NEW APPROACH IN APPLICATION OF MICROWAVE TEMPERATURE PROFILERS FOR LOCAL SYNOPTIC FORECAST.

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Abstract

The microwave temperature profilers became more and more common instrument for real time observations of thermal conditions of lower atmosphere. In general practice it was in use for air pollution monitoring mostly. Present work was based on implementation of MTP-5 microwave boundary layer temperature profiler for synoptic scale forecast of low atmosphere parameters. The measurements were made by MTP-5 in the central part of Krasnoyarsk City within the period September 2004- May 2006. Regional Department of Hydro Meteorological Service of Russia used the instrument on the regular base for now casting of harsh weather for air pollution. However, the regular 24 hours information about temperature profiles in first 1km layer, which is updated each 5 minutes, allows using it in synoptic scale forecasting algorithms. Such algorithm was developed more then 20 years ago. But one of the main parameter- heights of mixing layer was available just from sounding data. If even two times per 24 hours sounding data would be applied, the result of calculation can not be expanded for more then+/- 1 hour from the time of sounding release. The present report is aimed to demonstrate on the example of a few different synoptic situations, that remote temperature profiler use to be very important part of observational net for compensation the lack of data within a time between sounding launching.

Introduction

MTP-5 is microwave temperature profiler which was developed by Central Aerological Observatory of Roshydromet within 1992-1996.(Ivanov, Kadygrov 1994) It was tested in all World Centers of boundary layer investigation (Boulder, USA; Cardington, UK; Tsukubo, Japan; Obninsk, Russia). (Westwater et al 1999). Russian State Standard Committee certified MTP-5 as a tool of measurements in 1998. Roshydromet has accepted this instrument as a device, which can be used by State observational net on regular base, in 1999. Since that time the instrument was installed in 6 Regional departments of Roshydromet and is operating to the current days in duty 24 hours mode.

In parallel with implementation of MTP-5 on the observational net, the methodical background of routine usage of MTP-5 data was elaborated. The main intentions of the system developers were focused on the possibility of MTP-5 to provide so called “inertial forecast” for 1-2 hours ahead. Such a possibility is supported by the very fast rate of data update. MTP-5 can provide new temperature profile within each 5 minute. So the development of the thermodynamic instability(stability) can be visible even from Height-Time diagrams (Fig1.)

