# The Role of the Ocean in the Earth and Climate System

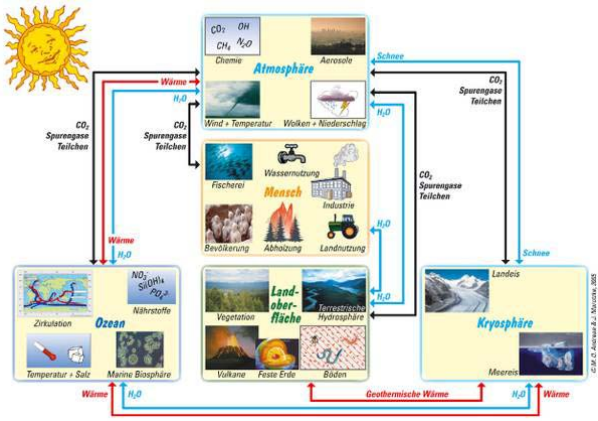
Prof. Dr. Karin Lochte
Alfred Wegener Institute for Polar and Marine Research
in the Helmholtz Association

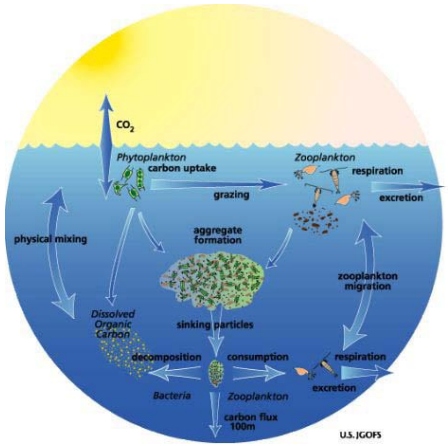
Foto: L. Tadday

EUROCEANS Conference, 12.-13. October 2010, Oostende

# Overview

- Changes in the Ocean
  - Acidification
  - Warming
  - Arctic Changes
- Actions required




# Changes in and risks to the Ocean

**Increasing $CO_2$ levels ….**

- Acidify the ocean waters
- Alter biological functions

**Global Warming ….**

- Alters ocean currents and stratification
- Changes the distribution patterns of organisms and alters ecosystems
- Melts sea ice and ice sheets
- Leads to sea level rise

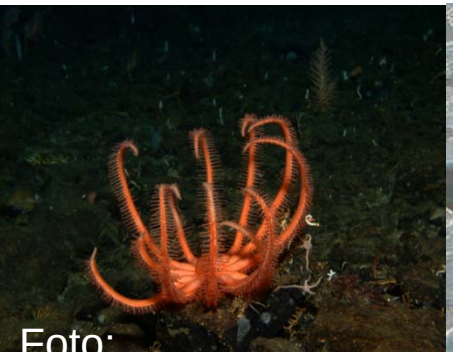


Foto:


Foto: AWI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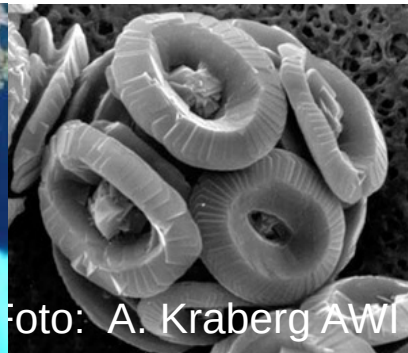
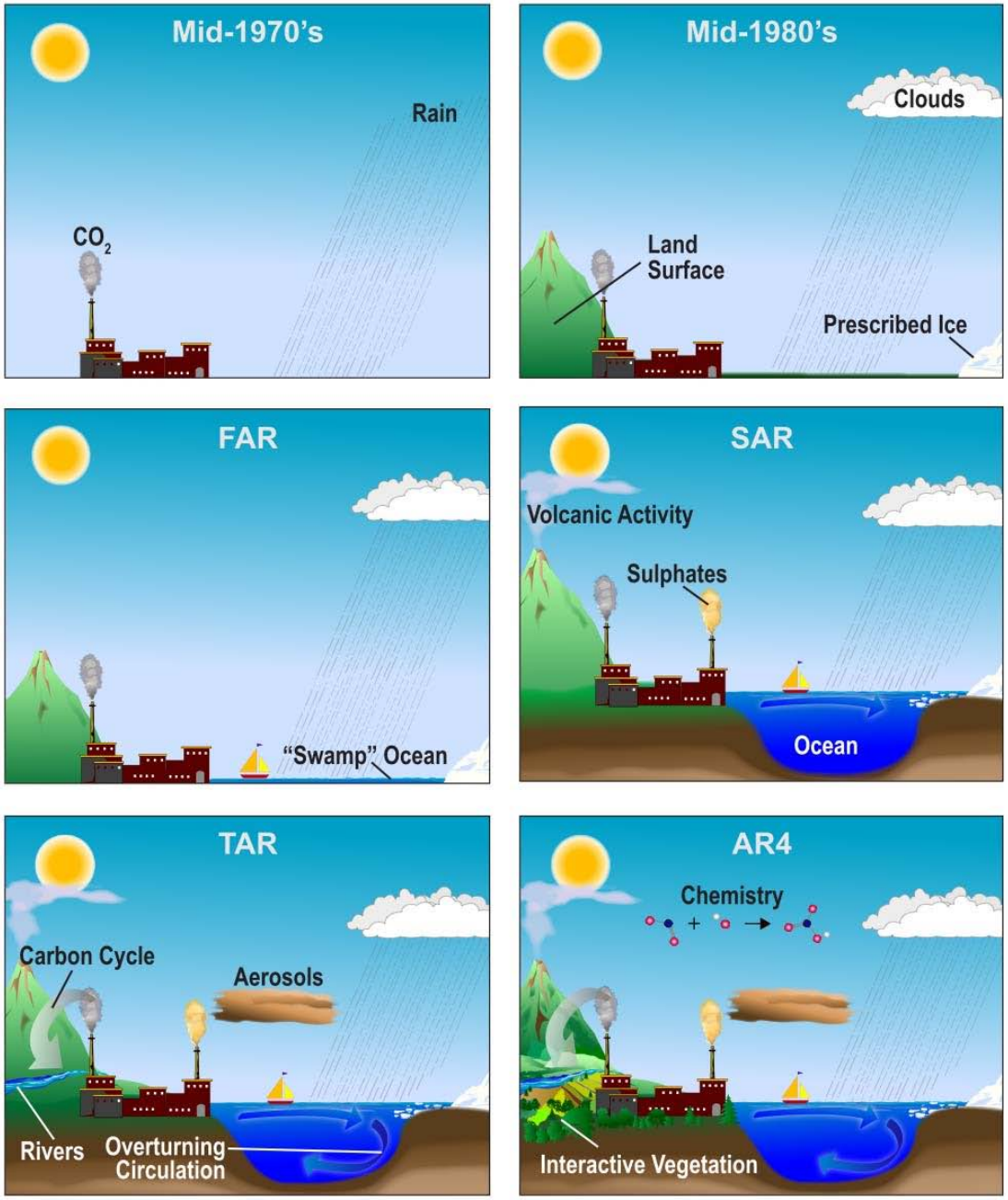


Foto: A. Kraberg AWI

# The World in Global Climate Models




**The Ocean is an integral part of the Earth system.**

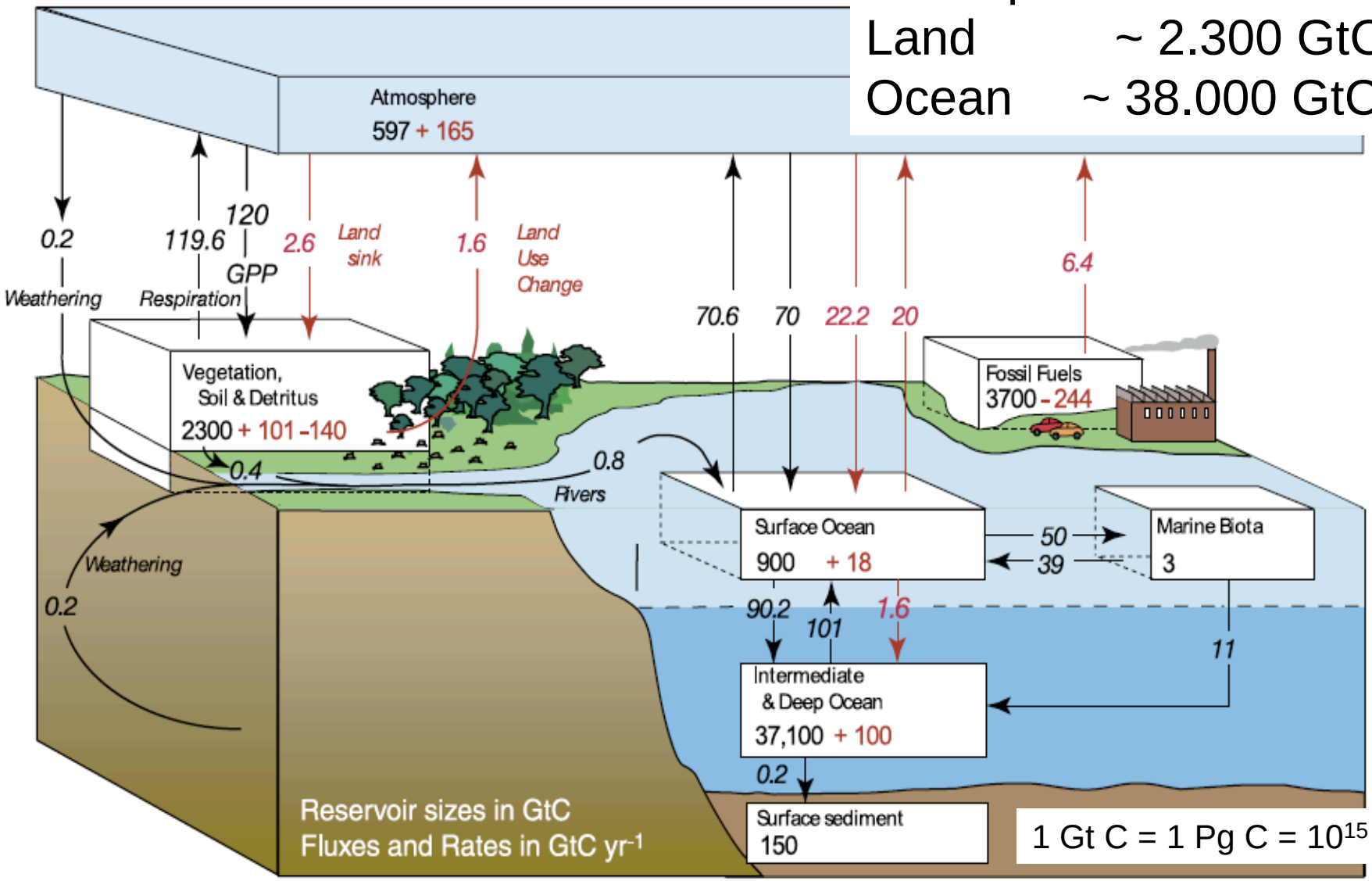
**The future of Earth can only be understood and modeled when we understand the oceans.**

