Seasonal analysis of gravity waves over the southern Andes and the Antarctic Peninsula by means of GPS radio occultations.

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Abstract

The Global Positioning System (GPS) Radio Occultation (RO) technique has global coverage and is capable of generating high vertical resolution temperature profiles of the troposphere and lower stratosphere with sub-Kelvin accuracy and long-term stability, regardless of weather conditions. Fluctuations in these profiles give information about gravity wave potential energy per unit mass (Ep).

This study employed 3850 temperature profiles obtained by the CHAMP (CHAllenging Minisatellite Payload) mission over the years 2002-2005. An analysis of monthly averages of Ep showed enhancements during September and October in the wave activity over the whole area.

Some of the most energetic RO events were detected over zones where the topography is expected to play an important role, however intense RO events were also found over the ocean. According to the morphology of the mountains in the studied region, a nearly-meridional line of sight (LOS) would improve the detection of mountain waves.

Dataset and analysis method

Up to 250 RO measurements are performed daily by the mission CHAMP. Between January 1, 2002 and December 31, 2004; a set of 3850 RO fell into 75-35 W and 35-70 S, our region of study. (See Figure 1)

The vertical resolution of the temperature profiles is aproximately 1.4 km in the stratosphere, therefore only waves with vertical wavelengths grater than 2.8 km can be detected.

Figure 1: Studied Region (red square).

Wave activity was quantified by calculating the mean potential energy per unit mass E_P through the relative temperature variance content in each profile[1]:

$$Ep = \frac{1}{2}\frac{g^2}{N^2}\frac{1}{z_2 - z_1}\int_{z_1}^{z_2}(T'/Tb)^2 dz \qquad (1)$$

Normalized temperature fluctuations, $(T'/Tb)^2$, were calculated as follows: The T profiles were low pass filtered, with a cutoff at 9km, obtaining Tb. The filter applied is nonrecursive and a Kaiser window was used. The filter was applied again to the difference $T - T_b$, now with a cutoff at 3 km, giving T' profiles, which isolate wavelengths between 3 and 9 km. Mountain waves in this region tipically belong to this range. The altitude interval (z_1 - z_2) was restricted to 18-28 km (i.e. above troposphere) in order to avoid spurious enhacement of T' due to the filtering in the region of the tropopause knee.

Seasonal Analysis

In order to examine seasonal variations of gravity wave activity, monthly means of Ep were calculated. Between 14 and 129 RO were averaged in each month.

As shown in Figure 2, September and October are the more intense months. This result is consistent with other works made over zones contained in our study region. [2][3][4]

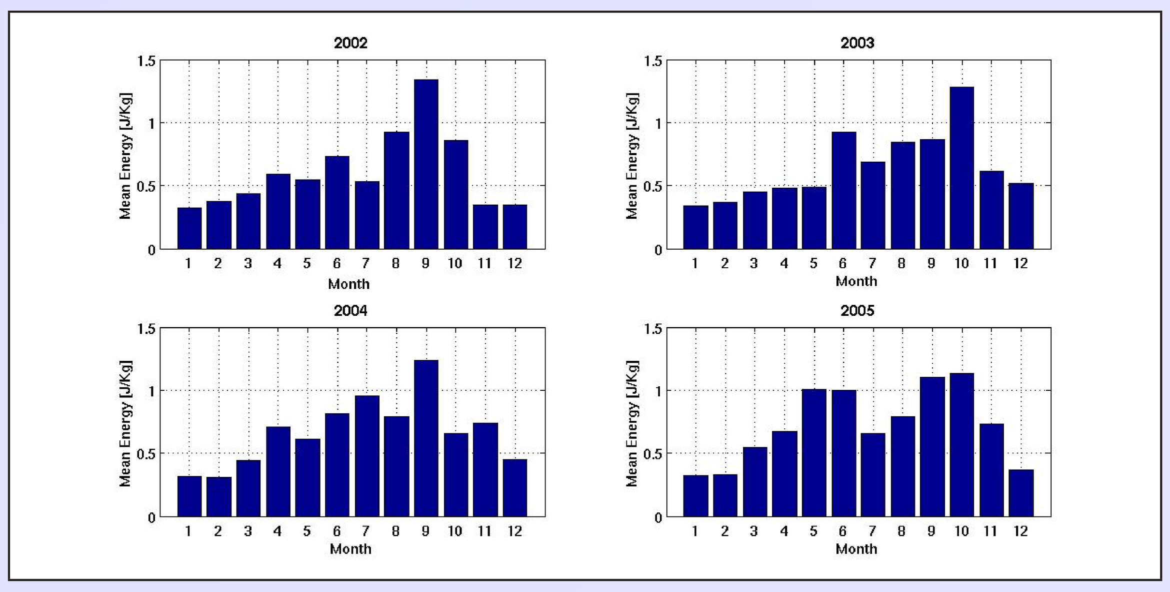

Figure 2: Monthly averages of Ep.

