Observations of CrIS and IASI noise and ECMWF model Covariances

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NWP Centers: CrIS Covariance Higher than IASI

Derive CrIS Noise Covariance

- Using 1 day of ICT data, derive noise error covariance

Mimic?? NWP (Noise+Model) Error Covariance

- Match ECMWF analysis/forecast to IASI, CrIS clear scenes
- Convert IASI observations (different noise) to CrIS
- Compare bias error covariances
- Try to convert CrIS error covariance to (IASI -> CrIS) error covariance and compare

- Day: Jan 18, 2016
- SDR Code: CCAST standard

NWP Data Assimilation

Data assimilation ingests the observations y and minimizes a cost function J

$$J = (x - x_b)^T B_x^{-1} (x - x_b) + (y - K(x))^T (E + F)^{-1} (y - K(x))$$

in order to find the best analysis increment to the model background $x - x_b$.

B_x: Background error covariance

K: CrIS RTA

$E + F = R$: Observation error covariance (often diagonal)

E: Instrument error covariance

F: Representativeness, nonlinearity, RTA covariances

NPW centers are finding R is larger for CrIS than IASI. *But* this is generally presented as correlations rather than covariances.

Present Status

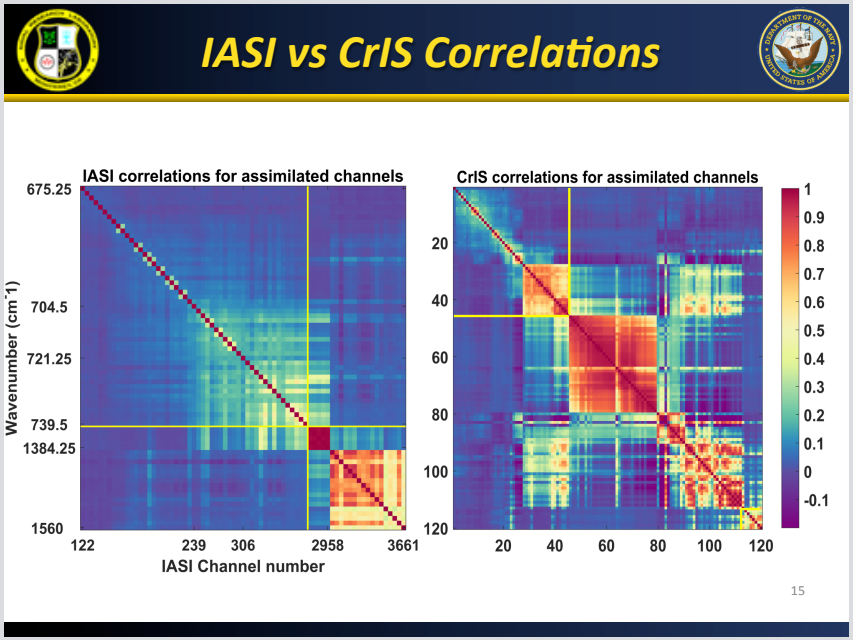
- A diagonal R was/is the norm in the past.
- Many centers working towards off-diagonal R
- This should lead to better use of sounder data, using lower error estimates.
- If practical, I hope this then leads to using more channels, esp. for CrIS which has low noise, but slightly wider Jacobians

Recent Relevant Journal Articles

- *Effect of self-apodization correction on Cross-track Infrared Sounder radiance noise*, Han et. al. (Applied Optics, 2015)
- *Infrared atmospheric sounder interferometer radiometric noise assessment from spectral residuals*, Carmine Serio et. al. (Applied Optics 2015)
- *Enhancing the impact of IASI observations through an updated observation-error covariance matrix*, Niels Bormann etc. al (QJRMS 2016)

NWP "Correlation" Observations for CrIS, IASI

NRL CrIS/IASI Error Correlation



ECMWF IASI Error Correlation

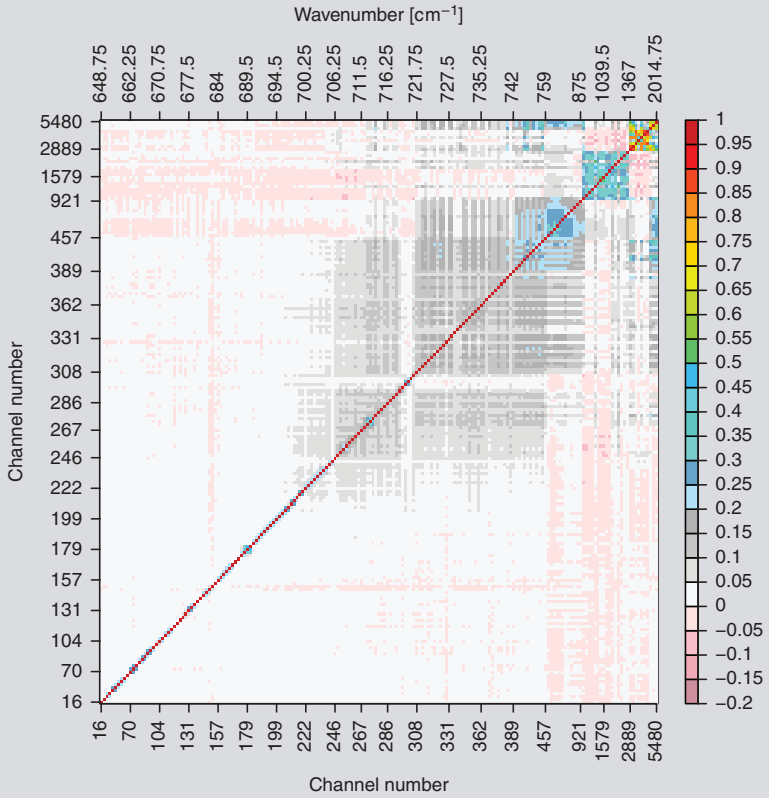


Figure 3. Observation-error correlations used in this study for assimilated IASI channels. See main text and Appendix A for further details.

Noise Correlation

- Following Han et. al., reproduce noise figures
- Expand from 512 points to 1-day (either Jan 18 or 20, 2016)
- Do SVD analysis to determine correlated noise, about 1-2% for Hamming (see Additional Material at end of talk)
- Effect of hamming on covariance and correlation matrices

Keep in mind:

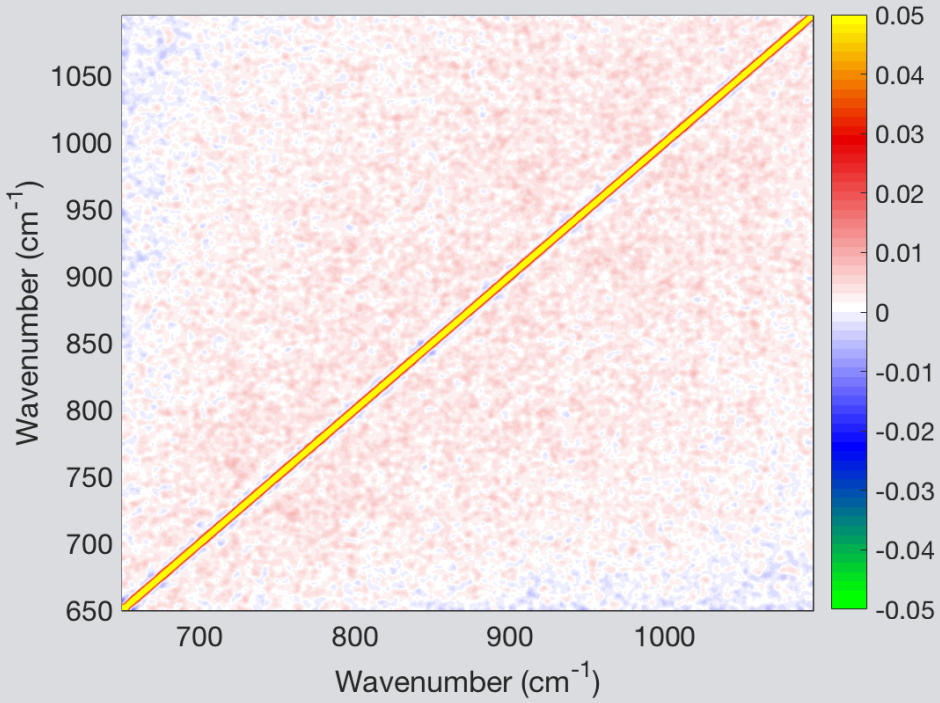
- noise = $\sqrt{(}cov_{i,i})$
- $corr_{i,j} = \frac{cov_{i,j}}{\sqrt{(}cov_{i,i} \cdot cov_{j,j})}$
- CrIS has lower noise than IASI
- CrIS Hamming has lower noise than Sinc

Noise Correlation Data Analysis

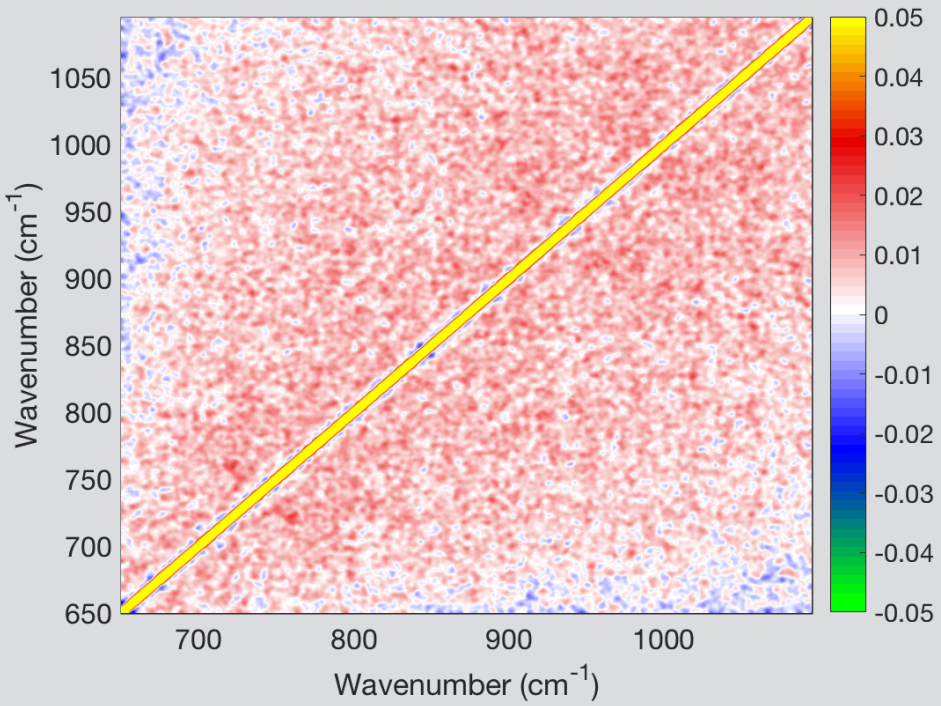
- One day of ICT (blackbody) calibrated data.
- Just substitude ICT_i into SDR equation instead of ES_i
- Remove resulting slow variation in ICT B(T) with a 31-point moving average smoother
- For SVD correlated noise analysis divide by nominal noise

