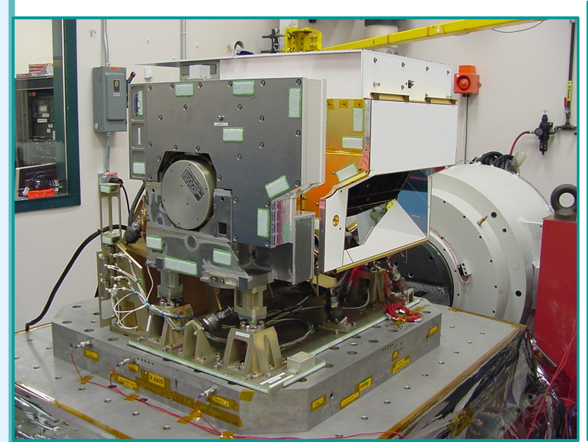
Spectral Calibration of the CrIS Instrument On-Orbit

Denise Hagan[1], Degui Gu[1], Gene Kratz[2], Denis Tremblay[3], Xia-Lin Ma[1], Wen-Hao Li[1]
[1]Northrop Grumman Aerospace Systems , [2]Raytheon Information Systems, [3]Science Data Processing Inc.

This poster describes a plan for validating the CrIS spectral radiances using Earth scenes. The Cross-Track Infrared Sounder (CrIS) will fly on the National Polar-Orbiting Operational Environmental Satellite System Preparatory Project (NPP) in 2011. The CrIS is a Michelson interferometer measuring the spectral range from 650 to 2550 cm^{-1}. The CrIS spectral calibration relies on an on-board laser metrology system whose stability is monitored using a reference neon wavelength. The instrument line shape parameters for CrIS were determined pre-launch and are not expected to vary significantly post-launch. However, initially on-orbit it may be necessary to adjust for shifts in the reference neon wavelength and the center FOV alignment to the interferometer boresight. Periodic checks of spectral stability will be performed using Earth scene atmospheric reference lines in the longwave region of the CrIS spectrum. The objective is to validate to much better than 10 ppm uncertainty (2 ppm desired) the channel centers of the CrIS calibrated radiances, and update the FOV position information used by the SDR algorithm for the spectral correction. The development of the Earth scene spectral calibration will use the EUMETSAT MetOp-A Infrared Atmospheric Sounding Interferometer (IASI) clear sky spectral radiances as proxy for CrIS.

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

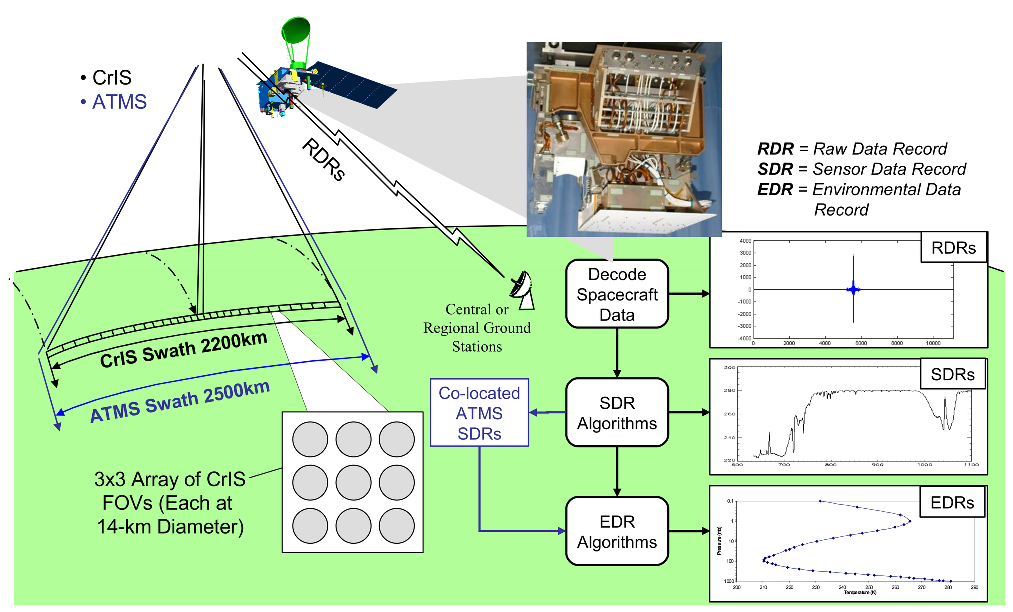
Band	Wavelength Range (cm-1)	(µm)	Sampling (cm-1)	No. Chan.
SWIR	2155-2550	4.64-3.92	2.5	159
MWIR	1210-1750	8.26-5.71	1.25	433
LWIR	650-1095	15.38-9.14	0.625	713

