GSICS Applications and the Need of a Solar Irradiance Reference Spectrum

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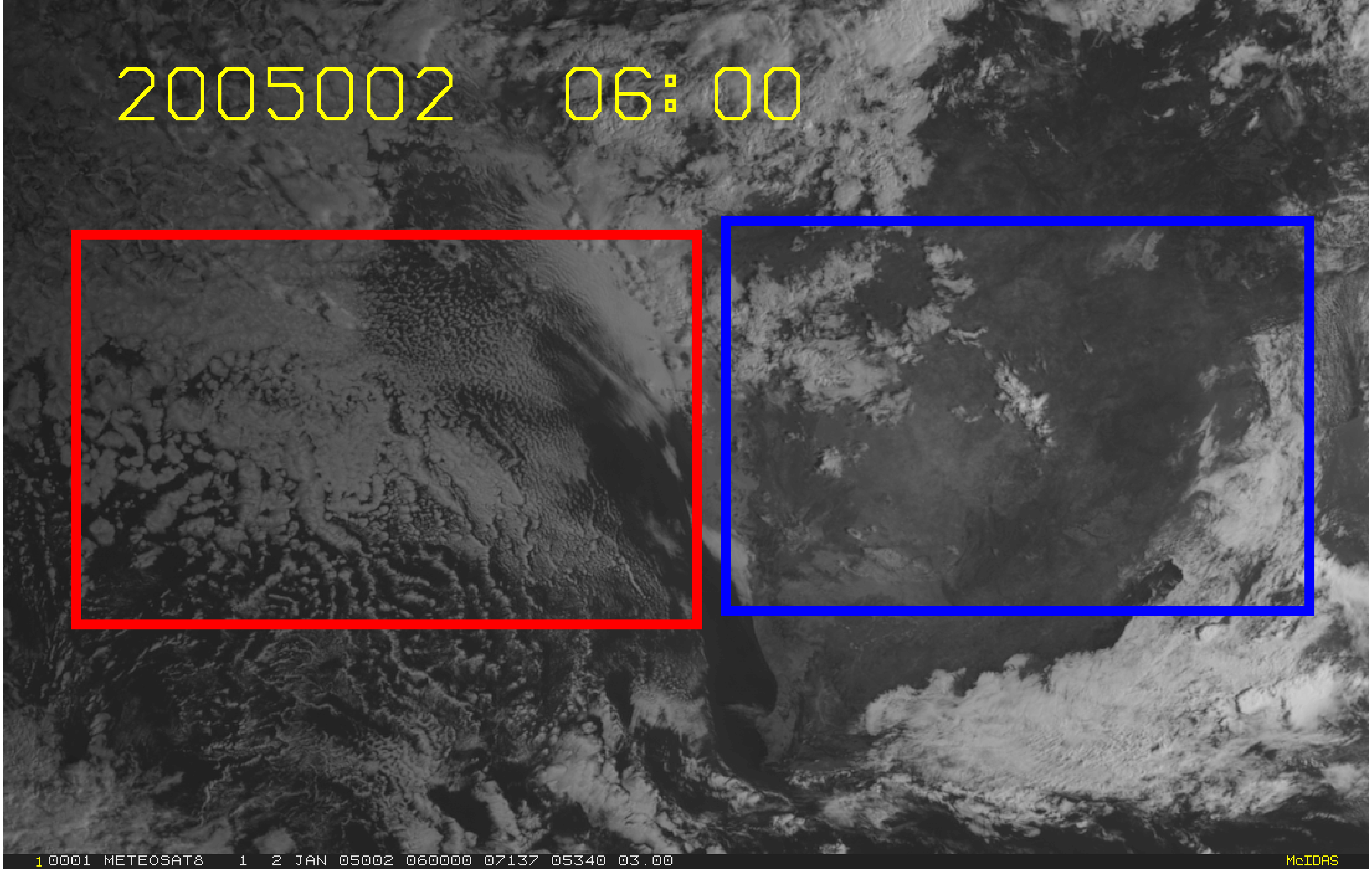
CERES Introduction

- CERES instruments are onboard the Terra (10:30 AM local equator crossing time), Aqua (1:30 PM), NPP (1:30 PM), and NOAA20 (1:30 PM) platform
- The CERES SW and LW broadband footprint radiances are converted to fluxes using the empirical CERES ADMs based on scene types based on MODIS imager cloud properties and GMAO MERRA atmosphere
- The instantaneous CERES 20-km nominal footprint fluxes are averaged in 1° by 1° regions
- The regional diurnal flux in between the Terra and/or Aqua CERES measurements need to be estimated to derive accurate daily flux means
- The daily regional fluxes are then temporally averaged monthly into CERES level 3 products
- The TOA monthly regional/global flux means are then used to monitor the Earth's radiation budget over time
- The CERES products can be subsetted, visualized and ordered here https://ceres.larc.nasa.gov/

