Solar Storm Early Forecasting — ”SolarCast-1”

Report of Contributions

Contribution ID: **1** Type: **not specified**

Data Driven Simulation of Solar CME Eruptions in Comparison with MRX Laboratory Eruption Experiments

Tuesday 10 November 2015 12:15 (45 minutes)

We compare observed CME eruptions with the results of GOEMHD3 numerical simulations of the Solar atmosphere based on data obtained by observations of the Sun and taking into account cross-scale coupling effects of turbulence. We compare our findings with those of current laboratory eruption experiments carried out at the Princeton Plasma Physics Laboratory (MRX).

Author: Prof. BUECHNER, Joerg (Max-Planck-Institute for Solar System Reserach)

Presenter: Prof. BUECHNER, Joerg (Max-Planck-Institute for Solar System Reserach)

Contribution ID: **2** Type: **not specified**

Reconstruction of meriodional flow speed of a solar dynamo model by data assimilation algorithm

Monday 9 November 2015 15:00 (30 minutes)

Accurate knowledge of time-variation in meridional flow-speed and profile is crucial for estimating a solar cycle's features, which are ultimately responsible for causing space climate variations. However, no consensus has been reached yet about the Sun's meridional circulation pattern observations and theories. By implementing an Ensemble Kalman Filter (EnKF) data assimilation in a Babcock-Leighton solar dynamo model using Data Assimilation Research Testbed (DART) framework, we find that the best reconstruction of time-variation in meridional flow-speed can be obtained when ten or more observations are used with an updating time of 15 days and a ≤10% observational error. Increasing ensemble-size from 16 to 160 improves reconstruction. Comparison of reconstructed flow-speed with "true-state" reveals that EnKF data assimilation is very powerful for reconstructing meridional flow-speeds and suggests that it can be implemented for reconstructing spatio-temporal patterns of meridional circulation.

Author: Dr MITRA, Dhrubaditya (NORDITA (Nordic Institute of Theoretical Physics), Stockholm)

Presenter: Dr MITRA, Dhrubaditya (NORDITA (Nordic Institute of Theoretical Physics), Stockholm)

Contribution ID: **3** Type: **Invited Key Topic Presentation**

Physics-based space weather forecasting based on high performance computing

Monday 9 November 2015 10:00 (45 minutes)

Space exploration is no gala dinner. Space is full of threats for humans and for their technology. Radiation from the Sun and form the Cosmos, magnetic storms, sudden emission of energetic particles are examples of the fascinating phenomena that besides being of great scientific interest are also a grave danger.
Modeling these processes is a grand challenge that modern scientific computing based on new emerging paradigms for parallel supercomputers can meet. New mathematical methods, new software developments and new computer hardware need to match the new data feeds from new space missions to reach this grandiose goal.
We describe the progress made in this field by the successfully concluded Soteria, Swiff and eHeroes projects and by the ongoing DEEP and DEEP-ER projects as well as the activities relative to the NASA four spacecraft mission MMS.

Author: Prof. LAPENTA, Giovanni (KU-Leuven, Dept. for plasma astrophysics, Belgium)

Presenter: Prof. LAPENTA, Giovanni (KU-Leuven, Dept. for plasma astrophysics, Belgium)

Contribution ID: **4** Type: **Invited Key Topic Presentation**

Polywell Fusion - Electrostatic Fusion in a Magnetic Cusp Bottle

Tuesday 10 November 2015 14:30 (1h 30m)

Nuclear fusion power is considered the ultimate energy source because of its nearly inexhaustible supply of cheap fuels, intrinsic safety, zero emissions and lack of long-lived radioactive waste. Despite tremendous progress in science and technology of fusion reactors, the general consensus has been, and still is, "fusion is always 20 years away". In this talk, I will introduce the Polywell fusion concept that may offer a low cost and rapid development path to power the world economically and sustainably.

As conceived by Dr. Robert Bussard at EMC2 in 1985, the Polywell fusion concept combines electric fusion with magnetic cusp confinement. This allows the Polywell reactor to be small, stable, and highly efficient. The successful development of Polywell reactor hinged on validating magnetic cusp confinement. Since 1994, EMC2 had built and operated successive test devices from Wiffle-Ball-1 (WB-1) to WB-8. Finally, EMC2 carried out an experiment that demonstrated dramatically improved high-energy electron confinement in a magnetic cusp system in late 2013. A committee of fusion science experts independently reviewed this work and stated that it was "a major achievement and a prerequisite to concept success". I will present a roadmap to complete the proof-of-principle test toward a net power producing Polywell fusion reactor for electricity generation.

