Sensing the upper and lower levels of the atmosphere during the 2009 equinoxes using GPS measurements

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ABSTRACT

This short-term work characterized the upper and lower levels of the atmosphere through Global Positioning System (GPS) measurements. The observations were conducted during the 2009 equinoxes from two pairs of conjugate polar observing stations: Husafell, Iceland (HUSA) and Resolute in Nunavut, Canada (RESO) and their conjugate pairs at Scott Base (SBA) and Syowa (SYOG) in Antarctica, respectively. The total electron content (TEC), an indicator of the upper atmosphere, and the precipitable water vapor (PWV), which served as the lower atmospheric response, were retrieved and analyzed. The results reveal a good relationship between TEC and PWV at each station during the onset day of the equinoxes, whereas an asymmetrical response was observed in the beginning of and after the equinoxes. In addition, the conjugate pairs were only consistent during the autumnal equinox. Thus, the high correlation was observed following the seasonal pattern for the onset day, while strong and moderate correlations were found only for the vernal equinox in Antarctica and the Arctic, respectively. This relationship reflects the fact that the intensity of solar activity during the solar minimum incident on the lower atmosphere through the conjugate points is associated with the variation of the Sun's seasonal cycle, whereas the TEC and PWV showed an opposite relationship.

1. Introduction

The use of the Global Positioning System (GPS) in a wide variety of applications has exploded in the last few years. With the advancement of GPS technology and the spread of the GPS network around the world to remote locations such as Antarctica, the application of GPS to tasks including monitoring atmosphere dynamics, positioning and tracking, meteorology, and geophysical surveying has become possible. Recently, GPS has become a powerful tool for quantifying the ionospheric total electron content (TEC) [e.g., Coco 1991, Wanninger 1993, Klobuchar 1996] and the atmospheric precipitable water vapor content (PWV) [e.g., Bevis et al. 1994, Businger et al. 1996, Rocken et al. 1997] in a cost-effective manner with global coverage and superior temporal and spatial resolution. This application of GPS can improve our understanding of the mechanisms driving ionospheric irregularities and the evolution of water vapor, two important factors in the relationship between solar activity and our atmosphere. Many studies have shown that perturbations in the ionosphere are clearly related to solar activity [e.g., Perrone and Franceschi 1998, Liu et al. 2011]. However, the impact of the ionosphere on the dynamics of Earth's atmosphere is still debated, and the interaction between the ionosphere and the lower atmosphere remains poorly explained.

To give a clear picture of "upper atmosphere" and "lower atmosphere" in this study, a brief definition is given. Scientists have defined both terms in various ways. In the context of meteorology, the "lower atmosphere" may be described as extending from the planetary surface (the troposphere) to the lower stratosphere, where the daily weather evolves. Thus, "upper atmosphere" refers to the entire region above the troposphere, including the mesosphere, the ionosphere and the thermosphere, which are identified by their temperature structure, density, composition and degree of ionization. Alternatively, the atmosphere can be divided into two different strata, the neutral atmosphere and the ionosphere, by considering the propagation of radio waves, such as GPS signals. The neutral atmosphere layer consists of three temperature-delineated regions: the troposphere, the stratosphere and part of the mesosphere. This layer is often simply referred to as the troposphere because the troposphere's effects dominate