Final Plenary Topics (Sample)

- Status of the Climate BP document
- Presenting ML and Cloud science highlights to WGII
- JPL statement on refractivity coefficients
- Special issue of GPS Solutions
- Best Practices for implementing polarimetric RO
- Move SW subgroup to 10AM MT
- Deadline for final meeting minutes
- Next IROWG (time and place)

NWP Sub-Group

Who's who?

Co-chairs:
Neill Bowler (UK Met Office)
Katrin Lonitz (ECMWF)

Members:
Benjamin Ruston (UCAR/JCSDA)
Jennifer Haase (SIO)
Ying-Then Chen (CWA)
Zih-Mao Huang (CWA)
Hsiao-Chun Lin (UCAR/COSMIC)
Shu-chih Yang (NCU)
Hailing Zhang (UCAR)
Stig Syndergaard (DMI)
Rob Kursinski (PlanetiQ)
Chi Ao (JPL)
Kuo-Nung Wang (JPL)
Hui Shao (UCAR)
Bill Kuo (UCAR)
Billy Gullotta (UCAR)
Chris Barsoum (Aerospace)
Guo-Yuan Lien (CWA (Taiwan))
Shu-Ya Chen (NCU)
Yong Chen (NOAA/STAR)
Chad Galley (JPL)
Josep M. Aparicio (ECCC)
Eum-Hee Kim (KMA)
Hyaung-Wook Chun (KMA)
Jonathan Brandmeyer (PlanetiQ)
Dominique Raspaud (Météo-France)
Jeremiah Sjoberg (UCAR)
Harald Anlauf (DWD)
Pawel Hordyniec (UPWR)
Nghi Do (UCSD)
Yasutaka Murakumi (JMA)
Shu-Peng Ben Ho (NOAA(STAR))
Delaynie Peters (Texas Abm Corpus Christi)
William Miller (U. Maryland)
Xuanli Li (EMC)
Ben Davis (UCSD)
Rick Anthes (UCAR)
Christian Marquardt (EUMETSAT)

Recommendation to CGMS

1. IROWG notes that the current observational network is very beneficial, and that degrading this brings negative impacts. **IROWG recommends that the degradation of current capabilities should be avoided, and achieving this via agency-funded missions avoids the risks associated with commercial data purchases. Initial results from ROMEX suggest that substantial increases in data volume can be beneficial to NWP forecasts.**

   The rationale for this statement is that agency funded missions can provide stable, continuous, long-term, traceable and reliable observations. The expertise of publicly funded data-processing centres is invaluable in assessing and archiving commercial data provision. They also help to reduce the risk to the global observing system if one or more commercial providers were to go out of business, or if the market became dominated by a single player. The CGMS baseline also provides a reference point against which the commercial companies can compare and innovate. It is helpful to have this baseline based upon multiple different satellite instruments / platforms.

Recommendation to CGMS

2. IROWG **recognises the rapid progress** that has been made in the **exploitation of commercial observations**.

   The progression to the routine operational assimilation of these data at a number of centres has been a demonstration of effective **inter-agency collaboration**.

   Commercial data has shown to provide good quality data and is much appreciated to contribute improving forecasts. IROWG appreciates the NOAA and EUMETSAT approach of sharing commercial data on a global licence and hope that other agencies continue to follow this approach.

Recommendation to CGMS

3. **IROWG recommends open communication and providing test data about changes to incoming data and it's quality, especially with regards to new commercial data purchases.** Such communication should be as early as possible - at least one month before a change in operational data feeds.

Recommendation to CGMS

4. **Buying agencies should not procure artificially degraded data.** Although adding small amounts of noise is unlikely to degrade NWP forecasts at present, this will typically become the observation of record and it will be impossible to test whether future NWP systems can extract further benefit from them.

Recommendation to CGMS

5. For reanalysis and other purposes, it is helpful to have archives of large RO quantities.

   IROWG recommends institutions to purchase full datasets (with all observations and low-level data) and to make these available to the global community. The procured data should also be archived by public agencies and be subject to regular reprocessing activities.

Update to recommendation to CGMS

IROWG continues to strongly support an **open data policy** towards the purchase of commercial RO data, and recommends that all agencies follow this policy. This includes the exchange of test data and report on data quality.

IROWG believes that the free and open exchange of data contributes to the greatest improvements in forecast quality, due to the ability to compare processing methods and assimilation techniques.

Closed - this is covered by CGMS best practice document

Action within IROWG

1. IROWG members to read the CGMS best practice document.
   Consider possible additions to best practice document or whether we need to create our own best practices of (new) RO data for NWP. Consider the needs of best practice for data purchase, data processing, testing and communication of data changes.

1. Christian will attempt to organise another ROMEX workshop before CGMS.
2. People should run extra ROMEX sensitivity experiments. We should avoid making the timeline too ambitious.
3. Should consider whether it would be possible to create a dataset from ROMEX which has approximately equal temporal coverage, and consider which users could use this.

Recommendation within IROWG

IROWG has noted that a number of important **research topics** which deserve attention in the coming years.

- IROWG encourages the **renewed lab measurements of the k1, k2 coefficients** as used in the calculation of refractivity.
- IROWG encourages studies to investigate **whether additional benefit can be extracted from RO measurements in the lower troposphere**. With a particular thought on how SNR affects this usefulness.
- Observation operators for **polarimetric and aircraft RO** are currently or have been developed. IROWG encourages **experimentation** with these new observations and operators.
- IROWG notes GNSS-R measurements are “home” to other working groups
- IROWG encourages further investigations into the impact of geographic distribution and also time distribution (homogeneous).

Recommendation within IROWG

IROWG recommendation: IROWG encourages technology and retrieval developments for improving planetary boundary layer profiling from GNSS-RO and their utilization in NWP data assimilation as well as the further exploitation of RO-derived water vapor.

Action: In the NWP subgroup, discuss specific examples of such developments so that the NWP centers can take action.

Ideas:

- Super-refraction - high SNR can be used to detect super-refraction.
- There is a need to update QC methods and observation uncertainties in the lower troposphere to make more effective use of RO data in the lower troposphere.
- Suggestion of a comparison of data in the lower troposphere (following a model of ROTrends). Rob Kursinski and Chi Ao volunteered to further investigate this in collaboration with the climate sub-group.
- PlanetIQ are exploring demonstrations of how high SNR allows better retrieval in the lower troposphere.
- This is a clear need within tropical cyclone modelling

Other discussion topics

Discussion next (timing) IROWG

No objections were raised to meeting in 2 years. Suggested to hold subgroup / ROMEX meetings in between.

