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SPACE WEATHER OBSERVATIONS THROUGHOUT LATINOAMERICA

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PROCEEDINGS

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Solar Instruments in the Argentine North-West: Facts, Applications, and Perspectives

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Several instruments devoted to the observation of the Sun were installed in the Andes mountains by 1997-1999. These instruments, which consisted of a coronagraph, an Hα telescope, and a submillimeter antenna, were at the heart of agreements with the Max Planck Institute for Extraterrestrial Physics and the Max Planck Institute for Aeronomy, both from Germany, and the Centro de Radio Astronomia e Astrofísica Mackenzie from Brazil. The deployment of this instrumentation marked the start of solar observations at the Observatorio Félix Aguilar (OAFA) and Complejo Astronómico El Leoncito (CASLEO) in the province of San Juan, Argentina. Two of these instruments, the submillimeter antenna and the H telescope, have been regularly observing the Sun for already two solar cycles, while the coronagraph has not been not operative since 2007. Following these steps and because of the clear skies, low water vapor content, and appropriate infrastructure, the solar physics group at CRAAM, through collaborations and with OAFA and CASLEO, continued building what is now called the Heliogeophysical Mountain Laboratory, which includes several instruments mainly in the high-frequency range of the solar spectra (GHz – THZ), as well as particle detectors. All these facilities have proven to be relevant, in combination with space-based remote sensing instrumentation, in the understanding of the origin and evolution of space weather solar drivers. We briefly describe the currently operating instrumentation and discuss a few examples in which their data have been used, as well as future perspectives for the development of solar observations in the region.

Three-dimensional tomographic reconstruction and MHD modeling of the low Corona during the last three solar minima

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Interest in predicting space weather is constantly pushes the advance of three-dimensional (3D) magnetohydrodynamic (MHD) models of the corona and solar wind, which in turn need to be validated with observational data. Solar rotational tomography (SRT) is currently the only observational technique capable of providing an empirical 3D description of the coronal thermodynamic structure on a global scale. We have systematically applied SRT to images provided by three generations of space telescopes to perform coronal tomographic reconstructions during the last three minima of solar activity (years 1996, 2008, 2019). During them, the large-scale organization of the corona-wind system is as simple as possible, revealing more clearly the differences between the closed (streamers) and open (coronal holes) structures, as well as between the fast and slow components of the solar wind. In particular, the last three minima are of particular interest since they belong to solar cycles during which the level of activity decreased systematically. Applied to images in multiple bands of the EUV range, the SRT allows to reconstruct the 3D distribution of the density and temperature of the corona in the range of heliocentric heights $r < 1.25$ R_sun, while applied Coronagraph images in visible light allow us to reconstruct the 3D distribution of coronal density in the range $r = 2.5 - 6.0$ R_sun. These ranges constitute the region in which the heating and acceleration of the solar wind occurs. For the periods studied we have also carried out numerical simulations based on the MHD-3D model of the corona and solar wind named Alfvén Wave Solar atmosphere Model(AWSoM), in order to carry out systematic validation studies. In this work we synthesize the most outstanding results regarding the comparison of the coronal structure between the minimum, validation of the AWSoM simulations, and the relationship between the coronal thermodynamic structure and the components of the solar wind.

SoloHI: Multi-viewpoint Catalog from the Sun to 1AU

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The Solar Orbiter mission, launched in February 2020, presents the perfect combination of remote sensing and in situ instruments that will allow us to understand the composition of the solar wind and study its source on the solar surface at the same time. The mission is predicted to reach a minimum perihelion of 0.28 AU with an inclination angle of at least 30 degrees above the orbital plane. Among the six remote sensing instruments on board the Solar Orbiter mission, the Solar Orbiter Heliospheric Imager (SoloHI) studies the inner heliosphere by observing photospheric visible light scattered by electrons in the solar wind. imagers at 1 AU.
In this work, we describe SoloHI events observed during the first remote sensing windows with a multi-viewpoint perspective. We list the primary details of the CME and we present the in situ data and remote sensing observations detected by other missions for each event listed. We also describe, when possible, the source characteristics (location, active region and link to available magnetograms) and perform a 3D reconstruction of the event with the Graduated cylindrical shell CME model.

Type II kilometric radio emissions: A complete list of events observed with TNR and analysis of associated shock waves

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In the present work we build a database of low frequency radio events by means of the analysis of all dynamic spectra of the TNR instrument, in the WindWAVES mission from NASA, extending a database built in a previous work. The list encompasses the years 1994-2021, including more than two full solar cycles. In this database also, we interrelate the detection of kilometric Type II (kmTII) radio emissions with interplanetary structures such as shock waves and ICMEs. We found a total of 320 events, out of which 136 have not been cataloged before. On the other hand, for 121 shock waves that could be associated with these radiofrequency events, we analyze their physical characteristics and compare them to those of the shock waves not associated with the radio events. The goal is to find which characteristics favor the production of kmTII radio waves, and what are the in-situ differences between them. The results show that shock waves associated with these radio waves are faster, produce greater changes in density, in magnetic field, and specially changes in the plasma beta due to the type of shock wave.

Anisotropies of cosmic ray flux: observations made from the space weather laboratory installed at the Argentine Marambio Antarctic base

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A new water-Cherenkov radiation detector, located at the Argentine Marambio Antarctic Base (64.24S-56.62 W), has been monitoring the variability of galactic cosmic ray (GCR) flux since 2019. One of the main aims is to provide experimental data necessary to study interplanetary transport of GCRs during transient events at different space/time scales.
We present the empirical corrections for atmospheric pressure and temperature on the observations made during one full year. From in situ pressure measurements we got the mean barometric coefficient. After that, the temperature effect is modeled using the isobaric layer associated with 100 hPa from ERA5 reanalysis. This model explains seasonal variations and changes on shorter time scales.
After the analysis and correction of the GCR flux variability due to the atmospheric conditions, a study of the periodicities is performed in order to analyze modulations due to heliospheric phenomena. We can observe two periods: (a) 1 day, associated with the Earth's rotation combined with the spatial anisotropy of the GCR flux; and (b) 30 days due to solar impact of stable solar structures combined with the rotation of the Sun. From a superposed epoch analysis and considering the geomagnetic effects on the asymptotic arrival directions, we find that the mean diurnal amplitude is 0.08% and that the maximum flux is observed in 15 LT (local time) direction in the interplanetary space. We interpret our result in the theoretical frame of the force-free GCRs equilibrium. In such a way, we determine the capability of Neurus to observe GCR flux variabilities at ground level, associated with the interplanetary modulation.

Recent Advances in Solar Physics in Argentina

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Investigations relevant to solar-terrestrial relations in Argentina started in the beginning of the XX century, together with the first systematic observations of sunspots and faculae. Throughout the decades, though not without adversities, Solar Physics has consolidated in the country, leading to state-of-the-art studies led by local researchers, at times also in collaboration with foreign colleagues. Nowadays, the research topics focus on phenomena and processes taking place from the outermost layers of the solar interior until the solar atmosphere and the interplanetary medium, covering various scales of space and time. The study of magnetic structures associated to active regions and their evolution is aimed at understanding the energy involved in eruptive events such as flares and coronal mass ejections, and the destabilization mechanisms behind them, as well as the genesis of solar magnetic fields. The analysis of various aspects of coronal mass ejections and related phenomena addresses their origins and evolution with space weather implications. Application of solar tomography techniques to visible light and EUV images of the inner solar corona for reconstruction of its 3D distribution of electron density and temperature, enables global validation of state-of-the-art 3D-MHD models of the corona and solar wind used for space weather prediction. On the numerical modeling side, the addressed science objectives include the analysis of quasi periodic pulsations through oscillations of coronal loops and filaments, supra-arcade downflows, and cut-off frequencies of magnetoacustic waves throughout the transition region and corona. In this talk I briefly review these recent and ongoing research efforts, with contributions from the scientists leading them.

The Sunrise UV spectropolarimeter and imager

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Solar activity is mainly driven by its magnetic field, which is structured on small scales. Consequently, detailed measurements of the solar magnetic field and plasma at small scales are required to answer some of the most difficult open questions in solar physics, many of which have important technological and social implications due to the strong Sun-Earth connection. Sunrise is a 1-m optical solar observatory carried aloft by a stratospheric balloon, that was developed to reach such a challenging measurement regime. Its main purpose is to avoid most of the seeing and absorption introduced by Earth's atmosphere to study magnetic fields and plasma flows in the Sun with very high spatial resolution and sensitivity. After two successful campaigns in 2009 and 2013, a new Sunrise flight is under preparation. The Sunrise III post-focus instrumentation has been completely renewed and includes three full-Stokes spectropolarimeters that simultaneously cover wavelengths from 314 to 860 nm, to probe magnetic fields at different heights in the solar photosphere and chromosphere. The most novel of these new instruments is the Sunrise UV Spectropolarimeter and Imager (SUSI). It is a single-slit grating spectrograph that operates in the 314-430 nm spectral range. SUSI aims at acquiring, for the first time, high-spatial-resolution maps of the solar magnetic field in the UV, making use of thousands of spectral lines that are not accessible from the ground. SUSI incorporates a dual-beam polarimeter based on a rotating wave-plate and a synchronous phase-diversity, wide-band channel used for context measurements and image restoration. We present the contributions of the partner group established in 2021 between the Max Planck Institute for Solar system Research and the University of Mendoza, Argentina, to the instrumental development and data reduction of SUSI. These include the specification, characterization and validation of the scientific cameras, development of instrumental simulation codes to support instrument design, polarimetric calibration, specification of the in-flight calibration sequences, and development of data reduction and analysis routines, among others.

Analyzing the Galactic Cosmic Ray flux in the passage of ICMEs and SIRs

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Galactic Cosmic Rays (GCRs) are high energy particles of galactic origin. Forbush Decreases (FDs) consist of abrupt decreases in the GCRs flux. These decreases are observed at ground level and measured by different instruments, as Neutron Monitors. It is well known that the passage of Interplanetary Coronal Mass Ejections (ICMEs) and Stream Interaction Regions (SIRs) are potential drivers of FDs. ICMEs are the interplanetary counterpart of Coronal Mass Ejections and their origins are in the active regions of the Sun. SIRs are formed when fast solar wind streams, that arise in the Sun Coronal Holes, interact with the slower ambient solar wind. In this work we use data from ACE Spacecraft and MCMurdo Neutron Monitors to study all the ICMEs that occurred in the period (1998-2016) and all the SIRs occurred in the period (1995-2009). We make a statistical analysis of all the ICMEs/SIRs, and then we apply the superposed epoch analysis (SEA) technique to different samples of events. Finally we analyze the difference and similarities of the FDs produced by both structures. We find that FDs produced by ICMEs are very sensible to the mean velocity of the structures. While in the FDs produced by SIRs, the mean velocity of them does not appear to affect the FDs amplitude.
We also find that the minimum of the GCRs flux in ICMEs occur at the middle of the ICME, while in SIRs the minimum of the GCRs flux is at the end of the SIR.

