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Reflections on developments, motivations and results of ocean research

Abstrakt

En översikt ges av havets roll för vårt samhälle, med tonvikt på dess betydelse för klimatet. Havet ger atmosfären det mesta av vattenångan som är den naturliga och nödvändiga växthus gasen för vårt klimat; tar upp en stor del av den extra koldioxiden från vårt fossila samhälle, liksom den resulterande värmeökningen, och fördelar den genom havsströmmarna. Havet ger oss föda som är den viktigaste källan till animaliskt protein för 2-3 miljarder av den fattigaste befolkningen. Effekten på havet av den av oss framkallade klimatförändringen är en gradvis uppvärmning, vilken nu nått två- till tretusen meters djup, och som sannolikt påverkar cirkulationen i havet och medför en gradvis höjning av havsnivån, tillsamman med den ökade avrinningen genom avsmältning av glaciärer. Upptaget av den extra koldioxiden leder till försurning som påverkar korallrev och skaldjur, krabbor, hummer, räkor och havskräftor. Föroreningen av havet genom tillförsel från land via vinden och avrinningen har stor påverkan på livet och förhållanden rent allmänt i havet. Den ökar sannolikt genom flera och förhöjda extrema väderleksförhållanden, i kombination med mindre syre i det varmare vattnet. Samhällets aktioner för att skydda havet och möjligen dämpa de berörda effekterna måste ta hänsyn till helheten, interaktioner mellan havet, atmosfären och den fasta jorden, återkopplingar mellan flera processer och förändringarna. Styrmedlen måste vara adaptiva. Detta är väl reflekterat i Havsrättskonventionen. Vetenskapens betydelse för att förstå och med stående observationer följa utvecklingen belyses, tillsammans med utvecklingen av ny teknik och hög datamaskin kapacitet vilket möjliggjort användande av dynamiska modeller för att förutsäga väderlek och säsongvariationer, inklusive riskfyllda extrema situationer.

Abstract

The paper presents an overview of the role of the ocean for our society, including the climate, providing most of the necessary natural greenhouse gas of water-vapor to the atmosphere; providing food for all also being the major source of animal protein for 2-3 billion of the most needing people. Impacts on the ocean from the climate change and other human-induced changes are highlighted, including pollution from land transferred by runoff and wind. The interactions between many different processes imply that an integrated and adaptive approach is required in management and governance responses. These include the need for ocean research and standing regular observations to understand and follow the development, so as to be able to adapt responsive actions accordingly. The development of ocean science over about 250-300 years is referred to, including the related process of increasing international cooperation and agreements on regulations. Some major results are highlighted including regarding the ocean circulation, ocean-atmosphere interactions and organic food productivity. The importance of technological developments is stressed, including high-capacity computer facilities, data transmissions through satellites of standing surface layer and deep water observations with use of data assimilation in dynamic modeling for making useful forecasts of hazardous conditions and seasonal variations. The applications also include increasing international cooperation and improved assessments of conditions and impacts. The significance of the International Decade for Ocean Exploration 1971-1980 is brought out, stimulating also the generation of the on-going UN Ocean Science Decade 2021-2030, which is associated with Agenda 2030. Contributions from ocean science and observations to human life and infrastructure risk-reductions as well as nutrition are indicated.

Introduction

The ocean plays a vital role in the global carbon cycle, regulates the climate, provides food, support food security and livelihoods for billions of people, in particular for coastal areas and the most vulnerable populations; provides ecosystem services, water vapor, oxygen, energy and other non-living resources; takes up most of the additional heat due to the increased greenhouse effect of added gases from human actions, and about one quarter to one third of the added carbon dioxide, with strong impacts on ocean ecosystems. Most of these life sustaining services are at risk from actions of the human society: pollution from land runoff and actions at sea; warming with changing temperature, salinity, fish migration, sea level rise, increased oxidation rates of organic material, algal blooms and loss of oxygen; acidification; disruption of ecosystem services in coastal zones and regional seas. Many social needs together with curiosity motivate ocean research. An integrated approach in research and management is required to find useful, acceptable solutions, involving natural and social sciences, economic and human health analyses. Can society provide and support the needed scientific and observation efforts, which must be sustained over extended periods of time? Has the ocean research and observation abilities reached the required levels of competence, infrastructure, resources and human capital, and if so how? The presentation recalls the foundation of ocean research, the motivations, indicates results, pointing at the role for and need of international cooperation and involvement of many science disciplines. The story goes back about 300 years, to the period of exploration. Oceanography as a science in its own right is considered to be related to the global English Challenger expedition1872-1876, although several smaller scale regional studies had been done before. International cooperation was involved from the start as well as several mainstream sciences as physics, chemistry, biology, geology. An early focus concerned the extension of life in the ocean. Governments were motivated through the need to provide sea food to growing urbanization driven by industrialization. Already then over fishing in restricted areas became a concern. The international cooperation became formalized through joint regional surveys, leading to the creation of the International Council for the Exploration of the Sea in 1902. This demonstrated the abilities of the growing ocean science community.