Geographical Variation

The geographical variation of Ep is examined by studying the distribution of the most energetics events. Figure 3 shows events with Ep > 4 J/kg. Enhancements around the Andes and the Antartic Peninsula are observed, suggesting orographic forcing of waves. Nevertheless, strong events are also registered over the ocean.

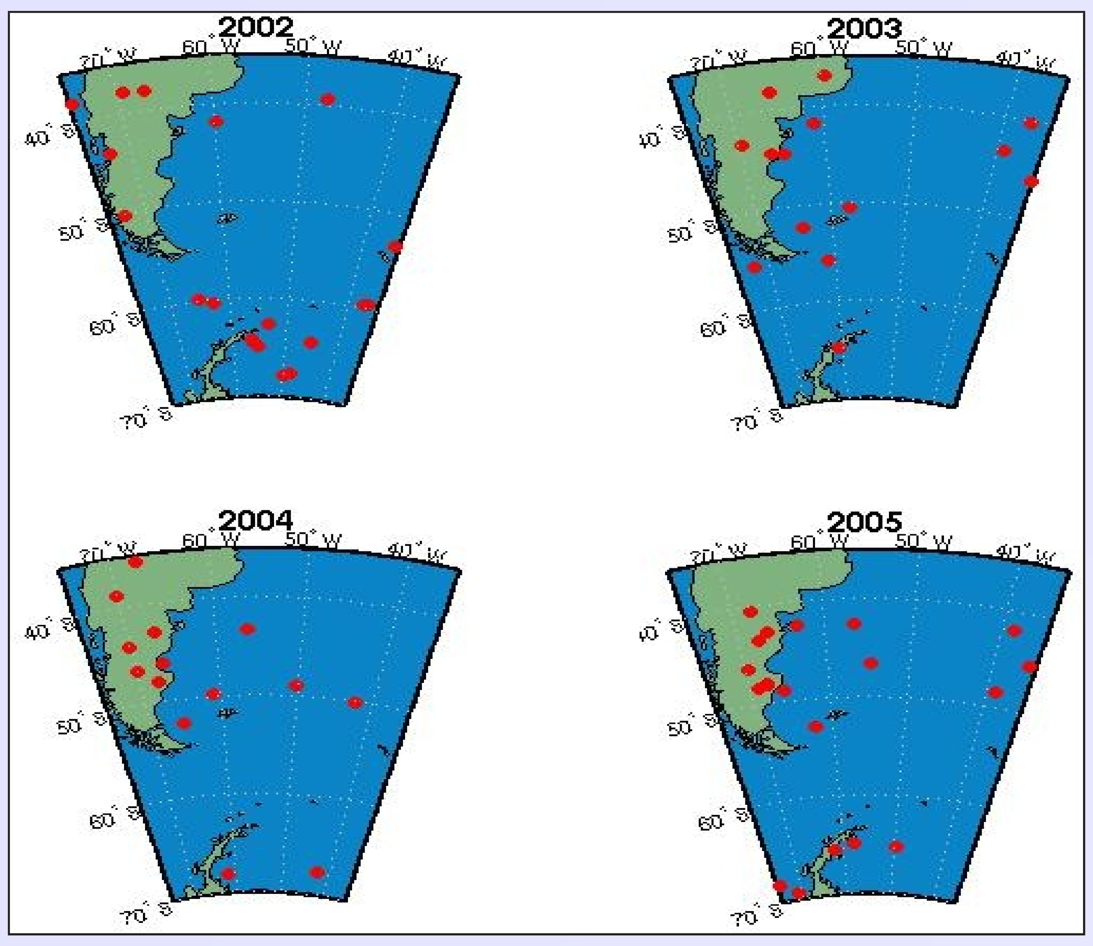

Figure 3: Distribution of intense RO.