Modeling the Solar Spectral Irradiance from the Solar Magnetic Flux: status and future work

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The radiative flux of the Sun in the extreme ultraviolet (EUV) range of the spectrum can drive several effects in the Ionosphere-Thermosphere-Mesosphere (ITM) system. For this reason, it is of utmost importance to properly understand its variations at all timescales. Direct measurements of the EUV irradiance can only be obtained from space. The availability of long-term records of such data is affected by diverse factors such as the degradation of the radiometers, the difficulties in cross-calibrating data from different instruments, and the lack of continuity of measurements at specific wavelengths or with similar technical specifications. As an alternative to quantify the EUV radiative flux, different proxies, such as the F10.7 and the MgII index, have been derived but they usually represent a single spectral band or define a specific solar feature. The most commonly used solar proxy is the F10.7 index (i.e. the solar flux at 10.7 cm) but unfortunately, it is now recognized that this index does not correctly describe the EUV flux at wavelengths below 102.5 nm. To investigate a viable alternative to the F10.7 cm, our work focuses on the modeling of Solar Spectral Irradiance (SSI) variations from the photospheric magnetic flux in the region of the spectrum below 102.5 nm. Our approach leverages observations from magnetograms that are assimilated into models to provide the full surface photospheric magnetic maps and the extrapolated coronal magnetic field, and ultimately retrieves the SSI at different EUV wavelengths. Furthermore, it uses additional EUV data sets from the twin spacecraft STEREO, particularly necessary for locations at which SSI measurements are not available. Here, we discuss the status and our plans to advance in the improvement of the capabilities to forecast the SSI variations.
This work is part of the NASA Living With a Star (LWS) Program, Focused Science Topic: "Beyond F10.7: Quantifying Solar EUV Flux and its Impact on the Ionosphere - Thermosphere - Mesosphere System".

Influence of the magnetic environment on CME deflections

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We study the low-coronal evolution of coronal mass ejections (CMEs) by reconstructing their 3D trajectory and the magnetic environment in which the source region is located. We analyzed a first event on 2008 Apr 09 and modeled it with magneto-hydrodynamic simulations. This event, the Cartwheel CME, exhibited a double deflection that has been reported and analyzed in previous work, but whose underlying cause remained unclear. The Cartwheel CME moved toward a coronal hole and against magnetic gradients. Using high-cadence full trajectory reconstruction, we accurately determined the location of the magnetic flux rope (MFR) and, consequently, the magnetic environment in which it is immersed. We find a pseudostreamer (PS) structure whose null point may be responsible for the complex evolution of the MFR in the initial phase. From the reconstruction of the pre-eruptive magnetic field, we estimate the dynamical forces acting on the MFR and provide a new physical perspective on the motion exhibited by the event. By setting up a similar magnetic configuration in a 2.5D numerical simulation we are able to reproduce the observed behavior, confirming the importance of the PS null point. In addition, we are studying a set of observed events with multiple viewpoints, including Solar Orbiter observations, to understand the mechanisms by which deflections occur under different magnetic scenarios.

Exploring the prospects for a vivid collaborative science between the GDC mission and the Ground-Based community

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The Geospace Dinamics Constellation (GDC) is NASA's upcoming heliophysics mission, scheduled for launch in the early 2030s. Comprising six identical satellites, GDC aims to serve as a focal point for coordinated ionosphere-thermosphere- mesosphere (ITM) science on a global scale. This coordination will involve the collaboration of space-based and ground-based asssets, simulations, and theory, all operating under the umbrella of the "ITM Great Observatory." To ensure effective coordination between GDC and the worldwide community's ground- based assets, the GDC science team has established a community group. This group serves as a platform to ground-based observers to gain insights into the GDC mission and its scientific objectives. Aditionally, it facilitates the coordination of ground-based efforts, enabling the utilization of GDC measurements to further enhance and expands broader ITM science goals. By fostering collaboration and information exchange, the GDC ground-based community group plays a crucial role in maximizing the scientific potential of GDC and its integration with ground-based observations. This collective effort will contribute to advancing our understanding of the ITM system and its dynamics, ultimately enhancing our knowledge of the Earth's dynamic space environment. Overall, the GDC mission represents an exciting opportunity for global collaboration in the field of ITM science.

Geomagnetic disturbances at mid- and equatorial latitudes

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The geomagnetic storm of May 12-13, 2021 was classified by the United States National Oceanic and Atmospheric Administration (NOAA) Space Weather Prediction Center as a period of "moderate" activity, registering as a G2 on the NOAA Geomagnetic Storm scale (G-scale), and reaching a maximum Kp index of 7. It began with a sudden impulse on May 12, 2021, and persisted through the early hours of May 13, 2021. While this storm may not have been a particularly large or atypical geomagnetic storm, the response of the power grid to this moderate event was significantly larger than expected in the US. Although much of the foundational work in space weather effects on infrastructure at the ground-level has been centered in Northern auroral regions, recent work has shown the importance of understanding geomagnetic disturbances at mid-latitudes and in the equatorial regions. This storm, and others like it, highlight the need for data across latitudes and hemispheres, and the potential infrastructure impacts of space weather across the globe. In this talk, we give an overview of mid-latitude and equatorial drivers of geomagnetic disturbances, discuss this event and its relevance to the mid-latitudes of the Southern hemisphere, and present a new analysis of why the largest impacts may not be driven by the largest geomagnetic storms.

Installation of Space Weather Observatories in Argentina

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The study of Space Weather involves the measurement of several variables related to the Sun- Earth connection. Some of these variables are measured in space, however, there are some parameters that can be measured from the ground too. Ground-based measurements are essential for understanding how space weather events impact the Earth's environment, life, and infrastructure. Among the values related to Space Weather that can be observed from the surface are disturbances in the geomagnetic field, spatial distribution of Total Electronic Content (TEC) in the ionosphere, intensity of UV radiation reaching the surface, precipitation of solar wind particles, physical parameters of ionospheric plasma, etc. These measurements are especially important for our country because we are located in the South Atlantic Magnetic Anomaly (SAMA). This is an area where the geomagnetic field is weaker and therefore with higher gradients than in other regions of the world. This makes us more vulnerable to space weather events. Currently, there are some Geomagnetic Observatories in our country that can be used as a basis for Space Weather Observatories, but they are not enough. We propose to expand and upgrade our network of Geomagnetic Observatories to include more instruments for space weather monitoring. This will help us to improve our scientific knowledge and our preparedness for space weather hazards.

Identification and 3D morphological modeling of solar coronal mass ejections using deep neural networks

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Coronal mass ejections (CMEs) are a major driver of space weather and thus can have important negative technological and social implications. Given our current inability to forecast the occurrence of a CME, it is crucial to assess their geoeffectiveness once they are ejected. Particularly relevant for this task are the identification and correct assessment of the CME 3D morphology in coronagraph images. In the last decade, Deep Neural Networks (DNN) have experienced enormous improvements in solving various machine-vision-related tasks, particularly excelling at image recognition and segmentation. One issue when trying to use these deep models for CME segmentation or related tasks using coronagraph images, is that no large, curated dataset exists that can be used for supervised training. To mitigate this, we produced a synthetic dataset of CME coronagraph images by combining actual quiet (no CME) coronagraph background images with synthetic CMEs, the latter simulated using the Graduated Cylindrical Shell geometric model (GCS). In this work, we present preliminary results of two DNN-based models. The first model is used to identify and segment the outer envelope of CMEs in a single image. This is done by fine tuning the pre-trained MaskR-CNN model to produce a GCS-like mask of the CME present in a single differential coronagraph image. The second model estimates the simplified 3D structure of the CME outer envelope from 2 and/or 3 simultaneous differential coronagraph images, acquired from different vantage points (spacecrafts). This model is implemented by adding a fully-connected, linear head to a pre-trained ResNet backbone, and is trained to produce the GCS model parameters that best fit the CME outer envelope in the input images.

Energy calibration and atmospheric corrections of a space weather particle detector, located at the Argentine Marambio base in the Antarctic Peninsula

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Neurus is a particle detector operated by the Argentinean space weather laboratory (LAMP, Laboratorio Argentino de Meteorología del esPacio), and located in the LAMP-Antarctic branch, in the Argentine Marambio base at the Antarctic Peninsula; the particle detector is part of the LAGO Collaboration (Latin American Giant Observatory). The main goal of this detector, based on the Water-Cherenkov effect, is to make observations of the flux variability of low-energy galactic cosmic rays (GCRs) for making space weather studies. Since 2020, the data acquisition system developed by LAGO, which consists of a commercial board Red Pitaya STEMLab working in an FPGA mode, has been operated autonomously and uninterruptedly. This allows us to obtain the flux of detected particles and the deposited energy in the water by them (mostly electrons, positrons, gammas, and muons). The passage of vertical muons through the detector can be identified as a hump in the histogram of the deposited energy, and this hump can be used to make the energy calibration of the detector. Thus, the evolution of particle fluxes may be discriminated against using different deposited energy bands, which can be useful to study the heliospheric modulation for different energies. In this work, we present the atmospheric corrections and energy calibration for two bands: electromagnetic and muonic. The results of this work will permit the implementation of an operative mode for the provision of real-time observations of the GCRs variability at different energies.

