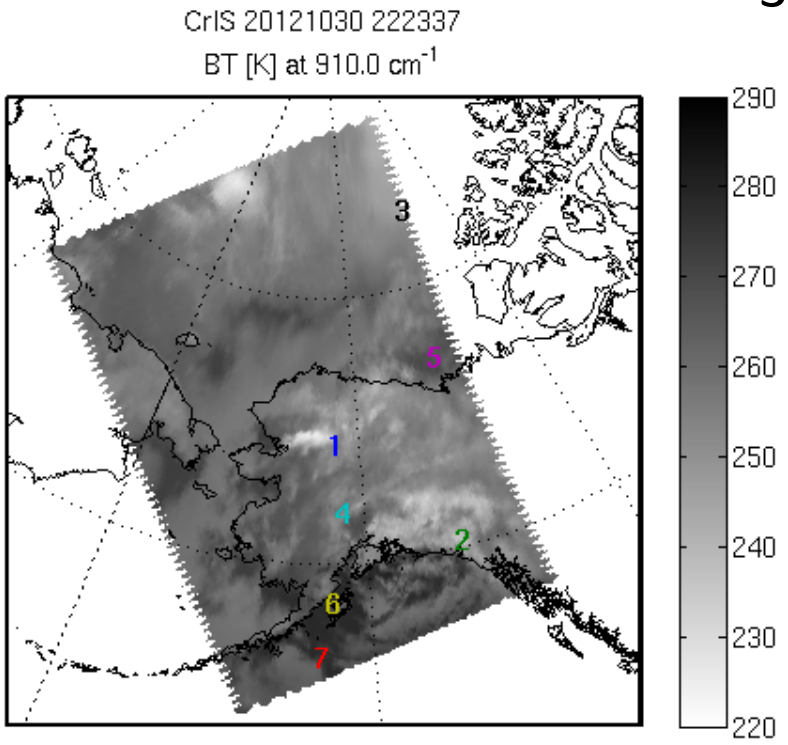
A Fresh Look at Hyperspectral Sounders:

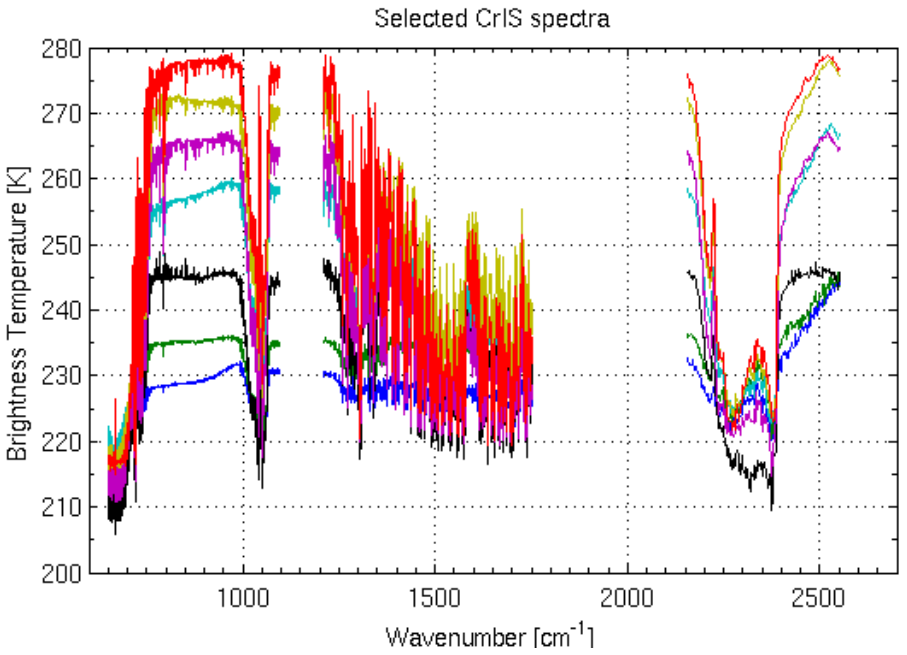
How 3-D Quantitative Information about the Atmosphere can Enhance Real-Time Applications and Decision Making

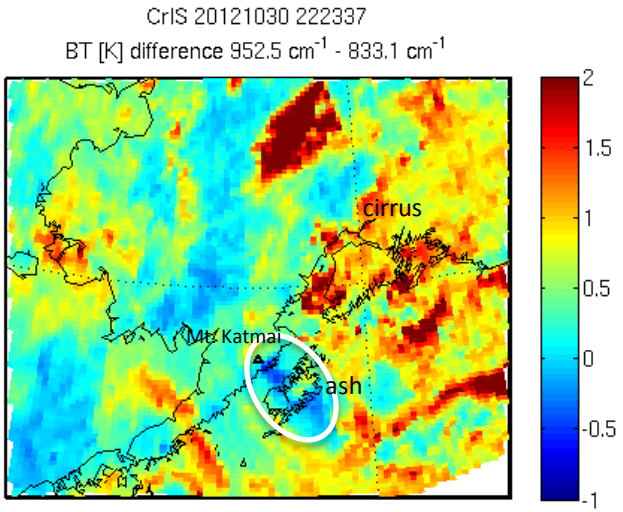
Nadia Smith, Elisabeth Weisz, William L. Smith Sr.

Space Science and Engineering Center, UW-Madison

30 Oct 2012







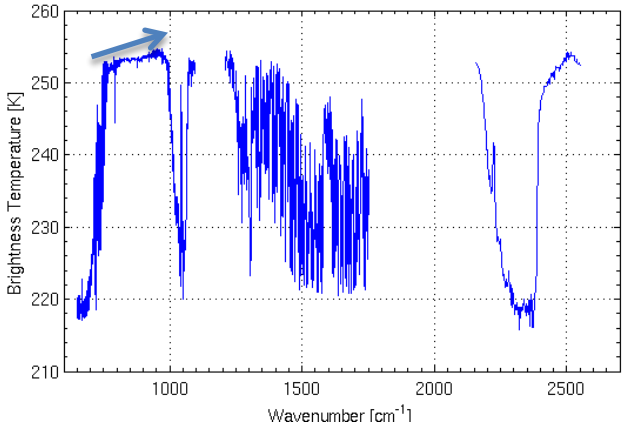
High-spectral resolution IR spectra contain signatures of

→ *Surface properties (type, temperature, emissivity, inversion…)*
→ *Temperature and humidity profiles*
→ *Cloud properties (altitude, temperature, optical thickness, ice/liquid content…)*
→ *Trace gases (O_3,CO,N_2O,CH_4 …)*
→ *Dust and volcanic ash (see image on the left)*

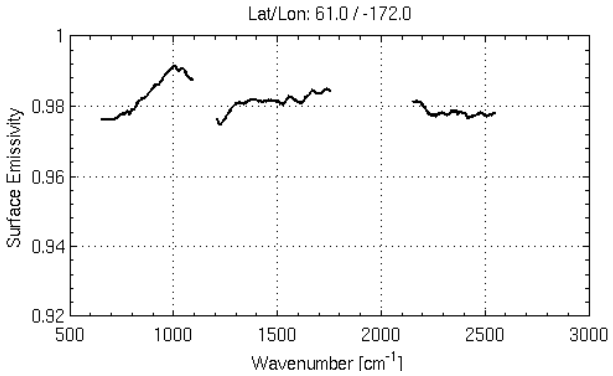
28 Jan 2013

CrIS FOV 86/40

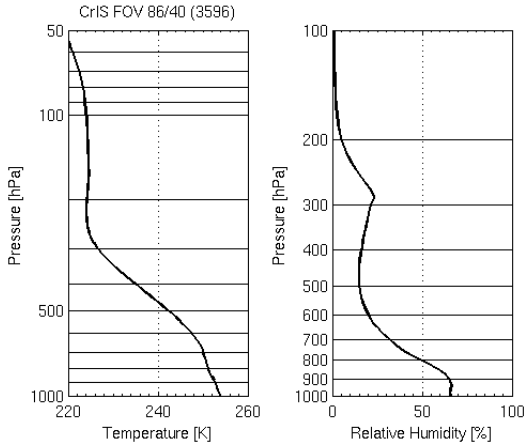
Brightness Temperature

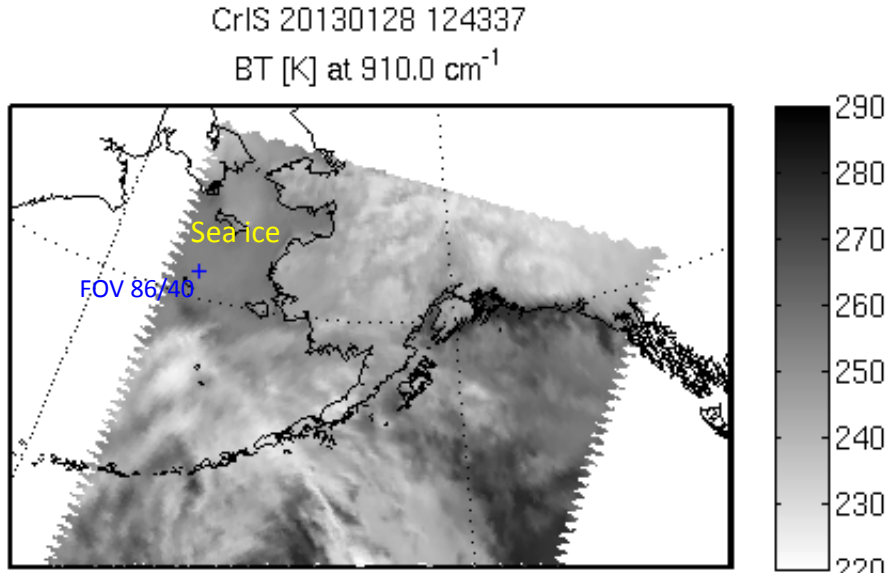


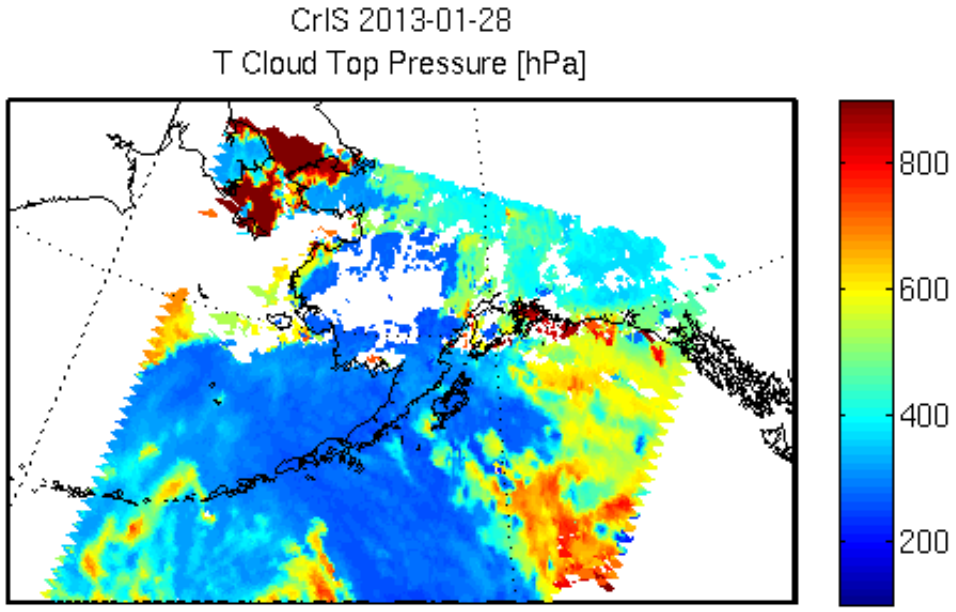
Surface Emissivity Retrieval



T and RH Profile Retrieval







UW Ultra-Spectral Retrieval Software Package

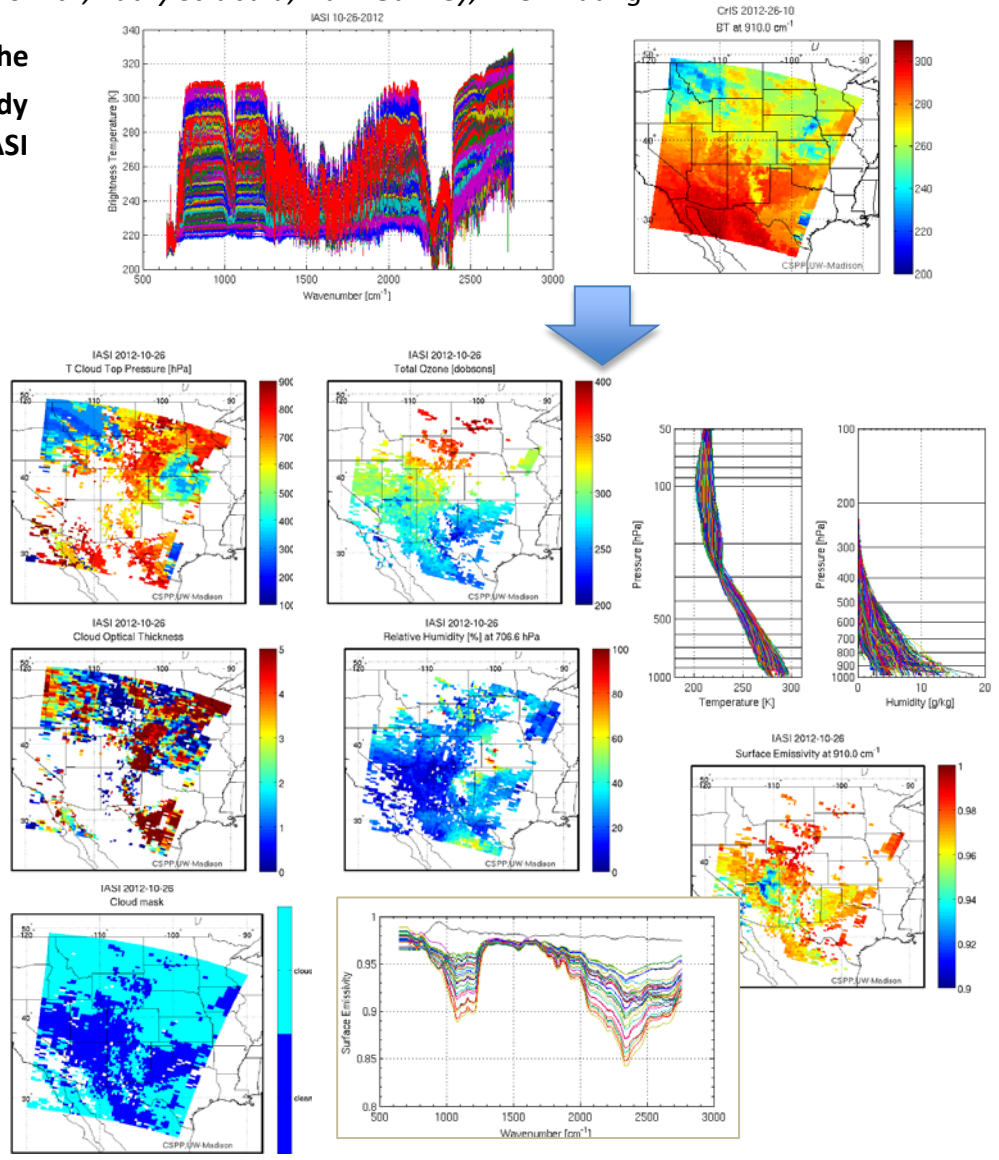
for AIRS, IASI and CrIS L1 to L2 processing

V1.0 Released under CSPP (Community Software Satellite Package) November 2012

Elisabeth Weisz, William L. Smith Sr., Nadia Smith, Kathy Strabala, Liam Gumley, Allen Huang

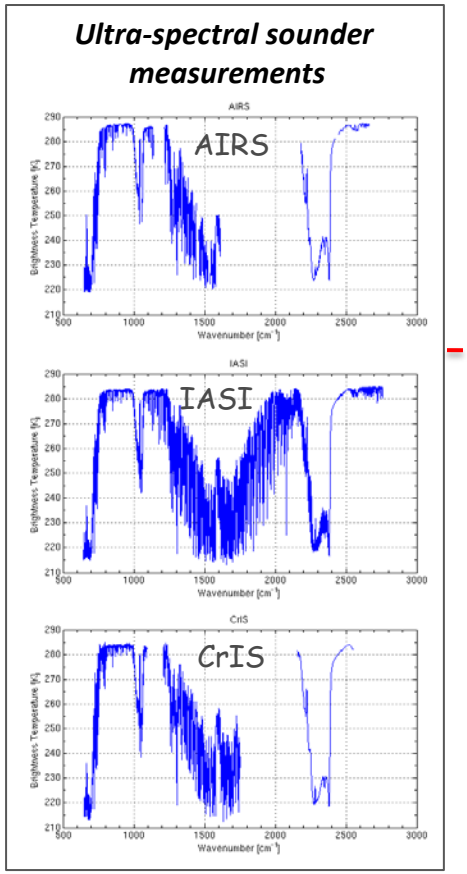
➔ **The dual-regression retrieval technique is used to retrieve the following single FOV products under clear and cloudy conditions from input direct broadcast or archived AIRS, IASI and CrIS L1 radiance files:**

- atmospheric temperature [K] at 101 pressure levels
- atmospheric moisture [g/kg] at 101 pressure levels
- atmospheric ozone [ppmv] at 101 pressure levels
- atmospheric relative humidity [%] at 101 pressure levels
- atmospheric dew point temperature [K] at 101 pressure levels
- surface skin temperature [K]
- surface emissivity (at full spectrum)
- total precipitable water [cm]
- precipitable water 1 (900 hPa to surface) [cm]
- precipitable water 2 (700 to 900 hPa) [cm]
- precipitable water 3 (300 to 700 hPa) [cm]
- total ozone amount (vertically integrated) [dobson units]
- lifted index [^{o}C]
- convective available potential energy [J/kg]
- CO2 concentration [ppmv]
- cloud top pressure [hPa]
- cloud top temperature [K]
- cloud optical thickness
- effective cloud emissivity
- cloud mask (values: 0 clear, 1 cloud)



Available at http://cimss.ssec.wisc.edu/cspp/

Direct Broadcast "Dual-Regression" Retrieval Algorithm Overview



Global clear soundings

Radiances (clear FM)

