

**Suomi
National Polar-orbiting Partnership
(NPP)**

VIIRS data product assessment

K. Turpie

Ocean Color Science PI

VIIRS Ocean Science Team (VOST)

Ocean Color Research Team Meeting

23 April 2012

Seattle, Washington

VIIRS Ocean Science Team (VOST)

Robert Barnes

Gene Eplee

Gwyn Fireman

Bryan Franz, **Co-I**

Chuck McClain, **Admin PI**

Gerhard Meister

Fred Patt, **PEATE Tech Lead**

Wayne Robinson

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Since the last OCRT Meeting Suomi NPP Successfully Launched!



5:48 EDT 28 October 2011





VOST Efforts

VOST Contributions 2003-Present

- Reviewed numerous project documents
- Reviewed science and operational code
- Successfully advocated instrument improvements
- Performed multiple analyses of the effect instrument performance on data quality
- Presented findings at numerous technical conferences
- Participated in test planning and data analysis
- VIIR ocean color data product quality assessment
- Development of time-dependent calibration
- Generation of VIIRS data products using NASA algorithms

VOST Contributions 2003-Present

- Reviewed numerous project documents
 - Reviewed science and operational code
 - **Successfully advocated instrument improvements**
 - Performed multiple calibration tests to improve VIIRS performance on-orbit
 - Presented findings to the VIIRS science team
 - Participated in the development of the VIIRS ocean color calibration strategy
 - Development of the VIIRS ocean color calibration strategy
 - Generation of VIIRS ocean color calibration strategy
- **Blocking Earth shine thru the calibrator screen**
 - **Clear water calibration site**
 - **Lunar calibration maneuvers**
 - **Significant reduction of optical crosstalk**
 - **End-to-end calibration system test**
 - **Spectral response characterization with SIRCUS**
 - **Characterization of crosstalk polarization effects**
 - **Improved polarization response characterization**

VOST Contributions 2003-Present

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 - Reviewed science and operational code
 - Successfully advocated instrument improvements
 - **Performed multiple analyses of the effect instrument performance on data quality**
 - Presented findings at
 - Participated in test p
 - VIIR ocean color data
 - Development of time
 - Generation of VIIRS c
- **Ocean color sensitivity analysis techniques**
 - **Crosstalk impact analysis**
 - **VIIRS Data Simulator**
 - **Predict impact of instrument effects.**
 - **Prepare team for flight data.**
 - **Exercise processing system prelaunch.**

Product Quality Assessment

VOST Question: Is the quality of the operational VIIRS Ocean Color Environmental Data Records (EDR) sufficient to meet NASA science objectives, including the continuation of the climate record established with EOS?

Approach: Evaluate prelaunch sensor characterization, algorithms, calibration and processing capabilities and compare EDR products against products generated with NASA calibration and algorithms.

Answer: Unlikely. Sensor appears to be performing well, but :
oEDR algorithms are out of date and inconsistent with established record,

ocalibration is forward-looking only, and
othere is no support for reprocessing.

Also precludes processing from Sensor Data Records (SDR).

Product Quality Assessment



OBPG Question: Is the current quality of the VIIRS Raw Data Records (RDR) sufficient for meeting NASA science objectives, including the continuation of the climate record established with EOS?

Approach: Evaluate results of reprocessing VIIRS sensor measurements using NASA standard algorithms and time-dependent calibration.

Preliminary Answer: Likely. So far, there are no insurmountable problems with VIIRS sensor measurements and reprocessing with NASA calibration and algorithms initially appears to produce ocean color products roughly comparable to SeaWiFS climatology.

Product Quality Assessment



VOST Future: To further quantify how closely (or not) operational EDR products meet NASA's science objectives, the VOST will compare them against :

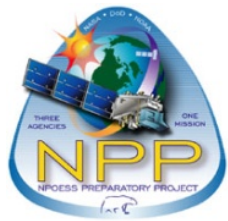
- flight data reprocessed with NASA time-dependent calibration and algorithms,
- the established CDR (cross sensor and climatology), and
- *in situ* data.

OBPG Future: To quantify how well the VIIRS sensor measurements meet NASA's science objectives, the OBPG will retrospectively compare the more refined NASA-generated VIIRS data record to :

- the established CDR (cross sensor and climatology), and
- *in situ* data.



The VIIRS Instrument



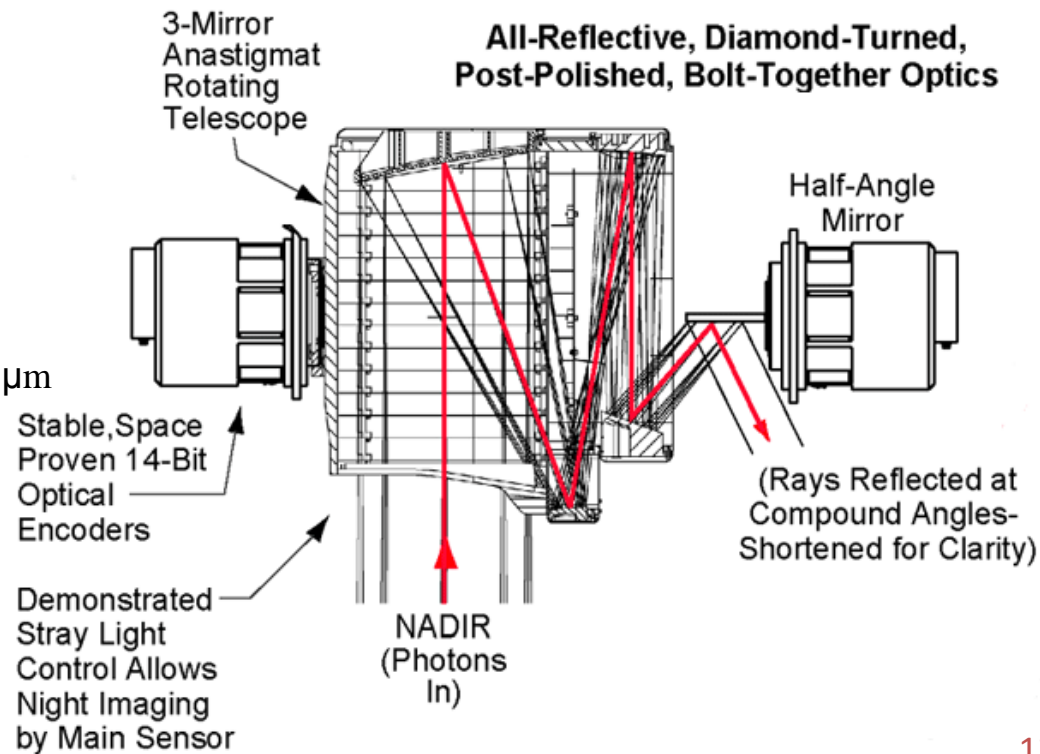
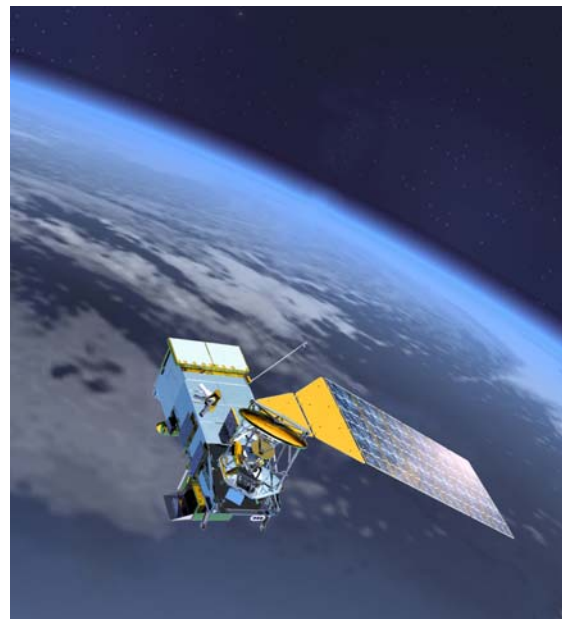
VIIRS OVERVIEW

PURPOSE: Global operational observations of land, ocean, & atmosphere parameters.

PREDECESSORS: AVHRR, OLS, MODIS, SeaWiFS

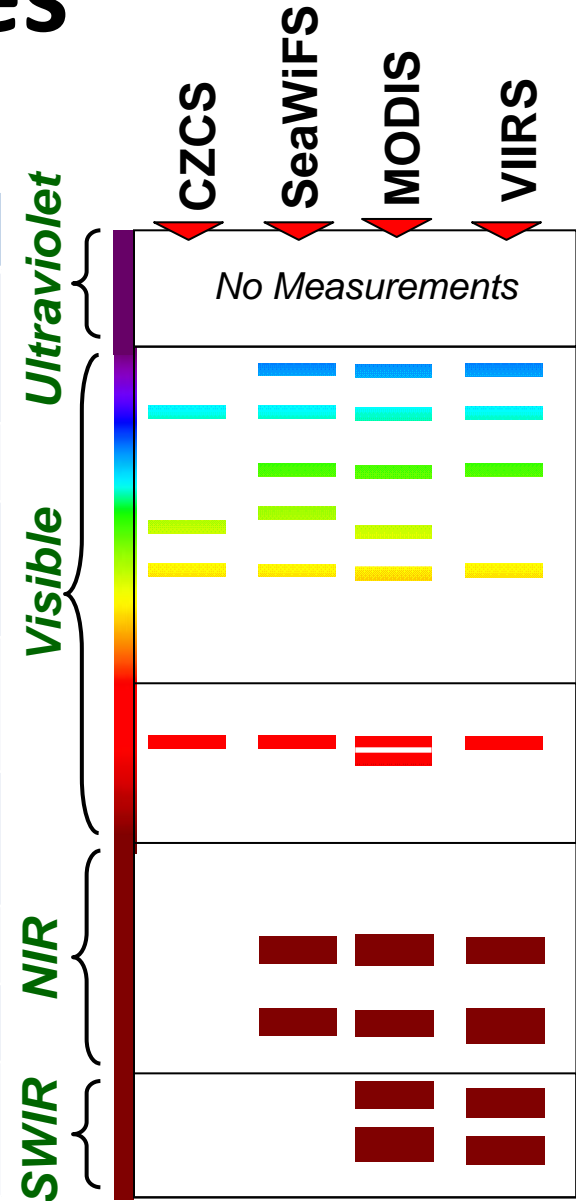
FACT SHEET

- **Multi-spectral crosstrack scanning instrument**
- **Rotating telescope design, similar to SeaWiFS**
- **Flies on Suomi NPP and every JPSS satellite**
- **Imagery and radiometry**
 - Imaging band at 0.4 km resolution (nadir)
 - Radiometric bands at 750m resolution
 - 12 bit quantization
 - Some bands have high and low gain modes
- **22 spectral bands (0.4 – 12.5 μm)**
 - 15 “reflective” VNIR-SWIR bands 0.4 – 2.3 μm
 - 3 “mixed” MWIR bands 3.5 – 4.1 μm
 - 4 “emissive” LWIR bands 8.4 – 12.5 μm
 - Automatic dual VNIR & triple DNB gains
- **Maximum swath width**
 - 3000 km



