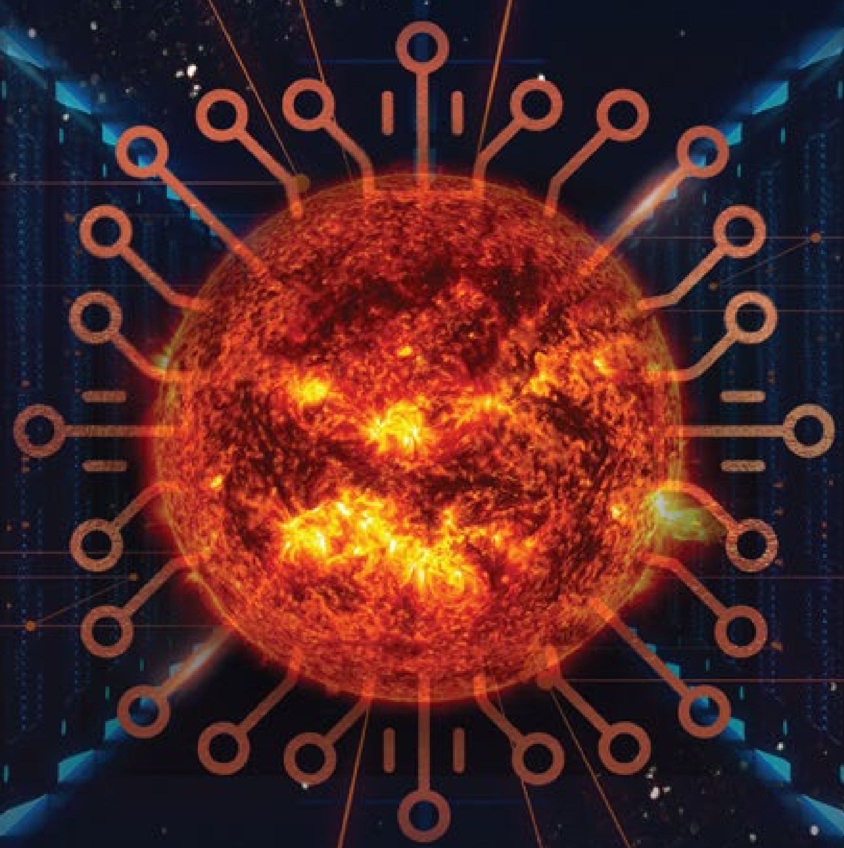
ABSTRACTS



MACHINE LEARNING AND COMPUTER VISION IN HELIOPHYSICS

MOSAIICS

19 - 21 APRIL 2023 SOFIA BULGARIA

INTERNATIONAL WORKSHOP

SESSION 1

EXPLAINABLE & PHYSICS - INFORMED MACHINE LEARNING

TITLE

Data-Driven Discovery of Fokker-Planck Equation for the Earth's Radiation Belts Electrons Using Physics-Informed Neural Networks (INVITED)

AUTHORS

Enrico Camporeale

AFFILIATION

NOAA

ABSTRACT

We use the framework of Physics-Informed Neural Network (PINN) to solve the inverse problem associated with the Fokker-Planck equation for radiation belts' electron transport, using 4 years of Van Allen Probes data. Traditionally, reduced models have employed a diffusion equation based on the quasilinear approximation. We show that the dynamics of "killer electrons" is described more accurately by a drift-diffusion equation, and that drift is as important as diffusion for nearly-equatorially trapped ~1 MeV electrons in the inner part of the belt. Moreover, we present a recipe for gleaning physical insight from solving the ill-posed inverse problem of inferring model coefficients from data using PINNs. Furthermore, we derive a parameterization for the diffusion and drift coefficients as a function of L only, which is both simpler and more accurate than earlier models. Finally, we use the PINN technique to develop an automatic event identification method that allows identifying times at which the radial transport assumption is inadequate to describe all the physics of interest.

TITLE

Physics informed neural networks and application to solar magnetic field simulations (INVITED)

AUTHORS

Robert Jarolim, Julia Thalmann, Astrid Veronig, Tatiana Podladchikova, Benoit Tremblay

AFFILIATION

University of Graz

ABSTRACT

Physics-informed neural networks (PINNs) provide a novel approach for numerical simulations, tackling challenges of discretization and enabling seamless integration of noisy data and physical models (e.g., partial differential equations). In this presentation, we highlight the new opportunities that are enabled through physics-informed machine learning. We will discuss the results of our recent study where we apply PINNs for coronal magnetic field simulations of solar active regions, which are essential to understand the genesis and initiation of solar eruptions and to predict the occurrence of high-energy events from our Sun. In order to provide for a non-linear force-free extrapolation of the coronal magnetic field, we optimize our network to match observations of the photospheric magnetic field vector at the bottom-boundary, while simultaneously satisfying the force-free and divergence-free equations in the entire simulation volume. We demonstrate that our method can account for noisy data and deviates from the physical model where the force-free magnetic field assumption cannot be satisfied. We utilize meta-learning concepts to simulate the evolution of the active region (AR) NOAA 11158. Our simulation of 5 continuous days of observations of the AR evolution at full cadence of 12 min of the HMI/SDO observations of the photospheric vector field (601 images), requires about 12 hours of total computation time. The derived evolution of the free magnetic energy and helicity in the active region, demonstrates that our model captures flare signatures, and that the depletion of free magnetic energy spatially aligns with the observed EUV emission from SDO/AIA. With this approach we present the first method that can perform realistic coronal magnetic field extrapolations in quasi real-time, which allows for advanced space weather monitoring. We conclude with an outlook on our ongoing work and the potential to extend this approach to MHD simulations.

TITLE

Artificial intelligence for space weather forecasting: data-driven and physics-informed approaches in research and operational settings (INVITED)

AUTHORS

Michele Piana, Sabrina Guastavino, Federico Benvenuto, Francesco Marchetti

AFFILIATION

Università di Genova

ABSTRACT

In my view, the usability of machine learning for space weather forecasting still poses the following three open issues: 1) Which is the most reliable way to quantitatively assess the prediction performances in the highly dynamical framework of heliophysics conditions? 2) Is the research-to-operation transition actually feasible by means of data-driven AI-based algorithms? And, eventually, 3) Can this transition be facilitated by encoding information provided by physical models into the computational procedures required for the training and optimization of the learning network schemes? Focusing on flares and coronal mass ejections forecasting, I will show that value-weighted skill scores are specifically appropriate for validating the prediction power of machine/deep learning algorithms, how the training procedure of neural networks can account for the part of the solar cycle progression when the prediction is requested, and to what extent deterministic propagation models and considerations about the physical dimension of data descriptors can be exploited to improve the forecasting power of machine learning.

SESSION 2

MACHINE LEARNING / COMPUTER VISION TECHNIQUES

ABSID: MCH23-01

TITLE

Deep Learning techniques implementation for the generation of stokes parameters and atmospheric parameters in the solar context

AUTHORS

Juan E. Agudelo Ortiz,
Germain N. Morales,
Santiago Vargas,
Sergiy Shelyag

AFFILIATION

NATIONAL UNIVERSITY OF COLOMBIA

ABSTRACT

The solar photosphere is the optical limit at which we can observe the greatest possible depth in the Sun. It is in it where structures generated by convective heating of the plasma in the solar interior are evident, and the border with the outer layers in the atmosphere solar. The study of the photosphere allows us to analyze the emergency zones of magnetic fields, whose evolution can give rise to explosive phenomena such as the so-called solar flares, and turbulent movements that can generate nanoflares. Despite the fact that solar observations are limited by the resolution of telescopes, for the last two decades, increasingly realistic simulations of the configuration of the solar interior and atmosphere have been developed, which use the magnetohydrodynamics equations and various conditions, depending on the particular characteristics and activity in each zone of the Sun, with which the physical properties and details of the structure of various solar regions can be studied. In this work the MURaM code is used to generate simulated physical parameters, such as density, temperature and velocity of the plasma, and the magnetic field, at different depths in the convective zone, and heights in the solar atmosphere. The main objective is, from the simulations, to train a 1D convolutional network model, which takes the values of density, temperature, magnetic field and velocity, in the normal direction to the solar surface along a column. The trained network is capable of generating the corresponding Stokes parameters, which describe the polarization state of light and provide relevant information on the magnetic properties of the medium. Based on this model, another version can be created that has an inverse functionality so that, now having the Stokes parameters as input, the corresponding physical parameters for the plasma and the magnetic field in the same domain (column) can be recovered.

ABSID: MCH23-44

TITLE

Understanding Predictability of Solar Proton Events from GOES statistical features and MHD coronal models

AUTHORS

Aatiya Ali,
Viacheslav Sadykov,
Alexander Kosovichev

AFFILIATION

GEORGIA STATE UNIVERSITY

ABSTRACT

Solar energetic particles (SEPs) and their propagation through the heliosphere and interactions with the Earth's atmosphere result in unfavorable consequences to numerous aspects of life and technology. Given the rare nature of these events, it is crucial to study data from the Sun at different solar cycles to develop the ability to reliably predict Solar Proton Events (SPEs). In this work we report the completion of a catalog of > 10 M e > 10 pfu SPEs observed by GOES satellites/detectors with records of their properties (start and end times, peak flux, fluence, etc.) spanning through Solar Cycles 22-24. Acatalog of daily proton and soft X-ray fluxes' statistical properties is also constructed for extending the SPE prediction effort presented by Sadykov et al. (2021). Using these catalogs, we discuss the application of machine learning for prediction of SPEs across these solar cycles, and emphasize effects of cycle-to-cycle differences in event statistics and feature importance. Further, by considering MHD models of the solar corona, we investigate the relevance of plasma conditions in regions of CME generation to the production of SPEs. We also discuss future work combining FORWARD emission modeling and COMP observations.

ABSID: MCH23-02

TITLE

A real-time solar flare alert system for early flare physics studies: Exploratory data analysis

AUTHORS

Milo Buitrago-Casas, Juliana Therese Vievering, Subramania Athiray Panchapakesan, Phillip C Chamberlin, Lindsay Glesener, Sam Krucker, Janet L Machol, Courtney L Peck, Marianne S Peterson, Katharine Reeves, Sabrina L Savage, Brent Smith, Amy R Winebarger, and Juan Carlos Martinez Oliveros

AFFILIATION

SPACE SCIENCES LAB - UC BERKELEY

ABSTRACT

In helio- and solar physics, it is of essential importance to accurately predict when and where the most extreme solar flares will occur. Improved forecasting capabilities would allow us to coordinate multiwavelength flare observations, which will improve our understanding of solar flare physics. To achieve this goal, we are developing a tool that uses real-time ultraviolet and X-ray signatures of flare onsets to provide information on the pre-flare and early flare stages. We have conducted an exploratory data analysis of historical datasets from the GOES/XRS and GOES/EUVS satellites to identify accurate predictors of early flare onset. We have found good correlations between the irradiance at 140.5 nm and the GOES class flare. We focus on finding early flare features that can be used to train ML models as the backbone of an early flare alert system. In the future, a tool like this will be used to trigger observations of the early stages of solar flares, a capability that will be essential for the first-ever solar-sounding rocket flare campaign scheduled for March 2024. The campaign will feature the FOXSI-4, Hi-C Flare, and SNIFS payloads.