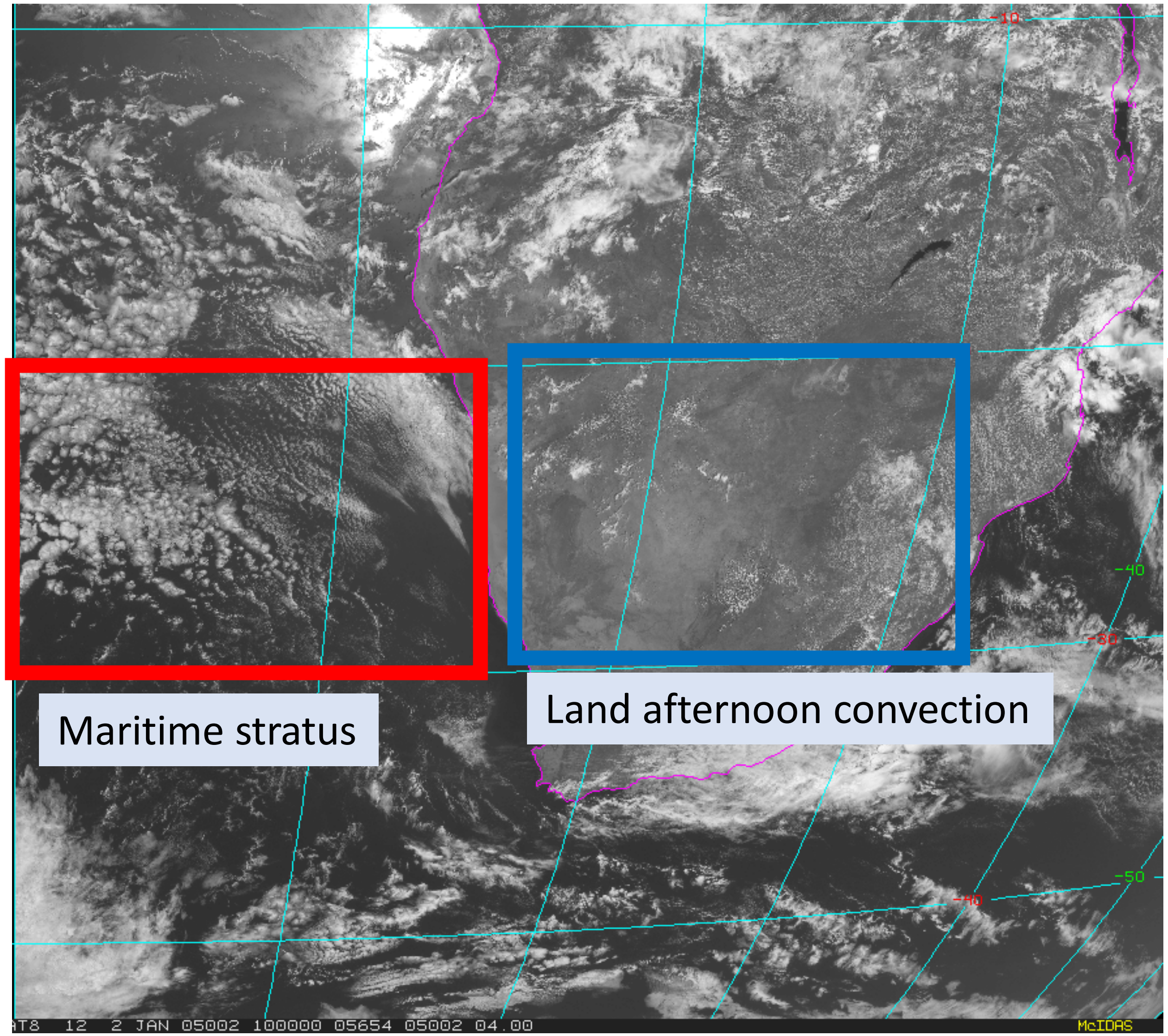
CERES Level 3 Products

- SSF1deg (CERES-only), SW fluxes assume constant daytime cloud conditions and LW fluxes assume linear changing meteorology between CERES measurements to model the diurnal cycle
  - Single satellite products
- SYN1deg, uses geostationary (GEO) derived broadband fluxes between CERES observations to model the diurnal cycle
  - Terra+Aqua+GEO(5 satellite) product
  - The instantaneous GEO fluxes are carefully normalized to the CERES flux
- EBAF, combines the stability of the SSF1deg product and the accuracy of the regional mean daily fluxes of the SYN1deg product
  - The TOA net flux is constrained to the ocean heat storage
  - The clear-sky fluxes are spatially complete, by computing sub-footprint clear-sky fluxes based on the MODIS pixel radiances.
  - The clear-sky flux now available for both the cloud free observed portion of region and for total (cloud removed) region

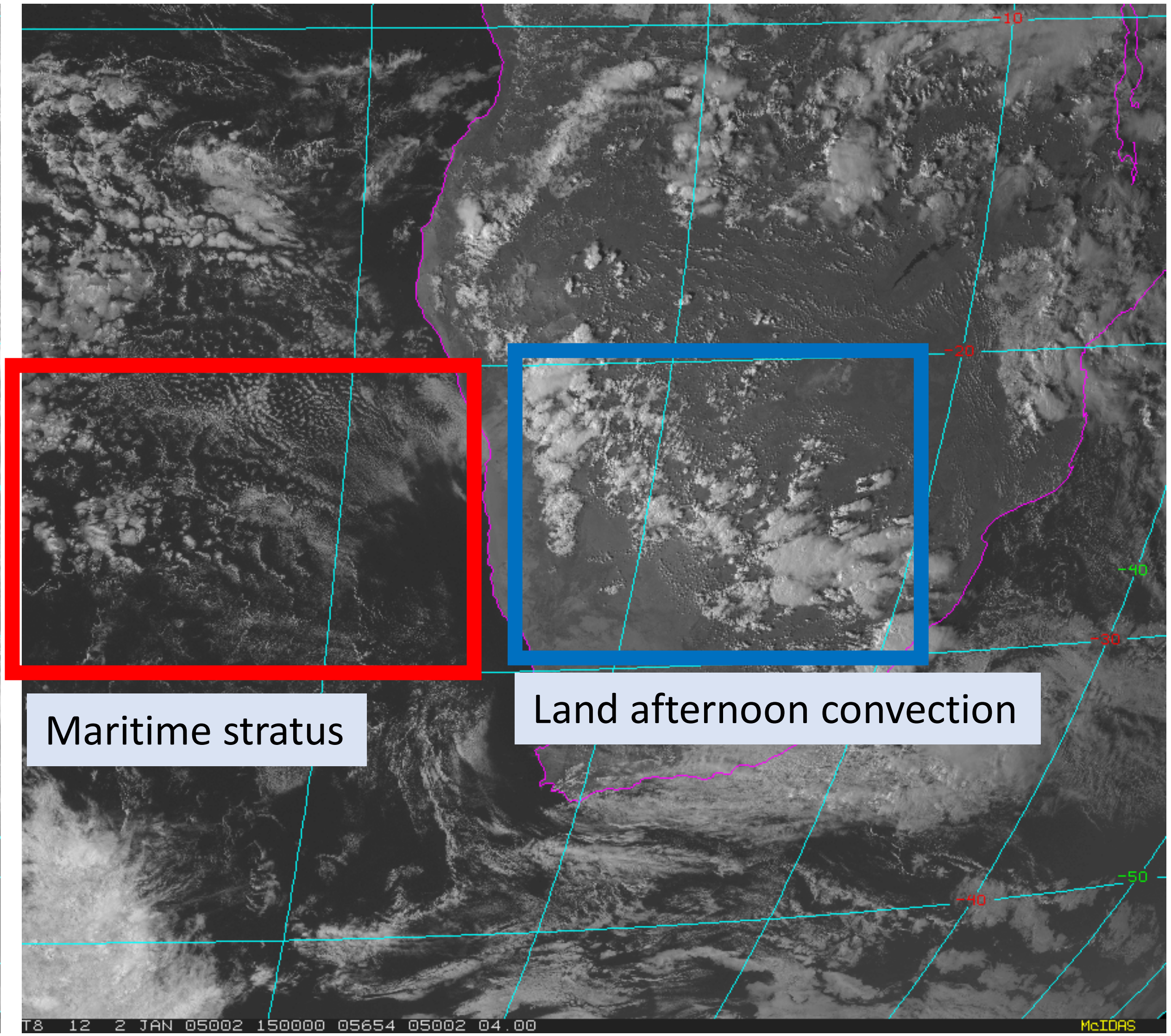


2005002 06:00
1 0001 METEOSAT8 1 2 JAN 05002 060000 07137 05340 03.00
McIDAS

Terra (10:30 AM) Overpass time



Aqua (1:30 PM) Overpass time

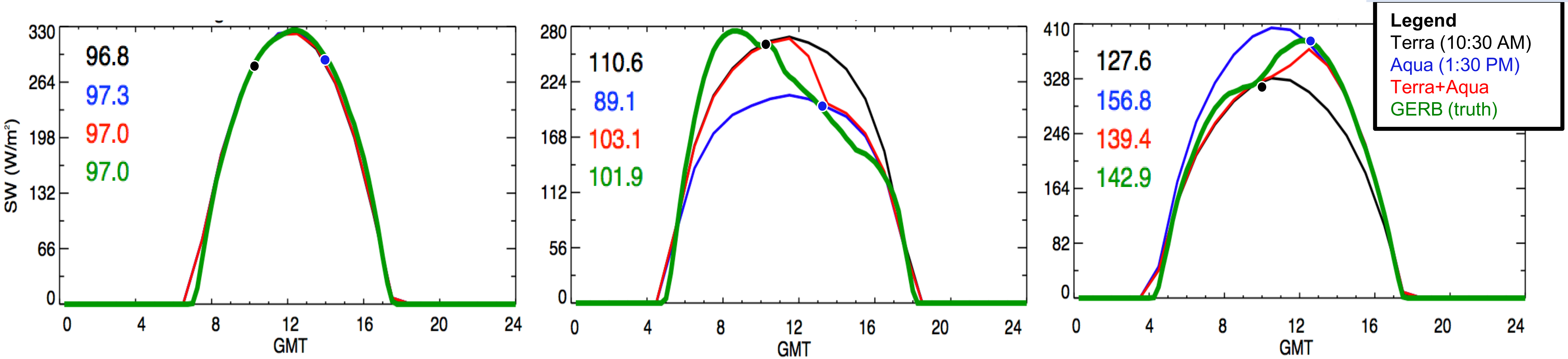


(SSF1deg) CERES-only TOA SW fluxes

- SW: assume the observed clouds are constant over the day and accounting only for changes in the sun position using a solar zenith angle dependent albedo models based on scene type

