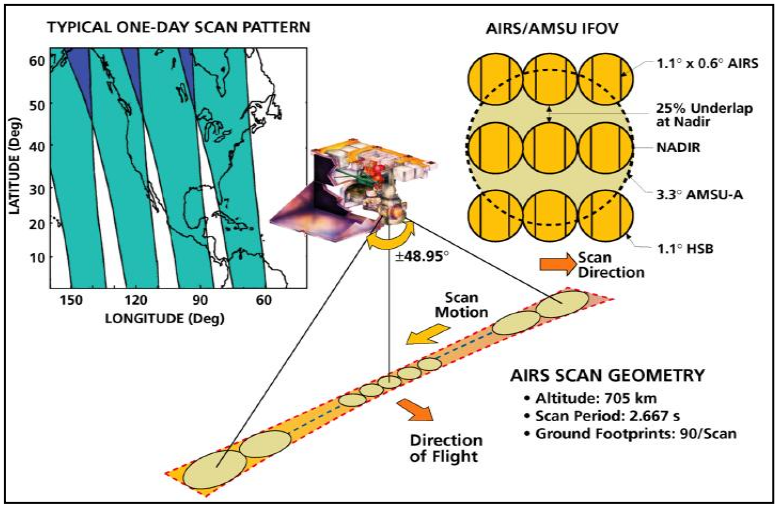
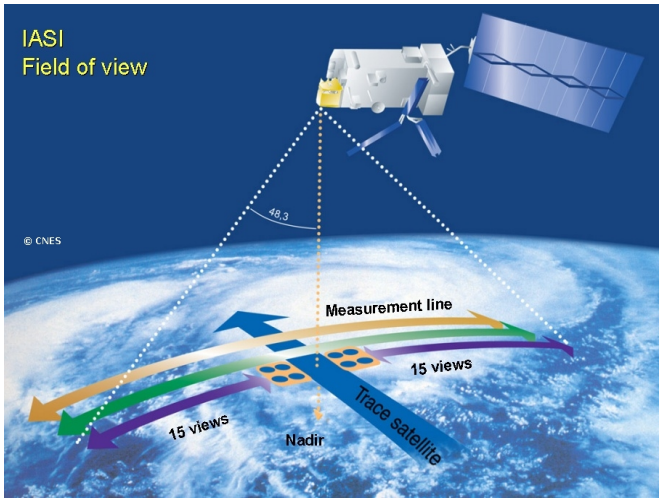
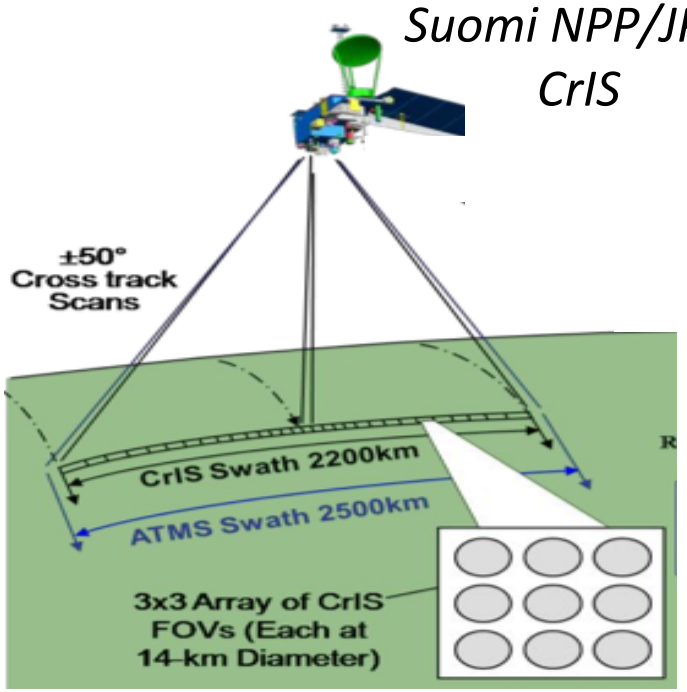
Comparison of Climate Variables from AIRS, IASI, and CrIS - CLARREO Implications

W. L. Smith, N. Smith, E. Weisz, and H.E. Revercomb





Suomi NPP/JPSS CrIS



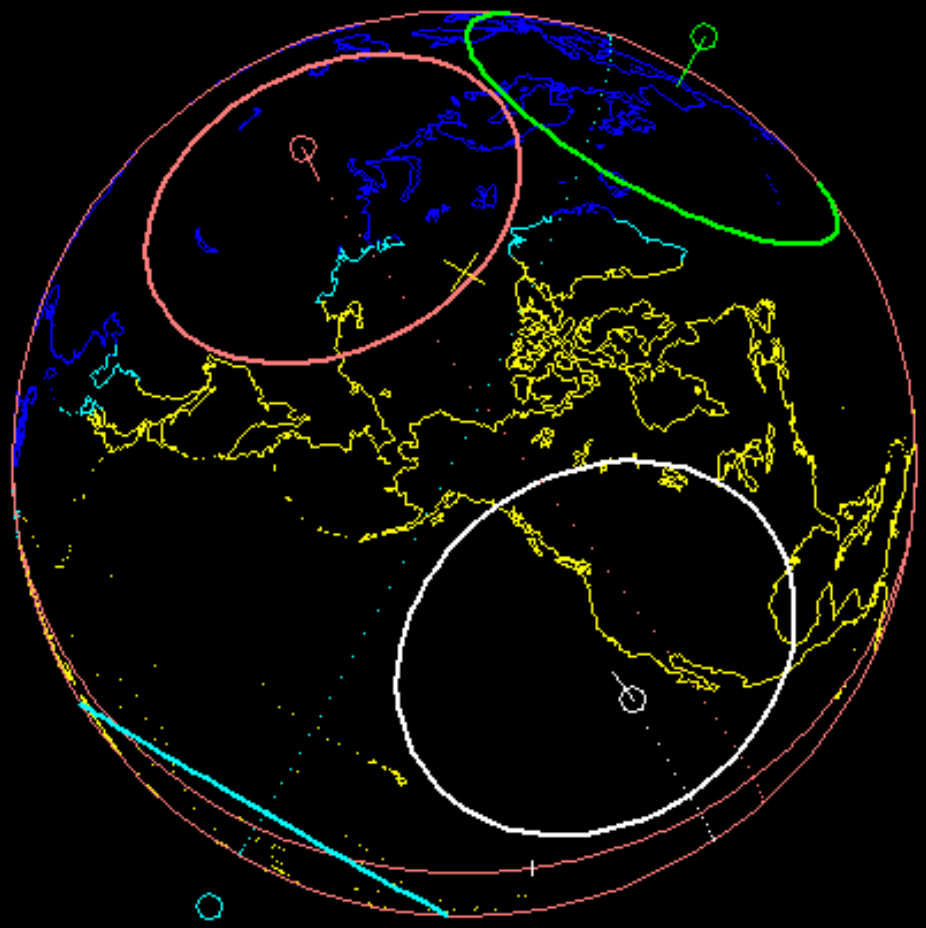
CLARREO SDT Meeting

NASA Langley Research Center, April 16-18, 2013

Ultra-spectral Measurement Characteristics

Satellite	Instrument	Spatial resolution	Spectral resolution	Spectral Range	Spatial Sampling
Aqua (1330 LST)	**AIRS (2002 -)**	3x3 13.5-km (50 km)	~1200 resolving power	645-2700 **cm^{-1}**	Contiguous Cross-track scan
Metop-A/B (0900/0930 LST)	**IASI (2006 -)**	2x2 12.0-km (50 km)	0.25 **cm^{-1}**	645-2760 **cm^{-1}**	Contiguous Cross-track Scan
SNPP (1330 LST)	**CrIS (2011 -)**	3 x 3 13-km (50 km)	0.6 **cm^{-1}**	645-2700 **cm^{-1}**	Contiguous Cross-track Scan
CLARREO Polar (All LST)	**IR-SW/MW**	**25 to 100-km (TBD km)**	**0.5 cm^{-1}**	**200-2700 cm^{-1}**	**Nadir**