ABSID: MCH23-45

TITLE

A Customized Distance Metric for Explainable In-Situ Solar Wind Clustering

AUTHORS

Daniel Carpenter,
Henry Han,
Liang Zhao

AFFILIATION

UNIVERSITY OF MICHIGAN ANN ARBOR

ABSTRACT

There are statistical differences between parcels of solar wind plasma, depending on the origin and observed parameters used. Physical observations, such as heavy ion composition and charge state distributions are measured on a continuum, departing from the commonly regarded bimodality of solar wind states seen when strictly separating by the ambient wind speed. These conditions observed in-situ are of direct consequence of heating, acceleration, and release processes, and unambiguously identify coronal structures. Machine learning methods of characterizing the in-situ solar wind leverage the more objective boundaries determined by dimensionality reduction and unsupervised deep clustering. These techniques have successfully accomplished this task in the past; however, there is room for introducing more explainable approaches. The definition of distance metric is one such way that the approach can be made more explainable, while also enhancing the quality of data embedding and downstream deep clustering. More interpretable customized distance metrics have been designed and explored in machine learning applications outside of heliophysics. Such work has resulted in an improvement of model performance, while also being more explainable and precise when it came to downstream data segregation and other analysis applications. Here, we present our work to develop a customized distance metric for in situ solar wind data, and discuss the process and design philosophy that goes into a metric specialized for this approach. We apply distance metrics in a dimension-reduction-stacking and deep clustering approach, and evaluate its performance with benchmark solar wind datasets in comparison with state-of-the-art methods.

ABSID: MCH23-47

TITLE

Three-dimensional reconstruction of ion flux in the Earth's northern cusp based on artificial neural networks

AUTHORS

Gonzalo Cucho-Padin,
David Sibeck

AFFILIATION

NASA GSFC

ABSTRACT

Magnetic reconnection on the dayside magnetopause represents the primary mechanism for transporting mass, momentum, and energy from the solar wind into the terrestrial magnetosphere. This energy transfer ultimately drives geomagnetic activity such as storms andsubstorms within the Earth's magnetosphere. Continuous investigation of magnetic reconnectionis diffi cult with current space-based instruments as spacecraft orbits restrict data in situobservations to at most a few minutes. Several studies have demonstrated that the location anddynamics of dayside magnetic reconnection can be inferred remotely from the time-energydispersion of ions in the Earth's cusps. However, individual spacecraft passes through the cuspslast only a few minutes. To overcome this problem, we generate a machine-learning-based model of the Earth's northern cusp using Cluster mission observations from 2001 to 2009 to reconstruct time-dependent, three-dimensional ion flux distributions. We implement a regression model using an artificial neural network (ANN) and several geomagnetic indexes and solar wind parameters as inputs, as well as ion flux acquired by the CIS/CODIF instrument onboard the Cluster mission as supervised outputs. Preliminary results show a high correlation between instrument observations and model outputs as a function of solar wind conditions. We demonstrate how this data-based model can be used to conduct comprehensive studies of the cusp and reconnection on the dayside magnetosphere for time-varying solar wind conditions.

ABSID: MCH23-60

TITLE

Insight on Flare Forecast with Explainable Deep Learning

AUTHORS

Gregoire Francisco,
Dario Del Moro,
Teresa Barata,
João Fernandes

AFFILIATION

UNIVERSITY OF ROME TOR VERGATA

ABSTRACT

Solar Flares are sudden and violent release of magnetic energy from the Sun's atmosphere in the form of electromagnetic radiation bursts. Being able to forecast Solar Flares accurately is essential to mitigate the risks associated with Space Weather, but it has been proven to be particularly challenging. Recently, Deep Learning Methods (DLMs) captured the interest of many researchers in the field and new data-driven approaches to the problem have been developed. With Explainability Methods (EMs) we can potentially reverse this data-driven approach to gather insight on the actual physics of the events. We apply EMs to DLMs trained on Solar Corona images which perform as well as models trained on Solar Photosphere magnetograms alone to forecast Solar Flares in a 24h forecasting window. In these preliminary results we confirm that our models efficiently learn known physical precursors, such as the presence of sigmoidal coronal structures, which are observational signatures of highly twisted and sheared magnetic fields in the Solar Corona. From this proof of concept we also verified that DLMs trained on Solar Corona images can be efficient to forecast Flares near the Solar Limb, where it is harder for models using magnetograms alone.

ABSID: MCH23-36

TITLE

Application of Deep Learning techniques for Stokes inversions using the Milne-Eddington approximation based on GRIS data

AUTHORS

Iaroslav Gorbachev,
Vigeesh Gangadharan,
Svetlana Berdyugina

AFFILIATION

LEIBNIZ-INSTITUT FÜR SONNENPHYSIK (KIS)

ABSTRACT

Optical spectral lines convey abundant information about the physical properties of the solar atmosphere. Interpretation of polarized spectra is typically based on inversion techniques: numerical methods that fit a guess model atmosphere to the observed polarized spectra. Inversions are computationally tedious, involving complex physical models that need to be solved numerically. One simple yet robust approach to such problem is based in the Milne-Eddington approximation, assuming an analytical solution for the radiative transfer equation. The main advantage of this approach is that a guess model atmosphere can be fitted to observed spectral lines extremely fast. Yet, the limitation is that magnetic fields and line-of-sight velocities are assumed to be constant, i.e. a non-stratified atmosphere is assumed. Additionally, thermodynamic effects are not properly included in this model, yet, it is used routinely for a first interpretation of spectropolarimetric data. One of the current challenges for solar data analysis is boosting computational power through parallelization strategies. Nevertheless, time spent on computations is very large. Therefore, a new strategy is required. We use fitted Stokes profiles obtained with the VFISV approach (Very Fast Inversion of the Stokes Vector; Borrero et al. 2011) for spectropolarimetric data obtained with GRIS at the GREGOR telescope as an input for feeding a neural network (NN) for a training process. As an output for the NN, we use the inversion parameters including line-of-sight velocity, magnetic field strength, azimuth and inclination. The NN applies a series of simple transformations on input data to produce an output. NN training means tweaking up coefficients of these simple transformations in order to suit input and outputs as accurately as possible. We will show how the physical parameters inferred by NN show an excellent agreement with the results obtained from inversions with a gain in time.

ABSID: MCH23-10

TITLE

Building a Coronal Mass Ejection source region catalogue for Machine Learning based space weather forecasting

AUTHORS

Julio Hernandez Camero,
Lucie M. Green,
Thomas D. Kitching

AFFILIATION

MULLARD SPACE SCIENCE LABORATORY

ABSTRACT

Coronal Mass Ejections (CMEs) are one of the most violent eruptions in the Solar System. Earth-directed CMEs can potentially cause disruptions to the magnetosphere, impacting Earth-based systems. Thus, there is great interest in developing a forecast method which can accurately predict whether an active region will be CME-productive or not and if it will be, over what timescale. Effective forecasting methods would also have the potential to aid our understanding of the physical mechanisms behind CME eruptions. However, so far no forecasting method is able to effectively predict the future eruptive behaviour of an active region. Although some observational signatures such as sigmoids indicate likely eruptive activity, they can be hard to identify and are not present before all eruptions. Today, machine learning (ML) methods are being increasingly used in the field of heliophysics. Thus, one may ask whether these methods could be the missing key to predicting CMEs. Our work focusses exploring how useful Convolutional Neural Networks can be in identifying characteristic features in photospheric magnetogram and AIA images that indicate a future eruption. Our first task is to produce a catalogue of CME-productive active regions that will be used for ML training purposes. We describe how we are producing such a catalogue using a combination of coronagraph CME detection catalogues, with catalogues of a number of on-disk observational signatures that indicate the eruption of a CME to identify the source region. Such signatures include dimmings, seen at around the time of the CME eruption, or flares, known to be associated with CMEs, along with spatio-temporal correspondence constraints. We believe that a CME-productive region catalogue based on a robust identification of on-disk CME launch signatures has the potential to become an extremely useful tool in the development of not only our own future forecasting methods, but also in the field of Space Weather in general.

ABSID: MCH23-30

TITLE

Multi-Hour-Ahead Geoelectric Fields Forecast Using Multi-fidelity Machine Learning Method

AUTHORS

Andong Hu,
Enrico Camporeale

AFFILIATION

COOPERATIVE INSTITUTE FOR RESEARCH IN ENVIRONMENTAL SCIENCES AT THE UNIVERSITY OF COLORADO BOULDER

ABSTRACT

A fundamental but still unresolved problem in the Geospace environment is forecasting the occurrence of Geomagnetic Induced Current (GIC) calculated by horizontal geoelectric fields (including Ex and Ey). Instead of dB/dt , we develop a new model to directly forecast Ex and Ey multi-hour-ahead using the multi-fidelity based Machine Learning method, SuperMag data and Magnetotellurics (MT) survey results. Ex and Ey are retrieved from SuperMag data and Magnetotellurics (MT) survey results over SuperMag stations inside the United States with 1-min resolution. We train two separated models (Ex and Ey) for each station. A simple ML model and SWMF model are used for comparisons. Generally, the developed model significantly outperforms both simple ML model and SWMF model. Finally, the SHapley Additive exPlanations (SHAP) method is used to investigate the importance of each parameter to horizontal geoelectric fields.

ABSID: MCH23-53

TITLE

Fast Feature Recovery for Flux Emergence Forecasting in the Photosphere using Neural Networks

AUTHORS

Matthew Lennard,
Benoit Tremblay,
Andrés Asensio Ramos,
Hideyuki Hotta,
Haruhisa Iijima,
Sung-Hong Park,
Suzana S. A. Silva,
Gary Verth,
Viktor Fedun

AFFILIATION

UNIVERSITY OF SHEFFIELD

ABSTRACT

Advances in modeling magnetic flux tubes evolving the Sun's convective region (see e.g. Hotta & Iijima, 2020; Chen et al, 2021) have provided access to high resolution data, which allow the study of the photospheric flows and their relationship with intense emerging magnetic flux. In the literature, photospheric velocity fields have been mostly inferred by employing optical feature tracking with, for example, local correlation tracking (LCT). While this is useful for understanding flows mainly on supergranular scales, its limitations cause the reproduction of velocity fields to be influenced easily by noise, creating holes and large spikes of error when performing tracking at higher resolutions. Recently, neural networks (NNs) such as DeepVel (DV) (see Asensio Ramos et al., 2017) have been developed for deriving transverse flows from as few as two consecutive images of the photosphere at a wide range of spatial resolutions and cadences by learning from numerical simulations. They can work for photospheric observations at a wide range of spatial resolutions and cadences. More specifically, the spatial and temporal scale are limited only by the training data, making NNs highly adaptable. The combination of speed and accuracy of recovering these data from a trained version of DV are an improvement on the often-used Fourier LCT (FLCT) algorithm. The spatial and temporal scales of information are limited only by the training data, making NNs highly adaptable. These highly detailed velocity fields can be used to analyse plasma flow organisation using methodologies such as the Finite-Time Lyapunov Exponent (FTLE). In this work, we have tested and compared the ability of both FLCT and DV to recover velocities from the R2D2 simulation. We have then found notable features within the FTLE field, which may be used to forecast flux emergence hours before there are any visible indicators, such as the appearance of pores or sunspots.

