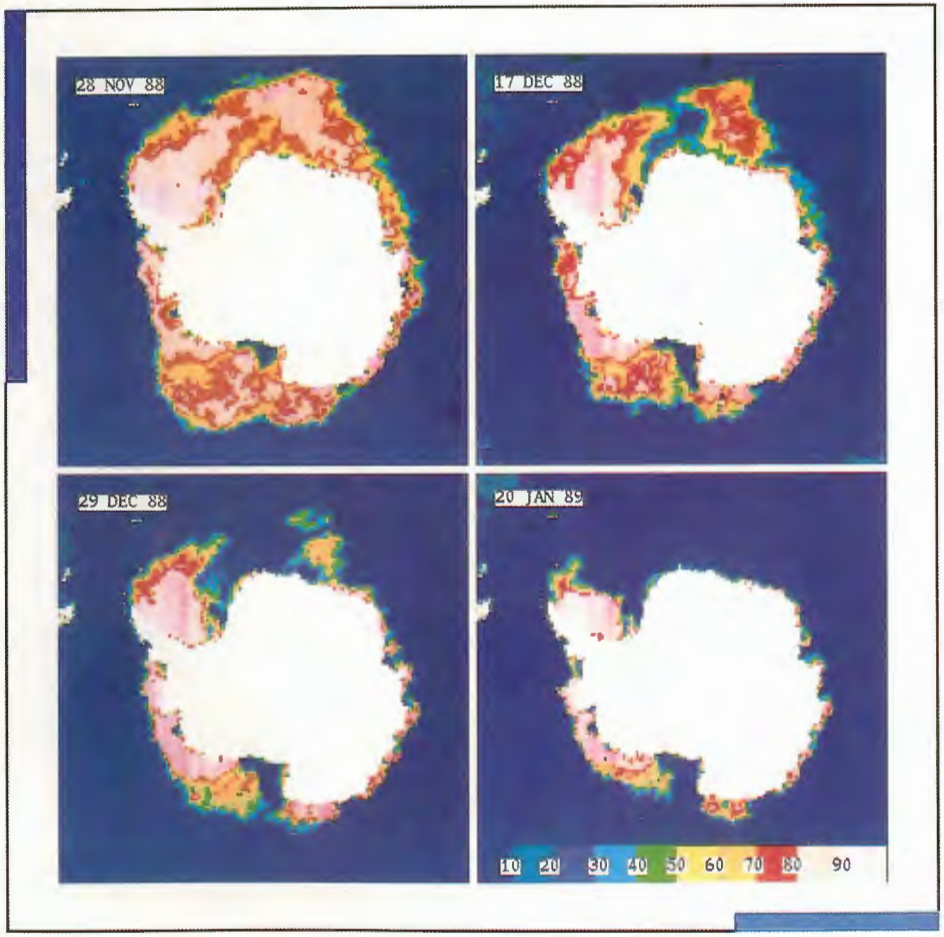
# Marine Sciences in the State of Bremen




Impulse aus der Forschung

Universität Bremen

# Ocean Research in the State of Bremen
# Investigations of Global and Regional Changes in Environmental Conditions

presented by
the "Kommission für Meeresforschung im Land Bremen" (KFM)

The "Kommission für Meeresforschung im Land Bremen", represented by the University, the Alfred-Wegener-Institute for Polar and Marine Research, and the various technical colleges in Bremen and Bremerhaven was formed in 1983, and since that time has been an important vehicle for the promotion of ocean research. This brochure presents the current state of the commission's accomplishments and offers suggestions for further developments in this field of the Bremen scientific infrastructure.

Compiled by G. Wefer, english translation by W. Hale

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Cover illustration:
The ice cover of the Antarctic Ocean region, as detected by the microwave sensor SSM/I. The sequence clearly shows the melting of the Antarctic ice belt in spring and summer. The superimposed scale shows the extent of the ice cover in percentage. White: solid ground; black: missing data. (Original data: NSIDC, Boulder, Co., USA; Artwork: Bildverarbeitungsgruppe des Instituts für Fernerkundung, B. Burns).