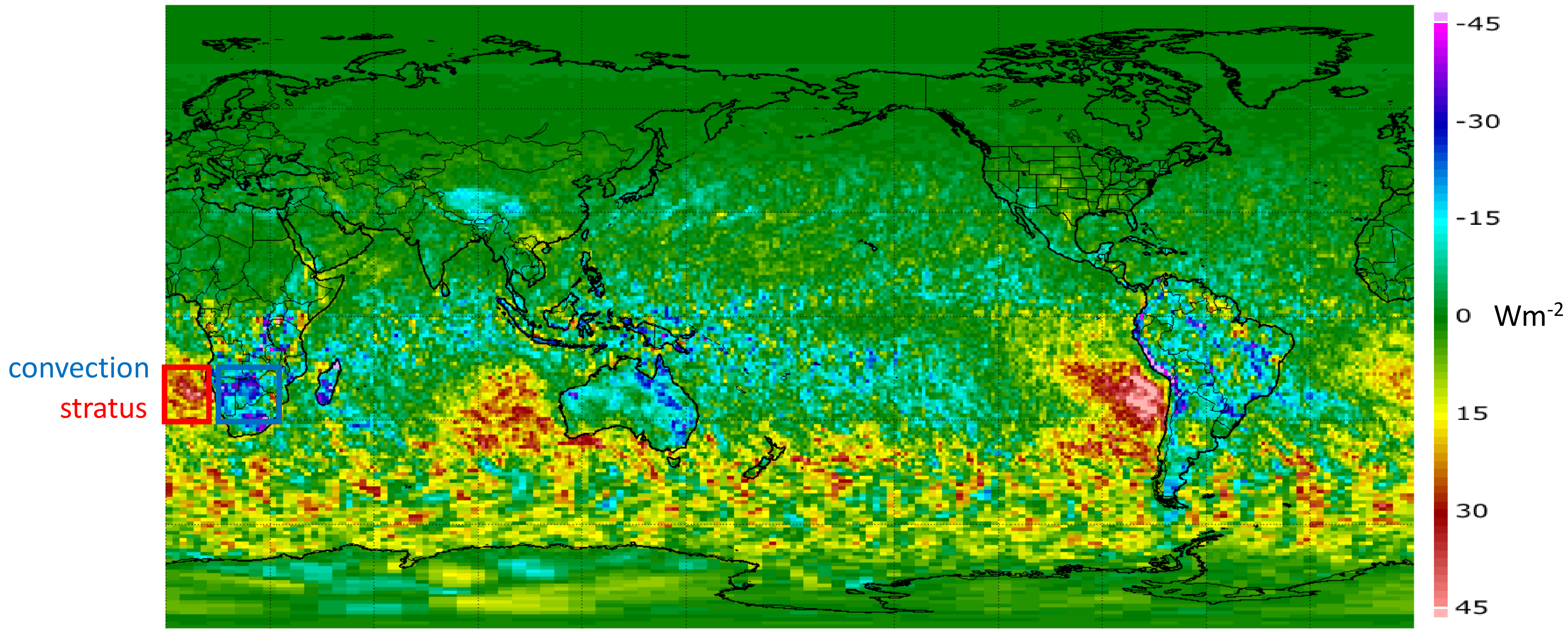
Monthly mean SW fluxes (Wm^{-2}) for January 2005

Algeria　　Namibian Stratus　　Zambia



• The clear-sky desert monthly mean SW fluxes over deserts are symmetric about noon and all datasets capture the diurnal cycle
• The stratus and land convection monthly mean SW fluxes will be biased as a function of satellite sampling time

Terra – Aqua CERES-only SW flux, January 2005

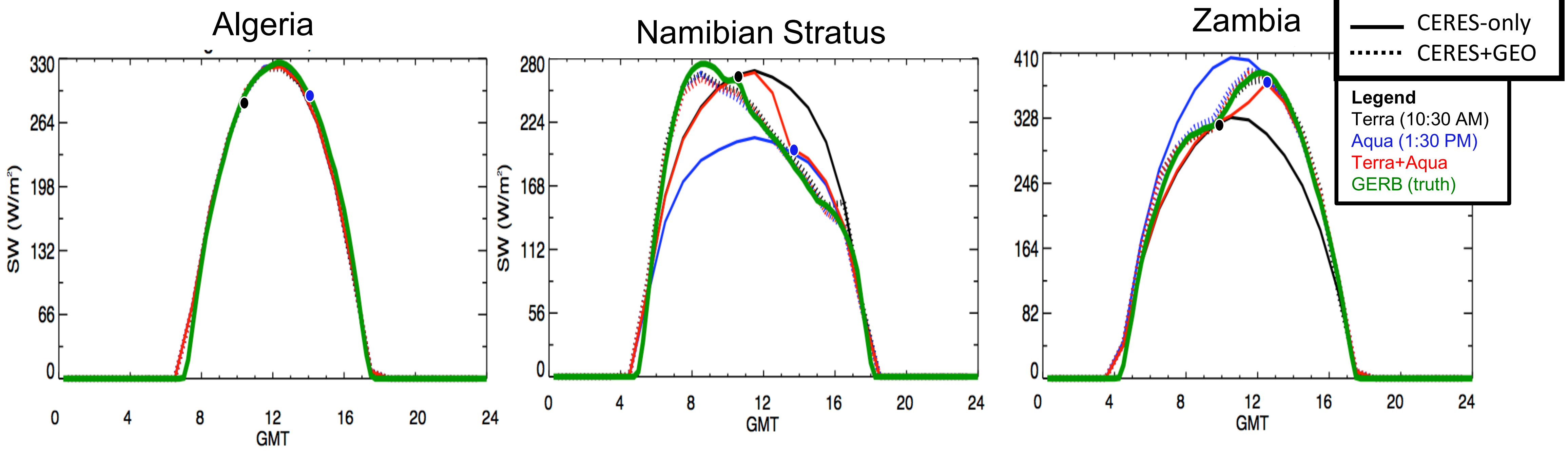


- The regional SSF1deg-Terra (10:30 AM) minus SSF1deg-Aqua (1:30 PM) monthly mean SW flux biases can exceed 25 Wm^{-2} for regions with strong diurnal cycles
- The January 2005 Terra and Aqua global mean SW flux is103.2 Wm^{-2} and 101.5 Wm^{-2}, respectively

(SYN1deg) CERES+GEO TOA SW fluxes

- The hourly GEO derived broadband fluxes are anchored or normalized onto the Terra and Aqua CERES measurements

