# 3rd INTERNATIONAL DOCTORAL SEMINAR ON GEODESY GEOINFORMATICS AND GEOSPACE

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**Extended Abstract for 3rd IDS3GEO 2019**

mr. sc. Mirko Husak dipl. ing. geod.

# Recalculation and computer programm challanges for calculating Sun rotation period about its axis using Sunspot observations by the Ruđer Bošković methods

Motivation

The works of Ruđer Bošković (1711-1787) the first *De maculis Solaribus* (1736) and the last *Opera* (1785) in fifth part *Opuscule II* deal with determing Sun rotation elements using Sunspot observations. *Opera* (1785) in *Opuscule II* describes detailed explanation and example of calculation of Sun rotation velocity where Bošković uses his own observations made 12th to 19th September 1777. Bošković's calculations use sexagezimal data using Briggs logarithm tables with base 10.

Problem statement

The implementation of Bošković's model in the computer program for calculating Sun rotation elements using Sunspot observations using Bošković method should useful tool for data processing of many available data sets. There are no attempts of recalculation and using Bošković method yet.

Approach

Recalculations – controls of the Bošković's calculations published 1785 in this work are made using: 1. Briggs logarithm tables, 2. pocket calculator, 3. spreadsheet calculator for personal computer, and 4. computer programm. During calculation control appeared many problems discussed in the paper.

Results

The calculation control process by hand is controlled parallely with pocket calculator and with the spreadsheet. In the begining of the control process appeared many dilemas regarding the precision of the claculations, and calculation precision influences to results in the steps and final results. Calculations that uses results from previous steps, the precision of the result depends on result in the previous step. The precisoin issues directly influences the results between the steps. Another calculation control is own computer programm implementation of the Bošković's algorithm. Original formulas are convenient for calculation by hand, step by step, but the original formulas are not convenient for the implementation in the computer programm code. Bošković's algorithm is converted and modified during programming process after the calculation control by hand step-by-step with logatithm tables and pocket calculator. The algorithm is streamlined during the computer program development with consultation the Bošković original text in old-French.

Conclusions

There were many problems in the calculation control because we do not calculate any more like Bošković did. Analysis of all Bošković's formulas and his calculations is converted in the streamlined mathematical model could be implemented in the computer programm and it is realized using Microsoft QuickBASIC 4.5, freeware, no-charging software including all needed funcionalities such as executive version of programm and using various data input and output formats. The programm code testing looks fuzzy, but Bošković's formulas for logarithmic calculation are modified step-by-step in structured algorithms and subroutines and linked with geometric interpretations Bošković (1736, last page) and Bošković (1785, page 561, Tom. V. Opusc. II Tab. IV).

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Title: Long-term evolution of coronal holes and related co-rotating interaction regions

We investigate a sample of persistent coronal holes which occurred over the time range 2007 - 2014 and were observed from multiple perspectives. From combined SOHO/EIT, STEREO and SDO EUV data, we extract coronal hole parameters such as area, location, magnetic field characteristics, and follow them in time. The resulting parameters are related to in-situ solar wind measurements at L1 from ACE/Wind. We show that coronal holes undergo several evolutionary steps that are characterized by specific value ranges in the extracted parameters. On a statistical basis, this supports the results from the case study performed by Heinemann et al. (2018), who found that the coronal hole evolution has three phases, growing, maximum and decaying phase. These phases are also mirrored in the in-situ proton bulk speed of the associated high-speed streams. In addition, we investigate if and how these evolutionary properties are reflected in the galactic cosmic ray measurements of the recurrent Forbush decreases.

# Physical principle for coronal hole boundaries extracted by intensity thresholds

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Coronal holes are areas of open magnetic field and are usually detected in EUV image data where they appear more dark compared to the ambient corona. Deriving reliably the coronal hole boundary is of high interest, as its area, underlying magnetic field, and other properties give important hints towards high speed solar wind acceleration processes and with that compression regions arriving at Earth. In this study, we statistically verify an intensity-based threshold method for identifying and extracting CHs from the physical standpoint using plasma properties (density, temperature and emission measure) derived from multi-wavelength remote sensing observations. Using the differential emission measure (DEM) analysis method by Hannah & Kontar (2012) on EUV data from the Atmospheric Imaging Assembly (AIA) on board the Solar Dynamics Observatory (SDO) as well as boundary conditions of CH plasma found in Saqri et al. (2019) we extract boundaries of over 100 CH during the whole SDO cycle (2010-2018). These boundaries are compared with boundaries we derive by varying the threshold of an intensity-based extraction method that uses 193A EUV observations. From this statistical analysis we are able to propose an optimal threshold range as well as relevant errors for the CH boundary. This study acts as a erorr estimation for further studies using the same or similar extraction methods for CH.

