Solar Spectral Irradiance from *Aura/OMI*: Cycle 24 and Extended Composite SSI Record

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SSAI/NASA GSFC

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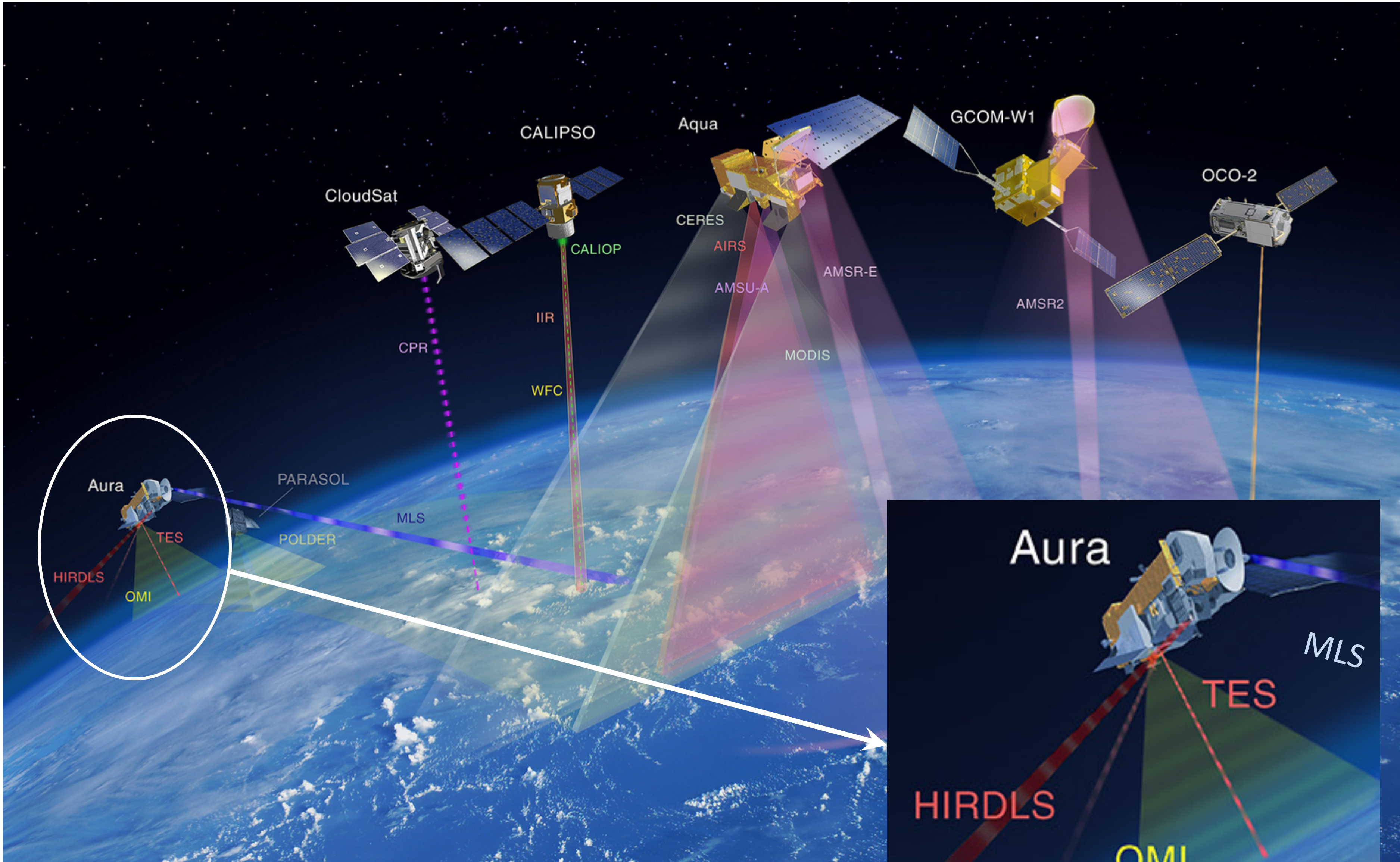


Aura, as part of the *"A-train"* constellation:

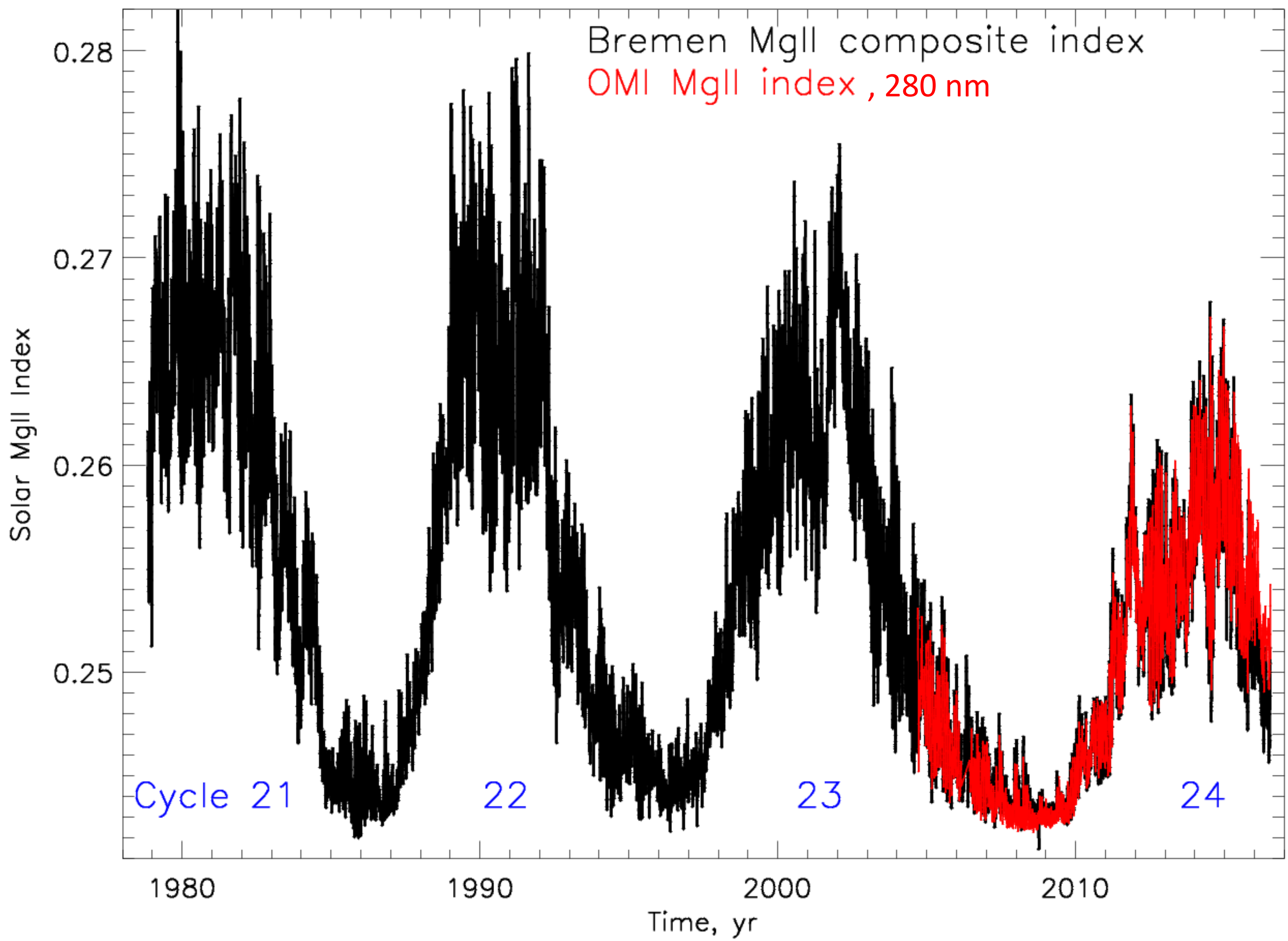
- launched July 15, 2004;
- lagging *Aqua* by 8-15 minutes;
- altitude = 705 km sun-synchronous orbit, ~13:45 LST equator-crossing time