Source: IPCC 2007

# Ocean - largest $CO_2$ storage in the global climate system

Source: IPCC 2007

Atmosphere ~ 600 GtC
Land ~ 2.300 GtC
Ocean ~ 38.000 GtC




1 Gt C = 1 Pg C = $10^{15}$ g C

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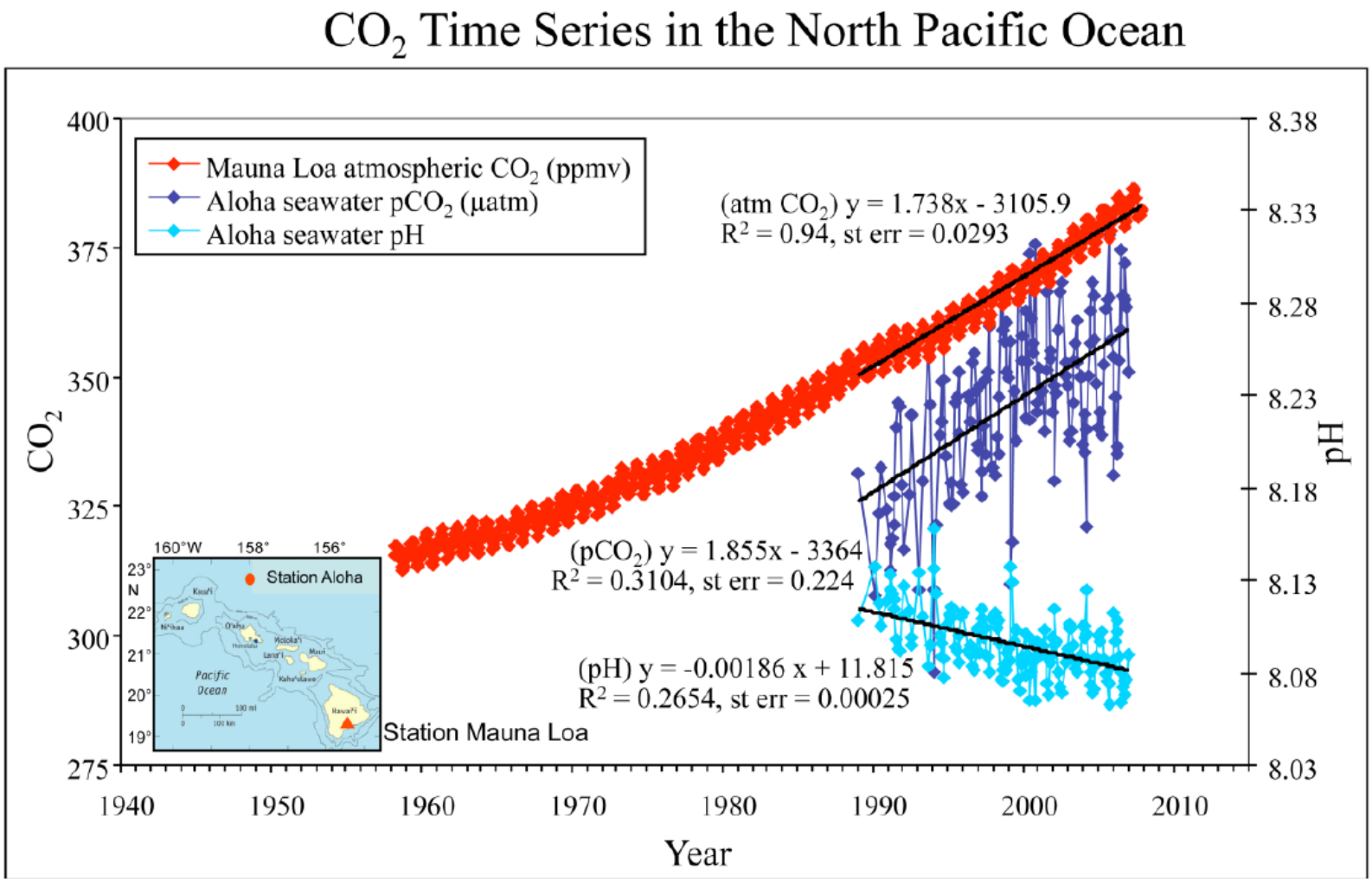
# Ocean acidification




(Fabry 2008).

→$CO_2$ increased 280 to 380 ppm in 200+ years, pH decreased by 0.1

→ By 2100, pH projected to decrease 0.5, possibly 0.77 eventually

# Ocean acidification

Results from a recent conference of the Ocean acidification projects
EPOCA (**E**uropean **P**roject on **Oc**ean **A**cidification)
BIOACID (**B**iological **I**mpacts of **O**cean **ACID**ification)
UKOARP (**UK O**cean **A**cidification **R**esearch **P**rogram)
in September 2010

The polar regions are especially sensitive to ocean acidification.
→ The solubilty of $CO_2$ is exceptionally high due to the low sea water temperatures in the polar regions
→ Carbonate concentrations are also lower
→The ability of polar organisms to compensate for an increased $CO_2$ concentration may be restricted further

**Future research should focus on interactions with other factors such as temperature and oxygen deficiency**

# Ocean acidification

**Hyas araneus**
Researchers found that larvae of Hyas araneus showed higher sensitivity towards ocean acidification in polar waters around Svalbard than in temperate waters around Helgoland. (Photo: Melanie Schiffer & Lars Harms)

**Serripes groenlandicus (Grönlandmuschel)**
The Greenland cockle reacts sensitive to ocean acidification. (Photo: Max Schwanitz)

# Ocean acidification – mechanistic understanding

## Combined Effects of $CO_2$ and Light on the $N_2$-Fixing Cyanobacterium *Trichodesmium* IMS101: Physiological Responses[1[OA]]

**Sven A. Kranz*, Orly Levitan, Klaus-Uwe Richter, Ondřej Prášil, Ilana Berman-Frank, and Björn Rost**

Alfred Wegener Institute for Polar and Marine Research, 27570 Bremerhaven, Germany (S.A.K., K.-U.R., B.R.); The Mina and Everard Goodman Faculty of Life Sciences, Bar Ilan University, Ramat-Gan, 52900 Israel (O.L., I.B.-F.); and Laboratory of Photosynthesis, Institute of Microbiology, Academy of Sciences of the Czech Republic, 37981 Třeboň, Czech Republic (O.P.)

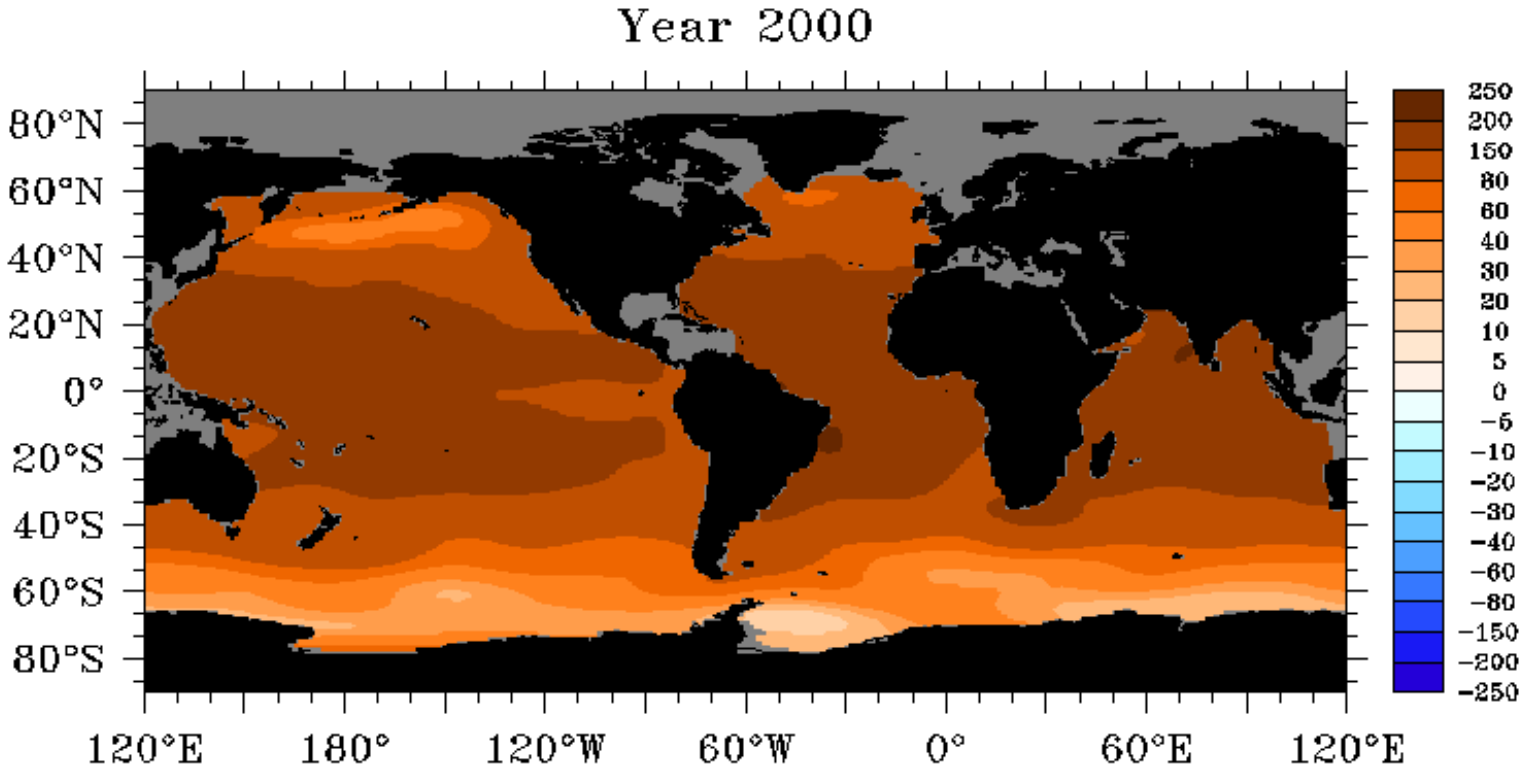
Inreasing $CO_2$ levels were found to enhance $N_2$ fixation and growth in *Trichodesmium erythraeum*.
We attribute these responses to changes in the allocation of photosynthetic energy between carbon aquisition and the assimilation of carbon and nitrogen under elevated $pCO_2$.

