MODIS Solar Diffuser (SD) Earth Shine Analysis

MODIS & SeaWiFS
Calibration Meeting
Feb. 11, 2004 (revised)

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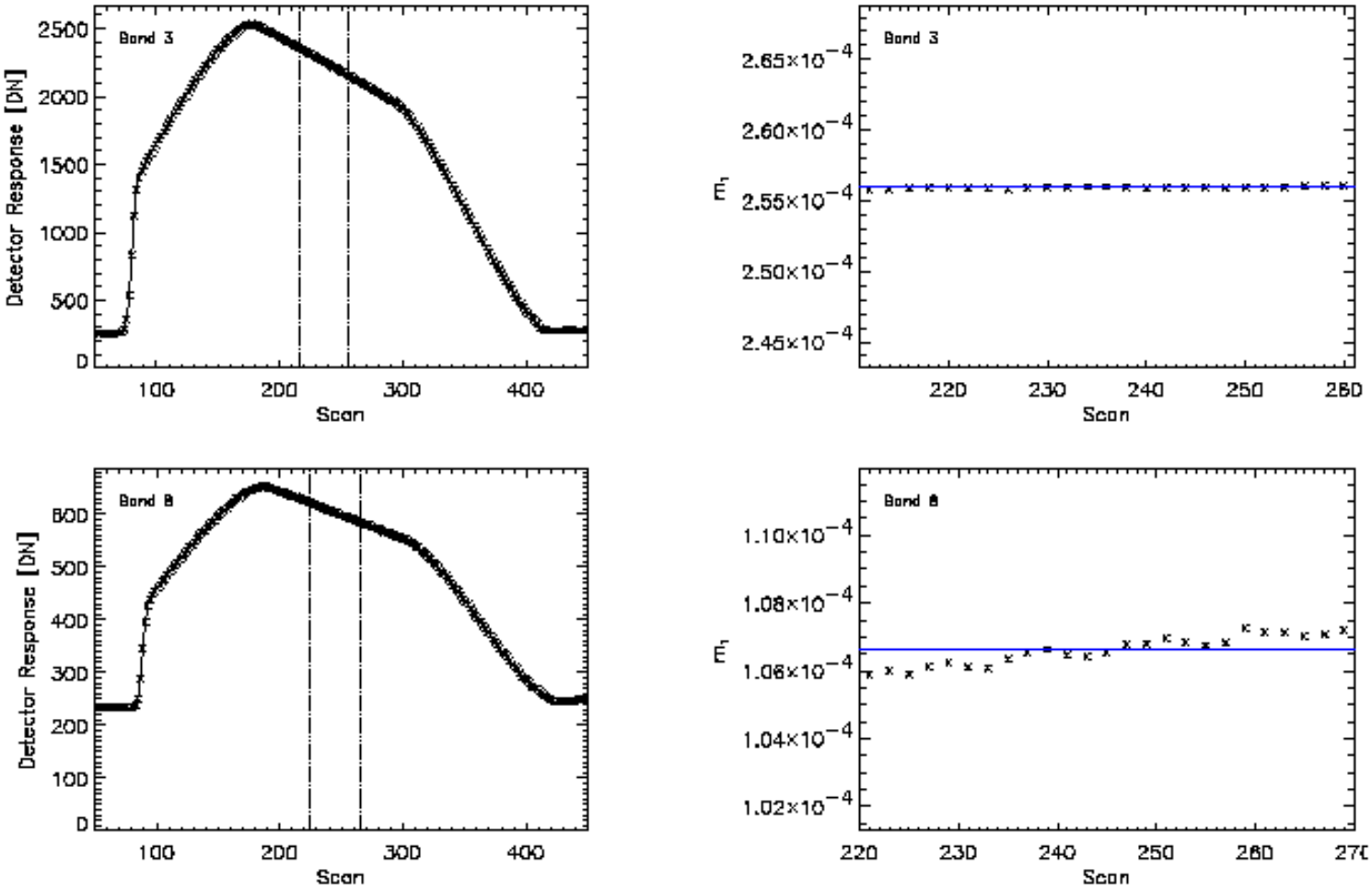
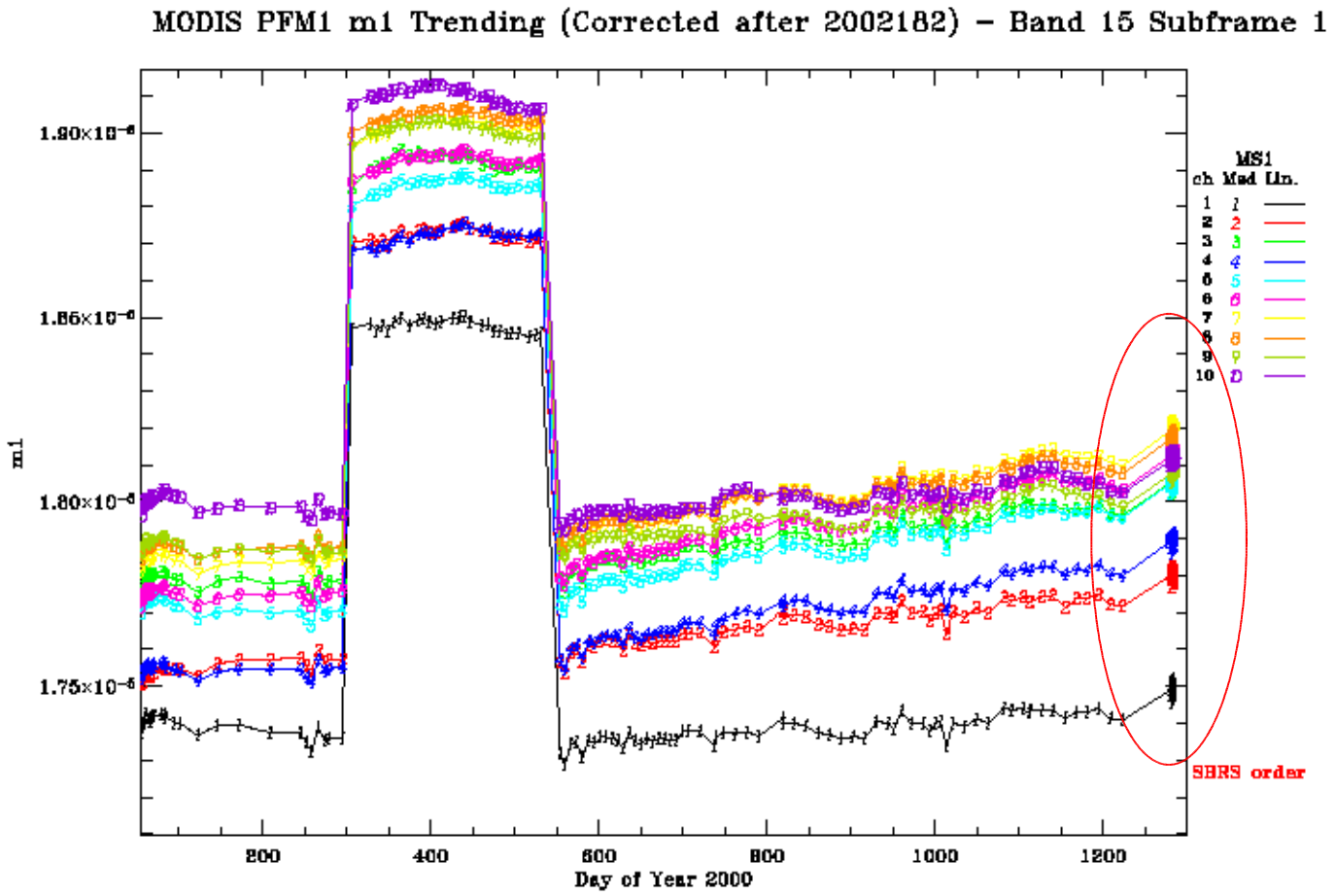


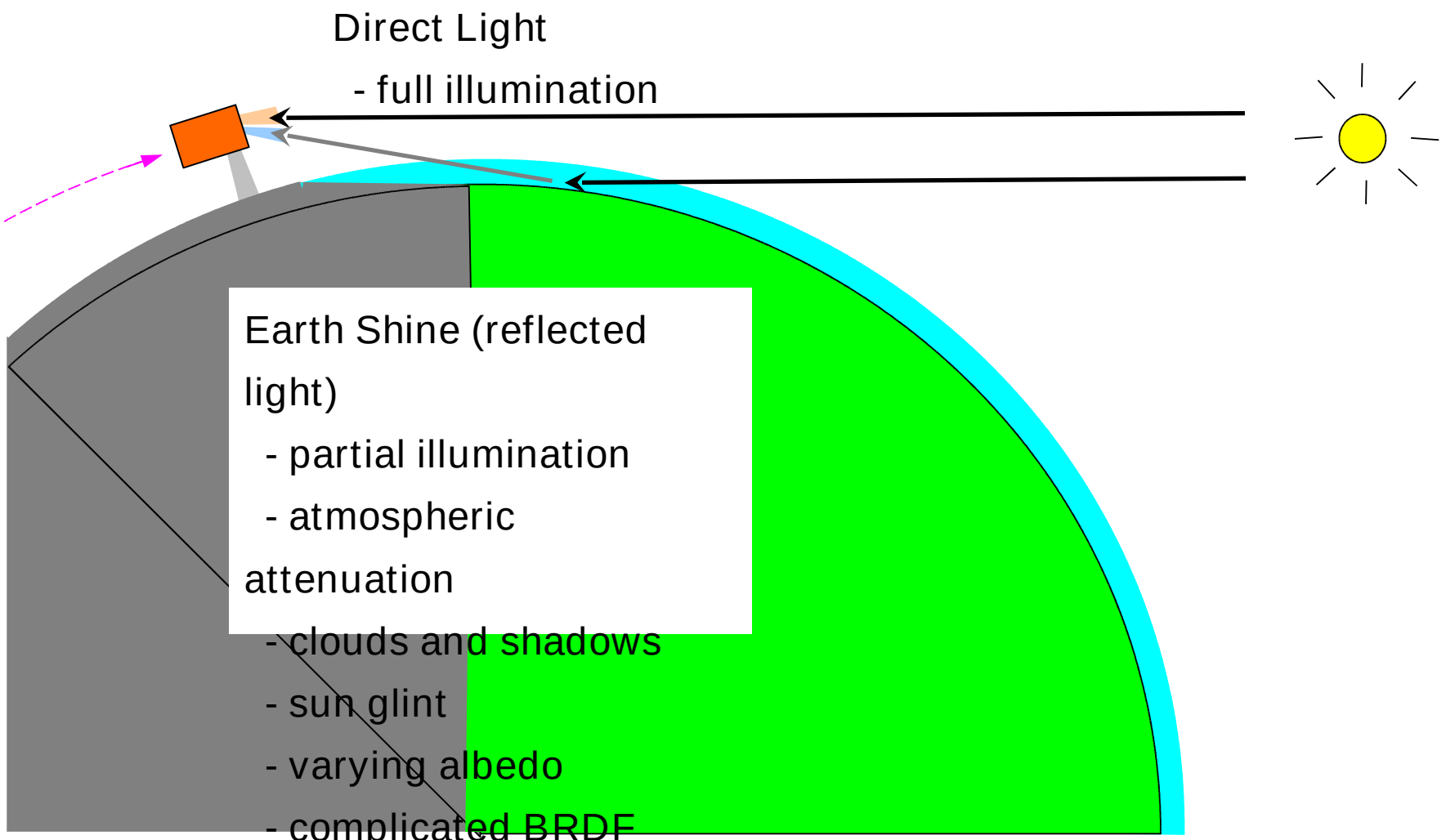
Figure 7: MODIS RSB m_1 computation examples. B3 does not use the SD screen while B8 uses the SDS in the calibration. Only a full solar illumination region (scans) is used in the m_1 computation

Xiong, X., J. Sun, J. Esposito, X. Liu, W. L. Barnes, and B. Guenther, "On-Orbit Characterization of a Solar Diffuser' s Bi-Directional Reflectance Factor Using Spacecraft Maneuvers," Proceedings Earth Observing Systems VIII, W. L. Barnes, ed., SPIE *5151* (2003).

