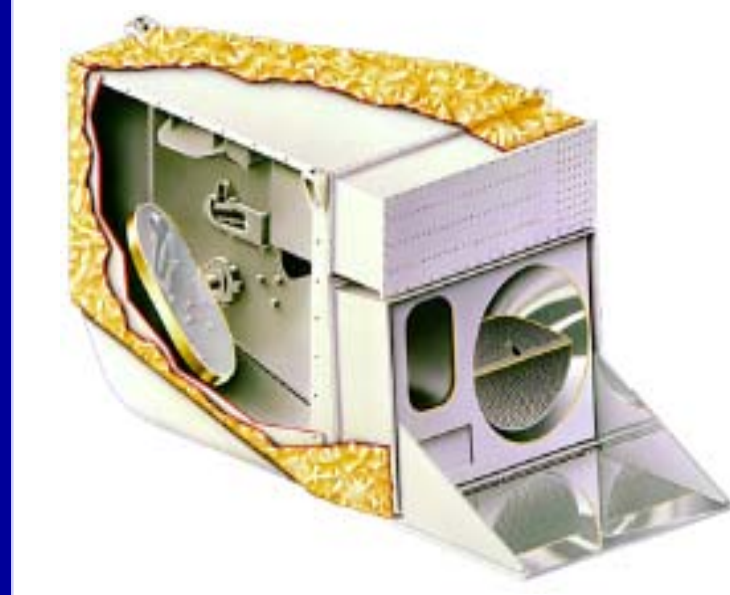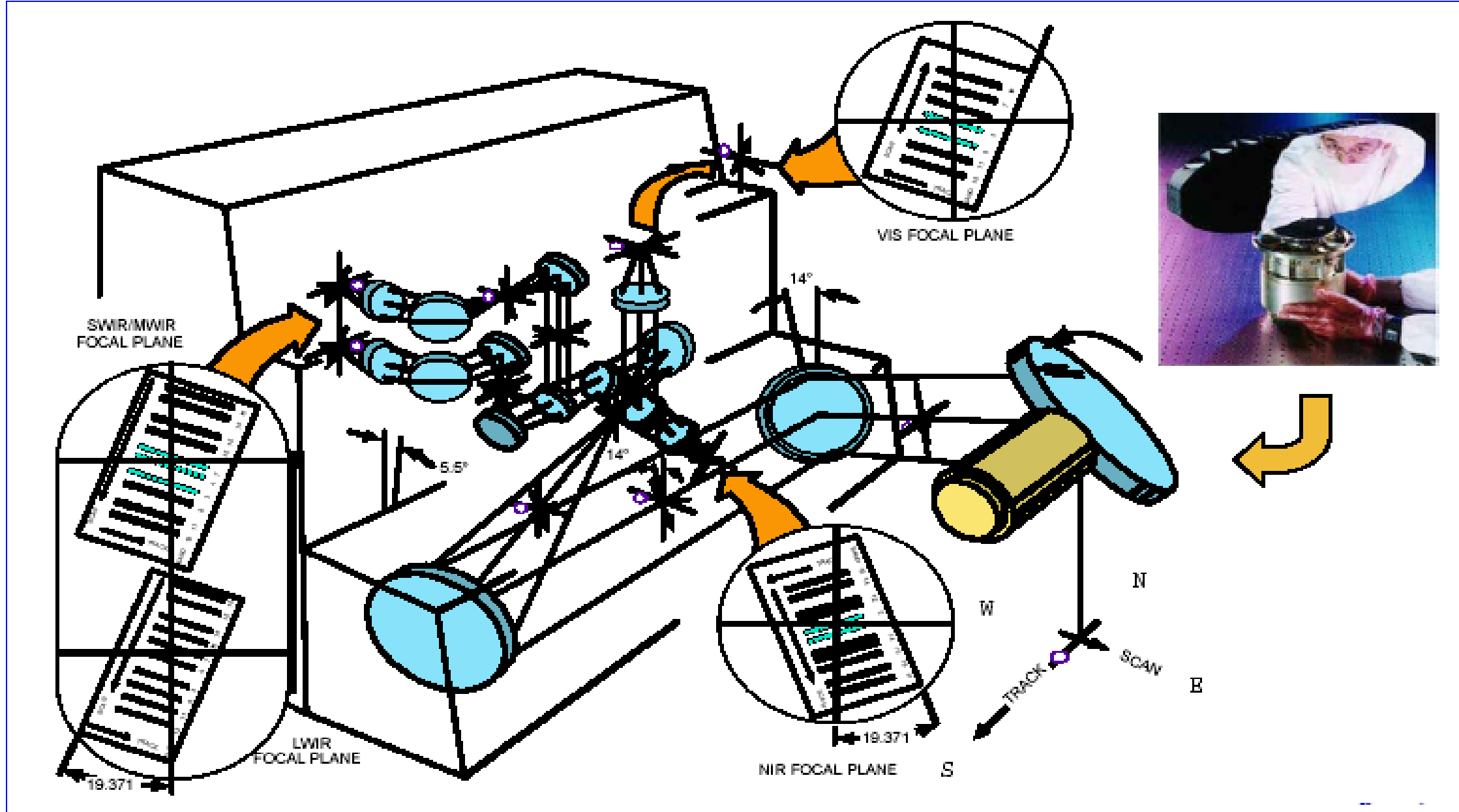# MODIS Reflective Solar Bands On-orbit Calibration

