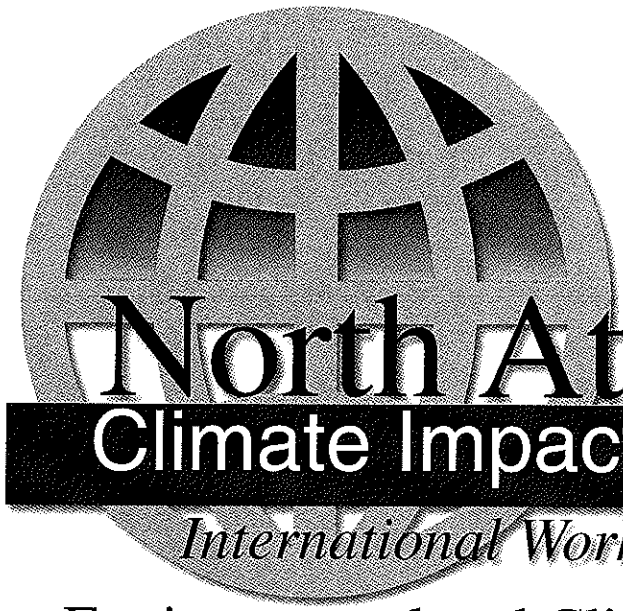


International Workshop on

Environmental and Climate Variations and their Impact in the North Atlantic Region

Reports of Ad-hoc Groups

North Atlantic Climate Impacts

International Workshop on Environmental and Climatic variations and their Impacts in the North Atlantic Reykjavik, Iceland

September 23.-26. 1998

Reports of Ad-hoc groups

Workshop Theme

The International Workshop on Environment and Climatic Variations and their Impact in the North Atlantic Region was organized by the Icelandic Research Council in co-operation with the National Science Foundation of the United States and the European Commission, Directorate General XII, Science Research and Development. Its was supported financially by a grant through the Icelandic Ministry of Education, Science and Culture.

During recent decades marked changes have taken place in the physical environment of the North Atlantic Ocean and these have had profound ecological consequences and socio-economic impact. Historical and paleoclimatic records indicate the periodic changes in the environment over decades or even centuries, sometimes on a large scale, are the rule rather than exception. Indication of some oscillatory regularity exist. The economic and social impacts of these variations in earlier centuries have often been quite dramatic. Being able to understand them and even partly, predict their progress over time would have important economic and social implications for the countries of the North Atlantic Region. It is also a prerequisite to understand global change processes and assessing the consequences.

The Workshop Objective

The workshop dealt with the following topics:

- *Physical and climatic variations in the North Atlantic on decadal to century time scales.*
- *Dynamics of biological systems and possible links to physical and climatic forcing.*
- *Prediction and regional impact assessment.*

100 scientists attended the workshop from 12 countries. The outcome of the workshop is presented in the summaries of key scientific issues that were identified.

The International Organizing Committee

Dr. Vilhjálmur Lúðvíksson
Director of the Icelandic Research Council

Dr. Michael Reeve
Head, Ocean Sciences Division, directorate for Geoscience, National Science Foundation

Dr. Ib Troen
Principal Scientific Officer • Climatology and Natural Hazards • European Commission, Directorate General XII

The Local Organising Committee

Dr. Vilhjálmur Lúðvíksson
Director of the Icelandic Research Council

Dr. Halldór Þorgeirsson
Head of International Affairs, Ministry of the Environment

Dr. Árný Erla Sveinbjörnsdóttir
Research Scientist, The University Science Institute

Professor Jón Ólafsson
The University of Iceland

Dr. Ólafur S. Ástþórsson
Research Director Environmental Section, The Marine Research Institute

Dr. Þór Jakobsson
Research Scientist, The Icelandic Meteorological Office

Dr. Kristján Kristjánsson
Assist. Director for Science, The Icelandic Research Council

North Atlantic Climate Impacts

International Workshop on
Environmental and Climate Variations and their Impact in the North Atlantic Region.

