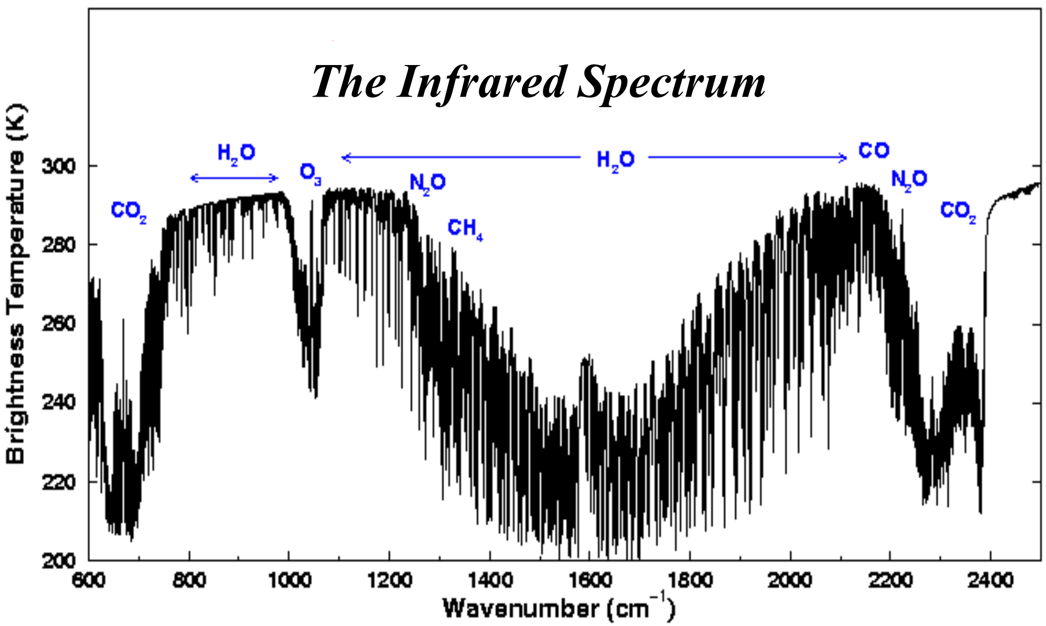
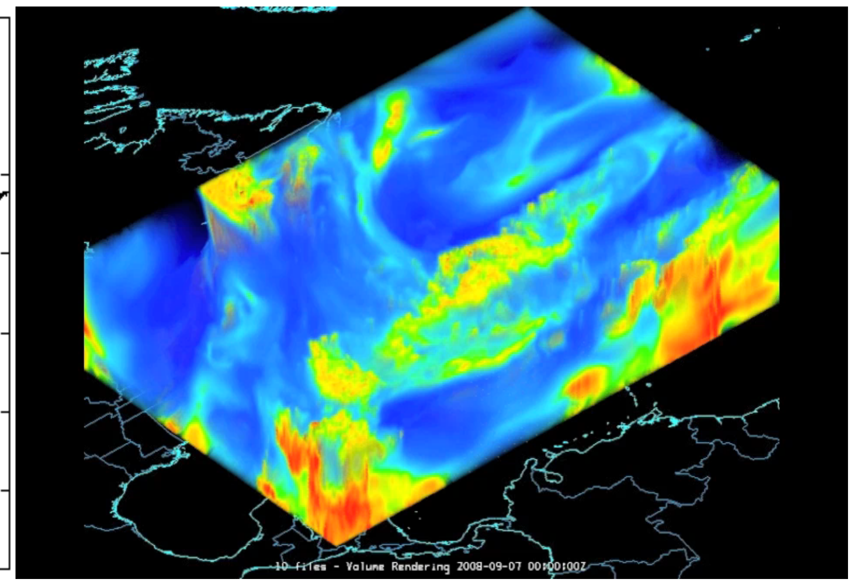
CLARREO – State Parameter Climate Retrieval

William L. Smith Sr., Elisabeth Weisz, Hank Revercomb, Steven Dutcher, Robert Knuteson
University of Wisconsin - Madison





Water Vapor Circulation

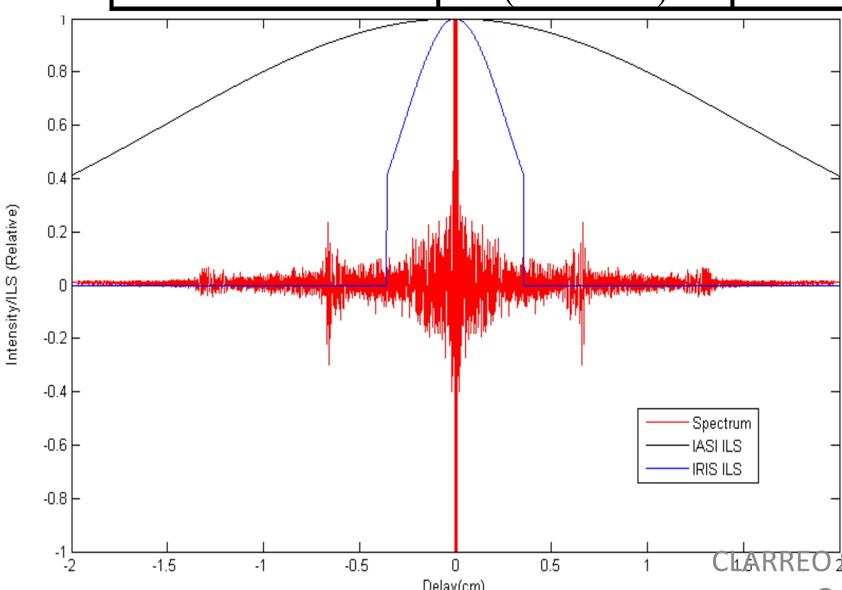
Observed Radiance Spectrum → **Climate Variable Analyses**

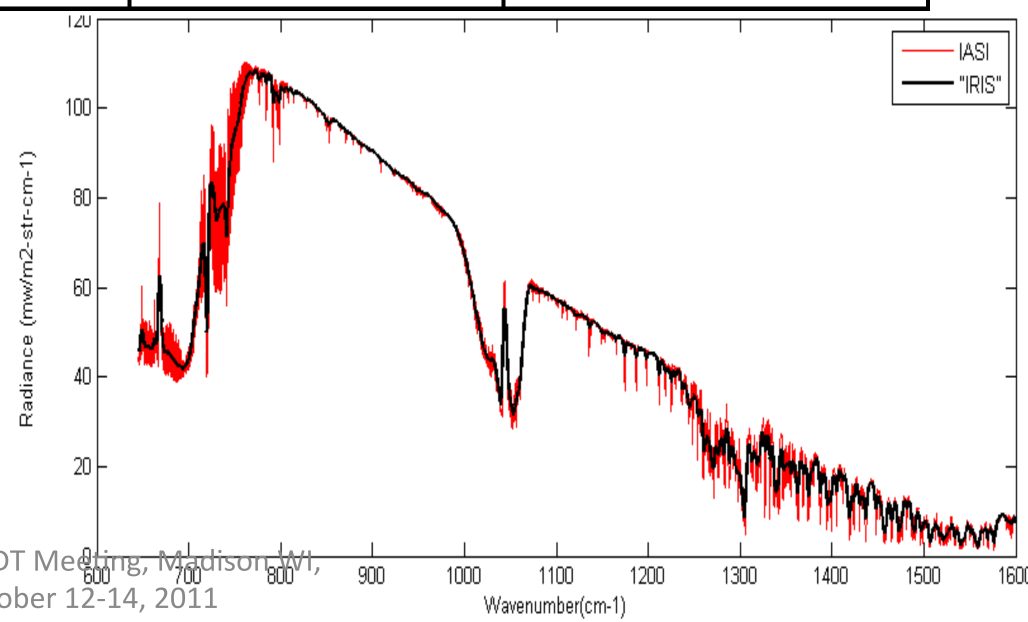
Desirable Features of Climate Retrieval Algorithm

- ***Linear dependence on radiance spectra***
  - Variation depends only on radiance (i.e., no other input variables)
- ***All sky***
  - clear and cloudy (0 - 100%)
- ***Independent of Field-of-View (FOV) size***
  - Can be applied to different instruments
- ***Retrieval Variables***
  - *Surface* : temperature & spectral emissivity
  - *Atmosphere* : T, H_2O, and O_3 profiles & CO_2 ppm
  - *Cloud* : height and optical thickness

