Polar-orbiting Sounder Applications for Alaska

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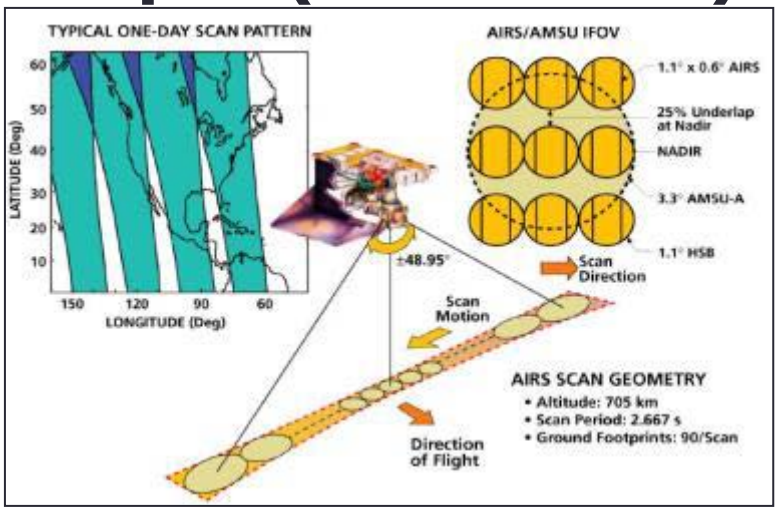
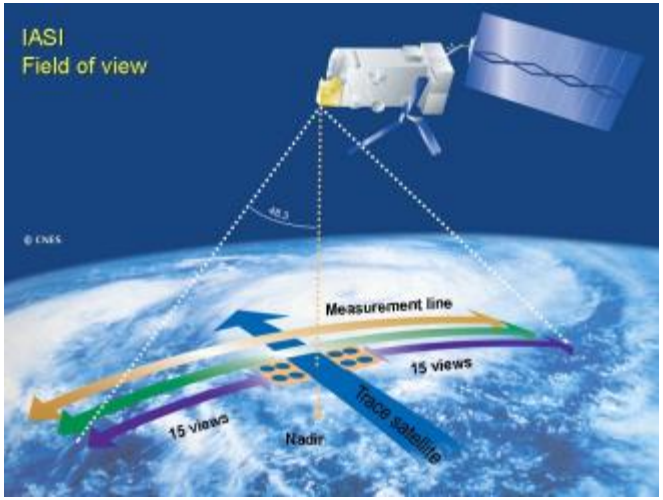
Proving Ground Outside CONUS – Alaska Aviation Forecast Facility, Anchorage AK, 18-19 June 2013

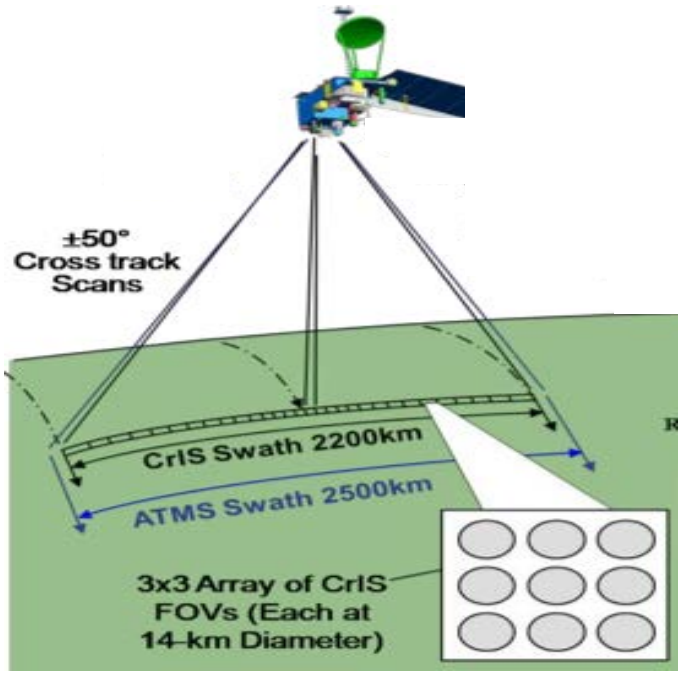
Satellites with Ultra-spectral Sounders

Aqua (13:30 LST)





Suomi NPP/JPSS (13:30 LST)



Metop A & B (10:20 & 9:30 LST)

AIRS

1330 Aqua-Train orbit

Atmospheric InfraRed Sounder
Grating spectrometer
166 kg, 256 W
13.5 km FOV at nadir, contiguous
Launched on NASA Aqua in 2002

IASI

930 JPSS orbit

Infrared Atmospheric Sounding Interferometer
Michelson interferometer
236 kg, 210 W
2x2 12 km FOVs at nadir, non-contiguous
Launched on Metop-A in 2006

Full scale model at 2010 IASI meeting

Exelis (ITT) / ABB (Bomem) Team

CrIS*

1330 JPSS orbit

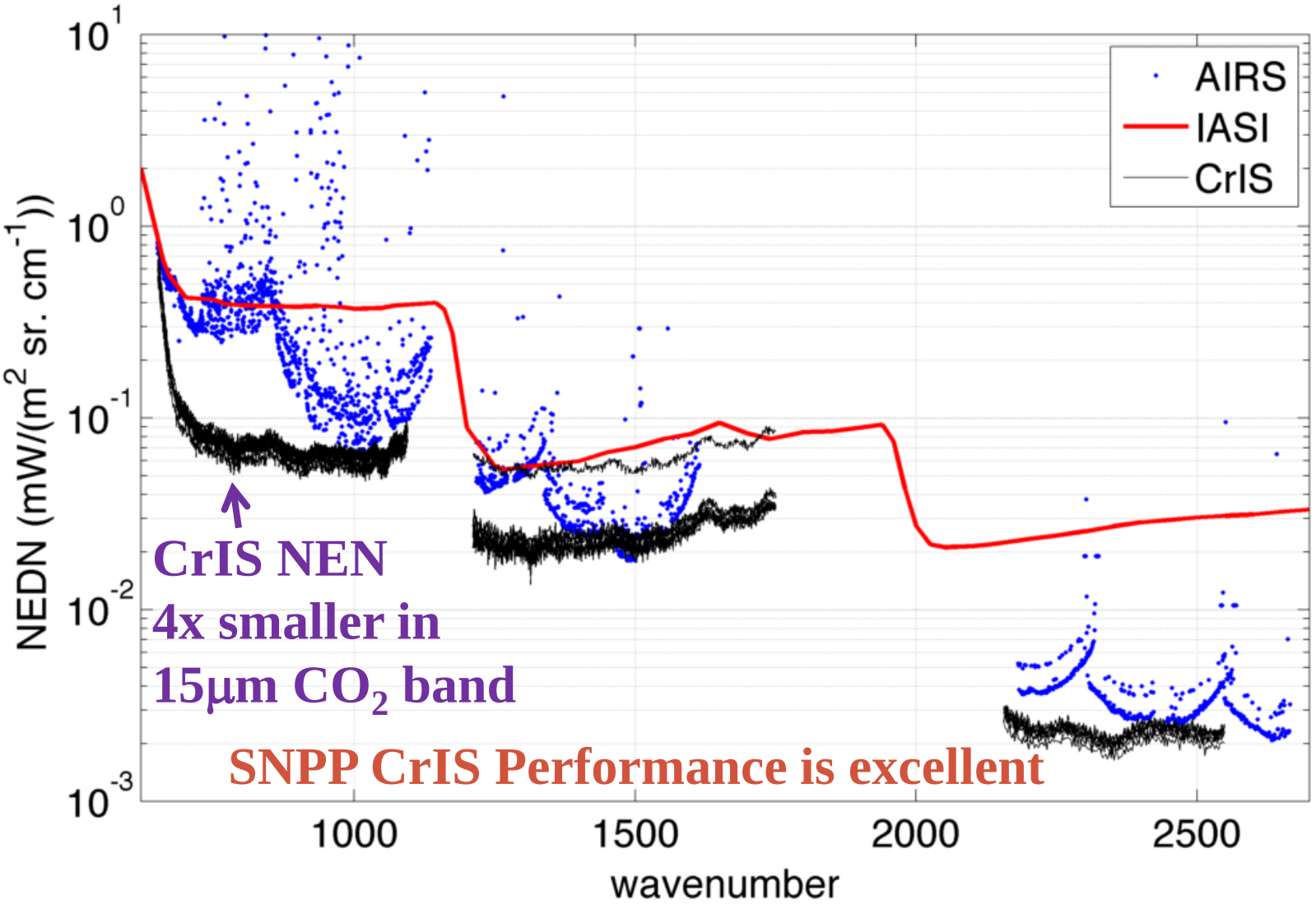
Cross-track Infrared Sounder
Michelson interferometer
146 kg, 110 W
3x3 14 km FOVs at nadir, contiguous
Launched on Suomi NPP, 28 Oct 2011

**** Passive cooler with vibration isolation that was not deployed***

CrIS ~ the size of HIRS

Noise Comparison

CrIS, AIRS, IASI



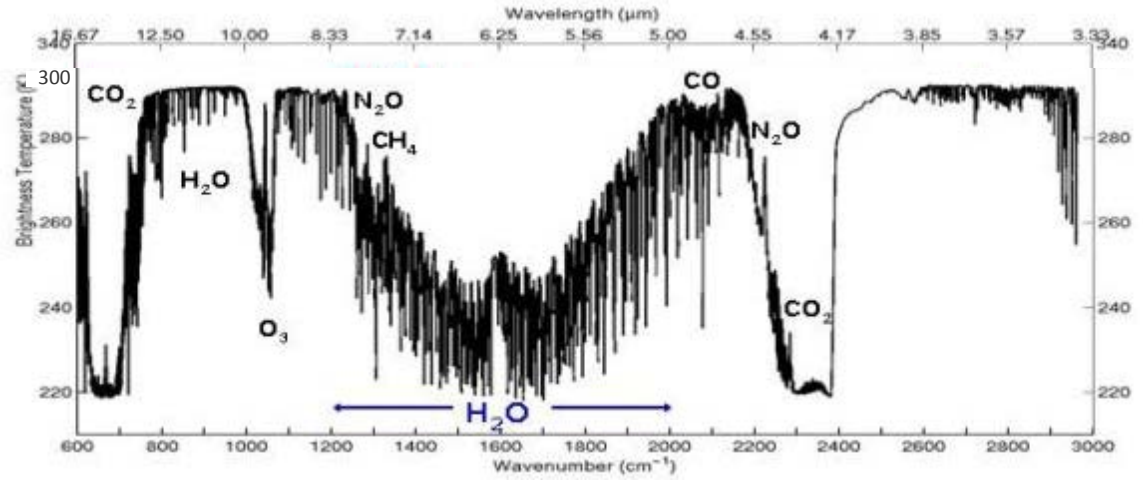
Ultra-spectral Sounding

- ***First Demonstrated with the UW High-resolution Interferometer Sounder (HIS) from the NASA ER-2 Aircraft***
- ***High S/N Enables Accurate De-convolution of Vertically Smeared Thermal Radiance Signals***

High Vertical Resolution Provided by High Spectral Resolution

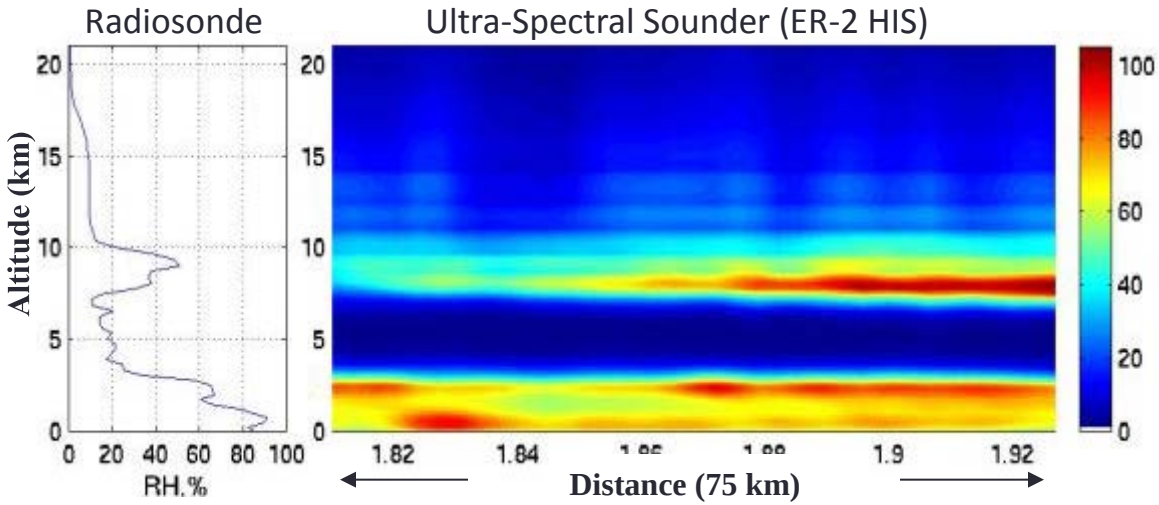
- Spectrum

Several thousand spectral channels are observed to profile the atmosphere with high vertical resolution



- Soundings

Ultra-spectral resolution sounder provides 1 K / 15% temperature and moisture accuracy for 1-2 km layers



UW Ultra-Spectral Retrieval Software Package

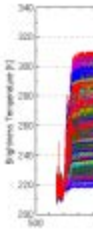
for AIRS, IASI and CrIS L1 to L2 processing

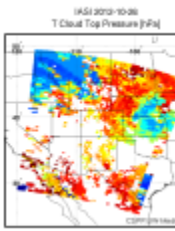
V1.0 Released under CSPP (Community Satellite Processing Package) November 2012

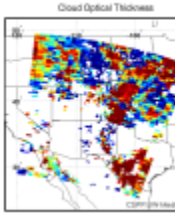
Elisabeth Weisz, William L. Smith Sr., Nadia Smith, Kathy Strabala, Liam Gumley, Allen Huang

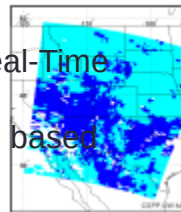
➔ **The dual-regression retrieval technique* is used to retrieve the following single FOV products under clear and cloudy conditions from input direct broadcast or archived AIRS, IASI and CrIS L1 radiance files:**

- 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)