Grand Hotel Reykjavík 23.-26. September 1998

Workshop Schedule

September 23rd

08:00-09:00	**Registration**
09:00-10:30	**Opening session. Chairman: Þorsteinn I. Sigfússon, IRC Iceland**
09:00-09:10	Welcome note - Vilhjálmur Lúðvíksson, IRC Iceland
09:10-09:20	Address by the Icelandic Minister of Science, Education and Culture **Mr. Björn Bjarnason**
09:20-10:10	**Keynote lecture - overall concepts;** *Atlantic Variability and Global Change.* **Robert Dickson, Lowestoft, UK**
10:10-10:30	Coffee
10:30-12:30	**1st session. Chairman: Christian Patermann,** **European Commission - DG XII - Science, Research and Development**
10:30-12:00	**Physical and climatic variations** • *Sea ice production and convection in the Odden ice tongue region of the Greenland Sea-* Peter Wadhams, Scotts Polar Research, UK • *Sea-Air Flux of CO2 over the North Atlantic-Nordic Seas-* Taro Takahashi. Lamont Doherty, USA • *Past, Present, and Future Glacier Fluctuations in Iceland: A Response to Climatic Variability in The North Atlantic.-* Richard S. Williams Jr., US Geological Survey/Oddur Sigurðsson, The National Energy Authority, Iceland
12:00-12:30	**Discussions**
12:30-14:00	Lunch
14:00-17:30	**2nd session. Chairman: Michael Reeve, NSF, USA**
14:00-15:30	**Biological response to environmental forcing** • *Time-space scales of zooplankton variation in the North Atlantic: the climate connection-* Peter Wiebe, Ann Bucklin, WHOI, USA • *A Sceptical Review of Climate Variation on Fish Populations* Ransom Myers, Dept. of Fisheries, Canada • *Growth in Plankton and Fish Stocks in Relation to Interannual to Decadal-Scale Climate Fluctuations - Examples from the Nordic Seas* Svein Sundby, Marine Res.Inst., Norway
15:30-16:00	Coffee
16:00-17:30	**Discussions**
17:30-19:00	Reception and Poster Exhibition

September 24th

09:00-12:00 **3rd session. Chairman: Peter Lemke, Inst. für Meereskunde**
Paleoclimate of the North Atlantic

09:00-10:30
- *The North Atlantic Ocean and Climate Change: Is The Ocean Circulation Unstable? Past and Future Perspectives.*
  Eystein Jansen, Univ. Of Bergen, Norway
- *Paleoclimates from deep ice cores North and South-*
  Árný E. Sveinbjörnsdóttir/Sigfús Johnsen, Univ. of Iceland, Iceland
- *Ice extent and late Quaternary stratigraphy, chronology and North Atlantic paleoceanograph; East Greenland and Iceland margins, Denmark Strait*
  John Andrews, INSTAR, Colorado, USA

10:30-10:50 Coffee
10:50-12:30 **Discussions**
12:30-14:00 Lunch

14:00-17:30 **4th session. Chairman: Alfred M. Beeton, NOAA, USA**
14:00-15:30 **Impact on resources and the economy**
- *Relation between environmental fluctuation and fisheries management* - Jakob Jakobsson/Hjálmar Vilhjálmsson, Marine Research Institute, Iceland
- *Impact of Environmental Changes and Fisheries Management.*
  Alain Laurec, European Commission DGXIV, EU
- *An Interdisciplinary Focus on Norse Greenland: Data from Multi Proxy Records.*
  Astrid Ogilvy, Associate Director, IAAR, Colorado, US

15:30-15:50 Coffee
15:50-17:30 **Discussion**

September 25th **Scientific excursion**

September 26th
09:00-12:30 **5th session. Chairman: Michael MacCracken, USGCRP, USA**
09:00-10:30 **Predictive capability - Integration and modelling**
- *The simulation of North Atlantic climate variability in coupled general circulation models* - Chris Gordon, UK. Met. Office, UK
- *The general circulation, thermodynamics, and biogeochemistry in the North Atlantic simulated by an isopycnic coordinate ocean general circulation model-* Helge Drange, Nansen Env. Remote Sensing Center, Norway
- *Decadal variability in the North Atlantic-* Sirpa Hakkinen, NASA, US

10:30-10:50 Coffee
10:50-12:30 **Discussion**
12:30-14:00 Lunch

14:00-17:30 **Closing session Implication for the science agenda of the next decade**
Chairman: Halldór Thorgeirsson, IRC, Iceland

- The main issues
- The concepts for cooperation
- Implementation and financing issues (views from the European Union, NSF and other funding bodies)

Discussion

Conclusion - Closing remarks

Farewell Banquet

TABLE OF CONTENTS

1st session:
Physical and climatic variations

The main issues:

1. **Improving the description and understanding of decadal climate variability in the North Atlantic, Nordic Seas and the Arctic Ocean involving the North Atlantic Oscillation (NAO), its possible forcing mechanisms and its interaction with the ocean circulation.**

A. **As the ocean's response to long-period amplification of the NAO in the 20th C seems to have different global change implications in each relevant area. Issues requiring particular attention include the following:**

(i) **In the open North Atlantic**
Does the variable production, advection, transformation and feedback of subtropical and subpolar mode waters (which are coordinated by the NAO) cause long-period changes in the NAO itself?

