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Research Network ARCTOS

Arctic SIZE

Overview of Impacts of a Changing Environment on Biodiversity

Paul Wassmann
UiT The Arctic University of Norway
Tromsø

The emphasis of the meeting is upon resilience in a changing Arctic

- Tendentious use of terminology
- What is resilience and what definition does it have for physical, ecological and socio-economic relations?
- Buffer capacity of an ecosystem to respond to perturbation?
- How much perturbation and what are the upper and lower limits of the buffer? How many perturbations?
- How to define the time intervals in which the buffering capacity is determined?

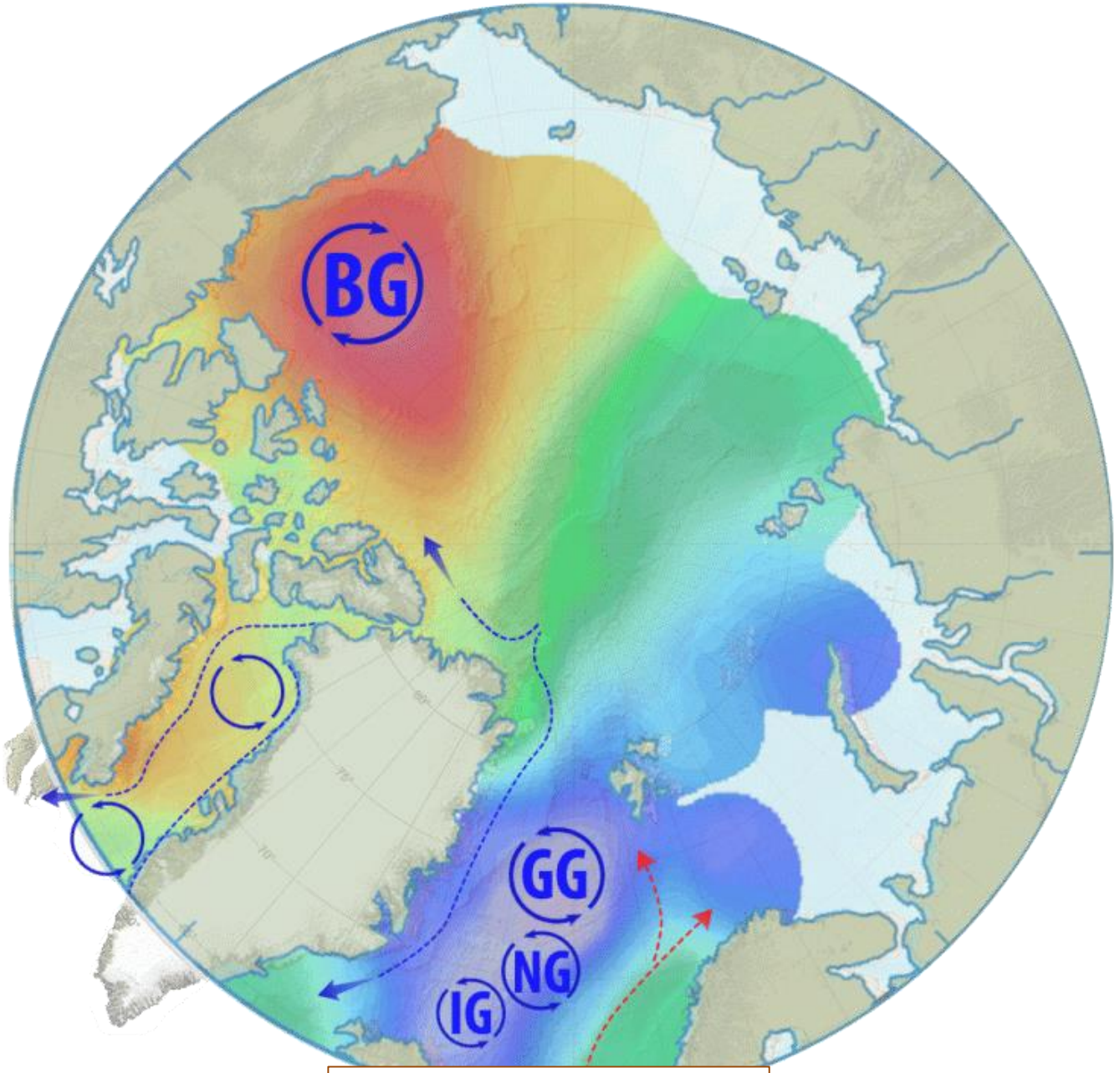
Resilience and biodiversity in the Arctic Ocean

- The youngest ocean
- The ocean with the lowest biodiversity
- Few endemic species
- The Ocean with the greatest climatic and ecological variability: 5 ice ages over a million years
- A continuous sequence of invasion, regression, recovery
- What is the resilience of such a variable system?
- And what is the length of the time to determine resilience? Decades, centuries, millennia?

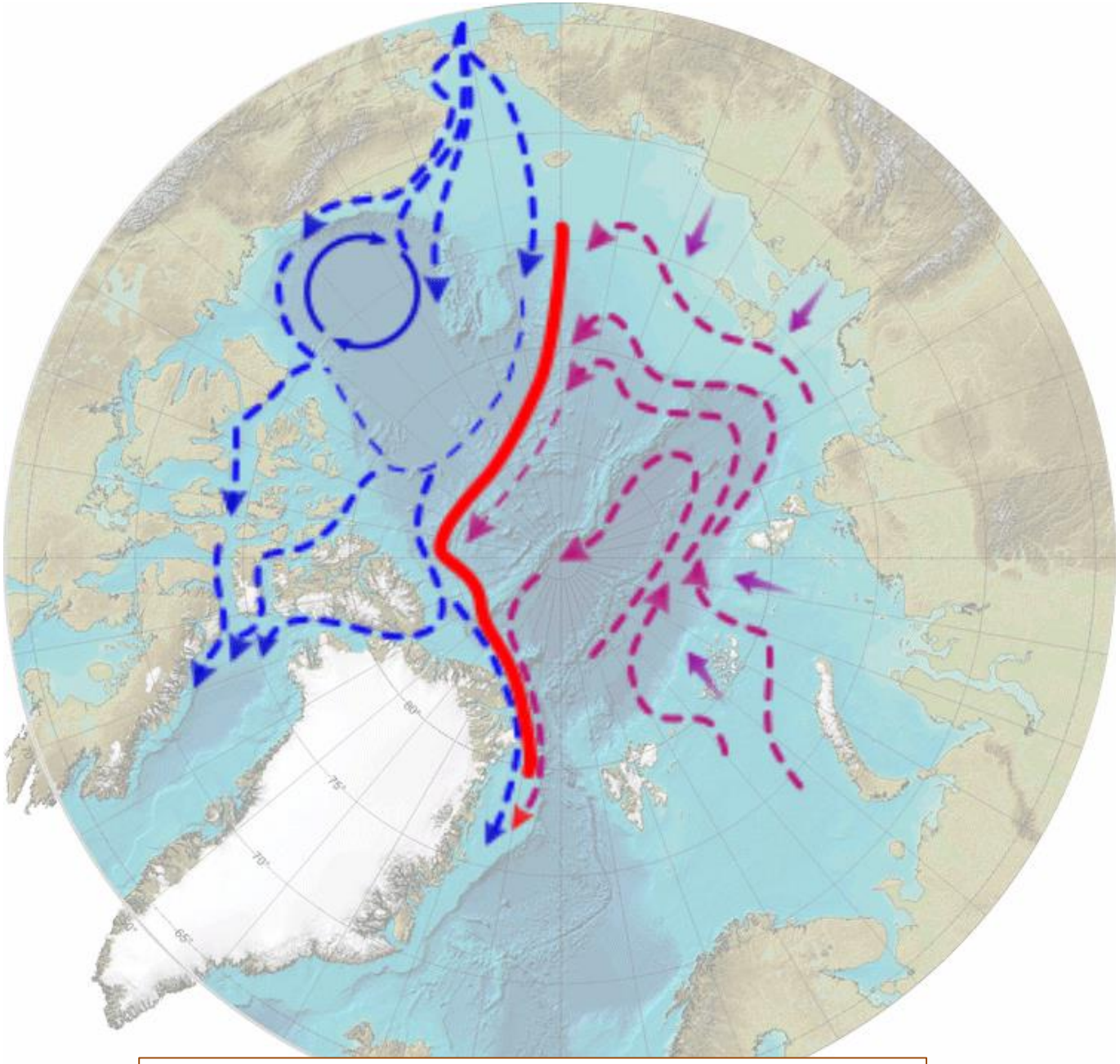
Definitions

- **Resilience** is the ability of a system to return to its initial state after a disturbance
- **Stability** refers to the disturbances frequency that a system faces

