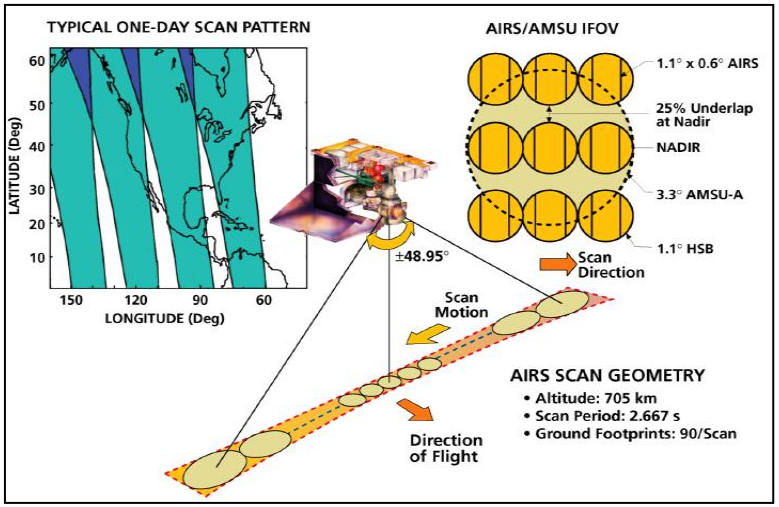
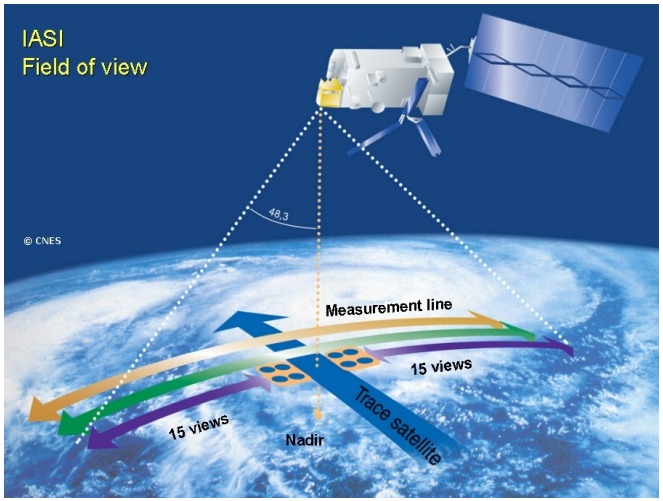
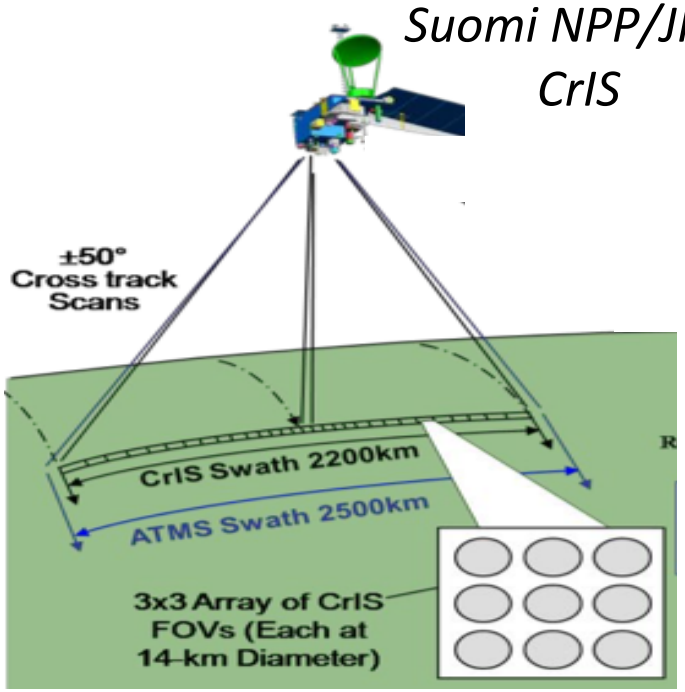
Differences between AIRS, IASI, and CrIS Sounding Retrievals – Implications for Climate Monitoring

W. L. Smith, Elisabeth Weisz, and H.E. Revercomb





Suomi NPP/JPSS CrIS

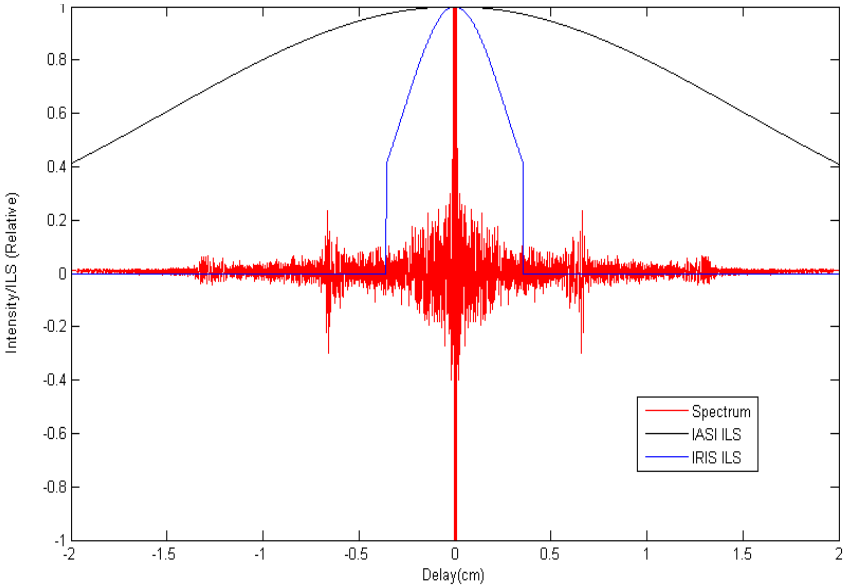


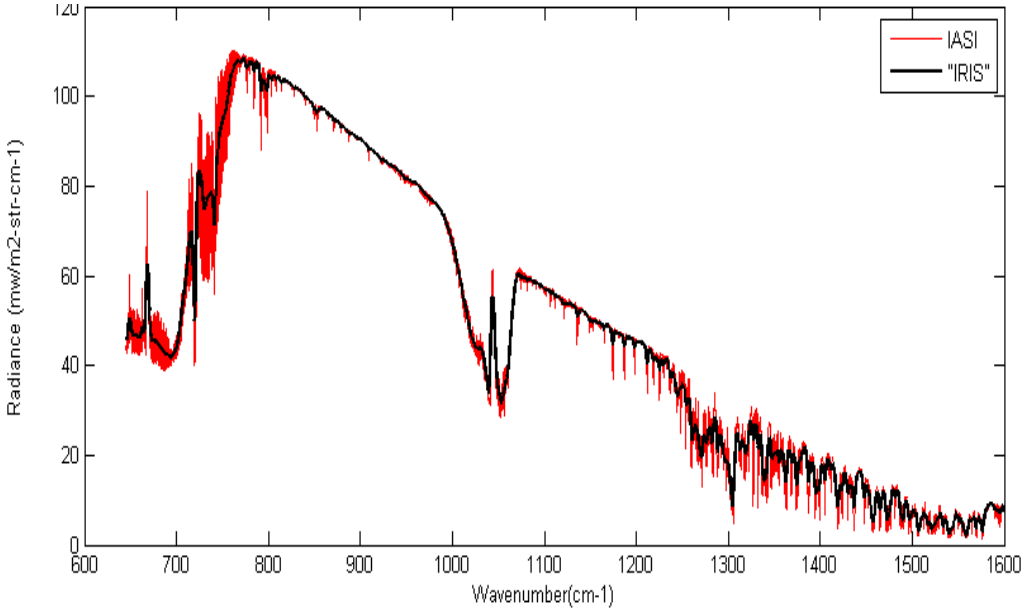
CLARREO SDT Meeting

Laboratory for Atmospheric and Space Physics, Oct. 16-18, 2012

Satellite Instrument Characteristics

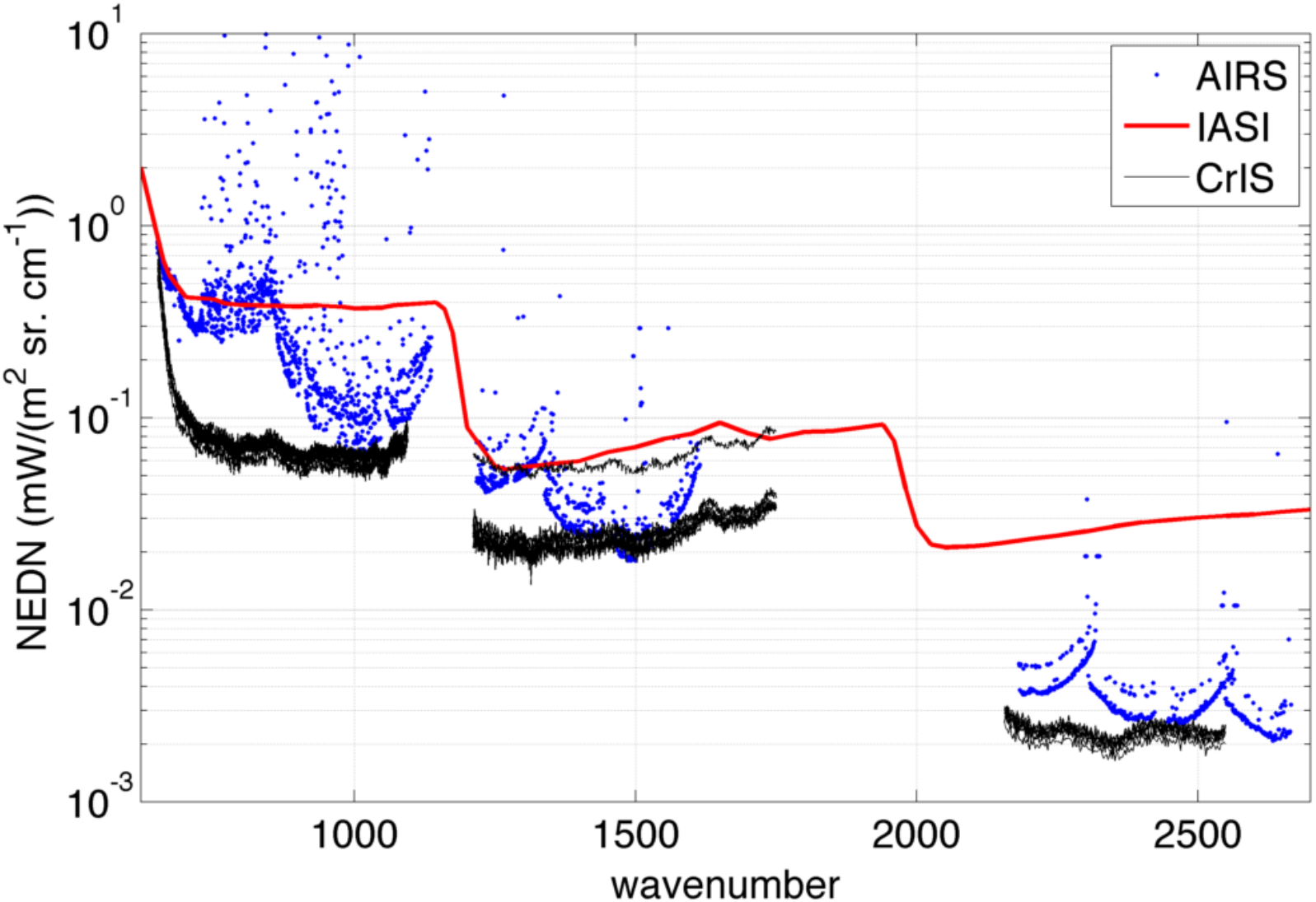
Instrument	Spatial resolution	spectral res. (cm^{-1})	spectral rng. (cm^{-1})	spatial sampling
IRIS (1970)	100 km	1.40	400-1600	Nadir
AIRS (2002 -)	3x3 13.5-km (50 km)	~1200 resolving power	645-2700	Contiguous Cross-track scan
IASI (2006 -)	2x2 12.0-km (50 km)	0.25	645-2760	Contiguous Cross-track Scan
CrIS (2011 -)	3 x 3 13-km (50 km)	0.6	645-2700	Contiguous Cross-track
CLARREO (??)	25 to 100-km (TBD km)	0.5	200-2700	Nadir