(ii) **In Nordic Seas**
May warming and freshening due to the amplifying NAO pass south in the regional circulation alter the hydrographic character of the Denmark Strait Overflow and thus, potentially, the global thermohaline circulation?

(iii) **In the Arctic Ocean**
Might the warming and spreading of the Atlantic-derived sublayer coupled with the loss/retraction of its insulating Cold Halocline Layer (CHL) in the Eurasian Basin lead to a loss or thinning of the sea ice?

B. **Data required for research on the main issue:**

Continued/expanded monitoring of the following types and sites is needed:

* Mode water characteristics at the main convective centres of Labrador, Greenland and Sargasso Seas;
* An Atlantic "Dec-Cen Array" of (not less than) 7 bottom-parked profiling CTDs during WCPP CLIVER;
* A measure of the amount and character of Atlantic inflow actually entering the Arctic Ocean (i.e. N and E of Svalbard)
* Decadal changes in the hydrography and transport of the Denmark Strait overflow;
* Continuation of long-term standard hydrographic sections in sea areas concerned;
* Monitoring of ice thickness in the Arctic Ocean and the fluxes between the Arctic Ocean and the North Atlantic.

2. **Improving the understanding of interdecadal variability and the possibilities for sudden climate change associated with the thermohalin circulation in the North Atlantic; the interactions with the climate of the regions surrounding the North Atlantic and the connections to other oceans.**

A. **The following issues are related to this fundamental issue:**

(i) Could emissions of greenhouse gases weaken or even halt ocean overturning in the North Atlantic, radically altering the regional climate?
(ii) Could global warning eventually lead to a dramatic cooling of the North Atlantic?
(iii) How sensitive is the thermohaline circulation in the North Atlantic to fresh water input?

3. **Improving the understanding of atmosphere-cryosphere-land surface-ocean interaction in the North Atlantic and the surrounding regions, using coupled regional and global models and observation data for validations and verifications of the models.**

A. **The principal scientific questions relating to this fundamental issue are:**

(i) The implications of a variable accession of fresh water at high latitudes for the North Atlantic thermohaline circulation;
(ii) The interactions of snow cover, sea ice, seasonally frozen ground, permafrost, Greenland ice sheet and glaciers in the North Atlantic climate system (in particular - a cryosphere/albedo feedback);
(iii) Increase in winter precipitation in high latitudes of the North Atlantic as a consequence of global warming;
(iv) Shut down of the deep water information in the high latitudes of the North Atlantic, as a result of increased surface fresh water supply;
(v) Retraction of the cold halocline layer in part of the Arctic Ocean.

(Recent observations have indicated that the river input from the Arctic shelves has been redistributed in the 1990's leading to a retraction of the CHL in the Eurasian Basin (and perhaps to a freshening of the Canada Basin).

Sea-Air CO_2 flux over the North Atlantic Ocean and Nordic Seas

Written by Taro Takahasi

Estimates for the net uptake of atmospheric CO_2 by the global oceans range between 1 and 2 Gigatons - carbon per year. The North Atlantic Ocean area north of 14°N takes up about 0.6 Gigatons - carbon/yr, representing 30~60% of the global uptake.

Based upon measurements of the sea-air pCO_2 difference made since 1970 to date, monthly distributions of climatological sea-air pCO_2 difference have been obtained over the North Atlantic for a reference year of 1990. The net sea-air flux of CO_2 has been computed using the pCO_2 data multiplied with the gas transfer coefficients. Until recently, the wind speed dependence of the gas transfer coefficient for CO_2 was not well known. The results of the field experiments conducted during the summer of 1998 by McGillis and Edson (WHOI) support the relationship formulated by Wanninkhof (Equation 1, JGR, 1992).

Using this relationship, we have obtained that the net CO_2 uptake flux by the North Atlantic is 0.34 Gigatons-carbon/yr over the area north of 50°N, and 0.26 Gigatons-carbon per year over the subtropical ocean area between 50°N and 14°N.

The net flux varies seasonally over a wide range due to the interactions of physical and biological processes. In the subarctic areas (N of 50°N), pCO_2 in surface ocean water is highest during winter months and lowest during spring through summer months. This is because deepwaters rich in CO_2 and nutrients upwell during winter, and CO_2 is consumed by the photosynthesis during spring and summer months. In contrast, pCO_2 in subtropical surface waters (14°N-50°N) is lowest during winter and highest during summer. This is due to the effect of temperature which exceeds the effects of biological production, and hence surface water pCO_2 values are controlled primarily by SST.

Although pCO_2 in surface waters in the vicinity of Iceland including the Denmark Strait areas has been monitored since 1982, a trend in the interannual changes has not been clearly identifiable as yet due primarily to the large and complex seasonal changes marking small interannual trend.