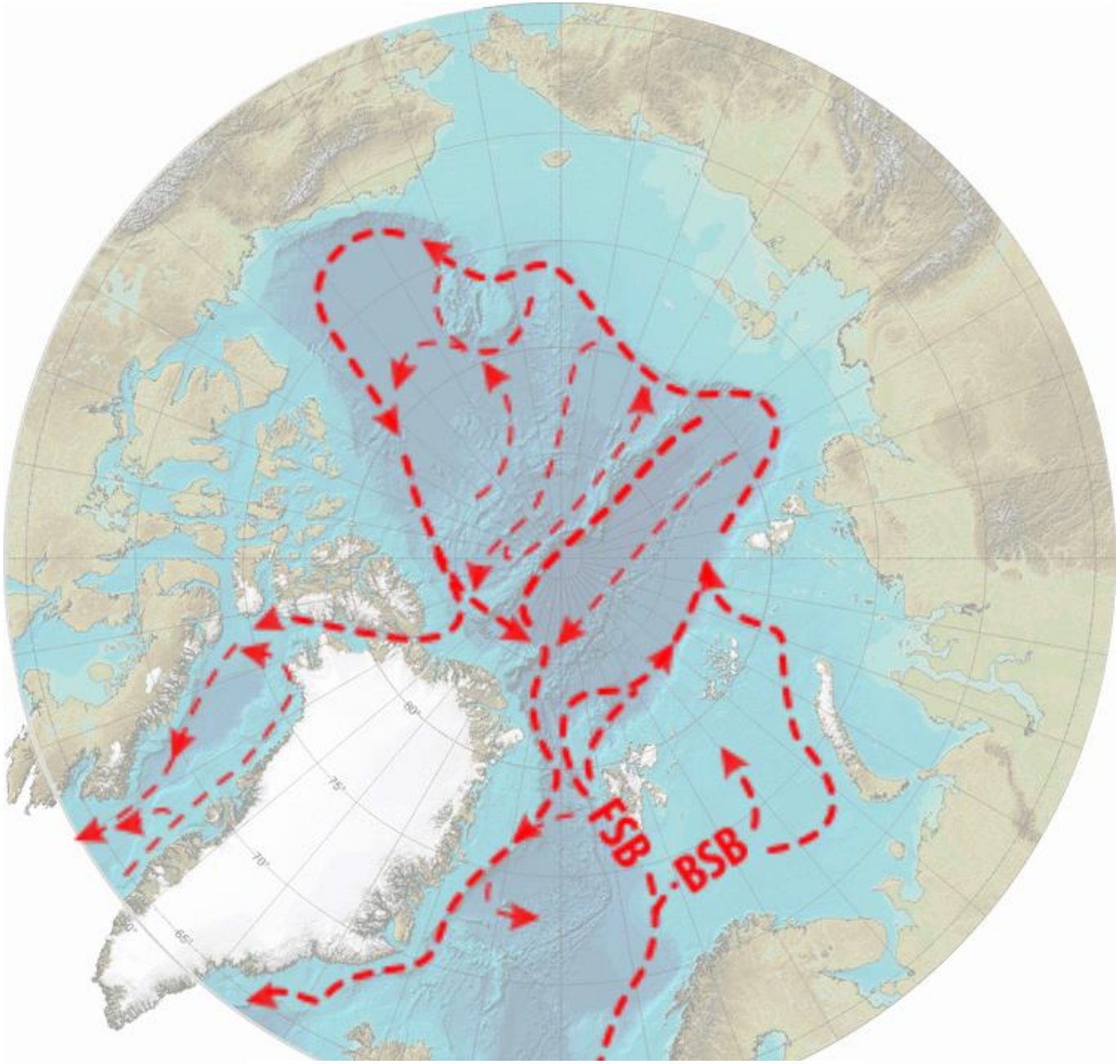
Physical setting and basic structure



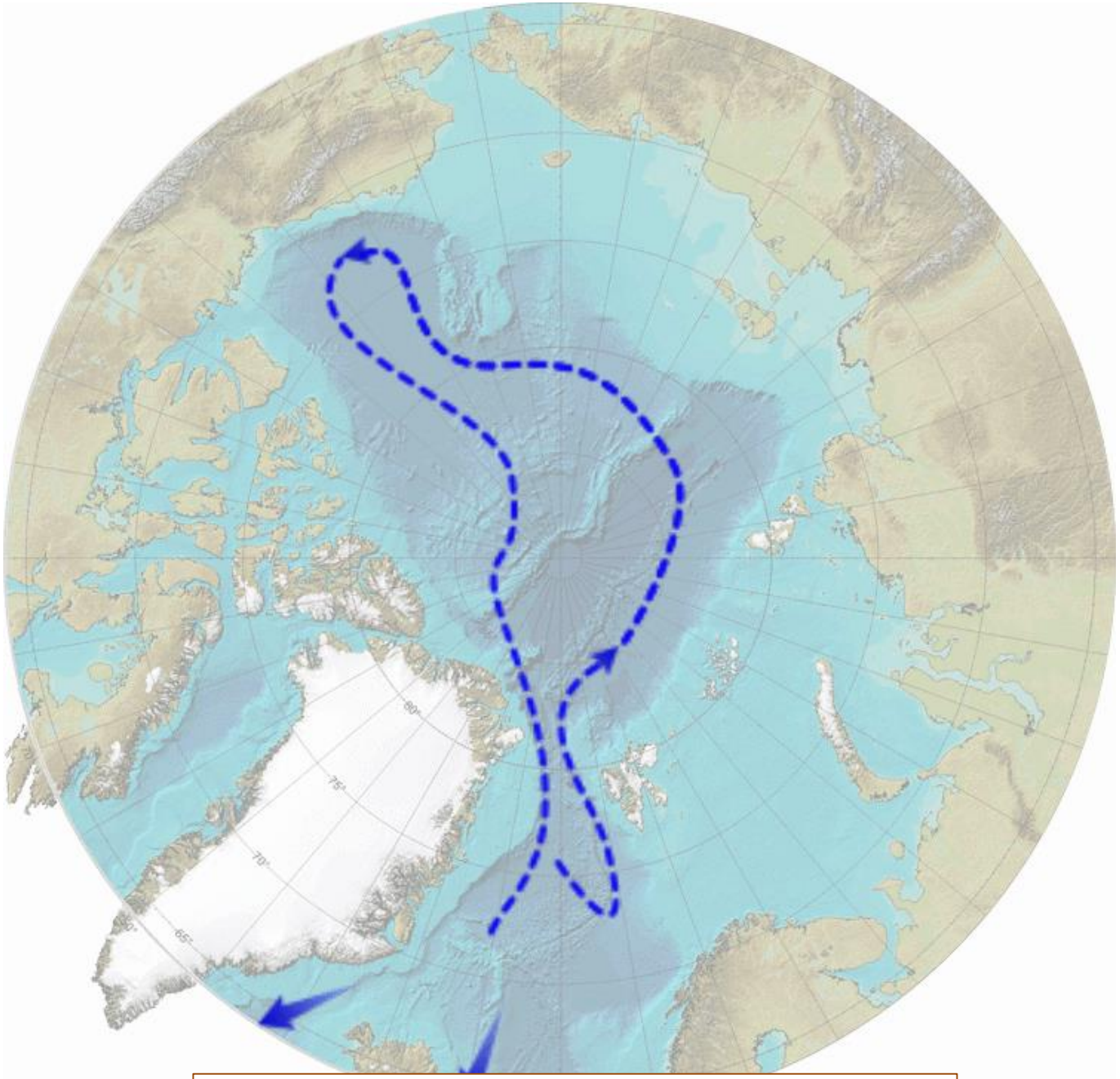
Surface Currents



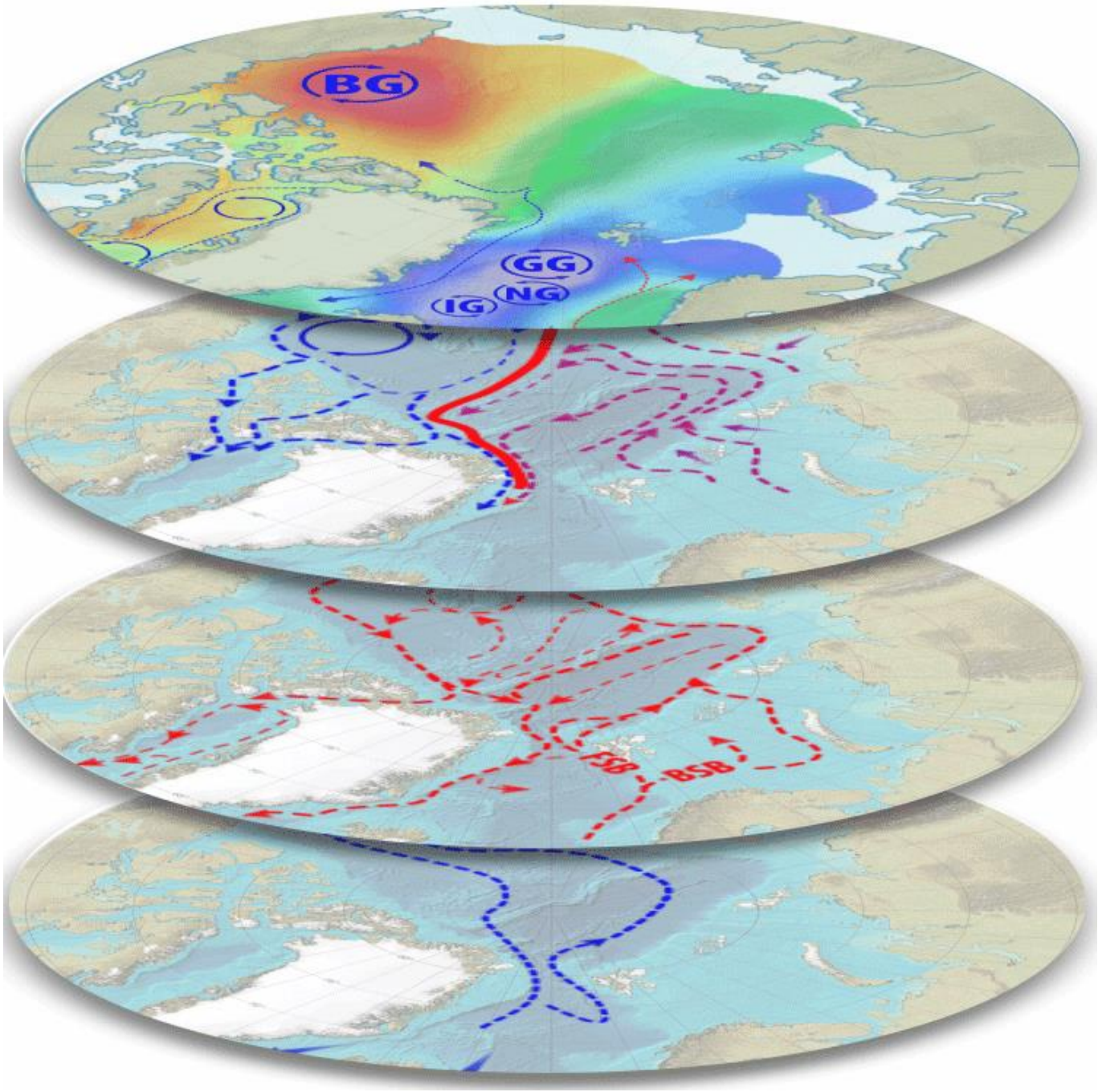
Halocline Waters (~ 50 – 200 m)



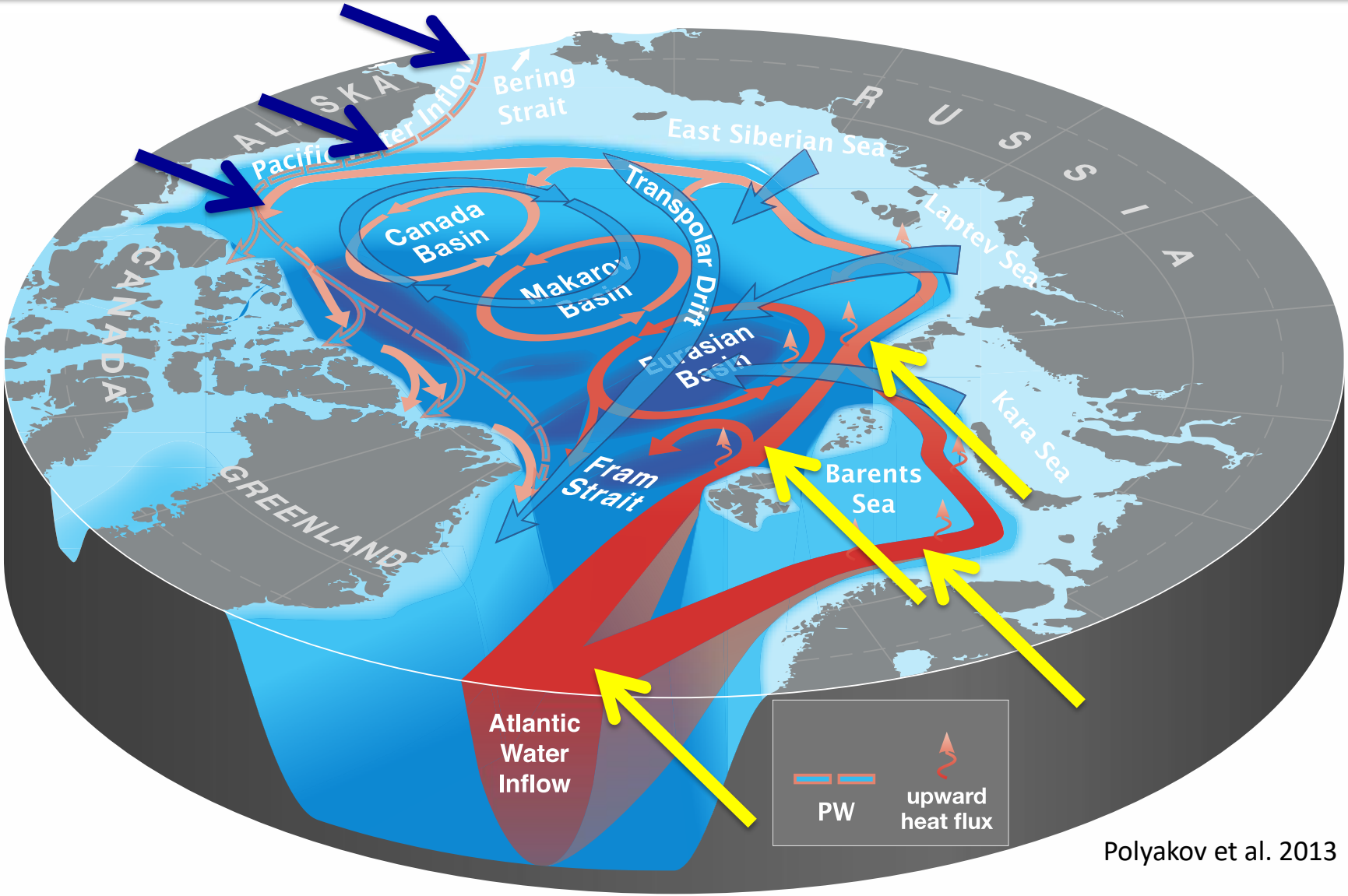
Atlantic Layer 200-800 m



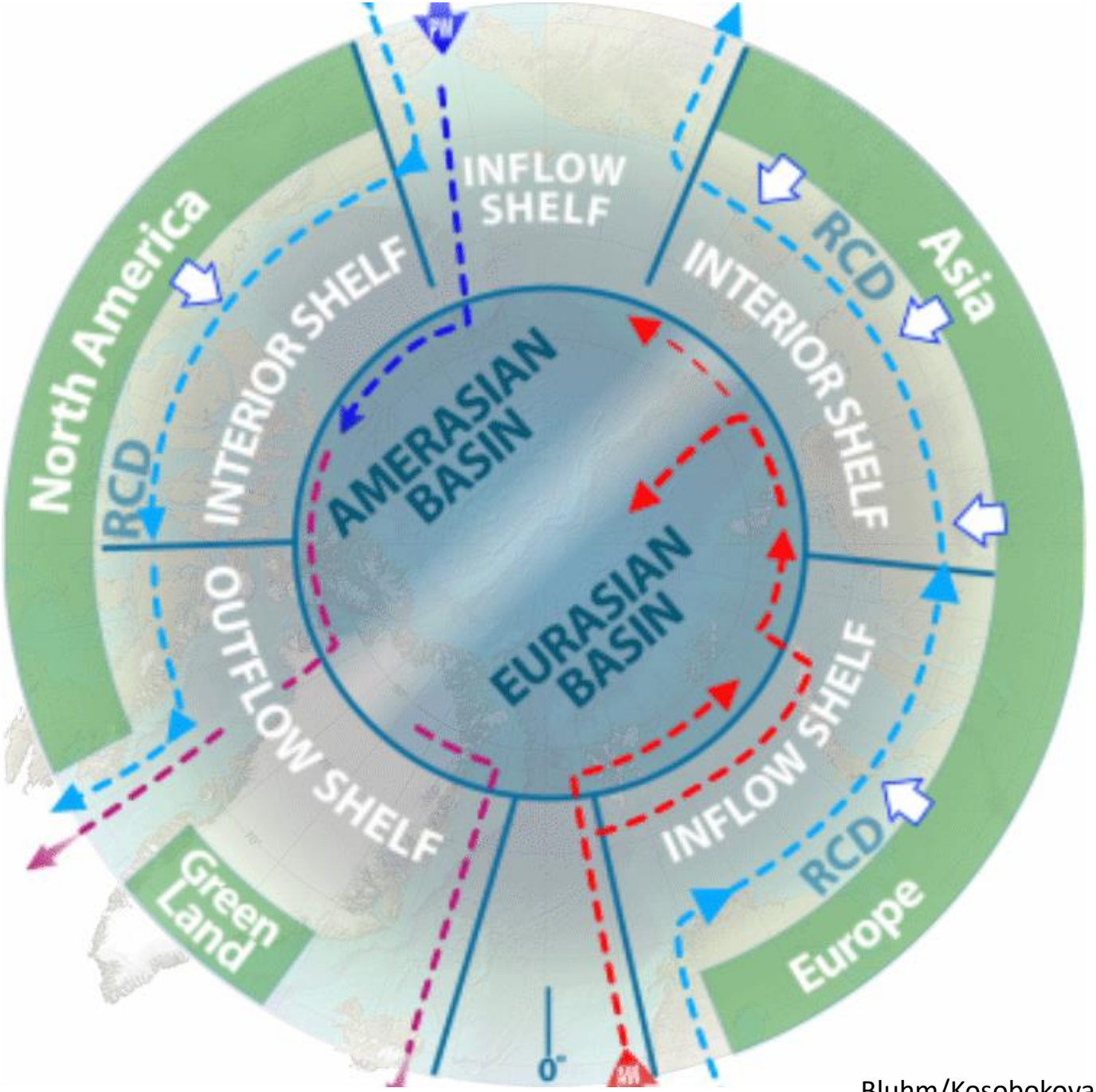
Deep Waters (below ~ 2000 m)


BG
GG
IG
NG
FSB
BSB

The Arctic Ocean is not a closed but a highly advective system



Polyakov et al. 2013



Bluhm/Kosobokova/Carmack, 2015

Basic ecosystem function of the Arctic Ocean

- Improving, but basically unknown, except the Barents Sea, Bering Sea/Straight and indigenous knowledge
- All ecological knowledge from the region will soon be outdated and “from yesterday”
- Evaluating resilience when the natural variability is unknown?
- Predictions and projections when not in steady state and previous steady state is unknown?

Forcing of ecosystems in times of global warming

We are haunted by the four apocalyptic riders of climate change in the Arctic Ocean

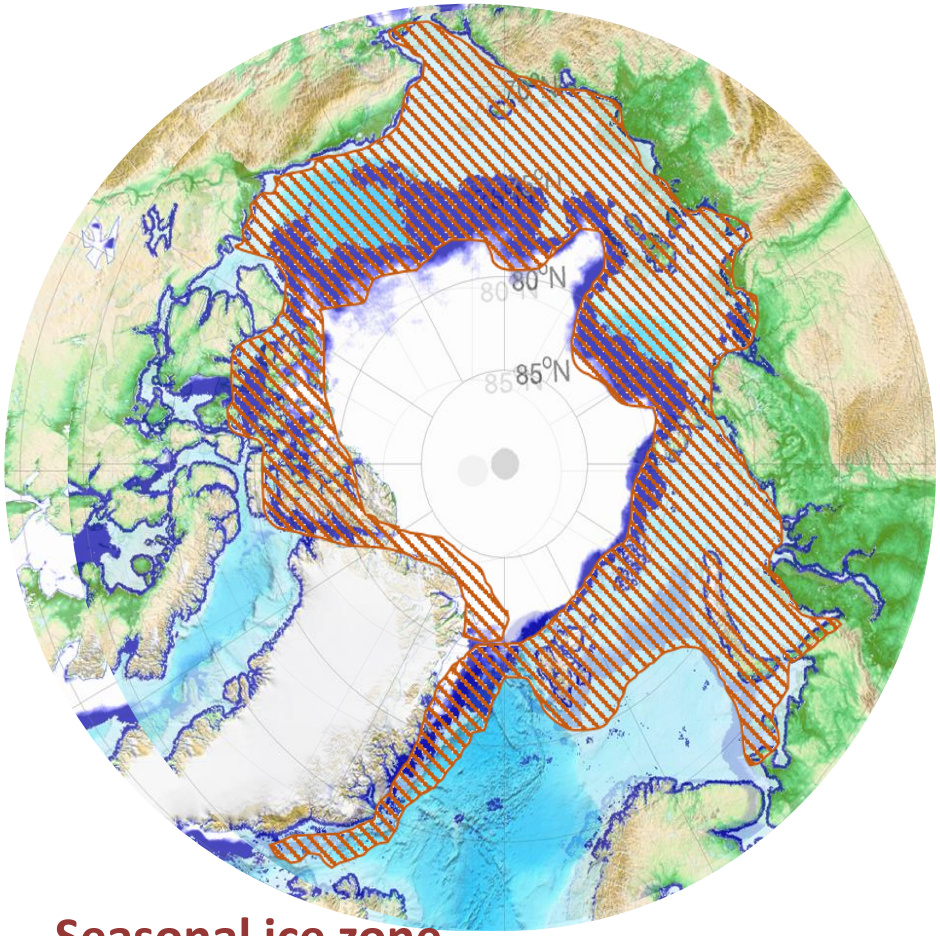
Warming
Ice
Light
Freshening

Ice melt and surface warming result in a) more low pressures and b) more stratification. Which determine productivity

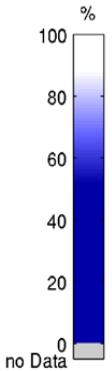
Ice retreats from shelves further north into the deep basins.

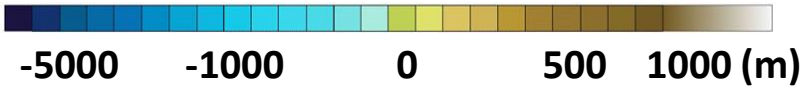
How will the ecosystem service of primary producers change?

