

# FEATURES OF ATMOSPHERIC TEMPERATURE PROFILING IN POLAR REGIONS

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## ABSTRACT

The most important part of the investigations of climate and meteorological conditions in Polar Regions is the monitoring of atmospheric boundary layer (ABL) parameters. Characteristic feature of the atmospheric boundary layer in polar latitudes is the presence of strong temperature inversions which are important for interactions with radiation cooling processes, advection of warm air and katabatic winds. In this connection the scientists of Central Aerological Observatory jointly with the specialists from the Radiophysical Research Institute in the end of '90th years of the last century designed the remote method of measuring temperature profiles of ABL based on measurements of self-emitting heat radiation of atmosphere on frequency near 60 GHz. The evolution of the equipment based on experiences and results of temperature profiles measurements with the use of polar version of microwave profilers in 2000-2012 are presented in the report.

## 1. INTRODUCTION

Microwave temperature profiler (MTP-5) has been developed as an instrument for continuous measurements of the temperature stratification in boundary layer. [1] The study of atmospheric boundary layer thermal structure is of huge interest for multiple applications, particularly it concerns works in Polar Regions. The first application for monitoring in polar region was for diamond quarry in Russian Yakutia region since 1992. The specific of this measurements was not only in wide range of the operating temperature (-60÷ -70°C), but also in the scanning of the depth of quarry (Fig.1).

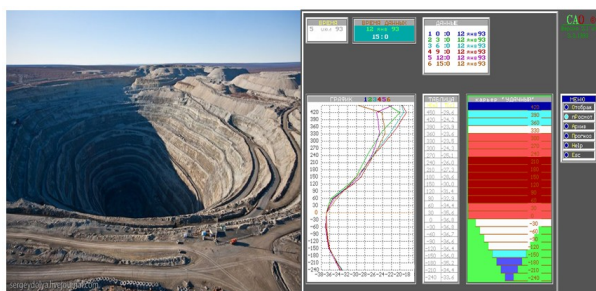


Figure 1. View of the diamond quarry in Russian Yakutia and example of the data. 12 January 1993.

Experience of creation and usage of this device allowed to make a version of MTP-5 for unattended work in

severe (extreme) weather events.

These devices also were utilized in Polar Regions: Kola Peninsula, north of Sakhalin island, Barrow station (Alaska), on ice-breaker in North Pole district during SHEBA (Surface Heat Budget of the Arctic Ocean) (Fig.2). The experience in use of these devices showed that it was necessary to have maximum height vertical resolution in lower layers of ABL for the investigations.

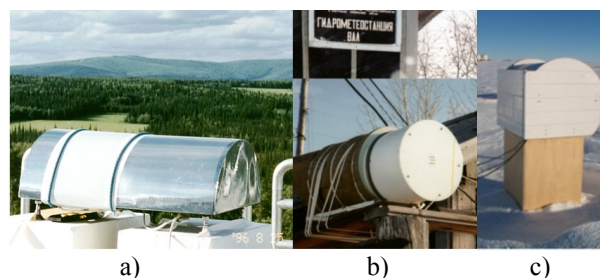


Figure 2. a) MTP-5 (one of the first versions) on Alaska (USA) 1996, b) North part of Sakhalin Island (Russia) 1999-2000 and c) MTP-5P Antarctica station Dome C 2002-2003 and 2004-2005.

All these requirements led to the creation of the new profiler MTP-5P – special version of the MTP-5 device (Fig. 2 c).

Evolution of the antenna's system and of other parts of the device has been based on the previous experiences of creation and usage and gave us a new upgraded version of MTP-5PE (Fig.3). MTP-5PE also has good vertical resolution in first 100 meters (10 m) due to the antenna system with a narrow beam (about 1 degree) and can operate in an ambient temperature range from -80 to +45 degrees.



Figure 3. MTP-5PE on Russian drifting station North Pole – 39: April 2012. 83.7N 111.9W.

## 2. Evolution of the technical parameters

From November 2002 to March 2003 profiler MTP-5P

successfully had passed tests on Antarctic French-Italian continental station Dome-C (75006°S and 123023°E, height above sea level 3233 m, distance from coast 1100 m) [2,3]. Successful tests of MTP-5P during Antarctic summer allowed to test MTP-5P in more severe conditions. It was realized on all-the-year-round French-Italian station “Concordia” (near Dome-C where expeditions made only in Antarctic summer).

