Title: Modelling of global ocean circulation and ocean-induced magnetic field

Author: Libor Šachl

Department: Department of geophysics

Supervisor: prof. RNDr. Zdeněk Martinec, DrSc., Department of geophysics

Abstract: The ocean modelling community commonly use several renown ocean general circulation models (OGCMs) such as NEMO, MOM and FESOM. These models have been developed by research groups for many years, which resulted in complex mathematical and numerical algorithms. There are geophysically relevant problems, such as the glacial isostatic adjustment, in which the global ocean plays an important role. Ocean circulation does not need to be modeled extremely complex, but other phenomena such as time changing geometry of ocean domain needs to be considered. Geophysical applications motivated us to develop a new OGCM called LSOMG. The LSOMG model is not meant to substitute the existing OGCMs but to provide a modelling framework for geophysical rather than purely oceanographic applications. LSOMG is a 3-D baroclinic ocean model fully parallelized using the MPI standard. It is forced by atmospheric fluxes (wind stresses, heat fluxes, etc.) but also by tides. The model can be run in a simplified 2-D barotropic version if 3-D effects can be neglected. LSOMG was tested in a series of simplified barotropic numerical tests: the tsunami and tidal numerical tests and the Munk problem. In the full baroclinic version, we tested the generation of the Ekman layer and the advection of tracers. Finally, we present realistic wind and tidally driven ocean circulations computed by the LSOMG model.

The second part of the thesis is devoted to the study of ocean-induced magnetic field (OIMF). The ultimate goal is to extract information about the ocean circulation from the observed OIMF, e.g., by Swarm satellites, and assimilate it into an OGCM. However, it is a challenging task since the OIMF has small amplitudes of about 2 nT maximum at Swarm altitudes. It is overlaid by the main, ionospheric and magnetospheric magnetic fields that are several orders of magnitude larger. We thus focus on the precision of forward modelling and study the impact of physical and numerical approximations. Namely, we inspected the impact of galvanic coupling, vertical stratification of ocean flow and electrical conductivity, self-induction and horizontal resolution on the numerically predicted OIMF. Another possibility is to use localized magnetic measurements at the sea bottom instead of satellite data. Consequently, we studied the toroidal magnetic field inside the ocean using fully 3-D versions of both LSOMG and the magnetic-induction solver Elmgiv. The toroidal magnetic field is zero at the surface but it is significant inside the ocean. According to our computations, its magnitude can reach 15 nT, i.e., it is about one order of magnitude larger than the OIMF at satellite altitudes.

Keywords: ocean modelling, global circulation, ocean-induced magnetic field