On variability of temperature profiles in the stratosphere: implications for validation

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Abstract Defining space-time collocation criteria for validation of measurements requires the information about natural variability of geophysical parameters. In this work, we analyzed the variability of small-scale structure of temperature field in the stratosphere using temperature profiles from radio-soundings at Sodankylä with small time difference between sonde launches. We found that the small-scale structures in temperature profiles become different when the horizontal separation of measurements exceeds 20-30 km. The set of the collocated temperature profiles has allowed obtaining experimental estimates of the horizontal structure function of temperature fluctuations. The spectral analysis of the profiles has shown that vertical wavenumber spectra of temperature fluctuations are similar, even for profiles separated significantly in space and in time (a few hundreds of kilometers, a few hours). Implications of these results for validation of high -resolution profiles are also discussed.

Main questions to answer:

- **How different temperature profiles can be in close collocations and with a small time difference?**
- **What are implications for validation of high-vertical-resolution temperature profiles?**

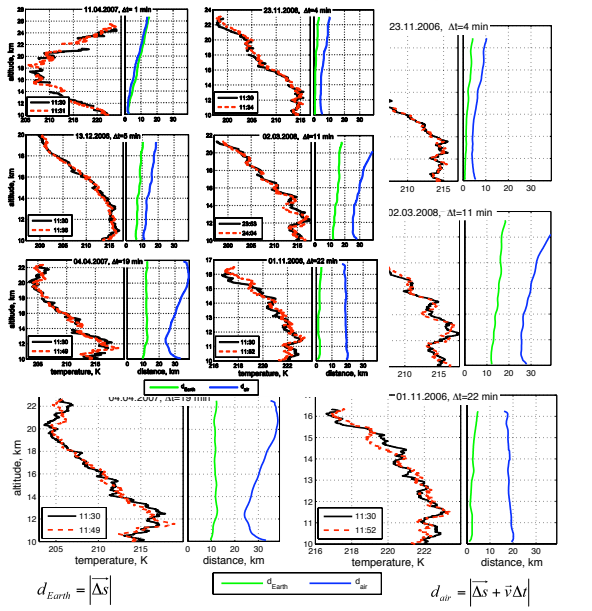
Data: collocated radio-soundings at Sodankylä

We selected data from PTU soundings at the Sodankylä station (67° N, 27° E) with time difference Δt<420 min (7 hours) between balloon launches. Majority of the collocated launches were made during the installation and testing of the automated sonde launching system in Sodankylä during 2006-2007 and during two SAUNA campaigns in March-April 2006 and in February-March 2007.

Year	Per year	Per month												Per time separation		
		J	F	M	A	M	J	J	A	S	O	N	D	< 30 min	30-120 min	120-420 min
2006	62	-	2	10	18	5	1	4	3	5	2	5	7	29(47%)	14(23%)	19(30%)
2007	110	10	39	12	5	3	10	9	12	3	1	3	3	17(16%)	20(18%)	73(66%)

All analyzed measurements were performed with Vaisala RS92-AGP radiosonde with DigiCora III ground equipment. Main characteristics:
- measurements of temperature, information about geolocation (GPS), wind velocity and direction
- vertical resolution ~10 m
- accuracy ~0.3K

Simple comparison of temperature profiles



$$d_{Earth} = |\Delta \vec{s}| \qquad d_{air} = |\Delta \vec{s} + \vec{v}\Delta t|$$

Figure 1: 1st and 3rd columns: examples of Sodankylä radiosonde temperature profiles corresponding to small time difference between sonde launches. 2nd and 4th columns: distances with respect to Earth dEarth and with respect to air d_{air}

Observations:
- The profiles measured on 11.04.2007 (1 min time difference between sonde launches) are practically identical
- Visual agreement between profiles rapidly drops with increasing time separation
- The small-scale structure in temperature profiles can differ significantly when the separation (with respect to air) exceeds ~20 km.

Experimental horizontal structure function

$$D_T(r) = \left\langle \left(T(\vec{r}_1) - T(\vec{r}_2)\right)^2 \right\rangle \qquad r = |\vec{r}_1 - \vec{r}_2|$$

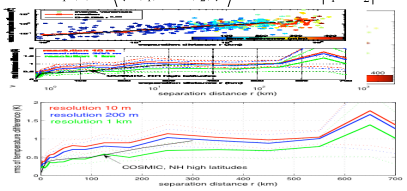


Figure 2: Top: experimental estimates of structure function (Eq. (1)), stars: values computed using collocated profile pairs, color indicates time difference; red line: median , circles mark the mid points of the bins used for data averaging; black line: fit by the power function. Only data with r<300 km used in the fit (solid line), the extension of the fit to r>300 km is indicated by dashed black line. Bottom: rms of temperature difference in collocated profiles as a function of separation distance, in linear scale. Solid lines: mean, dotted lines: inter-quartile range. Red: original resolution (~10 m), blue: vertical resolution 200 m, green: vertical resolution 1 km. (Red lines represent the same data in top and bottom subplots). Black line shows the COSMIC data adapted from [Anthes et al., 2008. BAMS] .

Comparison of vertical wavenumber spectra

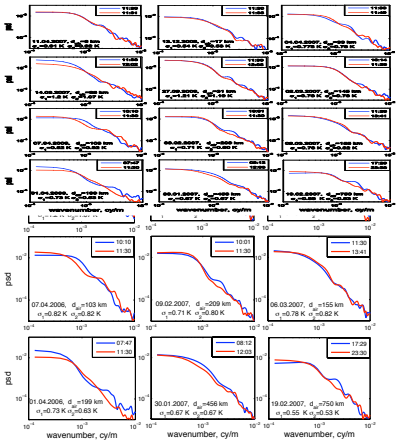


Figure 3: Examples of 1D vertical wavenumber spectra of relative temperature fluctuations in collocated radiosonde profiles

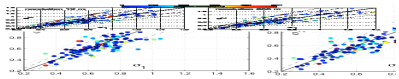


Figure 4: Scatter plot of rms of relative temperature fluctuations (in K) in collocated radiosonde profile pairs. Color denotes horizontal separation (distance with respect to air dair) of measurements. Left: profiles are in original resolution; right: profiles are smoothed down to 200 m vertical resolution. Solid line: y=x; dashed lines: y=1.2x and y=(1/1.2)x; dotted lines: y=1.4x and y=(1/1.4)x.

Observations:
- Spectra of temperature fluctuations look similar even for profiles significantly separated in time and space (a few hundreds of kilometers, several hours).
- For temperature profiles separated in the stratosphere by up to 500 km, rms of temperature fluctuations are within ±40% interval in majority (>95%) of cases.

Implications for validation

- Taking into account advection of air masses is important for computing the separation of measurements in the atmosphere and thus for defining collocation criteria.
- For similarity of small-scale structure, the profiles should be almost exactly collocated in time and in space.
- For profiles located at larger distance from each other, the natural variability can contribute significantly to the observed temperature difference.
- In statistical comparisons, natural variability should be taken into account.
- Application of spectral analysis gives an opportunity for checking whether small-scale fluctuations have realistic amplitude and spectral shape (attractive for validation of satellite measurements).