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 TEC's from several Global Positioning System (GPS) satellites, high-quality TEC's 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 SSUSI and SSULI instruments. 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 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 data quality flags; (5) Construct an executive system to control the running of the model and the data

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assimilation algorithms; and (6) Conduct a validation of the final AIM product, including assimilation, scientific, and applications validations.

R. W. Schunk has overall responsibility for the project. He is also developing the equatorial ionosphere model and is participating in the construction of the data assimilation algorithms. J. J. Sojka is the main person responsible for the data assimilation and data quality assessment algorithms. V. Eccles is responsible for the model's spatial grid system and for the construction of software to simulate the data that are currently not available. D. C. Thompson is responsible for constructing the executive system. He is also participating in the data assimilation work. All team members will participate in the AIM validation effort.

WORK COMPLETED

The equatorial ionosphere model was formulated for the E and F regions, and all of the algebra that has to be done prior to the implementation of the numerical algorithm was completed. The relevant transport equations were first cast in dipolar coordinates and then a further transformation was made to a sinh (x) coordinate for numerical stability and efficiency reasons.

Algorithms were developed to assimilate slant path TEC's from GPS satellites and then a study was conducted of how many ground receiving sites would be needed in order to do a reconstruction of a region of the equatorial ionosphere that contains plasma bubbles.

An algorithm was developed that relates mid-latitude neutral winds to measured N_mF_2 values. The algorithm was automated for a single station. We are now studying the longitudinal coherence of the wind so that we can determine the number of mid-latitude sites needed to reconstruct the global wind pattern from measurements of N_mF_2. The N_mF_2 values used in the algorithm development came from an extensive ionosonde data set we acquired from the National Geophysical Data Center (NGDC).

AIM is based on global, regional, and local grids, each with a progressively better spatial resolution. This grid system was defined for the exchange of information between model components. The software interfaces for model/grid-file exchanges were coded and tested for the ionosphere, atmosphere, high-latitude convection, and high-latitude particle precipitation (both electrons and protons).

When data are assimilated and ionospheric reconstructions are produced, it is important to establish the quality of the reconstruction. We are, therefore, investigating ways to automatically determine a 'skill score' for each ionospheric reconstruction.

We contacted Stefan Thonnard with regard to the Combined Ionospheric Campaign that was conducted in Puerto Rico between June 22-26. These data can be used in the AIM algorithm development and validation.

RESULTS

We have created an iterative assimilation model that starts from a zero wind condition and compares the measured N_mF_2 data with the model prediction. After each iteration, the wind pattern is gently adjusted for each UT. When the model result is within $\pm$ 5% of the measured N_mF_2, no further adjustment to the wind is attempted for the UT. Figure 1 shows the results from the iterative assimilation model for the WK545 station (Wakkanai, Japan) for winter conditions in 1981. Our assimilation model results are the solid lines; the IRI values are shown as + symbols; and the measurements are shown as a gray background (the width of the gray strip is +/- 10% for N_mF_2 and f_oF_2 and +/- 20% for h_mF_2). The average absolute error of our assimilative model is given as a number in the lower-left corner of the top three panels. Note the generally good agreement between the assimilative model and the data. The solid curve in the lower panel is the wind-induced vertical plasma drift obtained from our assimilation algorithm. For comparison, the squares show the vertical wind obtained from the empirical wind model developed by A. Hedin.

