The far-side solar magnetic index

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Abstract. Several magnetic indices are used to model the solar irradiance and ultimately to forecast it. However, the observation of such indices are generally limited to the Earth-facing hemisphere of the Sun. Seismic maps of the far side of the Sun have proven their capability to locate and track medium-large active regions at the non-visible hemisphere. We present here the possibility of using the average signal from these seismic far-side maps as a proxy to the non-visible solar activity which can complement the current front-side solar activity indices.

1. Introduction
Photospheric features of solar activity account for a large portion of the Total Solar Irradiance (TSI) variation, with a superimposed modulation due to the solar cycle [1]. Magnetic indices related to photospheric activity, such as the Mount Wilson Plage Strength Index (MPSI) and the Mount Wilson Sunspot Index (MWSI), as well as magnetic activity proxies such as \( F_{10} \), MgII and Ly-\( \alpha \) have been traditionally used as input to the modeling and prediction tools for TSI [2,3] and ultraviolet and extreme ultraviolet (UV/EUV) irradiance [4,5]. However, at each particular point in time, these indices contain information of the magnetic activity only for the solar hemisphere facing the Earth.

In this paper, we introduce the idea of using a Far-Side Magnetic Index (FSMI) to complement the front side ones. The FSMI is an integrated value over the full non-visible hemisphere calculated by averaging the seismic signal (phase-shift or travel time difference) produced by surface magnetic activity, namely plages and sunspots, on the waves. That is, a proxy to the photospheric magnetic activity in the far-side of the Sun.

2. Helioseismic far-side maps
Maps of the non-visible disk (far side) of the Sun calculated using the seismic holography technique [6,7] are able to detect medium-large active regions before they rotate onto the visible hemisphere. The Global Oscillations Network Group (GONG) project has been producing daily far-side maps of magnetic activity since 2005 that are available at http://gong.nso.edu/data/farside. In the last few years, new research has been incorporated resulting in an improved signal to noise in the far-side maps as well as the calibration of the signal in terms of magnetic field strength. Far-side maps showing a particular active region on the 5 and 9 of September 2010 are presented in Figure 1. These maps contain a single candidate, automatically highlighted by the process when the probability of appearance [8] is greater than
Figure 1. GONG far-side maps showing a single active region in the same heliographic coordinates on September 5 and 9 2010. Active region NOAA 11106 appeared on the East limb of the Sun on September 11 2010 at the same location.

70%. Active region NOAA 11106 appeared on the East limb of the Sun on September 11 2010 at the predicted location.

3. The far-side magnetic index (FSMI)
An integrated index of Far-Side Magnetic Activity has been calculated as an average of each individual helioseismic far-side map. We have arbitrarily ignored the positive phase shift in the maps and integrated only over the negative values, associated with magnetic features. Figure 2 shows the temporal variation for the period covering October 2002 to December 2006, the descending phase of solar cycle 23. The FSMI is shown as a running mean of 10 days to decrease the noise. A large increase in the FSMI can be seen associated to the large active regions that produced the Halloween flares in 2003.

The seismic far-side maps have been shown to be affected by a solar cycle variation, similar to the superimposed cycle modulation found in TSI measurements. In the case of the seismic maps, this cycle modulation has been associated to either global or localized structural changes in the solar convection zone [9]. To remove this variation each individual map is corrected by removing a 60-days average.

Figure 3 shows simultaneous observations of Ly-α (lasp.colorado.edu) and F10 (www.ngdc.noaa.gov), the calculated Mount Wilson Sunspot Index (www.astro.ucla.edu) and the Far Side Magnetic Index. The sequence spans from October 2002 to December 2006. The different indices have been scaled and shifted to aid the comparison.

The 27-day modulation due to the solar rotation is seen in both the front-side indices and the
Figure 2. FSMI from October 2002 to December 2006. The far-side calculated index is shown as a running mean of 10 days to decrease the noise. There is a clear spike associated to the October-November 2003 large active regions that produced the Halloween flares.

far-side one. Two particular scenarios have been highlighted (A and B) for which the far-side index shows an increase after (A) and before (B) the front-side indices reflect it. This time lag between the front-side indices and the far-side one is expected, as the active regions move from the front to the far side of the Sun and vice-versa.

4. Towards a global solar magnetic index

Since active regions emerge and decay in a semi-random manner on both the front and far side of the Sun, a correlation between the two data sets to infer a time lag and ultimately calibrate the index is not trivial, since it will be positive for certain periods, negative for others, and a complex mix for periods of high activity. In general, we expect to find a larger correlation between the FSMI and those indices that are proxies to large magnetic areas in the photosphere and lower chromosphere. To be able to compare these indices directly with the seismic signal due to photospheric activity, we need to calculate farside-like maps of the front side of the Sun, that is, use the same technique to map active regions in the front-side. That way, the integrated indices can be obtained simultaneously.

Although the seismic holography technique maps magnetic fields at the photosphere, a direct comparison of the far-side seismic maps with the chromospheric images (HeII 30.4 nm) of the EUVI instrument (STEREO-SECCHI), once the AHEAD and BEHIND spacecrafts cover the full far-side of the Sun would be interesting to complement the analysis. Future work also includes the calibration of the FSMI in terms of Ly-α, by comparing a front-side hemisphere seismic index with Ly-α simultaneous observations.

It has been shown that short term forecasting of UV irradiance can be improved when adding far-side seismic maps [10]. We expect that the integrated Far Side Magnetic Index will also help to complement the front-side indices for more accurate forecasting of solar irradiance.

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Figure 3. Simultaneous observations of Ly-α (lasp.colorado.edu), F₁₀ (www.ngdc.noaa.gov), the calculated Mount Wilson Sunspot Index (www.astro.ucla.edu) and the Far Side Magnetic Index. The sequence spans from October 2002 to December 2006. The different indices have been scaled and shifted in the Y axis to aid the comparison.

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