Assimilation Ionosphere Model

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LONG-TERM GOALS

Our main long-term goal is to develop an Assimilation Ionosphere Model (AIM) that provides reliable ionospheric specifications and forecasts. A secondary goal is to use the model to elucidate the physics associated with the creation, transport and decay of plasma density structures and to determine their effects on naval systems.

OBJECTIVES

Our main objective is to construct a physics-based, global, ionospheric specification-forecast model that is capable of ingesting a diverse set of real-time (or near real-time) measurements. The data to be assimilated include slant path Total Electron Content (TEC) from several Global Positioning System (GPS) satellites, high-quality TECs from selected satellites with radio beacons, in situ plasma parameters from the SSIES instrument package on the DMSP satellites, digisonde data from selected ground-based stations, and both line-of-sight UV emissions and deduced plasma parameters from the Naval Research Laboratory's Special Sensor Ultraviolet Limb Imager (SSULI) instrument and Johns Hopkins University Applied Physics Laboratory's Special Sensor Ultraviolet Spectrographic Imager (SSUSI) instrument. After AIM is constructed, a secondary objective is to use the model to study the sensitivity of the ionosphere to a wide range of external forcing functions. Of particular interest is the determination of the conditions leading to the creation of plasma density structures and irregularities.

APPROACH

Our approach to developing a reliable ionospheric specification-forecast model is to use a physics-based, global, ionosphere model as the basis for data assimilation. First, the physics-based model will be run for the geophysical conditions that pertain to the desired specification (year, day, time, $F_{10.7}$, Kp, Dst). The result will be a global electron density distribution. This simulated distribution will then be probed the same way instruments probe the real ionosphere and the simulated and measured instrument responses will be compared. The inputs to the global ionosphere model will be adjusted and the model rerun until the simulated and measured parameters agree at the locations and times that the data are available. Some of the algorithms needed for the construction of AIM are already available, but most must be developed. The specific tasks to be accomplished are as follows: (1) Construct an equatorial ionospheric model and couple it to our mid-high latitude model; (2) Develop data quality assessment algorithms for the different data types that we will consider for assimilation; (3) Develop software to simulate the data types that are currently not available; (4) Develop data assimilation algorithms and

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14. ABSTRACT

Our main long-term goal is to develop an Assimilation Ionosphere Model (AIM) that provides reliable ionospheric specifications and forecasts. A secondary goal is to use the model to elucidate the physics associated with the creation, transport and decay of plasma density structures and to determine their effects on naval systems.

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RESULTS

Our mid-latitude data assimilation models were used in several studies involving testing and validation, and these are listed in the Publications section. Most of our studies were connected with the CIC Caribbean campaign that took place during November 1997 and September 1999. The November study focused on mid-latitude data assimilation with both local and regional models. The models were capable of using the f_oF_2 and h_mF_2 from ionograms to generate either a local or a regional distribution of the induced plasma drift that was needed to reproduce the measured f_oF_2 and h_mF_2. Results from both the local model (AIM1.03L) and a regional model (AIM1.03R) were compared with the International Reference Ionosphere (IRI) as well as with GPS slant TEC measurements. Results from year-long studies for solar maximum conditions show that the accuracy of the local model (AIM1.03L) is about a factor of 2 better than the IRI. A month-long study with the regional assimilation model (AIM1.03R) indicated that it was almost as good as the local model. Finally, the Ramey ionosonde data were used to drive the local model (AIM1.03L) and the predicted GPS slant TECs were shown to be in good agreement with those measured by a GPS receiver at St. Croix.

In another study using CIC data from the September 1999 campaign, we separately used Arecibo incoherent scatter radar data and Ramey digisonde data to deduce vertical plasma drifts with the aid of our local assimilation model. The two data sets were taken simultaneously and both showed a significant day-to-day variability of the F layer, especially in the evening sectors. Our local assimilation model was able to track the day-to-day variability, and we obtained almost identical results with either the Arecibo ISR data or the Ramey digisonde data.

Recently, we initiated a collaborative effort with Drs. Stephen Thonnard and Sara McDonald at the Naval Research Laboratory in order to extend our data assimilation work to equatorial latitudes. These scientists inverted UV emissions at 1356 Å, measured by the ARGOS satellite, and obtained 2-dimensional electron density distributions versus altitude and latitude. The 2-D distributions correspond to the satellite orbit plane, which is at 2:30 hours LT. These scientists acquired a unique set of Ne distributions centered on the equator that clearly displays the variation of the equatorial anomaly with both UT (longitude) and geomagnetic activity. These data are extremely valuable for: (a) calibrating and validating ionospheric models; (b) understanding weather disturbances at low latitudes; and (c) providing inputs for data assimilation models.

