AIRS
(Atmospheric Infrared Sounder)
Regression Retrieval (Level 2)

Level 0 to Level 2

Level 0: raw data

Level 1A: geolocated radiance in counts

Level 1B: calibrated radiance in physical units

<u>Level 2: retrieved physical variables</u>

(temperature, humidity and ozone profiles, surface skin temperature, total precipitable water, total ozone content, cloud top height . . .)

Regression Model

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 Retrieval (1)

1. Calculate Regression Coefficients

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

2. Perform Retrieval (RTV)

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

Y… Measurements [nprofs x nchannels]

C ... Regression coefficients [nlevels x nchannels]

X ... Atmospheric variables [nlevels x nprofs]

Subscript tr refers to trainingset

Regression Retrieval (2)

1. Calculate Regression Coefficients

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

with

$$\Delta X_{tr} = X_{tr} - \mathrm{mean}(X_{tr})$$

$$\Delta Y_{tr} = Y_{tr} - \mathrm{mean}(Y_{tr})$$

2. Perform Retrieval (RTV)

$$\Delta X = C\ \ \Delta Y^{T} \quad \text{or} \quad X = \mathrm{mean}(X_{tr}) + C\ \Delta Y^{T}$$

with

$$\Delta X = X - \mathrm{mean}(X_{tr})$$

$$\Delta Y = Y - \mathrm{mean}(Y_{tr})$$

Principal Components (PC) Regression Retrieval

1. Calculate Regression Coefficients

$$M = Cov(Y_{tr})$$

$$U = eig(M)$$

$$A_{tr} = \Delta Y_{tr}\, U$$

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

2. Perform Retrieval (RTV)

$$X = mean(X_{tr}) + C\, A^{T}$$

with

$$A = \Delta Y\, U, \quad \Delta Y = Y - mean(Y_{tr})$$

M… covariance matrix [nchannels x nchannels]

U ... First few eigenvectors of M [nchannels x npc]

A ... Projection Coefficients (or amplitudes) [nsamples x npc]

The Trainingset

X_{tr} . . . Representative set of atmospheric variables including temperature, moisture, ozone, surface pressure, surface skin temperature and surface skin emissivities

Y_{tr} . . . Corresponding set of simulated radiances, calculated by a fast RT (radiative transfer) forward model

Radiance received by AIRS

$$R_\nu = \tau_{s\nu} \cdot \varepsilon_{s\nu} \cdot B_\nu(T_S)$$

← Upwelling IR radiation from surface

$$+ \int_{p_s}^{0} B_\nu(T(p)) d\tau_\nu(p)$$

← Upwelling IR radiation from atm. layers

$$- \tau_{s\nu} \cdot r_{s\nu} \cdot \int_{p_s}^{0} B_\nu(T(p)) d\tau_\nu^*(p)$$

← Reflected downwelling IR radiation

$$+ R_\nu^{sun} \cdot \cos(\theta) \cdot \tau_{s\nu}^{sun}(p_s) \cdot r_\nu^{sun}$$

← Reflected solar radiation

R…radiance, υ…wavenumber, *s*…surface, *p*…pressure, *sun*…solar,

T…temperature, *B*…Planck function, ε …emissivity,

τ…level to space transmittance, θ...local solar zenith angle

r…reflectivity, with $r = (1- \varepsilon)/\pi$,

τ^*…level to surface (downwelling) transmittance [$\tau^* = \tau_\upsilon^2(p_s) / \tau_\upsilon(p)$]

Fast Radiative Transfer Forward Model

- Fast Model Regression :
  - Computation of line-by-line Transmittance τ for FM training data set
  - Convolve with AIRS SRF (spectral response function)
  - Solve regression scheme τ = AC for coefficients C using predictors A

    (predictors are functions of T, p, absorber amount, scanang …)

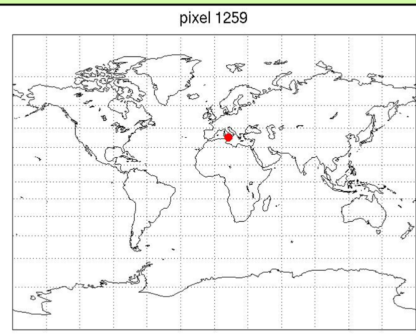
- Calculate transmittance τ for any other profile

- Solve RTE to get radiance R_v

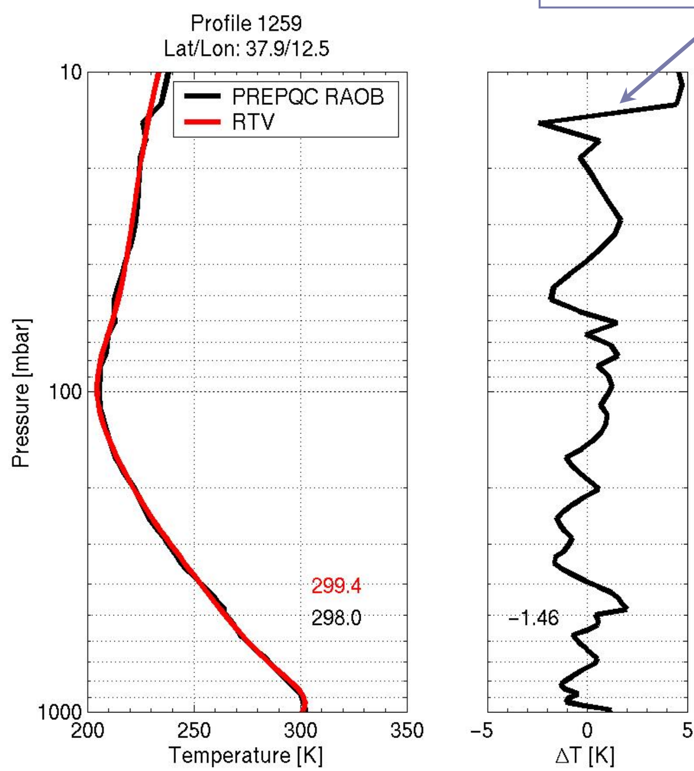
<u>IMAPP AIRS Regression Retrieval Results:</u>

Comparison with co-located radiosonde observations (RAOBs)

Co-located RAOB / AIRS single profile retrieval (RTV)



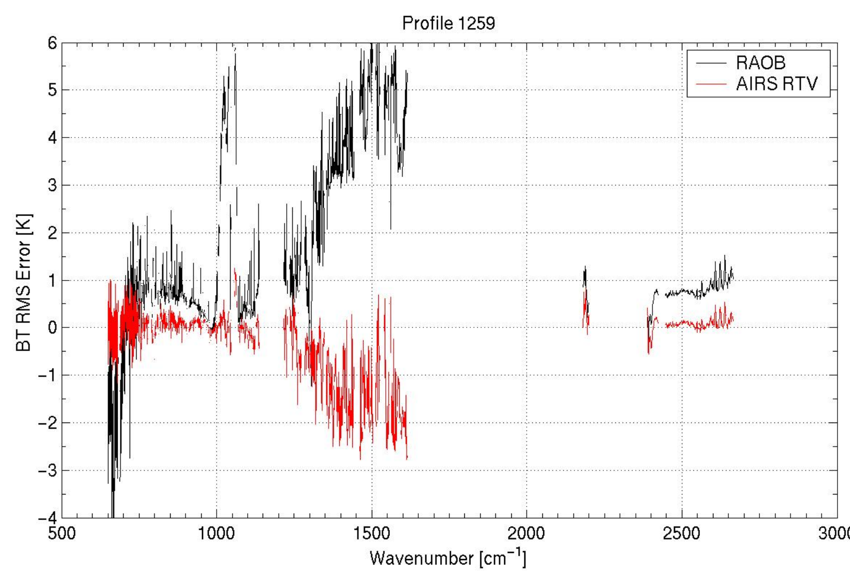
residual = observed minus calculated spectrum



RAOB – RTV

RAOB Residual (Obs – Calc BT)

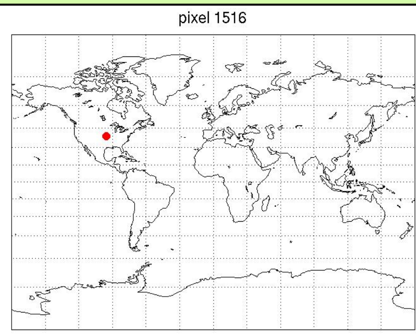
Retrieval Residual (Obs – Calc BT)



Temperature (pixel 1259)

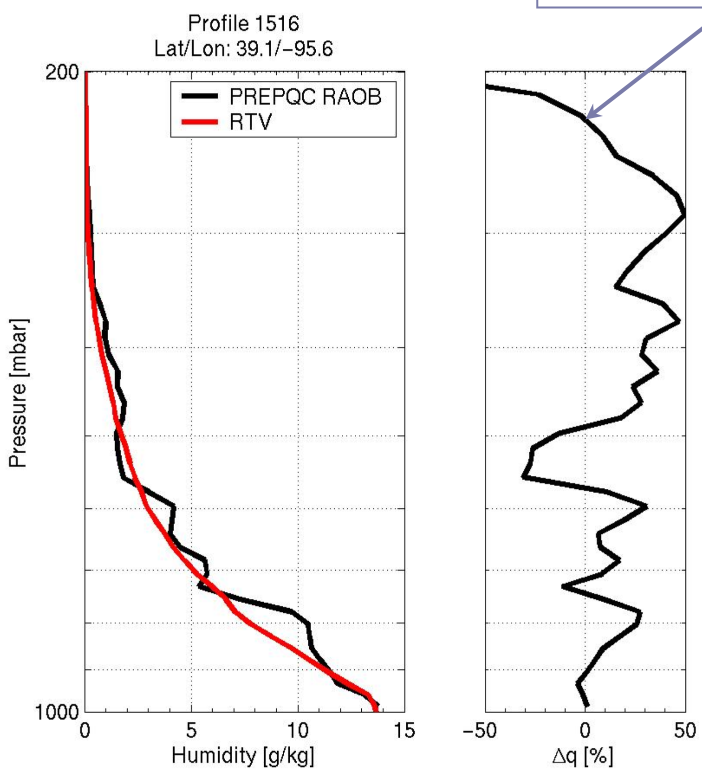
Brightness Temperature (BT) residual

Co-located RAOB / AIRS single profile retrieval (RTV)



residual = observed minus calculated spectrum

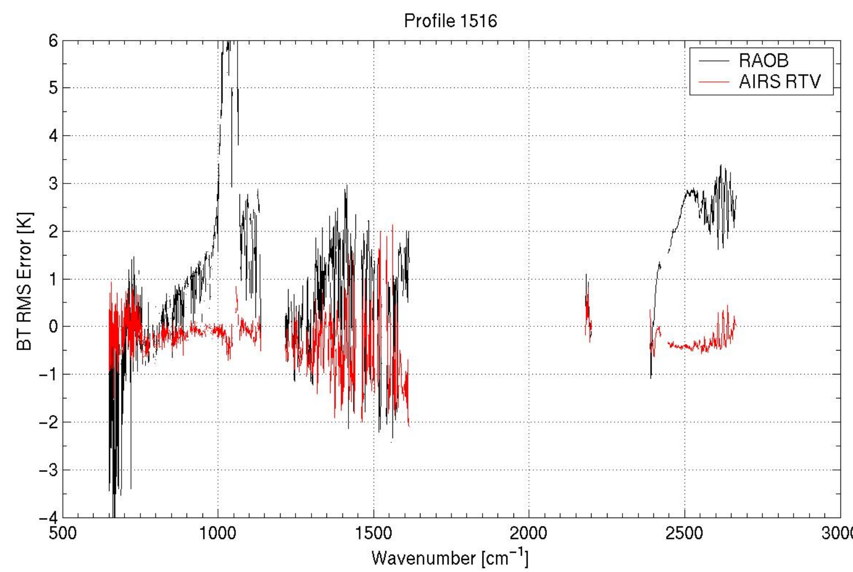
RAOB – RTV



Humidity (pixel 1516)

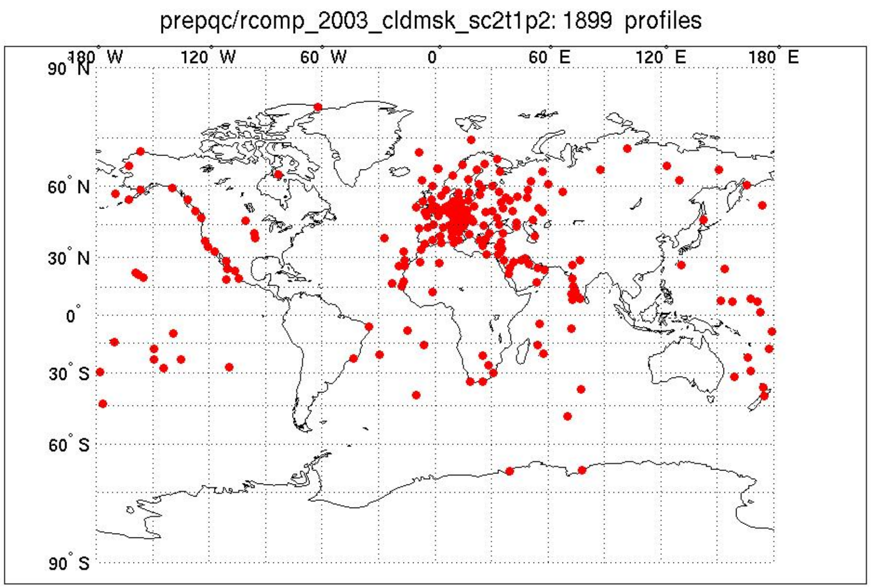
RAOB Residual (Obs – Calc BT)

