Quantifying the Variability of the Electron Density In the Ionosphere during SSW events

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Abstract:

Day-to-day variability in the F-region Ionosphere has been attributed to three sources: the solar flux variation, geomagnetic activity, and lower atmospheric forcing. It is difficult to evaluate the roles of these sources, but recently, our understanding of the mechanism as well as our modelling capability to incorporate the lower atmospheric forcing have significantly improved. These can be attributed to numerous recent studies on Sudden Stratospheric Warming (SSW) events. To analyze the SSW event of January 2009, we have to look at the NmF2 (F-region peak electron density) and the hmF2 (height of F-region peak electron density) observed datasets from the NGDC. We will compare these observed datasets with two models, the International Reference Ionosphere (IRI) model, which is an empirical model, and the Ionosphere-Plasmasphere Electrodynamics (IPE) model, which is a physics based model. In comparing the variability between the observations and the model, we will be able to more effectively quantify the role of the lower atmospheric forcing.

Sudden Stratospheric Warming (SSW):

A SSW is a huge meteorological event where the westerlies in the Northern Hemisphere either reverse directions abruptly or slow down significantly. The polar vortex will weaken or even break down completely. The warming aspect comes from a rise in stratospheric temperature by tens of degrees. **A key mechanism in SSW events is the propagation of planetary waves upward from the troposphere and their corresponding non-linear interaction with the zonal mean flow.** The potential benefit of this connection is the ability to predict the SSW a few days in advance, allowing for potential ionospheric forecasting.

Ionosphere:

The ionosphere is a casing of free electrons and ions that surrounds the earth from roughly 60 km to 800 km. There are two regions in the Ionosphere of note, but for the purposes of this research, the focus will be on the F2 region (Figure 1). Focusing on the F2 region is critical because it is furthest away from the recombination effects that could potentially conceal the lower atmospheric forcing effects. The F2 region is driven by dynamics, more so than chemistry. NmF2 and HmF2 (Figure 2) are two parameters that can be indicative of the large scale structure of the Ionosphere.

