Validation of the AIRS L1c Radiance Product: Spectral and Radiometric

AIRS Science Team Meeting

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Overview

- Radiometric validation of L1c "fill" channels
- Radiometric corrections for:
  - Instrument frequency drifts
  - Doppler effect

In general, L1c radiances are identical to L1b radiance, except for frequency shift corrections, unless there are significant errors due to:

- Detector popping
- C_{ij} errors (inhomogenous scenes)
- Poor detector performance (high noise, continuous popping, etc.)

L1c contains "fill channels" that do not exist in L1b to cover frequency gaps. This algorithm was developed by George Aumann and Evan Manning using simulated spectra provided by Sergio DeSouza-Machado.

L1c Characteristics

- Creates visually appealing spectra
- However, in general channels that are routinely corrected, and fill channels should not be used for science applications
- Fill channels are used to create the CHIRP ILS radiance product, but only for a few channels that are weakly dependent on the fill channel radiance
- The CHIRP application does require us to have a nominal value for the accuracy of the fill channel radiances

Grating Equation: Model Used for Frequeny Shifting

Basic equation for channel frequency:

$$\nu_i = \frac{m}{d(\sin(\alpha_i) + \sin(\beta_i))}$$

where α_{i} = incidence angle, β_{i} = diffracted angle, d = groove spacing, and m = grating order.

The angle of diffraction is computed from the linear positions y of the detectors on the focal using,

$$\beta_i = \tan^{-1}(y/F)$$

where $y = y_o + i * ds$. F = focal length of condensing mirror, ds is the detector spacing on the detector array, and i is the index nunber of the detector. We often call y "yoffset".

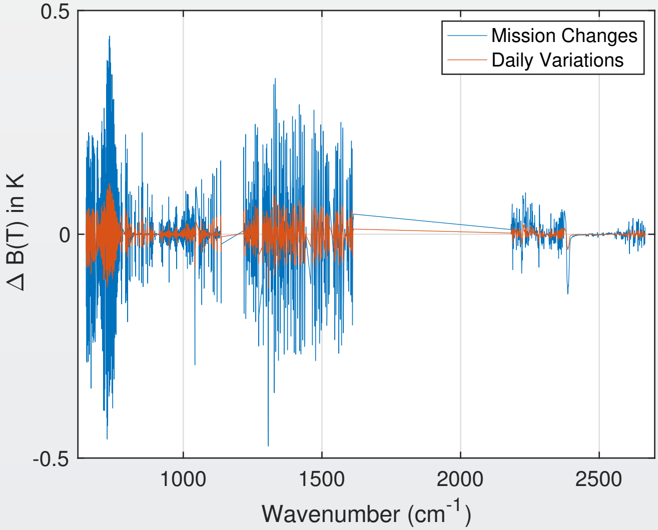
We measure y_o for each array, which varies with orbit phase and time. The time dependence includes secular, exponential, and. seasonal terms. The season terms are related to the satellite solar β angle.

Deriving AIRS Frequency Shifts

- Both the Doppler shifts and the instrument frequency shifts are measured by cross-correlating the observed spectral with spectral computed from the ERA reanalysisl
- We shift the computed spectra over a range of values. The AIRS true frequency scale is the same as the ERA computed scale when the cross-correlation reaches a maximum
- For the time dependence of the instrument frequency drifts we generally use an array in the water band that retains high spectral contrast over most observing conditions.

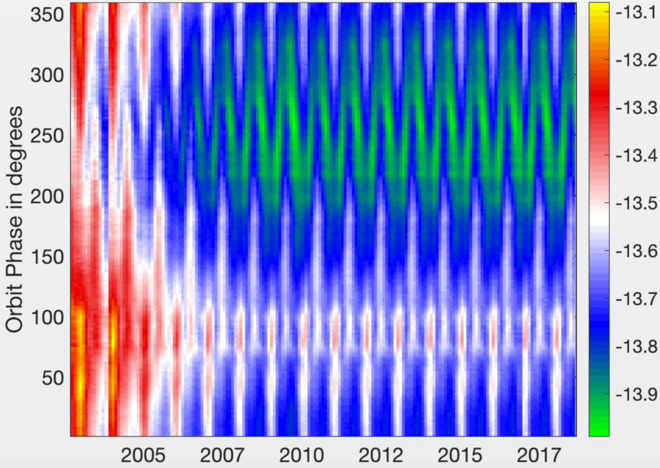
B(T) Sensitivity to Yoffsets

Max B(T) changes over (a) Mission, (b) Daily (orbit phase)