During the next hundred years the science developed in parallel to the technological developments and the needs of increasing populations and new States following decolonization. Climate changes over geological and modern time scales were specified by means of sediment core analyses, also supporting the plate tectonics theory; deep sea eruptions were discovered with ecosystems based on bacterial production of organic material; time series of regular observations clarified that variations in fisheries were coupled to basin wide oscillations over decadal time scales, and also influenced by variations in year class strengths and feeding; the existence of the western boundary currents was explained, starting with the Gulf Stream; the seasonal variations of primary production was explained and studies of organic production indicated that the potential for food from a wisely cultivated ocean is sufficient for our increasing marine food requirements. Basin wide surveys were made possible through new observing technologies involving drifting, oscillating buoys, satellite observations and data transmission. Parts of the ocean deep water circulation and the role of the ocean in the climate system were elucidated. Increasing computer capacities made it possible to develop dynamic coupled models which, with sustained observations and data assimilation, made forecasting of basin wide phenomena like the Pacific El Nino and the Indian Ocean monsoon feasible. Impacts on human health and ecosystems of land runoff and discards of various substances in coastal zones, regional seas and the open ocean were elucidated. Hazards originating from the ocean, including tsunamis, storm surges, cyclones, flooding have been understood sufficiently to make useful forecasts and warnings possible. Multiple sources of disturbances and threats to the marine environment have been identified and their effects are being studied, involving many science disciplines. Results of scientific analyses are being transmitted to management and regulatory mechanisms as well as the general public, including through global and regional assessments. One present challenge is dialogue with decision and policy makers and the public to help ensure use of scientific advancements to address multi-dimensional and cumulative effects and problems.

Initial developments of modern ocean studies

Initially scientifically related studies of the ocean were coupled to exploration, trade and colonization, mostly driven by European nations. Historical observations and ideas on the ocean conditions have emerged from our beginning. Migration from Africa seems to have followed a route along the coasts and estuaries. This has given a foundation to the idea of the importance of sea food for our development. Oceanography as a science in its own right is considered to have emerged with the English Challenger expedition 1872-76. Several regional research expeditions in the North Atlantic and the Mediterranean had been launched earlier, giving experiences and results to support the planning of the global Challenger expedition. This was international with participation of scientists from several countries. From the start ocean research needed international cooperation and involving established mainstream sciences. A major initial task was establishing how far into the water life existed, in particular its existence below the euphotic zone were sufficient light was available for photosynthesis. On the Challenger actions included trawling, dredging, sounding with wire, water sampling, magnetic and meteorological observations. The ship, provided by the Royal Navy, was equipped with auxiliary steam power and propeller making it possible to keep the ship on the oceanographic stations. The ship was specifically changed to fit the needs of science with laboratories, library and births. The expedition also benefited from the new photographic technology. The importance of technological developments for ocean observations had also been demonstrated by the use of telegraphy in establishing the first international cooperation and network for ocean observations from ships in the 1850´s. This cooperation with international exchange of data, resulting in production of sailing charts, was agreed through the first oceanographic conference in 1853 in Brussels. This was also a foundation for ocean research.

The analyses of the Challenger samples and data from over 360 stations also became an international cooperative effort based in Edinburgh. The whole was a very stimulating process for the new science discipline. Together with the need for cooperation in context of management of fisheries in restricted areas on agreed premises including scientific observations and analyses, the process also supported the gradual development of the formal international institution for ocean research, exchange and use in management, the International Council for the Exploration of the Sea, ICES, in 1902. Initially it was time limited to about 5 years. However, the success of the regional studies involving ships from several nations organized through the Organization led to its continuation, covering the whole North Atlantic region The latter half the 1800´s also saw a number of regional oceanographic expeditions and exploratory cruises, including Franklin to the Newfoundland region and Nordenskiöld with Vega through the north-east passage 1878-

