

## 1. Abstract

In order to better understand the energy input in the upper atmosphere in high-latitude regions, empirical models are created. These models calculate electric and magnetic fields, electric and magnetic potentials, and Poynting flux. The Poynting flux has been determined to be very important as a energy source term in the upper atmosphere e.g. (Lu, 1995). The 2005 Weimer Model (the newest of a series) is seen as a very good approximation for the energy input of the upper atmosphere. The HAO Empirical Model is another model that hopes to help our understanding of the interactions between geomagnetic conditions and the upper atmosphere energy input. To make sure that the HAO Empirical Model is working correctly, it has to be checked against an exciting model (The 2005 Weimer) to try and see if it is just as good or better for predicting. After comparing these two models in both electric and magnetic fields, electric and magnetic potentials, Poynting flux, and total flux it can be concluded that the HAO Empirical Model, though it has difference from the 2005 Weimer Model, is a good model for the conditions of the upper atmosphere energy input.

## 2. Definition of Problem

Take the 2005 Weimer Model and the HAO Empirical High Latitude Model and compare how they vary with clock angle, IMF strength, and dipole tilt angle in terms of electric potentials, magnetic potentials, electric fields, magnetic fields, Poynting flux, and Joule heating.

## 3. Background

Two models are being compared: 2005 Weimer and HAO Empirical High Latitude Model. Each model uses geomagnetic conditions (clock angle, IMF strength, and dipole tilt angle) to prediction the structure and strength of the electric field, magnetic field, and the Poynting flux; the 2005 Weimer also uses velocity and density of the solar wind in its calculations. These models do this by taking data from Dynamics Explorer 2 (DE-2) and fitted it to different functions (Weimer, 2005); the data used by the two models comes from different instruments on the DE-2. For calculating the Poynting flux however, the 2005 Weimer model doesn't use a data fitted method, instead it uses a pure mathematical method (Weimer, 2005); the HAO Empirical Model does use a data fitted method.

## Bibliography

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Richmond, A.D., and G. Lu, Upper-atmosphere effects of magnetic storms: a brief tutorial, *Journal of Atmospheric and Solar-Terrestrial Physics*, 62, 1,115-1,127, 2000

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## 4. Methodology

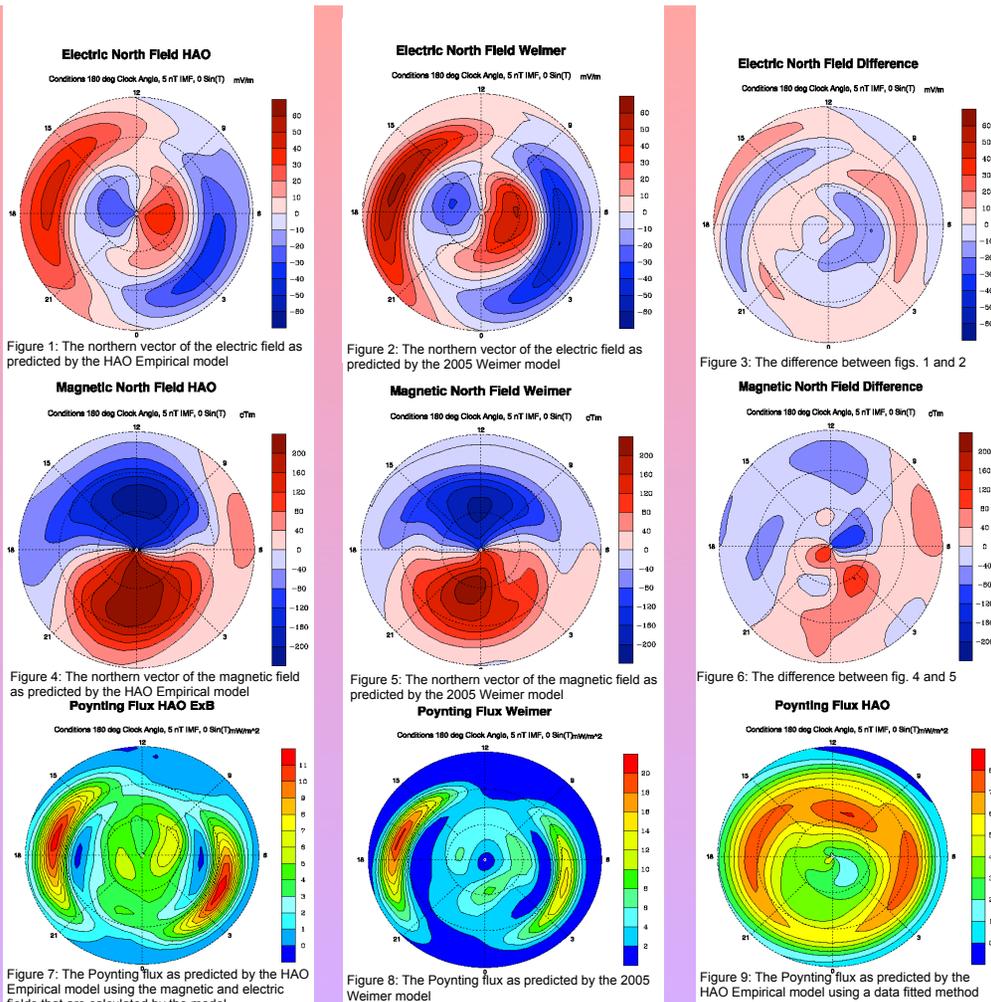
In order to compare the two models, a way to make the models output values for the same points was needed. This was done to the HAO model by adding a simple loop inside the FORTRAN code of the model that gives values for the points between the latitudes from 46.5 to 89.5 along all the magnetic local times. It was done for the 2005 Weimer model by changing his "gridpotentials" external files to match the points of the HAO model because the source code for the 2005 Weimer model wasn't available (Weimer, 2005).