Discussion next co-chair

Candidate should probably better come from other WG

Discussion AI activities

Some internal AI activities ongoing looking into using sat. observations

IROWG-10 Climate Subgroup

Andrea Steiner (Chair; WEGG, Austria)
Panagiotis Vergados (Rapporteur; JPL, USA)

IROWG-10 meeting minutes:

Climate Subgroup - Members/Visitors

Members: Julia Danzer (WEGC, Austria), Eric DeWeaver (NSF, USA), Ulrich Foelsche (Univ. Graz, Austria), Hans Gleisner (DMI, Denmark), Stephen Leroy (AER, USA), Johannes Nielsen (DMI, Denmark), Marc Schwärz (WEGC, Austria), Endrit Shehaj (MIT, USA), Andrea Steiner (WEGC, Austria), Matthias Stocker (WEGC, Austria), Panagiotis Vergados (JPL, USA), Anna Hall (U. Washington, USA), Paul Staten (IU Bloomington, USA), Sara Vannah (AER, USA), Jun Zhou (UMD, USA), Xin Jing (UMD, USA), Cong Dong (U. Washington, USA), Guojun Gu (UMD, USA), Walid Bannoura (NOAA-NESDIS, USA), Jens Wickert (GFZ, Germany), Kevin Nelson (JPL, USA), Feiqin Xie (TAMUCC, USA), Aodhan Sweeney (U. Washington, USA), Yuying Wang (York University, CANADA), Lauren Hill-Beaton (GSFC, USA), Jihyeok Park (KAIST, Korea)

Visitors:

1. Climate Subgroup – Recommendations to CGMS: (Main Recommendations)

1) **Ensure continuity and long-term availability of climate quality RO measurements with global coverage and full local time coverage through a coordinated and sustained effort. Operational GNSS RO missions for continuous global climate observations need to be established and maintained as a backbone to ensure continuity with at least 20,000 occultations per day. This could be achieved with satellites in sun-synchronous and low inclination orbits with satellites in at least four evenly-spaced orbital planes providing observations with uniform global coverage. Level 0 data need to be freely available for reprocessing.** The community is currently short of 20,000 evenly-distributed occultations per day, but IROWG acknowledges the recommendation of CGMS to achieve this target. For climate studies, the effects of local time-related sampling errors should be examined and minimized. We acknowledge the contributions of commercial data providers, pending validation of their climate data quality, including long-term and full access to the data by independent processing centers. Climate requirements should be taken into consideration when purchasing commercial data.

2) **Acknowledging CGMS recommendation WGIIA50.04 on long-term data access, we recommend that government agencies providing data, whether generated internally or purchased from commercial entities, ensure that all information necessary for independent processing towards climate data products is freely available (following WMO Unified Data Policy Resolution 1, GCOS requirements), including long-term archiving of all measured and acquired data without filtering, sub-selection, and "intentional degradation" (i.e., including the data not passing quality control), starting with level 0 data, and public data access, thus assuring full climate traceability.** This needs to include information on instrument/software updates and full documentation of the processing chains that keep track of any introduced changes/updates (e.g., POD-induced uncertainties). We also recommend that the impact of instrument software updates on climate products be evaluated beforehand. All level 0 data providers should make available phase data, amplitude data, and satellite orbit data in a well-documented format (such as NetCDF).

1. Climate Subgroup – Recommendations to CGMS:

3) **Data providers should ensure two data streams of RO climate data products: one regularly updated data version (interim CDR) and one uniformly reprocessed version (CDR).** The reprocessed version should always cover the full data time period until more recent processing versions are available.

4) **IROWG recommends that processing centers increase efforts on uncertainty estimation and make the methods and results publicly available through peer-reviewed publications**. One method of uncertainty quantification is to produce ensembles of processed observations ("perturbed retrieval ensembles") that include different processing assumptions and initialization information where the SI-traceability chain may be less robust (in accordance with the GCOS-143 Document).

5) **Promote funding of various reprocessing activities of RO climate data records from different independent RO processing centers** along with the principles for reprocessing climate data records of the WCRP Observation and Assimilation Panel (WOAP). Documentation of the historical evolution of processing systems for the provision of climate data records is important. **This should include gridded data together with uncertainty estimates and algorithm descriptions from multiple centers.**

6) We recommend to assess the **uncertainty in the refractivity coefficients that impacts the accuracy and traceability of RO climate time series and trends.** Significant progress was made at JPL in implementing an experiment to measure the refractivity of air, but such experiments currently lack the needed precision by the climate group. Required steps to improve precision have been identified by NASA/JPL, however further financial support is needed. **IROWG is pleased to see these initial laboratory refractivity experiments and encourages CGMs agencies to support this activity.**

7) We acknowledge the **success of the 3G meeting** which brought together the GNSS RO, the GRUAN and the GSICS communities in May 2014 in Geneva and recommend **organizing such meetings periodically by WMO**.

8) We recommend that **operational data providers additionally supply occultation prediction products**, aiding coordinated ground-based collocated measurements.

2. Climate Subgroup – Recommendations within IROWG:

1) **We recommend that IROWG continues to contribute to the development of GNSS RO as a climate monitoring system** by a) assessing the structural uncertainty of RO retrieval data, including differences between processing centers and between different RO instruments and missions, b) supporting the generation of multi-center ensembles of RO climate data records, c) studying the effect of changing spatial coverage with latitude, including characterizing the errors related to incomplete spatial and temporal coverage, and d) clearly communicating the usability and limitations of RO products (e.g., N, T, H2O) to the climate community.

2) **Continue to assess RO water vapor products** in terms of climate quality, information content, and random and systematic uncertainties, including characterization of the stability and inter-center homogeneity, guided by GEWEX and GCOS requirements.

3) **Encourage research into assessing the sources of bending angle uncertainties from different receivers and processing centers (which include SNR, clock noise, ionospheric residuals, calibration techniques etc.) and their impact on the estimates of long-term changes**, which is likely to extend the benchmarking capability of GNSS RO more robustly into the troposphere and higher into the stratosphere.

2. Climate Subgroup – Recommendations within IROWG:

4) **Issues of ionospheric correction and high altitude initialization should be further investigated to optimize the climate utility in the entire stratosphere**.

5) **We recommend that the IROWG community continues to compare RO products with other observations and to foster contributions to IPCC Assessment Reports and other international climate reports**.

6) **Continue participation in the wider scientific community.**

7) **Ensure a complete archive of navigation data bits in a standard format**. We recommend making this information available to the community. We recommend that current providers come up with a common nav bit format.