NPP	13056.3500	7202.24	98.74	101.44	824.24
AQUA	13056.7609	7077.79	98.23	98.83	699.79
METOPA	13056.5944	7195.54	98.67	101.30	817.54
METOPB	13057.1956	7195.62	98.72	101.30	817.62



METEOROLOGICAL SATELLITES 21:15 UT 21 MAR 13

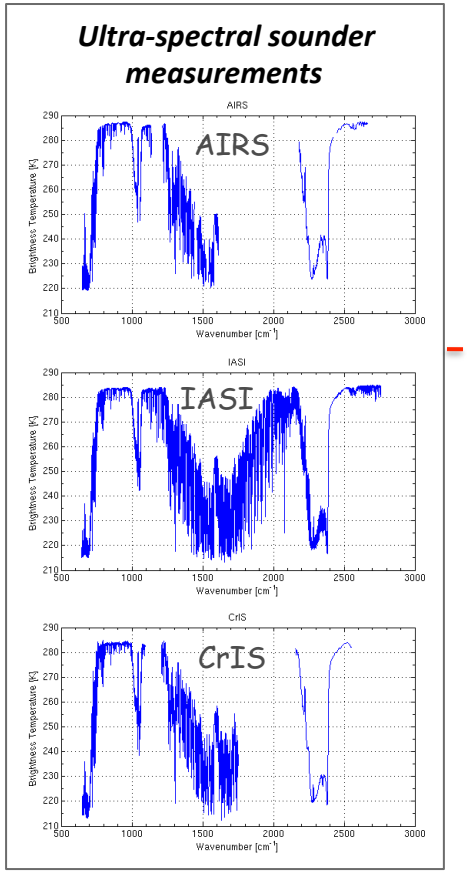
CLARREO - State Parameter Climate Retrieval Monitoring Climate Change from Polar Soundings

Desirable Features of a Climate Variable 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

*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.

"Dual-Regression" Retrieval Algorithm Overview



Global clear soundings

Radiances (clear FM)

Clear-trained regression coefficients

Global cloudy soundings

Radiances (cloudy FM)
Cloud height classes

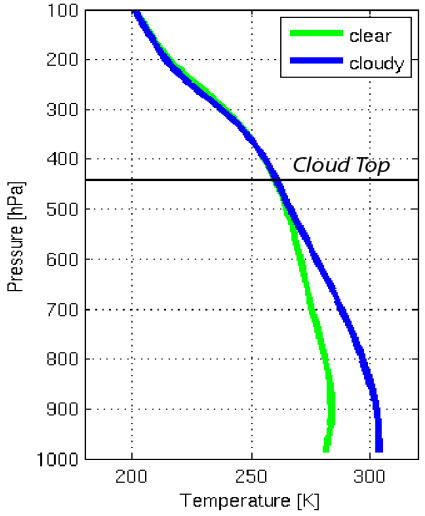
Cloud-trained regression coefficients

Theoretical Statistics

Radiance Observations

Clear-trained EOF regression retrieval

Cloud-trained EOF regression retrieval



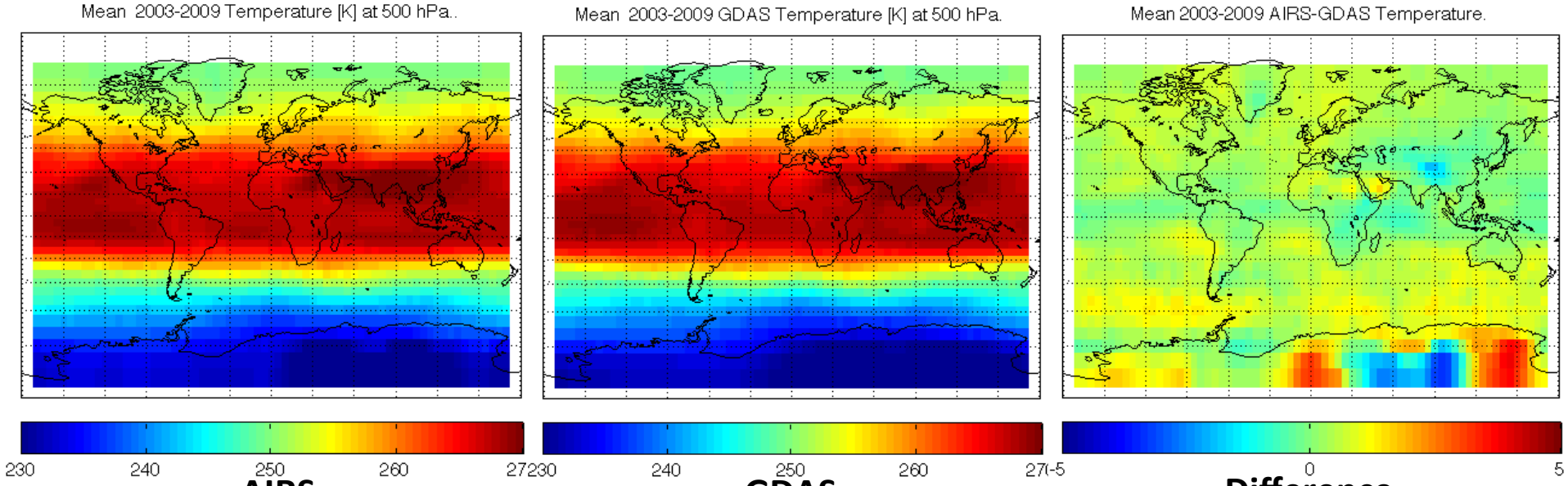
Cloud Top Altitude
Level where $T_{cloudy} > T_{clear}$ for $p > p_{cld}$

Final Profile
from cloudy and/or clear retrievals

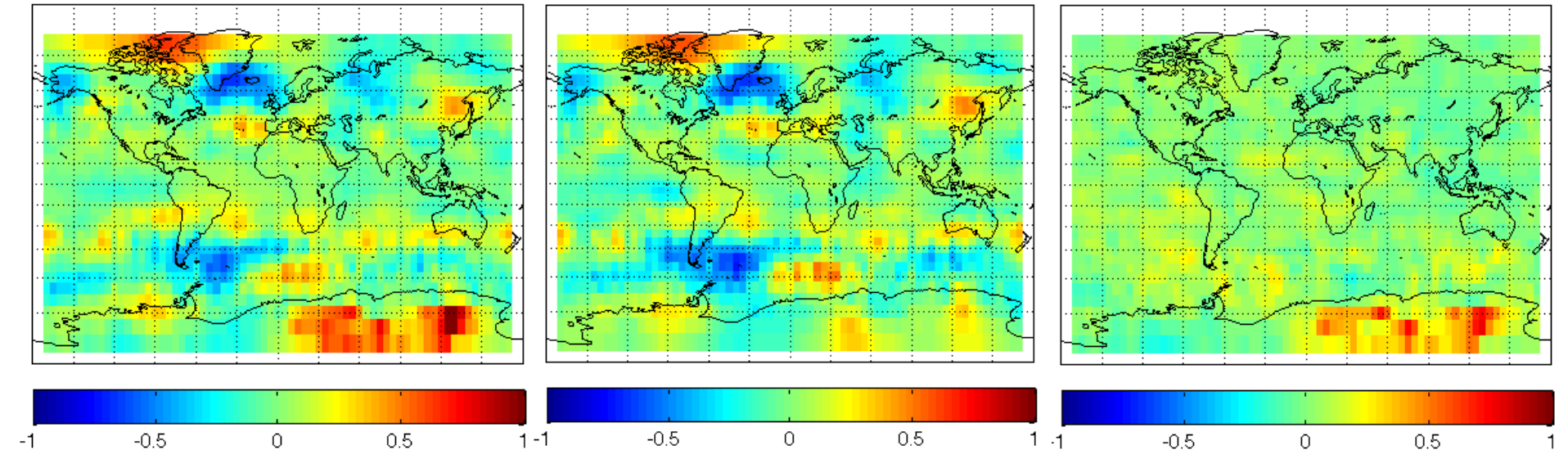
Temperature, Humidity and Ozone profiles, Surface and Cloud parameter at single FOV (15-km) resolution

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*.

