System of automated weather stations to collect and transmit environmental parameters

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Abstract. Results of the development and application of a weather registration system presented in the article. Concept of creating of distributed automated LoraWAN network of weather sensors to monitor climate parameters in real time is described. The time dependences of temperature, pressure and humidity in the southern part of the Tomsk city (Russia) for the period April-May 2019 are shown. The rate of change of temperature, pressure and air humidity on the night of April 18–19, 2019 was calculated. The possibilities of weather prediction based on meteorological data were estimated.

1. Introduction
Climate change has become a huge problem that all of humanity has faced. The most dangerous consequences are permafrost and ice caps melting, heavy winds and showers, desertification of the earth’s surface, etc. Severe hurricanes and forest fires have affected millions of people and caused them great damage over the past few years [1–4]. Farmers are one of those specialists who have to adapt their agricultural strategy to a new challenge. So, they need to regulate and control all stages of agricultural work tracking data about pressure, temperature, humidity, etc. from fields and lands [5].

This kind of data collects from remote and inaccessible areas, for another application area – from industrial work sites and environmentally hazardous areas to monitor changes and predict the consequences. It should be noted that the accuracy of the measurements obtained is not as important as the dynamics of changes in individual environmental parameters over large areas. Often cost plays a crucial role because hundreds of such sensors are locating in a large area and the problem of vandalism should also be taken into account. In recent years, there is publication activity in the development of a variety of meteorological complexes. However, most of them require a communication channel directly on the Internet, which is often difficult in the countryside. The presented developments of inexpensive meteorological complexes mainly require uninterrupted power supply and the presence of a router in the coverage area [6–11]. One way to organize a distributed network of weather sensors without direct access to the Internet is using a radio channel with the “LoRaWAN” protocol [12].

Unfortunately, digital farming that develop all around the world is not so widespread in Russia. But, National Research Tomsk State University (TSU) design this kind of systems helping local farmers and other consumers to control and predict climatic conditions. The very first step of this work was using of sensors in the greenhouse of the botanical garden of TSU [13]. It has a huge variety of
climatic conditions. Each climate requires quality control of temperature and humidity of the surrounding air, as well as temperature and soil moisture. Placing such system of sensors in the greenhouse allows to control the climate and quickly identifying malfunctions in the climate equipment. Another example of system application is the research station of the TSU in Kaybasovo [3], where the biotic cycle of carbon and its associated elements is studied, the migration of water-soluble substances from catchment ecosystems to water bodies. In all the cases described, it is required to control a set of environmental parameters, among which the temperature, pressure and humidity are basic.

This article discusses the possibility of using automated weather sensors in a distributed network based on LoraWAN protocol to control atmospheric pressure, temperature and humidity.

2. Automated climate data collection

Concept of “USKD-365P” system was developed to solve the task of collecting and transmitting weather data (Figure 1). The system is capable of providing autonomous collection, recording and transmission of climate data every hour [13].

![Figure 1. Block diagram of “USKD-365P” system](image)

The system provides data backup to a SD card in case of communication failure with the server. The power system, which is based on a lithium-ion battery, is completely autonomous. Recharge the battery is through the charge controller in the daytime. To ensure the collection of accurate, reliable and timely data, the “USKD-365P” system is equipped with microelectronic precision sensors. The first BMP280 sensor is a piezo-resistive atmospheric pressure sensor integrated into the microchip with dimensions 2.0x2.5x0.95 mm. This sensor is able to measure atmospheric pressure 300 ... 1100 hPa in the temperature range -40 ... + 85 °С with accuracy ± 0.12 hPa (at t = 25 °C) [4]. Sensor HTU21 manufactured provides the measurement of relative humidity (0 – 100%) and temperature (-40 ... +125 °C) in the “USKD-365P” system. Recalculation of relative humidity (RH) and temperature (T) of air from the measured signal (Sm) of the sensor is carried out according to equations 1 and 2, respectively:

\[
RH = -6 + 125 \frac{S_m}{2^{16}} \tag{1}
\]

\[
T = -46.85 + 175.72 \frac{S_m}{2^{16}} \tag{2}
\]

The calculation of the air dew point temperature is based on measurements of relative humidity and temperature through the partial pressure (PP) of the environment according to equations 3 – 4:

\[
PP = 10^{\left(\frac{176239}{T+23566}\right) - 8.1332} \tag{3}
\]
The accuracy of temperature measurement is ± 0.3 °C (at t = 25 °C), the accuracy of measuring relative humidity is ± 2% relative humidity (at t = 25 °C and relative humidity 20% – 80%). All air parameters sensors and real time clock chip DS3231 communicate with the microcontroller via protocol “I2C”, SD card and transmission module – via serial peripheral interface (SPI). As microcontroller an ATmega 328 chip is used. Data transmission to the receiver within a radius of 5 km occurs over the air via the LoRaWAN protocol in the frequency range from 862 to 893 MHz. Then, the data is transmitted to the server via the Internet. “USKD-365P” system is registered using the ABP (Activation By Personalization) method. The method consists in the fact that each device is assigned a unique address (DevAddr) and given two keys (NwkSKey and AppSKey). In turn, the server is informed about the device address and keys so that it can receive messages.

3. System testing
The “USKD-365P” system was tested for 21 days in the city of Tomsk (56°27'5.76 "north latitude; 84°58'19.42" west longitude) in conditions of low temperatures, rain, snow and complete glaciation. The goal was testing the autonomy and ability of the weather station to withstand the Siberian climate. In Figures 2, 3 shows the dynamics of pressure and relative humidity change. According to this Figure we can say that glaciation occurred on the night of April 19, 2019, because pressure dropped sharply.

Figures 4, 5 show the calculated increments of pressure, humidity and temperature for the local time interval from April 17 to 19, 2019.

\[
T_d = -\left(\frac{1762.39}{\log_{10}(RH \cdot \frac{PP}{100})} + 235.66\right)
\]

Figure 2. Measured time dependence of atmospheric pressure in the southern part of the Tomsk city during the period from April 16 to May 7 2019

Figure 3. Measured time dependence of relative humidity in the southern part of the Tomsk city during the period from April 16 to May 7 2019
Results and discussion
As a result, a weather station for autonomously collecting and transmitting climate data that can operate in severe environment was developed.

Analyzing the correlation between atmospheric pressure and relative humidity of the environment (Figure 3), we can see that on the night from 04/18/2019 to 04/19/2019 there is a sharp decrease in atmospheric pressure (by 17 mm Hg). In the same period (Figure 4), relative air humidity rose from 50% to 100%, which indicates precipitation. The nature of precipitation can be judged by temperature readings for the specified period. It can be seen that the temperature drops below 0 °C, which corresponds to snow. Using this system, it was possible to predict precipitation in the evening of April 18, 2019 with a probability of 90%.

Placement of these sensors allows to create dynamic model of climatic parameters in short and long-term perspective for any territory size. These digital dynamic models based on obtained data are helpful for climate change prediction.

Such sensors will make it possible to comprehensively monitor climatic parameters in key areas of the planet, revealing the smallest climate changes at an early stage. The developed system can be applied for digitalization of agriculture in agricultural holdings. It is proposed to place a network of such sensors in the fields and monitor the agroclimatic parameters of the environment.
Thereby, using the described device it is possible to assess the probability of changing weather conditions and, accordingly, minimize damage. For example, to minimize the impact of adverse weather conditions on expensive scientific equipment. The alarm system is implemented by evaluating the rate of change of climatic parameters, for instance, in case of precipitation the pressure derivative must be negative and the humidity positive.

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