8) **We recommend to have intercomparison studies of the PBL (refractivity, water vapor pressure, and other direct products), and of the determination methods of the PBL height.**

3. Actions to IROWG-8 From CGMS:

Space Weather Sub-Group

Chair: Irfan Azeem (NOAA, US)

Rapporteur: Erin Lynch (NOAA, US)

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
-
- 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.

Radio Occultation (RO) Technology and Innovative Techniques -> Innovation

IROWG-10

Boulder, CO

2024/09/18

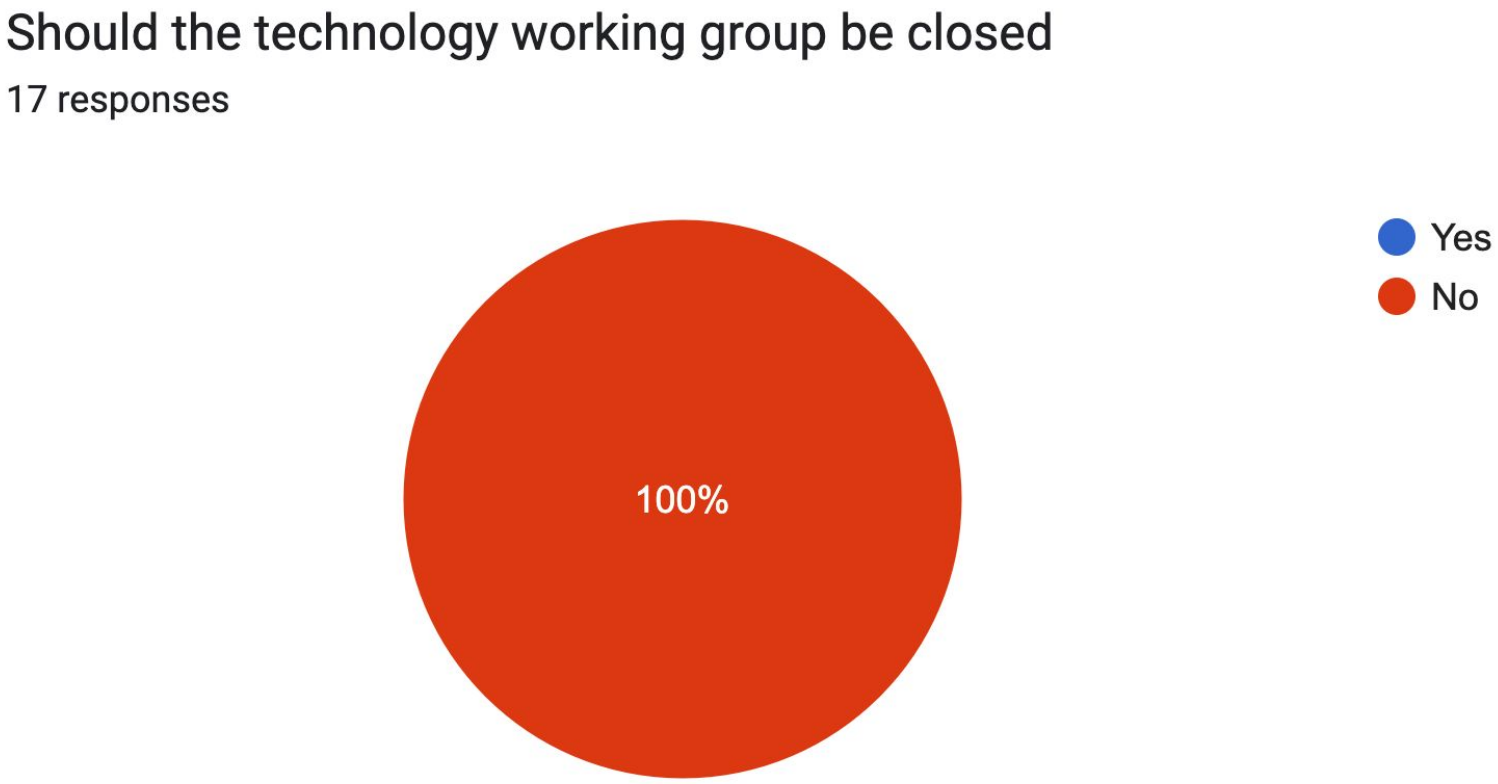
Summary

- Working group unanimously voted to remain a group
- Also voted to change name to “Innovation”

- Top recommendations
  - Planetary Boundary Layer retrieval development and utilization in NWP
  - Promote development of Polarimetric RO observations (orbital and airborne) and exploitation of those observations

- Other recommendations
  - RFI, Airborne Radio Occultation, GNSS-RO+R(grazing angle), coordinated RO data buy, LEO-LEO, residual iono correction, level0 data format

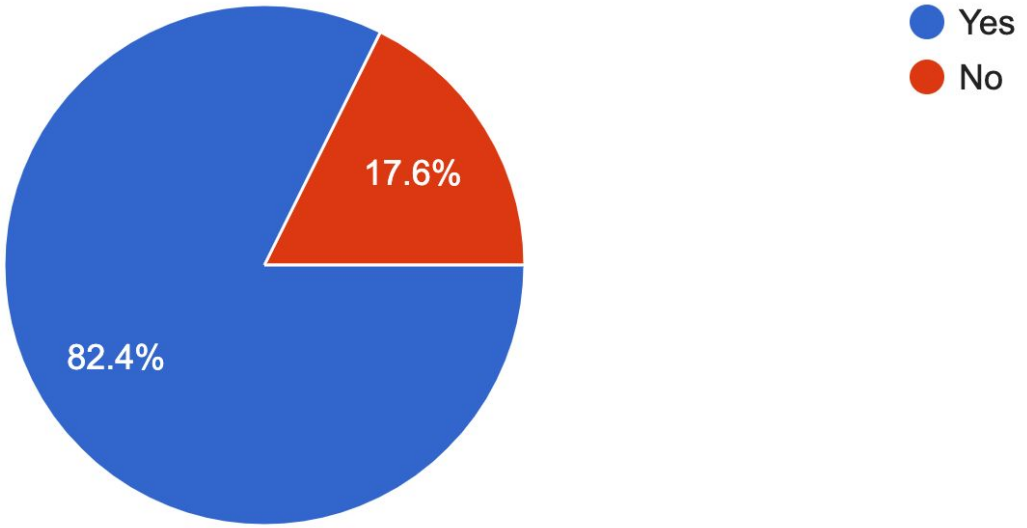
Should the technology working group be closed?



Shall we change the name of this working group to Innovation?

