GRAPE on line workshop, 1-3 July 2020

REPORT

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In light of the cancellation of the SCAR Open Science Conference 2020 due to the COVID-19 pandemic, an **online workshop** has been organized on topics related to the SCAR Expert Group **GRAPE** (www.grape.scar.org/) and to the new Proposal Planning Group (PPG) RESOURCE "Radio Sciences Research on AntarCtic AtmosphEre". The workshop has been taken place on **1-3 July 2020, 13:00-15:00 GMT each day, via Google Meet.** The workshop registration was free of charge. The workshop received about **100 registrations. On the average about 70 colleagues from all over the world participated** to the workshop along the three days, many of them had the possibility to interact actively by chat and by microphone. Several **Early Career Researchers/Students followed the workshop** as well. Fortunately, there have been few problems using Google Meet and all the presentations have been possible. We realized, above all on the first day, that more time is necessary between two presentations for technical problems.

The workshop program (http://www.grape.scar.org/index.php/conferences/on-line-workshop-2) included an **Opening Plenary Session** during which participants informed about upcoming polar campaigns in relation to the worldwide difficulties due to COVID-19 pandemic. Unfortunately, most of the planned Antarctic campaigns in the summer 2020-2021 will be stopped and hopefully postponed to 2021-2022. **New contributions on polar observational infrastructures from Finland, Norway, Turkey**, have been presented and welcomed from the GRAPE community. **Presentations by three invited Early Career Researchers/Students** closed the Opening Plenary Session. **Shreedevi P. R.,** from Beihang University, Beijing-China, presented the response of the high-mid latitude ionosphere during two geomagnetic storms in June 2015 driven respectively by Coronal Mass Ejection (CME) and Co-Rotating Interaction Region (CIR), using Total Electron Content (TEC) measurements derived from Global Positioning System (GPS). The role of storm time electric fields and neutral winds causing the ionospheric storm effects captured on TEC during both the storms was presented in detail. **Tsige Atilaw,** from Rhodes University, Grahamstown, South Africa & SANSA Space Science, Hermanus, South Africa, presented a study on the characteristics of Traveling Ionospheric Disturbances (TIDs) observed from the SANAE and Halley radars over Antarctica. Most TID events were observed at similar time from both radars, i.e., post-midnight, during geomagnetically quiet time. The frequency of the dominant wave of the TIDs were evaluated by using cross-spectral analysis of the backscatter power data from different locations in the radar field of view. **Emanuele Pica**, from Istituto Nazionale di Geofisica e Vulcanolgia, Rome, Italy, presented the SWIT (Space Weather Information Technology) infrastructure that coupled with the eSWua (electronic Space Weather upper atmosphere) web-platform provide Findable, Accessible, Interoperable, Re-usable (FAIR) ionospheric data in real time from the INGV network in polar region. In addition, the SWIT-eSWua system ensures the access to operational products related to the nowcasting and forecasting of different ionospheric parameters.

The second day, during the three parallel **Sessions**, invited and contributing presentations within GRAPE topics **highlighted current gaps in data/knowledge, next steps beyond the state of the art, and potential of international collaborations to facilitate and support the next steps**.

Finally, the third day, the **outcomes from the parallel Sessions** have been presented by the Sessions Conveners and wrapped up in the **Closing Plenary Session**.

The Sessions outcome by Conveners are detailed below.

Session 1 - Short and long-term variations of the neutral atmosphere (including Water Vapour, AGWs, airglow, mesosphere, thermosphere, low-high latitude connections). *Conveners: José Valentin Bageston (INPE, BR) & Monia Negusini (INAF, IT).*

The number of Session 1 participants was around 20 (reaching 22 at some moments).

