DEVELOPMENT OF MULTISCALE IONOSPHERE-THERMOSPHERE FORECASTING TECHNIQUES AND MODELS

Michael J. Keskinen
Code 6755
Space Experiments Section
Charged Particle Physics Branch
Naval Research Laboratory
Washington, DC 20375
phone: (202) 767-3215, fax: (202) 767-3553, e-mail: keskinen@ppd.nrl.navy.mil
Award #: N001497AF00002

LONG-TERM GOAL

The following is a brief list of three goals: (1) Develop a global ionospheric validated weather forecast model that is accurate at macro and meso scales; (2) Determine the role of GPS and UV remote sensing in ionospheric space weather specification and forecasting, and (3) Develop physics-based forecasting techniques and model for spread-F disturbances in the low latitude and equatorial ionosphere

SCIENTIFIC OBJECTIVES

The scientific objectives are: (1) Develop model of global ionospheric dynamics and structure including magnetospheric and atmospheric coupling for a range of geophysical conditions; (2) Develop schemes for the parameterization of mesoscale ionospheric structures and processes and inclusion into global ionospheric models; (3) develop GPS and UV optical data assimilation techniques for real-time updating of global ionospheric forecast models; (4) Compare GPS-derived ionospheric electron density profiles with global ionospheric forecast model predictions, and (5) Develop physics-based model for the three-dimensional nonlinear evolution of equatorial spread-F bubbles and their coupling to higher latitudes

APPROACH

A set of equations for continuity, momentum, energy, and current conservation have been solved using finite-difference techniques and applied to the global ionosphere with the capability of variable magnetospheric and thermospheric inputs. The code has been vectorized and run on the NRL Cray-EL computer. In order to develop GPS data assimilation we use techniques from meteorology called "nudging" whereby an ionospheric parameter, e.g., total electron content (TEC) or electron density profile can be assimilated into the code using a temporal relaxation method. We have collaborated with

Dr. Michael Reilly of Geoloc Corporation in this approach by using a GPS-derived electron density profile (EDP) from a GPS receiver in Hawaii and comparing this profile with the predicted EDP from the NRL global ionospheric forecast code. We are also collaborating with Drs. Mendillo and Aarons of Boston University, Dr. Kintner of Cornell, Dr. Basu and Sultan of Air Force Research Laboratory (Phillips Laboratory), and Dr. Reilly on the development of a forecast model of equatorial spread-F ionospheric disturbances. We are comparing the nonlinear evolution of equatorial spread-F bubbles using a GPS-derived EDP as an initial condition with ground-based radar observations. With Drs. Mendillo and Aarons we are comparing the

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 1997**	2. REPORT TYPE	3. DATES COVERED **00-00-1997 to 00-00-1997**

4. TITLE AND SUBTITLE **Development of Multiscale Ionosphere-thermosphere Forecasting Techniques and Models**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Naval Research Laboratory,Space Experiments Section, Code 6755,Charged Particle Physics Branch,Washington,DC,20375**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR’S ACRONYM(S) 11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**6**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

altitudinal and latitudinal extent of spread-F bubbles from our nonlinear code with their optical and GPS observations. With Dr. Kintner we are developing models for the east-west velocity of equatorial bubbles for use in Kintner's enhanced GPS-scintillation model. Finally, we are collaborating with Drs. Basu and Sultan from AFRL in the possible integration of our nonlinear spread-F code in the Air Force Coupled Ionospheric Scintillation Model (CISM) of the 55th Air Weather squadron.

