Modeling the solar spectral irradiance

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I Introduction

Modeling the solar spectral irradiance is necessary for different fields: solar, atmospheric and climate physics. In general, the reconstructions aim to generate the solar spectral irradiance (SSI) at a time where no measurement exists. Therefore, they are based on different solar indicators (named proxies), which have the property to correlate their variations with the SSI variation. The long term reconstructions are used in Climate science to study some particular epochs such as the Maunder minimum or the optima of the Middle age. However, reconstructions can be also used to fill a gap in a SSI time series due to a temporary interruption of an instrument operation in space. As in this case many proxies are available, it is expected that filling the gap by modeling will produce precise results.

Reconstructions are also used in the field of Earth and planetary atmosphere physics as the relevant space missions started in the 60's (*e.g.* the Orbital Geophysical Observatory series), *i.e* before the solar space missions were able to produce SSI time series. Here also, using moderm proxies allow production of precise SSI, which are the necessary input to the atmophere models. Then, the output of such models are compared to the measurements permitting validation of the photochemical processes implemented in the models.

Solar reconstructions employ different means leading to simulations either theoretical, semi-empirical or fully empirical methods. For the past periods, their inputs are generally the sunspots number, the cosmogenic isotopes concentration variation obtained from tree rings, and ice core soundings. These proxies constitute time series more or less without gaps, and have variable accuracy and precision generally time dependent. These proxies are the basic inputs of most of the models.

II Comparison between different reconstructions on short time scale

Comparison of short terms reconstructions with measurements allows us to evaluate the quality of the reconstructions. On the International Space Station (ISS), the SOLSPEC and SolACES instruments are in operation. Due to several constraints, the solar pointing is not achieved between 4 to 15 days per month, season dependent. The minimum gap occurred at solstice. Nasa and ESA have studied a change of the ISS attitude to fill the 4-day gap allowing a continuous solar rotation observation. This plan was first applied in December 2012. SSI data were simultaneously gathered by several spectrometers (SOLSTICE and SIM onboard SORCE, SolACES and SOLSPEC onboard the ISS, PREMOS onboard PICARD). These measurements and several reconstructions were compared for the solar Carrington rotation 2131 time frame. Given the solar rotation, the SSI presents a variation as a function of the day. The models used in this study are listed below.

In the UV:
MOCASSIM (Bolduc *et al*., 2012), MGNM (Thuillier *et al*., 2012), NRLSSI (Lean, 2000), SATIRE (Krivova *et al*., 2011), SEA (Shapiro *et al*., 2011), COSIR (Cessateur *et al*., 2014).

In the EUV: NRLSSI (Lean *et al*., 2011), SOLMOD (Haberreiter, 2011).

For the EUV and UV spectral domains, days of maximum and minimum SSI are found in agreement within one day with the measurements. The maximum to minimum SSI ratio during the solar rotation derived from the simulated SSI and from the measurements are compared:
In the EUV domain, these ratios are found wavelength dependent and greater than the observations (about 20%). Simulated absolute intensities need some adjustments (around 25 %), which is generally due to the reference spectra used in the reconstruction. Generally, empirical or semi-empirical models provide results closer to the measurements than theoretical models.
In the UV domain, we have carried out a detailed comparison at 215 nm. Variability is found around 1.01. With respect to the measurements, reconstructions variability may differ by about ± 0.002. As for absolute SSI predictions, they may differ by 10 %. A detailed analysis and discussion of these results are given by Thuillier et al. (2014).

III Comparison between different UV reconstructions on long time scale

The UV models used in the previous section are employed to simulate SSI at different epochs chosen at solar maximum and solar mininimum activity down to the 17th century. These reconstructions based on different solar proxies, are used to compare their properties in terms of variability and absolute value SSI. There is a general consensus in terms of variability and absolute values, however, the differences between models tend to increase toward the past and the shorter wavelength ranges. Reconstructed spectral irradiance and variability predictions have a certain consistency at the 5% level. However, at certain periods such solar minimum activity, SSI divergent predictions occur. Furthermore, spectral features generated by a model and not generated by the other models are kept whatever the simulated epochs. A detailed analysis and discussion of these results are given by Thuillier et al. (2013).

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