Use of the Moon as a calibration reference for NPP VIIRS

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Background

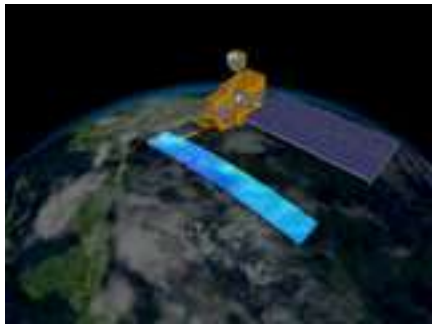
- Ocean color remote sensing imposes very stringent requirements on radiometric stability.
- SeaWiFS and MODIS have successfully used regular lunar observations to monitor radiometric stability in visible and (for SeaWiFS) NIR bands.
- VIIRS will be the source of Ocean Color continuity data sets, starting with the NPP launch in 2008.
- These and other sensors (e.g., ALI) have also used the Moon as a cross-calibration reference.
- Lunar observations utilize the model of spectral reflectance developed by USGS; this model has been validated over a small (few degrees) range of phase angles.

VIIRS Lunar Observation Approach

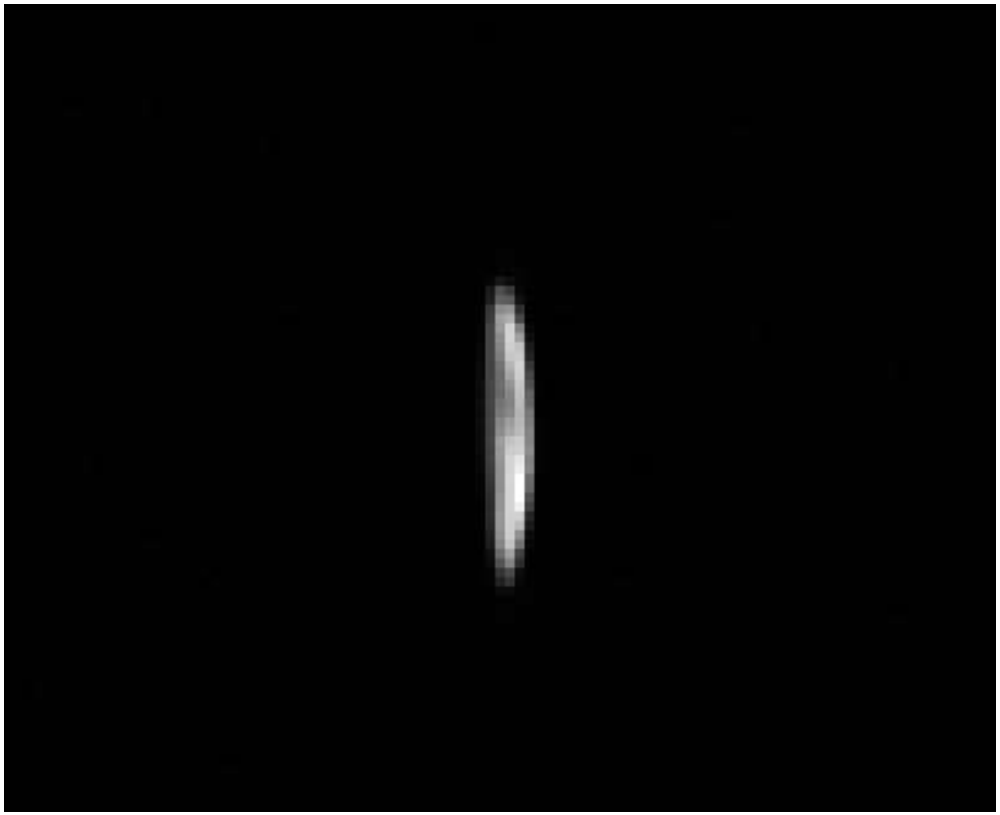
- VIIRS, like MODIS will observe the Moon through the Space View port.
- 8 or 9 observations are available per year.
- The following slide shows a MODIS observation of the moon

All Detectors (Band 8, 412nm)

MODIS scan:



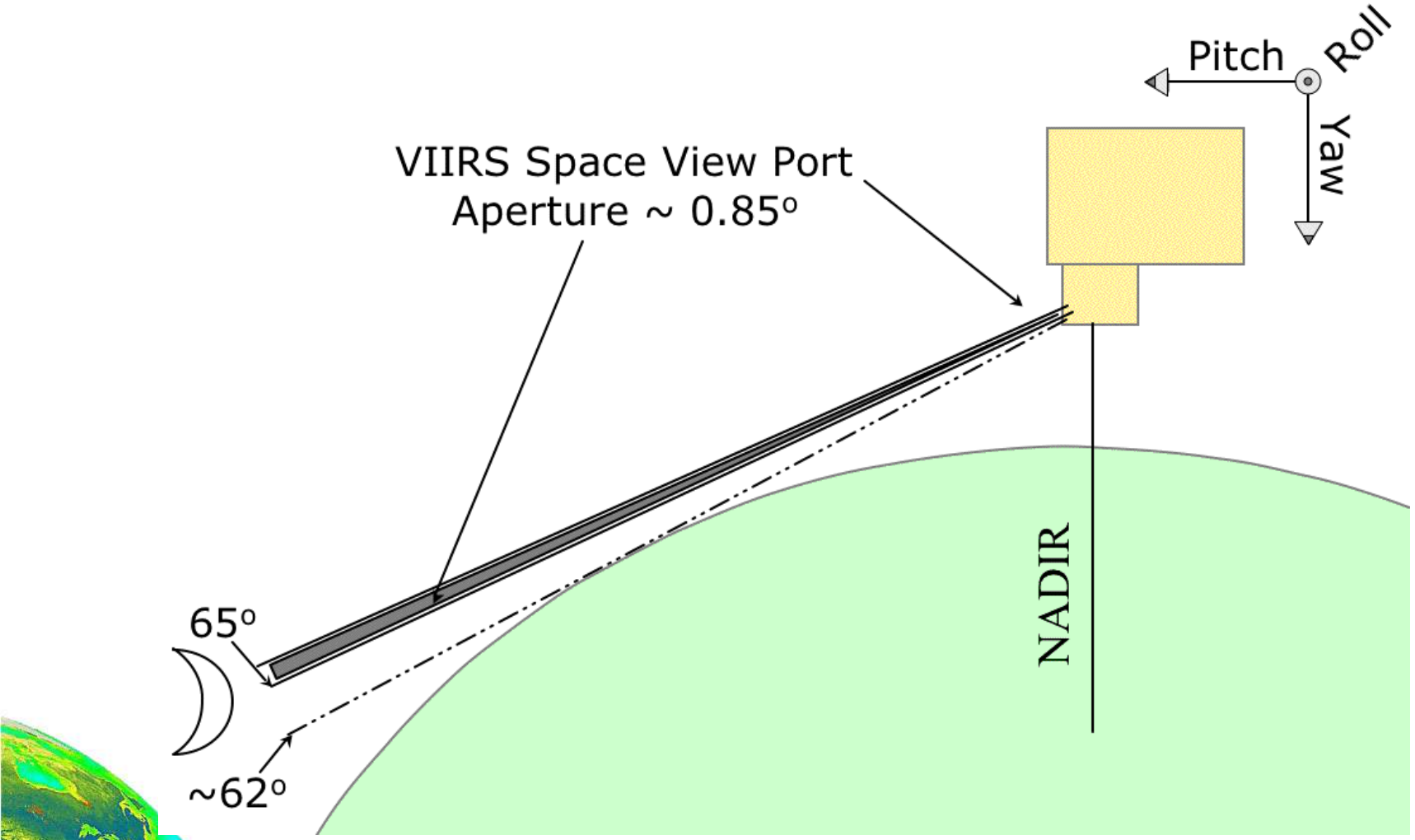
One detector:



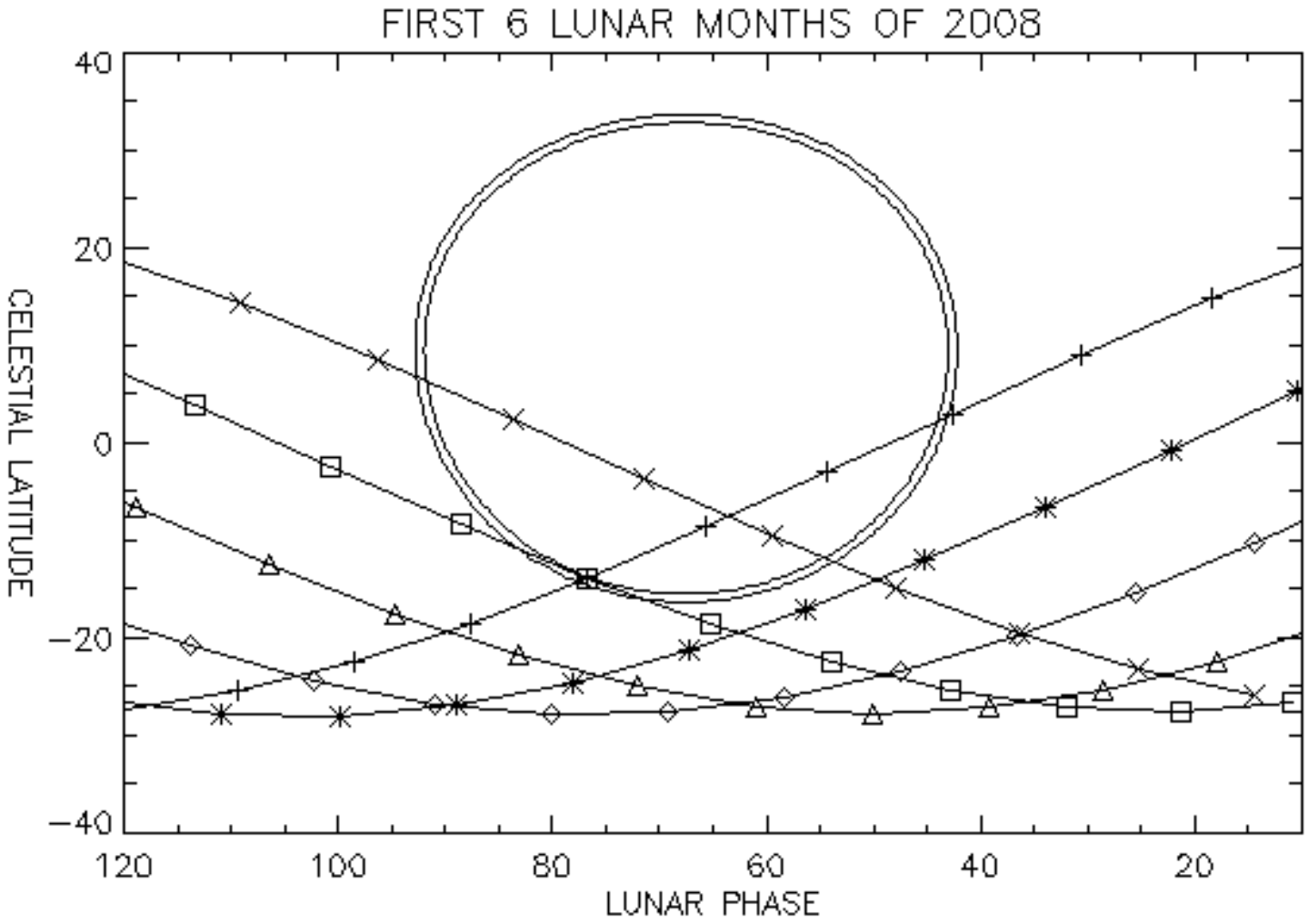
VIIRS Lunar Observation Approach

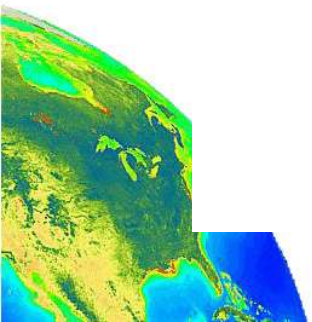
- At the nominal (nadir-pointing) spacecraft attitude, observations will occur over a range of phase angles > 10 degrees.
- Roll maneuvers are required to limit the phase angle range; a phase of 55 degrees is needed to support cross-comparisons with MODIS.

