AIRS, Trends and Climate

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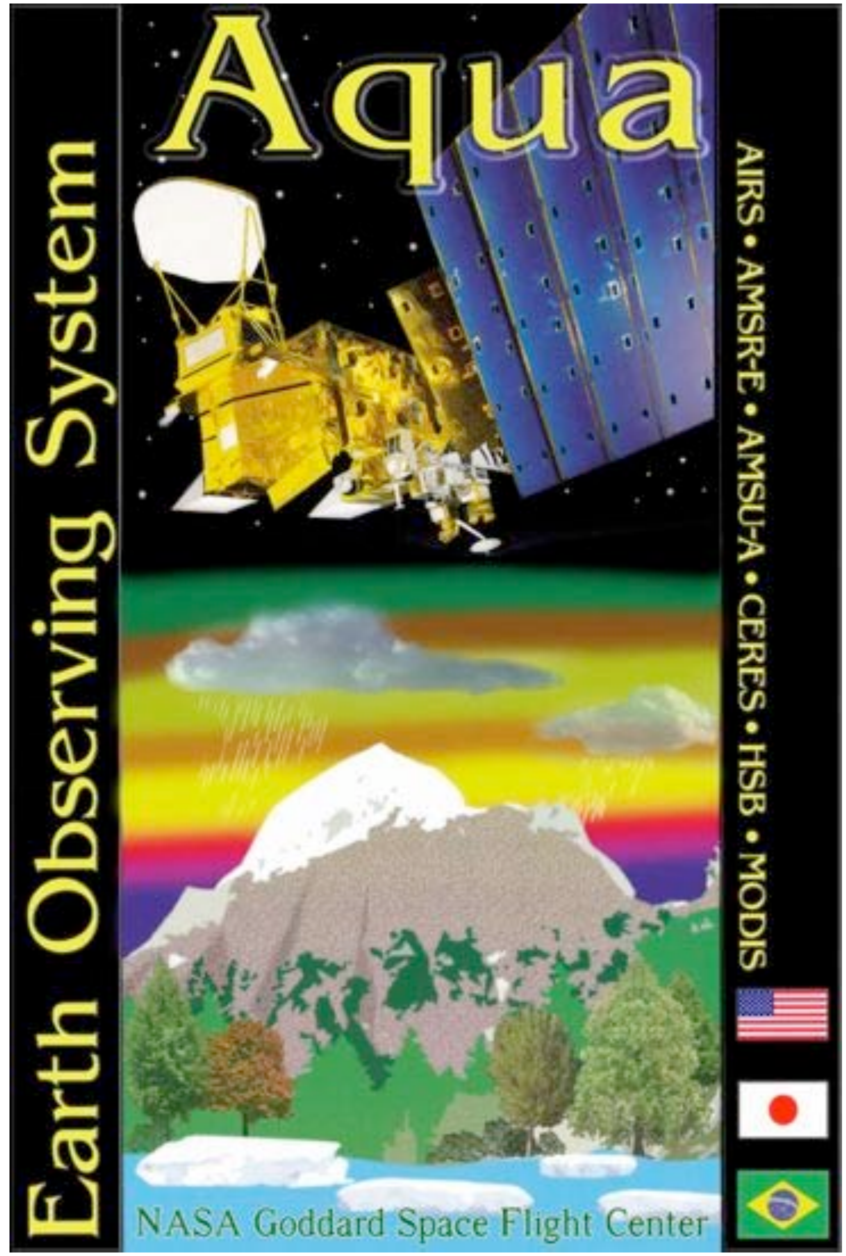
AIRS/AMSU/HSB

Spacecraft:	**EOS Aqua**
Instruments:	**AIRS, AMSU, HSB, MODIS, CERES, AMSR-E**
Launch Date:	**May 4, 2002**
Launch Vehicle:	**Boeing Delta II Intermediate ELV**
Mission Life:	**5 years**
Team Leader:	**Moustafa Chahine**

AIRS Project Objectives

1. **Support Weather Forecasting**
2. **Climate Research**
3. **Atmospheric Composition and Processes**



12 year lifetime predicted July 2006

AIRS, Trends and Climate

There are three key steps in generating climate quality data:

Design and build an instrument for climate quality data
- Minimize moving parts
- Thermostat the entire instrument
- "Freeze the calibration"

Create data subsets which are small enough for practical analysis
- It takes 1 hour to read one day of AIRS level 1b data
- We have now almost 1500 days of data
- Subsets a factor 1000 smaller than the L1b data are required.

Analyze the data in the subsets and verify that
- parameters which should not have trends don't
- parameters with expected trends do
- parameters with unexpected trends can not be explained by hardware or algorithm effects

AIRS, Trends and Climate

This afternoon session focuses on the analysis of trends visible in AIRS data.

There are five presentations:

→ Aumann: AIRS Calibration Data Subset (ACDS) for Climate Research

Strow: Zonal co2 trends from AIRS level 1b

Goldberg: Gridded Data Products for Climate Research

Susskind: Trends from monthly mean AIRS level 3 data

Hearty: Trends from AIRS level 2 data

Outline

What absolute calibration accuracy
and stability are required for climate applications?

Climatology and anomaly trend

Results from four years of AIRS data

Conclusions

What absolute calibration stability and accuracy are required for climate applications?

Better than 10 mK/year and 100 mK absolute

The stability of the measurements has to be better than the changes due to global warming

Warming at the surface is happening at 10 mK/year
Warming of the atmosphere is assumed to happen at 10 mK/year
The stratosphere appears to be cooling at about the same rate.

Absolute accuracy of 100 mK absolute calibration is required for transfer of trends between instruments. A 100 mK absolute uncertainty is the equivalent of 10 years of global warming.

Outline

What absolute calibration accuracy
and stability are required for climate applications?

Stability and accuracy of the AIRS radiances

Climatology and anomaly trend formalism

Results from four years of AIRS data

Conclusions

Before we analyze trends in AIRS data which may be of climate significance, we have to establish that the accuracy and stability of the AIRS data is of climate quality.

We use the RTGSST in the tropical oceans as reference to establish accuracy and stability of the AIRS data.

The RTGSST is the sea surface temperature on a 0.5 degree grid generated daily by NCEP in support of daily weather forecasting.