Satellite Instrument Characteristics

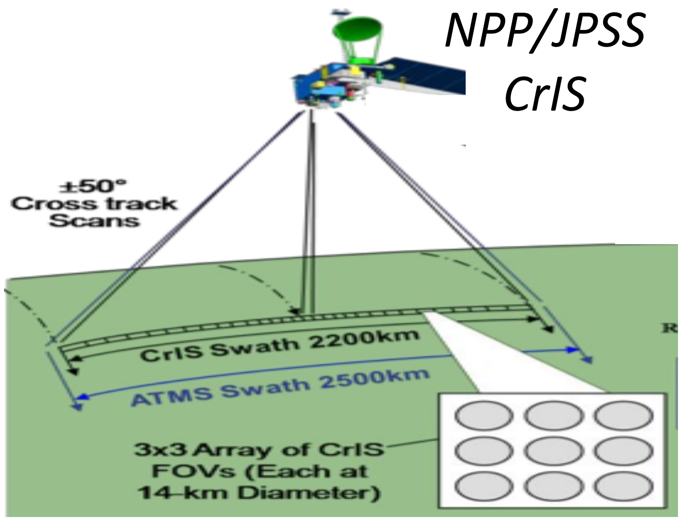
Instrument	Spatial resolution	spectral res. (cm^{-1})	spectral rng. (cm^{-1})	spatial sampling
IRIS (1970)	100 km	1.40	400-1600	Nadir
AIRS (2002 -)	3x3 13.5-km (50 km)	~1200 resolving power	645-2700	Contiguous Cross-track scan
IASI (2006 -)	2x2 12.0-km (50 km)	0.25	645-2760	Contiguous Cross-track Scan
CrIS (2011 -)	3 x 3 13-km (50 km)	0.6	645-2700	Contiguous Cross-track
CLARREO (??)	25 to 100-km (TBD km)	0.5	200-2700	Nadir



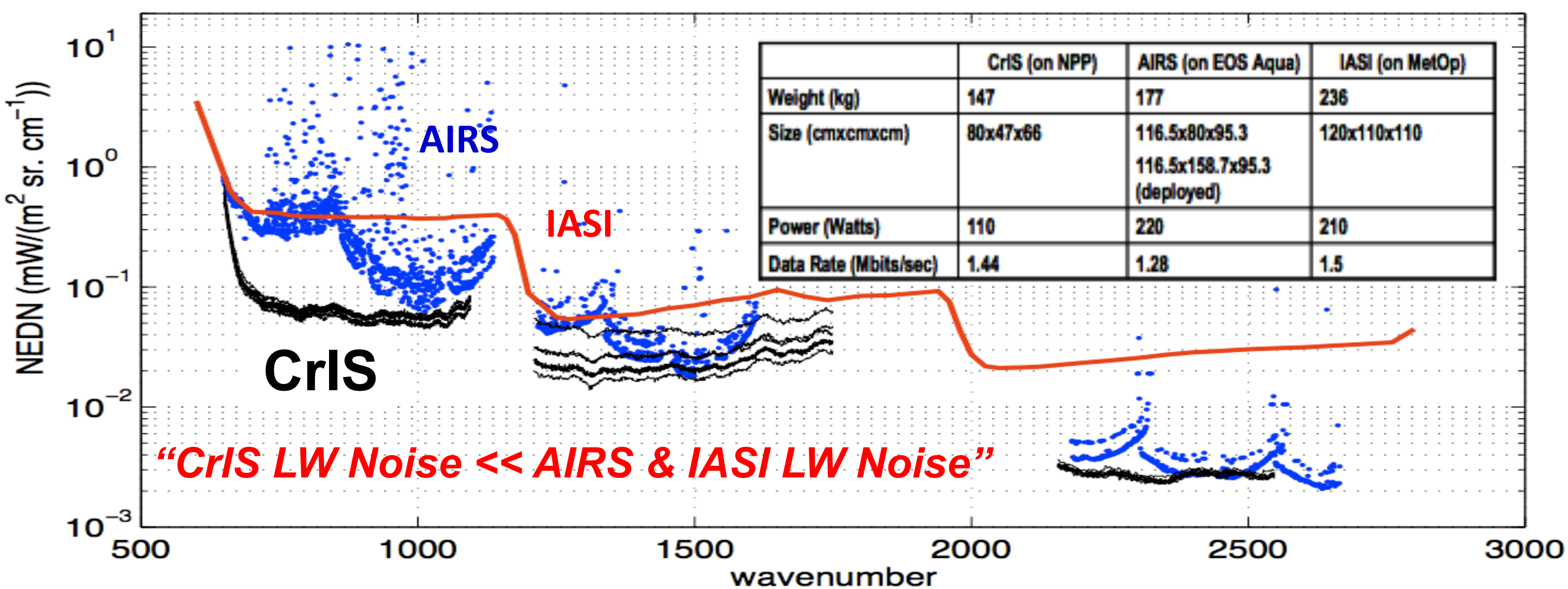


Cross-Track Infrared Sounder (CrIS)

NPOESS Preparatory Satellite – Launch: October 25, 2011



- Michelson Interferometer: 0.625,1.25, 2.5cm^{-1} (resolving power of 1000)
- Spectral range: 660-2600 cm^{-1}
- 3 x 3 HdCdTe focal plane passively cooled (4-stages) to 85K
- Focal plane 27 detectors, 1305 spectral channels
- 310 K Blackbody and space view provides radiometric calibration
- NEDT ranges from 0.05 K to 0. 5 K

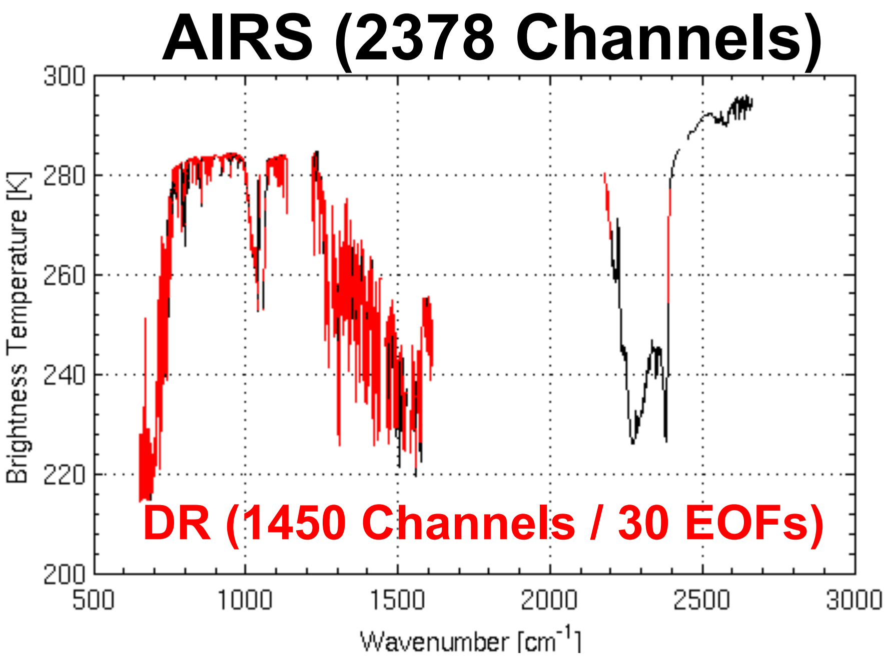


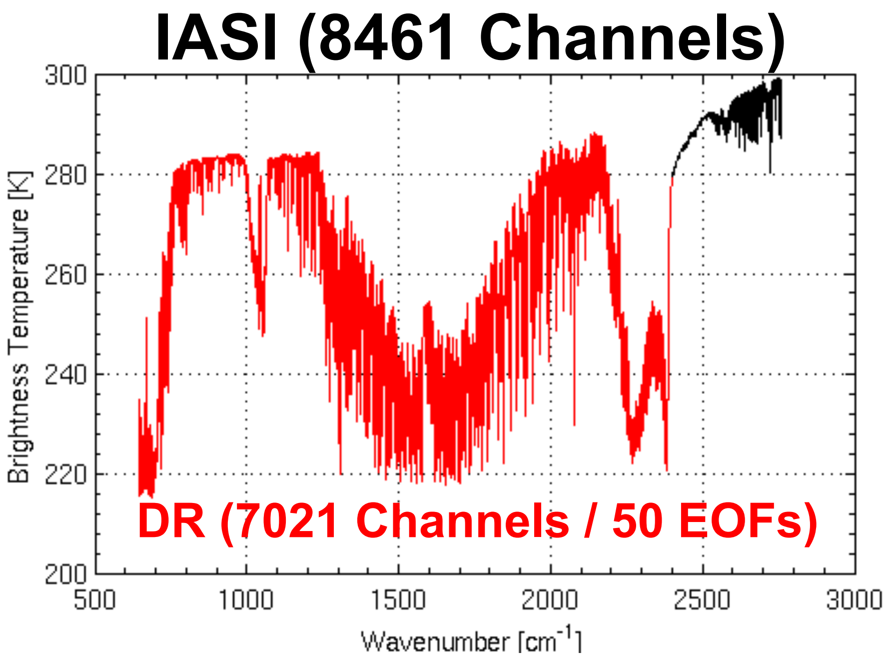
	CrIS (on NPP)	AIRS (on EOS Aqua)	IASI (on MetOp)
Weight (kg)	147	177	236
Size (cmxcmxcm)	80x47x66	116.5x80x95.3 116.5x158.7x95.3 (deployed)	120x110x110
Power (Watts)	110	220	210
Data Rate (Mbits/sec)	1.44	1.28	1.5