Author: Dr PARK, Jaeyoung (Energy Matter Conversion Corporation)

Presenter: Dr PARK, Jaeyoung (Energy Matter Conversion Corporation)

Contribution ID: **5** Type: **not specified**

First Results from Euhforia: A Physics-Based Forecasting-Targeted Inner Heliosphere Model

Monday 9 November 2015 10:45 (45 minutes)

In this work, we present the first results of the new physics-based forecasting-targeted inner heliosphere model Euhforia ('European heliospheric forecasting information asset') that we are developing.

Euhforia consists of a coronal model and a magnetohydrodynamic (MHD) heliosphere model with CMEs. The aim of the baseline coronal model is to produce realistic plasma conditions at the interface radius r = 0.1 AU between the two models thus providing the necessary input to the time-dependent, three-dimensional MHD heliosphere model. It uses GONG synoptic line-of-sight magnetograms as input for a potential (PFSS) field extrapolation of the low-coronal magnetic field coupled to a current sheet (CS) model of the extended coronal magnetic field. The plasma variables at the interface radius are determined by employing semi-empirical considerations based on the properties of the PFSS+CS field such as the flux tube expansion factor and distance to nearest coronal hole. The heliosphere model computes the time-dependent evolution of the MHD variables from the interface radius typically up to 2 AU. Coronal mass ejections (CMEs) are injected at the interface radius using a hydrodynamic cone-like model using parameters constrained from fits to coronal imaging observations. In order to account for the modification of the heliosphere due to the presence of earlier CMEs, the standard run scenario includes CMEs launched five days prior to the start of the forecast, while the duration of the forecast extends up to seven days.

In addition to presenting results of the modeling, we will highlight our on-going efforts to advance beyond the baseline in the forecasting pipeline. In particular we discuss our path towards using a time-dependent data-driven coronal model to drive the heliospheric model.

Author: Dr POMOELL, Jens (University of Helsinki)

Presenter: Dr POMOELL, Jens (University of Helsinki)

Contribution ID: **6** Type: **not specified**

Coronal mass ejection, space weather perspective

Tuesday 10 November 2015 10:30 (30 minutes)

In this presentation I will discuss the key solar wind parameters in Coronal Mass Ejections (CMEs) that determine their ability to disturb the near-Earth space environment. The emphasis is one those factors that are needed from solar modelling to improve the accuracy of long-lead time targeted space weather forecasts. The particularly important for determining the timing, magnitude and details of the magnetospheric response are the profiles of the interplanetary magnetic field north-south component, solar wind density and speed. Currently, our ability to predict even the intrinsic CME flux rope configuration is very limited. Furthermore, this intrinsic flux rope configuration may experience significant changes during the eruption, lift-off and its propagation from Sun to Earth, all which can dramatically affect its geomagnetic response. I will also shortly discuss another key driver of space weather storms, turbulent sheaths ahead of CMEs.

Author: Dr KILPUA, Emilia (University of Helsinki)

Presenter: Dr KILPUA, Emilia (University of Helsinki)

Contribution ID: **7** Type: **not specified**

Sub-Grid-Scale Description of Turbulent Magnetic Reconnection in MHD

Wednesday 11 November 2015 11:00 (30 minutes)

Magnetic reconnection requires, at least locally, a non-ideal plasma response. In collisionless space and astrophysical plasmas, turbulence could permit this instead of the too rare binary collisions. The possible influence of turbulence on the reconnection rate is investigated in the framework of a single fluid compressible MHD approach through simulations of a double Harris and force free current sheets, with finite guide magnetic fields. The goal is to find out, whether unresolved, sub-grid for MHD simulations, turbulence can enhance the reconnection process in high Reynolds number astrophysical plasma including force free and guide magnetic field. For this sake, evolution equations for the sub-grid turbulent energy and cross helicity according to Yokoi's (2013) model is solved simultaneously with the grid-scale MHD equations. Dependence on resistivity for large Reynolds number for the tested equilibria is interpreted obtaining the limit of fast magnetic reconnection and important relation between the molecular and turbulent resistivity is obtained. The turbulence timescale parametrising the sub-grid model controls the regime of reconnection rate in both equilibria, deciding whether reconnection takes place or if the system is just turbulent. This implies that turbulence play an important role on fast reconnection at situation of large Reynolds number while the amplitude of turbulence can still be small.

