# Contribution to IGRF-13 from Japan: A secular variation model using a numerical dynamo model and 4DEnVar data assimilation

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

1. Kobe University, 2. The Institute of Statistical Mathematics, 3. Kyushu University, 4. Tokyo Institute of Technology, 5. The University of Tokyo, 6. Kyoto University

The thirteenth generation of International Geomagnetic Reference Field (IGRF-13) was released by International Association of Geomagnetism and Aeronomy (IAGA) in December, 2019. Prior to the release, we submitted a secular variation (SV) candidate model for IGRF-13 using a data assimilation scheme and a magnetohydrodynamic (MHD) dynamo simulation code (Minami et al. submitted to EPS special issue for IGRF-13). Our candidate SV model was evaluated by IAGA Division V Working Group V-MOD and contributed to the final IGRF-13SV model with the optimized weight. This became the first contribution to the IGRF community from research groups in Japan. This was enabled by bilateral corroboration between Japan and France; in our data assimilation scheme, we used the French main field model (Ropp et al. 2020), which was developed from magnetic observatory hourly means, and CHAMP and Swarm-A satellite data. We adopted an iterative assimilation algorithm based on four-dimensional ensemble-based variational method (4DEnVar) (Nakano 2020), which linearizes outputs of our MHD dynamo simulation (Takahashi 2012; 2014) with respect to the deviation from a dynamo state vector at an initial condition. The data vector for the assimilation consists of the poloidal scalar potential of the geomagnetic field at the Earth’ s core surface, and flow velocity field slightly below the core surface, which was calculated by presuming magnetic diffusion in the boundary layer and tangentially magnetostrophic flow below it (Matsushima 2020). Dimensionless time of numerical geodynamo was adjusted to the actual time by comparison of secular variation time scales. For estimation of our IGRF-13SV candidate model, we first generated an ensemble of dynamo simulation results from a free dynamo run. We then assimilated the ensemble to the data with a 10-year assimilation window from 2009.50 to 2019.50 through iterations, and finally forecasted future SV by linear combination of the future extension parts of the ensemble members. We generated our final SV candidate model by linear fitting for the best linear combination of the ensemble MHD dynamo simulation members from 2019.50 to 2025.00. We derived errors of our SV candidate model by one standard deviation of SV histograms based on all the ensemble members. In the presentation, we plan to report our IGRF project through the bilateral corroboration with France, and describe our SV candidate model.

Keywords: IGRF, secular variation, dynamo, data assimilation

 