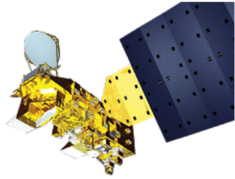
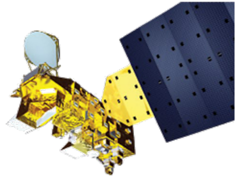


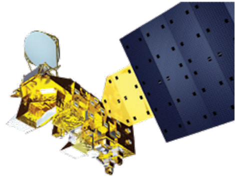
Radiometric Stability in 16 years of AIRS hyperspectral infrared data (SPIE OP-431-20)

Hartmut H. Aumann and Evan M. Manning
Jet Propulsion Laboratory, California Institute of Technology.
4800 Oak Grove Dr., Pasadena, CA 91109



- Why is radiometric stability so important.
- How do we measure it.
- Results

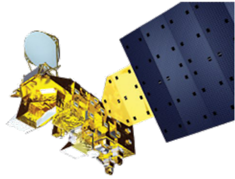
Why is radiometric stability so important?



- The mean global temperatures are warming at the rate of 10 mK/yr. To have a chance of identifying climate trends , an instrument has to be much more stable than 10 mK/yr

- Global warming related change related cloud cover will be small, but can only be done globally from space.

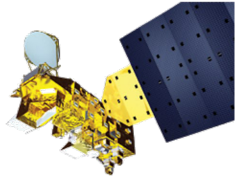
- When concatenating the data record from two instruments, it is difficult to eliminate all bias, but concatenation of the data records may be possible if both instrument are extremely stable.



How is stability established ?

- Use cloud-free data. We use cloud-filtered data.
- Use a stable reference. We use the NOAA SST
- Create an (obs-calc) time series using atmospheric window channels. This minimizes changes in atmospheric correction
- “obs” is the observed signal from the reference source (brightness temperature for AIRS)
- “calc” is the calculated expected signal based on the knowledge of the reference source, atmospheric and emissivity corrections and and the instrument characteristics
- Ideally (obs-calc) will have zero bias and zero trend.

Use cloud-filtered data



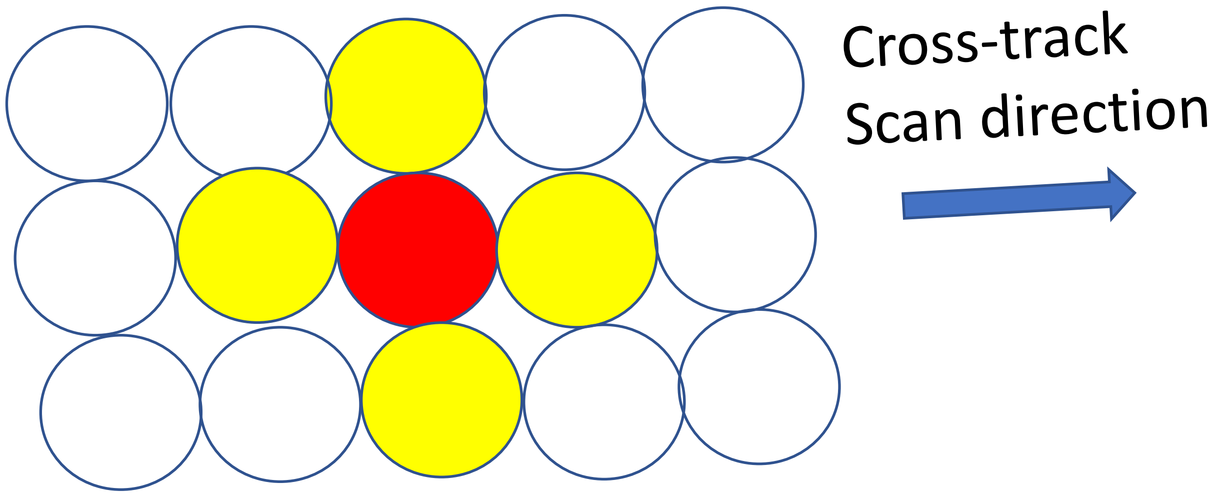
We created a random sampled data set of 24,000 spectra each day from the non-frozen oceans to find clear data.

Clear is determined by a 4 pixel spatial coherence test and a water vapor test.

Let bt1231 be the brightness temperature in the 1231 cm-1 window channel. The NeDT of this channels is 0.1 K.

Define cx1231 as the maximum of the absolute value of the difference in bt1231 between the test pixel (red) and its four nearest neighbors (yellow).

If cx1231<threshold, then the pixel is tested for uniform low clouds using a split window total water vapor sensitive channel.

