Atmospheric Profile and Cloud Parameter Retrievals from Hyperspectral Infrared Radiances

UW HS retrieval package V1.0

For AIRS, IASI and CrIS L1 to L2 Processing

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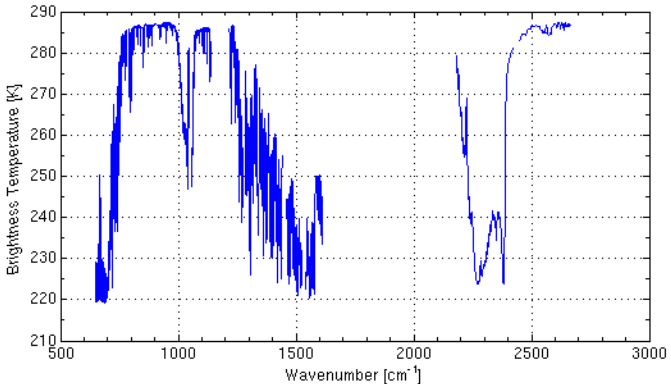
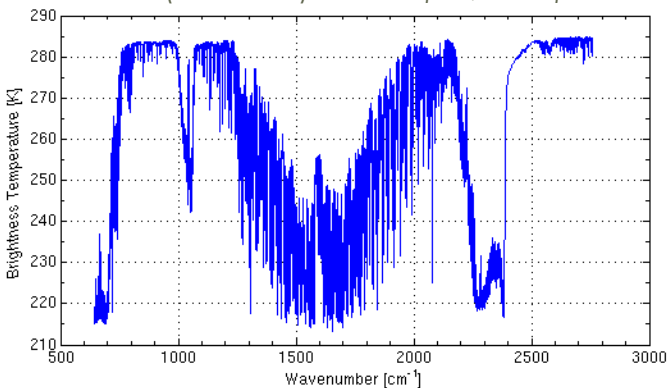
Introduction

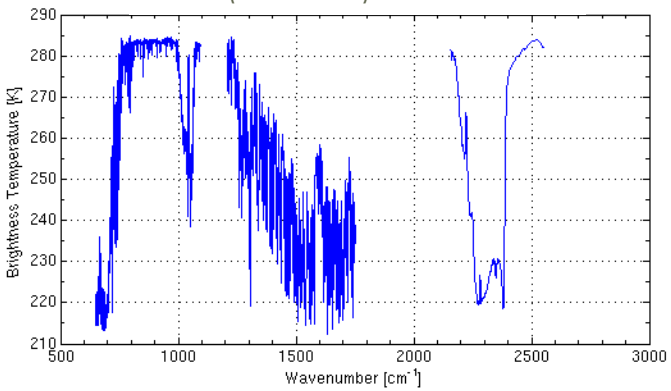
AIRS (nch=2378) *on Aqua*



IASI (nch=8461) *on Metop-A, Metop-B*



CrIS (nch=1305) *on Suomi-NPP*



We want to provide the scientific community with the ability to obtain real-time production of accurate physical parameters (profiles, surface and cloud products) from hyper-spectral radiance measurements (AIRS, IASI, CrIS) at single FOV resolution.

Accurate soundings under clear and cloudy conditions (thin, broken) provide mesoscale atmospheric structure information needed to improve NWP and severe weather forecasts.

The UW hyper-spectral retrieval package, based on the Dual-Regression (DR) retrieval algorithm, is the only publicly available retrieval software package to convert hyper-spectral radiance measurements (Level 1) to retrieval (Level 2) products.

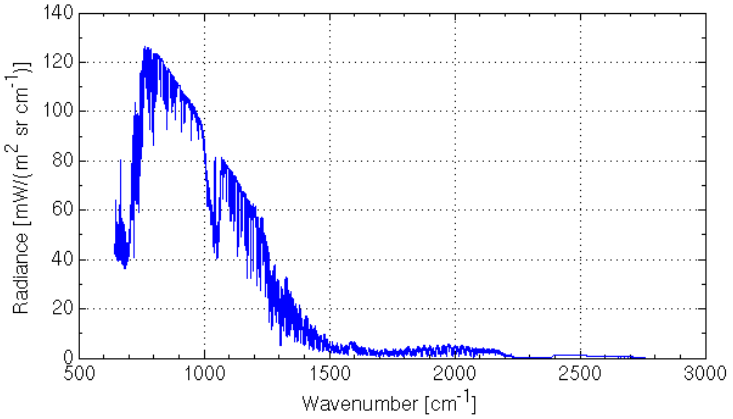
Infrared Radiance and Brightness Temperature Spectrum

