CrIS Sensor Cal-Val Readiness for NPP Satellite Mission

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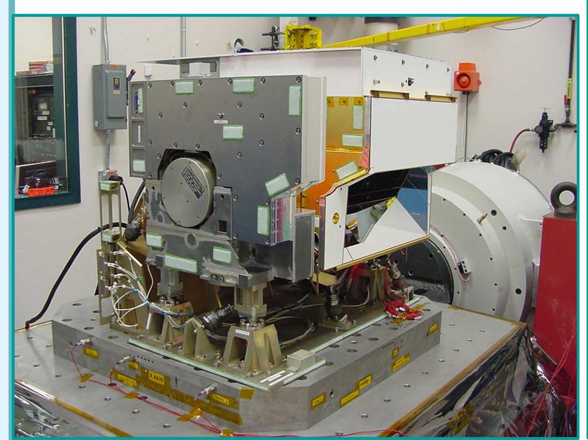
This paper describes pre-launch analysis tools to support the on-orbit calibration and validation of the Cross Track Infrared Sounder (CrIS), planned for launch in late 2011 on the NPP satellite. The Cross-Track Infrared Sounder (CrIS) was delivered to the National Polar-Orbiting Operational Environmental Satellite System Preparatory Project (NPP) spacecraft in June, 2010, and is undergoing test and integration as the first payload proof-in-concept supporting the Joint Polar Satellite System, a series of spacecraft which provides the PM polar orbit, supporting environmental remote sensing for the NOAA/NASA climate research and operational weather programs. The CrIS radiometrically and spectrally calibrated radiance products are used in conjunction with the Advanced Technology Microwave Sounder remapped calibrated radiances to provide retrieved profiles of atmospheric temperature and moisture under clear and cloudy conditions. The sounding community that includes government, academia and industry experts is preparing for on-orbit validation of the CrIS radiance (SDR) and environmental (EDR) data products, and assimilation of those products into the numerical weather prediction centers. The verification of the sensor pre-launch calibration and the ability to tune the SDR and EDR algorithms to achieve optimal performance are key components of the validation process. This presentation describes analysis tools developed thus far to support CrIS cal-val readiness.

<u>CrIS Sensor Overview:</u> 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).



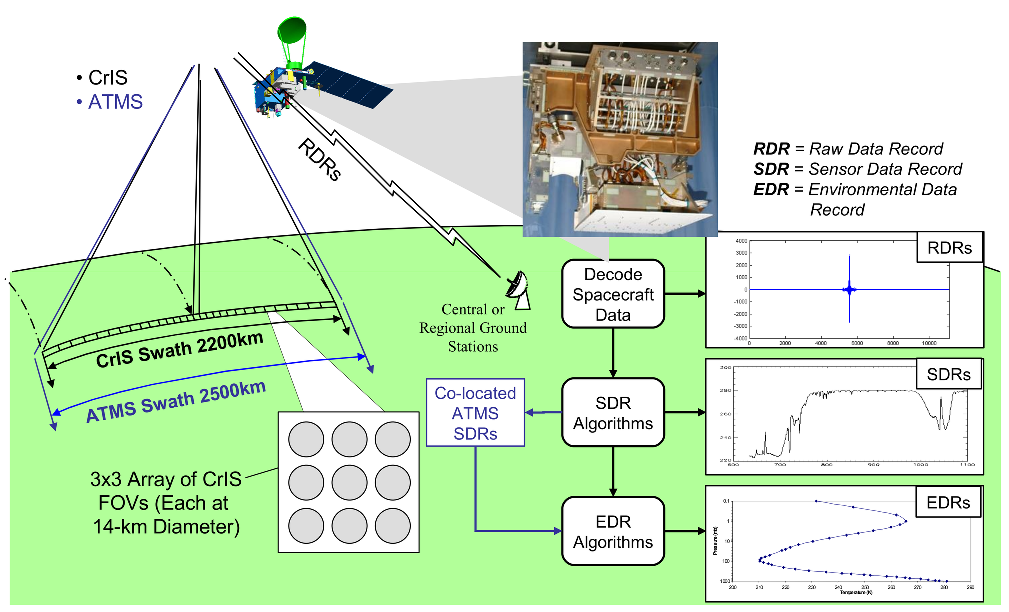
<u>Key Technical Aspects of CrIS:</u>
Fourier Transform Spectrometer
14 km nadir FOV spatial resolution
Fields of Regard with 3 x 3 FOVs
Photovoltaic Detectors in 3 bands
4-Stage Passive Detector Cooler
2200 km swath width
On-board internal calibration target (ICT)
Supplier: ITT
Key subcontractors:
ABB 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