Ozone Monitoring Instrument (*OMI*)

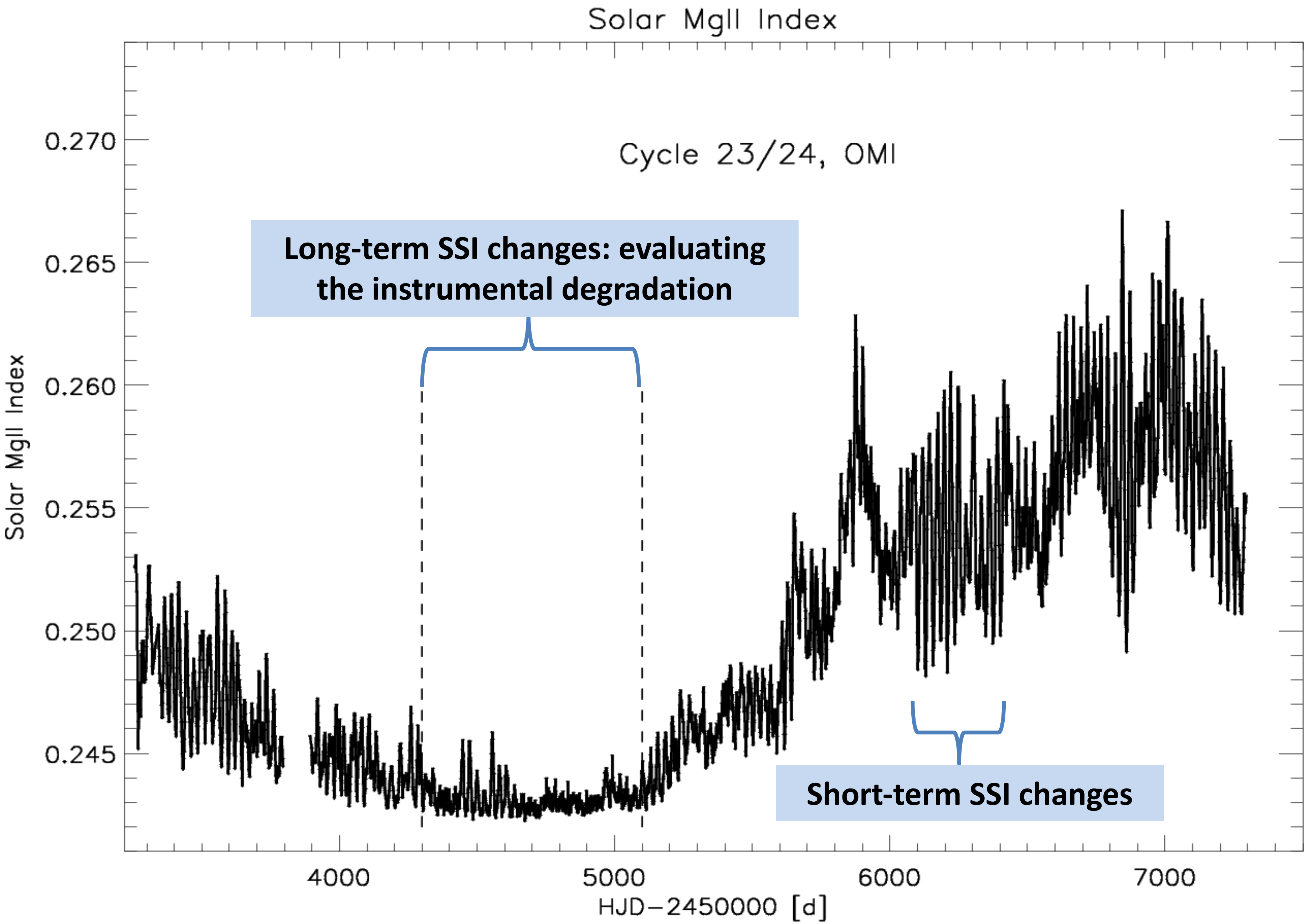
- Primary science goal: Atmospheric trace gases (O_3, SO_2, NO_2, etc.).
- Nadir-viewing, 'pushbroom' single monochromator with a 2-D CCD:
  - 264-504 nm spectral range (2 UV and 1 Vis channel);
  - 0.4-0.6 nm spectral resolution;
  - 30-60 simultaneous x-track FOVs.
- No end-to-end calibration performed on orbit.
- Once/day solar measurements:
  - 30-60 disk-integrated solar spectra (`Sun-as-a-star').
- **Very stable instrument; Over the mission lifetime (2004-present):**

  3-8 % change in the optical throughput;

  < 0.01 nm change in the wavelength registration.