Recent studies on the diazotrophic cyanobacterium *Trichodesmium erythraeum* (IMS101) showed that increasing $CO_2$ partial pressure ($pCO_2$) enhances $N_2$ fixation and growth. Significant uncertainties remain as to the degree of the sensitivity to $pCO_2$, its modification by other environmental factors, and the physiological mechanisms responsible. To address these questions, we examined the responses of *Trichodesmium* IMS101 grown under a matrix of low and high levels of $pCO_2$ (150 and 900 $\mu$atm) and irradiance (50 and 200 $\mu$mol photons $m^{-2}$ $s^{-1}$). Growth rates as well as cellular carbon and nitrogen contents increased with increasing $pCO_2$ and light levels in the cultures. The $pCO_2$-dependent stimulation in organic carbon and nitrogen production was highest under low light. High $pCO_2$ stimulated rates of $N_2$ fixation and prolonged the duration, while high light affected maximum rates only. Gross photosynthesis increased with light but did not change with $pCO_2$. $HCO_3^-$ was identified as the predominant carbon source taken up in all treatments. Inorganic carbon uptake increased with light, but only

# Ocean Acidification

The magenta line (visible from 2025 on in the Weddell Sea), separates Aragonit saturated water (orange) from undersaturated water (blue), indicating the beginning solution of Aragonit.

[Movie credit: James Orr, LSCE/CEA-CNRS France]

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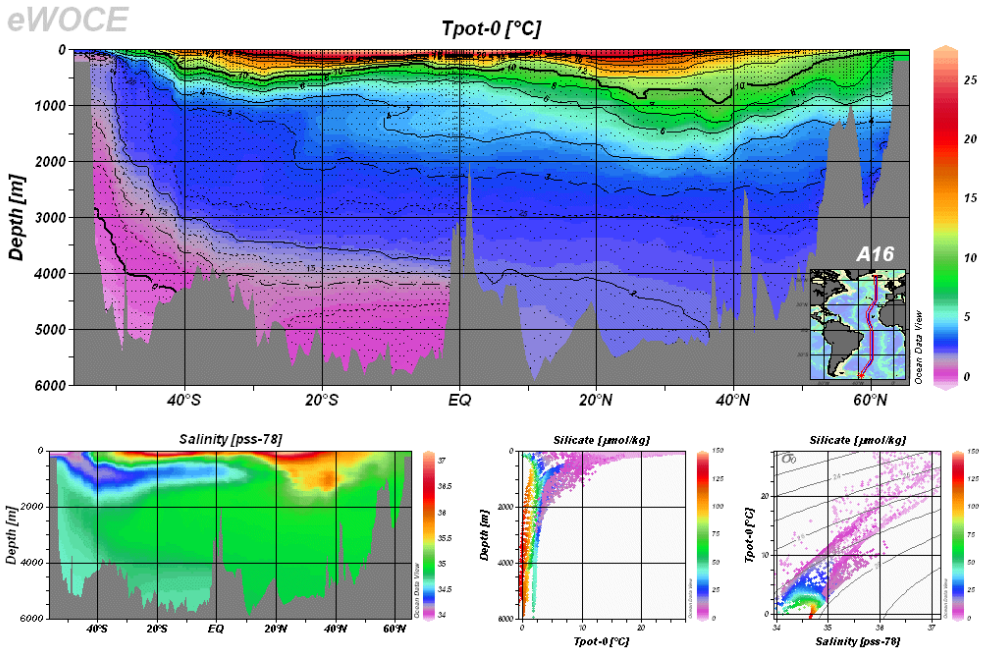
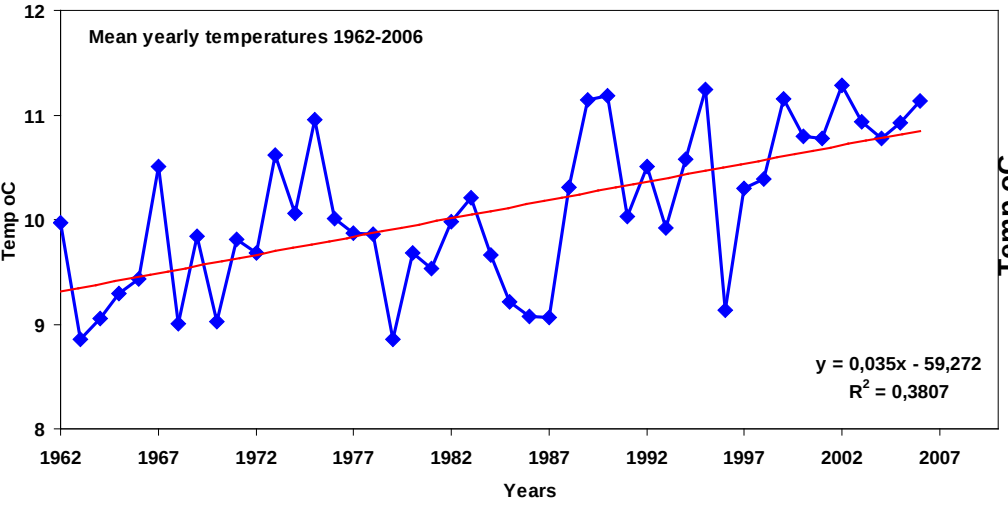


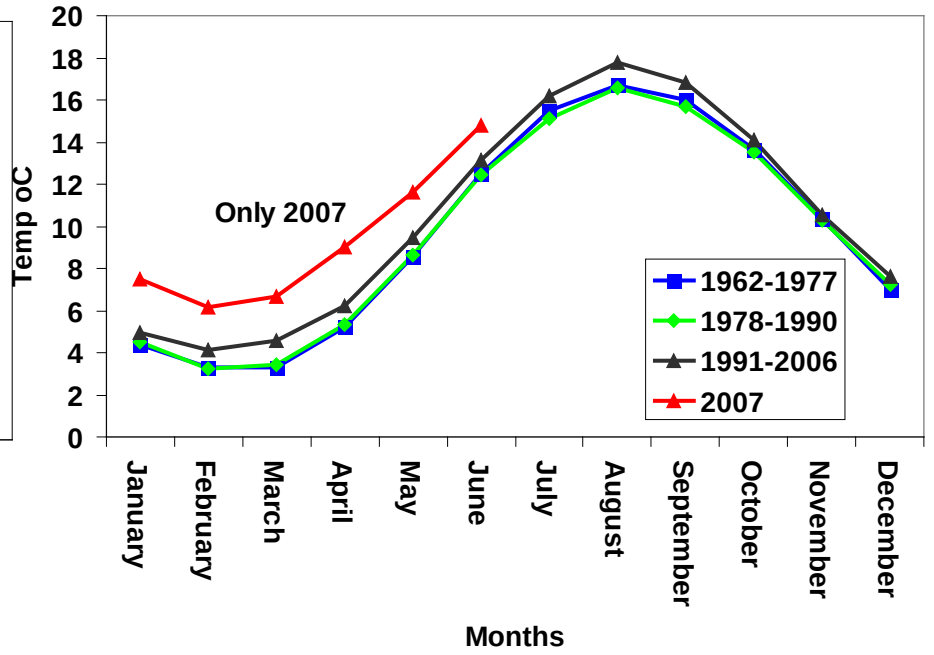
# Global Warming – Ocean Warming

Average temperature rise of 1.5° C in the North Sea since 1962 (data from Helgoland Reede)

**Annual mean**




**Monthly mean**

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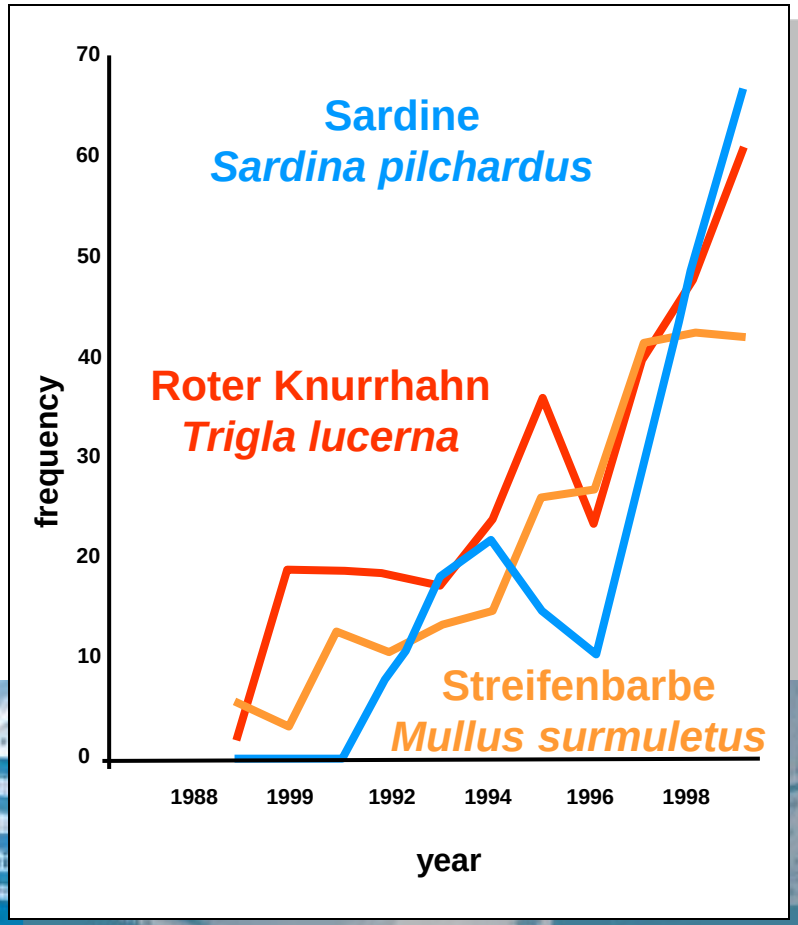
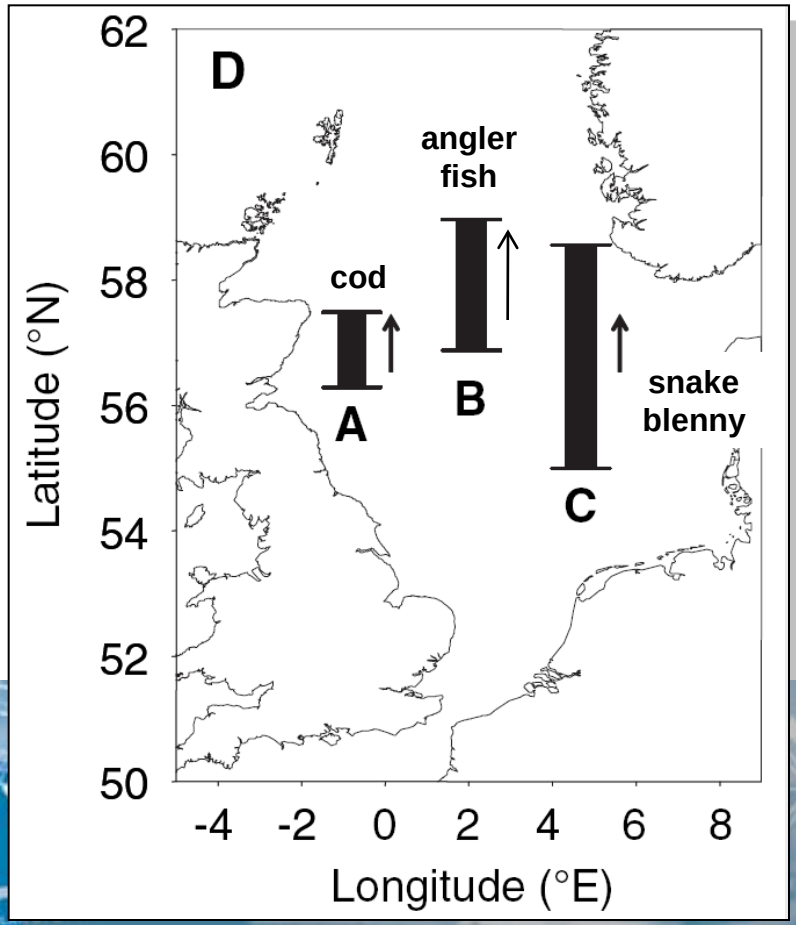
## Increased occurrence of “southern” fish species