1.1) Mesosphere/Thermosphere & Ionosphere

The first invited talk was done by **Tracy Moffat-Griffin** (BAS, UK), bringing the topic of Gravity Waves in Antarctica, defining this type of phenomena, explaining its importance, and then presenting the ANGWIN scientific group, their goal, and the mains results based on examples of observations and modelling studies. **José V. Bageston** (INPE, BR) focused on the main instrumentation used at Comandante Ferraz Station for mesospheric and lower thermosphere studies: all-sky airglow imager, camera to capture noctilucent clouds (and gravity waves), and a meteor radar. Results have been shown on Travelling Ionospheric Disturbances, Auroral Arc observed in the upper thermosphere/ionosphere, gravity waves, and an example of recent result (winds) from the Ferraz meteor radar. **Lourivaldo Lima** (State University of Paraíba-UEPB, BR) presented interesting results on planetary waves observed over Ferraz station, by using meteor radar winds, and also some aspects of non-linear interaction between tides (mainly the semi-diurnal tide) and planetary waves. **Edith L. Macotela** (University of Oulu, Finland) showed periodic and sporadic perturbations of long periodicity in the northern hemisphere (Finland) by using the VLF (Very Low Frequency) data, and concluded that atmospheric parameters (e.g. Ne of the sporadic e-layer and NO between 80 and 90 km), appear to modulate the sensitivity of the daytime VLF perturbations. **Loredana Perrone** (INGV, IT) showed a method to obtain thermospheric parameters (O, O2 and N2), exospheric temperature (Tex), vertical plasma drift W, and total solar EUV flux from ionosonde observations, by using a physical model of the F region and mathematical techniques that can be applied at polar regions providing ionosonde data.

1.2) Troposphere

Eric Pottiaux (ROB, BE), invited, focused on GNSS-derived water vapour observations at high latitudes. The first part was devoted to long-term Integrated Water Vapour (IWV) variability. Different datasets were used: ground-based (GPS), satellite-based (GOMESCIA), and NWP model (ERA-Interim) data. There is an overall agreement between datasets in both Arctic (better) and Antarctic (worst) regions. Normalized linear trends were presented: the highest moistening over Antarctica was found, but a closer agreement between mean moistening values of different techniques was found in the Arctic. The Antarctic moistening seems driven by surface warming, while the Arctic IWV variability can be explained by a combination of Surface Temperature, Tropopause pressure, precipitation, and the North Atlantic Oscillation. The second part of the talk was on the Operational GNSS Processing as a contribution to weather models. GNSS data was analysed providing hourly-updated monitoring of the water vapour in the Arctic and Antarctic zones, and these products are used for data assimilation in global NWP models (via E-GVAP). Higher quality products can be made available upon request for specific studies in the Arctic and Antarctic zones. **Noelia Santos** (Universidad de Buenos Aires, AR) focused on how atmospheric conditions affect the cosmic ray observations from the Marambio LAGO site. Due to the geomagnetic field, lowest-energy cosmic rays reach the Antarctic atmosphere and can carry information about the Heliosphere and possible transient events. A cosmic ray detector was installed in the Argentinian Antarctic base in 2019, to measure the flux of secondary cosmic rays. By analysing the long-term raw data, correlation with atmospheric parameters has been found and effects removed. A seasonal modulation was found in the flux. Data is available in real-time for Space Weather aims. **Suchithra Sundaram**, an independent researcher, presented studies of the sea ice variability at high latitudes as contribution to the climate change. Changes in ocean/atmosphere/cryosphere parameters affect the global climate and can be explained through teleconnection mechanisms. An analysis of circulation and precipitation data has been carried out for the

Indian Ocean and Southern Ocean region to understand their impact on the Antarctic sea ice and preliminary results have been shown. A teleconnection is proposed between Indian summer monsoon – Indian ocean subtropical high - Antarctic precipitation, and its impact on sea ice over the Indian Ocean Sector of the Antarctic is proposed.

During the closing discussion, some aspects of the talks with the speakers were deepened. Possible collaborative works were discussed, and there are possibilities of increasing raw data and techniques to retrieve IWV in polar regions putting together groups and trying to involve other experts to join in a common effort (Eric Pottiaux and Monia Negusini); there are possibilities of integrating water vapour measurements in the troposphere (Eric Pottiaux) with tropospheric gravity waves sources and the observed waves in the mesosphere (José V. Bageston and Tracy Moffatt-Griffin) since the occurrence of deep clouds, (inferred by integrated water vapour) are known as potential wave sources via convective processes. Also, joint studies between the upper mesosphere (José V. Bageston) and the lower thermosphere/ionosphere (Edith L. Macotela) are possible by using VLF data to identify oscillations associated with gravity waves in the D ionosphere region.

Session 2 - Short and long-term variations of the ionosphere and plasmasphere (including multi-instruments and modelling). *Conveners: Nicolas Bergeot (ROB, BE) & Emilia Correia(INPE,BR)*

The number of Session 2 participants was around 20 (reaching 24 at some moments).

