Assessment and Comparison of MODIS and VIIRS SD On-orbit Degradation

X. Xiong[1], J. Butler[1], J. Fulbright[2], A. Angal[2], H. Chen[2], and Z. Wang[2]

[1]Sciences and Exploration Directorate, NASA/GSFC, Greenbelt, MD

[2]Science Systems and Applications Inc., 10210 Greenbelt Road, Lanham, MD

(J. Fulbright: currently with Columbus Technologies and Services, Inc., Greenbelt, MD)

CALCON 2015, Logan, UT, August 24-27, 2015)

Outline

- **Background**
- **Characterization of SD On-orbit Degradation**
  - On-board Calibrator - Solar Diffuser Stability Monitor
  - Characterization Methodologies
- **Results and Discussion**
  - Changes in SD Bi-directional Reflectance Factor (BRF)
  - Changes in SDSM Detector Responses
  - Challenging Issues
- **Concluding Remarks**

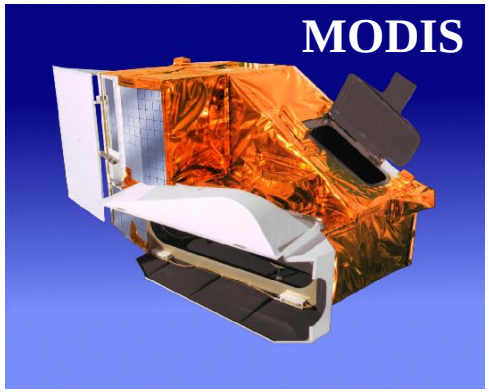
Background

MODIS

- Spectral range: 36 bands between 0.4 µm and 14.5 µm
  - 20 RSB and 16 thermal emissive bands (TEB)
- Focal plane assemblies (FPA): VIS, NIR, SMIR, and LWIR
- Spatial resolution: 250, 500, 1000 m
- On-board Calibrators: SD, SDSM, BB, SV, SRCA

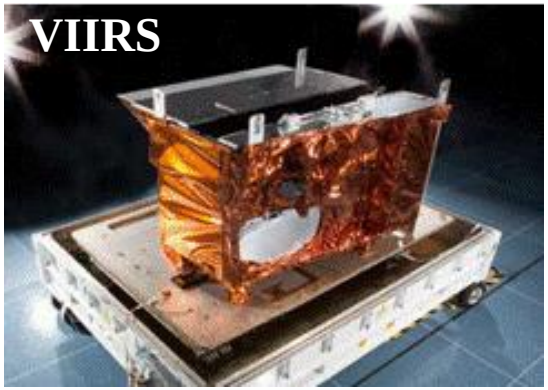
VIIRS

- Spectral range: 22 bands between 0.4 µm and 12.5 µm
  - 15 RSB, including 1 day night band (DNB), and 7 TEB
- Focal plane assemblies (FPA): VIS/NIR, SMIR, and LWIR
- Spatial resolution: 375 and 750 m
- On-board Calibrators: SD, SDSM, BB, SV
- Pixel aggregations and bowtie deletion



Terra 1999-present

Aqua: 2002-present



S-NPP 2011-present

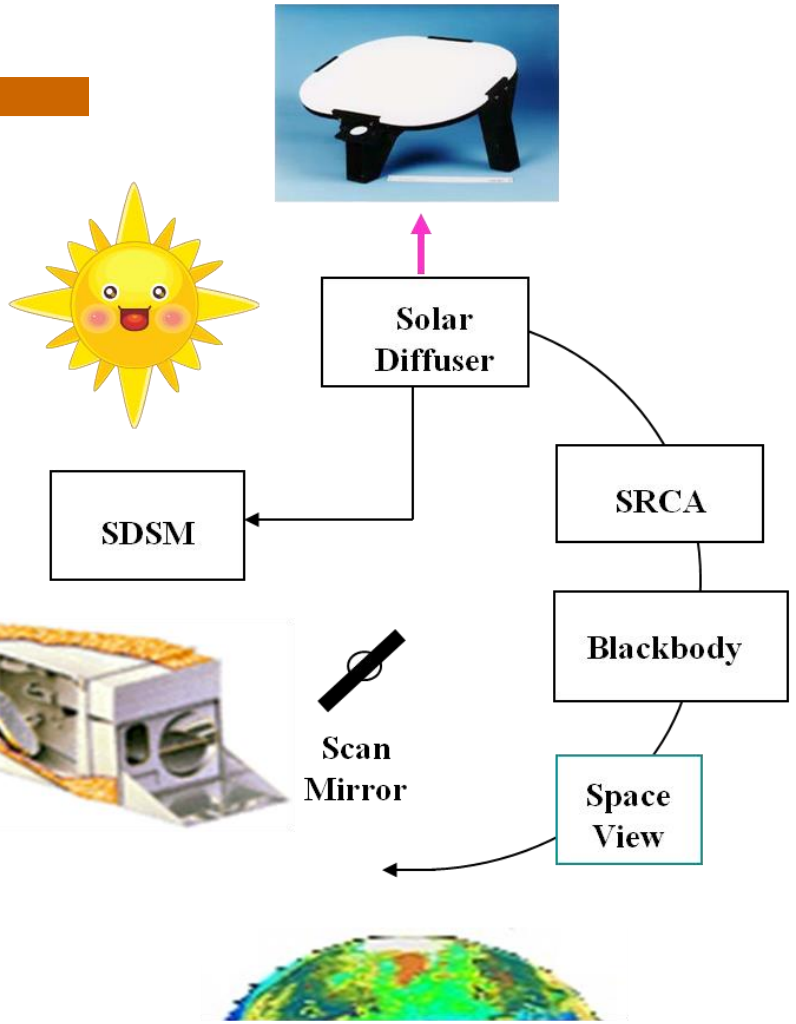
JPSS-1: 2017

Reflective Solar Bands (RSB) Calibration
(Similar for MODIS and VIIRS)

MODIS RSB On-orbit Calibration Coefficients (m_1)

$$m_1 = \frac{BRF_{SD} \cdot \cos(\theta_{SD})}{< dn^*_{SD} > \cdot d^2_{Earth-Sun}} \cdot \Gamma_{SD} \cdot \Delta_{SD}$$

$$\Delta_{SD} \propto \frac{\overline{dc_{SD}}}{dc_{Sun}}$$

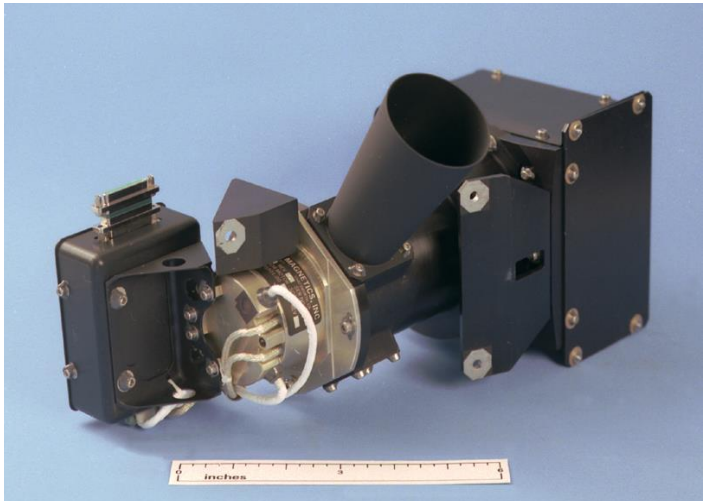


Δ_{SD}: SD degradation factor
Γ_{SD}: SD screen vignetting function
d: Earth-Sun distance
dn*: Corrected digital number (sensor)
dc: Corrected SDSM digital count