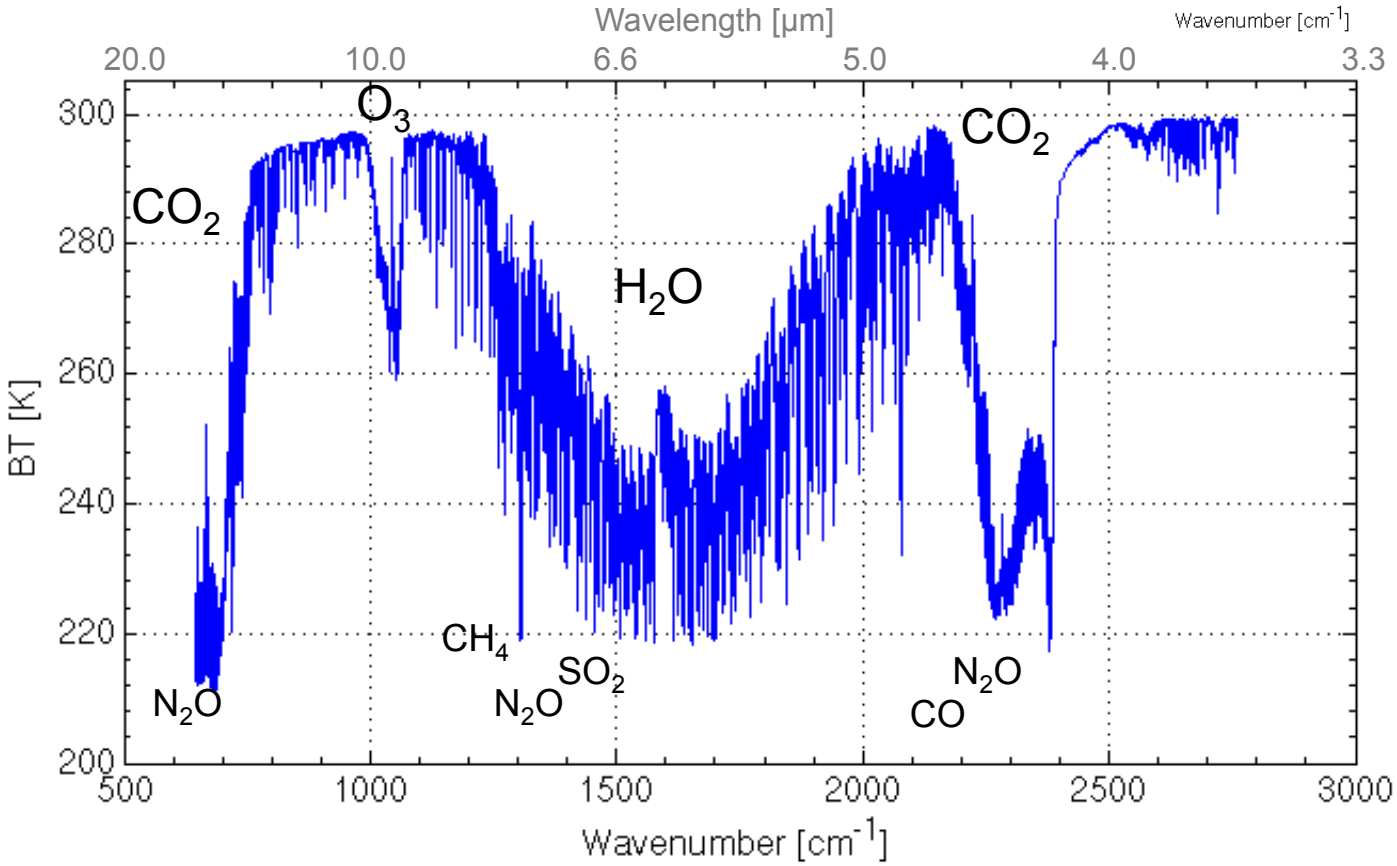
Planck Function

$$B_\nu(T) = \frac{2hc^2\nu^3}{\exp(\frac{hc\nu}{kT}) - 1}$$

Upwelling IR radiation

$$R_\nu = \int_{z_0}^{\infty} B_\nu(T(z)) \frac{d\tau_\nu(z)}{dz} dz$$

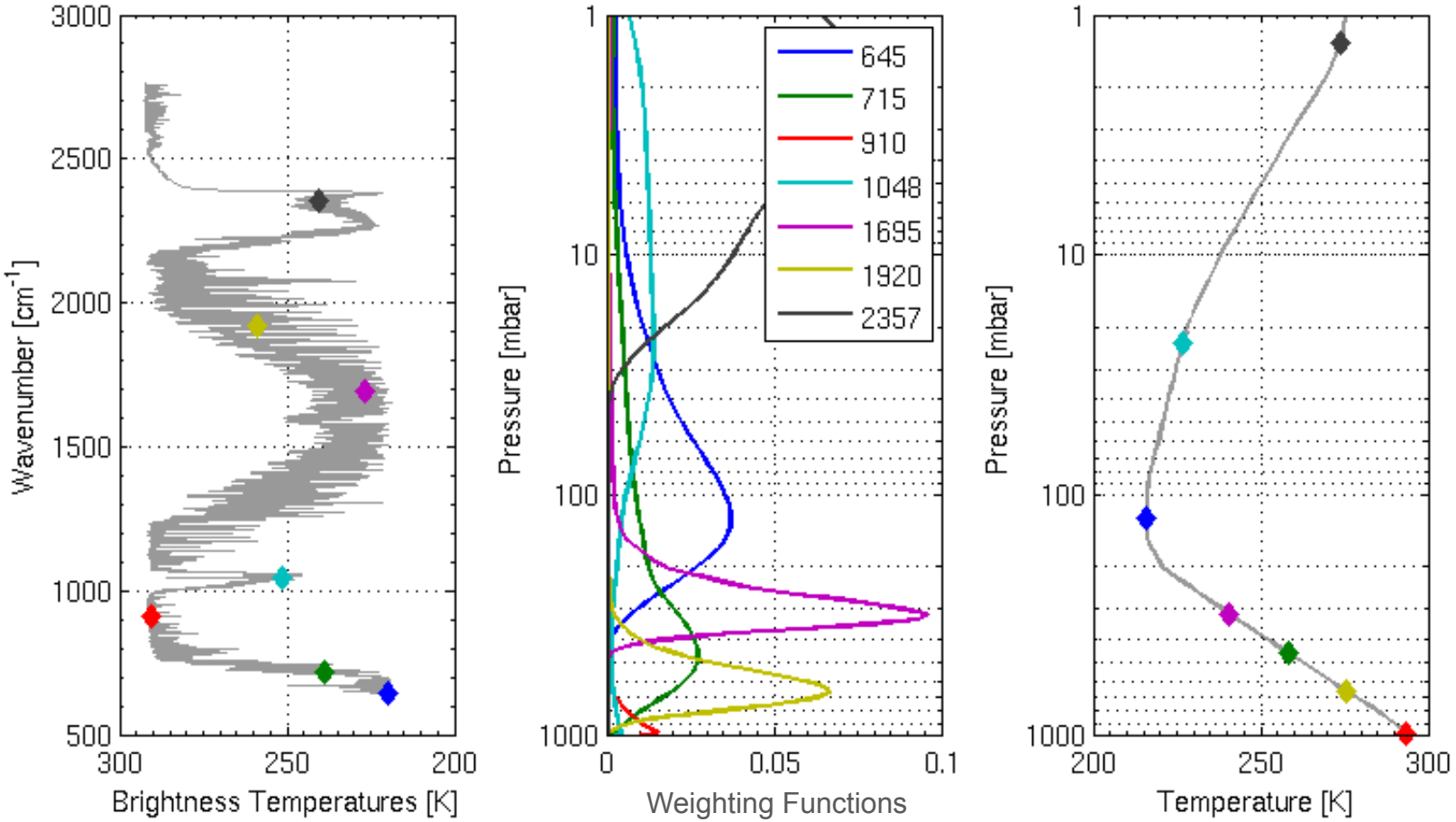




Atmospheric Temperature Profile Retrieval

$$R_\nu = \int_{ps}^{0} B_\nu(T(p)) W_\nu(p)\, dp$$

$$W_\nu(p) = \partial\tau_\nu(p) \Big/ \partial \ln p$$



High-spectral measurements → Profiles at high-vertical resolution

Regression Basics 1

1. Regression Model

$$X = C\ Y^T$$

2. Least squares regression solution

$$C = X\ Y\ (Y^T\ Y)^{-1}$$

Y … Measurements [nprofs x nchannels]

C ... Regression coefficients [nlevels x nchannels]

X ... Atmospheric variables [nlevels x nprofs]

Regression Basics 2

Simple Regression Retrieval

1. Calculate Regression Coefficients

$$C = X_{tr}\, Y_{tr}\, (Y_{tr}^{T}\, Y_{tr})^{-1}$$

X_{tr} … training profiles, surface and cloud parameters

Y_{tr} … training simulated radiances

2. Perform Retrieval (RTV)

$$X = C\ Y^{T}$$

X … retrieval product

Y … real radiance measurements

Regression Basics 2

Simple Regression Retrieval

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Eigenvector Regression Retrieval

1. Calculate Regression Coefficients

$$C = X_{tr}\, A_{tr}\, (A_{tr}^{T}\, A_{tr})^{-1}$$

X … training profiles, surface and cloud parameters

$A_{tr} = Y_{tr}U$…compressed training radiances [nprofs x npcs]

U…first few eigenvectors of $Cov(Y_{tr})$ [npcs x npcs]

2. Perform Retrieval (RTV)

$$X = C\, A^{T}$$

A … real compressed radiance observations, A=YU

X … retrieval product

Regression Retrieval Summary

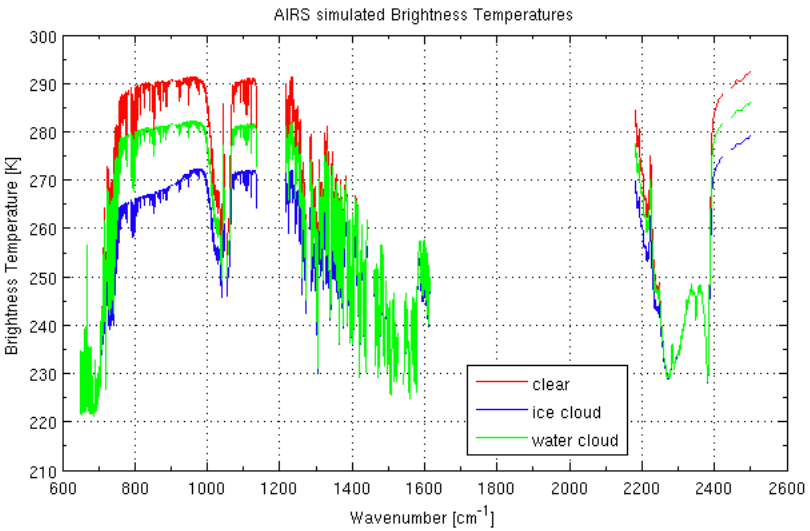
Training Set

↓

Simulated Radiances

↓

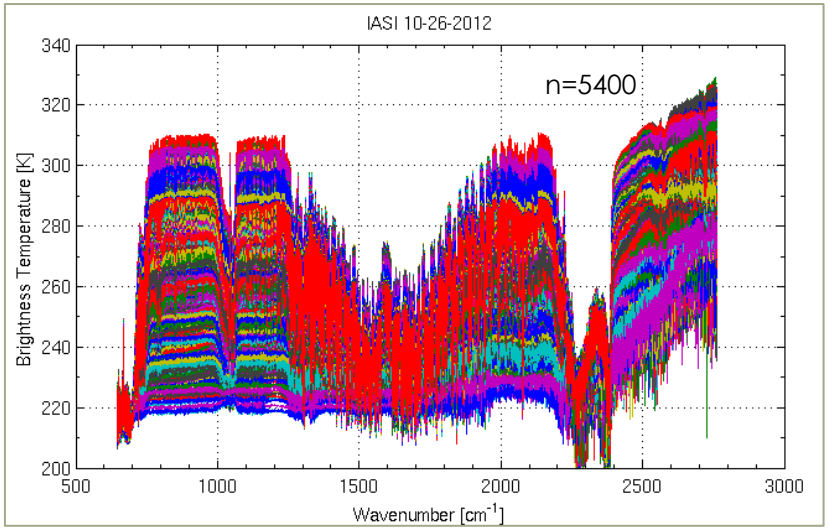
Regression Coefficients



Radiances
AIRS L1B, IASI L1C, CrIS SDR

Retrieval

Temperature, Moisture and Ozone profiles, Surface and cloud parameters ….