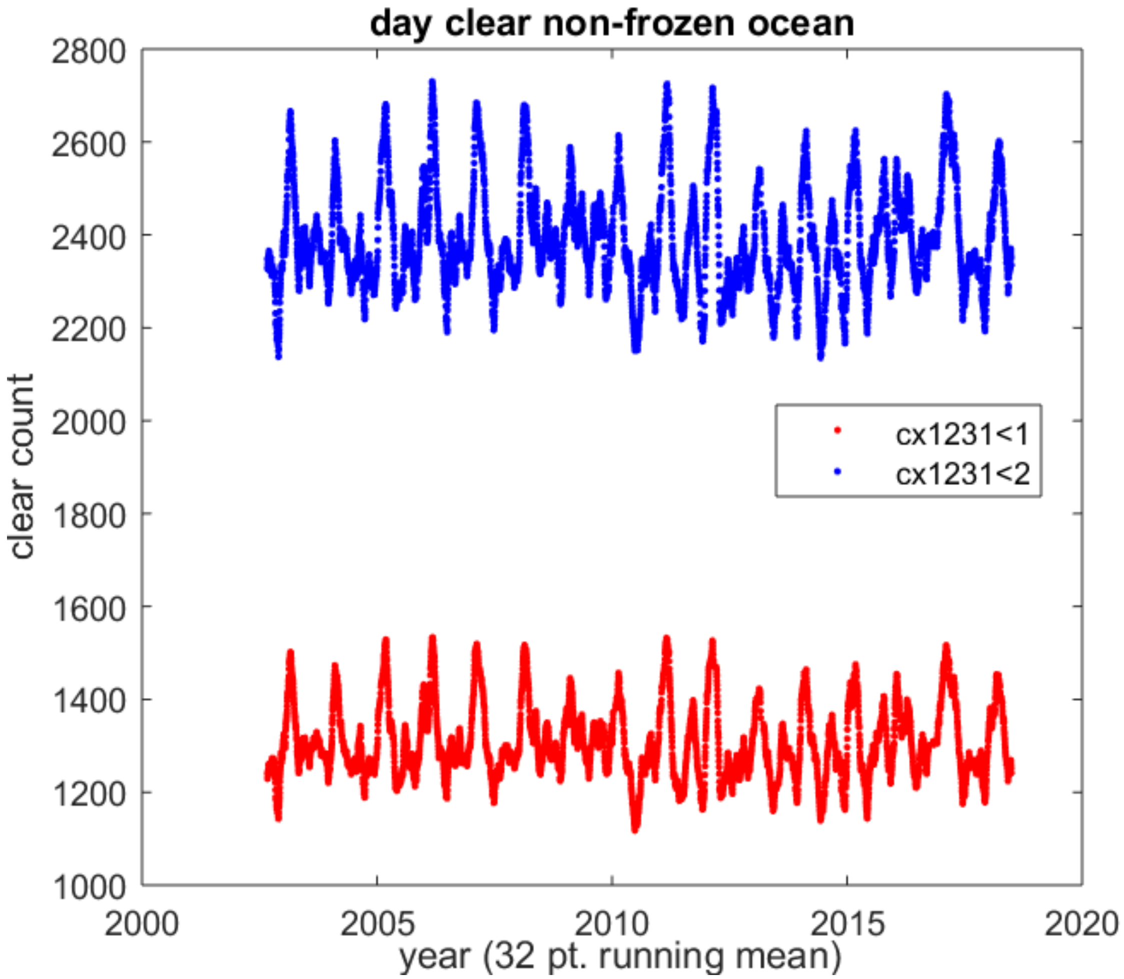


AIRS has 13 km diameter footprints at nadir

A spectrum which passes both tests is spatial coherence clear.

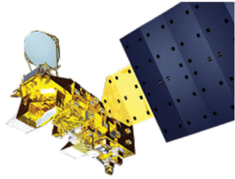
National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California
Atmospheric Infrared Sounder

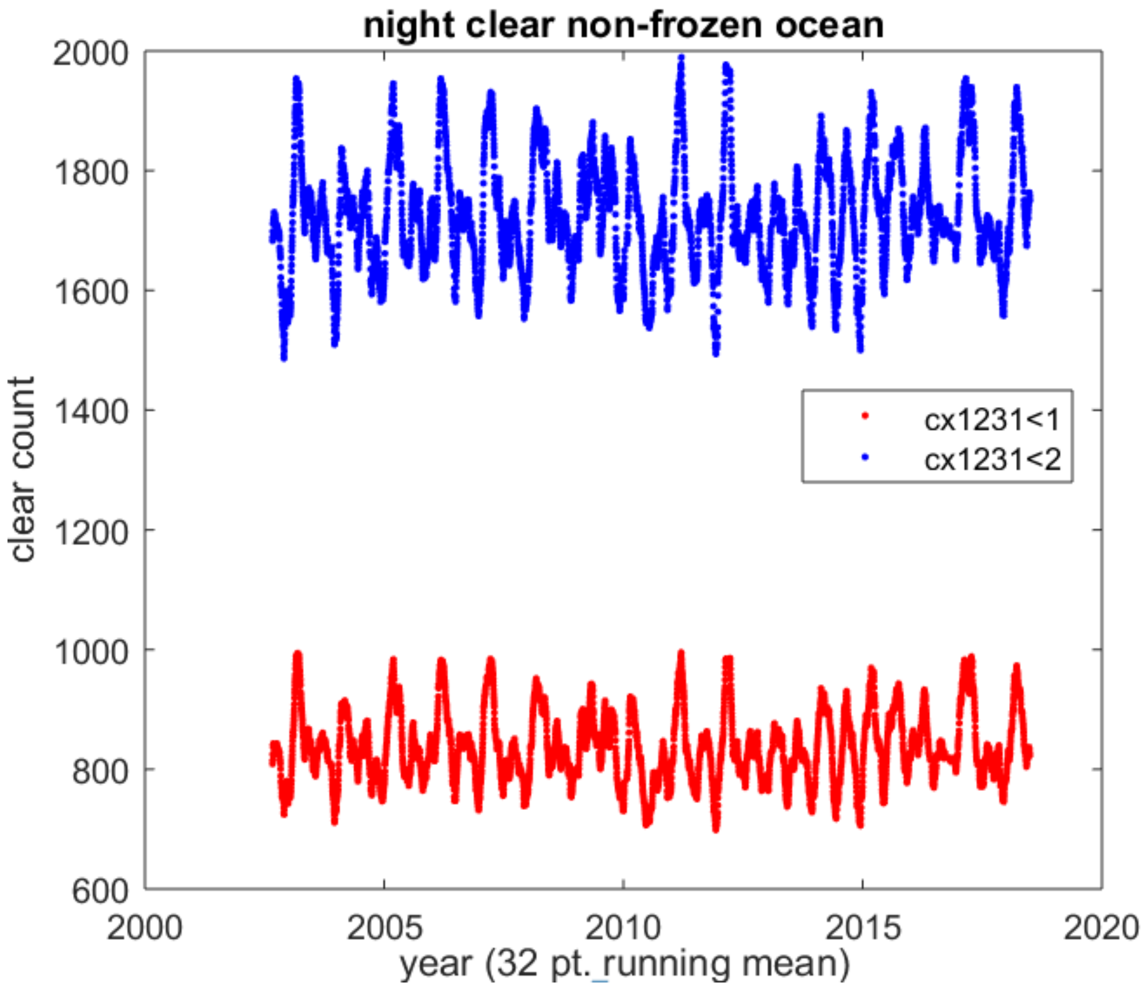
There are enough “clear” footprints each day to create stable daily mean statistics.



