



Global climate change and regional impacts on marine ecosystems

Svein Sundby

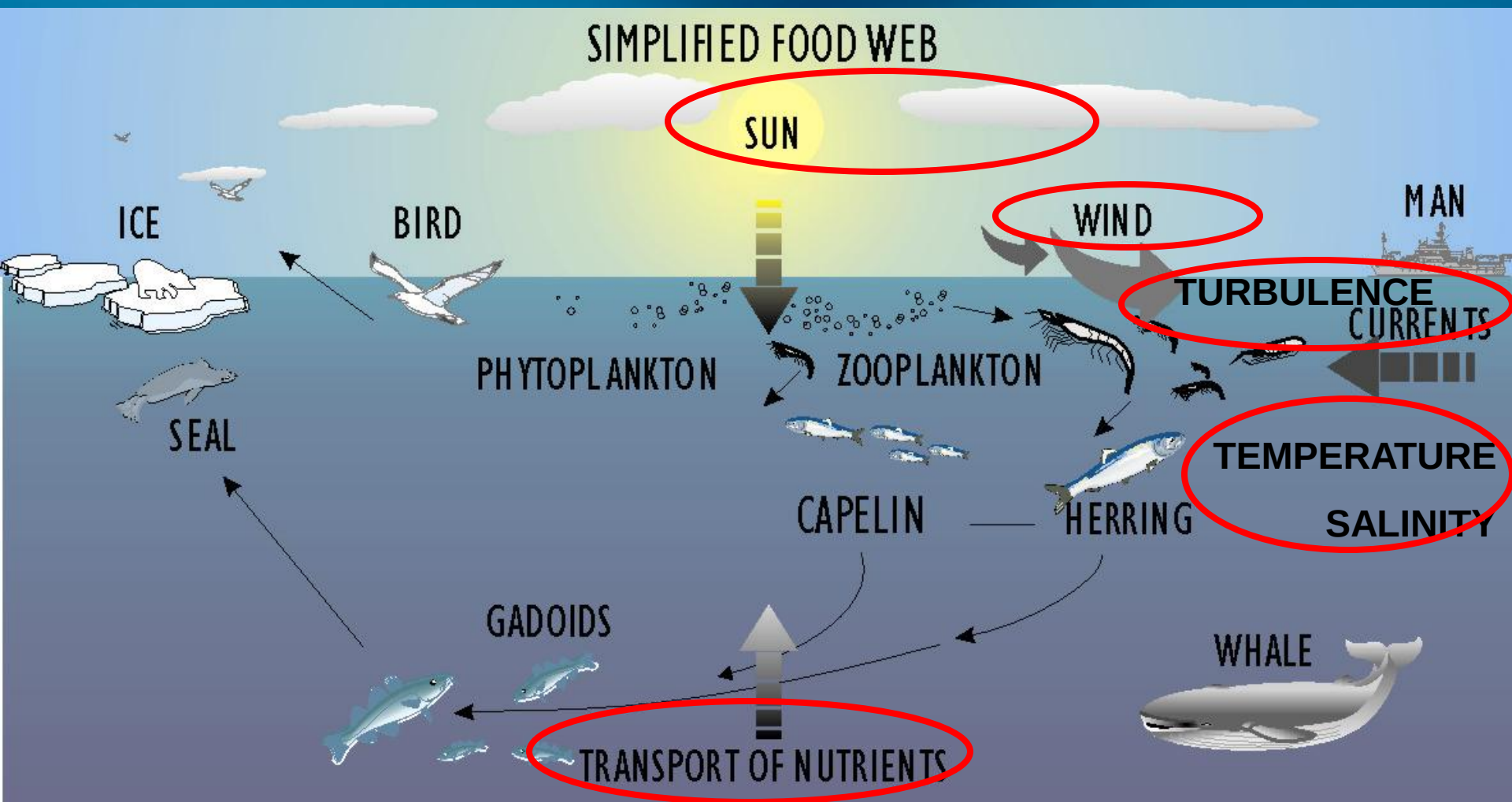
**The legacy of Nansen in marine research
Relevance to development cooperation in fisheries**

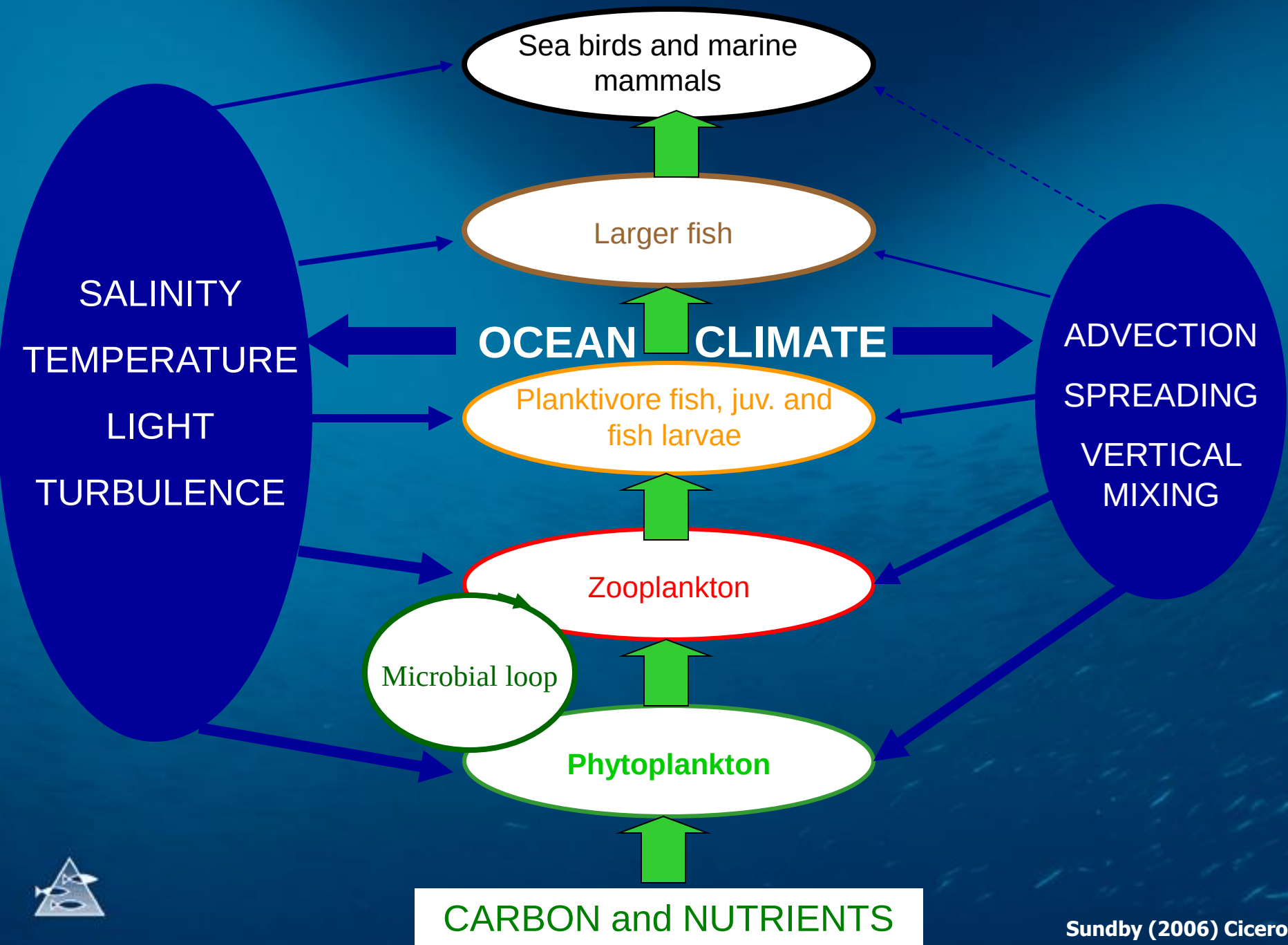
EAF-Nansen Project mini-seminar, Oslo, 13 October 2011



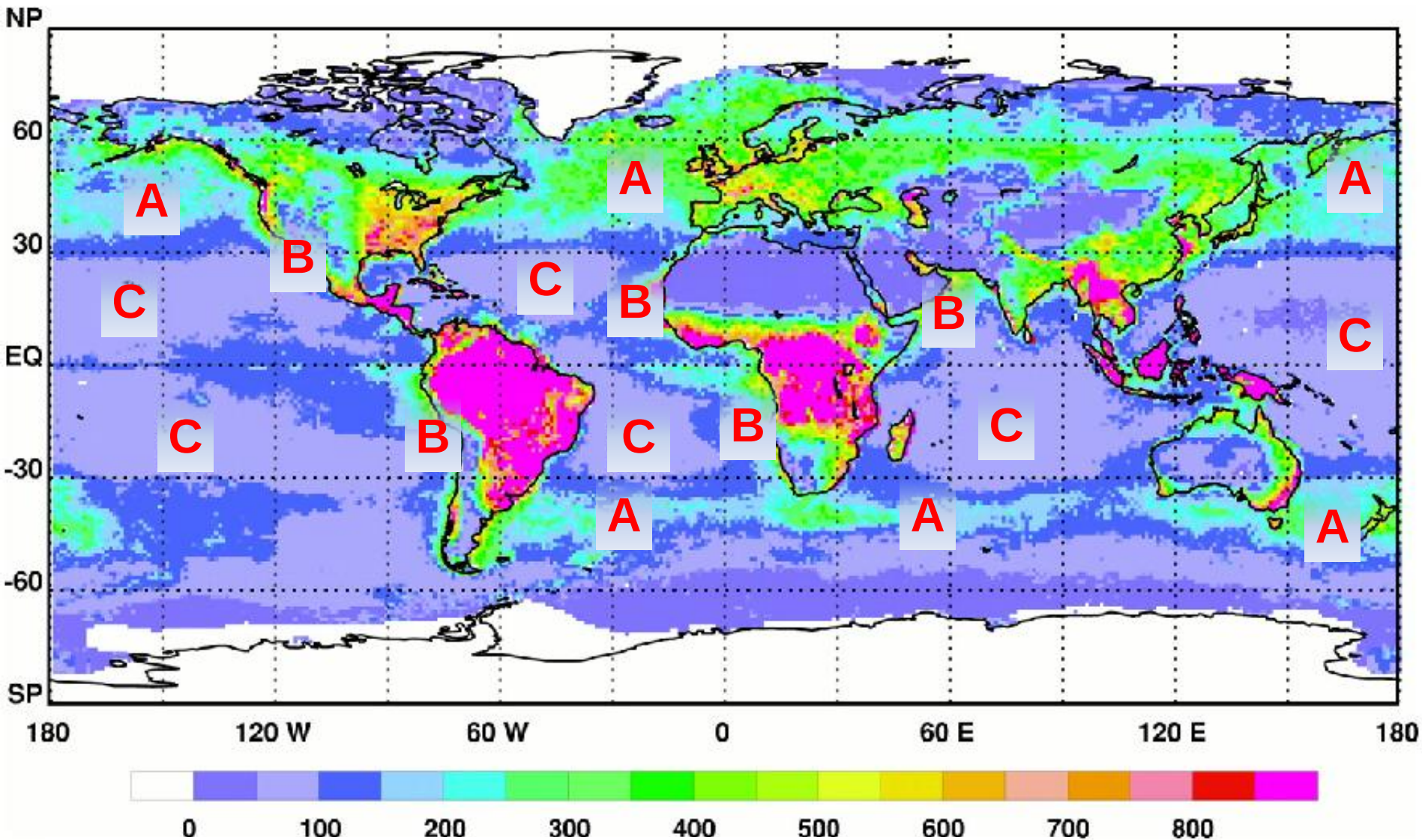
HAVFORSKNINGSINSTITUTTET
INSTITUTE OF MARINE RESEARCH

Food web and climate variables in the Barents Sea



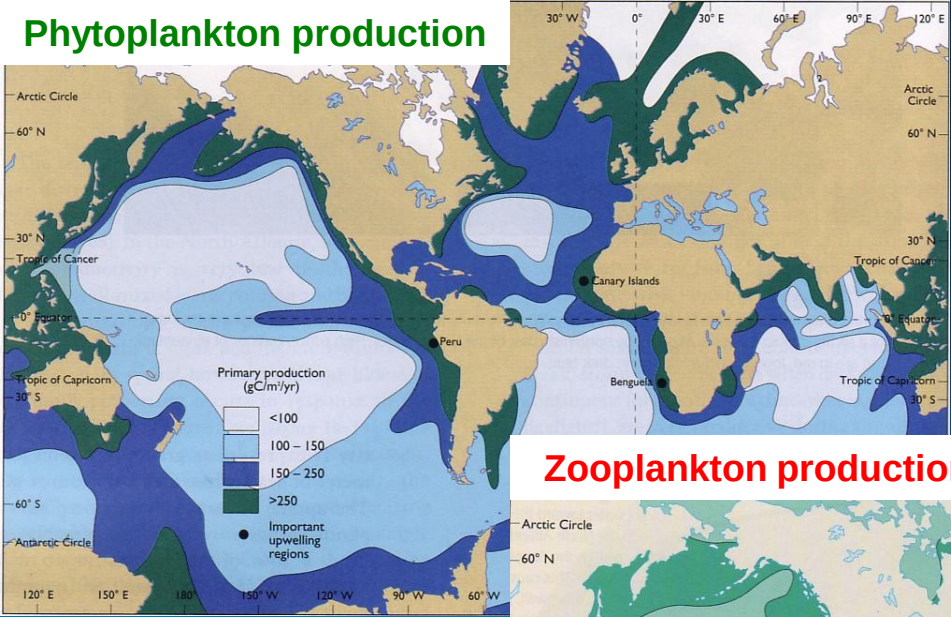


Global primary production $104.9 \times 10^{15} \text{ g C year}^{-1}$ (46.2 % Ocean / 53.8 Land)



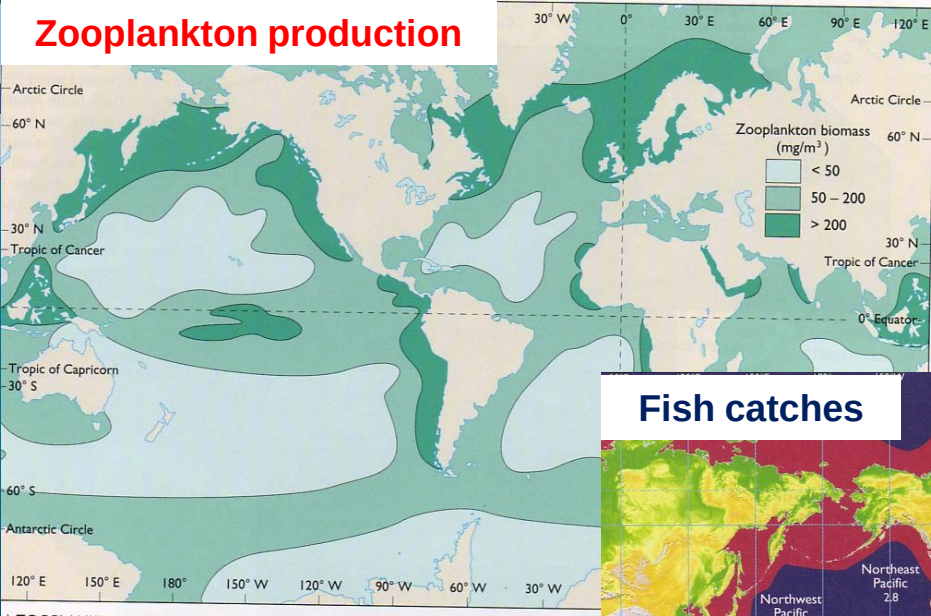
- A High-latitude spring-bloom systems
- B The large upwelling systems
- C Mid-ocean gyre systems

Phytoplankton production

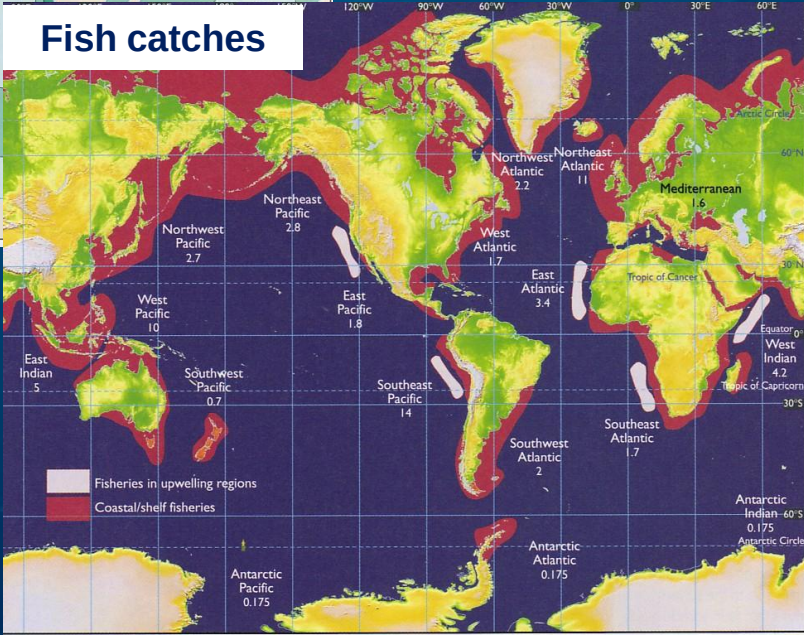


At large scales spatial distribution and abundance at different trophic levels are correlated

