Trends in the global tropopause estimated from GPS radio occultation data

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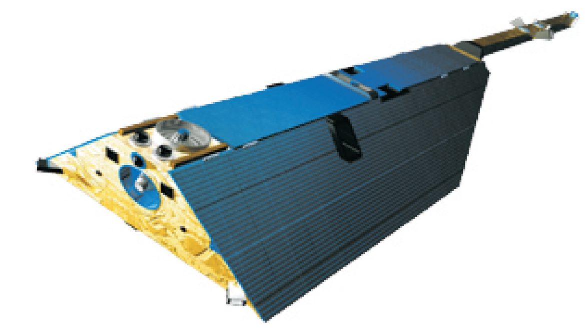
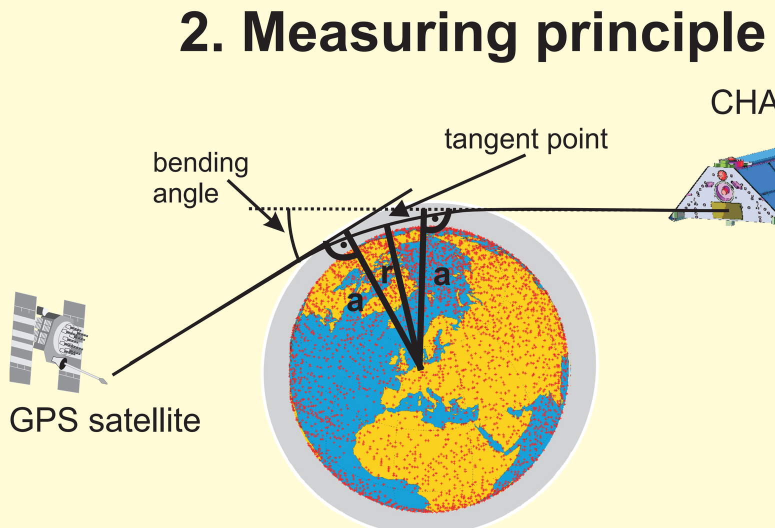


1. Abstract

This study discusses global tropopause pressure and temperature trends based on zonal monthly mean GPS radio occultation data from the German CHAMP satellite mission for the period May 2001-May 2008 (85 months). A data gap of missing CHAMP data in July 2006 was filled with radio occultation data of the U.S.-German GRACE mission. A global decrease of the tropopause pressure of 0.15±0.10 hPa/yr and an increase of the tropopause temperature of 0.05±0.01 K/yr during the observation period is found. This results from the first long-term GPS radio occultation data set are compared with trends from ECMWF, NCEP, and radiosondes.

2. Measuring principle of GPS radio occultation



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

$$n = n(r)$$

$$N = (n-1)\, 10^6 = 77.6\frac{p}{T} + 3.73\cdot 10^5 \frac{p_w}{T^2}$$

n: refractive index; a: impact parameter; N: refractivity; p: pressure; T: temperature; p_w: water vapour pressure

Fig. 1: GPS radio occultation principle.

