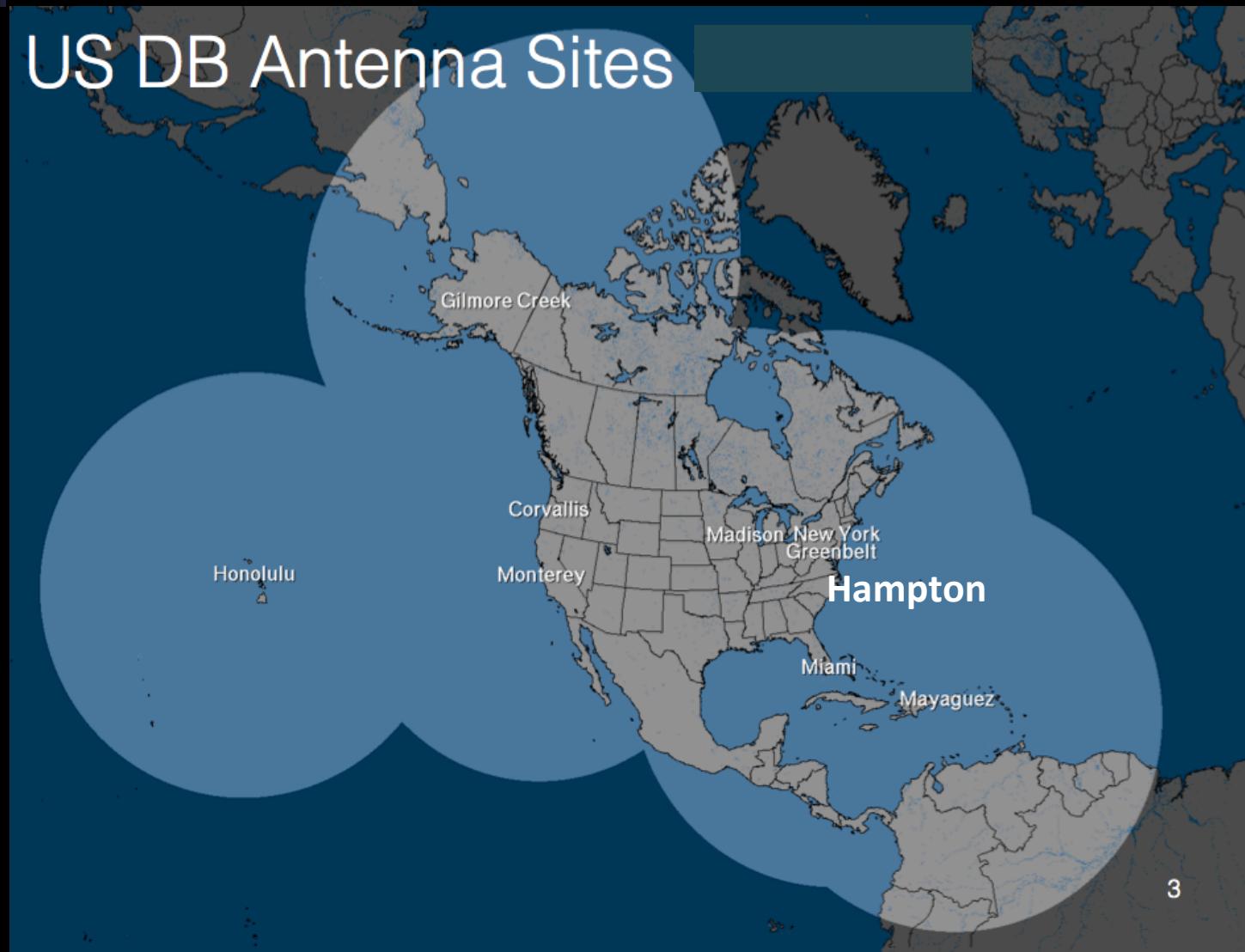




Level-2 sounding retrieval generation algorithms and severe weather applications



CSPP (Community Satellite Processing Package) is a collection of software systems for processing data from meteorological satellites.

The primary goal of CSPP is to support users who

- Receive satellite data via direct broadcast;
- Create Level 1B and higher level products and images in real time.

Funding is supplied by JPSS and NOAA.

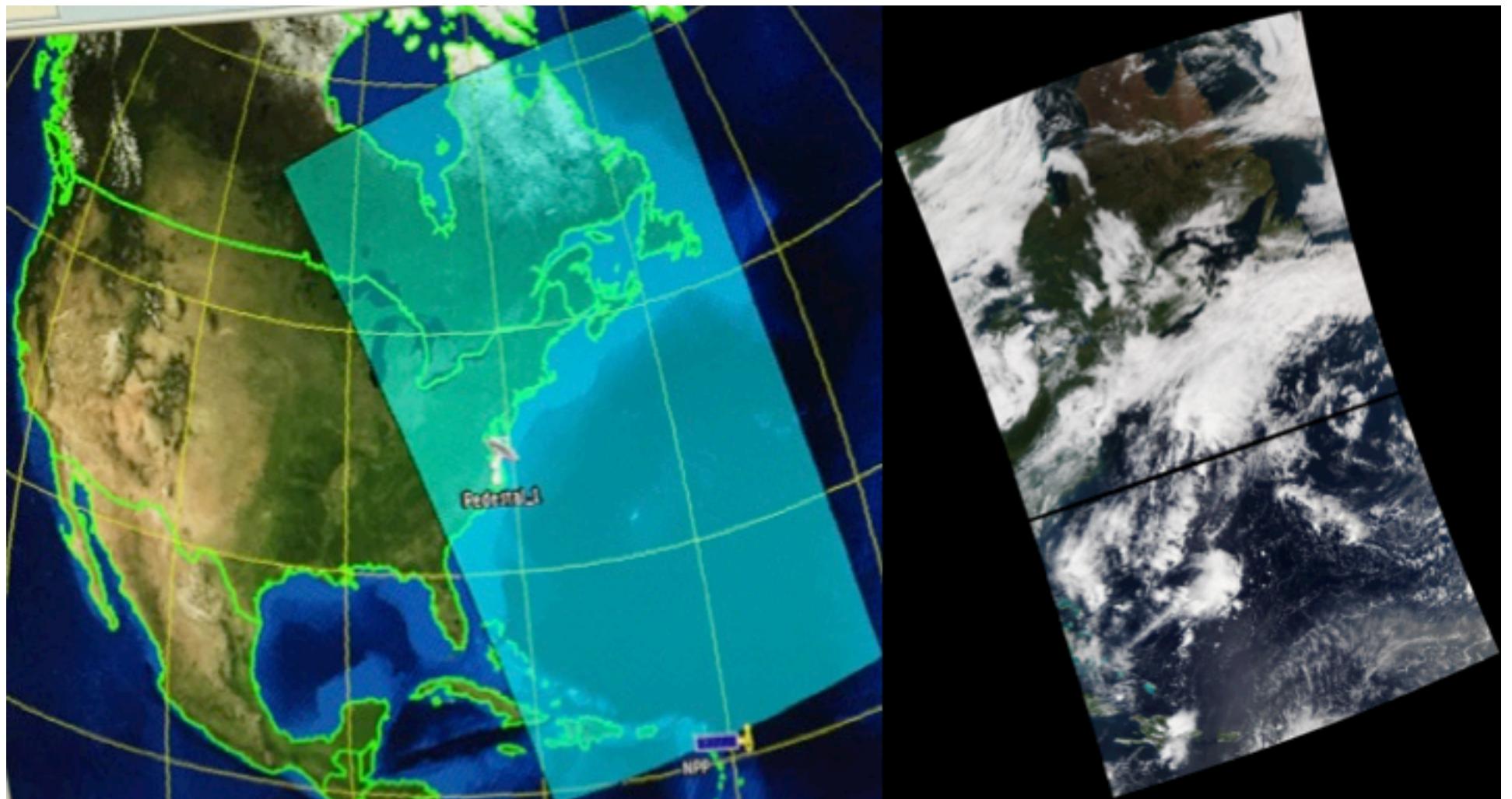
CSPP Satellite/Sensor/Product Matrix



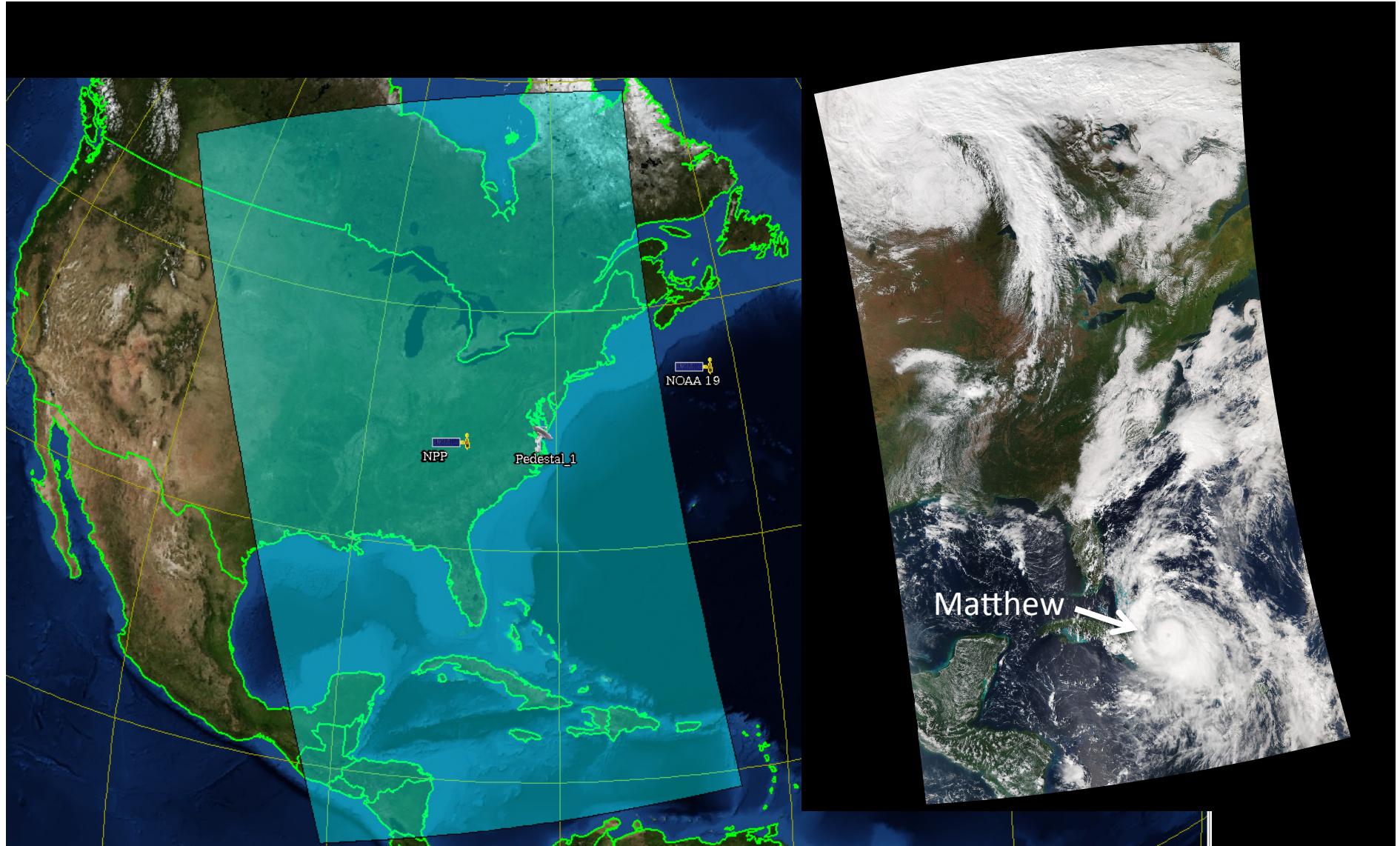
Satellite	Multispectral Imager	Infrared Sounder	Microwave Sounder
Suomi NPP	VIIRS <i>SDRs (Level 1B), Images, Visualization, Clouds, Aerosols, Land, Ocean</i>	CrIS <i>SDRs (Level 1B) Atmospheric Profiles, Clouds, Visualization</i>	ATMS <i>SDRs (Level 1B), Atmospheric Profiles, Precipitation, Visualization</i>
NOAA-18/19	AVHRR <i>Clouds, Aerosols, Land Surface, SST, Visualization</i>	HIRS <i>Atmospheric Profiles</i>	AMSU, MHS <i>Atmospheric Profiles, Precipitation</i>
Metop-A/B	AVHRR <i>Clouds, Aerosols, Land Surface, SST, Visualization</i>	IASI <i>Atmospheric Profiles, Clouds, Visualization</i>	AMSU, MHS <i>Atmospheric Profiles, Precipitation</i>
Terra	MODIS <i>Images, Visualization</i>	N/A	N/A
Aqua	MODIS <i>Images, Visualization</i>	AIRS <i>Atmospheric Profiles, Clouds, Visualization</i>	AMSU <i>Atmospheric Profiles, Precipitation, Visualization</i>

First HU SNPP Direct Broadcast Image

Below is the first SNPP VIIRS (Visible Infrared Imager Radiometer Suite) true color visible image acquired using the new HU DBS receiving system (September 28, 2016) (17:17:28 UTC)

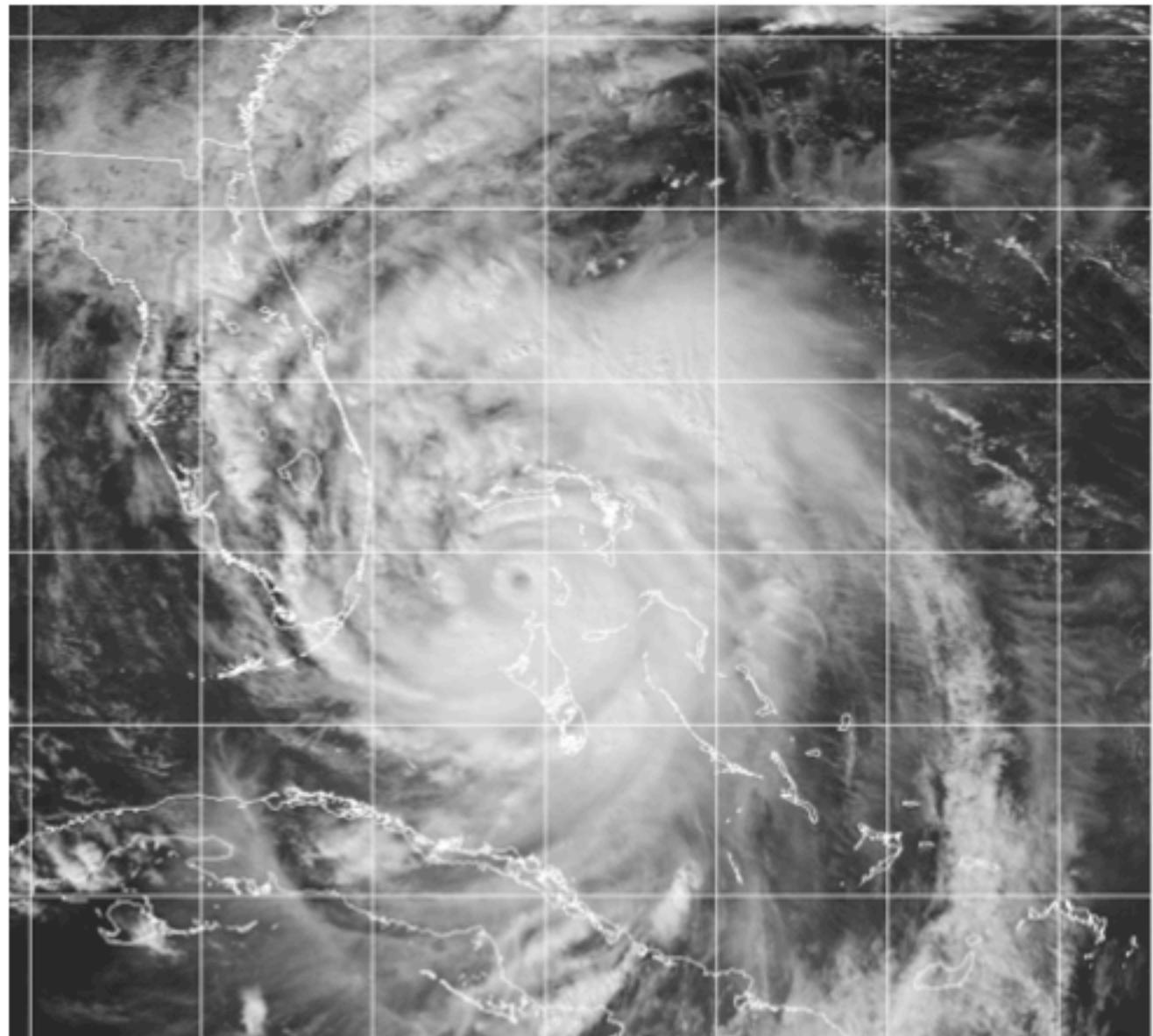
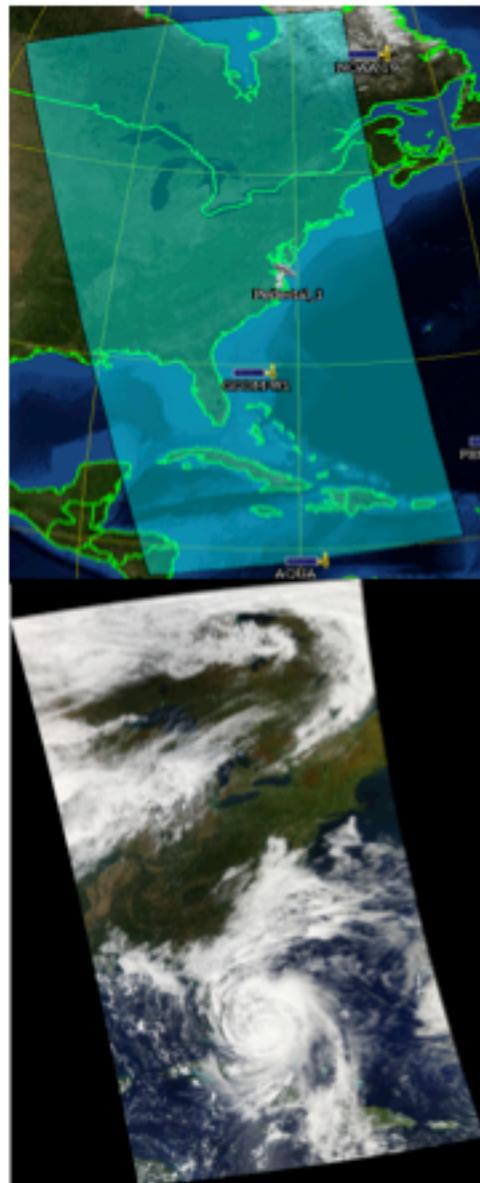