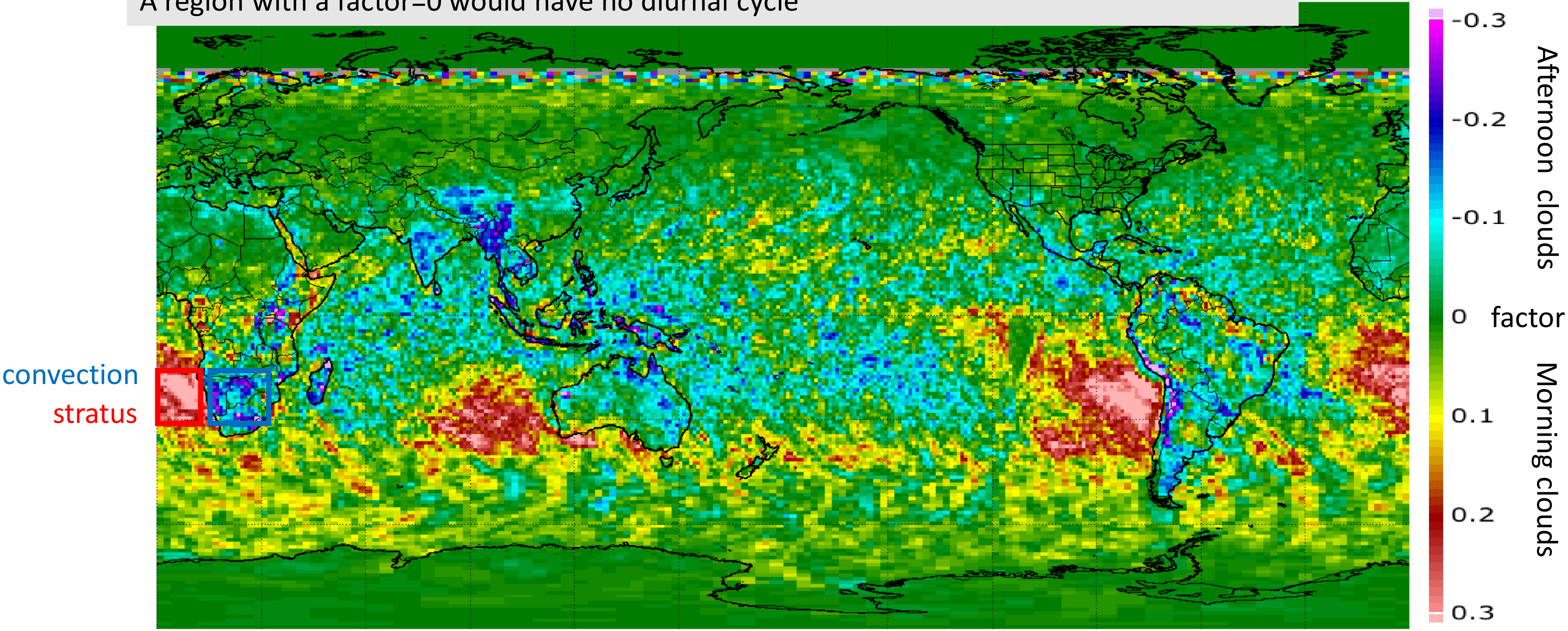
Monthly mean SW fluxes (Wm^{-2}) for January 2005



- The 1-hourly SW CERES+GEO derived BB fluxes replicate the GERB fluxes more accurately than CERES-only single satellite SSF1deg fluxes
- The combined Terra and Aqua fluxes are also close to GERB

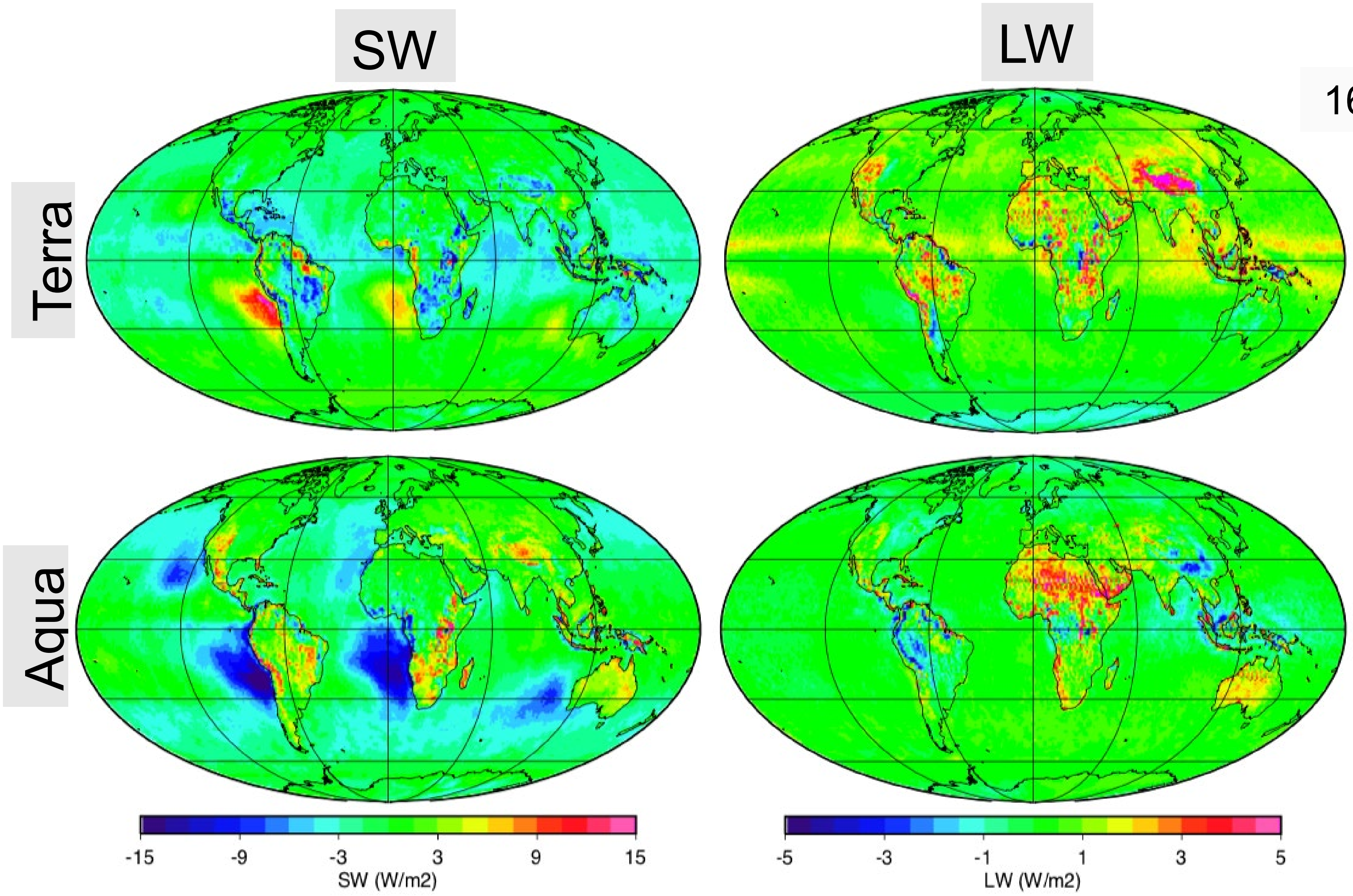
CERES+GEO, Morning - Afternoon SW flux factor, January 2005

factor = morning flux minus afternoon flux divided by total flux based on Terra+Aqua+GEO.
A region with a factor=0 would have no diurnal cycle



- The (SYN1deg) CERES+GEO can easily identify the regions with strong diurnal cycles

CERES-Only (SSF1deg) minus CERES+GEO (SYN1deg) fluxes



16-year global means (July 2002-June 2018)

Wm^{-2}	SSF-Terra (10:30)	SSF-Aqua (1:30)	SYN-Terra/Aqua/GEO
SW	96.30	96.12	97.24
LW	239.31	238.87	238.66
Net	4.42	5.03	4.13

- 16-year regional differences can be as large as 25 and 8 Wm^{-2} in the SW and LW respectively
- However, accounting for the regional diurnal flux increases the global SW flux 1.1 Wm^{-2}, neither Terra or Aqua capture the complete maritime stratus or land convection diurnal cycle
- The SSF-Aqua global mean LW is within 0.2 Wm^{-2}. Land afternoon convection peaks at 18 PM.

Global Space-based Inter-Calibration System

What is GSICS?

- Global Space-based Inter-Calibration System
- Initiative of CGMS and WMO
- Effort to produce consistent, well-calibrated data from the international constellation of Earth Observing satellites

What are the basic strategies of GSICS?

