EXPERIMENTAL STUDY OF RAIN-INDUCED ACCURACY LIMITS FOR MICROWAVE REMOTE TEMPERATURE PROFILING.

Arkady Koldaev*, Evgeny Miller , Arkady Troitsky*** ,**
Sergey Sarichev*

*Scientific Production Association "Typhoon", Russia
** Central Aerological Observatory, Russia
*** Scientific Research Radiophysics Institute, Russia

ABSTRACT

Wide implementations of the microwave remote sensing technique into the routine net observations, makes it actual to defined clearly the real accuracy limitations of that measurements induced by the different natural factors. For instance it is well known that rain precipitation influence very much on microwave measurements of the temperature profiles, in the atmosphere boundary layer. Nevertheless the numerical estimates of such interference, based on the experimental data, are still or not available or not so reliable. Due to these, we have conducted the field tests during the summer season 2009 and the results going to be presented in the current report.

1. DESCRIPTION OF THE EXPERIMENT

The experiment was carried out on the base of Obninsk World Meteorological Centre. And as a special, we have used their 300m meteorological tower. The tower was used as a reference for temperature measurements because it is equipped with certified and officially approved temperature sensors. The sensors were installed with the height step equal to 50m. For remote temperature profiling we have used microwave temperature profiler MTP-5HE ("ATTEX", Russia) [1], which provides temperature profile retrieval with the same 50m height step. The remote sensing instrument has been installed at about 700m east from the meteorological tower. The direction for scanning beam of MTP-5HE was pointed to the tower. The information about rain precipitation along the path between remote sensing instrument site and the tower were provided by 3 micro-radar rain sensors DROP ("Aqua Nubis", Russia) [2]. One rain sensor was installed near the tower, second at remote sensing site and the third in the middle. The general view of the remote sensing site (on the roof of the 7 floor building) is presented at the Fig. 1

Figure 1 *The photo of the equipment installed on the roof of the building 700 m apart from the tower.*

The map of the space distribution of the different type of the instruments is presented on the Fig. 2

