



Commission G Triennial Report 2021-2023

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Chair Commission G

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1. Chair's Comments

Commission G deals with the study of the ionosphere to provide the broad understanding necessary to support space and ground-based radio systems. Specifically, the Commission focuses on: 1) the local, regional, global morphology and modelling of the ionosphere, 2) studies on ionospheric space-time variations and the impacts of space weather on systems, 3) the development of tools and networks to measure ionospheric properties and trends, 4) the theory and practice of radio propagation in and through the ionosphere, 5) the application of ionospheric information to radio systems. The Commission G is historically very active as reflected by the extensive participation in the URSI flagship meetings and working groups. Commission G demonstrated an increasing training capacity (a specific working group is dedicated to this activity) and the consequent capacity to attract young students and early career scientists on its topics. New scientific areas, also driven by the interest of international organizations outside URSI, are emerging/growing such as the Machine Learning approaches in the ionosphere and radio-propagation studies, the monitoring and modelling of the ionosphere at high latitudes (thanks to the renewed interest of radio sciences within SCAR - Scientific Committee on Antarctic Research), and the extra-terrestrial explorations for on-going and future missions.

To the success of Commission G over the last 2 years generously contributed Commission Vice Chair, ECRs, working group chairs and session conveners. I sincerely thank Dr. Keith Groves, Commission G Vice Chair, and the three Early Commission Representatives: Dr. Sean Elvidge, that will finish this year his action as ECR, Dr. Bruce Fritz and Dr. Dario Sabbagh, for their support in all the actions related to the Commission G. I would like to thank also the past Commission G Chair Dr. Iwona Stanislawska (2014-2017), that helped me above all after the unexpected, sadden, and painful news that Prof. Patricia Doherty, former Chair of Commission G 2017-2021, passed away on 14 July 2022. I thank Pat very much for what I have learned under her guidance since 2017 and that I have tried to apply since AT-RASC 2018. Finally, my acknowledgement to the working group and task force chairs for keeping things going in various activities, to the Commission G session conveners for all the URSI meetings



and to the Technical Advisory Group for their feedback in planning the scientific sessions and the other activities of the Commission.

2. In Memoriam

The following friends and colleagues from the URSI Commission G community passed away since our last commission report in 2021:

- Ljiljana R. Cander, passed away in 2022. Engineer, she spent most of her time working in RAL's Radio Communications Research Unit (UK), where she led a wide range of studies related to the impact of space weather on communications systems. She was a member of the Ionospheric Expert Team at ESA and European industry to understand the critical role of the ionosphere in determining the performance of EGNOS.
- Herbert C. Carlson, passed away in 2023. He served as Director of the Ionospheric Research Department at the Arecibo Ionospheric Observatory, as a Program Director at the National Science Foundation, and as Deputy Division Director and Chief Scientist for the Air Force Air Force Research Laboratory. While at the NSF, Carlson created a new national program office, the Upper Atmospheric Research Facilities, as well as several national and international programs while at the Air Force Geophysics Laboratory.
- Patricia H. Doherty, passed away in 2022. Physicist, she was director and senior research scientist at Boston College's Institute for Scientific Research and an internationally recognized leader in space weather and its impact on global navigation systems. Specific research initiatives during her career included radio wave propagation, focusing on ionospheric effects in satellite-based navigation, including Satellite-Based Augmentation Systems and the Federal Aviation Administration's Wide Area Augmentation System. At the time of her death, she was vice president of the International Union of Radio Science (URSI) and former chair of URSI's Commission G, Ionospheric Radio and Propagation.
- W. Ross Stone, passed away in 2023. He held several leadership positions with the IEEE Technical Activities Board for more than four decades and received the 2023 IEEE Richard M. Emberson Award "for sustained contributions to and impactful leadership in the IEEE Technical Activities publication enterprise." In addition to his contributions to IEEE, Stone served as editor for more than 20 years of The Radio Science Bulletin. He was a Fellow of the Chinese Institute of Electronics, the Electromagnetics Academy, and URSI. For his activities within URSI he served all the URSI Commissions.

We honour all our departed colleagues for their scientific excellence, their commitment to ionospheric and radio propagation research, and to Commission G.

3. Conferences

AP-AT RASC 2022: The third URSI Atlantic Radio Science Meeting (AT-RASC) was coupled with the Asia Pacific Radio Science Meeting (AP-RASC) due to the COVID 19 Pandemic that impacted the GASS2020 (shifted to 2021) and the consequent impossibility to organize two



conferences (AT and AP) in 2022 with few months of distance each other. The AT-AP RASC was held on 29 May to 3 June 2022 in Gran Canaria, Spain, in a hybrid format. Commission G hosted 12 Sessions with 121 presentations in total and supported four other sessions led by other commissions. Among the G sessions, particular emphasis was given to the Special Session on Ionospheric effects of the Hunga Tonga volcanic eruption of 15 Jan 2022, organized at very last moment just after the event, thanks to the flexibility of the AT-AP RASC LOC. A session was organized focusing on the Machine Learning, and Prof Ivan Galkin from Commission G, INAG Working Group, gave a lecture in the Plenary Session on this topic. A total of 14 Young Scientist papers were submitted to Commission G, eight of them received a Young Scientist award.

The list of AP-AT RASC sessions included:

- G01 GNSS Radio Occultation: Measurements, data assimilation & models
- G02 Novel radio instruments & technology for Space Weather models, validation, and testing
- G03 Ionospheric Space Weather & Impacts on Technological Systems
- G04 Advances on ionospheric perturbation indices & scales
- G05 Machine Learning methods for ionospheric modelling: state of the art & future actions

- G06 Advances in Incoherent Scatter Radars & Global Open Science Cloud services
- G07 (Ionospheric) Space Weather operational services
- G08 Modern ionosonde research & weather operations
- G09 Limits of predictability of ionosphere behaviour
- G10 Open Session
- GBC1 HF Radars for Science and Surveillance
- SG Ionospheric effects of the Hunga Tonga volcanic eruption of 15 Jan 2022 (invited)

- JG Mutual Benefit between radio astronomy and ionospheric science
- HGE Meet the HGE experts.
- EFGH Natural Electromagnetic Noise & Radio Sensing Applications in Terrestrial & Planetary Environment
- HEG Atmospheric, Ionospheric, Magnetospheric & High Energy Effects of Lightning Discharges

URSI GASS 2023: The 35th URSI General Assembly and Scientific Symposium will be held on 19 to 26 August 2023 in Sapporo, Japan. For the upcoming GASS, Commission G was very active with the organization of 20 sessions, the contribution to other four sessions led by other commissions, a special session within WIRS devoted to Patricia Doherty, and the cooperation for the FCEGH Workshop on Radio Science and Engineering of Disaster Risk Reduction and Management.

