Changes in phytoplankton and zooplankton production in the Nordic and the Arctic Seas under a warmer climatic regime.

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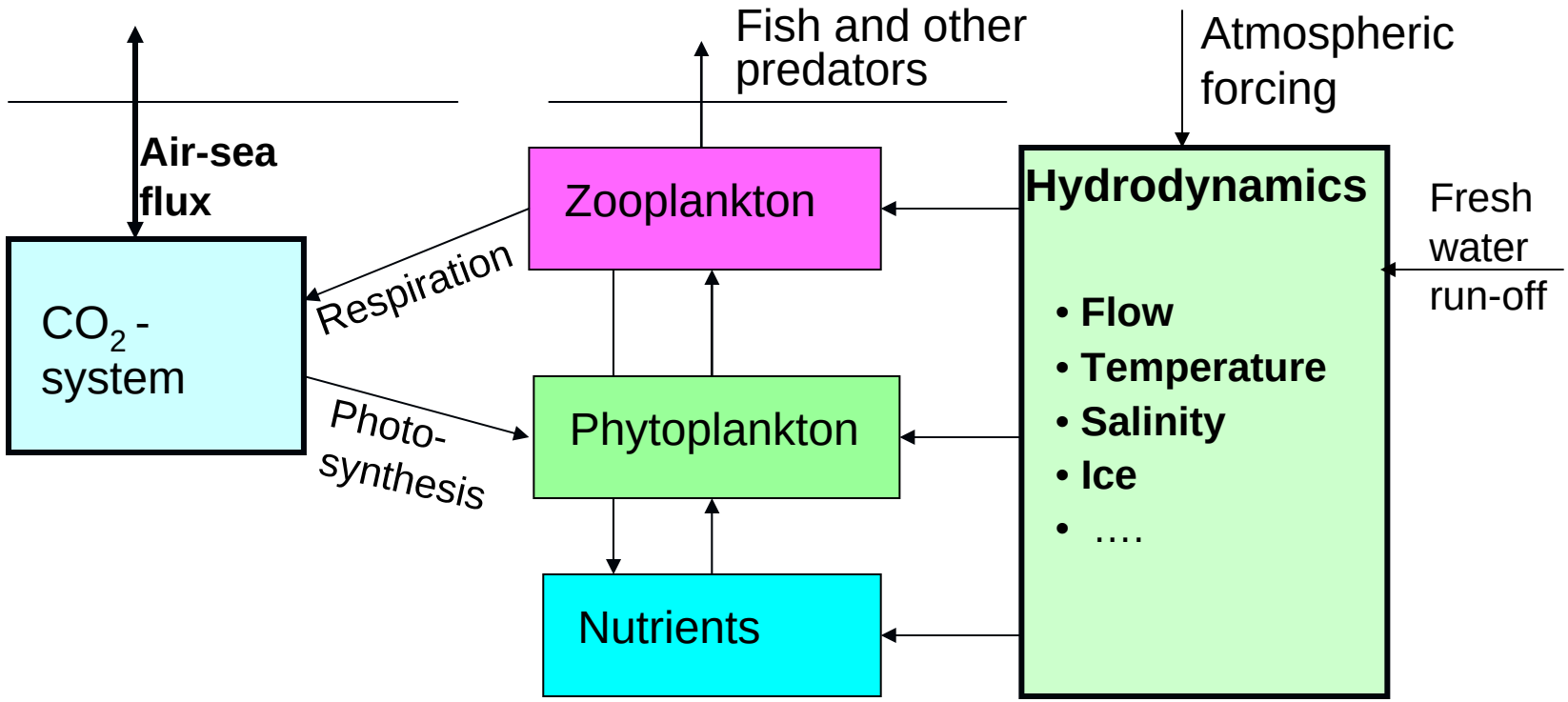
Outline

- A short model description and a few results
- Model experiments using different atmospheric forcings:
  - IPCC A1B (and A2)
  - Modified reanalysed data

The SINMOD Basic Model Components



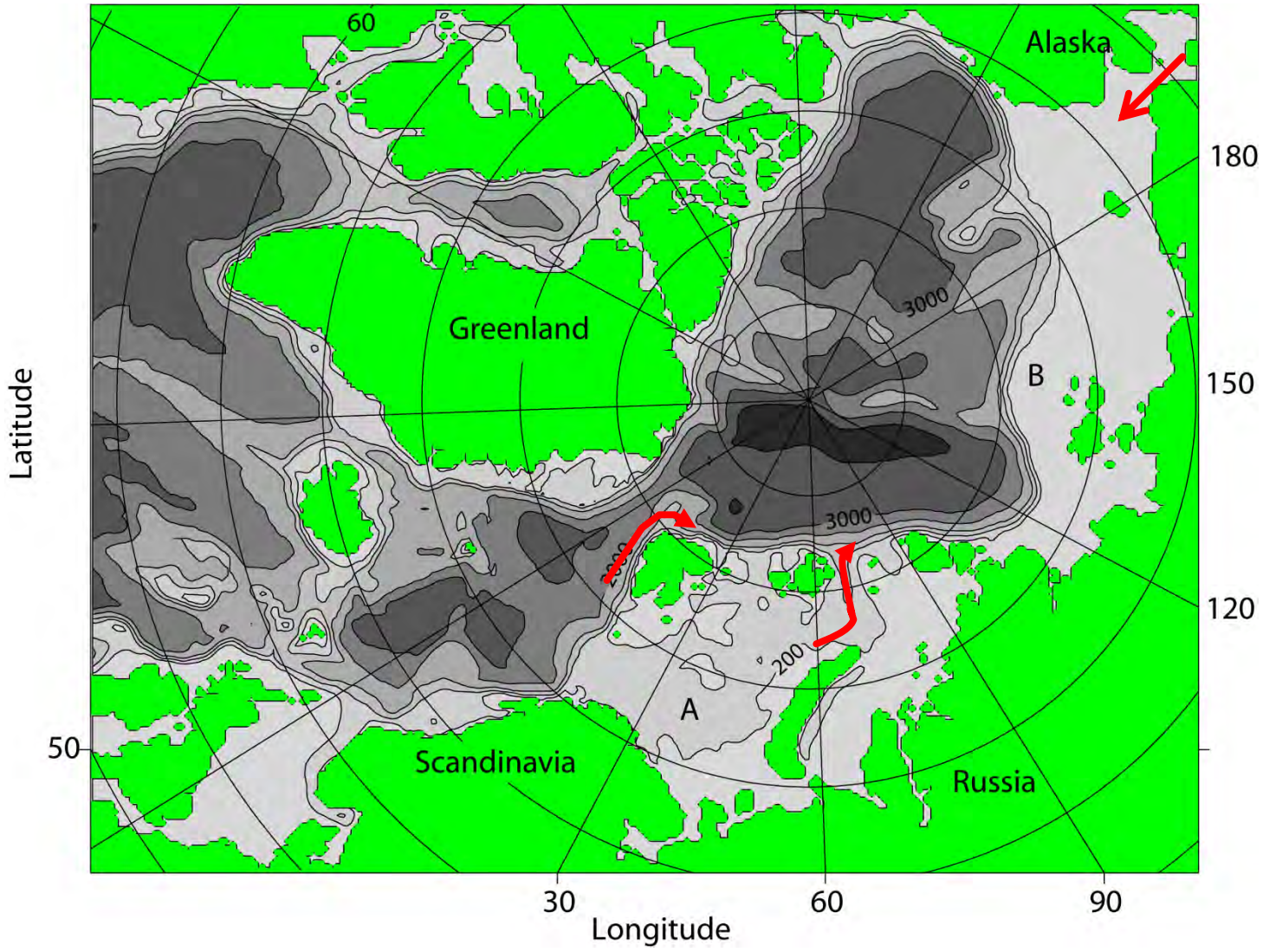
The SINMOD hydrodynamic model

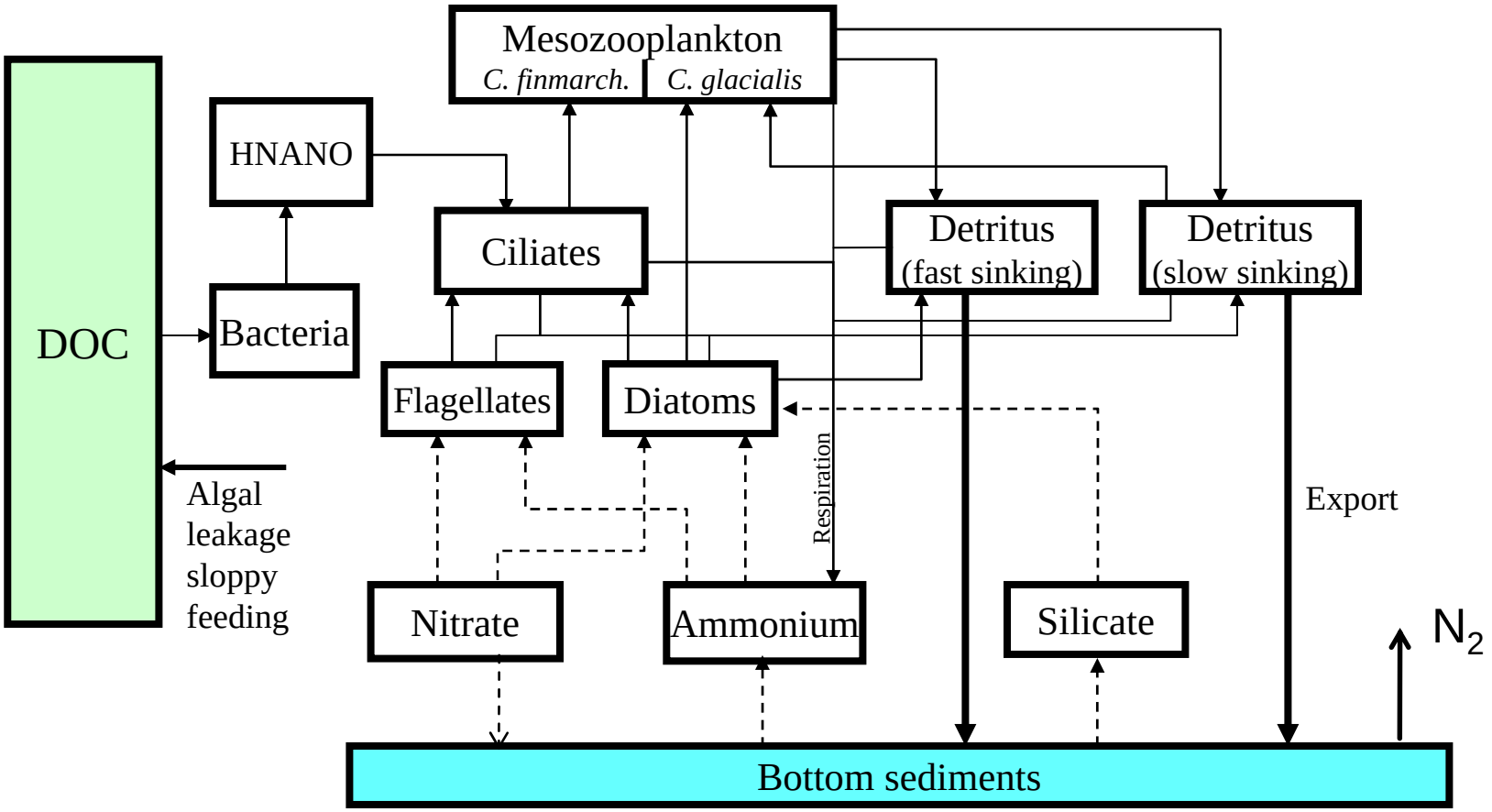
- **Model characteristics**
  - z-level model
  - Mode splitting
  - EVP ice model (Hibler 1979, Hunke 1997)

- **Initialisations**
  - Temperature and Salinity: WOCE data: http://www.nodc.noaa.gov/woce_v3/
  - Ice. A course specification and then spin-up for 20 years.

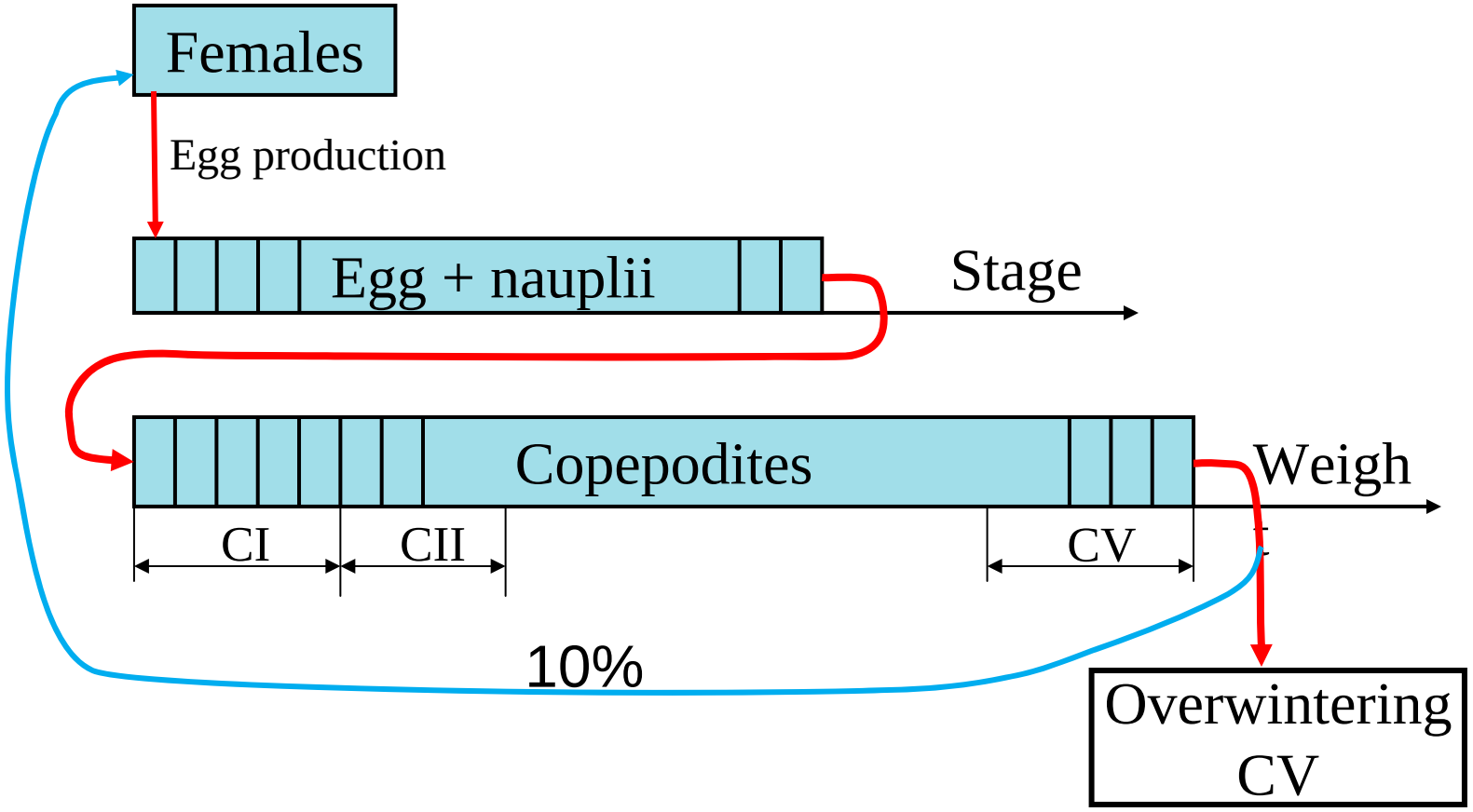
- **Forcing**
  - Atmosphere: ECMWF (ERA40, ERA INTERIM)
  - For the Climate runs:
    - ECHAM 5 - Max Plank model.
    - ERA40 and specified increase in air temperature
  - Freshwater run-off from rivers surrounding the model domain