The seasonal ice zone domain at present (size 2/3 of Europe)



Seasonal ice zone

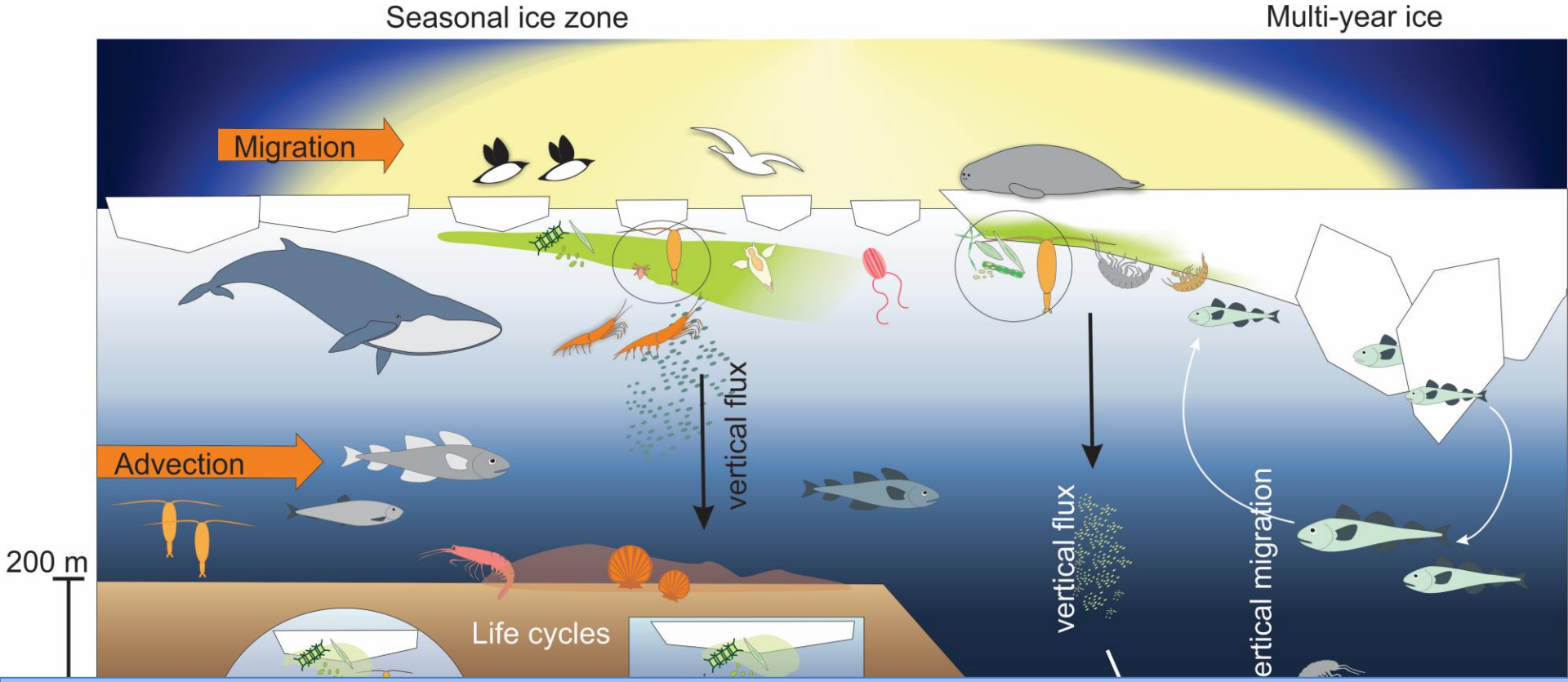




M. Fernandez-Mendes

Map: Jakobsson et al., 2012; Sea ice concentration:

The “riders” will fundamentally change the function and ecology of the seasonal ice zone. But how?

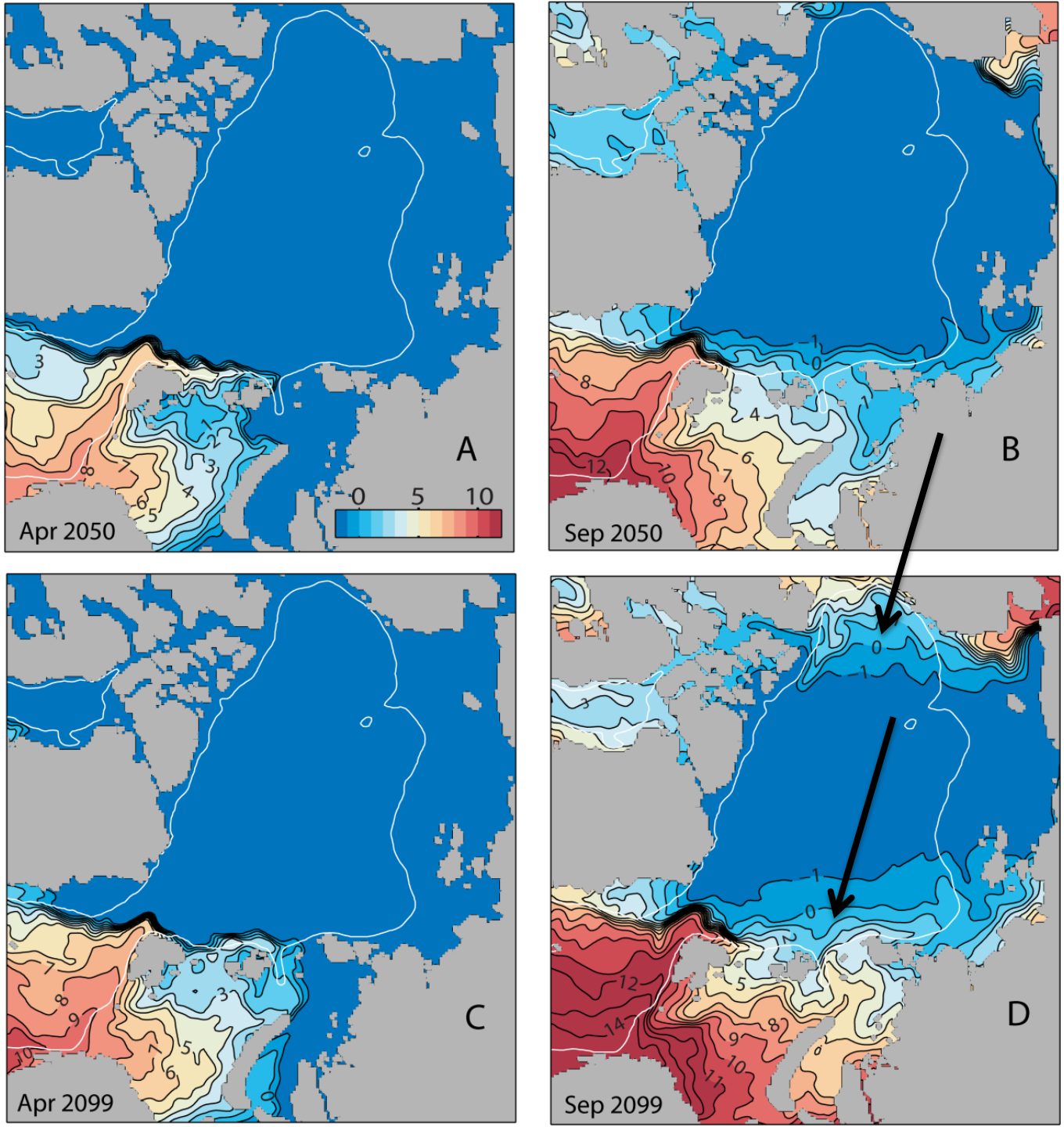


Dedicated, coordinated and system-ecological investigations throughout the seasonal ice zone of **all sectors** are mandatory to comprehend and manage the Arctic Ocean.

This is still **not** the case!

Projections of primary and zooplankton production

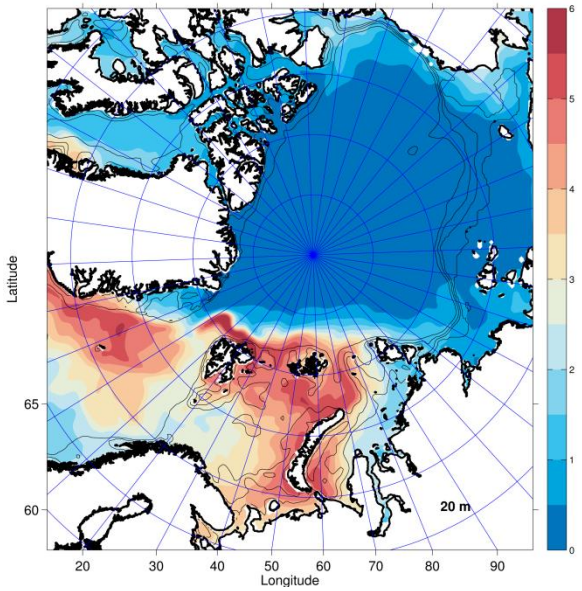
- SINMOD model

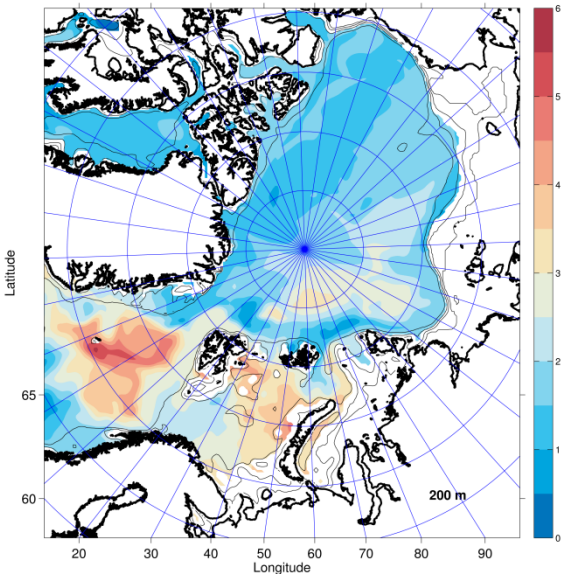


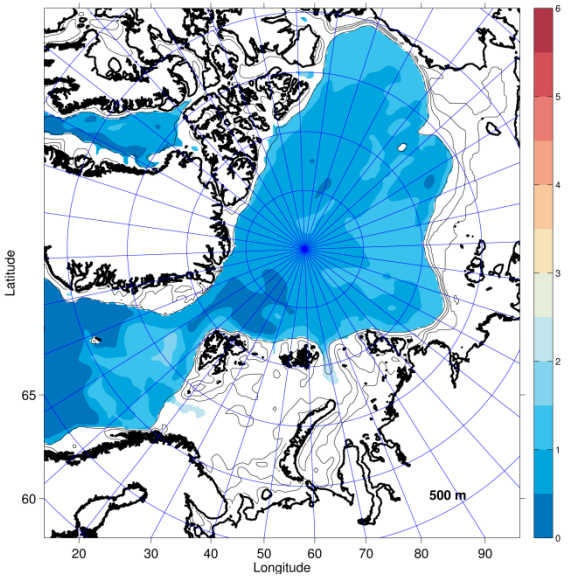
Surface temperature in the AO: April (left) and September (right)

2050 (upper)
2099 (lower)

Modelled temperature changes at 20 (uppr), 200 (left) and 500 m (right) between first and last decades of 21st century



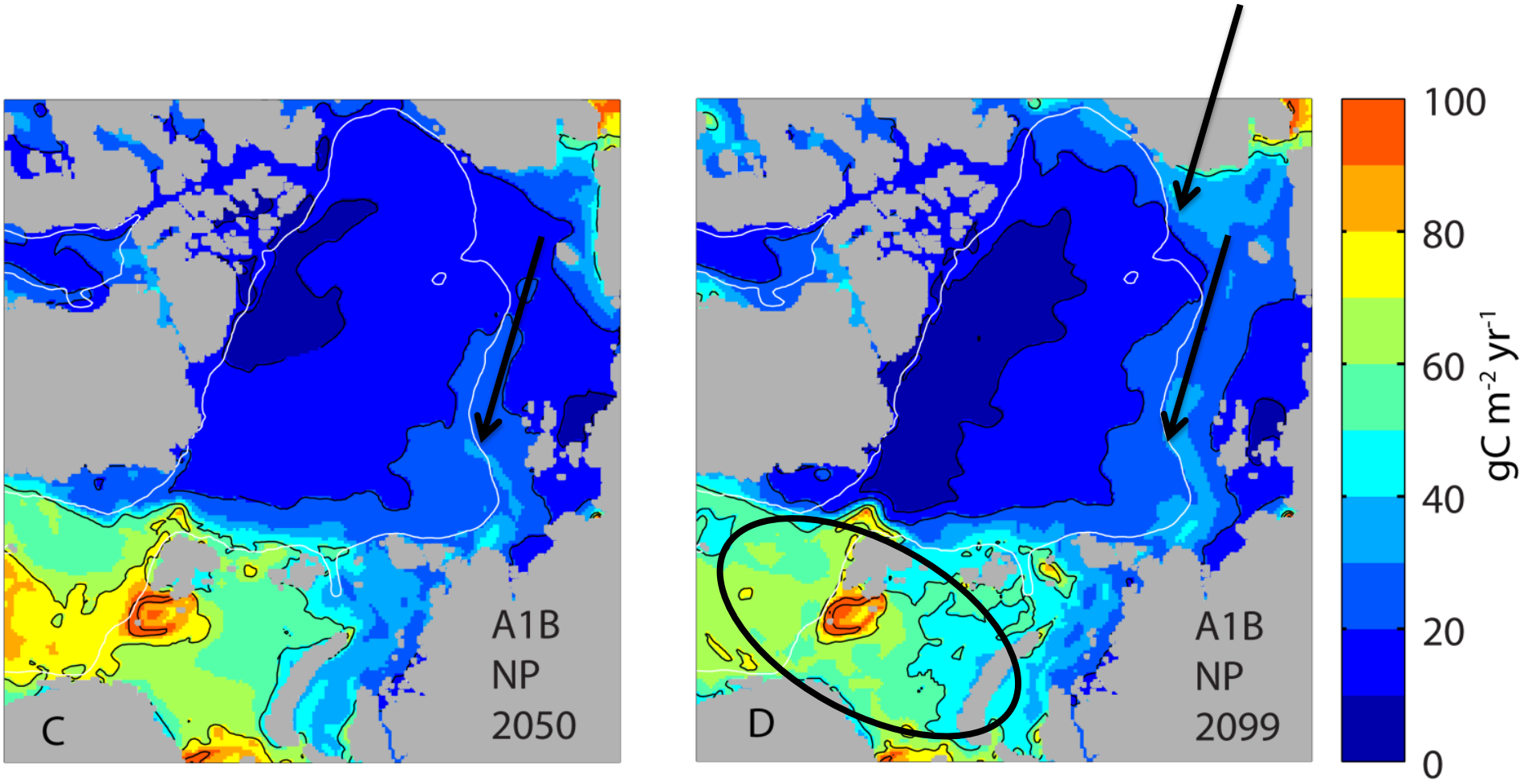


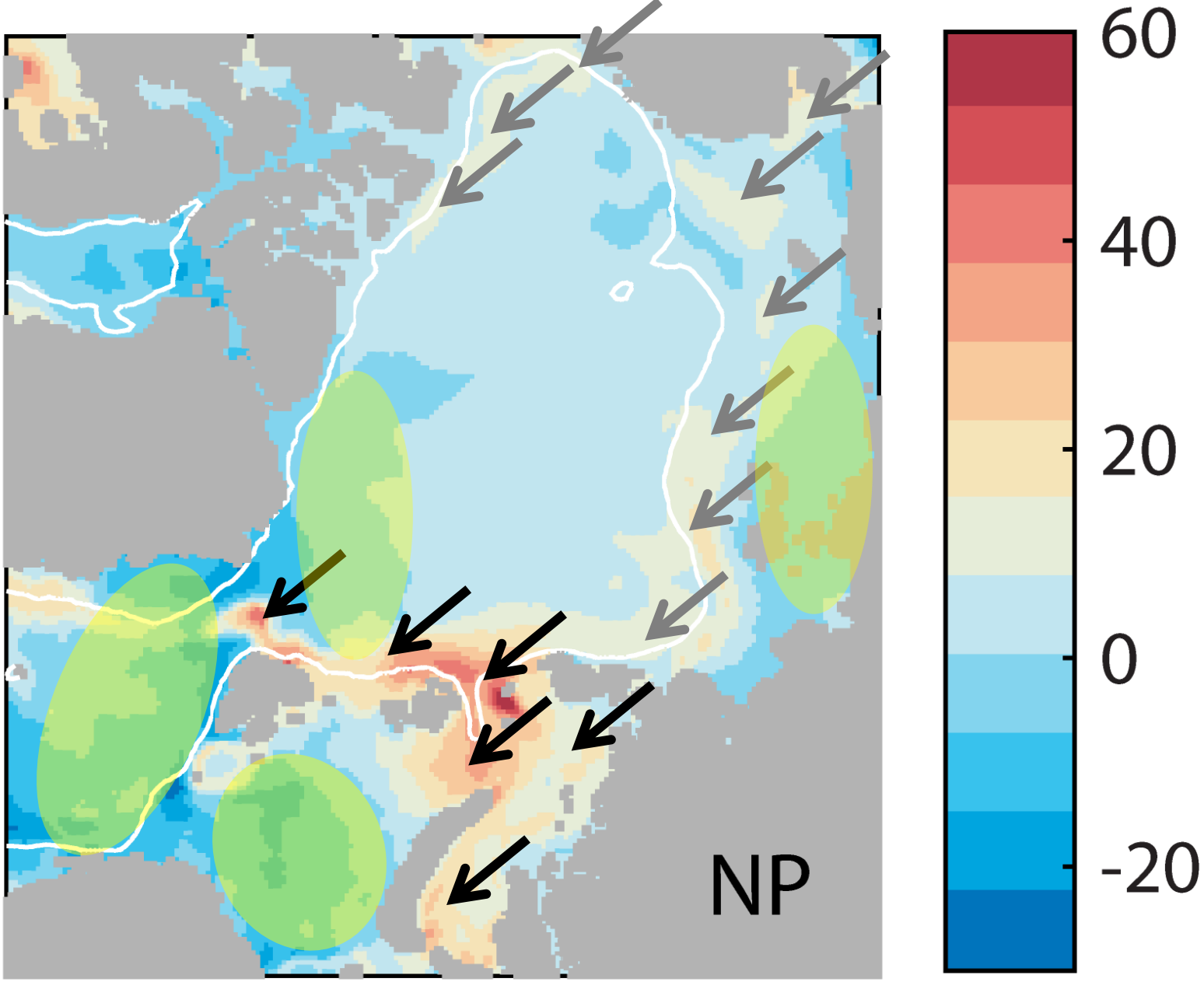


Warming

- Shelves and shelf breaks, particular in productive regions
- Central Arctic Ocean not affected
- Warming in surface layer (up to 200 m)
- Warming mainly in autumn
- Good chances for many lower trophic organisms to fins niches and to survive

