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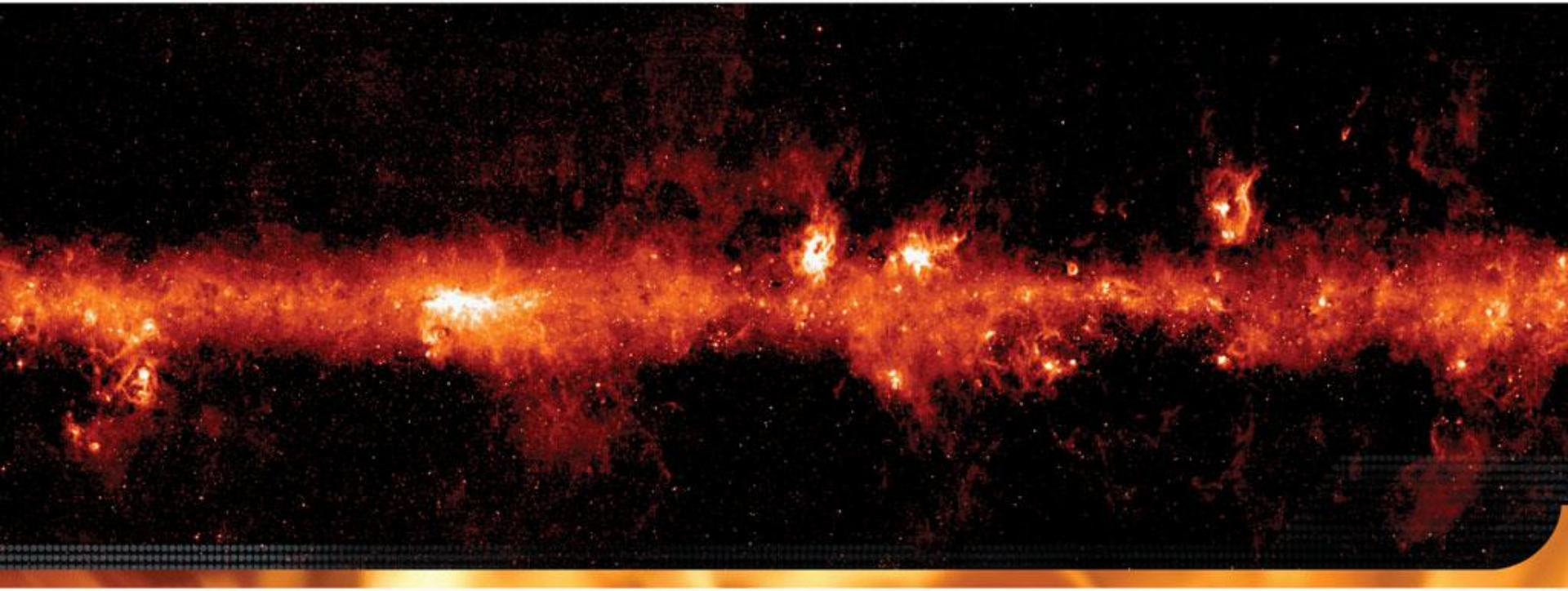


Cross-track Infrared Sounder (CrIS) Instrument In-flight Performance CALCON 2012

Vladimir Zavyalov, Gail Bingham, Mark Esplin, Mark Greenman, Deron Scott, Brandon Graham, Charles Major, and Lee Phillips

August 30, 2012

Outline

- **CrIS on-flight performance assessment**
  - NEdN – Noise Equivalent delta Radiance (Noise)
  - NEdN trend
  - Radiometric
- **Summary**

NEdN Estimation Approach

1. Earth Scene (ES) SDRs are calibrated using ITT Exelis science and the CrIS SDR algorithm V2.18b with fixed ILS (IDPS approach)
2. ICT and DS interferograms are substituted instead of ES data and calibrated using the same SDR algorithm
3. NEdN from Earth scene data is estimated using Principal Component Analysis (PCA). 30-50 Principal components (PCs) are retained for spectra reconstruction.
4. The total NEdN from calibrated ICT and DS spectra is estimated by the standard deviation technique (150-300 spectra)
5. The random noise component is estimated using PCA (1PC for ICT and DS) and spectrally correlated noise can be estimate from **:

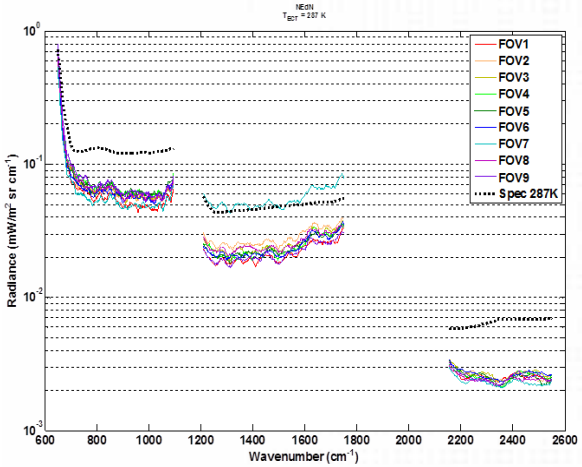
$$NEdN^2_{total} = NEdN^2_{random} + NEdN^2_{corr}$$

6. It is found that NEdN estimated from imaginary DS spectra is most sensitive to the external vibration and instrument performance
7. Total and random components of imaginary spectra NEdN are estimated the same way as real spectra NEdN

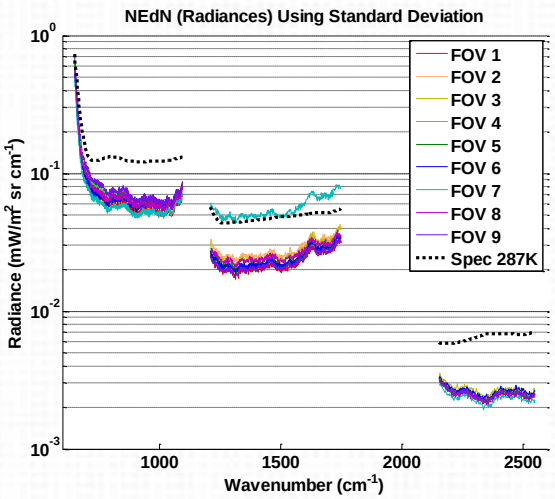
**Details of PCA technique: V. Zavyalov et all, Proc. SPIE, 8176, 817606, 2011.

