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

- Preliminary analysis of uncertainties

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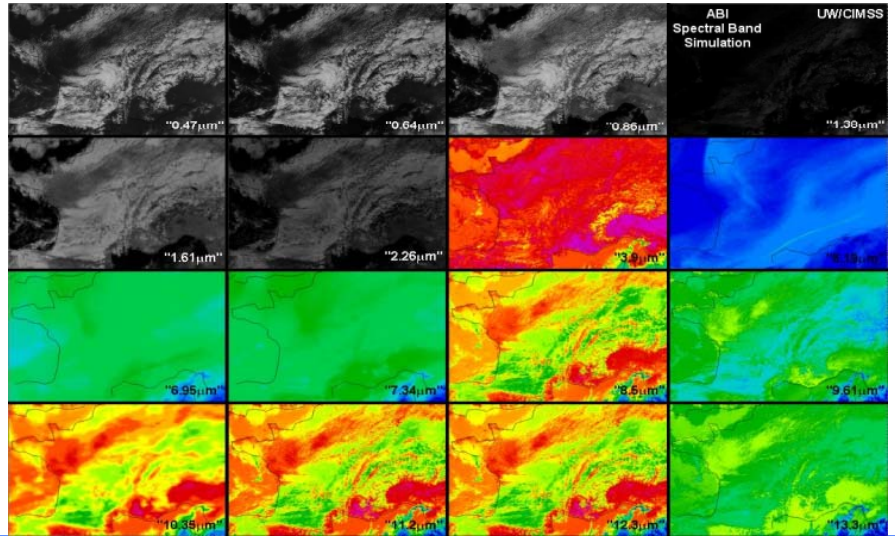
S. Miller (CIRA-CSU) T. Stone (USGS)

Outline

- GOES-R ABI instrument and the need for lunar calibration
- Assessing lunar irradiance models through comparison with Hyperion lunar observation
- Statistical comparison between lunar irradiance model predictions for GOES-R

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

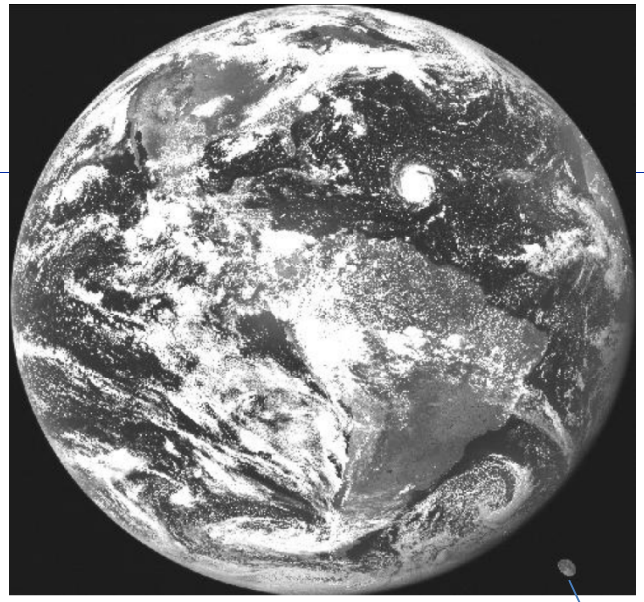


UW/CIMSS

Calibration with Moon for GOES-R ABI

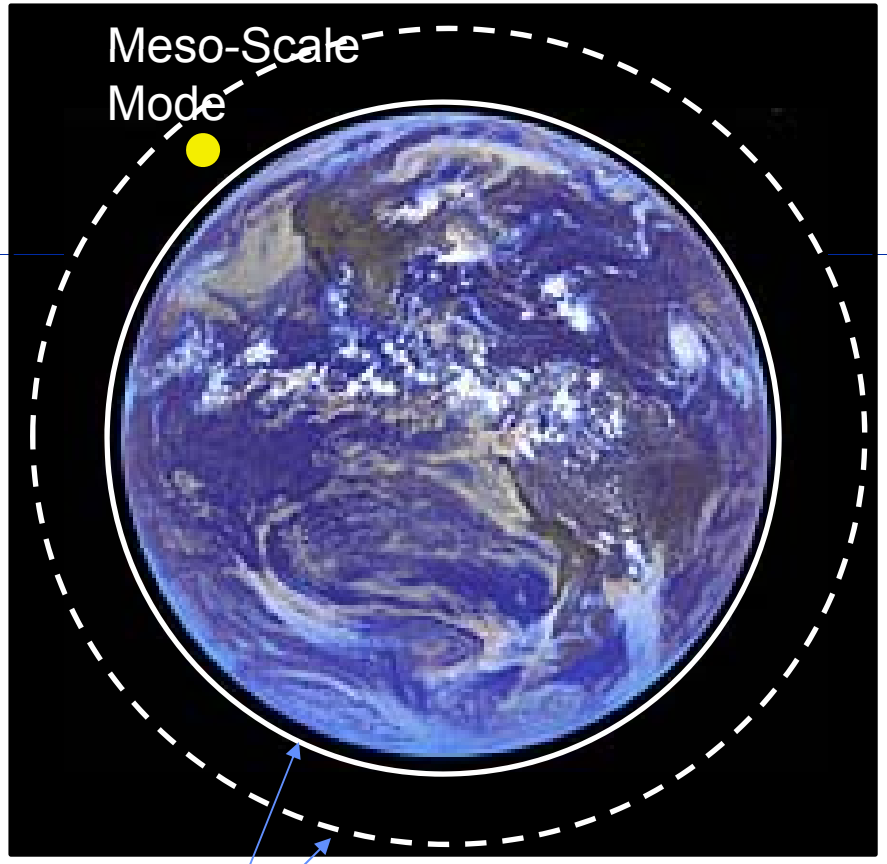
- Photometric stability of the lunar surface, < 10^{-8} /year.
- Smooth reflectance spectrum (no atmosphere)
- Accessible to all spacecraft and utilizing the full optical path of the spacecraft instrument (overcome limitation of on-board calibration systems)

Lunar Appearance in GOES-R ABI Field of Regard (FOR)