LongWave Noise Correlations

Sinc Noise Correlation



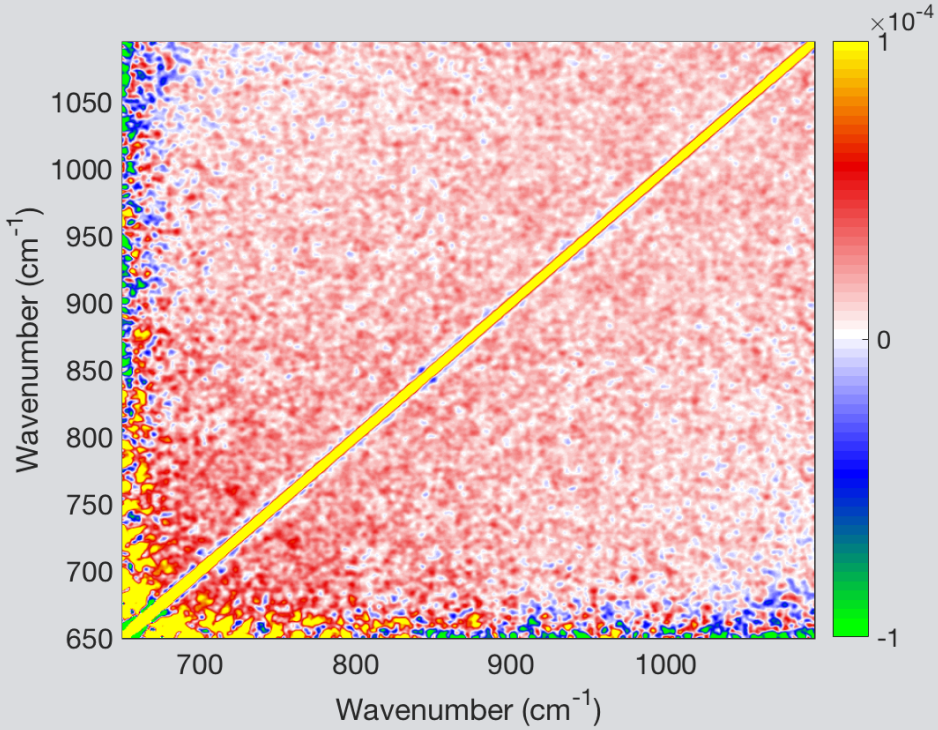
Hamming Noise Correlation



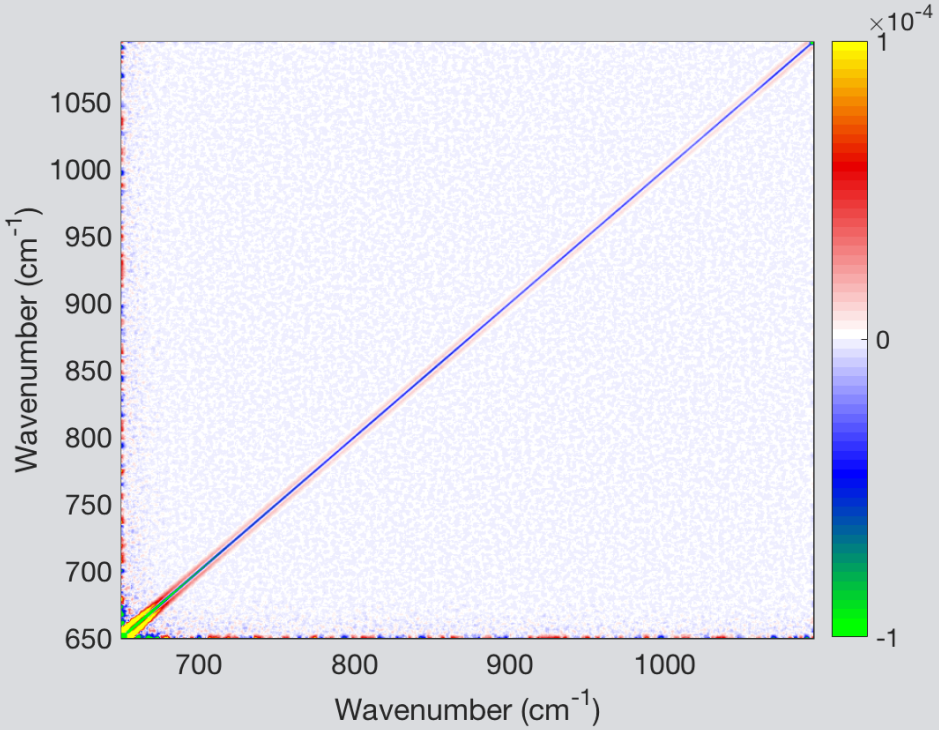
These smoothed correlation matrices suggest off-diagonal correlated noise at the 2% level. Higher for hamming.

LongWave Noise Covariance

Sinc (or Hamming) Noise Covariance



Hamming - Sinc Covariance

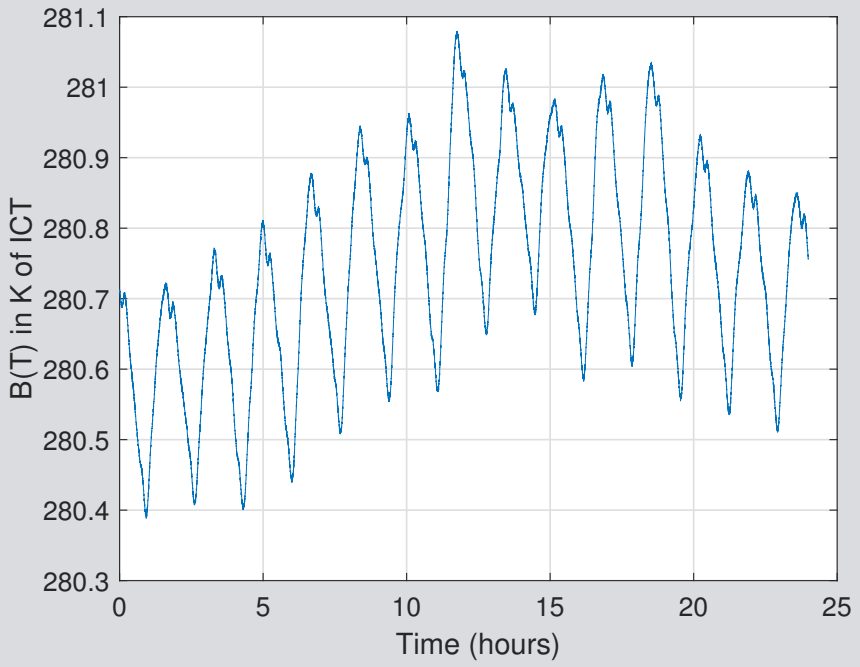


No difference between Sinc and Hamming off-diagonals!
Lower Hamming noise increases off-diagonal correlations.

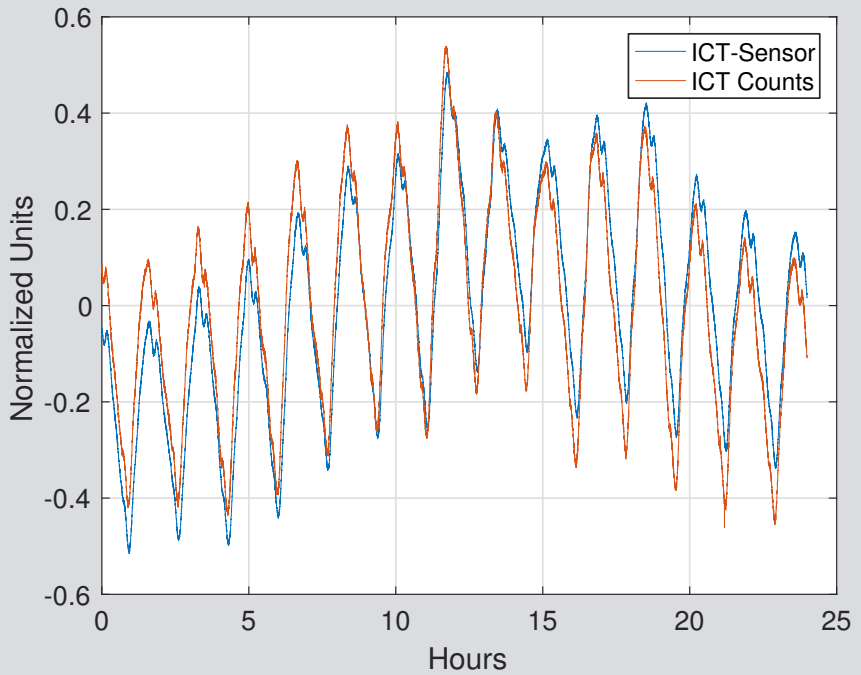
Other Sources of Correlation?

- ICT environmental model? (in longwave ± -0.04 to -0.01K)
- ICT calibration variability, esp. over orbit?
- **Small** orbital calibration errors *could* produce these correlations; TVAC results (day in the life?)
- IASI blackbody has a constant temperature