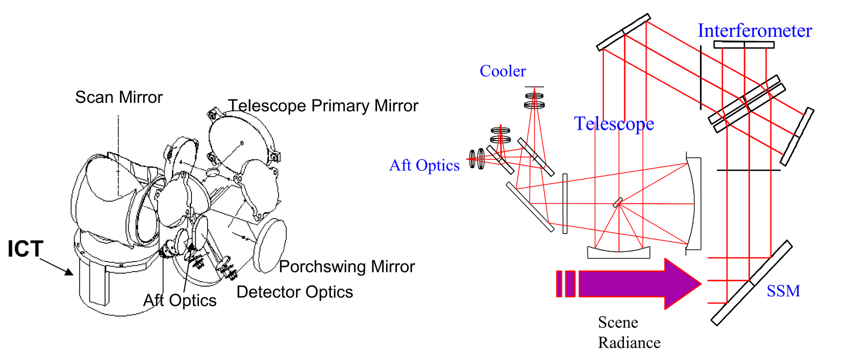
Band	Absolute Radiometric Uncertainty
LWIR	0.45%
MWIR	0.58%
SWIR	0.77%

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

Optical Schematics Showing Key Components for Onboard 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 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 and neon lamp.





Laser Metrology Spectral Calibration System

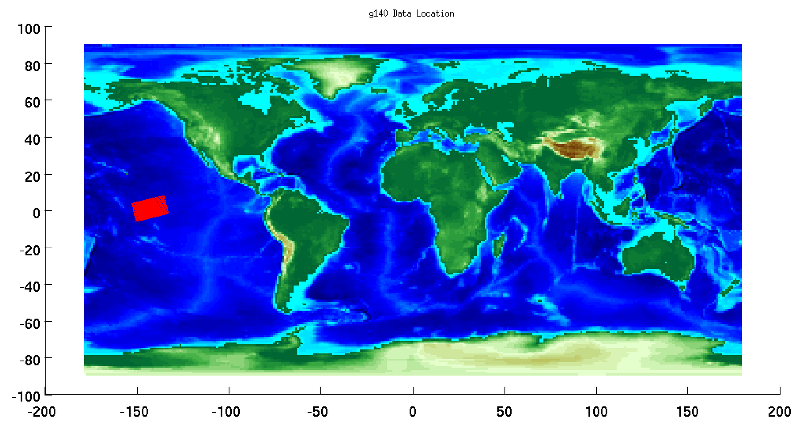
The wavelength measurement system provides a laser wavelength measurement based on the comparison of the wavelength of the metrology laser and a filtered neon lamp. The filtered neon lamp is injected in the interferometer with the same optical path as the metrology laser. Metrology detectors convert the optical signal to an electrical signal. This occurs nominally once per orbit, to determine precise metrology laser wavelength based on neon reference wavelength (at ~703.45 nm).

Criteria for Spectral Calibration Using Earth Scenes

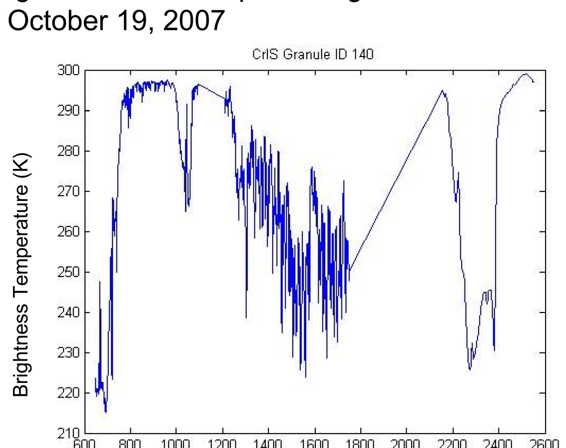
- Use LWIR spectral regions with well separated line features, relatively free of continuum effects
- Use multiple line features in emission and absorption spectral regions:
  - CO_2 Emission Region (671 cm^{-1} to 690 cm^{-1})
  - CO_2 Absorption Region 722 cm^{-1} to 759 cm^{-1}
  - Single Water Vapor Line at 784.3 cm^{-1}
- Achieve needed S/N Ratio of ~900 via multi-scene processing (15-20 CrIS scanlines, focusing on near nadir Earth scenes) (S/N equivalent to amount of interpolation needed between adjacent channel centers to resolve 1 ppm)
- Adjust MWIR and SWIR by equivalent values determined from LWIR spectra