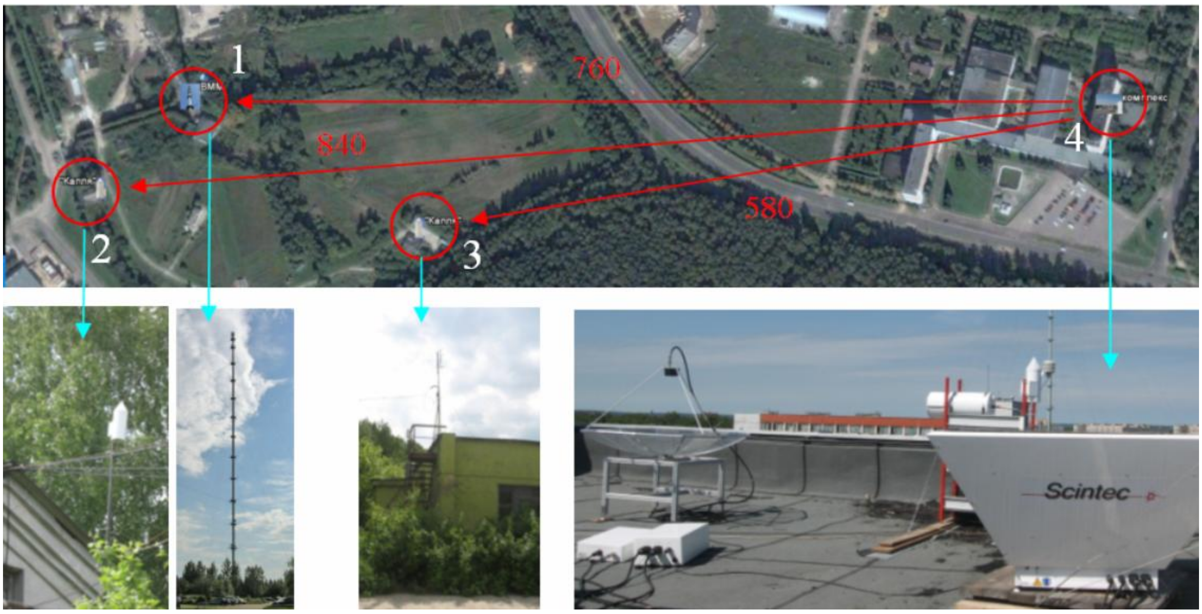

Figure 2 *The map of the space distribution of the equipment.*

Such type of the location of the equipments during experiments allows us to get not only data about intensity and quantity of precipitations (Figure 3) but we have got the data about spatial distribution of the rain as a function of the time (Figure 4). This spatial distribution of the parameters of liquid precipitation plays the key role in the better understanding of the physical mechanism of distortion of the data by the complex scattering effects of the microwave radiation in rain. The investigation of the spatial distribution of the rain should allow us to get dependences between brightness temperatures dynamics and temperature heterogeneous on the path.

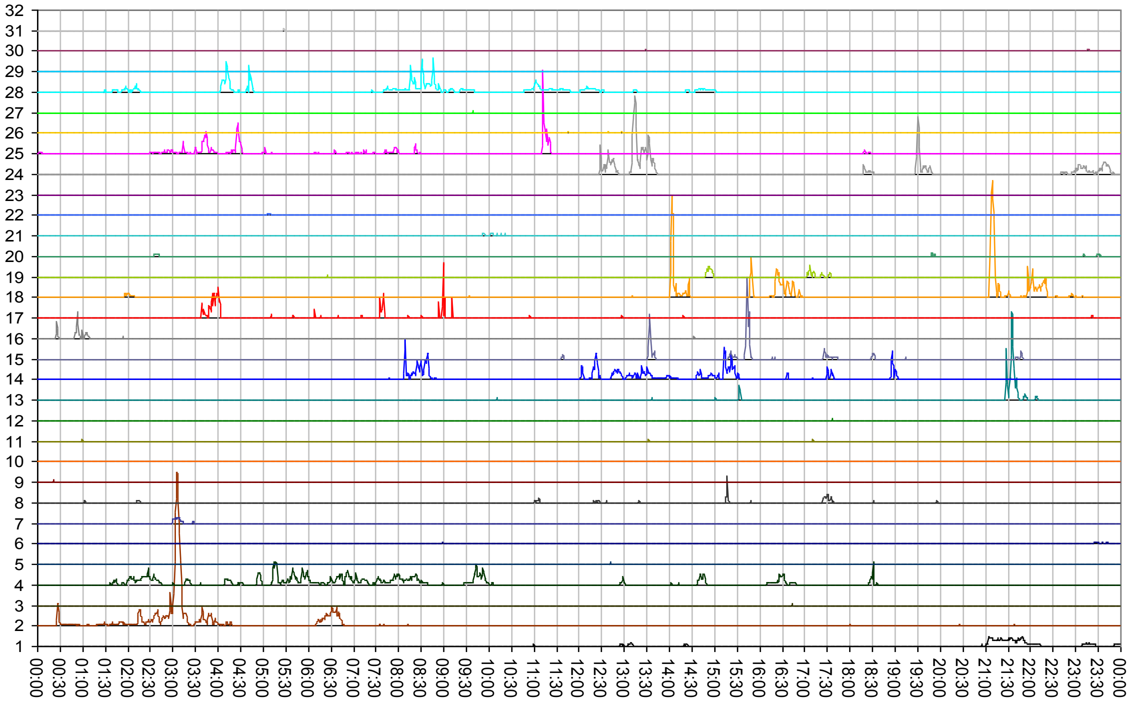

Figure 3 *Example of the precipitation during August period for each day from 1 up to 31. The intensity of each rain is shown in comparative scale.*