Model domain

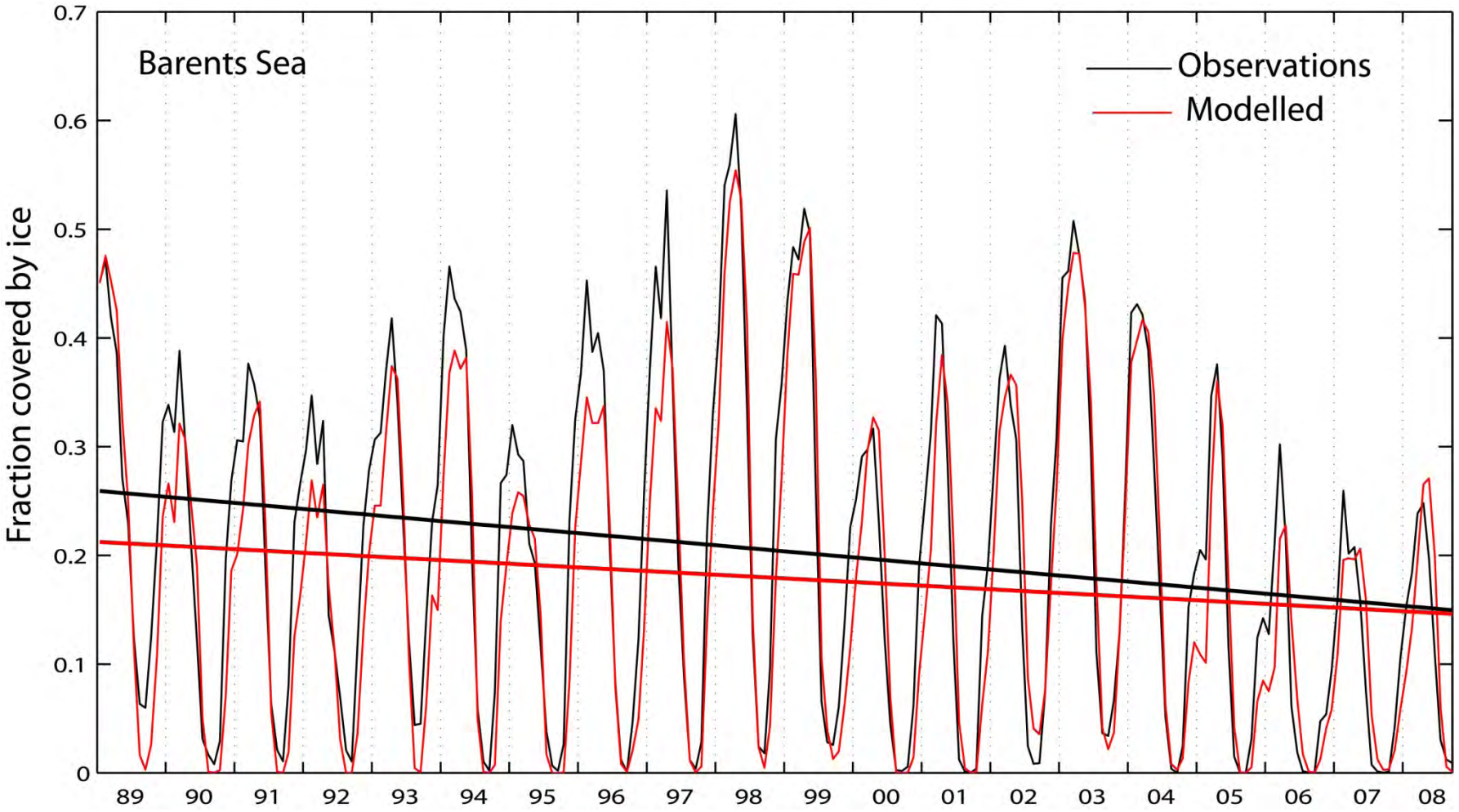



Mesozooplankton
C. finmarch.
C. glacialis
HNANO
Ciliates
Detritus
(fast sinking)
Detritus
(slow sinking)
DOC
Bacteria
Flagellates
Diatoms
Respiration
Export
Algal
leakage
sloppy
feeding
Nitrate
Ammonium
Silicate
N2
Bottom sediments

