Nighttime Ion Temperature Variations Observed by ROCSAT-1 Satellite

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Abstract

Based on ion temperature measured by Ionospheric Plasma and Electrodynamics Instrument (IPEI) onboard the first satellite of Republic of China, ROCSAT-1, which had been operated at 600 km altitude with a 35^o inclination during 1999-2004, quiet-time ion temperature distributions were constructed to investigate longitudinal, latitudinal and seasonal variations of topside ionospheric ion temperature in the nighttime sector during the solar maximum year of 2000. The distributions indicate that ion temperature troughs exist for all seasons and ion temperature crests appear only at solstices. The temperature troughs are located near the dip equator but centers of the temperature troughs move slightly to the summer hemisphere at solstices. The temperature crests are located in the winter hemisphere but have a narrow latitudinal coverage. Both the maximum in the temperature crests and the minimum in the temperature troughs are located in a longitudinal region of negative magnetic declination (South Atlantic region) during the June solstice and in the longitudinal region of positive magnetic declination (North Pacific region) during the December solstice. Such variations are attributed to neutral wind patterns in the nighttime sector and the geometry of geomagnetic field lines. They can be identified with the ROCSAT measurements on field-aligned ion flow and O^+ percentage.

Ion Temperature

The IPEI instrument consists of an ion trap to collect ion fluxes, a pair of drift meters to measure the arrival angles of the ion flow, and a retarding potential analyzer to obtain the current-voltage curves for analysis of ion temperature, ion composition and the ram flow. Since ROCSAT can cycle twice almost all the solar local times and geographic longitudes during each season, the seasonal variations can be studied adequately by the ROCSAT observations in the low-latitude region. A complete set of ion data from 5 February 2000 to 4 February 2001 is setup to study the statistical averages of the seasonal, diurnal, longitudinal, and latitudinal variations of the topside ionospheric ion properties.

In this paper, changes in the ion temperature are further examined in Figure 1 for three alternative nighttime hours in geographic longitude versus geographic latitude for four different seasons to highlight the contrast in the development of ion temperature. The plots are arranged in columns from left to right for 2200-2300 LT, 0000-0100 LT, and 0200-0300 LT. The seasonal variation is arranged in panels from top to bottom for the March equinox, the June solstice, the September equinox, and the December solstice. A thick green line is drawn in each panel to indicate the magnetic dip equator.

From Figure 1, we can see that temperature troughs are all existed for all longitudes. In the later hour, centers of the temperature troughs are deeper and shifted to the summer hemisphere. The minima of the temperature troughs are distributed at longitudes of negative and zero magnetic declination during the June solstice and at longitudes of positive magnetic declination during the December solstice.

Temperature plateaus in the summer hemisphere with dip latitudes higher than 30^o are gradually reduced as local time progresses. Temperature crests in the winter hemisphere with dip latitudes around 10^o are more prominent at longitudes of negative magnetic declination during the June solstice and at longitudes of positive magnetic declination during the December solstice. Meanwhile, the magnitude of the temperature crests are also gradually reduced but still existed for all night.