Earth Scene Selection Criteria

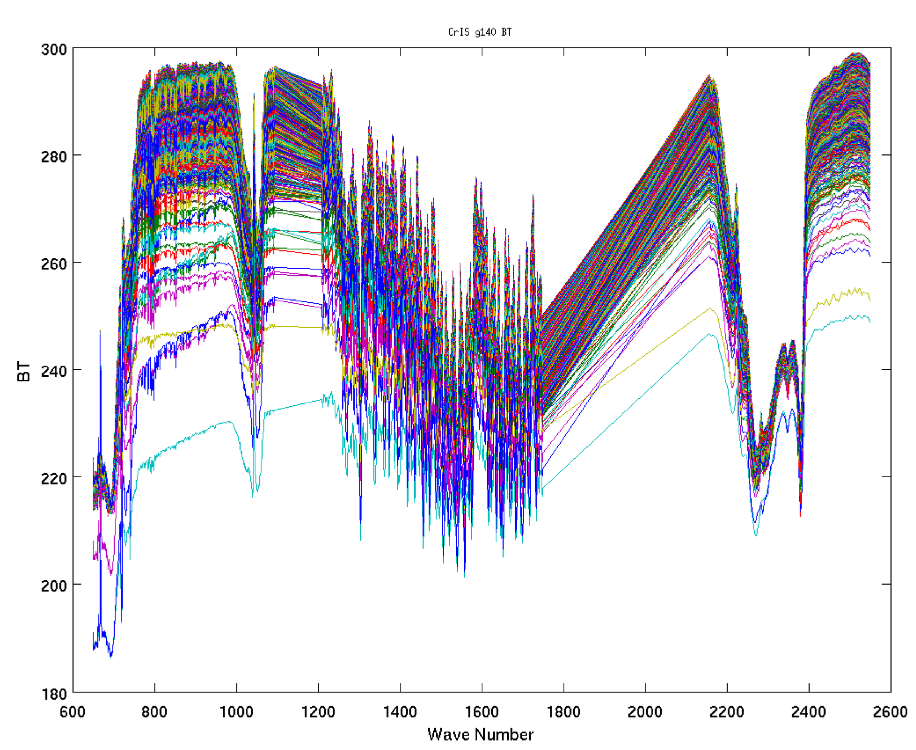
- Ocean only scenes in bulk latitudes (+/-45° of Equator)
- Near nadir views (FORs 13, 14, 15, 16, 17, 18)
- Low thermal contrast test for 9 FOVs in a FOR (possibly use IR clear scene classification in EDR algorithm)
- Compare EDR derived SST and/or atmosphere-corrected window radiances which closely match NWP SST (within 3°C)



