Ionosphere Variability I: Advances in observational, monitoring and detection capabilities

Paper outline (Preliminary)

Abstract

1. Introduction

Introduction to the objectives of the paper - link to SW roadmap considerations relevant to ionospheric observations/monitoring/detection:

- Observational coverage
- Quantify the vulnerability of technological infrastructure to space weather phenomena jointly with the stakeholder groups
- Standardization of (meta-) data and product metrics - Harmonized (online) access to data.

2. Ionospheric Observations

This sections aims at discussing experimental infrastructure available for observing the ionospheric ionization in the Earth's ionosphere including both ground- and space-based instruments. The discussion shall highlight new installations, new or upgraded instrumentation, as well as new or upgraded observational network establishments. The emphasis will be given in recent developments (2015 - present) with references in the previous SW roadmap (Schrijver et al. 2015).

2.1 Ground-based experiments

Potential contribution from

- Ionosondes, ISRs, GNSS, HF radars, SuperDARN, EISCAT (EISCAT 3D+)
- Data from high frequency (HF) amateur radio reporting networks
- LOFAR

2.2 Space-based experiments

Recent missions: COSMIC-2 radio occultation; Swarm; ICON; ...

3. Ionospheric Indices and Scales

Ionospheric indices and scales as powerful tools for ionospheric monitoring and detection purposes - they are highly appreciated in user-oriented applications. Special attention to results established by gathering together the scientific and users' communities.

4. Access to facilities and data

This section aims to discuss topics relevant to data availability/access - Ongoing initiatives that aim to facilitate improvements in the access to ionospheric research facilities and data sources.

- Standardization of (meta) data - Harmonized access to near-Earth space data: ontology and data models / e-science applications
- Ionospheric data quality issues

5. Discussion and Conclusions

Discussion of the results to identify progress/gaps and make suggestions for future actions as input to

- G2B second paper
- Tier 3, 4 papers

References

1. Alfonsi, L., Cilliers, P. J., Romano, V., Hunstad, I., Correia, E., Linty, N., ... & Riley, P. (2016). First observations of GNSS ionospheric scintillations from DemoGRAPE project. *Space Weather*, *14*(10), 704-709.
2. Altadill, D., Segarra, A., Blanch, E., Juan, J. M., Paznukhov, V. V., Buresova, D., ... & Belehaki, A. (2020). A method for real-time identification and tracking of traveling ionospheric disturbances using ionosonde data: first results. Journal of Space Weather and Space Climate, 10, 2.
3. Anthes, R., & Schreiner, W. (2019). Six new satellites watch the atmosphere over Earth's equator. Eos, 100. https://doi.org/10.1029/2019EO131779
4. Araujo-Pradere, E., Weatherhead, E. C., Dandenault, P. B., Bilitza, D., Wilkinson, P., Coker, C., ... & Paznukhov, V. (2019). Critical issues in ionospheric data quality and implications for scientific studies. Radio Science, 54(5), 440-454.
5. Borries Claudia, Volker Wilken, Knut Stanley Jacobsen, Alberto García-Rigo, Beata Dziak-Jankowska, GuramKervalishvili, Norbert Jakowski, IoannaTsagouri, Manuel Hernández-Pajares, Arthur A. Ferreira, Mainul M. Hoque Erratum to “Assessment of the capabilities and applicability of ionospheric perturbation indices provided in Europe” [Adv. Space Res. 66 (2020) 546–562] Advances in Space Research, Volume 67, Issue 2, 15 January 2021, Pages 919-920
6. Belehaki Anna, IoannaTsagouri, David Altadill, Estefania Blanch, Claudia Borries, Dalia Buresova, Jaroslav Chum, Ivan Galkin, José Miguel Juan, Antoni Segarra, Cristhian Camilo Timoté, Kostas Tziotziou, Tobias G. W. Verhulst and Jurgen Watermann, An overview of methodologies for real-time detection, characterisation and tracking of traveling ionospheric disturbances developed in the TechTIDE project, J. Space Weather Space Clim., 10 (2020) 42, DOI: https://doi.org/10.1051/swsc/2020043
7. Belehaki, A., S. James, M. Hapgood, S. Ventouras, I. Galkin, A. Lembesis, I. Tsagouri, A. Charisi, L. Spogli, J. Berdermann, and I. Häggström (2016), The ESPAS e-infrastructure: Access to data from near-Earth space, Adv. Space Res. 58, 1177– 1200, doi:10.1016/j.asr.2016.06.014.
8. Belehaki, A., Reinisch, B., Galkin, I., Altadill, D., Buresova, D., Francis, M., ... & Stankov, S. (2015, May). Pilot network for identification of travelling ionospheric disturbances. In Proceedings of the 14th International Ionospheric Effects Symposium (pp. 284-291).

