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

IROWG-10

Boulder, CO

2024/09/18

Attendees

Rob Kursinski (PlanetiQ, USA), John Braun (UCAR, USA)
Ramon Padulles (ICE/CSIC-IEEC, Spain), Estel Cardellach (ICE/CSIC-IEEC, Spain),
Feiqin Xie (TAMU-CC, USA), Kuo-Nung (Eric) Wang (JPL, USA),
Stig Syndergaard (DMI, Denmark), Chi Ao (JPL, USA),
Jade Morton (CU, USA), Josef Innerkofler (WEGC/UniGraz, Austria),
Tom Meehan (JPL, USA), Garth Franklin (JPL, USA),
Franciois Vandenberghe, (JCSDA, USA), Kate Lord (SIO, USA),
Noah Barton (SIO,USA), Kuo-Nung (Eric) Wang (JPL, USA),
Anitia Paz (ICE/CSIC-IEEC, Spain), Bing Cao (SIO, USA),
Ming Chen (University of Maryland, USA), Yong Chen (NOAA, USA),
Guojuan Gu (UMD, USA)

Summary

- Working group unanimously voted to remain a group (17 votes)
- Also voted to change name to “Innovation” (14 yes, 3 no)
- Participants would like to sit in on meetings of the other 3 groups

- 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 ionosphere correction,
  - level0 data format

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

Planetary Boundary Layer (PBL)

- Current Status
  - NWP use of RO data in lower troposphere is still limited, discarding most of the data in the PBL
- 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 a PBL research group
  - Seven related oral presentations at IROWG-10 (Monday afternoon and Tuesday morning) from Zhen, Xie, Wang, Ao, Syndergaard, Vannah, Kursinski
  - Multiple posters also presented
- Future needs and recommendations
  - Encourage development and implementation of GNSS-RO observations and retrieval techniques to improve profiling of the PBL including improved knowledge of their uncertainty.
  - Encourage development and implementation of data assimilation methods that will enable NWP systems to better leverage and utilize those PBL observations including their representativeness uncertainty.
  - Encourage an intercomparison project for lower troposphere/PBL observations (following a model of ROTrends).
    - Rob Kursinski and Chi Ao volunteered to further investigate this in collaboration with the NWP and climate sub-groups.

Polarimetric Radio Occultation (PRO)

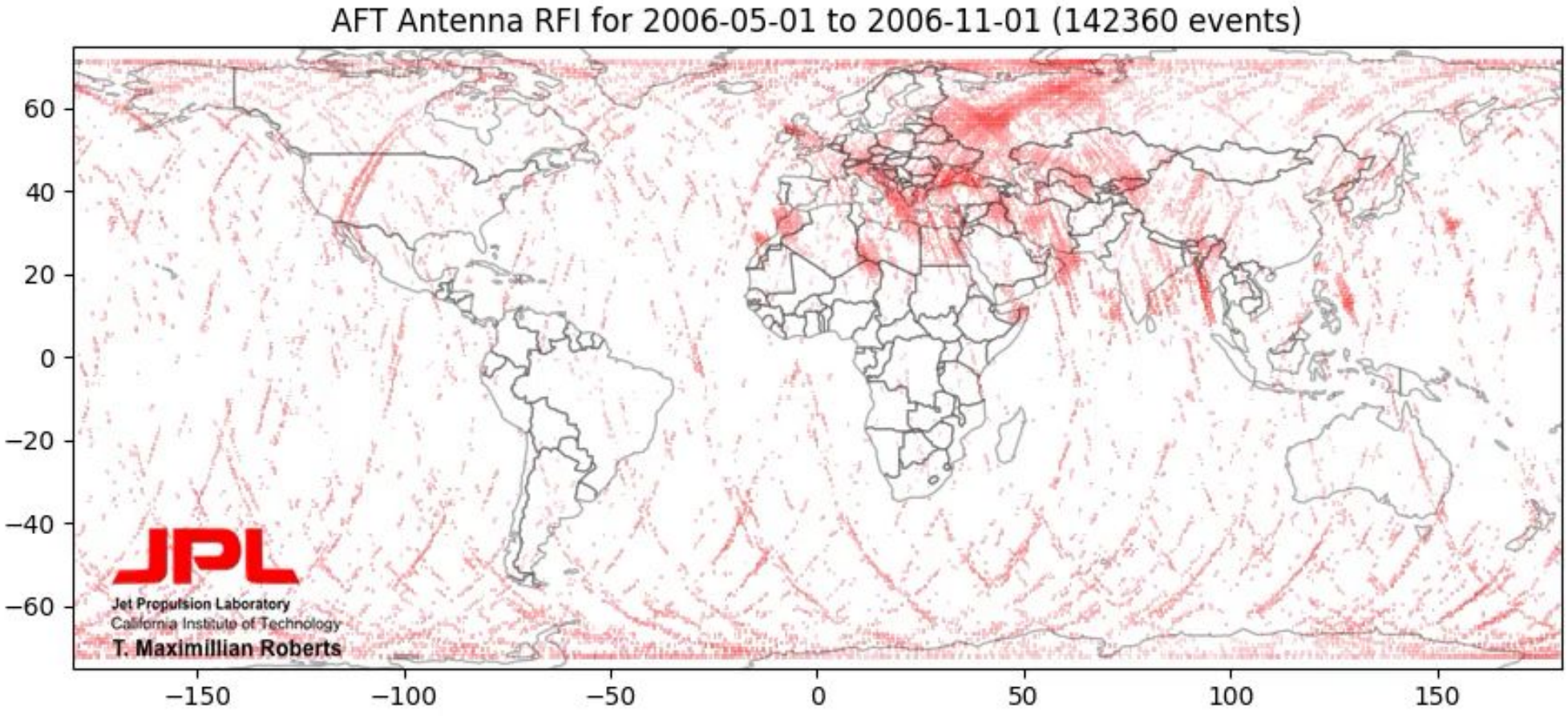
- Promote development of Polarimetric RO observations (orbital and airborne) and retrievals and use of those observations
- Current Status
  - PRO data now collected by PAZ, Spire, and PiQ but only some of this data is available to everyone
- Progress since IROWG-09
  - Cal-Tech workshop hosted workshop 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 Haleakala, Maui, Hawaii collecting baseband data for past few years, for mountain top RO.
  - Simple forward operators have been developed, including ECMWF, ICE
  - PlanetiQ now measuring 1100+ PRO per day and doubling that via next launch in 1st qtr 2025
- Recommendations
  - See draft of Cardellach et al report from PRO working group
  - Develop forward operator to use in NWP systems to enable a NOAA pilot