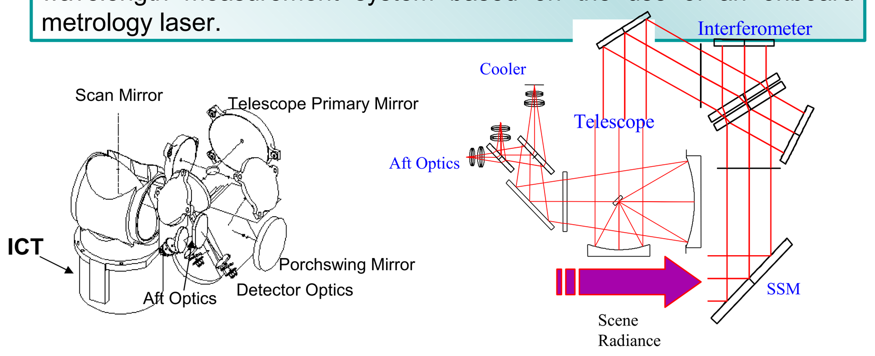
ILS Shape	Spectral Uncertainty <1.5% of FWHM of ideal on-axis ILS
Spectral Uncertainty	<10 ppm FM1 <5 ppm FM2

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.



Key Cal/val Pre-launch Sensor Characterization Analyses:

<u>Radiometric</u>
- 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

<u>Spectral</u>
- Bench CO2 laser for ILS characterization and LWIR spectral calibration
- Spectral calibration with gas cell

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

NPP Mission Phase →

Pre-launch Sensor Characterization, SDR Algorithm Testing and Product Development	Launch and Sensor Activation	On-Orbit Check Out	ICV	Long-term Monitoring
Team Components				
NGST, ITT UWisc, SDL, U Maryland, MIT, IPO/NOAA Raytheon (RIS, IDPS), Aerospace	NGST, ITT, NASA	NGST,ITT,UWisc, SDL, U. Maryland, Raytheon, NASA, NOAA/IPO, MIT	NGST,ITT,UWisc, SDL, U. Maryland, NASA, JPL, Goddard, Langley, NOAA/IPO, Raytheon, AFWA, Aerospace	NGST, NOAA
Team Products				
Sensor LUTs from FM Testing including SDR algorithm updates and analysis software, ROPs	First Light Spectra	Data Inventory RDR-SDR Verification, Calibrated spectra	Radiance Match-up Products, Sensor Trending Products, Visualization PGE Products	Trending Products

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

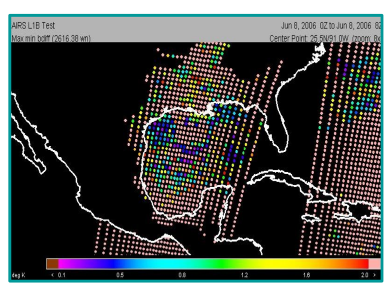
CrIS Earth Scene Validation Approach (Following Heritage Methods):

<u>Radiometric</u>
- 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

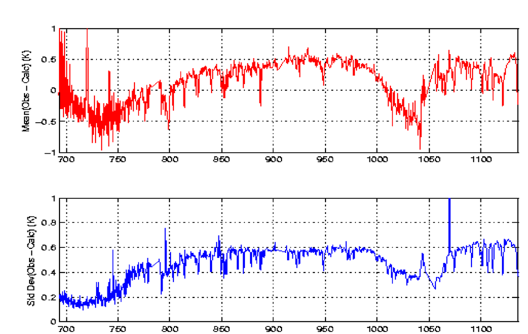
<u>Spectral</u>
- Clear FOV comparisons of spectra with modeled radiances - needed for updating forward model Optimal Spectral Sampling tables to match correct ILS
- Spectral comparisons (cross-calibration) with other satellite instruments (AIRS, IASI, VIIRS)
- Comparisons with aircraft underflight FTIR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