79. These activities were to some extent made possible through the change of climate from the cold Little Ice Age to the warmer modern period, with a regional temperature increase of about 2 degrees, starting 1850-1870. The on-going industrial revolution also led to strong urbanization, in particular of the coasts.. This in turn led to the need for food from the sea to the growing population moving from farming to industries. This all stimulated governmental interest in ocean research for food and for transport. An initial joint, synoptic survey of the Skagerack and northern Kattegatt with 5 Swedish ships was organized in 1890, followed by a similar Danish effort in 1991. Cooperative international surveys were carried out in 1893-94 over a larger region involving 5 countries. The re-appearance of the herring in Swedish waters in the winter of 1877-78 triggered further studies on the fishing grounds investigating possible connections between the water, current and meteorological conditions and the occurrence of fish. Small-scale local surveys were not enough leading to support of international cooperative investigations over larger areas of the ocean. The idea of international cooperation to achieve studies of the whole northern Atlantic through a common plan was presented by Otto Pettersson at a Conference in Copenhagen in 1892. A plan was subsequently developed covering the Baltic, the North Sea and adjacent waters of the North Atlantic. This was successfully implemented in 1893. It stimulated continuation and led to creation of ICES and further regional surveys. The governments were motivated by the fisheries conditions and the growing concern for over fishing in congested areas of regional shelf seas. The technological development led to much more efficient fishing in the open sea far from the coasts. The concern for this also leading to over fishing was corroborated in the 1960´s through decline of the herring stocks, partly due to over fishing. By that time the role importance of particular strong year-classes of fish for the annual yields also over some years had been demonstrated in the 1920´s. However, then as now the science had difficulties carrying the day in negotiations regarding the size and limitations of allowed catches.

A maturing phase for oceanography at the global scale

After the Second World War ocean research and observations gradually took off at global level, benefiting from the technological returns of the War. The international cooperation also grow over a period of 2-3 decades with increasing number of ocean scientists, ocean research institutions and acceptance of oceanography as a dedicated university study. A major motivation was basic, curiosity-driven science to learn about the ocean. International bodies for the cooperation were established and grow in numbers over the rest of the Century. At first however major support came from private sources. This was the case with the Swedish expeditions into the Mediterranean in 1946 with the Skagerack and around the world with Albatross in 1947-48. These were to a large degree based on new technologies. In particular the piston core development by my father Börje Kullenberg, making it possible to retrieve undisturbed sediment cores up to 30 m long, played a major role for the foundation of the expeditions. Analyses of the cores from the expeditions initiated paleo-oceanography and laid the ground for studies of past climate changes and triggered further interest in the plate tectonics and continental drift hypothesis. This together with other results of the Albatross expedition stimulated much further development of ocean research. The same was the case with the Danish Galatea expedition around the world 1950-52. In particular it applied the new carbon 14 method to obtain a global coverage of the ocean primary production. It also used the Albatross winch and my father´s calculations on wire resistance in streaming water for deep sea trawling to large depths. These firmly demonstrated the existence of a great diversity of life in the deep sea.

These and other results stimulated the creation of the Special Committee for Oceanic Research, SCOR of ICSU in 1957, and the Intergovernmental Oceanographic Commission of UNESCO in 1960. These two developments mark major achievements at the global level of the ocean science community. They confirmed the importance for society of ocean research and observations as well as acknowledging the need for government support with participation at a global level. They were achieved over a period of about hundred years.

Other major results included the explanation of the existence of the Gulf Stream and subsequently other western boundary currents. These are major features of the upper layer oceanic circulation, reaching up to about 1000 m depth. The Gulf Stream is coupled to the trades and the equatorial currents going from east to west, the closed Caribbean which forces the east moving water to turn pole wards, to the north on our half and the rotation of the Earth. This provides an apparent force, the Coriolis force, which varies with latitude, for zero on the Equator. The water being forced along the North American coast thus is subject to the change of rotation, vorticity, which it does not like. A compensation is needed, which is provided from the friction along the coast and shelf. The friction gives rise to a voracity opposite to the one given by the change of latitude from south to north. The result is essentially no voracity change, and the water package is happy. This model was formulated in equations and is confirmed. The implication is that the strength of the Gulf Stream can vary depending upon the strength of the trades and the equatorial current but will not disappear as long as the other forces remain. The Stream turns off the coast at about Cape Hatteras and takes a more easterly direction. This forces the North Atlantic Current which carries the relatively warm water towards Europe around our latitudes, with an extension northwards towards the Arctic on the eastern side along the Scandinavian coast. The strength and northward penetration of the warm water flow can be influenced by climate changes. During the cold periods it may weaken and during the extended ice ages it may be completely cut off. The frontal zones in the atmosphere and the ocean are then pushed southwards, and likewise the North Atlantic current with a direction towards the European continent at latitudes of Portugal.

