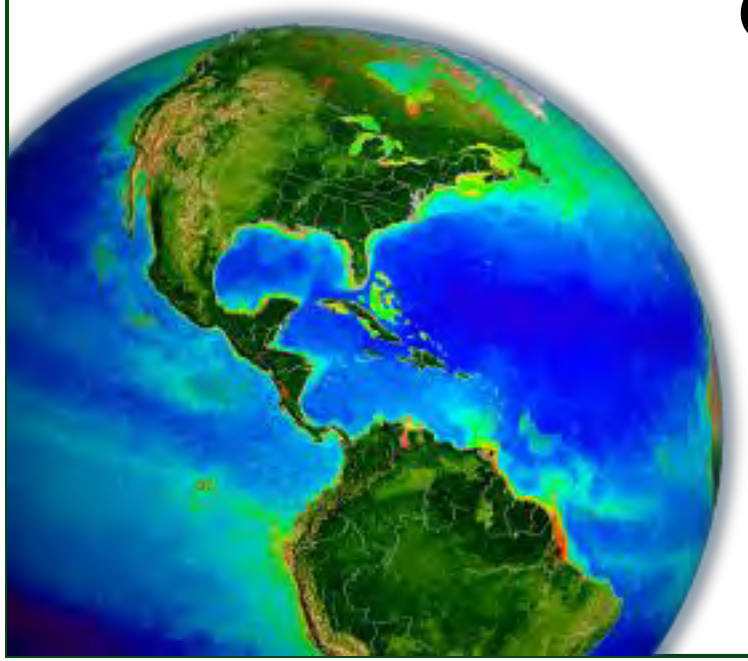
SNPP VIIRS On-Orbit Calibration for Ocean Color Applications



Gene Eplee, Kevin Turpie, Gerhard Meister, Fred Patt, and Bryan Franz

NASA Ocean Biology Processing Group

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OBPG VIIRS On-Orbit Calibration Methodology

On-orbit calibration of the Suomi National Polar-Orbiting Partnership Visible Infrared Imaging Radiometer Suite for ocean color applications

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The NASA Ocean Biology Processing Group (OBPG) developed two independent calibrations of the Suomi National Polar-Orbiting Partnership (SNPP) Visible Infrared Imaging Radiometer Suite (VIIRS) moderate resolution reflective solar bands using solar diffuser measurements and lunar observations, and implemented a combined solar- and lunar-based calibration to track temporal changes in radiometric response of the instrument. Differences between the solar and lunar data sets have been used to identify issues and verify improvements in each. Linearization of the counts-to-radiance conversion yields a more consistent calibration at low radiance levels. Correction of a recently identified error in the VIIRS solar unit vector coordinate frame has been incorporated into the solar data and diffuser screen transmission functions. Temporal trends in the solar diffuser stability monitor data have been evaluated and addressed. Fits to the solar calibration time series show mean residuals per band of 0.067%–0.17%. Periodic residuals in the VIIRS lunar data are confirmed to arise from a wavelength-dependent libration effect for the sub-spacecraft point in the output of the U.S. Geological Survey Robotic Lunar Observatory photometric model of the Moon. Temporal variations in the relative spectral responses for each band have been assessed, and significant impact on band M1 (412 nm) lunar data has been identified and rectified. Fits to the lunar calibration time series, incorporating sub-spacecraft point libration corrections, show mean residuals per band of 0.069%–0.20%. Lunar calibrations have been used to adjust the solar-derived radiometric corrections for bands M1, M3, and M4. After all corrections, the relative differences in the solar and lunar calibrations for bands M1–M7 are 0.093%–0.22%. The OBPG has achieved a radiometric stability for the VIIRS on-orbit calibration that is commensurate with those achieved for SeaWiFS and Aqua MODIS, supporting the incorporation of VIIRS data into the long-term NASA ocean color data record. © 2015 Optical Society of America

OCIS codes: (280.0280) Remote sensing and sensors; (280.4788) Optical sensing and sensors; (280.4991) Passive remote sensing; (010.1690) Color; (010.5630) Radiometry; (120.0280) Remote sensing and sensors.

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1. Introduction

The Suomi National Polar-Orbiting Partnership (SNPP) Visible Infrared Imaging Radiometer Suite (VIIRS) was launched into an 824 km sun-synchronous

Applied Optics 54, 1984-2006 (2015)

OBPG On-Orbit Calibration Updates

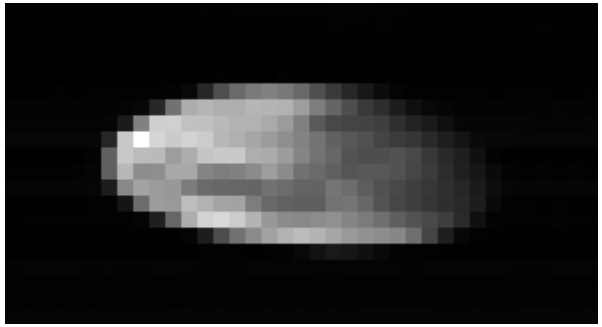
- An additional year of solar/lunar observations (Jul 2014–May 2015).

- Empirical libration angle corrections extended to sub-solar point:
  - Scatter in lunar data small enough for residual sub-solar libration effects to be observed in addition to sub-spacecraft libration effects.
  - Corrections result in a further reduction of scatter in lunar observations.

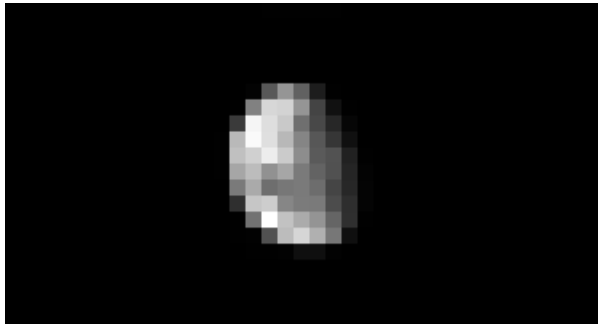
- First substantive derivation of SWIR band calibration:
  - Sun Pointing Anomaly in March 2012.
  - Residual libration effects also observed in SWIR band lunar data.

- Absolute calibration of solar observations using diffuser measurements:
  - Vicarious calibration compensates for gain changes to bands M1-M6.
  - 2% gain change for band M7.
  - Absolute calibration sets response for SWIR band solar time series.