ICT Calibrated Temperature vs Time



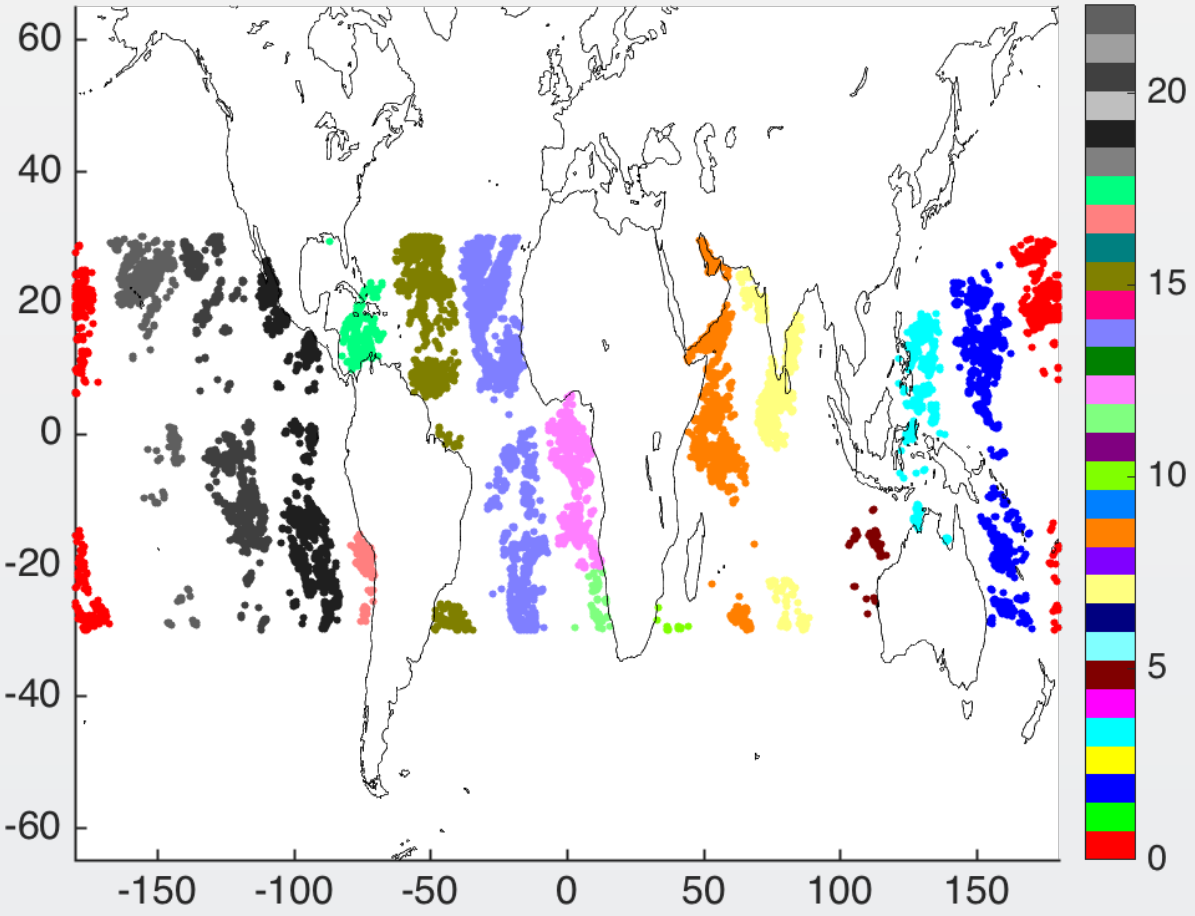
Scaled ICT T-sensor vs (ICT-SP) Counts



Bias Correlation Data Analysis

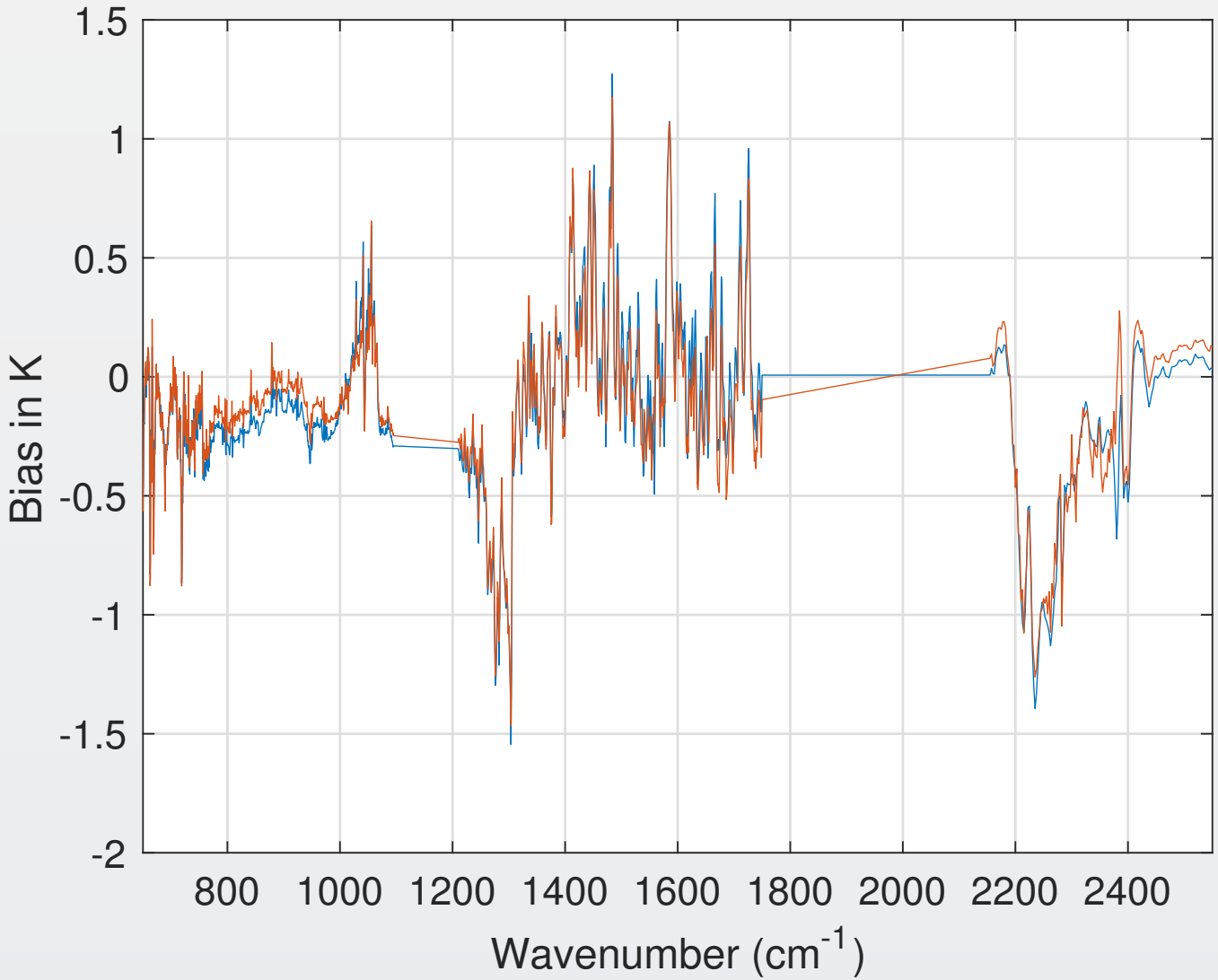
- Clear ocean scenes, tropical to keep F smaller
- Convert IASI to CrIS ILS "IASI->CrIS"
- Modify CrIS to have "IASI->CrIS" noise
- Concentrate on 650-750 cm^{-1}
- F covariance clearly dominates rest of LW and MW (SST, water vapor)
- ??? Our F is *larger* than NWP and mixes background and observation errors, and has no integration of the model to the observation time, etc etc. We are using ECMWF 3-hour forecast/analysis
- ??? Consequently, our results are, at most, only useful for relative comparisons

Clear Scene Locations for CrIS



Color is hour.

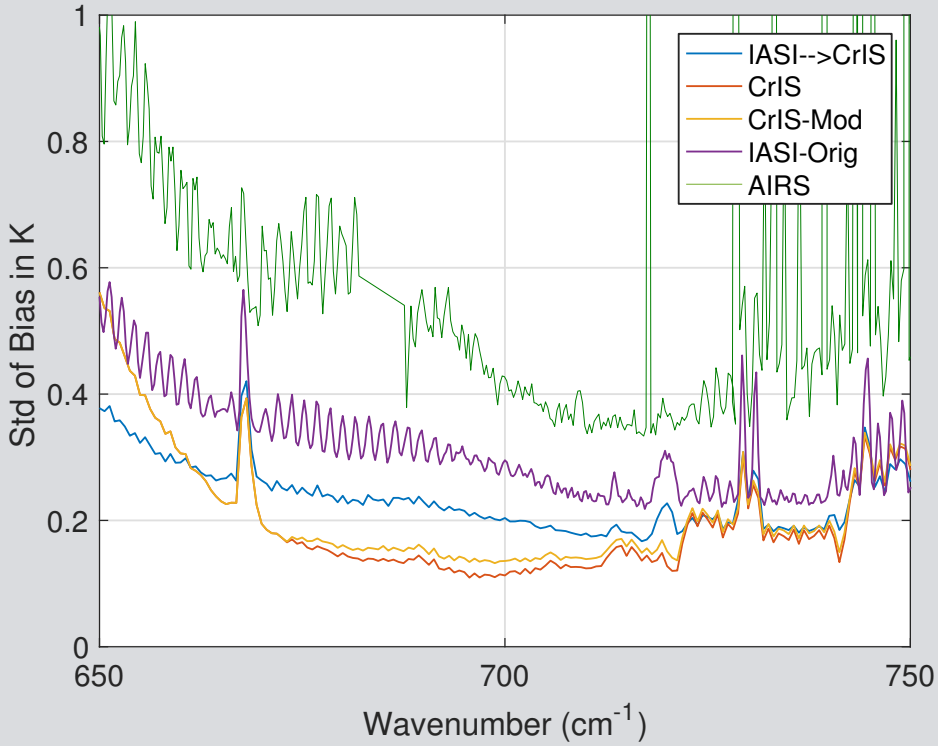
CrIS and IASI Clear Biases



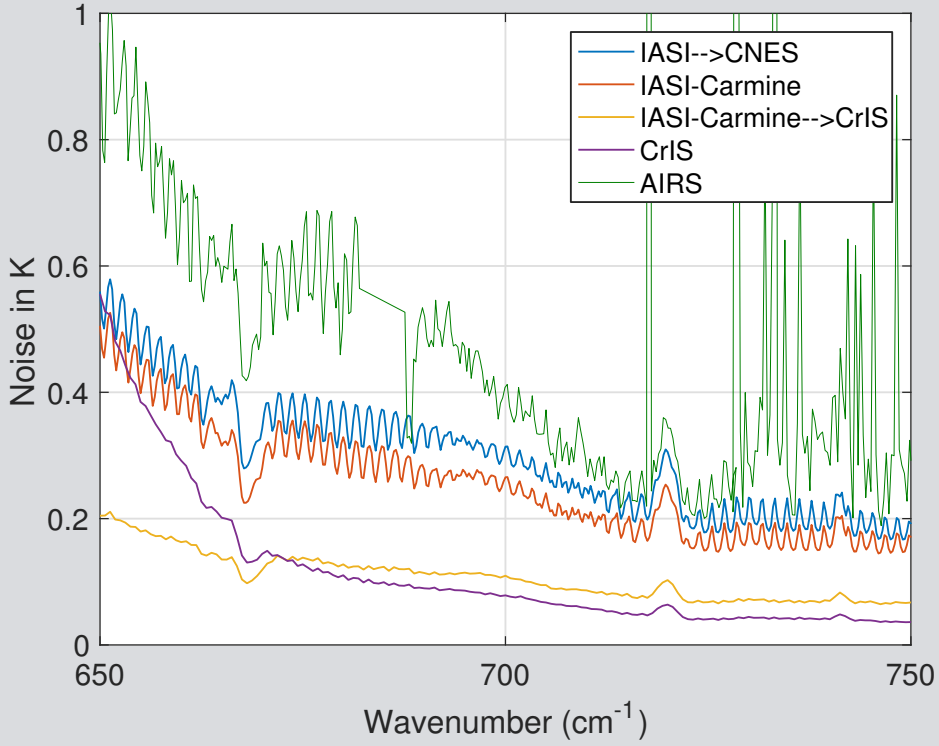
Night is similar, IASI 0.2K warmer in window region.

