# Measurement technique and instrumentation for experimental studies in the ocean

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The main research fields of contemporary oceanology are reviewed. The efficiency of the research fleet of the Russian Academy of Sciences is analyzed, and some recommendations on its enhancement are given.

My wish to publish this paper in the journal *Atmospheric and Oceanic Optics* is caused by two reasons. First, I would like to take part in the issue dedicated to the 75th birthday of Academician Vladimir Evseevich Zuev, who founded the Institute of Atmospheric Optics and the Tomsk Scientific Center and initiated foundation of this journal. Second, current and especially future instrumentation for oceanological studies necessarily includes remote measurers of hydrophysical fields in the surface ocean layer, and the satellite communication channel with self-sufficient and drifting stations and stationary measuring systems changes principally the approach to experimental studies in ocean. In this connection, laser measuring systems and measurers of meteorological parameters developed at the Institute of Atmospheric Optics can certainly find use in new-generation of oceanological measuring systems. For this reason, this paper can be considered as invitation to discussion on oceanological instrument-making and, if possible, to co-operation in this field.

## Main research fields of contemporary oceanology

To avoid subjective formulation of the main research fields in contemporary oceanology, let us refer to the documents which give the publicly approved formulations of these fields.

The Federal Program "Global Ocean" is the document which tends to cover all the fields of contemporary oceanology, but it is still incomplete and cannot be considered in full measure as a guide. During recent three years the document describing the priority research fields of the Shirshov Institute of Oceanology was considered two times and now it is well developed. However, it is mostly directed toward financial support granted for these purposes, and so considers only current problems to be solved immediately.

In 1987 the representative group of USSR scientists from different institutions have developed the document "Forecasting of the opening up of the World Ocean up to 2000." This document contained thoroughly considered suggestions, which could lay in the base of a new program of the World Ocean survey. However, "perestroika" started, and works in this field were stopped. All the above listed documents certainly give sufficiently full description of the problems of contemporary oceanology and take into account the actual situation in our country. For this reason, I believe that it is impossible to express some criticism on them. However, the most well-formulated and most complete is, in my opinion, the State Research and Technical Program of Complex Studies of Arctic and Antarctic Seas and Oceans. Oceanology in our country was guided by this program during four decades, but it retains its urgency till now.

In one of the versions of this program, Leonid " rekhovskii formulated two main problems in studying the World Ocean, namely, creation of the thermodynamic model of the World Ocean and study of the ocean–atmosphere interaction with due regard of the continental influence.

Then the program received its further development and became more detailed. In its latest version it was oriented toward the following priority purposes:

– study of the part of ocean and polar areas in formation of weather anomalies and weather forecasts, as well as in determination of possible climatic changes on the globe;

– determination of the biological productivity of oceans and seas for fishery purposes and prediction of the state of marine resources, as well as development of biological principles of marine culture;

– investigation into the composition and structure of the Earth's crust and upper mantle under oceans and seas for the study of regularities in oil and gas formation, as well as in abundance of metallic and non-metallic mineral resources, and for exploration of mineral resources;

– evaluation and prediction of changes in ecological situation on Russian seas based on complex oceanographic studies, development of recommendations and prediction of social and economic development of seaside regions based on the methodology of complex management of coastal zones;

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– creation of efficient systems for monitoring of marine and polar processes, obtaining of characteristics of the World Ocean and Arctic regions and their parameters (including key processes that form extreme conditions), compilation of interactive databases and expert systems for informational support of the economic and legal activity associated with ocean and Arctic regions, and lowering the risk of human activity;

– study of parameters of the sea medium in the interest of the Russian Navy.

For achieving these goals, nine research fields were formulated and headed by leading scientists of our country.

Certainly, in spite of the above-listed programs, institutes of the Russian Academy of Sciences and other research institutions of our country took an active part in some global projects, in particular, in the "Polymode" International Project (by the initiative and under the leadership of G.I. Marchuk), the "Sections" Project, the "Mega-Polygon" Project (by the initiative of A.S. Monin). Such projects, which join the resources of the whole country and sometimes several countries, are certainly the main motto for the oceanologists.

" esides, while speaking about the research fields of contemporary oceanology, we should necessarily note the international research projects in this area:

– World Climate Research Program (WCRP),

– World Wide Weather (WWW) Program,

– Integrated Global Observing Strategy (IGOSS),

– International Oceanographic Data Exchange (IODE),

– Global Ocean Observing System (GOOS),

– Global Climate Observing System (GCOS).

Nevertheless, coming back to the beginning of the discussion, there is no escape from the conclusion that the State Research and Technical Program of Complex Studies of Arctic and Antarctic Seas and Oceans most completely covers all fields of current and future oceanology. For many years this program served the guide for many experimental researches in ocean conducted by various institutes in our country.