<u>Geolocation</u>
- 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

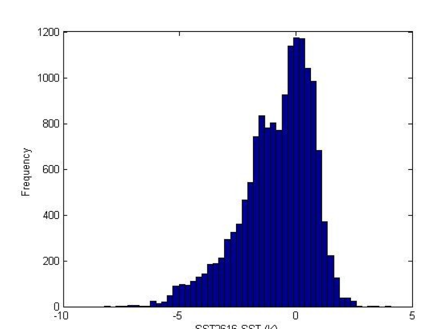
Proxy CrIS SDR Validation Data Products



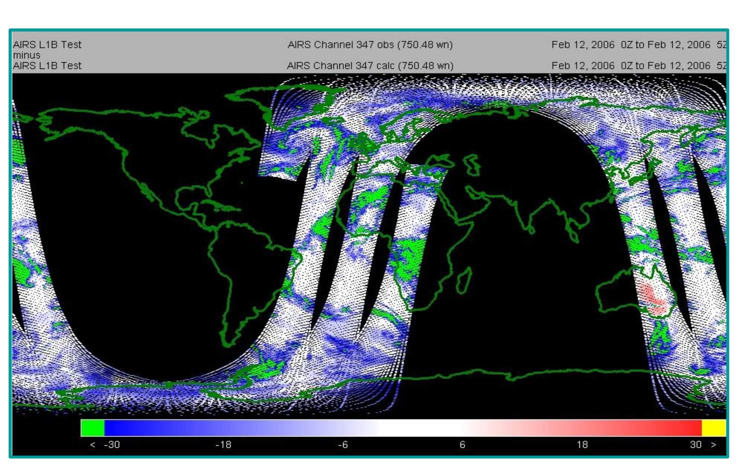
AQUA AIRS clear FOR search module - Utilizes spatial coherence test threshold for clear ocean detection As confidence in VIIRS and CrIS geolocation is gained, VIIRS data can be used to identify clear CrIS FOVs



[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



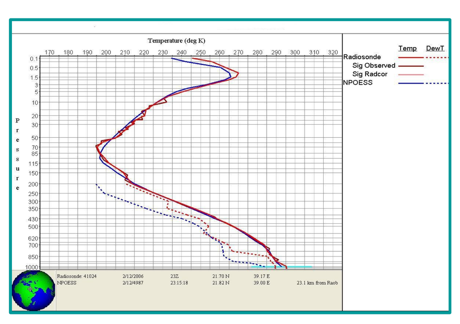
AQUA AIRS NCEP GFS model match module
[AIRS SDR] minus [AIRS SDR simulated from model defined atmosphere]

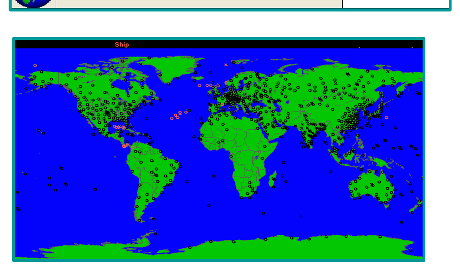
Validation is based on comparisons of CrIS radiances with:

(3)other satellite sensors (AIRS, IASI)

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

(3) In situ surface observations (using CrIS atmospheric window channels)



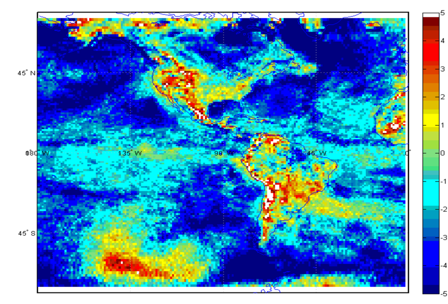


Match-ups with the global radiosonde network is also the backbone of the CrIMSS EDR validation

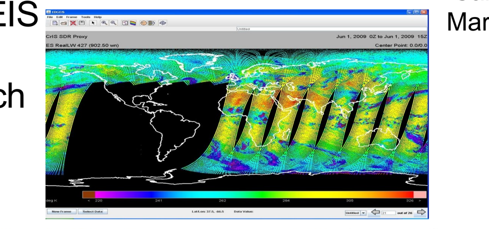
The Cal-Val analysis tools developed following the NPOESS CrIS SDR Cal-Val Plan: NPOESS CrIS Sensor Data Record (SDR) Calibration and Validation Plan – NPP - D47856-01 – Rev B (10/01/2010), a collaborative industry-government effort. Cal-Val tools developed in four areas:
- **(1) Cal/Val Truth Match-ups-via flexible Product Generation Executable (PGE) software**
- **(2) SDR Data Quality and Sensor Trending PGEs**
- **(3) Cal/Val Analysis Tools to Support Radiometric, Spectral and Geolocation Validation**
- **(4) SDR Algorithm Development Area Test and Verification**