Dual-Regression Retrieval

Global Clear Soundings

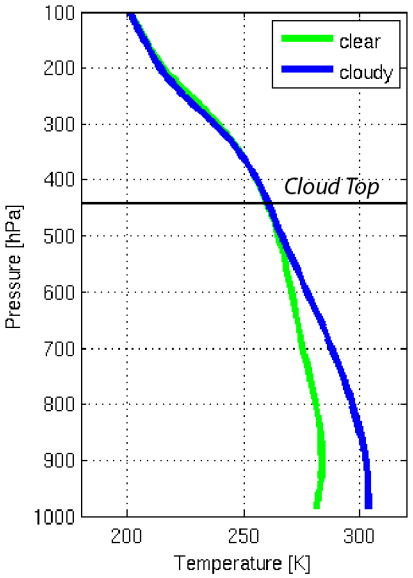
Radiances
(calculated with clear FM)

Clear trained
EOF regression results

Global Cloudy Soundings

Radiances
(calculated with cloudy FM)
8 cloud height classes (100-1000 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 level
- cloud-trained below cloud level

Dual-Regression Retrieval Parameters

- atmospheric temperature [K] at 101 pressure levels
- atmospheric humidity [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 instrument spectral resolution
- total precipitable water (vertically integrated from 100 hPa to surface) [cm]
- precipitable water 1, 2, 3 (vertically integrated from 900 hPa to surface, 700 to 900, 300 to 700 hPa) [cm]
- total ozone amount (vertically integrated) [dobson units]
- lifted index [^{o}C]
- convective available potential energy [J/kg]
- CO_2 concentration [ppmv]
- cloud top pressure [hPa]
- cloud top temperature [K]
- cloud optical thickness
- effective cloud emissivity
- cloud mask (values: 0 clear, 1 cloud)

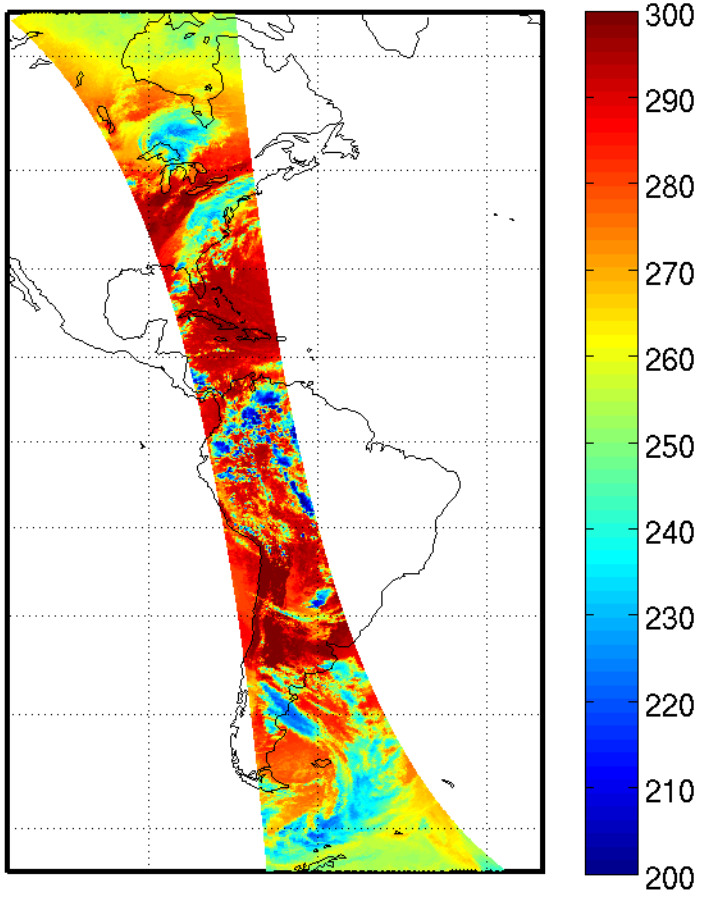
We also output:

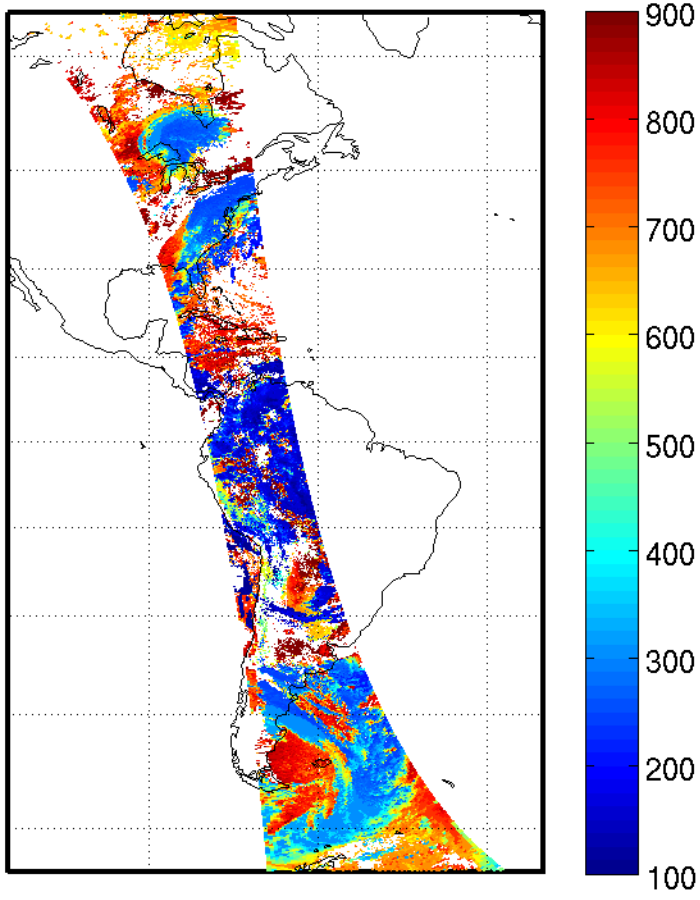
- latitude [degrees] , longitude [degrees]
- pressure levels [hPa]
- surface emissivity wavenumbers [cm^-1]
- channel index (indices of good channels used in retrieval)
- quality flag (1 x 3)
- GDAS surface pressure, temperature and relative humidity (gdas values interpolated to sounder grid)

Output Format: hdf5

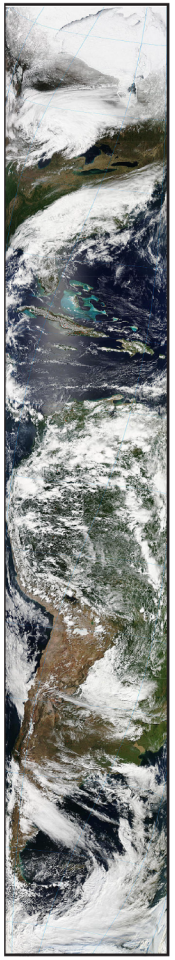
Runtime: ~200 sec /12150 FOVs ➔ ~0.02 sec/FOV