## Summary

*Structure*

*The establishment of the Alfred-Wegener-Institute for Polar and Marine Research (AWI) in 1980 and its subsequent merging (in 1986) with the Institute for Ocean Research and the development of departments for marine research at Bremen University (Marine Geosciences, Marine-Biology, -Chemistry, and -Physics) have led to an extensive potential for research and teaching in ocean research in the state of Bremen. For this reason the Wissenschaftsrat determined in its 1989 report that the Bremen Ocean Research Program deserved special recognition for its developments in the fields of Marine Geosciences, Physical Oceanography, and Remote Earth Sensing. Research of the ocean and polar regions presently makes up the greatest portion of Bremen's natural sciences. Activities in this field are supported by considerable funds from Bremen as well as extensive external grants.*

*In specific disciplines the ocean sciences program at Bremen University has achieved internationally recognized results. Examples of this include the Sonderforschungsbereich 261, "The South Atlantic in the Late Quaternary", a cooperative special research program of the University and AWI established by the Deutsche Forschungsgemeinschaft (DFG - the German Research Foundation), and the graduate lecture series "Material Flux in Marine Geosystems", established in 1990, also by the DFG. A further example of the significant development of ocean research in Bremen is the decision of the Max Planck Society to create an institute for marine microbiology here, and the new location of an Ocean Drilling Project core repository at Bremen University.*

*This brochure contains an outline of the development phase of marine research in Bremen, produced by the "Kommission für Meeresforschung im Land Bremen" (KfM). Among other purposes it should serve as a foundation for the further development of this field in Bremen. Most of Bremen's marine study contributes in some way to climate and environmental research, and to the overlying theme of Global Change. This key position and aim continue to be a focal point in the plans for the future, in which the following three problems will be addressed with top priority:*

- *The ocean as one of the main components of the earth's climate systems.*
- *The seas, especially the shallow near-coastal zones, as sources of food and raw materials.*
- *The environmental impact on the seas from anthropogenic input.*

*The investigation of these topics will be carried out in national cooperation as well as through participation in international programs.*

*Main topics of research in Bremen*

*Marine research in Bremen will be enhanced through the cooperative efforts of the Alfred-Wegener-Institute, Max Planck Institute and Bremen University, which have already formed joint research groups in Marine Geosciences, Marine Biology, and Physics and Chemistry of the Oceans and Atmosphere. The investigations have been geographically concentrated in the Atlantic Ocean, particularly in the polar region and in the eastern Pacific. In increasing cooperation with German coastal states, other countries on the North Sea, and partners from the Third World, scientific foundations for the protection and use of coastal waters will also be investigated.*





*Through fruitful cooperation with scientists, the industrial ocean technology based in Bremen also reaps significant benefits. Special emphasis is given to remote sensing, sea floor measurements, and automatic probing technology, not only for the deep ocean regions but also for shallow seas and coastal areas. As a result of the expansion of ocean measuring technology at Bremen University these fields will continue to expand in the coming years. Underwater robotics, including the development of unmanned measuring instruments, new sensor systems with the accompanying data processing for operations in remote sensing and under water, will play an increasing part in the scope of the Global Ocean Observing Systems (GOOS). Through the close cooperation between research institutions and industry such tasks can be tackled with very good prospects of success.*

*Ocean research (and geoscience in general) as a globally directed field, can only be carried out successfully through united international efforts. European cooperation plays a great role in ocean technology and investigations into the anthropogenic impact on the oceans. Close coordination of the work in Bremen with other German research institutes is imperative not only with respect to the scientific themes, but also in the financing of the various projects. The mutual efforts are necessary for effectively coping with the logistic details of ship use and large instrument deployment.*

*Further development*

*The rapid growth in marine research in the State of Bremen, which has resulted in extensive participation in highly funded international research projects, has to be consolidated in the coming years. For one thing some research projects must be completed through additional personnel and, for another, basic equipment must be improved in order to insure the long-term continuation of existing projects.*

*Future areas of research with highest priority will concentrate on the following themes:*

1. *The role of the ocean in the carbon cycle and climatic development: today and in the past.*
2. *The role of living organisms in biogeochemical processes.*
3. *Recording marine environmental pollution and working toward its reduction.*
4. *Ecology of tropical shallow seas with respect to the importance for Third-World countries.*


## I. Investigations of fundamental processes

The investigations of fundamental processes in the ocean - especially at the ocean/atmosphere and ocean/sediment interfaces - are of primary importance in estimating the effects of human activity on the environment. Investigations of special significance are, for example:

- the observation of physical, chemical and biological processes near the ocean surface with the help of remote sensing devices (airplanes or satellites),
- the currents and horizontal structure in the ocean,
- the material transport in the ocean, especially the biochemical and geochemical cycles,
- the structure and dynamics of life communities in the ocean,
- understanding the role of the ocean in the global climate system,
- the composition and structure of the sediments and rocks of the deep sea, continental shelves and shallow seas.

## II. Contributions to the problem of global environmental changes

*Climate*

There is growing concern that an increase of "greenhouse" gases in the atmosphere, partly as a result of the use of fossil fuels and extensive deforestation, will cause a global warming over the next 50 to 100 years. In order to better understand the effects of these gases on the environment, their paths between the atmosphere, ocean and sediment must be determined and the resulting effects on climate must be predicted based on computer models. The amplitudes of fluctuations of various climate components can be estimated with useful accuracy for the past history of the earth. This information also provides clues for climatic development in the future.

