A Multi-year Comparison of Lower Stratospheric Temperatures from CHAMP Radio Occultation Data with MSU/AMSU Records

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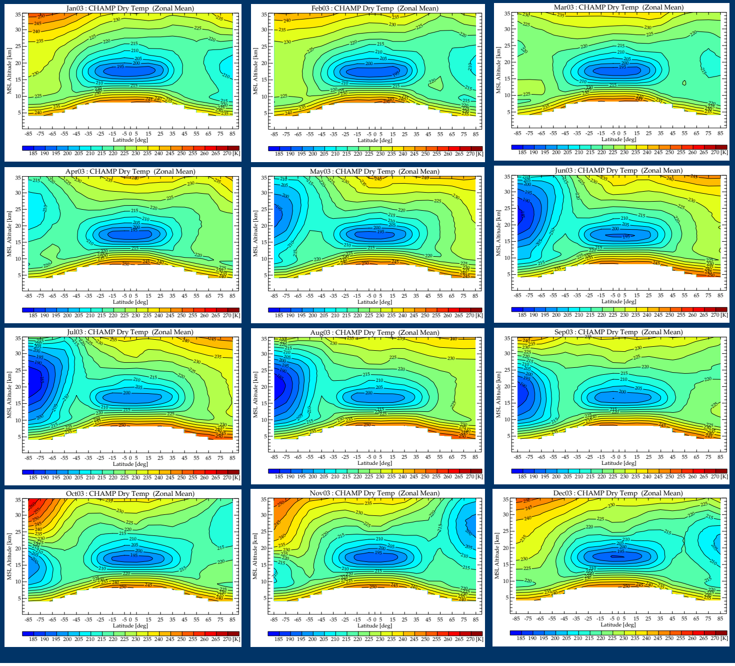
1. Introduction and Background

The principal source of satellite-based upper air temperature records for the last ~25 years was the Microwave Sounding Unit (MSU), since 1998 also the Advanced MSU on U.S. NOAA satellites (Fig. 1b). The MSU/AMSU channels provide information on layer-average stratospheric and tropospheric temperatures based on measurements of Earth's microwave emission at different frequencies. Comparisons of upper air temperature show discrepancies not only with respect to radiosonde data but also between MSU datasets stemming from different retrievals. The main problems are the inter-calibration between the series of satellites and the correction for diurnal drift addressed differently in the retrievals.

In this respect the Global Navigation Satellite System (GNSS) radio occultation (RO) technique (Fig. 1a) offers new possibilities by providing high quality observations of the atmosphere. Besides high accuracy ($\Delta T < 1$ K for individ. profiles) and vertical resolution (0.5-1.5 km) in the upper troposphere and lower stratosphere region one of the most important properties regarding climate studies is the long-term stability due to intrinsic self-calibration. Since late 2001 the German research satellite CHAMP (CHallenging Minisatellite Payload for geoscientific research) continuously makes RO observations, yielding about 160 atmospheric profiles per day. Based on RO orbital data and phase delay measurements provided by the GeoForschungsZentrum Potsdam, temperature retrievals and climatologies (Fig. 2) are derived at the Wegener Center/Uni Graz.

In this study we compute synthetic MSU temperatures from the CHAMP RO temperature climatologies for the upper troposphere/lower stratosphere region and compare our results with recent MSU temperature records within the last six years (2001–2006).

Figure 2: *CHAMP temperature climatologies, example year 2003; monthly-mean, zonal-mean climatologies from January 2003 to December 2003 (10 deg lat. bands, alt. gridding 0.2 km).*



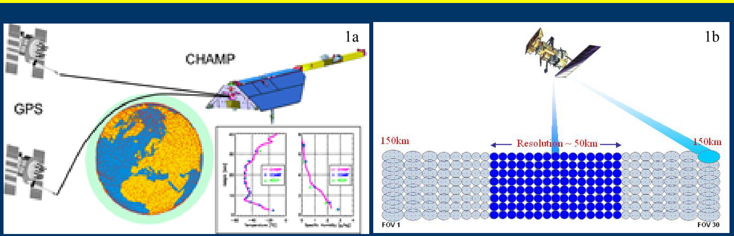


Figure 1: *GPS radio occultation (1a), an active limb sounding method, uses radio signals from a GPS satellite, which are received onboard the CHAMP satellite. The relative motion of the satellites provides a scan through the atmosphere (source: GFZ Potsdam, 2002). The AMSU (MSU) (1b) is a passive microwave sensor measuring along a sub-orbital swath the Earth's microwave emission in channels using the 60 GHz oxygen absorption line (source: http://amsu.ssec.wisc.edu).*

2. Data

CHAMP RO Temperature Climatologies: Monthly-mean zonal-mean CHAMP RO temperature climatologies at a 10° latitude resolution as function of pressure up to 2.5 hPa (~40 km) were used. CHAMP climatologies are available for Sep 2001 to Dec 2006 (including GRACE RO data for Jul 2006, where CHAMP has an RO data gap).

ECMWF Analyses at the same resolution as CHAMP were used for reference.

MSU/AMSU Brightness Temperatures provided by the University of Alabama in Huntsville (UAH) (version 5.1) and by Remote Sensing Systems (RSS), CA, USA (version 2.1) were used. Monthly-mean brightness temperature anomalies are provided on a 2.5° x 2.5° latitude/longitude grid together with 20-yr monthly means (1979–1998). These climatological means are used for the computation of absolute temperatures from anomalies. In addition, we calculated 5-yr monthly means (2002–2006) in order to relate all anomaly data sets to the same time period.