High Priority Recommendations

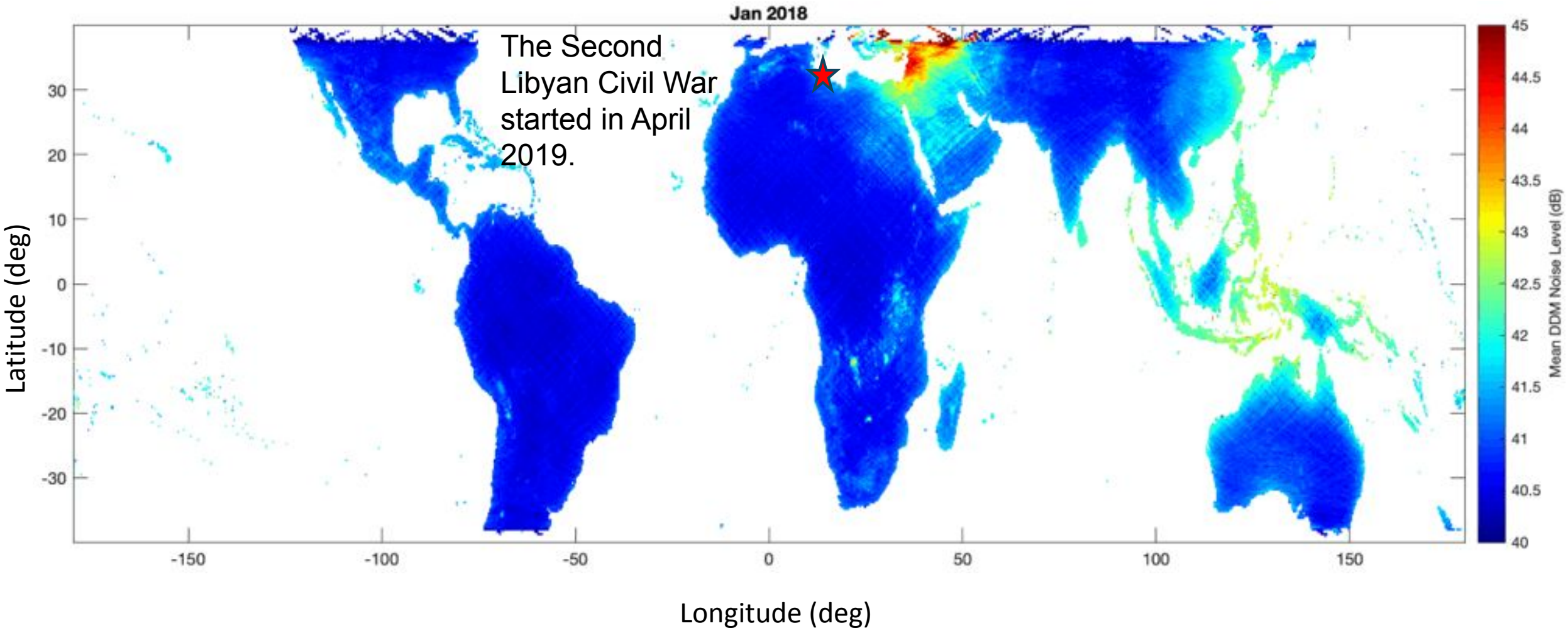
RFI

- 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
- Recommendation
  - Identify and develop methods to identify RFI and approaches to mitigate the effects of RFI

