Construction of a SORCE-based Solar Spectral Irradiance (SSI) Record for Input into Chemistry Climate Models

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Project Goals

Goal 1: *Produce a Solar Irradiance (SSI) record for input to chemistry climate models*
- Produce a daily SSI composite spectral record suitable for CCM transient studies over SC23 &24
- Record mostly based on observed SSI of SORCE SIM and SOLSTICE

Goal 2: *Extend wavelength coverage and gap fill record for daily coverage*
- CCM's require very broad wavelength coverage (110-100,000 nm), compliance with the TSI, and uncertainty estimates
- Record extended in wavelength and gap-filled in time with SRPM
- SRPM is a semi-emperical model that uses solar images as input

Goal 3: *In-depth comparison of SORCE observations with Fontenla et al. (2011 & 2015) Solar Radiation Physical Model (SRPMv2)*

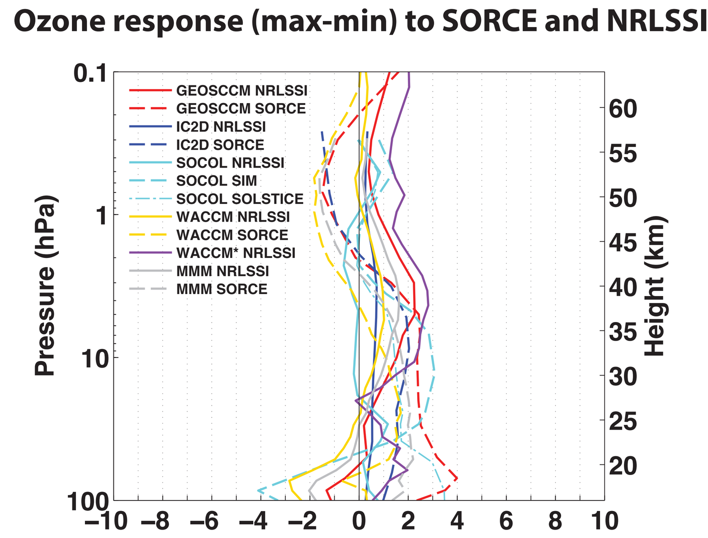
Project Goal 1: Produce a SSI record suitable for whole atmosphere chemistry-climate transient model studies

In terms of both solar and Earth atmosphere observations Solar Cycle 23-24 is the best observed solar cycle in history
- SORCE, SDO, + other valuable records
- SABER, AIRS, MLS, ECMWF re-analysis, +ESA assests & limb scanning experiments

Advanced and well-documented chemistry-climate models are available to use SSI input and compare against Earth atmosphere observations
- WACCM, HAMMONIA, GISS, + multiple other models that participated in comparative studies (see for example Eyring et al., 2010; Austin et al., 2008)

We propose to construct and document a daily broad wavelength solar spectrum intended for transient model simulations.
- This effort will follow the steps performed for the production of the SIRS reference spectrum (Woods et al. 2009) and the Merkel et al. 2011 WACCM time slice study

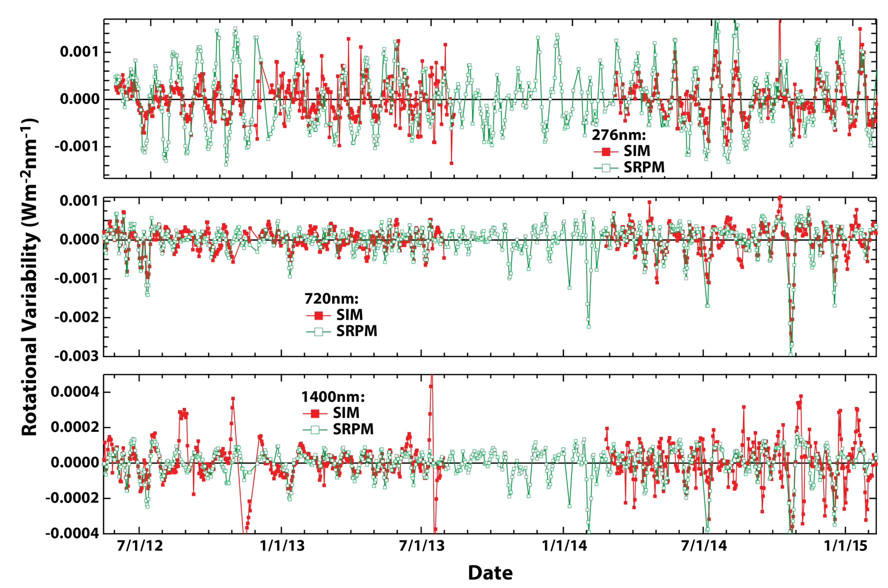
Ozone response (max-min) to SORCE and NRLSSI