MODIS Characterization Support Team
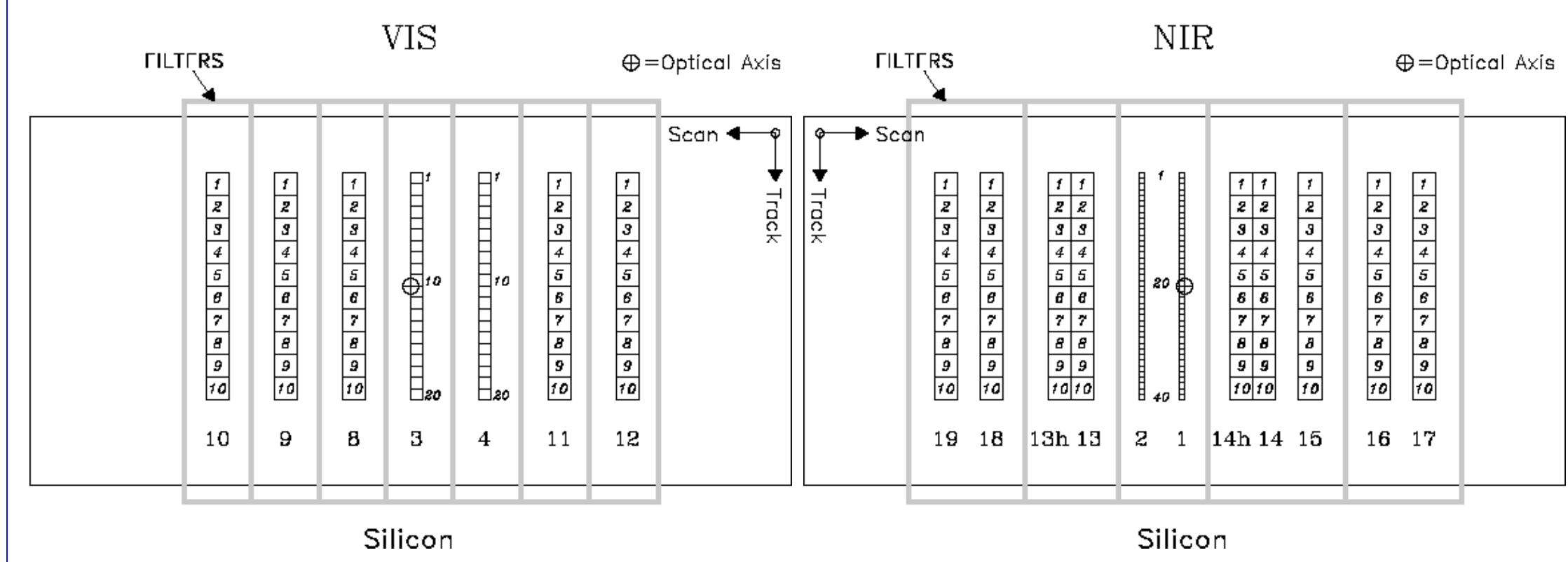

Introduction

- The **MOD**erate Resolution **I**maging **S**pectroradiometer (**MODIS**) is a key instrument for NASA's Earth Observing System (**EOS**). It is onboard both **Terra** spacecraft (launched on December 18, 1999) and **Aqua** Spacecraft (launched on May 4, 2002).

- MODIS's 2-sided paddle wheel scan mirror provides a -55 to +55 degree scan of the Earth covering 10 km (at nadir) along track by 2330 km along scan swath.

- MODIS has 36 spectral bands, among which 20 are reflective solar bands (RSBs) ranging from 0.41 to 2.3 microns, with spatial resolution (at nadir) of 250 m (bands 1-2), 500 m (bands 3-7) and 1000 m (bands 8-19,26).

- RSBs are calibrated on-orbit by an onboard Solar Diffuser (SD) panel, the Moon, and an onboard Spectro-Radiometric Calibration Assembly (SRCA)

VIS and NIR Focal Plane Assemblies Layout

RSB Key Specifications

Band	CW (nm)	BW (nm)	IFOV (m)	Ltyp (W/m^2/sr/μ)	Lmax (W/m^2/sr/μ)	Lcloud (W/m^2/sr/μ)	SNR
1	645	50	250	21.8	685	457	128
2	858	35	250	24.7	285	293	201
3	469	20	500	35.3	593	570	243
4	555	20	500	29.0	518	559	228
5	1240	20	500	5.4	110	138	74
6	1640	24	500	7.3	70	68	275
7	2130	50	500	1.0	22	27	110
8	412	15	1000	44.9	175	573	880
9	443	10	1000	41.9	133	585	838
10	488	10	1000	32.1	101	539	802
11	531	10	1000	27.9	82	538	754
12	551	10	1000	21.0	64	528	750
13L	667	10	1000	9.5	32	471	910
14L	678	10	1000	8.7	31	440	1087
15	748	10	1000	10.2	26	373	586
16	869	15	1000	6.2	16	286	516
17	905	30	1000	10.0	185	252	167
18	936	10	1000	3.6	256	267	57
19	940	50	1000	15.0	189	244	250
26	1375	30	1000	6.0	90	113	150
13H	667	10	1000	9.5	32	471	910
14H	678	10	1000	8.7	31	440	1087