Lunar Calibrations

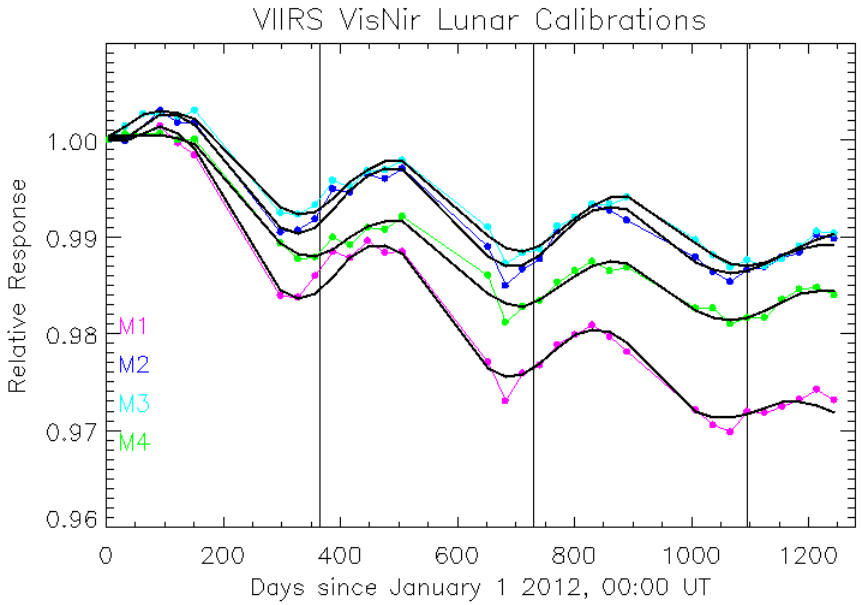


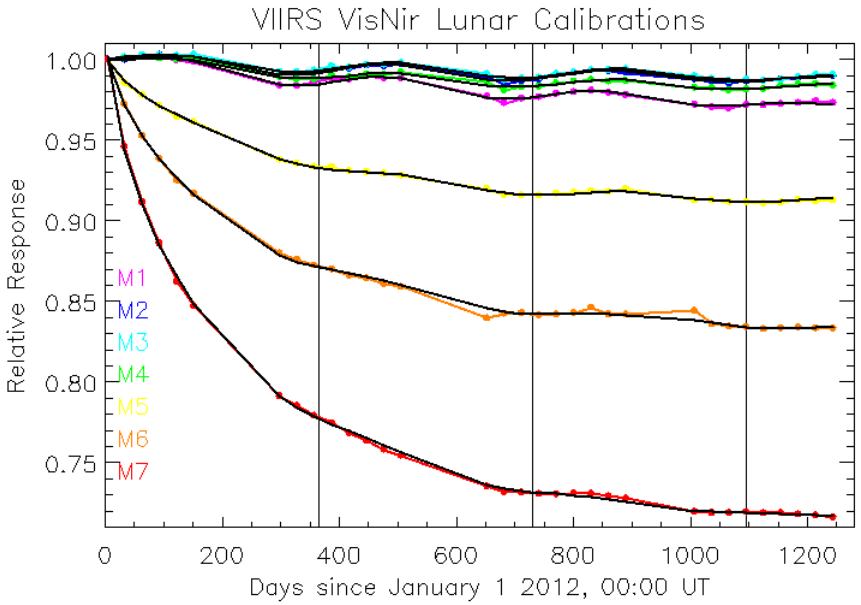
Band 4
Unaggregated



Band 6
Aggregated

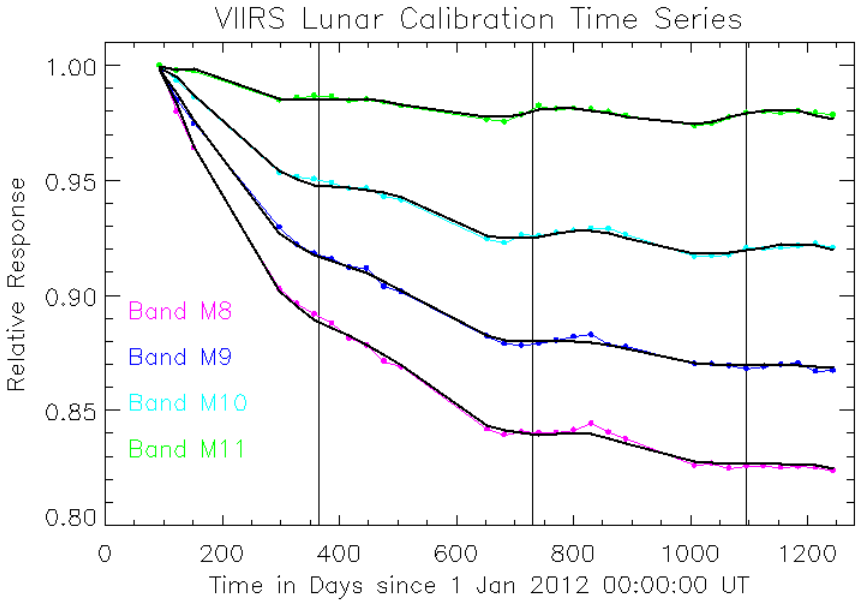
Lunar Calibration Time Series



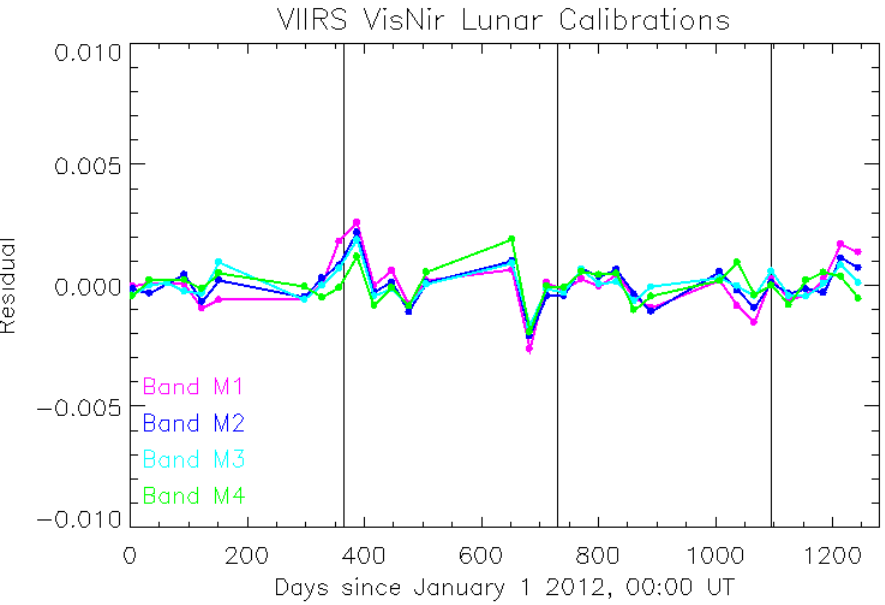


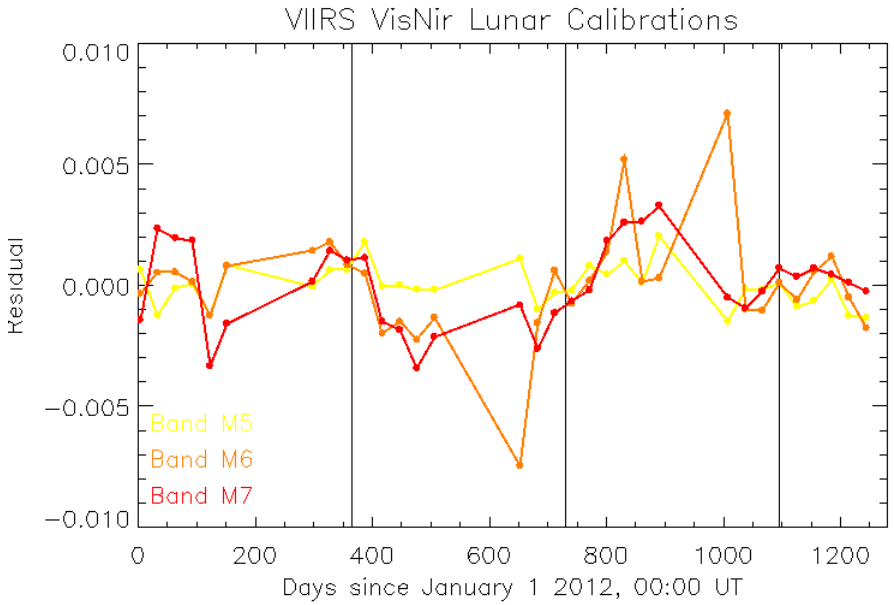
Lunar time series are ratios of VIIRS observations to USGS ROLO model predictions made using time-dependent VIIRS spectral response functions.

Fits are exponentials of time plus linear functions of sub-spacecraft and sub-solar libration angles.

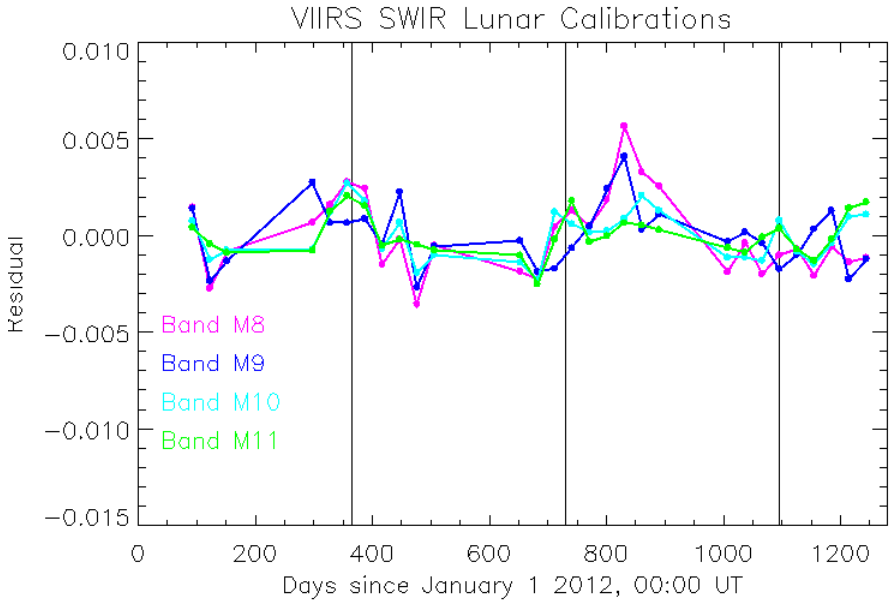


Lunar Calibration Fit Residuals

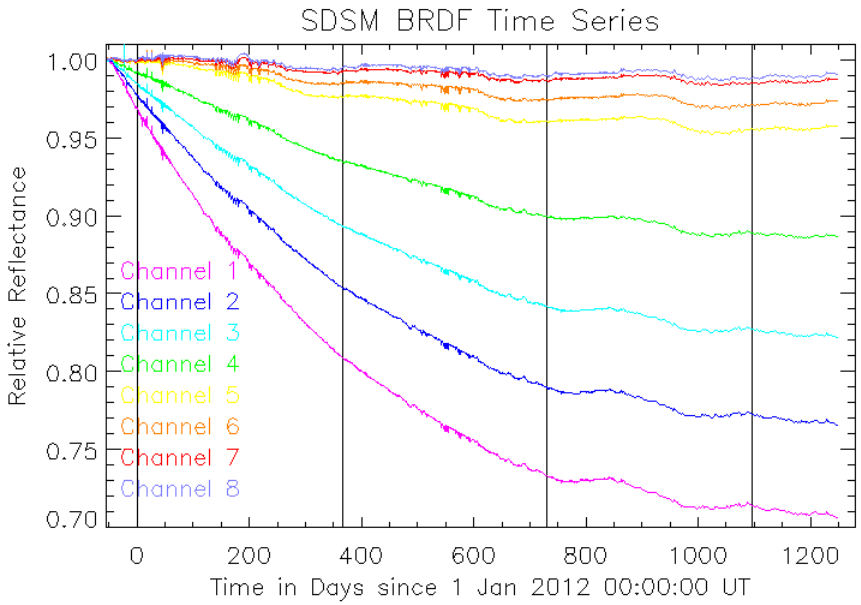




The sub-spacecraft and sub-solar libration corrections capture the periodic signals in the lunar time series.

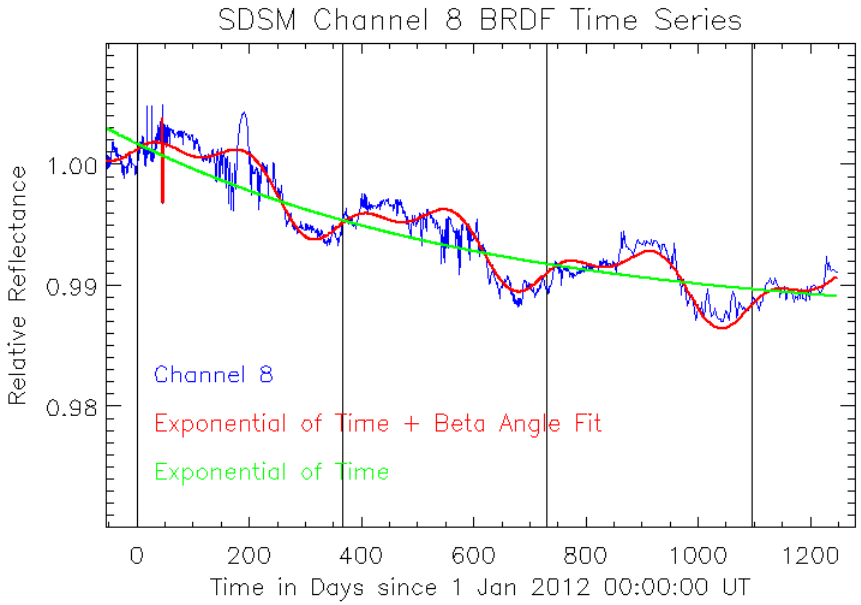


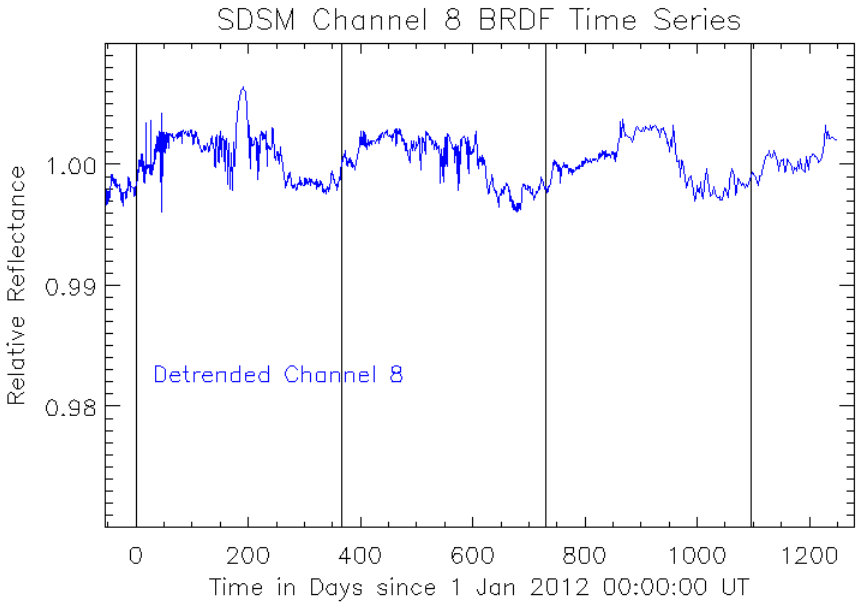
SDSM Calibrations



Channels 1-7 correspond to bands M1-M7.
Channel 8 (935 nm) tracks SDSM performance.