ICT: Real Spectra NEdN

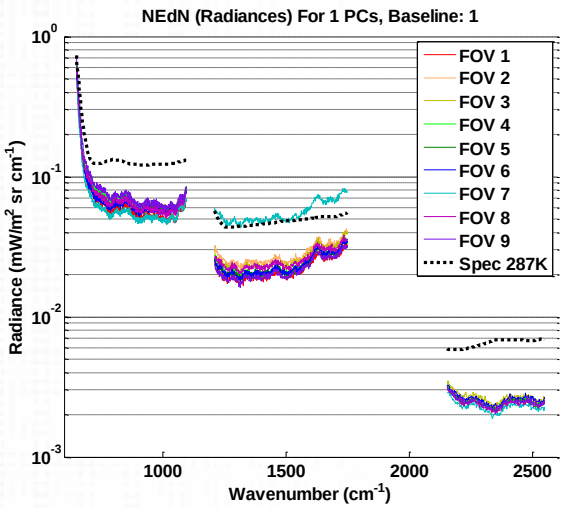
IDPS SDR product: Total NEdN



SDL: Total NEdN



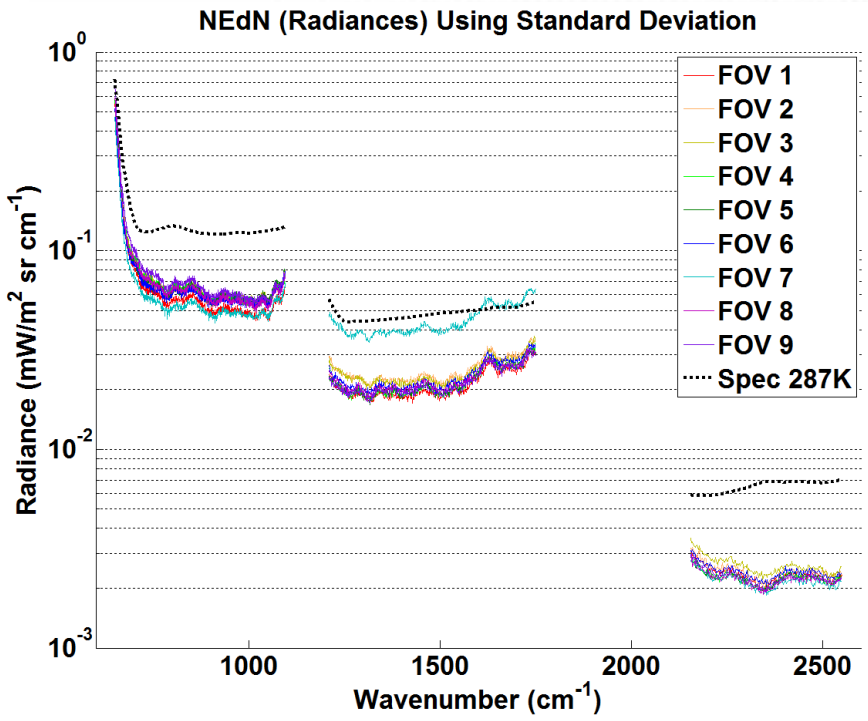
SDL: Random NEdN component



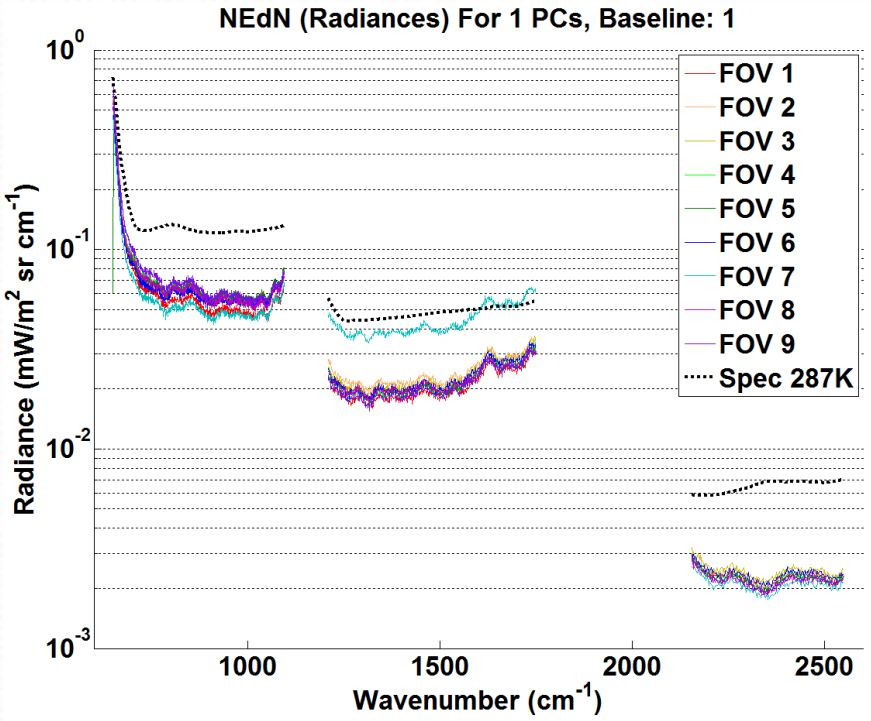
- **Results from IDPS SDR product and SDL estimations from ICT are practically the same**
- **MWIR FOV7 is out family as it was during ground TVAC4 and S/C TVAC ground tests**
- **SDR algorithm estimates NEdN over 30 ICT spectra and reports the average NEdN over 17 adjacent spectral bins**

DS: Real Spectra NEdN

Total NEdN

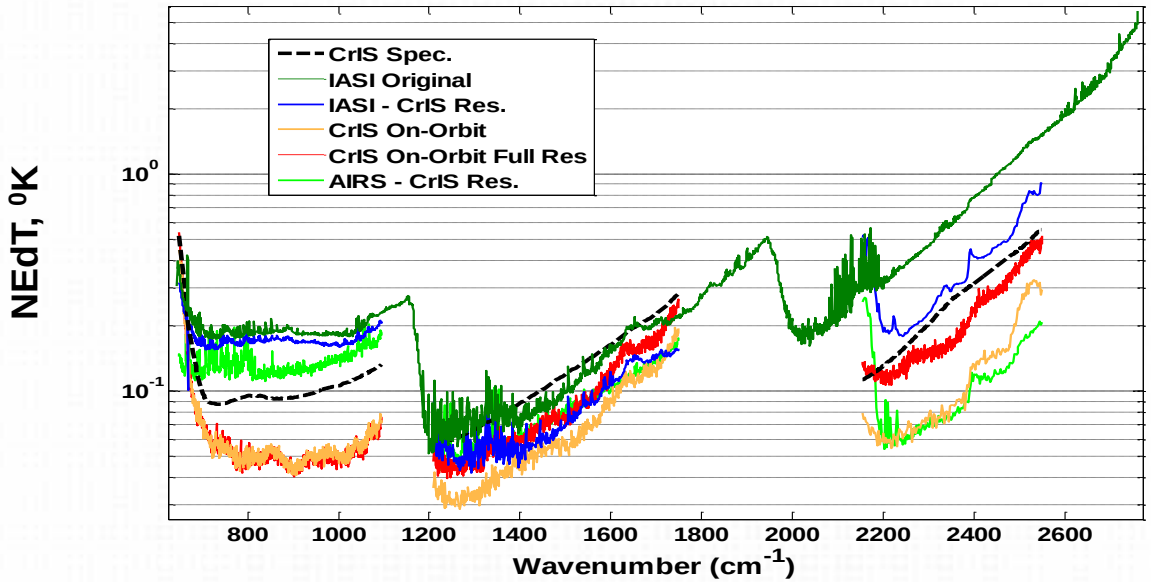


Random NEdN component



- **Both ICT and DS real spectra NEdN do not exhibit significant contribution of spectrally correlated noise**

CrIS NEdT vs AIRS and IASI



- CrIS NEdT performance exceeds spec requirements (estimated at T=270K)
- CrIS has smaller noise level than AIRS and IASI even at full spectral resolution in the MWIR and SWIR spectral bands
- NEdT is estimated using SDL's PCA approach with 30 PCs
- CrIS exhibits a smaller noise level in LWIR (~x3.5) and SWIR (~x3) spectral bands than noise estimated from IASI and AIRS spectra reduced to CrIS spectral resolution