GOES-12 Observation

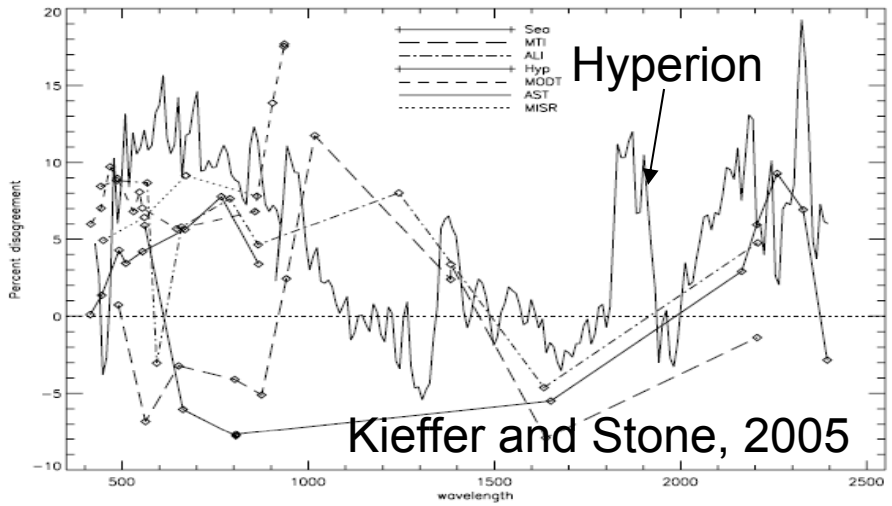
Wu et al., 2006



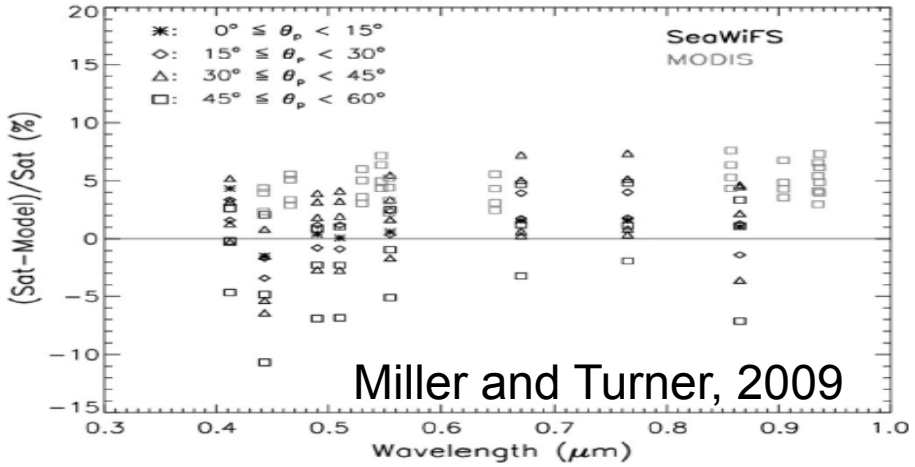
GOES-R ABI: Moon's appearance within the annular ring between Earth's limb margin and the outer boundary of the ABI's field of regard

Lunar Spectral Irradiance Models

ROLO Model vs. Observation



MT2009 Model vs. SeaWiFS, Aqua

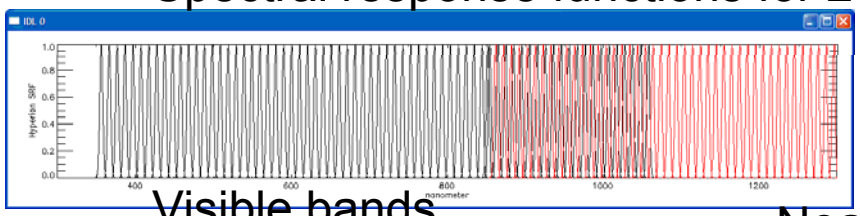


- USGS ROLO model (Kieffer and Stone, 2005)
  - Collected radiometric measurements for more than 8 years
  - Derived from 32 spectral bands (23 Visible, 9 SWIR)
  - ~ 340 fitting coefficients, mean absolute fit residual is ~1%
  - Supporting various satellite instrument calibration
- Miller-Turner (2009) (MT2009) model
  - 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

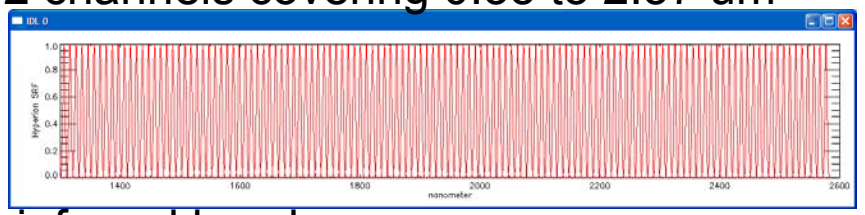
Assessing Lunar Irradiance Models through Comparing with Hyperion Lunar Observation

- Hyperion is on-board of the Earth Observing One (EO-1) Mission, launched in November, 2000.
- 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 λ = 579.45 nm

(2004-12-27)

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

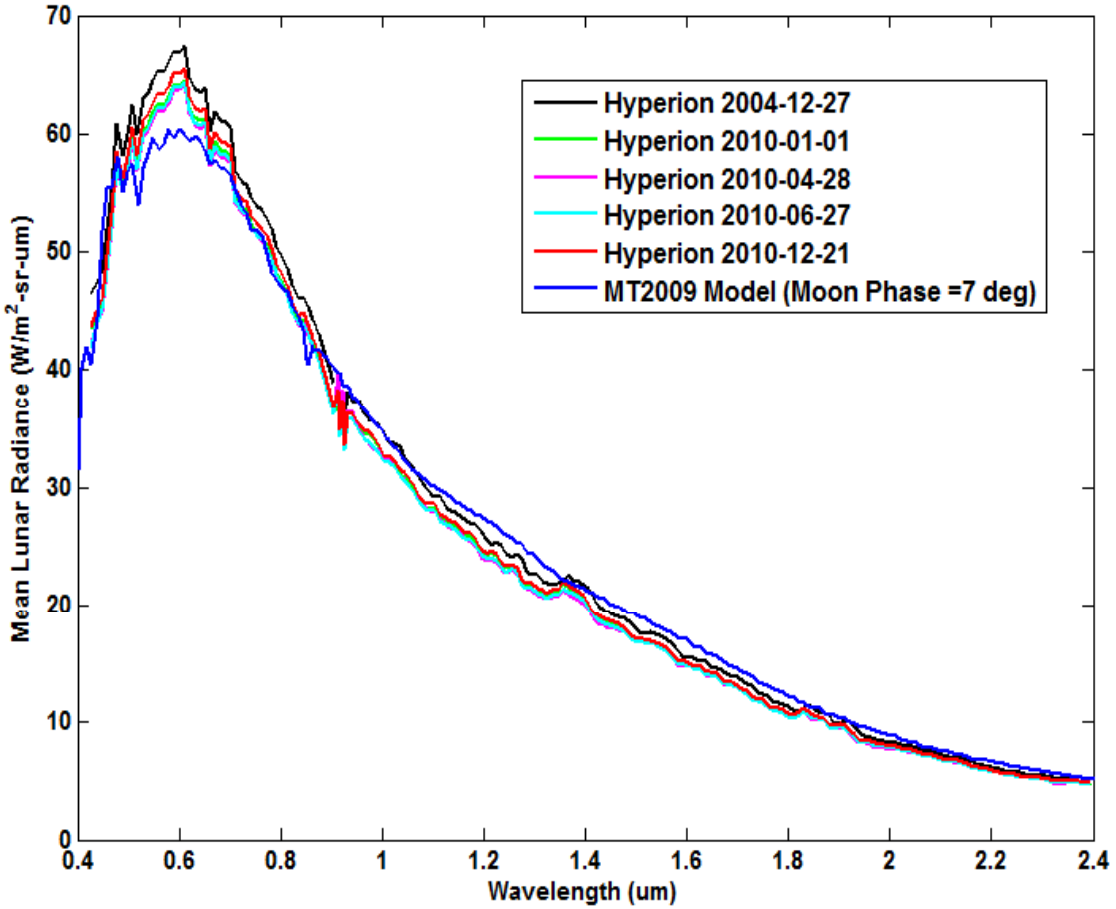
(2010-01-01)