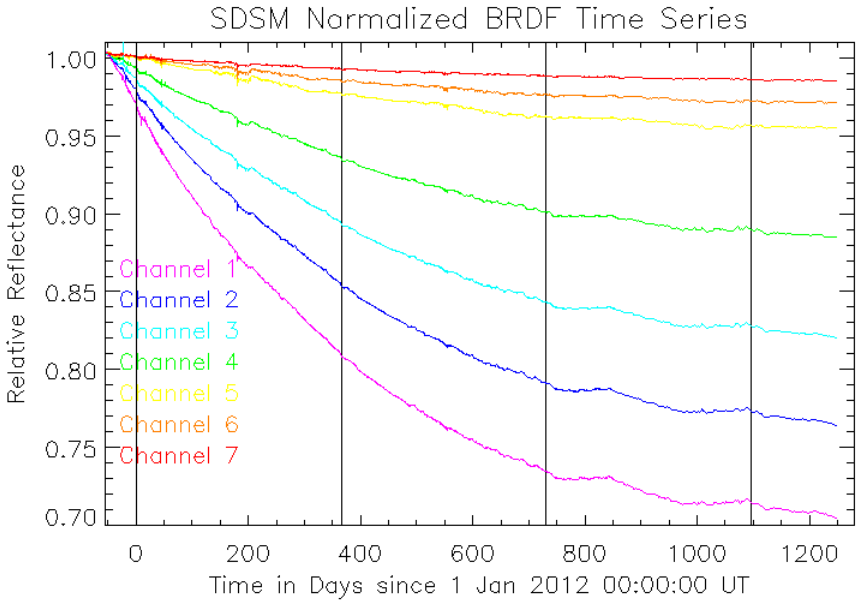
SDSM Calibration Time Series



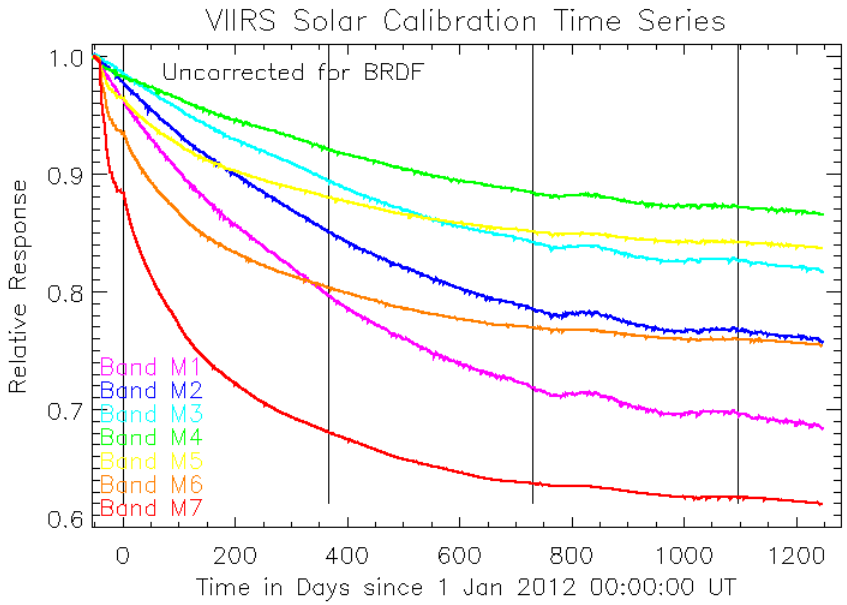


SDSM channel 8 (935 nm) is fit with an exponential function of time plus a linear function of solar beta angle.

Normalization of channels 1-7 by detrended channel 8 reduces noise and beta angle dependence without changing temporal dependence.

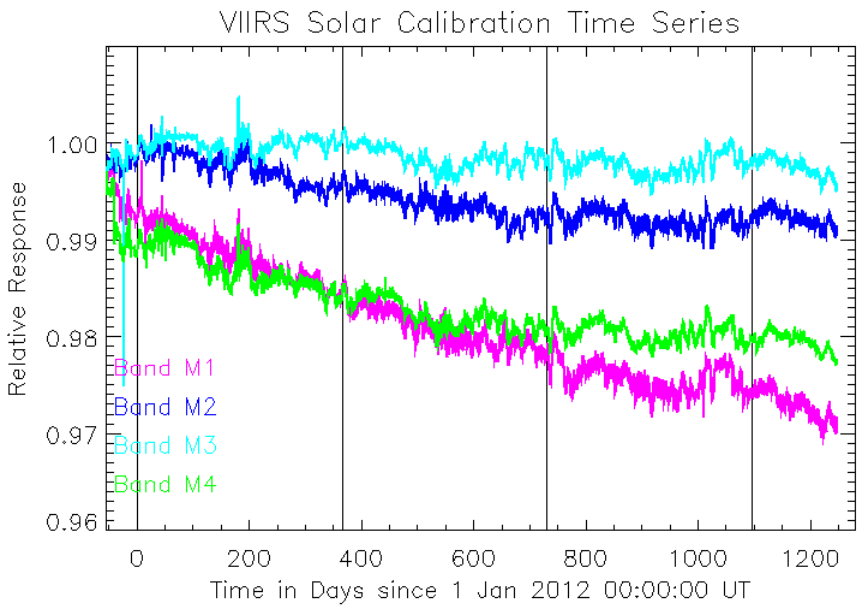


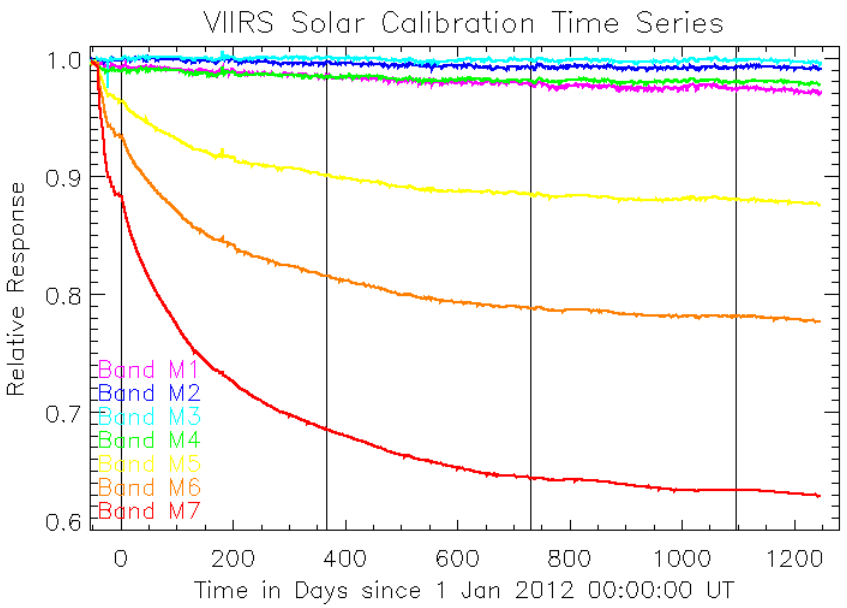
Solar Calibrations



Solar calibration time series for band M1-M7, uncorrected for diffuser BRDF degradation.

