Advanced Microwave System For Measurement of ABL Thermal Stratification in Polar Region

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Abstract

Study of atmospheric boundary layer thermal structure is a huge interest for multiple applications, particularly it concerns works in polar regions. In the end of the past century in Central Aerological Observatory was designed microwave temperature profiler MTP-5P assigned to measure temperature profiles in polar regions. MTP-5P successfully worked in 2001-2005 both in Russian polar regions and on Antarctic station Concordia where ambient temperature fells down to -78 C in winter time.

Experience of creation and usage of this device allow to make a new upgraded version of MTP-5PE. MTP-5PE also has good vertical resolution in first 100 meters (10 m) due to antenna system with a narrow beam (less than 1 degree) and can operate in an ambient temperature range from -80 to +45 degrees. In MTP-5PE installed new radiometer with increased sensitivity and stability, antenna system and scanner system were redesigned completely thus considerably decrease dimensions of device and enhance calibration accuracy. Device has passed successful tests and comparisons with radiosondes data.

Introduction

The most important part in investigations of climate and meteorological conditions in Antarctic region is a monitoring of atmospheric boundary layer (ABL) parameters. Characteristic feature of an atmospheric boundary layer in Polar latitudes is a presence of strong temperature inversions which are important for interactions with radiation cooling processes, advection of worm air and concretion. On the continental Antarctic stations repetition of days with surface temperature inversions amount up to 96% while temperature drop between upper and lower limits runs to 25-30^0. Most often a layer with maximum values of a temperature inversions gradient spreading to heights 300-400 m and above to 800-900 m observing isothermal profile. For explorations of temperature inversions was used data of radiosondes. One of major feature of this method is a high vertical resolution and wide range of measuring heights. But this method has considerable disadvantages: a lot of consumables needs, presence of qualified personal for sounds launching, difficulties of launching in hurricane winds. Besides, radiosounding doesn't provide continuity of temperature profile measurements because usually sondes launches not often than four times in 24 hours. In this connection scientists of Central Aaerological Observatory jointly with specialists from Space Research Institute and Radiophysical Institute in the end of '90^{th} years of the last century designed new remote method of measuring temperature profiles of ABL based on measurements of self-emitting heat radiation of atmosphere on frequency 60 GHz [1]. On a basis of this method were created industrial development types of temperature profilers MTP-5 which successfully passed serial of international comparison tests, certificated by Federal Agency on Technical Regulation and Metrology and Roshydromet and now used both in Russia and in foreign countries [2].

a) b)

Fig.1 a) MTP-5 on Alaska (USA) 1998-1999 and b) North part of Sakhalin island (Russia) 1999-2000

Profiler MTP-5 provides measurements of temperature profiles in automatic mode from the Earth surface up to 1000 meters with resolution 50-100 meters continuously and in all weather conditions. Low power consumption is one of advantages of profilers (20-40 W), light weight (15 kg) and low operational cost because of absence needs in consumables and automatic operational mode. This devices also used in polar regions: north of Yakutia, 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 1). Experience of using this devices showed that for investigations of polar ABL there is need to have maximum height vertical resolution in lower layers of ABL. All this requirements leads to creation of new profiler MTP-5P – special version of the MTP-5 device (Fig 2).

Fig.2. MTP-5P Antarctica station Dome C 2002-2003 and 2004-2005

Form November 2002 to March 2003 profiler MTP-5P successfully had passed tests on Antarctic French-Italian continental station Dome-C ($75^0$06'S and $123^0$23'E, height above sea level 3233 m, distance from coast 1100 m). Successful tests of MTP-5P during Antarctic summer allowed to continue 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).

Technical parameters

Polar profiler has vertical resolution 10-20 m on first 100 meters above Earth surface and keeps full capacity for work at very low temperatures (down to -80^{0}C). 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 0,5^0, scanner made in Netherlands company Kipp & Zonnen, microprocessor device and meteo protection system (Fig 3).

a) b) c)

Fig.3 General overview of MTP-5P

Utilization of large antenna mirror which necessary for thin beam causes problems with meteo shield. In contrast to MTP-5 the MTP-5P has fixed radio transparent covering of antenna (Fig 3a, 3c – with covering, 3b – pushed off), in this result device need maintenance in conditions of liquid precipitation. For solving this problem was created new modification of device which keeps advantages of polar version and high-altitude modification MTP-5HE. In table 1 showed technical characteristics of different polar devices. Active meteo shield makes device unattended for any weather conditions, newest antenna system provides high accuracy of temperature profiles measurements in a layer of 100-200 m, and utilization of receiver with frequency 56,6 GHz provides availability to install temperature profiles up to 1000 meters.