In 12000 random day samples of the non-frozen oceans we typically find 1400 “clear” with the cx1231<1K condition, twice as many with the cx1231<2K condition.

There are more clear day samples than clear night samples

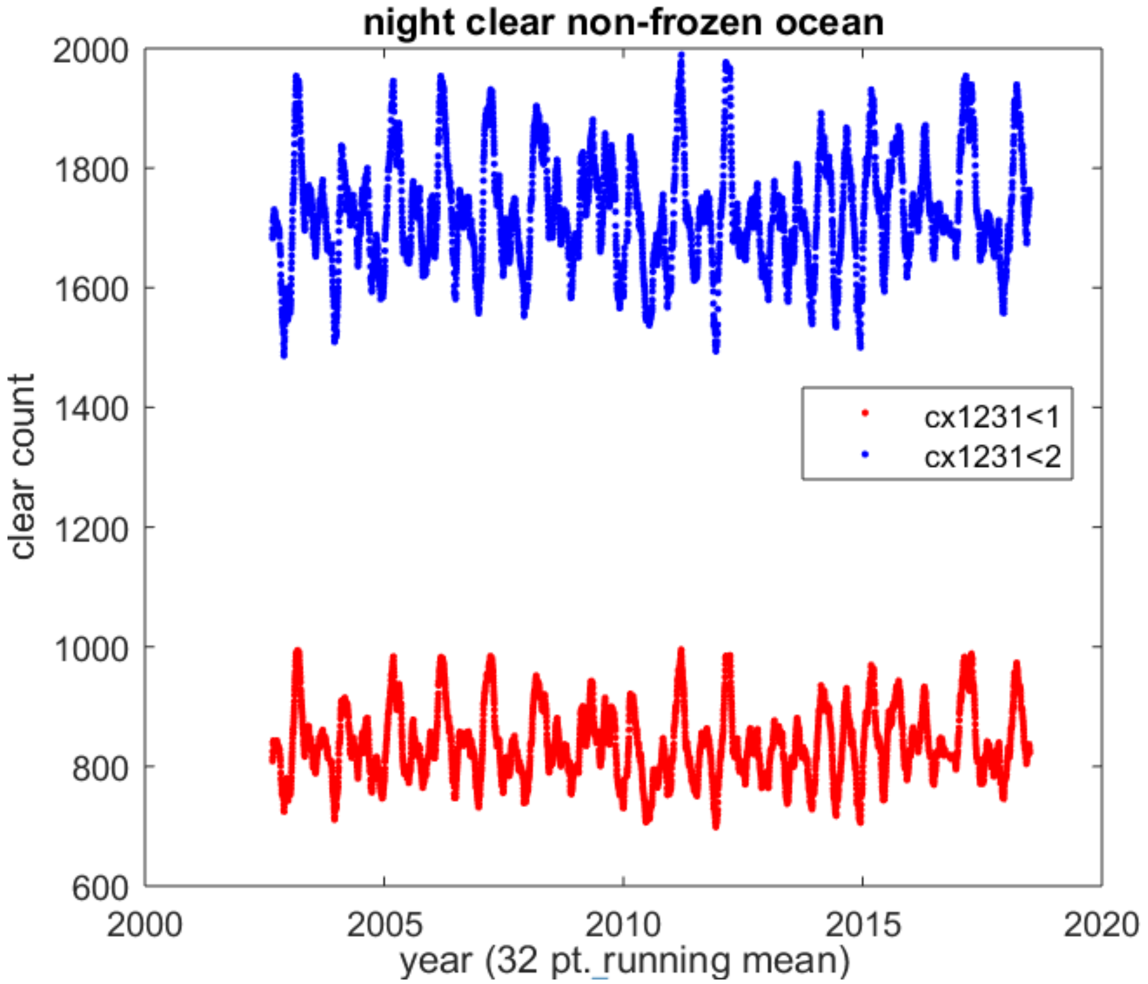




In 12000 night samples of the non-frozen oceans we typically find 900 “clear” with the cx1231<1K condition, twice as many with the cx1231<2K condition.