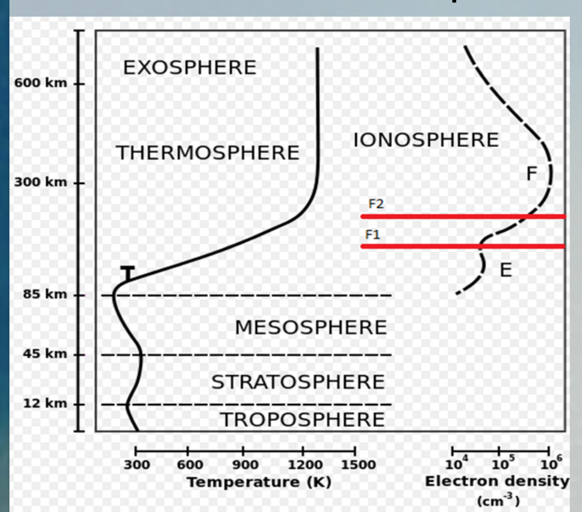


Figure 1. Vertical profile of atmosphere as a whole

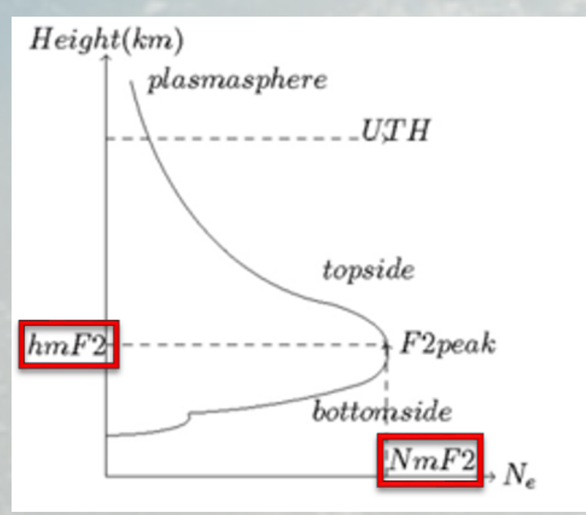
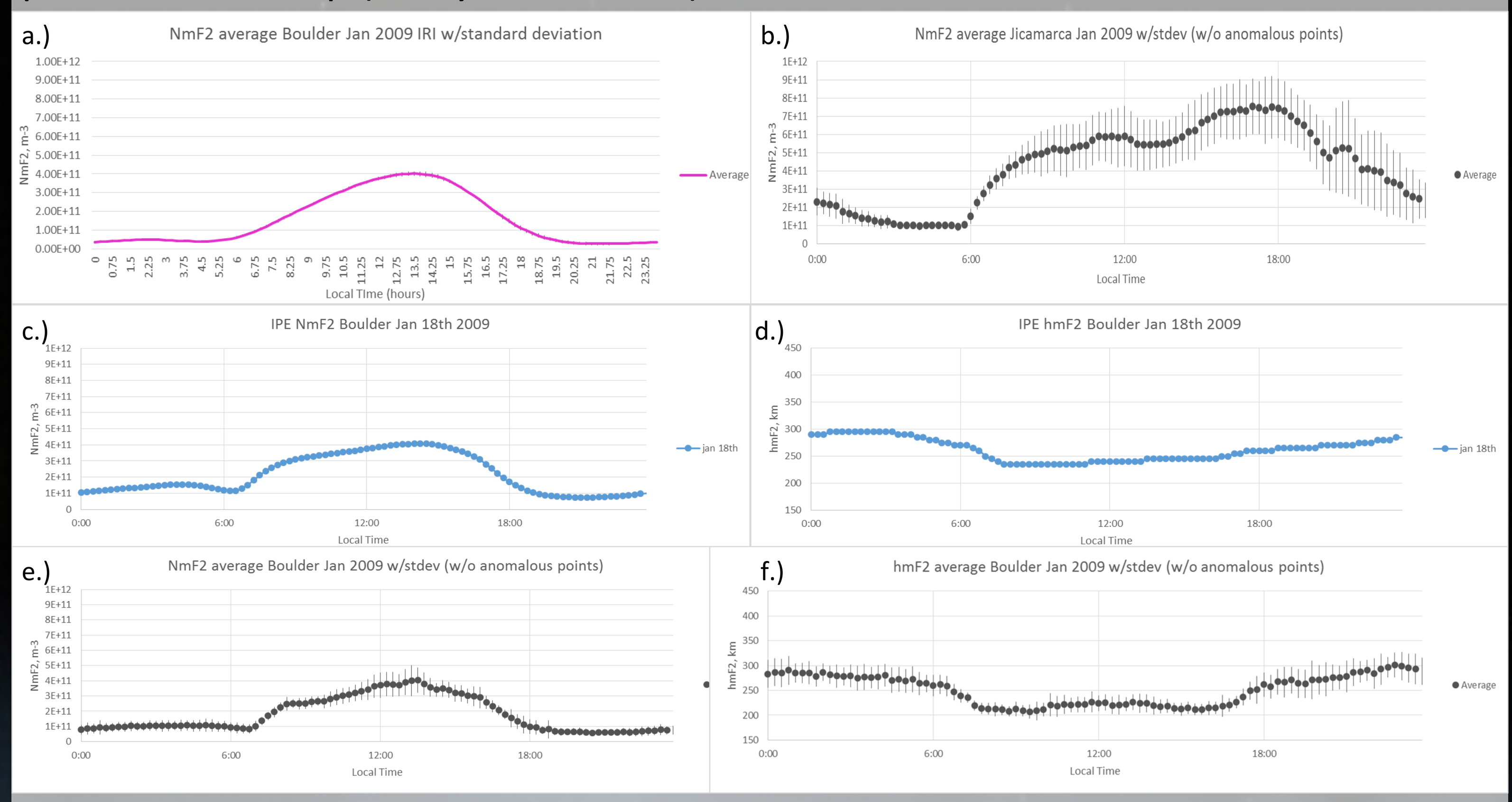


Figure 2. Vertical profile of the F region.