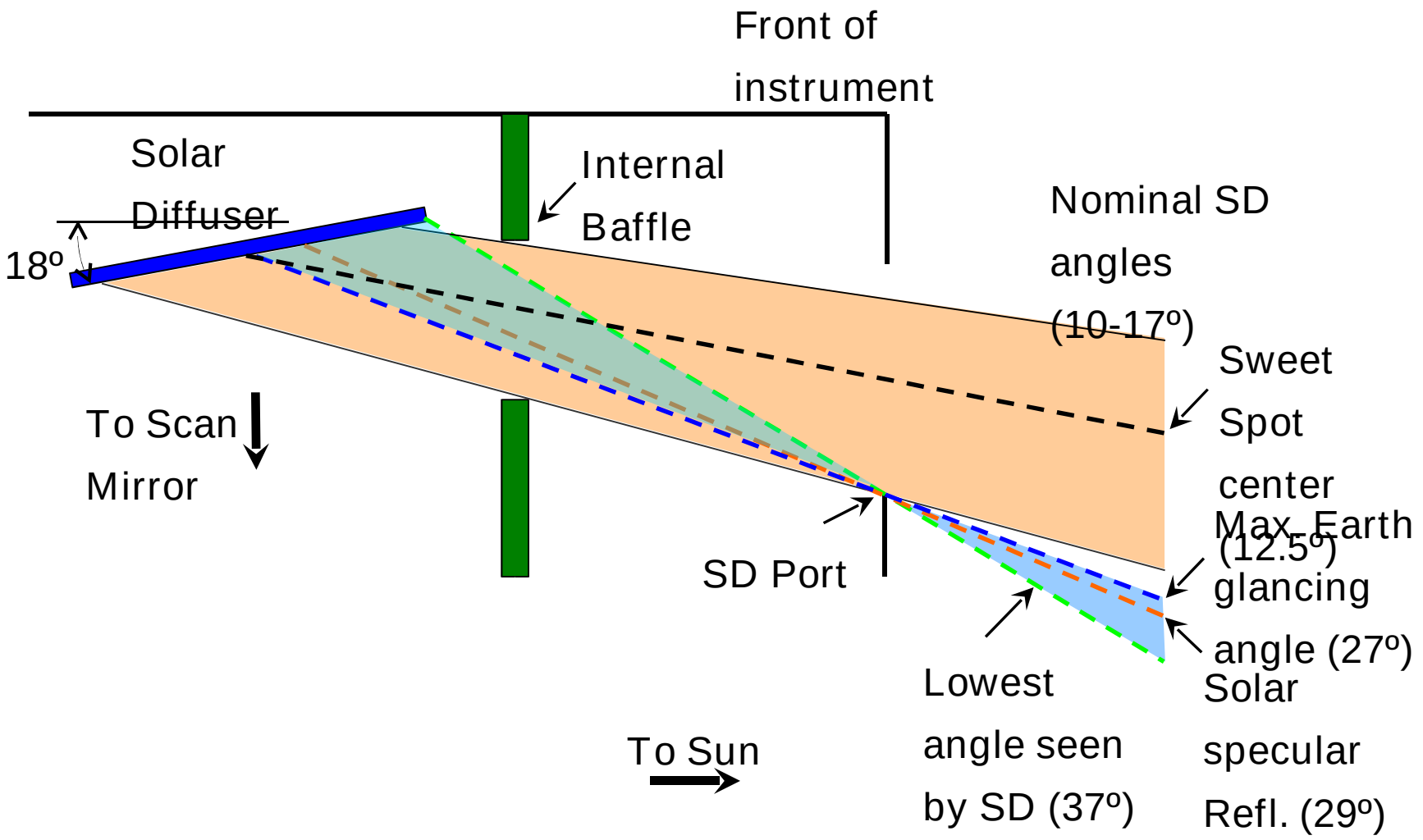
Understanding SD measurement variation – What is the Earth shine contribution?



Simplified SD Geometry



MODIS Solar Diffuser Geometry

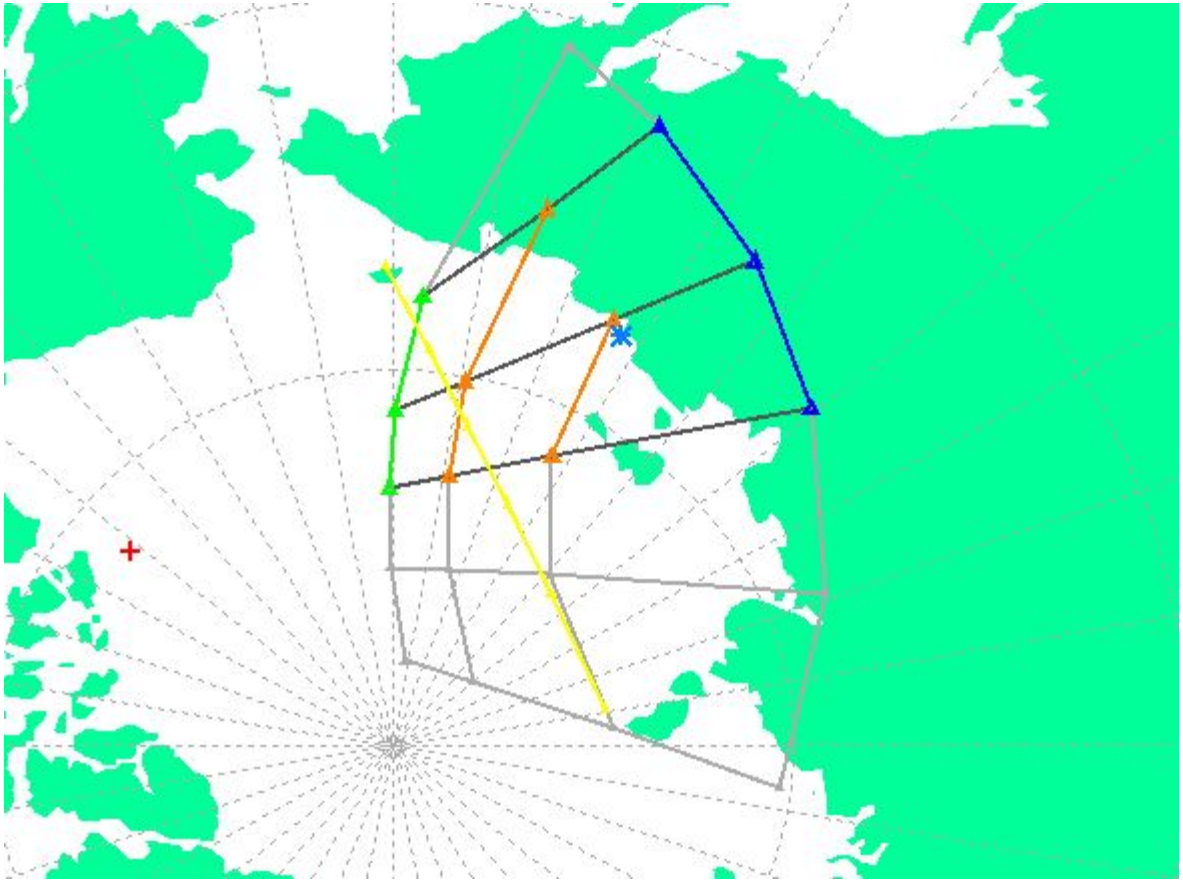


MODIS Solar Diffuser Stray Light Analysis

- Analysis program
  - Fortran with IDL display logic
  - Uses Two Line Element ephemeris
  - can easily be run for additional cases
- Estimates:
  - location of stray light from Earth's surface
  - sub-satellite point
  - solar specular reflection point
- Separately calculates stray light within normal SD left-to-right view and for full view left-to-right extent
  - angles estimated from instrument drawings

Solar Diffuser Stray Light from Earth Surface (1 of 3)

2000/059.0435.91 (14.205º) – Start of "sweet spot"

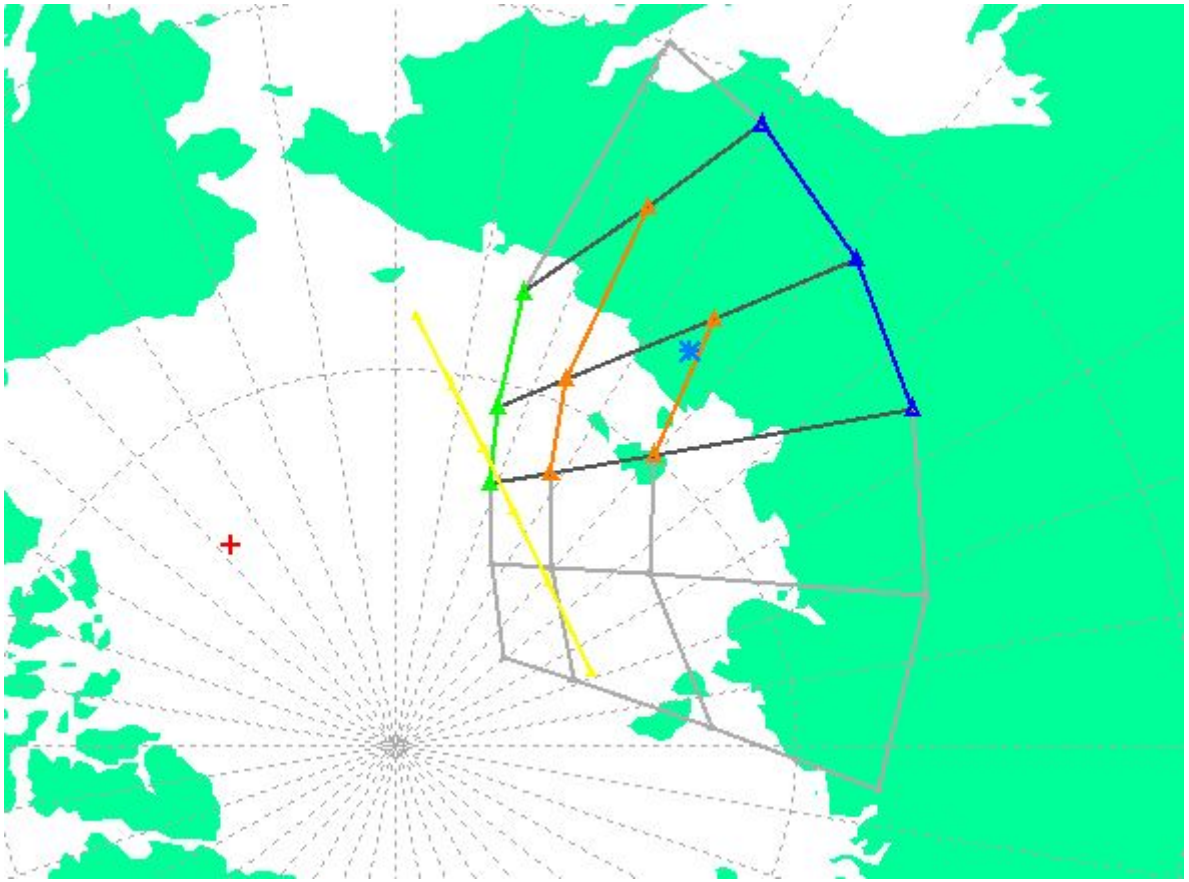


Key:

- Red plus – Sub-satellite point
- Yellow line – Terminator
- Green line – Lowest angle seen by SD (37.2º)
- Orange lines – 4º and 8º above lowest SD angle (33.2º and 29.2º)
- Dark blue line – Earth limb (glancing angle, 27º to 32º)
- Light blue star – Specular reflection angle (view zenith = solar zenith, relative azimuth = 180º)
- Light gray line – Stray light from sides

Solar Diffuser Stray Light from Earth Surface (2 of 3)

2000/059.0436.92 (10.824º) – End of “sweet spot”

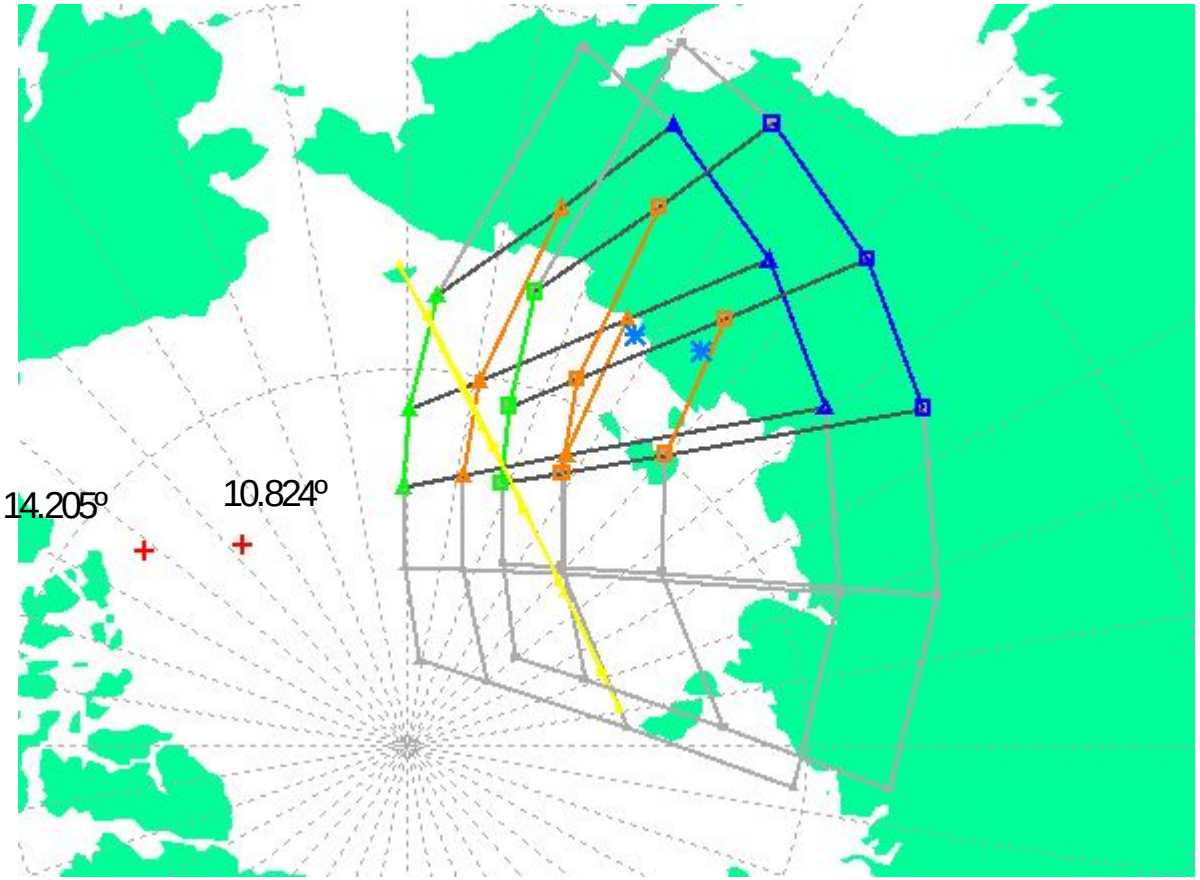


Key:

- Red plus – Sub-satellite point
- Yellow line – Terminator
- Green line – Lowest angle seen by SD (37.2º)
- Orange lines – 4º and 8º above lowest SD angle (33.2º and 29.2º)
- Dark blue line – Earth limb (glancing angle, 27º to 32º)
- Light blue star – Specular reflection angle (view zenith = solar zenith, relative azimuth = 180º)
- Light gray line – Stray light from sides

Solar Diffuser Stray Light from Earth Surface (3 of 3)

2000/059.0435.91 and 0436.92 (14.205º and 10.824º)



Key:

- Red plus – Sub-satellite point
- Yellow line – Terminator
- Green line – Lowest angle seen by SD (37.2º)
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- Dark blue line – Earth limb (glancing angle, 27º to 32º)
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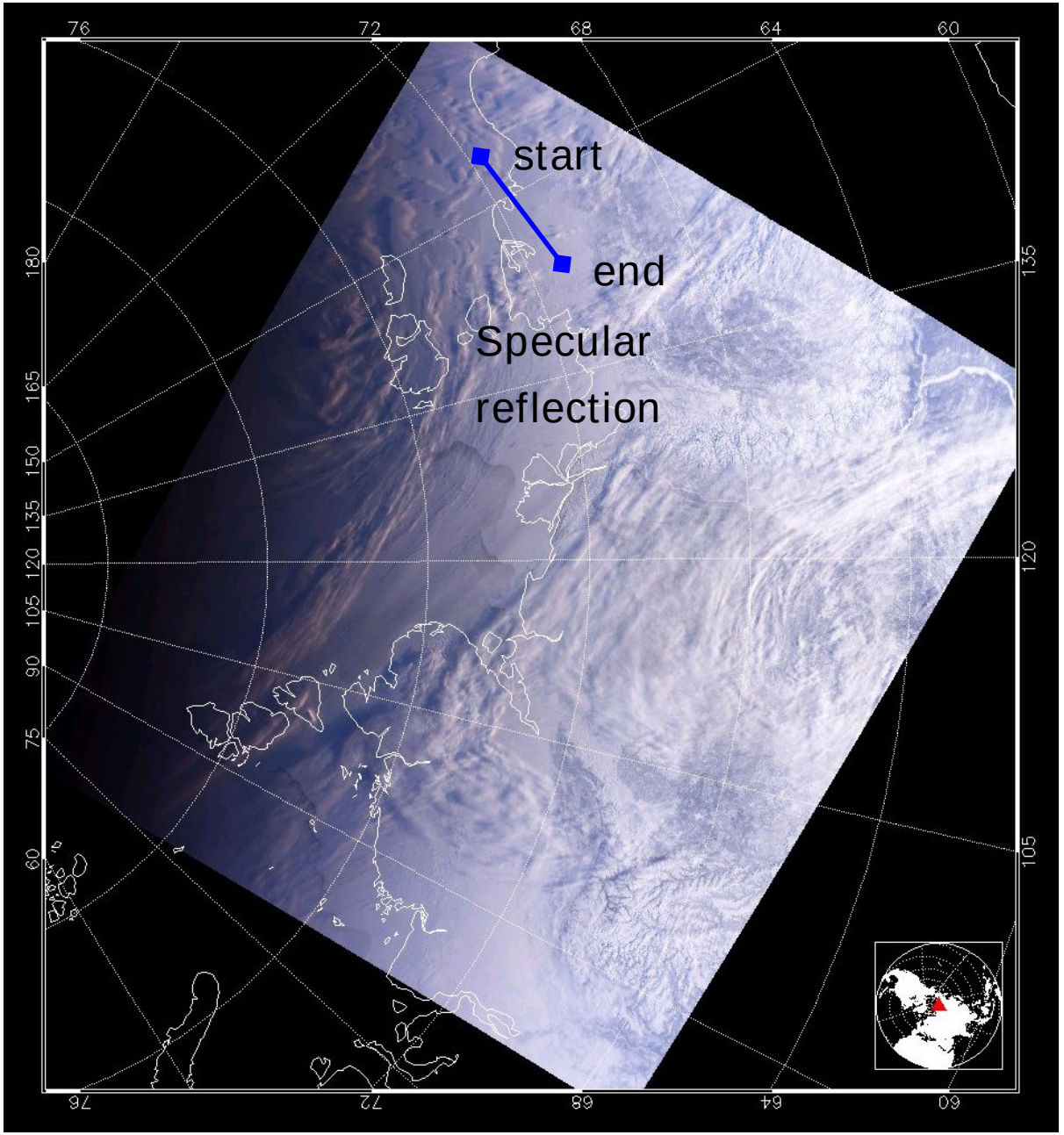
- Light gray line – Stray light from sides