*$CO_2$-Problem*

The ocean plays an important role in the carbon cycle. Of the $CO_2$ released by mankind, 60% remains in the atmosphere today to enhance the "greenhouse" effect. Part of the remaining 40% is taken up by the world ocean.

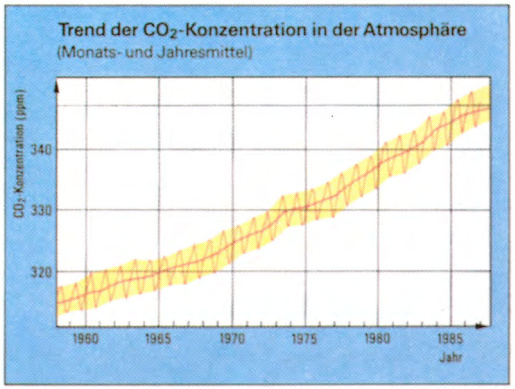


Fig. 1:
The trend of $CO_2$ concentration since 1958: monthly and yearly average values in the atmosphere (in ppm), measured at the Observatory of Mauna Loa, Hawaii. (From: Zur Sache - Schutz der Erdatmosphäre - 5/88).

The ocean thereby retards and subdues the human impact on climate. There are still, however, great uncertainties concerning the retention and transport of $CO_2$ in the ocean. Because the ocean contains 50 times more $CO_2$ than the atmosphere, small changes in the $CO_2$ exchange between the two can have a significant effect on the $CO_2$ content of the atmosphere. In order to better understand the potential effects of an atmospheric increase in "greenhouse" gases on climate, our understanding of ocean circulation, worldwide transport of heat and fresh water as well as the global carbon cycle must be greatly improved. For this reason, two international research programs were created: the World Ocean Circulation Experiment (WOCE), and the Joint Global Ocean Flux Study (JGOFS). These two programs are core projects of two larger-scope programs: the International Geosphere-Biosphere Programme (IGBP) and the World Climate Research Program (WCRP).



Bremen University and AWI are intensively involved in these international programs, both in the development and coordination of the programs, and in the field and modeling work.

*World Ocean Circulation Experiment*

The WOCE includes extensive measurement programs by research ships, satellites, various automatic measuring stations and moorings as well as projects for the development of global 3-dimensional circulation models, some of which are coupled with atmospheric factors and consider biological and chemical processes. The goals of the WOCE project are:

a) To create an inventory of oceanic circulation and to explore the physical processes which affect the long-term condition of the ocean.
b) To develop and test models of global ocean circulation, in order to make climatic predictions possible.
c) To develop methods for recording long-term changes in ocean circulation.

*Bremen's contribution to WOCE*

Our field investigations for WOCE are concentrated in the South Atlantic Ocean including the Weddell Sea. With the help of ships, drifting buoys, moorings and satellite data over several years, the heat, freshwater, sea ice and mass transport in theAntarctic Circumpolar Current will be recorded, and the water-mass modifications resulting from the atmosphere-ocean-ice interactions will be determined. A special field of interest of Bremen University is the estimation of large-scale water-mass exchange determined from the distribution of certain trace elements.
The modeling calculations of AWI include a high-resolution representation of the Antarctic Circumpolar Current, the circulation of the Weddell Eddy with consideration of the sea ice and shelf ice, and detailed descriptions of the sea ice development in connection with the atmospheric and oceanic boundary conditions.

