Inferring geomagnetic secular variation using MHD/kinematic dynamo modeling with data assimilation

*Futoshi Takahashi[1], Shin ya Nakano[2], Takuto Minami[3], Hinami Taniguchi[4], Ryosuke Nakashima[4], Masaki Matsushima[5], Hisayoshi Shimizu[6], Hiroaki TOH[7]

1. Faculty of Sciences, Kyushu University, 2. The Institute of Statistical Mathematics, 3. Division of Frontier Planetology, Department of Planetology, Graduate School of Science, Kobe University, 4. Graduate School of Science, Kyushu University, 5. Department of Earth and Planetary Sciences, School of Science, Tokyo Institute of Technology, 6. Earthquake Research Institute, University of Tokyo, 7. Data Analysis Center for Geomagnetism and Space Magnetism, Graduate School of Science, Kyoto University

Secular variation (SV) of the Earth's magnetic field is governed by the advection and diffusion processes of the magnetic field within the fluid outer core. The IGRF (International Geomagnetic Reference Field) offers the average SV for the next five years to come, which has been estimated in various methods. In general, forecasting the evolution of a non-linear system like the geodynamo in the Earth's core is an extremely difficult task, because the magnetic field generation processes are controlled by the complex interaction of the core flows and the generated magnetic field. Data assimilation has been a promising scheme forecasting the geomagnetic SV as demonstrated in literatures (Kuang 2010, Fournier et al. 2015), where time dependency is controlled by a numerical dynamo model. While Ensemble Kalman Filter (EnKF) has been a popular method for data assimilation in geomagnetism, we apply a different data assimilation procedure, that is, four-dimensional, ensemble-based variational scheme, 4DEnVar. Applying the 4DEnVar scheme iteratively, we have derived a candidate SV model for the latest version of the IGRF. In evaluating SV, two forecasting strategies are tested, in which core flows are assumed to be steady or time-dependent. The former approach is favored in Fournier et al. (2015), where the magnetic field evolves kinematically by the flows prescribed to be time-independent in the initialization step. On the other hand, we have adopted linear combination of magnetohydrodynamic (MHD) models to construct a candidate as the best forecast (Minami et al. 2020). It is likely that which strategy is more suitable to forecasting SV depends on assimilation scheme and/or numerical dynamo model. However, we have little knowledge on the issue at present. In this study, we investigate results of MHD and kinematic dynamo runs with a 4DEnVar scheme in order to have a grasp of the properties of the scheme in the 5-year forecast process. Also, MHD and kinematic runs are compared to infer internal dynamics responsible for SV in the geomagnetic field.

Keywords: Secular variation, MHD dynamo, Kinematic dynamo, Data assimilation, IGRF

