ADVANCED ATMOSPHERIC BOUNDARY LAYER TEMPERATURE PROFILING WITH MTP-5HE MICROWAVE SYSTEM

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1. ABSTRACT

The MTP-5, a ground based temperature profiler, has been widely used since 1991 for investigation of the atmospheric boundary layer. The MTP-5 is an angular scanning single-channel passive microwave instrument with a frequency in the center of molecular oxygen absorption band (60 GHz). It can measure the thermal emission of the atmosphere with sensitivity 0.04 K at 1 s integration time from different zenith angles. On the basis of this measurements, it is possible to retrieve temperature profiles at the altitude range up to 600 m. But for many applications it is needed to have altitude range up to 1 km. For those applications was developed advanced MTP-5HE instrument which has a new low noise receiver, new profile retrieval algorithm and shifted central frequency. The MTP-5HE system had successful comparison with radiosondes data within the COST720 WG2. Action "Integrated Ground-based Remote Sensing Stations For Atmospheric Profiling" at aerological station Payerne, Switzerland, in March-April, 2004.

2. INTRODUCTION

The investigation of atmospheric boundary layer (ABL) covers many areas: (atmospheric dynamics, radiation, turbulence, cloud physics, numerical modeling, air-sea interaction. Applications of this investigations are air pollution, urban climate, short-term meteorological forecasting. One of the important measurement parameter in ABL is temperature profile (Garrat, 1994). Temperature profiles in ABL are classified as stable, neutral and convectively unstable with a capping inversion somewhere between several meters and 2 km in height. Knowledge of ABL temperature profiles is important in many applications: e.g. forecasting pollution near big factories and power station, regional weather forecasting, radio wave propagation etc. Last decade or so for temperature profiling in ABL were used passive microwave radiometers with the frequencies in molecular oxygen absorption band (Westwater, 1993). One of the widely used instrument was MTP-5H - a single channel an angular-scanning microwave temperature profiler (Troitsky et al, 1993). It can measure the thermal emission of the atmosphere with sensitivity 0,04K at 1 s integration time from different zenith angles (Kadygrov and Pick, 1998). On the basic of this measurements it is possible to retrieve temperature profiles at the altitude range up to 600 m (Westwater et al, 1999). But for many applications it is needed to have altitude range up to 1 km (Kadygrov et al, 2002, Kuznetsova et al, 2004). For those applications was developed advanced MTP-5HE instrument (HE – height extension).

3. DESCRIPTION OF ADVANCED PROFILER

Maximum altitude for ground-based microwave temperature profilers depends first of all from the central frequency. If the central frequency is in the center of molecular oxygen absorption band (about 60 GHz), the maximum measured altitude is about 600 m, for the frequency about 53 GHz (on the wings of oxygen band) the maximum measured altitude is about 5 km. For sufficient accuracy of the temperature profile retrieval in ABL it is needed to have high sensitivity of the radiometer (ΔT_b) which can be calculated from equation $\Delta T_b = \frac{T \cdot k}{\sqrt{\Delta f \cdot \tau}} (K)$, where T – noise factor of the radiometer, k – depends from radiometer type ($k \approx 1 \div 3$ for different type of radiometer); τ – time of integration; Δf – radiometer bandwidth.

MTP-5H instrument had ΔT_b = 0,04 K at 1 sec integration time and bandwidth about 4 GHz. For the frequencies in the absorption line wings impossible to use such wide bandwidth: it is needed to be about 200÷400 MHz. So, the noise – factor of MTP-5HE radiometer needed to be 2÷3 times less in contrast with MTP-5H for about the same sensitivity. Finally MTP-5HE has following main technical parameters: central frequency 56 GHz, bandwidth 400 MHz, improved receiver with sensitivity 0,08 sec at 1 sec integration time, and new improved algorithm for temperature profile retrieval. During one year MTP-5HE was in continuous operation mode at aerological station Dolgoprudny, Russia, and had successful comparison with radiosonde in aerological station Payerne, Switzerland, during COST-720 Action "Integrated Ground-based Remote Sensing Stations For Atmospheric Profiling".

4. COMPARISONS IN PAYERNE

The main goals of the campaign in Payerne were:

- Test ground-based temperature and humidity profiling systems;

- Study in particular their ability to detect ABL phenomena like temperature inversion presence, formation and dissipation of fog and low clouds;
- Test cloud detection systems (passive and active ground-based systems);
- Provide a dataset for studying the possibility of system integration for improving temperature and humidity profiling with ground-based remote sensing systems.

