



Inter-comparison of Terra and Aqua MODIS

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Outline



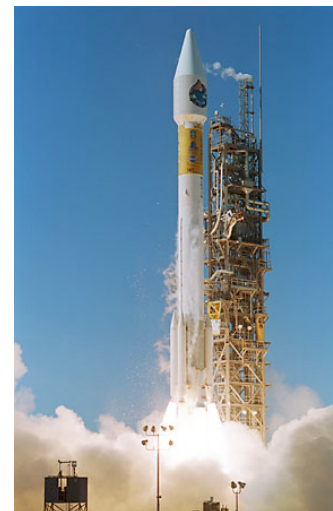
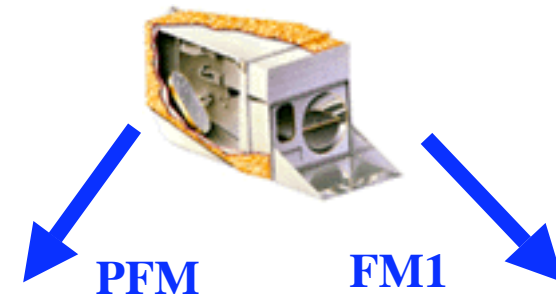
- Introduction
 - Instrument Background
 - MODIS On-orbit Calibration (SD and Moon)
- Inter-comparison of Terra and Aqua MODIS Using Lunar Observations
 - Approach and results for thermal emissive bands
- Inter-comparison of Terra and Aqua MODIS Using AVHRR
 - Approach and results for reflective solar bands
- Summary



Instruction

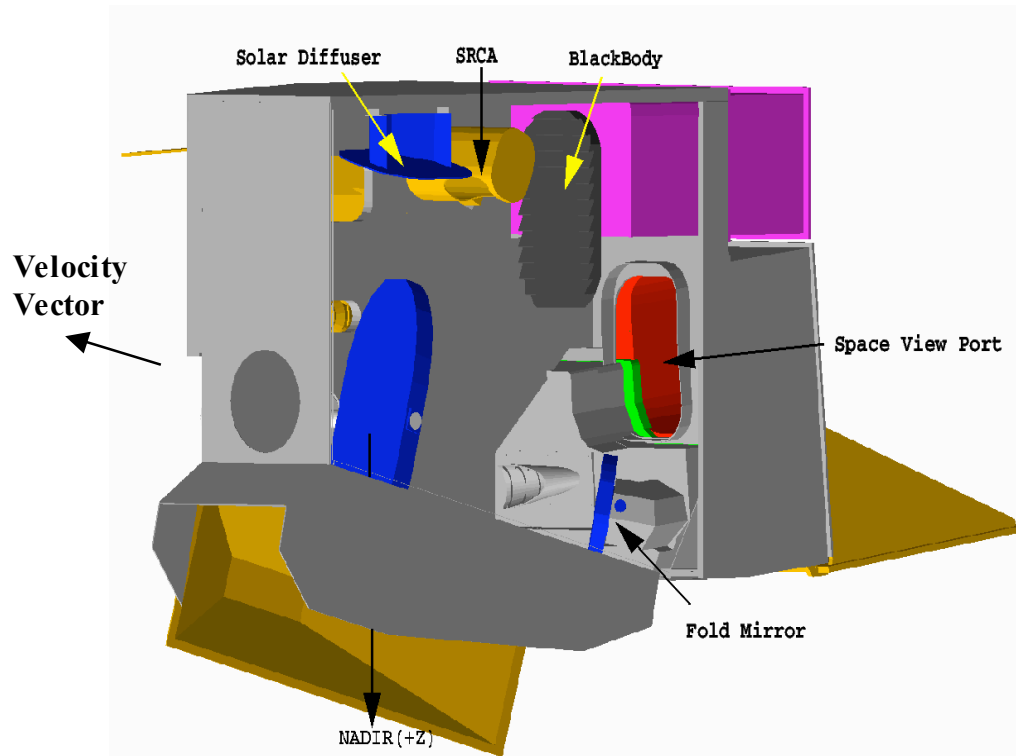
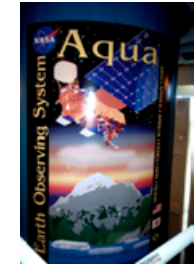


- MODIS is on both Terra and Aqua spacecraft.
Terra (EOS-AM) launched on 12/18/99 (first light 02/24/00)
Aqua (EOS-PM) launched on 05/04/02 (first light 06/24/02)
 - <http://terra.nasa.gov/>
 - <http://eos-pm.gsfc.nasa.gov/>
- Improved (over heritage sensors) spatial, spectral, temporal resolutions
- Broad range of applications
 - Land, oceans, atmosphere
 - Close to daily global coverage
 - Morning & afternoon observations
- Extensive pre-launch and on-orbit calibration activities





Instrument Background

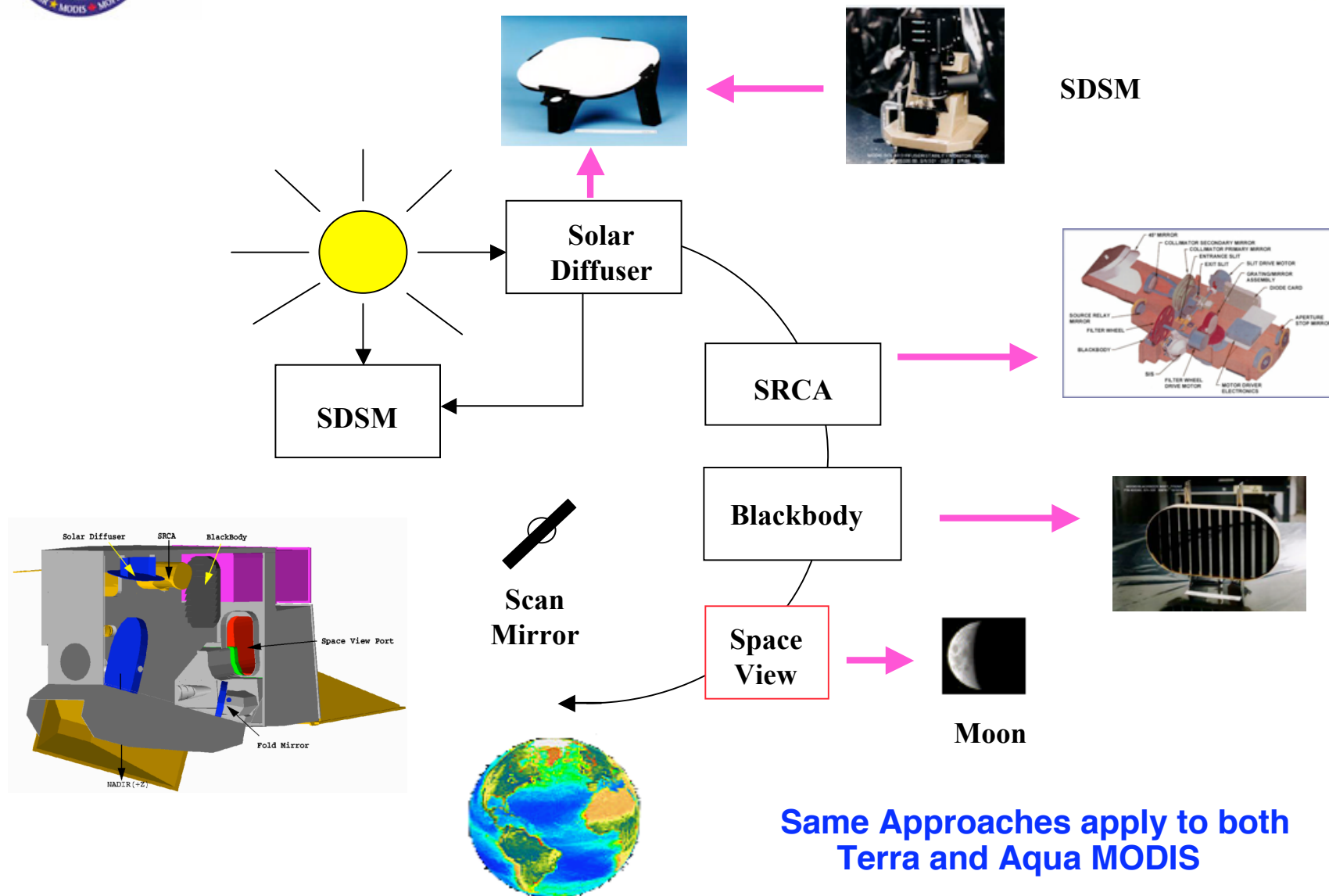


Pre-launch to On-orbit Calibration Transfer
SD characterized with reference traceable to NISR
reflectance standard
BB characterized with a large aperture Blackbody
Calibration Source (BCS)