9. Béniguel, Y., Cherniak, I., Garcia-Rigo, A., Hamel, P., Hernández-Pajares, M., Kameni, R., Kashcheyev, A., Krankowski, A., Monnerat, M., Nava, B., Ngaya, H., Orus-Perez, R., Secrétan, H., Sérant, D., Schlüter, S., and Wilken, V.: MONITOR Ionospheric Network: two case studies on scintillation and electron content variability, Ann. Geophys., 35, 377–391, https://doi.org/10.5194/angeo-35-377-2017, 2017.
10. Béniguel, Y. (2019). Ionospheric scintillations: Indices and modeling. Radio Science, 54, 618–632. https://doi.org/10.1029/2018RS006655
11. Cesaroni, C., Spogli, L., Alfonsi, L., De Franceschi, G., Ciraolo, L., Monico, J. F. G., ... &Bougard, B. (2015). L-band scintillations and calibrated total electron content gradients over Brazil during the last solar maximum. Journal of Space Weather and Space Climate, 5, A36.
12. Chilcote, M., LaBelle, J., Lind, F. D., Coster, A. J., Miller, E. S., Galkin, I. A., & Weatherwax, A. T. (2015). Detection of traveling ionospheric disturbances by medium-frequency Doppler sounding using AM radio transmissions. Radio Science, 50(3), 249-263.
13. Ferreira Arthur Amaral , Claudia Borries, Chao Xiong, Renato Alves Borges, Jens Mielich, Daniel Kouba, Identification of potential precursors for the occurrence of Large-Scale Traveling Ionospheric Disturbances in a case study during September 2017, J. Space Weather Space Clim. 10 32 (2020), DOI: 10.1051/swsc/2020029
14. Frissell, N. A., Baker, J. B., Ruohoniemi, J. M., Greenwald, R. A., Gerrard, A. J., Miller, E. S., & West, M. L. (2016). Sources and characteristics of medium-scale traveling ionospheric disturbances observed by high-frequency radars in the North American sector. Journal of Geophysical Research: Space Physics, 121(4), 3722-3739.
15. Frissell, N. A., Kaeppler, S. R., Sanchez, D. F., Perry, G. W., Engelke, W. D., Erickson, P. J., ... & West, M. L. (2022). First Observations of Large Scale Traveling Ionospheric Disturbances Using Automated Amateur Radio Receiving Networks. Geophysical Research Letters, e2022GL097879
16. Galkin, I., Froń, A., Reinisch, B., Hernández-Pajares, M., Krankowski, A., Nava, B., ... & Batista, I. (2022). Global Monitoring of Ionospheric Weather by GIRO and GNSS Data Fusion. Atmosphere, 13(3), 371.
17. Ghobadi, H., Spogli, L., Alfonsi, L., Cesaroni, C., Cicone, A., Linty, N., ... &Cafaro, M. (2020). Disent angling ionospheric refraction and diffraction effects in GNSS raw phase through fast iterative filtering technique. GPS Solutions, 24(3), 1-13.
18. Gulyaeva, T.L., Arikan, F., Sezen, U., Poustovalova, L.V. Eight proxy indices of solar activity for the International Reference Ionosphere and Plasmasphere model. J. Atmos. Solar-Terr. Phys., 172, 122-128, https://doi.org/10.1016/j.jastp.2018.03.025, 2018.
19. Guo, Q., Zheng, Y., Chernogor, L. F., Garmash, K. P., & Rozumenko, V. T. (2019, July). Passive HF Doppler radar for oblique-incidence ionospheric sounding. In 2019 IEEE 2nd Ukraine Conference on Electrical and Computer Engineering (UKRCON) (pp. 88-93). IEEE.
20. Ho, S.-P., Anthes, R.A., Ao, C.O., Healy, S., Horanyi, A., Hunt, D., Mannucci, A.J., Pedatella, N., Randel, W.J., Simmons, A., Steiner, A., Xie, F., Yue, X. & Zeng, Z. (2019). The COSMIC-FORMOSAT-3 radio occultation mission after 12 years: Accomplishments, remaining challenges, and potential impacts of COSMIC-2 (2019). Bulletin of the American Meteorological Society, 100, online version: https://journals.ametsoc.org/doi/pdf/10.1175/BAMS-D-18-0290.1