Zooplankton production



Fish catches

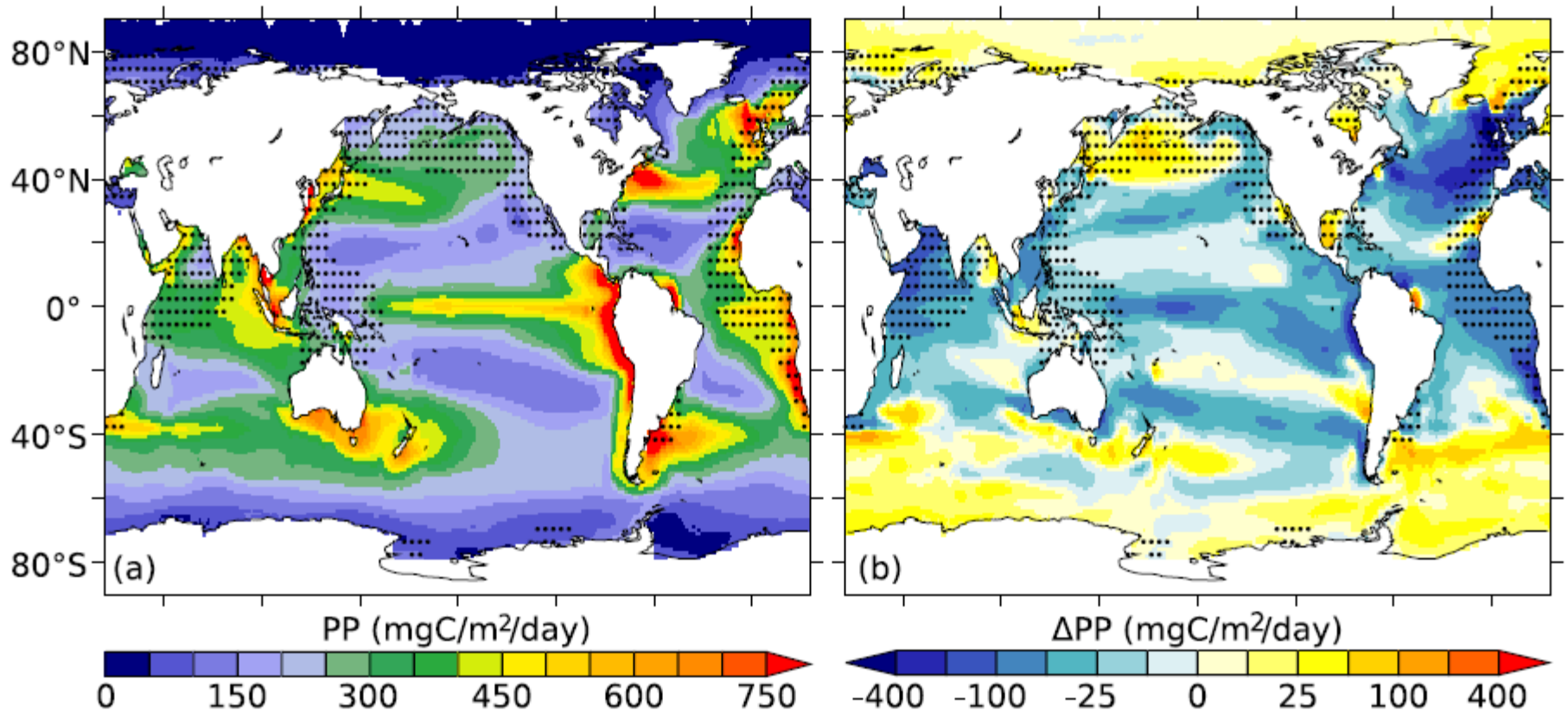


**The microscopic marine
plants**

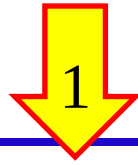
Globally modeled phytoplankton production (average of a group of different models)

Pre-industrial production
(1860s)

Change in production at
the end of this century
(2090s)

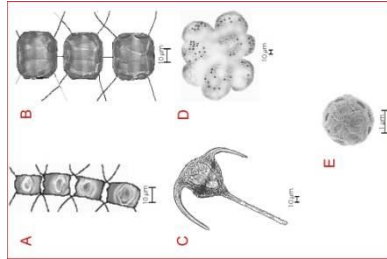


LIGHT → latitude, season, clouds



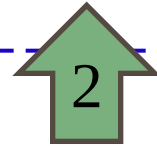
PHOTIC ZONE
10-100 m

TEMPERATURE



NUTRIENT
RECYCLING

zooplankton
phytoplankton
microbes
temperature

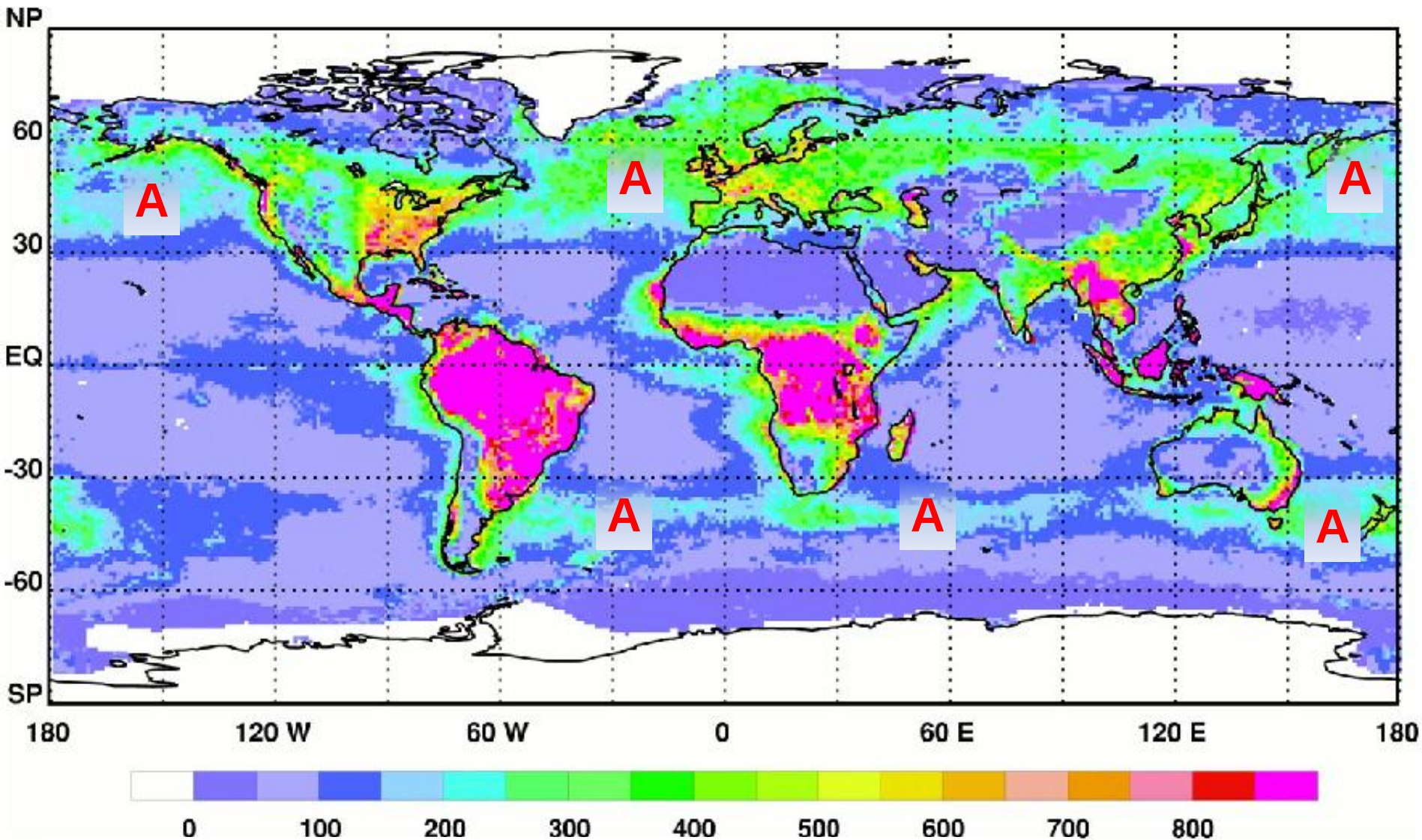


NUTRIENTS
&
MICRONUTRIENTS

→ upwelling, vertical mixing

FACTORS DETERMINING PHYTOPLANKTON
PRODUCTION & DYNAMICS

Global primary production 104.9×10^{15} g C year⁻¹ (46.2 % Ocean / 53.8 Land)



- A High-latitude spring-bloom systems
- B The large upwelling systems
- C Mid-ocean gyre systems

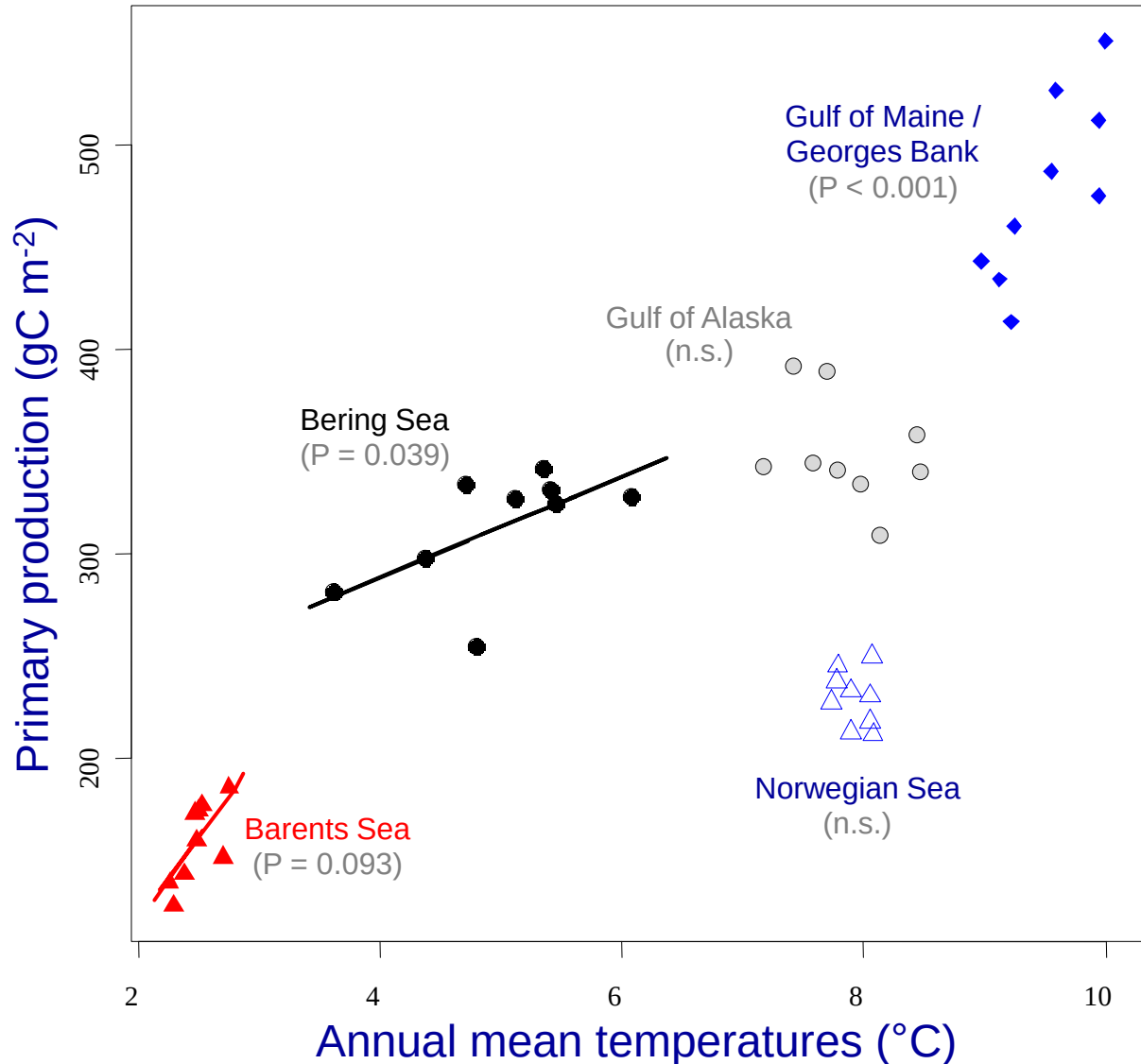
A

Phytoplankton in **high-latitude (arctic and boreal)** marine ecosystems

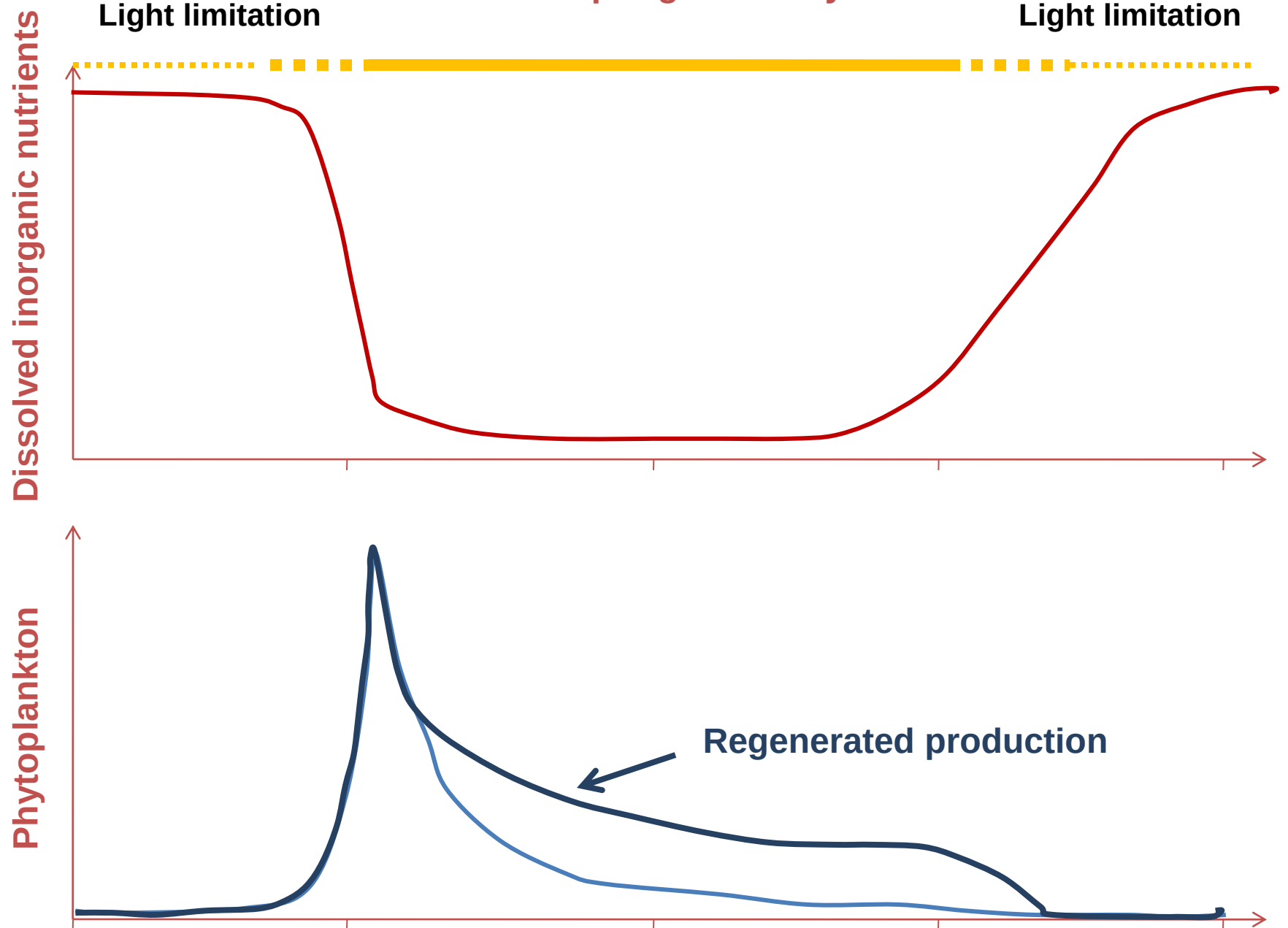
Temperature controls primary production at high-latitude marine ecosystems