# Machine learning methods for classification of green infrastructure in city areas

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**Abstract:**

The moment when satellite imagery has become widely available, different methods are being developed to get precise information from these satellite images as quickly as possible. Most commonly, satellite imagery is analyzed by methods of supervised classification or machine learning methods. Basic principle of machine learning is to determine unknown data based on predetermined known data sets. The first mention of machine learning dates in 1943 when neurophysiologist McCulloch proposed neural networks. However, development of machine learning models is connected with the development of computers and in that manner increased usage of machine learning modules is at the end of 20th century.

Nowadays, most commonly used machine learning method for analyzing satellite imagery is the support vector machine. Other considered machine learning methods are artificial neural network, naive Bayes and random forest. Since the development and usage of machine learning modules has been going on for about 30 years there has been a lot of scientific papers published. However, most of papers has been done on satellite imagery with high spatial resolution such as imagery from satellite missions IKONOS; QuickBird, Worldview or GeoEye-1, or on satellite imagery with low spatial resolution such as imagery from satellite missions Landsat. Since high resolution images provide best classification results, main limitation is that such images are not free of charge. The 23rd of June 2015 was launched first satellite in satellite mission Sentinel 2 and products of this mission are satellite images with spatial resolution of 10 meters, and free of charge. Since that date several authors made different analysis on this satellite images, but none did thorough analysis of machine learning modules on Sentinel 2 satellite imagery with the focus on classification of green infrastructure in city areas.

In this work there will be presented differences between support vector machine, artificial neural networks, naïve Bayes and random forest machine learning modules and how each module affects the classification results. Machine learning modules will be tested on Sentinel 2 satellite imagery. During accuracy assessment main focus will be on classification quality of green urban areas for city of Varaždin and city of Osijek.

***Keywords:*** *Machine learning modules, accuracy assessment, green infrastructure, Sentinel 2*

Utilizing galactic cosmic rays to understand the Sun-to-Earth evolution of CMEs

Traditionally, to identify ICMEs in the in-situ measurements, mostly plasma and magnetic field measurements are regarded. However, one of the very common in-situ signatures of ICMEs, as well as other interplanetary transients are Forbush decreases (FDs), i.e. short-term reductions in the galactic cosmic ray (GCR) flux. FD phenomena are caused by the interaction of GCRs with a magnetic structure, therefore it is expected that different types of interplanetary substructures cause different types of GCR depressions, allowing us to distinguish between shock/sheath, flux rope and SIR-type of FDs. Moreover, since the interaction of GCRs and CME magnetic structure (presumably flux rope) occurs all the way from Sun to Earth, FDs should also reflect the evolutionary properties of CMEs, which is supported by the results from recent modeling efforts (Dumbovic et al., 2018, ApJ). The evolutionary process of different magnetic structures in interplanetary space will be discussed in the scope of selected case studies, utilizing a number of multi-instrument and multi-spacecraft observations, together with modelling. This research has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 745782.

# Development of procedures to determine the movement of railway embankments using Unmanned Aerial Systems (UAS)

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**Abstract**

Deformation measurements of linear infrastructure objects such as railway embankments have a significant disadvantage in the fact they are carried out at discrete locations or in specific measuring locations along the embankment. In such circumstances, the application of unmanned aerial systems has a big and insufficiently researched perspective. The aim of the research is to develop methods for measuring spatial deformation of railway embankments using unmanned aerial systems, which would deformation measuring in classic way on railway embankments (geodetic benchmarks, inclinometers, clinometers, sliding micrometers) replace with faster, cheaper and more effective continuous measurement using unmanned aircraft. This can be achieved by systematic analysis and interpretation of all parameters that affect the applicability and repeatability of measurements changes in the shape and volume of railway embankments in time, comparing the measurement results by using unmanned systems with other classic measurement techniques.