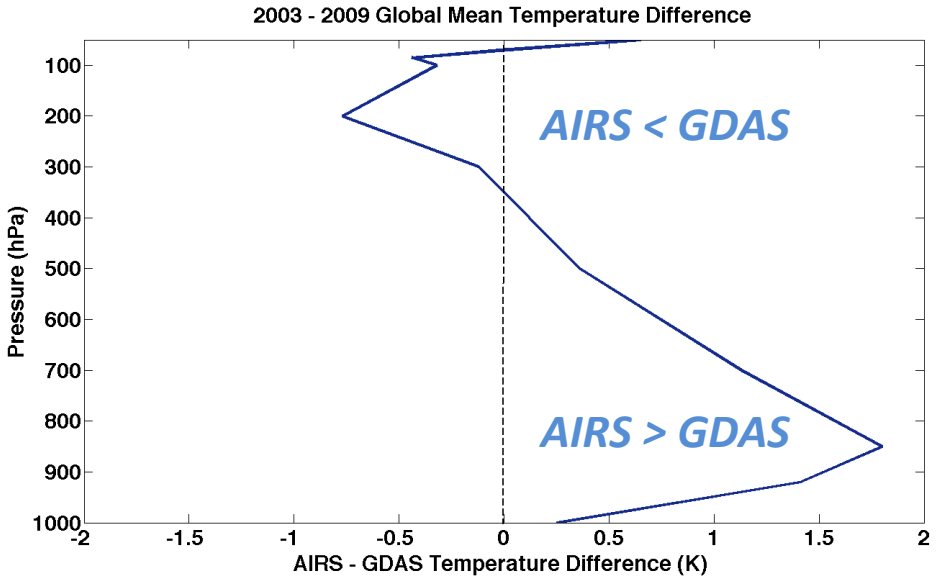
500-hPa (5-km) Temperature AIRS Vs. GDAS
7-yr (2003-2009) Mean & Annual Trend (Feb+Aug)