Table 1 The technical specification for MTP-5P and MTP-5PE versions

	MTP-5P	MTP-5PE
HEIGHTS RANGE	0-600 m	0-1000 m
SENSITIVITY (WITH TIME CONSTANT OF MEASUREMENTS 1 SEC)	0,05 K	0,05 K
RATE OF MEASUREMENTS	300 sec	300 sec
WEIGHT	80 kg	25 kg
POWER CONSUMPTION	100-400 W	max 120 W average 60 W
CALIBRATION	self calibrated	self calibrated
DIAGNOSTICS	self calibrated	self calibrated
TEMPERATURE RANGE	-80^{O}C - +40^{O}C	-80^{O}C - +45^{O}C

In Moscow the MTP-5PE has been calibrated by using of special microwave target with different temperatures. After this, the radiometer has been tested more than one month in original meteo protection (MTP-5HE). There is no differences for this procedures in meteo protection MTP-5HE and MTP5-PE versions. During this period the systems of thermo stabilization, the stability of microwave unit and other parts of technology were tested. The procedures of the self calibration has been tested too. The procedures of self calibration have made correction by using 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 [3]. On Table 2 the distribution of the errors are shown.

Fig. 4 General overview of MTP-5PE and photo of antenna system.

Table 2

H [m]	The distribution of the RMS error 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

Results of measurements

Profiler MTP-5P provides continuous (every 5 min.) measurements of temperature profiles of ABL on station Concordia during a period from November 2004 to December 2005 (Fig 5). Device was installed near of station building and had operated in automatic mode. There were no failures of device although temperature had drops to -79^{0}C. Almost continuous all-the-year-round data about

dynamics of temperature inversions of ABL had got for the first time in History of Antarctic atmosphere investigations [4].

