Creating a single radiance climate record from AIRS, IASI and CrIS.

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CALCON Meeting
June 2018. Utah State

Acknowledgements: NASA grant: NNX16AQ68G. 'A homogeneous infrared hyperspectral radiance and level 3 climate record combining NASA AIRS, JPSS CrIS and Eumetsat IASI.'

Overview

Overview

- Objectives.
- The Sensors and Measurements.
- The Methods.
- Some Results.
- Future Plans.

Objectives

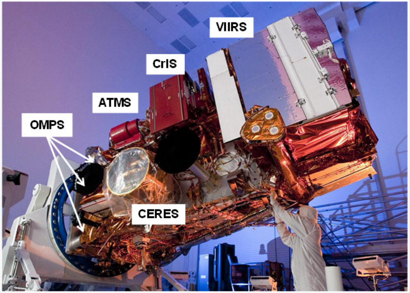
- Longest possible continuous global radiance record for climate studies.
- Utilization of different (but similar) sensors spanning multiple lifetimes.
- Provide common framework for forward model and geophysical retrieval.
- Direct traceabilty of calibration uncertanities to retrieved quantities.
- Current application to NASA AIRS (2002 - present) and NOAA CrIS (2012 - present).

Challenges

- How to connect the radiance spectra of the two sensors and retain as much spectral information as possible without sacrificing precision.
- How best to compare the observations of the Earth from the two sensors:
  - How long a time period and how many observations are required.
  - How best to deal with spatio-temporal sampling differences.
  - How best to independently validate.
- What does the result tell us about relative calibration accuracies.

Data

The Sensors and Measurements



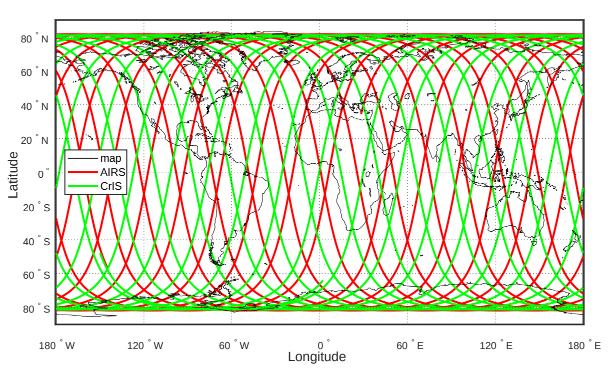
AIRS vs CrIS

- Sun-synchronous, 98-deg inclination, similar fields of view (see later).
- Similar global coverage, 16-day repeat period, AIRS completes 233 and CrIS completes 227 orbits in 16-days (later).
- Much spectral overlap across 4 μm to 15 μm.
- CrIS is an interferometer, ILS is sinc. spectral resolution 0.625 to 2.5 cm^{-1}, (originally).
- AIRS is a spectrometer, resolving power from 1100 to 1300 approx.
- Comparable noise figures.
- Creating a common radiance record and inter-comparing earth observations requires carefully accounting for instrument and sampling differences.

AIRS vs CrIS Sampling

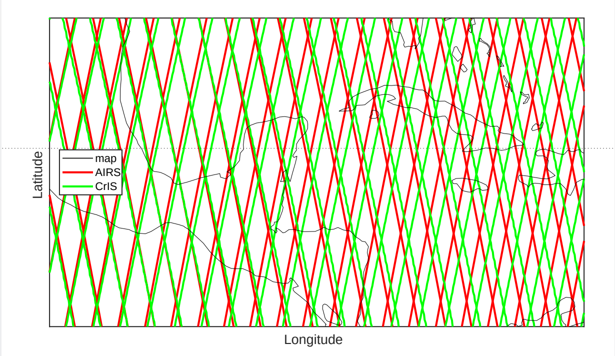
- Daily: 2,916,000 observations:
  - Nadir to approx $\pm 60 deg$ cross-track.
  - AIRS: 90 cross-track FOVs.
  - CrIS: 9 x 30 cross-track FOVs.
- Field of view about 14 km diameter.
- CrIS has motion compensation AIRS does not.
- Orbits pass in and out of phase.
- For trending and inter-comparison studies equal areas must be equally weighted. (we are most interested in global and zonal averages).