Bias Std and Noise

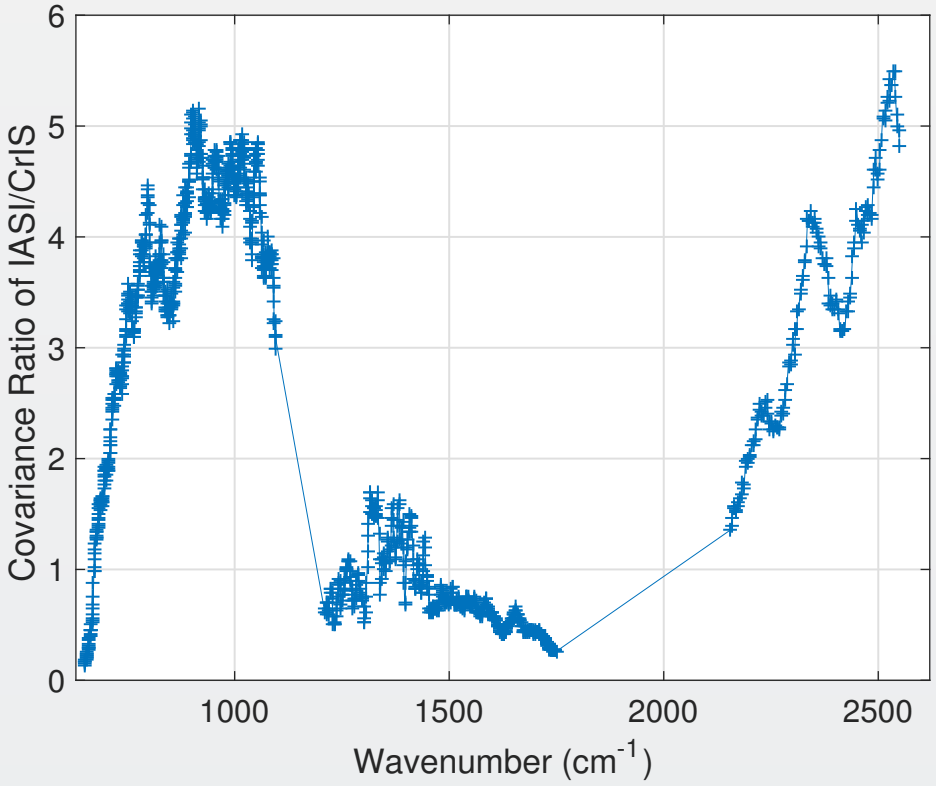
Bias Std

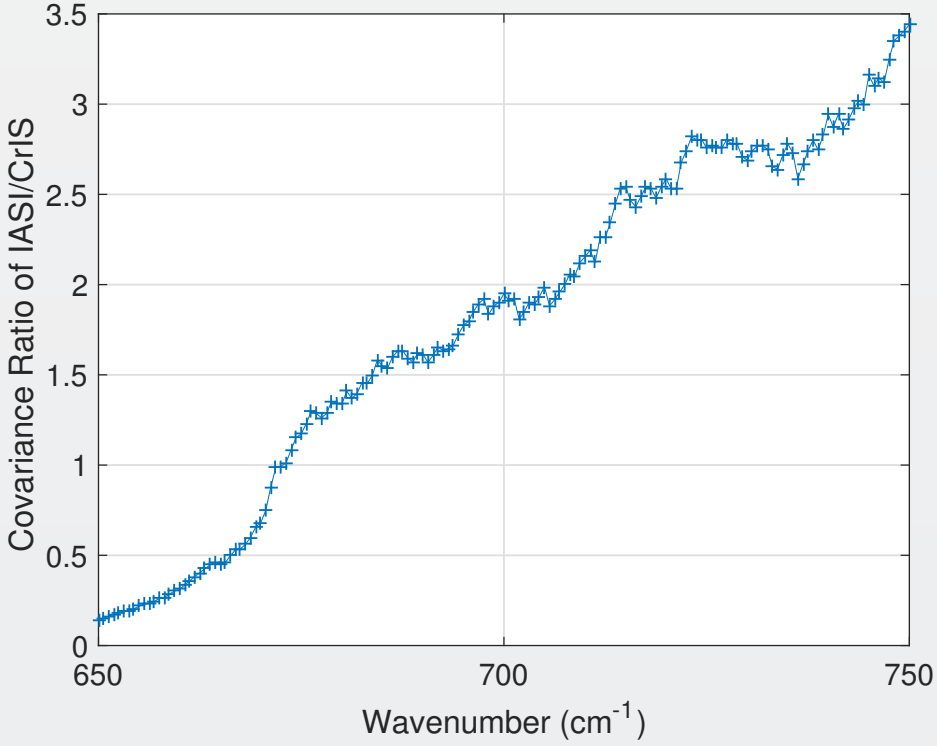


Noise



Covariance Ratios (IASI/CrIS)



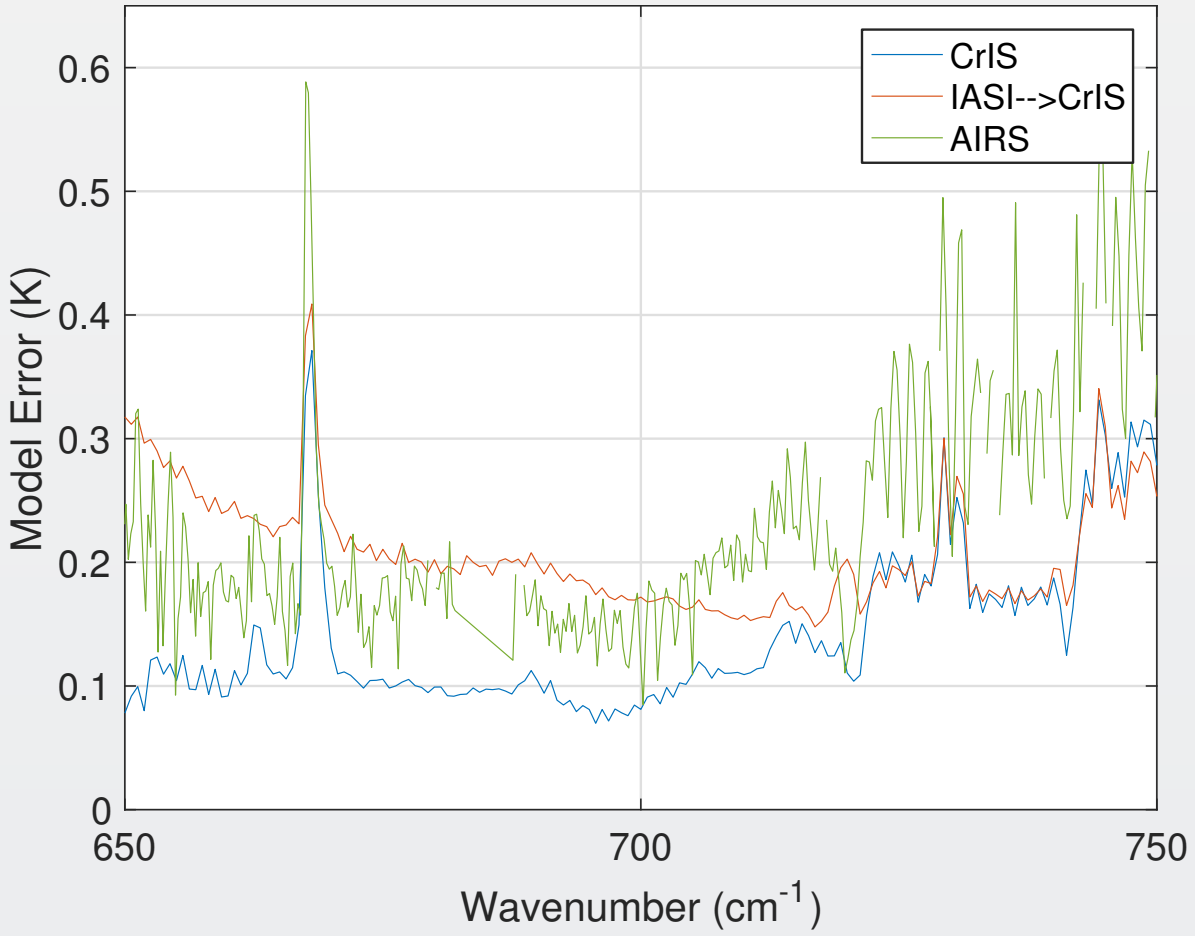


F covariances (Representativeness, RTA, etc.) constant between instruments

E covariances scale with instrument noise

Low noise implies higher off-diagonal correlations

Effective Model Error

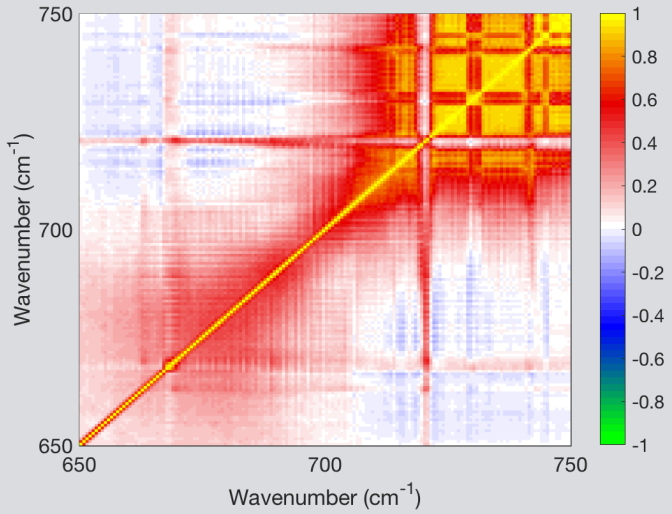


IASI model error up to 3X larger than CrIS??