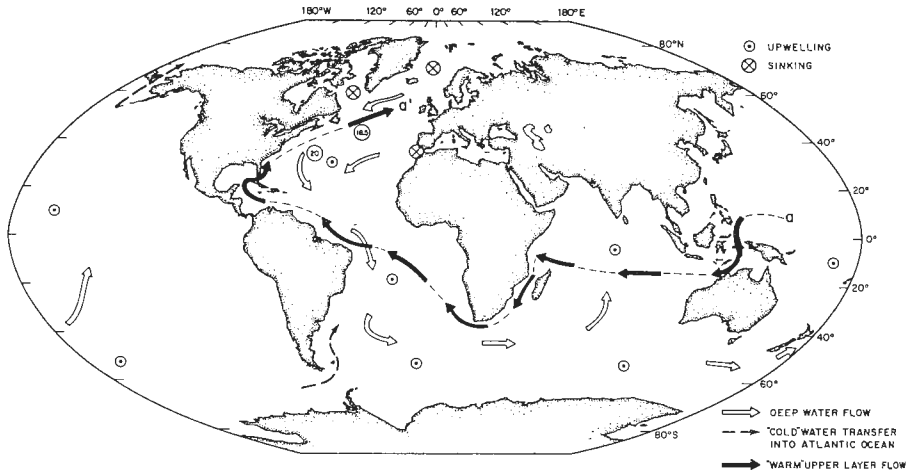


Fig. 2:
Structure of the worldwide thermohaline circulation cell, which is closely tied to the formation of North Atlantic Deep Water (NADW). The solid arrows show the presumed warm water path, by which the sinking NADW in the North Atlantic is replaced. The empty arrows show the path of the bottom water. (Redrawn and modified from: GORDON 1986, J. Geoph. Res. 91: 5037-5046).

*Joint Global Ocean Flux Study*

The JGOFS program also includes extensive measurement programs using ships and satellites and its goals are:

a) To investigate the processes in the ocean which determine the time-dependent transport of carbon and associated biogenic elements in the water, and to clarify the gas and material exchange between the ocean, atmosphere and sediment.
b) To develop models which will predict the reaction of the oceanic biogeochemical processes to anthropogenic disturbances.

*Bremen's contributions to JGOFS*

Within the framework of the SFB (Special Research Project) 261, the effect of atmospheric $CO_2$ on the mass budget of the South Atlantic will be investigated. As a result of the consumption of $CO_2$ by planktonic algae, there is a close relationship between productivity in the ocean and the $CO_2$ content of the atmosphere. Oceanic productivity fluctuations in the past may have contributed to the $CO_2$ variations discovered in investigations of polar ice cores. Other projects deal with the coalescence of plankton (aggregate formation) which is related to the sinking of carbon through the water column; with the biological basis of production, release, and retention of organic substances (by micro- and macro-organisms); and with the decay of organic substances on the sea floor and in the upper sediment layers. In addition, the vertical transport of trace elements will be investigated, which is mainly steared by biogenic particles. These studies will be supported through the further development of instruments for measuring light transmission in the ocean, the improvement of sediment age-dating methods, and through remote sensing by satellites to record the distribution of chlorophyll in the surface waters.
The analysis of organic and inorganic trace elements in the atmosphere, sea water, pore water and sediments is carried out in the modern laboratories at AWI and Bremen University.

**III. Contributions to the research, use and protection of the shallow seas (North Sea, tropics, polar seas)**

The physical, biological and chemical processes in the coastal and shelf regions are of increasing interest with regard to the geological processes and ecological relationships in the ocean. These processes determine the absorption and sensitivity of the shallow seas with regard to pollutants and nutrients. Many of the on-going marine processes are closely tied to organic activity, so that the environmental changes introduced in coastal regions depend on biologic efficiency of the individual systems. These investigations are also included as sub-projects of the IGBP.

*shallow water research*

The State of Bremen is participating in numerous investigations of shallow seas in various climatic zones, including projects in the German Bays, in the tidal flat areas, in polar waters, and off the west coast of South America. The new Center for Marine Tropical Ecology will fill the existing gaps in the low latitudes and will provide developmental help from the scientific community. Numerous countries of the Third World have been advised by the industrial nations to intelligently manage and protect the resources of the coastal regions. The expertise of local ocean researchers can be very usefully employed toward this end.
From its beginnings in 1920, the former Institut für Meeresforschung (IfM - Institute for Marine Research) in Bremerhaven concentrated its efforts on the North Sea and the living communities found there. With the creation of the AWI, the focus of marine research in Bremerhaven has shifted more



toward the polar seas in recent years. Research activities in the North Sea, however, have not been completely abandoned. These studies will continue in cooperation with Bremen University and the Max Planck Institute.

*Working on one's doorstep*

Shallow-water research is an indispensable foundation for solving regional environmental problems, on which the University, the MPI, and a large part of the AWI participate in a cooperative effort. Working "on one's doorstep" gives the next generation of scientists the economic justification for access to field-work and allows the testing of new methods and instruments. With the research vessel "Victor Hensen", a fully equipped ship is available to serve this purpose as well as to help in scientific partnership with institutes of the Third World working in tropical coastal waters.
The alarming condition of the North Sea is an impelling reason for the AWI to look for new forms of national and international cooperation. For this purpose, in March 1990, the International Council for Marine Research together with the "Intergovernmental Oceanographic Commission" (IOC) arranged an extensive method comparison for the quantification of pollutant impact, in which the vessel "Victor Hensen" participated along with other research vessels. In a North Sea Symposium held by the AWI in June 1990 (commissioned by the Bundesminister für Forschung und Technologie - BMFT), the German research strategy for the handling of the environmental problems of the North Sea was outlined, and it was mandated that the institutions in the State of Bremen would play a significant role. Among other projects, the AWI contributes the results of decade-long investigations of the bottom-dwelling fauna of the German Bay, and of the DFG project, "Fronts in the German Bay". A further benefit is its rich experience in the ambitious quantitative analysis of trace elements in sea water, in sediments, and in organisms. In their efforts to estimate the anthropogenic impact on sea life, the marine biologists at Bremen University have the advantage of experience in the investigation of environmental adjustment and the effects of pollutants on marine organisms. Chemists, zoologists and microbiologists of the university have been participating for many years in projects of environmental research in the North Sea.

