AN ACTIVE DATABASE FOR DIGITAL IONOSONDE NETWORKS[1]

G. Khmyrov(1), T. Bullett(2), I. Galkin(3), A. Kozlov(4), D. Kitrosser(5), B. Reinisch(6)

(1) ***Center for Atmospheric Research, University of Massachusetts Lowell, 600 Suffolk Street, Lowell, MA 01854 USA, Grigori_Khmyrov@uml.edu***

(2) ***Space Vehicles Directorate, Air Force Research Laboratory, Hanscom AFB, MA 01731 USA, Terence.Bullett@hanscom.af.mil***

(3) ***As (1) above, but E-mail: Ivan_Galkin@uml.edu***

(4) ***As (1) above, but E-mail: Alexandre_Kozlov@uml.edu***

(5) ***As (1) above, but E-mail: David_Kitrosser@uml.edu***

(6) ***As (1) above, but E-mail: Bodo_Reinisch@uml.edu***

ABSTRACT

A new information system actively manages data from the digital ionosonde network in support of a variety of ionospheric modeling and comparison projects. As the result of the progress in interactive data processing technologies, database management, remote control, and networking solutions, an integrated working environment has been created that gives access to the wealth of manually validated ionogram-derived ionospheric data. The new information system includes the "Digital Ionogram Data Base" (DIDB), the expert ionogram scaling tool "SAO Explorer", and the "Automated Data Request Execution Subsystem" (ADRES) to manage data requests and monitor their status from inception to the final report.

INTRODUCTION

Specification of the ionospheric plasma conditions by means of HF vertical-incidence sounding [1] involves a studious manual effort to interpret the acquired imagery data, *ionograms*. In spite of a long and continuing history of automating the process of ionogram interpretation, or *scaling* [2, 3, and many others], the quality of ionogram *autoscaling* is often still inferior to the quality of human analysis. Meanwhile, the demand for ionospheric characteristics derived from ionograms keeps increasing in respect to their accuracy, cadence, dependable coverage worldwide [4,5], and availability in real time over Internet [6], all at a minimal cost. With increasing number of applications relying on the "ground truth" extracted from ionograms, a staggering task of quality control and validation of the autoscaled data has emerged.

While increasing attention is placed on development of techniques for automated quality control of autoscaling results (e.g., [7]), this paper concentrates on placing the process of *manual validation* of autoscaled data into the framework of computer technologies that is convenient for both data validation experts and the end users. This effort resulted in creation of an integrated working environment that is capable of accepting a data request and taking the necessary steps to return the appropriate data, and also to remotely control the sounder schedule, data acquisition, alerting scalers, and generating the final report. Demanding the highest possible degree of accuracy for the ionogram-derived characteristics, this system now sets a new standard for management of ionosonde data.

DIGITAL IONOGRAM DATA BASE

The ionospheric characteristics extracted from ionograms have long been available through the network of *World Data Centers* (WDC), where they are stored in the commercial strength databases, conveniently accessible via the WWW interface "SPIDR" [8]. While remaining the major tool for accessing a great variety of geo, solar and space physics datasets, the WDC-SPIDR was not designed to provide its users with the capability of interactively validating the autoscaled ionogram data. Arranging such validation process necessarily involves provision of raw ionogram data for reference, mating the database to an ionogram editing tool, and allowing online submissions of the edited/validated data back to the database.

[1] UML was supported by AF contract F 19628-96-C-0159

The need for a small, dedicated project was identified to establish an interactive, concurrent, read/write access to an archive of ionograms and scaled data. Dubbed DIDB for Digital Ionogram Data Base, a pilot project of this kind was started in 2001 at UMASS Lowell for the data collected from the network of some 40 digisonde sounders (see Fig. 1 for the locations of contributing stations).