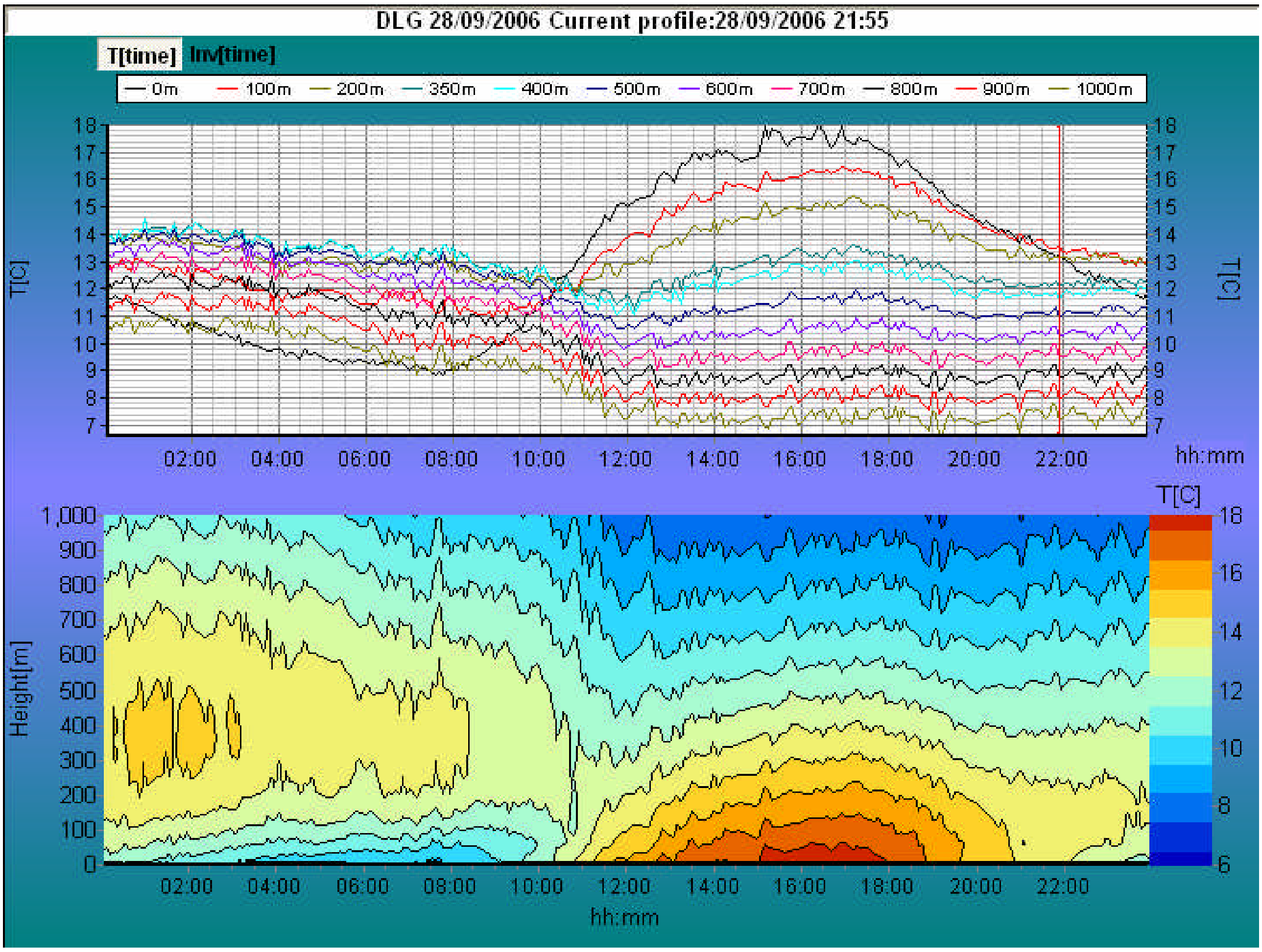

Fig1. Height-Time cross-section of boundary layer temperature field

Nevertheless, the situation changed due to experience of the “end users”, who are Duty Synoptic of Regional Departments of Roshydromet. As far they had the direct access to the current synoptic situation analysis and MTP-5 data, they start to observe very definite correlation of thermodynamic field of boundary layer and synoptic situation. Thus the intention to use MTP-5 in wider applications then simple now casting was created. The presented article is the first approach in development of the synoptic scale forecast based on MTP-5 data.

Observational background

The observational background that was used for development of a new approach is based on simultaneous analysis of MTP-5 data and synoptic situation. MTP-5 data can be presented in a few different forms. Prime of them is just a plot of air temperature profile with height resolution about 50m. The temperature profile can be updated every 5 minute, and the standard update rate is 10 minute. The time series of the temperature profiles are used to compose so called “temperature field”, which is height-time cross-section of the boundary layer temperature (Fig.1).

Temperature time series composed from the temperatures at each individual height retrieved from the profil every 10min. (Fig. 2). Other possible representation could be “field of instability energy” or “ field of virtual temperature”. Different of these forms can be used for the more obvious correspondence with the current synoptic situation.

As an example of such direct and obvious correspondence the next typical situation can be presented:

1. Passing of the warm front.

The screen with temperature time series for different height indicates that with the general temperature increase, the atmosphere boundary layer became much more uniform (Fig.2). It can be seen that the temperature can be the same at the different height of boundary layer within a few (up to 1 2) hours.