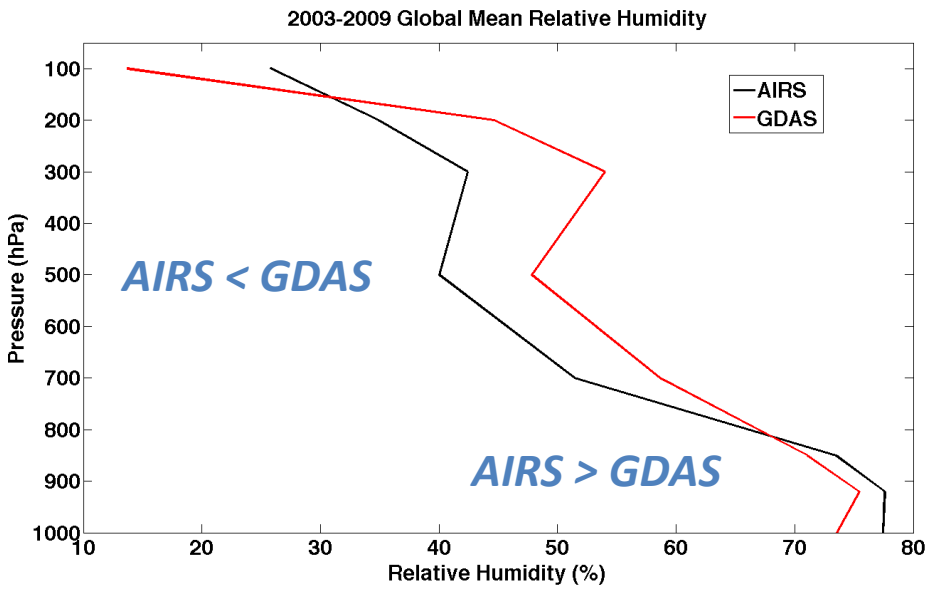


AIRS **GDAS** **Difference**

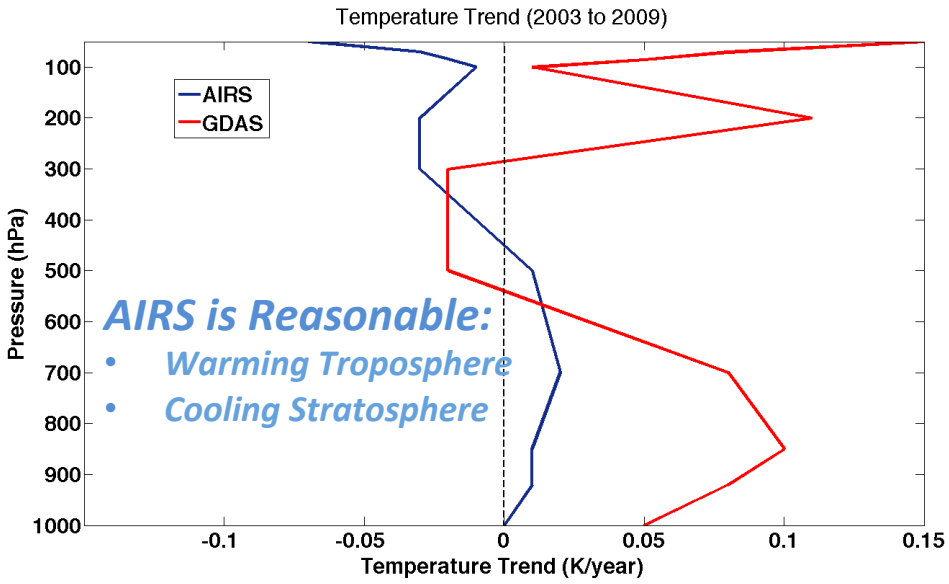


AIRS Vs. GDAS 2003 – 2009 Climate Statistics

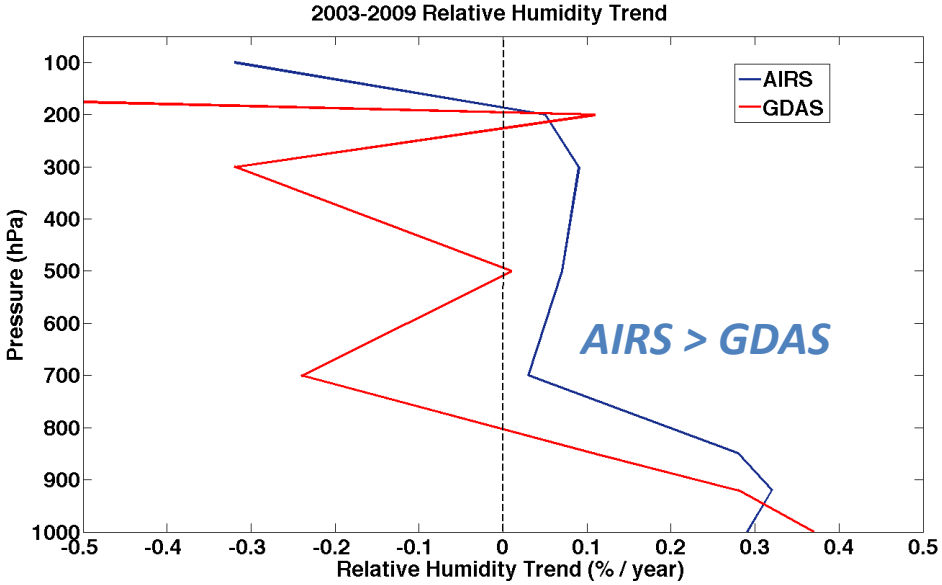




Temperature

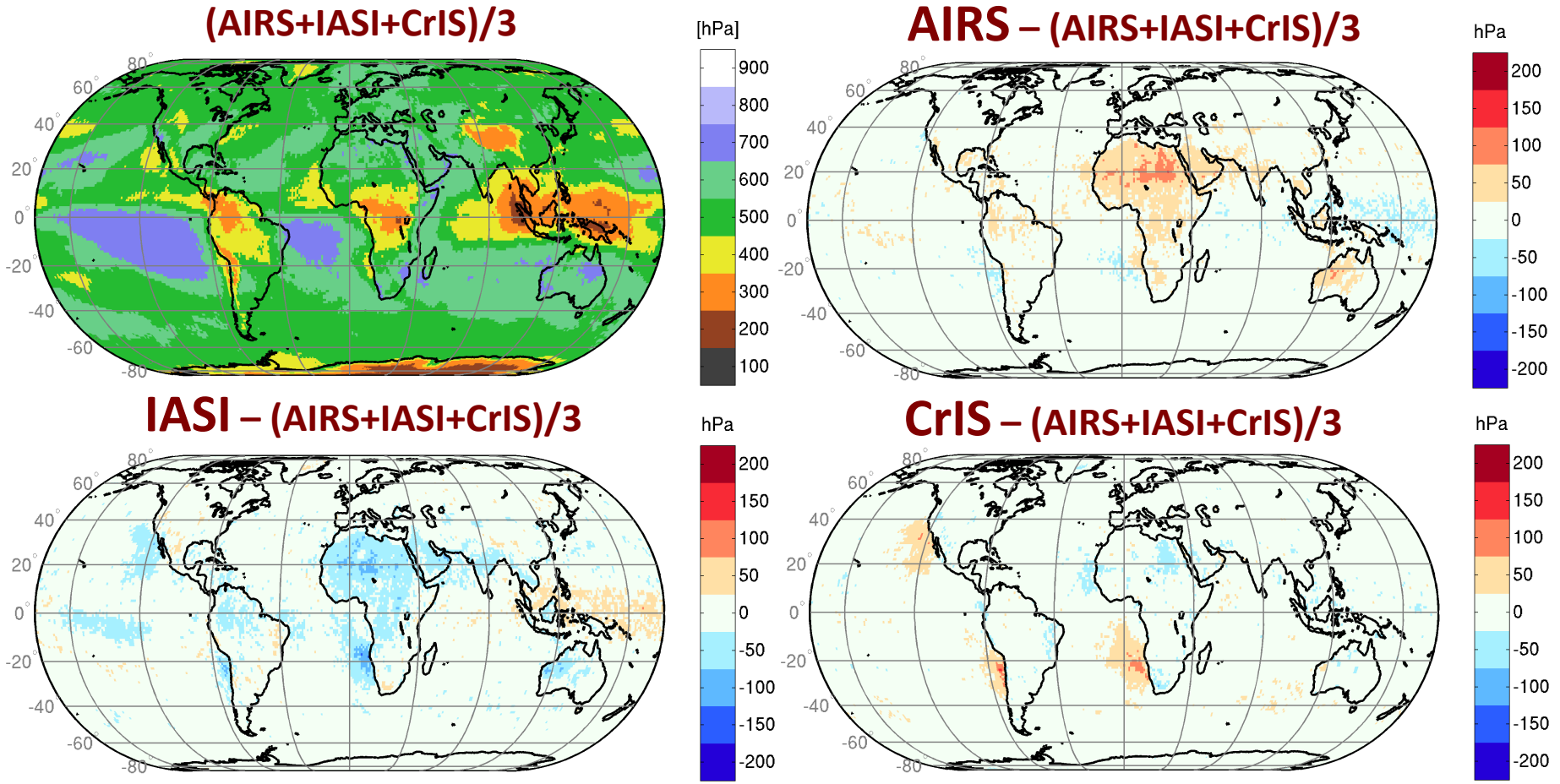


Relative Humidity



Comparing AIRS, IASI, and CrIS 2012 Annual Means*

Annual Average Cloud Height and Deviations from AIRS+IASI+CrIS (2012)



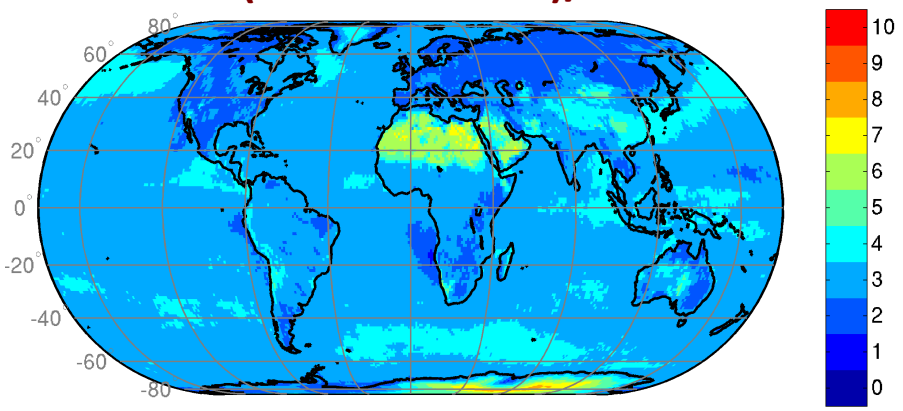
CrIS (land) and AIRS (ocean) have smallest differences with respect 3 Instrument Mean IASI and CrIS Opposite Sign Over West Coastal Stratus Regions (diurnal dependence ?)

- **Annual mean is defined as the average of the months of February, May, August, and November.**
- The gridding was performed using the technique described by Smith, N, W.P Menzel, E. Weisz, A. Heidinger and B.A. Baum, 2013, "A uniform space-time gridding algorithm comparison of satellite data products: Characterization and sensitivity studies" JCAM, 52: 255–268)

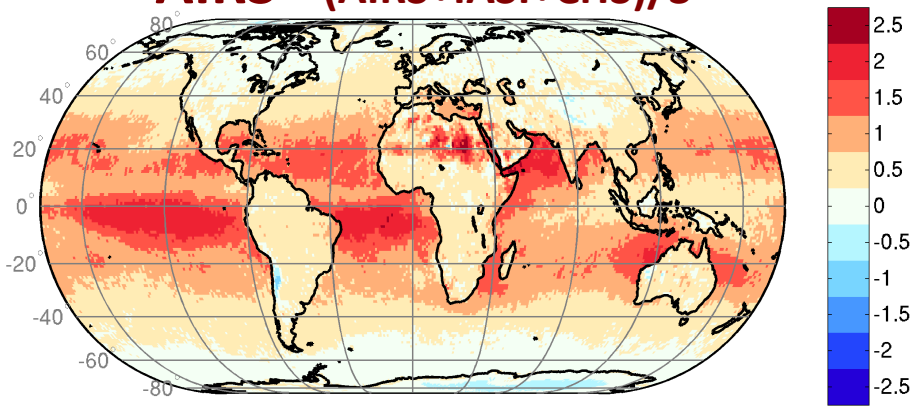
Comparing AIRS, IASI, and CrIS 2012 Annual Means

Annual Average Cloud Optical Depth and Deviations from AIRS+IASI+CrIS (2012)