Shall we change the name of this working group from: Receiver Technology and Innovative RO Techniques To Innovation

17 responses



Ranking of Recommendations

Ranking	Topic	Importance 10 is highest priority 1 is lowest priority
1	Encourage technology and retrieval developments for improving planetary boundary layer profiling from GNSS-RO and their utilization in NWP data assimilation	9.06
2	Promote development of Polarimetric RO observations (orbital and airborne) and exploitation of those observations	8.94
3	Identify Radio Frequency Interference (RFI) sources and develop strategies for mitigation	7.35
4	Develop GNSS observations from airborne platforms for operations and testing new technology	7.29
5	Encourage the development of synergistic GNSS radio occultation (grazing angle) and GNSS reflectometry	6.59
6	Encourage CGMS to coordinate purchase of commercial RO data	6.59
7	Advance LEO-LEO occultation development towards a demonstration mission	6.53
8	Improve removal of residual ionosphere correction for GNSS-RO	5.41
9	Formation of IROWG working group on “level0” data formats	3.76

Top Recommendations

PBL

- Encourage technology and retrieval developments for improving planetary boundary layer profiling from GNSS-RO and their utilization in NWP data assimilation
- Current Status
  - NWP is still not optimally using RO data in lower troposphere, generally discarding data higher than PBL area
- Progress since IROWG-09
  - Operational duct detection in COSMIC-2
  - Increased duct measurements from PiQ
  - Improved retrievals from JPL combining RO with passive sounders, and grazing angle observations
  - 1DVAR retrievals from JPL to constrain from IWV
  - GMAO assimilating PBL height
  - Stephen Leroy has initiated PBL research group
  - Six oral presentations at IROWG-10 (Monday afternoon) from: Zhen, Xie, Wang, Ao, Syndergaard, Vannah
  - Multiple posters also presented
- Future Needs
  - Improve data assimilation methods to leverage PBL observations
  - How to use PBL observations considering refractivity bias in current RO observations
- Recommendations
  - Encourage an intercomparison project for PBL observations

Polarimetric Radio Occultation (PRO)

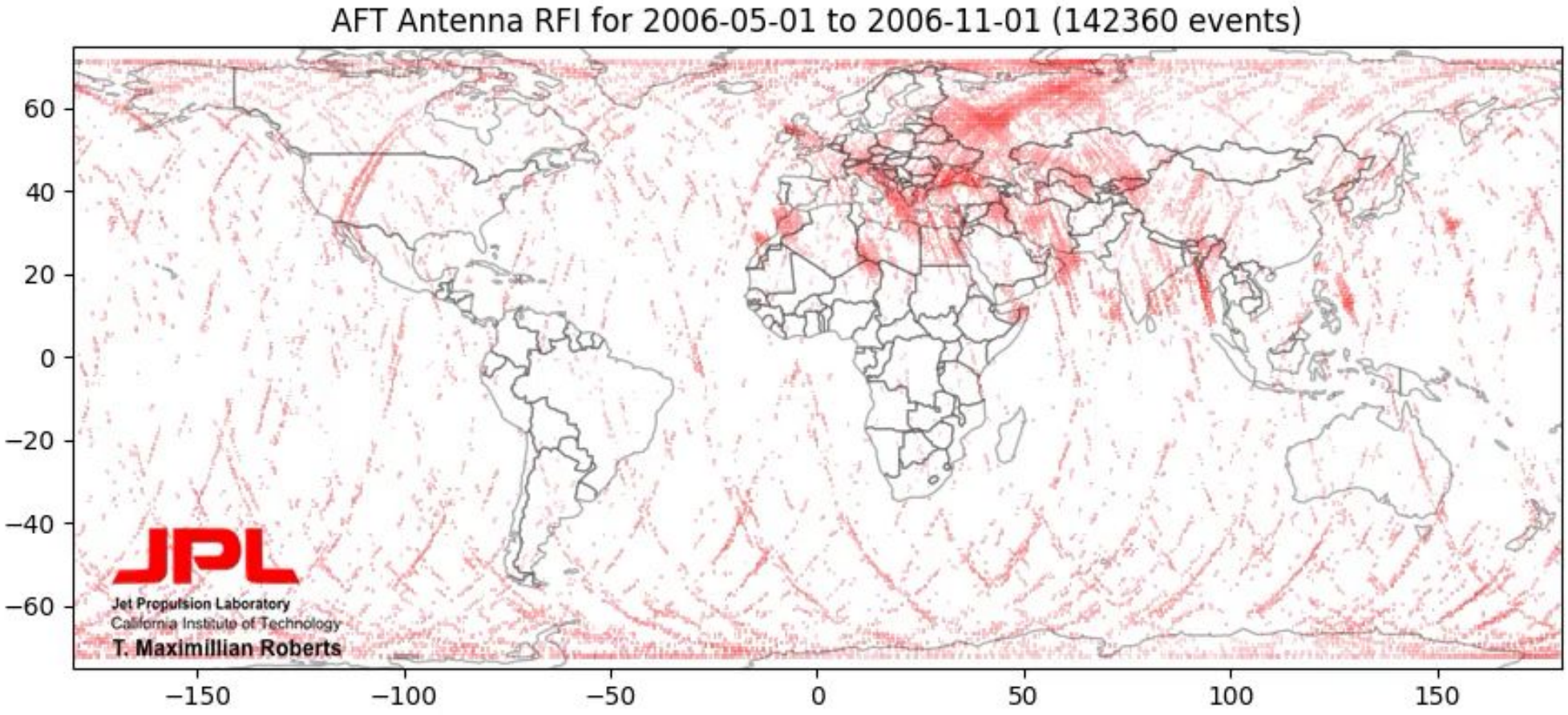
- Promote development of Polarimetric RO observations (orbital and airborne) and retrievals and use of those observations
- Current Status
  - PRO data now collected by PAZ, Spire, and PiQ
  - Not all this data is available
- Progress since IROWG-09
  - Cal-Tech workshop hosted workshop with JPL and ICE in November 2023
    - Advances in the Use of Global Navigation Satellite System Polarimetric Radio Occultation Measurements for NWP and Weather Applications (https://doi.org/10.1175/BAMS-D-24-0050.1)
  - Cardellach leading PRO working group at IROWG-10 (see report)
  - New BUFR format contains PRO observation data set
  - PRO data has been used to evaluate NWP cloud parameterization schemes
  - ARO data has been collecting data for atmospheric rivers and hurricanes for past two years. This data has not been fully analyzed yet.
  - CU has high gain, dual-pol station on Hawaii collecting base band data for past few years, for mountain top RO.
  - Simple forward operators have been developed, including ECMWF, ICE