- **36 spectral bands (4 FPAs)**
 - Reflective solar bands (1-19, and 26)
 - Thermal emissive bands (20-25, 27-36)
- **3 nadir spatial resolutions**
 - 250m (1-2), 500m (3-7), and 1km (8-36)
- **On-Board Calibrators:**
 - Solar diffuser (SD)
 - SD stability monitor (SDSM)
 - Blackbody (BB)
 - Spectro-radiometric calibration assembly (SRCA)
 - Space View (SV)



On-orbit Calibration Schematic



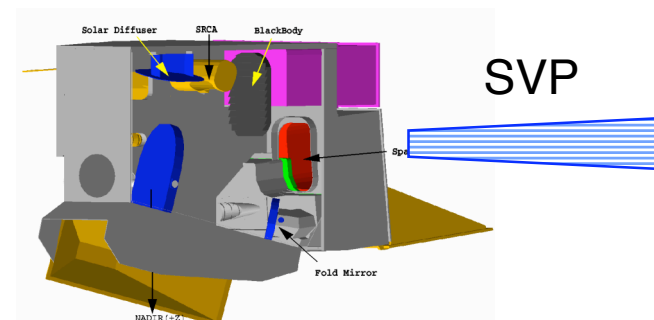
Same Approaches apply to both
Terra and Aqua MODIS



MODIS Lunar Observations and Applications



- Applications of Using the Moon:
 - Radiometric stability (RSB)
 - Inter-comparison (Terra and Aqua MODIS, MODIS and SeaWiFS, MODIS and MISR)
 - Others (*SPIE proceedings V4881, V5234*)
 - Optical leak assessment (LWIR PC bands)
 - Operational configuration evaluation (SMIR)
 - Spatial characterization
- Lunar Observations through Space View Port:
 - Nighttime orbits
 - 0-20° spacecraft roll maneuvers
 - 55° phase angle





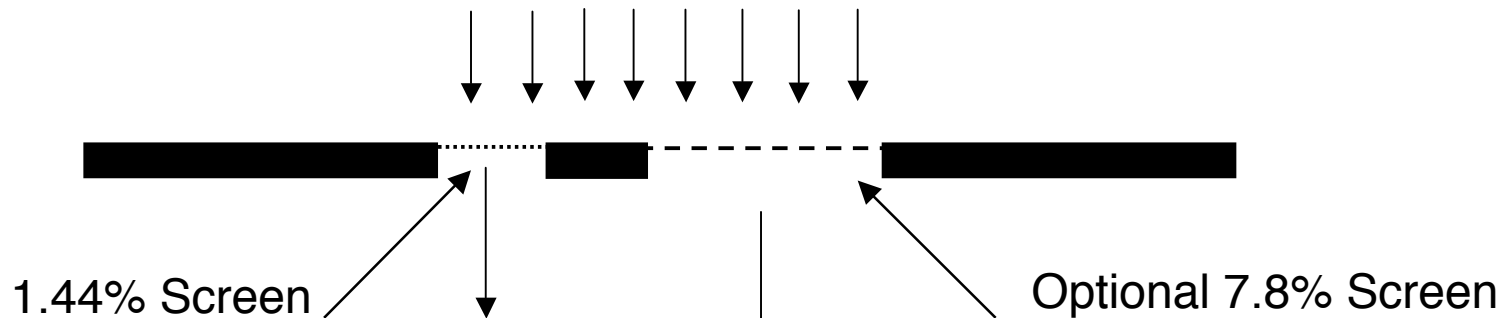
MODIS RSB Calibration Using SD



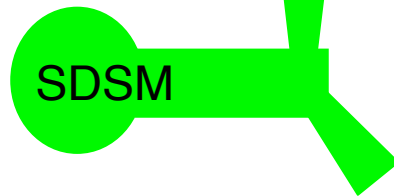
Reflectance

$$\rho_{EV} \cdot \cos(\theta_{EV}) = m_1 \cdot dn_{EV}^* \cdot d_{Earth-Sun}^2$$

Sun



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



Scan Mirror (MODIS)

$$m_1 = \frac{BRF_{SD} \cdot \cos(\theta_{SD})}{\langle dn_{SD}^* \rangle \cdot d_{Earth-Sun}^2} \cdot \Gamma_{SD} \cdot \Delta_{SD}$$



SD

Δ_{SD} : SD degradation factor;
 Γ_{SD} : SD screen vignetting function
 d : Earth-Sun distance
 dn^* : Temperature and RVS corrected digital number;
 dc : Digital count of SDSM

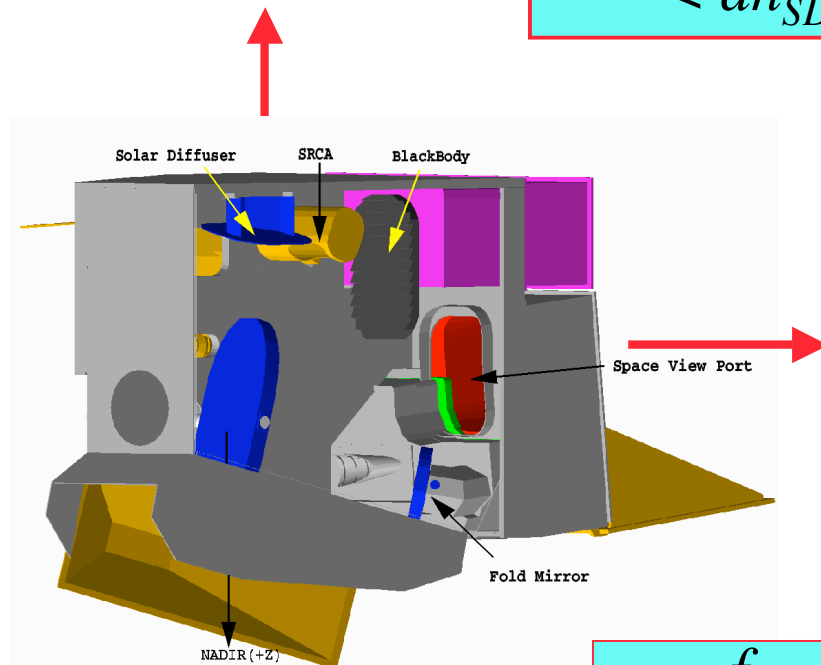


MODIS RSB Calibration Using the Moon



SD Calibration

$$m_1 = \frac{BRF_{SD} \cdot \cos(\theta_{SD})}{\langle dn_{SD}^* \rangle \cdot d_{Earth-Sun}^2} \cdot \Gamma_{SD} \cdot \Delta_{SD}$$



Moon Calibration

$$m_1 = \frac{f(\text{view_geometry})}{\langle dn_{Moon}^* \rangle}$$

$$f = \frac{f_{\text{phase-angle}} \cdot f_{\text{libration}} \cdot f_{\text{over-sampling}}}{d_{Sun-Moon}^2 \cdot d_{Modis-Moon}^2}$$



Using the Moon for Inter-comparison



- Lunar observations
- Lunar irradiance: measured (MODIS) and modeled (Kieffer/Stone)
 - Viewing geometry
 - Over Sampling
- Inter-comparison of Terra and Aqua MODIS
- Inter-comparison of MODIS and SeaWiFS