IPCC A1B scenario (+3.8°C by 2100)
Annual Harvestable Production
(down-scaled IPPC A1B)





Difference in the harvestabel production at the end of this century (g C m^{-2} y^{-1}) (2100 minus today)

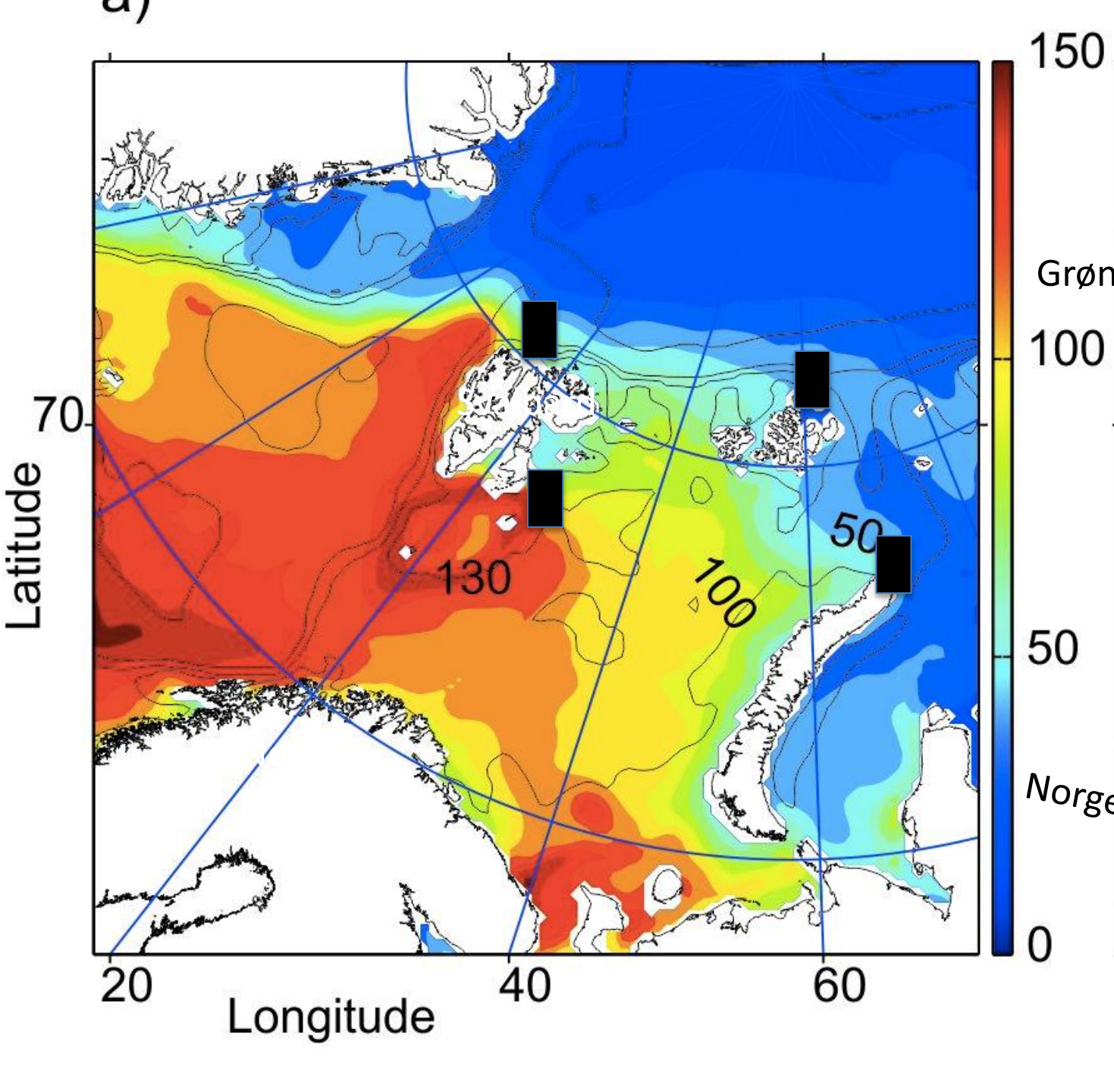
Productivity

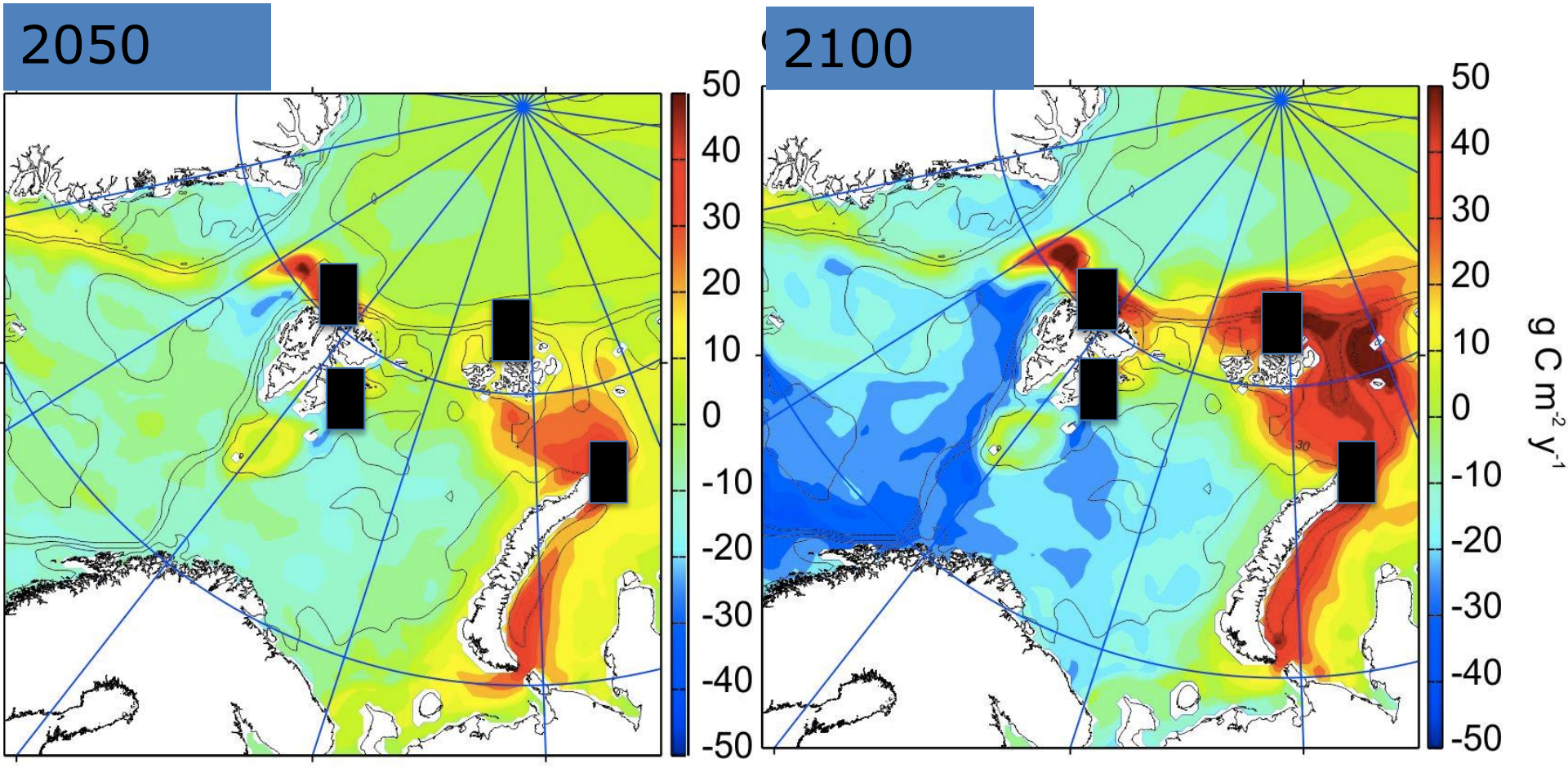
- The Arctic Ocean rim
- Hot (doubling to tripling of present day productions)
- Warmish (may be a doubling?)
- Cool (staying low or drecrease)

Increased fisheries in the Arctic Ocean?

- We cannot have a sustainable fishery on a new production of 8 g C m^{-2} y^{-1}

Placing marine protected areas on the map, for what purpose?