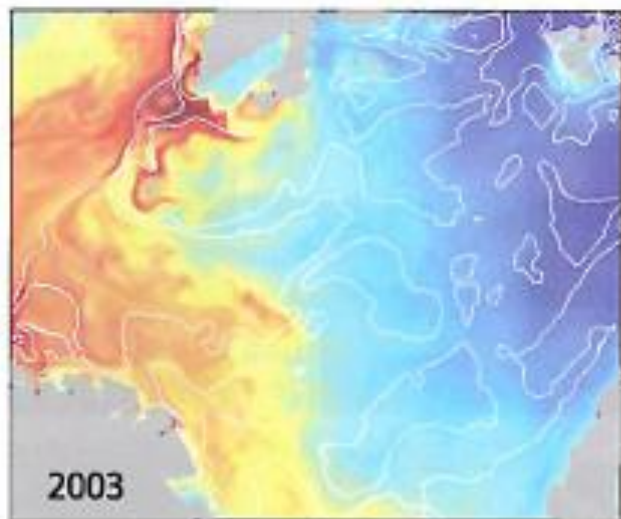


Global warming increases productivity

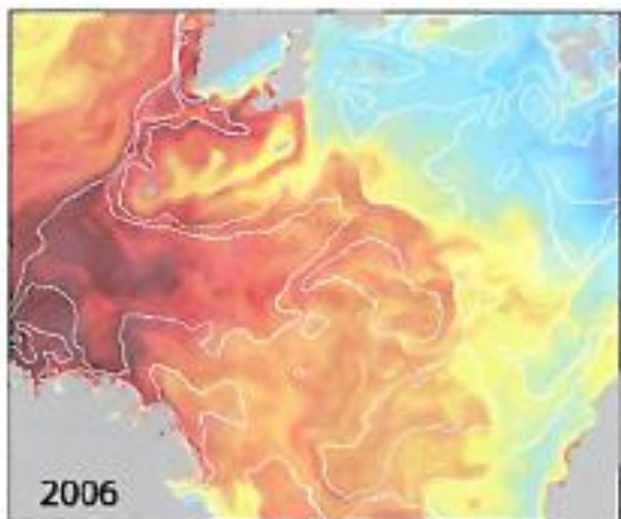


The arctic spring bloom dynamics



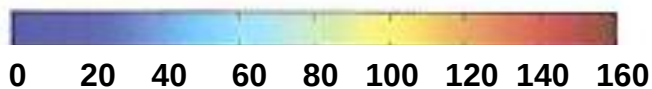


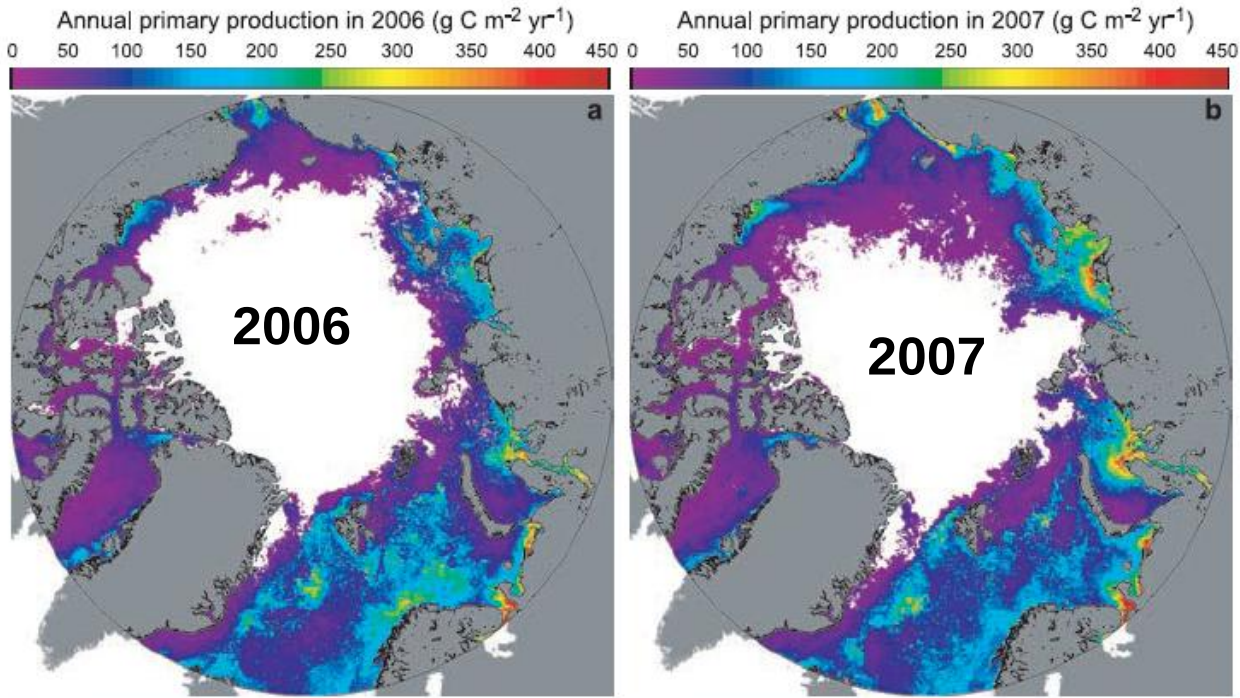
Cold year



Warm year

**Annual primary production
upper 50 m (g C /m²/year)**





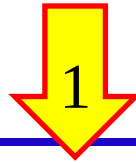
Annual primary production

Increasing
primary
production
where the ice
disappears

A

High-latitude spring-bloom ecosystem

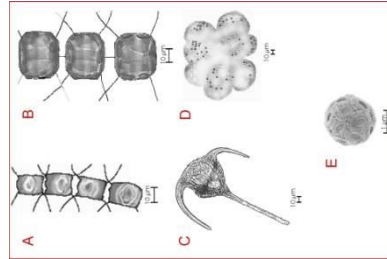
LIGHT → latitude, season, clouds



+
less ice cover

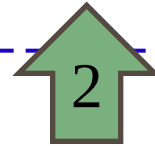
PHOTIC ZONE
10-100 m

TEMPERATURE



NUTRIENT
RECYCLING →

zooplankton
phytoplankton
microbes
temperature



NUTRIENTS

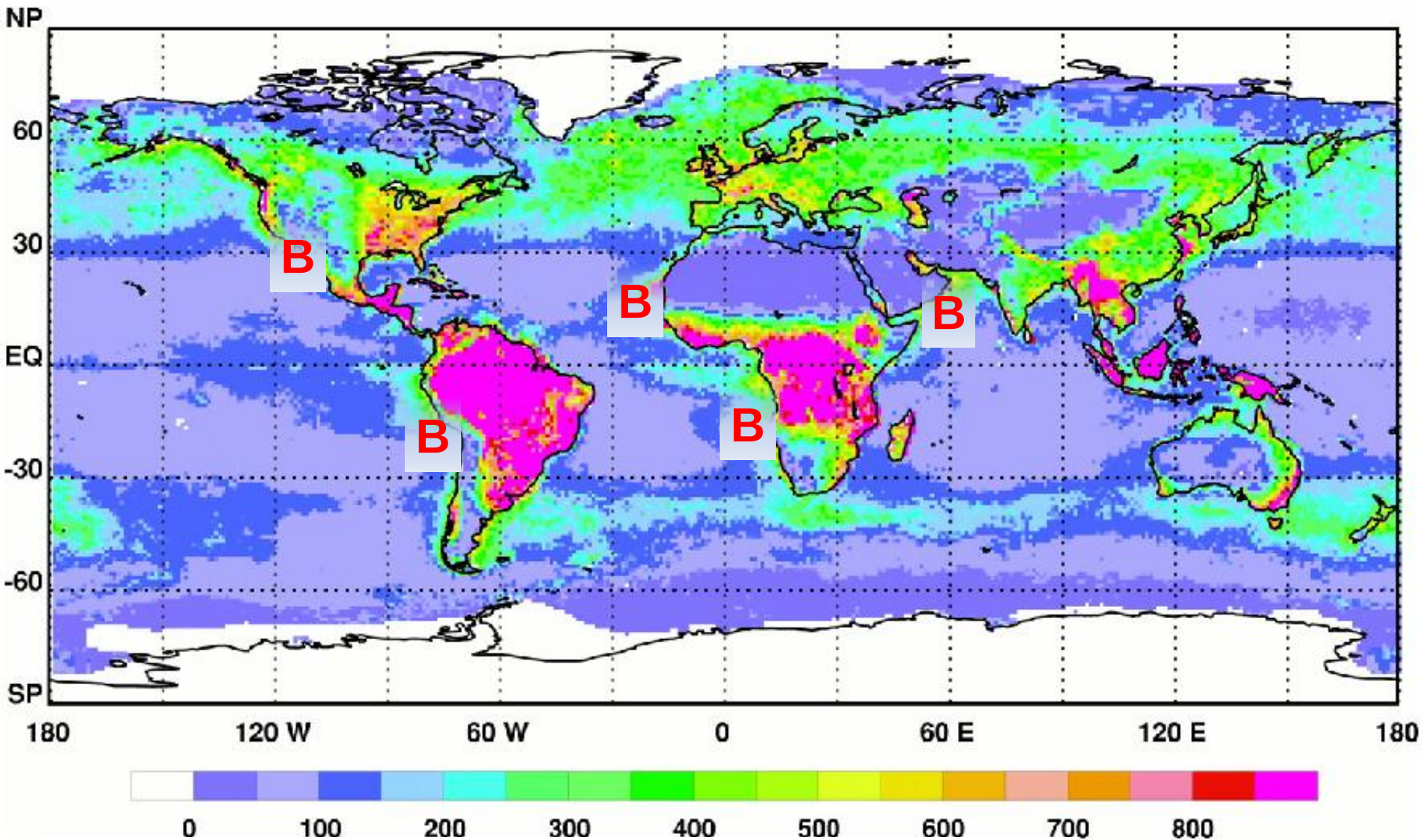
&

→ upwelling, vertical mixing

MICRONUTRIENTS

FACTORS DETERMINING PHYTOPLANKTON
PRODUCTION & DYNAMICS

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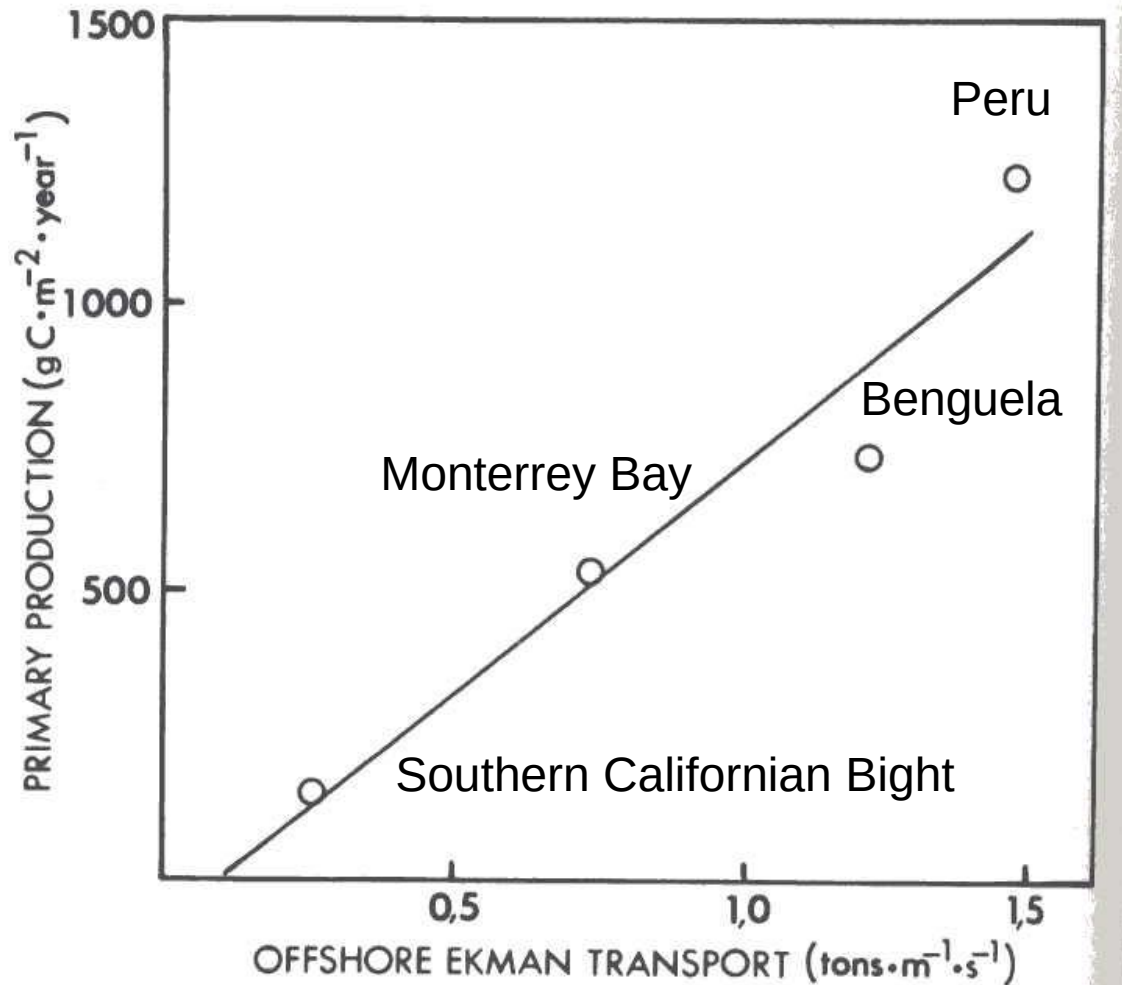
B

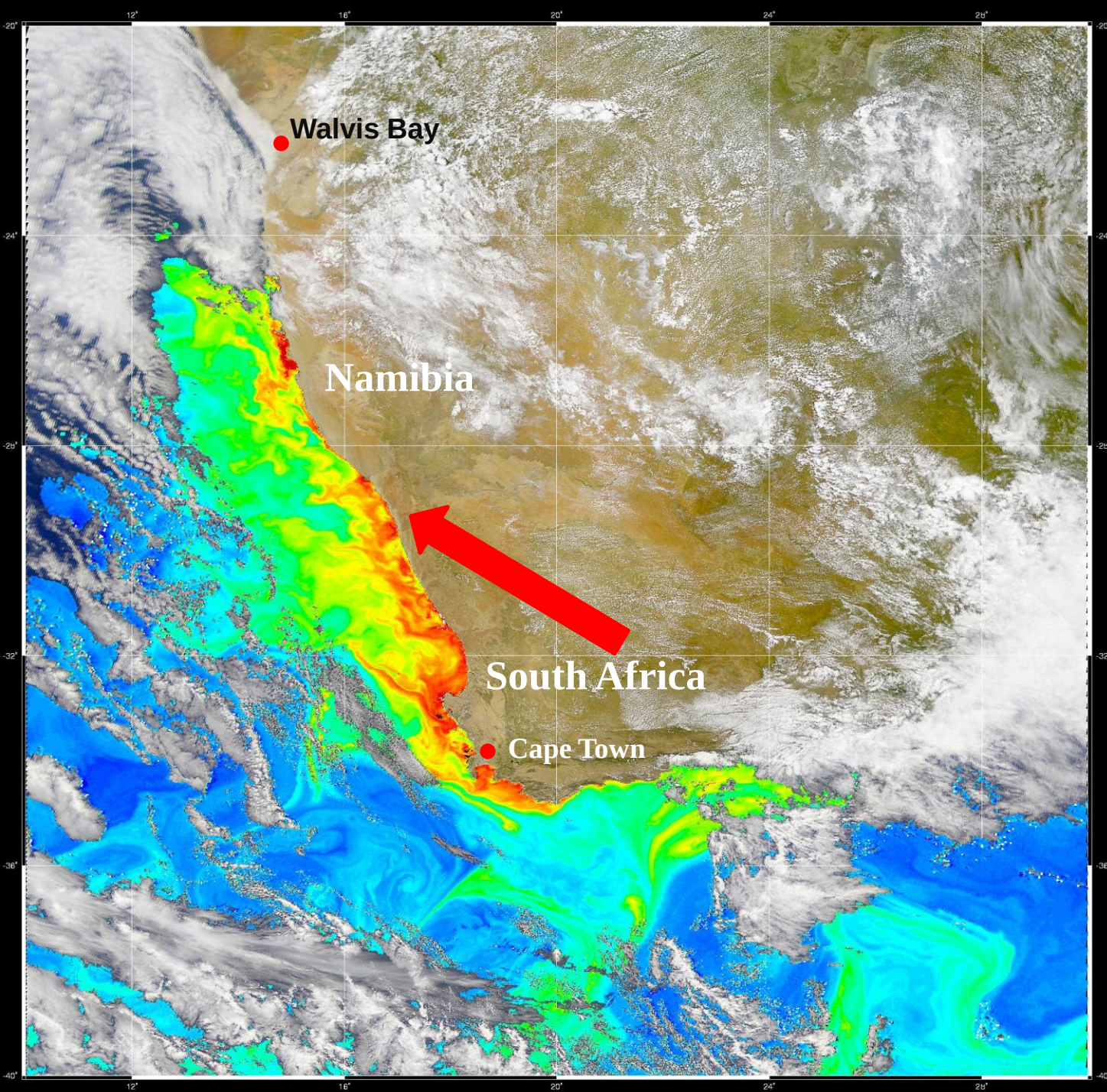
Primary production in **upwelling ecosystems**