In the tropical oceans the RTGSST is verified daily using about 1000 buoys drifting along the equator. The calibration of each drifting buoy at the better than 0.1 K level is NIST traceable.

Data from any infrared sounder can not be interpreted at the better than 100 mK level in the presence of clouds. We restrict our analysis to carefully cloud-filtered ocean data. Four years of these data are available in the AIRS Calibration Data Subset (ACDS). Details in Aumann et al. 2004 Denver SPIE.

Good cloud-filtering requires very high SNR in the individual spectra. Poor cloud-filtering results in erroneous biases. Massive data averages for climate do not require high SNR, but retain any bias in the data.

The key channel for establishing calibration stability and accuracy is the 2616 cm-1 window channel. This channel is used to measure the sea surface temperature, sst2616, using radiative transfer. Details are found in Aumann et al. 2006 JGR paper. No bias tuning or empirical regression is used. This sst2616 is compared with the RTGSST.

Two fairly readable references on trend analysis

Physics and Chemistry of the Earth 27 (2002) 399–403

Detecting environmental changes and trends

Elizabeth C. Weatherhead [a,*], Amy J. Stevermer [a], Barry E. Schwartz [b]

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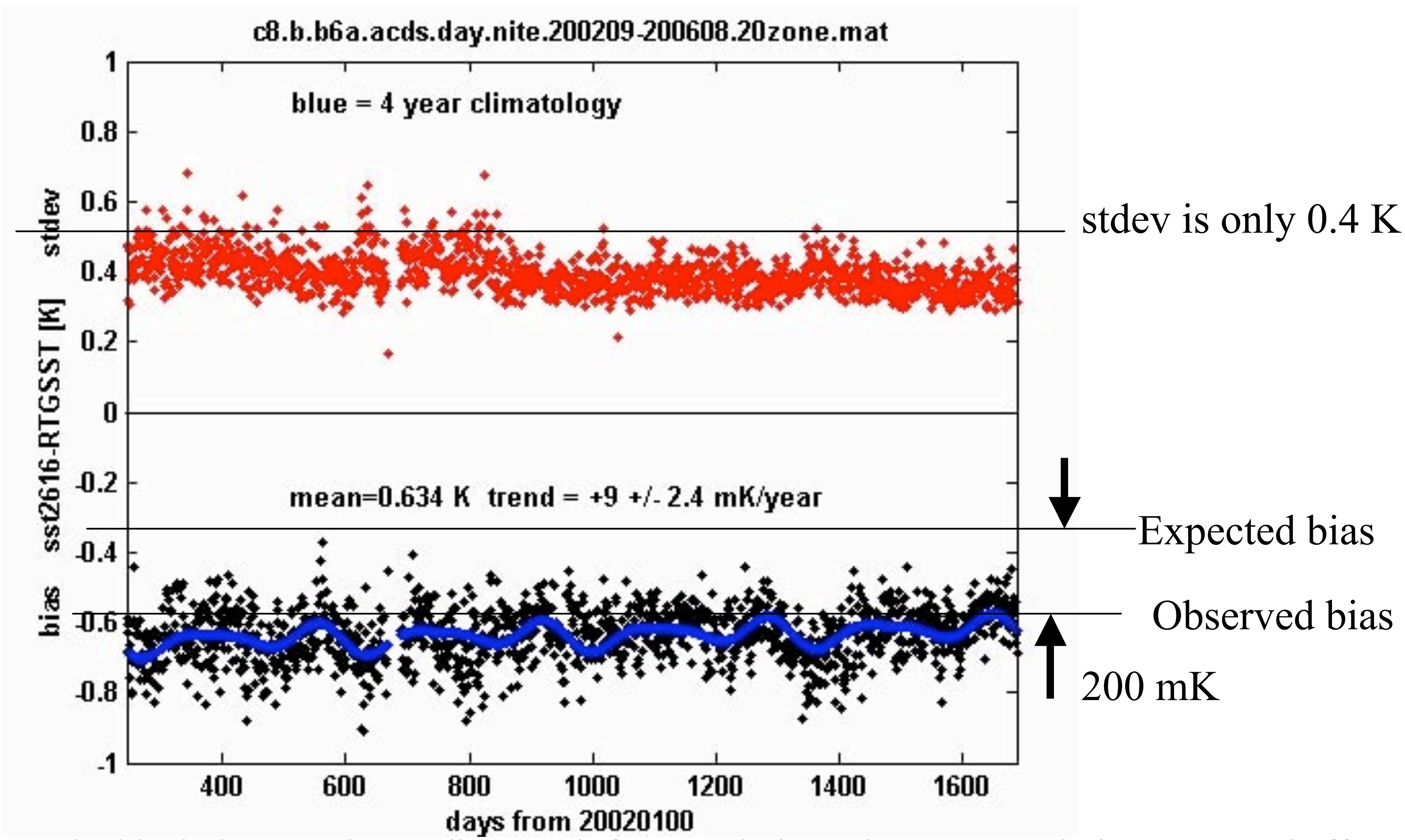
Received 19 October 2001; received in revised form 21 November 2001; accepted 23 November 2001

Santer, B.D., T.M.L. Wigley, J.S. Boyle, D.J. Gaffen, J.J. Hnilo, D. Nychka, D.E. Parker, and K.E. Taylor, 2000: Statistical significance of trends and trend differences in layer-average temperature time series. *Journal of Geophysical Research*, **105**, 7337–7356.

The second reference deals with the effects of autocorrelation

4 years of night-time comparisons of 2616 cm-1 with the RTGSST are within 200 mK of the expected value. The trend is +9.0 +/- 2.4 mK/year



The black dots are the median result from each day. There are no obvious seasonal effects.
The blue curve is the 4 year climatology
The red dots are the standard deviation of the 5000 clear spectra each day

H. H. Aumann

Establishing the stability of one channel verifies the stability of the on-board calibration source, its thermometry and the detector electronics chain.

Stability thus established is a necessary, but not sufficient condition for the stability of all channels in a grating array spectrometer.

Repeating this analysis for a number of window channels at 1231 cm-1, 943 cm-1, and 790 cm-1 produces similar results.

These three channels are not as good as 2616 cm-1 in terms of atmospheric transmission, but they can be used day and night.