Results:

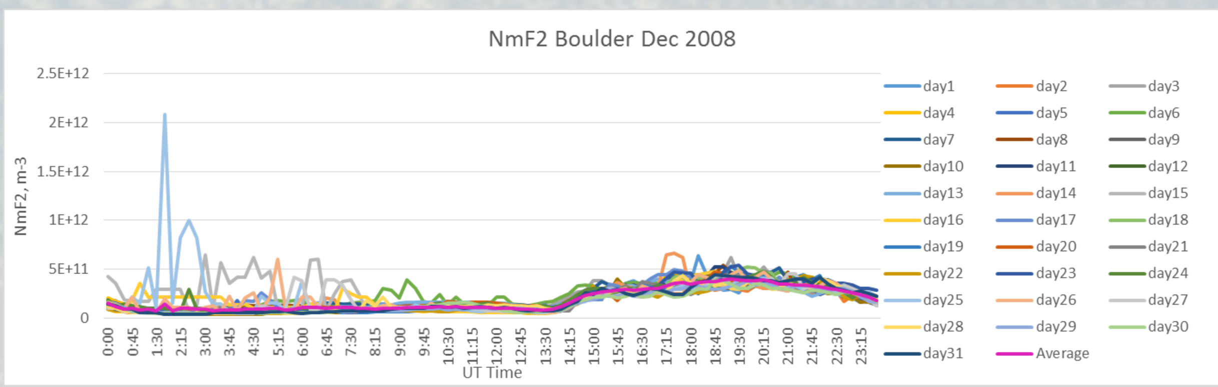
We plotted NmF2 and hmF2 once for each month (Jan 2009, Feb 2009, Dec 2008) and once for each location, Boulder (40°S, 105°W) and Jicamarca (12°S, 76°W), along with an average line plotted with the standard deviation at each point or time step (every 15 minutes).

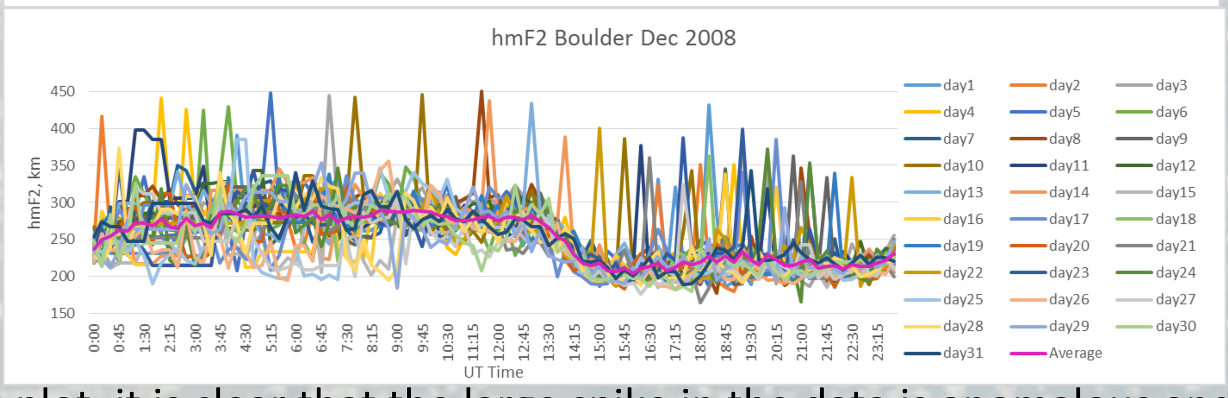


The first plots we made were using the IRI model (a) and then the observed data (b, e, f). Because the IRI is an empirical model and its main two parameters are Kp index and solar flux, both relatively consistent, there is virtually no standard deviation as seen by the figure 3a., compared to the observed data in figure 3e. By comparing c.) and e.) together and d.) and f.) we are provided with some interesting insight into how the IPE model predicts the NmF2 and hmF2 values. The similarity between the two plots is very important. It shows that the IPE model can accurately depict the NmF2 and hmF2 values, both of which are quite characteristic of the large scale structure of the Ionosphere. While there is only one day (just before onset of SSW) in the IPE model, the absence of any anomalous points would likely lead to much less variation than what is seen in the observed data. Comparing Jan 2009 (SSW) to other months, we have yet to find definitive differences between the SSW event and non-SSW events. This may be due to the inconsistency of the data.

Methodology:

NOAA's National Centers for Environmental Information, formerly the National Geophysical Center (NGDC) provides archived Ionosonde Data for the public. Through the Space Physics Interactive Data Resource (SPIDR) portion of the NGDC, they provide ionosonde data across the world. There is no quality scan before this data gets disseminated, providing additional challenges in understanding the data. Here are some examples of the raw data plotted, with clearly anomalous points:





In the NmF2 plot, it is clear that the large spike in the data is anomalous and there are numerous anomalous points in the hmF2 plot as well (note: UT time here). Since there is no quality scan in the data, it must be done manually to get rid of the variation in the plots.