Characterization of SD On-orbit Degradation

On-board Calibrator - Solar Diffuser Stability Monitor (SDSM)

Improvements



MODIS has 9 SDSM detectors

VIIRS has 8 SDSM detectors

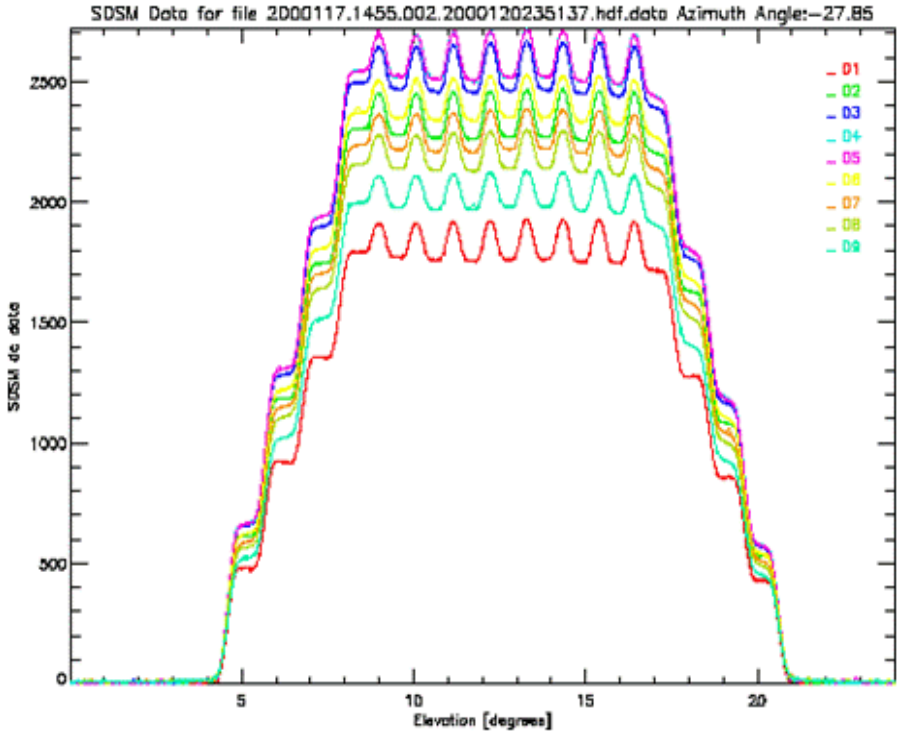
SDSM detector wavelengths (unit: μm)

SDSM Detector	D1	D2	D3	D4	D5	D6	D7	D8	D9
MODIS	0.412	0.466	0.530	0.554	0.646	0.747	0.857	0.904	0.936
VIIRS	0.412	0.445	0.488	0.555	0.672	0.746	0.865	0.935	

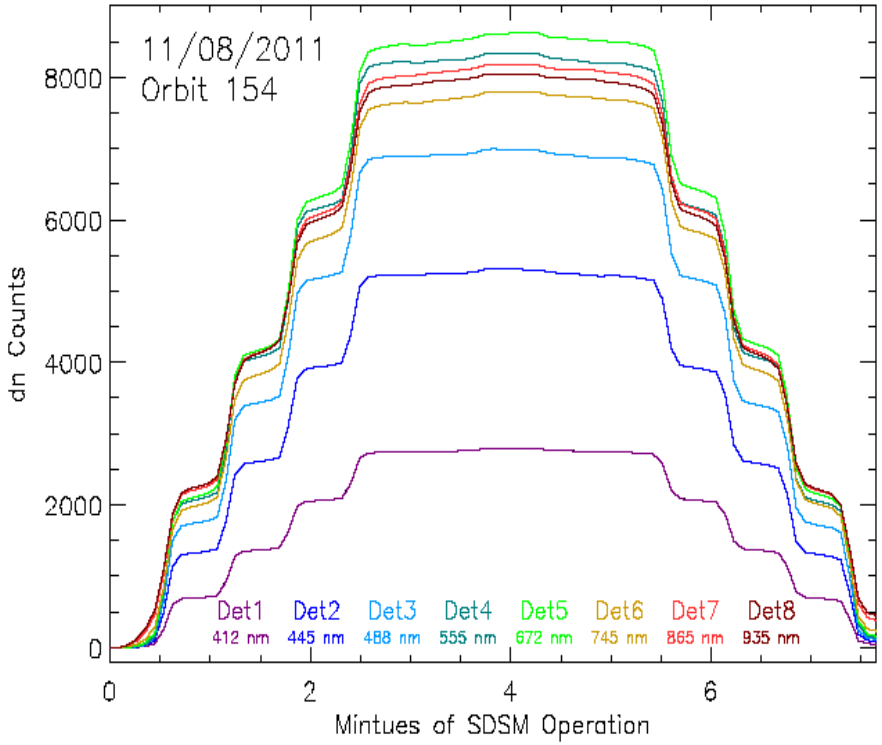
VIIRS SDSM Design Improvements

Lessons from MODIS led to improved design for VIIRS SDSM

- ✓ MODIS SDSM design artifact was eliminated in VIIRS
- ✓ Large ripples seen in MODIS SDSM Sun View responses no longer exist in VIIRS



MODIS SDSM Sun View Responses



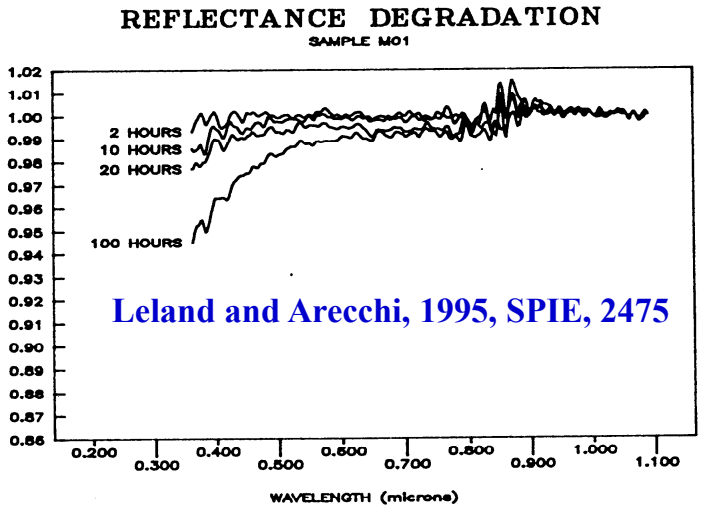
VIIRS SDSM Sun View Responses

SD Degradation Characterization Methodologies

MODIS

At mission beginning **Current implementation**

$$\Delta_{SD} \propto \frac{\overline{dc_{SD}}}{\overline{dc_{Sun}}} \Rightarrow \left\{ \frac{dc_{SD\_view}^{D1} / dc_{Sun\_view}^{D1}}{dc_{SD\_view}^{D9} / dc_{Sun\_view}^{D9}} \right\} \Rightarrow \left\{ \frac{dc_{SD\_view}^{D1} / dc_{Sun\_view}^{D1}}{dc_{SD\_view}^{D9} / dc_{Sun\_view}^{D9}} \right\} \Delta_{SD}^{D9}$$