Sub-Orbit Track for One Day



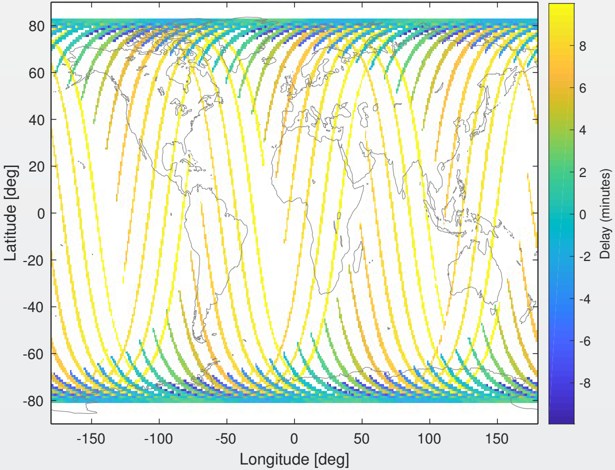
- Notice the increasing density from equator to pole.
- Global coverage, but notice variable phase shift w/ longitude.

Sub-Orbit Track for 16 Days



- Notice the phase shift from day to day.

AIRS and CrIS Coincident FOVs



- Most simultaneous nadir observations (SNOs) occur at high latitudes, with fewer nearer the equator, where they also have a systematic time delay.

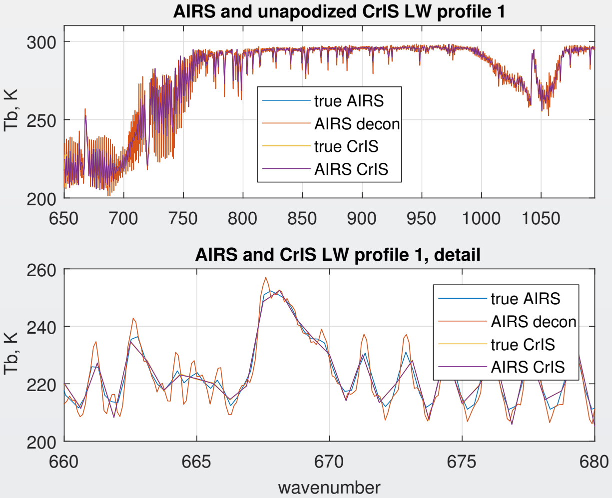
Methods

Methods.1 - Spectral

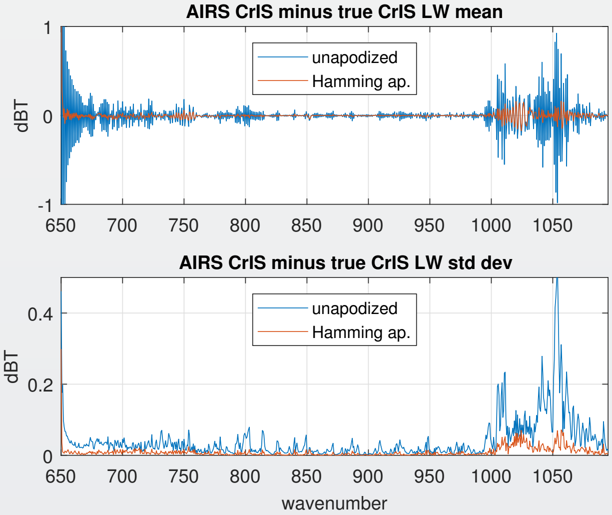
- Reference: "AIRS Deconvolution and the Translation of AIRS to CrIS Radiances with Applications for the IR Climate Record" Howard E. Motteler, L. Larrabee Strow (In publication w/ IEEE).
- Key points:
  - AIRS is a grating spectrometer with 2378 channels whose spectral response functions were determined pre-flight and recorded at $0.1cm^{-1}$ resolution.
  - For translation to CrIS, the AIRS channels are 'regularized' to 2645 channels.
  - The AIRS spectra are de-convolved to an intermediate resolution of $0.1cm^{-1}$
  - The overlap of neighbour SRFs allows the deconvolution to recover resolution beyond that of separate SRFs.
  - The reconvolution to the CrIS ILS is straightforward.
  - Spectral bands common to both sensors provide available channels.