VIIRS Space View Port Geometry

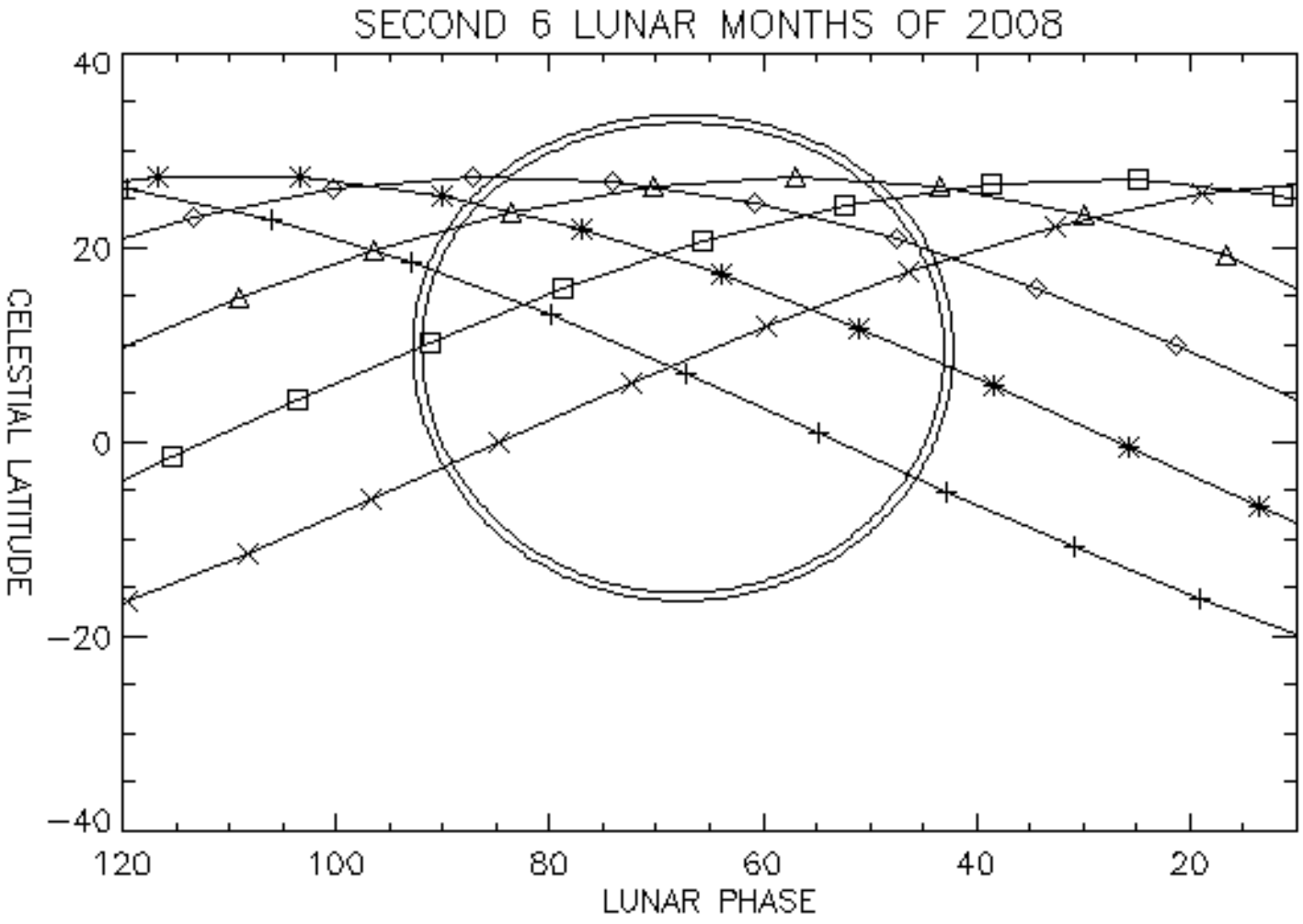


VIIRS Lunar Views in 1st Half of 2008

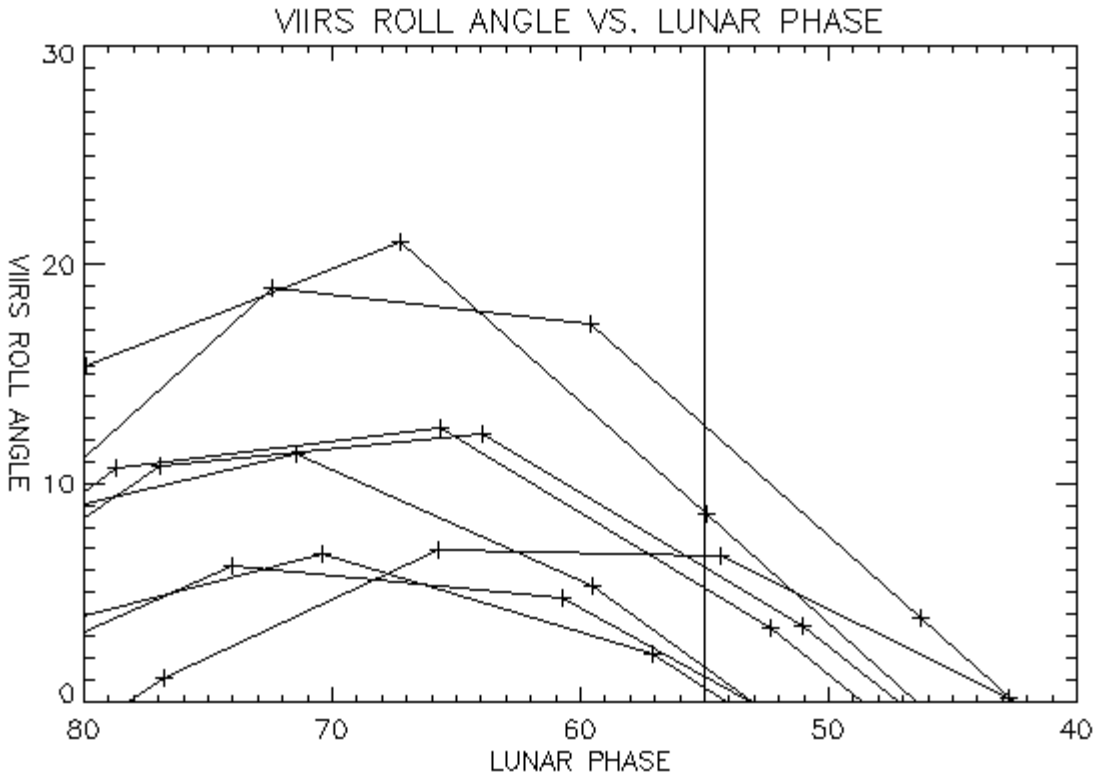




VIIRS Lunar Views in 2nd Half of 2008



Required Roll Angles for 55° Lunar Phase

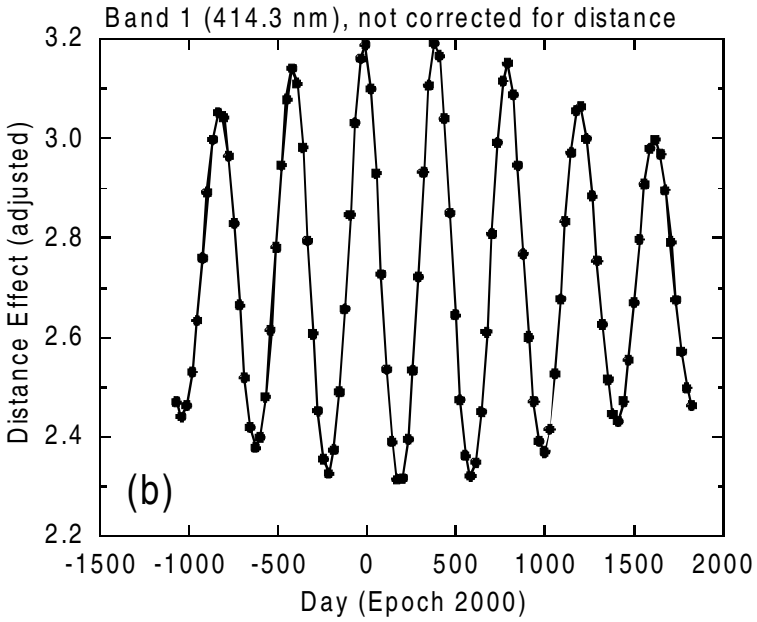


The USGS Lunar Model

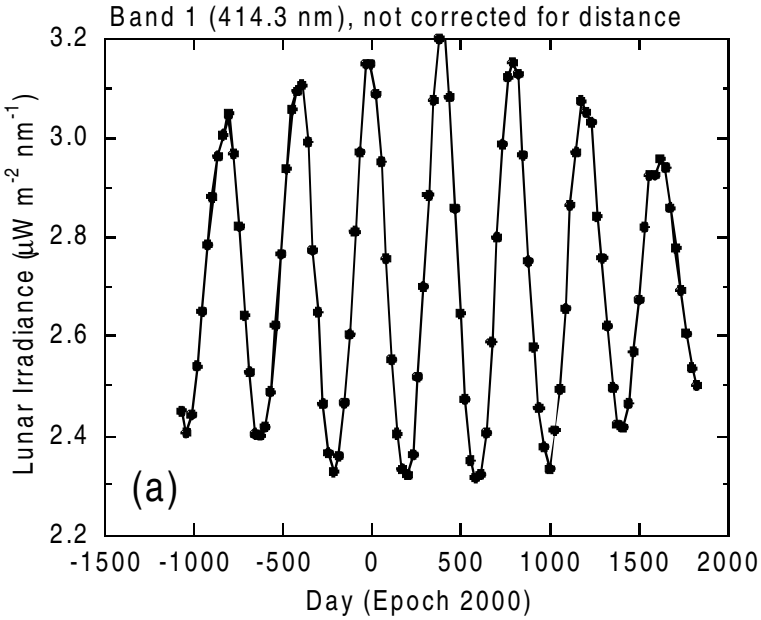
- H. Kieffer et al. have developed a lunar irradiance model to account for reflectance changes with lunar phase and libration.