Noise Comparison

CrIS, AIRS, IASI



CLARREO - State Parameter Climate Retrieval

Desirable Features of Climate Retrieval Algorithm

- ***Linear dependence on radiance spectra (EOFCs)***
  - Variation depends only on radiance (i.e., no other input variables)
- ***All sky***
  - clear and cloudy (0 - 100%)
- ***Independent of Field-of-View (FOV) size***
  - Can be applied to different instruments
- ***Retrieval Variables***
  - *Surface :* temperature & spectral emissivity
  - *Atmosphere :* T, H_2O, and O_3 profiles & CO_2 ppm
  - *Cloud :* height, optical depth, and particle diameter

Direct Broadcast "Dual-Regression" Retrieval Algorithm[1]

Global Clear Soundings

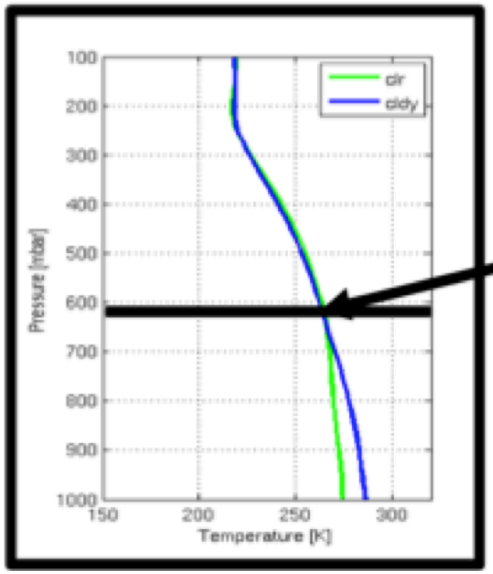
Radiances (calculated with clear FM)

Clear trained EOF regression results

Global Cloudy Soundings

Radiances (calculated with cloudy FM) 8 cloud height classes (100-900 hPa)

Cloud trained EOF regression results



Cloud Top Altitude

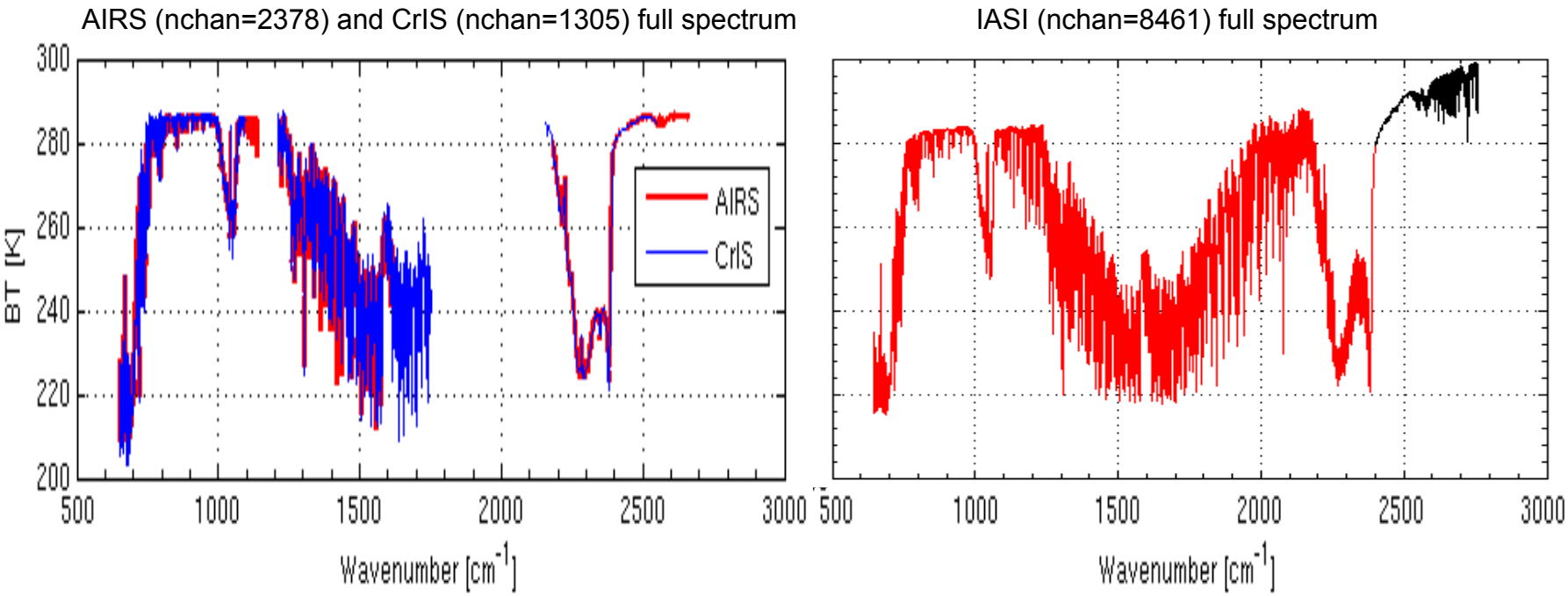
level where T(cloudy)>T(clear) for $p>p_{cld}$

Final Profile

- *clear-trained above,*
- *cloud-trained below cloud level*

[1]Smith, W. L., E. Weisz, S. Kirev, D. K. Zhou, Z. Li, and E. E. Borbas, 2012: Dual-Regression Retrieval Algorithm for Real-Time Processing of Satellite Ultraspectral Radiances. *J. Appl. Meteor. Clim. http://dx.doi.org/10.1175/JAMC-D-11-0173.1.*

AIRS, CrIS, and IASI Sounding Channels



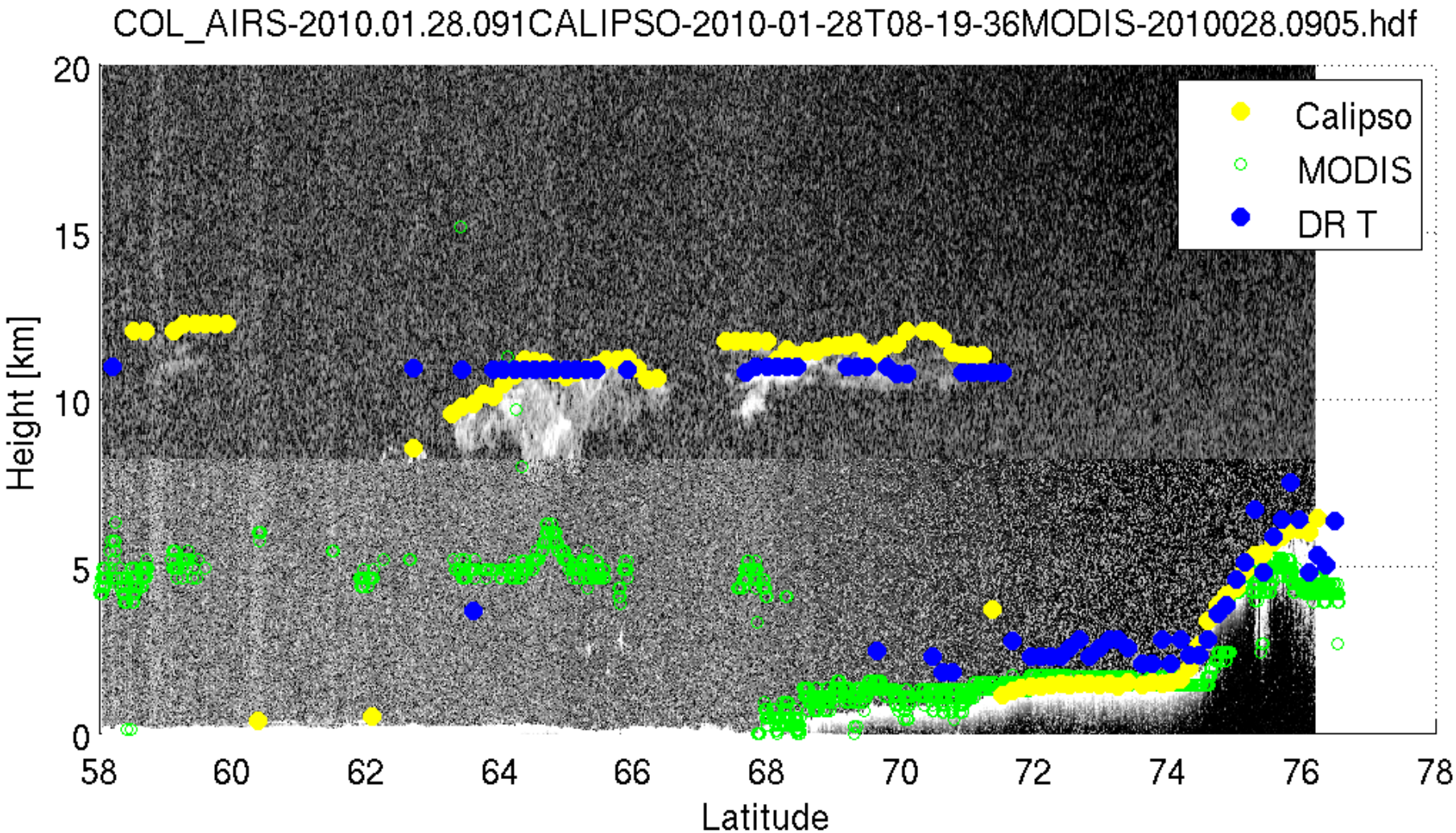
- In the retrieval channels from 665 cm-1 to 2400 cm^{-1} are used.