ABSID: MCH23-24

TITLE

A Machine Learning Enhanced Approach for Automated Sunquake Detection in Acoustic Emission Maps

AUTHORS

Vanessa Mercea,
Alin Razvan Paraschiv,
Daniela Adriana Lacatus,
Anca Marginean,
Diana Besliu-Ionescu

AFFILIATION

TECHNICAL UNIVERSITY OF CLUJ-NAPOCA

ABSTRACT

Sunquakes are seismic emissions visible on the solar surface, associated with some solar flares. Although discovered in 1998, they have only recently become a more commonly detected phenomenon. Despite the availability of several manual detection guidelines, to our knowledge, the astrophysical data produced for sunquakes is new to the field of Machine Learning. Detecting sunquakes is a daunting task for human operators and this work aims to ease and, if possible, to improve their detection. Thus, we introduce a dataset constructed from acoustic egression-power maps of solar active regions obtained for Solar Cycles 23 and 24 using the holography method. We then present a pedagogical approach to the application of machine learning representation methods for sunquake detection using AutoEncoders, Contrastive Learning, Object Detection and recurrent techniques, which we enhance by introducing several custom domain-specific data augmentation transformations. We address the main challenges of the automated sunquake detection task, namely the very high noise patterns in and outside the active region shadow and the extreme class imbalance given by the limited number of frames that present sunquake signatures. With our trained models, we find temporal and spatial locations of peculiar acoustic emission and qualitatively associate them to eruptive and high energy emission. While noting that these models are still in a prototype stage and there is much room for improvement in metrics and bias levels, we hypothesize that their agreement on example use cases has the potential to enable detection of weak solar acoustic manifestations.

ABSID: MCH23-16

TITLE

Towards a technique for automatic detection and characterisation of oscillations in solar filaments

AUTHORS

Manuel Luna

AFFILIATION

UNIVERSIDAD DE LAS ISLAS BALEARES

ABSTRACT

Solar filaments are cold structures levitating in the solar corona. They are supported against gravity by a magnetic field called a filament channel with a magnetic flux rope structure. These sheared magnetic structures are produced by photospheric motions but also global motions of the solar plasma such as its differential rotation. In this sense, the structure of the magnetic field of the solar filaments could evolve over the solar cycle. The filaments are often subject to global oscillations. These are very common and a large part of the filament oscillates almost in phase triggered by an external energy disturbance such as a flare or a jet. It has been shown that these oscillations are directly related to the structure of the magnetic rope and the field strength. In a first phase, a spectral technique has been developed that allows us to obtain the filaments that undergo oscillations. However, we are developing techniques that will allow us to massively detect these global oscillations and to obtain the period of oscillation, the direction of oscillation, its amplitude, the damping period, etc. This will allow us to study how the solar filaments oscillate during the solar cycle and therefore shed light on how these structures evolve during the cycles.

ABSID: MCH23-14

TITLE

Non-Deterministic Models of Solar Wind Propagation from L1 to the Earth

AUTHORS

Connor O'Brien,
Brian Walsh,
Ying Zou,
Samira Tasnim,
Huaming Zhang

AFFILIATION

BOSTON UNIVERSITY

ABSTRACT

For the last several decades, continuous monitoring of the solar wind has been carried out by spacecraft at the first Earth-Sun Lagrange point (L1). In order to be usable by those studying the interaction between Earth's magnetosphere and the solar wind, those data must be propagated to some point closer to the Earth. The "state of the art" tool to propagate measurements from L1 (roughly 200 RE upstream) to Earth is the planar propagation method. This method, along with extensive instrument cross calibration, is used to construct the OMNI database. Although OMNI often performs well, it is nearly 20 years old and both technology and our physical understanding of solar wind propagation have evolved significantly since it was developed. It includes a number of known limitations including: Assuming all solar wind observed at L1 reaches the Earth "as-is", ignoring processing from L1 to the bow shock and the boundaries between flow parcels; Failing to include physically meaningful uncertainties; Stopping propagation at the nose of the bow shock and not providing an additional point at the subsolar magnetopause where energy transfer actually takes place. Motivated by these known limitations with the OMNI database, this project's objective is to develop an accurate L1-to-Earth solar wind propagation system using non-deterministic neural networks that provide predictions of parameters at the nose of the bow shock and the nose of the magnetopause, along with uncertainties for each measurement. These novel networks are shown to outperform the algorithms used to construct OMNI in both the solar wind and magnetosheath, as well as provide additional functionality due to the probabilistic nature of their outputs.

ABSID: MCH23-38

TITLE

Removing cloud shadows from ground-based solar imagery

AUTHORS

Jay Morgan,
Amal Chaoui,
Adeline Paiement,
Jean Aboudarham

AFFILIATION

UNIVERSITÉ DE TOULON, LIS LAB

ABSTRACT

All ground based observatories face a same problem: images may be polluted by terrestrial clouds. These clouds are often thin, due to no observations being usually performed in case of thick clouds. We propose a new method to remove these cloud shadows, based on deep learning. We evaluate our method on CaII and Halpha images from three different observatories, and a new dataset of synthetic clouds applied to real observations. Quantitative assessments are obtained through various image restoration quality metrics in a first instance, then through quantifying the enhanced automatic filament detection. We demonstrate improved results with regards to the traditional cloud removal technique, on different cloud types and textures. Faster computation times are also obtained.

ABSID: MCH23-49

TITLE

Automatic classification of Range-Time-Intensity maps of Equatorial Spread-F

AUTHORS

Susan Palacios,
Marco A. Milla

AFFILIATION

PONTIFICIA UNIVERSIDAD CATOLICÁ DEL PERÚ

ABSTRACT

The global navigation satellite systems (GNSS) and communication systems in the equatorial zone are being disturbed by a nighttime ionospheric phenomenon called Equatorial Spread-F (ESF). This phenomenon is related to plasma density irregularities at F-region height in the ionosphere. Since Peru is in the equatorial zone, studies of the ESF have been conducted for many years by the Jicamarca radar in the JULIA mode. As a result, measured power is recorded in Range-Time-Intensity (RTI) maps. These RTI maps show the temporal and spatial (height) occurrence of the ESF, allowing us to observe morphological patterns (bottom-type, bottom-side, radar plumes). This study aims to automatically classify the ESF patterns in the RTI power maps measured with JULIA. The database of these observations is available in Madrigal. The classification is based on machine learning algorithms. In particular, we are testing the following techniques, Random Forest (RF), eXtreme Gradient Boosting (XGBoost), and Neural Networks. The features used for the classification are statistical pattern information and upper atmospheric physical parameters.

ABSID: MCH23-22

TITLE

Modeling Solar Images from SDO/AIA with Denoising Diffusion Models

AUTHORS

Francesco Pio Ramunno, André Csillaghy

AFFILIATION

UNIVERSITY OF APPLIED SCIENCES NORTH WESTERN SWITZERLAND (FHNW)

ABSTRACT

Heliophysics lacks enough X-flare data to train a supervised algorithm to forecast flares. The data set is skewed due to the rare physical event, resulting in a unbalanced data set. Generative deep learning models may be used to produce high-quality images in different solar activity levels and overcome this issue. In this work we train a denoising diffusion model. Data is forward diffused with Gaussian noise and then the model steadily reverses diffusion and recovers input data. AIA instrument data are used and, in particular, the 17.1 nm band which shows coronal loops, filaments, flares, and active regions. Additional channels may be used. The GOES spacecraft X-ray measurements were utilised to classify each image using the solar flare scale (A, B, C, M, X), we used 1000 time steps and the Classifier Free Guidance to guide the generation. We labeled the sun activity using only three classes: A, B, and C+M. This avoids M-X label imbalance. UMAP reduced data dimensionality and cluster metrics, and FID evaluated our generator. Cluster metrics can compare the generated image distribution to the real image distribution. To compute the FID we used CLIP and IV3 as feature extractors. The Cluster Error for the ground truth and generated images is 0.08 (the lower the better), the Cluster Distance is 0.98 and 0.96, respectively (the closer to 1 the better), and the Cluster Standard Deviation is 0.93 and 0.9, respectively (the more is near to 1 the better it is). IV3 FID is 4.71, CLIP 0.13. (lower is preferable). The cluster metrics reveal that the model can uniquely synthesise all the training set activity and generate realistic sun images with varied activity levels without mode collapse. As future work, we want to focus on the higher energy regimes C, M, and X, so we can produce high-activity images and fix the unbalancing issue, moving towards building a diffusion model that can identify out-of-distribution events.

ABSID: MCH23-40

TITLE

Segmentation, grouping and classification of sunspots from ground-based observations using deep learning methods

AUTHORS

Niels Sayez,
Christophe De Vleeschouwer,
Véronique Delouille,
Sabrina Bechet,
Laure Lefèvre

AFFILIATION

UCLOUVAIN, STCE/ROYAL OBSERVATORY OF BELGIUM

ABSTRACT

The paper introduces a fully automatic system that processes ground-based white light (WL) solar observations from the USET facility in Belgium in order to detect, aggregate, and classify sunspot groups according to the McIntosh scheme. Sunspot segmentation is based on a convolutional neural network (CNN), trained from pseudo-labels obtained by thresholding the WL images. Our work demonstrates that, despite the fact that CNN is trained on error-prone pseudo-labels, it is able to provide segmentation that is more accurate than the masks directly obtained by image thresholding. CNN-based prediction also offers the advantage of being robust to the presence of clouds. Given the sunspot mask, a mean-shift algorithm is used to aggregate sunspots into sunspot groups. The proposed clustering approach has the capability to account for the area of each sunspot as well as for prior knowledge regarding the spatial distribution, i.e. the shape, of a group. A sunspot group, defined by its cropped bounding box, its segmentation mask, and its location on the Sun, is fed into a CNN multitask classifier, predicting the three characters in the McIntosh system. The tasks, corresponding to each character, are organized hierarchically to mimic the dependency of the second and third characters on the first. Our experiments showed that when compared with classical thresholding, segmentation using CNNs brings an enhancement up to 17% of F1 score in detection of the smallest sunspots while keeping comparable Intersection over Union (IoU). We compare our clustering method with the USET sunspot group catalog. Our automated clustering method was able to separate the sunspot groups with an accuracy of 90%. While our classifier is based only on WL images recorded from the ground and thus more prone to noise e.g. atmospheric seeing and clouds, it shows comparable performances to methods using continuum and magnetogram images from SDO/HMI.

ABSID: MCH23-19

TITLE

Deep learning image-burst stacking for post-processing of high-resolution ground-based solar observations

AUTHORS

Christoph Schirninger,
Robert Jarolim,
Astrid Veronig,
Christoph Kuckein

AFFILIATION

INSTITUTE OF PHYSICS, UNIVERSITY OF GRAZ

ABSTRACT

Modern ground-based solar observations provide unprecedented details of small-scale structures, which fosters our understanding of plasma dynamics and solar magnetism. Earth's turbulent atmosphere imposes a significant challenge that limits the spatial resolution of solar observations. In this study, we present a deep learning method that aims at mitigating the atmospheric degradation effects on high-resolution solar images by combining the information from an image burst into a single enhanced observation. We build on unpaired image translation, where we translate short-exposure image stacks into a target high-quality domain. As input we use speckle bursts from the GREGOR Telescope. For our training target we experiment with Speckle reconstructed images, and Hinode SOT observations. We evaluate our method by comparing to state-of-the-art methods for image reconstruction like Speckle reconstruction. Our deep learning approach has the potential to effectively reconstruct solar images in real-time and to mitigate atmospheric seeing effects.