In our initial work, we were concerned with the technical aspects of how to take existing ionospheric models and interface them to this new data, so that we can make an assessment of how best to ingest the data into advanced assimilation models. As a first step in this direction, the Ionospheric Forecast Model (IFM) was run for the September 1999 period and the resulting numerical database was reduced to 2-D Ne distributions versus altitude and latitude centered on the geographic equator. Figure 2 shows examples of such 2-D distributions obtained from the IFM for the 03-hour LT plane. Each panel shows an Ne distribution at a different UT (i.e., longitude) for -37° to 37° N geographic latitudes and for 100 to 800 km altitudes. The longitudes are 322.5°(Mq036), 262.5°(Mq044), 82.5°(Mq020), 22.5°(Mq028), 202.5°(Mq004), and 142.5°(Mq012). The panels are 4 hours apart in UT. The electron densities are color-coded, with blue corresponding to low values and red to high values. At 03 hours LT, the equatorial anomaly crests are weak and the peak altitudes are significantly lower than those in the early evening (not shown). Nevertheless, these model results can be directly compared to the 2-D distributions obtained from the ARGOS UV data, and the comparisons should elucidate the mechanisms that drive the low-latitude ionosphere (e.g. electric fields and neutral winds).

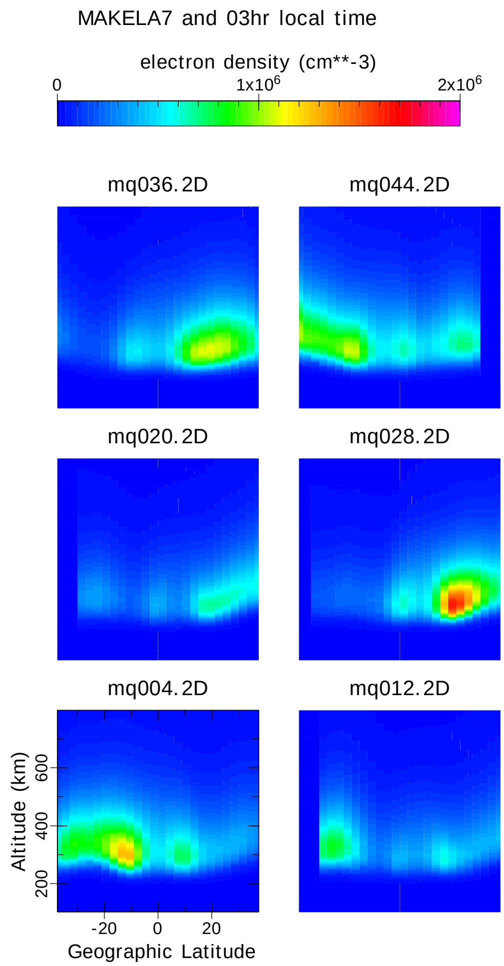

Fig. 2 Model electron density distributions versus altitude and geographic latitude for the 03-hour local time plane. The simulation is for September 1999 (day 258).

IMPACT/APPLICATIONS

When completed, AIM will provide reliable ionospheric specifications and forecasts on a global, regional, or local grid system. The resulting ionospheric density distributions can then be used for a wide range of applications, including HF communications and geolocations, over-the-horizon (OTH) radars, surveying and navigation systems that use GPS data, and surveillance.

TRANSITIONS

AIM results are being used as part of the Combined Ionospheric Campaign that is under the direction of Stefan Thonnard. As part of the CIC effort, we are conducting AIM simulations in support of the Arecibo ISR measurements being analyzed by Makela and Kelley at Cornell University. We are also working with Gary Bust of the University of Texas comparing AIM and tomography results.

RELATED PROJECTS

This project is related to a project at Utah State University titled "Global Assimilation of Ionospheric Measurements (GAIM)." The USU project focuses on Kalman filter data assimilation techniques, as applied to both the ionosphere and upper atmosphere. The gridded ionospheric model structure and the mid-latitude assimilation model (AIM-L) developed as part of this AIM project have been delivered to USU to spearhead the USU GAIM initiative. Data sets that we collected under AIM have also been delivered to the USU GAIM program.

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