MAR650 Lecture 7: Arctic Ocean Ecosystem

The observational events:

Chapman and Walsh (1993):

- The annual mean air temperature has increased by 2-3^{o}C since 1950;
- The winter mean air temperature has increased by ~4^{o}C since 1950.

Arctic Climate Impact Assessment (ACIA) (2005):

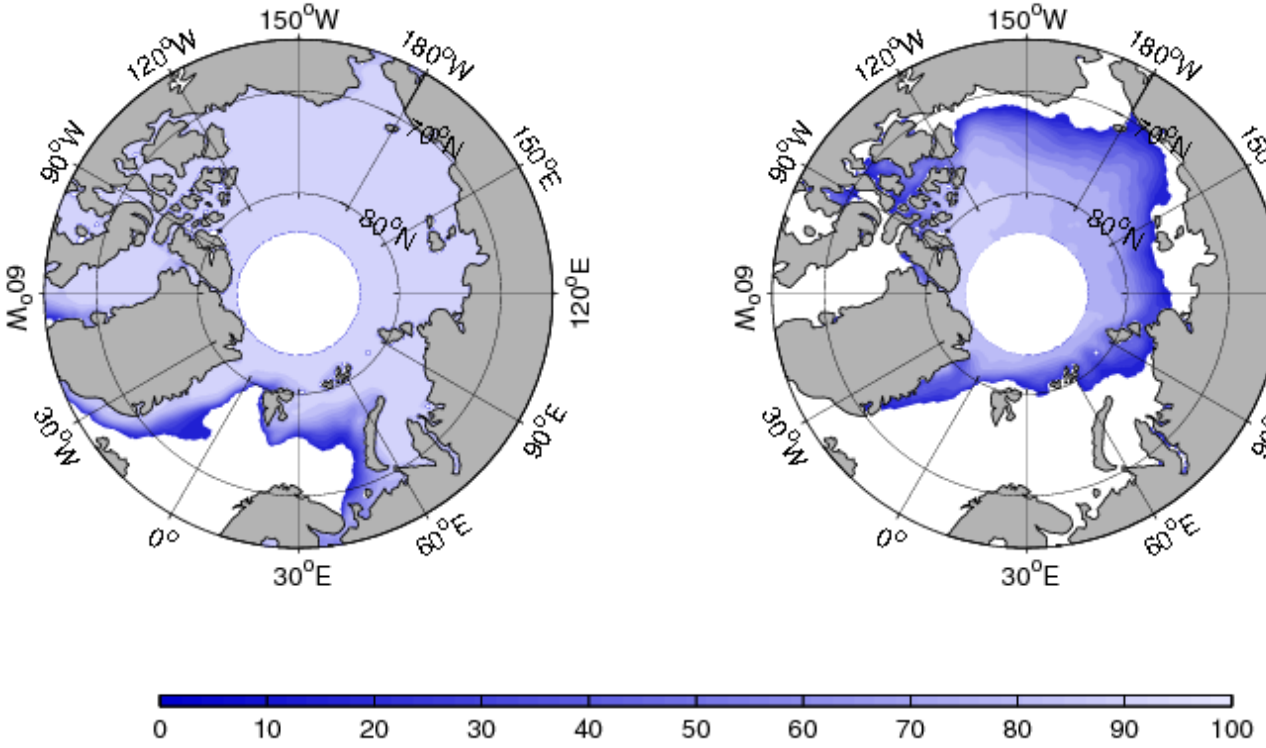
- The annual mean air temperature has increased by 4-5^{o}C at the end of the 21st century.

Results:

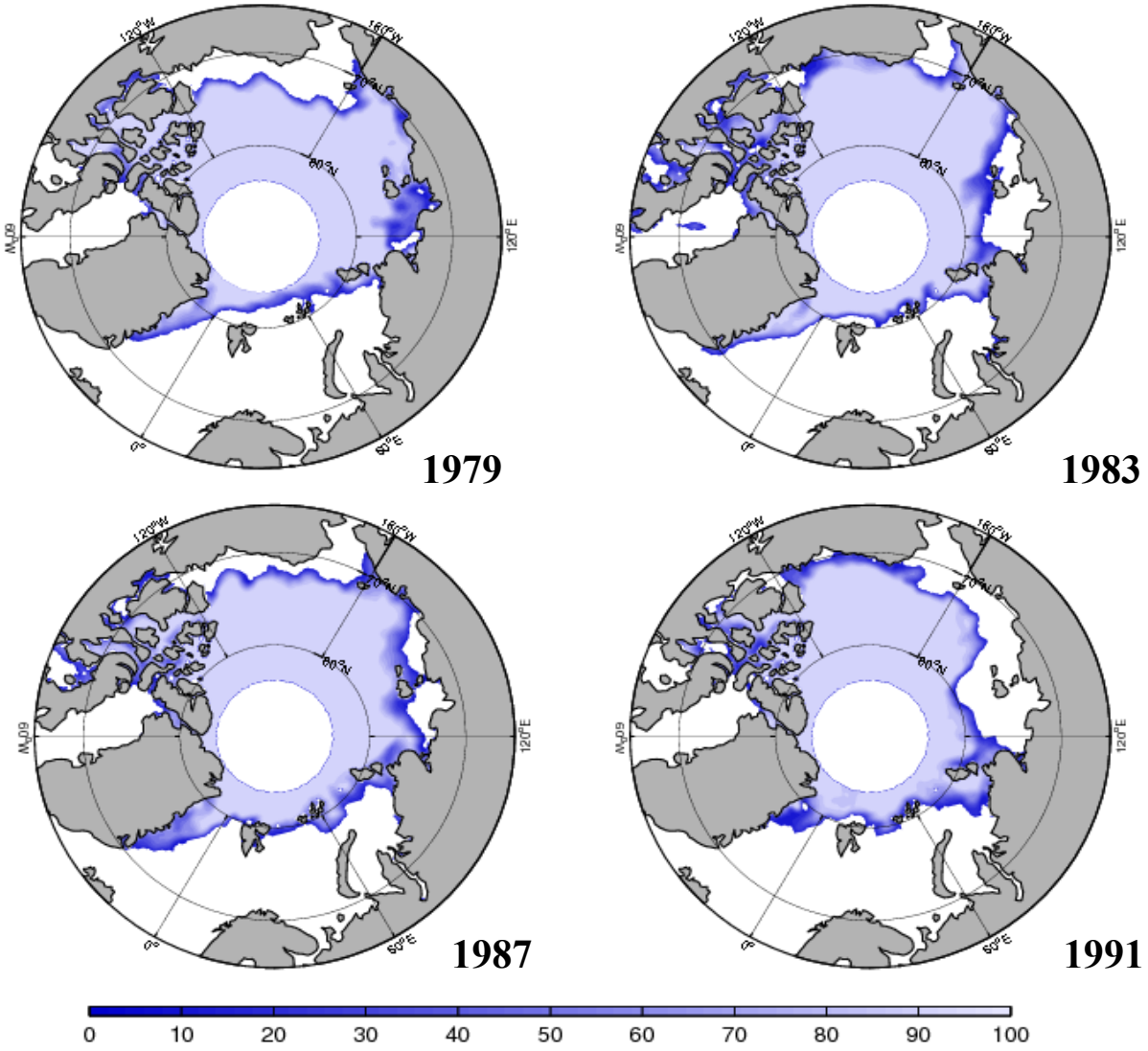
- The sea ice cover in the Arctic Ocean has significantly reduced in the last decades;
- The length of ice melting in summer has increased;
- The open water area enlarges in the summer.