- Improve on-orbit calibration by developing an integrated inter-comparison system
  - Initially for GEO-LEO Inter-satellite calibration
  - Being extended to LEO-LEO
- Best practices for calibration & characterisation

This will allow us to:

- Improve consistency between instruments
  - Towards Interoperability
- Reduce bias in Level 1 and 2 products
- Support Cal/Val of new instruments
- Provide traceability of measurements
- Retrospectively re-calibrate archive data
- Better specify future instruments

Background

- New generation LEO and GEO imagers use onboard solar diffusers for inflight radiometric calibration
- Solar diffusers provide a stable reflectance source for converting satellite measured counts to calibrated reflectance
- Accurate conversion of reflectance to radiance requires precise knowledge of incoming solar irradiance values within a channel's bandwidth.
- Inconsistency between solar irradiance models (**Thuillier**, **Kurucz**, **Neckel and Labs,** etc) used by different satellite operators induce additional channel-specific biases in their L1B radiance products

L1B products

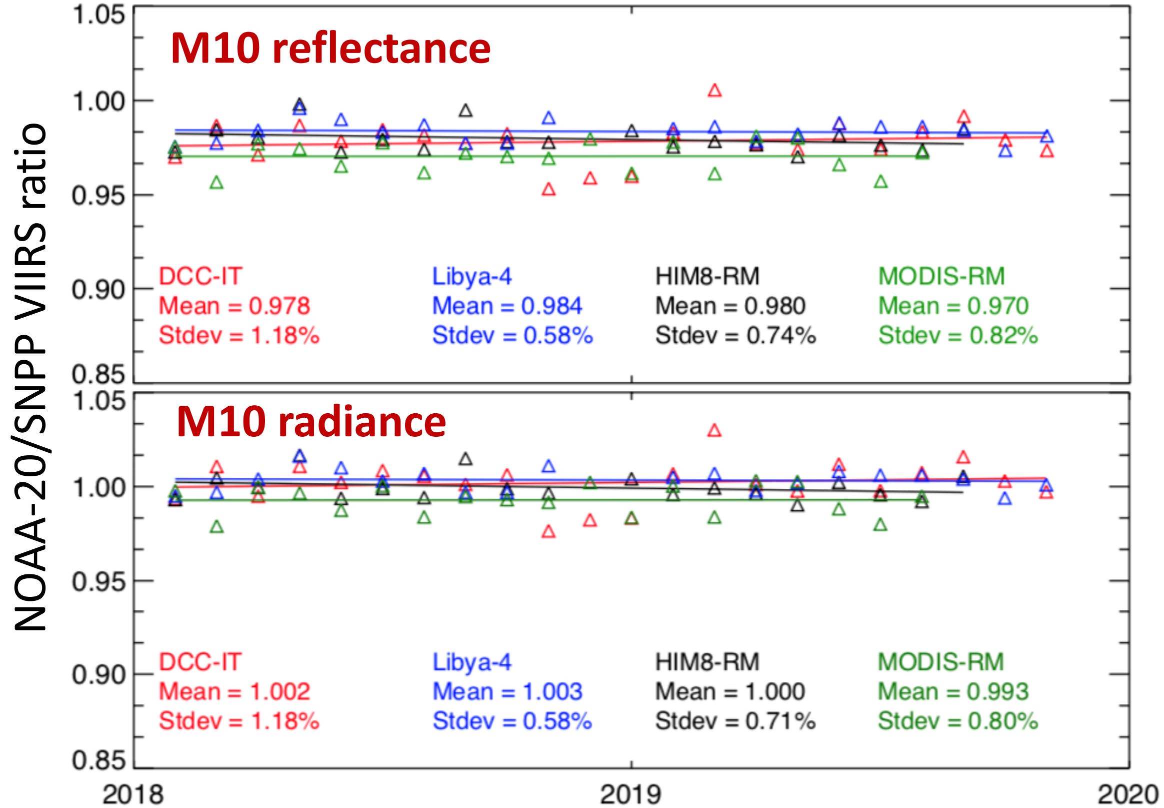
- The L1B product solar spectra are used to convert reflectance to radiance is not easily found or documented
- For example, various solar spectra used for MODIS and VIIRS
  - MODIS-MCST (Thuillier, Neckel and Labs, and Smith and Gottlieb for parts of the solar spectra)
  - NPP-VIIRS MODTRAN (Kurucz)
  - NOAA-20-VIIRS Thuillier
- For sensors with no onboard visible calibration reference (most GEOs), the observed radiance needs to be converted to reflectance using a solar spectra

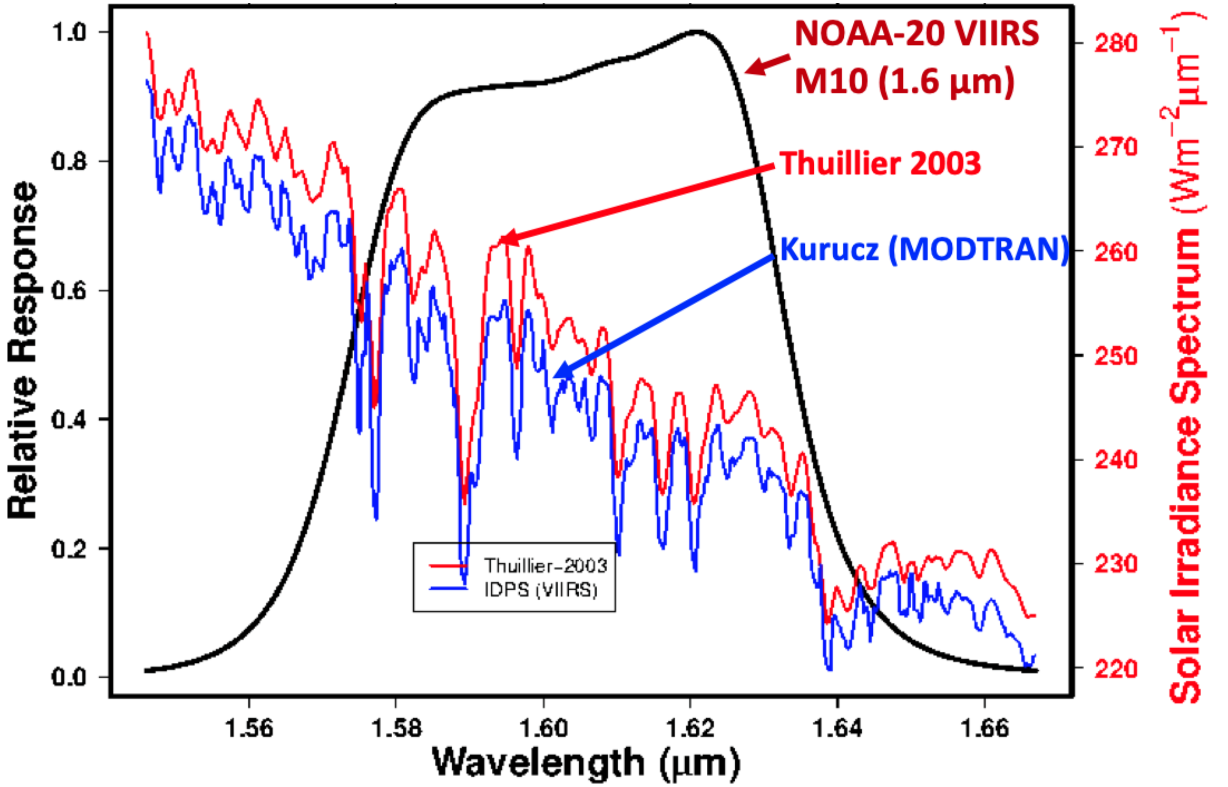
Motivation

- The GSICS and CEOS communities would like a recommended solar spectra for
  - A standard solar spectra to convert reflectances (based on solar diffuser) to radiances for publicly available L1B product
  - A standard solar spectra for to convert radiances (non solar diffuser) sensor to reflectances
  - A standard spectra for use in accounting for spectral band differences between sensors. This is especially important for the more broad spectral response functions found on many older satellite sensors
  - A standard spectra for use in characterizing Moon and Earth targets, such as deserts, deep convective clouds, polar ice (Dome-C). This is to establish the target absolute reflectance as a function of wavelength for these invariant targets

Case study 1: VIIRS inter-comparison

- Two VIIRS instruments onboard SNPP and NOAA-20 VIIRS use different solar irradiance models
- Radiometric biases between the two VIIRS instruments should be assessed independently for their L1B radiance and reflectance products
- For example, M10 (1.6 µm) channel radiance and reflectance biases can be off by ~2%.



