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

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Project Goals

Goal 1: Solar Spectral Irradiance (SSI) input for Chemistry Climate Models (CCM)

- Produce a daily SSI composite spectral record suitable for CCM transient studies over Solar Cycle 23 and 24.
- This record mostly based on observed irradiance of SORCE SIM and SOLSTICE

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

- CCM’s requires very broad wavelength coverage (110-100,000 nm), compliance of the integrated spectrum with the TSI, and uncertainty estimates
- Record extended in wavelength and gap-filled in time with SRPM
- Image preparation in progress

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

- Please see Eugene Avrett’s presentation later in this session
Project Goal 1: SSI for CCM studies

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 assets & 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
Project Goal 2: Produce a daily SSI record

- SSI record requires:
  1. Very broad wavelength coverage (110-100,000 nm)
  2. Documented uncertainty estimates
  3. Compliance of the integrated SSI record with the TSI

1) Composite Components:

![Graph showing spectral irradiance vs wavelength with different data sources and their wavelength ranges.]

<table>
<thead>
<tr>
<th>Spectral Source</th>
<th>Wavelength Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOL MUV/FUV</td>
<td>115.5-239.5</td>
</tr>
<tr>
<td>SIM/SOL MUV</td>
<td>239.5-307.2</td>
</tr>
<tr>
<td>SIM Vis1</td>
<td>310-947.5</td>
</tr>
<tr>
<td>SIM IR</td>
<td>952.5-1600.</td>
</tr>
<tr>
<td>SIM ESR/SRPM</td>
<td>1600-2400.</td>
</tr>
<tr>
<td>SRPM</td>
<td>2400-100000</td>
</tr>
</tbody>
</table>

- Spectral composite extends over ~ 8 of magnitude in irradiance and ~3 orders of magnitude in wavelength
Project Goal 2: Degradation analysis for SIM V22-to-V23

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

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

<table>
<thead>
<tr>
<th>Observation form Version 22 analysis</th>
<th>Version 23 activity</th>
</tr>
</thead>
</table>
| • Rate of degradation evolves as a function of time. Most likely caused by slow exhaustion trace materials that adhere to the surface of the prism and cause degradation
• Therefore solar exposure alone will over-estimate degradation. | • Analyze single wavelengths where time series is expected to be flat (691 nm). Adjust exposure time to ensure flatness, then recalculate kappa based on this exposure time
• Extend analysis into UV and IR |

Save-hold events induce changes in prism light path thereby changing the transmission of the instrument. Breaks the coherence of the SIM A & B spectrometers. Instrument trending different after safe-hold events

• Modify ray path \(a_{\text{detector}}\) to remove changes in local degradation slope.

*Every change triggers a compete mission reprocessing*

Please See Stéphane Béland’s Poster for more details
Project Goal 2: 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.
Project Goal 2: Compliance with TSI

- A correction factor will be developed to ensure integrated SSI matches the TSI (to conserve total energy in model studies).
- Application of correction factor will be a user option.

3) Final composite will contain time & wavelength uncertainty estimates
- Noise equivalent irradiance (day-to-day noise)
- RMS differences from SIM A-to-B comparisons
- Additional analysis of uncertainties at safe-hold boundaries
Project Goal 3: SRPM spectral synthesis

- 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)
  - 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.
Project Goal 3: PSPT feature masks

- PSPT=Precision Solar Photometric Telescope
- Good agreement achieved between the two PSPT sites; combination provides complete overlap with SORCE and extends back to solar maximum time period
- AIA to be included after 2010 to supplement PSPT feature masks
Project Goal 3: SRPM status

Photospheric

Cononal

Near UV

- Significant improvements in the MUV by identifying and including sources of ‘missing’ opacity.
- Improved agreement with SOLSTICE 0.1 nm

- Computed variation of the SSI between the SC 23 maximum (2001/05/17) and SC23 minimum (2008/09/15) for SRPMv2
Project Goal 3: Observations compared to SRPM

- From SRPMv1, but v2 should have same response in visible & IR
  - SIM Version 22
  - Variability dominated by photospheric and lower chromospheric emissions

- Adapted from Fig 20, Fontenla et al. (2011), JGR
  - Variability dominated by chromospheric and low transition region emissions
Summary/Actions moving forward

1. Data processing through the SORCE project continues,
2. SIM Version 23 explores alternate methods of evaluating the degradation model. The most recent SOLSTICE processing will also be applied.
3. Accumulating, curating, and refining PSPT images is in process
4. Spectral synthesis using SRPMv2 from this image set will occur in 2016. Comparison studies will begin after image record is completed.
   – Cycle 23 will be emphasized first half of 2016, Cycle 24 study intended for the second year of this effort.