Photo 1. MTP-5HE in Payerne, Switzerland, March 2004

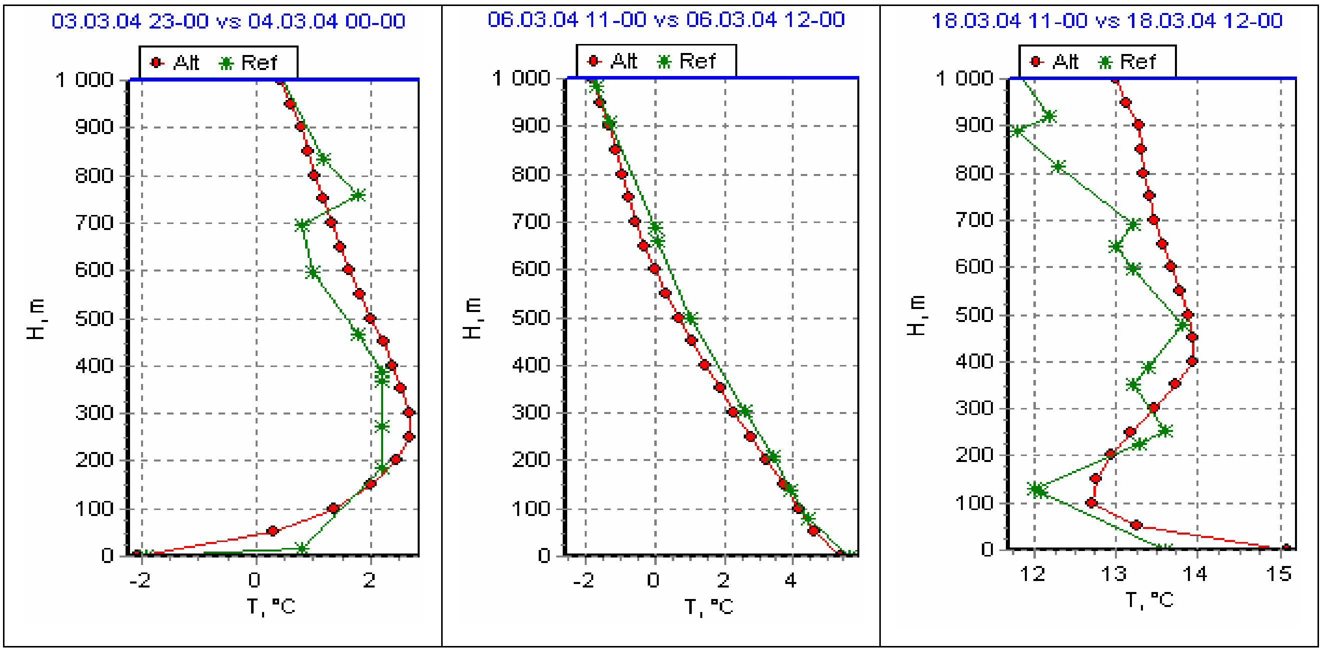


Figure 1. Results of the comparison with radiosondes.
(Alt-MTP-5HE data; Ref- radiosondes)

Regular measurements of ABL temperature profiles were provided by MTP-5HE profiler from March, 3, 2004, up to the April, 5, 2004. The measurement cycle was 5 minutes. The MTP-5HE instrument was installed at height 8 m from the ground surface (499 m above sea level), with radiosondes site at the distance about 50 m. (Photo 1). All in all, about 63 radiosondes launches taked part in comparison with 9633 profiles obtained from MTP-5HE profiler. At Fig. 1 are shown some results of comparison of remote sensing data with radiosonde ABL temperature profile data. It is possible to see that not only ground-based, but even elevated temperature inversion were retrieved with sufficient accuracy. At Fig. 2 are shown statistical results of radiosonde and MTP-5HE data comparison, and in Fig. 3 – same results, but separated for different atmosphere stratification (adiabatic or with temperature inversion), where:

$dA_v(h)$ – mean deviation for height h;

$dA_{v\ mean}$ – mean total deviation; RMSD(h) – root mean square deviation for different h; RMSD – root mean square deviation for all data.