There is a seasonal cycle in the clear count related to the SST,

The clear count is extremely stable



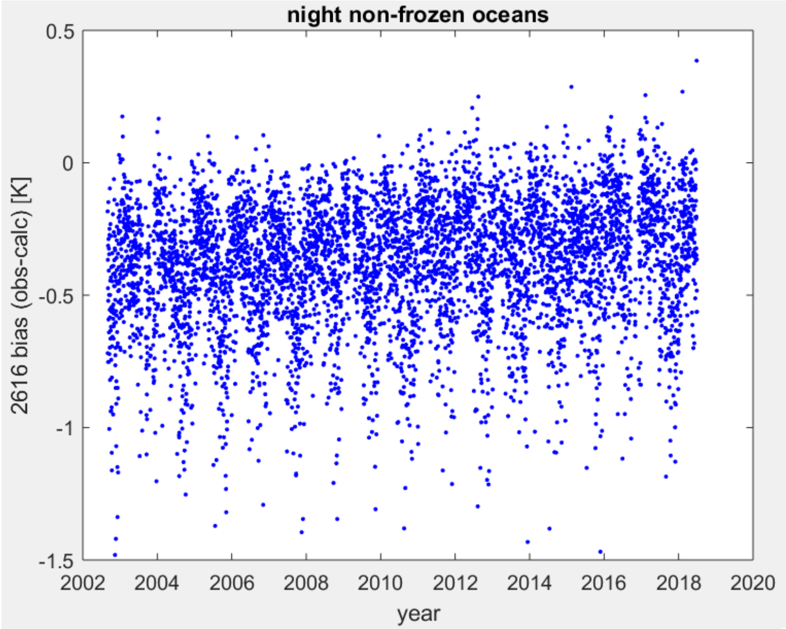
In 12000 night samples of the non-frozen oceans we typically find 900 “clear” with the cx1231<1K condition, twice as many with the cx1231<2K condition.

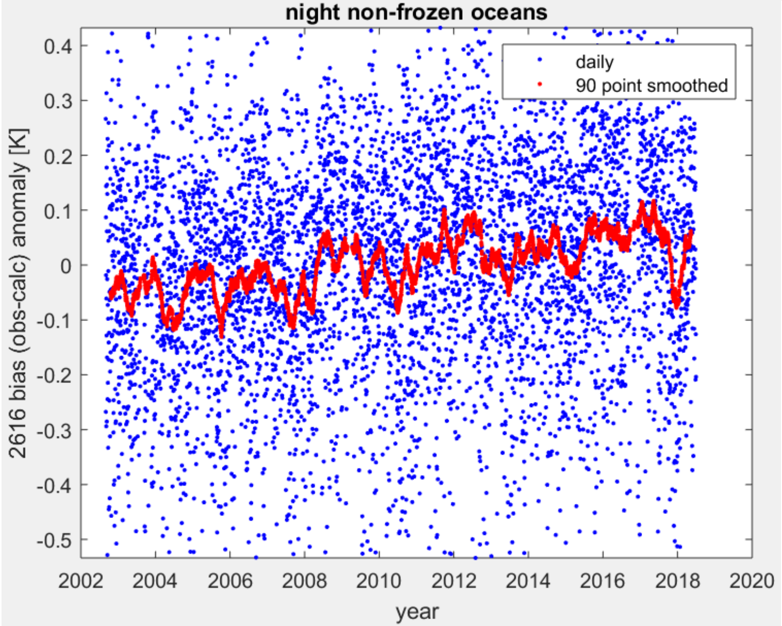
There is a seasonal cycle in the clear count related to the SST,

The anomaly is the data with the annual variability removed.

The anomaly trend in the clear count is smaller than 0.02%/year

2616 (obs-calc)

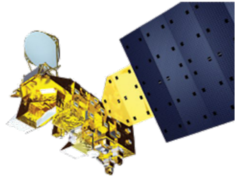




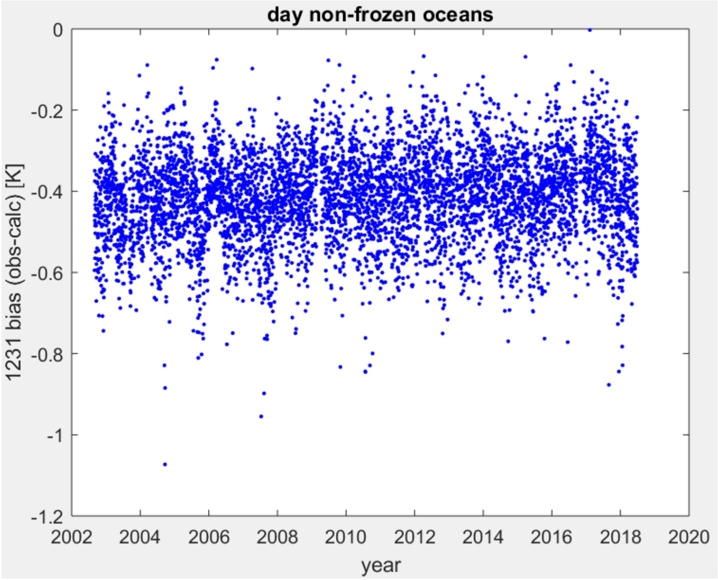
Can’t be used during the day, bcause we are not correcting for reflected sun light.

At night (obs-calc) has a cold bias of -0.39 K
with a pronounced seasonal variability.
This means that a certain class of uniform clouds (probably low stratus clouds) is not rejected by the cloud filter.

