

Prediction of Equatorial Spread F Based on Assimilation of Daytime GPS Data

Michael C. Kelley

School of Electrical and Computer Engineering

318 Rhodes Hall, Cornell University

Ithaca, NY 14853

phone: (607) 255-7425 fax: (607) 255-6236 email: mikek@ece.cornell.edu

Award Number: grant N00014-03-1-0243

LONG-TERM GOALS

Under ONR grant N00014-03-1-0243 we will explore the value of airglow imagers in the testing of assimilative models of the equatorial ionosphere. We have made data exchange agreements with both the Jet Propulsion Laboratory and the Air Force Research Laboratory in this regard. Our first goal is to verify conditions calculated by the models prior to the breakout of Equatorial Spread F (ESF), a severe ionospheric weather phenomenon. The second goal is to see if data assimilation can be used to predict these conditions and subsequently predict ESF itself. A third goal is to calibrate GPS occultation data using the Arecibo radar and then apply this method to determine the off-equatorial E-region conductivity.

OBJECTIVES

The objectives of the project are:

- (1) to develop the software needed to calculate the expected airglow from the equatorial ionosphere using the outputs of ionospheric models;
- (2) to compare the model results with the actual airglow;
- (3) to use the data assimilation techniques to predict the airglow characteristics and, eventually, ESF;
- (4) to use GPS occultations to determine the off-equatorial *E*-region conductivity.

APPROACH

We will work closely with two leading data assimilation modeling groups, one at the Jet Propulsion Laboratory (JPL) and one at the Air Force Research Laboratory (AFRL). Once we verify the airglow diagnostic we will move on to test the assimilation aspects of both models. Finally, we will use those techniques to predict ESF. The airglow system also detects the depletion zones that are so disruptive to communications and navigation systems and hence can be used to check the predictions of severe weather. Concerning GPS, we will first calibrate the COSMIC system using incoherent scatter radar, then apply it to (4) above.

Report Documentation Page				Form Approved OMB No. 0704-0188	
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.					
1. REPORT DATE 30 SEP 2006		2. REPORT TYPE		3. DATES COVERED 00-00-2006 to 00-00-2006	
4. TITLE AND SUBTITLE Prediction of Equatorial Spread F Based on Assimilation of Daytime GPS Data				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) Cornell University,School of Electrical and Computer Engineering,318 Rhodes Hall,Ithaca,NY,14853				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 Same as Report (SAR)	18. NUMBER OF PAGES 5	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

WORK COMPLETED

We chose April 1/2, 2002 as our first control day (without a Convective Ionospheric Storm/Equatorial Spread F). The airglow observation for the night is presented in Figure 1. Airglow calculations using the output of the International Reference Ionosphere (IRI) have been completed (Figure 2) and compared to the actual airglow observed on December 8/9, 2002. The predicted airglow maximum lies much lower on the horizon as viewed from Maui than that which we observe. This is not surprising since electric fields can create a much higher ionosphere at the equator than IRI predicts. This is one reason ESF occurs!

Figures 3 and 4 show comparisons with JPL's climatological model and assimilative model, respectively, for this date. Clearly, a lot of work needs to be done. Presentations were made at the CEDAR meeting as well as to the Communications and Navigation Outage Forecast System (C/NOFS) science working group concerning our plans.

Figure 5 shows one calibration of the COSMIC GPS occultation experiment, which is quite good. We are exploring the reasons for the discrepancy, using airglow data. Many more passes will be examined.