Wind control
phytoplankton production
in upwelling regions



Global warming
probably increases
productivity

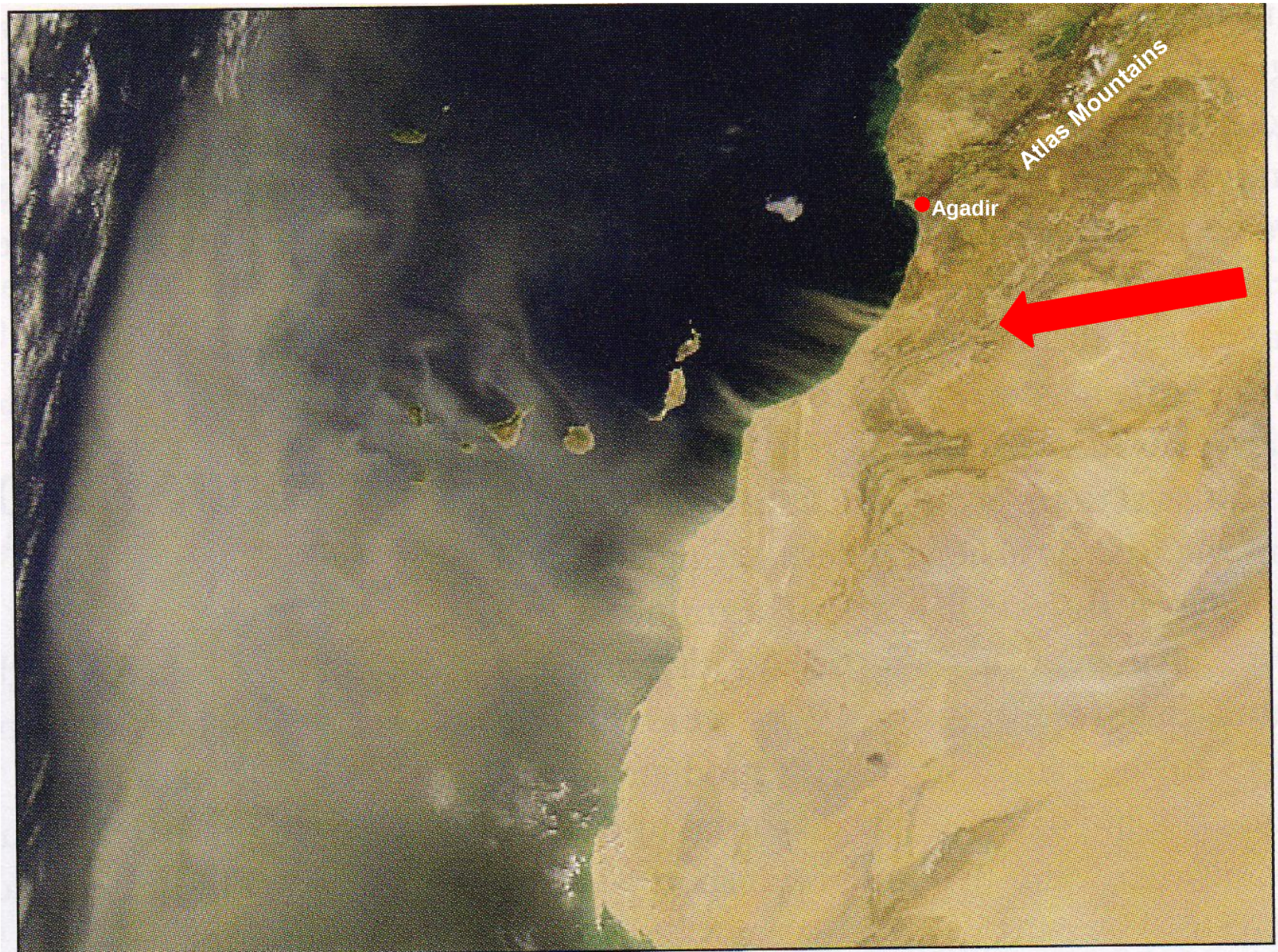




Benguela
upwelling
system –

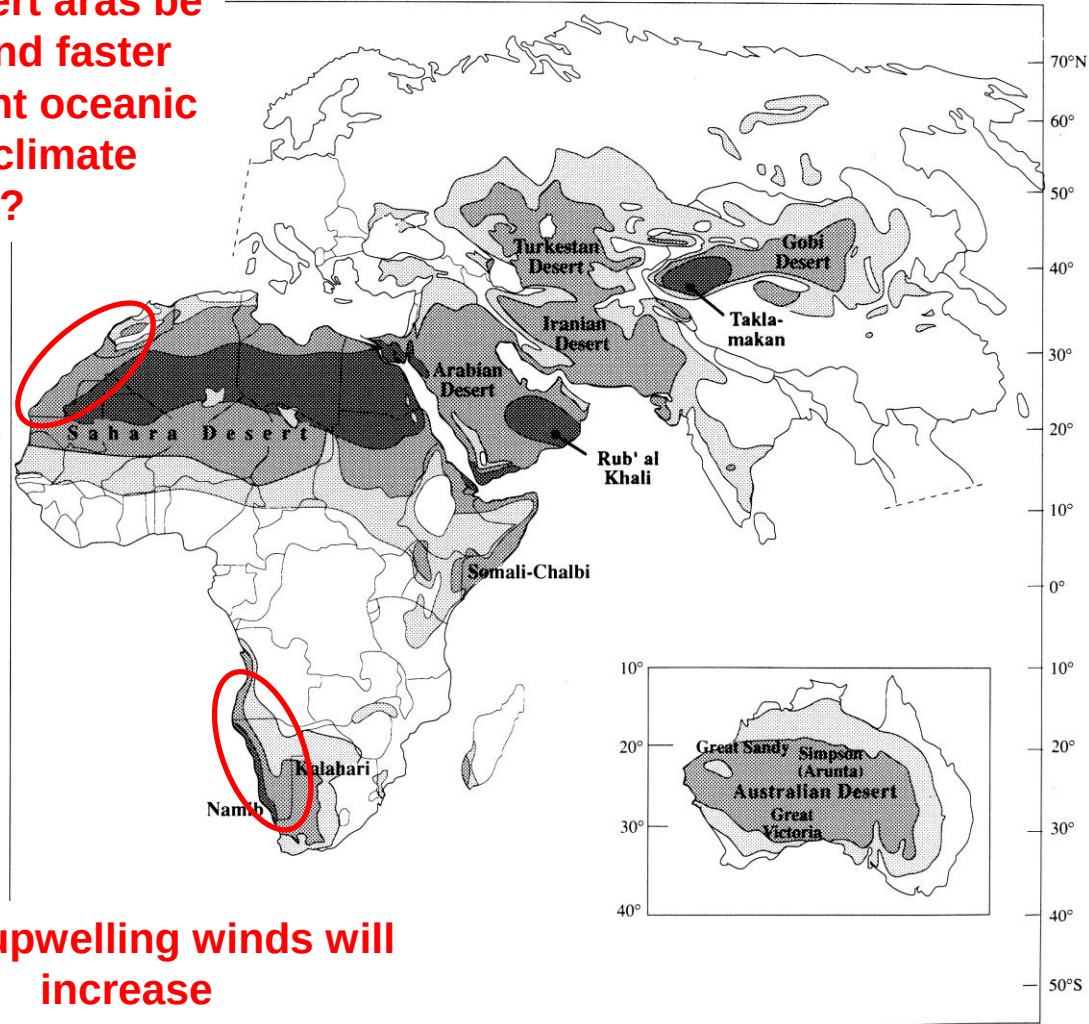
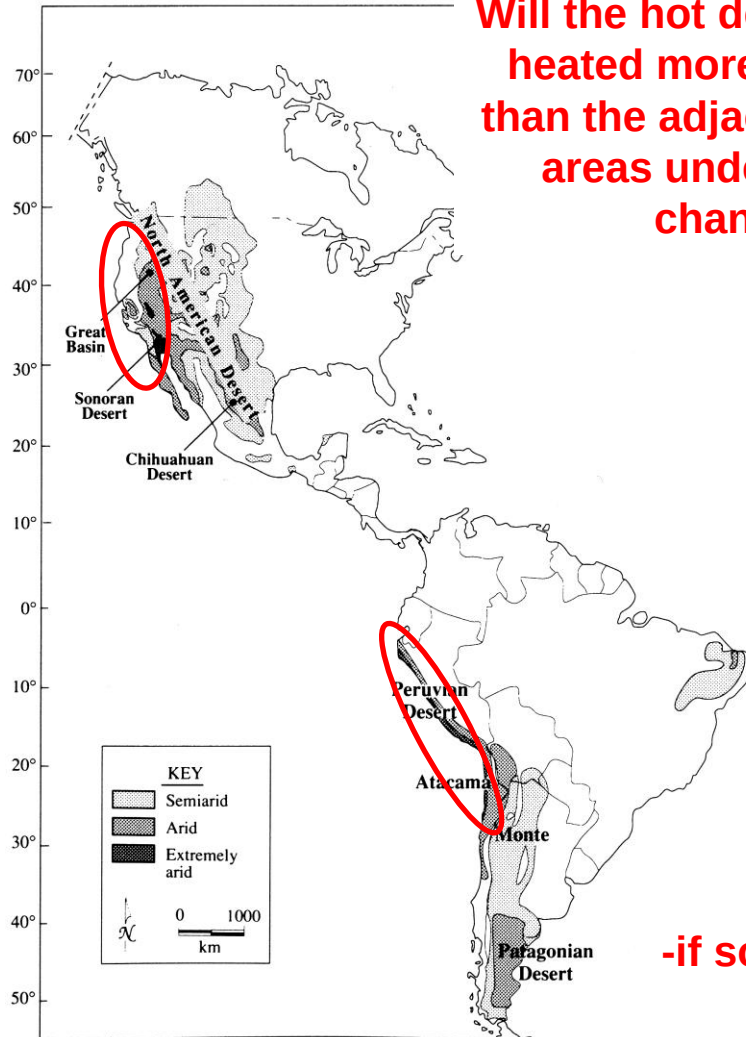
Forced by the
southeasterly
winds

Dust transport from Sahara across the Canary Current



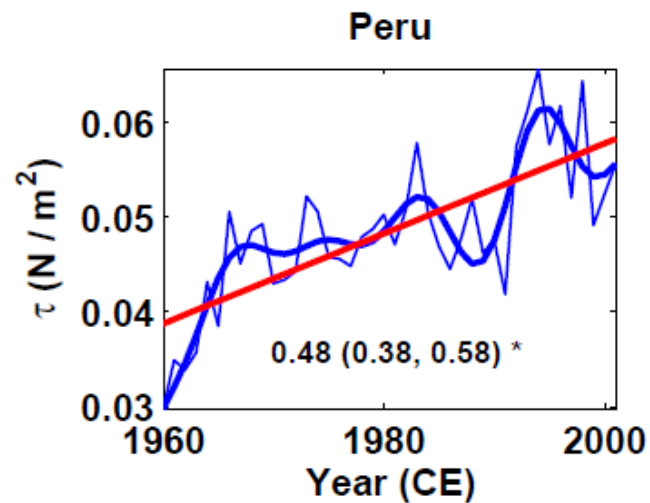
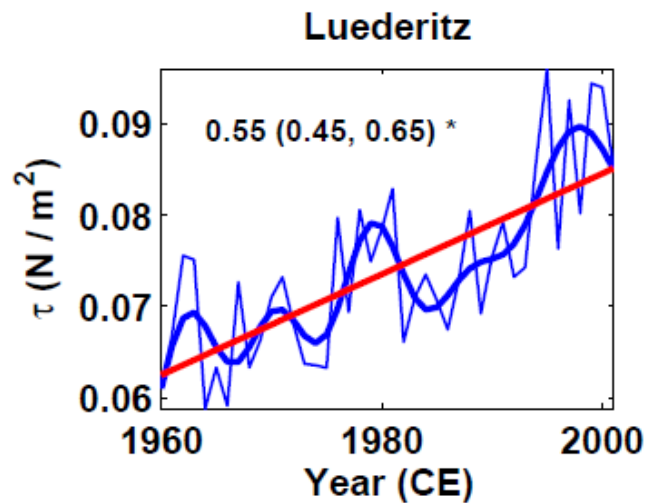
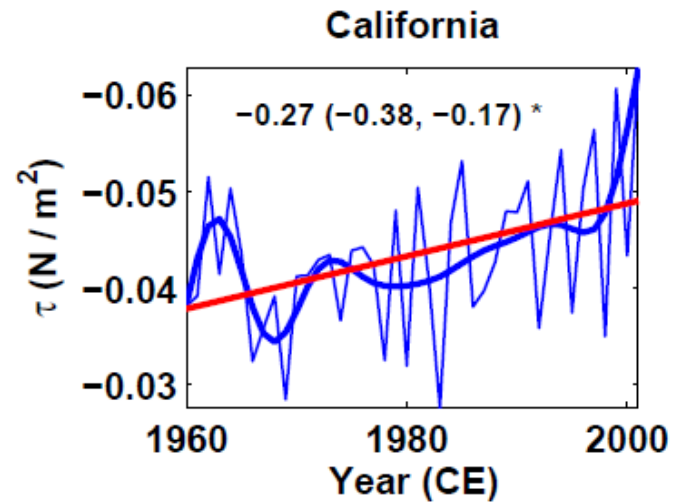
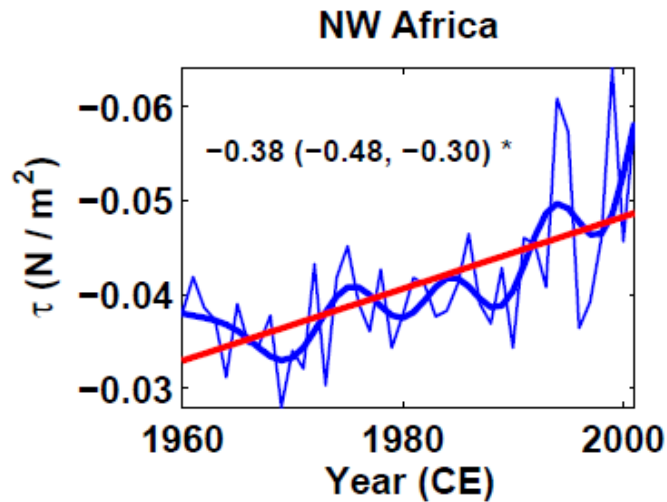
Arid lands around the world

Will the hot desert areas be heated more and faster than the adjacent oceanic areas under climate change?



-if so, upwelling winds will increase

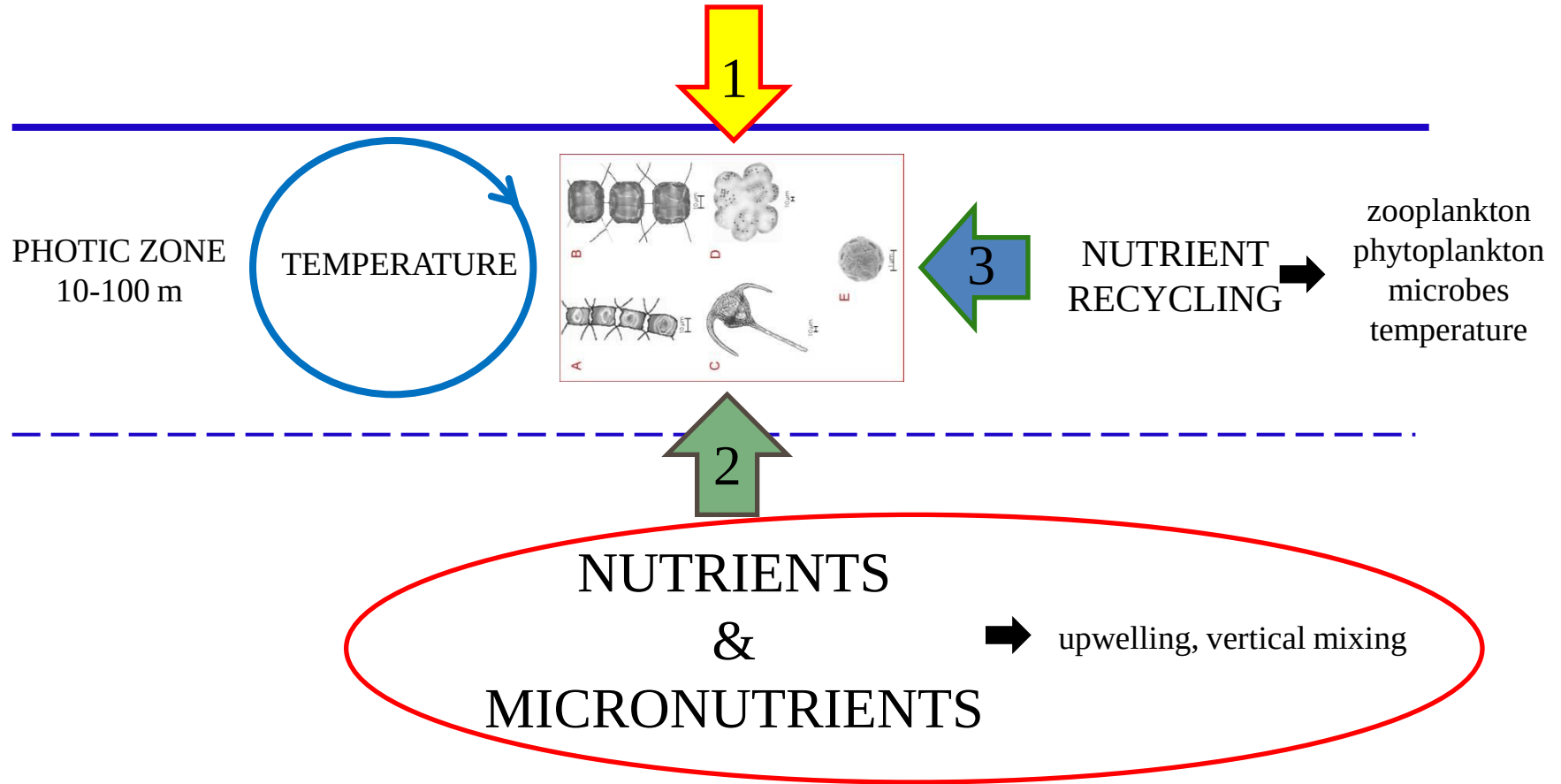
- and wind forcing has increased in all the four large upwelling ecosystems since 1960



B

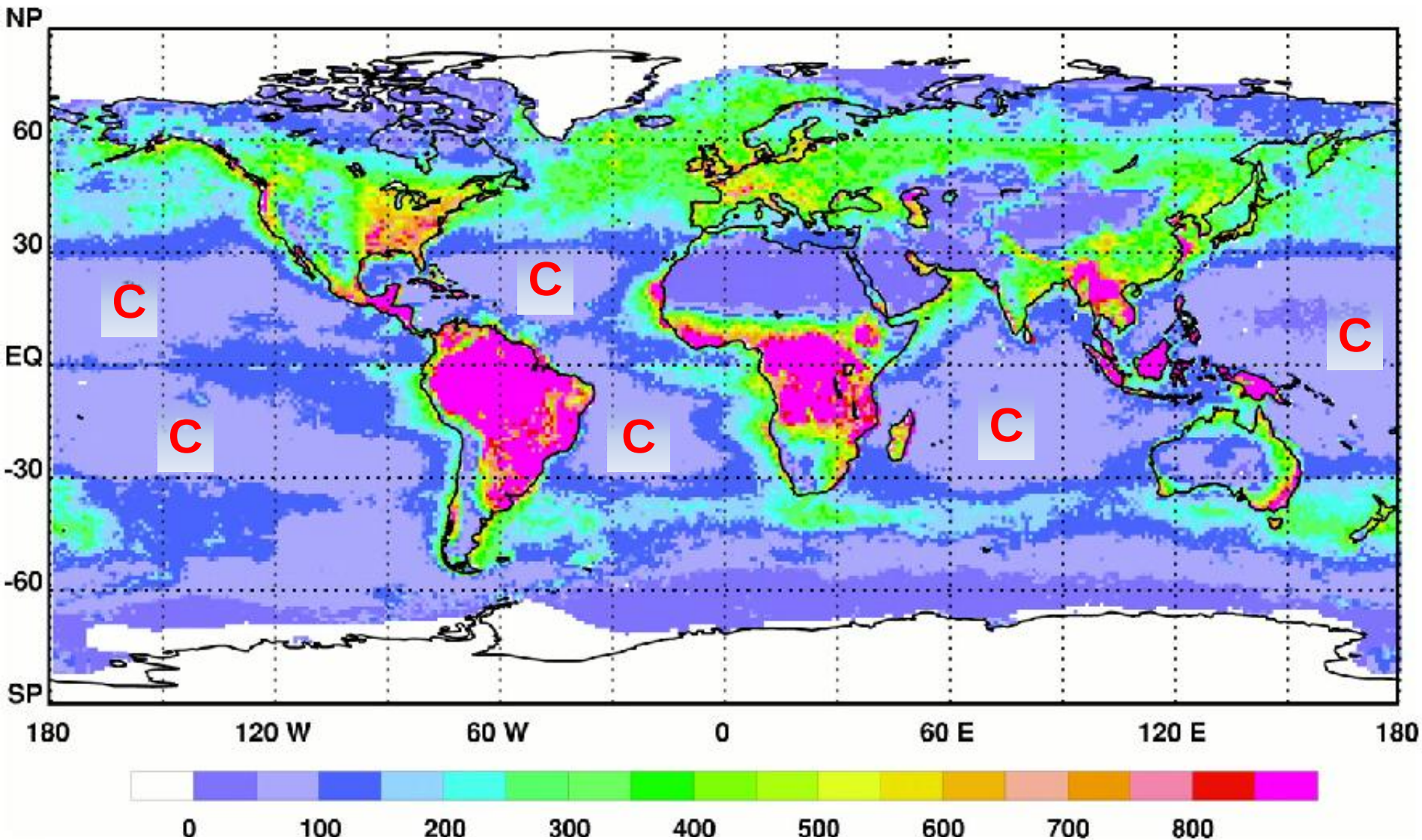
Upwelling ecosystem

LIGHT → latitude, season, clouds



**FACTORS DETERMINING PHYTOPLANKTON
PRODUCTION & DYNAMICS**

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Steady-state conditions for the tropical ocean

