Report on Dr Jakub Velimsky habilitation thesis

ELECTROMAGNETIC INDUCTION IN THE EARTH'S MANTLE AND OCEANS
Forward and inverse modelling

The document prepared by Dr Velimsky as a scientific report for his habilitation is organised in four parts, an introduction, a section on the forward solution of global (spherical) induction in a conductive planet, a section about inverse theory, a conclusion with a summary of the application of the theory developed, a brief description of his current work and references. The appendices include eight of Dr Velimsky's publications in international journals.

Dr Velimsky is a renowned researcher in the field of global electromagnetic induction. He published 7 scientific papers as 1st or single author and (at least) 5 as a co-author in well known international journals in geophysics. He participated in numerous international conferences and actively participated in the building of the ESA's SWARM project, the mission and the exploitation of the magnetic data produced by the mission.

Dr Velimsky used his strong mathematical and physical background to develop a successful solution of the 3-D global induction inverse problem in time domain (TD) with the clear idea to apply it to real data, namely satellite magnetic data. The 3-D forward solution is very nicely presented in the manuscript. In this part, Dr Velimsky endeavours to develop and prove all steps of the forward problem with all possible sources. Whilst a few TD solutions have been proposed in the literature, Dr Velimsky has developed a TD forward and inverse solution tested on both synthetic and real data with some very interesting and promising results. The choice of TD was guided by the transient nature of the inducing magnetospheric magnetic field but is very challenging for both theoretical and numerical reasons. The first publications present early work on 1-D inversion in TD and some applications of the 3-D forward code. The SWARM mission was the opportunity to focus on the TD 3-D inverse solution. Dr Velimsky's solution emerged as one of a very few techniques able to actually inverse in 3-D satellite magnetic data. The success of the inversion was at first strongly impeded by the great difficulty to manage satellite data for induction studies. Indeed the formal separation in internal and external fields, the complexity of the source field and the data noise and gaps in the satellite time series make the modelling of magnetic satellite very difficult. Thus Dr Velimsky and his colleagues had to develop specific techniques in data processing to overcome some of the difficulties which led to an apparently successful 1st real inversion of the SWARM data in a paper in preparation mentioned in the conclusion of the manuscript. There is still much work needed to account for the full resolution of the satellite data. The current results are still limited to very long wavelengths. Some new approaches are suggested, for instance to include the source field SHE coefficients as unknown, use a more sophisticated source field geometry than a simple ring current. Why not include magnetic observatory data ? It seems that maturation is still needed to actually obtain geodynamically useful 3-D global distribution of conductivity. Regrettably the current work and the projects for the future are only briefly mentioned in the manuscript. Finally is the TD SH solution the way to go for global induction ? At the time of habilitation, such a discussion would be interesting. Dr Velimsky is the expert able to address this question.

In parallel, Dr Velimsky was also interested in other sources of EM induction, in particular motional induction by the ocean tides and ocean currents within the Earth magnetic field. Dr Velimsky's forward code is well suited to tackle this problem and was used in cooperation with others to study the tidal signal in the satellite magnetic fields, raising some fundamental questions, in particular in the role of the toroidal magnetic field induced by the water motion of the oceans within the water layer. There is indeed a growing interest to model both the static and transient magnetic field raising from global oceanic current and observable at satellite altitude. Monitoring the large scale motion of oceanic masses through magnetic measurements is of great interest if possible.

Dr Velimsky contributed greatly to global induction in the earth. His time domain solution allows to study various processes, some not yet addressed. I can foresee applications to planetary studies with the availability of satellite data for Mars and Mercury, more later. His solution, although mathematically complicated and numerically demanding has the potential to understand the joint process of external and internal induction, motional induction signals and possibly internal source induction ? Thus on the basis of this manuscript and my knowledge of the field and Dr Velimsky contribution to it, I certainly agree to award Dr Velimsky the habilitation to become associate professor to pursue research in this domain and form future researchers in global EM induction.

Professor Pascal Tarits