HU Direct Broadcast VIIRS True Color Image of Hurricane Matthew (10/5/2016 2:30 EDT)

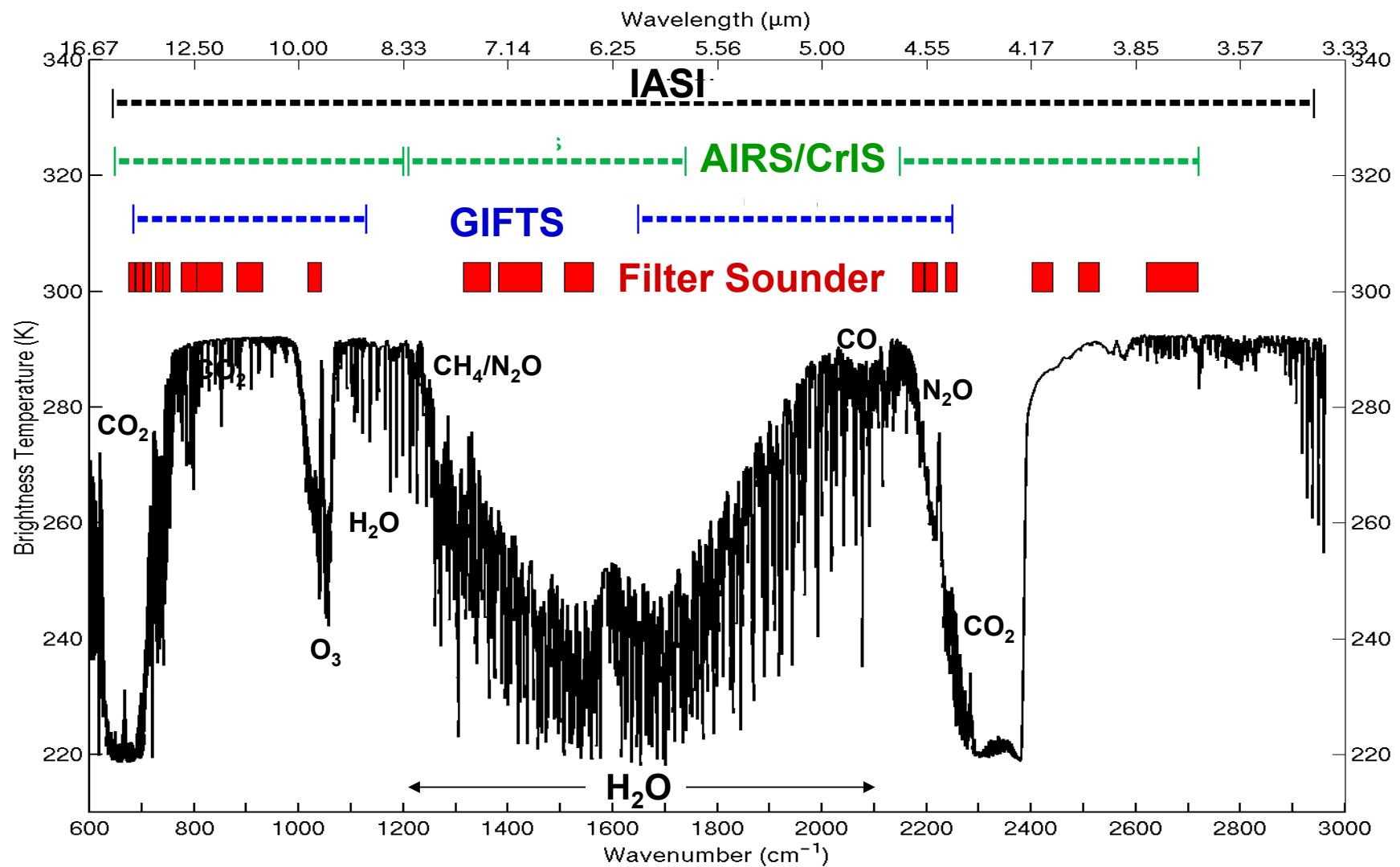


HU Direct Broadcast MODIS Images

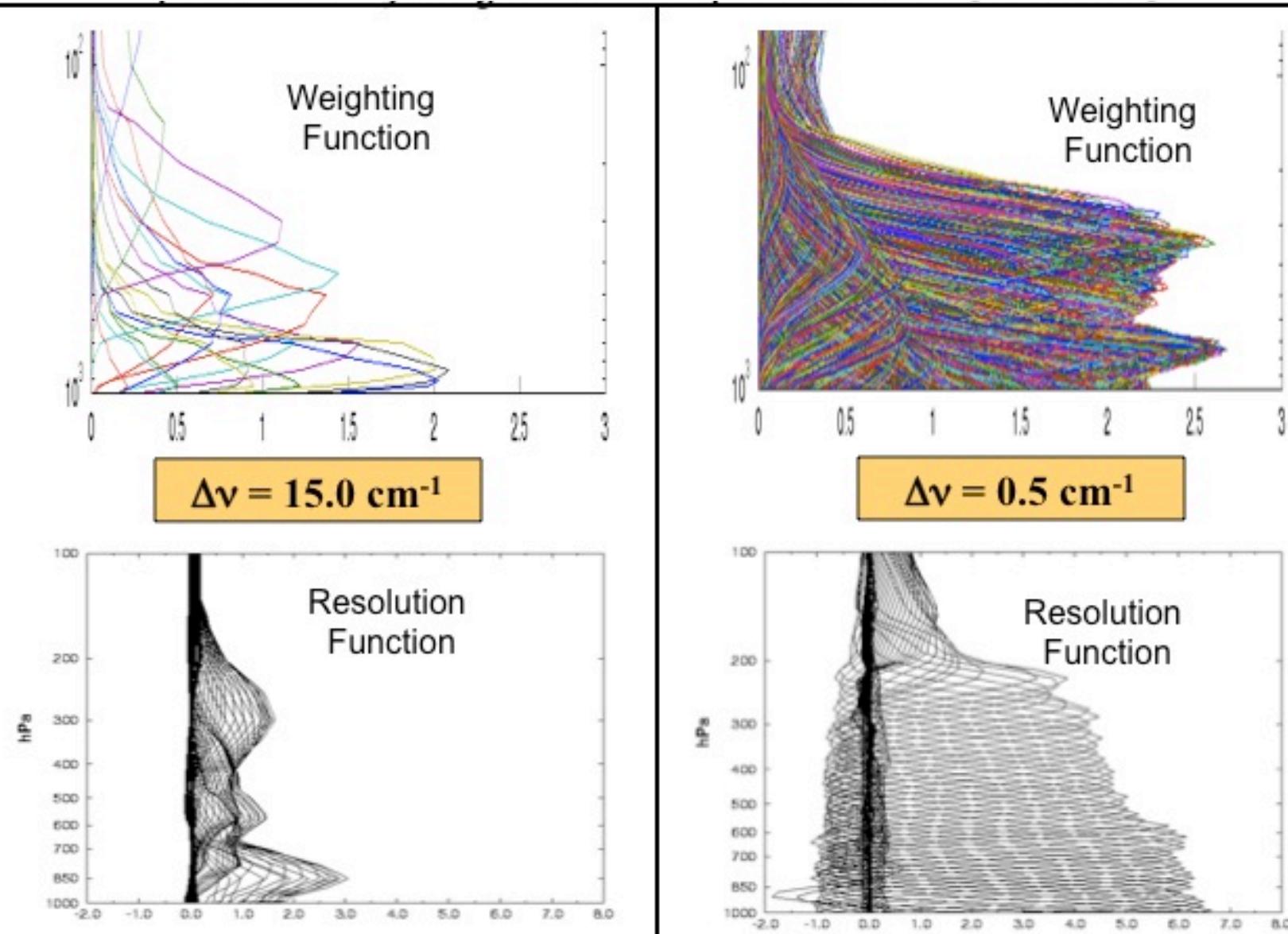
Hurricane Matthew (10/6/2016 2:15 PM EDT)



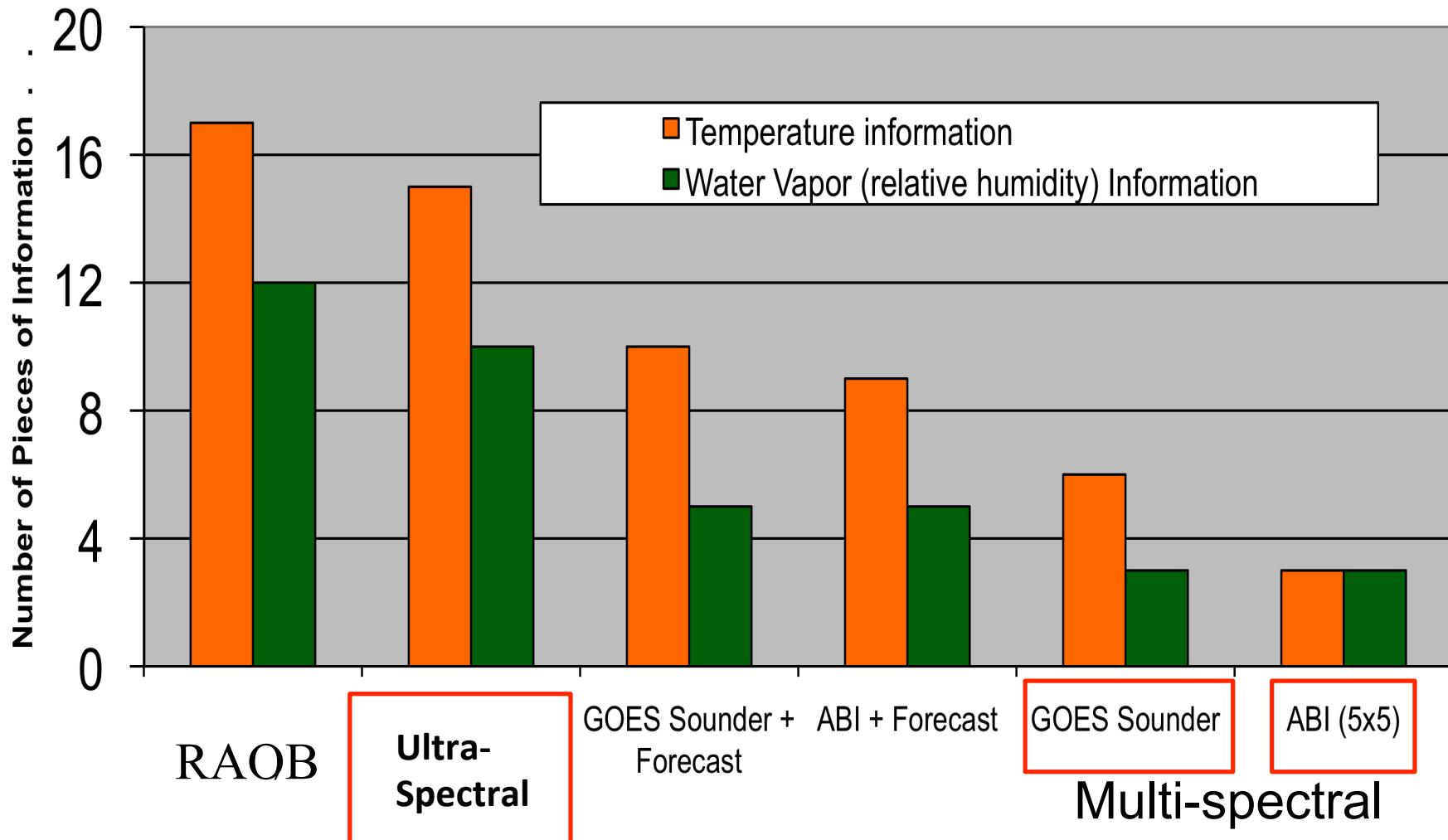
New Era: Spaceborne Ultraspectral Resolution



Multi-spectral to Ultra-spectral



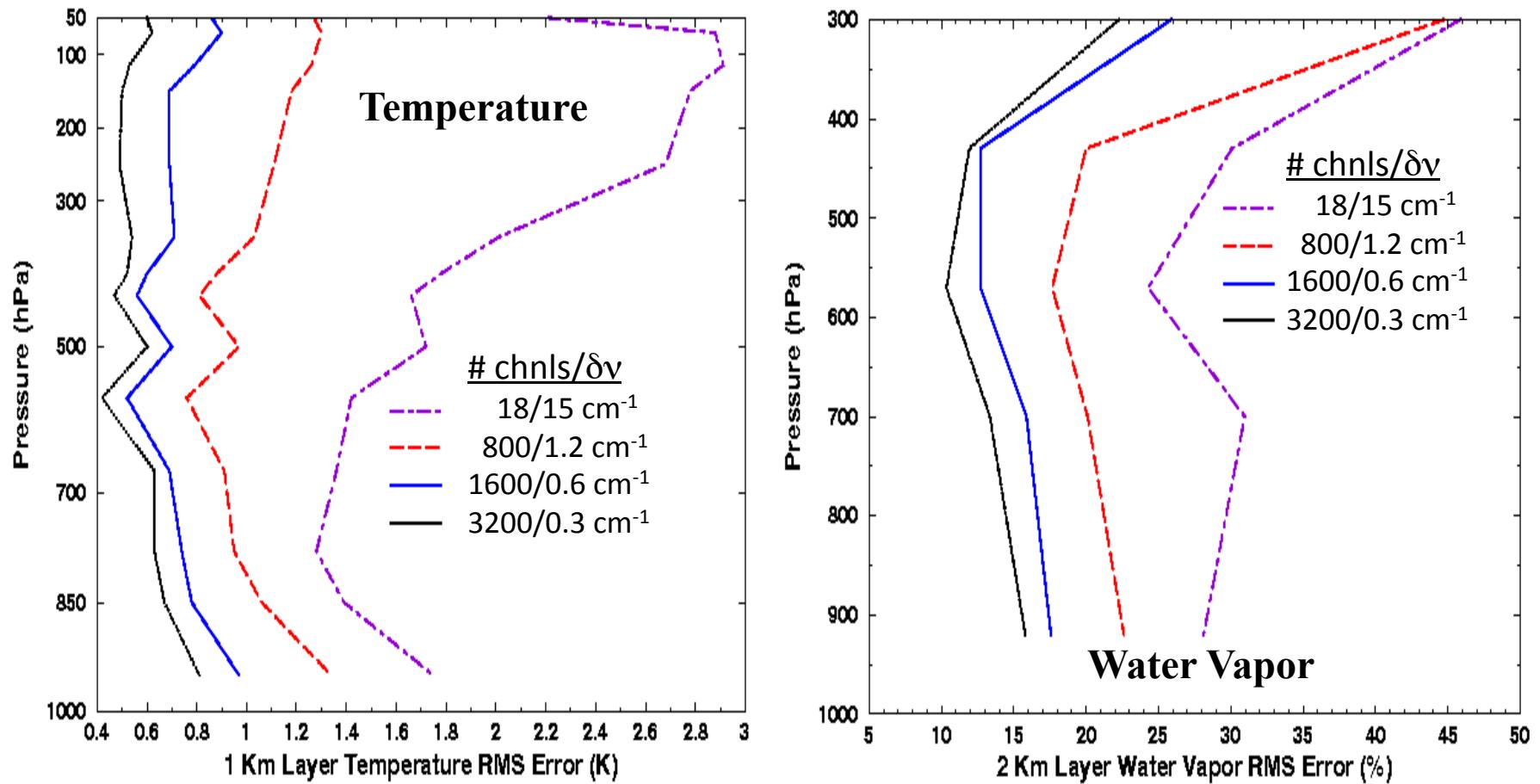
Profile Information Content



Information Content Ratio: Ultra-spectral / Multi-spectral = 3-4

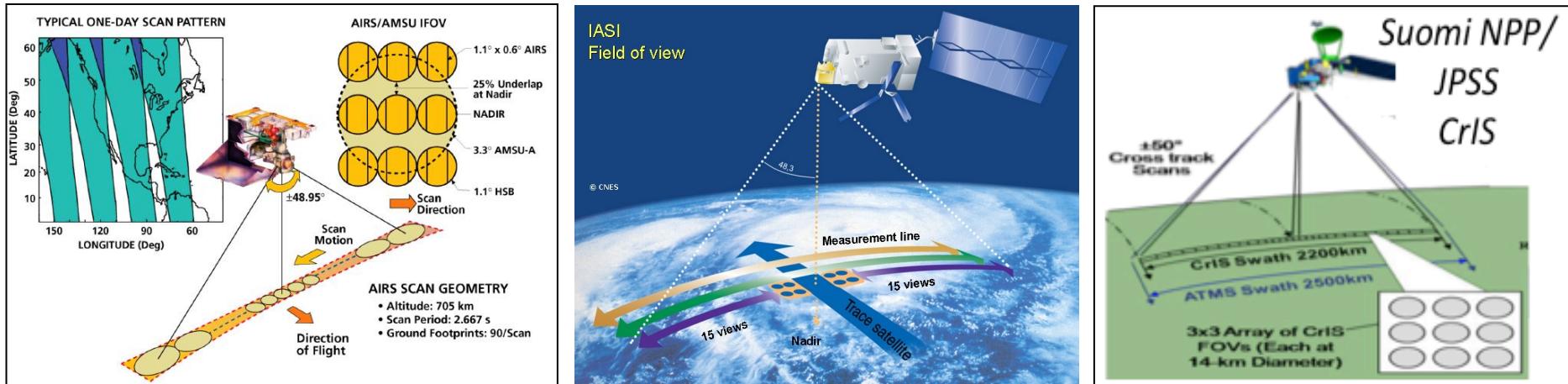
Retrieval Accuracy Vs Spectral Resolution

(i.e., number of spectral radiance observations)



The vertical resolution and accuracy increases greatly going from multi-spectral to ultra-spectral resolution. The improvement in ultra-spectral performance is proportional to the square root of the number of channels (i.e., S/N)