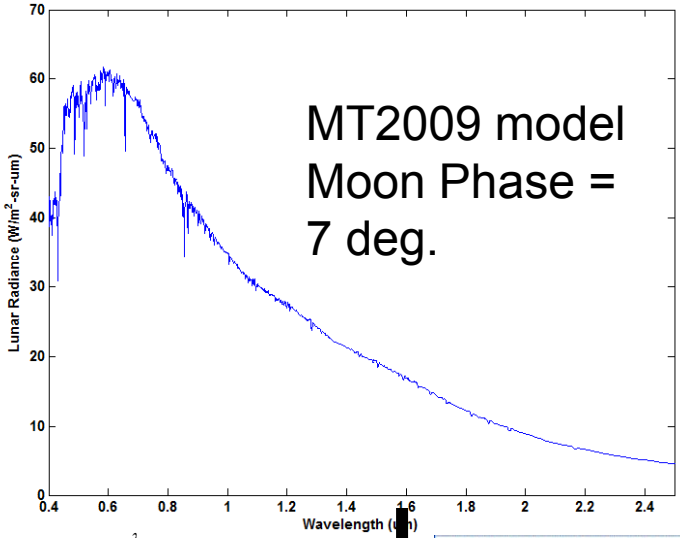
(2010-04-28)

(2010-06-27)

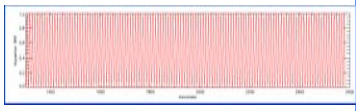
(2010-12-21)

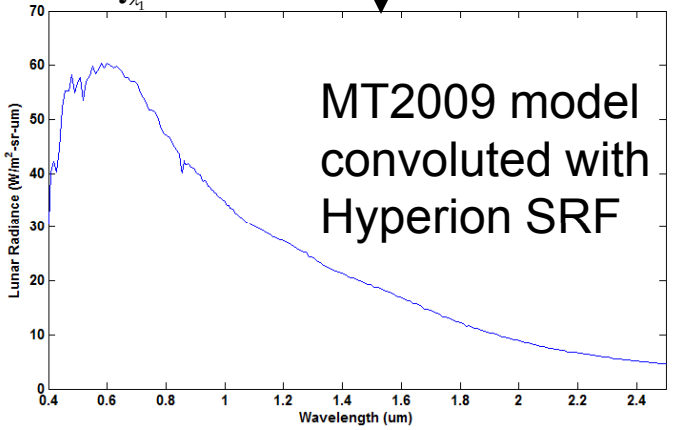
Mean Lunar Spectral Radiance from Hyperion Observation





$$L_{Hyp} = \frac{\int_{\lambda_1}^{\lambda_2} L_{MT.} RSF_{Hyp}(\lambda) d\lambda}{\int_{\lambda_1}^{\lambda_2} RSF_{Hyp}(\lambda) d\lambda}$$