ABSID: MCH23-27

TITLE

A Cluster of Machine Learning Enabled Magnetometer System For Online Training And Prediction of Geomagnetic Disturbances

AUTHORS

Talha Siddique,
Md. Shaad Mahmud,
Amy Keesee

AFFILIATION

UNIVERSITY OF NEW HAMPSHIRE

ABSTRACT

In the past literature, Machine Learning (ML) models have been trained using ground magnetic components and solar wind data to analyze and predict geomagnetic disturbances. However, such data suffer from background noise and require baseline correction. The conventional baseline correction process is offline; hence, the available data cannot be used in real-time. The traditional ML approach is to train the model offline on historical data. The approach assumes that the training and test dataset has independent and identical distributions (i.i.d). The assumption does not hold in practice, as the data distribution of a natural system like solar wind and Earth's geomagnetic activity are subject to shift over time. Therefore, the ML models are susceptible to data and parameter uncertainty. The proposed work aims to address the gaps above by implementing an array of low-cost ML-enabled magnetometer systems that can perform baseline correction and predict geomagnetic components in real-time through online learning. A unit system consists of a PNI RM3100 magnetometer connected to an iBUG development board. The iBUG board is an ML-enabled Internet of Things (IoT) edge platform with long-range wireless communication capability. ML models are deployed in each of the iBUG boards. They are trained to accomplish- 1) real-time calibration and prediction of baseline corrected values using the data collected by the sensor and 2) using the baseline corrected data and Real-Time Solar Wind (RTSW) data from National Oceanic and Atmospheric Administration (NOAA), predict the changes in the ground magnetic component. The resultant forecasts are determined using an online ML paradigm called Peer-to-Peer (P2P) Federated Learning (FL). In P2P FL, the models on the edge devices are trained online. The edge devices communicate with each other to aggregate the estimated parameters. Monte Carlo simulation can be performed in real-time to obtain prediction uncertainty for better reliability.

ABSID: MCH23-12

TITLE

Mitigation of Radio Frequency Interference in Solar Radio observations using Generative Adversarial Networks

AUTHORS

Jeremiah Scully,
Ronan Flynn,
Peter Gallagher,
Mark Daly

AFFILIATION

TECHNOLOGICAL UNIVERSITY OF THE SHANNON

ABSTRACT

Radio astronomy is a vital tool for astronomers to study the Universe and has seen a wave of renewed interest and advancement over recent years. Next-generation radio telescope arrays such as LOFAR are developed to be significantly more sensitive compared to older traditional telescopes, which as a result also make them more susceptible to radio frequency interference (RFI). Radio RFI may contaminate the signal received by such radio telescopes. This highlights the need for effective RFI mitigation techniques in radio astronomy. We present a deep learning-based RFI mitigation approach that aims to identify and remove RFI within solar RFI-corrupted spectrogram observations in an unsupervised approach using a modified RFI Removal generative adversarial network (RFIR-GAN) framework. By using observed examples of SRB data containing RFI, we can train RFIR-GANs to identify and remove the effects of RFI within observed images. Furthermore, we evaluate the model's generated results using human perception, then we illustrate a 37.85% increase in image similarity using a metric known as Fréchet Inception Distance.

ABSID: MCH23-03

TITLE

Forecasting Space Weather with Physics-Based Input and Temporal Convolutional Neural Networks

AUTHORS

James Wanliss

AFFILIATION

PRESBYTERIAN COLLEGE

ABSTRACT

The development of early warning systems and extension of forecasting time is a critical demand for real-world applications, such as extreme space weather originating in solar flares, coronal mass ejections, and other solar phenomena. Long Short Term Memory networks (LSTMs) are a type of recurrent neural network (RNN) capable of realizing long-term dependencies. LSTMs are purposefully designed to avoid the long-term dependency problem and do not rely on specific assumptions about the data such as time series stationarity. This makes them useful for the study of physical problems where persistence is a clear feature of the nonstationary data, such as extreme space weather. In this paper we apply the PyTorch machine learning framework to study the global magnetic storm index Dst, a strong metric of space weather. As input we include a previously developed physics-based complexity measure based on symbolic dynamics. The measure representation algorithm decreases the computational burden and makes it possible to directly compare statistical properties of the model and the multifractal complexity measure produced from Dst. Next, we compare results of LSTMs with a new application of Temporal Convolutional Neural Networks (TCNN) to extend previous space weather forecasting methods.

SESSION 3

MACHINE LEARNING / COMPUTER VISION APPLICATIONS IN HELIOPHYSICS

ABSID: MCH23-50

TITLE

Parametrization of solar active regions using Variational Autoencoders

AUTHORS

Jorge Amaya

AFFILIATION

ESA

ABSTRACT

In previous publications we have demonstrated that an unsupervised classification of the flaring activity of solar active regions is extremely difficult using only the SHARP parameters provided by the HMI instrument onboard SDO. This has inspired some authors to make use of classical deep learning techniques to extract visual hints of solar activity. These techniques were mainly based on the use of vanilla autoencoders. While this technique showed promising results, it did not produce very accurate reconstructions. But more importantly, the bottleneck in these methods contains hundreds, or thousands, of parameters rendering the categorization of solar active regions extremely difficult. In this presentation we show how to produce accurate reconstructions that require only six (6) parameters in the bottleneck of our neural network architecture. Using Variation Autoencoders we manage to compress images of solar active regions to a very small parameter dimension that can simplify their classification. This technique also allows to generate never seen before active region images, due to the continuous nature of the latent space.

ABSID: MCH23-21

TITLE

Automated CME detection and tracking in HI

AUTHORS

Maike Bauer,
Tanja Amerstorfer,
Christian Möstl,
Ute V. Amerstorfer,
Martin A. Reiss,
Hannah T. Rüdisser,
Rachel L. Bailey

AFFILIATION

GEOSPHERE AUSTRIA

ABSTRACT

Being able to forecast the arrival of coronal mass ejections (CMEs) in real-time plays a central role in mitigating the potential consequences of severe space weather events. Currently, detection and tracking of CMEs as they move through the heliosphere is done manually. We want to implement an automatic detection and tracking algorithm that works with data from different HI instruments. The unprecedented number of currently active spacecraft carrying HI instruments will give us the ability to train our model using a variety of data. Developing and testing such an algorithm is particularly relevant at this time given the launch of Vigil in the mid-2020's. Vigil will act as a space weather monitor at the L5 point where it will be able to provide continuous, real-time HI observations of the Sun-Earth line. We present an initial proof of concept using the Mask-RCNN algorithm on STEREO-HI data to prove the feasibility of the project. We give an overview of possible future steps and challenges.

ABSID: MCH23-15

TITLE

Classification of Solar Flares using Data Analysis and Clustering of Active Regions

AUTHORS

Hanne Baeke,
Jorge Amaya,
Giovanni Lapenta

AFFILIATION

KU LEUVEN

ABSTRACT

Solar energetic activity poses a serious threat to the near-Earth environment. It poses radiation hazards to astronauts and spacecrafts and causes geomagnetic storms that can disable satellites and knock out power grids, with large economic impact. Solar active regions are the main source of this energetic activity. Their strong and complex magnetic fields can lead to magnetic reconnection – the main mechanism for solar flare formation and coronal mass ejections. We studied the threat level of active regions by clustering them based on magnetic field properties. The data set combines a reduced factorization of SHARP properties of active regions and their flaring activity. The SHARP magnetic field parameters are integrated values of surface magnetic vectors, over the active regions. Extensive data reduction and transformation, using machine learning techniques, is performed on the magnetic field parameters to enhance the SHARP data. Outliers are detected with clustering method HDBSCAN, redundant information is eliminated with Common Factor Analysis and sparse autoencoders add sparsity to the parameters. Finally, sampling methods are used to create a balanced data set, with a similar amount of weak and strong flaring active regions. The classification of the active regions is conducted using both supervised (based on K-Nearest Neighbors) and unsupervised (based on K-means and Gaussian Mixture Models) clustering. The results show that supervised clustering is effective in identifying strong X- and M-flares, while unsupervised classification can differentiate inactive regions, C/M-flaring regions and extremely active X-flare regions. However, we are unable to detect clear boundaries in moderate flaring activity levels (C- versus M-flares).

ABSID: MCH23-51

TITLE

Machine Learning/Mathematical Morphology coupling for solar features detection

AUTHORS

Slava Bourgeois,
Robertus Erdélyi,
Teresa Barata,
Ricardo Gafeira,
Orlando Oliveira

AFFILIATION

UNIVERSITY OF SHEFFIELD

ABSTRACT

We seek to identify and classify solar features such as sunspots, facular regions, filaments, jets, and pre-eruptive configurations of Coronal Mass Ejections (CMEs), whose behaviour influences solar activity in both the short and the long term, and therefore Space Climate and Space Weather (SW). We have developed Mathematical Morphology (MM) algorithms, based on set theory, which are effective to pinpoint all these different types of features. For instance, we have determined sunspots areas in the Solar Dynamics Observatory (SDO)/ Atmospheric Imaging Assembly (AIA) intensity images with this MM method, and we have compared the obtained values with existing solar databases (e.g., the Debrecen Heliophysical Observatory (DHO) catalogue or the Mandal et al.'s catalogue: "Sunspot area catalogue revisited: Daily cross-calibrated areas since 1874"). The good agreement between the MM results and the existing catalogues validates the method, which we then apply to the SDO/HMI magnetograms for contouring the different magnetic polarities in order to identify the so-called delta-sunspots, which are thought to be strongly correlated with the onset of powerful solar flares. However, the MM method also has limitations as it is affected by the strong effect of adverse weather conditions in solar images, and the fine-tuning of its parameters can only be done manually. In this way, Machine Learning (ML) techniques could prove to be very useful when combined with the MM method in what is called a Morphological Neural Network. The Neural Network would be able to complement the MM method, make it automatic, and allow us to obtain better performance metrics with more reliable results.

ABSID: MCH23-11

TITLE

Equatorial Plasma Bubble Prediction Model Using Satellite Data

AUTHORS

Suhaila M. Buhari,
Mardina Abdullah,
Liow Yu Yi

AFFILIATION

UNIVERSITI TEKNOLOGI MALAYSIA

ABSTRACT

The occurrence of ionospheric irregularities such as Equatorial Plasma Bubble (EPB) has become a crucial topic in space weather and space climate initiatives. EPB could induce serious error to technological applications such as space-based communication and navigation systems. The occurrence of EPB is ubiquitous and the prediction is not possible until now. Large-scale wave structure (LSWS) that appear in the late evening is believed to be the source of the occurrence of the EPB in the post-sunset time. The LSWS that occur at the bottom side of ionospheric layer will be observed using Low Earth Orbiting Satellite (LEOS) data. The LSWS could be detected in the late evening and the investigation of its characteristics will be useful in predicting the occurrences of EPB after post-sunset time. Therefore, this study is intended to; 1) obtain the occurrence of LSWS from LEOS data; 2) investigate the characteristics of the LSWS that cause the occurrence of the EPB in the post-sunset time; and 3) develop prediction model of EPB using machine learning algorithm, based on the characteristics of the LSWS. The output from the prediction model would be used to predict the occurrence of post-sunset EPB as early as in the late evening. The prediction model of EPB is important to eliminate error in GPS/GNSS navigation systems. The reliability of GPS/GNSS navigation system is crucial for future technological applications such as automotive, aviation, UAVs and agriculture that require high precision positioning up to submillimeter accuracy.