Polar-Orbiting Ultra-Spectral Sounders

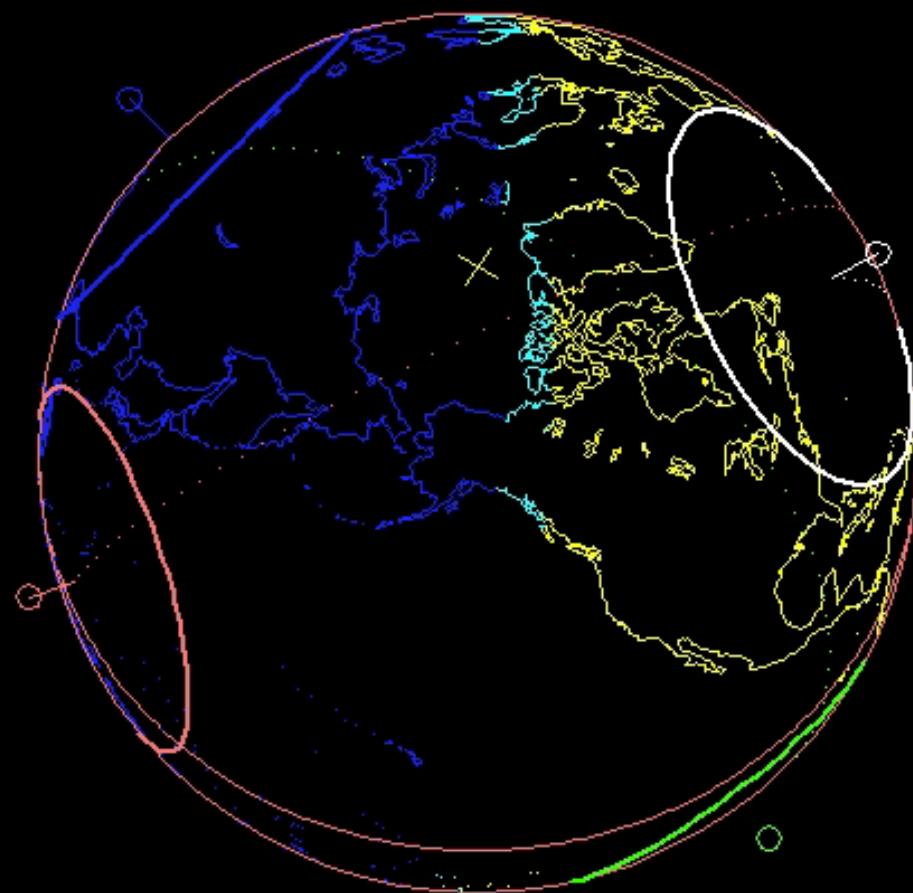


Instrument	AIRS	IASI	CrIS
Satellite	EOS Aqua	Metop-A, Metop-B	Suomi-NPP
Type	Grating Spectrometer	Michelson Interferometer	Michelson Interferometer
Spectral resolution	0.5 – 2 cm ⁻¹	0.25 cm ⁻¹	0.625 (LW), 1.25 (MW), 2.5 cm ⁻¹ (SW)
Spectral range	650 – 2670 cm ⁻¹ (15.4 – 3.7 μm)	645 – 2760 cm ⁻¹ (15.5 – 3.62 μm)	650 – 2550 cm ⁻¹ (15.4 – 3.9 μm)
Number of Detectors/Channels	4756 / 2378	12 / 8461	27 / 1305
NEDT range	0.05 - 0.5 K	0.1 – 0.75 K	0.05 – 0.5 K
Spatial Resolution (at nadir)	13.5 km	12 km	14 km
Launched	2001	2006, 2012	2011

The Ultraspectral Satellite System – Metop-A, Metop-B, Aqua, and S-NPP

Satellite	Altitude (Km)	Period (min)	Equator crossing Time	Node
Metop-A	817	101	09:31	Descending
Metop-B	817	101	10:28	Descending
Aqua	708	98.4	13:30 +/-25	Ascending
S-NPP	830	101	13.30+/-25	Ascending

NPP	13056.3500	7202.24	98.74	101.44	824.24
AQUA	13056.7609	7077.79	98.23	98.83	699.79
METOPA	13056.5944	7195.54	98.67	101.30	817.54
METOPB	13057.1956	7195.62	98.72	101.30	817.62



METEOROLOGICAL SATELLITES

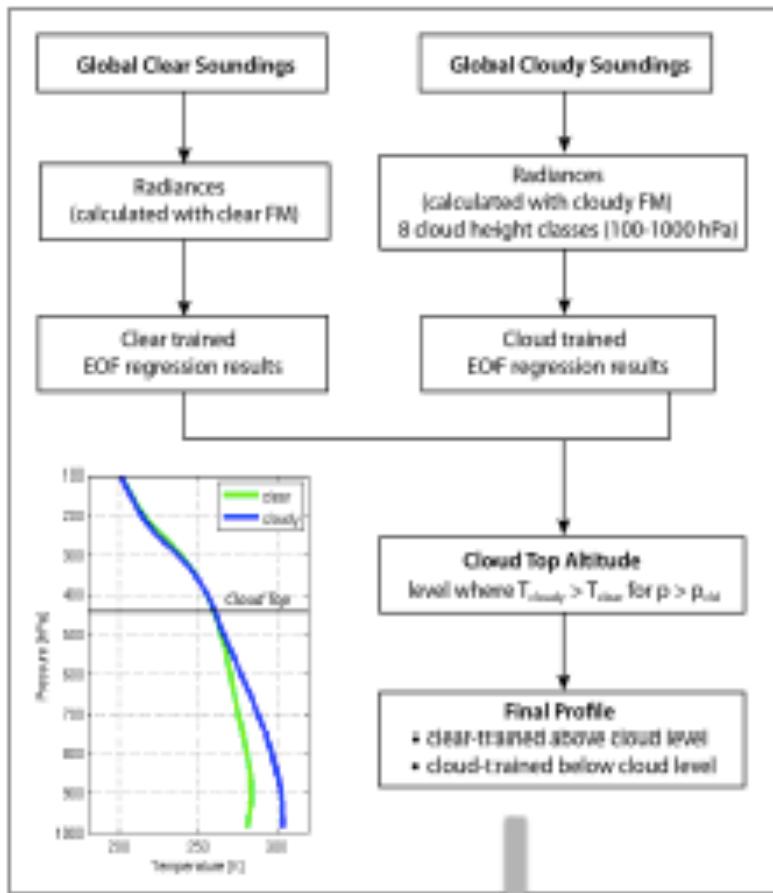
15:57 UT 23 FEB 13

Hyperspectral Retrieval Software in CSPP

University of Wisconsin-Madison CrIS,
AIRS and IASI Hyperspectral Retrieval
Software (latest version April 2014)

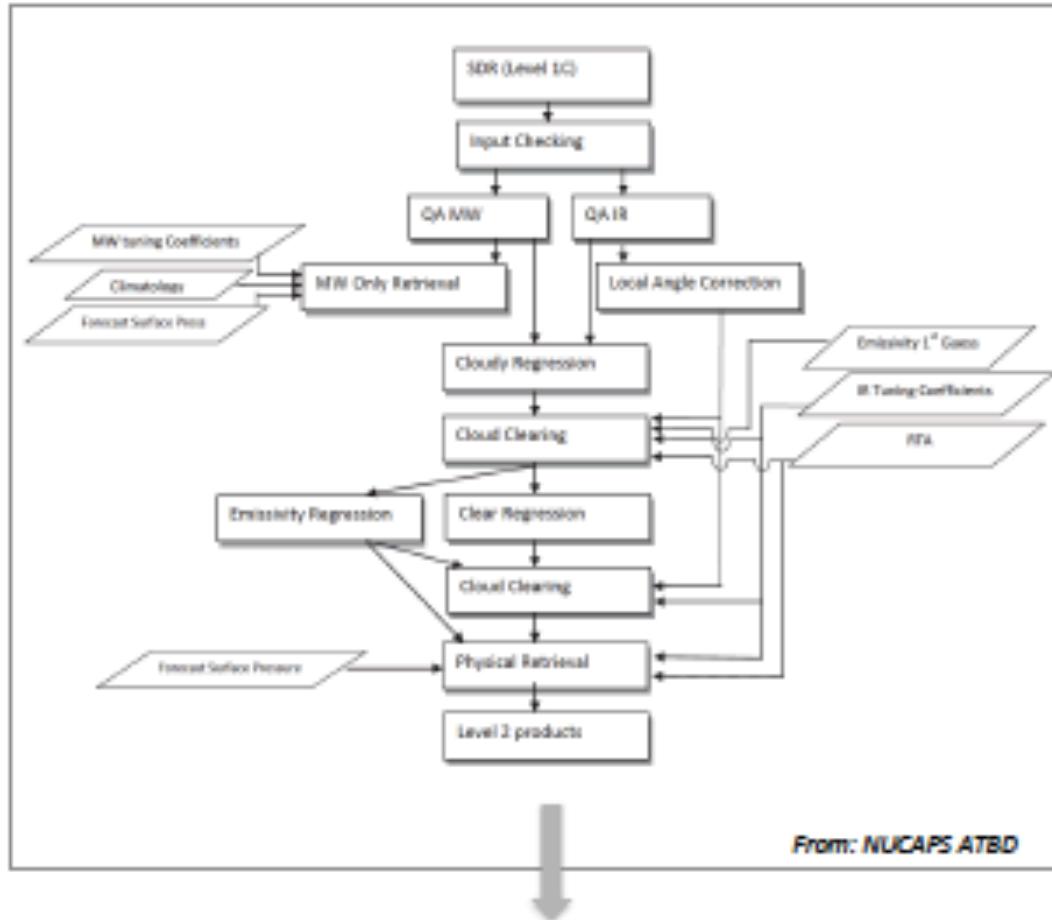
NOAA Unique CrIS/ATMS Processing
System (NUCAPS) EDR Software
Version 1.0 Release (February 2015)

HSRTV Dual-Regression



L2 Products: temperature, water vapor and ozone profiles, cloud and surface parameters.
NUCAPS also outputs trace gas retrievals such as methane and carbon monoxide.

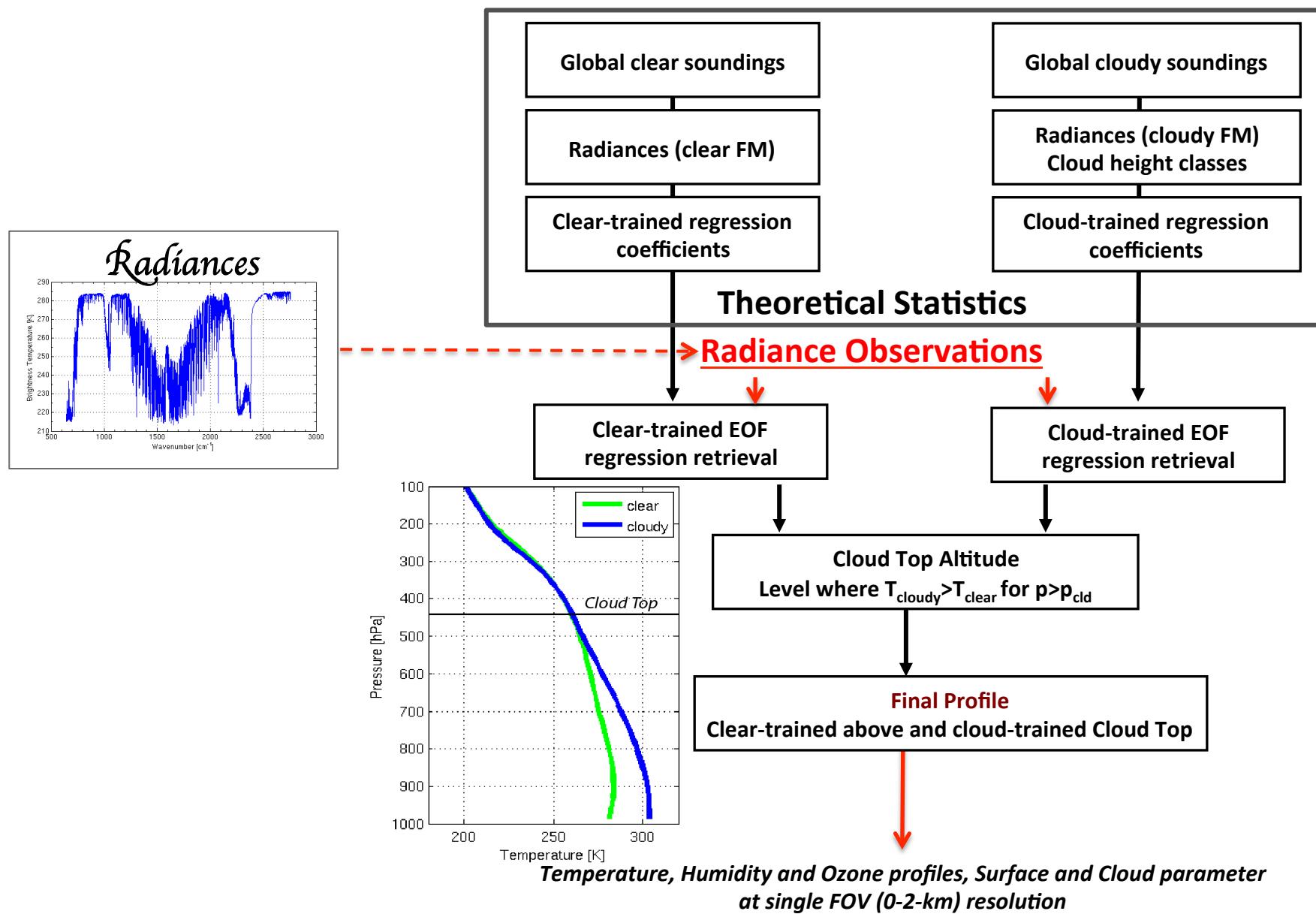
NUCAPS



Main Differences

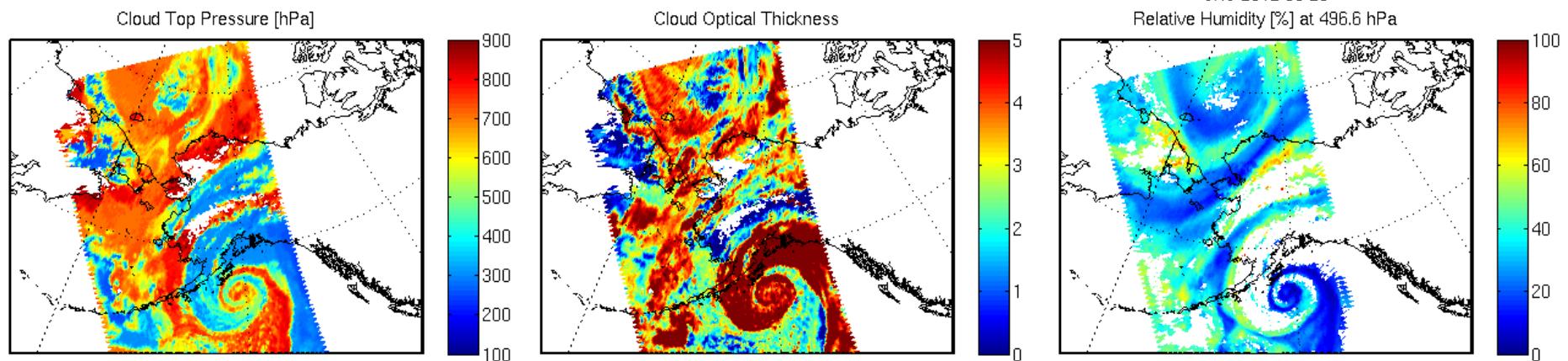
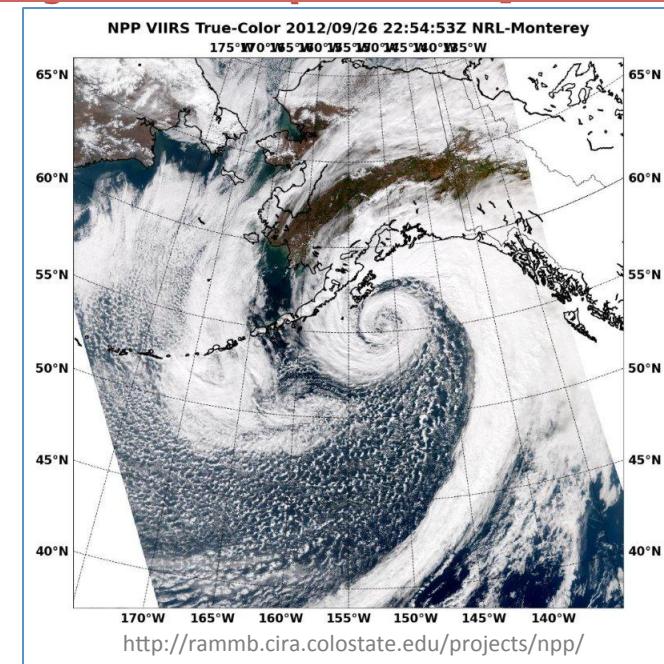
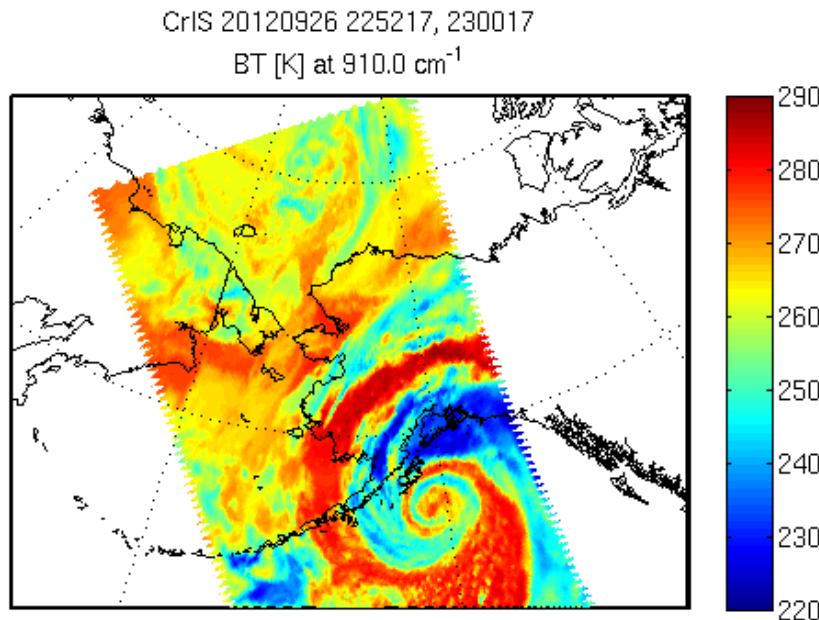
Dual-Regression (UW/CIMSS)	NUCAPS (NOAA)
Research	Operational
Regression solution	Optimal estimation solution
Optimized for speed	Optimized for accuracy
Infrared only	Infrared plus microwave
Single FOV resolution (~14 km at nadir)	3x3 array (~50 km at nadir)
No retrievals below thick clouds	Retrievals below clouds
Multi-instrument (AIRS, IASI, CRIS)	Single instrument (CrIS)