Calanus Population model

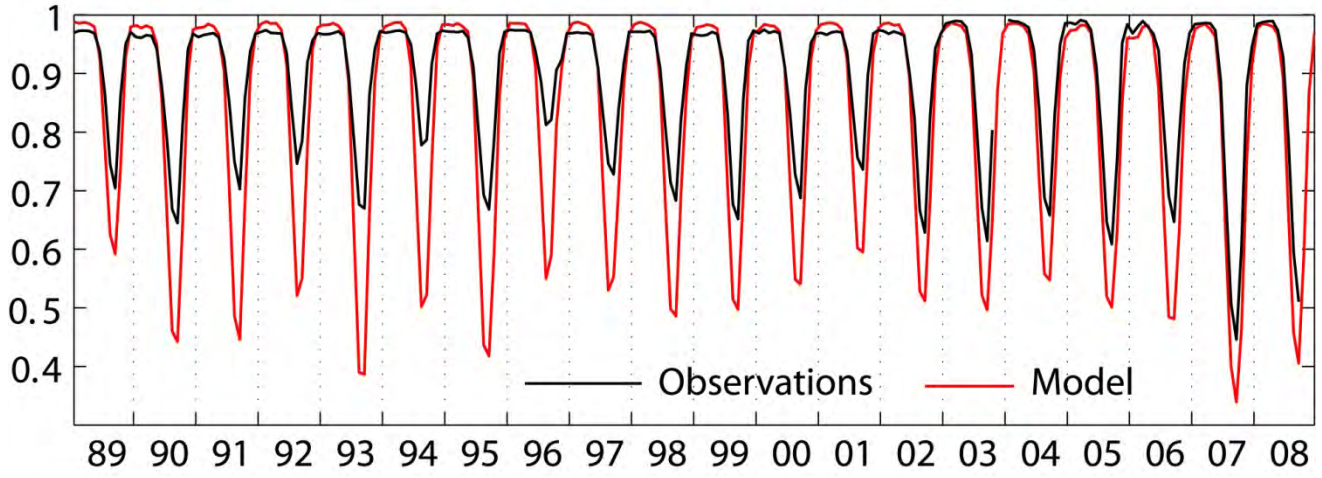


Barents Sea. Fraction covered by ice. ERA Interim forcing
Observes and Simulated

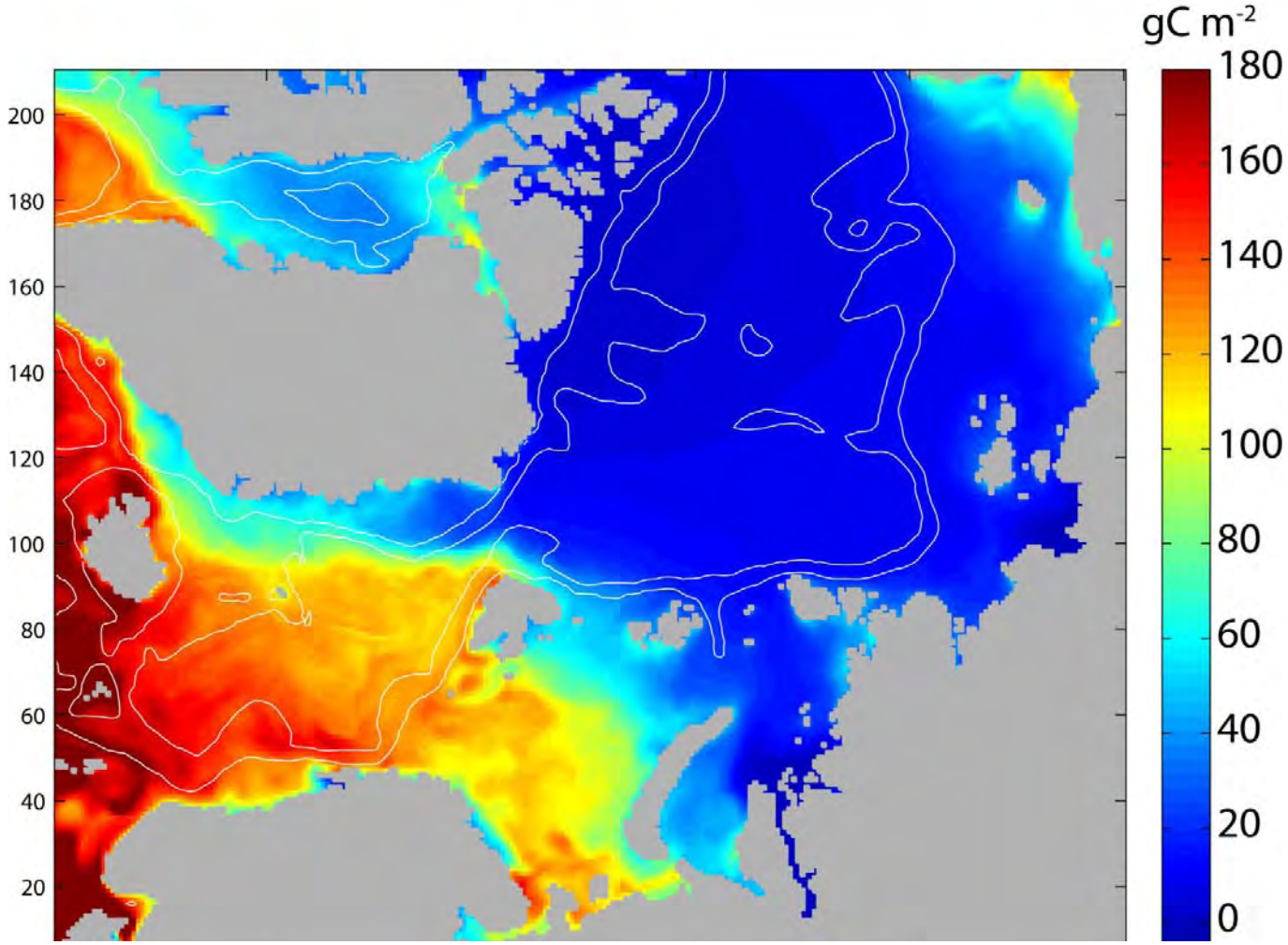


Arctic Ocean. Fraction covered by ice. ERA Interim forcing

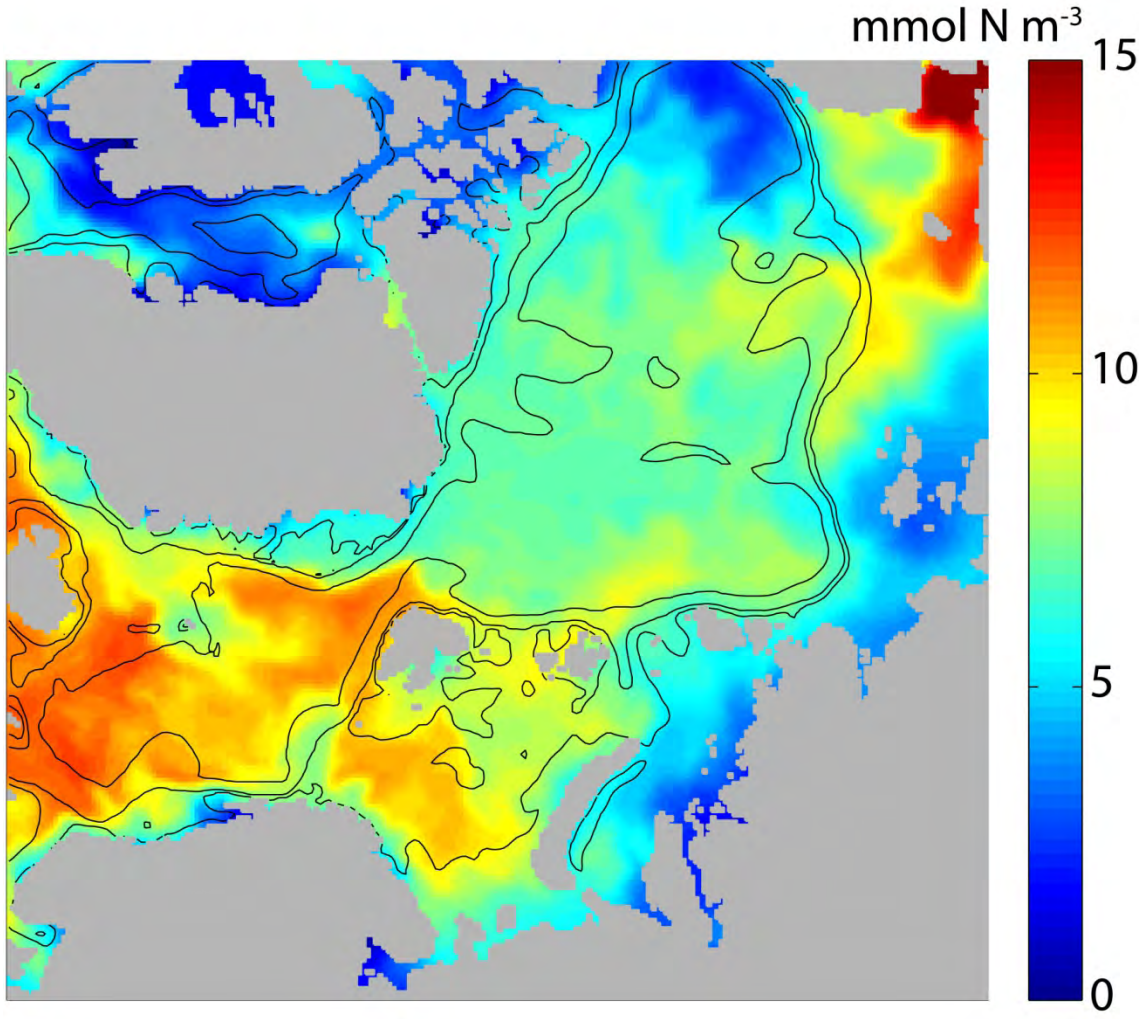
Observes and Simulated



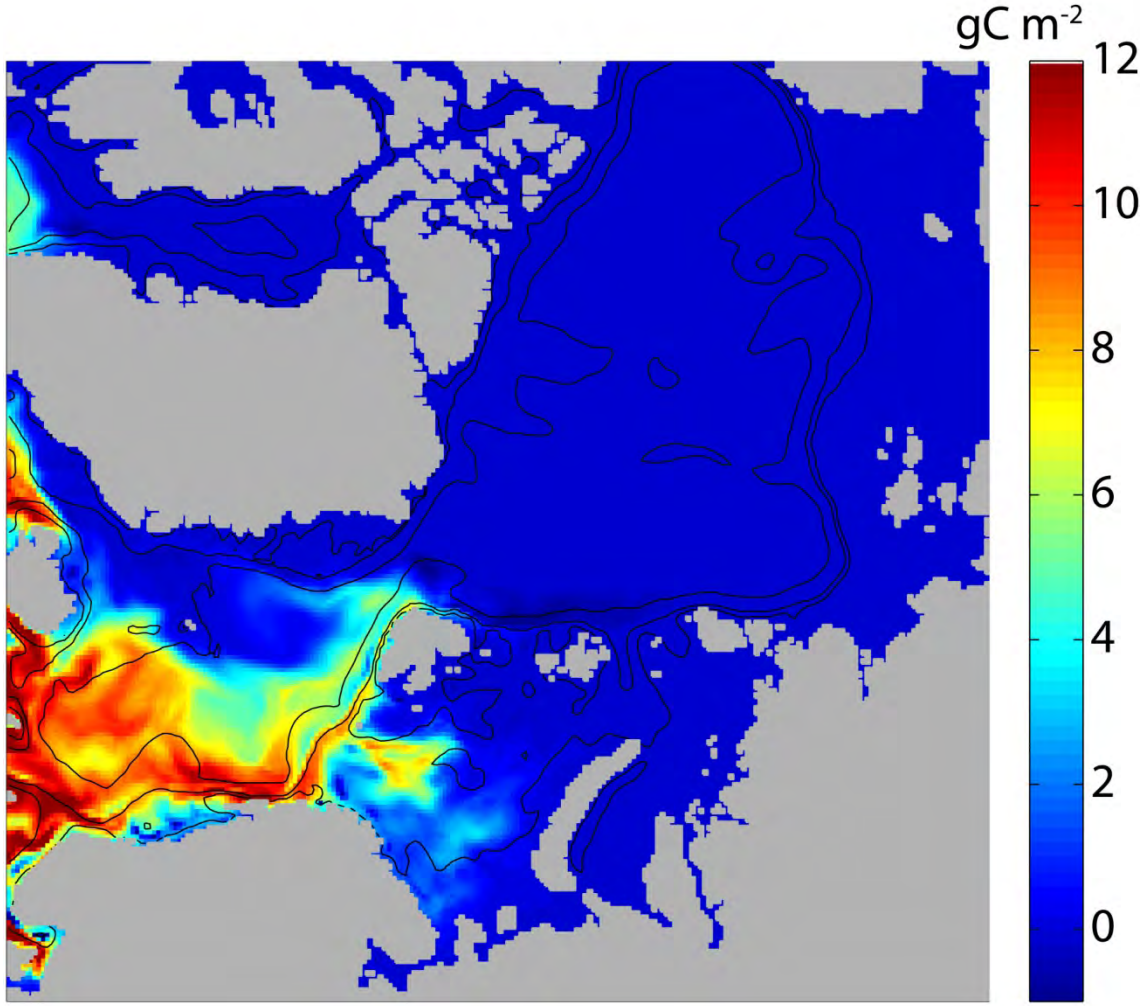
Annual Mean (2003-2008) Gross Primary Production (GPP). Forcing: ERA Interim



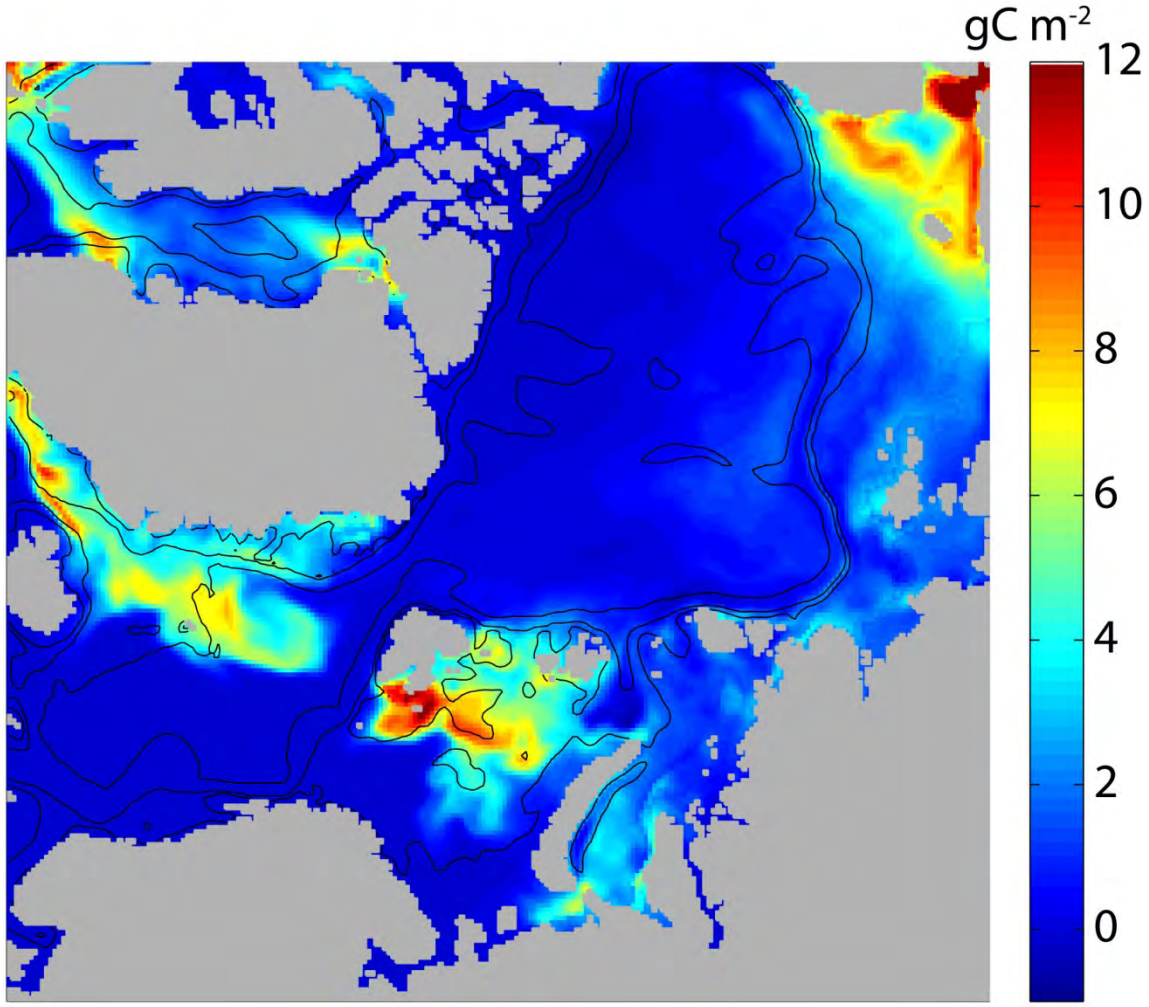
Surface nitrate, Winter



Annual *C. finmarchicus* production. Mean 2003-2008. Forcing: ERA Interim



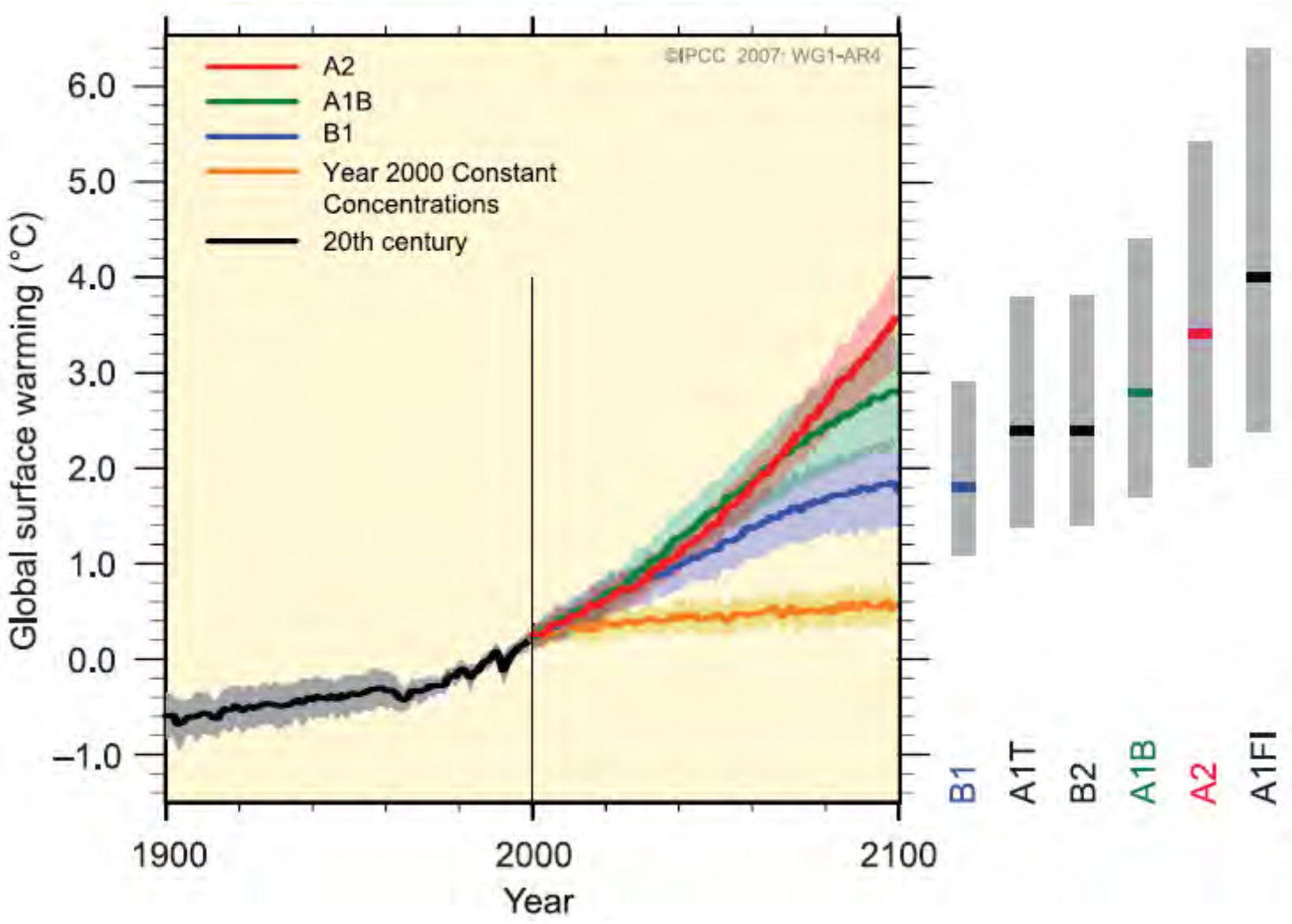
Annual *C. glacialis* production. Mean 2003-2008
Forcing: ERA Interim



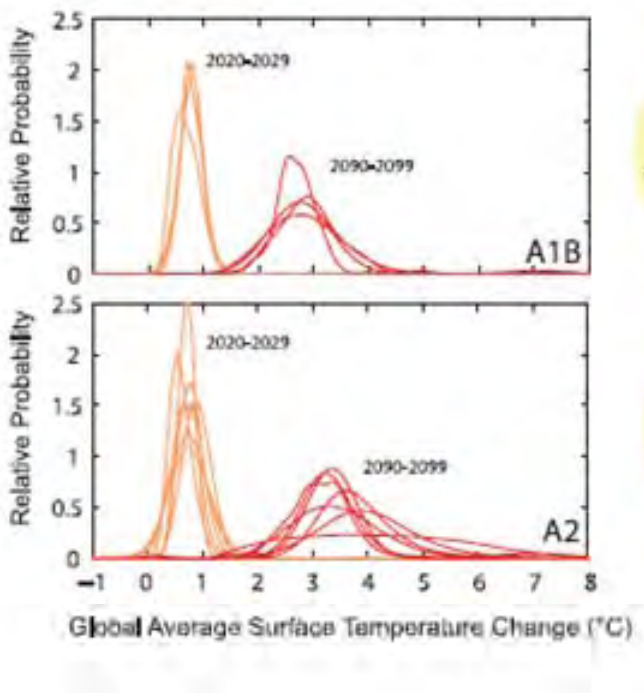
Climatic experiments

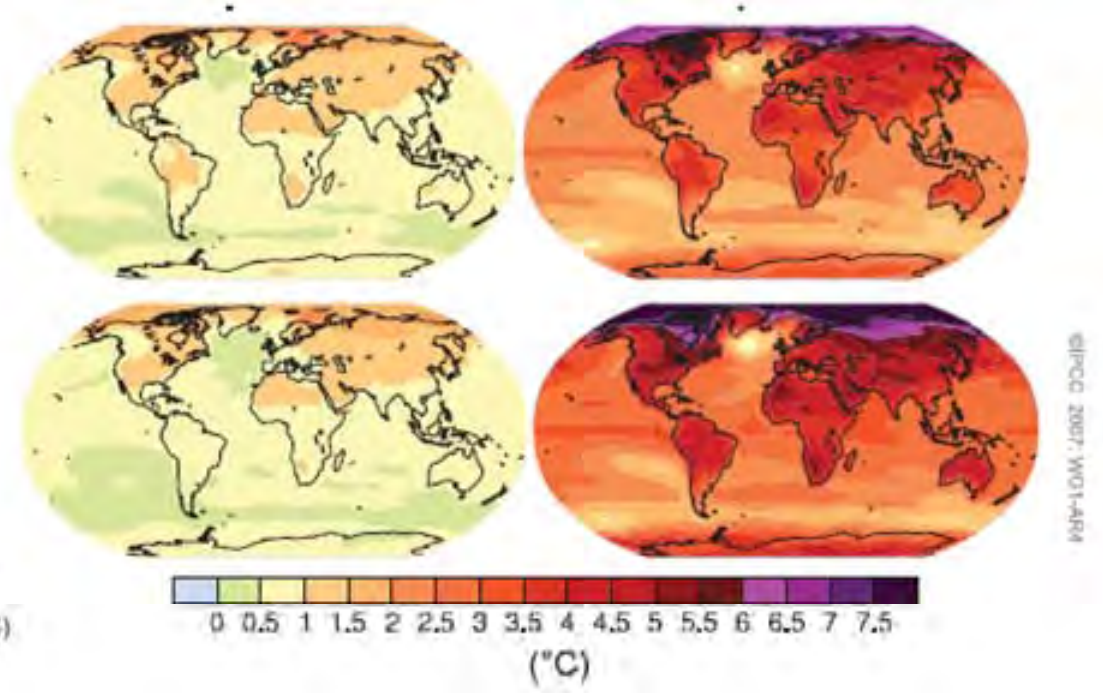
1. Atmospheric input from Climate models
    1. A2 – Global, coarse resolution model
    2. A1B – Regional, high resolution model
2. Use present reanalysed atmospheric forcing and increase air temperature to melt down the summer ice.

