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Atmospheric Chemistry and Physics Discussions

Interactive comment on "The southern stratospheric gravity-wave hot spot: individual waves and their momentum fluxes measured by COSMIC GPS-RO" *by* N. P. Hindley et al.

Anonymous Referee #1

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In this article, N. P. Hindley et al. uses temperature profiles gathered by the COSMIC GPS radio-occultation (RO) constellation to document the activity of gravity waves at subpolar latitudes in the southern hemisphere stratosphere. Previous studies have shown that this place is a hotspot for gravity wave activity as large-amplitude waves are generated above major orographic features (Andes and Antarctic Peninsula) and are free to propagate to the stratosphere during the middle-atmosphere wintertime westerlies. Yet, this enhanced wave activity is not only observed in the vicinity of the major mountain ridges but extends over a large longitudinal sector over the Austral Ocean. While the origin of this feature is still a matter of debate, it is suspected that this broad

hotspot may be related to the so-called missing drag issue in the southern hemisphere: the fact that the stratospheric vortex breaks down too lately in state-of-the-art numerical simulations, which is associated with a deficit of gravity-wave momentum flux at 60°S in these simulations. The authors provide both classical (i.e., all-profile gravity-wave potential energy, E_p) and more advanced (i.e., wave-1D E_p) diagnostics of wave activity in the southern hemisphere. In any case, I have found that the methodology is described with much care and rigor, as are the limitations of the GPS RO dataset to study gravity waves. The authors show that this southern hemisphere gravity-wave hot spot is well described by the global, multi-year GPS RO temperature profiles, and extends from June to October-November. They provide further support for a significant meridional refraction of mountain waves into the stratospheric jet core, as initially suggested by Sato et al. (2012). The comparison between the all-profile and the wave-1D E_p is first used to reveal the intermittency of mountain waves near the mountain ridges. Yet, the authors interestingly suggest that the longitudinal extension of the gravity-wave hotspot may be linked to a more zonally-uniform gravity-wave source around Antarctica. Last, the authors show that reasonnable gravity-wave momentum fluxes can be obtained with GPS RO temperature profiles during the initial deployment phase of the satellite constellation, which may be used in future similar missions.

In brief, I have found that the article is generally very well written, and that it provides novel and interesting results. I have a number of minor points and only one major comment. Once the authors have addressed these different points, I consider that this article can be published in ACP.

Major comment

I have found that the authors provide convincing arguments that the broad longitudinal enhancement of gravity wave activity is likely to be associated with a nearly uniform gravity-wave source at 60°S. In particular, I think that it is quite unlikely that the Andes and Antarctic Peninsula could generate waves with horizontal wavelengths much longer than 350 km, and thus significantly contribute to the gravity-wave activity enhancement east of 20E. On the other hand, I am less convinced by the authors claim (in particular around p3185 l13-26; p3199, l9-16; p3200 last pararaph and p3201 first paragraph) that Figure 4 supports that this broad gravity-wave source is likely to be a local stratospheric source (either secondary generation from primary mountain waves or stratospheric jet adjustment or instabilities). I have mainly two reservations:

- first, the fact that Figure 4 shows that E_p peaks around 20-35 km in August above the Austral Ocean (letting apart the orographic waves at 60W) may result from an observational effect associated with the GPS-RO dataset. As shown on Figure 3, the zonal wind increases from the tropopoause to 35 km at 60°S in August, which will result in an increase of the vertical wavelength of westward propagating gravity waves. Some of these waves may thus be invisible in the GPS-RO dataset below 20 km (vertical wavelength less than twice the GPS-RO vertical resolution, i.e., 2.8 km), but become more and more resolved as the wind increases above. O'Sullivan and Dunkerton (1995) for instance show that waves generated around the tropospheric jet have vertical wavelengths of a few kilometers. The maps on Figure 2 are furthermore much reminiscent of the spiral structure of the Southern Hemisphere storm track with less activity over the Pacific Ocean (see, e.g., Hoskins and Hodges (2005)), so that this broad gravity-wave feature may actually be associated with non-orographic waves generated in the tropopsphere
- then, it is written in the article that the quantity displayed on Figure 4 (and Figure 3) has been normalized, but this normalization has not been explicited. Raw E_p is not density weighted (cf. Eq. (3)), so that it is expected to increase as $\exp(z/H)$ for linear waves, with H the density-scaled height. Is the normalization used by the authors supposed to counterbalance this increase? Otherwise, one can not deduce from the peak of E_p at 30 km on Figure 4 that it is associated with a local source: it may rather be the altitude where gravity waves generated below

deposit most of their momentum. I therefore strongly suggest that the authors present a explicitly density-weighted version of Figure 4, so that one will be able to assess where the waves observed above the oceans are primarily generated.

Minor Issues

- p3178, l25 (and p3179, l2): Actually, waves with $\lambda_H \lesssim 2 \times 270$ km are unlikely to be detected (Nyquist wavelength).
- p3179 l2-7: It is recalled here that most of the orographic waves generated above the Andes or by the Antarctic Peninsula have "westward oriented horizontal wavenumber vectors", while the "COSMIC occultations in this region tend to be preferentially aligned towards the north-south axis". I would like that the authors further develop this point, and in particular discuss how it could affect the sensitivity of the measurements to wave disturbances. One issue that strikes me for instance is that the HIRDLS soundings are performed in a direction almost perpendicular to the GPS occultations in this region. I thus wonder what is the meaning of the comparisons performed in section 4: how can both techniques be sensitive to the same waves there? Which technique is the best suited to obaserve zonally propagating waves in this region? And what is the validity of λ_H derived from the GPS RO there?
- p3181 l29-p3182 l5: I also observe on Figure 2 that one does not observe a continuous decrease of E_p as one goes farther East in the "leeward" region of increased E_p. This seems to be in contradiction that most of these waves are of orographic origin. On the other hand, your discussion here seems to make the implicit assumption that the waves were generated above the mountains and "have long dwell times".
- p3183, l28-29: You may recall here to which altitude range does this 2500 km

horizontal propagation distance correspond?

- p3184 l6-9: This is actually somewhat striking that the Antarctic Peninsula does not show up very clearly in your dataset, while it has been recognized as a major hotspot by several previous studies. Could you discuss whether this could be an effect of the RO orientation at high latitudes, or if it is due to the vertical wavelength range in which the GPS RO are most sensitive?
- p3187, l1: Is this normalization really needed?
- p3188 l2: unless I have missed something, this 1K lower and 10 K upper limits appear here for the first time without real justification. Do you use the lower limit to avoid including noise in your analysis? Why do you need an upper limit? How sensitive are your results if you change these limits?
- p3189, l20: I would add “detected by the wave 1D method” between “waves” and “themselves”.
- p3190, l2-8: Both sentences have very similar meaning.
- p3191, l17: typo: $3 < T'$
- p3194, l20: See remarks p3179 l2-7: Is the RO orientation not too problematic here, as the waves are expected to be mostly zonally propagating?
- Figure 11: could you label the longitudes on this plot? Why are you limiting these maps to the South America sector?

References

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