We recommend strongly that the seasonal measurements program should be strengthened and continued so that the interannual changes in the CO_2 chemistry of the source water regions for NADW can be documented.

2nd Session
Biological Response to Environmental forcing

Background

The main fish resources of the northern North Atlantic (Labrador, Iceland, Greenland, Norwegian and Barents Seas) live in marine ecosystems of high but strongly fluctuating production. The strong fluctuations in the production is a result of the fact that many key species live at the low range of the temperature habitat and that vital rates are particularly sensitive to temperature fluctuations at this lower range. Therefore, there is no doubt that temperature is an important climate parameter for production in the sea. Even though we know from laboratory studies much about how temperature influence growth rates of individual fish we know little about the integral effects of temperature through ecosystem responses and how this influence fish population growth.

There is increasing evidence of that fish production in these northern regions is strongly influenced by changes in the production on lower trophic levels, particularly on the production of copepods. A key issue for further research is therefore to focus on how temperature influence fish production directly and how it influence the production indirectly through trophic transfer. These are also key issues for the GLOBEC Programme.

Secondly, it is important to increase our understanding of how other climate parameters, like wind-induced mixing and turbulence, light conditions and advection of water masses influence the production of marine ecosystems.

All these climate parameters are more or less interlinked, but we have little knowledge on how the linking is, because they vary on very different temporal and spatial scales. Increased research efforts on understanding the dynamics of decadal-scale climate variations, as is now focussed by CLIVAR Programme, could contribute to better understanding of the interlinkage between the various climate parameters and of the driving forces behind climate variations.

An important tool for analysing the various effects of climate variations on fish resources is by further development of models for zooplankton production and trophodynamic models. Secondly, establishing new time series on climate and marine resources and maintaining old ones should be a prioritised issue.

Building upon the progress and results of GLOBEC and TASC a Grand Challenge is to create a collaborative program of physicists, biologists and modellers to build and test a coupled physical/biological model that can effectively caricature the space and time variation of a broadly distributed and dominant member to the North Atlantic zooplankton community, namely Calanus finmarchicus.

Such a model developed for a single species for the entire North Atlantic basin would pave the way for the development of models for other species and more elaborate models for the ecosystem as a whole. An ocean basin scale analysis through observation and modelling should lead to a fundamentally new understanding of ecosystem dynamics and allow prediction of response to climatic variation.

Main issues:

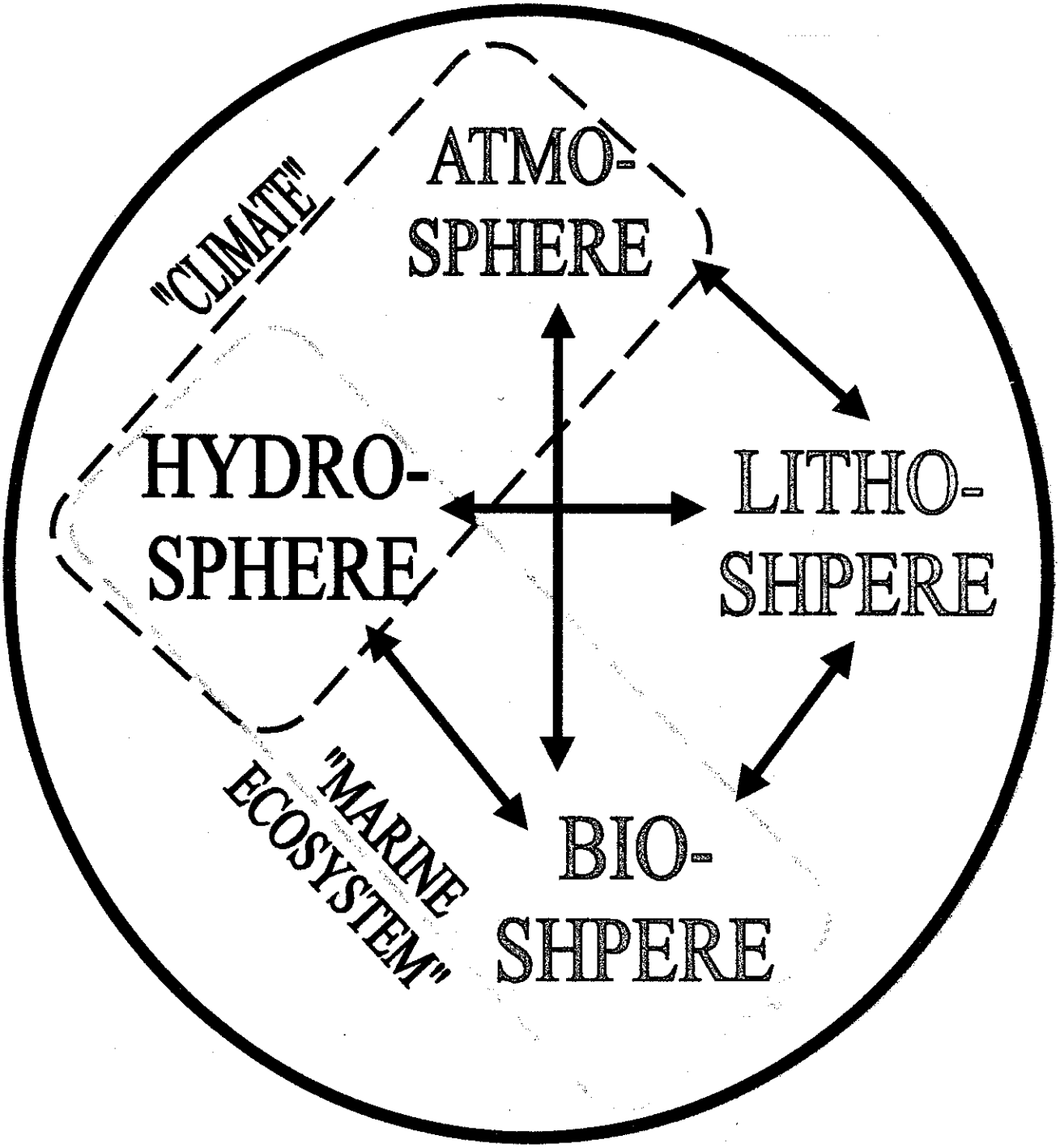
- The Biosphere is composed of complexes of inter-dependent species
- Genetic variation within species also has spatial and temporal structure
- Biogeographic domains at a range of spatial scales can be related to physical structures in the oceans
- Only glimpses of spatio-temporal variability are available:
  - + - Observations of interannual - decadal variability for some species over various scale variability
  - + - Century time scale variability for paleo-record species and some economically important ones
  - + - Millennial time scale variability only for paleo-record species