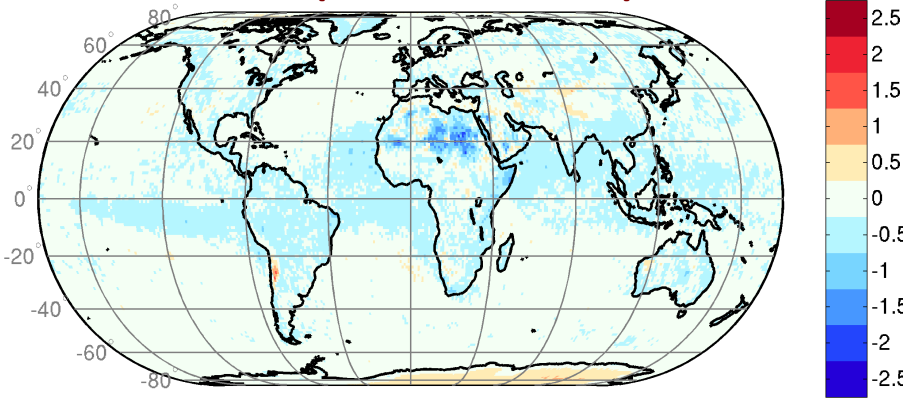
(AIRS+IASI+CrIS)/3



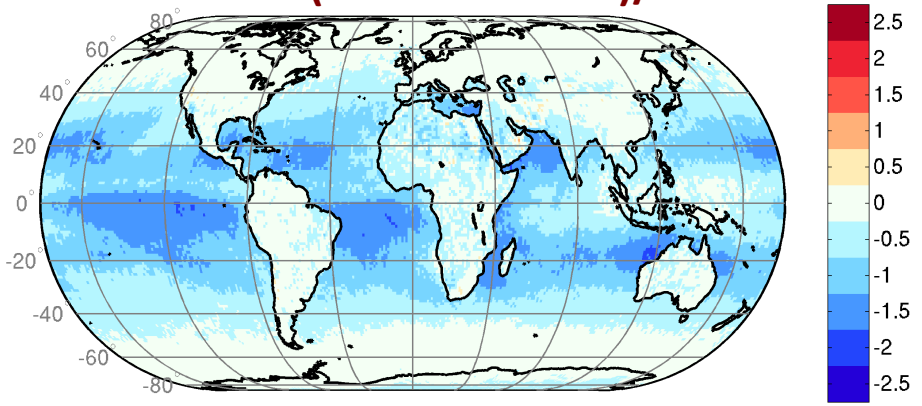
AIRS – (AIRS+IASI+CrIS)/3



IASI – (AIRS+IASI+CrIS)/3



CrIS – (AIRS+IASI+CrIS)/3

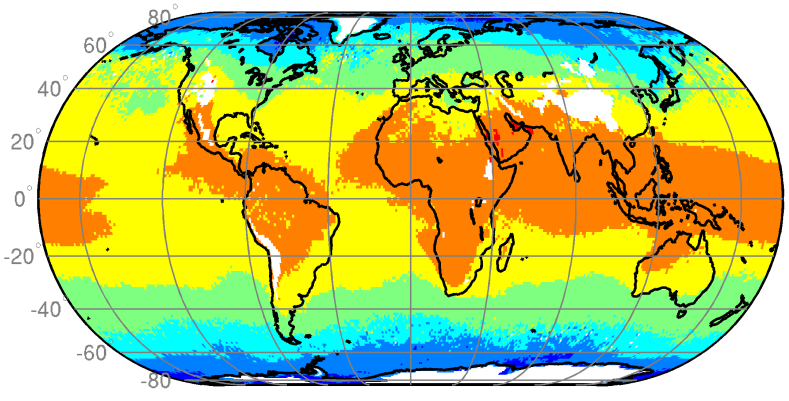


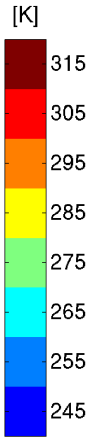
IASI has smallest differences with respect to Mean of the Three Instruments AIRS and CrIS of Opposite Sign (i.e., no diurnal dependence)

Comparing AIRS, IASI, and CrIS 2012 Annual Means

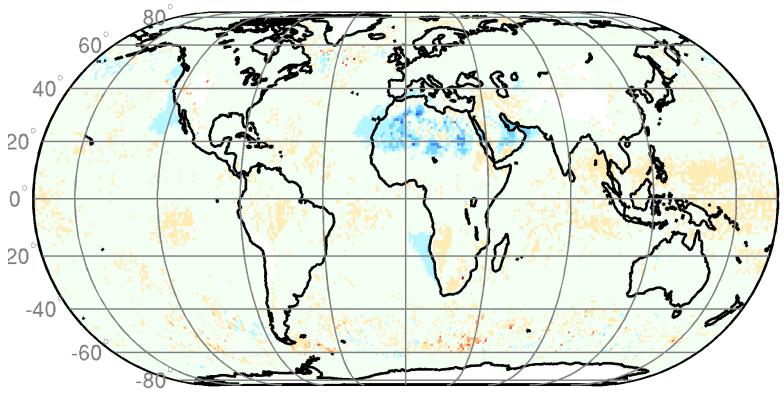
Annual Average 850 hPa T and Deviations from AIRS+IASI+CrIS (2012)

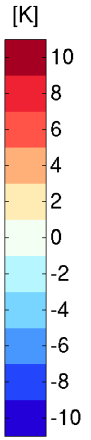
(AIRS+IASI+CrIS)/3



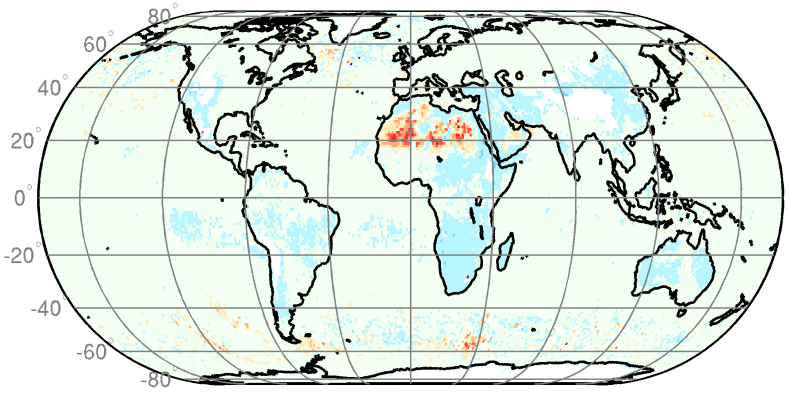


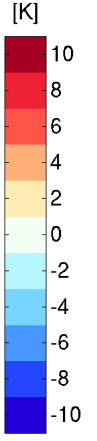
AIRS – (AIRS+IASI+CrIS)/3



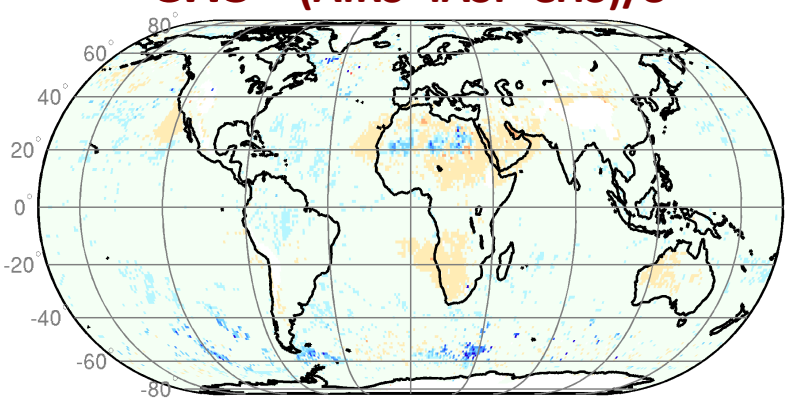


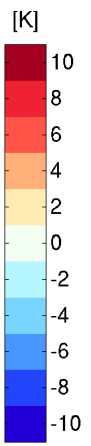
IASI – (AIRS+IASI+CrIS)/3





CrIS – (AIRS+IASI+CrIS)/3



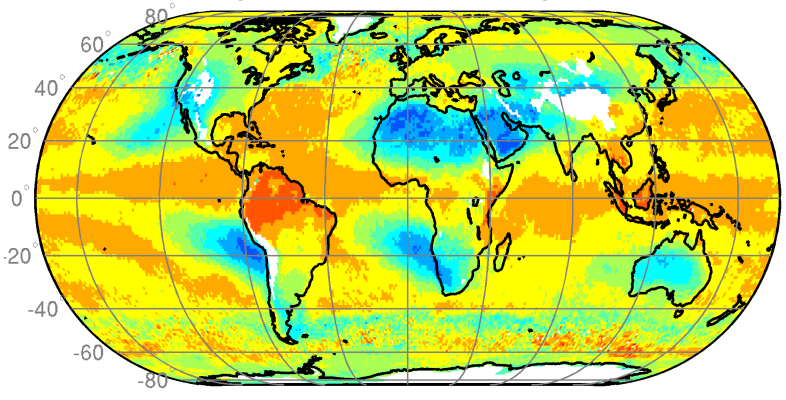


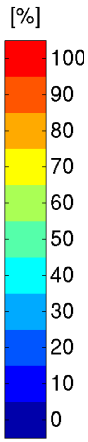
CrIS has smallest T differences with respect to Mean of the Three Instruments
CrIS and AIRS in Agreement in their Difference wrt IASI (i.e., diurnal dependence ?)