Ehrich & Stransky. (2001)

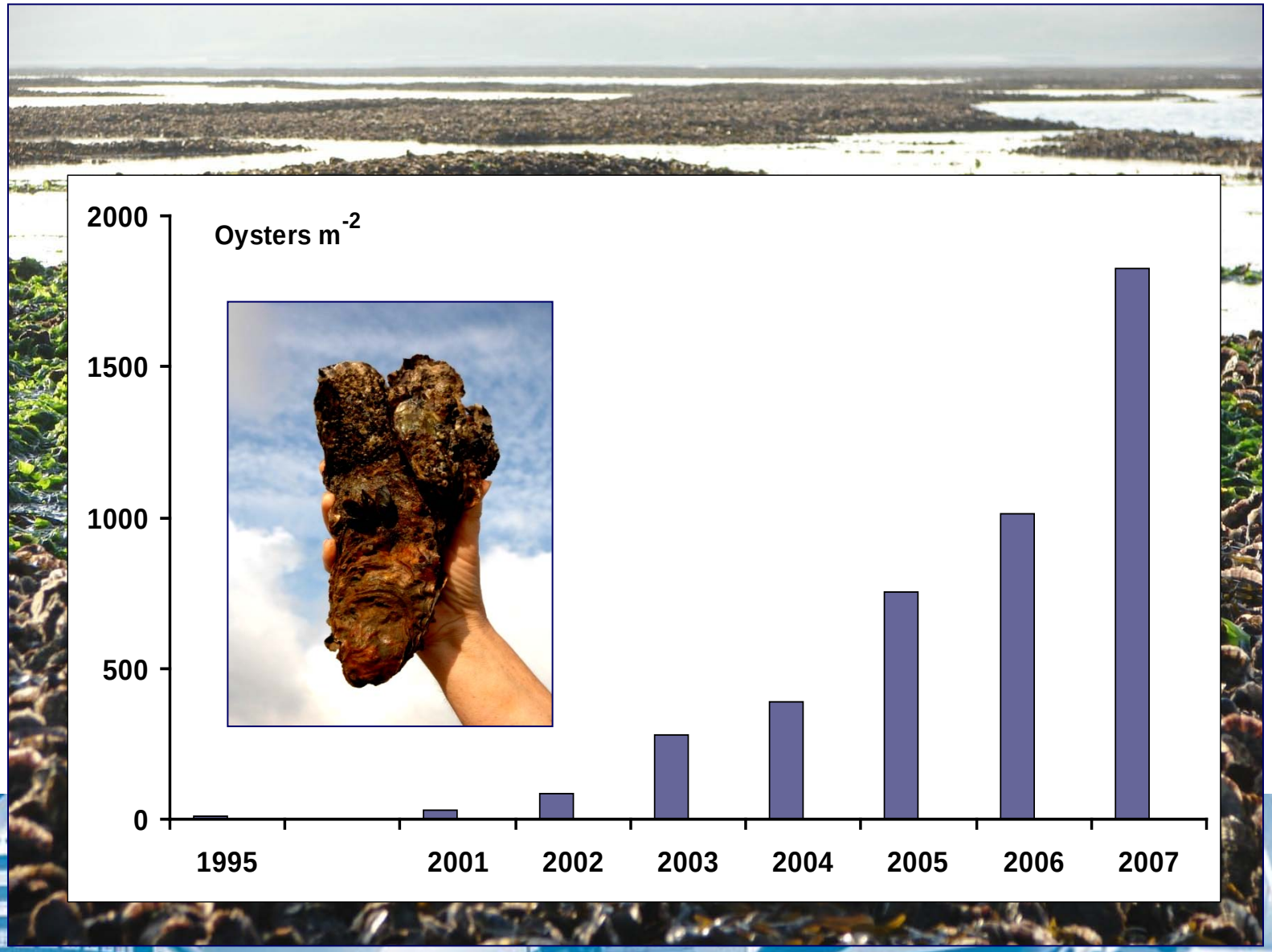



## Migration of boreal fish species northwards

Perry et al. (2005)

