A global analysis of gravity wave activity in the upper troposphere and lower stratosphere region derived from GPS radio occultation data

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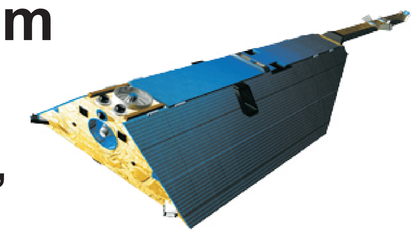

1. Abstract

We discuss the global gravity wave (GW) activity expressed by the specific potential energy in the UTLS region derived from CHAMP (2001-2008). The GW analysis is based on vertical detrending ($_z$<10 km) of the measured temperature profiles by applying a Gaussian filter in two different ways: (i) filtering of the complete profiles and (ii) separate filtering for the tropospheric and lower stratospheric parts. The separate filtering method significantly reduces the usually observed GW activity enhancement in the tropopause region which highly depends on the performance of the complete filtering method to reproduce the change in the temperature gradient at the tropopause.

2. Measuring principle of GPS radio occultation

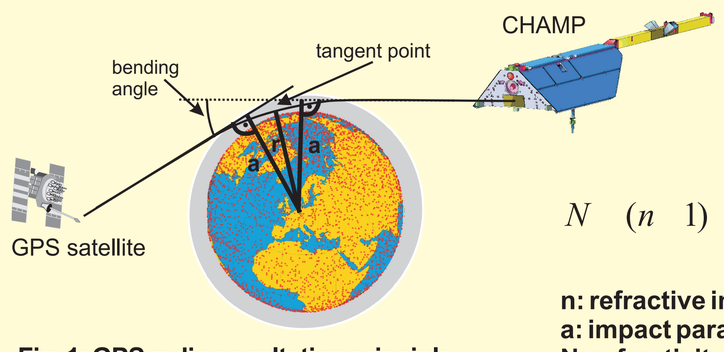

Fig. 1: GPS radio occultation principle.

$$\ln n(r) \quad \frac{1}{\pi} \int_a da' \frac{\alpha(a')}{\sqrt{a'^2 \quad a^2}}$$

$$n \quad n(r)$$

$$N \quad (n \quad 1) \quad 10^6 \quad 77.6\frac{p}{T} \quad 3.73 \quad 10^5 \frac{p_w}{T^2}$$

n: refractive index **p: pressure**
a: impact parameter **T: temperature**
N: refractivity **p_W: water vapour pressure**

3. The data base

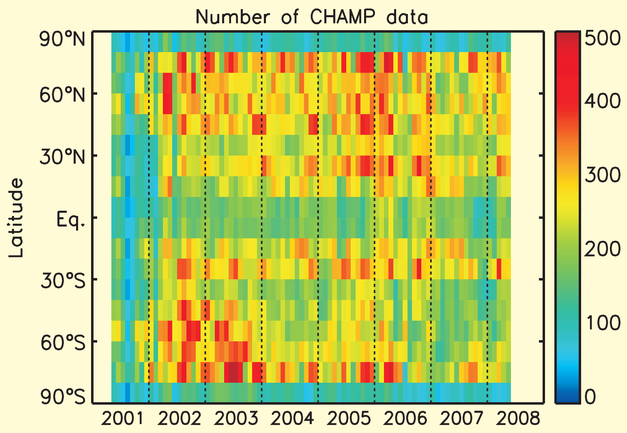

Fig. 2: Number of monthly CHAMP temperature profiles between May 2001 and May 2008.

For our study the Earth was divided into 34 zonal bands centered between 77.5°N and 77.5°S with a stepwide of 5° and two 10° bands for 85°N and 85°S. For the complete period a total number of about 348,000 temperature profiles is available where GW parameters could be successfully determined. From about 0.8% of the profiles the tropopause determination failed, mainly in the polar regions during winter. For the determination of the tropopause the traditional WMO definition, i.e. the lapse rate tropopause (LRT) was used.

4. Data analysis - the complete and separate method

According to the linear theory of GWs the measured temperature profile T(z) is expanded into a background temperature and a perturbation T'(z) which can also be considered as a fluctuation.

$$T(z) \quad T(z) \quad \overline{T}(z) \qquad (1)$$

$$\overline{T'^2} \quad \frac{1}{z_2 \quad z_1} \int_{z_1}^{z_2} T'^2(z)dz \qquad (3)$$

here: z_2-z_1 = 2 km (3a)

$$N^2(z) \quad \frac{g}{\overline{T}} \quad \frac{\overline{T}}{z} \quad \frac{g}{c_p} \qquad (2)$$

$$E_p(z) \quad \frac{1}{2} \quad \frac{g}{N}^2 \quad \frac{T'^2}{\overline{T}} \qquad (4)$$

