**MTM Observations Using Three Incoherent Scatter Radars**

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**Abstract**

We compare incoherent scatter radar (ISR) observations of the midnight temperature maximum (MTM) collected at three sites: the Jicamarca Radio Observatory, Peru; the Millstone Hill Observatory, USA; and the Arecibo Observatory, Puerto Rico. Jicamarca and Arecibo are at similar geomagnetic latitudes in opposite hemispheres but are at different geographic latitudes. We use data from the Millstone Hill Observatory during low-sun-solar-activity conditions to analyze ionospheric parameters closer to Arecibo.

**Introduction**

The midnight temperature maximum (MTM) is a local maximum in the neutral temperature around midnight. It is thought to be caused by the combination of in-situ thermal excitation, neutral momentum coupling and lower atmosphere tidal waves penetrating into the thermosphere. The absence of any plasma production by absorption of XUV radiation during the night allows the electrons and ions to temperatures to relax to the neutral temperature in the thermosphere. Variations in the nighttime plasma temperatures, and densities determined by ISR techniques, should reflect the MTM in the neutral temperature TN. We characterize the MTM in terms of amplitude, time of occurrence and width. We present data on the seasonal dependence of the amplitude and time of occurrence of the MTM along with an analysis of the altitude dependence. These three sites allow us to examine the latitudinal extent of the MTM. Data from Millstone Hill are obtained using south pointing low elevation scans. This provides us with data between 30° and 34°N. We have observed the MTM at multiple altitudes, between 250 and 400 km at all three sites. Nights with simultaneous observations of the MTM using the Arecibo ISR and the Millstone Hill ISR are analyzed. Preliminary results indicate that the MTM occurs later at Millstone Hill and earlier at Jicamarca. It also appears that the amplitude is greater at higher latitudes.

**This Work**

For this study we are comparing MTM data taken from three different sites: the Jicamarca Radio Observatory, Peru, the Millstone Hill Observatory, USA, and the Arecibo Observatory, Puerto Rico. Jicamarca and Arecibo are at similar geomagnetic latitudes in opposite hemispheres but are at different geographic latitudes. We use data from the Millstone Hill Observatory during low-sun-solar-activity conditions to analyze ionospheric parameters closer to Arecibo.

**Arecibo**

Two important characteristics of the MTM are amplitude of the enhancement and time of occurrence, both determined here by a function that takes into account diurnal, semidiurnal and tidal components. The resulting curve is shown in Fig. 2(a). In order to obtain reliable data, nighttime ion and electron temperatures must be equal. Figure 2(b) shows that ion and electron temperatures are equal during the time the MTM is observed.

**Jicamarca and Arecibo**

The Jicamarca Radio Observatory allows us to study the MTM in the southern hemisphere and very close to the magnetic equator. Figure 5(a) shows an MTM at Jicamarca on 11 March 2011 at 24 LT.

**Model Comparisons**

The MTM has been studied using incoherent scatter radar (ISR) and the B&M model developed at MIT Haystack. This model reproduces the MTM from 6 March 1999. The model outputs what is expected for a given day of the year but no yearly dependence. The model shows that the MTM is at ~27°N ± 2 LT (Fig. 12(a)) and ~1.1 LT (Fig. 12(b)). The amplitudes are smaller than the observation.

**Summary**

The MTM results indicate large day-to-day variability in the upper atmosphere. Data were fitted using a function including different tidal modes. Proper determination of TN values depends on the incoherent conditions. At Arecibo at night, a ratio T/ΔT different than one implies had TN for the ratio to be set to one; and at Millstone Hill the ratio can be different than one, and data can still be used.

The MTM occurs earlier in local summer at Arecibo, consistent with the B&M study at Jicamarca. Conversely, recent results from Jicamarca indicate a later occurrence time when compared with the B&M study.

A statistical analysis of the MTM amplitude shows a slightly earlier and greater amplitude MTM at Jicamarca when compared to Arecibo. Results from both show the MTM occurring later and with greater amplitude when compared to Arecibo.

Model results from WAM and the ISRM are consistent with the radar observations of the MTM. They also show similar large variability. Imaging observations show MTM effects occurring at higher latitudes in the southern hemisphere.