Thus part of the upper layer, essentially wind-driven ocean circulation was explained. The influence of the warm water over such large distances depends on the heat capacity of the water. The distribution of heat in our climate system is very much dependent upon the water and its circulation. The memory of the water is much larger than that of the air. The ocean surface currents transfer heat towards the poles in amounts equal to that in the atmosphere. In the process the North Atlantic loses more heat to the atmosphere than it receives from the incoming solar radiation. This is compensated through a transfer pf heat from the Pacific and Indian Oceans to the Atlantic. The important connection between the ocean basins is through the Southern Ocean. There is a surface layer flow towards the north into the Atlantic from the Southern ocean originating in both the other oceans. Thus the heat balance is conserved in the ocean system. What about the water balance? The compensation flow from the Atlantic to the other oceans occurs through the deep and bottom water circulation. The waters of the ocean basins are interconnected through the Global Thermohaline Conveyor Belt. This combined upper and deeper layer, ocean circulation is driven by the heat and salt content of the water and their differences in space and variations in time. The warm surface layer flow reaches the northern latitudes of Labrador, Greenland and Norwegian Seas. During the way it loses heat to the atmosphere, but the major cooling occurs at the high latitudes. Evaporation also leads to it becoming a little more salty and both factors influence its density. In the northern seas it becomes heavier than the underlying water and sinks towards the bottom. Through this process the deep and bottom water in the ocean is formed, and mainly in the northern seas, coupled to the Arctic. The deep water formed there can only return towards the south, passing between Iceland and Greenland across the sill there and sinking into the deep Atlantic. It continues its path towards the south across the Equator into the South Atlantic and towards the other ocean basins. Thus the heat and mass balances are maintained. The Thermohaline process also explains the relatively uniform low temperature of 2-4 degrees of the ocean water below about 1000 m depth. The time scale of the circulation of a parcel through the Conveyor Belt varies between hundred and thousand years.

Much of this explanation of the ocean circulation has been confirmed through series of observations of various types of natural chemical tracers in the water. The refinement of sampling and measuring technologies over the decades has played a large role. It is also obvious that this scientific result could not have been obtained without cooperation, pooling of resources and large oceanographic institutions with considerable human and infrastructure resources. From a very few such institutions before the War, the number had increased considerably during the rest of the Century. In smaller countries like ours cooperation between the nations succeeded to compensate for the lack of size. We could thus participate in the global development, through both human and other resources. The scientific results and the political developments gradually led to the realization that the global cooperation be extended to include legal regimes.

Global recognition confirmzed

The recognition among governments of the importance of the marine resources and the need to ensure a reasonable distributed use of these resources together with an agreed intergovernmental governance mechanism for their exploitation, use and for settling disputes formed the basis for the development of the law of the sea. The initial attempts around 1950 were premature and did not produce satisfactory results. The process took off again following an evaluation of the importance for development and in particular the new States of the ocean resources produced by the new small island State of Malta. The evaluation was presented to the UN General Assembly by the ambassador of Malta, Dr Arvid Pardo, in the fall of 1967. This led to continued discussions at the UN level, and initiation of formal negotiations for the Law of the Sea in 1974. These resulted in an agreement for the UN Convention on the Law of the Sea in 1982. The new independent states following the decolonization after the War played a very large role for this achievement. It also stimulated their interest in ocean and coastal research and observations. The scientific community was strongly involved but was not always happy about parts of the development. This in particular concerned the freedom of marine research. However, sufficient compromises were found. In the end the establishment of the Exclusive Economic Zones up to 200 nautical miles from the coast line was confirmed and written into the Convention. This constitutes a very large transfer of natural living and non-living resources to the coastal states. It can be understood as a support to the development of many of the new independent states. It was based on demands due to the rich fisheries zones outside South America, in particular Chile and Peru which extended their fisheries zones 200 nautical miles from the coast. This was the origin of the EEZ. However the scientific discoveries of other rich resources in the zone including oil, gas, metals, diamonds and in many areas much living resources, supported the idea of an EEZ. The Convention, referred to as UNCLOS, entered into force in November 1994. Sweden ratified it in 1996. USA has so far not ratified it. The Convention also introduced the concept of the Common Heritage of Mankind (Humankind), and designated the sea floor and resources below it beyond national jurisdiction as the Area of the Common Heritage. This should not be confused with the traditional idea of the commons of a village on land, an area available for all in the village to use and abuse freely without accountability. The Common Heritage on the contrary includes rules and regulations for its use with a designated organization to manage it, namely the International Seabed Authority, of the UN system. This idea of the Common Heritage is based on the scientific discoveries and inventories already in the 1960´s of many valuable resources in the Area, and these should be available under responsibility for all states to benefit from.