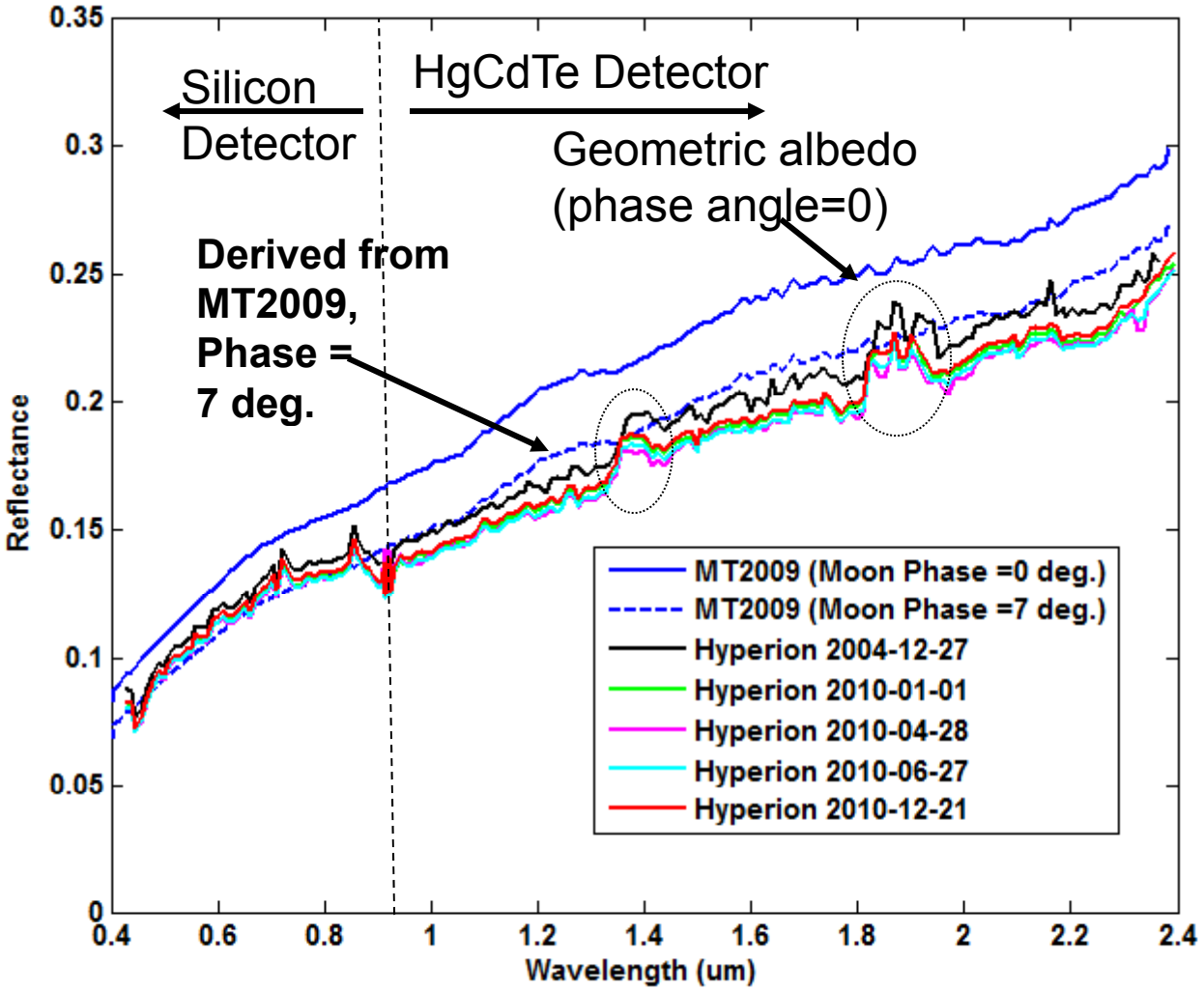




Moon's Reflectance: Hyperion vs. MT2009 Model

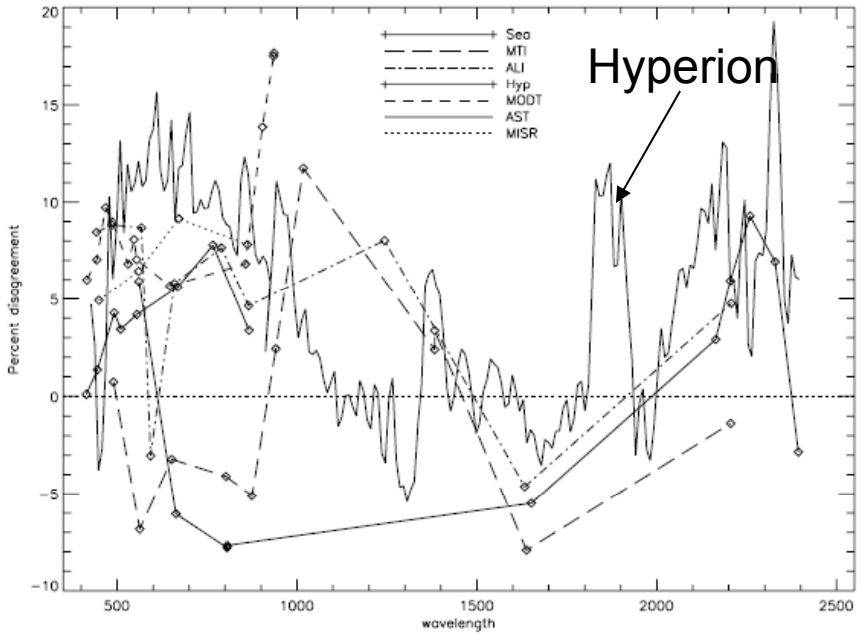
$$\rho = \frac{\pi L(\lambda) d^2}{Esun}$$

- 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)



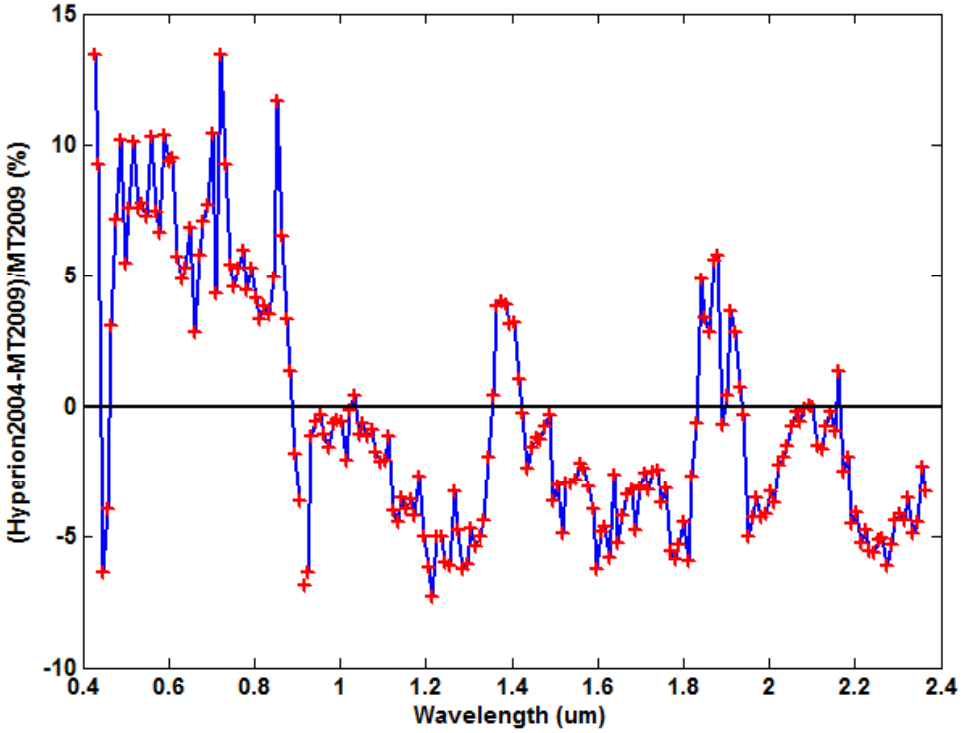
Assessing Model-Hyperion Observation Difference