Quality Scanning:

To quality scan this dataset, we had to go back to look at the original ionogram images from which the NmF2 and hmF2 values have been obtained. By going through the data and selecting suspicious points, the timestamp of the point can be used to find the specific Ionogram that is associated with the anomalous data point.

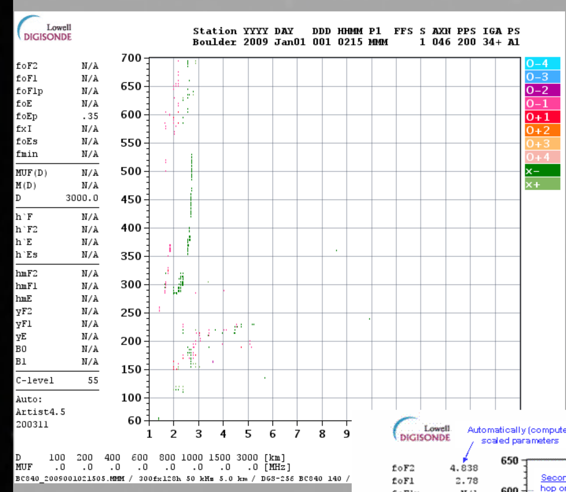


Figure 4. Example of a poor ionogram due to faint returns

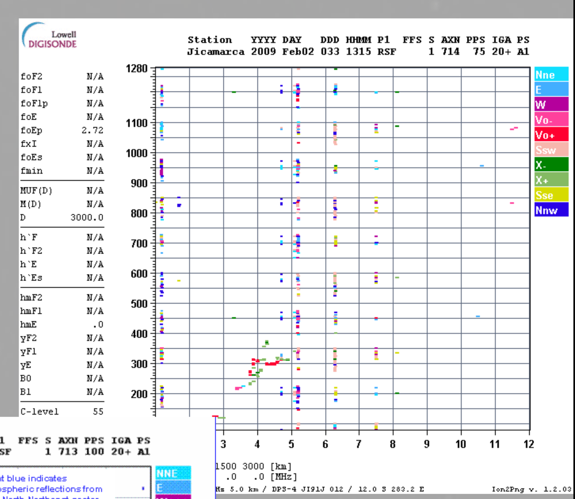


Figure 5. Example of a poor ionogram, likely caused by an error in the ionosonde

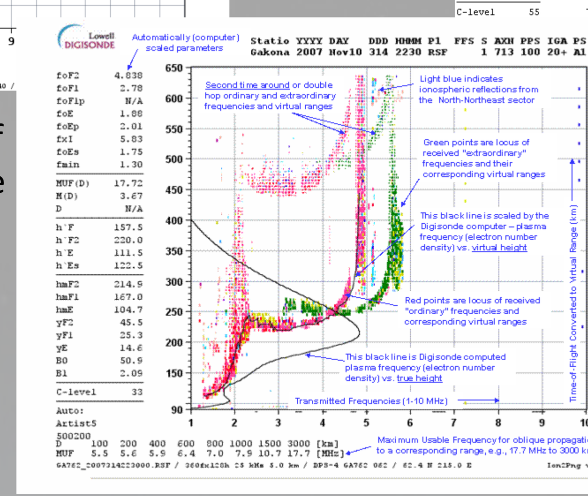


Figure 6. Example of a good Ionogram

After comparing data points with the Ionogram image, it is clear which points are anomalous, and thus which points can be exempted in an attempt to reduce the variation.

Conclusions:

We have determined the importance of quality scanning data in order to make sense of the findings. When comparing the IPE model and observed data, we see significant similarities. This means that with the WAM model driving the IPE model, the IPE model can accurately depict past events, and thus may be able to forecast events in the future. When it comes to the variation in electron density, the IPE model can reduce the variability and may be able to quantify the effects of lower atmospheric forcing. We also did confirm an increase in electron density at low latitudes compared to mid latitudes.

Future Work:

To continue this research more effectively, a code must be written to take out anomalous points from observed data. Then we will continue running the IPE model for multiple days and multiple stations to compare the variability with the goal of quantifying the variability of electron density.

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