Dual Regression Retrieval Algorithm

- **Classified linear Dual-Regression (DR)**
  - **Very fast (real-time) all-sky temperature, water vapor, ozone profiles plus surface skin temperature and spectral emissivity, cloud pressure and optical depth and total CO_2 concentration retrieval algorithm**
- **Non-linear dependence on cloud pressure and humidity accounted for by classification (9 cloud height / H_2O classes within 5 CO_2 classes)**
- **Training Data Sets for Robust Retrievals**
  - **Large (15,704 clear sky and 19948 cloudy sky) global all season radiosonde / remote region ECMWF analysis data set**
  - **Cloud altitudes diagnosed from humidity profile**
  - **Surface skin temperature and emissivity and cloud microphysical properties based on empirical data sets with Gaussian random perturbations**
  - **UMBC SARTA and Texas A&M / U. Wisconsin Cloud RTM for radiances**

AIRS & IASI Channels Used





CrIS Channel Selection and EOF number will be similar to AIRS

Technique – Dual Regression

- Linearizes Cloud and Moisture Dependence through classification
- Based on single 40-yr Global Profile Data Set & Calculated Radiances

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 (100-900 hPa)

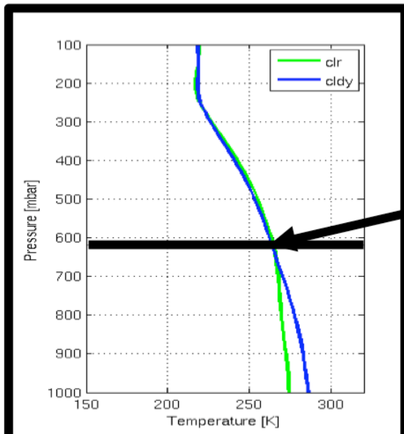
↓

Cloud trained EOF regression results

↓

Cloud Top Altitude

level where T(cloudy)>T(clear) for p>p$_{cld}$



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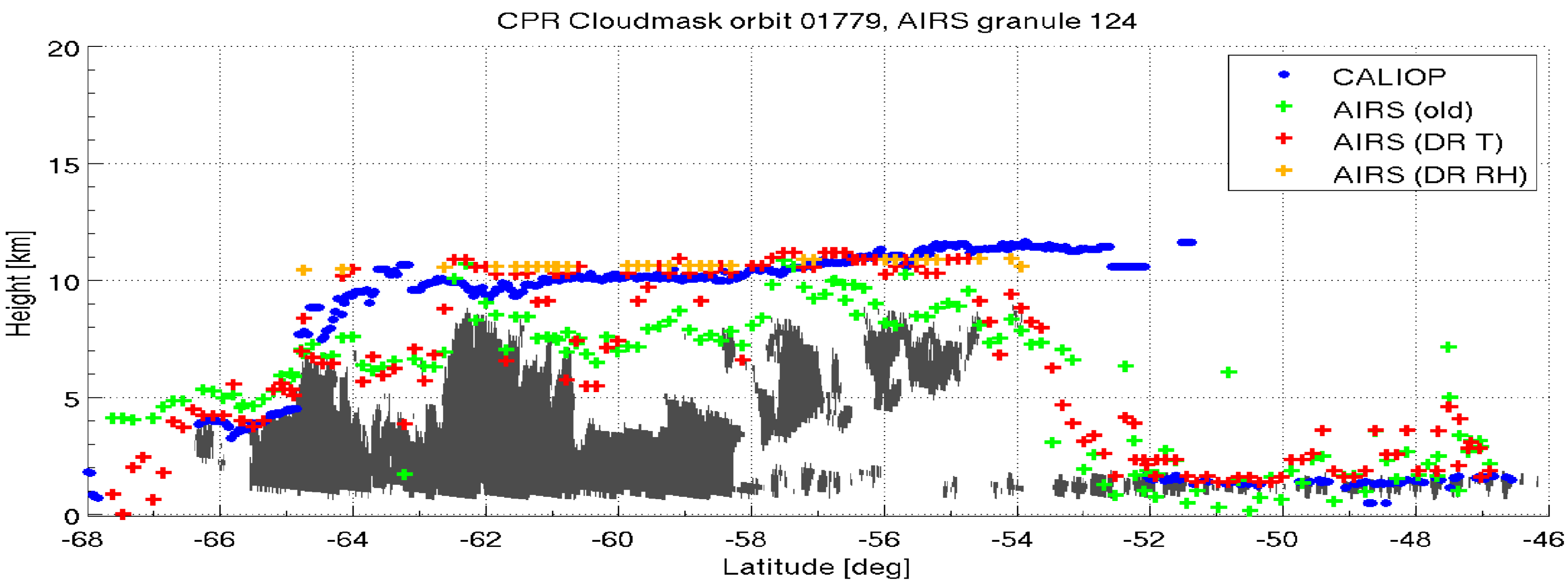
Final Profile [1]

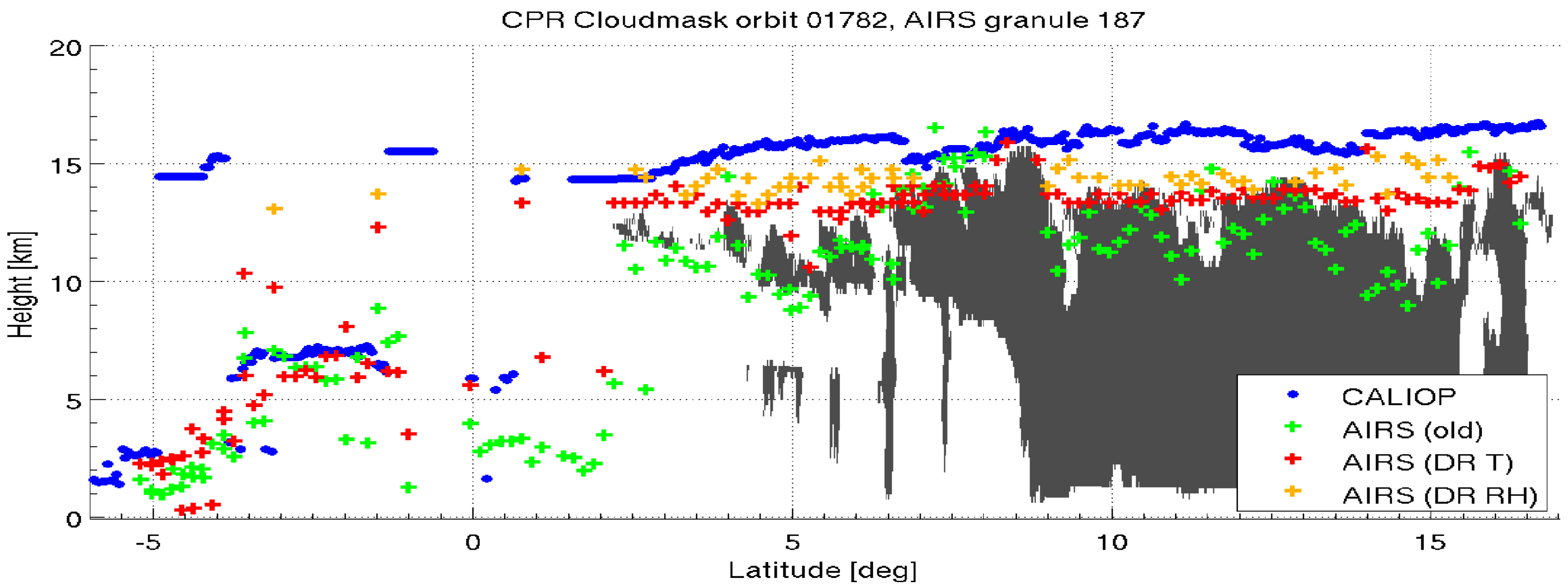
•clear-trained above,
•cloud-trained below cloud level

[1] Initial cloud-class selected from 8 200-hPa overlapping cloud layer class regressions (solution is one closest to layer mean)