This resulted in 196 oral presentations, 85 poster presentations and 10 online presentations. A total of 31 Young Scientist papers were submitted to Commission G, a success demonstrating the activities carried out by the dedicated working group on capacity building



and training is working well to the scope of attracting new generation of scientists on the Commission G topics. Fifteen Young Scientists have been awarded; they will be listed in the URSI website at https://www.ursi.org/young_scientists.php.

I would take this occasion to thank very much Dieter Bilitza that will give the Commission G tutorial titled: The International Reference Ionosphere - A Commission G Success Story.

This list of GASS2023 sessions includes:

G01: GNSS Radio Occultation and zenith data from Low Earth Orbit: advancements on measurements, data assimilation and models

G02: Novel radio instruments and techniques for Space Weather model validation and testing

G03: Ionospheric Space Weather and Impacts on Technological Systems

G04: International Reference Ionosphere: Improvement, Validation and Usage

G05: Advances in Irregularities and Scintillation Studies

G06: Advances in Machine Learning methods for ionospheric modelling

G07: Science with Modern Ionosondes and Associated Instrumentation and Models

G08: New results and contemporary developments in incoherent scatter radar

G09: HF Radars for Science and Surveillance

G10: International Beacon Satellite Studies

G11: Limits of predictability of ionosphere variability: search for its chaotic and deterministic components

G12: Ionosphere monitoring & modelling review

G13: Upper atmospheres and ionospheres at planetary bodies

G14: The high-latitude ionosphere

G15: Techniques, Methods, and Issues for Real Time Ionospheric Modelling

G16: The crucial role of integrated research infrastructures for monitoring and modelling the upper atmosphere.

G17: Open Session

GH1: Meteors, collisional EMPs, and other Highly Transient Space Plasma Events

GH2: Plasma Instabilities in the Ionosphere

GHE: Seismo Electromagnetics (Lithosphere-Atmosphere-Ionosphere Coupling)

4. Working Groups and Task Force Reports

WG1: Ionosonde Network Advisory Group (INAG)

Chair: I.A. Galkin (USA); Vice-Chairs: J.B. Habarulema (RSA), Baiqi Ning (China); INAG Bulletin Editor: K. Wang (Australia). Membership registrations: 585.

Celebrations of the 90th anniversary of the regular observations of the ionosphere started on January 11, 1931 at Slough observatory in the UK resulted in ionogram contributions from 68 ionosonde observatories to the commemorative page at INAG hosting server, <https://www.sws.bom.gov.au/IPSHosted/INAG/web-79/90yrAnnivIonograms/index.html>.

1.1. Ionosonde Data Availability and Products

Ionosonde observatories of GIRO (Global Ionosphere Radio Observatory, <https://ggeo.uml.edu>) continued sharing their measurement data with the central repositories at the World Data Centers in USA, Russian Federation, and Japan, as well as the Lowell GIRO Data Center (LGDC). New data products are being developed to address emerging applications that rely of high frequency (HF) domain of communications and demand ionospheric weather monitoring:

- a. Starting September 2021, the GIRO network provides near-real-time maps of MUF(3000) - the highest frequency that can be used for HF transmission via the ionosphere between two points 3000 km apart - to an international consortium of space weather agencies operating a prototype alert system for civil aviation (Figure 1).

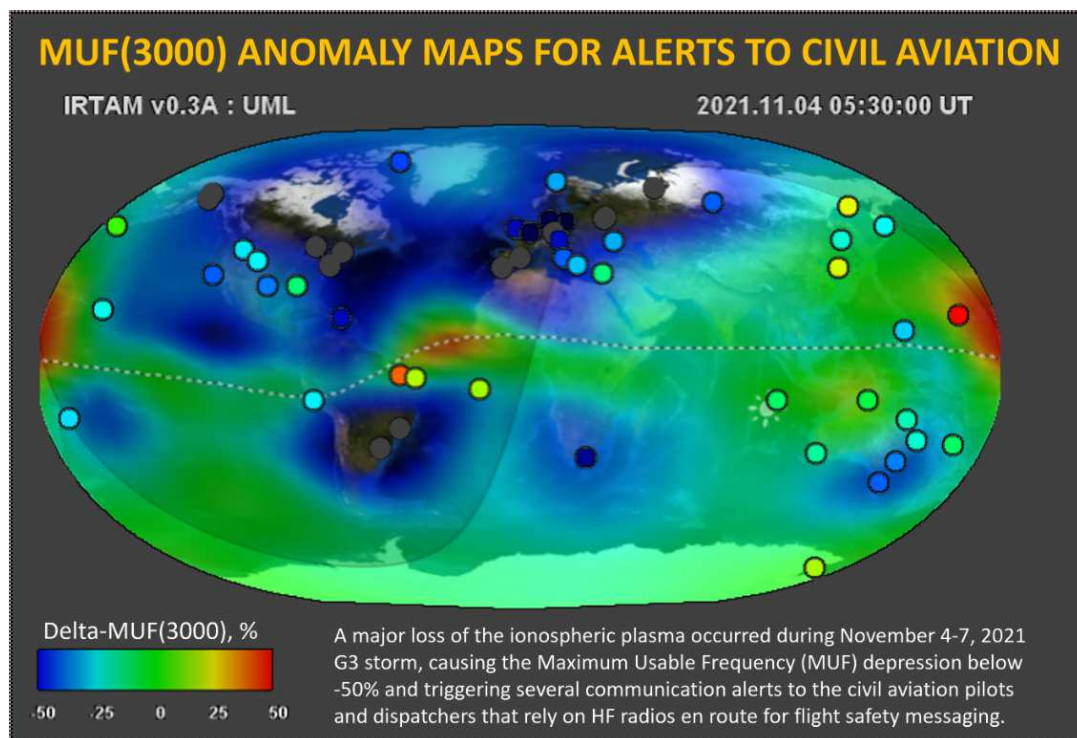


Figure 1. Global near-real-time reporting of MUF(3000) anomaly maps are now produced using inputs from GIRO ionosondes (color dots) for deliveries to the EDC data server at NICT, Japan.