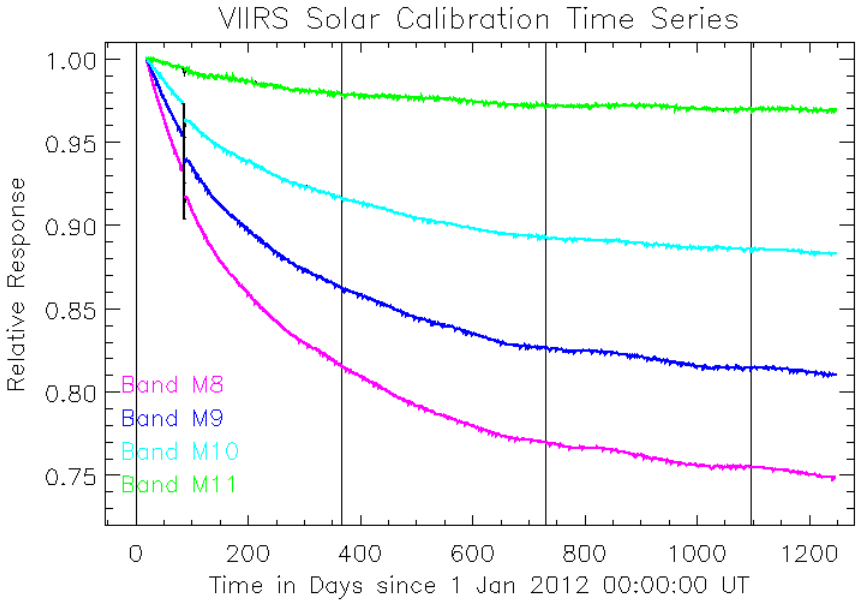
Solar Calibration Time Series



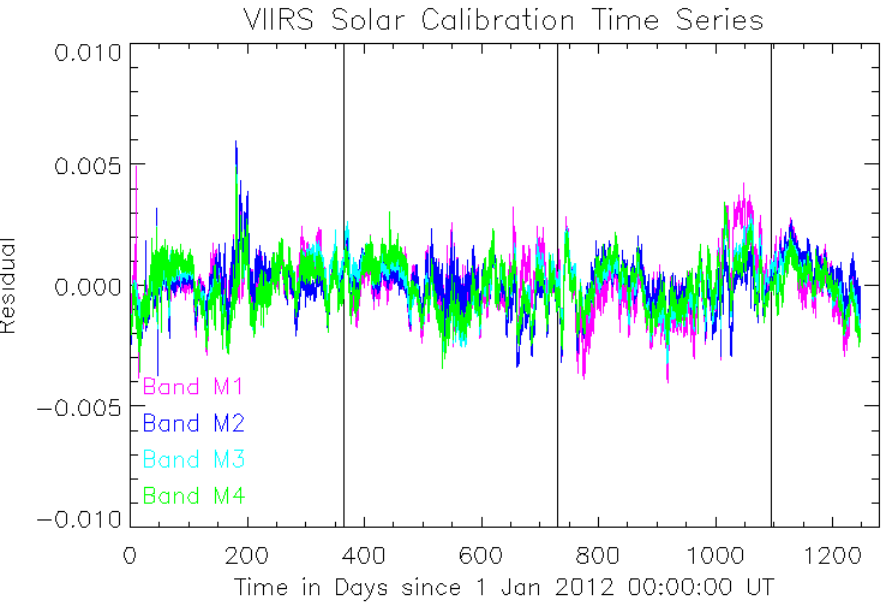


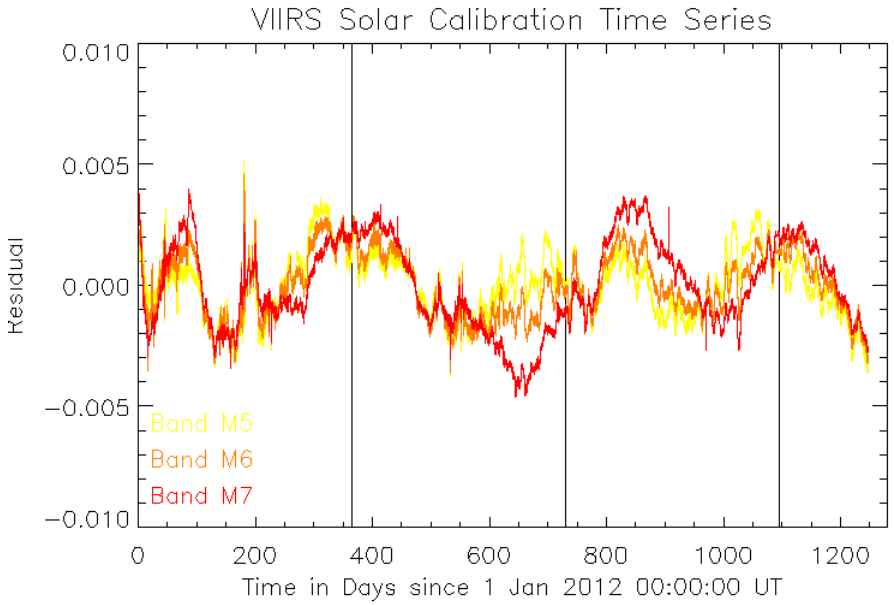
Bands M1-M7 are corrected for diffuser BRDF degradation by SDSM-derived H-factors (channels 1-7 normalized by detrended channel 8).

SWIR band radiometric responses changed discontinuously during March 2012 Sun Pointing Anomaly.

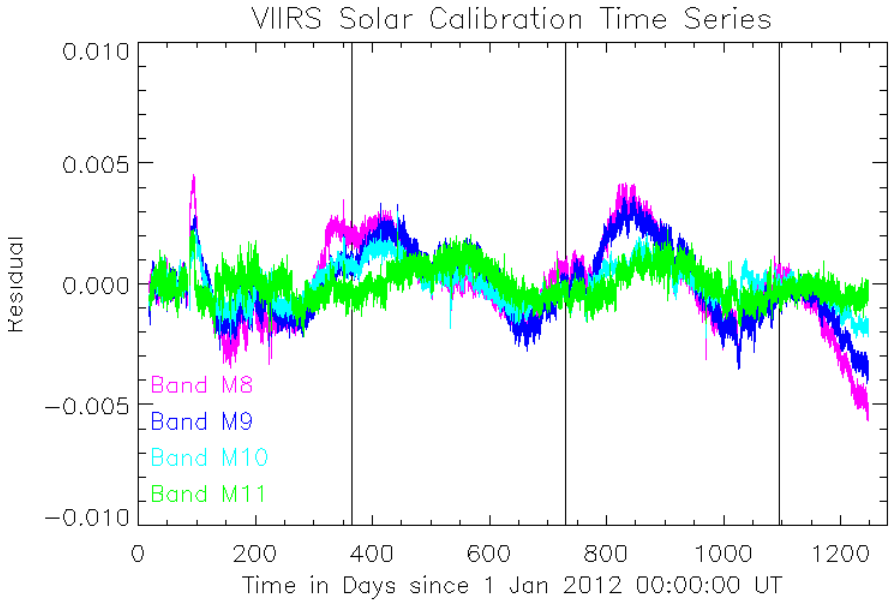


Solar Calibration Fit Residuals





The detrended SDSM channel 8 normalization and the latest screen transmission / diffuser BRDF functions derived by VCST minimize periodic signals in the solar time series.

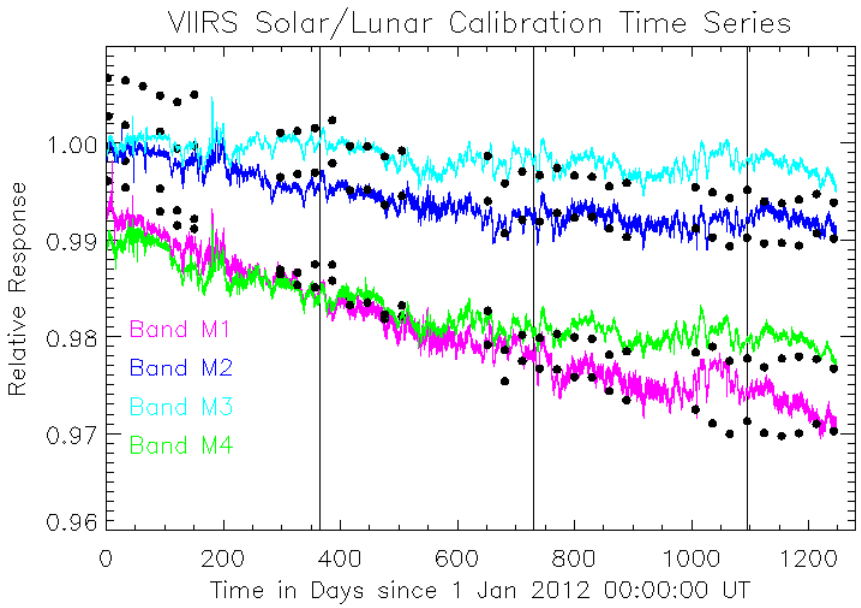


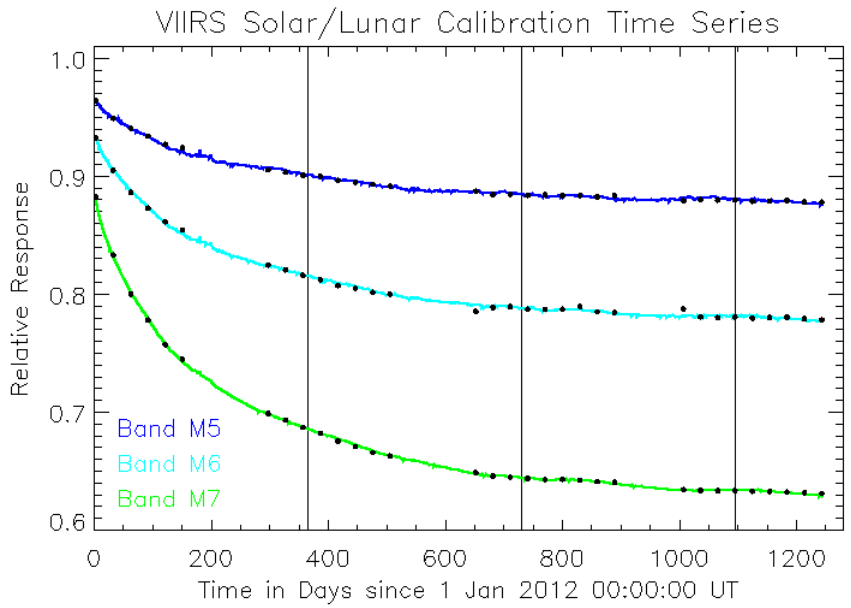
Solar / Lunar Calibration Comparisons

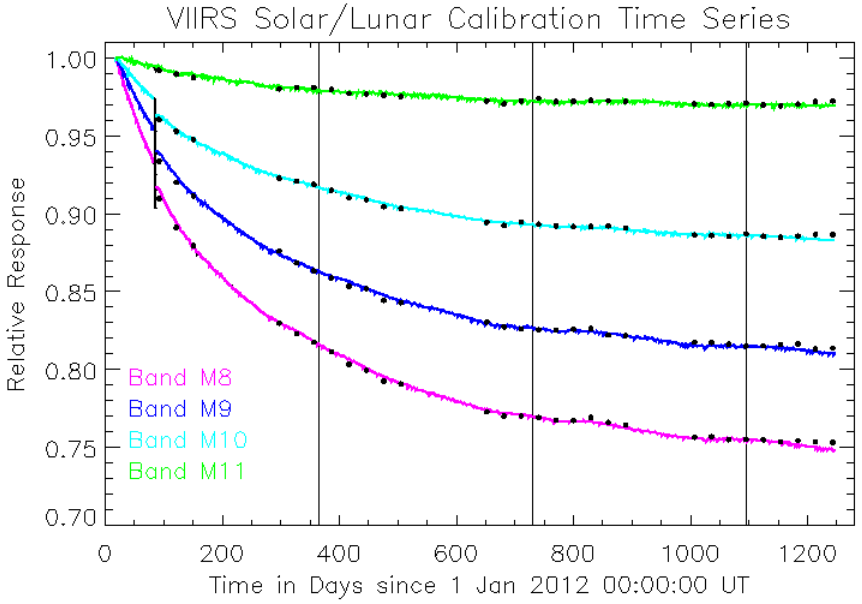
VIIRS observes the solar diffuser and
the space view (Moon)
at the same angle of incidence (60.2°)
on the half-angle mirror.