Percent ozone variability due to solar irradiance

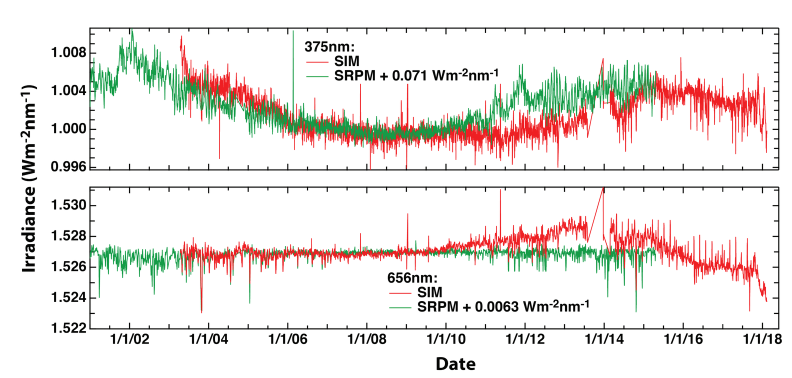
The most sensitive part of the Earth's atmosphere is near the stratopause (~1hPa). SORCE observations an anti-solar effect at this altitude (see Merkel et al. 2011) that is in agreement with instruments that measure O_3 emission measurements (i.e. SABER, MLS, SME)

Project Goal 3 (con't): Goal 3: In-depth comparison of SORCE observations with SRPMv2: Towards a SIM/SRPM2 composite



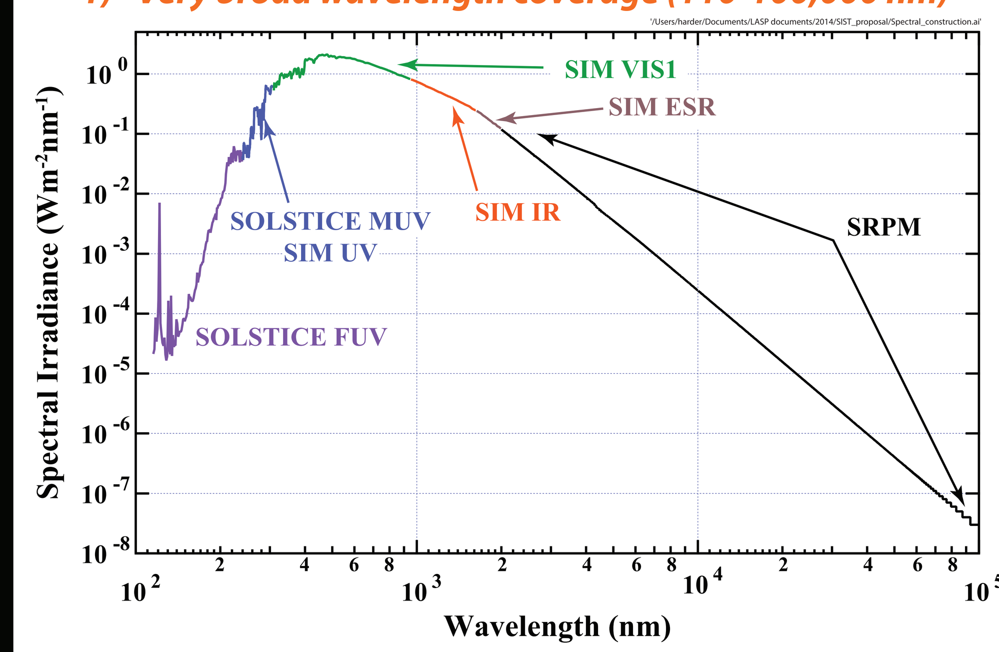
SIM & SRPM2 show a remarkable agreement on rotational time scales throughout the spectrum. Because of this SRPM2 makes a 'drop-in' replacement for missing SORCE data, espcially during the August 2013-April 2014 extended safe-hold. However, at some UV wavelengths SRPM2 appears to have a slightly larger rotational modulation, but a smaller long-term variation. This suggests a greater role of the quieter network regions that are more difficult to observe and model than the larger contrast facula/plage and umbra/penumbra regions of the Sun.