Retrieval Residual (Obs – Calc BT)

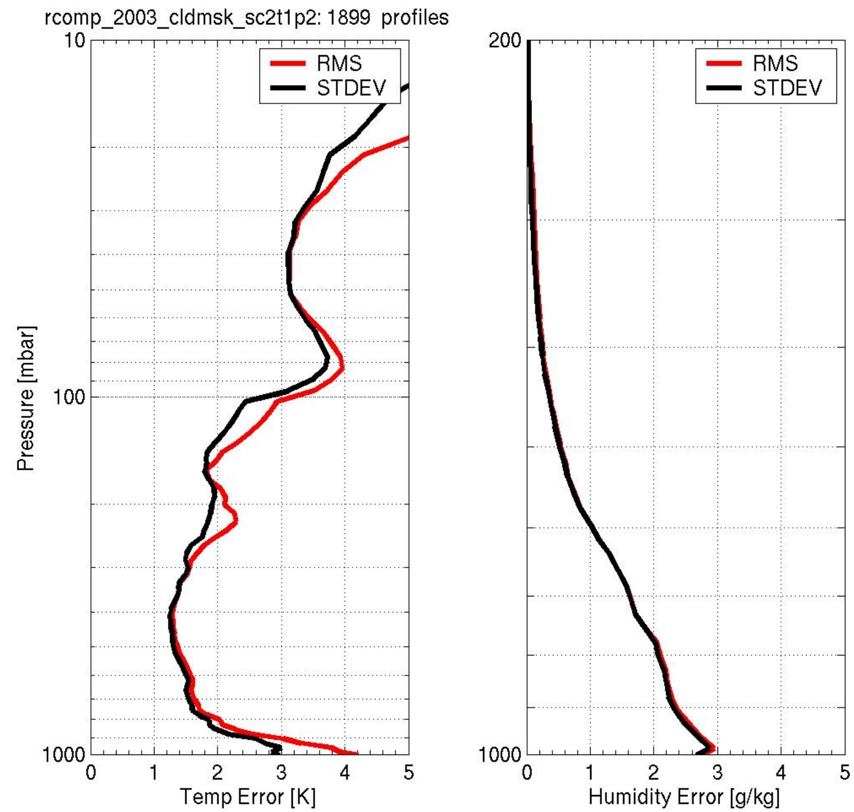


Brightness Temperature (BT) residual

Co-located RAOB / AIRS retrieval statistics (1899 profiles)



RMS of RAOB – RTV
STDEV of RAOB – RTV



Temperature Humidity

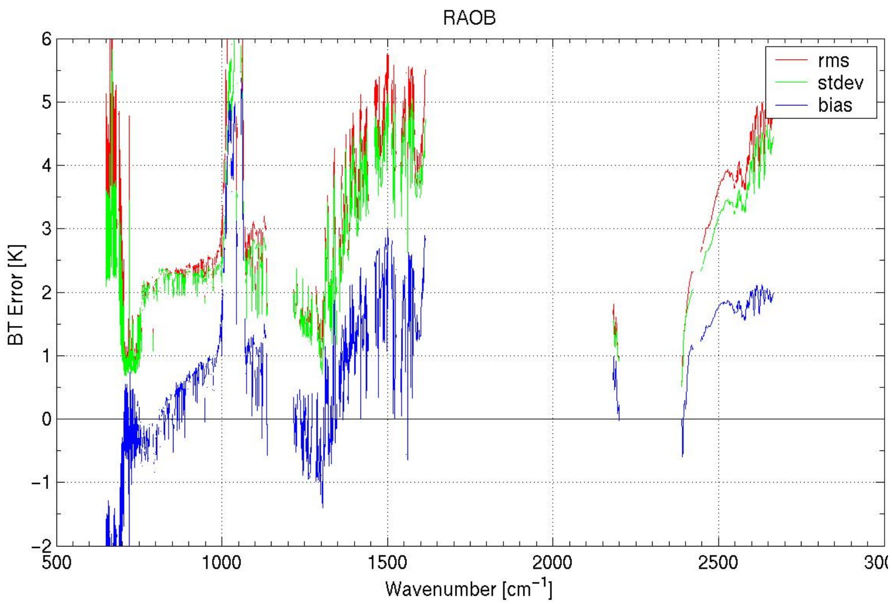
Co-located RAOB / AIRS retrieval statistics (1899 profiles)

RMS of Residual (Obs – Calc BT)

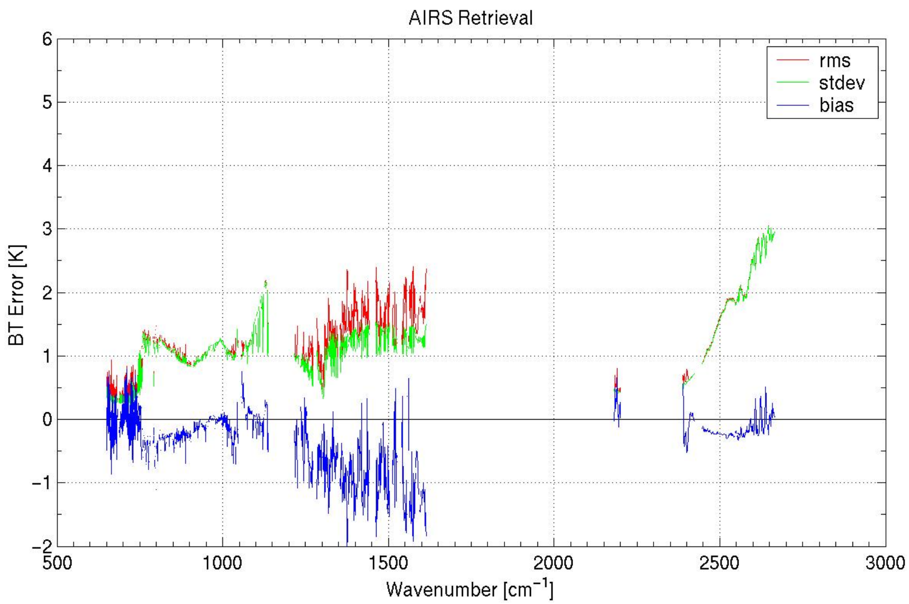
Stdev of Residual (Obs – Calc BT)

Mean of Residual (Obs – Calc BT)

Radiosonde Observations



AIRS Retrieval



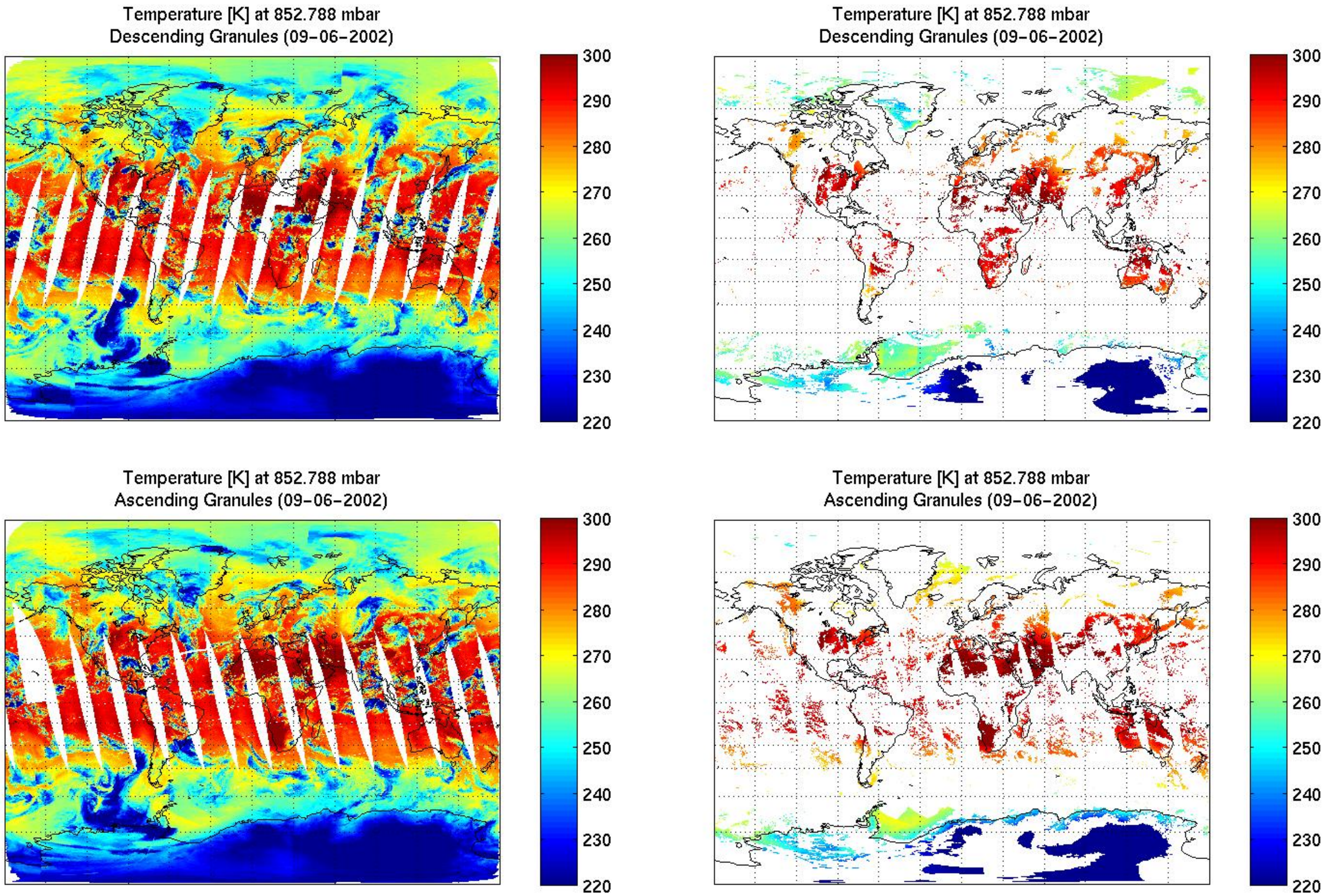
<u>IMAPP AIRS Regression Retrieval Results:</u>

Global (240 granules) retrievals and retrievals over the CIMSS direct broadcast area