AIRS CTOP • 18 April 2012

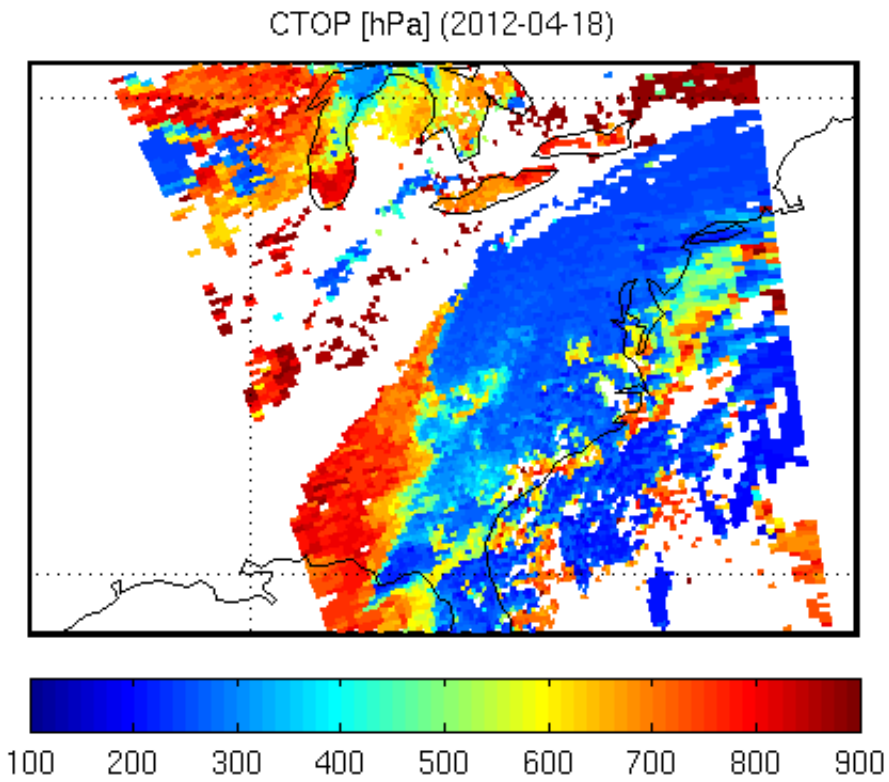




MODIS VIS



AIRS CTOP • 18 April 2012



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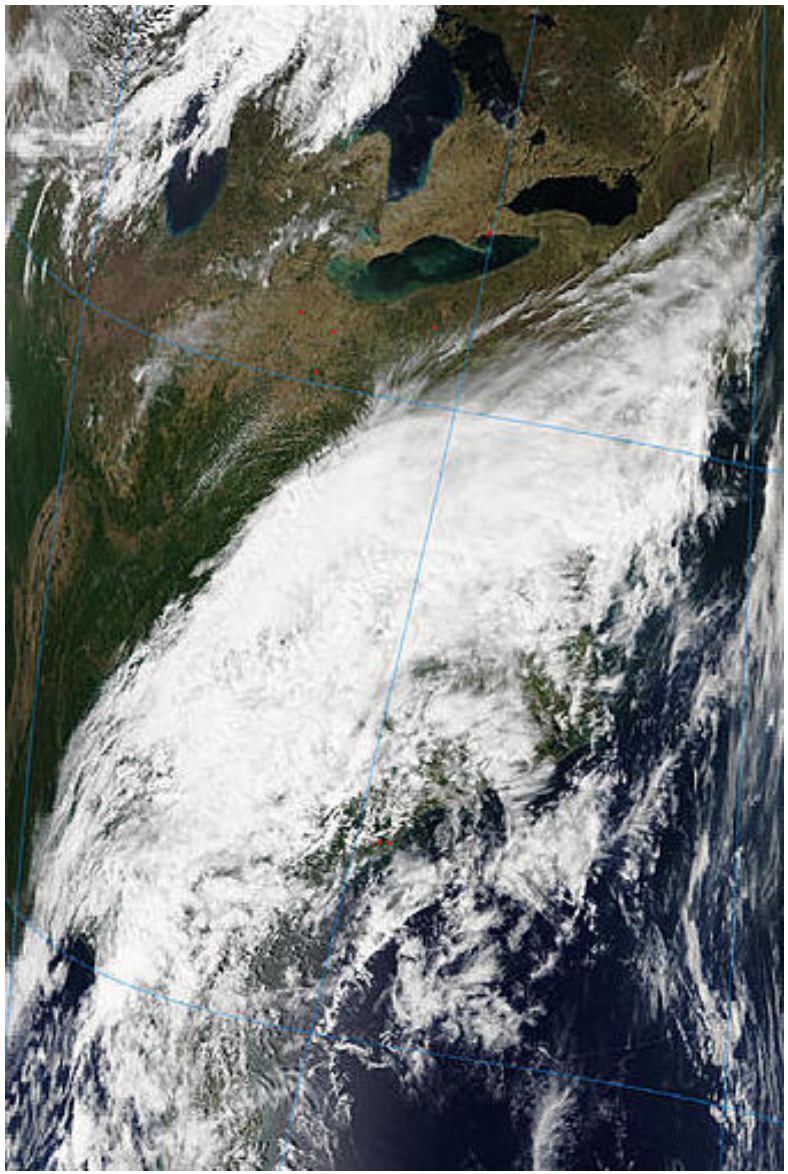
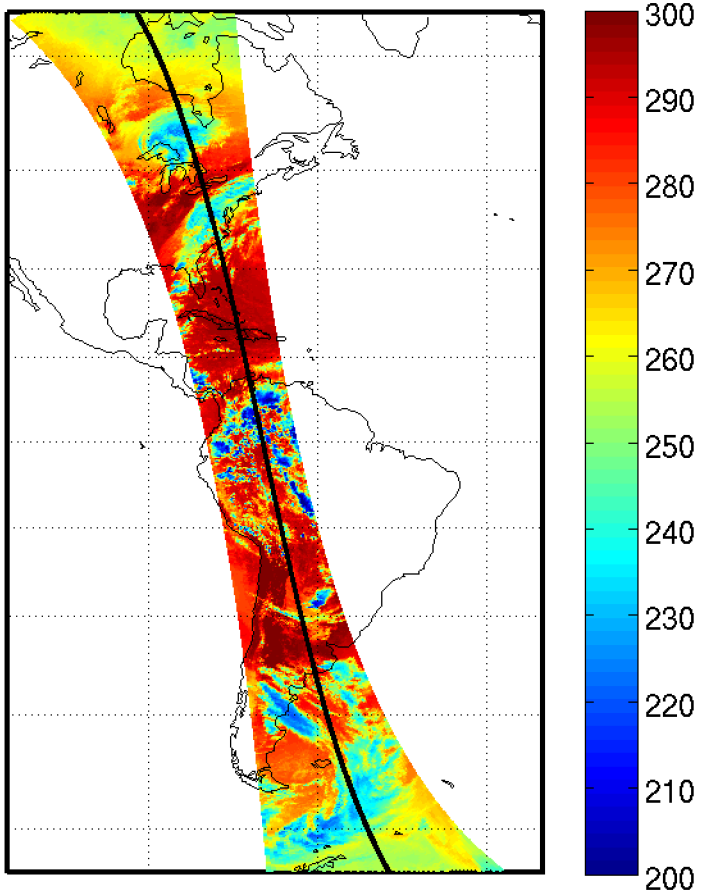
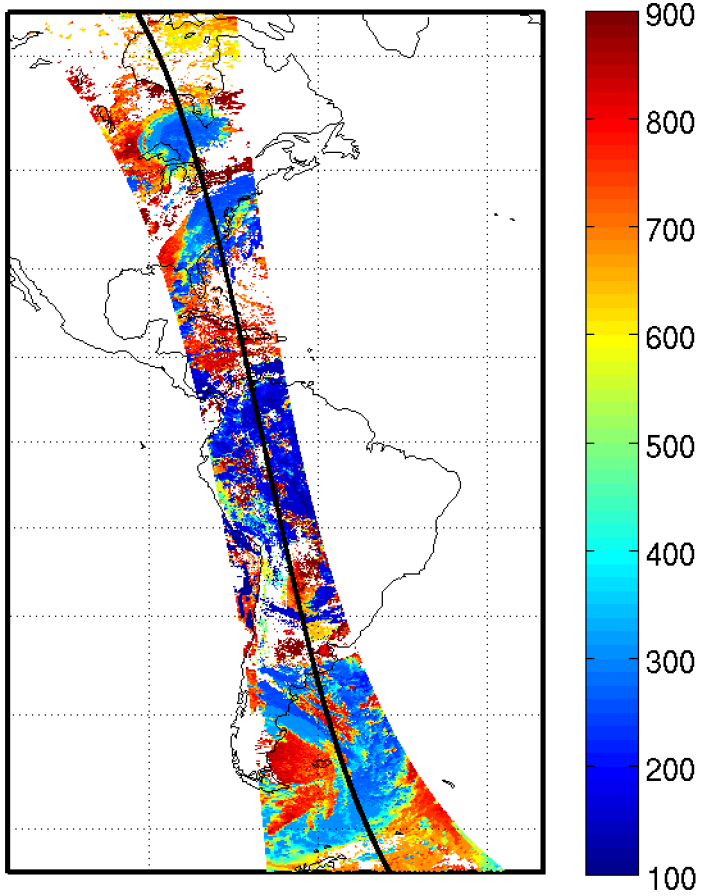