Unmanned Aerial System (UAS) is a non-crew aircraft that can be monitored by remote controller or fly independently using a pre-programmed flight plan. With the development of GNSS (Global Navigation Satellite System), INS (Inertial Navigation System), digital cameras and various other mobile measuring sensors, the choice of UAS with customized equipment for various purposes, justifies economic and other requirements for high quality data collection from the air. Basic requirements that UAS must meet in order to be used for terrain mapping is performing a scheduled flight, ability to carry recording and navigation equipment, flight autonomy as well as the ability to absorb vibrations and other external influences during the flight itself.

To produce a three-dimensional model of terrain or an object it is necessary to record a higher number of photographs with mutual longitudinal and transverse overlapping, and the goal is to link these photos to a single entity and generate a point cloud of interest area.

The hypothesis of the research is that using Unmanned Aerial Systems can greatly supplement, improve, and even completely replace the classic ways of measuring deformation of railway embankments, mapping, volume determination, transverse cross sections, and other parameters required for engineering analysis. Furthermore, low-budget UAS equipped with a photographic camera can achieve the quality of photogrammetric measurements, sufficient to measure deformation of the railway embankments.

***Keywords***: *Unmanned Aerial Systems (UAS), railway embankment, photogrammetry, deformation monitoring, point cloud*

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Title:
Coronal mass ejections and space weather effects

Abstract:
Earth-directed coronal mass ejections (CMEs), with their embedded magnetic fields and shocks ahead, compress and reconnect with the Earth‘s magnetic field and are the main drivers of strong geomagnetic storms. The impact of strong events may endanger critical ground-based infrastructure such as power grids or disrupt communication and navigation systems. Due to such Space Weather effects, CMEs and related phenomena are an area of intense research interest. Important scientific knowledge could be achieved by closely monitoring and investigating the Sun-to-Earth “chain of action” of solar activity (evolution of surface magnetic fields, flares and CMEs), simultaneous measurements of near-Earth space (in-situ plasma and magnetic field) and geomagnetic activity (response to different atmospheric layers down to ground-induced currents). This overview talk covers and discusses our recent understanding of the physical processes about the initiation and propagation of CMEs, their interaction with the solar wind and other ejecta, and consequences for Space Weather.

**Can we use coronal dimmings as application for space weather forecasting?**

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Coronal dimmings are temporary regions of reduced extreme-ultraviolet emission that form in the wake of CMEs in the low corona due to plasma evacuation. As they are observed prior to the appearance of CMEs in white-light coronagraphs, coronal dimmings provide early information on the associated CME and build an important back-up in case no coronagraphic data are available. Especially, for Earth-directed events they are of interest because they provide immediate information whether a halo CME is front or back sided. For a set of 62 Earth-directed events, we established the statistical relationship between coronal dimmings and their associated CMEs using optimized multi-point SDO and STEREO data. We found that the dimming area, its brightness and the total magnetic flux within the dimming region strongly correlate with the CME mass, while their corresponding derivatives (i.e. the area growth rate, the brightness change rate, and the total magnetic flux change rate) show the highest correlations with the CME speed ($c = 0.6 - 0.7$). Based on these results we aim to provide early CME parameter estimates for real-time space weather forecasting based on observations of coronal dimmings. By applying a multiple linear regression model, we use our dataset to identify the best combinations of dimming parameters to calculate the CME mass and its maximal speed. We will also aim to derive coronal dimming cut-off relations to predict fast ($> 1000$ km s $^{-1}$) and massive Earth-directed CMEs ($> 5 \times 10^{15}$ g).

# Understanding the Heliospheric Radiation Environment in Preparation for Human Exploration of Mars

Jingnan Guo [School of Earth and Space Sciences, University of Science and Technology of China, Hefei, China]

Potential radiation damage to astronauts induced by Solar Energetic Particles (SEPs) and Galactic Cosmic Rays (GCRs) in space is one of the most important risks for future human space missions, especially interplanetary missions such as to Mars which requires a long mission duration of at least 2-3 years. To evaluate such radiation risks for deep space missions, in particular in preparation for future human exploration of Mars, the Radiation Assessment Detector (RAD) was designed to detect and analyze the most biologically hazardous energetic particle radiation during the cruise to Mars and on the Martian surface as part of the Mars Science Laboratory (MSL) mission.