Motivation:
Concern over how effectively
SDSM observations track
solar diffuser BRDF degradation.

Initial Solar / Lunar Calibration Comparisons

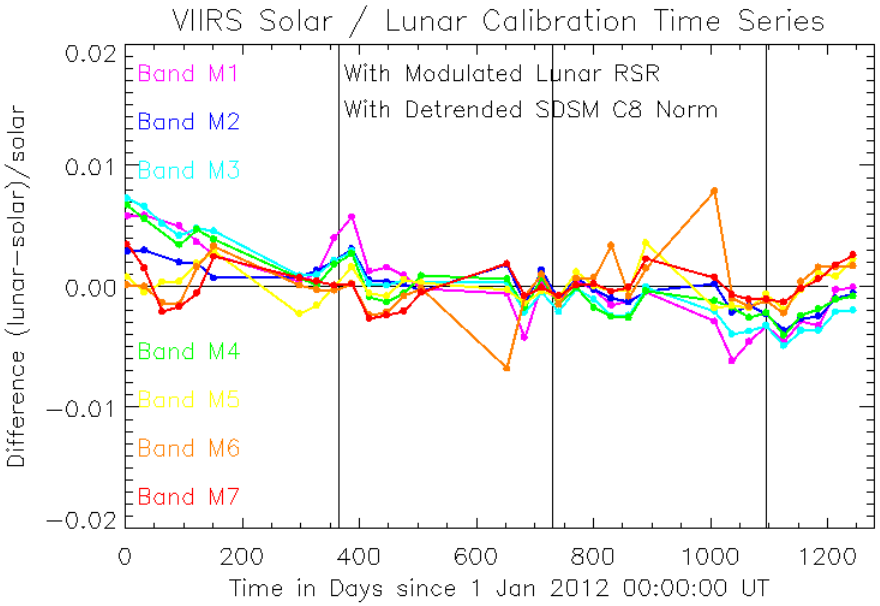


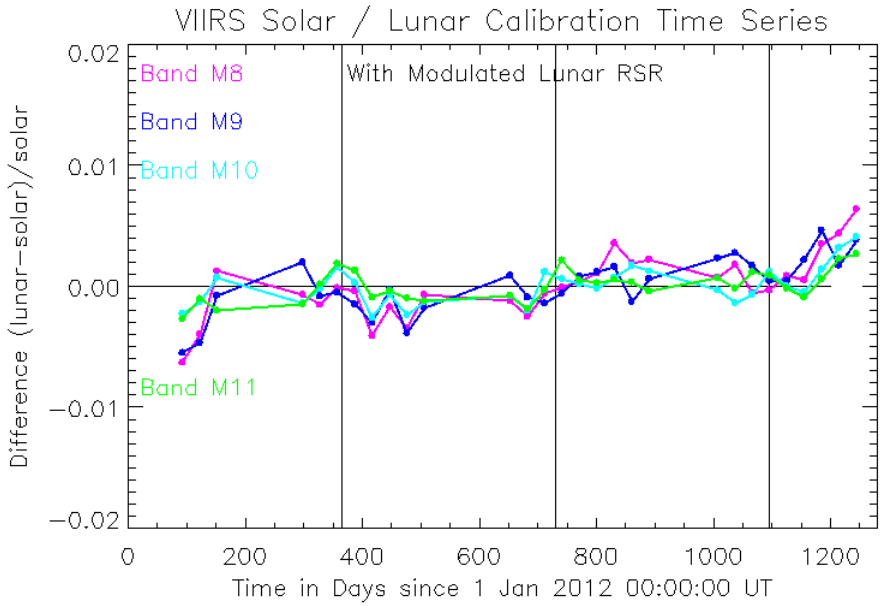




Single normalizations are applied to each band of the lunar time series to account for calibration biases.

Initial Solar / Lunar Calibration Differences





Point-by-point calibration differences are computed using closest solar observation to each lunar observation.

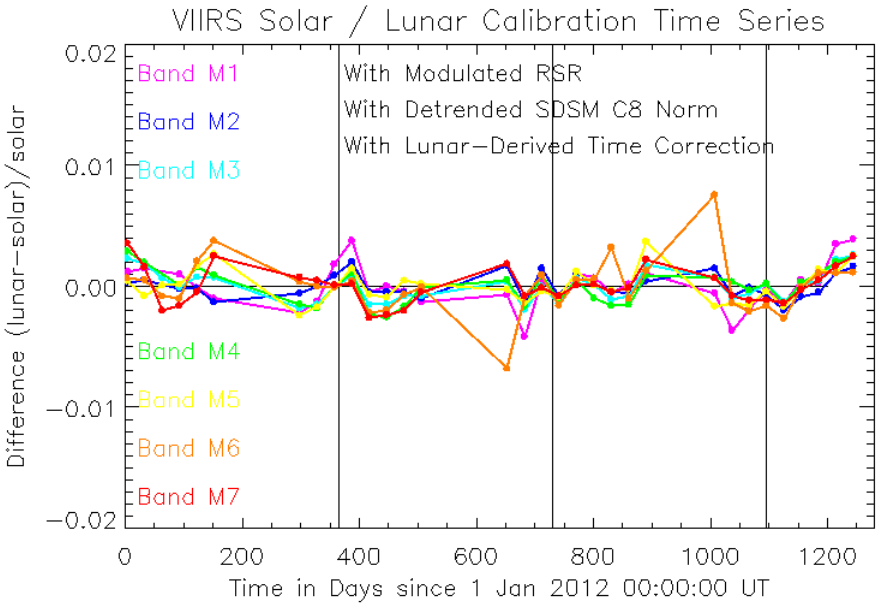
Slopes of the differences provide lunar-derived adjustments for the solar calibration time series.

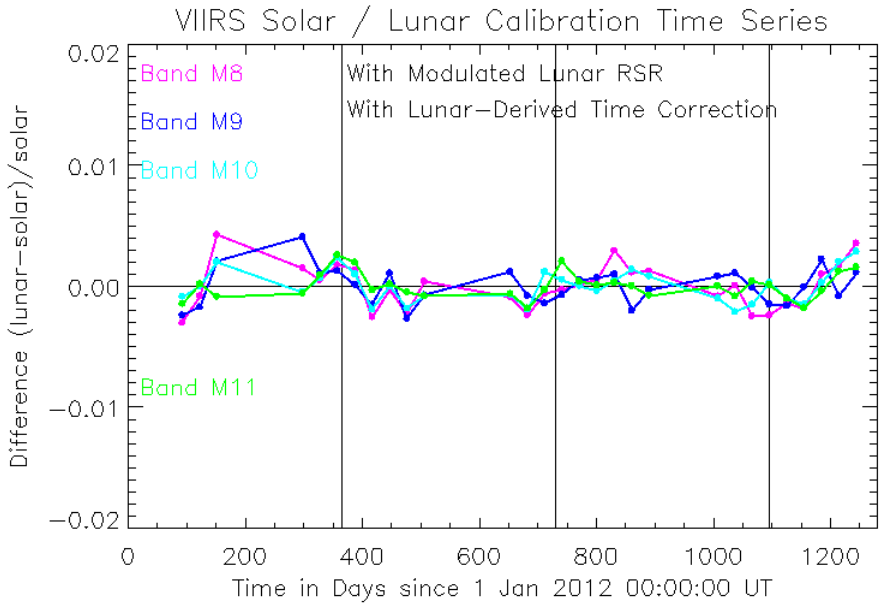
Solar / Lunar Calibration Differences

Band	λ (nm)	Initial Slope	Final Slope
M1	412	-6.898E-06	3.580E-08
M2	445	-3.799E-06	9.644E-09
M3	488	-7.608E-06	4.284E-08
M4	555	-5.676E-06	2.638E-08
M5	672	-4.689E-07	2.663E-10
M6	746	8.946E-07	1.707E-10
M7	865	1.565E-07	-5.090E-11
M8	1240	5.354E-06	1.931E-08
M9	1378	5.059E-06	1.789E-08
M10	1610	2.305E-06	3.144E-09
M11	2250	2.060E-06	3.110E-09

Units for the slopes are fractional change per day.

Final Solar / Lunar Calibration Differences





Solar / lunar differences with the lunar-derived adjustments applied to the solar calibration time series.

Lunar time series provides long-term stability reference for each band while solar time series provides per-detector, per-gain calibration.

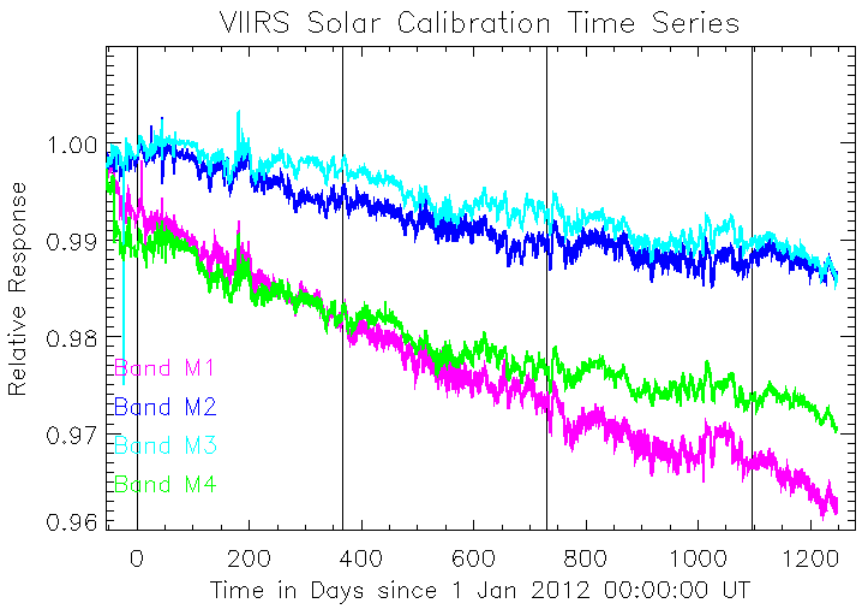
Final Solar / Lunar Calibration Comparisons

