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**Geoelectromagnetic analysis for fundamental understanding and hazard mitigation**

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Geoelectric fields induced in the Earth's electrically conducting interior during geomagnetic storms can interfere with the operation of electric-power grids, damage transformers, and even cause blackouts. Coupled three-dimensional (3D) modeling of space weather events and the Earth’s electromagnetic induction effects could be used for real-time, operational evaluation of on-going induction hazards and for scenario analyses of extreme-events that might occur in the future (e.g. Love et al. 2014). Such modeling requires knowledge of 3D electrical conductivity structure of the deep Earth, particularly at lithospheric depths.

Earth conductivity can be estimated through interpretation of measured geomagnetic and geoelectric activity. Survey measurements of geomagnetic and geoelectric field variation across periods of 1-sec (and shorter) up to about 10,000-sec can be obtained from temporary, ground-level deployments of sensors (e.g. Chave & Jones 2012). These magnetotelluric data can be inverted to obtain local and regional models of Earth conductivity in the crust, lithosphere and upper mantle down to a depth of about 400 km (e.g., Meqbel et al, 2014 and many others). Magnetic field data collected with satellites (e.g. Friis-Christensen et al. 2006) and at magnetic observatories (e.g. Love & Chulliat 2013) can be interpreted at periods much longer than 1-day and inverted for deep Earth mantle conductivity across a depth range of about 400 -1600 km (e.g., Kuvshinov & Olsen 2006; Kelbert et al. 2009).

Improved fundamental understanding of Earth structure and improved assessments of induction hazards can be obtained from geoelectromagnetic analysis of the “dead-band” periods of 10,000-secs to 1-day through 3D modeling of the magnetosphere, ionosphere, ocean, and solid-Earth in coordination with enhanced geomagnetic field measurement. In particular, magnetic field data could be collected from multiple magnetometer satellites deployed simultaneously in a variety of low-Earth orbits (both polar and non-polar). These data and those from ground-based magnetic observatories would enable joint inversion for models of deep-Earth interior conductivity at lithospheric depths, and physics-based parameterization of the Earth’s surrounding geospace environment. The models would be validated by comparing predicted geoelectric fields against those directly measured. The models could also be used in forward calculations needed for operational hazard assessment.

Chave, A. D. & Jones, A. G., 2012. The Magnetotelluric Method, Cambridge Univ. Press, Cambridge, UK.

Friis-Christensen, E., Lühr, H., Hulot, G., 2006. Swarm: A constellation to study the Earth’s magnetic field, Earth Planets Space, 48, 351-358.

Kelbert A., Schultz, A. & Egbert, G. D., 2009. Global electromagnetic induction constraints on transition-zone water content variations, Nature, 460, 1003-1006, doi:10.1038/nature08257.

Kuvshinov, A. & Olsen, N., 2006. A global model of mantle conductivity derived from 5 years of CHAMP, Ørsted, and SAC-C magnetic data, Geophys. Res. Lett., 33, L18301, doi:10.1029/2006GL027083.

Love, J. J. & Chulliat, A., 2013. An international network of magnetic observatories, Eos, Trans. AGU, 94(12), 373-374.

Love, J. J., Rigler, E. J., Pulkkinen, A. & Balch, C. C., 2014. Magnetic storms and induction hazards, Eos, Trans. AGU, 95(48), 445-446, doi:10.1002/2014EO480001.

Meqbel, N. M., Egbert, G. D., Wannamaker, P. E. & Kelbert, A., 2014. Deep electrical resistivity structure of the northwestern U.S. derived from 3-D inversion of USArray magnetotelluric data, Earth Planet. Sci. Lett., 402, 290-304, doi:10.1016/j.epsl.2013.12.026.