Map showing location for sample data granule #140 for Focus Day October 19, 2007

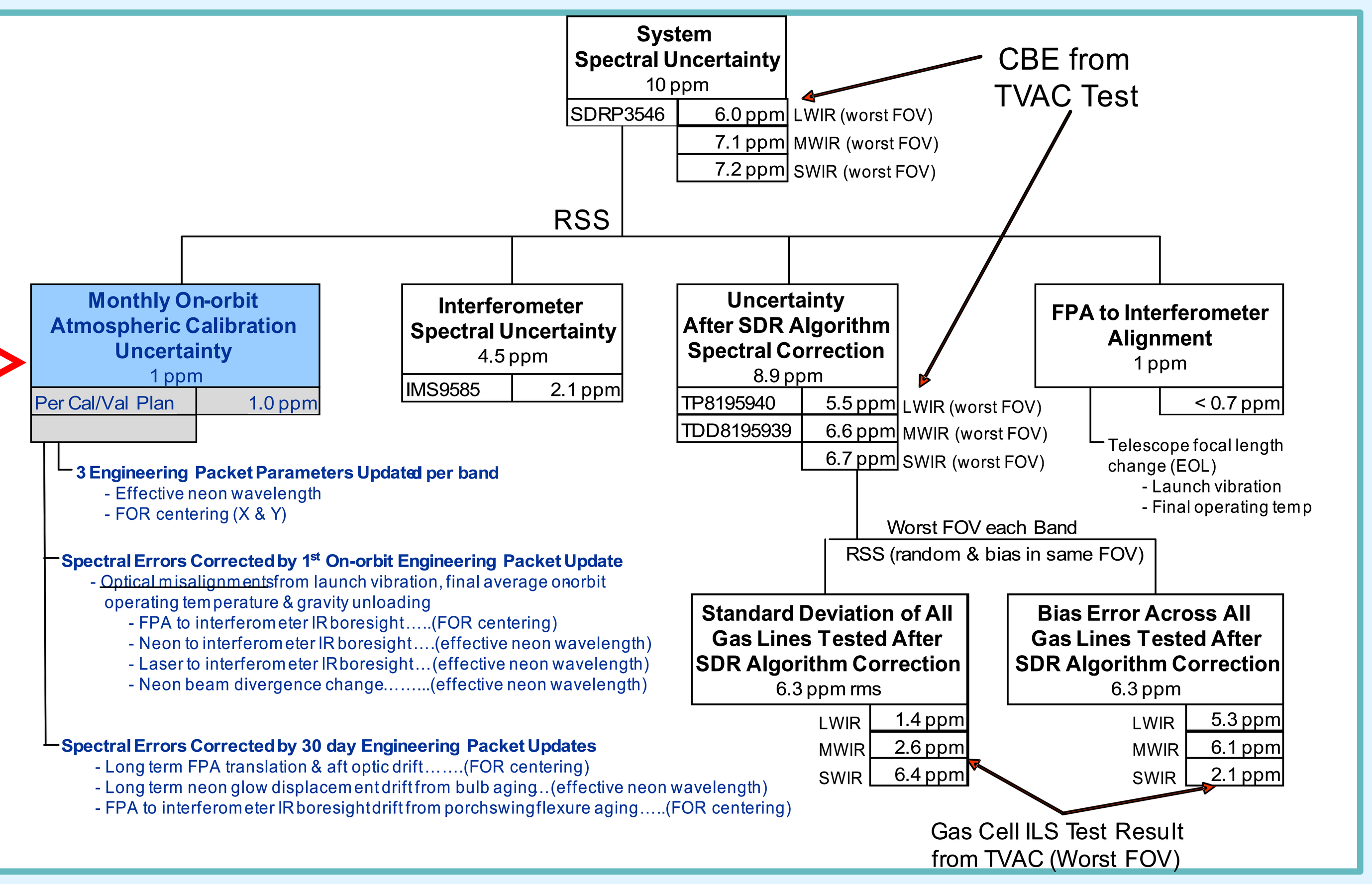


Example of preferred CrIS proxy spectrum for spectral validation



All brightness temperature spectra for Data Granule #140. Each CrIS proxy (IASI) data granule contains about 600 spectra. Only spectra with maximum brightness temperature, that meet CrIS FOR spatial uniformity criteria, will be used in spectral validation analyses.

The required system spectral uncertainty allocation, resulting from combined instrument pre-launch TVAC characterization and the SDR algorithm spectral correction, includes a term for accurate atmospheric calibration to update the ILS parameters if needed. The only sensitive ILS parameter which may shift due to launch vibration is FOV offset. This can change by 3 ppm without retuning instrument line shape (ILS) parameters.



