Global Ionospheric Radio Observatory (GIRO): Status and Prospective

Ivan A. Galkin[1] *and* ***Bodo W. Reinisch***[1,2]

[1] University of Massachusetts Lowell, Center for Atmospheric Research
600 Suffolk Street, Lowell, MA, USA, Tel: +1 978-934-4900, Fax: +1 978-459-7915
Bodo_Reinisch@uml.edu, Ivan_Galkin@uml.edu

[2] Lowell Digisonde International, LLC,
175 Cabot Street, Lowell, MA 01854, USA, Tel: +1 978-735-4752, Fax: +1 978-735-4754

Abstract

The Global Ionospheric Radio Observatory (GIRO), http://giro.uml.edu, acquires and disseminates HF ionospheric sounding data from 64 Digisonde locations in 27 countries. GIRO publishes its 30+ million record holdings over the Internet, provides an interactive read/write environment to experts of data interpretation, and forwards real-time data for measurement assimilation and radio propagation and space weather forecast. Of importance to the ionospheric community are the long-term data holdings of manually validated electron density profiles for modeling purposes, studies of the autoscaling uncertainty, and validation of alternative measurement techniques. Real-time GIRO feeds will be used to build an assimilative International Reference Ionosphere model.

1. Introduction

Mitigation of adverse space weather effects is one of the global challenges in a technologically advanced society. To address the challenge, research agencies around the world have been tasked to deliver understanding, accurate global specification, and predictive models of the Earth's ionosphere. Success toward this goal critically depends on the capability to monitor the near space plasma environment.

Global ionospheric specification comes with a suite of technical and methodological challenges. Remote sensing instrumentation is complex and scarce; data feeds from spaceborne sensors are often subject to ground systems latency, and acquired data typically require expert manual interpretation and post-analysis before they can be used. Solutions to the challenges are sought by continuously evolving new and existing techniques for ionospheric nowcast and rapid data assimilation.

The Global Ionospheric Radio Observatory (GIRO) [1], http://giro.uml.edu, is a collaborative, multi-nation project whose objective is to acquire and disseminate HF ionospheric sounding data from current and upcoming worldwide locations of Digisonde sounders [2] (Figure 1). In a concerted international effort, GIRO publishes its 30+ million record data holdings collected from 64 Digisonde locations in 27 countries, provides an interactive read/write environment to experts of data interpretation, and forwards real-time data to regional warning centers for measurement assimilation in ionospheric models for forecasting HF radio propagation and space weather.

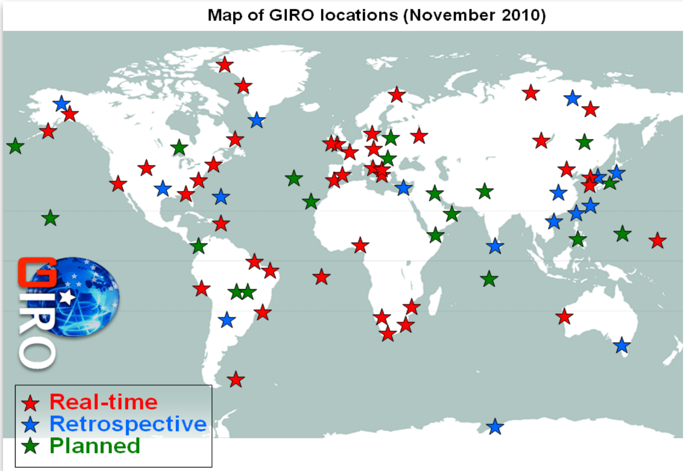

Figure 1. Map of digisondes contributing data to GIRO. Red stars identify online digisondes providing data to GIRO in near-real-time, blue stars denote locations whose retrospective data collections are held in the GIRO archives, and green stars correspond to digisonde installations planned for 2011-2012.