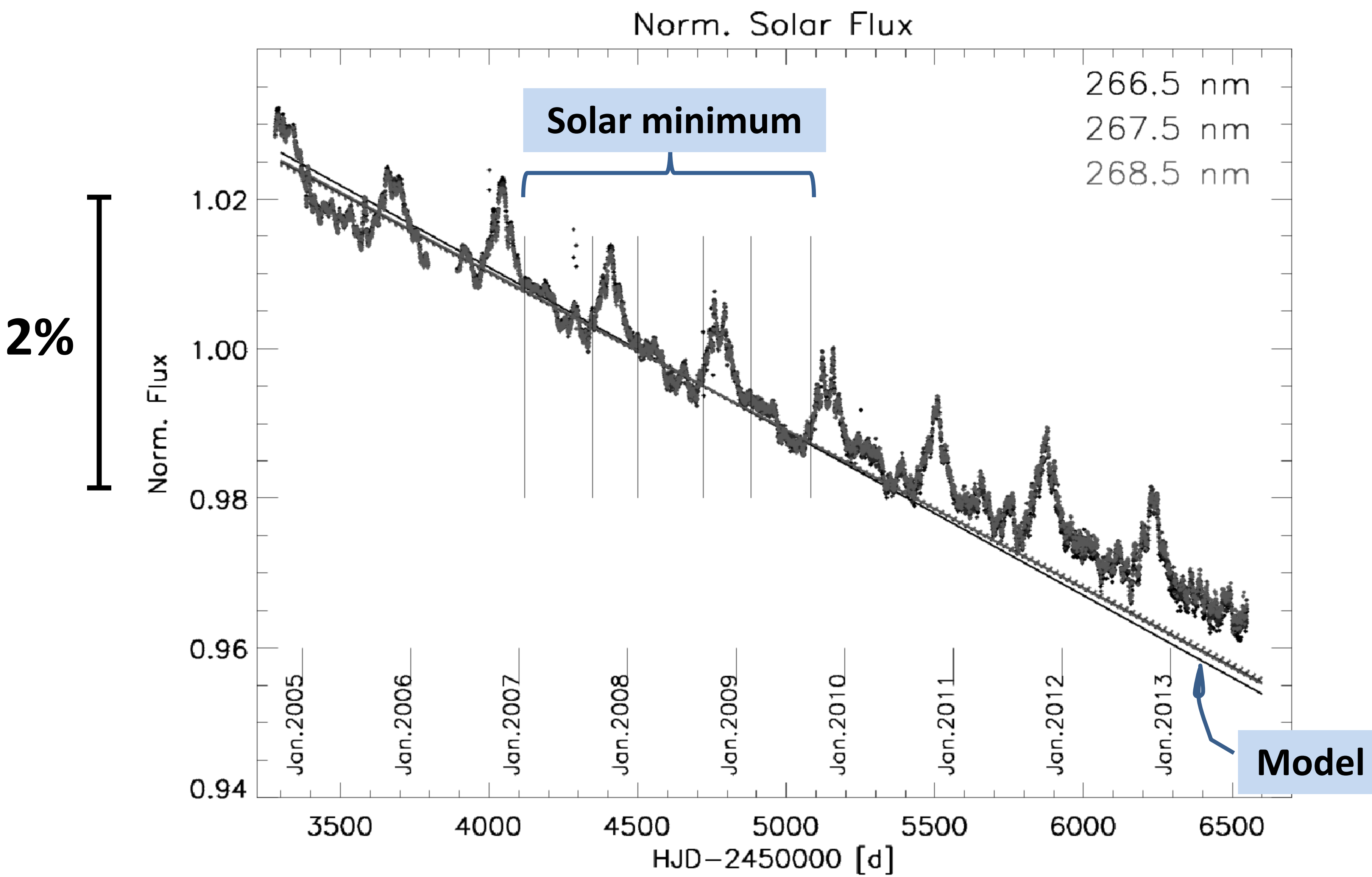


Bremen composite (M. Weber): *http://www.iup.uni-bremen.de/gome/gomemgii.html*

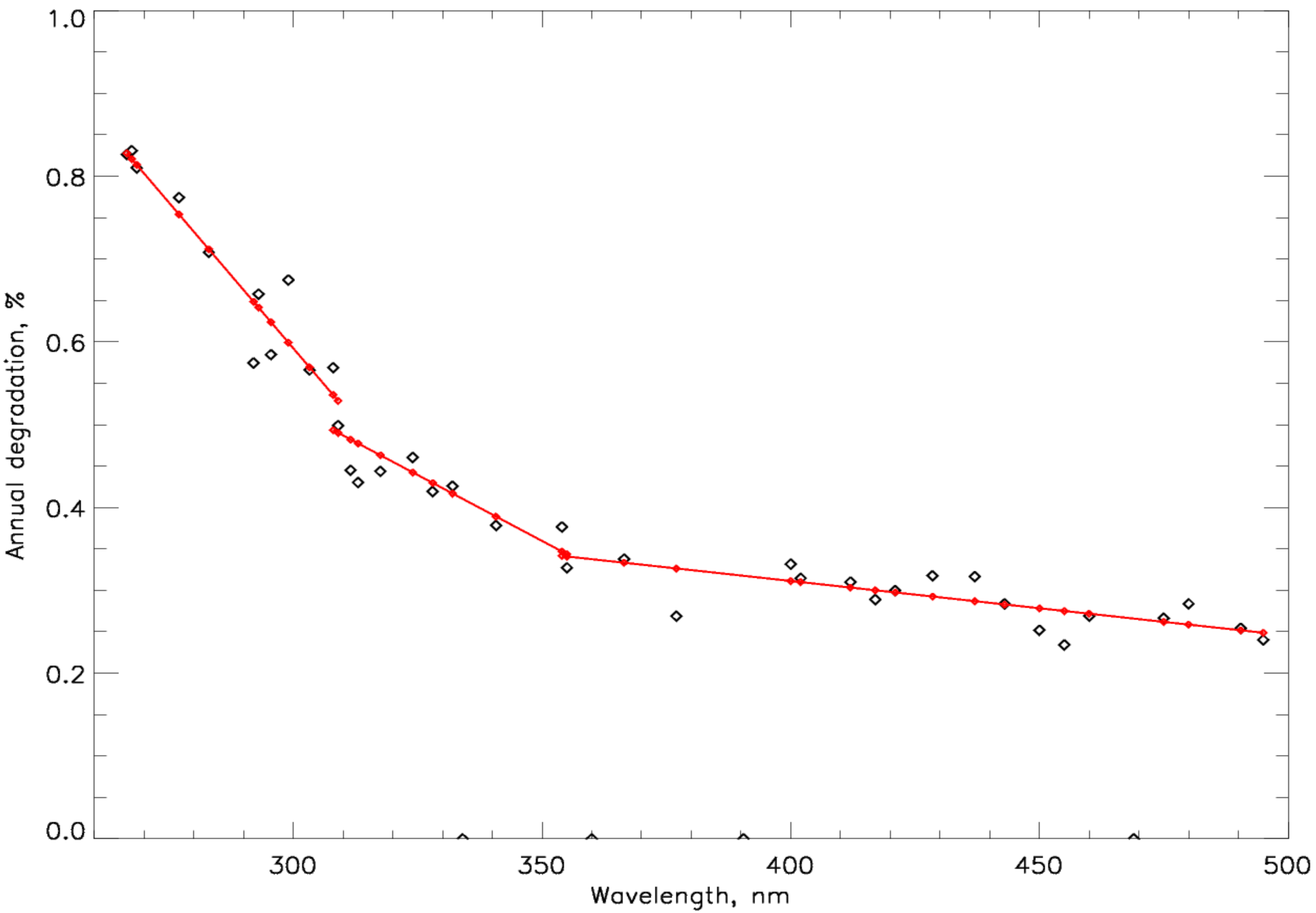


More details in: *DeLand and Marchenko* (2013), JGR: Atmospheres, *118*, 3415

Building the degradation model for *OMI*

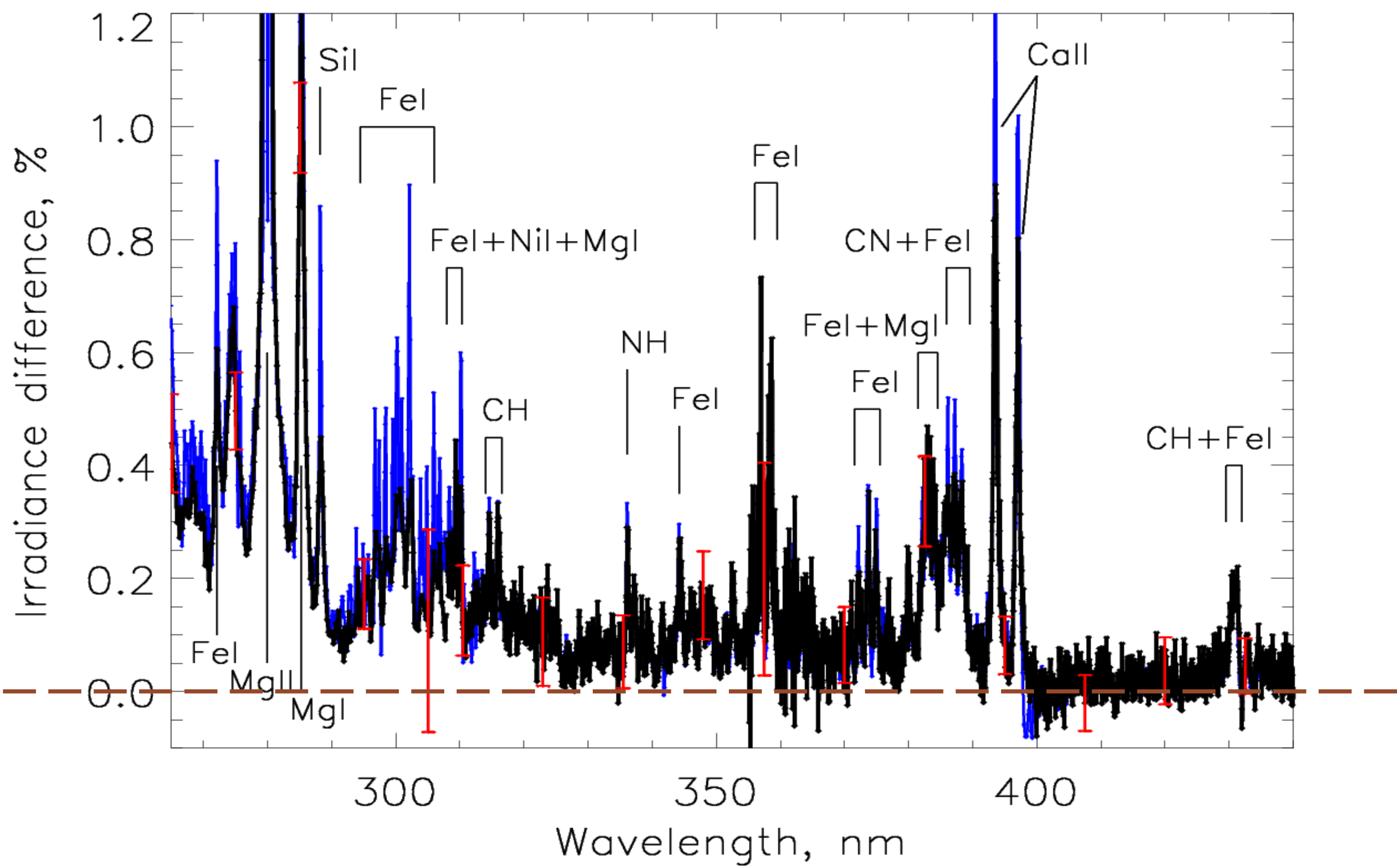


