Comparing Hyperion-Observed with Model-Predicted Lunar Irradiances in Support of GOES-R ABI Calibration

- Preliminary analysis of uncertainties

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Acknowledgement:
GOES-R CWG team members, and
Stuart Frye, Lawrence Ong, Steve Ungar, and Elizabeth Middleton (NASA/GSFC)
S. Miller (CIRA-CSU) T. Stone (USGS)
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GOES-R ABI Instrument

- GOES-R will be launched in 2015
- ABI Covering 16 spectral channels
  - 6 Reflective Solar bands (VIS/NIR), and 10 Emissive Thermal bands (Thermal Infrared)
  - Spatial resolution
    - 0.5 km for the visible band
    - 1 km for the near infrared
    - 2 km for the thermal infrared
### Calibration with Moon for GOES-R ABI

- Photometric stability of the lunar surface, < $10^{-8}$/year.
- Smooth reflectance spectrum (no atmosphere)
- Accessible to all spacecraft and utilizing the full optical path of the spacecraft instrument (overcome limitation of on-board calibration systems)
GOES-R ABI: Moon’s appearance within the annular ring between Earth’s limb margin and the outer boundary of the ABI’s field of regard

Wu et al., 2006
Lunar Spectral Irradiance Models

**ROLO Model vs. Observation**
- USGS ROLO model (Kieffer and Stone, 2005)
  - Collected radiometric measurements for more than 8 years
  - Derived from 32 spectral bands (23 Visible, 9 SWIR)
  - ~ 340 fitting coefficients, mean absolute fit residual is ~1%
  - Supporting various satellite instrument calibration
  - Incorporated
  - Solar source observation
  - Lunar spectral albedo data
  - Covering 0.2-2.8 um spectra with 1-nm resolution.
  - Benchmarked against observation and ROLO model
  - Publically available

**MT2009 Model vs. SeaWiFS, Aqua**
- Miller and Turner, 2009

*Graphs showing spectral irradiance models and comparisons with observations.*
Assessing Lunar Irradiance Models through Comparing with Hyperion Lunar Observation

- 242 spectral channels covering visible and SWIR.
- Pushbroom sensor with two spectrometers. 256 pixels, 30 m on the ground, 7.65 km swath.
- Can be used to integrate the hyperspectral data to synthetic bands equivalent to those of instrument being developed such as GOES-R ABI.
- Observing moon regularly (mostly at moon phase = 7 degree). No atmospheric absorption when observing the moon.

Spectral response functions for 242 channels covering 0.35 to 2.57 um

Visible bands
Near infrared bands
Five Lunar Observations from Hyperion Analyzed

at $\lambda = 579.45$ nm

- Lunar Phase $\sim 7$ degree
- Different view is due to observing the moon from different latitudes.

(2004-12-27)

(2010-01-01)

(2010-06-27)

(2010-12-21)

(2010-04-28)
Mean Lunar Spectral Radiance from Hyperion Observation

MT2009 model
Moon Phase = 7 deg.

\[ L_{Hyp} = \frac{\int_\lambda L_{MT,RSF_{Hyp}}(\lambda)d\lambda}{\int_\lambda RSF_{Hyp}(\lambda)d\lambda} \]

MT2009 model convoluted with Hyperion SRF
Moon’s Reflectance: Hyperion vs. MT2009 Model

\[ \rho = \frac{\pi L(\lambda)d^2}{E_{\text{Sun}}} \]

- Lambertian Surface
- Reflectance is relatively consistent with that from MT2009 model
- Different detectors between Visible and SWIR bands contribute to discrepancies.
- Anomalies (1.35 - 1.42 um), (1.82-1.93 um), appear to be correlated with atmospheric water absorption bands [Datt et al., 2003] (possibly over-compensated from prelaunch calibration)
Visible band differences are similar (5-10%), SWIR band differences above 2 um are different. Overall difference is 5-10%.
Supporting Lunar Calibration of GOES-R ABI Instrument

ABI Spectral Response Function Bands (1-6)
Expected Lunar Irradiance for GOES-R ABI Bands as Derived from Hyperion, ROLO, and MT2009

Date: 2016-04-22 18:26:01, Moon-Phase ~7 degree

ROLO model prediction is obtained from Stone [2011] to NOAA.
Distribution of lunar appearance events for ABI used for MT2009 and ROLO model comparison

Lunar Phase Angle Occurrence (164 cases in total)

Lunar Libration
MT2009 vs. ROLO (Model-to-Model) Differences and Uncertainties for GOES-R ABI Channels

Over all lunar Phase Angles

- Difference depends strongly on the wavelength bands.
  - Difference is the largest for infrared band $\lambda > 2\mu m$;
- Uncertainty is large
- Need to differentiate the contributions from different lunar phases to the overall difference
Lunar Phase Angle Dependence

- Lunar phase: angle between Sun-Moon vector and Moon-satellite vector
- Lunar phase is signed: Waning (+), Waxing (-)

Schmidt and Walter, 2009
MT 2009 vs. ROLO Model Difference depends on lunar phases and wavelength: large differences for waning lunar phase and near full moon due to opposition effect.
MT2009 vs. ROLO (Model-to-Model) Differences and Uncertainties for GOES-R ABI Channels

- For lunar phase < 30 deg., the model-to-model difference < 5% for visible band;
- The model-to-model difference is large for lunar phase > 30 deg. or infrared band \( \lambda > 2 \text{um} \);
- Uncertainty is large for \(|\text{lunar phase}| < 10 \text{ deg.}| \);
Summary

- Performed uncertainty analysis of lunar irradiance for GOES-R ABI instrument with data from Hyperion, MT2009 and ROLO models.
- Performed statistical model-to-model comparison between MT2009 and ROLOR models for ABI channels.
- Lunar calibration is promising, but more work is needed to improve accuracy and precision.