Clear-trained regression coefficients

Global cloudy soundings

Radiances (cloudy FM)
Cloud height classes

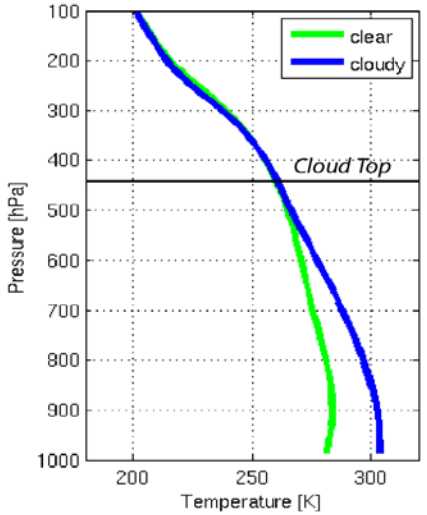
Cloud-trained regression coefficients

Theoretical Statistics

Radiance Observations

Clear-trained EOF regression retrieval

Cloud-trained EOF regression retrieval



Cloud Top Altitude
Level where $T_{cloudy} > T_{clear}$ for $p > p_{cld}$

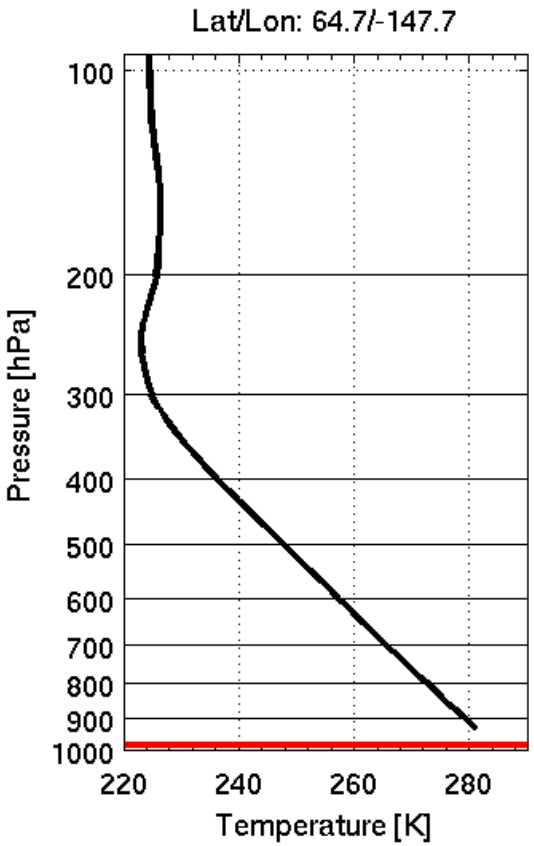
Final Profile
from cloudy and/or clear retrievals

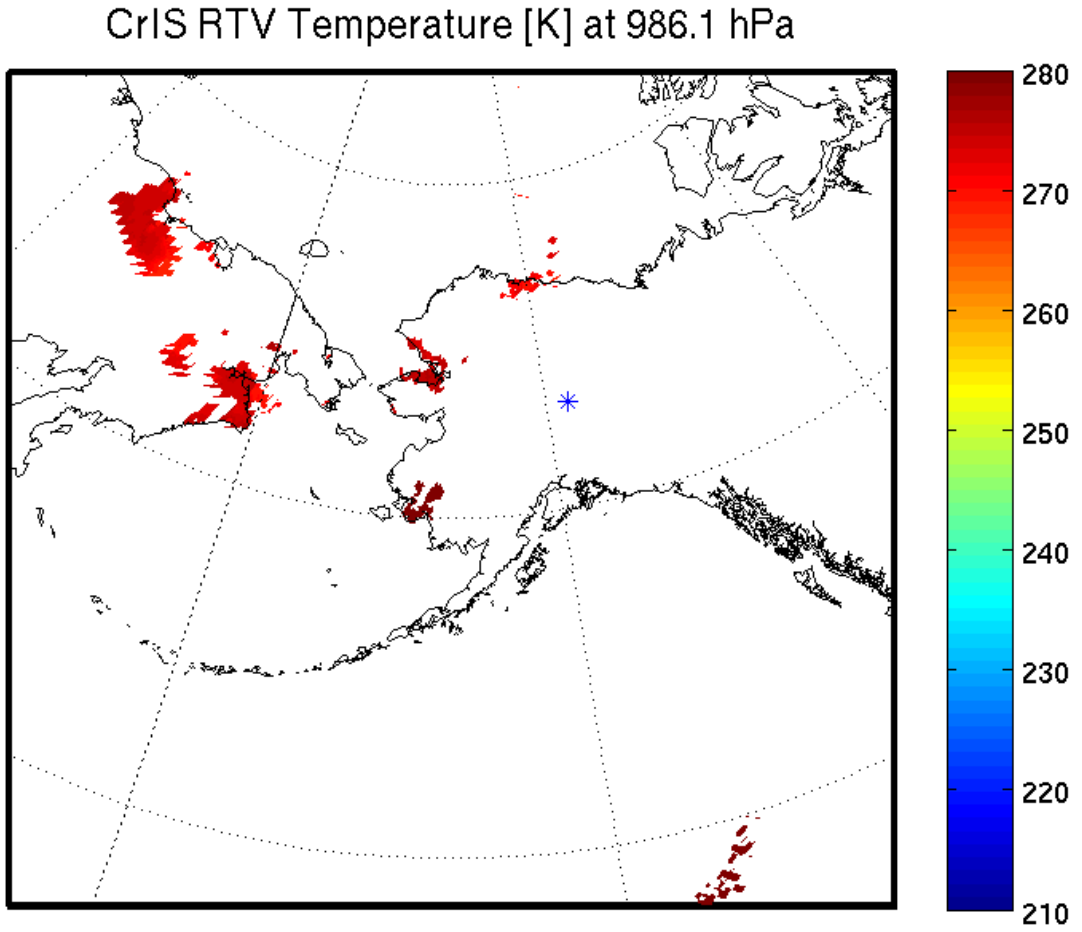
0.02s / FOV

Temperature, Humidity and Ozone profiles, Surface and Cloud parameter at single FOV (15-km) resolution

- 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.
- Weisz, E., W. L. Smith, N. Smith (2013), Advances in simultaneous atmospheric profile and cloud parameter regression based retrieval from high-spectral resolution radiance measurements, Submitted to *JGR-Atmospheres*.

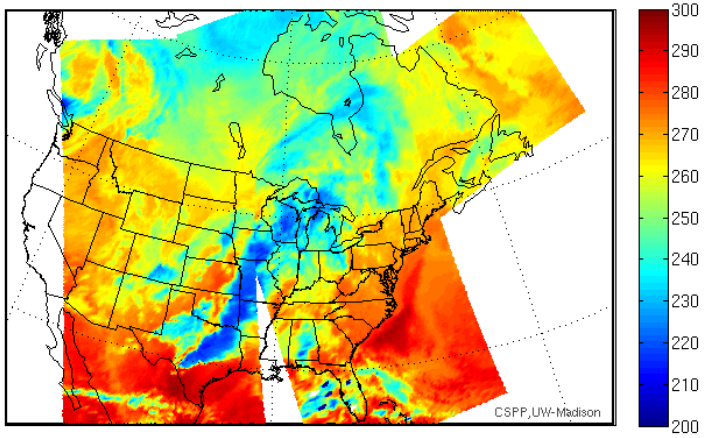
A look at the vertical nature of sounder retrievals



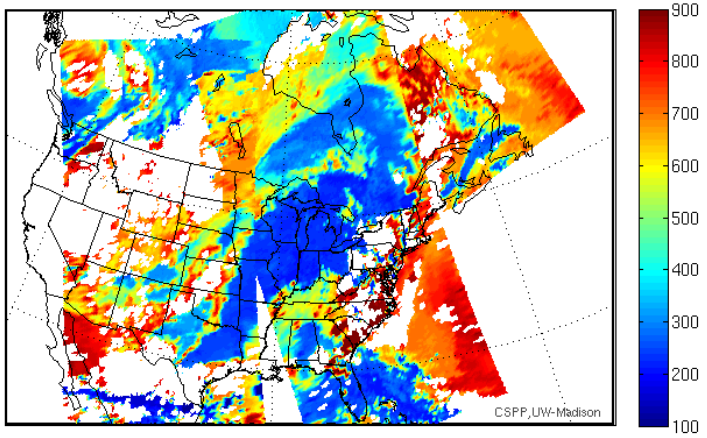


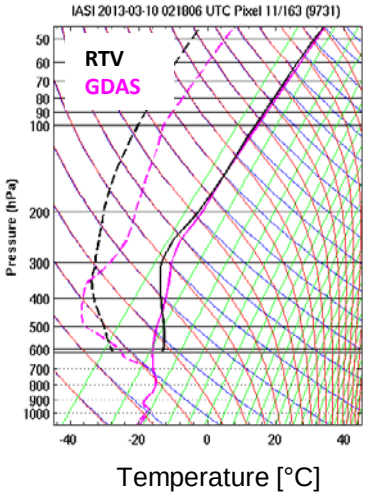
CrIS and IASI

Metop-B IASI Brightness Temperature [K] at 910 cm^{-1}
00:43, 02:18, 03:59 UTC

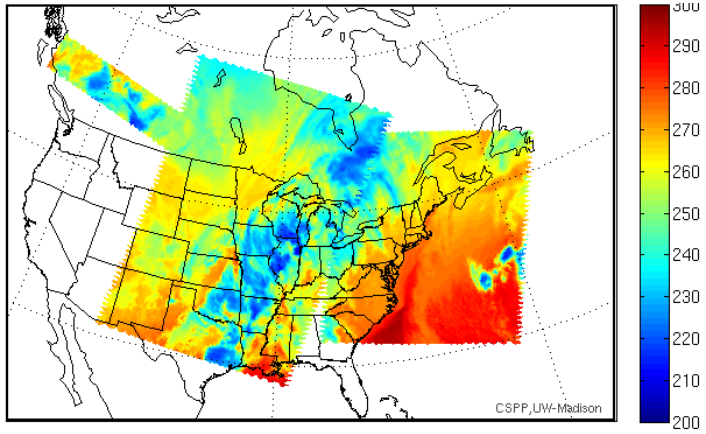


Metop-B IASI Cloud Top Pressure [hPa]
00:43, 02:18, 03:59 UTC

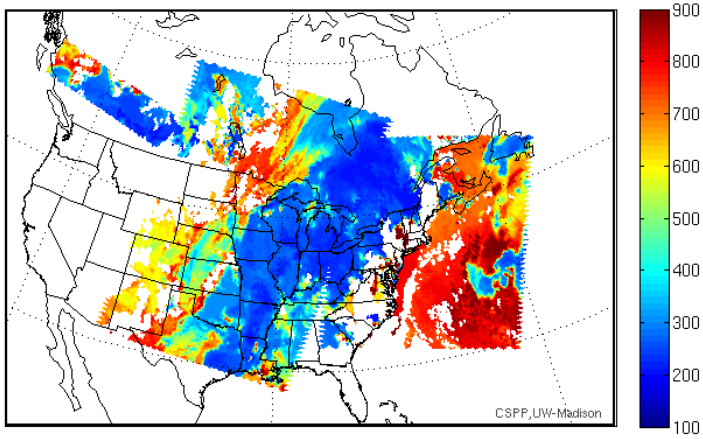


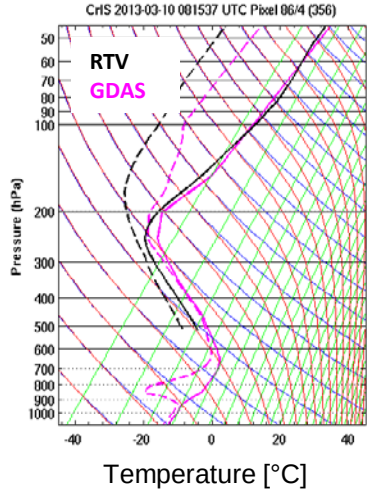


CrIS Brightness Temperature [K] at 910 cm^{-1}
06:34, 08:14, 09:56 UTC



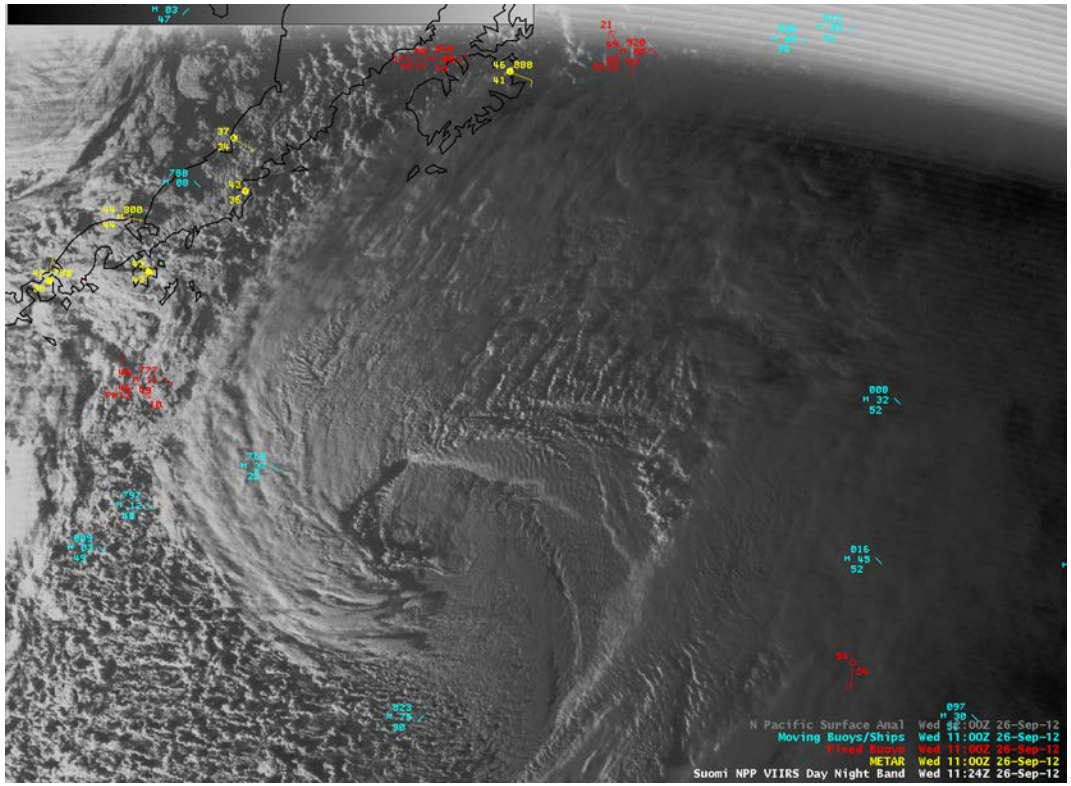
CrIS Cloud Top Pressure [hPa]
06:34, 08:14, 09:56 UTC

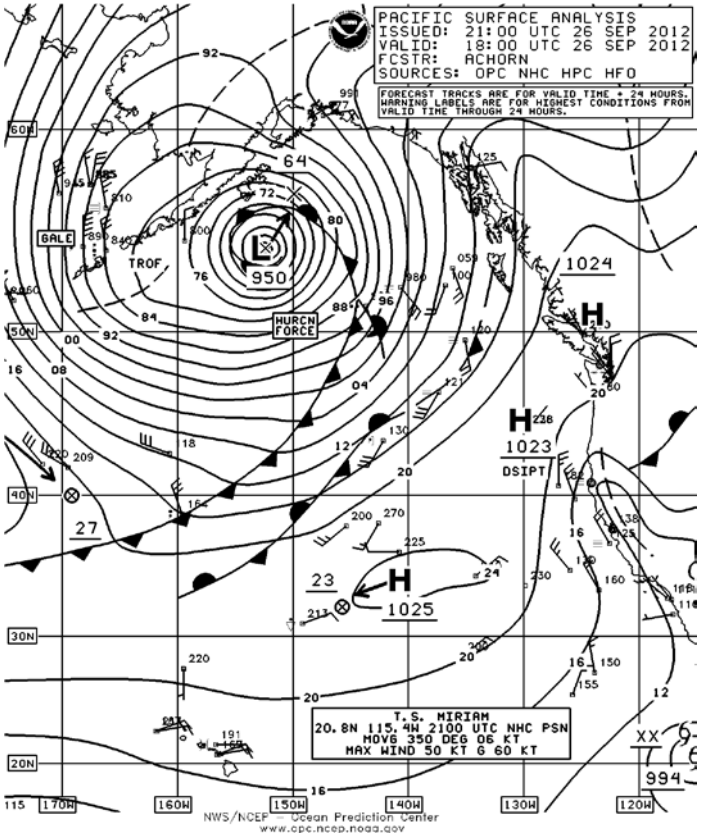




VIIRS Day/Night band

Suomi NPP VIIRS 0.7 μm Day/Night Band and 11.45 μm IR channel

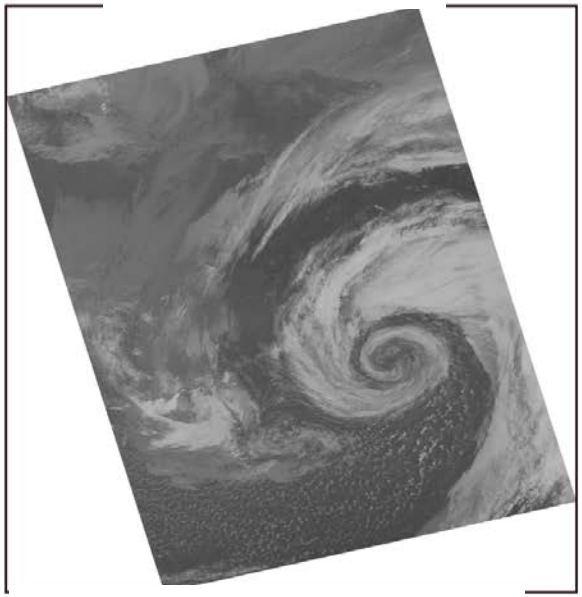




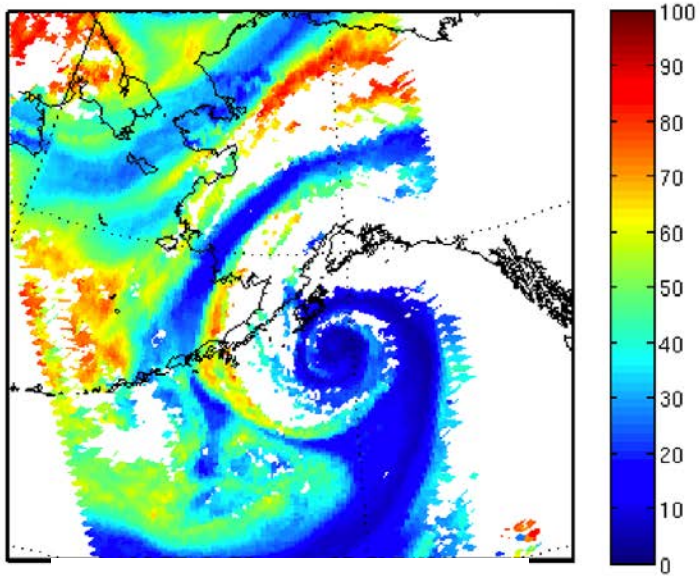
From: http://cimss.ssec.wisc.edu/goes/blog/archives/date/2012/09/26