The ice concentration averaged over 1979-1994

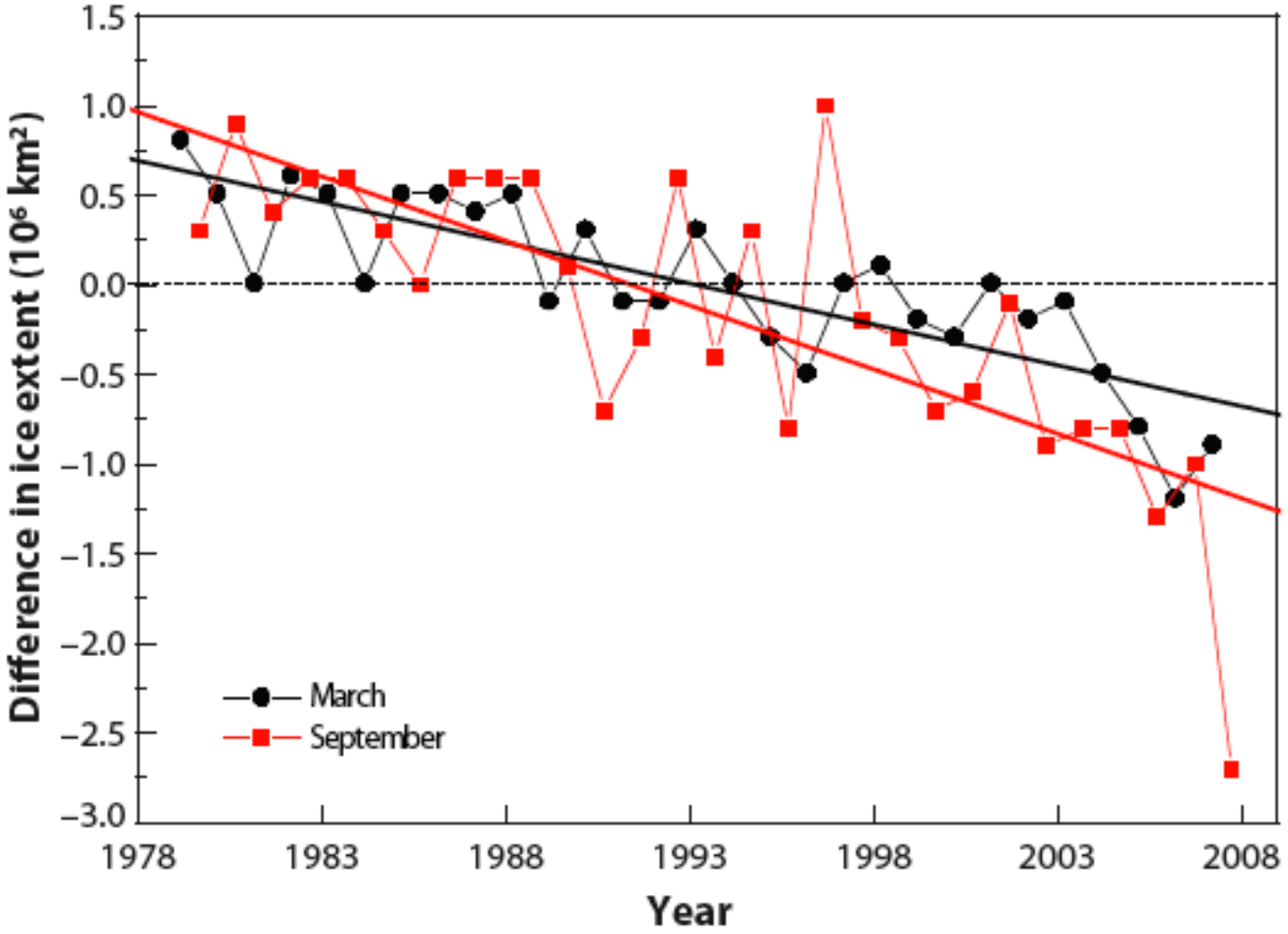
Winter **Summer**



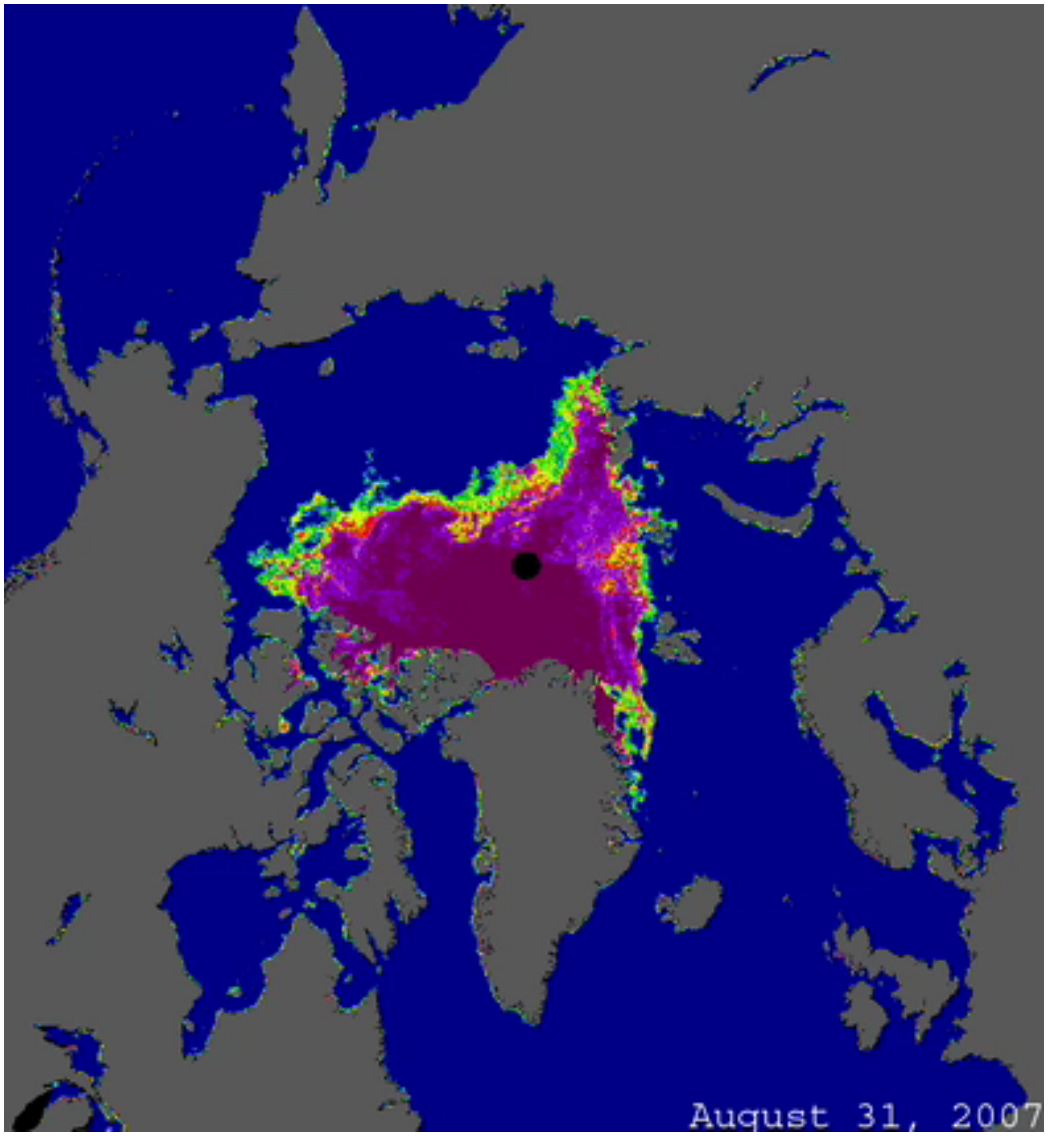
Monthly average fields of the ice concentration in Sept. 1979, 1983, 1987 and 1991