ICT: Imaginary Spectra NEdN

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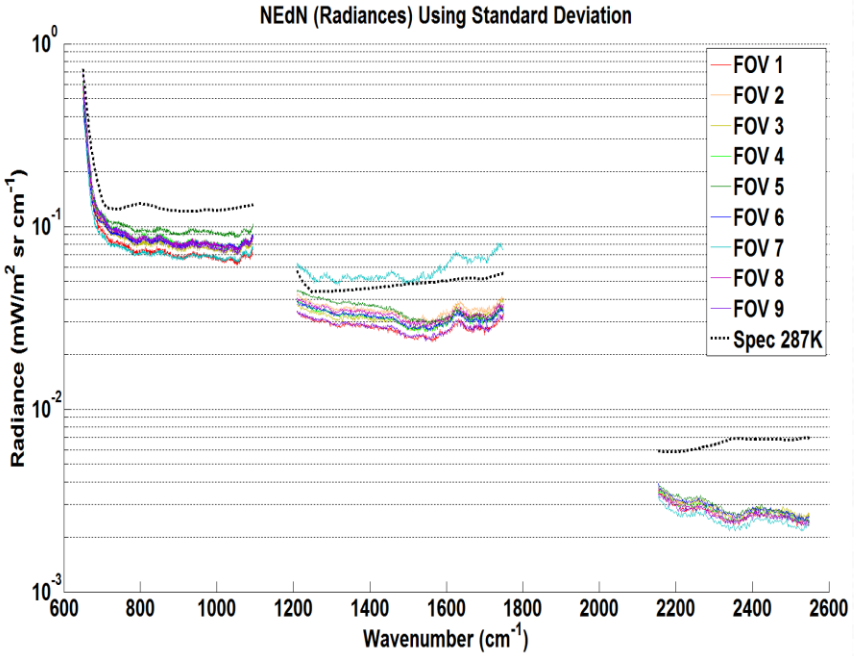
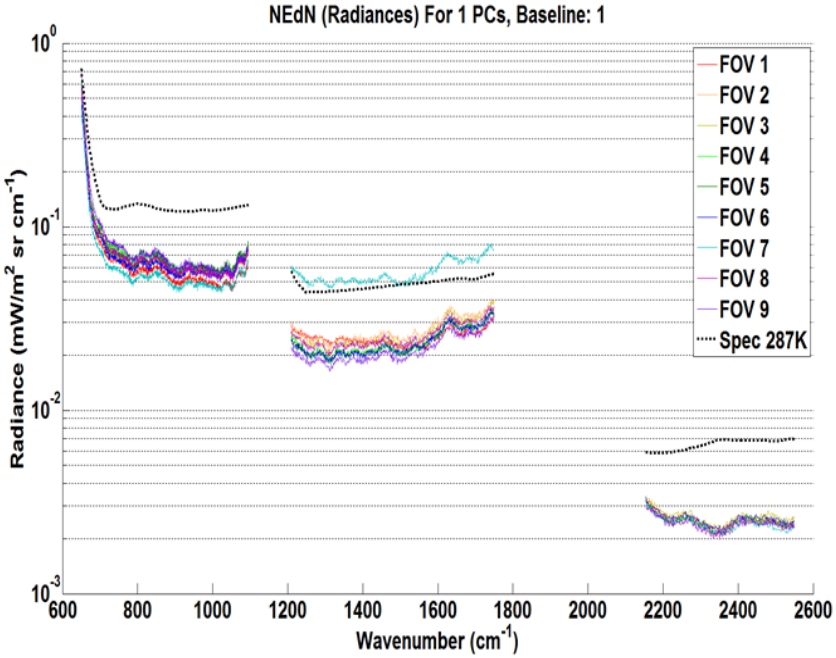
Total NEdN



Random NEdN – 1 PC



- **Small contribution of correlated noise is seen in LWIR and MWIR**

DS: Imaginary Spectra NEdN

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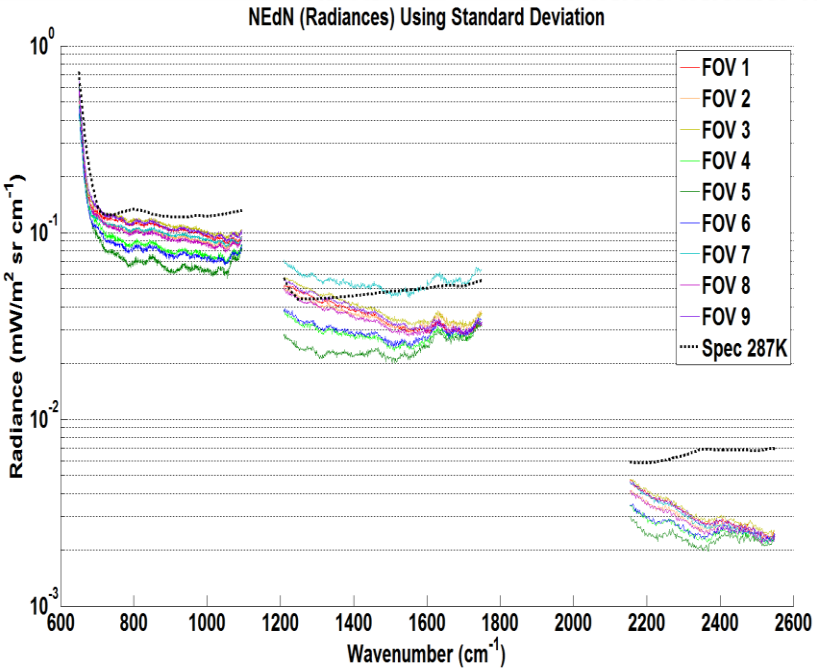
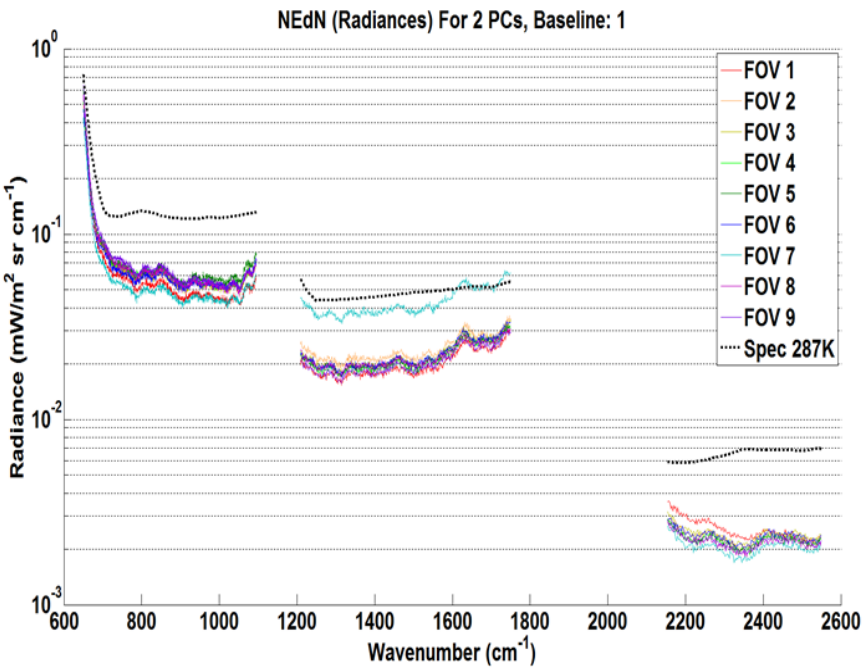
Total NEdN



Random NEdN – 2 PCs



- **A small contribution of correlated noise is seen in all spectral bands**

TVAC4 MN: DS Imaginary Spectra NEdN

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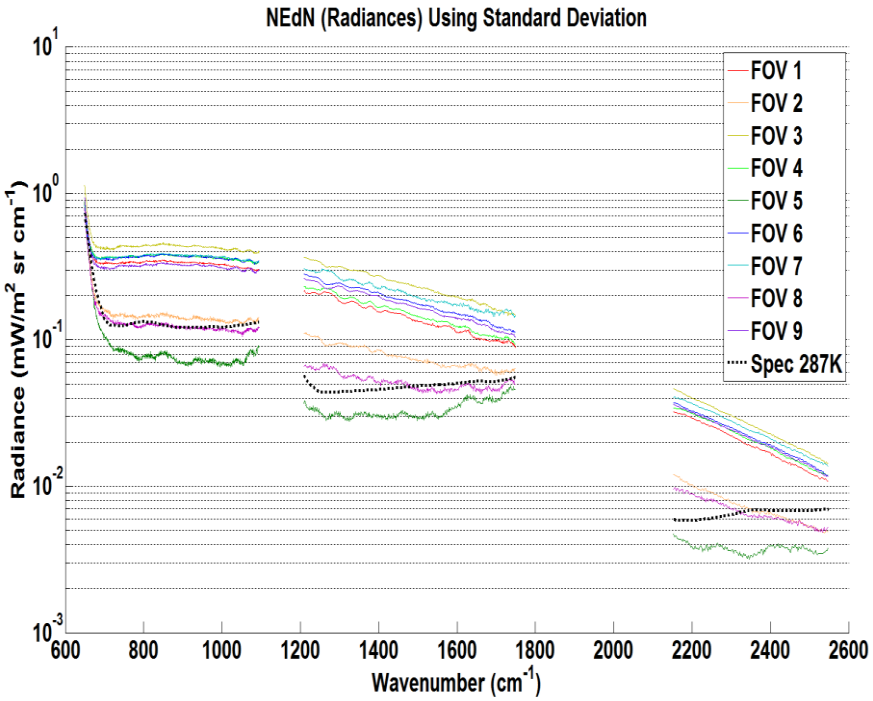
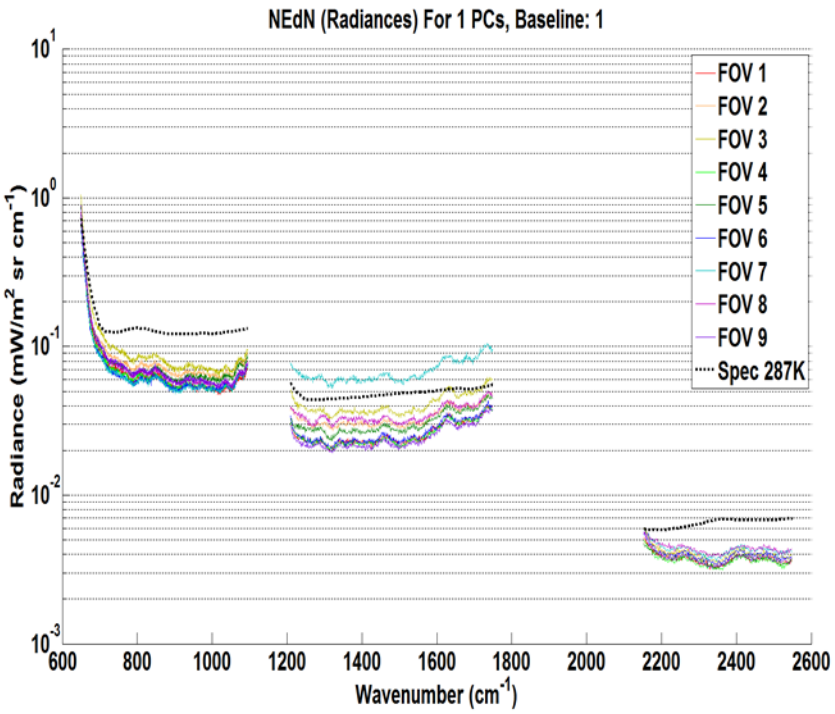
Total NEdN