Alfvenicity of the solar wind near Earth

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It is a well known fact that, in the presence of intense interplanetary disturbances (such as Interplanetary Coronal Mass Ejections ICMEs or Stream Interaction Regions SIRs) the interaction between the solar wind and the terrestrial magnetosphere generates geomagnetic storms and substorms. However, notable geomagnetic variations have also been observed in the absence of such transient structures. Previous studies have shown that certain increases in the levels of MHD turbulence in the solar wind may have a very important role in the coupling of the solar wind with the magnetosphere at high latitudes [e.g., D'Amicis et al., 2009]. It has even been suggested that the relationship between the interplanetary medium and the magnetosphere is controlled by the level of turbulence in the solar wind [Borovsky & Funsten, 2003]. In this work, we use data from two instruments on board the ACE satellite: SWEPAM and MAG, during the period of time between 03/1998 - 12/2009. Furthermore, we make use of the ICME events catalog of Richardson & Cane [Richardson & Cane, 2010] and the SIR events catalog of Jian [Jian et al., 2006]. We perform a statistical study of turbulent properties of the solar wind in the terrestrial environment, splitting Parkerian solar wind and transient events. The results of this study will help to better understand the geomagnetic fluctuations near polar regions, and will provide elements to develop operational products in Space Weather in Antarctic regions.

Correlations between Kappa distributions and collision parameter in space plasmas at 1 AU

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Particle collisions play an important role in establishing thermal equilibrium in a fluid. In fact, the non-thermal characteristics observed in solar wind plasma, such as temperature anisotropy and beam velocity, appear to be regulated by collisions. In works like Kasper et al. [1], a new parameter of study is introduced: collisional age, which estimates the collision frequency compared to plasma packet flight times. Kasper et al. [1] concludes that while non-thermal solar wind is generally associated with high velocities, these distributions suggest that the occurrence frequency is actually determined by the collisional age. On the other hand, Bale et al. [2] demonstrated that the temperature relationship has a stronger correlation with the number of Coulomb collisions than other parameters like solar wind velocity. It is expected that low-collision plasma can exhibit other non- thermal characteristics, such as distributions with high-energy tails that exceed a Maxwellian distribution. Kappa distributions are considered a suitable approach for studying particle distributions in astrophysical plasmas, particularly due to the supra-thermal energy tails found in plasmas outside classical thermal equilibrium. In Eyelade et al. [3], these Kappa distributions are studied in the Earth's magnetosphere, revealing direct correlations between the Kappa index, energy, and plasma beta parameter. Our work focuses on studying correlations between the collision parameter and Kappa distributions at 1 AU using data provided by the freely accessible THEMIS satellite. References [1] J. C. Kasper y col., The Astrophysical Journal, 2017, 849, 126 [2] S. Bale y col., Physical review letters, 2009, 103, 211101 [3] A. Eyelade y col., The Astrophysical Journal, 2021, 253, 34

Characterizing the Solar Activity using the Visibility Graph Method

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In this work, the Sun and its behavior are studied by means of complex networks. The complex network was built using the Visibility Graph (VG) algorithm. This method maps time series into graphs in which every element of the time series is considered as a node and a visibility criterion is defined in order to connect them [1]. The VG method has been widely used to analyze various systems such as pulsating variable stars [2], solar activity [3,4] and blazars [5]. Using this method, we construct complex networks for magnetic field and sunspots time series encompassing four solar cycles, and various measures such as degree, clustering coefficient, mean path length, betweenness centrality, eigenvector centrality and decay exponents were calculated. In order to study the system in several time scales, we perform both a global, where the network contains information on the four solar cycles, and a local analysis, involving moving windows. Some metrics correlate with solar activity, while others do not. Interestingly, those metrics which seem to respond to varying levels of solar activity in the global analysis, also do in the moving windows analysis. Our results suggest that complex networks can provide a useful way to follow solar activity, and reveal new features on solar cycles. References: [1] Lacasa, L.; Luque, B.; Ballesteros, F.; Luque, J.; Nuno, J.C. From time series to complex networks: The visibility graph. Proc. Natl. Acad. Sci. USA 2008, 105, 4972–4975.

Implementation of a portable site-testing instrument for solar Observations

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One of the factors that most affect ground-based astronomical observations is the seeing caused by atmospheric turbulence. To counteract this effect, adaptive optics elements are used in modern telescopes. In order to quantify this phenomenon, an instrument called scintillator can interpret thermodynamic fluctuations within an atmospheric cell (Seykora, 1993). With a series of photodetectors, which respond to the twinkling of moonlight, the scintillator probes the turbulence structure along the line of sight through the atmosphere (Hickson, 2002). The measured quantities are time series of intensity fluctuations received by the individual detectors in the array, from which the turbulence profile can be inferred. This work describes the implementation of a site-testing instrument that measures solar scintillation, therefore used to examine the quality of the sky in order to find favorable places for installing a ground-based facility for observing and monitoring the Sun from Colombia.

Observational Validation of the Modeling and Simulation of a CME

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One of the factors that most affect ground-based astronomical observations is the seeing caused by atmospheric turbulence. To counteract this effect, adaptive optics elements are used in modern telescopes. In order to quantify this phenomenon, an instrument called scintillator can interpret thermodynamic fluctuations within an atmospheric cell (Seykora, 1993). With a series of photodetectors, which respond to the twinkling of moonlight, the scintillator probes the turbulence structure along the line of sight through the atmosphere (Hickson, 2002). The measured quantities are time series of intensity fluctuations received by the individual detectors in the array, from which the turbulence profile can be inferred. This work describes the implementation of a site-testing instrument that measures solar scintillation, therefore used to examine the quality of the sky in order to find favorable places for installing a ground-based facility for observing and monitoring the Sun from Colombia.

Ensemble forecasts of geomagnetic indexes

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Solar activity can affect the dynamics of the Earth's magnetosphere and ionosphere, in what is called "the sun - solar wind – magnetosphere – ionosphere interaction [1]. In particular, during a geomagnetic storm the ring current of the Earth's magnetosphere can produce large perturbations of the horizontal component of the magnetic field observed at the ground at low latitudes. These variations are usually quantified using the storm weather disturbance index (Dst) that estimates the intensity of the ring current and is used to monitor the severity of the storm. In this work we propose and study an ensemble of linear evolution models of Dst, properly weighted through a "skill measure", driven by solar wind variables [2] as a convenient and flexible strategy to model and forecast the behavior of Dst and its uncertainty over time. In order to improve the forecast it is neccesary to know if this "skill measure " is an indicator of the behavior of a particular storm, that is why we propose a genetic algorithm method that allows to predict Dst in a short time. The data is taken from the OMNI dataset. References: [1] Gosling, J. T. (1993), The solar flare myth, J. Geophys. Res., 98(A11), 18937– 18949, doi:10.1029/93JA01896. [2] Burton, R. K., McPherron, R. L., and Russell, C. T. (1975), An empirical relationship between interplanetary conditions and Dst, J. Geophys. Res., 80(31), 4204–4214, doi:10.1029/JA080i031p04204.

Impact of the solar wind on intrinsic and induced planetary magnetospheres

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Even though most planets in our solar system are surrounded by their own intrinsic magnetospheres, a few of them (such as Mars) develop induced magnetospheres as a result of the impact of the solar wind with their ionospheres. An interesting variety of plasma processes take place from the interaction of the solar wind with either intrinsic or planetary magnetospheres, such as shocks, magnetic reconnection or the development of turbulence. Much progress has been made in our understanding of these processes from in-situ measurements performed by missions to all solar system planets.
In the present talk, we report results of multifluid simulations to study the generation of structures arising from the interaction between the solar wind and planetary magnetospheres, such as perpendicular shocks and magnetic pile-up boundaries.

Study of the Kp (global) and Ksa (local) indices behavior during a period of solar minimum activity (2020)

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The geomagnetic indices are crucial for quantifying disturbances in the Earth's magnetic field, mainly caused by solar wind. These disturbances can lead to geomagnetic storms, which may disrupt the operation of electric power transmission systems, especially at high latitudes, as well as damage critical infrastructures relying on space-based assets. A well-known global indicator of the geomagnetic activity is the Kp index (INTERMAGNET-GFZ Potsdam) that do not consider the observatories in South America. On the other hand, we have recently developed the Ksa index, which is obtained from the Embrace Magnetometer Network (Embrace MAgNet -INPE). It is designed to obtain regional geomagnetic peculiarities such as South America Magnetic Anomaly (SAMA). Thus, in this study, we perform a comparison of these two indices during 2020, which is a period of minimum solar activity. We compared the seasonal variations of Kp and Ksa indices by analyzing the Pearson correlation coefficients. The results show that the correlation is moderate for both periods (solstices and equinoxes), and the Ksa index tends to exhibit higher values than the Kp index during the period of minimum solar activity, which we assume to be related to the SAMA's influence.

Evolution of relativistic electrons in the radiation belt during geomagnetic storms.

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The adiabatic and non-adiabatic behavior of relativistic electrons in the outer radiation belt during strong geomagnetic storms is studied using data from multiple observational platforms simultaneously: the Van Allen Probes, ARASE, and THEMIS satellites. The analysis of electron fluxes shows an enhancement of relativistic electrons during the recovery phase after the strong depletion occurred during the main phase of storms. The maximum electron flux appears at the L-shell well described by the Tverskaya relation. In order to study whether the adiabatic mechanisms are relevant to explain the behavior of relativistic electrons, we first analyzed the electron spectra and found that they fit well to a power-law function. For a fixed L-shell, the power-law index is commonly conserved during the pre-storm time, increases during the main phase, and decreases during the recovery phase. The long time conservation of the slope of the electron spectra can be considered as evidence of a dominant contribution of adiabatic processes, as it is difficult to explain this effect by other processes such as acceleration and losses of relativistic electrons. Nonetheless, the strong changes observed in the electron spectra slope related to the storm phases can be related to different processes leading to the electron loss or acceleration, such as the interaction with ULF waves.

Study of the variation of plasma pressure in the Earth's magnetosphere during geomagnetic storms using satellite data and numerical modeling

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The maintenance of magnetostatic equilibrium is the first problem that should be solved while we are analyzing any plasma configuration. It is not yet fully understood how the magnetosphere reaches magnetostatic equilibrium and what specific conditions are necessary to maintain it. Unraveling these processes requires knowledge about the 2-D distribution of plasma pressure for different geomagnetic conditions. In this work, we have obtained a self-consistent numerical solution for the dipole magnetic field disturbances caused by plasma pressure in the case of an azimuthally symmetric plasma distribution specified in the near Earth's magnetosphere. These results are complemented with the use of actual data measured by high-orbit satellite missions, such as THEMIS, RBSP or MMS. The primary outcome is the development of a novel methodology enabling the calculation of the Earth's magnetic field depression caused by a two-dimensional pressure profile during intense geomagnetic storms.