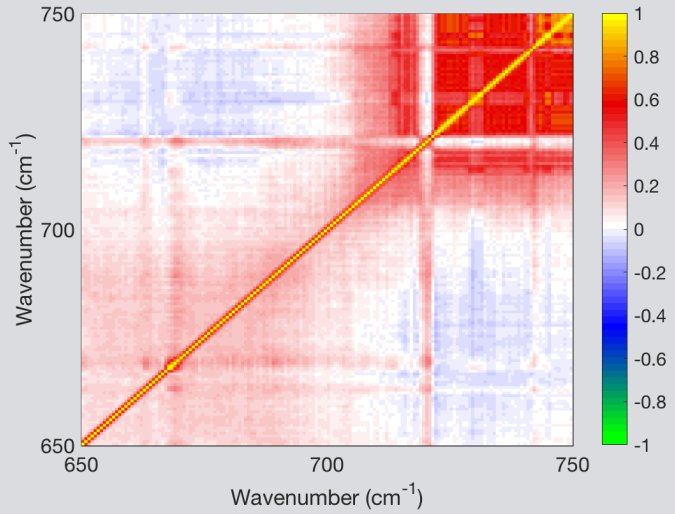
$F = \sqrt{(std^2 - inoise^2)}$

CrIS vs IASI Correlations

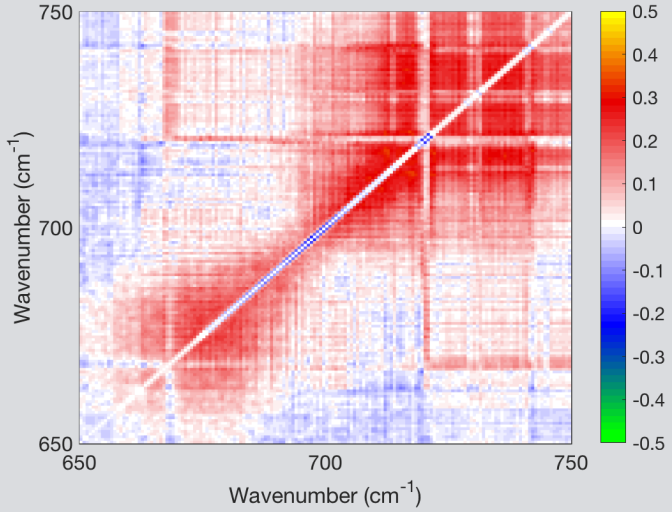
CrIS



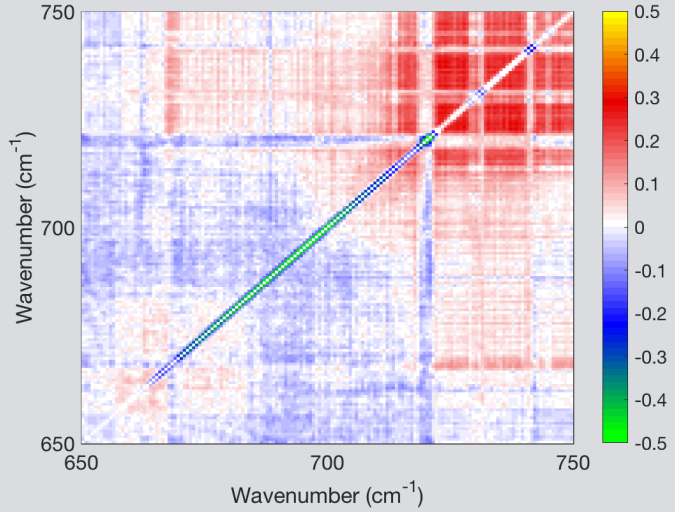
IASI



(CrIS + IASI Noise) - IASI

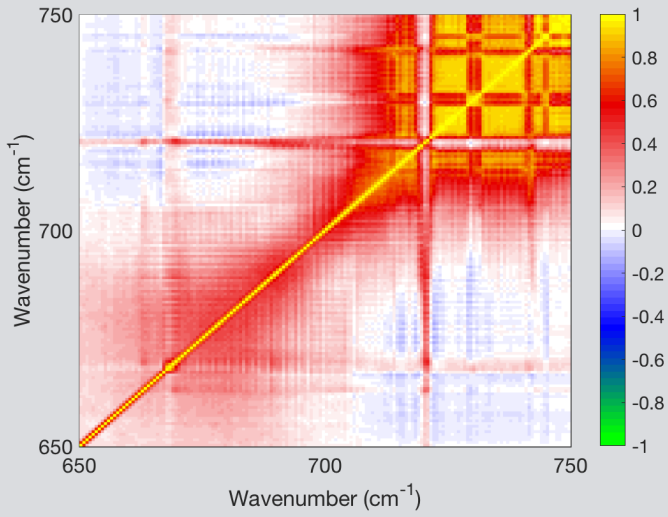


(CrIS + IASI Std) - IASI

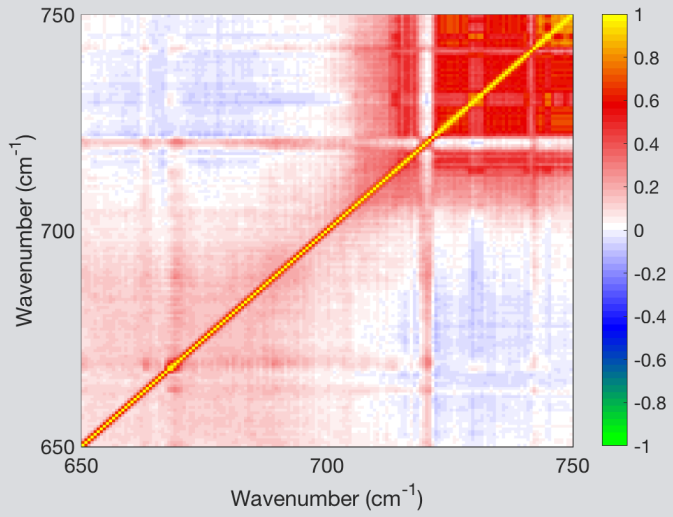


Day vs Night Correlations

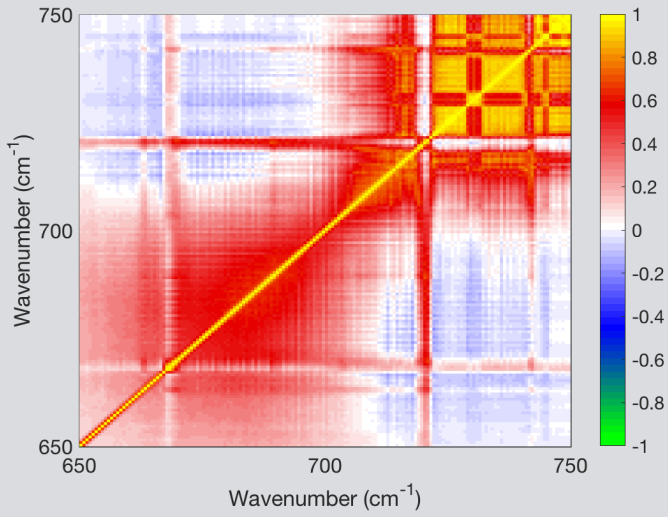
CrIS Night



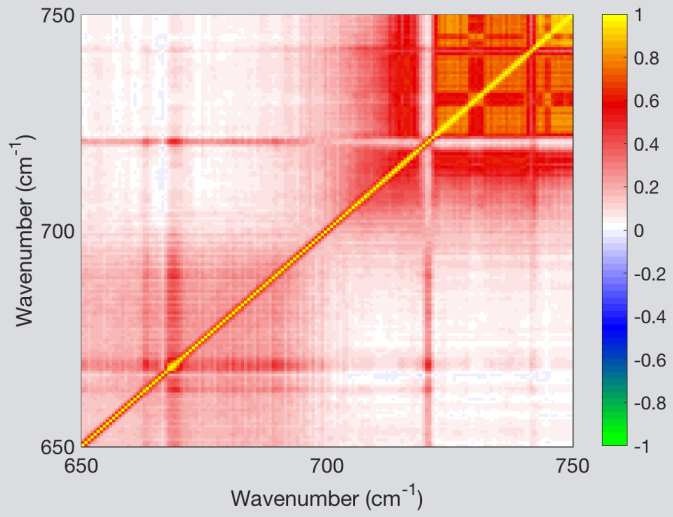
IASI Night



CrIS Day

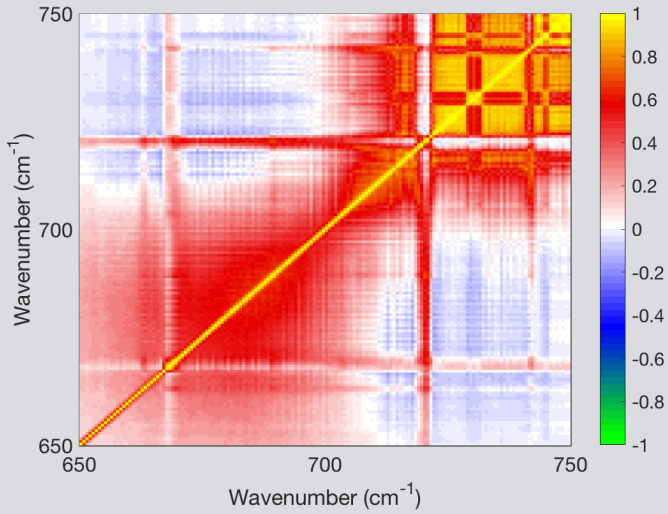


IASI Day

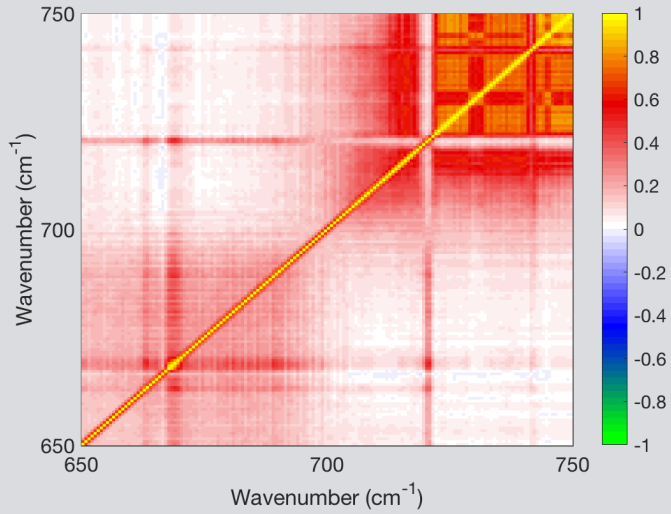


Corrected Day Correlations

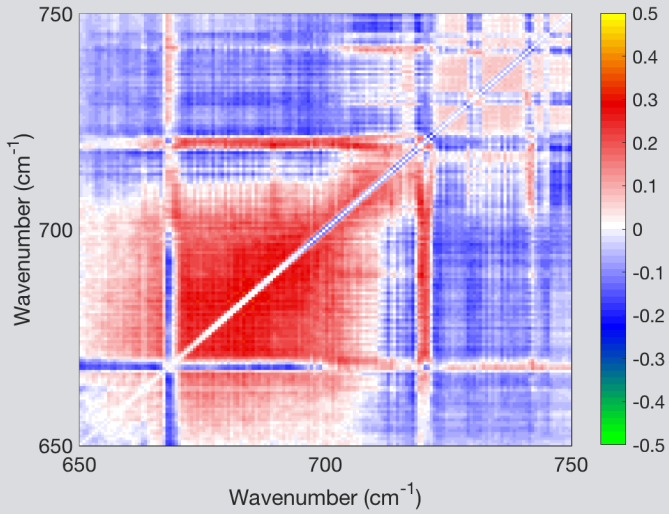
CrIS



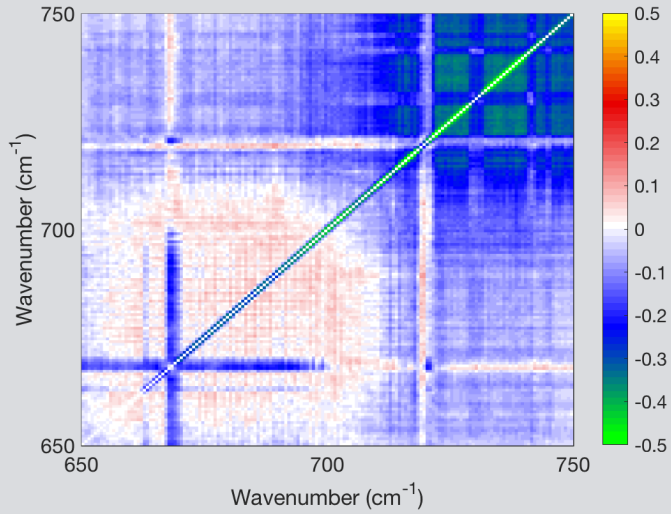
IASI