Low Pressure System Gulf of Alaska (26 Sep 2012)

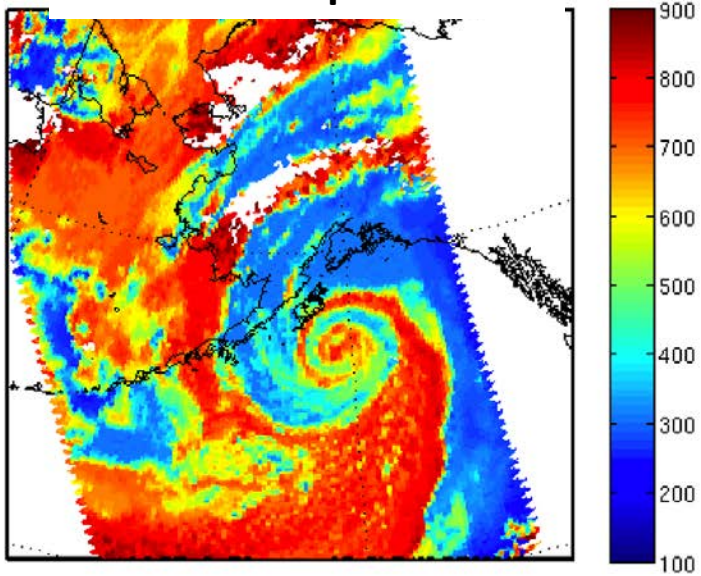
VIIRS 11.45 um



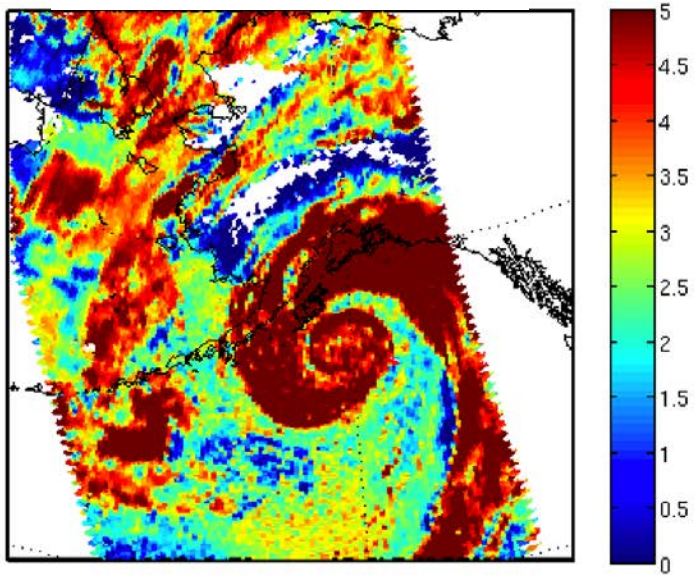
CrIS Relative Humidity



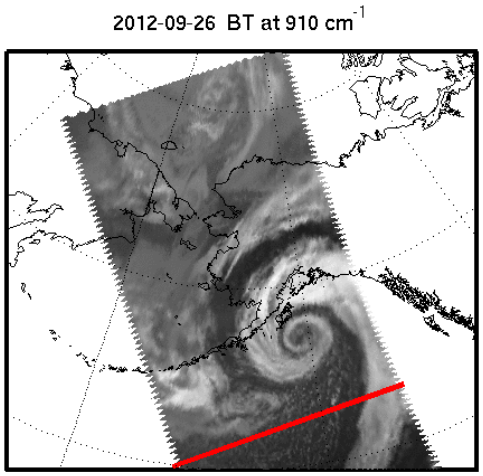
CrIS Cloud Top Pressure



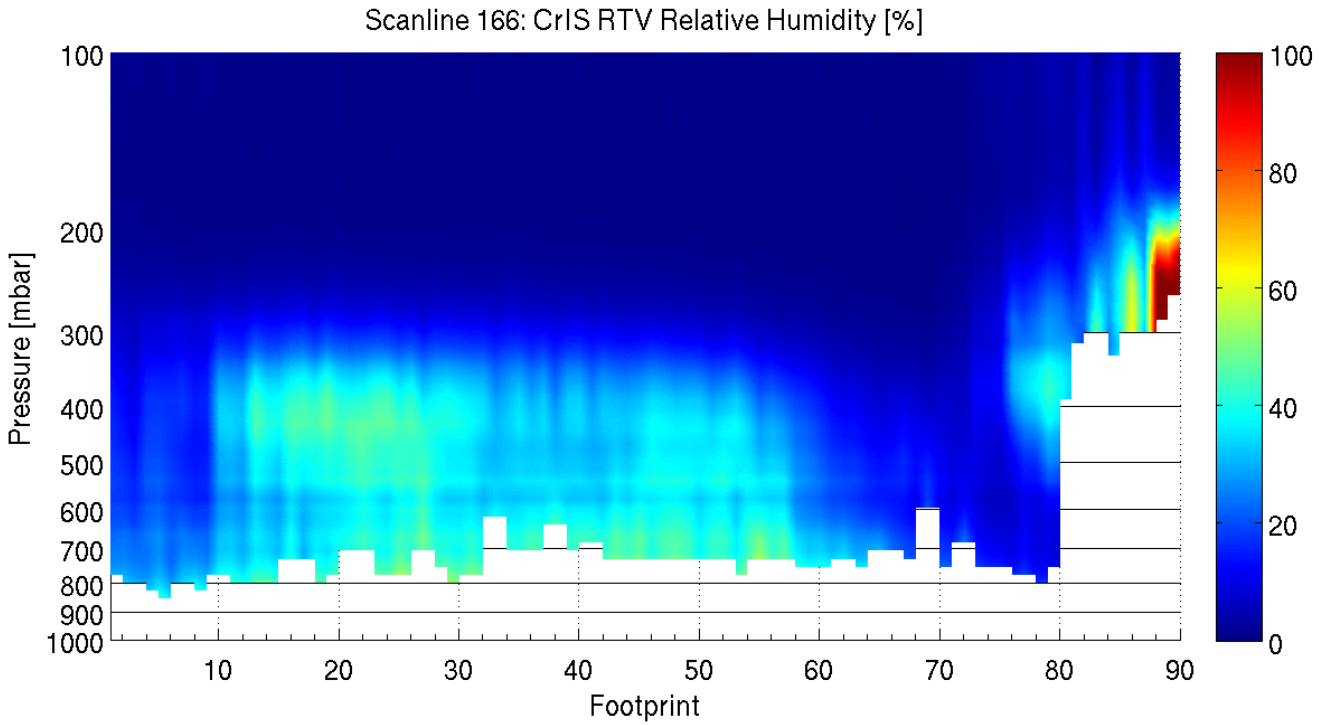
CrIS Optical Thickness



Transect of vertical information through granule

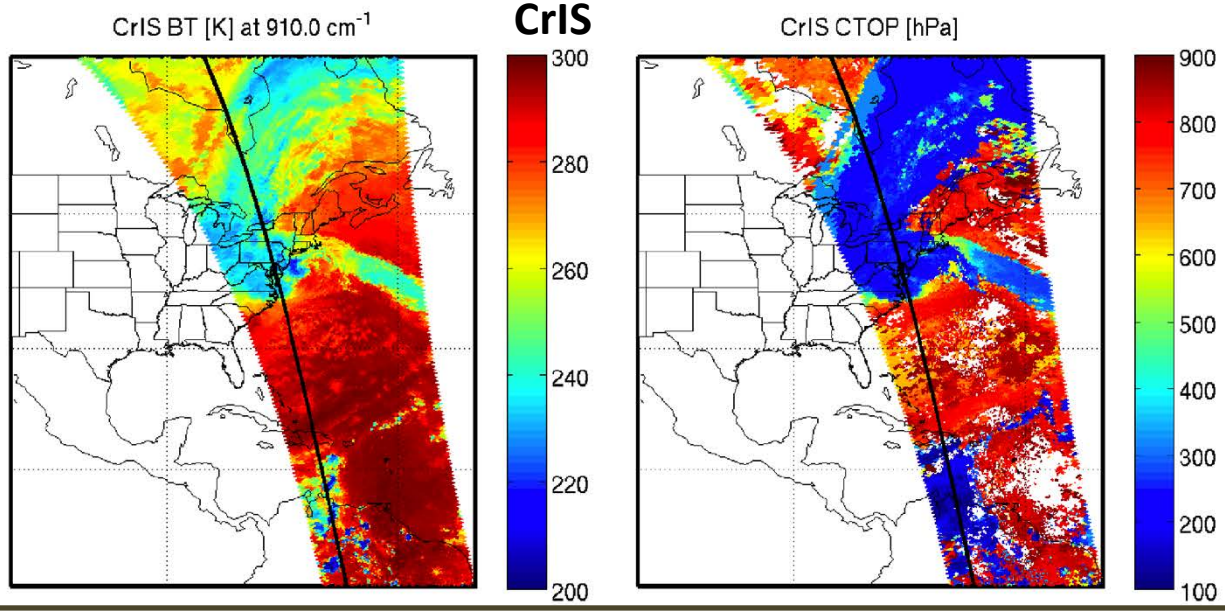


CrIS Relative Humidity

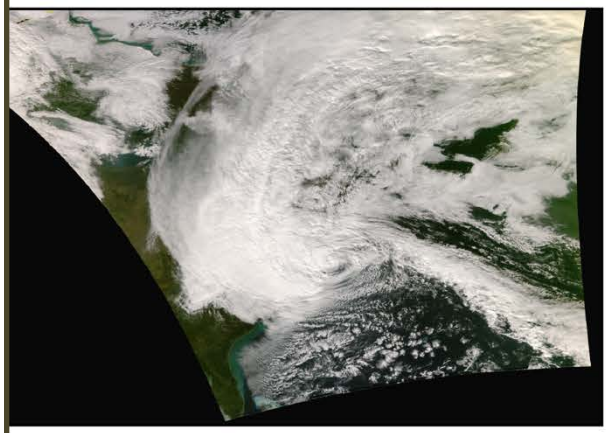


Severe Weather Support: Hurricane Sandy (29 Oct 2012)