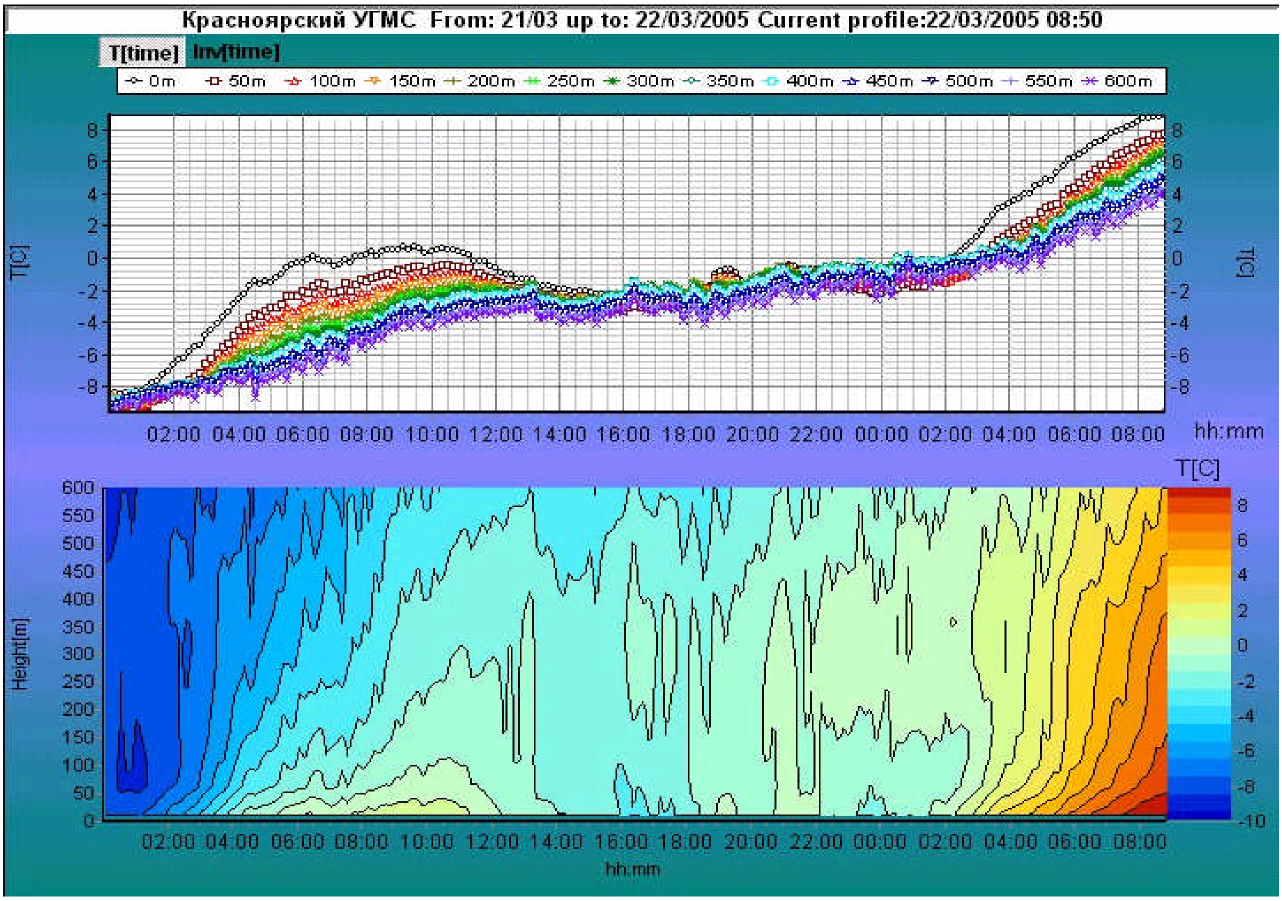

Fig.2 Increase of the temperature before Warm front passing and long period of uniform boundary layer after the front passed.

2. Passing of the cold front

The screen with height-time temperature field cross-section is more informative for diagnostic of the cold front passing (Fig.3). The time series of the temperature at different heights indicates passing of the cold front also, but at the bottom screen we can see obvious change of the air mass at around 19:00 on May 19, 2005.