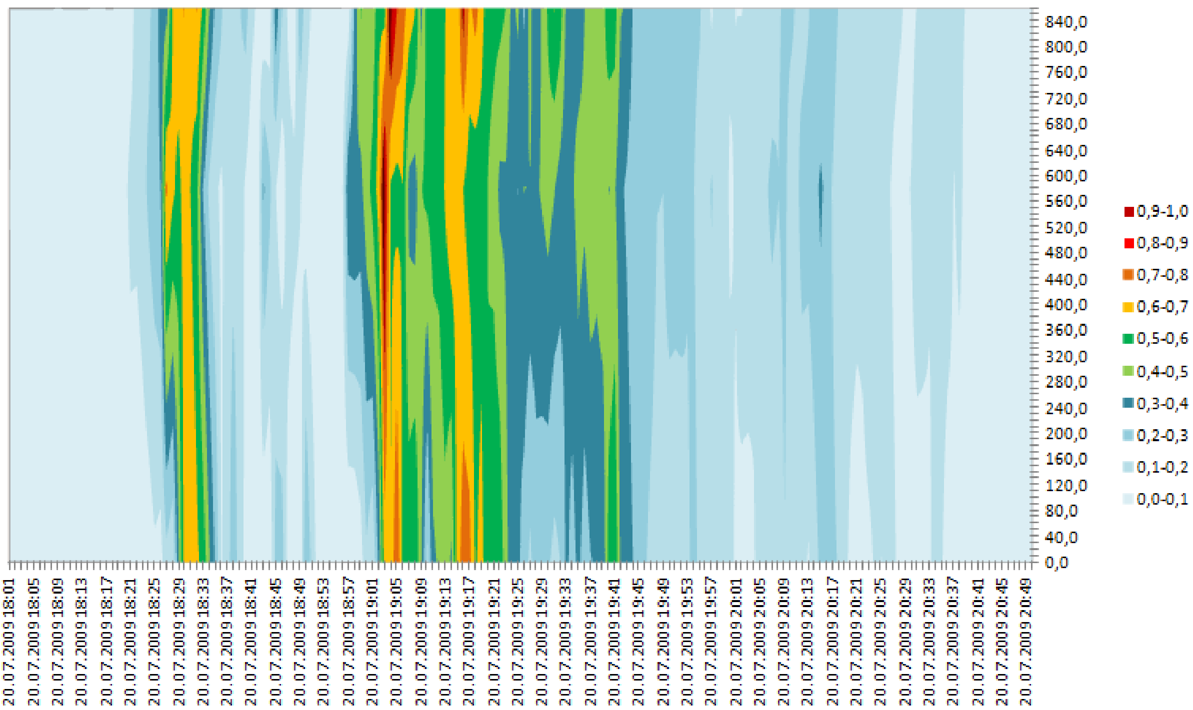

Figure 4 *Spatial distribution of the rain as function of the time (20 August 2009).*

2. THE DATA PROCESSING PROCEDURES

On the figure 5 are shown the examples of comparison for adiabatic profile and during temperature inversion.

All the data after quality control has been calculated as hour-average profiles and interpolated in same heights for comparison procedures.

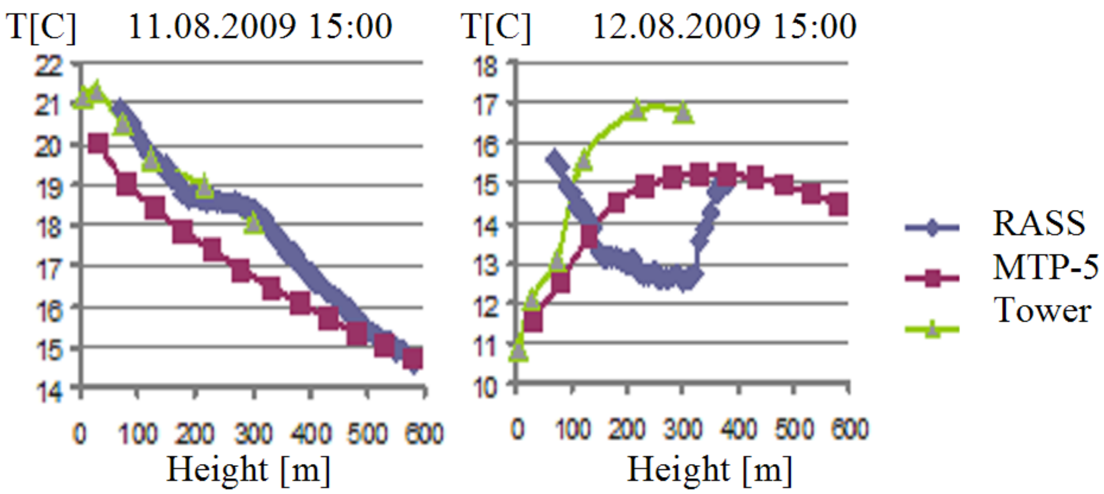

Figure 5*The examples of comparison for adiabatic profile and when temperature inversion was.*

