Comparing GPS Radio Occultation Temperature Records with MSU/AMSU and Radiosondes for the Lower Stratosphere

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Der Wissenschaftsfonds.

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Overview

Stratospheric Temperature Records

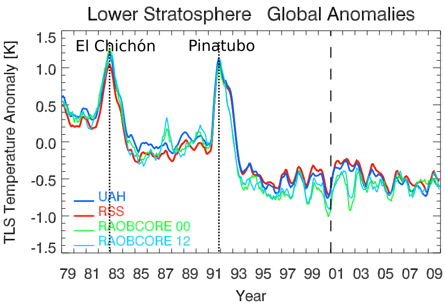

Fig.: TLS anomalies (relative to 1979–1997)

Principle available temperature records:

- Radiosondes
- (Advanced) Microwave Sounding Unit (A)MSU
- More recently: Radio Occultation (RO)

Comparatively large changes in stratospheric temperature observed in the last decades

Radiosondes

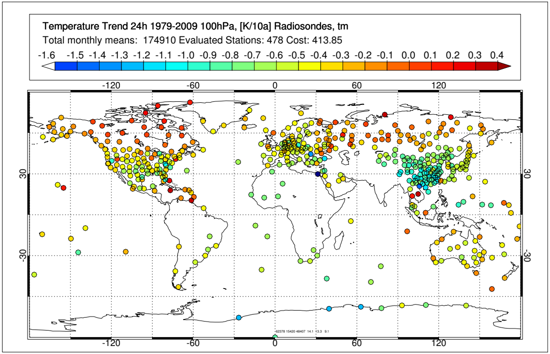

Fig.: Locations of (good) radiosonde stations and trend values. (Source: L. Haimberger)

- Longest data series, going back to 1958
- Sampling errors introduced by sparse representation of many regions (such as southern hemisphere)
- Homogenization is a demanding task

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(Advanced) Microwave Sounding Unit

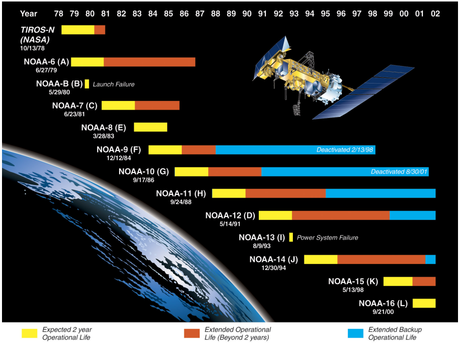
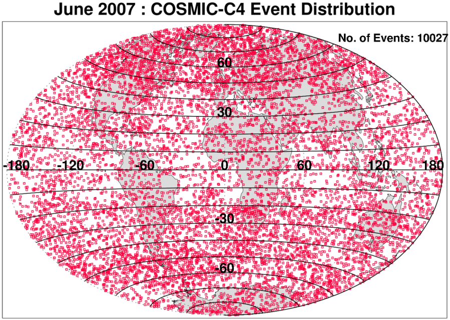


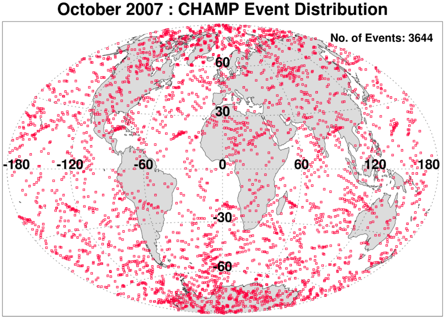
Fig.: Past NOAA polar orbit satellites; most recent: NOAA-19. (Source: GSFC, NASA)

- Monitoring atmospheric temperatures since 1979
- Principal (longest) source of satellite-based upper-air temperature records
- Passive microwave nadir sounder, providing information on layer-average stratospheric and tropospheric brightness temperatures
- Very good global coverage

GPS Radio Occultation

needs no introduction





- Active limb sounding; retrieve profiles of atmospheric variables from phase delays and orbit data
- Quite good global coverage (depending on the mission/nr. of satellites)

Motivation for Using Independent Data

Some quotations

"A major difficulty in developing understanding of stratospheric temperature trends are uncertainties regarding the homogeneity of observational data." (Randel et al. (2009))