978-1-4244-6051-9/11/$26.00 ©2011 IEEE

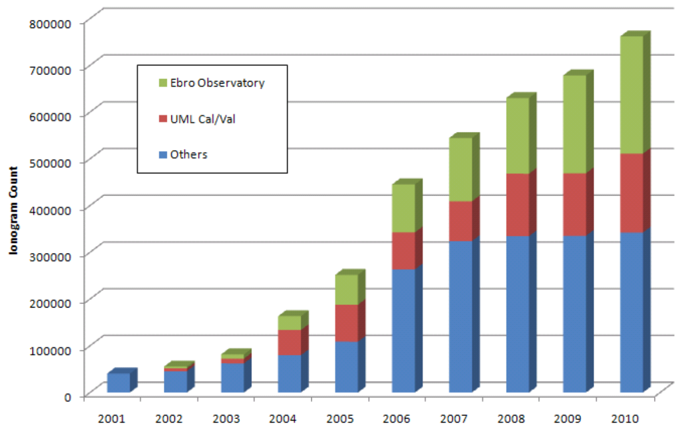

Figure 2. Progress in submission of ionogram-derived electron density profiles manually validated by GIRO experts. Major contributions to GIRO repository of validated EDP come from the Ebro Observatory in Spain and UML Cal/Val project for calibration and validation of ultraviolet instruments of DMSP spacecraft [4].

2. Ground Truth Data Holdings

Of particular importance to the ionospheric research community are the long-term data holdings of electron density profiles (EDP) derived from ionogram measurements [3] that have been manually validated by ionogram interpretation experts. Validated EDP data are used as the ground truth in ionospheric diagnostics for modeling purposes, studies of the autoscaling uncertainty, and calibration of alternative measurement techniques. Figure 2 presents the progress in acquisition of the manually validated EDP data; total number of submitted records has reached the 750,000 mark.

3. Drift Measurements

In addition to ionogram records, the GIRO repository includes Doppler skymaps and plasma drift velocity charts [5] that use digisonde echo location capability to detect reflections of transmitted signals from irregular plasma structures in the ionosphere and place the detected echoes on the skymap plane using their zenith and azimuth angles of arrival. Figure 3 presents two Doppler skymaps acquired during the February 2010 BRIOCHE heating campaign at HAARP, Alaska, that involved Digisonde observations of the ion outflows associated with artificial ducts produced by the HF heating [6]. The Doppler skymap in the left panel of Figure 3 was made just before the HF-heating, while the skymap on the right was recorded two minutes into the heating period. The color bar gives the measured Doppler shifts of each echo. Negative Doppler shifts indicate upward motion.

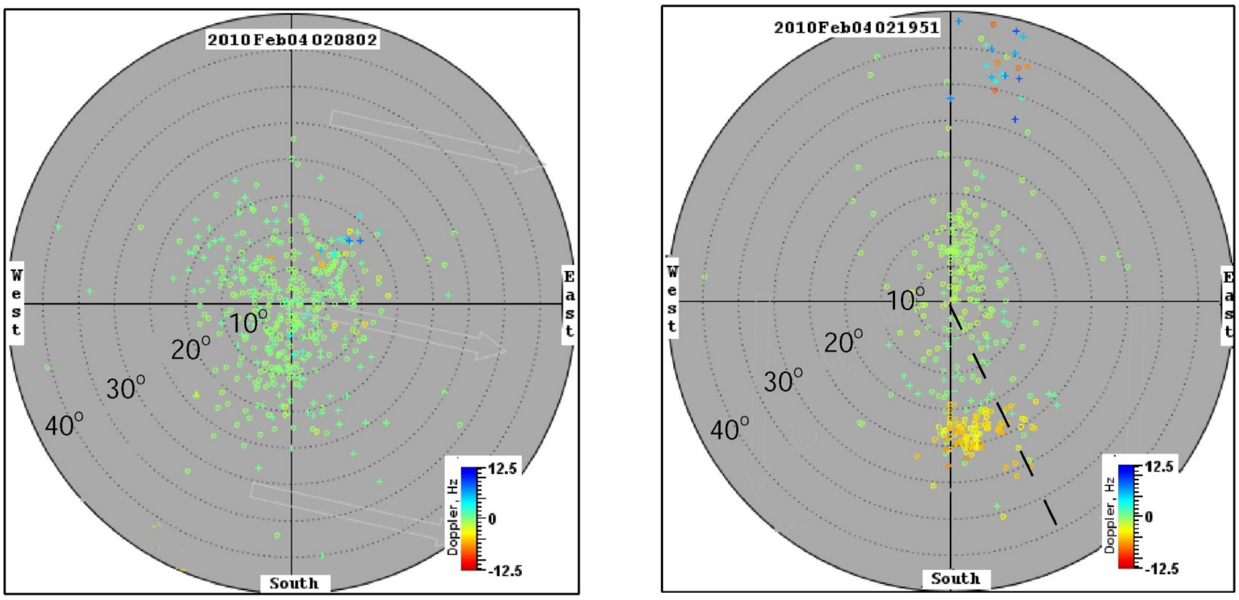

Figure 3. Doppler sky maps from the HAARP Digisonde during the heating experiment 02/04/10: (left) 2 min prior and (right) 9 min into the HF-heating [6].