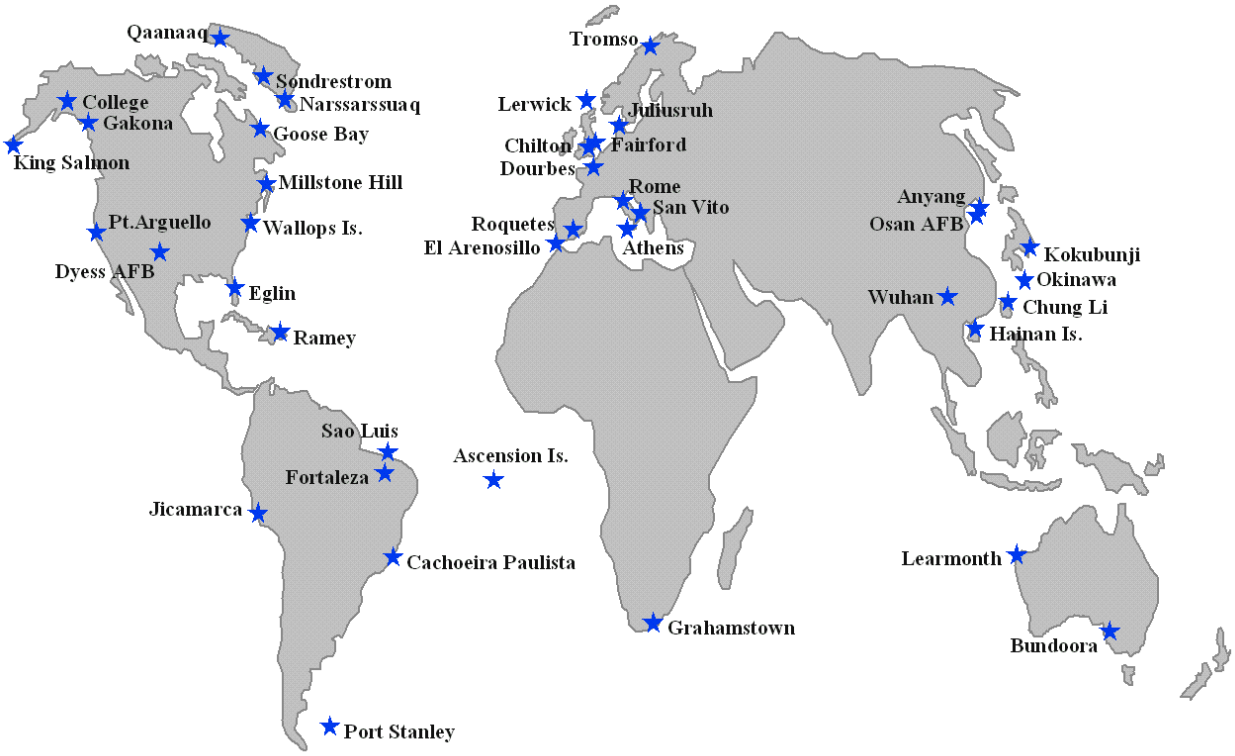

Fig. 1. Online digisonde stations contributing to DIDB

The central piece of the DIDB is a relational DBMS Interbase 6.0 by Borland Software Corporation, chosen for its reliability and minimal administration expense. The database structure is designed to include the binary digisonde ionograms together with multiple scaling records for each ionogram. By relaxing the conventional scenario "one ionogram – one set of derived characteristics", the DIDB creates new possibilities for multiple trace identifications, storage of alternative ionogram interpretations, and a variety of comparative studies of the automated ionogram processing quality. In particular, the new technology makes it possible to store several simultaneously observed auroral E layers, which is of special interest to high latitude ionospheric research. In addition to the multiple versions of ionogram scaling, the DIDB maintains a single subset of commonly used ionospheric characteristics for each ionogram, which can be quickly accessed by the end users looking just for the best ionogram interpretation. A hierarchy of expert ranks and quality flags is used to automatically select one best value among existing versions.

SAO EXPLORER, INTERACTIVE IONOGRAM ANALYSIS TOOL

The new database can work interactively with the SAO-Explorer, the fourth generation tool for digisonde data visualization. The SAO Explorer is primarily used for manual verification and editing of autoscaled digisonde ionograms. It is also a tool for the in-depth study of particular periods of time or locations where background ionograms are required to aid with data interpretation. The SAO-X workstations are granted both read and write access to the DIDB allowing full scale, platform-independent, concurrent, remote operations with the archived data. Any ionogram interpretation expert can register for write permission and edit the data remotely. In addition, the SAO-X workstations connect to the SPIDR database to read retrospective ionospheric data from other locations.

ADRES SUBSYSTEM FOR VALIDATED DATA REQUESTS

The SAO Explorer tool has the ability to access all ionogram-derived data available in DIDB, both validated and not. Another addition to the project, an Automated Data Request Execution Subsystem (ADRES), was developed in support of low-tolerance applications that accept only validated data into their processing scheme. The ADRES accepts the time period and sounder location from the requesting party and takes all required steps to acquire the data, arrange for their validation, and deliver the data report to the user. Fig. 2 shows the decision flow diagram of ADRES.