Comparing AIRS, IASI, and CrIS 2012 Annual Means

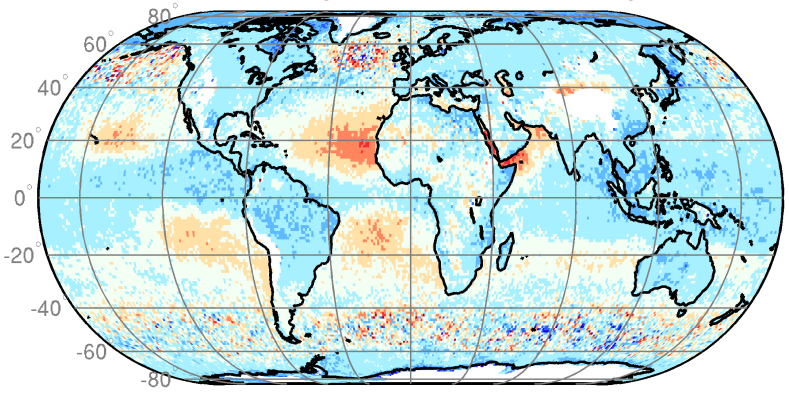
Annual Average 850 hPa RH and Deviations from AIRS+IASI+CrIS (2012)

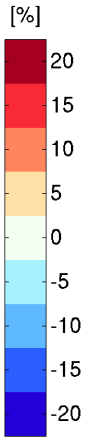
(AIRS+IASI+CrIS)/3



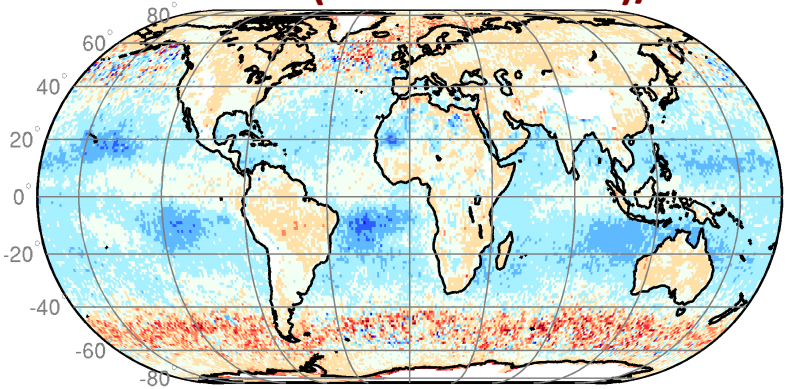


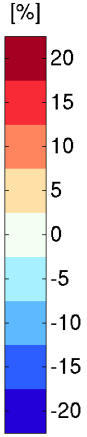
AIRS – (AIRS+IASI+CrIS)/3



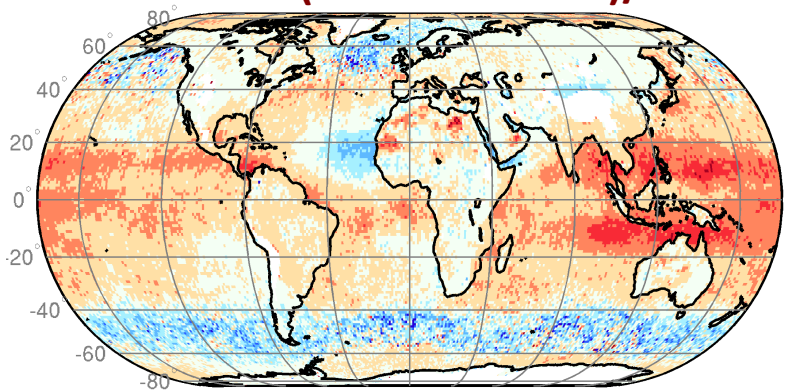


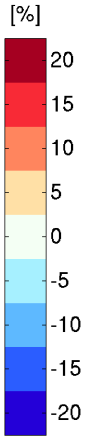
IASI – (AIRS+IASI+CrIS)/3





CrIS – (AIRS+IASI+CrIS)/3



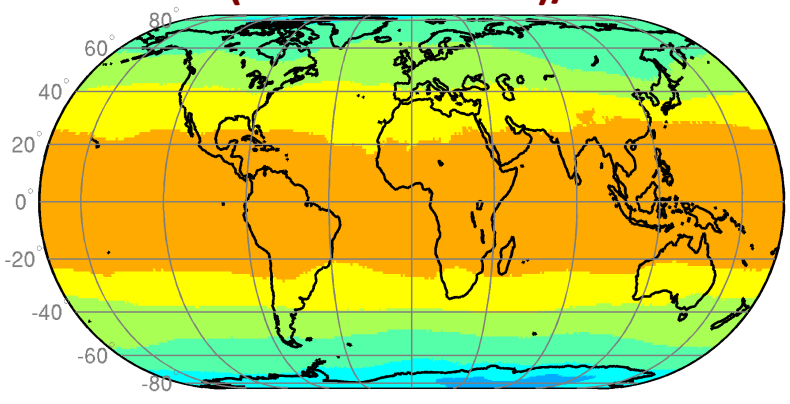


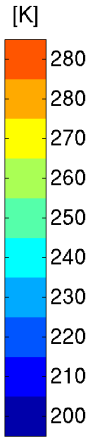
AIRS has smallest T differences with respect to Mean of the Three Instruments
CrIS and AIRS of Opposite Sign (instrument dependence ?)

Comparing AIRS, IASI, and CrIS 2012 Annual Means

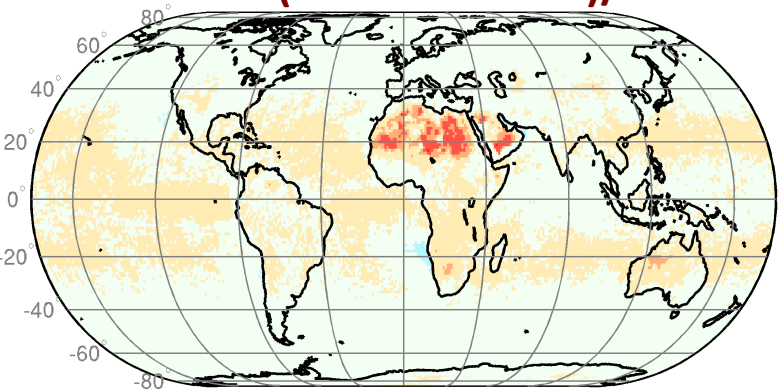
Annual Average 500 hPa T and Deviations from AIRS+IASI+CrIS (2012)