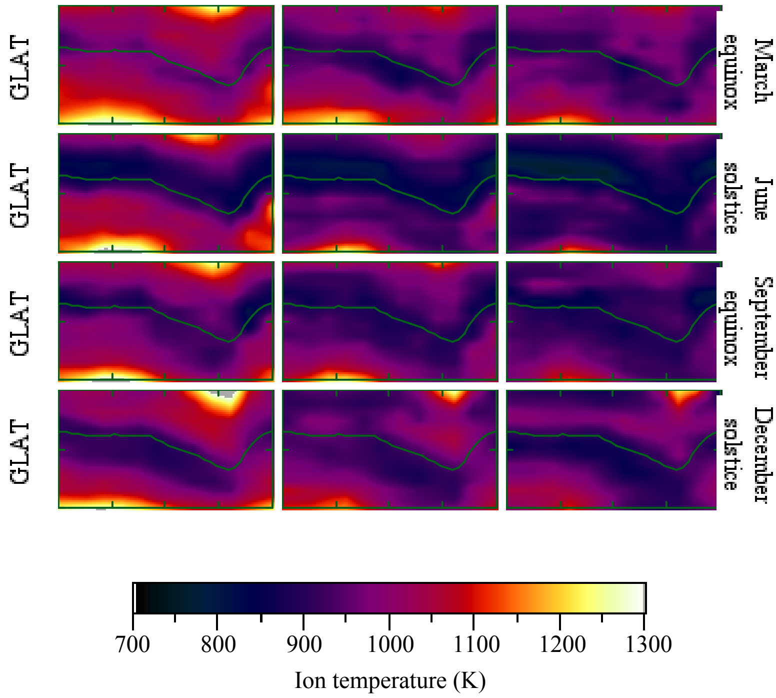

Figure 1. Ion temperature variations observed by ROCSAT-1 satellite at 600 km altitude for geographic longitude versus geographic latitude in year 2000. The plots are arranged in the horizontal direction for local time sectors from 2200-2300 LT, 0000-0100 LT to 0200-0300 LT and in the vertical direction for seasons from the March equinox, the June solstice, the September equinox to the December solstice. A thick green line is drawn in each panel to indicate the magnetic dip equator.

Field-aligned Ion Flow

It is well known that nighttime ion temperature in the topside ionosphere at low latitudes is greatly affected by field-aligned interhemispheric plasma flows (Hanson et al., 1973; Bailey et al., 1973; Venkatraman and Heelis, 2000). It is necessary to exam local time variations of field-aligned ion flow patterns observed by ROCSAT in Figure 2 to compare with the corresponding ion temperature distributions. Figure 2 has the identical layout as in Figure 1. The ion flow parallel to the field line (northward) is shown in red color and anti-parallel (southward) in blue.

In this nighttime sector, zonal winds are directed in the eastward direction within the ROCSAT coverage (Blum and Harris, 1975). As for meridional winds, they are mostly directed from summer to winter hemisphere at solstices and equatorwards at equinox. These neutral wind features are probably used to explain our observations on the field-aligned flows. The high downward flows are observed at longitudes of negative magnetic declination during the June solstice and at longitudes of positive magnetic declination during the December solstice. We believe the plasma expansion in the summer hemisphere results in the shifting of the temperature troughs and the plasma compression in the winter hemisphere produces the temperature crests.

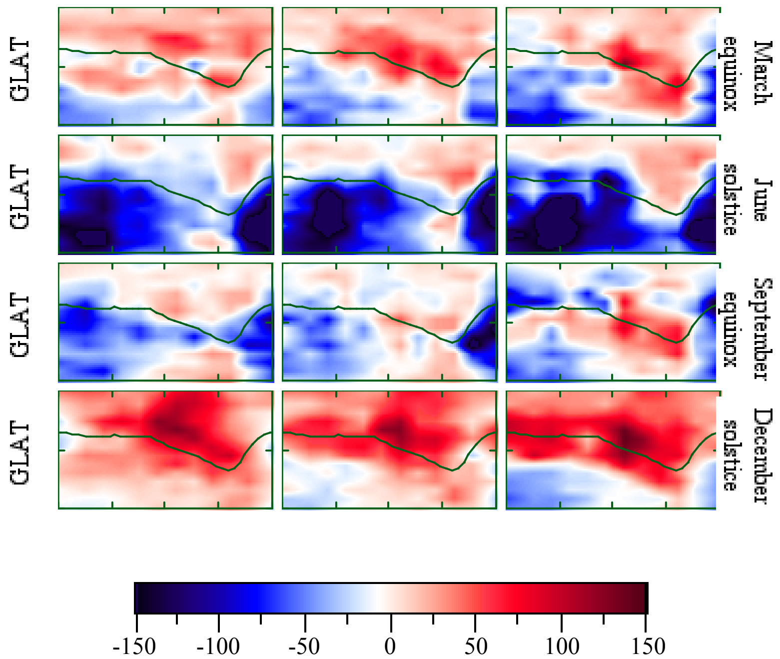

Figure 2. Field-aligned ion flow velocities observed by ROCSAT at 600 km altitude for geographic longitude versus geographic latitude in year 2000. The plots are arranged as in Figure 1. The ion flow parallel to the field line (northward) is shown in red color and anti-parallel to the field line (southward) in blue.