Results.1 - Spectral

- The method is verified using calculations from 49 standard atmospheric profiles.



- Hamming apodized spectral are used for science (note the ringing at band edges in the up-apodized spectra).

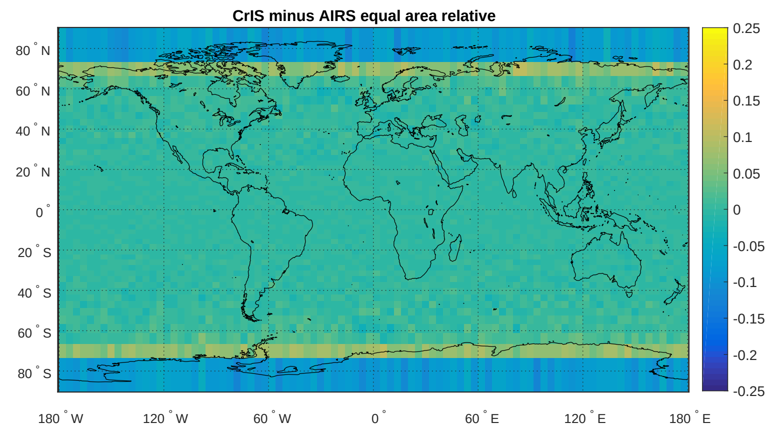


Methods.2 - Spatio Temporal

- Comparison tests of orbital parameters shown here are done with a 16 day data set from 20 Apr to 5 May 2016, chosen for no missing data.
- Latitude bands are used to test equal area weighted subsetting, and equal area bins to examine differences in mean time and observations between AIRS and CrIS samples.
- Equal area bins are formed from 24 equal area latitude bands from pole to equator (48 total) and longitude steps of 4 degrees.
- The following plot shows the relative number of observations (FOVs) of AIRS and CrIS for the full swath and for 16-day accummulation.

