Automatic weather station ArcticMeteo: first field test results

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Abstract. A technical description of an experimental sample of an automatic weather station (AWS), ArcticMeteo, designed to operate in remote and hard-to-reach areas under extreme climatic conditions is presented. The AWS provides measurements of some basic and specific meteorological parameters. Since the beginning of 2020, the AWS has been tested in real and critical conditions at the IMCES SB RAS meteorological site. Results of measurement of meteorological parameters during a storm in Tomsk on 26 May 2020 are given.

1. Introduction

Due to the intensive development of the Arctic region of the Russian Federation, including the development of navigation along the Northern Sea Route, the construction of new civil and military airfields, etc., it is necessary to organize hydrometeorological support for all types of economic activities based on the use of modern measuring instruments. To tackle scientific problems related to climate and environmental research in this region, it is necessary to obtain regular comprehensive information on the state of the environment. One of the sources of such information is automatic weather stations (AWSs). The currently available Russian AWSs consisting of domestically produced sensors can measure only a minimal set of meteorological values and are inferior in accuracy and reliability to foreign counterparts. The need to develop new technical solutions is due to the complexity of the use (or complete absence) of sensors that allow one to make automatic measurement of meteorological values and transfer of measured values without the participation of an observer. It is also necessary to ensure the autonomy and operability of measuring sensors in hard-to-reach areas with extreme climatic conditions for a long time (up to one year). Foreign commercial AWSs of Vaisala (Finland) MAWS201 and WXT520 and Campbell Scientific, Inc., (USA) METSENS 600 do not fully meet the requirements for operation in the Arctic region. In order to tackle the problem of import substitution, IMCES SB RAS has completed the development and manufacture of an experimental model of the AWS ArcticMeteo, which is designed to work in remote and hard-to-reach areas with difficult climatic conditions [1].

2. Experimental model of ArcticMeteo automatic weather station

IMCES SB RAS has completed the development and production of the ArcticMeteo automatic weather station (AWS) experimental sample intended to operate in remote and hard-to-reach areas
with extreme climatic conditions [1]. The expertise was gained during the design of the AMK-03 AWS [2] and its modifications for specific applications, and the AWS subsequent serial production by the LLC "Sibanalitpribor" [3] has been implemented.

The ArcticMeteo AWS provides measurements of meteorological quantities included in the main list of Roshydromet [4]: ambient temperature, wind speed, wind direction, relative humidity, atmospheric pressure, underlying surface temperature, and liquid precipitation amount. The measurements taken by the AWS also include meteorological quantities from an additional list [4], namely, snow depth, incoming solar radiation, and soil temperature profile.

The "ArcticMeteo AWS consists of measuring devices (sensors) and a set of basic and auxiliary peripheral equipment (Figure 1). The sensors for measuring the above-mentioned meteorological quantities are based on optical, acoustic, and electronic measurement techniques. The principal sensors are mounted on an M-82 mast 2 m and 10 m above ground level; auxiliary equipment and a rain gauge are placed at a distance from the mast.

The wind measuring unit, WMU, provides measurement of instantaneous, mean (time-averaged), maximum and minimum horizontal wind speed $V$ in the range from 0.1 to 60 m/s with an inaccuracy of $\pm(0.1 + 0.02V)$ at $V < 30$ m/s and not exceeding $\pm10\%$ at $V \geq 30$ m/s. The horizontal wind direction is registered in the range from 0 to 360 degrees (inaccuracy not exceeding $\pm4$ degrees) and the vertical wind speed is measured up to 15 m/s (inaccuracy less than 10%). Measurements are carried out based on an acoustic method [2].

The same method is used to define time-averaged, maximum and minimum air temperatures $T$ ranging from $-60$ to $+55$ °C with an inaccuracy of $\pm 0.5$ °C by the ATMU unit.

The HPMU unit uses electronic sensors to measure time-averaged, maximum and minimum values of relative humidity in the range from 15 to 100 % with an inaccuracy of $\pm 2.5$ and $\pm 5\%$ at $T \geq 0$ °C and $T < 0$ °C, respectively. Atmospheric pressure measurement is performed in the range from 520 to 800 mmHg with an inaccuracy of $\pm 0.5$ mmHg.

A non-contact radiation method is utilized for measuring instantaneous and time-averaged, maximum and minimum values of the underlying surface temperature from $-60$ to $+55$ °C (inaccuracy of $\pm 1$ °C) using the USTMU unit.