2.1) Plasmasphere

An invited talk was given by **János Lichtenberger,** from the Eötvös University (Hungary), on the different structures (small and large in the plasmasphere) as seen by Arase satellite and ground VLF network. The main conclusions are that the plasmasphere is not a smooth region as the models suggest and that plasmasphere contains both large scale (e.g. plums, shoulders, notches) and small-scale structures (Corotating Plasmaspheric Irregularities, density cavities/Inner trough), not only at the plasmapause. **Fabien Darrouzet** (Royal Belgian Institute for Space Aeronomy, BE) showed that the plasmasphere electron density can be studied in a bi-polar approach by using ground VLF network and Cluster satellite data. Also, 3D numerical models are useful tools to provide average values of the plasmasphere density. However, more data needs to be interpreted using the multi-instrumental approach. **Romain Maggiolo** (Royal Belgian Institute for Space Aeronomie, BE) showed the influence of the planetary magnetic field on the ion escape from terrestrial planets. Romain, made a comparison of the ion escape from Venus, Earth and Mars, to investigate the importance or not of a magnetise body on ion escape as determine by satellite missions. One of the main conclusions is that he estimated similar loss rate for magnetized and un-magnetized planets. One open question is: do these ions come back into the system, and where do they come from? The paper by C.P. Anil Kumar, was withdrawn.

2.2) Ionosphere

Adriana Gulisano (invited) from the Instituto Antártico Argentino (Argentina), presented the different activities done in Antarctica concerning ionospheric parameters (foF2, TEC, …). She introduced the new TEC map products based on multi-GNSS constellations (GPS, GLONASS, Galileo, Beidou), which cover the entire South America sector, south Atlantic, South West Africa, and the Antarctica peninsula (http://wilkilen.fcaglp.unlp.edu.ar/ion/latest.png). She also highlighted the data gaps in the southern hemisphere in general. **Bindu Mangla** (Manav Rachna International University, India) focused on the daily and seasonal variations of ions at the F2 layer (O+, O2+ ….) during the 1995 solar minimum. This study has been done using the SROSS C2 satellite data, launched in 1994. The data are available for the period 1995-2001. **Christian Gutiérrez** (UBA-FCEN-DCAO, AR) showed the correlations in between Interplanetary Coronal Mass Ejections (ICME) inducing solar wind parameters changes monitored by ACE satellite (|B|,

density, Vx ….) and the galactic cosmic rays intensity as measured by neutron monitors from ground stations. He showed that faster ICMEs cause larger decreases in the flux of galactic cosmic rays (up to 20%) than slower ICMEs (2%). Finally, **Haixia Lyu** (UPC-IonSAT, ES) presented the use of UQRG global TEC maps to study the features of vertical electron content distribution over polar regions and to characterize the climatology of the representative features. She showed different features obtained from these global products such as the Tongue of Ionization, the trough, flux transfer events, theta-aurora, ionospheric convection patterns and storm enhanced density.

The closing discussion focused on the need to investigate the connection between the ionosphere and plasmasphere. Cluster mission is a useful tool for the interhemispheric comparison of the plasmasphere. Generally speaking, there is still the lack of ground based stations: e.g. to complement the VLF network new deployments in Finland and Alaska are planned. Same conclusion can be argued for the digisondes and GNSS IGS stations. The impact of the geomagnetic storms on plasmaphere need to be deeply investigated as well the contribution of the plasmasphere to ions loss. Comparisons between the occurrence frequency of plasmaspheric and ionospheric plumes, shoulders, notches, should be investigated. All available satellites data for ionospheric purposes need to be take into account, e.g. the SROSS-C2 satellite (India) data from 1995 to 2001, and data from COSMIC- GRACE – CHAMP satellites missions. F. Darrouzet and A. Gulisano could act as leaders for plasmapshere and ionosphere joint studies.

Session 3 - Space weather impact on radio measurements at high latitudes (including multi-instrument data analysis). *Conveners: Pierre Cilliers (SANSA, ZA) & Luca Spogli (INGV, IT)*

The number of Session 3 participants was up to 33.