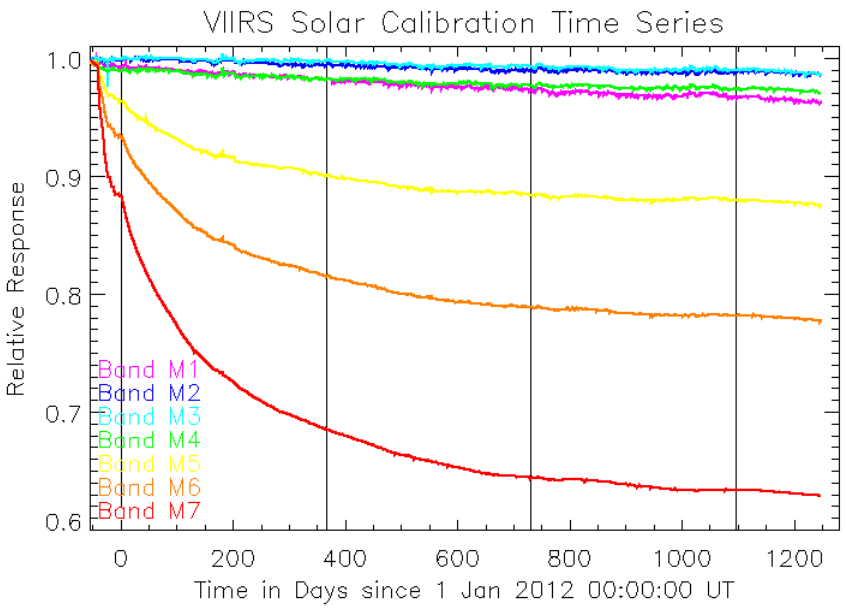
Band	Solar Residuals	Lunar Residuals	Solar / Lunar Differences
M1	0.117	0.0983	0.180
M2	0.0937	0.0790	0.0996
M3	0.104	0.0635	0.124
M4	0.100	0.0716	0.143
M5	0.135	0.0858	0.139
M6	0.134	0.229	0.231
M7	0.182	0.172	0.149
M8	0.174	0.206	0.185
M9	0.145	0.161	0.153
M10	0.0788	0.127	0.134
M11	0.0661	0.104	0.109

RMS residuals and RMS differences are in percent.

VIIRS calibration stability is comparable to that achieved for heritage instruments (SeaWiFS, Aqua MODIS).

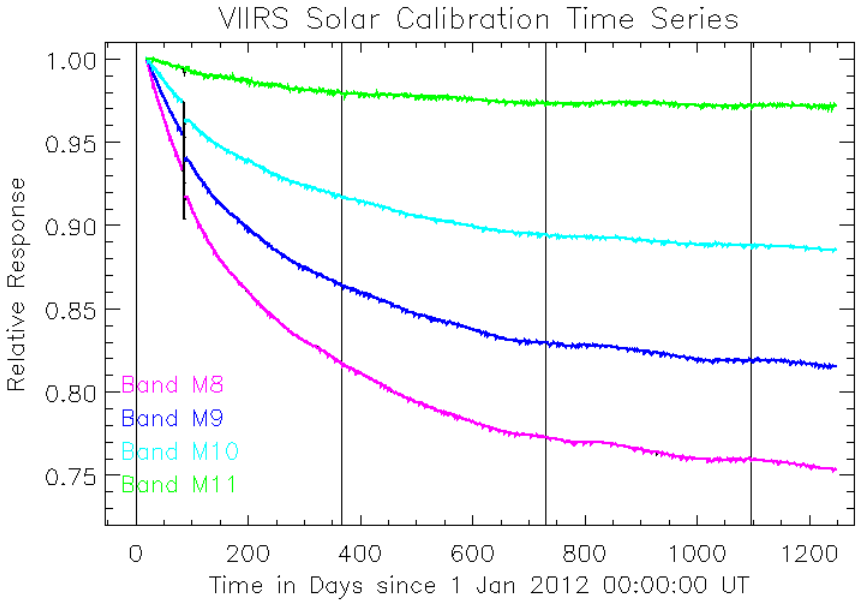
Lunar-Adjusted Solar Calibration Time Series



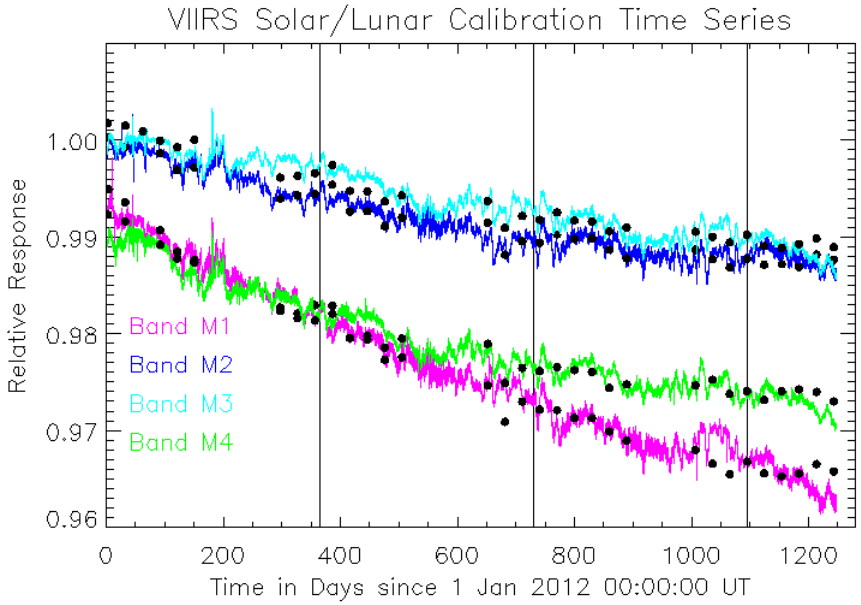


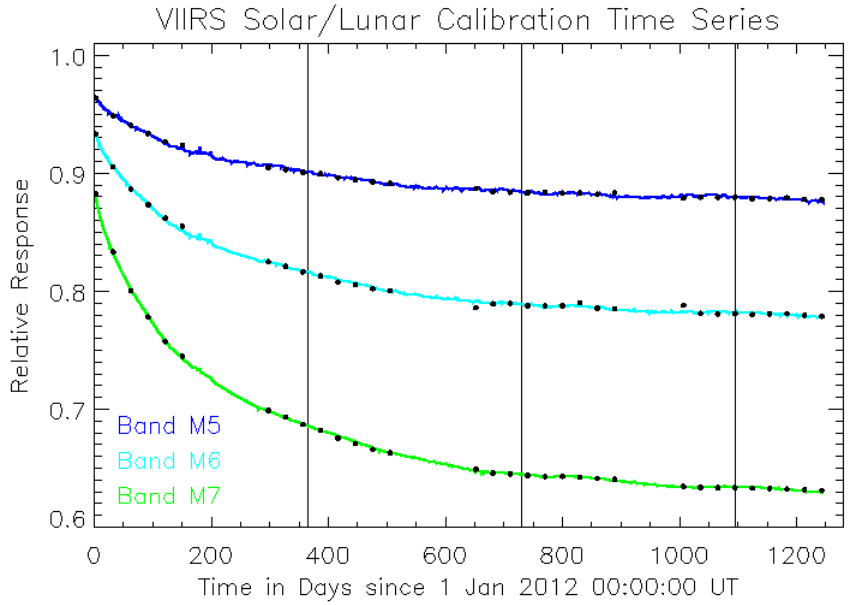
Vicarious calibration is applied to bands M1-M6.

Fits to lunar-adjusted solar calibration time series for bands M1-M7 provided the calibration used for Reprocessing 2014.0.