The PMU unit is based on the principle of obtaining and analyzing shaded drop images. The unit provides measurement of the daily amount of liquid precipitation ($Q_d$) in the range from 0 to 500 mm
with an inaccuracy of $\pm (0.1 + 0.2 Q_d)$ mm; in addition, measurements of liquid precipitation intensity, start time, and rainfall duration are possible.

On the basis of the acoustic location method, the SHMU unit is designed to measure snow depth from 2 to 100 cm with an inaccuracy of $\pm 2$ cm at a snow depth of less than or equal to 20 cm and $\pm 10\%$ at a snow depth of more than 20 cm.

Using the differential method of registration of electromagnetic radiation, the SRIMU unit determines the total incoming solar radiation in the range from 0.1 to 1.60 kW/m$^2$ with an inaccuracy of $\pm 11\%$.

To measure soil temperatures at depths from 10 to 100 cm with an interval of 10 cm, the STPMU unit is equipped with a series of contact temperature sensors and measures temperatures in the range from $-50$ to $+55$ °C with an inaccuracy of $\pm 0.7$ °C.

The main functions of the DAATS are acquisition, processing, and transmission to an external server of data collected from meteorological measurement units and service systems: the system of combined power supply, SPS; the check system of functioning ATMU and WMU units, FCS; and the automatic calibration system of the ATMU and WMU units, SAC. Data transmission to the external server is carried out via the cable channel, the cellular and satellite communication channel performing in automatic mode with a period set by the user or in the "by user request" mode.

The SPS is required to ensure the AWS work in remote areas in the absence of stationary power supply systems. The system of combined power supply contains the following power supply sources: batteries with a total capacity of 900 Ah (6150 Ah), a photoelectric station on the basis of a solar panel with a capacity of up to 1.5 kW, a wind turbine with a capacity of up to 1 kW, and a fuel cell generator (methanol as a raw material). The battery capacity is designed to ensure automatic continuous monitoring by the AWS in the maximum consumption mode for two days without the recharging possibility.

3. Experimental results
Since 2020 the AWS has been installed at the IMCES SB RAS meteorological site, where in-situ testing is carried out under real and extreme weather conditions. The AWS successfully withstood the tests under storm conditions observed on May 26, 2020 in Tomsk. On that day, according to the criteria described in [5, 6], the hazardous phenomena "Very strong wind" (wind speed at gusts of at least 25 m/s or an average speed of at least 20 m/s) and "Large hail" (hailstone with a diameter of 20 mm and more) were registered.

As seen in Figure 2, during the storm a maximum wind gust of 24.9 m/s was recorded, and the maximum precipitation intensity observed at the same time as the largest wind gusts reached about 100 mm/h. The total daily amount of precipitation was 24.5 mm.

The day under consideration was characterized by intense thunderstorm activity. According to Figure 3 made by using data from the World Lightning Destination Network WWLLN [7], 248 lightning discharges in the near zone were observed. This zone is limited to a 16-km radius from the ArcticMeteo AWS installation point corresponding to visual observations of thunderstorms at the weather stations [8]. The maximum intensity (14 discharges/min) was noted at the same time as the strongest wind gusts and the maximum precipitation intensity.

For a seven-month period of full-scale tests (from February to August 2020), the operability of all measuring units and service systems of the AWS have been checked. The design documentation was corrected and the material part of the AWS in whose work failures were found was revised. The configuration of the AMS construction has also been changed in order to increase its vandal resistance, in particular, against polar bears.
Figure 2. Measuring results of basic meteorological quantities by the ArcticMeteo AWS on May 26, 2020 (the abscissa shows the local time in hours).
Figure 3. Changes in the thunderstorm intensity ($I_{th}$, discharges/min) in the near zone of the ArcticMeteo AWS installation point.

4. Conclusions
The developed AMS ArcticMeteo provides measurement of some meteorological parameters which are included in a list of major elements according to a classification of Roshydromet: air temperature, three-component wind vector, relative air humidity, atmospheric pressure, underlying surface temperature, and liquid atmospheric precipitation, and a number of meteorological parameters from an additional list: snow depth, incoming solar radiation, and soil temperature. The AWS is equipped with a combined power supply system which ensures a long period of autonomous operation. The thus received meteorological information can be transmitted to a remote server via satellite and GPRS communication channels. External clients can receive information from the server database in graphical or tabular form for any period of interest (day, week, month, etc.).

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