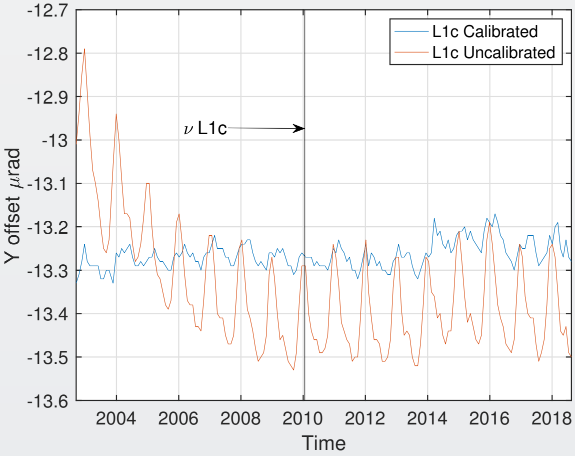
Yoffset is Retrieved from Observations

- yoffset as a function of time and orbit phase

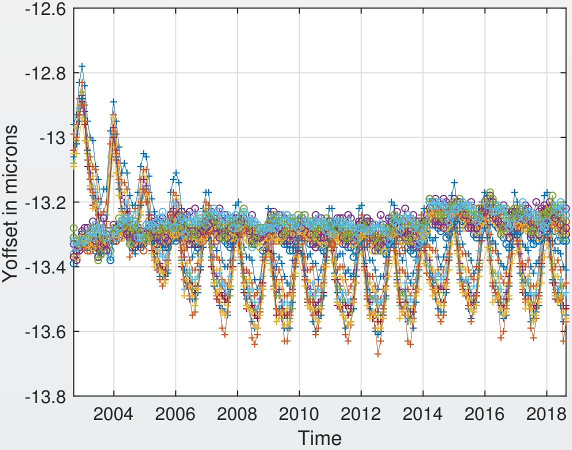


L1c Yoffsets

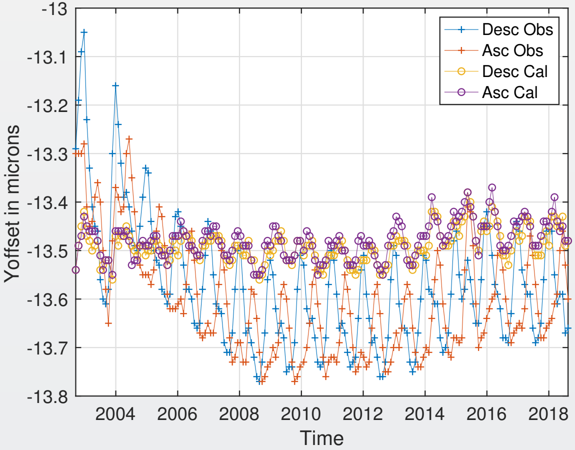
- Descending equator
- Raw L1c (no ν calibration)
- L1c adjusted to new fixed L1c ν grid