“Dual-Regression” Retrieval Algorithm* Overview



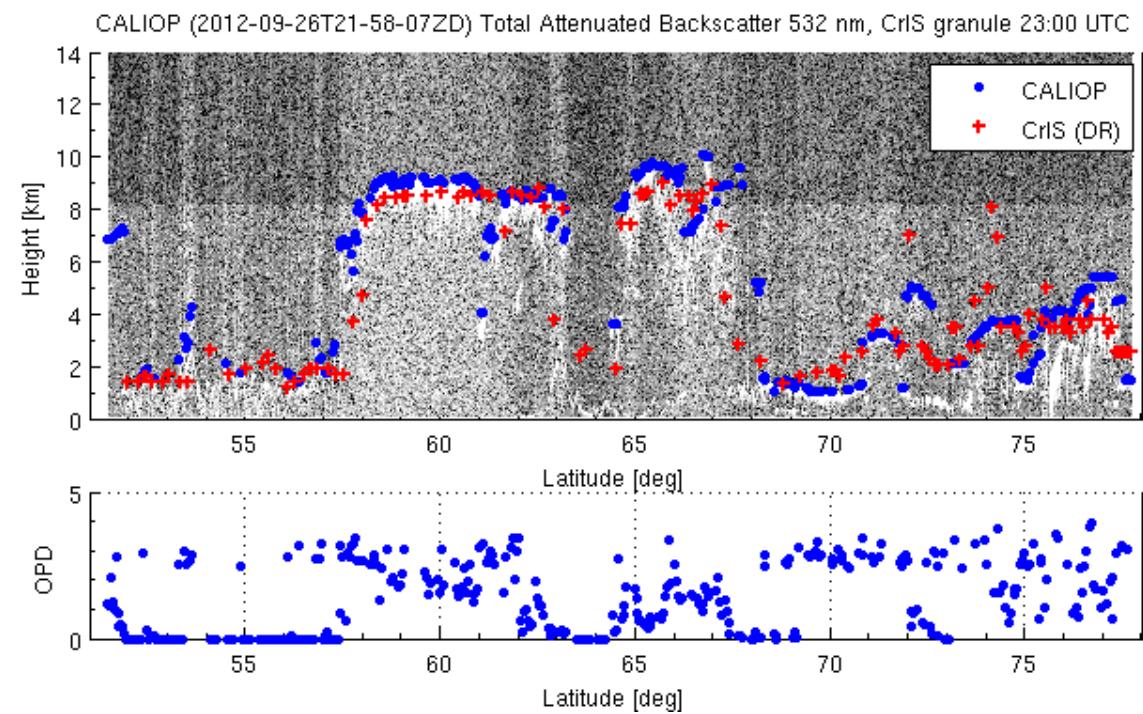
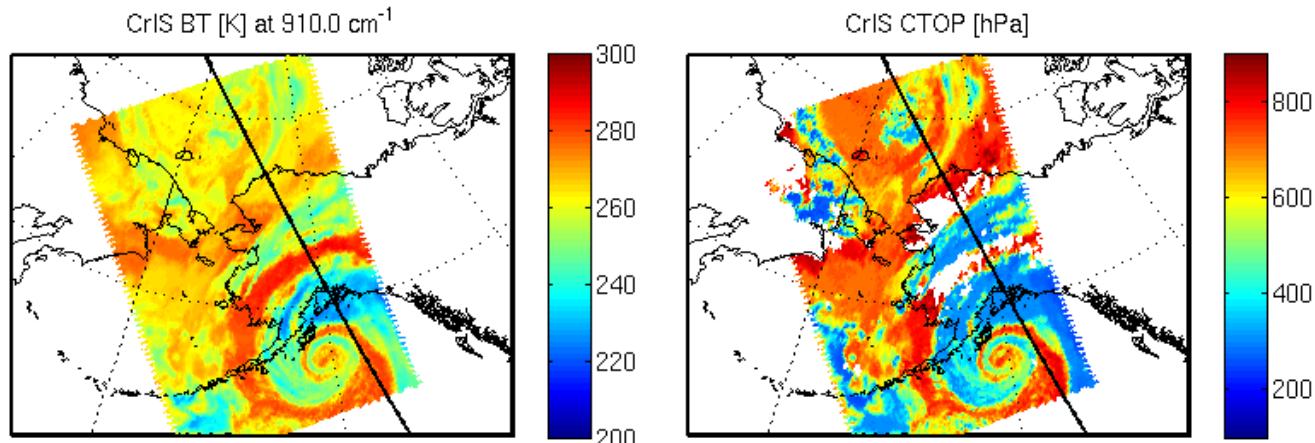
* Smith, W. L., E. Weisz, S. Kirev, D. K. Zhou, Z. Li, and E. E. Borbas (2012), Dual-Regression Retrieval Algorithm for Real-Time Processing of Satellite Ultraspectral Radiances. *J. Appl. Meteor. Clim.*, 51, Issue 8, 1455-1476.

Gulf of Alaska Low Pressure System (26 Sept 2012)



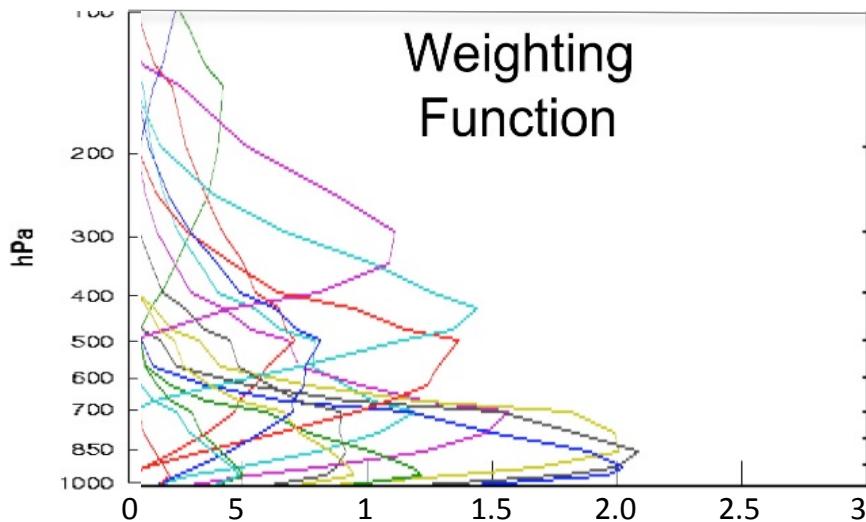
Sounding retrievals provide quantitative interpretation of satellite imagery

CrIS CTH Comparison with CALIPSO (26 Sept 2012)



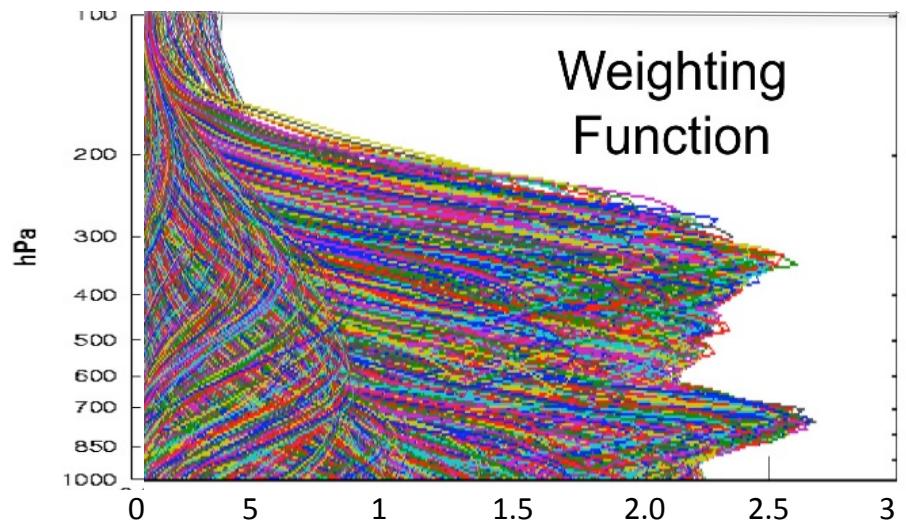
Poor Sounding Vertical Resolution Causes Problem with Direct Assimilation of Satellite Profiles

Filter Sounders (e.g., HIRS)

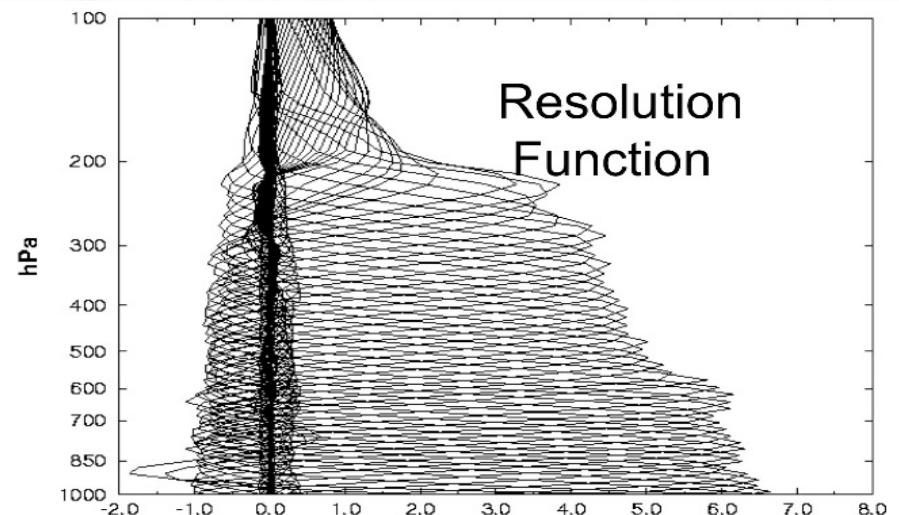
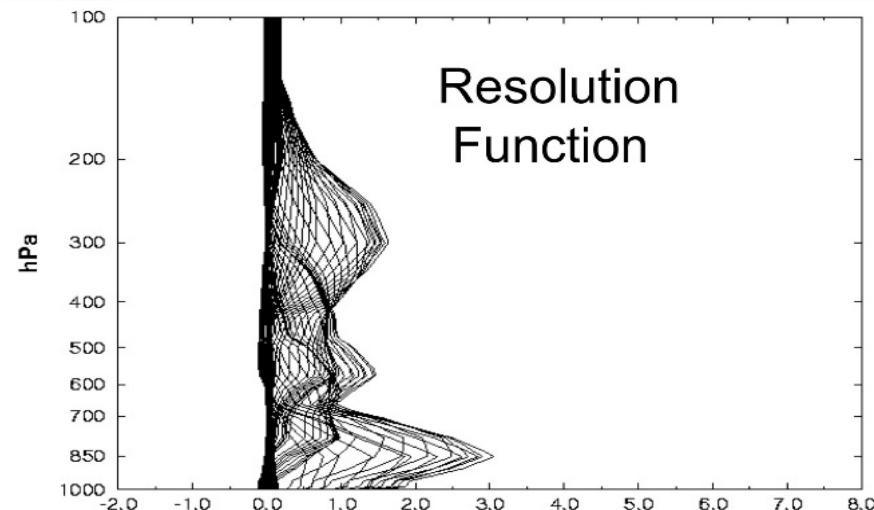


$$\Delta\nu = 15.0 \text{ cm}^{-1}$$

Interferometer Sounders (e.g. CrIS)



$$\Delta\nu = 0.5 \text{ cm}^{-1}$$



How Can We Transform Radiances to Vertical Profiles?

Prof. Verner Suomi, the “Father of Satellite Meteorology”, provided the answer many years ago. He said the problem of satellite profile retrieval is similar to that of trying to separate the Yolk from the White in a scrambled egg.

The answer: Feed the scrambled egg back to the chicken



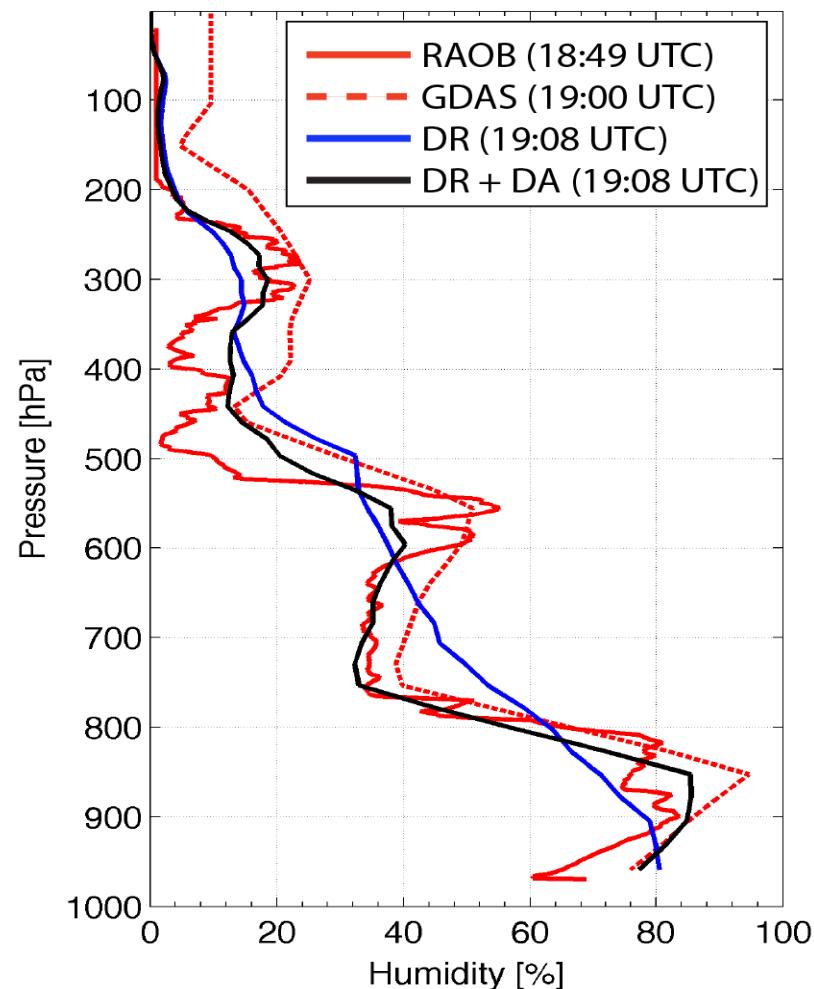
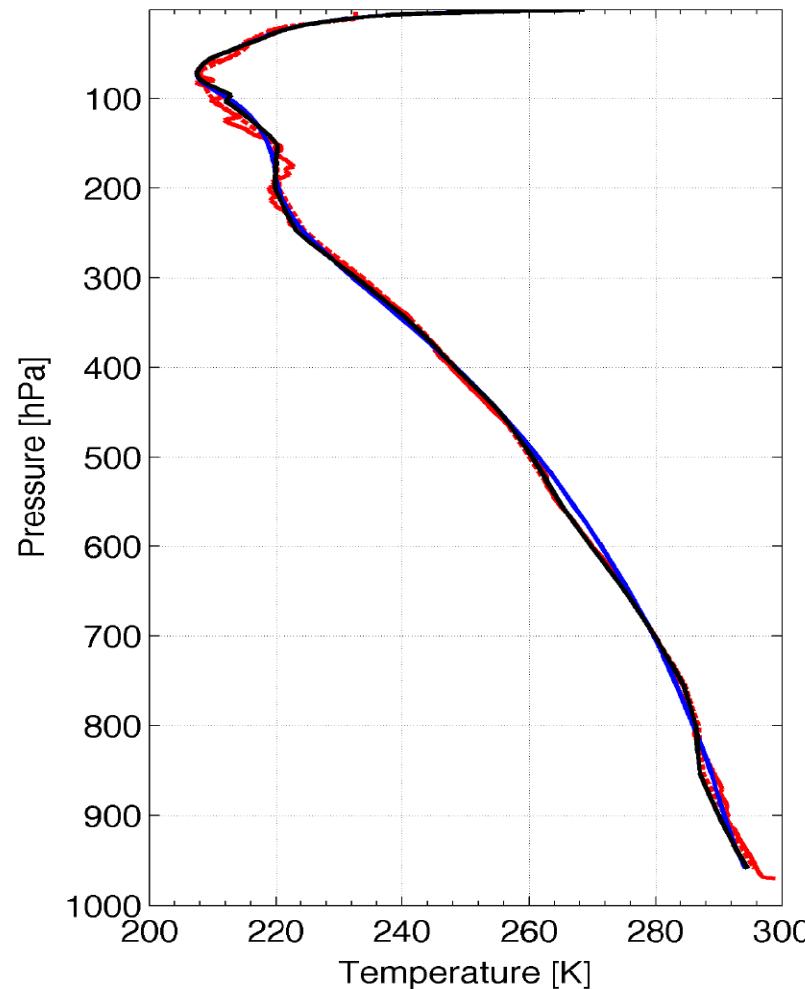
Spectral Radiances → Models → Vertical Profiles

