Chronicle

New Challenges for North Sea Research – 20 years after FLEX ′76

(Summary, results and conclusions of the International Symposium)

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Abstract

The present state of North Sea research was assessed and examined at an International Symposium in Hamburg. Specific attention was devoted to the issues of external forcing, internal dynamics, and new methods and experiments. In the concluding discussion Grand Challenges for North Sea research were formulated.

1. Introduction

The International Symposium *New Challenges for North Sea Research – 20 years after FLEX ′76* took place in Hamburg from 21 to 23 October 1996 under the auspices of the European Commission (EC) and the International Council of the Exploration of the Sea (ICES). The abstracts and proceedings have been published in two volumes:

- Berichte aus dem Zentrum für Meeres- und Klimaforschung, Reihe Z, Nr. 2, Hamburg 1997, 281 pp.
- Deutsche Hydrographische Zeitschrift, Vol. 49, Nr. 2/3, Hamburg/Rostock 1997, 451 pp.

The editor-in-chief of *Oceanologia* suggested that a summary of the Conference should also be published in this journal, for the conclusions are relevant for Baltic Sea research.

2. Background

The North Sea and the surrounding coastal area is an economic centre and home to around 100 million people from eight highly developed countries of northwest Europe. Its diversity and its sustainability have a high political, economic and social value both for the riparian states and the European Union. This is the case at present and will not change in the future.

A necessary basis for an environmentally sound treatment of the North Sea is the scientific understanding of the structure and functioning of this marine system with its physical, chemical and biological components. Considering its tremendous importance for society, North Sea research is an integral part of many national research programmes and of those of the European Union.

The North Sea is thus one of the most intensively investigated shelf seas on Earth, and its scientific exploration is an example for similar regions in other parts of the World Ocean. This fact, however, should not lead us to neglect further analysis and modelling of this marine system. There are still questions of vital importance to society to be answered by scientists, such as: To what extent are the observed changes in the North Sea definitely due to external causes, *e.g.* human influence, and to what extent are they a manifestation of natural variability? Or: What will be the ecological status of the North Sea in the next century if the current burden of environmental stress continues? The present high level of North Sea research is a good foundation for taking up these questions and for setting an example for other environmentally stressed shelf seas.

The symposium served as a forum for examining our present state of knowledge about the North Sea system and for using it as a basis for developing perspectives for further research. On the one hand, existing global initiatives for studying the World Ocean, *e.g.* LOICZ, GEWEX, CLIVAR, GOOS, GLOBEC, were to be taken into account. On the other hand, it was to be an open discourse among European experts, beyond the sphere of current research policies, for the purpose of developing visions which could be realised in future international and national research programmes and projects. These discussions were stimulated by the desire to formulate current Grand Challenges in North Sea Research and the field experiments that they would entail.

The now classic Fladen Ground Experiment (FLEX) of 1976, a joint European effort that brought significant impetus to North Sea research, served as a take-off point for the discussions.

3. The Symposium

Keeping in mind the changes in the North Sea and their potential causes, the programme of the symposium was divided into two main theme groups, *External Forcing* and *Internal Dynamics*. In addition, there were sessions on new research methods and a final discussion to synthesise the results.

A External forcing

1 Interaction with the atmosphere

2 Interaction with the North Atlantic Ocean

3 Interaction with the Baltic Sea

4 Interaction with the land

B Internal dynamics

5 Stratification, fronts and meso-scale features

6 New developments in biological oceanography

7 Interannual and decadal variability

8 Benthic processes

9 Morphodynamic evolution

C New methods and experiments

10 New observational techniques

11 New modelling techniques

12 Synthesis and ideas for a new experiment

In all, there were 44 oral presentations and a poster session with 40 contributions.

The symposium was supported financially by the German Federal Ministry of Education, Science, Research and Technology, the German Research Council and the European Union, DG XII. The International Council for the Exploration of the Sea (ICES) gave notional support.

138 persons from seven countries attended the symposium.

4. Results

The speakers, the chairpersons and other participants formed a representative cross-section of European expertise in North Sea research. In this respect, the contents of the presentations, the assessment of

knowledge and research deficits as well as the impetus for future programmes can be regarded as characteristic from national and international viewpoints. In the following, the most important results of the individual sessions will be summarised, synthesised and evaluated.

In the session *Interaction with the atmosphere* there was a consensus that the dynamics of the North Sea and the fluxes of matter are decisively influenced by weather and climate as well as by atmospheric emissions. Meteorological components must therefore form an integral part of North Sea research. Important research deficits were seen in the emissions from seawater into the atmosphere, *e.g.* ammonia, fluxes of organic micropollutants as well as quantitatively exact energy budgets.