[2] Retrieval below cloud set equal to missing if Max(Tclr-Tcld) >25 K

Cloud Altitude Validation-Lidar/Radar



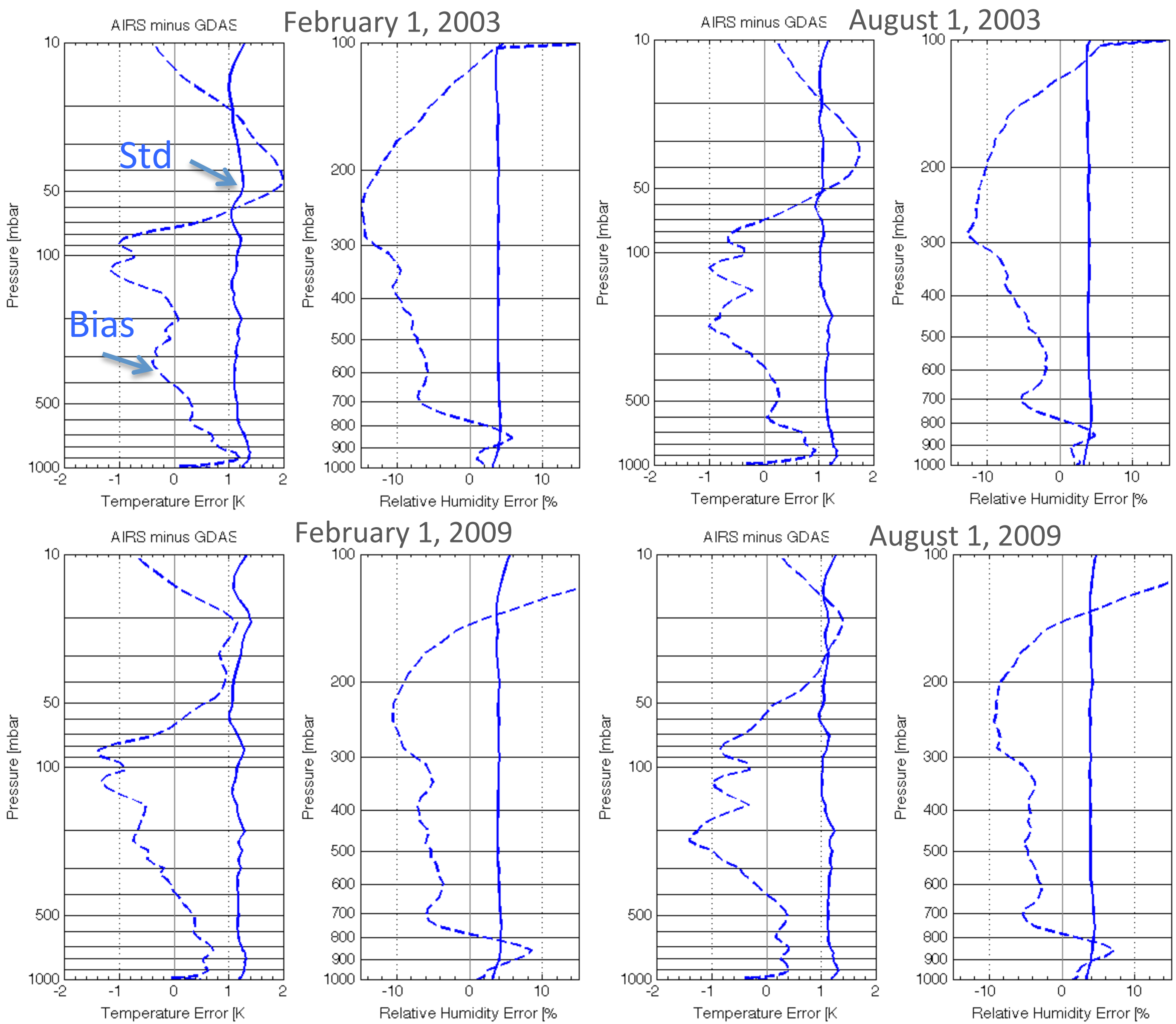


Climate Variables Retrieved

- Temperature Profile (K)
- Water Vapor Mixing Ratio Profile(g/kg)
- Relative Humidity Profile (%)
- Ozone Profile (ppmv)
- Surface Skin Temperature (K)
- Total Precipitable Water (cm)
- CO_2 Concentration (ppm)
- Cloud-top Altitude (hPa)
- Thin Cirrus Cloud-top Altitude (hPa)
- Effective Cloud Optical Depth
- Atmospheric Stability (Lifted Index)

AIRS Climatology based on retrievals from nadir-only full resolution (13-km) observations binned into 10-degree latitude-longitude grid cells

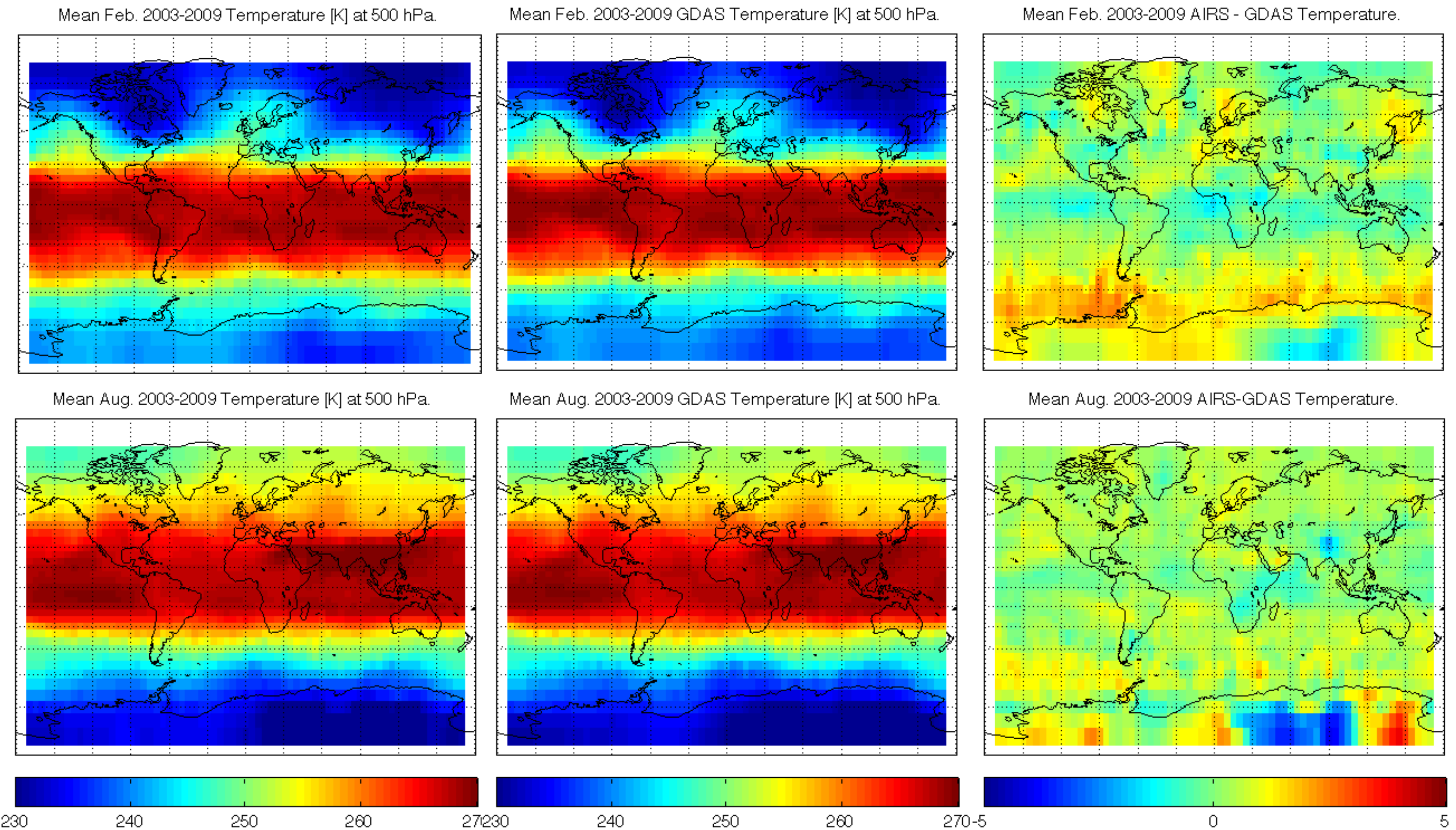
Single Day AIRS Vs GDAS Global Comparisons (N=32,400)



Comparisons with the NCEP Global Data Assimilation System (GDAS) product shows the the AIRS DR retrieval error characteristics are very stable on a global basis.