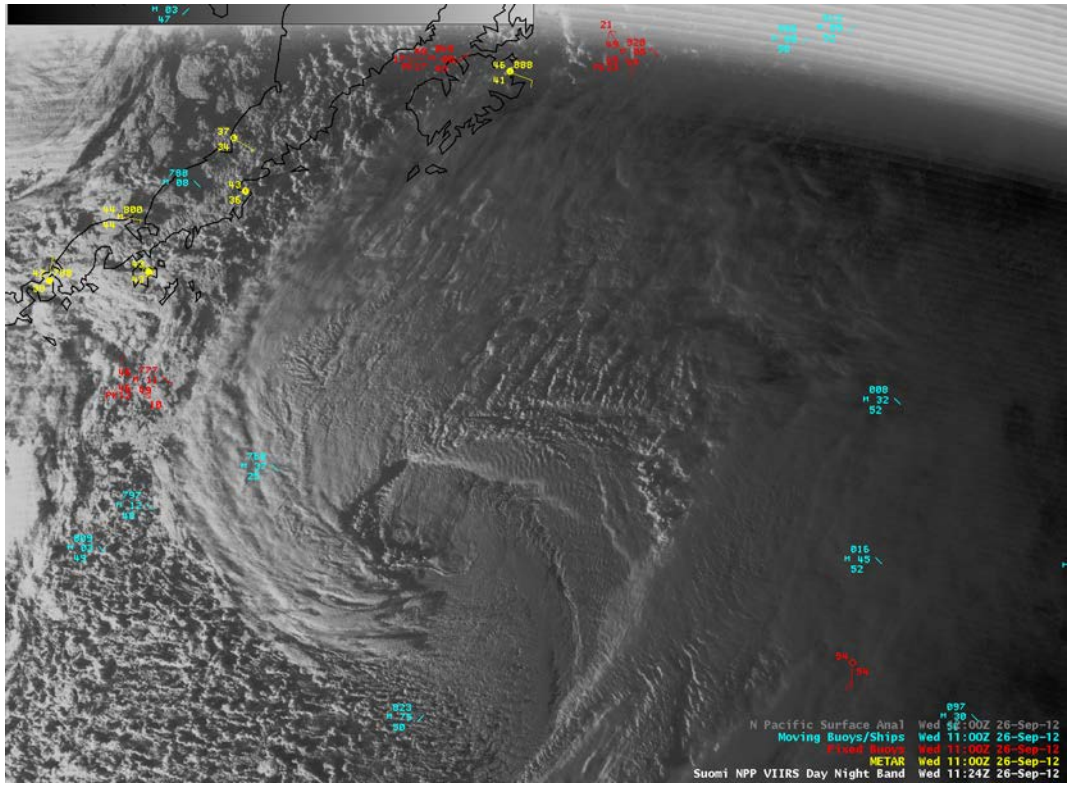


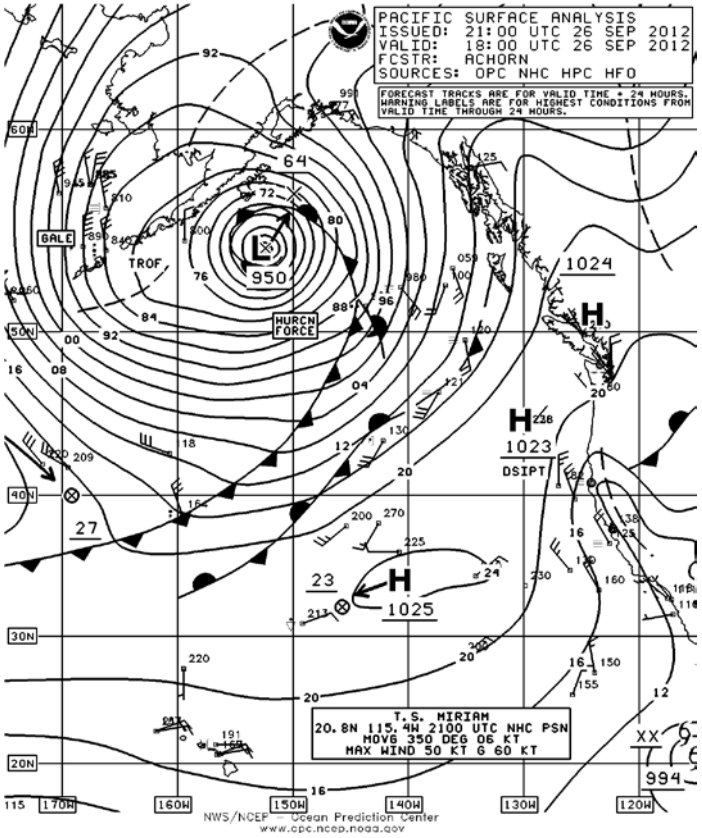
Available at http://cimss.ssec.wisc.edu/cspp/

- 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, Accepted for publication in *JGR-Atmospheres*.

Gulf of Alaska low pressure system (26 Sept 2012)

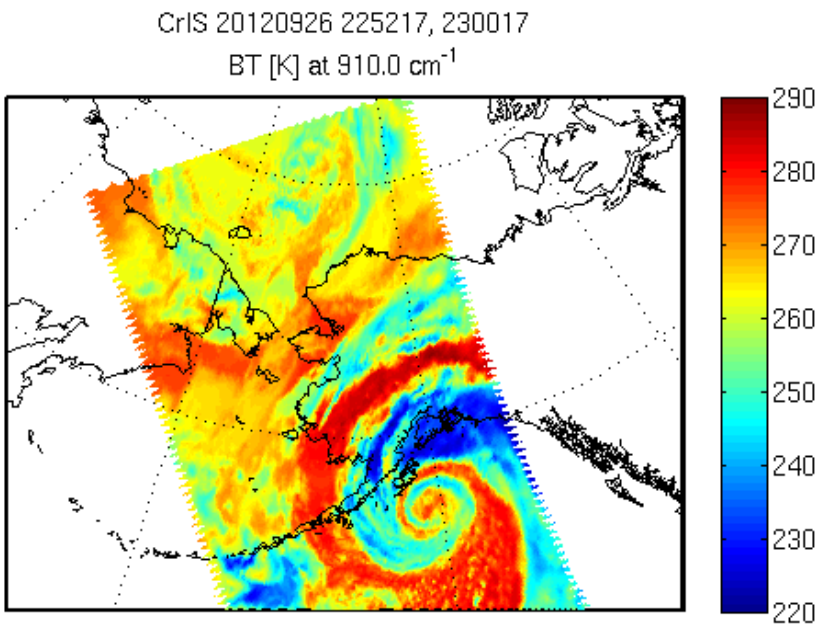
Suomi NPP VIIRS 0.7 μm Day/Night Band and 11.45 μm IR channel

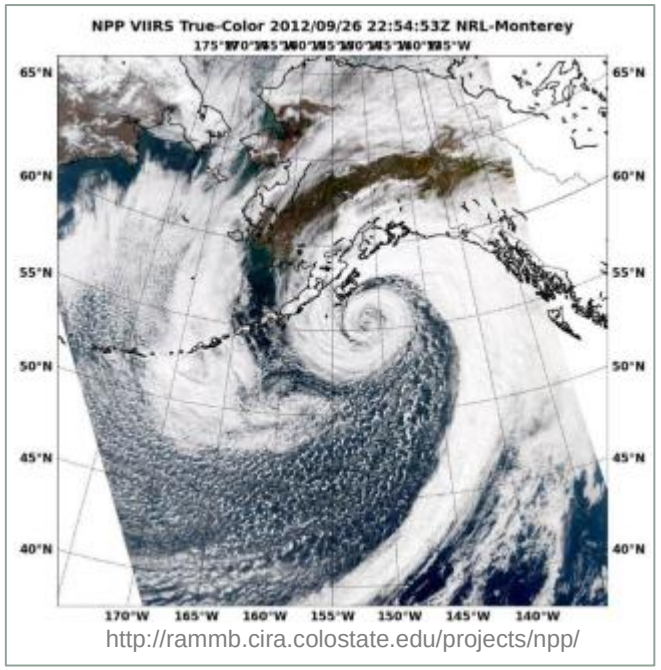




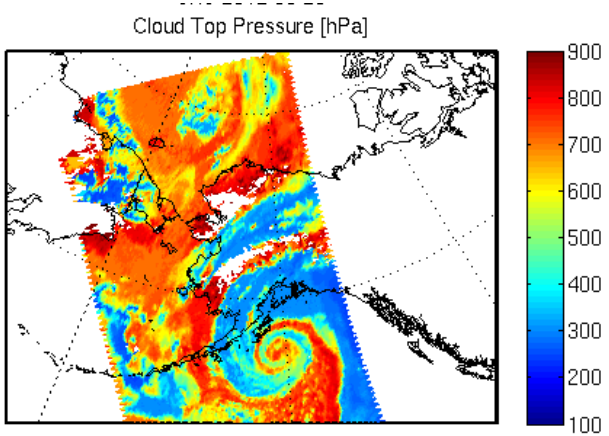
From: http://cimss.ssec.wisc.edu/goes/blog/archives/date/2012/09/26

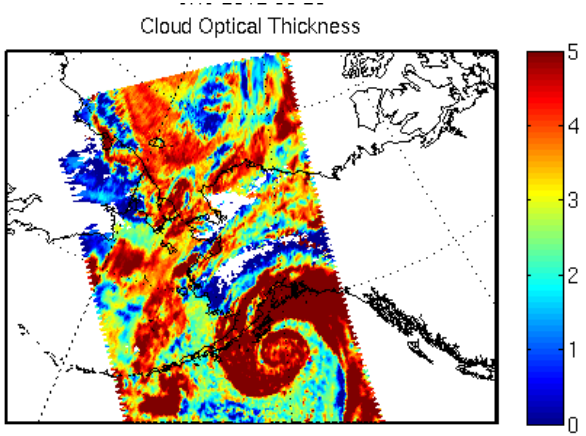
Gulf of Alaska low pressure system (26 Sept 2012)

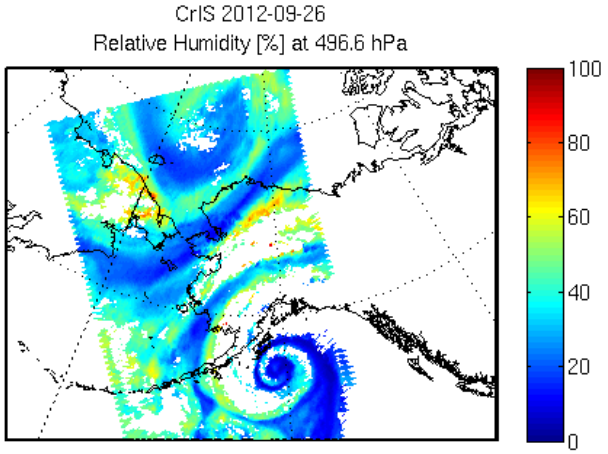




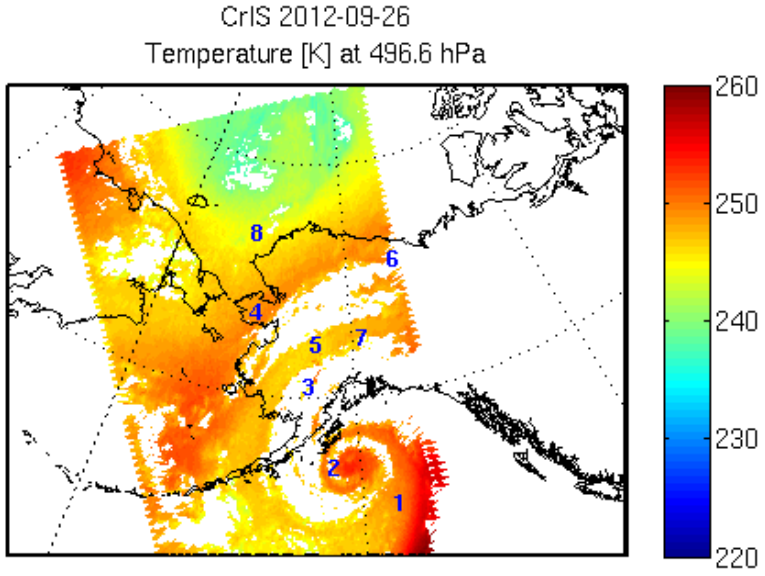
http://rammb.cira.colostate.edu/projects/npp/

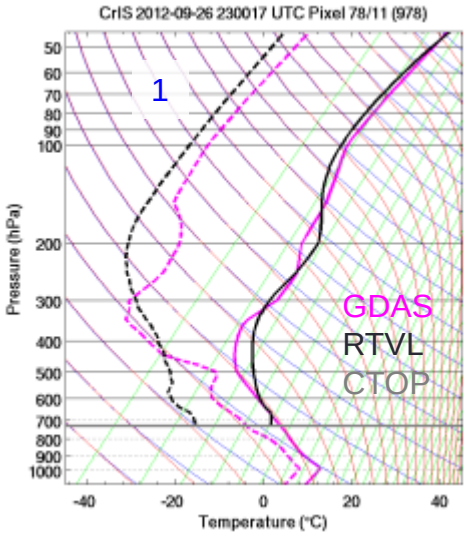


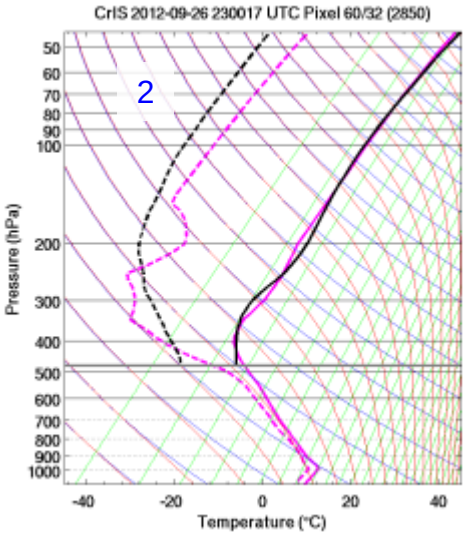


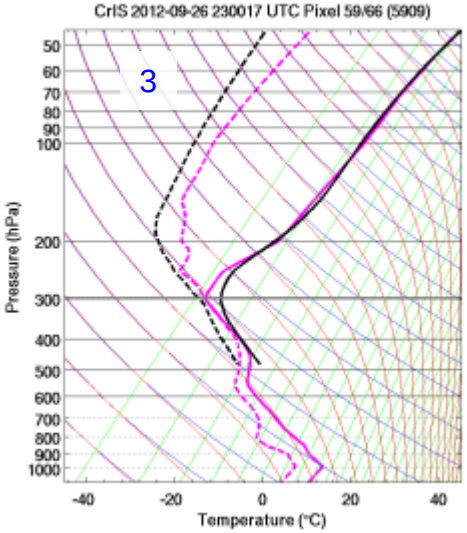


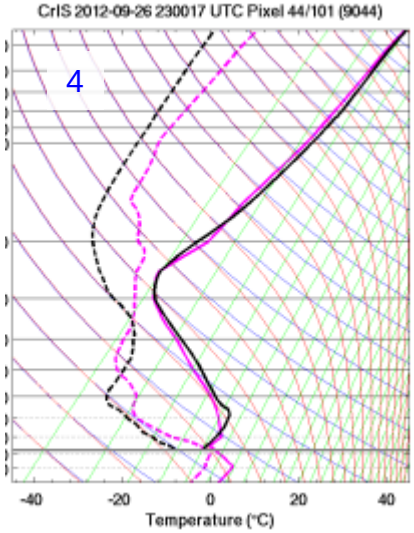
Skew-T (26 Sept 2012)