IPCC scenarios and projected global warming

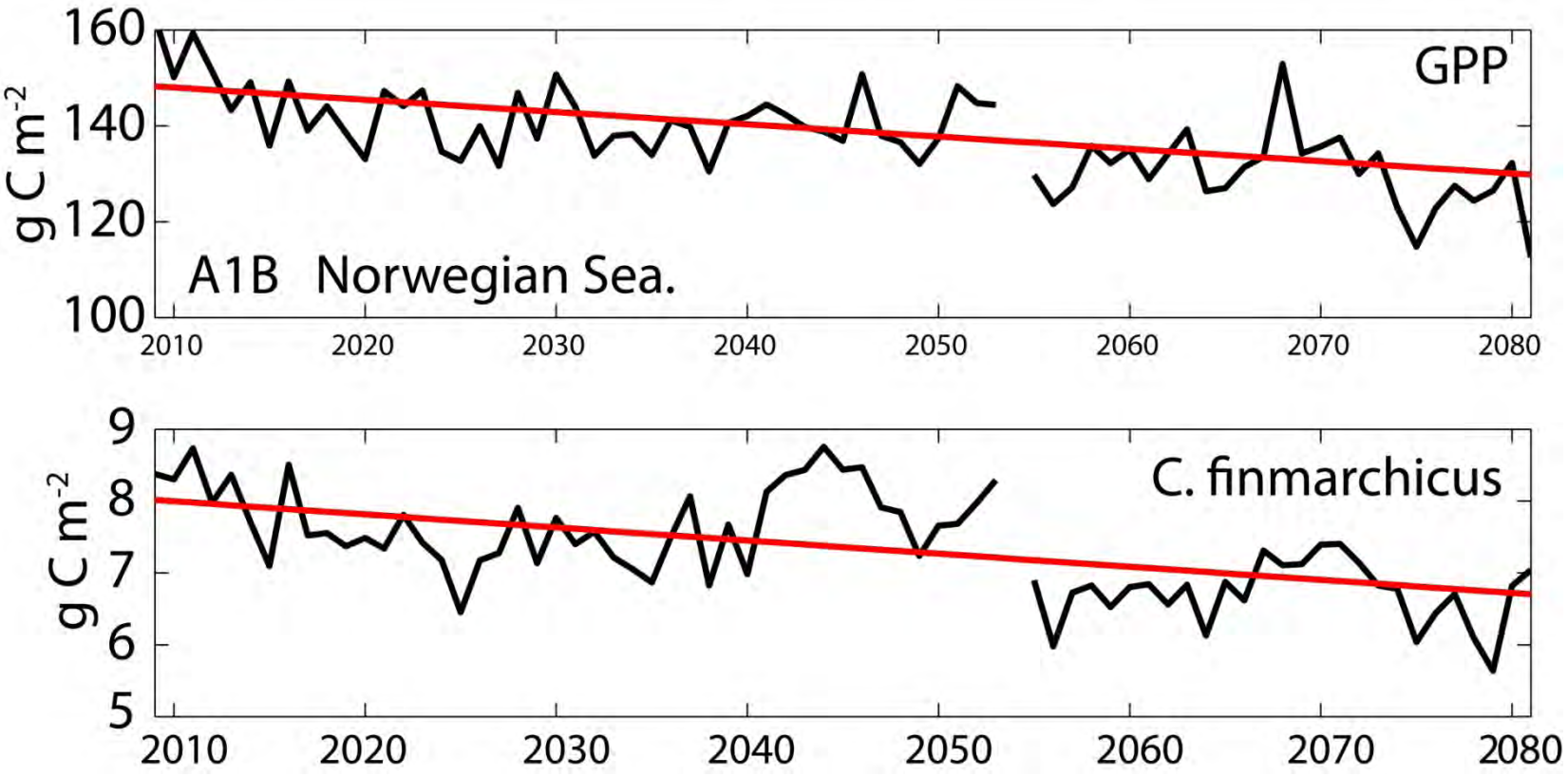


Projections of surface temperatures

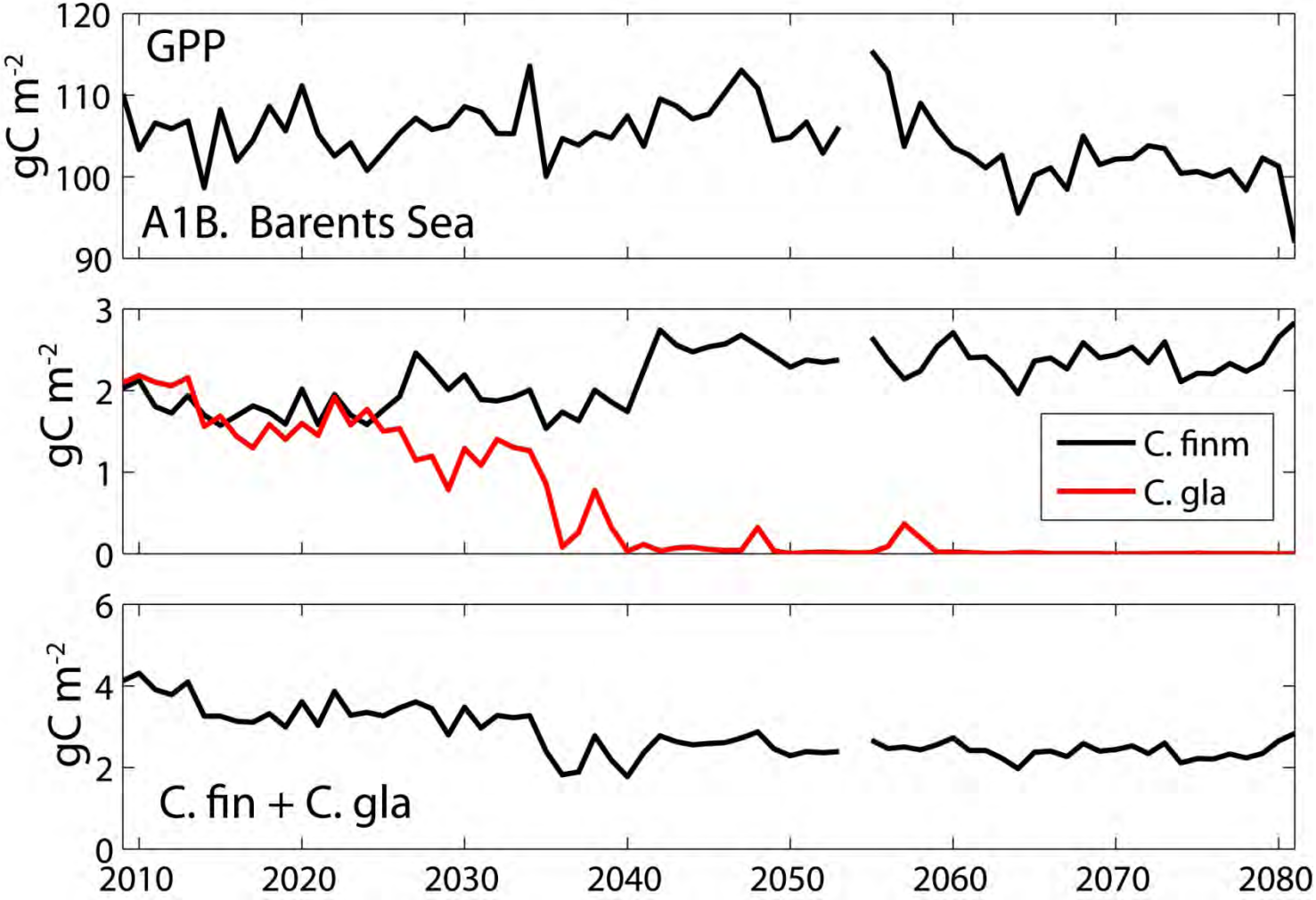




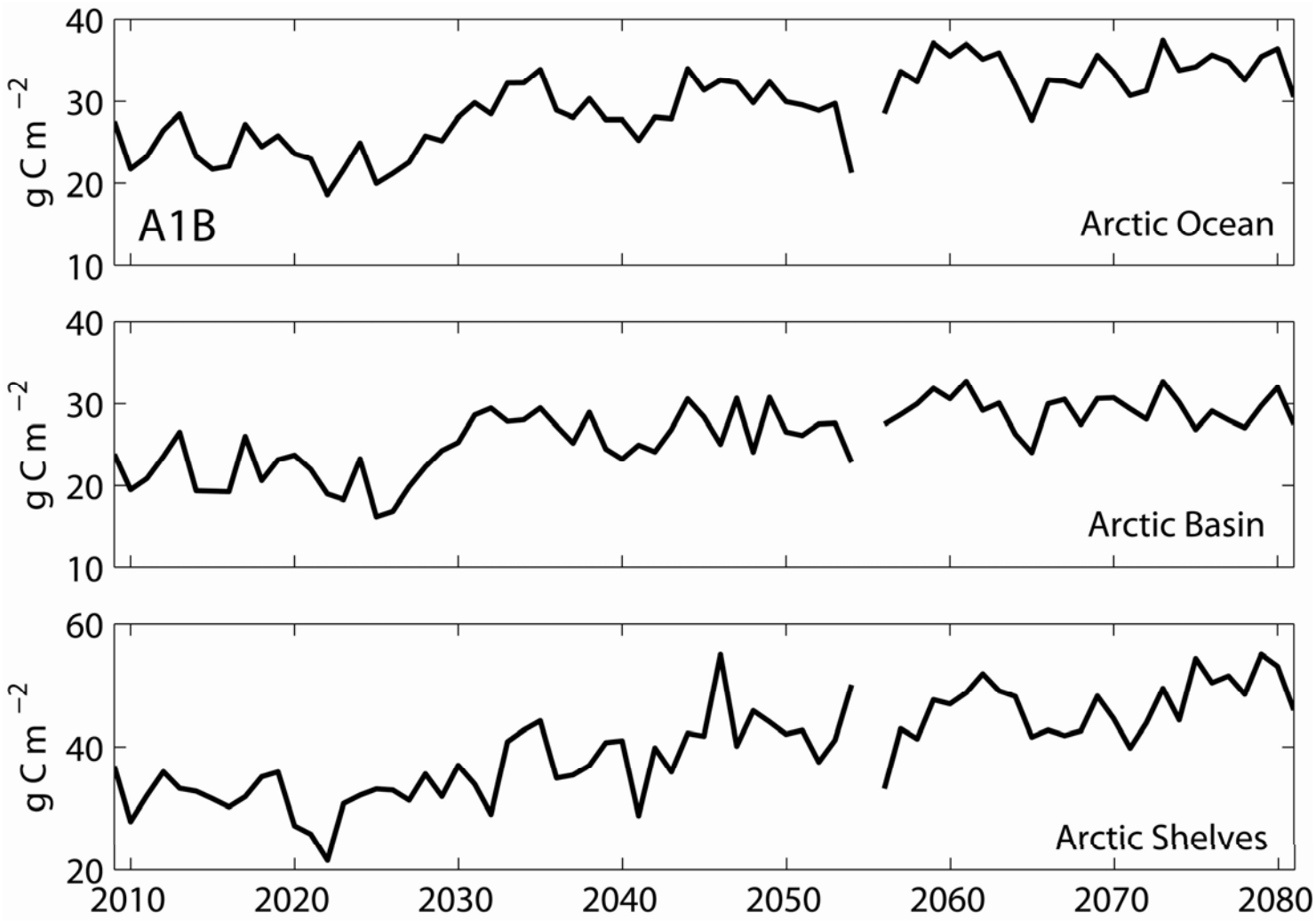
A1B. Annual Primary and secondary production Norwegian Sea



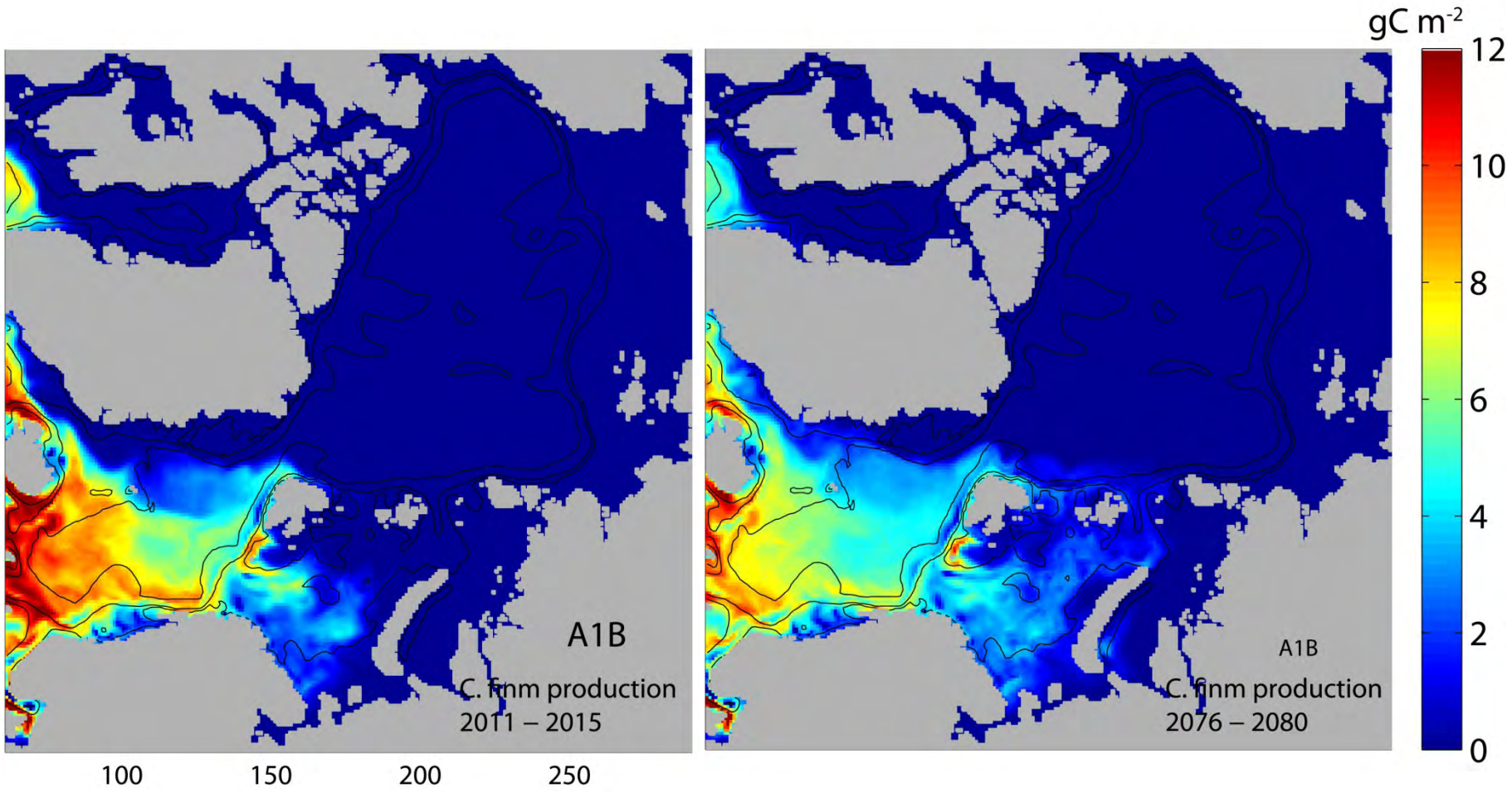
A1B. Annual Primary and secondary production Barents Sea



