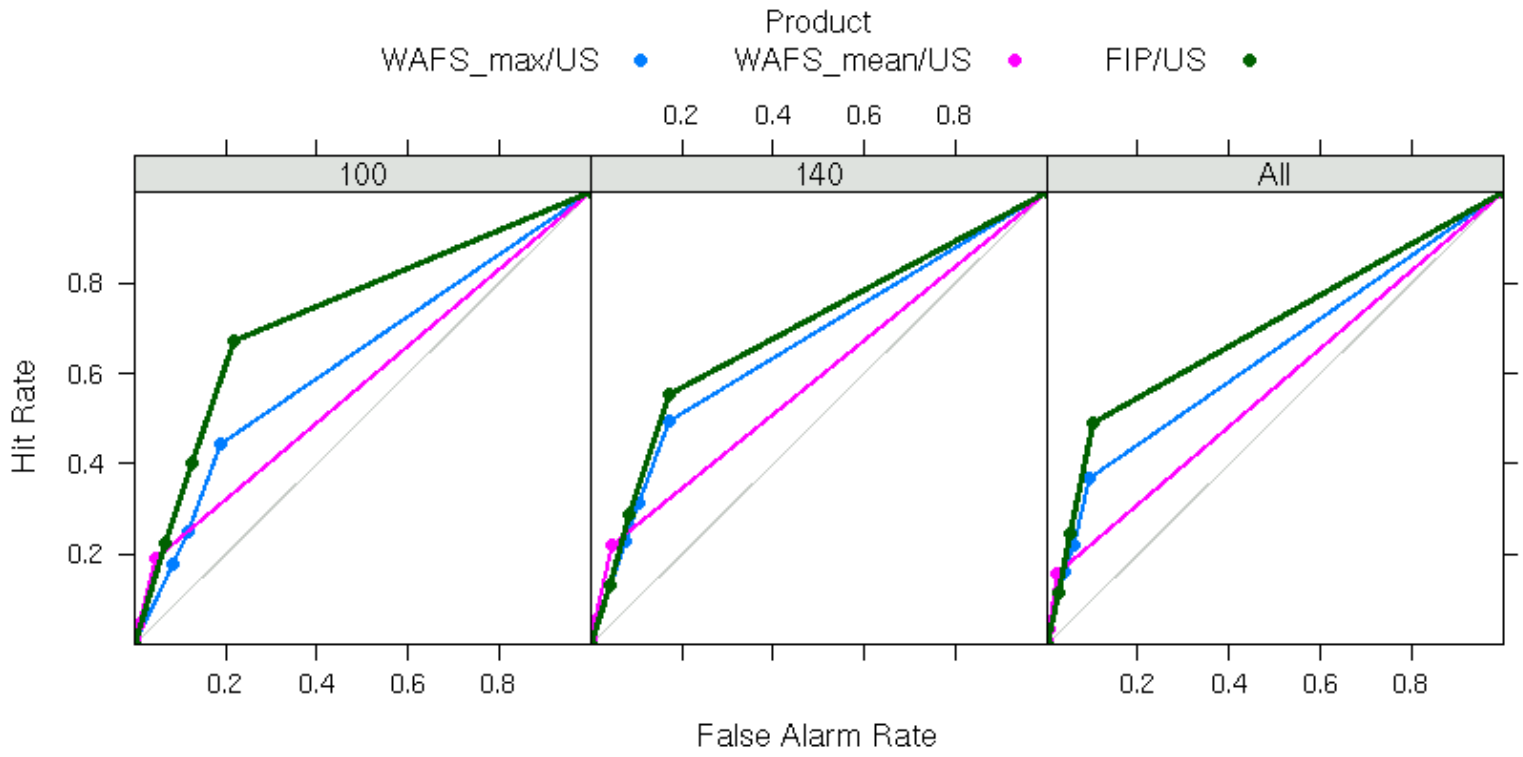
(Statistics for 0.1 threshold, FL100/140,
6- and 12-hr leads, CONUS domain)



FIP seemingly outperforms the US algorithm over CONUS at the 0.1 threshold

Diagnostic Comparison: Forecast Icing Potential (FIP)

(Statistics for FL100/140, 6- and 12-hr leads, CONUS domain)



ROC Thresholds: 0.1, 0.3, and 0.5

Slopes might indicate more information in algorithm below 0.1

Overall Summary

- CLIP diagnostic shown to agree strongly with CIP over the CONUS domain, at the trace threshold
- The UK icing grid appears to outperform the US icing grid at the 0.1 threshold for both the max and mean attributes
- Both icing grids appear to outperform the SigWx icing product
- A diagnostic comparison of the US icing grid with FIP over CONUS seems to indicate information in the algorithm below the 0.1 potential threshold
  - Adjust algorithm or calibrate output?