VIIRS Features

Characteristic	SeaWiFS	MODIS	VIIRS
Band Set (nm)	412, 443, 490, 510, 555, 670, 765, 865	412, 443, 488, 531, 547, 667, 678, 748, 869	412, 445, 488, 555, 672, 746, 865
Nadir Pixel Size	1.1 km	1 km	0.75 km
SNR Range	364 to 1010	726 to 2219	540 to 1239
Polarization Sensitivity	< 0.25% (Vis) < 0.5% (NIR)	1% to 6%	0.5% to 2.5%
Out-of-Band (worst case)	5.7% @865nm	3.8% @748 nm	4.9% @551 nm
Crosstalk?	None	SWIR	VisNIR
Tilt	-20,0,+20°	0°	0°
Detectors per Scan	1	10	16



VIIRS Features

Characteristic

Band Set (nm)

Nadir Pixel Size

SNR Range

Polarization

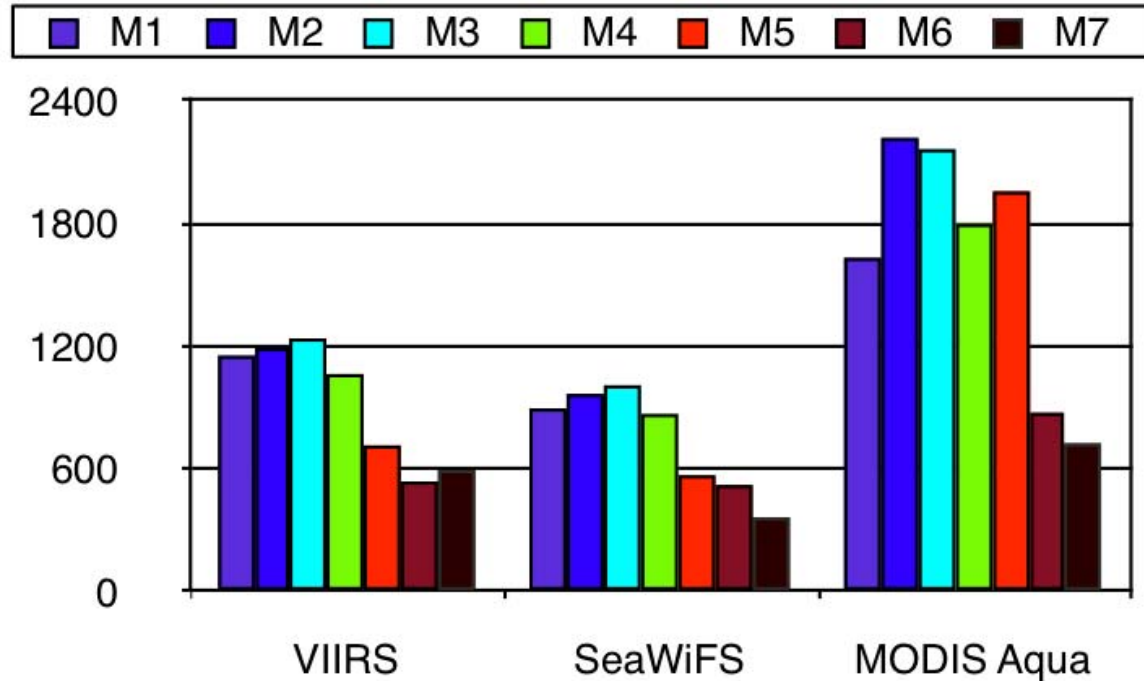
Sensitivity

Out-of-Band
(worst case)

Crosstalk?

Tilt

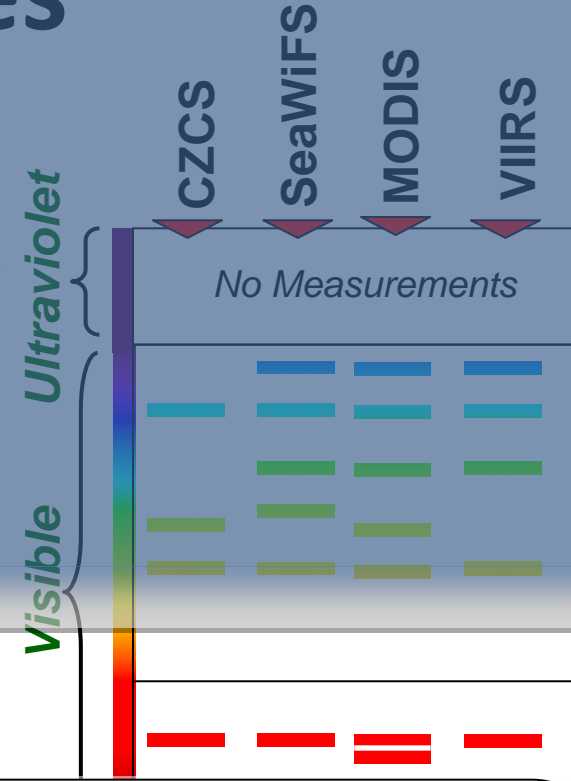
Detectors per
Scan



- ▶ VIIRS SNR here is based on typical L_t for ocean.
- ▶ Noise averaged over all six aggregation zones.
- ▶ Overall, noise levels are comparable to SeaWiFS, 3:1 agg zone having better SNR.

VIIRS Features

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Out-of-Band (worst case)

Crosstalk?

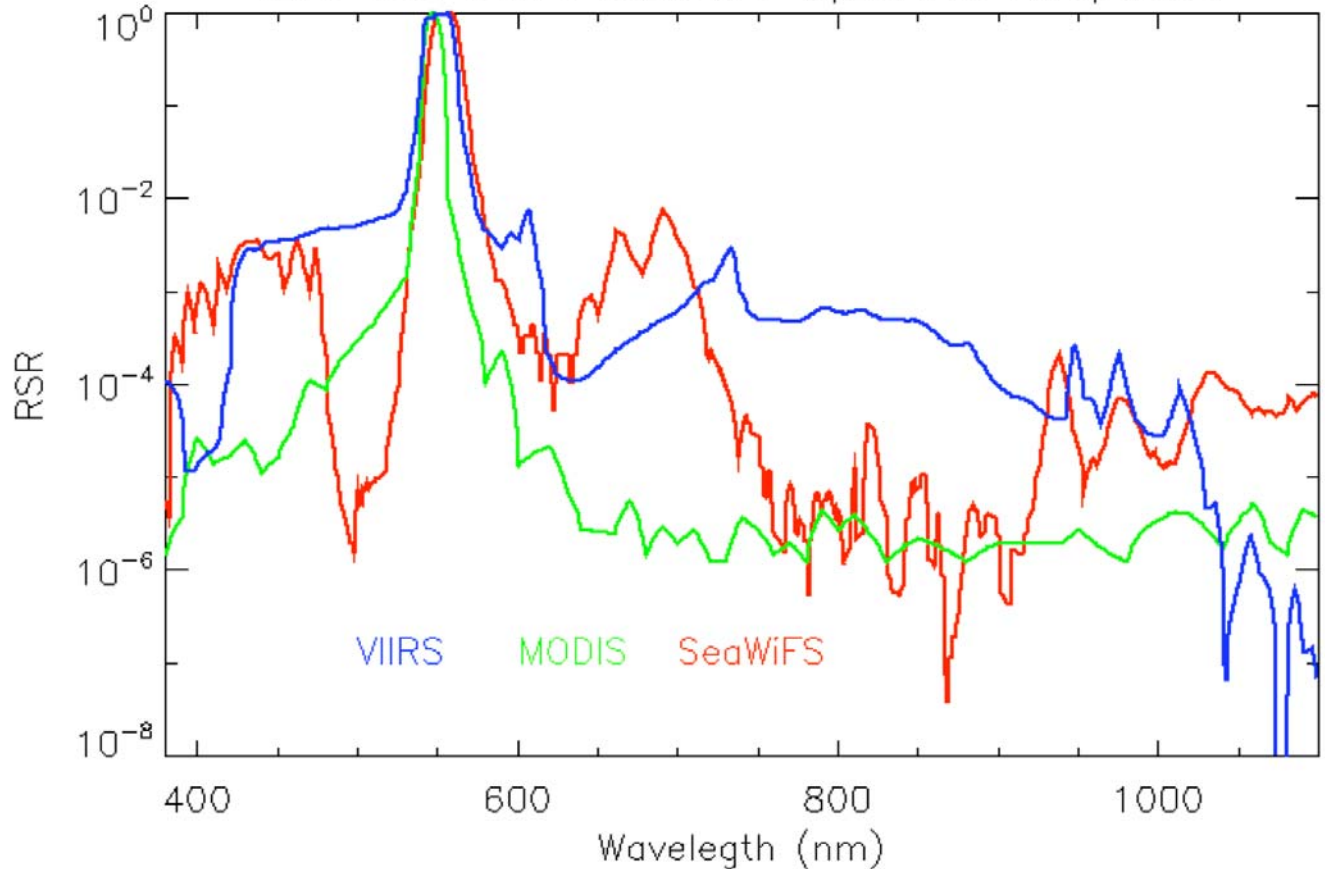
Tilt

Detectors per Scan

- ▶ Apparatus used to characterize MODIS and VIIRS polarization response was abandoned.
- ▶ Rotated polarizer sheets were used instead; similar to method used for SeaWiFS.
- ▶ Resulting characterization for VIIRS polarization response was much better quality than what was done for MODIS.

OUT-OF-BAND LIGHT LEAKS

555 nm Band Relative Spectral Response



- ▶ Similar to worse cases for SeaWiFS or MODIS.
- ▶ The blue light leak in the green band is the greatest concern, as shown above.

Characteristic

Band Set (nm)

Nadir Pixel Size

SNR Range

Polarization
Sensitivity

Out-of-Band
(worst case)