ROLO Model vs. Hyperion



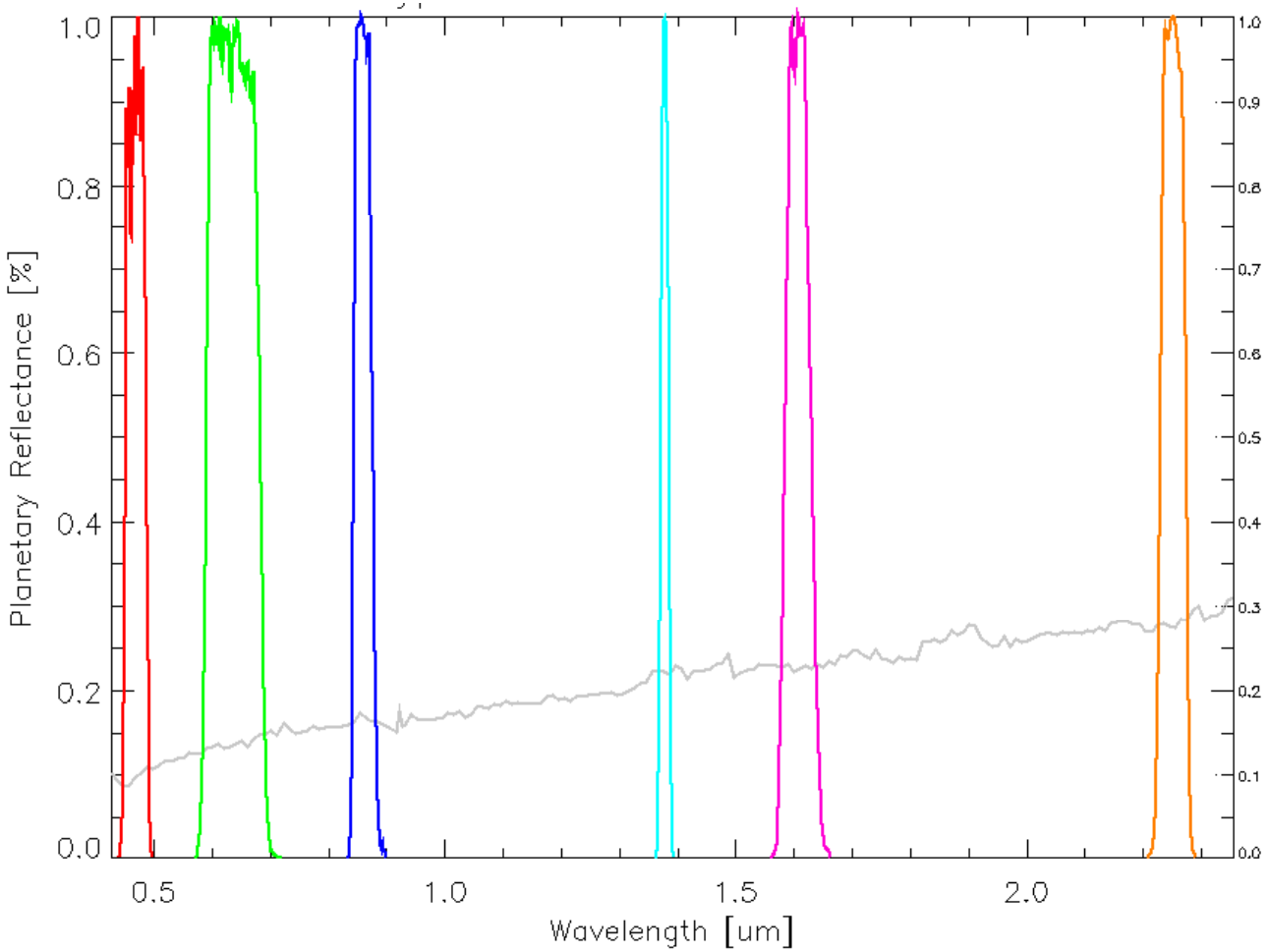
Kieffer and Stone, 2005

Difference between Hyperion 2004 Reflectance and Derived Reflectance from MT2009



• Visible band differences are similar (5-10%), SWIR band differences above 2 um are different. Overall difference is 5-10%.

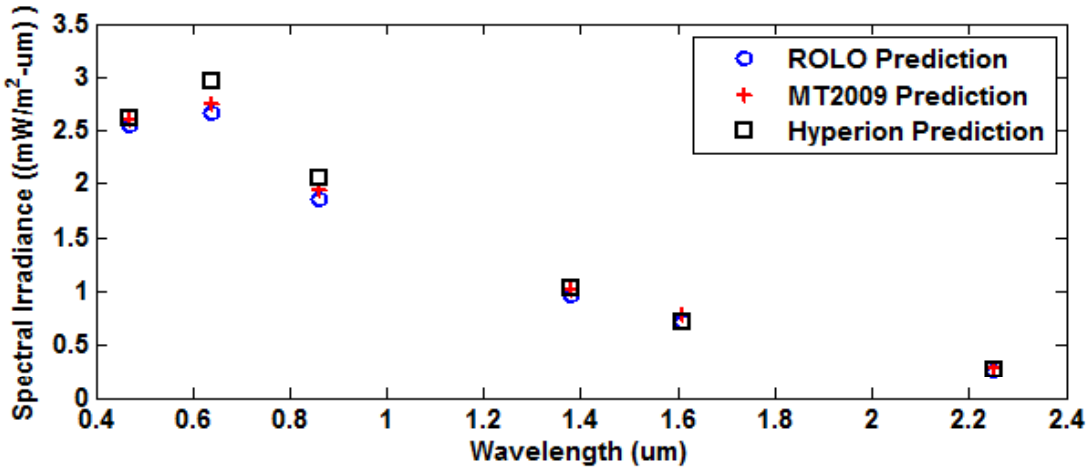
Supporting Lunar Calibration of GOES-R ABI Instrument

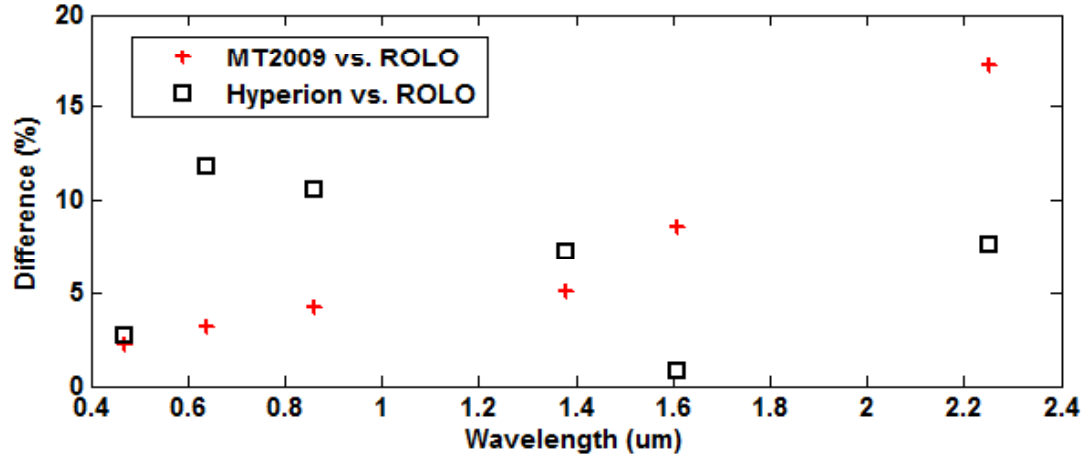


ABI Spectral Response Function Bands (1-6)