De-Aliasing Using Forecast Model Profile

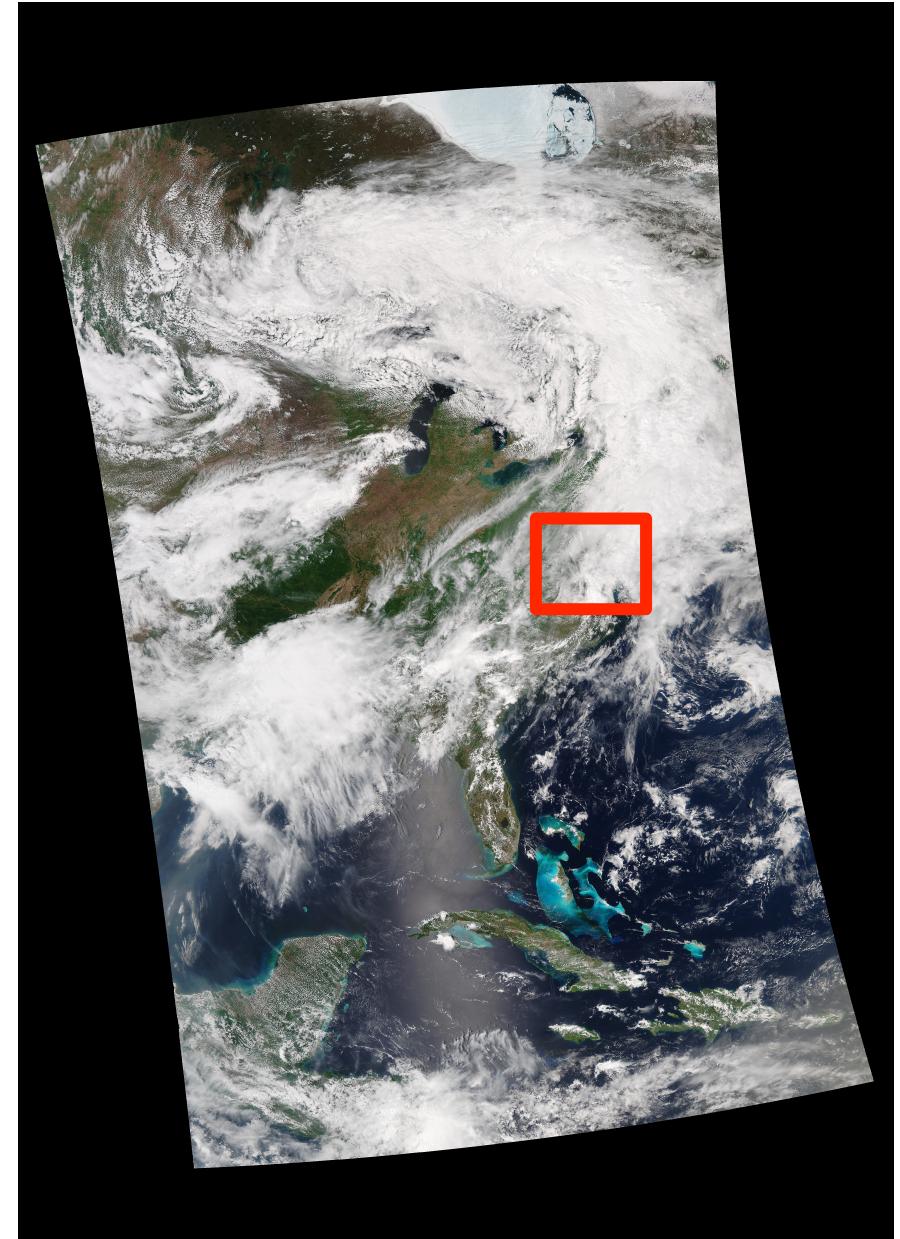
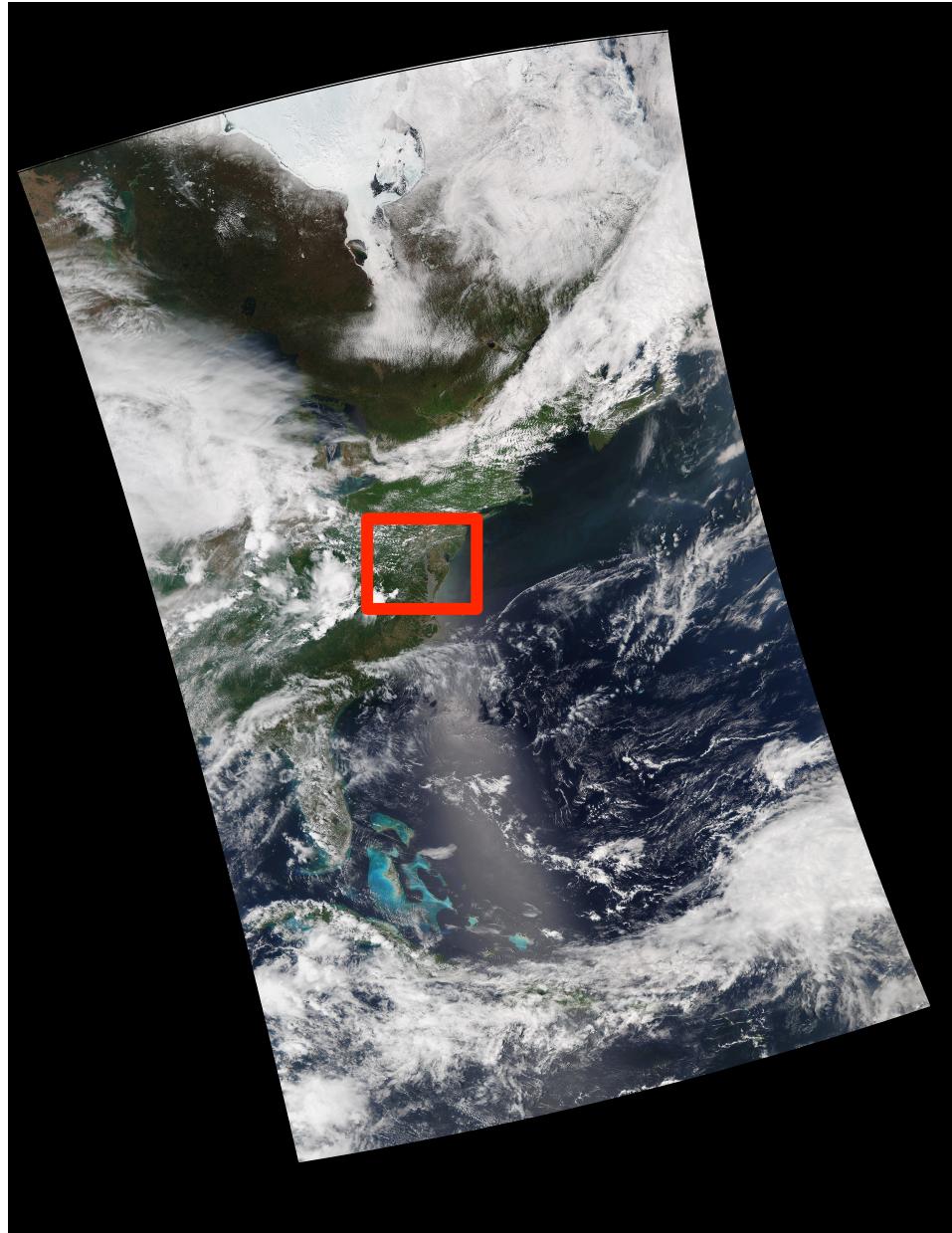
Problem: DR method uses a global statistical training data set. Imperfect skill, due to lack of vertical resolution in radiances leads to a vertical aliasing error.

Solution: Calculate radiance spectrum from forecast profile (FP) and perform DR retrieval using simulated forecast radiances.

Vertical Alias = Forecast Simulated Retrieval– Forecast Profile

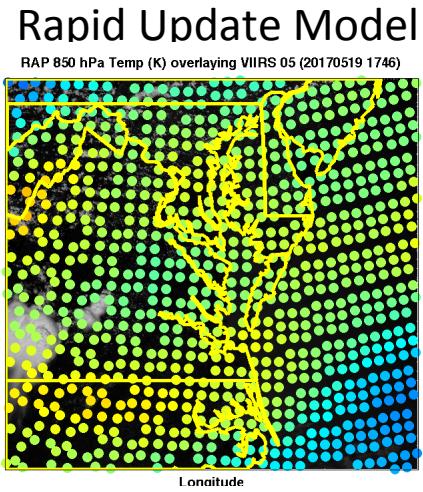
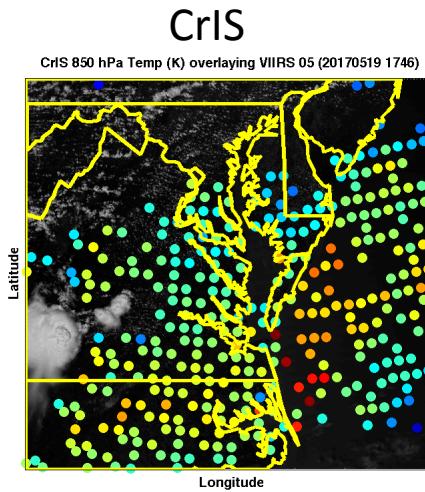


May 19 Vs. May 22, 2017

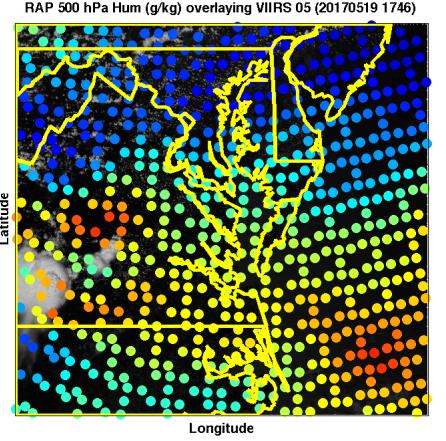
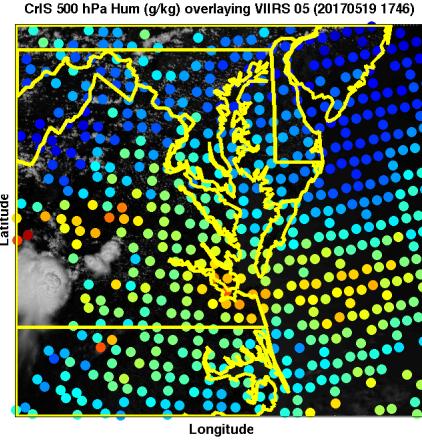
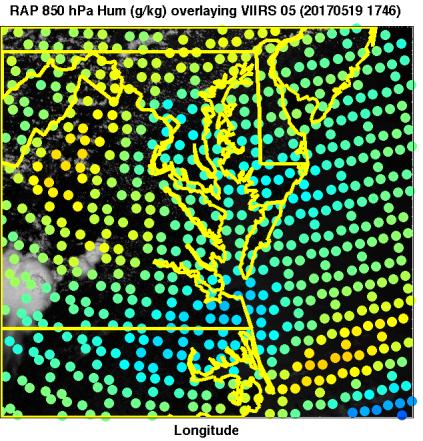
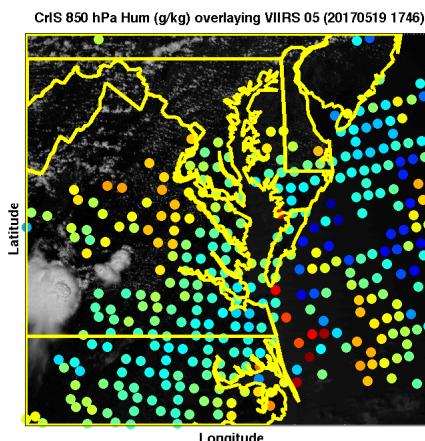
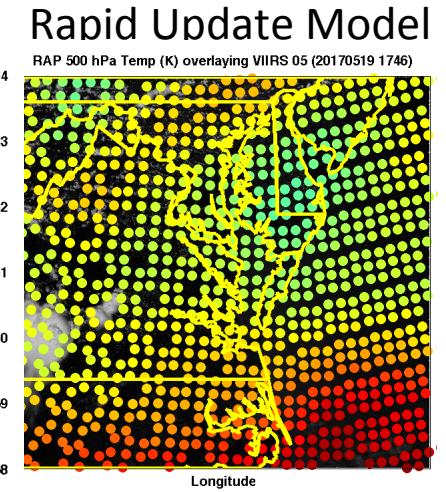
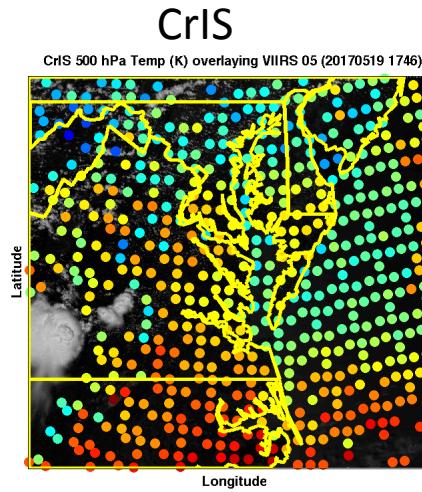


May 19, 2017 Hampton Roads Area

850 hPa Temperature



500 hPa Temperature



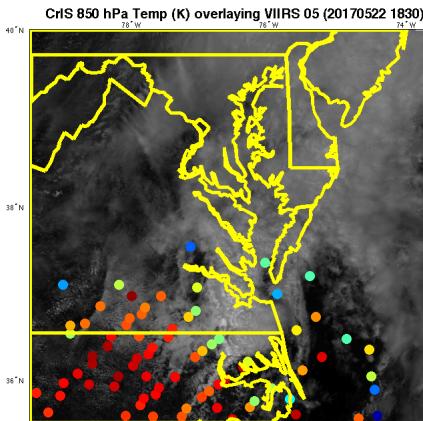
850 hPa Absolute Humidity

500 hPa Absolute Humidity

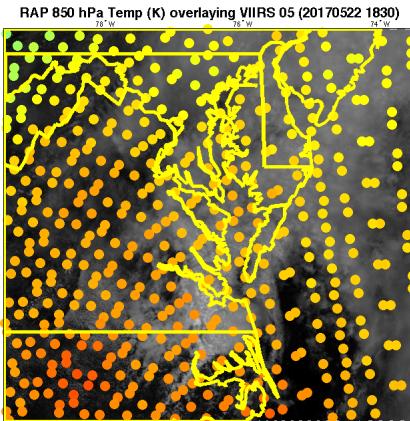
May 22, 2017 Hampton Roads Area

850 hPa Temperature

CrIS

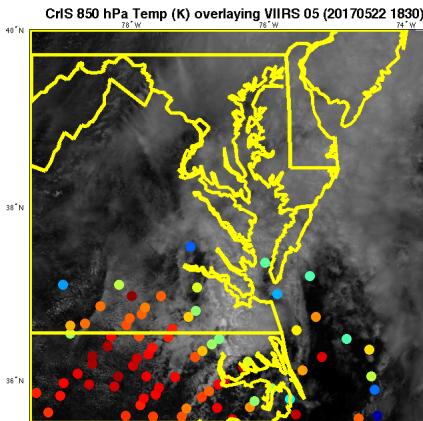


Rapid Refresh Model

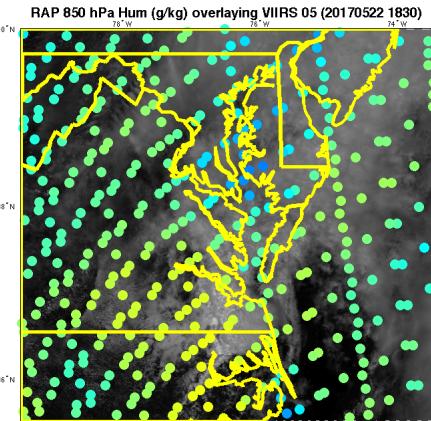
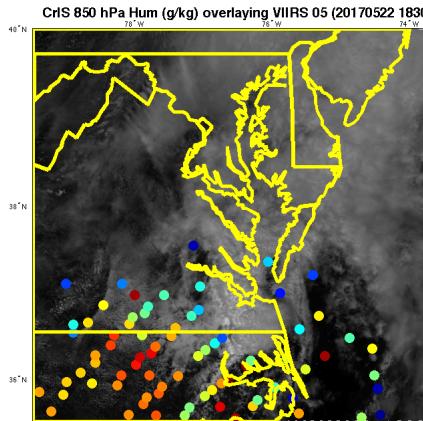
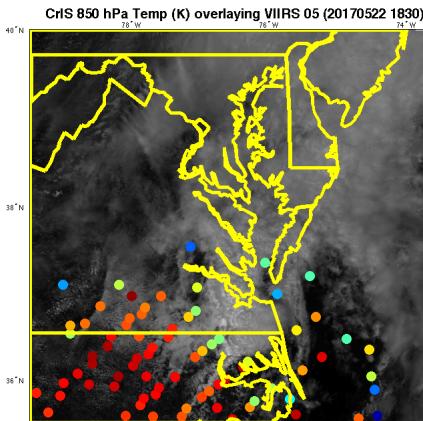


500 hPa Temperature

CrIS



Rapid Refresh Model



CrIS

Rapid Refresh Model

850 hPa Absolute Humidity

CrIS

Rapid Refresh Model

500 hPa Absolute Humidity

Lifted Index Stability Parameter

The **lifted index (LI)** is the temperature difference between an air parcel lifted adiabatically $T_p(p)$ and the temperature of the environment $T_e(p)$ at a pressure height in the troposphere of 500 hPa (mb). When the value is positive, the atmosphere (at the respective height) is stable and when the value is negative, the atmosphere is unstable.

