# Statistical Averages of F-Layer Electron Density, Electron Temperature and Ion Temperature over Millstone Hill

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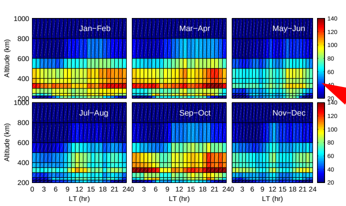
## 1. Introduction

Regional and local models can be very useful, given that global models may smear out features which are unique to a particular region. Millstone Hill (42.6$^o$ N, 288.5$^o$ E) is a midlatitude site in Eastern North America, but at an L value of 3 it lies near the plasmapause boundary and may be considered "subauroral" during geomagnetically disturbed conditions. In this region, the 12$^o$ offset between geomagnetic and geographic latitudes may also result in interesting regional and local ionospheric phenomena. All Millstone Hill incoherent scatter radar data collected since 1978 are available through the Madrigal Database. Sets of empirical models for basic and derived incoherent scatter parameters, including *Ne*, *Te*, *Ti*, electric fields and parallel drifts, are being developed from this extensive dataset. Applying them to validate and improve theoretical models as well as the empirical IRI [*Bilitza*, 2000] will result in better operational models for engineering and educational applications, and also help resolve outstanding scientific issues, e.g., the dependence of annual and solar cycle variations of *Ne*, the storm-time "dusk effect", the dependence of *Te* and *Ti* on magnetic activity, etc. They can also be embodied by other specific models to provide background specification of the ionosphere or basis functions. This poster concerns local measurements of three scalar parameters *Ne*, *Te* and *Ti*. made over 150-1000 km height range in the 25-year period from February 1976 to August 2001. *Holt and Zhang* [2001] described the ion drifts results, and *Holt et al*. [2001] summarized the regional and local ionospheric models for Millstone Hill.

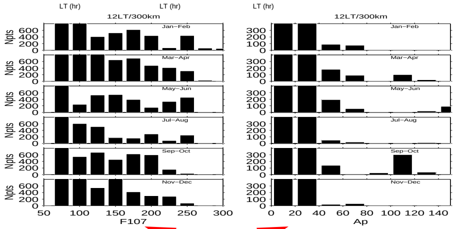
## 2. Madrigal Database

Our data are archived in the Madrigal online database system at MIT Millstone Hill Observatory, which contains an extensive body of ground-based measurements and models of the Earth's upper atmosphere and ionosphere. The basic data format is the same as used by the NSF CEDAR program, which maintains a CEDAR Database at NCAR. The standard CEDAR Database format evolved from the one used by the earlier incoherent scatter database, which in turn evolved from a format developed at Millstone Hill in 1980. Data files are easily exchanged between the two sites, but Madrigal has a significantly different emphasis. It is a robust, World Wide Web based system capable of managing and serving archival and real-time data, in a variety of formats, from a wide range of instruments.

## 4. Data Distribution




Data density distributions versus height and local time for 6-month bins. Data density is defined as the number of data points for a given bin over the height interval. The cell color represents the density for the lower-left corner grid.




Histograms of the number of data points for 6-month bins versus F107 (left), the previous day solar 10.7 cm flux index, and Ap (right), the ap index for the previous 3 hours. Data numbers are for a specific bin whose grid values are 1200 LT and 300 km.

## Abstract

Millstone Hill I.S. radar observations of the electron density, electron temperature and ion temperature made since 1976 over 150-1000 km height range have been analyzed, using a bin-fit technique, to construct local models of ionospheric climatology and to show ionospheric variation patterns in terms of solar and geomagnetic activity dependences and of seasonal and diurnal features. Data from the large database are binned according to local time, altitude, and day number (season). A sufficient number of data points is found to be present in every bin and to be well distributed with respect to the solar activity index F107 and to the geomagnetic activity index Ap essentially when Ap<40. A multiple regression is performed for each bin using a function containing linear terms of F107 and Ap to give a set of fitting coefficients. The linear approximation is found to be generally valid for these climatology ionospheric models. Generated by such local models, primary variation patterns for the electron density and plasma temperatures exhibit good agreements with many previous results obtained for Millstone Hill and for other midlatitude sites, such as, for the electron density, the midday and sunrise "seasonal anomaly", midday "bite-out", solar activity dependences, geomagnetic responses, and for the electron temperature, the "predawn effect", morning and afternoon peaks, the unusual winter night temperature, etc. Newly revealed features include the semiannual variation of the electron density above the *F*2 peak at Millstone Hill, and the solar activity dependence of the electron temperature.