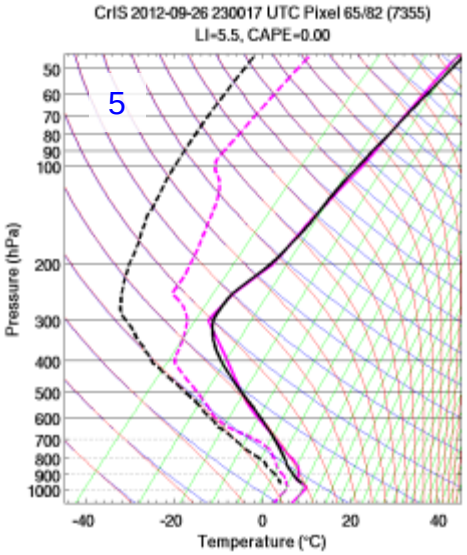


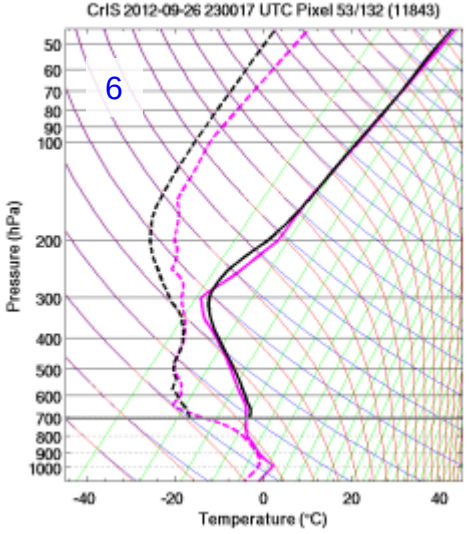




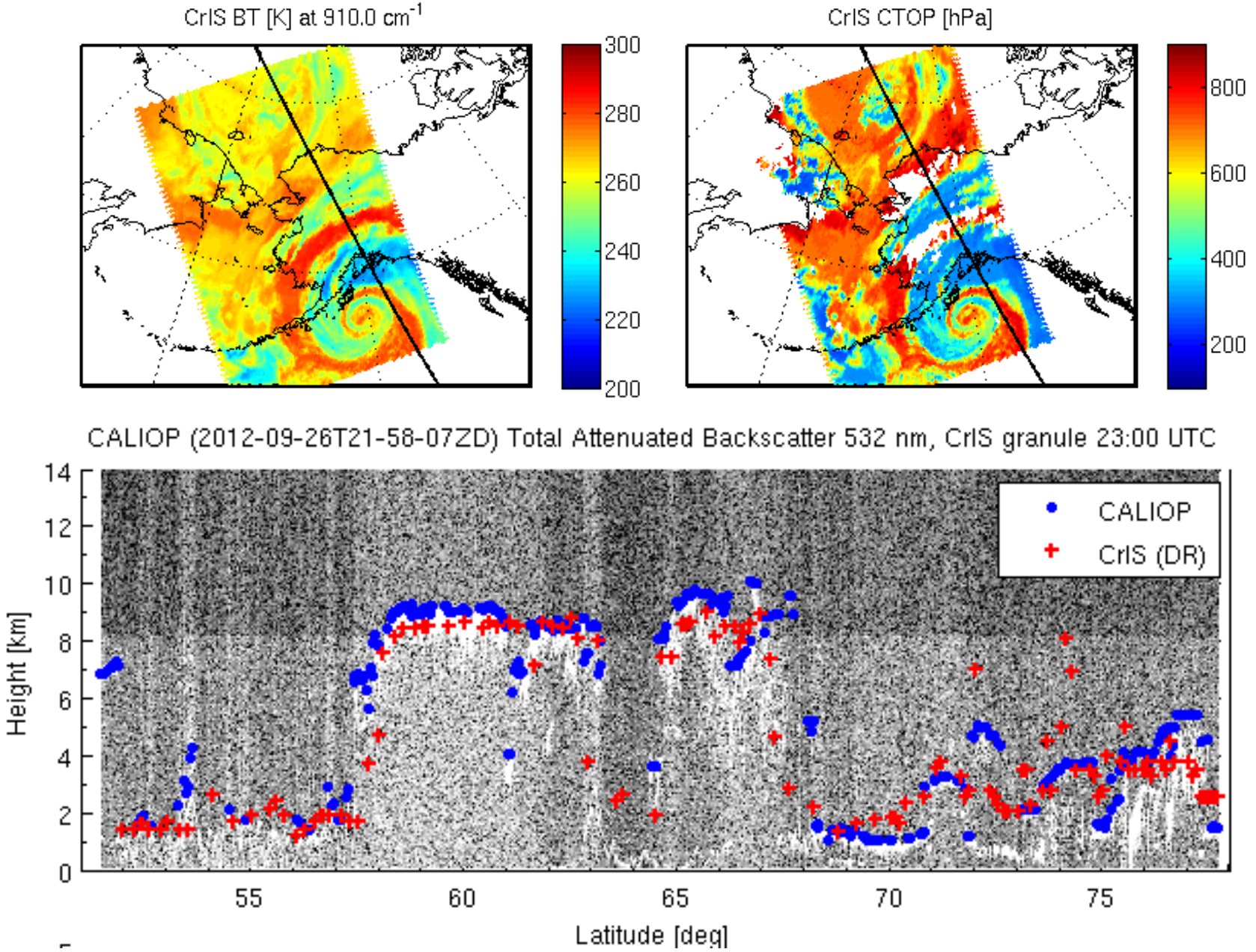




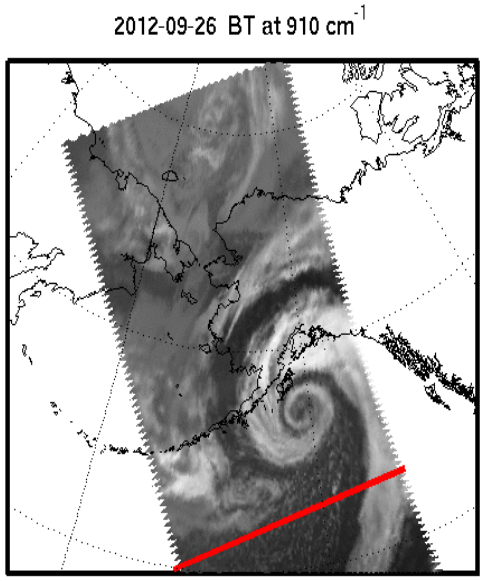


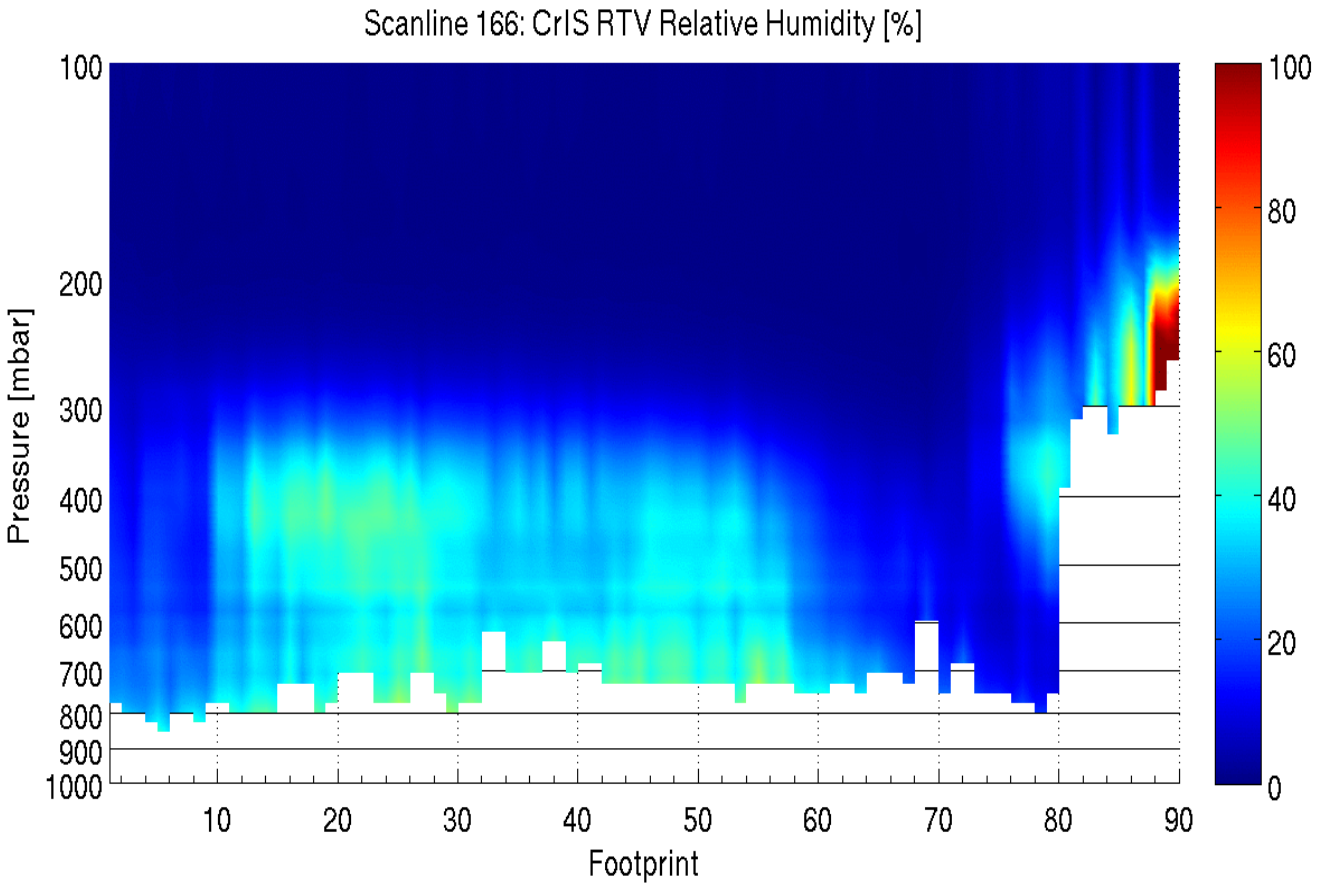


CrIS CTH Comparison with CALIPSO (26 Sept 2012)



RH south-north cross-section Movie (26 Sept 2012)





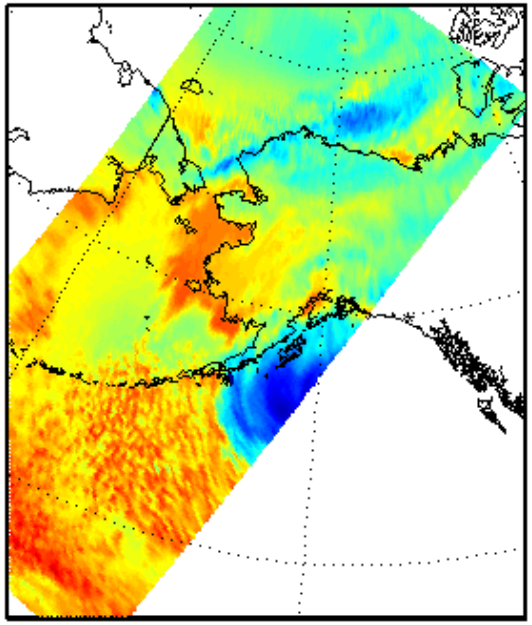
Sounding retrievals provide 3-d structure of storm systems

Temperature Surface to 100 hPa Movie (26 Sept 2012)

IASI, CrIS and AIRS (01 Nov 2012)