    But, echos of millennial changes are "found" in genetic variability of present day individuals

Key questions:

1. What are the associations between key & economically important species and Atlantic biogeography?
   "Census of the Fishes"
2. Can we infer century-millennial spatial fluctuations in economically important species from species represented in the paleo-record?
3. What is the genetic variation in present day key species?
4. What combinations of physical and biological processes act to maintain present day species assemblage and stock structures?
5. What are the consequences of loss of genetic variation for the resilience of species/stock structures to climate fluctuations?

ATRONOMICAL FORCING



A Grand Challenge

Building upon the progress and results of GLOBEC, TASC, and Mare Cognitum, a Grand Challenge is to create a collaborative program of physicists, biologists and modellers to build and test a coupled physical/biological model that can effectively caricature and space and time variation of a broadly distributed and dominant member to the North Atlantic zooplankton community, *Calanus finmarchicus*.

Such a model, developed for a single species for the entire North Atlantic basin would pave the way for the development of models for other species and more elaborate models for the ecosystem as a whole.

An ocean-basin scale analysis through observation and modelling should lead to a fundamentally new understanding of ecosystem dynamics and allow prediction of responses to climatic variation.

3rd Session
The Paleoclimate of the North Atlantic

Key scientific issues:

- **Calibration of records**
  - how do we develop modern calibration in terms of marine climate?
  - a calibration data base?
  - co-operation between people working on the modern environment and the paleoenvironment?
  - ice cores (temperature calibration)?

- **The Holocene**
  - a need for ultra-high record
    - extend the instrumental record on a timescale of the NAO