In all cases the sst is derived from radiative transfer using 24 climatology profiles with Tsurf>273 K at six scan angles. Details for sst1231 are found in Aumann et al. 2006

The AIRS data are stable relative to the RTGSST

	night	day
790 cm-1 channel stability	+11.6 +/- 3.9	+11.1 +/- 3.1 mK/year
943 cm-1 channel stability	+12.9 +/- 3.0	+9.2 +/- 3.2 mK/year
1231 cm-1 channel stability	+8.7 +/- 2.7	+6.0 +/- 2.9 mK/year
2616 cm-1 channel stability	+9.0 +/- 2.4	+5.0 +/- 5.0 mK/year*

There appears to be a small trend and a frequency dependence. The trend could be an artefact of the change in the RTGSST software in May 2004.

The frequency dependence could be indicative of a change in the cloud contamination of the cloud-filtered spectra.

* sst2616 not corrected for reflected light

Now that we have convinced ourselves that the AIRS radiances meet climate quality requirements for accuracy and stability, we can look at 4 year anomaly trends.

The anomaly is the difference between the data and the seasonal climatology (generated from four years of data)

Trend tested for +/-30 degree tropical ocean

1. co2 effect at 2388 cm-1
2. cirrus using the 943-790 cm-1 gradient
3. upper tropospheric water using 1560 cm-1 \
4. count per day of spectra identified as “clear”
5. predict bt1231 from bt2616 with water correction

The weighting function of 2388 cm-1 is due to co2 absorption and peaks at about 5 km altitude.

The brightness temperature trend at 2388 cm-1 (bt2388) shows the cooling expected from about 1.5 ppmv per year increase co2.

Day and night independently show the same trend.

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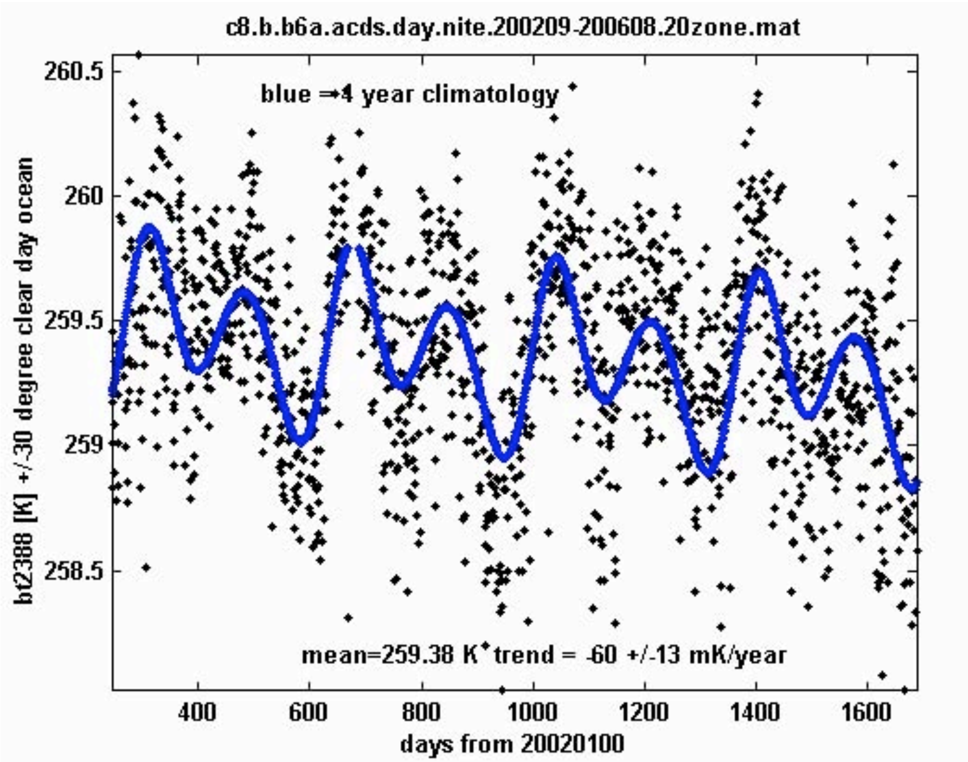
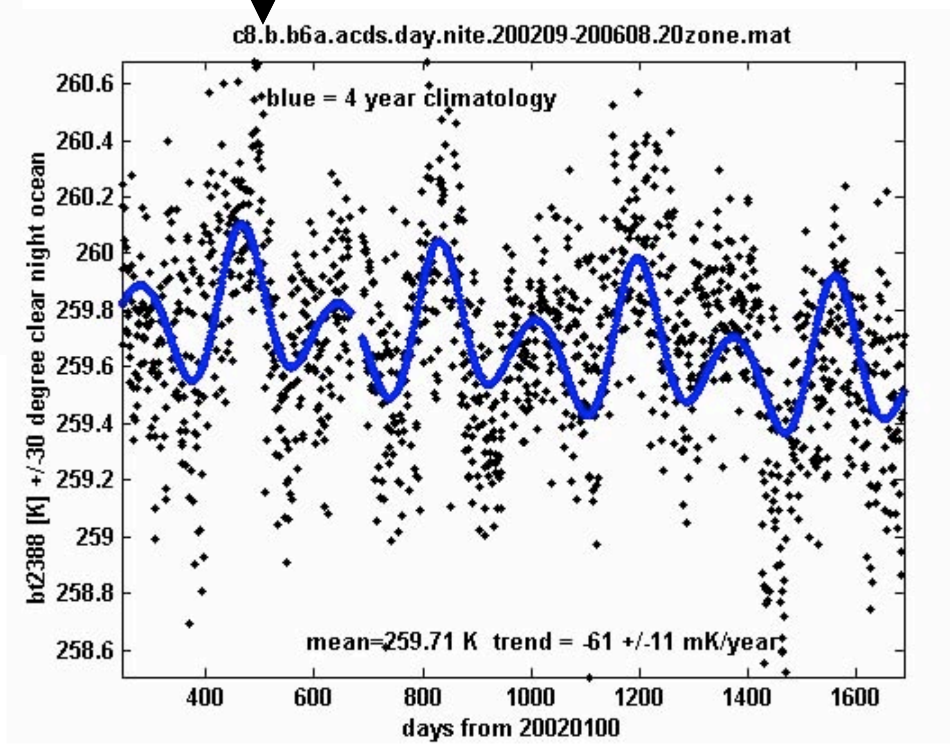


day -60 +/- 13 mK/year

night -61 +/- 11 mK/year



We consider a trend significant if it exceeds the estimated one sigma trend uncertainty by a factor of two.