Prior to the heating (left panel) the irregularities were evenly distributed around the sky view with the Doppler shifts on all echoes close to zero, indicating that there is little or no motion of the reflecting irregularities, neither vertical nor horizontal. Two minutes into the heating a tight cluster of reflections appeared within 5° of magnetic zenith

(MZ) (Figure 3, right panel). Note that the yellow color corresponds to a negative Doppler shift, which is proportional to the average upward speed along the magnetic field line. Soon after the heater was turned off the strong “fast” echoes from the MZ disappeared. Since the detected echoes come from the magnetic zenith, the measured line of sight velocity corresponds directly to the plasma motion along the magnetic field line. The Digisonde line-of-site velocity measurements had been validated by comparison with collocated incoherent radar measurements [7].

Figure 4 shows a waterfall display of the Doppler shift $\Omega(r')$ measured for a given probing frequency f_p of 3810 kHz at different virtual ranges r' between 335 and 370 km. As above, negative Doppler shifts correspond to upward motion. Figure 4 reveals that the ion velocity increases with altitude, at 335 km $V_{up}^{\|} = 55 \pm 8$ m/s, and at 370 km $V_{up}^{\|} = 70 \pm 24$ m/s.

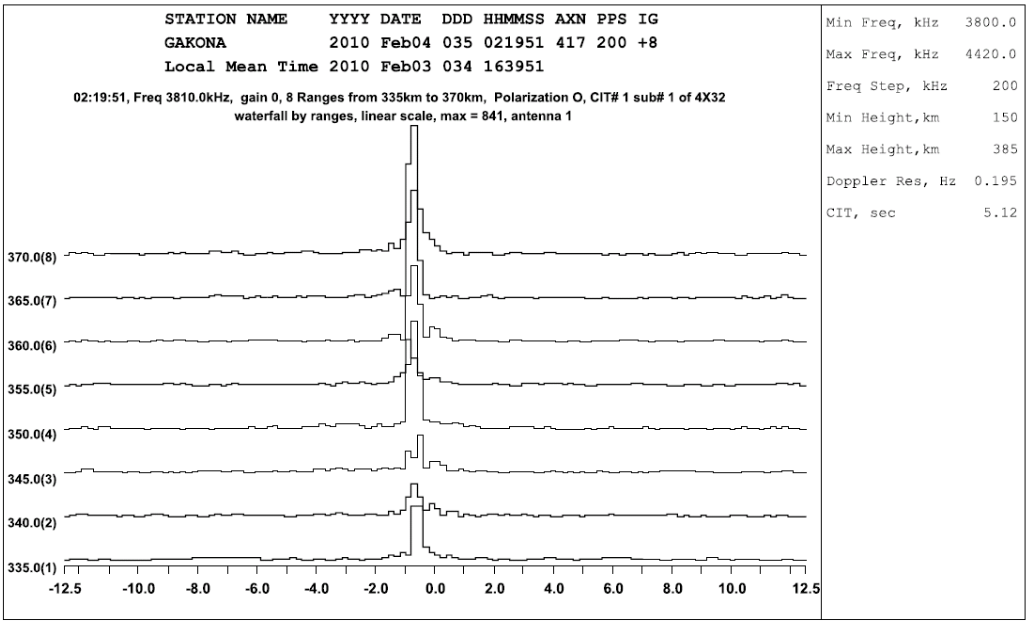

Figure 4. Doppler shifts at altitudes from 335 km to 370 km for a probing frequency of 3.8 MHz [6]