- This model has been used with considerable success, but only for a small range of phase angles; for MODIS this range has been centered at 55 degrees.
- The model does not currently support the full range of VIIRS reflective bands, but can be extended for this purpose (ALI used as surrogate).
- Reference stability is <0.1%/year, assuming limited phase range.

“Flatness” of the Lunar Reference

Distance Effect



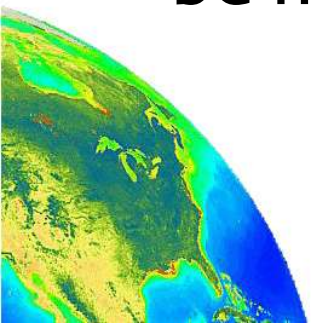
Lunar irradiance



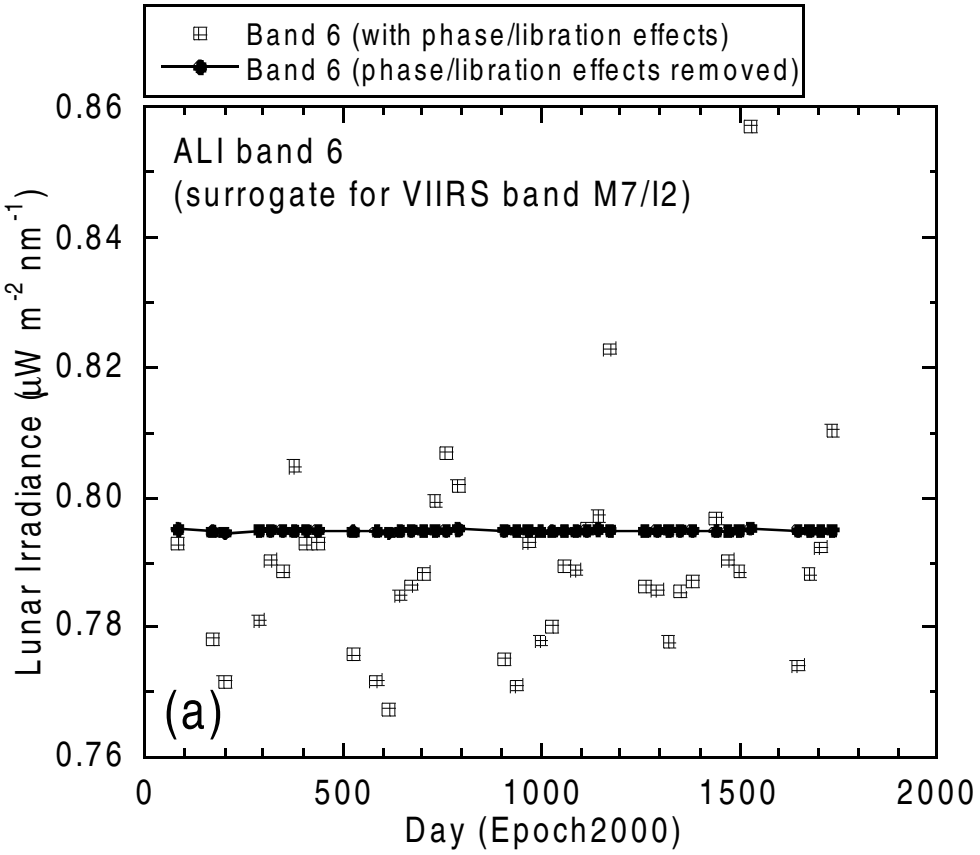
Phase and libration changes depend on 4 input parameters in the USGS lunar model