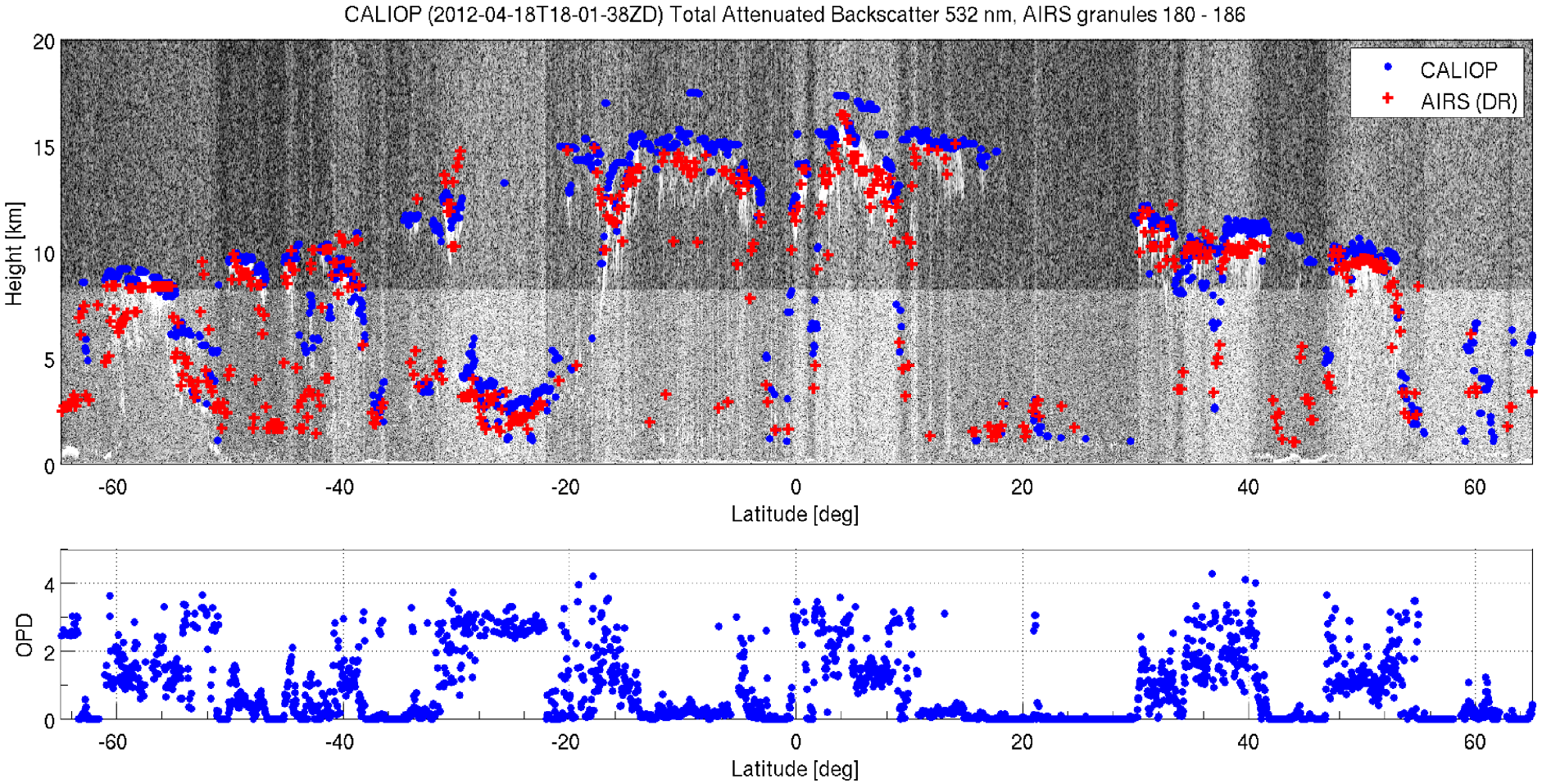
AIRS CTOP • 18 April 2012





MODIS VIS

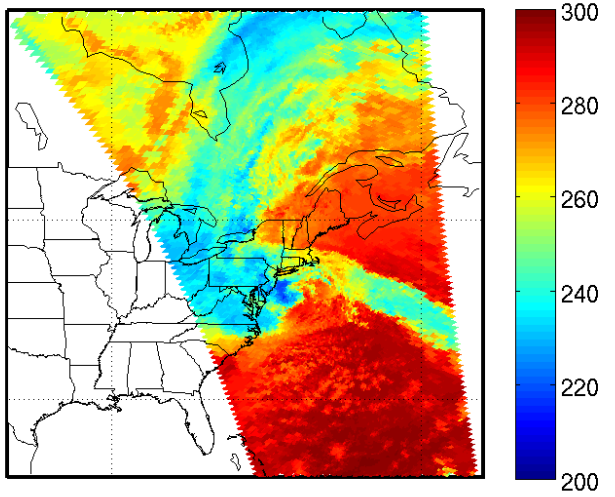
AIRS CTOP • April 18 2012 • Comparison with CALIPSO



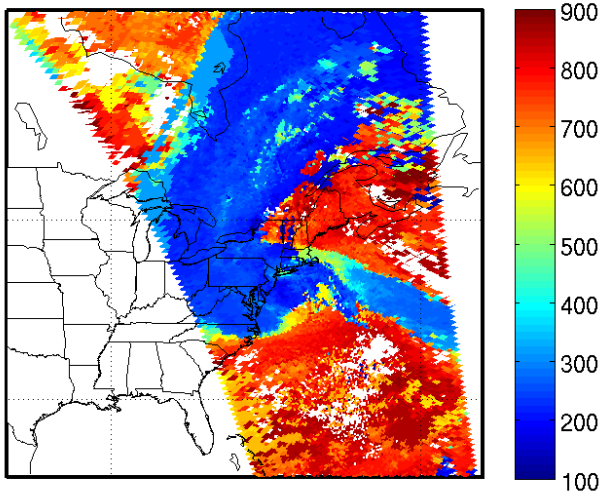
CrIS CTOP • Super-Storm Sandy 29 Oct 2012

CrIS 17:19-17:43 UTC

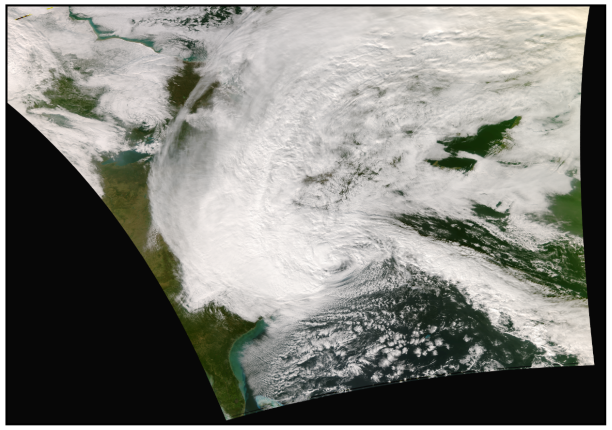
CrIS BT [K] at 910.0 cm^{-1}



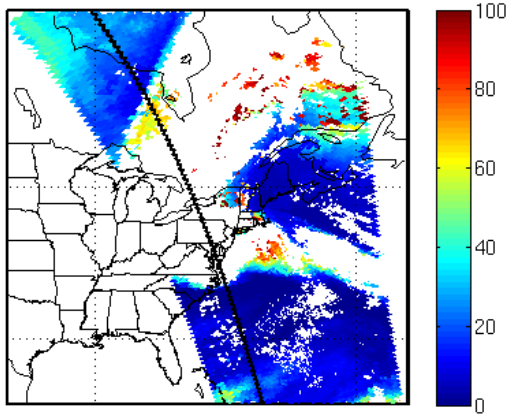
CrIS CTOP [hPa]



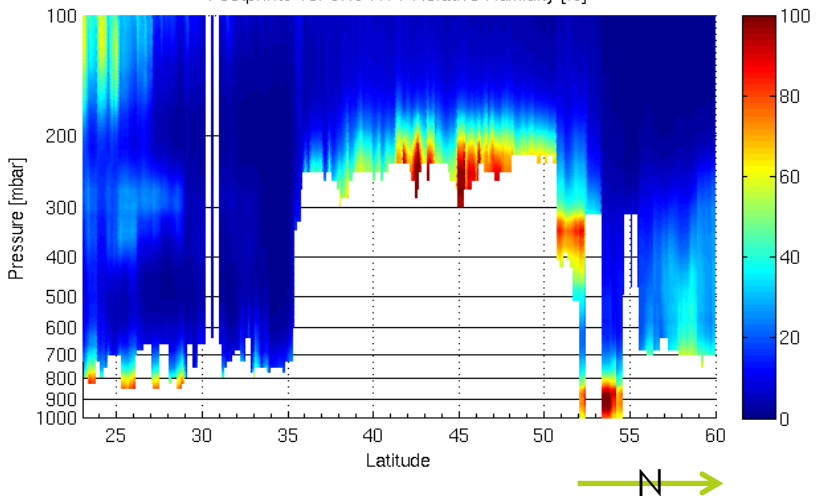
VIIRS True Color (29 Oct 2012)