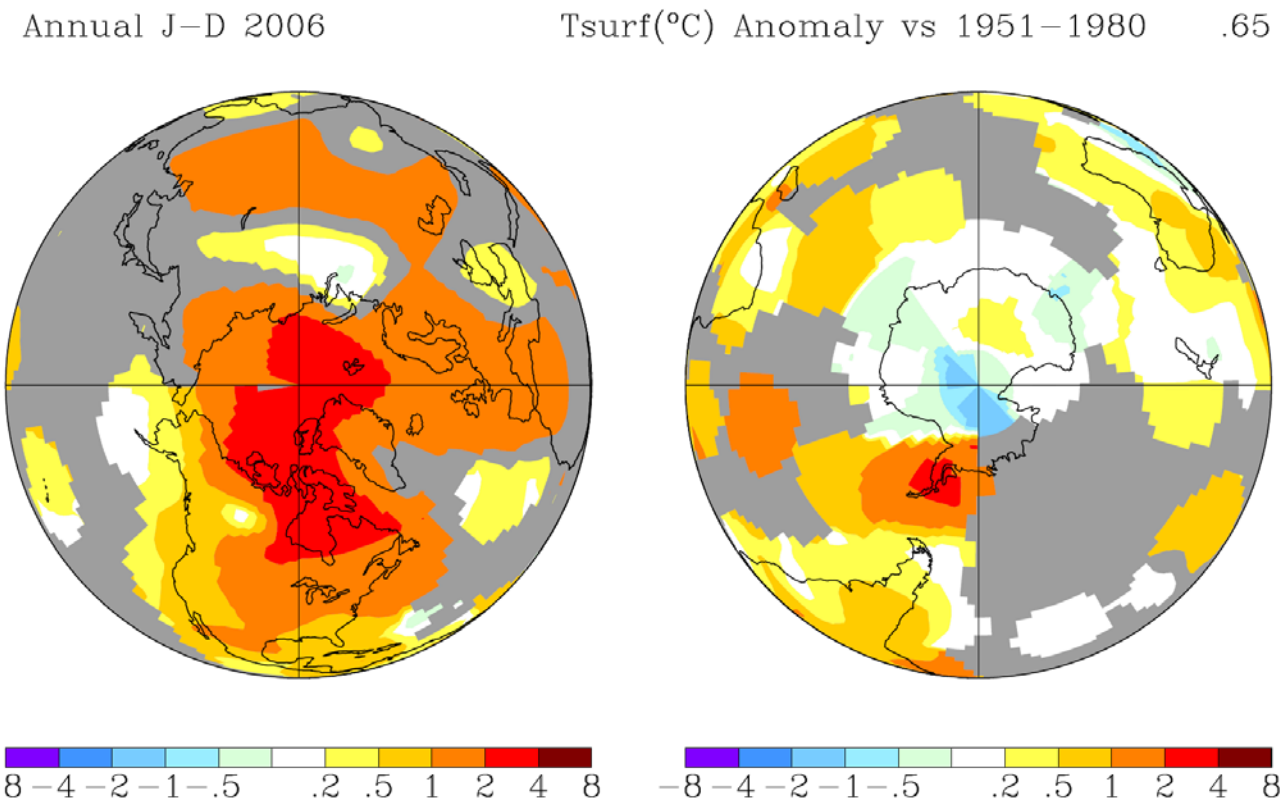


# Invasion of Pacific Oyster in the North Sea Wadden Sea



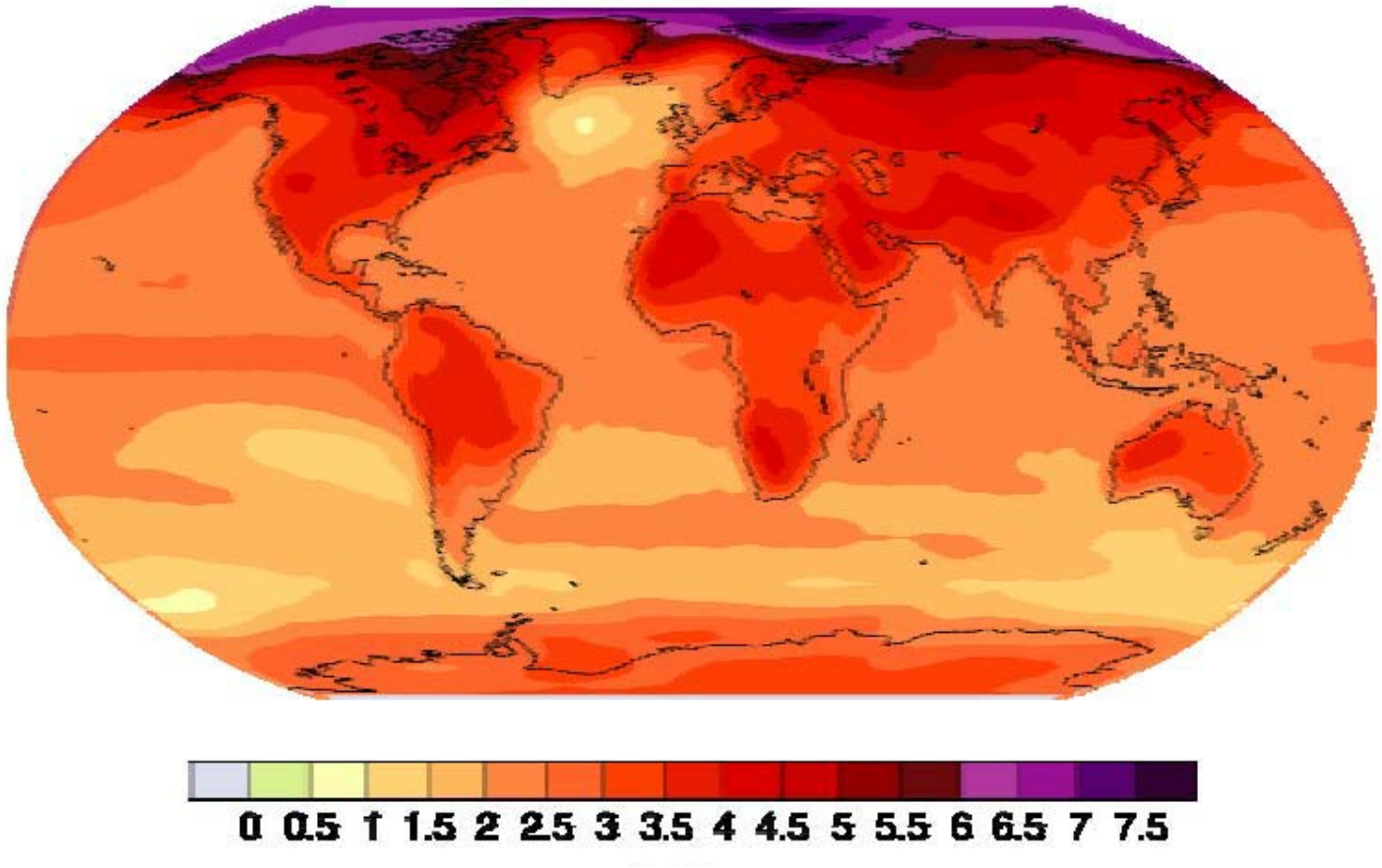

K. Reise, AWI)

# Geographical pattern of surface warming




Differences in surface temperature in 2006 compared to the average from 1951 to 1980 with greatest temperature increases in the **Arctic Ocean**, **Antarctic Peninsula**, and **central Asia**.
(Map based on data from NASA GISS Surface Temperature Analysis.)

# Global Warming




Projected surface temperature changes for the late 21st century (**2090-2099**). The map shows the multi-AOGCM average projection for the A1B SRES scenario. All temperatures are relative to the period 1980-1999. (IPPC 4AR)

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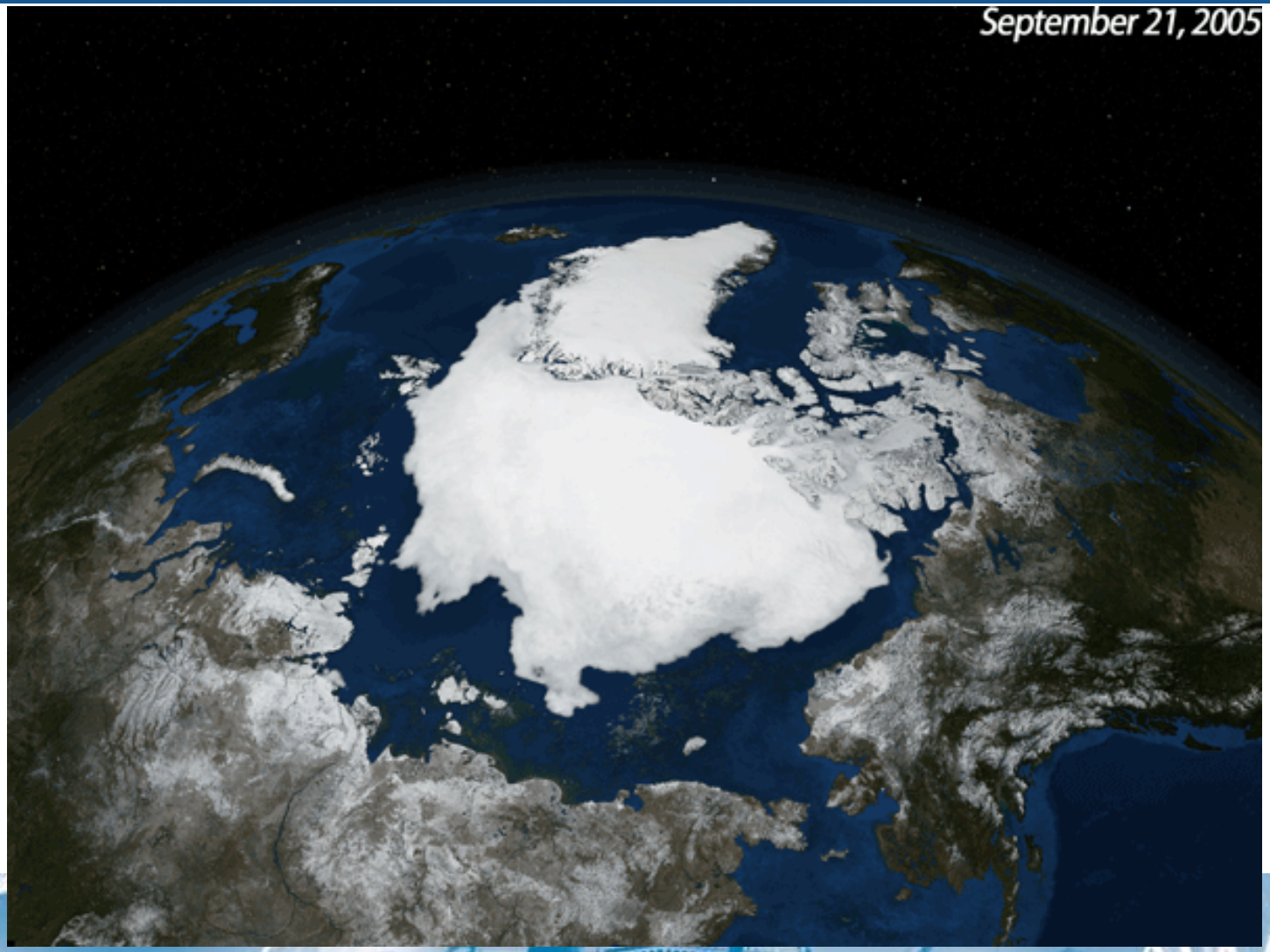
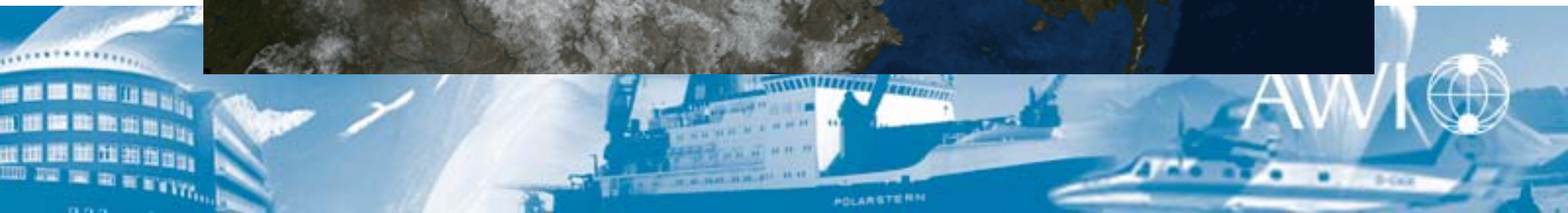
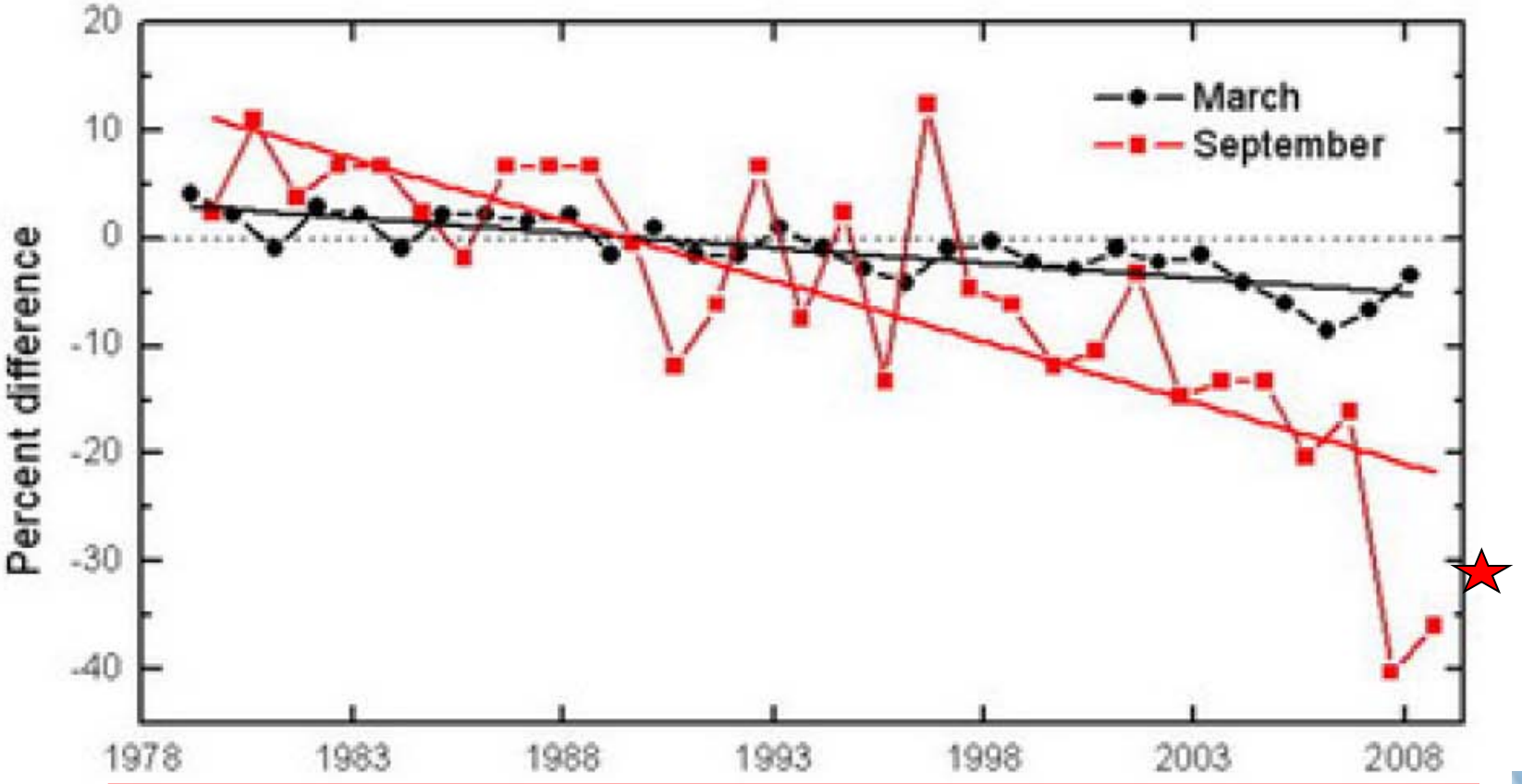
# Arctic Sea Ice extension