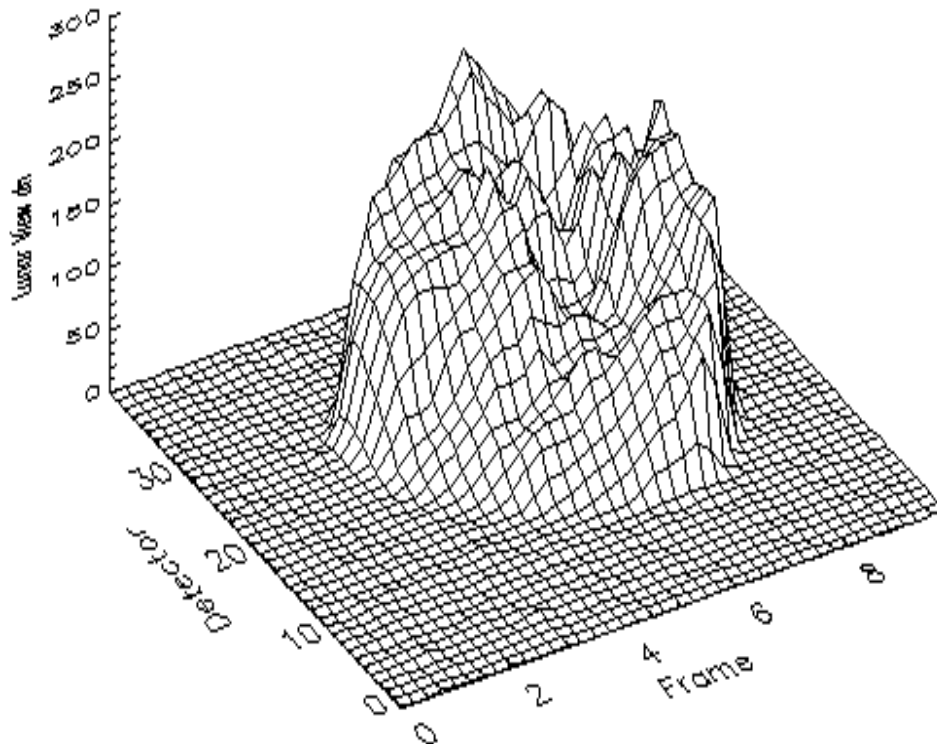
$$\frac{I_{Terra_MODIS} / I_{Model}}{I_{Aqua_MODIS} / I_{Model}}$$



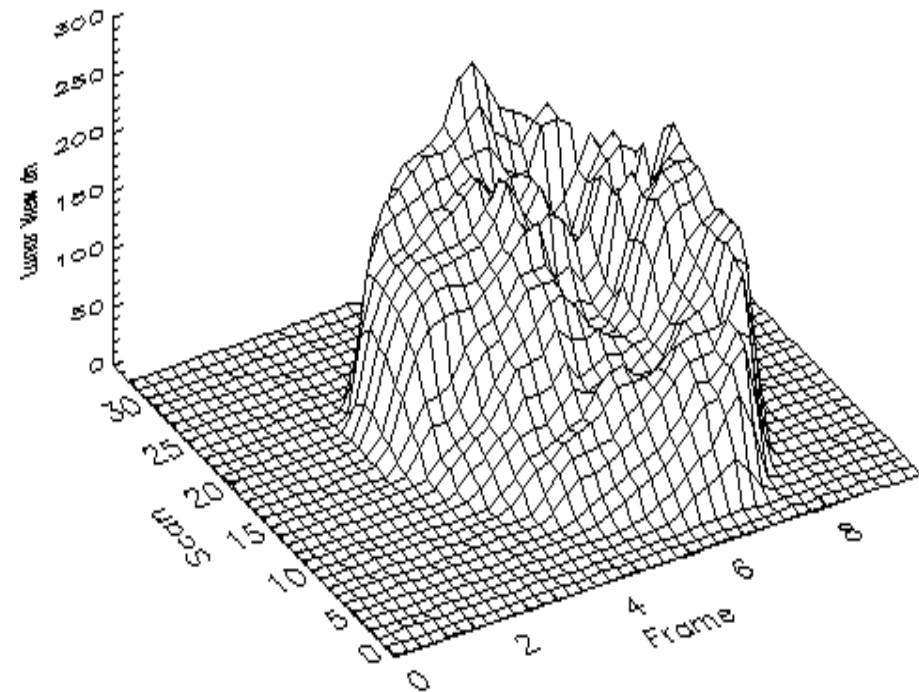
MODIS Lunar Observations



Aqua MODIS B1 (12/03/2003)



Single Scan, All detectors



Single detector, All scans



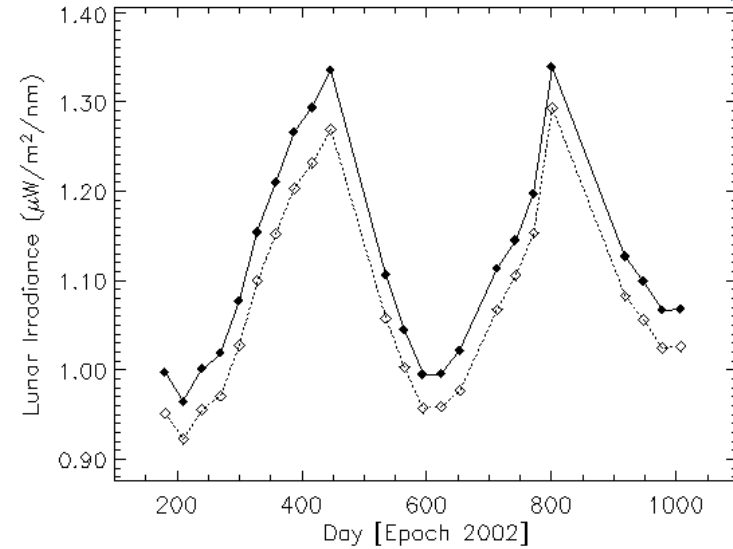
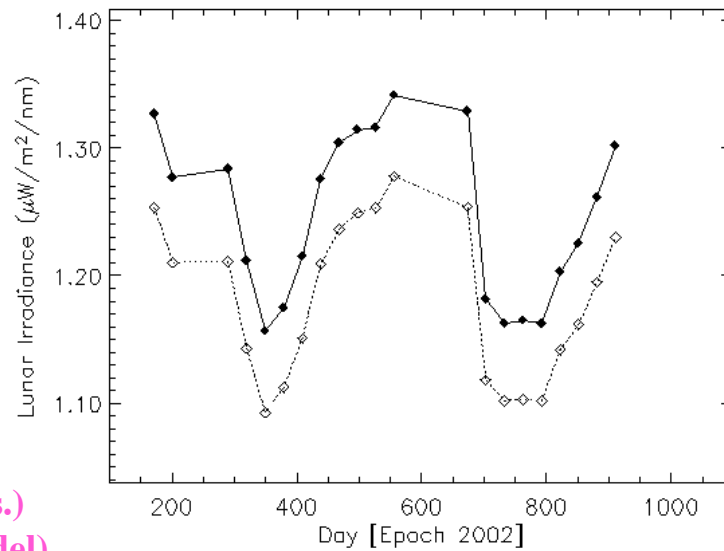
Lunar Irradiance: Measured and Modeled