WORK COMPLETED

We have completed the following: (1) First-principles Global Ionospheric Forecast Model (GIFM) code written and implemented on NRL CRAY computer; code run for solar maximum, solstice, and low geomagnetic activity; (2) GPS-derived EDP has been compared with GIFM predictions at midlatitudes; (3) Two hours of GPS data from a single receiver for EDP specification has been successfully applied to GPS receiver in Arequipa, Peru for October 18, 1996; (4) GPS-derived EDP has been used as an initial condition to drive the nonlinear evolution of equatorial spread-F bubbles for near real-time applications; (5) Nonlinear evolution of equatorial spread-F bubbles using GPS-derived EDP validated with ground-based Jicamarca incoherent scatter radar observations, and (6) Nonlinear evolution of equatorial spread-F bubbles computed using vertically inhomogeneous background ionospheric profile supplied by Air Force Research Laboratory

RESULTS

The NRL GIFM has been run for a limited range of geophysical conditions. The comparison between GIFM output and GPS-derived electron density profile is a new direction. A sample vertical EDP taken from GIFM is shown in Figure 1, on page 4. GPS has the promise of being used not only for real-time EDP specification for quiet conditions but also as an initial and boundary condition to drive mesoscale ionospheric processes in the form of equatorial spread-F bubbles. Figure 2 shows, on page 5, the GPS-derived EDP at an equatorial station located at Arequipa, Peru and the EDP as measured using the Jicamarca incoherent scatter radar located nearby to the northwest. Figure 3 shows, on page 5, the nonlinear evolution of equatorial spread-F bubbles and depletions using the GPS-derived EDP as an initial condition. The Rayleigh-Taylor -driven bubble can reach altitudes of 500-600 km on the order of an hour. Figure 4 shows, on page 6, the Jicamarca radar map on the same night with agreement in general size, structure, and vertical extent. This is the first use of GPS derived parameters to initialize mesoscale ionospheric dynamical processes.

IMPACT/APPLICATION

The development of the NRL GIFM will permit global forecast capability over a range of spatial scales. This will generate an improved understanding of the cause-effect relationships in the near earth space weather environment for a variety of conditions. In addition, the development of a predictive model for equatorial spread-F will allow for the improved operation of communication, navigation, and positioning systems operating in and through low latitude regions.

TRANSITIONS

The NRL GIFM model will be used by Dr. Michael Reilly to improve the global empirical models that are used for GPS environmental specification. Global empirical models are not accurate during disturbed storm periods. In addition the NRL GIFM could be used as tactical ionospheric space weather nowcasting and forecasting model. The low latitude and equatorial spread-F models and codes will be used by the Air Force in their physics-based CISM scintillation model. In addition, the nonlinear spread-F code will be used to interpret airglow and GPS data in the low latitude and equatorial ionosphere by researchers at Boston University and Cornell University.

RELATED PROJECTS

In the area of global ionospheric modeling, Utah State and the Air Force Research Laboratory currently are actively engaged. However, the NRL GIFM is the first global model to incorporate the effects of mesoscale structure and real-time GPS data assimilation techniques. In addition, NRL has the most sophisticated model and nonlinear code to study the evolution of equatorial spread-F bubbles and their coupling to higher latitudes currently in use.

REFERENCES

Keskinen, M.J., M.H. Reilly, and M. Singh, 1997. "A combined GPS-updated ionospheric climatological and mesoscale regional model for equatorial spread-F nowcasting," *Radio Sci.*, submitted.

Keskinen, M.J., S.L. Ossakow, and P. Sultan, 1997. "Inhomogeneous hemispheric coupling effects on the nonlinear evolution of equatorial spread-F bubbles," *Geophys. Res. Lett.*, submitted.

Keskinen, M.J., S.L. Ossakow, S. Basu, and P. Sultan,1997. "Magnetic-flux-tube-integrated evolution of equatorial ionospheric plasma bubbles," *J. Geophys. Res.*, in press.

Keskinen, M.J., M.H. Reilly, and M. Singh, 1997. "Initial development of the NRL GIPM global ionospheric prediction model," *Radio Sci.*.

Keskinen, M.J., and M.H. Reilly, 1997."Small scale ionospheric specification using RIBG and GPS," *Proc. Ionospheric Effects Symposium*, Arlington, VA, p. 112.