In figure 4, a map of Ep for June to November over the four years is showed. An increase is seen at the East of the Antarctic Peninsula, suggesting orographic origin of the wave activity.

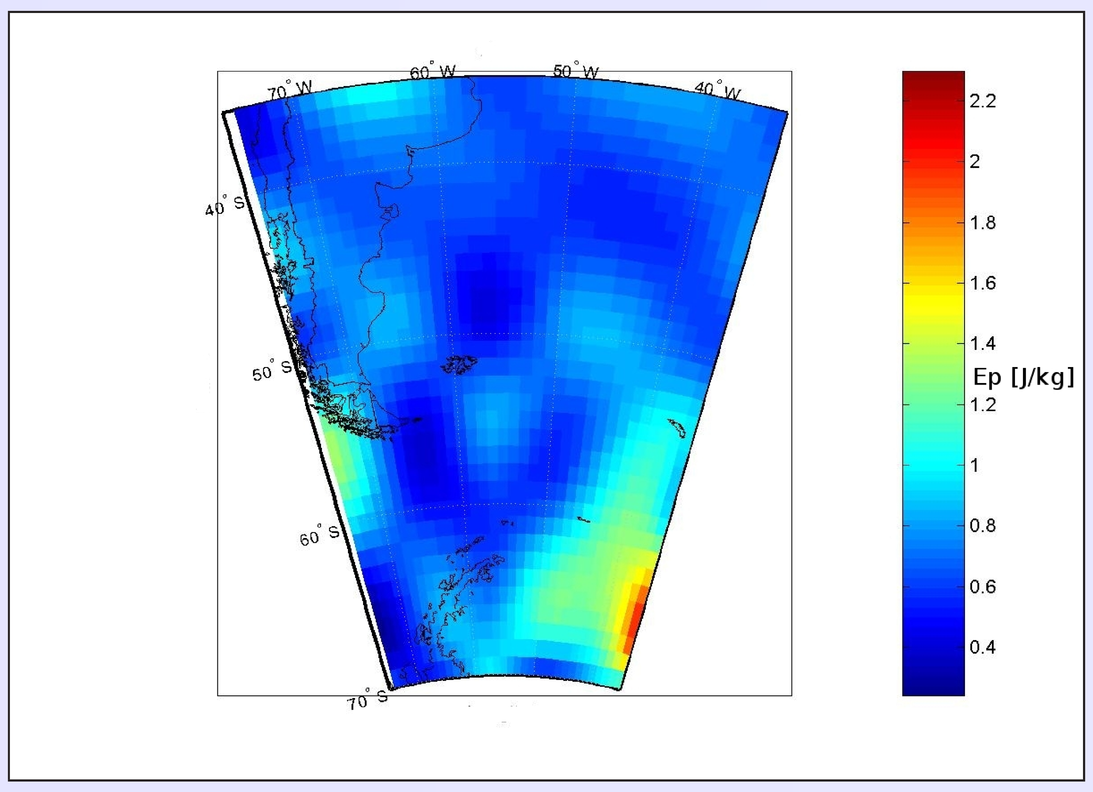

Figure 4: GW map for June to November over 2002-2005.

LOS Dependence

Mountain waves have horizontal wavelengths of tens to hundreds of kilometers, therefore detection depends on the angle between LOS and the wavefront [1]. A few degrees disalignement of LOS with respect to wavefronts enhaces the ability of GPS-RO of resolving gravity waves.

In the region studied, the Andes and the Antartic Peninsula provide a meridional obstacle for Westerlies, thus generating nearly meridional wavefronts. This fact would facilitate the detection of waves by RO with a nearly North-South LOS orientation.