SIM & SRPM2 on longer time scales show distinctive differences. In the cases where the spectral variations are dominated by chromospheric components the agreement tends to be good, such as the case for 375nm. In photospheric componets, agreement is good in the descending phase of cycle 23, but with a different appeareance in the rising phase of 24. For the SIM/SRPM composite work will be done to evaluate degradation correction in the instrument and account for possible missing component in the model.



Project Goal 2: Extend wavelength coverage and gap fill record for daily coverage

SSI record requires:
1) *Very broad wavelength coverage (110-100,000 nm)*



Spectral Source	Wavelength Range (nm)
SOL MUV/FUV	115.5-239.5
SIM/SOL MUV	239.5-307.5
SIM Vis1	310-974.5
SIM IR	952.5-1600.
SIM ESR/SRPM	1600.-2400.
SRPM	2400-100000

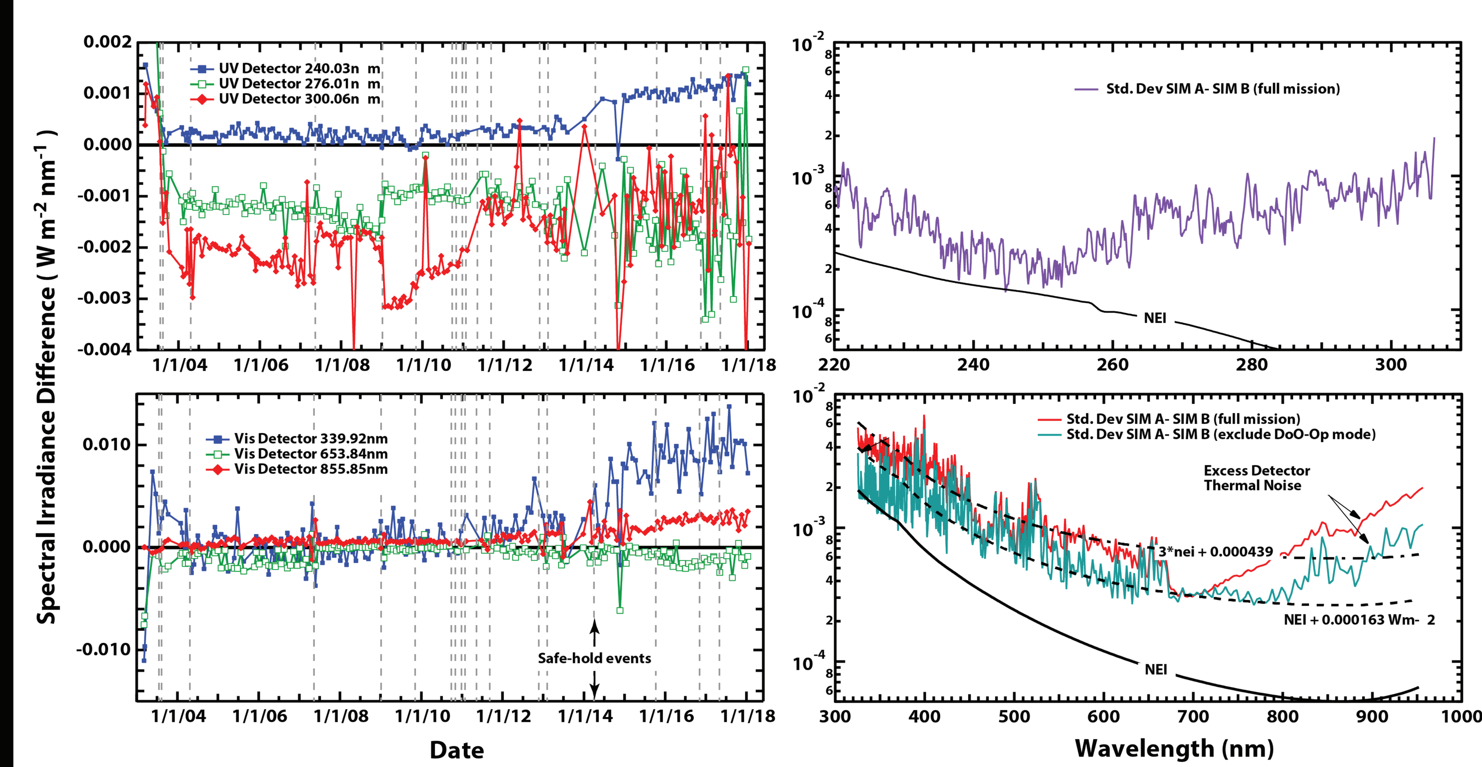
Spectral composite extends over ~ 8 orders of magnitude in irradiance and ~3 orders of magnitude in wavelength