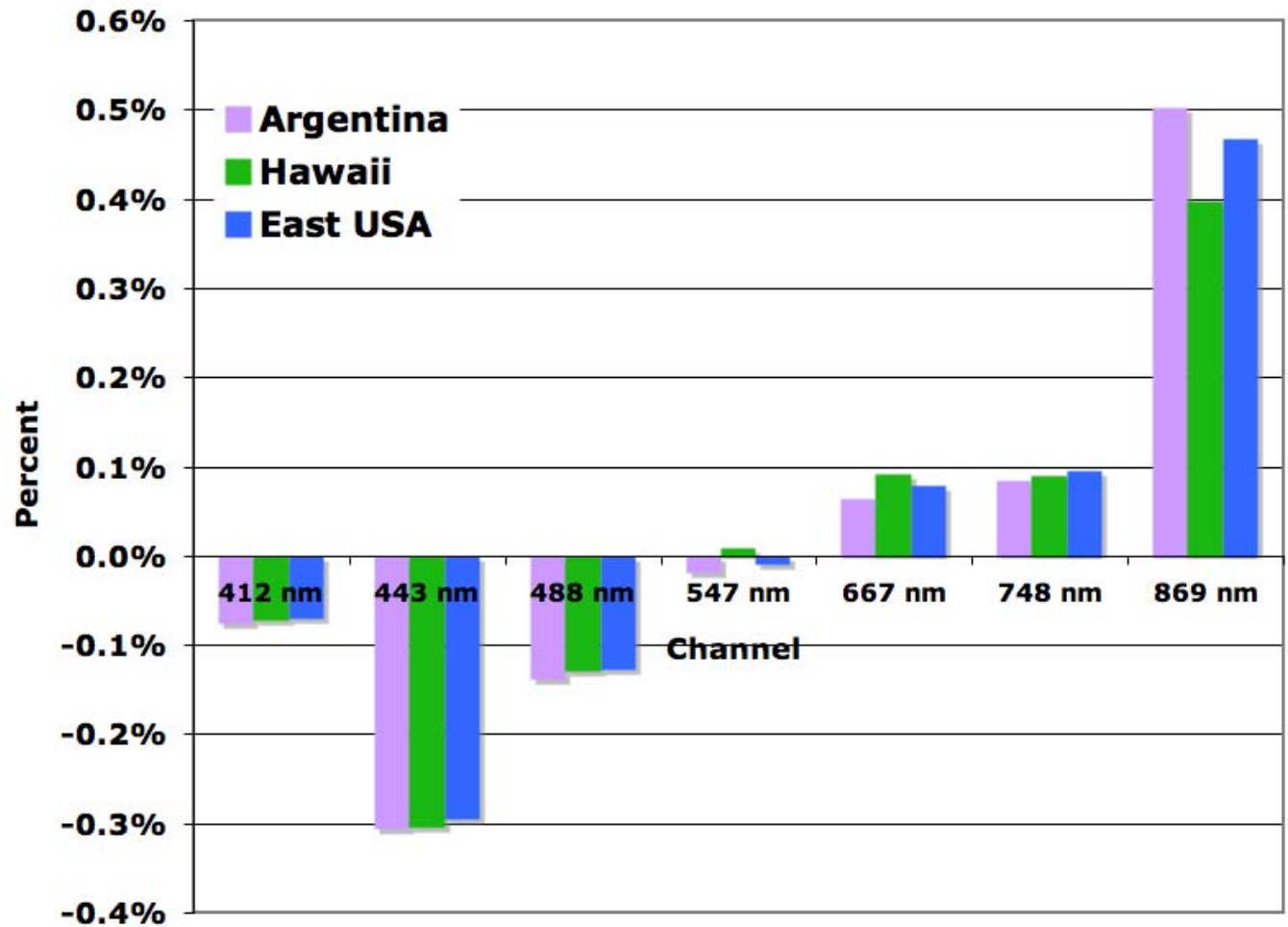
Crosstalk?

Tilt

Detectors per
Scan

OPTICAL CROSSTALK

L_t Median Relative Error



Characteristic

Band Set (nm)

Nadir Pixel Size

SNR Range

Polarization
Sensitivity

Out-of-Band
(worst case)

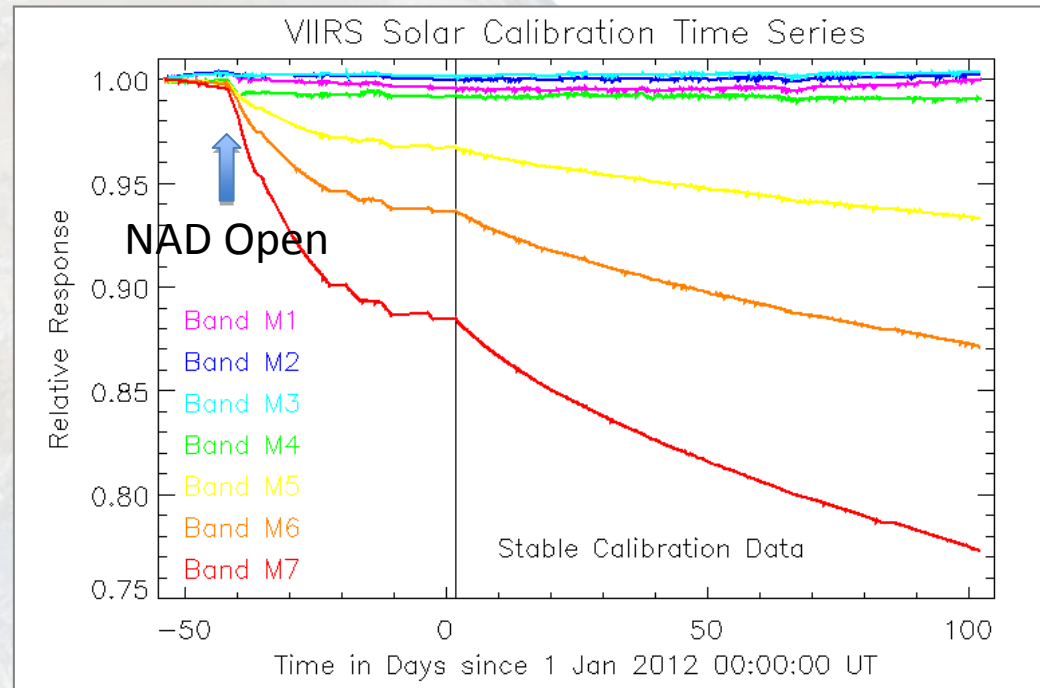
Crosstalk?

Tilt

Detectors per
Scan

Mirror Degradation

- Mirrors contaminated $\text{WO}_3(?)$ during manufacture.
- Causes severe, progressive loss in NIR and SWIR bands response when exposed to UV.
- Testing with witness samples suggest worst case of 30% lost in 895 nm band (M7).



- Might impact ocean color data quality at some point in the mission.
- However, while the instrument is operating normally, the resulting degradation is smooth and trackable.
- Early lunar measurements show strong agreement solar diffuser calibration (see plots on calibration slides).

A grayscale satellite image of Earth, showing cloud cover and landmasses. The image is centered on the Americas, with North and South America visible. The text "VIIRS Data Features" is overlaid in the center.

VIIRS Data Features

VIIRS Features

Granule Feature	MODIS	S-NPP VIIRS
Sun Sync Orbit	Terra – Descending Aqua – Ascending	Ascending
Equator Crossing Time	Terra – 1030 Aqua – 1330	1330
Altitude (km)	705	824
Scan Coverage (km)	1354	3000
Time Coverage	5 mins	85.4 secs
No. of Scans	203	48 ¹
No. Dets per Scan	10 (Mod res)	16 (Mod res)
Aggregation Zones	None	6 (3 types)
Data Format	HDF4	HDF5 ²
L1 Data Band Org	Separate SDS's	Separate Files
Data Distribution	OC Website	CLASS ³

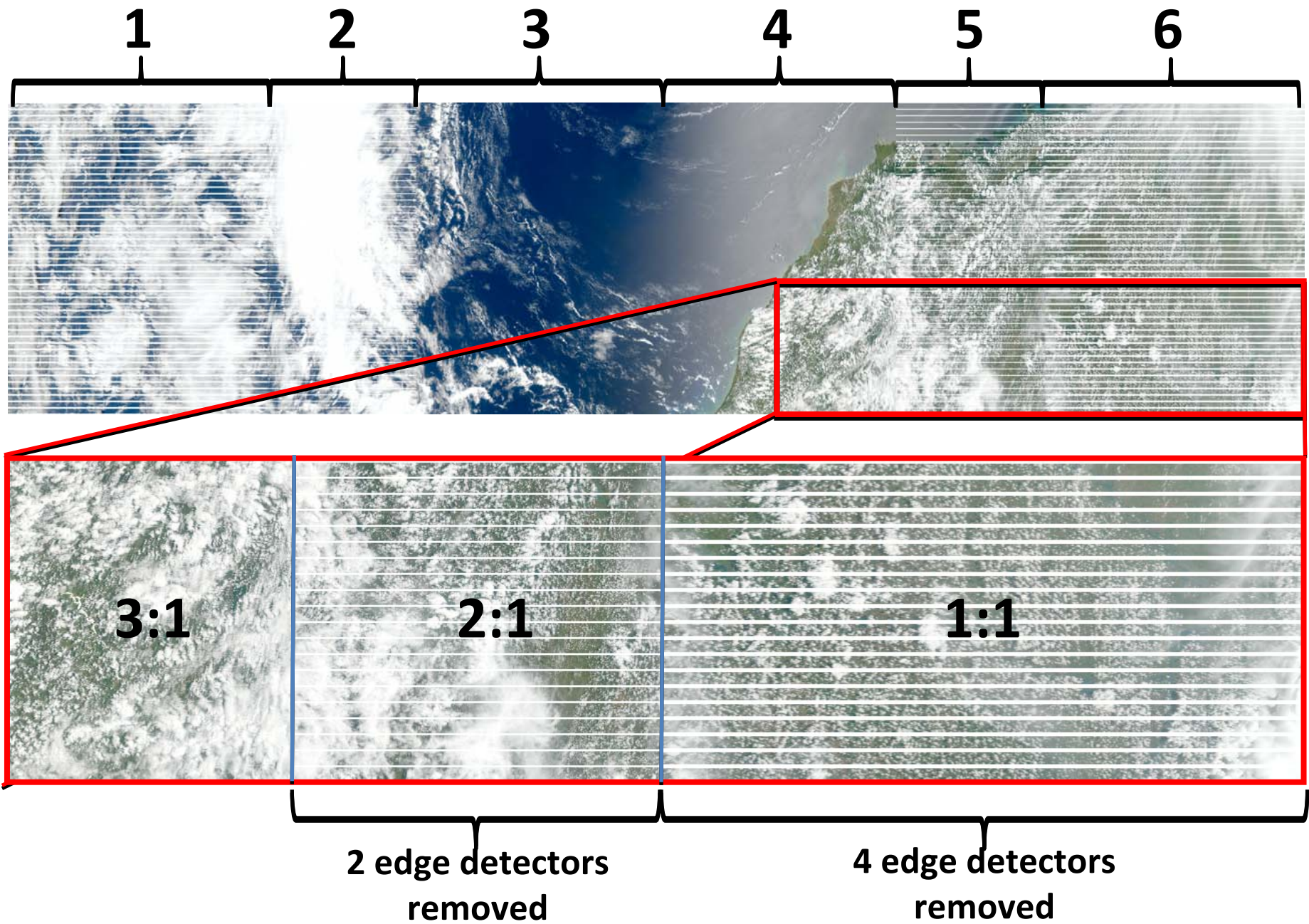
RDR = L0
SDR = L1b
EDR = L2
? = L3*

*** There is no operational equivalent to L3**

1- some granules on contain 47 scans.