Leland and Arecchi, 1995, SPIE, 2475

VIIRS

$$H(t) = \frac{dc_{SD} \cdot \tau_{SDSM}}{dc_{SUN} \cdot BRDF(t_0) \cdot \tau_{SDS} \cdot \cos\theta_{inc}}$$

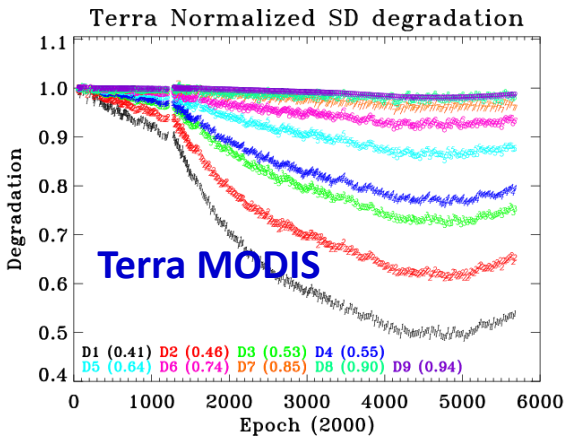
The normalized time series of Δ (for MODIS) or H (for VIIRS) => SD degradation

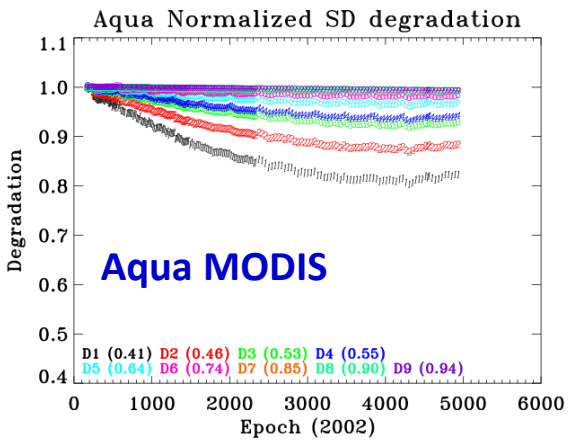
Results and Discussion

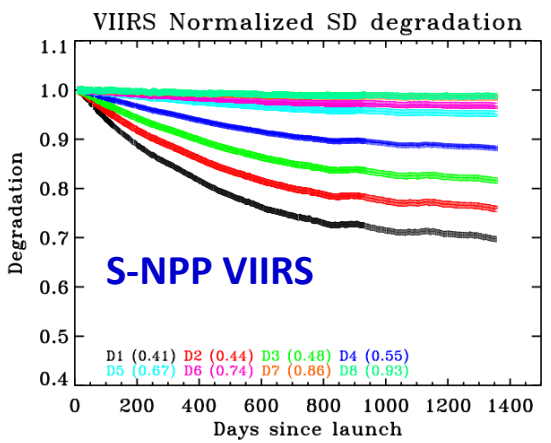
- **Changes in SD Bi-directional Reflectance Factor (BRF)**
- **Changes in SDSM Detector Responses**
- **Challenging Issues**
  - SDSM detector OOB response
  - Wavelength-dependent degradation of SDSM detector
  - Wavelength-dependent degradation of SD BRF

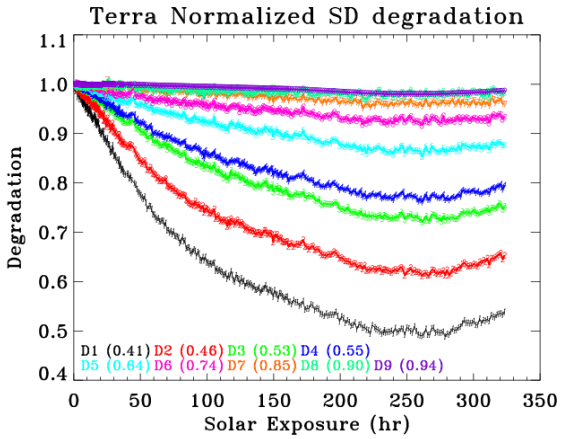
SD Degradation

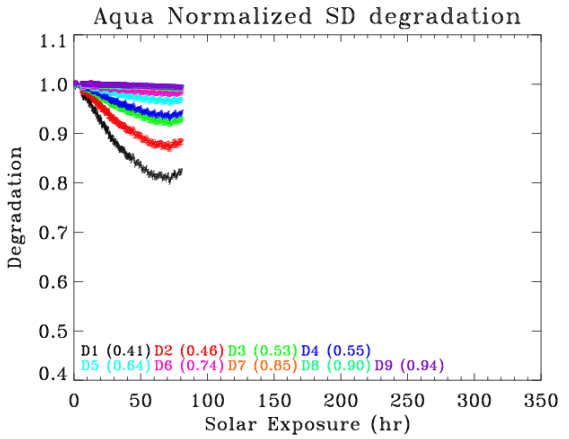
SD degradation as a function of time (day of mission operation)