M3 Results: Descending, All Latitudes

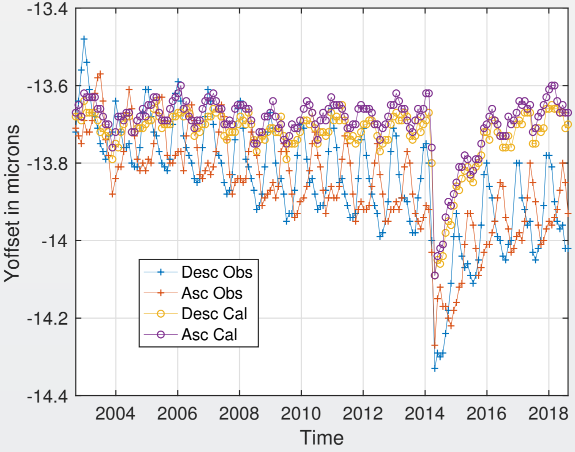


M10 Results



-13
-13.1
-13.2
-13.3
-13.4
-13.5
-13.6
-13.7
-13.8
Yoffset in microns
2004
2006
2008
2010
2012
2014
2016
2018
Time
Desc Obs
Asc Obs
Desc Cal
Asc Cal

M4a Results



-13.4
-13.6
-13.8
-14
-14.2
-14.4
Yoffset in microns
2004
2006
2008
2010
2012
2014
2016
2018
Time
Desc Obs
Asc Obs
Desc Cal
Asc Cal

Doppler Effect

Fractional doppler shift given by:

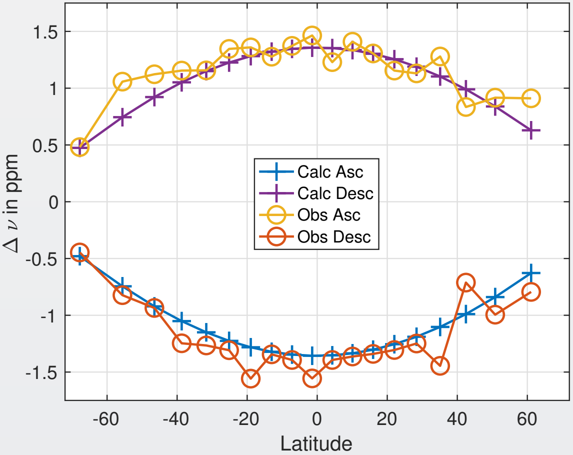
$$\frac{\Omega R_e}{c} \sin(\theta_{zenith}) \cos(lat_{sub}) |sin(\theta_{azimuth})|$$

where, $\Omega = 7.292 \times 10^{-5}$ (earth's rotational velocity, rad/sec)
R_e = 6.3781×10^{8} (earth radius, cm)
c = 2.99792×10^{10} (speed of light, cm/sec)

See Yong Chen et.al., Applied Optics, September 2013

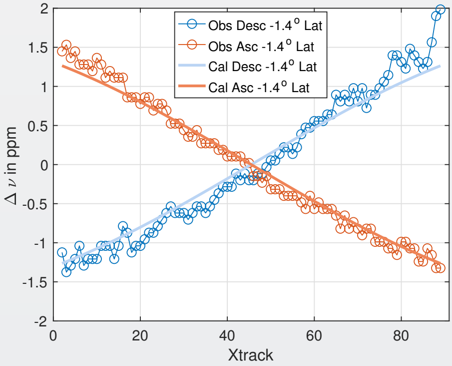
Measurement of AIRS Doppler Shifts versus Latitude (M3)

- Performed using cross-correlation with simulated radiances
- Showing mean shift (xtrack(1:45) - xtrack(46:90))

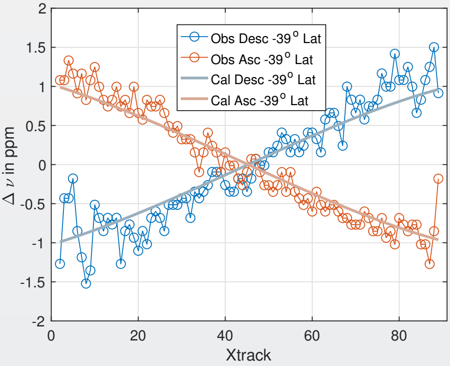


Doppler Shifts versus Cross-Track Index (M3)