MSL was launched on November 26, 2011 and landed on Mars on August 6, 2012 after a 253-day, 560-million-kilometer cruise. During most of the cruise phase, RAD made detailed measurements of the cosmic ray (including both SEPs and GCRs) radiation environment inside the spacecraft traveling through the interplanetary space. The day after MSL's landing, RAD was switched back on and started making the first-ever measurements of the cosmic ray induced energetic particle radiation environment on the surface of Mars and has been collecting data for more than six years, approximately three Martian years, since then. Both the deep-space radiation environment inside the spacecraft and the surface radiation field on Mars measured by RAD provide insight into the radiation hazards that would be associated with a human mission to Mars and give indications of possible risk mitigation strategies for future human exploration of the red planet.

In this lecture, we review and discuss (1) RAD measured cruise phase radiation environment from both GCRs and SEPs as well as the variance in the GCR radiation due to heliospheric modulation, (2) the Martian surface spectra and flux of energetic particles (both charged and neutral) detected by RAD and the validation of particle transport models based on these measurements, (3) the absorbed dose and dose equivalent rate from GCRs and their time evolution influenced by both the atmospheric changes and heliospheric dynamics, (4) the detected SEP events and their potential radiation risks, (5) the heliospheric space weather environment at Mars using RAD as a space weather monitor, and finally (6) state-of-art modeling of particle transport through the Martian atmosphere in preparation of forecasting potential radiation hazards related to possible extreme solar eruptions.

Given the efficient heliospheric shielding against the GCR radiation which is omnipresent and the main radiation source for long-term interplanetary exploration, it is perhaps more sensible to carry out manned missions to Mars during solar maximum years. However, timely forecasting and sufficient shielding are needed for mitigating radiation risk against sporadic and potentially hazardous SEP events. This requires correct modeling of the interactions of energetic cosmic ray particles with the local shielding environment, i.e., the spacecraft or the Martian atmosphere and regolith. Besides, better understanding of the underlying physics in the processes of the acceleration, injection and interplanetary transport of SEPs is needed to advance and improve our space weather predictions of the potentially hazardous radiation environment.

# Influence of initial coronal hole parameters on numerical simulations of coronal waves

I. Piantschitsch, B. Vršnak, M. Temmer,
T. Podladchikova, A. M. Veronig, J. Čalogović

We performed 2.5D numerical simulations of magnetohydrodynamic waves and their interaction with coronal holes of varying shape. Moreover we compared the interaction results of different incoming waves, circular-shaped ones as well as those which propagate perpendicular to the wave front in every point. We found that the density structure of the reflected and transmitted waves strongly depend on the combination of incoming wave and shape of coronal hole. We present a detailed analysis of morphology and kinematics of reflected, refracted and transmitted waves.

**Title**: Multi-spacecraft observation of supra-thermal electrons for the wide CME on March 12, 2012

**Abstract**: On March 12, 2012, a very fast Coronal Mass Ejection (CME) with a speed of about 2000 km/s was released from the Sun. Its interplanetary counterpart (ICME) was detected in-situ on March 15, 2012 by spacecraft located at L1 close to the Earth, and by STEREO A. When the ICME arrived, they had an angular separation of ~100 degrees. The Earth crossed the East flank of the structure and showed unambiguous ICME in-situ signatures, while STEREO A crossed the West flank and showed less clear markers. At the moment of the eruption, the CME was surrounded by three different coronal holes, which were located with respect to the CME launch site East (negative polarity), South-West (positive polarity) and West (positive polarity). This matches with the polarity observed in-situ at 1 AU. Apart from this, supra-thermal electrons show both signatures of bidirectionality and its absence as the spacecraft transits the ICME, indicating that only part of ICME remained a closed structure, whereas the other parts were eroded, possibly due to interaction with the fast solar wind. We investigate the early kinematics of the CME using the Graduated Cylindrical Shell (GCS) model, the differences between the signatures of the ICME observed by Earth and STEREO A at 1 AU and the interaction process with the surrounding CHs.