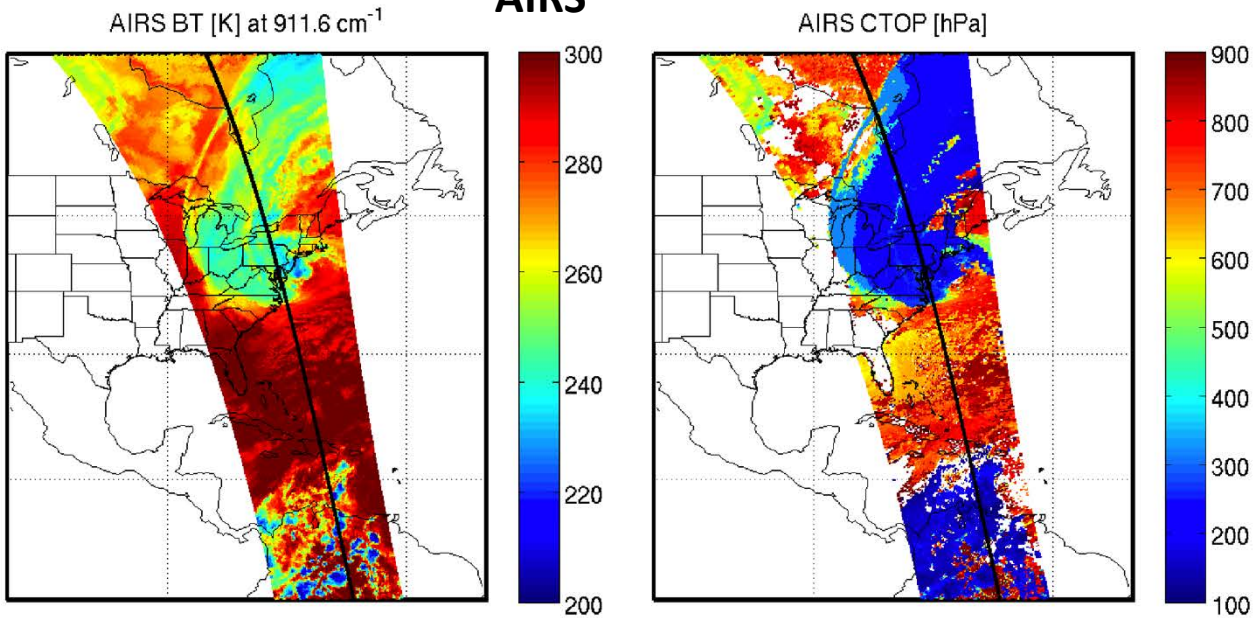
CrIS



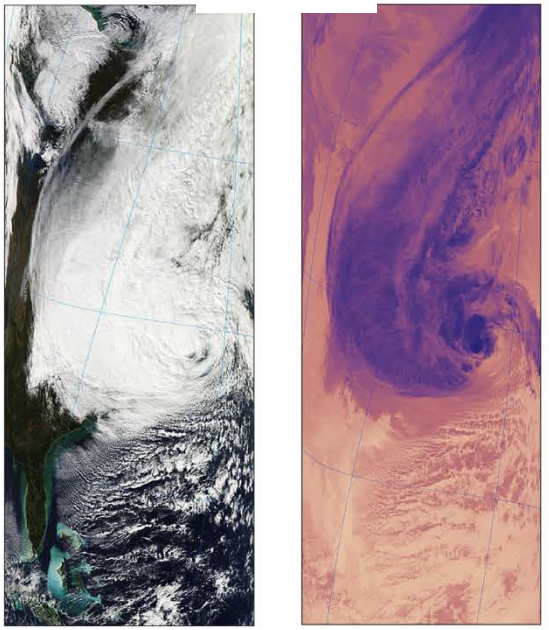
VIIRS



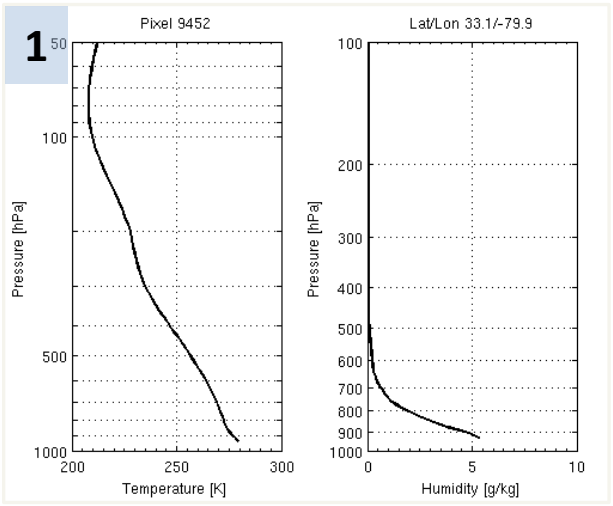
AIRS

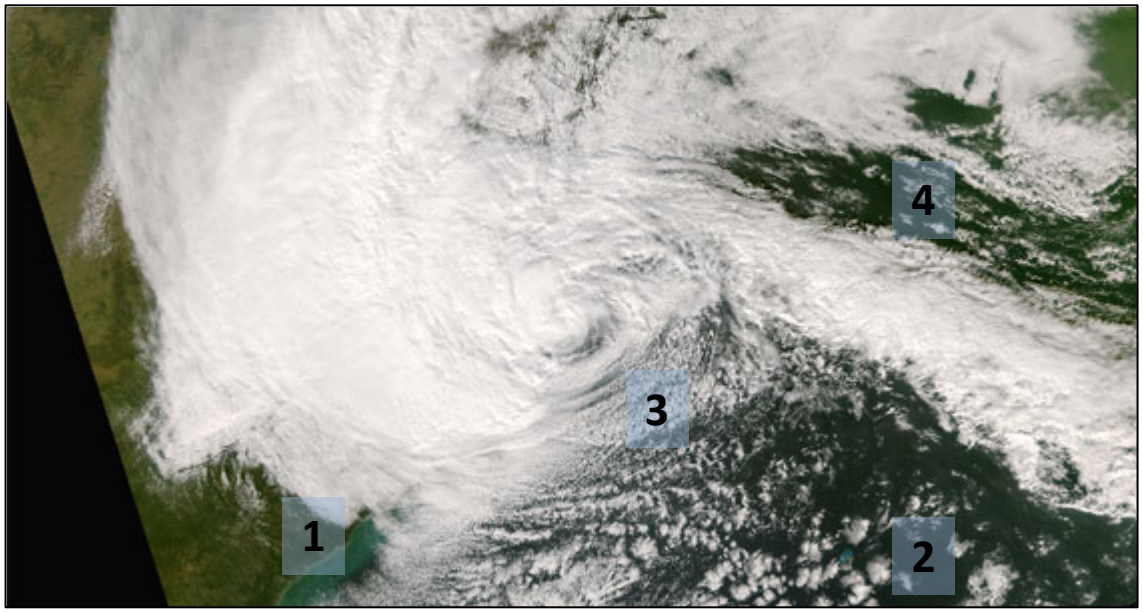


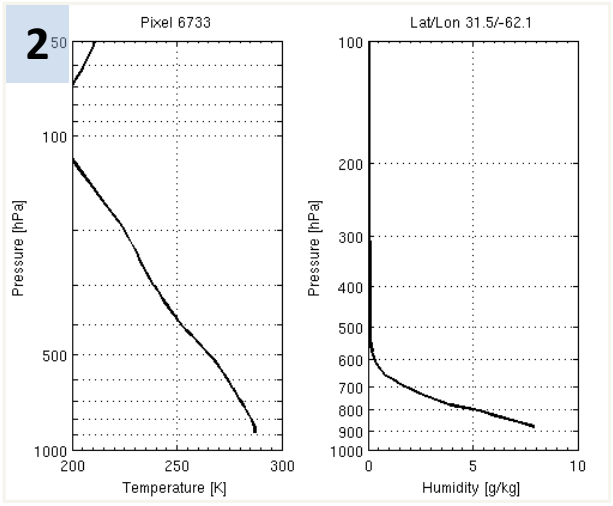
MODIS

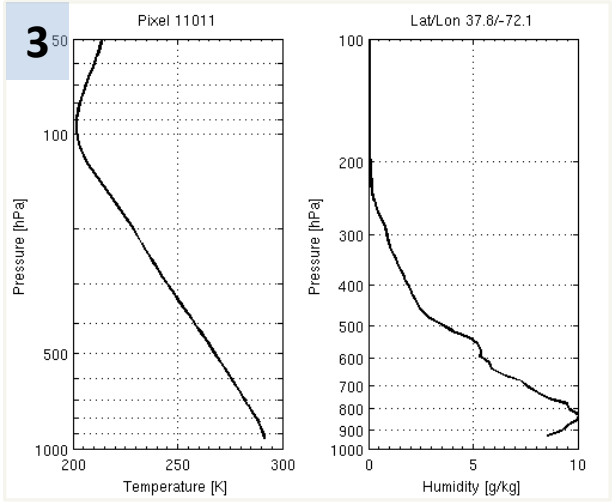


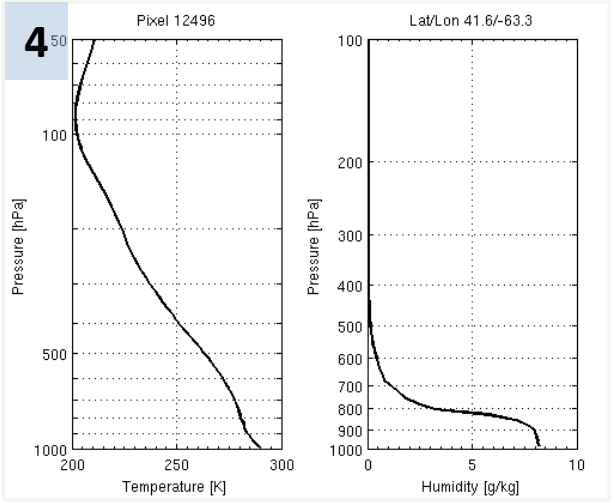
Severe Weather Support: Hurricane Sandy (29 Oct 2012)



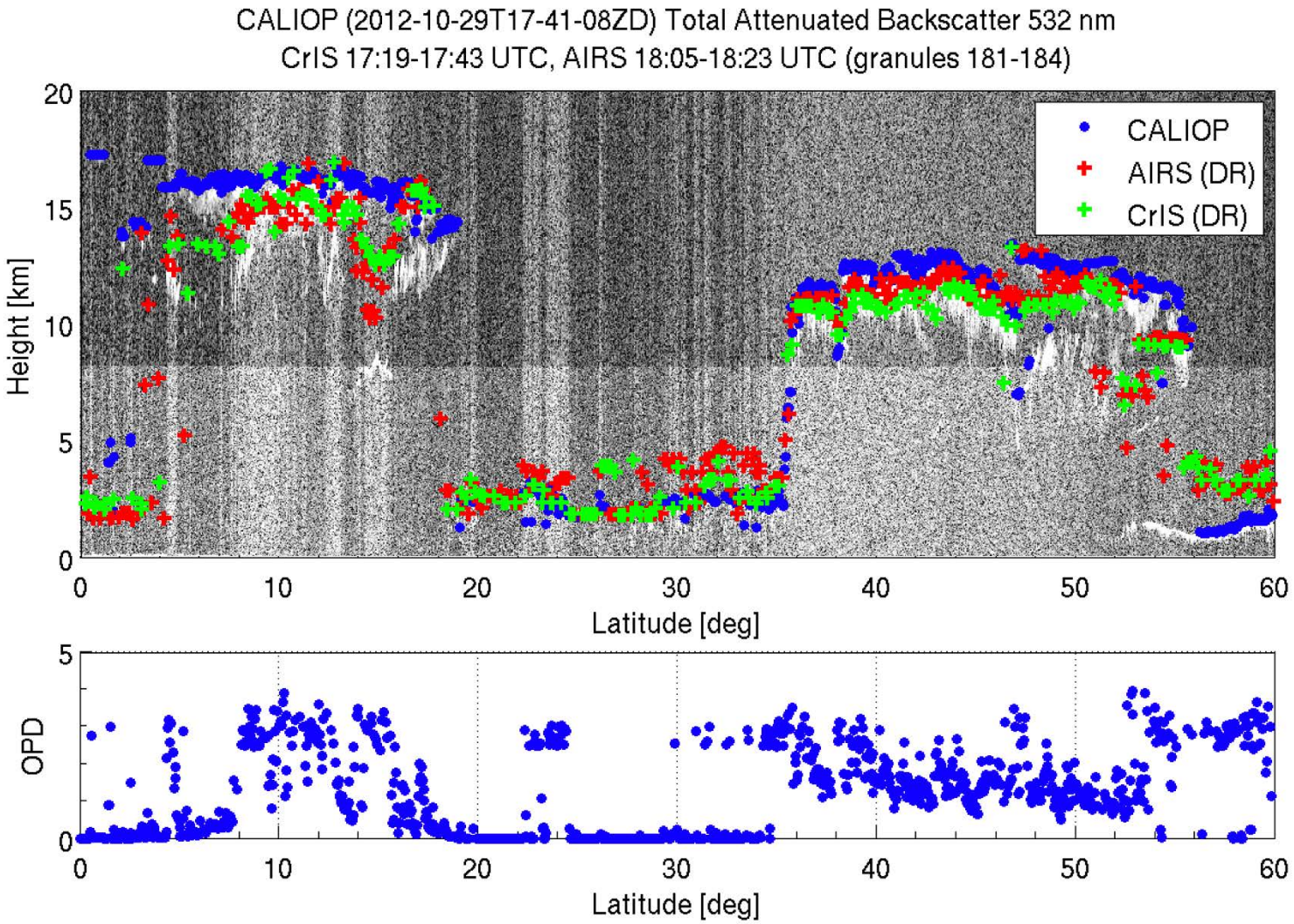






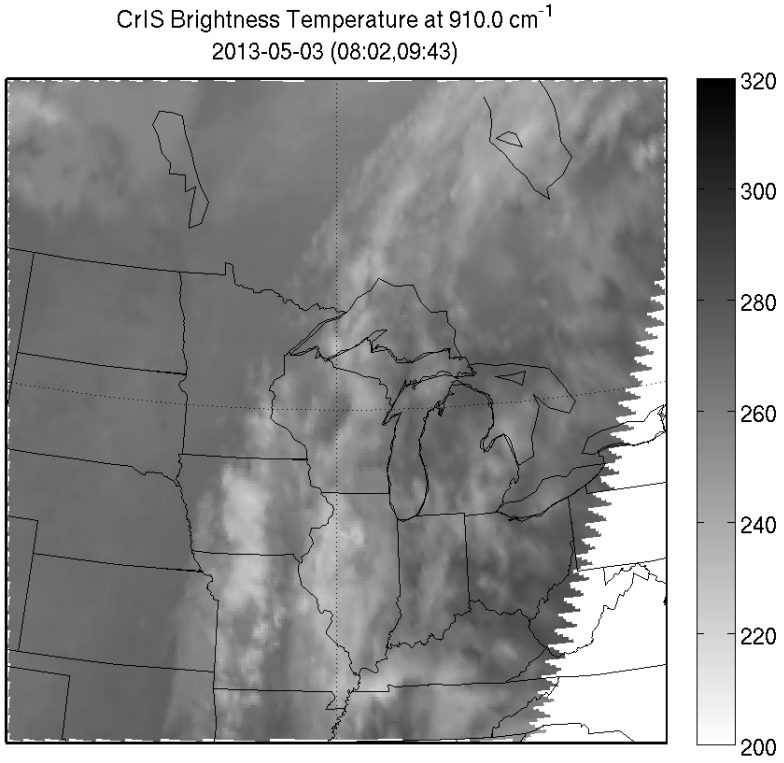


Severe Weather Support: Hurricane Sandy (29 Oct 2012)

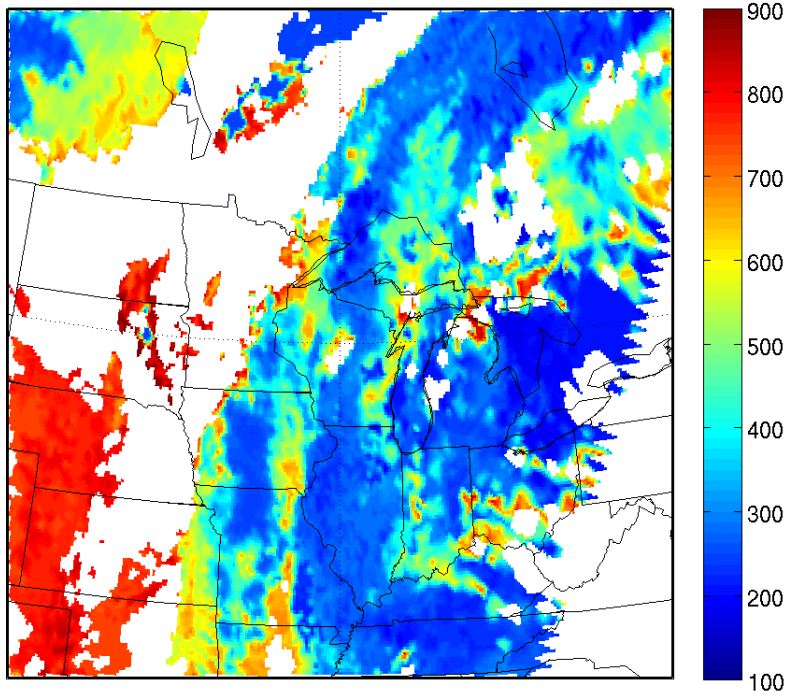


Time-series of Direct Broadcast Sounder Data and Retrievals (3–16 May 2013)