Random NEdN – 1 PC



- Very large contribution of correlated noise is seen in all spectral bands
- FOV5 exhibits practically no correlated noise contribution

Contribution of Correlated Noise in Imaginary Spectra to Total NEdN

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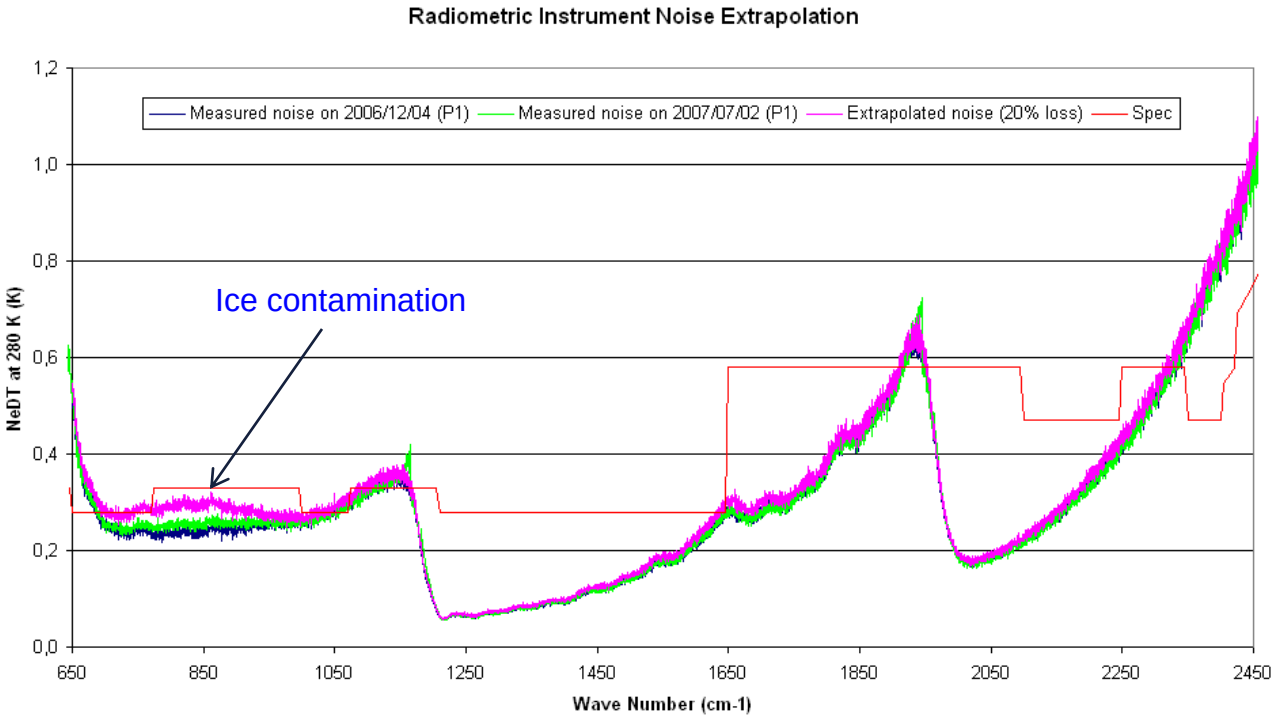
	On-orbit	TVAC4 MN	TVAC4 PQH
ES-EST	LWIR – small MWIR – small SWIR – small	LWIR- large MWIR – large SWIR – large	LWIR – large MWIR – large SWIR – large
ICT	LWIR - small MWIR – small SWIR – little	LWIR – little MWIR – little SWIR – little	LWIR – small MWIR – small SWIR – small
DS	SWIR – small MWIR – small SWIR – small	SWIR – very large MWIR – very large SWIR – very large	SWIR – very large MWIR – very large SWIR – very large

little - can be barely noticed
small - comparable with random noise
large - exceeds random noise
very large - exceeds random noise several times

- **On-orbit NEdN estimated from the imaginary spectra (ES, ICT, and DS) exhibits much smaller contribution of correlated noise as compared to the ground test data**
- **No signs of vibration are seen in the NEdN data**
- **Small contribution of correlated noise in imaginary NEdN is normal**
- **DS exhibits largest contribution of correlated noise**

CNES/IASI Presentation:

Instrument Radiometric Noise



- IASI radiometric noise as a function of wave numbers and time for pixel 1
- The impact of ice pollution is clearly visible around 850 cm $^{-1}$
- Ice contamination also can be detected in optical transmission (decrease in spectral response)
- B. Tournier, CNES, ANGLET, November 13–16, 2007

ICT Derived Average NEdN

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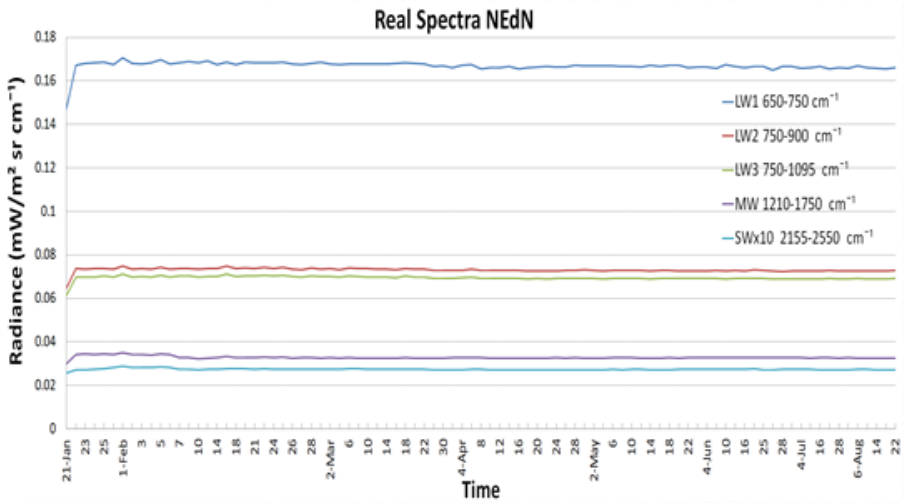
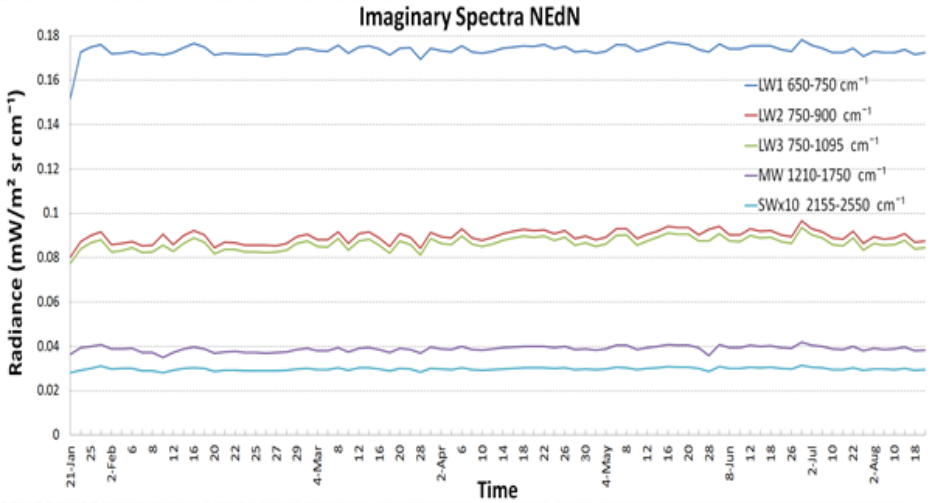
Real spectra NEdN