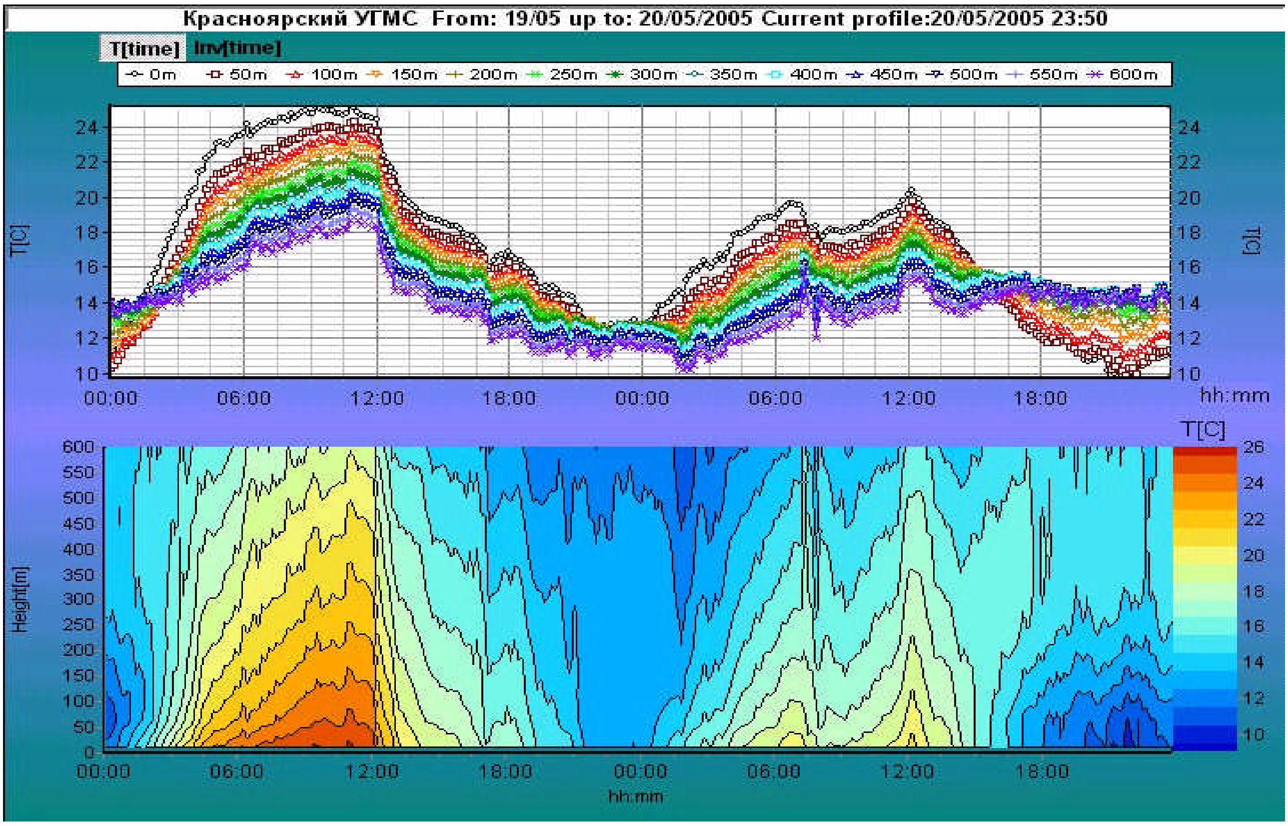

Fig.3. Passing of the cold front at 19:00 on 19 May 2005.

3. Winter/Summer anticyclone.

The situations with winter and summer anticyclones are very similar. It is better to analyze the situation with composing of the joint picture from the records of a few consequent days. Such a composition picture is presented on the Fig.4 This plot represents temperature time series for more then 3 weeks of Siberian Winter anticyclone. It is very clear that not just the fact of inversion can be predicted, but exact time of it maximum as well as the depth of inversion can be predicted very well.