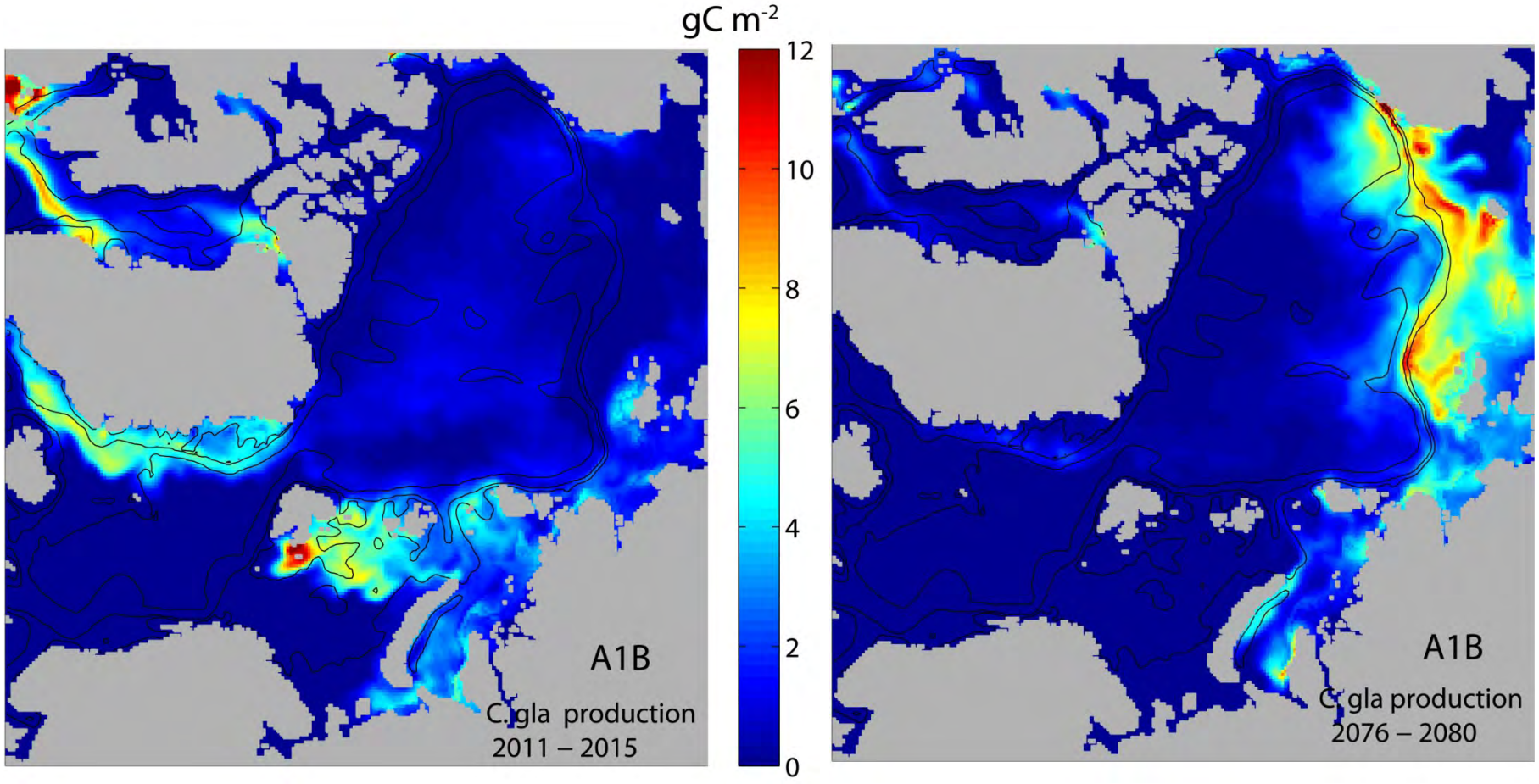
A1B. Annual gross primary production

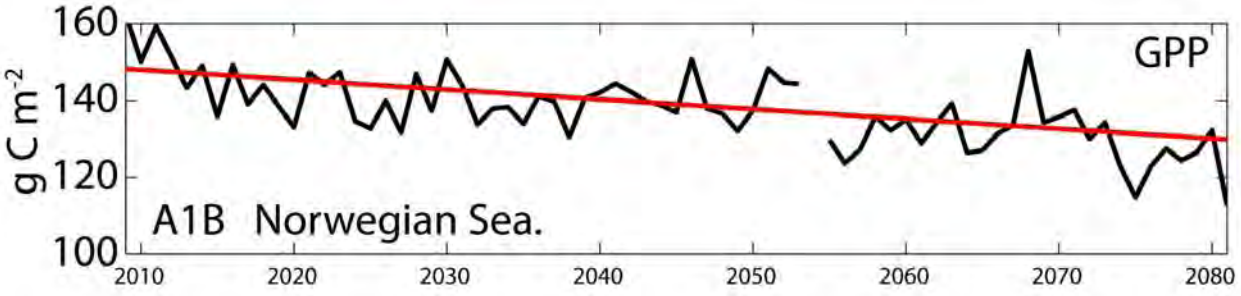


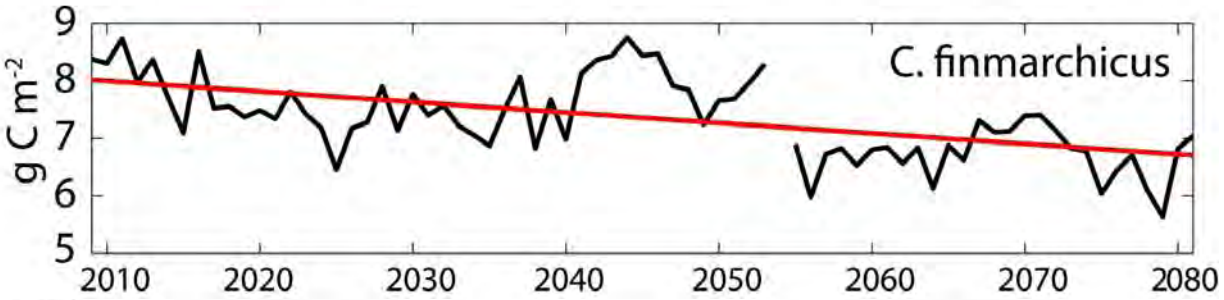
Annual mean production of *C. finmarchicus*

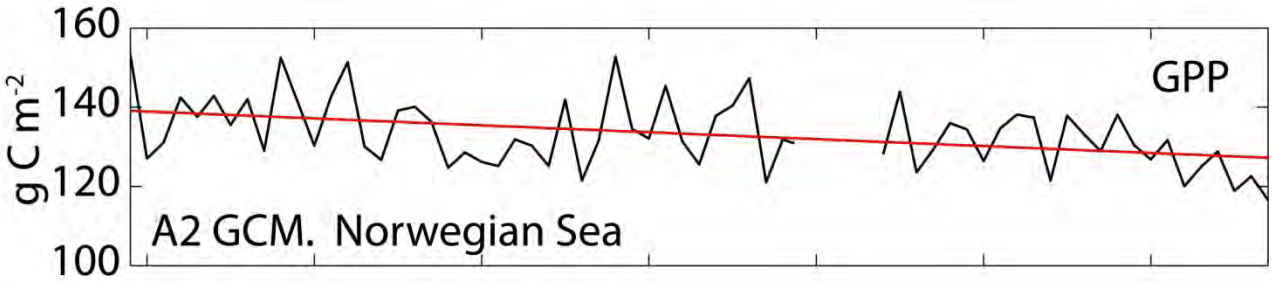


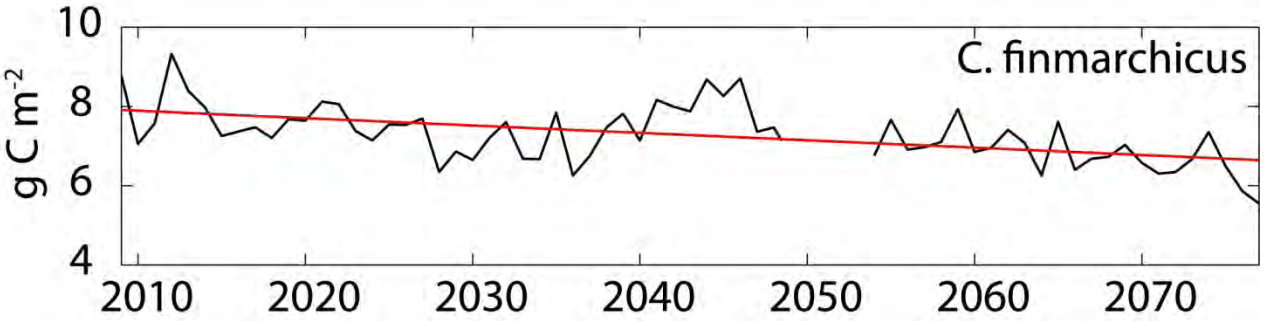
Annual mean production of *C. glacialis*




GPP
A1B Norwegian Sea.
g C m-2
160
140
120
100
2010
2020
2030
2040
2050
2060
2070
2080