3. The data base

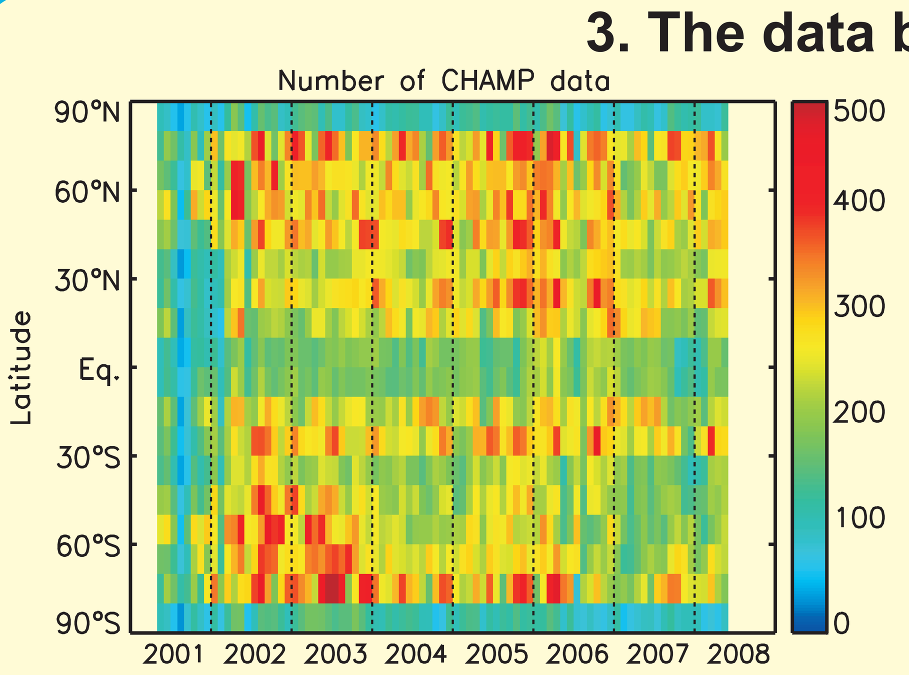


Fig. 2: Number of monthly CHAMP temperature profiles between May 2001 and May 2008.

For our study the Earth was divided into 18 zonal bands centered between 85°N and 85°S with a stepwide of 10° (Fig. 2). For the complete period a total number of about 348,000 temperature profiles is available where tropopause 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 WMO definition, i.e. the lapse rate tropopause (LRT) was applied to each profile between 500 and 50 hPa.