## Analysis of efficiency of research fleet of the Russian Academy of Sciences

The necessity of development of a new approach to organization of marine missions under current political and economic conditions requires the efficiency of the research fleet of RAS to be closely analyzed.

Archived materials on missions of research vessels since 1965 until now were analyzed, and the data on the number of research cruises and research staff involved in them were obtained.

Figure 1 shows these data for the period since 1965 until 1990, and Fig. 2 shows the same but for the period since 1990 until 1998. The comparative analysis of Figs. 1 and 2 shows that as the economic situation in our country changed (more precisely, was catastrophically aggravated), the number of research missions decreased by 10 times. At the same time, it should be noted that all the problems on studying oceans and inland seas (development and production of sea food and mineral resources, frontier guard and national defense, ecology, further development of climate studies and long-term weather forecasting, safe navigation, etc.) remain, and they should be solved regardless of changing political situation.

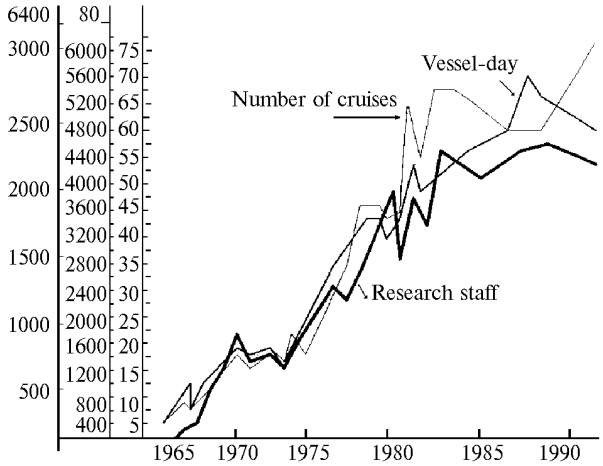


**Fig. 1.** Research missions into the oceans in 1965–1990.

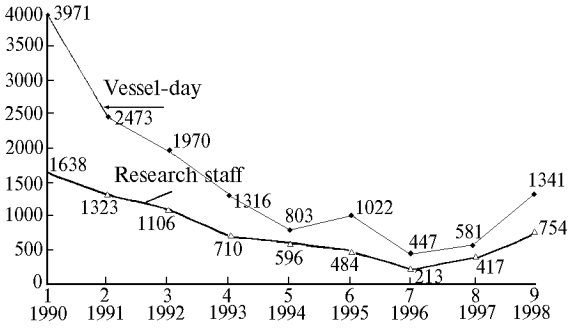


**Fig. 2.** Research mission into the oceans in 1990–1998.

Note that the period since early 60's until early 90's was a "golden era" of oceanology. However, the closer analysis of reports allows the conclusion to be drawn about inefficient planning of missions concerning not only the regions for research, but also the research goals as well.

Figure 3 shows the data on the number of missions conducted in different regions of the World Ocean. The plot shows a large number of marine missions in the equatorial zone (more than 83% of the total number of missions in the Atlantic, Pacific, and Indian oceans since 1965 until 1976).

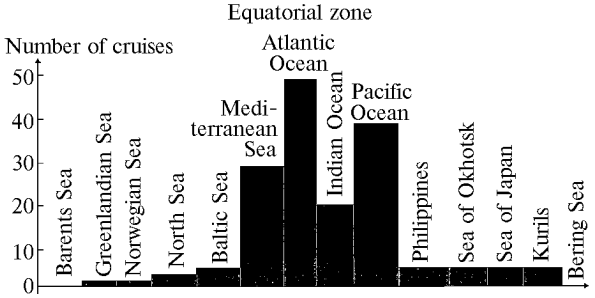


**Fig. 3.** Cruises of research vessels in different regions of the World Ocean since 1965 until 1976.

A large number of missions were conducted by initiative programs of individual scientists. Cruise programs usually listed programs and projects of different level which should guide studies during the cruise, but corresponding reports even did not mention any results of these programs. However, these shortcomings in organization are successfully balanced by the progress achieved in studying the nature of the World Ocean in that years.

Since 1991 until now the situation with oceanic missions, repair, and maintenance of research vessels has changed markedly, unfortunately, to the worse. The federal funding of the researches has been essentially cut. It is sufficient to say that the Shirshov Institute of Oceanology now receives about 3% of federal support relative to that received before 1990, that is, funding has actually been decreased by 30 times.