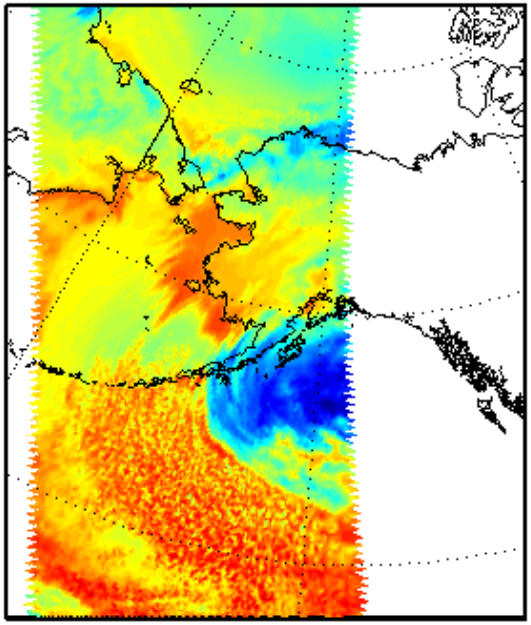
21:29 UTC

IASI 20121101 212954
BT [K] at 910.0 cm^{-1}



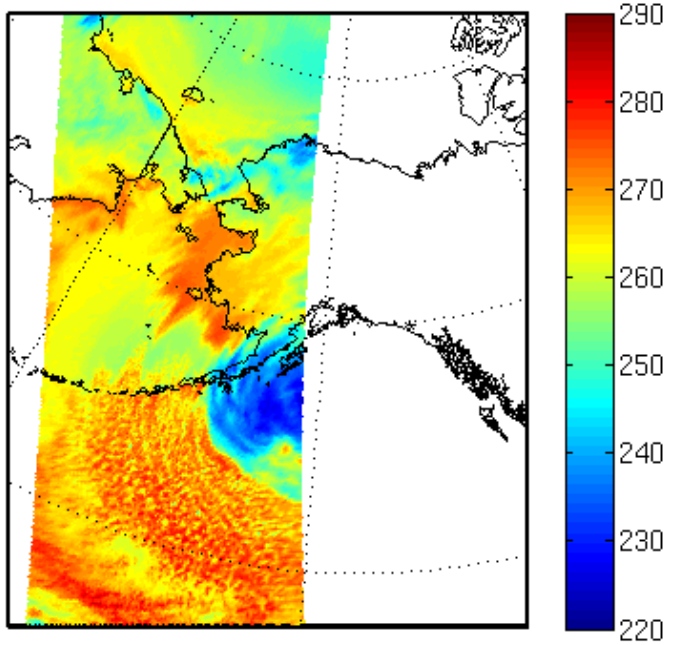
23:19 UTC

CrIS 20121101 231921
BT [K] at 910.0 cm^{-1}



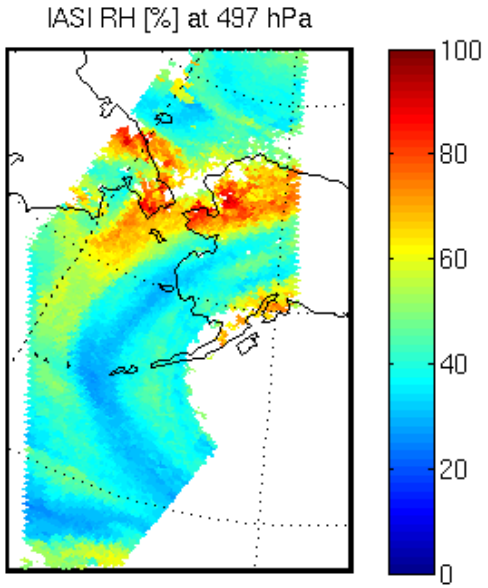
23:47 UTC

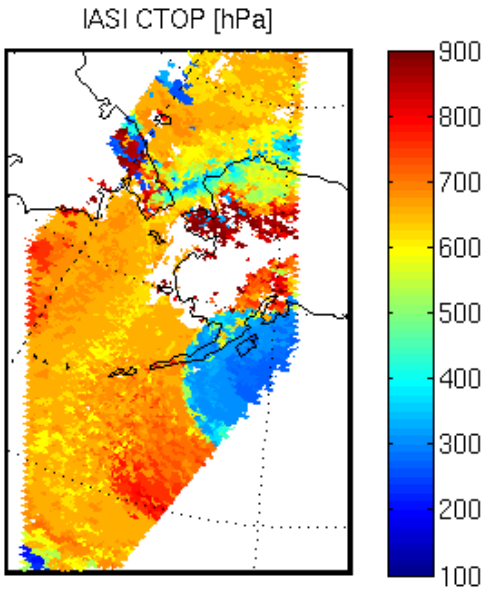
AIRS 20121101 234731 G239
BT [K] at 911.6 cm^{-1}



IASI and CrIS differences 500 hPa RH & CTOP (01 Nov 2012)

21:29 UTC





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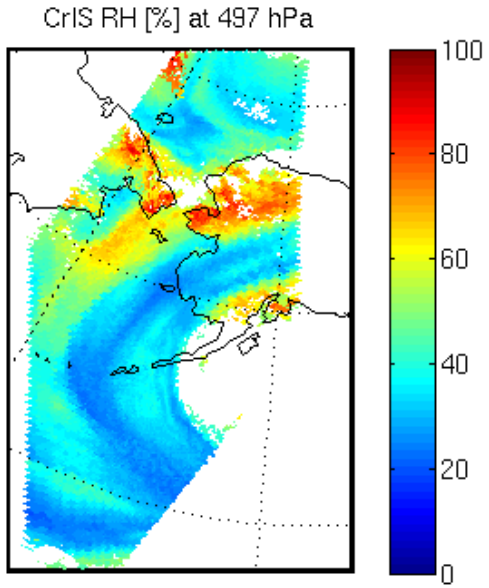
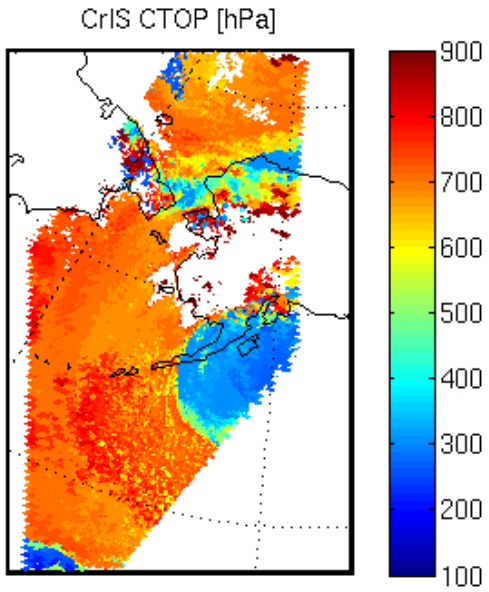
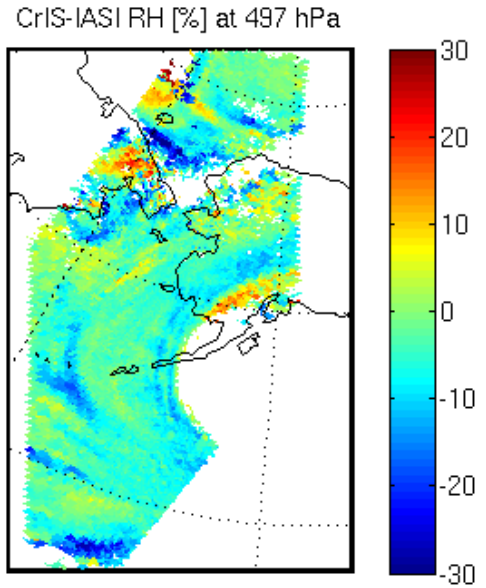
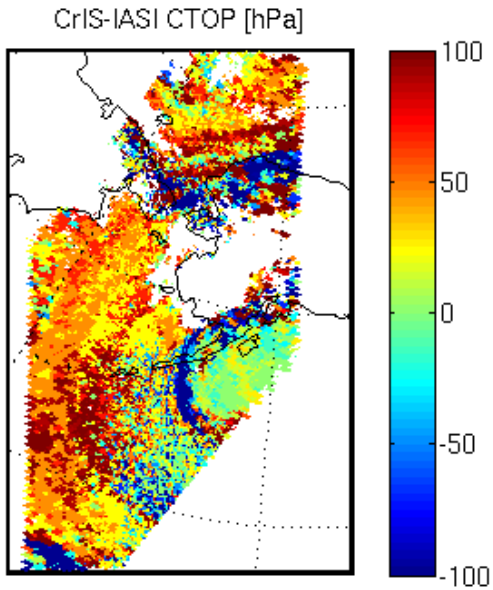




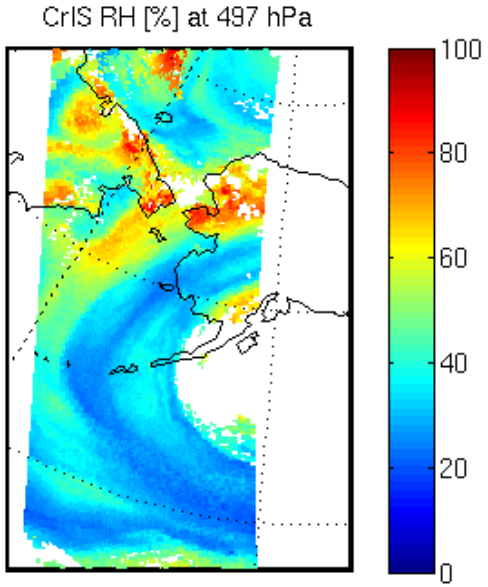
~ 1.8 hour change

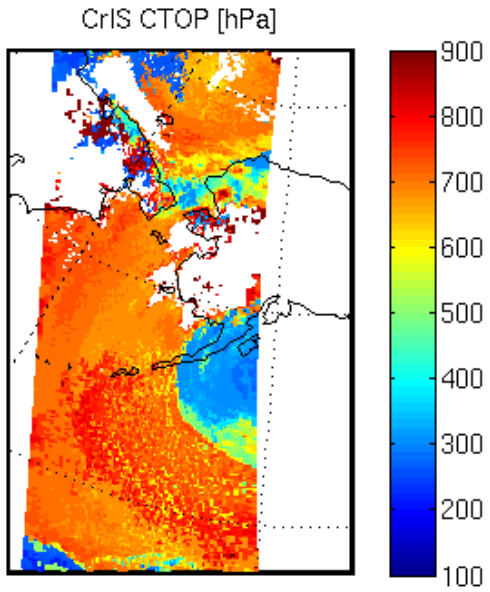




CrIS and AIRS differences 500 hPA RH & CTOP (01 Nov 2012)

23:19 UTC





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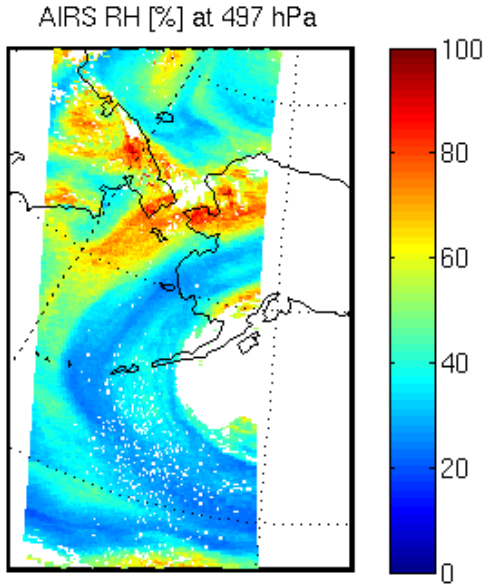
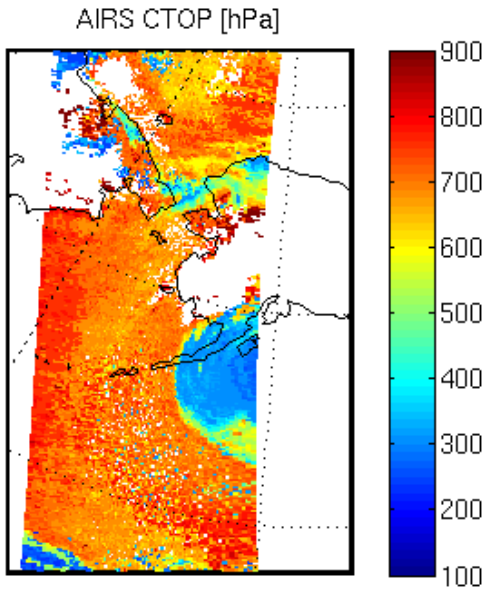
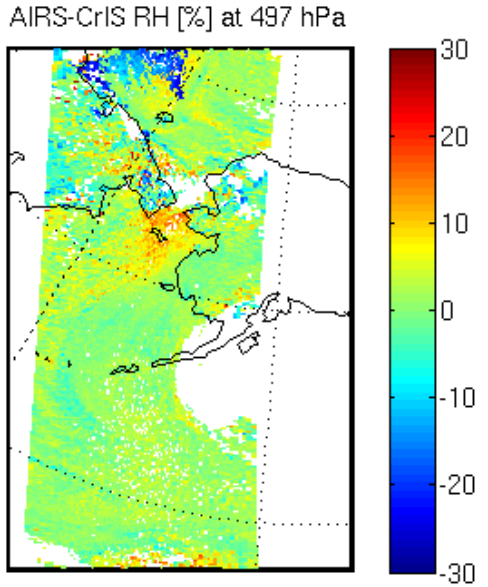
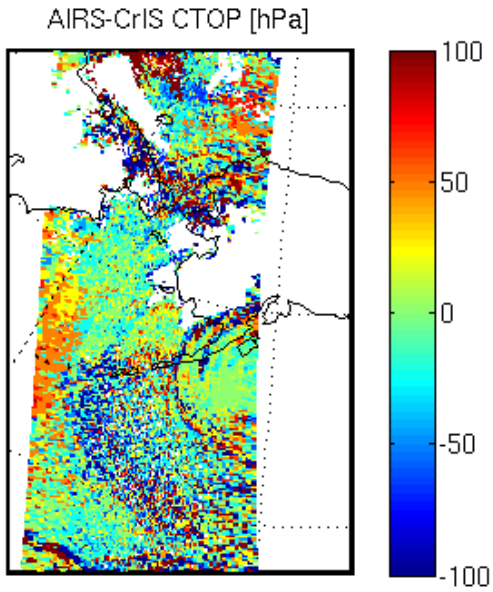




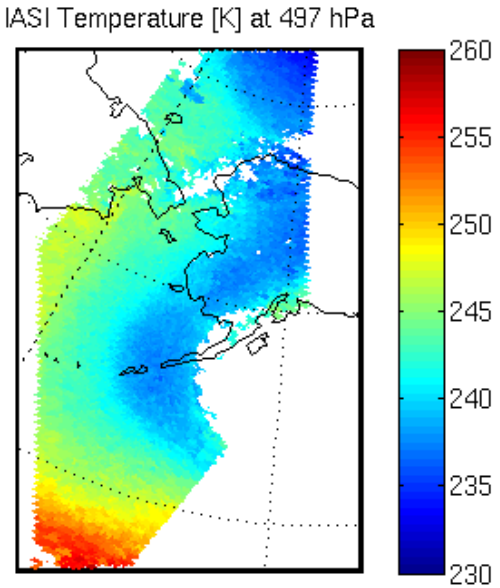
~ 38 min change

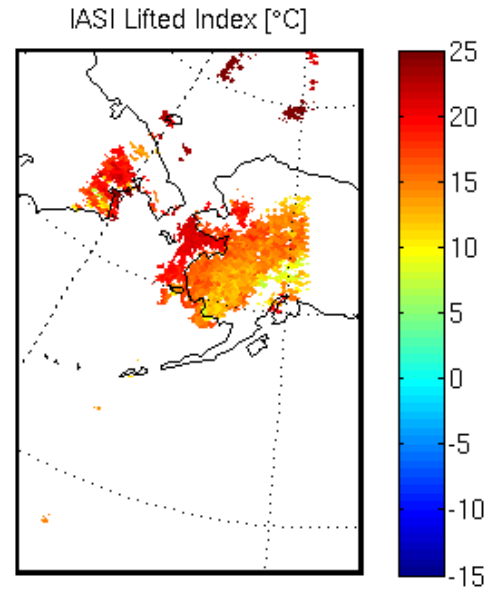




IASI and CrIS differences 500 hPa T & LI (01 Nov 2012)

