Space Weather Sub-Group

Chair: Irfan Azeem (NOAA, US)
Rapporteur: Erin Lynch (NOAA, US)

Coordination Group for Meteorological Satellites

IROWG
INTERNATIONAL RADIO OCCULTATION WORKING GROUP

CGMS COORDINATION GROUP FOR METEOROLOGICAL SATELLITES
CGMS

2024 Sub-Group Attendees

- **Chair:** Irfan Azeem (NOAA, US)
- **Rapporteur:** Erin Lynch (NOAA, US)
- **Members:** Tony Mannucci (NASA JPL), Deepali Aggarwal (Clemson University), Tom Meehan (JPL), Jude Salinas (NASA), Nick Pedatella (UCAR), Jan Weiss (UCAR), Jaehee Chang (KAIST), Doug Hunt (UCAR), Irina Zakharenkova (UCAR), Iurii Cherniak (UCAR), Lindsey Hayden (UCAR), Charles Quilis Alfonso (BTH), Marc Gasbarro (NOAA), Jade Morton (University of Colorado, Boulder)

Executive Summary

- 4 new recommendations from the sub-group for CGMS consideration
- Updates to language of 2022 IROWG Recommendations to CGMS for Space Weather
- 4 new recommendations from the sub-group for IROWG consideration
- 7 new actions opened coming out of the sub-group meeting
- 4 actions that were open from IROWG-9 closed

Recommendations to CGMS

1. IROWG recommends CGMS to support a workshop to better coordinate efforts of the CGMS/SWCG Ionospheric RO Optimization task group and the IROWG space weather sub-group.
   - Advocacy amongst agencies is needed to fund the development of an ionospheric RO OSSE framework which would enables studies to address the necessary occultation density and latency requirements for achieving certain levels of specification accuracy and assimilative models.
   - The workshop will also help inform the definition of a space weather RO benefit study akin to ROMEX.
   - Close coordination between the two teams is needed to plan how a space weather ROMEX could be organized.
2. IROWG recommends that relevant agencies undertake a ROMEX-like study for space weather.
   - Ionospheric RO data is now being assimilated in NOAA operational models on an experimental basis. Space Weather ROMEX study can help articulate the benefit of RO measurements in improving global ionospheric specification.

Recommendations to CGMS

3. IROWG strongly recommends close coordination with CGMS to protect GNSS bands from man-made RFI
   - Growing concerns related to RFI. This is particularly evident in the data from COSMIC-2 Signal-to-Noise Ratios (SNRs), where clear signs of interference can be observed. RFI hotspots have been detected in various regions, including the Middle East, raising further concerns.
4. IROWG recommends a workshop to facilitate coordination between relevant groups to examine approaches for reducing ionospheric residual errors in neutral atmospheric retrievals.
   - IROWG-9 identified steps to reducing ionospheric residual errors in neutral atmospheric retrievals. These efforts are best handle within NWP and/or Climate sub-groups.
   - Space weather group offers to provide support to either NWP subgroup or climate subgroup to address issue of reducing ionospheric residual error in neutral atmospheric retrievals.
   - Held a mini workshop on this topics many years ago. IROWG recommends to re-initiate this joint workshop.

Recommendations to IROWG

1. Update language from IROWG-9 recommendations
2. New recommendation related to ionospheric data assimilation techniques/models (previously a recommendation within the Space Weather sub-group)

Recommendations to IROWG

- **Per CGMS priority HLPP 1.1.4 (optimised system for atmospheric and ionospheric RO observations), on-going and future GNSS RO missions (including commercial providers) should incorporate the following key ionospheric monitoring capabilities in their sensors:**
  - (a) low data latency (<30 minutes, 15 minutes goal);
  - (b) continuous tracks of data spanning tangent altitudes from below 90 km up into the zenith hemisphere to the maximum extent, lasting at least 8 min;
  - (c) sensor contribution to slant total electron content (TEC) ~~with~~ should enable 3 TECU & 0.3 TECU absolute and relative accuracy, respectively;
  - (d) amplitude and phase scintillation indices;
  - (e) high rate (50Hz or higher, as dictated by the GNSS signal being observed) observations of amplitude **and** phase (both) ~~scintillations~~ at ionospheric tangent altitudes when either amplitude **or** phase scintillation is present.

  When considered as a whole, RO systems should make ionospheric measurements with approximately uniform geographic and local time coverage over the globe on a daily basis.