ABSID: MCH23-35

TITLE

Forecasting solar wind speed from solar EUV images

AUTHORS

Daniel Collin,
Stefano Bianco,
Guillermo Gallego,
Yuri Shprits

AFFILIATION

GFZ GERMAN RESEARCH CENTRE FOR GEOSCIENCES

ABSTRACT

One of the main sources of solar wind disturbances are coronal holes which can be identified in extreme ultra-violet (EUV) images of the Sun. Previous research has shown the connection between coronal holes and an increase of the solar wind speed at Earth. In this study, we propose a new machine learning model predicting the solar wind speed originating from coronal holes. We detect coronal holes by applying a recently introduced segmentation algorithm to solar EUV images. Based on that, we derive coronal hole characteristics, which are used as input to the model to predict the solar wind speed. We put a special focus on learning the geoeffective coronal hole areas, by splitting up the solar surface into multiple sectors of different latitudes and longitudes. This approach enables to predict the disturbances up to approximately 5 days in advance. We show that our model can accurately predict the solar wind speed with a temporal resolution of one hour during time periods when the solar wind is dominated by coronal hole activity. Moreover, we compare our results to other state-of-the-art models.

ABSID: MCH23-28

TITLE

Exploring U-net + LSTM networks for classification and segmentation of evolving granular structures

AUTHORS

Saida Milena Díaz Castillo,
Andrés Asensio Ramos,
Svetlana Berdyugina

AFFILIATION

LEIBNIZ INSTITUTE FOR SOLAR PHYSICS - KIS

ABSTRACT

Solar granulation is the visible signature of convective cells emerging from the upper layer of the convection zone towards the solar surface. High-resolution images have revealed the complexity of the granulation, evidencing special phenomena such as exploding granules or granular lanes, which are known to be directly related to the emergence of small-scale magnetic flux. Unveiling the nature of magnetic emergence in granules requires statistical studies, which are in turn supported by the effective identification and localization of the different evolving structures. The exploration and development of new automatic tools have become crucial to perform statistics on a large amount of data expected by new/upcoming instrumentation e.i. DKIST or Sunrise III. In this contribution, we present the current advances of our classification algorithm of solar granulation based on neural network segmentation including the exploration of Long Short-Term Memory (LSTM) modules for covering the temporal dimension of evolving granules classes. An initial model was tested using U-net architecture in a supervised approach using continuum intensity of the IMaX instrument onboard the Sunrise I and their corresponding segmented maps labelled using the multiple-level technique (MLT) and also by hand as a training set. We study the performance of this approach to assess the versatility of the U-Net architecture for single-frame segmentation. We found an interesting potential of the U-Net to identify granules reaching matching in pixels greater than 80%, achieving high levels of accuracy in the identification of the intergranular network and allowing the effective separation of granular morphologies. We identify per-class accuracy levels of around 60% in single snapshots which is substantially reduced when temporal sequences are included as extra channels. LSTM modules added within the deep layers of the network seem to improve the prediction accuracy compared with the previous case.

ABSID: MCH23-25

TITLE

A Universal Method for Solar Filament Detection from H-alpha Observations using Semi-supervised Deep Learning

AUTHORS

Andrea Diercke,
Robert Jarolim,
Christoph Kuckein,
Sergio Javier Gonzalez Manrique,
Marco Ziener,
Astrid Veronig,
Carsten Denker,
Werner Pötzi,
Tatiana Podladchikova,
Alexei Pevtsov

AFFILIATION

LEIBNIZ INSTITUTE FOR SOLAR PHYSICS (KIS)

ABSTRACT

Filaments are omnipresent features in the solar chromosphere. Their location, properties and time evolution can provide important information about changes in solar activity and assist the operational space weather forecast. Therefore, filaments have to be identified in full disk images and their properties extracted from these images. Manual extraction is tedious and takes too much time; extraction with morphological image processing tools produces a large number of false-positive detections. Automatic object detection and extraction in a reliable manner allows us to process more data in a shorter time. The Chromospheric Telescope (ChroTel), Tenerife, Spain, the Kanzelhöhe Solar Observatory (KSO), Austria, and the Global Oscillation Network Group (GONG), provide regular full-disk observations of the Sun in the core of the chromospheric H-alpha absorption line. We will present a machine learning application allowing us to reliably extract solar filaments from H alpha filtergrams. First, we train the object detection algorithm YOLOv5 with labeled filament data of ChroTel H-alpha filtergrams. The accuracy of the object detection is very high and it is possible to apply the algorithm to other H-alpha filtergrams, i.e., GONG data, to create a larger training data set for the further steps. In a second step, we apply a semi-supervised training approach, where we use the bounding boxes of filaments, that were created with YOLOv5, to learn a pixel-wise classification of solar filaments. Therefore, we utilize a standard deep learning model for semantic segmentation, i.e., U-Net. With the resulting segmentation masks, physical parameters such as the area or tilt angle of filaments can be easily determined and studied. In a last step, we apply the filament detection and the segmentation of filaments on a different H-alpha data set belonging to KSO, to estimate the general applicability of our method.

ABSID: MCH23-57

TITLE

Artificial neural network based spatio-temporal deconvolver for refinement of solar images

AUTHORS

Henrik Eklund

AFFILIATION

Stockholm University

ABSTRACT

The point spread function generally constitutes the resolution element in astronomical observations, which degrades the intensity contrasts and leaves structures at smaller angular resolution unresolved. The solar atmosphere is highly dynamic and the intensity of the radiation is strongly connected to small-scale dynamics, which can be used to improve the analysis of solar observations. An artificial deep neural network is trained to recognise dynamic patterns of features in both the spatial and temporal domains, to perform estimations on the intensity contrast degradation. The same technique is shown to also be applicable on for instance estimating the height of formation of the radiation. The neural network is trained on radiative transfer calculations from 3D MHD Bifrost simulations of the solar atmosphere and is applied to perform estimations on millimeter wavelength observations with ALMA to acquire more precise intensities and corresponding height of formation. The deep neural network can to large accuracy increase the contrasts of the observations and distinguish whether a small-scale brightening event or feature is well resolved and to what degree its intensity is over or underestimated. Using this method as a diagnostics tool for small-scale dynamic features in solar ALMA observations, where the intensity is closely related to the plasma temperature, enables to study the potential heating at small scales at the upper layers of the solar atmosphere.

ABSID: MCH23-62

TITLE

deARCE solar burst detection system applied to unlabeled e-Callisto data

AUTHORS

Mario Fernandez,
Javier Bussons,
Manuel Prieto

AFFILIATION

UNIVERSITY OF ALCALA

ABSTRACT

We present the application of a solar burst detection system on e-Callisto spectrograms which have not been labeled through expert visual inspection. e-Callisto is an international network of solar radio spectrometers that stands out mainly for its large number of observatories. This results in data geo-redundancy at certain longitudes, which allows for the confirmation (or rejection) of the occurrence of a particular solar event. During the 2012-2019 period, e-Callisto spectrograms are available, but there are no reports listing solar events. Therefore, our goal is to fill this gap with predictions generated by an automatic detection system based on convolutional neural networks (deARCE). In addition, due to the tricky nature of the data, the use of spectrograms from multiple observatories simultaneously is a key factor in providing greater reliability to the results. Such results will be provided via monthly reports similar to those found on the e-Callisto website under ”Event lists >=2020” (https://www.e-callisto.org/Data/data.html).

ABSID: MCH23-06

TITLE

PCA-NN model for TEC with space weather parameters as predictors: tuning of NN algorithms and input parameters

AUTHORS

Ricardo Gafeira,
Anna Morozova,
Teresa Barata,
Tatiana Barlyaeva

AFFILIATION

INSTITUTO DE ASTROFÍSICA E CIÊNCIA DO ESPAÇO

ABSTRACT

A proposed PCA-NN model for the total electron content (TEC) for the mid-latitudinal region (Iberian Peninsula) uses the principal component analysis (PCA) to decompose TEC variations into different modes and to reconstruct/forecast amplitudes of these modes using neural networks (NN) with different sets of space weather parameters as predictors. Convolutional and recurrent NN algorithms are tested with different sets of predictors. The results are compared to ones produces by a PCA-NN model with a simple feedforward NN with weight backpropagation. The performance of the models is tested on 3.5 years of observational data obtained at the declined phase of the 24th solar cycle, which allows us to estimate the models' performance in relation to the solar activity level.

ABSID: MCH23-37

TITLE

Probing the True Nature of CMEs using GCS-based Large Statistics of Multi-viewpoint Observations

AUTHORS

Harshita Gandhi,
Ritesh Patel,
Vaibhav Pant,
Dipankar Banerjee,
Huw Morgan

AFFILIATION

ABERYSTWYTH UNIVERSITY

ABSTRACT

CMEs are large eruptions of magnetised plasma from the sun whose kinematic properties, such as angular width, speed, and so on, are impacted by projection effects and hence provide a less accurate estimate of the true parameters. As a result, the behaviour of CMEs should be investigated stereoscopically. Thus, this extensive cohort analysis uses forward modelling on multi-viewpoint coronagraph data to examine the 3-dimensional morphology and kinematic parameters of 360 bright CMEs between 2007 and 2021. We also statistically analyse computed CME parameters before and after SR segregation. We classify the sources as active region (AR), active prominence (AP), and prominence eruption (PE). The overall speed and width distribution varies slightly before and after SR segregation, with a significant variation in the slope in the speed-width plot, which is 5.26 (all CMEs combined with CC = 0.40), 7.22 (AR-based CMEs with CC = 0.47), and 3.88 (AP-based CMEs with CC = 0.32), with no significant correlation found for CMEs from PE, clearly indicating that AR and AP contribute significantly to the overall speed-width analysis. We show how the Bootstrap method could help find the uncertainty in the speed measurement. Given the limited number of CME frames in the inner coronagraph field of view and the constraints of GCS fitting, only 70 of the total 360 events were selected for a separate study to examine the CME kinematics in the inner-outer link. We find an empirical relation between the true speed and the predicted speed of CMEs in both studies. We conclude that true speed varies by a factor of 1.3 in the inner and outer corona, which may be used in future missions investigating the inner-middle corona to quickly identify true speed once projected speed is known. These findings create a sufficient database for using Machine Learning to predict the effect of CMEs on Earth and near-Earth space.

ABSID: MCH23-20

TITLE

Martian bow shock detection with machine learning

AUTHORS

P. Garnier,
V. Genot,
M. Azib,
B. Renard,
B. Sanchez-Cano

AFFILIATION

IRAP,
UNIVERSITE TOULOUSE 3

ABSTRACT

The Martian interaction with the solar wind leads to the formation of plasma boundaries upstream of the planet. Their dynamics are complex due to the combined influence of external and internal drivers, and they plays a significant role in the global martian interaction in particular through the atmospheric erosion. It is thus of major importance to provide large catalogs of these boundary crossings to the community. We report here the use of supervised machine learning algorithms to automatically detect the martian bow shock crossings based in particular on the Mars Express data. We will also discuss the limits of the methods used.