From D. K. Perovich and J. A. Richter-Menge
(Annu. Rev. Marine Sci, 2009, 417-441)

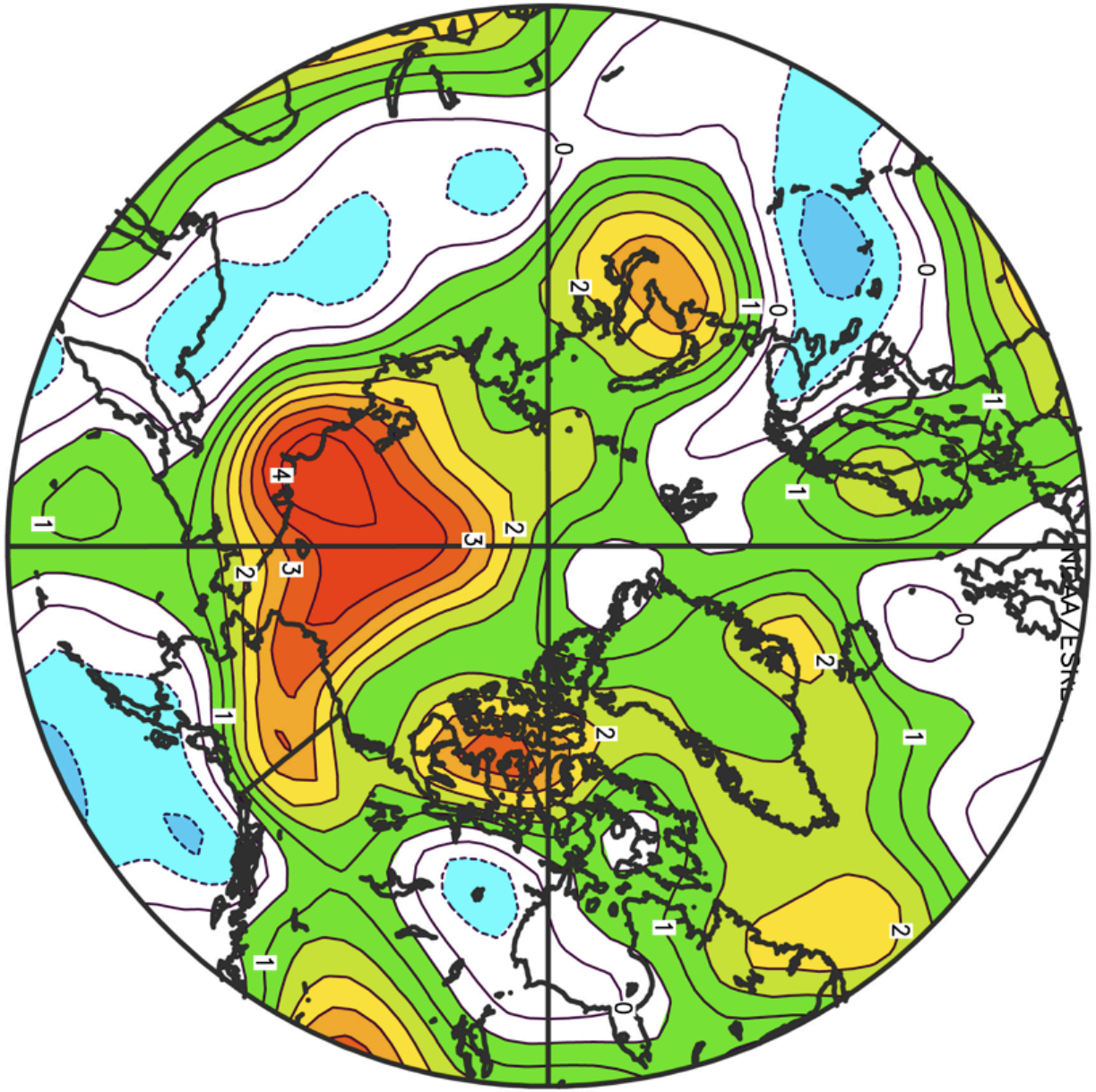


Arctic Sea ice in summer 2007, an animation downloaded from www.nsidc.org/



Images from NASA Earth Observing System Advanced Microave Scanning Radiometer- Institute of Environmental Physics at the University of Bremen,: National Snow and Ice Date Center.