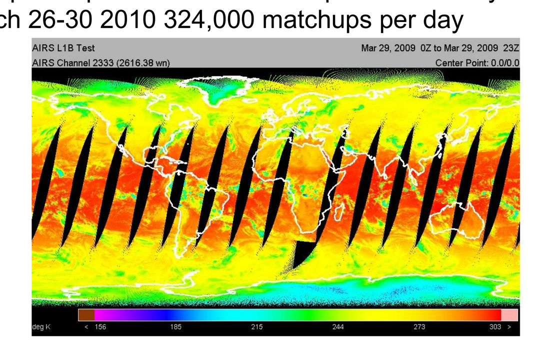
(1) Truth Match-Ups

10 PGEs developed and tailored for SDR/EDR match-ups (tested on heritage data) and integrated into NPOESS Science Investigator-led Processing System (NSIPS) at NSOFS
- PGE0010 -- CrIS EDR/Radiosonde/NCEP GFS Match
- PGE0020 -- CrIS clear fov detection and NCEP RTGSST/SDR match
- PGE0030 -- CrIS clear fov detection and NCEP GFS/SDR match
- PGE0040 -- CrIS EDR Skin temperature retrieval and NCEP GFS surface temp
- PGE0050 -- CrIS SDR capture and subsetting for EDGEIS
- PGE0060 -- IASI/radiosonde/NCEP GFS match
- PGE0070 -- CrIS EDR/radiosonde/NCEPGFS/IASI match
- PGE0080 -- ATMS SDR match to NOAA18 AMSU-A
- PGE0090 -- ATMS SDR match to METOP AMSU-A
- PGE0100 -- ATMS SDR match to NOAA19 AMSU-A

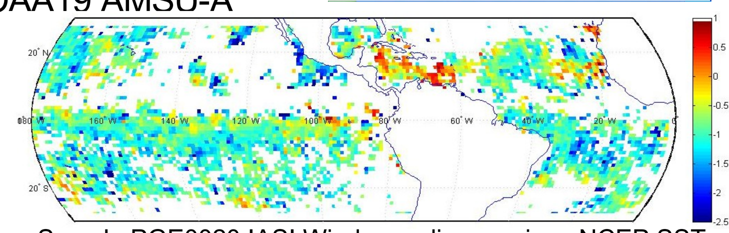


Sample output for PGE0040 Graph shows 4 days March 26-30 2010 324,000 matchups per day





Sample PGE0050 EDGEIS output for 2616 cm^{-1} window channel

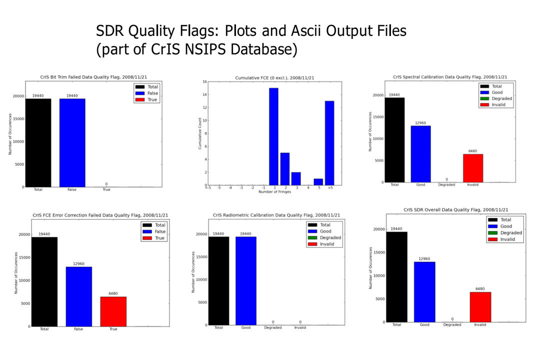


Sample PGE0020 IASI Window radiance minus NCEP SST ~ 6/1- 6/6 2010 (1 degree bin averages) 54905 matchups

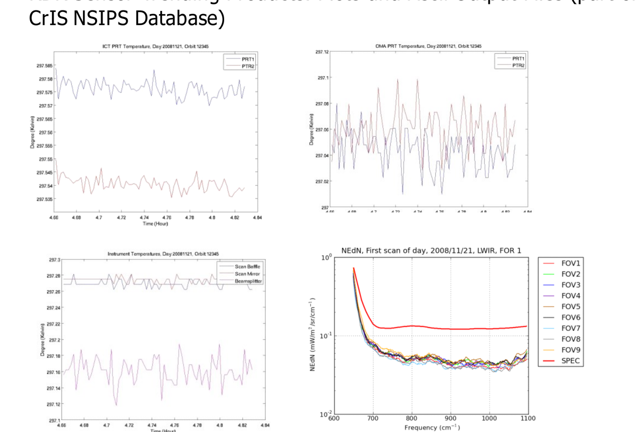
(2) SDR Data Quality and Sensor Trending

3 PGEs tailored for trending sensor parameters and data quality flags
- DQF-A -- data quality flag with quality levels) (tested on TVAC data)
- DQF-B -- data quality flag with floating point values (tested on TVAC data)
- CrIS SDR Trending -- sensor telemetry parameters critical to radiometry, spectral calibration; (tested on TVAC data)

SDR Quality Flags: Plots and Ascii Output Files (part of CrIS NSIPS Database)