  --- AIRS = 1258 (30 PCs)

  --- CrIS = 1245 (30 PCs)

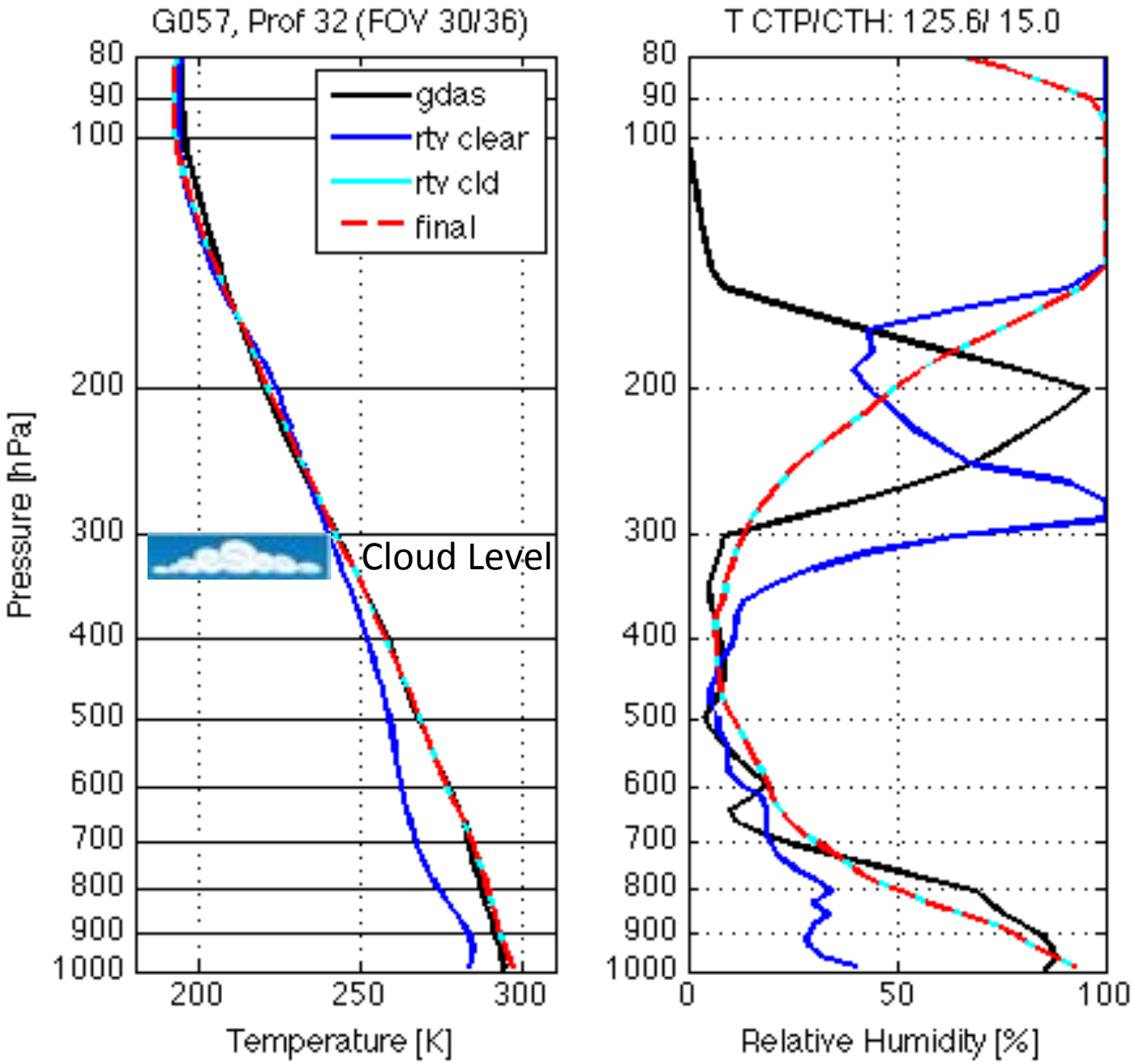
  --- IASI = 7021 (50 PCs)

DR Cloud Altitude Validation Using Lidar

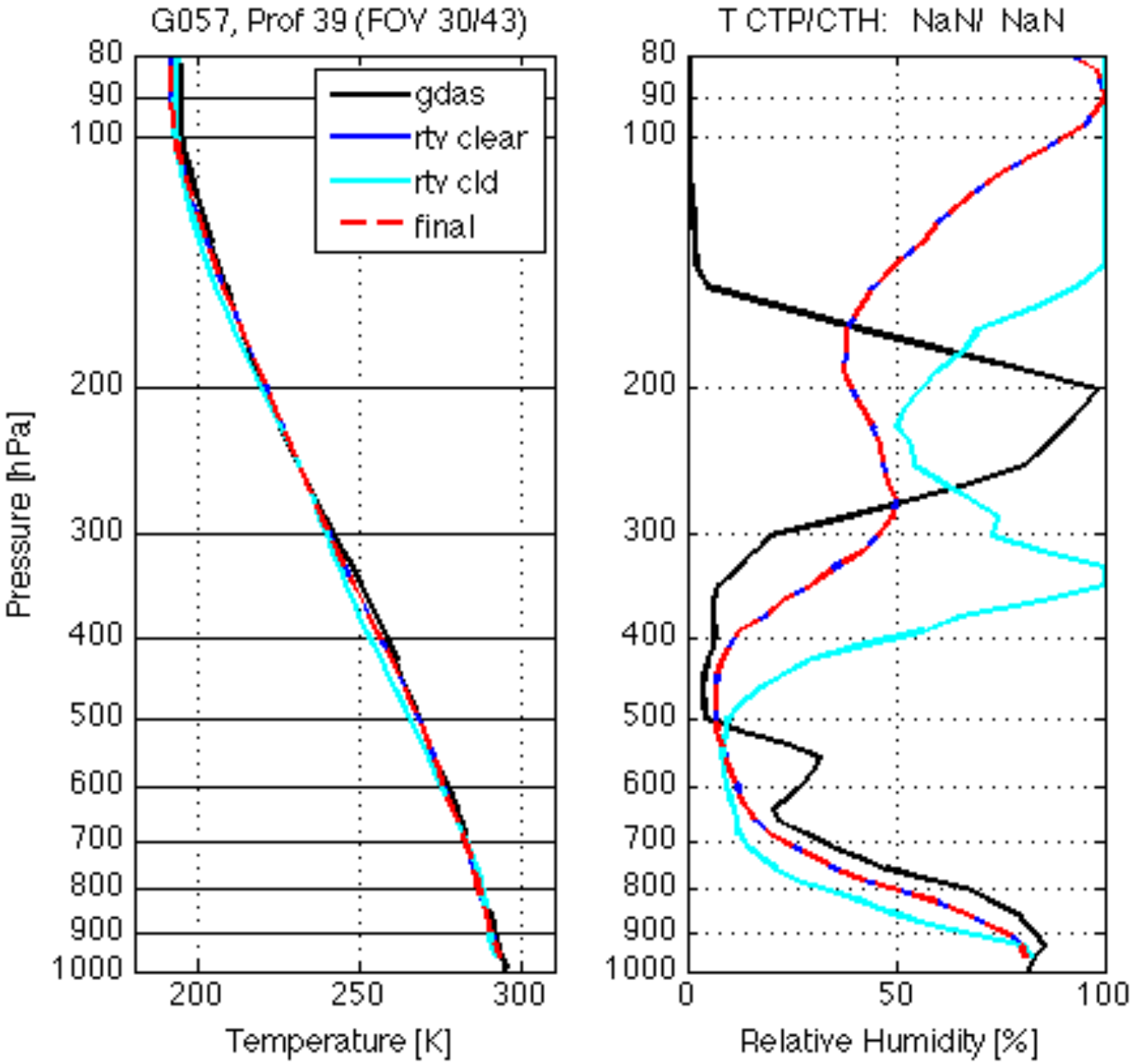


For Cirrus Cloud Heights, 15-km Resolution Ultraspectral Resolution (AIRS DR T) Provides Higher Accuracy Than 1-km Low Spectral Resolution (MODIS)

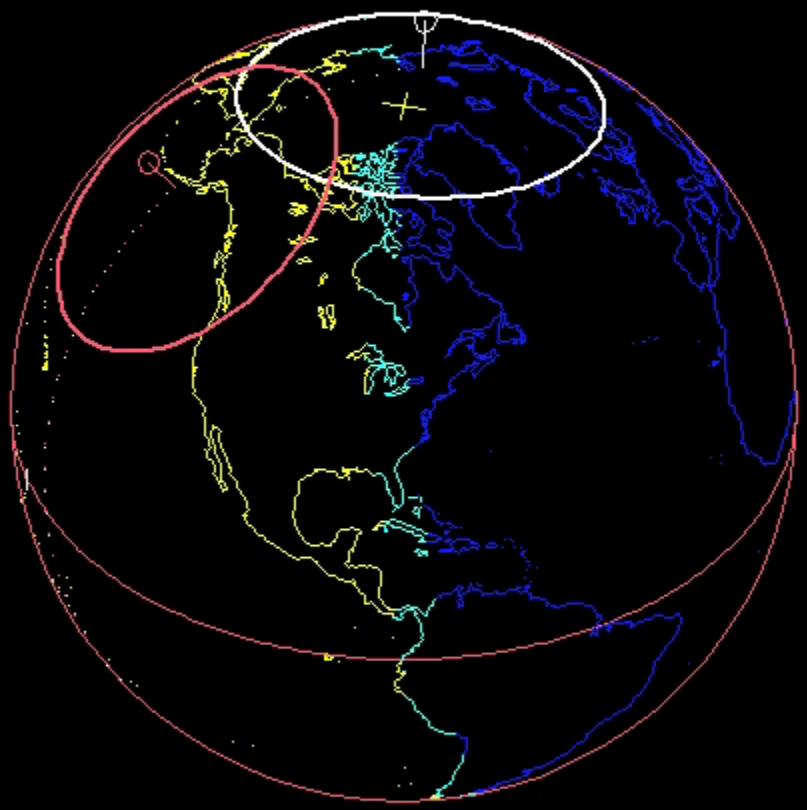
DR Sounding Example (Cloud)



DR Sounding Example (Clear)



NPP	12062.8791	7202.18	98.71	101.44	824.18
AQUA	12061.3531	7077.72	98.22	98.83	699.72
METOPA	12060.6586	7195.64	98.71	101.30	817.64