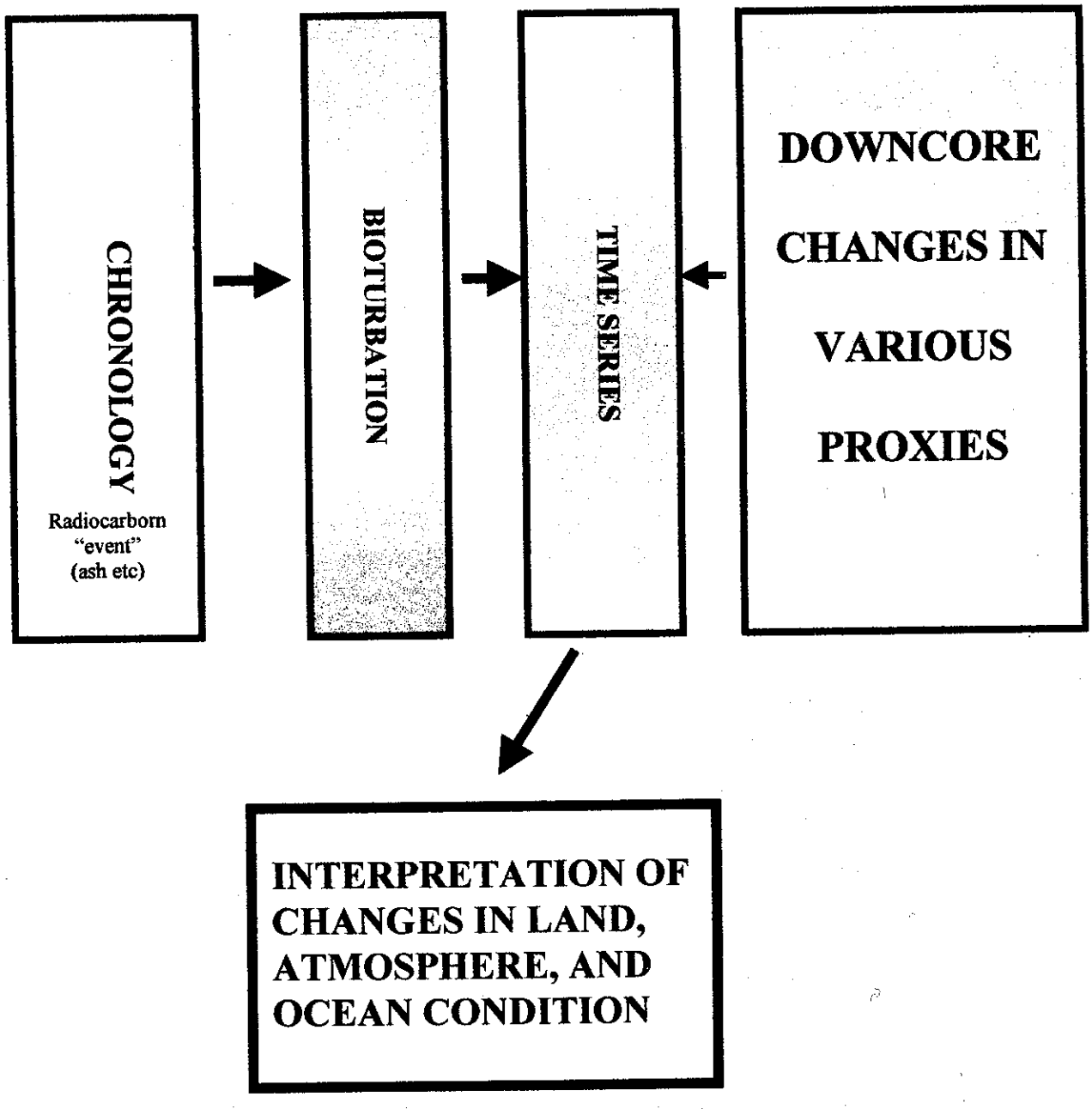
    1999: IMAGES (International Marine Global Changes)
    Cruise with the *Marion Dufresne* "Very high-resolution studies of changes in the hydrography and land/ocean interactions, North Atlantic Ocean"

- **Cyclicities**
  - Heinrich events, Dansgaard/Oescher cycles and 1500 yr oscillations
    - aim at better understanding

- **The Eemian**
  - the need for good Eemian record (ice cores, marine cores…)
  - correlation between the ice core, marine and the terrestrial records

- **The texture of climate**
  - how does the Greenland site correspond to Europe?
    - < 20 yr periods: Greenland and N-Europe in antiphase (see-saw in temperature), but not when looked at on longer terms.