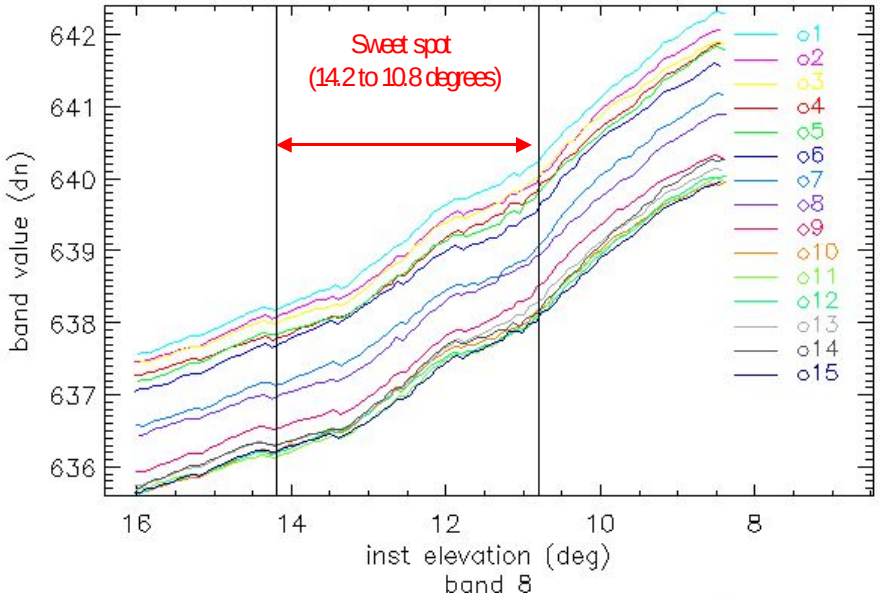
L1B Data from 2000/059.0440

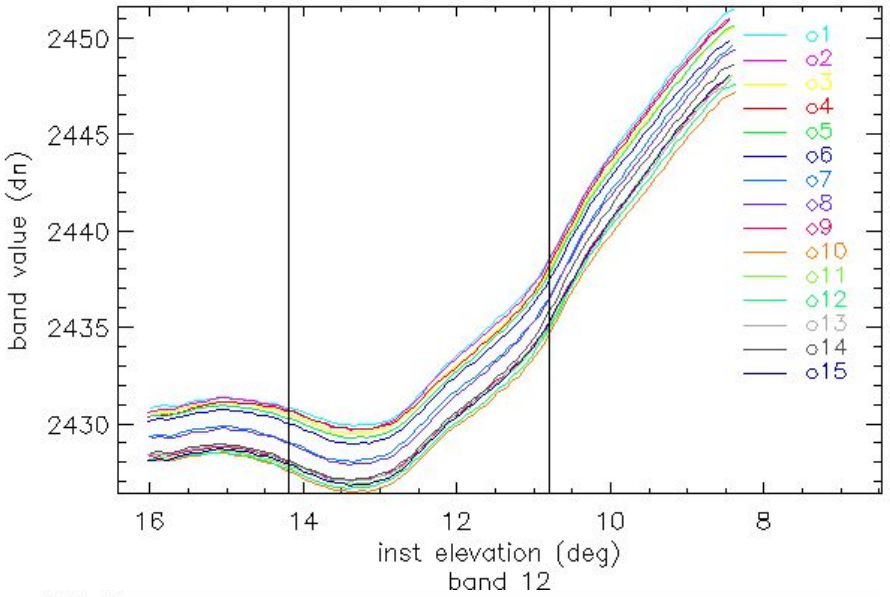


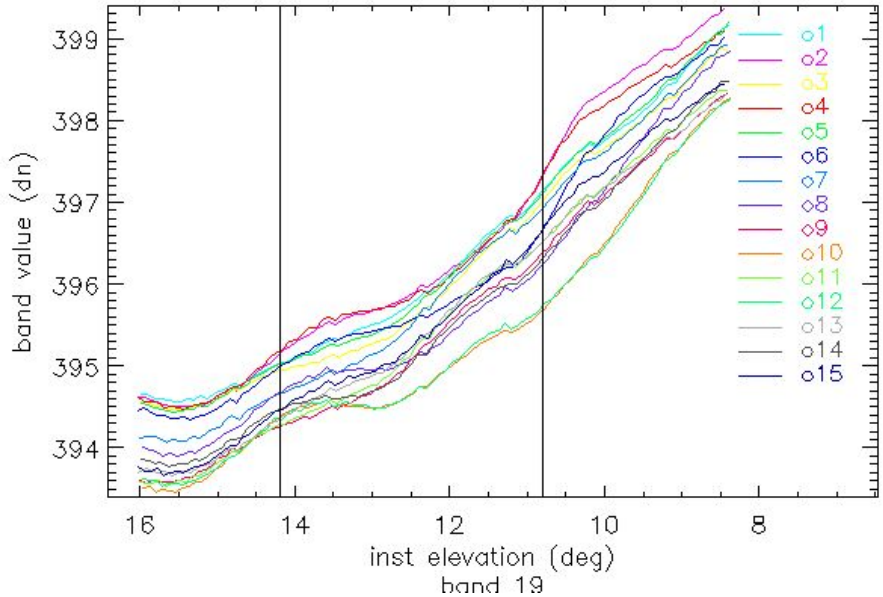
MODIS/Terra Stray Light Analysis

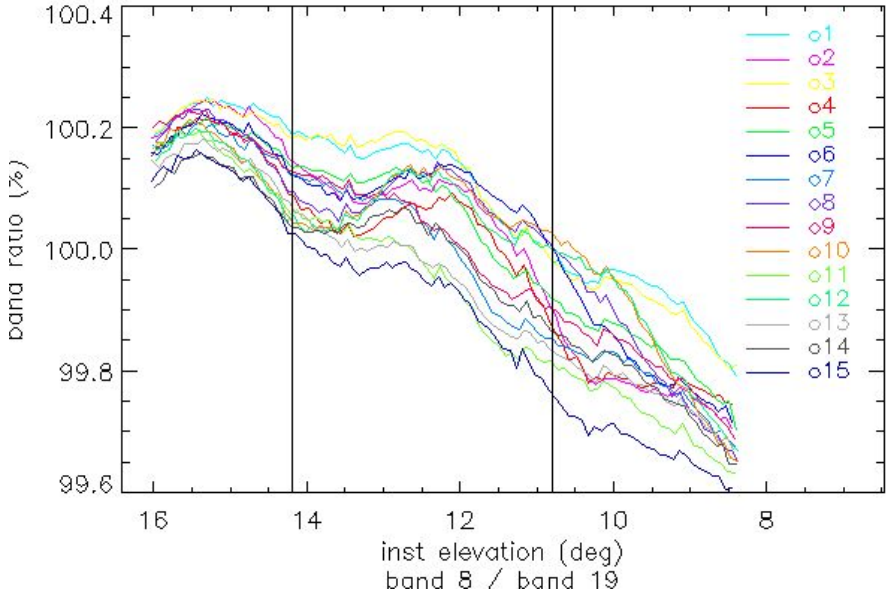
- Purpose: study effects of stray light (earth-shine) on MODIS Solar Diffuser (SD) results
- Analysis notes:
  - only non-saturated non-thermal bands shown
  - data is from 15 orbits starting with 2003/183.2010 – first data after SD door anomaly
  - background/bias (from space view) subtracted
  - all values are band averages for all SD samples in a scan
  - both mirror sides used – smoothing performed (3 scans, triangular weighting)
  - corrected for SD/sun cosine angle and SD BRF
  - additional smoothing performed in scan direction (21 scans, triangular weighting)
  - no temperature correction

MODIS/Terra SD Values for Selected Bands
2003/183.2010 (o1: first orbit) to 2003/184.1915 (o15: last orbit)