OMI Degradation Rate: Irradiances



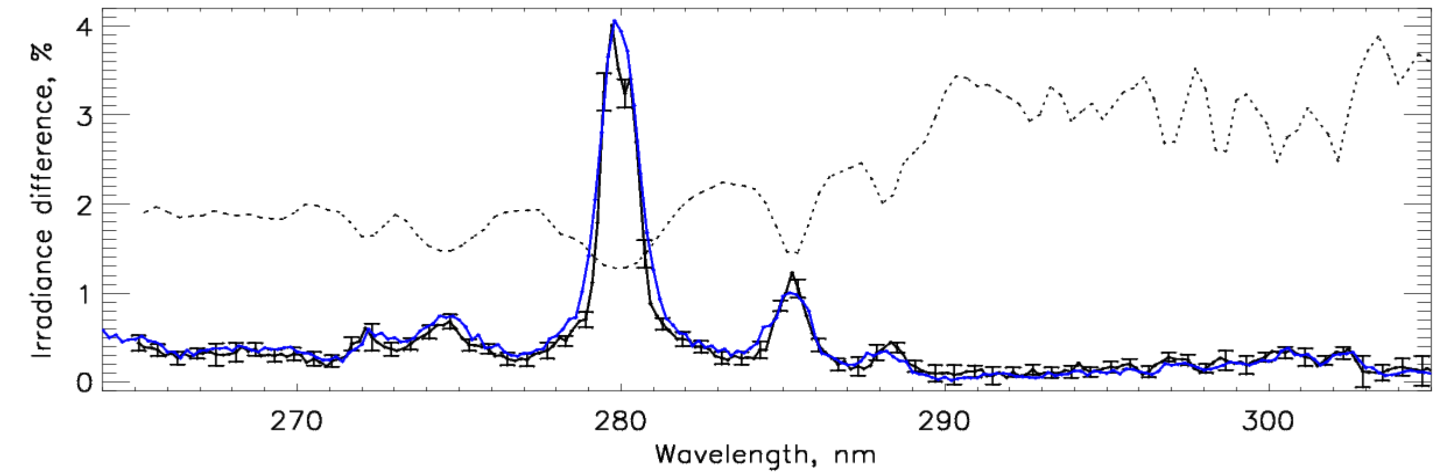
More details in: *Marchenko and DeLand* (2014), ApJ,*789*, 117

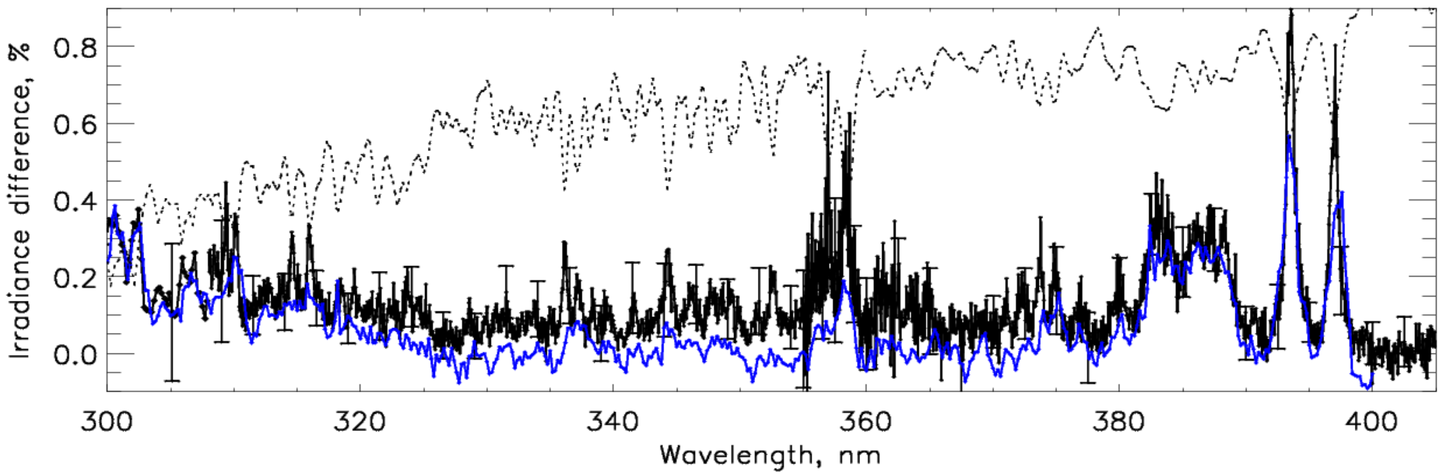
Short-term (rotational) SSI changes in Cycle 24



Black: *OMI*, with 2σ uncertainties (red bars);
Blue: *GOME-2* (2x higher spectral resolution cf. *OMI*)