SESSION: IONOSPHERE AND UPPER ATMOSPHERE

Long-term trends in the ionosphere due to anthropogenic and natural forcings and its relevance to space weather

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In addition to regular changes such as daily and seasonal, and irregular variations of transient character, the Earth's ionosphere presents long-term trends. They have been of interest since a pioneering study in 1989 suggesting that the long-term increase of greenhouse gases concentration due to anthropogenic activity will produce a global cooling in the upper atmosphere together with the global warming in the troposphere. Since then, the study of of long-term changes in the upper atmosphere, and particularly in the ionosphere, has become a significant topic in global change research with many results already published. Even though anthropogenic forcing seems to be the main trend driver until now, there are also other ionospheric long-term change forcings of natural origin. Among them is the secular variation of the Earth´s magnetic field, which affects not only the electron density, but currents flowing in the ionosphere and magnetosphere, ionospheric conductivity, and radio wave propagation as well. The ionosphere, as a part of the space weather environment, plays a crucial role through the modulation of the global electrodynamic circuit, its coupling to the magnetosphere and as a key medium for communication, sounding and navigation. Certainly it could be said that space weather cannot be understood without reference to the ionosphere. Thus, a thorough understanding of its variability in all time scales becomes crucial. In this work, theoretical and experimental results on ionospheric trends linked to anthropogenic effect and Earth's magnetic field secular variations are analyzed together with their relevance for space weather. These trends, although weak when compared to other regular or irregular ionospheric variations, are steady and may become significant in the future and of importance, even now, for long-term space weather forecasts. Understanding them will certainly shed light on the physics of several ionospheric processes essential for space weather comprehension.

Vertical total electron content and geomagnetic variations during X-class solar flares in 2022.

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We analyzed the ionospheric and geomagnetic response to the most intense X-class solar flares recorded in 2022 during quiet geomagnetic conditions. We studied the influence of each solar flare using measurements from the Global Navigation Satellite System (GNSS) and geomagnetic observatories located at mid- and sub-auroral latitudes. Geomagnetic field variations, dB, and vertical total electron content variation, $\Delta VTEC$, were obtained at different solar zenith angles. We used X-ray measurements from the Geostationary Operational Environmental Satellite (GOES) program, to evaluate the delay between maximum X-ray flux and VTEC and dB maximum values.

This work presents a study of the ionospheric and geomagnetic response to three X-class solar flares with different morphologies.

We have found that the maximum VTEC and dB are one to two minutes later than the maximum X-ray flux. Δ VTEC variation depends on the flare position on the solar disc and the geographic location of the GNSS station.

On the other hand, dB depends on the time and position of ionospheric currents and the influence of the equatorial electrojet in the observatories.

Study of Ionospheric Disturbances Produced During Solar Wind Oscillatory Event Using GNSS Observations.

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The solar wind has influence on the magnetospheric convection. Because of the variations of the interplanetary magnetic field (IMF) and solar wind dynamic
pressures (PSW) can change the magnetospheric electric field and affect the mid- and low-latitude ionosphere through penetration process. Huang et al. (2002)
studied quasi-periodic ionospheric disturbances using Millstone Hill radar observations and associated these disturbances with penetrating magnetospheric electric fields.

In our work, the vertical total electron content (VTEC) obtained from GNSS measurements shows the ionospheric variability during a transient and oscillatory event in the interplanetary magnetic field (IMF), consequently in magnetospheric electric fields. The global coverage of GNSS observations allows us to calculate the VTEC at distributed permanent geodetic stations with different geomagnetic latitudes and local times. Therefore, we can analyze the penetration of magnetospheric electric fields when the ionospheric conditions are different.

Our preliminary results show almost periodic variations in VTEC at stations close to the Millstone Hill radar. The calculated ionospheric disturbances are similar to those obtained in the electron density recorded in the radar. We implement numerical tools like Wavelet transform and Wavelet Coherence to study the oscillation of studied parameters and the cause-effect relationship between them.

We conclude the relationship between the ionosphere and IMF is higher at mid- high latitudes and local times close to noon

Traveling ionospheric disturbances in the far field induced by tsunamis.

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Every so often, large tsunamis affect countries on the Pacific Ring of Fire. These events can cause Traveling Ionospheric Disturbances (TIDs), which reach the ionosphere due to the production and propagation of gravity waves. TIDs can be observed several thousand kilometers away from the source. Total Electron Content (TEC), calculated indirectly using signals from Global Navigation Satellite System (GNSS) receivers, enables the detection of TIDs. Additionally, an instrument can be used to measure the behavior of the ionosphere from the ground without integrating the entire electron column and observe the TID. In this case, by incorporating a vertical component, an ionosonde enhances the spatial and temporal resolution provided by TEC, facilitating the detection of TID effects on the ionosphere. This work aims to identify TIDs several thousand kilometers away from the source in the South Pacific, comparing the results with tsunami models and data. This procedure allows us to observe signals that arrive after or at the same time as the tsunami reaches the coasts, but also others that are detected hours before the wave completes its journey over the Pacific Ocean. Establishing a possible association between these TID parameters and transpacific tsunamis would contribute to understanding the mechanisms involved and could aid in the development of early warning systems in near real-time in the future.

Estimation of F-region plasma parameters using perpendicular-to-B spectral measurements with AMISR14 at Jicamarca.

Milla Marco A.[1], Fabiano Rodrigues[2], Karim Kuyeng[3], Joab Apaza[3] , Roberto Flores[3] , Elías Huaripuma[1] , and Danny Scipión[3]
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Incoherent scatter spectral measurements pointing perpendicular to the geomagnetic field can be conducted with the AMISR14 radar that is located at the Jicamarca Radio Observatory in Lima, Peru. Such observations show relatively narrow spectra with side peaks at the lower hybrid resonance frequency for a magnetized plasma. In order to model these measurements, we have followed the general framework of the incoherent scatter theory described in Kudeki & Milla [2011] and Milla & Kudeki [2011]. The model accounts for the effects of Coulomb collisions as described by a simplified Fokker-Planck collision model with constant friction and diffusion coefficients. In addition, since the measured spectra are the result of contributions coming from different directions illuminated by the radar beam, we have to consider the beam shape in order to weight and integrate the modeled spectra along the direction in which the magnetic aspect angle varies. Based on this model, we have conducted spectral fittings of the radar measurements in order to obtain estimates of the magnetic field intensity and of the electron and ion temperatures as functions of range and time. The estimations obtained are in agreement with the values expected for the geomagnetic field intensity and for the plasma temperatures at F-region ionospheric heights. In this work, we will describe the spectral incoherent scatter model applied to fit the radar measurements, as well as, the results obtained with this procedure.

Thermospheric dynamics across South-America: a ground-based network perspective.

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The low-latitude upper atmosphere displays enriched dynamics arising from the coupled interaction of the ionospheric electric fields and thermospheric wind fields, influenced by Earth's magnetic field topology. This interaction give rise to various phenomena such as the Equatorial Ionization Anomaly or plasma irregularities, which lead to plasma redistribution and feedback to the driving factors. In the South American sector, the presence of the South Atlantic Magnetic Anomaly hinders regular spaceborne observations of thermospheric drivers using airglow spectrometer techniques. Consequently, ground-based instrumentation, particularly Fabry-Perot Interferometers (FPIs), has been the primary source of thermospheric observations in this region. While many of these observations have been individual efforts, recent years have seen the emergence of FPI networks that have unveiled storm-time thermospheric dynamics and provided evidence of ion-neutral coupling effects on longitudinal variations of winds. This review aims to explore the main efforts utilizing ground-based FPI networks in this region, as well as ongoing initiatives to establish a distributed observatory for studying thermospheric dynamics.

Automatic Segmentation and Classification of Range-Time-Intensity maps of Equatorial Spread-F.

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In the Peruvian ionosphere, a phenomenon that can disturb the global navigation satellite systems (GNSS) and radio communication systems is called Equatorial
Spread F (ESF). This nighttime phenomenon starts at the bottom of the ionospheric F- region and is related to forming plasma density-depleted areas (bubbles). ESF studies
have been conducted for years using the Jicamarca ionospheric radar operating in the JULIA mode. The radar backscatter power is registered in Range-Time-Intensity (RTI) maps showing temporal vs. height occurrence. These RTI maps evidence different morphological patterns (bottom-type, bottomside, radar plumes, and others). Since the type of morphological patterns is related to the ESF evolution, identifying each pattern and analyzing its occurrences can help the models forecast the ESF. In this work, we aim to automatically segment and classify the ESF patterns in the RTI maps using machine learning and deep learning algorithms. Leveraging the RTI maps available for more than 20 years, a comparison between different techniques such as Random Forest (RF), eXtreme Gradient Boosting (XGBoost), Neural Networks, and U-Net Convolutional Neural Networks (CNN) is conducted. As a result, the U-Net architecture shows the best performance for segmenting and classifying the ESF. The features used in the segmentation and classification are the RTI maps, geospace physical parameters, and feature textures.

Multi-index analysis of ionospheric disturbances driven by internal and external physical mechanisms during two space weather events.

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In this work, we present a study of the ionospheric disturbances observed over South America during two space weather events. To accomplish this, we examined maps of two ionospheric indices: the Disturbance Ionosphere indeX (DIX) and the Rate of Change of the Total Electron Content Index (ROTI). For this analysis, we have specifically chosen two significant space weather events of the solar cycle 24: an intense geomagnetic storm that took place on March 17-18, 2015 (St. Patrick's Day geomagnetic storm) and a preceding geomagnetic substorm that occurred on March 10- 13, 2015. Our results reinforce that the ionosphere can undergo disturbances of different levels resulting from a combination of internal and external physical processes. For instance, the DIX showed the effects of disturbed electric fields during the intense geomagnetic storm. At the same time, ROTI maps showed unusual equatorial plasma bubbles (EPBs) near sunrise. On the other hand, the DIX showed changes in the equatorial ionization anomaly (EIA) crests during the substorm occurrence, whereas ROTI maps indicated a weakening of the night-time EPBs. We based these conclusions on observing the behavior of the indices before, during, and after the space weather events under study. Finally, observational data, such as All-Sky Imagers and Ionosondes, along with geomagnetic indices (e.g., Kp, AE), were also used to support our analysis.

Integrated behavior of ionospheric indexes in South America during the Saint Patricks geomagnetic storm.