RFI: 2006-2018



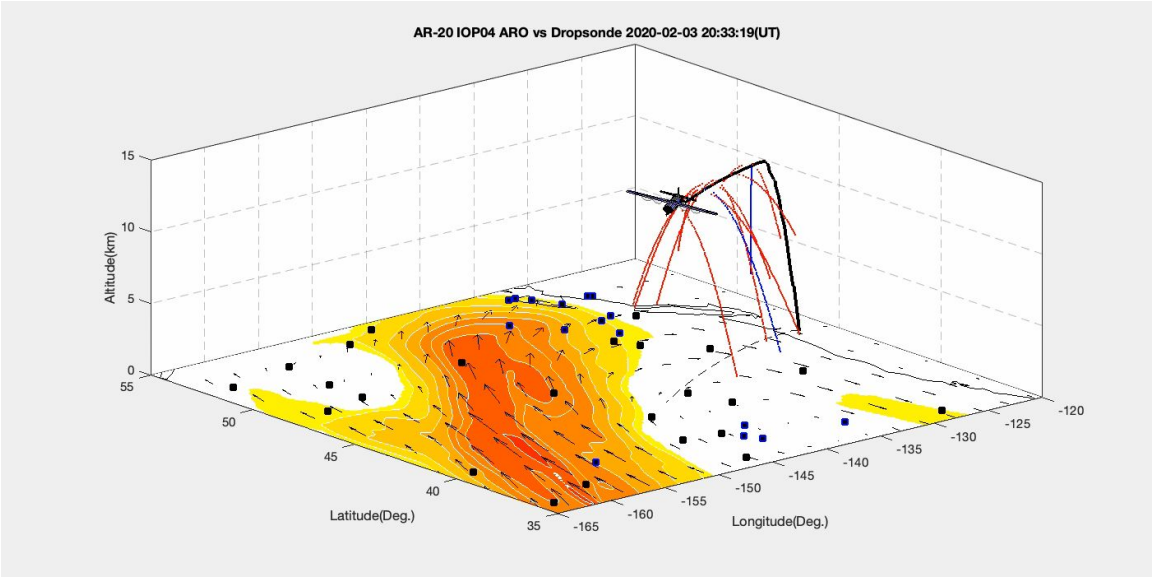
RFI Mapping Using CYGNSS Satellites (CU)



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.

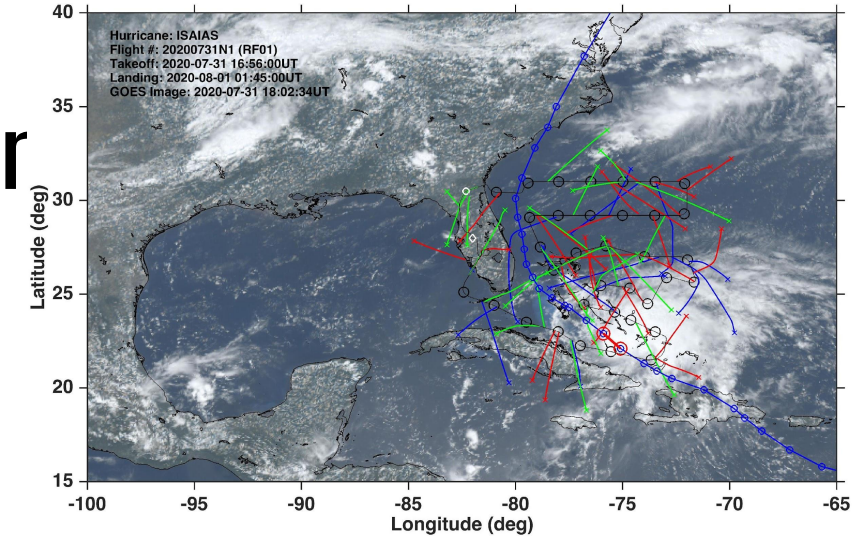
From Jade Morton

Airborne Radio Occultation

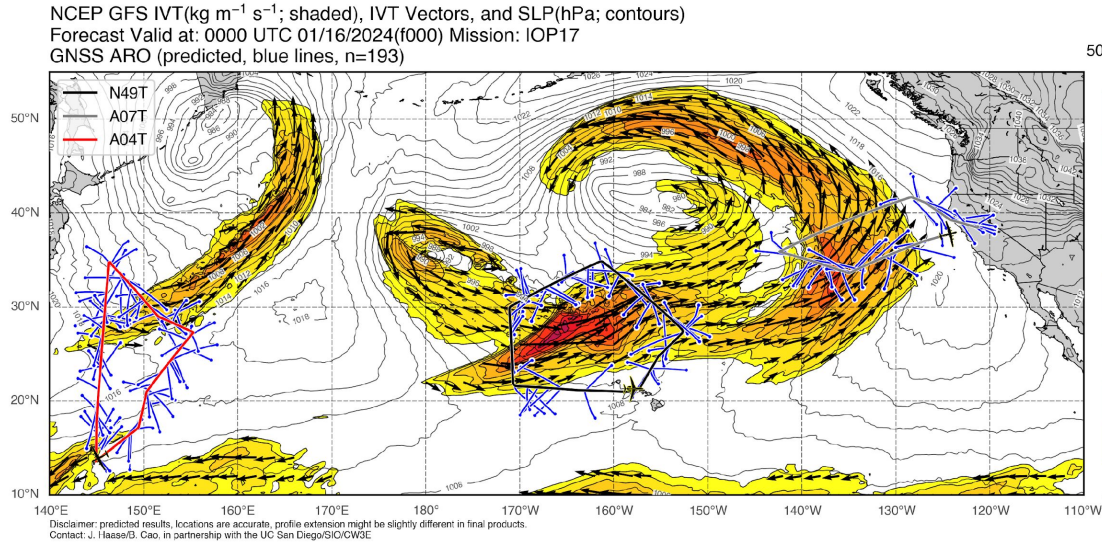


- ARO profiles are densely distributed over the targeted areas.
- Slanted ARO profiles (blue/red) extend the aircraft sensing area from underneath (by dropsondes) toward sideways.

J. Haase, B. Cao and the ARO team at UCSD/SIO



- ARO covers the larger environment around hurricane during one synoptic-survey flight.



- ARO from multiple aircraft captures Pacific basin-wide atmosphere rivers.

