Structure and Variability of the Tropopause Obtained from CHAMP Radio Occultation Temperature Profiles

Madineni Venkat Ratnam, Gerd Tetzlaff, and Christoph Jacobi

Institute for Meteorology, University of Leipzig, *vratnam@uni-leipzig.de*

Summary. The global structure and variability of the tropopause observed using CHAMP/GPS radio occultation observations from May 2001 through September 2003 are presented. Tropopause temperature and height observed by CHAMP/GPS has been compared with radiosonde observations at a sub-tropical site. At polar latitudes, the tropopause sharpness found to be highest in summer and lowest in winter with slight differences between hemispheres.

Key words: Tropopause, radio occultations

1 Introduction

Using tropopause characteristics as indicator for climate variability has focused international interest on this region of the atmosphere ([1]). However, due to the coarse vertical resolution of ECMWF or other analysis data, and the uneven distribution of radiosondes with gaps especially over Oceans, at low latitudes and in the polar regions, the comprehensive investigation of tropopause characteristics is difficult. A new and promising tool to analyze the tropopause characteristics and variability are GPS radio occultation data, which are characterized by high vertical resolution and global sampling. The latter is particularly advantageous in the tropics, where radiosonde measurements are sparse. Moreover, radio occultation observations are calibration-free, therefore have excellent long-term stability, and they are insensitive to clouds and rain.

Recently, using GPS/MET observations, the variability of the tropical tropopause region was studied by [2,3]. They showed the high accuracy of GPS/MET retrievals especially in tropics. It is also reported that sub-seasonal variability of tropopause temperature and height appears to be related to wave-like fluctuations (such as gravity and Kelvin waves) and significant correlations are also found between GPS/MET observations and outgoing long wave radiation data. However, these studies are restricted to tropical latitudes.

Using CHAMP measurements, extended analysis of the tropopause region is possible using the advantages of this system. These are a larger number of occultations compared to GPS/MET due to improved GPS receiver technique (JPL's state-of-the-art 'BlackJack' flight receiver) and optimized occultation infrastructure that allows continuous atmospheric sounding independent of the Anti-Spoofing mode of the GPS system.

For the present study we use level 3 version 004 data from May 2001 to September 2003 that are produced by GFZ Potsdam [4]. Besides this data, temperatures observed with radiosondes are also collected to compare with CHAMP/GPS data.

2 Comparison with standard radiosonde data

Before analyzing tropopause characteristics by radio occultation data, the observed temperature profiles need to be compared with other well-established techniques. We use standard pressure-level radiosonde temperatures (10-30 km) over a sub-tropical latitude (Pan Chiao, Taiwan, 25°N, 121°E) to compare with CHAMP/GPS data. Notwithstanding the global coverage of CHAMP occultations, very close coincidences with radiosonde ascents are very rare. Therefore differences of ± 2° latitude, ± 20° longitude and ± 2 hours have been accepted for coincidences of ground based and satellite derived profiles. It is true that comparison with one radiosonde is not a validation. Furthermore, the radiosonde data are not high-resolution results, however, Pan Chiao radiosonde ascents of similar resolution have been used to study tropopause characteristics [5]. Fig. 1 therefore gives an impression, which structures are visible in the CHAMP GPS data in comparison with the standard analyses of radiosondes. To give an impression of the representation of the tropopause in both datasets, an example of vertical temperature profiles is shown in Fig. 1, left panel.

The results for all seasons (with a total of 59 profiles meeting the above men-

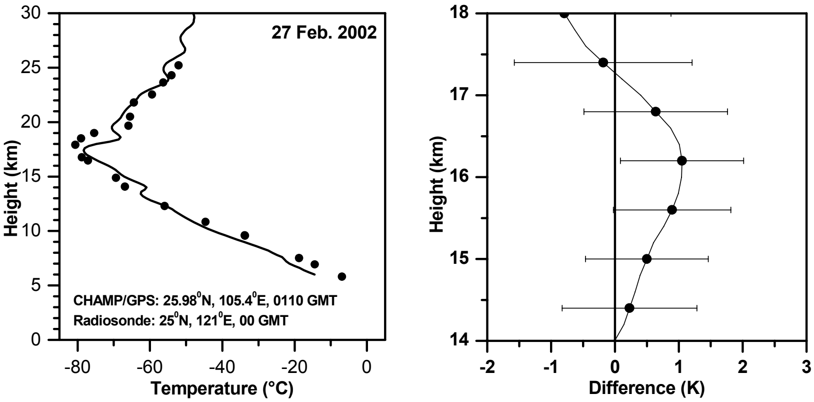

Fig. 1. Example of a CHAMP radio occultation temperature profile together with radiosonde data (left panel). In the right panel the mean differences radiosonde-CHAMP are plotted for 59 profiles of nearest coincidence.

tioned criteria) are shown in the right panel of Fig. 1. The differences observed with CHAMP-radiosonde measurements are plotted between 14 and 18 km during May 2001 to June 2002. The "error bars" show the standard deviation. The comparison of the CHAMP profiles with radiosonde shows excellent agreement. Near the sub-tropical tropopause (around 16 km), the mean deviation is about 0.5-1 K, with colder CHAMP data, which also has been observed by [6] using ECMWF analysis. This is possible due to a better vertical resolution of radio occultation measurements in comparison to the analyses that were available on standard pressure levels (radiosonde). This comparison reveals the high accuracy of CHAMP/GPS measurements, especially at a sharp tropopause, which is more often seen at tropical latitudes.