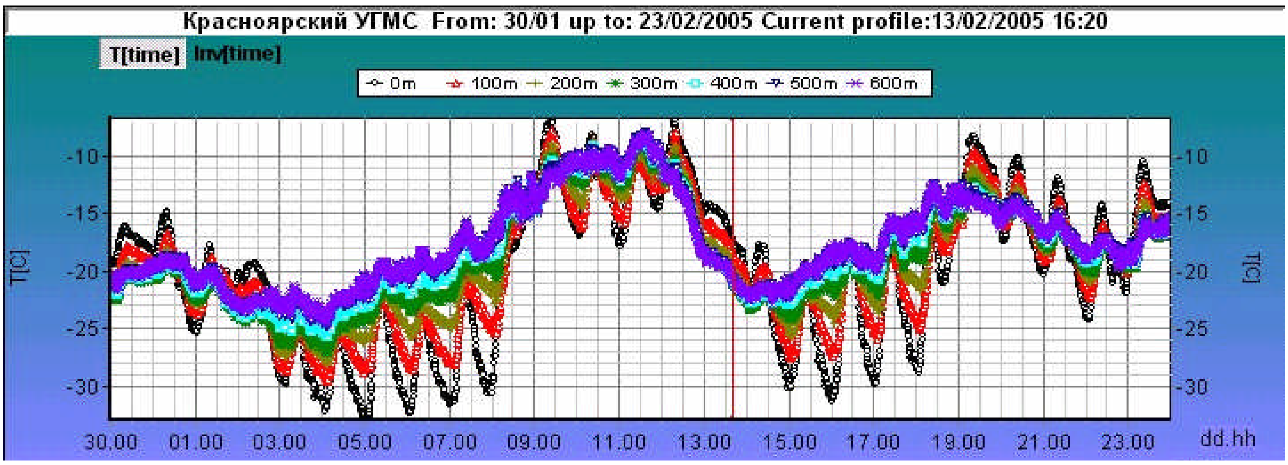

Fig.4 Long Siberian winter anticyclone with repetition of every day inversions.

Linear model for forecast of pollution accumulation

To formalize the observational events mentioned above, we have proposed the simplest linear model for formation of the criteria, which can be useful for synoptic scale forecast of pollution accumulation (PA). Such a model can be expressed as a linear regression equation composed with three natural components and three unknown coefficients:

$$PA= a \times H + b \times V + c \times S \quad (1)$$

In this equation a,b,c are unknown coefficients of regression. **H** is the index, which corresponds to the height of the mixing layer. **V** is the index, which corresponds to the average wind speed within the mixing layer. **S** is the index, which corresponds to the current synoptic situation. Indexes are used instead of real values, just to get all values in (1) at the same scale.

It is no questions that the parameters composed the equation (1) are the main parameters, which led to the pollution accumulation, but the impact of each parameter to the final sum is a question. For this reason the waiting coefficients a,b,c were introduced into the equation. If it will be seen from the experimental testing of this linear model, that some of index has predominant meaning, then it can be accounted by the increase of corresponded coefficient.

The general ideas for corresponding of the index to the current conditions are described below:

a) **H** index is calculated on the base of MTP-5 data about temperature profile in the boundary layer. It is well known that the temperature stratification is the main factor for vertical turbulent exchange. Simply speaking the vertical exchange is still possible if the temperature gradient at each given height is still higher (in absolute value) then the dry adiabatic gradient. The height where these two gradients (calculated from MTP-5 data and dry adiabatic) start to be equal one to other is decided the height of mixing layer. To simplify the calculation in (1) the next table of corespondents for **H** was accepted.

Index	Mixing layer [m]
3	300
4	400
5	500
6	600
7	700
8	800
9	900
10	1000 and more

Tab.1 Correspondence of H to the real mixing height calculated from MTP-5 data.

b) **V** index is calculated on the base of sounding data, when it is available (day and night time release) and extrapolated in between on the base of ground level wind speed. It is no need to explain that the horizontal wind is the main factor for pollution dispersion. But as soon we assume that pollution are accumulated within of mixing layer, thus the average wind is calculated just within the mixing layer. To simplify the calculations in (1), the next table of correspondence for **V** was accepted.