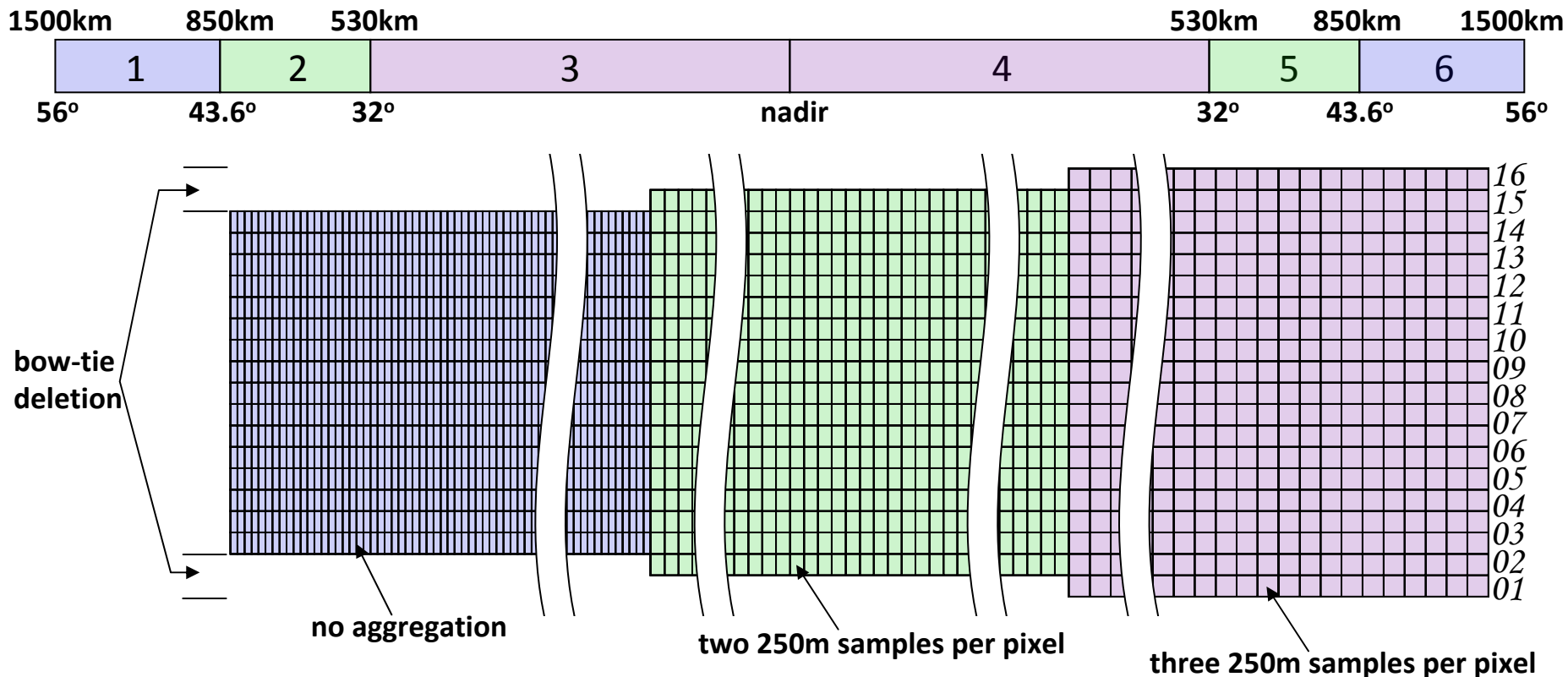
2- OBPG eval prods are in HDF4 format; conventions same as MODIS and SeaWiFS.

3- OPBG L0-L3 eval prods available via OC website.



The Anatomy of a VIIRS Scan

Scan Aggregation Zones



source: MDFCB, 4 Nov 2004

Dual-gain Bands - samples aggregated on ground.

Singe-gain Bands - samples aggregated on-board (only M6 for ocean bands).



VOST Calibration

Solar Calibration

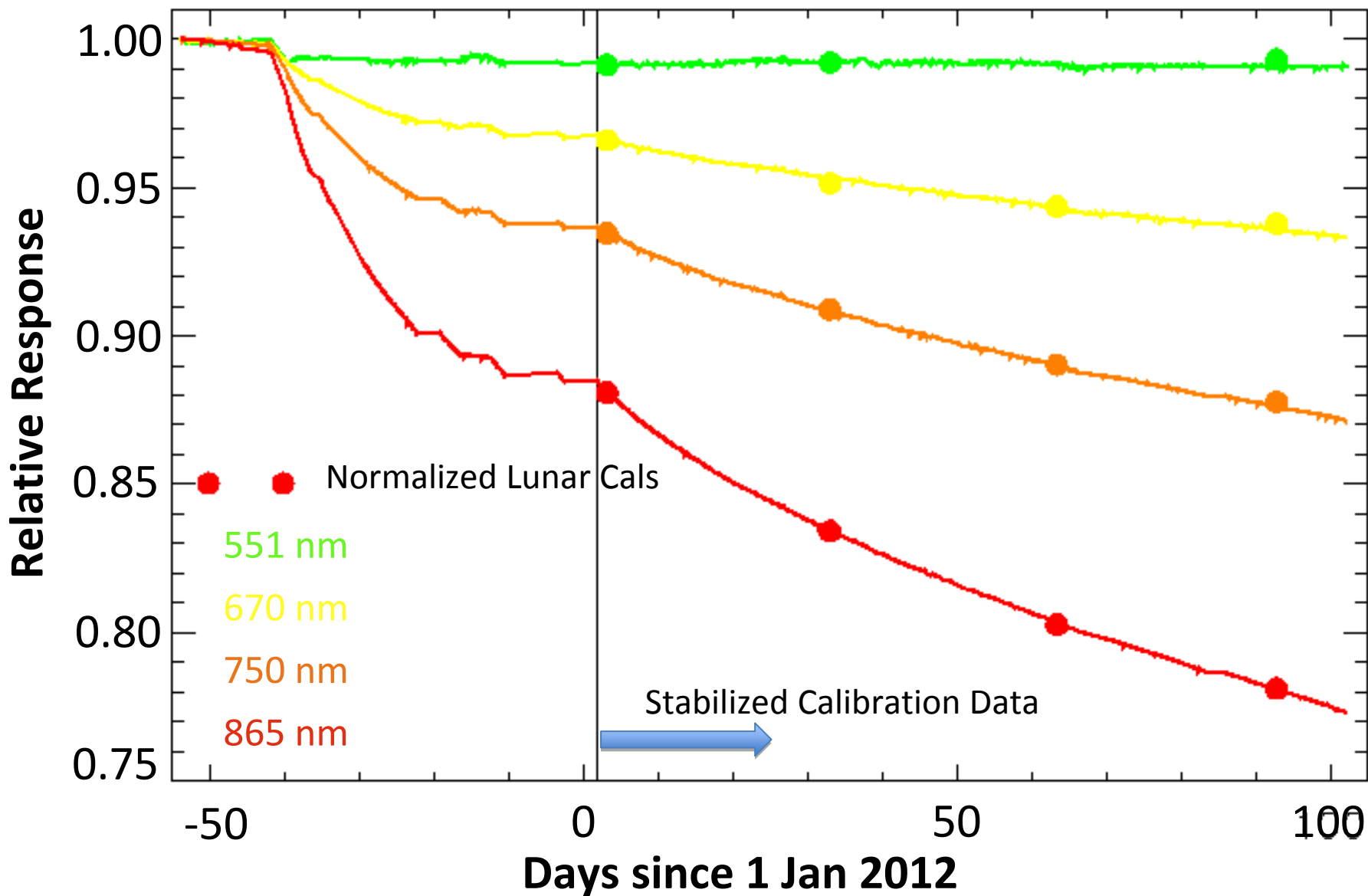
- **VOST pre-launch counts-to-radiance conversion uses linearization of ATBD eqns.**
- **Solar Diffuser (SD) is used to track changes in instrument response from prelaunch.**
- **SDSM tracks changes in SD. (Quis custodiet ipsos custodes?)**
- **VOST developed a time-dependent capability to support reprocessing.**

Lunar Calibration

- **Lunar calibration - Successful measurements :**
 - partial bands in Jan (412 & 443 nm bands were clipped),
 - Jan serendipitous measurements for 412, 443, and 488 nm bands,
 - dual rolls in Feb (measured all bands in VisNIR and SWIR),
 - missed in Mar but got serendipitous for seven bands (green, red, 2 NIR, and 3 SWIR), and
 - sector rotation in Apr; captured and co-registered all bands.
- **Next measurement is scheduled for the 2 May.**
- **Measurements verify the solar cal and can replace it if need be later in the mission.**
- **Can incorporate lunar measurement trending in calibration after at least one year of acquisitions.**