Globally Retrieved Temperature at 850 mbar

Descending Grans

Ascending Grans

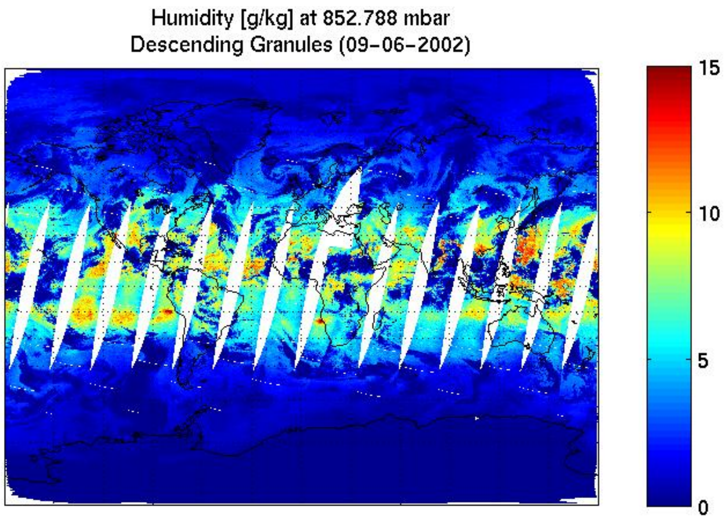


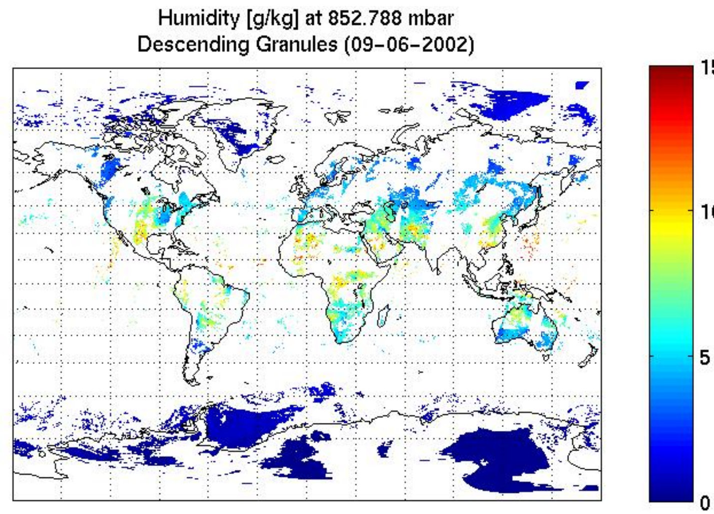
Without Cloudmask

With Cloudmask

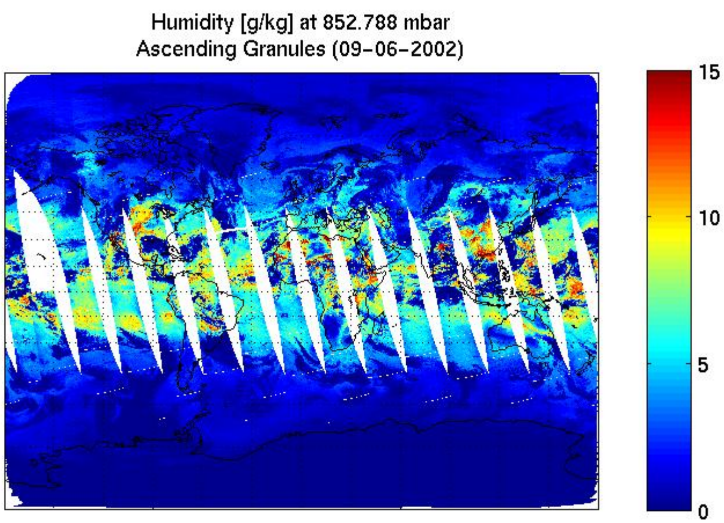
Globally Retrieved Moisture at 850 mbar

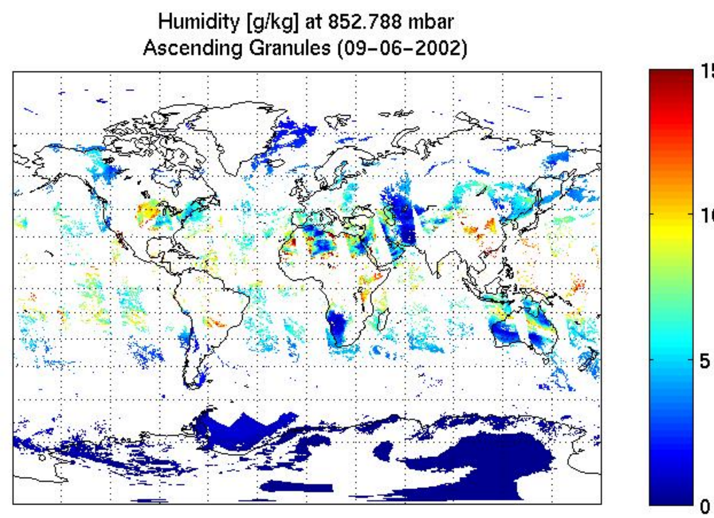
Descending Grans





Ascending Grans



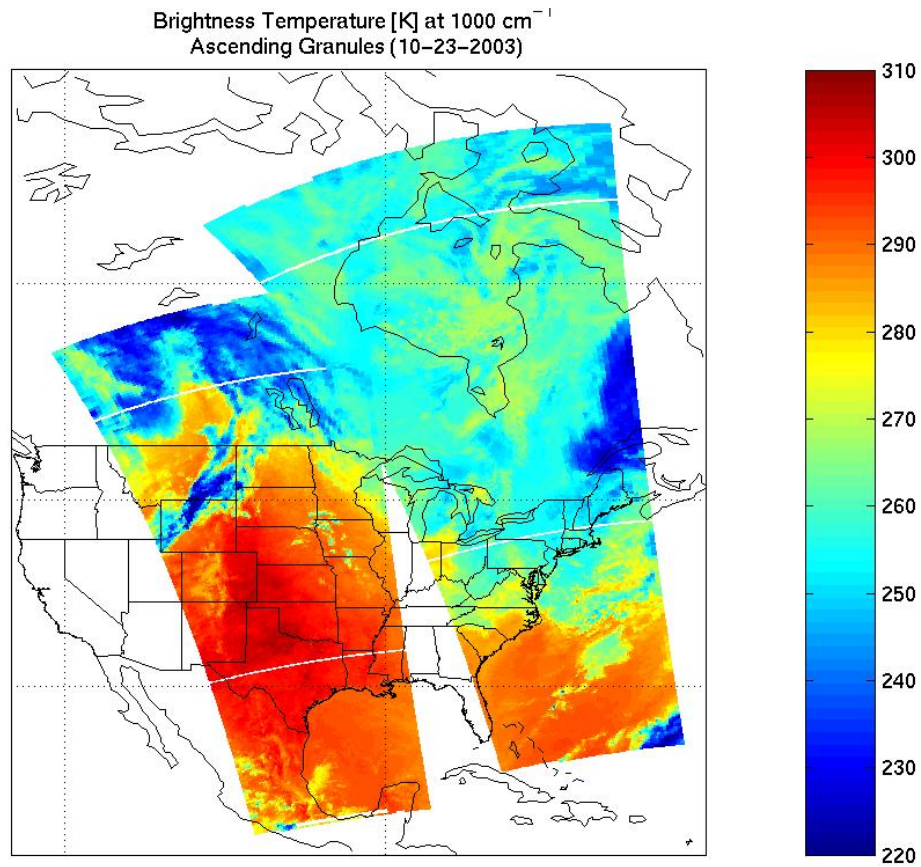


Without Cloudmask

With Cloudmask

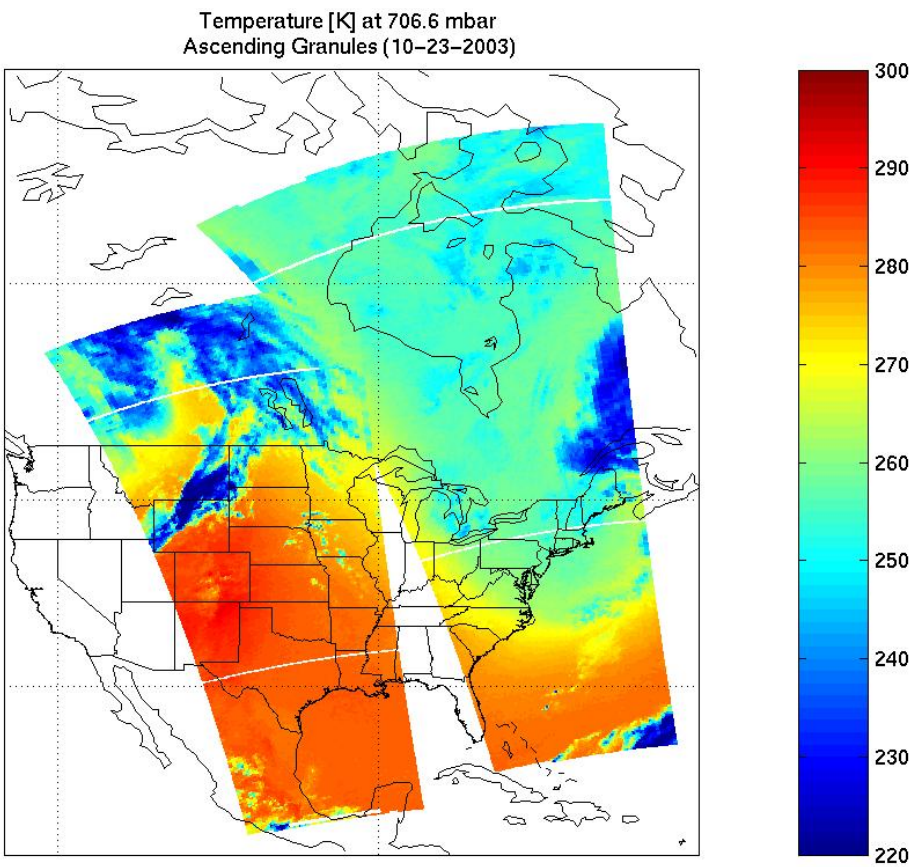
CIMSS Direct Broadcast area: AIRS measurements (10-23-2003)

Brightness Temperature [K] at 1000 cm^{-1} (no cloudmask)

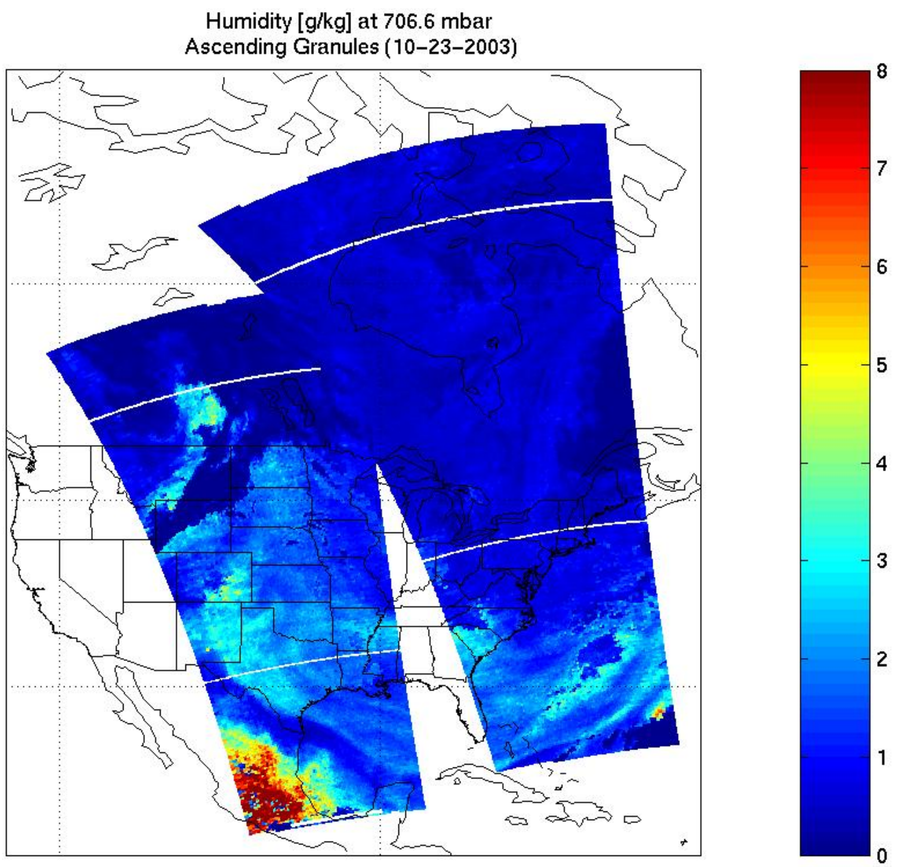


CIMSS Direct Broadcast area:
IMAPP AIRS Retrieval (10-23-2003)

Temperature [K] at 700 mbar (no cloudmask)

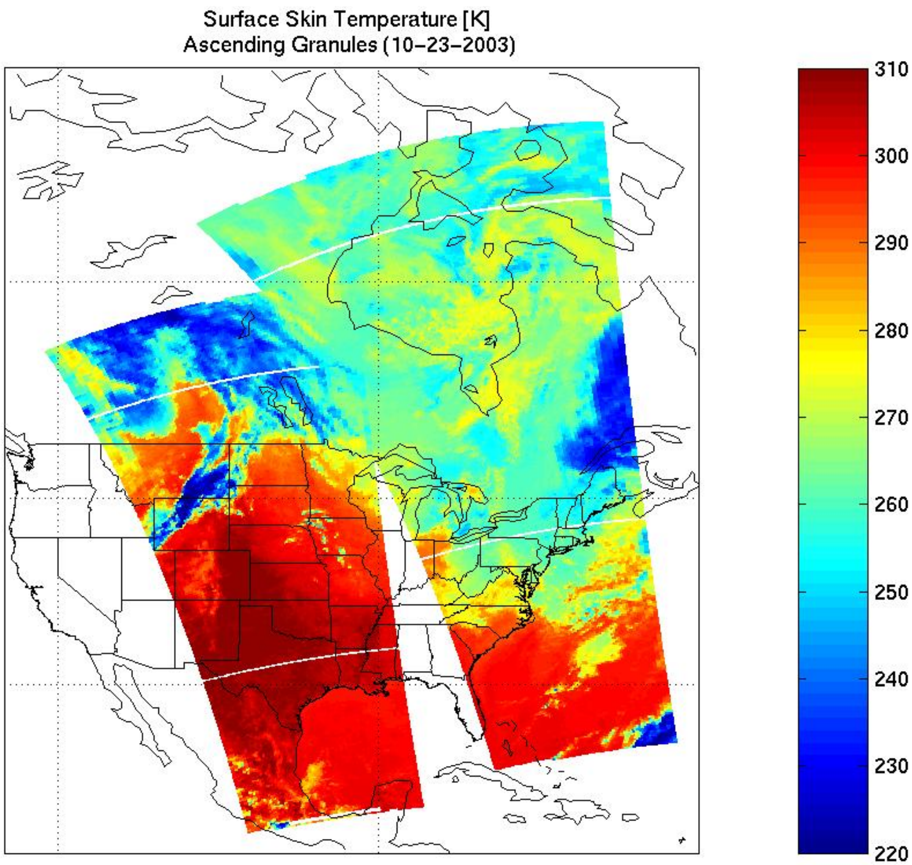


Humidity [g/kg] at 700 mbar (no cloudmask)