**Authors**: Fernando Carcaboso, Mateja Dumbović, Manuela Temmer, Raúl Gómez-Herrrero, Stephan Heinemann, Veronika Jercic, Jarvier Rodríguez-Pacheco

**Reconstructing the latitudinal position and the geometry of Coronal Holes with EUHFORIA model**

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We investigate the capability of the empirical solar wind model adopted in EUHFORIA (European heliospheric forecasting information asset) to recreate the geometry and size of coronal holes, and subsequently of the fast solar wind. The empirical solar wind model follows that of Wang-Sheeley-Arge model, and combines the Potential Field Source Surface (PFSS) and the Schatten Current Sheet (SCS) models. The outer boundary of the PFSS model is placed at a radius of Rii, and the inner boundary of the SCS model at Ri. Considering that the Ri lies below the Rii we take a series of sets of the two radii by varying Rii within the interval [1.4, 3.0]Rs with a step of 0.1Rs, and the Ri within the interval [1.3, 2.8]Rs with the same step. The study is repeated for 12 coronal holes exhibiting different longitudinal and latitudinal extent and patchiness. We compare the modelled coronal holes with boundaries obtained by remote sensing EUV observations using the CATCH tool (Collection of analysis tools for coronal holes). Preliminary results of the study indicate that a previously defined pair of PFSS and SCS radii results in underestimated coronal hole sizes. It also indicates that different radii sets give better results for different types of coronal holes.

# Geographic Criminal Profiling

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**Abstract:**

The interest in modeling criminal spatial behavior has increased considerably over the last few decades. The scientists have developed theories on how to analyze crime patterns and criminal behavior in relation to space (Butorac, 2017). The umbrella term that encompasses these theoretical approaches is called Environmental Criminology. It includes routine activity theory, the geometric theory of crime, rational choice theory and pattern theory which is the meta-theory of the other three approaches (Andresen, 2009). Rational choice theory is used to model social and economic behavior. It explains the decision-making process of the individual. In Criminology it is used to understand the logic in offenders' site selection which is driven by its associated effort, risk, cost, and reward. Routine activity theory postulates that crime is found at the convergence in space and time of a suitable target, absence of capable guardians and offender which occurs in everyday life activities. People are beings prone to habits. Our everyday life is pervaded by routines and we create our own awareness space that emphasizes the home base, neighborhood, paths to get to work, school, entertainment place, store, etc. Most of the offenders found suitable targets within their everyday routines, where the paths of the victim and the offender intersect in time and space. Geometric theory of crime states that crimes are patterned non-randomly and non-uniformly across the territory. This theory assumes hotspots and coldspots. Hotspots represent the places with a high concentration of crime events (Trotta, 2014). Crime pattern theory explains the patterns of offenders by exploring their awareness space, crime nodes, paths and edges, crime attractors and crime generators and the influence of the environmental backcloth (wider social, cultural, legal, spatial and temporal dimensions of a place). This also includes the physical dimensions as well as the populations located or transitory within that space (Brantingham & Brantingham, 1993). The theory has an emphasis on cognitive levels of awareness and interpretation and the complexity of human decision-making (Brantingham & Brantingham 1999). Therefore most of human's activities are in correlation with the surrounding environment and in that sense, it can be modeled so the crime cannot be considered separately from the environment in which it occurs (Butorac, 2017). The methodology that includes all these theories is called Geographic Profiling. It is an investigation methodology for analyzing the crime locations that are connected to one serial offender in order to limit the area where the offender has his residence.

Over the years there has been a debate among scholars about the different methods for the most fitting model that would give the best prediction. The scientists have been developed many strategies to describe spatial behavior of offenders which are mainly based on two categories of spatial models. The spatial distribution models which have the objective to determine the anchor location with a summary statistic of the pattern of crime site and spatial interaction models that represent the models where the spatial behavior is characterized according to probability distance functions (Trotta, 2014). Spatial distribution models are based on the different spatial statistics formulations, while the basis for the spatial interaction models have different distance decay functions. Most of the researches are based on the calculating of Euclidian distances under a presumption of isotropic space (not considering the topographic characteristics of the terrain). Trotta (2014) highlights that the majority of researches are developed and established in the USA and they cannot be applied with the same success on the smaller countries which are characterized by the small intercity distances, concentric organization of cities and irregular road networks.

Within the next few years we plan to explore the most frequent crime particularities at the territory of the City of Zagreb.

The research proposal includes the following goals:

1. To examine different methods for geographic profiling on the patterns that are typical for Croatia, City of Zagreb;
2. To compare the raster and network analysis using the available road network;
3. To explore the methods of updating the existing road networks using the satellite images, aerial images and/or digital elevation model;
4. To implement the topographic conditions in distance decay kernel functions;
5. To explore the possibilities of implementing the methods of machine learning.