Figure 4 shows the data on the number of research vessels involved in missions. The plot shows that less than a half of research vessels are involved in research cruises (even short-term ones). Though, a new form of missions has arisen: missions on leased vessels, but these vessels are, as a rule, passing and carry a small number of investigators. Although the materials (see Fig. 4) indicate that about a half of vessels are involved in research missions, the total duration of missions became 7–8 times shorter as compared to that in 1990, which was the last year favorable for oceanology.

| Years | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 |
|---|---|---|---|---|---|---|---|---|
| Vessels of RAS | 21 | 21 | 13 | 14 | 10 | 9 | 8 | 10 |
| Leasing | 1 | 1 | 1 | 0 | 0 | 5 | 4 | 5 |

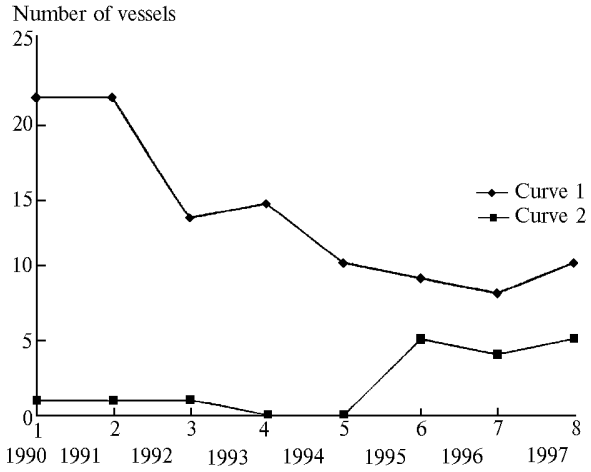


**Fig. 4.** The number of vessels involved in research missions: vessels of the Russian Academy of Sciences (curve *1*), leased vessels (curve *2*).

In 1998 a total of 31 missions of the total duration of 1314 days were conducted, and 753 investigators took part in them. This is seven times lower than in 1990.

For analysis, let us consider funding of research vessels of RAS and possibilities of their commercial use, as well as suggestions how to enhance the efficiency of oceanic missions.

Cruises of research vessels may receive financial support from the following sources:

– Federal Program "Global Ocean";

– grants (contracts) for research works in the ocean from home customers;

– grants (contracts) for research works in the ocean from foreign firms;

– joint international research projects supported by contracts with the corresponding partial support of a mission;

– joint international research projects.

All these financial sources are active to some degree, but their organization in most cases is not planned and centralized, but only initiative.

A rich experience has recently been gained in the commercial use of research vessels. Research vessels are have special design and cannot be used as passenger and cargo vessels in full measure. The experience of using research vessels for such purposes showed that this activity is not profitable. The situation with freight of research vessels for passenger transportation to hard-to-reach regions, such as Antarctic and Greenland, is much the same. After a season in the Antarctic, vessels have no money even for maintenance and necessary annual repair.

## Suggestions how to enhance the efficiency of marine missions

The suggestions can be conditionally divided into three groups:

1) Development of a new generation of oceanological instrumentation.

2) Upgrade of shipborne research equipment.

3) Development of a new methodology of oceanic missions.

Once implemented, these suggestions can enhance the efficiency of every individual research vessel.

*Development of new technologies of experimental studies in ocean* is mostly caused by new generation of measuring instruments available on the market. However, this aim can be achieved only at long-term joint works of specialists in various field of oceanology. The new methodology of research missions in ocean is a combination of works on the development of new measuring instruments and technology of observations using them, as well as planning of works in a particular cruise.

*Upgrade of the shipborne research equipment.* For the last decade the research equipment set aboard vessels was not upgraded, and the emergence of new devices and technologies requires the full equipment to be replaced and the shipborne research equipment to be upgraded.

One more aspect of enhancement of the efficiency of research cruises in ocean is the necessity of taking into account current projects and programs of the International Oceanographic Committee which are in progress.

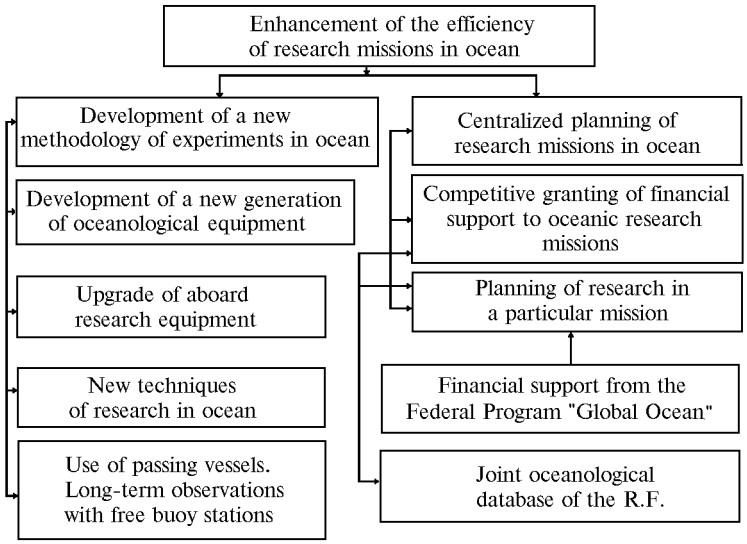


**Fig. 5.** General scheme of enhancement of the efficiency of oceanic research missions.

Cooperation in this case should be far from competition and directed toward selection of such research fields that are insufficiently presented in the international projects and programs.