CrIS Brightness Temperature



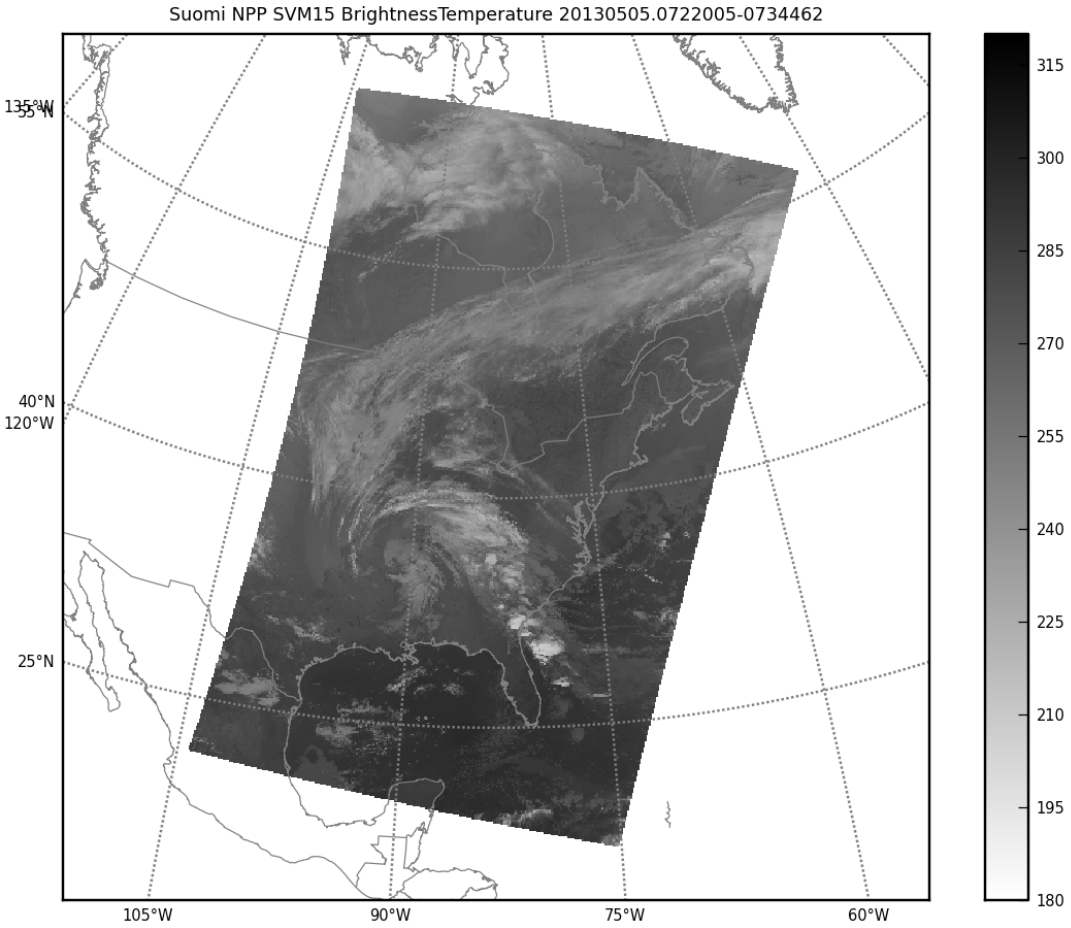
CrIS Cloud Top Pressure



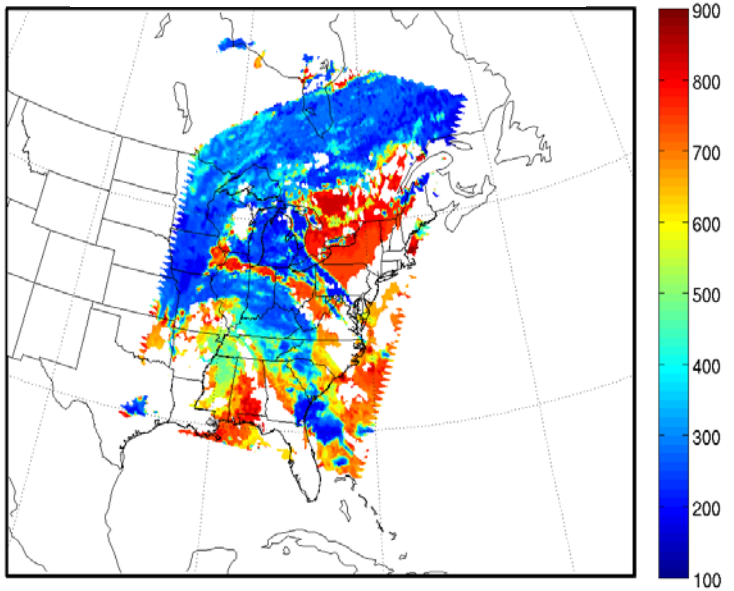
Imager–Sounder pairing

05 May 2013, 07:22 UTC

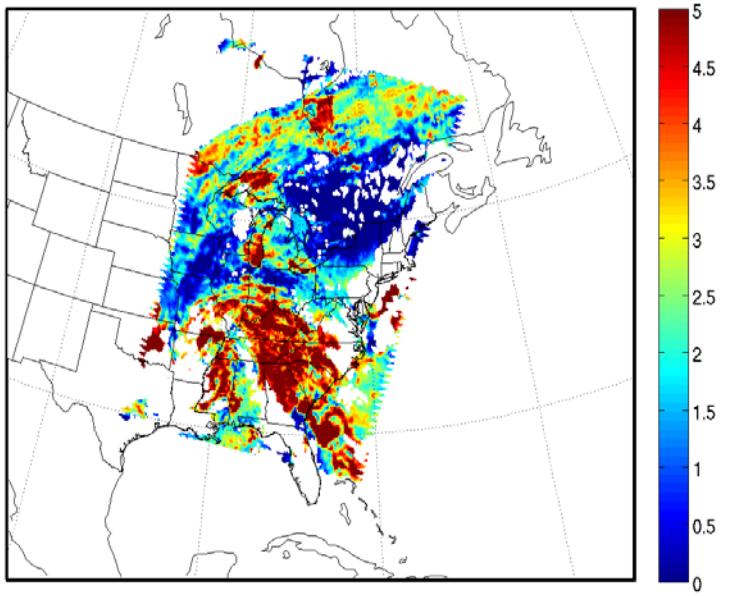
VIIRS M-band 15



CrIS Cloud Top Pressure



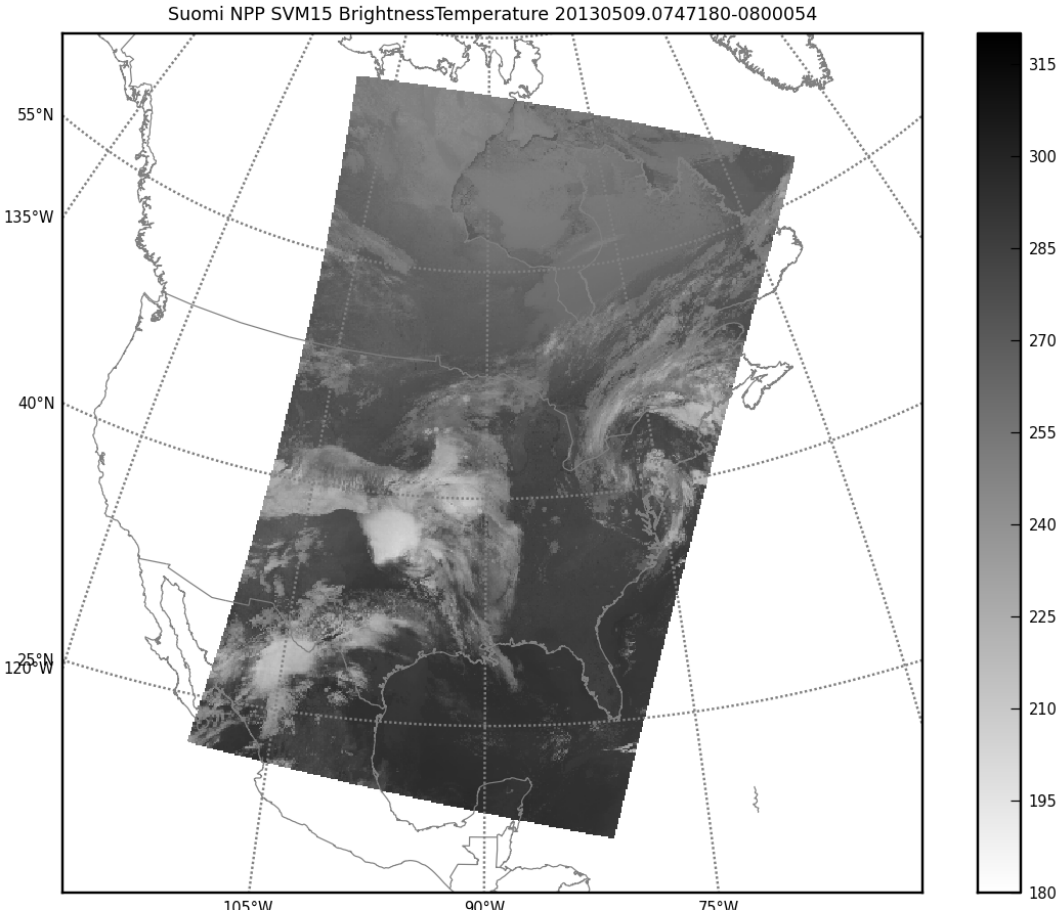
CrIS Cloud Optical Thickness



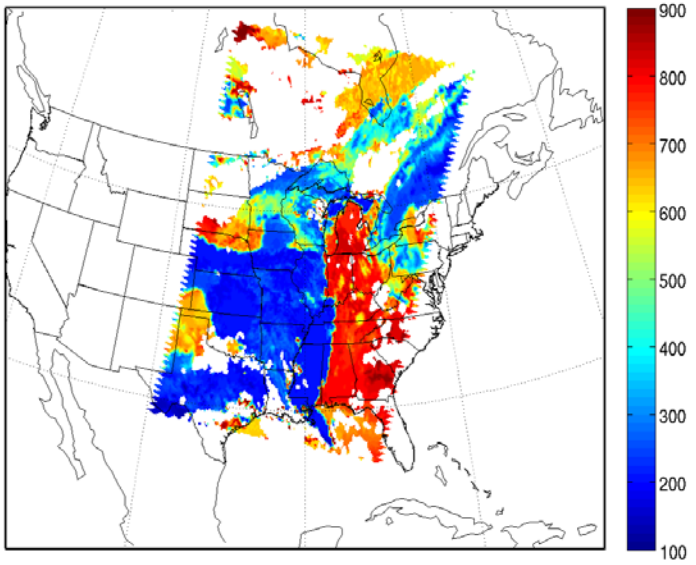
Imager–Sounder pairing

09 May 2013, 7:47 UTC

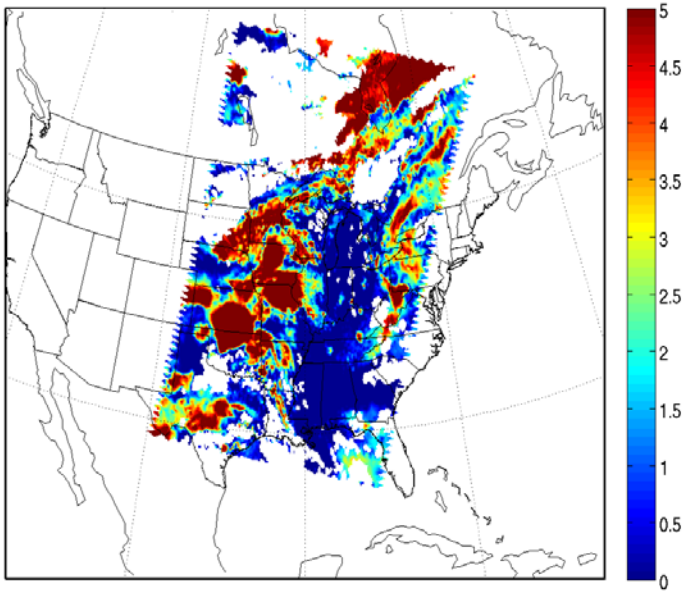
VIIRS M-band 15



CrIS Cloud Top Pressure



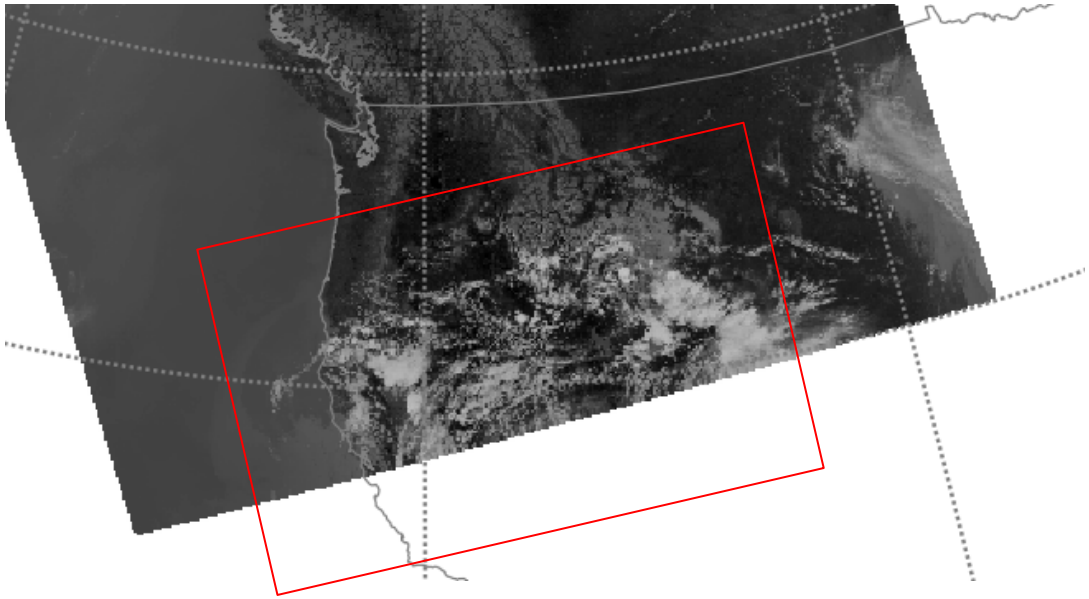
CrIS Cloud Optical Thickness



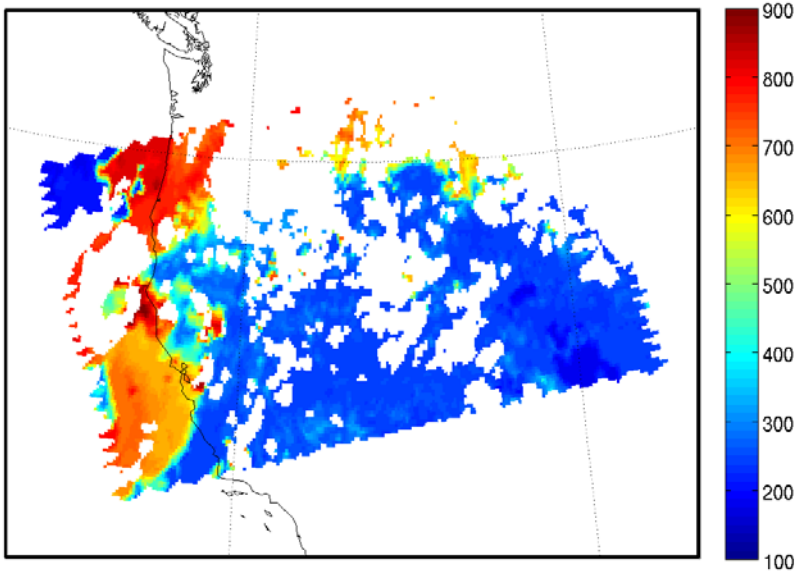
Imager–Sounder pairing

05 May 2013, 20:32 UTC

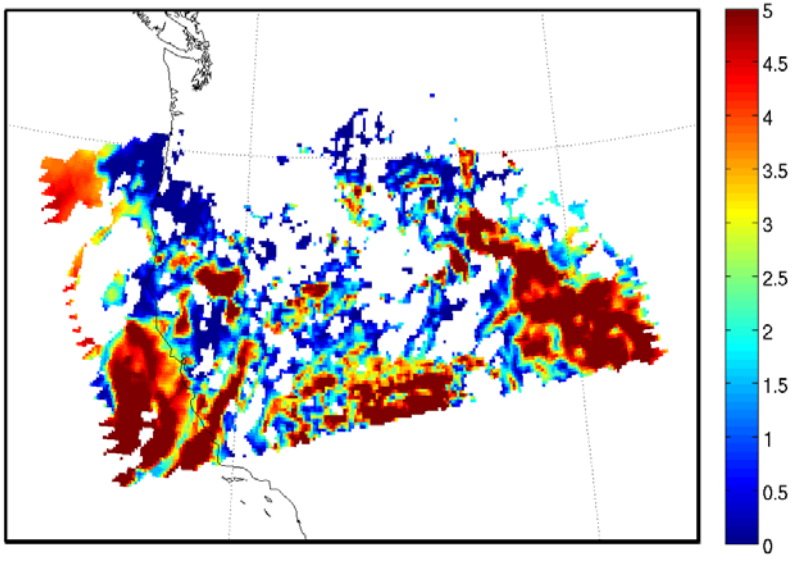
VIIRS M-band 15



CrIS Cloud Top Pressure

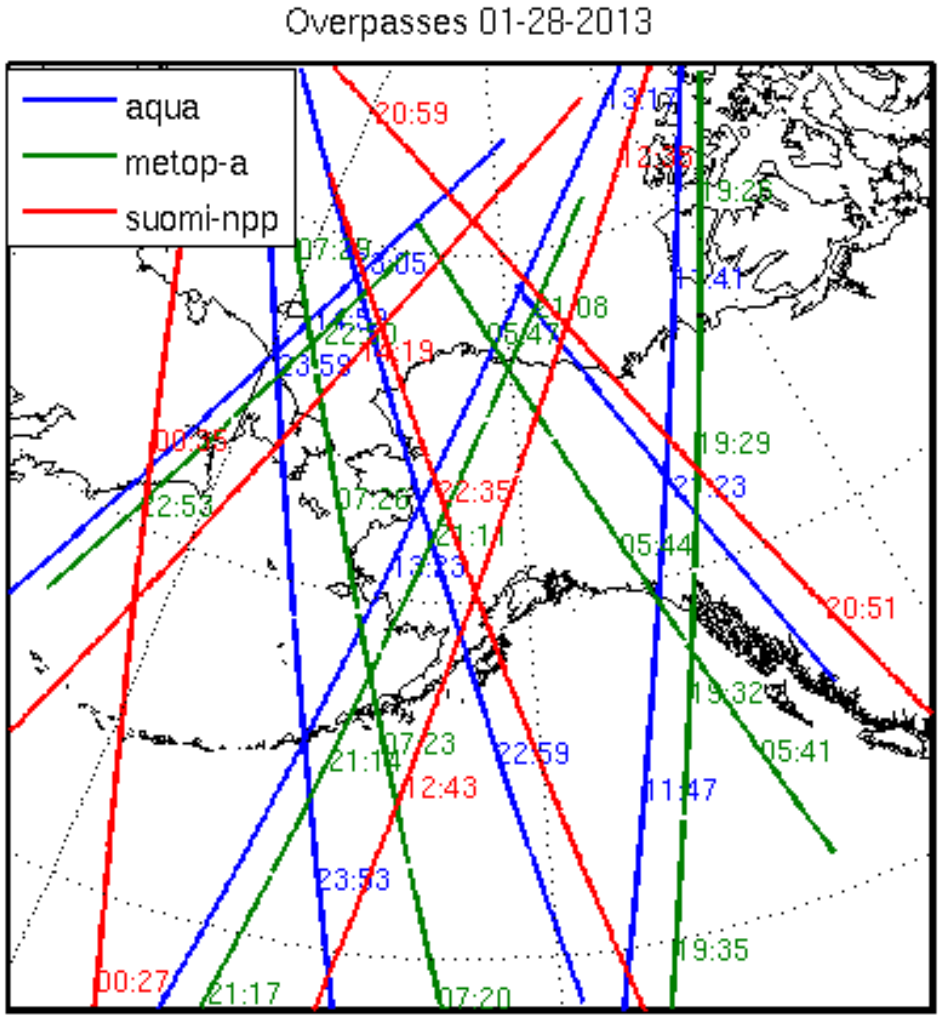


CrIS Cloud Optical Thickness

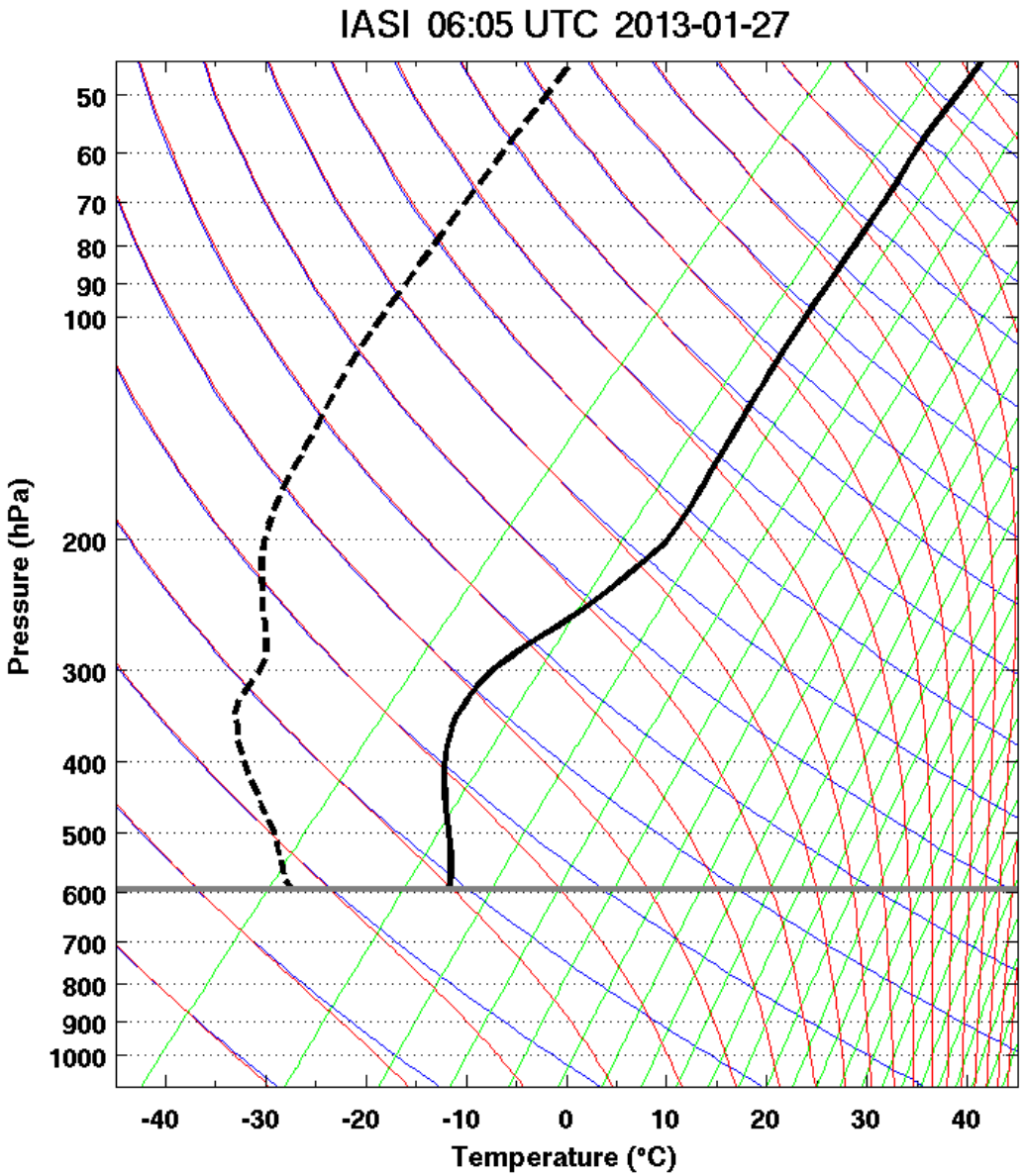


Making use of the high frequency of satellite overpasses at high latitudes

AQUA, Metop-A, SNPP passing over Alaska on 28 Jan 2013

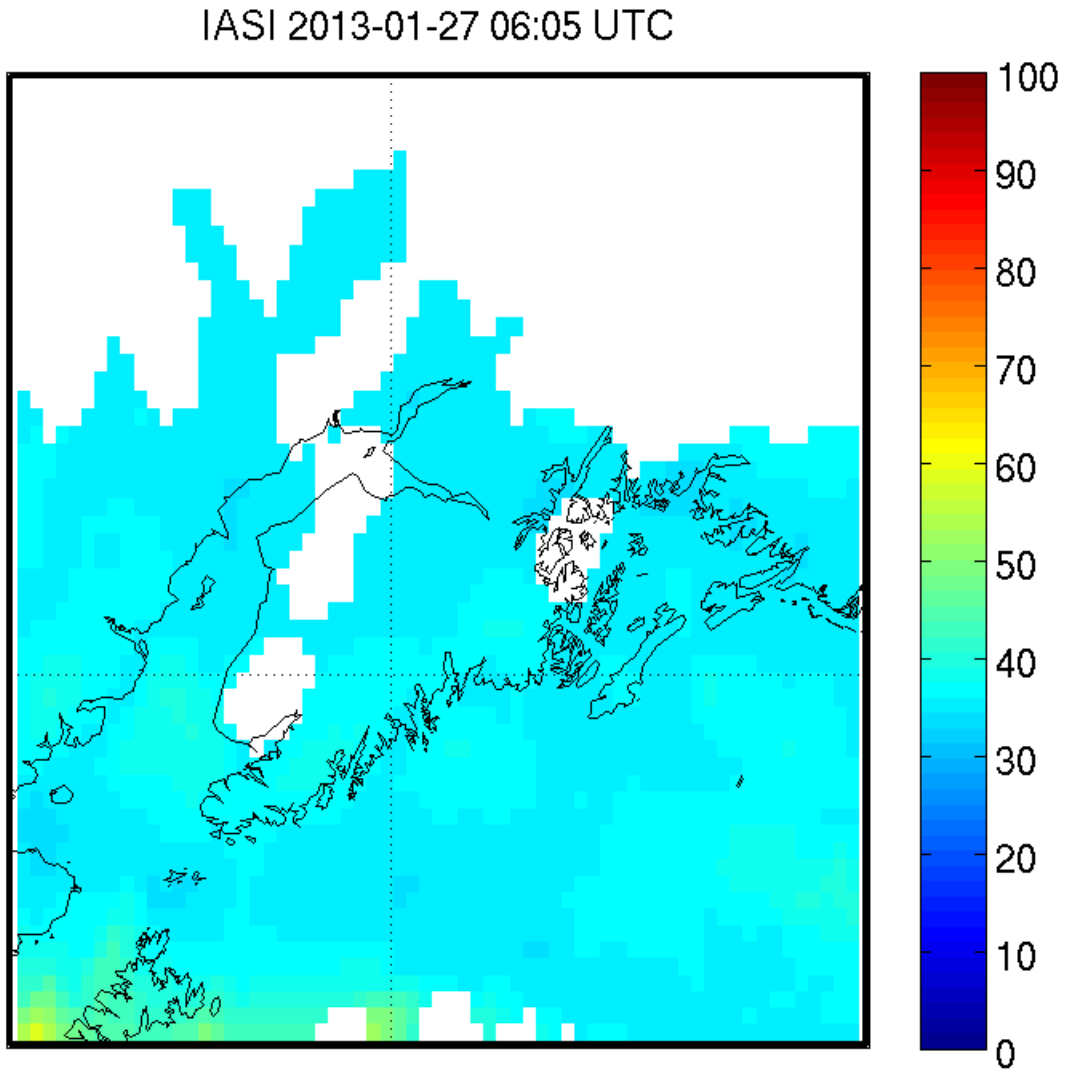