The decade of the 1970´s was also dedicated as the International Decade of Ocean Exploration. This was based on the need to develop the ocean research and observation capabilities of all states to make it possible for them to benefit from the resources and the potential of the new Convention. International and institutional cooperation was a basic principle for the programmes of the Decade. The research programmes included a wide range of activities, from the global climate, geology, plate-tectonics to small scale mixing and frontal zone studies and distributions of phyto- and zoo-plankton and the function of the different ecosystems of the ocean. These included the coastal up-welling ecosystems where the very rich fisheries are found as those outside Chile and Peru. Cooperative pollution studies were also part of the Decade programmes, which included the biological effects of the polluting substances on living resources in the sea and on human health. The research concerning the deep sea floor led to the discovery in 1975 of the hydrothermal vents, first in the eastern Pacific. These are eruptions from the interior of the sea floor. They have subsequently been found in most ocean areas often associated with geological features as the boundaries between tectonic plates. The associated ecosystems are based on bacterial production of organic material. This feeds a number of living creatures from fixed attached animals to moving crabs. An ecosystem totally different from the one we are based on. The bacterial parts contain many elements which have turned out to have great potential for pharmaceutical applications and developments, including of antibiotics and potentially cancer curing products or cancer like infections, as well as for several other applications potentially useful in production processes. The related sampling, analyses and processes are the focus of large research and development efforts. This involves leading institutions from USA, China, South Korea and Japan. The parts in the ocean included in the Area of the UNCLOS are presently subject to both much research and negotiations for an addition to the Law of the Sea or the Convention on Biological Diversity or even a separate convention.

Research results related to the climate change problem

The role of the ocean in the climate system continues to be a central research subject through- out the whole period. Early on climatologists and meteorologists did not think the role of the ocean was really significant. Most initial climate models only included the ocean as a bottom boundary layer. This has changed since the 1990´s, together with the increasing understanding of the deep ocean circulation and its importance in transfer of heat and freshwater. This includes the deep water formation process at high latitudes, in particular the Northern North Atlantic and the Arctic and its role in the Thermohaline circulation as indicated earlier. This depends on the density of the water which is determined by its heat and salt content. These properties vary with the exchange of heat and water, evaporation and precipitation, with the atmosphere, whiand distributes it trough the ocean circulation together with the long memory of the water.ch is much depending upon the latitude. The temperature of the surface water also plays a large role in the exchange of other gases with the atmosphere, including oxygen and carbon dioxide. Warmer water takes up less of both gases then colder water. The ocean provides many services to our climate. It takes up over 90 % of the additional heat in the atmosphere due to the increased green-house effect. The warming leads to a change in the distribution of evaporation and precipitation, which influence the salt distribution and the density of the surface water. We can then expect a change in the deep water formation amplitude at least and the Thermohaline circulation. Observations have been obtained which indicates a change in the mass transport of the flow of deep water from the Arctic area. However, it is still not proven beyond doubt how much it may be or the larger implications. A second very important service of the ocean is its uptake of carbon dioxide. It takes up in the range of one quarter to one third of the additional carbon dioxide injected into the atmosphere from our fossil energy sources. This leads to an acidification of the ocean water due to the transformation of the carbon dioxide into carbon acid. This has very serious consequences for the ocean ecosystems, in particular the coral reefs and the shell forming resources as crabs, mussels, lobster, due to the dissolution and decrease of carbonate ions in the water. The warming of the water leads to less uptake of carbon dioxide, less oxygen in the water and an increased rate of oxidation with faster consumption of the dissolved oxygen. The resulting gradual deoxygenation of the ocean waters is currently subject to much research as regards the rates and the implications.