21. Huba, J. D., Heelis, R., & Maute, A. (2021). Large-Scale O+ Depletions Observed by ICON in the Post-Midnight Topside Ionosphere: Data/Model Comparison. Geophysical Research Letters, 48(7), e2020GL092061.
22. Immel, T. J., England, S. L., Mende, S. B., Heelis, R. A., Englert, C. R., Edelstein, J., ... & Sirk, M. M. (2018). The ionospheric connection explorer mission: mission goals and design. Space Science Reviews, 214(1), 1-36.
23. Jakowski, N. and M. M. Hoque (2019) Estimation of spatial gradients and temporal variations of the total electron content using ground based GNSS measurements, Space Weather, Wiley. ISSN 1542-7390, doi: 10.1029/2018SW002119
24. Jayachandran, P.T., A.M. McCaffrey, Y. Wang, D.R. Themens, C. Watson, B. Reid, Q.-H. Zhang, and Z. Xing (2021), Global Positioning System (GPS) Scintillation Associated with a Polar Cap Patch, Remote Sensing, doi: 10.3390/rs13101915
25. Kero, J., Kastinen, D., Vierinen, J., Grydeland, T., Heinselman, C. J., Markkanen, J., & Tjulin, A. (2019). EISCAT 3D: the next generation international atmosphere and geospace research radar.
26. Kriegel, Martin und Jakowski, Norbert und Berdermann, Jens und Sato, Hiroatsu und Wassaie Mersha, Mogese (2017) Scintillation measurements at Bahir Dar during the high solar activity phase of solar cycle 24. Annales Geophysicae. 35, 97–106
27. Koustov, A. V., P.V. Ponomarenko, C.J. Graf, R.G. Gillies, and D.R. Themens (2018). Optimal F region electron density for the PolarDARN radar echo detection near the Resolute Bay zenith. Radio Science, 53, 1002–1013. doi: 10.1029/2018RS006566
28. Mainvis A. and V. Fabbro, "Detection and Characterization of Ionospheric Activity at High Latitude from SAR Measurements," IGARSS 2020 - 2020 IEEE International Geoscience and Remote Sensing Symposium, 2020, pp. 5446-5449, doi: 10.1109/IGARSS39084.2020.9323568.
29. Mersha, M. W., Lewi, E., Jakowski, N., Wilken, V., Berdermann, J., Kriegel, M., &Damtie, B. (2020) A method for automatic detection of plasma depletions by using GNSS measurements. Radio Science, 55, https://doi.org/10.1029/2019RS006978
30. McCaffrey, A. M., P.T. Jayachandran, D.R. Themens, and R.B. Langley (2017). GPS Code Bias Estimation: A Comparisons of Two Methods, Advances in Space Research, 59(8), doi: 10.1016/j.asr.2017.01.047
31. Mushini, S. C., Skone, S., Spanswick, E., Donovan, E., &Najmafshar, M. (2018) Proxy index derived from All Sky Imagers for space weather impact on GPS. Space Weather, 16, 838–848. https://doi.org/10.1029/2018SW001919
32. Nishitani, N., Ruohoniemi, J.M., Lester, M. et al. Review of the accomplishments of mid-latitude Super Dual Auroral Radar Network (SuperDARN) HF radars. Prog Earth Planet Sci 6, 27 (2019). https://doi.org/10.1186/s40645-019-0270-5
33. Nykiel G., Zanimonskiy Y.M., Yampolski Y.M., Figurski M. (2017) Efficient Usage of Dense GNSS Networks in Central Europe for the Visualization and Investigation of Ionospheric TEC Variations. Sensors, 17(10):2298, DOI: 10.3390/s17102298
34. Nykiel G., Zanimonskiy Y., Koloskov A., Figurski M. (2019) The possibility of estimating the height of the ionospheric inhomogeneities based on TEC variations maps obtained from dense GPS network, Advances in Space Research, Vol. 64, Issue 10, 2002-2011 pp. DOI: 10.1016/j.asr.2019.06.008