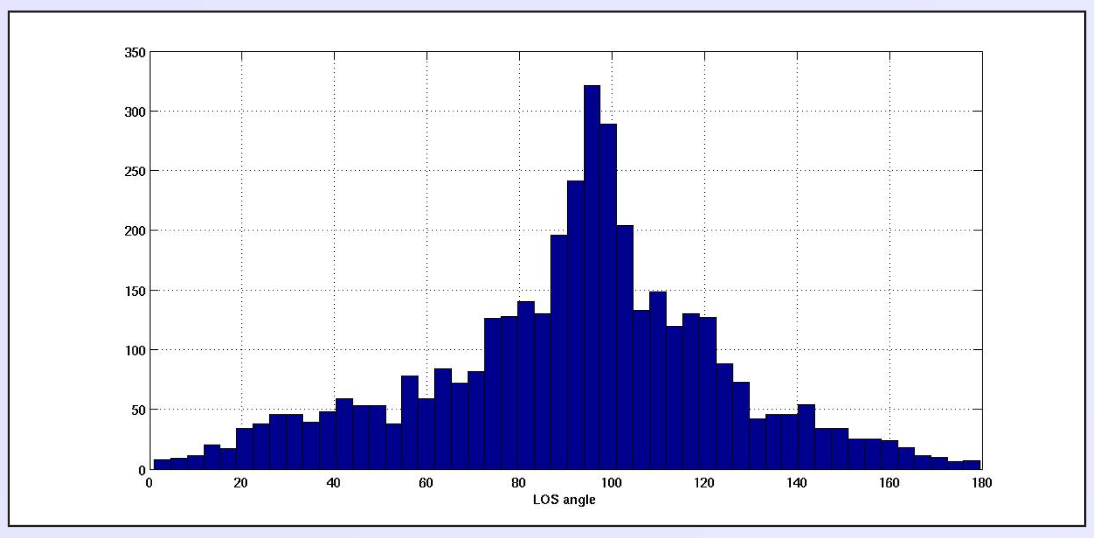

Figure 5: LOS direction histogram.

As seen in Figure 5, most of the LOS directions fall in the range of 90-110 degrees, where the angle is taken from the West-East direction.

This is the configuration needed for a better detection of the expected wavefronts in the zone.

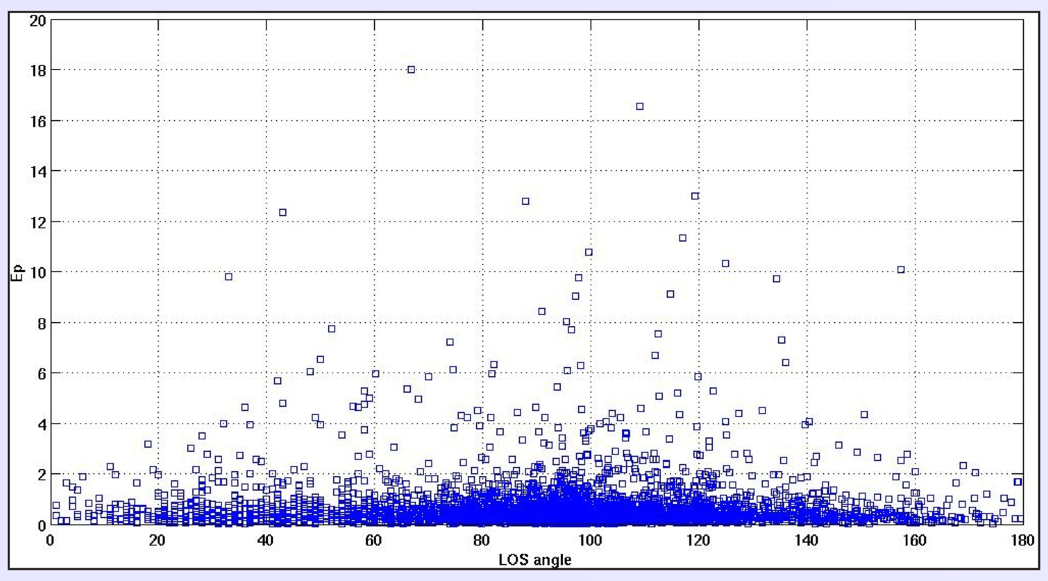

Figure 6: Ep vs LOS angle.

In Figure 6, the E_p for each RO is plotted against the LOS angle. It may be seen that the most energetic RO have LOS direction in the range of 90 $\pm$ 45 degrees.

Concluding Remarks

A study performed for the years 2002-2005 for RO in the region 75-35W, 35-70S shows energetic cases close to the Andes mountains and the Antarctic peninsula. However, some cases also occur over the ocean. We do not know the wave source of these events.

As expected, the most energetic cases are found when the LOS is nearly aligned with the expected wavefronts, i.e. in the N-S direction.

References

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