- b. Starting December 2021, new online ionospheric weather service is provided at LGDC, publishing the latest 28-hour charts of key ionospheric characteristics, available at

<https://giro.uml.edu/rix/gambit-local-nowcast/> (Figure 2). New service has become a popular tool for Ham radio community,

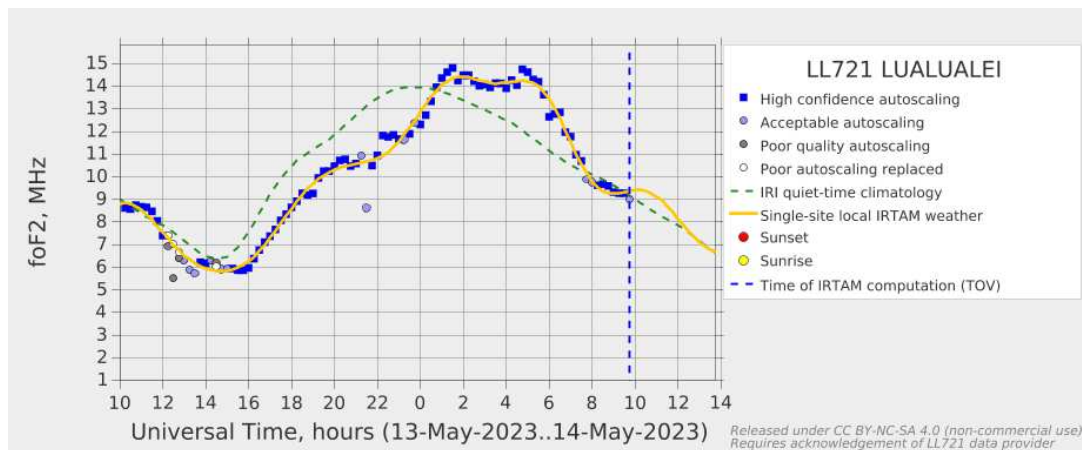
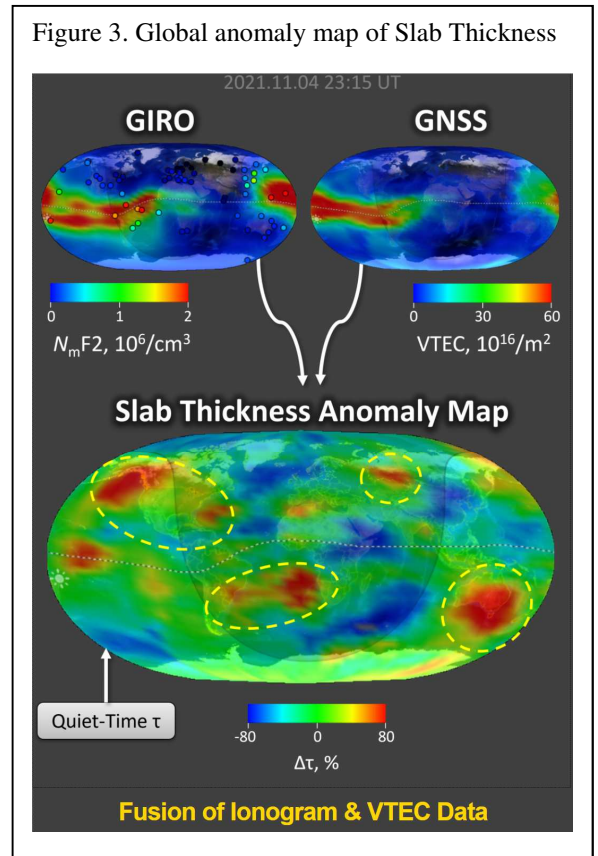


Figure 2: Local 28-hour Ionospheric Weather Chart published by LGDC

c. Arrangements are completed to operate near-real-time service that fuses data products from GIRO and International GNSS Service (GIS) to produce live global maps of the effective ionospheric slab thickness and its deviation from the expected quiet-time behavior (Figure 3). Current latency in GNSS Global Ionospheric Maps (GIMs) is about 1 hour, to be reduced to 15 minutes. At the time of the report, the new capability is available only in GAMBIT Explorer software, <https://giro.uml.edu/GAMBIT>, and not yet published online for access over the Web.

- Production of the anomaly maps of slab thickness involve several services in the USA, Poland, Spain, and China that allow rapid access to GNSS vertical total electron content (VTEC), peak density N_mF_2 data from the IRI-based Real-Time Assimilative Model (IRTAM), and their quiet-time counterparts needed to compute the weather-minus-climate deviations Δ .





- The bottom panel of Figure 3 shows a fused-data $\Delta\tau$ map, a weather-minus-climate anomaly metric computed by subtracting the quiet-time τ reference that is built from the climatology map of the peak density NmF2 from IRI and the average VTEC map within a 30-day sliding-window.
- Slab thickness anomalies demonstrate high sensitivity to storm time disturbances.

1.2. New ionosonde observatories and GIRO membership

In 2021-2023, new installations of ionosondes were made in Al Dhafra AF Base (UAE), Chung-Li (Taiwan), Thule (Greenland), and Tromso (Norway).

Unfortunately, geopolitical changes in 2021-2023 resulted in the significant loss of GIRO capability as ionosonde observatories in Russia (15 locations) and China (5 locations) stopped real-time data streaming to WDCs and LGDC.

1.3. Publication activities

High levels of publications involving ionosonde measurements continues to be observed, currently at about 700 articles per year and growing.

IRI Task Force (URSI/COSPAR Working Group)

Prepared by Dieter Bilitza (USA).

IRI Chair - Vladimir Truhlik (Czech Republic), COSPAR Vice-Chair- Andrezj Krankowski (Poland), URSI Vice-Chair-Ivan Galkin (USA)

The URSI/COSPAR IRI Working Group organized a session during the COSPAR General Assembly in Athens, Greece in July 2022 on the topic of 'Real-time and retrospective ionosphere modelling with in-situ and GNSS satellite data'. The 1 ½ day session was well attended and presented several different approaches to improving the quality of real-time forecasts with the help of data assimilation into the background IRI model. The primary data sources were GNSS TEC observations, ionosonde recordings, as well as COSMIC radio occultation data. The IRI Working Group held a business meeting at the end of the conference week and decided on several organizational changes and model improvements. The group thanked David Altadill for his 8 years (the maximum allowed due to COSPAR rules) of service as Working Group Chair and elected Vladimir Truhlik as new IRI Chair. Andrezj Krankowski was re-elected as COSPAR Vice-Chair and Ivan Galkin as URSI Vice-Chair. The IRI Working Group has two Vice-Chairs because it is an Inter-Union Working Group. IRI-related sessions have been proposed for the 2023 URSI General Assembly in Sapporo, Japan and for the 2024 COSPAR Scientific Assembly in Busan, South Korea. Both sessions have been accepted and organizational preparations are underway.