35. Nykiel G., Zanimonskiy Y.M., Yampolski Y.M., Figurski M. (2017) Efficient Usage of Dense GNSS Networks in Central Europe for the Visualization and Investigation of Ionospheric TEC Variations. Sensors, 17(10):2298, DOI: 10.3390/s17102298
36. Pignalberi, A., Pezzopane, M., Rizzi, R., & Galkin, I. (2018). Effective solar indices for ionospheric modeling: a review and a proposal for a real-time regional IRI. Surveys in geophysics, 39(1), 125-167.
37. Reinisch, B., Galkin, I., Belehaki, A., et al.(2018). Pilot ionosonde network for identification of traveling ionospheric disturbances. Radio Science, 53,365–378. https://doi.org/10.1002/2017RS006263
38. Sato H., H., M. T. Rietveld, M.T., Jakowski, N. (2021) GLONASS observation of artificial field-aligned plasma irregularities near magnetic zenith during EISCAT HF experiment, GRL, https://doi.org/10.1029/2020GL091673
39. Sato, H., Kim, J. S., Jakowski, N., & Häggström, I. (2018). Imaging high-latitude plasma density irregularities resulting from particle precipitation: spaceborne L-band SAR and EISCAT observations. Earth, Planets and Space, 70(1), 1-8.
40. Spogli, L., Ghobadi, H., Cicone, A., Alfonsi, L., Cesaroni, C., Linty, N., ... & Cafaro, M. (2021). Adaptive Phase Detrending for GNSS Scintillation Detection: A Case Study Over Antarctica. IEEE Geoscience and Remote Sensing Letters.
41. Schreiner, W. S., Weiss, J. P., Anthes, R. A., Braun, J., Chu, V., Fong, J., et al. (2020). COSMIC-2 radio occultation constellation: First results. Geophysical Research Letters, 47, e2019GL086841. https://doi.org/10.1029/2019GL086841
42. Schrijver, Carolus J., et al. "Understanding space weather to shield society: A global road map for 2015–2025 commissioned by COSPAR and ILWS." Advances in Space Research 55.12 (2015): 2745-2807.
43. Themens, D. R., P. T. Jayachandran, and R. B. Langley (2015), The nature of GPS differential receiver bias variability: An examination in the polar cap region, J. Geophys. Res. Space Physics, 120, 8155–8175, doi:10.1002/2015JA021639.
44. Tveito, T., Vierinen, J., Gustavsson, B., and Narayanan, V. L.: Planetary radar science case for EISCAT 3D, Ann. Geophys., 39, 427–438, https://doi.org/10.5194/angeo-39-427-2021, 2021.
45. Verhulst, T., Altadill, D., Mielich, J., Reinisch, B., Galkin, I., Mouzakis, A., ... & Kouba, D. (2017). Vertical and oblique HF sounding with a network of synchronised ionosondes. Advances in Space Research, 60(8), 1644-1656.
46. Watson, C., R.B. Langley, D.R. Themens, A.W. Yau, A. Howarth, and P.T. Jayachandran (2017). Receiver bias estimates and validation of e-POP GAP-O ionospheric radio occultation measurements, Radio Sci., doi: 10.1002/2017RS006453
47. Wilken V., M. Kriegel, N. Jakowski and J. Berdermann (2018) An ionospheric index suitable for estimating the degree of ionospheric perturbations, J. Space Weather Space Clim. 2018, 8, A19, doi: 10.1051/swsc/2018008