Investigation of Sub-Grid Scale (SGS) terms for dynamo simulations in a rotating spherical shell

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The flow in the Earth's outer core is expected to have vast length scale from the geometry of the outer core to the thickness of the boundary layer. Because of the limitation of the spatial resolution in the numerical simulations, sub-grid scale (SGS) modeling is required to model the effects of the unresolved field on the large scale fields. We model the effects of sub-grid scale flow and magnetic field using a dynamic scale similarity model. Four terms are introduced for the momentum flux, heat flux, Lorentz force and magnetic induction.

In the present study, we adapt the dynamic scale similarity methods to Calypso, which is a numerical dynamo model using spherical harmonics expansion. Spatial filtering operations is required for the scale similarity model. The spatial filtering in the horizontal directions is done by taking the convolution of the Gaussian and spherical harmonics expansion by following Jekeli (1981). The Gaussian filter is applied explicitly in the radial direction. We evaluate the SGS terms in the fluid shell using a snapshot of a fully resolved dynamo simulation using 0.4 and 1/4 coarser resolution in each direction. The evaluated SGS term evaluated has a good correlation with the SGS term directly evaluated on the fine grid to 0.4 times coarser resolution of the reference resolution. The dynamic scale similarity model does not well represent SGS terms near the outer boundary around the equator. The reason is that smaller scale flow motion is excited near the outer boundary than that for the main convective region. Consequently, simulation domain does not have enough spatial resolution to satisfy the scale similarity model near the outer boundary around equator. The scale of the convection around equator near the outer boundary controls the required resolution to work the present SGS model properly.

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