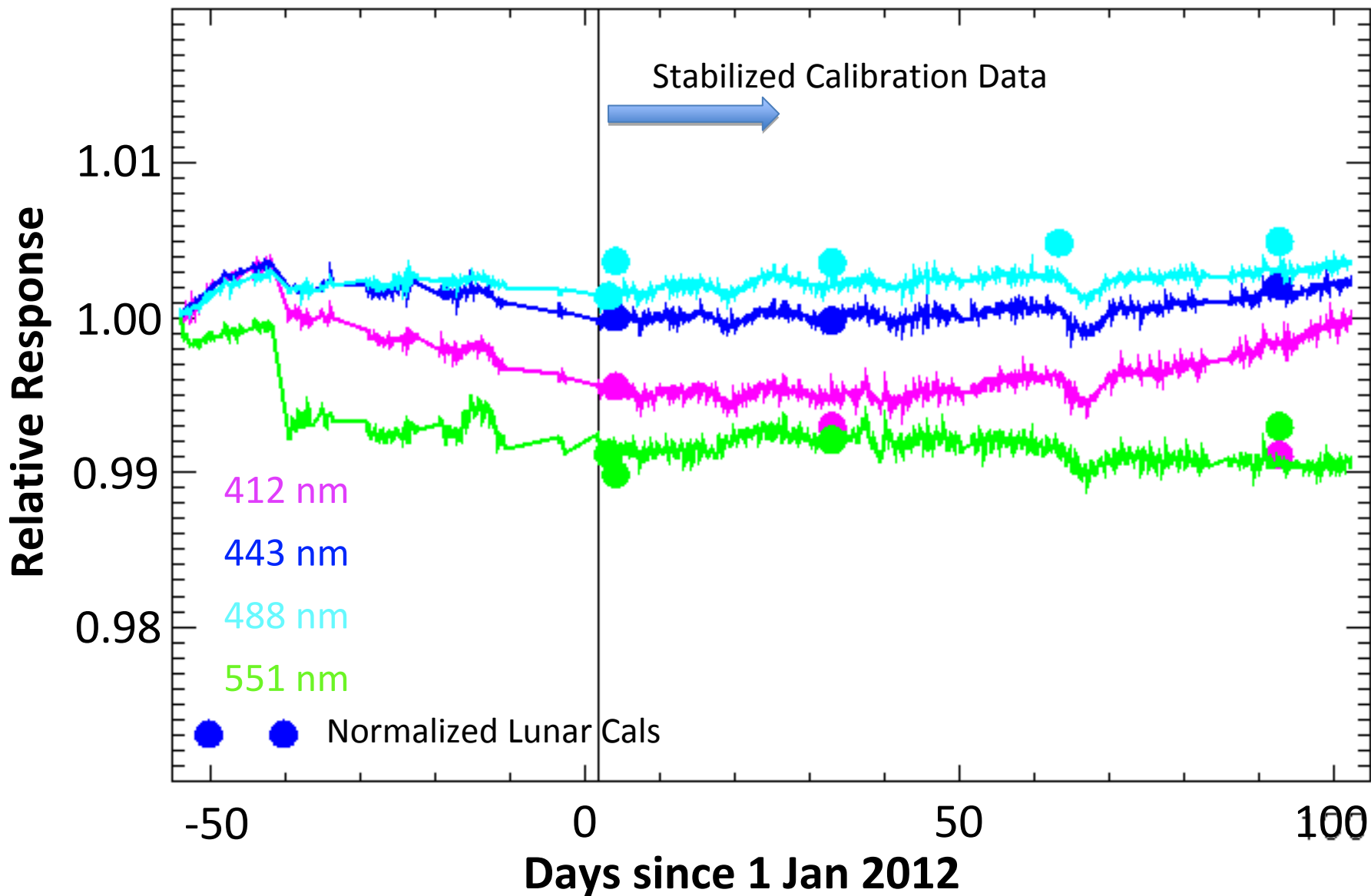
NASA VIIRS SOLAR CALIBRATION

with Verification OF Lunar Measurements



NASA VIIRS SOLAR CALIBRATION

with Verification OF Lunar Measurements

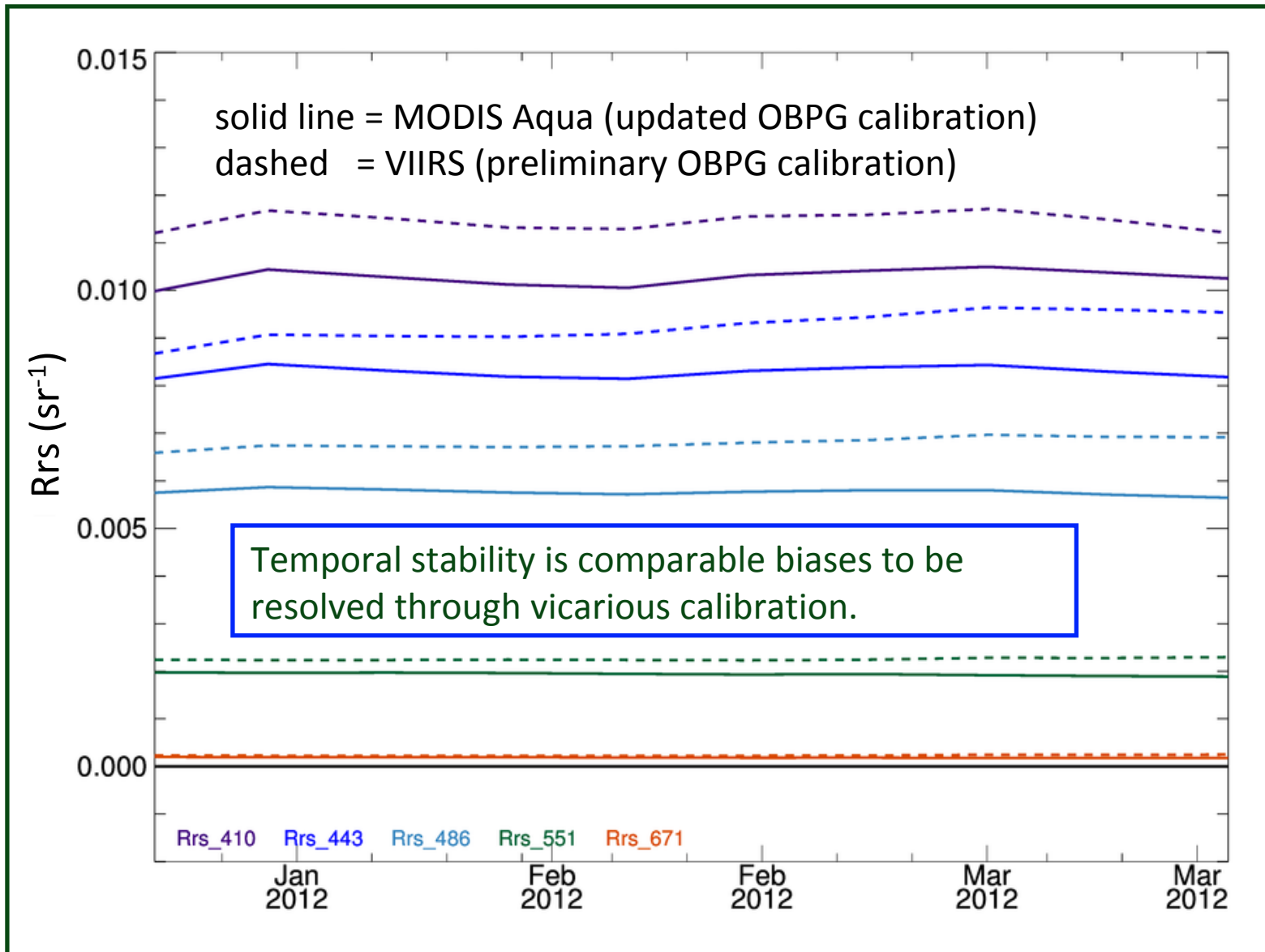




Initial Results

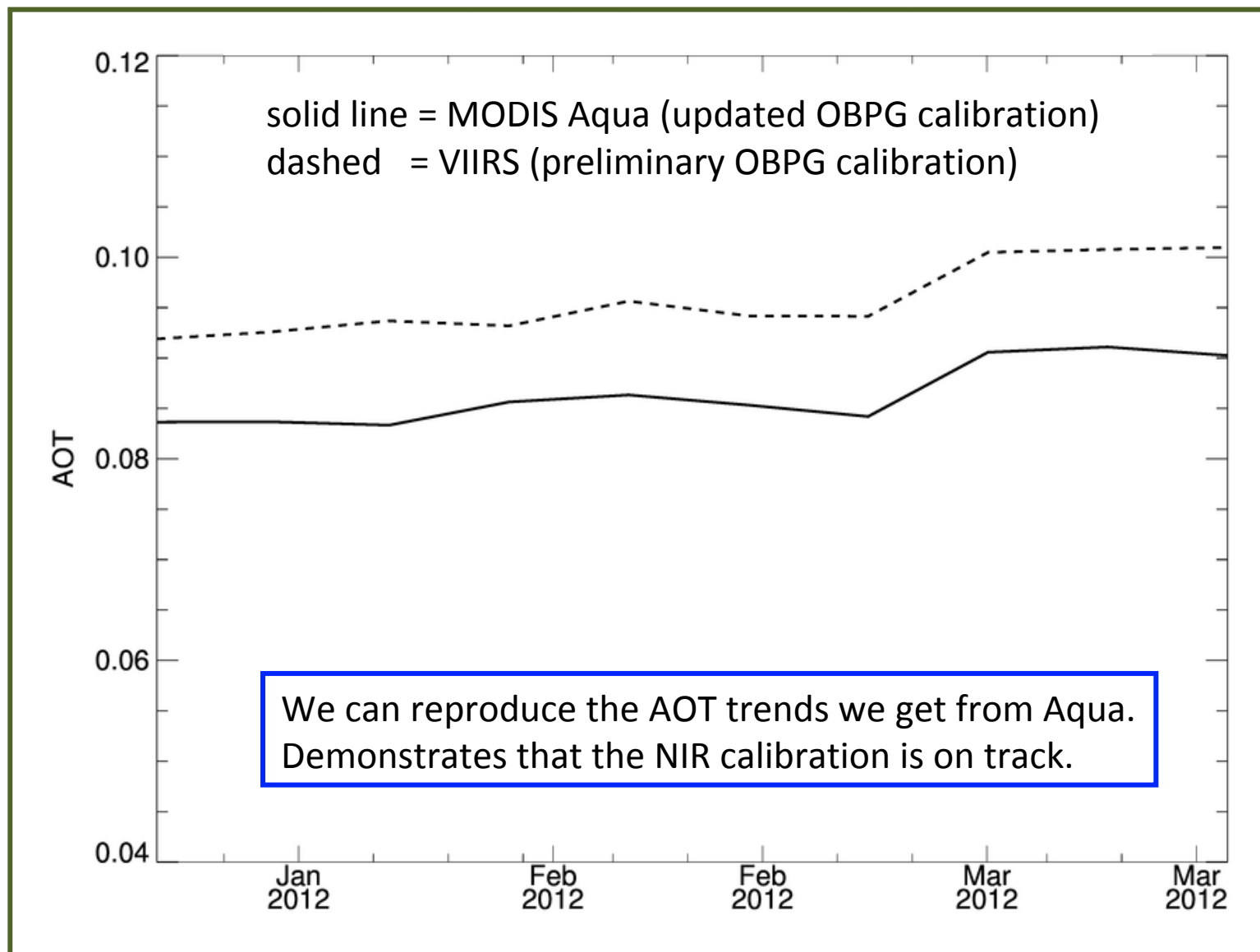
VIIRS & MODIS Aqua Deep-Water Rrs Trends

NASA Calibration and L2 Processing



VIIRS Deep-Water Aerosol Optical Thickness Trends

IDPS L1Bs vs OBPG L1Bs, Both with NASA L2 Processing



VIIRS & MODIS Aqua Deep-Water Chl

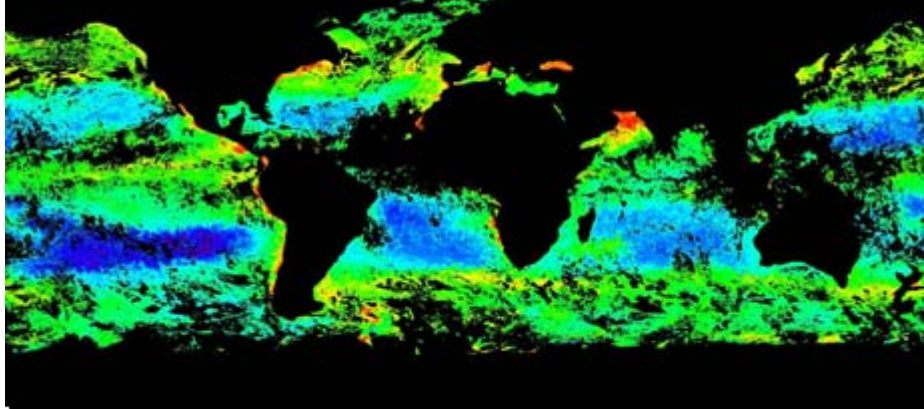
NASA VIIRS L2, EDR, & MODIS Aqua

NPP VIIRS L2 Chl (Deep Water)

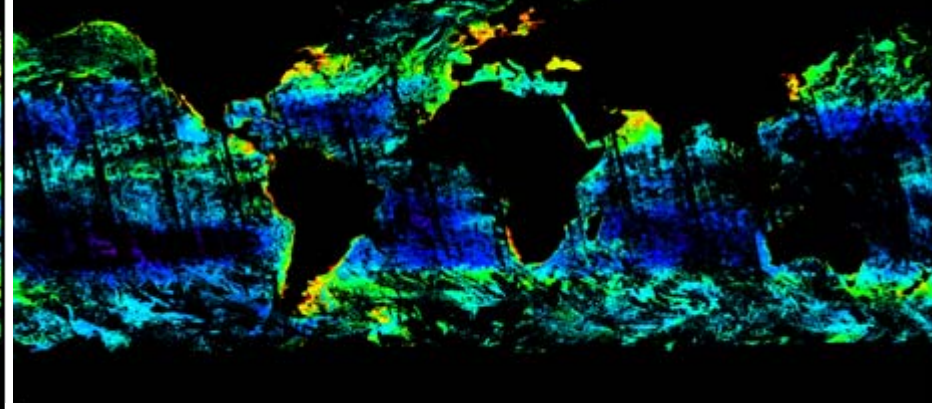
NPP VIIRS EDR Chl

Composite: Day 73-80

NASA calibration, L2 algorithms, and flags Composite: Day 73-80

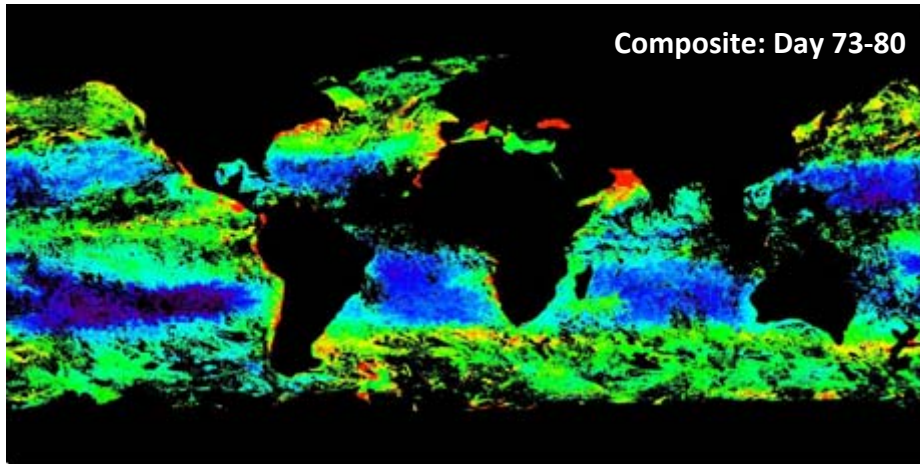


NOAA calibration, EDR algorithms, and flags

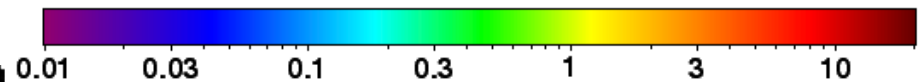


Aqua MODIS Chl (Deep Water)

