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Article

Towards the Conceptional Design of Coastal Wave Database around the Sakhalin Island

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Abstract

The present article describes the observation system and the outline of recorded data of the field experiments carried out in the Sea of Okhotsk, mainly at the coast of the Sakhalin Island in 2016-2019. LMNAD (Laboratory of Modeling of Natural and Anthropogenic Disasters) conducted a series of field experiments and meteorological observations. The coastal wave data were obtained by the instrument system developed by the authors' group, taking account of the shallowly longshore. The article also mentions the unique instrumentation, stepwise developed autonomous wave recorder.

Every wave recorder's data was transmitted to the onshore center by electrical devices. Before too much data collected, the authors should think about the database, for instance, whether the database is of international format or of regional one, and necessity of a datacenter. In a decade to come, the database will remain a regional one. When the data grow up to a long-term dataset of coastal wave around the Sakhalin Island, the database would probably be extended to the internationally available data. The present article notes an initial stage of a conceptual design of a coastal wave database around the Sakhalin Island, for the moment, which was composed of the data of the field experiments carried out in the Sea of Okhotsk in 2016-2019.

Keywords: coastal zone, monitoring, wave characteristics, data collection, database

1. Introduction

Due to everlasting activities of the industries in survey and extraction of oil and gas in the shelf area around the Sakhalin Island, the necessity of reliable assessment of costs of the construction of the shore and offshore infrastructures arises. Together with it, the safety in their constructions and installations of the infrastructures has been more strictly and widely appreciated. The climate and oceanographical information in this area are vital for both.

The present paper describes the approaches to respond these demands with the use of software and hardware measures of observations, for instance, by a systematically developed autonomous mobile system equipped with a group of sensing devices. The paper also mentions the outline of the field experiments conducted in the vicinity of the Cape Svobodni in Mordvinova bay of the Island of Sakhalin, in 2016-2019, and the algorithms of processing of recorded data through the experiments. Currently, there are several methods of monitoring sea ice environment and wave climate in the coastal zone of the Sakhalin Island [Kurkin *et al.* 2017]. The observation of remote-sensing image of satellites is one of them. However, in this area, those data possess significantly lower resolution compared to aerial survey data in the field and are often poor under the conditions of dense cloud coverage and other adverse weather conditions.

Observations with the use of aircrafts and/or unmanned drones covering the whole target area would be another way, only if their easy operations be established on a financial and safety footing. The financial and personal supports, including AI producers, will absolutely be necessary for the microwave satellite system.

In this context, the platforms, that are, ground-vehicles patrolling along the water area to monitor sea ice conditions and wave climate were utilized during the field experiments in 2016-2017 [Kurkin *et al.* 2016–2017 (AMRK)].

Remote sensing methods, that are currently used, are the appropriate methods of coastal zone research. To transmit the senor data to the onshore center, transducers and/or wide-range lasers are utilized. A serious problem lies on the onshore center. The sizes of the onshore centers need usually about several square meters. The centers demand very high electric power and must be set up at high and stationary place.

It can be said that the centers are handicapped by their high-cost facilities.

Before too much date collected, the concept of the database must be discussed, and a conceptual design of the database should be initiated through considerations of easiness of dealing with and accessibility to the database, and trustworthiness. Current states of the database design are briefly noted.

2. Field experiments

Field experiments were performed at the shore of the Sea of Okhotsk in 2016-2019, applying various instruments, mostly the platforms which are unmanned ground-mobile multi-purpose units with the capability of transmitting many measurement data of wave climate in the coastal zone.

During the experiments performed in 2019, a system of telemetry and evaluation of wave and meteorological climate in the coastal zone was tested with the use of the autonomous measurements system, which was integrated into a unified information network. Marine-based radiolocation station (FURUNO FAR, RLS Mikran), meteorological station with the autonomous power source (VIOSALA) supported their consecutive work during the whole experiments and assisted well in the transmission of self-made blocks of the measured data by hydrodynamic pressure sensors in shallow water near the shore.