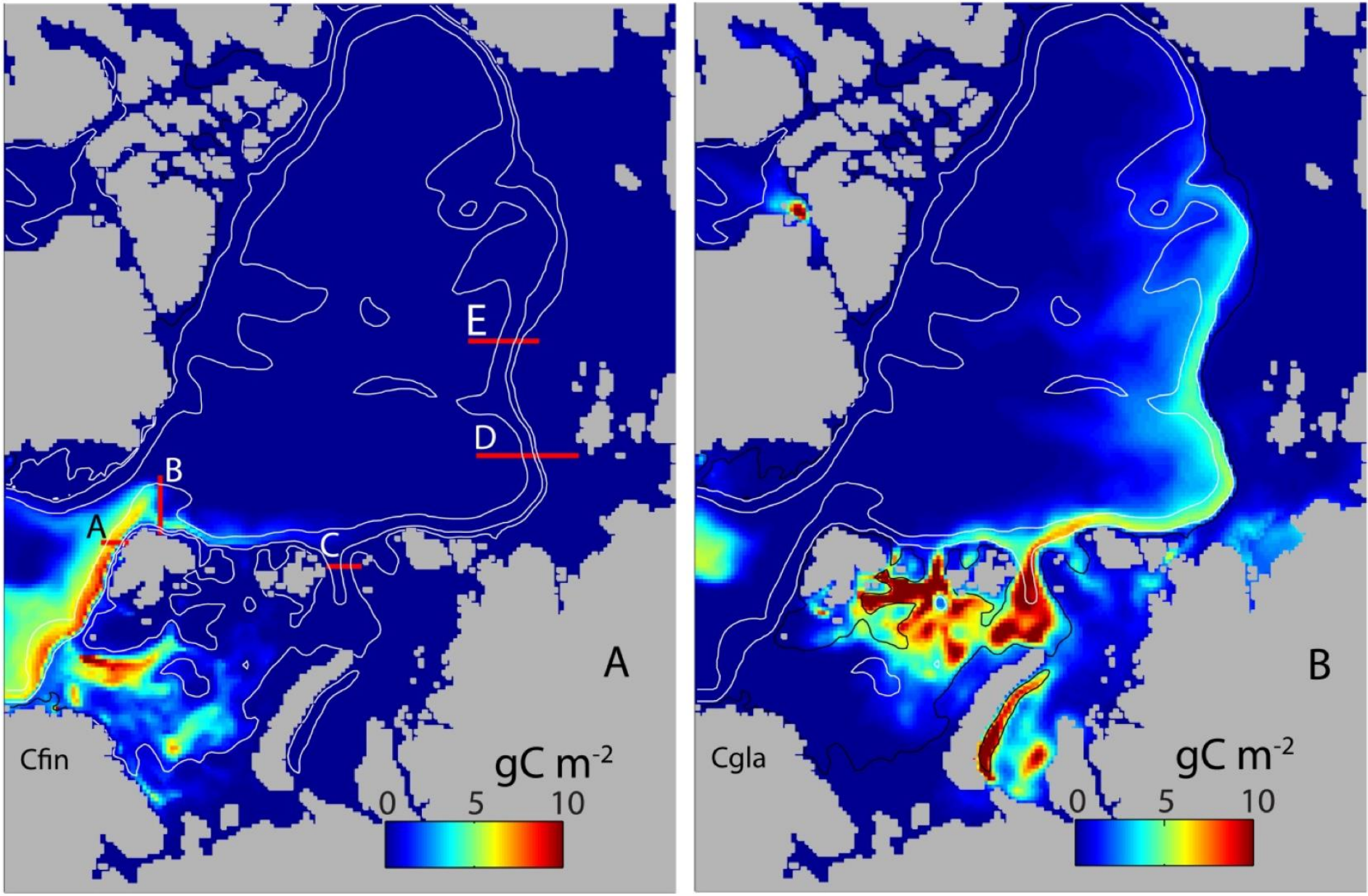

a)
150
Grøn
100
50
Norge
0
70
Latitude
130
100
50
20
40
60
Longitude



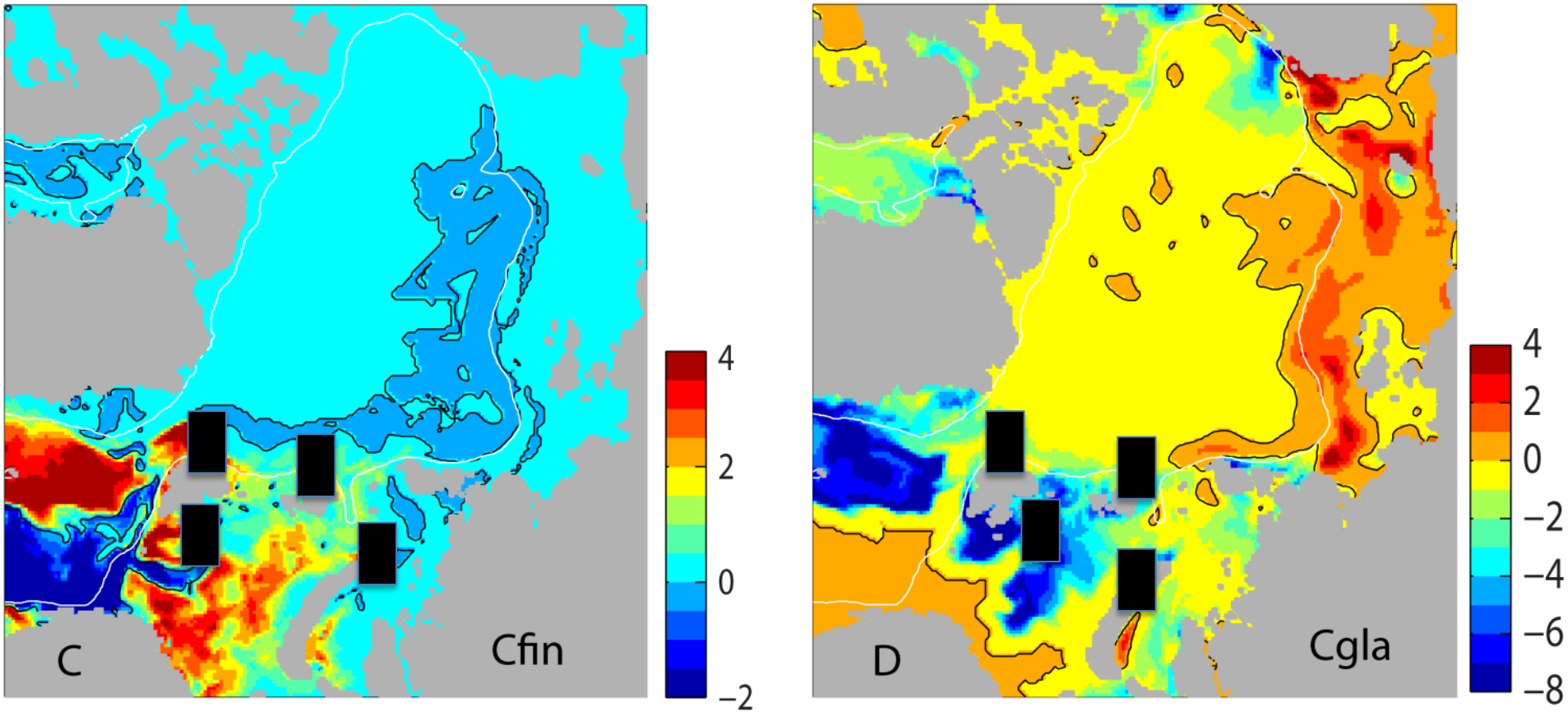
Increase in primary production

Decrease in primary production

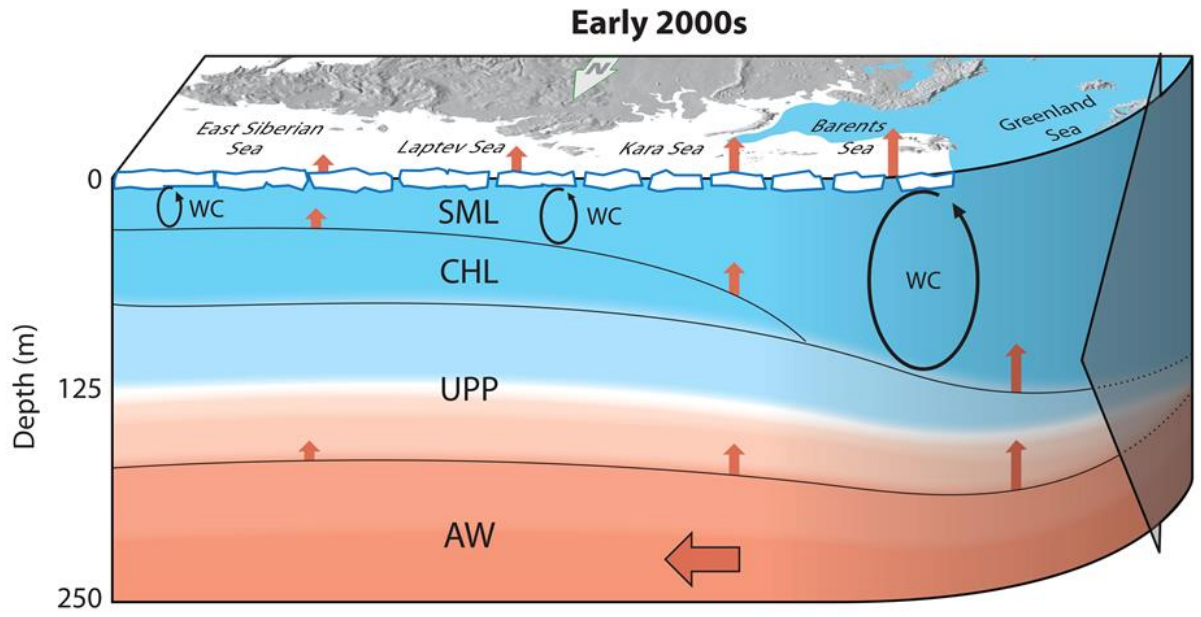
Biodiversity: Atlantic and arctic meso-zooplankton distribution and advection



Simulated annual average (2004-2008) biomass (g C m^{-2}) of atlantic *Calanus finmarchicus* (A) and arctic *C. glacialis* (B).



Difference in production of *C. finmarchicus and C. glacialis* (2100 versus today)
(g C m^{-2} y^{-1})

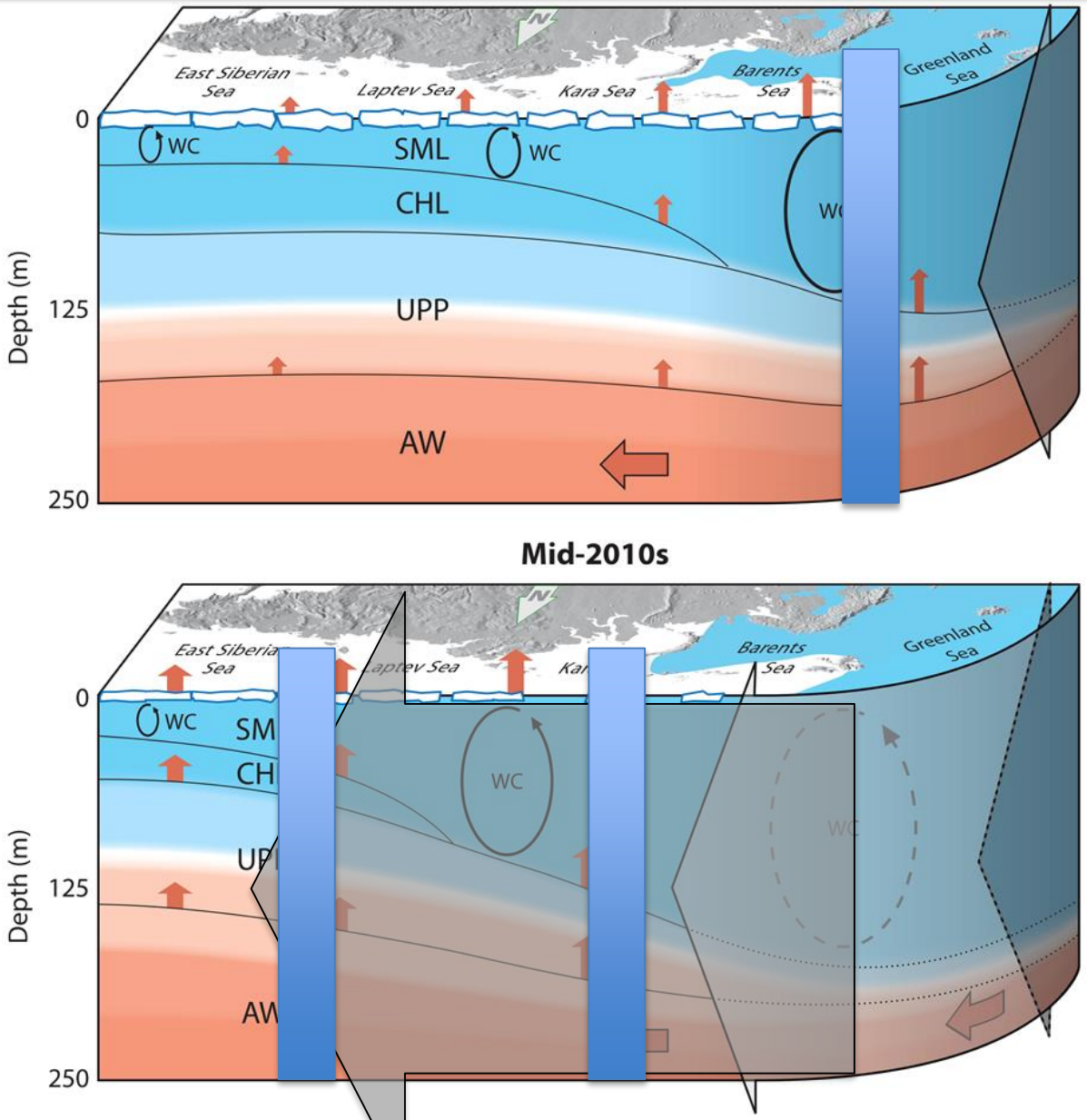

Early 2000s
East Siberian Sea
Laptev Sea
Kara Sea
Barents Sea
Greenland Sea
0
125
250
Depth (m)
WC
SML
WC
CHL
WC
UPP
AW

I. Polyakov

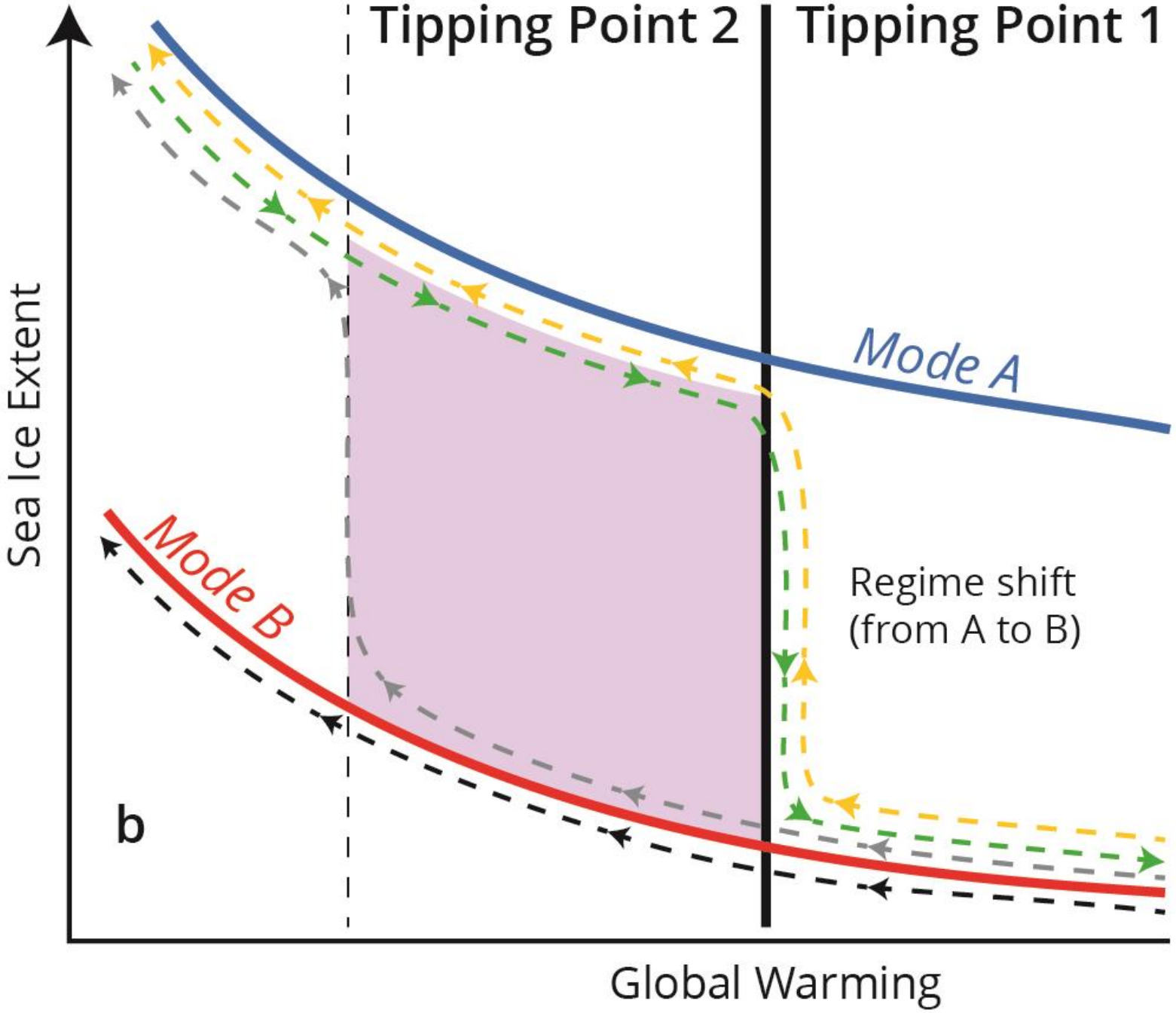
Climate change along the Eurasian shelf

- Current atlantification will move deep-water formation from the Greenland Sea into the Nansen Basin: great conveyor belt
- First of all: what are the global implications of that change?
- How will that influence the biodiversity in the Arctic Ocean?

Where do you place MPAs and what do you protect in them? Functional biodiversity changes currently on a decadal scale

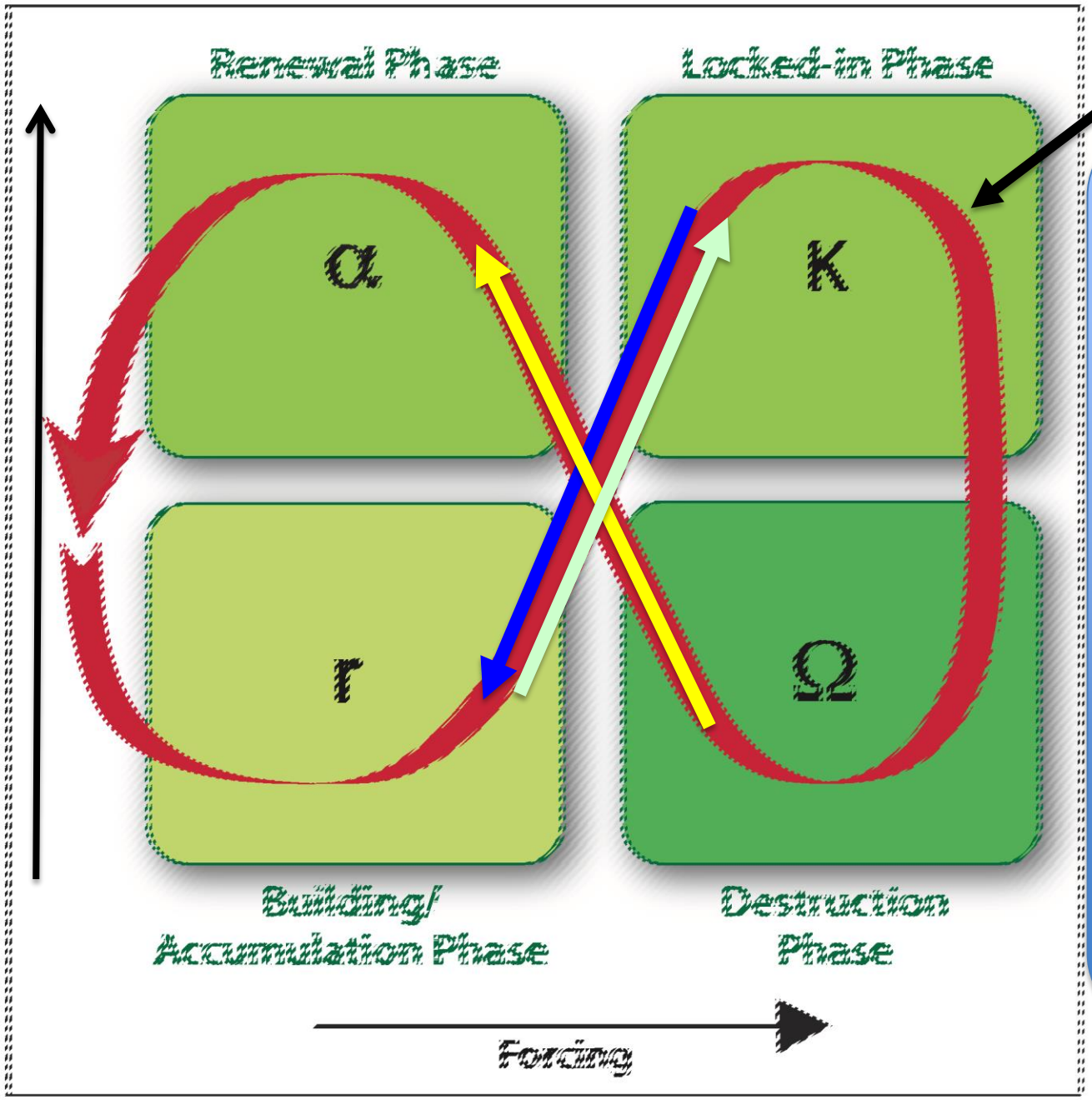


The extraordinary challenge of Arctic tipping points and regime shifts


Tipping Point 2
Tipping Point 1
Mode A
Mode B
Regime shift
(from A to B)
b
Sea Ice Extent
Global Warming

Which pathway will various ecosystems take?

- We have no idea
- Time series provide possibilities, but there are few, almost none of them
- Catch statistics?