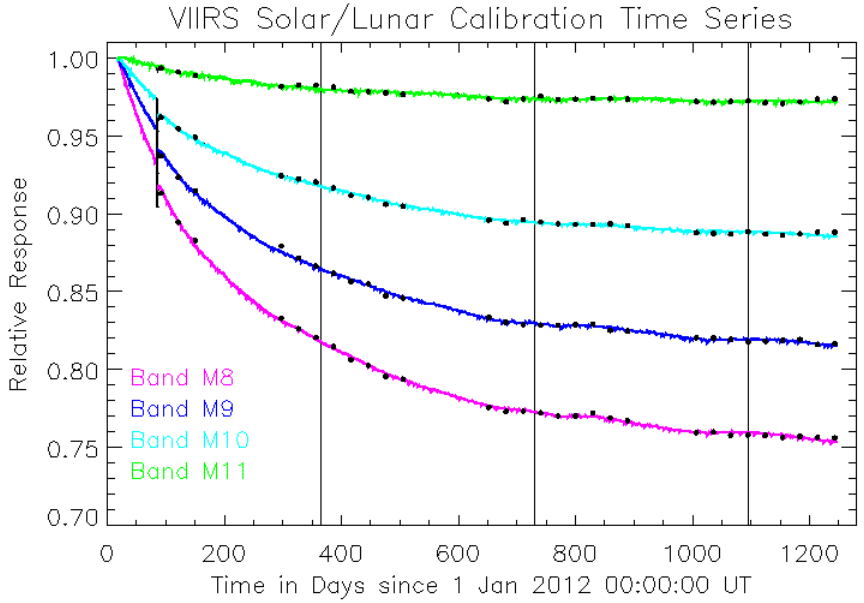


Final Solar / Lunar Calibration Comparisons

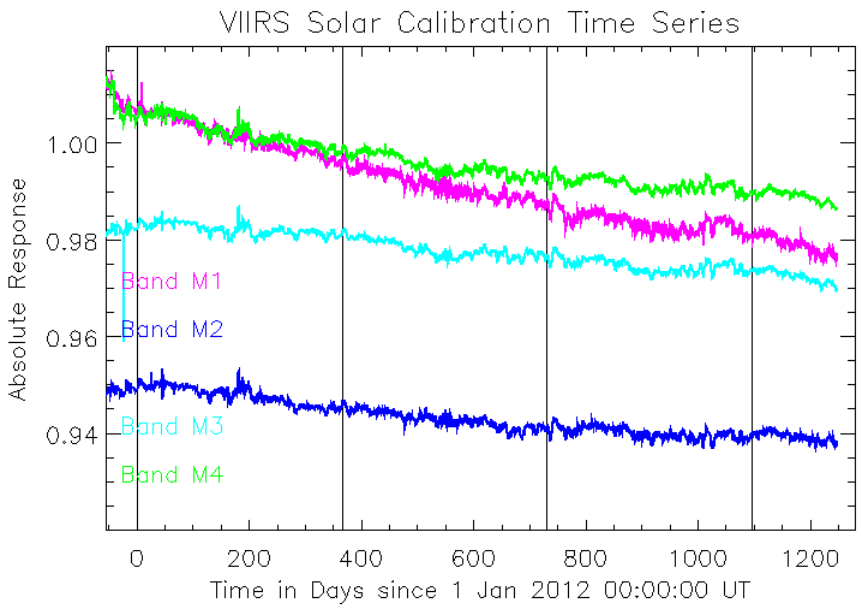


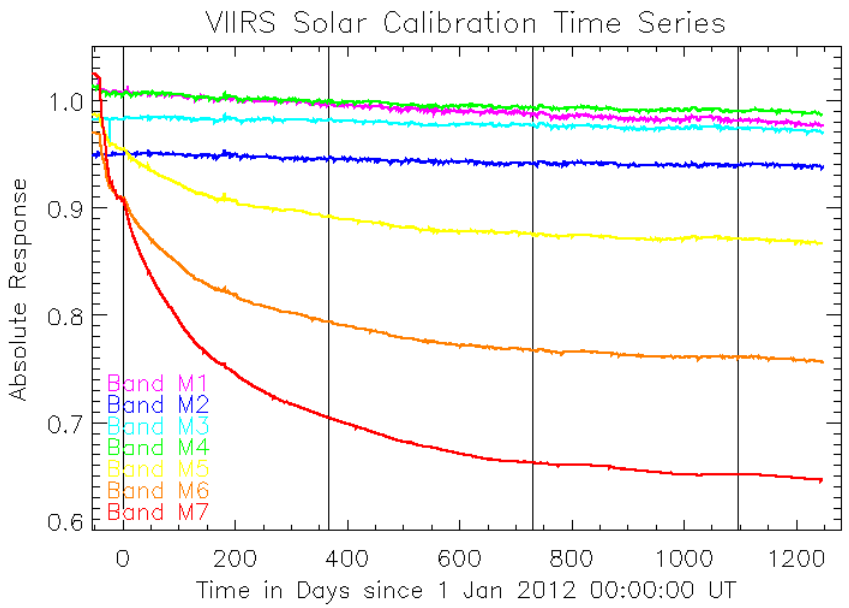


Bands M1-M4 show the greatest effect of the lunar-derived adjustment to the solar calibrations.



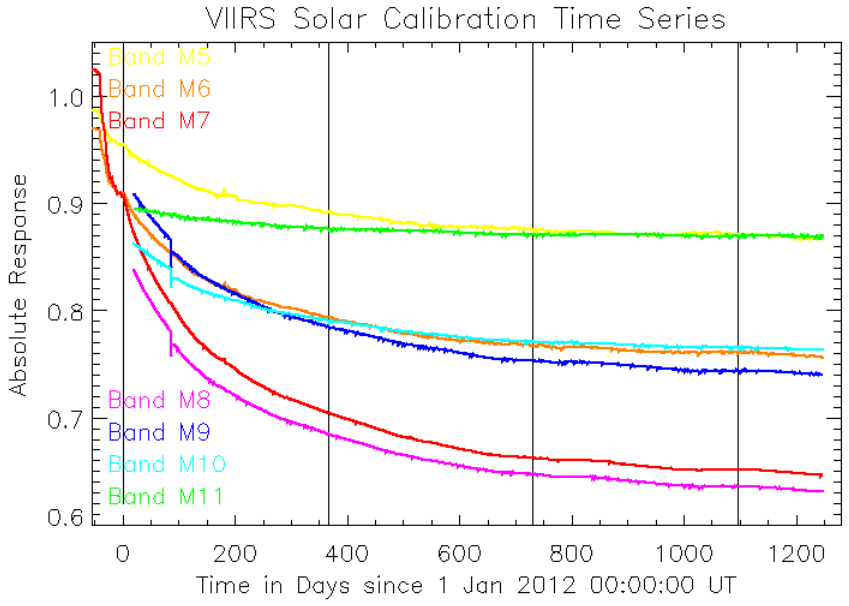
Absolute Solar Calibration Time Series





Responses for bands M8-M11 are consistent with NIR Degradation Anomaly.

Fits to lunar-adjusted SWIR band solar calibration time series are under evaluation by OBPG for an alternate atmospheric correction scheme.