"The more independent versions the better, but we contend that three independent derived datasets is probably the minimum in order to get a handle on the magnitude of likely structural uncertainties." (Thorne et al. (2005))

"Regarding 2001–2006 trends, UAH and RSS exhibit a statistically significant cooling trend difference to CHAMP globally (-0.30 to -0.36K/5yrs)." (Steiner et al. (2007); similar results in Ho et al. (2007))

"Accurate determination of the MSU/AMSU temperature trends is essential in resolving global warming debate, validating climate model simulations, and for framing policy decisions on global change." (Zou and Wang (2009))

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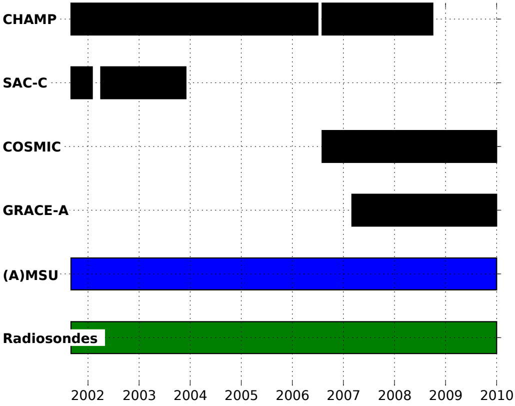
Structural Uncertainties

- Climate trend studies have to face the problem of *structural uncertainties* in these datasets due to changing instrumentation and observation practice over the last decades
- Demanding intercalibration and homogenization procedures are required to establish a climate record for radiosondes and MSU data
- Uncertainties concerning the magnitude of upper-air trends remain—need independent measurements to assess structural uncertainties
- GPS Radio Occultation (RO) technique is self-calibrating and very accurate with high vertical resolution, making it well suited for climate studies; but only few years of data available up to now

Data Used

1. RO temperature climatologies
   a Retrieved at Wegener Center Graz, based on phase delay and orbit data provided by UCAR, Boulder; WEGC OPSv5.4
2. (A)MSU brightness temperatures
   a University of Alabama (UAH); UAHv5.3
   b Remote Sensing Systems (RSS); RSSv3.2
   c NESDIS/STAR, NOAA; STARv2.0
3. Radiosondes
   a RAOBCORE, University of Vienna; RAOBCOREv1.4
   b RICH, University of Vienna; RICH
4. ECMWF Analysis
   a Used as a reference field to estimate the sampling error of RO climatologies

Data Timeframe



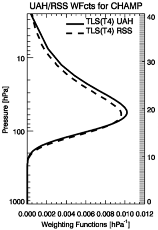
Sampling (profiles per day)

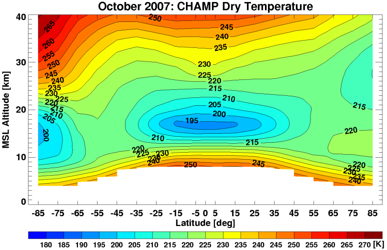
- RO: ≈ 100 to 2000
- (A)MSU: ≈ 30000
- Radiosondes: > 1000 stations

Study Method

- MSU: Layer-average brightness temperature: TLS weighting function describes the relative contribution of the lower stratosphere layer;

TLS spans 10–25 km in altitude, with a peak near 18 km.





- RO: Calculation of comparable synthetic MSU brightness temperatures using the radiative transfer model RTTOV9.3
- Radiosondes RAOBCORE/RICH: MSU-equivalent TLS temperature anomalies provided by University of Vienna
- Anomalies (relative to 2002–2009) and anomaly differences for the regions: Global (70°S–70°N), Tropics (20°S–20°N), and NH/SH extra-tropics (30°–70°)