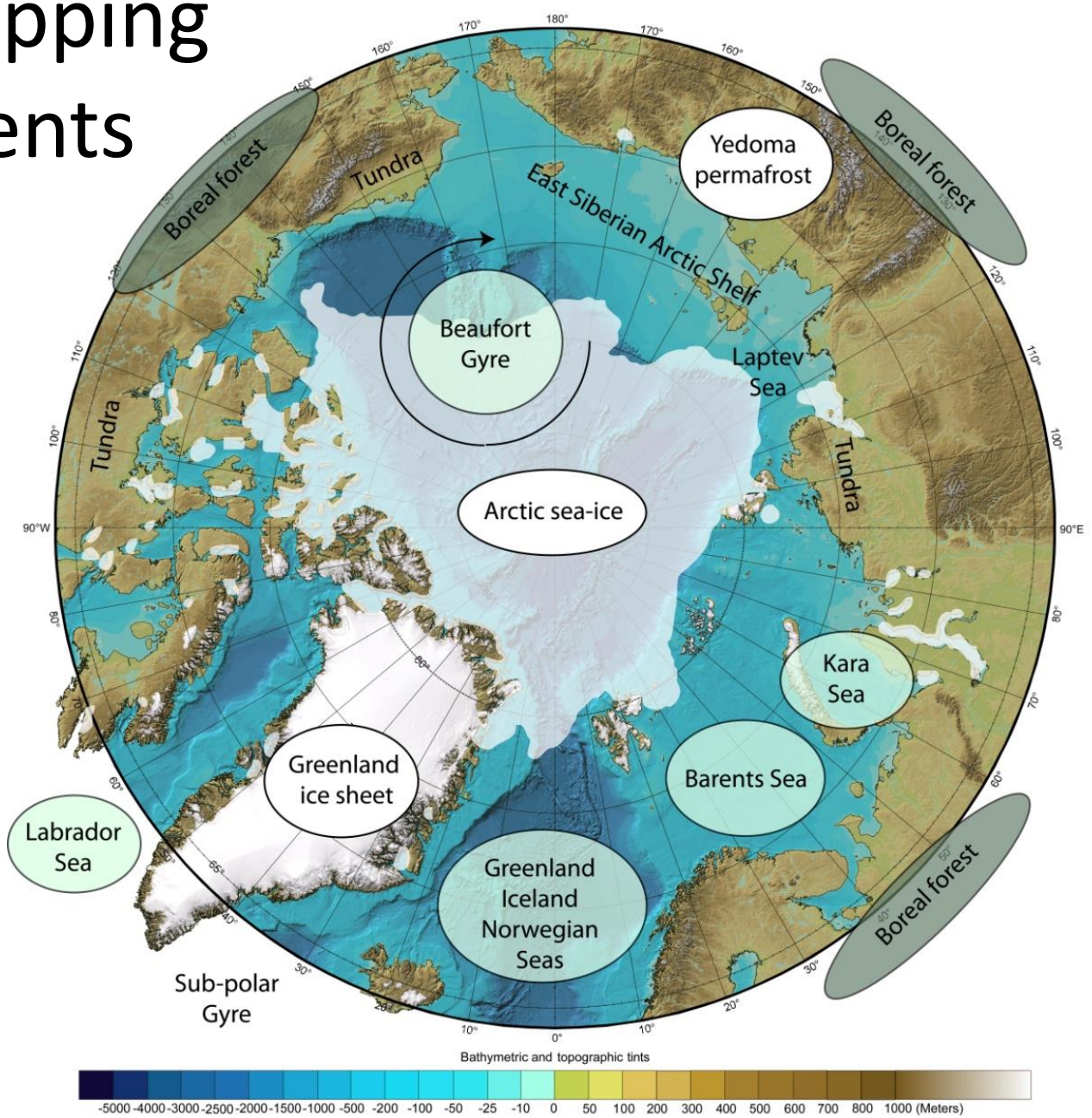


Ecosystem development

Adaptive cycles and tipping points

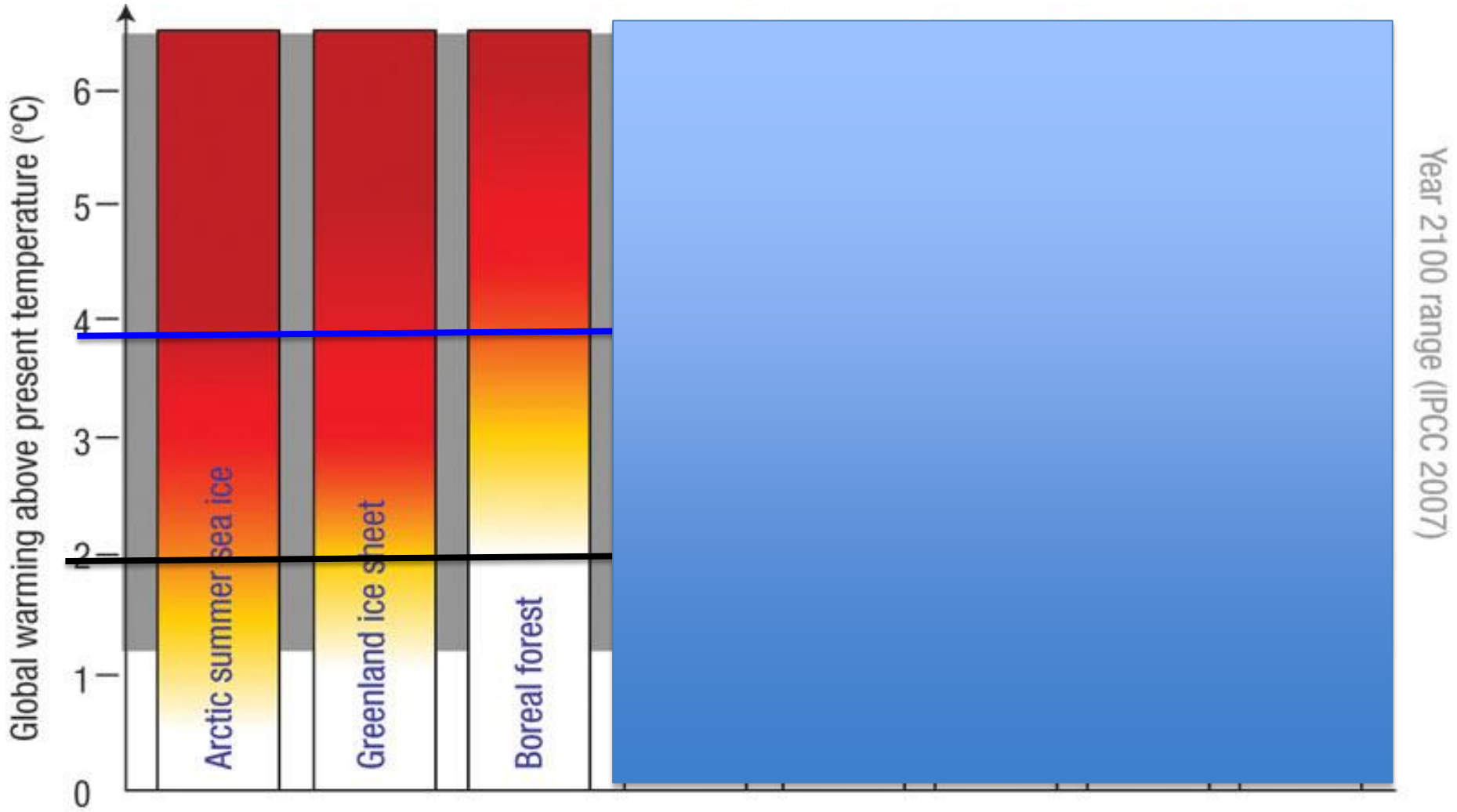
Resilience Sustainability

Arctic tipping elements

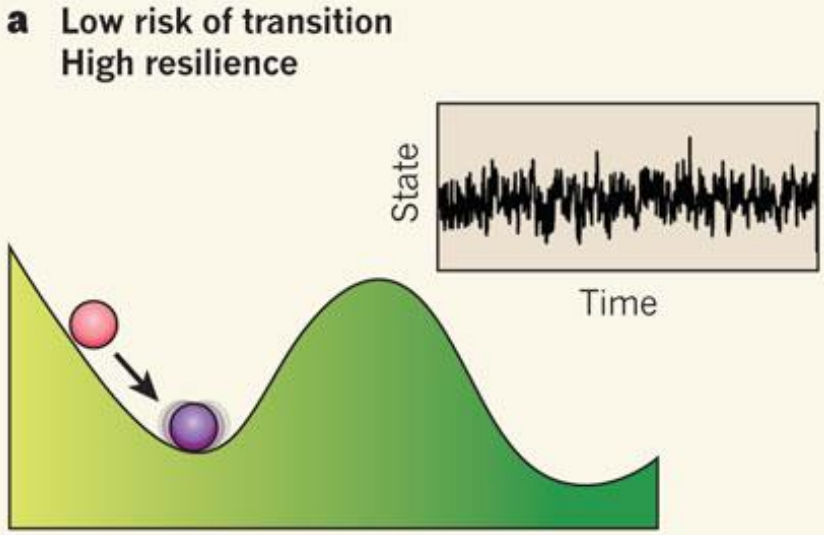


Lenton (in press) *AMBIO*

Estimates of proximity



Lenton & Schellnhuber (2007) *Nature Reports Climate Change*



Resilience is the ability of a system to return to its initial state after a disturbance

Stability refers to the disturbances frequency that a system faces

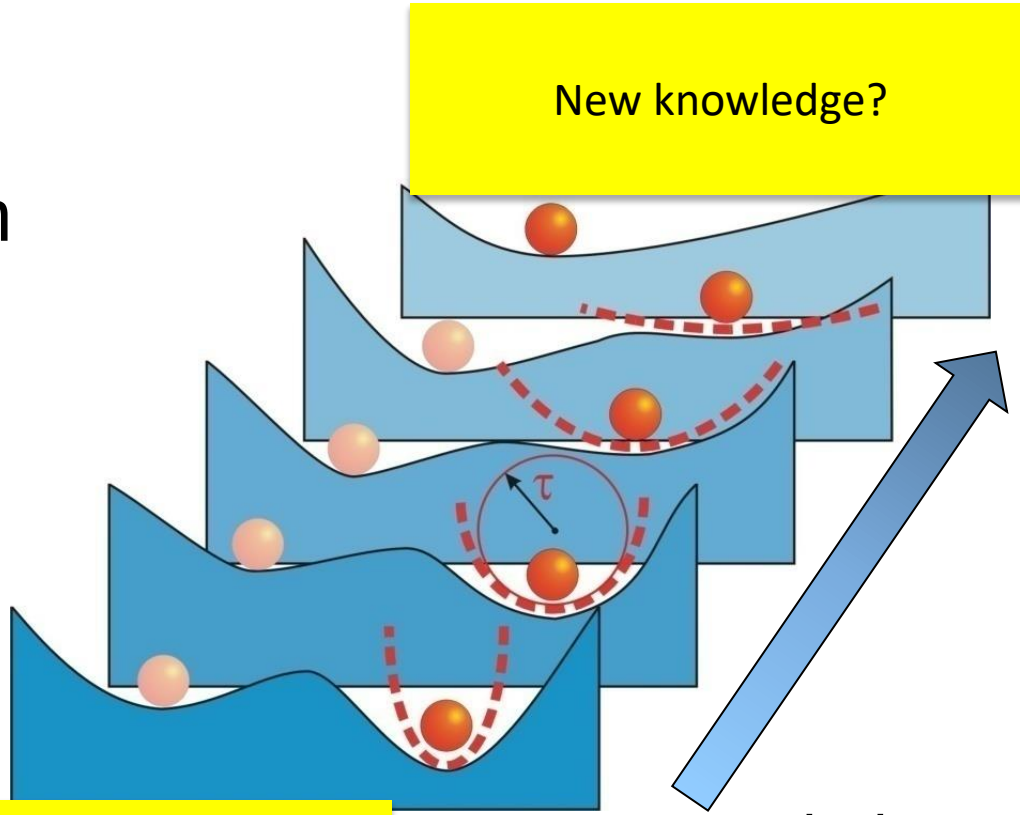
Ecosystems knowledge and resilience

- Our knowledge reflects the time interval and the ecosystem state from which the knowledge is derived
- How relevant is this knowledge after a tipping point is reached and a new and unknown phase of ecosystem function is in place?

Early warning prospects

Generic early warning sign

- Increase in velocity
- Increasing variability
- Skewed responses



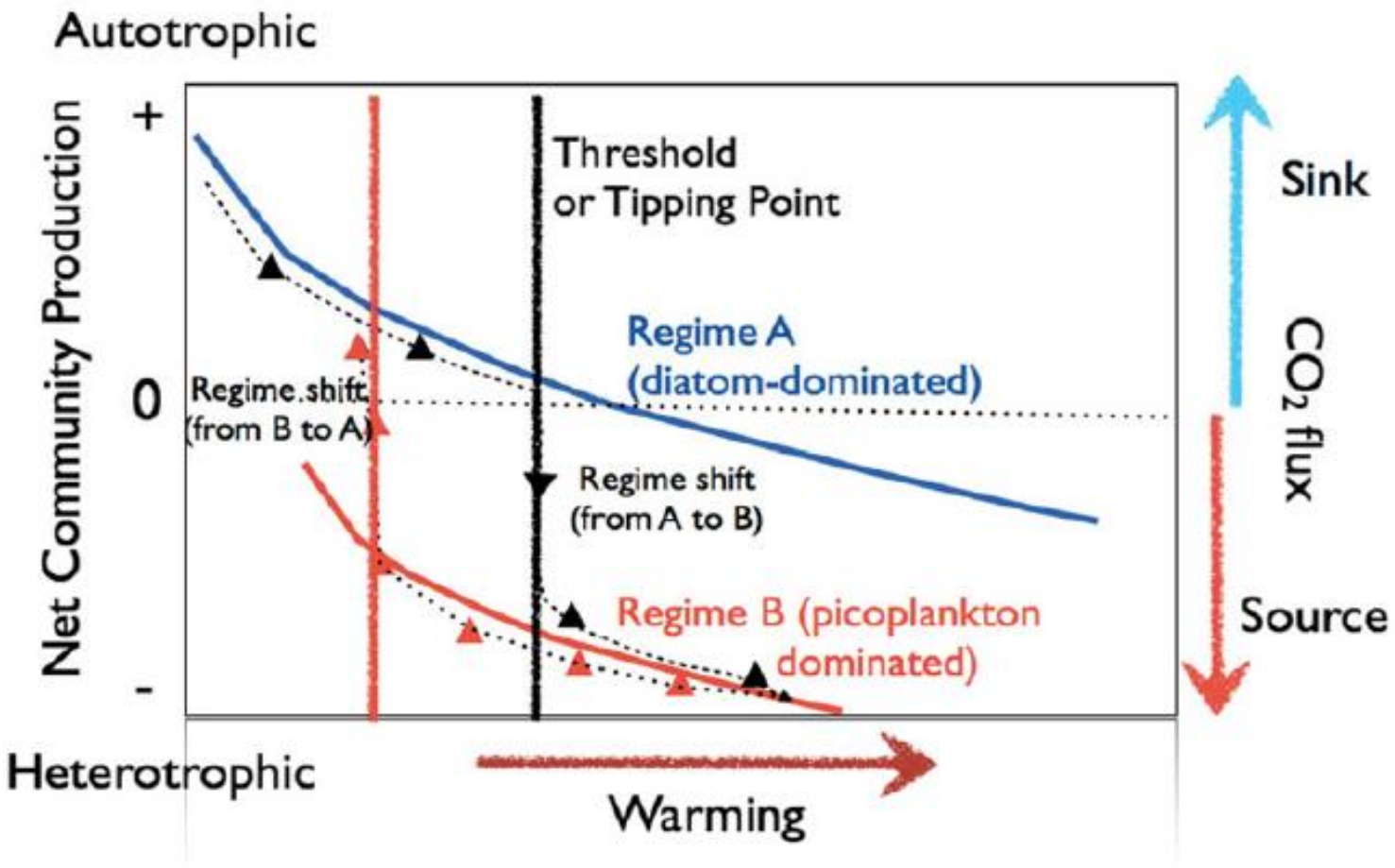
Held & Kleinen (2004) *GRL* 31: L23207; Lenton et al. (2008) *PNAS* 105(6): 1786-1793