The IRI Working Group has successfully applied for an IRI-related COSPAR Capacity Building Workshop. The workshop entitled 'Improved Real-time Ionospheric Predictions with Data from Space-borne Sensors and GNSS' will be held in Daejeon, South Korea on May 6 - 19, 2023.

The current roster of the working group includes 66 members from 29 countries providing the team with access to a wide range of data and model inputs.

Publications:

Bilitza D, B. Reinisch (eds.), International Reference Ionosphere – Progress and New Inputs, Advances in Space Research, Volume 68, Issue 5, pp. 2057-2256, 1 Sep 2021.

Truhlík, Vladimír, Dieter Bilitza, Dmytro Kotov, Maryna Shulha, and Ludmila Tříšková. 2021. "A Global Empirical Model of the Ion Temperature in the Ionosphere for the International Reference Ionosphere" Atmosphere 12, no. 8: 1081. <https://doi.org/10.3390/atmos12081081>

Bilitza, D., Pezzopane, M., Truhlik, V., Altadill, D., Reinisch, B. W., & Pignalberi, A. (2022). The International Reference Ionosphere model: A review and description of an ionospheric benchmark. *Reviews of Geophysics*, 60, e2022RG000792. <https://doi.org/10.1029/2022RG000792>

WG2: Studies of the Ionosphere Using Beacon Satellites

Chair: P. Doherty (USA); Vice-Chairs: B. Nava (Italy), A. Krankowski (Poland)

The Beacon Satellite Studies Group is interdisciplinary, servicing science, research, applications, and engineering interests. The prime objective is to study the ionosphere using beacon satellite signals. This working group continued to be active in its traditional fields, namely compilation, exchange and dissemination of information, communication and exchange of experience of various organizations of relevance (augmentation systems for GPS based satellite navigation, international and national advisory bodies, the United Nations Office for Outer Space Affairs (UNOOSA), the Institute of Navigation, the NASA International Space Weather Initiative (ISWI) and others), providing advice and collaboration on request. These activities were carried out by correspondence and through attendance at conferences and other meetings including all the URSI Triennium Meetings.

The most notable activities of this study group are the Beacon Satellite Symposia. After a fore runner organized at the Max-Planck Institut fur Aeronomie at Lindau, Germany, in 1970 the series started in 1972 with the first Symposium at Graz, Austria and continued at time intervals between two and four years. To date, there have been 19 symposia held in different countries including Russia, USA, Italy, India, Finland, China, Argentina, the United Kingdom, Poland, Hungary, and Spain. All these events were organized by the Chairs of the Beacon Satellite Studies Group together with a local chair and organizing committee consisting of URSI Commission G members. These meetings provide unique opportunities for ionospheric scientists from all over the world to meet and collaborate on the ionospheric effects on radio propagation and space weather.



Group Photo – Beacon Satellite Symposium 2022, Boston, USA

The most recent Beacon Satellite Symposium (BSS) was held at Boston College, USA on 1-5 August 2022. The symposia are the primary event held triennially by the Beacon Satellite Studies Group of the International Union of Radio Science (URSI) Commission G. This BSS symposium was a great success with many sessions dedicated to the study of space weather phenomena, their characteristics and effects, monitoring the ionosphere and space weather with ground and space-based receivers, radio occultation techniques and measurements, advances in ionospheric modeling and much more. BSS 2022 was held in honor of Patricia Doherty, BSS Chair, who passed away suddenly on July 14th, 2022.

The opening session included welcome remarks by Dr. Keith Groves (Chair of the LOC and URSI Commission G vice-Chair), Bruno Nava and Andrzej Krankowski (co-Chairs of the Beacon Satellite Studies Group). Session descriptions, abstracts and the program can be viewed at the symposium website: <https://www.bc.edu/content/bc-web/research/sites/institute-for-scientific-research/events-conferences/bss2022.html>.

The meeting was held in hybrid format with a total of 151 attendees. Individuals from 16 different countries participated both in-person and on-line, including Brazil, Argentina, Peru, Nigeria, India, Uganda, Canada, United Kingdom, Italy, Germany, Poland, Norway, Taiwan, France, and the USA. An additional eight nations were represented in the on-line component of the meeting: Cote D'Ivoire, South Africa, Ukraine, China, Russia, Cyprus, Greece, and Japan. There were 89 oral presentations and 41 posters presented.

Thanks to the generosity of the sponsors, including Boston College, URSI, SCOSTEP, NSF and ICG, several participants from developing countries received financial support to participate in this prestigious event.



Discussions on the next Beacon Satellite Symposium are now taking place. It will be held in 2025 and possible candidates for the next venue have already been proposed. Additional announcements will be made in due time.

WG3: Incoherent Scatter

Chair: A. J. Kavanagh (UK) [2021 – 2023].

Incoming Chair: Lindsay Goodwin (USA), Incoming Vice Chair: Marco Milla (PERU’)

During the period 2021-2023, Andrew Kavanagh (British Antarctic Survey) acted as the Chair of the URSI Incoherent Scatter Working Group. The usual operating procedure was affected by the pandemic and so a vice chair was not properly identified in this period. During this time the URSI ISWG has carried out its principal task of coordinating the combined World Day operations of all the global incoherent scatter radar facilities around the world. For the 2021-2022 years the same process was employed as described for 2020:

- Call for proposals in the spring – via several mailing lists.
- Distribution of proposals to the radar operators and representatives
- Open invite for the community to review the submitted proposals and offer feedback via email, with an offer of video-link discussion if requested.

The tables below show the World Day allocations for 2022 and 2023. The process for arranging World Day intervals for 2024 is underway at the time of writing.

Some experiments are based on alerts: the start of a sudden stratospheric warming event, or an incoming coronal mass ejection, etc. These World Days will have a specific period within which the alert should happen. The demand for World Days has been quite high, which has required the combining of experiments with similar aims and/or similar operations.