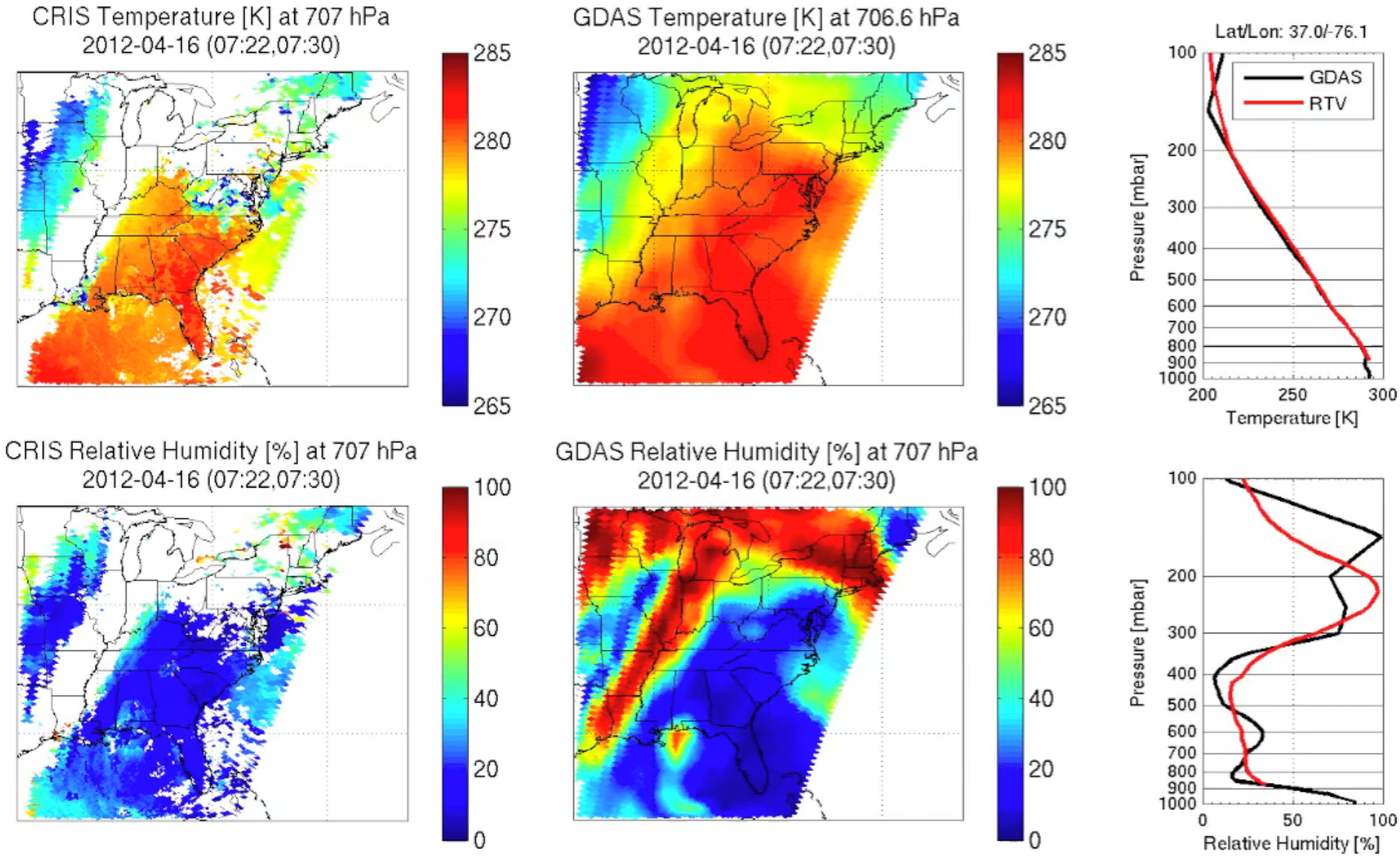


METEOROLOGICAL SATELLITES 23:33 UT 1 MAR 12

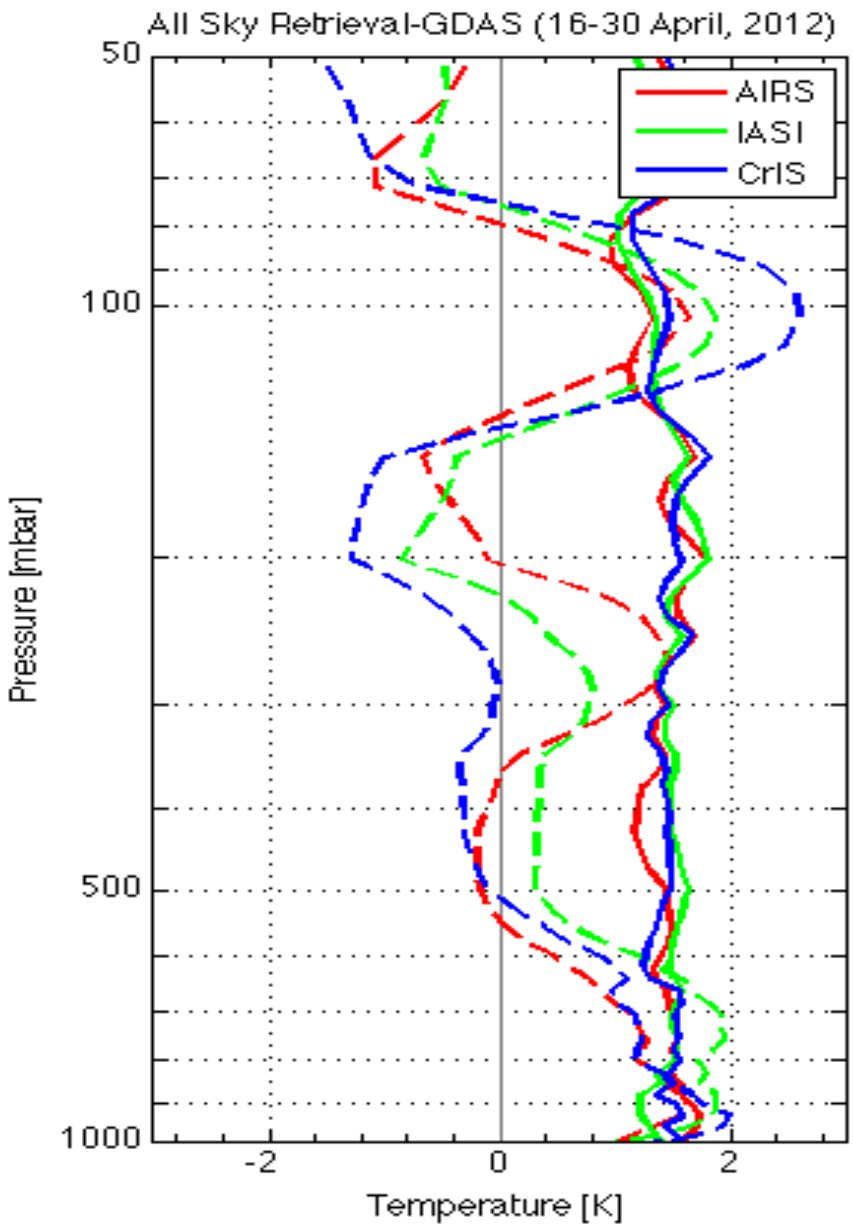
Ground Remote Atmospheric Sounding Project (GRASP) Validation Campaign (16 – 30 April, 2012)

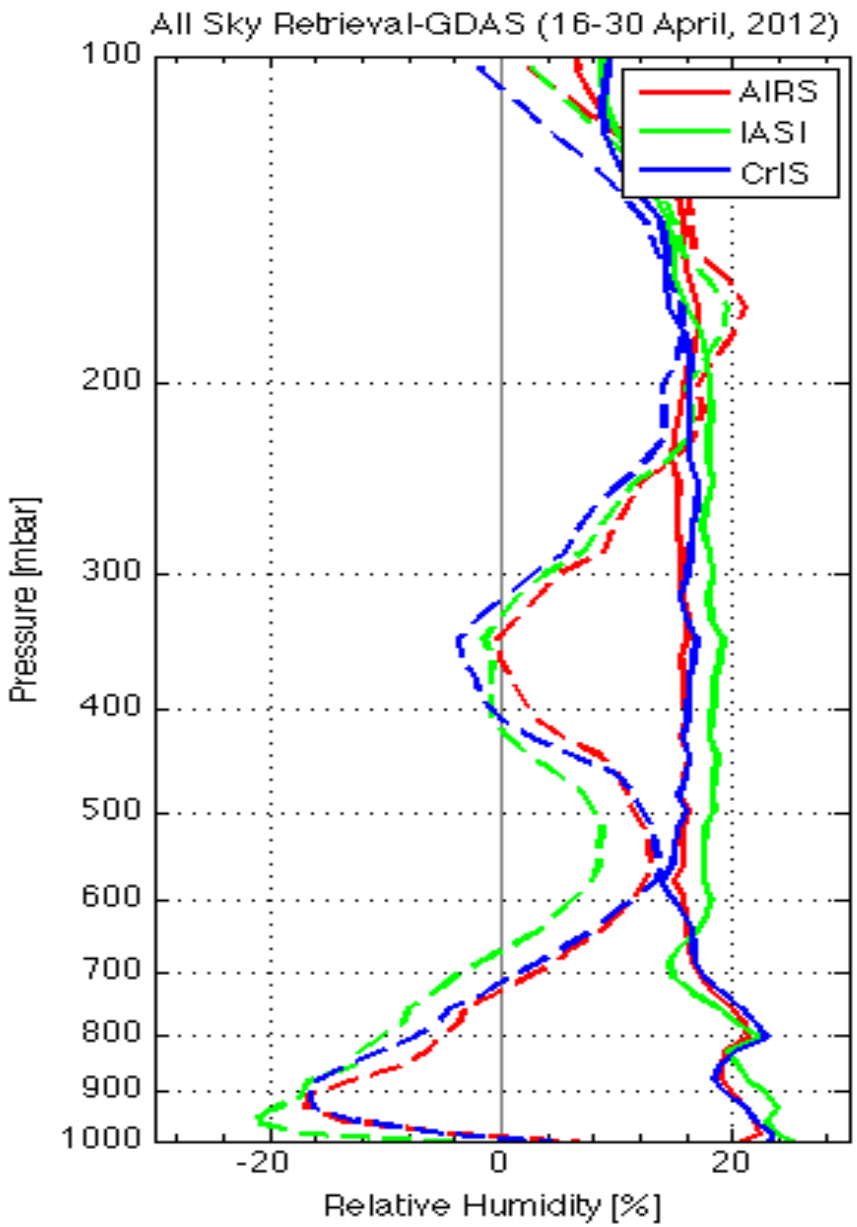
A comprehensive data set for validating and improving satellite and ground based remote sensing measurements

- ***Satellite*** *sounding data was collected and processed for all Metop, Aqua, and Suomi NPP orbits within view of Hampton University (HU)*
- ***Radiosondes*** *were launched from HU at satellite overpass times*
- *Quasi continuous* ***upward looking FTS*** *measurements were made for determining PBL temperature, moisture, and trace gas structure*
- ***Raman LIDAR*** *measurements were made for deriving cloud, aerosol, and free troposphere temperature and water vapor profiles*
- *Continuous measurements of* ***surface meteorological and radiative flux parameters*** *(P, T, Q, V, LW Flux, SW Flux) were obtained*
- ***All-sky camera*** *operated for identifying cloudiness during radiation and meteorological measurements*