Author: WIDMER, Fabien (Max Planck Institute for Solar System Research)

Co-author: Prof. YOKOI, Nobumitsu (University of Tokyo)

Presenter: WIDMER, Fabien (Max Planck Institute for Solar System Research)

Contribution ID: **8** Type: **not specified**

Application of data assimilation techniques to heliospheric modelling: two preliminary studies

Monday 9 November 2015 14:30 (30 minutes)

Data assimilation techniques are a way to obtain a better estimate of the state of a system by combining modelling (i.e., simulations) and measures of relevant quantities. Let us assume that an evolution law for the system is known and that observations of the system are available. A transfer matrix which maps the state to the observations is also known. Then, it is possible to obtain an 'a posteriori', improved estimate of the system state by correcting an 'a priori'estimate with a factor obtained by appropriately combining observations, the a priori estimate and a measure of the reliability of the model and of the observations. Data assimilation methods are routinely used in fields, such as meteorology, ionospheric modelling, radiation belt dynamics, oceanic studies, where a variety of observations are available. Their application to heliospheric or solar modelling is just in its infancy.

We present here two preliminary studies. In [Innocenti et al, 2011], Kalman filtering techniques are applied to an empirical solar wind forecasting model [Vršnak et al, 2007]. It is shown that Kalman filtering can improve the quality of the forecasts and extend the period of applicability of the baseline model. In a subset of cases, some degree of robustness toward solar transient activity not accounted for in the original model is also provided. In [Skandrani et al, 2014], the representers technique is used to assess how process and model state errors propagate in a MagnetoHydro Dynamic (MHD) code, FLIP-MHD, used for the simulation of solar wind propagation from the source surface to the Earth. The aim is to understand the impact of source surface input parameters on the evolution of MHD heliospheric models and the potentialities of data assimilation techniques in solar wind forecasting. The representer technique allows one to understand how far from the observation point the improvement granted from the assimilation of a measure propagates.

Author: Dr INNOCENTI, Maria Elena (KU-Leuven, Dept. for plasma astrophysics, Belgium)

Co-author: Prof. LAPENTA, Giovanni (KU-Leuven, Dept. for plasma astrophysics, Belgium)

Presenter: Prof. LAPENTA, Giovanni (KU-Leuven, Dept. for plasma astrophysics, Belgium)

Contribution ID: **9** Type: **not specified**

Accelerated k-means Clustering on Multi-Core and GPGPU

Wednesday 11 November 2015 10:00 (30 minutes)

Realistic simulations in plasma physics employ a large number of particles, usually beyond existing computer memory limits. To solve the problem, Particle-In-Cell (PIC) codes use the K-means clustering method to obtain a compact representation for so many particles by introducing mega-particles with "weight". However, the computational complexity of k-means is NP-hard to solve. Simpler heuristic algorithms such as Lloyd's exist, but their complexity still grows like O(n^2) with the number of particles. In addition, particle count is not constant during involved physical scattering processes, which may lead to exponential particle increase with simulation time.

The talk will present two main approaches for solving the performance bottleneck. First, combining KD-tree decomposition with a multi-core parallelization scheme based on OpenMP. Second, parallelize the algorithm on the GPGPU. Performance benchmarks, implementation issues and other remarks will be discussed.

The work is a joint effort performed at NBI during a PRACE project and ongoing activities.

Authors: Dr TRIER FREDERIKSEN, Jacob (Niels Bohr Institute); Mr MALÝ, Lukáš (VŠB-TUO: Technical University of Ostrava); Dr BURGDORFF KRISTENSEN, Mads Ruben (NBI); Mr BUTRASHVILY, Mordechai (Tel-Aviv University)

Presenter: Mr BUTRASHVILY, Mordechai (Tel-Aviv University)

Contribution ID: **10** Type: **not specified**

Energy based Active-Contours Methods for Scientific Image Segmentation

Wednesday 11 November 2015 14:30 (30 minutes)

Segmentation is a process used to identify objects within an image, including their boundary and other properties. Therefore, it serves as a key component in many image processing workflows, including scientific observation purposes. Most traditional methods use gradient information to extract object features and perform segmentation. However, there are drawbacks with such methods as they fail in the presence of noise, when object boundaries cannot be identified with gradients or even present convergence problems and numerical instability.