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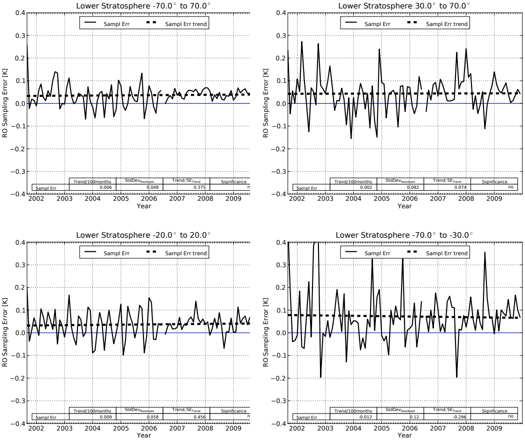
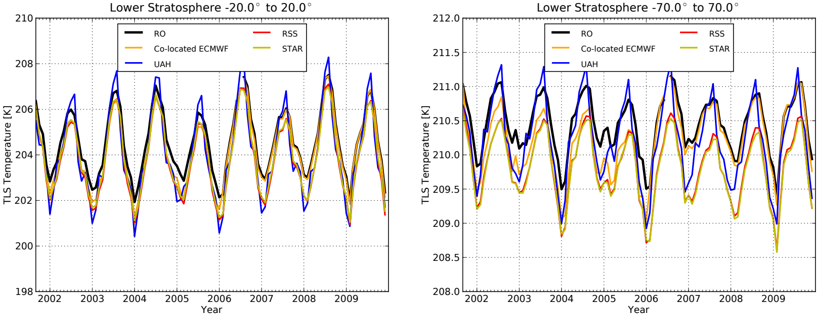
RO Sampling Error Considered



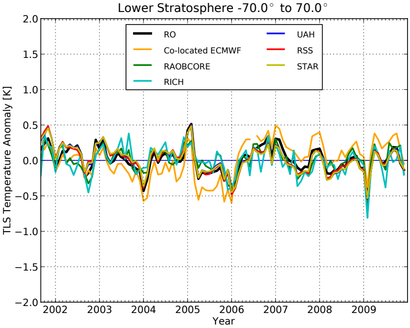
- Use ECMWF reference data (full and co-located) to estimate the RO sampling error (caused by spatial and temporal under-sampling)
- The estim. sampl. error is then subtracted from the RO data
- No trend found in the sampling error

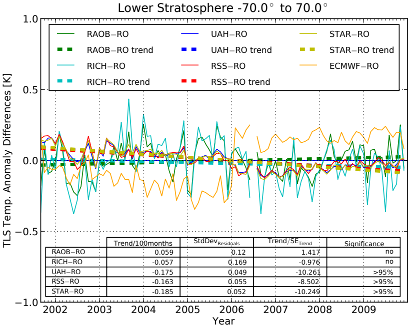
Absolute Temperatures



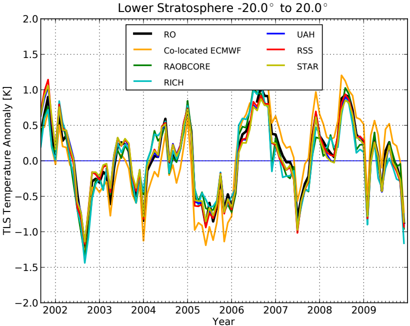
RO, ECMWF, MSU (UAH), MSU (RSS), MSU (STAR)

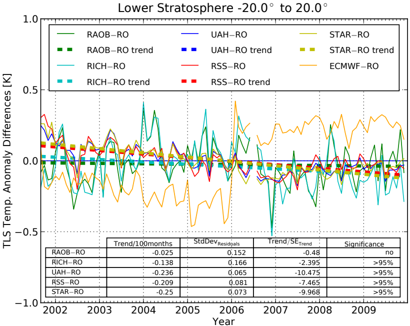
- Look at monthly anomalies to de-seasonalize data
- Look at differences between anomalies to remove climatological variability common to both datasets, isolates differences due to measurements and processing



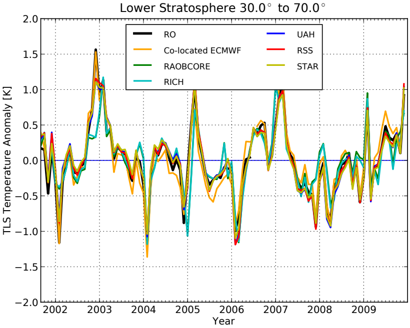


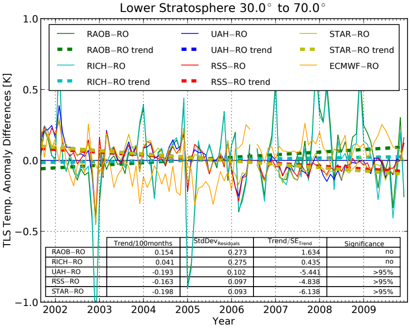
	Trend/100months	$StdDev_{Residuals}$	$Trend/SE_{Trend}$	Significance
RAOB–RO	0.059	0.12	1.417	no
RICH–RO	-0.057	0.169	-0.976	no
UAH–RO	-0.175	0.049	-10.261	>95%
RSS–RO	-0.163	0.055	-8.502	>95%
STAR–RO	-0.185	0.052	-10.249	>95%