No 2 sigma or better unexpected trends were identified by the analysis of the +/-30 degree ocean zone in any not-co2 related quantity.

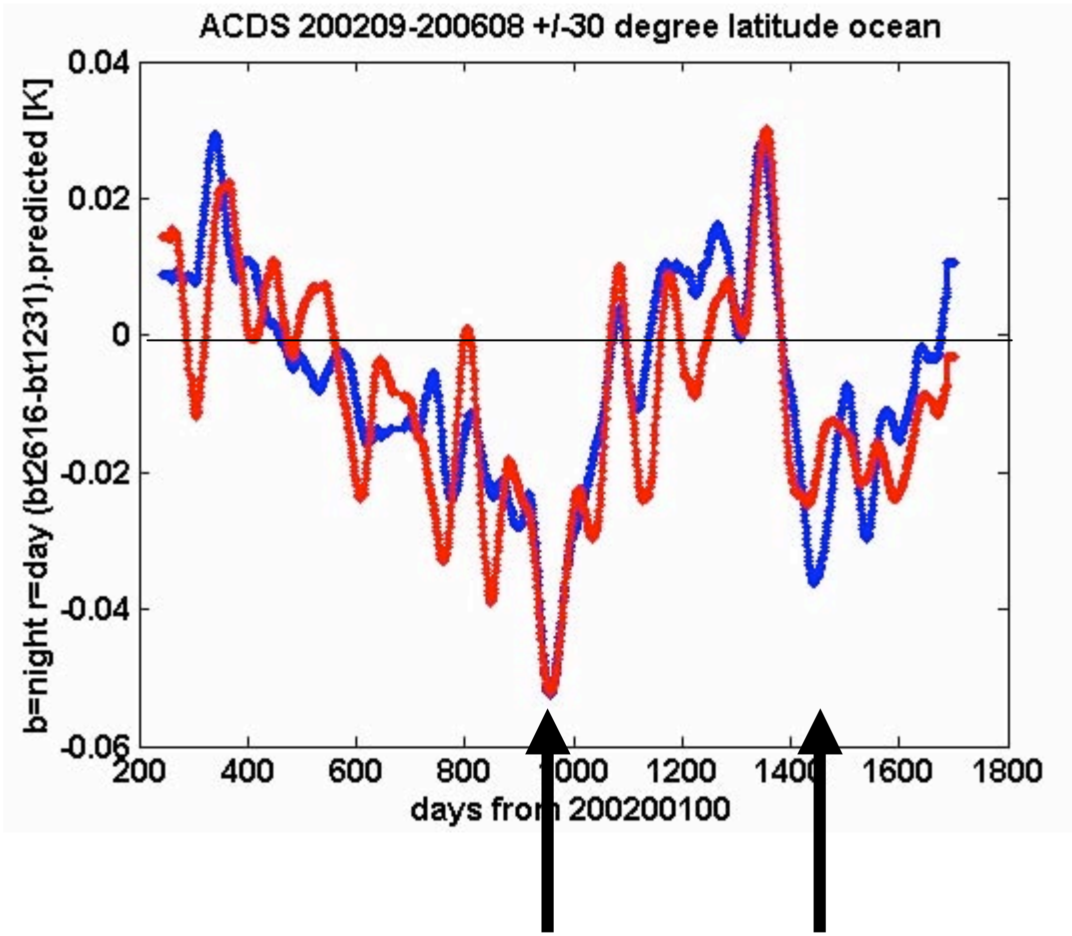
One has to be very careful with the interpretation of trends from 4 years of data:

1. The tropical oceans are probably the most stable part of the climate system and will show the least trends. Higher latitudes may be better.

2 The presence of inter-annual variability and multi-decadal oscillation create false trends, but the trend uncertainty will also be high.

The ability to predict bt1231 from bt2616 under clear conditions appears to be modulated by some unexpected inter-annual variability