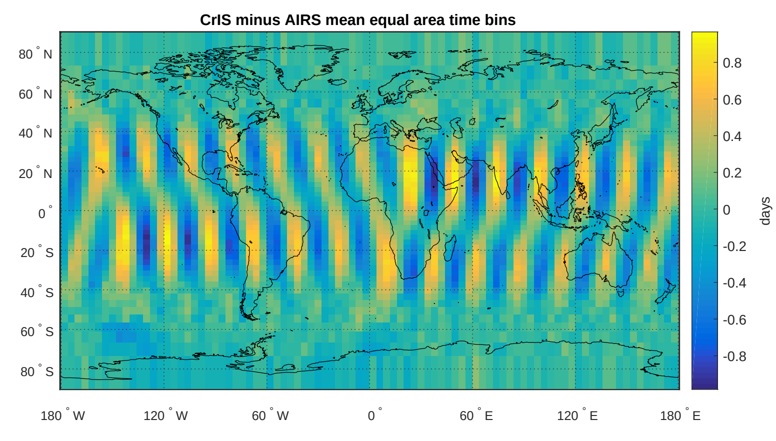
Results

Relative Obs Counts for 16 Days



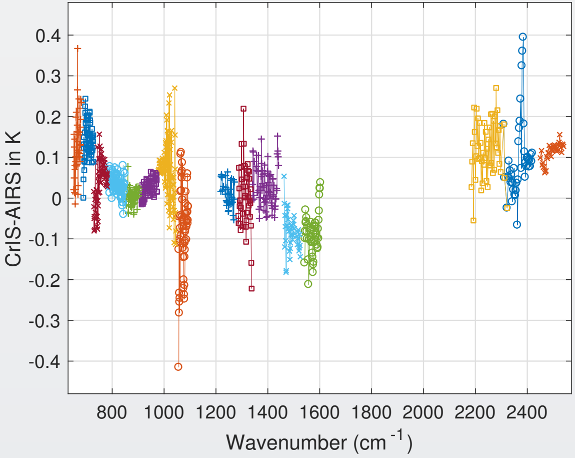
- By taking only nadir observations, or restricting to short periods results in much more highly variable differences that are spatially coherent across the globe.

Time Differences for 16 Days



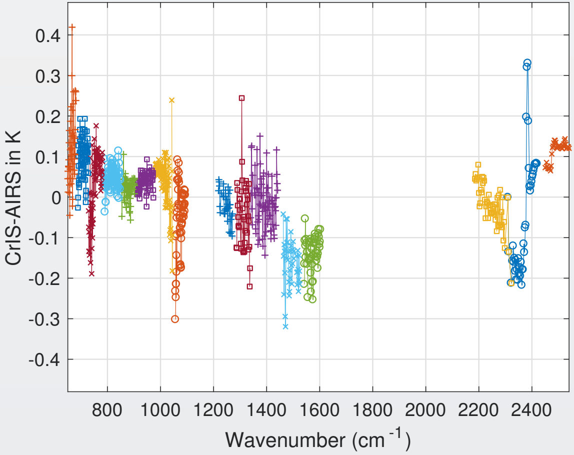
SNO results

- Six months of 'global' AIRS and CrIS SNOs are used to determine the mean bias between them. The AIRS spectral channels have been translated to the CrIS ILS.



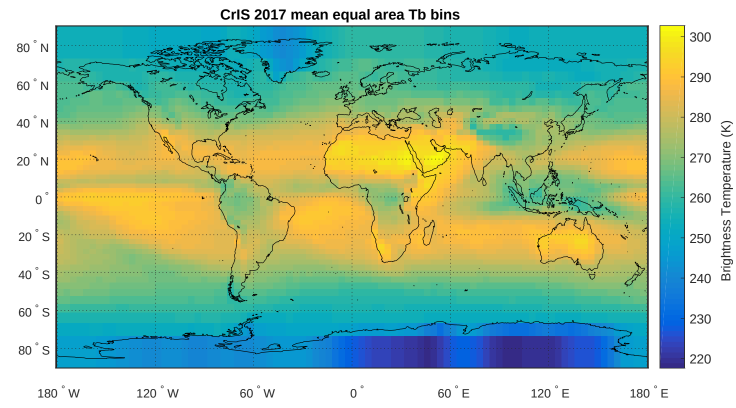
Equal Area Random Full Scan Results

- Six months of global random full-swath AIRS and CrIS are used to determine the mean bias between them. The AIRS spectral channels have been translated to the CrIS ILS.



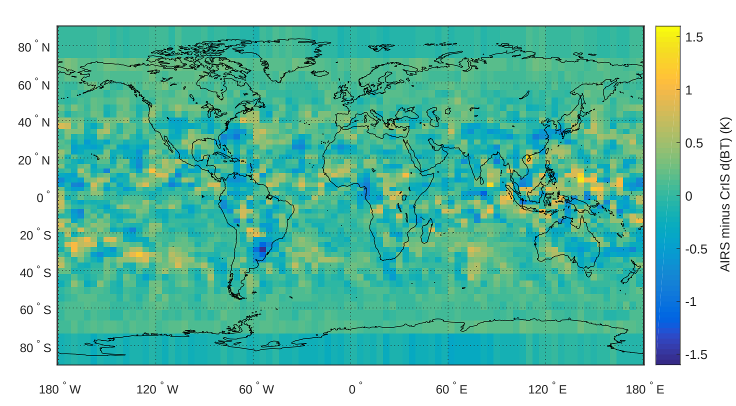
Equal Area Temperature map

- CrIS brightness temperature map for 2017 for $902 cm^{-1}$ channels, mean values in equal area bins.