Arctic temperature anomalies-June to July 2007
(NECP/NCAR Reanalysis)

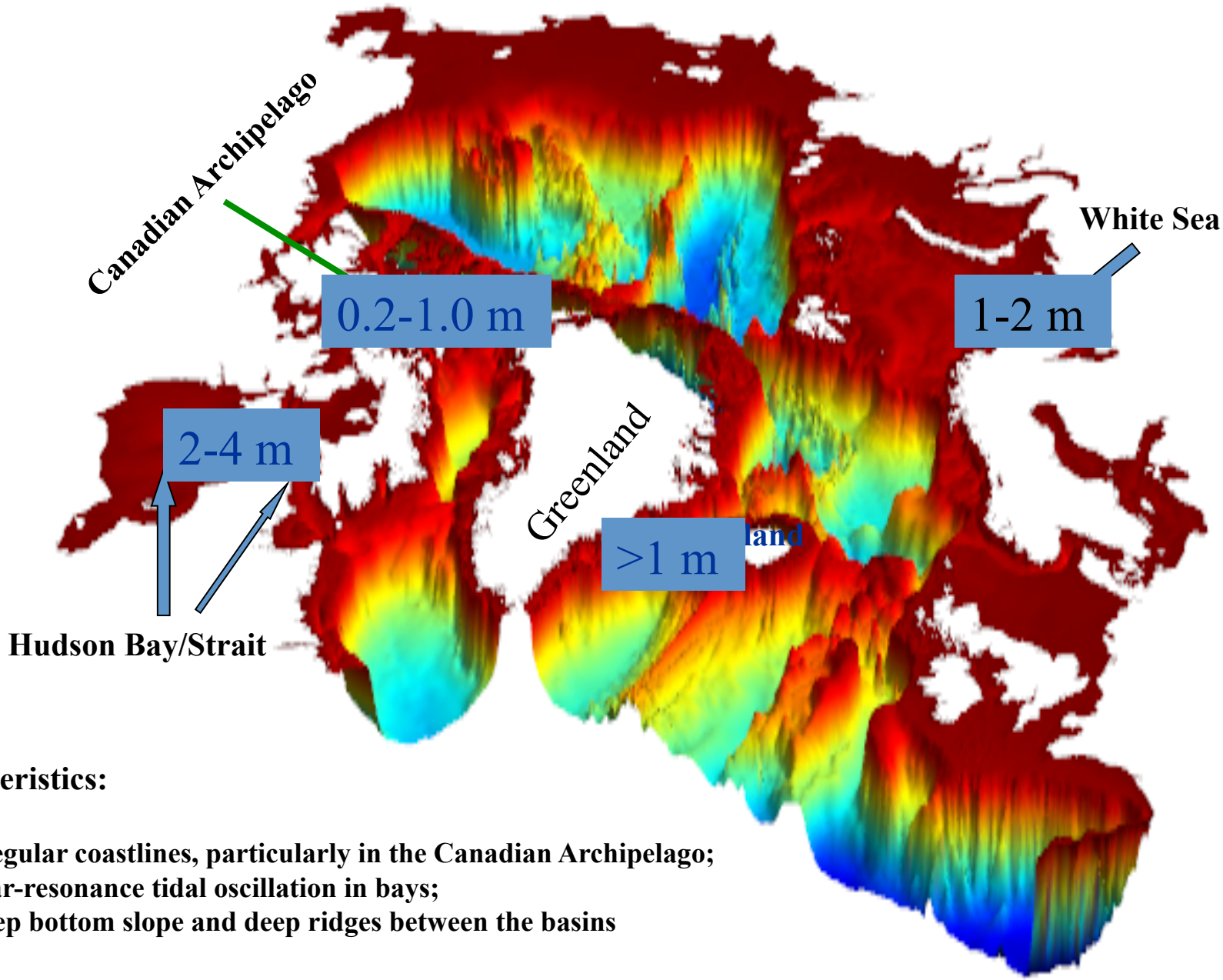


Physical and Biological Responses:

- Enlarging the open water area intensifies the upwelling at the shelf break and increases the nutrient transport from the interior to the shelf and thus produces a favor condition for the growth of phytoplankton. This also can increase the air-sea flux of CO_2;

- Reduction of the sea ice in turn reduce the sea ice algae community;

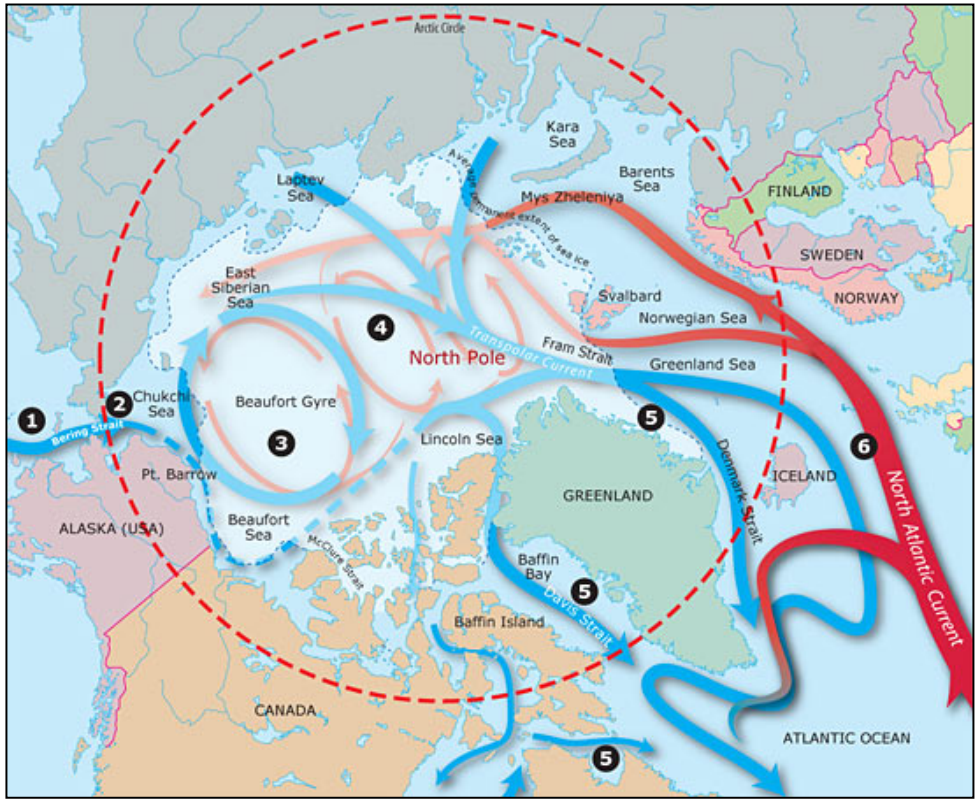
- Ice-melting increases the water transport to the downstream area and thus directly or indirectly influence the coastal ecosystem, particularly on the US northeast region (the Gulf of Maine/Georges Bank, etc).