All these issues would fit within the broad IGBP/PAGES and CLIVAR Programmes.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BIOTURBATION
TIME SERIES
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CHANGES IN
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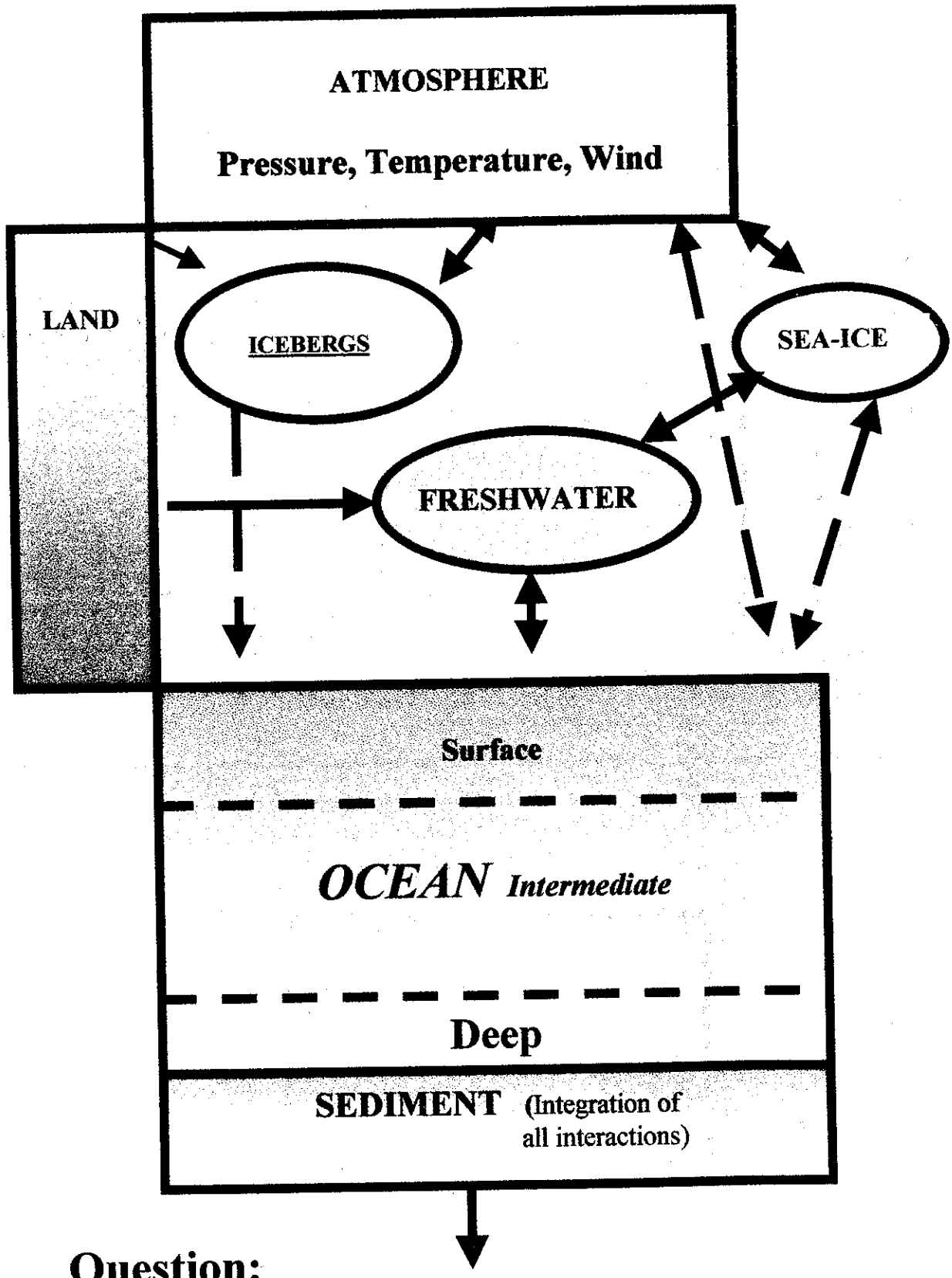
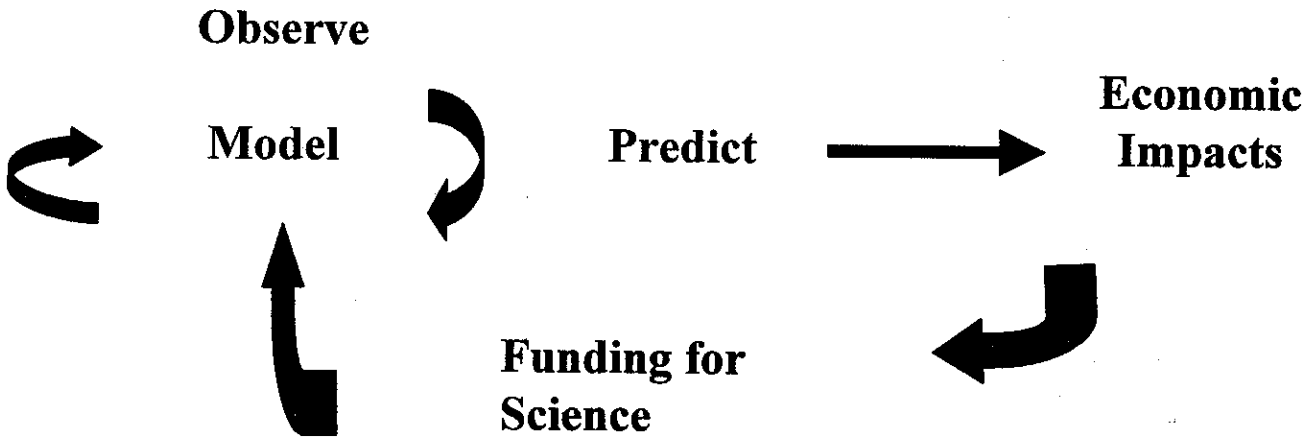
INTERPRETATION OF
CHANGES IN LAND,
ATMOSPHERE, AND
OCEAN CONDITION



Question:

How well can we read this record ????????