The HAO model outputs a data file for each unique set of conditions (clock angle, IMF Strength, and dipole tilt angle) that it is given to calculate. The Weimer 2005 model does much the same thing by outputting the data into a text file. Once these files are created, MATLAB is used to process the data to convert both sets into the same units and format; MATLAB was also used to make the data file for the difference plots by simply subtracting the Weimer data from the corresponding HAO data. Once the data files are in the correct format, a NCAR Command Language (NCL) script was used in order to plot them. Then a visual inspection of the three plots (HAO field, Weimer field, and Difference) was done to look for structural and strength variations.

## 5. Results

More than 500 plots were created using the process described in section 4 (Methodology). From the plots, it can easily be seen that the two models have some similarities as well as some differences. When you vary the clock angle in both models, you get very similar patterns for both the electric and magnetic fields and the Poynting flux. One of the things observed is that for the electric fields, the 2005 Weimer model is consistently larger in field strength, while the opposite is true for the magnetic field strength; this occurs for varying clock angle and IMF strength, season variations cause the 2005 Weimer magnetic field to be stronger. Also, some of the difference plots are showing a large variation between the two models at the outer regions; this is caused from assumptions made by the designers of the models. The 2005 Weimer Model assumes a region at 0 in lower latitudes, this region varies with the conditions that are inputted; the HAO model doesn't have this 0 region at lower latitudes around it, so this region of greater variation can be ignored.

Even though there are local regions of large variation where the difference can be 75% or even 100% of the values that the models are giving if one looks at the plot globally most of the difference values are small compared to the values that the models are giving. When the Poynting flux is compared, the HAO fitted data plots are always much larger than the Weimer 2005 model. This phenomena come from the HAO model's Poynting flux being data fitted and the 2005 Weimer's Poynting flux being purely calculated from the electric and magnetic fields that it predicts that have smoothed. With all the plots, the major differences occur when the extremes (0 degree clock angle, low/high IMF strength, and dipole tilt angles away from equinox) are used, so both models are good at prediction energy input under normal conditions. This comparison has also led to the data fitted HAO Poynting flux model is being reworked because it showed strong bias in the residuals and differences from the 2005 Weimer.



## 6. Next Step

The HAO model will be used in a General Circulation Model to look at how the energy input influences the Thermosphere. The General Circulation Model along with the model that will help to advance our understanding of Thermosphere. The model itself will be used to create a new model that looks at both spatial and temporal small scale variations, which could be a major source for energy.