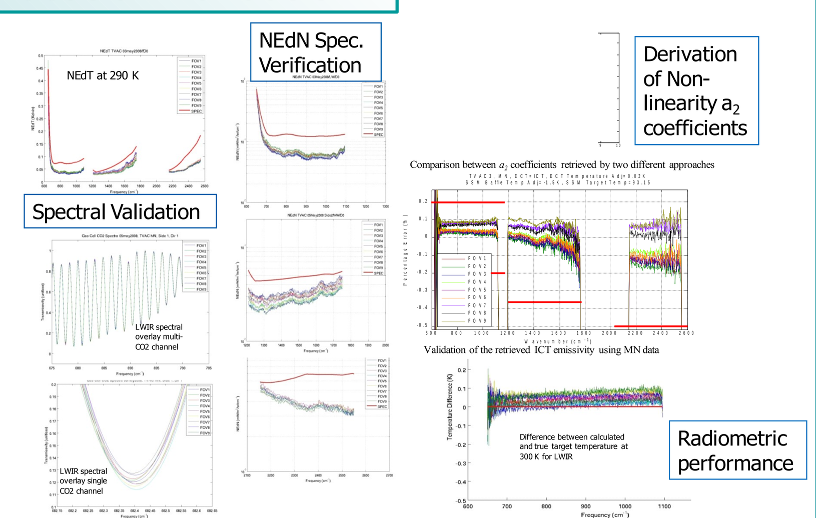
RDR Sensor Trending Products: Plots and Ascii Output Files (part of CrIS NSIPS Database)

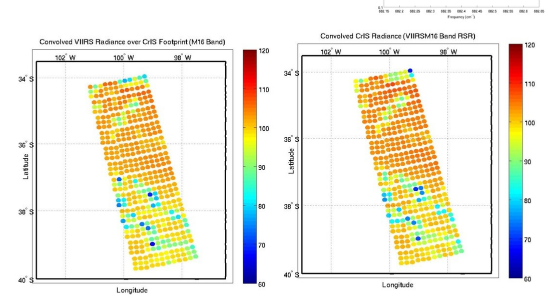


(3) Analysis Tools to Support Radiometric, Spectral and Geolocation Validation

Tools for analyses of PGE output include extraction, trending, subsetting, statistical reduction.

Methods and software tools developed to support sensor characterization during CrIS TVAC being adapted for on-orbit Cal/Val. These include:
- NEdN: using ICT and Deep Space
- Spectral response: Verification of FOV center positions and ILS/spectral overlay
- ICT environmental model verification of performance
- Non-linearity on-orbit characterization, correction, error reduction and optimization using quadratic method and adjustments to linear in-band detectors
- Cross-talk estimation
- Radiance stability from orbit to orbit
- Verification of Earth pointing parameters



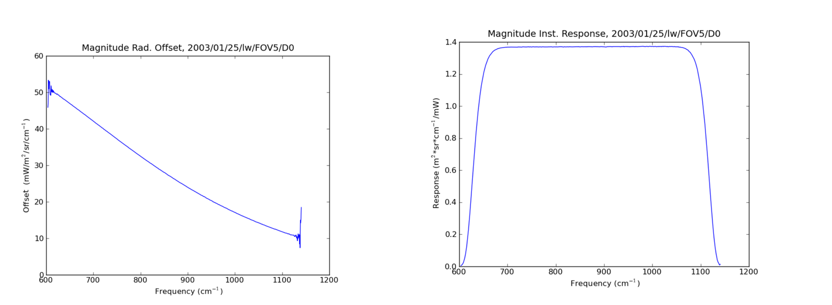


CrIS radiance spectrally convolved with VIIRS RSR

VIIRS radiance spatially convolved with CrIS footprint (after geolocation correction).

(4) SDR Algorithm Development Area Test and Verification

The CrIS SDR algorithm resides offline at NGAS/NSIPS in the Algorithm Development Area, which resembles the operational AIX environment. The SDR code has been modified to extract intermediate products for diagnostic analyses. Multiple products are extracted including instrument response, instrument radiometric offset, integrated magnitude, imaginary part of radiometric ratio (mean and standard deviation).



SUMMARY

CrIS cal/val tools are relatively mature but still operating on heritage, proxy and TVAC data. Tools are being developed to address radiometric, spectral and geolocation calibration.

Tools have been developed in four categories:
- (1) Truth matchups
- (2) SDR data quality and sensor trending PGEs
- (2) Analysis tools for RDR/SDR evaluation, coefficient derivation, higher level processing of PGE outputs
- (3) Diagnostic intermediate product generation from operational SDR code using ADA IBM AIX operating environment

Functionality of PGEs for SDR matchups, data quality monitoring and sensor trending software in place; tested using TVAC, synthetic and CrIS proxy data. Follow-on work needed for:
- Additional tuning for CrIS-specific channels
- Automation of double-differencing methods
- More PGE testing with CrIS proxy (IASI) data
- Automation of spectral calibration using Earth scenes