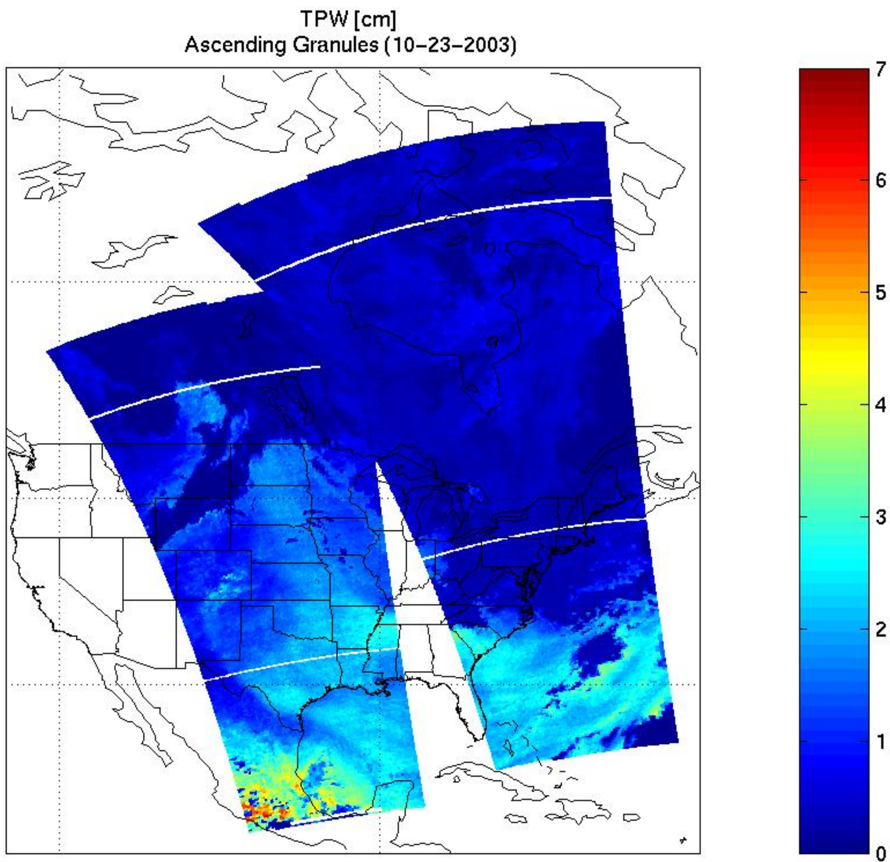


CIMSS Direct Broadcast area:
IMAPP AIRS Retrieval (10-23-2003)

Surface Skin Temperature [K]
(no cloudmask)

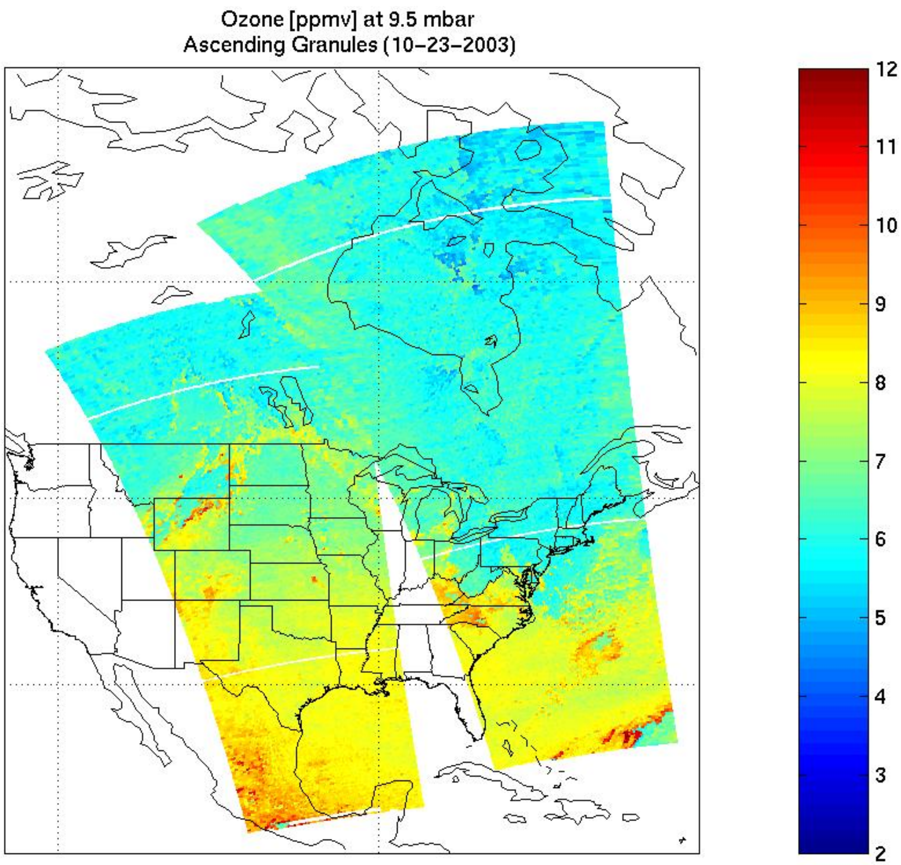


Total Precipitable Water [cm]
(no cloudmask)

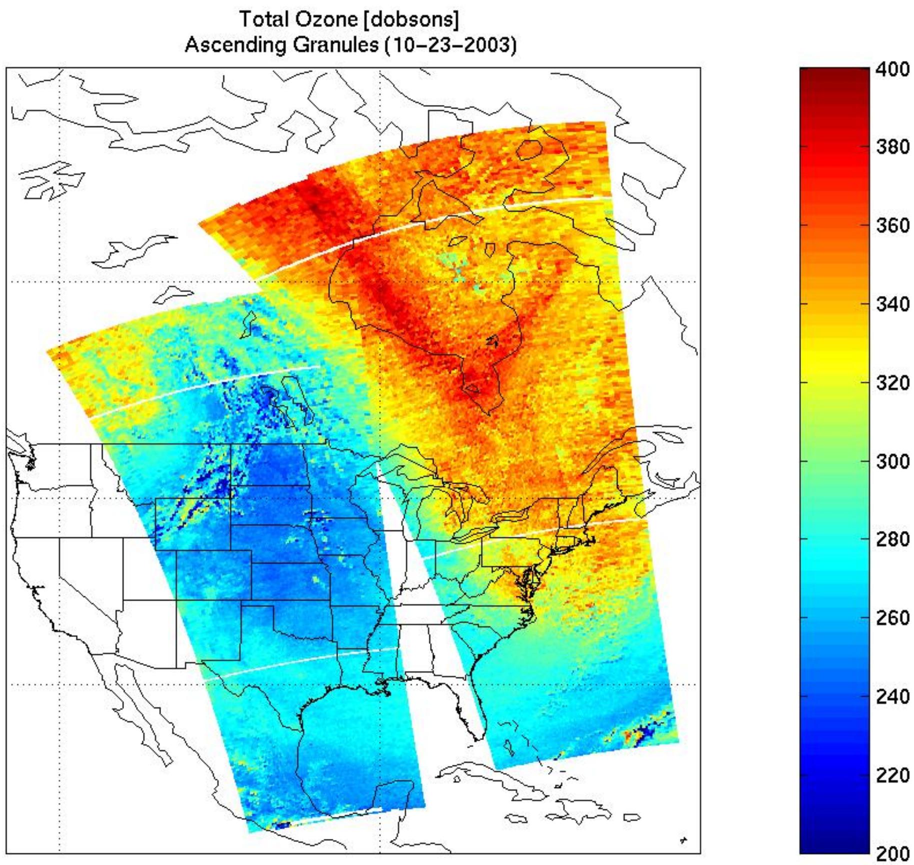


CIMSS Direct Broadcast area: IMAPP AIRS Retrieval (10-23-2003)

Ozone [ppmv] at 9.5 mbar
(no cloudmask)

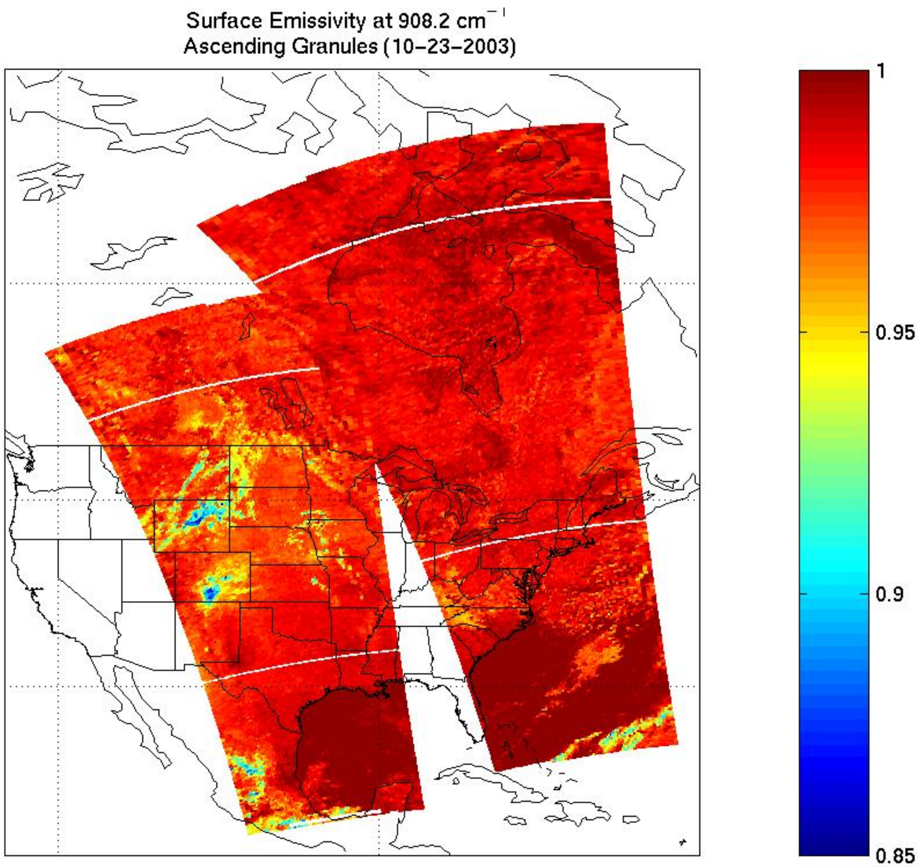


Total Ozone [Dobson Units]
(no cloudmask)

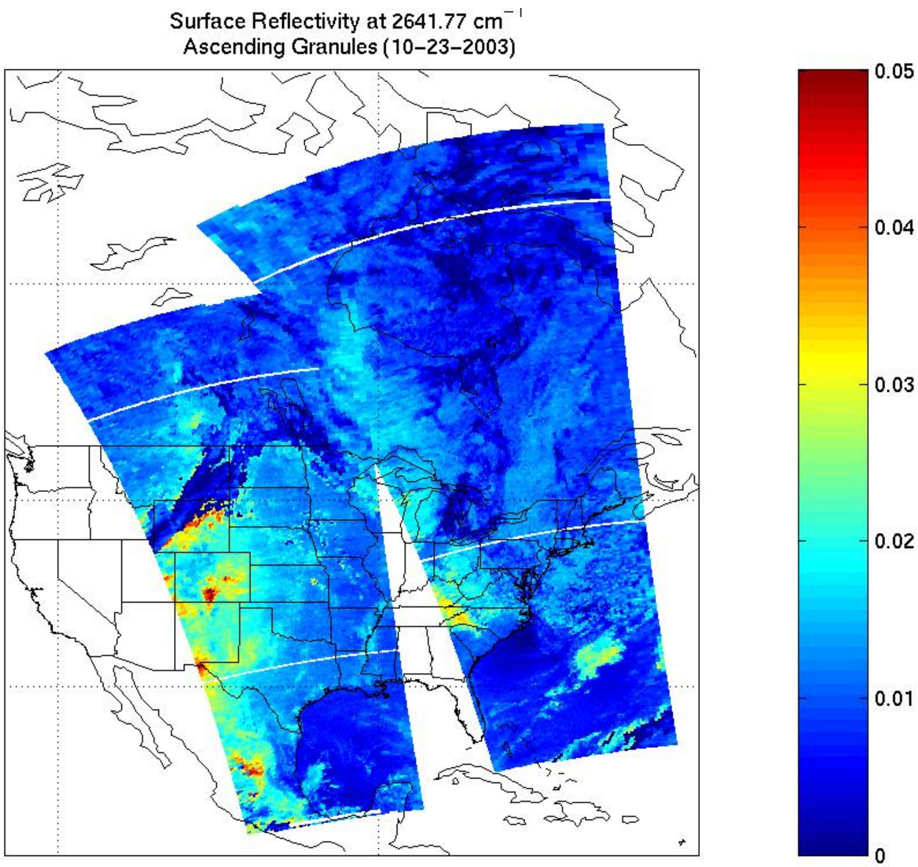


CIMSS Direct Broadcast area:
IMAPP AIRS Retrieval (10-23-2003)

Surface Emissivity at 908 cm^{-1}
(no cloudmask)