ABSID: MCH23-39

TITLE

Can a deep learning approach of detecting solar radio bursts perform better than the interquartile range threshold outlier detection method? (RETRACTED)

AUTHORS

A. Gunessee,
Marqué, C.;
Martinez Picar, A.;
Dolla L.;
Delouille, V.

AFFILIATION

ROYAL OBSERVATORY OF BELGIUM

ABSTRACT

Anyone familiar with the field of solar radio burst detection and classification knows the cumbersome task of having to go through daily observations and manually recording the type of solar radio burst occurring in the spectrograms. Past non-AI based approaches have been applied to avoid or reduce that particular hindrance but with mixed results. One of these methods is an outlier detection rule, namely the interquartile range (IQR) threshold method which is currently running on the spectrograms of the CALLISTO instrument of the Royal Observatory of Belgium. Briefly, this method registers a burst when the brightness distribution over time of the spectrogram is higher than the sum of the third quartile with the product of 1.5 and its IQR. This simple criterion can be subject to many false positives and false negatives too, where false positives would be mainly due to RFIs. With the recent rise of big data and AI, we present a prototype model of detecting solar radio burst using YOLOv5. The initial prototype was trained on 306 images and resulted in a precision of 59.5% and a recall of 65.9%. This prototype also made us aware that this initial model iteration was susceptible to falsely detecting lightning strikes as bursts. Following these promising results and valuable lessons learnt, another round of annotations was just completed with roughly 1300 new images, and another class being added to the annotated data, that is, lightning strikes. The new annotations will allow the prospective model to not only detect if and how many solar radio bursts are present in a spectrogram but also classify which types are there. Ultimately, being able to correctly differentiate between genuine solar radio bursts and RFIs, and further classifying them into their different solar radio bursts types would be beneficial to monitoring solar activity and useful to the space weather community.

ABSID: MCH23-17

TITLE

Turning Noise into Data: Characterization of the Van Allen Radiation Belt Using SDO Spikes Data

AUTHORS

Spiridon Kasapis,
Barbara J. Thompson,
Juan V. Rodriguez,
Raphael Attie,
Gonzalo Cucho-Padin,
Daniel da Silva,
Meng Jin,
William D. Pesnell

AFFILIATION

NASA AMES

ABSTRACT

The Solar Dynamics Observatory (SDO) is a solar mission in an inclined geosynchronous orbit. Since commissioning, images acquired by Atmospheric Imaging Assembly (AIA) instrument on-board the SDO have frequently displayed “spikes”, pixel regions yielding extreme number of digital counts. These are theorized to occur from energetic electron collisions with the instrument detector system. These spikes are regularly removed from AIA Level 1.0 images to produce clean and reliable data. A study of historical data has found over 100 trillion spikes in the past decade. This project correlates spike detection frequency with radiation environment parameters in order to generate an augmented data product from SDO. We conduct a correlation study between SDO/AIA data and radiation belt activity within the SDO’s orbit. By extracting radiation “spike” data from the SDO/AIA images, we produce a comprehensive data product which is correlated not only with geomagnetic parameters such as Kp, Ap and Sym-H but also with the electron and proton fluxes measured by the GOES-14 satellite. As a result, we find that AIA spikes are highly correlated with the GOES-14 electrons detected by the MAGED and EPEAD instruments at the equator (where the two satellites meet) with Spearman’s Correlation values of $\rho=0.73$ and $\rho=0.53$ respectively, while a weaker correlation of $\rho=0.47$ is shown with MAGPD protons for the two year period where both missions returned data uninterruptedly. This correlation proves that the SDO spike data can be proven useful for characterizing the Van Allen radiation belt, especially at areas where other satellites cannot.

ABSID: MCH23-55

TITLE

Improving LOFAR Solar Radio Imaging Observations With Machine Learning

AUTHORS

Kamen Kozarev,
Oleg Stepanyuk,
Zornitsa Markovska,
Mohamed Nedal,
Mattia Mancini,
Pietro Zucca

AFFILIATION

INSTITUTE OF ASTRONOMY AND NATIONAL ASTRONOMICAL OBSERVATORY, BULGARIAN ACADEMY OF SCIENCES

ABSTRACT

Low-frequency interferometric radio imaging observations (20-300 MHz) of the quiet Sun holds important information about the state of the large-scale corona and the young solar wind, as well as non-burst activity too dim to be observed in spectral data. The Low Frequency Array (LOFAR) telescope is one of the most capable instruments in this respect. However, high quality processed images are still difficult to obtain, mostly due to ionospheric and radio frequency interference (RFI) effects. To mitigate these effects on low-frequency radio solar interferometric imaging, we have begun a program employing machine learning (ML) techniques to improve LOFAR solar observations. Such methods allow us to remove bad quality baselines, observations with radio frequency interference, and observations with significant ionospheric influence. In addition, the high-fidelity and sensitivity of LOFAR allow us to apply automated snapshot lucky imaging to solar data, selecting only the best images for further study. Here, we outline our approach, and present initial results.

ABSID: MCH23-07

TITLE

Forecasting the Transit Time of Earth-directed Halo CMEs Using Artificial Neural Network: A case study application of GCS forward-modelling technique

AUTHORS

Felix N. Minta,
Satoshi Nozawa,
Kamen Kozarev,
Ahmed Elsaid,
Ayman Mahrous

AFFILIATION

EGYPT-JAPAN UNIVERSITY OF SCIENCE AND TECHNOLOGY, BASIC AND APPLIED SCIENCE INSTITUTE, DEPARTMENT OF SPACE ENVIRONMENT

ABSTRACT

Mitigating the lethal threats caused by coronal mass ejections (CMEs) on human and space operations can be accomplished with a fast and accurate forecast of Earth-directed CME transit times. The current paper presents a robust Cascade Forward Neural Network (CFNN) framework to predict the transit times of Earth-directed halo CMEs using a total of 290 CME/Interplanetary coronal mass ejections (ICME) pairs of datasets for the past two and half decades (solar cycle; SC 23, 24, 25). It is the first time incorporating deprojected speeds into a machine learning framework to mitigate uncertainties due to projection effects during CME transit time prediction. The CFNN model forecasted the transit times of 87 Earth-directed CMEs and recorded a mean absolute error (MAE) of 7.3 hours. In addition, 5 selected fast-moving (energetic) halo CME episodes during the deep phases (solar minima) of SC 25 were reconstructed using the Graduated Cylindrical Shell (GCS) forward-modelling technique. The events were predicted using the CFNN model (MAE =4.5 hours) in comparison with the Drag-Based model (DBM; MAE = 6.2 hours) and Empirical Shock Arrival model (ESA; MAE= 13.5 hours) to evaluate the robustness and the flexibility of the CFNN framework as well as the reliability of the CME 3D speed as a proxy for the space speed. The CFNN framework demonstrated satisfactory performance in contrast to previously used models by minimizing CME arrival time prediction errors due to projection effects. Hence, the study validated the efficiency of the GCS model for studying the 3D kinematics of CMEs and emphasized the essence of utilizing deprojected speeds in machine learning frameworks as better alternatives for fast, reliable, and accurate CME arrival (transit) time predictions

ABSID: MCH23-05

TITLE

Automatic recognition of solar radio bursts in NenuFAR observations

AUTHORS

Pearse C. Murphy,
Stéphane Aicardi,
Carine Briand,
Baptiste Cecconi

AFFILIATION

OBSERVATOIRE DE PARIS LESIA

ABSTRACT

Solar radio bursts are some of the brightest emissions at radio frequencies in the solar system. The emission mechanisms that generate these bursts offer a remote insight into physical processes in solar coronal plasma, while fine spectral features hint at its underlying turbulent nature. During radio noise storms many hundreds of solar radio bursts can occur over the course of a few hours. Identifying and classifying solar radio bursts is often done manually although a number of automatic algorithms have been produced for this purpose. The use of machine learning algorithms for image segmentation and classification is well established and has shown promising results in the case of identifying Type II and Type III solar radio bursts. The data rates of modern spectrometers such as NenuFAR are often too large to archive multi-hour solar observations at their native temporal and spectral resolution. Here we use a convolutional neural network to identify the time and frequency ranges of solar radio emission in NenuFAR observations. We show that the neural network can successfully locate solar radio emission in dynamic spectra with high accuracy. We also discuss how the outputs of this network can be used to make decisions on whether or not an observation should be archived at full resolution.

ABSID: MCH23-42

AUTHORS

Mohamed Nedal,
Kamen Kozarev,
Nestor Arsenov,
Peijin Zhang

AFFILIATION

INSTITUTE OF ASTRONOMY AND NATIONAL ASTRONOMICAL OBSERVATORY, BULGARIAN ACADEMY OF SCIENCES

TITLE

Predicting the Solar Energetic Proton Integral Flux with Deep Learning Models

ABSTRACT

Solar energetic protons (SEPs) can pose a threat to various space-based and terrestrial assets, making the prediction of SEP flux critical for ensuring their protection. In this study, we employ variant models of the Long-Short Term Memory (LSTM) neural network to predict the SEP integral flux in three energy bands (>10 MeV, >30 MeV, and >60 MeV) using data from the OMNI database over four solar cycles (1976 – 2019). Our models use daily-averaged data for long-term forecasting (3-day, 5-day, and 7-day ahead) and hourly-averaged data for short-term forecasting (6-hour, 12-hour, and 24-hour ahead). The input features include the F10.7 index, sunspot number, soft and hard X-ray fluxes, solar wind speed, and average interplanetary magnetic field strength. The model results demonstrate a remarkable accuracy, revealing its significant potential. The model effectively captures both short-term and long-term fluctuations in solar activity. Further research is being conducted to benchmark against other established models for SEP flux prediction, as well as to enhance the model's capabilities and extend its application to SEP spectra prediction.

ABSID: MCH23-18

TITLE

Predicting Solar Activity (flares, CMEs & SEPs) using Machine-Learning (INVITED)

AUTHORS

Athanasios Papaioannou

AFFILIATION

NATIONAL OBSERVATORY OF ATHENS

ABSTRACT

Solar flares and coronal mass ejections (CMEs) are two of the most energetic solar eruptive events spotted on the surface of the Sun, both of which can trigger Solar Energetic Particles (SEPs). As of yet, however, we do not fully comprehend the physical mechanism that triggers solar eruptions and even more we fail to understand when SEPs are accelerated, injected and then transported from the Sun to the inner heliosphere. Due to the significant rise in the accumulated data -- mostly concerning flares and CMEs but also, to an extent, SEPs -- in recent years machine learning (ML) algorithms have been developed by the scientific community. Such algorithms empirically determine signatures of solar eruptions, leading to either a fractional or a holistic prediction of the solar activity. In this talk, I will discuss prediction efforts of flares, CMEs and SEPs focusing on the application of various ML algorithms (such as: e.g. support vector machines (SVM), neural networks (NN) in the fully connected multi-layer perceptron (MLP) implementation, random forests (RF) and decision trees (DTs)).Consequently, current challenges (i.e. frameworks, optimal data-sets, validation) will be highlighted, with the way forward concluding this talk.