“Flatness” of the Lunar Reference

- Comparisons with the lunar model are made for the time and location of the satellite instrument.
- They include phase and libration effects
- The analysis presented here gives an estimate of the “flatness” of the lunar reference.
- The lunar measurements by the satellite instrument can provide a quality control check for phase and libration effects in the model. Look for phase and libration dependencies in the comparison results. An extended series of satellite measurements may be necessary

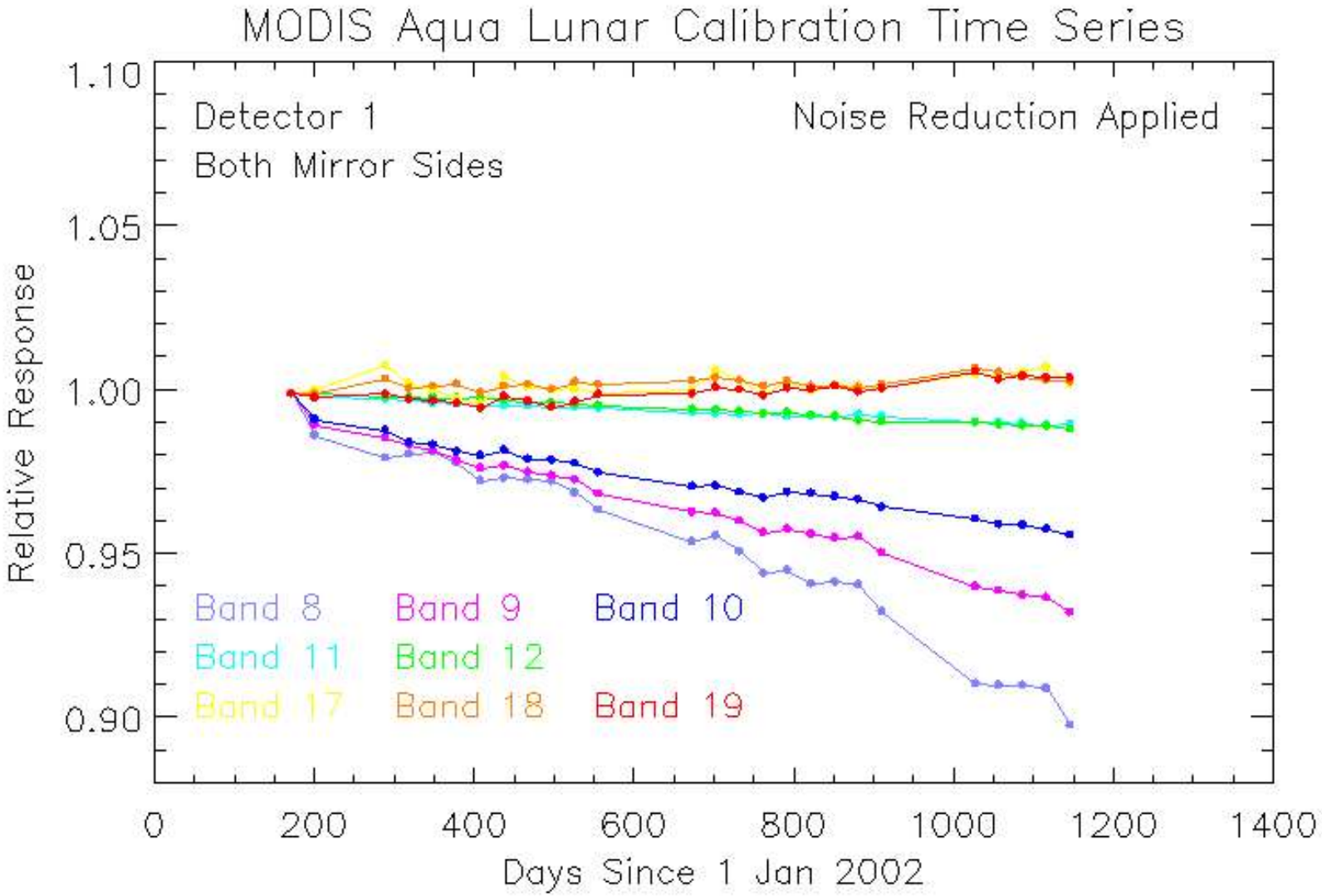


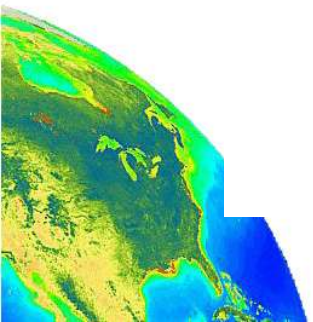
Lunar Model Results for ALI Band 6 (866 nm)



41 measurements, phase angles from 52° to 56°
Squares – model values (including phase/libration)
Circles – model values (phase/libration effects removed)