# Trend of Sea ice in the Arctic

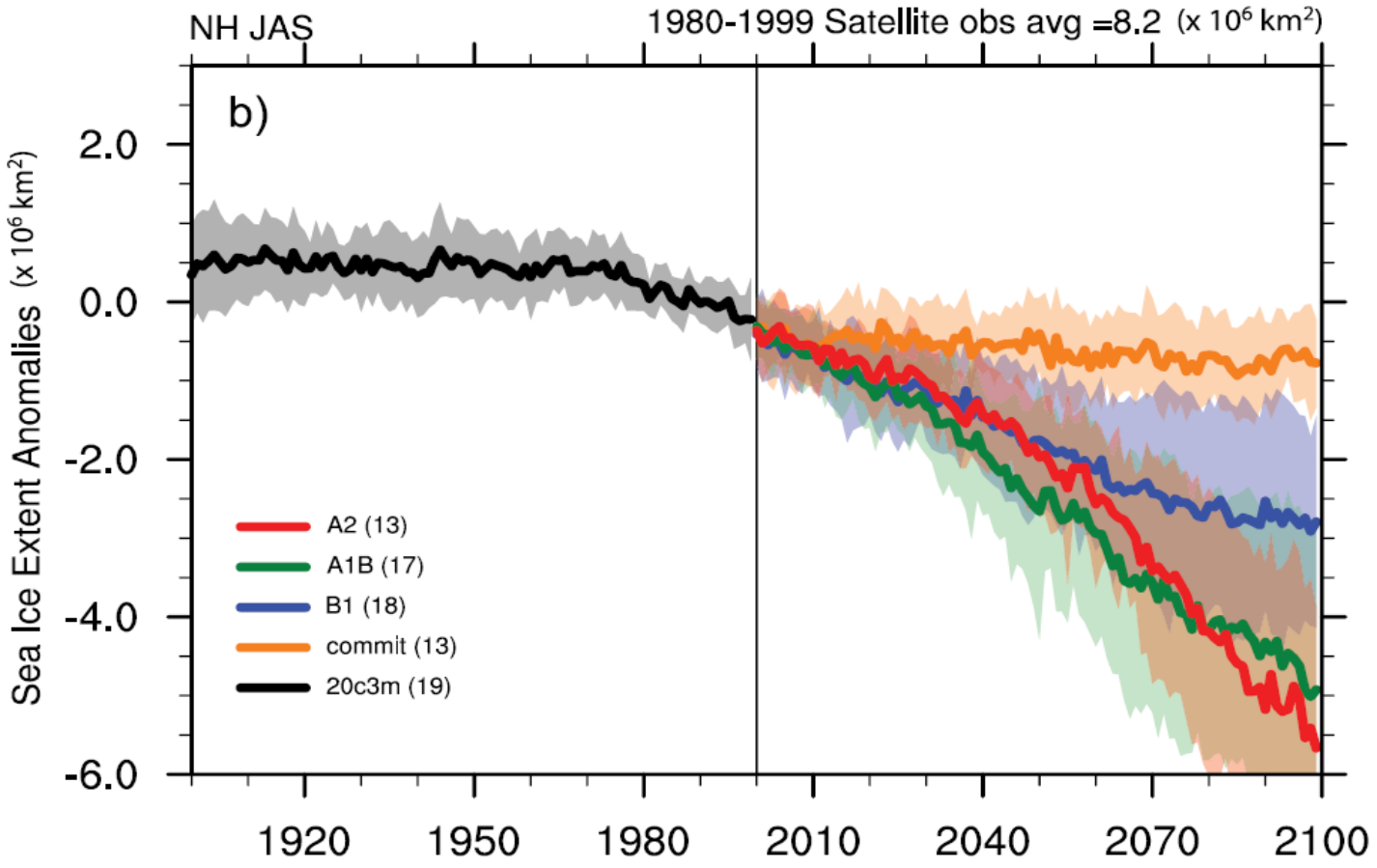
**Winter-trend: -2.8% per decade**




**Summer-Trend: -11.8% per decade**

Richter-Menge et al., 2008 (Arctic Report Card)

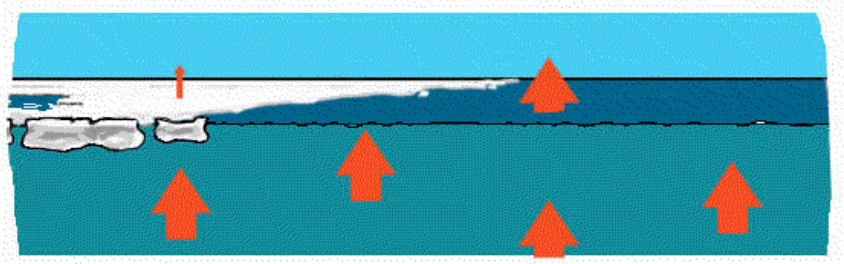
# Model of Arctic sea ice - projections for 21st century

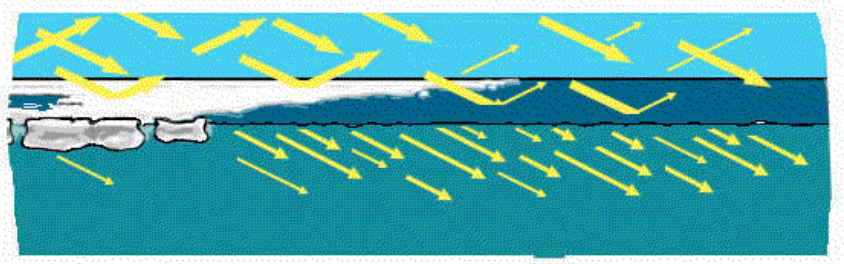



Scenarios of future reduction of summer sea ice extent in the Arctic. The anomalies relative to the average sea ice coverage (1980-1999: 8.2. Mio km$^2$) are modeled according to the standard IPCC scenarios (Meehl et al. 2007)

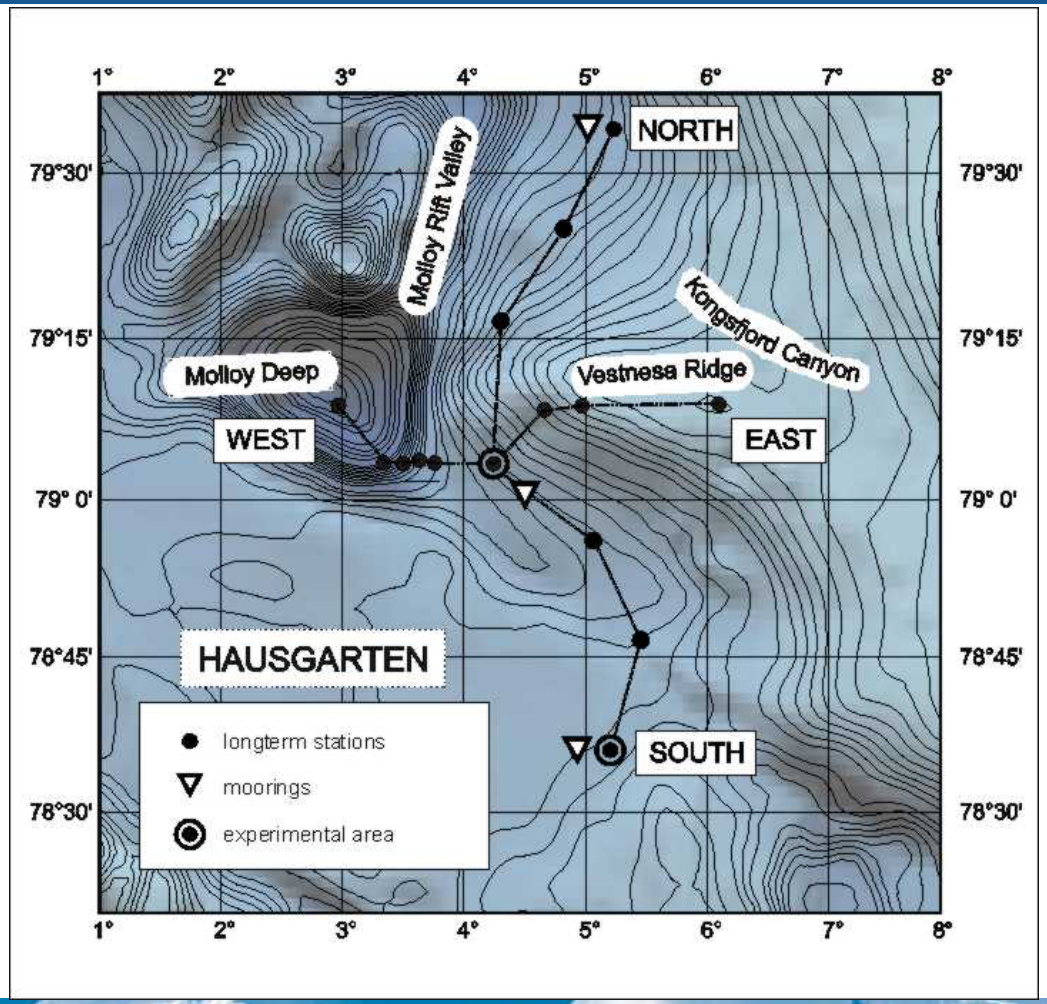
# Role of sea ice in the climate system

- …insulates the relatively warm ocean water from the cold polar atmosphere.
- …regulates exchanges of heat, moisture and salinity in the polar oceans.
- …has a much higher albedo (reflectivity) than the open ocean surface.
- …is an important habitat for organisms from microalgae to ice bears.