2) *Documented uncertainty estimates*

$$pd(\lambda,t) = \left((1-a_{detector})\cdot exp(-\kappa \cdot t_{expos} \cdot f') + a_{detector} exp(-\frac{\kappa \cdot t_{expos} \cdot f'}{2})\right)$$

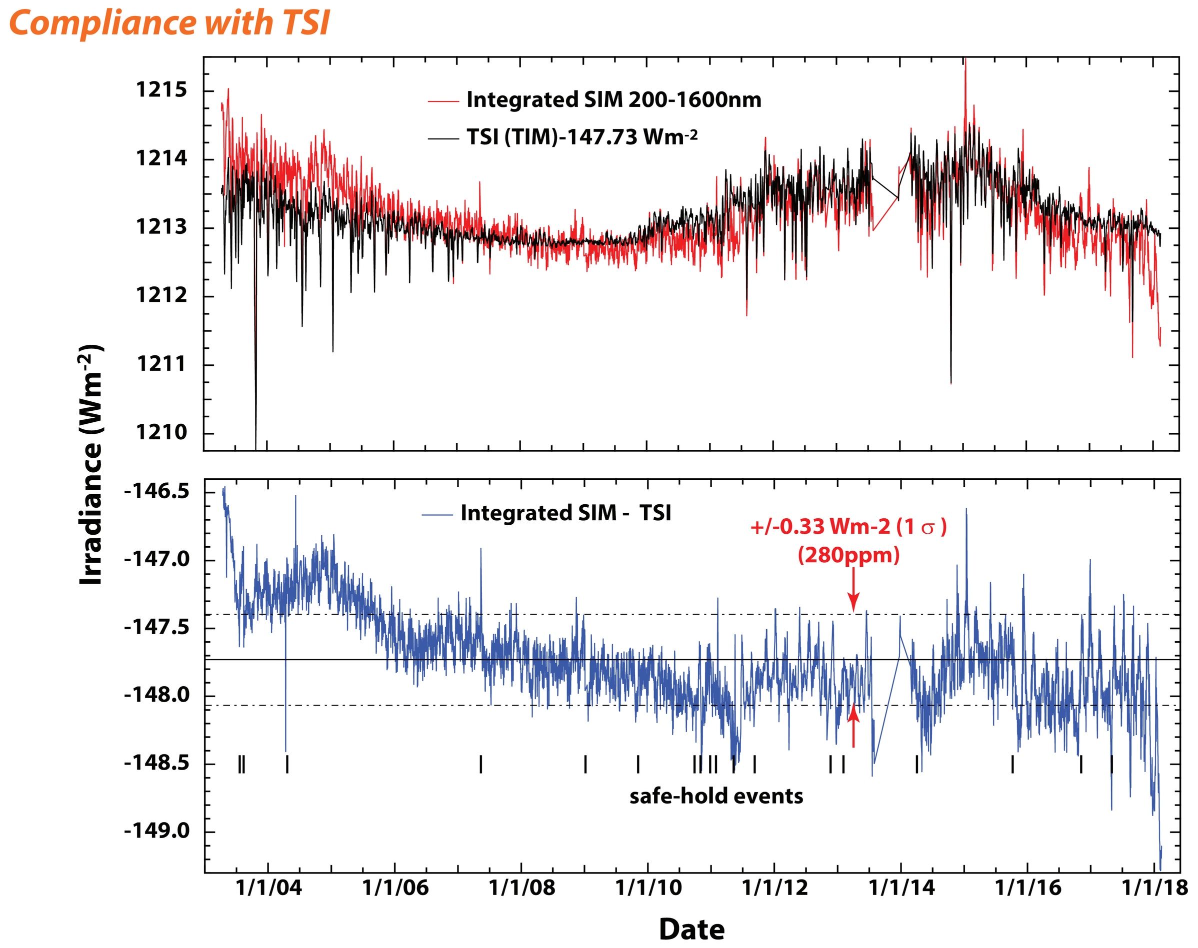
SIM Degradation measurement equation

Degradation model constraints:
- SIM A & SIM B must produce the same irradiance time series
- Integrated SSI must match TSI within limits of its spectral range
  - Integral constraint does not rule out systematic errors but bounds their magnitude



Uncertainty estimate from SIM A-B differences
- Small changes in character occur at the boundaries of the safe-hold events
- UV differences influenced by the more-structured spectrum
