Cross-Track Infrared Sounder Science Data Record Pre-launch Calibration and On-orbit Validation Plans

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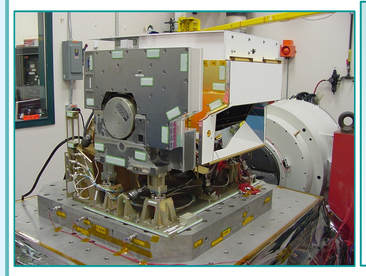
This paper describes key performance characteristics of the NPOESS CrIS Flight Model 1 determined during prelaunch calibration activities, and plans for verification and validation of the in-flight radiometric and spectral instrument calibration as a coordinated effort of industry and government teams.

CrIS Sensor Overview: **The CrIS is a Michelson interferometer covering the spectral range of 3.9 to 15.4 μm (650 to 2550 cm^{-1}). CrIS provides cross-track measurements of top-of-atmosphere (TOA) radiances to permit the calculation of vertical profiles of temperature and moisture in the Earth's atmosphere. There are three bands in the CrIS spectral range each having different spectral resolutions: long-, mid-, and short-wave (denoted as LWIR, MWIR, and SWIR, respectively).**



Key Technical Aspects of CrIS:
Fourier Transform Spectrometer
14 km nadir FOV spatial resolution
Fields of Regard with 3 x 3 FOVs
Photovoltaic Detectors in 3 bands
4-Stage Passive Detector Cooler
2200 km swath width
On-board internal calibration target (ICT)
Supplier: ITT
Key subcontractors:
ABB Bomem: Interferometer, ICT, SDR Algorithm
DRS: Detectors
AER: EDR Algorithm

Performance Requirements

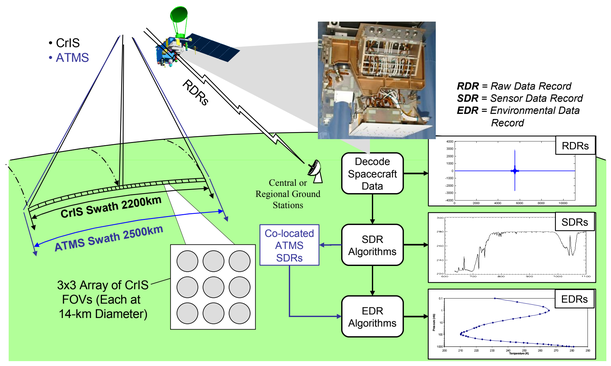
Band	Wavelength Range (cm-1)	(μ m)	Sampling (cm-1)	No. Chan.
SWIR	2155-2550	4.64-3.92	2.5	159
MWIR	1210-1750	8.26-5.71	1.25	433
LWIR	650-1095	15.38-9.14	0.625	713

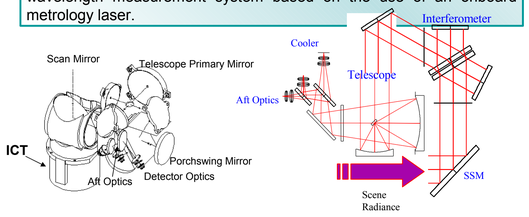
ILS Shape	Spectral Uncertainty <1.5% of FWHM of ideal on-axis ILS
Spectral Uncertainty	<10 ppm FM1 <5 ppm FM2

Band	Absolute Radiometric Uncertainty
LWIR	0.45%
MWIR	0.58%
SWIR	0.77%

Optical Schematics Showing Key Components for Onboard Radiometric Calibration

The Scene Selection Mirror (SSM) views the internal calibration target (ICT) and deep space during the scan sequence thus providing calibration measurements for each Earth swath scan. The ICT is a wedge-shaped cavity design embedded with two temperature sensors that are traceable to the National Institute of Standards. In addition, a sophisticated radiometric model has been developed to accurately capture contributions of surrounding elements seen by the instrument when viewing the ICT. Spectral calibration is achieved through a wavelength measurement system based on the use of an onboard metrology laser.



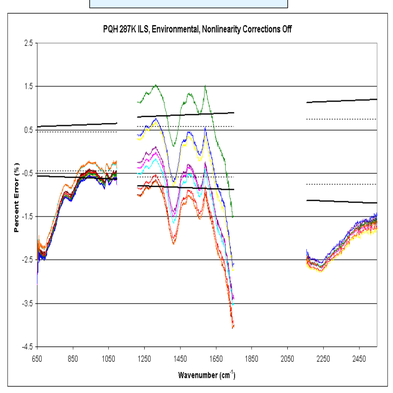


Instrument Linearity

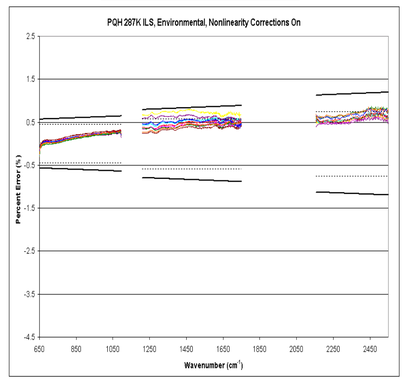
Non-linearity highest in MWIR (~0.5%); smallest in SWIR