# Observation of changes in the deep ocean




**HAUSGARTEN** – the northernmost observation site regularly sampled since 1999. Situated at the sensitive gateway between the North Atlantic and the central Arctic Ocean (depth 1000 – 5500m, area 70 x 110 km).

Source: M. Klages, AWI

# Organic matter at the sea floor

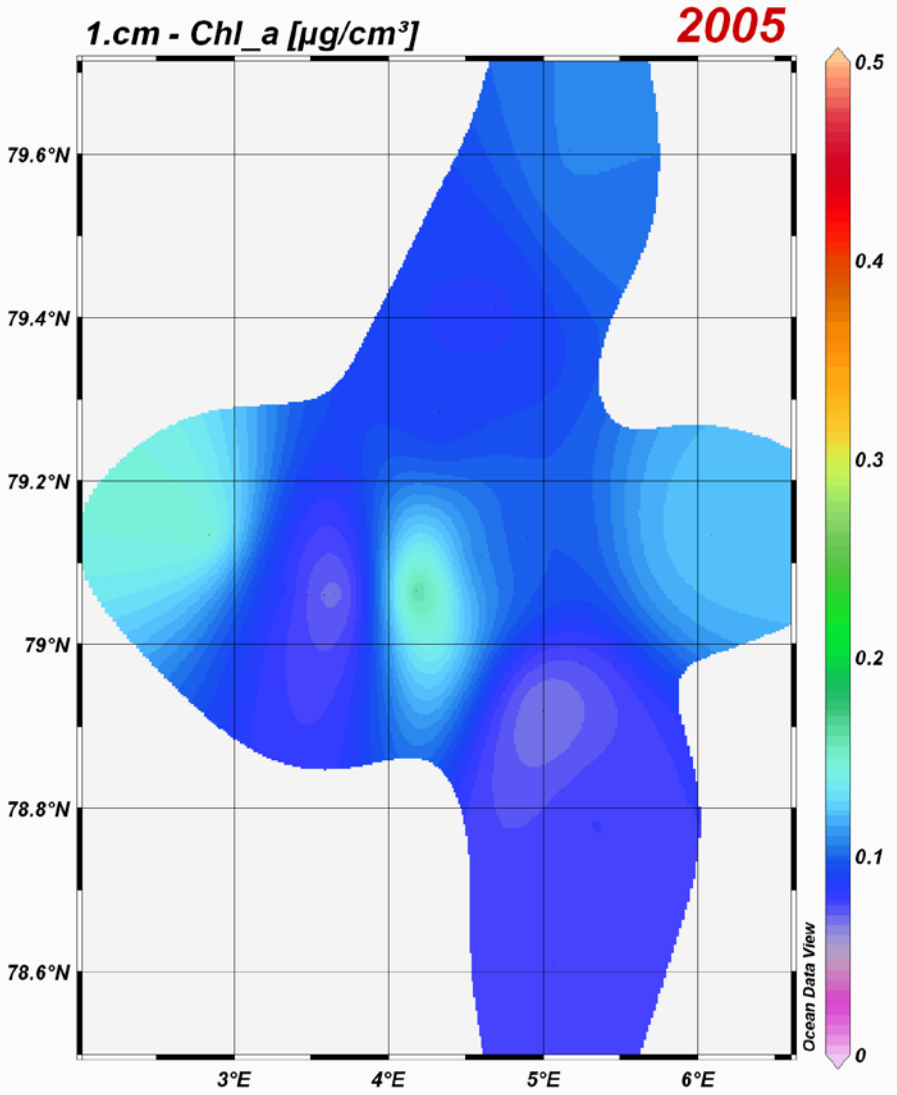
Decrease in organic matter (algal debris) was observed in the sediment from 2000– 2005.

•Retreat of the ice edge towards the north

•Occurrence of different algae in the surface waters

•Constant sea water temperature increase even at 2500m depth since 1999

•Decrease in abundance of some macrofauna species

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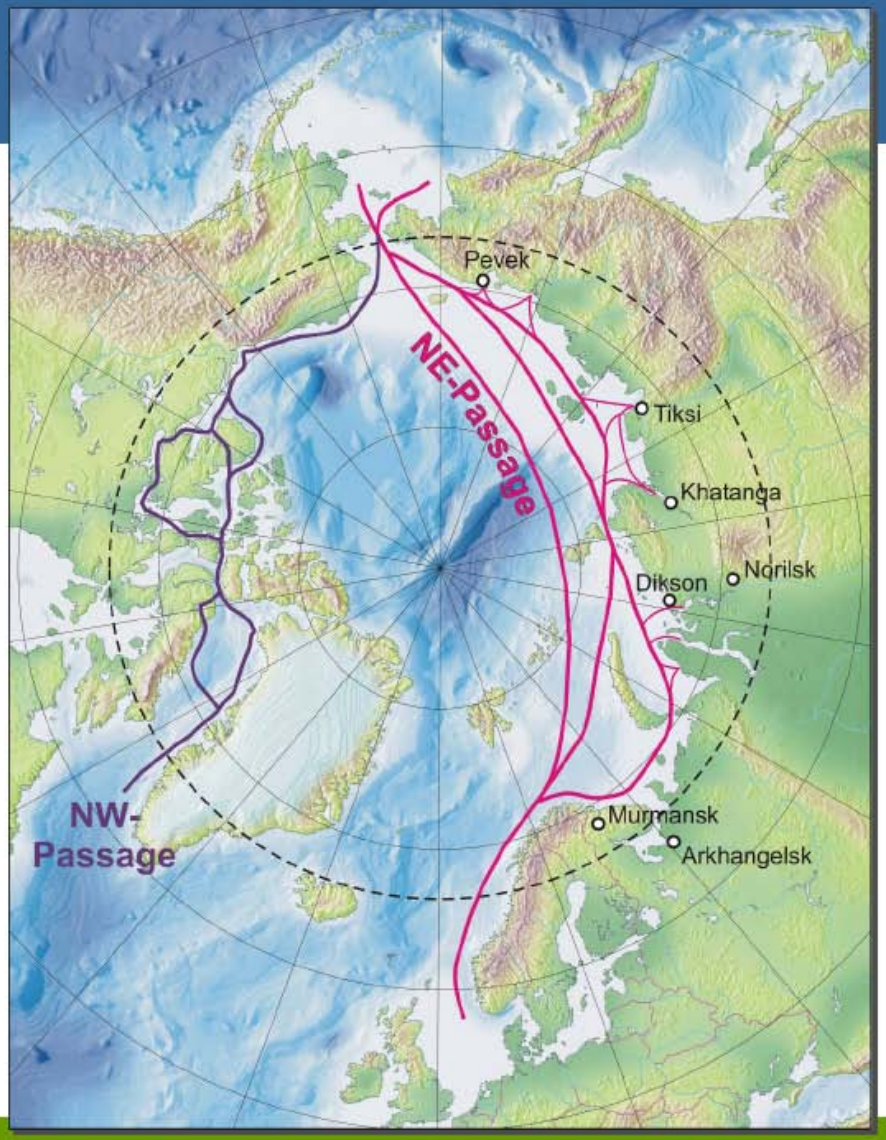
# New shipping routes in the Arctic Ocean