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

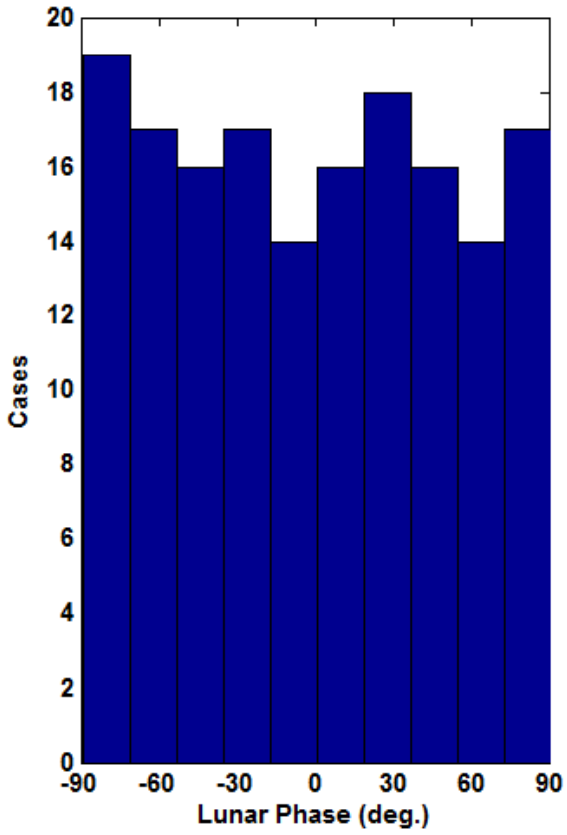


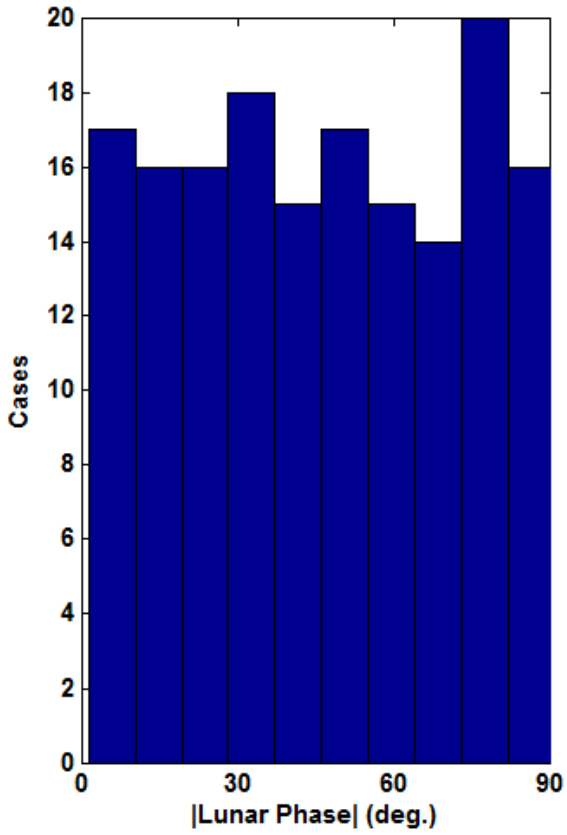


ROLO model prediction is obtained from Stone [2011] to NOAA.

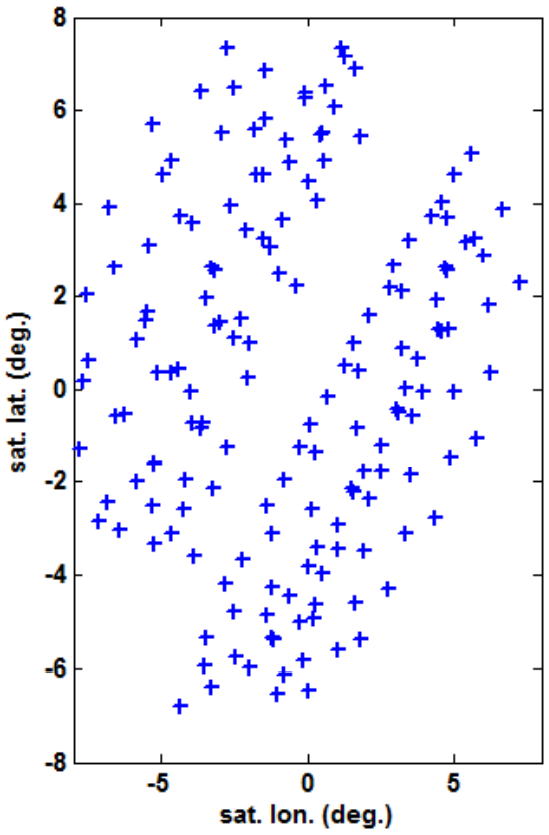
Distribution of lunar appearance events for ABI used for MT2009 and ROLO model comparison

Lunar Phase Angle Occurrence (164 cases in total)