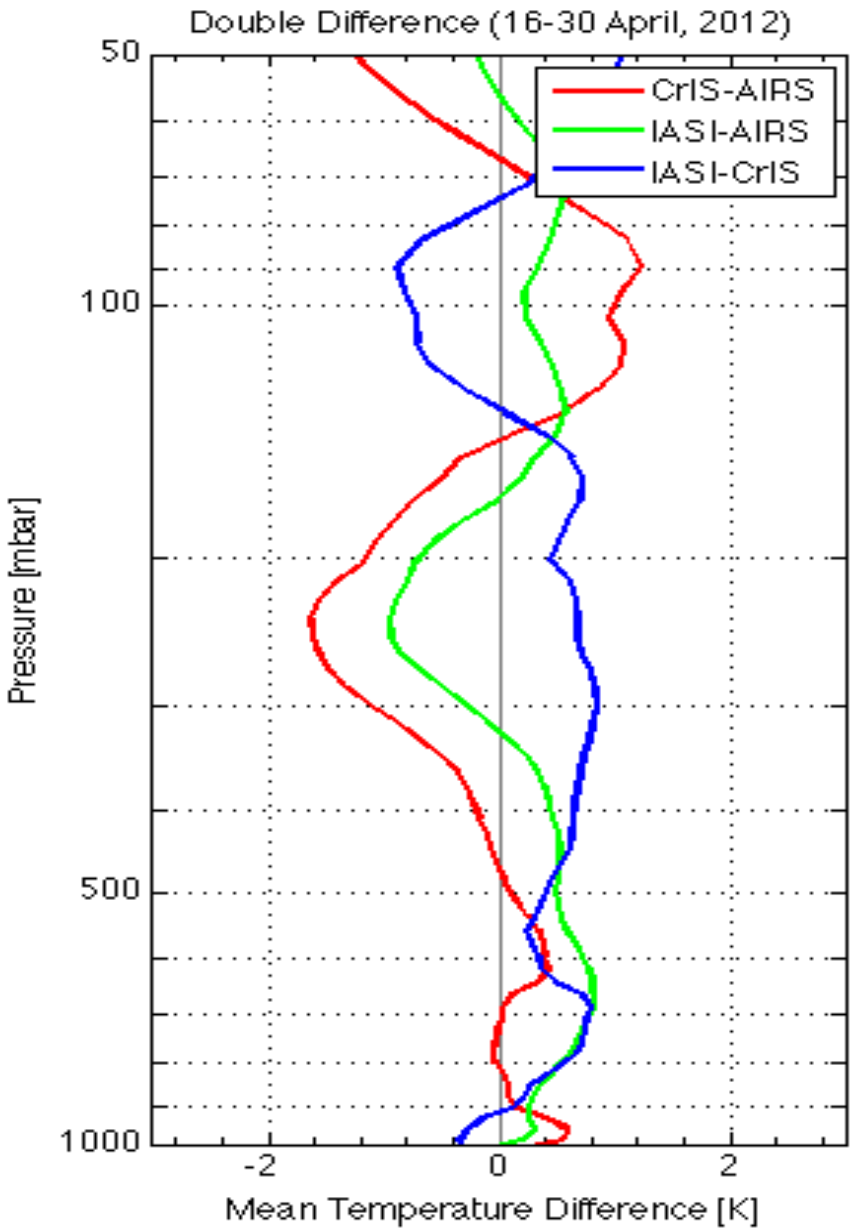

CRIS Temperature [K] at 707 hPa
2012-04-16 (07:22,07:30)
285
280
275
270
265
GDAS Temperature [K] at 706.6 hPa
2012-04-16 (07:22,07:30)
285
280
275
270
265
Lat/Lon: 37.0/-76.1
GDAS
RTV
Pressure [mbar]
100
200
300
400
500
600
700
800
900
1000
200
250
300
Temperature [K]
CRIS Relative Humidity [%] at 707 hPa
2012-04-16 (07:22,07:30)
100
80
60
40
20
0
GDAS Relative Humidity [%] at 707 hPa
2012-04-16 (07:22,07:30)
100
80
60
40
20
0
Pressure [mbar]
100
200
300
400
500
600
700
800
900
1000
0
50
100
Relative Humidity [%]

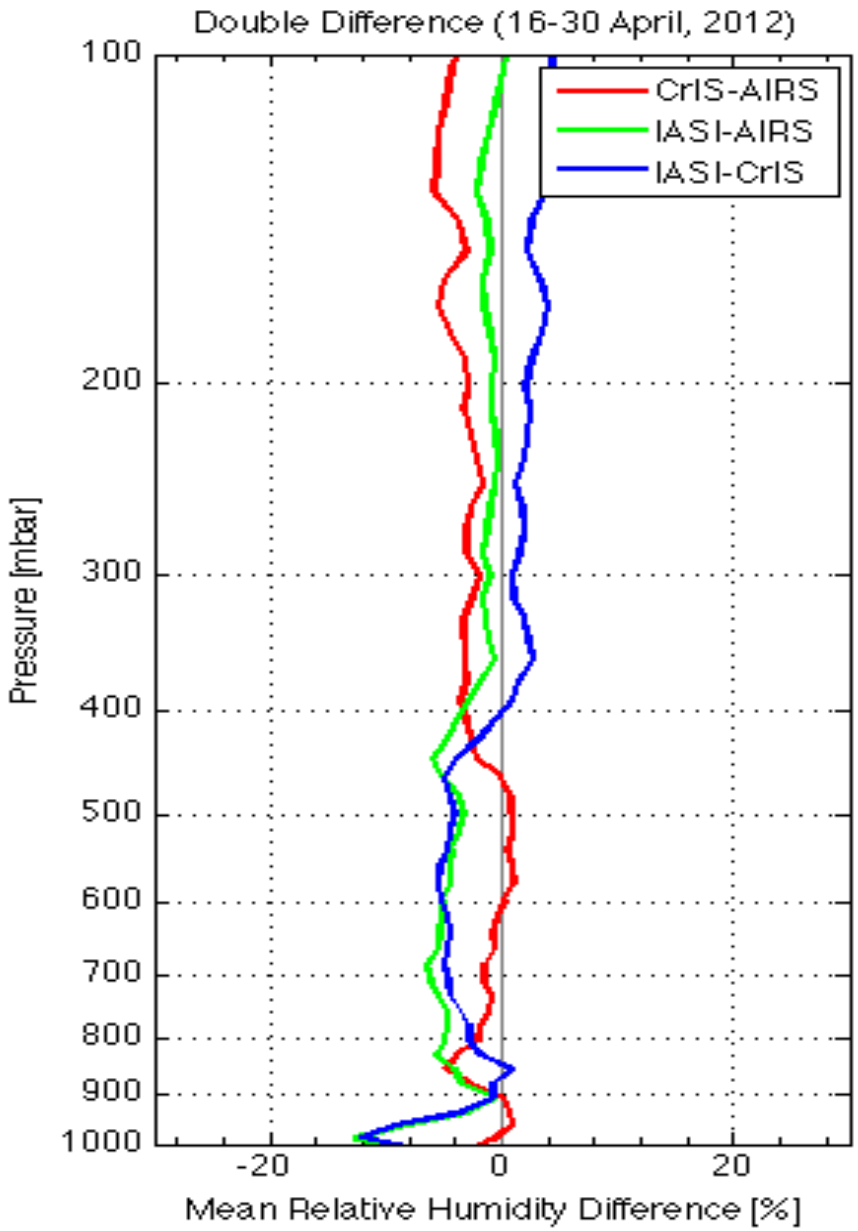
GRASP Statistics (25-60N; 60-100W)





GRASP (Mean Double Difference)