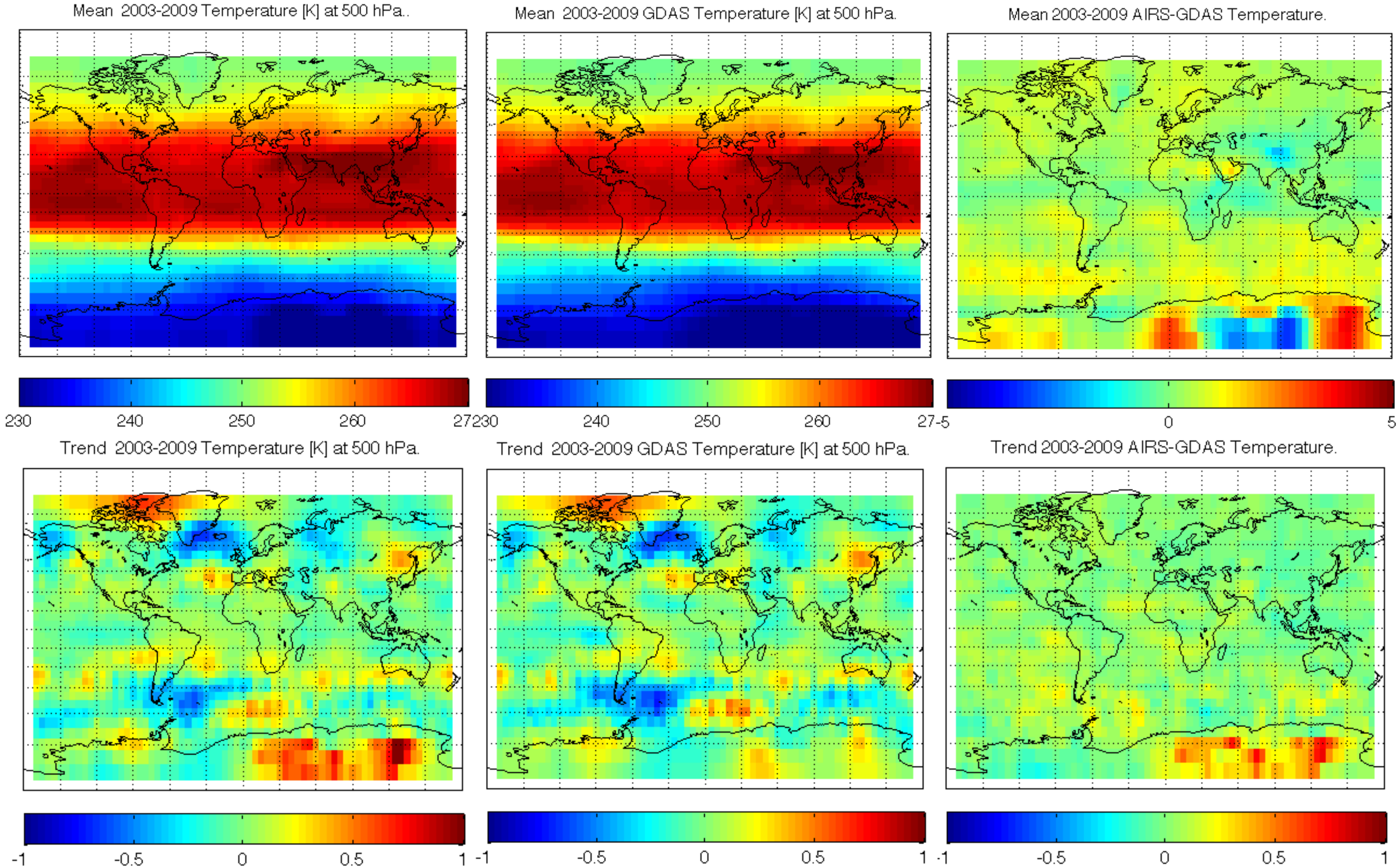
The global mean and standard errors are nearly invariant with month and year

500-hPa (5-km) Temperature February Vs August AIRS & GDAS 7-yr (2003-2009) Mean and Difference



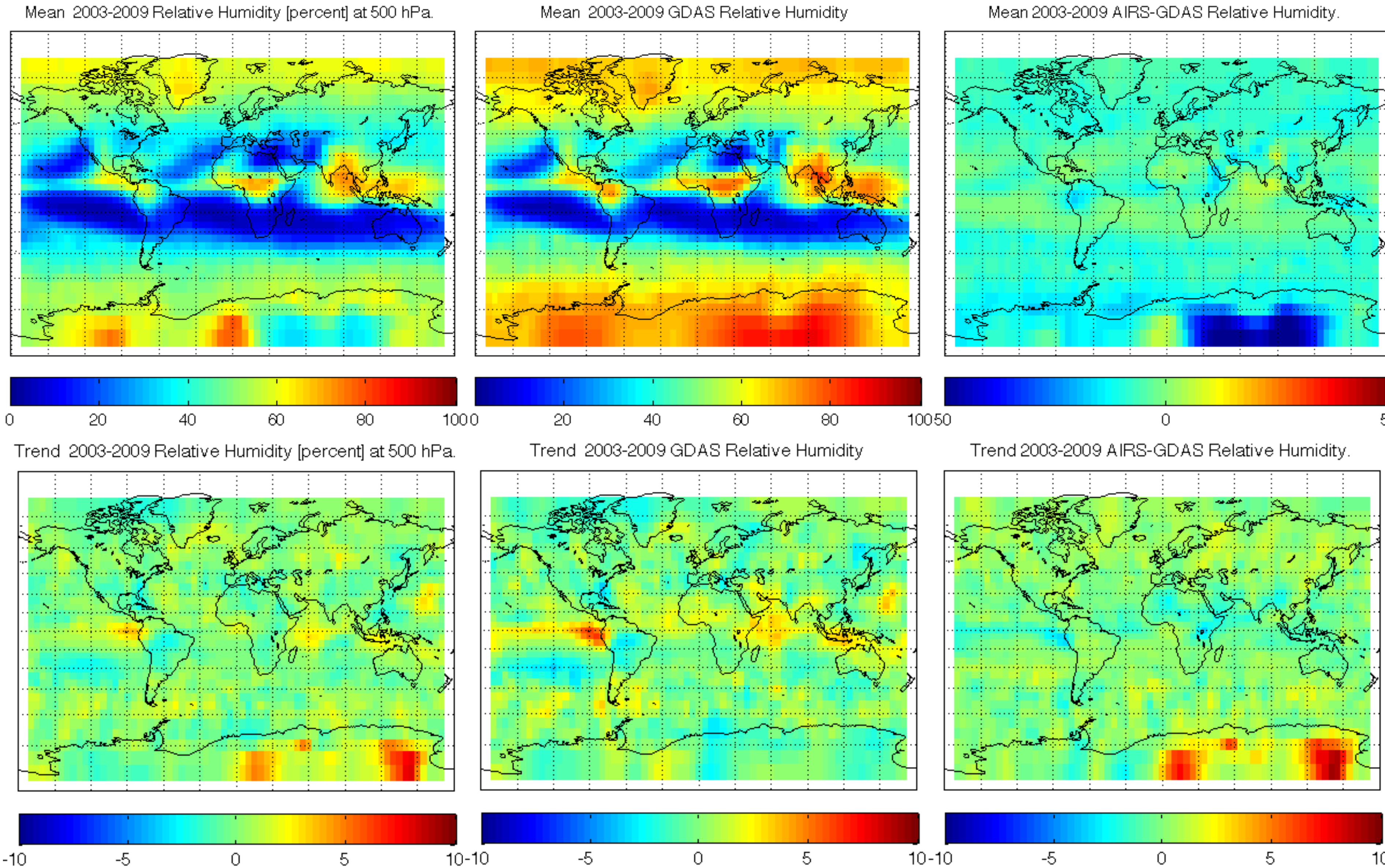
Monthly mean AIRS nadir-only temperature observations compare favorably with the assimilation of all available operational in-situ and satellite meteorological data

500-hPa (5-km) T AIRS Vs GDAS 2003-2009 (Feb+Aug)



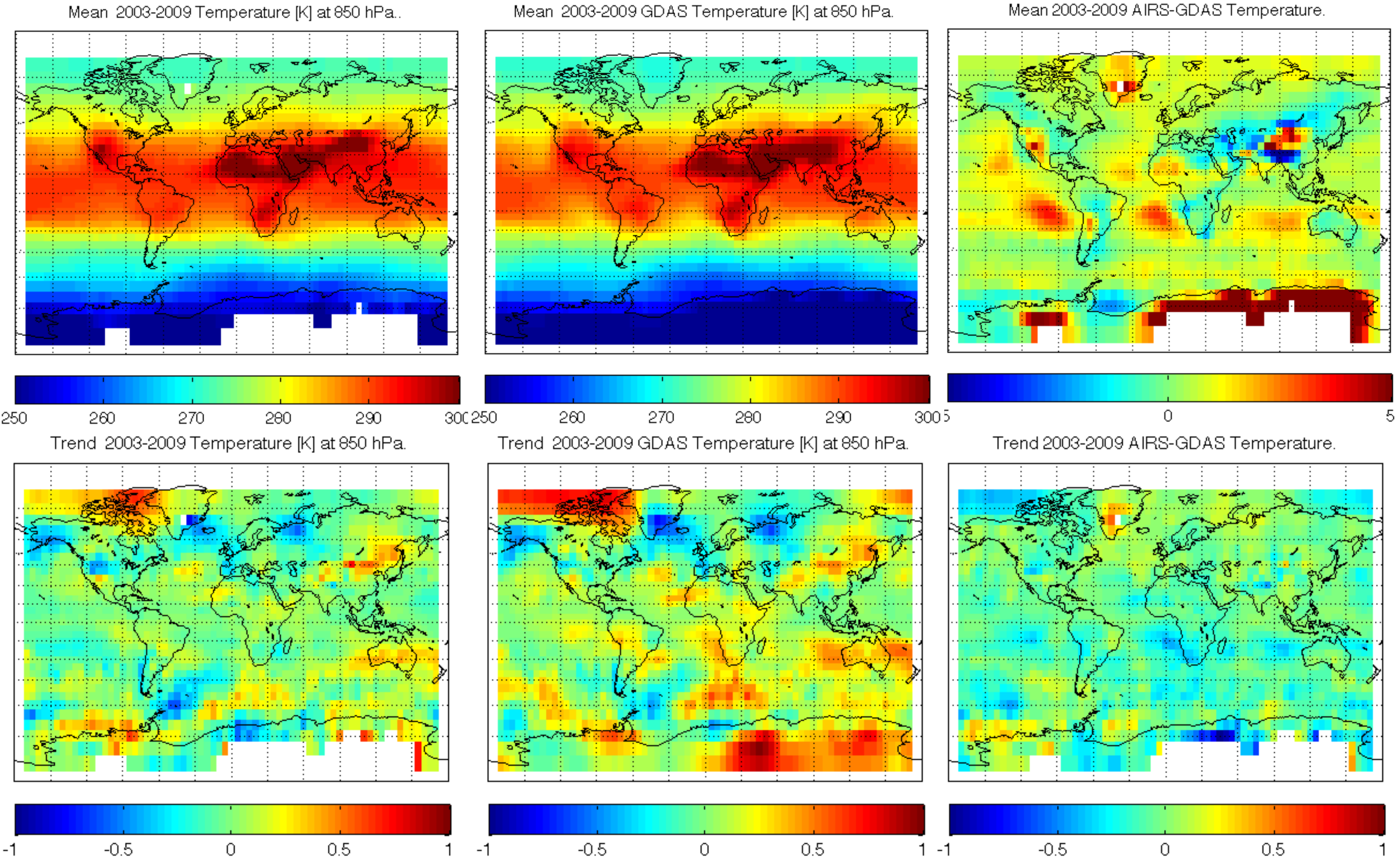
The sign of all regional temperature trends in the AIRS retrievals are validated with GDAS. Some significant differences in magnitude exist, particularly in the Southern Hemisphere.