IMPACT/APPLICATIONS

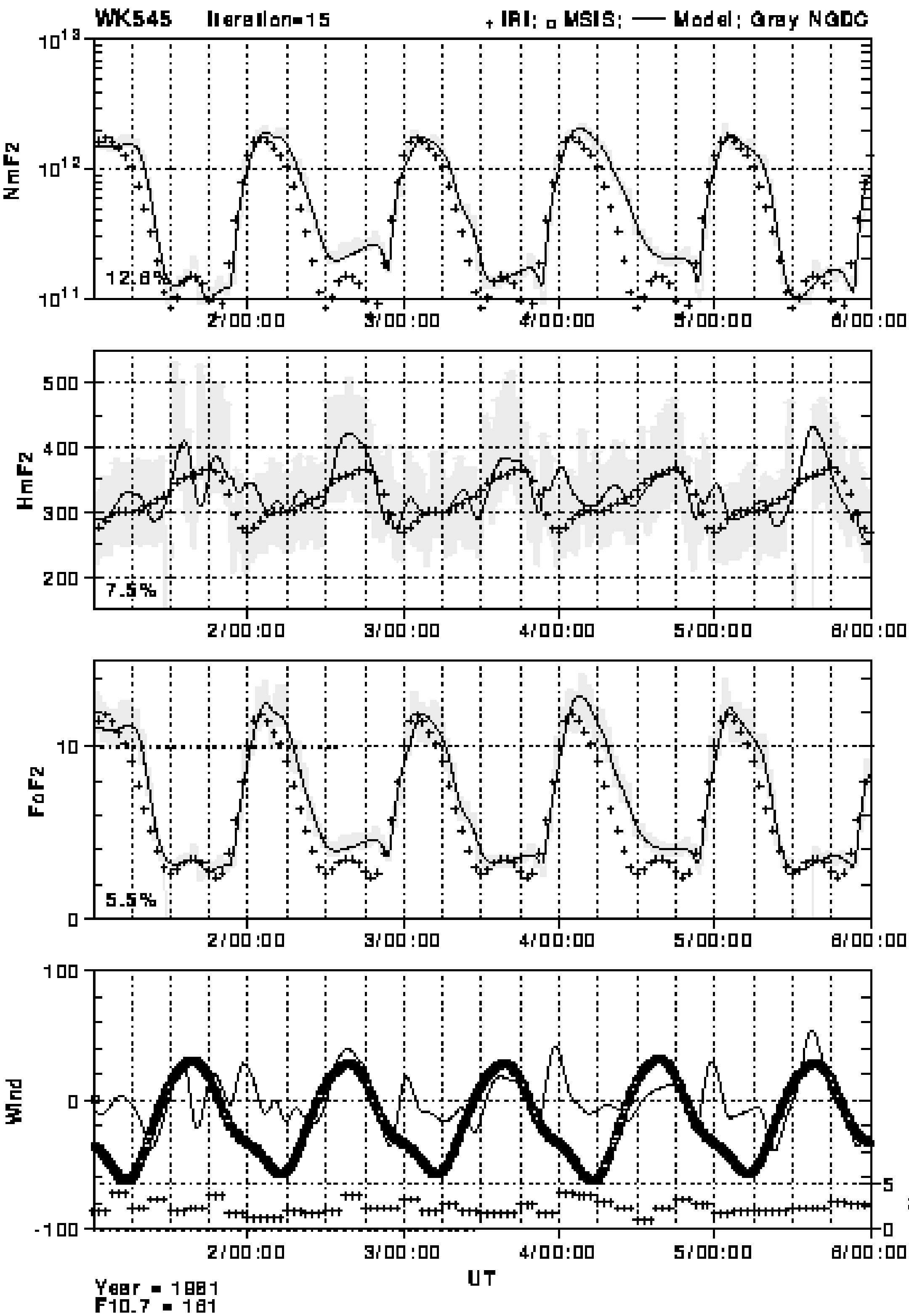
When completed, AIM will provide reliable ionospheric specifications and forecasts on a global, regional, or local grid system. The resulting ionospheric density distributions can then be used for a wide range of applications, including HF communications and geolocations, over-the-horizon (OTH) radars,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

TRANSITIONS

When completed, AIM will be available for use at both centralized and regional locations.

RELATED PROJECTS

AIM algorithms are being used as part of the Combined Ionospheric Campaign that is under the direction of Stefan Thonnard. The algorithms will help elucidate the physics governing the equatorial ionosphere and the data collected will also help validate the AIM algorithms.



WK545
Iteration=15
+ IRI; ▫ MSIS; — Model; Grey NGDC
NmF2
12.8%
HmF2
7.5%
FoF2
5.5%
Wind
Kp
2/00:00
3/00:00
4/00:00
5/00:00
6/00:00
UT
Year = 1981
F10.7 = 181

Figure 1.