This effect is +/-40 mK

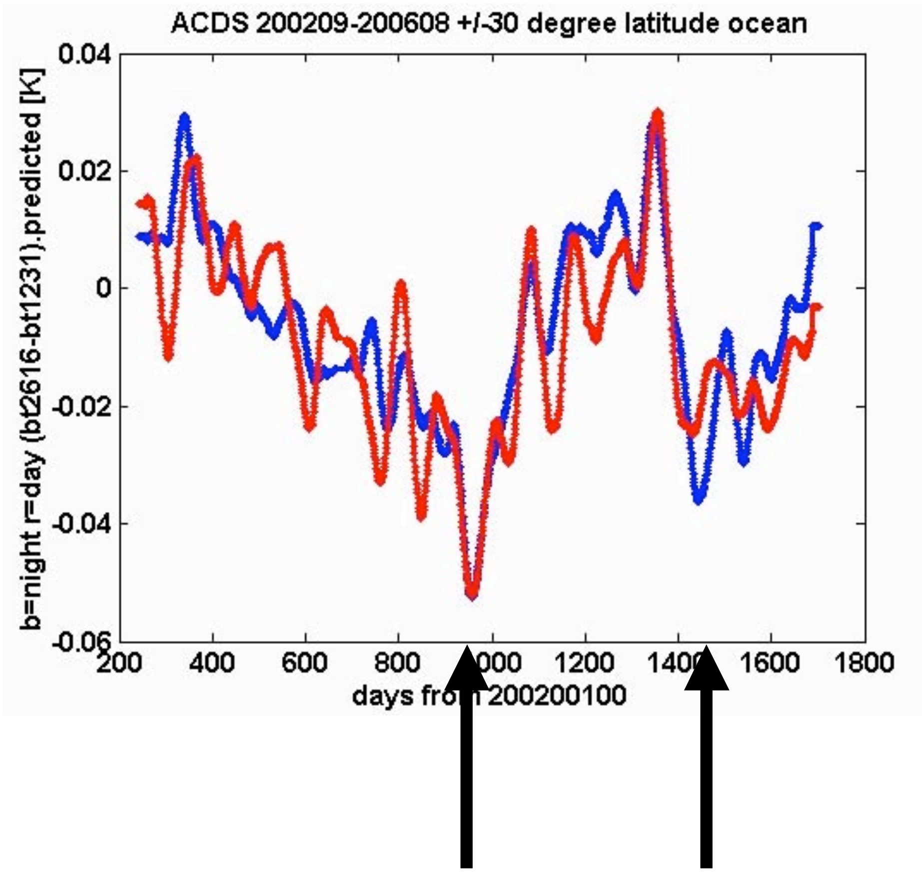


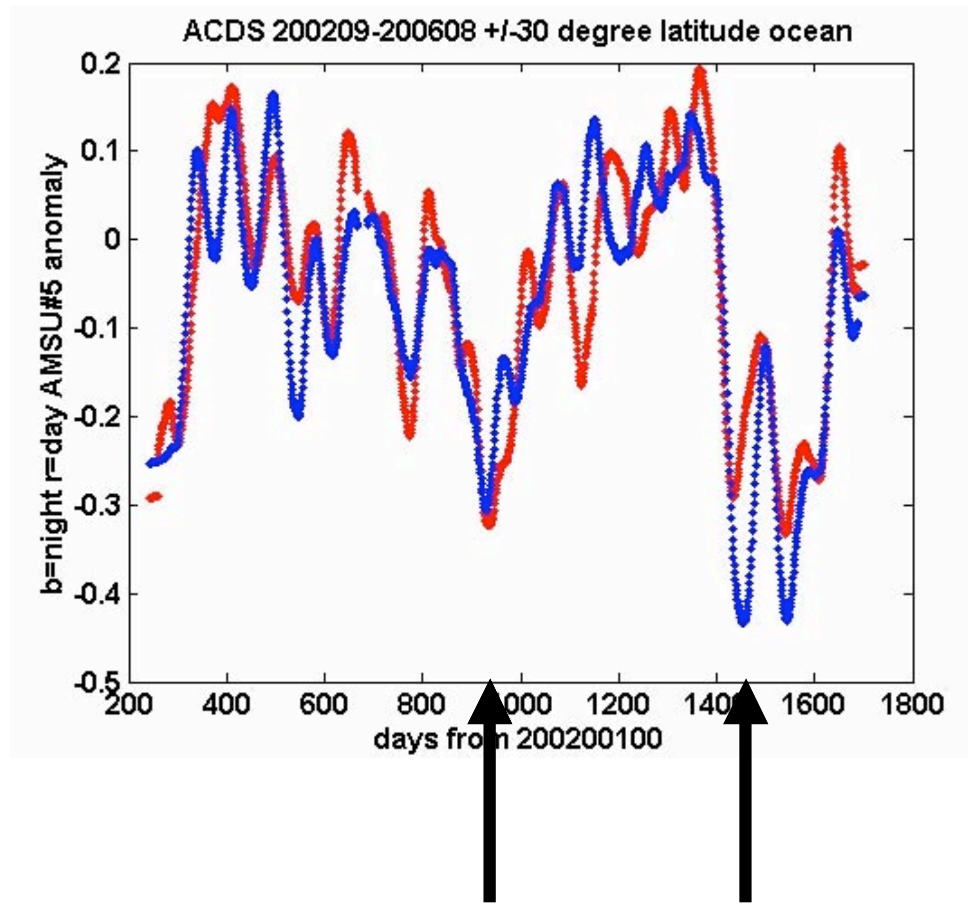
Did anything noteworthy happen?

The inter-annual variability shows interesting anomaly correlation

sst2616 – sst1231 anomaly

AMSU #5 anomaly





What happened?

Outline

What absolute calibration accuracy
and stability are required for climate applications?

4 year climatology and anomaly trends formalism

Results from four years of AIRS data

Conclusions

Conclusions

The AIRS radiance trends can be evaluated with confidence at the 10 mK/year level.

At this level, the effect of the co2 increase on the radiances is the only trend in four years of tropical ocean analysis.

Some interesting inter-annual variability shows up in the anomalies in unexpected places.

There is a good anomaly correlation between AIRS and AMSU.

The strange patterns in the anomalies may be correlated with other major events.

Conclusions (continued)

Climate quality data have to be accurate to 100 mK and stable to better than 10 mK/year

To achieve this with AIRS we

Minimized moving parts
Thermostated the entire instrument
"Froze the calibration"

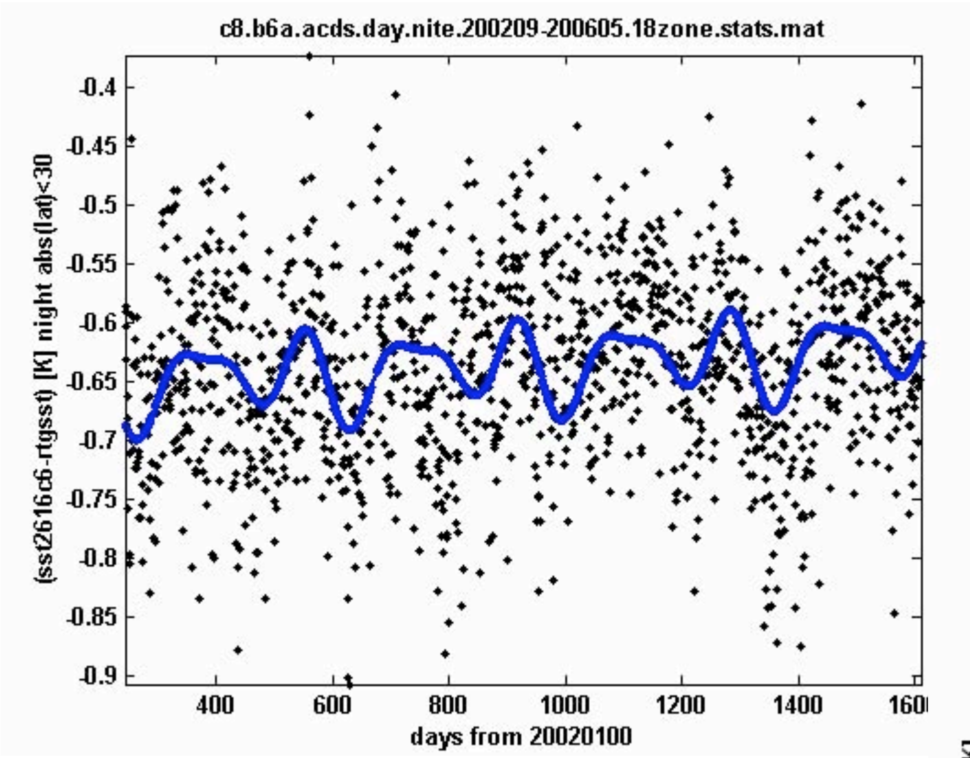
Four years of AIRS data have demonstrated that this design approach leads to climate quality data.

