RESULTS OF RADIO HOLOGRAPHIC ANALYSIS OF GPS OCCULTATION SIGNALS REGISTERED DURING CHAMP AND GPS/MET SMALL SATELLITES MISSIONS

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ABSTRACT

In this contribution new applications regarding the GPS radio occultation (RO) method in geophysical researches are presented: (1) measuring the vertical gradients of the refractivity in the atmosphere and electron density in the lower ionosphere, (2) investigation of the internal wave’s activity in the atmosphere, (3) study of the ionospheric disturbance on a global scale. The new directions may be conducive for investigating the connections between processes in the atmosphere and mesosphere, and for analyzing the influence of space weather phenomena on the lower ionosphere.

1. WAVE STRUCTURES IN THE ATMOSPHERE

Significant refinements and modernizations in the RO technique have been introduced in recent years [1]. This has lead to an increase in the accuracy of the RO method and helped create the opportunity of devising new applications in geophysical researches. One potential application is in the investigation of gravity wave (GW) activities from temperature variations in the 5-40 km interval retrieved from the phase part of the GPS RO hologram [2,3]. These studies have shown that atmospheric observations conducted by satellites with the GPS occultation method are powerful in examining the gravity wave distribution around the world with an almost uniform quality. However, it is difficult to estimate key gravity waves parameters, such as the altitude distribution of their phase and amplitude, or intrinsic phase velocity by employing the phase of GPS signals.

The importance of the amplitude channel of the GPS radio holograms for the RO investigation of the atmosphere and ionosphere has been noted formerly [4,5]. The different inherent sensitivities of the amplitude and phase of the RO signals to the wave structures in the atmosphere and ionosphere [6] have been established.

For example, in Figure 1, a comparison of the amplitude data and perturbations of the vertical refractivity gradient is shown for the CHAMP RO event 0001, February 23, 2003,
Figure 1. Comparison of the amplitude data (curve 1) and perturbations in the vertical gradient of the refractivity (curve 2). The wave structure is clearly seen in the amplitude data in the 8-40 km height interval. The increasing vertical period is observed in the 15-35 km interval.

around the tropical region in the Sahara desert. The amplitude variations in the 80-110 km height interval (curve 1 Figure 1, right panel) appeared to be connected to sharp electron density gradients in the lower ionosphere [6]. The wave structure is clearly witnessed in the perturbations of the vertical refractivity gradient in the 8-40 km interval (curve 2 in Figure 1, right panel). The vertical period of the wave structure grew from 0.8-1.0 km in the 8-25 km interval to 3 km in the 30-40 km interval. This is in agreement to an increasing intrinsic phase speed of the GW with height by 3-3.2 times. Above 40 km, the amplitude of the vertical gradient perturbations weakened by 3 fold. However, the wave structure with a changing vertical period was evident in the 40-90 km interval and the ionospheric influence was seen in the 80-110 km interval.

Figure 2. Left panel: the vertical profiles of the amplitude (curve 1) and phase (curve 2) of GW. Right panel: the height dependence of the intrinsic phase speed of GW.
The perturbations in the vertical refractivity gradient can be recalculated to the temperature gradient variations, temperature variations and subsequently, the horizontal wind perturbations via the polarization relationships [4,5]. In Figure 2, left panel, the portrait of GW is shown. Curve 1 and 2 indicate the phase and amplitude dependence of GW on height. The general form of the GW phase as a function of height (curve 1) reveals a decrease in the vertical spatial frequency of GW in the 20-40 km interval (this is in response to an increase in the spatial period of GW). The sharp changes in the phase confirm to the height where the amplitude of GW is below the noise level and the coherence in GW has disappeared. These regions can correspond to the boundaries of the wave breaking altitudes, where the energy of GW is transmitted to the turbulent structures within the stratosphere. The amplitude of GW is at its maximum in the 8-40 km interval. The height intervals between 43~45 km and 59~63 km can be considered as the boundaries of the GW breaking areas. One can estimate the intrinsic phase speed of the GW \( \nu_i \) from the dispersion relationship [4,5]. As seen in Figure 2 (right panel), the value \( \nu_i(h) \) changes in the 2-16 m/s interval. The sharp variation of the intrinsic phase speed near the 41 km height can be related to the GW breaking boundary.

**Figure 3.** Seasonal dependence in the global distribution of strong ionospheric CHAMP RO events, where the \( S_4 \) index is greater than 0.2 for March and July 2004 (left panel and right panel, respectively). The circles and crosses show the geographical position of the tangent point T (Figure 1). The circles correspond to the night events (20 h – 08 h LT), while the crosses are related to day events (08 h – 20 h LT).

2. PLASMA PERTURBATIONS IN THE LOWER IONOSPHERE

The geographical distribution of strong ionospheric events (with an \( S_4 \) index greater than 0.2) for all types of the amplitude scintillations in the CHAMP RO signals at 1575.42 MHz, is demonstrated in Figure 3. The distribution of the ionospheric events indicates that they are concentrated in some regions (e.g., the equatorial and geomagnetic North and South polar zones in Figure 3). Strong activity in some equatorial regions may be connected with the evening ionospheric disturbances that arise after sunset, 20-24 hours of local time, in accordance with earth-based measurements reviewed earlier [7]. The number of intense
ionospheric events increases with time in the northern Polar Regions from May – July 2001 to November – December 2001. The number of strong ionospheric events also increases in the southern equatorial region during the same time period. These changes indicate two important mechanisms governing the ionospheric disturbances. The first is connected to the processes of ionizations caused by fast electrons moving from the magnetosphere to the Polar Regions, while the second is related to the effects of solar radiation. The influence of solar radiation can be associated with the seasonal changes.

3. CONCLUSIONS

The amplitude variations in GPS occultation signal can be used to measure the perturbations in the vertical gradient of the refractivity and temperature in the atmosphere. The GW polarization relationships can be applied to find the horizontal wind perturbations and its vertical gradient as function of height.

The amplitude of the GPS signals is also a radio holographic indicator of the ionospheric disturbances in the trans-ionospheric links, including the RO links and the satellite-to Earth links. The seasonal, geographical and temporal distributions of the CHAMP RO events with high $S_4$ index values showed a dependence on solar activity and indicated two mechanisms of ionization: (1) ionization owing to the fast electron moving in the downward direction from the magnetosphere and (2) solar radiation.

It follows that the amplitude part of the GPS RO radio holograms is important for new applications of the RO method to analysis of the wave phenomena in the atmosphere and ionosphere, and for experimentally studying the connections between processes in the atmosphere, mesosphere and ionosphere and solar activity.

REFERENCES