3 Tropical and midlatitude tropopause

To demonstrate the potential of CHAMP tropopause analysis, Fig. 2 shows the cold point tropopause temperatures in December 2001 between 50°S and 50°N. The coldest temperatures are found near the equator. Minimum temperatures are lower than 185 K, but non-zonal structures are well visible with the coldest tropopause over the Indonesian sector.

Fig. 3 shows the tropopause height and temperatures near the equator (±10^{o} latitude) obtained using CHAMP observations during May 2001 to Dec. 2002. Tropopause height and temperature show a clear annual cycle with peaks during Northern Hemisphere winter and summer, respectively. The annual mean equato-

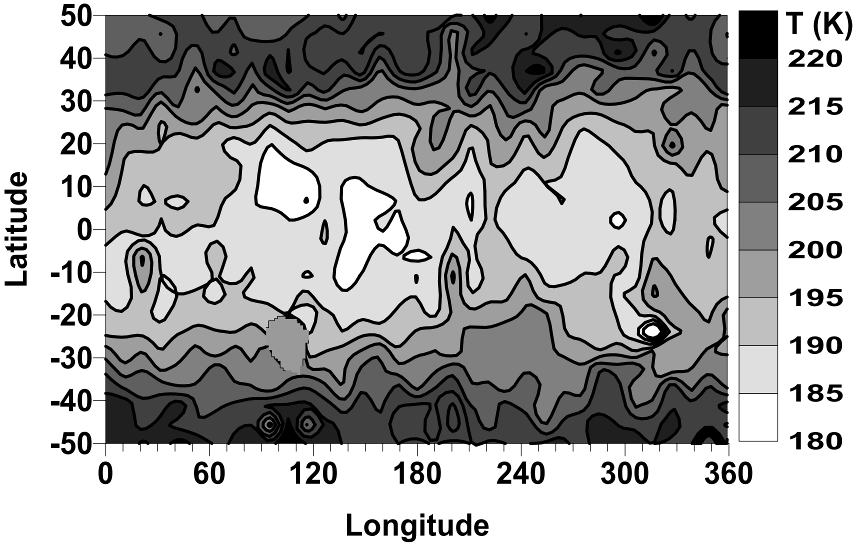

Fig. 2. Latitude-longitude plot of the cold-point tropopause temperature in December 2001.

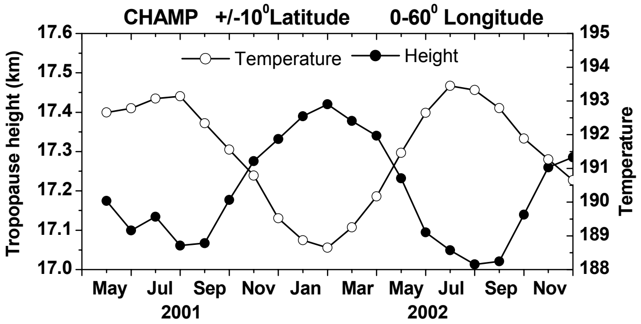

Fig. 3. Time series of the monthly mean zonal mean tropical tropopause height and temperature. Data between 10°N and 10°S are used.

rial tropopause height and temperature is 17.2 km and 191.5K, respectively. Using 30 years (1961-1990) of data from a radiosonde network, [7] reported corresponding values of 16.9 km and 197.7 K. While the height is comparable with the CHAMP data, the radiosonde temperature is 6 K higher, probably due to the lower vertical resolution of standard radiosonde analyses. However, one has to take into account that here we compare a rather short CHAMP data set with a climatological statistics, so that conclusions should be drawn with caution. For more detailed analyses of the tropical tropopause region the reader is referred to [8].

4 High-latitude tropopause

Fig. 4 shows the comparison of the radiosonde and CHAMP observed polar mean tropopause sharpness over both the Artic and Antarctic. Radiosonde results have been taken from [9]. The sharpness is defined as the change of the vertical temperature gradient across the tropopause [10]. The CHAMP results over Central Antarctica (upper left panel) and also over Eastern Europe/Western Siberia (70-80N; 40-100E, upper middle panel) are very similar to those obtained with the radiosonde network data. The error bar in the figure shows the standard deviation obtained while averaging over the time period of May 2001-Sep. 2003.