21:29 UTC





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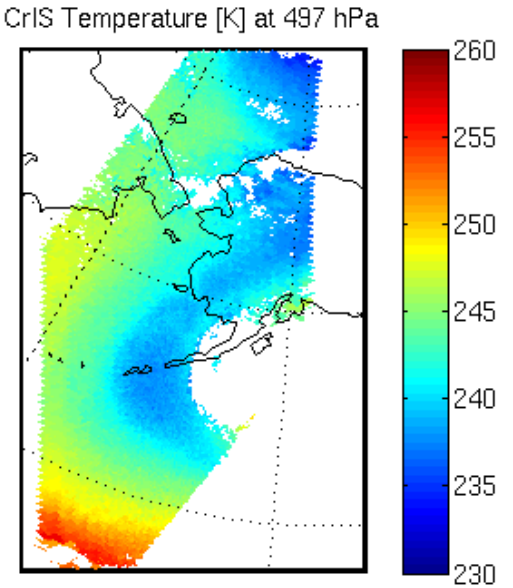
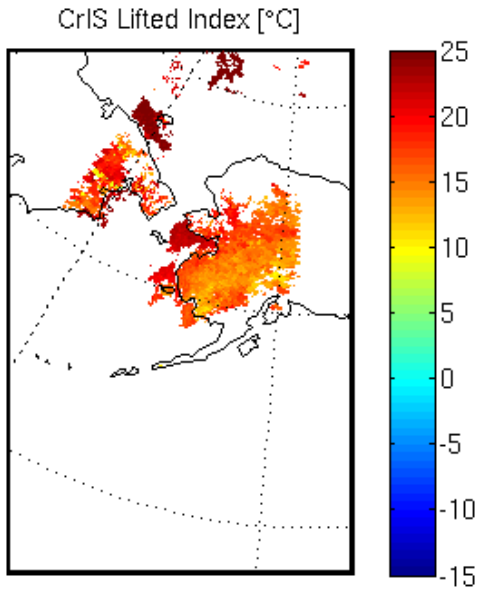
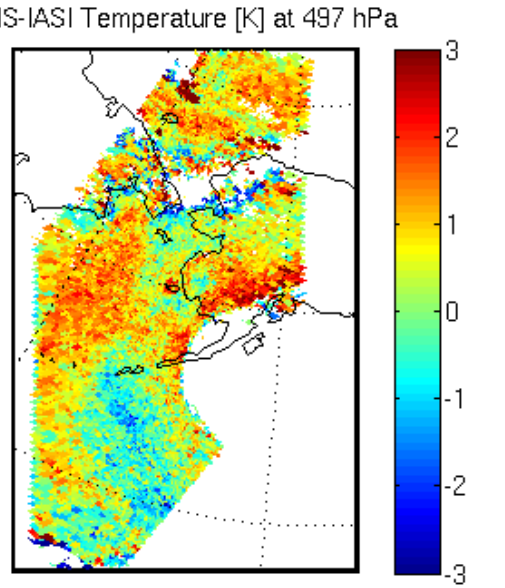
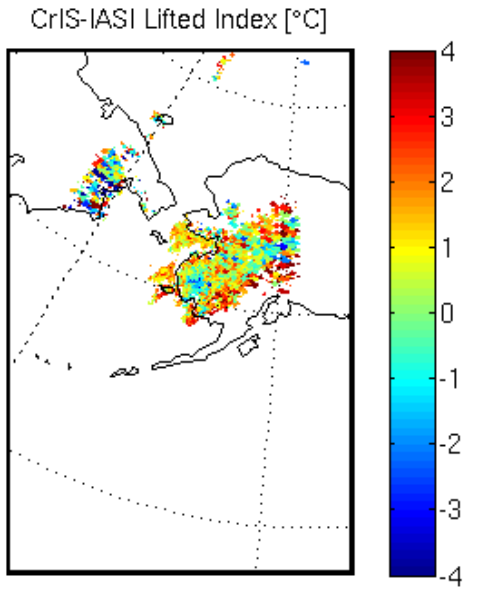




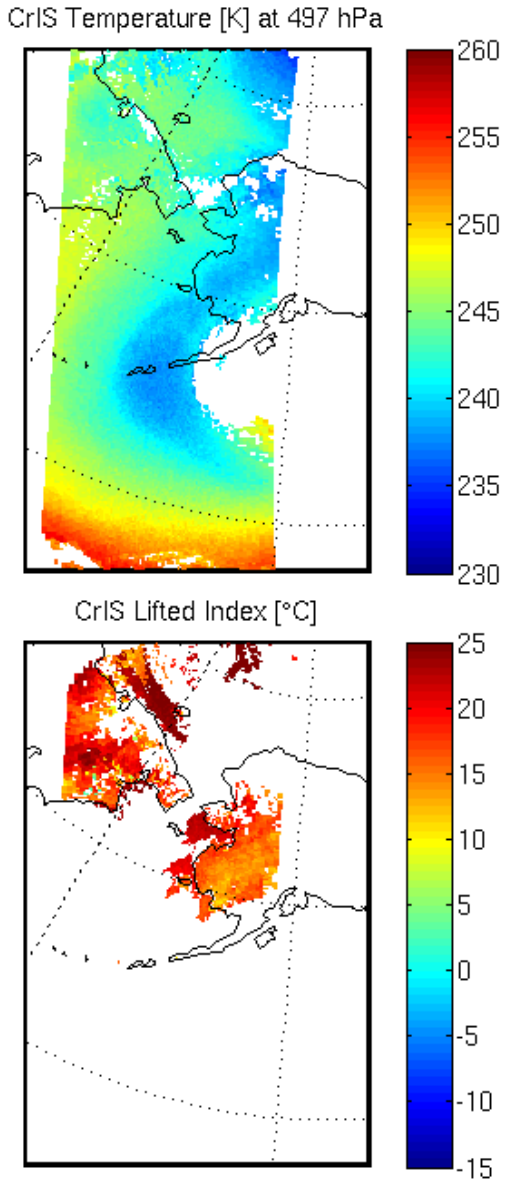
~ 1.8 hour change



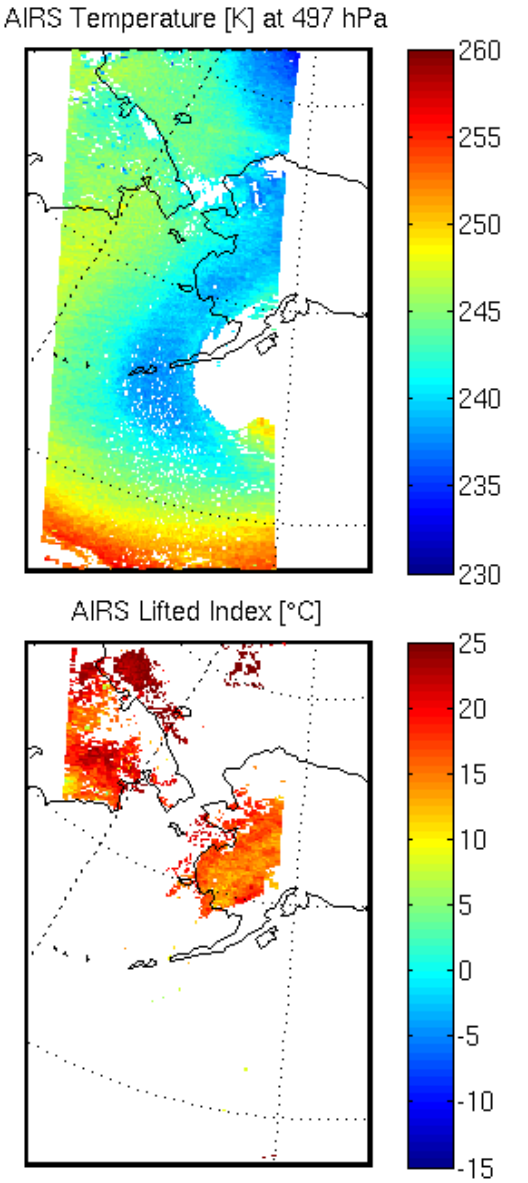


CrIS and AIRS differences 500hPa T & LI (01 Nov 2012)

23:19 UTC



23:47 UTC



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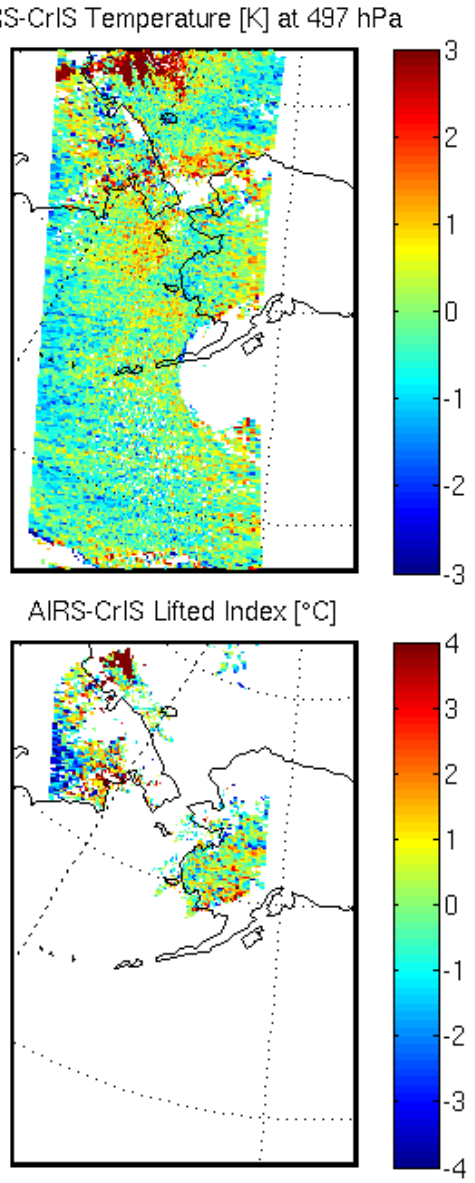
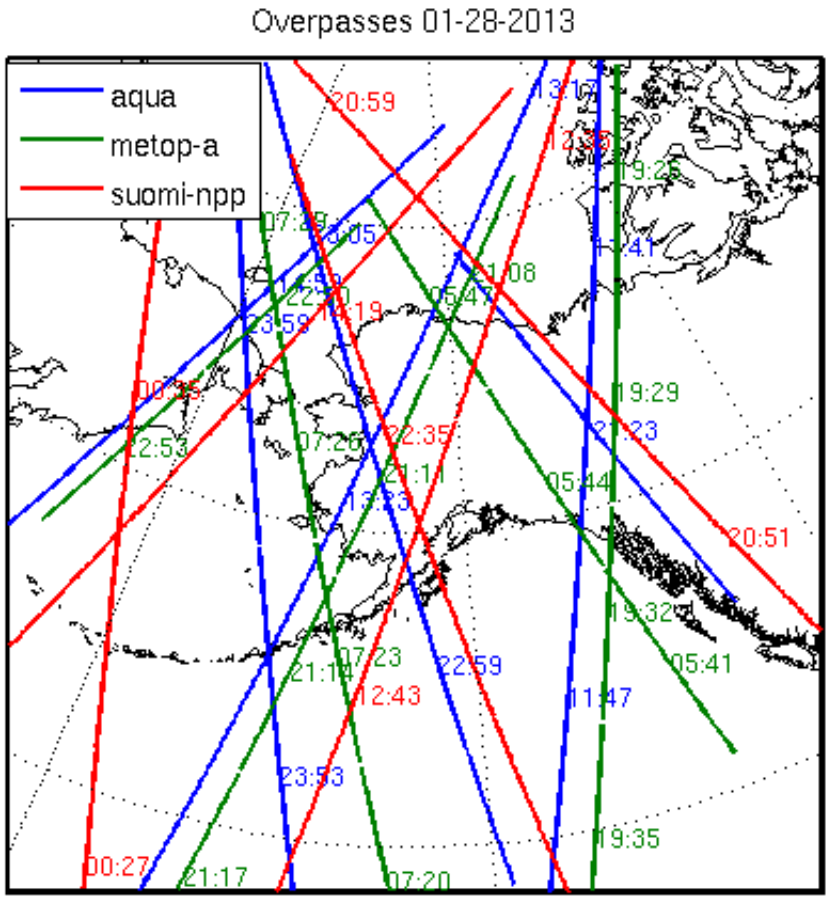
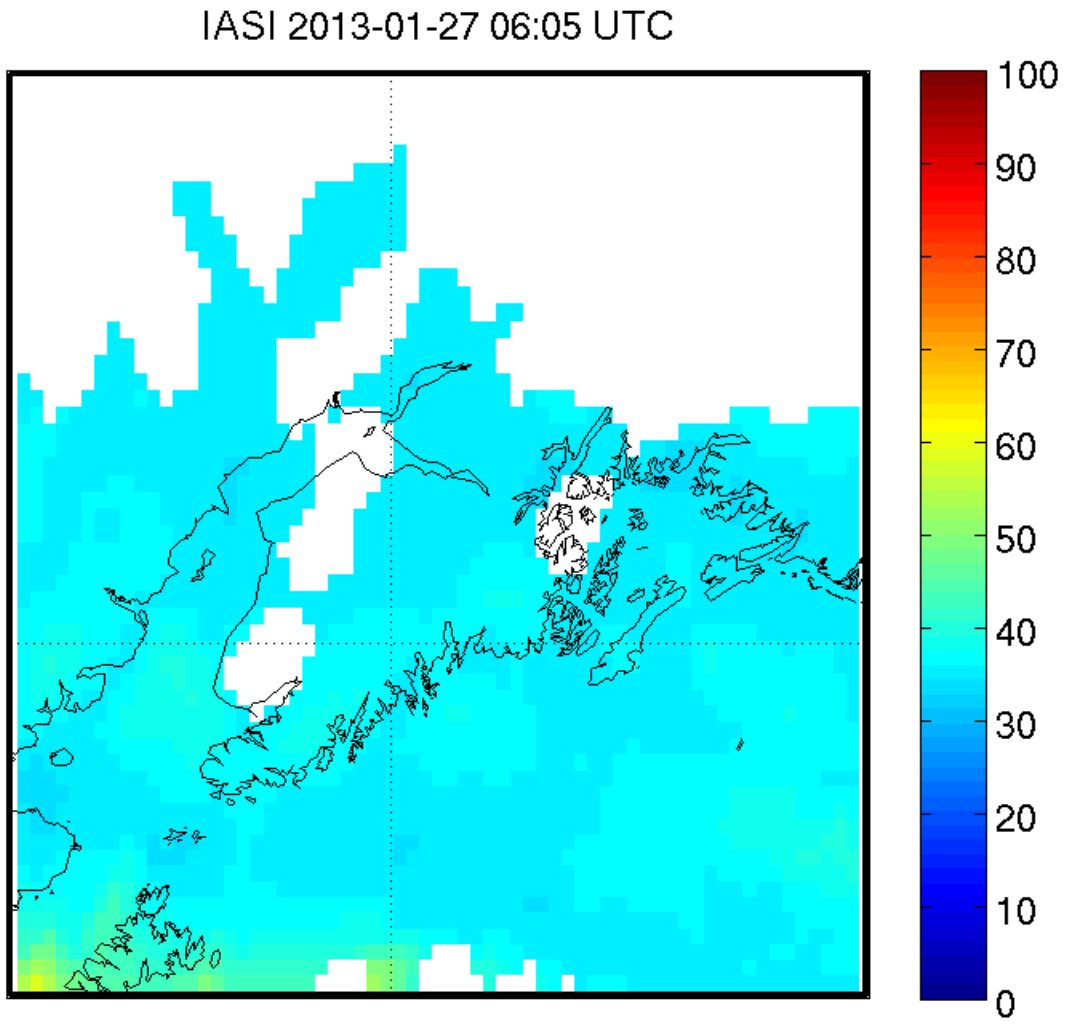