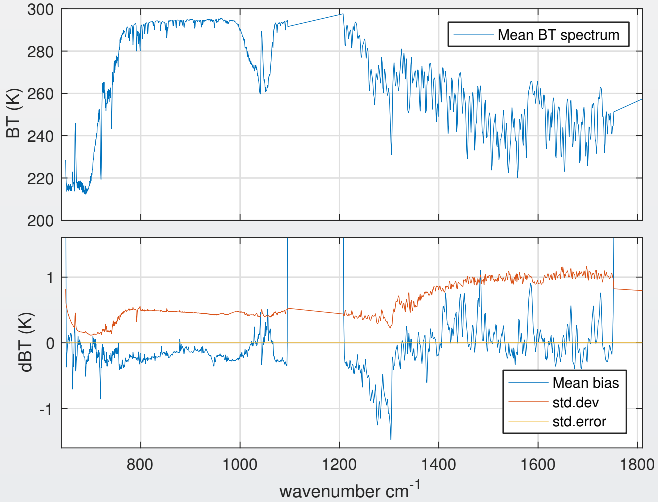
Equal Area Temperature map

- AIRS minus CrIS brightness temperature map for 2017 for 902cm^{-1} channels, mean values in equal area bins.



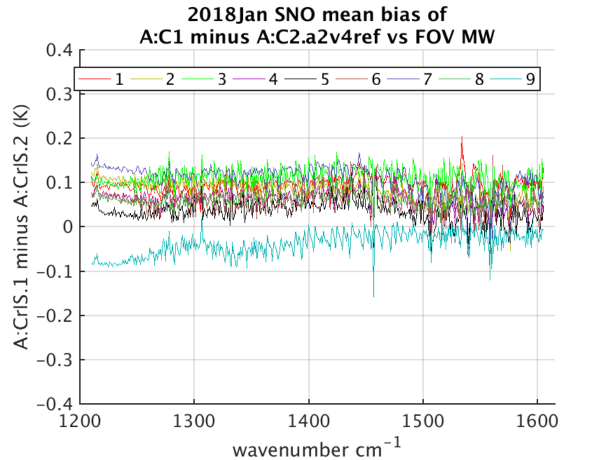
2017 Clear Tropical Ocean Bias

- CrIS Observations minus calculations for a 16-day average of clear tropical ocean views.



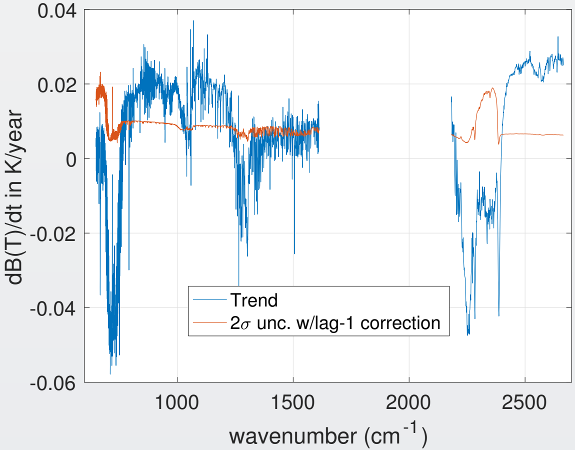
Benefit of Third Satellite to Connect Two Others

- Suomi-NPP CrIS and JPSS-1 CrIS (NOAA-20) are 45 minutes apart in same orbit:- no SNOs.
- Use Aqua AIRS to connect and monitor bias trends via SNOs.