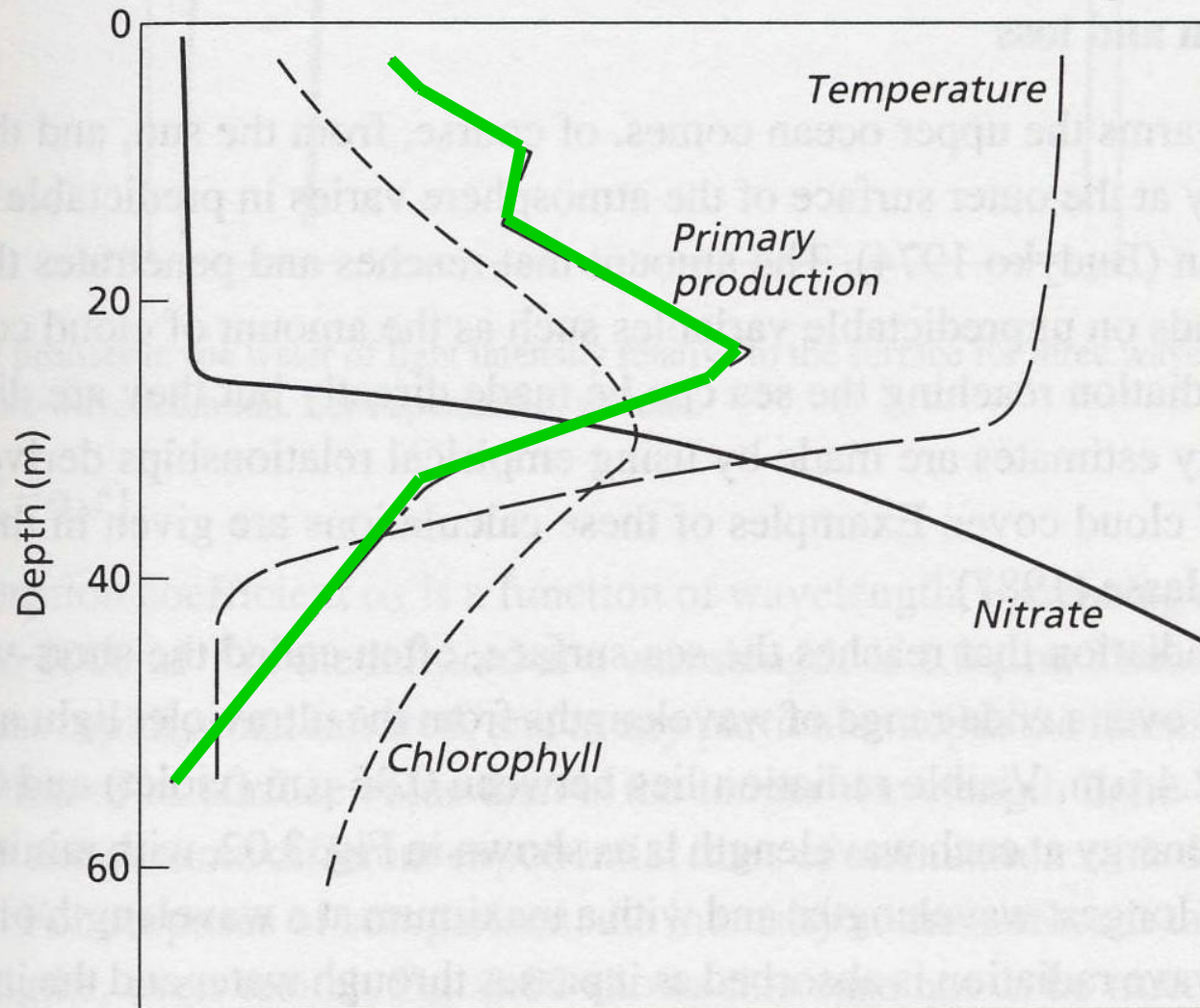


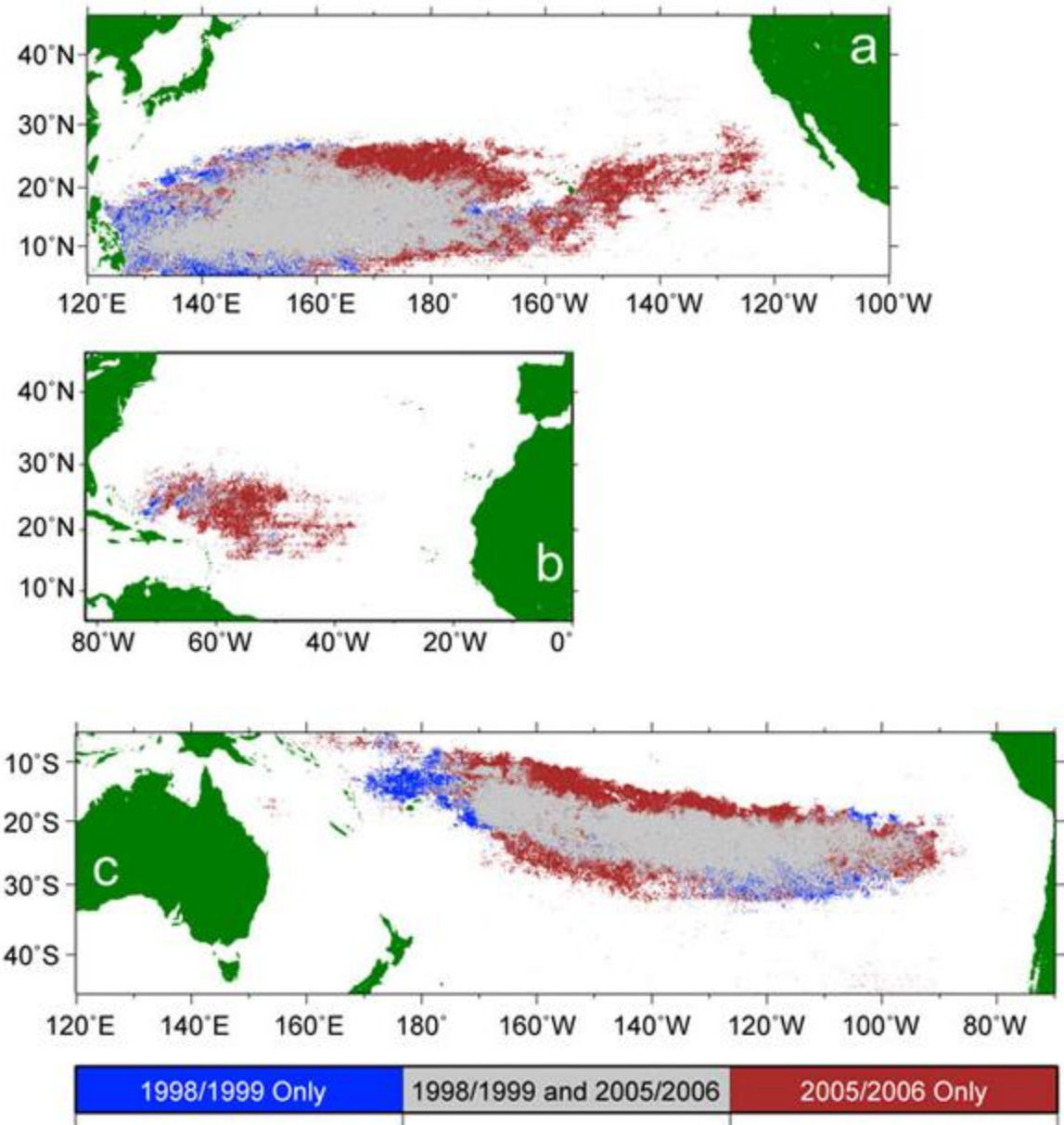
Fig. 3.01 Schematic diagram showing typical vertical structure of the water column in tropical latitudes ('typical tropical structure'—TTS). Note that the thermocline and the nutricline are at the same depth. The peak of primary production is more shallow than the peak of chlorophyll (= phytoplankton biomass).

C

Primary production in mid-ocean gyres – oligotrophic systems

Thermal stratification controls primary production oligotrophic marine ecosystems.

Global warming reduces productivity

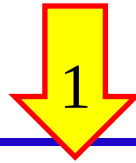


Polovina *et al.* (2007)

C

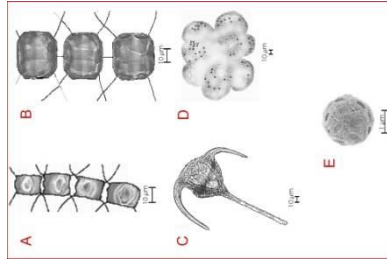
Low-productive ocean-gyre ecosystems

LIGHT → latitude, season, clouds



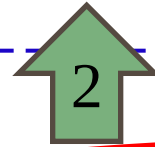
PHOTIC ZONE
10-100 m

TEMPERATURE



NUTRIENT
RECYCLING

zooplankton
phytoplankton
microbes
temperature

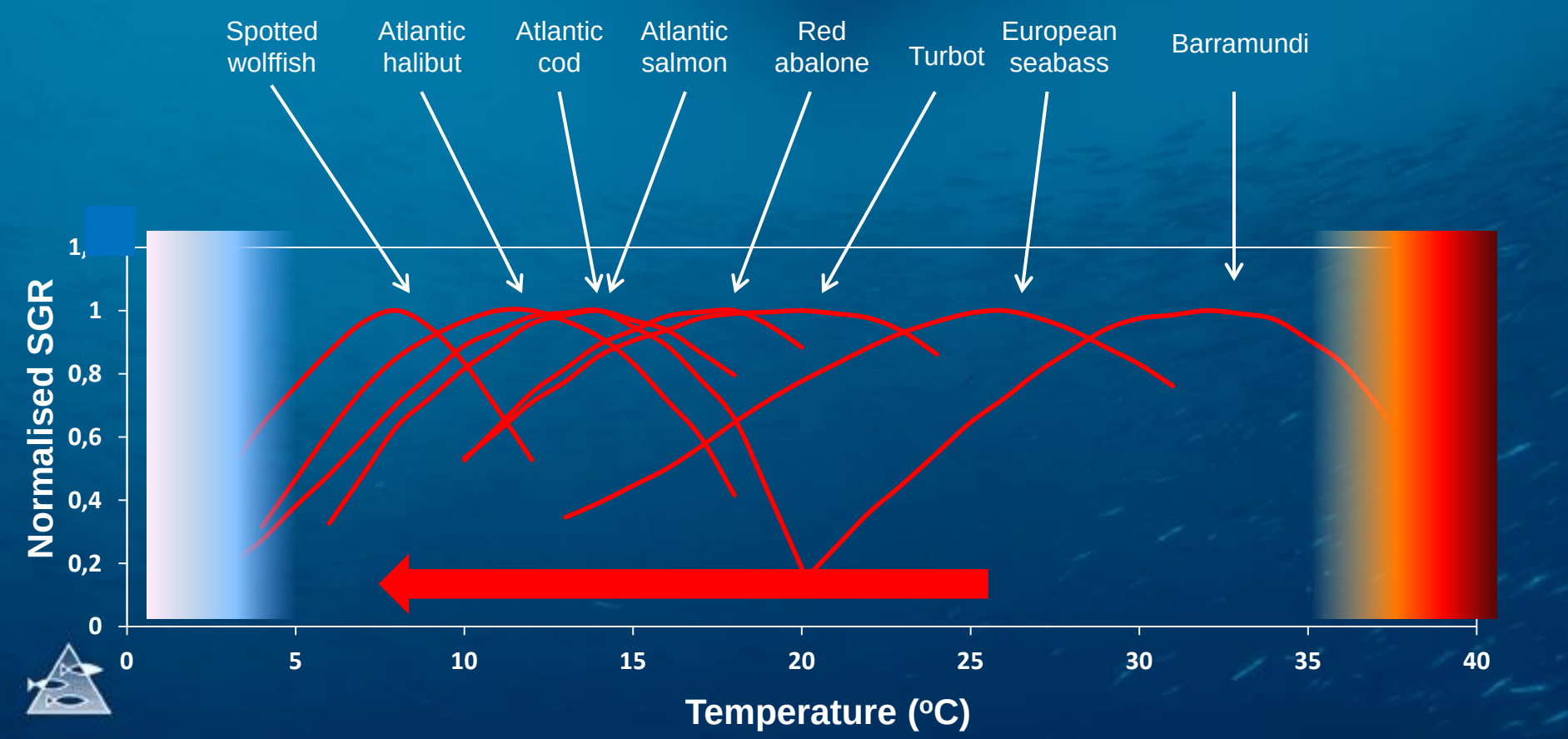


NUTRIENTS
&
MICRONUTRIENTS

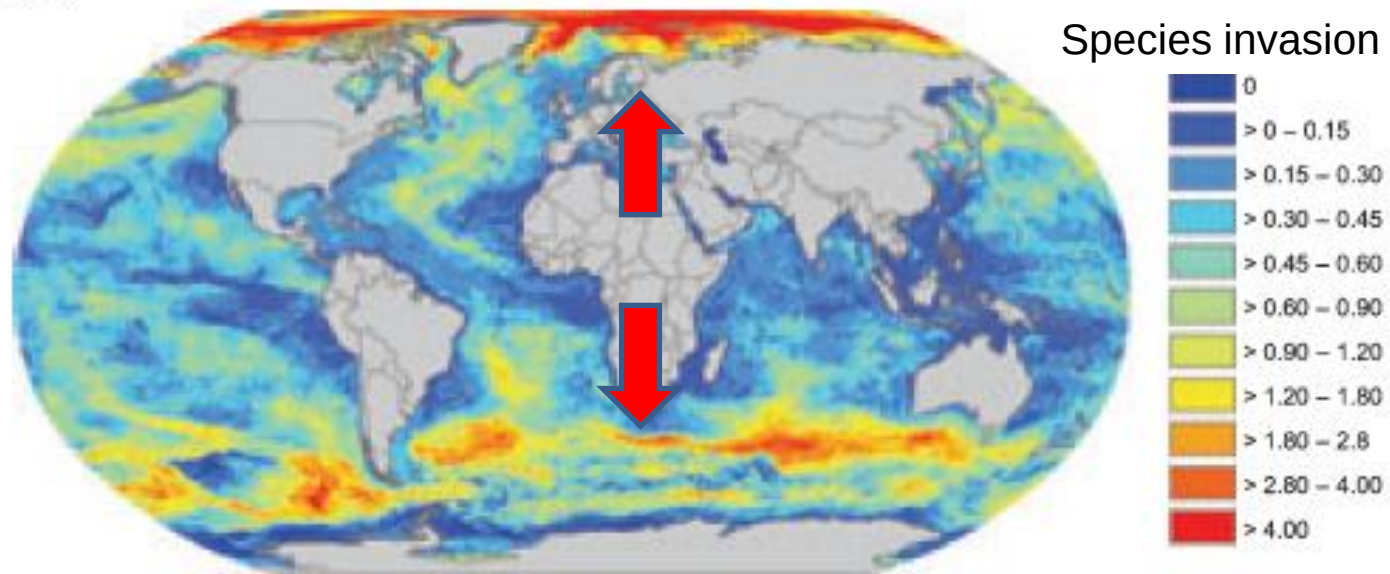
→ upwelling, vertical mixing

FACTORS DETERMINING PHYTOPLANKTON
PRODUCTION & DYNAMICS

Spotted wolffish: *Imsland et al. (2006)* Aquaculture
Atlantic halibut: *Jonassen et al. (1999)* Journal of Fish Biology ; *Björnsson and Trygvadóttir (1996)* Aquaculture
Arctic charr: *Larsson and Berglund (1998)* Journal of Fish Biology
Atlantic cod: *Otterlei et al. (2000)* Can J. Aquat. Fish.; *Björnsson et al. (2007)* Aquaculture
Atlantic salmon: *Handeland et al. (2008)* Aquaculture
Pollock: *Person-Le Ruyet et al. (2006)* Aquaculture
Red abalone: *Steinarsson and Imsland (2003)* Aquaculture
Turbot: *Imsland et al. (2001)* Aquaculture ; *Van Ham et al. (2003)* Aquaculture
European seabass: *Person-Le Ruyet et al. (2004)* Aquaculture
Barramundi: *Katersky and Carter (2007)* Aquaculture

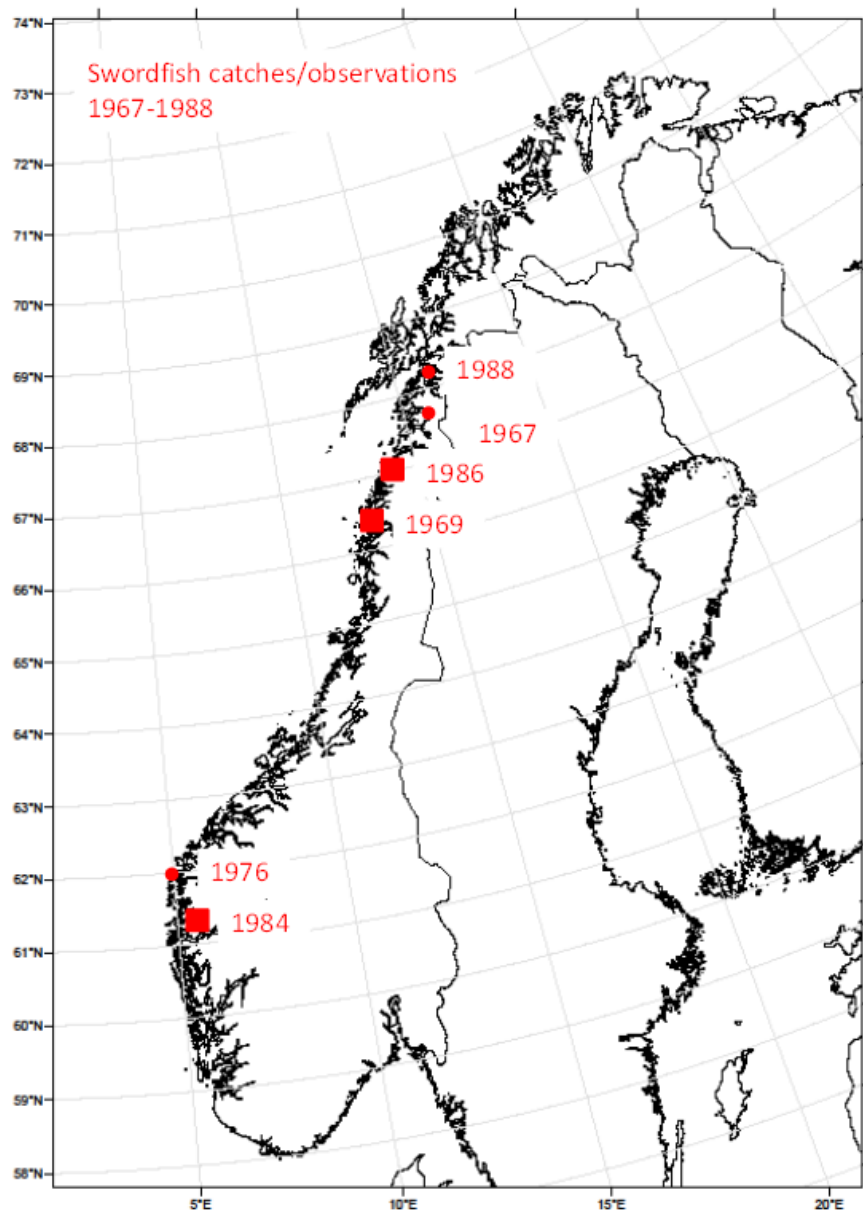


(a)



