E-region Neutral Temperature Climatology at Mid-latitudes

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Introduction

Data obtained from the Millstone Hill incoherent scatter radar (42.6N, 71.5W) during the interval 1987 through 2000 have been analyzed to obtain an empirical model of neutral temperature in the lower thermosphere. The database used in this study covers over 180 days spread over 14 years, and spans the altitude range from 105 to 140 km.

The model presented is an extension of Millstone Hill Ionospheric Plasma Model (see http://www.haystack.mit.edu/madrigal/Models/) and utilizes the same approach and binning techniques.

Local measurements of ion temperature (assumed to be equal to neutral temperature at 105 -140 km) are binned in 1 hour local time and 5 km altitude. In each bin, the dependencies on solar and magnetic activity are determined through a least squares fit to the following equation:

$$Tn = A + B * F10.7 + C * Ap + D * Ap*F10.7$$

where Tn is neutral temperature, A-D are the fit coefficients, F10.7 is the previous day's solar flux index, and Ap is the geomagnetic index for the previous 3 hours.

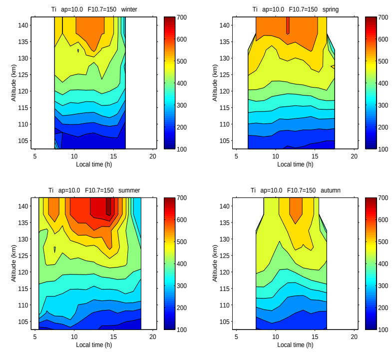
Inputs to the model are the F10.7 index (which provides a measure of solar irradiance) and the Ap index (which provides a measure of geomagnetic activity). The purpose of the model is to produce neutral temperature which, from statistical point of view, should be observed under those conditions.

The experiments were assigned to 4 different seasons as follows:

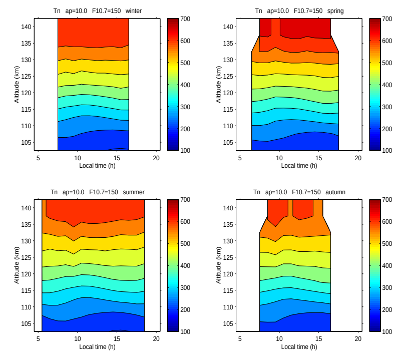
winter 45 > daynumber < 299
spring 45 < daynumber <= 115
summer 115 < daynumber < 229
autumn 229 <= daynumber <= 299,

which leads to relative scarcity of data in spring and autumn. Furthermore, autumn season has the smallest number of data due to fewer experiments.

Only day-time data are available at these altitudes due to low signal-to-noise ratio at night. Currently, the model limits the local time coverage for a particular season based on number of points in the bin and quality of the fit for the bin. Approximately 12 hours of data are available at summer time and 8 hours in winter.



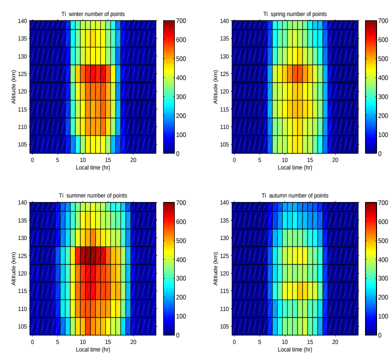
Example of ISR model output for Ap=10 and F10.7=150 for different seasons. Contours values are shown for every 50 K.



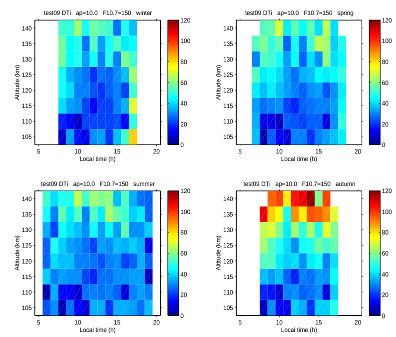
Example of MSIS-86 model output for Ap=10 and F10.7=150 for different seasons. Contours values are shown for every 50 K.

To compare ISR neutral temperature to MSIS-86 neutral temperature, we bin MSIS results in the same manner as experimental data, i.e. every experimental data point is associated with data point from the MSIS model for exactly same time and altitude, and MSIS bins are fit with the same equation.