Short-term SSI variations: Cycle 24 *vs*. Cycle 21



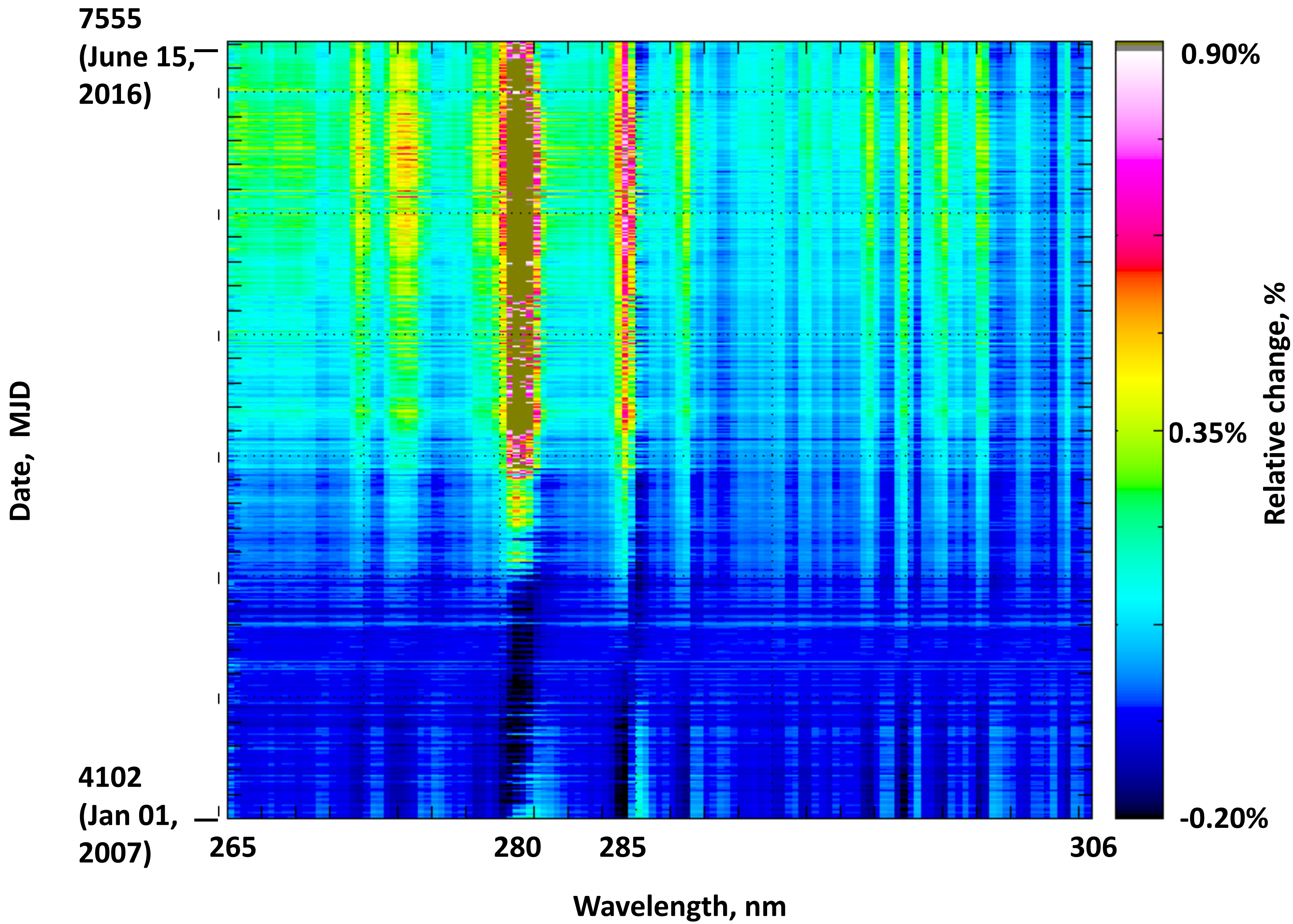


Blue line: The short-term (rotational) SSI changes from *DeLand and Cebula* (1993), adjusted to match OMI results at the peak of the MgII line

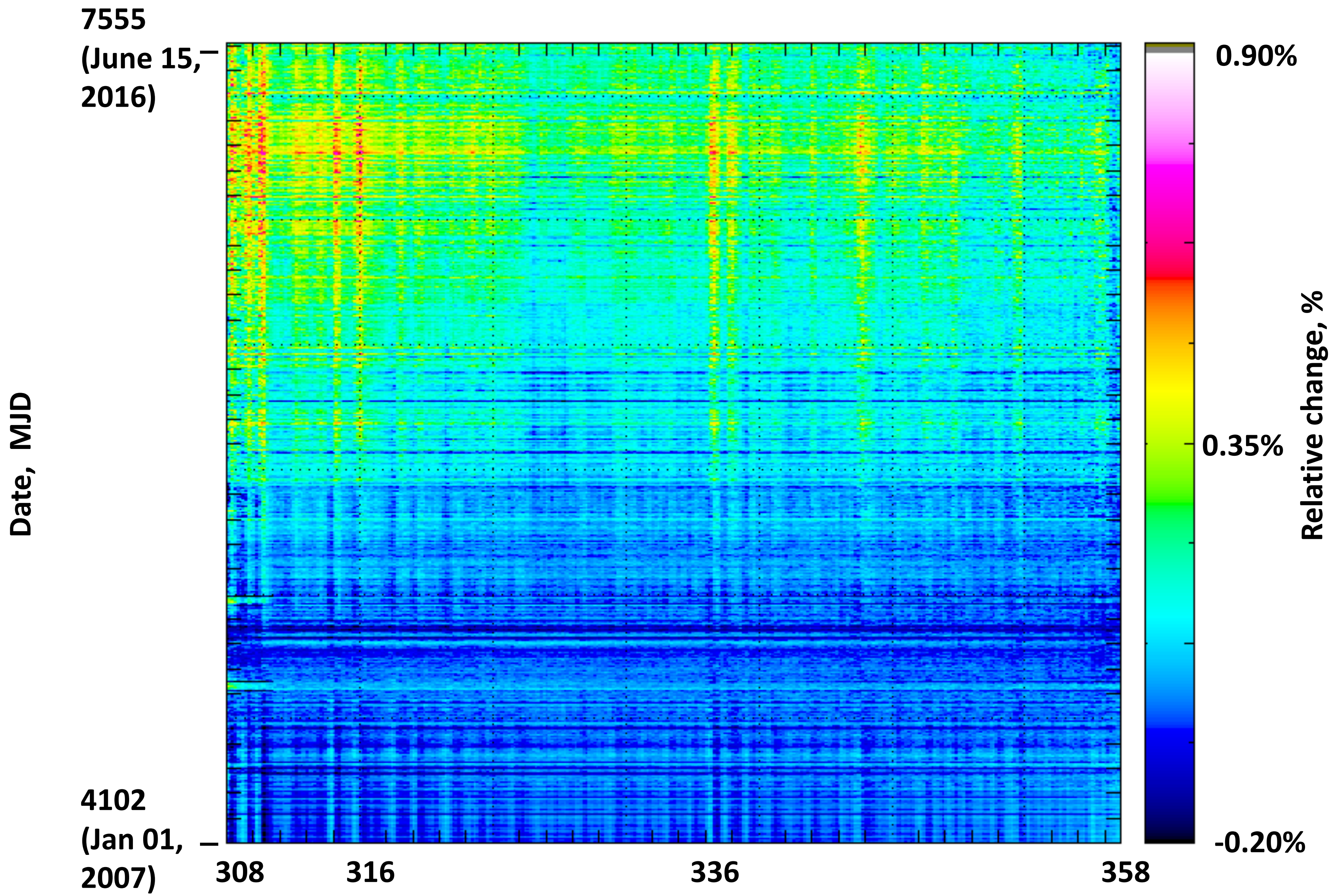
Black line: The short-term Cycle 24 SSI changes derived from *OMI* data.

Dotted line: A scaled solar spectrum (to provide spectral position references).