As an example research results from the use of high-resolution sediment cores with records covering the past 1000 years from the central Baltic, the Gotland Basin, in combination with ecosystem modeling are presented (Kabel et al 2012). These results elucidate the situation of the Baltic Sea ecosystem during periods of climate oscillations from the warm Medieval Climate Anomaly about 950-1250, to the cold Little Ice Age about 1350-1850, and to the current Modern Warm Period from about 1900. The natural temperature differences have been established to be about 2 degrees, from warm to cold and back to warm. Presently the on-going warming is mainly related to non-natural additions of greenhouse gases from our global society. The research shows the temperature increase in the Baltic surface layer on basis of paleo thermometry (TEX 86) to be at least 2 degrees C. from the Little Ice Age to the Modern Warm Period. In parallel with the warmer period the anoxic areas in the bottom water of the central Baltic began to expand. This is shown in the accumulation of laminated sediments with high levels of Total Organic Carbon, TOC. During the cold period the sediments were homogeneous with low levels of Total Organic Carbon. It thus appears that the warm sea surface triggers anoxia. This is shown to be related to an increase of blooms of cyano bacteria, blue green algae. The spread of such blooms related to an increase of the sea surface temperature has been observed world wide. Up to around 1900 the SST in the Gotland Basin was less than 16 degrees, going down to around 14 degrees around 1840. During the Medieval Climate Anomaly 950-1250 laminated sediments with high levels of TOC were present in the sediments, and the SST was about 2 degrees higher than during the subsequent cold period. Pigment studies showed occurrence of cyanobacteria blooms also during the warm Medieval Climate Anomaly. During the present warm period higher diatom productions are also shown in the sediment records, but these are likely due to nutrient inputs from land runoff. The modeling presented in the study showed high spread of anoxic deep waters for the modern Baltic. However, when the model was run with the low SST and nutrient inputs similar to about hundred years ago, corresponding to the cold period, the results showed well oxygenated deep water with minimum oxygen levels of about 5 ml per liter. Model runs with high nutrient loads as presently found but with the low SST showed high oxygen content in the deep waters. This result can be seen to confirm the importance of the high SST having a strong effect on the occurrence of cyanobacteria blooms. Other regional climate change studies also show increase of SST similar to the one found in the Baltic. The implication for management of the Baltic problem of deoxygenation seems to be that the decrease of nutrient inputs must be much more drastic than so far in order to have the desired effect. The increase of the SST seems to be the dominant factor.

Other aspects of the role of the ocean in the climate system and implications of the changes were given in my presentation at Strömstad in 2019. Let me only here recall the change of the sea level due to the warming in combination with the runoff from melting glaciers and the continental ice sheets of Greenland and the Antarctica. The rate of the sea level increase has changed from about 1 mm per year in the middle of the last century to about 5 mm per year at present. The rate is likely to increase further. It is also to some extent depending upon the regional situation, such as continental rise or subsidence. This in particular is of great concern for several coastal mega cities, in the Americas and in Asia. We do have a sea level problem, also in our country along parts of the west coast and in the south. Careful planning of the use of low lying coastal areas is required to avoid future disasters or disruptions. In some areas coastal protections are needed, and are being undertaken already. Due to the uplift of parts of northern Scandinavia the sea level rise is so far compensated there.

Risk reduction

Important results of ocean research and observations are also evident in the service of risk reduction. These services concern warnings of tsunamis, cyclones, storms, flooding and storm surges, and also other events as harmful algal blooms, all hazards originating from the ocean and of great potential consequences for many land areas, population centers and various uses of the coastal areas. The tsunami warning system is based on sensors mounted on the sea floor feeling under water volcanic eruptions, and transmitting the signal to receiving centers. The eruptions can generate a wave action through the pressure wave in the water. Such a long ave moves with a speed of square root of gH in deep water with g the gravity and H the water depth. This means speeds of up to 200 m per second in 4000 meters depth. The wave is barely noticeable in the deep open ocean. However, when approaching shelf seas and the coastal zone the wave height increases proportionally to the depth. At the shore line the incoming wave can be noted through an initial withdrawal of the water line on the beach, the water is like sucked out. This does not last long but can safe lifes of people on the beach if observed. The warning system however is based on the signal from the sea bed eruption and the analysts at the receiving center. The staff there can issue a warning for a tsunami for the appropriate zone or region. The recipients of the warning then have a very limited time to react, order of hours or less. Training is needed to be able to use the warning in a useful way. This service was initiated by the USA for the Pacific following a couple of deadly tsunamis in the 1960´s. A warning center was established in Hawaii. It was in 1965 transformed into an international tsunami warning center, under the auspices of IOC of UNESCO and