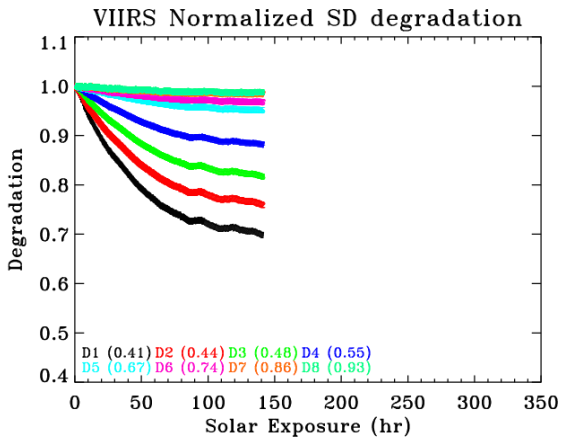








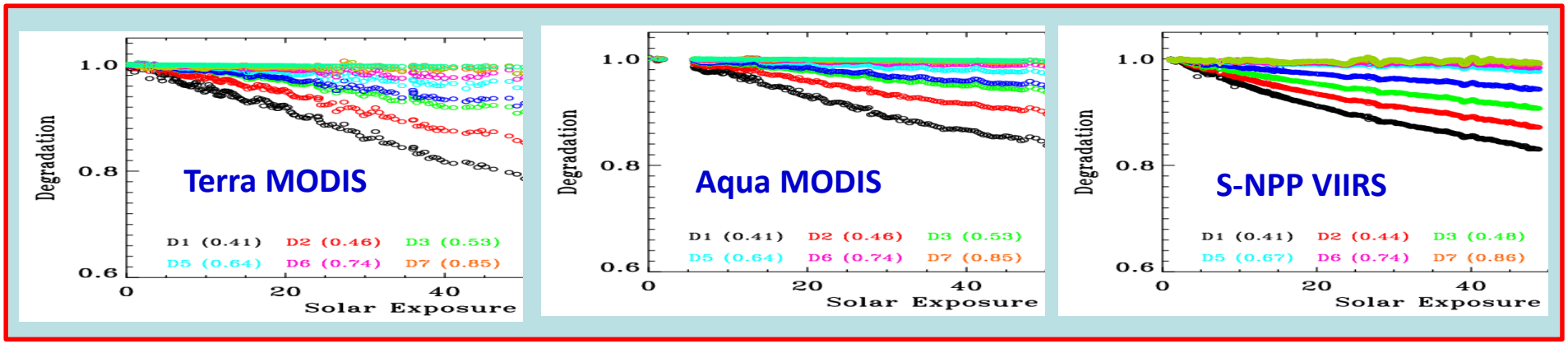


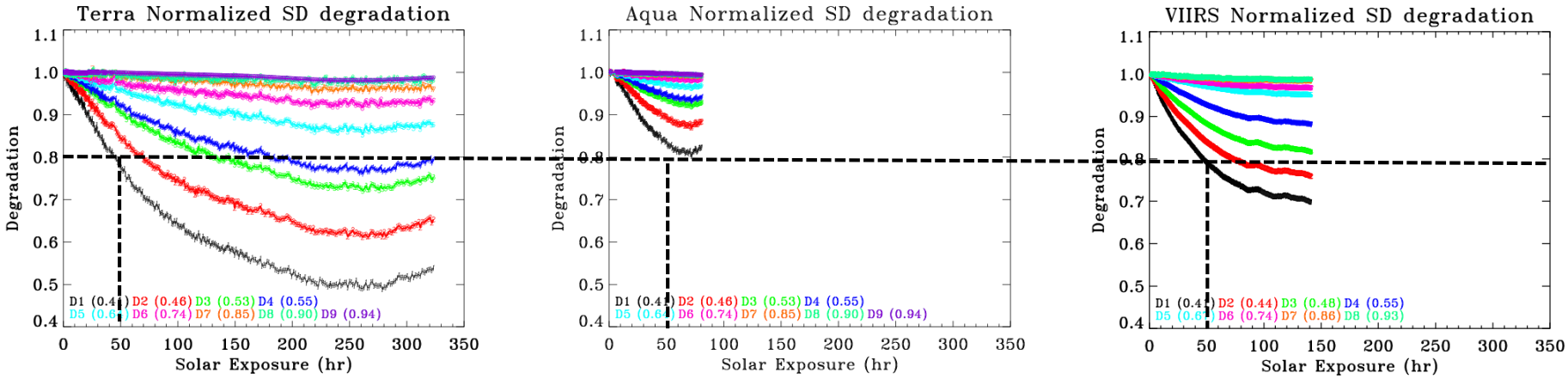


SD degradation as a function of SD solar exposure time

SD Degradation

First 50 hrs in exposure time (Terra, Aqua, SNPP: 1500, 3400, 450 days in operation)

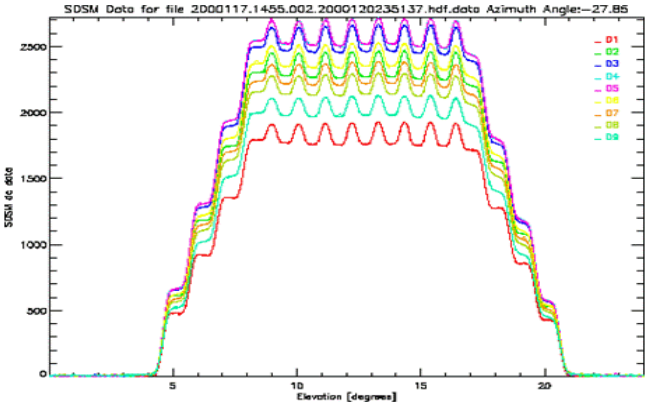




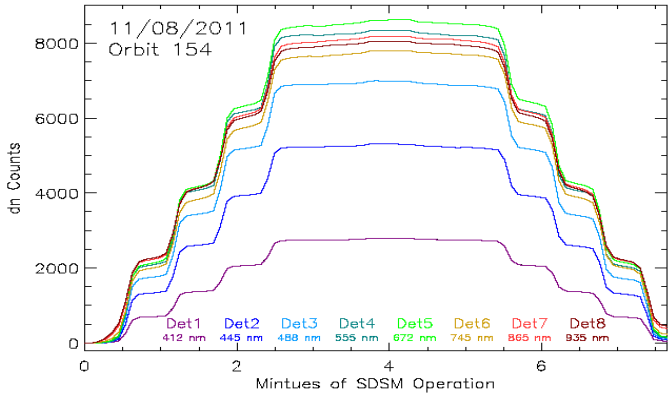
SD degradation as a function of SD solar exposure time