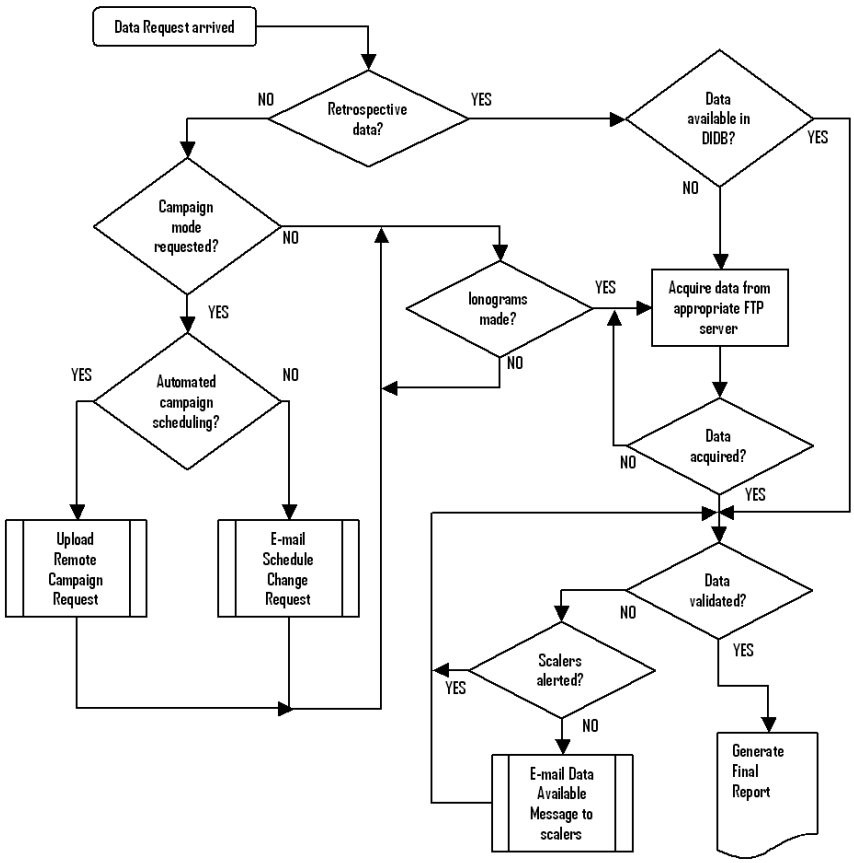

Fig. 2. Flowchart of ADRES executing a data request

If the requested data are already in DIDB and are validated, the ADRES generates the report immediately. A provision is made to manage the requests for special modes of ionosonde operation (e.g., high ionogram rate during a satellite pass over the station, a coordinated campaign, or an event of interest) and data that are not available in DIDB or are not manually validated. The ADRES has a mechanism to automatically read incoming requests to adjust programs and schedules of the Internet-enabled digisondes. To acquire digisonde data, the ADRES maintains a list of FTP servers where the ionogram data can be found. A number of digisonde stations deliver their real time data directly to a WDC and to DIDB. As soon as the data are ingested, a message is generated to the SAO-X operators to validate/edit the autoscaling results. When the quality control procedure is completed, the final report is generated and delivered to the requesting party. Each step of the request execution is monitored, and the status of each request is available for remote access, just like any other data stored in the database.

Applications of the ADRES subsystem include the calibration and validation of space-borne UV sensors measuring ionospheric electron density profiles, and of the ionosonde TEC by comparing ITEC [9] with the total electron content

data from the TOPEX mission. These campaigns provide a first opportunity to demonstrate the power of global ionosonde networking for quick access to ionospheric electron density distributions.

SUMMARY

The establishment of a global Internet-connected digital ionosonde network with standardized data formats was the first gigantic step to make ionosonde data user friendly. The new information system introduced in this paper was the missing second step. The new system, which includes the Digital Ionogram Data Base (DIDB), the expert ionogram scaling tool "SAO Explorer", and the Automated Data Request Execution Subsystem (ADRES), provides organized freedom to ionogram data management and remote digisonde station control.

REFERENCES

[1] B.W. Reinisch, "Modern Ionosondes," in *Modern Ionospheric Science*, H. Kohl, R. Ruster, and K. Schlegel, Eds. European Geophysical Society, 37191 Katlenburg-Lindau, Germany, pp. 440-458, 1996.

[2] B.W. Reinisch and X. Huang, "Automatic Calculation of Electron Density Profiles from Digital Ionograms, 3, Processing of Bottomside Ionograms," *Radio Sci.*, Vol. 18, pp. 472-492, 1983.

[3] I.A. Galkin, B.W. Reinisch, G.A. Ososkov, E.G., Zaznobina, and S.P. Neshyba, "Feedback neural networks for ARTIST ionogram processing," *Radio Sci.*, Vol. 31, pp. 1119-1128, September/October 1996.

[4] B.W. Reinisch, "The Digisonde Network and Databasing," *WDC-A for Solar-Terr. Phys., Report UAG-104*, pp. 8-15, 1995.

[5] J. Buchau, T.W. Bullett, A.E. Ronn, K.D. Scro, and J.L. Carson, "The Digital Ionospheric Sounding System network of the US Air Force Weather Service," *WDC-A for Solar-Terr. Phys., Report UAG-104*, pp. 16-20. 1995.

[6] I.A. Galkin, D.F. Kitrosser, Z. Kecic, and B.W. Reinisch , "Internet access to ionosondes," *J. Atmos. Solar-Terr. Phys.*, Vol. 61, pp. 181-186, February 1999.

[7] R.O. Conkright and L.F. McNamara, "Quality control of automatically scaled vertical incidence ionogram data," *Proc. Ionosph. Effects Symp. IES-96*, pp. 99-103, May 1996.

[8] R.O. Conkright, "SPIDR on the Web: Space Physics Interactive Data Resource Online Analysis Tool," *Proc. URSI XXVI GA*, Toronto, Canada, p. 491, August 1999.

[9] X. Huang and B.W. Reinisch, "Vertical total electron content from ionograms in real time," *Radio Sci.*, Vol. 36, pp. 335-342, March/April 2001.