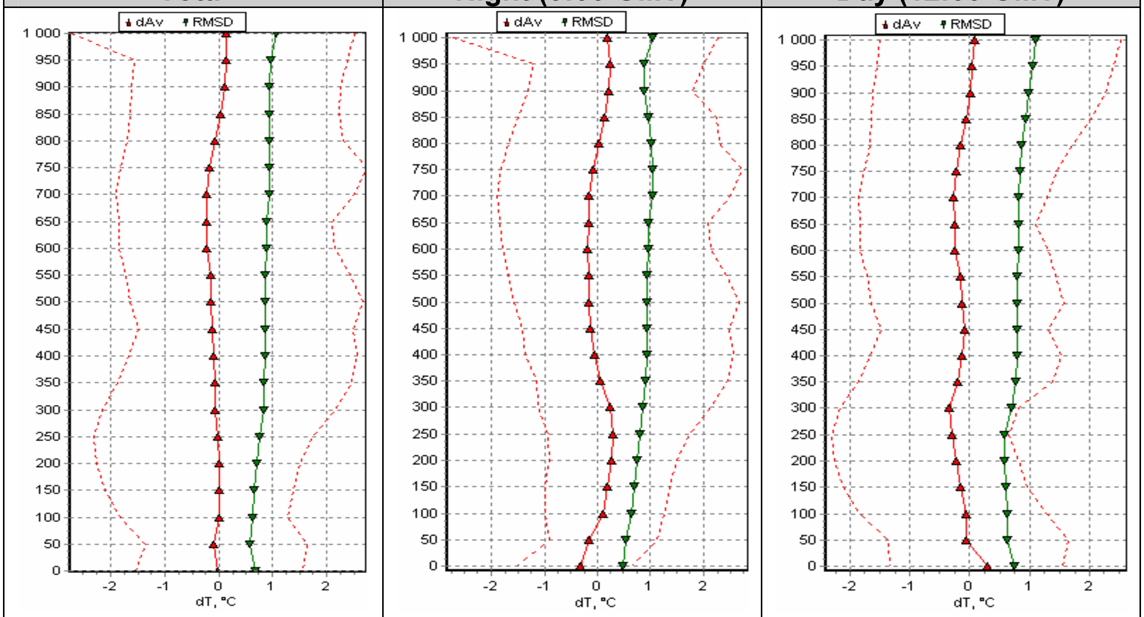
	Total	Night (0:00 GMT)	Day (12:00 GMT)
	 a	b	c
dAv_{mean} [degree,C]	-0.05	0.02	-0.12
Average Error	0.67	0.71	0.63
RMSD [degree,C]	0.85	0.89	0.80
Num profiles	63	31	32

Figure 2. The results of radiosound and profiler data comparison.
In figures are shown the values of dAv(h) and RMSD(h) and maximum and minimum deviations obtained for total statistics (a), for nocturnal (b) and diurnal (c) sounds

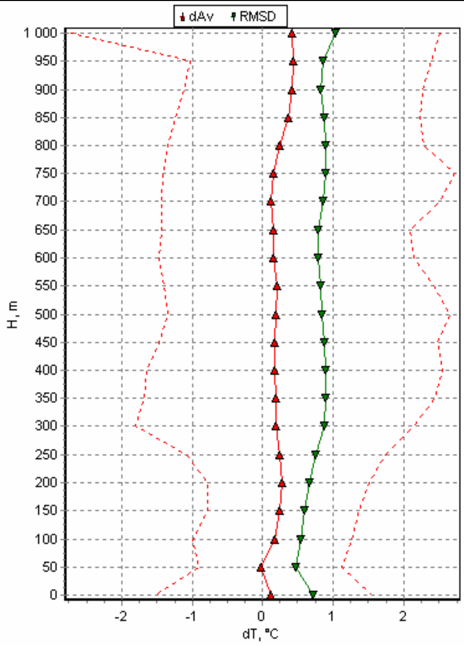
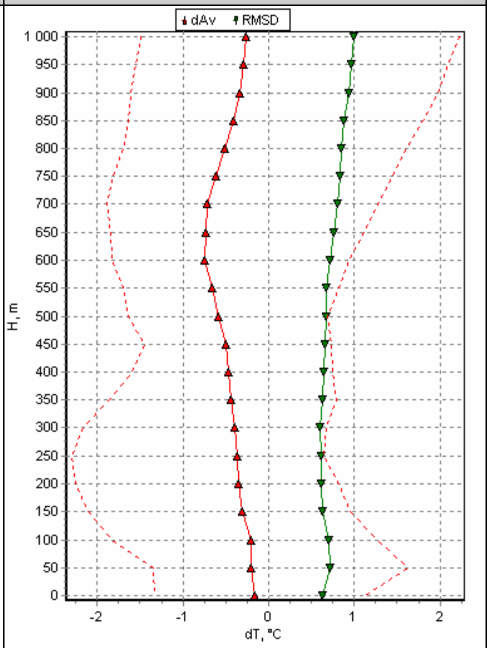
	Inversion	Adiabatic
	 a	 b
dAv_{mean} [degree,C]	0.22	-0.44
Average Error	0.64	0.60
RMSD [degree,C]	0.81	0.76
Num profiles	37	26

Figure 3. The results of radiosound and profiler data comparison for different stratifications
In figures are shown the values of dAv(h) and RMSD(h) and maximum and minimum deviations obtained for statistics when inversion was observed (a) and without inversions (b).

5. CONCLUSION

Results of testing MTP-5HE – a new modification of single-channel an angular-scanning microwave temperature profilers - and comparison with radiosondes data from aerological station Dolgoprudny (Russia) and Payerne (Switzerland) confirmed that it can provide continuous ABL temperature profiles measurement in altitude range 0÷1000 m with accuracy about 0,5-0,8°C.

6. ACKNOWLEDGMENTS

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