(CrIS + IASI Noise) - IASI

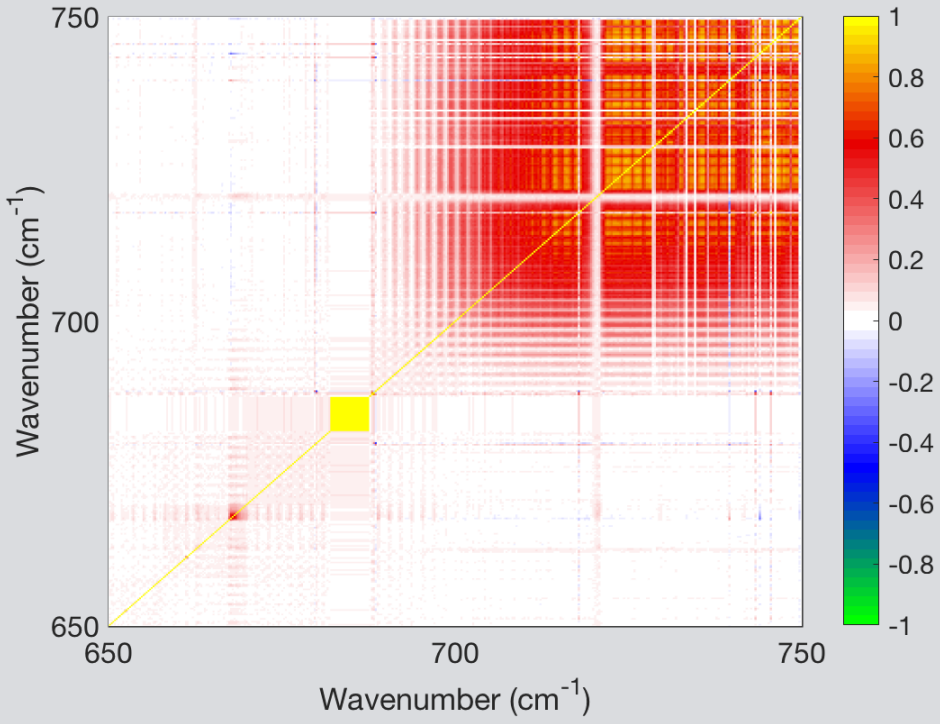


(CrIS + IASI Std) - IASI

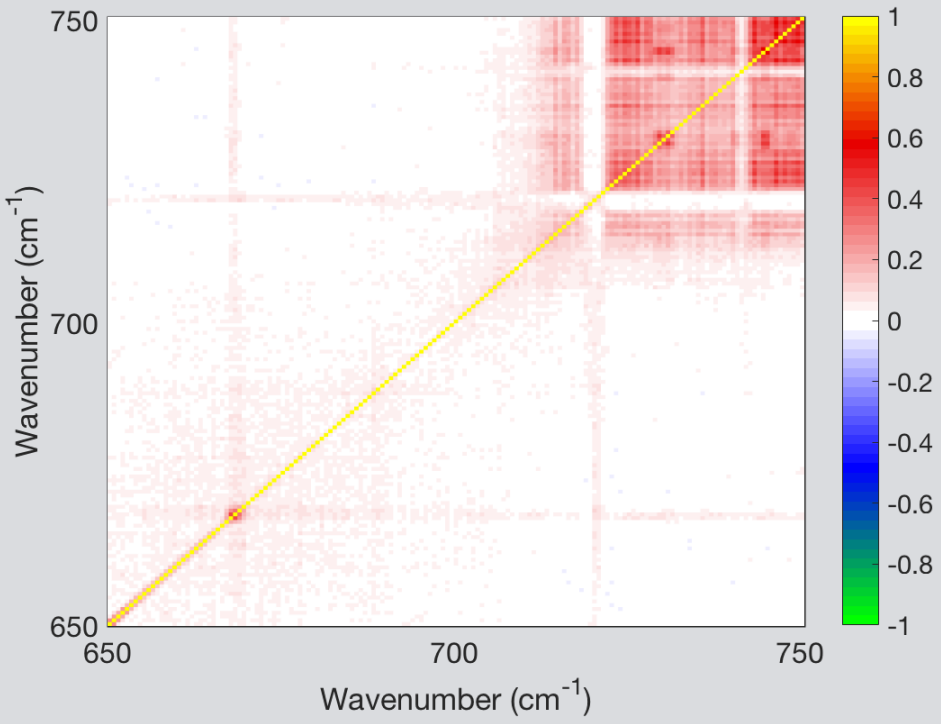


AIRS vs CrIS Covariances

AIRS Correlations

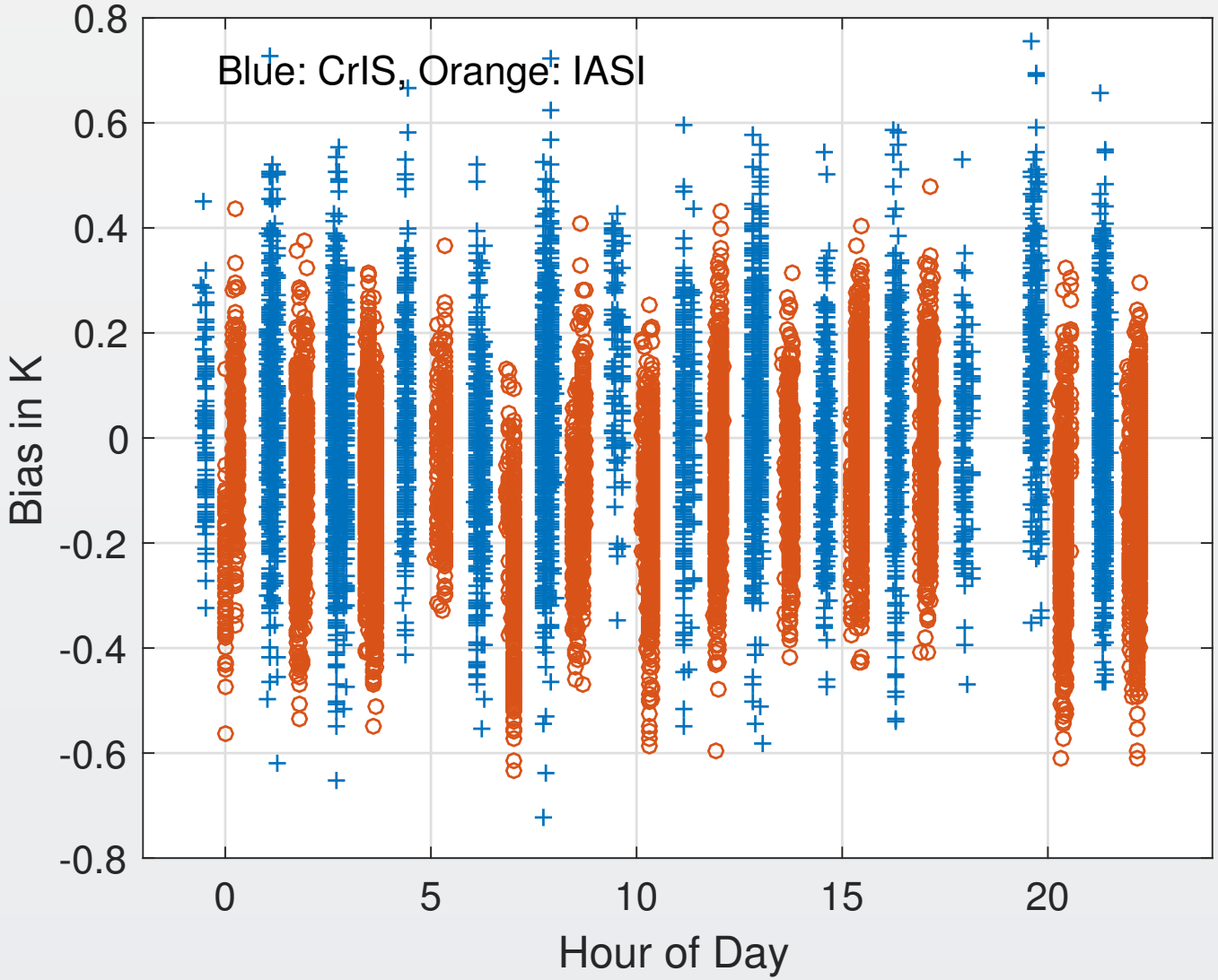


CrIS Converted to AIRS noise

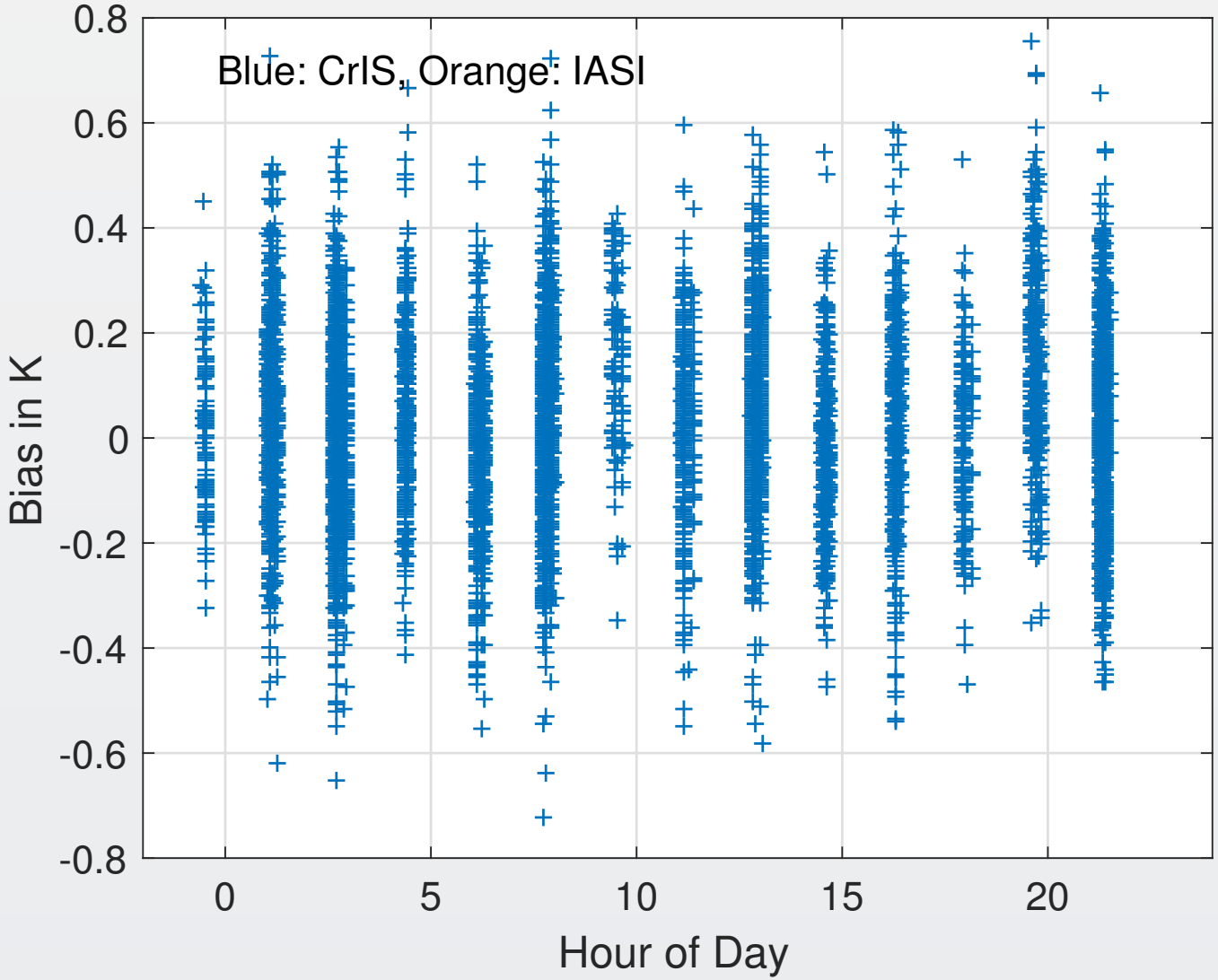


Suggests that there are no detectable problems with CrIS channel correlations, relative to AIRS.

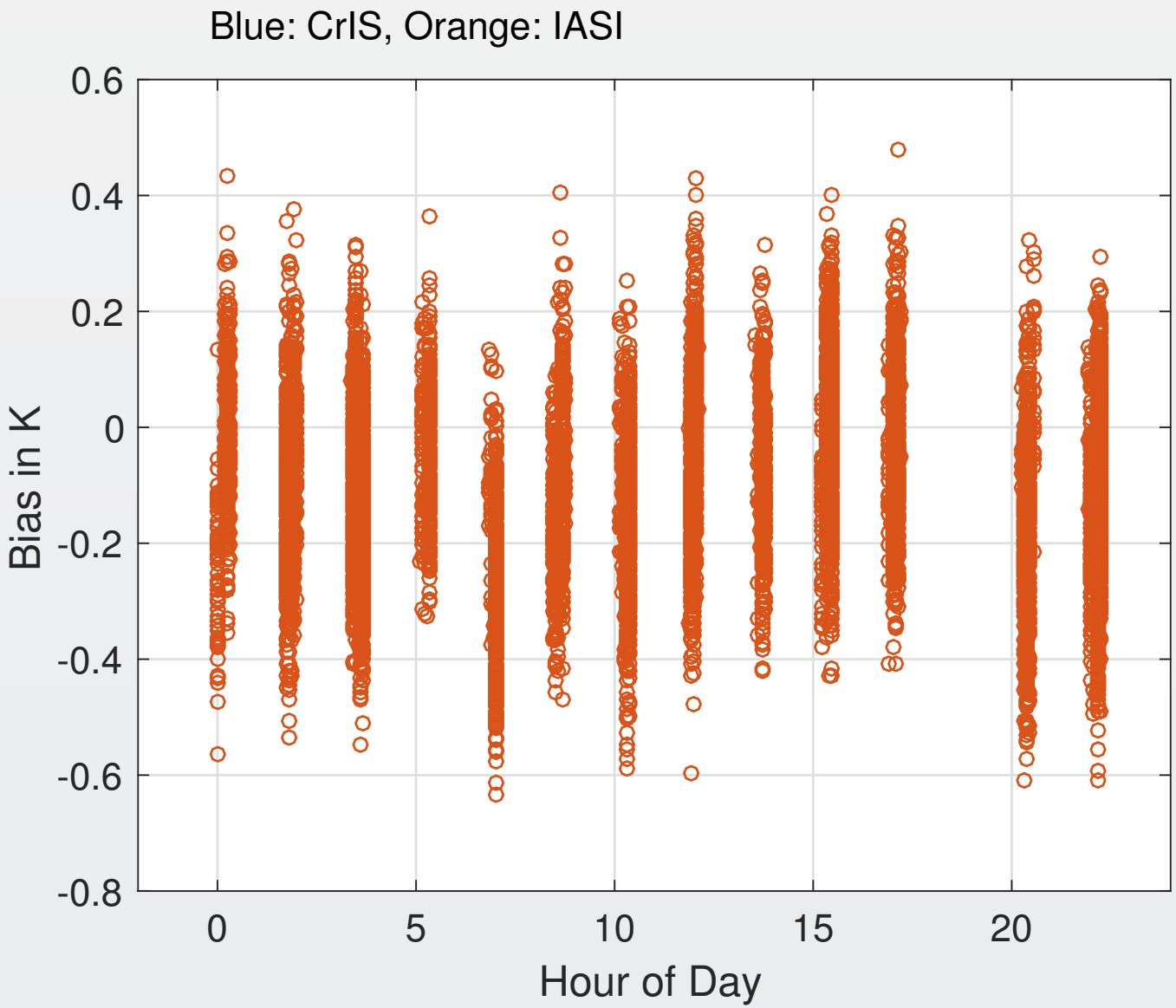
Problem with LongWave IASI Biases?



Problem with LongWave IASI Biases?



Problem with LongWave IASI Biases?



Conclusions

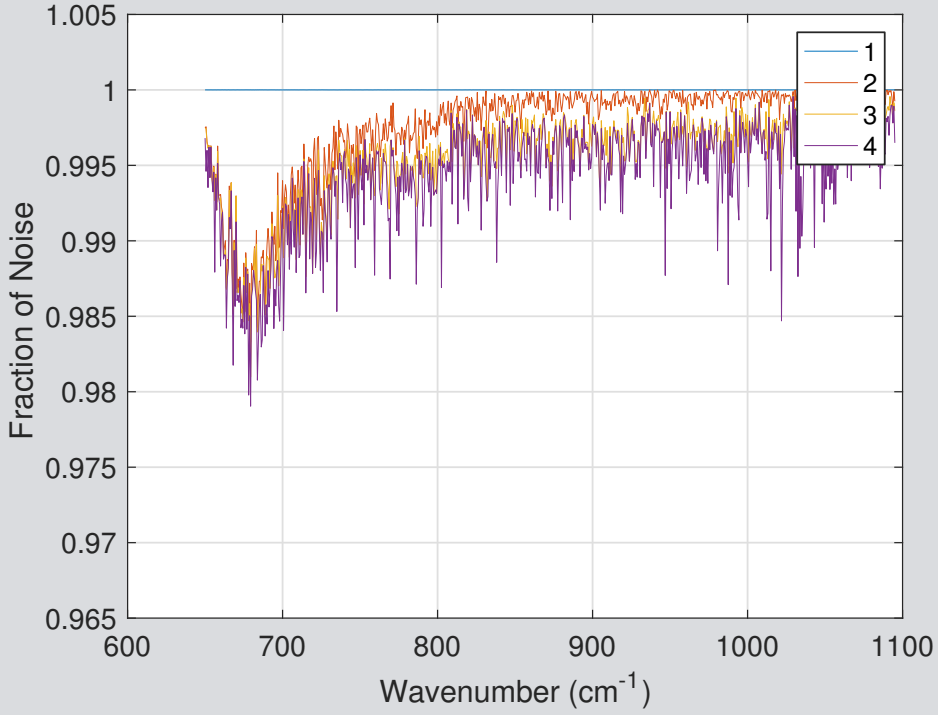
- How can NWP utilize low noise of CrIS?
- Could CO_2 be the cause of some of these correlations? Rd-do analysis in Spring when N/S gradient exists.