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 sounding of mid-troposphere from commercial planes (Xie et al., 2024)”
- 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

Reference:

Xie F., Nelson, K. J., Chan, B. C., Goel, A., Kosh, J., & Vergalla, M. (2024): First Results of Airborne GNSS Radio Occultation Sounding from Airbus Commercial Aircraft, *Geophy. Res. Lett.*, 51, e2024GL110194. https://doi.org/10.1029/2024GL110194

LEO-LEO

- Encourage International space agencies (in particular NASA, ESA and CAS, where LEO-LEO proposals were pending) to support mission preparation and implementation projects towards LEO-LEO microwave occultation demonstration missions.
- Progress since IROWG-09 and current status
  - Limited progress since IROWG 9
  - Chinese administration had mission proposal, which was not funded.
  - Wegener Center/ROM SAF postponed work on forward operator for LEO-LEO.
  - JPL has worked on LEO-LEO technique supported by NASA decadal survey PBL incubation and internal JPL project to demonstrate transmit/receive capability with SDR
    - Eric Wang has developed forward simulation operator (FSO)
  - PIQ sang the praises about very innovative LEO-LEO technology in RFI response to NOAA (hallelujah)
  - ICE has implemented forward operator for hydrometeoric PRO which is applicable for LEO-LEO frequencies.
- Recommendations
  - Recommend development of NWP-compatible forward operator and perform OSSEs & EDAs for LEO-LEO observations.

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 DO4
- Need to stabilize the price and quantities to be purchased

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 using Spire data
  - 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)

Residual Ionosphere Errors

- Current status
  - Didn’t discuss much
  - Ionospheric scintillations during solar maximum are degrading RO profiles of the atmosphere
  - Solar storm in May 2024 degraded the occultation processing causing many profiles to not pass QC.
- Progress since IROWG-09
  - Awareness that ionosphere during solar maximum can degrade neutral atmosphere
- Recommendations
  - Identify ways in which ionosphere can degrade neutral atmosphere profiles
  - Identify potential approaches to mitigate that degradation

Level-0 Data Format

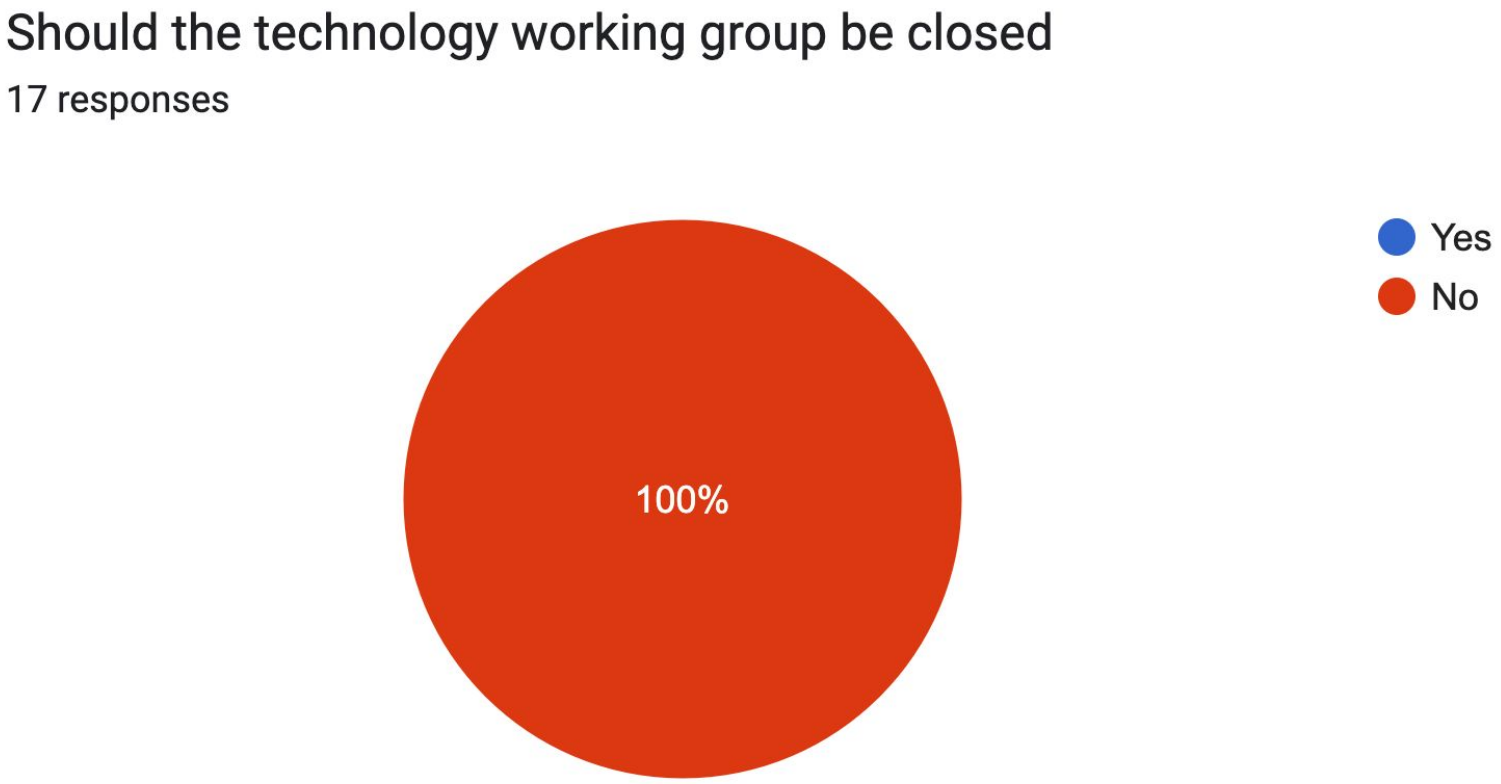
- Formation of IROWG working group on “level0” data formats