-1.4° Latitude

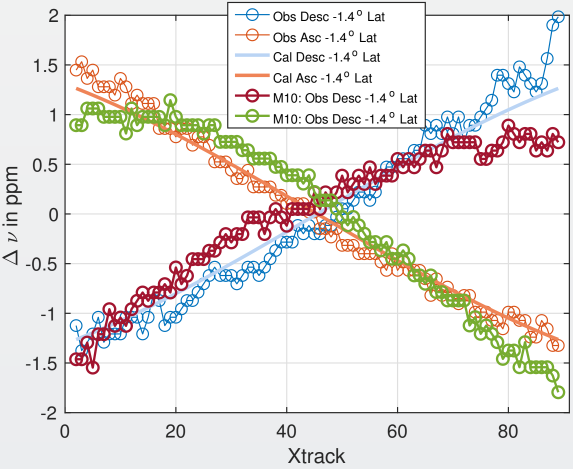


-39° Latitude



Doppler Shifts using M10 versus M3

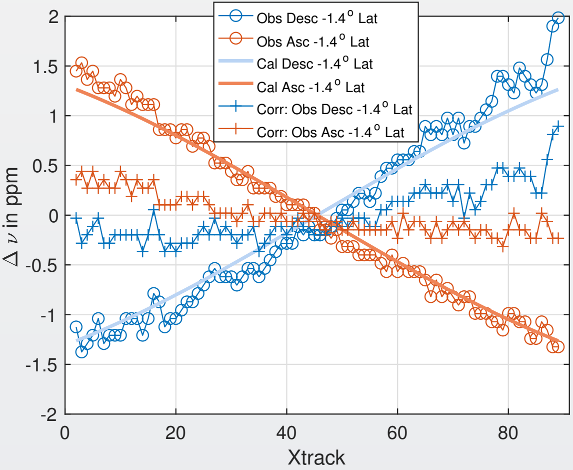
- How similar are Doppler shifts using M10 instead of M3?



- M10 shifts have some curvature, but show same nominal behavior
- Other studies indicate M3 is best for high-quality frequency shifts

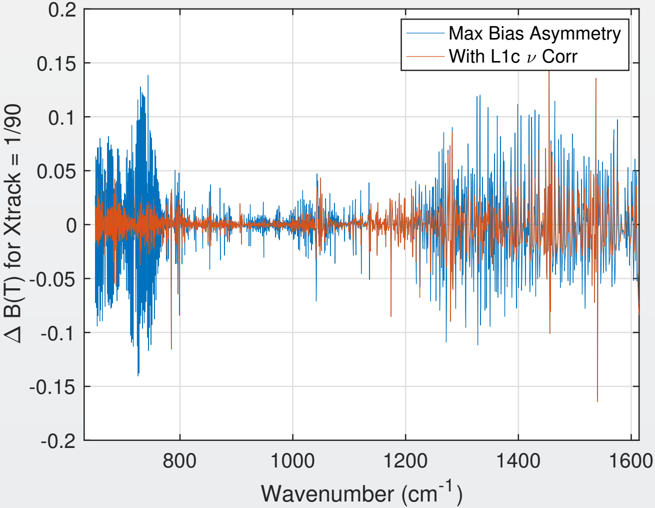
Doppler Shift Closure Exercise

- Apply theoretical Doppler shifts to data and re-measure observed shifts



- Reasonably good closure achieved

Subtract Ascending from Descending for Full Range

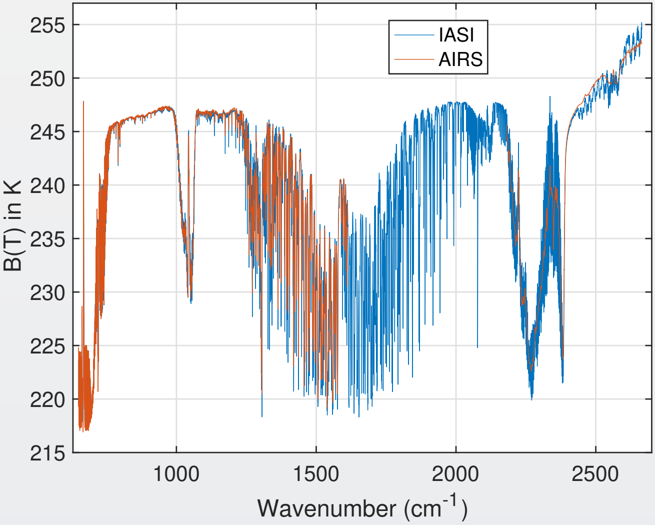


- This is ±45° latitude average
- Hash phases different for corrected L1c than un-corrected (see zooms)