ABSID: MCH23-23

TITLE

Predicting the Geoeffectiveness of CMEs Using Machine Learning

AUTHORS

Andreea Pricopi,
Alin Paraschiv,
Diana Ionescu,
Anca Marginean

AFFILIATION

HIGH ALTITUDE OBSERVATORY NCAR|UCAR

ABSTRACT

Coronal mass ejections (CMEs) are the most geoeffective space weather phenomena, being associated with large geomagnetic storms, and having the potential to cause disturbances to telecommunications, satellite network disruptions, and power grid damage and failures. Thus, considering these storms' potential effects on human activities, accurate forecasts of the geoeffectiveness of CMEs are paramount. This work focuses on experimenting with different machine-learning methods trained on white-light coronagraph data sets of close-to-Sun CMEs, to estimate whether such a newly erupting ejection has the potential to induce geomagnetic activity. We developed binary classification models using logistic regression, k-nearest neighbors, support vector machines, feed-forward artificial neural networks, and ensemble models. At this time, we limited our forecast to exclusively use solar onset parameters, to ensure extended warning times. We discuss the main challenges of this task, namely, the extreme imbalance between the number of geoeffective and ineffective events in our data set, along with their numerous similarities and the limited number of available variables. We show that even in such conditions adequate hit rates can be achieved with these models.

ABSID: MCH23-46

TITLE

Dynamic time based eruptive flare prediction using machine learning

AUTHORS

Hemapriya Raju,
Saurabh Das

AFFILIATION

IIT INDORE

ABSTRACT

Solar eruptions such as CMEs, flares disrupt geomagnetic and communication systems on Earth. While flares are abrupt, bright events that occur in the solar atmosphere and emit massive amounts of energy in the 10^28 to 10^32 erg range, CMEs are intense eruptions that hurl plasma into interplanetary space. CMEs can be found in conjunction with flares, filaments, or independent. Although both flares and CMEs are understood as triggered by a common physical process magnetic reconnection, yet, the degree of association is unknown. In this work, we study the time series of magnetogram data derived from SHARP (Space weather HMI Active Region Patches) to understand eruptive flare mechanism using Machine Learning models SVM,LDA and Deep learning model LSTM. Here, we use 18 SHARP parameters as input to our Machine Learning model from the year 2011-2021. The task here is to perform binary classification, hence two classes, predicting whether a flare will be accompanied by CMEs or not. We initially attempt to study the features at different time lags that will be more responsible for eruptive flare. For example, MEANSHR shows deviated mean between two classes at 48h time lag, while MEANGBZ shows it at 8-24 h time lag before the event occurrence. Therefore, we determine the appropriate time lag for each feature using our Deep Learning model LSTM, coupled with ML models SVM and LDA, to perform binary classification. We further attempt to study the model's predictions and behaviour using Explainable ML methods such as variable-importance measure and shapley.

ABSID: MCH23-13

TITLE

Automatic Detection of Interplanetary Coronal Mass Ejections

AUTHORS

Hannah T. Rüdisser,
Andreas Windisch,
Ute V. Amerstorfer,
Christian Möstl,
Martin A. Reiss,
Rachel L. Bailey,
Tanja Amerstorfer

AFFILIATION

AUSTRIAN SPACE WEATHER OFFICE, GEOSPHERE AUSTRIA

ABSTRACT

Interplanetary coronal mass ejections (ICMEs) are one of the main drivers for space weather disturbances. In the past, different approaches have been used to automatically detect events in existing time series resulting from solar wind in situ observations. However, accurate and fast detection still remains a challenge when facing the large amount of data from different instruments. For the automatic detection of ICMEs we recently published a deep learning pipeline which has been trained, validated and tested on Wind, STEREO-A and STEREO-B data. We shortly present results of this work and talk about our current attempt to extend its application to a real time scenario in order to investigate its eligibility for functioning as an early warning system.

ABSID: MCH23-34

TITLE

Understanding CME deflections

AUTHORS

M. Valeria Sieyra,
Mariana Cécere,
Hebe Cremades,
Abril Sahade,
Francisco A. Iglesias,
Marilena Mierla,
Guillermo Stenborg,
Andrea Costa,
Matthew West,
Elke D'Huys

AFFILIATION

CCEA PARIS-SACLAY

ABSTRACT

The analysis of the deflection of coronal mass ejection (CME) events plays an important role in the improvement of the forecasting of their geo-effectiveness. To better understand the governing conditions of CME deflections we performed an exhaustive analysis of several events showing large deflections along a one-year time interval during the rising phase of solar cycle 24. We inspected the 3D trajectory of CMEs and the associated filaments with respect to their solar sources by means of a forward model and a tie-pointing tool, respectively. We applied these techniques to solar corona observations at different heights and wavelengths onboard PROBA2, SDO, STEREO and SOHO. Inspired by previous works, we analysed the influence of the surrounding magnetic energy density in the deflection of both structures using PFSS extrapolations. In agreement with previous reports, most of the CME deflections are oriented with the direction of the magnetic energy decrease while for prominences the deflection seems to be related to the strength of the magnetic field. Through a kinematic analysis of both structures, we found a relation between the CME and filament speeds to the amount of deflection and deflection rates, respectively. For both structures, we also shown that most of the deflection occurs at altitudes lower than 2.5 solar radii. Based on this observational evidence and with the aim to understand the effect of a pseudostreamer (PS) on a flux-rope (FR) eruption, we perfomed numerical simulations of this scenario. The combined magnetic field of the PS and the FR results in the formation of two magnetic null points, which are decisive in the direction and intensity of the FR deflection. Moreover, the PS lobe acts as a magnetic cage enclosing the flux-rope and the total unsigned magnetic flux of this cage results in a key parameter determining the eruption of the flux-rope.

ABSID: MCH23-31

TITLE

SuNeRFs: The Sun as a (fully-resolved) Star

AUTHORS

Benoit Tremblay, Robert Jarolim, Kyriaki-Margarita Bintsi, Miraflor Santos, Anna Jungbluth, Andrés Muñoz-Jaramillo, James Paul Mason, Sairam Sundaresan, Angelos Vourlidas, Cooper Downs, Ronald M. Caplan

AFFILIATION

HIGH ALTITUDE OBSERVATORY

ABSTRACT

EUV-observing instruments are limited in numbers and are mainly constrained to viewing the Sun from the ecliptic. SDO (2010-present) provides images of the Sun in EUV from the perspective of the Earth-Sun line. Two additional viewpoints are provided by the STEREO-A (2006-present) and STEREO-B (2006-2014) satellites pulling Ahead and falling Behind of Earth's orbit. No satellites observe the solar poles directly. However, a complete image of the 3D Sun is required fully understand its dynamics (from eruptive events to space weather in the solar system), to forecast EUV radiation to protect our assets in space, to relate the Sun to other stars, and to generalize knowledge of the Sun-Earth system to other host stars. To maximize the science return of multiple viewpoints, we propose a novel approach that unifies and smoothly integrates data from multiple perspectives into a consistent 3D representation of the solar corona. We leverage Neural Radiance Fields (NeRFs): Neural networks that achieve state-of-the-art 3D scene representation and generate novel views from a limited number of input images. We adapted a Sun NeRF (SuNeRF) to generate a representation of the 3D Sun, with the inclusion of radiative transfer and ray sampling that matches the physical reality of optically thin plasma in the solar atmosphere. We trained a SuNeRF model using a 3D MHD simulation of the EUV corona, with the training set limited to viewpoints that were captured from the ecliptic to reflect the limitations of current space-based observations. Using non-ecliptic viewpoints as ground truth, we validated the SuNeRF's ability to provide state-of-the-art results in 3D representations of the Sun, including the poles, despite learning only from ecliptic viewpoints. SuNeRFs are an example of how deep learning techniques can be used to enhance observational capabilities by the creation of virtual instruments that can, for example, fly out of the ecliptic and be placed anywhere in the solar system.

ABSID: MCH23-33

TITLE

Performance analysis of AI generated solar farside magnetograms in EUHFORIA

AUTHORS

Senthamizh Pavai Valliappan,
Jasmina Magdalenic,
Hyun-Jin Jeong

AFFILIATION

ROYAL OBSERVATORY OF BELGIUM

ABSTRACT

EUHFORIA 2.0 (EUropean Heliospheric FORecasting Information Asset, Pomoell & Poedts, 2018) is a 3D MHD model of solar wind and CMEs (coronal mass ejections) which reconstructs the evolution of inner heliospheric plasma over the time. The lack of accurate background solar wind modelling affects the prediction of arrival time of CME in all similar models. The validation of EUHFORIA at multiple radial distances and at multiple vantage points could improve its background solar wind modelling potential. With recent flyby missions like Parker Solar Probe, the performance of EUHFORIA at short radial distances from the Sun can be analysed and improved. Our comparative study of solar wind simulations by EUHFORIA with the in situ data of PSP, shows that using GONG synoptic magnetograms as input to EUHFORIA does not always provide accurate modelling of the solar wind parameters. The inaccuracy of modeled plasma parameters is more often found for the times when the PSP is at the farside of the Sun. Artificial Intelligence (AI)-generated Solar Farside Magnetograms (AISFMs) created using Solar Terrestrial Relations Observatory (STEREO) and Solar Dynamics Observatory (SDO) were made publicly available recently (Jeong et al., 2022). We run EUHFORIA employing the synoptic magnetograms, constructed from the HMI observations and synthetic AISFMs, with an aim to study and improve modelling results at multiple vantage points.

ABSID: MCH23-52

TITLE

Automatic Detection of Interplanetary Coronal Mass Ejections

AUTHORS

Aparna Venkataramanasastry, Petrus Martens

AFFILIATION

BAY AREA ENVIRONMENTAL RESEARCH INSTITUTE

ABSTRACT

Filaments are large observable absorption features on the disk of the Sun usually seen in Hα, He 10830 and He 304Å. In our recent statistical study of comparing filaments with Interplanetary Coronal Mass Ejection (ICMEs) from two solar cycles, we have shown that in 75% of the filament eruptions, the axial magnetic field direction of the filament is retained after eruption. That is, a filament on the Sun having a southward component of the axial field will, 75% of the times, have the same field direction when CME reaches Earth. This prediction mechanism has the potential to save to millions of dollars in the times when corrective action does not have to be taken upon detection of a CME with a northward axial field for example. We utilized the method of chirality along with magnetograms to obtain the axial field directions of the filaments in our study. We deem that this prediction mechanism will be useful for both current and future space missions. In the present work, we have taken the first step in the direction of automating the above prediction mechanism. The first step being the automatic detection of filament chirality. We have used an open source neural network algorithm to train a set of Hα images obtained from Helio Research, Inc. Helio Research filament data are 0.9" resolution and a small field of view compared to the GONG images. However, considering that the observatory was run based on funding and availability of observers, the dataset is smaller compared to that if we had from GONG. However, owing to the better quality of the images, we deem it is worthy of treatment and useful as a testcase to measure the possibility of chirality detection using computers. The dataset consists of about 500 different filaments, including those that were augmented. We will present the results of this study and seek to learn any improvisations that can be made.