Characteristics:

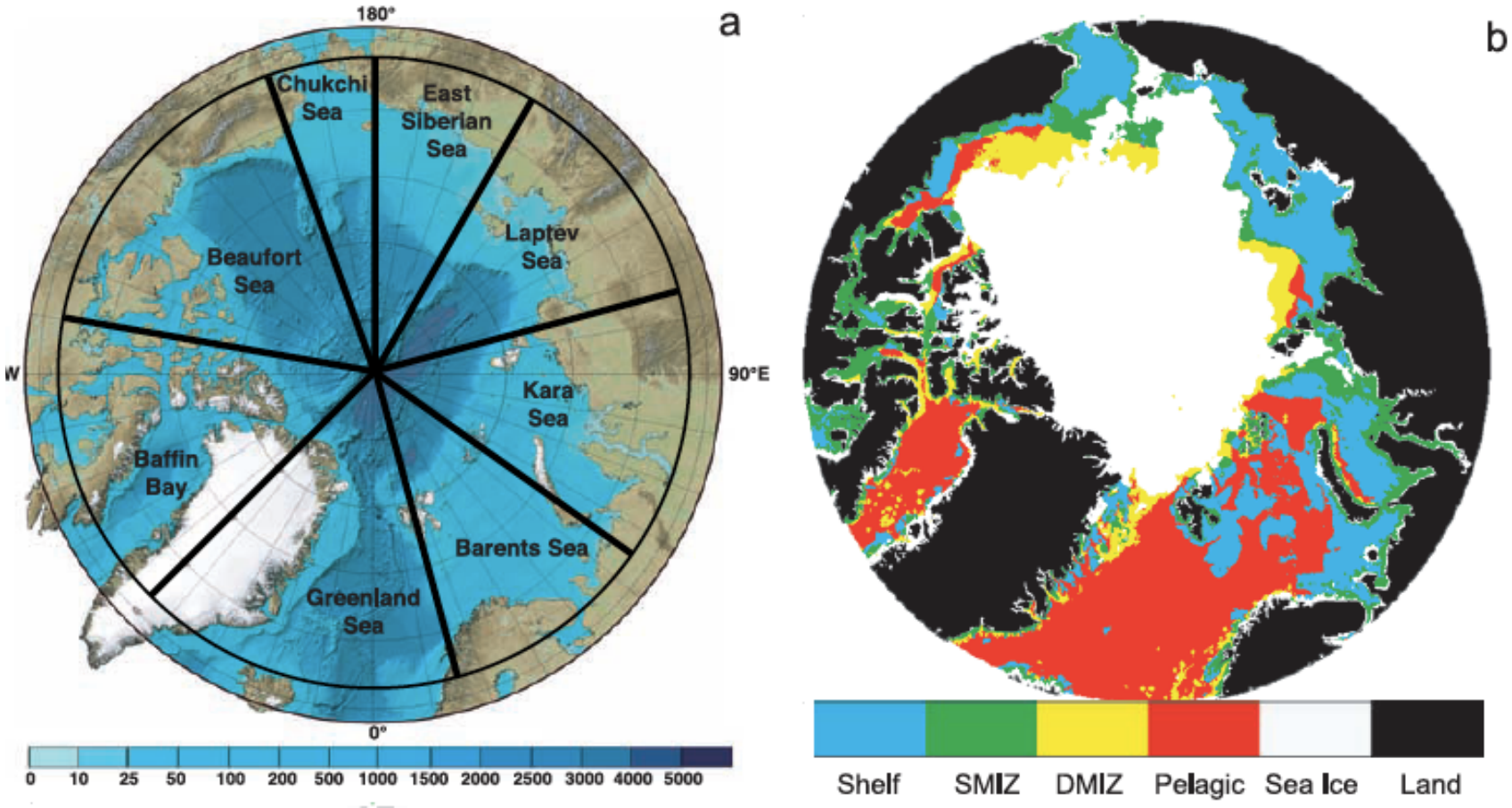
1. **Irregular coastlines, particularly in the Canadian Archipelago;**
2. **Near-resonance tidal oscillation in bays;**
3. **Steep bottom slope and deep ridges between the basins**