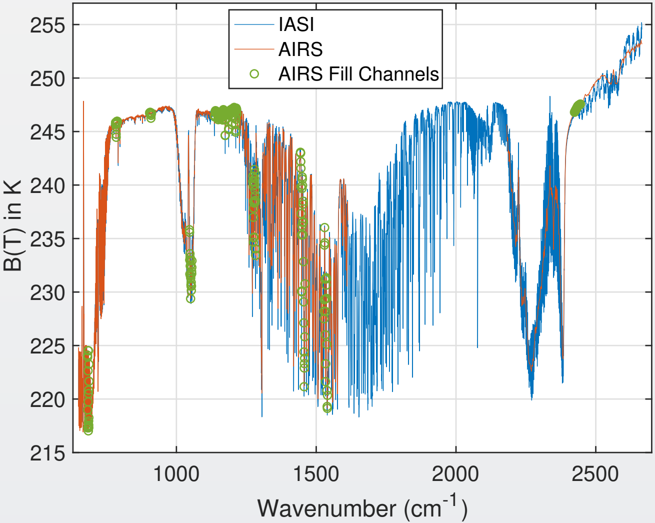
Validation of L1c Fill Channels

- Use IASI and AIRS SNOs
- Convert IASI to the AIRS ILS
- Compare IASI2AIRS radiances to AIRS L1c

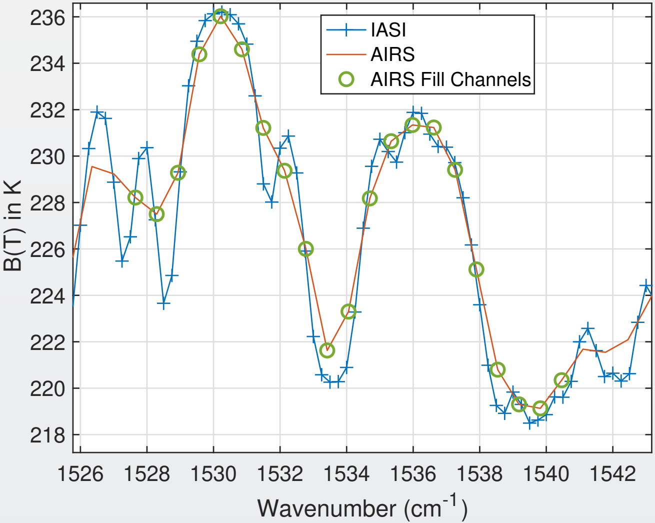
Native Resolution Spectra



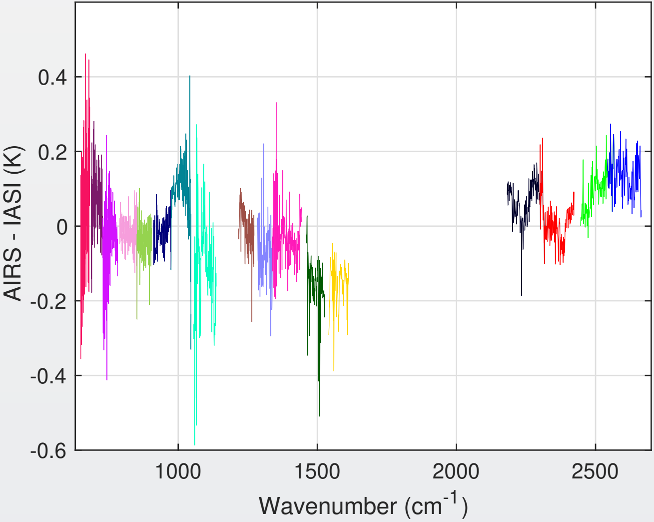
Native Resolution Spectra with Fill Channels Marked



