CDR DEVELOPMENT PROJECT

Enabling Consistent Calibration of Multispectral Solar Reflective Imager Data for Climate Data Record Development Using the Moon

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CDR Team Meeting
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Outline

- Project Description
- Production and QA Approach
- Applications
- Schedule & Issues

Project Description

- Project: An independent evaluation of calibration of visible channel imagers on meteorological satellites using the Moon as a reference source
- Goals: consistent calibration to a common scale; long-term calibration stability with high precision
- Approach: apply established methods of lunar calibration to succession of satellites using archived image data
  - The Moon is an ultra-stable, but non-uniform, solar diffuser
  - To utilize the Moon as a reference requires a lunar model to normalize its varying brightness – USGS lunar irradiance model
  - Lunar calibration analysis provides sensor temporal response trending/correction and cross-comparison with sub-percent precision
- Product: sensor calibration for use in CDR

Project Description

CDR(s)	Period of Record and Temporal Resolution	Spatial Resolution & Projection Used (if applicable)	Update Frequency	Data file distinction criteria	Inputs	Uncertainty Estimates (in percent or error)	Collateral Products (unofficial or unvalidated & produced alongside)
Quantitative calibration assessment for GEO meteor-ological satellite visible channel imagers	January 1995 to present Continuous temporal resolution (analytic form)	Instrument native spatial resolution	Monthly for current operational satellites	Defined by sensor/ satellite; applied to visible and NIR channels	Level-0 image pixels; imaging time-stamps	• 1-2% relative radiometric calibration and inter-instrument bias evaluation • ~5% absolute radiometric calibration • <0.1% per year calibration stability	Cross-comparison with other vicarious calibration methods

Production Approach

- Lunar calibration: comparison of lunar irradiances between measurements taken by sensors and the reference standard provided the USGS lunar model

- Inputs: images of the Moon
  - Captured by chance – coincidence of Moon position with routine imaging schedule; predicted by orbit and ephemeris
  - Dedicated Moon observations – for GOES since 2005 (GOES −10)

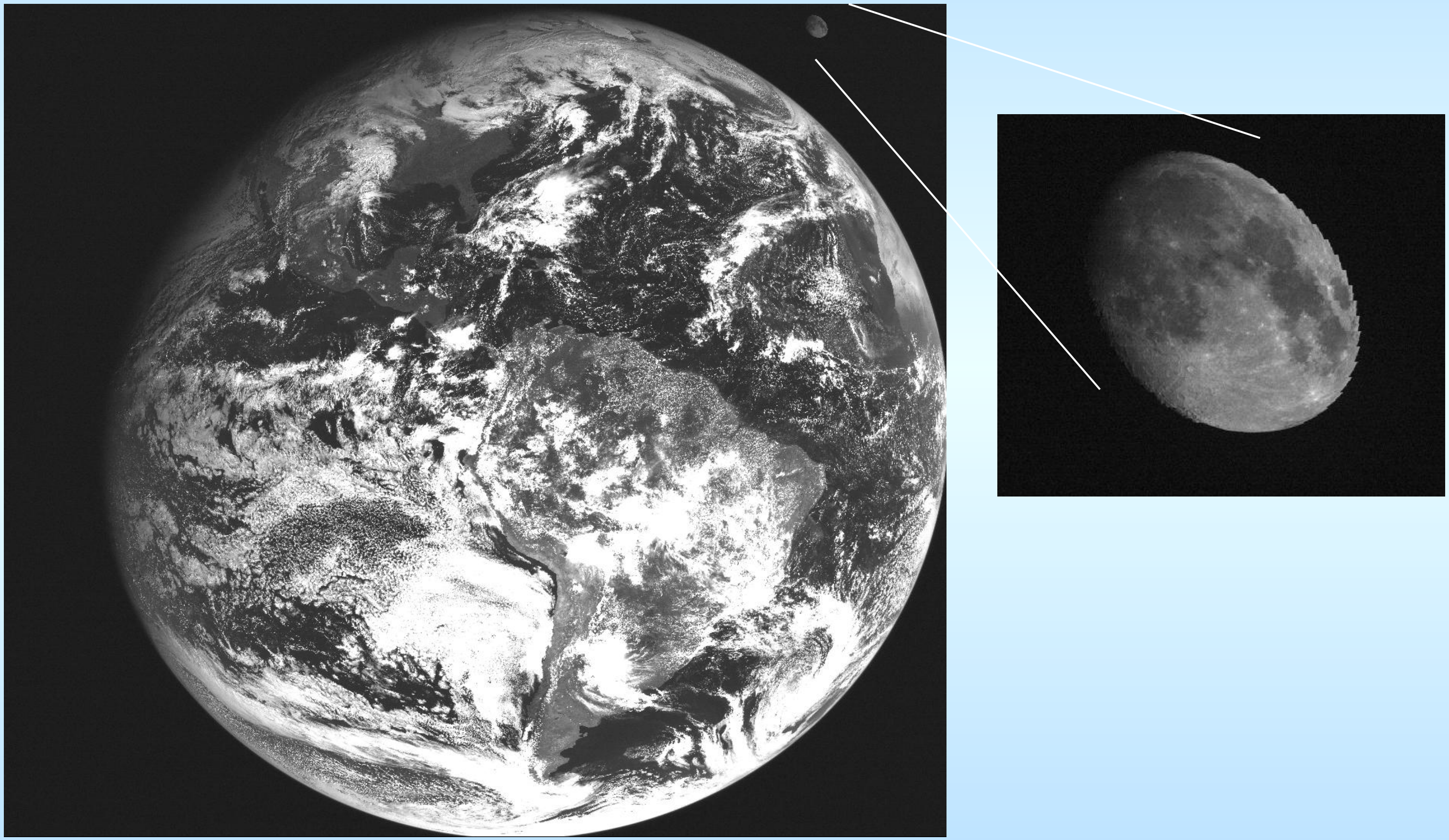
- Measurements from images
  - Spatial integration to irradiance:
  - Pixel conversion to radiance using specified calibration coefficients
  - Selection of pixels on the Moon disk