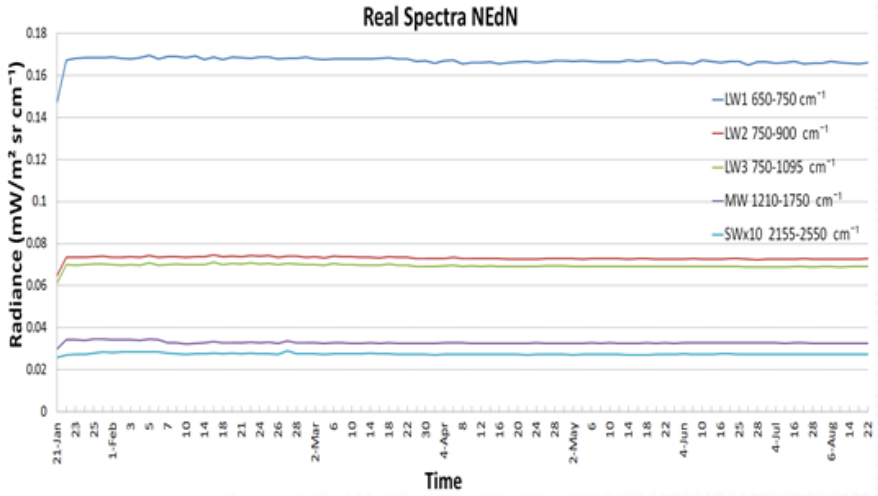
Imaginary spectra NEdN



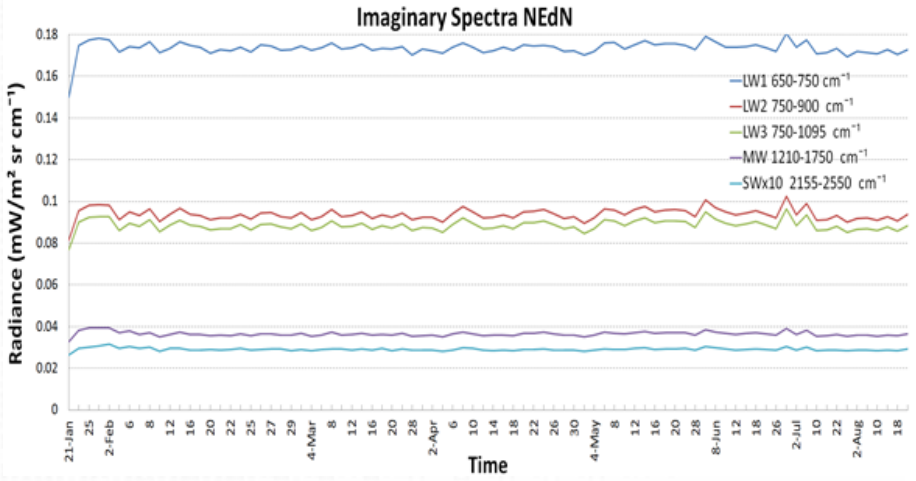
- **NEdN was averaged over all FOVs and over the spectral regions:**
  - LWIR: 650-750 ; 750-900; and 750-195 cm^{-1}
  - MWIR: Entire band 1210-175 cm^{-1}
  - SWIR: Entire band 2155-2550 cm^{-1}
- **NedN trend from January 21 to August 22, 2012**
- **NEdN is very stable in both real and imaginary parts of the ICT spectra**

DS Derived Average NEdN

Real spectra NEdN

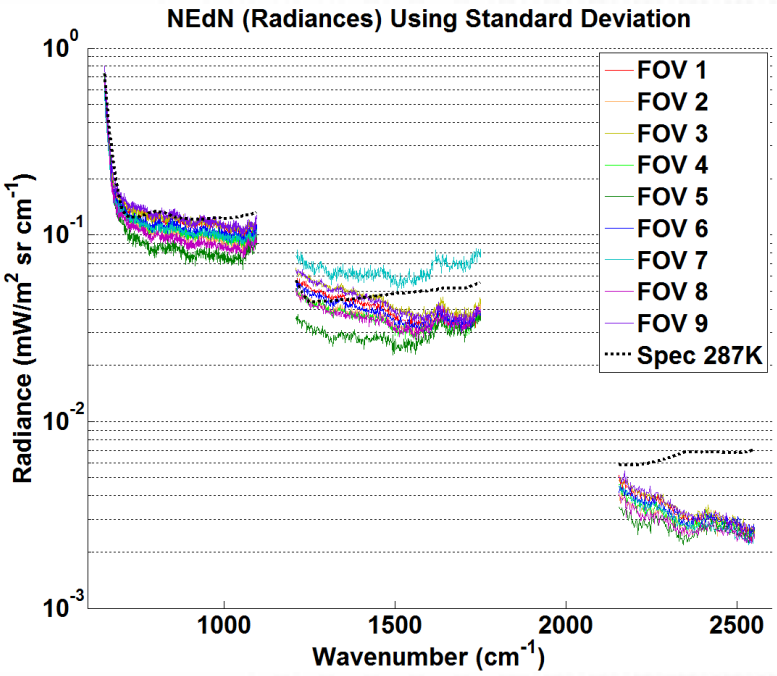


Imaginary spectra NEdN

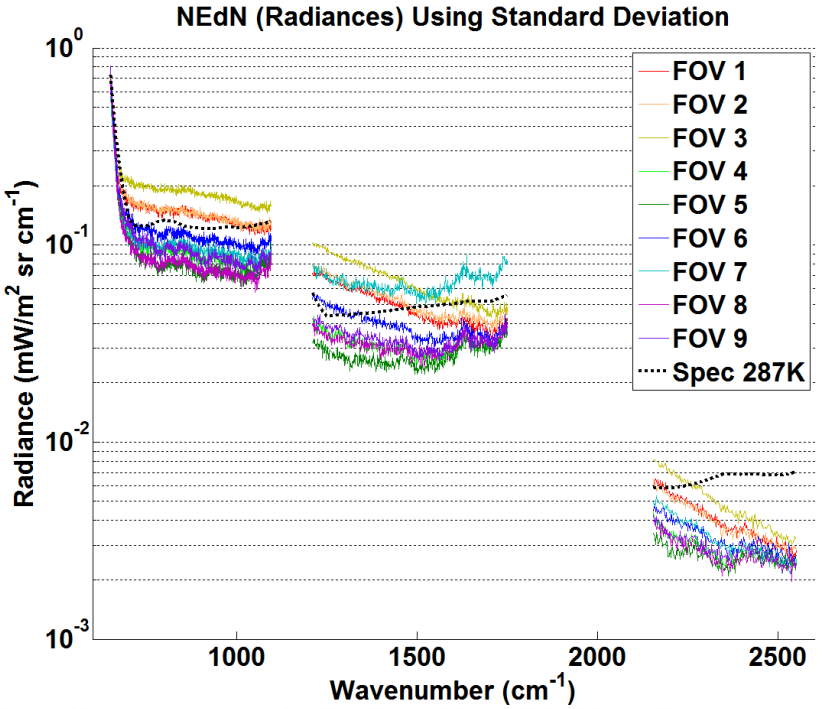


- **NEdN was averaged over all FOVs and over spectral regions:**
  - LWIR: 650-750 ; 750-900; and 750-195 cm^{-1}
  - MWIR: Entire band 1210-175 cm^{-1}
  - SWIR: Entire band 2155-2550 cm^{-1}
- **NedN trend from January 21 to August 22, 2012**
- **NEdN is very stable in both real and imaginary parts of the ICT spectra**
- **Both ICT and DS Imaginary NEdN exhibit small orbital fluctuations**