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

Backup Slides

- Results from topic survey

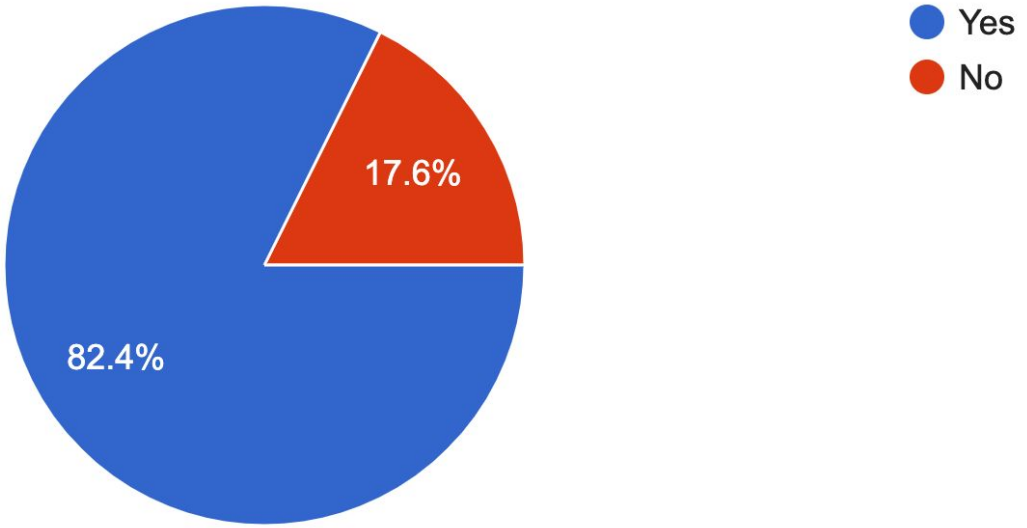
Should the technology working group be closed?



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



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

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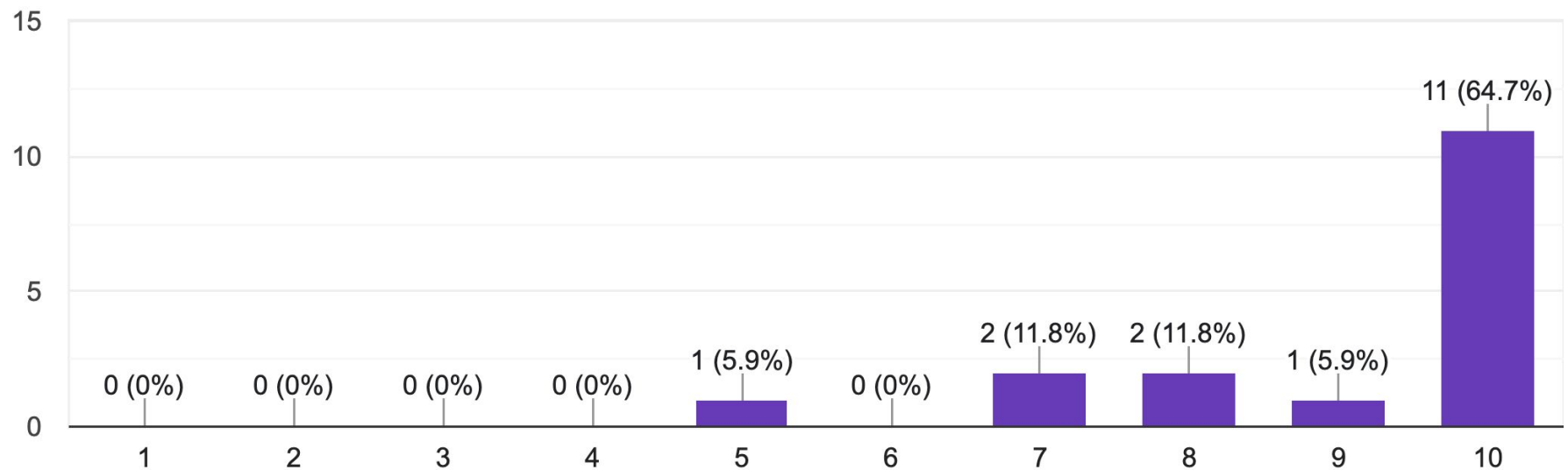
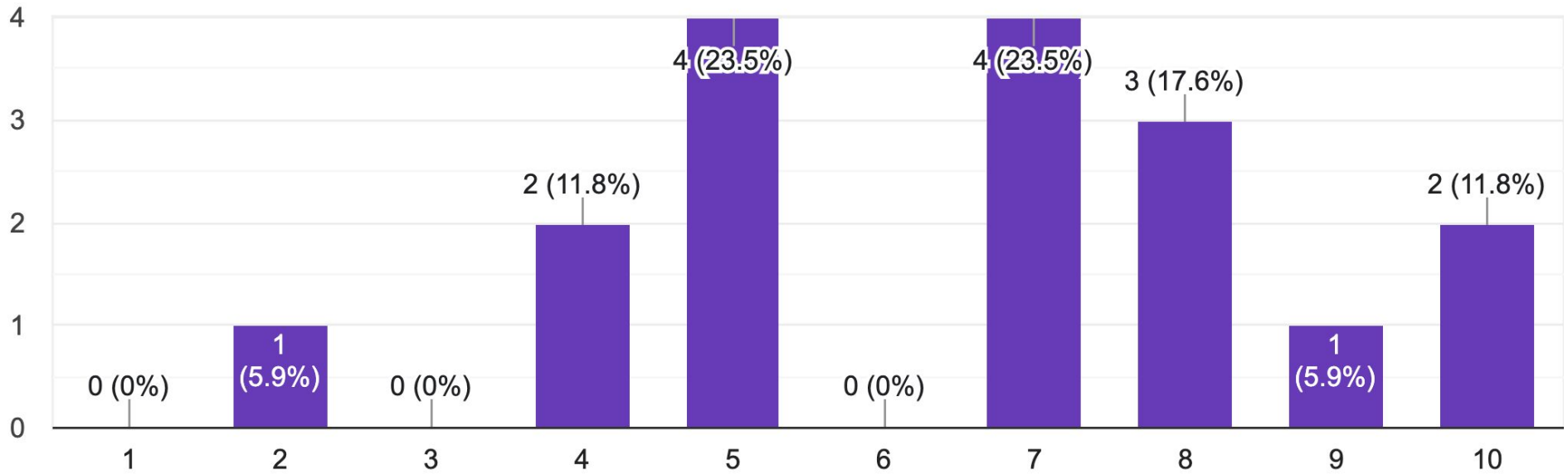


