Constraining Holocene solar forcing by "detection and attribution"

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Understanding climate change requires quantification of the major forcing factors (e.g. solar, volcanic, greenhouse gases). At the PAGES' Solar Forcing working group's first workshop in 2012 we addressed the role of solar forcing by trying to quantify it and then feed the results into climate models. The resulting model runs were then compared with paleoclimatic data. This approach turned out to be unsatisfactory for two reasons.

First, direct satellite based measurements of the total solar power arriving at the top of the atmosphere (total solar irradiance, TSI) and its spectral distribution (spectral solar irradiance SSI) have only been available since 1978. Because the Sun has been in a state of very high activity during this period all our detailed instrumental information about the Sun is not representative for periods of normal or low activity such as the Maunder minimum (1645-1715 AD). Also, as a result of degradation effects and discrepancies between different types of instruments there is still no generally accepted composite of TSI even for the instrumental period.

As physical solar models are not yet capable of reproducing observed solar variability, and in particular long-term TSI and SSI changes, the only information on decadal to millennial scale changes in solar activity available today is based on cosmogenic radionuclides such as ^{10}Be and ^{14}C. Although these reveal the relative level of solar activity, converting this into a quantitative solar forcing in Wm^{-2} remains unsolved. This is the reason why published TSI reconstructions usually resemble each other in shape but have a large spread of amplitudes (Fig. 1).

The second complication in assessing the role of solar forcing is that quantifying the climate's response to solar forcing is difficult. For example, it seems that SSI plays an important role in atmospheric chemistry and dynamics. But in order to study its effect, quantitative data for all forcings and reliable long-term paleoclimate records for model validation are needed – both of which are currently unavailable at the required quality. Also, different models respond differently to the same forcing change, raising the fundamental question of whether all relevant feedback processes of the climate system have been implemented correctly.

These difficulties motivated us to "put the cart before the horse" and to investigate ways to assess the role of solar forcing directly from paleodata. One challenge of this detection and attribution approach is to detect those climatic events in the past which can unambiguously be attributed to solar forcing changes. This requires a large number of millennial scale records of well-dated paleodata with high temporal and spatial resolution. Fortunately such work is in progress (e.g. the PAGES 2k initiative) and promising new paleodata were presented during the workshop.

Another challenge of this approach is that the state of the climate system at a specific point in time reflects the integral response of the system to all forcings. For example, periods of low solar activity (e.g. Dalton minimum, 1790-1830) can coincide with volcanic eruptions (e.g. Tambora, 1815). Furthermore, due to feedback mechanisms, forcings can also affect the climate system long after their initial occurrence.

To tackle these issues, the workshop participants recommend:

- Choosing periods of extreme solar activity that show minimal interference with volcanic eruptions for solar signal detection and attribution exercises.
- Using the fact that solar forcing has cyclic components with well-defined periodicities to discriminate between solar and volcanic forcing
- Identifying regions of high sensitivity for solar forcing based on existing paleodata and model runs. New local paleodata should be produced for these regions.
- Intensifying efforts to forward-model paleodata.
- Not using hemispheric or global mean temperature, because these average out regional changes and shifts in climatic features.

This was the last workshop of the PAGES Solar Forcing Working Group. The outcome of this and of the previous meetings will serve as the basis for the Solar Working Group synthesis product consisting of several publications.

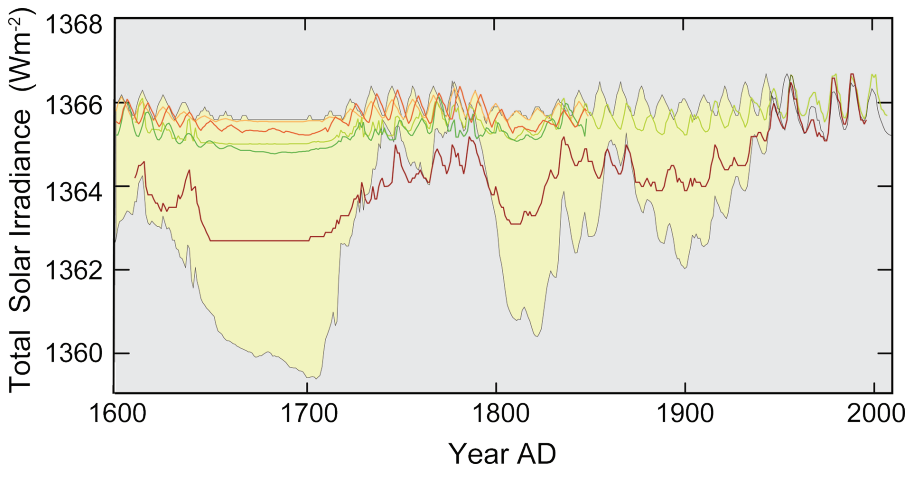

Figure 1: Seven reconstructions of total solar irradiance for the past 400 years (for details see Schmidt et al. 2012).

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REFERENCES

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