4th Session
Impact on Resources and Economy



- **Explanation is useful even when prediction is not**
- **Scenario modelling - replacing the steady state assumption**

Scientific issues:

1. Need for "environmental economics" to translate into:
   a) understanding of environment in human behaviour (individual and collective)
   b) justifying the use of resources for research
2. Hindcasting to:
   a) improve structure of models
   b) give us longer time series
3. Particular science issues:
   a) TASC
   b) Biological consequences of projected ocean climate change

The Approach

The impact of changes in the environment on human communities have been obvious for many years, as have the impacts of human settlements and economic activity on the local environment. Communities have learned how to interact with their local environment in

ways which are sustainable, or they have altered it and in some cases suffered adverse consequences. Long term and large scale (global) impact of human activities have not been obvious until fairly recently. To date societies have had limited success in regulating their economic activities in order to mitigate expected (or actual) adverse consequences of global changes. One of the reasons for this is that we lack the "environmental economic" tools which are needed in order to take account of dispersed and remote (in time and space) adverse impacts in individual and collective decision making. A second reason is that the scientific basis for evaluating impacts is weak.

1. The new "environmental economics" should consider what use of resources is justified in order to improve the science base. Careful analysis of past changes in environment and climate proved one means of judging future impacts, but we have a few long term data series.
2. There are many scientific tools which can be used to reconstruct past changes, including sampling (cores, tree rings, otoliths using microchemistry etc) modelling and archaeology. In addition to providing us with longer time series, such hindcasting can be used to test our models of the dynamics of change and to improve their structure.
3. Biology consequences of ocean climate change were discussed at several points during the meeting. Calanus finmarchicus occupies a key position on the food web of much of the North Atlantic and a proposed Grand Challenge for science has been put forward elsewhere. The credibility of the models currently used as the basis of most North Atlantic fisheries management advice is under increasing scrutiny because they do not include the effects of a changing environment. This can be justified to some extent if such models are only looking ahead one year at a time but different models are needed to consider long term sustainability and ecosystem.

5th Session
Predictive Capability - Integration and modelling

Key issues:

- Internal variability modes
  - NAO
  - 1500 year cycle?
- Forced climate changes
  - orbital forcing (glacial cycles)
  - meltwater
- Understanding physical mechanisms
  - role of ocean in NAO
  - mechanisms of past .... (e.g., D-O)
  - links between ocean connection, heat transport, SST variations
- Predictability?
- Impacts

Modelling Approaches

- Coupled GCM's
- Ocean (incl. sea ocean) only, forced by atmospheric data
- Atmosphere only, forced by SST + sea ice
- Simplex models
  - long runs
  - many runs
  - isolate mechanisms

These are all needed!

Future directions

- Improving physics and resolution (connection, overflows, eddy mixing, topography, sea ice ...)
- include more components
  - continental ice sheets
  - biogeochemistry
  - vegetation
- impacts / ecosystem modelling

Implementation and financing issues

- It was concluded that issues of the workshop called for co-ordinated international research effort. The release of science policies from cold war dominated issues opens up new vistas of possibilities for close cooperation on research on environmental issues and climate changes.

- The possibility of common or co-ordinated US-European calls for proposals was raised.

- The planned action on environmental and climate change issues under EU's 5th Framework Programme was presented. Additional information on Key Actions are now available (see **http://www.cordis.lu**).

    - A total of 2.125 MECU is foreseen for the Thematic Programme on the environment and energy.

    - About 900 MECU will be devoted to the themes related to the issues of the workshop.

- In the US the Global Change Research Programme (USGCRP) covers the input of theFederal funded agencies. A total of 1.864 m US$ is requested for fiscal year 1999. The largest share is channelled through NASA or about 73.60% and 10.03% through NSF's grant programmes, (see **http://www.gcrio.org/ocp99/appendixA.html**).

- The programme on environmental research recently approved by the Government of Iceland was presented. A total of about 255 MIKR., or about 3 MECU, are budgeted for the period 1999-2004. Of this over 2 MECU are related to the themes of the workshop. While small on absolute international scale, it represents a substantial relative investment by Iceland.