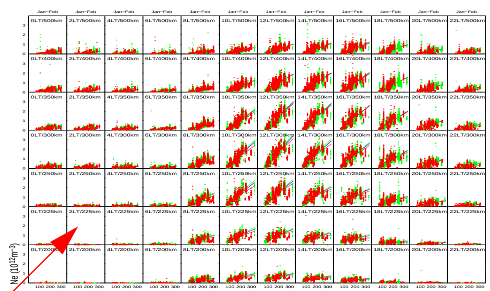
## 3. Bin-Fit Technique

The measured *Ne*, *Te* and *Ti* are separated into various bins according local time (x-direction), altitude (y-direction), and day number (to represent seasonal variations, s-direction). In x-direction, 24 hourly bins are set; in y-direction, 12 altitudes bins are set at grid values 150, 175, 200, 225, 250, 300, 350, 400, 500, 600, 800, and 1000 km.There are 6 day-number bins, each of which contains data largely for 2 months. Then we determine the solar and geomagnetic activity dependences for each bin by a least squares fit to the following equation:

$$P = b0 + b1\,(F107 - \langle F107 \rangle) + b2\,(Ap - \langle Ap \rangle) + b3\,(F107 - \langle F107 \rangle)(Ap - \langle Ap \rangle),$$

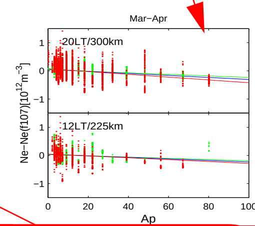
where *P* is either *Ne*, *Te* or *Ti*, the bs are fitting coefficients, F107 is the previous day's 10.7 cm solar flux index, and Ap is the 3-hourly equivalent range index *ap* for the previous 3 hours. The deviations of actual data from the model represent the remaining day-to-day variability due to such causes as tidal forcings, gravity waves, and uncertainties in the solar EUV flux and high latitude forcings which are difficult to accurately specify. While the physics involved in ionospheric responses to F107 and Ap is rather complicated, we opt to the linear approximation for simplification, so that our fitting procedure can produce correct general trends of variations. As illustrated later, the linear function used in this climatology model is generally valid for most bins.

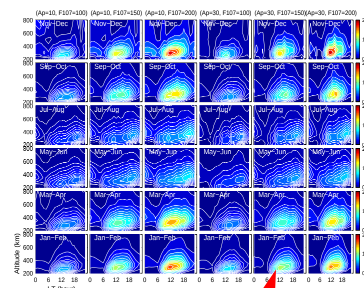
## 5. Ne Results




Ne (above)/Te (below, left)/Ti (below right) variations versus F107 index for July and August. Each frame, corresponding a data bin with time and altitude grid values marked, contains Ne data by green and red dots and model values by green, red and blue lines. The green dot group is for Ap index smaller than the average, and the red dot group is for the remaining Ap index. The green line is for model values with the lower quarter Ap as the model input, the red line is with the upper quarter Ap as input, and the blue line is with the average Ap as input.

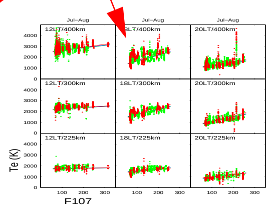
Electron density responses to Ap index changes for March and April. The F107 effect has been reduced by subtracting our Ne model values with only F107-related terms included from the Ne data (dots) or from our model (lines). By comparing the green dot group, for F107 smaller than the average, and the red dot group, for F107 greater than the average, we see no significant differences indicating that the F107 effect has been well removed.



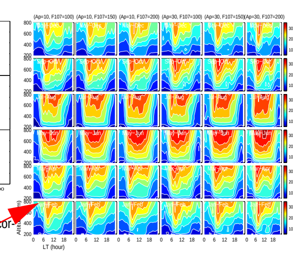



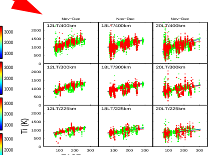

Contour plots of the model Ne in the time and height plane for 6 sets of solar and magnetic activity indices: (Ap, F107); the model Ne is computed for each bin grid with our model coefficients. (Ap, F107) values are changed for frames from left to right, and the grid value of the day number (month) is changed for frames from bottom to top. Ne scaled with color bars is in unit of $10^{12}$ $m^{-3}$.

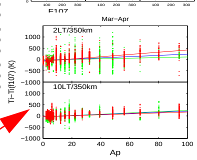
## 6. Te and Ti Results




Te model contour plots. See figure captions for the corresponding Ne plots.



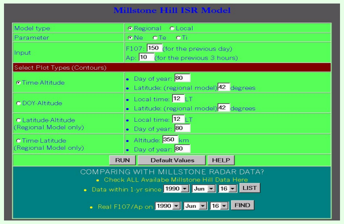




Ti responses to Ap index changes. See figure captions forth corresponding Ne plots.

## 7. Model Availability

Fortran Code available;
http://www.haystack.edu/madrigal/Models/isrm_form.html
http://www.openmadrigal.org/

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