High Priority Recommendations

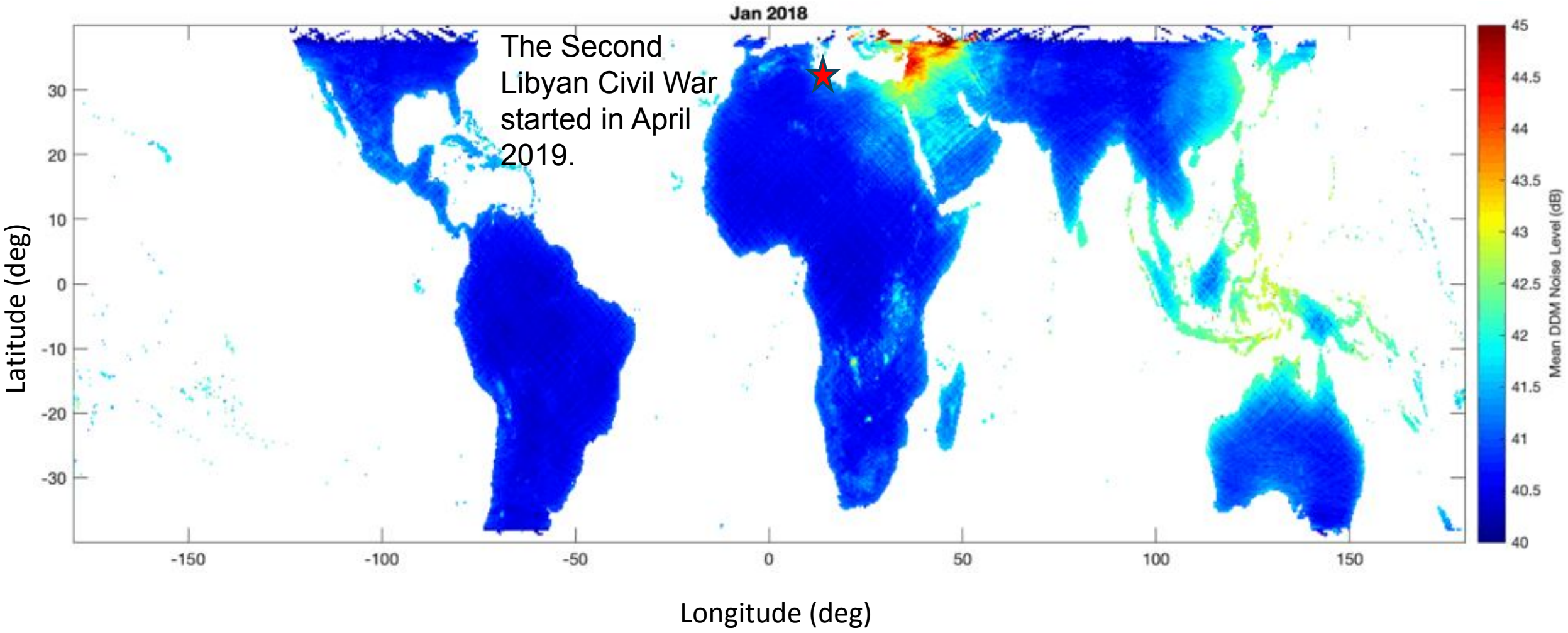
RFI

- Current Status
  - RFI is becoming a more significant problem
- Progress since IROWG-09
  - ML methods have been developed at CU
  - JPL RFI algorithm is being used for operational processing at UCAR
  - L5 is getting worse
  - Cross talk between satellites is potentially increasing

RFI: 2006-2018



RFI Mapping Using CYGNSS Satellites (CU)



Wu, K., Y. J. Morton, C. Chew, "Detection and mitigation of radio frequency interference in GNSS-R data," *Proc. ION GNSS+,* DOI: 10.33012/2022.18482, 2022.

From Jade Morton

Airborne Radio Occultation (ARO)

- Develop GNSS observations from airborne platforms for operations and testing new technology

- Current status
  - ARO now being routinely collected as part of atmospheric river intensive observations and hurricane reconnaissance projects
  - TAMUCC has demonstrated ARO on commercial planes (add reference)
- Progress since IROWG-09
  - JEDI operator has been written
  - BUFR format is documented
  - Realtime data delivery is ready for demonstration during NOAA campaigns
  - OL tracking needs to be improved
- Recommendations
  - Innovation group believes ARO is sufficiently developed so that it should be considered for operational implementation
  - Explore ways to broadly implement on commercial airlines

LEO-LEO

- International space agencies (in particular NASA, ESA and CAS, where LEO-LEO and GNSS-RO&-Reflectometry proposals are pending) to support mission preparation and implementation projects towards LEO-LEO microwave occultation and GNSS-RO&-Reflectometry demonstration missions. This should include recommending new OSSEs & EDAs for the LEO-LEO observations.
- Current Status
  - Not much
  - Chinese administration had proposal, but not funded.
  - Wegener Center/ROM SAF has recommended that leo-leo assimilation work be tabled
    - Forward operator for leo-leo has been postponed
  - JPL has leo-leo technique being supported by NASA decadal survey pbl incubation and internal JPL project to demonstrate transmit/receive capability with SDR
    - Eric has developed forward simulation operator (FSO)
  - PIQ sang praise to NOAA about very innovative leo-leo technology (hallelujah)

- Progress since IROWG-09
  - ICE has implemented forward operator for hydrometeoric PRO. This is applicable for leo-leo techniques.

Commercial Data Buy

- **<u>Encourage CGMS to coordinate purchase of commercial RO data</u>**
- Current status
  - EUMETSAT, NOAA, NASA and DoD
- Progress since IROWG-09
  - NOAA RODB-02 is now in DO2

GNSS-RO and R

- Encourage the continued development of synergistic GNSS radio occultation and GNSS reflectometry.
- Current Status
  - GNSS-RO+R data now collected by Spire, and PiQ
  - GNSS-R now collected with grazing angle (RHCP) and near nadir reflections (LHCP)
    - GNSS NNR group is growing and is somewhat separated from RO community.
- Progress since IROWG-09
  - NOAA has OSW CWDP pilot evaluation ongoing
  - Lots of work for atmospheric, ionosphere, altimetry, water surface boundary mapping, water surface, ocean, inland water bodies, sea ice and some glaciers
  - CGMS recommended that GNSS-R methods participate in other CGMS groups (ocean surface winds and land surface)

Level-0 Data Format

- Formation of IROWG working group on “level0” data formats

- Current status
  - Nominal working group formed during IROWG-09
- Progress since IROWG-09
  - Not much, maybe a google drive