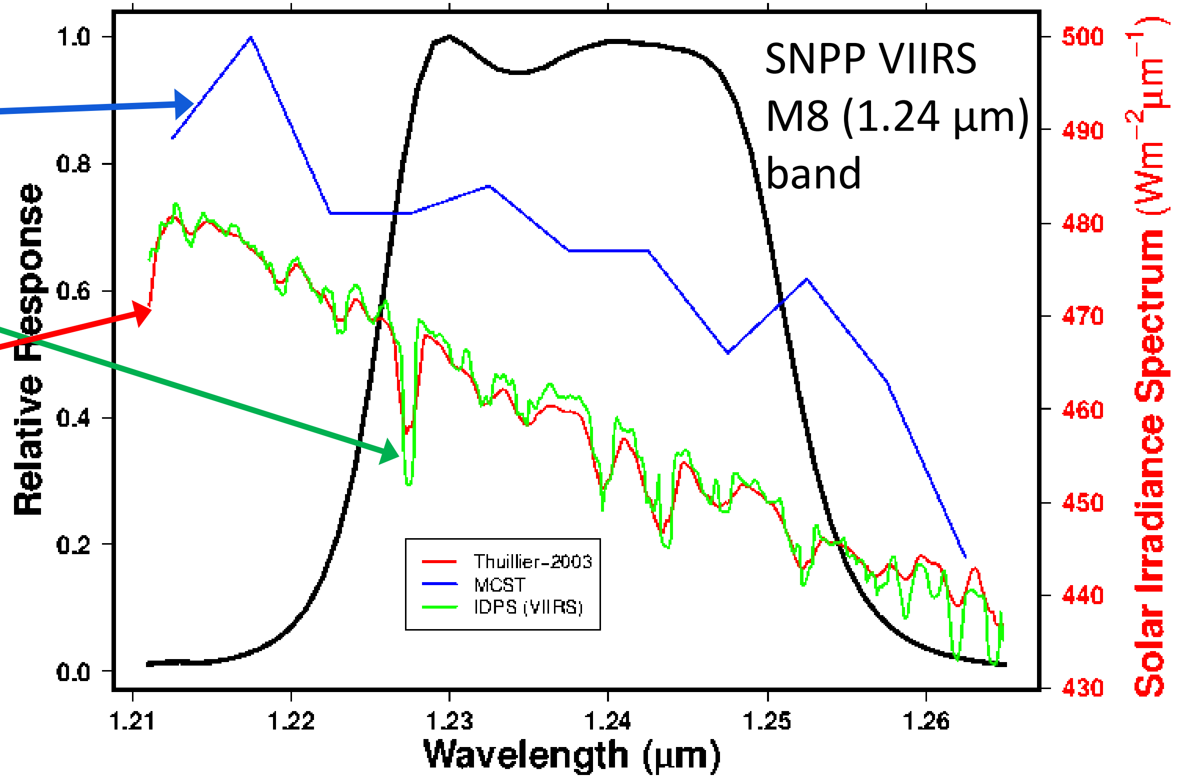


Band integrated solar irradiance values for M10 (1.6 µm)		
Thuillier 2003	Kurucz (MODTRAN)	Difference
249.73	244.3	2.2%

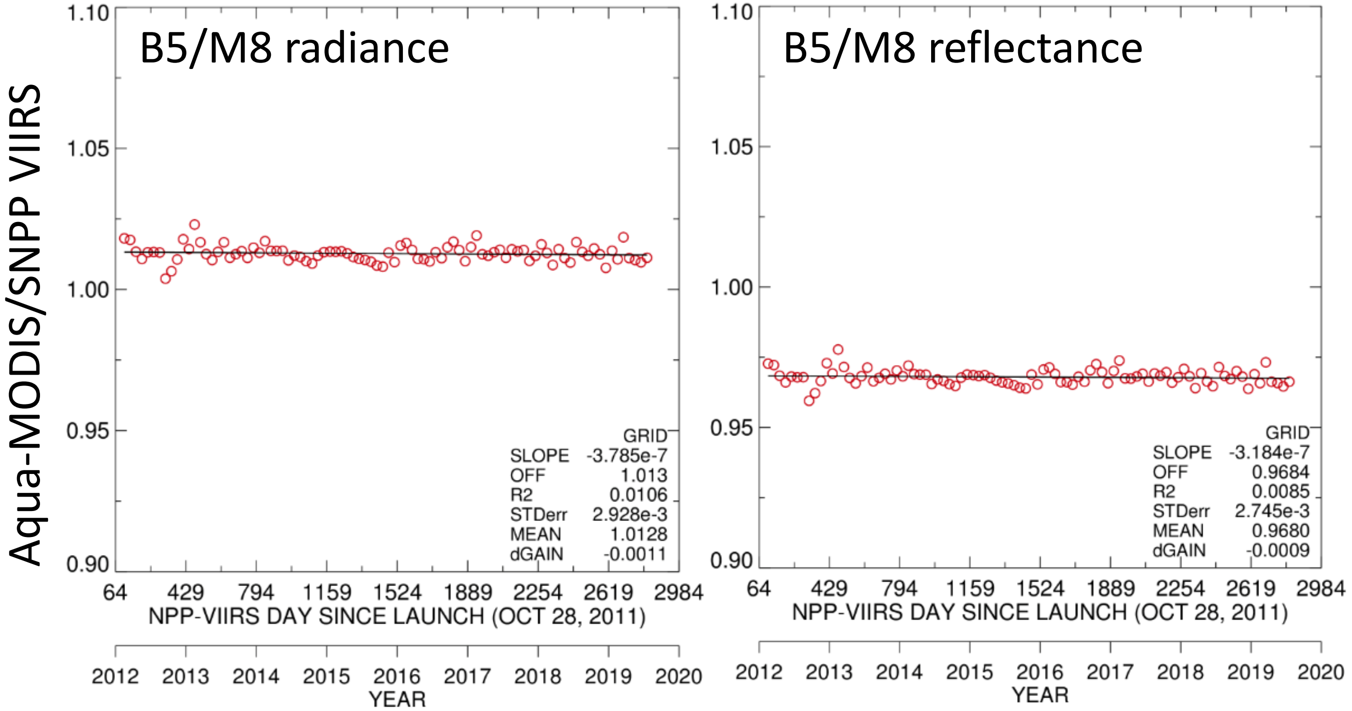
NASA LaRC Solar spectrum tool: https://cloudsway2.larc.nasa.gov/cgi-bin/site/showdoc?mnemonic=SOLAR-CONSTANT-COMPARISONS

Case study 2: Radiometric scaling between VIIRS to MODIS

- Aqua MODIS uses mix of **Thuillier**, **Neckel and Labs**, and **Smith and Gottlieb** solar spectra
- SNPP-VIIRS uses **Kurucz (MODTRAN) solar spectra**
- NOAA-20 VIIRS uses **Thuillier 2003 spectra**