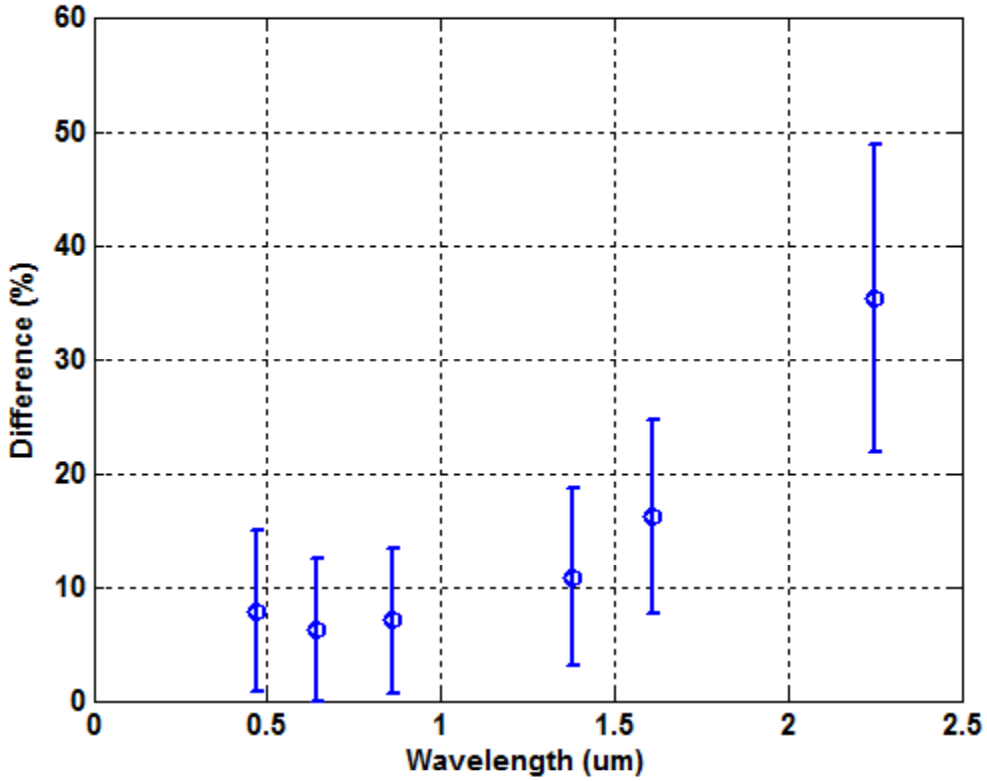


Lunar Libration



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

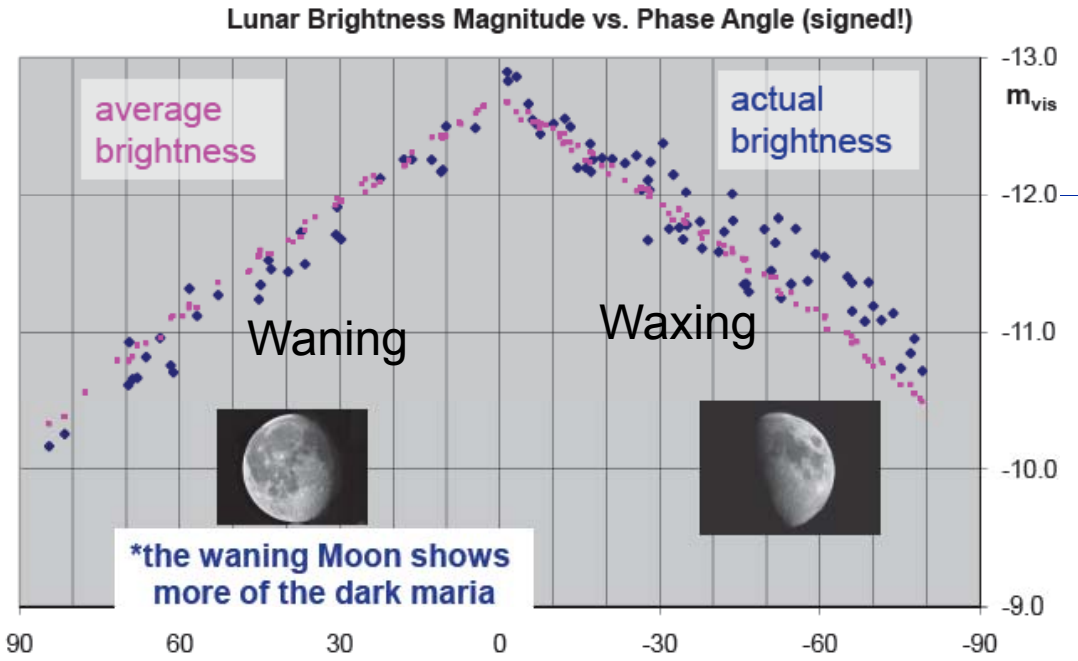
Over all lunar Phase Angles

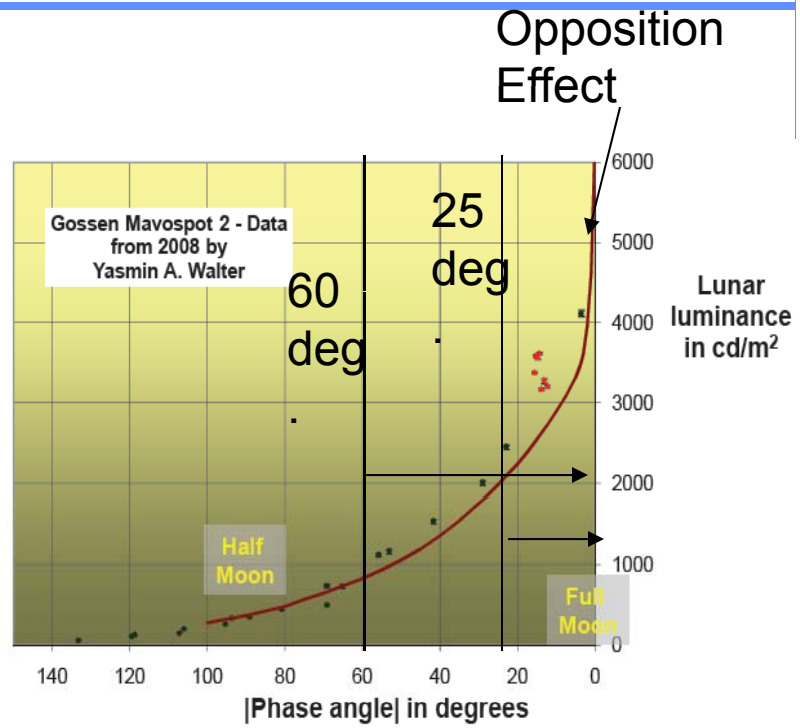


GOES-R ABI Channels

- Difference depends strongly on the wavelength bands.
  - Difference is the largest for infrared band λ> 2um;
- Uncertainty is large
- Need to differentiate the contributions from different lunar phases to the overall difference