To compare temperatures measured by profiler, tower and RASS were calculated the next parameters:

Deviation dTt(h)

$$dT^t(h) = T^t_5(h)-T^t_{tower}(h), \qquad (1)$$

where h=0, 48, 96, 192, 276м, $T^t{}_5(h)$-temperature, measured by MTP-5 (or RASS data), $T^t{}_{tower}(h)$-tower data.

Mean deviation for height h - dAv(h)

$$dAv(h)= \frac{1}{N_p}\sum_t dT^t(h), \qquad (2)$$

where Np = count of the averages profiles.

Mean total deviation

$$dA_{vmean}= \frac{1}{N_p}\sum_h dAv(h), \qquad (3)$$

RMSD(h) – root mean square deviation for different h.

RMSD – root mean square deviation for all data

Table 2

	count of profiles	dA_{vmean}	RMSD
MTP-5-Tower	8463	-0.68	0.68
RASS-Tower	1247	0.26	1.45

3. RESULT OF COMPARISONS

The results of three month continuous measurements are presented in the report. The most dramatic situations, as it was expected in before, were connected with shower rain over the remote sensing site. But the events with heavy rain, which were observed just at tower site, could lead to about 2 K deviations between reference and remote temperature profiles.

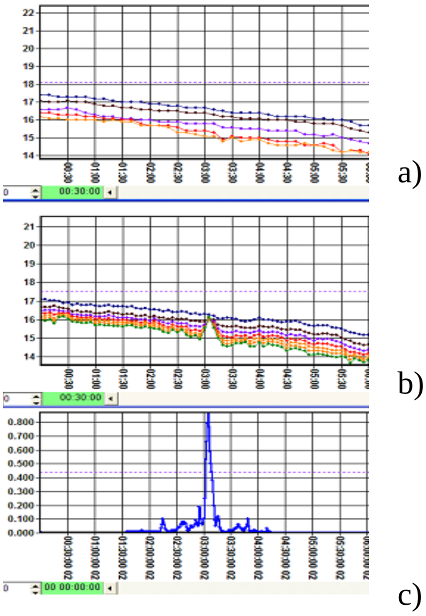

Figure 6. Synchronized time series of the temperature on different height levels as measured by the meteorological tower (a); temperature on different height levels as measured by MTP-5 (b); rain intensity as measured by rain sensor "DROP"(c) 2009/08/01

It was observed more then 50 rain events with intensity up to 80 mm/h. As usual intense rain was short in time (30-50 min) and drizzle could be lasting up to 8 hours. All the data can be sorted on a four different trends. These trends are specified by the absolutely different type of deviation of the retrieved temperature profile with respect to the data from meteorological tower.

The example of the first type is presented on the Fig. 6. In this case, the day cycle cooling temperature profile, that is smoothly observed by the "in-situ" sensors on the tower (see 6 "a"), can not be retrieved by the microwave radiometer (see 6 "b"). And the temperatures, which are obtained from microwave radiometer for all measured height layers are lifted to the hottest (lower in height) temperature layer. As it can be seen on 6 "c" the maximum of rain intensity corresponds in time to the maximum of such lifting.

This type is easiest for interpretation from the point of view of classical radiation transfer theory: rain, as a deep absorbing media for 5mm wavelength, just blocks "remote" abilities of the MTP-5, so all the radiation is received from the first height layer despite of the value of the scanning angle.