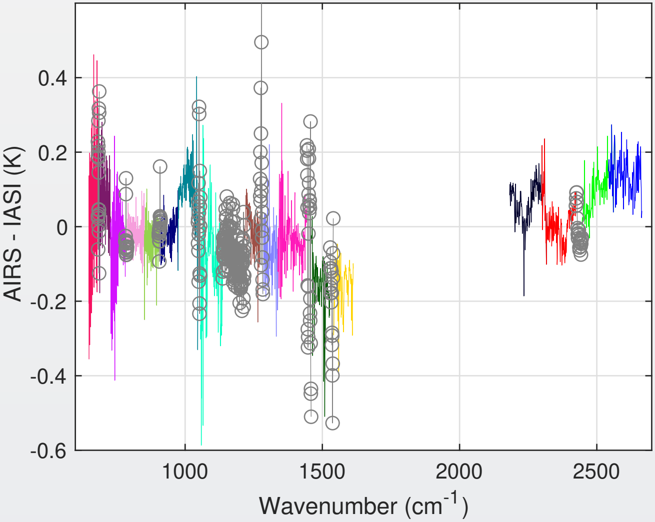
Zoom in Midwave



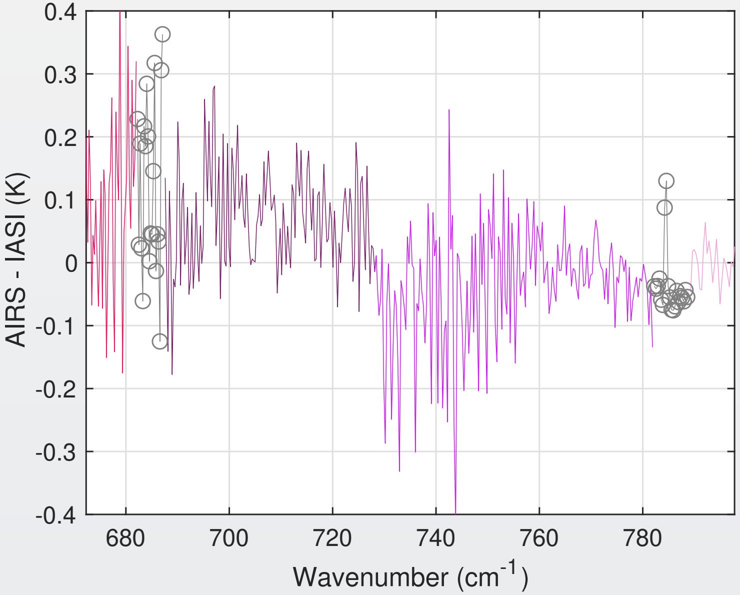
Now Convert IASI to AIRS ILS and Compare



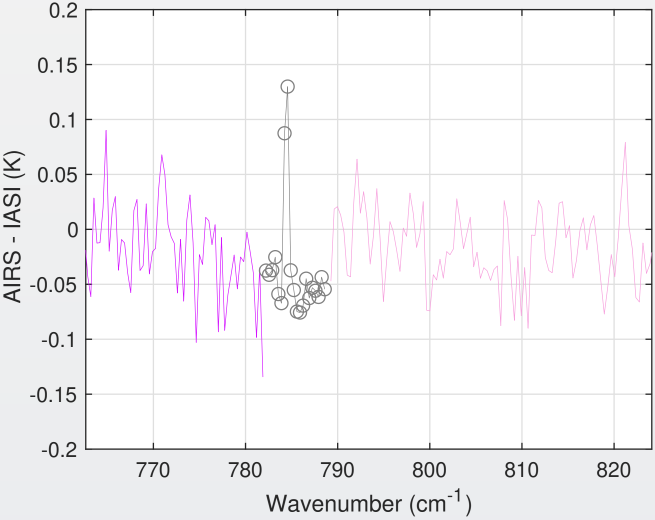
Now Convert IASI to AIRS ILS and Compare with Fill Channels