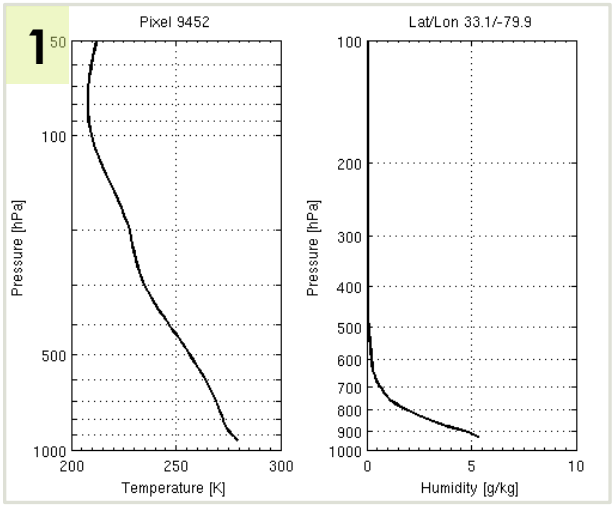
CrIS RH [%] at 400 hPa

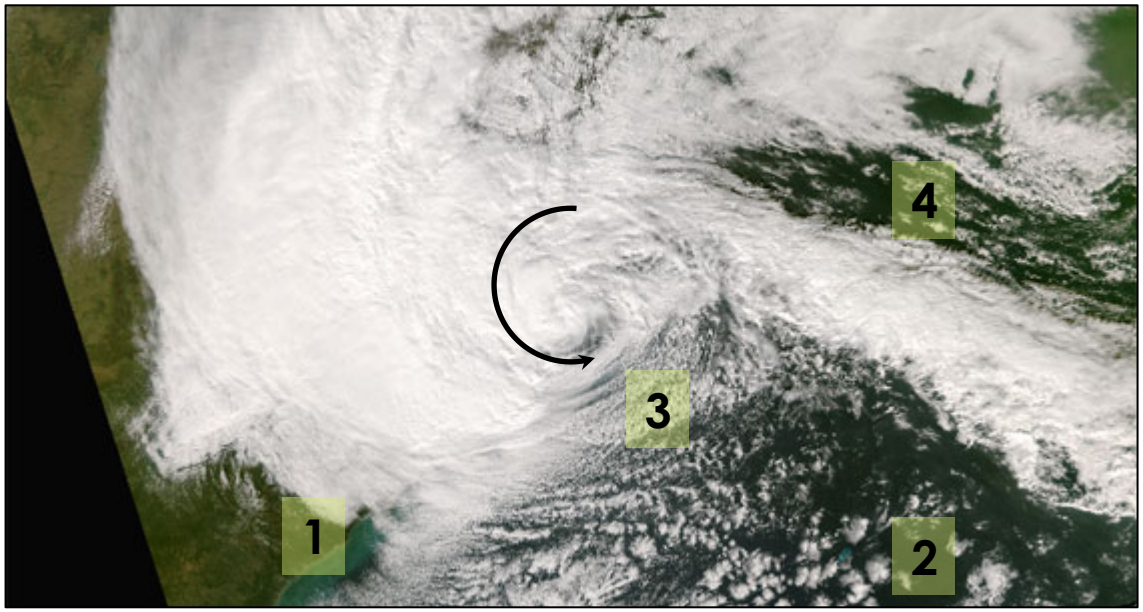


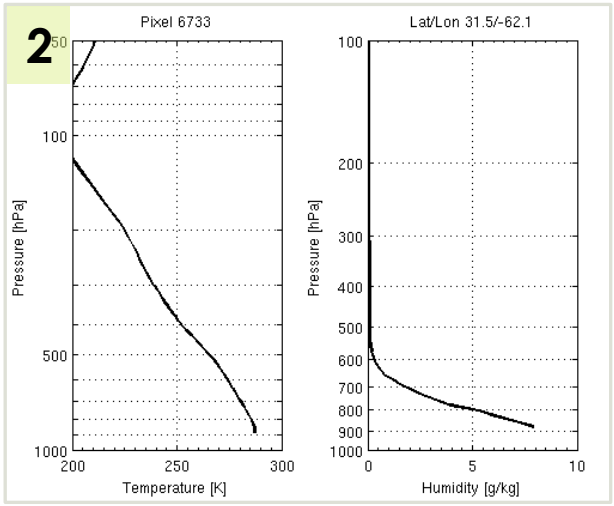
Footprints 16: CrIS RTV Relative Humidity [%]

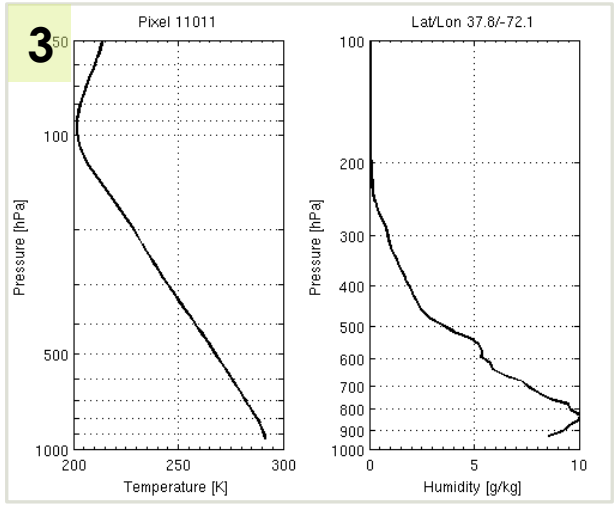


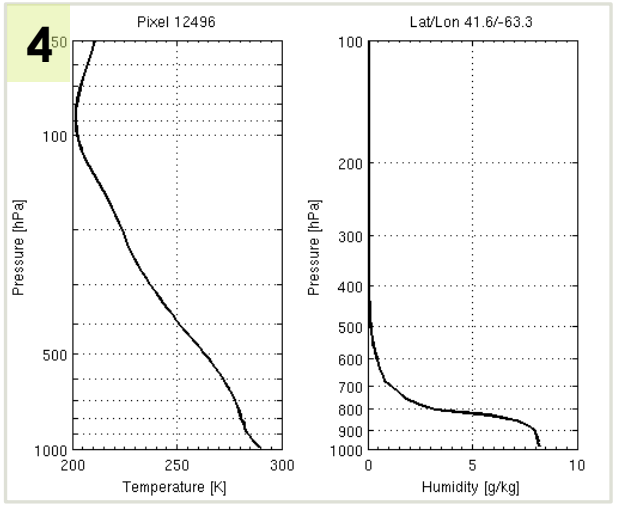
CrIS Profile Retrievals • Super-Storm Sandy 29 Oct 2012