28 Jan 2013 – satellite overpasses used to create atmospheric water vapor animation



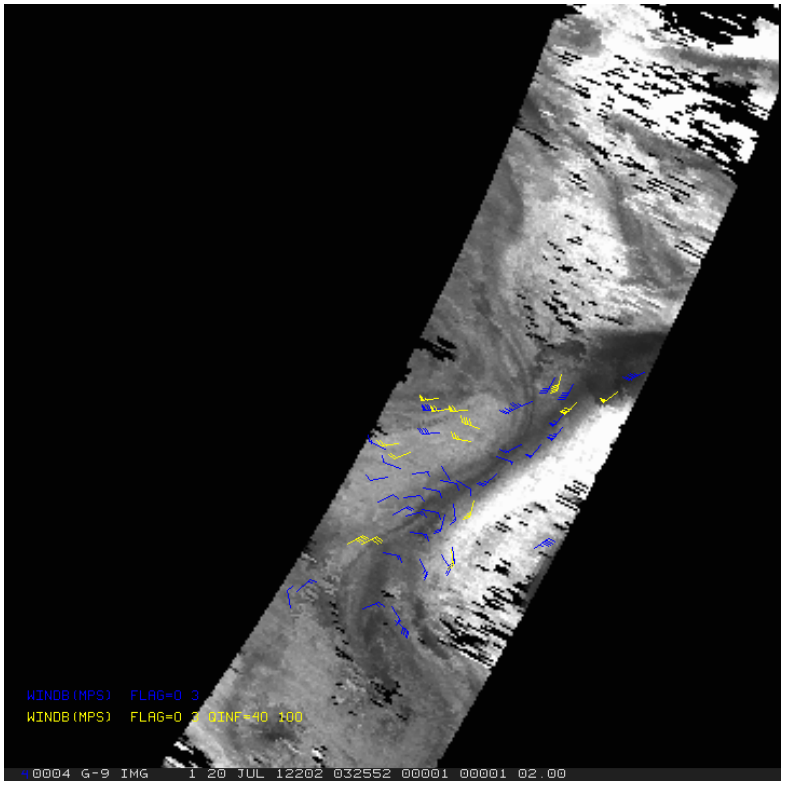
Note: AIRS 23:53 (G239) and 23:59 (G240) from 01-27-2013

Moisture Changes and Motion from Consecutive Polar Satellite Overpasses of North Alaska

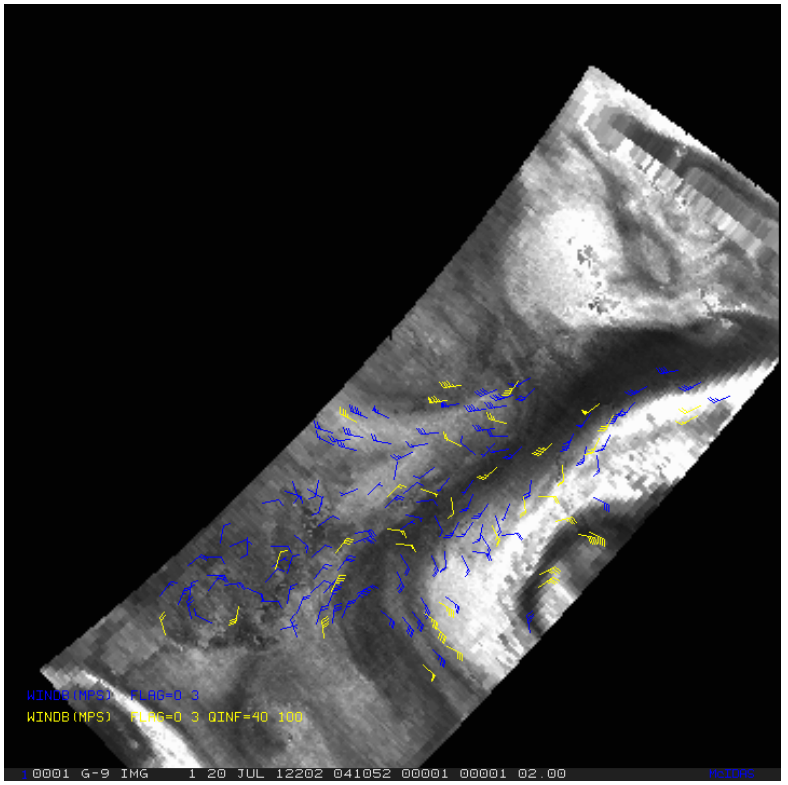


Relative Humidity [%] at 300 hPa Movie (27 - 29 Jan 2013)

AIRS and ATMS H_2O Retrieved Winds at 400hPa



AIRS 20 July 2012 0505 UTC



ATMS 20 July 2012 0551 UTC

Specific humidity retrievals.
All winds (blue); Quality controlled winds(yellow)

Consecutive Water Vapor Soundings Provide Altitude Resolved Atmospheric Motion Vectors

Summary

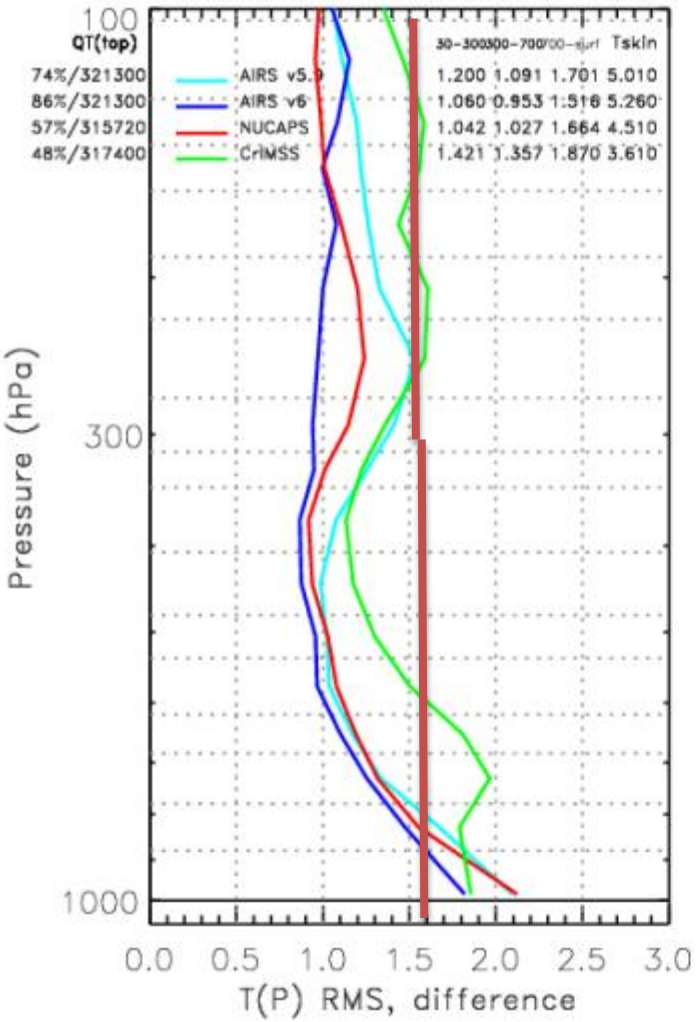
- There are four satellites in Polar orbit carrying ultraspectral sounding instruments
- These four satellites provide high temporal resolution sounding and imagery for the Alaskan region
- The sounder data provides quantitative interpretation of weather imagery (e.g., the altitude of cloud and moisture features)
- High temporal frequency of polar satellite soundings at high latitudes enables the observation of atmospheric tendencies (e.g., stability change) and moisture flux and wind profiles

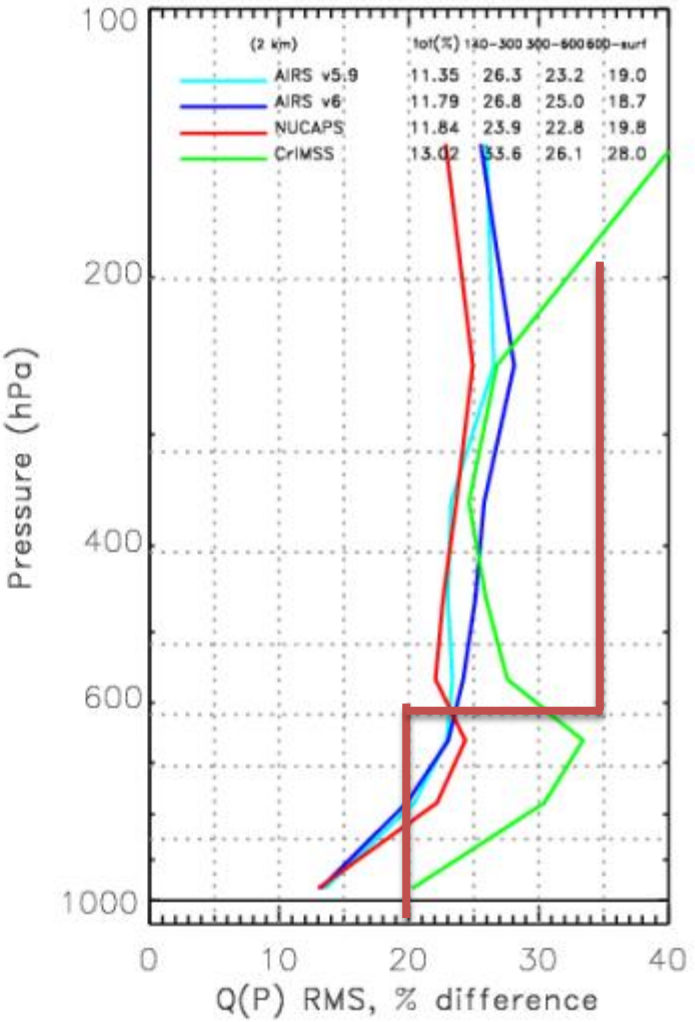
Comparison of CrIMSS and NUCAPS EDRs

	CrIMSS-EDR	NUCAPS-EDR
Methodology	Simultaneous Optimal Estimation	Sequential Singular Value Decomposition
Channels used	All, except non-LTE in daytime	Selected subsets
Clouds	Cloud clearing, 3-cluster approach	Cloud clearing, 9-FOV approach
Forward model	OSS for both IR and MW	Sarta for IR, MIT for MW
Apodization	Blackman-Harris	Hamming
Regularization	T/q/O3/ε covariance matrices	dR/dX for state parameters held constant + smoothing
EDRs IPs RIPs	AVTP, AVMP, AVPP O3-IP RIPs: SST, LST, emissivity	AVTP, AVMP, z(p), CCR, O3, CO, CO2, CH4, HNO3, SO2, N2O, SST, LST, emissivity, cloud fraction and pressures, convective parameters
Format	42, 1-km AVTP layers 22, 2-km AVMP layers	All profiles on 100 levels (~0.025 km) Full state (can compute radiances).
Maturity Schedule	Beta: July 2012 Provisional: Dec. 2012 Stage.1 Validated: June 2013 Stage.2 Validated: Dec. 2013	Beta: Apr. 2012 (internal only) Provisional: July 2012 (internal only) Stage.1 Validated: Feb. 2013 Stage.2 Validated: Apr. 2014

NUCAPS vs CRIMSS vs AIRS

Statistics for May 15, 2012 focus day in which Aqua and NPP orbits has high coincidence.