Changes in SDSM Detector Responses

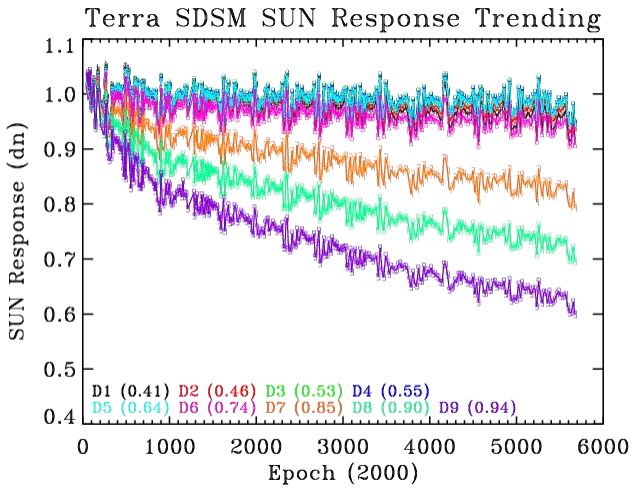
MODIS SDSM Sun View Responses



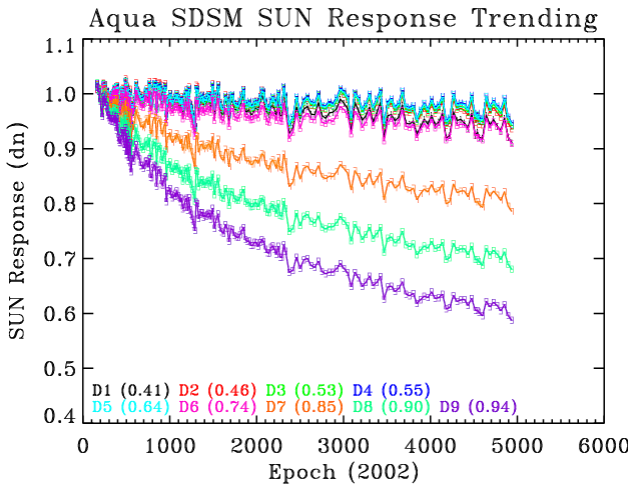
VIIRS SDSM Sun View Responses



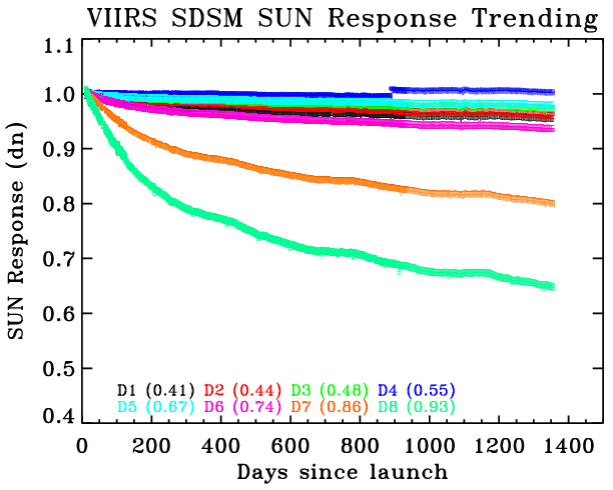
Terra MODIS



Aqua MODIS



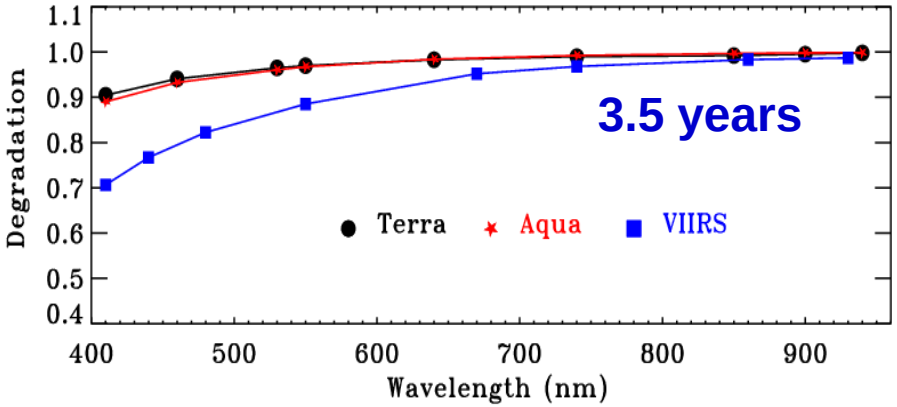
S-NPP VIIRS

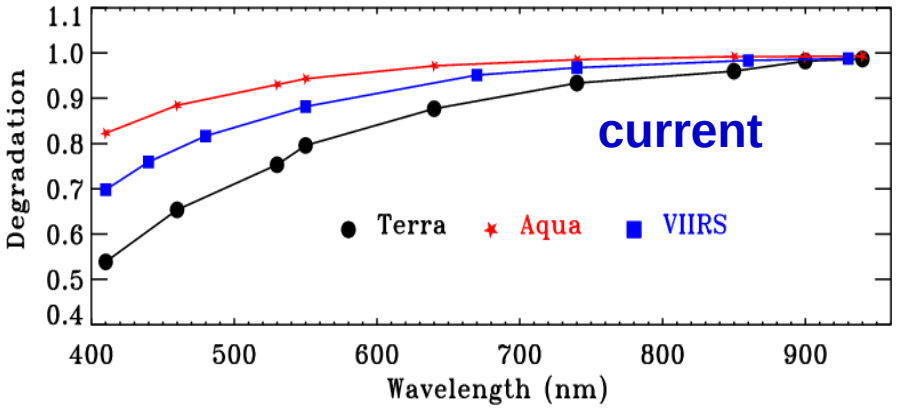


Xiong et al, "On-orbit performance of MODIS solar diffuser stability monitor", JARS 2014