The session started with the invited paper by **Paul Prikryl** from Natural Resources, Canada. Paul demonstrated the benefit of using an array of instruments and models to better understand the dynamics of the high latitude ionospheric during auroral substorms. Using data from the Canadian High Arctic Ionospheric Network (CHAIN) and real-time GPS receivers of RT-IGS network that are monitored by the Canadian Geodetic Survey, he showed that large GPS signal phase variations map to regions of strong westward electrojet and to the poleward edge of the eastward electrojet. He also introduced the use of the spherical elementary currents systems to investigate the variations of the ionospheric currents and the corresponding changes in the formation of ionospheric irregularities. **Wojciech Miloch** (Department of Physics, University of Oslo, Norway) was invited to present results from recent coordinated efforts in Antarctica and in the Arctic for the studies of dynamics of plasma irregularities and related GNSS scintillations. Miloch showed the synergism of combining ground-based observations with the in-situ measurements made by sounding rockets and satellite observations by the polar orbiting Swarm satellites. The key outcome was that this approach gives a comprehensive understanding of processes in the polar ionosphere and this is an important step in developing physics-based models for plasma irregularities. The invited talk by **P. T (Jay) Jayachandran** (Physics Department, University of New Brunswick, Canada) challenged the notion that the scintillation measurements (S4 and $\sigma\phi$ and spectral slope p), now being routinely used for ionospheric parameter estimation (IPE), can distinguish between different types of polar ionospheric structures that give rise to ionospheric scintillation, e.g. Sporadic E, Arcs, and Patches. Using 100 Hz sampling rate data from CHAIN GPS receivers and other instruments (ionosondes, incoherent scatter radars and all-sky imagers), he demonstrated that the spectral slope distribution of the raw amplitude and phase of GPS measurements is similar for these different structures with an average spectral index of -2. The key outcome of the work he presented is the need for multi-instrument observations to understand the underlying physical mechanisms that produce scintillation. **Iurii Cherniak** (COSMIC Program Office, UCAR, USA) showed the usefulness of data from a dense array of ground-based GNSS receivers combined with LEO GPS (Occultation) observations, for measuring the amplitude and phase of GNSS signals to investigate the ionospheric responses to Space Weather drivers. Space Weather driven auroral and

equatorial irregularities caused strong amplitude and phase scintillations of GPS/GNSS signals, which seriously affected the performance of precise positioning and navigation-based services on a global scale like EGNOS and WAAS. The key outcome of their work is proof of the benefit of GNSS being a preferred tool to address concerns about the operational performance of navigation systems in polar regions. **Stefan Lotz** (SANSA, ZA) showed that, combining data from the SuperDARN, magnetometers, riometers, VLF stations, ionospheric scintillation receivers and GNSS receivers deployed at SANAE-IV, Gough Island, Marion Island and on the SA Agulhas II polar research ship, provide an excellent opportunity for synergic observations of Space Weather impacts on the polar ionosphere. Integration of the Space Weather data from SANAE-IV with that of other stations in the Queen Maud Land region will enhance our capability to provide Space Weather products related to air traffic navigation to and in Antarctica. Using VLF and scintillation observations on 29 May 2020 from some of the South African high latitude observatories, Stefan demonstrated the impact of the first M-class flare of solar cycle 25 and the need for multi-instrument observations to better understand the spatial distribution of the impact of the storm. **Olga Maltseva** (Research Institute for Physics, Southern Federal University, Russia), by using GNSS data from five Antarctic stations, presented disturbances of the diurnal TEC during the geomagnetic storm period 7-17 March 2012 and the dependence of these disturbances on solar parameters and geomagnetic indices. The almost complete identity of the correlation coefficients of TEC with the indices AE, PC, and Kp provided a sound basis for the prediction of such disturbances from predicted values of either of these parameters. She also demonstrated how data gaps in foF2 can be filled using TEC observations, thus illustrating the synergism of multi-instrument observations in the Antarctic. **Vanina Lanabere** (Universidad de Buenos Aires, Dept Ciencias de la Atmósfera y los Océanos, AR) gave an overview of the Space Weather activities of LAMP *(Argentinian Space Weather Laboratory)* since 2014, including the designation of LAMP as the Argentina Regional Space Weather Warning Centre of the International Space Environment Service. LAMP deployed several instruments including a solar telescope, ionosondes, magnetometers and an all-sky imager in Southern Argentina, and manages a particle detector at the Marambio base on the Antarctic Peninsula and a magnetometer at the year-round Belgrano II base on the Confín Coast, Coats Land in Western Antarctica. Members of LAMP are actively involved in Space Weather research. LAMP has a number of operational Space Weather products, which it is willing to share with other research institutions.

The concluding discussion involved the speakers and several of the participants, expressing enthusiastic support for collaboration on a research paper, which would demonstrate the application of diverse observations to the study of the polar ionosphere. The proposed topic of the paper is an analysis of the 25-26 August 2018 geomagnetic storm, through an integration of the bi-polar ionospheric response, using data from ground-based instruments (including SuperDARN & VLF) and space-borne instruments (Swarm, DMSP, Cluster, Van Allen Probes) of which the data is readily available and for which the participants have demonstrated substantial expertise. The paper will combine spectral (and multiscale) analysis, ROTI, scintillation, DPR analysis, SECS analysis and focus on the Impact of ionospheric disturbances on navigation.