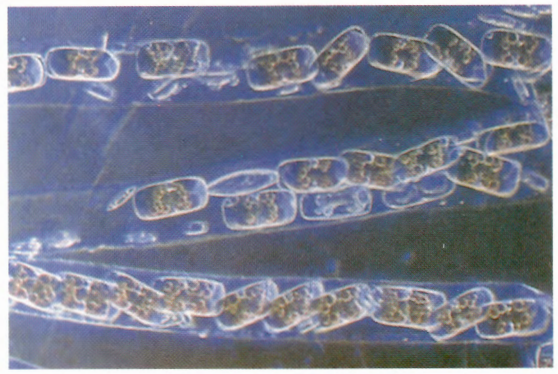

Fig. 3:
Siliceous algae, Amphipleura sp. (diatom), formation of aggregates in tubes of mucus, Helgoland 1985.

## IV. Teaching and educational programs of marine and environmental research

*Teaching of marine science*

The potential for marine research that has been realized in the last decade has promoted the development of a varied program in the teaching of marine science at Bremen University. In the biology, geology/paleontology, geophysics, physics and chemistry programs, elective courses have been established for marine biology, geology, geophysics, chemistry, and physics of the ocean and atmosphere. These classes, along with graduate and doctoral studies, allow specialization within the normal courses of study.

The teaching program in Bremen combines a solid marine science education with active participation by the marine research students. It also provides a foundation in terrestrial and limnological environmental research regarding trace analysis of pollutants in various matrices, addresses the pollutant cycles and their potential dangers, and deals with possibilities for prevention as well as disposal of dangerous materials. The students who are educated here are therefore competent in the important environmental problem areas. Because of their training a broad professional field is open to them.

New stimuli for doctoral students in the field of marine research are anticipated from the creation of a graduate lecture series, "Material Flux in Marine Geosystems". Under a federal/state agreement, the first 55 of these lecture courses were appropriated by the DFG as of the end of 1990. The purpose of these lecture series is to expand on the traditional system of individual support for doctoral students. The lecture group system allows the students to develop their dissertations within a systematic and interdisciplinary program in connection with various research groups with coordinated research themes.

## V. Resources and Methods of Marine Research

The investigation of the ocean and atmosphere relies greatly on field measurements and development of computer models. Logistically, this requires research ships, observatories, satellites, high-performance computer systems and databases. In addition, modern ocean measurement techniques, both direct and indirect, highly precise chemical analyses, and complex numerical methods for computation of models are required.

*Research vessels and observatories*

Availability of the icebreaker "Polarstern" has allowed the Bremen marine researchers to enter into the investigation of the polar regions, previously sparsely studied, but a vital component in the global climate system. This ship, the research air planes, and the observatories in the Antarctic (Georg-von-Neumayer, Georg-Forster, and O'Higgins) and the Arctic (Ny-Alesund), contribute significantly to the cooperation with the aforementioned international programs, and in some areas represent the leading role. For work in the North Sea and shelf regions, the very efficient research ship "Victor Hensen" is available. This ship is useful as well in tropical regions and is also employed for teaching purposes.

*Physical measurement technology*

Ocean measurement programs reap benefits from modern technology in various forms, including measuring instruments, techniques for locating and positioning, and telecommunications. These systems must remain in a continuous state of development. Some of these newly developing systems represent worldwide market opportunities in the form of marine technology products. One clear example of this is the development by Bremen industry of the Hydrosweep and Parasound systems, both of which enormously improved the seafloor measurement technology and have since been installed in numerous German and foreign research vessels. These kinds of advances in technology also result from a very close cooperation between the manufacturers and the scientific users. This cooperation is already being promoted through the technological European Union program EUROMAR.



Fig.4:
The two Research Vessels METEOR and POLARSTERN in Capetown Harbor (March 1990).