Composite: Day 73-80



Chlorophyll a concentration (mg / m³)



- VIIRS L2 is comparable in range and distribution to updated MODIS Aqua.
- EDR differences are visible.
 - Flags present differences.
 - Calibration may dominate differences

Conclusions

- VOST has invested several years of effort working with NPP VIIRS.
- NPP VIIRS is currently performing well; performance anomalies are correctable.
- Generating NASA VIIRS evaluation products to answer VOST and OBPG questions.
 - NASA evaluation products are based on same L2 algorithms used to generate NASA science and climate quality datasets from SeaWiFS and MODIS.
 - Implemented a time-dependent calibration strategy based on solar diffuser and lunar measurements.
 - Generating L3 products to support comparisons (there is no operational L3 product).

Conclusions

- EDR products cannot be evaluated prior to 6 Feb; quality too poor. (VOST Question)
- Evaluation can begin now that sufficient EDR data has been collected. (VOST Question)
- With NASA calibration and processing, the VIIRS products are qualitatively comparable in dynamic range and stability to SeaWiFS climatology based on a limited time series.
- Early mission assessment suggests that application of a time-dependent calibration and common algorithms to VIIRS sensor measurements could continue the EOS climate data record. (OBPG Question)



Kiitos paljon!

VOST Contributions 2003-Present

- Reviewed numerous project documents
 - Reviewed science
 - Successfully advoc
 - Performed multip
 - performance on d
 - Presented findings
 - Participated in tes
 - VIIR ocean color d
 - Development of ti
 - Generation of VIIRS data products using NASA algorithms
- Instrument Requirements
 - Waiver Requests
 - Characterization Test Plans
 - Test Analysis Reports
 - Contractor Anomaly Impact Analysis Reports
 - Theoretical Basis
 - Product Performance Specifications
 - Data Format and Interface Specifications

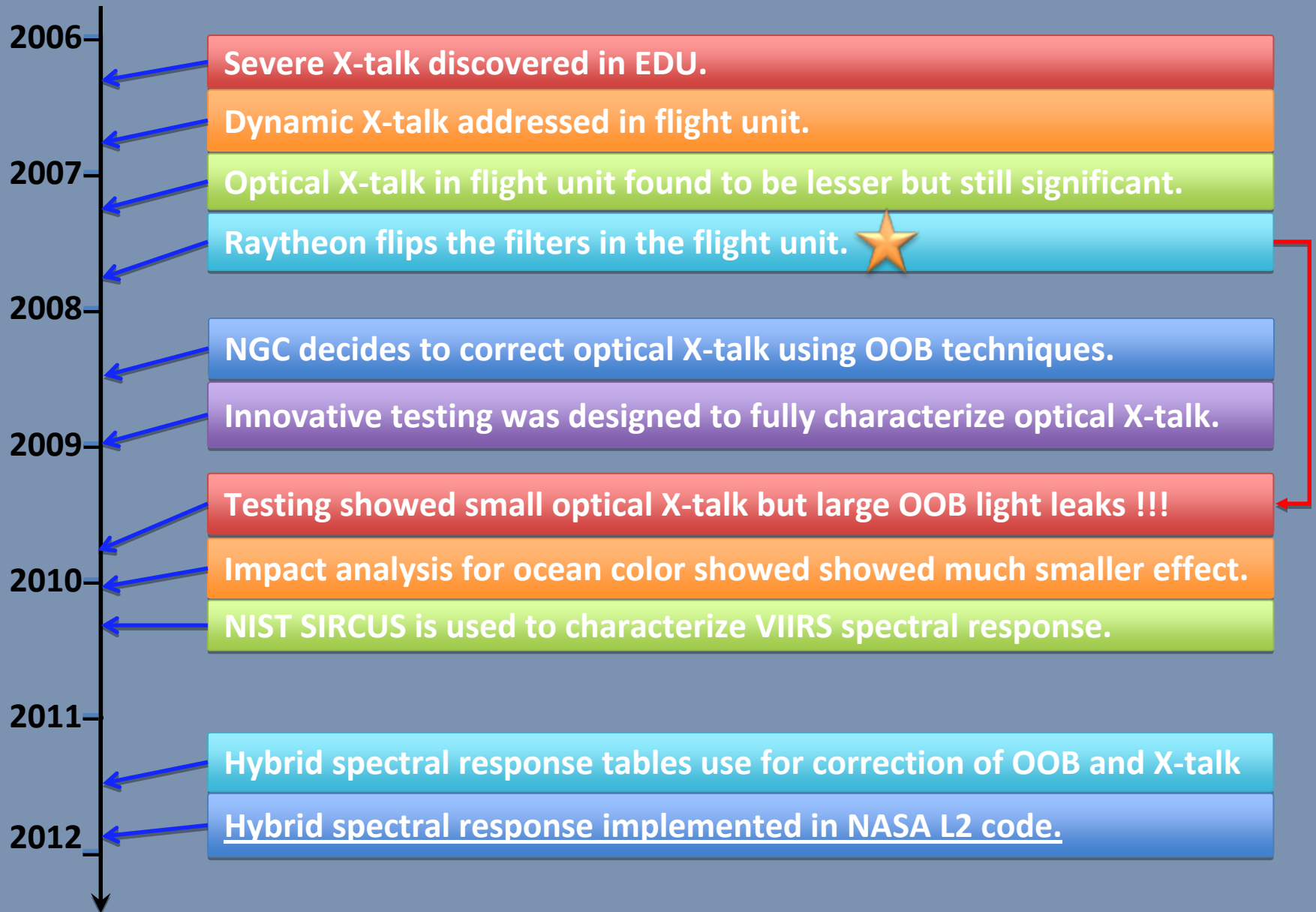
VOST Contributions 2003-Present

- Reviewed numerous project documents
 - **Reviewed science and operational code**
 - Successfully advocated for improvements
 - Performed multiple code audits and performance optimization
 - Presented findings and recommendations to the science team
 - Participated in technical reviews and discussions
 - VIIR ocean color correction
 - Development of operational algorithms
 - Generation of VIIR data products
- **Identified coding errors.**
 - **Provided sun glint correction code.**
 - **Noted NASA improvements that were missing:**
 - **NIR correction,**
 - **Improved aerosol models,**
 - **Revised whitecap correction,**
 - **BRDF correction,**
 - **Band pass adjustments, and**
 - **Chl based on Carder algorithm.**

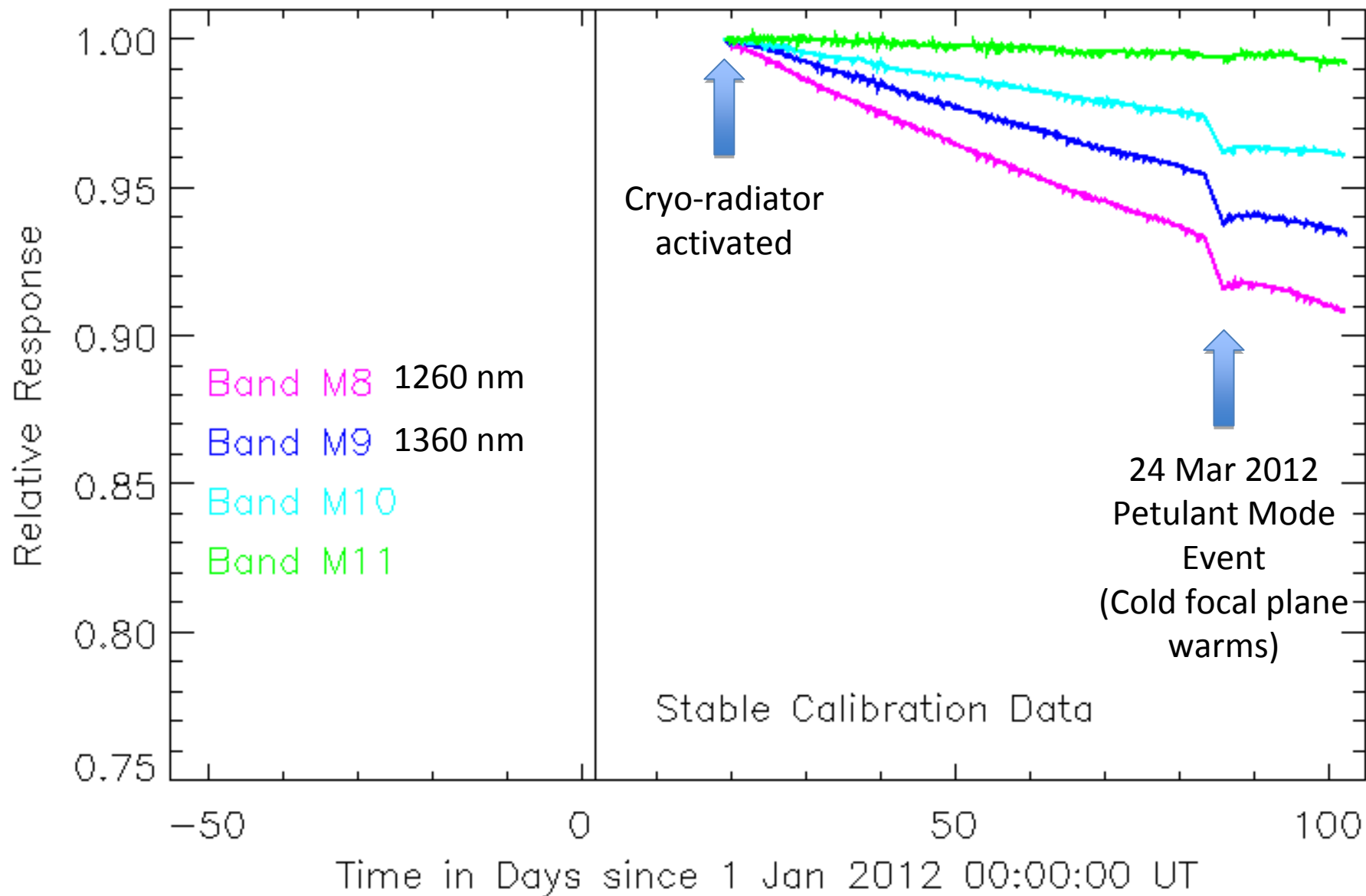
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- **Development of time-dependent calibration**
- **Generation of VIIRS data products using NASA algorithms**