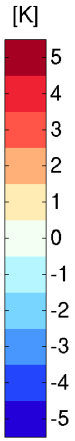
(AIRS+IASI+CrIS)/3



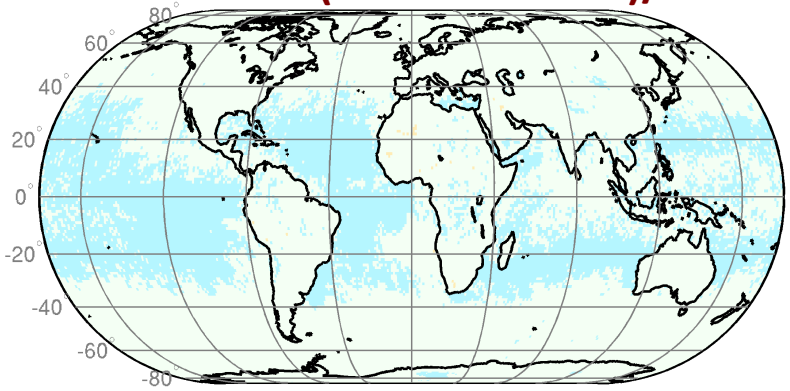


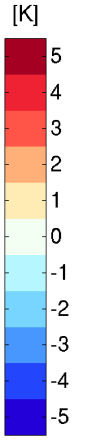
AIRS – (AIRS+IASI+CrIS)/3



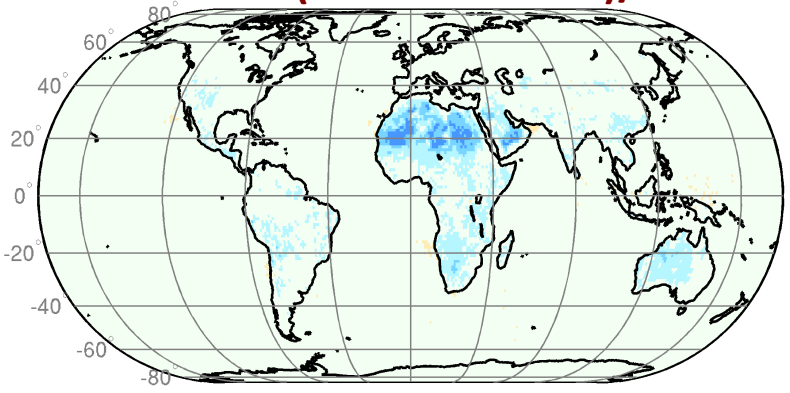


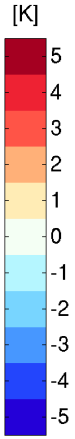
IASI – (AIRS+IASI+CrIS)/3





CrIS – (AIRS+IASI+CrIS)/3



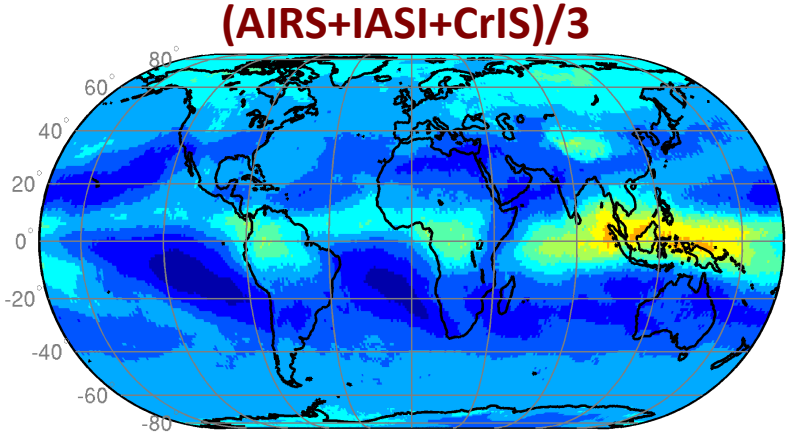


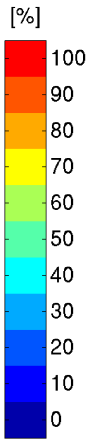
CrIS has smallest RH differences with respect to Mean of the Three Instruments
CrIS and AIRS Opposite Sign Over North Africa (instrument dependence ?)

Comparing AIRS, IASI, and CrIS 2012 Annual Means

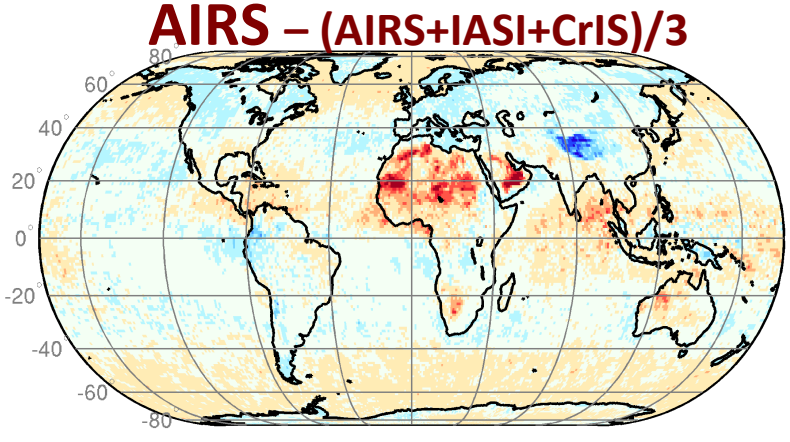
Annual Average 500 hPa RH and Deviations from AIRS+IASI+CrIS (2012)