*Technology exchange*

In terms of technology exchange, it would also be desirable to include smaller operations that are in the initial stages of development. The continuously growing amounts of data make international agreements for

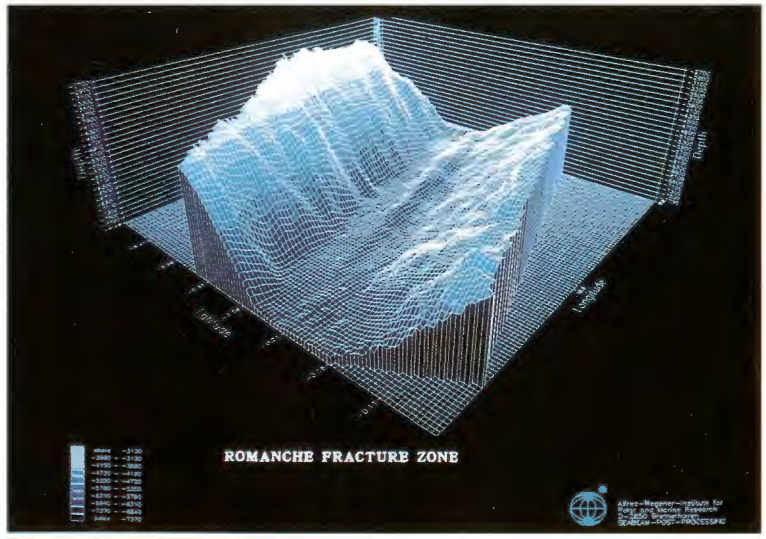


Fig. 5:
Three-dimensional model of the seafloor, a part of the Romanche-Fracture Zone (Central Atlantic) after measurements with the HYDROSWEEP deep-sea echosounding system (AWI, Bremerhaven).

data management necessary. Preliminary work toward this end is being carried out through the development of database systems at the AWI and in the Marine Technology Transfer Office at Bremen University.
Ideas for the development of new measuring techniques often originate in the scientific institutes. Prototyps of these instruments are subsequently passed on to industry. Hopes for the near future include new sensors attached to robots which can take samples and automatically functioning measuring stations for remote regions. Work has already begun in these fields at the technical schools and at the AWI.

*Remote sensing and image processing*

Through the analysis of electromagnetic and acoustic waves, remote sensing technology provides evidence concerning the distribution of meteorological, oceanographic, chemical and biological quantities. Various methods can provide either high-resolution local data or larger area distribution patterns up to a global scale. The major vehicles which carry these instruments are remote-sensing airplanes and satellites. There are also, however, methods of remote sensing which can be applied from a ship. The ocean surface structure has been studied in Bremen based on analysis of remote sensing data. From these studies important evidence has come to light in the areas of bottom topography, the motion of the sea, ocean currents, oceanic eddys, internal waves and water pollution by oil.

Fig. 6:
Iceberg in the Bransfield Strait (Antarctic).

In recent years, measurement procedures have mainly concentrated on the area near the atmosphere/water interface, for example surface temperatures, wind speed and ice cover (see cover illustration), in an attempt to obtain atmospheric data such as water content or precipitation rates. In addition to the development of new sensors, a critical aim is the preparation of new analytic procedures for extensive data sets and verification experiments. This involves to a large extent methods of digital picture and signal processing, which require both high-performance computers and numerous special peripheral instruments.

*Chemical analysis*

The rapid development of instrumental analysis over the past 15 years has expanded the ability to acquire minute physical data by orders of magnitude. This trend has been especially important in the field of marine research because of the very low concentrations of trace elements and organic components (whether as natural elements or as anthropogenic input) in sea water and other marine matrices.



For researching the distribution of natural trace elements, tracking anthropogenic pollutants, and for using trace materials as evidence for oceanic processes, working groups at Bremen University and the AWI have assembled sophisticated trace element analysis systems which are optimized for various purposes. Because many trace element studies being planned require stringent methodical control with respect to separation from matrix, isolation and identification, even with the recent advancements in instrument sensitivity the desired parameters and not easily or routinely available. Still, the number of natural and anthropogenic components that can be discerned is continuously growing, so that more possibilities are opening up for using trace elements as tracers for biochemical and physical processes in the oceans. The continued development of new methods for trace analysis will continue to flourish accordingly.

*Mathematical modeling*

Modeling of the ocean-atmosphere-ice system requires substantial computer resources. For advancement in efforts toward modeling the global climate, efficiently implemented numeric algorithms are required. Numerical methods are therefore being worked out at the AWI which will allow the use of large computers toward this end.