O^+ Percentage

The O^+ percentage observed by ROCSAT is shown in Figure 3. It is clear that O^+ percentage is usually high at the dip equator. At equinoxes, the O^+ percentage is low in the South Atlantic and Africa region and in the North Pacific region. However, the O^+ percentage is only low in the South Atlantic and Africa region during the June solstice and in the North Pacific region during the December solstice.

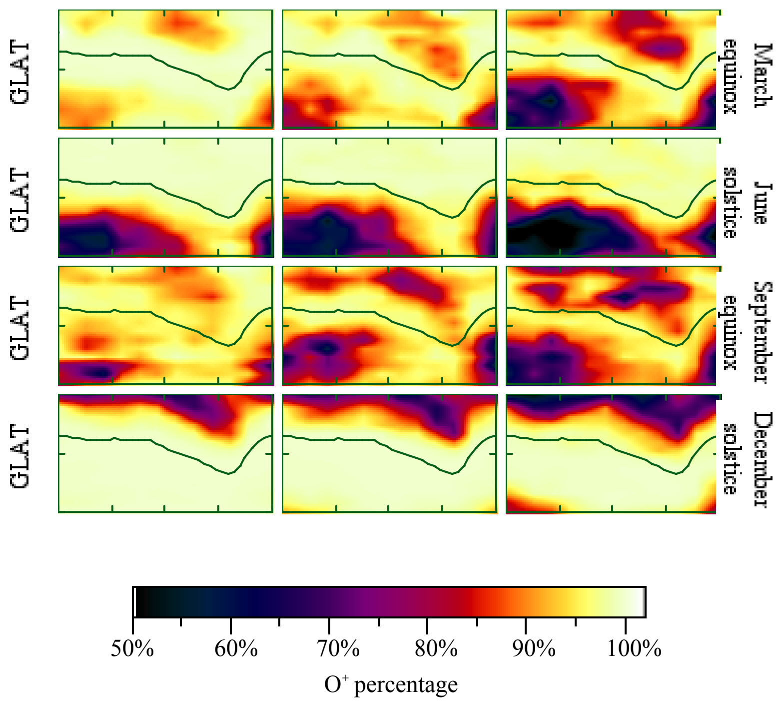

Figure 3. The composition percentage for O^+ observed by ROCSAT at 600 km altitude for geographic longitude versus geographic latitude in year 2000. The plots are arranged as in Figure 1.

The plasma expansion/compression processes are also affected by O^+-H^+ transition height. The location of the highest plasma expansion is expected to be in the field line just under the O^+-H^+ transition height and the location of the highest plasma compression is lower than the field line of the O^+-H^+ transition height (Heelis et al., 1978; Venkatraman and Heelis, 1999). Therefore, we expect the latitudinal coverage of the temperature crests are limited by the low O^+ percentage.

Summary

The ion temperature, field-aligned flow, and O^+ percentage measured by ROCSAT-1 have shown several significant results in the nighttime sector:

Low ion temperature troughs exist for all seasons and high ion temperature crests appear only at solstices. The temperature troughs are located near the dip equator but centers of the temperature troughs move slightly to the summer hemisphere less than 5° in dip latitudes at solstices. The temperature crests are located around 10° dip latitude in the winter hemisphere. Both the maximum in the temperature crests and the minimum in the temperature troughs are found in the South Atlantic region during the June solstice and in the North Pacific region during the December solstice. The temperature variations are attributed to the neutral wind patterns and the geometry of geomagnetic field line on the field-aligned plasma transport. The plasma expansion (cooling) in the summer hemisphere result in the shifting of temperature troughs and the plasma compression (heating) in the winter hemisphere forms the temperature crests. The reduction of O^+ percentage in the winter hemisphere limits the latitudinal coverage of the temperature crests.

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