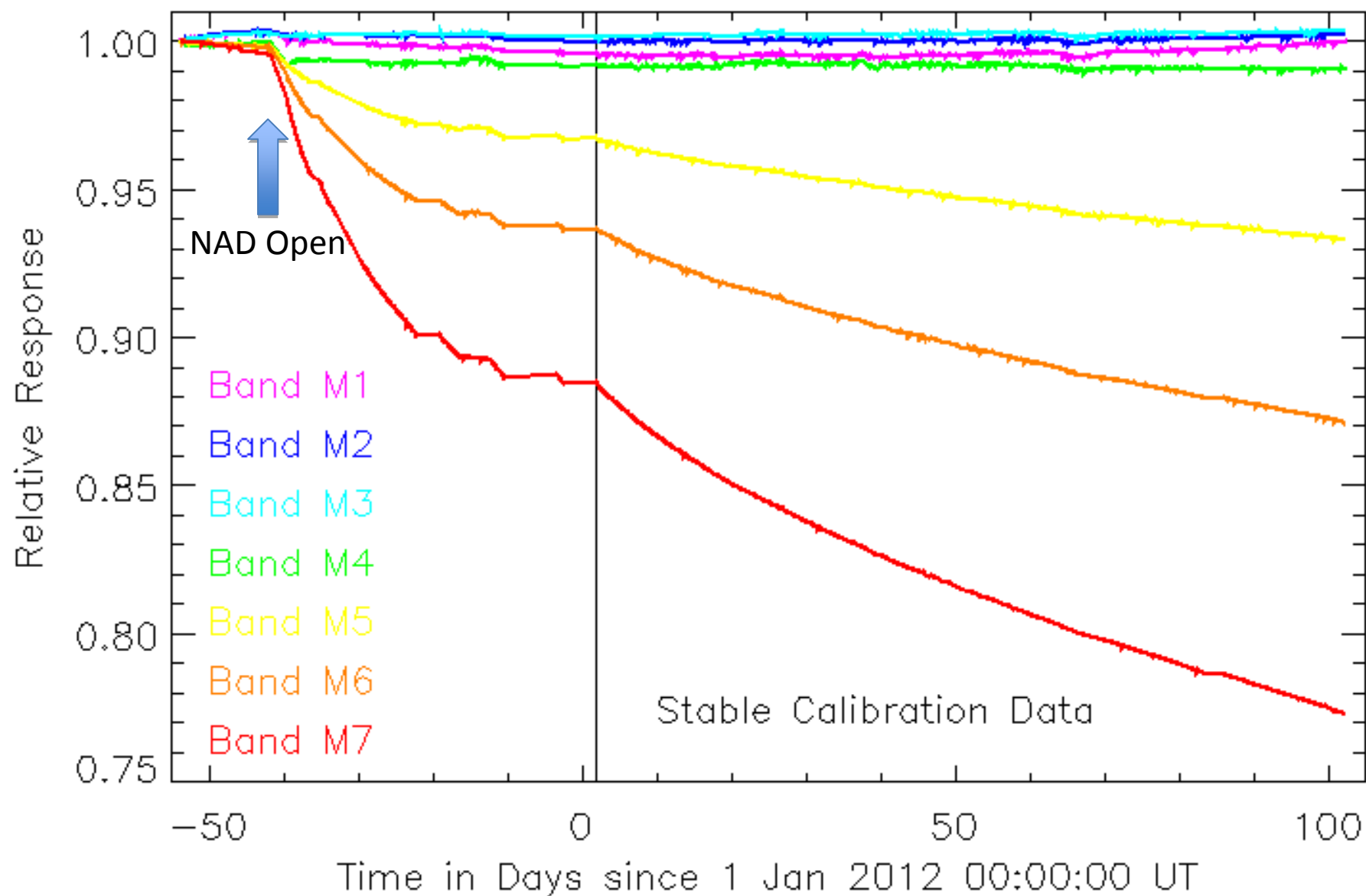
THE RISE AND FALL OF THE CROSSTALK ISSUE