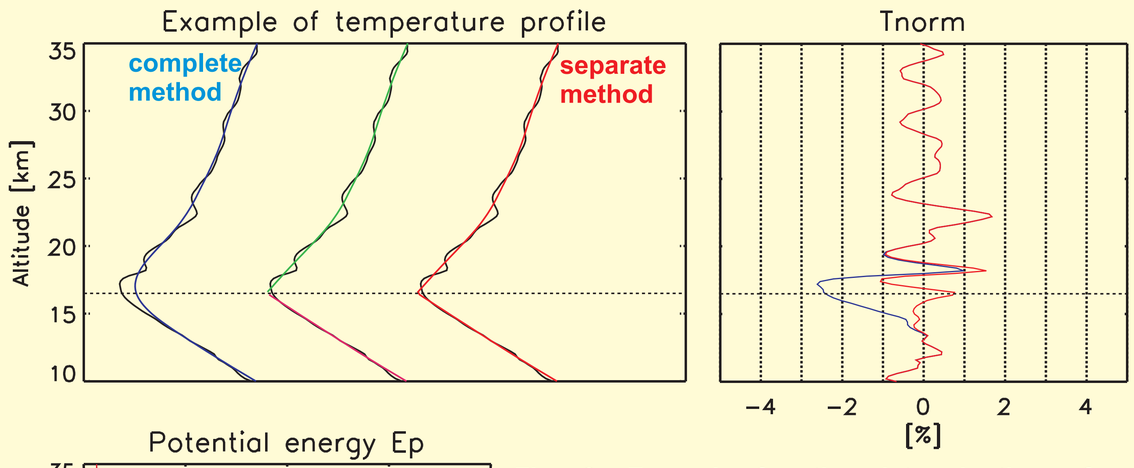

Fig. 3: Example for the determination of a temperature background profile with the complete and separate filtering method.

In our approach we separate each temperature profile into a tropospheric (below the tropopause) and stratospheric (above the tropopause) part and deploy a Gaussian filter for each part of the profile. Finally, the temperature background profile is constructed from the two single background profiles.

5. Data analysis - start and end point handling

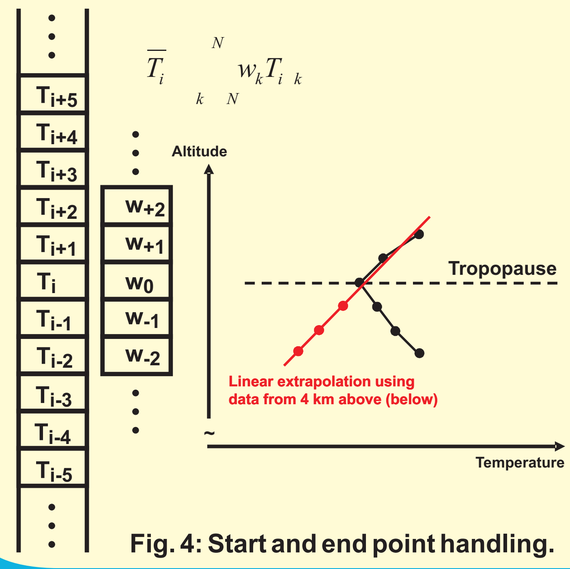

Fig. 4: Start and end point handling.

To avoid data lost at the beginning and end of the filtered profiles due to the application of central filter weights (w_i), the measured temperature profile (T_i) is extrapolated beyond the first (last) data point using the data of the first (last) 4 km interval. The choice of the interval length slightly influences the final potential energy distribution at the tropopause.