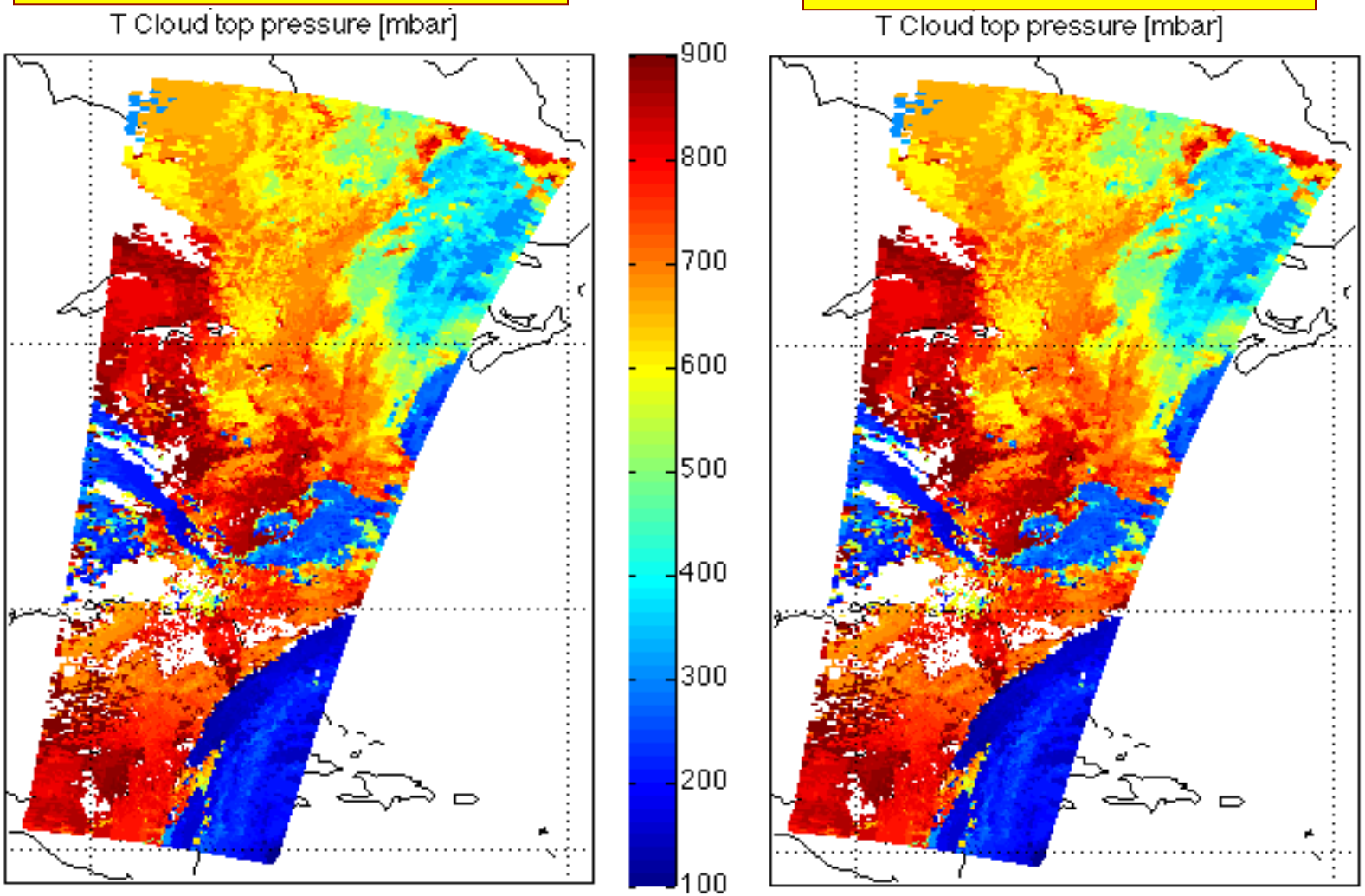




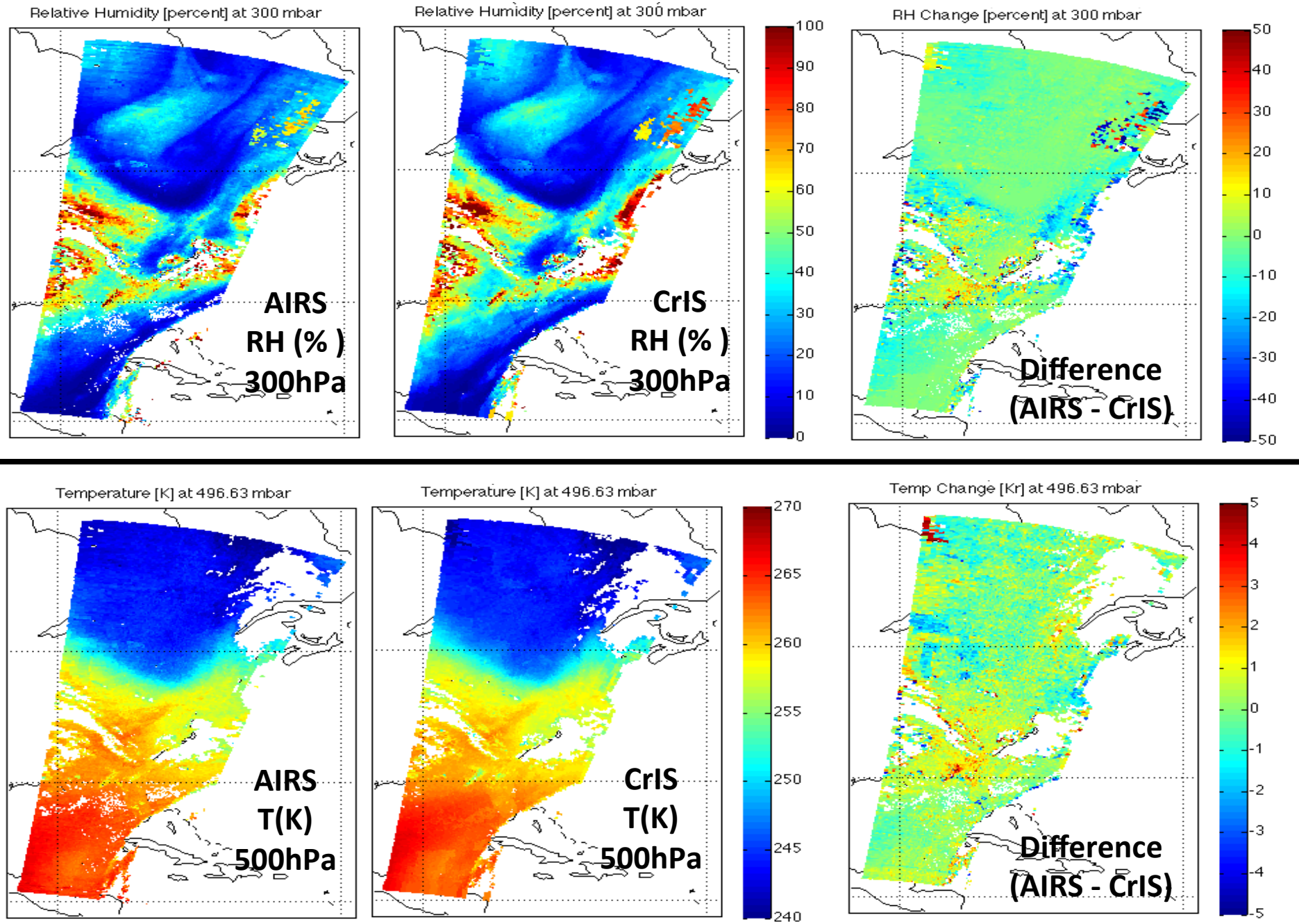
Aqua and Suomi NPP orbits, Eastern NA April 27, 2012

AIRS granules
Start times: 07:17 UTC
AIRS granule size: 90x270
(24300 FOVs)

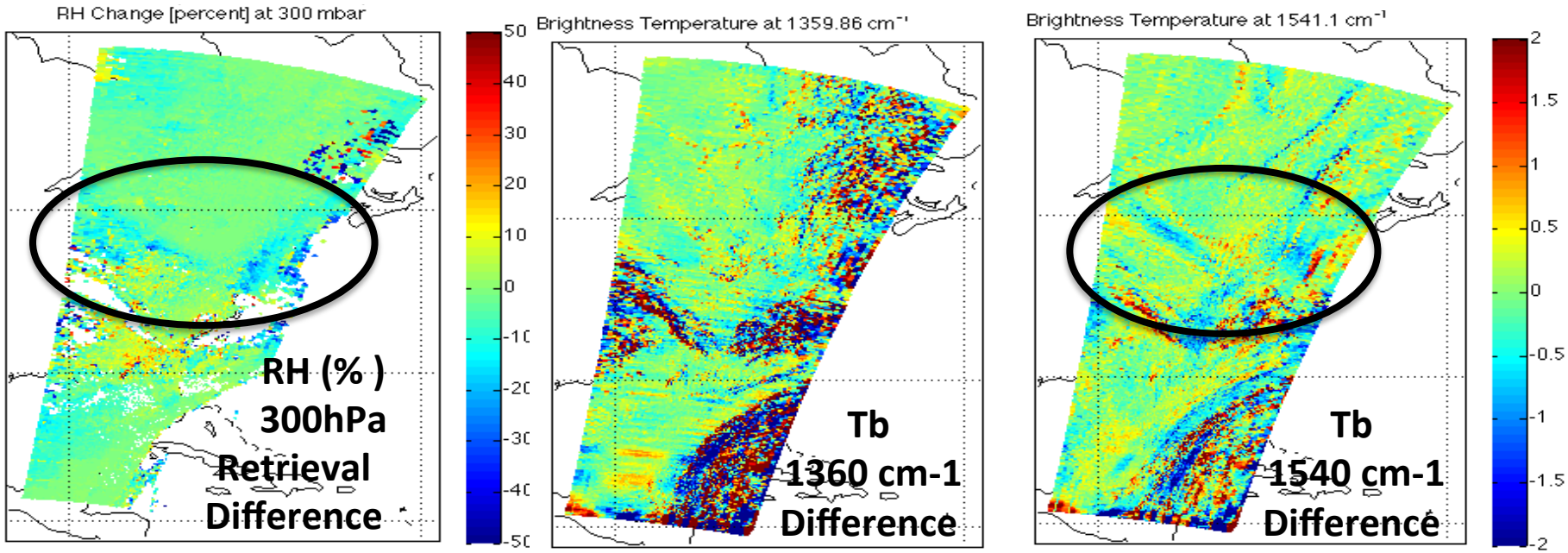
CrIS granules
start times: 07:12 UTC
CrIS granule size: 90x270
(24300 FOVs)

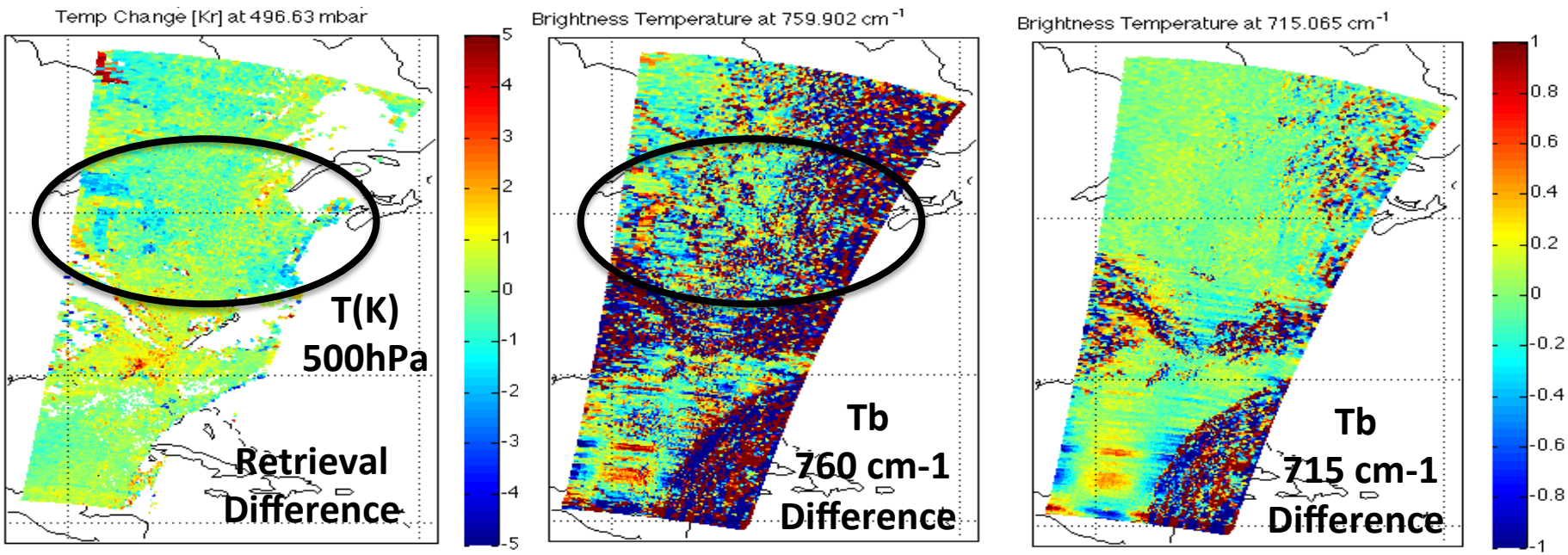


AIRS & CrIS Retrievals (April 27, 2012)



Retrieval Reflections of Radiance Differences (April 27, 2012)





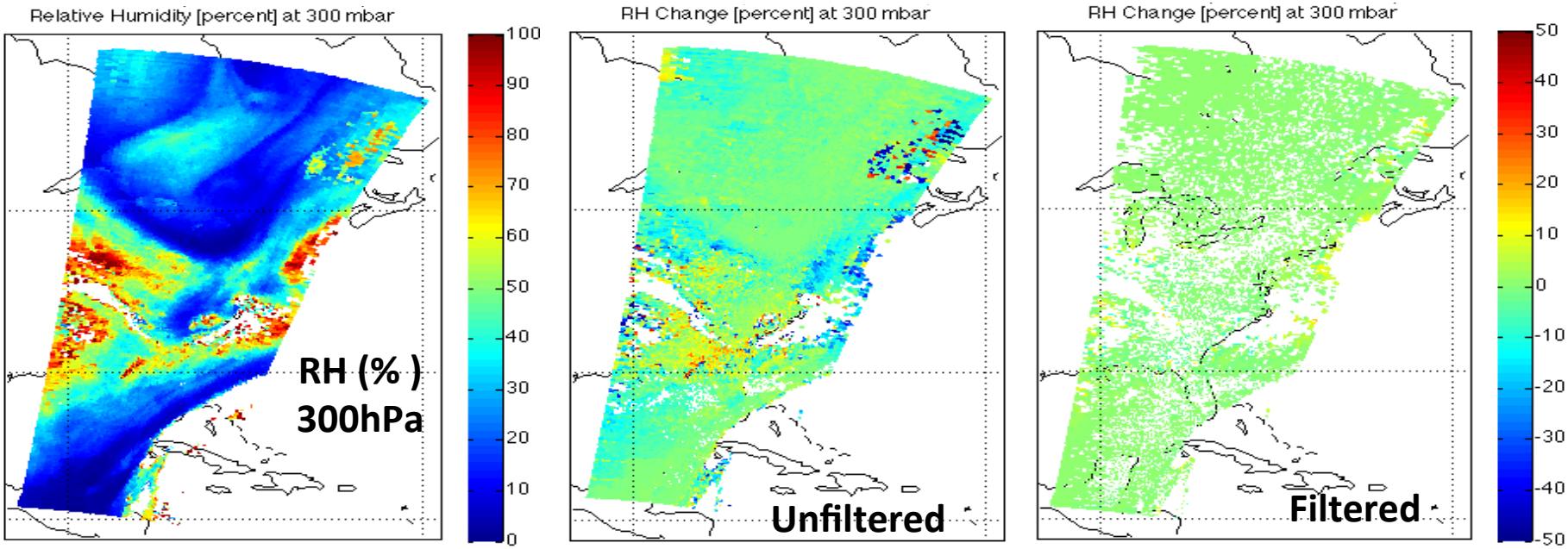
Error Filtering AIRS – CrIS Retrieval Differences