ICSU. During the following decades several attempts were made to expand the warning system to include other ocean regions beyond the Pacific. However, Governments in the concerned regions were not inclined to support such a development. It was not until after the tsunami in December 2004 that there emerged support from Governments to proceed establishing the warning system with installment of necessary sensors and other equipment, under the auspices of the United Nations. The IOC of UNESCO was requested to take the lead to implement the action. Now there are functioning, tested systems in several other regions. The approach used for the development in the Pacific has been employed. A similar process has also been applied to build warning systems for other hazards originating from the ocean which can be reasonably forecasted on bases of reliable observations and observing systems, such as cyclones, storms, surges, seiches, floods. These can all give rise to inundation of water and sea level rise variations at the coast, of several meters. The waves can have large impacts on life and infrastructure. The warnings are normally issued through the meteorological or other appointed national services. In most cases a national or regional hazard warning center is established, with support from the regional Governments.

Nutrition from the ocean

Finally some attention should be given to the important role for our nutrition from the marine food produce. It was this concern that initiated the international research cooperation. What has the research subsequently provided in this respect? The nutrition research has confirmed the importance of sea food for our health and development. How much consumption of sea food during our migration from Africa has contributed to our brain development remains as far as I can note to be appreciated. Concern for over fishing in restricted areas was one of the motivations for the development of international regional ocean surveys. Presently most of our traditional species are over fished or close to that level of exploitation. Only about 15-20 % is still on the more safe side. The fish are also influenced by the environmental conditions. The species and populations are influenced by the change of temperature. The warming leads to migration of the fish to areas where they find the temperature they are used to. The migration to other areas is of great concern for the fisheries since it leads to the fisheries also shifting into new areas, possibly under a different national control. This process may lead to conflicts between the fishing nations. The fish are also depending upon the food. This may be other fish and larvae as well as phytoplankton and zoo-plankton. Production at this level of the right species plays a large role for the fish populations. The ocean research has elucidated the interrelation ships. Variations of abundance can depend upon oscillations over decadal time scales across ocean basins, as in the case of anchovy fisheries in the Pacific, variations in coastal up welling as in the Pacific during El Nino events or in the Indian Ocean during shifting in time and intensity of the south-west monsoon. In many regional seas the nutrient balances have been changed from the naturally occurring ones due to transfer from land of fertilizers. This change has led to a change in species of plankton available for the higher levels. The warming of the surface layer has led to a shift as well to a predominance in some regions of the cyanobacteria. The on-going changes in physical conditions in the open ocean influencing the availability of nutrients in the near surface layer has led to a decrease of primary production in these areas for instance in the Pacific. Fluctuations have been recorded in the Atlantic of the production through repeated north-south sections with a plankton recorder, in use since before the War, providing multi decadal time series. Long time series of observations using the same methods, or when changing them ensure intercalibration with the previous ones, are a prerequisite for identifying fluctuations and seeking explanations, which may lead to identifying the forces and their sources. An important problem in this connection is to separate natural from man-induced forcing, and separate fluctuations from long-time changes. The ocean science community has since the end of the 1800´s provided advice to the fisheries industry and the related decision and policy makers on the yields of various species. Uncertainties are large, and there are many difficulties.