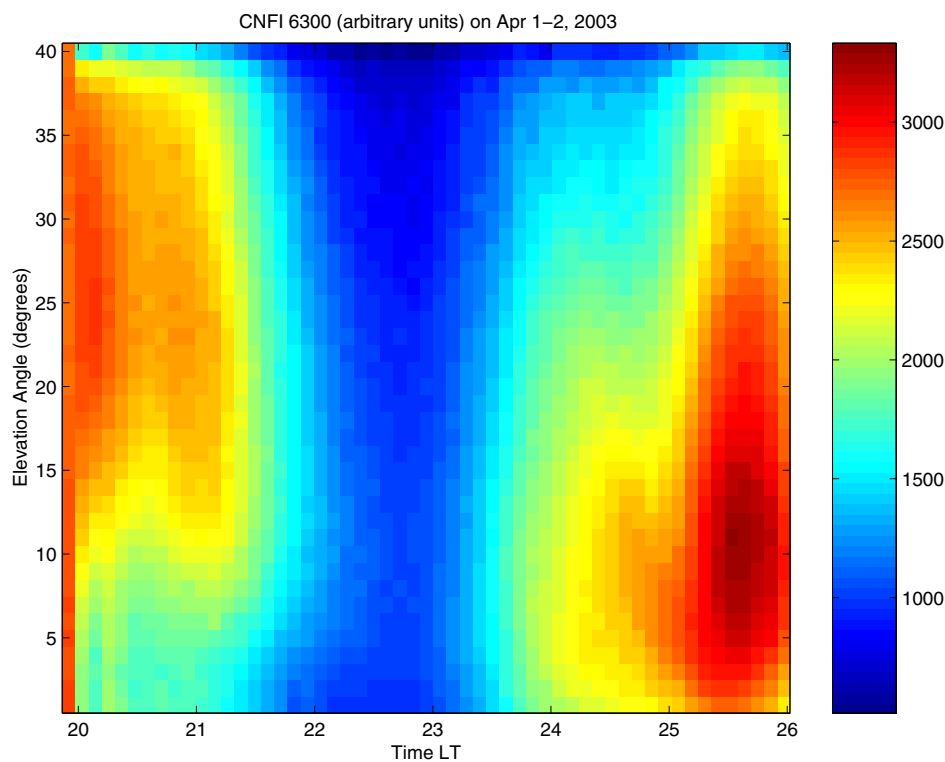


Figure 1. Airglow observations.

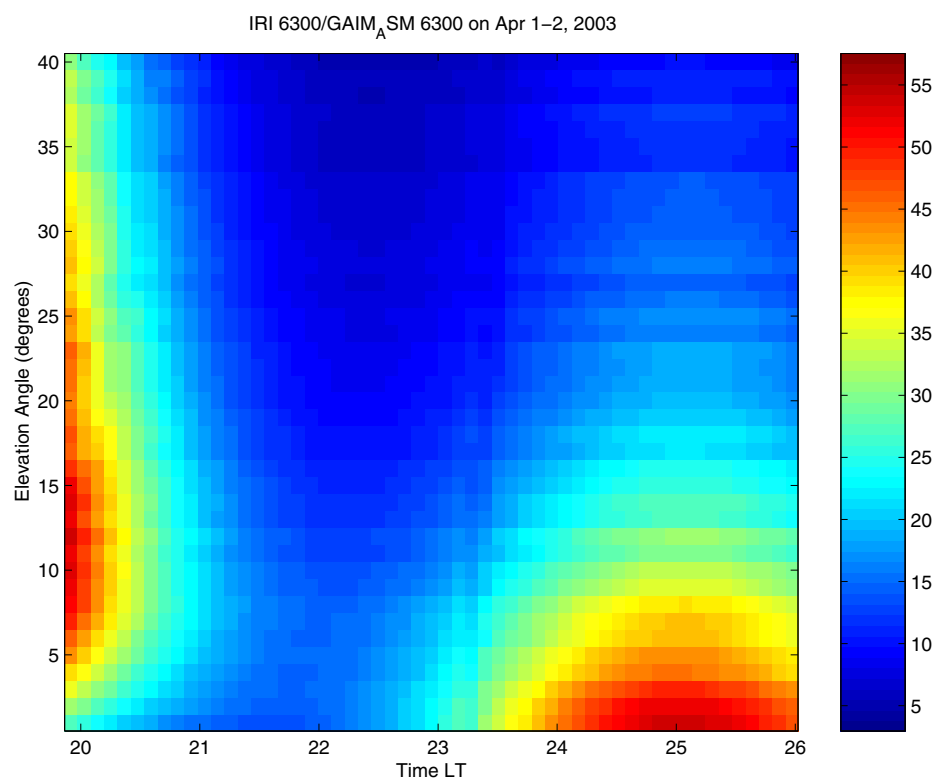


Figure 2. Airglow prediction using IRI.