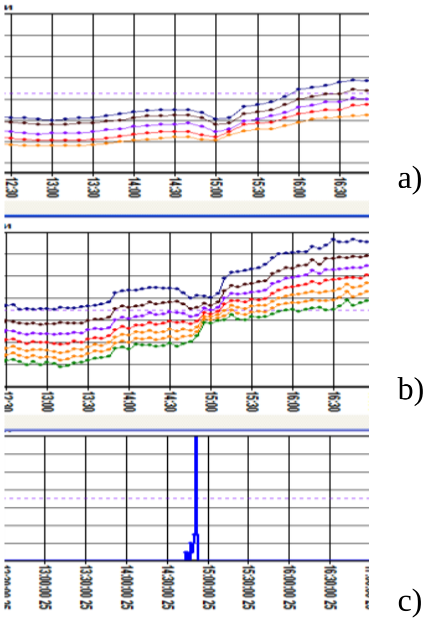

Figure 7. Synchronized time series of the temperature on different height levels as measured by the meteorological tower (a); temperature on different height levels as measured by MTP-5 (b); rain intensity as measured by rain sensor "DROP"(c) 2009/07/25

The example of the second type is presented on the Fig. 7. In this case, the day cycle warming temperature profile, that is smoothly observed by the "in-situ" sensors on the tower (see 7"a"), experience normal cooling at all height levels. This cooling is caused by very well known downdraft motion of the air mass produced by falling drops of the rain. But on the fig. 7"b" we can see that the temperature profile, retrieved by the microwave radiometer, has the trend to the isothermal profile. And this intention is maximized at the period of maximum rain intensity (see 7"c").

It is necessary to emphasize that such type of reaction of microwave remote sensing profiler is most common. Because it is demonstrated by different authors with the use of different microwave systems, it was decided that the boundary layer temperature profile has a tendencies to isothermal structure during the rain. Nevertheless our data demonstrates that the rain event is not enough for the isothermal stratification of the temperature profile. At this time, the reference tower profile remains adiabatic during rain, but parallel shifted by the cooling air mass. The explanation of this second trend is not so obvious and need to be explored in more detail.

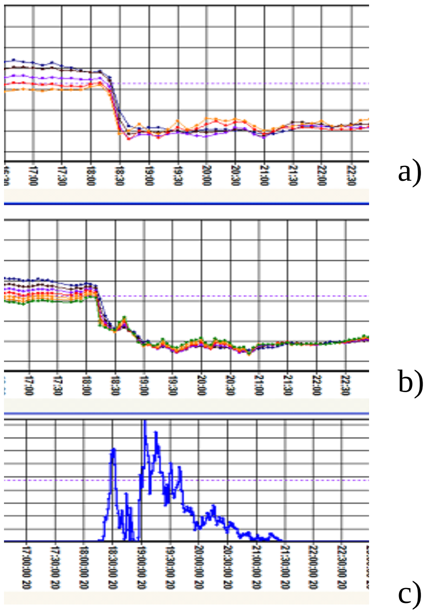

Figure 8. Synchronized time series of the temperature on different height levels as measured by the meteorological tower (a); temperature on different height levels as measured by MTP-5 (b); rain intensity as measured by rain sensor "DROP"(c) 2009/07/20

The example of the third type is presented on the Fig. 8. In this case, we can observe the intervention of the cold air mass produced by the cold atmospheric front. The evidence for such a suggestion is in sharp change of air temperature at all height levels (see 8"a"). It looks like that this weather conditions really creates the isothermal temperature profile in the boundary layer. So the microwave radiometer retrieval of isothermal temperature profile is just adequate to the real stratification (see 8"b").

This phenomenon is opposite to the first trend, because, as can be seen on fig.8"c", the intensity of the rain over 10mm/h not influence on the data of remote sensing at all - the data still looks like "proper"! But this is just visible opposition and "proper" data are really close to the "in-situ" measured ones only because of layer of water on the radio transparent dome of the device.

If layer of water is more or less stable (and it is true due to the rain duration on Fig. 8"c"), thus the radiation received by MTP-5 from all scanning angle will be approximately the same and equal to the thermodynamic temperature of the air on the height of the device installation. Due to this, the retrieval process will give us isothermal profile with the mean temperature as it is near the ground. And because atmospheric process creates the isothermal temperature profile in reality, we have simply lucky case, when "artificial" profile corresponds to the real atmospheric one.