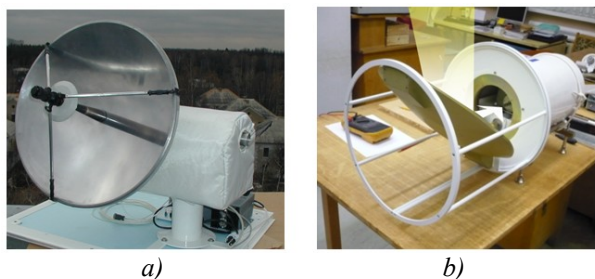


Figure 4. MTP-5P (a) and MTP-5PE (b) are shown without radio-transparent covering.

Polar profiler has vertical resolution 10-25 m on first 100 meters above Earth surface and keeps full capacity for work at very low temperatures (down to -80C). Main parts of device are high sensitive microwave radiometer tuned on frequency 60 GHz (5 mm wave length), antenna system which provides width of directional diagram 0,50, scanner made in the Netherlands company Kipp&Zonen, microprocessor device and meteo protection system (Fig. 4 a). Applying of large antenna mirror which was necessary for thin beam caused problems with meteo shield. In contrast to MTP-5 the MTP-5P fixed radio transparent covering of antenna (Fig 4 a), with the result that the device needed maintenance in conditions of liquid precipitation.

Table 1 the distribution of the errors are shown

H [m]	The distribution of the RMS errors in dependence of height for MTP-5PE version, T[C]	Error in determination of the height dh [m]	Displayed height interval [m]
50	0.25	10	10
100	0.30	25	10
200	0.40	50	25
300	0.50	75	50
400	0.70	100	50
600	0.90	150	50
800	1.00	200	50
1000	1.20	250	50

For solving this problem a new modification of device which kept advantages of polar version and high-altitude modification MTP-5HE was created (Fig 4 b). Active meteo shield makes device unattended for any weather conditions, the newest antenna system provides high accuracy of temperature profiles measurements in

a layer of 100-200 m, and using of receiver with frequency 56,6 GHz provides availability to install temperature profiles up to 1000 meters. The theoretical distribution of the errors in temperature profiles measurements and retrieval as inverse task were confirmed as result the statistical comparison with the operational radiosonde observations (RAOBs). The corresponding root-mean-square (RMS) error and error in determination of the height for temperature profile are shown in Table 1.

In Moscow the MTP-5PE has been calibrated by the use of special microwave target with different temperatures. The procedures of the self calibration also have been tested. The procedures of self calibration have made the correction by the use of the algorithm in software by use signal from horizon and sensors data. This technology is well known and applicable for MTP-5 because it work in range near 60 GHz [4, 5].

### 3. Results of measurements

In Antarctica, long-lived stable ABLs are in direct contact with the free atmosphere. Then the standard theory of the nocturnal stable ABL is not applicable. Instead of the ABL as such, we need to consider a two-layer system consisted of the ABL and the capping inversion developing in the course of time due to the persisting radiative cooling of the ice/snow surface. [3] Here, ABLs - the layers with large turbulent kinetic energy - are generally shallow (about 30 m), while the capping inversions, with rather low turbulent kinetic energy but strong temperature fluctuations and hence pronounced turbulent potential energy, could be quite deep. From the mean temperature profiles it is impossible to distinguish between the ABL and the capping inversion. [3]

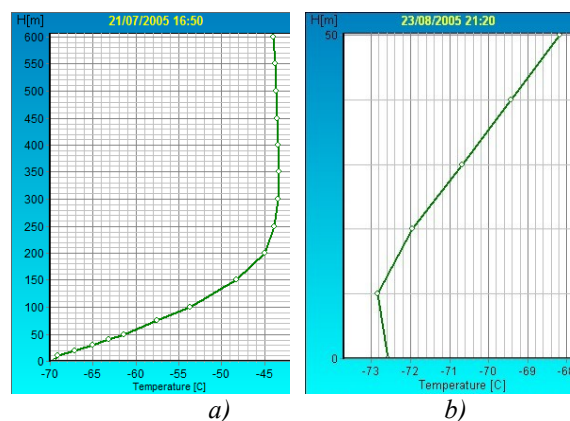


Figure 5. The example of the temperature profiles typical for winter season (a) and with elevated inversion in first 50 m (b) have been measured on station Dome-C in July-August 2005.

The example on Fig.5 (a) illustrates the typical temperature profiles for winter season for stable

boundary layer and good resolution of the first 50 m temperature stratification. The dynamic of the atmospheric temperature profiles for the stable boundary layer on August 2005 is shown in Figure 6.

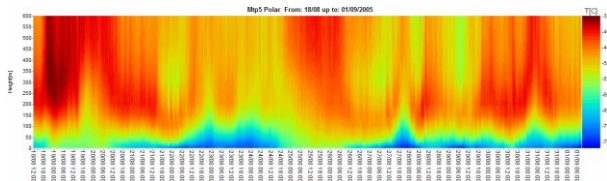


Figure 6. Temperature profiles evolution on August 2005 at station Dome-C.