Unni Justsen with 22 kg swordfish
in Vinjefjorden, Mid Norway,
November 2006





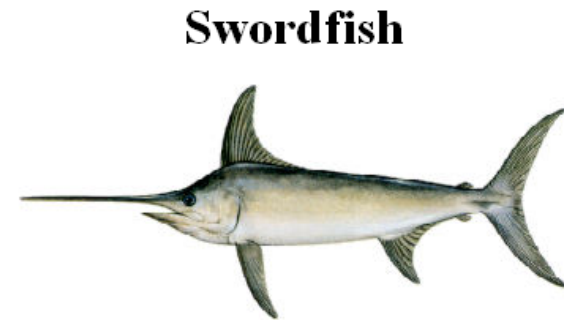
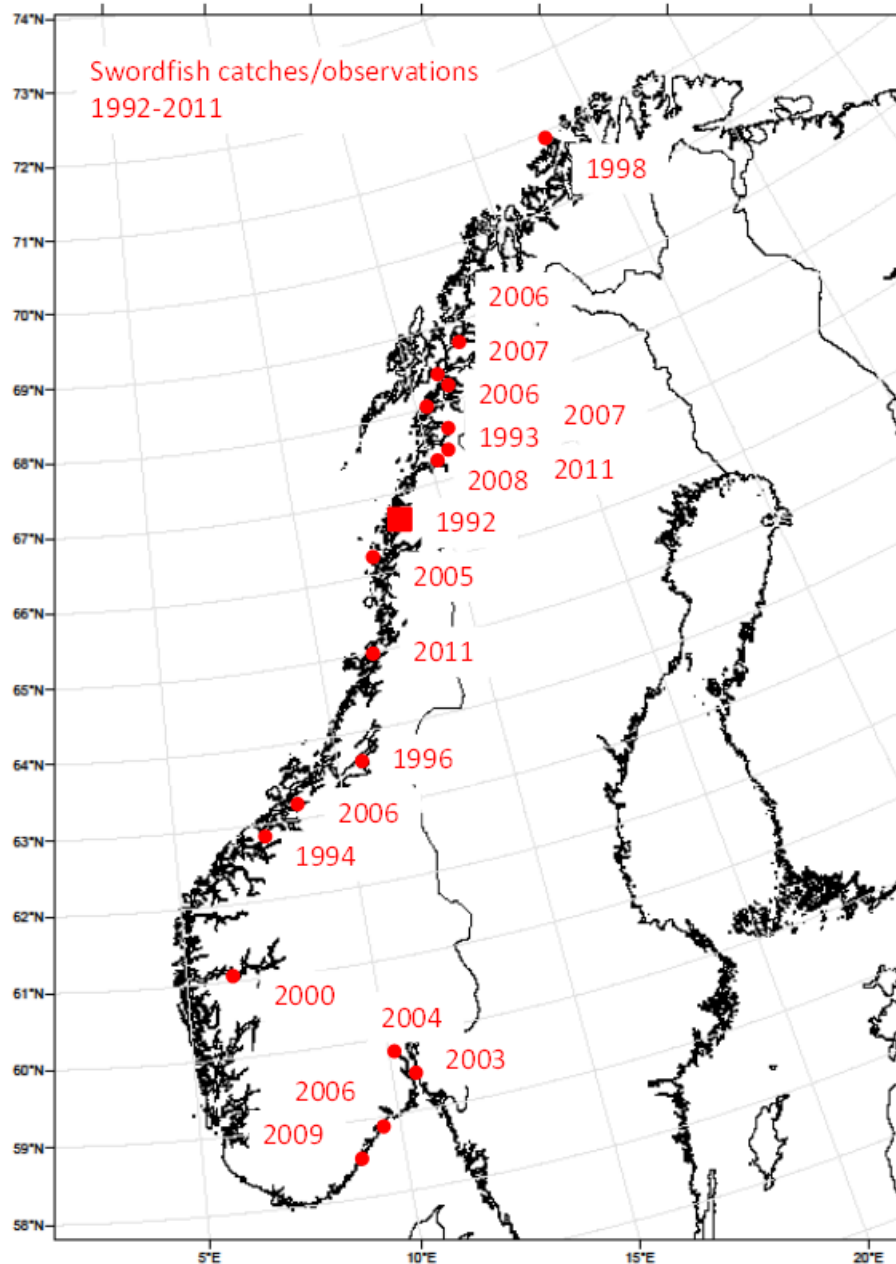
Swordfish



Family Xiphiidae, SWORDFISHES
Xiphias gladius

Observations 1967-1990

Figure 1. Catches and observations of swordfishes along the Norwegian coast and in the fjords period 1967-1988. Circles show exact location of the observation. Where exact locations are not indicate approximate location.

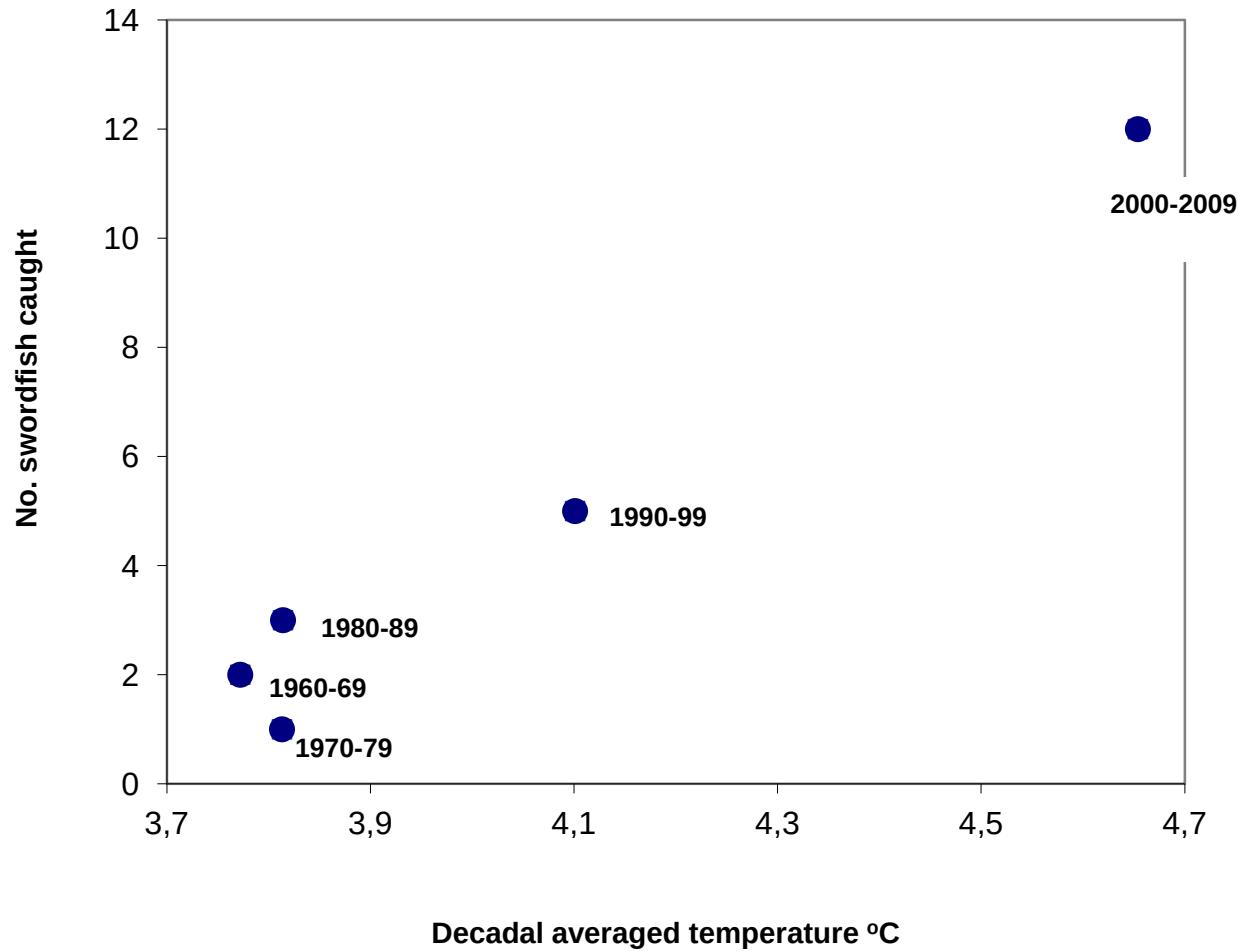


Family Xiphiidae, SWORDFISHES
Xiphias gladius

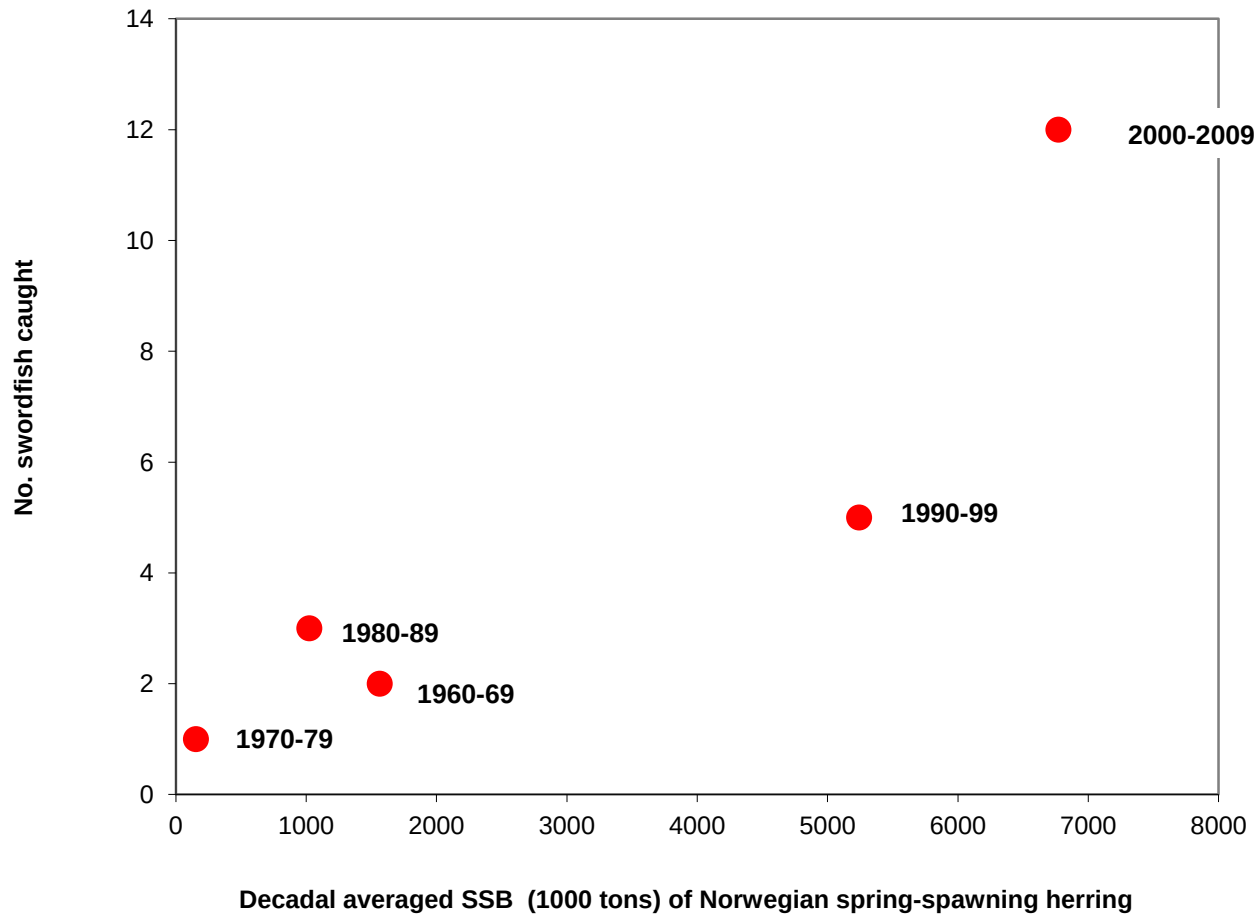
Observations 1990-2011

Figure 2. Catches and observations of swordfishes along the Norwegian coast and in the fjords during the period the period 1992-2011. Circles show exact location of the observation. Larger square indicates approximate location where exact location is not known.

No of swordfish caught in each decade versus the decadal averaged temperature of the northeastern North Atlantic (Temperature based on the Kola Section time series in the Barents Sea).



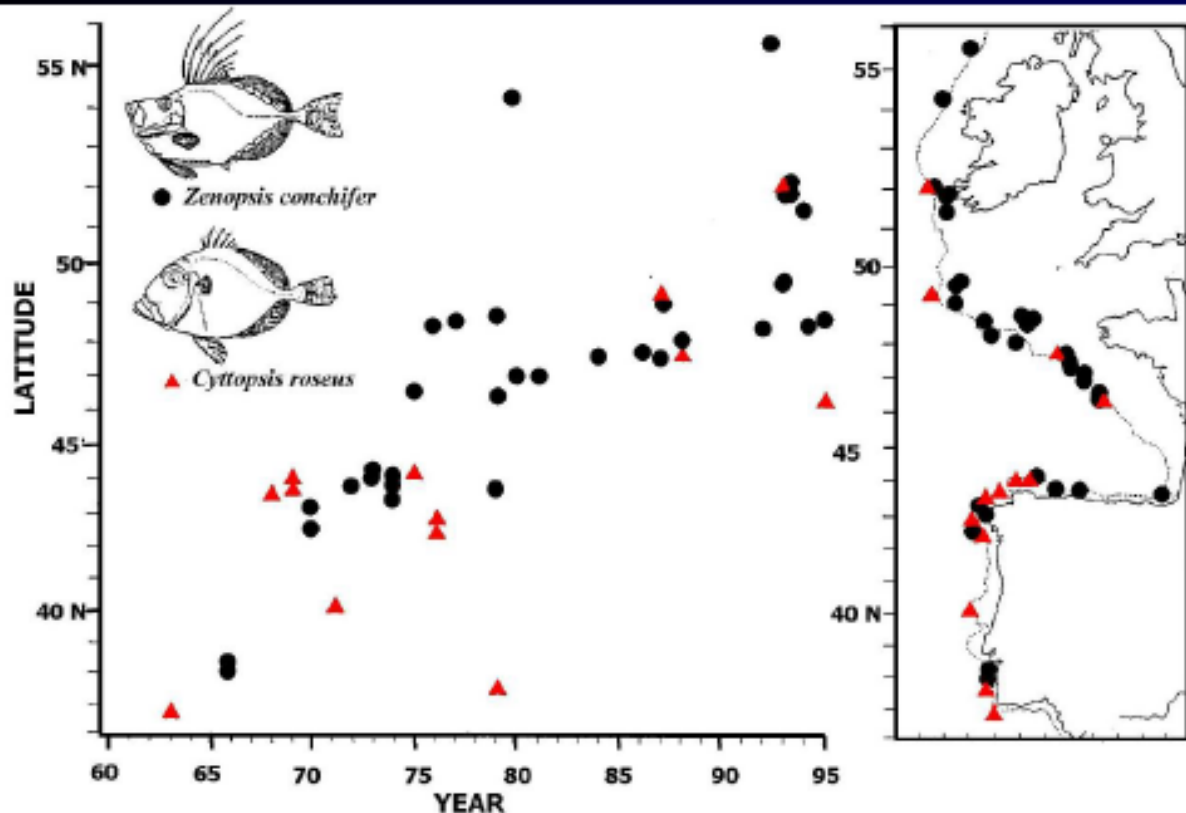
Number of swordfish caught in each decade versus the decadal averaged spawning-stock biomass (in 1000 tonns) of Norwegian spring-spawning herring.