C. finmarchicus
g C m-2
9
8
7
6
5
2010
2020
2030
2040
2050
2060
2070
2080

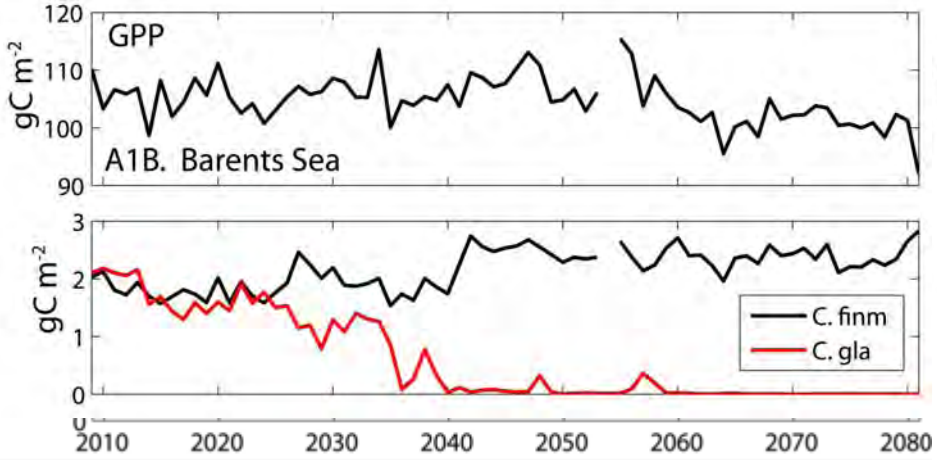

GPP
A2 GCM. Norwegian Sea
g C m-2
160
140
120
100


C. finmarchicus
g C m-2
10
8
6
4
2010
2020
2030
2040
2050
2060
2070

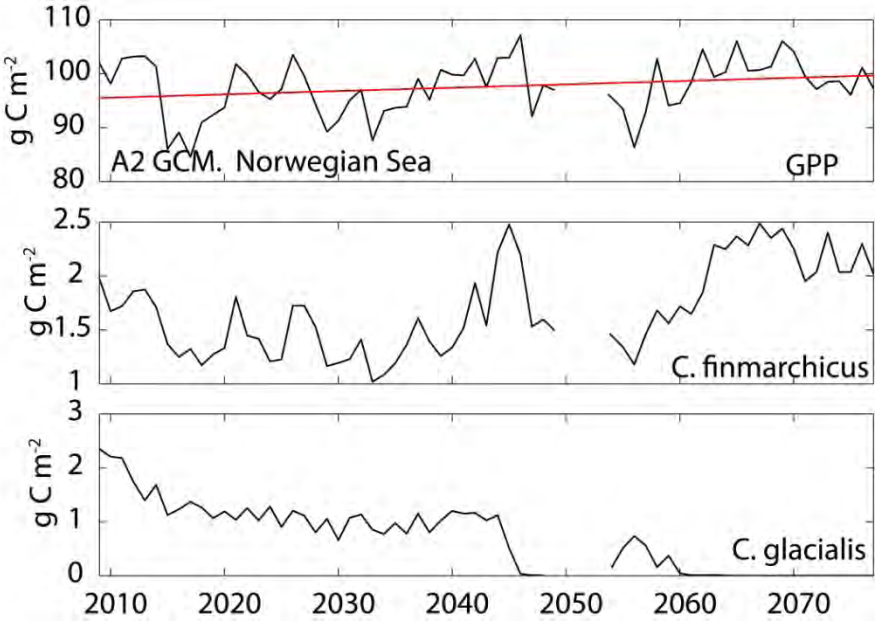
A1B (GCM) vs A2

A1B (GCM) vs A2
Barents Sea

A1B



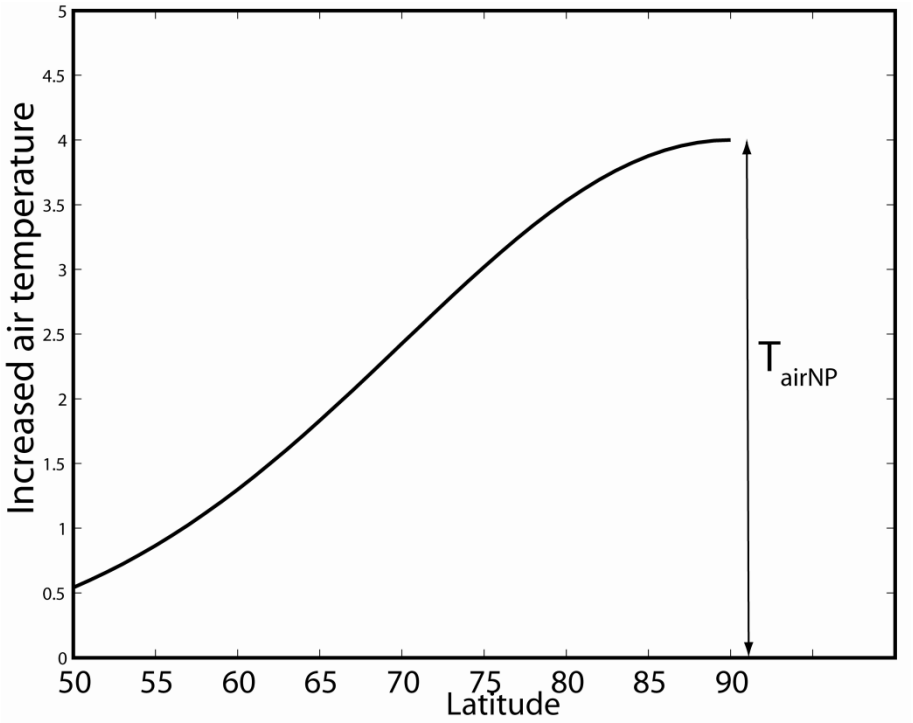
A2



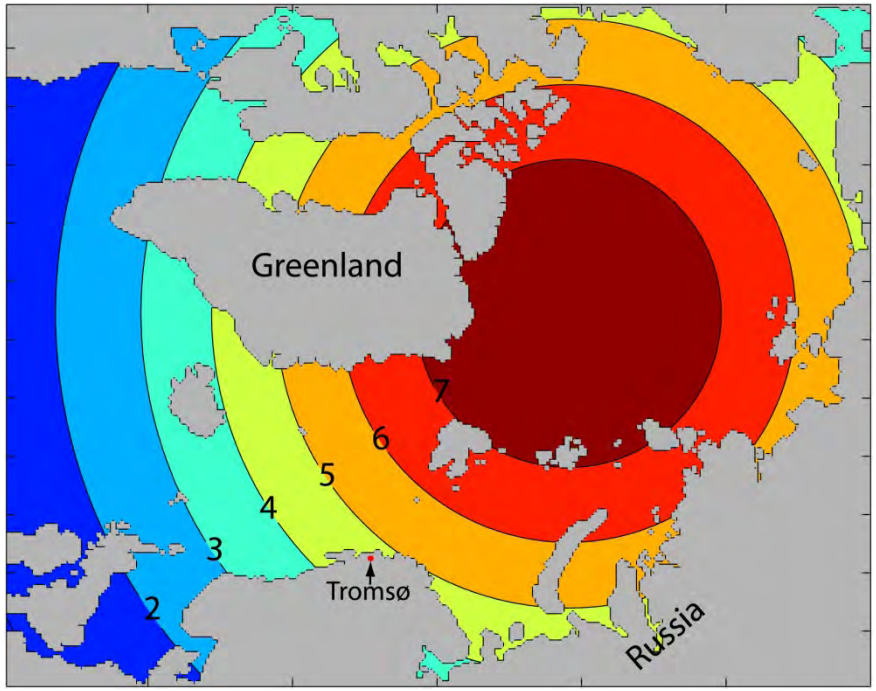
Specified increased air temperature.

Depending on Latitude

$$T_{air} = T_{air}^{ECMWF} + f_T(Latitude)$$



Example: T_{airNP}=8°C

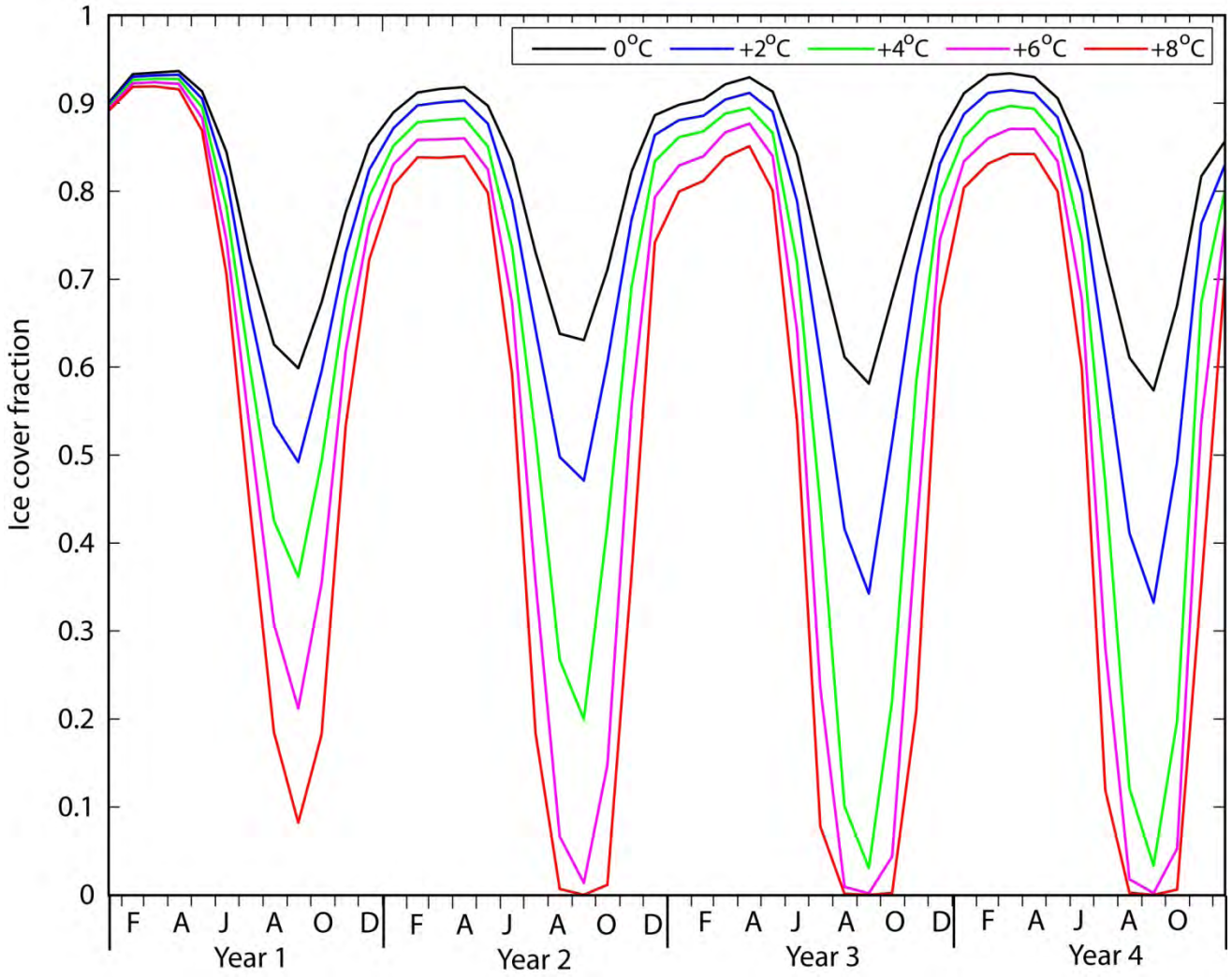


Simulations

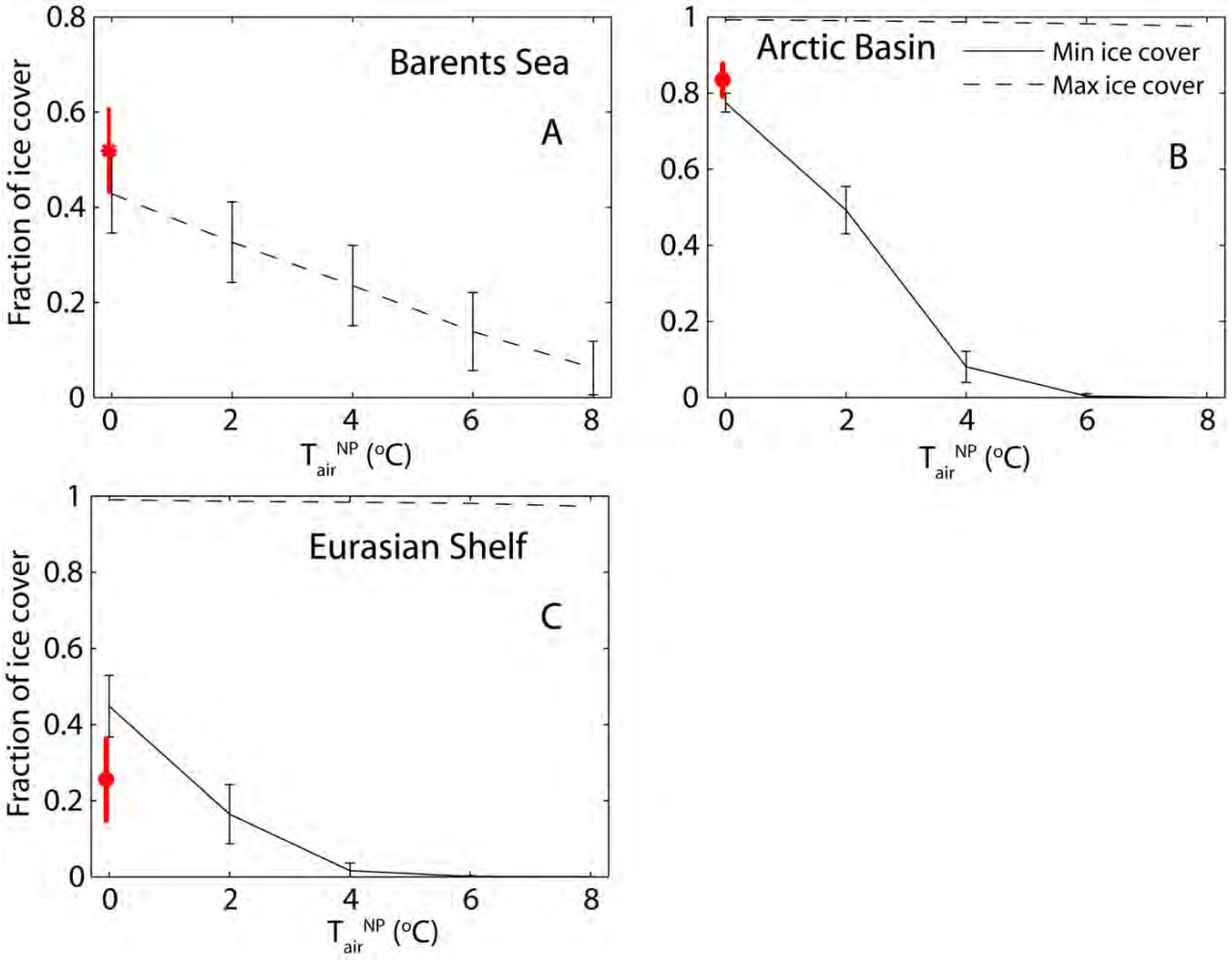
- Standard run, ECMWF data (ERA40), i. e. $T_{airNP} = 0$. (1979-2007)
- 4 scenarios using:
  1. $T_{airNP} = +2$ °C
  2. $T_{airNP} = +4$ °C
  3. $T_{airNP} = +6$ °C
  4. $T_{airNP} = +8$ °C