Aqua MODIS

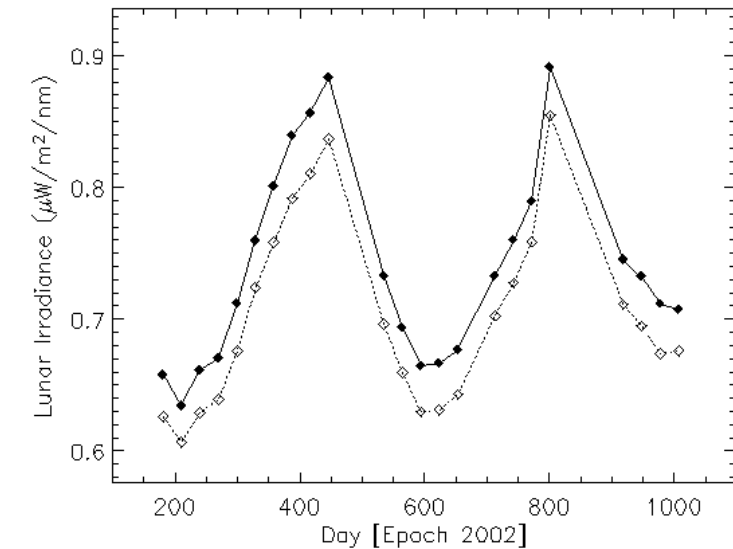
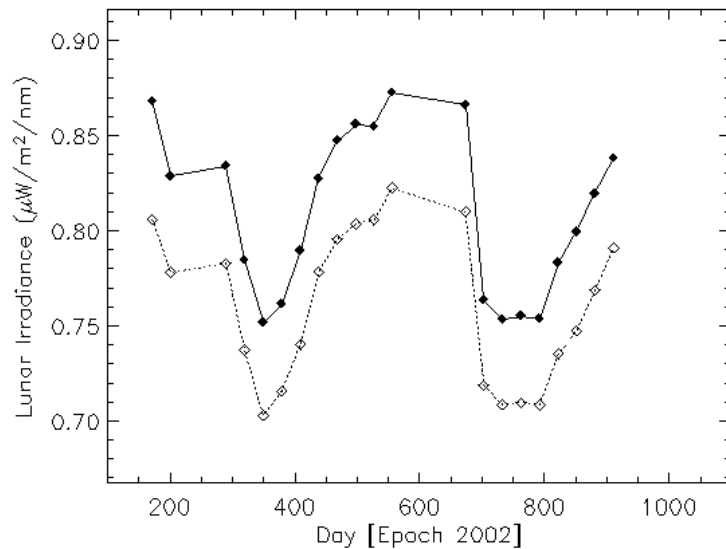
Terra MODIS

B1



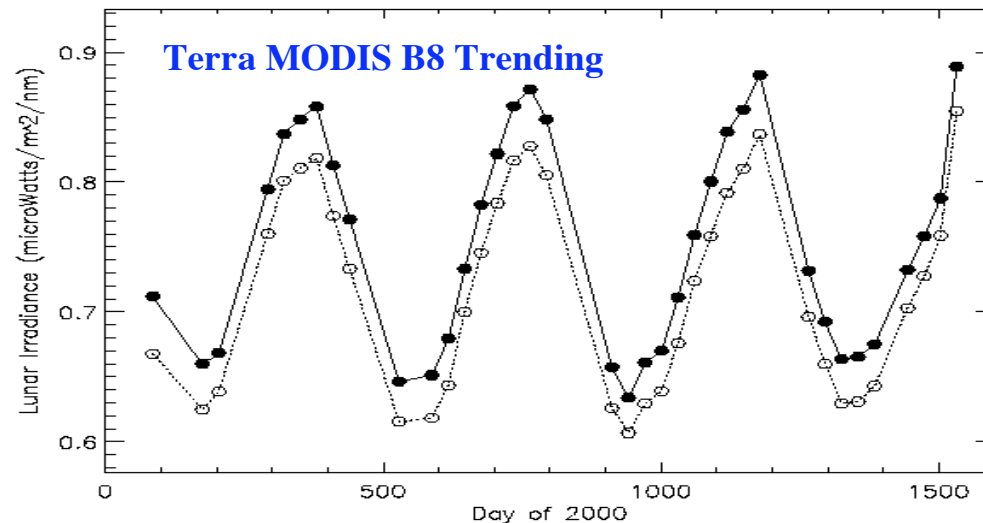
Solid (Meas.)
Circle (Model)

B8

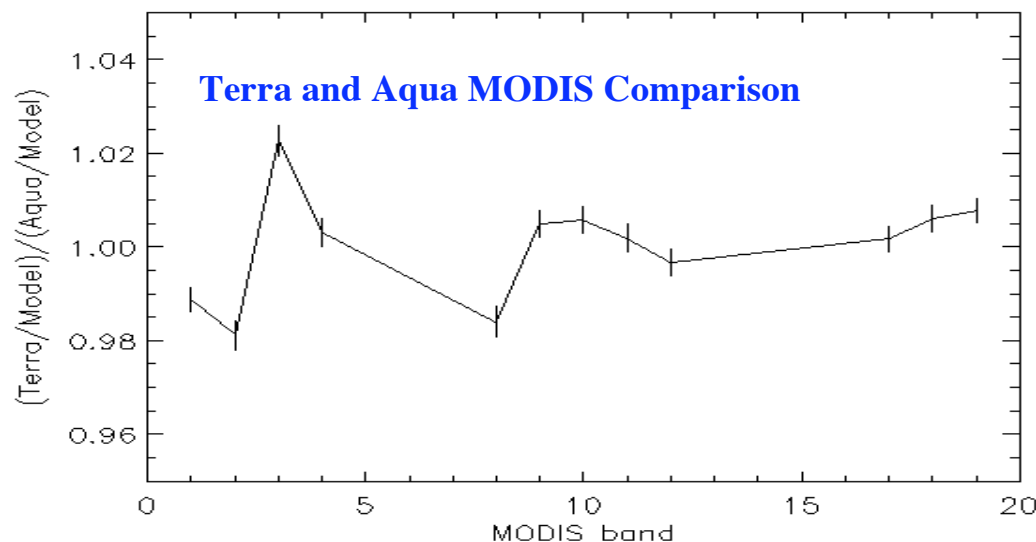




Inter-comparison of Terra and Aqua MODIS



MODIS RSB Uncertainty:
2% in reflectance
5% in radiance



$$\frac{I_{Terra_MODIS} / I_{Model}}{I_{Aqua_MODIS} / I_{Model}}$$

Uncertainty Sources:

- (1) Model
- (2) Measurement



Inter-comparison of MODIS and SeaWiFS



Terra DSM and SeaWiFS Lunar Observations (April 14, 2003)

SeaWiFS				MODIS				Ratio
Band No.	Wavelength (nm)	Measured I $\text{W/m}^2/\text{nm}$	Model I $\text{W/m}^2/\text{nm}$	Band No.	Wavelength (nm)	Measured I $\text{W/m}^2/\text{nm}$	Model I $\text{W/m}^2/\text{nm}$	
1	412	1.790	1.757	8	412	1.805	1.714	0.97
2	443	2.190	2.130	9	442	2.143	2.026	0.97
				3	466	2.465	2.316	
3	490	2.574	2.437	10	487	2.526	2.319	0.97
4	510	2.589	2.458	11	530	2.617	2.463	0.99
5	555	2.776	2.631	12	547	2.704	2.523	0.98
5	555	2.776	2.631	4	554	2.663	2.539	1.01
				1	647	2.596	2.512	
6	670	2.744	2.556	1	647	2.596	2.512	1.04
7	765	2.480	2.266					
8	865	2.009	1.886	2	857	1.974	1.855	1.00
				17	904	1.912	1.705	
				18	935	1.822	1.574	
				19	936	1.815	1.572	

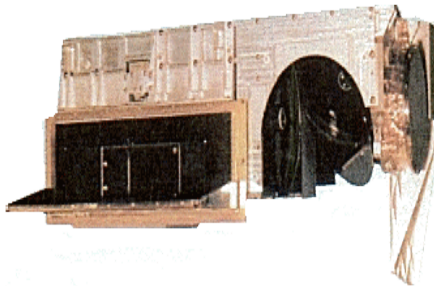


Using AVHRR for Inter-comparison



- Near simultaneous (nadir) observations from orbit intersection
 - Pixel by pixel matching
 - Uniform scene
- MODIS bands 31 and 32 versus AVHRR channels 4 and 5 (11 μ and 12 μ)

