Towards a Better Understanding of the Causes and Consequences of Geomagnetic Perturbations.
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Introduction: Disturbances in the magnetic field at the Earth's surface, or surface geomagnetic perturbations (B_{GEO}), have played a major role in the development of space physics research, by (1) providing a remote sensing tool for electric currents that define the electrodynamics of the magnetosphere-ionosphere (M-I) system; (2) providing a wide range of diagnostics (geomagnetic activity indices, model validation tools); (3) improving our understanding and ability to predict geoelectric fields and geomagnetically induced currents (GICs); (4) providing a long term-record of geomagnetic storms and other phenomena. Multiple factors contribute to B_{GEO} simultaneously: the spatial and temporal scales of the M-I source currents, ionospheric electrical conductivity and related spatial gradients, the Earth conductivity and related spatial gradients, each of which are multiscale phenomena. Past work mostly examined these factors independently, but multiple factors can affect B_{GEO} simultaneously. The superposition of multiple M-I current systems in B_{GEO} further increases the complexity of this problem. As a result, fundamental research and potentially novel data analysis methods are needed to improve our understanding of the causes and consequences of B_{GEO}. For example, addressing the question, "How do the multiple spatial and temporal scales present in the magnetosphere, ionosphere, and ground affect the generation of geomagnetic fields, geoelectric fields, and GIC?" requires research targeting many different multi-scale phenomena (e.g., interplanetary shocks, substorms and auroral electrojets, wave activity) and observations and models that can account for variability in the magnetosphere, ionosphere, and ground simultaneously.

This presentation summarizes ongoing Solar and Space Physics Decadal Survey discussions with a variety of stakeholders in the ground magnetometer research community concerning future needs and opportunities for fundamental research related to B_{GEO}, applications in space weather nowcasts/forecasts and model validation, education and public outreach, and the instrumentation and facilities to support progress in all these areas. Future progress is needed in several areas, including, for example, (1) more realistic ground conductivity models incorporated into analysis of B_{GEO} so that telluric currents can be separated from M-I currents; (2) fundamental research to understand the sources of B_{GEO} along with targeted improvements in the spatial and temporal sampling of B_{GEO} and geoelectric fields by, for example, the development of low-cost, high-quality instrumentation; (3) both fundamental and applied research to improve our understanding of how the multiple spatiotemporal features of B_{GEO} couple to GIC; (4) both fundamental and applied research to improve space weather forecasts that rely on B_{GEO}; (5) all stakeholders who need B_{GEO} measurements should work together to intelligently design new coverage and instrumentation requirements – governmental policies (e.g., interagency solicitations) are needed to promote collaborations in this area. Progress in these areas can be further advanced by continuing and expanding interdisciplinary (e.g., seismology and magnetotelluric research communities) and international collaborations.