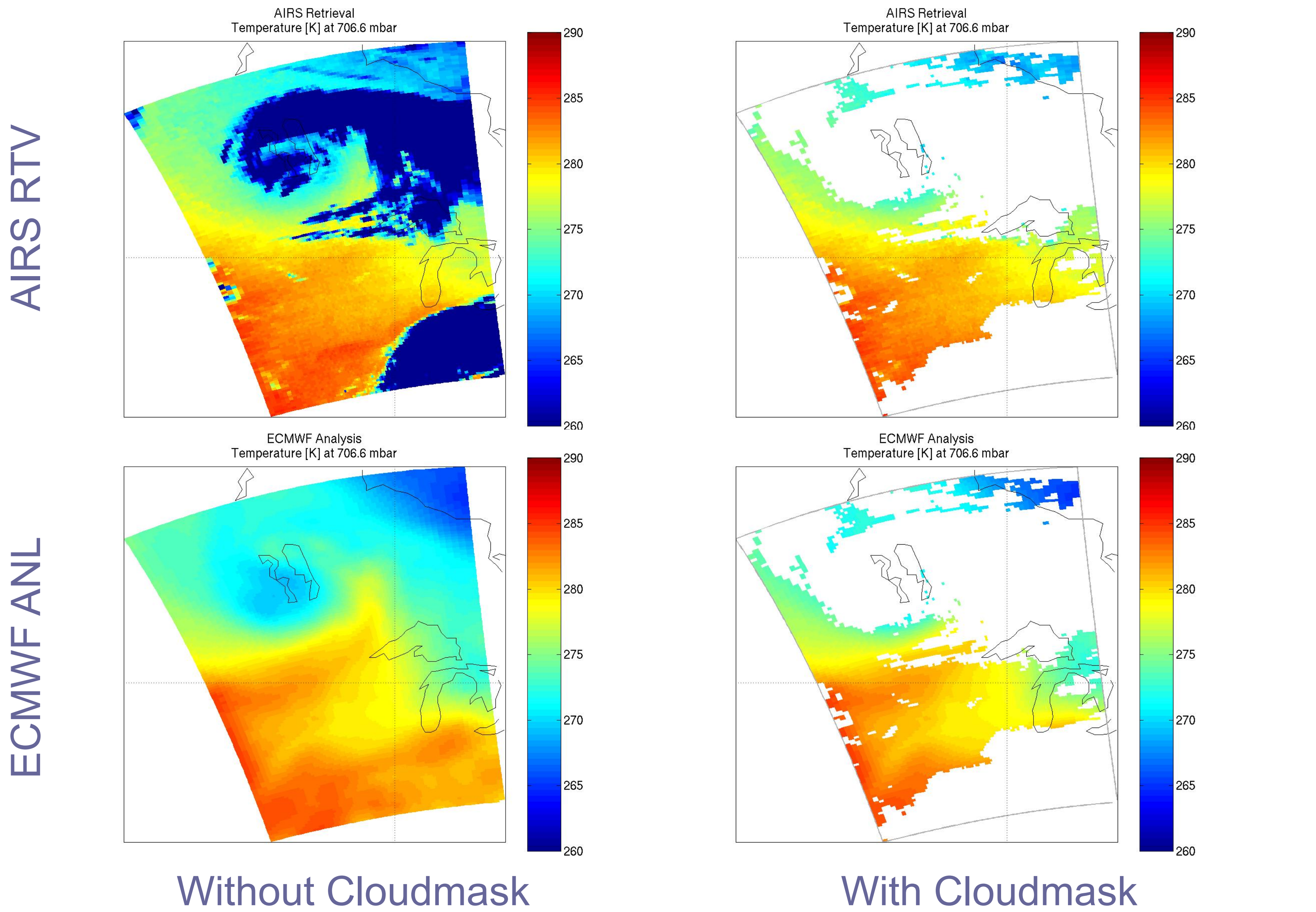
Surface Reflectivity at 2641 cm^{-1}
(no cloudmask)



IMAPP AIRS Regression Retrieval Results:

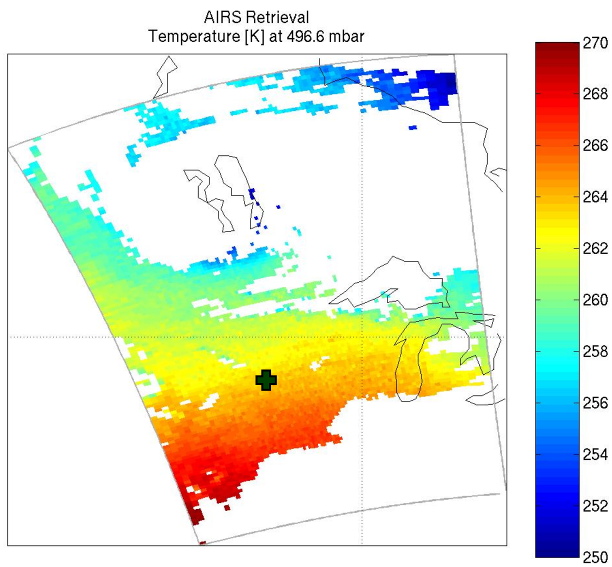
Comparison with ECMWF analysis fields

AIRS RTV vs. ECMWF Analysis: Temperature at 700 mbar (G192, 09-02-2003)