  Simulation period: 1979 - 2007

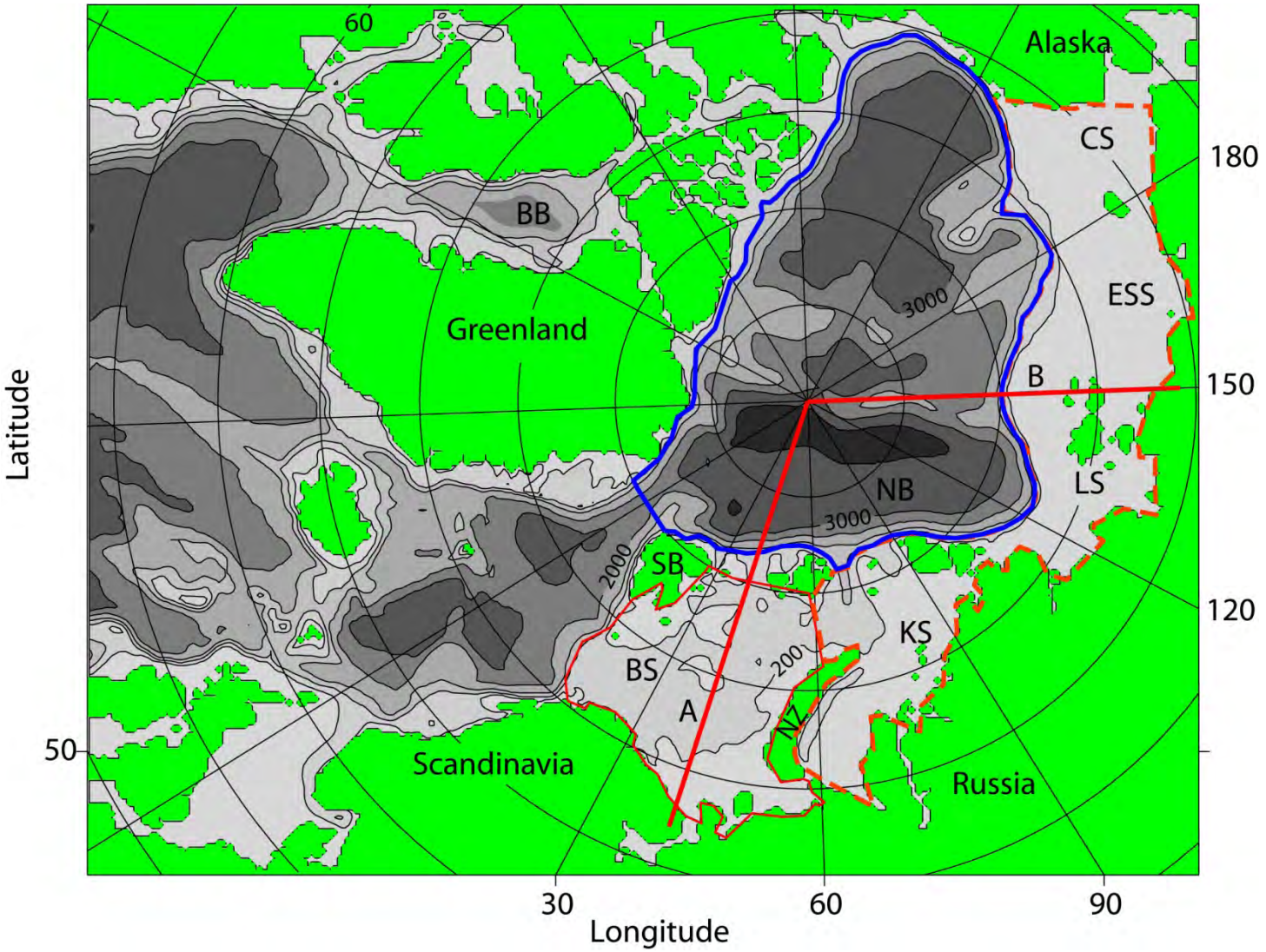
Arctic Ocean.
Fraction covered with ice



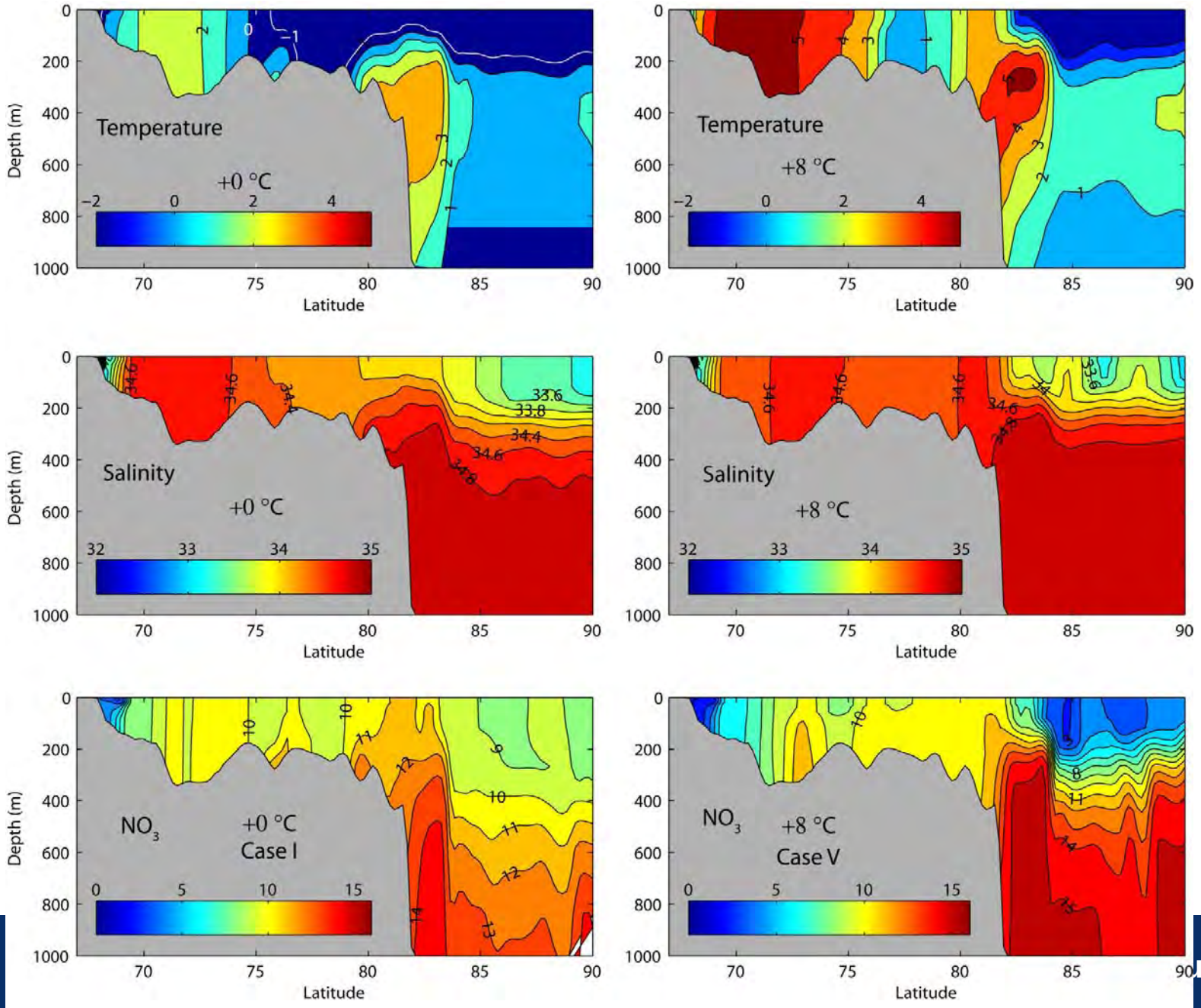
Minimum ice cover
(Barents Sea: Max ice cover)

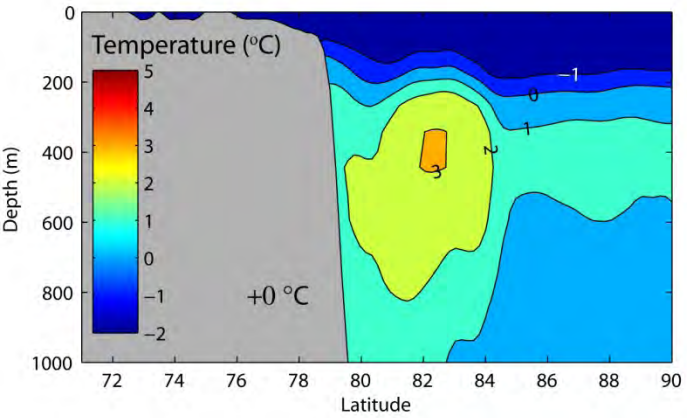


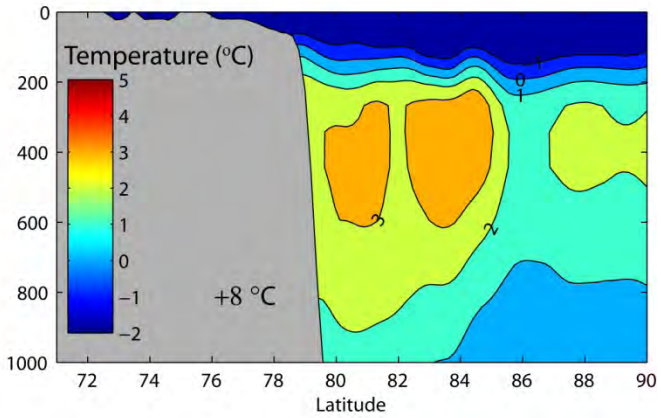
Sections

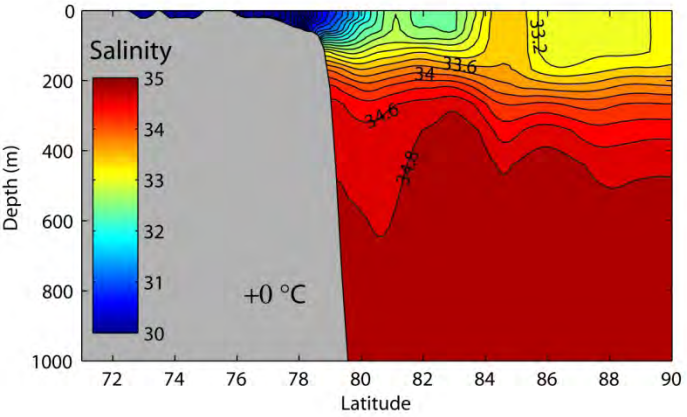

60
Alaska
CS
180
BB
ESS
3000
Greenland
B
150
Latitude
NB
LS
3000
2000
SB
120
KS
200
BS
A
NZ
50
Scandinavia
Russia
30
60
90
Longitude