Thunderstorm Potential:

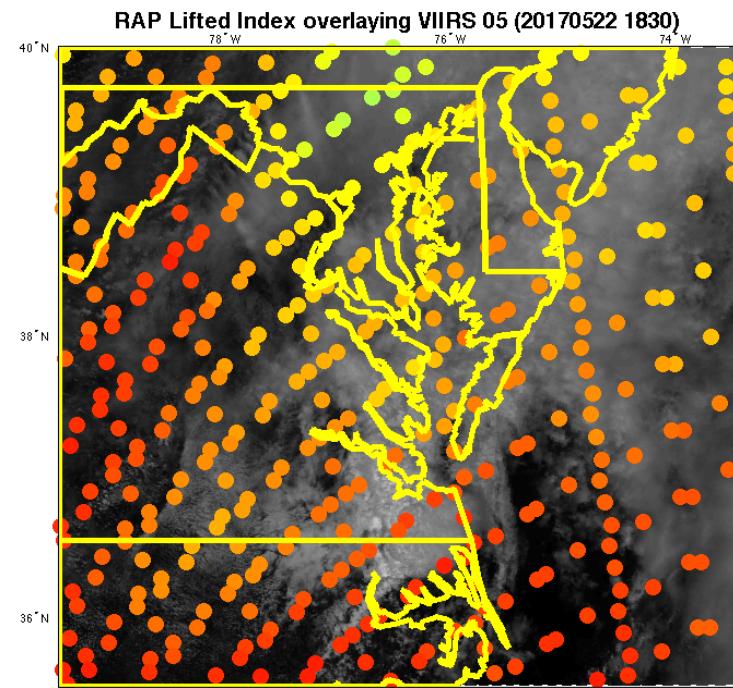
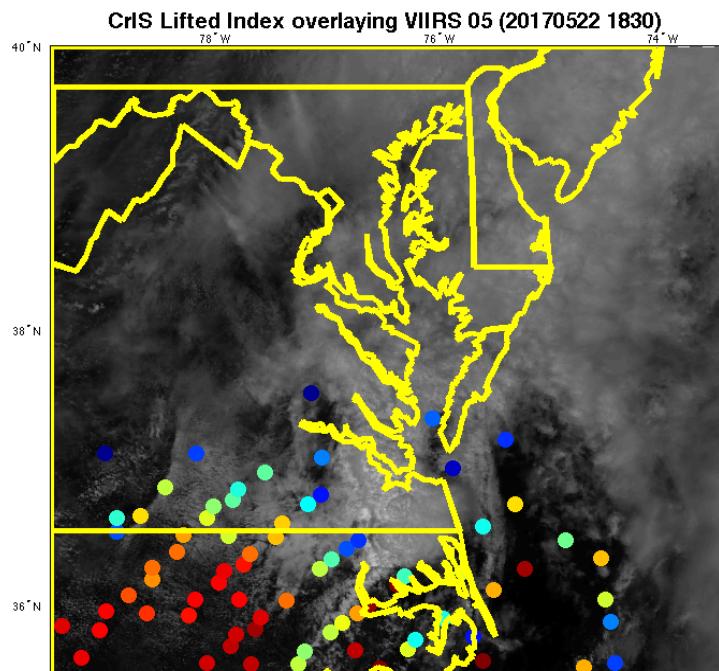
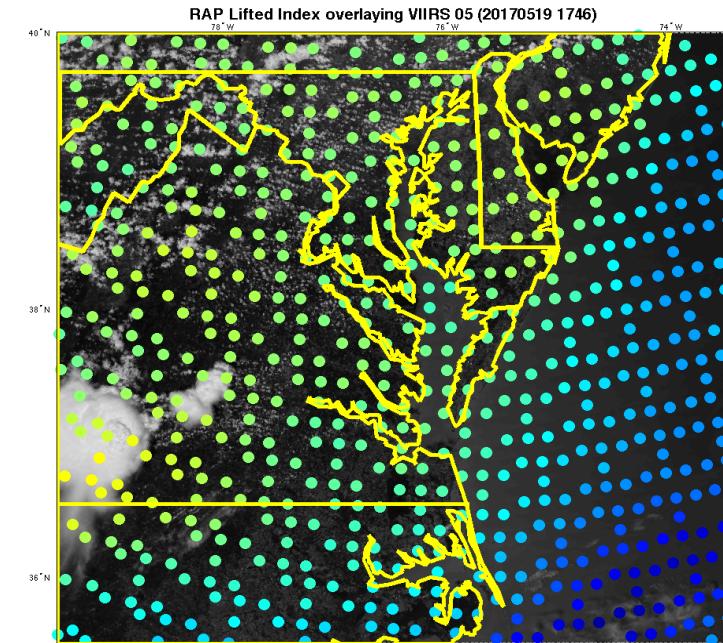
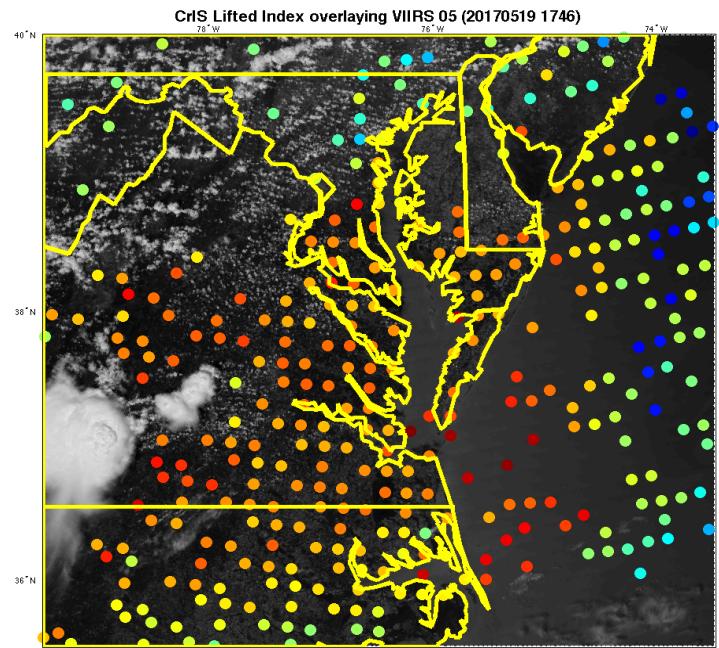
< -5 Very Unstable: Strong Thunderstorm Potential

-3 to -5 Unstable: Thunderstorm Probable

0 to -2 Marginally Unstable: Thunderstorms Possible

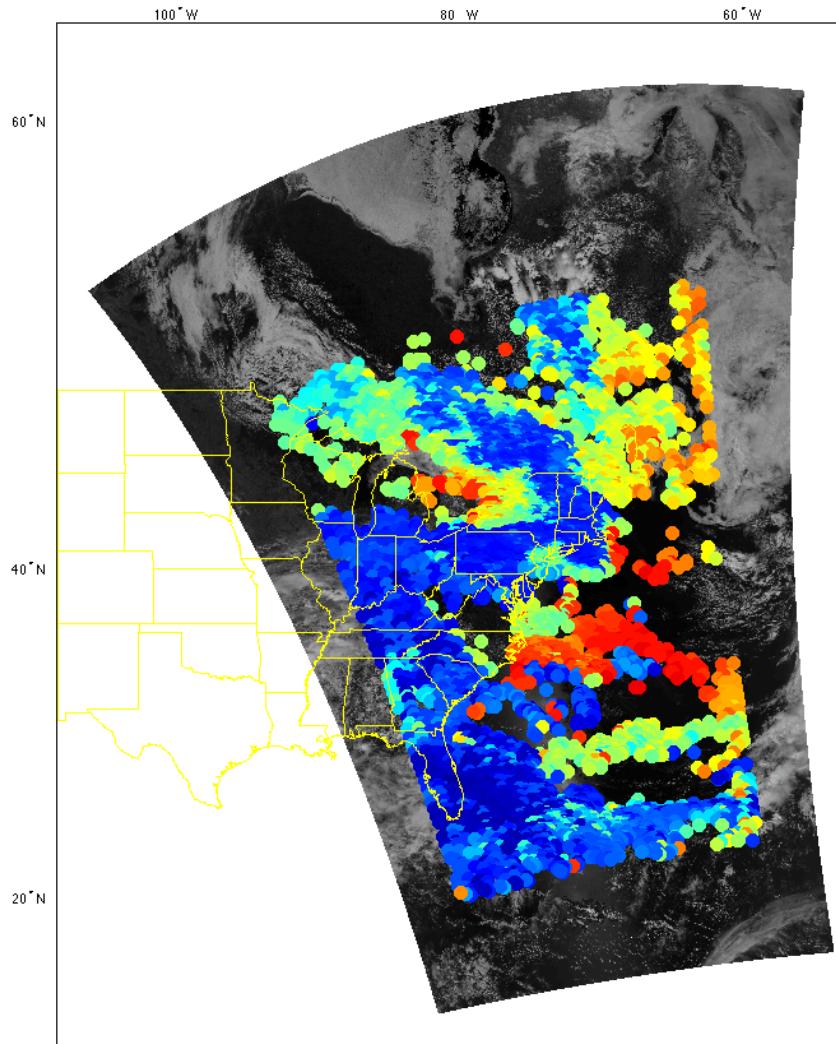
>0: Stable: Thunderstorms Unlikely

Lifted Index

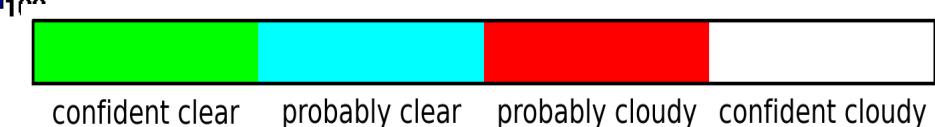
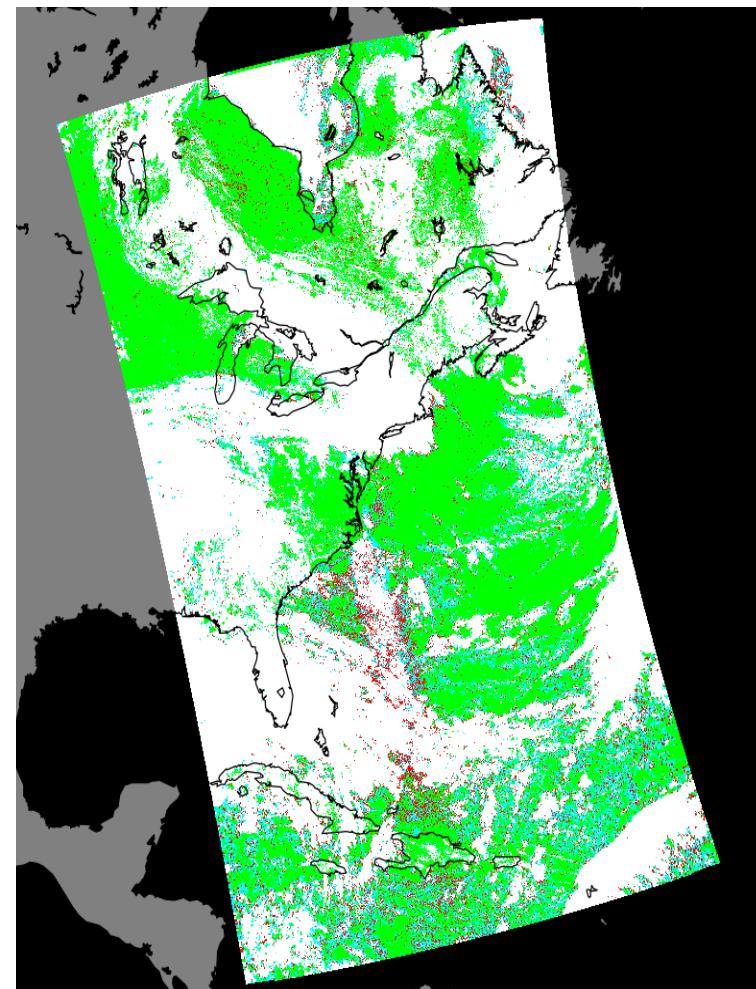


SNPP CrIS June 4, 2017 (17:46 UTC)

CrIS Cloud Pressure

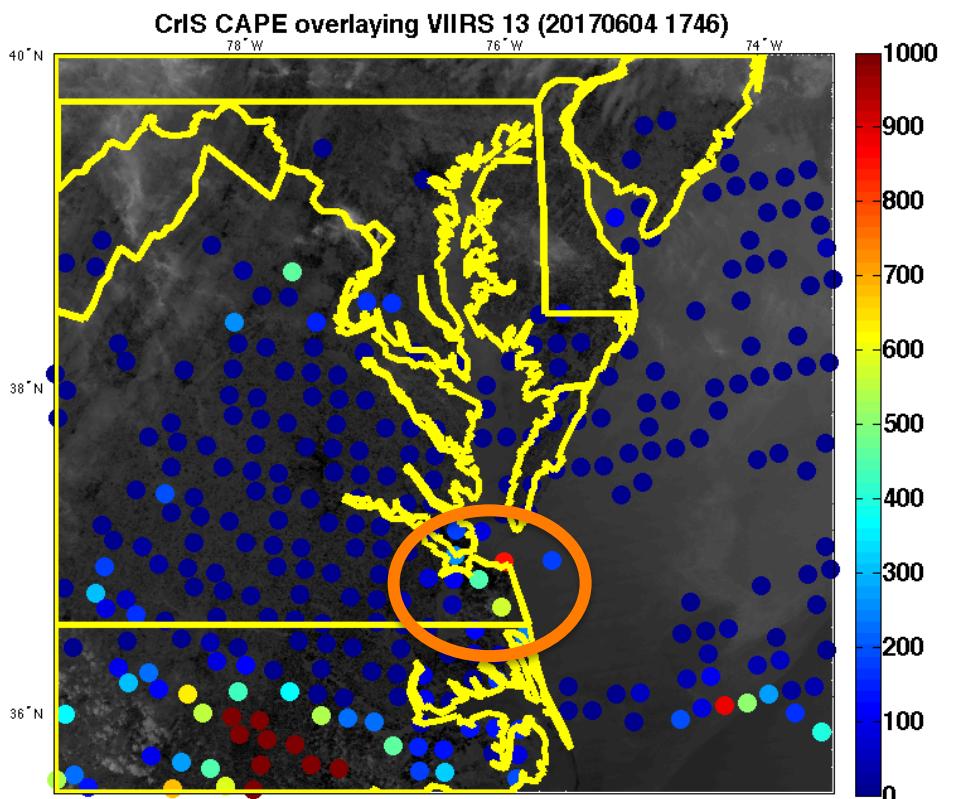
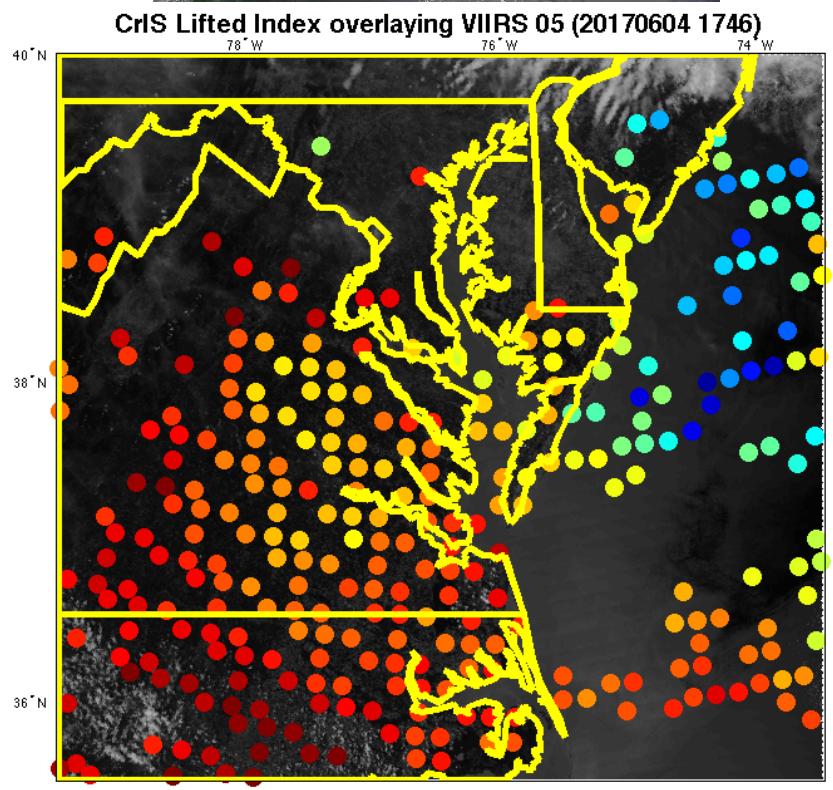
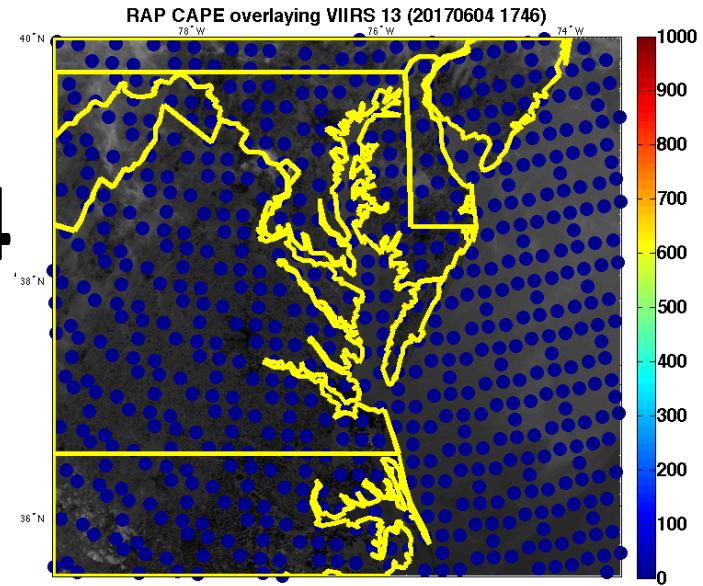