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In Latin America, interest in space weather studies has increased, particularly in three countries, Brazil, Mexico and Argentina (Denardini et al., 2016a, Mendoza et al., 2019a). MAGGIA (UNLP + CIC, Argentina) has developed ad hoc computational software, AGEO 19.12; which freely provides the entire scientific community with real-time and post remote sensing products of the atmosphere. MAGGIA is the only provider of these products for Latin America making full use of all satellite constellations (i.e., GPS, GLONASS, Galileo and BeiDou) and all available observation bands (five frequencies). We employed the software developed at MAGGIA making use of GNSS observations to study the behavior of ionospheric indexes: ROTI (Rate of TEC Index), W (Weather Index) and DIX (Disturbance Ionosphere Index) during the St. Patrick's Day geomagnetic storm on March 17 and 18, 2015 over South America.
We make a new implementation of the DIX presented by Jakowski et al. 2012 to study the ionospheric region of South America, with a great number of GNSS stations and using multiple frequencies. The highlight point is the generation of carrier-phase ionospheric observables using AGEO 19.12 to calculate the ROTI and DIX indexes free of systematic errors. The W-index was generated from maps of VTEC over South America produced by MAGGIA. We conclude that the degree of ionospheric disturbance due to the geomagnetic storm shows regional differences when we compare the ionospheric indexes results at low, mid, and high geomagnetic latitudes.
We can affirm that the three indexes are quality tools to provide temporal and spatial ionospheric information over South America during study event.

On the problem of GNSS observation coverage for the IGS ROTI maps for the Southern hemisphere.

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The Earth's ionosphere responses to Space Weather with the global redistribution of plasma density, creates favorable conditions for generation of ionospheric plasma irregularities and gradients. The storm-induced ionospheric irregularities are responsible for radiowaves scintillation and can seriously affect satellite-to-earth radio signals propagation. The International GNSS Service (IGS) diurnal ROTI maps ionospheric product was initially developed to characterize ionospheric irregularities over the Northern Hemisphere using ground-based GPS observations. This ROTI maps demonstrated good performance to monitor occurrence and intensity of high and mid-latitude ionospheric irregularities at this region. Recently, we introduced new experimental IGS ROTI maps that can cover additionally area of the Southern hemisphere and low latitude regions. The main problem toward this task is that existing GPS observations are distributed non-uniformly around the globe. Major part of GPS stations operates in the Northern hemisphere. In the equatorial region, there are available GPS observations from 400 stations, for the Southern hemisphere's middle/high latitudes, we have only 150 GPS stations providing regular observations, and these stations locate mostly in South America. With modification of basic IGS ROTI mapping approach, we can create diurnal ROTI maps for the Southern hemisphere and equatorial regions even on this limited dataset. However, further extension of GPS networks in South America is of crucial importance. We analyzed performance of new ROTI maps to represent well-known features of storm-time ionospheric irregularities development over Southern hemisphere's high/mid latitudes and comparison with the Northern hemisphere results. For low latitudes area, we examined sensitivity of resulted maps to detect plasma irregularities associated with equatorial plasma bubbles in South America. The IGS ROTI Maps with the global coverage are important for further studies of ionospheric irregularities' occurrence and spatial distribution and assessment of the Earth's ionosphere responses to Space Weather events of different intensity during new solar activity cycle.

SuperDARN In Latin America.

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SuperDARN is a network of high frequency (HF) radars used for space weather research observations. The network is operated by an international collaboration that involves scientists from around the world. The original development of SuperDARN began in the 1990's as part of the International Solar Terrestrial Physics program (ISTP). Since that original development, SuperDARN has grown and flourished, and continues to make significant contributions to the science goals of ISTP. The network has evolved in several ways since the original conception as a northern hemisphere auroral zone array of radars for mapping convection. It has expanded poleward to cover the polar cap, and equatorward to cover mid latitudes. Today's network comprises radars observing over regions from the mid-latitudes to the central polar cap to differing degrees in both the northern hemisphere and the southern hemisphere. New radars continue to be developed, including the newest radars in the network, a pair of radars in Iceland that came on line earlier this year.
Development of the network in Latin America has been limited to a single radar in the Islas Malvinas operated by the British Antarctic Society. Looking to the future, we hope to expand the network by building radars in Patagoinia to provide observations over the Southern Ocean to complement the coverage of radars on the Antarctic continent. This presentation will give an overview of the present network status and science, and discuss some of the plans for future development.

NASA's Geospace Dynamics Constellation—Providing the first Systematic Measurements of Global Magnetospheric Energy Inputs and Ionosphere-Thermosphere Responses.

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The Geospace Dynamics Constellation (GDC) is NASA's next strategic Living With a Star mission. GDC's goals are: 1) Understand how the high-latitude ionosphere-thermosphere system responds to variable solar wind/magnetosphere forcing; and 2) Understand how internal processes in the global ionosphere-thermosphere system redistribute mass, momentum, and energy. Planned for launch by the end of the decade, GDC will use six identical observatories, each identically instrumented to fully characterize the magnetospheric drivers of the I-T system as well as the global response of the ionized and neutral gases. GDC will do this with a series of orbital configurations that will enable it to study the widest range of spatial and temporal scales to date, ranging from hundreds of kilometers and several seconds to tens of minutes, and extending through the regional to the global scale. This talk presents GDC's current status, measurement capabilities, sampling scheme, and model development efforts and show how GDC will fit into the larger Heliophysics ecosystem, by 1) obtaining critically needed scientific observations; 2) providing a source for real-time space weather and situational awareness, as well as retrospective studies to further the science of space weather; 3) serving as a "strategic hub" for other space-based and ground-based efforts that want to leverage GDC to perform complementary science.

To get the most benefit from GDC's observations, it will be critical to identify partnerships with other research efforts in the ITM and Geospace arenas, including those utilizing space-based, ground-based, or theoretical investigations. We particularly would like to discuss with groups who are planning or considering observational campaigns during the GDC era, to find ways to leverage GDC observations to do synergistic science that could not be done otherwise.

Challenges to observe ionospheric Storm-Enhanced Density and Tongue-of-Ionization structures in South American sector .

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During geomagnetic storms, large ionospheric plasma density enhancements can occur at middle and polar latitudes. One of the most dramatical phenomena that can affect the midlatitude ionosphere is so called Storm-Enhanced Density (SED)—a localized plume of largely enhanced total electron content (TEC) that moves poleward and sunward from lower latitudes toward higher latitudes. Sharp plasma density gradients (¿ 10x) can be found at the edges of the SED plume and they can lead to intense scintillations of the received GNSS signals and to performance degradation of GNSS-based systems even at midlatitudes. When SED plume enters into the polar cap near noon, it transforms into a large-scale polar Tongue of Ionization (TOI) structure. In polar cap, the electron density within TOI can be 2-10 times larger than the background values. Most SED structures have been observed and reported in the American longitudinal sector, namely over continental North America, using dense networks of GNSS receivers. Model simulations show that SED/TOI structures may occur symmetrically in both hemispheres. However, in the Southern Hemisphere, we have a very limited global coverage of GNSS receivers at middle and high latitudes. The largest spatial coverage is provided by several regional networks of GNSS receivers in South America. On several representative cases of geomagnetic storms, we present results of observations the SED/TOI structures in this region of the Southern Hemisphere on the base of existing ground-based GNSS observations and multi-instrumental measurements onboard ESA's Swarm satellites. We will discuss the observational problems and challenges on existing data coverage by GNSS and ionosondes in the southern part of South America and Antarctica. Advancements in these areas could provide a better understanding of space weather effects in the Southern Hemisphere and globally.

Ionospheric response on geomagnetic storms for near high- and mid-latitudes in South America.

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The geomagnetic storms that occurred during the last two decades will be analyzed regarding their impact on the ionosphere for latitudes that cover Antarctica, and the southern parts of Argentina and Chile. The Dst index will be used as a criteria for selecting disturbed time periods, Vertical Total Electron Content derived from five CORS GNSS receivers with long historical records will characterize the ionospheric behavior.
This study shows increasing plasma density changes, when compared to mean values obtained during geomagnetically quiet periods, that have a preponderance during autumn, winter, and spring at mid- latitudes and in winter at near high-latitudes. These positive changes are observed more frequently during daytime. On the other hand, decreasing plasma density changes do not present a seasonal pattern for any latitude sector and they occur predominantly at nighttime.
A pattern of solar activity dependence of the geomagnetic storms was also found. Results achieved from this study will contribute to a better understanding of the space weather in the upper Antarctic atmosphere.

Quiet day curve for riometer: Analysis and comparison of methods.

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The RIOMETER is a passive instrument that measures the intensity of the cosmic signal that reaches the Earth's surface. With the adequate analysis of this signal, it is possible to determine the attenuation suffered by them, when traveling through the ionosphere, particularly at the altitudes of the D region.
Both in the most basic zenithal beam instruments and in the more sophisticated multi-beam (or image RIOMETER), multifrequency, or mesospheric radar instruments, it is extremely important to obtain a correct reference curve corresponding to a calm day (Quiet Day Curve - QDC) in order to carry out this analysis. That "Quiet Day" is, in its most basic form, the attenuation suffered by the signal on those days when the ionosphere is undisturbed.
Since the beginning of the use of this technique, various methods have been developed and proposed to obtain this QDC, with varying degrees of implementation complexity and advantages. In general, the selection of one of these methods is based on the type of analysis we are interested in performing with the RIOMETER data, levels and nature of the interference at the site, noise, etc.
In this work, we analyze and apply several methods to take the QDC, according to Tanaka-Moro, of Percentile, of the point of inflection and based on Fourier Analysis, with data from RIOMETERs based on the Trelew Geophysical Observatory (National University of La Plata), Chubut, Argentina, and discuss the results to compare the methods.

Study of sudden impulses and the influence of Magnetic Anomaly in South America.

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The solar wind interacts with the magnetic field through the Earth's magnetic reconnections, and consequently, the magnetosphere is configured. Thus, different plasmas and current systems could exist in such times. This behavior changes in the pattern of this recognition and magnetosphere parameters. A first response to solar plasma changes in the magnetic field is an increase of the H component of the field, called Sudden Impulse (SI) or Sudden Commencement (SC), that precedes a geomagnetic storm. Additionally, in the Brazilian sector, there is an important peculiarity concerning the Earth's magnetic field called the South American Magnetic Anomaly (SAMA). In this context, the present work analyzes the morphological characteristics of four SC events in stations inside and outside of the SAMA for the year 2021.

Understanding the ionospheric's state by the Generalized Linear Models.