The talk will present the Chan-Vese Active Contour approach for image segmentation and why it is a great fit for astrophysical image processing. The method is based on level-set functions for contour representation and variational calculus for energy minimization (Euler-Lagrange). Further extensions of the method for multi-phase images and a statistical interpretation will be presented as well.

Authors: Mr BUTRASHVILY, Mordechai (Tel-Aviv University); Prof. SOCHEN, Nir (TAU)

Presenter: Mr BUTRASHVILY, Mordechai (Tel-Aviv University)

Contribution ID: **11** Type: **not specified**

Global MHD simulations of ejections of magnetic flux ropes

Wednesday 11 November 2015 14:00 (30 minutes)

Magnetic flux ropes ejections are considered a progenitor of Coronal Mass Ejections (CMEs) and their occurrence usually follows a long lasting equilibrium in the solar corona. Magnetic flux ropes form in the solar corona due to the evolution the coronal magnetic field driven by photospheric motions and flux emergence events and when magnetic flux ropes become unstable their ejection may turn into a CME releasing plasma and magnetic flux into the interplanetary space. Although state of the art simulations can explain flux rope ejections, to perform these studies from realistic configurations merged into the global corona is key to shed light on still standing questions: what is the impact of a flux rope ejection on the global configuration of the corona? Can a single ejection accelerate or trigger ejections in different locations?

However the size of the full coronal domain and the different time scales involved pose considerable challenges. To this end we couple the Global Non-Linear Force-Free Field (GNLFFF) model applied to observed magnetograms to 3D MHD simulations of the global corona. The GNLFFF is tailored to describe the slow magnetic evolution of the corona that leads to a flux rope formation, while the MPI-AMRVAC software is a numerical MHD model that keeps a general approach and can effectively model a fast flux rope ejection.

We will present our model and how its potential in the Space Weather forecast context and some preliminary results.

Author: Dr PAGANO, Paolo (University of St Andrews)

Co-author: Dr MACKAY, Duncan H. (University of St Andrews)

Presenter: Dr PAGANO, Paolo (University of St Andrews)

Contribution ID: **13** Type: **not specified**

Current and Future Challenges in Space Weather Science - a Forecaster's Perspective

Monday 9 November 2015 12:00 (30 minutes)

Real-time operational space weather forecasting is still a difficult task that requires specific observational inputs and modeling that are discussed in this presentation, with an emphasis on solar and interplanetary weather. The use of observational data to produce reliable predictions requires development of physical models and empirical/statistical methods. Scientific basis of space weather forecasting is discussed from the perspective of operational space weather forecasting service being run at the ISES Regional Warning Center Belgium. Several important problems are addressed in detail: solar and interplanetary magnetic field configuration, geometry of coronal mass ejections, acceleration and propagation of energetic particles. Possible ways of improving our predictive capabilities are discussed.

Author: Dr ZHUKOV, Andrei (Royal Observatory of Belgium)

Presenter: Dr ZHUKOV, Andrei (Royal Observatory of Belgium)

Contribution ID: **14** Type: **not specified**

Hot coronal jets and cool surges

Tuesday 10 November 2015 10:00 (30 minutes)

Although studied for a few decades now, the collimated plasma ejections detected in the EUV and X-Ray spectral ranges still contain many unsolved puzzles concerning the underlying coronal structures and the basic physical processes at work in them. The initial 2D numerical models of the 1990s provided basic physical insight in spite of the low spatial resolution and unrealistic values for the coronal parameters. In the meantime, both observations and theory have progressed considerably: observationally, the latest space missions provide simultaneous high-resolution coronal, photospheric and chromospheric data; for the theoretical work, highly efficient numerical codes with massive parallelization are available that can cope with processes from the top of the convection zone to the corona, in some cases including modules for a realistic equation of state, radiation transfer and heat conduction. This presentation aims at summarizing some recent progress in the understanding of the physics of the ejection phenomena, both of the hot, colimated coronal jets and of the associated cool surges.