S E S S I O N 4

MACHINE LEARNING- AND COMPUTER VISION-BASED TOOLS

ABSID: MCH23-26

TITLE

SPRINTS: A machine learning ecosystem for forecasting solar-driven events and scientific event crowd-sourcing (INVITED)

AUTHORS

Alexander Engell,
Brianna Maze,
Harold Farmer,
Jeremy Loomis,
David Falconer

AFFILIATION

NEXTGEN FEDERAL SYSTEMS

ABSTRACT

We present the Space Radiation Intelligence System (SPRINTS) and its current capabilities to forecast solar energetic particles (SEP) using streamlined data-driven and machine-learning processes. SPRINTS is designed as a community ecosystem to ensure scientific transparency and can be deployed to any infrastructure environment. Its current data is comprised of GOES X-ray and proton data from 1986-present and ACE/DSCOVR from 1997-present in a Timescale database with APIs. It also uses the Parquet data formats in tandem with database for optimal UI reactiveness. The time-series database is supported by flare, SEP, and CME event catalogs as well as event associated catalogs such as flares associated with SEPs, CMEs and radio bursts. Within the framework of SPRINTS, these catalogs can be improved through scientific crowd-sourcing methods (e.g., versioning) thereby allowing critical alignment of both underlying data and event relationships. This forms a ML-ready dataset process for the community interested in establishing consistent train, test and validation and verification processes when building models to predict flares, SEPs, and CMEs. SPRINTS is coupled to the MagPy forecasting capability whereby it takes probabilistic forecast parameters of interest based on free-energy proxies for flare parameters including flare flux, fluence and peak ratio of the long and short X-ray channels required by the post-eruptive ML models developed. This gives a continuous pre- and post-eruptive forecasting capability as new information (e.g., flare eruptions and CME kinematic) becomes available to the system. We will present initial models results for the Air Force Research Laboratory SEP forecast requirements. SPRINTS is currently providing forecasts in real-time through a REST API to the CCMC SEP Scoreboard and has supporting dashboards near-real time forecasts, historical analysis, and event relationship analysis.

ABSID: MCH23-54

TITLE

Benchmark Datasets for Solar Weather Forecasting Applications

AUTHORS

Manolis K. Georgoulis

AFFILIATION

RCAAM OF THE ACADEMY OF ATHENS

ABSTRACT

In view of today's plethora of methodologies implemented for forecasting the extreme solar end of space weather, a standardization of prediction frameworks that can serve as testbeds for new methods and allow immediate and straightforward comparisons with existing ones is paramount. We outline a concept for such a framework that draws from the classical notion of a theory, namely, a set of rational ideas based on observation or empirical knowledge that leads to testable predictions. Standard datasets, that we call benchmark datasets here, along with different forecasting models and an all-encompassing verification process, facilitate and enable the proposed concept. While performance verification needs to follow preset skill scores and statistical metrics, comparing these parameter values between models (machine learning or conventional) trained and tested on different data sets is practically meaningless. This is the core objective behind defining benchmark datasets. Machine learning methodologies, in particular, rely on benchmark datasets. Several examples of benchmark datasets are given, with some of them readily available online. Horizontal or vertical expansion of such datasets that aim to strengthen or widen the forecasting purposes and scopes, are also discussed. Moreover, combining different benchmark datasets leads to enhanced datasets that can also be called and treated as benchmarks.

ABSID: MCH23-41

TITLE

Feasibility study of data-driven Autonomous Service for Prediction of Ionospheric Scintillations (ASPIS)

AUTHORS

Simon Mackovjak,
Peter Butka,
Viera Maslej-Krešňáková,
Matej Varga,
Adrián Kundrát,
Samuel Amrich

AFFILIATION

SLOVAK ACADEMY OF SCIENCES

ABSTRACT

The ultimate purpose of the ASPIS (Autonomous Service for Prediction of Ionospheric Scintillations) system, that is currently in development, will be to protect vulnerable technologies from the unexpected consequences of extreme space weather events in the Earth's interface region. The scope of the activity is to study if it is feasible to develop a data-driven service based on machine learning techniques that will use relevant available data for a particular location as an input and autonomously provide information about the presence of ionospheric scintillation in a specific time ahead as an output. The activity is supported by ESA / PECS program in Slovakia and will be finished in Q3/2023. In the contribution, details of the motivation, data and ML techniques used will be presented.

ABSID: MCH23-61

TITLE

ARCAFF Project Early Results

AUTHORS

Maloney, S.,
Gallagher, P.T.,
Murray, S.,
Kiss, T.,
Pierantoni, G.,
Terstyanszky, G.,
Farkas, A.,
Lovas, R.

AFFILIATION

DIAS

ABSTRACT

The Sun is an enigmatic star that produces the most powerful explosive events in our solar system – solar flares and coronal mass ejections. Studying these phenomena can provide a unique opportunity to develop a deeper understanding of fundamental processes on the Sun, and critically, to better forecast space weather. The Active Region Classification and Flare Forecasting (ARCAFF) project will develop a beyond state-of-the-art flare forecasting system utilising end-to-end deep learning (DL) models to significantly improve upon traditional flare forecasting capabilities.
The large amount of available space-based solar observations are an ideal candidate for this type of analysis, given DL effectiveness in modelling complex relationships. DL has already been successfully developed and deployed in weather forecasting, financial services, and health care domains, but has not been fully exploited in the solar physics domain. ARCAFF will increase the accuracy and timeliness of current operational flare forecast products and create new time series flare forecasts with uncertainties. The forecasts will be benchmarked against current systems using international community standards. The datasets and codes developed for ARCAFF will be made openly available to support further research efforts and encourage their re-use. The five key objectives of ARCAFF are:
1. Active region classifications using magnetogram cutouts
2. Active region localisation and classification using full disk magnetograms
3. Point-in-time flare prediction using full disk magnetograms
4. Point-in-time flare prediction using full disk multimodal observations
5. Time series flare prediction based on time series of full disk multimodal observation
This presentation will provide a short overview of the project and present early results from the the first two ARCAFF topics, 1) AR classifications using magnetogram cutouts and 2) AR localisation and classification using full disk magnetograms.

ABSID: MCH23-59

AUTHORS

Mattia Mancini,
Pietro Zucca

TITLE

Making LOFAR Data Accessible to the Solar and Space Weather Community

AFFILIATION

ASTRON

ABSTRACT

Solar radio bursts are events typically associated with solar flares or coronal mass ejections. However, the emission mechanism and related properties are still not fully understood. In addition, solar radio bursts impact infrastructures on Earth directly. Moreover, combined with signals at other frequencies can be used as the precursor of other space weather phenomena such as particle showers (e.g. Laurenza 2018). However, to fully characterize their properties and study their space weather impact, continuous monitoring of the solar activity is necessary to capture as many events as possible. The LOFAR telescope is a radio instrument capable of monitoring solar activity, providing data fundamental in studying new forecast proxies and providing alerts. Although, to provide to the users community with alerts an automatic algorithm has to be trained with an extensive and continuous stream of data. Since 2010, several LOFAR observational campaigns aimed at observing the Sun have been available in the LOFAR archive. However, the data size and format is complex, making the processing challenging. A more science-ready and accessible catalogue is key for fully exploiting and sharing with the scientific community scientifically interesting datasets. In the past year we processed part of the LOFAR archive with an automatic processing framework called ATDB and collected several examples of the solar bursts' dynamic spectra. In this work we present our catalogue and how to access it. Furthermore, we will illustrate our preliminary effort in classifying the bursts type through a machine learning model based on an autoencoder network. In conclusion, we will introduce IDOLS (Incremental development of LOFAR Space-Weather) project started in March 2022 where we are using a dedicated LOFAR station to monitor solar activity.

ABSID: MCH23-56

TITLE

ARTop: a program to calculate novel topology-based predictive metrics of active region magnetic field structure.

AUTHORS

Christopher Prior,
D. MacTaggart,
B. Raphaldini

AFFILIATION

DURHAM UNIVERSITY

ABSTRACT

We present a new program, ARTop, which calculates novel metrics of emerging active region magnetic fields from HMI magnetogram data, with the hope it can be used in machine learning protocols to improve the prediction of flaring and eruptive activity in CME's. The main underlying quantity calculated is the field line winding, a fundamental topological quantity which underpins the magnetic helicity (Prior & MacTaggart 2020). We have shown metrics built from it are robust to noise and utilise the in-plane components of the magnetic field which crucially determine when strongly current carrying structure emerges (or submerges) into (or from) the region. It has been shown to correctly diagnose the nature of magnetic flux ropes where other transverse metrics fail (MacTaggart et al. 2021) and also show some promising but tentative solar flare prediction capabilities (Raphaldini et al. 2022).

ABSID: MCH23-48

AUTHORS

Oleg Stepanyuk,
Kamen Kozarev

AFFILIATION

INSTITUTE OF ASTRONOMY AND NATIONAL ASTRONOMICAL OBSERVATORY, BULGARIAN ACADEMY OF SCIENCES

TITLE

Advanced Multi-Instrument Image Processing and Feature Tracking for Remote CME Characterization with Convolutional Neural Network

ABSTRACT

Solar eruptive events are complex phenomena, which most often include coronal mass ejections (CMEs), CME-driven shock waves, solar flares and filament eruptions. After nearly a half century of research, a broad theoretical discussion aiming to shed light on various physical aspects of the phenomena still goes on nowadays, which sets demands for more advanced techniques for analysis of ground-based (COSMO K-Cor, LOFAR) and remote (SDO AIA, SOHO space missions) instruments data. In recent years Machine Learning (ML) and Deep Learning (DL) methods have become more frequently applied in solar physics. Nevertheless, application of data-driven approaches for tracking of CME-related phenomena is still problematic due to insufficiency of training sets, while usage of a few available algorithmic non-data driven software packages has severe limitations due to complexity of their setup and processing chains. Recently (J. Space Weather Space Clim., 12, 2022) we have demonstrated a new method for smart characterization and tracking of solar eruptive features based on the a-trous wavelet decomposition technique, intensity rankings and a set of filtering techniques. The described approach was implemented in the Wavetrack code. In this work we use Wavetrack to generate training sets for data-driven feature extraction and characterization with Convolutional Neural Networks (CNN). We present pre-trained models, demonstrate data-driven characterization and tracking of solar eruptive features on a set of CME-events followed by discussion about optimal CNN topology and training setup for solar eruptive feature segmentation.

ABSID: MCH23-43

TITLE

The Very First NASA AI/ML Crowdsourcing Challenge Results Using SOHO/LASCO Data

AUTHORS

Katya Verner

AFFILIATION

NASA/HQ/ HELIOPHYSICS

ABSTRACT

Can we advance research in Heliophysics, Space Weather and technology in new ways? What is the best way to do it? Open Innovation or Crowdsourcing platforms are very beneficial in bringing together large numbers of people with all types of backgrounds, skills, and expertise. They provide unique opportunities, valuable products and services. I discuss the benefits of this approach to the scientific community. The challenge was supported by NASA Open Source Science Initiative (OSSI), Center of Excellence for Collaborative Innovation (CoECI) and Topcoder. It attracted about 600 people from 74 countries, offered several innovative solutions and found new comets. I will present my experience using heliophysics data and working with the crowd developing AI/ML tools, which include AI/ML based discoveries. I discuss the benefits of this approach to the heliophysics scientific community overall: Open Science Challenges can lead to a new results and discoveries; Attract NASA enthusiasts and high-level professionals from various research areas; Build innovative pathways and approaches, which are beyond our traditions views; Scientific community expressed a huge interest in area of AI/ML applications; Can bring out of box solutions in a very fast ways; Really effective way for developing and sharing new AI/ML data, tools. Here are a few examples what participants say about participating in this challenge:
“I am interested in NASA and space exploration in general, so being able to work with real data from a NASA space telescope is very exciting.”; “ An interesting problem with a large scientific impact”; “Had no experience working with data from the Solar and Heliospheric Observatory (SOHO), which proved to offer its own set of challenges”

MACHINE LEARNING
AND COMPUTER VISION
IN HELIOPHYSICS

19 - 21 APRIL 2023
SOFIA BULGARIA

MOSAIICS