Farther South

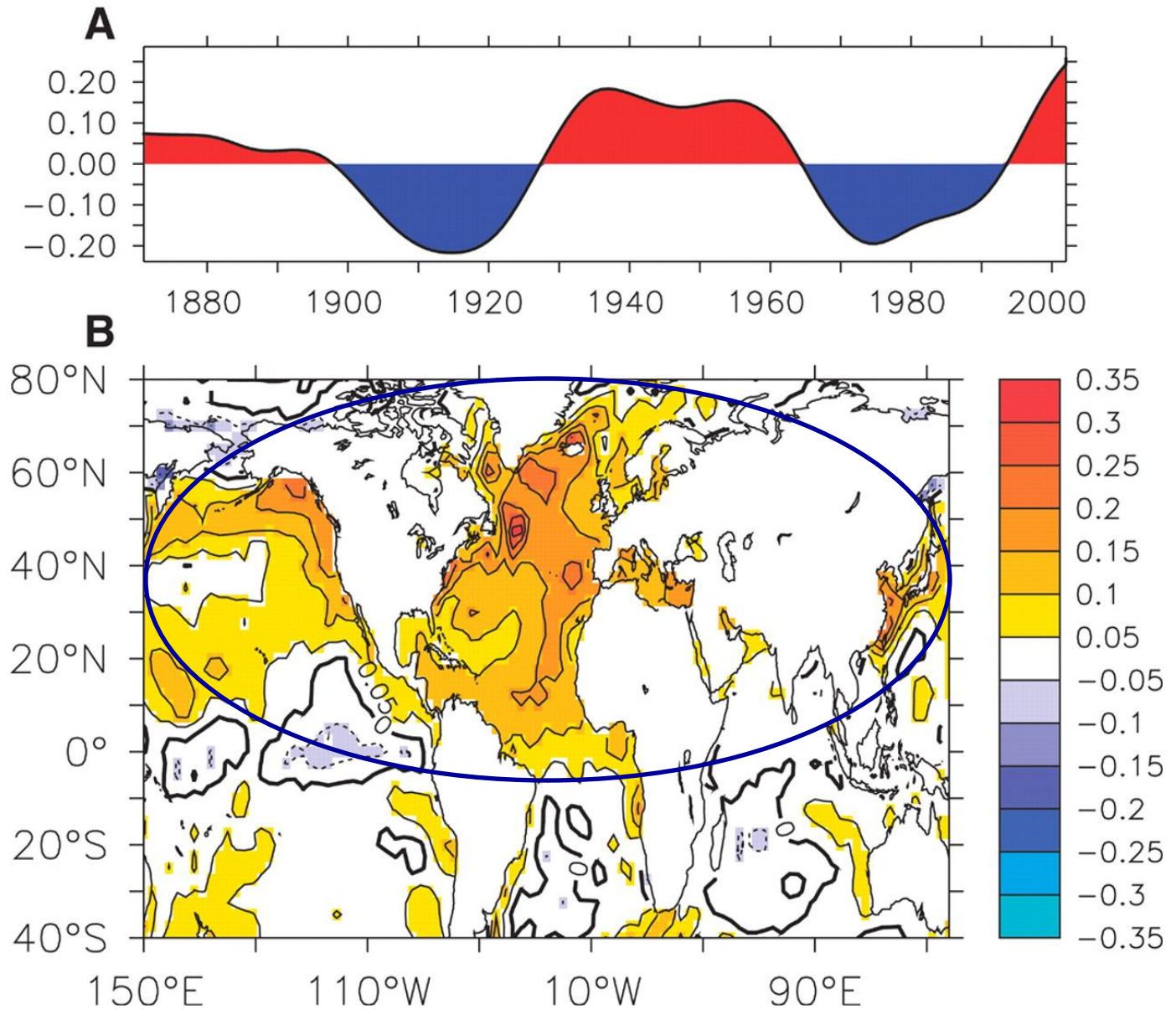
General northward displacement of commercial and non-commercial species of fish.

- In North Sea northward displacement of fish at rate of 7 km per year over 1990s, 7 times faster than on land (Perry, 2004)

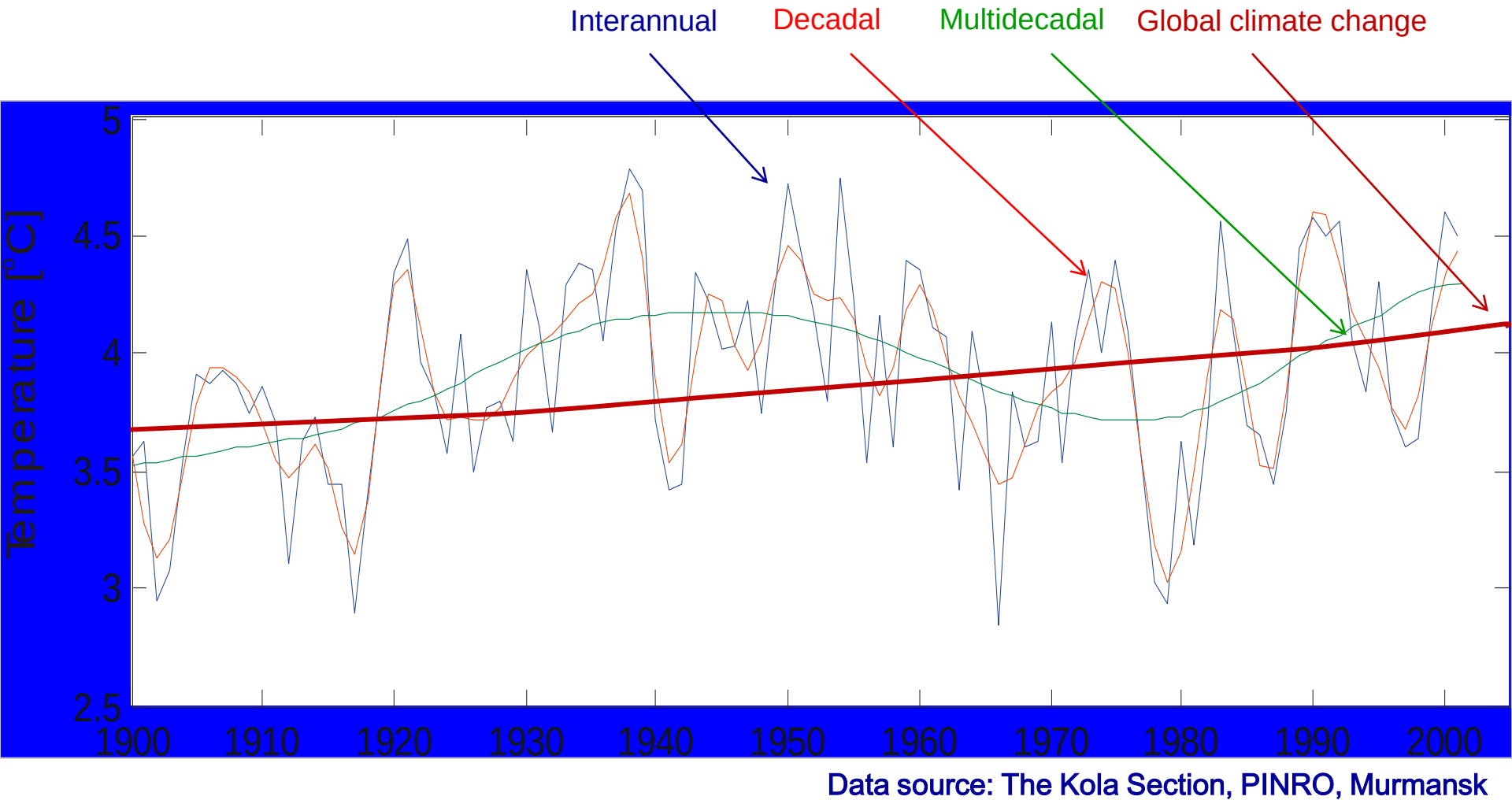


- Acceleration of southern species moving north from Iberian Peninsula to West of Scotland (Quero et al., 1998)

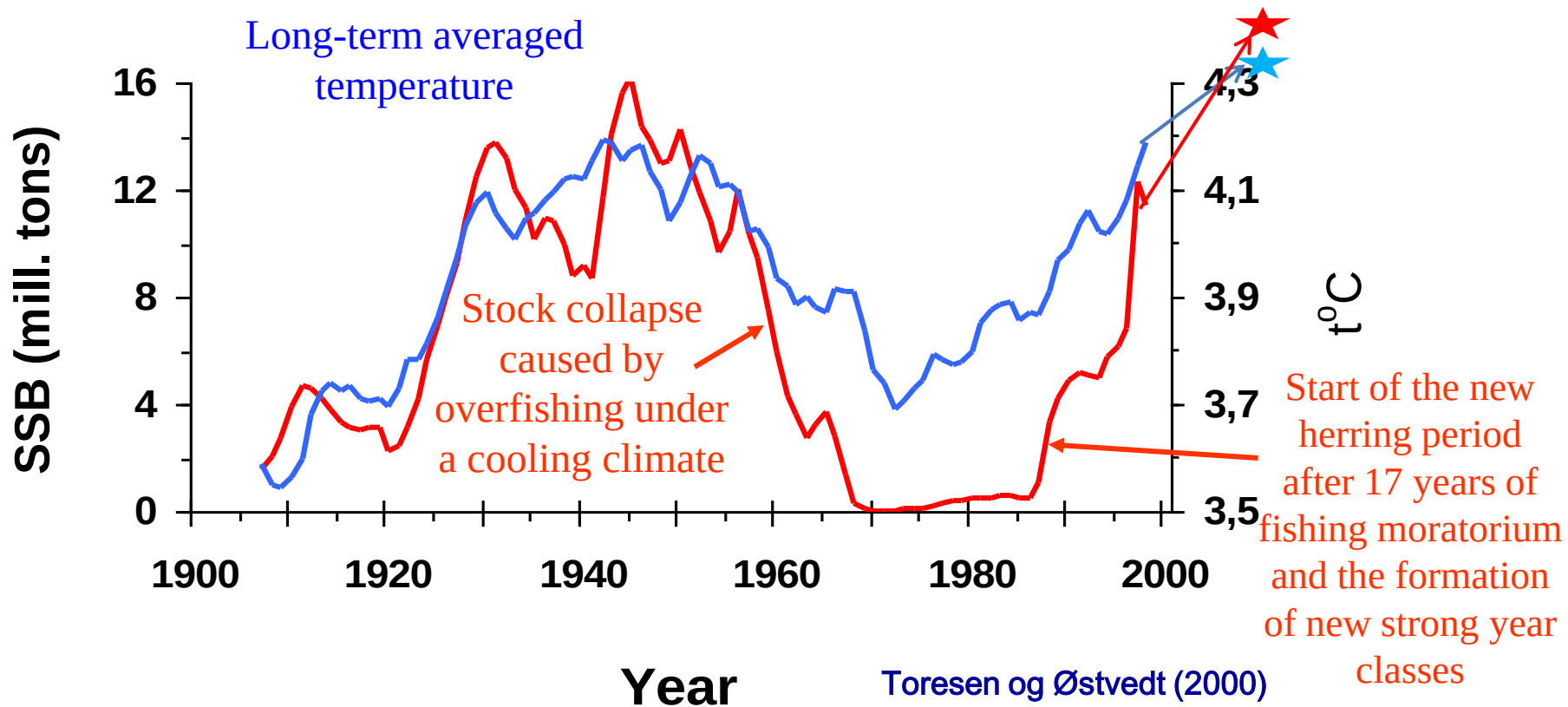
The Atlantic Multidecadal Oscillation (AMO) 1873-2000



Ocean climate oscillations in the North Atlantic



Spawning stock biomass (SSB) of Atlantic herring and the longterm-averaged temperature



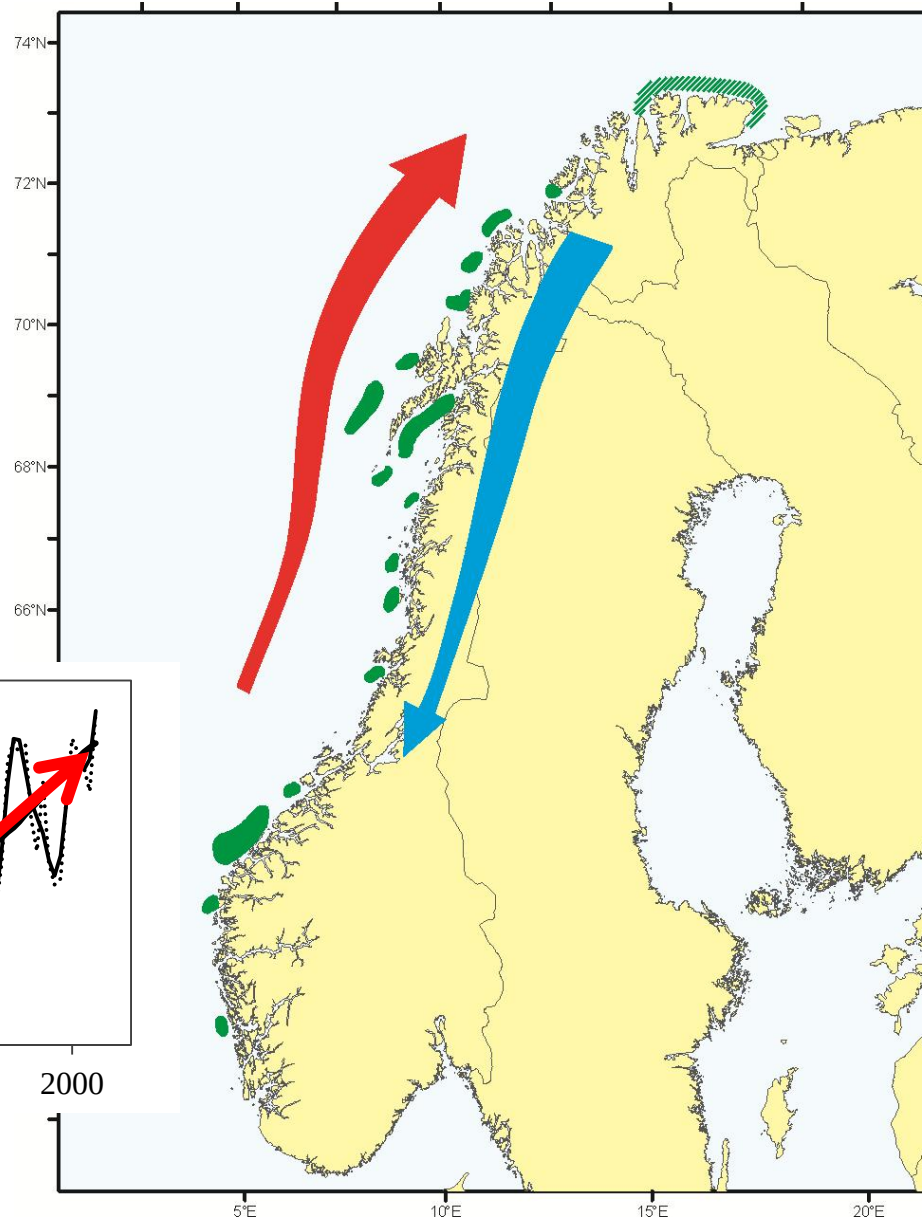
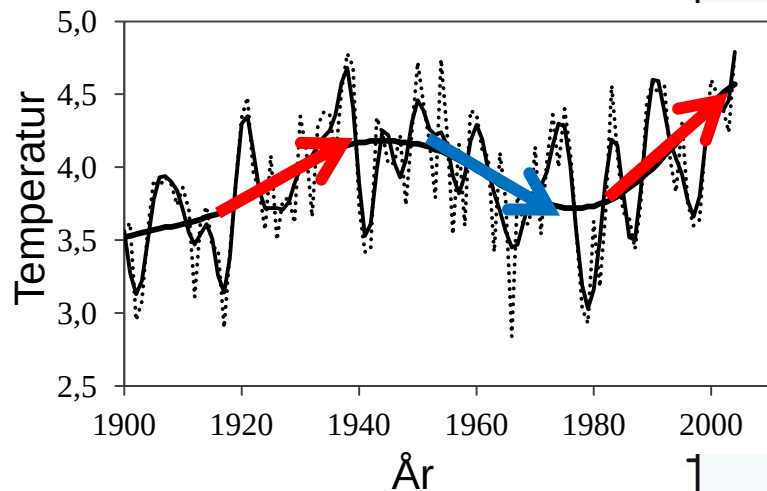
Climate response from Northeast-Arctic cod

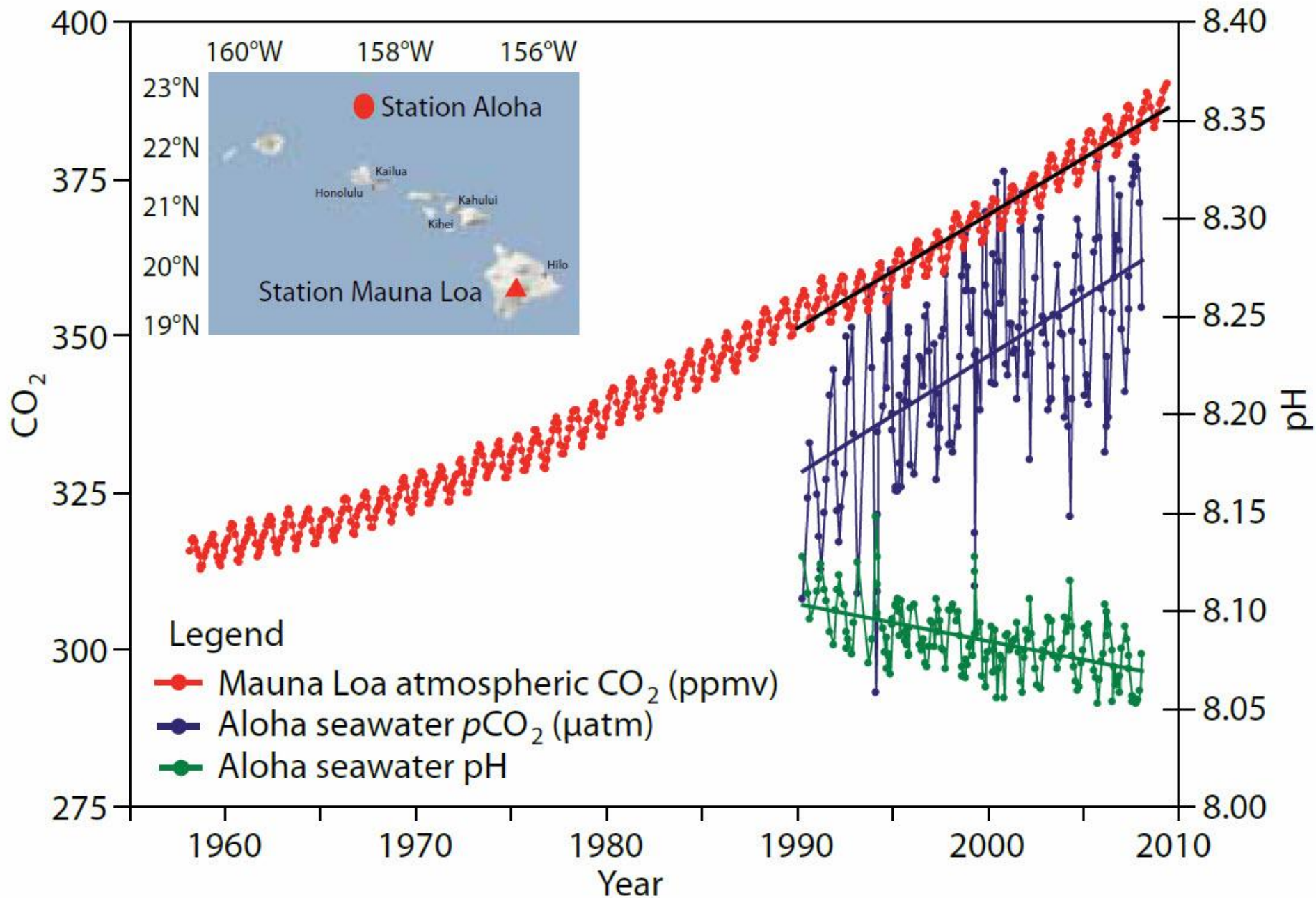
In warming phases:

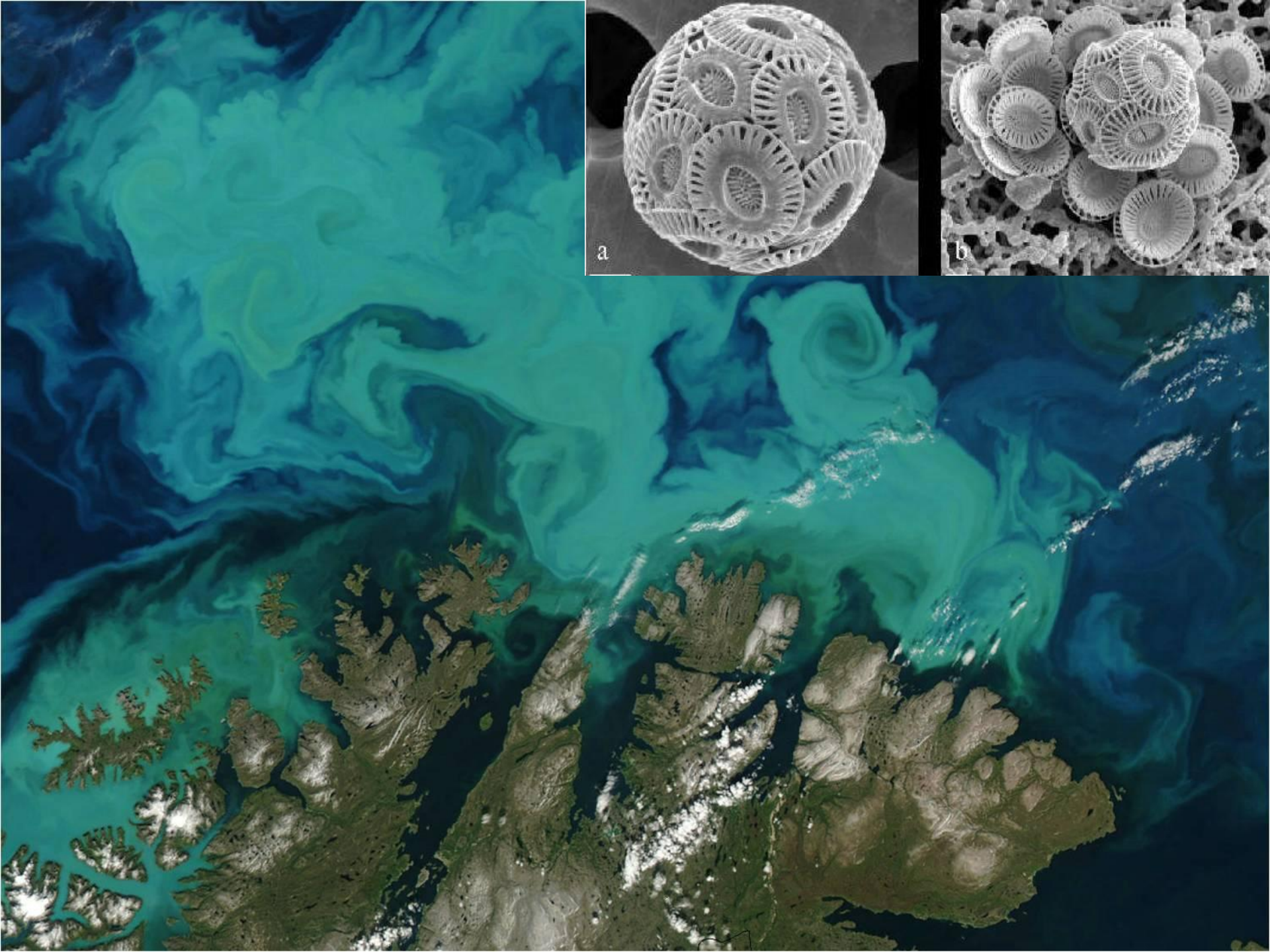
- Spawning sites displaced northward
- Increasing spawning stock

In cooling phases:

- Spawning sites displaced southward
- decreasing spawning stock









Beachy Head, the result of many thousands of years of coccolithophore formation (photograph from Encyclopædia Britannica Online).

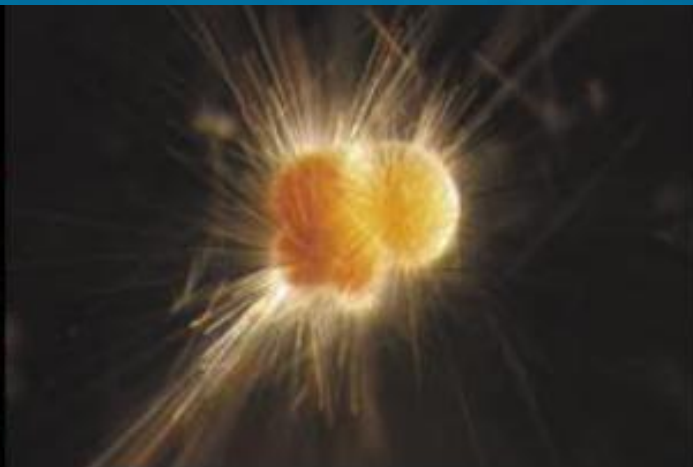




Coral (*Millepora tenella*)



Coralline algae (*Amphiroa anceps*)



Foraminifer (*Globigerina bulloides*)



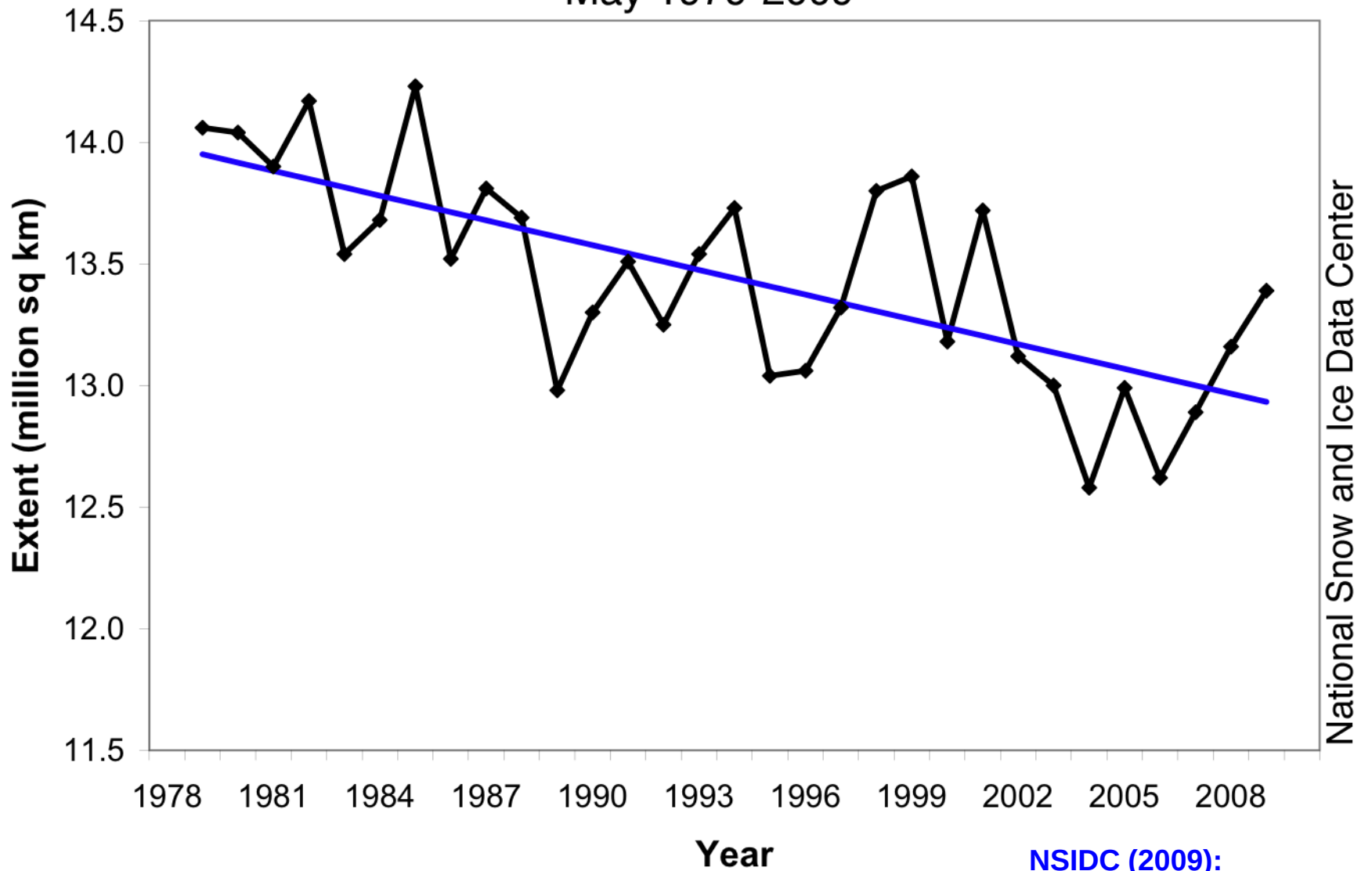
Coccolithophorid (*Emiliana huxleyi*)



Protropod (*Limacina helicina*)



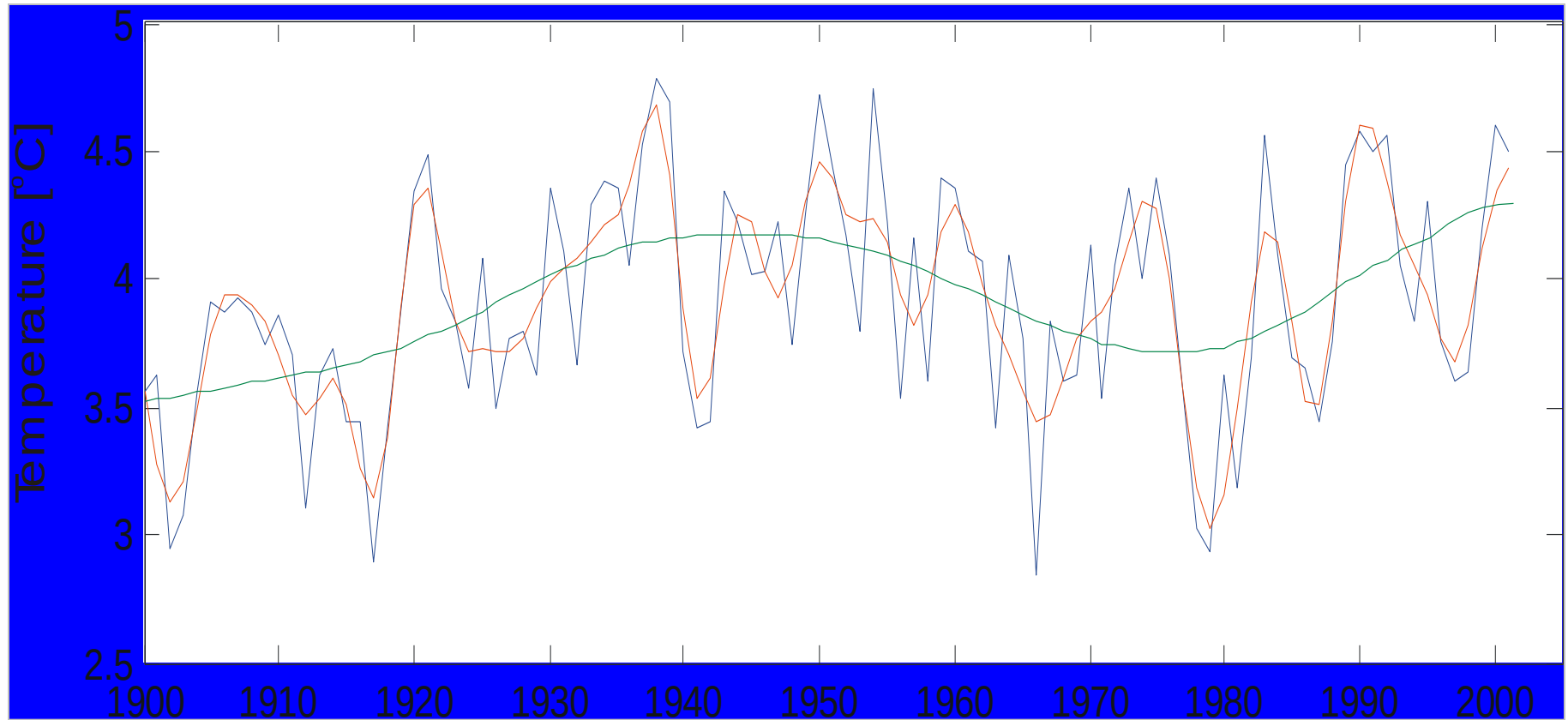
Average Monthly Sea Ice Extent May 1979-2009



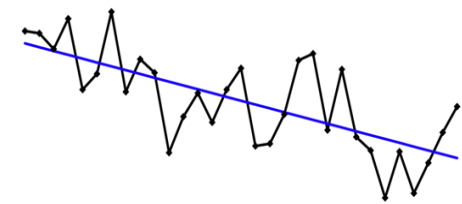
National Snow and Ice Data Center

[NSIDC \(2009\):
http://nsidc.org/arcticseaicenews/](http://nsidc.org/arcticseaicenews/)

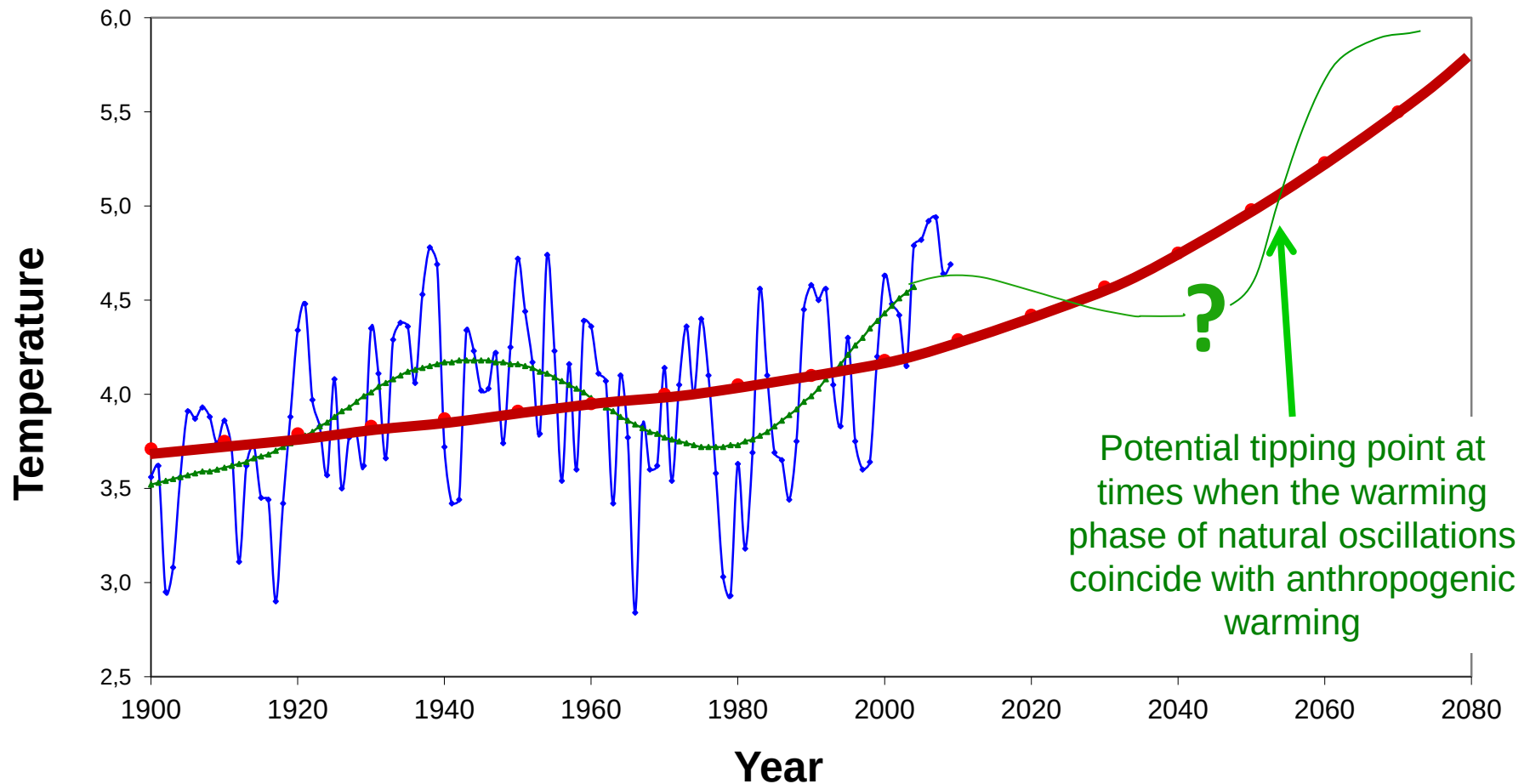
Ocean climate oscillations in the northern North Atlantic



How would we have interpreted development of Arctic sea ice extent if we had satellite data from the 1930s?



Barents Sea modelled climate change and observations



Conclusions

- Impacts of climate change on marine ecosystems is not uniform but varies depending on the critical physical and biological mechanisms
- High-latitude and upwelling ecosystems have the potential of higher production under climate change
- Low-latitude and mid-ocean gyre ecosystems will most probably decrease the productivity under climate change
- Long-term natural climate variability masks the effects of - and the predictability of - anthropogenic climate change
- Ocean acidification is the "dark horse" and impacts will be uniformly negative across all marine ecosystems