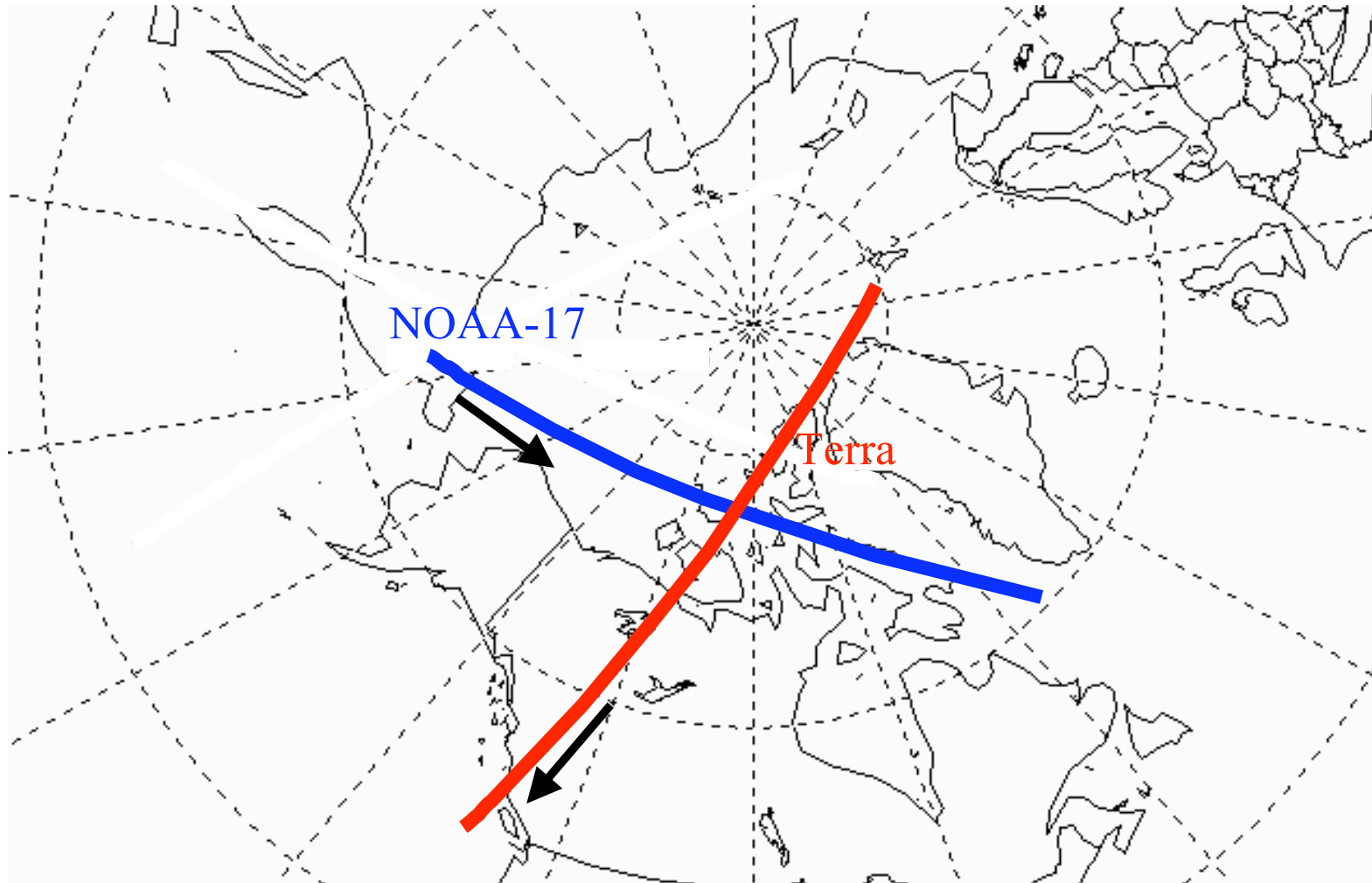
$$\begin{aligned} &\{BT(Terra_MODIS) - BT(AVHRR)\} \\ &\{BT(Aqua_MODIS) - BT(AVHRR)\} \end{aligned}$$





Terra vs. NOAA-17 Orbit Intersection

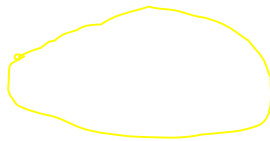
December 25, 2002, 06:12GMT, latitude: 77.8N, longitude: 104.1W





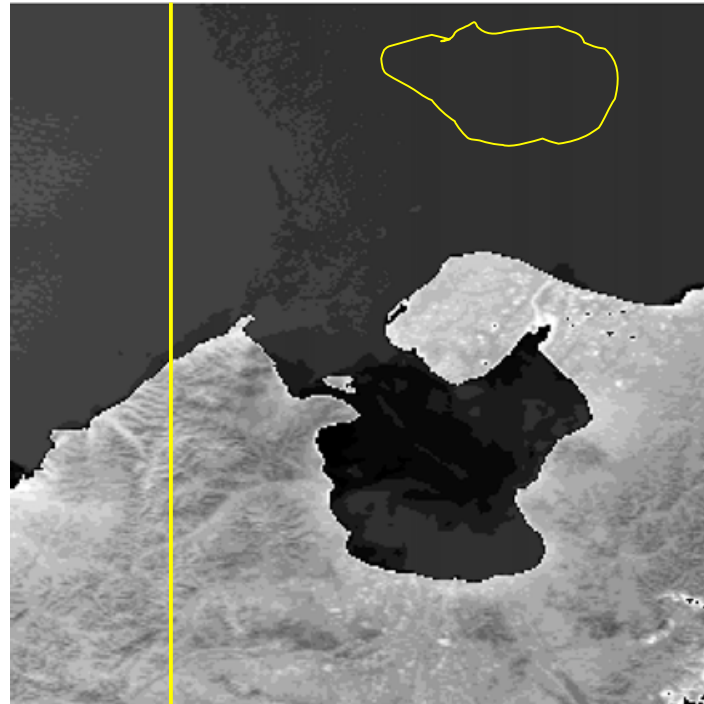
Orbital interception at: 00:47 (GMT), July 5, 2001

Terra MODIS, band 31



Nadir

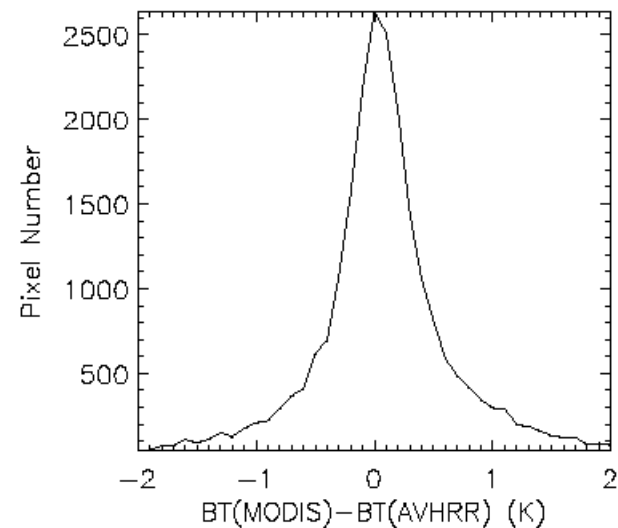
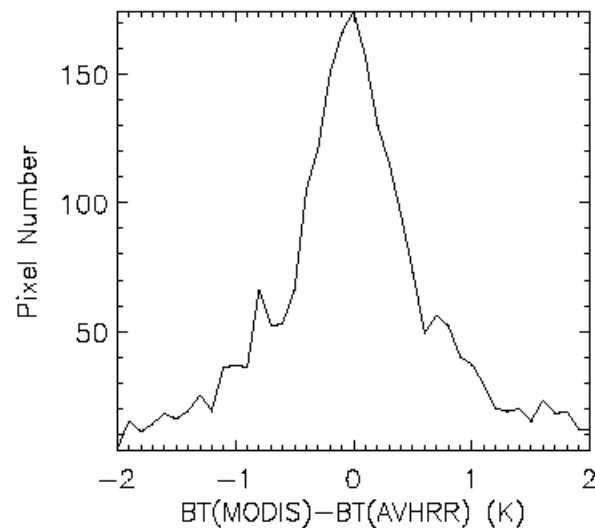
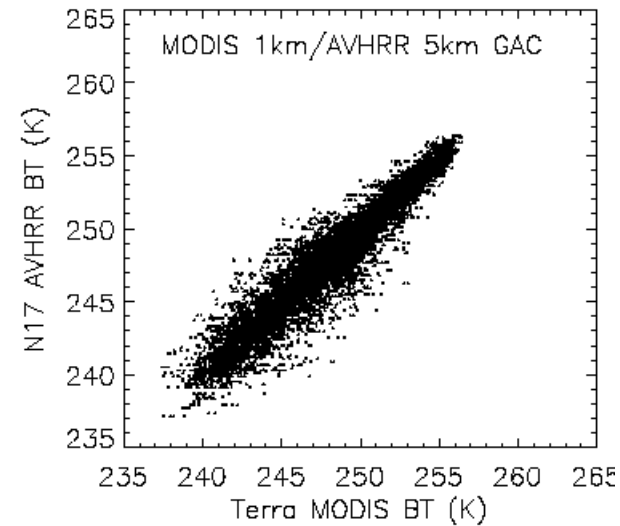
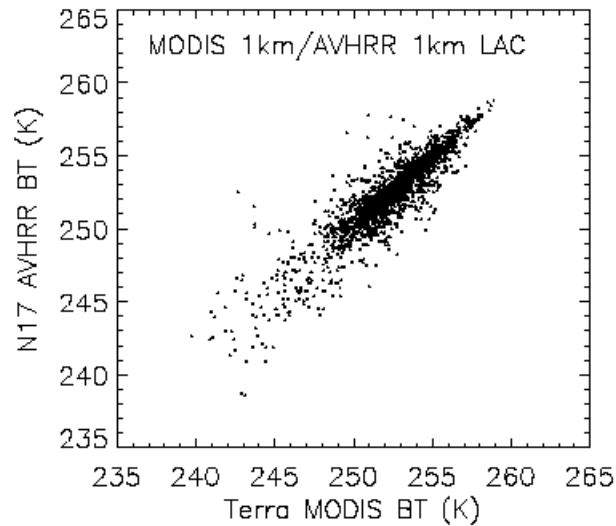
NOAA16 AVHRR, channel 4