- If NWP includes observation covariances, can they now increase the number of channels used?
- CrIS channels *may* have slightly higher correlations than IASI, but maybe due to other IASI issues?
- IASI calibration appears to vary slightly with some orbits?
- JPSS-1 CrIS will have a better blackbody, will that change these observations?
- Exactly how well does the CrIS ICT temperature match the ICT emission over time? What can TVAC tell us?
- AIRS correlations larger than equivalent CrIS in the 725-750 cm^{-1} region

Additional Material

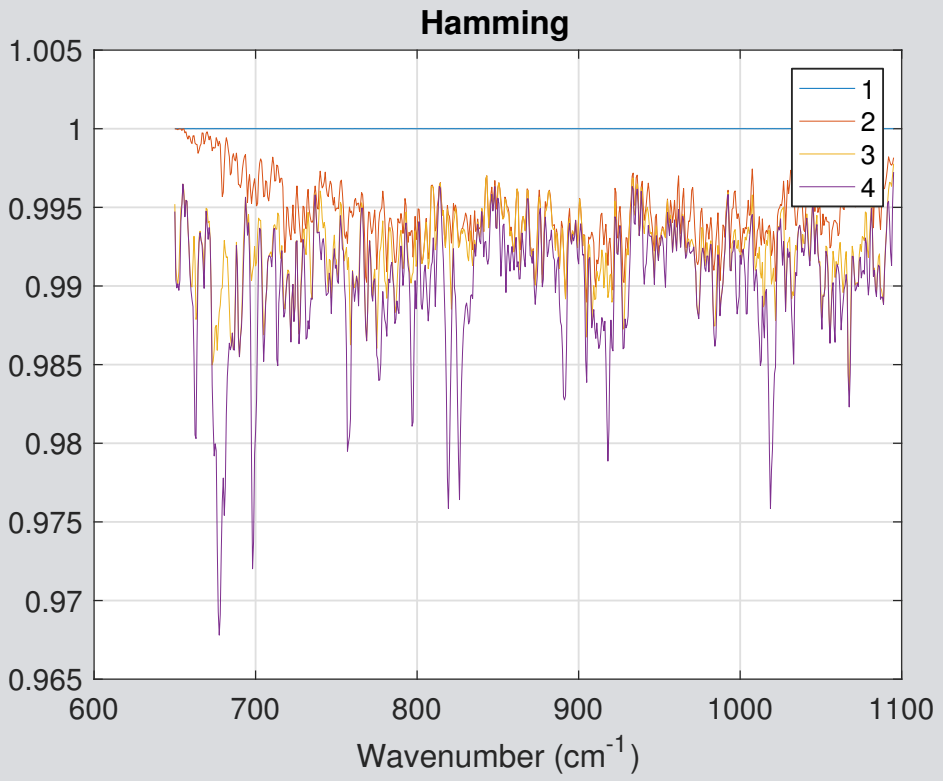
SVD analysis of CrIS correlated noise is shown on the next three slides.