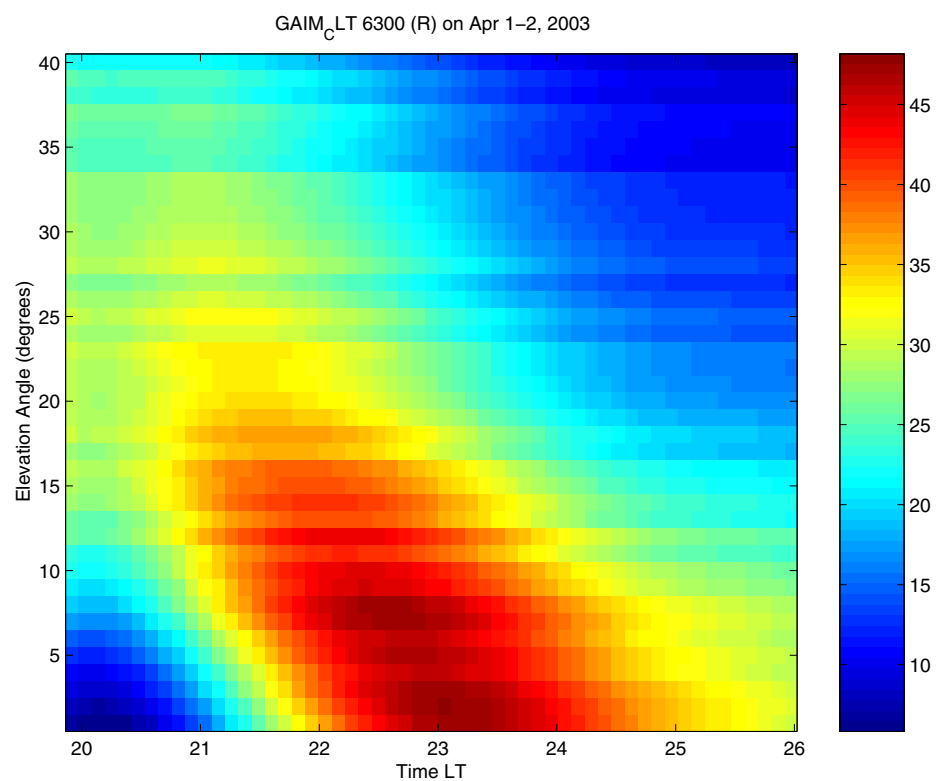


Figure 3. Airglow prediction using only climatology (JPL-GAIMC).

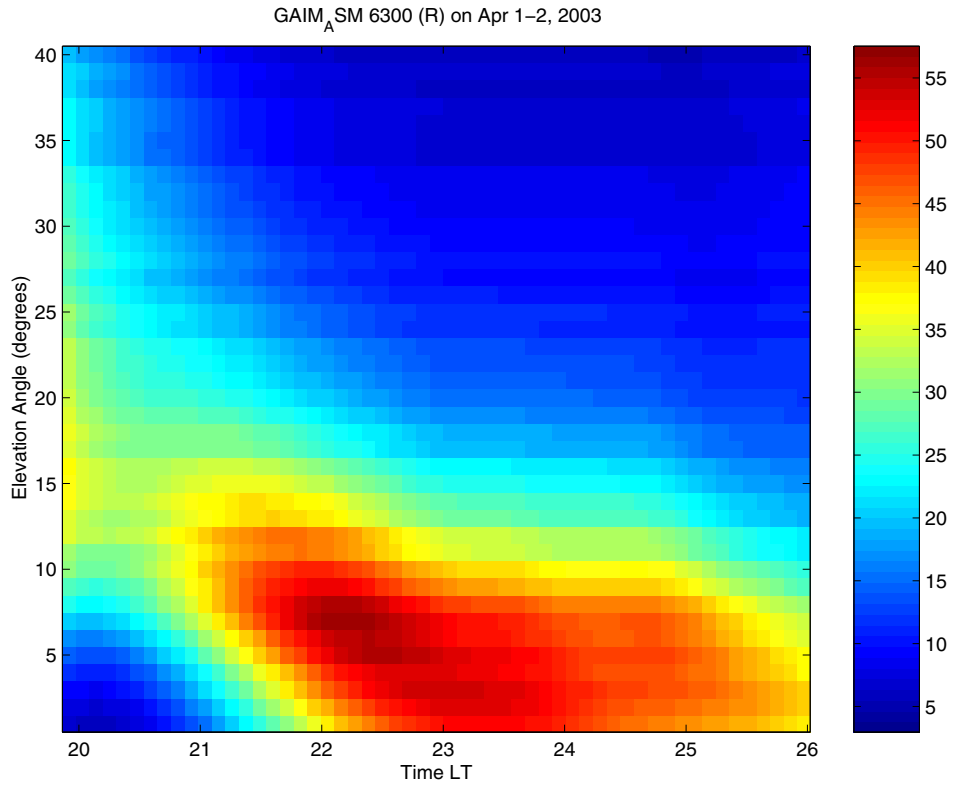


Figure 4. Airglow prediction with assimilation (JPL-GAIMA).