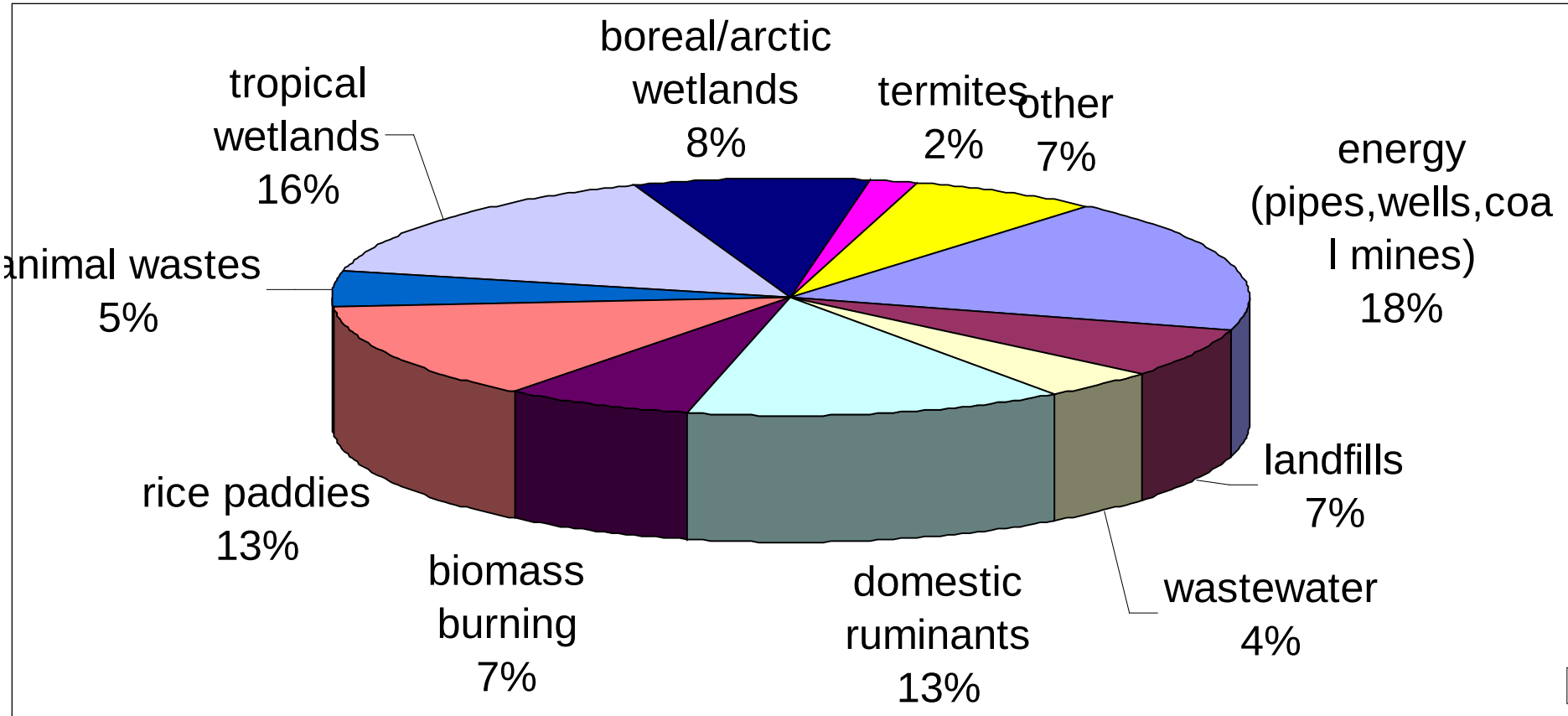


Trace Gas Products fro Hyperspectral IR sounders

gas	Range (cm^{-1})	Precision (Goal)
O_3	1025-1050	10%
CO	2080-2200	15%
CH_4	1250-1370	20 ppb
CO_2	680-795 2375-2395	2 ppm 2 ppm
SO_2	1340-1380	500%
HNO_3	860-920 1320-1330	40% 25%
N_2O	1250-1315 2180-2250	10% 10%
$CFCl_3$ (F11)	830-860	20%
CF_2Cl (F12)	900-940	20%
CCl_4	790-805	50%

Held Fixed

Methane Sources



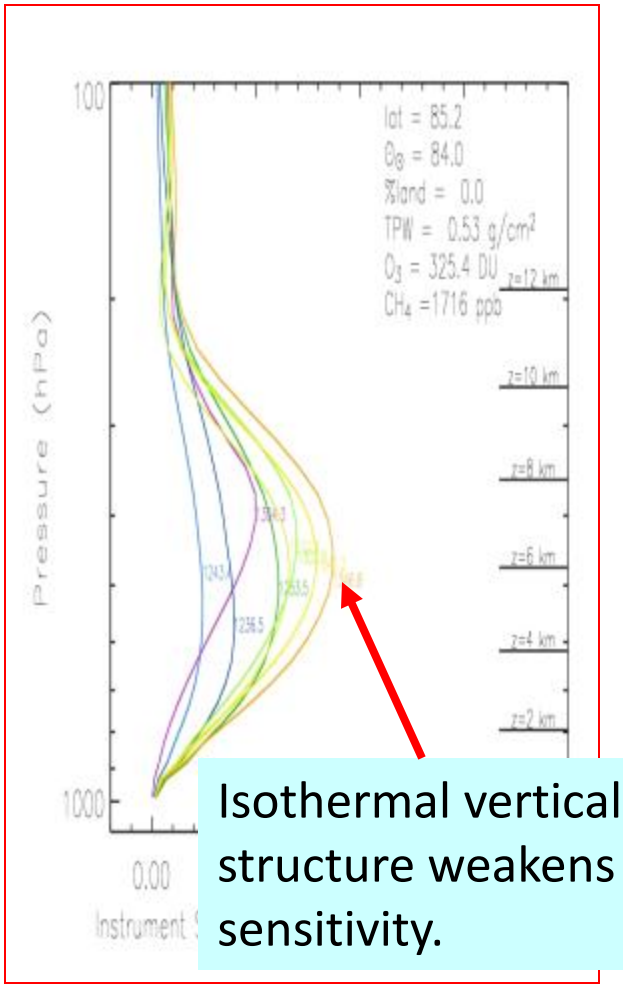
Ref.: Lelieveld, 1998 & Houwelling 2002 (600 Tg total)

Note: Approximately 50% of sources are anthropogenic

Trees (Keppler et al. 2005) may contribute 62-235 Tg (10-35%), mostly in tropics

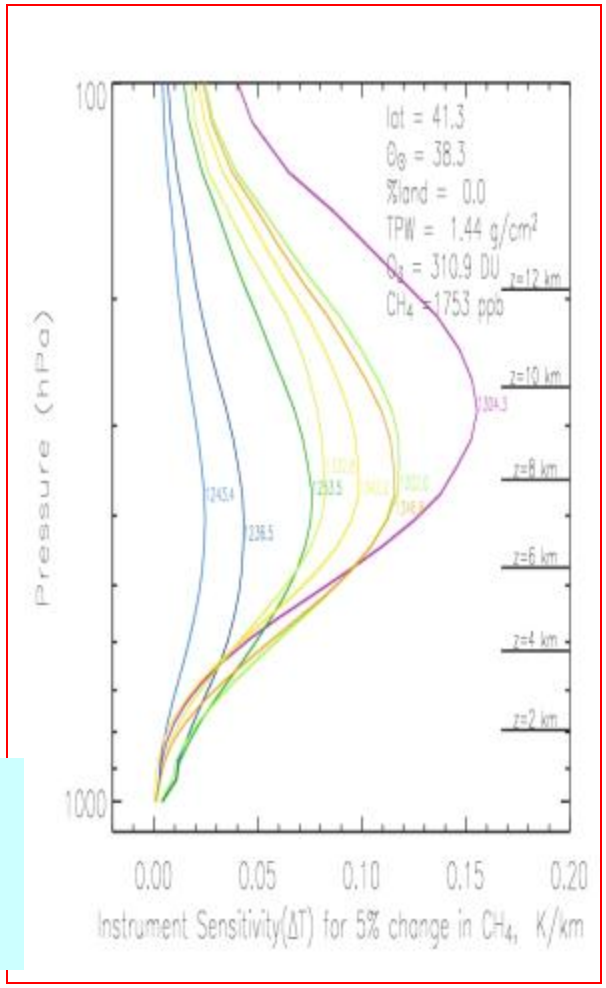
AIRS CH_4 Kernel Functions are Sensitive to $H_2O(p)$ & T(p)

Polar

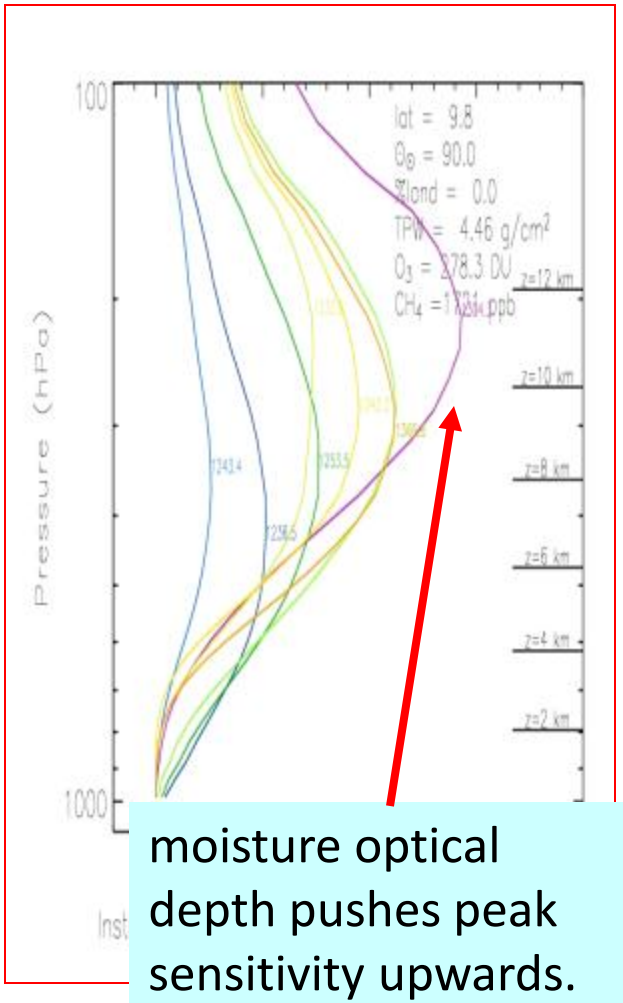


Isothermal vertical structure weakens sensitivity.

Mid-Latitude



Tropical

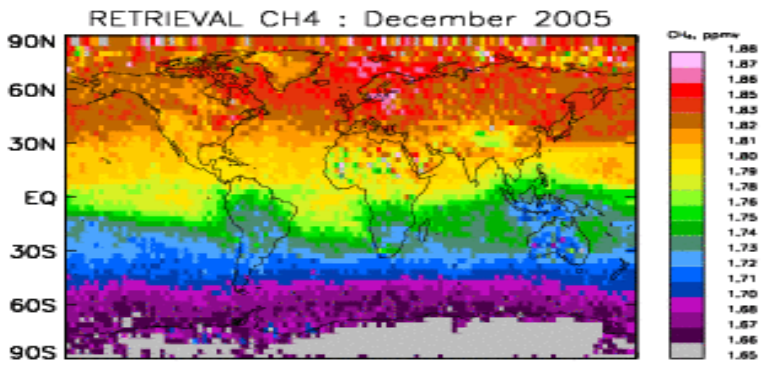


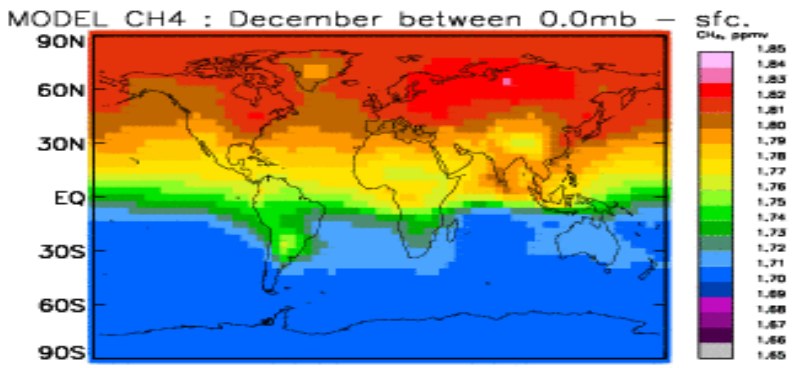
moisture optical depth pushes peak sensitivity upwards.

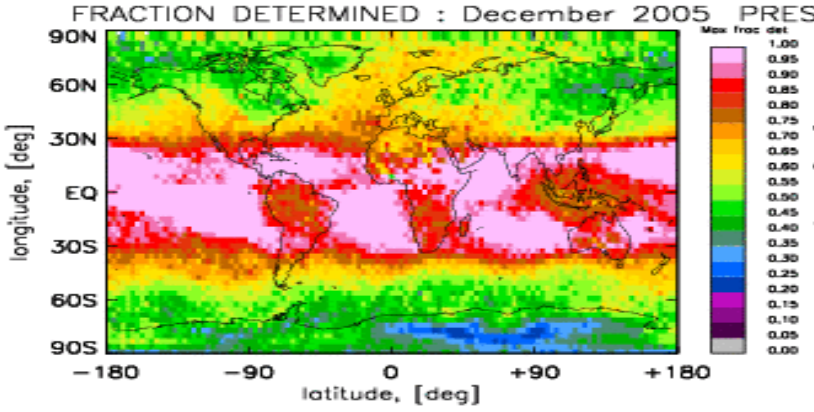
Also providing the vertical information content to understand CH4 product

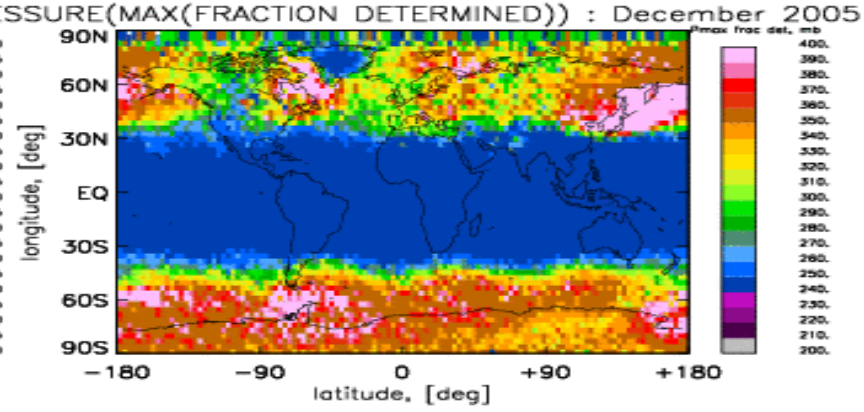
AIRS mid-trop measurement column

CH4 total column f/ transport model (Sander Houweling, SRON)









