GLOBAL DISTRIBUTIONS OF TEMPERATURE VARIANCES DIFFERENT STRATOSPHERIC ALTITUDES FROM GPS/MET DATA

N. M. Gavrilov(1), N. V. Karpova(1)
Ch. Jacobi (2)

(1) Atmospheric Physics Department, Saint-Petersburg State University, Russia,
(2) Institute for Meteorology, University of Leipzig, Germany

Poster available at
http://www.uni-leipzig.de/~jacobi/docs/EGS2002_5.pdf

This study was supported by INTAS under grant 991-1186.

1 - SUMMARY

The GPS/MET measurements at 2 – 35 km altitude are used to obtain global distributions of mesoscale refraction index (dry temperature) variances at different stratospheric altitudes.

Individual temperature profiles are smoothed using second order polynomial approximations in 7 km thick layers centered at 2, 5, 10, 15, 20, 25, 30 and 35 km. Refraction index deviations from smoothed values and their variances are obtained for each profile and are averaged for each month of year during the GPS/MET experiment.

Global distributions of temperature variances have inhomogeneous structure. Locations and latitude distributions of the variances maxima and minima of the variances depend on altitudes and season. The reasons for the small-scale and mesoscale refraction index perturbations could be mesoscale turbulence and internal gravity waves.

Magnitudes of the refraction index variances are larger in the regions of tropospheric jet streams and of equatorial deep convection.
2 - Radio Wave Refraction Index

Low-orbit GPS satellite usually gives vertical profiles of radio wave refraction index at heights 5 – 60 km with high resolution in altitude. The refraction index, $N$, is connected with atmospheric parameters through the following expression:

$$N = (n - 1) \times 10^6 = 77.6 \frac{p}{T} + 3.73 \times 10^5 \frac{e}{T^2} + 4.03 \times 10^7 \frac{N_e}{f^2} + 1.4W,$$  \hspace{1cm} (1)

- $p$ atmospheric pressure [hPa]
- $T$ atmospheric temperature [K]
- $e$ water vapor partial pressure [hPa]
- $N_e$ electron number density [m$^{-3}$]
- $W$ liquid water content [g/m$^3$]

Stratosphere: only first term $\rightarrow$ “dry temperature” $T$.
Below 15 km: humidity terms in (1) become substantial.
Above stratosphere errors of eliminating ionospheric contribution become comparable with the dry temperature term in (1).

Dynamical processes in the atmosphere lead to the variations $\delta p$ and $\delta T$ of parameters in (1), which cause the variations of the refraction index $\delta N$.

For small-scale turbulence and low-frequency short internal gravity waves (IGWs) usually $|\delta p/p| < |\delta T/T|$. Therefore, we have

$$\left| \frac{\delta N}{N} \right| = \alpha \left| \frac{\delta T}{T} \right|,$$  \hspace{1cm} (2)

- $\alpha \approx 1$ in the stratosphere
- $\alpha > 1$ in the troposphere, where humidity is high
For the GPS/MET satellite height step of the data is $\Delta z = 0.2$ km. Tsuda et al. (1999) analyzing internal gravity waves (IGWs) from GPS/MET data used approximation of the temperature vertical profiles with a smooth mathematical function and calculation of deviations from these profiles. Polynomial ones are frequently used for the analysis of radiosonde and satellite vertical profiles of atmospheric parameters.

Fig. 1 shows examples GPS/MET temperature profiles with polynomial (2\textsuperscript{nd} order) at different height fitting layers thickness $\delta z = 5$, 10 km. Further increase in $\delta z$ leads to worse fitting. One may conclude that optimum thickness of fitting height layer is about $\delta z \sim 7$-10 km. Comparison of 2\textsuperscript{nd} and 3\textsuperscript{rd} order fit shows that the cubic approximation gives practically the same results as the quadratic one. Therefore, the quadratic approximation is sufficient for fitting of GPS temperature data in the stratosphere.

Here we select 7-km thick layers centered at 2, 5, 10, 15, 20, 25, 30, 35 km. For each vertical profile of refraction index measured with GPS/MET satellite we made a quadratic fit and calculated variances of residual N inside each layer, binned into months also. To get two-dimension distributions the data for each layer were interpolated to a regular grid using weighted averaging over circles with 8° radius centered at each grid point.
Figs. 2 - 5 show N variances at different heights in January, April, July and October, respectively. At 15–30 km variances of N reflect the variances T. In the troposphere and at high altitudes variances of N are not equal to that of temperature, but may reflect small and mesoscale dynamical changes in the atmosphere.

Horizontal distributions of variances in Figs. 2-5 change with height. At 2–5 km the N variances have maxima at midlatitudes and may reflect orographic peculiarities. At 10 km maxima are concentrated between 20° and 60° in both hemispheres. These maxima correlate with tropospheric jet streams having maxima at altitudes 10-12 km.

At 15–25 km one can see maxima at low latitudes. They may be connected with deep convection there. At 20–25 km there are maxima of N variation at high northern latitudes. At 30 km N variances are smaller than below. One can see large variances in the northern hemisphere. The variances increase at 35 km, with maxima near the equator.

Variance distributions in July (Fig. 4) and January (Fig. 2) are similar, except for a dominance of variances in southern hemisphere above altitude 20 km in July instead of northern hemisphere in January in Fig. 2. An analysis of variance distributions in April and October (Figs. 3, 5) shows more symmetric distributions during spring and autumn compared to winter and summer.
Fig 1. Example of GPS/MET dry temperatures (black lines) and running quadratic polynomial fit (red lines) with height intervals for approximation of 5 km (a) and 10 km (b). Deviations from the approximations are shown at right section of the plots.
Fig. 2. Latitude-longitude distributions of the refraction index relative variances from GPS/MET satellite data for different altitude layers in January. Left and right numbers show altitudes in km.
Relative Refraction Index/Dry Temperature Standard Deviation from GPS/MET Satellite Data for April

Fig. 3. As in Fig. 2, but for April.
Fig. 4. As in Fig. 2, but for July.
Relative Refraction Index/ Dry Temperature Standard Deviation from GPS/MET Satellite Data for October

Fig. 5. As in Fig. 2, but for October.