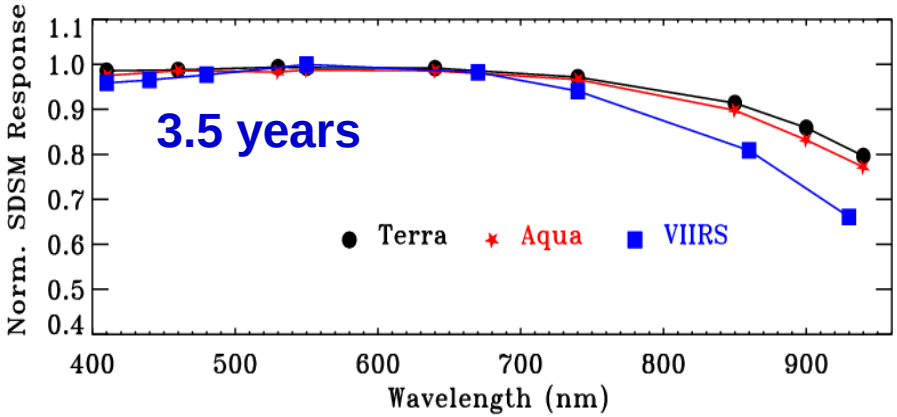
Wavelength Dependent Degradation

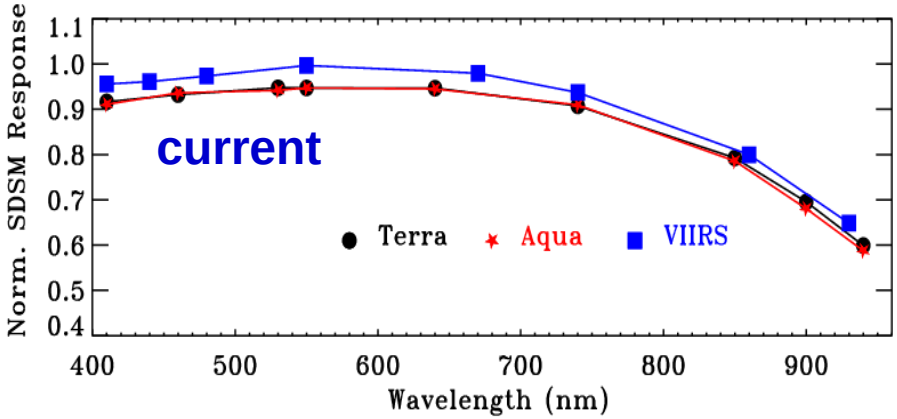
SD degradation



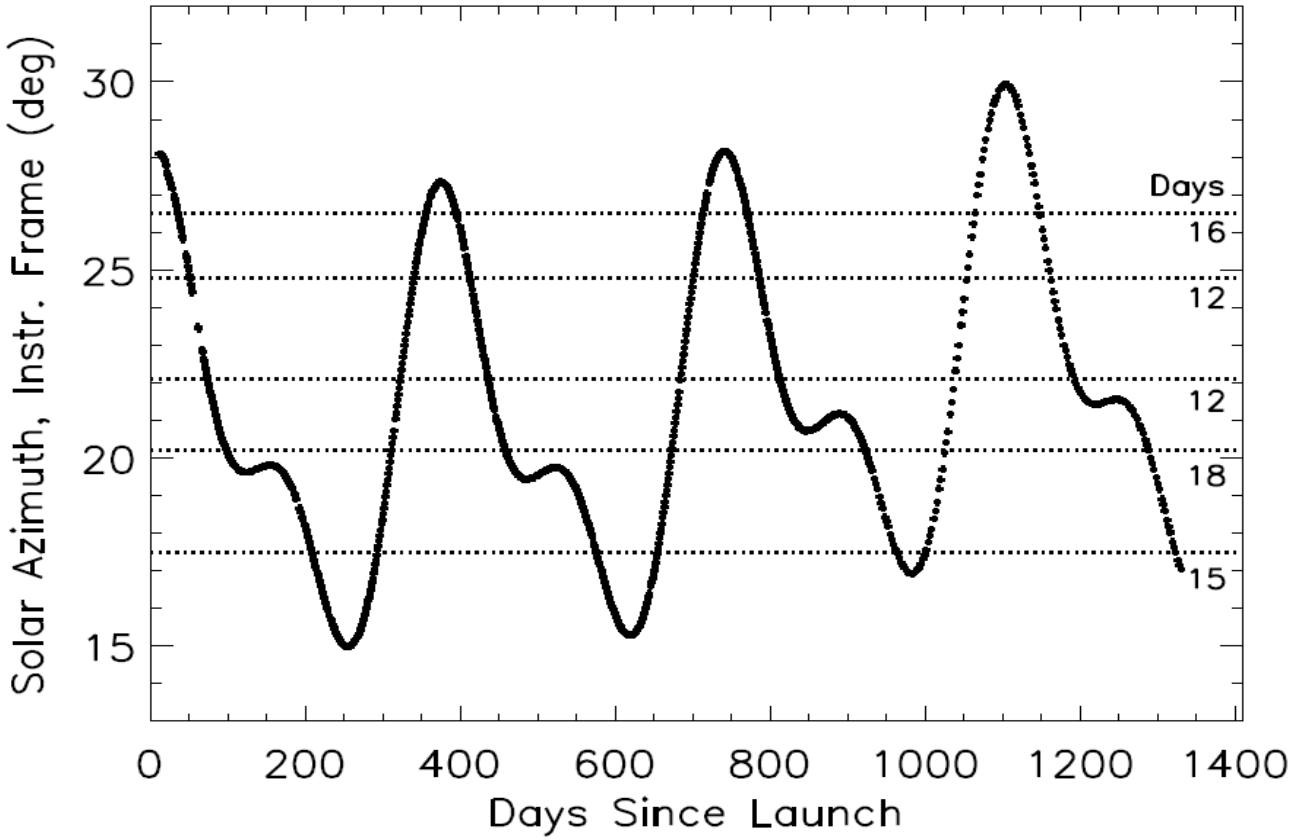


SDSM detector degradation



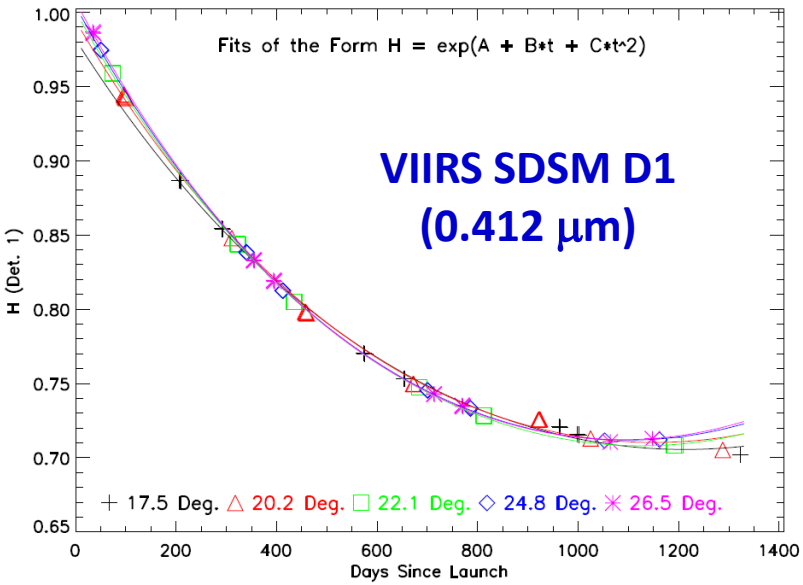


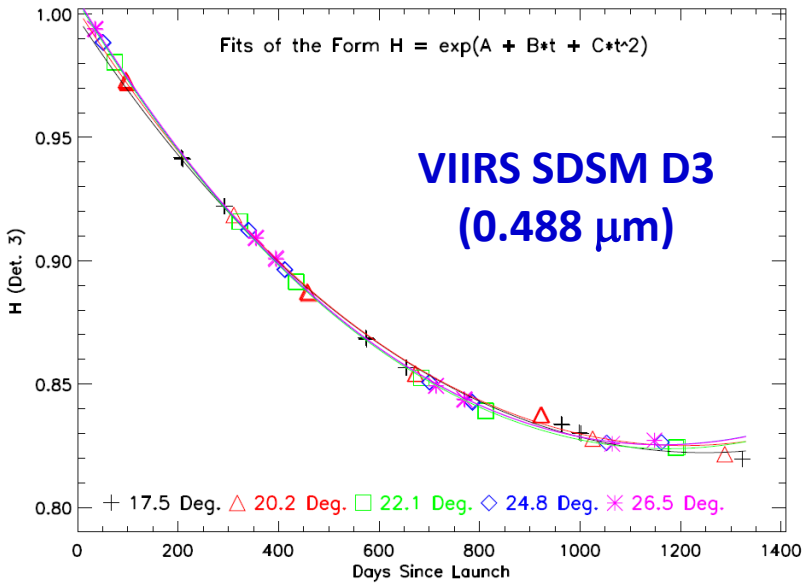
Is SD on-orbit degradation (*not the BRDF*) dependent on solar illumination angles? If so, how much?