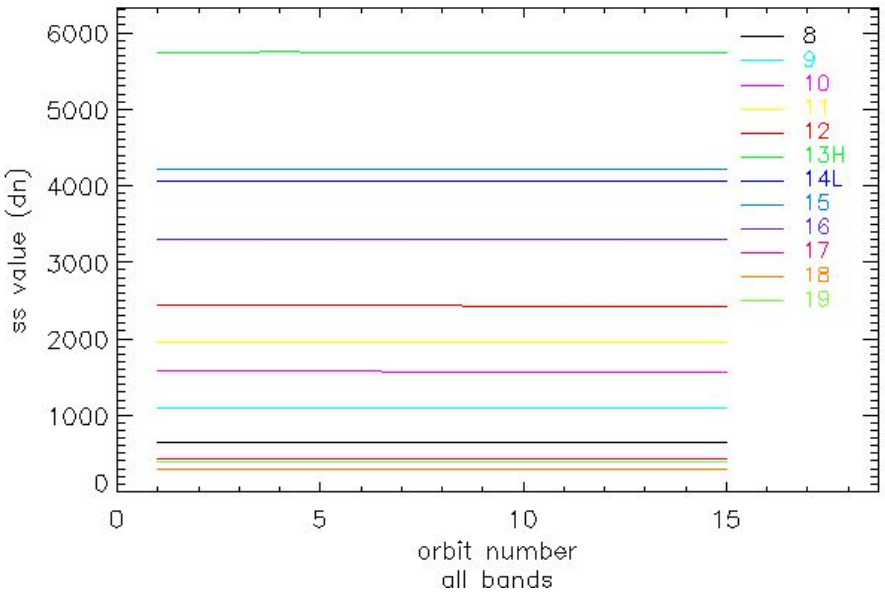


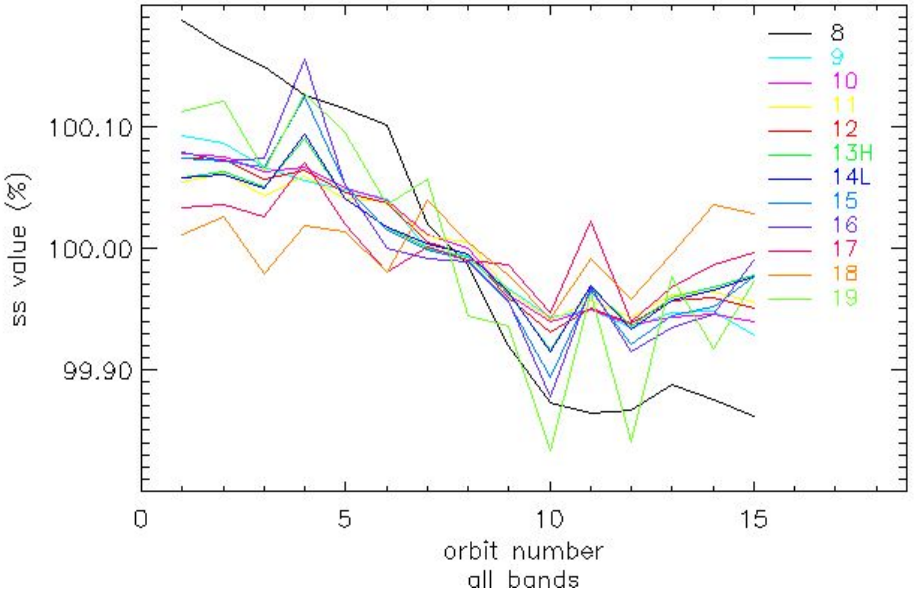


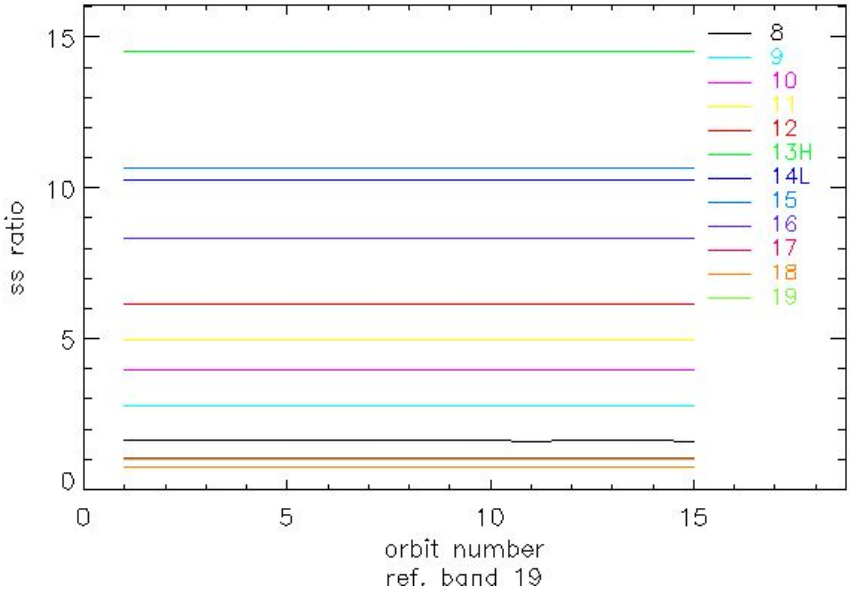


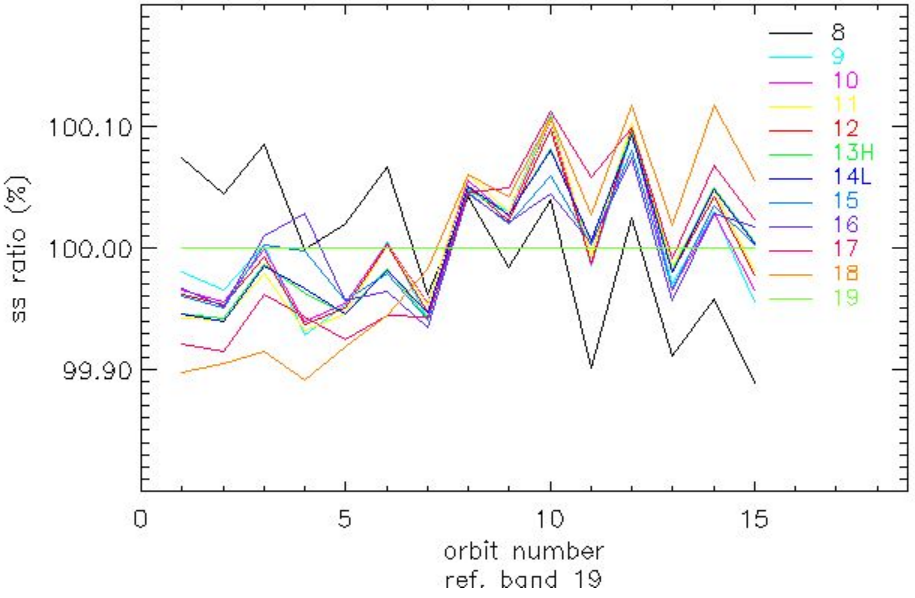


MODIS/Terra Sweet Spot Values and Ratios for Ocean Bands
2003/183.2010 (first orbit: 1) to 2003/184.1915 (last orbit: 15)









Sweet Spot Summary

- Earth shine features are visible
  - see bands 12 & 19
- Effect in sweet spot is small (during this one-day period)
  - at SD radiances +/- 0.2 %
  - largest effect is for band 8
- More analysis of stray light on SDSM needed

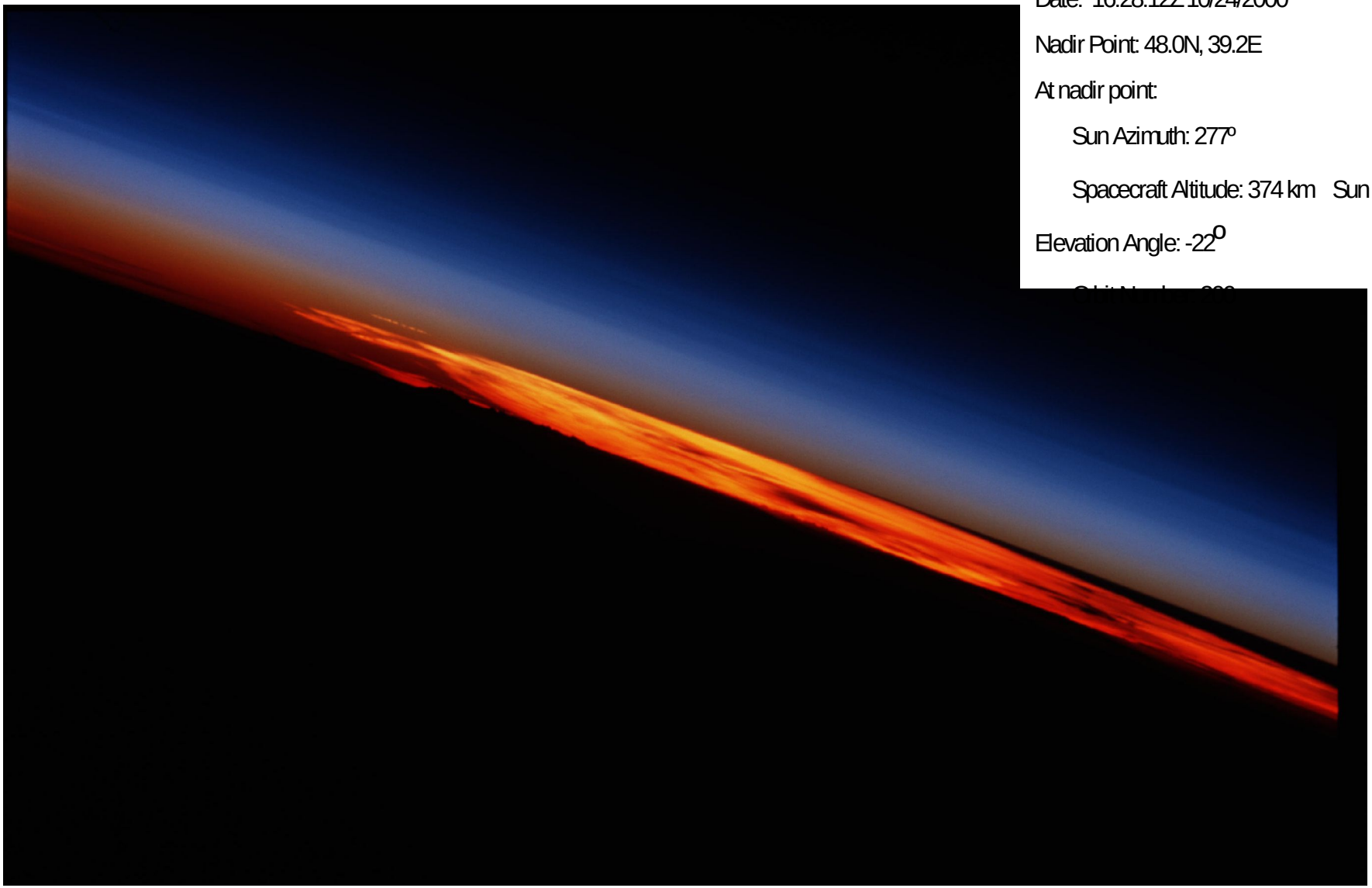


Image STS092-316-24

Date: 16:28:12Z 10/24/2000

Nadir Point: 48.0N, 39.2E

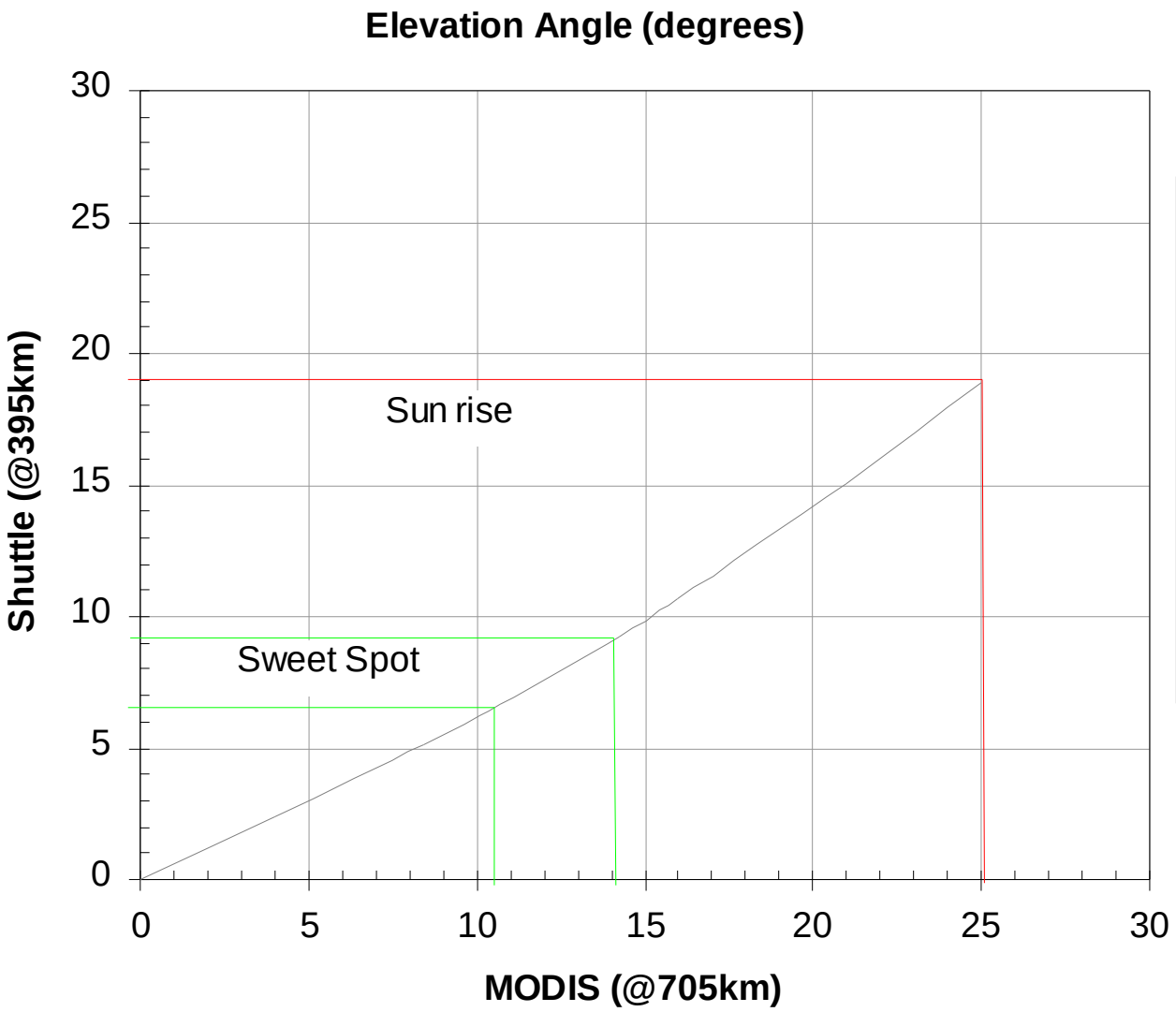
At nadir point:

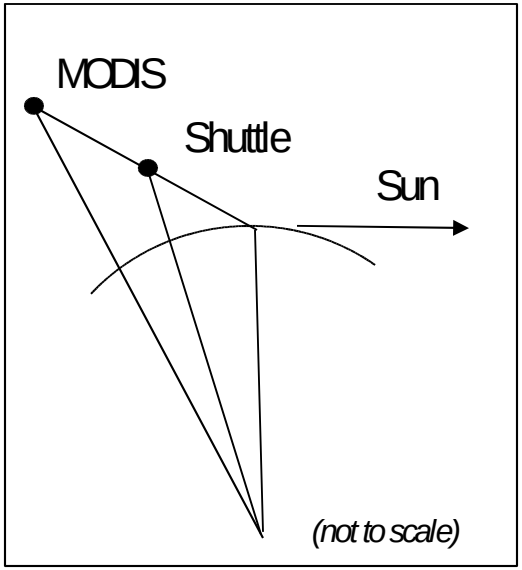
Sun Azimuth: 277º

Spacecraft Altitude: 374 km Sun Elevation Angle: -22º

Limb images courtesy of Earth Sciences and Image Analysis Laboratory,
NASA Johnson Space Center (http://eol.jsc.nasa.gov)

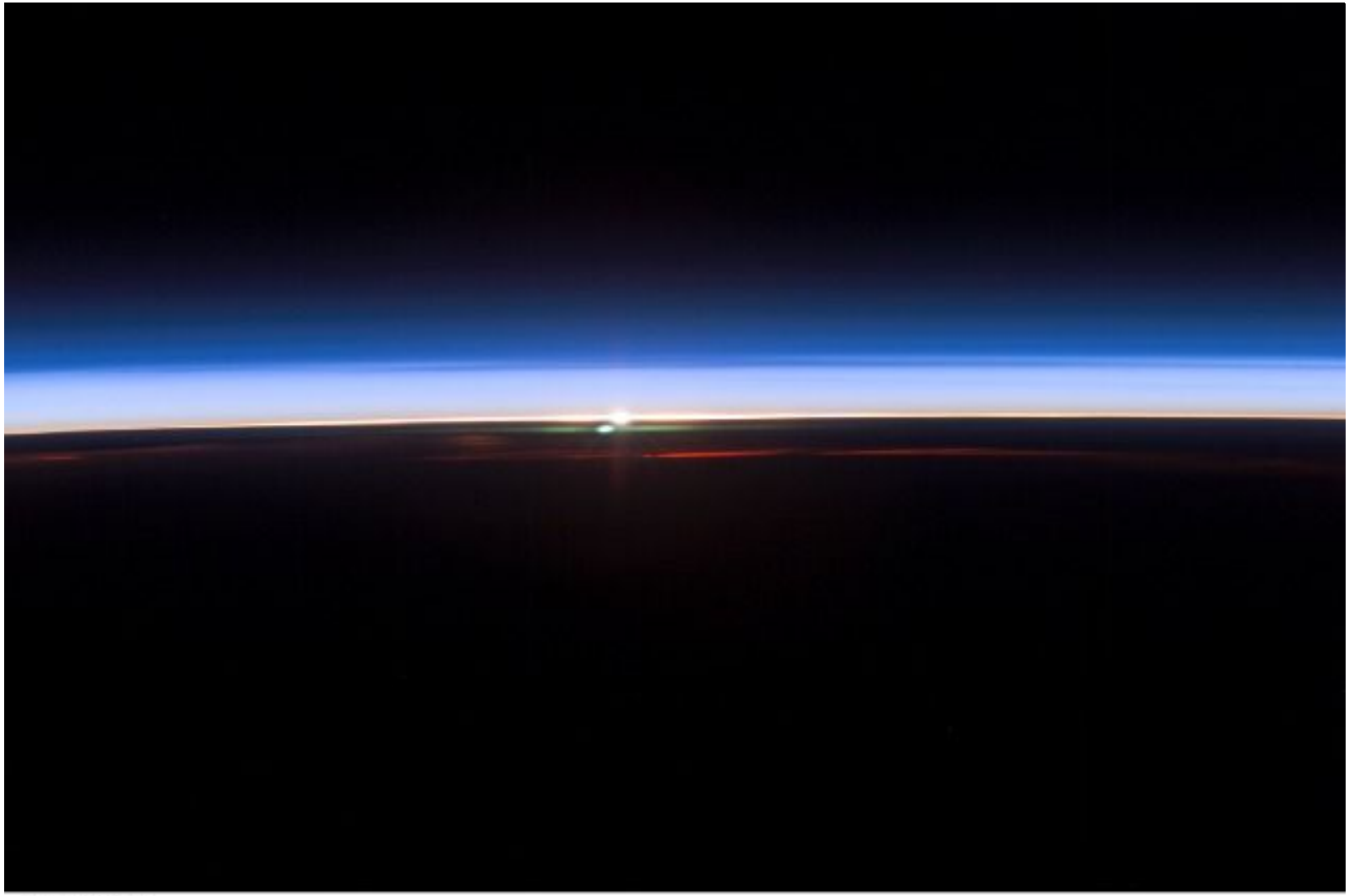
MODIS vs. Shuttle/Space Station Geometry





Frame 24 Time: 14:01:23Z Nadir Sun El: -08

Pacific Ocean 09/12/1995 STS069-725 398 km Alt.



Frame 17719 Time: 06:40:39Z Nadir Sun El: -20

Atmospheric Limb 10/20/2003 ISS007E 383 km Alt.

Frame 10805 Time: 10:17:01Z Nadir Sun El: -05

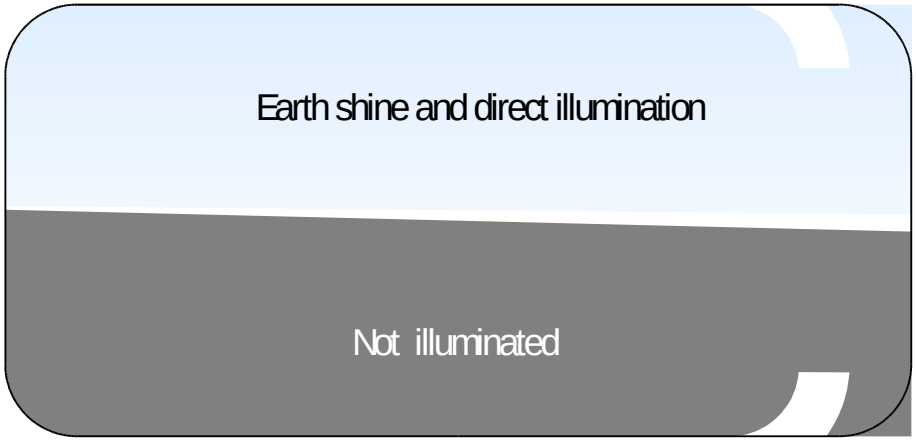
Pacific Ocean 07/21/2003 ISS007E 377 km Alt.

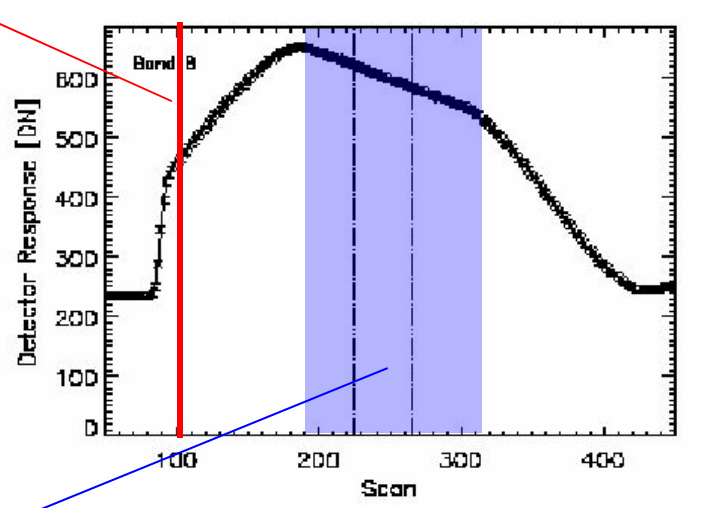
SD Spectral Response Asymmetry

- SD analysis for areas during partial illumination can be used to estimate degree of SD Earth-shine contamination
- Some detectors primarily see the top half of the SD (detectors 6-10) and others the bottom half
  (detectors 1-5)
- During ramp up from partial (50% or more) to full illumination, spectral differences in the ratio of the top half vs. bottom half (T/B) are partially due to Earth-shine contamination of the SD top half
- Other effects may include (expected to be small):
  - SD BRF
  - Non-linear gain
  - Residual bias
- Before analysis the following effects must be removed:
  - Sample times of different bands (because of focal plane location)
  - Individual detector gain differences
  - Band-to-band registration