Skewplot of Temperature at Anchorage, AK
27-29 Jan 2013

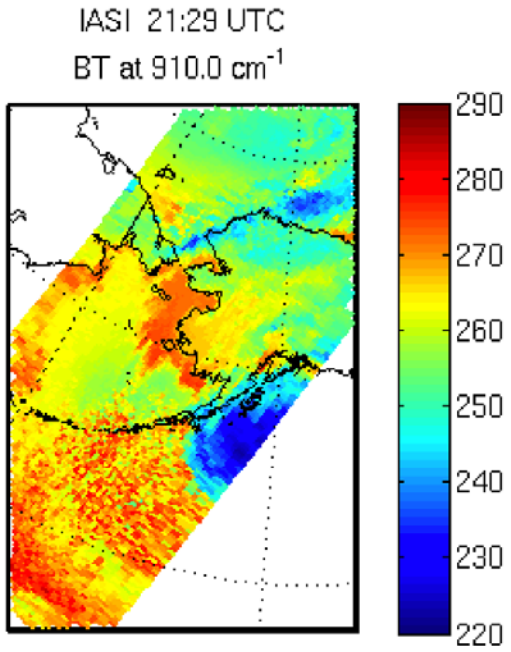


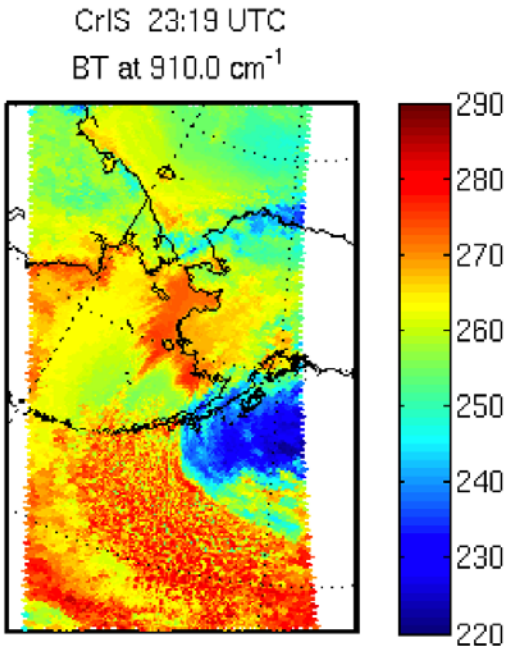
Relative Humidity [%] at 300 hPa (27 - 29 Jan 2013)

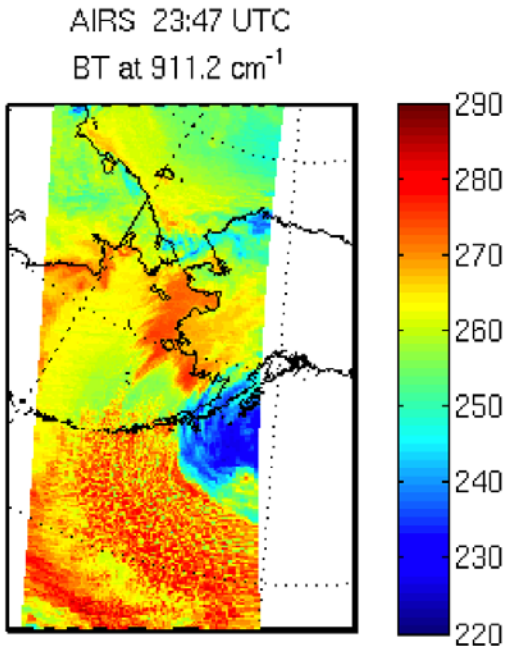
Time-series of three instruments: AIRS + CrIS + IASI

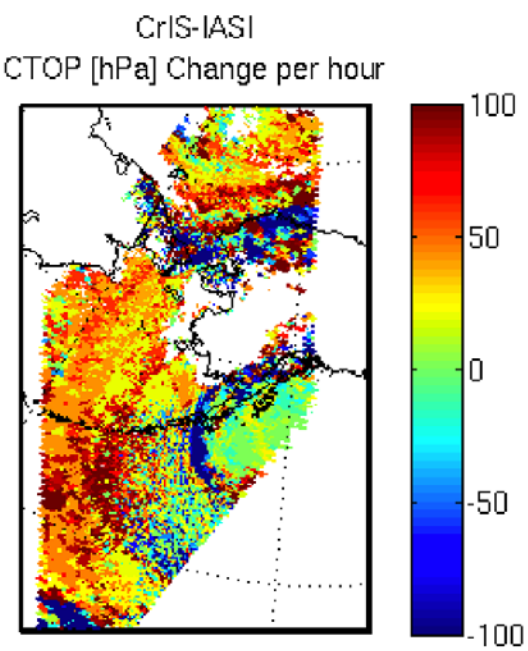


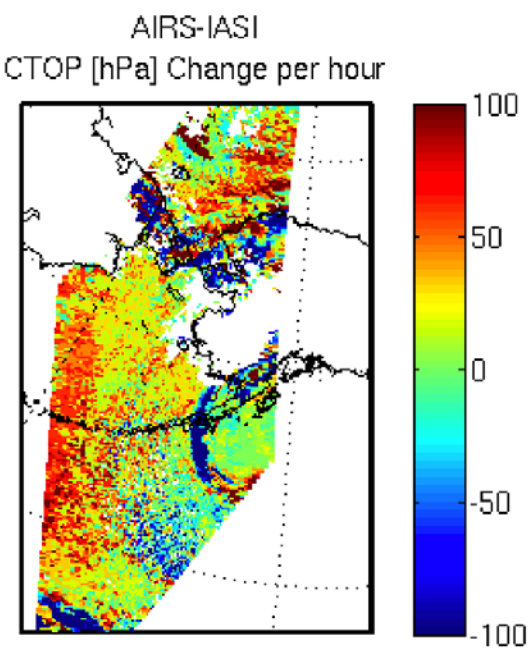
Time Tendencies (CTOP change per hour) Examples

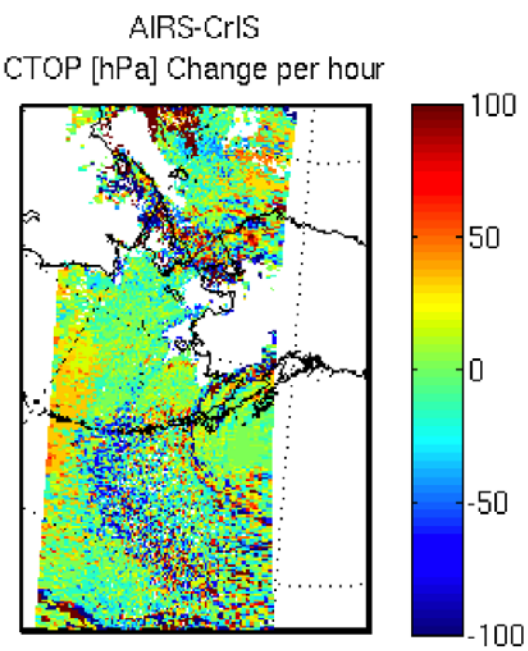




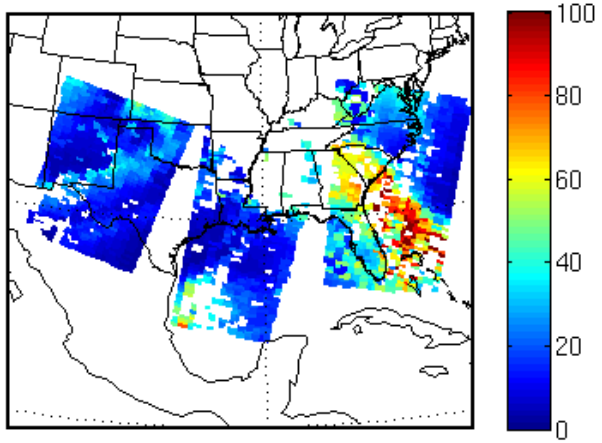


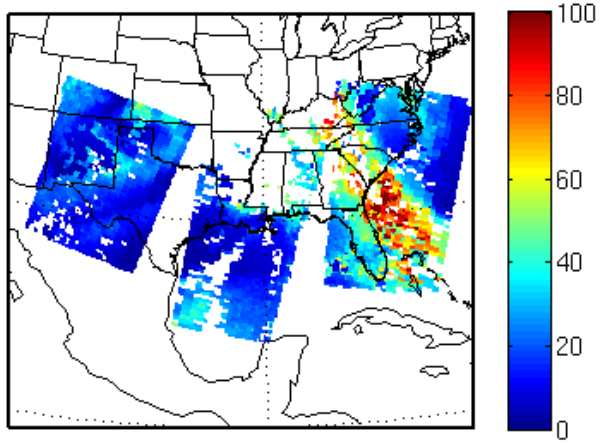




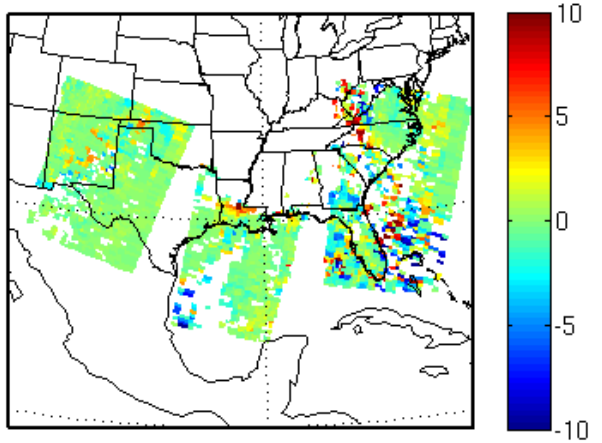


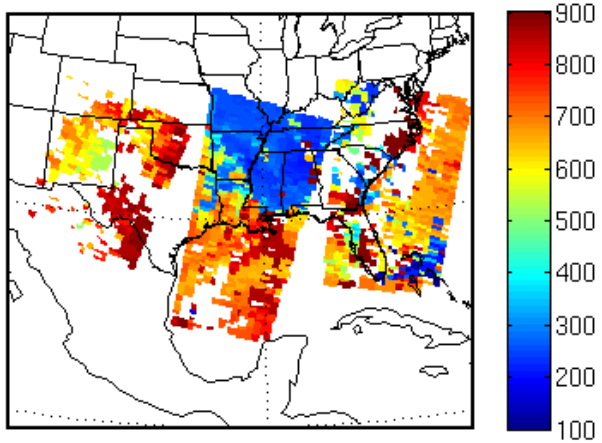
IASI Metop-A/Metop-B Time Tendencies (10 March 2013)

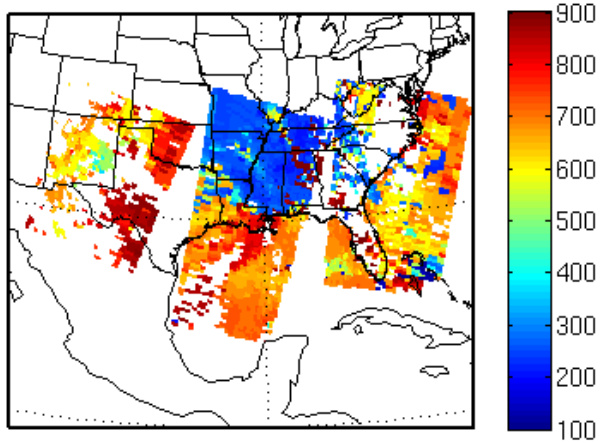


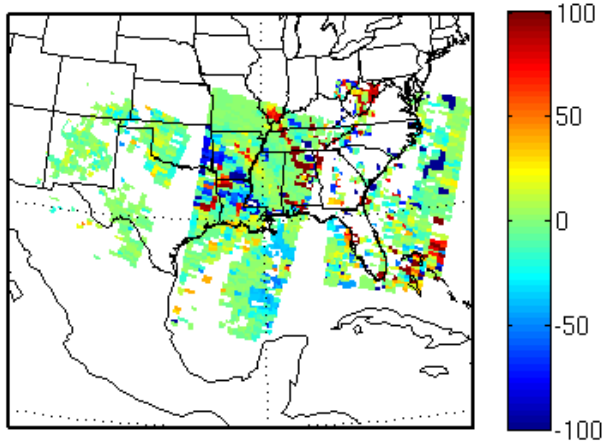


Change per hour



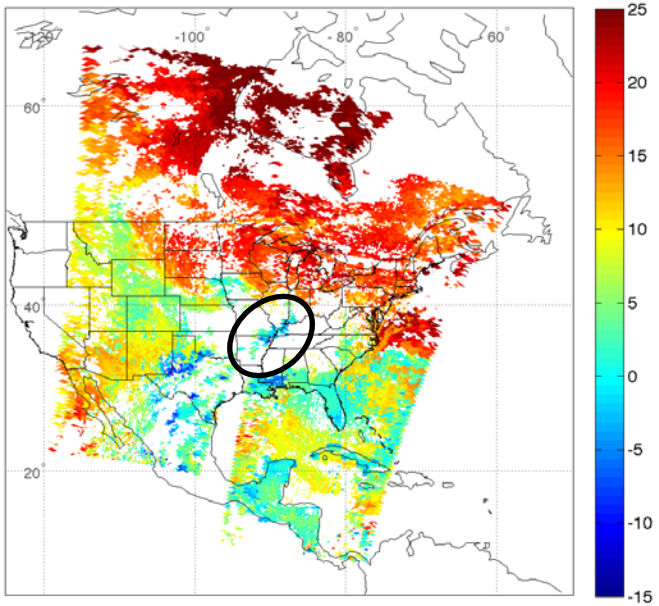




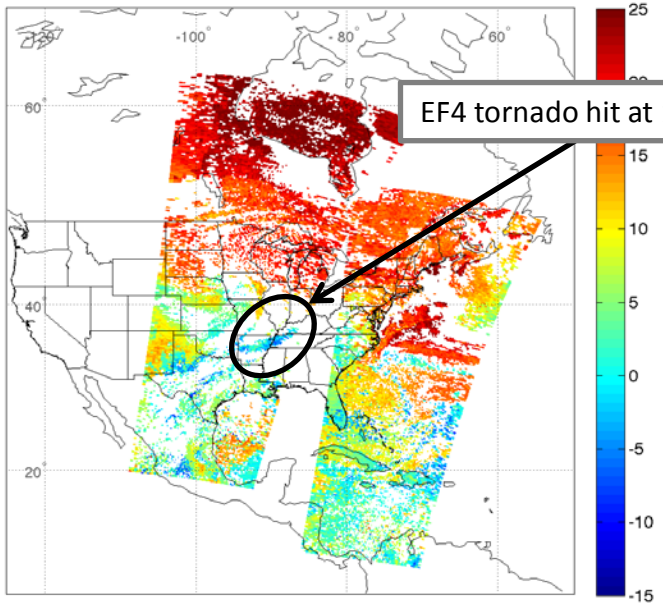


Tornado Outbreak in U.S. Midwest (Feb 2012)

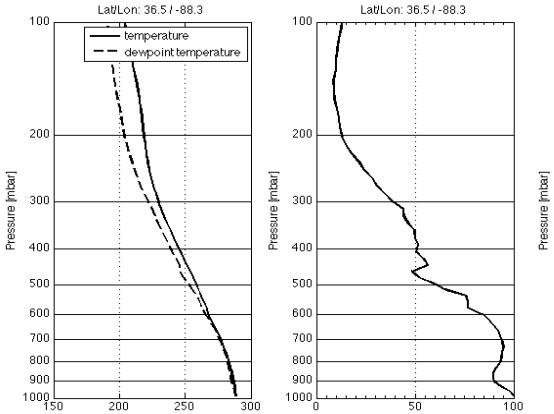
CrIS Lifted Index [°C]



AIRS Lifted Index [°C]