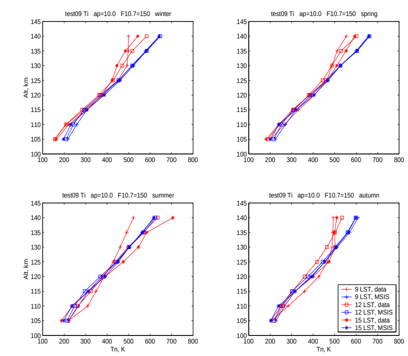
The most prominent difference between ISR data and MSIS-86 is the lack of diurnal and seasonal temperature variations given by MSIS for the available daytime coverage and overestimate of temperature by MSIS in 130-140 km range in winter, spring, and autumn.. MSIS temperature below 130 km is practically identical for all seasons, while by 140 km MSIS winter temperature exceeds summer temperatures by 20-30 K. MSIS spring temperature exceeds autumn temperature by as much as 70 K. In contrast, ISR data show that above 130 km summer is warmer than winter at all available times. Spring-fall ISR temperature difference are of the same order as given by MSIS.



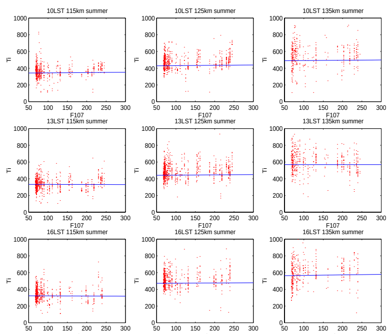
Number of points included in each 1-hour, 5 km bin shown separately for each season.



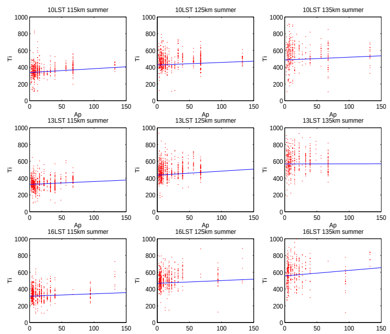
To get the measure of dispersion in the derived model, characterizing both spread of data due to uncertainties and the goodness of fit, we calculate errors from the covariance matrix using number of degrees of freedom and chi-square estimate. The figure shows estimates of error for every bin for different seasons. In general, errors do not exceed 20-40 K at altitudes below 135 km and increase up to ~70 K at 140 km. The largest errors are found in autumn season, mainly due to the smaller number of points per bin.



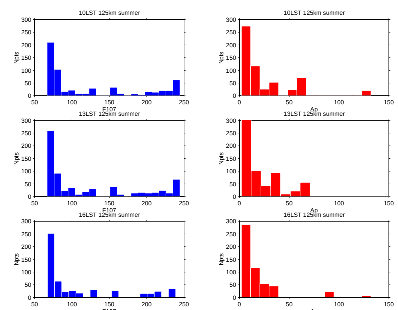
Comparison of ISR experimental model and MSIS at 9, 12 and 15 LST for different seasons shows general good agreement for all seasons, especially at noon time and below 130 km. At higher altitudes, the discrepancy increases and reaches 100-150 K for 9 LST and 15 LST time bins.



Data (red dots) distribution as function of F10.7 compared to fit (blue line) for several time/altitude bins confirms that dependence on F10.7 can be described by a linear function.



Same as previous figure, but for Ap.



Histogram of data distribution depending on level of F10.7 (left) and Ap (right) for several bins illustrates abundance of data for low solar activity and low geomagnetic activity and relative scarcity of data for moderate solar activity and disturbed conditions.

Summary

- Using E-region temperature measurements by Millstone Hill incoherent scatter radar (42.6N, 71.5W) during the interval 1987 through 2000, we compile temperature climatology and build a model of day-time neutral temperature in the altitude range 105-140 km.
- Comparison with MSIS-86 model shows general good agreement at altitudes below 130 km and highlights inadequate MSIS representation of diurnal and seasonal changes in temperature.
- Though dependence of neutral temperature on solar activity and geomagnetic activity at the altitudes of 105-140 km can be described by a linear function, the slope of the function is relatively small and in most cases does not exceed the estimated error in temperature.

Future plans

- Fine-tune the model to account for effects of undersampling during moderate solar activity and disturbed conditions
- Make model ouput available through Madrigal database
- Extend model to higher altitudes and combine with local F-region model