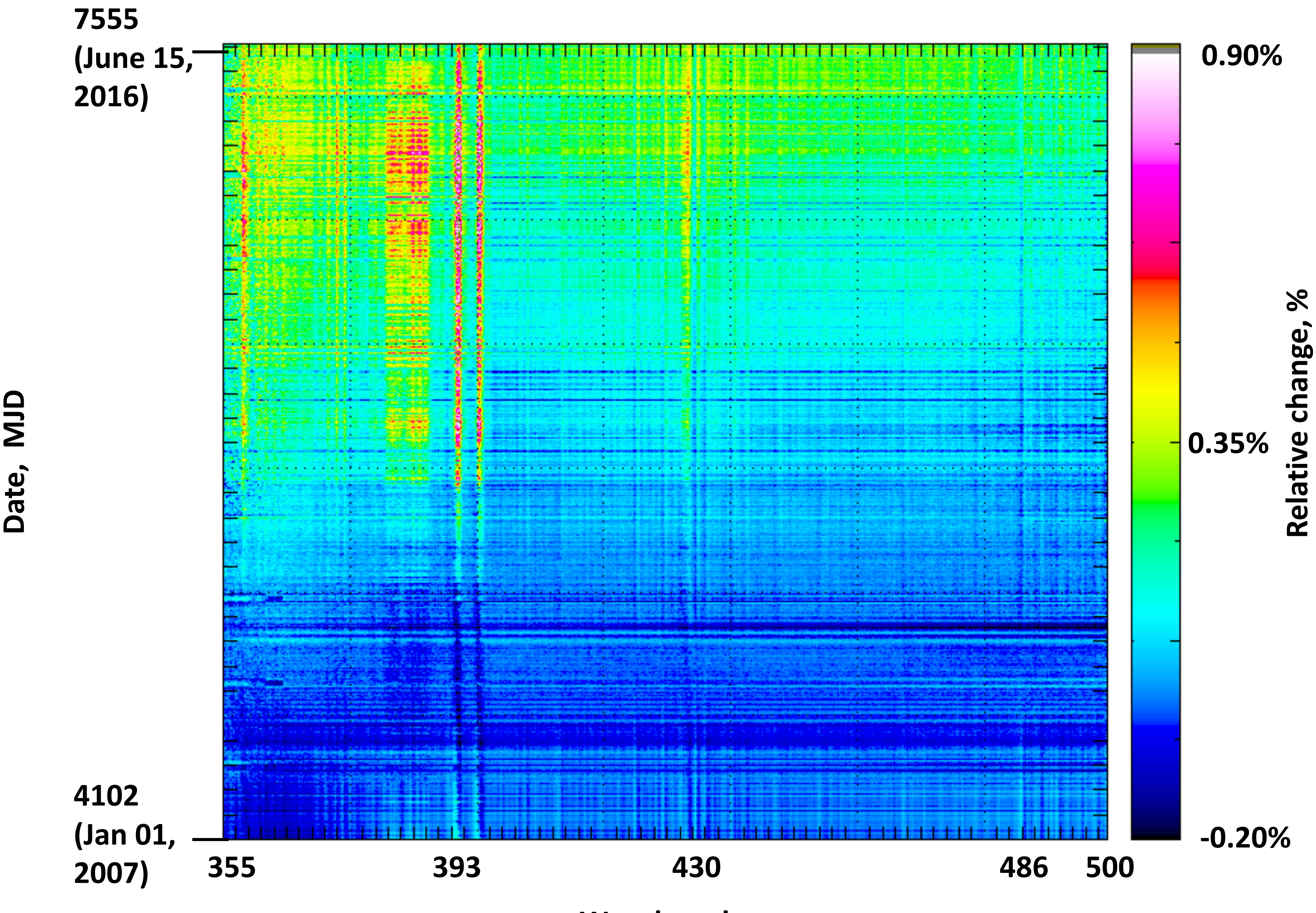
Normalized daily SSI changes from OMI data – UV1



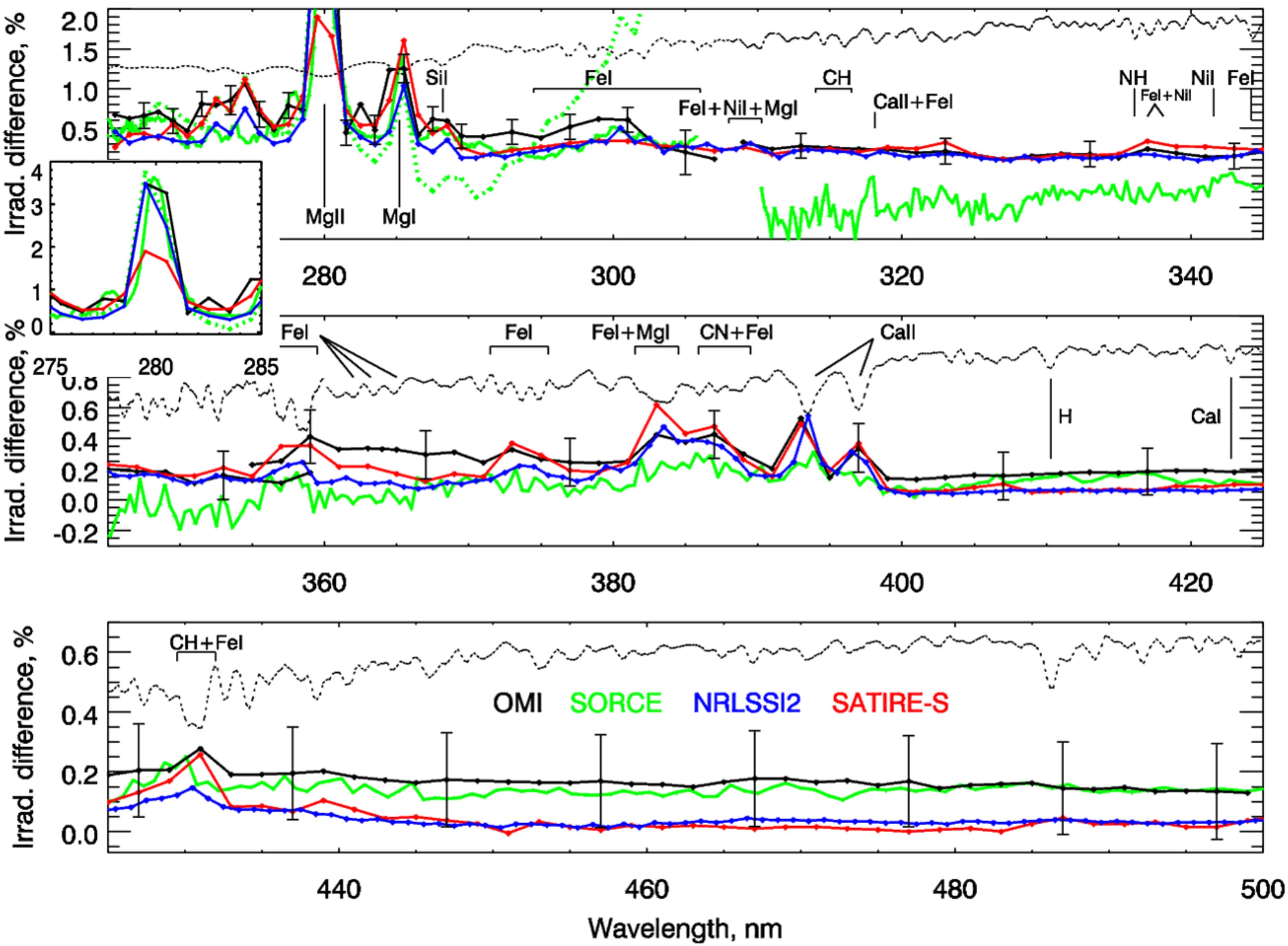
Normalized daily SSI changes from OMI data – UV2