DS Imaginary NEdN



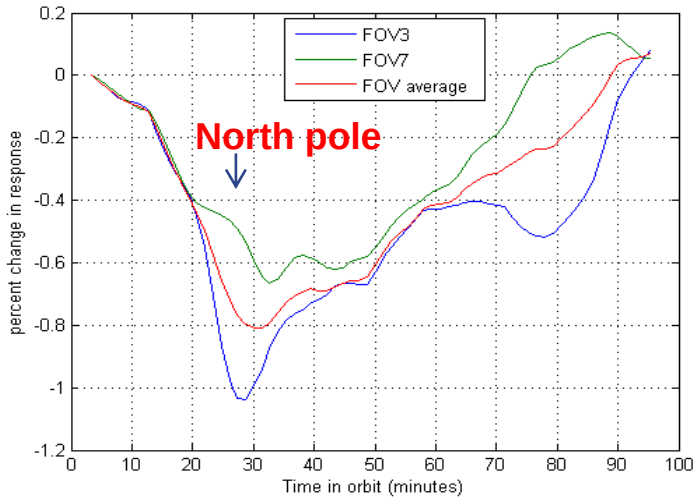
Time 0 near the Equator



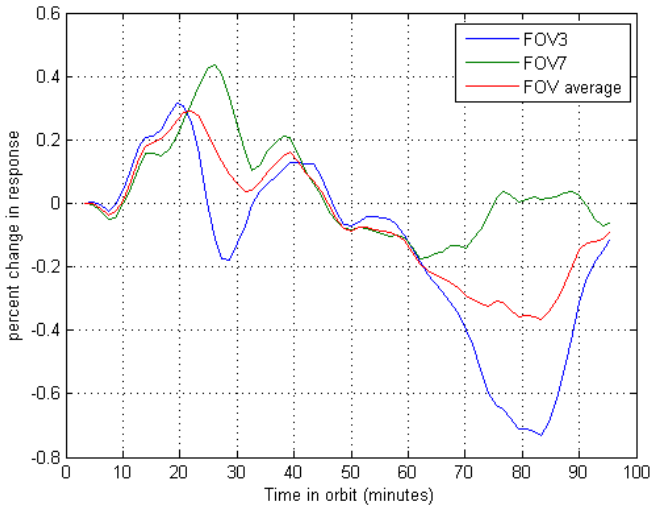
Time 30 near the North Pole

- **Increased NEdN near the North Pole for corner FOVs (1,3,7, and 9)**
- **Higher NEdN due to correlated component (PCA analysis)**

Integrated Response Difference Orbital Position



2155 – 2300 cm^{-1}

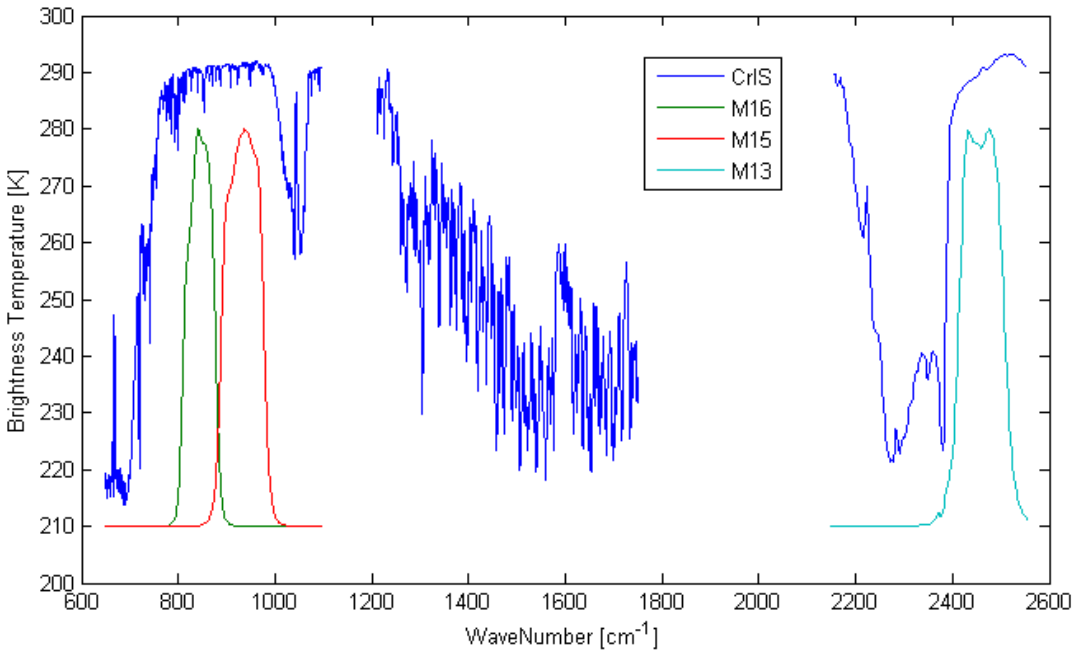


2300 – 2550 cm^{-1}

- Two points in the orbit with large FOV to FOV differences
- The North pole at 25 minutes and the South pole at 76 minutes
- The largest effects are seen near the location where NPP crosses the terminator

Note: No radiometric errors in calibrated radiances
(See details in Mark Esplin poster)

CrIS - VIIRS Intercomparison

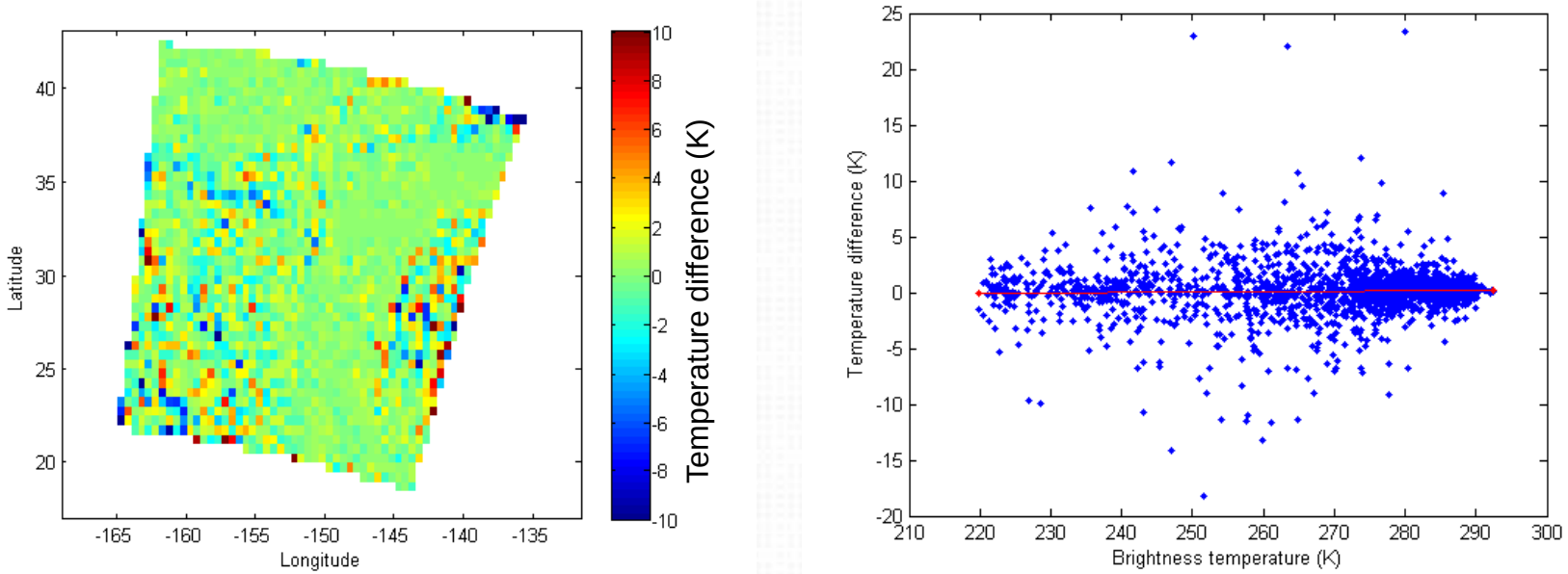


$$\frac{(\ )\ (\ )}{(\ )}$$

Where:
R_{eff} = Effective radiance
R = CrIS radiance
S = VIIRS spectral response function