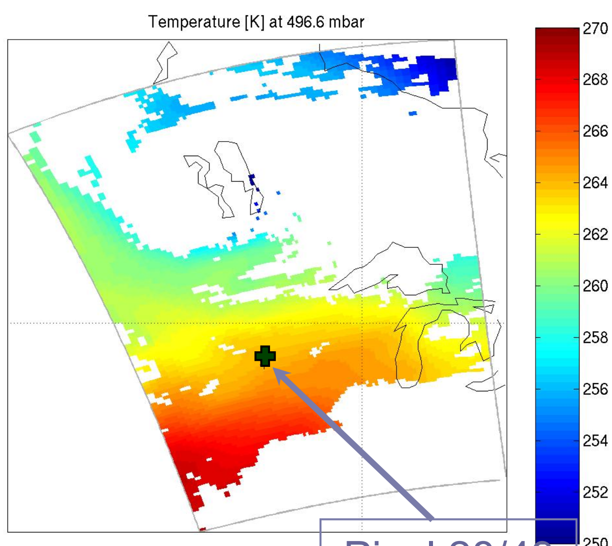


AIRS RTV vs. ECMWF Analysis: Temperature at 500 mbar and at selected pixel

AIRS RTV



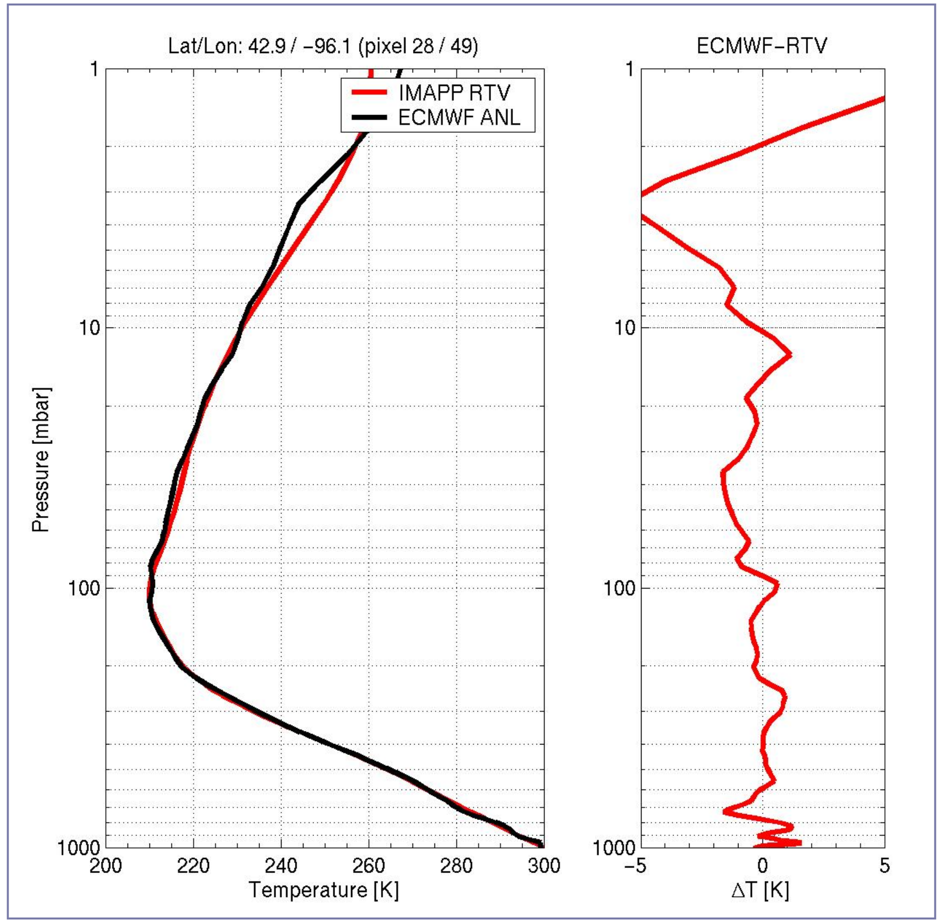
ECMWF ANL



Pixel 28/49

ECMWF ANL
IMAPP RTV

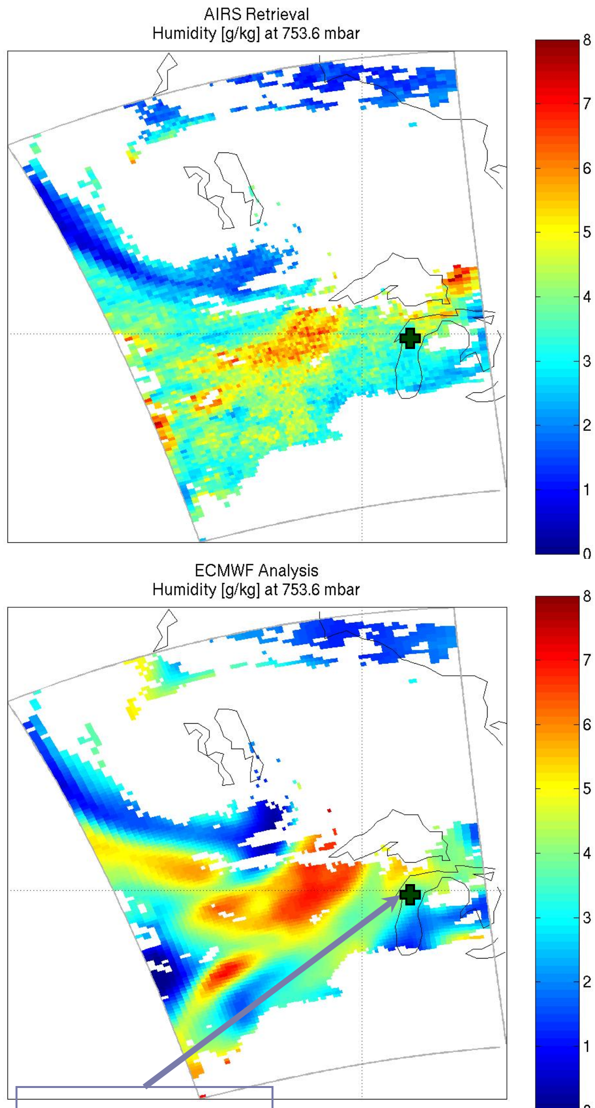
ECMWF – IMAPP RTV



AIRS RTV vs. ECMWF Analysis: Humidity at 750 mbar and at selected pixel

AIRS RTV

ECMWF ANL

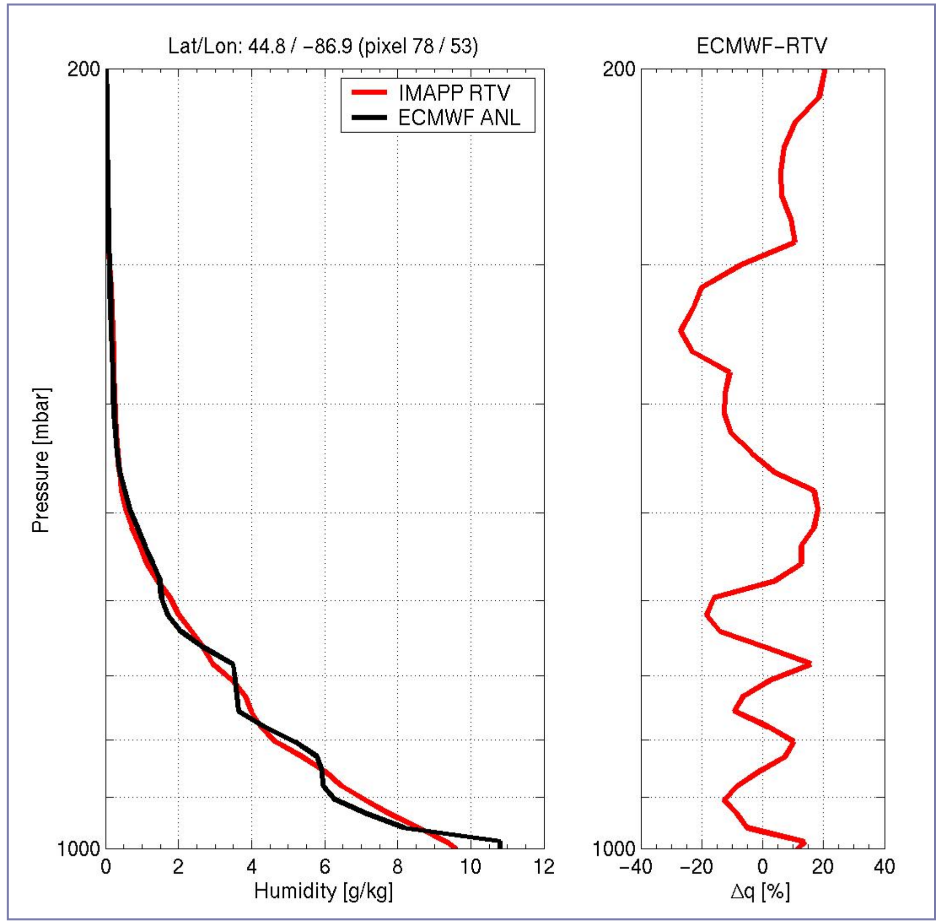


Pixel 78/53

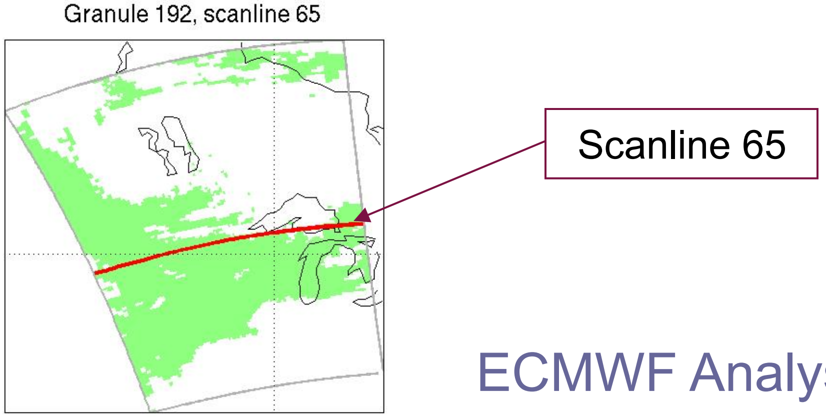
ECMWF ANL

IMAPP RTV

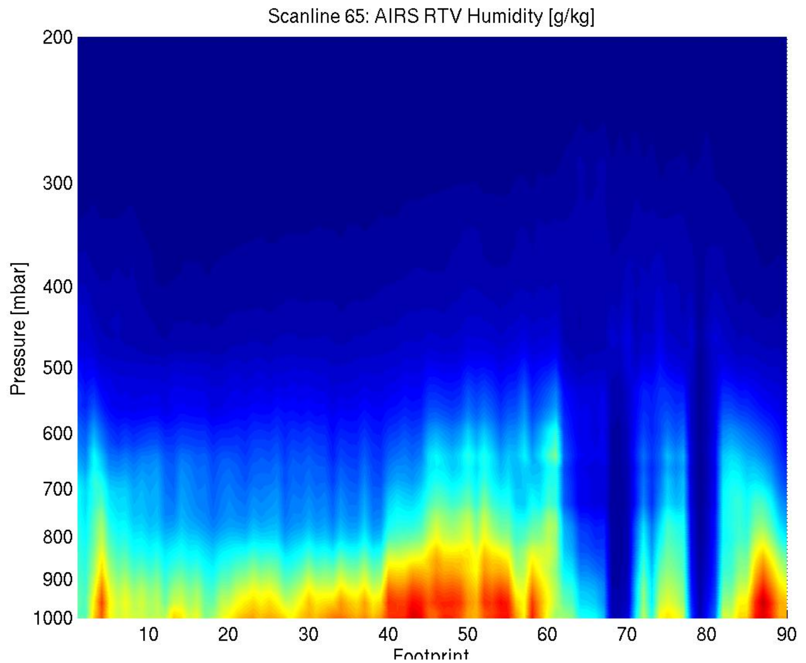
ECMWF – IMAPP RTV



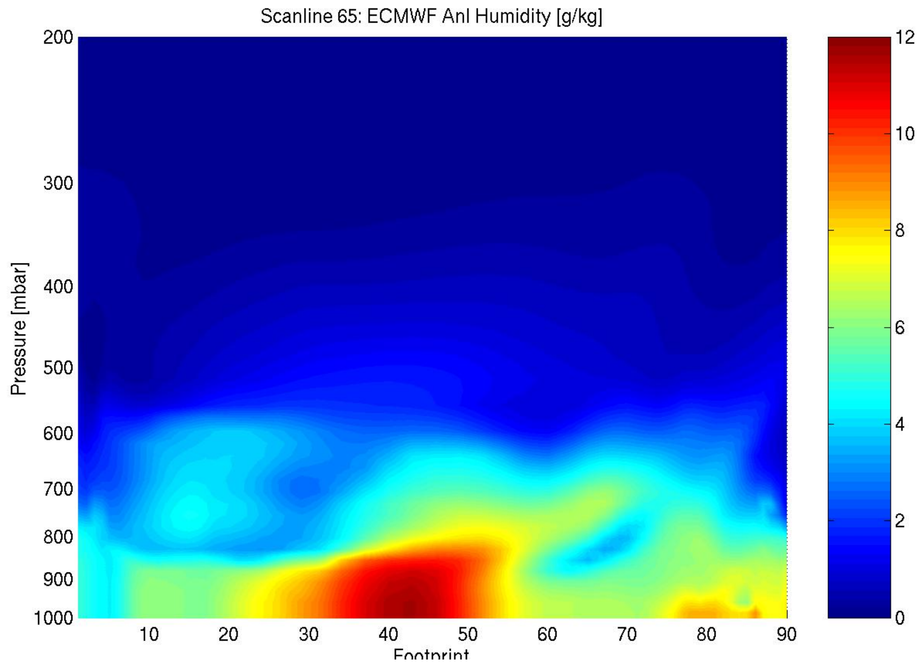
AIRS RTV vs. ECMWF Analysis: Humidity along scanline 65 (without cloudmask)



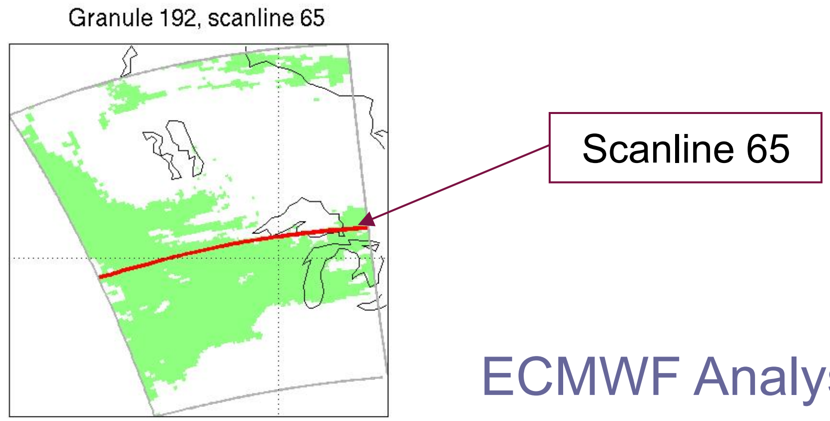
IMAPP AIRS Retrieval



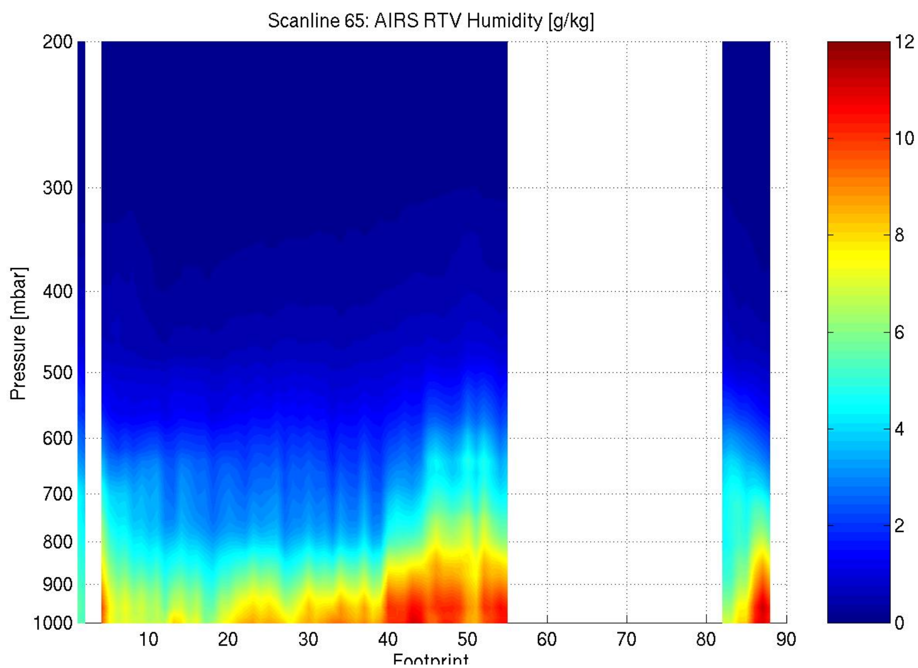
ECMWF Analysis



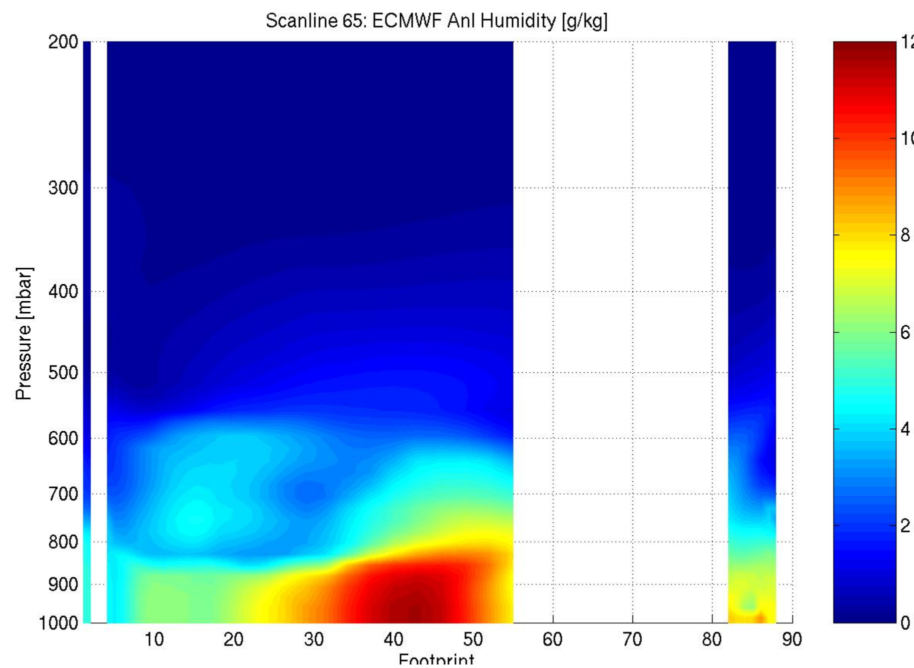
AIRS RTV vs. ECMWF Analysis: Humidity along scanline 65 (with cloudmask)



IMAPP AIRS Retrieval



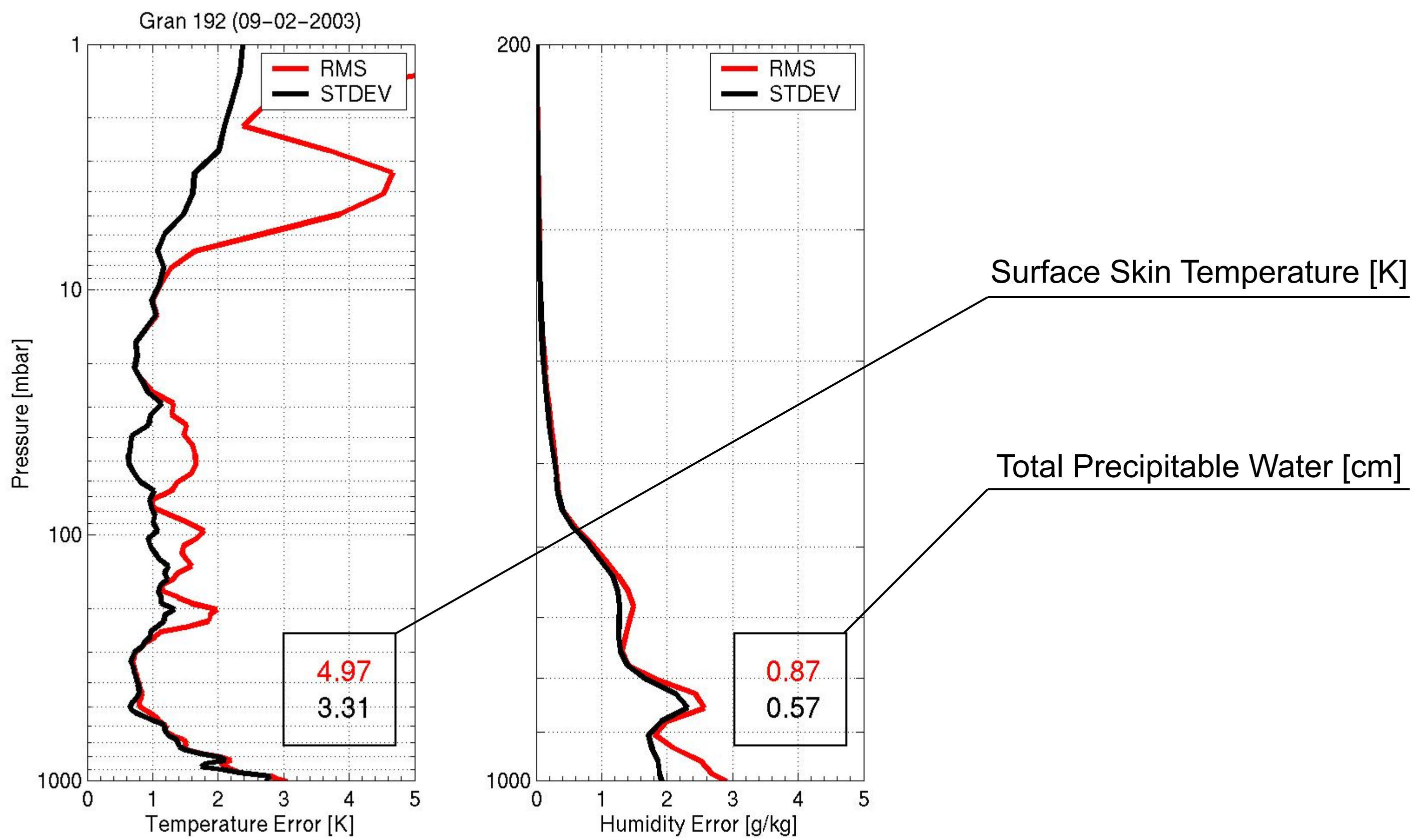
ECMWF Analysis



RMS and STDEV of ECMWF minus AIRS RTV (G192, 09-02-2003, 4758 clear pixels)