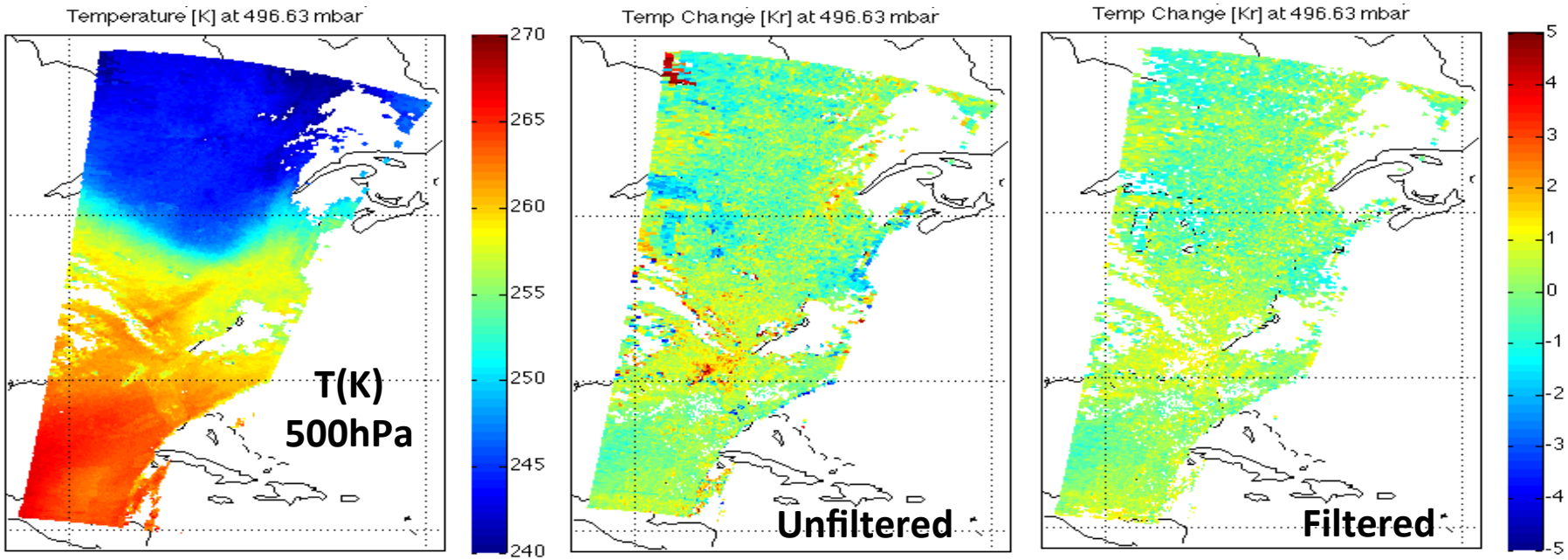
- **Single Sample Noise Gross Air Check**
  - Delete Retrievals where $ABS(T_{airs} - T_{cris}) > 1.5$

- **Large Scale Bias Adjustment**
  - $RH_{airs}^* = a_o + a_1 Rh_{cris}$
  - $T_{airs}^* = b_o + b_1 T_{cris}$

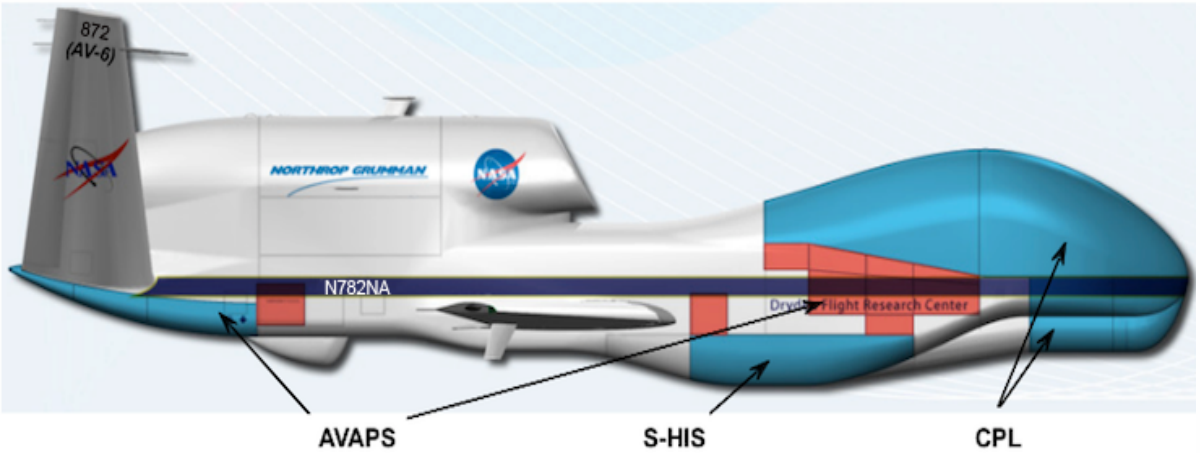
  where the regression coefficients = a_o, a_1, b_o, b_1 are computed from the noise filtered AIRS and CrIS retrieved parameters

Filtered Vs Unfiltered AIRS & CrIS Retrievals (April 27, 2012)





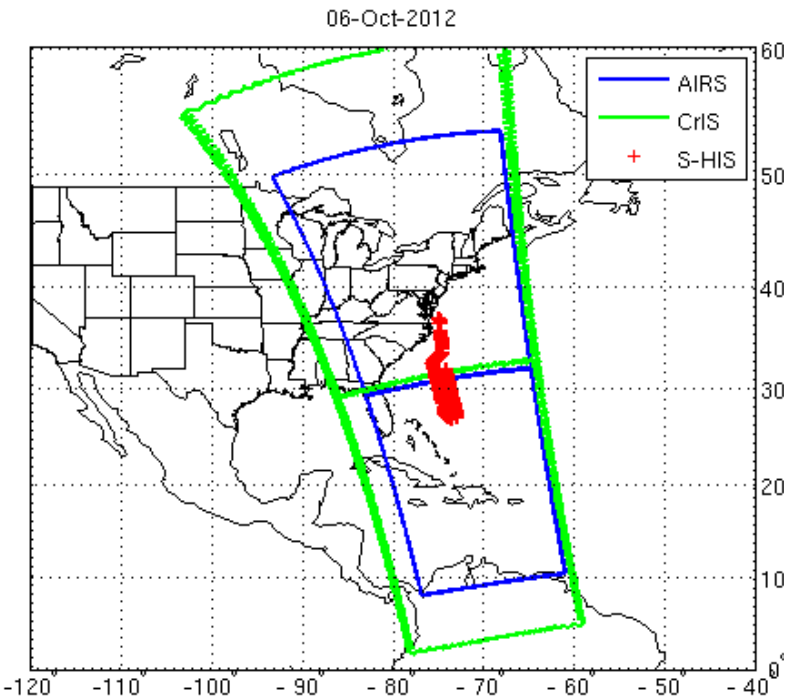
The Hurricane an Severe Storm Sentinel (HS3) Mission

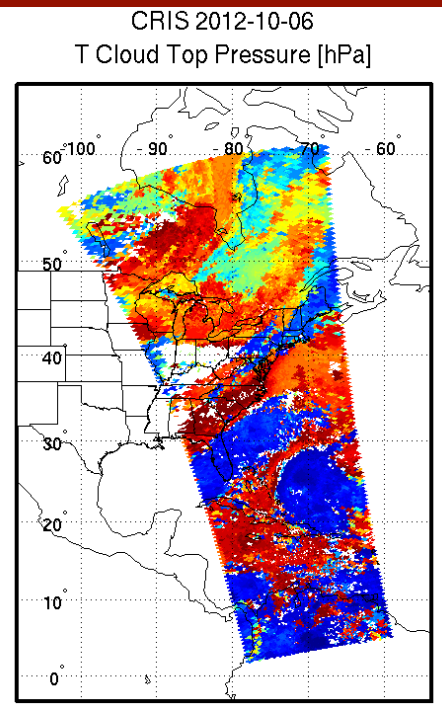


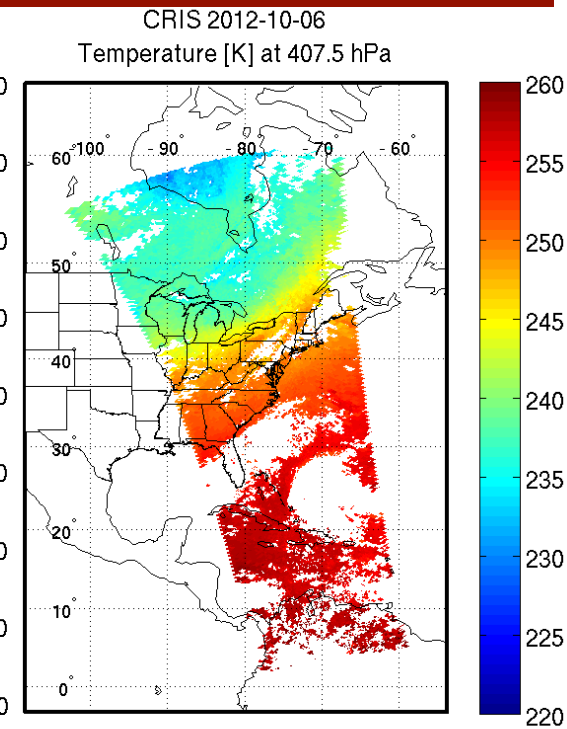
Endurance	> 30 hours
Range	>10,000 nmi
Service Ceiling	65,000 ft
Airspeed (55K+ ft)	335 KTAS
Payload	1,000-1,500 lb
Take-off Weight	26,750 lb
Length	44 ft
Wingspan	116 ft

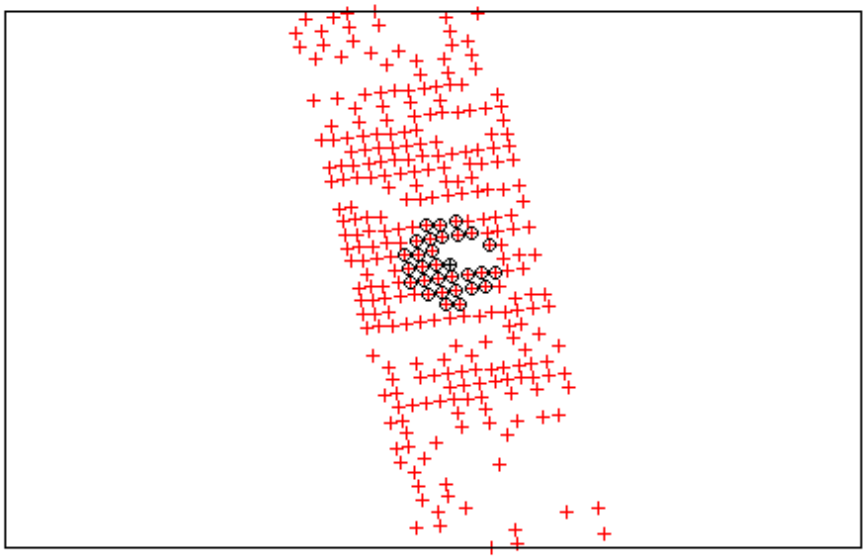
- The GH is a fully autonomous aircraft
- The GH communicates with the ground via both satellite and direct line-of-sight links
- The GH flight mission is monitored and controlled using a ground station that is staffed by pilots and a mission director
- The GH instruments are remotely operated by scientists and a payload manager

