Farside Imaging of the Sun – A Crucial Component in Future Space Weather Forecasting.

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Background: The measurement of magnetic activity on the solar surface is a crucial element of modern space weather forecasting. The nearside regions of high magnetic concentration (known as active regions) can be directly observed while for the farside regions, at present, we mostly rely on indirect methods. Farside maps are produced by applying techniques in local helioseismology. These farside maps have been very successful in forecasting the strong active regions prior to their arrival on the frontside. Figure 1 shows an example, in the identification of NOAA 12786 (region R2 in the figure), the strongest active region of the current cycle 25 so far, about eight days before it rotated to the Earth-side view[1]. These maps also allow us to track the evolutionary changes in active regions after they disappear from Earth's view, hence for a longer period (Figure 1, region R1).

The successful predictions of the size, strength, location, and arrival time of active regions on East limb of the Sun are important for forecasting energetic space weather events near the limb as well as improving global magnetic field models. Farside imaging may also provide a long-term forecast of UV flux, which is an important component for the atmospheric drag for LEO satellites. Observations clearly demonstrate that active regions are the sources of most highly energetic flares, and these flares produce CMEs, SEPs etc. that directly impact the space environment. In addition, initial studies show that solar-wind[2] and irradiance forecasts can be improved by including the farside.

Current Status: Farside helioseismic mapping is being routinely done using the ground-based observations from Global Oscillation Network Group (GONG) as well as the space observations from HMI onboard *SDO*. These maps are computed by employing phase-sensitive seismic holography[3]. This technique is based on the principle that there is a phase shift (travel time delay) between waves going into and out of a region of high magnetic field concentration.

One of the major requirements for reliable farside maps is the high duty cycle (>85%) in the helioseismic observations. A recent study based on 18 years of GONG observations shows that such high duty cycle can usually be achieved with a ground-based network of 6 sites[4]. Reported mean and median in this study are 93.5% and 97%, respectively. This duty cycle is similar to instruments on a GEO due to periodic eclipses.

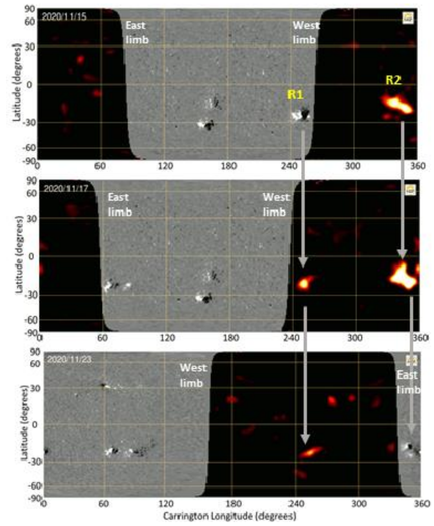

Figure 1: Farside helioseismic maps (black background) and frontside magnetograms (grayscale) derived from GONG observations for three days. Top (2020-11-15): Region R1 (NOAA 12781) is about to cross the West limb while a strong active region R2 has emerged on the farside, Middle (2020-11-17): strong helioseismic signature indicating the presence of R1 after crossing the limb while R2 continues to grow, Bottom (2020-11-23:) R1 is still present on the farside even after a week of its crossing the West limb and R2 appeared on the East limb as NOAA 12786. R1 later returned to frontside on 2020-11-30 as NOAA 12790.

Future Directions: Farside maps can be refined by improving the sensitivity of measurements and developing new approaches to decrease the noise level for better interpretation of farside maps in respect to magnetic flux. This will allow us to improve the detectability of active regions on farside and quantify the probability of their emergence on the Earth-side, thus enabling better characterization of their EUV irradiance and flaring potential. It is important to mention that the existing GONG network has been operational for more than 25 years and needs to be upgraded with improved capabilities. ngGONG is such an endeavor proposed jointly by NSO and HAO.

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References:[1] Jain K., Lindsey C. and Tripathy S.C. (2021) *RNAAS, 5*, 253. [2] Arge C. N. et al. (2013) *Amer. Inst. Phys. Conf. Ser.*, *1539,* 11-14. [3] Lindsey C. and Braun D. (2017) *Space Weather 15,* 761-781. [4] Jain K. et al. (2021) *PASP 133,* 105001.