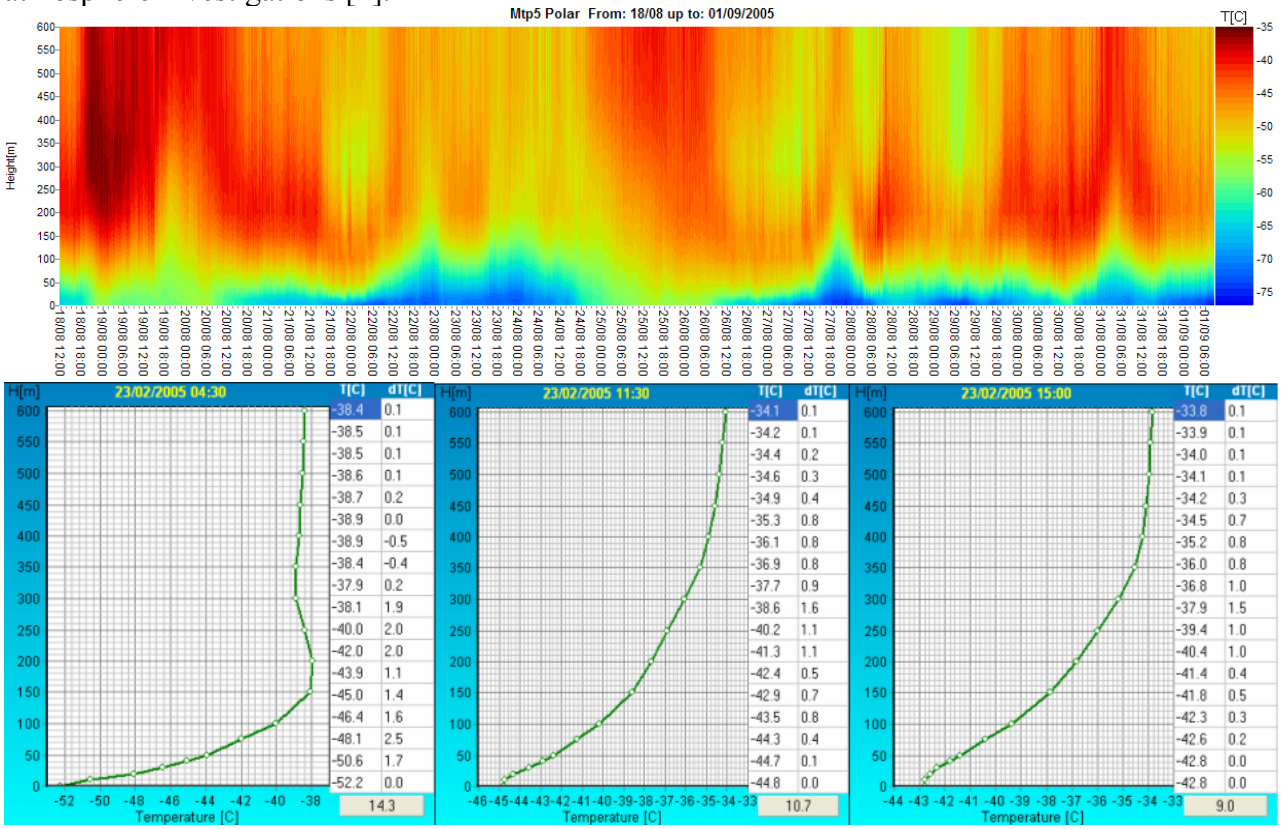

Fig 5

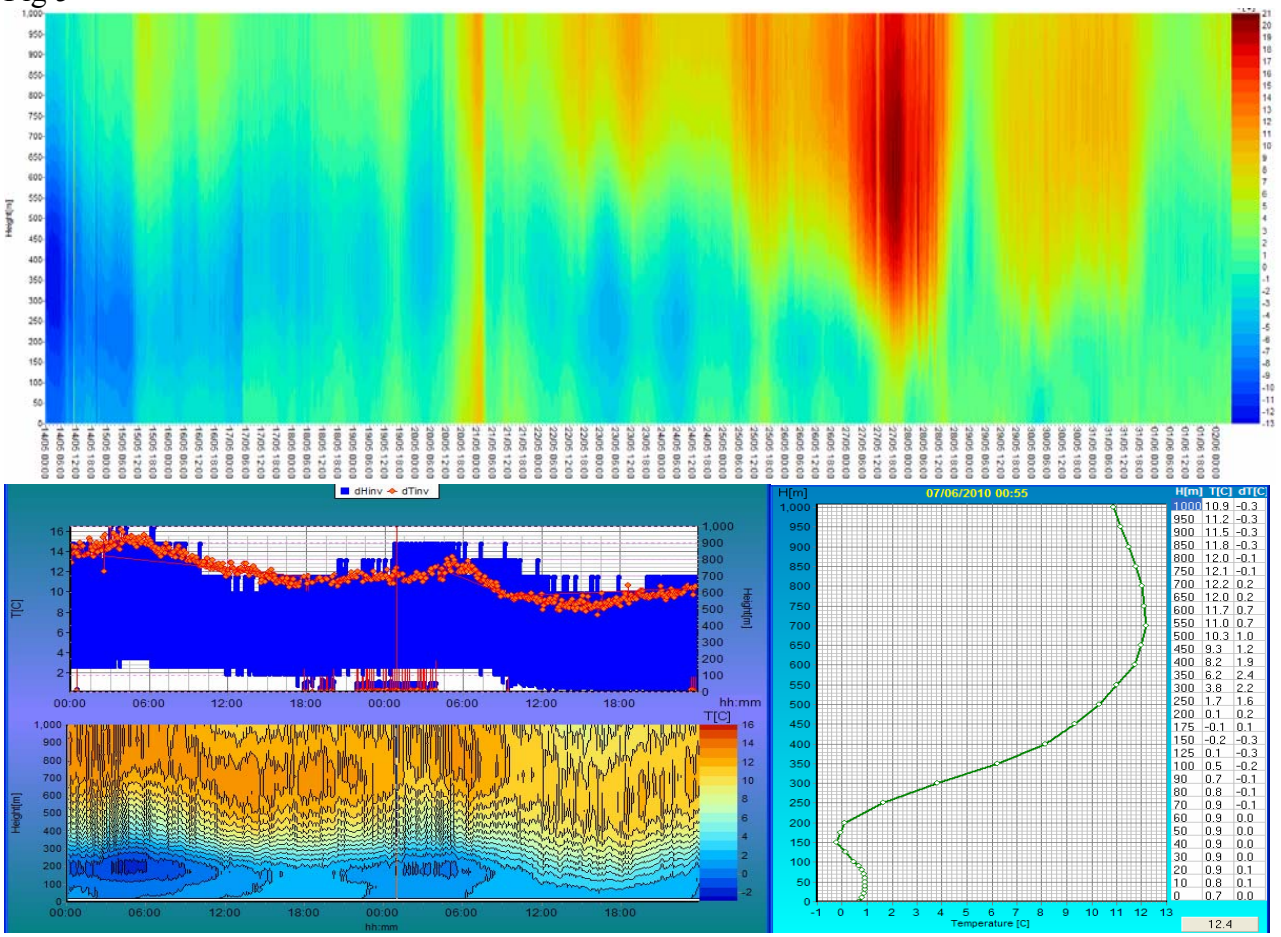

Fig 6 The example of the data time series for polar region were measured by use MTP-5PE version.

New measurement system MTP-5PE allowed to get temperature profiles up to heights 1000 meters (example of observations showed on Fig 6). Besides, high resolution capabilities of antenna system and installation algorithm quality allowed observe double inversion in polar region in a 300 meters layer (Fig 6).

References

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