HadAT2 Radiosonde Data: Synthetic MSU temperatures calculated from HadAT2 radiosonde data are provided by the Hadley Centre/Met Office, UK, as monthly-mean zonal-mean (5° latitude resolution) anomalies with respect to the 1966–1995 monthly mean.

3. Method

The data sets are analysed on basis of (near-)global (70°S–70N) and zonal means, tropics (20°N–20°S), Northern hemisphere extratropics (30°N–70°N), and Southern hemisphere extratropics (30°S–70°S). Global MSU weighting functions *wf* were applied to compute synthetic MSU temperatures from CHAMP RO temperatures. Different wfs are provided by UAH and RSS, which we interpolated to CHAMP pressure levels p (Fig. 3). Synthetic MSU temperatures T_{MSU} were then computed with UAH and RSS wfs for the lower stratosphere channel (TLS/T4) as follows.

$$T_{MSU} = \frac{\sum_{i=1}^{N} T_i(p_i) * wf_i}{\sum_{i=1}^{N} wf_i}$$

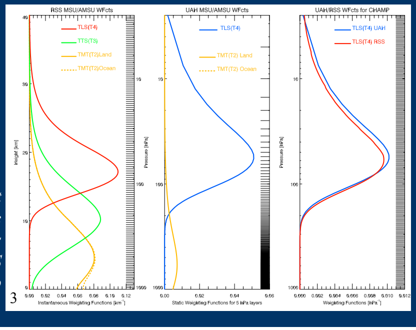


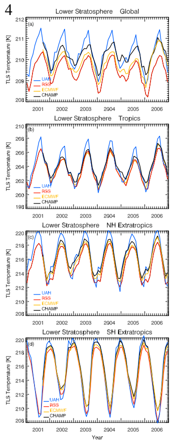
Figure 3: *MSU/AMSU weighting functions: Instantaneous wfs as function of height provided by RSS (left), mean static weighting functions for 5 hPa layers provided by J. Christy, UAH (middle), TLS wfs from RSS and UAH interpolated to CHAMP pressure levels (right panel).*

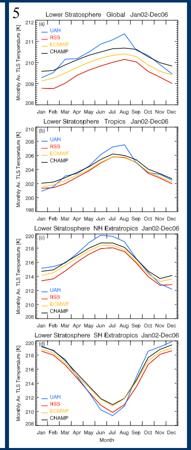
4. Results

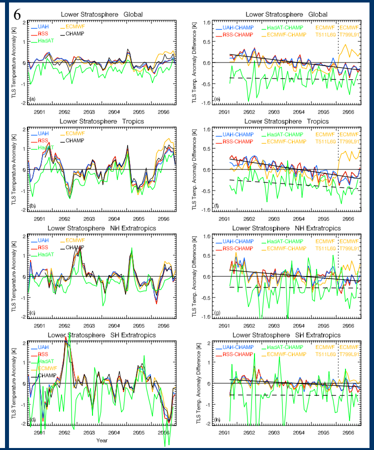
Figure 4: Absolute MSU TLS brightness temperature for the global region (4a), the tropics (4b), the NH extratropics (4c), and the SH extratropics (4d), respectively. Comparison of TLS temperature records from UAH (blue) and RSS (red) with the mean synthetic MSU temperature computed from CHAMP RO (black) climatologies. Also a synthetic MSU record based on ECMWF (yellow) analyses is shown.

Figure 5: The 2002–2006 monthly means of lower stratospheric temperatures for UAH, RSS, ECMWF, and CHAMP RO, shown for the same regions (5a-5d) as in Figure 4.

Figure 6: Left Panels: TLS temperature anomalies wrt 2002–2006 monthly means for UAH, RSS, ECMWF, and CHAMP RO, shown for the global region (6a), the tropics (6b), the NH extratropics (6c), and SH extratropics (6d), respectively.
Right Panels: Differences of TLS anomalies for UAH-CHAMP, RSS-CHAMP, HadAT-CHAMP, and ECMWF-CHAMP for the four regions (6e-6h). Indicated is the mean trend for UAH/RSS-CHAMP (black) and the trend for HadAT2-CHAMP (black-dashed).







5. Conclusions

TLS Absolute Temperature: CHAMP TLS temperatures globally agree better with UAH temperatures outside the summer season and with RSS within summer, the main reason being the different monthly means of UAH and RSS where UAH exhibits a stronger annual cycle with a more pronounced summer season. ECMWF temperatures agree better with RSS until Feb 2006, then they fairly closely follow CHAMP. The very likely cause is a change in ECMWF resolution to T799L91, leading to an improved representation of the temperature field in the range of the weighting function maximum.

TLS Temperature Anomalies: Overall very good agreement of CHAMP anomalies with UAH, RSS, and ECMWF anomalies for intra-annual variability (RMS difference < 0.1K globally, tropics, < 0.2 K extratropics). HadAT2 anomalies show significantly larger differences (factor of two) and a systematic cold offset of about −0.4 K.

2001−2006 Trends: UAH and RSS exhibit a statistically significant cooling trend difference to CHAMP in the tropics (~ −0.44 K/5yrs) and globally (~ −0.35 K/5yrs) indicating that the MSU/AMSU TLS temperature record overestimates the early 21st century cooling in the tropical UTLS region but also globally (> 95% confidence level).

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