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The Ground Based Augmentation System (GBAS) in Brazil is important for air navigation but can be the unavailable for a long time by external factors which affect the ionosphere's state. The literature provides the variables that most likely influence this unavailability, such as magnetic latitude, time, solar activity, and space weather conditions. However, we are not aware of any probabilistic model based on these variables that could be applied to improve the availability of GBAS systems. This work explores that venue by searching for parsimonious models based on generalized linear models. These models are designed to operate at aerodromes in Brazil, where GBAS systems have limited use. They incorporate long term measurements of ionosphere instabilities in that region. A well-designed model is expected to provide reliable probabilities of observing harmful scintillation in the ionosphere, potentially enabling the safe use of GBAS during the night at low latitudes when conditions of sufficiently low probability are met.

Ionospheric medium-term trends over Concepción, Chile, and its possible association with ENSO.

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Recent studies have highlighted the existence of a strong coupling between the lithosphere, lower atmosphere and the ionosphere. While the impacts of short-term events like earthquakes, tsunamis, volcanic eruptions, and thunderstorms on the local ionosphere have been well-documented, the association between a medium-term phenomena such as the El Niño Southern Oscillation (ENSO) and the ionosphere remains relatively unexplored, likely due to the complex nature of the system. This study aims to investigate the potential association between the ENSO phenomenon and the ionosphere, focusing specifically on the impact on the critical frequency of the F2 layer (foF2) during both daytime and nighttime. foF2 represents the maximum frequency at which radio waves can be reflected by the ionosphere, and variations in this parameter can have significant implications for radio communications and navigation systems. To achieve this objective, an extensive dataset comprising measured ionospheric parameters over Concepción (36.8°W, 73.0°W), Chile, and ENSO indices will be analyzed. In order to corroborate this analysis, other ionospheric stations and other instruments will also be used. Understanding the influence of ENSO on the local ionosphere will contribute to improved predictions and modeling of ionospheric behavior, benefiting various applications that rely on ionospheric conditions, such as radio communications, satellite navigation, and space weather forecasting.

Application of Proper Orthogonal Decomposition Method on foF2 Data from IRI model for the Latin American region.

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Proper Orthogonal Decomposition (POD) is a mathematical technique used to extract dominant patterns or modes of variation from high-dimensional datasets. In this study focused on Latin America's foF2 (maximum frequency of the F2 ionospheric layer) data, POD is employed to decompose the time series into fundamental components that contribute to its variability.
The foF2 data series used in this study covers a time period from 1960 to 2022 and extends from 30°N to 90°S and from 120°W to 20°E. The spatial resolution of the grid used is 3°x3°, providing detailed coverage of the Latin American region. These data were generated using the International Reference Ionosphere (IRI) (Bilitza et al., 2022), an empirical model of the ionosphere that utilizes data from a global network of instruments such as ionosondes, satellites, and rockets. The IRI is widely adopted as a standard model within the scientific community.
By applying the POD method to the foF2 data series for Latin America, the main components contributing to the observed variability can be identified. These components may include temporal trends, seasonal cycles, short-term fluctuations, and spatial patterns. The orthogonal decomposition allows for the separation and individual analysis of these components, providing a deeper understanding of the underlying processes affecting foF2 variability. This is particularly useful for identifying anomalies, atypical behavioral patterns, or significant changes over time and space. Understanding and characterizing these patterns can provide valuable insights into the underlying processes and dynamics of the ionosphere, which directly contributes to our understanding of space weather conditions.

Development of a radiofrequency signal generator for ionosonde radar transmitter using red pitaya.

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The Jicamarca Radio Observatory (JRO) is a facility of Instituto Geofísico del Perú (IGP), dedicated to monitor the upper atmosphere with different instruments like radars, GNSS receivers, magnetometers, among others. Ionosondes is a type of HF radar that uses multiple frequencies to examine the ionosphere and could provide estimates of electron density. The purpose of this work is to develop a low-cost radiofrequency signal generator for the ionosonde radar transmitter based on the SDR Red Pitaya Signal Lab 250-12. The generator consists of an SoC FPGA Zynq-7020 with a sampling frequency of 250 Msps, and it can transmit modulated signals with a frequency sweep ranging from 1 MHz to 60 MHz, providing the possibility of using it with other CW radars. For the design, the Vivado development environment from Xilinx-AMD was used. The hardware synthesis was based on the VHDL hardware description language, using a behavioral description style for the modules, such as the SPI controller, register map, numerically controlled oscillator (NCO), OOK modulator, multiplexer, synchronization module with a 10 MHz GPS clock input, and trigger for signal transmission initiation. Subsequently, all the mentioned modules and IP Core Clocking Wizard were integrated using the structural description style in the Vivado software. Additionally, an embedded system was used for register writing through the SPI protocol. The initial tests were carried out at the Vertical Incidence Pulsed Ionospheric Radar (VIPIR) located at the IGP-JRO, where pulsed signals were successfully transmitted using the radiofrequency signal generator. Ionograms were obtained using both the VIPIR receiver and the Ionospheric Echoes Receiver (IER) based on USPR.

Estimation of spectral parameters from oblique Equatorial Electrojet echoes using a double skewed Gaussian model at the Jicamarca Radio Observatory.

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Coherent echoes from the equatorial electrojet (EEJ) region are detected in Perú at the Jicamarca Radio Observatory by using an array of 16 Yagi antennas with a main beam pointed obliquely to the west with a 35 deg elevation. The spectrum of these observations are composed of two types of echoes (Type I and Type II) from which we can estimate their main spectral parameters such as Doppler shift and spectral width independently for each type. Previously, the method applied to obtain these parameters was a standard fitting approach based on a double Gaussian model. However, in some cases, the shape of the spectral measurements are not symmetric. Based on simulations, we determined that the skewed shape of the oblique EEJ spectrum comes from the fact that the measured spectrum is the result of the sum of spectral contributions coming from different heights, with different Doppler shifts and spectral widths weighted by the antenna beam shape. The overall result is an asymmetric spectrum with a peak that does not coincide with the average Doppler shift. Thus, in order to account for this effect, we have implemented a double skewed Gaussian distribution model to fit the oblique EEJ measurements and estimate their spectral parameters. In this work, we present the results obtained in the simulation showing the skewed shape of the spectrum. Based on our simulations, we have also proved that the shift of the skewed Gaussian model can be interpreted as the Doppler Shift. In addition, an example of the new fitting procedure is shown in comparison with the classical Gaussian fitting where it can be seen the better agreement between data and the double skewed Gaussian model. Moreover, these new results will change zonal wind estimations in the EEJ region that uses EEJ Type II Doppler shifts as input.

Ionospheric Response to a Strong Geomagnetic Storm using ionosonde data in Argentina.

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In this study, we investigate the ionospheric disturbances caused by a strong geomagnetic storm (maximum Kp = 7) occurring between February 26th and 28th, 2023. The geomagnetic storm onset began on 26th February at 19:27 UT with a Sudden Storm Commencement (SSC), with a main phase reaching Sym-H = -161 nT at 12:12 UT on February 27th, and followed by a long-lasting recovery phase until March 2nd.
The main scope of this work is to use ionosonde data in Argentina for space weather studies. We analyze the ionospheric response using data from two ionospheric stations deployed in Argentina: a) Tucumán (Latitude 26,9 S; Longitude 294,6 E), a low latitude station; and b) Bahía Blanca (Latitude 38,7 S; Longitude 62,3 W), a mid-latitude station. We used autoscaled data for the critical frequency of the F2 layer (foF2) from AIS-INGV ionosondes installed in the mentioned locations. During the main phase of the geomagnetic storm, we observed in both stations a significant decrease in foF2 implying the presence of an ionospheric storm with a negative phase. We observed also, a positive phase ionospheric storm in Bahía Blanca during the recovery phase of the geomagnetic storm (not observed in Tucumán). The addition of complementary data (from other instruments) and further analysis, are planned in future steps to improve this study.

Quality improvements to the spectral data acquired from HF multi-static sounding system at the magnetic Equator.

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The HF radar is a continuous wave multistatic radar composed of three transmitting stations and six receiving stations operating at two frequencies (2.72 MHz and 3.64 MHz) for ionospheric sounding. The system is deployed at the magnetic Equator in the regionally along the central coast and highlands of Peru. HF radar uses signals modulated with three different pseudo-random noise codings by each transmitter. This configuration allows the detection of the following parameters as a group delay (pseudorange), the Doppler shift, Signal-to-Noise (SNR). These measurements are used to estimate the regional plasma density as a function of space and time, to complement the Spread-F data obtained from the Jicamarca Radio Observatory main radar, improving its forecasting (Hysell, D. L., 2019).
These final parameters (altitude, SNR, Doppler shift) are obtained through the processing of the spectral data acquired from the signals of each HF transmitter. In order to improve the measurements of the final parameters obtained by the HF radar, an evaluation of the quality and consistency of the spectral data was realized. These involved a series of modifications such as the implementation of a multifrequency transmission system and a cluster detection algorithm to classify coherent echoes as signals and discard the noisy zone, resulting in spectral data free from interference and reducing the storage size of each spectra.
This work will present a brief description of the HF radar, the work done to improve the detectability of coherent echoes in the spectral data that influences to improve the Spread-F forecast and the comparisons between the final parameters.

Ionospheric Fluctuations Induced by Thunderstorms in the Central Region of Argentina.

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Global Navigation Satellite Systems (GNSS) measurements allow for the calculation of the Total Electron Content (TEC) present in the ionosphere. TEC is defined as the integrated electron density along the signal path from the satellite to the GNSS receiver (Lay et al. (2015)). It can be dynamically perturbed by both external and internal influences (Ogunsua et al. (2020)). In terms of internal influences, thunderstorms occurring in the troposphere can generate wave-like structures in the ionospheric plasma known as Atmospheric Gravity Waves (AGWs) (Lay et al. (2013); Lay et al. (2015)). These waves can be detected through GNSS measurements (Vadas and Liu (2013)). Therefore, the objective of this study is to investigate the ionospheric variations caused by thunderstorms that occurred during the night (00:00 UTC-08:00 UTC) of November 10, 2018, in the central region of Argentina. The data used were the TEC which was computed from GNSS measurements provided by Argentine Continuous Satellite Monitoring Network (RAMSAC by its Spanish acronym) stations and the atmospheric electrical activity data which were provided by the Earth Networks Total Lightning Network (ENTLN). As a result, oscillations in the ionosphere were observed at all RAMSAC stations, even at a distance of 1000 km. These perturbations had periods of up to 100 minutes and peak-to-peak amplitudes of up to 1.35 TECU (1 Total Electron Content Unit $= 10^{16}$ electrons/m^2). It was found that AGWs with the highest peak-to-peak amplitudes coincided with periods of intense Atmospheric Electrical Activity (AEA). Finally, it was observed that on stormy days, the peak-to-peak amplitudes of the waves were approximately 2.91 times larger than on non-stormy days.