3. Observation system

The instrumentation was composed of an integrated autonomous unit. The software and algorithm were developed for the purpose of control, registration, and comparison of the data. The next chapter describes the outline of this system and the software for correlation of the data obtained from various devices with the use of the sensor-fusion technology, which is still under development.

As noted in Chapter 2, the radar station, Mikran "River" RLS (Mikran "Reka" RLS) was recognized as an effective element in the field work.

"Reka" «River» is a highly technological radio navigation system, particularly in river transport field, which can monitor and control a navigation situation at every moment. Based on the state-of-the-art broadband signal technology, digital solid state transmit/receive module ensures a highly accurate target detection and identification even of small-sized objects like people, sea ice floats, buoys, etc., in any weather conditions. With this exclusive technology, a radio navigation system REKA has been designed, manufactured, and tested in viewpoints of performance, reliability, and quality requirements, compatible with compass, echo sounder, GPS, AIS, etc.

The measurement system was composed of the following units.

a) Mikran "River" MRS-1000 radiolocation station. The operational frequency of RLS was 9500 MHz, wavelength 3 cm, and horizontal polarization. The range resolution was 3 m in the direction angle of 1°. Rotation speed of RLS was 24 rpm, and discrete period was 2.5 seconds.

b) Vaisala WXT520 meteorological station did the duty of measuring wind speed and direction, ambient air temperature, relative humidity, atmospheric pressure, and amount of precipitation.

c) GPS with a positioning system.

The measurement platform was equipped with the following devices

a) Self-made watertight case with a set of hydrodynamic pressure sensors; maximum measurement frequency was 13 kHz.

b) Submerged hydrodynamic pressure sensors with an anchor, installing RLS's field of view in the specified range from 30 to 60 degrees (to avoid the shadows from the buildings on the shore).

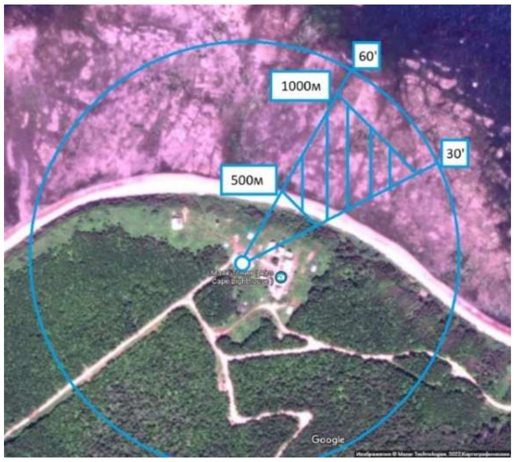

Fig. 1. Ray tracing scheme of the Mikran "River" RLS during the experiment conducted in Cape Svobodni in 2019

The cooperations of the multi-agents in the Sakhalin Island created the formation of radiolocation scan system in 2019. Brief scheme of RLS installation is shown in Figure 1.

RLS emitter covered the horizontal detection area from 30 to 60 degree and from 500 to 1000m from the emitter point.

Self-recording quartz pressure transducer APB-K14 was used to determine the water pressure at the point of observation. This device provides the sea level parameters, sea wave height, with a high resolution in real time, and transmits the data through the connected cable system. The transducer APB-K14 is equipped with quartz pressure and temperature transducers, as well as output for external device control. However, when such transducers are used in the field, their backgrounds should be reminded.

By the quartz transducer, pressure and temperature are converted into electrical signals, where quartz crystal will oscillate at a particular frequency when a driving signal is applied to the crystal. As physical properties of the crystal change, because of changes in temperature and pressure, the oscillation frequency changes. In quartz transducers, the oscillation frequency is measured and converted to electrical signals which vary as the pressure and temperature applied to the crystal varies. APB-K14 equips with an automatic checking unit.

While the transducer APB-K14 was installed in stationary mode on the bottom of the sea or fixed at a certain depth of water, the transducer provided the wave climate data during the whole period of the observation. The data were collected and extracted for the analysis of wave parameters.

For the present, both of remotely obtained data (Table 1) and on-site data (Table 2) of coastal waves were recorded and stored in a temporary data file. As clearly shown in Table 1, the remotely measurements contain a difficulty in carrying out calibrations of the recorded data.