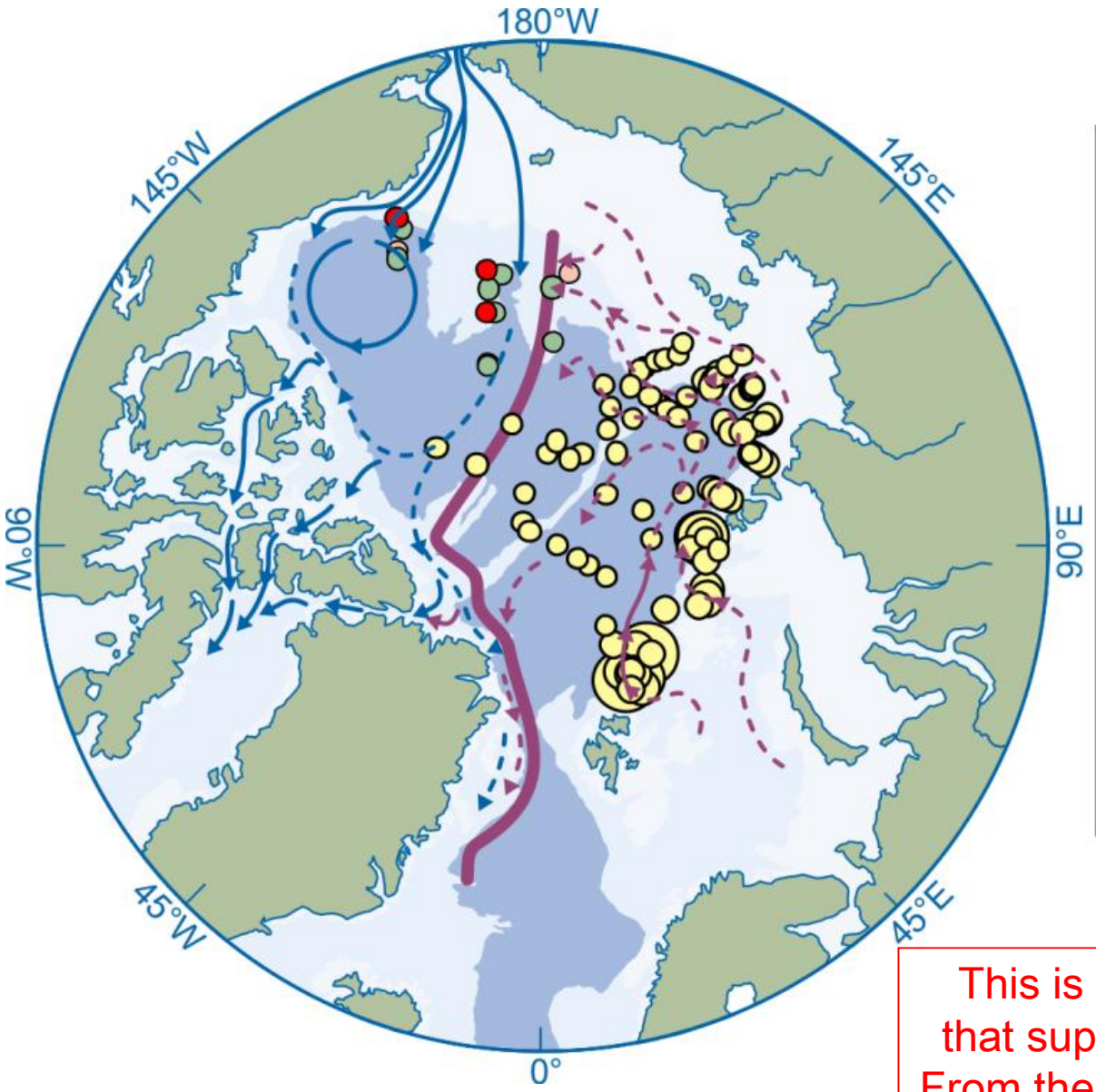
Ecosystems knowledge and resilience

- I am not a climate change nerd, although accused for climatic determinism
- I am aware of the cultural, sociological and psychological implication of my questions!!!!
- However, I know that nature is first and increasingly determines the living conditions in the Nigh North
- I am one of the people of the Arctic, although not belong to the peoples of the Arctic

MPA networks are an important idea, but how significant are the terms resilience, stability and indigenous knowledge for their establishment?

Photo: A. Sveen


Autotrophic
Net Community Production
+
0
-
Threshold
or Tipping Point
Regime A
(diatom-dominated)
Regime shift
(from B to A)
Regime shift
(from A to B)
Regime B (picoplankton
dominated)
Sink
CO_2 flux
Source
Heterotrophic
Warming



Copepod abundance (ind m^{-2})

Jenks Natural Breaks

- 0 - 862
- >862 - 3,002
- >3,002 - 5,848
- >5,848 - 12,348
- >12,348 - 41,680

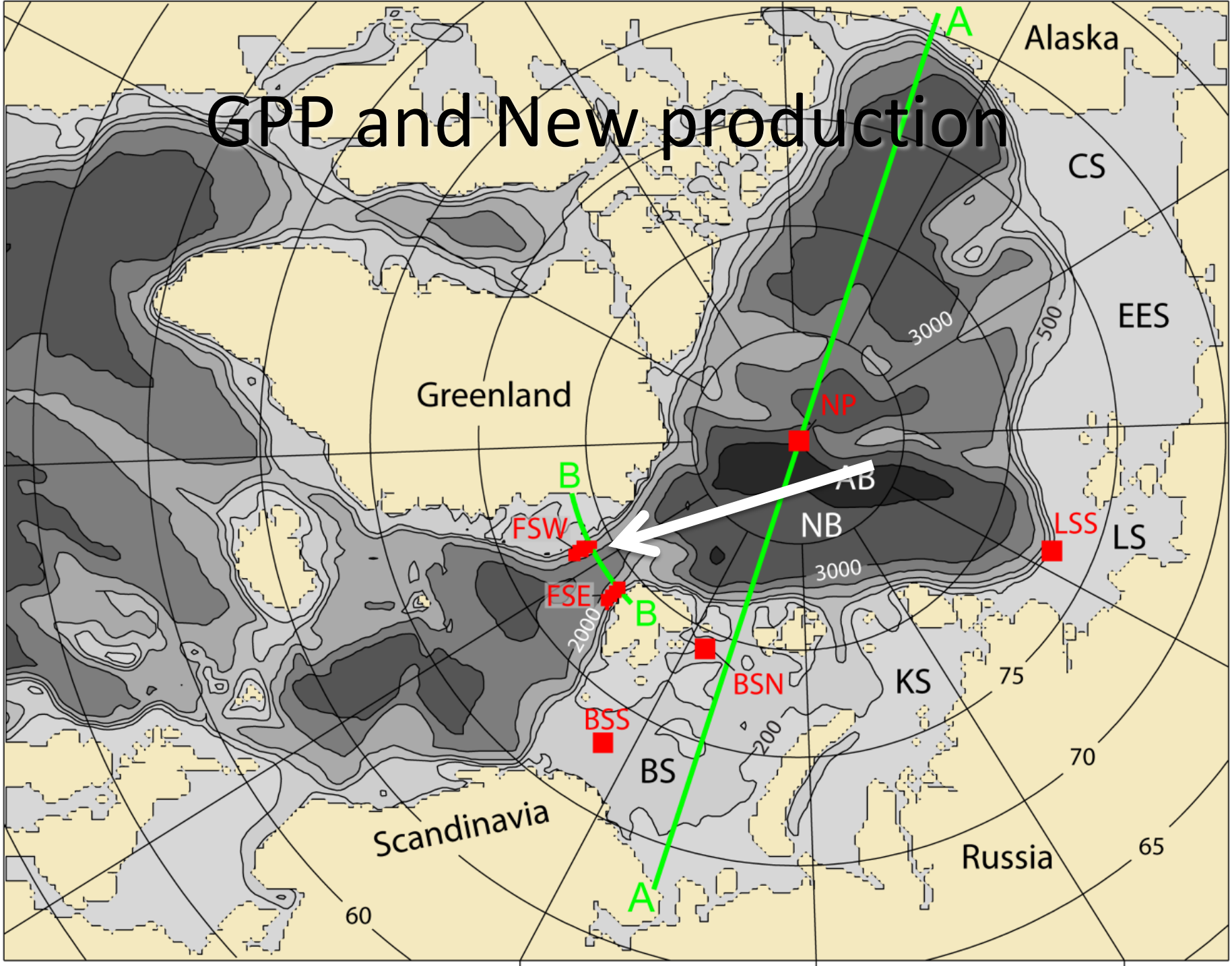
- *Calanus finmarchicus*
- *Neocalanus cristatus*
- *Metridia pacifica*
- *Eucalanus bungii*

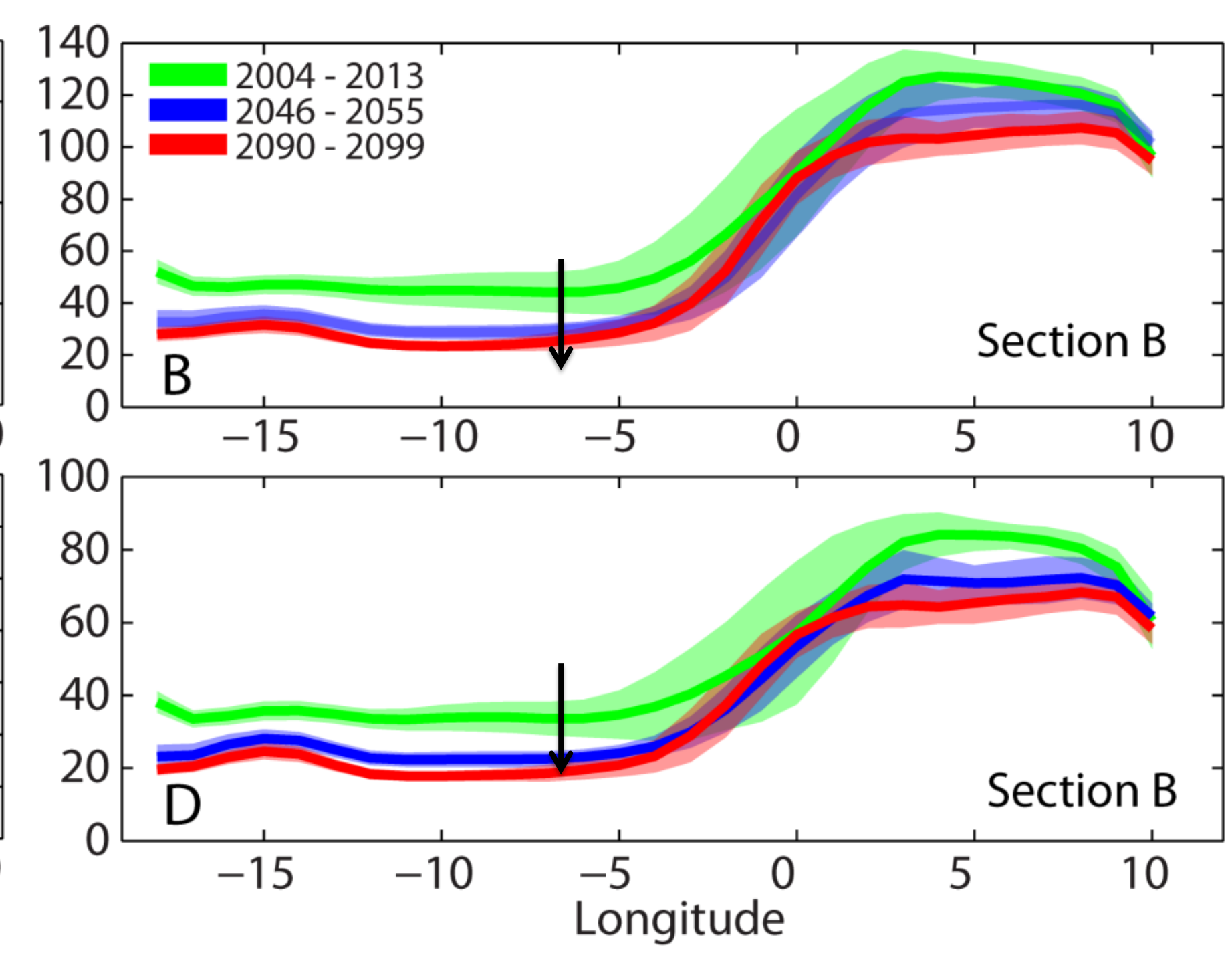
This is the Ecology of Advection that supports the AO with biomass From the Atlantic and Pacific oceans