All-sky tropical ocean ray-matching



NASA LaRC Solar spectrum tool:
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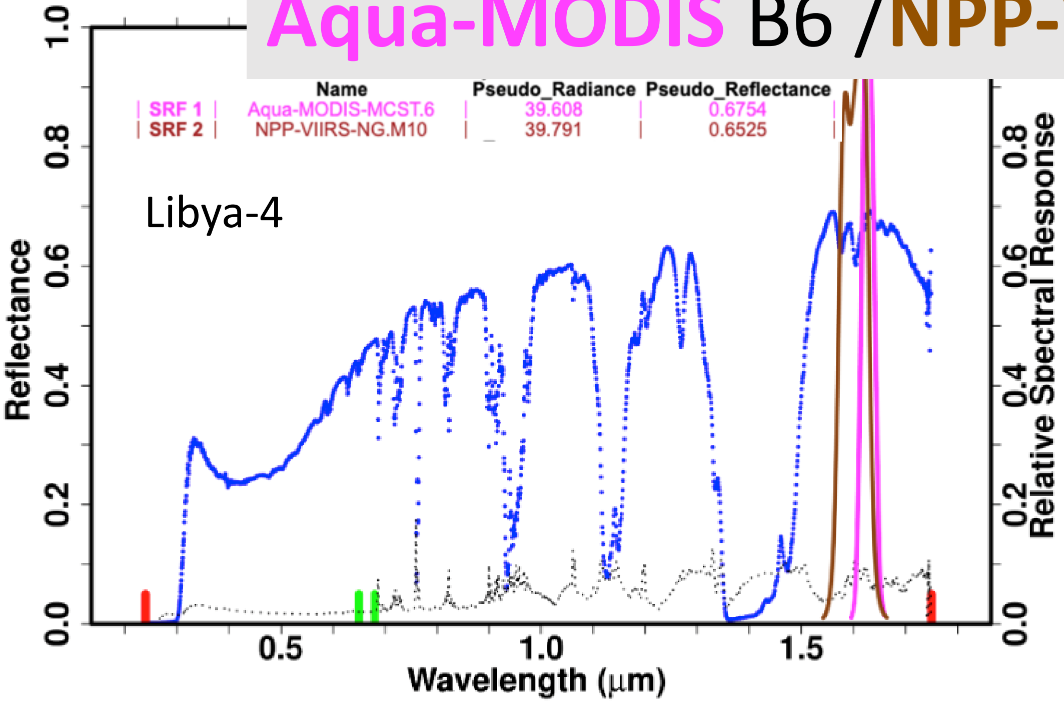
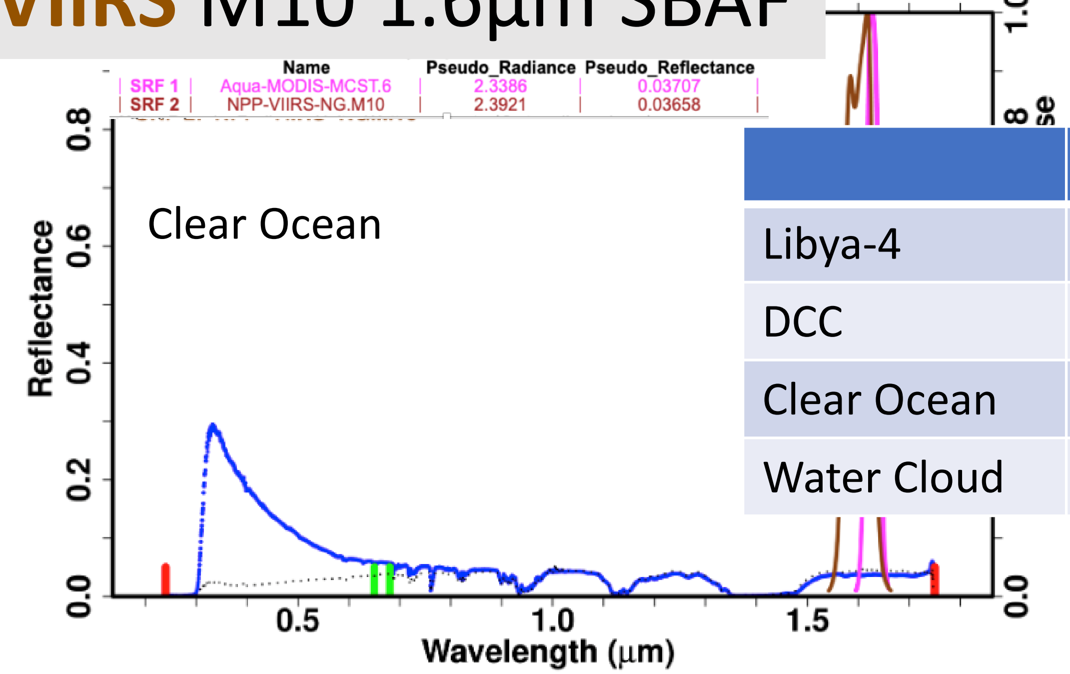
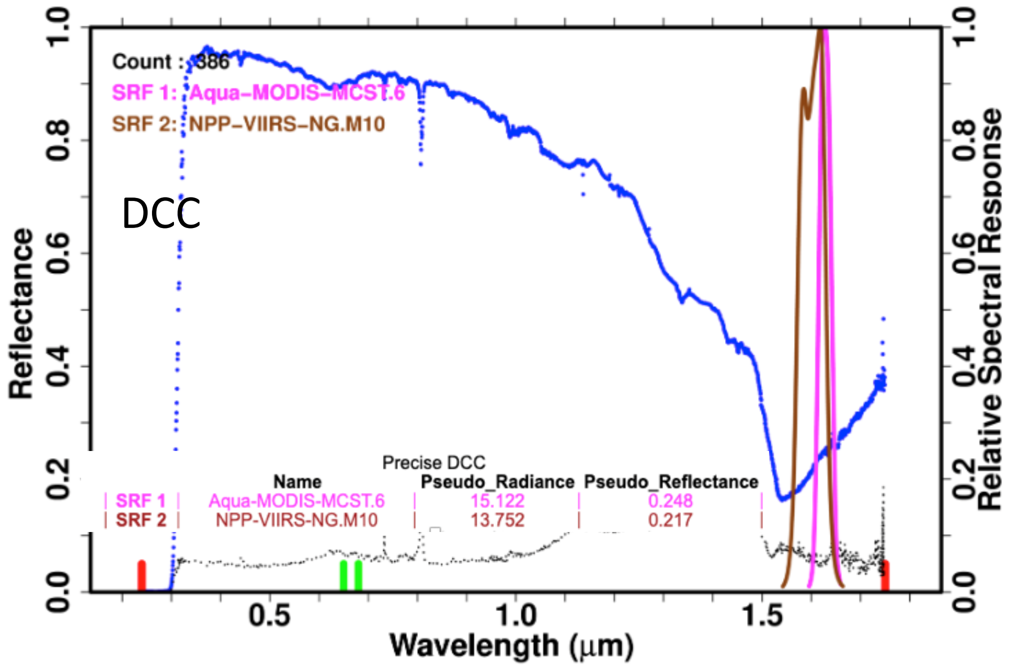
MODIS radiance (C6.1) is 1.3% brighter than VIIRS, however, MODIS reflectance is 3.2% darker than VIIRS, for 1.24 µm band