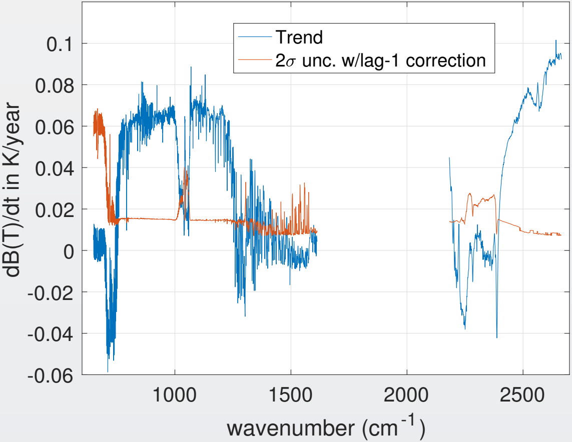
Long Term Trend - Global

- Using 10 years of SST climatology AIRS stability is estimated to be 0K/year +-0.003K/year.
- This plot shows the 15-year trend of Global Average Radiance.



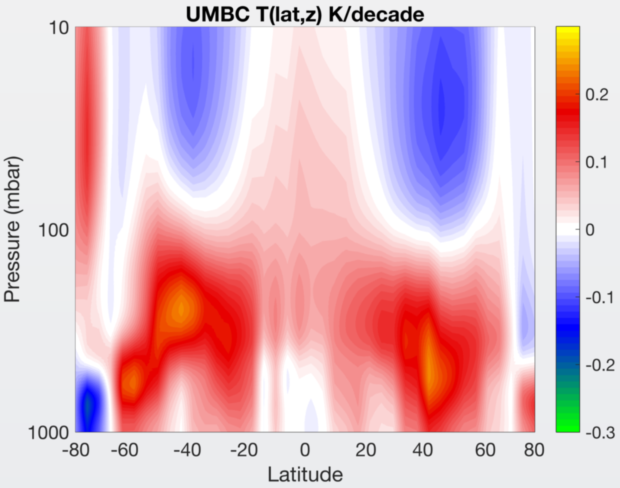
Long Term Trend - North Pole

- This plot shows the 15-year trend of North Polar (+77 to 90 ° N) Average Radiance.



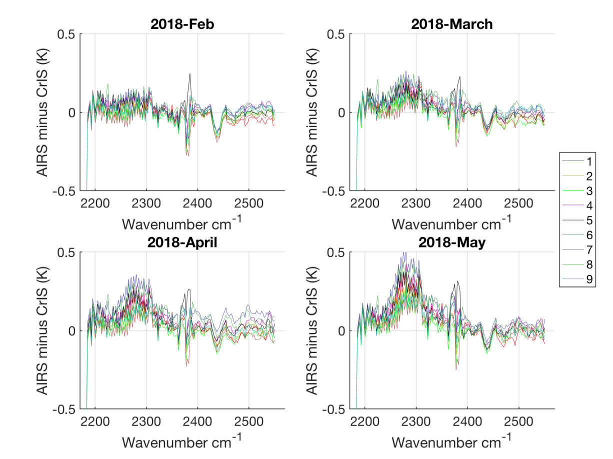
sample: 14-year AIRS Temperature Trend

- This plot shows the temperature trend derived from 14-years of AIRS radiances corrected for interannual variability and error covariance.



sample: J1 CrIS:AIRS Bias, SW band

- This plot shows the first four months of the AIRS:J1.CrIS for the SW band using SNOs.



Conclusions

Conclusions and Future Work

- Current generation of Earth viewing hyperspectral sounders for weather get global observations suitable for climate studies.
- A common hyper-spectral channel set can be established for creating long time series from several generations of sensors.
- Spatial and temporal sampling differences cause subtle differences in gridded data.
- Global and zonal average radiance records from multiple sensors can be compared more readily than gridded data.
- A third sensor such as AIRS is a valuable asset when determining biases between two other such as NPP.CrIS and JPSS1.CrIS.
- With care we can connect different sensors to better than 0.1 K.
- Next compare global trends from AIRS, CrIS and IASI.