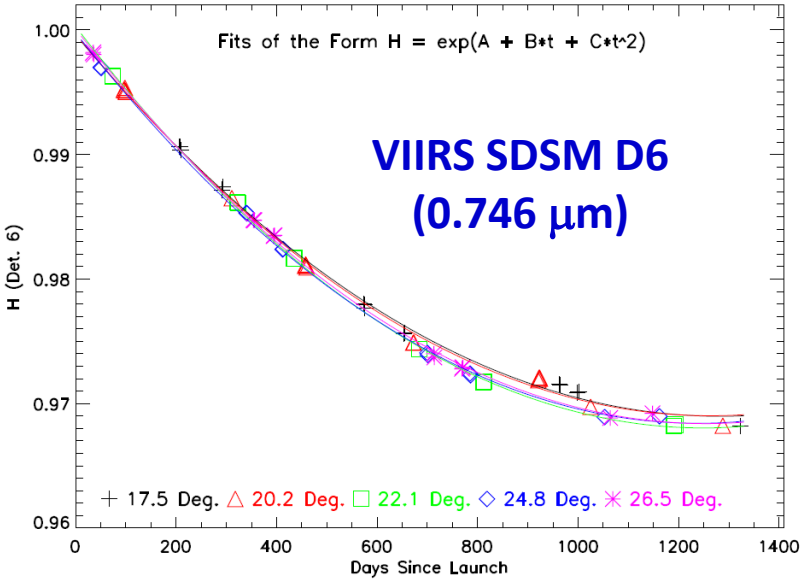


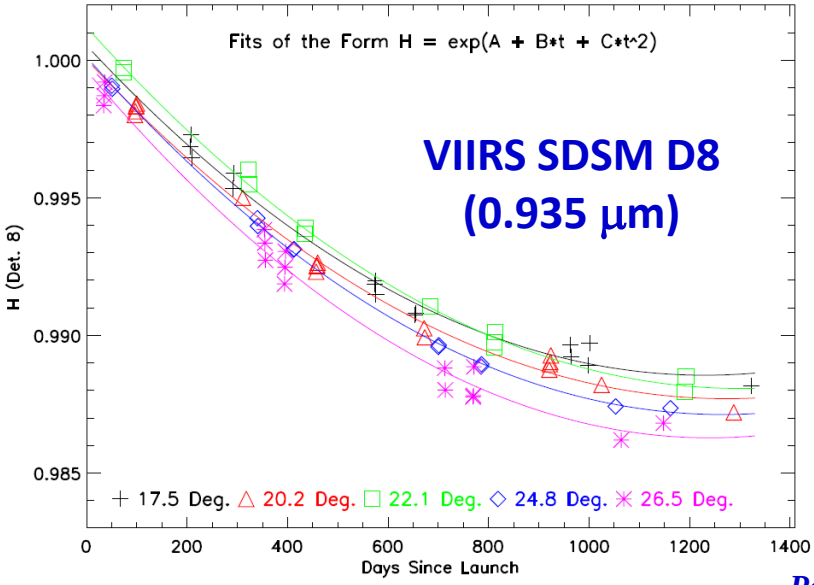
With sufficient SDSM data over time, one can track and compare SD degradation at a number of fixed solar illumination angles (methodologies developed for MODIS but more useful for VIIRS

SD Degradation at 5 Different Solar Azimuth Angles (17.5-26.5^{o})