Corrected Lunar Measurements for MODIS Aqua

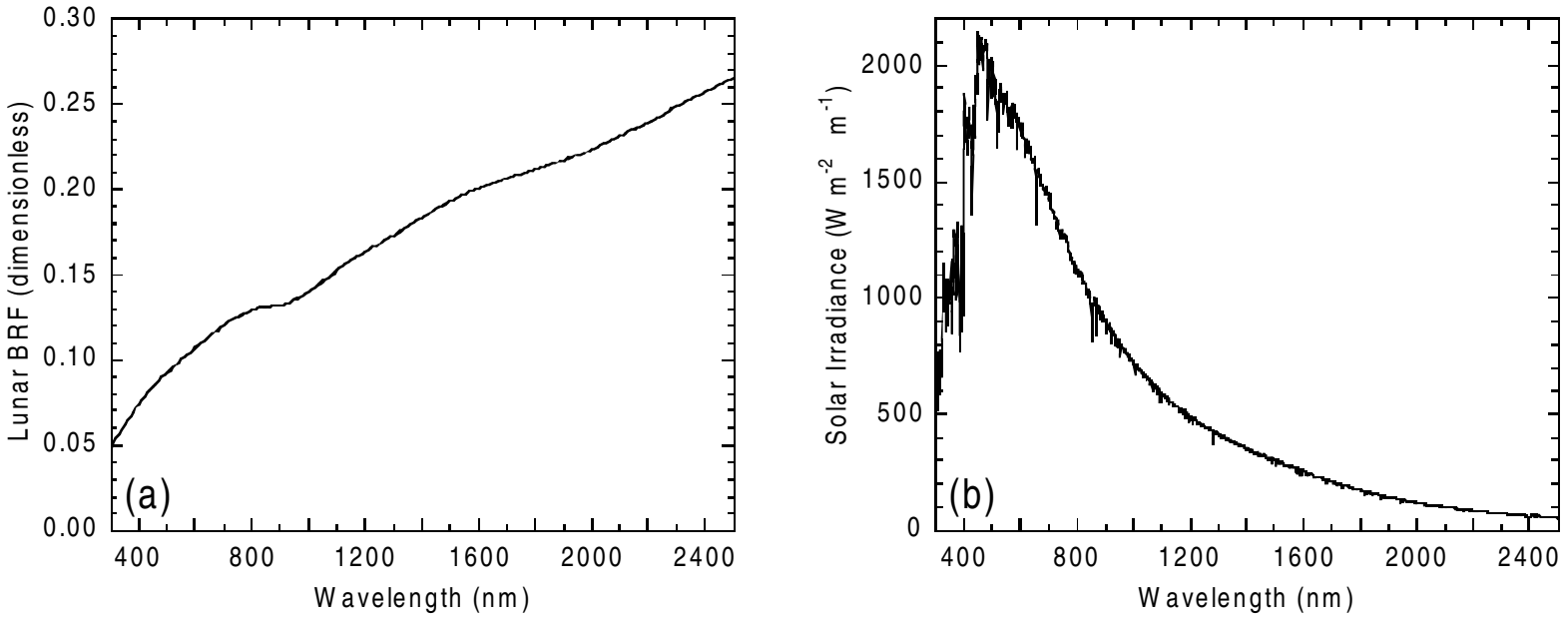




Instrument Cross-Calibration

- Uses relative differences in lunar spectral irradiance measurements
- Requires two models: solar spectral irradiance and lunar spectral reflectance
- Both models must be well known – in terms of relative spectral changes
- Irradiance changes with wavelength are much greater than reflectance changes

Instrument Cross-Calibration



(a) Lunar spectral reflectance (lunar model)
(b) Solar spectral irradiance (Thuillier et al., 2004)

Cross-Calibration with MODIS

- Nearly all VIIRS bands are within 10nm of the corresponding MODIS bands.
- Stability of the lunar surface allows for accurate cross calibration of the two sensors, provided that the phase angle limitation is maintained (i.e., VIIRS roll maneuvers during lunar views).
- The accuracy of the USGS model allows comparisons even for non-concurrent observations (expected gap between Terra MODIS and NPP VIIRS)

Nominal MODIS/VIIRS Cross-Calibration

MODIS Band	Center Wavelength (nm)	Lunar Reflectance (dimensionless)	VIIRS Band	Center Wavelength (nm)	Lunar Reflectance (dimensionless)	Wavelength Difference (nm)	Reflectance Difference (%)
8	414.3	0.07678	M1	412.1	0.07639	-2.2	-0.5
9	442.4	0.08228	M2	445.6	0.08288	3.2	0.7
10	486.6	0.09010	M3	490.4	0.09072	3.8	0.7
12	546.7	0.09939	M4	555.3	0.10061	8.6	1.2
4	553.7	0.1004	M4	555.3	0.1006	1.6	0.2
1	646.2	0.1128	I1	640.8	0.1120	-5.4	-0.7
2	856.6	0.1303	M7/I2	865.0	0.1305	8.4	0.2
5[b]	1248.3	0.1666	M8	1239.8	0.1658	-8.5	-0.5
6[b]	1629.1	0.2004	M10/I3	1610.7	0.1993	-18.4	-0.5
7[b]	2113.5	0.2296	M11	2249.6	0.2409	136.1	4.9

For most band pairs, reflectance differences in the model are small.

If the uncertainties in the reflectance differences are ±50% of their values, then the Moon should provide an adequate cross calibration reference.