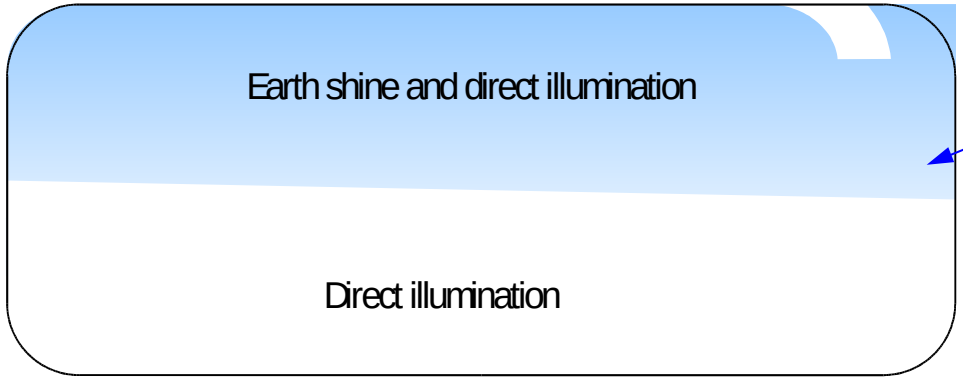
SD illumination

50% illumination



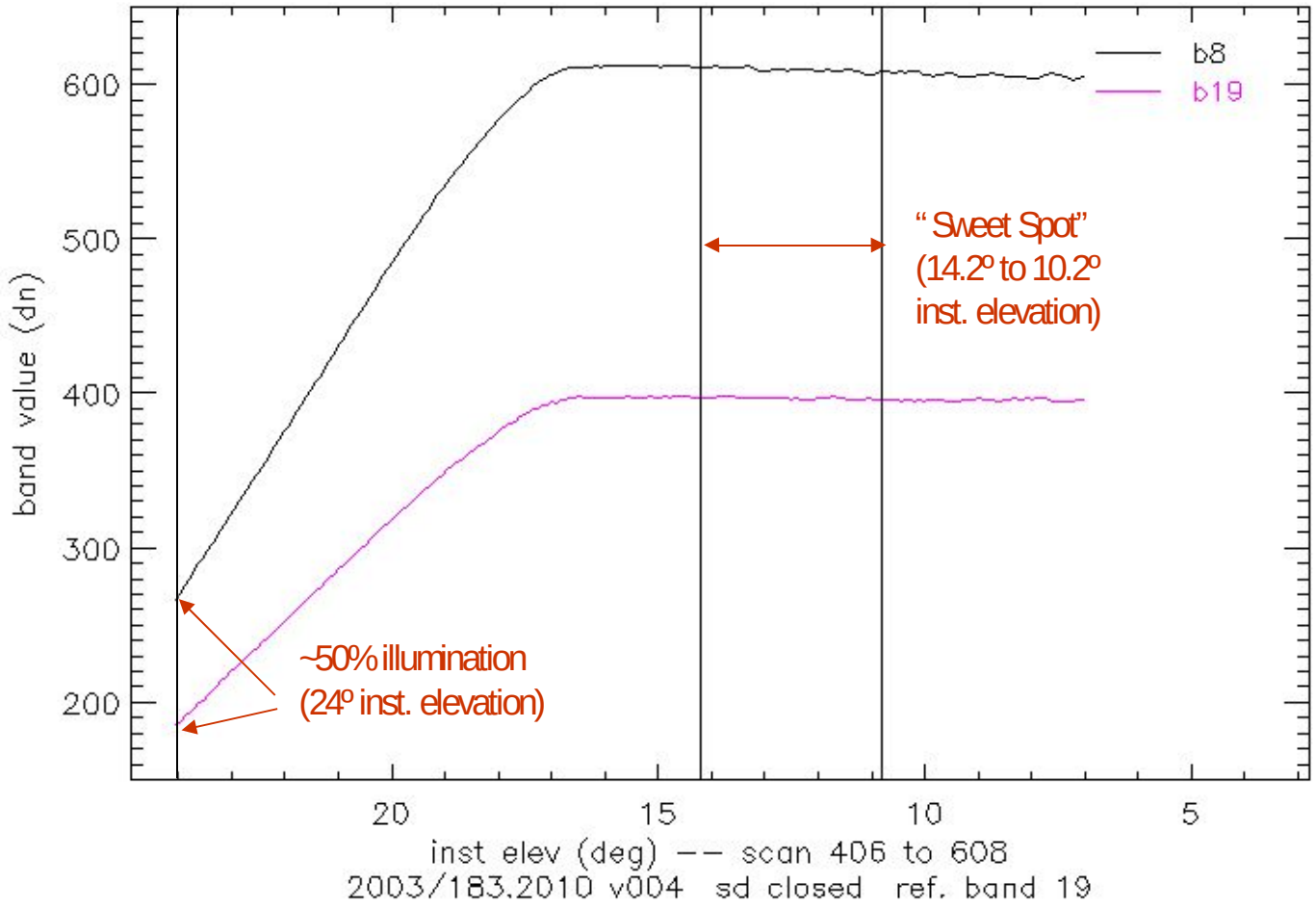


Full illumination



(notional)

SD response from partial to full illumination



Spectral Contamination

- Absolute contamination is not as important as the relative variation in the sweet spot. This latter effect is only +/- 0.2% (B8 over a single day)

$$L_{sd} = L_{sun} + L_{earth}$$

$$L_{sd}(t) = L_{sd} + ?L_{sd}(t) = L_{sun} + L_{earth} + ?L_{earth}(t)$$

$$L_{earth} = -1.5\% L_{sun} \quad \text{(for B8)}$$

$$?L_{earth}(t) = +/- 0.2\% L_{sun} \quad \text{(for B8 – one day)}$$

Simulation of Sun-glint at High Solar Zenith

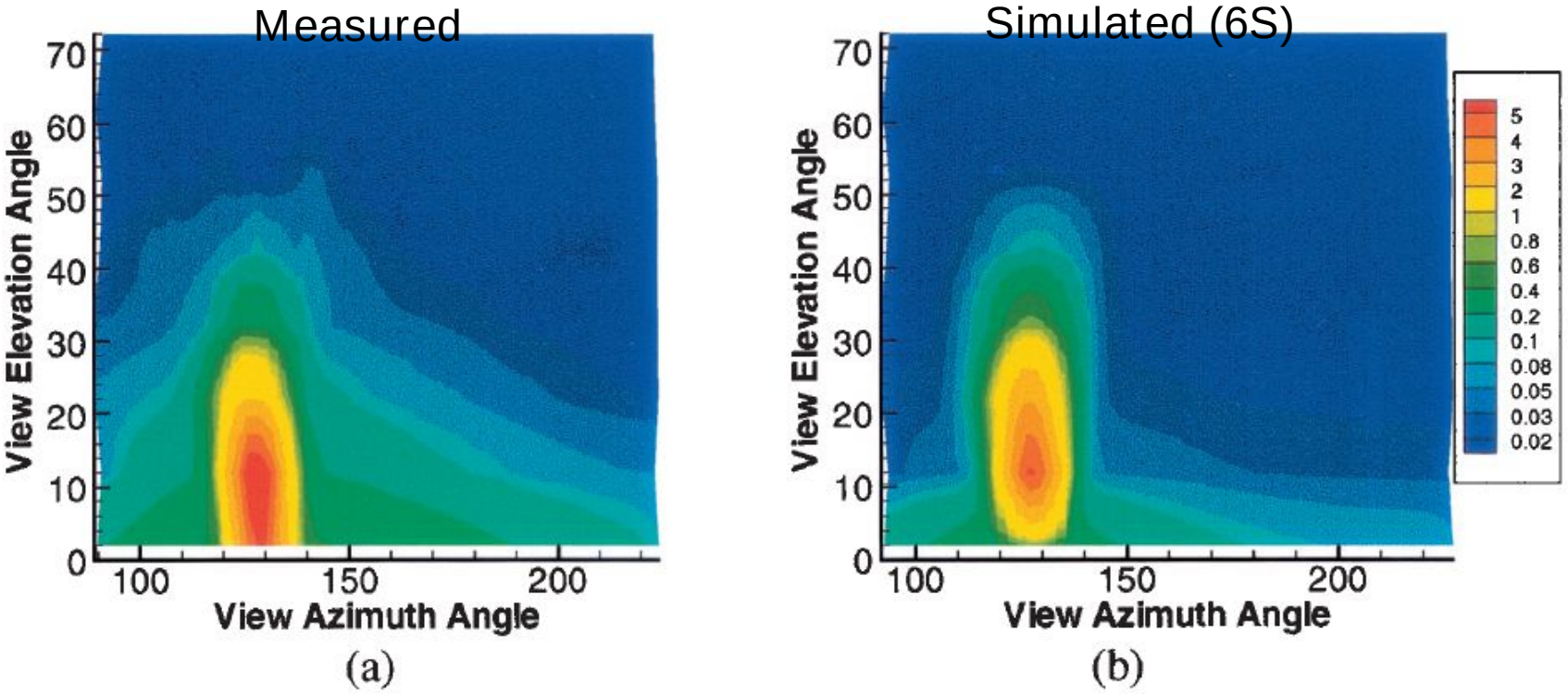


Fig. 5. (a) Measured and (b) simulated reflectances for Jan. 6 at 08 LST. SZA is 83.1. Wind speed is 5.8 m/s and wind direction is 251.4. AOD is 0.056.

sunglint from a coastal ocean platform

Wenying Su, Thomas P. Charlock, and Ken Rutledge

10 December 2002 / Vol. 41, No. 35 / APPLIED OPTICS 7369

Next Steps

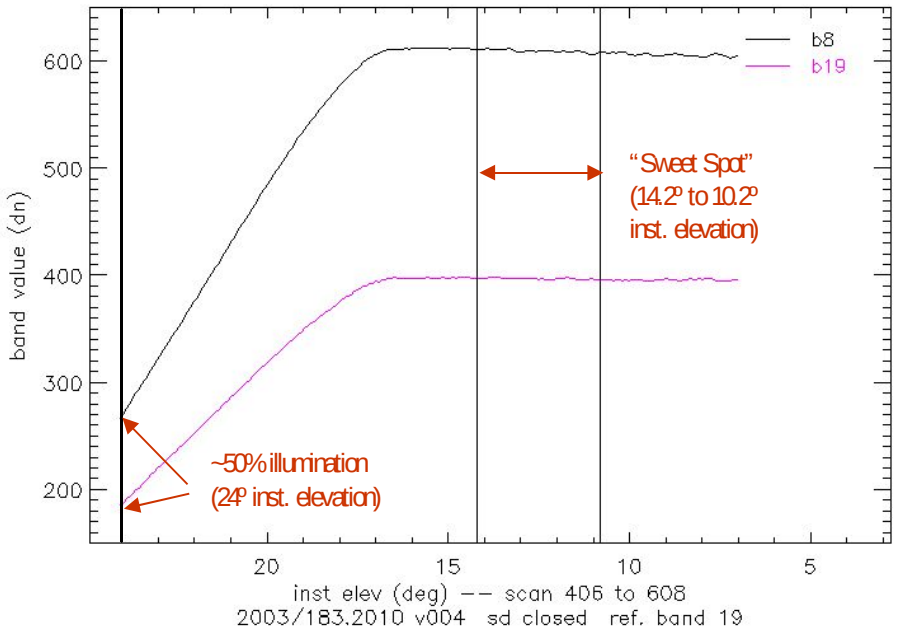
- Better understand spectral dependence by simulation of various surface components (snow, vegetation, water) and atmospheric components (aerosols, clouds, water vapor)
- Better understand individual detector's view of SD
- Better understand Earth-shine contribution to SDSM measurements
  - what is the Earth-shine contribution (if any)?
  - what is the SDSM response to non-uniform SD – which part of the SD does the SDSM see?
- Better understand the variability of the SD measurements since SD door fixed open
- Understand impact on NPP/VIIRS – very similar solar diffuser geometry