Residual Ionosphere Errors

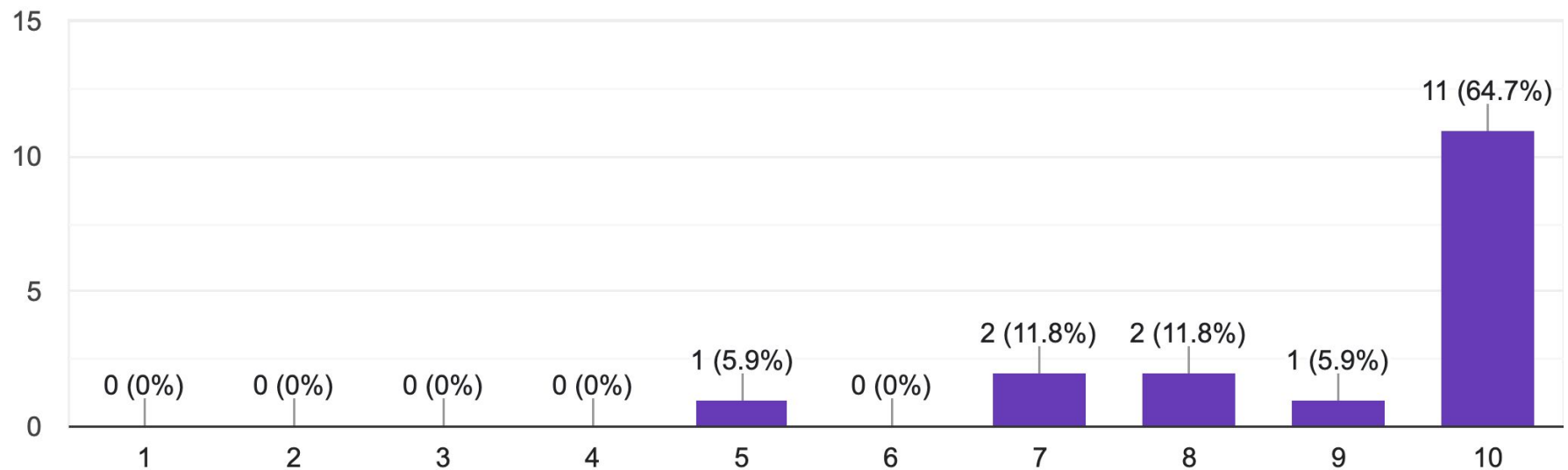
- Current status
- Progress since IROWG-09

Backup Slides

- Results from topic survey

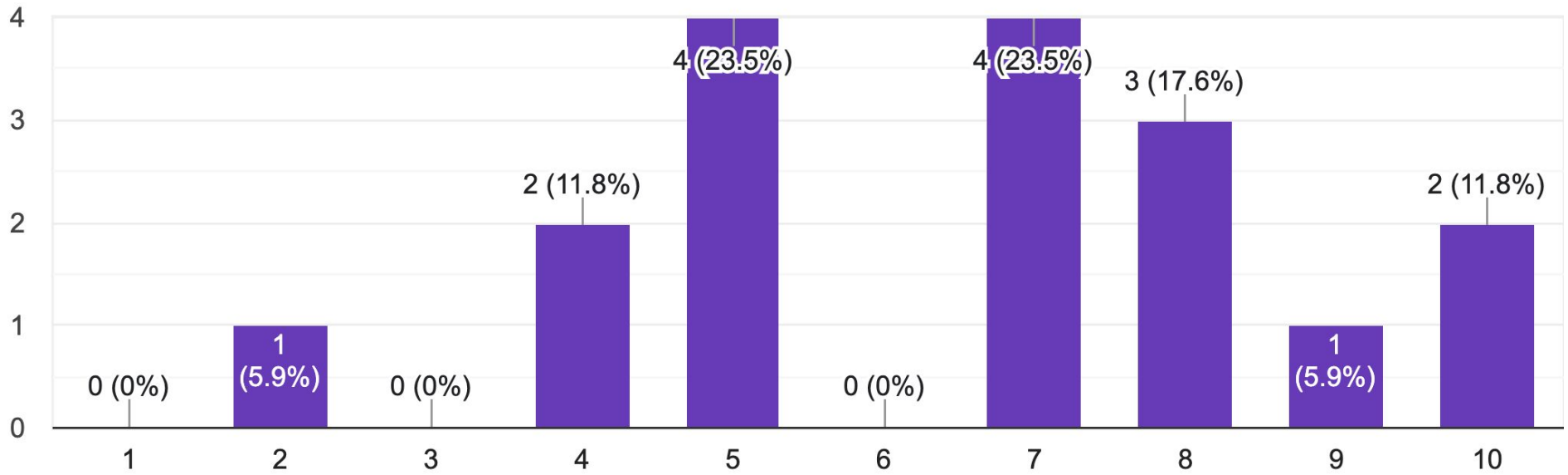
Encourage technology and retrieval developments for improving planetary boundary layer profiling from GNSS-RO and their utilization in NWP data assimilation

17 responses



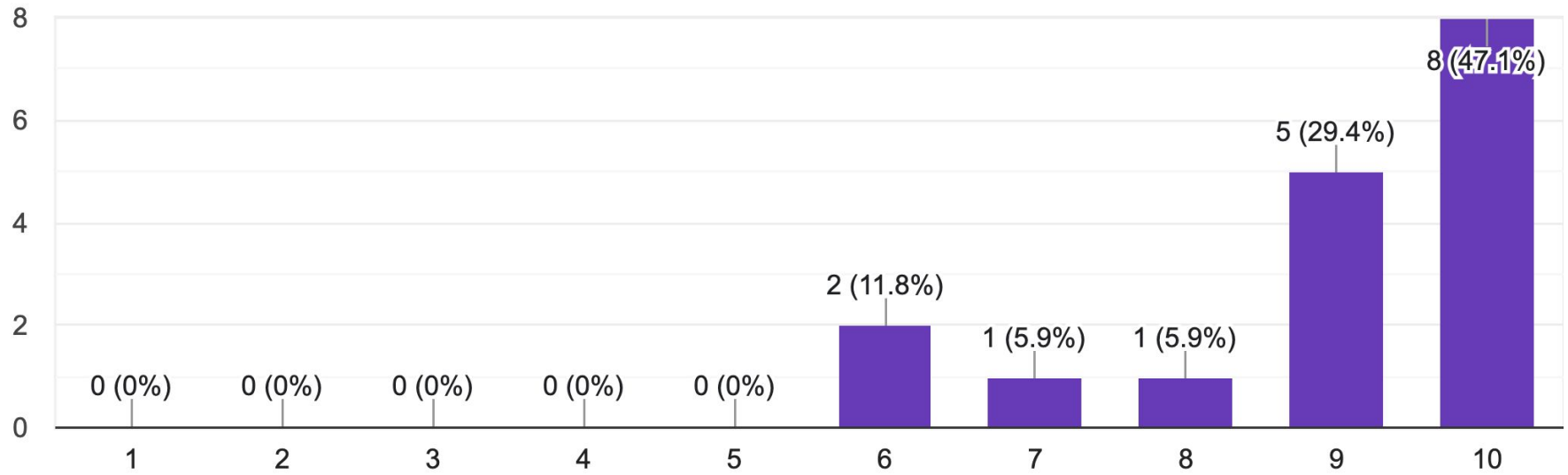
Advance LEO-LEO occultation development towards a demonstration mission