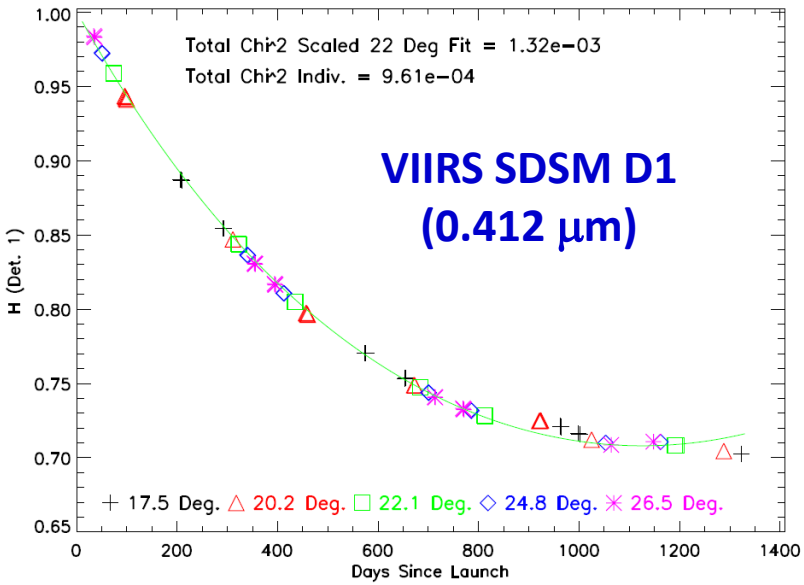


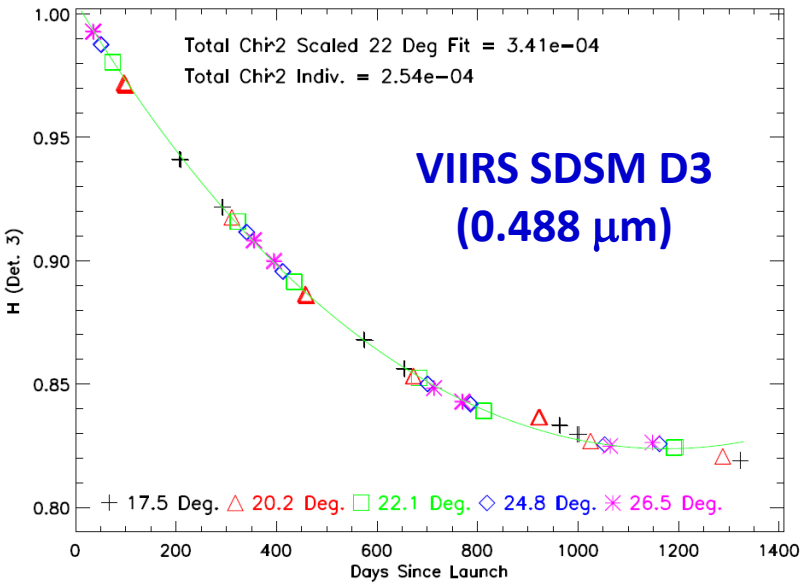


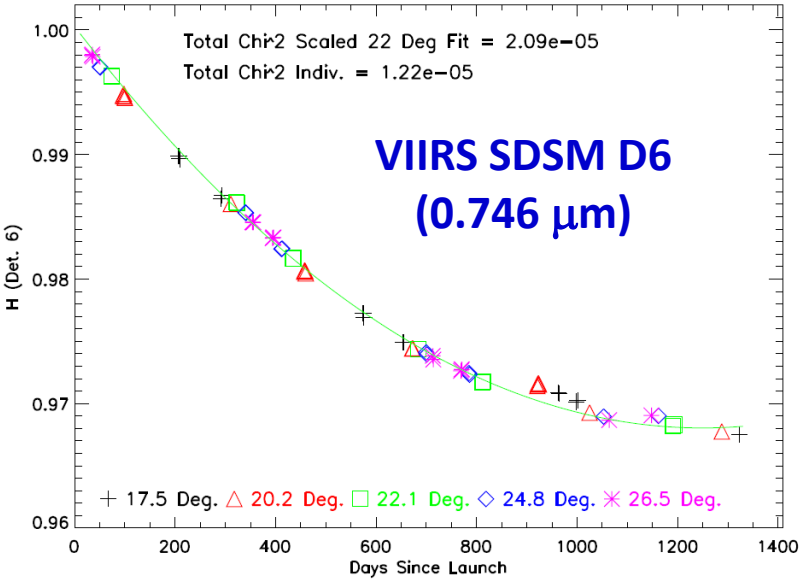


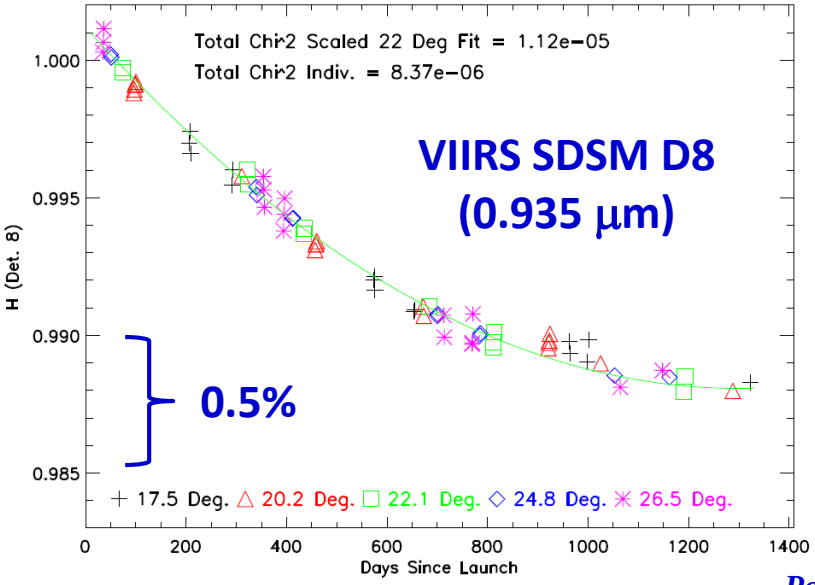


Normalization to remove BRF differences at different illumination angles

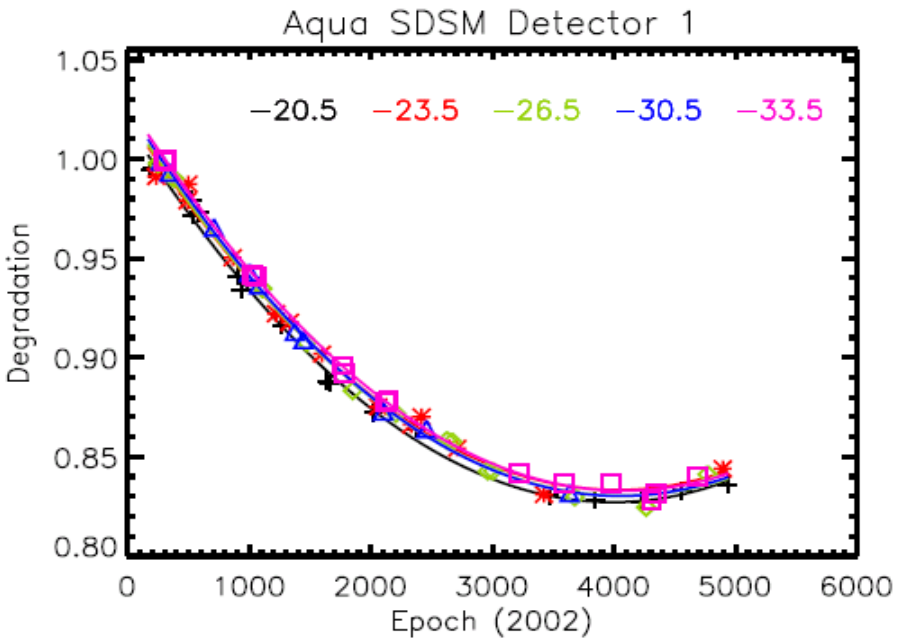


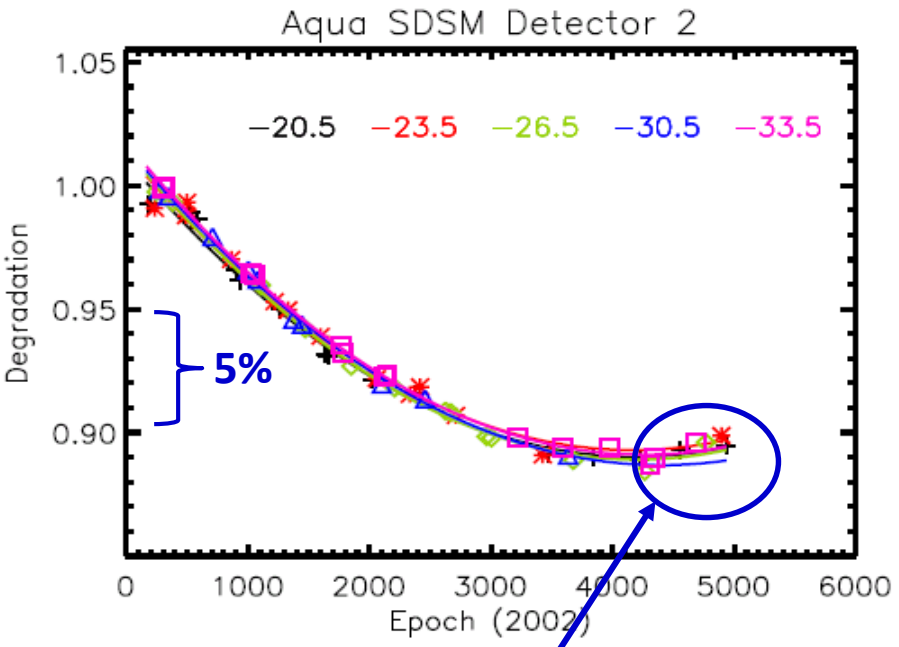






Similar Analysis Performed for Aqua MODIS





With changes in overall degradation trend:
pay attention to data (sample) distribution

Challenging issues for MODIS: SDSM and its operation frequency

Results and Discussion

- Changes in SD bi-directional reflectance factor (BRF)
- Changes in SDSM Detector Responses
- **Challenging Issues**
  - SDSM detector OOB response
    - Not enough information from pre-launch characterization
    - SD degradation could be under/over-estimated
  - Wavelength-dependent degradation of SDSM detector
    - Changes in SDSM detector's RSR (OOB/IB) => SD degradation accuracy
    - Need initial SDSM detector's RSR
  - Wavelength-dependent degradation of SD BRF
    - Need to be considered when deriving RSB calibration coefficients for bands with non-negligible OOB responses

Concluding Remarks

- **SDSM operation and calibration performance has been satisfactory in support of sensor RSB on-orbit calibration**
  - Improved design of VIIRS SDSM => better performance
- **Larger SD degradation at shorter (VIS) wavelengths whereas larger SDSM detector degradation at longer (NIR) wavelengths**
  - Different causes: exposure to solar UV vs exposure to high-energy protons
- **Angular dependent SD degradation examined**
  - Small for S-NPP and Aqua MODIS (±0.2% level < SD degradation UC)
  - More challenge for Terra MODIS (impact due to SD screen)
- **Challenging issues to be examined for future improvements**
  - OOB responses + wavelength-dependent SD and SDSM detector response degradation