Table 1. Equipment for remotely measurements

Measurement type	Equipment	Measurement items	Disadvantages
Ground-based sounding	Radio detecting and ranging equipment (RLS)	Wave height, speed and direction of flow, surface wind	Calibration of devices with the use of real data is required
	Lidar system	Pollution of water environment and the coast, wave breaking	Calibration of devices with the use of real data at the certain point of research is required Low range of operation (compared to RLS)
Aviation sounding	Radiolocation device	Speed and direction of flow, surface wind speed	Inability to conduct continuous long-term research in the chosen field. Calibration of devices with the use of real data is required
Satellite sounding	Altimeter	Ocean surface altitude, surface wind, wave height. Film contamination	Inability to conduct continuous long-term research in the chosen field. Calibration of devices with the use of real data is required
	Radiolocation synthesis of the aperture	Film contamination, surface wind, wave height.	

On the other hand, the in-situ measurements also have weaknesses. The area of measurements is limited (Table 2). Together with them, as most of the measurement devices require their power sources. The autonomous mobile measurement platforms will relatively be superior in operations of long-term wave climate research in the remote areas of the coast, even at hard-to-reach locations.

In-situ experiments, subaqueous pressure sensor was installed in the sensor system, for the necessity in correlation with the RLS operation and by comparison of the intensity of reflected signal with the right data of wave height in a certain point [Young *et al.*] Submerged hydrodynamic pressure sensor installed on the sea bottom with a weighting attachment was used to compare the intensity of the reflected signals with those of the real wave height.

Taking account of the development in hardware and software systems for observations and analyses of sea wave climate, the utilization of the autonomous mobile platforms will currently be relevant. This system is capable of evaluations of the wave climate of the remote areas in the coastal zone as mentioned above.

For the moment, an easy-handling data storage system is vital for the long-term coastal data, both of wave and meteorological ones, while the authors are giving thorough consideration to the final data format.

Table 2. Equipment of on-site measurements

Equipment	Measurements	Disadvantages
Floating beacon with an accelerometer	Statistical and spectral characteristics of waves, velocity and direction of the wind, velocity of the flow	Small area measurement Possibility of losing the device
Floating beacon with a hydrostatic pressure sensor		
Floating beacon with a hydrometric flowmeter		
Subaqueous pressure sensor	Wave height, flow velocity	Small area measurement There is no real-time data transfer in the autonomous systems. Possibility of losing the device
Acoustic pressure sensor	Wave height, flow velocity	Small area measurement There is no real-time data transfer in the autonomous systems. Possibility of losing the device
Capacitive wave gage	Wave height	Point measurement Construction fragility
Resistive wave gage		

The autonomous mobile platforms, equipped with sensor arrays, have a capability of performing panoramic observations of environmental phenomena in the coast, as well as in the flooded zones. The systems are appropriate for a long-term installation through being capable of recording uninterrupted data and the ability to cover the observation areas at several hundred meters away from the shoreline, which can pursue research in the coastal zone at any time and beyond the initial scope. However, it should be noted that the trustworthiness of the data received via the contact method of floating beacons, capacitance wave gages, and subaqueous pressure sensos depends on the natural conditions at the time of measurements [Rodin *et al.* 2016].

4. Data visualization

Self-made software (the development is in progress) can read the recorded dump files of the performed experiments and select separate snapshots of analyzed intensity as the results of RLS operation. The software is also capable of extracting the data package in the format in accordance with the following specification:

Specification:

The cartesian file data contains Cartesian coordinates and intensity. The columns are written in the following order: X coordinate, Y coordinate, I signal strength.

The polar file data contains the polar coordinates of the current segment together with signal strength. The columns are written in the following order: R vector (radius and the number of readings on the beam), angle Φ, I — signal intensity.

APB-K14, with its hardware and software, by using RLS calibration factors, provided the visualized data, as shown in Fig.2. The procedure of producing significant wave heights require the RLS calibration factors. The procedure does not much time for the processing.