Advance LEO-LEO occultation development towards a demonstration mission

17 responses



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

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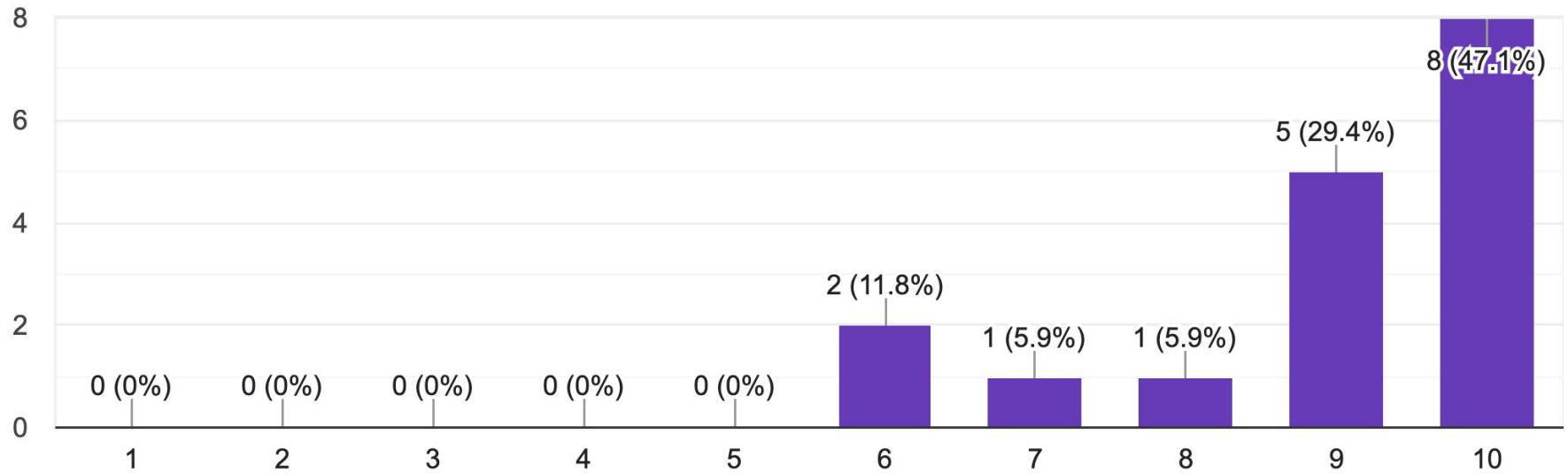
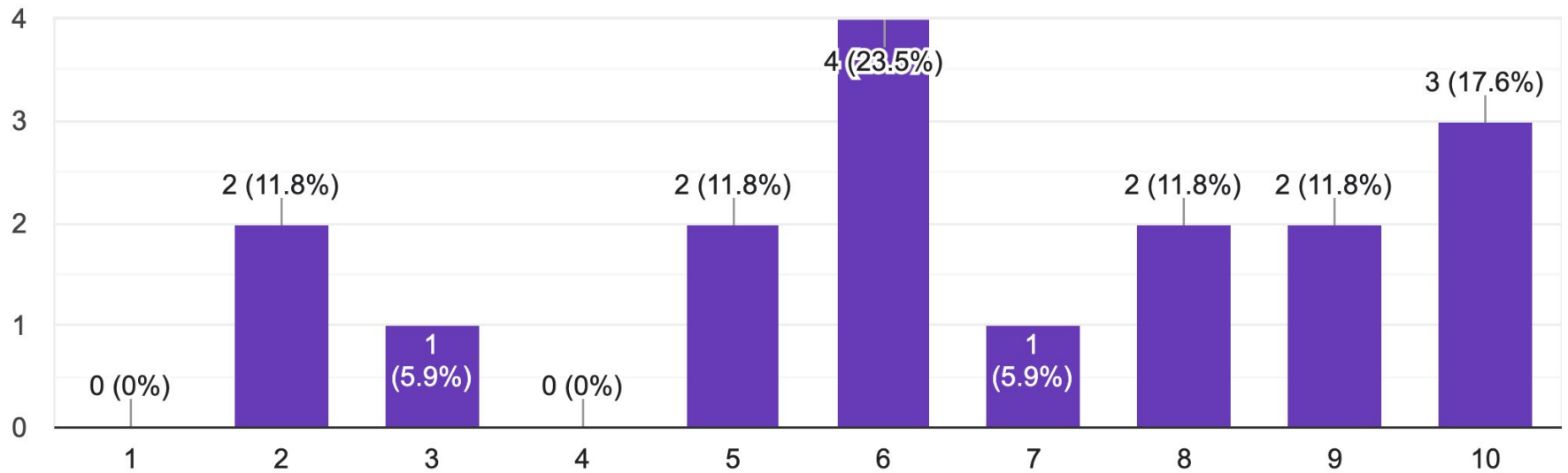