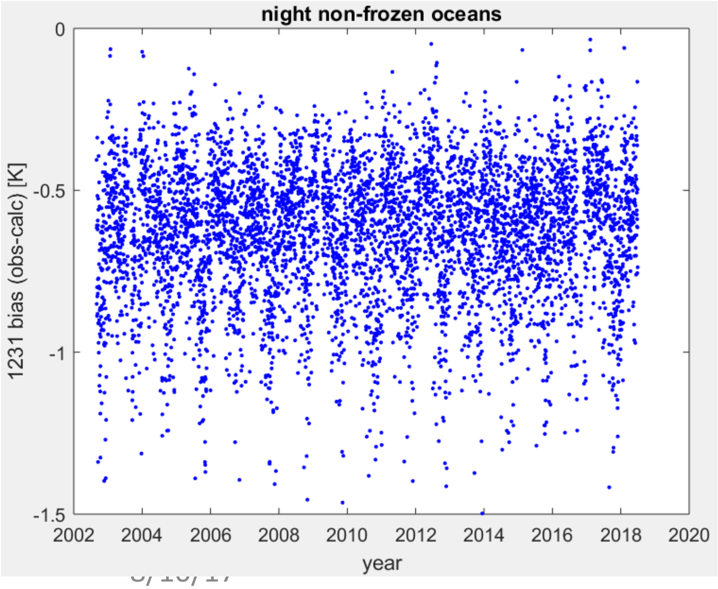
The seasonal variability is removed in the anomaly calculation.
The anomaly trend of (obs-calc) is +7.5± 0.64 mK/yr
i.e. the negative bias is getting less negative.



1231 (obs-calc)

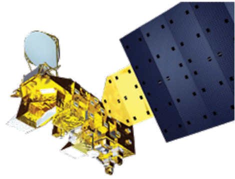


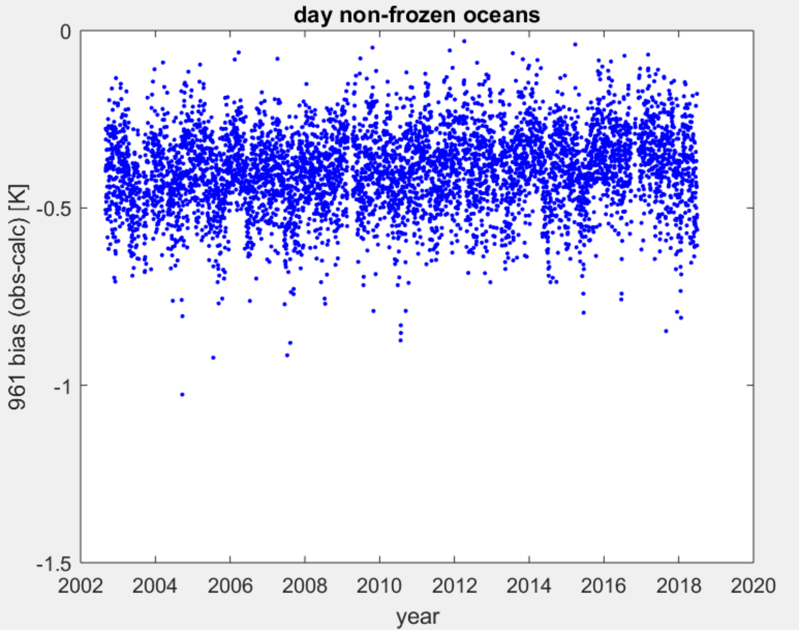
During the day (obs-calc) has a cold bias of -0.41K which decreases at the rate of +2.6 ± 0.30 mK/yr



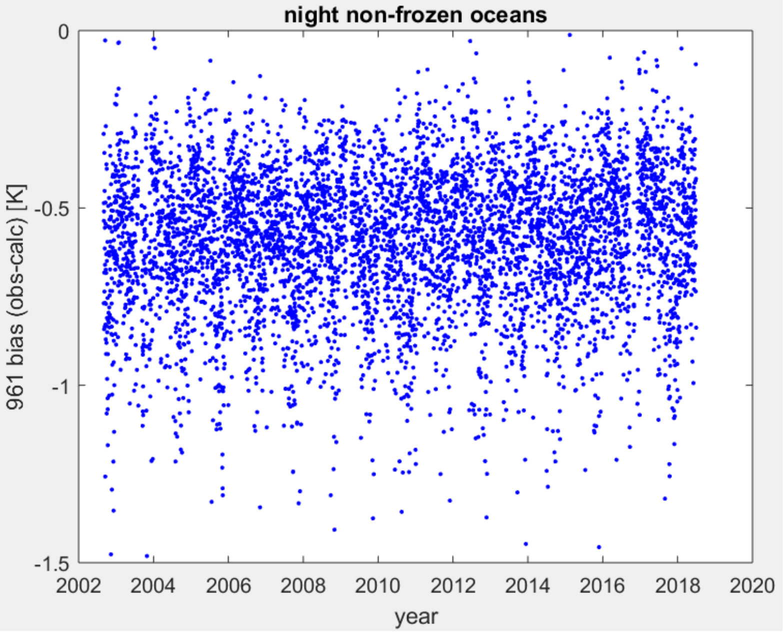
At night (obs-calc) has a cold bias of -0.62K which is decreasing at the rate of +1.4± 0.6 mK/yr
with a pronounced seasonal cycle and much more variability than the day result.

961 (obs-calc)

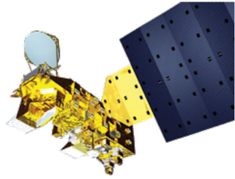




During the day (obs-calc) has a cold bias of -0.39K which decreases at the rate of +3.7 ± 0.29 mK/yr



At night (obs-calc) has a cold bias of -0.58K which is decreasing at the rate of +2.0± 0.6 mK/yr with a pronounced seasonal cycle and much more variability than the day result.