4. The global tropopause

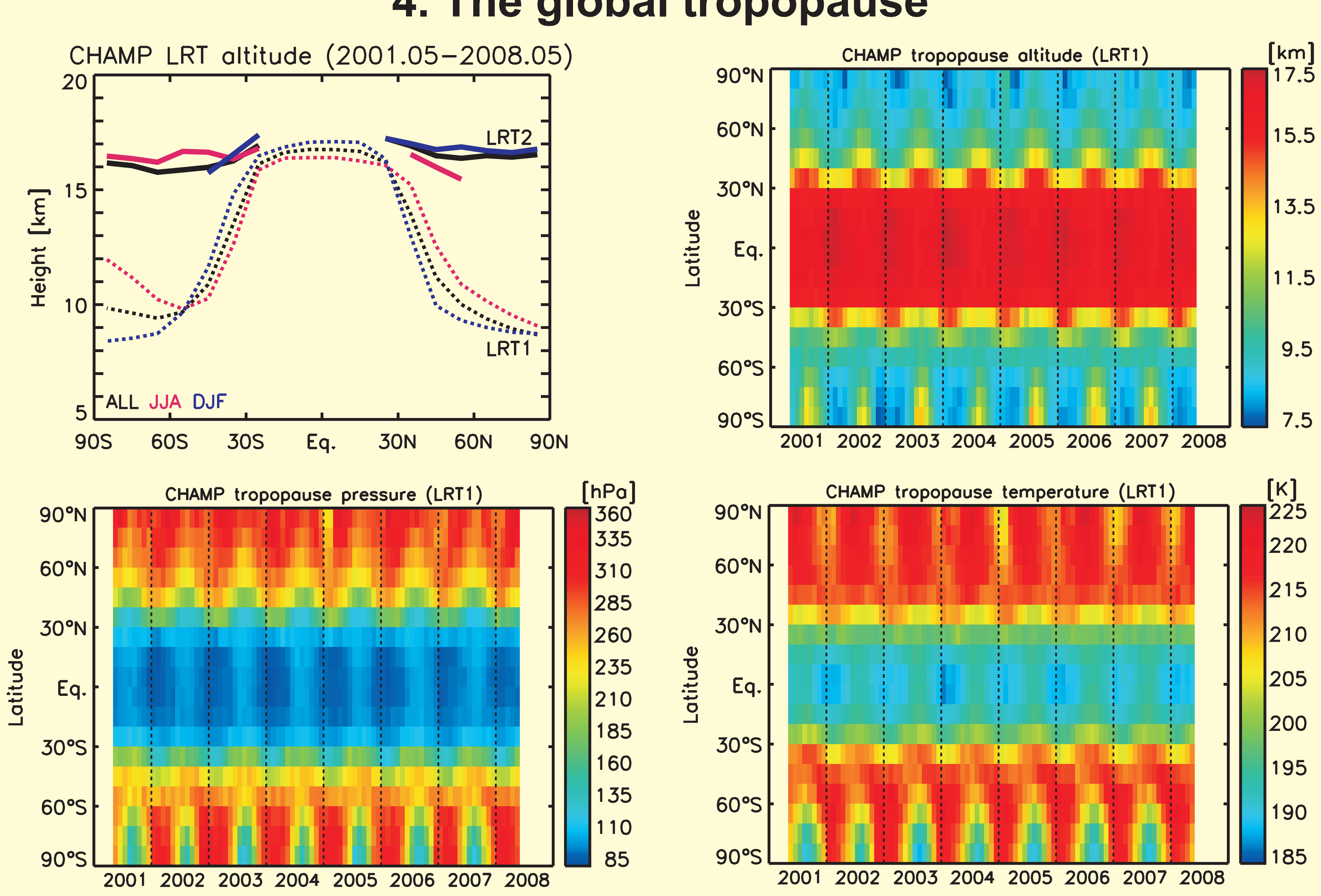


Fig. 3: CHAMP tropopause parameters based on monthly means between May 2001 and May 2008.

Zonal monthly means of (multiple) tropopause parameters were computed from individual high-resolution CHAMP temperature profiles. Fig. 3 presents climatological zonal mean values of the first (LRT1) and last (LRT2) lapse rate tropopause altitude (top left) for the northern hemispheric winter (DJF) and summer (JJA) months. LRT2 values are only shown if the occurrence frequency of multiple tropopauses is larger than 20%. The following trend analysis considers only the first LRT.

The other images show the monthly mean tropopause altitude, pressure, and temperature derived from CHAMP for the time interval May 2001 and May 2008. The latitudinal resolution is 10°.

The tropopause has a strong meridional structure. The strongest gradients in tropopause parameters occur between 30° and 60° on both hemispheres. Highest and coldest tropopause altitudes and temperatures are found in the equatorial region during northern hemispheric winter.

5. The analysis method

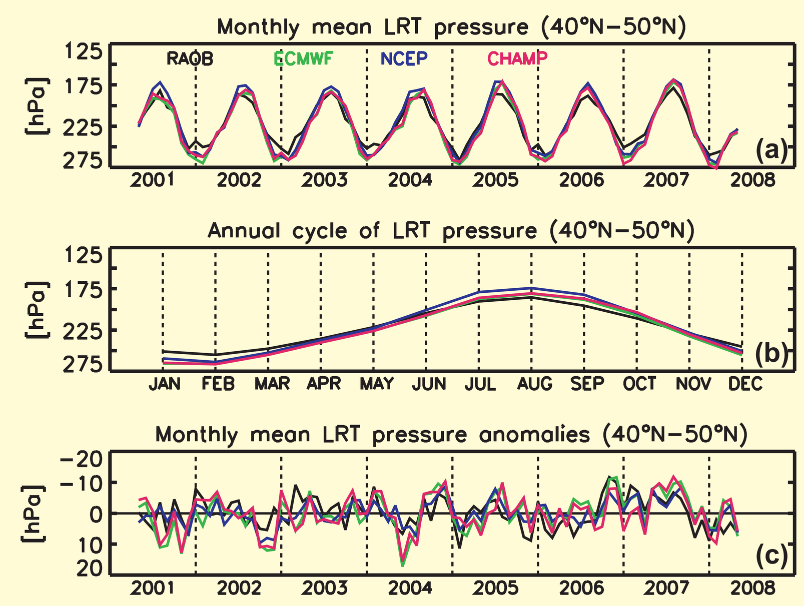


Fig. 4: Example for the determination of monthly zonal mean LRT pressure anomalies (c) deduced from monthly mean LRT pressure data (a) and the annual cycle (b).