Encourage the continued development of synergistic GNSS radio occultation and GNSS reflectometry.

17 responses



Formation of IROWG working group on “level0” data formats

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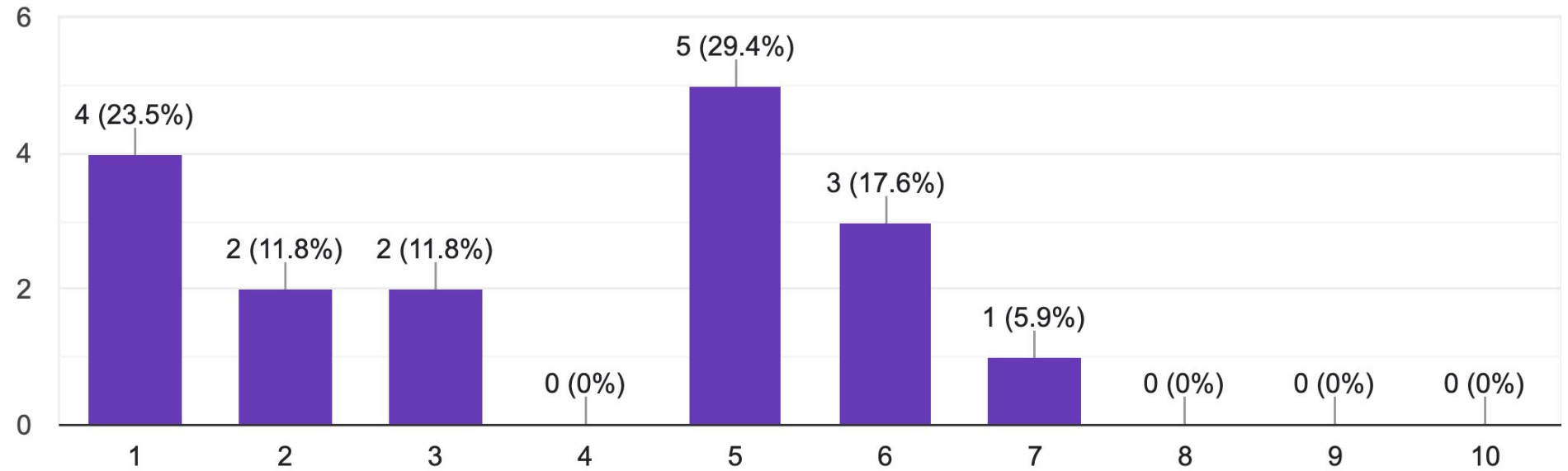

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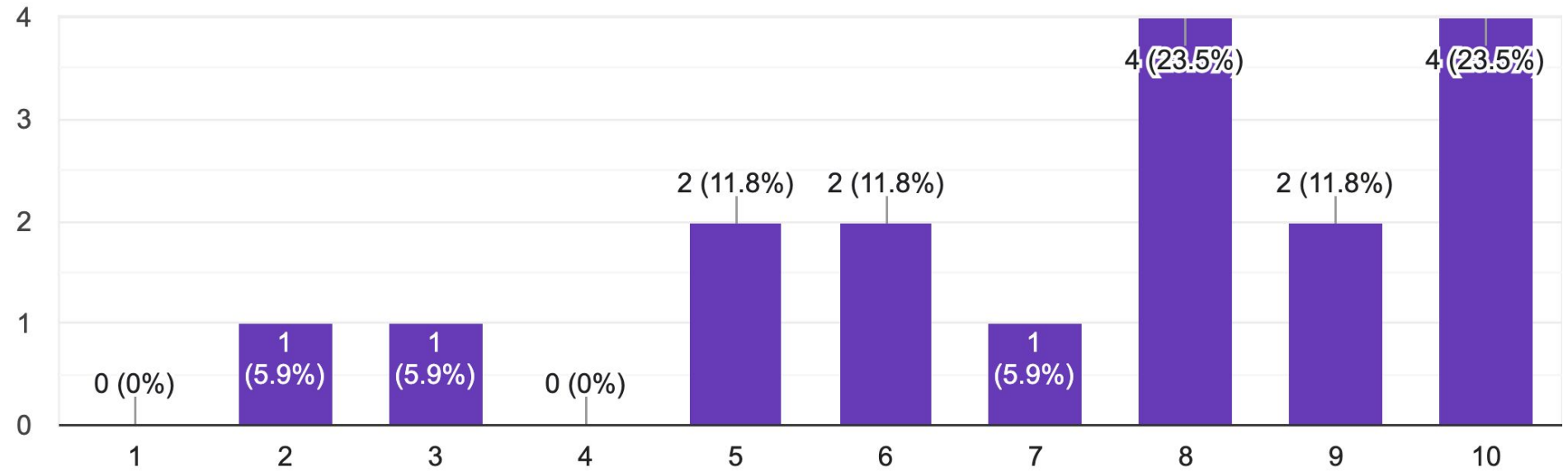