The bias and trends in the three window channels are small but not the same.

Night Bias is -0.39K, -0.62K and -0.58K
Day bias is na, -0.41K and -0.39K at 2616, 1231 and 961, respectively

Night trend is +7.5, +2.1, and +1.4 mK/yr
Day trend na , +2.6, and +2.1 mK/yr at 2616, 1231 and 961, respectively

Trends for 11um window channels at 961 and 1231 cm^{-1} channels are typically +2 mK/year. The cold bias in (obs-calc) is decreasing. The decrease is more at night than during the day.

The trend for the 4 um window channels at 2616 cm^{-1} channels at night is significantly large (+7.7 mK/yr) than in the 1231 and 961 cm^{-1} channels. .

National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California
Atmospheric Infrared Sounder

The trends in the window channels are small, but why are the trend not the same?

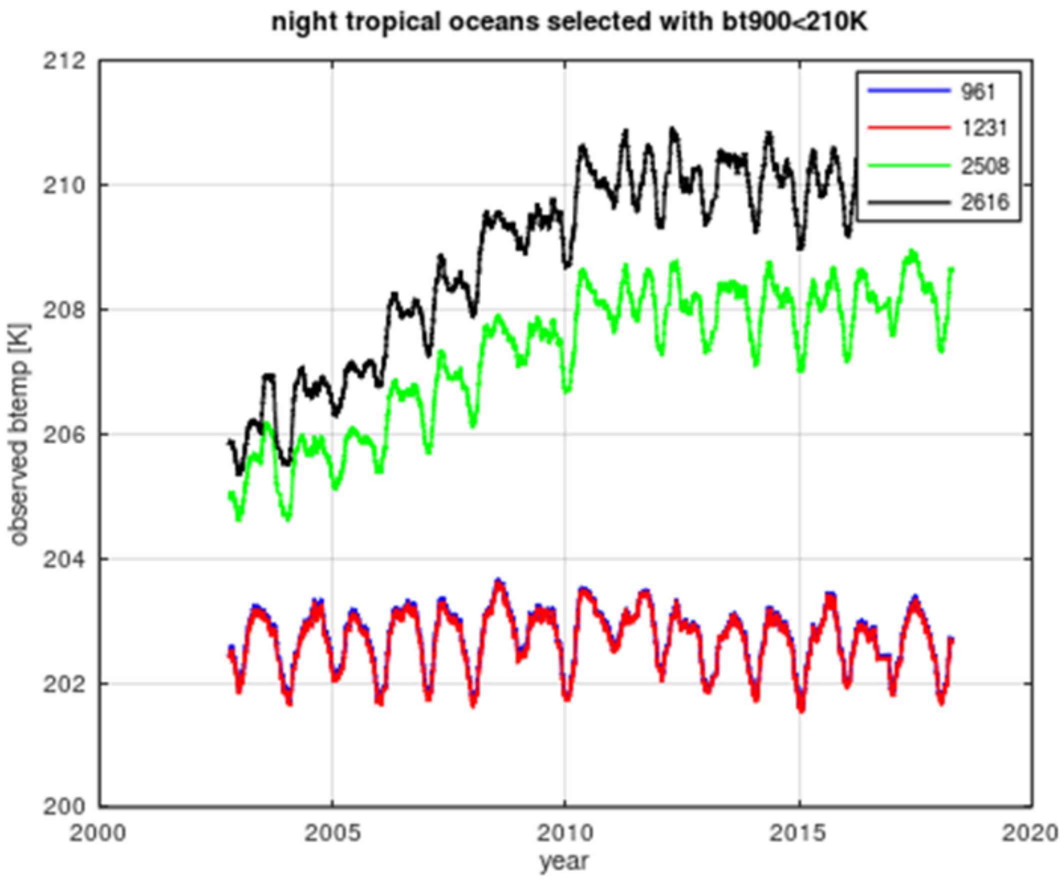
The current working hypothesis is contamination of the scan mirror. The resulting scattering is wavelength dependent.

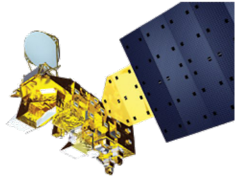
The effect of scattering is most pronounced when looking at extremely cold scenes surrounded by warm scenes at night. We use Deep Convective Clouds (DCC) for this test.

There is no effect in the 11um window channels.

There is a 4 K change between 2002 and 2011 in the 4 um window channels. The effect stabilized in 2011.

It may be a coincidence that in 2011 the AMSRE scan mirror was stopped due to excessive bearing friction





Why is there a trend in the (obs-calc) bias?

There is a cold bias of between 0.4 and 0.6K in (obs-calc) depending the channel.

We see a 2 mK/yr warming trend (decreasing cold bias) in the AIRS 11um window channels.
It does not appear to be related to scan mirror contamination.
The fact that it is significantly less during the night than during the day suggests a geophysical effect.

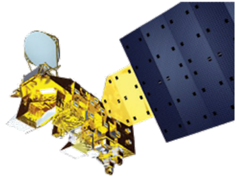
We see a 7 mK/yr warming trend (decreasing cold bias) in the AIRS 4 um window channels.
This could be an instrument artifact related to scan mirror contamination.
The cold bias in (obs-calc) is decreasing, i.e. fewer clouds are leaking into the clear filter.

The "clear" count is stable at the less than 0.02%/year level.