Author: MORENO-INSERTIS, Fernando (Instituto de Astrofisica de Canarias)

Co-author: Dr GALSGAARD, Klaus (NBI)

Presenter: MORENO-INSERTIS, Fernando (Instituto de Astrofisica de Canarias)

Contribution ID: **15** Type: **not specified**

Particle acceleration in coronal and interplanetary shocks: quasilinear and hybrid-Vlasov simulations

Tuesday 10 November 2015 11:30 (45 minutes)

We present a study of particle acceleration at travelling coronal / interplanetary shocks. We use three simulation codes for the purpose: (1) the global CSA Monte Carlo simulation code; (2) the local SOLPACS Monte Carlo simulation code, and (3) the Vlasiator hybrid-Vlasov code, initially developed for global magnetospheric simulations, but used here for local simulations of interplanetary shocks. CSA and SOLPACS solve the evolution of the coupled system of energetic particles and Alfvénic turbulence upstream of a shock, using the quasilinear approximation in the description of wave-particle interactions. CSA simplifies the resonance conditions between the particles and the waves, whereas SOLPACS uses the full quasilinear description of the interaction. They compute the intensity of accelerated particles and the power spectrum of resonant Alfvén waves on a single magnetic field line connected to the shock. The advantage of this statistical approach is that large spatial domains can be covered without extensive computational demand, as the wave length of the resonant fluctuations is not resolved by the simulation. However, in this approximation no information on the wave phases can be obtained. Vlasiator, on the other hand, resolves the ion scale fluctuations in front of the shock in full. This allows investigations of wave forms in the foreshock, but limits the extent of the computational domain possible with present computational resources. Furthermore, the Monte Carlo codes use the gyrotropy assumption, whereas Vlasiator solves the 3D velocity distributions in full.

Our study is focused in the comparison of the simulation results with each other to reveal the range of validity of the codes in terms of energy spectra and spatial distributions of particles and the power spectra of waves in the foreshock region. We will discuss the implications of the results to shock acceleration in the solar corona and interplanetary medium and the possibilities to move towards operational models forecasting the evolution of large gradual SEP events.

Author: Prof. VAINIO, Rami (Department of Physics and Astronomy, University of Turku, Finland)

Co-authors: Dr AFANASIEV, Alexandr (Department of Physics and Astronomy, University of Turku, Finland); Dr BATTARBEE, Markus (Department of Physics and Astronomy, University of Turku, Finland); Prof. PALMROTH, Minna (Finnish Meteorological Institute, Helsinki, Finland); Dr VON ALFTHAN, Sebastian (CSC - IT Centre for Science, Espoo, Finland); Dr GANSE, Urs (Department of Physics, University of Helsinki, Finland); Mr PFAU-KEMPF, Yann (Finnish Meteorological Institute, Helsinki, Finland)

Presenter: Prof. VAINIO, Rami (Department of Physics and Astronomy, University of Turku, Finland)

Contribution ID: **16** Type: **not specified**

Magnetic Nulls in Kinetic Simulations of Space Plasmas

Wednesday 11 November 2015 11:30 (30 minutes)

We present the first ever systematic attempt to study magnetic null points and the associated magnetic energy conversion in kinetic Particle-in-Cell simulations of various plasma configurations. We address three-dimensional simulations performed with the semi-implicit kinetic electromagnetic code iPic3D in different setups: variations of Harris current sheet, dipolar and quadrupolar magnetospheres interacting with the solar wind; and a relaxing turbulent configuration with multiple null points. Spiral nulls are more luckily created in space plasmas: in all our simulations except lunar magnetic anomaly and quadrupolar mini-magnetosphere the number of spiral nulls prevails the number of radial nulls by a factor of 3-4. We show that often magnetic nulls do not indicate the regions of intensive energy dissipation. Energy dissipation events caused by topological bifurcations at radial nulls are rather rare and short-living. The so-called X-lines formed by the radial nulls in the Harris current sheet and lunar magnetic anomaly simulations are rather stable and don't exhibit any energy dissipation. Energetic events are more common in the vicinity of spiral nulls enclosed by magnetic flux ropes with strong current at their axes (resembling magnetic islands). These null lines or pinches efficiently dissipate magnetic energy due to secondary instabilities such as the two-stream or kinking instability, accompanied by changes in magnetic topology.