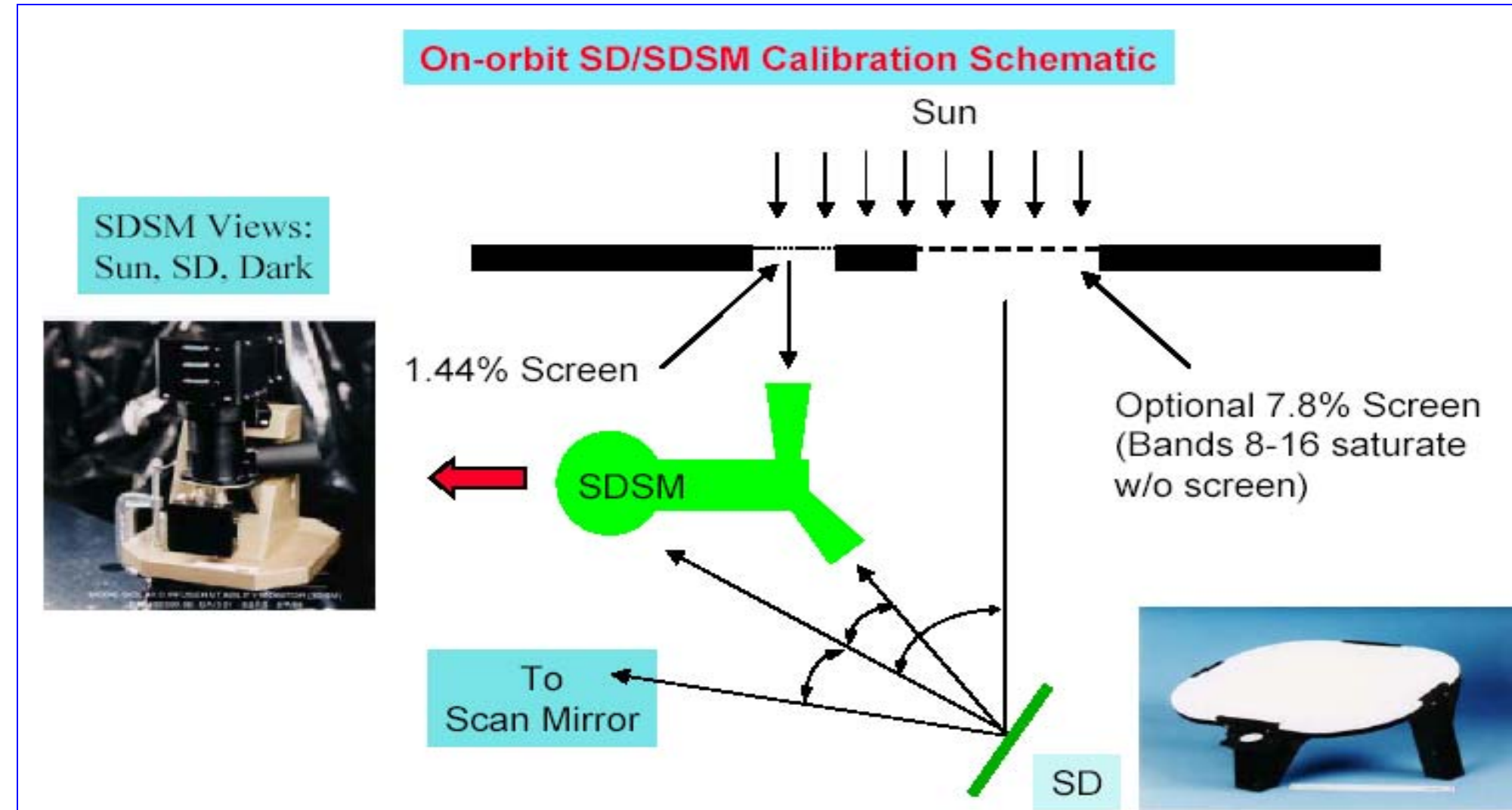
RSB On-orbit Calibration Algorithms

Retrieval Algorithm

Reflectance
$$\rho_{EV} \cdot \cos(\theta_{EV}) = m_1 \cdot dn_{EV}^* \cdot d_{Earth-Sun}^2$$
$$dn_{EV}^* = dn_{EV} \cdot (1 + k_{INST} \cdot \Delta T_{INST}) / RVS_{EV}$$

Radiance
$$L_{EV} = m_1 \cdot dn_{EV}^* \cdot E_{Sun} / \pi$$

E_{SUN}: 0.4-0.8 μm Thuillier et al., 1998; 0.8-1.1 μm Neckel and Labs, 1984; Above 1.1 μm Smith and Gottlieb, 1974

On-orbit SD/SDSM Calibration Schematic

SDSM Views: Sun, SD, Dark

1.44% Screen

Optional 7.8% Screen (Bands 8-16 saturate w/o screen)

SDSM

To Scan Mirror

SD

SD/SDSM Calibration Algorithm

Scaling factors m1 from SD

$$m_1 = \frac{pIBRF_{SD} \cdot \cos(\theta_{SD})}{<dn_{SD}^*> \cdot d_{Earth-Sun}^2} \cdot \Gamma_{SD} \cdot \Delta_{SD}$$

SD (BRF) degradation from SDSM

$$\Delta_{SD} = \frac{dc_{SD}}{dc_{Sun}}$$

pIBRF$_{SD}$: pre-launch SD BRF
Γ$_{SD}$: SD screen vignetting function (1 for open mode)
dn*$_{SD, EV}$: MODIS detector's "corrected" digital number
dc$_{Sun, SD}$: SDSM detector's digital count
d$_{Earth-Sun}$: Earth-Sun distance

