Calculations of Solar Irradiance:
monthly means from 1882 to 2008, annual means from 1610 to 2008
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Files of total solar irradiance:
TSI_WLS_ann_1610_2008.txt, TSI_WLS_mon_1882_2008.txt
Files of annual solar spectral irradiance:
spectra_1610_2000a.txt, spectra_2000_2008a.txt
Files of monthly solar spectral irradiance:
spectra_1882_2000m.txt, spectra_2000_2008m.txt

The overall approach for estimating past changes solar irradiance, both total and spectral, involves the parameterization of an observed (i.e., recent) time series of irradiance either spectrally integrated (i.e., total) or at a given wavelength (in a 1 nm bin) in terms of the proxy indicators needed to represent the known wavelength-dependent sources of variability in that time series. For total solar irradiance and for the spectral irradiance at wavelengths longer than 300 nm there are two main sources of variability, the dark sunspots and the bright faculae, which are represented by, respectively, the sunspot blocking function and the Mg index. The sunspot blocking function is obtained from visible-light images of the position and areas of individual sunspots on the Sun's disk (*Lean et al., 1998*) and the Mg index is obtained by extending the *Viereck et al (2004)* composite record with the cross-calibrated SORCE Mg index of *Snow et al. (2005).* For wavelengths from about 30 to 300 nm, the variations are primarily caused by emission from bright plages (alone), which approximately overlay the visible faculae, and the Mg index is used as a proxy for the sources of these variations. For the parameterizations of the shortest EUV and X-ray emissions (mainly at wavelengths below about 27 nm) the 10.7 cm radio flux is also used, in addition to the Mg index, to account for emission from hot coronal plasma overlying the bright plage.

The model of total solar irradiance variations is determined by direct multiple regression of the sunspot and facular time series with a time series of TSI, as described in *Fröhlich and Lean (2004).* The specific parameterization used for these reconstructions is that given in *Fröhlich and Lean (1998)* and *Lean (2000),* which used the PMOD composite available at that time, but the derived components are relatively independent of which of the available composite time series (PMOD, ACRIM, SARR) is used. Furthermore, the partitioning of the sunspot and facular signals is almost identical when just the SORCE/TIM data are used: even though the SORCE data commenced only in 2003, the TIM factor of three higher precision than prior measurements enables ready and reliable separation with a shorter time series that is needed for measurements of lesser precision. The absolute scale of the TSI reconstruction is that of the PMOD composite – to transfer the time series to the TIM scale (recommended because of the TIM's higher accuracy, verified by NIST), multiply by 0.9965.

Because the measurements of the solar spectral irradiance have traditionally suffered from various types of wavelength-dependent instrumental degradation, and because the time series are insufficiently long (nor adequately precise) to reliably cover a number of solar cycles, the multiple regression that determines the relative contributions of the sunspot and facular proxies to the observations is undertaken using multiple regression of detrended time series (long term trends are removed from both the proxies and the irradiance prior to performing the multiple regression), as described in specifically for the UV spectrum. In essence, this means that the associations are determined from a subset of the range of possible variations. The reconstruction of the irradiance from the proxy indicators (using the proxies themselves, i.e., not detrended) therefore assumes that the proxies and the irradiance behave in similar ways over both rotational and solar cycle time scales. This direct multiple regression approach is applied to the wavelength range 120 to 300 nm using the UARS/SOLSTICE data and to the wavelength range 0 to 120 nm using the TIMED/SEE data. For wavelengths longer than 300 nm, where there are no measurements prior to 2003, the spectral dependence of the variability is determined from the spectral dependence of the sunspot blocking and facular brightening, as described in detail in *Lean (2000).* The total irradiance from 120 to 100000 nm is constrained in absolute magnitude such that the total equals the actual bolometric observations of total solar irradiance (modeled separately). Thus the spectral and total irradiance changes are reconstructed self-consistently. The absolute scale of the solar spectral irradiance reconstruction is such that the integral matches the PMOD composite – to transfer the time series to the TIM scale, multiply each spectral band by 0.9965 (note that this factor is much smaller than the absolute uncertainties in the solar spectral irradiance measurements).

After about 1950, solar activity levels during minima have been approximately level, according to the 10.7 cm radio flux (i.e. the solar irradiance at wavelength of 10.7 cm). The key uncertainty in reconstructing irradiance prior to 1950, when there were no direct irradiance measurements at any wavelengths, is the lack of knowledge (and understanding) of longer-term irradiance variations that may underlie the 11-year activity cycles, and vary slowly as solar activity evolves over multi-decadal time scales. Since sunspot observations are available since 1610, and do not show a significant long-term trend, the origin of a slowly varying irradiance components, if it exists, derives from changes in faculae (others have also speculated that long-term changes in the solar interior may also produce secular irradiance changes). While such longer-term variations are speculated, they have not yet been detected in the observational record (which is thus far too short and not sufficiently precise). The variations in the assumed background component used in these reconstructions are based on simulations using a solar flux transport model of the long-term evolution of the Sun's total magnetic flux in response to changing magnetic fields, indicated by the sunspot numbers, as described by *Wang et al (2005)*. The flux transport simulations indicate that the amplitude of the background component is a factor of 4 to 5 smaller than had been assumed in prior reconstructions based on variations in Sun-like stars (e.g., the long term variations in *Lean et al., 1995* and *Lean 2000*). As a result, and described in *Lean et al (2005),* the most recent reconstructions of total and spectral irradiance have a varying background facular component whose magnitude is reduced by 0.27 compared with the facular component adopted in the earlier reconstructions of *Lean (2000).* In the present reconstruction, which was reported in IPCC AR5, this varying component tracks the smoothed (11-year) sunspot numbers.

Because of the uncertainty in the background component, two time series are provided for total solar irradiance; one for just the 11-year cycle alone, and a second with the 11-year cycle plus the varying background. The TSI record can thus be altered if it is desired to investigate scenarios with altered backgrounds.

Further documentation of the approach is given in:

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