The *Interaction with the North Atlantic Ocean*, particularly with its current and climate system, is the main cause of decadal variability in the North Sea. Natural variability on the scale of years to decades in the circulation, in the heat and freshwater budgets, and, to some extent, in the populations of planktonic and benthic organisms as well as in fish stocks is caused by oscillations in the Atlantic ocean/atmosphere system. The transport mechanisms between the Atlantic and the North Sea over the shelf edge have not been sufficiently clarified in models and observations.

The *Interaction with the Baltic Sea* is not of the same importance for the entire North Sea, but it is of great significance for the circulation and the ecosystem in the Skagerrak area and the Norwegian Coastal current. Since the major outflow from the North Sea occurs in this region, the system as a whole is influenced. This lends weight to the demand for coupled Baltic/North Sea models.

The *Interaction with the land* is predominantly directed seawards. It manifests itself in the natural and anthropogenic inputs of matter (freshwater, suspended particulate matter, nutrients and contaminants) which occur via the water and air pathways. The main emphasis of current research is on the mesoscale dynamics and the carrying capacity, or time-lag function, of the estuaries, the Wadden Sea and coastal areas. Regional atmospheric models show that there are significant deviations from the large-scale air circulation in this transitional zone that have a decisive influence on coastal processes.

The significance of the theme group *Stratification, fronts and meso-scale features* for the global scale in the North Sea emerges from the fundamental processes of mixing, convection, upwelling, production and decomposition, deposition and re-suspension which occur on this scale. These in turn are influenced by small-scale processes (turbulence, internal waves and biological turnover), which are resolved neither in field experiments nor in model calculations. The main problems lie in the transition from the smaller

to larger scales (parameterisation, bulk properties) and in the classification and combination of different time scales for physical, chemical and biological parameters in observations and model simulations.

The session *New developments in biological oceanography* reflected the dualism of the classical food chain models controlled by primary production on the one hand, and the research into the reaction potentials of all populations belonging to an ecosystem on the other. For decisions on successful research strategies, comprehensive synoptic data sets on the dynamics of regional systems are lacking. The present view is that these should concentrate on 'key species' for the North Sea and include all developmental stages and components.

Interannual and decadal variability of the marine system is of such current interest in society and science because it is on this scale that the changes perceived in our surroundings occur (Global Change). The basic structure of the symposium, *External forcing and internal dynamics* culminated in this topic. The external forcing consists of the effects at the outer boundaries of the North Sea and the anthropogenic influences on the system. The occurrence of decadal variability as a result of the combined effects of external and internal factors, of physical and biological components, of the accumulation of short-term and regional events, modelling and, finally, its prediction is one of the greatest challenges in North Sea research.

In the session *Benthic processes* it became clear that the role of the benthos in the North system, particularly in pelago-benthic coupling, is not adequately understood. There is a lack of field data as well as model development. This is one of the most pressing needs with regard to the determination of fluxes of energy and matter in the North Sea and their budgets, for which it is not sufficient to consider only physical and geochemical processes. Moreover, the structure and the functioning of the various trophic levels in the pelagic and benthic system must be taken into account, here again with respect to key species.

Morphodynamic evolution applies to the entire North Sea, but it is only in the coastal regions that it is of practical interest. In these regions, however, there is an acute sensitivity to this aspect, as was demonstrated by the media reaction to the example of the fate of the island of Sylt. This theme group highlights the accumulation of the effects of small-scale processes (tides, waves, storm surges, coastal constructions) on long-term trends that are of vital importance to people living on the coast (changes in the coastline and shipping lanes). It is a matter of highly complex interactions between hydrodynamic, sedimentological and biological processes, which have been neither adequately observed nor modelled. At present, only

simple statistical and empirical-conceptual models are available for practical forecasts. The three-dimensional prognostic simulation of morphodynamics is a great scientific challenge.

New observational techniques which have been developed in the twenty years since FLEX ′76 can provide novel types of data sets and open up possibilities for new measurement strategies. Of primary importance is the integration of field and model data. New probes are capable of measuring turbulence parameters directly and with high resolution, making them finally available for physical and biological models (diffusion coefficients, microscales). There are still deficits with regard to long-term data sets at fixed positions (decadal scale) and the automation of chemical and biological sampling.