Correct screen effect

$$\left\{ \frac{dc_{SD\_view}^i / dc_{Sun\_view}^i}{dc_{SD\_view}^0 / dc_{Sun\_view}^0} \right\}$$

SD BRF and SD Screen VF

- Prelaunch BRF is used (validated on-orbit)
- SDS VF is derived on-orbit
- On-orbit yaws for BRF and VF
  - Two sets of Terra yaws, 4/2000, 12/2002-1/2003
  - One set of Aqua yaws, 6/2002
  - Each set of yaws
    12 (or 6) SDS open (BRF, VF)
    12 (0r 6) SDS closed (VF)

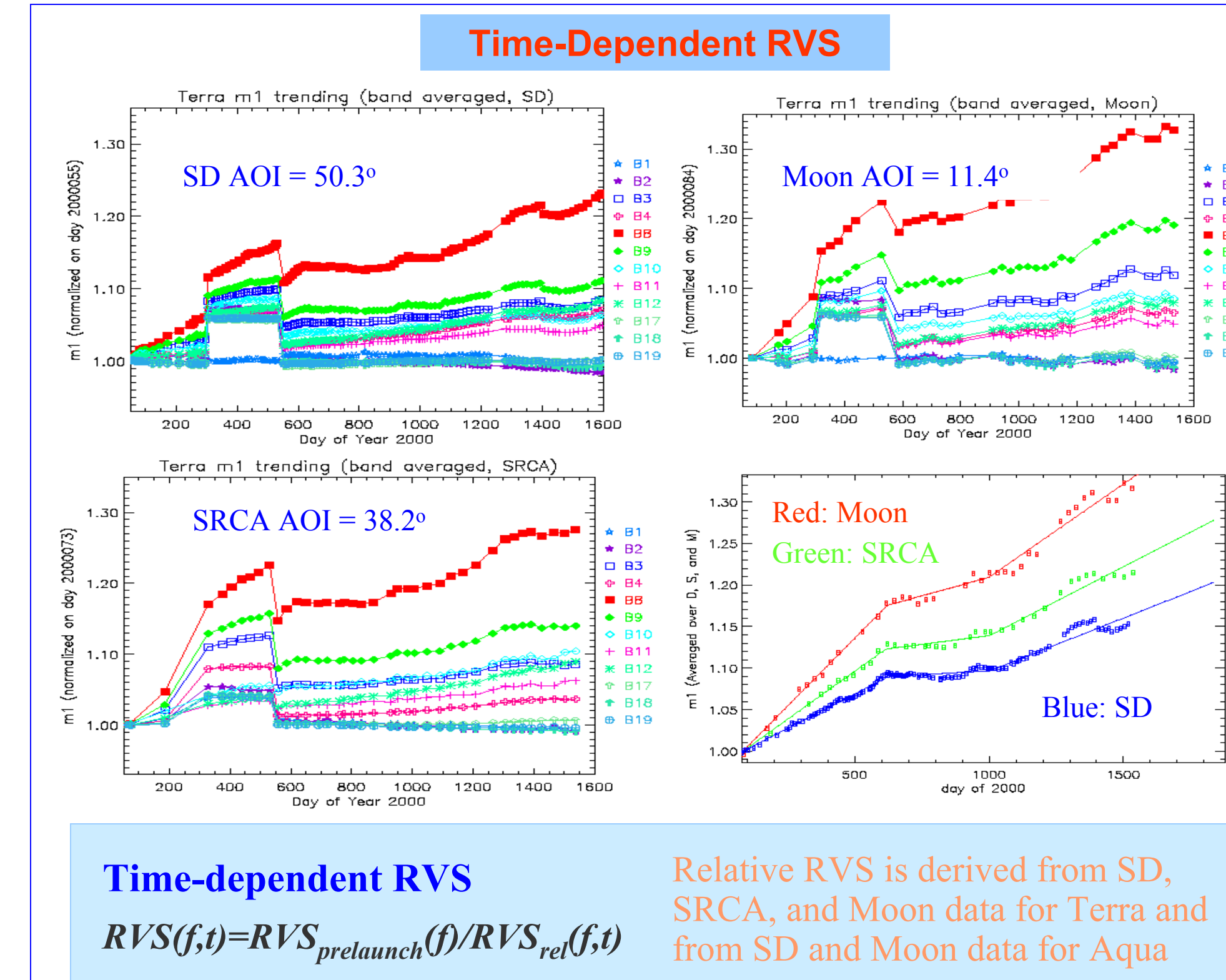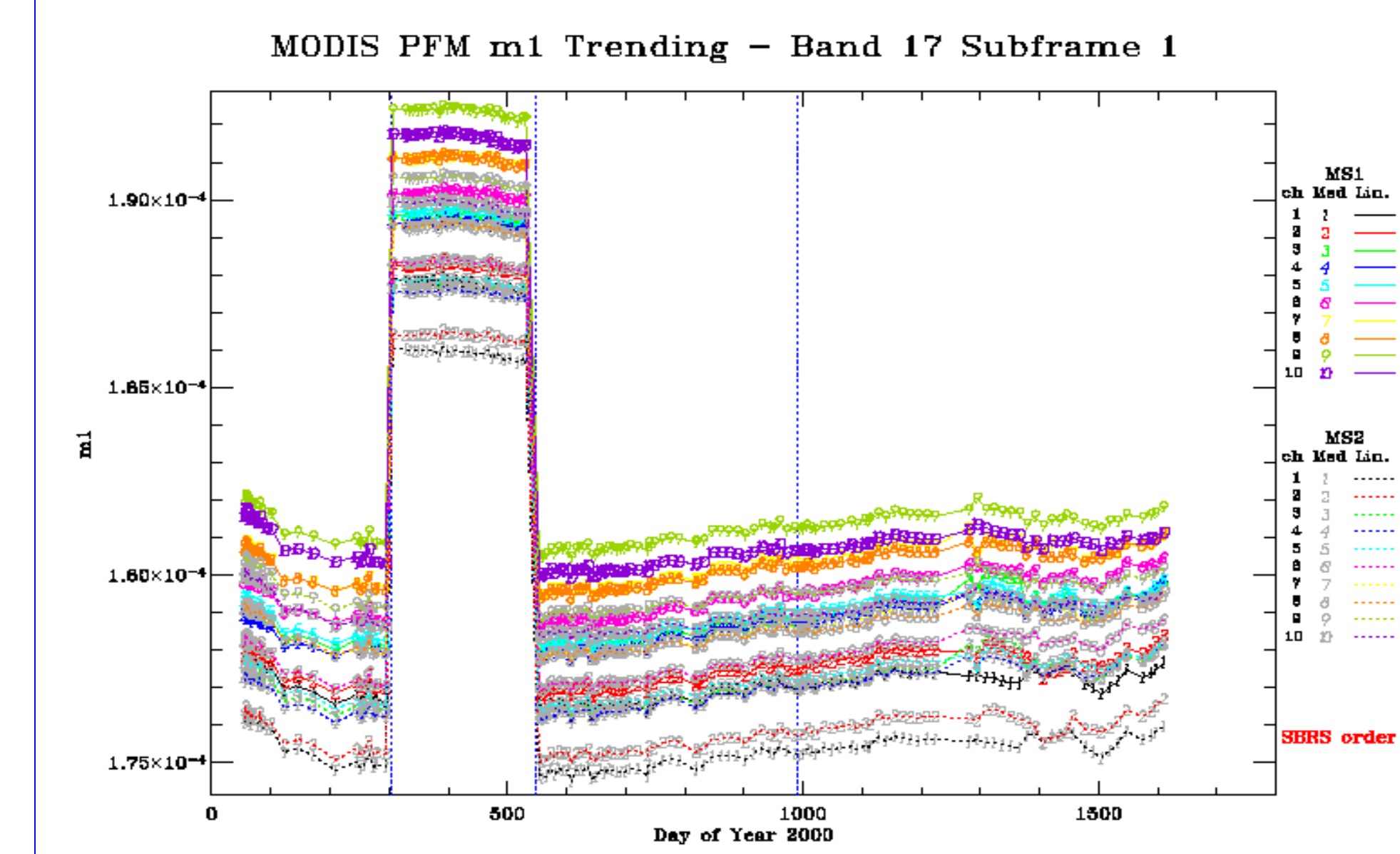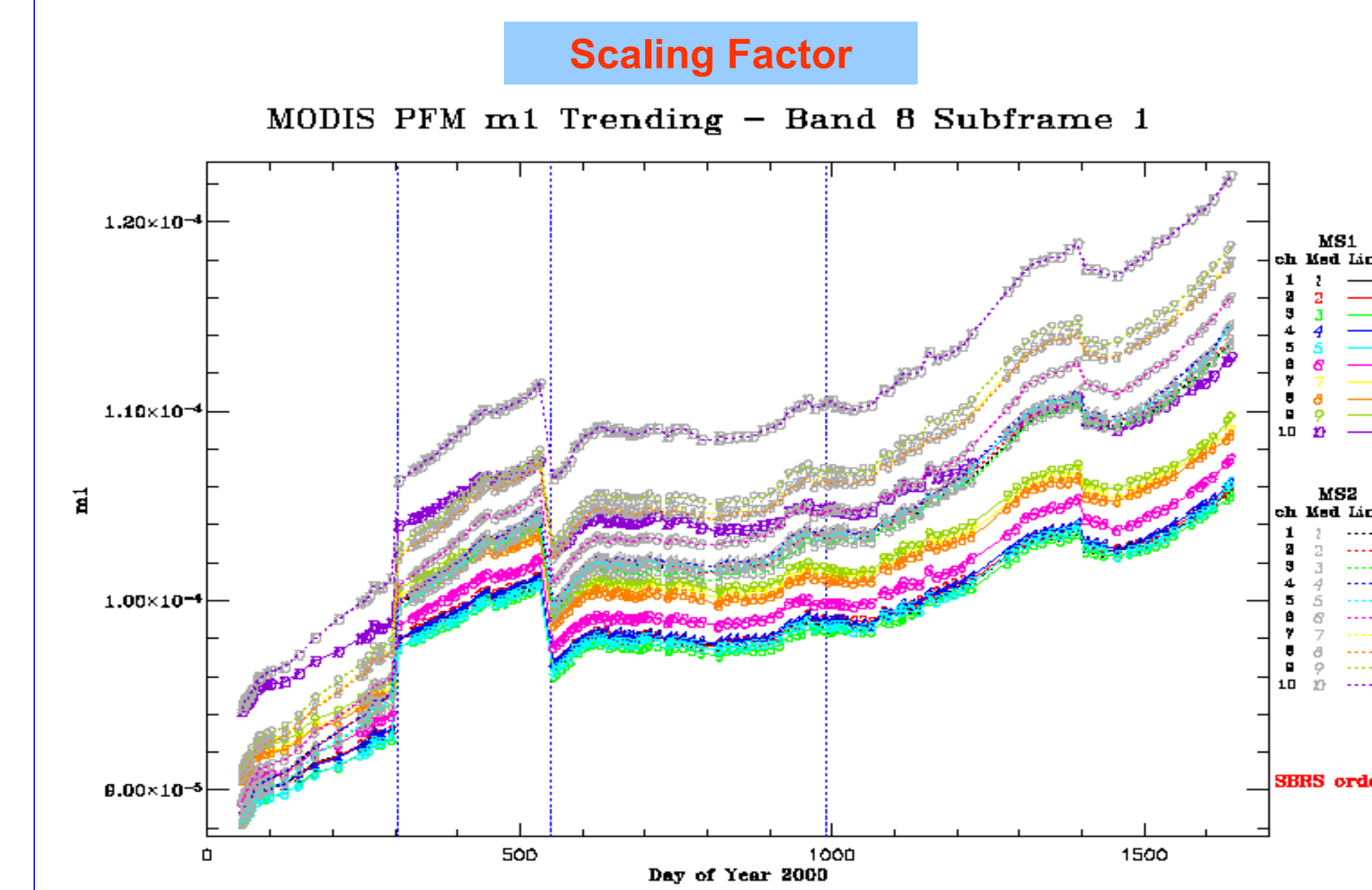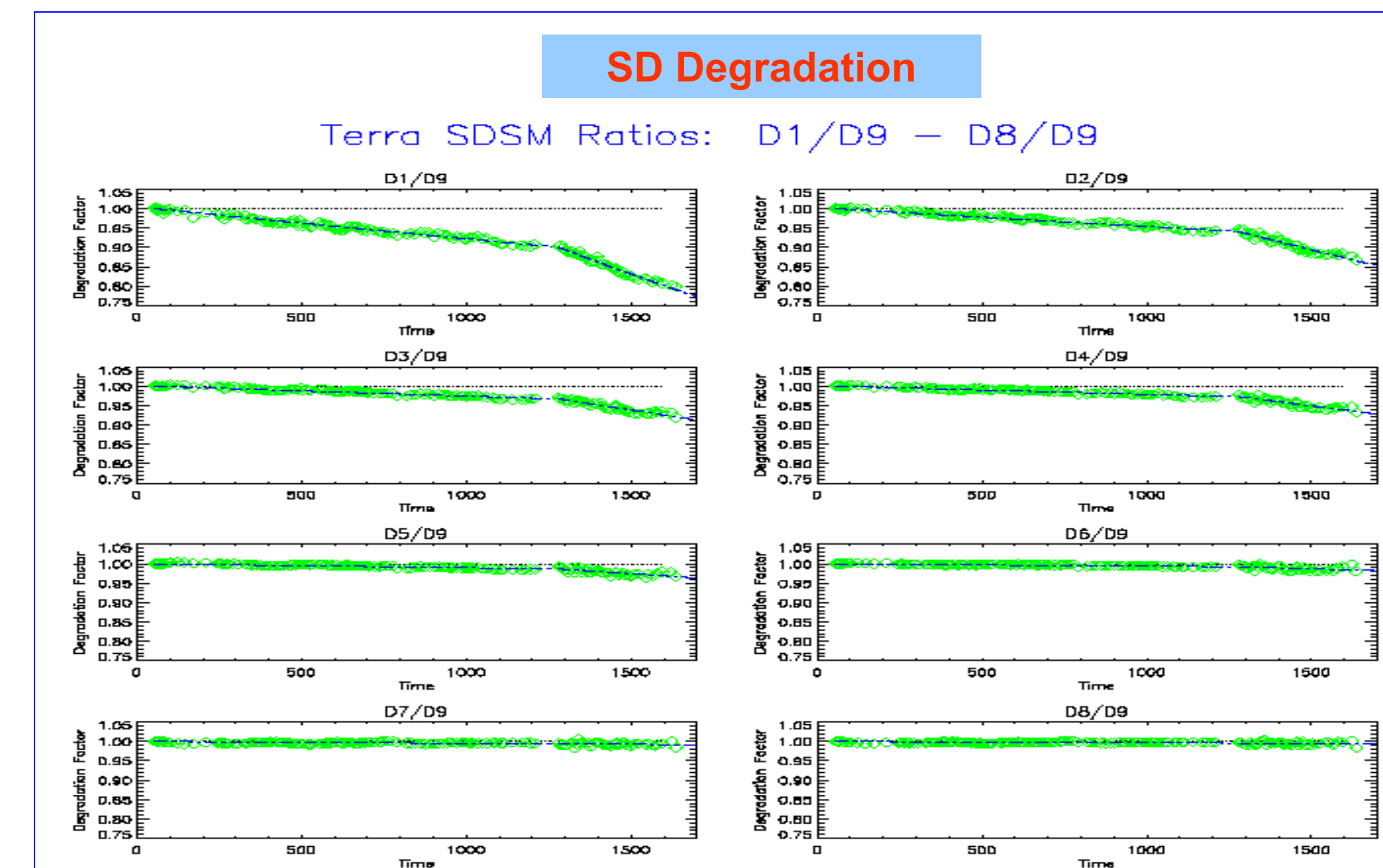| Prelaunch BRF UNcertainty	
NIST Reference	0.50
SBRS Characterization	0.70
NIST Transfer to MODIS	0.50
SD σ$_{Spatial}$	0.70
Pre-launch to on-orbit	0.50
SD BRF Characterization	0.50
Spectral Interpolation	0.10
Stray Light	0.30
Total BRF Uncertainty (RSS)	1.44