2022

Name	Proposer	Start Date	Duration (days)	Alert period
ISR observations during a campaign of Interhemispheric Coupling Study by Observations and Modeling (ICSOM)*	K. Sato (Department of Earth and Planetary Science, The University of Tokyo)	27 Jan	5	~15 Jan – 15 Feb
2022 Coordinated Observations of Geospace Storm (CONGS-22)**	S. Zhang (MIT Haystack Observatory)	22/3/2022	7	
Global Coverage of High Latitude E-region Winds and Ion Drifts (Winds)	S. Kaeppler (Clemson)	20/6/2022	5	
2022 Coordinated Observations of Geospace Storm (CONGS-22)**	S. Zhang (MIT Haystack Observatory)	21/9/2022	5	

*note 1: Dates are based on past requests and scheduling. 10 days were allocated for a stratwrm alert – without the alert a 5-day run was operated within the period.

**note 2: CONGS-22 was alert based and operated in March, there was no September operation.



2023

Name	Proposer	Start Date	Duration (days)	Alert period
Dynamics, electrodynamics, temperature and electron density in the lower and upper thermosphere and ionosphere during sudden stratospheric warming (SSW)*	L. Goncharenko (MIT Haystack Observatory)	29 th January	7	5/01/2023 to 15/02/2023
Morphology and causative mechanism of Ionospheric Descending Layers (Descending Layers)	S. Dharmalingham (Arecibo Observatory - University of Central Florida)	Merged with SSW due to similar requirements		
Equinox Transition Study (Equinox Transition)	W. Wang (High Altitude Observatory, National Center for Atmospheric Research)	19 th March	7	
2023 Coordinated Observation of Geospace Storm (CONGS-23)	S. Zhang (MIT Haystack Observatory)	Merged with Equinox Transition due to similar requirements		
Morphology and causative mechanism of Ionospheric Descending Layers (Descending Layers)	S. Dharmalingham (Arecibo Observatory - University of Central Florida)	19 th June	5	
Morphology and causative mechanism of Ionospheric Descending Layers (Descending Layers)	S. Dharmalingham (Arecibo Observatory - University of Central Florida)	21 st Sept	5	
2023 Coordinated Observation of Geospace Storm (CONGS-23)	S. Zhang (MIT Haystack Observatory)	Merged with Descending Layers due to similar requirements		

Note 1: SSW operated for 7 days at the end of the alert period. This was merged with Descending Layers due to the similar operational requirements.

Note 2: CONGS-23 and Descending layers were combined since they want similar observations. However, this requires Descending layers to occur in late September rather than October.

WG4- Capacity building and training

Chair C. Cesaroni (Italy), co-Chairs J. Owlendo (Kenya), B. Nava (Italy), Patricia Doherty (USA)

The "Capacity building and training" working group deals with the activities related to the training of students and young scientists, especially from developing countries. The main objectives of the working group are:

- Organize international workshops especially for young scientists from developing countries
- Facilitate visits exchange for young scientists by spreading news about opportunities and by putting in place action for funds raising
- Organize periodical webinar for sharing new research among the commission G community



From the late 2021 to 2023 the following activities have been carried out:

- **MaSAG23-** Mathematics for Signal processing and applications in Geophysics and other fields, Summer School and Conference, Rome, Italy, 15-20 May 2023 (http://people.disim.univaq.it/~antonio.cicone/2023/MaSAG23/MaSAG23_homepage.html). The goal of the Summer School is to bring out the knowledge about non-linear data analysis tools for signal processing to the next generation of researchers. The topics of the courses will include reviews of modern signal processing tools. **The Summer School will be followed by a 1-day Capacity Building workshop** about Radio Sciences techniques for Space Weather. The two-day Conference that will close the event will give to the young researchers the opportunity to meet and listen to talks given by top researchers working both in the development of new tools for signal processing, their mathematical analysis, their applications to modern geophysical and other applied fields problems, as well as to discover new open problems in Geophysics and other fields of research.
- **Webinar “Probing the polar ionosphere in-situ and remotely”**, by Wojciech Miloch (University of Oslo) 14 February 2023, 13:00 UTC. The webinar falls within the activities carried out by Commission G addressed to SCAR. The webinar is also within the initiatives promoted by AGATA (Antarctic Geospace and Atmosphere Research) Scientific Research program Planning Group (<https://www.scar.org/science/agata/home/>). About 70 attendees from different organizations and Countries participated to the webinar. Only technical support.
- **VERSIM**, VLF and ELF Remote Sensing of Ionospheres and Magnetospheres, School and Workshop, 5-11 November 2022, Sodankyla, Finland (<https://www.sgo.fi/Events/VERSIM/#about>). VERSIM is an international group of scientists that are interested in studying the behaviour of the magnetosphere and ionosphere by means of ELF and VLF radio waves, both naturally and artificially generated. Since 2004, VERSIM workshops have been the occasion to present and discuss recent results, new techniques and encourage collaboration within the space physics community. **In this edition, the first VERSIM school has been organized** to allow students and early career scientists to the field to get familiarized with essential VERSIM topics. Only technical support.
- **African Capacity Building Workshop on Space Weather Effects on GNSS**, 3-14 October 2022, ICTP Trieste, Italy (<https://indico.ictp.it/event/9831/>). This capacity building workshop was intended to provide an in-depth view of Space Weather phenomena, including their effects on technological systems. Specific tutorials about GNSS and the exploitation of their signals for ionospheric studies have been given with the aim of enhancing the knowledge and the research capabilities of young scientists, principally from African Countries. It was a hybrid event involving more than 100 students (about 30 student on-site + more than 70 students on line).
- **21ST International Beacon Satellite Symposium**, 1-5 August 2022, Boston College, USA. The workshop and school are described in the WG 2 dedicated to the studies of



the ionosphere using beacon satellites (<https://www.bc.edu/bc-web/research/sites/institute-for-scientific-research/events-conferences/bss2022.html>).

- **2nd Workshop on Space Weather**, in the frame of the 9th Annual IEEE Conference on Wireless for Space & Extreme Environments (Online, October 12-14, 2021) (<https://attend.ieee.org/wisee-2021/program/workshops/>). This workshop aimed at pin-pointing the state-of-the art technologies and initiatives facing the Space Weather threats and its impacts in extreme environments, with a particular focus on space and aviation domains. The workshop focused on technical presentations from different research and application Space Weather communities. The workshop covered two days, with 12 regular contributions and 3 invited talks and panel discussion. Only technical support.