Root Mean Square (RMS) Error

Standard Deviation



Temperature

Humidity

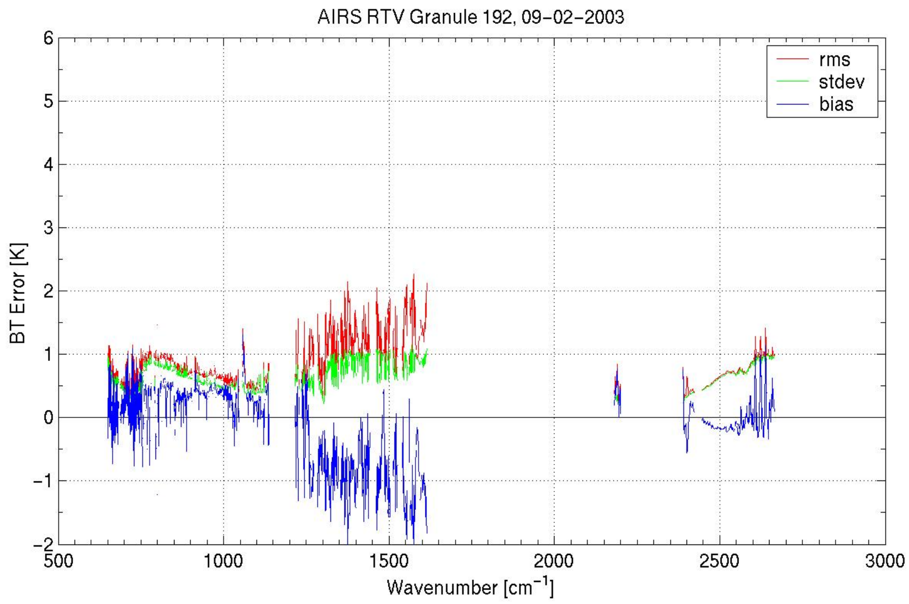
AIRS RTV vs. ECMWF Analysis: Spatial mean of Brightness Temperature (BT) residual

RMS of Residual (Obs – Calc BT)

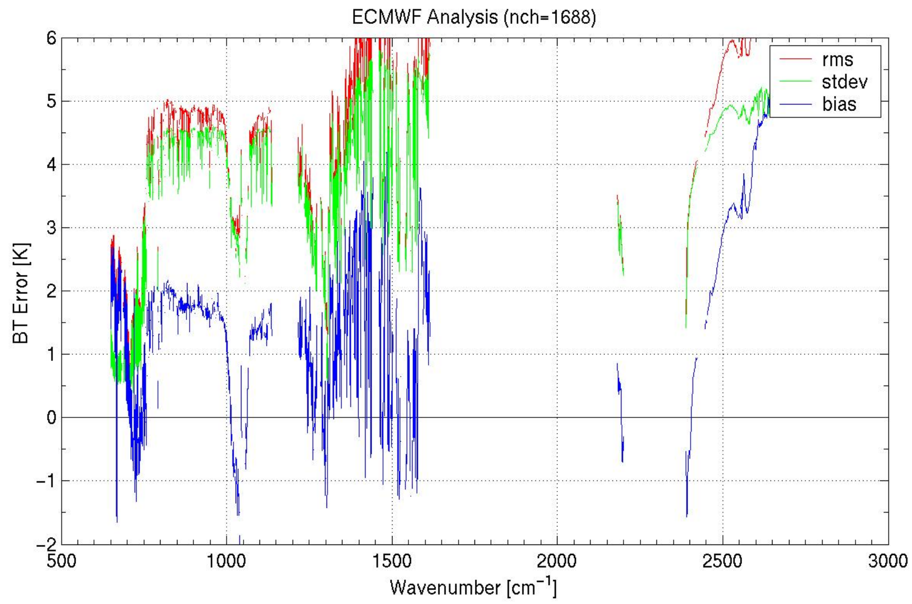
Stdev of Residual (Obs – Calc BT)

Mean of Residual (Obs – Calc BT)

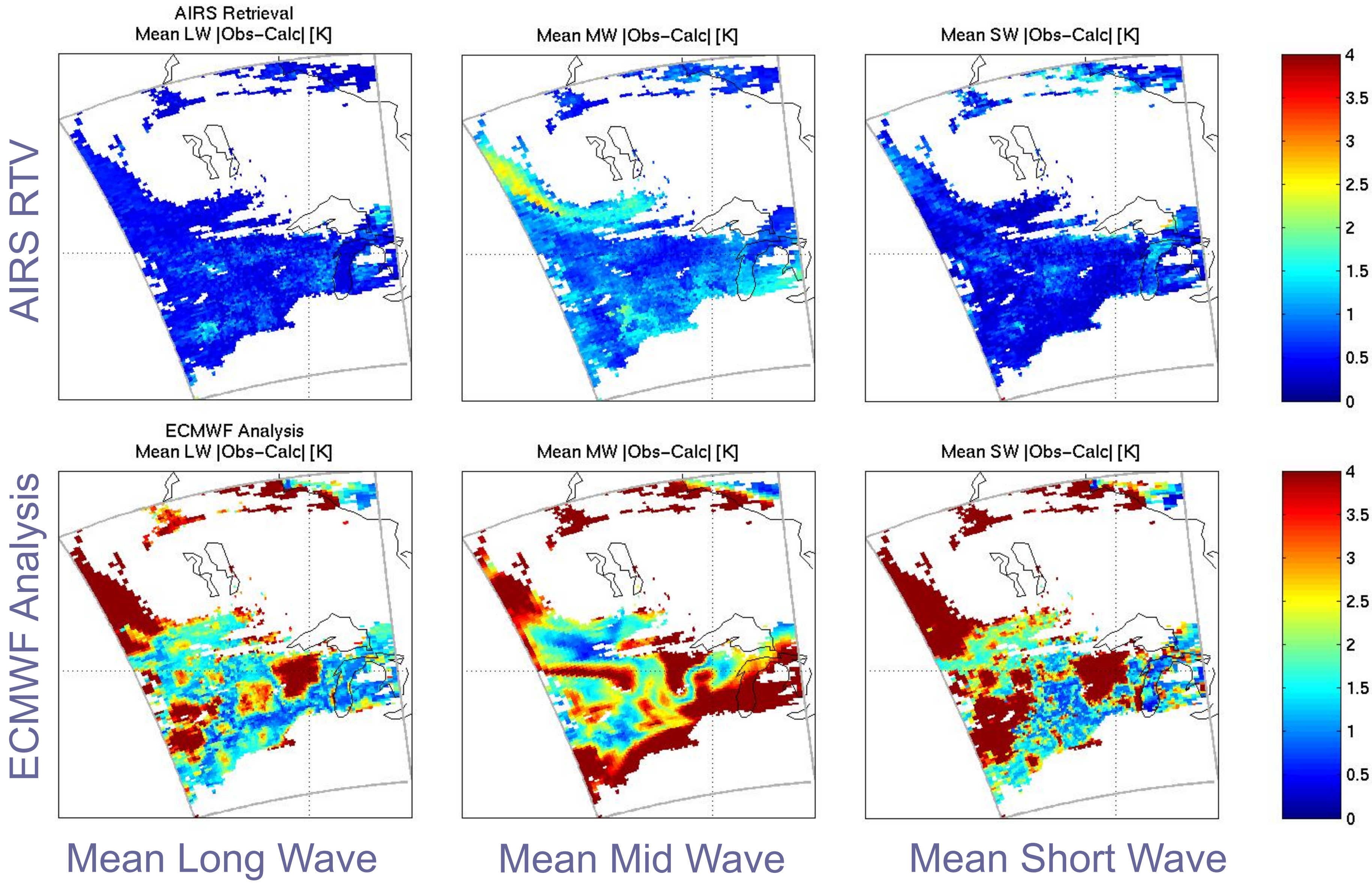
IMAPP AIRS Retrieval



ECMWF Analysis



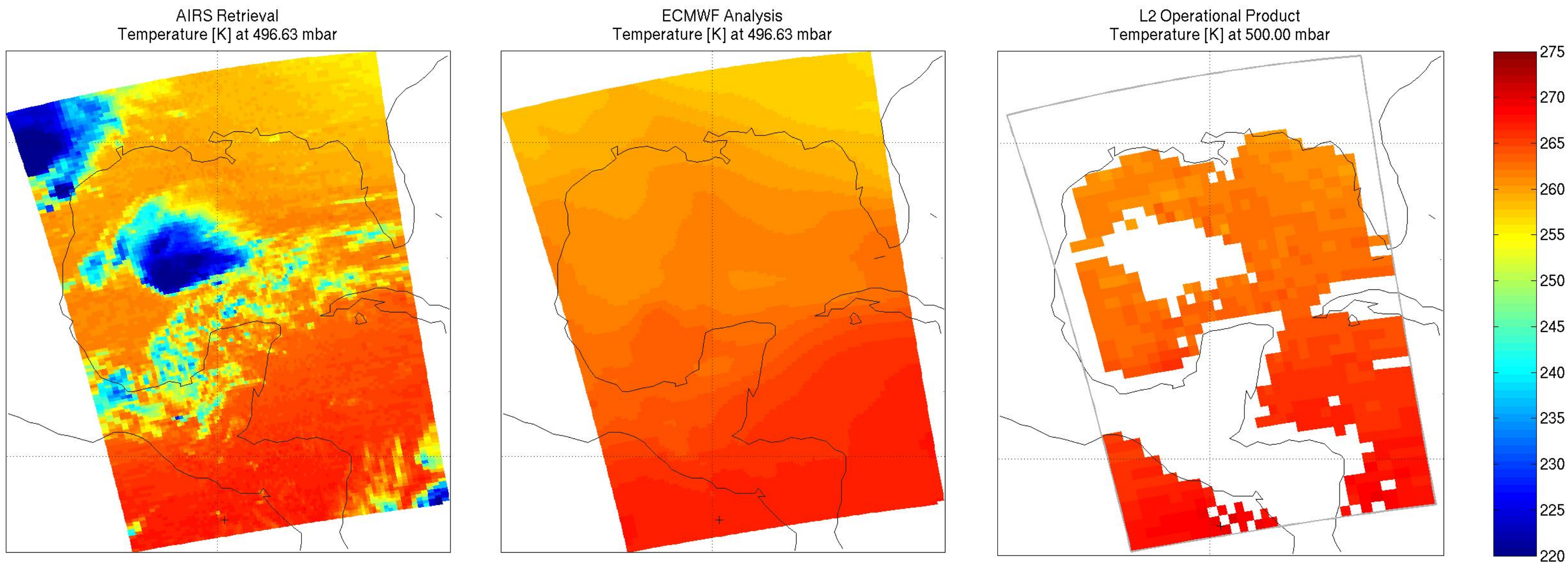
AIRS RTV vs. ECMWF Analysis: Spectral mean of Brightness Temperature (BT) residual



IMAPP AIRS Regression Retrieval Results:

Comparison with ECMWF analysis fields
and L2 operational product

AIRS RTV vs. ECMWF Analysis vs. Operational Product: Temperature at 500 mbar (G192, 04-04-2004)



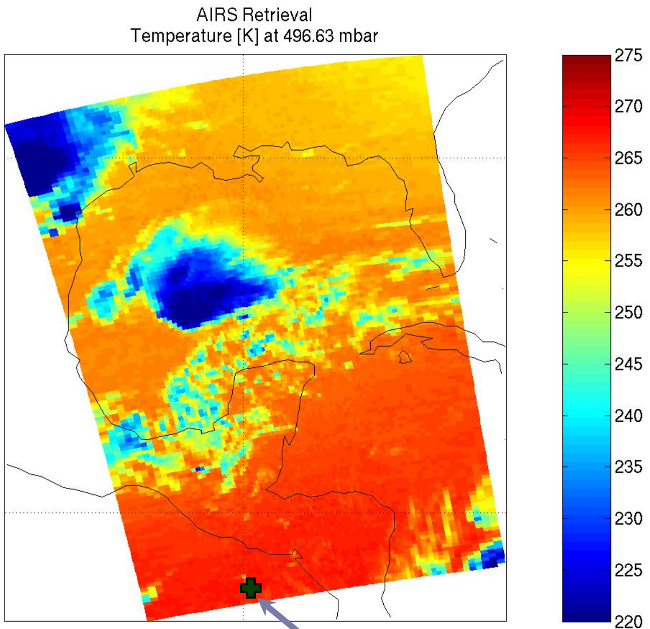
IMAPP AIRS RTV

ECMWF ANL

Operational AIRS RTV

- available on AMSU footprint (=3x3 AIRS FOVs) only
- missing areas → retrieval not successful or not validated yet