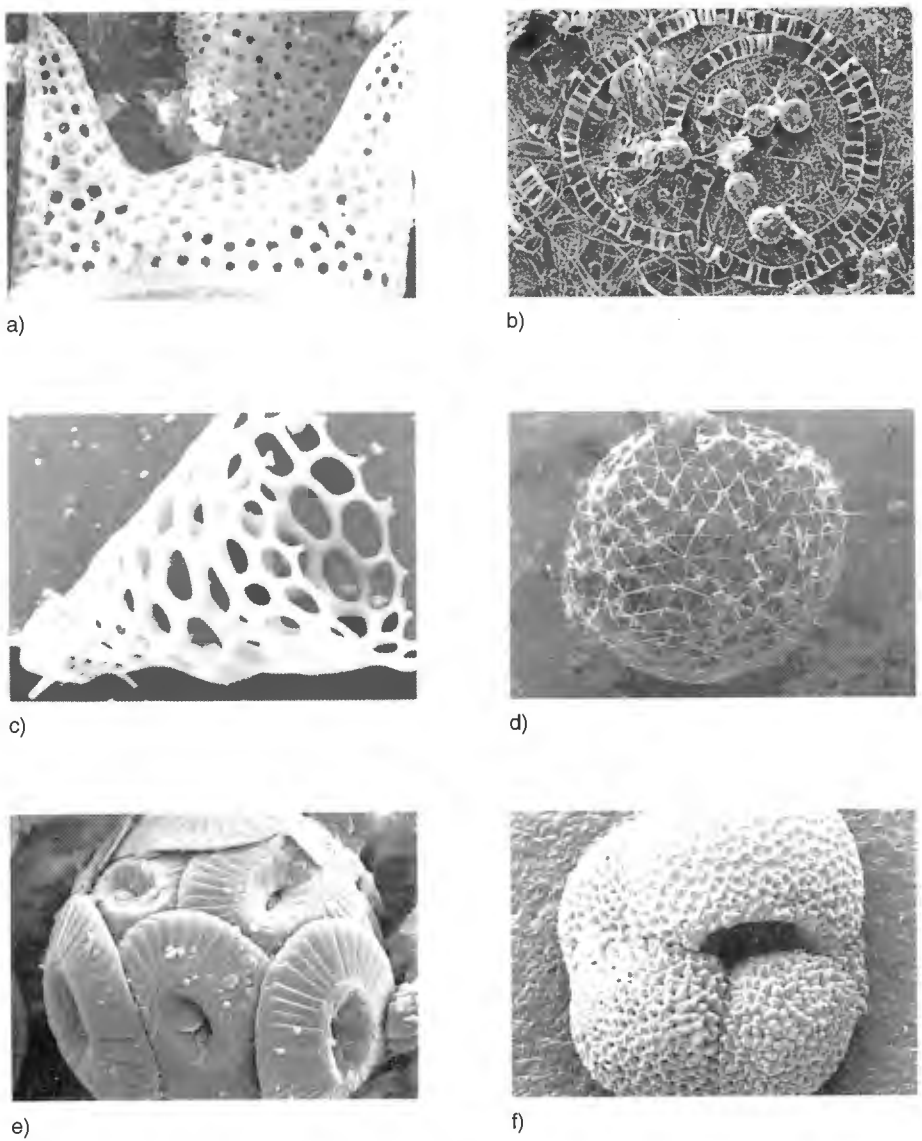

Fig. 7:
Scanning electron microscope photographs of primary and secondary producers, also important sources of information for paleoceanographic reconstruction: a) diatom, b) diatom chain, c) and d) radiolaria, e) coccolithophoridae, f) planktonic foraminifera.



## VI. Development Plans for the State of Bremen

The international projects WOCE and JGOFS began in 1989 and will run for about 10 years. Cooperation with these programs will continue to grow in the future with the establishment of the following professorships (some already filled, some planned):

*Establishment of new departments*

- Microbiology with emphasis on marine microbiology (microbial decay of organic substances),
- Marine technology with emphasis on sensors (including technology of sea-floor measurement),
- Paleoceanographic modeling (modeling of past circulation and mass balance in the oceans),
- Organic geochemistry (organic trace materials, including pollutants),
- Paleoceanography (reconstruction of the history of oceanic circulation and climate),
- Environmental geophysics,
- Petrology of oceanic crust.

The Max Planck Institute (MPI) for Microbial Ecology is including sedimentary microbiology as one of their major themes for study, which contributes significantly to the understanding of the carbon cycle in the ocean.

*Max Planck Institute for Microbial Ecology*

Investigations at the Max Planck Institute include the processes of microbial transformation of organic and inorganic materials near the sea floor. The objects of investigation are the marine sediments as well as other aerobic and anaerobic substrates with dense microbial populations. The studies include natural bacterial communities, their living environments and their metabolic activities. For this work new microsensors are employed at the sediment-water interface.