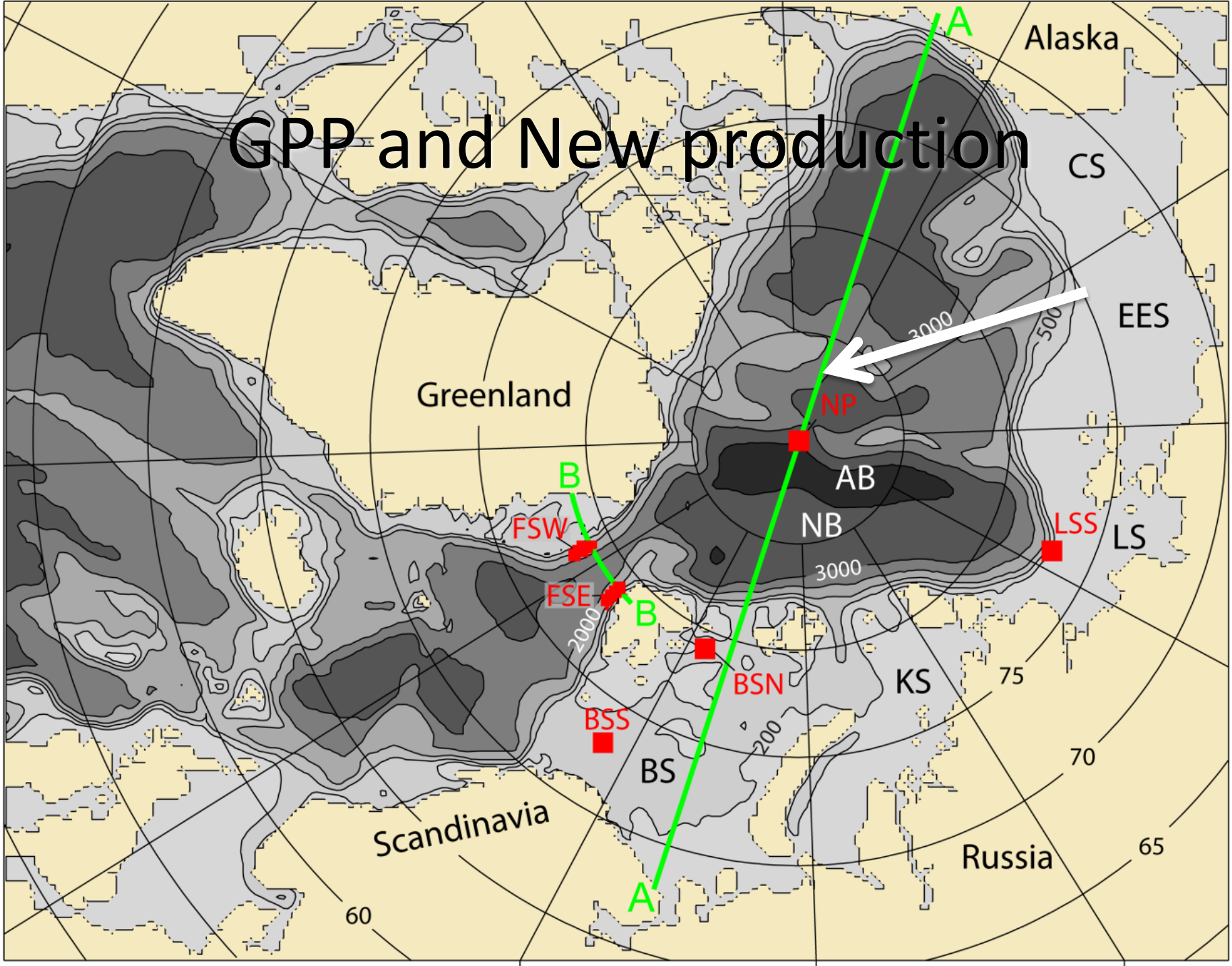
Bluhm/Kosobokova/Carmack, 2015

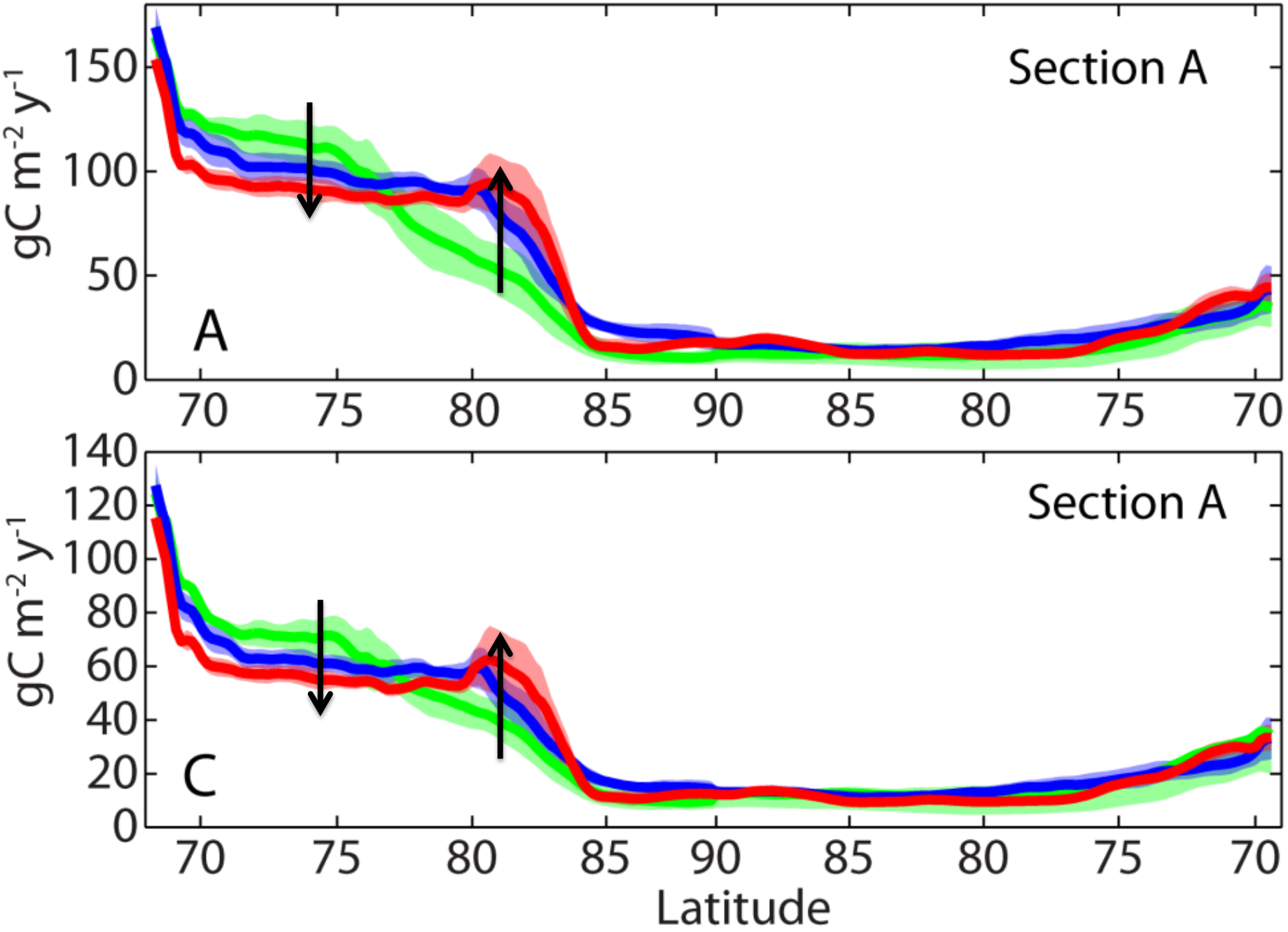
Big and principal changes in primary production?

- Locally yes, but large scale no

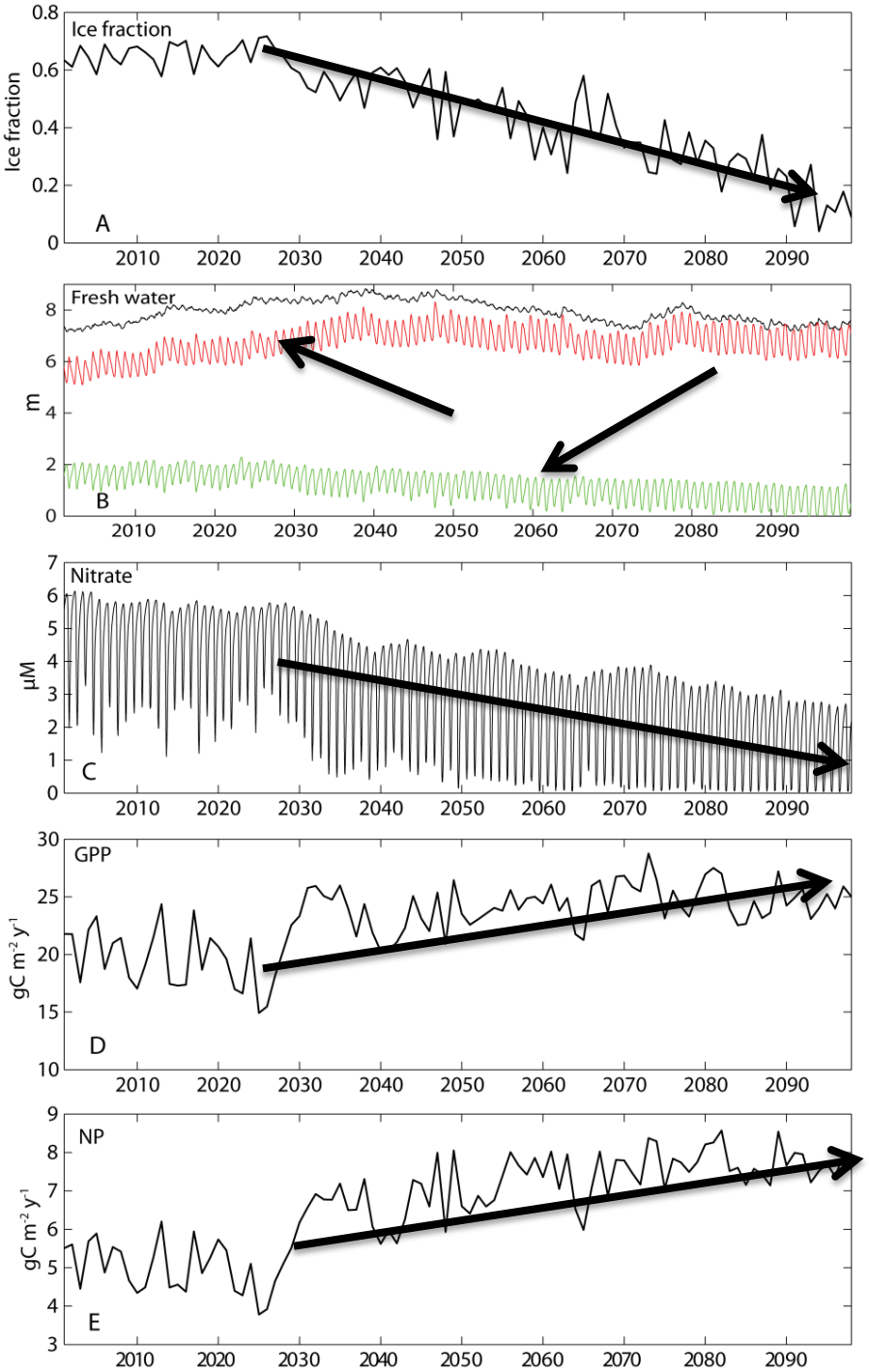

GPP and New production
A
Alaska
CS
EES
3000
500
Greenland
NP
B
AB
FSW
NB
LSS
LS
3000
FSE
2000
B
BSN
KS
75
BSS
200
70
BS
Scandinavia
Russia
65
60
A


2004 - 2013
2046 - 2055
2090 - 2099
B
Section B
D
Section B
Longitude

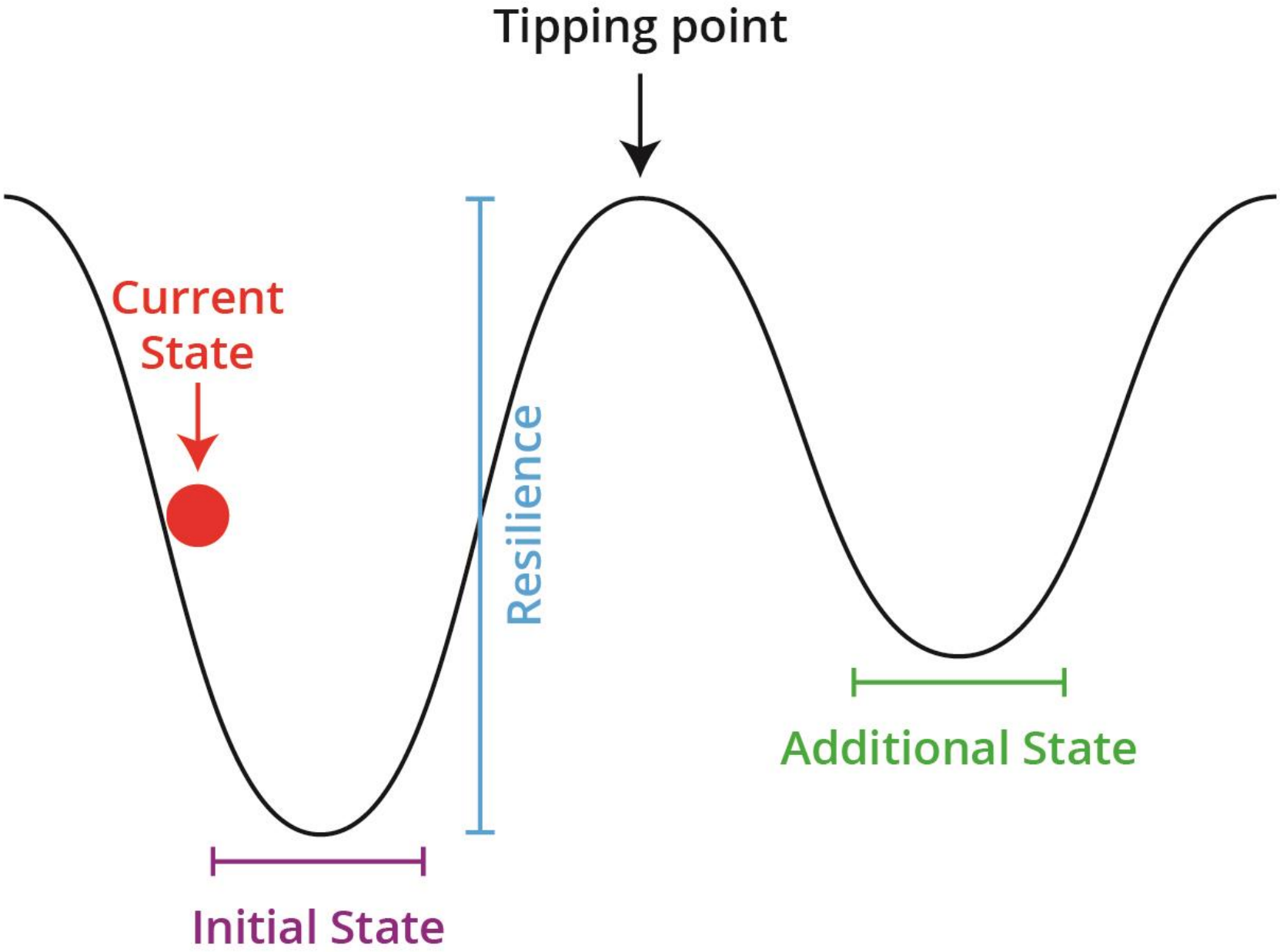

GPP and New production
A
Alaska
CS
EES
3000
500
Greenland
NP
AB
NB
LSS
LS
B
FSW
FSE
B
2000
3000
BSN
KS
75
BSS
200
70
BS
Scandinavia
Russia
65
60
A


Section A
A
gC m-2 y-1
150
100
50
0
70
75
80
85
90
85
80
75
70
Section A
C
gC m-2 y-1
140
120
100
80
60
40
20
0
Latitude

Increased fisheries in the central Arctic Ocean?



Entire central Arctic Ocean

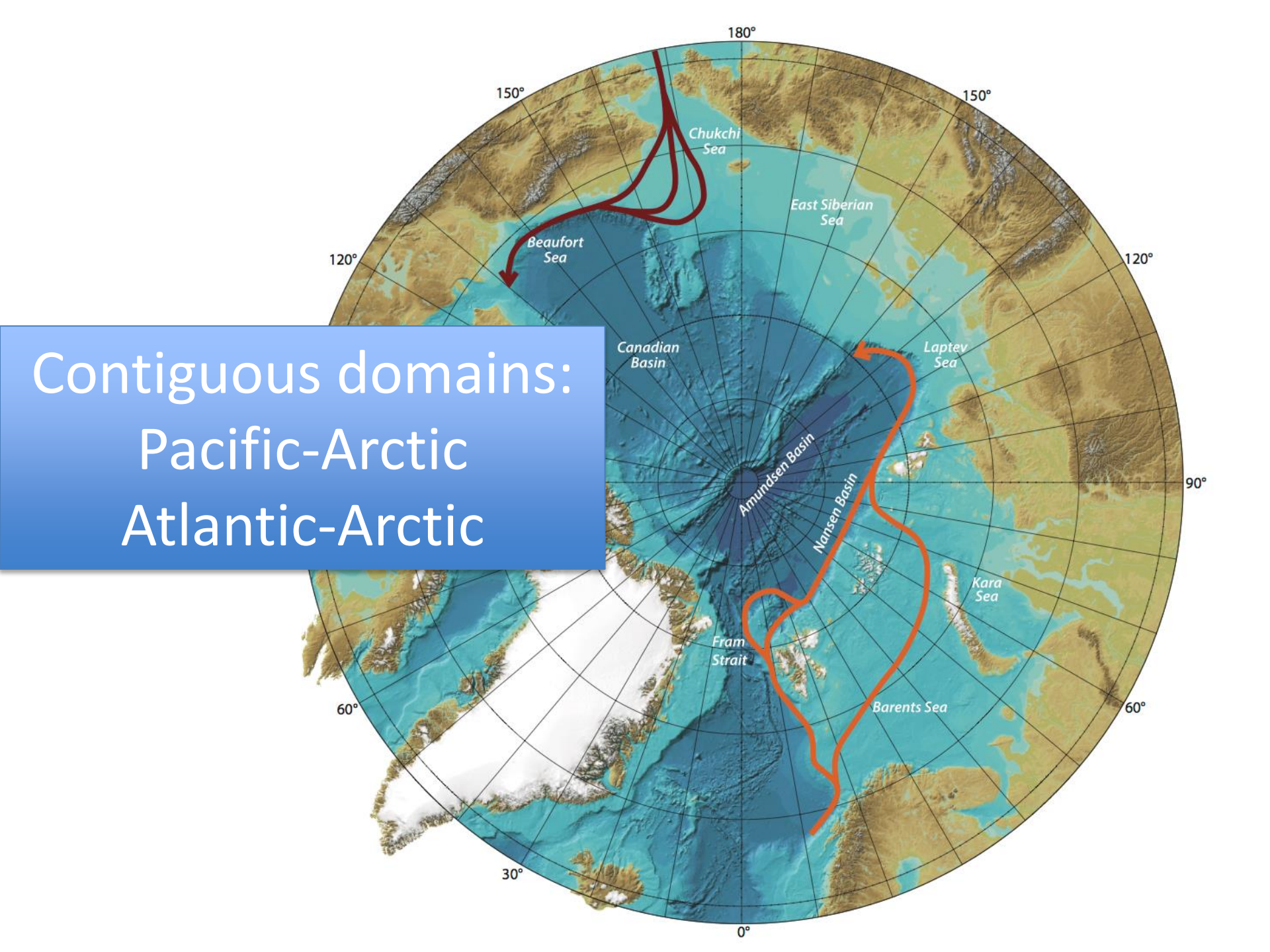

Tipping point
Current State
Resilience
Additional State
Initial State

Inflow shelves may not be self-sustained systems

- How much area in the western Fram Strait and the adjacent Greenland/Norwegian Sea is necessary to support the zooplankton biomass that is advected into the Arctic Ocean north of Svalbard?
- How should we address the potential for a sustained fishery in the new Arctic Ocean of tomorrow?

- The foreseeable future looks bright!

- Increased fisheries
- Shorter ship transportation
- Increased oil/gas and mining options
- How can we make sure that **shorter**, **increased** and **more** results in sustainability?


Contiguous domains:
Pacific-Arctic
Atlantic-Arctic
180°
150°
150°
120°
120°
90°
60°
60°
30°
0°
Chukchi Sea
East Siberian Sea
Beaufort Sea
Canadian Basin
Laptev Sea
Amundsen Basin
Nansen Basin
Kara Sea
Fram Strait
Barents Sea

Cfin biomass in box north of Svalbard (g C m^{-2})