500-hPa (5-km) RH AIRS Vs GDAS 2003-2009 (Feb+Aug)



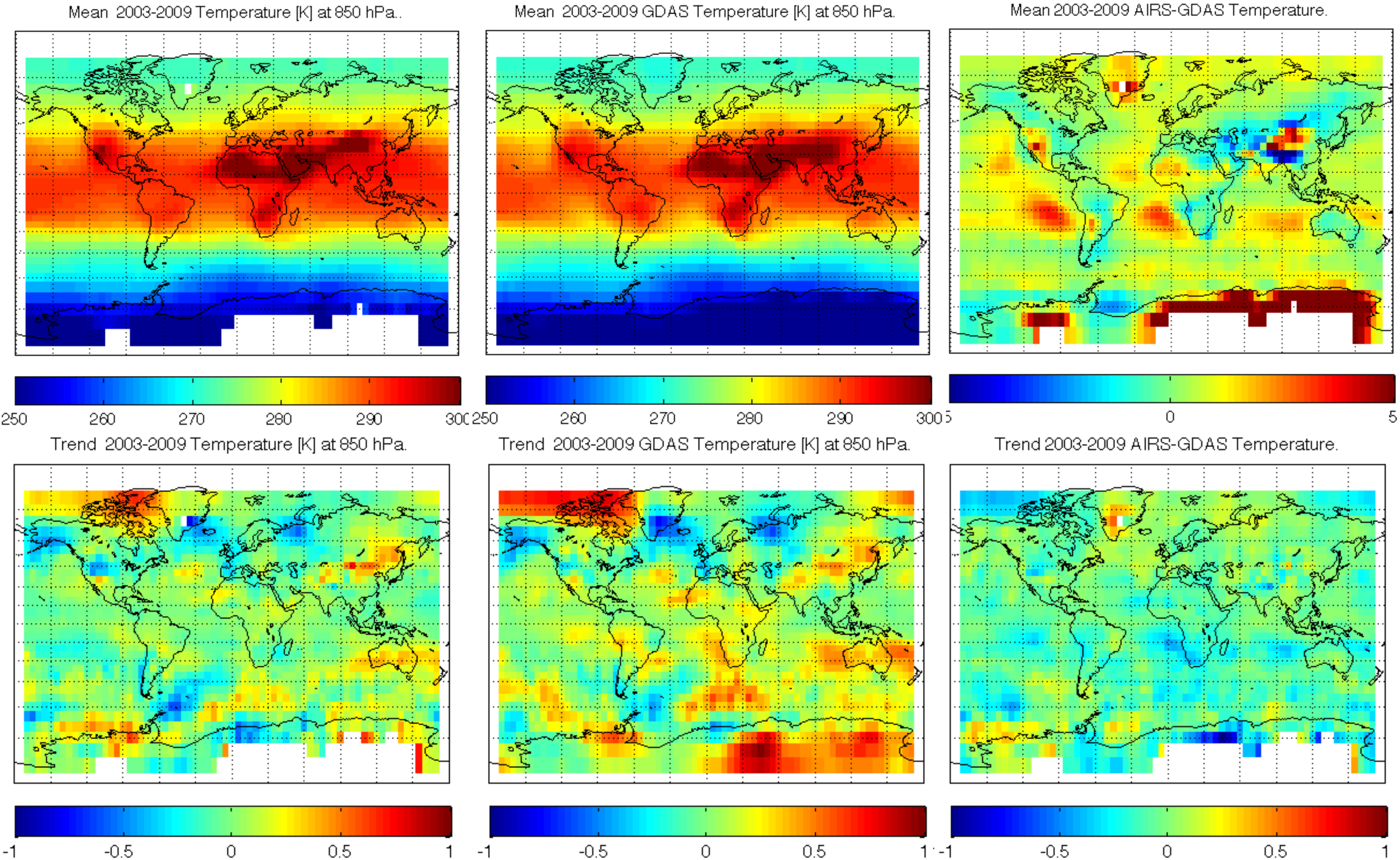
The sign of most regional humidity trends in the AIRS retrievals are validated with GDAS. Some significant differences in magnitude exist, particularly in the eastern tropical Pacific.

850-hPa (2-km) T AIRS Vs GDAS 2003-2009 (Feb+Aug)



Good agreement between AIRS below cloud level DR temperature retrievals and GDAS is obtained. The sign of all significant trends in the AIRS retrievals is validated with GDAS.

850-hPa (2-km) RH AIRS Vs GDAS 2003-2009 (Feb+Aug)