Upper and deep water current patterns in the Pan-Arctic Region

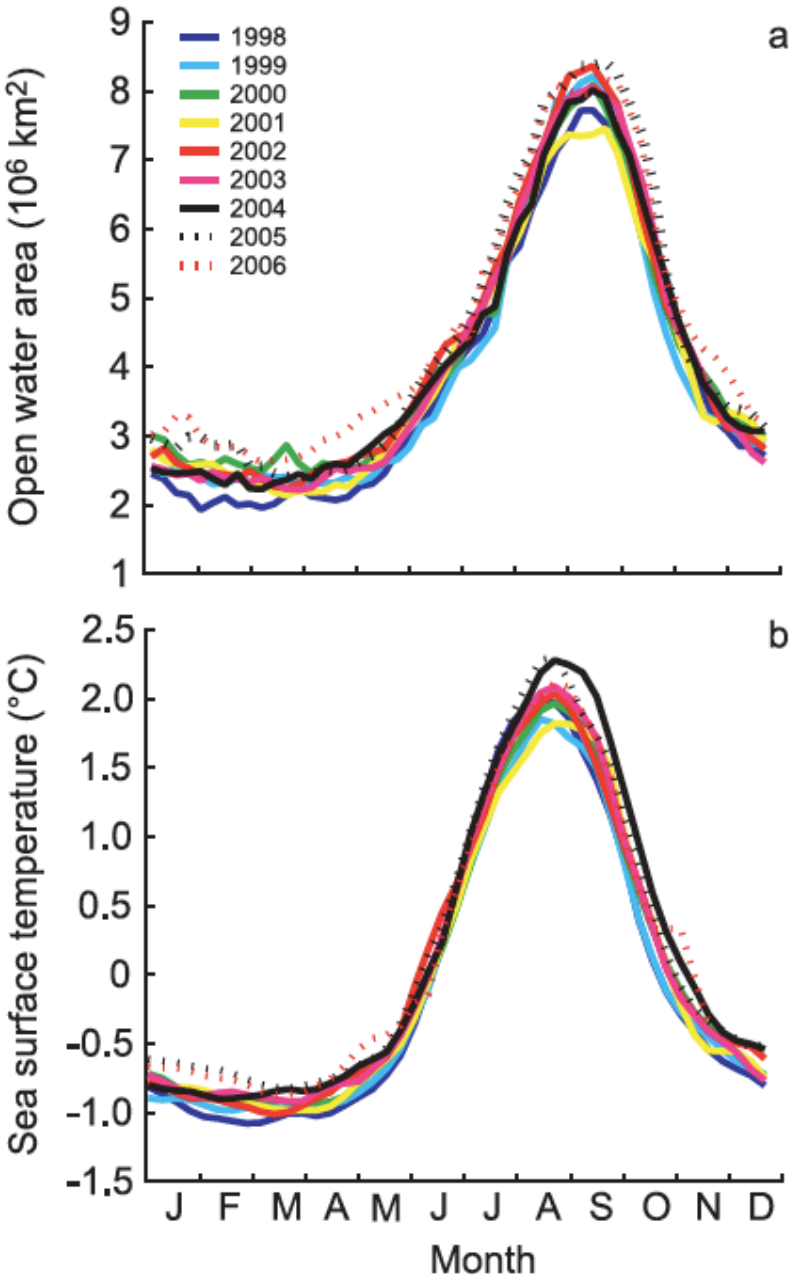


Graphics from Woods Hole Oceanographic Institution

Pabi et al. (2008), JGR-Ocean, 13, C08005, doi:10.1029/2007JC004578

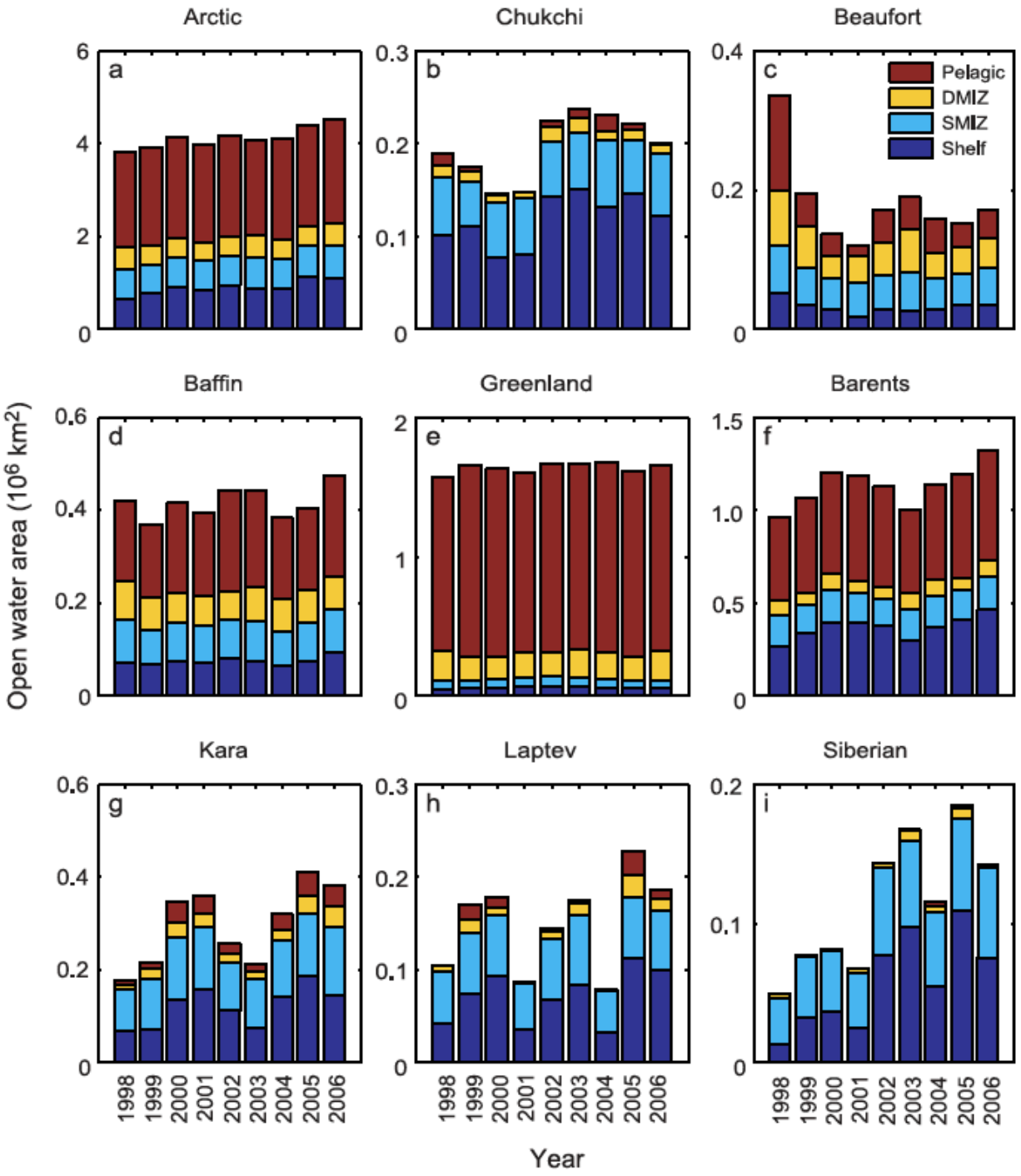


DMIZ: the deep water marginal ice zone;
SMIZ: the marginal ice zone over the continental shelf



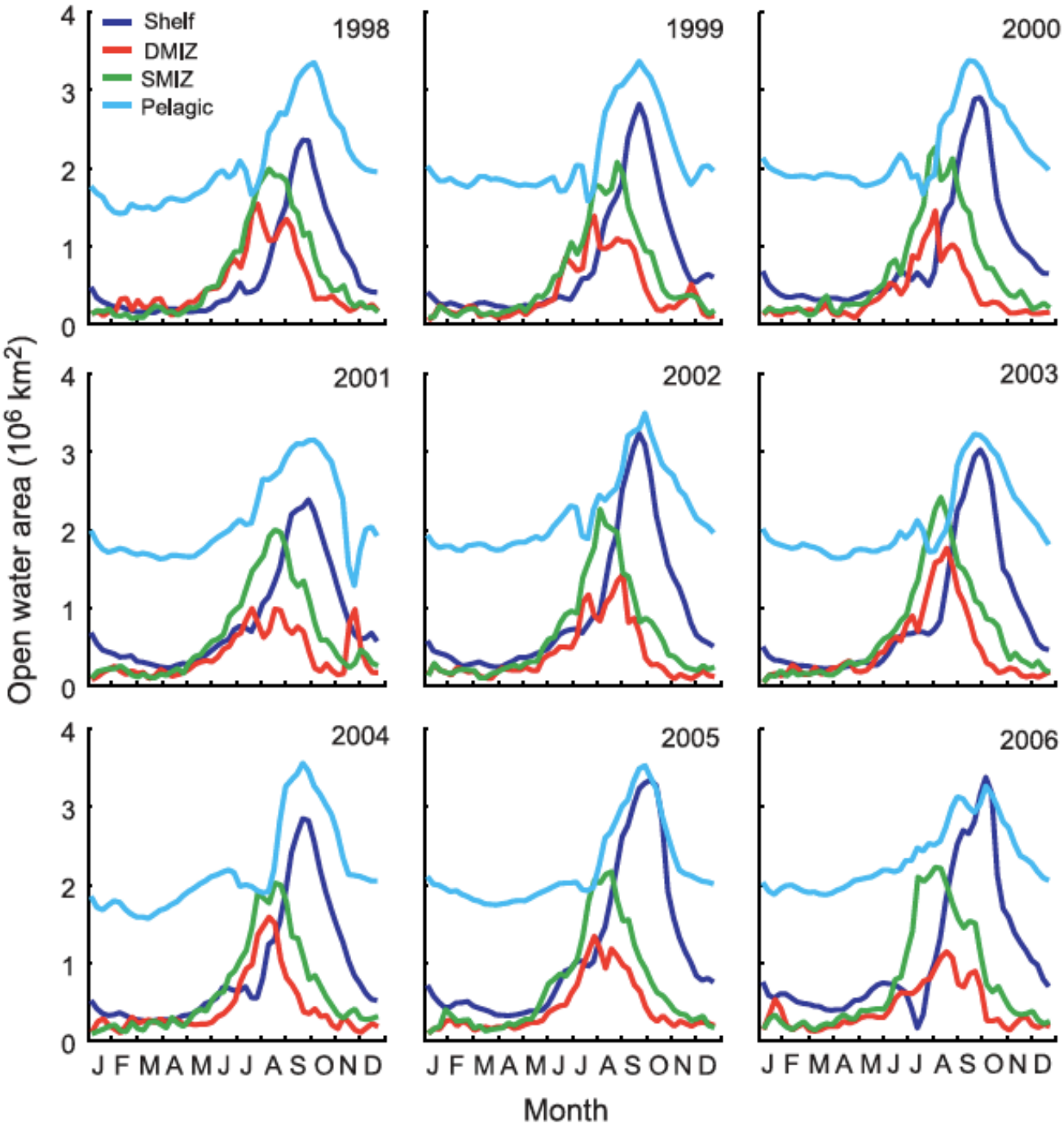
Weekly change of the open water area and SST [*Pabi et al.* (2008)]