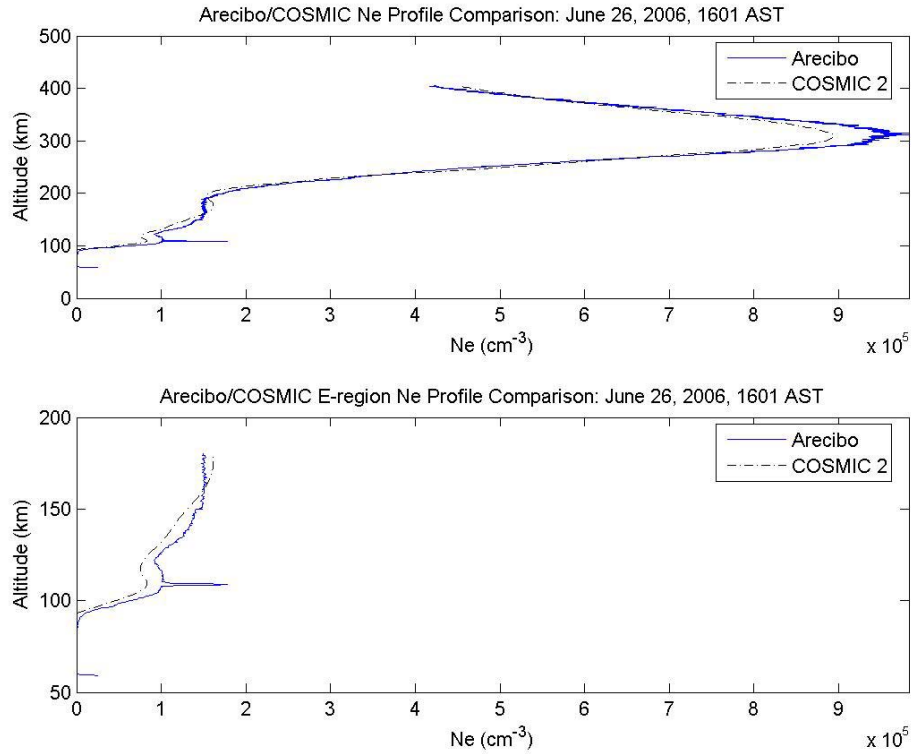


Figure 5. First calibration from the COSMIC GPS occultation experiment.

RESULTS

We have published a *Geophysical Research Letters* article entitled “On measuring the off-equatorial conductivity before and during convective ionospheric storms” [Kelley *et al.*, 2004] under this grant and will present our calibration results twice at meetings in 2006. We hope to publish comparisons such as those above with as many as four models: IRI, AFRL, GAIM-JPL, and GAIM-USU.

IMPACT/APPLICATIONS

There is a great need for testing data assimilation methods in ionospheric space weather research. We will do this in one of the most important and severe space weather research areas. We feel that our testing methods will have an impact on the development of both the JPL and AFRL assimilation models. The latter is a crucial component in a major DOD effort to predict communications and navigation outages in the C/NOFS Program. We also have some hope that by assimilating daytime TEC values and satellite electric field patterns we can predict ESF in the post-sunset period. GPS occultations are also to be used for assimilation models. Our calibration work is crucial in testing the validity of these data.

TRANSITIONS

No transitions have occurred as yet but we anticipate that airglow observations and occultation data will play an important role in the development and testing of ionospheric models.

RELATED PROJECTS

None.

PUBLICATIONS

Kelley, M.C., V.K. Wong, G.A. Hajj, and A.J. Mannucci, On measuring the off-equatorial conductivity before and during convective ionospheric storms, *Geophys. Res. Lett.*, 31, L17805, doi:10.1029/2004GL020423, 2004. [published, refereed]

Kelley, M.C., and M.J. Nicolls, Penetration of solar wind and magnetospheric electric fields to the inner magnetosphere, Fall AGU meeting, 2006. [accepted, refereed]

Kelley, M.C., V.K. Wong, M.J. Nicolls, A. Mannucci, and J. Chau, Calibration of COSMIC ionospheric profiles using incoherent scatter radars, Fall AGU meeting, 2006. [accepted, refereed]