Solar Wind – Magnetosphere – Ionosphere Coupling

Jurgen Watermann
jfwConsult, La Tetrade, Chemin de Pichot, 83440 Tourrettes, France
[jfw@cnrs-orleans.fr]

Abstract

Energy released from the Sun reaches the Earth in two principal forms, electromagnetic waves and streams of charged particles (called solar wind) with an embedded magnetic field (interplanetary magnetic field, IMF). Although the energy density of the solar electromagnetic radiation is several orders of magnitude larger than the energy density of the charged particle stream the latter plays a more profound role for space weather in the Earth environment, largely as a result of highly variable electrodynamic coupling between the solar wind and the magnetosphere (the part of geospace which is controlled by the geomagnetic field). Consequently this lecture focusses on the latter.
We first outline the main characteristics of the solar wind and the interplanetary magnetic field at the Earth's orbit, the formation of the magnetosphere and its dependency on solar wind conditions and the electrodynamic coupling between solar wind and magnetosphere including merging between the IMF and the geomagnetic field. Thereafter we explain how the ionospheric electric field is generated from two sources, one resulting from the corrotation of the upper atmosphere with the Earth and the other from the convection of the solar wind plasma across the geomagnetic field. This leads us to consider the various electric current systems which are established in the magnetosphere-ionosphere system and which play a substantial role for magnetosphere-ionosphere coupling. We put particular emphasis on the high-latitude regions where the coupling via electric currents is more efficient than at other latitudes.
Two categories of violent interaction between the disturbed solar wind are then considered, namely geomagnetic storms and substorms. These two are responsible for the most pronounced space weather effects in the Earth enviroment. However, one of the more spectacular manifestations of space weather, the aurora, is suppressed here because it is discussed in detail in a companion lecture.

We neither discuss the origin of the solar wind nor the origin of disturbances such as CMEs and CIRs nor the physical and chemical processes which lead to the partial ionization of the upper atmosphere and thus to the creation of the ionosphere. They are the subjects of companion lectures.

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Room: Kastler Lecture Hall @ Adriatico Guest House

Dr. Jurgen Watermann is a physicist who specialised in space physics but has research experience also in solid Earth geophysics, geomagnetism and marine electromagnetics.
He graduated in 1976 from the University of Goettingen (Germany) with a diploma (M.Sc. equivalent) in physics and obtained in 1984 from the same university the doctorate (Ph.D. equivalent) in physics with specialisation in geophysics. His thesis dealt with the observation and analysis of spatially and temporally coincident fluctuations of the geomagnetic field and of the phase path of vertically incident HF radar soundings of the ionosphere.
From 1977 until 1984 he worked as a research and teaching assistant at the Institute of Geophysics, University of Goettingen. During those years his research focussed on natural electromagnetic induction in the Earth's crust and upper mantle and on electrodynamics of the mid- and high-latitude ionosphere.
In 1984 he transferred to the Max Planck Institute for Aeronomy (later renamed to Max Planck Institute for Solar System Research), Katlenburg-Lindau (Germany) where he worked on Spacelab-1 experiments on the interaction between artificially created electron beams and the ionospheric plasma environment.
In 1986 he joined the Ionosphere Radar Group of the Herzberg Institute of Astrophysics, National Research Council, Ottawa, Canada where he employed various coherent scatter radar systems (Canadian predecessors of SuperDARN) to study plasma instabilities in the high-latitude ionosphere.
In 1989 he moved to the United States and worked as a research physicist at SRI International (formerly Stanford Research Institute) in Menlo Park, California. He pursued research on magnetosphere-ionosphere coupling using multi-instrument multi-point observations with emphasis on the Sondrestrom (Greenland) incoherent scatter radar and spacecraft of opportunity.
From 1993 until 1999 he stayed with the NATO SACLANT Undersea Research Center in La Spezia, Italy, where he was in charge of a research project on natural and anthropogenic electromagnetic signals in a marine environment, recorded with island-based and sea bottom magnetometers.
Afterwards he joined the Space Physics and Geomagnetism group of the Danish Meteorological Institute in Copenhagen and became project scientist for the Greenland magnetometer array and later also for the Greenland digisonde system (on behalf od the US Air Force).
He became involved in many international scientific collaborations with the objective to study multiple aspects of solar wind-magnetosphere-ionosphere coupling for which he exploited extensively the Greenland magnetometer data. During that period he developed an interest in space weather research and its application and became active in the European space weather scene through participation in the ESA Space Weather Applications Pilot Project and the COST Action 724 on the science of space weather.
He left Denmark in 2007 to take up a two-year fellowship with "Le Studium" in France and became associated with the CNRS Laboratory for Physics and Chemistry of the Environment and Space (LPC2E) in Orleans.
He worked on various topics in space science while continuing his deep involvement in European space weather activities and in particlular in the COST Action ES0803 on space weather products and services.
In 2010, after having moved to south-eastern France, he founded jfwConsult, a micro-enterprise specialising in scientific-technical consulting in space physics.