- The maximum open water area generally occurs in late August and early September;
- Remarkably inter-annual variability, during which 2002 and 2005 had a larger open area during summer;
- The annually mean SST increased from -0.07° C in 1998 to 0.26°C in 2006;
- Seasonal and inter-annual variability of the open water area is correlated well to that of SST, but it is unclear if the change of SST is caused by the open water area or vice versa.
- Mixed layer depth in summer ~15-20 m.



Annual mean open water area in selected regions over 1998–2006 (Pabi et al., 2008)

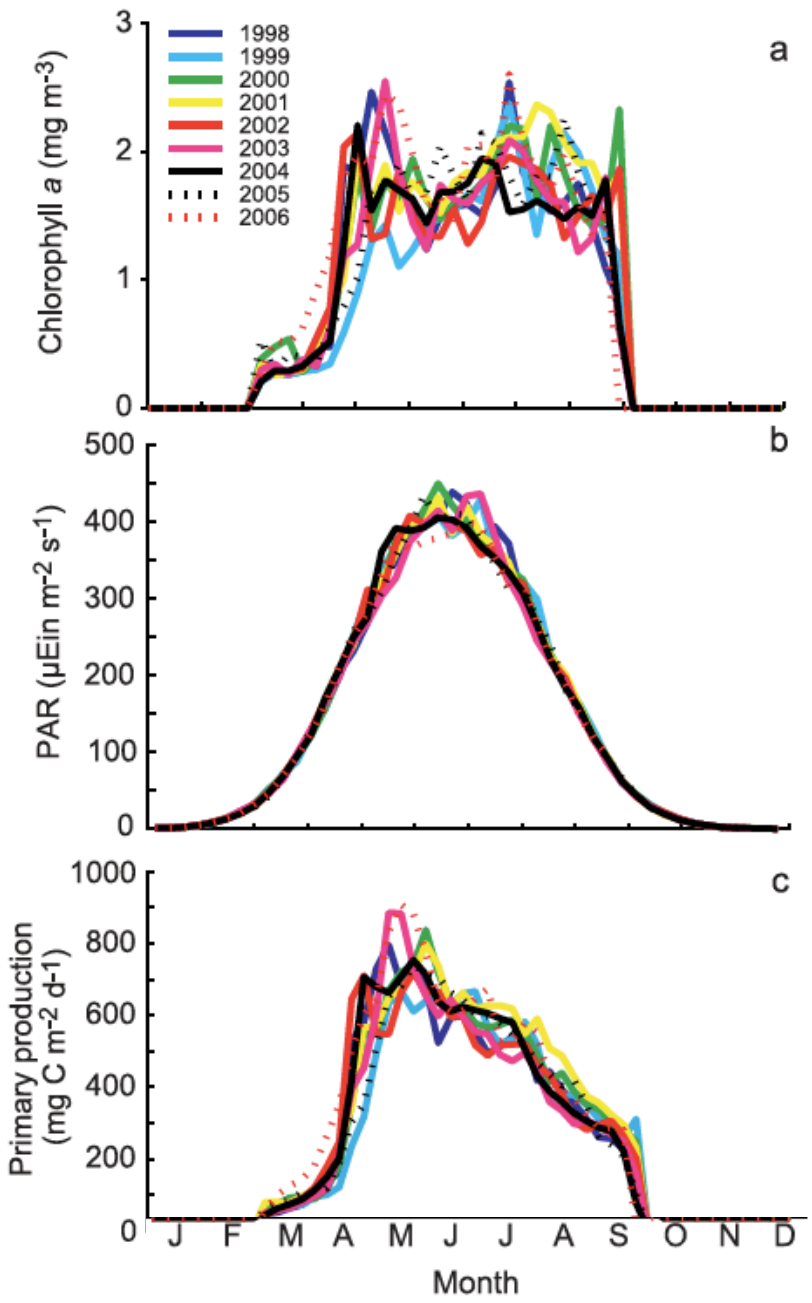
- The open water areas in Barents, Kara and Siberian sectors have greater increases;
- SMIZ is slightly smaller than the shelf province
- DMIZ is generally is smallest of the four ecological provinces



Weekly changes of the open water area in the four ecological provinces over 1998–2006.

1. Timings are different;
2. Changing rates are different
3. Year to year is different

From Pabi et al. (2008)