LongWave Noise Correlations

Sinc

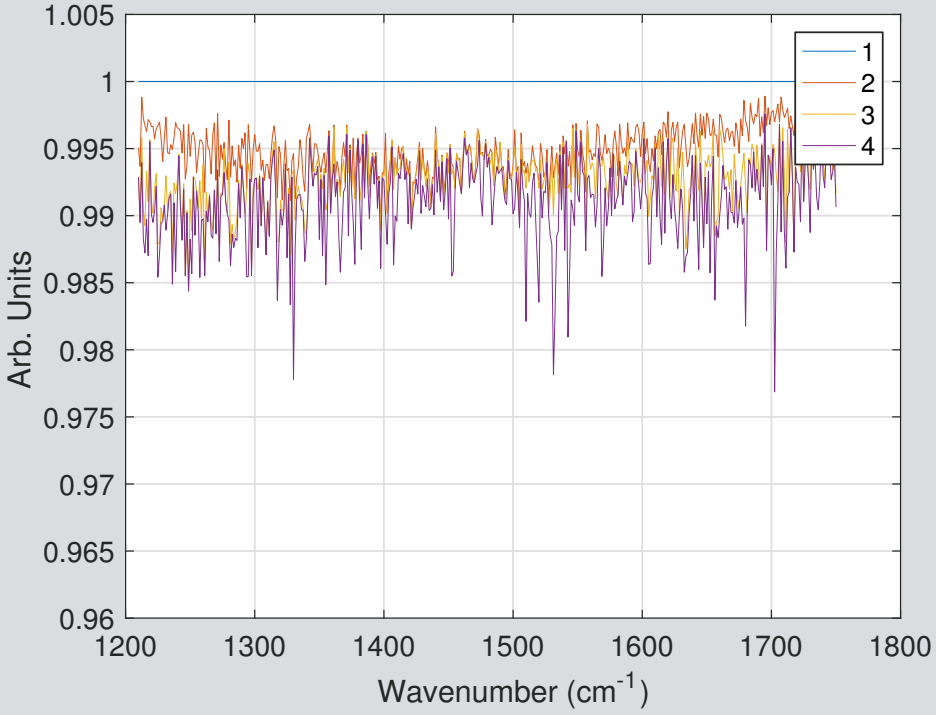


Hamming

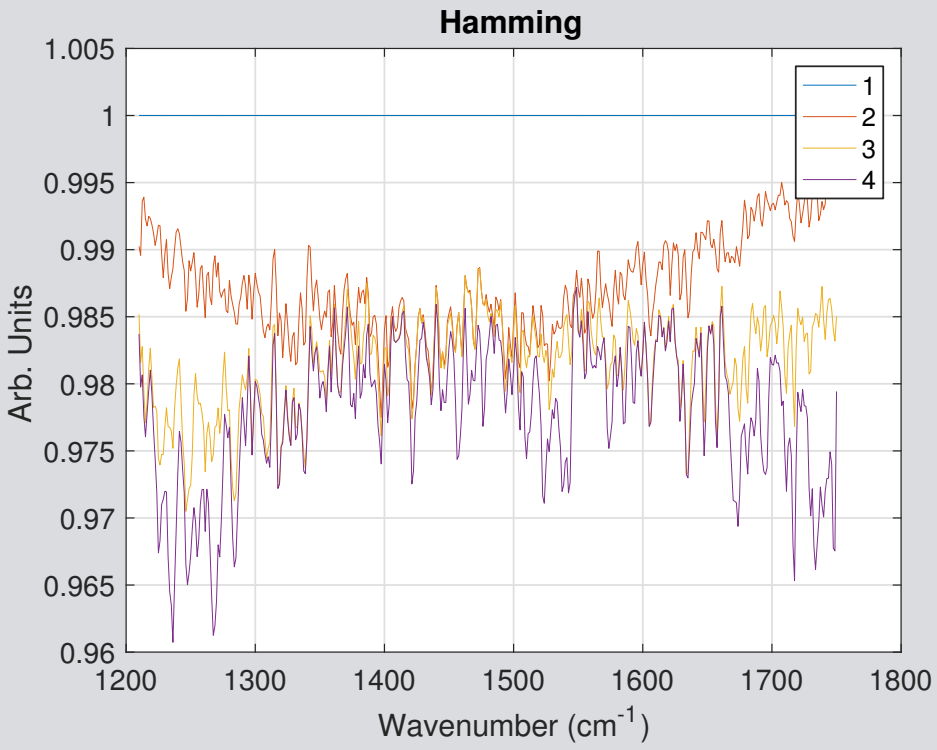


MidWave Noise Correlations

Sinc

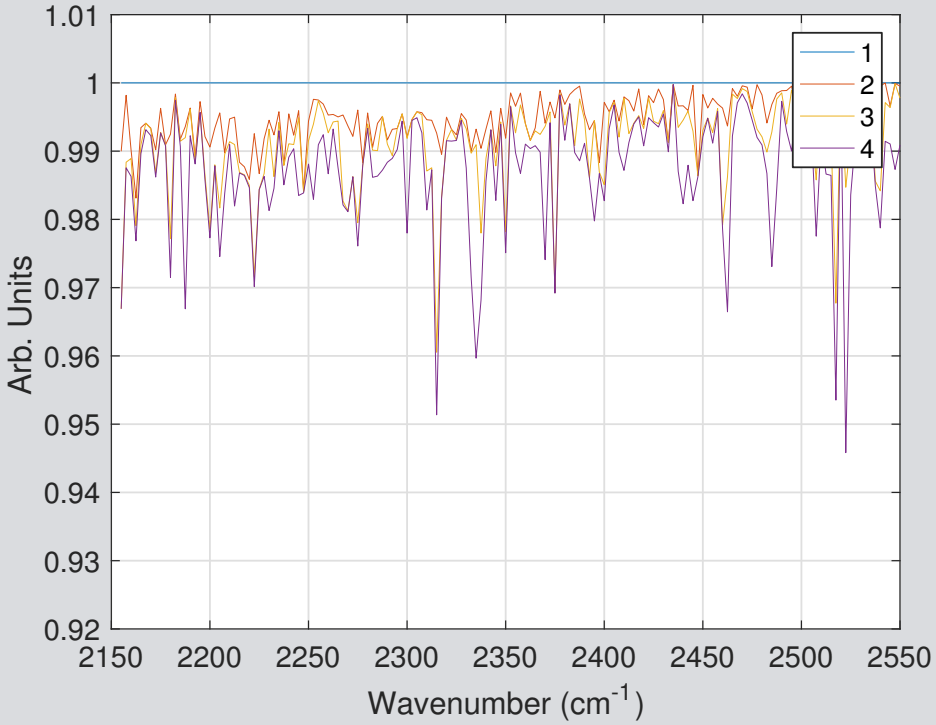
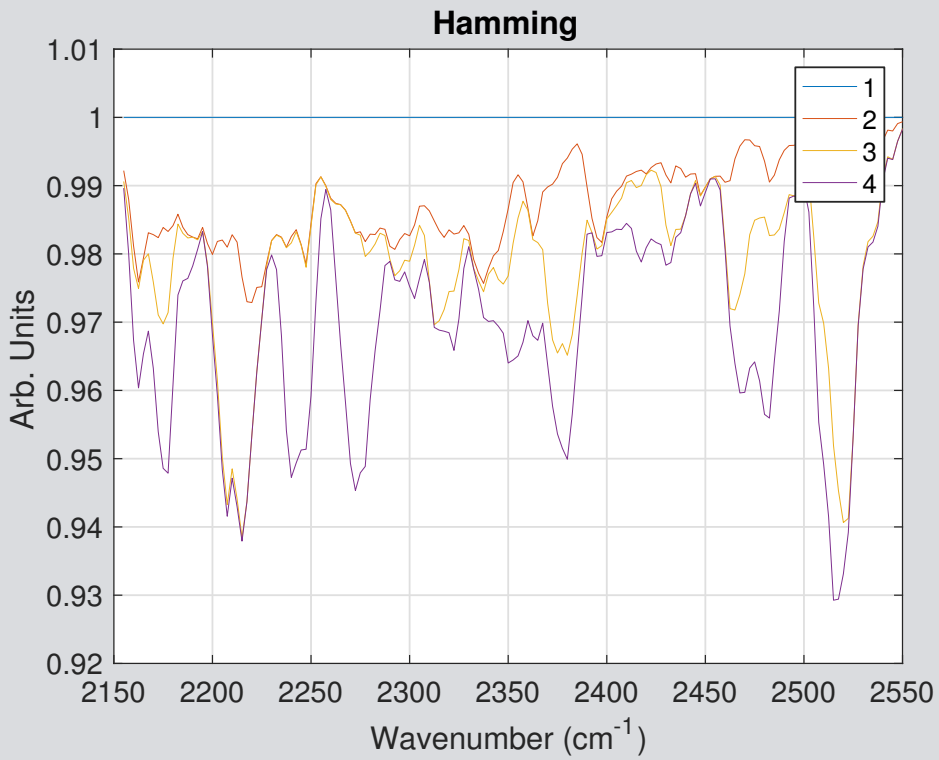


Hamming



ShortWave Noise Correlations

Sinc



Hamming