Calibration Validation:
Ocean Color Data Reprocessing 2014.0

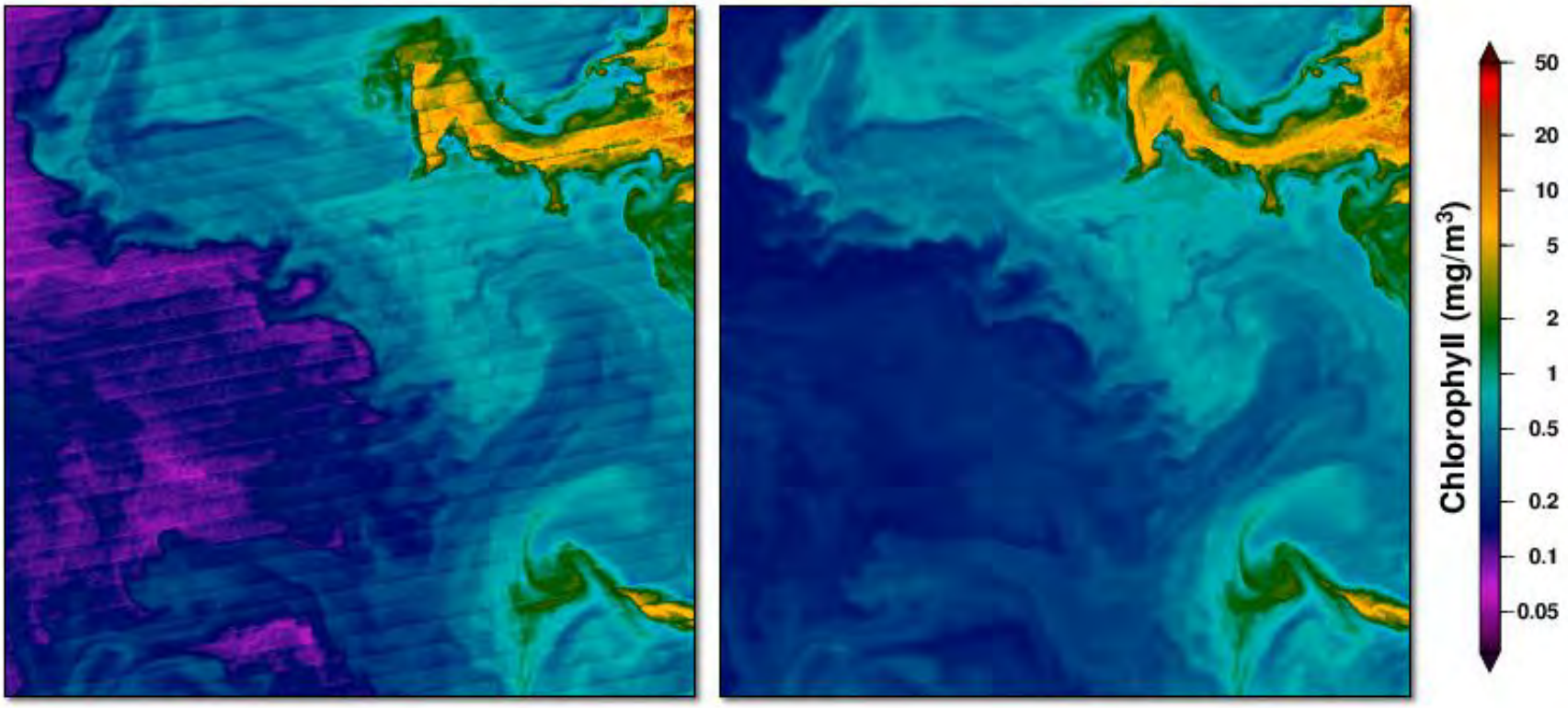
Earth Day 2015

Image courtesy of
Norman Kuring,
NASA OBPG

Improved Calibration Yields Improved Chlorophyll Retrievals

Reprocessing 2013.1

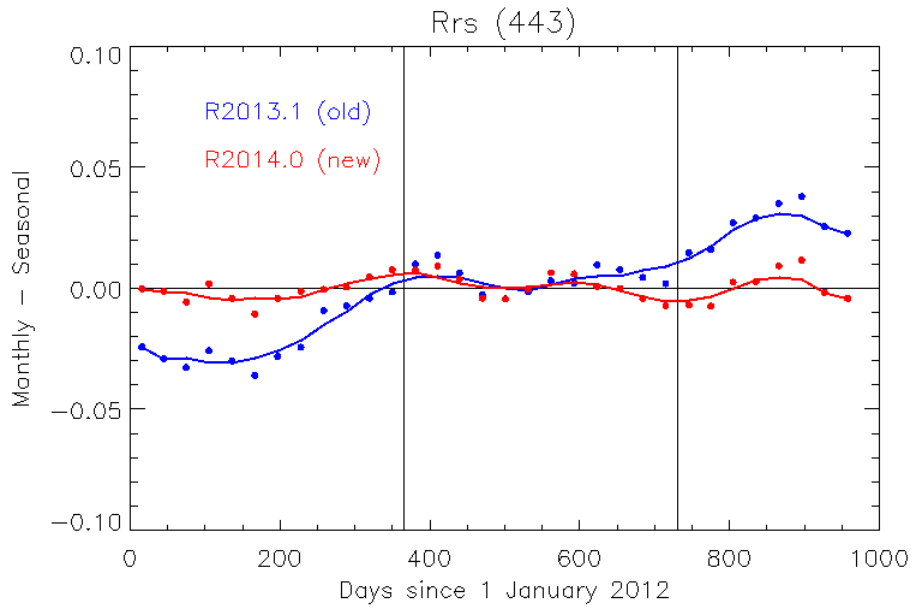
Reprocessing 2014.0

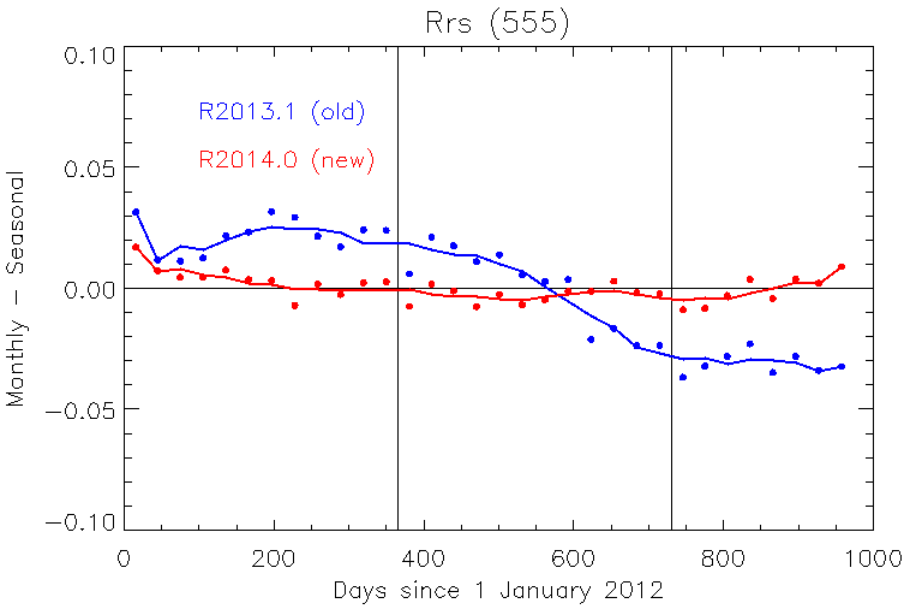


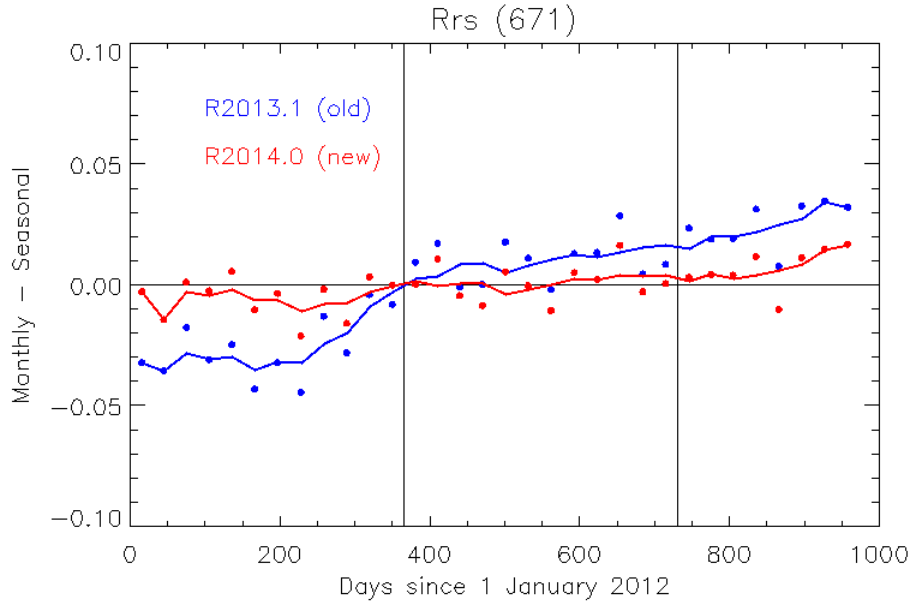
Calibration includes detector relative corrections to reduce image striping artifacts.

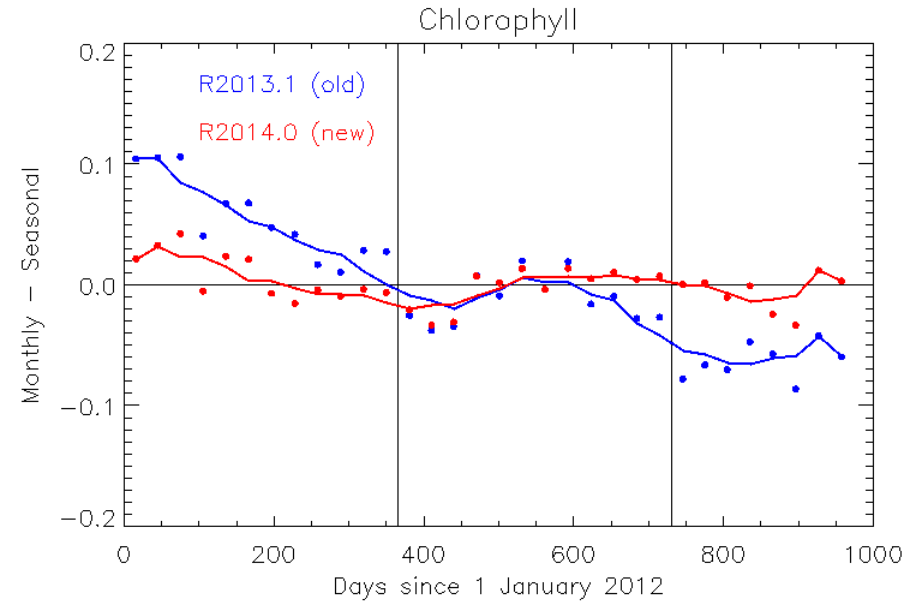
Improved VIIRS Ocean Product Temporal Stability

Global Mean Deep-Water Anomaly Trends



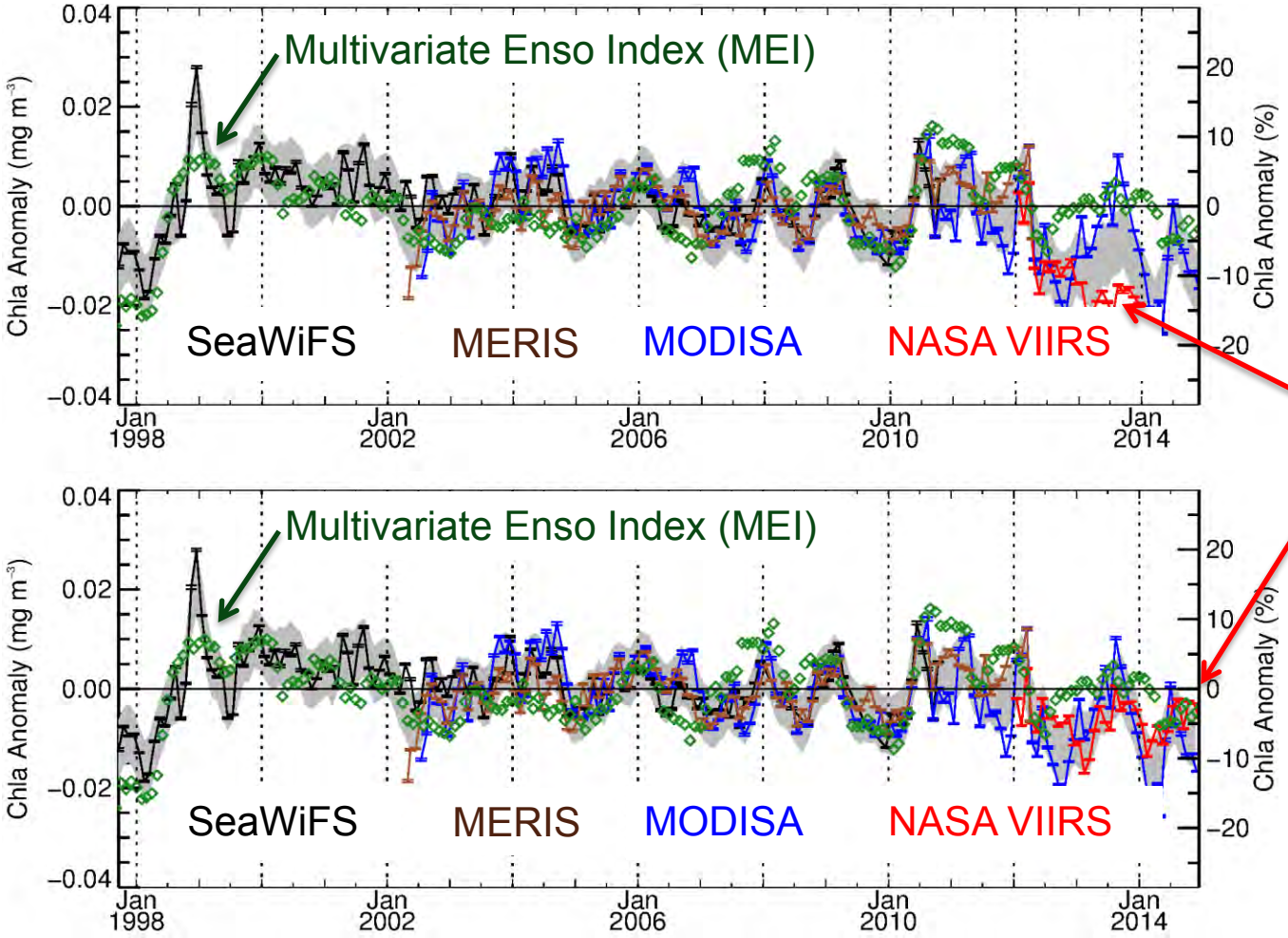






Global Mid-Latitude (+/- 40°) Chlorophyll Anomaly

Showing improved agreement of VIIRS with MODISA, MEI, and historical norms after R2014.0 reprocessing



VIIRS R2013.1

calibration issue resolved

VIIRS R2014.0

Following *Franz, B.A., D.A. Siegel, M.J. Behrenfeld, P.J. Werdell (2015). Global ocean phytoplankton [in State of the Climate in 2014]. Bulletin of the American Meteorological Society, submitted.*

OBPG VIIRS On-Orbit Calibration Summary

- Significant elements of lunar calibration methodology include:
  - Use of modulated RSRs in ROLO model for lunar geometry corrections.
  - Application of empirical sub-spacecraft and sub-solar point libration corrections to VIIRS measurement / ROLO prediction ratios.
- Significant elements of solar calibration methodology include:
  - Use of latest screen transmission / diffuser BRDF functions from VCST.
  - Use of detrended SDSM channel 8 time series to normalize H-factors.
  - Interpolation of H-factors to time basis of F-factors, allowing point-by-point correction of F-factors for diffuser BRDF degradation.
  - Derivation of absolute calibration of F-factors from the solar diffuser measurements, making SWIR bands useable for ocean color retrievals.
- Solar / lunar calibration comparisons:
  - Differences provide lunar-derived adjustments to the solar calibration time series and resulting F-factor LUTs.
  - VIIRS calibration stability comparable to that achieved for heritage instruments (SeaWiFS, Aqua MODIS).
- VIIRS ocean color data quality is sufficient for global trend studies.

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Thank You

Suomi-NPP / VIIRS