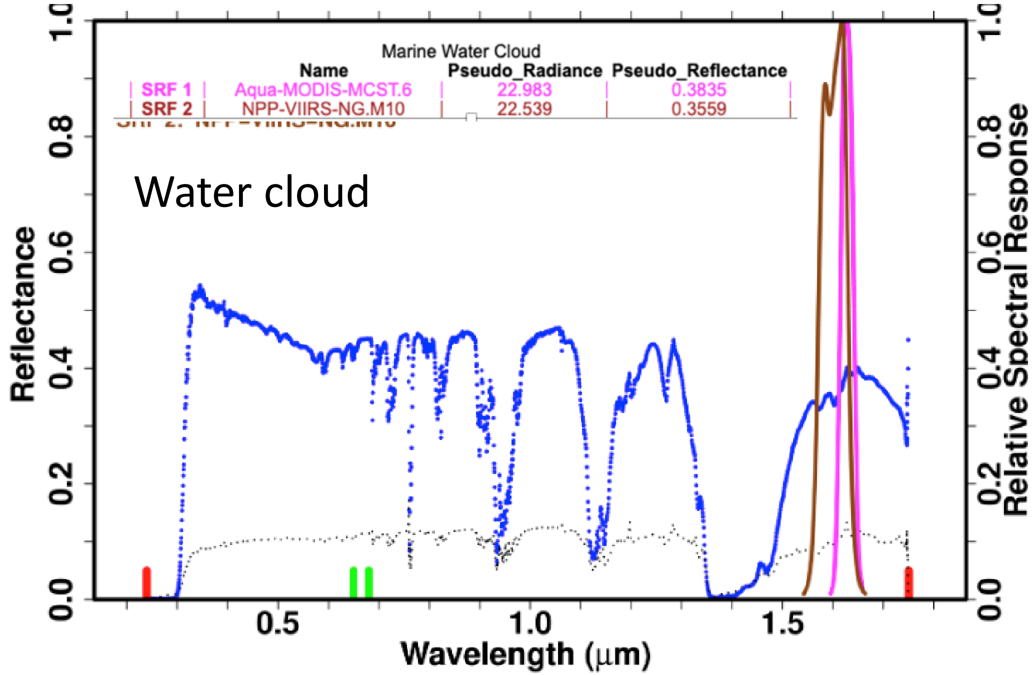
Aqua-MODIS B6 /NPP-VIIRS M10 1.6µm SBAF





	SBAF
Libya-4	3.5%
DCC	14.2%
Clear Ocean	1.3%
Water Cloud	7.8%

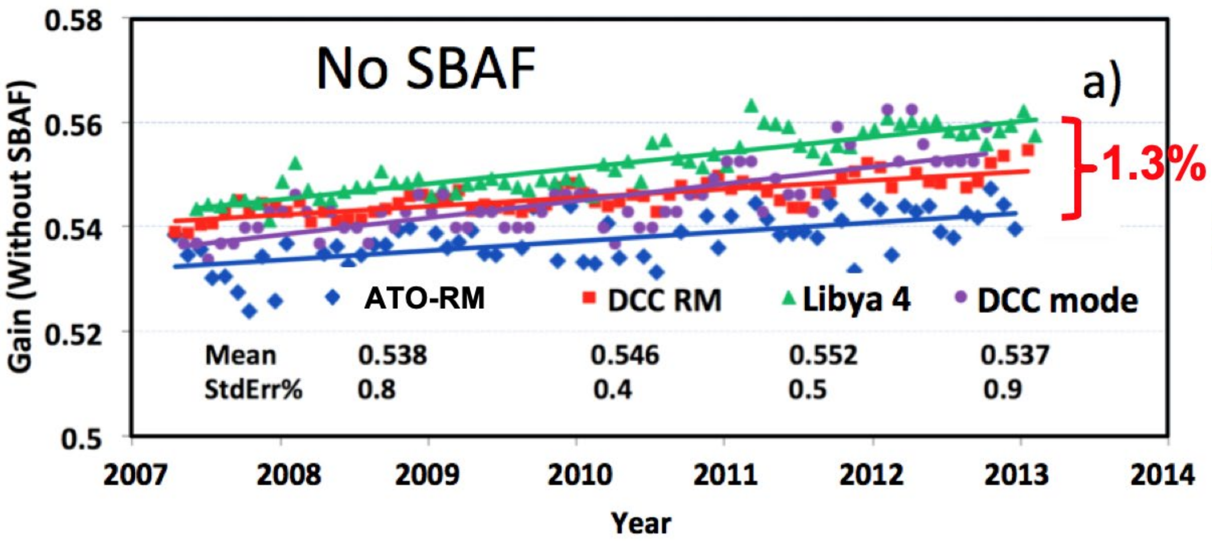


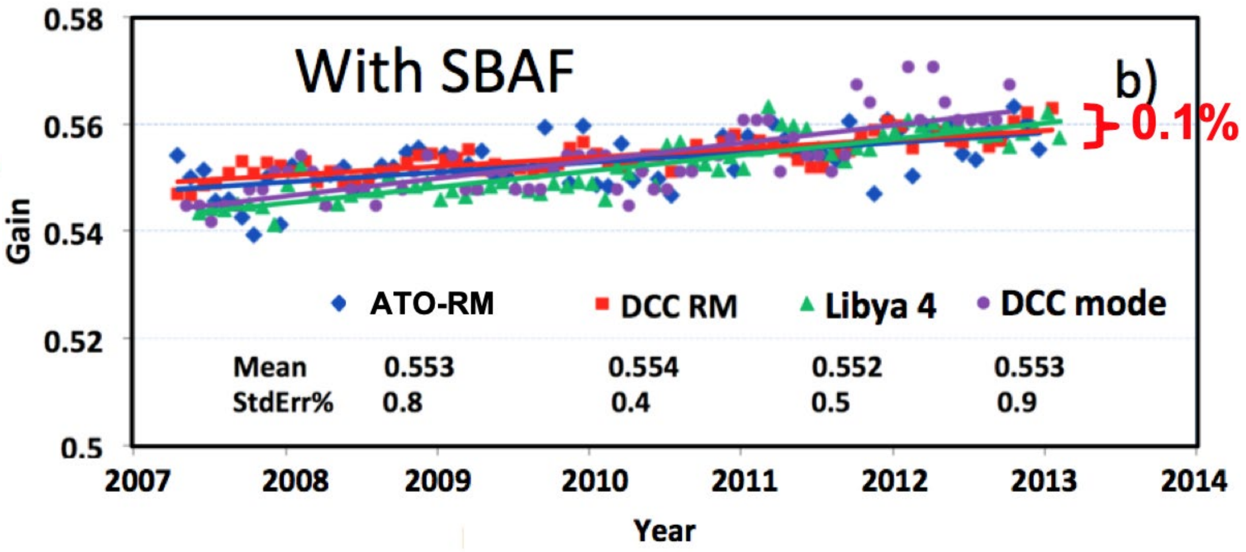


SBAF is a function of scene type
Verify SBAF by using multiple scene type calibrations

Impact of spectral band adjustment factors

0.65 µm band





4 independent inter-calibration of Meteosat-9 and Aqua-MODIS

Each has a unique spectral band adjustment factor

Multiple methods that agree verify the Meteosat-9 scaling factor with MODIS

GSICS solar spectra web meeting 2016-12-01

- The SCIAMACHY, SORCE SOLTICE, OMI, Solspec solar spectra were presented
- CEOS uses Thuillier as the official solar spectra
- The best approach was to split the solar spectra into two components, the UV portion or time varying portion 0.20µm to ~0.45µm, and the remaining non-time varying spectra 0.45µm to >2.5µm.
- Best to combine “low resolution” observed solar spectra (quiet sun) with high resolution radiative transfer modeled spectra

GSICS solar spectra web meeting 2017-02-14

- Solspec, Greg Kopp, SOLID SSI composite, tis-ssi-v02r00 solar spectra were presented
- GSICS has a reference solar spectra web page, that describes the product, the reference, and the data for download
  - http://gsics.atmos.umd.edu/bin/view/Development/ReferenceSolarSpectrum
  - Still accepting datasets
    - Short description
    - Data file
    - Reference paper or documentation
    - Contact information
- There was some discussion of the wavelengths with the greatest discrepancy between solar spectra, to look at more closely
- In the end, there were not enough volunteers to construct and a concrete way forward amongst the solar community

Conclusion

- The goal is to get the highest resolution spectra over the entire UV/visible/NIR wavelength range.
  - Perhaps separate the time-varying and the stable part ~0.45 µm
  - We also aim to have an associated uncertainty for the recommended solar spectra
- We would like to have a recommendation from the solar spectra community that represents best practices
  - The spectra need not be perfect, but to start the effort of using the recommended spectra for harmonization among satellite products for consistency across L1B products
- The GISCS/CEOS recommended solar spectra acceptance requirements
  - publicly available with version control
  - With an associated referenceable paper, documentation