Distributed intelligent measuring and information system for monitoring coastal environmental parameters

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Abstract. The article presents the results of the study of ways to create distributed measuring networks to control the parameters of the surrounding coastal marine environment and atmosphere. The device, the principle of operation and the measuring capabilities of the meteorological station and the measuring buoy are considered. An example of an intelligent hydrometeorological adaptive system for controlling the parameters of the coastal water area is presented.

1. Introduction
Due to the ubiquity of wireless networks, the development of machine-to-machine interaction technologies, and the growth of computing power, there is now a widespread use of automated information and monitoring systems in the maritime industry [1]. In coastal areas of the sea, where field variability has completely different spatial and temporal scales, the characteristics of the observational system should correspond to the specifics of marine dynamics. At present, operational contact observations in the coastal areas of the seas are very limited, and satellite methods for reconstructing hydrometeorological characteristics are focused mainly on the conditions of the open ocean and do not ensure the efficiency of observations [2].

The use of well-established algorithms for recovering parameters in relation to shelf zones and inland seas where, in addition to short wind accelerations, coastal currents and various dynamic processes, distortions can be introduced by complex bottom topography and coastal orography is more inappropriate. At the regional level, the problem of the “last mile” remains unresolved, connected with the provision of customer-oriented information about the state of coastal sea zones, weather and environmental conditions to local consumers. As an example of consumers of this type, one can name the population living in coastal territories, local authorities and administrations, municipalities, subjects of the resort and recreational business. This problem is mainly due to the lack of reliable information directly in the areas of interest of consumers, for example, in places of swimming and recreation, in potentially hazardous areas of storm and sewage discharge, coastal shipping routes, etc.

Prompt acquisition of data on the values of surface and subsurface temperatures makes it possible to control the development of such a phenomenon as upwelling, when, under the influence of a wind surge, or other reasons, the surface heated layer of water is “pulled” into the open sea and cold subsurface waters emerge to the surface. The release of cold water with a temperature of 5-10 degrees below normal can occur in a very short time. Therefore, it is important to warn people with problems with the cardiovascular system or prone to colds about the development of upwelling in a timely manner.
An increase in water turbidity occurs due to rainwater runoffs or storm sewers carrying silt and clay, or during a storm, when sand and silty sediments rise from the bottom. A very important feature of turbidity control is the timely detection of leaks in sewer pipes in order to perform urgent repairs.

Timely warning of the development of a storm is important information to warn about the danger of swimming. The developed waves together with coastal currents are extremely dangerous even for well-trained people, especially in areas with rocky relief. Therefore, information about the parameters of the sea can help prevent accidents on the water.

2. Measuring devices
Monitoring of hydrometeorological and environmental parameters of coastal waters is provided by a system of distributed measuring devices. A meteorological station is used to control meteorological parameters. It measures air temperature and humidity, atmospheric pressure, wind speed and direction and the amount of precipitation. To control hydrological parameters, a measuring buoy is used, which provides contact measurements of water temperature in the surface and subsurface layers of the sea, hydrostatic pressure, and turbidity of sea water. Wave parameters are calculated based on hydrostatic wave data.

2.1. Weather station
The meteorological station consists of a tripod mast with meteorological parameters sensors and a remote block (figure 1).

![Figure 1. Meteorological station.](image-url)

The mast is equipped with sensors for wind parameters, air temperature and humidity, and a rainfall sensor. The portable unit is a plastic cylindrical case, inside of which there are a GSM communication terminal, a GPS/GLONASS receiver, a controller with a non-volatile real-time system RTC, a module for measuring atmospheric pressure, and a power supply. Outside the case, there is a barometric port of the atmospheric pressure measurement channel, a switch tape, a weather station operation indicator LED and a sealed connector for connecting a connecting cable and external power supply. The cable provides power supply to the remote sensors of meteorological parameters and the exchange of data between them and the controller of the remote unit.

A cup anemometer with a Davis 6410 weather vane (Davis Instruments) is used as a wind parameter sensor. According to the sensor data, at each measurement interval with a duration of 10 minutes in the remote unit controller, the following are estimated: vector-averaged values of the wind speed and direction over the interval; the maximum value of the wind speed. Air temperature and humidity are measured with HDC1080DMBT sensors (Texas Instruments). The air temperature sensor is housed in a ventilated Davis 7714 (Davis Instruments) enclosure protected from solar radiation.
data of the temperature and humidity sensor, at each measurement interval of 10 min duration, the average values of air temperature and humidity are estimated in the controller of the external unit. The atmospheric pressure meter is made on the basis of a piezoresistive transducer type MS5534 (Intersema). The sensor of the meter communicates with the surrounding atmosphere through a barometric port located in the upper part of the body of the remote block. According to the data of the pressure sensor, the average value of atmospheric pressure is estimated at each measurement interval with a duration of 10 minutes in the controller of the remote unit. A Davis 7852.804 sensor (Davis Instruments) was used as a precipitation amount sensor. According to the sensor data in the main unit, the amount of precipitation is calculated for periods of 10 minutes, a day and a month.