Thank you for our attention.

The AIRS data are freely available from the DAAC at GSFC
To learn more about AIRS visit http://www.jpl.nasa.gov/airs

The daily ACDS data since 20020831 is available via FTP from
ftp://g0dps01u.ecs.nasa.gov/AIRS/AIRXBCAL.003/

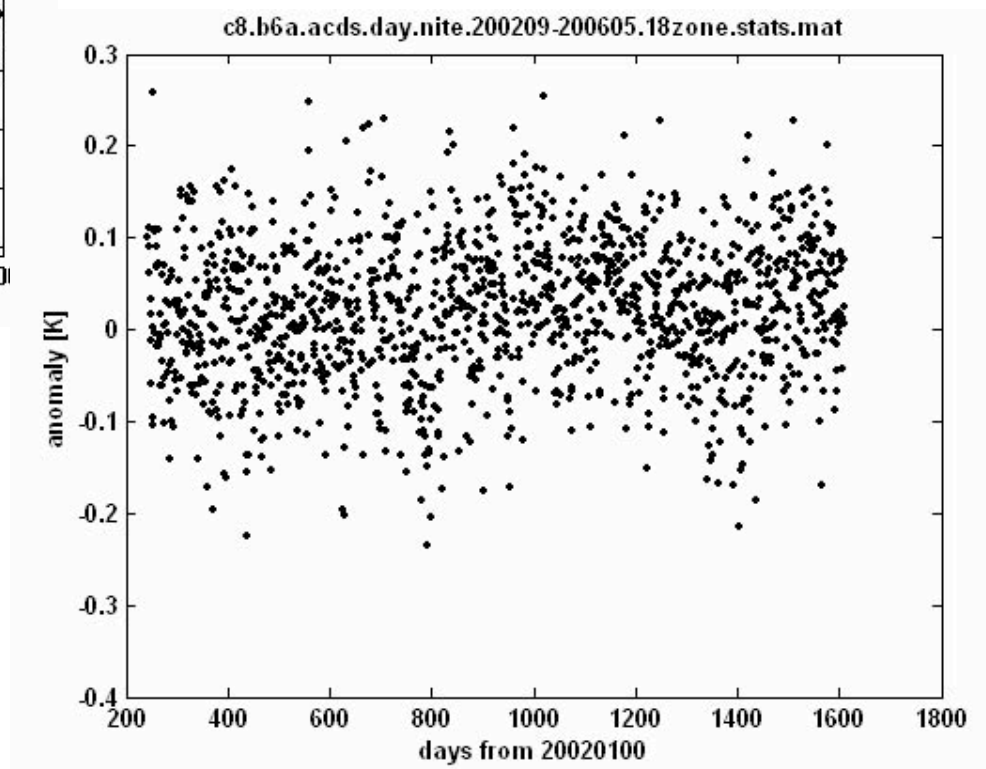
There is a small trend at night for sst2616-rtgsst



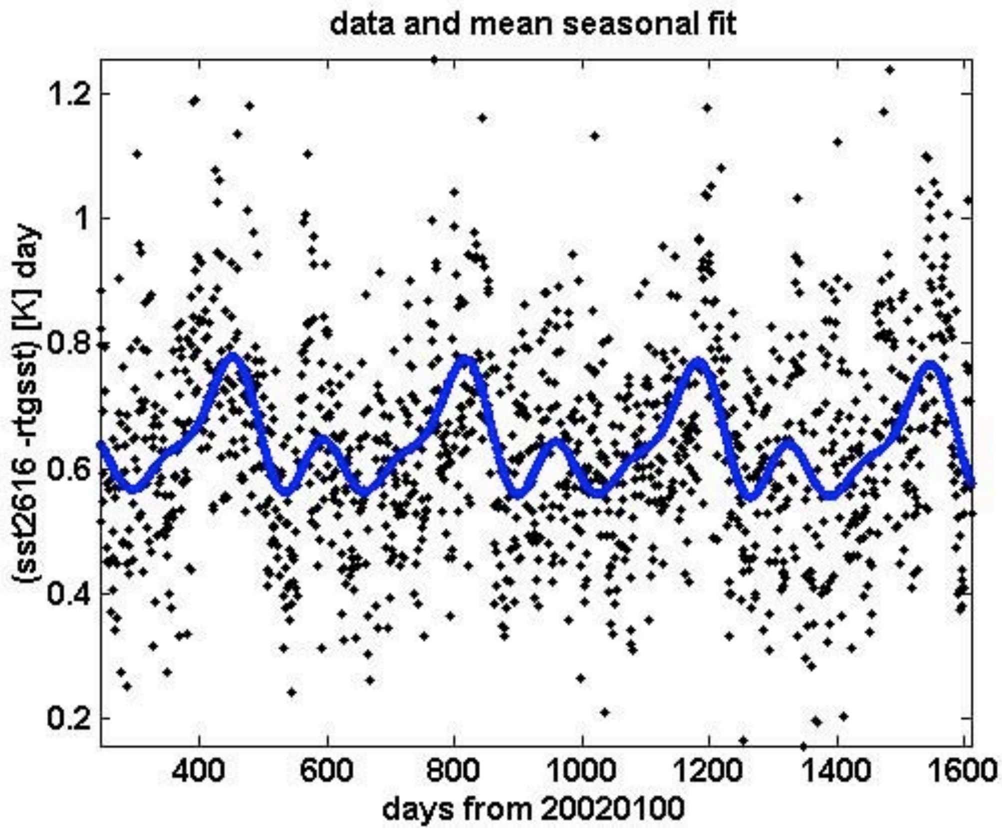
The black dots are the median from each day
The blue trace is the four seasonal mean