On Figure 9 are shown the example of time series with the rain (intensity less than 0.12 mm/min or 7.2 mm/h during about one hour) when there is no influences in comparison of the tower and profiler data. It means that just the fact of rain isn't enough to destroy the microwave remote measurement. But of course, it should lead to some limitations in accuracy of remote sensing. And, any way, the effect of rain has about the same period as the period of the rain (see Fig. 6-9).

In Table 3 are shown the summary statistical results of comparison for days with rain and without one. It is interesting to pay attention to the fact that RMSD is about 20% less during the rain with respect to the clear sky conditions.

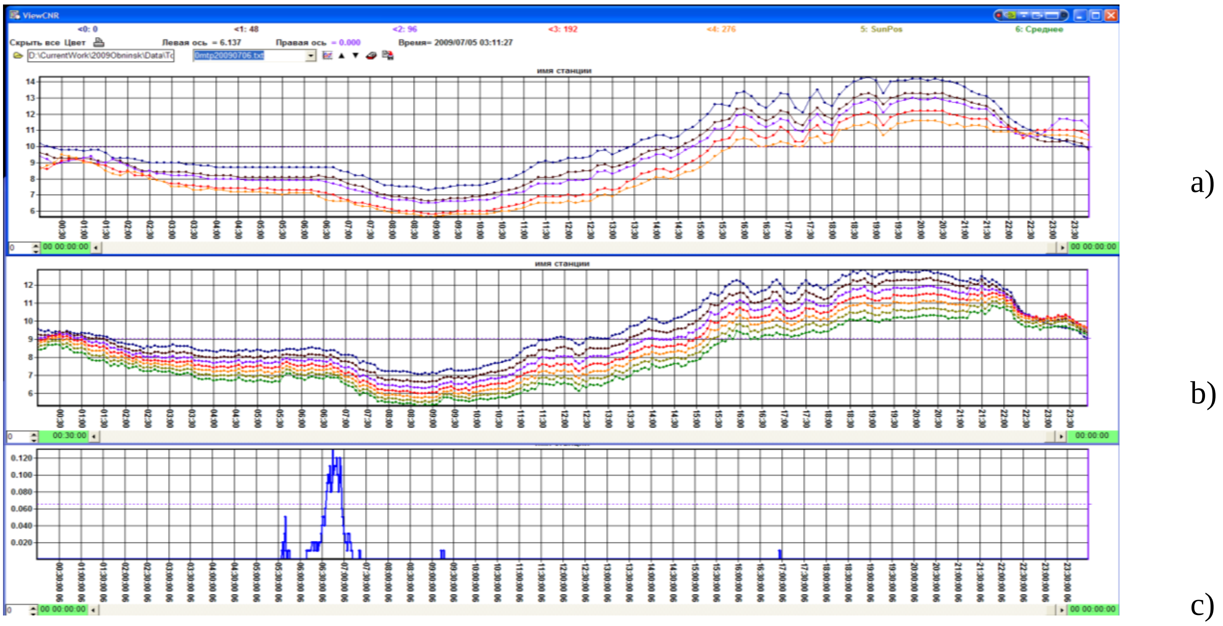

Figure 9. Synchronized time series of the temperature on different height levels as measured by the meteorological tower (a); temperature on different height levels as measured by MTP-5 (b); rain intensity as measured by rain sensor "DROP"(c) 2009/07/05

Table 3

	Number of days	dA_{vmean}	RMSD
MTP-5-Tower	61	-0.68	0.68
Rain	30	-0.22	0.57
without rain	31	-0.83	0.71

REFERENCES

[1] Troitsky A.V., Gaikovich K.P., Gromov V.D., Kadygrov E.N., and Kosov A.S., 1993. Thermal sounding of the atmospheric boundary layer in the oxygen band center at 60 GHz. *IEEE Trans. on Geoscience and Remote Sensing*, *v.* **31**, N 1, pp. 116-120

[2] Koldaev A.V., Gusev A.I., Konovalov D.A. 2006 The low cost microwave rain sensor: State certification and implementation on the observational network, *TECO-2006 - WMO Technical Conference on Meteorological and Environmental Instruments and Methods of Observation,Geneva, Switzerland,* **P1(13)**