$$I = \Omega_p \sum_{i=1}^{N_p} L_i$$

L_i = pixel radiance
Ω_p = pixel solid angle
N_p = # of pixels on Moon

Production Approach

GOES−12 2008-11-10 14:45



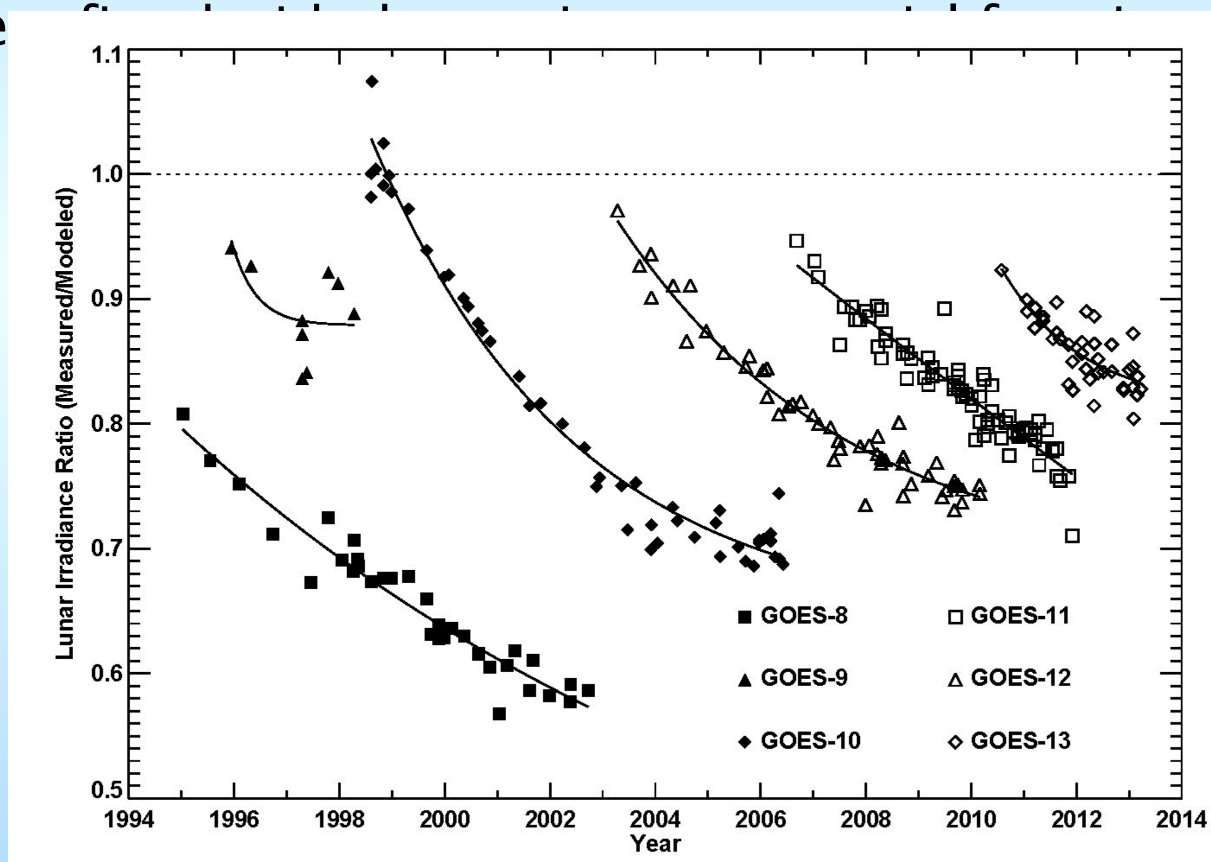
Production Approach

- Model-generated reference lunar irradiance
  - Analytic model form, accommodates any view geometry
  - System inputs: observation time, and instrument (satellite) location @ time; sensor spectral response
  - Model outputs are adjusted for instrument spectral bands, image acquisition properties (e.g. oversampling), actual distances
  - Results are directly comparable to sensor-measured values
- Measurement/model comparisons
  - Normalizes lunar brightness variations (primarily w/phase)
  - Time-series of comparisons reveal sensor response changes
  - Temporal changes are quantified to develop calibration corrections, directly applicable to radiance data products
  - Applying these corrections stabilizes sensor response, allows cross-comparison and inter-satellite bias evaluations