The anomaly shows no significant residual seasonal patterns.

trend for sst2616-rtgsst
= 9.0 +/- 2.4 mK/year



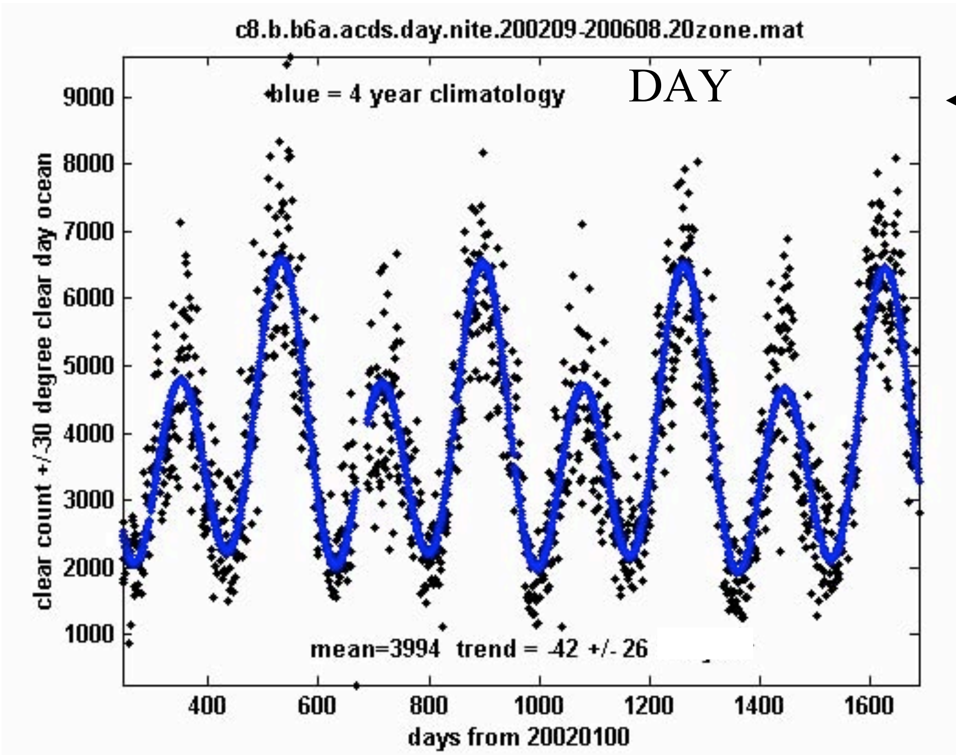
The day time trend for sst2616-rtgsst of 5 +/- 5 mK/year is insignificant. The +0.6 K offset is due to reflected light



The black dots are the median from each day
The blue trace is the four seasonal mean

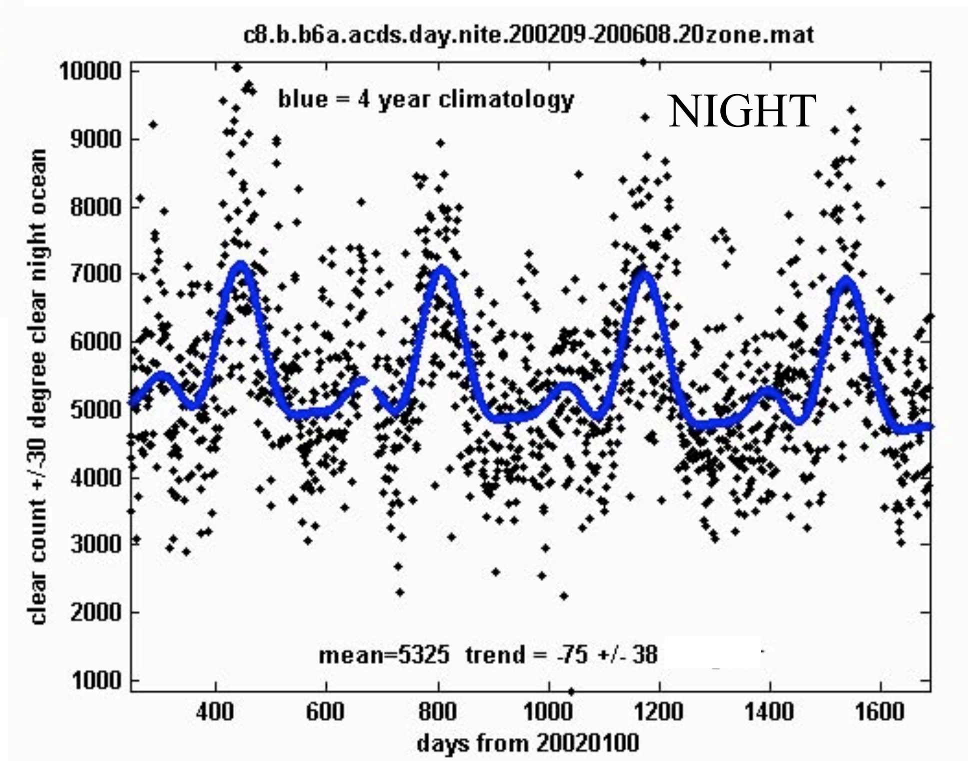
H. H. Aumann

The count of clear spectra in the tropical oceans appears to be decreasing day and night by about 1%/year. Less clear = more clouds.



-42 +/- 26 day/year day time

-75 +/- 38 day/year night time



The trend does not meet the 2 sigma significance test

The decrease in the number of spectra identified as clear is intriguing.

We test the stability of the data by relaxing the clear filter spatial coherence from cx2616=0.5 to cx2616=0.7. This doubles the yield of "clear" spectra

	cx2616=0.7	cx2616=0.5
day	-72 +/-43 in 7000 = -1.0%	-41+/-26 in 3664 = -1.1%
night	-116+/-60 in 9530 = -1.2%	-75+/-38 in 5325 = -1.4%
day bias	-0.269 K	-0.244 K
night bias	-0.668 K	-0.623 K

The result is very consistent.

The cx2616<0.7 spectra are obviously not as clear as the cx2616<0.5 spectra. During the day the cold bias increases 25 mK, at night 45 mK.

Similar stability is observed with the other trends.