Nadir



Inter-comparison of Terra MODIS and AVHRR (17) in the $11\mu\text{m}$ band on Nov 25, 2002



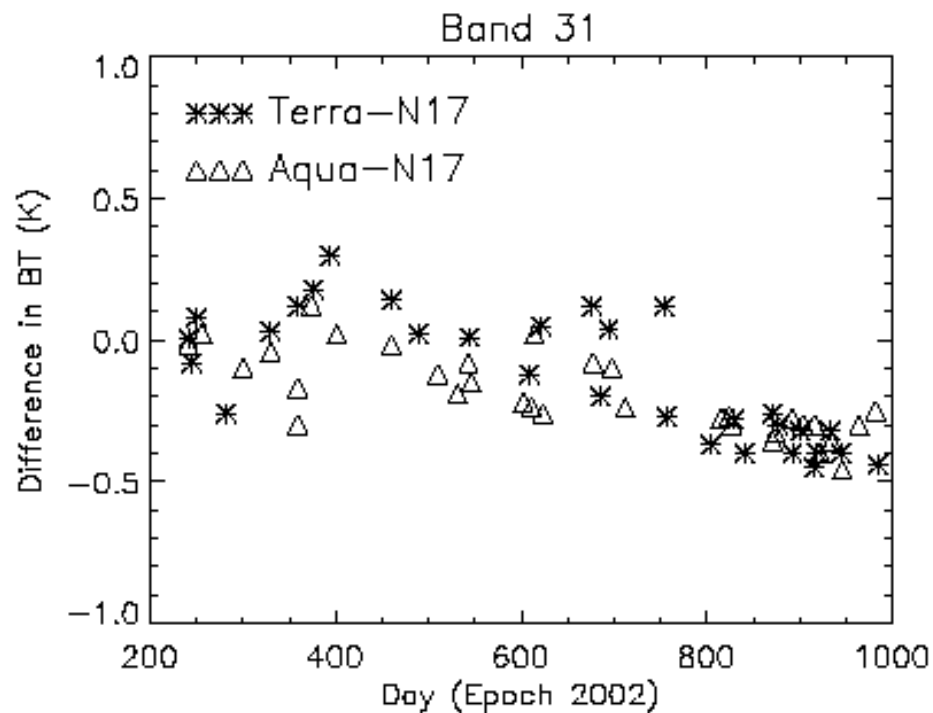


Inter-comparison of Terra and Aqua MODIS Using N-17 AVHRR

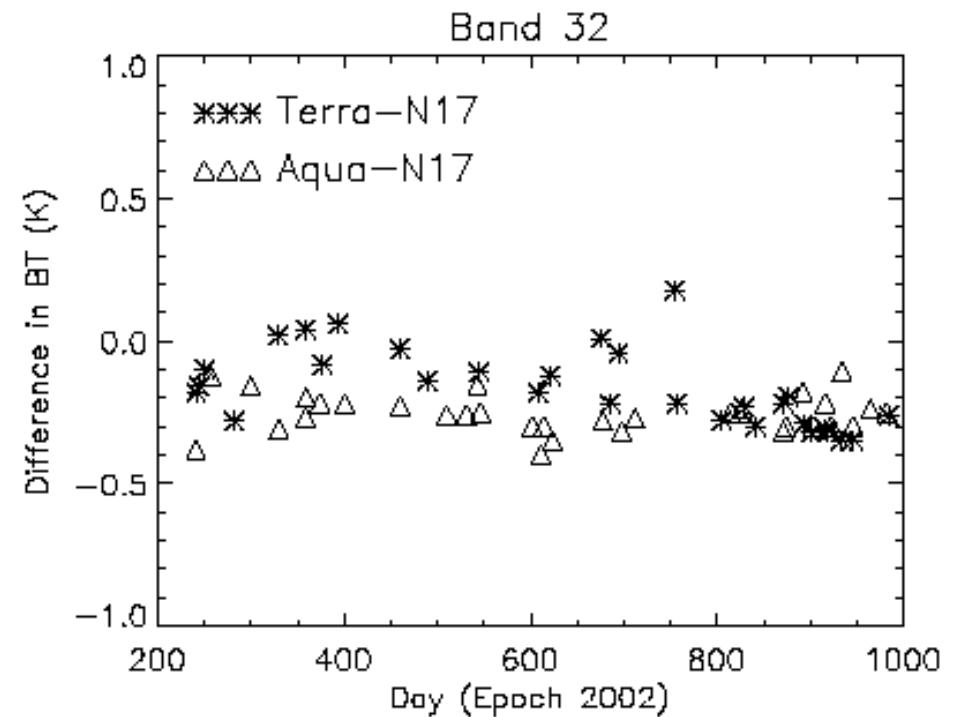


MODIS Band 31 and 32

Uncertainty: 0.35K; NEdT = 0.05K at 300K



$$\Delta BT = 0.08 \pm 0.15K$$



$$\Delta BT = 0.14 \pm 0.12K$$

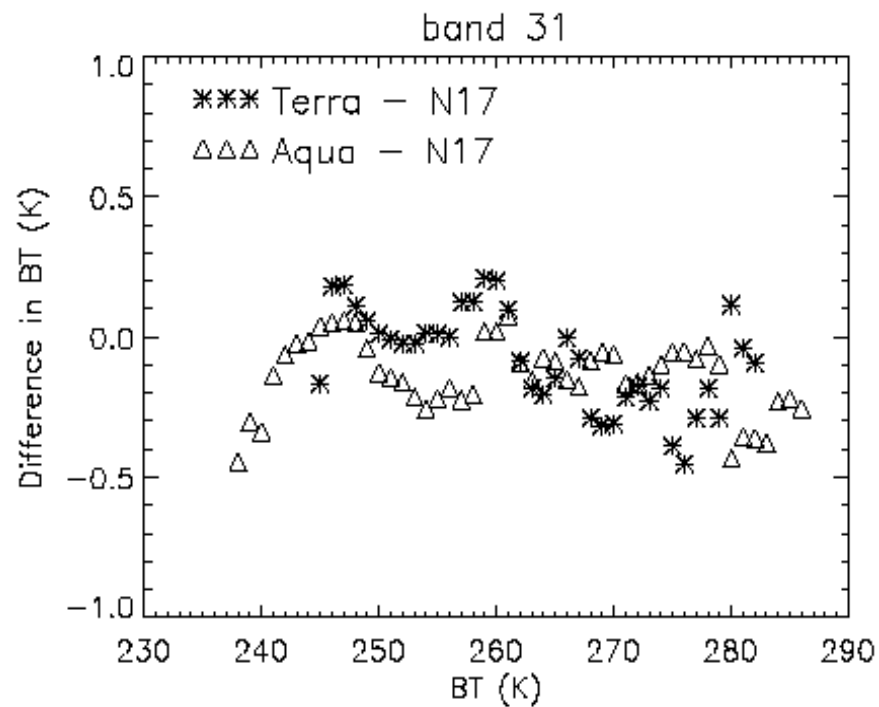


Inter-comparison of Terra and Aqua MODIS Using N-17 AVHRR

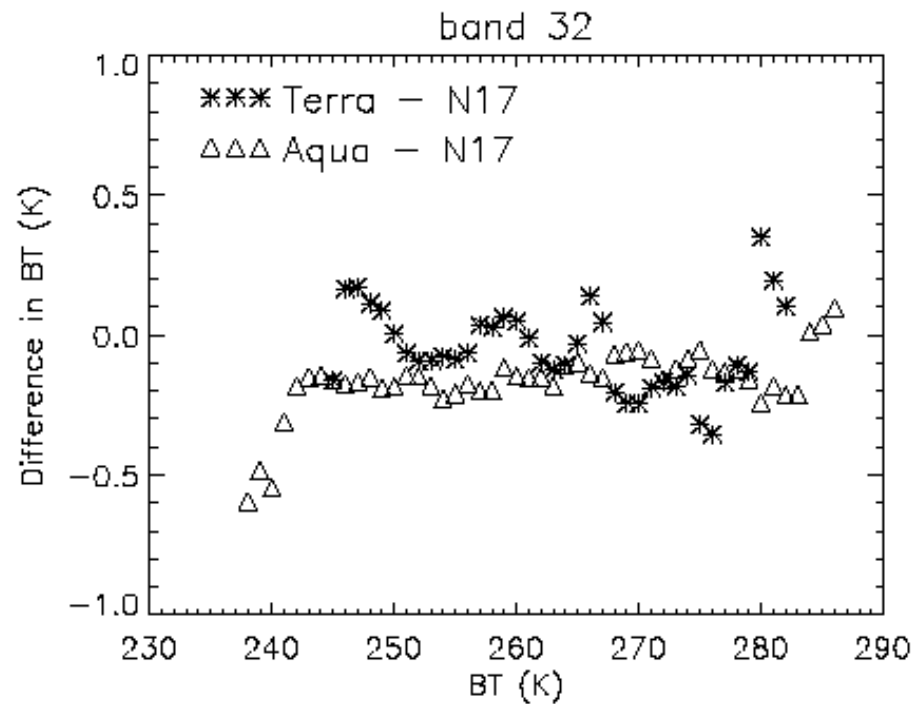


MODIS Band 31 and 32

Uncertainty: 0.35K; NEdT = 0.05K at 300K