SUPIM-INPE as a predictor of the ionospheric impact of solar eclipses.

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Historically, solar eclipses have been astronomical events that have fascinated humanity. The ionosphere, the conductive layer of the atmosphere, depends directly on solar radiation, so it is affected during solar eclipses. Some of the ionospheric layers are more affected than others. SUPIM-INPE is a model that has worked well over South America during the 2019 and 2020 eclipses. The modifications of the model for these eclipses were done in two independent steps: 1) considering the decrease in solar EUV radiation of the chromosphere, and 2) in the solar corona. Based on what has been learned in those previous studies, some modifications have been made in order to improve the measured observed response. Specifically, the thermospheric wind model has been updated, and the neutral composition changes observed during eclipses have been considered. This work presents the predictions of the ionospheric response to the two following eclipses that will occur in America, the solar eclipse of October 14, 2023 and April 8, 2024.

Customization of Magnetic and Ionospheric Scales for Latin America

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Several efforts have been made recently to develop new tools based on ionospheric indices and magnetic index to improve our knowledge of the space weather effects at the global and regional scales. In this regard, our research group has work for develop the DIX (Disturbance Ionospheric) Index and the Ksa (K for South America). The first is an ionospheric index derived from the Global Navigation Satellite System (GNSS) data and the second a local geomagnetic index developed to overcome the need for observatories in the South American sector providing data for binding the "planetary" Kp index. Concerning the ionospheric indices, we have primarily focused on studies about the detection (or detectability), and measurement of parameters related to EPBs (latitudinal extension and velocity) a low-latitude phenomena that is particularly present in the Brazilian sector. The regional magnetic index was also designed to obtain the regional geomagnetic peculiarities of the Brazilian sector such as the influence of the South America Magnetic Anomaly (SAMA). Thus, in the present work, we present and discuss results from studies recently published and under preparation related to the use of these indices.

CURRENT SPACE WEATHER CAPABILITIES IN LATIONOAMERICA

Activities and new capabilities of the LAMP space weather center

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In this presentation, we will provide the latest information on activities and capabilities of the Argentine Space Weather Laboratory ('Laboratorio Argentino de Meteorología del esPacio, LAMP). LAMP is an interdisciplinary center focused on space weather, solar-terrestrial physics, energetic particles, and atmospheric sciences. Its headquarters are in Buenos Aires and it has its own Antarctic laboratory in Marambio base over the polar circle, where space weather conditions in the Antarctic peninsula are monitored in real time. Additionally, a new LAMP laboratory is in preparation to be installed inside the polar circle where more facilities are planned to be installed. These laboratories have major capabilities to expand instrument networks in Argentina and Latin America. LAMP develops different types of activities, covering capacity building, fundamental research, numerical modeling, development of scientific instruments, instrument operation and maintenance of data flow in real-time, research to operations, development, and implementation of operational products, among others. In particular LAMP develops operative activities since 2016, it was appointed as the Argentinean Regional Warning Center by ISES (the International Space Environment Service) in 2019, Members of LAMP also participated in the panel that created the PRESTO program of SCOSTEP. Products and communications on precursors of enhancements of the level of Sun-Earth coupling (e.g., monitoring in real time conditions at the Sun and in the solar wind near Earth using own products) are also being developed for the community and stakeholders. In this presentation, we will describe the general activities developed by LAMP, its capabilities to increase the development of space weather in the region, and our next steps forward.

Observing the space from the Peruvian sector

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[1]Radio Observatorio de Jicamarca, Perú

The Jicamarca Radio Observatory - JRO, a 61-year facility of Instituto Geofísico del Perú - IGP, is dedicated to monitor and study the ionosphere from the magnetic equator. The IGP-ROJ is mainly dedicated to estimate ionospheric composition and zonal and vertical drifts. Due to its privileged location, ionospheric irregularities like Equatorial ElectroJet (EEJ), 150-km echoes, and Equatorial Spread-F have been also detected and studied over the years. IGP-JRO attracts researchers from all over the world to install instrumentation collocated with the main radar. This includes optical instrumentation like All-Sky Imagers and Fabry-Perot Interferometers. Also, a Low Latitude Ionospheric Network (LISN) of instruments like ionosondes, GNSS receivers, and magnetometers has been installed around Peru and South America. These instruments are operated and maintained by IGP-JRO. In this work, we are going to present the instrumentation installed in Peru and South America used to monitor the space weather. This will include the description of the data repository from all the observations, and possibilities for collaboration. Finally, an update of the latest calculations of local Dst, and K index estimated from the network operated at Jicamarca for space weather applications.

Space Weather in México

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The Mexican Space Weather Service (SCIESMEX) and the National Space Weather Laboratory (LANCE) were established in 2014 and 2016, respectively, with a primary focus on observing, monitoring, and warning about space events that can have significant impacts at low latitudes, particularly on the Mexican territory. SCIESMEX publishes a weekly report on space weather events, disseminated through social networks, and operating an early warning system for the National Civil Protection System. This early warning system specifically targets events that have the potential to significantly affect Mexico. Meanwhile, LANCE is actively involved in the development of instrumental networks to gather data on various space weather phenomena. These include ionospheric disturbances, geomagnetic variations, cosmic ray fluxes, interplanetary disturbances, solar radio bursts, and geomagnetic induced currents in the national electricity grid. By utilizing regional data collected through these networks and incorporating information from international sources such as NASA and NOAA satellites, SCIESMEX and LANCE are able to effectively monitor space weather phenomena that impact low latitudes.

Iterated AI Models for Space Weather.

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Machine Learning (ML) tools are becoming very popular in space physics, as they allow to cope with the inherent complexities that driven dissipative systems display. This is particularly true when we talk about modeling the solar wind-ionosphere-magnetosphere (SMI) system. Many models and methods are being proposed to increase our understanding of the SMI system, to catch the time scales that are at play, or the best variables to be considered when forecasting in space weather applications. These methods constantly face common ML issues such as overfitting, insufficient or noisy data, that turns out to be very challenging to work around given the nature of the usual ML techniques. For example, a great number of indices are regularly used to characterize the SMI system, and their interactions are not fully understood. Naively, we could ask the ML technique to sort out these couplings. However, this is normally not viable due to overfitting, and insufficient and noisy data. Therefore, we have developed strategies, within the same ML framework used to reconstruct the model, to ascertain what are the relevant and robust variables that should be included in such a model. In addition, we compare the robustness of the models optimized by 1-step vs iteration, where the later should provide a more reasonable dynamical description of the system.

Current Space Weather capabilities in Latinoamerica

Costa, Joaquim [1,2]
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In this presentation, we will outline the current status of space weather monitoring and forecasting capabilities in Latin America. This encompasses ground-based observations, satellite data, and collaborative efforts with international space weather agencies. We will also delve into the ongoing research concerning solar and geomagnetic storms and their potential impact on regional technologies. Furthermore, we will discuss the effects of severe space weather events on specific latitudes within Latin America, including disruptions to radio communications, GNSS signals, and satellite operations in the region's ionosphere, mainly considering the peculiarities over the South America.
Latin America's contributions to solar observations and understanding solar influences on space weather will be highlighted, emphasizing the region's active involvement in this vital area of research.
As space weather events significantly affect aviation services, we will explore the implications for the region, particularly focusing on potential impacts on radiation dose in the region of SAMA with some extension to Antarctica.
Emphasizing the importance of public awareness, we will underscore the efforts made in space weather education and outreach, educating the public and relevant industries about space weather's impacts and providing guidance on responding to space weather alerts and warnings.
The evolution of space weather research and collaborations within the region will be showcased, illustrating partnerships with international space weather research organizations.
Finally, we will address the state of preparedness for emergencies and resilience within Latin America, exploring how governments and industries are readying themselves to minimize the impact of severe space weather events on critical infrastructure and services.

MAGGIA contributions to space weather studies.

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MAGGIA, at Facultad de Ciencias Astronómicas y Geofísicas (FCAG-UNLP), is a multidisciplinary laboratory focused in both basic and applied research, since its creation. Three research groups can be distinguished at present, Space Weather and Terrestrial Atmosphere, Geodesy and Geodynamics, Astrometry and Terrestrial Rotation and a working group centered on geoscientific applications for the oil and gas industry. In addition, scientific instruments and operational services are actively developed and provided.

As regards Space Weather and Terrestrial Atmosphere, our expertise consists mainly in ionopsheric variabiliy analysis and modelling, using GNSS, altimeter, LEO and geomagnetic data. In particular we have experience in regional and global ionospheric anomaly analysis using PCA and wavelets and; solar-terrestrial interaction analysis associated with flares, coronal mass ejections, high speed streams and solar wind integrating geomagnetic indexes and VTEC evolution. Currently we are actively working on VTEC forecast using Machine Learning (ML) techniques, computation of quasi-real time ionospheric indexes and interaction between troposphere and ionosphere through gravity waves. Our laboratory produce: quasi-real time multi-constellation GNSS regional VTEC maps every 15 minutes since 2019, and ZTD/IWV in situ values every 50 minutes since 2020.

Our research group distinguishes the following areas to focus its efforts in the near future: cooperation with international organizations involving participation in Ionosphere group, pilot project for combination of VTEC and ROTI/DIX maps, operational forecasts of different parameters that describe the Sun-Earth space, current state of the existing system observatory. This challenge can be addressed through strengthening local and international cooperation to profit from the complementary observation modelling capabilities of the research groups involved.

Network for Solar System and Ionospheric/atmospheric Studies (NeSSI)

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The NeSSI project consists in a network of astrophysic stations for occultation and monitoring of solar system bodies, together with instrumentation for ionospheric/atmospheric studies such as meteorit cameras, magnetometers, radars and ionospheric receptors.

On the astrophysical side, the detection of stellar occultations requires the deployment of small telescopes with fast câmeras in áreas of several km of extension, allowing for direct measurements of size and shapes of asteroids and other solar system, as well as providing invaluable improvement to orbit accuracy mostly relevant for future space missions. Instrumentation for ionospheric/atmospheric studies deployed in these stations, with good observing conditions and large coverage in the territory, could permit new meteorit detections, support in space debris analysis, and several ionospheric studies requiring particular locations due to regional magnetic anomalies such as those in either the NW, NE or South of Argentina.