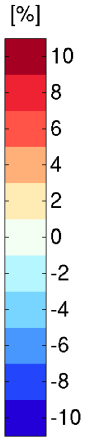
(AIRS+IASI+CrIS)/3



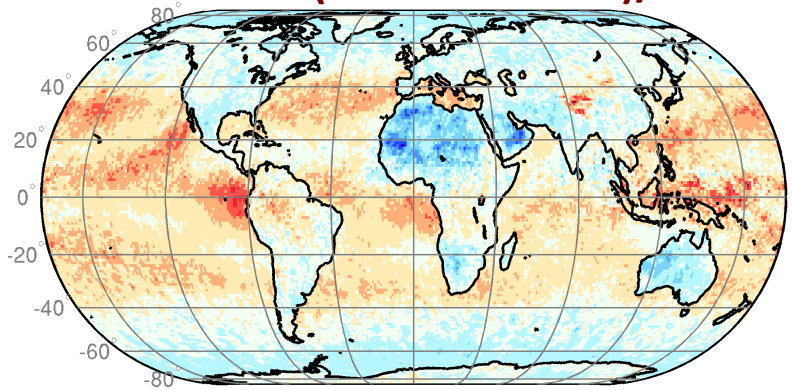


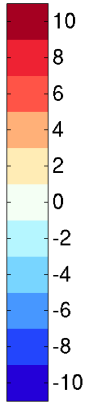
AIRS – (AIRS+IASI+CrIS)/3



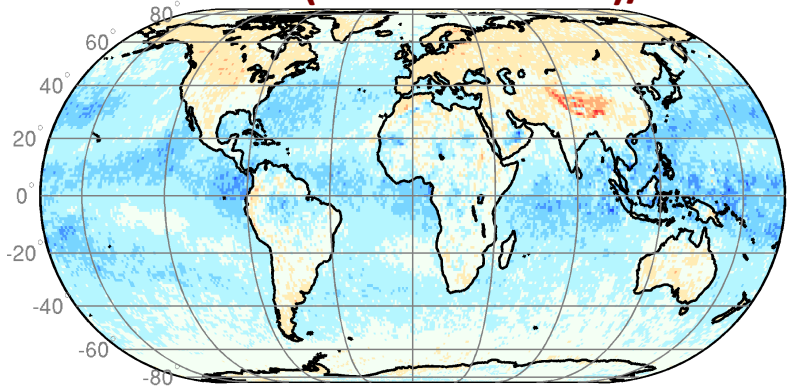


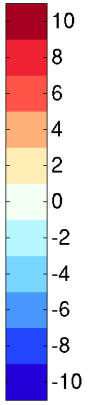
IASI – (AIRS+IASI+CrIS)/3





CrIS – (AIRS+IASI+CrIS)/3

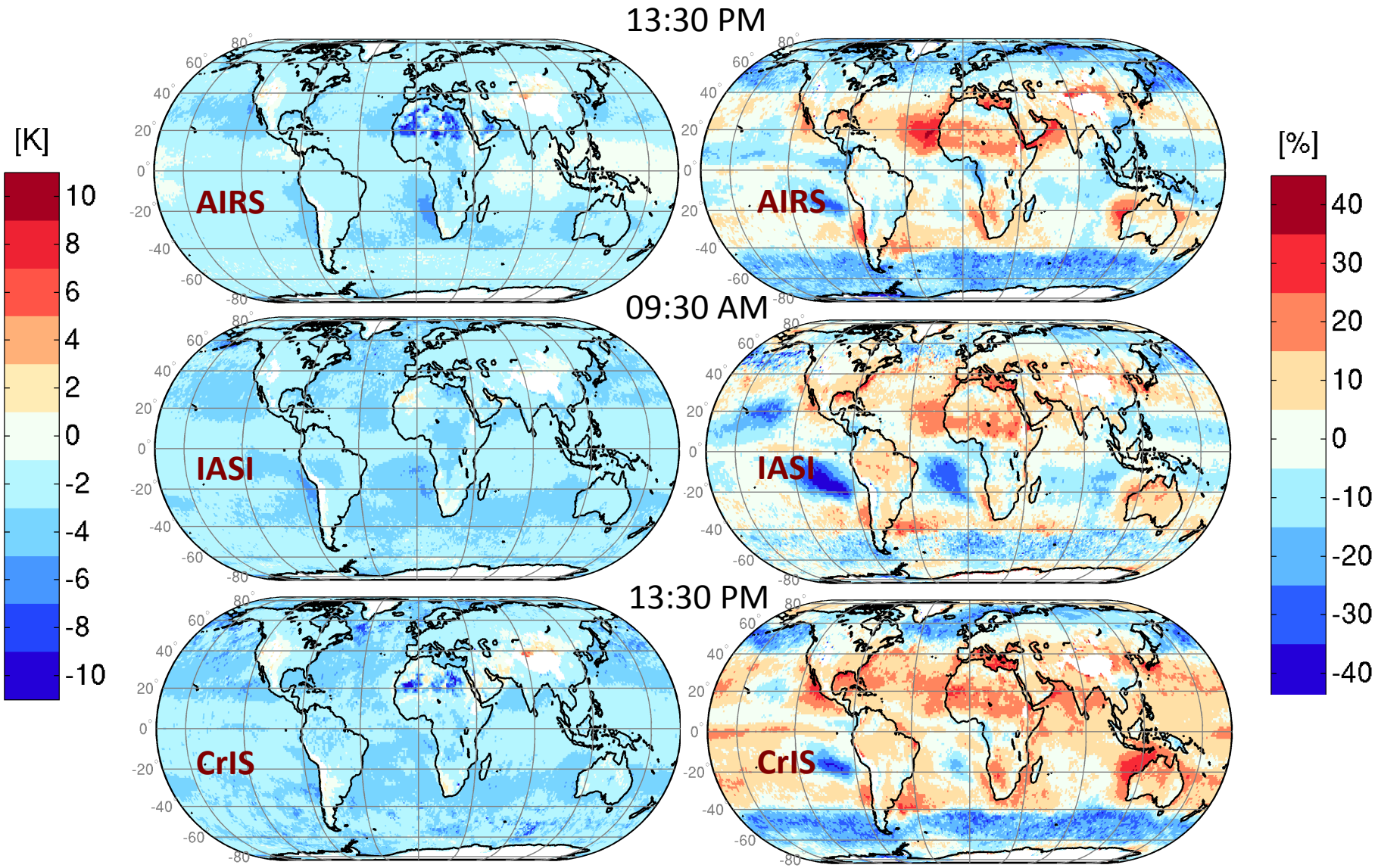




AIRS (water) & CrIS (land) Have Smallest RH Differences wrt 3 Instrument Mean

Comparing AIRS, IASI, and CrIS Annual Means

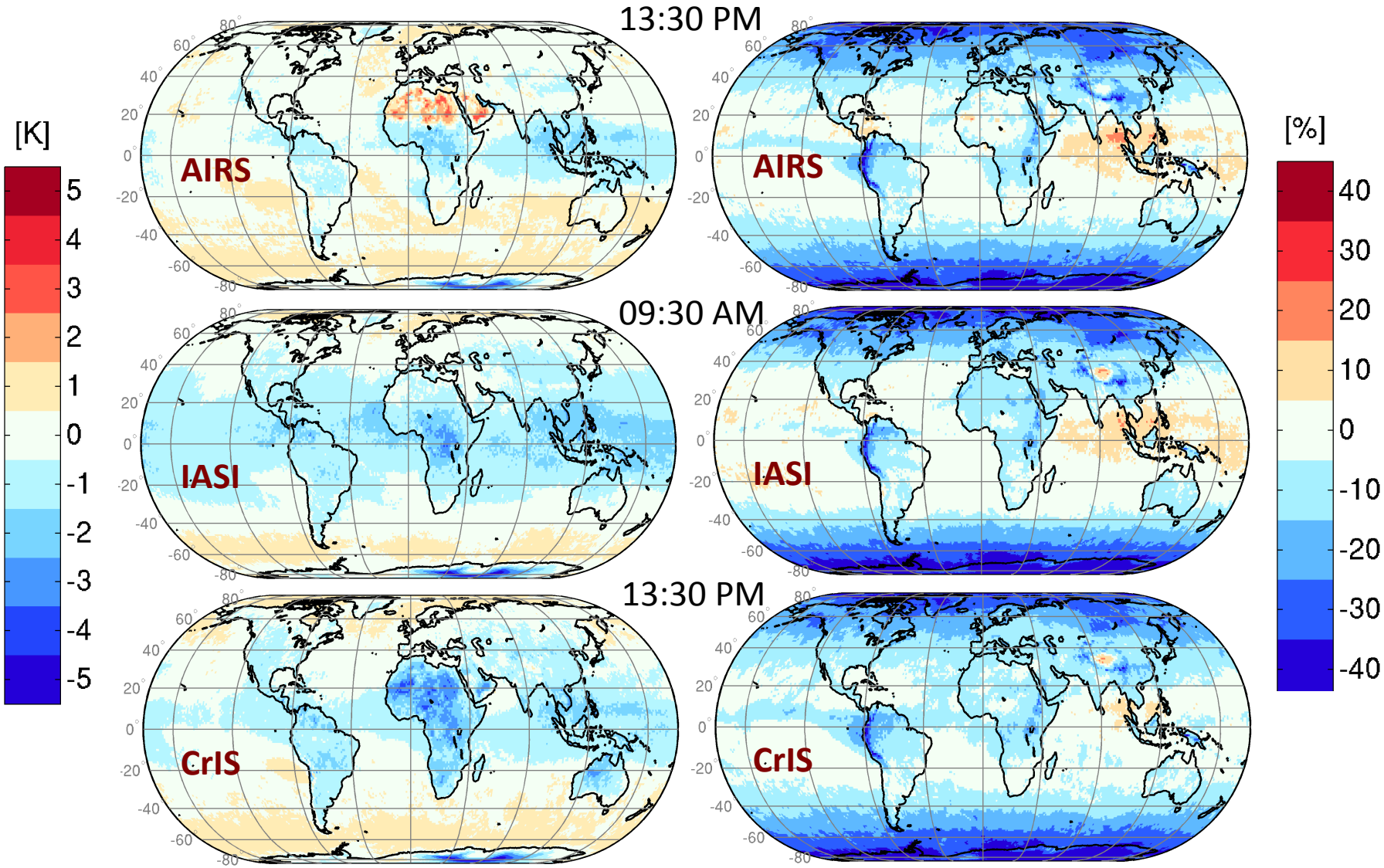
Annual Average 850 hPa T & RH Deviation From GDAS for AIRS, IASI, and CrIS (2012)



All Three Instrument "Agree" In Their Differences With Respect to GDAS

Comparing AIRS, IASI, and CrIS Annual Means

Annual Average 500 hPa T & RH Deviation From GDAS for AIRS, IASI, and CrIS (2012)



All Three Instrument "Agree" In Their Differences With Respect to GDAS

Summary and Conclusion

1. Deviations of AIRS, IASI, and CrIS from the mean of the three instruments:
   - Cloud heights from all three instruments are in excellent agreement
   - Cloud optical depth differences can be as large as 2
   - Regional temperature differences can be as large as 3 degrees
   - Regional relative humidity differences can be as large as 15 %
2. Differences appear to be more instrument related rather than being diurnal sampling related
3. The three instruments (AIRS, CrIS, and IASI) agree in their deviations from analyses of operational data (i.e., GDAS)
4. These preliminary results support the need for a common absolute reference in orbit (e.g., CLARREO)