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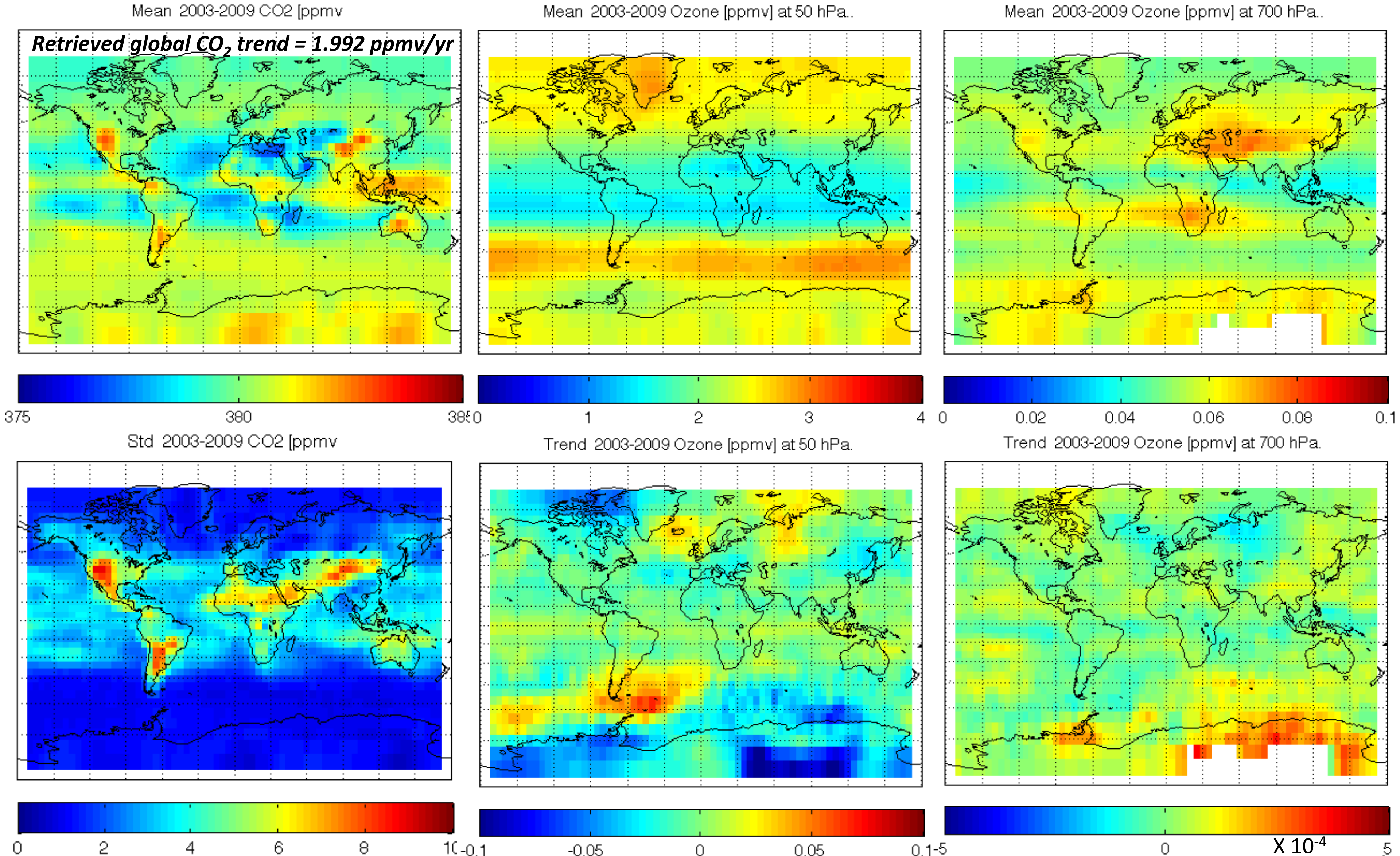
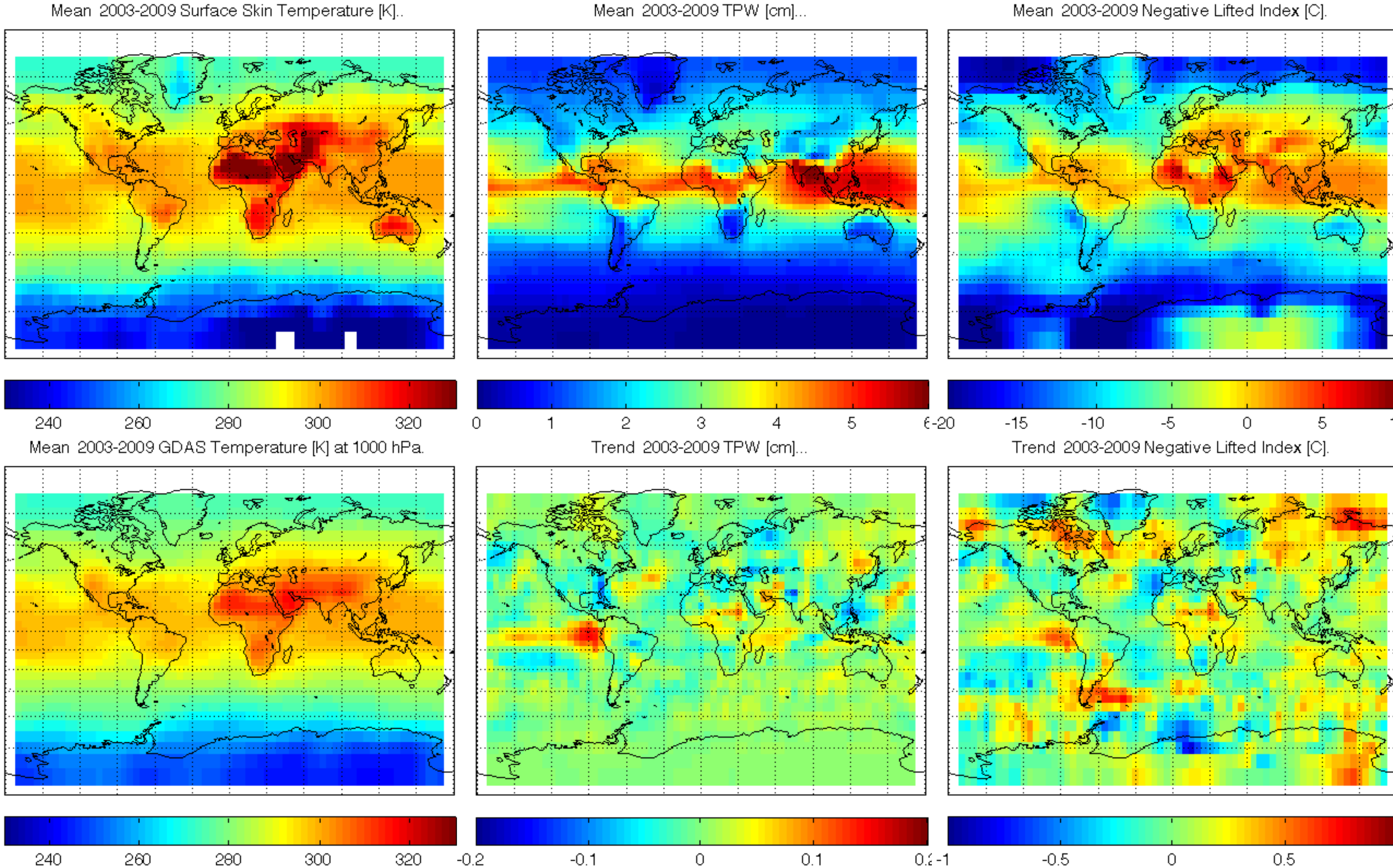
2003-2009 Carbon Dioxide and Ozone(Feb+Aug)



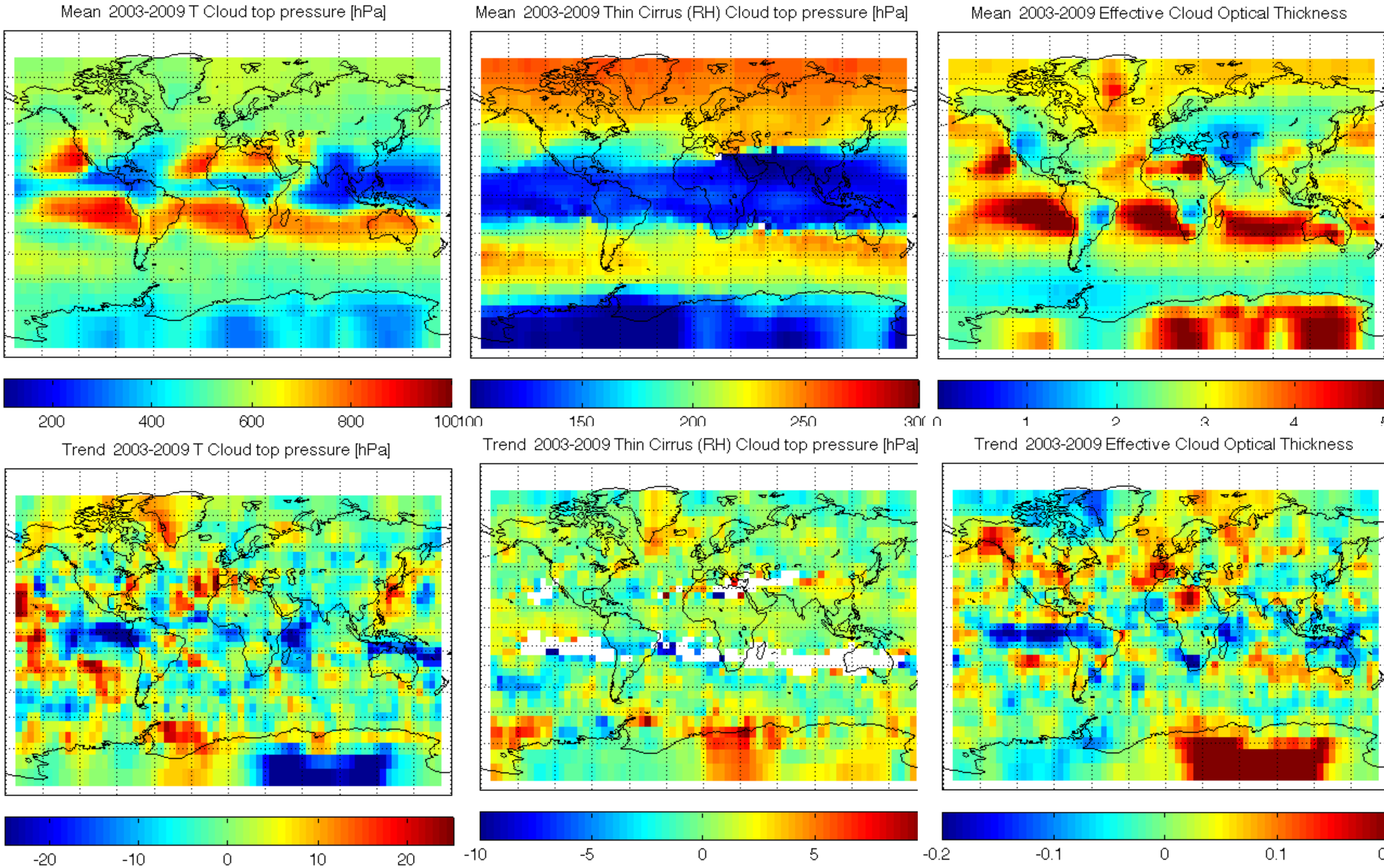
CO_2 global mean and standard deviation are consistent with known fire source regions. Retrievals resolve differences between stratospheric and tropospheric ozone

2003-2009 T_{sfc}, Total Precipitable H_2O, and Stability



AIRS T_{skin} is consistent with GDAS T_{air}. AIRS TPW indicates trend towards stronger El-nino's during observation period. No large scale trends in atmospheric stability .