Figure 5 shows the general scheme of how to enhance the efficiency of research missions. Let us consider the suggestions.

The problem of developing the up-to-date oceanological equipment seems, at the first sight, ill-timed and hard-to-solve in the nowadays financial situation in our country. However, this is not really the case. The development of electronics now gives the way for advent of a new generation of oceanological measuring equipment.

For the past 20–25 years electronics made a real break through in its development (electronic lamps were replaced by semiconductors and then by chips). The structure, circuitry, size, and power consumption of measuring devices have changed drastically. This opens up wide capabilities of creating information and measurement systems using new electronic elements.

*Development of new methods for conversion of measured oceanological parameters into electric signals and development of parametric series of primary transducers.* These problems are also connected with the development of radioelectronics, since now we have the capability of converting analog signals by earlier unknown methods. An example is an acoustooptical transducer, whose size earlier was so large that it could not be considered as a primary transducer. "esides, by now there are some advances in the development of parametric series of primary transducers for a large number of parameters of hydrophysical fields.

*New technologies in instrument-making and application of modern materials.* This field is important nowadays and especially for our country, since in 1985–1995 an access was opened to a great number of earlier secret new technologies in modern instrument-making and production of various new materials, for example, composite materials, which can be used for making strong bodies of measuring devices. "esides, it should be noted that new capabilities have been opened in co-operation in production of some units or devices as a whole. Enterprises earlier engaged by state plan orders can now be involved in such co-operation.

*Satellite and acoustic communication channels.* The new technical capabilities of transmitting information from a measurement site to a processing center not only change the configuration of new measuring devices, but provide prerequisites for changing the entire scheme of experimental research in the ocean, that is, for developing a new methodology of research missions and new technology of experimental data acquisition.

*Development of new methodology of research cruises, their organization, and planning.* The necessity of solving this problem was formulated objectively in connection with the development of measuring instrumentation and communication facilities in oceanology and other fields, but significant reduction of federal funds granted for research missions accelerated this process. The development and wide use of self-sufficient buoy stations, drifters, and stationary measuring systems allow abandoning the traditional scheme of a research cruise including works at stations, sections, and sites. Thus we can pass to systematic observations, which give long observation series of oceanological parameters at wide expanses of the ocean. The application of multichannel self-sufficient buoy stations with determination of their coordinates from the results of observations at reference sections and sites and the use of satellite communication channels for information transfer allow long-term systematic observations for several months and even several years.

Capabilities of modern instrument-making are such that self-sufficient buoy stations can be equipped with multichannel and multipurpose measuring devices, and

the experimental data obtained with them can satisfy the needs in all research fields of modern oceanology. These technical capabilities strongly change the structure, organization, and planning of works in oceanic research missions.

Thus, development of new techniques of experimental studies in ocean becomes obvious and rather urgent. A research vessel is used not only as a platform for observations at a particular point in the ocean, but as a supplier of self-sufficient, drifting, bottom, and stationary observing systems. In this case, passing fishing, merchant, hydrographic, ice-breaking, and other vessels can be used to save money.

" esides, we should return to centralized planning of research missions on the national scale, that is, the Ministry of Resources, the Ministry of Ecology, the Academy of Sciences, and the Hydrology and Meteorology Service should organize co-ordinated and, if possible, complex missions. In this connection, the part of the Federal Program "World Ocean" should be increased up the actual level of federal program. Research programs of shipborne missions should be considered at the level of branch oceanographic commissions and approved by the Ministry of Science and Technology. Competitions for oceanic mission grants should become a part of this process.

We would like also to dwell on the problem of accessibility of experimental results. All the data obtained in oceanic experiments, both primary and preprocessed (but still not ready for publication) should be accessible on request for any institution in our country.

" esides, requirements to the documents that regulate transfer of data into the joint oceanological database of the R.F. should be revised, since the available documents are now out of date and are not fulfilled by participants of the oceanic research.

## References

1. G.V. Smirnov, in: *Proceedings of the Fifth International Scientific Research Conference on Up-to-date Methods and Tools for Oceanographic Studies* (Institute of Oceanology RAS, Moscow, 1999).