IMPROVING POLAR FIELD OBSERVATIONS FROM THE GROUND G. J. D. Petrie[1], A. A. Pevtsov[1], A. R. Marble[2,3] and V. Martínez Pillet[1], [1]National Solar Observatory, 3665 Discovery Drive, Boulder, CO 80303, [2]Cooperative Institute for Research in Environmental Sciences, CU Boulder. [3]NOAA Space Weather Prediction Center, 325 Broadway, Boulder, CO 80305

The Sun's polar magnetic fields dominate the global structure of the corona and heliosphere [1], and the Earth spends most of the solar cycle magnetically connected to the polar coronal holes [2]. However, the polar fields are difficult to observe from (near) Earth [1]. Their magnetic configuration is relatively simple with predominantly near-vertical field lines, but this corresponds to transverse field orientations as seen from Earth, where the polar fields are observed with a large (>80°) viewing angle. Moreover, the ~kG facular fields that dominate the poles are small (~5″ across as observed from Earth) and sparsely distributed: the overall polar field is only of order 10 G [3]. The Zeeman effect makes these transverse signals much harder to observe than the longitudinal ones; typically, sensitivity to transverse fields is one order of magnitude lower [4]. This reduced sensitivity renders the polar fields relatively poorly constrained in our current modeling efforts.

The Global Oscillations Network Group (GONG) instrument was initially designed to measure Doppler velocities. Magnetograms were added later using a half-wave plate, but the instrument design is not optimal for this application. The instrument has issues with the magnetic zero-point that needs constant monitoring in the reduction pipelines. Moreover, GONG provides only line-of-sight (LOS) fields, unlike the Synoptic Optical Long-term Investigations of the Sun Vector Spectro-Magnetograph (SOLIS/VSM) [5] and NASA's Solar Dynamics Observatory Helioseismic and Magnetic Imager (SDO/HMI) [6]. Increased magnetic sensitivity, resolution, and well-calibrated vector capabilities are mandatory for improved solar wind modeling. This is particularly relevant for the solar polar regions, where all current synoptic data fail to provide satisfactory sensitivity [7], and for addressing the "open flux problem" [8], the persistent underestimation of the radial interplanetary magnetic field by heliospheric models using surface magnetograms. This problem has been linked to issues with polar field data [9] but, in contrast, [10] found larger discrepancies under solar activity maximum than minimum conditions.

High-resolution measurements are available from the Hinode Solar Optical Telescope Spectro-Polarimeter (SOT/SP) every March and September using visible spectral lines [3], and less frequently from, e.g., the Tenerife Infrared Polarimeter (TIP II) [11] at the 70cm Vacuum Tower Telescope (VTT) using the Fe I infrared (IR) lines near 1.56 micron. These IR lines have sensitivities to LOS fields twice that of visible lines used by the VSM, HMI and SOT/SP, and four times higher for transverse fields [12], besides smaller image disturbances from the Earth's atmosphere. Indeed, [13] found some evidence of reduced signal in SOT/SP vector data at the highest latitudes. The Daniel K. Inouye Solar Telescope's (DKIST) 4m mirror will enable its spectro-polarimeters to resolve facular structures well, at visible and IR wavelengths, all the way to the pole, in the photosphere and chromosphere, but with limited spatio-temporal coverage.

To improve polar field observation from the ground, we estimate that a telescope with a 50cm aperture is required to collect enough photons to achieve the necessary (10^{-4}) polarization sensitivity, and to measure the line-of-sight field with a sensitivity of 1 G per 0.5″ pixel, with ground-layer adaptive optics to achieve 1″ spatial resolution with stable image quality. A full-disk spectro-magnetograph similar to the SOLIS/VSM observing the Fe I line at 1564.8 nm and the He I line at 1083.0 nm, could give photospheric and chromospheric coverage with the required sensitivity.

A network of such telescopes (e.g., next-generation GONG, or ngGONG) would produce data essential to the security and reliability of the nation's technology vulnerable to space weather, complement other ground-based solar physics facilities such as DKIST, and improve real-time modeling of the heliosphere, which is also crucial for encounter, multi-messenger missions such as Parker Solar Probe and Solar Orbiter.

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