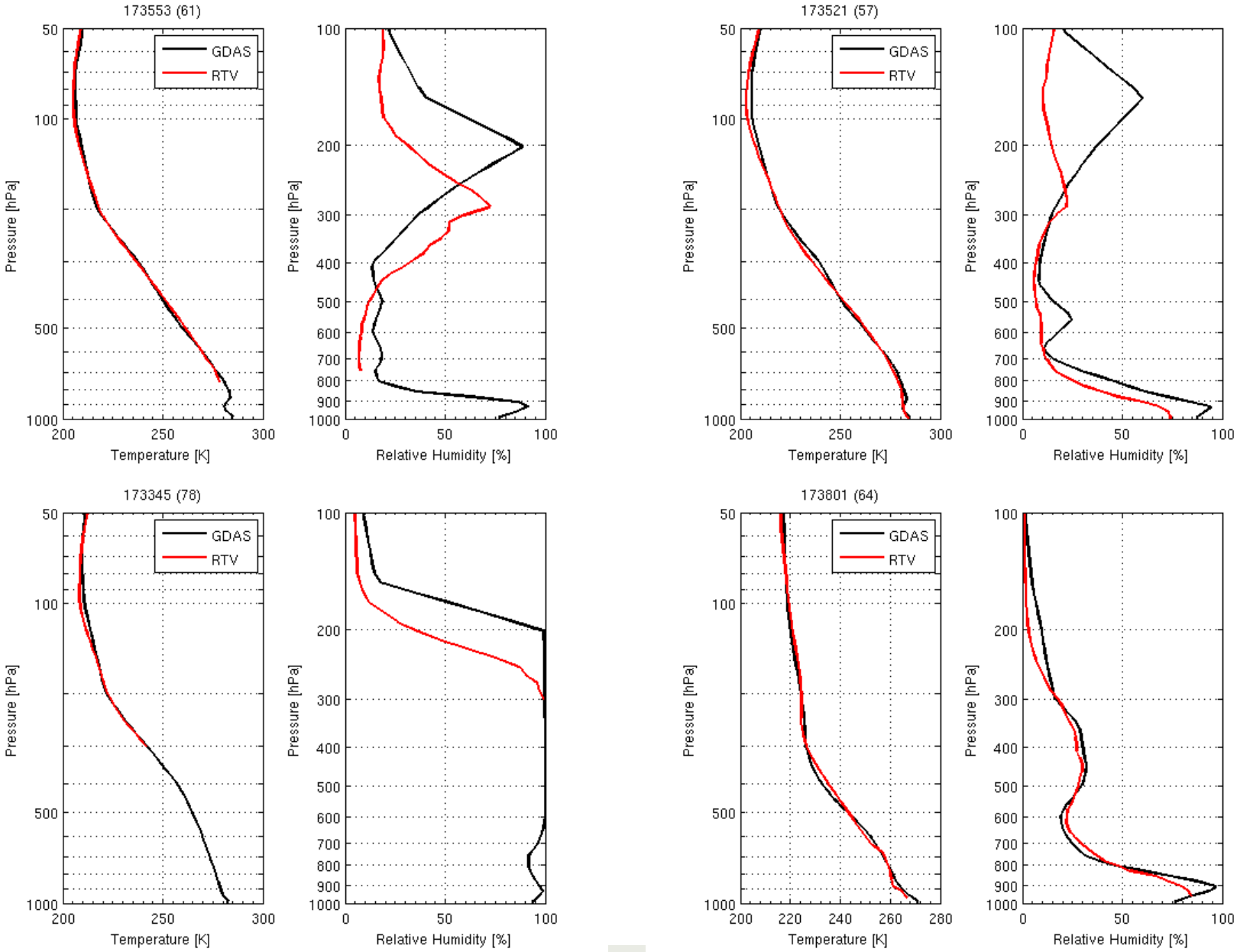








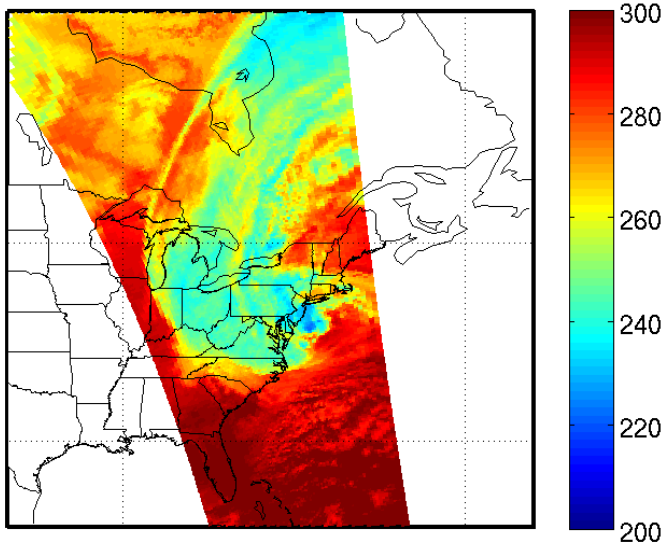
CrIS Profile Retrievals • Super-Storm Sandy 29 Oct 2012



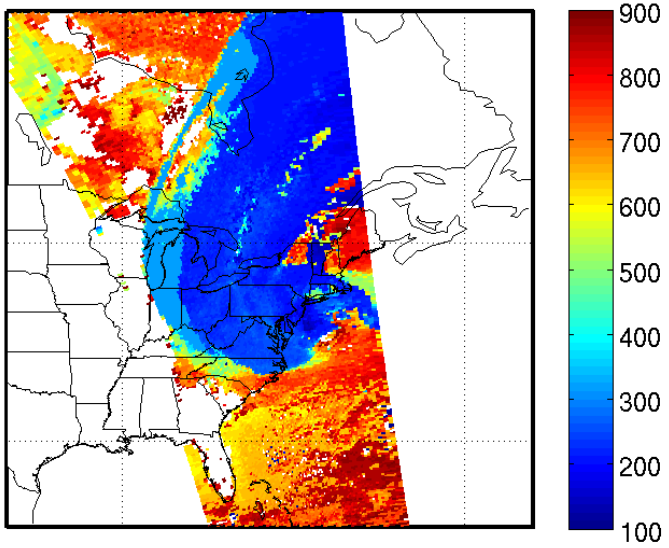
AIRS CTOP • Super-Storm Sandy 29 Oct 2012

AIRS 18:05-18:30 UTC

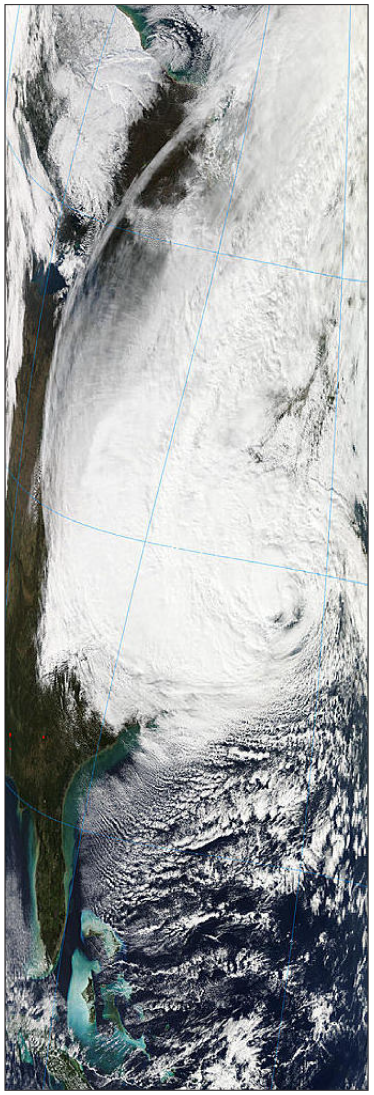
AIRS BT [K] at 911.6 cm^{-1}



AIRS CTOP [hPa]