On-Orbit Lunar and SRCA Calibration

SV Port

$$m_1^{Moon} = \frac{f_{pa} f_{lib} f_{os}}{d_{SM}^2 d_{MM}^2} \sum dn_{Moon}^*$$

$$m_1^{SRCA} = \frac{f_{light-source-output}}{dn_{SRCA}}$$

pa: Phase angle; Lib: Librations; os: Over-sampling; SM: Sun-Moon; MM: Moon-MODIS

On-Orbit Performance

SD Degradation

Terra SDSM Ratios: D1/D9 — D8/D9

Scaling Factor

MODIS PFM m1 Trending – Band 8 Subframe 1

MODIS PFM m1 Trending – Band 17 Subframe 1

Time-Dependent RVS

SD AOI = 50.3°

Moon AOI = 11.4°

SRCA AOI = 38.2°

Red: Moon
Green: SRCA
Blue: SD

Time-dependent RVS
$RVS(f,t)=RVS_{prelaunch}(f)/RVS_{rel}(f,t)$

Relative RVS is derived from SD, SRCA, and Moon data for Terra and from SD and Moon data for Aqua

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Special Calibrations and Challenging Issue
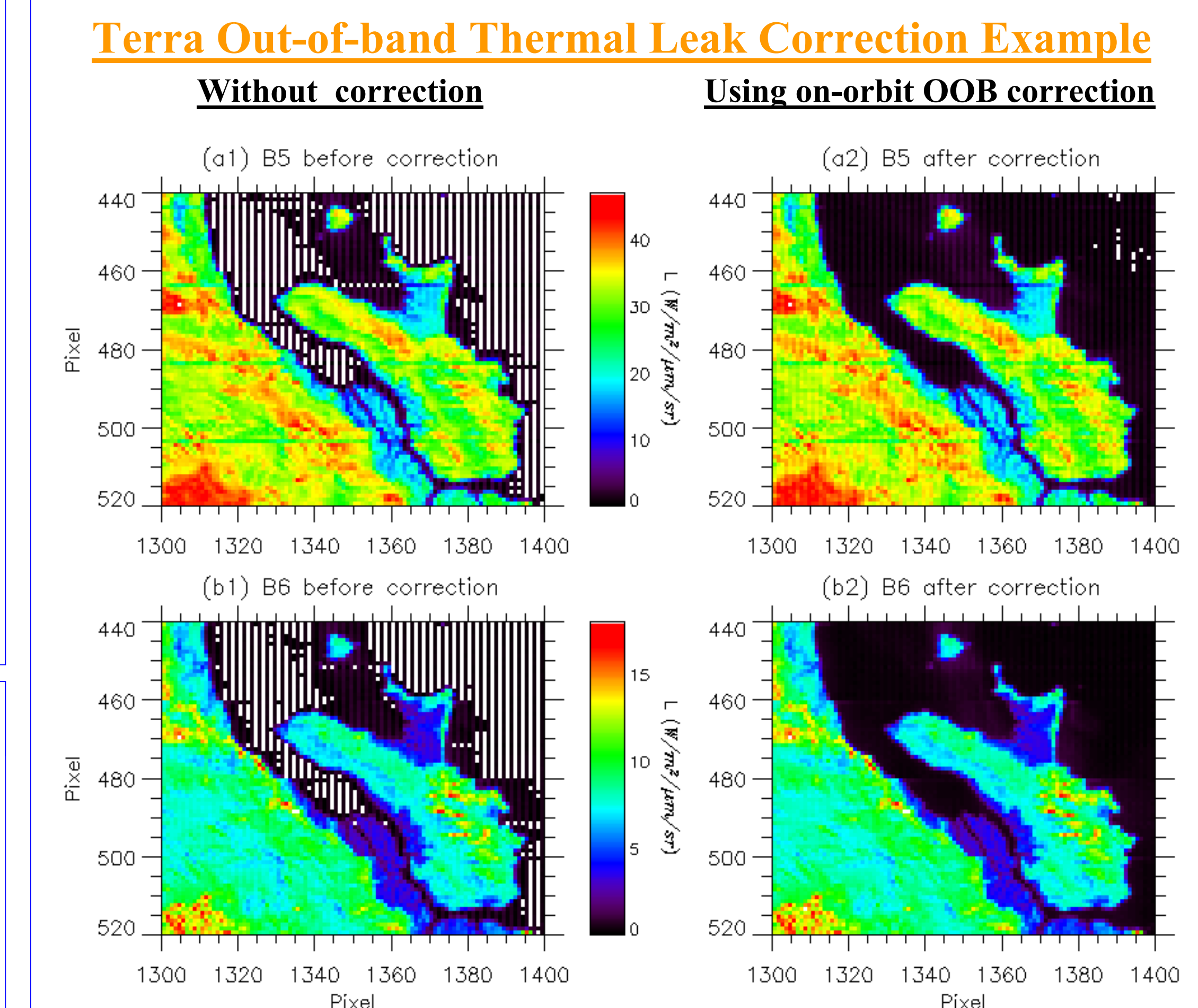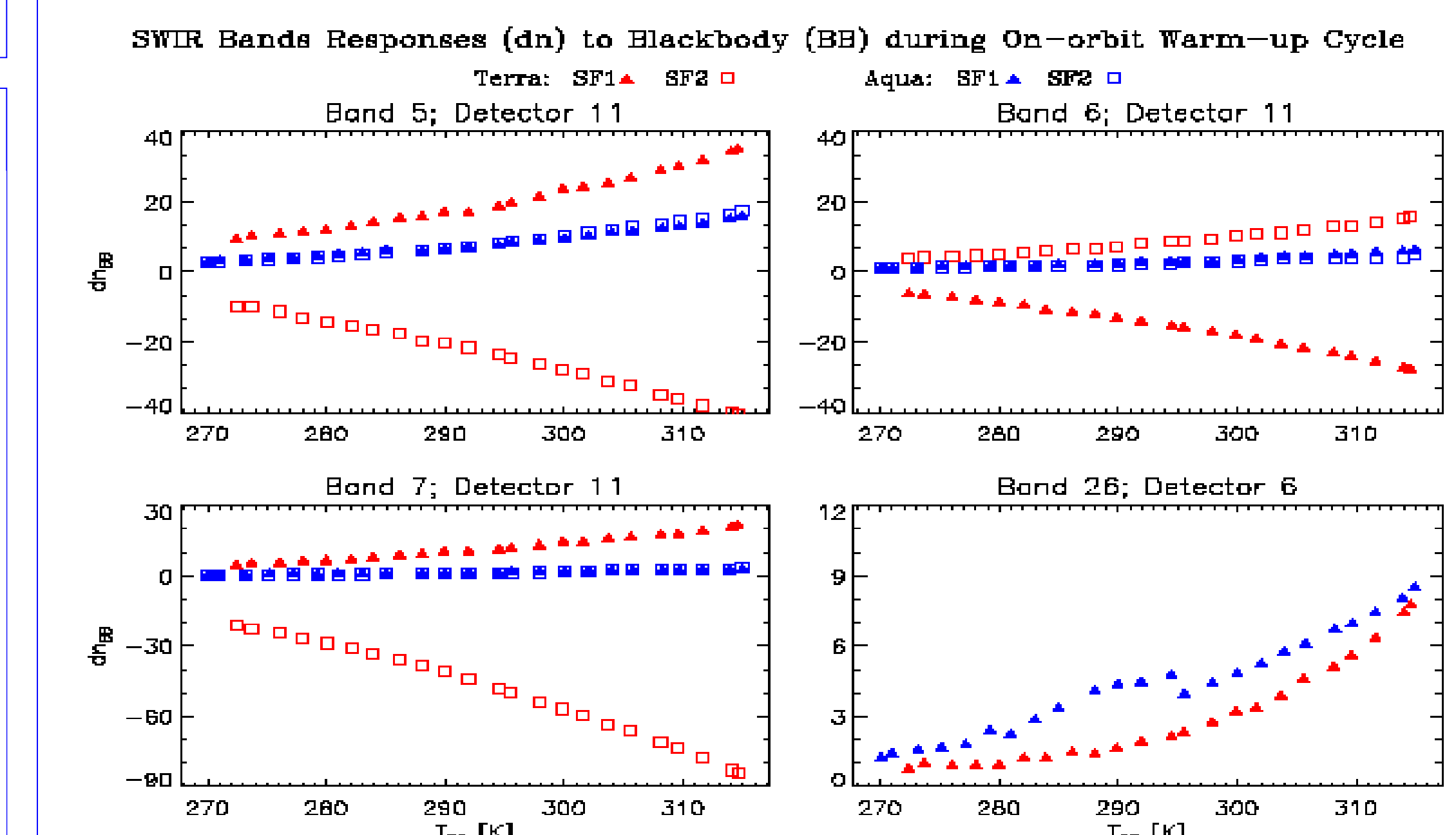
Thermal Leak Correction for SWIR Bands

Algorithms:
- Using a linear approach between the SWIR signals

$$dn_{EV}^{'}(B_{SWIR}) = dn_{EV}^{'}(B_{SWIR}) - x\_oob\_1(B_{SWIR}) \cdot dn_{EV}(B_{Surrogate})$$

- dn'_{EV}: uncorrected Earth view signal after background subtraction
- dn'_{EV}: corrected Earth view signal after OOB correction
- x_oob_1: linear correction coefficient
- $B_{Surrogate}$ is B28 for Terra and B25 for Aqua
- The cross-talk coefficents are derived from Nighttime Day Mode (NTDM) data
- The correction is also used in the m1 calculation

SWIR Bands Responses (dn) to Blackbody (BB) during On-orbit Warm-up Cycle

Terra Out-of-band Thermal Leak Correction Example

Without correction   **Using on-orbit OOB correction**

Challenging Issues

- m$_1$ shows annual oscillation for the Ocean bands
  - 0.5% for B8, 0.4% for B9, and 0.3% or less for other bands
  - This might be true since it was also observed in Moon and SRCA scaling coefficients
- m$_1$ shows daily oscillation
  - The oscillation is band and detector dependent and can be as large as 0.4% for some bands
- Accuracy of time-dependent RVS
- Striping

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