$\Delta BT = 0.08 \pm 0.15K$



$\Delta BT = 0.14 \pm 0.12K$

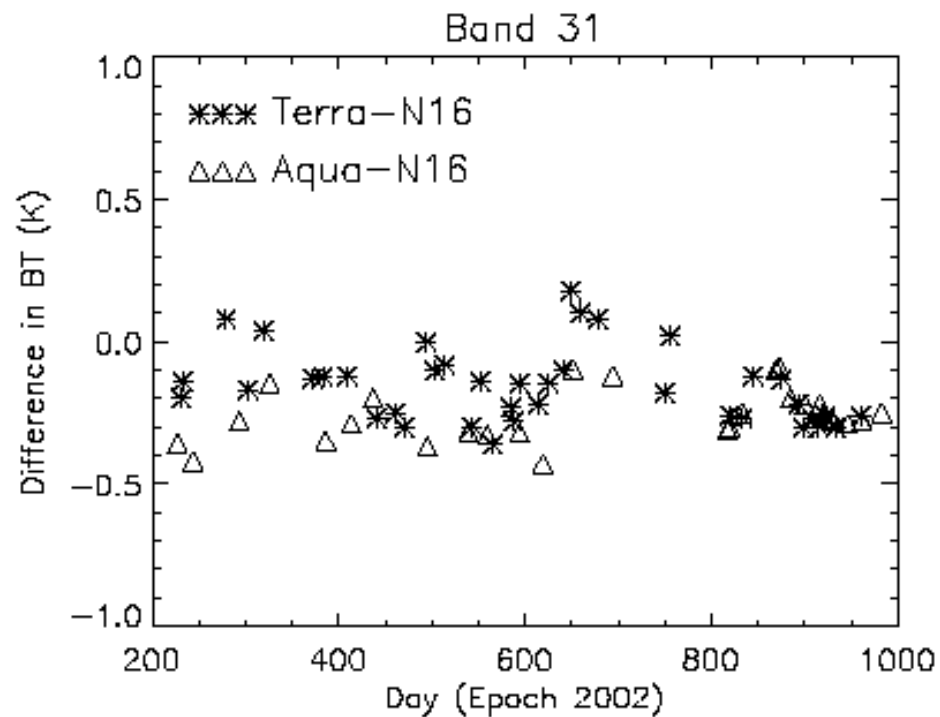


Inter-comparison of Terra and Aqua MODIS Using N-16 AVHRR

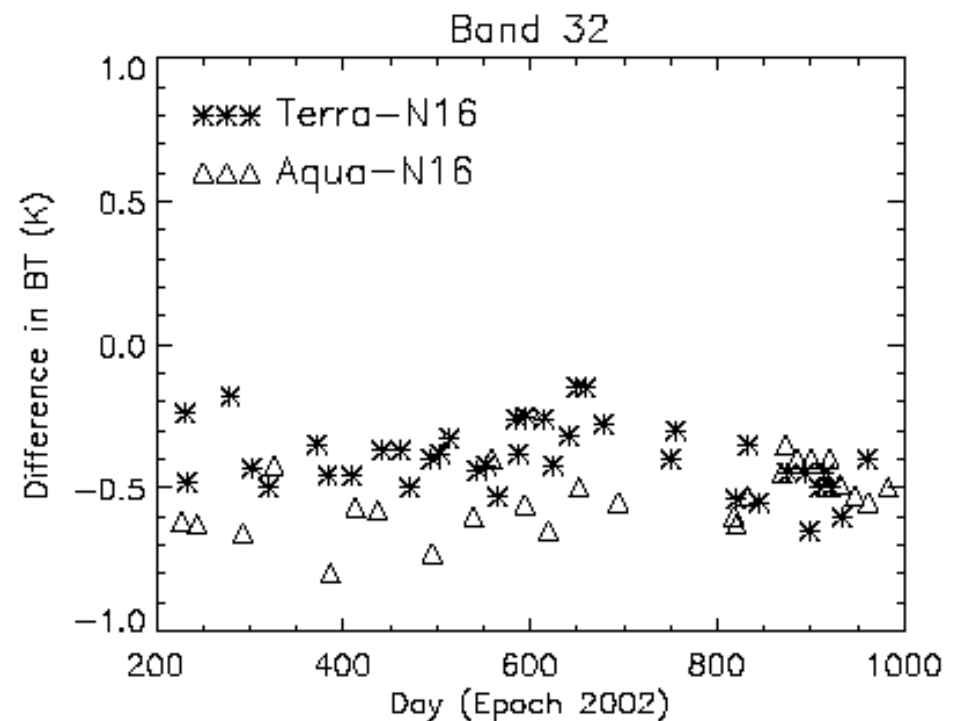


MODIS Band 31 and 32

Uncertainty: 0.35K; NEdT = 0.05K at 300K



$$\Delta BT = 0.10 \pm 0.10K$$



$$\Delta BT = 0.19 \pm 0.11K$$

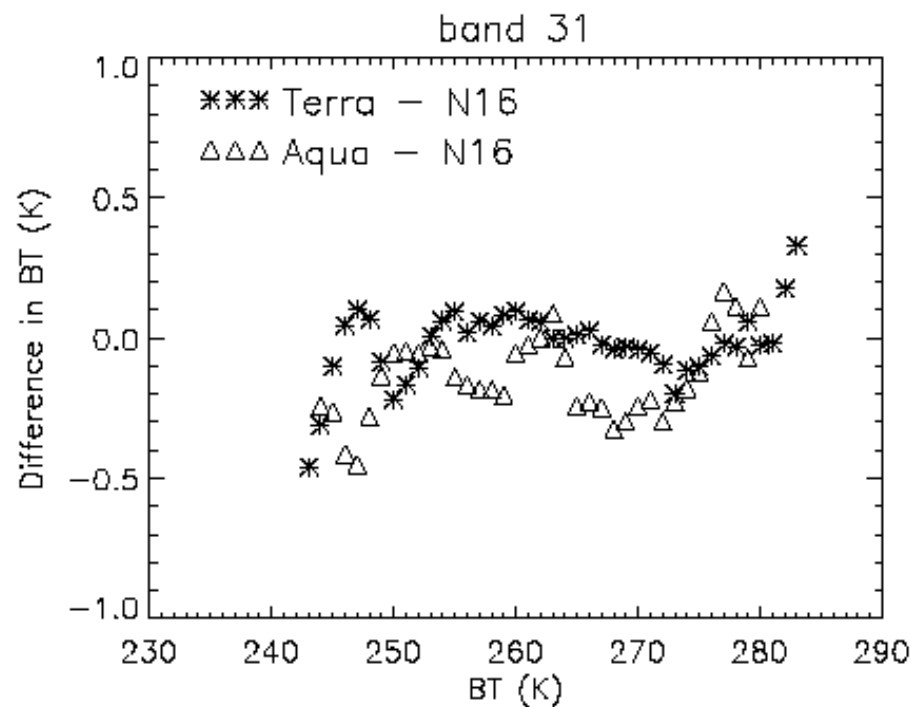


Inter-comparison of Terra and Aqua MODIS Using N-16 AVHRR

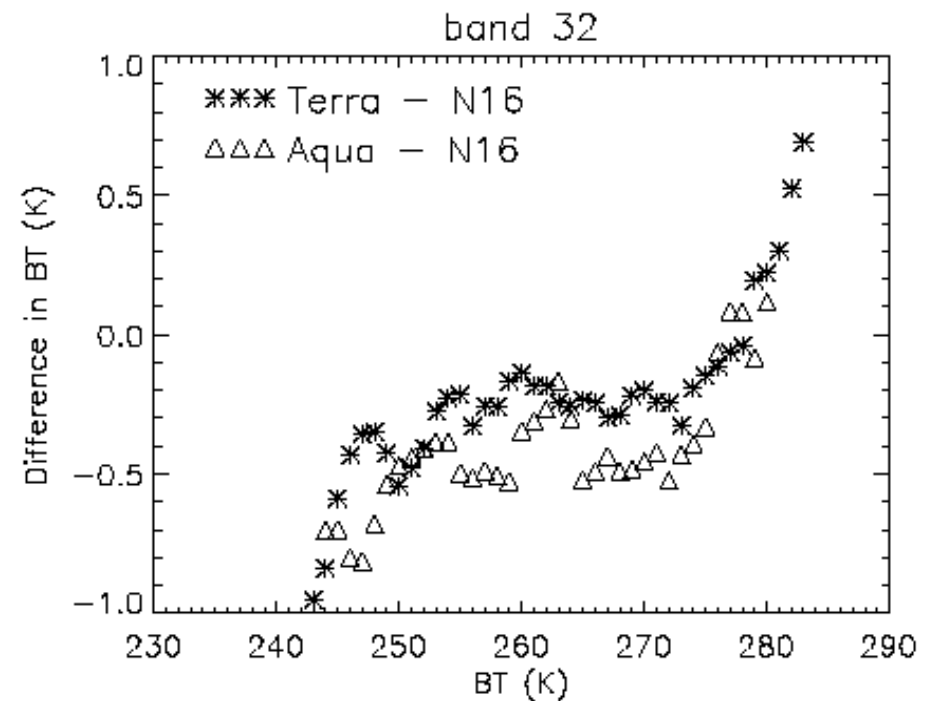


MODIS Band 31 and 32

Uncertainty: 0.35K; NEdT = 0.05K at 300K



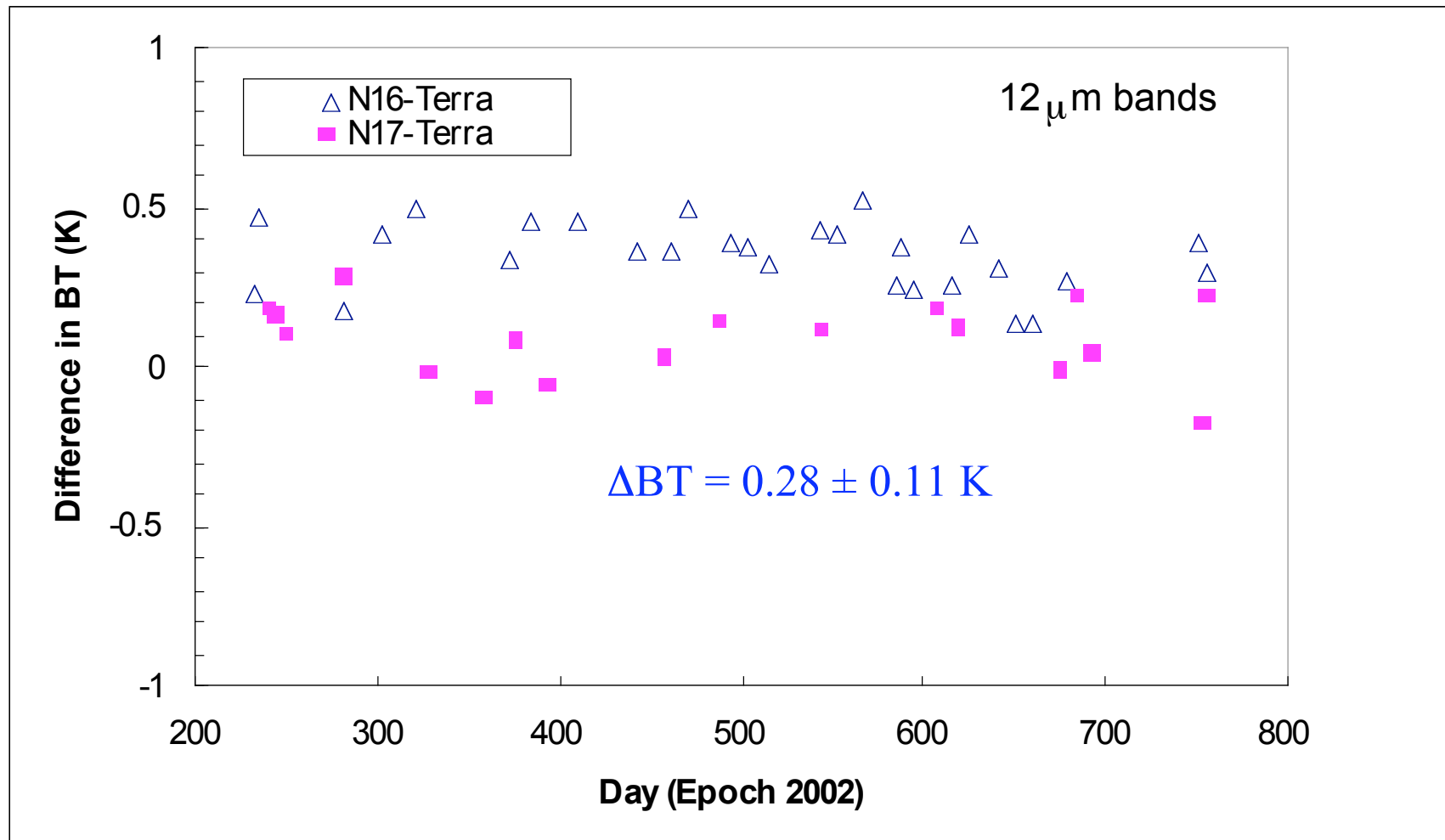
$$\Delta BT = 0.10 \pm 0.10K$$



$$\Delta BT = 0.19 \pm 0.11K$$



Inter-comparison of NOAA-16 and 17 AVHRR Using Terra MODIS (12 μ m band)





Summary



- Lunar Observations
 - Support on-board calibration
 - Provide long term stability trending
 - Allow inter-comparison among sensors
- Sensors' Simultaneous Observations (orbital intersection)
 - Inter-comparison
- Consistent Terra and Aqua MODIS Calibration
 - RSB using the Moon
 - TEB using AVHRR

Terra MODIS 500m resolution image on day 2004/051 at 10:35 UTC
RGB from Bands 1 (645nm), 4 (555nm), 3 (469nm)