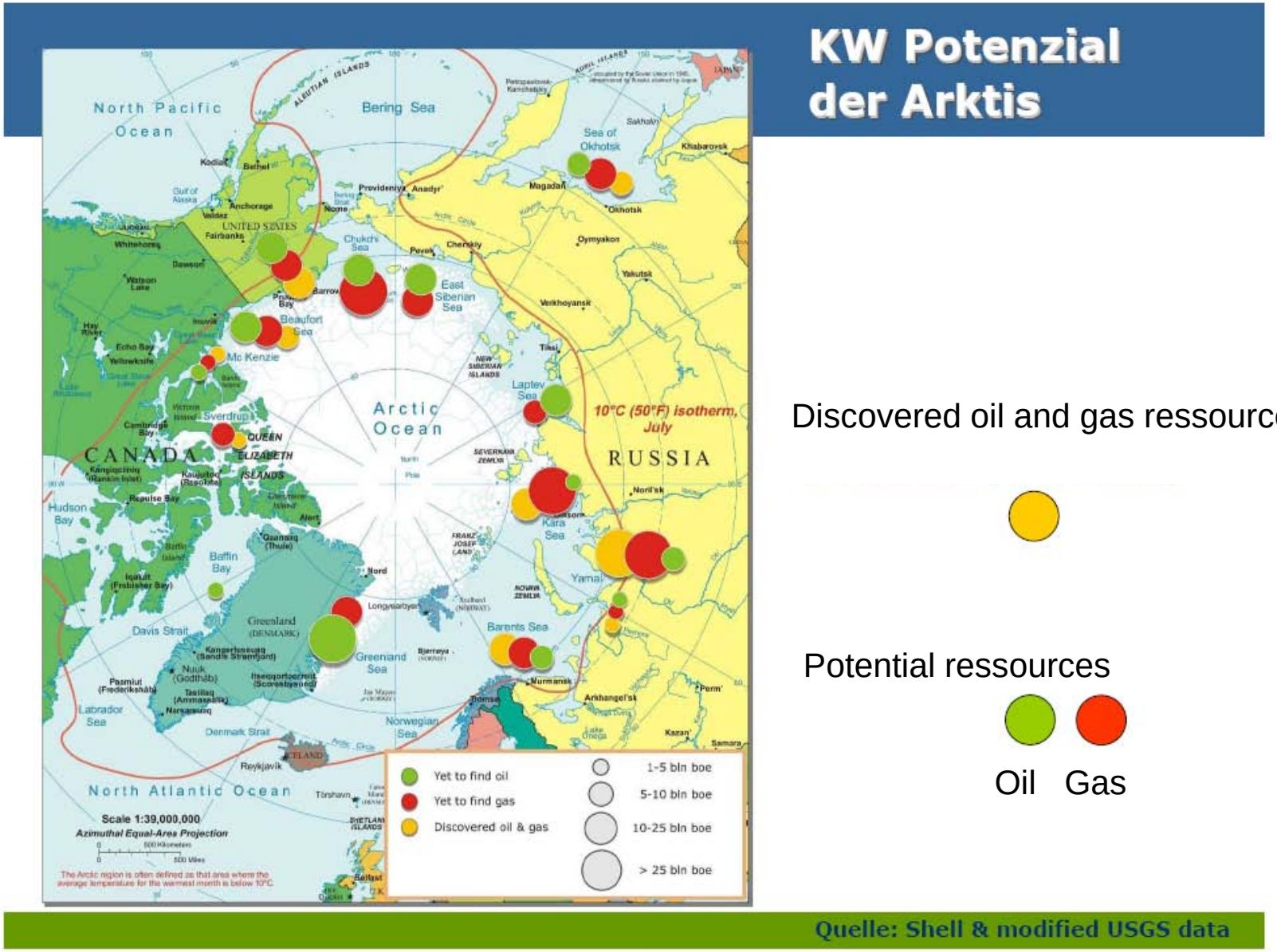



**Northern Sea Routes**

- NE-Passage
- NW-Passage

Shortening of sea routes to Asia by ca. 30%

# Mineral Resources in the Arctic ocean




Discovered oil and gas ressources

Potential ressources

Oil Gas

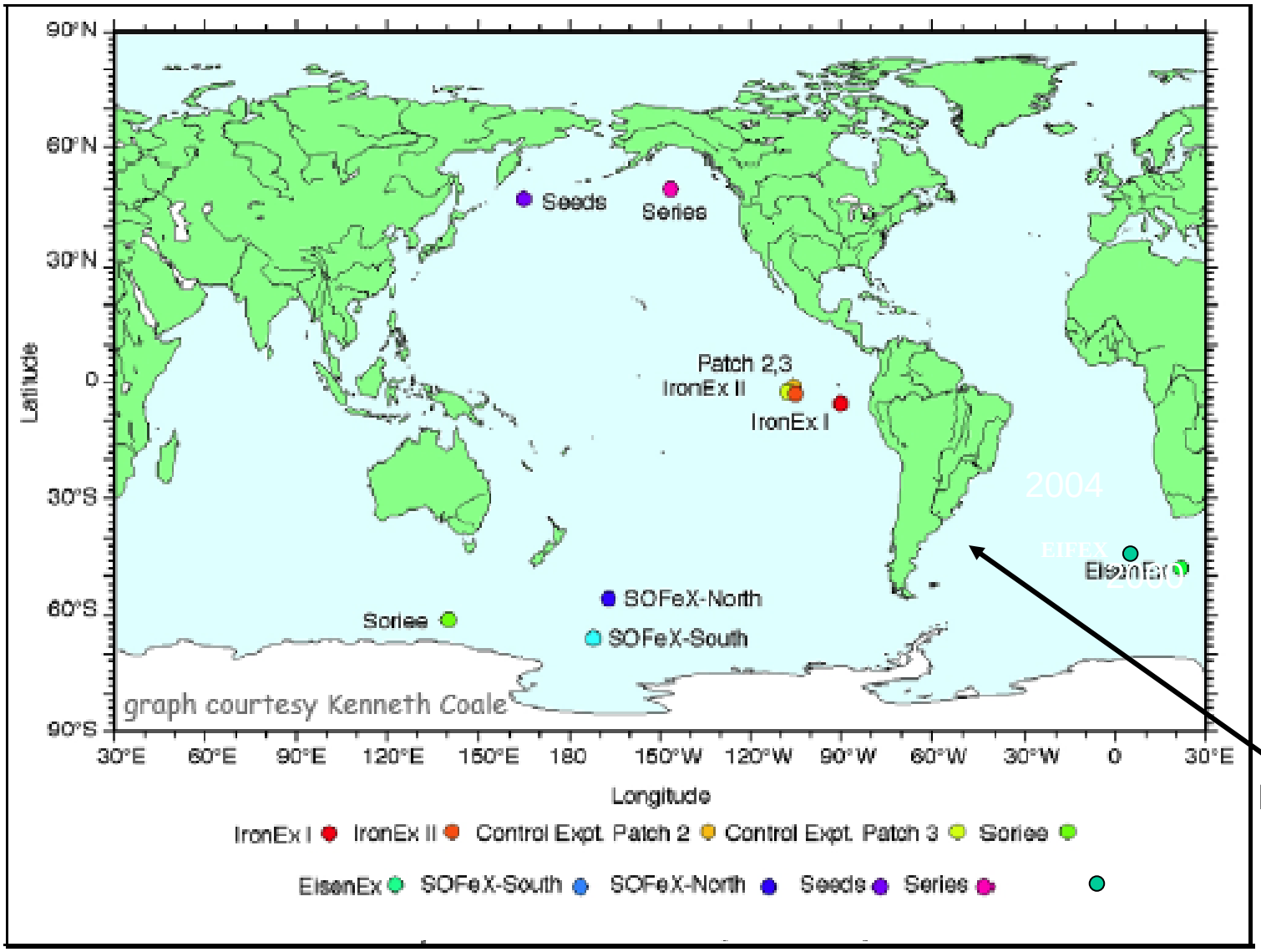
Quelle: Shell & modified USGS data

# Marine Protected Areas (MPA)

**Tuesday 28th of September 2010**
**OSPAR Commission have now established six marine protected areas in the North-East Atlantic**

Six marine protected areas, covering a total area of 285 000 $km^2$ have been established by OSPAR ministers and the Portuguese government. They have been designed to protect a series of seamounts and sections of the Mid-Atlantic Ridge along with a range of vulnerable deep-sea habitats and species. This move works towards the goal of implementing representative systems of MPAs by 2012 committed to under the World Summit on Sustainable Development and the Convention on Biological Diversity (CBD).

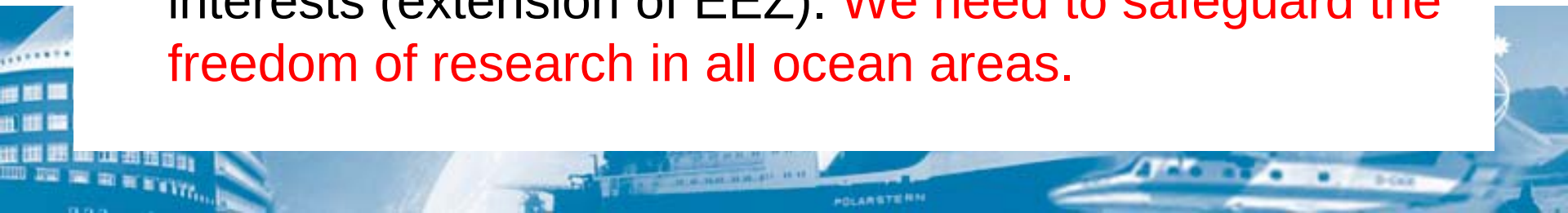
# Geoengineering - e.g. Iron Fertilisation?

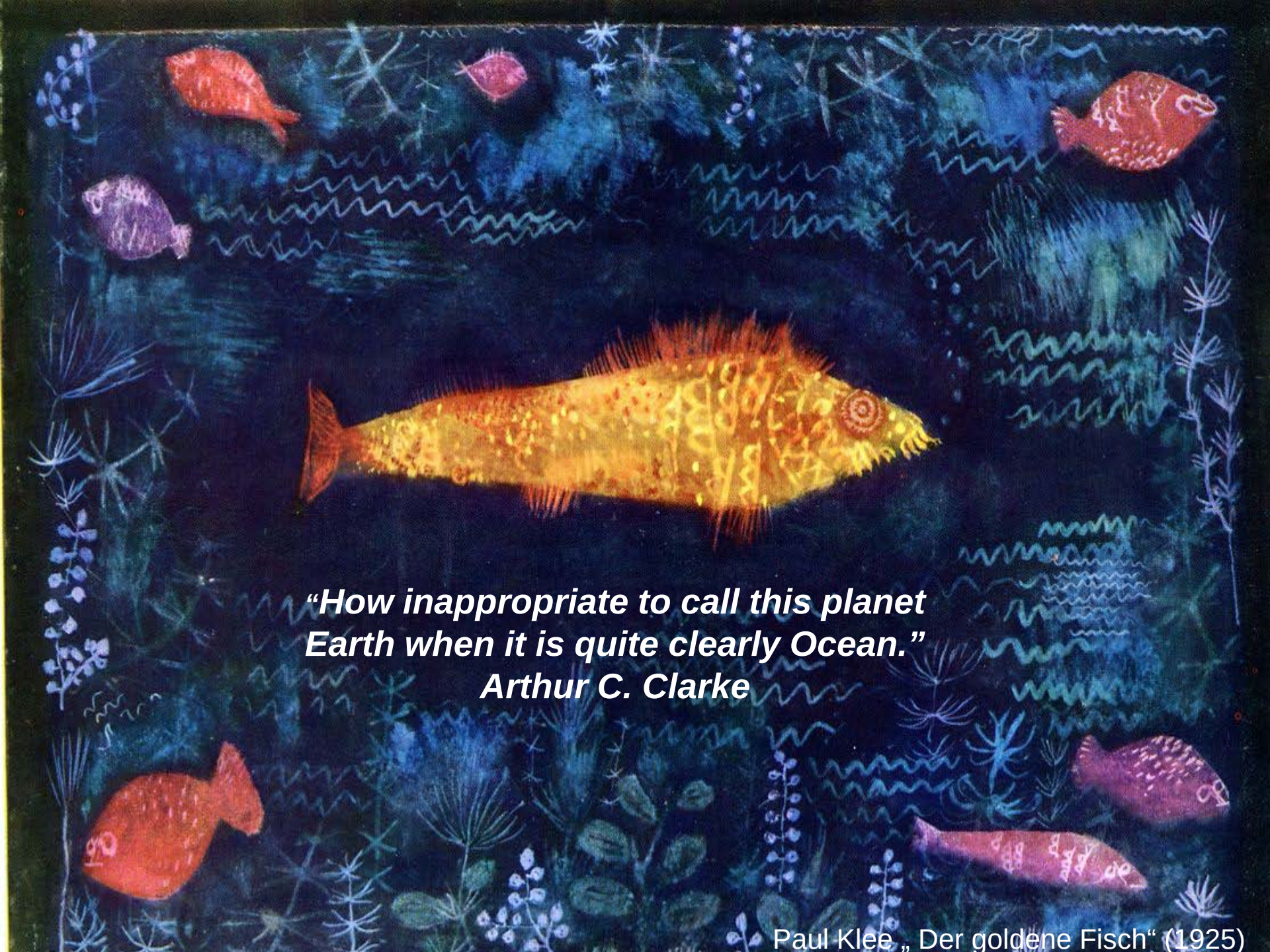



LOHAFEX

# Actions required

1. The ocean is the driver of the Earth's heat exchange and the hydrological cycle, it provides many services in the biogeochemical cycling of elements (including carbon!). We need to significantly improve our understanding of the processes and changes in the ocean in order to predict future developments.
2. The ocean is part of the future of human societies. It harbors many untapped resources. We need to develop protective measures if we want to use these resources in a responsible and sustainable way.
3. The ocean will become more and more target of national interests (extension of EEZ). We need to safeguard the freedom of research in all ocean areas.






Paul Klee „ Der goldene Fisch“ (1925)