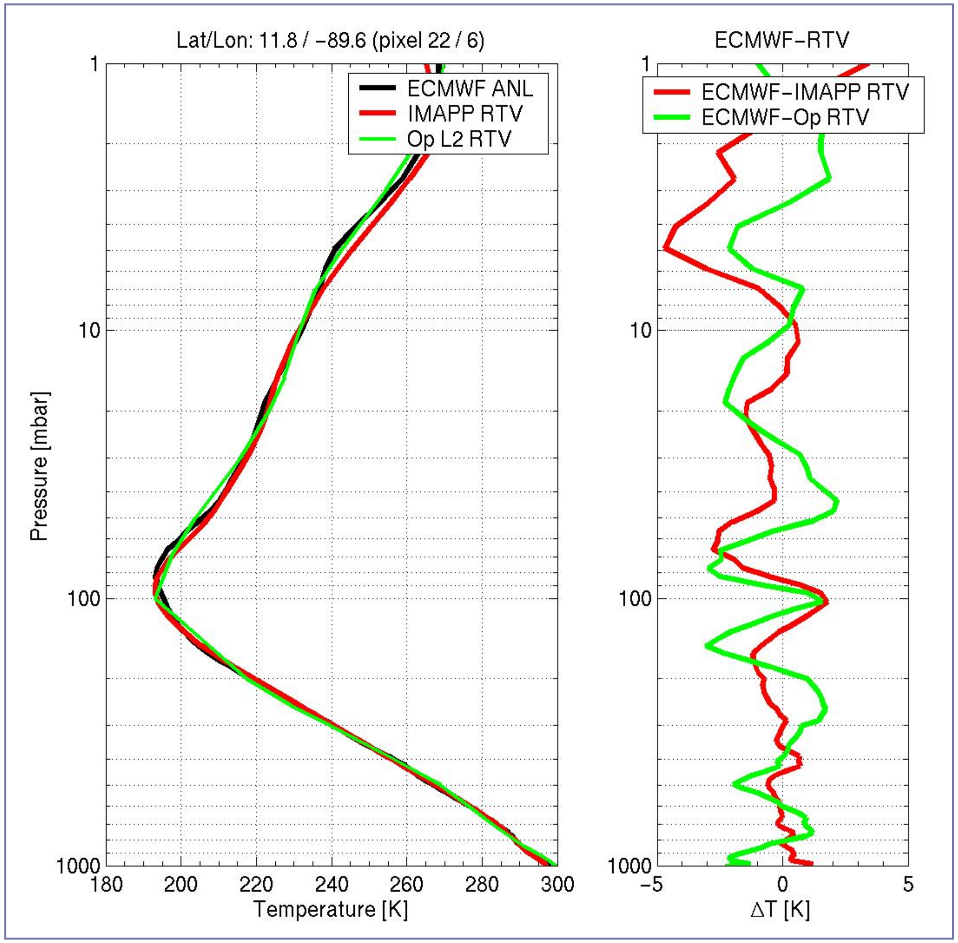
AIRS RTV vs. ECMWF Analysis vs. Operational Product: Temperature at selected pixel



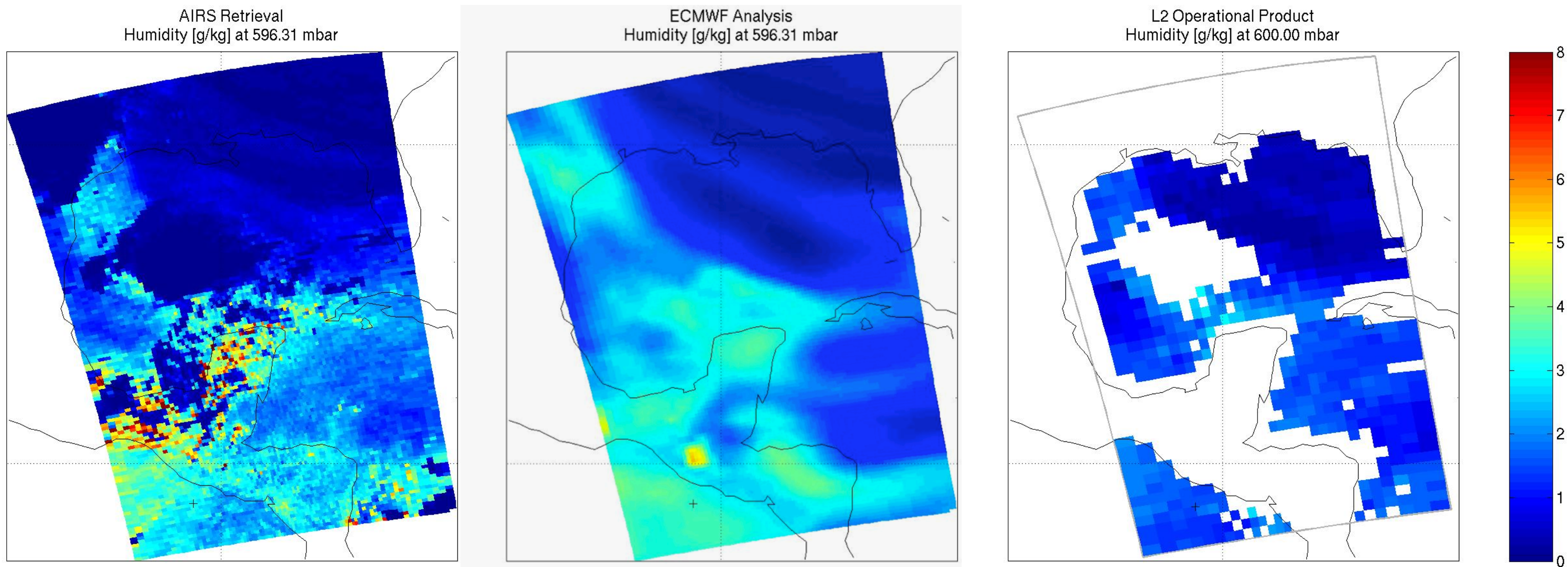
Pixel 22/6

ECMWF ANL
IMAPP RTV
OP RTV

ECMWF – IMAPP RTV
ECMWF – OP RTV



AIRS RTV vs. ECMWF Analysis vs. Operational Product: Humidity at 600 mbar (G192, 04-04-2004)



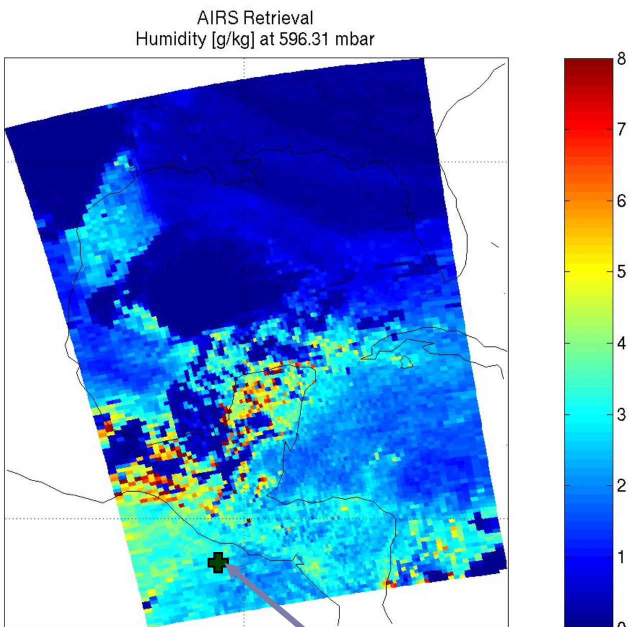
IMAPP AIRS RTV

ECMWF ANL

Operational AIRS RTV

- available on AMSU footprint (=3x3 AIRS FOVs) only
- missing areas → retrieval not successful or not validated yet

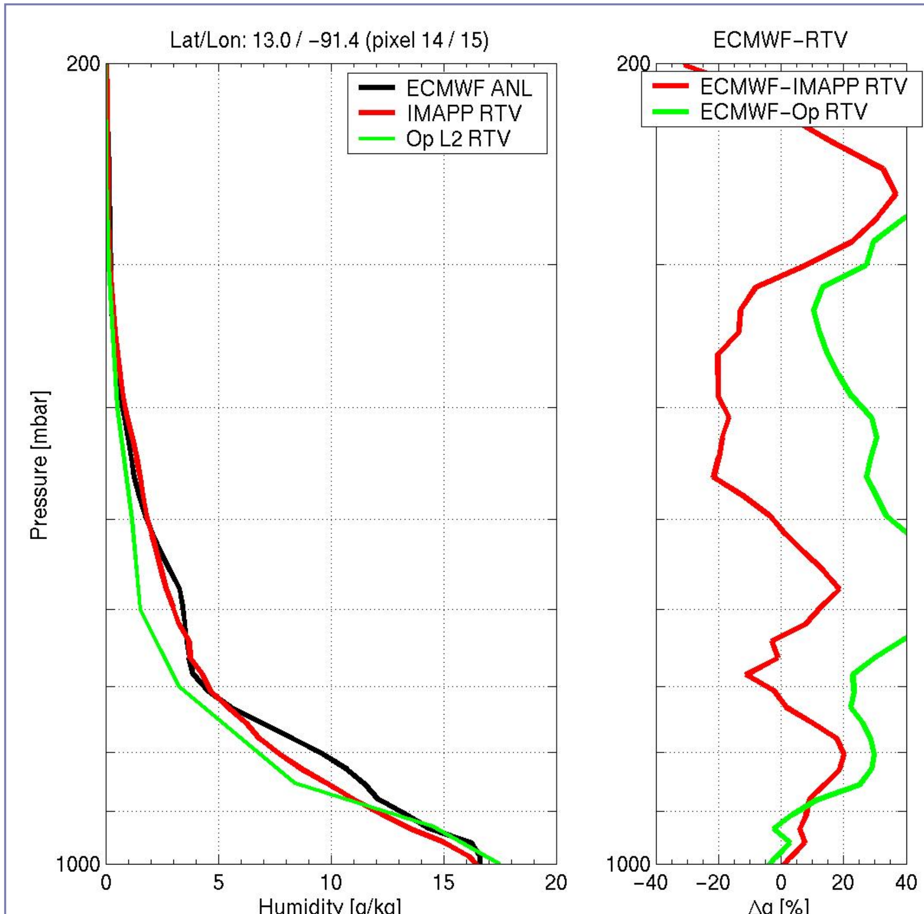
AIRS RTV vs. ECMWF Analysis vs. Operational Product: Humidity at selected pixel



Pixel 14/15

ECMWF ANL
IMAPP RTV
OP RTV

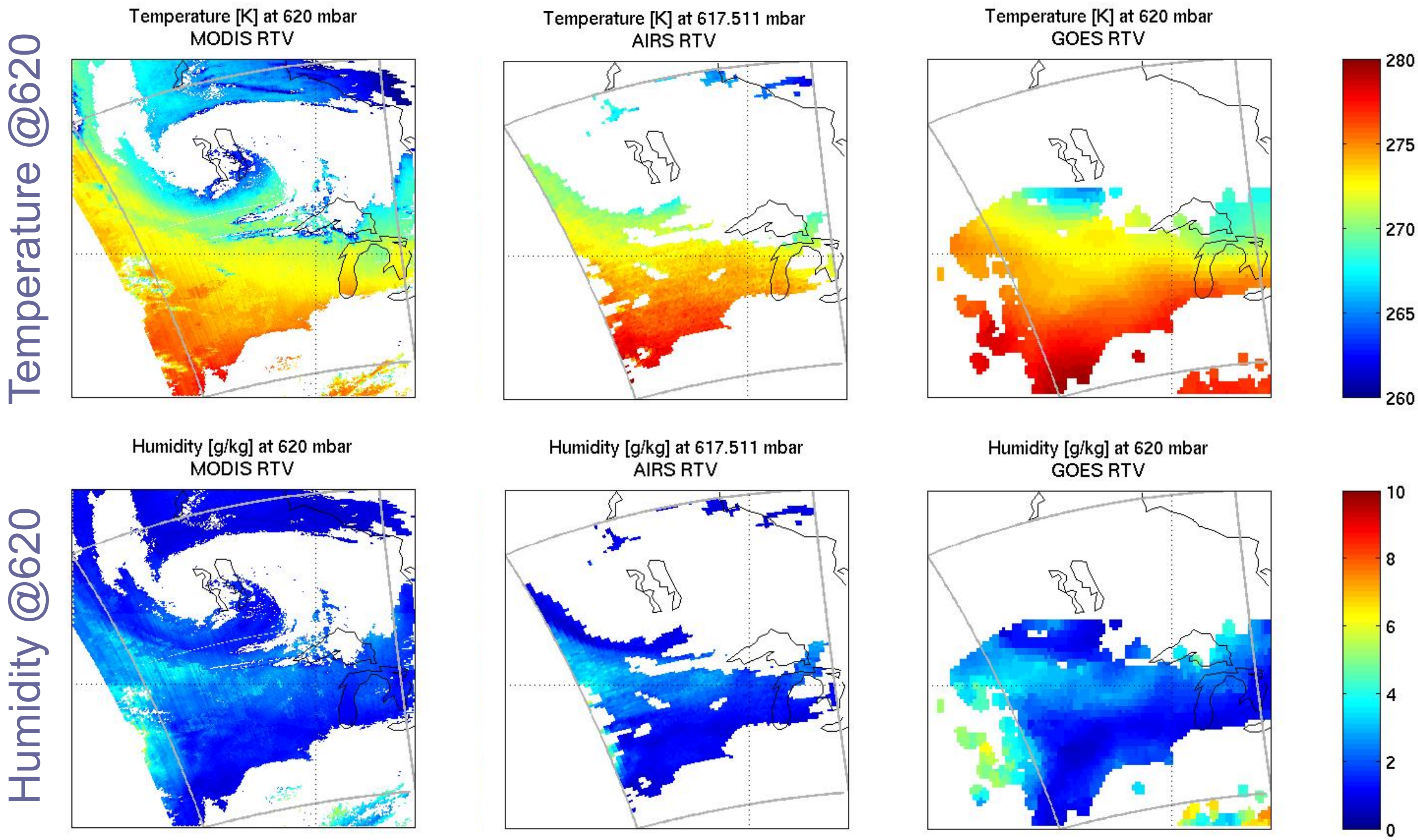
ECMWF – IMAPP RTV
ECMWF – OP RTV



IMAPP AIRS Regression Retrieval Results:

Comparison with MODIS and GOES retrievals

MODIS RTV vs. AIRS RTV vs. GOES RTV: Temperature and Humidity at 620 mbar (G192, 09-02-2003)



MODIS RTV AIRS RTV GOES RTV