Day/night differences in the trend for 15 years are not consistent with instrument artifacts.

Our results could be consistent with a climate signal related to the predicted expansion of the downwelling branch (dry air = less clouds, more clear) of the Hadley Cell in a warmer climate.

Summary



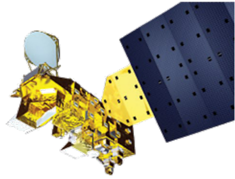
(obs-calc) in the oceans under clear conditions is a very useful tool to analyze instrument performance.

We see a 400 mK cold bias in the AIRS data. This is related to a cloud leak into the clear filter

The cold bias is decreasing at the rate of 7 mK/yr in the 4um window channel. This could be an instrument artifact related to scan mirror contamination.

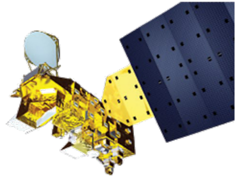
The cold bias is decreasing at the rate of 2 mK/yr in the 11um window channels, This is not scan mirror contamination. It could be another artifact.

It could also mean that we see the predicted widening if the descending branch of the Hadley cell in a warmer climate. Once this is sorted out, we may have an interesting climate paper.



The detection and elimination of instrument artifacts and the detection of climate signals area inseparable.

Thanks for your attention



Why is there a cold bias in (obs-calc)?

We are using the RTGSST for the calculations. The RTGSST is a day/night average of the floating buys at 2 meters below the surface.   AIRS measures the skin temperature. The bias has a clear seasonal component. This means that part of the bias is clouds in the “clear” data.

The bias has several component:

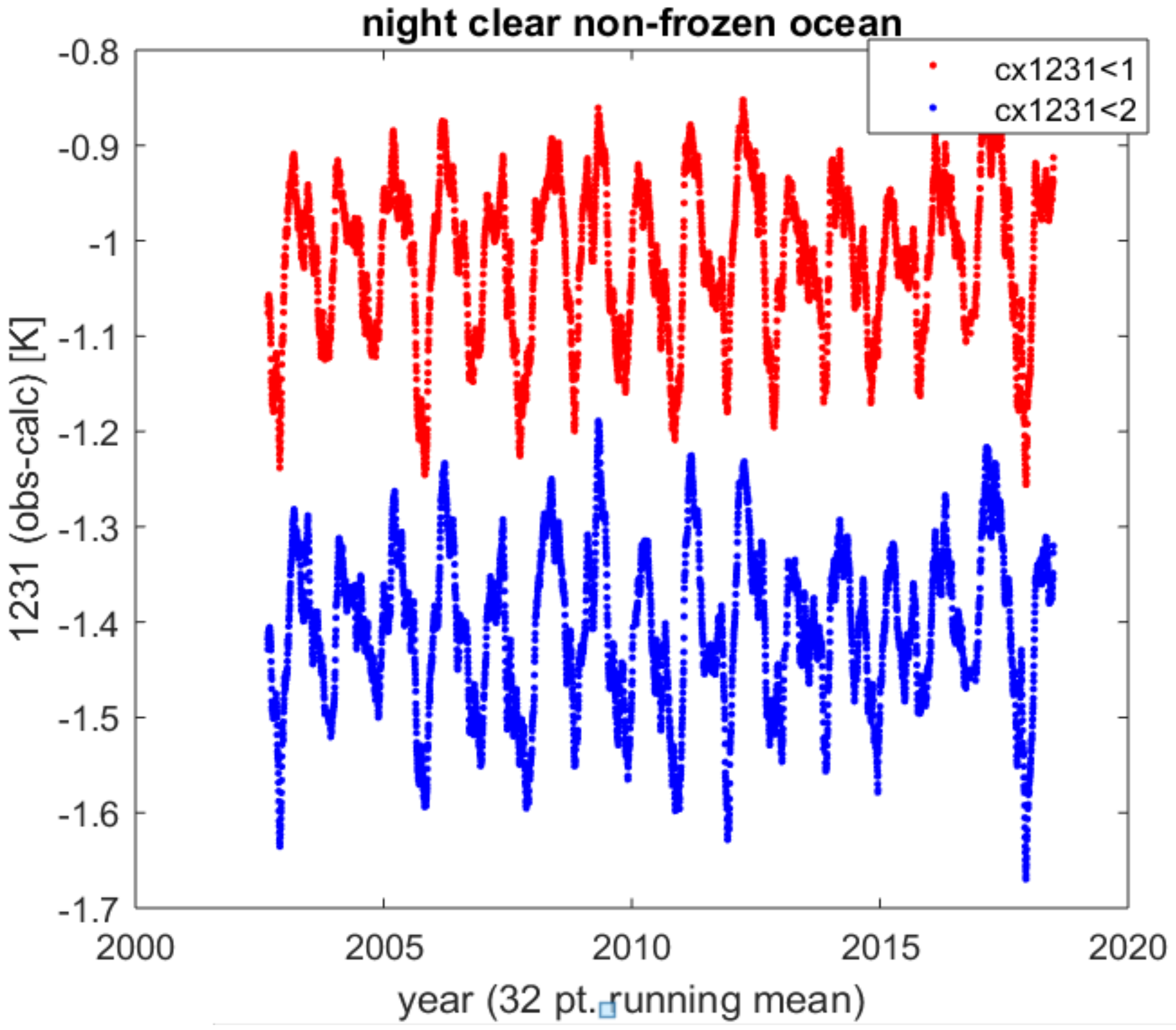
a). The RTGSST is a day/night average, which is assumed to be 0.18 K too cold during the day, 0.18 K too warm during the night. This is a statistical correction appropriate to the tropical zone for a 1:30 PM orbit, but not the non-frozen oceans.

b). The RTGSST is the temperature at the buoy depth of 2 meter below the surface. AIRS measures the skin temperature which is assumed to be 0.18K warmer.