Normalized daily SSI changes from OMI data - VIS

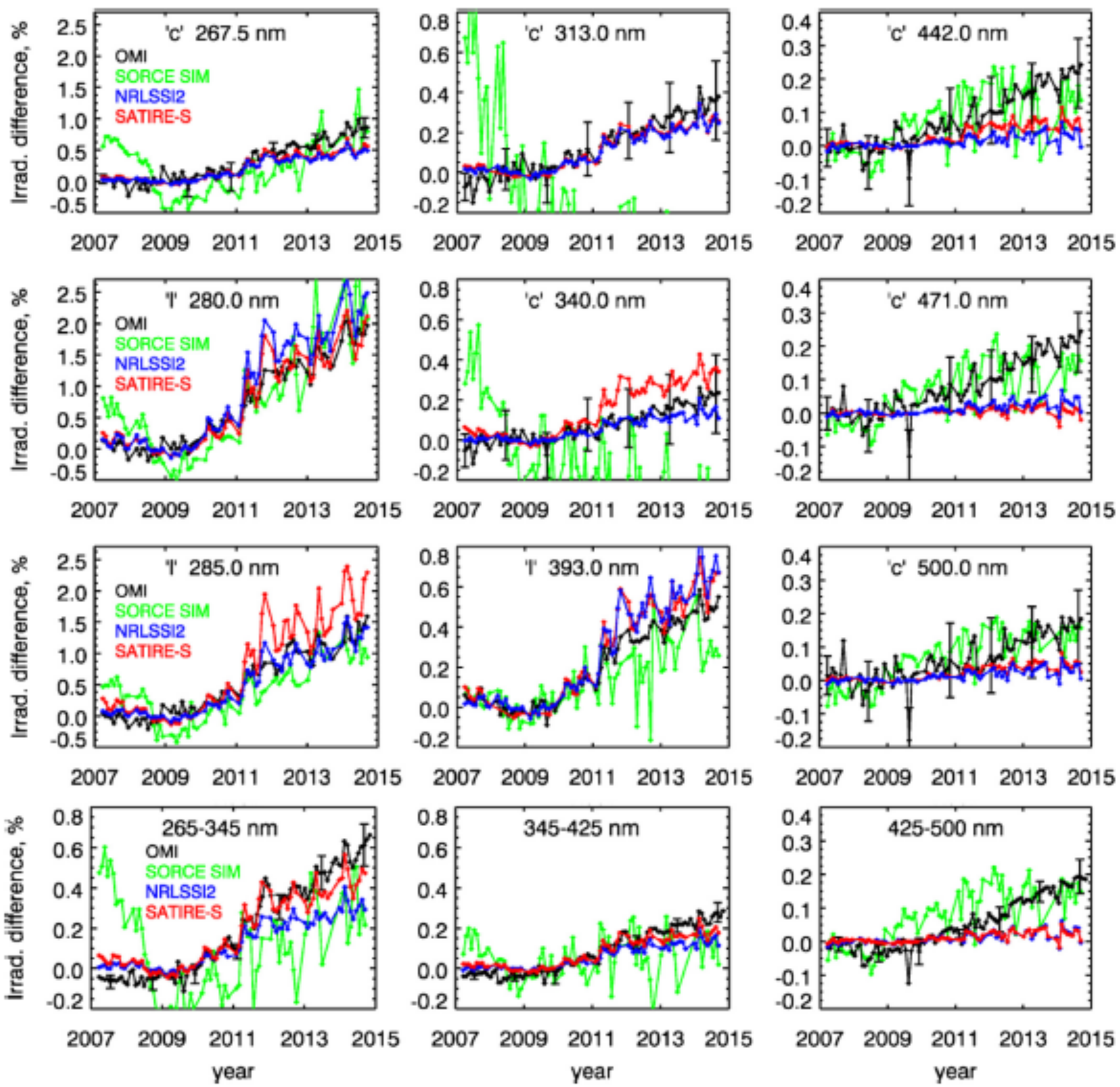


Normalized SSI Changes (max *vs*. min) for Cycle 24



More details in: *Marchenko et al*. (2016), SWSC*, 6,* A40

Normalized SSI Time Series for Cycle 24



More details in: ***Marchenko et al*. (2016), SWSC, *6*, A40**

OMI Status and Future Improvements

- Daily irradiance data up to July 2016 are available on-line at http://sbuv2/gsfc.nasa.gov/solar/omi/. Proxy index data up to January 2017 are also available.
- Better workaround desired for missing data. Features such as bad pixels, dead pixels, random telegraph signal (RTS) noise have grown from 2-3% in 2005 to ~12% in 2016.
- Better treatment for the goniometry-related changes in throughput.
- Provide improved wavelength resolution of the degradation model to ~1 nm from the current 2-5 nm intervals.
- Possibly determine individual degradation coefficients for each row of CCD.

Improved Composite Solar Spectral Irradiance Product Using SBUV/2 and OMI Data

A project within the NASA Solar Irradiance Science Team (SIST)

Matthew DeLand, Sergey Marchenko, Ramaswamy Tiruchirapalli (*SSAI*)

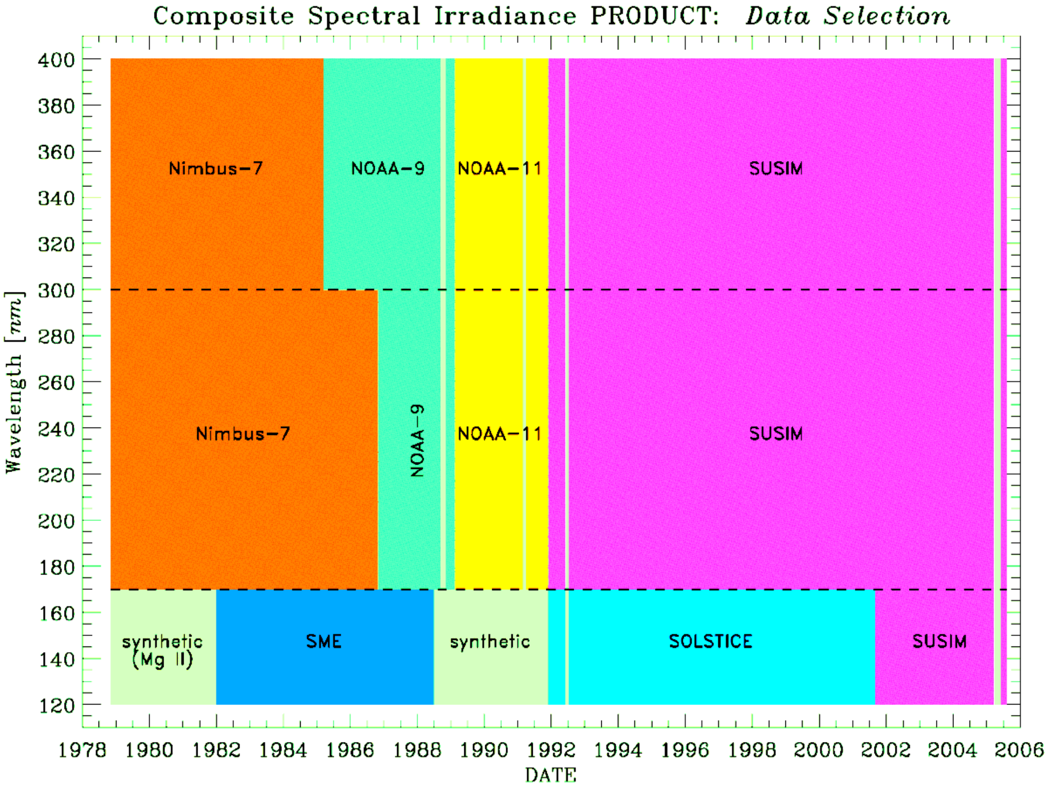
Linton Floyd (*SSRC*)

Overview of Project

- Begin with existing composite SSI data set [*DeLand and Cebula*, 2008].
- Address issues identified by other users (*e.g.* step changes) and review data to reduce outliers.
- Create UARS SUSIM reference spectra for 2000-2005.
- Use these data to create calibrated NOAA-16 and NOAA-17 SBUV/2 irradiance data for 2001-2007 (or longer).
- Develop daily irradiance product for Aura OMI covering 2007-2016.
- Add new SBUV/2 and OMI data sets to create extended composite SSI data set covering November 1978 – present.