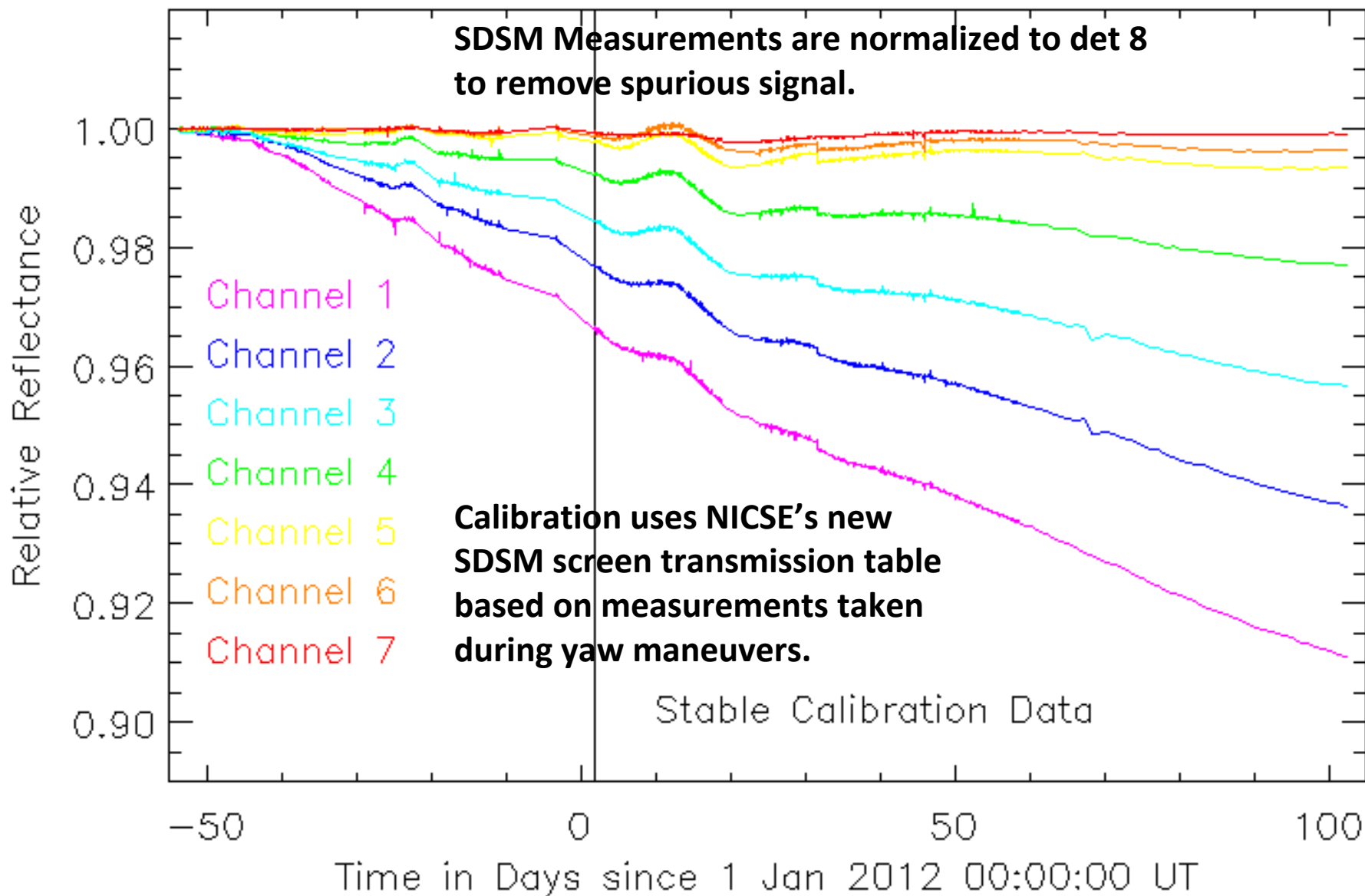
VIIRS Solar Calibration Time Series



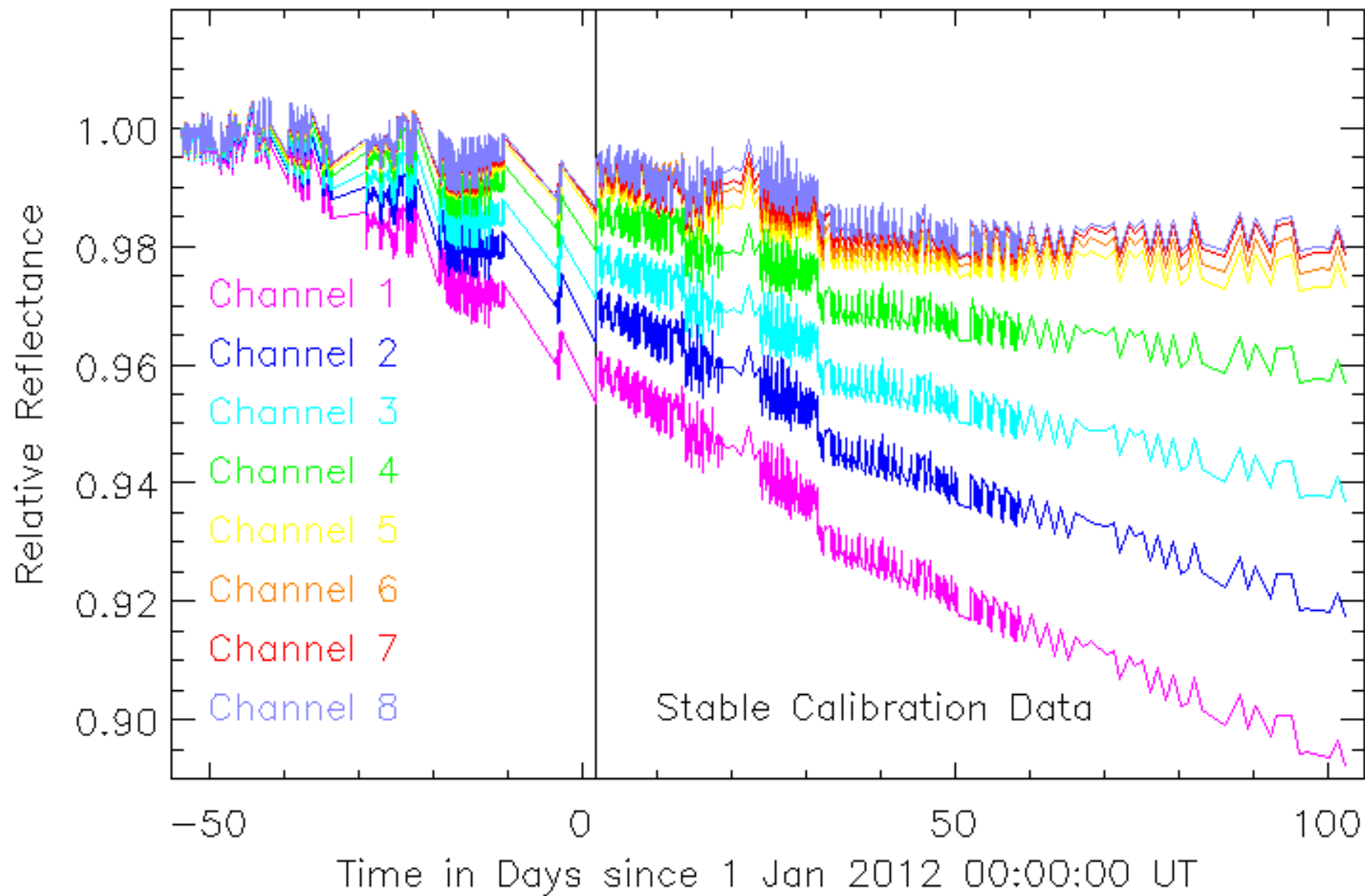
VIIRS Solar Calibration Time Series

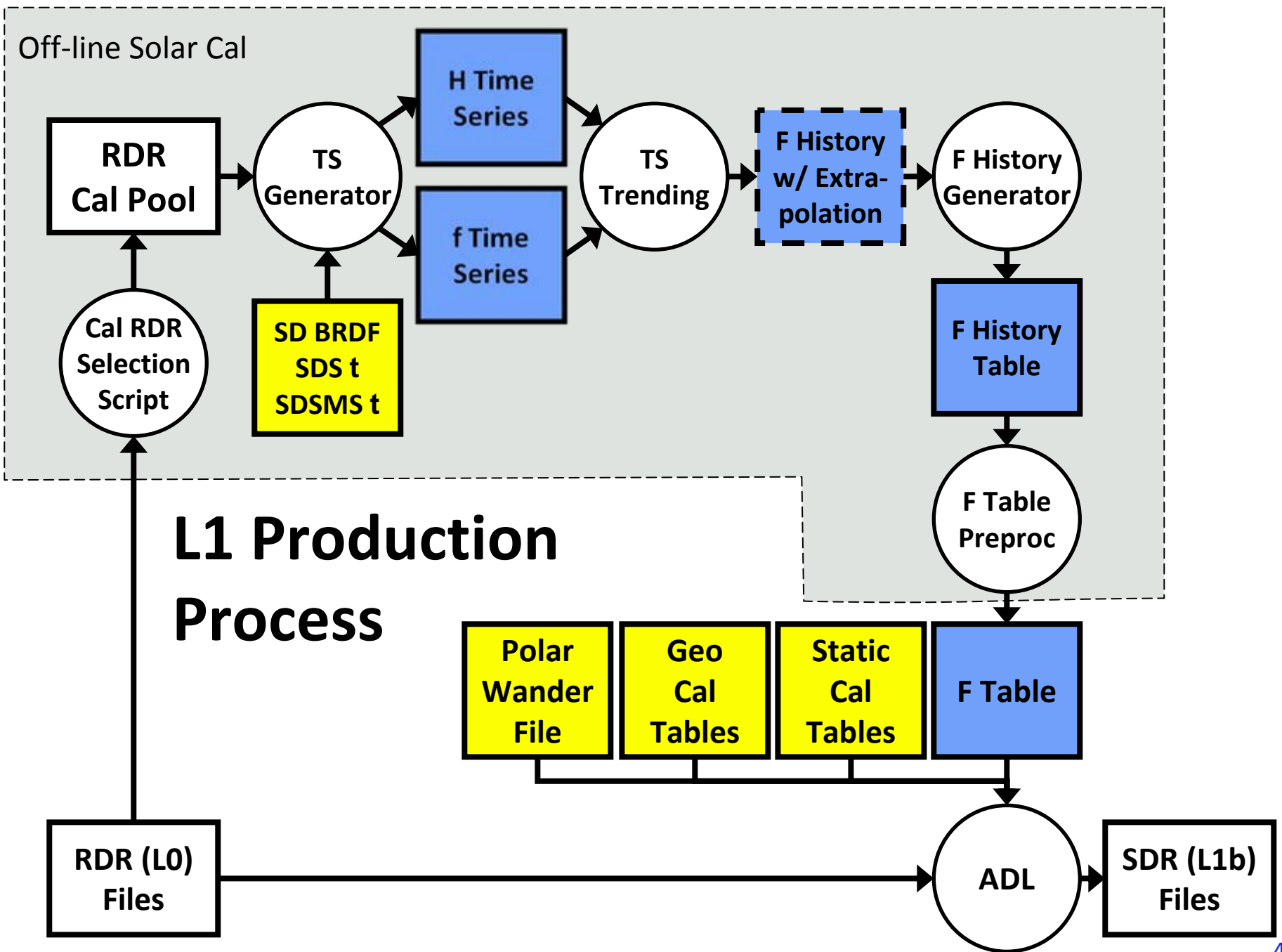


SDSM Normalized BRDF Time Series

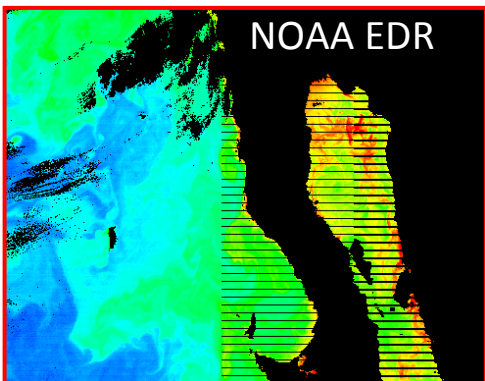


SDSM BRDF Time Series

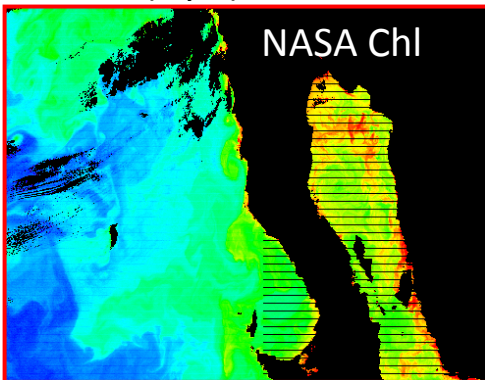




10 Feb 2012 (Day 41)

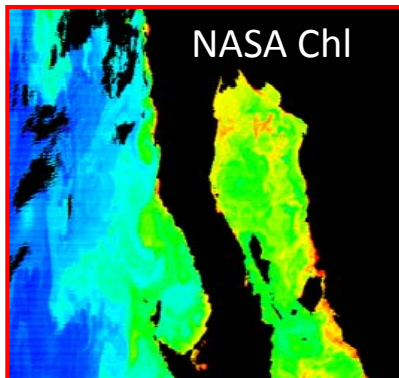


10 Feb 2012 (Day 41)



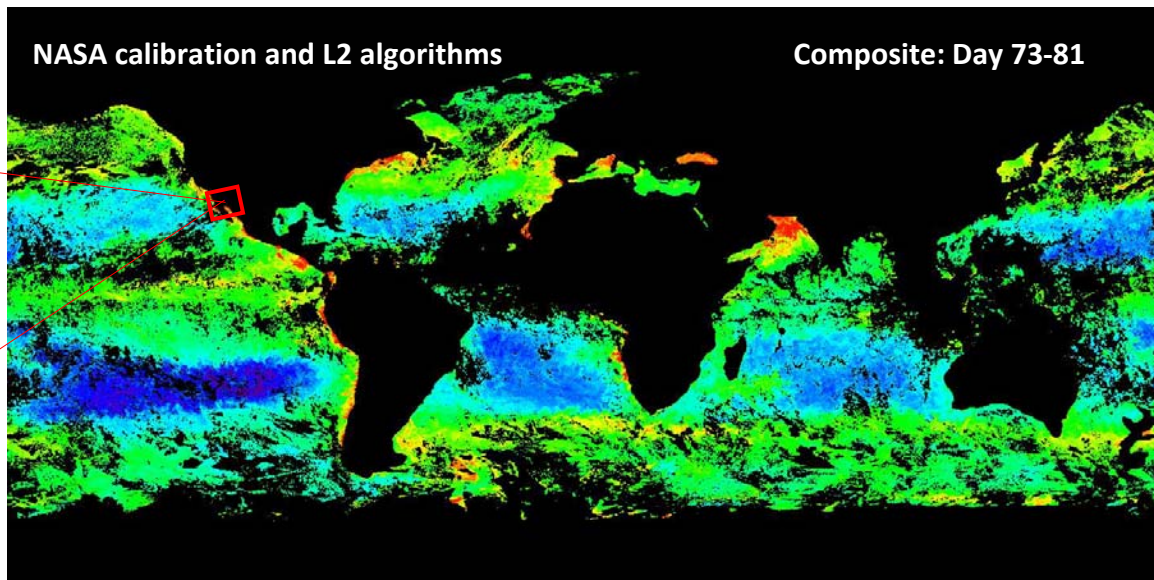
Horizontal stripes caused by bow-tie deletion
EDR has additional pixel trimming

10 Feb 2012 (Day 41)



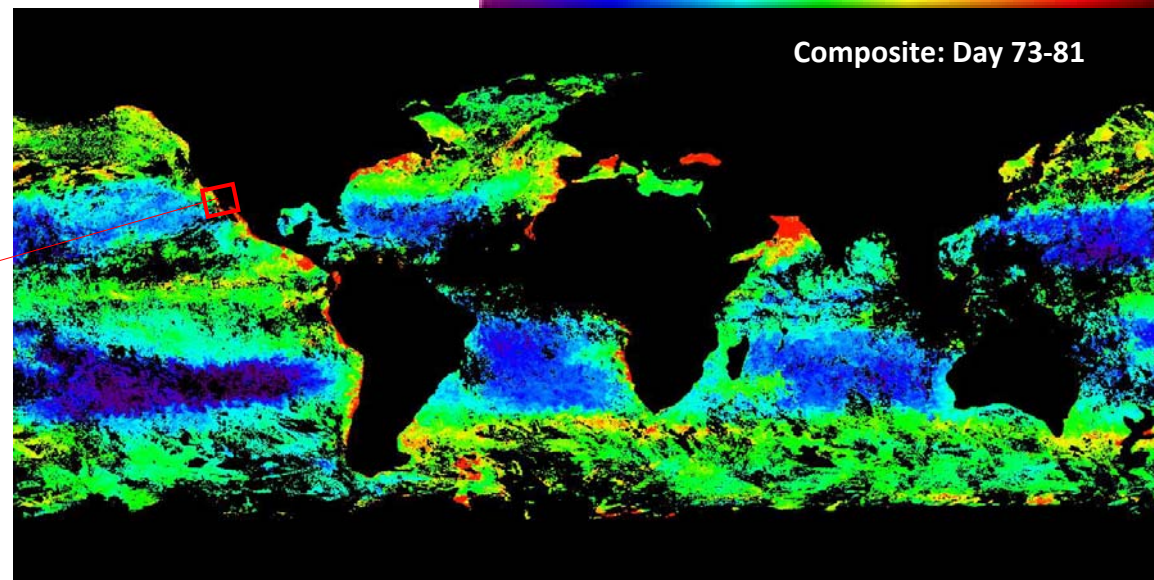
Projections of the above VIIRS and MODIS
swath cutouts projections are different.

NPP VIIRS Chl



0.01 – 1.0 mg m⁻³

Aqua MODIS Chl



Vicarious Calibration



- **Vicarious calibration**

- **Initially based on Ocean Surface Reflectance Model using HOT and BATS sites.**
- **Will use surface values later in the mission, e.g., MOBY (depending on availability and quality).**