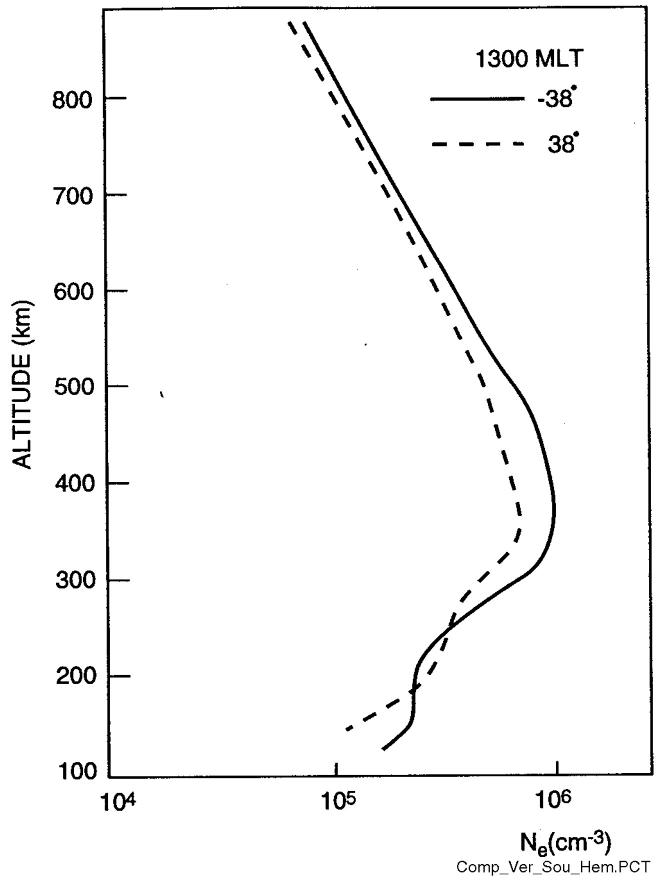

Figure 1. Comparison of Vertical Electron Density Profiles From GIRM in the Northern and Southern Hemishpere