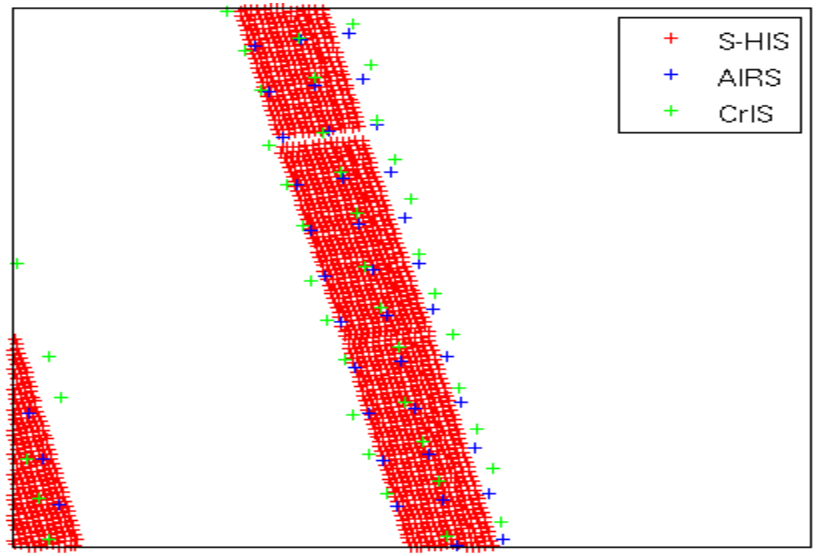
Suomi NPP Cal/Val Flight (Oct. 6 2012)



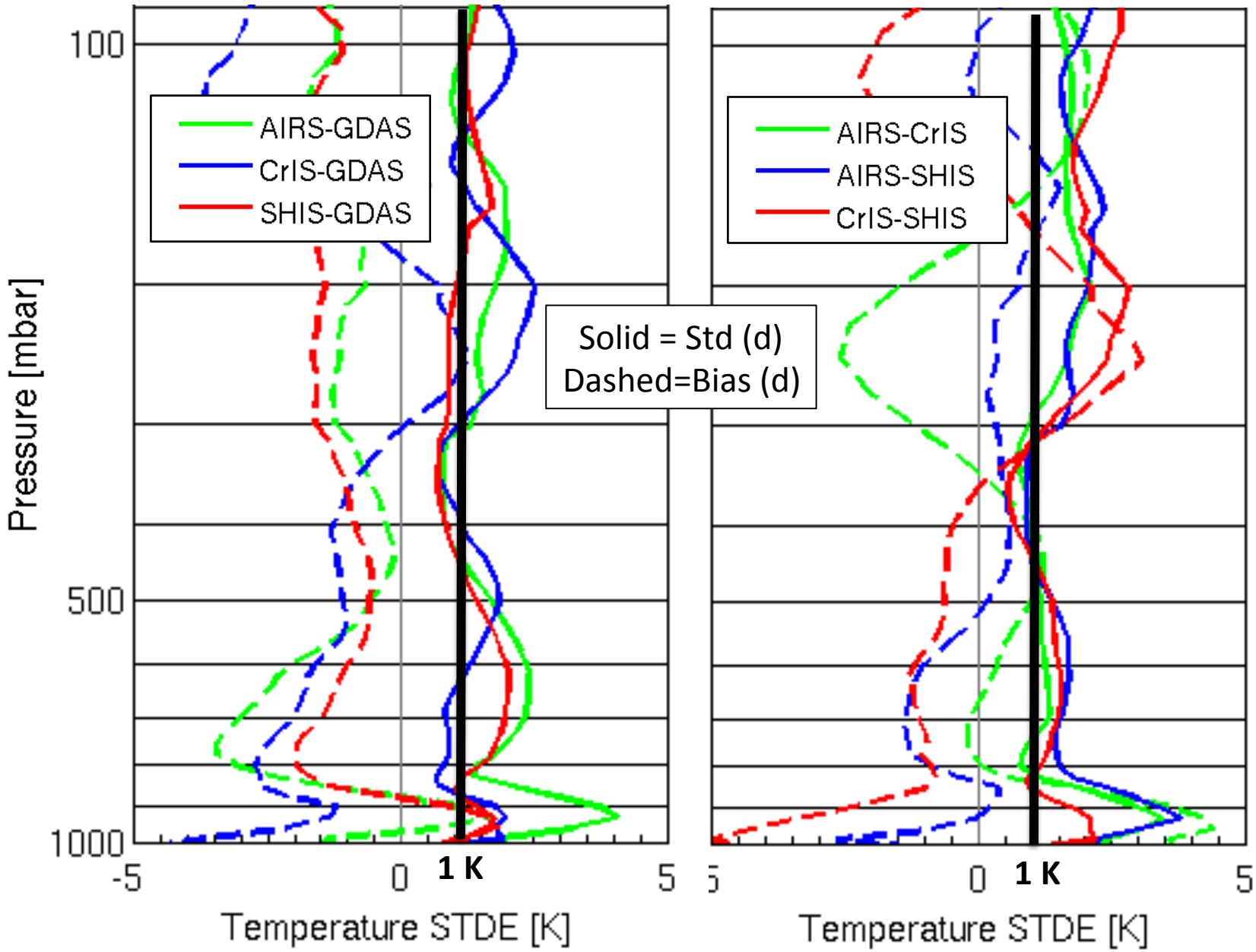




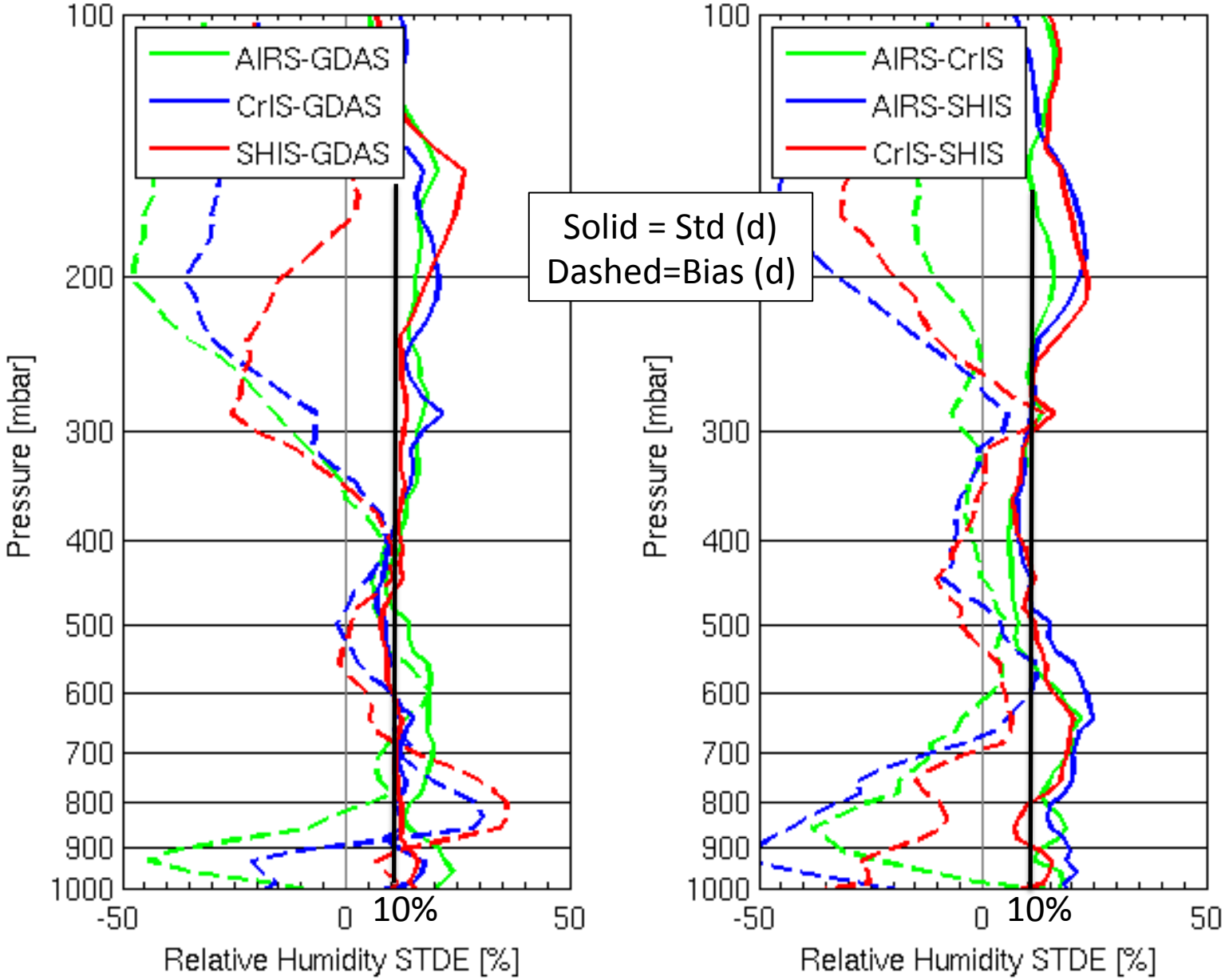




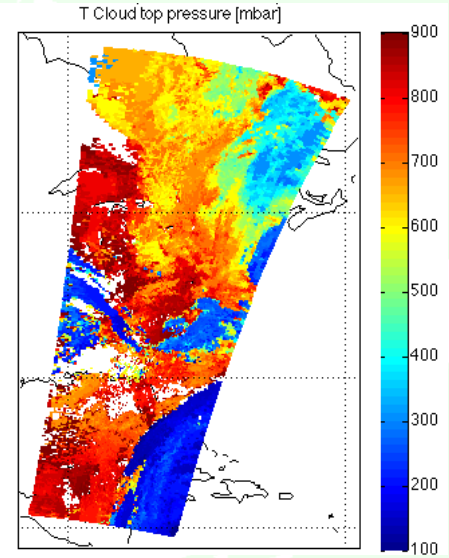
Suomi NPP Cal/Val Flight (Oct. 6 2012)



Suomi NPP Cal/Val Flight (Oct. 6 2012)



Summary



- **Dual Regression Retrieval**
  - **Accuracies better than**
    - **2 K & 20 % Absolute (Relative to GDAS)**
    - **0.5 K & 5 % Relative (Instrument Differences)**
- **Synoptic Scale Bias**
  - ***Synoptic scale patterns of AIRS/CrIS retrieval differences result from small synptic scale differences in radiance observations.***
  - ***Although relatively small, could be significant for regional climate change studies if they were to persist in monthly averaged data***
  - ***Given the magnitude of ultraspectral sounders in orbit today (AIRS, CrIS, IASI-A, IASI-B), these biases can be eliminated through cross calibration of the various sensor retrievals***
  - ***The next step is to compute regional monthly mean averages of sounding variables from the various ultrspectral sensors in orbit in order to determine the accuracy to which regional climate change can be assessed through the analysis of CLARREO atmospheric profile retrievals***