Monthly zonal means of LRT parameters are determined. Values with more than three standard deviations away from the mean are excluded. Finally, monthly zonal anomalies are estimated by subtracting the annual cycle from each individual monthly mean. The LRT height anomalies are the basis for linear trend calculations. To include the QBO into the LRT trend results a multiple regression was applied with the 70 hPa monthly mean zonal wind data from Singapore radiosonde station as a proxy for the QBO.

6. Zonal trends

Fig. 5 summarizes the results for the LRT pressure and temperature trends for the different data sets, but for the same time interval. Generally all data sets are consistent with nearly negative LRT pressure trends in the extratropics and positive trends in the tropics. Largest differences occur in the regions of the subtropical and polar jet streams.

The course of the extratropical LRT temperature trend curves agrees well. Largest deviations, also in the sign of the trends, are found in the tropics between NCEP and the other data sets.

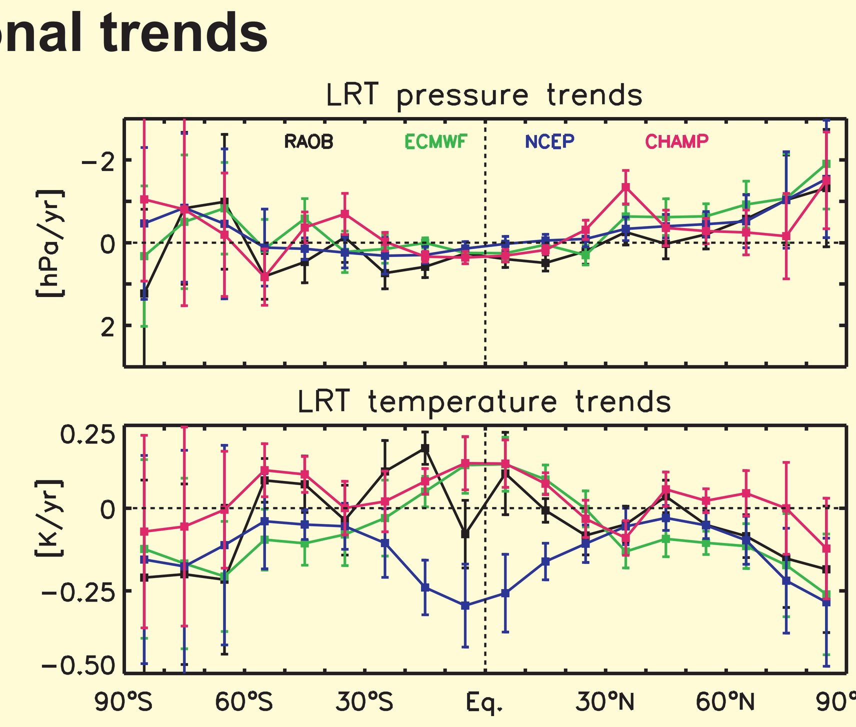


Fig. 5: Annual LRT pressure and temperature trends from different data sources (CHAMP: red; ECMWF: green; NCEP: blue; radiosondes: black). Error bars denote the 2-sigma confidence intervals.

