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Variability of the Sun

The Sun is the powerhouse that drives the Earth’s climate. No understanding of climate change is possible without an understanding of the behavior of the Sun.

5.1 SOLAR IRRADIANCE

5.1.1 Introduction

We know from geological evidence that, over the past million years (and more), the Earth has gone through many thermal cycles of glaciation ("Ice Ages") and intervening warm periods. It is widely believed that variations in the Earth’s orbit are associated with these climate changes, although the correlation of models with geological data is not perfect (Rapp, 2012). Other factors, including variation of solar irradiance, may also be involved. The last great Ice Age peaked some 20,000 years ago and we have been in a post-glacial warming period for the past 11,000 years.

We also have evidence that, over the past millennium or so, there have been smaller fluctuations in the Earth’s climate. The Medieval Warm Period (MWP) and the Little Ice Age (LIA) represent fluctuations during this time period. Since these events occurred prior to the recent major industrialization, they were due to land clearing and naturally occurring phenomena, possibly variations in total solar irradiance (TSI), changes in ocean currents, and, for short periods, volcanic eruptions.

Today, we are in a period of global warming, and it is not immediately clear whether long-term variability of the TSI might have contributed significantly to this effect. The Earth is clearly warmer in the early 21st century than it was in any period over the past 500 years or so. How much (if any) of this could be due to an increase in TSI?

It has often been assumed in the past that the TSI is quite constant over long time periods, and, indeed, many papers and books refer to the “solar constant”. However, there is no experimental basis for this assumption. Since 1978,
measurements of TSI have commenced in space. While relative variations in TSI are measured with apparently high precision, absolute calibration has been more difficult (Scafetta, 2009). Nevertheless, we have seemingly good relative measurements of TSI over a period of about 30 years (see Figure 5.1). These measurements indicate that the TSI varied slightly (about 0.1%) over the past few 11-year solar cycles. However there are no data prior to 1978. As Krivova et al. (2009) emphasized: “Solid assessment of the solar forcing on the Earth’s climate is still plagued, among other factors, by a shortage of reliable and sufficiently long irradiance records.” If we simplistically extrapolate these data backward in time, such variations appear to be too small to explain the temperature variations in the MWP or the LIA. Woods (2008) reported recent results from a new satellite that monitors the Sun with significant new instrumentation (Total Irradiance Monitor (TIM) on the Solar Radiation and Climate Experiment (SORCE) satellite). Their absolute calibration indicated that the average TSI is about 1.361 W/m² as compared with a previously indicated value of 1.365 W/m². The new instruments measure spectral distribution in addition to TSI. A very interesting finding from the new instruments is that, during the course of an 11-year solar cycle, while the TSI only varies by about 0.1%, the irradiance in the UV part of the spectrum varies by about 10 to 30 times more than that (Krivova et al., 2009). It is not immediately clear what effect this might have on the Earth’s climate. Krivova et al. provided a good summary of what is known about spectral irradiance. Kopp1 set up a calibration system for instruments that measure TSI. His estimates for the best approximation to TSI are shown in Figures 5.1 and 5.2. Kopp and Lean (2011) concluded:

“The most accurate value of total solar irradiance during the 2008 solar minimum period is 1360.8 ± 0.5 W/m² according to measurements from the TIM ... and a series of new radiometric laboratory tests. This value is significantly lower than the canonical value of 1365.4 ± 1.3 W/m² established in the 1990s, which energy balance calculations and climate models currently use. Scattered light is a primary cause of the higher irradiance values measured by the earlier generation of solar radiometers in which the precision aperture defining the measured solar beam is located behind a larger, view-limiting aperture. In the TIM, the opposite order of these apertures precludes this spurious signal by limiting the light entering the instrument.”

While this changes the absolute calibration of the TSI, the relative change across solar cycles remains as previously understood. A number of graphs in this chapter are tuned to the previous calibration of the TSI and, these should be scaled back by the factor 1361/1365. However, the absolute values of TSI are not very important. The changes in TSI over time are of the greatest interest.