Non-linearity correction minimizes radiance differences (spread) between FOVs

BEFORE CORRECTIONS



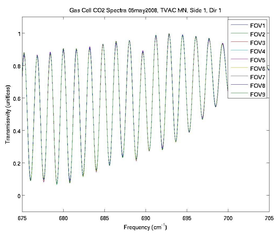
AFTER CORRECTIONS

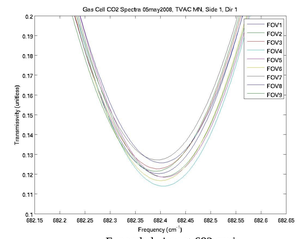


Spectral Calibration and Instrument Line Shape

FM1 meets FWHM spec allocation with margin (better than 5 ppm)

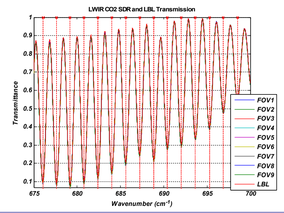
ILS correction results in less than 0.2% peak to peak residual error





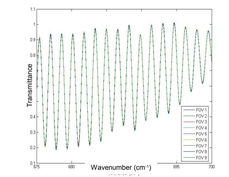
Expanded view at 682 cm^{-1}

Overlay of 9 FOVs for measured CO_2 spectrum

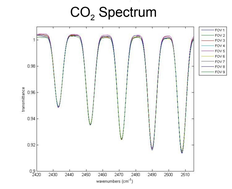


Spectral measurements vs. line-by-line spectral calculation by ITT

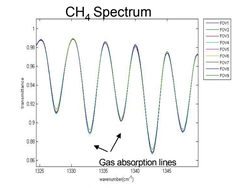
Spectral calibration is determined from hot temperature blackbody measurements of gas cells filled with carbon dioxide (LWIR band), methane (MWIR band) and hydrogen bromide (SWIR band)



CO_2 Spectrum



CH_4 Spectrum



HBr Spectrum

Key Cal/val Pre-launch Sensor Characterization Analyses:

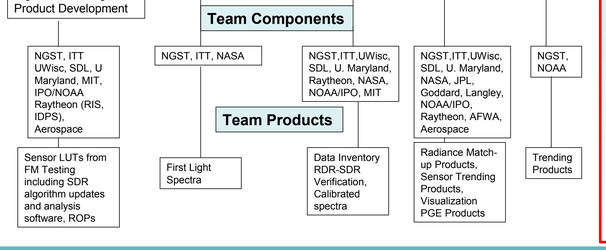
Radiometric
- Verify Fringe Count Error (FCE) detection and correction
- Verify radiometric calibration and assess instrument internal emission
- Determine instrument NEdN
- Dynamic interaction analysis
- Scan scenario test analysis and long-term radiometric stability
- Short and long-term repeatability
- Linearity (ICT with ECT at various temperature)
- Onboard digital filtering verification
- Scene Selection Module (scan mirror) precision and variability
- ICT NIST traceability

Spectral
- Bench CO2 laser for ILS characterization and LWIR spectral calibration
- Spectral calibration with gas cell

Spatial
- Slit FOV and Spot FOV (co-registration of FOVs)
- Instrument to spacecraft boresight

Key Milestones for CrIS Cal-Val

TVAC Completion	NPP Launch	First Light	ICV	Operational Mode
11/08		L+55 days	L+90 days	L+300 days
Prelaunch Preparation Activities	Sensor Activation Phase	Sensor Check Out and Performance Optimization Phase	Baseline Commissioning Phase	Long Term Monitoring Phase
		Beta	Provisional	Validated



CrIS Earth Scene Validation Approach (Following Heritage Methods):

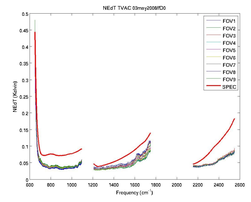
Radiometric
- Clear FOV comparisons of spectra with modeled radiances
- Laser and neon lamp stability using atmospheric absorption lines as verification
- Radiance comparisons with other satellite instruments (AIRS, IASI, VIIRS)
- Radiance comparisons with aircraft underflight FTIR measurements
- Subsetting and trending of window radiances and skin temperature with SST.RTG
- Comparisons of cloud-cleared radiances with modeled clear sky radiances
- Subsetting and trending to establish scan angle effects, local and regional bias
- Calibration of ATMS retrievals (essential for quality CC radiance) - Bias correction from co-located raobs or NWP

Spectral
- Clear FOV comparisons of spectra with modeled radiances - needed for updating forward model Optimal Spectral Sampling tables to match correct ILS
- Spectral comparisons (cross-calibration) with other satellite instruments (AIRS, IASI, VIIRS)
- Comparisons with aircraft underflight FTIR spectra