Existing Composite SSI Product

- Uses 1 nm binned products from each instrument.
- Normalize each data set to reference spectrum.
- Select single data set for each large spectral and temporal region.
- Fill data gaps with synthetic data.

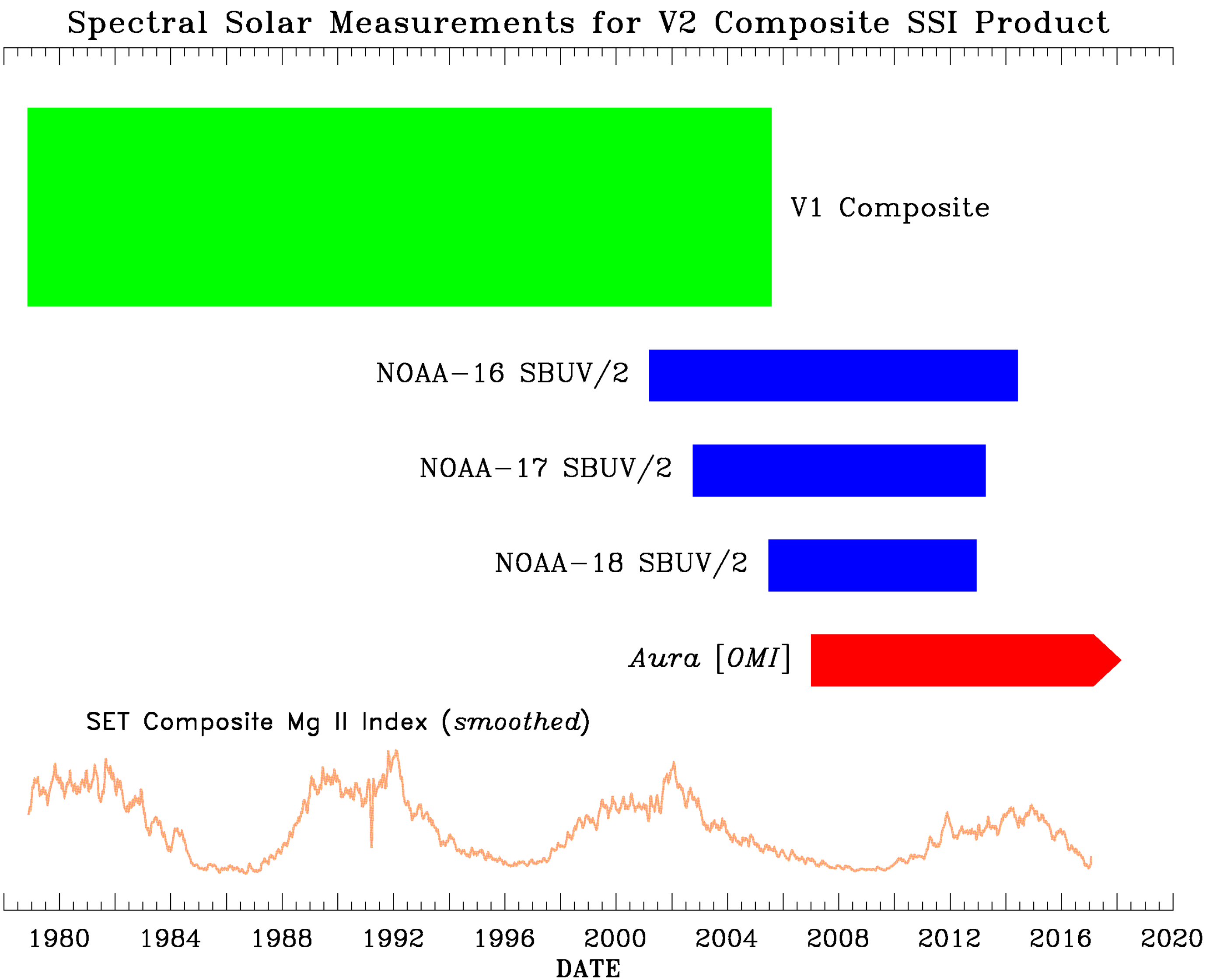


DeLand and Cebula, *J. Geophys. Res.* (2008)

Limitations of Current SSI Product

- Data set stops in mid-2005. First look at extending with SORCE data showed many differences in mid-UV [*DeLand and Cebula*, 2012].
- Step changes in time series at some inter-instrument transitions have been noted by other users. They should be removed.
- Current normalization spectrum (ATLAS-1) corresponds to high solar activity in 1992. Need lower activity level to best merge more recent data sets.
- Improve screening for outliers.

Timeline of New SSI Data



Extended SBUV/2 Data

- NOAA-16 daily spectra (170-400 nm) cover Mar 2001 – Sep 2007 [+ spring 2008] before significant orbit drift issues appear (shadowing of solar diffuser).
- NOAA-17 daily spectra cover Oct 2002 – Dec 2010 before shadowing starts.
- Use same long-term correction approach as applied to NOAA-9 and NOAA-11 in V1 composite SSI data set:
  - Use UARS SUSIM reference spectra in place of SSBUV flights as absolute reference
  - Create "Day 1" ratio between NOAA-16 and SUSIM to remove calibration bias
  - Compare concurrent NOAA-16 observations to reference spectra on selected dates to establish benchmarks for correction
  - Create smooth fits (wavelength, time) for degradation function to correct SBUV/2 data

Next Steps for SIST Project

- Apply revisions to individual data sets in current SSI product (treat NOAA-9, NOAA-11 data at scan level).
- Extend set of SUSIM solar change spectra used for NOAA-16 SBUV/2 degradation analysis.
- Apply same degradation correction approach to NOAA-17 SBUV/2 data set.
- Begin evaluation of multiple data sets during overlap period in 2007-2009 to determine optimum transition between SBUV/2 and OMI data.

Variability and Uncertainty

- The individual data sets used for the V1 composite SSI product quote typical long-term uncertainties of ±2% at 200-250 nm and ±1% at 300-400 nm.
- This uncertainty provides reasonable confidence for observed solar cycle amplitude values at $\lambda < 260$ nm, but does not constrain observations at longer wavelengths.
- We believe that the OMI long-term irradiance uncertainty is ±0.1-0.3% at most wavelengths, increasing to ~0.5% at some wavelengths between 275-300 nm.
- This estimate is supported by comparisons to NRLSSI2 and SATIRE-S results.
- This uncertainty is comparable to the magnitude of our observed solar cycle variations at most wavelengths between 300-500 nm.