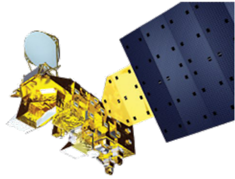
c) AIRS measures the skin temperature under clear conditions. The skin temperature for clear areas is likely to be warmer than the buoys during the day (obs warmer than expected) and colder at night (obs colder than expected).

National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California
Atmospheric Infrared Sounder

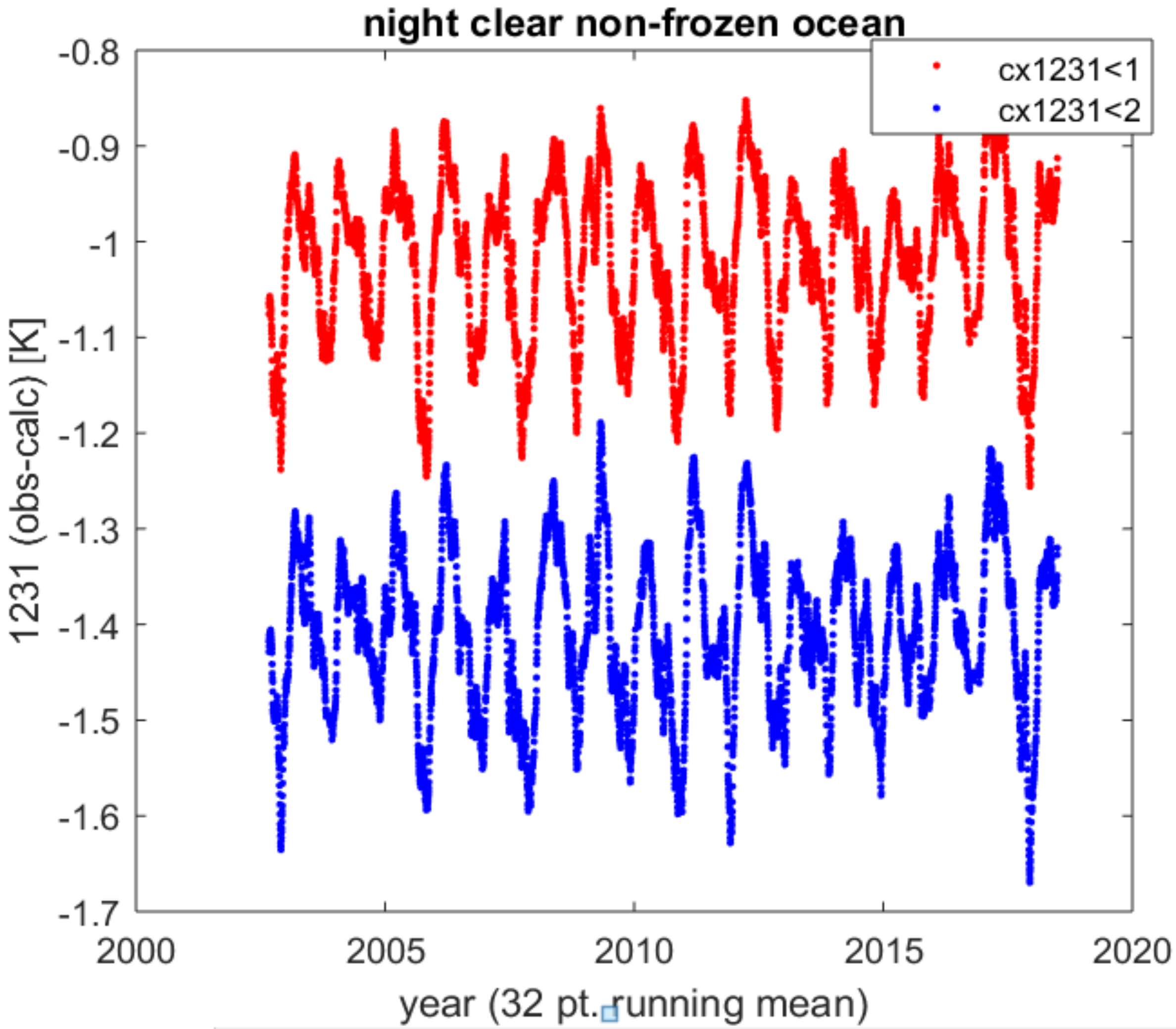
Use the 1231 cm-1 window channel for the illustration of bias in (obs-calc)



- The bias in (obs-calc) shows the seasonal cycle of the SST.
- The bias in (obs-calc) changes from -1.4K to -1K with a tighter clear filter
- This means that we have a seasonal cloud contamination.
- Extrapolated to cx1231=0 (perfect filter) there remains a 0.4K cold bias.



The anomaly trend in (obs-calc) is a measure of instrument stability



The night trend for cx1231<1K is +1.0±0.4 mK/year,

The night trend for cx1231<2K is +0.41± 0.4 mK/year

The day trend for cx1231<1K is +2.2±0.3 mK/year

The day trend for for cx1231<2K is +1.6 ± 0.3 mK/year

The cx1231<2K trends are consistently smaller than the cx1231<1K trends.

The night anomaly trends are consistently smaller than the day anomaly trends.