Lunar Phase Angle Dependence



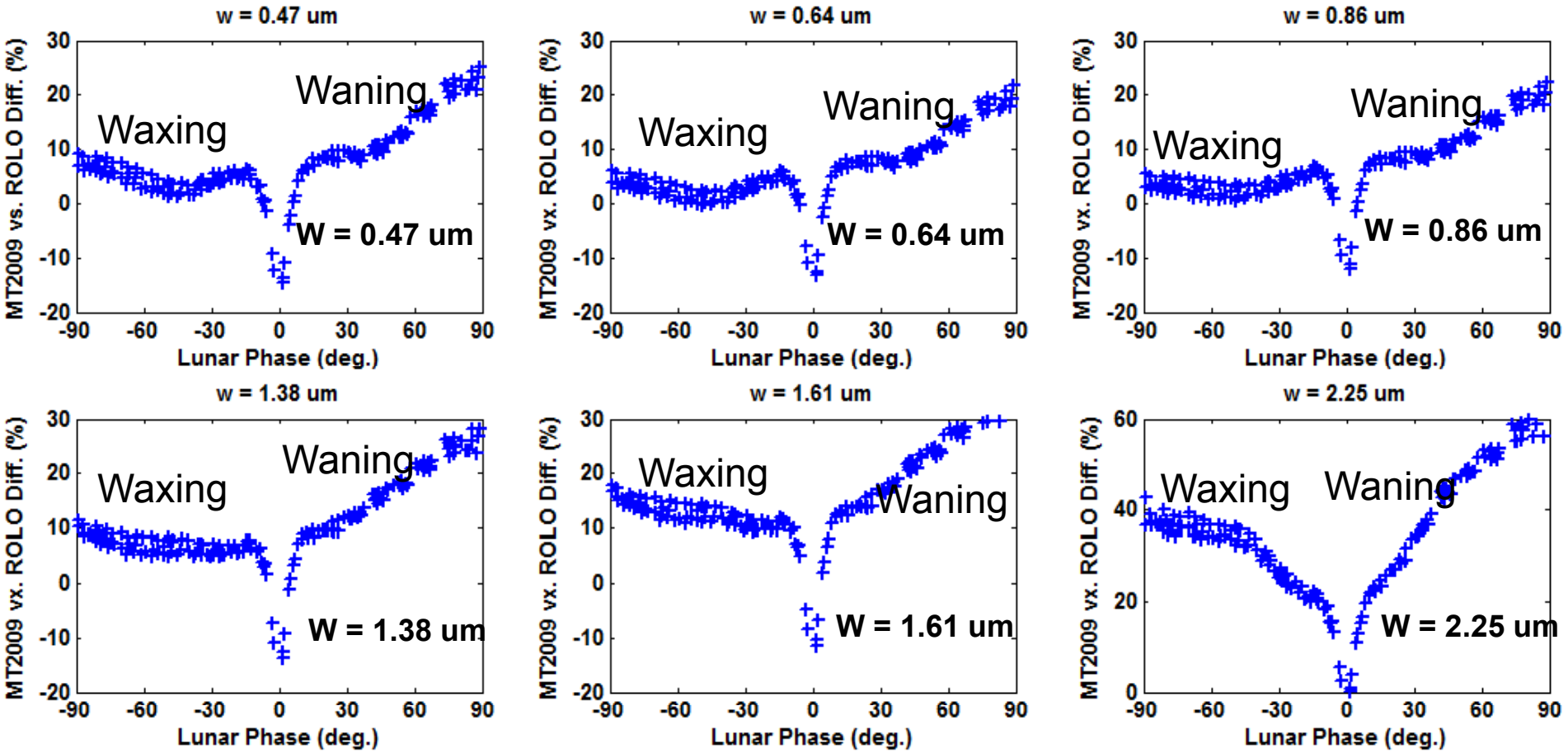


Lunar Phase Angle

Schmidt and Walter, 2009

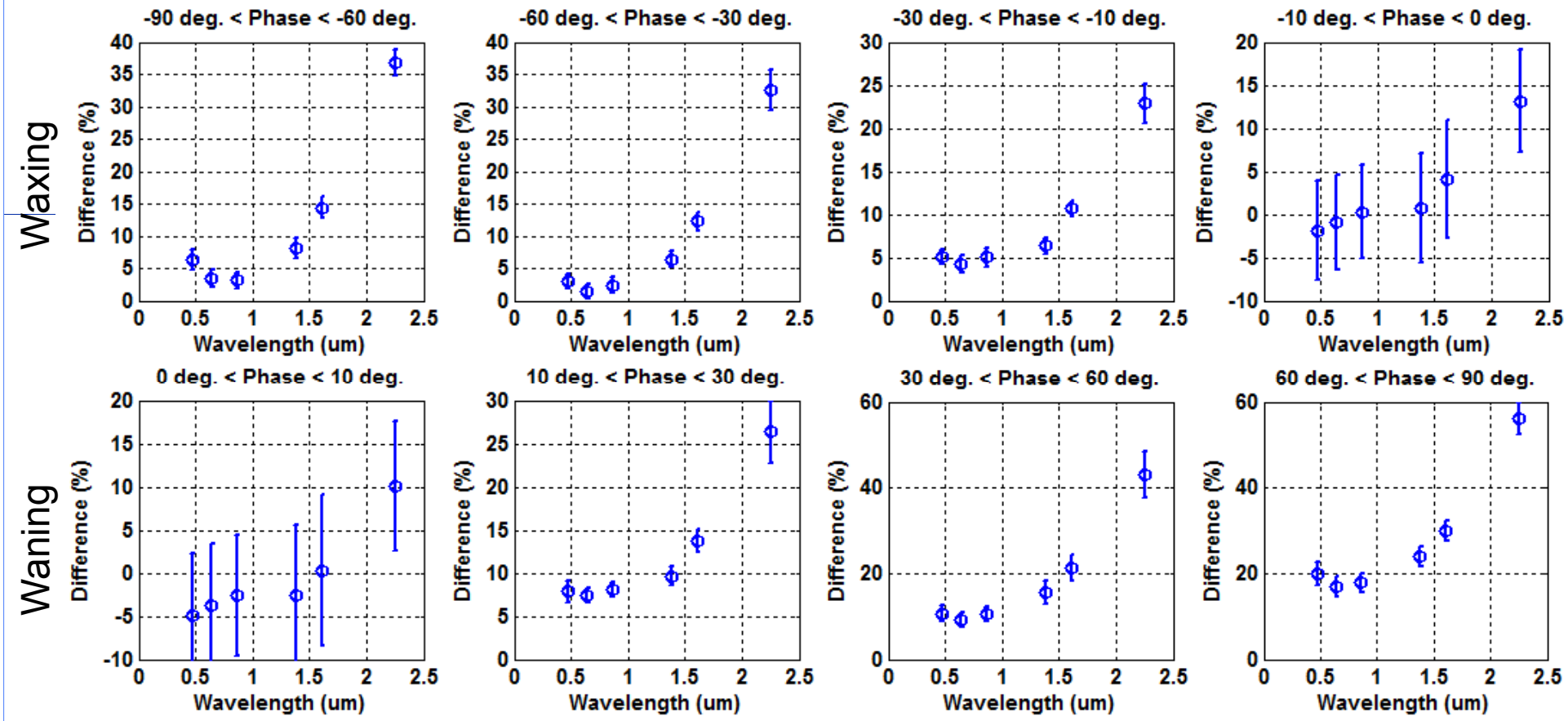
- Lunar phase: angle between Sun-Moon vector and Moon-satellite vector
- Lunar phase is signed: Waning (+), Waxing (-)

MT2009 vs. ROLO Model Comparison for GOES-R ABI Channels



• 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 λ> 2um;

  Uncertainty is large for |lunar phase| < 10 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.