WG GEH: Seismo Electromagnetics (Lithosphere-Atmosphere-Ionosphere Coupling)

Co-chairs: S. Pulinets (Russia), M.Y. Hobara (Japan), H. Rothkaehl (Poland)

During the accounting period (after the report for URSI GASS 2021 in Rome), the members of the Inter-commissions GEH Working group “Seismo-Electromagnetics (Lithosphere-Atmosphere-Ionosphere Coupling) actively participated in many international events (conferences, symposia, workshops)

- JpGU, 3- 6 June 2021, Japan
- IAGA-IASPEI, 21-27 August 2021, Hyderabad India
- European Seismological Commission 37th General Assembly, 19-24 September 2021
- AP-AT-RASC, Gran Canaria, 29 May – 3 June 2022
- 44th COSPAR Scientific Assembly, 16 July – 24 July 2022, Athens Greece
- URSI-JRSM (Japan Radio Science Meeting), 1-2 September 2022
- EMSEV 2022 International Workshop, 22-24 August 2022, Taiwan

New monograph was published where the Seismo-Electromagnetic thematic was presented:

Pulinets S., Ouzounov D., Karelin A., Boyarchuk K. Earthquake Precursors in the Atmosphere and Ionosphere. New Concepts. Springer Nature. 2022. 312 p.
<https://link.springer.com/book/10.1007/978-94-024-2172-9>

The Working group activity was concentrated on the three main subjects:

1. Further development of the physical mechanisms of pre-earthquakes ionospheric/electromagnetic anomalies generation
2. Statistical confirmation of the pre-earthquake ionospheric/electromagnetic anomalies existence
3. Development of the technologies of automatic identification of the pre-earthquake ionospheric//electromagnetic anomalies
- 4.

Results of these activities could be found in the following publications:

- Schekotov, A., M. Hayakawa, and S. M. Potirakis, Does air ionization by radon cause low-frequency earthquake precursor? *Natural Hazards*, 2021. Doi:10.1007/s11069-020-04487-7
- Schekotov, A., D. Chebrov, M. Hayakawa, and G. Belyaev, Estimation of the epicenter position of Kamchatka earthquakes, *Pure and Applied Geophysics*, 2021. Doi:10.1007/s00024-021-02679-1
- Chowdhury, S., S. Kundu, T. Basak, M. Hayakawa, S. Gosh, S. Chakraborty, S. K. Chakrabarti, and S. Sasmal, Numerical modeling of lower ionospheric reflection parameters by using International Reference Ionosphere (IRI) model and validation with Very Low Frequency (VLF) radio signal characteristics, *Advances in Space Research*, vol. 67, 1599-1611, Jan. 2021. Doi://10.1016/j.asr.2020.12.017
- Politis, D. Z., S. M. Potirakis, Y. F. Contoyiannis, S. Biswas, S. Sasmal, and M. Hayakawa, Statistical and Criticality Analysis of the Lower Ionosphere Prior to the 30 October 2020 Samos (Greece) Earthquake (M6.9), Based on VLF Electromagnetic Propagation Data as Recorded by a New VLF/LF Receiver Installed in Athens (Greece), *Entropy*, 23(6), 676; 2021. <https://doi.org/10.3390/e23060676>
- Sasmal, S., S. Chowdhury, S. Kundu, D.Z. Politis, S.M. Potirakis, G. Balasis, M. Hayakawa, and S.K. Chakrabarti, Pre-seismic irregularities during the 2020 Samos (Greece) earthquake (M=6.9) as investigated from multi-parameter approach by ground and space-based techniques, *Atmosphere*, 12, 1059, 2021. <https://doi.org/10.3390/atmos12081059>
- Hayakawa, M., J. Izutsu, A. Schekotov, S. S. Yang, M. Solovieva, and E. Budilova, Lithosphere-atmosphere-ionosphere coupling effects based on multiparameter precursor observations for February-March 2021 earthquakes (M~7) in the offshore of Tohoku area of Japan, *Geosciences*, 11, 481, 2021. <https://doi.org/10.3390/geosciences11110481>
- Pulinets S.A., Davidenko D.V., Pulinets M.S., Atmosphere-ionosphere coupling induced by volcanoes eruption and dust storms and role of GEC as the agent of geospheres interaction, *Adv. Space Res.*, 69 (12) 4319-4334, 2022, <https://doi.org/10.1016/j.asr.2022.03.031>
- Pulinets S.A., Khegai V.V., Legen'ka A.D., and Korsunova L.P., New Parameter for Analysis of Ionospheric Disturbances and the Search for Ionospheric Precursors of Earthquakes Based on Barbier's Formula, *Geomagnetism and Aeronomy*, 2022, Vol. 62, No. 3, pp. 255–262, DOI: 10.1134/S001679322203015X
- Adil M. A., Pulinets S. A., Şentürk E., Abbasi A. R., Budnikov P., GNSS atmosphere seismology for equatorial earthquakes: a case study from Central America, *GPS Solutions*, 26:112, 2022 <https://doi.org/10.1007/s10291-022-01300-9>
- Pulinets, S.; Vičić, B.; Budnikov, P.; Potočník, M.; Dolenc, M.; Žalohar, J. Correlation between Shear-Traction field and Atmospheric Chemical Potential as a tool for earthquake forecasting. In: Proceedings of the 3rd European Conference on Earthquake Engineering and Seismology, Bucharest, Romania, 4–9 September 2022. Editura Conpress Publ., ISBN 978-973-100-533-1, pp. 3623-3627
- Nina A., Biagi P. F., Pulinets S., Nico G., Mitrović S.T., Čadež V.M., Radovanović M., Urošev M., Popović L.Č., Variation of the VLF signal noise amplitude during the period of intense seismic activity in Central Italy from 25 October to 3 November 2016, *Frontier in Environmental Studies*, 2022, DOI 10.3389/fenvs.2022.1005575
- Pulinets, S. (2022). Thermodynamic Instability of the Atmospheric Boundary Layer as a Precursor of an Earthquake. In: Brenig, L., Brilliantov, N., Tlidi, M. (eds) *Nonequilibrium Thermodynamics and Fluctuation Kinetics. Fundamental Theories of Physics*, vol 208. Springer, Cham. pp. 313-323 https://doi.org/10.1007/978-3-031-04458-8_16
- Pulinets, S.; Budnikov, P. Atmosphere Critical Processes Sensing with ACP. *Atmosphere* 2022, 13, 1920. <https://doi.org/10.3390/atmos13111920>
- Titova, M.A., Zakharov, V.I. & Pulinets, S.A. Interpretation of Ionospheric Disturbances During the Largest Earthquake by the Using the Differentiated Approach for the Special Methods to Processing Satellite Radio Signals. *Geomagn. Aeron.* 62, 783–801 (2022). <https://doi.org/10.1134/S0016793222060159>
- Nina A., Biagi P.F., Pulinets S., Nico G., Mitrović S.T., Čadež V.M., Radovanović M., Popović L.Č. Analysis of the Solar Terminator Shift Determined from the VLF Signal Amplitude in the Period Around the Intense Seismic Activity in Central Italy from 25 October to 3 November 2016. *Serb. Journal of Geosciences*. 2022, 8, No. 1, 9–14. <https://doi.org/10.18485/srbjgeosci.2022.8.1.2>
- Chowdhury, S., S. Kundu, S. Ghosh, M. Hayakawa, A. Schekotov, S. M. Potirakis, S. K. Chakrabarti, S. Sasmal, Direct and indirect evidence of pre-seismic electromagnetic emissions associated with two large earthquakes in Japan, *Natural Hazards*, <https://doi.org/10.1007/s11069-022-05271-5>