Expected practical objectives of this research and scientific contribution to criminal investigators:

1. Finding the optimal geographic profiling methodology for the City of Zagreb and certain categories of crime with specific spatial-temporal-social circumstances and supplementing kernel functions with topographic conditions increasing the credibility of the applied model and thus the final result, i.e. the area of the perpetrator's expected residence;
2. In the education of criminal investigators, it is possible to use geographic profiling models for simulating and investigating environmental impacts of the commission of criminal offences;
3. By treating neural networks at a large set of actual data contained and systematized into patterns of the perpetrator, criminal offense, and target, it would be possible to form trained neural networks for the most common criminal offenses. The application of a trained network to a new case can, by means of experimental criminology, point to and/or facilitate the interpretation of some facts relevant to the particular case;
4. Training neural networks and their use can significantly contribute to a better understanding of the conditions and circumstances that lead to the criminal behavior. It is believed that this feature is important not only in its practical operational use, but also in the training of future criminal investigators.

***Keywords:*** *Environmental criminology, Geographic profiling, Machine Learning, Spatial Analysis*

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# Investigating the evolution and interactions of the September 2017 CME events with EUHFORIA

**Camilla Scolini**[1,2], Luciano Rodriguez[2], Manuela Temmer[3], Jingnan Guo[4], Mateja Dumbovic[3], Jens Pomoell[5], Stefaan Poedts[1]

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Coronal Mass Ejections (CMEs) and their Interplanetary counterparts (ICMEs) are the primary source of strong space weather disturbances at Earth and other places in the heliosphere. Key parameters determining the geo-effectiveness of CMEs are their plasma dynamic pressure and internal magnetic field intensity and orientation. In addition, phenomena such as the interaction with other CME structures along the way, or the pre-conditioning of interplanetary (IP) space due to the passage of previous CMEs, can significantly modify the properties of single CME events and influence their geo-effectiveness. Therefore, investigating and modeling such phenomena via physics-based heliospheric models is crucial in order to assess and improve our space weather prediction capability in relation to complex CME events.

In this regard, we present a comprehensive analysis of the CME events that erupted from AR 12673 during the unusually active week of September 4-10, 2017, with the aim of validating for the first time the prediction capabilities of the EUHFORIA model in the case of complex CME events. As AR 12673 rotated along with the solar disk, CMEs were launched over a wide range of longitudes, interacting with each other and paving the way for the propagation of the following CMEs. Following the eruptions, ICME-related signatures were observed at both Earth and Mars, while associated particle events were reported at Earth, Mars, and STEREO-A. In terms of impact on Earth, an intense geomagnetic storm, triggered by a strong southward magnetic field associated to an ICME sheath, was recorded on September 8, 2017.

In order to study these CME-CME interactions and their influence on the geo-effectiveness of single CMEs, we simulate the events using the EUHFORIA model. With the intent of preserving a predictive approach, we use kinematic, geometric and magnetic input parameters for the CMEs as derived from remote-sensing and multi-spacecraft observations of the CMEs and their source regions. We model CMEs first using an over-simplified cone model, and then a more realistic flux-rope model so to quantify the improvement in the prediction of the interplanetary magnetic field and CME geo-effectiveness at Earth in the latter case. Furthermore, we investigate the modelling of CME-CME interactions considering the spatial and temporal evolution of ICMEs in terms of their shocks, sheaths and ejecta structures in the heliosphere, and we quantify the impact of such phenomena on the propagation and evolution of single CME events. Results from this study will not only benchmark our current prediction capabilities in the case of complex CME events, but will also provide better insights on the large-scale evolution and interaction of complex CME events in the inner heliosphere.

**Space Weather chains connecting the Sun to Earth**

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Space weather is driven by the variability of the solar magnetic field. Major space weather events are due to sudden reconfigurations of the coronal field that lead to energy releases and eruptions forming flares and coronal mass ejections. These solar events result in a variety of manifestations that affect the Earth's space environment, its magnetosphere and uppermost atmosphere. There are basically three ways how the Sun affects the Earth's space environment: the electromagnetic radiation, the plasma flow (solar wind) and the high-energy charged particles. In this review, we will discuss the solar sources of major space weather events, the relevant transport and coupling processes in the interplanetary space and their interaction with the Earth's magnetosphere and upper atmosphere.