FOUR YEARS OF ABSOLUTELY CALIBRATED HYPERSPECTRAL DATA FROM THE ATMOSPHERIC INFARED SOUNDER (AIRS) ON THE EOS AQUA:

Trends and trend uncertainties

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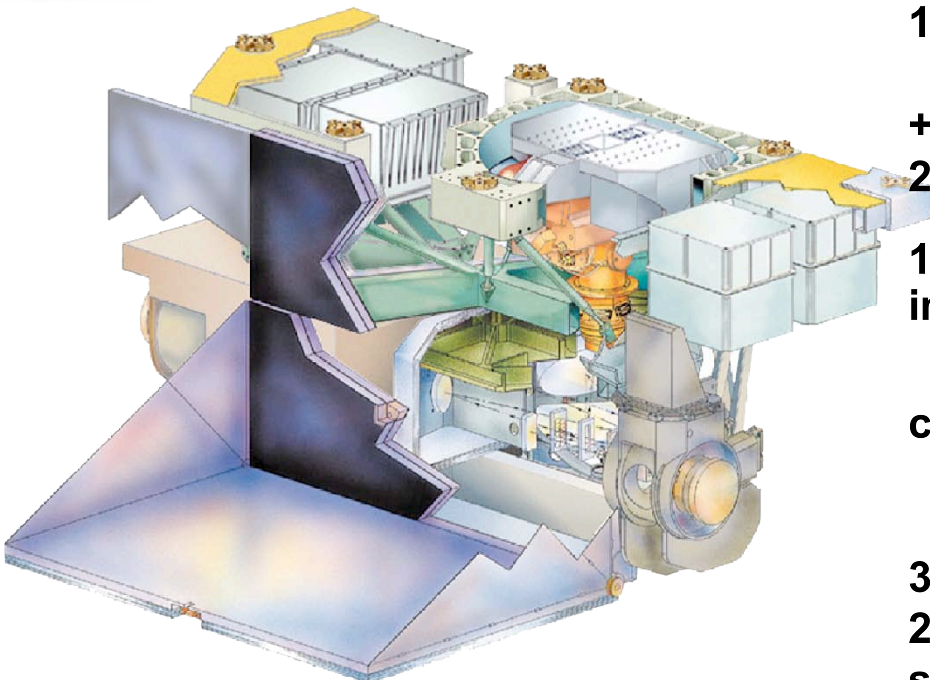
24 July 2006

AGU 2006 Western Pacific Geophysics Meeting (WPGM), 24-27 July 2006, in Beijing, China.
Session A02: Satellite Instrument Calibration: The Challenges of Global Climate Change and Numerical Weather Prediction



AIRS on EOS Aqua
705 km altitude polar orbit
14 orbits per day

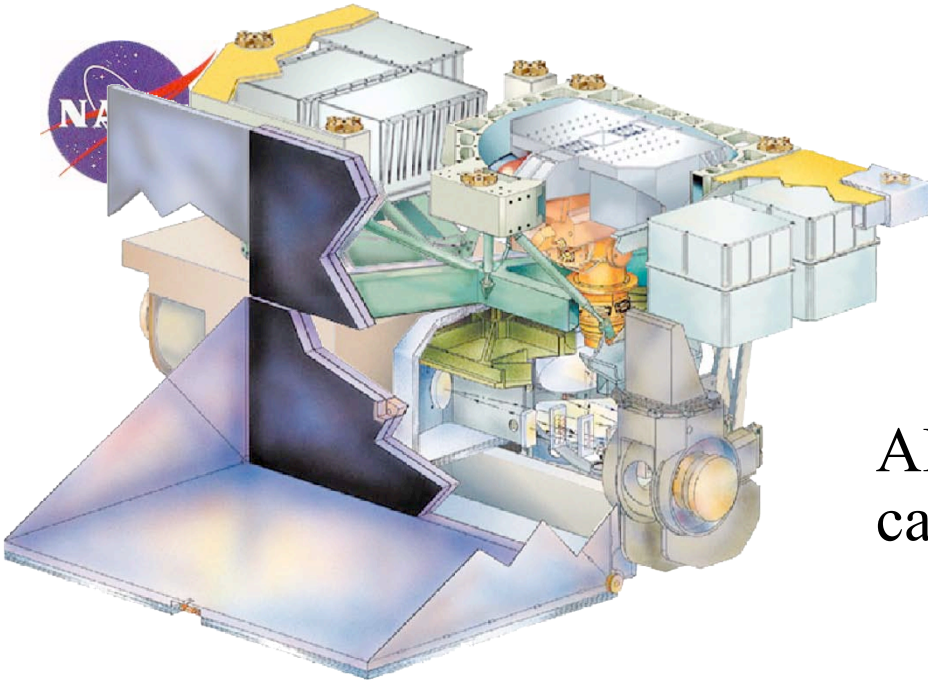
+/- 50 degree cross-track scanning
2.9 million spectra per day

13.5 km IR FOV at nadir
imaging with 98% overlap

cooled grating array spectrometer
58K detectors

3.7 – 15.4 microns
2378 spectral channels
spectral resolution 1200
spectral sampling 2400 (Nyquist)

NeDT= 50%tile better than 0.2K at 250K



AIRS was designed, built and calibrated for climate quality data

Designed to achieve better than 3% absolute radiance accuracy between 200K and 360 K and 3.7 – 15.4 microns for 5 years.

Full aperture wedge cavity blackbody at 308 K (+/-10 mK)

Spectrometer optical bench cooled to 156 K +/-10 mK

One blackbody view and four space views every 2.67 seconds

Prelaunch calibration with NIST secondary standard between 220 K and 340 K, at 6 scan angles and at three spectrometer temperatures.

The expectation from AIRS were achieved

Chahine et al. 2006 BAMS 15 July

12 hour forecast impact in 5 days achieved in both hemispheres
LeMarshal et al. 2006 BAMS 15 July

RAOB equivalent accuracy achieved relative to the RAOB matchups at mandatory levels
Divacarla et al. 2006 JGR

The expectation from AIRS were achieved

Better than 0.2 K absolute accuracy
Tobin et al. 2006 JGR

Stability better than 16 mK/year
Aumann et al . 2006 JGR

The cloud filtered data shown in the following are Level 1b. The L1b calibration has for most detectors not changed since September 2002. The data are available as the ACDS from the DAAC.