The session on *New modelling techniques* demonstrated the high standard of hydrodynamic and thermodynamic modelling of the North Sea. Current fields as well as temperature and salinity distributions can be calculated immediately with high temporal and spatial resolution as soon as the necessary forcing at the atmospheric and seaward boundaries is established. Usually, these are calculated using large-scale models with less resolution. The physical North Sea models are now at a stage where they can be applied to other shelf seas. New challenges are seen in the coupling with models for the Atlantic, the atmosphere and biological processes. Computer capacity still limits basin-wide three-dimensional resolution of baroclinic eddies and smaller scale processes. Ecosystem models are at an even less advanced stage. Today, they are capable of describing the order of magnitude of mass turnover but not the seasonal dynamics. Large data sets for nutrients and the lower trophic levels are still needed for the validation of ecosystem models.

After the conclusion of the scientific sessions, discussion concentrated on *Synthesis and ideas for a new experiment*, beginning with short statements by the advisory committee and the keynote speakers. This final discussion concentrated on three questions:

- What is the Grand Challenge in North Sea research within the next decade?
- What is the most appropriate research strategy?
- Do we need a new big experiment? If so, which one?

There were many valuable and interesting contributions, but it was not possible to come up with clear-cut answers – at least not in the 90 minutes available to the nearly 100 participants present, which is understandable. The result is more a generally accepted catalogue of suggestions regarding the substance and strategy of future North Sea

research and the appropriate experiments. It is now necessary to set priorities among the pressing questions and to develop one – or several – Grand Challenges for interdisciplinary projects at the European and national levels. Important future tasks are:

- Forging stronger links to the societal needs of our time (Agenda 21), such as climate change, biodiversity, operational oceanography (GOOS), fisheries, protection of marine habitats, reduction of contamination, sustainable use and coastal management.

- Gaining more knowledge about interannual and decadal variability and their causes.

- Modelling of the interactions between the physical and biological components of the marine ecosystem.

- Development of prognostic models for predicting the marine ecosystem and coastal morphodynamics on a decadal scale, including episodes and extreme events, scenario calculations.

- Investigating the interactions between the North Atlantic Ocean and the North Sea.

- Stronger consideration of key species in biological modelling in contrast to the food chain approach.

With regard to experiments the following suggestions were made:

- Identification of key regions with regard to external forcing (shelf edge, Skagerrak) or to process studies (German Bight, Fladen Ground).

- Long-term observations at selected sites on the northwest European shelf (GOOS, moorings, regular profiles) together with short, process-oriented field experiments with comprehensive, high-resolution measurements of the ecosystem.

- Harmonisation of European and national experiments.

Finally, there was agreement that, in spite of research deficits, our knowledge should be exported to other shelf seas, particularly in the East Asian region. This would benefit both sides.

5. Conclusions

In spite of the diversity of suggestions and viewpoints, which ranged from science to socio-economics, from the specific to the general, analysis and synthesis yields the following conclusions:

(1) North Sea research serves and is funded by society. Grand Challenges must be oriented towards the 'political agenda'. They should formulate important scientific questions arising out of the societal context.

(2) Taking this background into consideration, the following Grand Challenges were formulated for the North Sea:

- The interactions between the North Atlantic and the Northwest European shelf. This topic has particular relevance for questions on climate change and its effects on the North Sea ecosystem. It requires a (previously non-existent) synthesising approach to the ocean and its marginal sea, concentrated field measurements at the shelf edge and innovative coupled models on the global and regional scale for ocean and atmosphere.

- The interactions between the physical and biological subsystems of the Northwest European shelf. This topic particularly concerns biodiversity, fisheries, protection of marine habitats, in short, the 'health' of the North Sea. It requires development of new, coupled physico-biological models that are capable of resolving the marine ecosystem hierarchically, from interannual variations to seasonal processes and key species.

- Integration of routine field measurements, remote-sensing data and model calculations into an operational system for marine now- and forecasting. This topic applies to monitoring, sustainable use and management of marine resources. Its expected output will be software packages for the optimal monitoring and management of the shelf waters.

(3) It seems self-evident that these Grand Challenges should best be pursued within both the European and national frameworks in a harmonised division of labour. Great Britain and the Netherlands will probably concentrate a great deal of effort on investigating the interactions with the Atlantic, in particular on the fluxes at the shelf edge. The topic of interactions between the physical and biological

components in the North Sea System on scales from days (events) to years (decadal variability and global change) on the basis of validated coupled models could be a focal point for Germany (perhaps also Belgium, Great Britain and Norway). The theme area of operational forecasting and management is already being emphasised in the MAST-programme of the EU and will also be concentrated on in national EURO–GOOS projects.