Production Approach

Time series of lunar irradiance comparisons

- Pixel radiance conversion using constant calibration coefficients
- He of time



Production Approach

GOES imager calibrations based on lunar irradiance comparisons

- Quadratic temporal correction to pre-launch calibration coefficients
- Pixel radiance conversion from DN to Watts/m^2 sr μm

$$L_{\text{pix}} = C_t(\text{DN} - \text{DN}_{\text{sp}})$$

$$C_t = C_0\left[a_0 + a_1(t - t_0) + a_2(t - t_0)^2\right]$$

	C_0	t_0	a_0	a_1	a_2
GOES–8	0.5502	04-10-1995	1.269	1.755E-04	0.0
GOES–9	0.5492	08-07-1995	0.996	5.088E-04	-4.166E-07
GOES–10	0.5582	03-21-1998	0.923	3.044E-04	-4.480E-08
GOES–11	0.5562	06-21-2006	1.063	1.213E-04	0.0
GOES–12	0.5771	04-01-2003	1.036	1.902E-04	-2.657E-08
GOES–13	0.6118	04-14-2010	1.062	2.211E-04	-8.676E-08

Validation & Quality Assurance

Uncertainty Evaluations

- Uncertainty in measurements from images
  - Sensor response/radiometric calibration
    - scan mirror angle dependence — consecutive image pairs
  - Lunar disk image pixel selection methods
    - ellipse fitted to lunar limb (skew-corrected images)
    - lunar disk area computed from geometry; check on oversampling
- Uncertainty in lunar model reference values
  - Satellite and Moon/Sun position errors
    - negligible differences seen in lunar model results
  - Accommodation of instrument spectral bands
- Uncertainty in derived calibration corrections
  - Propagation of errors to fitted parameters

Uses & Applications

- Project outcome is a quantitative calibration evaluation for meteorological satellite visible-channel imagers
  - intended users are CDR developers
  - provides consistent and stable calibration
  - enables enhanced data quality and inter-operability of datasets across satellite platforms
- Precision achievable can meet sensor calibration requirements for detecting climate change
  - 0.1% per year calibration stability (NISTIR 7047)
  - on-orbit calibration against a stable external reference provides the only assured means for tracking degradation of optical systems operating in the space environment

Uses & Applications

- Radiance data products (visible wavelengths) potentially gaining enhanced QA for CDR development:
    - Global albedo – particularly cloud amount and optical properties
    - Land cover; snow and ice cover
    - Ocean color – >90% of the radiance received by satellite instruments in blue/green wavelengths originates from atmospheric scattering, thus tightly constrained calibration requirements; SeaWiFS has achieved <0.1% per year calibration stability using the Moon and USGS system
    - Aerosols – e.g. optical depth, scattering properties
    - Vegetation indices – typically differential spectral measurements

Schedule & Issues

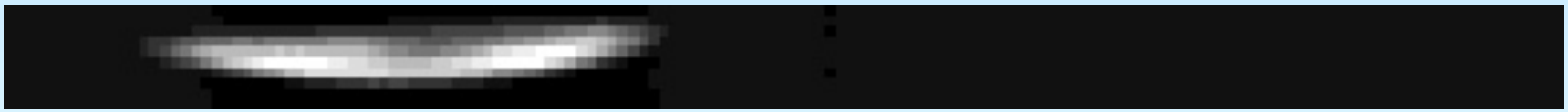
- Accomplishments: Major project tasks have been mostly completed
  - Image processing and lunar calibration analysis done
  - Time-dependent calibrations developed for GOES–8 through GOES–13, Meteosat–8 and 9
  - Uncertainty analysis conducted, propagated to calibration parameters
  - Plan to continue processing current operational GOES (13 and 15) through Fall 2013

- Milestones to finish development & testing
  - “beta version” completed: whitepaper presenting GOES VIS imager calibration expressions
  - Final technical report with calibrations and quantitative uncertainties to be delivered to NOAA by end of this year

- Risks or concerns
  - Not accomplished: applying lunar calibration to AVHRR
    - the Moon is observed by AVHRR in space view, which sets the space clamp level
    - problems evaluating background (space) level with Moon intrusion

- How can the CDR Program better assist you?
  - Disseminate this calibration analysis to CDR developers who use image data from these instruments
  - Current GEO satellites continue to acquire Moon images; how to extend this work?

NOAA−16 AVHRR 2002-12-12 16:37 Ch.2 Space-view



stretch applied to show background level behavior

time ⟶