- Kundu, S., Chowdhury, S., Gosh, S., Sasmal, S., Politis, D., Potirakis, S.M., Yang, S.S., Chakrabarti, S.K., and Hayakawa, M., Seismogenic anomalies in Atmospheric Gravity Waves observed from SABER/TIMED satellite during large earthquakes, *J. Sensors*, vol. 2022, Article ID 3201104, 2022. <https://doi.org/10.1155/2022/3201104>
- Gosh, S., S. Chowdhury, S. Kundu, S. Sasmal, D. Politis, S.M. Potirakis, M. Hayakawa, S. Chakarabarti, and S. Chakraborti, Unusual surface latent heat flux variations and their critical dynamics revealed before strong earthquakes, *Entropy*, 24, 23, 2022. <https://doi.org/10.3390/e24010023>
- Biswas, S., Chowdhury, S., Sasmal, S., Politis, D. Z., Potirakis, S. M., and Hayakawa, M., Numerical modelling of sub-ionospheric Very Low Frequency radio signal anomalies during the Samos (Greece) earthquake ($M=6.9$) on October 30, 2020, *Adv. Space Res.*, 70, 1453-1471, 2022. <https://doi.org/10.1016/j.asr.2022.06.016>
- Nickolaenko, A.P., Schekotov, A.V., Hayakawa, M., Romero, R., and Izutsu, J., Electromagnetic manifestation of Tonga eruption in Schumann resonance band, *J. Atmos. Solar-terr. Phys.*, 2022. <https://doi.org/j.jastp.2022.105897>
- Hayakawa, M., A. Schekotov, J. Izutsu, S. S. Yang, M. Solovieva, and Y. Hobara, Multi-parameter observation of seismogenic phenomena related to the Tokyo earthquake ($M=5.9$) on 7 October 2021, *Geosciences*, 12, 265, 2022. <https://doi.org/10.3390/geosciences12070265>
- Ghosh, S., S. Sasmal, M. Naja, S. Potirakis, and M. Hayakawa, Study of aerosol anomaly associated with large earthquakes ($M\geq 6$), *Adv. Space Res.* 2022. <https://doi.org/10.1016/j.asr.2022.08.051>
- Hobara, Y., M. Watanabe, R. Miyajima, H. Kukuchi, T. Tsuda, and M. Hayakawa, On the spatio-temporal dependence of anomalies in atmospheric electric field just around the time of earthquakes, *Atmosphere*, 2022, 13, 1619. <https://doi.org/10.3390/atmos13101619>
- Rapoport, Yu., V. Reshetnyk, A. Grytsai, V. Grimalsky, A. Liashchuk, A. Fedorenko, M. Hayakawa, A. Krankovski, L. Blaszkiewicz, and P. Flisek, Application of spectral analysis and information entropy to data of VLF disturbances in the Earth-ionosphere system, *Sensors*, 2022, 22, 8191. <https://doi.org/10.3390/s22218191>
- Politis, D. Z., S. M. Potirakis, S. Kundu, S. Chowdhury, S. Sasmal, and M. Hayakawa, Critical dynamics in stratospheric potential energy variations prior to significant ($M\geq 6.7$) earthquakes, *Symmetry*, 2022, 14, 1939. <https://doi.org/10.3390/sym14091939>
- Kimura, R., Y. Ando, K. Hattori, and M. Hayakawa, Numerical estimation of source current intensity causing ULF emissions associated with earthquakes by using WLP-FDTD method, *J. Atmos. Electr. Letters*, vol. 41, No. 2, p.52-57, 2022 (in Japanese).
- Pulinets S., Budnikov P., Karelin A., Žalohar J. (2023) Thermodynamic instability of the atmospheric boundary layer stimulated by tectonic and seismic activity. *Journal of Atmospheric and Solar-Terrestrial Physics*, 246, 106050, <https://doi.org/10.1016/j.jastp.2023.106050>
- Pulinets M.S., Budnikov P.A., Pulinets S.A., Global Ionospheric Response to Intense Variations of Solar and Geomagnetic Activity According to the Data of the GNSS Global Networks of Navigation Receivers, *Geomagn. Aeron.* 63, No 2, 202–215 (2023)
- Yutsis, V.; Kotsarenko, A.; Grimalsky, V.; Pulinets, S. On the Radon-Related Mechanism of the Seismo- and Volcanogenic Geomagnetic Anomalies: Experiments in Tlamacas Mountain (Volcano Popocatepetl Area) and Electrode Effect Model. *Atmosphere* **2023**, 14, 705. <https://doi.org/10.3390/atmos14040705>
- Pulinets S.A., Khegai V.V., Legen'ka A.D., Korsunova L.P., The Effectiveness of the Relative δ -Barbier Parameter in the Search for Ionospheric Precursors of Earthquakes, *Geomagnetism and Aeronomy*, 2023, Vol. 63, No. 3, pp. 309–317. DOI: 10.1134/S001679322360008X
- Hegai, V.; Zeren, Z.; Pulinets, S. Seismogenic Field in the Ionosphere before Two Powerful Earthquakes: Possible Magnitude and Observed Ionospheric Effects (Case Study). *Atmosphere* 2023, 14, 819. <https://doi.org/10.3390/atmos14050819>
- Biswas, S., S. Kundu, S. Sasmal, D.Z. Politis, S.M. Potirakis, and M. Hayakawa, Preseismic perturbations and their inhomogeneity as computed from ground-based investigation during the 2016 Fukushima earthquake, *J. Sensors*, vol. 2023, Article ID 7159204, 23 pages, 2023. <https://doi.org/10.1155/2023/7159204>
- Politis, D.Z., S. M. Potirakis, S. Sasmal, F. Malkotsis, D. Dimakos, and M. Hayakawa, Possible pre-seismic indications prior to strong earthquakes that occurred in Southeastern Mediterranean as observed simultaneously by three VLF/LF stations installed in Athens (Greece), *Atmosphere*, 14, 673, 2023. <https://doi.org/10.3390/atmos14040673>
- Mezentsev, A., A.P. Nickolaenko, A.V. Shvets, Yu.P. Galuk, A. Yu. Schekotov, M. Hayakawa, R. Romero, J. Izutsu, and I.G. Kudintseva, Observational and model impact of Tonga volcano eruption on Schumann resonance, *J. Geophys. Res.: Atmospheres*, 128, e2022JD037841, 2023. <https://doi.org/10.1029/2022JD037841>