- **An effective CrIS radiance is formed for each VIIRS band using the indicated equation**
- **For both CrIS and VIIRS, spatial radiances are averaged into 0.5 degree latitude and longitude bins**

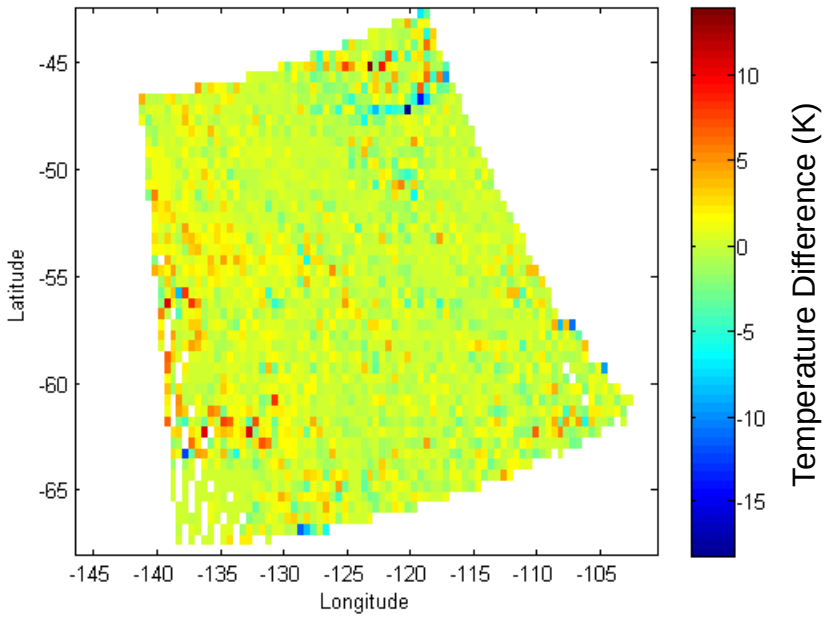
Example CrIS - VIIRS Intercomparison

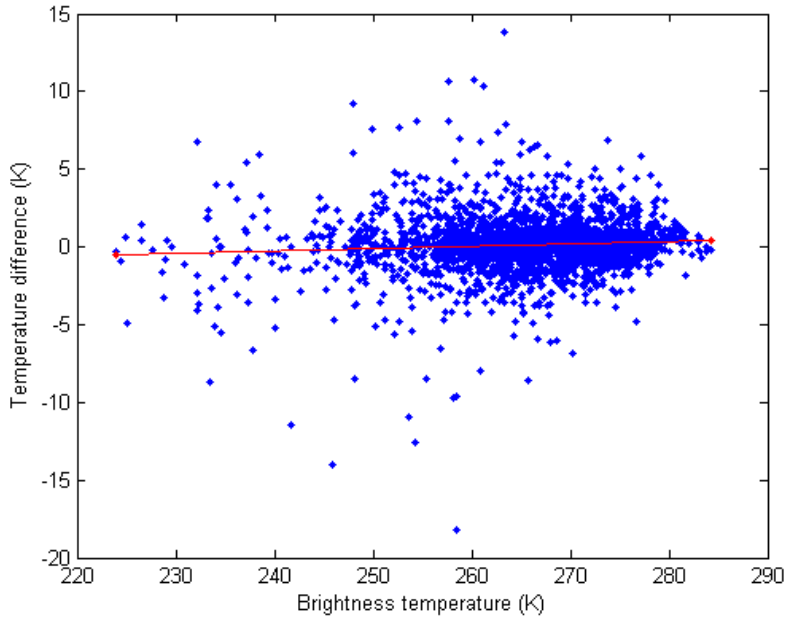


CrIS – VIIRS Difference

- Pacific Ocean near Hawaii February 25, 2012
- VIIRS band M15
- Average difference 161 mK with standard deviation 2.3 K
- Selecting uniform scenes can be used to reduce scatter

Example CrIS - AIRS Intercomparison

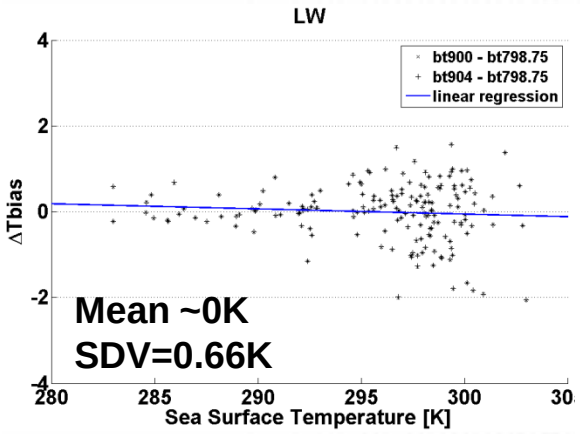




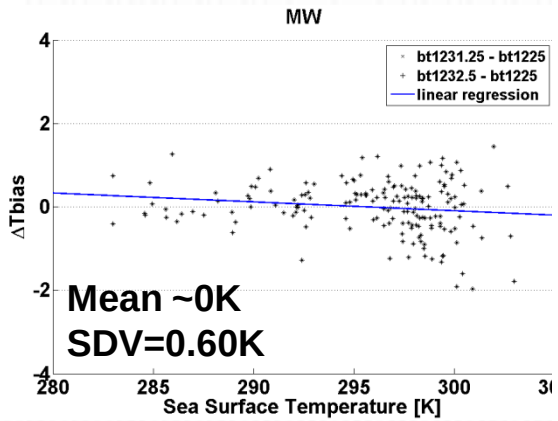
- CrIS AIRS SNO (Simultaneous Nadir Overpass) occurred February 25, 2012 at 22:42 over the South Pacific
- Average difference 159 mK with standard deviation 1.8 K
- Averaged into 0.5 degree latitude and longitude bins
- LWIR window region (911 to 915 cm^{-1})

CrIS Window Channels – SST (MyOcean)