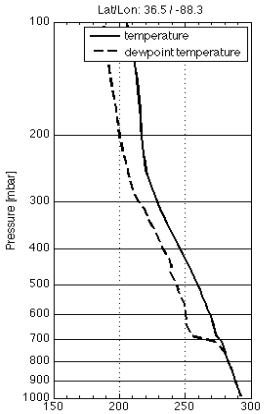
CrIS Retrieval at 07:11 UTC



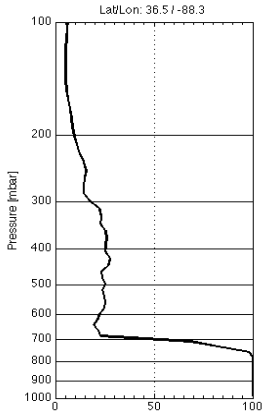
Temperature [K]

Relative Humidity [%]

AIRS Retrieval at 08:23 UTC



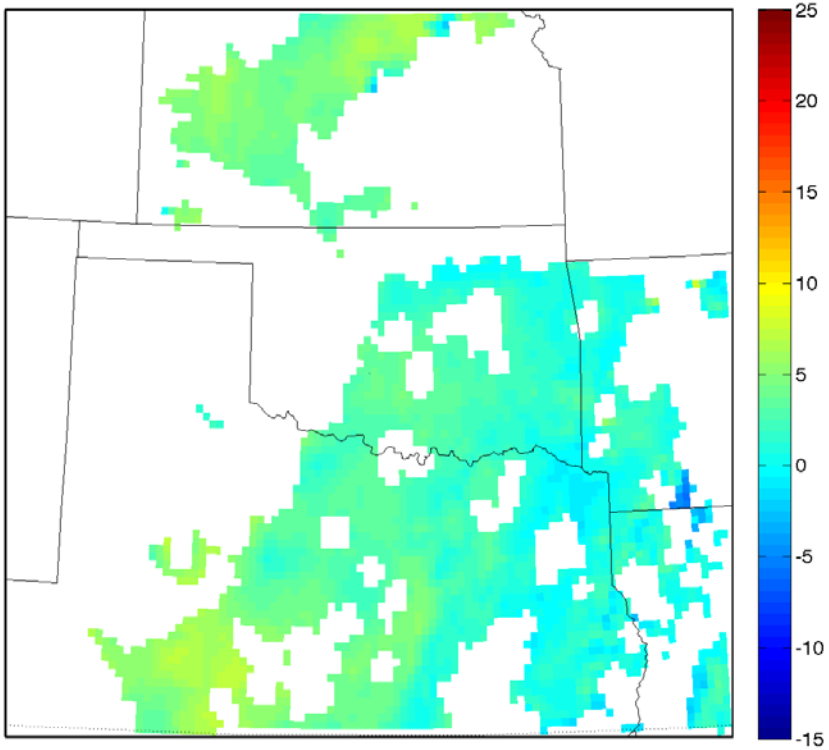
Temperature [K]



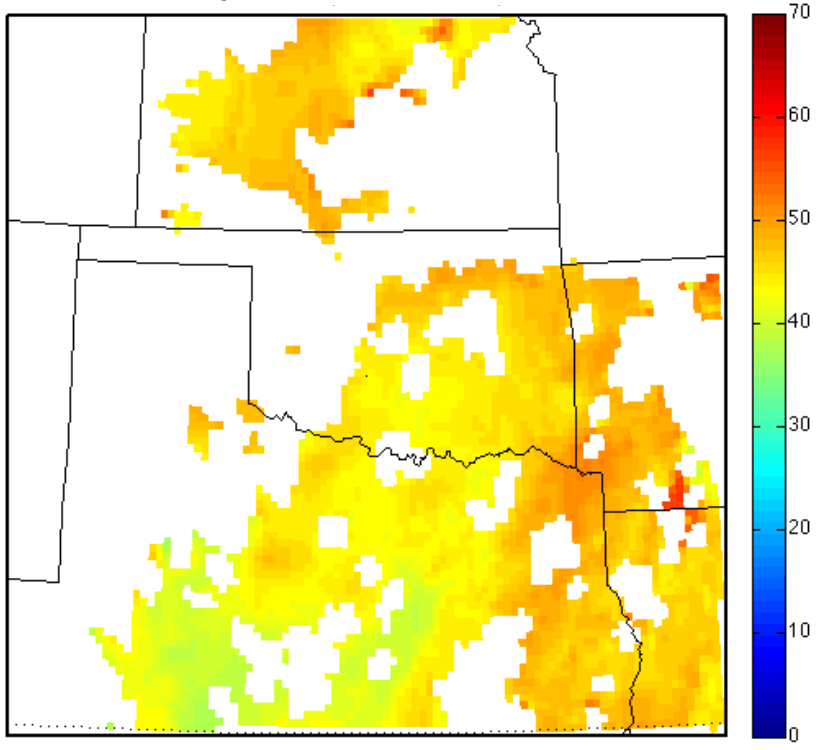
Relative Humidity [%]

CrIS Stability Indices
20 May 2013 ~07:43 UTC (02:43am)

Lifted Index

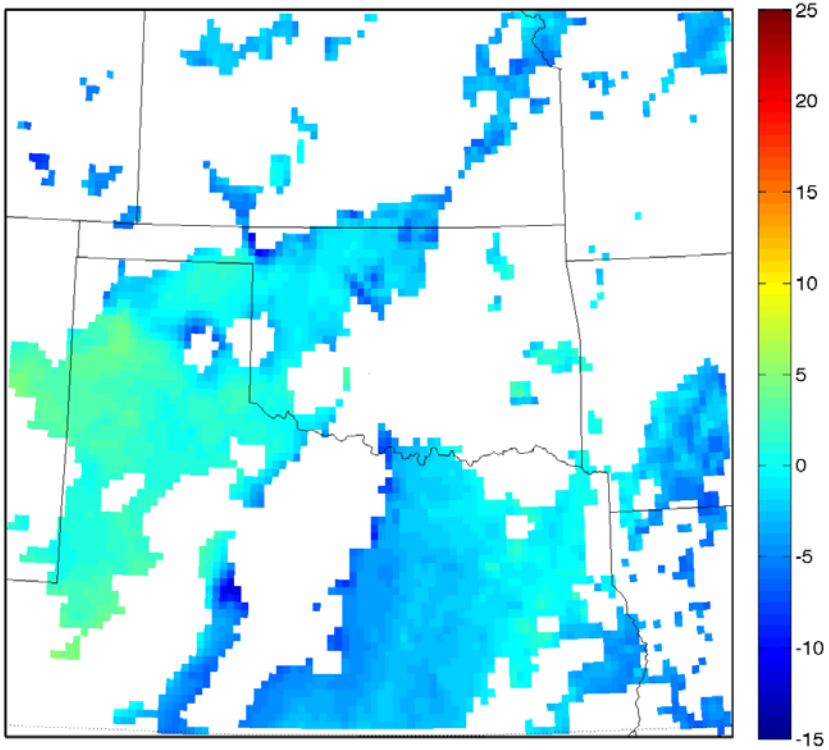


Total Totals

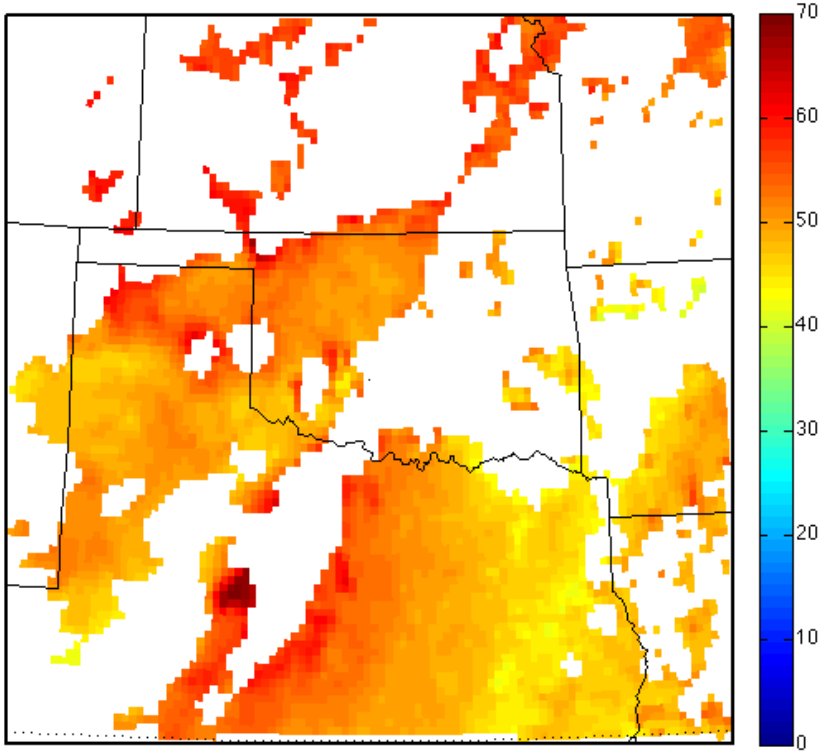


CrIS Stability Indices
20 May 2013 ~19:07 UTC (2:07pm)

Lifted Index

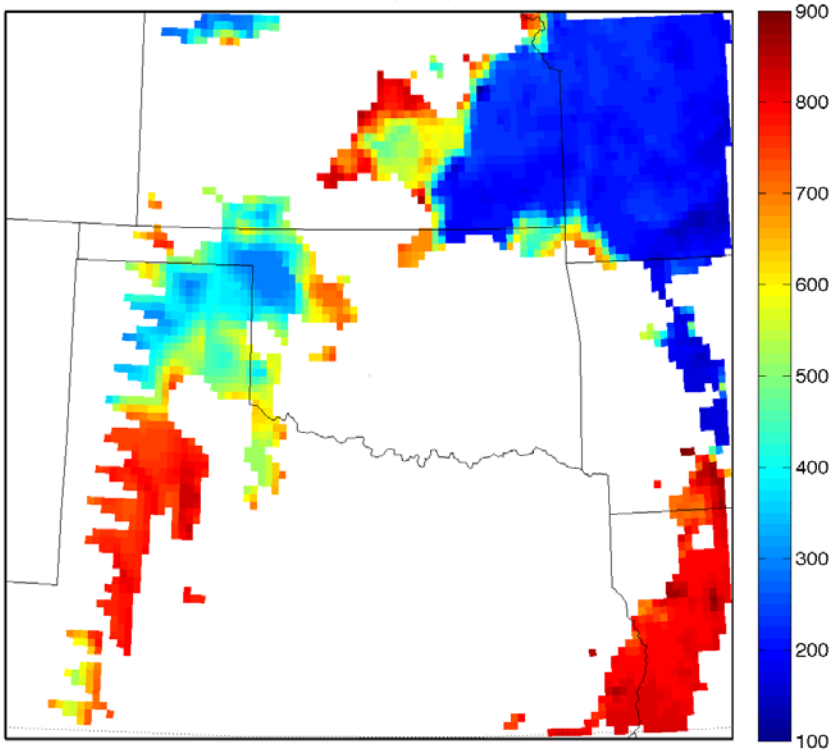


Total Totals

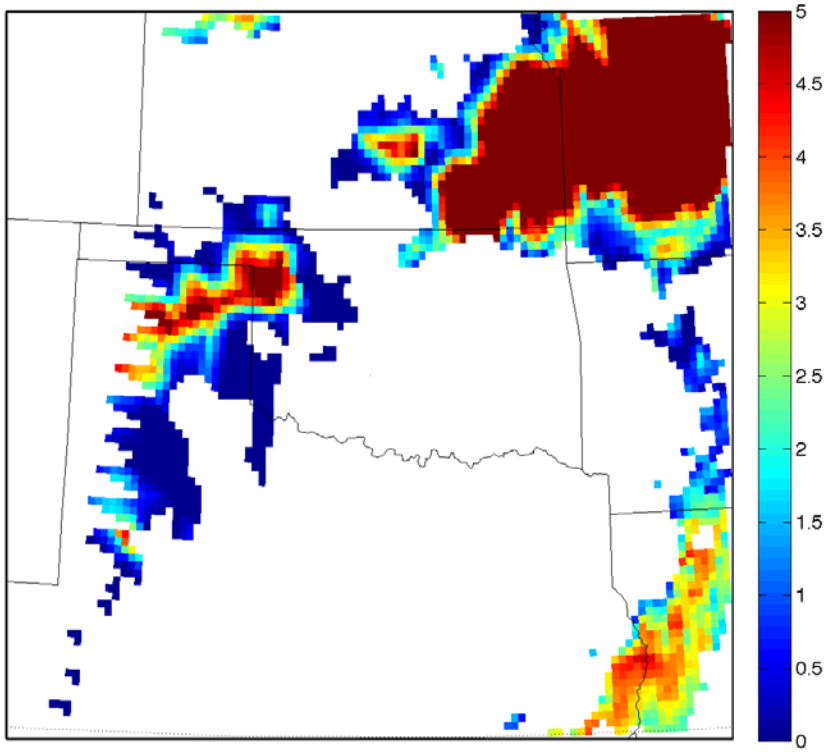


CrIS cloud parameter retrievals
20 May 2013 ~07:43 UTC (02:43am)

Cloud Top Pressure

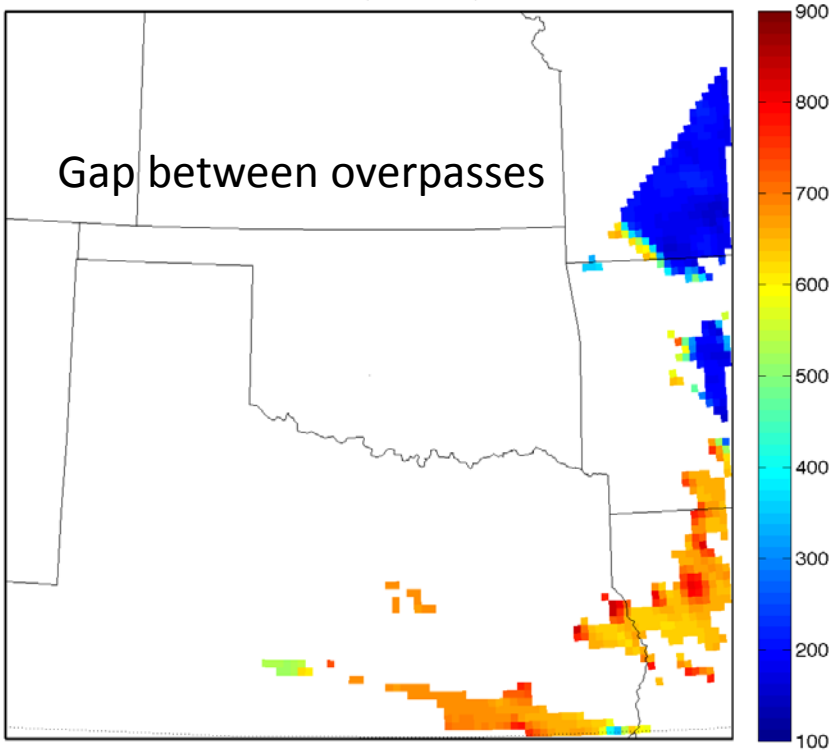


Cloud Optical Depth

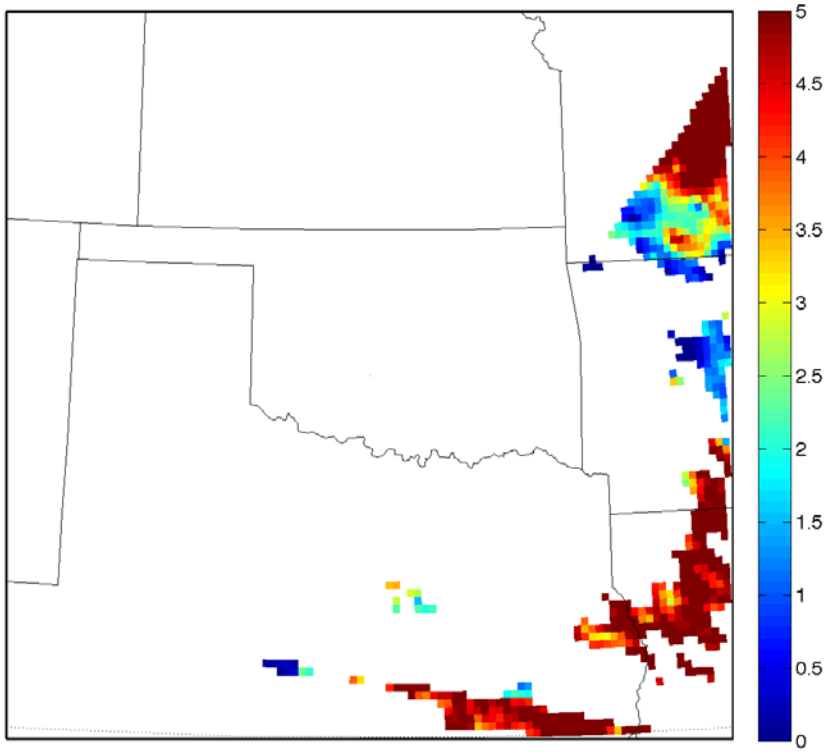


AIRS cloud parameter retrievals
20 May 2013 ~08:23 UTC (03:23am)