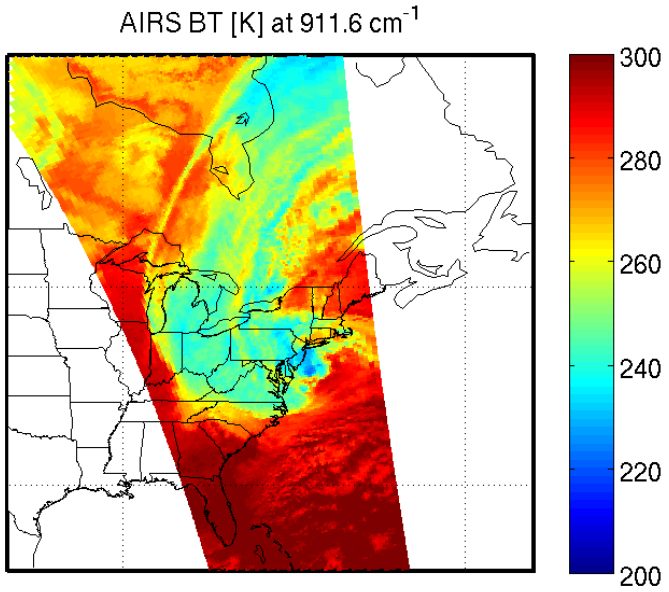


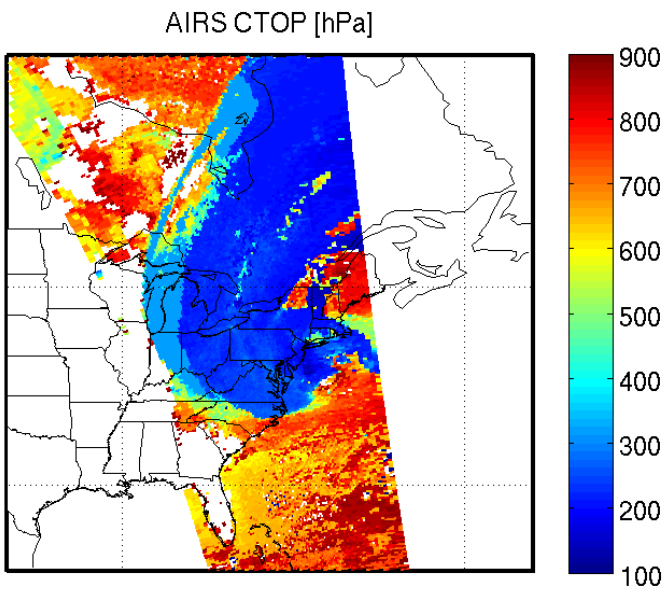
MODIS VIS

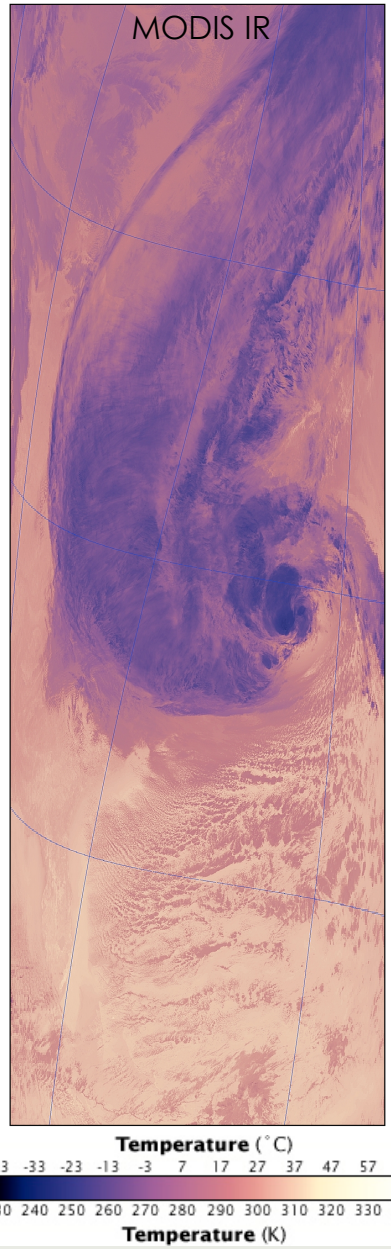


AIRS CTOP • Super-Storm Sandy 29 Oct 2012

AIRS 18:05-18:30 UTC

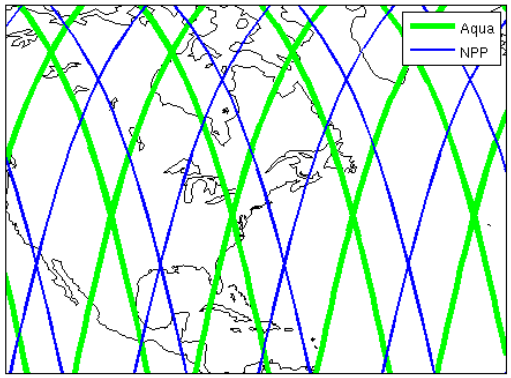




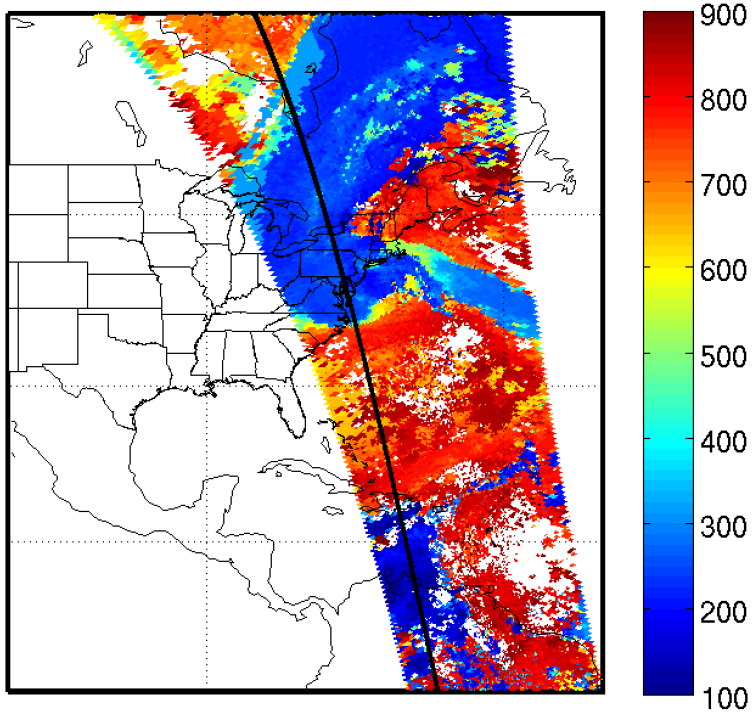


CrIS and AIRS CTOP • Super-Storm Sandy 29 Oct 2012

Aqua and NPP orbital tracks (10-29-12)

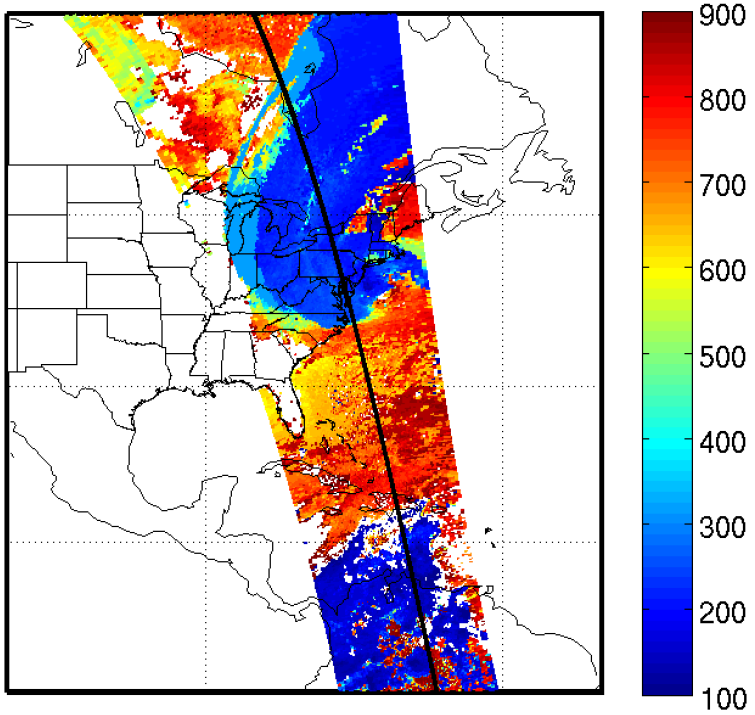


CrIS CTOP [hPa]



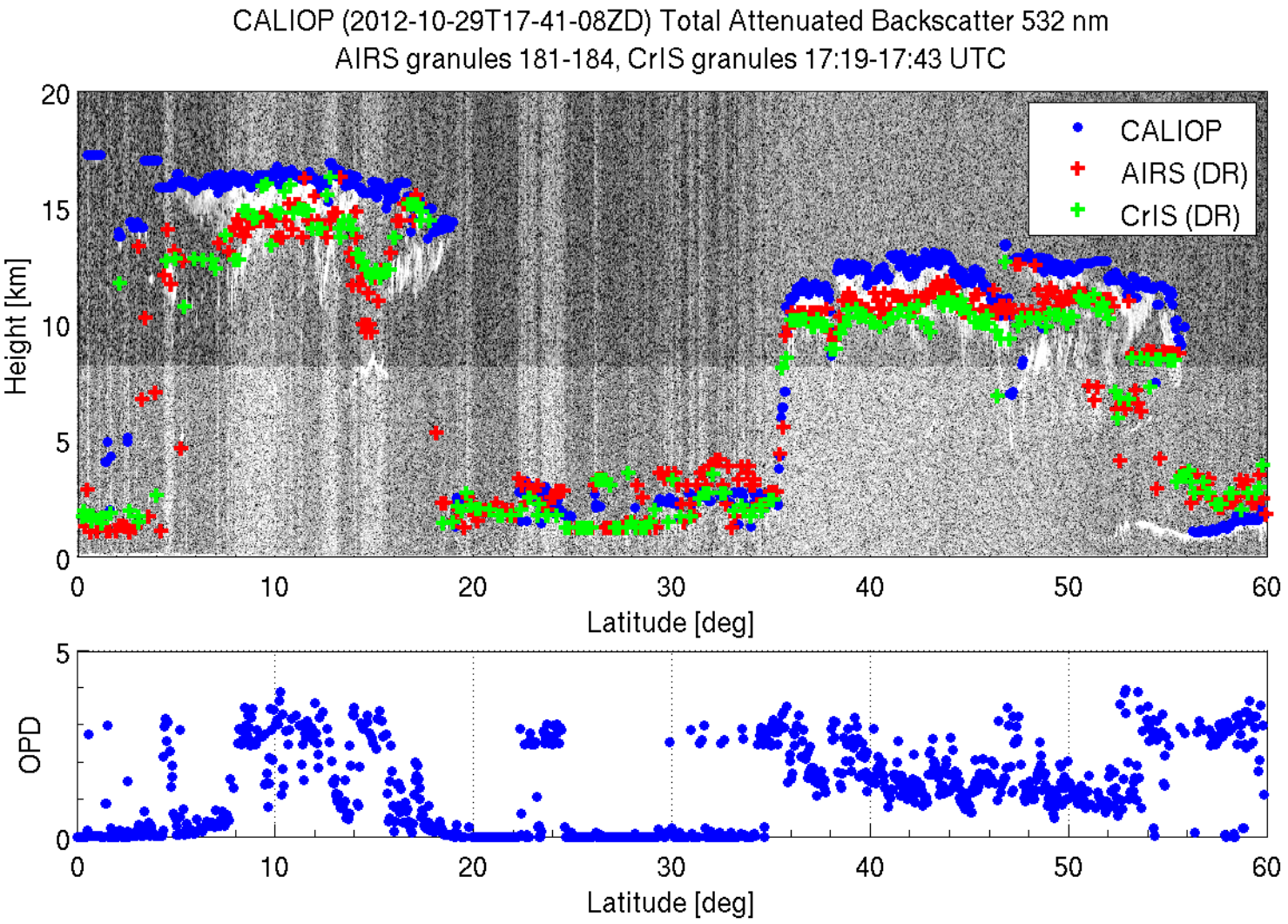
CrIS 17:19-17:43 UTC

AIRS CTOP [hPa]



AIRS 18:05-18:30 UTC

CrIS and AIRS CTOP • Super-Storm Sandy 29 Oct 2012



Summary

What do we have:

*A **one-of-a-kind** retrieval algorithm*

- *which can be applied to AIRS, IASI or CrIS radiances*
- *it is computationally efficient (i.e. can be applied in real-time)*
- *provides accurate sounding profiles, surface and cloud parameters under any sky condition (anywhere on the globe twice daily)*
- *It is freely available as part of CSPP and can be downloaded from **http://cimss.ssec.wisc.edu/cspp/***

Current and future tasks:

- More case studies (AIRS, CrIS, IASI on Metop-A and Metop-B, aircraft)
- AIRS + CrIS case studies to investigate atmospheric moisture transport
- Use of more trace gases, microwave channels, etc.
- Alternate solution for training-sets and forward model
- Sounder + imager (e.g. CrIS + VIIRS) applications
- Study global and long-term (climate) trends
- Use of retrieval products in NWP and weather forecasts