2003-2009 Cloud Pressure Altitude and Optical Thickness



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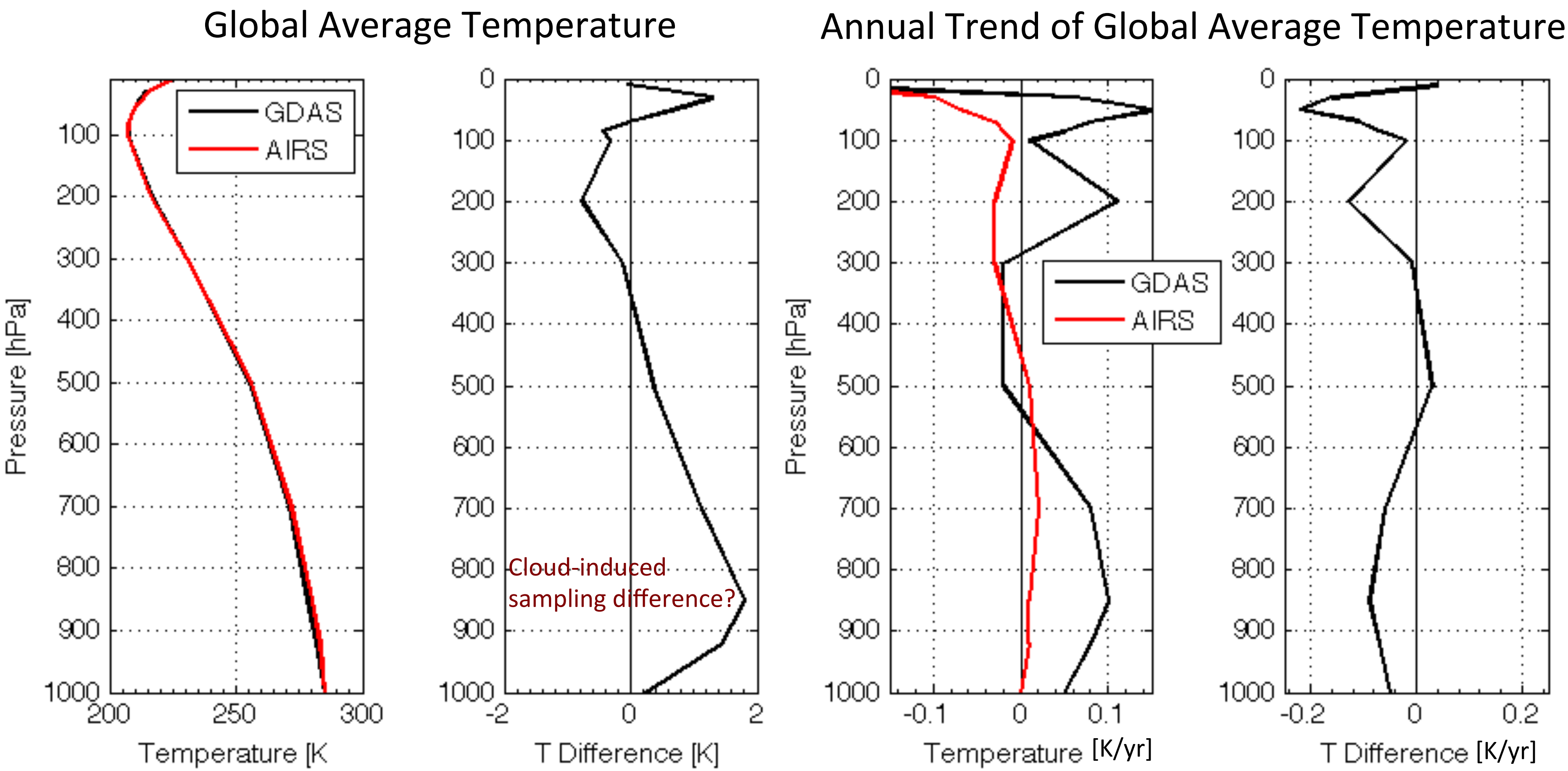
Global Average Temperature and Trends

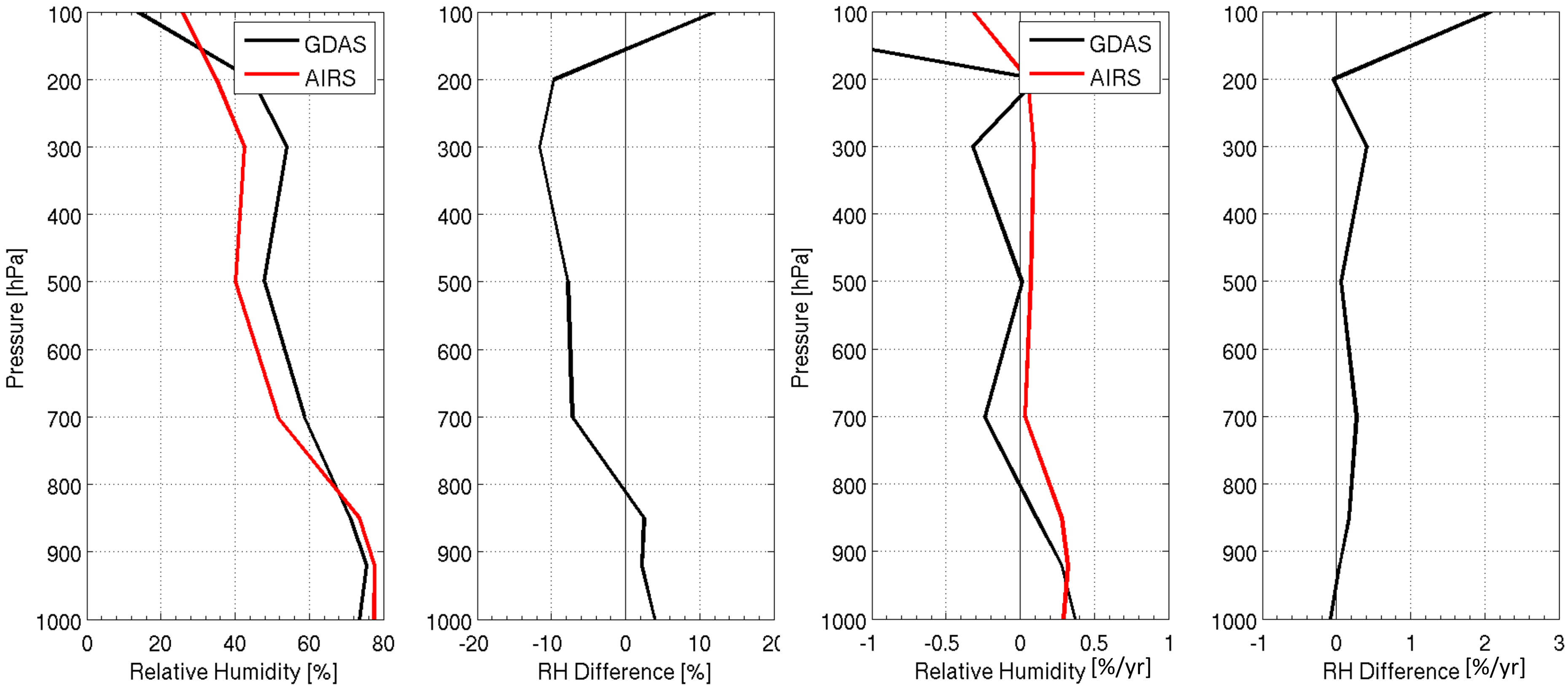


AIRS indicates a warmer globally averaged lower troposphere than GDAS. AIRS vertical temperature trend profile is consistent with GHG induced global warming expectations (i.e., a warming lower tropsophere and cooling upper troposphere and stratosphere.

Global Average Humidity and Trends

Global Average Humidity

Annual Trend of Global Average Humidity



AIRS indicates a wetter lower troposphere and drier mid-upper troposphere than GDAS. Both AIRS and GDAS indicate a moistening lower troposphere with little time variation at upper tropospheric levels. Overall absolute agreement is close to radiosonde accuracy.

Conclusions

- *A robust method for retrieving atmospheric properties solely from ultra-spectral IR satellite measurements (e.g., CLARREO) has been developed*
- *Application of the algorithm to seven years of AIRS nadir-only observations for 10-degree horizontal grid boxes indicate that the retrievals can diagnose significant regional climate trends. Global mean values and annual trends compare favorably with the NCEP Global Data Assimilation System (GDAS) product*
- *Bias differences between AIRS and GDAS lower tropospheric temperature may be due to differences in spatial and diurnal sampling of the data (e.g., gaps in AIRS sampling caused by dense cloudiness)*
- *The impact of clouds and diurnal sampling on the AIRS climatology needs to be better defined through additional studies using global operational data re-analysis results*

Future Work

- **Produce 9-yr AIRS Climatology (2003-2011)**
  - Validate 9-yr climatology using re-analysis products
  - Publish AIRS results
- **Conduct Comparison Studies**
  - Study instrument, diurnal sampling, cloud impacts
    - 5-yr IASI Vs AIRS climatology (2007-2011)
    - 5-yr GPS climatology (with S. Leroy)
    - Monthly average regional and global results from NPP CrIS
- **Produce 40-yr IASI-IRIS Differences (1970-2010)**
  - Reduce IASI to IRIS space and spectral resolution
  - Compare to other climate data sets