Author: Dr OLSHEVSKY, Vyacheslav (KU Leuven)

Co-authors: Dr DIVIN, Andrey (University of St. Petersburg); Mr CAZZOLA, Emanuele (KU Leuven); Prof. LAPENTA, Giovanni (KU-Leuven, Dept. for plasma astrophysics, Belgium); BO PENG, Ivy (KTH Royal Institute of Technology); Dr DECA, Jan (University of Colorado Boulder); INNOCCENTI, Maria Elena (KU Leuven); Dr MARKIDIS, Stefano (KTH Royal Institute of Technology)

Presenter: Dr OLSHEVSKY, Vyacheslav (KU Leuven)

Contribution ID: **17** Type: **not specified**

Measurements of coronal fields met by CME-driven shocks and determination of 3D CME kinematic

Monday 9 November 2015 16:00 (45 minutes)

The knowledge of coronal magnetic fields is of fundamental importance in order to understand the evolution of the main drivers of geomagnetic storms: solar wind and coronal mass ejections. Nevertheless, measurements of these fields are very difficult. Recently it has been shown that remote sensing UV and WL observations of shocks propagating into the corona and associated with major solar eruptions can be used to derive not only the strength, compression and deflection of coronal fields met by the shock, but also 2D maps of coronal field strength. The first part of this talk will summarize most recent results we obtained on these topics. Moreover, forecasting of geomagnetic storms also requires a good knowledge of the CME kinematic. Over the last 11 years it was shown that coronagraphic polarimetric observations of CMEs acquired by a single spacecraft can be used to infer the 3D direction of propagation of CMEs, using the polarization ratio technique. The second part of this talk will focus on this technique.

Author: Dr BEMPORAD, Alessandro (INAF-Turin Astrophysical Observatory)

Presenter: Dr BEMPORAD, Alessandro (INAF-Turin Astrophysical Observatory)

Contribution ID: **18** Type: **not specified**

Data driven modeling

Tuesday 10 November 2015 09:30 (30 minutes)

To reproduce the dynamical evolution of active regions in the Sun, it is required to use more realistic models. To a lowest order the magnetic field may be represented by simple field extrapolations based on the photospheric magnetic field distribution. This has been standard for many years. To reproduce the evolution of the magnetic field, a correct representation of the boundary stressing has to be imposed. This represents the difficult part of the project that needs to be improved.
Here we show a preliminary result from a direct data driven experiment of an active region.

Author: Dr GALSGAARD, Klaus (NBI)

Co-author: Dr MADJARSKA, Maria (Armagh Observatory)

Presenter: Dr GALSGAARD, Klaus (NBI)

Contribution ID: **19** Type: **not specified**

Terrestrial gamma-ray flashes, antimatter and hadrons correlated to lightning events

Wednesday 11 November 2015 09:30 (30 minutes)

For two decades thunderstorms have been observed to emit terrestrial gamma-ray flashes (TGFs), flashes of photons with single quantum energies of up to 40 MeV, as well as positron and neutron beams.
TGFs, the only known natural events with energies of several tens of MeV, are produced through the Bremsstrahlung process by high-energy electrons which are accelerated in the vicinity of conducting lightning channels. Although most electrons which are accelerated in the electric field of lightning channels, scatter with air molecules and do not gain sufficiently high energies, there is a small probability of some electrons not colliding too frequently and reach energies of up to tens of MeV. Once high-energy photons have been created, they can produce electron positron pairs through pair production at air nuclei and hadrons (neutrons as well as protons) through photonuclear processes.
We will present an overview of how to model the acceleration and scattering of electrons ahead of lightning channels as well as the motion of photons, positrons and hadrons through the atmosphere. We will present the spatial and energy distribution of these species at source altitude and at satellite altitudes (500 km) and briefly describe the relevance on human beings.

Author: Dr KOEHN, Christoph (DTU Space, Lyngby, Denmark)

Co-authors: Dr CHANRION, Olivier (DTU Space, Lyngby, Denmark); Dr NEUBERT, Torsten (DTU Space, Lyngby, Denmark)

Presenter: Dr KOEHN, Christoph (DTU Space, Lyngby, Denmark)

Contribution ID: **20** Type: **not specified**

Welcome