Cloud Top Pressure

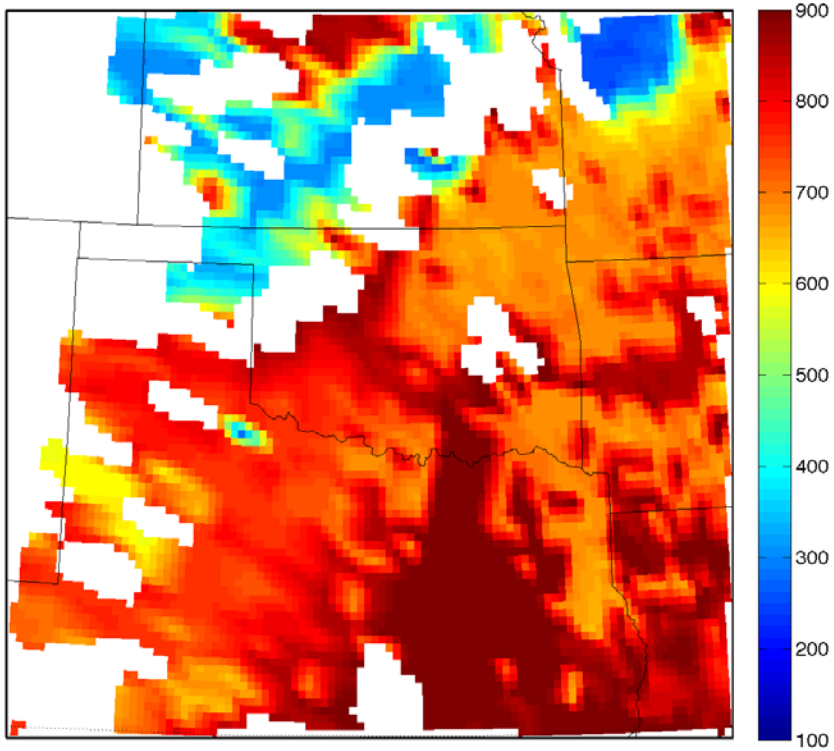


Cloud Optical Depth

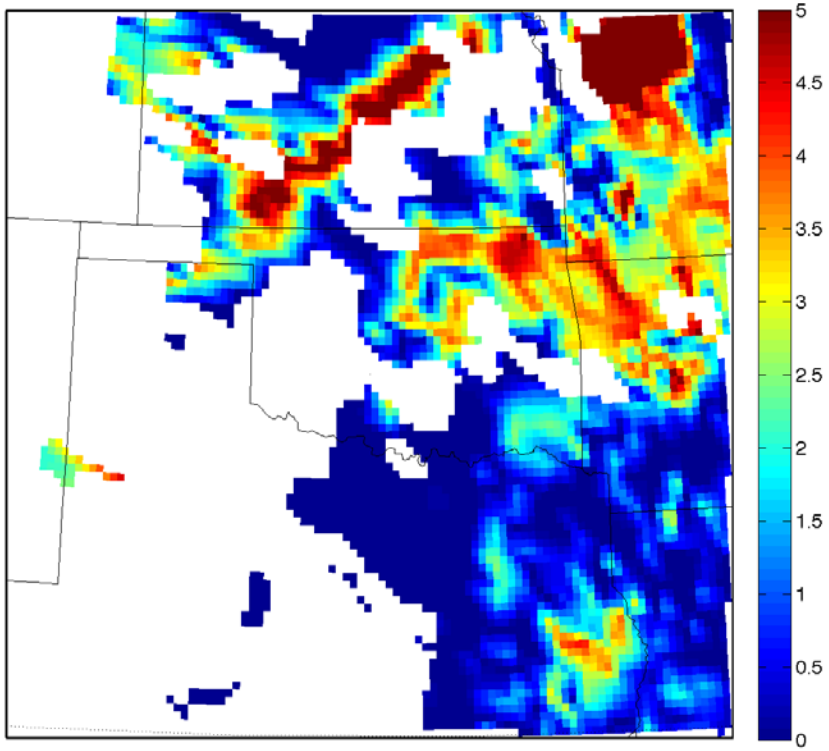


IASI Metop-A cloud parameter retrievals
20 May 2013 ~15:56 UTC (10:56am)

Cloud Top Pressure

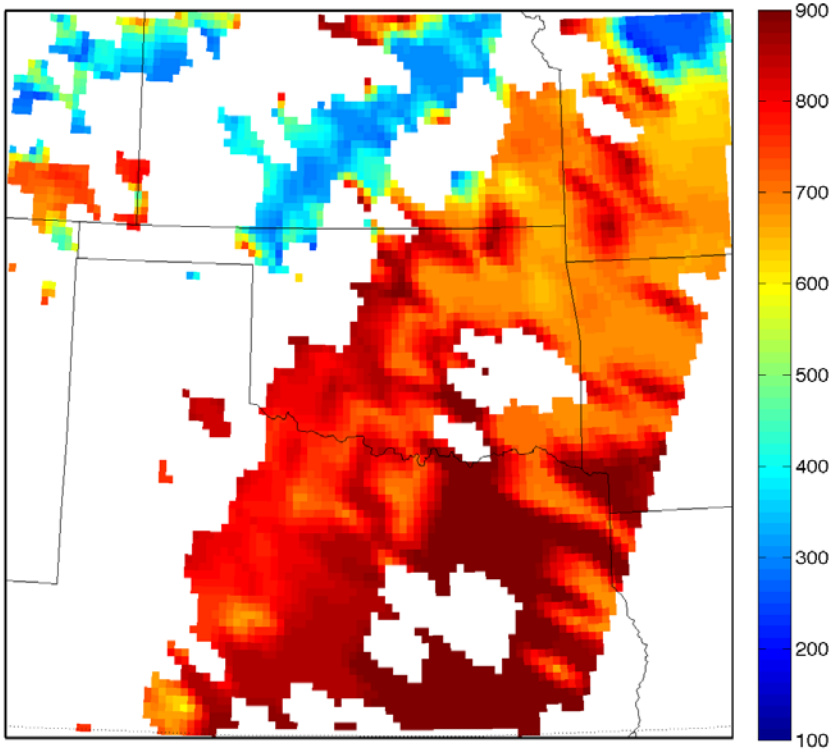


Cloud Optical Depth

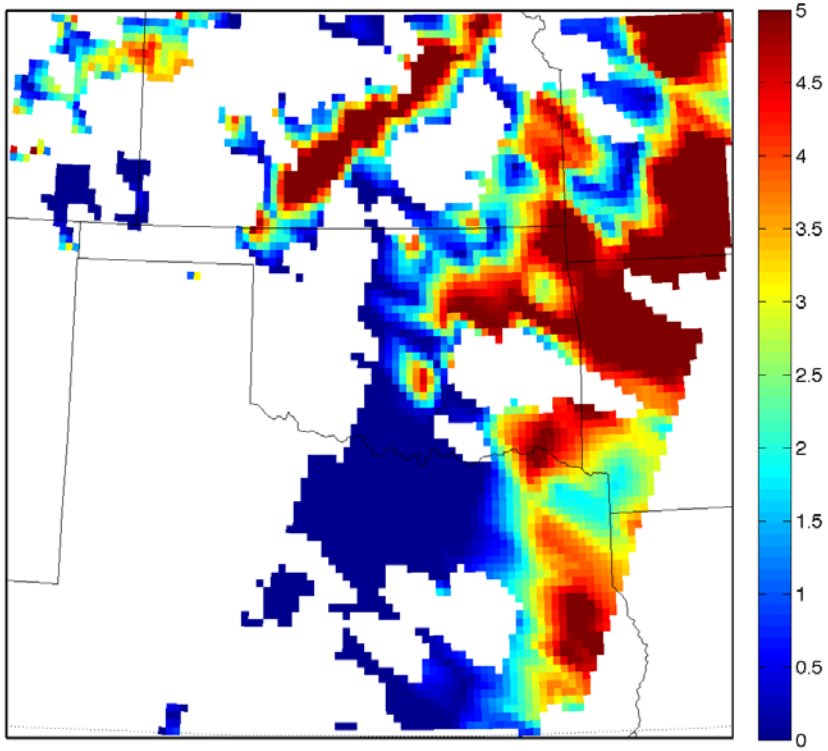


IASI Metop-B cloud parameter retrievals
20 May 2013 ~16:51 UTC (11:51am)

Cloud Top Pressure

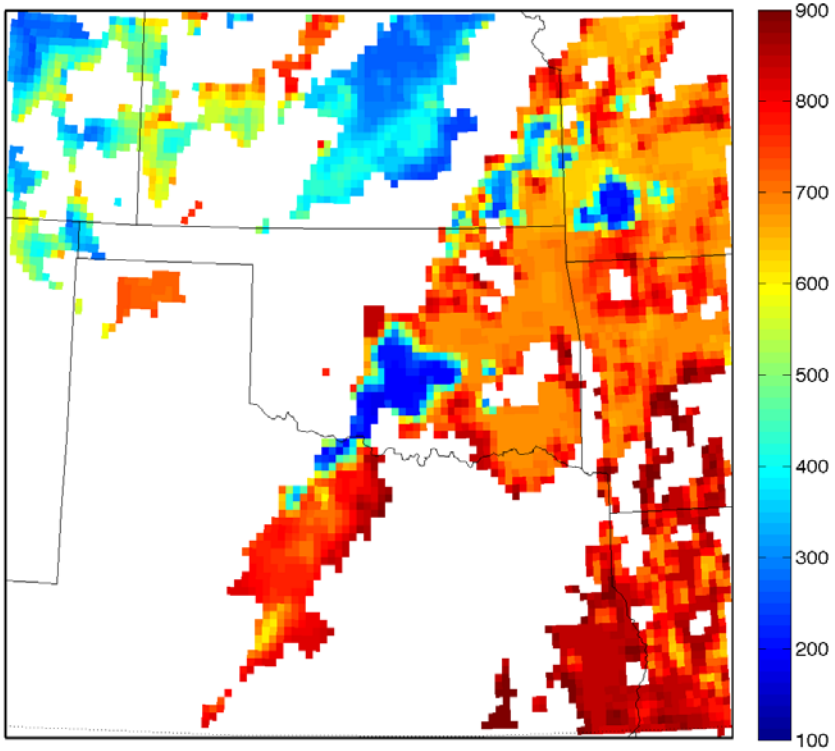


Cloud Optical Depth

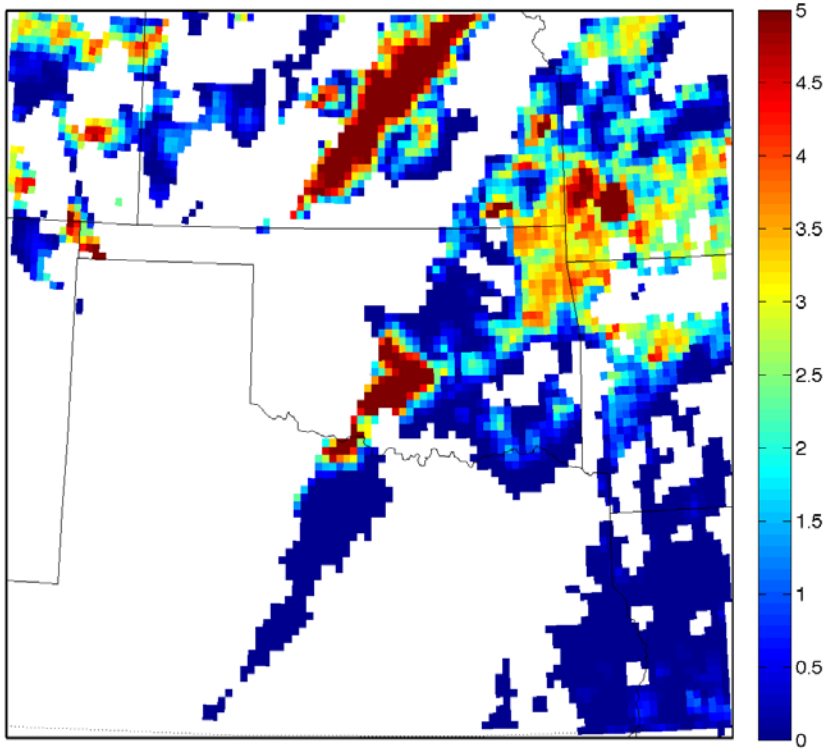


CrIS cloud parameter retrievals
20 May 2013 ~19:07 UTC (2:07pm)

Cloud Top Pressure

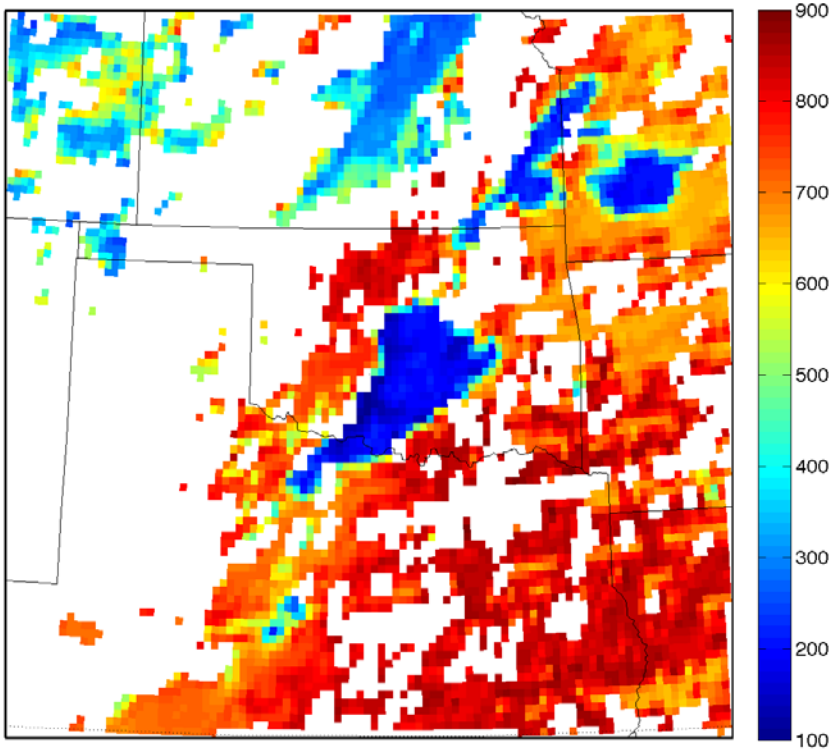


Cloud Optical Depth

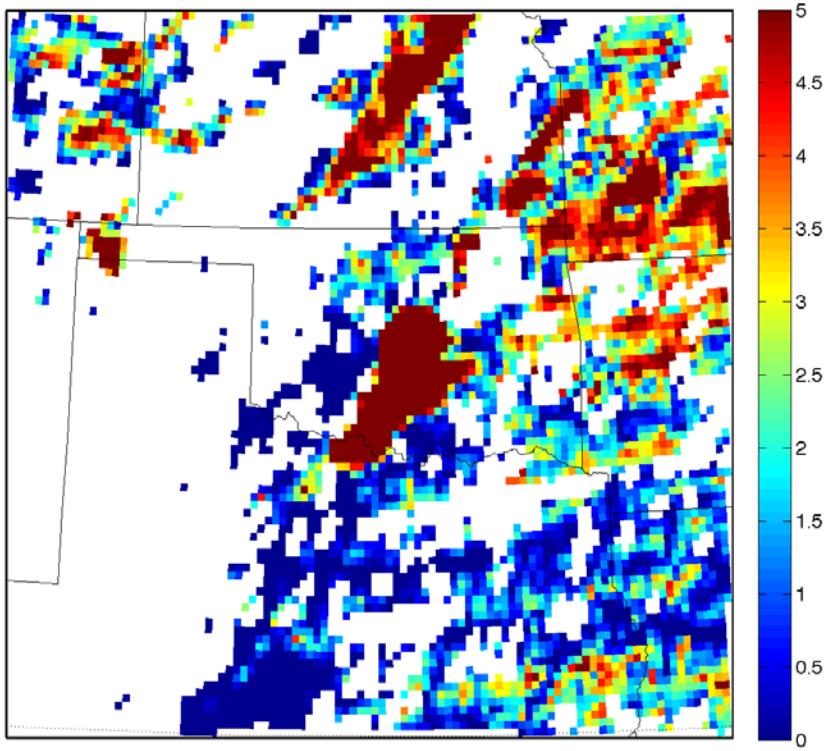


AIRS cloud parameter retrievals
20 May 2013 ~19:35 UTC (2:35pm)

Cloud Top Pressure



Cloud Optical Depth



Summary

The Dual-Regression (DR) algorithm[1,2] available as part of CSPP on http://cimss.ssec.wisc.edu/cspp/, provides **single field-of-view** products (temperature, humidity and ozone profiles, surface and cloud parameters, stability indices) under **clear and cloudy conditions** from input Direct Broadcast (DB) or archived Aqua-**AIRS** (Atmospheric Infrared Sounder), Metop-**IASI** (Infrared Atmospheric Sounding Interferometer) and NPP-**CrIS** (Cross-Track Infrared Sunder) radiance measurements.

These parameters are used to

- measure temperature **trends**, water cycle, cloud properties, and trace gases (regional and global)
- study **time tendencies** of atmospheric parameters (e.g. lifted index) from consecutive overpasses
- add **quantitative information** to MODIS/AVHRR/VIIRS imagery
- improve weather prediction, **forecasting** and climate models

[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., 51*, Issue 8, 1455-1476.

[2] Weisz, E., W. L. Smith, N. Smith (2013), Advances in simultaneous atmospheric profile and cloud parameter regression based retrieval from high-spectral resolution radiance measurements, Submitted to *JGR-Atmospheres*.

Current and Future work

- **Time tendencies** (multi-instrument time-series analysis, quantifying change)
- In close collaboration with GINA and forecasters in Alaska: include sounder retrievals in **regional forecast systems** (AWIPS)
- **Climatologies** from archive data (EUMETSAT conference): climate data records
- Adding additional **trace gases** to retrieval product suite: CO, CH4
- Develop readily interpretative products (classification), **indicators**, value-added information/data products
- Regionalize algorithm and products: **monitoring** and quick response
- Improve **access** to quick looks and data products
- Investigate adding microwave retrievals to profiles below clouds

[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., 51*, Issue 8, 1455-1476.

[2] Weisz, E., W. L. Smith, N. Smith (2013), Advances in simultaneous atmospheric profile and cloud parameter regression based retrieval from high-spectral resolution radiance measurements, Submitted to *JGR-Atmospheres*.

Ideas for types of information derived from sounder retrievals

- Classifying cloud heights into three nominal classes; high, medium low.
- Average vertical soundings into broader layers. At the moment they are defined along 101 levels from surface to top of atmosphere.
- Calculate additional indices of atmospheric stability that forecasters are used to or find particularly useful in certain cases.
- Derive compound products that can serve as indicators of weather features or onset of change, e.g. combining low level moisture and surface temperature.
- Derive geostrophic winds and moisture fluxes
- Calculate and archive regional statistics that can be used to calculate trends over time
- Include profile retrievals for use in regional data assimilation models

Contact us

Available at http://cimss.ssec.wisc.edu/cspp/

- Elisabeth Weisz: elisabeth.weisz@ssec.wisc.edu
- Nadia Smith: nadia.smith@ssec.wisc.edu

[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., 51*, Issue 8, 1455-1476.

[2] Weisz, E., W. L. Smith, N. Smith (2013), Advances in simultaneous atmospheric profile and cloud parameter regression based retrieval from high-spectral resolution radiance measurements, Submitted to *JGR-Atmospheres*.