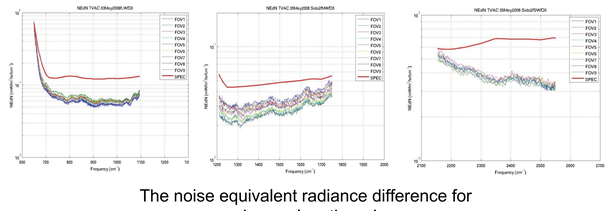
Geolocation
- Geolocation performance evaluation and co-registration with ATMS – update ATMS footprint matching coefficients; update local angle adjustment table
- Coastline crossings using clear FOVs and window channels; cross comparisons with VIIRS window channels

Instrument NEdT/NEdN

Instrument noise is very low (≤0.1K) and well below instrument specifications



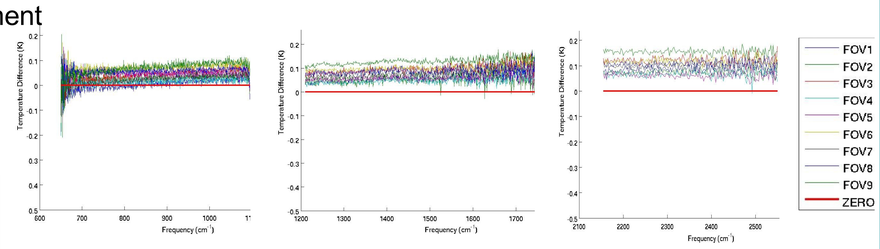
The noise equivalent temperature difference for the full spectrum (Mission Nominal)

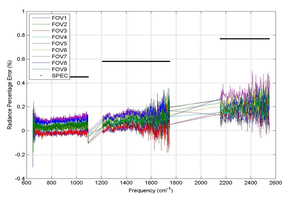


The noise equivalent radiance difference for each wavelength region

Radiometric Accuracy

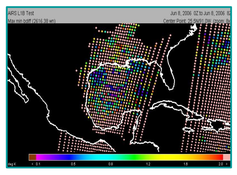
Radiometric measurement uncertainties are well below instrument specifications



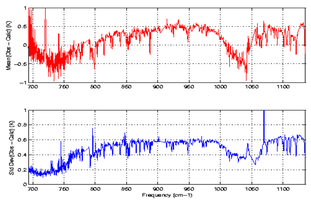


Temperature difference between measured scene brightness temperatures and in situ ECT reference temperature for each wavelength band (ECT = ICT in situ temperatures)

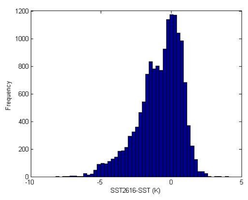
Proxy CrIS SDR Validation Data Products



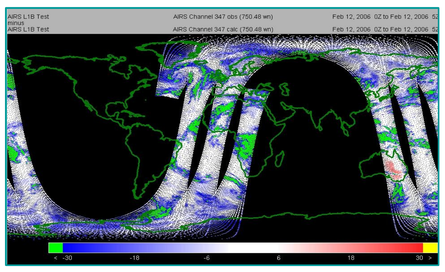
AQUA AIRS clear FOR search module - Utilizes spatial coherence test threshold for clear ocean detection As confidence in VIIRS and CrIS geolocation is gained, VIIRS data can be used to identify clear CrIS FOVs



[AIRS SDR] minus [AIRS SDR simulated from final retrieved atmosphere] for spatial coherency corresponding to clear FORs in Gulf of Mexico scene (red = bias; blue = std)



Radiometric trending approach: Real time global NCEP SST (RTG.SST) compared to AIRS adjusted window radiance (2616 cm^{-1}). A different channel selection will be used for CrIS



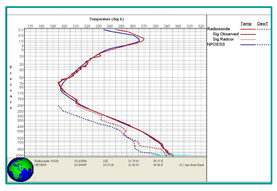
AQUA AIRS NCEP GFS model match module [AIRS SDR] minus [AIRS SDR simulated from model defined atmosphere]

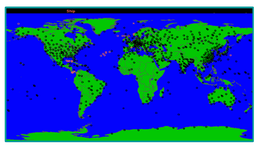
Validation is based on comparisons of CrIS radiances with:

(3)other satellite sensors (AIRS, IASI)

(2) RTA forward model calculations (derived from radiosonde and weather forecast temperature and moisture profiles)

(3) insitu surface observations (using CrIS atmospheric window channels)





Match-ups with the global radiosonde network is also the backbone of the CrIMSS EDR validation

Summary

- **Instrument pre-launch TVAC calibration of FM1 sensor is complete**
- **Instrument performance is excellent**
- **The CrIS SDR calibration plan, a joint effort of industry and government teams, has been baselined: Plan incorporates**
  - **Comprehensive list CrIS SDR tasks**
  - **Instrument on-orbit operating procedures**
  - **Cal-val tools**
  - **Timelines for validation campaigns**
  - **On-orbit characterization and SDR algorithm updates**
- **In development: Cal-Val tools and procedures needed to evaluate instrument measurement accuracy and adjust in-flight calibration parameters**

Several groups contributed to the CrIS pre-launch calibration, including verification of SDR algorithm:

ITT (Instrument Vendor)
Northrop Grumman (Prime Contractor)
University of Wisconsin SSEC
MIT Lincoln Laboratory
Space Dynamics Laboratory
University of Maryland Baltimore