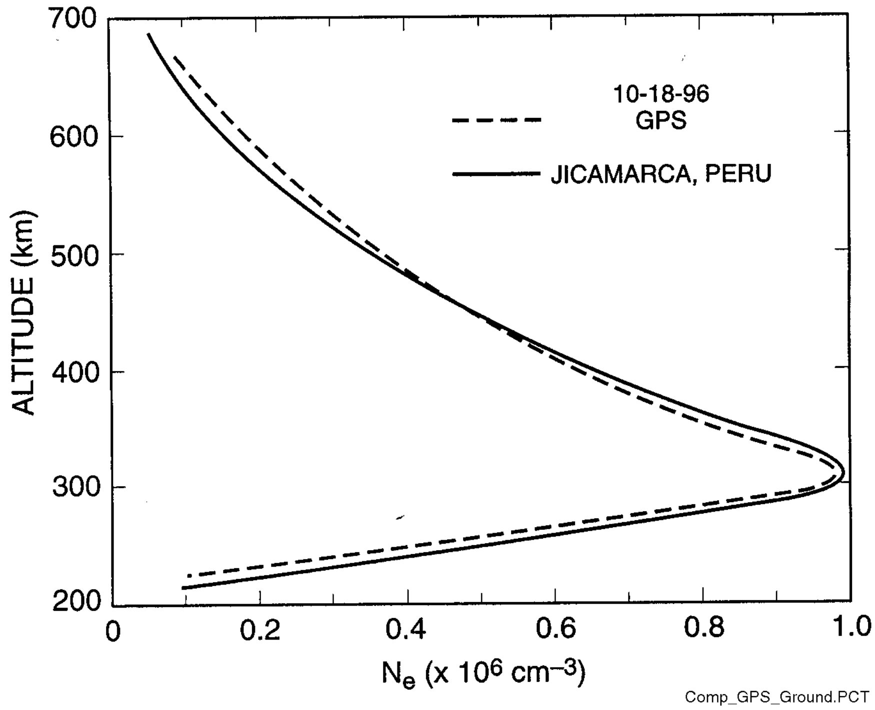

Figure 2. Comparison of GPS-Derived EDP and Ground-Based Radar Measurements

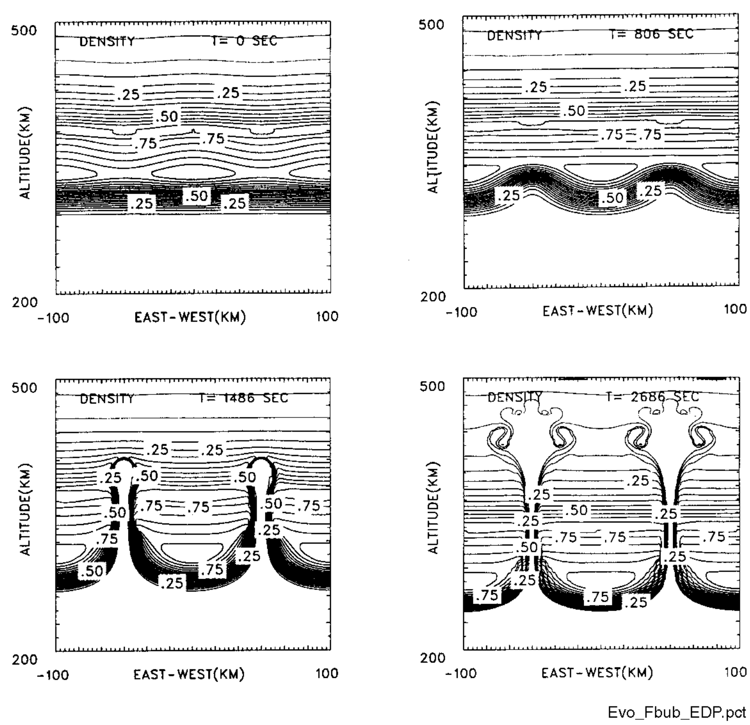

Figure 3. Evolution of Equatorial Spread-F Bubbles Using GPS-Derived EDP

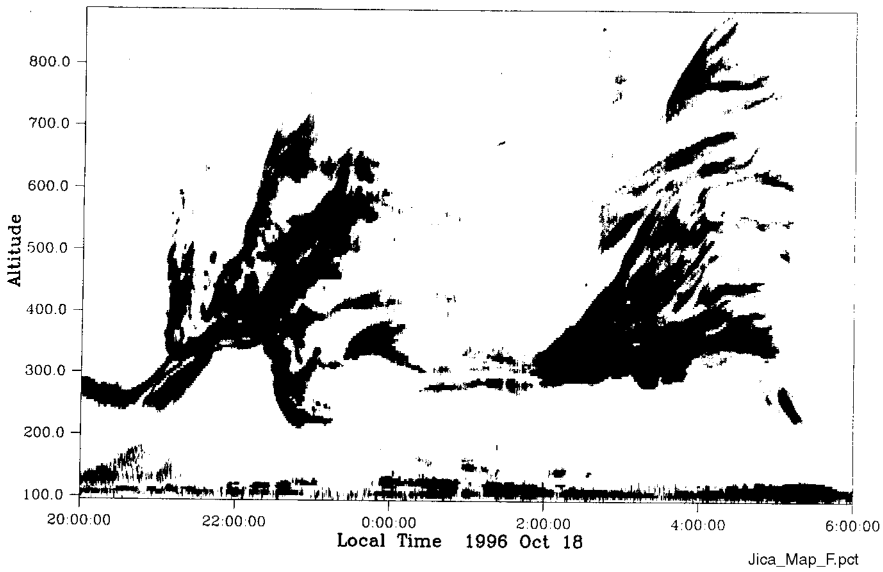

Figure 4. Jicamarca Range-Time-Intensity Map of Equatorial Spread-F