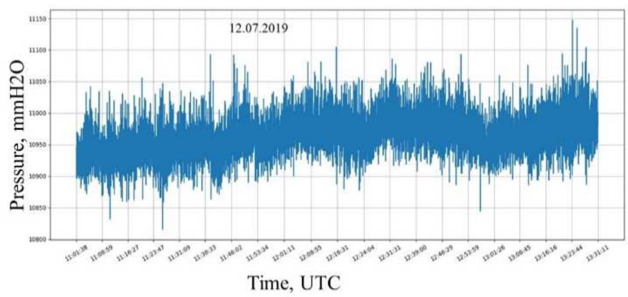

Fig. 2. Example of APB-K14 data visualization

The observation system was set up in stationary mode on the bottom of the sea or fixed in water layer and providing coastal data during the whole period of research. The coastal wave data parameters were extracted from the recorded data and analyzed.

Visuization procedure generates the dump file, about 6-10 GB in the present case. Juts for an example, Fig.3 shows visualized dump files of the Mikran RLS. Cape Svobodni case in 2019.

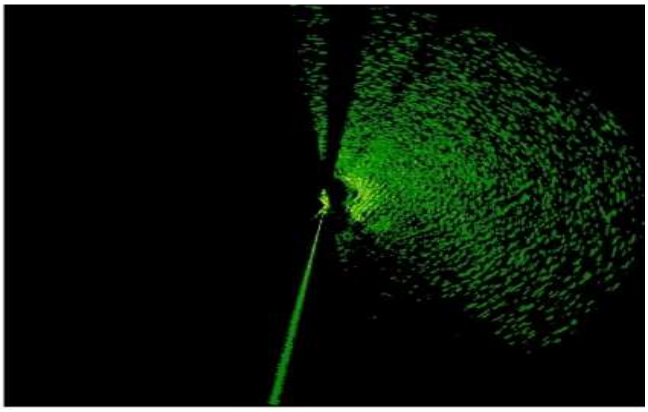

Fig. 3. Visualization of dump files recorded during the experiments of recording the Mikran “River” RLS. Cape Svobodni, 2019.

5. Conceptual design of the database

A database is indispensable through the visualization procedure of coastal wave, although it might simply be an easy-handling one.

We live in an age when the most of information are transmitted and exchanged each other in wireless systems. The coastal wave data around the Sakhalin Island obtained by bearing hardship should be accessible to any person’s and organization’s demands with relation of the other data.

A relational database has been used in a wide range of data and is rated it matured and reliable. Especially, a well-designed database will enjoy several benefits and strengthen it with other big database such as the World Ocean Database (WOD) that is world’s largest collection of uniformly formatted, quality controlled, publicly available ocean profile data. The authors find the prospect of the relational database. The relation with the WOD will raise up the authors’ database to the larger one, which will lead to apply the machine learning tool, and even deep learning in future. The deep learning would be able to improve the accuracy of satellite microwave sensing data.

The initial database composes of the materials for 2016-2017 on coastal wave climates.

6. Conclusion

The authors described the approaches to respond scientific and technological demands around the Sakhalin Island with the use of software and hardware measures of observations. In particular, the systematically developed autonomous mobile platforms equipped with sensor arrays worked well. The field experiments performed with those platforms were finished successfully in the vicinity of the Cape Svobodni in Mordvinova bay of the Island of Sakhalin, in 2016-2019. The authors confirm that the algorithms of processing of recorded data through the experiments operated well. A large amount of oceanographical and meteorological data were obtained and preserved in the storage files.

In the case of extremely high waves, stormy weather, and especially high and low tides, the platforms were found useful. Two normative modes, summer-mode, and winter- mode, are arranged for the platforms.

To respond rapidly advance in marine observation technology, further developments of instrumentation and algorithm have been planned. The first term will begin early in 2023.

The stored materials should be publicly available coastal marine profile data. World Ocean Database is good guide to establishment of the coastal Sakhalin Island database, as the WOD is one of the largest and trustworthy relational databases.

The authors has just stood at the starting point of composing the relational database of the coastal marine climates around the Sakhalin Island.

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