Backup Slides

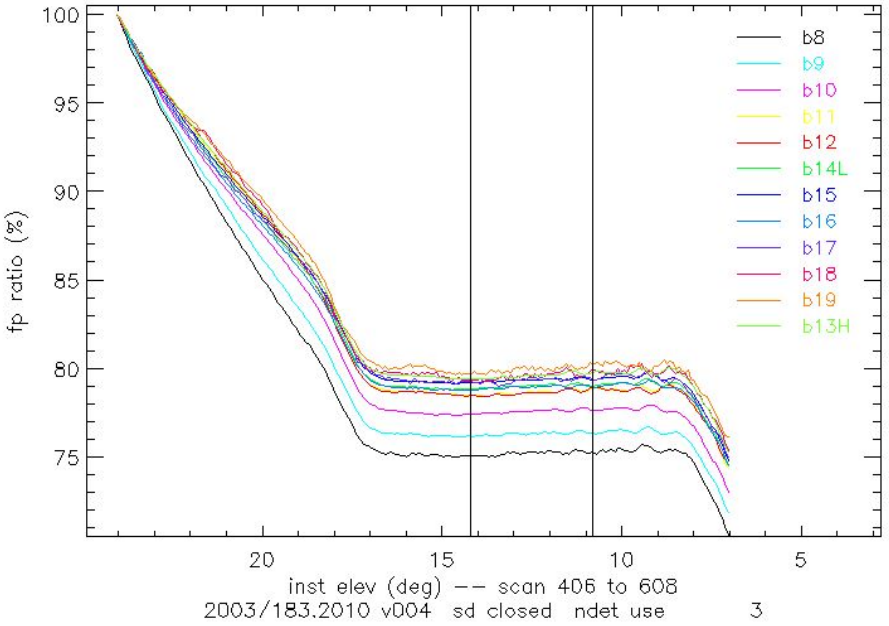
SD Spectral Response Asymmetry – Preliminary Analysis

- Caveats – data not corrected for:
  - Individual detector gains
  - Band-to-band offsets
  - Sampling time
- These results do not agree with individual detector m1's (computed in the sweet spot)

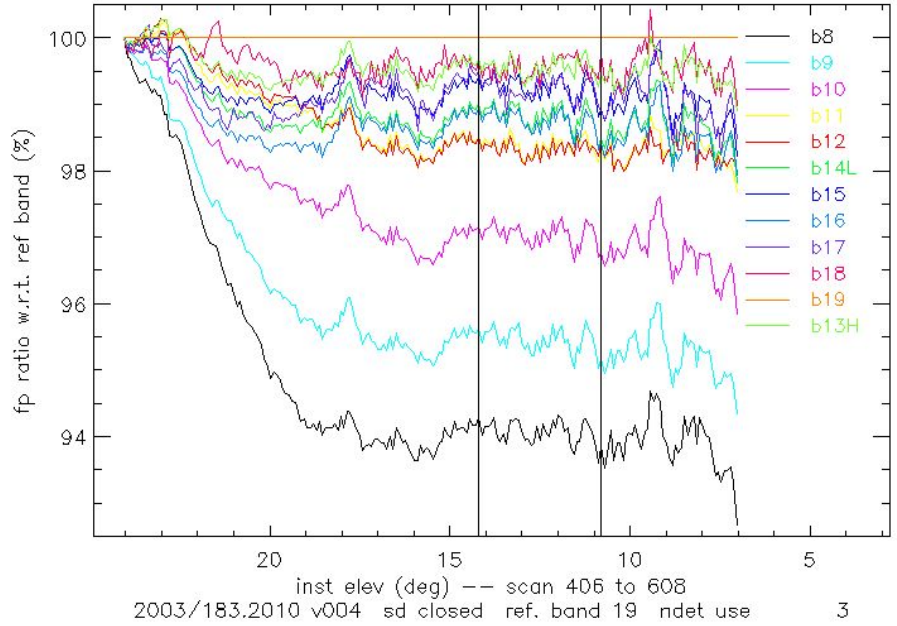
SD Response during from partial (~50%) to full illumination



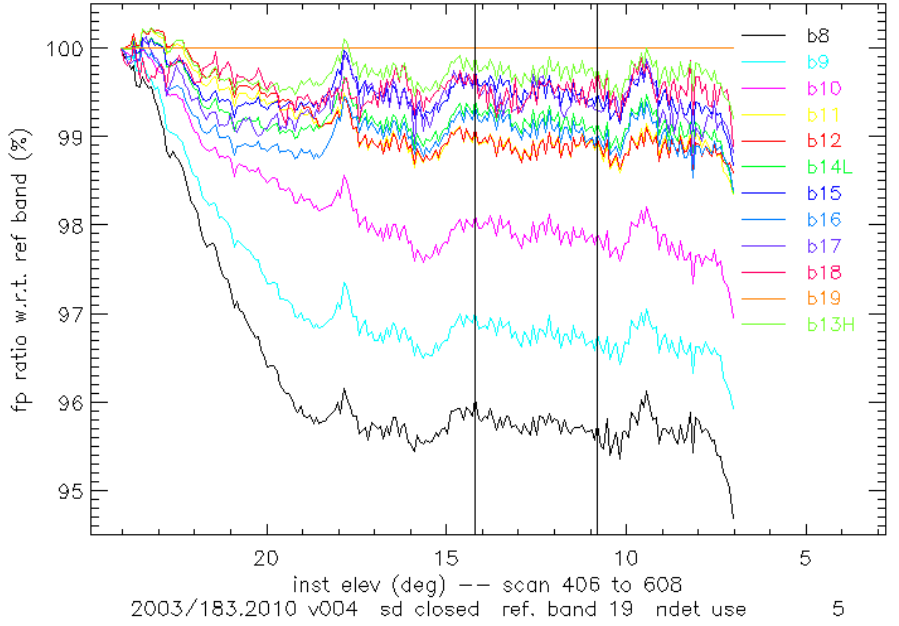
Top vs. Bot (T/B) ratio (3 detectors)



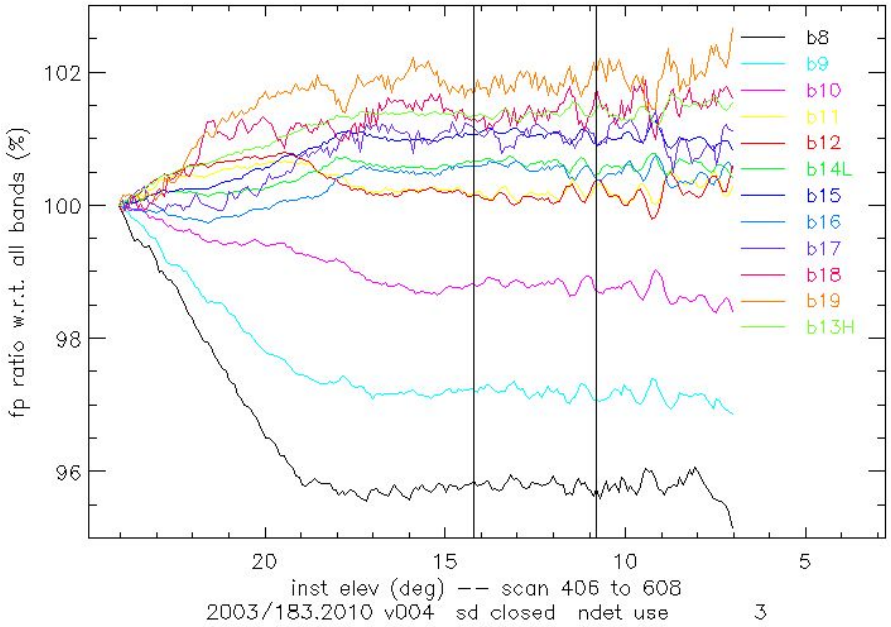
T/B ratio w.r.t. Band 19 (3 detectors)



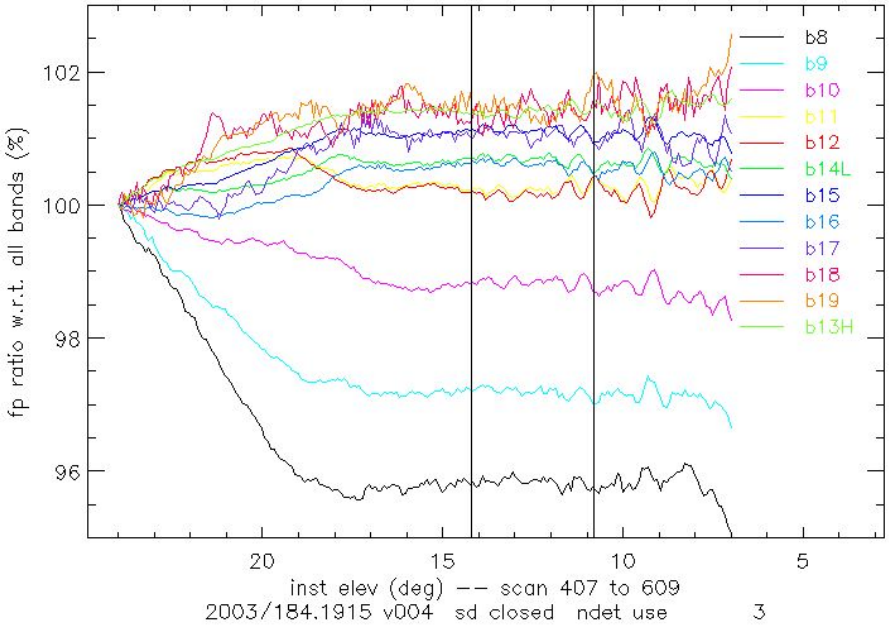
T/B ratio w.r.t. Band 19 (5 detectors)



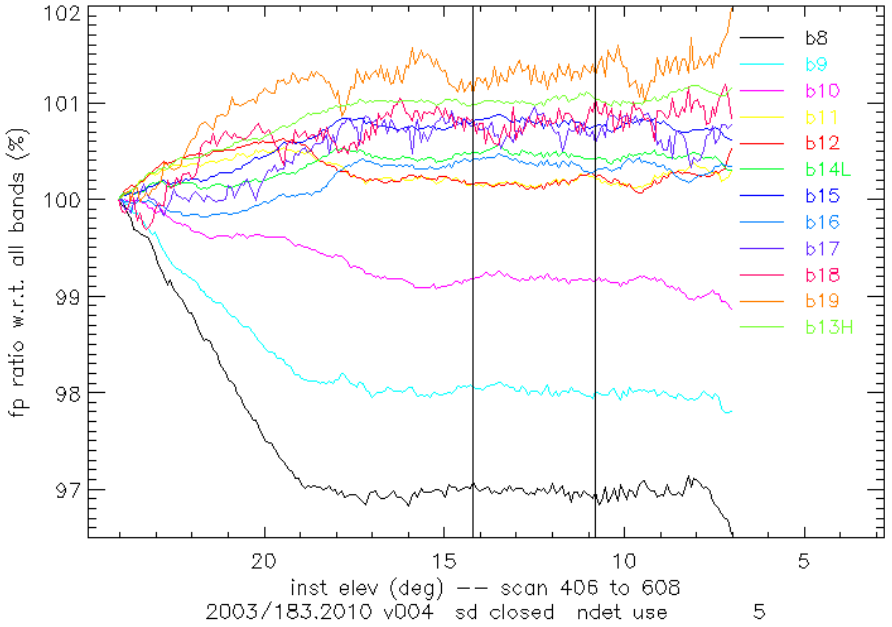
T/B ratio w.r.t. all bands (3 detectors) – day 183



T/B ratio w.r.t. all bands (3 detectors) – day 184



T/B ratio w.r.t. all bands (5 detectors) – day 183



T/B ratio w.r.t. all bands (5 detectors) – day 184