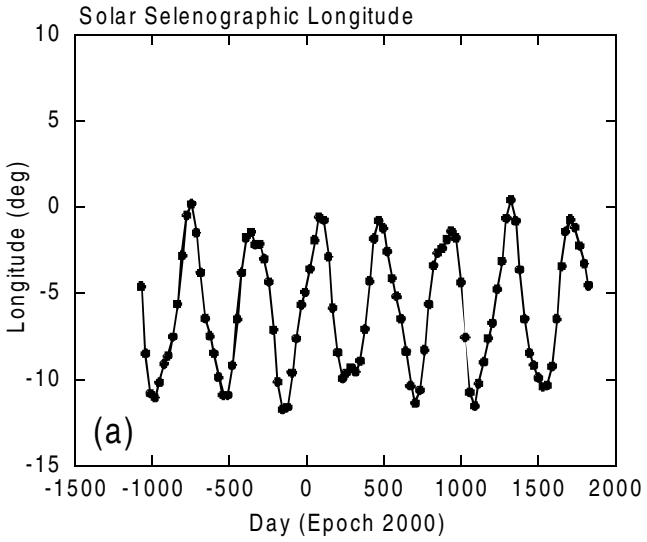
Uncertainties in the solar irradiance model must be considered, too.

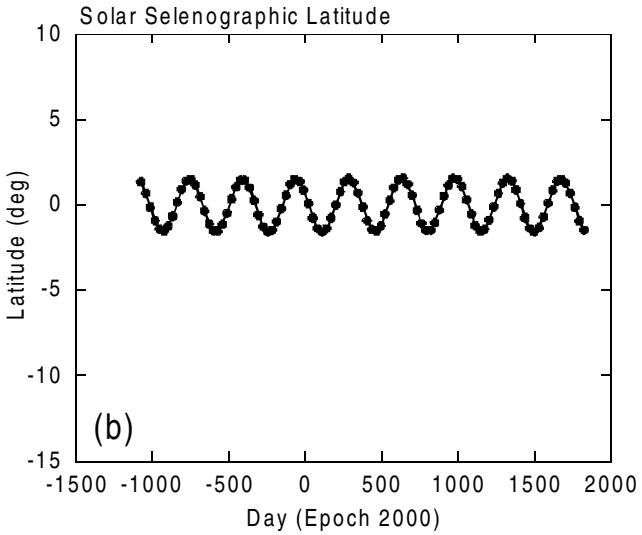
Conclusions

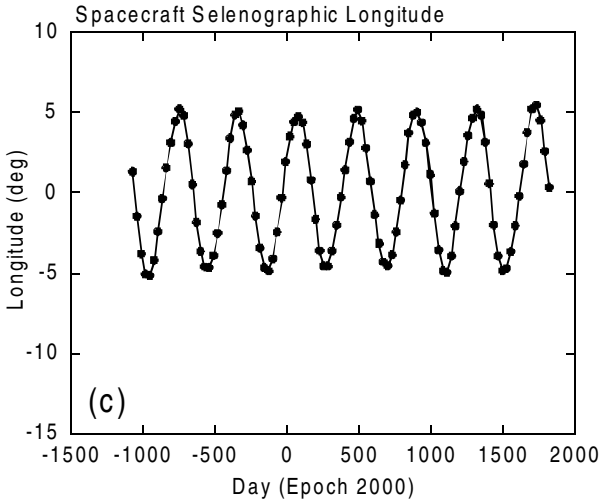
- The Moon has proven to be an invaluable reference for monitoring satellite sensor radiometric stability.
- VIIRS can make typically 9 lunar observations per year; these measurements can be used with the USGS lunar model to accurately track the radiometric stability, but only with a limited phase angle range.
- The model will also support cross-comparisons of NPP VIIRS with Terra MODIS, but only if measurements are made close to 55 degrees phase.
- Both of these restrictions require roll maneuvers of up to 15 degrees during lunar views.

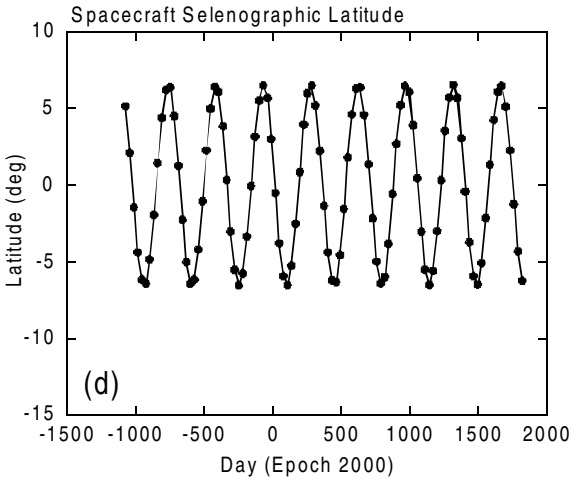
Backup slides

4 parameters for phase and libration modeling









Advantages of moon over solar diffuser:

- no earthshine (hardware solution for NPP in progress, but not assured)
- constant absolute reflectance (no monitoring necessary)
- known directional reflectance
- no vignetting from SD screen (detector dependent effect in MODIS)
- far field measurement
- completely independent of the SD