Remote sensing of magnetic fields around the Earth

Outside of the laboratory, geomagnetic fields have never been remotely sensed (Patton et al., 2012). This is in sharp contrast to stellar magnetic fields (Zirker, 2009). If geomagnetic fields could be measured remotely at the nanoTesla (nT) level or better, our understanding of the processes that produce geomagnetic fields would advance markedly. Like the gravitational field, the magnetic field is one of very few important measured fields that are determined almost exclusively in-situ. This inability to remotely sense these fields has hindered the utility of their measurement. A Remote Atmospheric Magnetics Workshop (http://core2.gsfc.nasa.gov/research/purucker/rema.html), sponsored by the Office of Naval Research, was held in Washington DC on 25-26 April, and highlighted advances in this frontier area, focusing on lab and field-based studies.

Two topics of interest to geomagnetism were covered: 1) Remote sensing of magnetic fields in the mesosphere (Higbie et al., 2011) using Na excited with GuideStar technology, and 2) remote sensing of magnetic fields in the lower atmosphere augmented by lasers that can be tuned to provide backward lasing.

In overviews by Potashnik, Patton, and Budker, the requirements for atomic magnetometry were elaborated. The remainder of the meeting was devoted to presentations of ongoing and planned studies devoted to achieving that goal. In the next few paragraphs I highlight some of the most tantalizing possibilities.

The mesosphere, the boundary between the atmosphere and ionosphere, is one of the most poorly observed regions in all of space because access is solely by rocket or remote sensing. As discussed by Kane, a proof of concept test for remote sensing in the mesosphere is under development for the Kuiper telescope near Tucson. The laser will be pulsed near the Larmor frequency where measurements of the magnetic field will be attempted using Na in meteoric layers (Withers et al., 2008). The magnetic sensitivity goes as 1/(t*root(N)) where N is the number of returned photons detected and t is the coherence lifetime, and models suggest that nT level measurements may be possible.

In the atmosphere and mesosphere, backward lasing would allow for the efficient sampling of remote regions as the beam returns, and has been successfully used on the meter scale in the laboratory with lasers (Dogariu et al., 2011). In addition to lasers, this technique might be implemented with radar and R. Miles, in his talk, presented a thought experiment on how the radar approach, and a variety of pumping concepts, might be used with Xe^{129} to achieve resonance behavior that could be interrogated for magnetic intensity.

Many processes in the near-Earth environment produce magnetic fields. The measurement of those fields in frontier regions such as the mesosphere offers the promise of discovery and further insight into those processes.

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