- Visible differences tend to follow noise curves – excess temperature noise at long wavelengths increases uncertainty. Particularly present during the SORCE DO-Op mode (Day-only operation mode) that started in April of 2014.

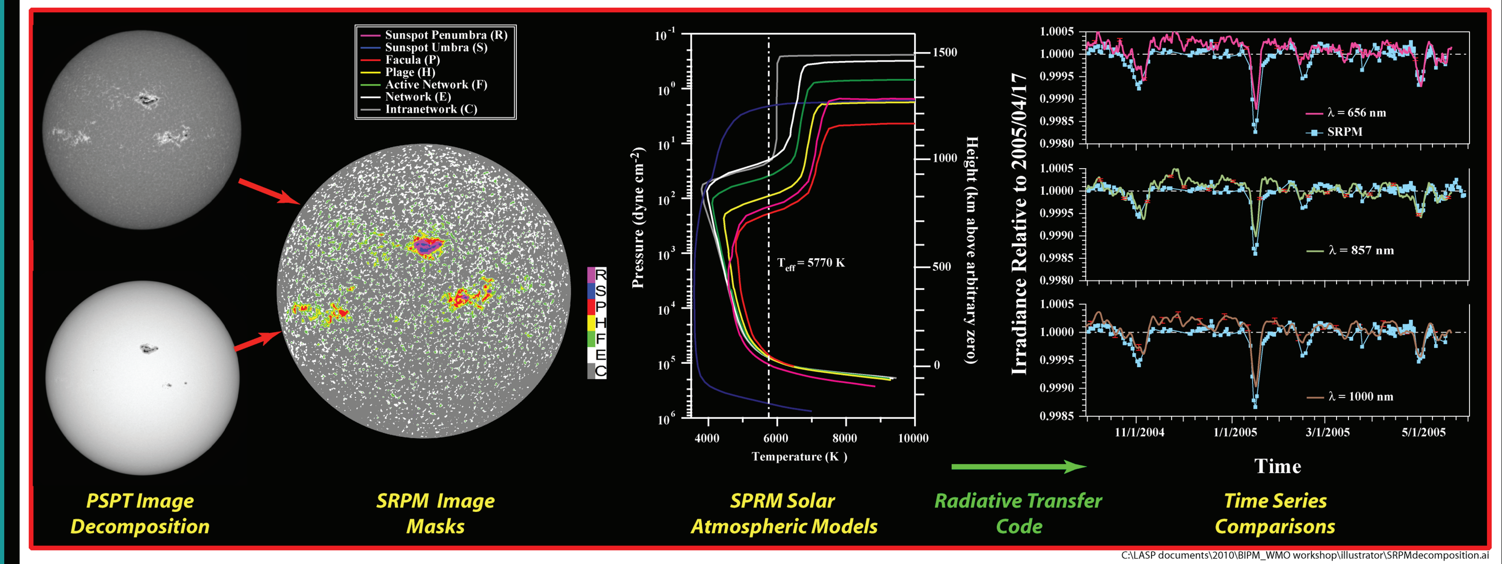
2) *Compliance with TSI*



After accounting for long wavelength portion of the spectrum integrated SIM agrees with the TSI to $0.33 Wm^{-2}$ (280 ppm)

Final composite will contain time & wavelength uncertainty estimates:
- Noise equivalent irradiance
- RMS differences from SIM A-to-B comparisons
- Additional uncertainty contributions at safe-hold boundaries
- User option for correction factor to match TSI (to conserve total energy in model studies)