Encourage CGMS to coordinate purchase of commercial RO data

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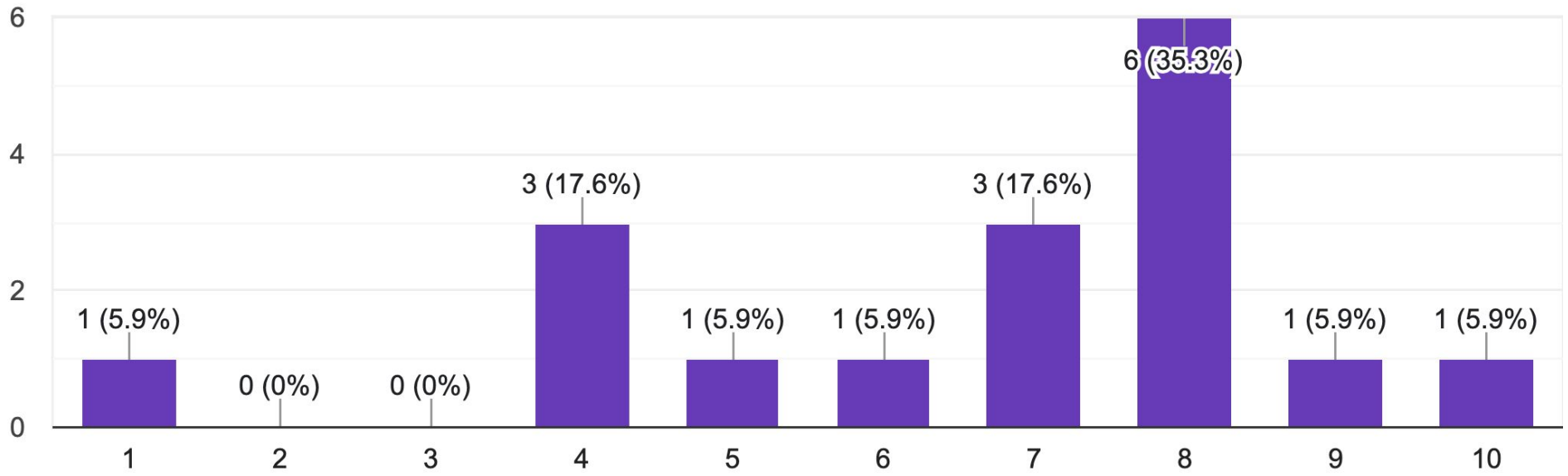
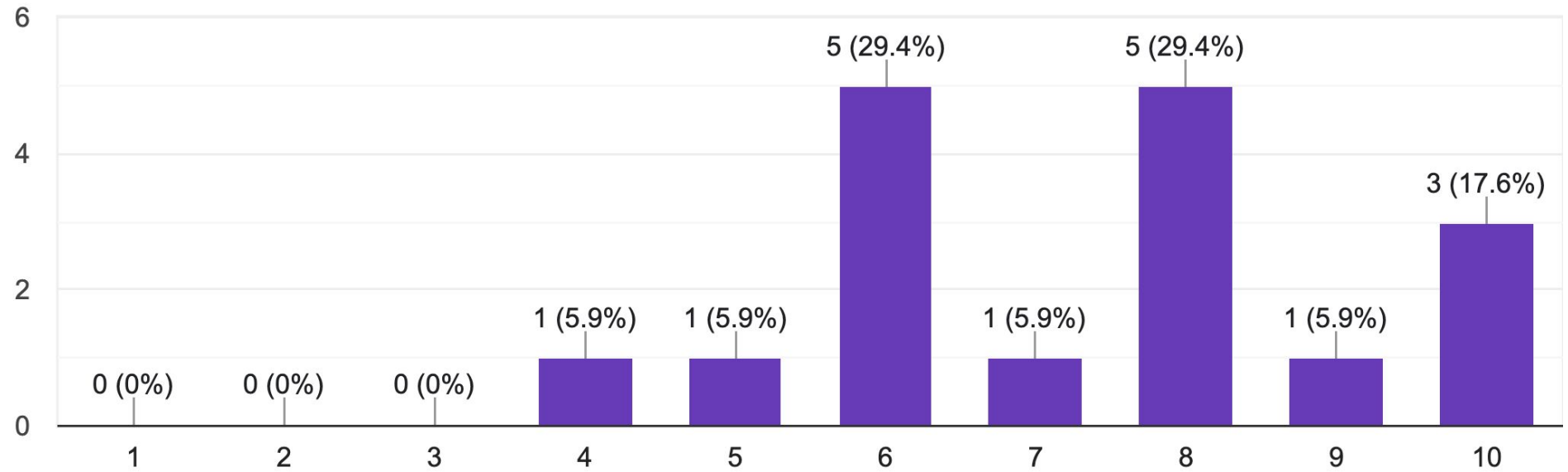


Identify Radio Frequency Interference (RFI) sources and develop strategies for mitigation

17 responses



Improve residual ionosphere correction for GNSS-RO