There exist significant differences between radiosonde and CHAMP observations over of Alaska-Canada (70-80N, 200-260E) in some months, but above all over Eastern Europe/Asian higher midlatitudes (55-60N; 40-100E). The reason for these observed discrepancies could be partly attributed to the different times of observations. We have to take into account that CHAMP observations data still base upon few years. Possible differences therefore should be further investigated using additional observations from CHAMP and other GPS radio occultation missions in future.

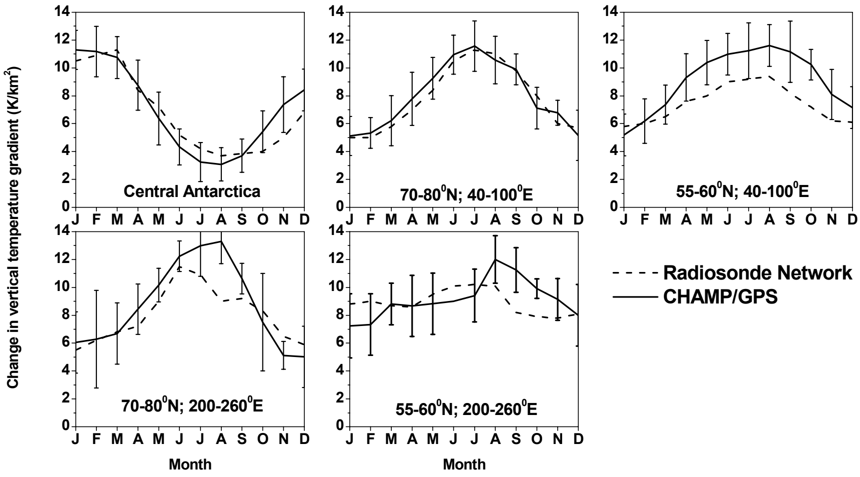

Fig. 4. Comparison CHAMP/GPS observed tropopause sharpness with data observed by the radiosonde network (taken from [6]). Note the different time interval that data are referring to (radiosondes 1989-1993, CHAMP 2001-2003).

5 Conclusions

Using CHAMP GPS radio occultation temperature profiles it is possible to obtain a global picture of the tropopause temperature and height. Since the temperature profiles are available with high vertical resolution, the results, particularly for the tropics, are superior to those obtained from standard radiosonde analyses. In addition, the global coverage of GPS profiles allows the construction of global fields without limitations due to insufficient data coverage.

Monitoring tropopause parameters has proven to be an appropriate mean for detecting climate variability and man-made influence on climate [1]. The potential for improving the quality of tropopause monitoring through GPS radio occultation makes these satellite measurements an important tool for further climate research.

Acknowledgements: We wish to thank GFZ Potsdam and the CHAMP team for providing CHAMP/GPS data. This study was supported by DFG under grant JA 836/4-2.

References

1. Sausen R, Santer BD (2003) Use of changes of tropopause height to detect human influences on climate. Meteorol Z, NF *12*: 131-136.
2. Randel WJ, Wu F, Rios WR (2003) Thermal variability of the tropical tropopause region derived from GPS/MET observations. J Geophys Res 108: 10.1029/2002JD002595.
3. Nishida M, Shimizu A, Tsuda T, Rocken C, Ware RH (2000) Seasonal and longitudinal variations in the tropical tropopause observed with the GPS occultation technique (GPS/MET). J Meteorol Soc Japan *78*: 691-700.
4. Wickert J, Schmidt T, Beyerle G, König R, Reigber C, Jakowski N (2004) The radio occultation experiment aboard CHAMP: Operational data analysis and validation of atmospheric profiles. J Meteorol Soc Japan, Special issue 'Application of GPS Remote Sensing to Meteorology and Related Fields', *82(1B)*: 381-395.
5. Thulasiraman TS, Nee JB, Chen WN, Chen JH (1999) Temporal characteristics of tropopause and lower stratosphere over Taiwan during 1990-1995. J Atmos Solar-Terr Phys *61*: 1299-1306.
6. Wickert J, Reigber C, Beyerle G, König R, Marquardt C, Schmidt T, Grunwaldt L, Galas R, Meehan TK, Melbourne WG, Hocke K (2001) Atmospheric soundings by GPS radio occultation: First results from CHAMP. Geophys Res Lett *28*: 3263–3266.
7. Seidel JD, Ross RJ, Angell JK, Reid GC (2001) Climatological characteristics of the tropical tropopause as revealed by radiosondes. J Geophy Res *106*: 7857–7878.
8. Schmidt T, Wickert J, Beyerle G, König R, Reigber C (2004) Tropopause parameters derived from CHAMP. This issue.
9. Zängl G, Hoinka KP (2001) The tropopause in the polar regions. J Clim *14*: 3117-3139.
10. Wirth V (2000) Thermal versus dynamical tropopause in upper tropospheric balanced flow anomalies. Quart J Roy Meteor Soc *126*: 299-317.