Fraction Determined from AIRS Radiances

Peak Pressure of AIRS Sensitivity

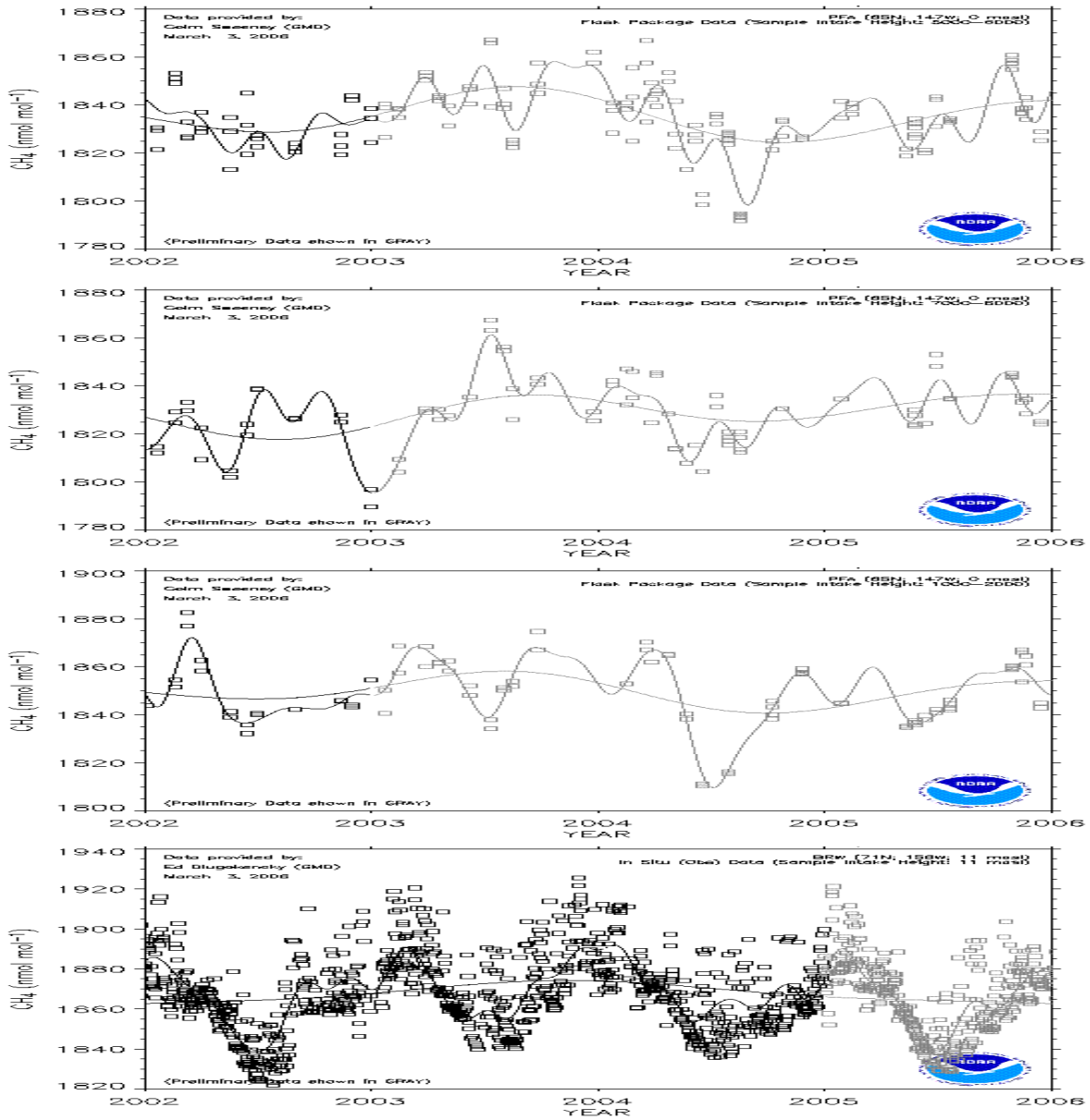
CMDL Flask Data Poker Flats, Alaska shows that the Seasonal cycle is a function of altitude

7.5 km
385 mb

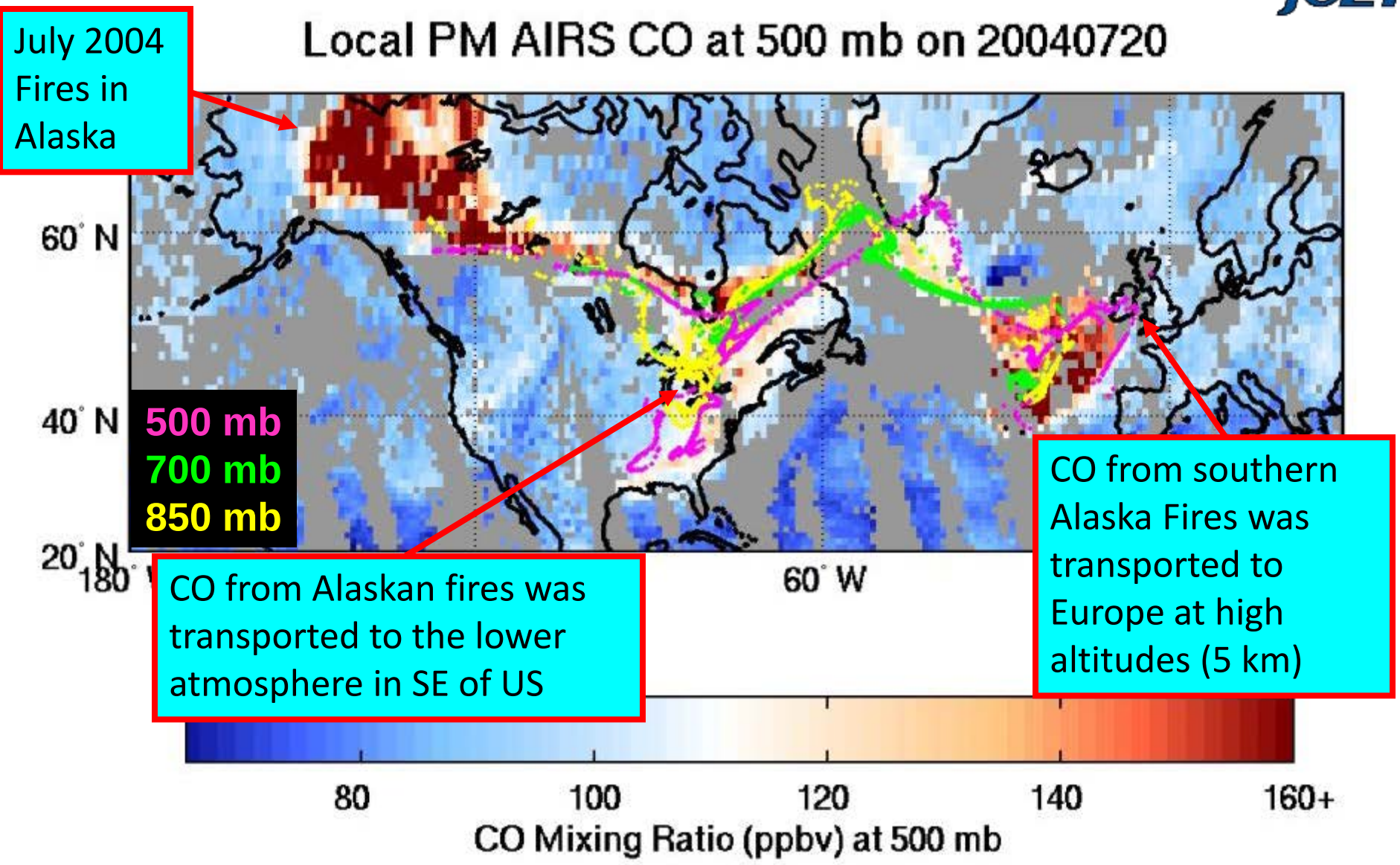
5.5 km
500 mb

1.5 km
850 mb

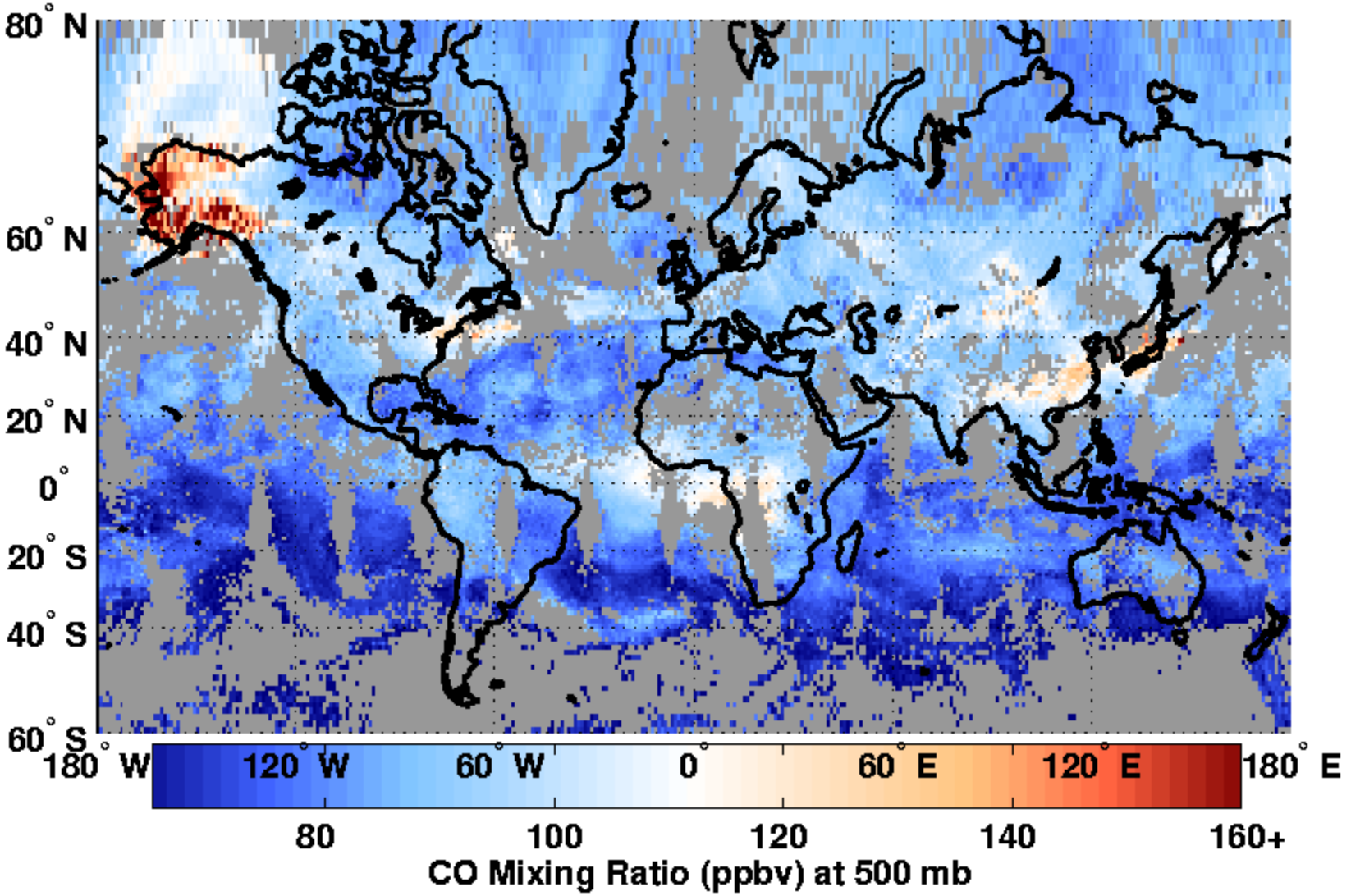
Surface Flasks
(Barrow)



Example of AIRS CO Product and Use of Trajectory Models



July 2004 AIRS Daily Global CO



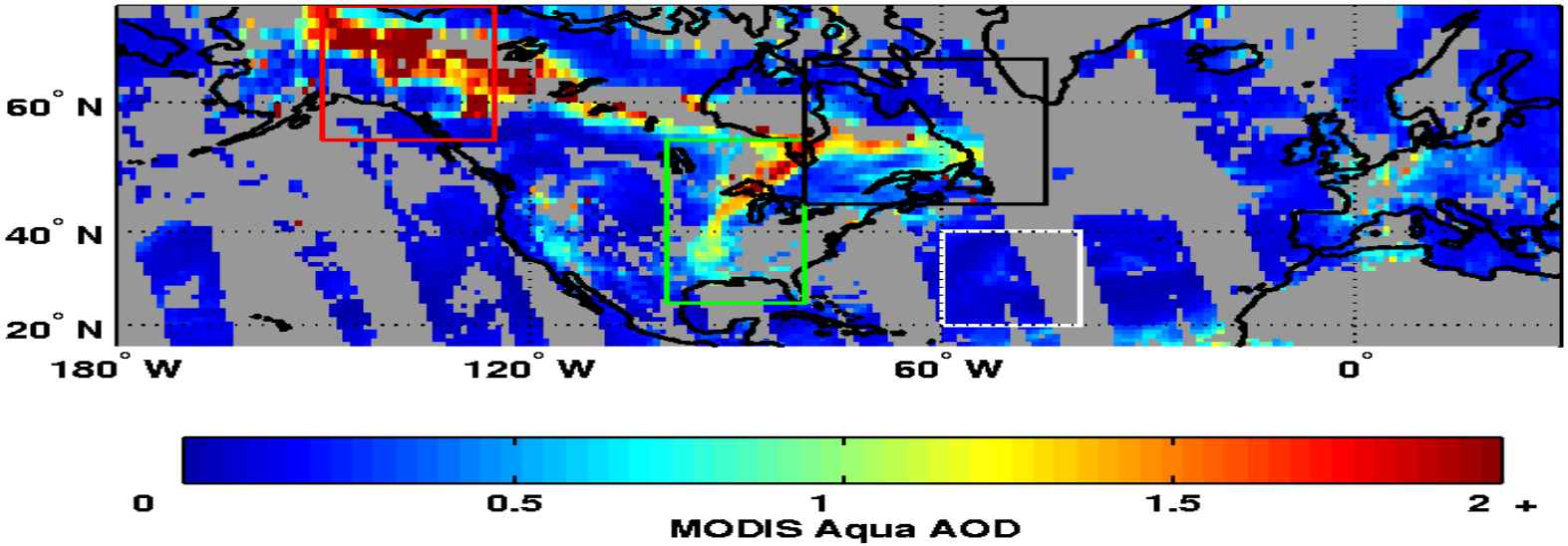
UMBC

JCET

UMBC

JCET

Local PM MODIS Aqua AOD on 20040718



From Wallace McMillan, UMBC

Local PM AIRS CO at 500 mb on 20040718