17 responses



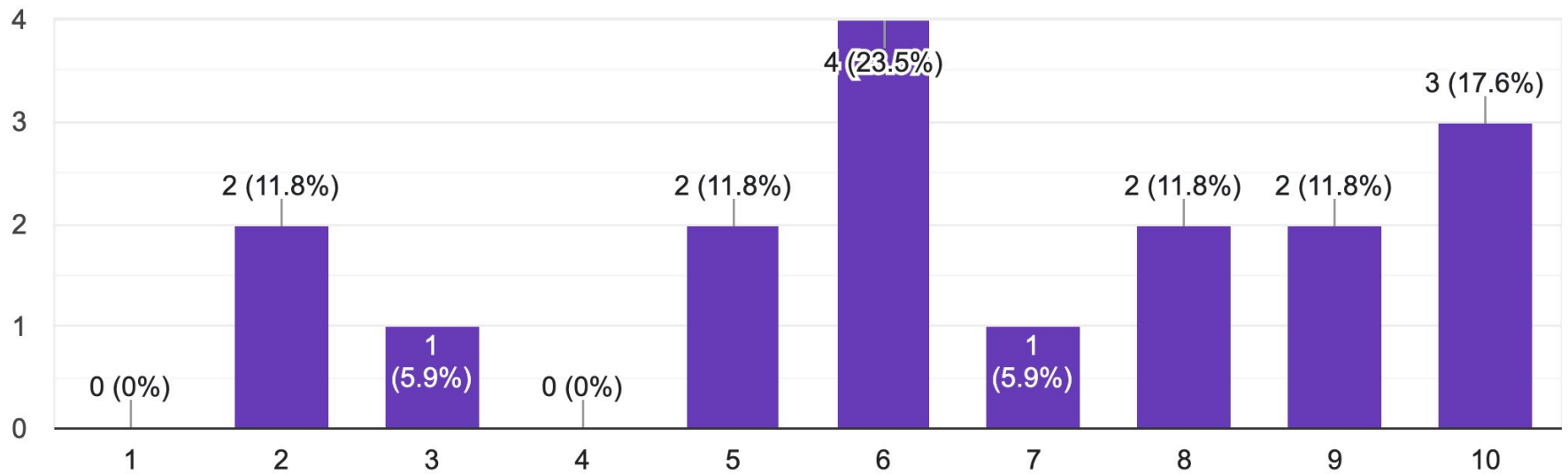
Promote development of Polarimetric RO observations (orbital and airborne) and exploitation of those observations

17 responses



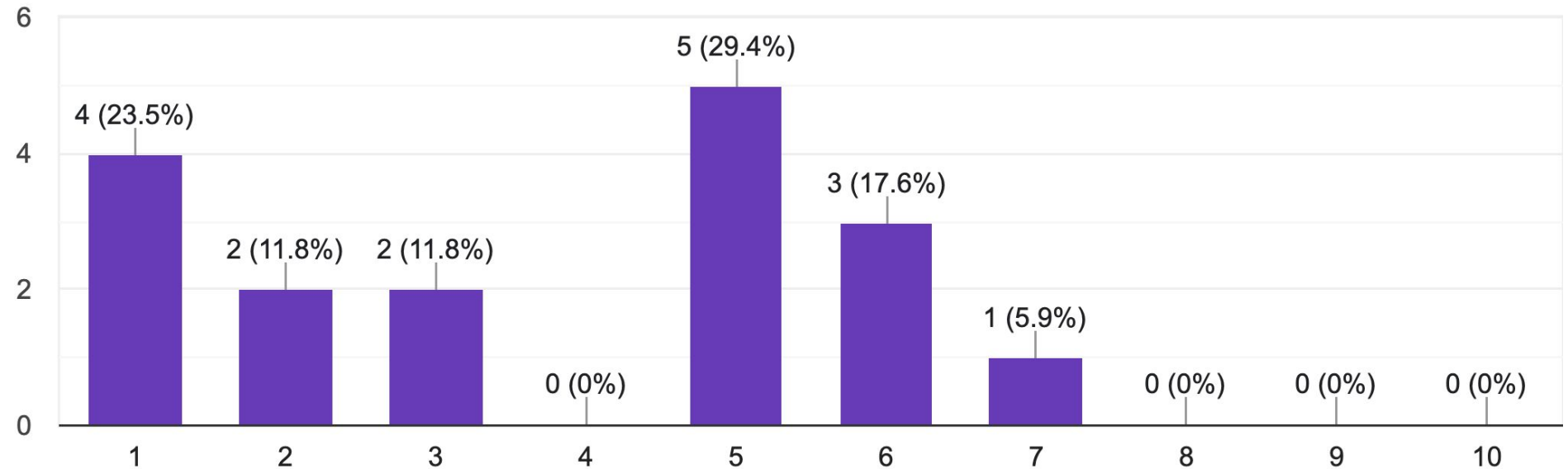
Encourage the continued development of synergistic GNSS radio occultation and GNSS reflectometry.