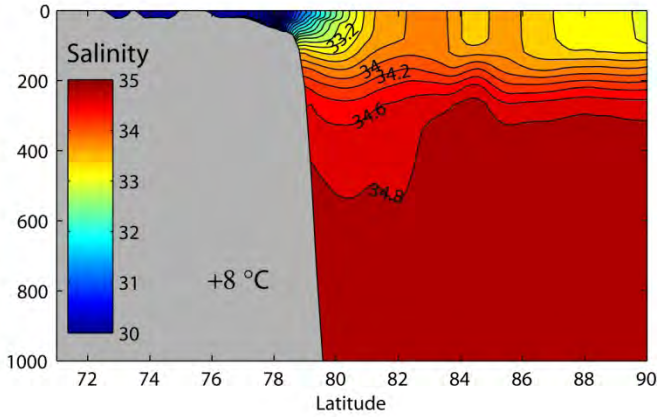
Section along 40 °E. April

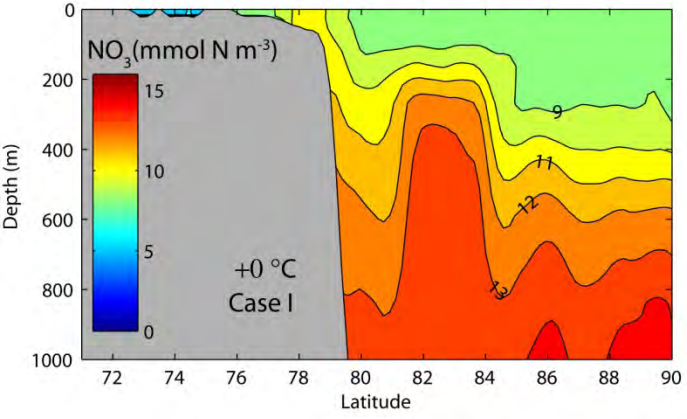


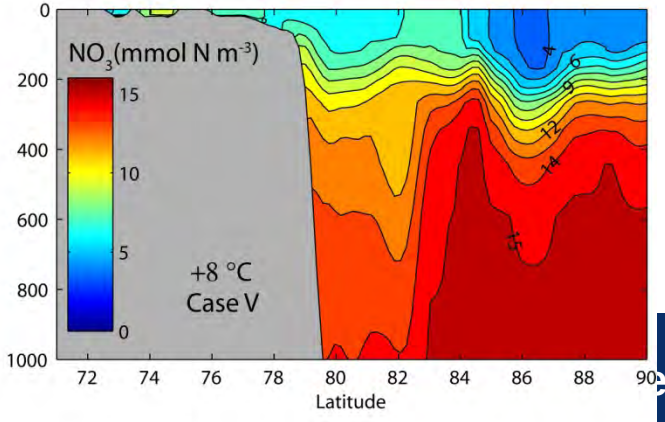




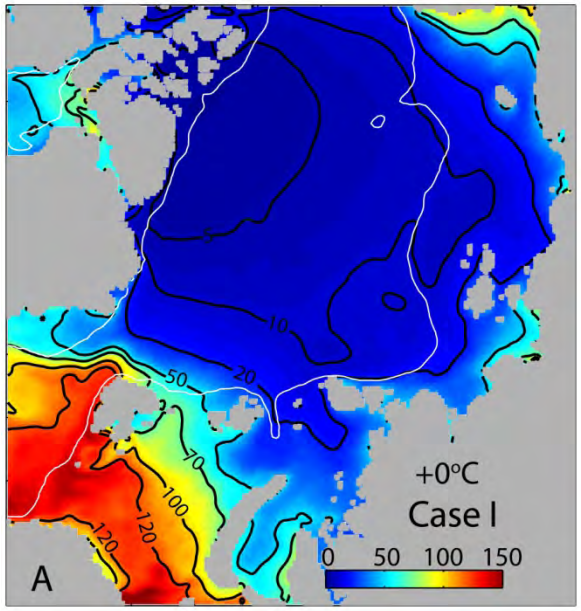


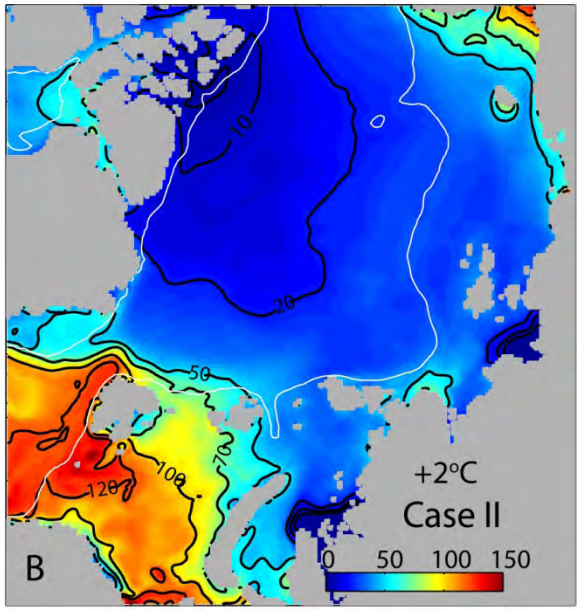


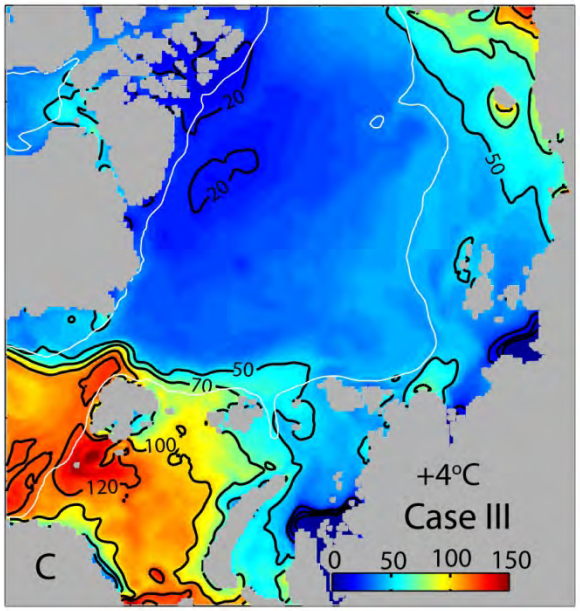


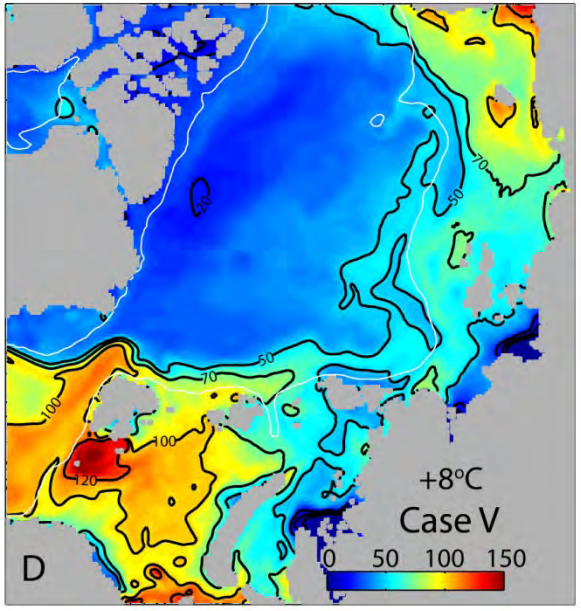


Section along 150 °E. April



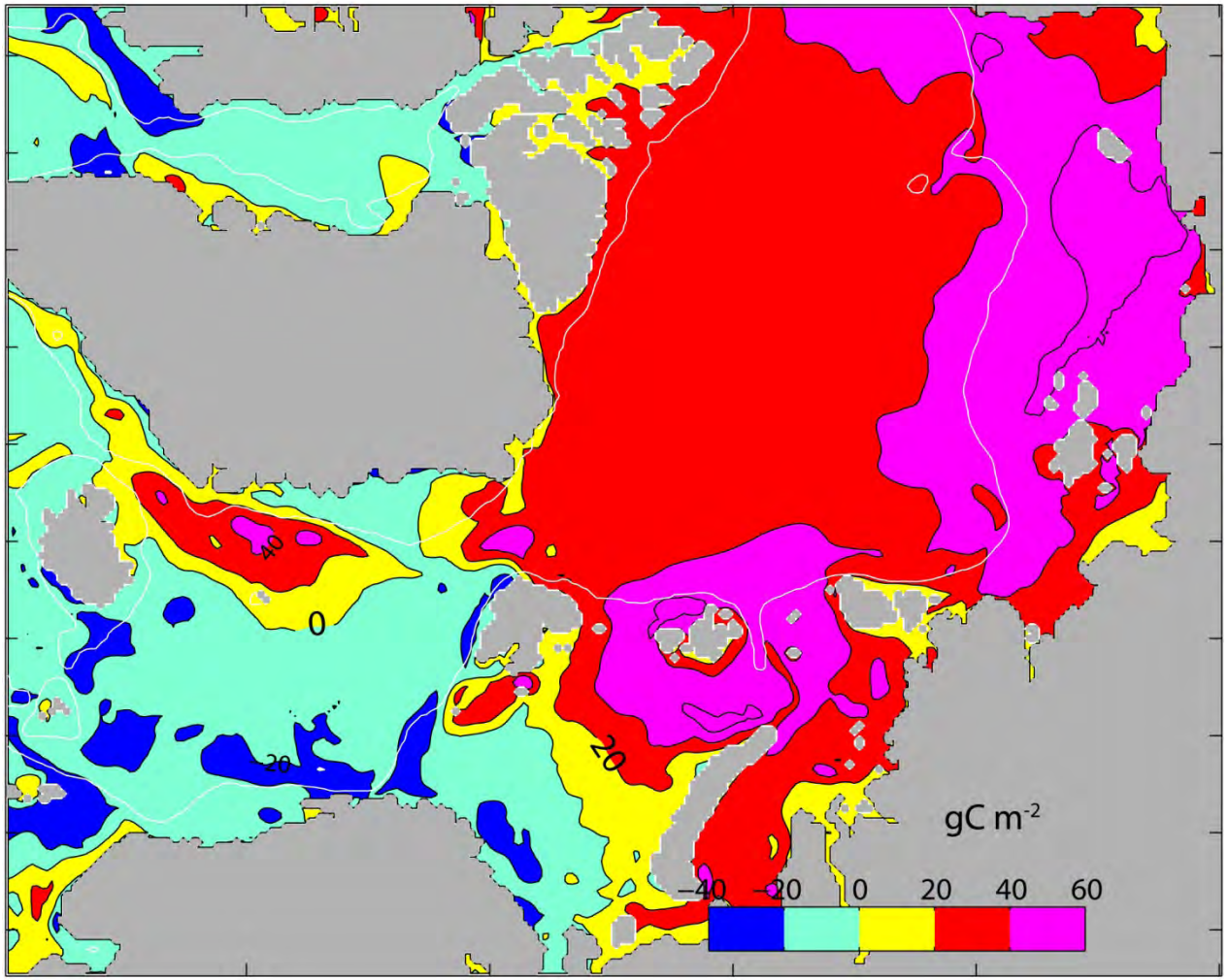


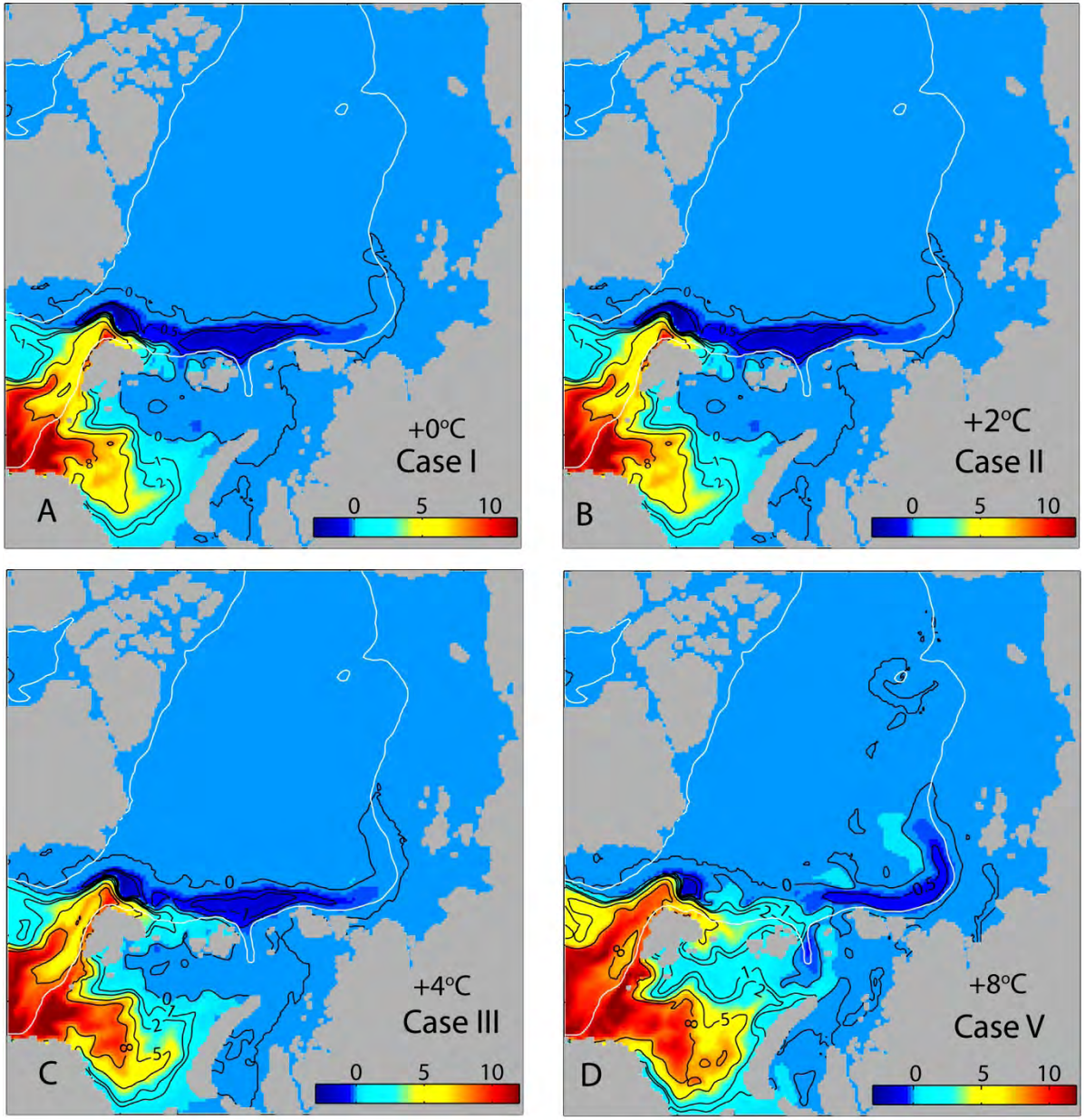




Gross Primary production (gC m^{-2})

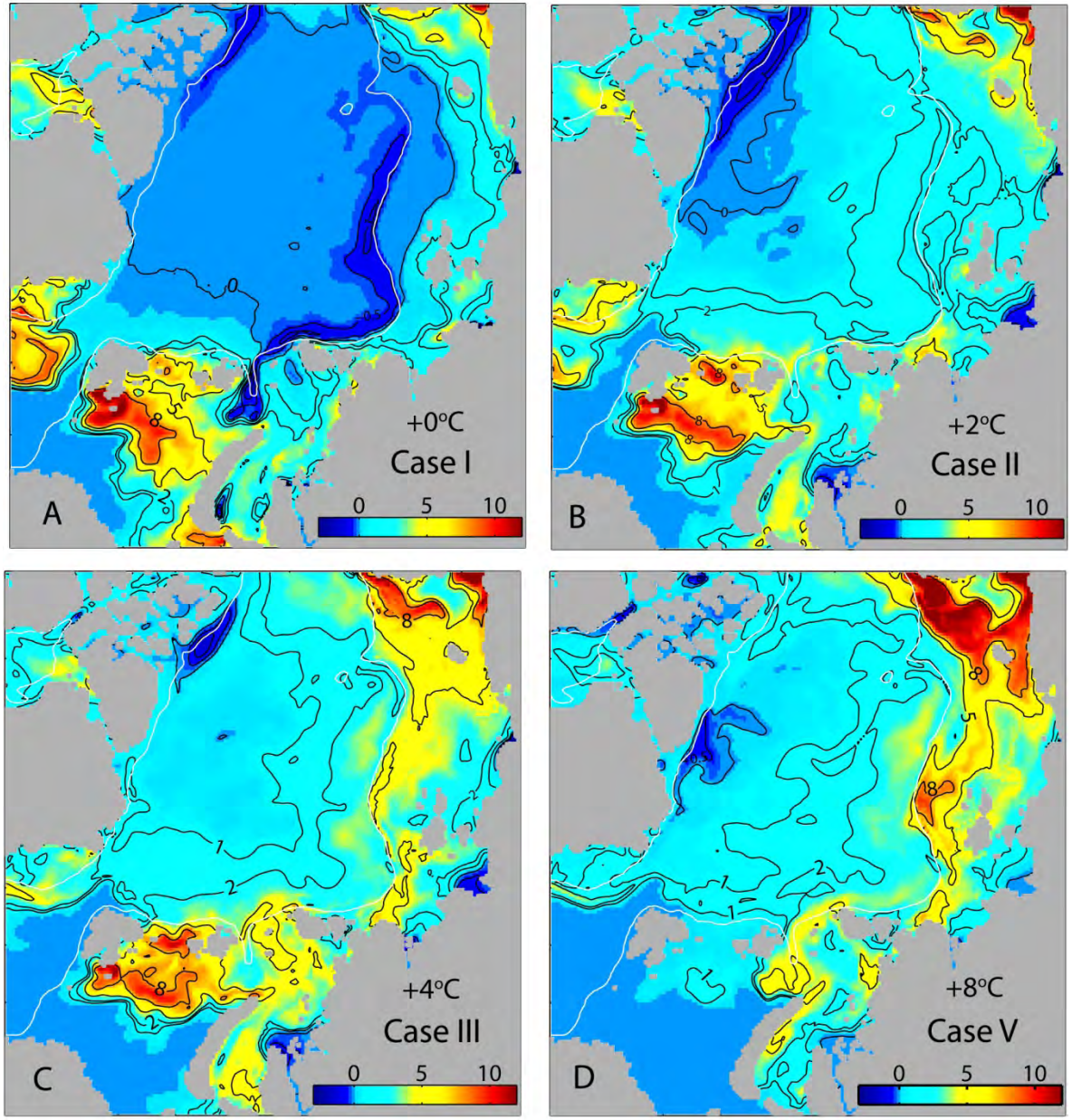
Differece in GPP (gC m^{-2})
CaseV – Case I



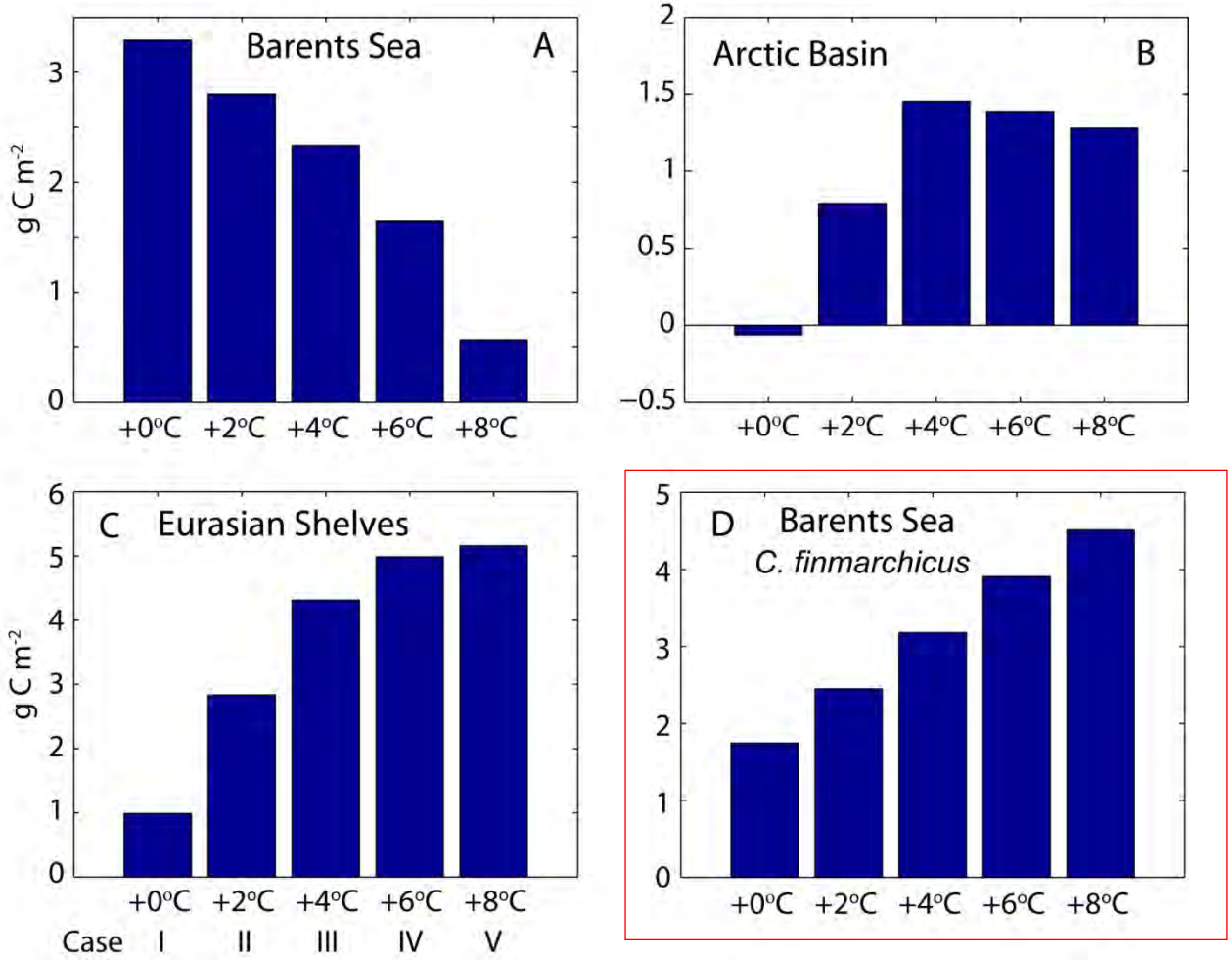


Production of *C. finmarchicus* (g C m^{-2})

Change in the distribution of *C. glacialis*



Annual Production (gC m^{-2})
C. glacialis



Major findings

Warming may cause:

1.Primary production will increase 2 or 3 fold in the Arctic. But stratification limits nutrient supply from below.

2.C. glacialis production will increase in the Arctic Ocean.

3.C. glacialis will disappear from the Northern Barents Sea.

4.Total primary production in the Barents Sea increases only slightly and decreases in the Norwegian Sea

5.C. finmarcicus production increases in the Greenland and Iceland Seas.