On-orbit ILS Tuning Process

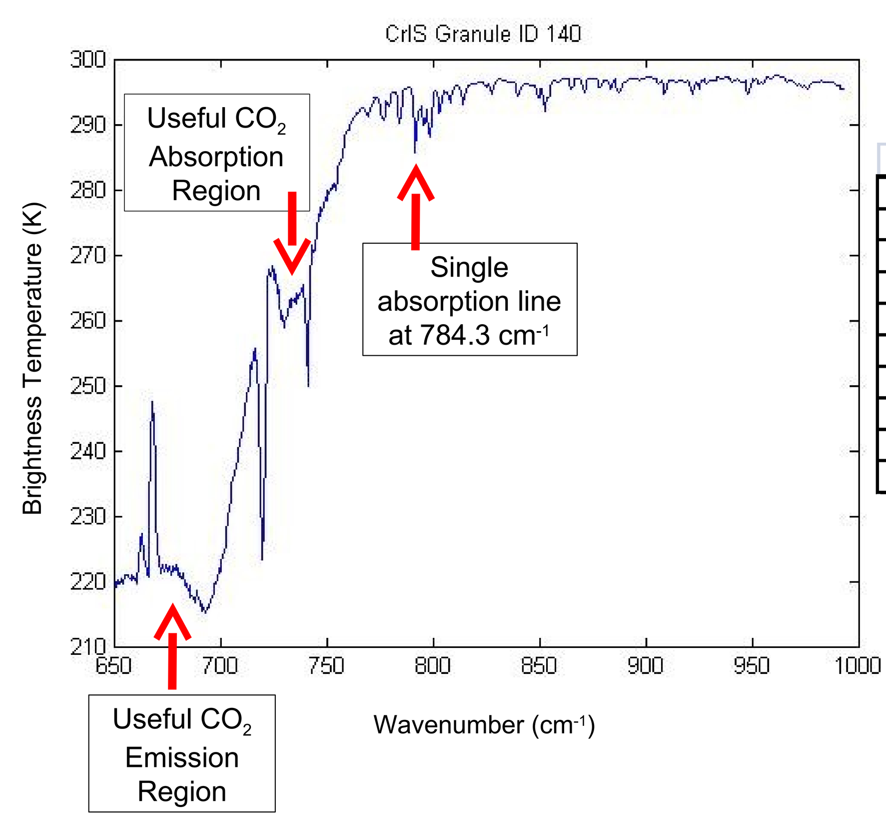
- Observed Earth spectrum is compared to a "Truth" spectrum
- EDR algorithm provides Truth spectrum on user grid via temperature, moisture and pressure profile retrieval combined with Optimal Spectral Sampling (OSS) forward radiative transfer model
- EDR algorithm applies Hamming or Blackman-Harris apodization to SDRs in order to generate an Observed spectrum
- Observed & Truth spectra are interpolated to 1 ppm resolution
- Line centers are determined for Observed and Truth spectra
- Differencing generates a ppm error for each line center
- FOV 5 (center FOV in FOR) offset correction in urad is determined as well as neon wavelength correction based on ppm errors from each FOV

Initial on-orbit tuning of ILS parameters will be performed but adjustments are expected to be small:
- Effective neon wavelength adjustment < +/-2 ppm
- FOV 5 centering to instrument boresight <110 urad or <3 ppm in spectral error
- No adjustment of band to band relative neon wavelength is planned
- Any ppm adjustment determined for LWIR will be applied to MWIR and SWIR bands, while retaining the relative neon offsets determined from ground testing

Subsequent checks are planned every 30 days primarily for validation purposes

Processing Method

- Process selected clear -sky ocean scene SDR granules using operational EDR code, retaining forward model calculated radiance spectra and radiance residuals as outputs
- Compare selected line centers of Truth spectra with Observed spectra, assuming error tolerance of about 100 ppm
- Interpolate observed SDR radiance data and forward model 'truth' data using sinc interpolation method
- Estimate line centers of interpolated data, based on minimum and maximum criteria, and determine averages of line center errors for dataset
- Use ppm errors in corner and side FOVs of CrIMSS FOR to determine ILS center FOV 5 offset in urad for in-track and cross- track axes
- Use ppm error in center FOV to determine neon wavelength adjustment in ppm



Approximate line centers used for Spectral Calibration (default values in cm^{-1})

671.32	emission	723.88	absorption	743.8	absorption	758.8	absorption
672.88	emission	725.52	absorption	745.36	absorption		
676	emission	727.08	absorption	746.84	absorption	784.32	absorption
677.6	emission	728.52	absorption	748.36	absorption		
679.2	emission	730.08	absorption	749.84	absorption		
680.76	emission	731.6	absorption	751.36	absorption		
682.36	emission	733.24	absorption	752.84	absorption		
684	emission	734.76	absorption	754.32	absorption		
685.6	emission	736.2	absorption	755.8	absorption		
687.2	emission	737.72	absorption	757.28	absorption		

LWIR Spectral Region and Absorption/Emission Lines for Spectral Validation

SUMMARY

A plan for developing spectral validation of CrIS radiances using Earth scenes is being implemented

MetOp IASI data for the JPSS Cal-Val 'Focus' Day October 19, 2007, provide CrIS proxy data for the spectral calibration tool development work

The goal is to develop a procedure that can be automated to support ILS updates as needed for the CrIS SDR engineering parameter (packet) files

Acknowledgement
The authors acknowledge the work carried out by Joe Predina of ITT Geospatial Systems in the development of the CrIS On-orbit and Spectral Calibration Validation and Maintenance Recommended Operating Procedure.

AMS 91st Annual Meeting
Poster #651