The joint, multipurpose installations of instrumentation in an extended network has the relevant advantage of a common use of infrastructure as well as logistic support and technical assistance.

Argentine National Meteorological Service and its relationship with Space Weather

Gil, María Ines[1]
[1] *Servicio Meteorológico Nacional.*
A Space Weather (SW) definition, given by the U.S. National SW Plan, says it refers to conditions on the Sun and in the solar wind, magnetosphere, ionosphere, and thermosphere, which can influence the performance and reliability of space-borne and ground-based technological systems and which can affect human life and health.
The argentine National Meteorological Service (SMN) through two of its areas have a straight relation with the SW definition presented. The aim of this work is to show the connections between SW and the SMN as a geomagnetic data producer as well as a user of SW instant reports for flight schedules. On one hand, monitoring the earth magnetic field (EMF) is one of the centennial activities done by our SMN. Magnetosphere conditions and its variations in time and space are recorded on every magnetic observatory and station installed on the ground all over the world. Today, belonging to the SMN, there are still active two magnetic observatories (PIL and ORC)since 1904 and a new magnetic station (CIP, 2015). Each of these sites continuously record the state of the EMF on the earth surface, evidencing the close relationship that exists, mainly, between Earth and Sun.
On the other hand, the SW definition refers to the effects that solar/space events have on earth, particularly in human activities. Here the SMN is implicated as a user of updated SW data. Aeronautical safety depends, not only on the atmospheric meteorological conditions, but also on the ionospheric ones that can affect aircrafts technological systems. These information is provided by SW data centres and applied on the aeronautical messages to inform actual environmental conditions for flights.
Although each area is at different points of the SW data route, both work in mostly an operative manner, providing a service to science or to aircraft crews.

LOOKING TO THE FUTURE

Thoughts on Space Weather Research Collaboration and Cooperation

Spann, James [1], *Jamie Favors* [2], *Genene Fisher* [3],
[1]*NASA HQ Space Weather Lead*
[2]*NASA HQ Space Weather Deputy for Missions and Programs*
[2]*NASA HQ Space Weather Deputy for Science and Research*
The evolving landscape of society's presence in space and the impacts of the dynamic nature of space environment of ground and space-based infrastructure, has given birth to the need for better understanding and characterization of near-Earth and interplanetary space. The applied expression of solar and space physics is space weather research and forms the basis for addressing this need. Space weather does not respect geopolitical boundaries and thus its research by its very nature international in scope. In response to this societal need, NASA has created the NASA Space Weather Program that seeks to advance the science of space weather to empower a technological society safely thriving on Earth and expanding into space. It does this with the establishment of a space weather capability that supports robotic and human space exploration and meets national, international, and societal needs by advancing measurement and analysis techniques, and by expanding knowledge and understanding for transitioning into improved operational space weather forecasts and nowcasts. NASA recognizes that this endeavor must include multinational participation.
This talk will provide insight to the NASA Space Weather Program and explore various approaches that could lend themselves to international collaborative investigations and cooperative pursuits. Examples of current activities will be presented, and potential future ideas will be discussed with a particular emphasis on Latin American opportunities.

International Cooperation and ESA Space Weather System

Luntama, Juha-Pekka [1], Alexi Glover [1]
[1]European Space Agency

Space weather is a global threat to the safety of human made infrastructure in space and on Earth. Space weather is also a challenge to human and robotic space exploration. The impacts of moderate solar events can be detected by operators of sensitive infrastructure and an extreme space weather event could permanently damage satellite systems that enable many services and applications that we utilise in our daily lives. Large scale blackouts caused by power grid damage from Geomagnetically Induced Currents is one of the worst scenarios for a major solar event situation.

European Space Agency has been developing since 2009 a comprehensive Space Weather System consisting of the Space Weather Service Network, Space Weather Coordination Centre, Data System and Space Weather Monitoring System utilising ground based and space borne sensor systems. International collaboration and data exchange is central part of the development of this system. This presentation will explain the objectives and drivers of the ESA Space Weather System development, current status of the system and services, and the plans for the coming years. The presentation will particularly highlight international cooperation objectives, needs and opportunities with particular focus on cooperation with actors in Latinoamerica.

NOAA's Space Weather Observations to Provide Operational Space Weather Capability

Talaat, Elsayed [1]
[1]National Oceanic and Atmospheric Administration (NOAA)

The National Oceanic and Atmospheric Administration's (NOAA's) Space Weather Next (SW Next) Program will ensure observations support the forecasting of space weather events such as geomagnetic storms, ionospheric disturbances, solar wind, solar flares and coronal mass ejections (CMEs) as well as providing backbone measurements necessary for research. The Space Weather Observations Programs Division, a joint NOAA and NASA office, is managing both the Space Weather Follow On (SWFO) and SW Next program. The projects under SW Next program will provide for the continuity of the SWFO-L1 mission, as well as other needed and new multi-point observations into the 2030s to minimize the economic and societal impacts from space weather events. SW Next is closely collaborating with the European Space Agency (ESA) on the Vigil mission (2029), which will carry NOAA's Compact Coronagraph 3 (CCOR-3) as part of its extensive payload and will provide measurements from the Lagrange 5 (L5) point. Furthermore, future SW Next missions include observations at GEO and LEO with space weather measurements improving on those provided by the ongoing GOES-R and the historic POES programs. These measurements, to be made available through the Space Weather Prediction Center (SWPC) and the National Centers for Environmental Information (NCEI), are expected to significantly enhance the accuracy and timeliness of National Weather Service (NWS) forecasts, as well as provide unprecedented opportunities for research and applications in academia and industry.

The Space Weather Operational Readiness Development (SWORD) Center – a focal point for international collaboration in space weather research.

Berger, Tom [1], Tuija Pulkkinen, Daniel Baker,Tamas Gombosi, and the SWORD Team.
[1]Space Weather Operational Readiness Development (SWORD) Center

The Space Weather OperaAonal Readiness Development (SWORD) Center is an internaAonal, mulA-disciplinary focal point where space weather researchers, operaAonal forecasters, industry partners, and the space weather community will collaborate on transformaAve research to improve forecasts and nowcasts of the orbital and cis-lunar space environment. SWORD research will focus on coupling the UMich Geospace model, part of the Space Weather Modeling Framework (SWMF), with the CU Whole Atmosphere Model with Ionosphere Plasmasphere Electrodynamics (WAM-IPE), both of which are currently operaAonal at the NOAA Space Weather PredicAon Center (SWPC). In addiAon, SWORD will develop new data assimilaAon systems, based on the NOAA JEDI framework, for both the operaAonal WAM-IPE model and the NCAR Whole Atmosphere Community Climate Model – Extended (WACCM-X) research model. SWORD research will include advanced physics- informed machine learning research to enhance computational efficiency as well as cloud-based model development and deployment systems to accelerate the transition to operations at NOAA. SWORD consists of research teams from the University of Colorado(CU) Boulder, the University of Michigan (UMich) Ann Arbor, NCAR's High AlAtudeObservatory, the University of Alaska, and the University of Iowa, in partnership withAmazon Web Services, SpaceX, LeoLabs, GeoOpAcs, and Muon Space. In addition to close coordinaAon with NOAA/SWPC through the NOAA Technical TransiAon RepresentaAve (TTR), SWORD will leverage international partnerships with the UK Met Office Space Weather OperaAons Center and the South African Space Agency Space Weather ForecasAng Office to expand the reach of NASA space weather research. OpportuniAes for addiAonal internaAonal partnerships are acAvely encouraged. SWORD public outreach and educaAonal development efforts will be coordinated through the University of Alaska Space Weather UnderGround (SWUG) program.

Highlights of Space Weather Tools and Resources at the Community Coordinated Modeling Center .

Zheng, Yihua [1] plus the CCMC team
[1]NASA Goddard Space Flight Center, Space Weather Laboratory, Greenbelt

In this presentation, we showcase a diverse array of tools and resources offered by the Community Coordinated Modeling Center (CCMC) to advance space weather research and support space weather services. Highlights include the Run-on-Request (RoR) and continuous run simulation services, the multi-purpose integrated Space Weather Analysis (iSWA) system (has been used for space weather monitoring, anomaly resolution, and education), space weather event database DONKI, the validation tool called CAMEL, and various scoreboard activities serving as model validation efforts before a space weather event/condition occurs (this type of pre-event validation enhances the accuracy and credibility of space weather predictions from the community). In addition, CCMC's is an active participant providing strong support for NASA's Heliophysics Big Year activities. Above all, our team welcomes collaborations in the broad range of áreas. Through this presentation, we aim to inspire engagement and collaboration among latinoamerican scientific communities and CCMC.

Argentine Antarctic Space Weather Observatory: AASWO.

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A new space weather laboratory was inaugurated in February/2019 at the Argentinean Antarctic Marambio base. This laboratory has its own building, it was constructed and is maintained by LAMP ('Laboratorio Argentino de Meteorología del esPacio', Argentine Space Weather Laboratory). Different space weather instruments are in operation since 2019, including a cosmic rays detector, magnetometers, a meteorological station, among others. The laboratory is able to withstand extreme weather conditions (-60 Celsius and winds of more than 200 km/h). Its infrastructure is designed for having power with redundancy by gel batteries and built with materials resistant to Antarctic conditions, and it makes possible GPS time stamp for the recorded data, thermal control for the interior of the building (stable in the range 20-22 Celsius), data acquisition in real time (5 minutes from Antarctic to the servers of LAMP located in the south American continent). Data from these instruments are processed and offered by LAMP as operative space weather products in its web-portal. Additionally, a new LAMP laboratory is in preparation to be installed in another Argentinean base, inside the polar circle, where more space weather instruments are planned to be installed. These laboratories make up the Argentinean Antarctic Space Weather Observatory (AASWO), which has major capabilities and will permit the expansion of space weather instrument networks in Argentina and Latin America.
Antarctica is a prime location for space sciences observations and given that there is a clear gap in monitoring and scientific instrument coverage in this region, the southernmost in the world, AASWO will allow us to significantly enhance space weather capabilities in our society.
An AASWO description will be presented, focusing on the Antarctic laboratory in Marambio (in operations from 2019) and the new laboratory in construction, planned to be installed during this summer campaign.