Marine sediments regulate the material budget of the oceans through the decay of particulate organic substances and the regeneration of nutrients. The remineralization processes on the seafloor are important in terms of the extent of plankton productivity. Information about the past compositions of the ocean and the atmosphere can be extracted from marine sediments. These kinds of analyses are achieved through the fieldwork of the MPI on biogeochemical processes and their dynamic function in marine ecosystems. These investigations extend from the regions of the coastal seas (Baltic Sea - North Sea transition) to the deep sea (including the Antarctic and South Atlantic). Through cooperation with the biologists and geoscientists at Bremen University and the AWI, the investigations of microbial and biogeochemical processes by the researchers at MPI take on additional significance.

*Consolidation of operations thus far*

In the coming years marine research at Bremen University should be consolidated through a strengthening of the scientific positions. Without an improvement in the available equipment, the ongoing programs - largely supported by external funds - cannot continue with a long-range view. The future work of highest priority will concentrate on the following themes:

1. The role of the ocean in the carbon cycle and in climate development: today and in the past.
2. The role of organisms in biogeochemical processes.
3. Understanding the distribution and fate of marine pollutants.
4. The ecology of tropical shallow seas from the point of view of Third World countries.

*Goal: The role of the ocean in the carbon cycle and climate*

Investigation of the oceanic carbon cycle requires extensive field work which can only be accomplished through international and national cooperation because the expense would be too great for any individual nation. For logistical reasons the German investigations are concentrated in the Atlantic Ocean and the associated polar regions. In addition to measurements from ships and airplanes, the Bremen research establishment makes extensive use of satellites in conjunction with bouys and moorings. This activity contributes to the development of sensors and the creation of algorithms for data analysis. The Bremen scientists create appropriate data bases from which they develop models.

Measurements of the carbon cycle must be carried out in the form of long-term process-oriented investigations in various geographical regions (coastal seas, the oceans, specific production systems). For the State of Bremen the preferred areas of study are the North Sea, theAtlantic Ocean and the Polar Regions. Within the water column the production layers of greatest interest are those near the surface and at the water-sediment interface. Critical themes are the biology and ecology of organisms, their capacity for producing and storing carbon, as well as the breakdown of organic substances by microorganisms. In addition, the transformation processes between solid and liquid phases need to be understood (mineral formation and dissolution). The biological release and utilization of dissolved organic substances also requires further investigation. An expansion of the teaching and research capacity in this field has already been achieved through the formation of the marine biology Max Planck Institute and the creation of a "Marine Microbiology" position.

*Goal: Pollution research*

An important task for the future using automated measuring systems is the observation of pollutants in coastal areas near industrial regions as well as in the open ocean. Computer-assisted information systems can greatly assist decision-making in the struggle against waste in the oceans. These tasks will be addressed through close cooperation between resident industrial companies and scientific institutes. The State of Bremen supports the development of concepts for marine environmental protection which takes into account the role of the sediment and the organisms which live therein. The sediments should not be viewed only as a sink for pollutants, because when they contain a great deal pollutants they can be stirred up and release considerable amounts back into the water. An example of this is the mud deposited in harbour basins. Ocean mining in shallow seas and in the deep sea is confronted with similar problems.

*Goal: Tropical Ecology*

The ecology of the tropical shallow seas, especially with respect to the countries of the Third World, is studied in a Bremen research center. A reasonable interaction of research, teaching and development aid takes place under which the following themes are at the forefront:

- marine ecological impacts of the urbanization of tropical coasts,
- ecological basis of the standing crops of sessile organisms (algae, mussels, snails) in coastal waters,
- effects of increased current and wind factors (increased sea floor erosion) as well as undersea mining on the ecology of shallow waters, for example coral reefs.

The particular research works, promoted and supported by the "Deutschen Akademischen Auslandsdienst" (DAAD), the "Gesellschaft für technische Zusammenarbeit" (GTZ), the "Bundesminister für Forschung



und Technologie" (BMFT) and the "Bundesminister für Umwelt" (BMU) will be complemented by the training of able students and the advanced education of scientists of the Third World Countries.

The marine research program in Bremen has developed rapidly in the past 10 years. In order to meet the great scientific challenges of future climatic and environmental research, a continued concentration on the topics described here is required, along with the consolidation of scientific positions and expansion of the sub-disciplines in order to round off the spectrum and strengthen the overall program.

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Photographs: G.-O. Kirst (Fig. 3), Geol.-Pal. Institut Universität Kiel and AWI Bremerhaven (Fig. 7), G. Wefer (Figs. 4,6,8), M. Segl (back cover).

Fig. 8:
King Penguins near Grytviken (South Georgia).

Back Cover:
Instrument deployment on Research Vessel METEOR.