Table 1 shows the ranges, errors and resolution of the measured parameters.

| Measured parameter          | Range         | Error | Permission |
|-----------------------------|---------------|-------|------------|
| Average wind speed, m/s     | from 0 to 50  | ±5%   | 0.1        |
| Maximum wind speed, m/s     |               |       |            |
| Wind direction, °           | from 0 to 360 | ±3    | 1          |
| Atmospheric pressure, hPa   | from 850 to 1055 | ±3 | 0.1        |
| Air temperature, °C         | from -40 to 60 | ±0.2  | 0.1        |
| Air humidity, %             | from 0 to 100  | 2%    | 0.1        |
| Precipitation, mm           | from 0 to 999  | 4%    | 0.2        |

2.2. Measuring buoy

The measuring buoy consists of surface buoyancy, a cable-rope line and a module for measuring hydrostatic pressure and subsurface water temperature (figure 2).

![Figure 2. Measuring buoy.](image)

Surface buoyancy is a polycarbonate sphere with a diameter of 380 mm, inside which there are a GSM cellular network modem, a GPS/GLONASS receiver, a controller with a non-volatile real-time system RTC, modules for measuring sea surface temperature, seawater transparency control and power supply voltage, a source power supply, reed switch. Outside the buoyancy, there are a switch tape, contacts for the sensor of the relative duration of the surface buoyancy in the submerged position, sensors for the temperature of the surface layer of the sea and transparency, a cable-cable line entry unit.

The cable-rope line is used for electrical and mechanical connection of surface buoyancy with a module for measuring hydrostatic pressure and temperature of subsurface water.

The module for measuring hydrostatic pressure and temperature of the subsurface water layer is made in a robust steel sealed case and consists of an interface, hydrostatic pressure and temperature sensors. In the lower part of the body there are elements for fastening to the bottom anchor.
The hydrostatic pressure meter is made on the basis of an integral digital piezoresistive transducer type MS5535C (Measurement Specialties). According to the results of measurements of the hydrostatic pressure sensor, the calculations of wave parameters are carried out for one measurement period: significant wave height, average wave height, average height of 10% of the largest waves, highest wave height, average wave period, average wave period of considerable height [3]. The water temperature in the surface and subsurface layers is measured using integrated digital thermometers DS18B20 (Dallas Semiconductor).

| Measured parameter                                              | Range                        | Error  | Permission |
|------------------------------------------------------------------|------------------------------|--------|------------|
| Water temperature in the surface and subsurface layers of the sea, °C | from 0 to 30                 | ±0.2   | 0.04       |
| Hydrostatic pressure, hPa                                        | from 0 to 2000               | ±10    | 1          |
| Turbidity of sea water, mg/dm³                                  | less than 6 mg/dm³           | 5      | 1          |
|                                                                  | ("transparent")             |        |            |
|                                                                  | from 6 to 30 mg/dm³          |        |            |
|                                                                  | ("medium turbidity")         |        |            |
|                                                                  | more than 30 mg/dm³          |        |            |
|                                                                  | ("turbid")                  |        |            |

Table 2. Parameters measured by the buoy.

3. Intelligent system for monitoring environmental parameters

The existing monitoring systems have limited possibilities for studying physical processes characterized by high dynamics of parameter variability over the interval from units to tens of minutes. This disadvantage can be eliminated by using a controlled measuring network to build an intelligent monitoring system with adaptive adjustment of the spatial and temporal resolution of measurements to the rate of variability of the values of the monitored parameters [4]. An example of such a network consisting of a measuring buoy and a meteorological station is shown in figure 3.

![Figure 3](image)

**Figure 3.** Block diagram of an intelligent measuring network.

The server, using two-way GSM telecommunication networks, receives the measured information, processes it and transmits it to users using the network Internet [5]. The server also sends commands to the measuring devices according to predefined rules. The administrator controls the operation and initial configuration of the network of measuring devices. Subsequent adjustment of the operation modes of the network elements is carried out automatically based on the analysis of measurement data by mathematical models and algorithms. Standard measurement periods: weather station - 10 min; measuring buoy - 1 hour.

To check the decisions made, the measuring buoy was installed in the water area of Martynova Bay in Sevastopol, and the meteorological station was installed on the roof of a building on the seashore not far from the buoy.
Table 3 shows the criteria for switching the measuring buoy to the critical measurement mode equal to 15 minutes [6]. The transition of the buoy to the critical measurement mode occurs when at least one of the presented conditions is met. The critical mode is turned off when all the conditions presented are not met.

**Table 3. Criteria for the transition to a measurement period of 15 minutes.**

| №  | Parameter                      | Data source     | Meaning | Gradient     | Mean     |
|----|-------------------------------|-----------------|---------|--------------|----------|
| 1  | Sea surface temperature       | Buoy            | -       | More - 1 °C/h | -        |
| 2  | Direction of the wind         | Weather station | W, NW, N (247 – 359°, 0- 22°) | -           | Average value over 2 hours |
| 3  | Wind speed                    | Weather station | more than 5 m/s | -           | -        |
| 4  | Significant wave height       | Payment         | more than 0.7 m | -           | -        |
| 5  | Precipitation                 | Weather station | more than 4 mm/h | -           | Average for 1 hour |

If necessary, it is possible to manually control the users of switching the measuring buoy to the critical mode. This allows for better measurements of the local rapid variability of environmental parameters and provides a significantly better quality of distributed monitoring of dynamic processes in the marine environment.

The developed system is scalable and allows connecting various types of measuring platforms to it.

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