6. Comparison of the complete and separate method

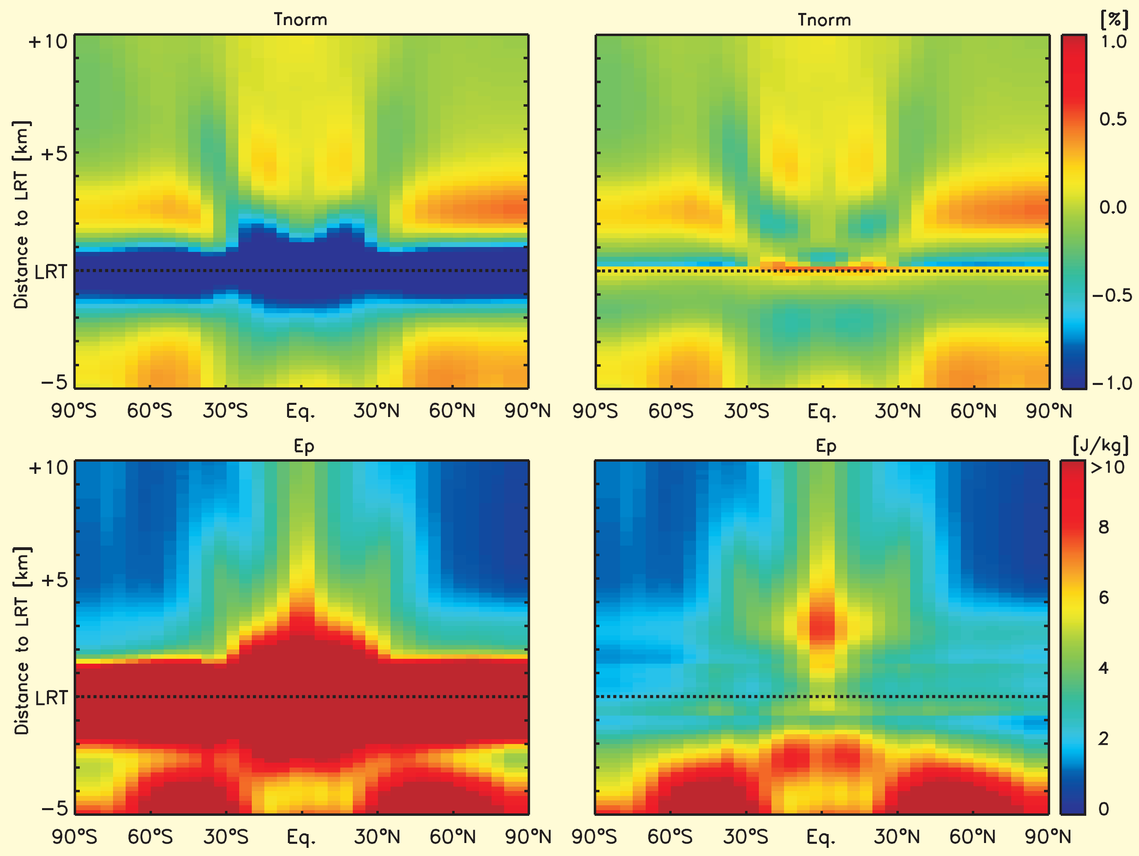

Fig. 5: Climatological normalized temperature (top) and potential energy (bottom) relative to the LRT for the complete (left) and separate (right) filtering method and the time interval from May 2001 to February 2008. The horizontal dashed line marks the lapse rate tropopause.

The differences between the complete and separate methods are apparent. The complete method (Fig. 5, left) disallows a detailed evaluation of the GW parameters in a ~2-3 km band around the tropopause. The separate method in that altitude range reduces the wave parameters significantly and globally.
For the discussion of the zonal monthly mean potential energy in different altitude regions Fig. 6 shows potential energy deduced with the separate method averaged over three heights ranges: between the LRT and 5 km below (left), between the LRT and 5 km above (middle), and between 5-10 km above the tropopause (right).

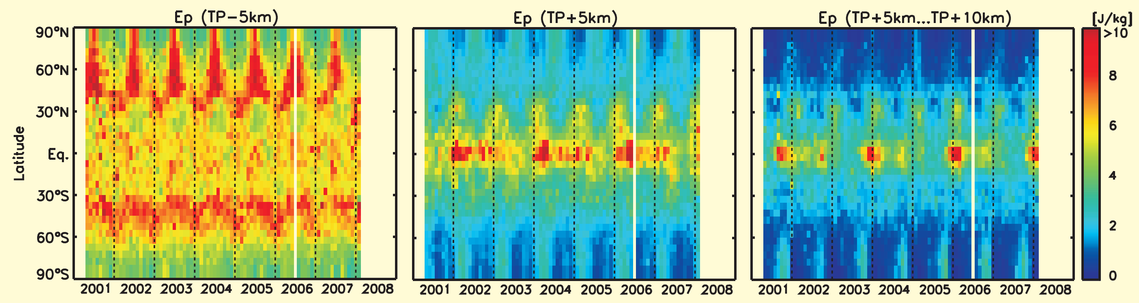

Fig. 6: Zonal monthly mean potential energy averaged over different altitude intervals.

7. Error discussion

Generally, the GW analysis offers at several points possibilities to influence the final potential energy distribution, not only in the tropopause region. The main points are: (1) The use of temperature variance according Eq. 3 or usage of non-averaged variances T'^2. (2) The width of the sliding window for the temperature variance (Eq. 3a). (3) The interval width for the extrapolation at the start and end points for the filtering (Fig. 4).

References

Schmidt et al., 2008: Global gravity wave activity in the tropopause region from CHAMP radio occultation data, Geophys. Res. Let., 35, doi:10.1029/2008GL034986.

Acknowledgement:
We thank all other members of the CHAMP team for their contributions to this study.

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