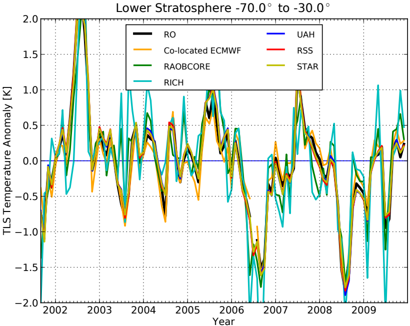


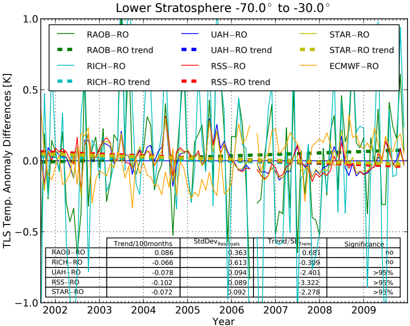
	Trend/100months	$StdDev_{Residuals}$	$Trend/SE_{Trend}$	Significance
RAOB–RO	-0.025	0.152	-0.48	no
RICH–RO	-0.138	0.166	-2.395	>95%
UAH–RO	-0.236	0.065	-10.475	>95%
RSS–RO	-0.209	0.081	-7.465	>95%
STAR–RO	-0.25	0.073	-9.968	>95%





	Trend/100months	$StdDev_{Residuals}$	$Trend/SE_{Trend}$	Significance
RAOB–RO	0.154	0.273	1.634	no
RICH–RO	0.041	0.275	0.435	no
UAH–RO	-0.193	0.102	-5.441	>95%
RSS–RO	-0.163	0.097	-4.838	>95%
STAR–RO	-0.198	0.093	-6.138	>95%





	Trend/100months	$StdDev_{Residuals}$	$Trend/SE_{Trend}$	Significance
RAOB–RO	0.086	0.363	0.681	no
RICH–RO	-0.066	0.613	-0.309	no
UAH–RO	-0.078	0.094	-2.401	>95%
RSS–RO	-0.102	0.089	-3.322	>95%
STAR–RO	-0.072	0.092	-2.278	>95%

Discussion

Dataset	b [K/100mon]	$StdDev_{Resid.}$	b/SE_b	Significant
GLOBAL				
RAOB–RO	0.059	0.12	1.42	no
RICH–RO	-0.057	0.169	-0.98	no
UAH–RO	-0.175	0.049	-10.26	>95%
RSS–RO	-0.163	0.055	-8.50	>95%
STAR–RO	-0.185	0.052	-10.25	>95%
TROPICS				
RAOB–RO	-0.025	0.152	-0.48	no
RICH–RO	-0.138	0.166	-2.40	>95%
UAH–RO	-0.236	0.065	-10.48	>95%
RSS–RO	-0.209	0.081	-7.47	>95%
STAR–RO	-0.25	0.073	-9.97	>95%

Summary

- Significant differences in Radio Occultation and (A)MSU lower stratospheric temperature record Sep2001–Dec2009 in all regions, most pronounced in the tropics, where differences are also significant for RO and RICH
- Confirms former study[2]; using most recent datasets and longer time period shows similar (but smaller) differences
- Known error sources for RO data cannot explain the difference (high-altitude initialization bias drifts, dry/physical temperature difference, mean sampling error are about one magnitude *smaller* than detected trend differences[3])
- Possible explanation: Strong tropical warming in upper troposphere better resolved in RO?

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[2] Steiner et al. JGR (2007)
[3] Steiner et al. Springer book (2009); Suppan MSc. thesis (2010)

Outlook

- Still too short time range, vulnerable to the choice of time frame
- Account for radiosonde sampling errors
- Compare tropospheric channels TTS, TMT
- Incorporate more datasets: 2010, MetOp-A, ERA-Interim
- Benefit of having independent measurements of atmospheric variables to estimate structural uncertainties

Thank you for your attention!