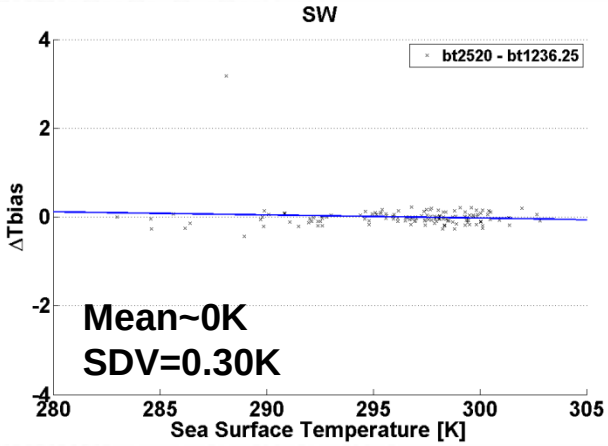
LWIR: 900, 904 cm^{-1}



MWIR: 1231, 1232.5 cm^{-1}



SWIR: 1293 cm^{-1}



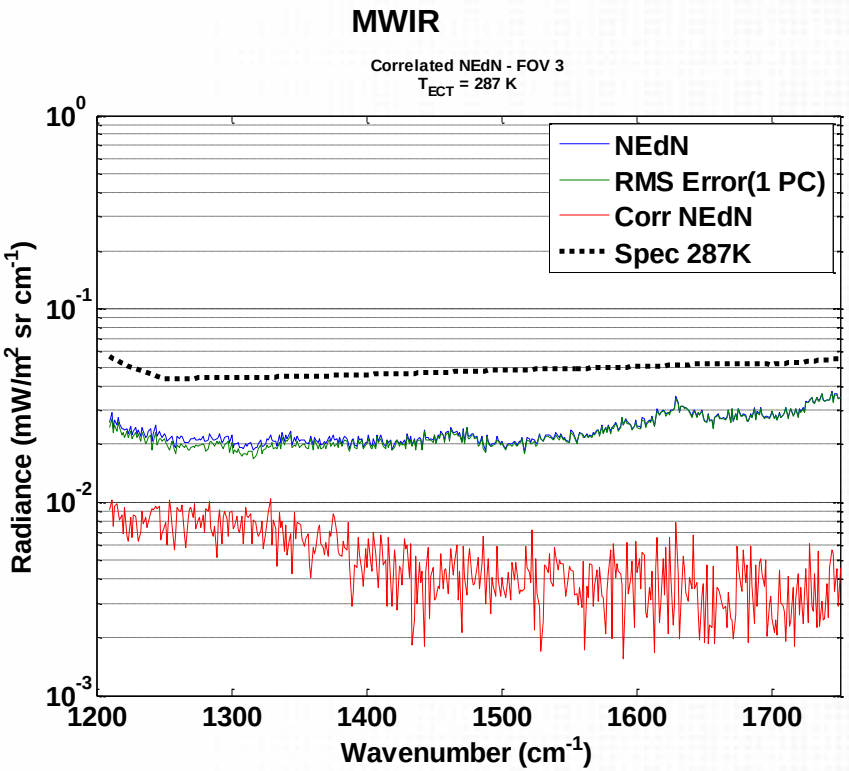
- 672 collocated radiosonde (over ocean, clear sky, night time) data were collected during June-July 2012
- 173 locations passed clear-sky criterion
- BT in selected window channels were corrected for atmospheric transmission (AIRS team approach: H. Aumann, SPIE proc., 2003)
- Corrected BT in selected window channels is then compared with SST from MyOcean site (satellite observations and modeling field data)

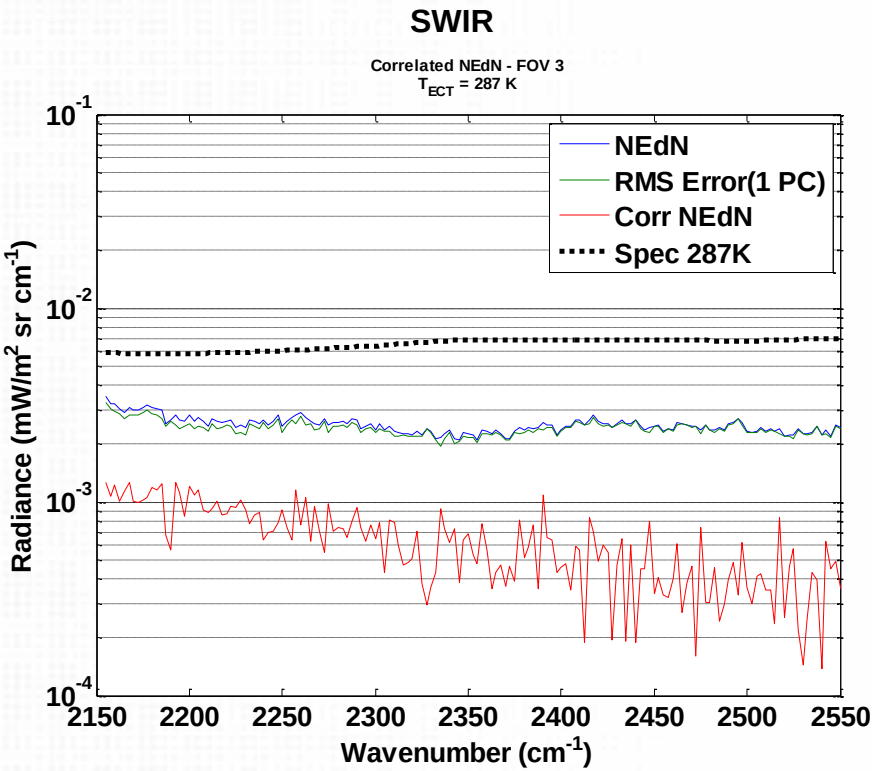
Summary

- *CrIS instrument on-orbit performance is excellent and stable*
- *Instrument noise is a significantly lower specification and stable*
- *Preliminary results confirmed that CrIS has excellent radiometric calibration*
- **On-orbit NEdN estimated from imaginary spectra (ES,ICT, and DS) exhibits much smaller contribution of correlated noise as compared to the ground test data**
- **No signs of vibration or ice contamination are seen in the NEdN data**
- **Cal/Val activities for provisional SDR quality are in progress**

Backup Slides

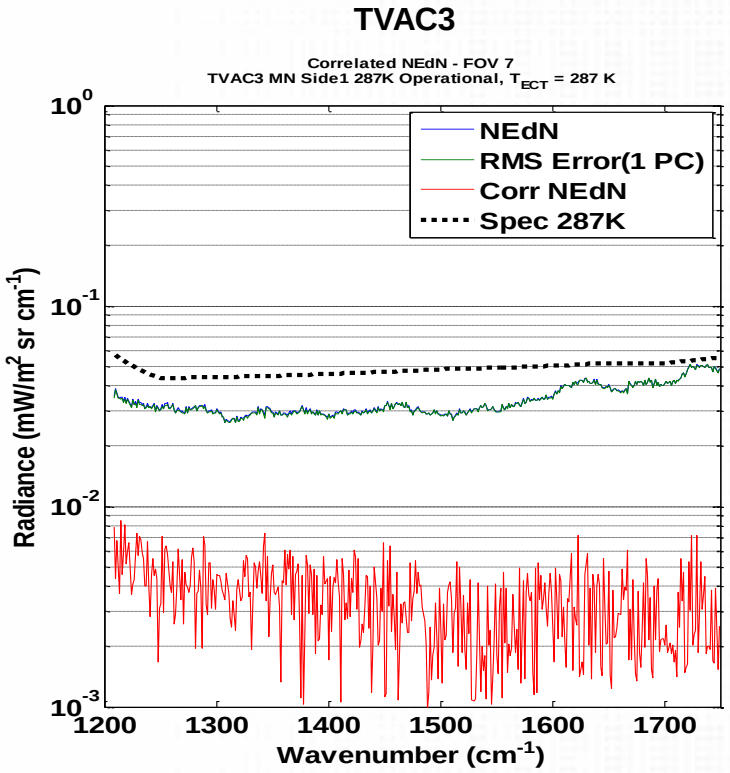
Orbit 1194, DS FOV 3: Correlated/Uncorrelated NEdN

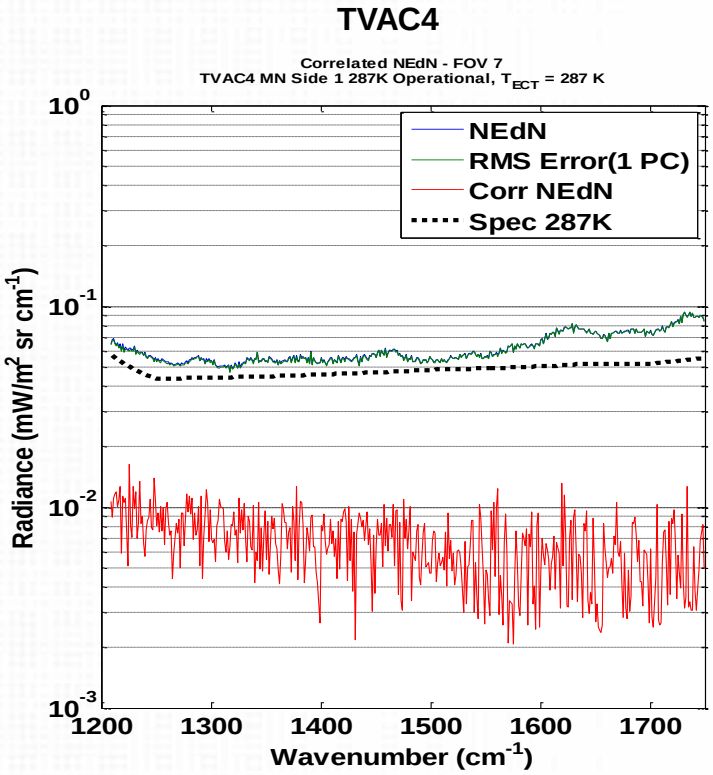




- Negligible contribution of correlated noise is seen in MWIR and SWIR for corner FOV3

Random (RMS) and Correlated NEdN: MWIR FOV7 (Out of Spec During TVAC4)





- Random noise component dominates NEdN in MWIR FOV7 during both the TVAC3 and TVAC4 tests
- The same is true for MWIR FOV7 during the S/C TVAC test and for MWIR FOV2 during the TVAC3 test