VIIRS Cloud Mask

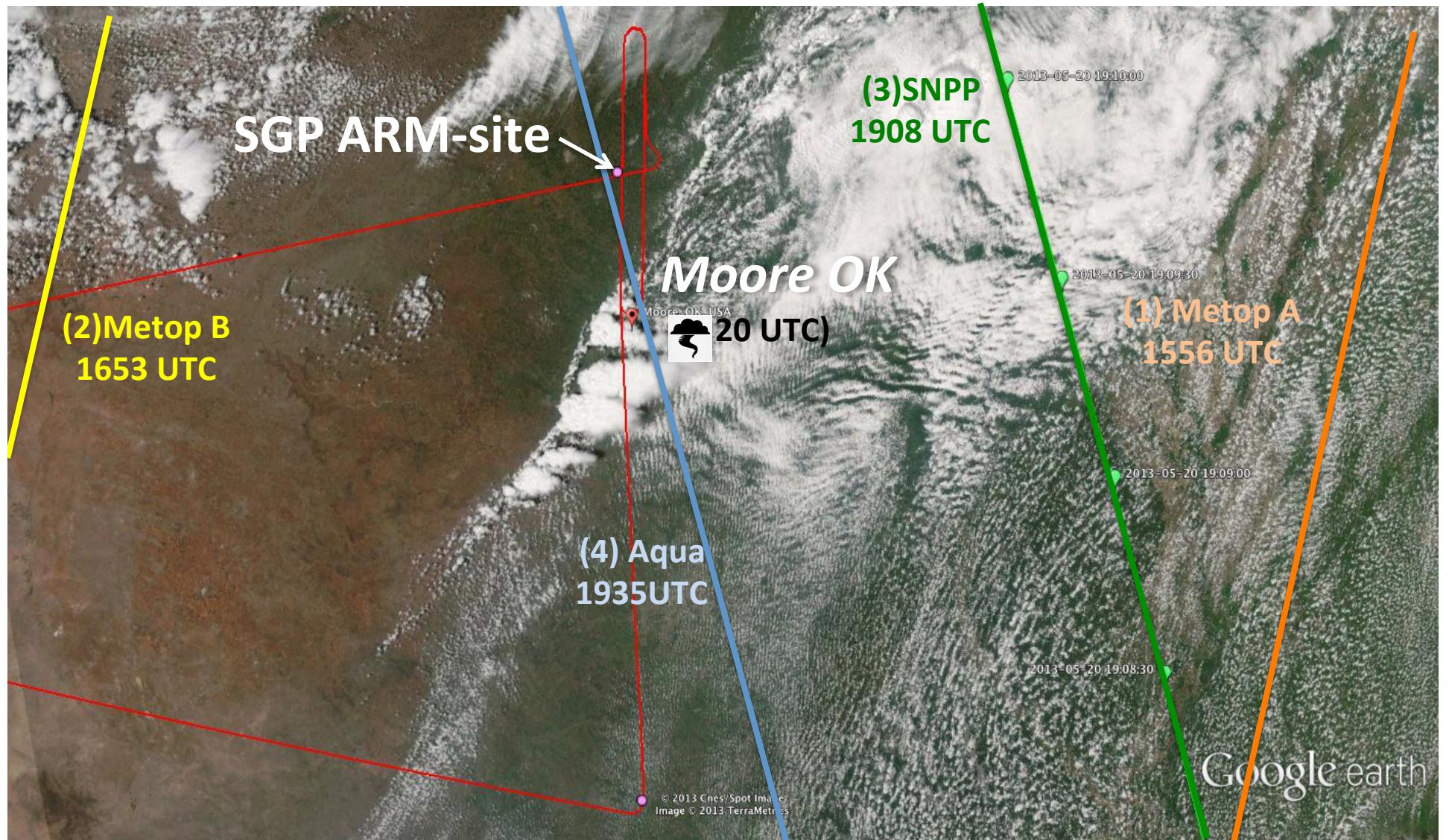




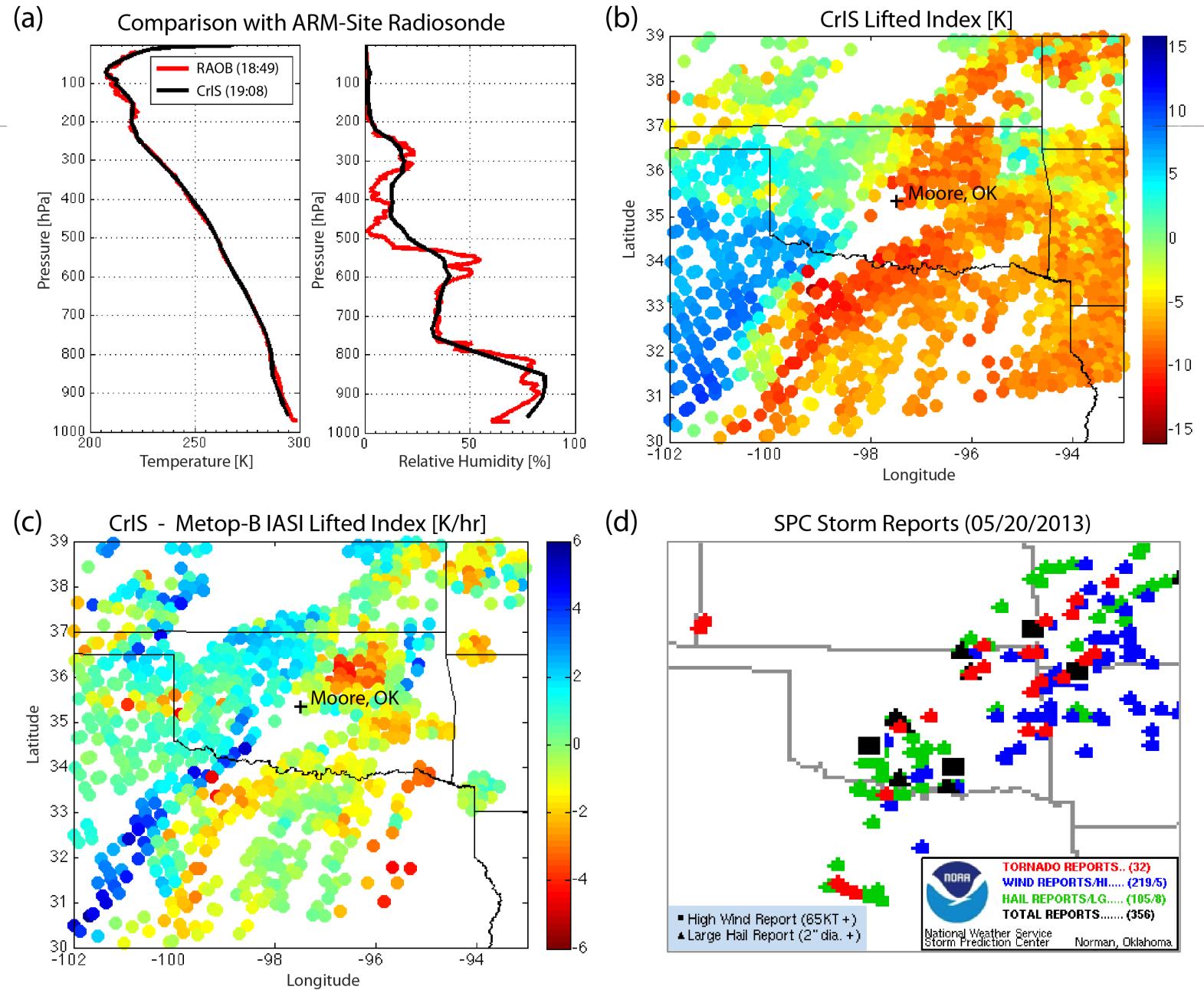
June 4
2017

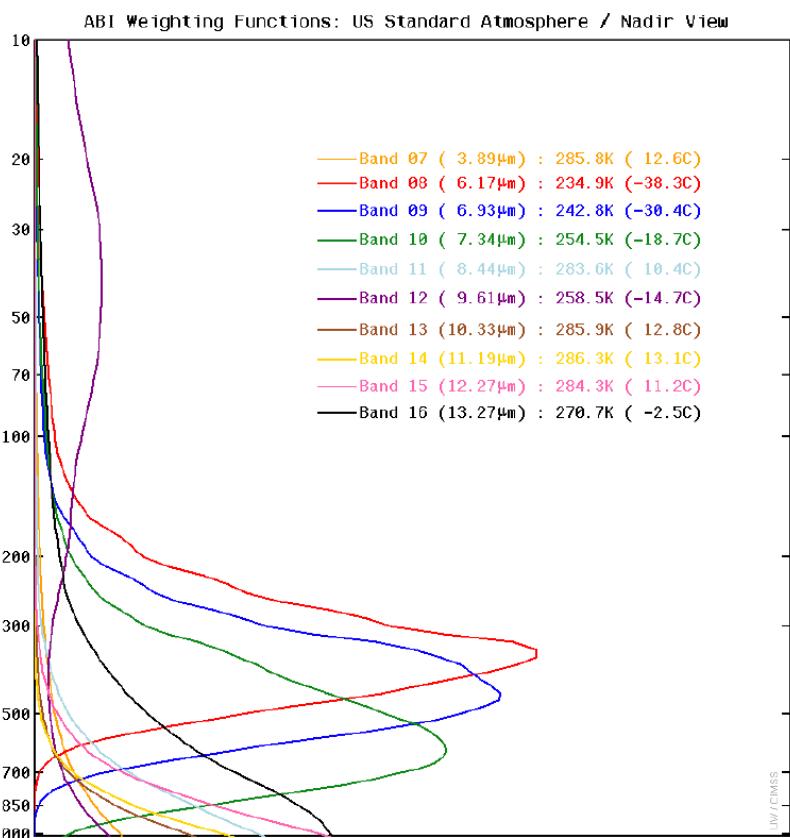
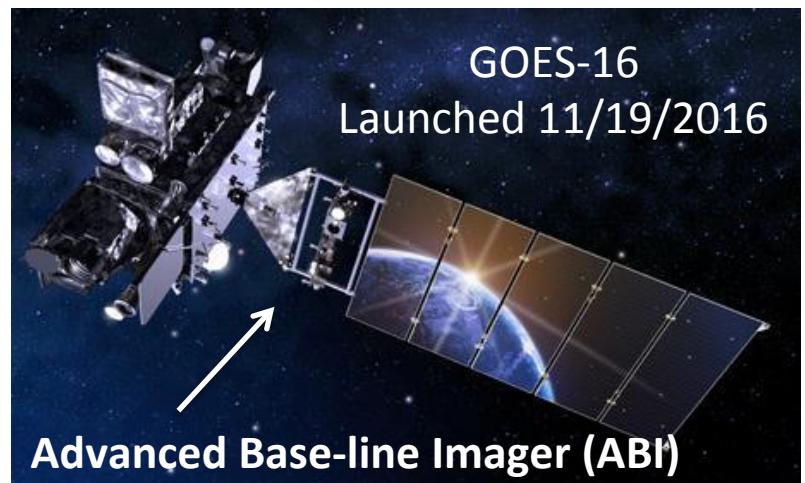
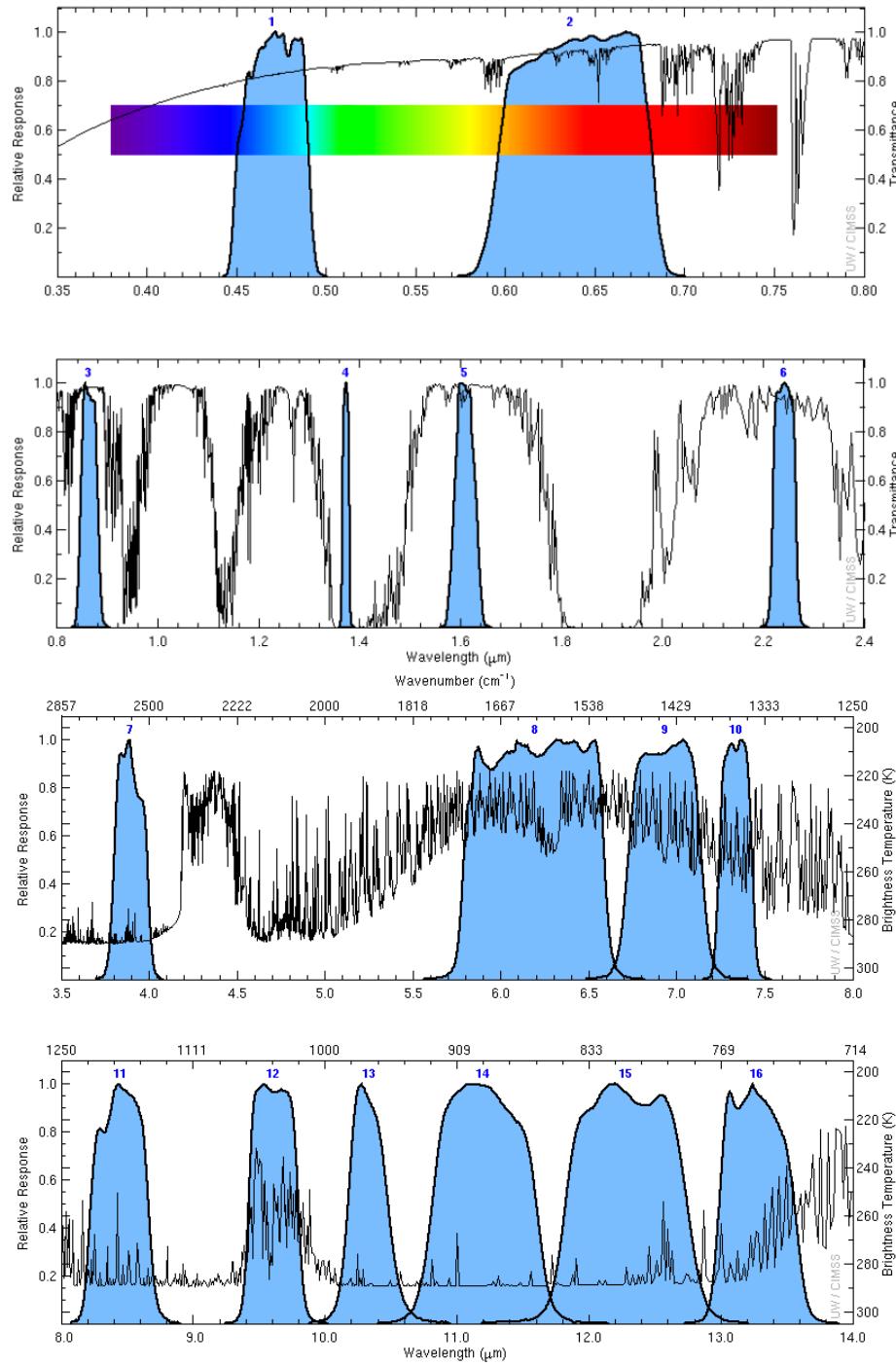


HU DBS Objective is to Improve Mid-Atlantic Region Weather Forecasts Using Combination of Polar +Geo (e.g., GOES-R) Sounding Data (~ 15 min Refresh)

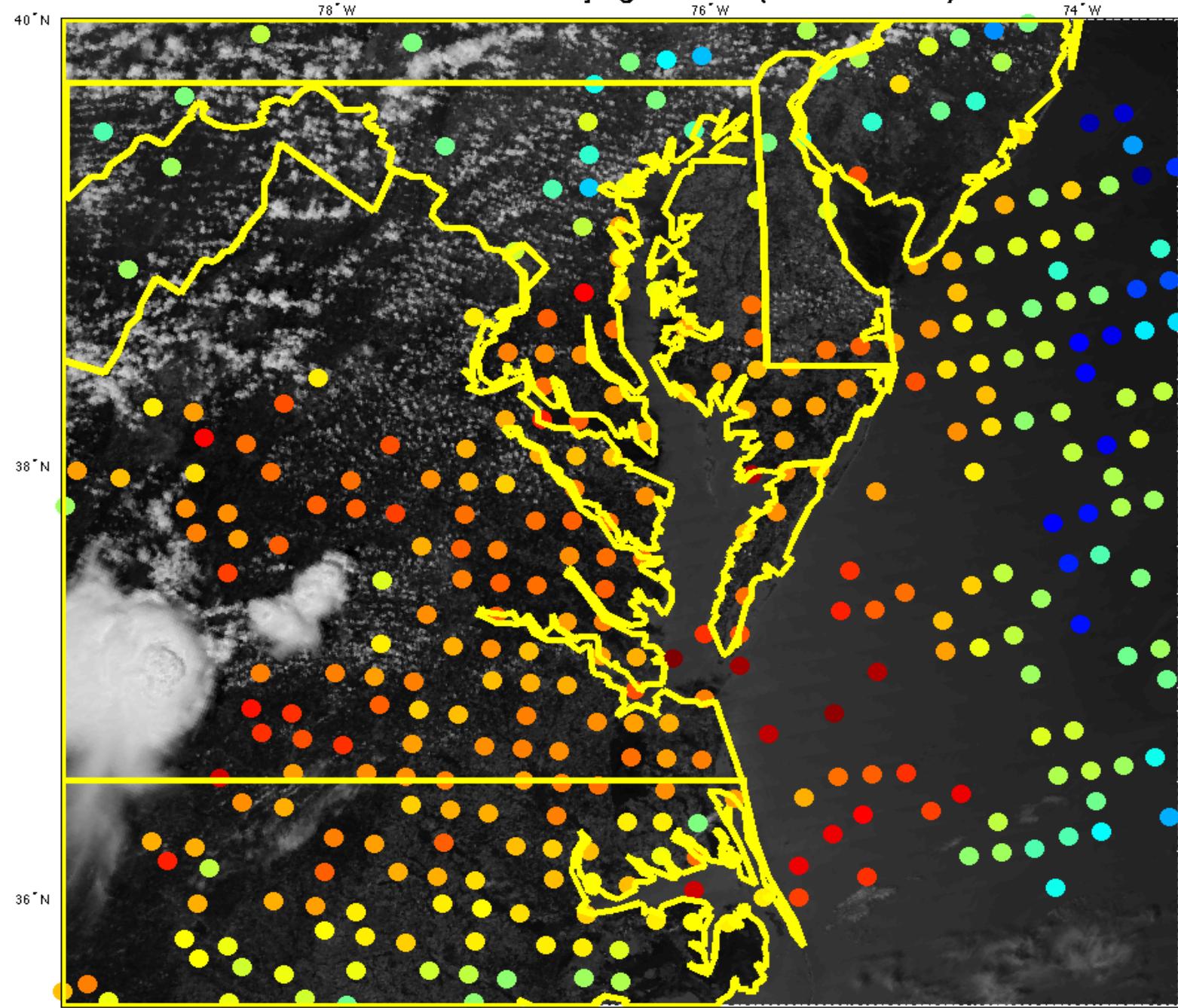


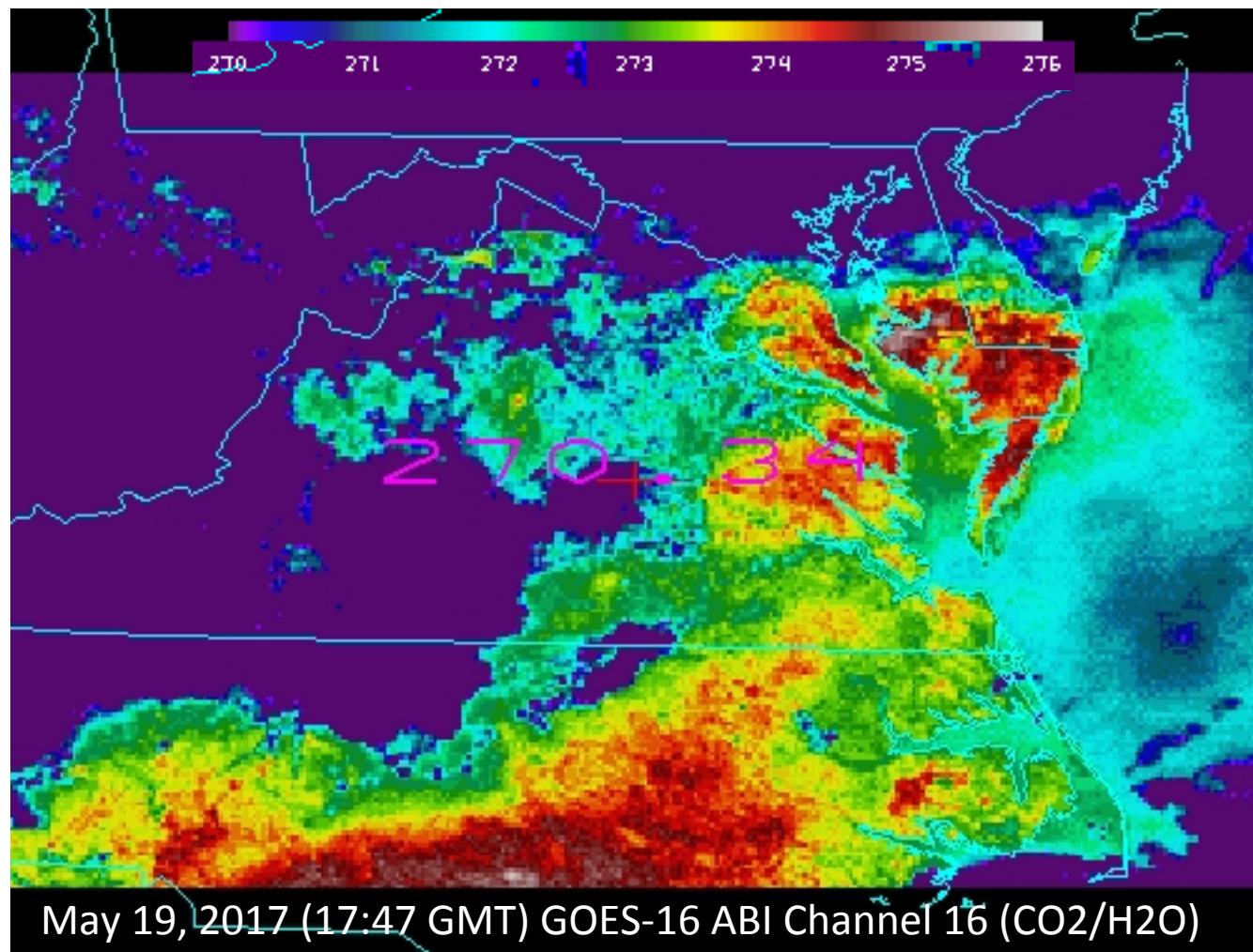
Using Stability Tendency to Predict Severe Convection