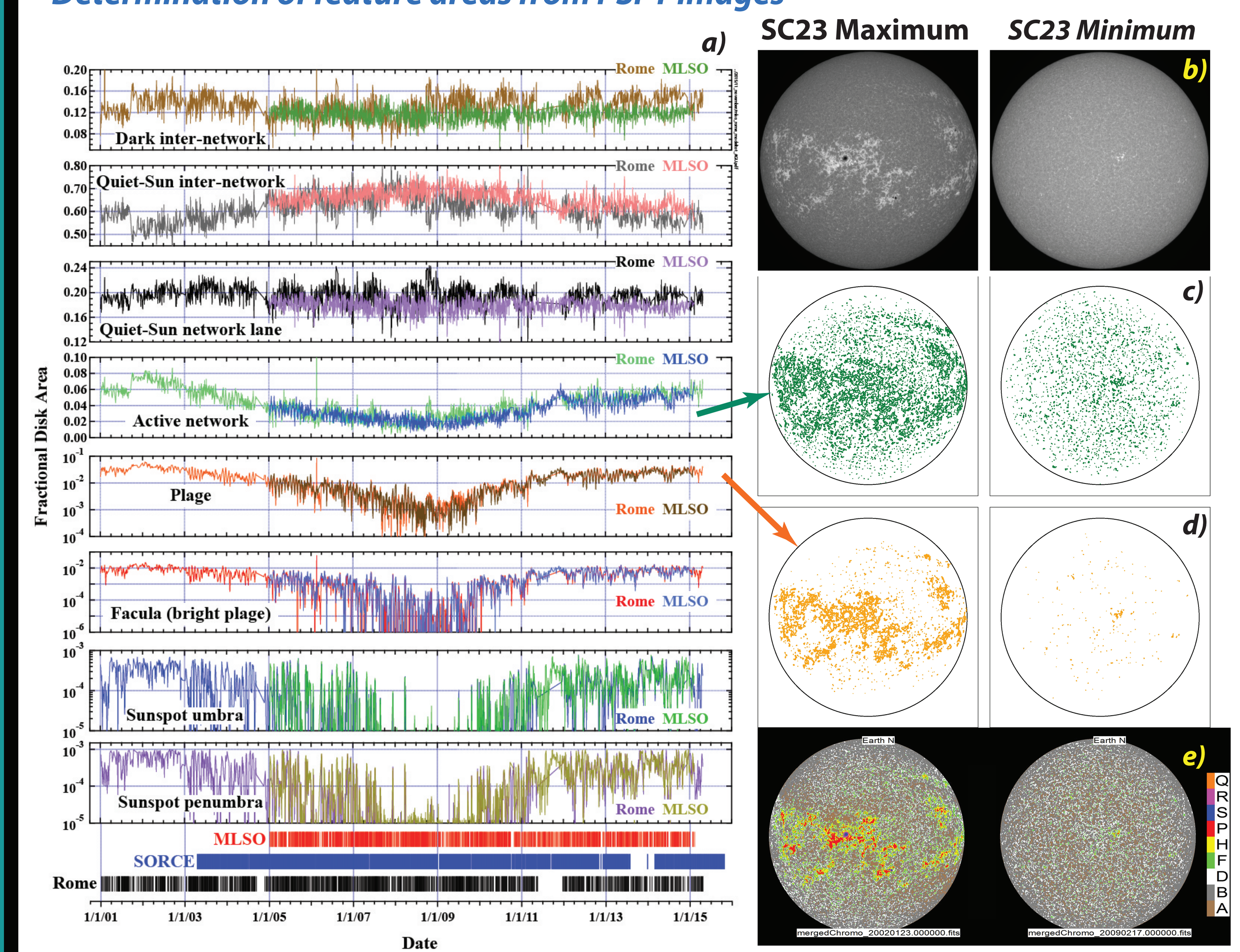
Project Goal 3: In-depth comparison of SORCE observations with SRPMv2



SRPM combines solar feature areas with physics-based solar atmospheric spectral models at high spectral resolution to compute the emergent intensity spectrum

This project will use images from 3 sources:
- Rome PSPT (courtesy of Ilaria Ermolli, Rome Observatory, OAR)
- Mauna Loa PSPT (courtesy of Mark Rast, Mauna Loa Solar Observatory, MLSO)
- AIA images processed during the rising phase of Cycle 24 as part of Fontenla's SERFS project
  - (http://www.galactitech.net/John/SERFS/Images/)
  - AIA image processing particularly valuable since MLSO images are currently unavailable.