Created a new action

Recommendations to IROWG

- IROWG recognizes the importance of space weather applications of RO data. IROWG recommends that ~~RO and~~ non-RO missions that use dual-frequency GNSS receivers for their orbit determination needs should make available to the operational and research communities all necessary low-level (level 0) data and metadata required to produce accurate overhead TEC data from the GNSS receiver. All RO missions should provide level 0 data and meta data to derive topside TEC, and to the extent possible, level 0 data and meta data to derive TEC occultations.
- IROWG strongly supports an open data policy towards the purchase of commercial RO data and recommends that all agencies follow this model. IROWG stresses the importance of free and unrestricted access to essential RO data including archived raw or low-level (level 0) data, as collected on orbit.
- IROWG recommends operational Global Navigation Satellite System (GNSS) RO missions for continuous global climate observations to be established and maintained as a backbone to ensure continuity and long-term availability of climate quality RO measurements with global coverage and full local time coverage on a daily basis.

Recommendations to IROWG

- Encourage development/improvement of ionospheric data assimilation models to take full advantage of ~~the FS7/C2 and other~~ all available (including commercial providers) GNSS ~~RO~~ data, i.e. RO, topside TEC, and GNSS-R (both grazing angle and nadir) ~~(also from commercial providers)~~ for specification and prediction of the ~~low latitude~~ ionosphere, including both its large-scale properties such as the F-layer and bottom side, and small-scale properties related to ionospheric scintillation effects.
- Encourage development of more accurate ~~1DVAR~~ retrievals of ionospheric electron density profiles (there was already a presentation at IROWG-8 and there has been one also at IROWG-9).
- Coordinate with space weather activities throughout the CGMS Space Weather Coordination Group (SWCG) and the WMO Expert Team on Space Weather (ET-SWx). Whenever possible, members of each of these teams should attend each other's meetings. See action IROWG9-01.

IROWG-9 Recommendations within sub-group

- Verify that the WMO OSCAR database properly documents the abilities of current and future missions to obtain ionospheric data per Recommendations to CGMS #1-2 above.

Being addressed by the CGMS SWCG Iono. RO System Optimization Task Group

- Expand the sub-group membership in the areas of personnel associated with operational space weather support centres and members of the international science community involved in the development and evaluation of assimilative ionospheric and scintillation models.

Created an action (IROWG-10 Action 6)

- Space Weather sub-group team members should continue to advocate for and support greater incorporation of ionospheric radio occultation science topics (such as the development of space weather data assimilation models) within existing ionospheric science venues.

Created an action (IROWG-10 Action 2)

- Undertake studies which address the necessary occultation density and latency to achieve certain levels of specification accuracy with assimilative models.

Created a recommendation to CGMS (IROWG-10 Recommendation 1)

- Investigate the possibility of determining accurate thermospheric density from GNSS receiver tracking data. (UCAR is doing this)

Created an action to refer to SWCG (IROWG-10 Action 4)

Action items from IROWG-10

1. Coordinate with the Innovation sub-group(J. Morton)
2. Organize session e.g AGU, EWS, JPGU (I. Azeem)
3. Explore 3 TECU/0.3 TECU requirements – OSE (J. Weiss)
4. Request CGMS/SWCG group for Information to enable thermopsheric density estimation (E. Lynch)
5. Request WMO SW Expert Team to advocate mobile phone providers to release TEC data (E. Lynch)
6. IROWG to invite SWPC member of the WMO SW Ex Team to speak and participate in the subgroup (I. Azeem)
7. Organize subgroup virtual meeting every 4 months (I. Azeem)

Action items from IROWG-9

- Action IROWG9-01:
- Irfan Azeem to investigate whether there is a NOAA/SWPC person that is involved in the WMO Expert Team on Space Weather (ET-SWx) that could attend the IROWG to increase the interchange between our group and others within WMO that are concerned with space weather.
- Due Date: October 1, 2022/ CLOSED
- https://community.wmo.int/en/governance/commission-membership/commission-observation-infrastructure-and-information-systems-infcom/standing-committee-earth-observing-systems-and-monitoring-networks-sc-2020-2023/expert-team-space-weather-et-swx

- Action IROWG9-02:
- Paul Straus to investigate whether or not there are ionospheric applications that might significantly benefit from direct broadcast (low latency) GNSS sensor data.
- Due Date: Next IROWG/ CLOSED with a negative
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- Action IROWG9-03:
- Riccardo Notarpietro to explore the possibility of obtaining TEC from reflectometry and whether this should be a focus of future sub-group advocacy.
- Due Date: Next IROWG/ CLOSED – Ongoing studies have demonstrating the potential of obtaining TEC from GNSS-R.