An example: herring fisheries at the west coast and the North Sea

The variations of the herring at the Swedish-Norwegian west coast may demonstrate this. From about 800 we know that periods of 20 to 60 years length with very rich herring fisheries were interrupted by much less yields (Höglund 1976). Until about 1900 the fisheries was bounded to the coast in fjords and bays, and the herring may have been found much further out at sea. The technological developments at the shift of the century and further on provided for a much more efficient fisheries, including the search for the fish. The increasing fisheries led to over fishing. It threatened a destruction of the north European herring. The hypothesis of periodicity in the appearance of the herring was launched in 1879 and was related to the periodicity of sun spots. However later research has disputed this idea. Herring periods have certainly occurred but their periodicity cannot be confirmed. The periods of rich fisheries have had an important influence on the development of the region, exemplified by the establishments of Marstrand and Dragsmark monasteries in 1100 and 1200, and population on some of the islands along the coast. The latest period was 1877-1906. In November 1877 the herring suddenly entered the archipelago. The population was not prepared except some of the fishermen. They had available nets for fishing from the land. However, from 1903 the fisheries benefited from boats with motors, leading to catching the fish in the open sea. The herring trawl was introduced in 1910-1911. The herring came into the Skagerack around mid-November and left for the North Sea in March-April, and the first Skagerack period of herring fisheries extended into the 1920´s. The herring originated to about 70-80 % from the North Sea, and the rest from Skagerack and Kattegatt. In the early 1920´s the yearly yield decreased to one quarter or even less compared to previous years. The full grown North Sea herring did not enter the Skagerack during the winter period, and it kept away for about 2 decades. It came back in the winter 143-44 and the new rich fishing period lasted 12 years. During this period fishermen from Bohuslän in 1945 started fishing in the North Sea at Fladen Ground with bottom trawling; in Denmark a different technology was used "parflyttrålen", and the Danish fisheries became a competitor. During the years 1963-65 the herring again invaded Skagerack giving large catches, with up to ten nations participating in the fisheries during the winter of 1965. This led to large over fishing, and no such rich fishing period had returned by the last decades of the century. Which natural process provided the high yields? The large importance of strong year classes for the rich fisheries has been shown by the Norwegian Johan Hjort in the 1920´s and later by the Swedish K.A. Andersen in his paper from 1958. He showed that a strong year class from 1937 supported a rich herring fishery in the Kattegatt, the Sound and the Southern Baltic. This continued there during the whole War and the years immediately after (K. A. Anderson 1958). He has also proved the importance of rich year classes for the good fishing years 1912 and 1913, 1916-1920, and that during years of low fisheries there were no strong year classes, namely 1922-26, 1930-31 and 1935-36 (K. A. Anderson 1942). Clearly this research required reliable data over all the decades.

Some conclusions

The fisheries-related research has provided advice to fisheries management for over a century. The advice provides estimates of allowable catches to help ensure maintained healthy stocks. The decisions on quotas for different species and nations, and restrictions in time and space for the fishing is however made through negotiations involving many interests and taking into account many social, political and national interests. The way the scientific results and advice is communicated to the users is very crucial. Scientists are not normally good at this. Special education for this part of the process is needed, and the involvement od social sciences, including political sciences, as well as economics, in order to help achieve the desired results in the negotiations. The required dialogue between different interests is often not catered for. Ocean research has now reached this insight, and is becoming more interdisciplinary and multidisciplinary, which is needed to address the multi-dimensional threats to the ocean, partly induced by our society. Ocean research is expensive, and there is an interest to address national priorities. This has become more clear over the decades. Initially the research was curiosity driven basic research. Presently much of the research is directed towards solacing socially important problems and is implemented through national agencies rather than purely science-based institutions. There is then the need that the research results be transferred into applications and that science-based solutions to the problems are understood and accepted by the policy and decision makers as well as the general public. However, the application of the research results may be limited by the understanding of the relevant agencies and other users of the research results, lack of communication between the communities and missing ability to reshape the results to actually solve the problems at hand. Ideally the users need a training similar to the scientists and they in turn need a training similar to the users. This ideal may to some extent be achieved by exchanges and through the involvement of some special people, having the right inclination. In any case communication and dialogue is needed to build trust and understanding. The adaptive management approach is one important step. The research community should be able and willing to communicate their results to others in a generally understandable mode. Often these transitions depend upon some critical people in the various communities of researchers, industries and national agencies as well as among policy makers. The barriers between the communities are often cultural and social and based on preconceived inclinations. The ocean research community has demonstrated abilities to cooperate and coordinate between disciplines and institutions. This is shown through the large programmes as the World Climate Research Programme, the Joint Global Ocean Flux Studies, the Coastal Up welling Ecosystem programme and the success of the International Decade for Ocean Exploration, the building of the Global Ocean Observing System and the Ocean Hazard and Risk Reduction Programme. The ocean research community has reached a level of capacity and maturity required to meet the demands of the UN Ocean Science Decade and the response needed to address the multitude of threats to the ocean.

Keywords: *climate change; ocean research, observations and changes; impacts, effects and responses; technology, dynamic modeling*.

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Abbreviations

ICSU International Council for Science Unions

EEZ Exclusive executive zone

SCOR Special Committee for Oceanic Research

UNCLOS United Nations Convention of the Law of the Sea

UNESCO United Nations Educational, Scientific and Cultural organization