Determination of feature areas from PSPT images



Thresholds for determining solar features for bright and quiet sun contributions are found from convolving the PSPT filter function with the radiated emission from each model separately and accounting for the center-to-limb variation in 10 annular rings in the image.

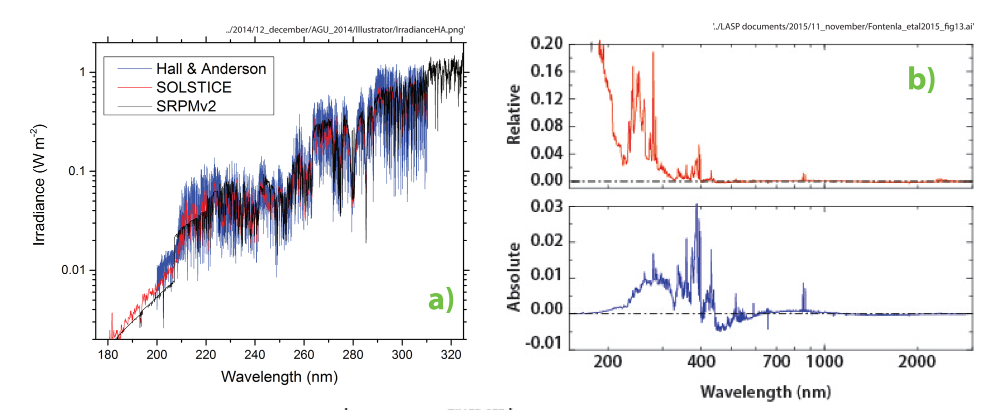
Description of panels a) through e):

Panel a:
- The time series of the eight features identified in PSPT images from Rome Observatory and Mauna Loa Solar Observatory covering the range from 2001 to the present.
- The bottom segment of this panel shows the combined observation record for PSPT & SORCE. These three observations will allow complete daily coverage of SC 23-24 without a gap in the record.

Panel b:
- Ca II images from Rome PSPT for solar maximum (2002/01/23) and solar minimum (2009/02/17)

Panel c/d
- Contributions from active network and plage structure on the Sun are shown separately in these two panels.
  - Active network shows a lower rotational modulation than the brighter plage and facular regions.
  - From panel a), the network contribution changes over the solar cycle by about a factor of 2.4 whereas the plage contribution changes by a factor of 5.5.
  - Active network plays an important role in determining the depth of the solar cycle minimum and has a different contribution in every solar cycle.

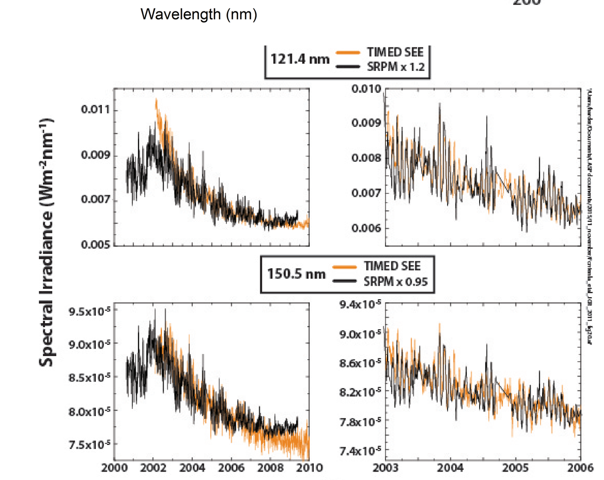
Panel e:
- SRPM data masks showing the combined 8 contributions.



Spectral Synthesis with SRPM:

Panel a)
Significant improvements in the MUV by identifying and including sources of 'missing' opacity
Improves agreement with the 0.1 nm resolution SOLSTICE spectrum

Panel b)
Computed spectral variation of the SSI between SC23 max and SC23 min.



Observations compared to SRPM

Panel c)
Comparison in the FUV. Variability dominated by chromospheric and low transition region emissions