WG GJFEH: Interdisciplinary Space Weather

Co-chairs: I. Stanislawska (Poland), R. Fallows (Netherlands)

The advanced state of space physics as well as the progress of techniques and technology meant that the development of space weather gained new acceleration.

This indicated the need to intensify interdisciplinary collaborations, which, with access to improved, innovative tools and methods, have just become an additional impulse for development.

Programs and research conducted constitute our significant contribution to scientific and especially in operational works. The working group activities have concentrated on following three main subjects. One of them is developing radio science modeling and technological tools for space weather. Radio science for space weather services, including instant monitoring, forecasts, global and local warnings and alerts, is perhaps the biggest challenge of today and holds a special place for our demanding infrastructure of everyday life. Space investigations and exploration are based on the use of propagating electromagnetic waves, so, that WG participants are the wide base for planetary missions.

URSI interdisciplinary Space Weather Working Group members actively participate in Space Weather related organizations and associations, many international events (conferences, symposia, workshops) and organizations:

- International Space Environment Service ISES
- COSPAR International Space Weather Action Teams (ISWAT)
- WMO Inter-Programme Team on Space Weather Information, Systems and Services (IPT-SWElSS)
- UN expert Group on Space Weather
- European Space Weather and Space Climate Association
- Horizon H2020, European Space Surveillance Tracking SST
- ESA Space Safety SSA programme
- International Space Weather Initiative
- Low-Frequency Array (LOFAR)
- PECASUS - Pan-European Consortium for Aviation Space weather User Services for ICAO
- Scientific Committee on Antarctic Research

The results and conclusions are included in scientific papers as for instance in **COSPAR SPACE WEATHER ROADMAP 2023**, and in several expert documents as **the guidelines for ITU World Radiocommunication Conference 2023 (WRC-23)**, several WMO documents and ICAO papers.



WG FCGEH- Risk and Disaster Management (Inter URSI Commissions)

Chair (T. Tanzi, France, COMM F),...co-chairs Commission G (C. Cesaroni, Italy; A. Ippolito, Italy)

The suggested scientific topics are:

- *Identifying precursors based on seismic events, lightning events.*
- *Application of weather radars (fast scans...).*
- *Space-weather with regard to its impacts on satellite communications and high-latitude power transmission (Geomagnetically Induced Currents).*

Commission G contributions 2022-2023 to the WG have been the following:

- A special session organized within AT-AP RASC 2022 on a "hot-topic" related to the ionospheric effects of the Hunga Tonga volcanic eruption of 15 January 2022. The special session, organized by Giorgiana De Franceschi and Claudio Cesaroni, wanted to promote an open discussion on international efforts and future capabilities for real time detection of ionospheric effects driven by natural hazards. This spectacular event is likely of interest to a wider audience within URSI, outside of only the ionospheric research community. The session had eight invited talks from distinguished authors who were very active in the topic and more than 50 participants in the audience. One aspect of the ionospheric effects of volcanic eruptions that may be of practical interest is the possibility of using ionospheric monitoring to provide an early warning when such an event occurs.
- Invited talk from Commission G community to the FCEGH Workshop on Radio Science and Engineering of Disaster Risk Reduction and Management, planned within GASS2023 (19-26 August 2023, Sapporo, Japan). The invited talk, that will be given by Elvira Astafyeva, is titled "Development of ionosphere-based methods for Disaster Risk Assessment in near-real-time". This contribution aims to present recent advances in ionospheric detection of earthquakes and tsunamis, and new developments toward NRT tsunami risk assessment from the ionosphere.

5. Funding and sponsorship

The URSI Board provided the Commission with a budget at the start of the biennium (2022-2023). The funds assist travel for the Chair, Vice Chair, and ECRs for their participation in the meetings together with additional funds to be used for sponsorship of Commission G meetings and members. For the period of late 2021 to 2023, Commission G sponsored the following events:

- Venice, Italy, 9-13 October 2023, ICEAA-IEEE APWC dual conference, (only technical support. A special Session is organized titled "Remote Sensing of the Earth's System to Mitigate the Impact of Natural Events on Technological Infrastructures")



- Rome, Italy, 15-20 May 2023, MaSAG23 - MATHematics for Signal processing and applications in Geophysics and other fields, 500 euros for travel assistance for young scientists
- Kuala Lumpur, Malaysia, 30 October - 2 November 2023, ISAP 2023 (only technical support)
- Sodankyla, Finland, 5-11 November 2022, VERSIM 2022 Workshop, 500 euros but this financial support was not needed.
- Cleveland, Ohio, USA, 12-14 October 2021, 2nd Workshop on Space Weather -online (only technical support)
- Trieste, Italy, 3-14 October 2022, African Capacity Building Workshop on Space Weather Effects on GNSS, 1000 euros for travel assistance for young scientists
- Boston College, MA, USA, 1-5 August 2022, Beacon Satellite Symposium, 2000 euros for travel assistance for young scientists

6. Thank you.

As the outgoing chair of Commission G, I thank very much the URSI Board and Commission G for this great experience. I thank the members of the Technical Advisory Group of the Commission that included, besides Chair, Vice-Chair, ECRs: Luca Spogli (Italy), Paul Cannon (UK), David Themens (Canada), Mike Warrington (UK), John Bosco Habarulema (RSA), Iwona Stanislawski (Poland). Iwona served also as Associate Editor for Radio Science Bulletin during this period.

I wish the greatest success to the incoming Chair, Dr. Keith Groves, who demonstrated his capabilities as Vice Chair and to the future Vice- Chair and ECR that will be appointed during GASS2023.

Sincerely,

Giorgiana De Franceschi