Index	Value of correspondence [m/c]
3	1-3
4	4
5	5
6	6
7	7
8	8
9	9
10	10

Tab.2. Correspondence of V to calculated average wind speed within the mixing layer.

c) **S** index corresponds to the general synoptic situation, which is responsible for the long-term development of the situation. In contrast to the two previous factors, this synoptic factor is not so obvious. For that reason we have used, (for the purpose of current article) the indexes, which are ordinary used for determination of the definite synoptic situation. The table of these index is presented below. It can be seen that in general the increase of **S** index is corresponding to the increase of the total rapidity of the synoptic process:

Index	Synoptic Situation
3	Anti cyclone center with duration more then 36 hours
4	Warm front
5	Expanded field of high pressure
6	Peripheral part of anti cyclone
7	Central part of slowly moved cyclone
8	Back side of cyclone
9	Peripheral part of slowly moving anti cyclone
10	Well developed cyclone or fast air mass change

Tab .3. Correspondence of the S index to the current synoptic situation.

For the first approach it was decided to use all unknown coefficients in (1) equal to 1 with positive sign. The point is that: as increase of the mixing height H, as increase of the average wind V, as fast synoptic processes S are working in the same direction to eliminate the pollution accumulation.

Experimental testing of the linear model.

The experimental testing of the model described above was carried out on the base of 4 days observations during Summer 2005, when the synoptic situation was changed. Night inversions were observed, but the pollution accumulation was different from day to day. Synoptic situation for all the period can be characterized as the expanded field with the high pressure with warm front peripheral periodically.

The every day index estimates including the fact measurement of the pollution accumulation (PAF) are presented at the Tab.4.

Parameter	Part of day	13 July 2005	14 July 2005	15 July 2005	16 July 2005
H	day	8	8	7	7
	night	8	3	3	3
V	day	3	4	3	3
	night	7	3	3	3
S	day	6	3	4	4
	night	5	5	5	5
PA	day	17	15	14	14
	night	20	11	11	11
PAF	day	0,23	0,4	0,38	0,3
	night	0,22	0,33	0,32	0,3
Prognostic group	day	Low	High	High	High
	night	Low	High	High	High

Tab.4. Every day PA index estimate for 4 consequent observational days

The analysis of the above cases permits us to construct the preliminary table of classification for forecast groups, which are composed with three forecasting situation: accumulation of the pollution, short time accumulation of the pollution, dispersion of the pollution. The tab.5 presents numerical correspondence of PA index and the real measured index of pollution accumulation PAF. As it was expected the maximum value of PAF is corresponded to the minimum value of PA because, as it was discussed above, the maximum values of the model components corresponds to the situation with the pollution dispersion.

Prognostic group	Expected pollution	PAF	PA			Meteorological conditions
			day	night	24 hours	
1	High	>0.30	9-16	9-13	9-15	Accumulation
2	Increased	0.21-0.30	17-20	14-16	16-18	Sort time accumulation
3	Low	<=0.20	21-30	17-30	19-30	Dispersion

Tab.5 Forecast group classification.

Conclusion

Even with the simple linear model it was shown that there is direct dependence between PA index, which is calculated on the base of MTP-5 data and real accumulation of the pollution. It is necessary to emphasize that the inversions were existing during nighttime along all the dates under analysis. However the real pollution accumulation was sufficiently different at all these days.

The second remark, which use to be made is in the fact that we have used a,b,c coefficients equal to 1. But as can be seen in the Tab.5, the value of PA index can be intersected in some day/night situation. For this reason, the prognostic criteria seem to be oblate. We think that the processing of the wide data base with MTP-5 and synoptic data will allow to vary a,b,c coefficients to construct more adequate model.

Acknowledgment

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References

Ivanov A., Kadygrov E. (1994) The method and technique for remote measurements of boundary layer temperature profile. WMO Report N 57. Instruments and Observing Methods. WMO/TD N 588, Geneva, 407-412

Westwater E.R., Han Y., Irisov V.G., Leuskiy V., Kadygrov E.N., Viazankin A.S. (1999) Remote sensing of boundary layer temperature profiles by a scanning 5-mm microwave radiometer and RASS: Comparison Experiments. Journal of Atmosp., and Ocean. Techn., vol. 16, 805-818