17 responses



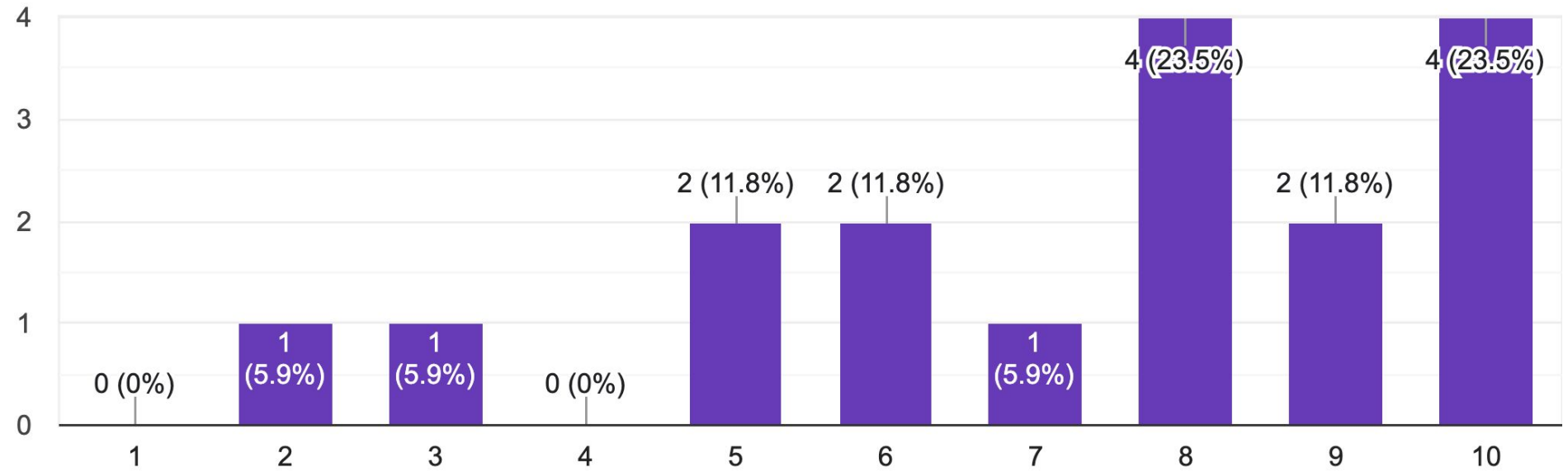
Formation of IROWG working group on “level0” data formats

17 responses



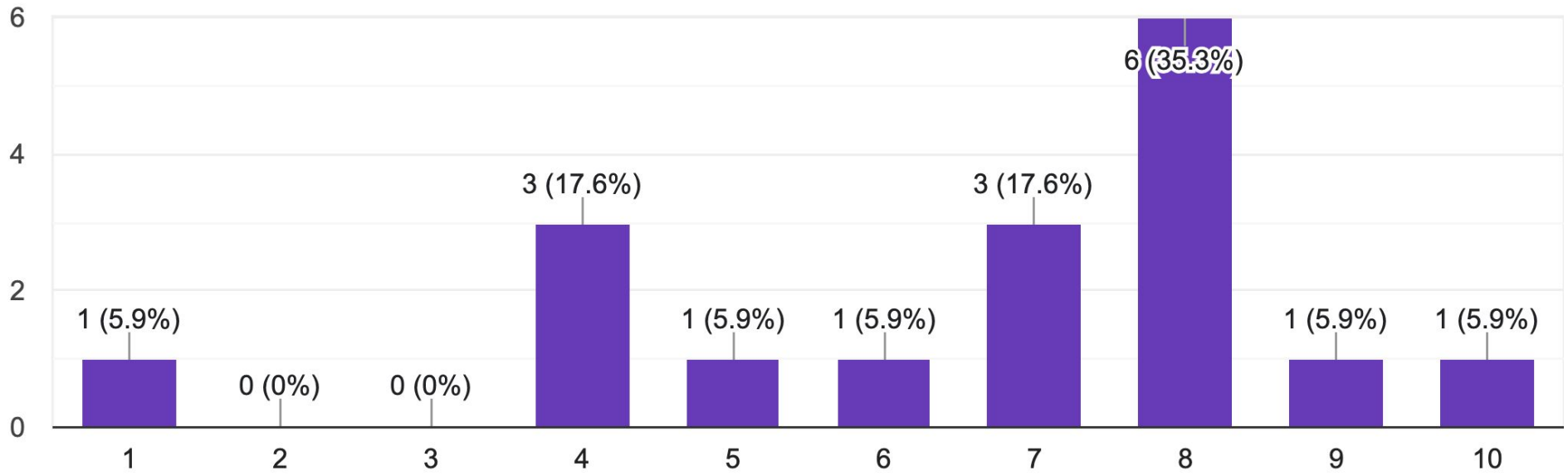
Develop GNSS observations from airborne platforms for operations and testing new technology

17 responses



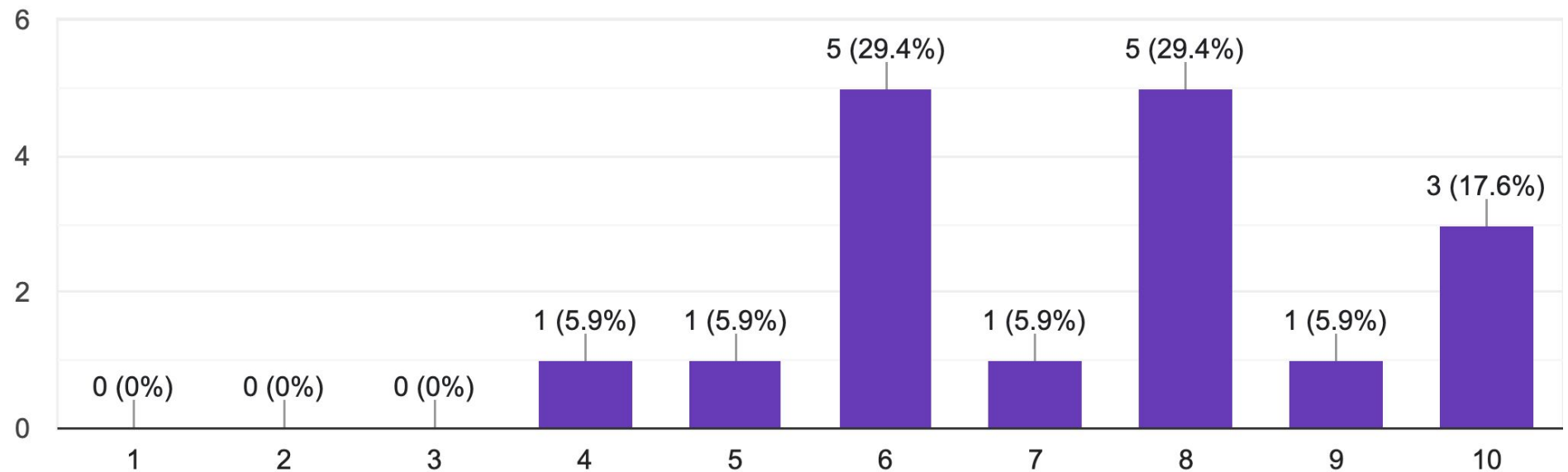
Encourage CGMS to coordinate purchase of commercial RO data

17 responses



Identify Radio Frequency Interference (RFI) sources and develop strategies for mitigation

17 responses



Improve residual ionosphere correction for GNSS-RO