Hoeffler Consulting Group (HCG), Anchorage, Alaska, has installed a meteorological monitoring station located on Endeavor Island, adjacent to Endicott Island, 28 kilometres northeast of Prudhoe Bay, Alaska. Endicott and Endeavor Islands are man-made gravel islands 4 kilometres offshore in the Beaufort Sea on Alaska's northern shoreline. The Endeavor Island meteorological monitoring station, which began operation on May 15, 2010, is instrumented with a Kipp & Zonen, MTP-5PE, for the purpose of obtaining atmospheric temperatures at multiple levels up to 1,000 meters above ground level. The intent is to use the resulting temperature profiles to support atmospheric modeling necessary for permitting petroleum development in the area.

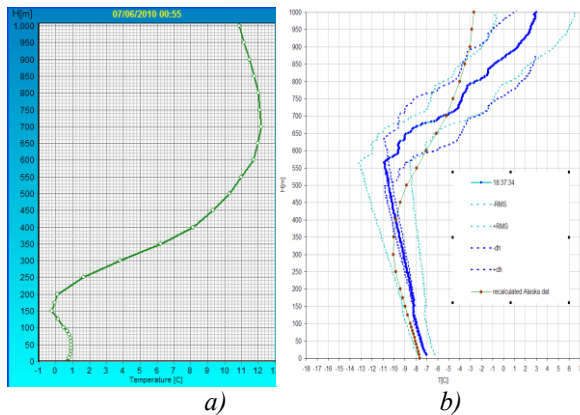


Figure 7. The examples of the temperature profiles typical for Endeavor Island summer 2010.

New measurement system MTP-5PE allowed to get temperature profiles up to heights 1000 meters (example of observations showed on Fig 7). Besides, high resolution capabilities of antenna system and installation algorithm quality allowed observe double inversion in polar region in a 300 meters layer (Fig 7 a) and retrieval high elevated inversion (Fig.7 b). The blue line is the RAOB data and green line with red dot is MTP-5PE profile. The example of the errors of comparison is shown with borderlines of the errors distribution for temperatures and heights (Tab.1).

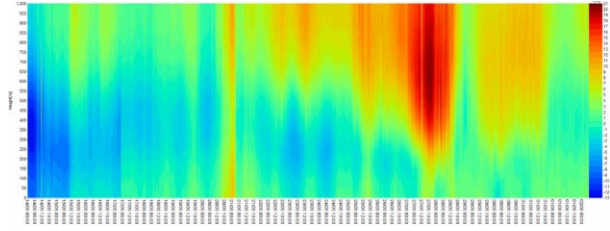


Figure 8. The example of the temperature profiles evolution for polar region was measured by use MTP-5PE version, Endeavor Islands, May and June 2010.

The profiler MTP-5PE provides continuous (every 5 min.) measurements of the temperature profiles of ABL on Russian polar drifting station-39 (Arctic and Antarctic Research Institute - AARI of the Russian Federal Service on hydrometeorology and environmental protection) since April 2012 (Fig.9).

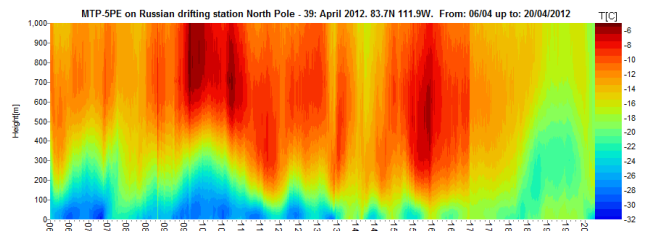


Figure 9. The example of the data time series for polar region were measured by use MTP-5PE version (April 2012.).

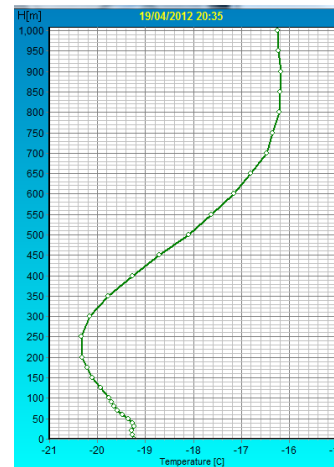


Figure 10. Temperature profile with twice elevated inversion is shown. 20:35, 19 April 2012.

Device was installed on station and had operated in automatic mode. There was unusual dynamic of the inversion in boundary layer during this period (Fig.9, 10). There are no possibilities to receive the data in on-line mode and authors expect to do more detail analysis when new data will be available.

#### 4. REFERENCES

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