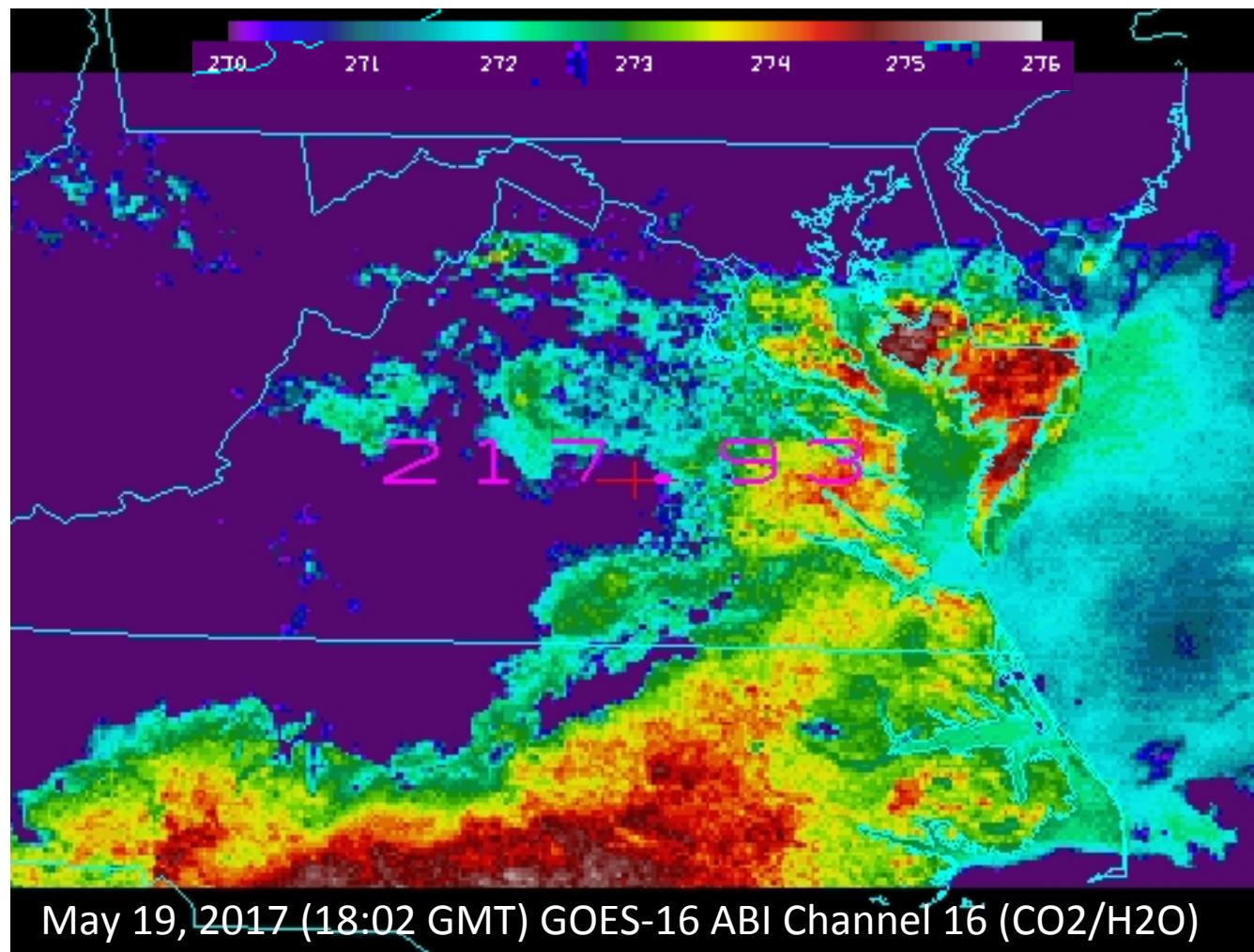


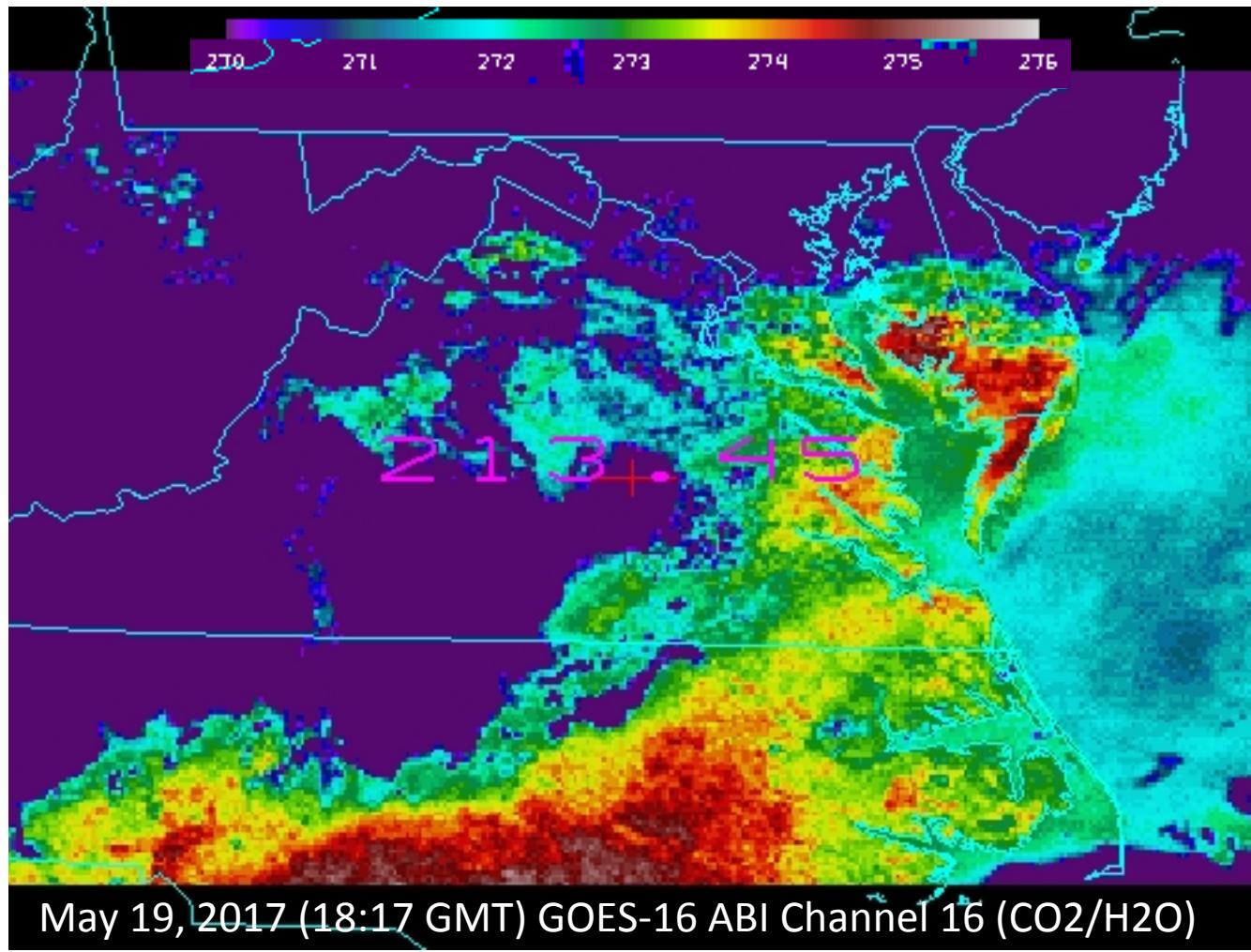


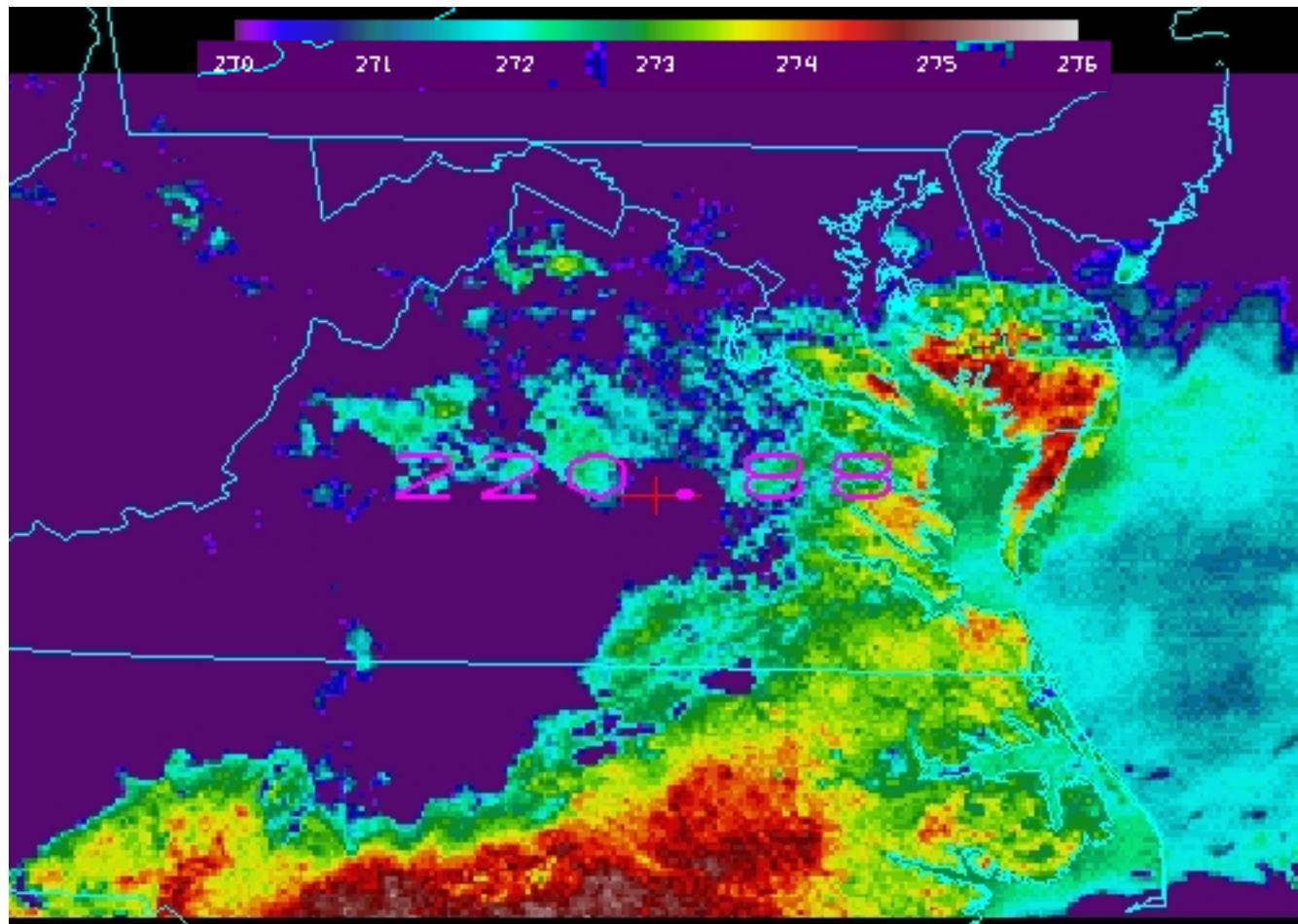
CrlS Lifted Index overlaying VIIRS 05 (20170519 1746)



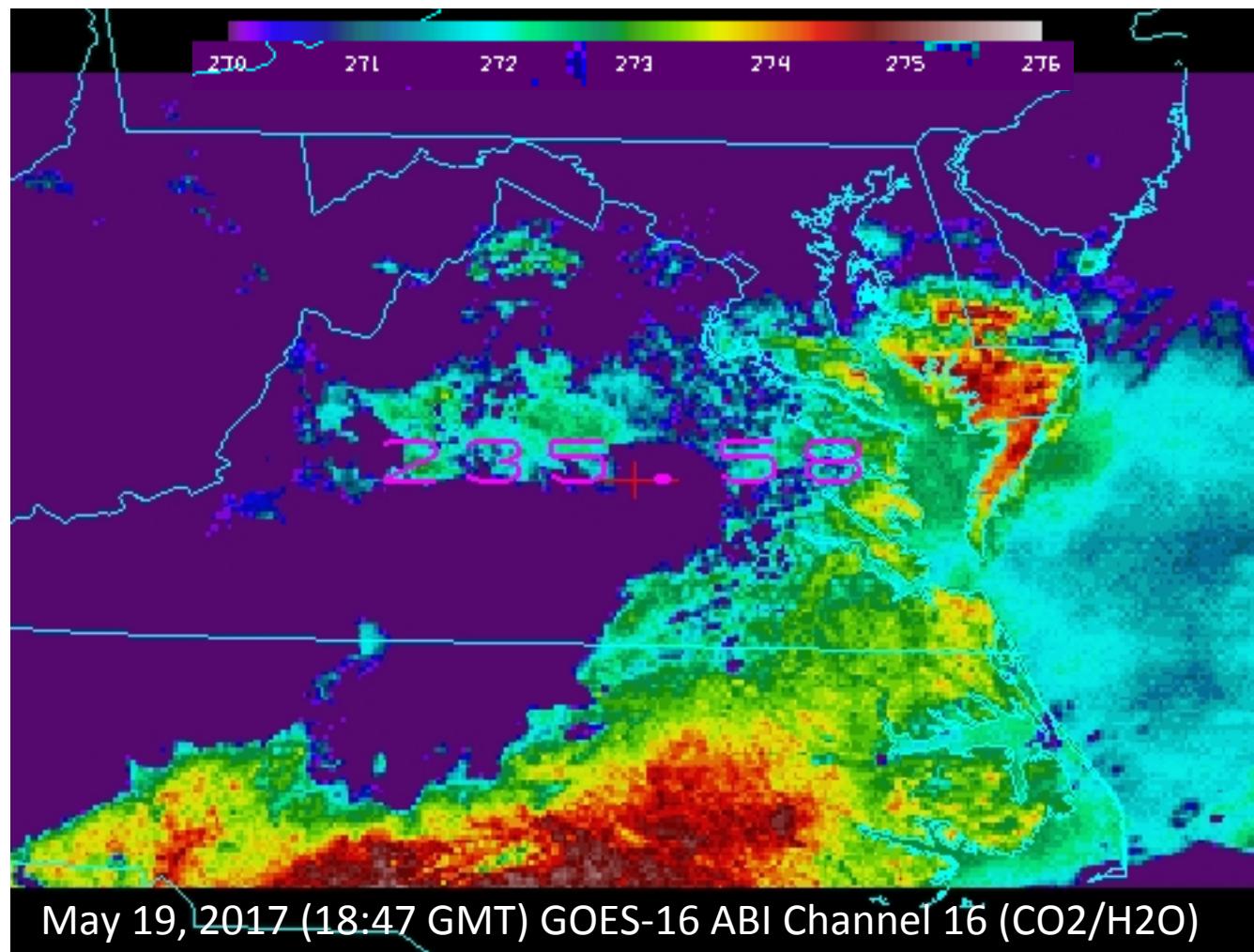








May 19, 2017 (18:32 GMT) GOES-16 ABI Channel 16 (CO₂/H₂O)



HU DBS Sounding Development

Improve Localized Severe Weather Warnings

- Real-time CrIS Sounding Products
- Real-time IASI Sounding Products & IASI/CrIS sounding and stability (1-3 hr) time derivatives
- GOES-16 ABI DR Retrieval Enactments
 - 15-km horizontal resolution to 2-km ABI res.
 - 1 to 10-hr time resolution to 15 min ABI res.
- Weather Research Forecast (WRF) Model
 - 2-km resolution
 - Assimilate 15-min interval DBS soundings