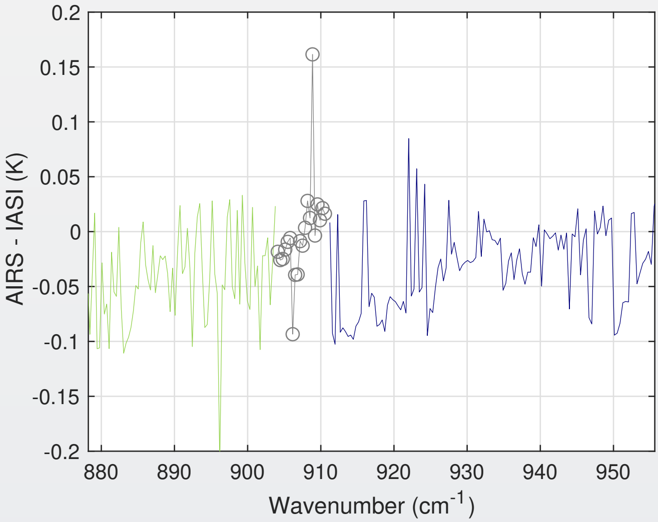
Zooms of AIRS - IASI



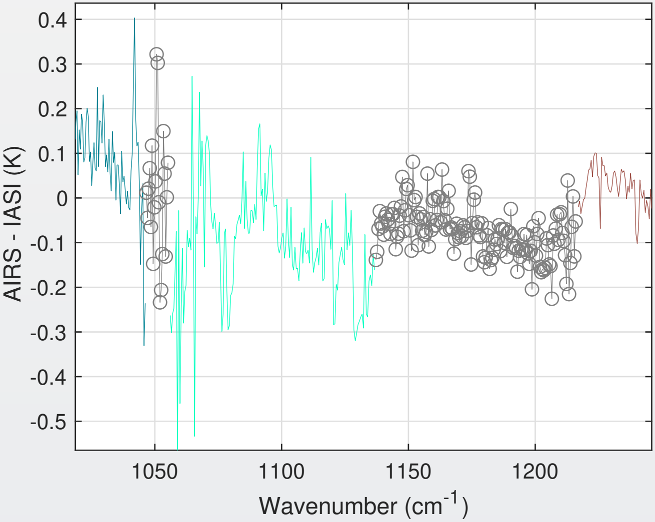
Zooms of AIRS - IASI



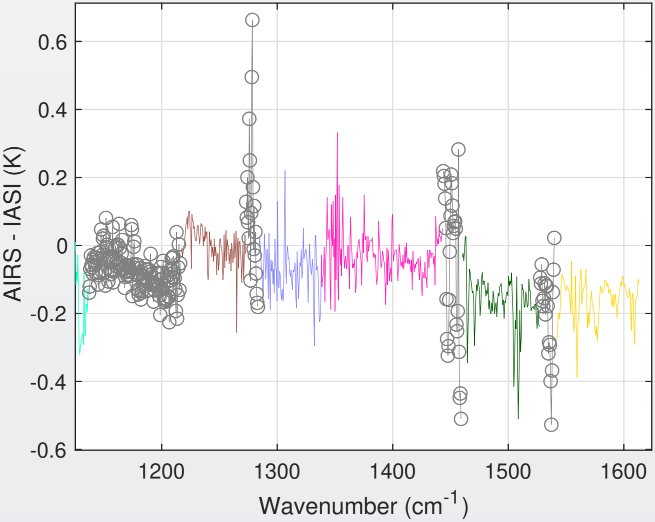
Zooms of AIRS - IASI



Zooms of AIRS - IASI



Zooms of AIRS - IASI



Conclusions

- AIRS instrument frequency drifts largely eliminated in L1c
- Some short-term problems in a few arrays after March 2014
- Doppler effects largely removed
- L1c fill channels radiances quite good!, sufficient for CHIRP
- Except in mid-wave water, where some improvements might be nice

User Visible Changes

- New AIRS frequency scale!
- 2650 channels
- Retrievals need a new RTA
    - New L1c RTA exists
    - See talk by Chris Hepplewhite