7. Regional and global trends

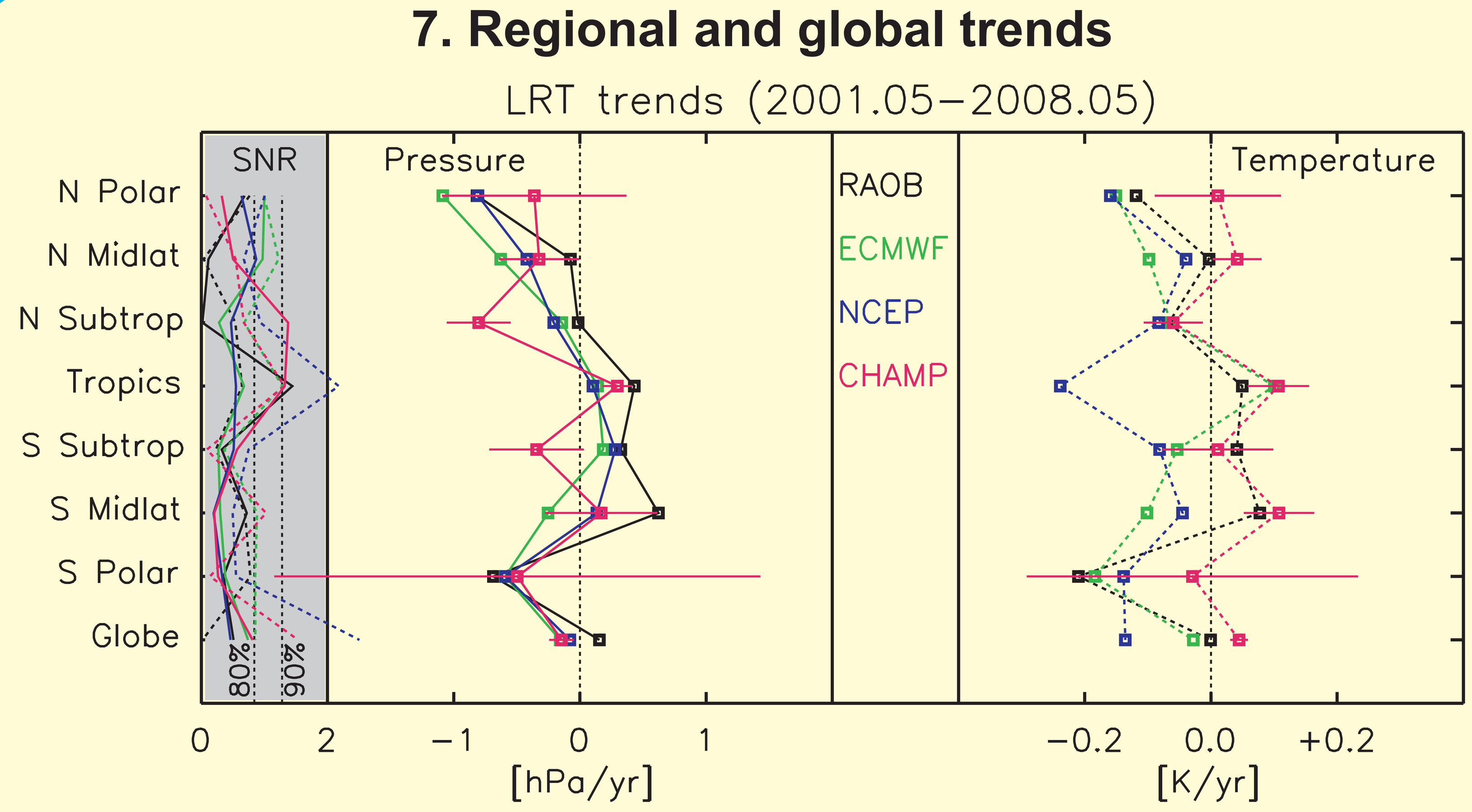


Fig. 6: Annual trends of LRT pressure and temperature for different geographical regions and global (CHAMP: red; ECMWF: green; NCEP: blue; radiosondes: black). The corresponding SNR (LRT pressure: solid lines; LRT temperature: dashed lines) is shown left.

The best agreement for the LRT pressure trends for different geographical regions between all data sets is achieved in the tropics and polar regions. Largest deviations for the LRT temperature trends occur on the southern hemisphere.

The estimated SNR of the derived tropopause trends are mostly small, leading only to a generally weak statistical significance of the trends.

8. Summary

Global LRT trends per year (May 2001 - May 2008)

	CHAMP	ECMWF	NCEP	radiosondes
p [hPa/yr]	-0.15±0.10	-0.16±0.14	-0.08±0.16	0.15±0.20
T [K/yr]	0.05±0.01	-0.03±0.02	-0.14±0.04	0.00±0.02

References

Schmidt et al., 2008: Global tropopause height trends estimated from GPS radio occultation data, Geophys. Res. Lett., 35, doi:10.1029/2008GL034012.

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