4. Real-time GIRO data and assimilation

GIRO has agreements with 42 Digisonde observatories to receive near-real-time feeds of the ionogram and their characteristics derived automatically by the ARTIST autoscaler [8,9] within minutes after the measurement completion. Development of robust techniques for assimilation of ARTIST data continues to be an active research topic. The proposed Rapid Assimilation Platform for Insight and Discovery (RAPID) [10] will become a testbed for new approaches. The RAPID concept of operation is to abstract the essence of the model-versus-data differences using harmonic analysis in both spatial and temporal domains. In particular, RAPID will rely on representation of the 24-hour running window of foF2 values as a 6th order diurnal harmonic expansion compatible with the CCIR-67 and URSI-88 empirical models of foF2 [11]. Using the same URSI-88 expansion formulation as in International Reference Ionosphere (IRI) model [12], observed differences between the IRI model and GIRO real-time data feeds can be now used to adjust the static monthly coefficients of the foF2 expansion. Such “assimilative” IRI can potentially present an interesting alternative to the physical assimilative models such as Global Assimilation of Ionospheric Measurements (GAIM) [13]. As an empirical model, IRI is free from deficiencies of the theoretical understanding of the ionospheric behavior and of excessive computational demands associated with the full physics specification. Updates to the standard IRI could be rapidly evaluated and periodically released to the end users of IRI in form of small sets of corrective factors for the existing expansion coefficients. We have started investigating a variety of important tasks associated with building an assimilative “real-time” extension of the IRI.

5. Conclusion

The steadily increasing use of GIRO data repositories and the real-time feeds by scientists, engineers, students, and radio amateurs across the globe, especially from developing countries, suggests that the GIRO Portal is an important service to the ionosphere and space weather community.

6. References

1. B. W. Reinisch and I. A. Galkin, "Global Ionospheric Radio Observatory (GIRO)" *Earth, Planets, and Space,* 2011 (accepted).

2. B. W. Reinisch, I. A. Galkin, G. Khmyrov, A. Kozlov, and D. F. Kitrosser, "Automated collection and dissemination of ionospheric data from the digisonde network", *Adv. Radio Sci.*, **2**, 2004, pp. 241-247.

3. X. Huang and B. W. Reinisch, "Vertical electron density profiles from the digisonde network", *Adv. Space Res.*, **18**, 1996, pp.121-129.

4. B. W. Reinisch, J. Scali, and D. Haines, "Ionospheric drift measurements with ionosondes", *Ann. Geofis.*, **41**, 1998, pp. 695–702.

5. Paxton, L.J., D. Morrison, Y. Zhang, H. Kil, B. Wolven, B.S. Ogorzalek, D.C. Humm, and C.-I. Meng, "Validation of remote sensing products produced by the Special Sensor Ultraviolet Scanning Imager (SSUSI): a far UV-imaging spectrograph on DMSP F-16", *Proc. SPIE*, **4485**, 2002, pp. 338-348.

6. G. M. Milikh, E. Mishin, I. Galkin, A. Vartanyan, C. Roth, and B. W. Reinisch, "Ion outflows and artificial ducts in the topside ionosphere at HAARP", *Geophys. Res. Lett.*, **37**, L18102, doi:10.1029/2010GL044636, 2010.

7. J. L. Scali, B. W. Reinisch, C. J. Heinselman, and T. Bullet, "Coordinated digisonde and incoherent scatter radar F region drift measurement at Sondre Stromfjord", *Radio Sci.*, **30**, 1995, pp. 1481–1498, doi:10.1029/95RS01730.

8. B. W. Reinisch, and X. Huang, "Automatic calculation of electron density profiles from digital ionograms, 3, Processing of bottomside ionograms", *Radio Sci.*, **18**, 1983, pp. 477-492.

9. I. A. Galkin, G. M. Khmyrov, A. V. Kozlov, B. W. Reinisch, X. Huang, and V. V. Paznukhov, "The ARTIST 5", in *Radio Sounding and Plasma Physics, AIP Conf. Proc. 974*, 2008, pp. 150-159.

10. I.A. Galkin, D. Bilitza, B. Reinisch, G. Grinstein, and X. Huang, "Rapid Assimilation Platform for Insight and Discovery with Application to Space Weather Research", *Fall AGU Meeting*, San Francisco, CA, 13-17 December 2010.

11. W. B. Jones, R.P. Graham, and M. Leftin, "Advances in ionospheric mapping by numerical methods", *ESSA Tech. Rep. ERL 107 – ITS 75*, US Government Printing Office, Washington, DC, 1969.

12. Bilitza, D. and B.W., Reinisch, "International Reference Ionosphere 2007: Improvements and new parameters", *J. Adv. Space Res.* **42**/4, 599-609, doi:10.1016/j.asr.2007.07.048, 2008.

13. R. W. Schunk, L. Scherliess, J.J. Sojka, and D. Thompson, "Global Assimilation of Ionospheric Measurements (GAIM)", *Radio Sci.*, **39**, RS1S02, doi:10.1029/2002RS002794, 2004.