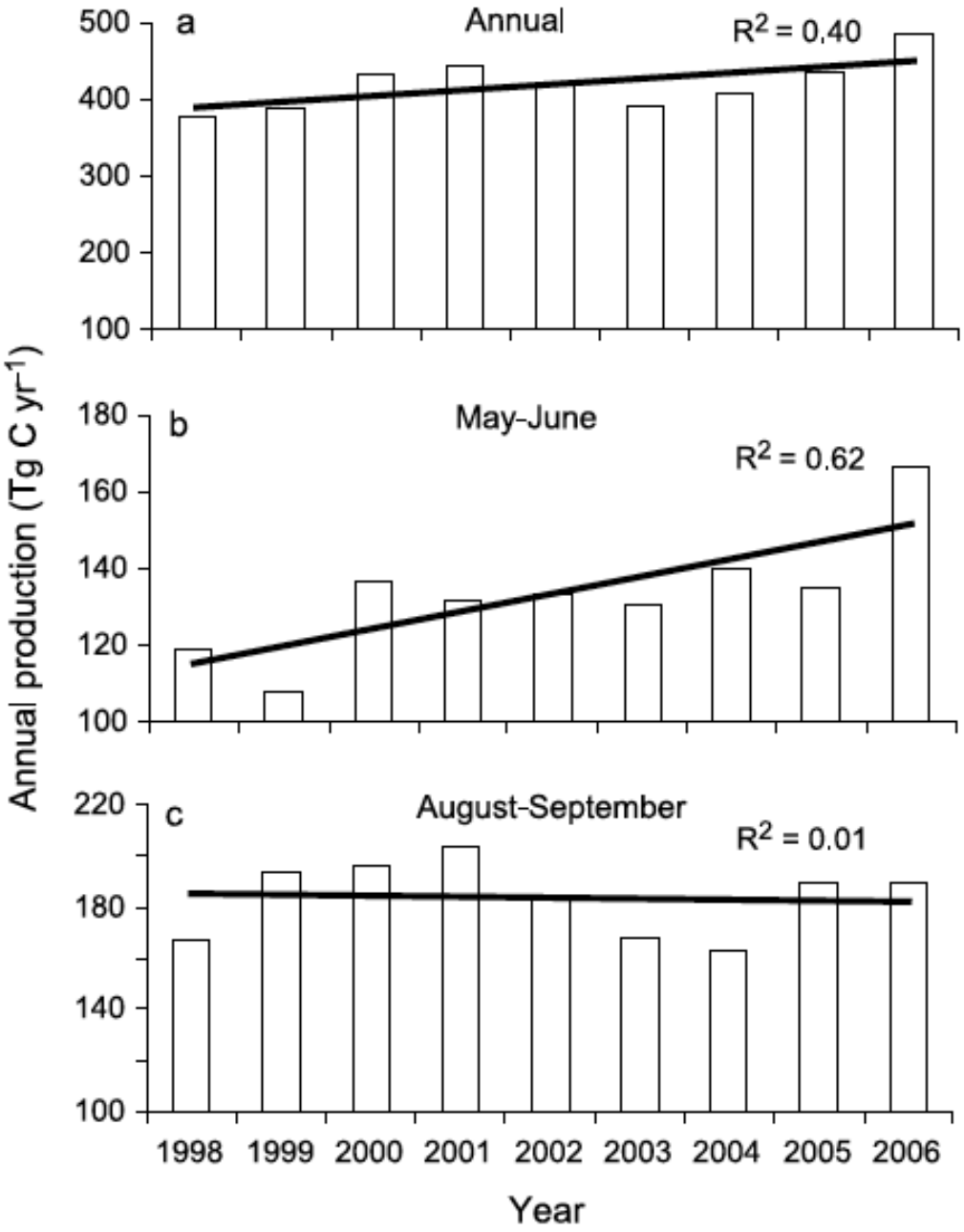


Chl-a concentration

PAR

Daily Primary Production

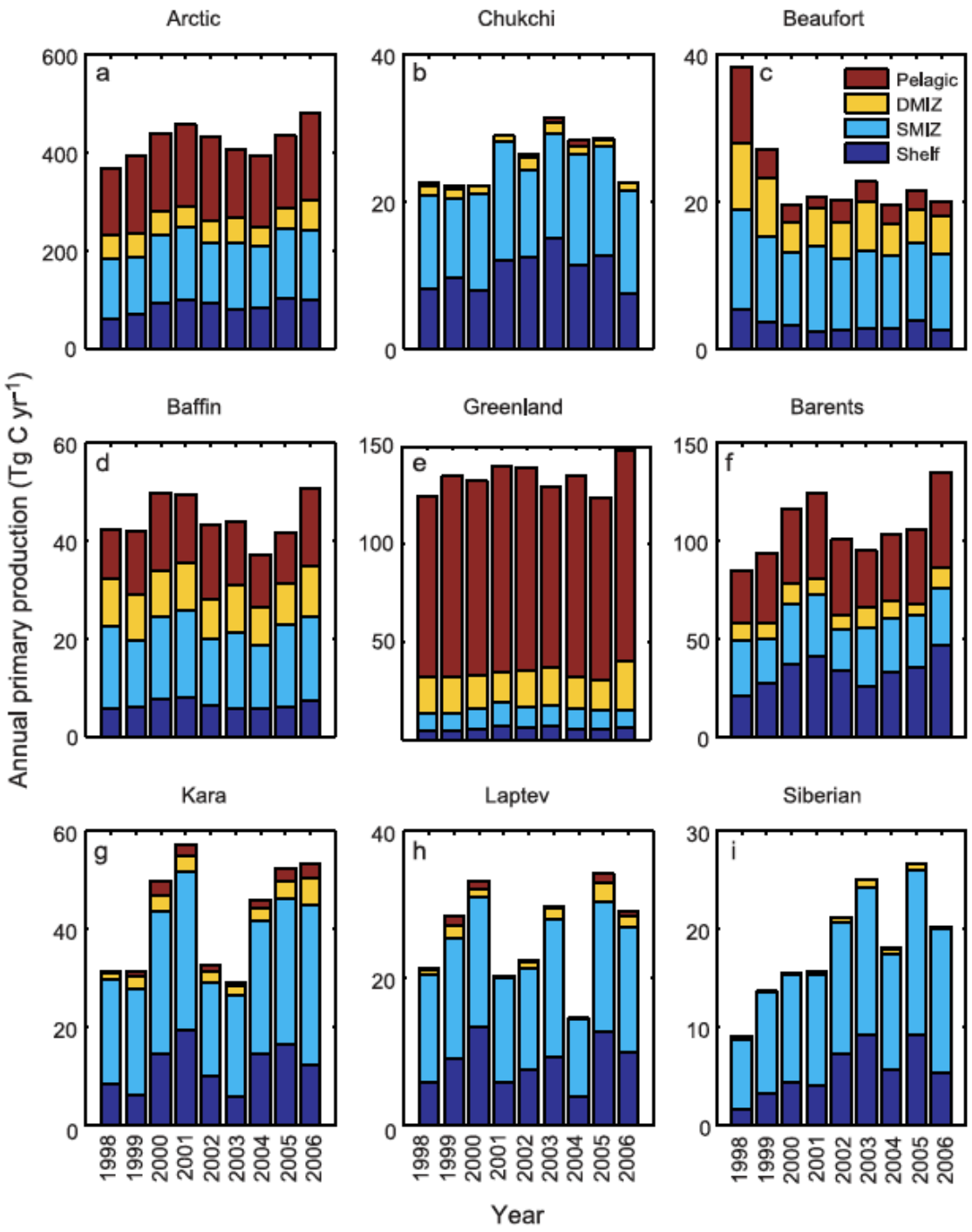
Total Primary production



a: Annual

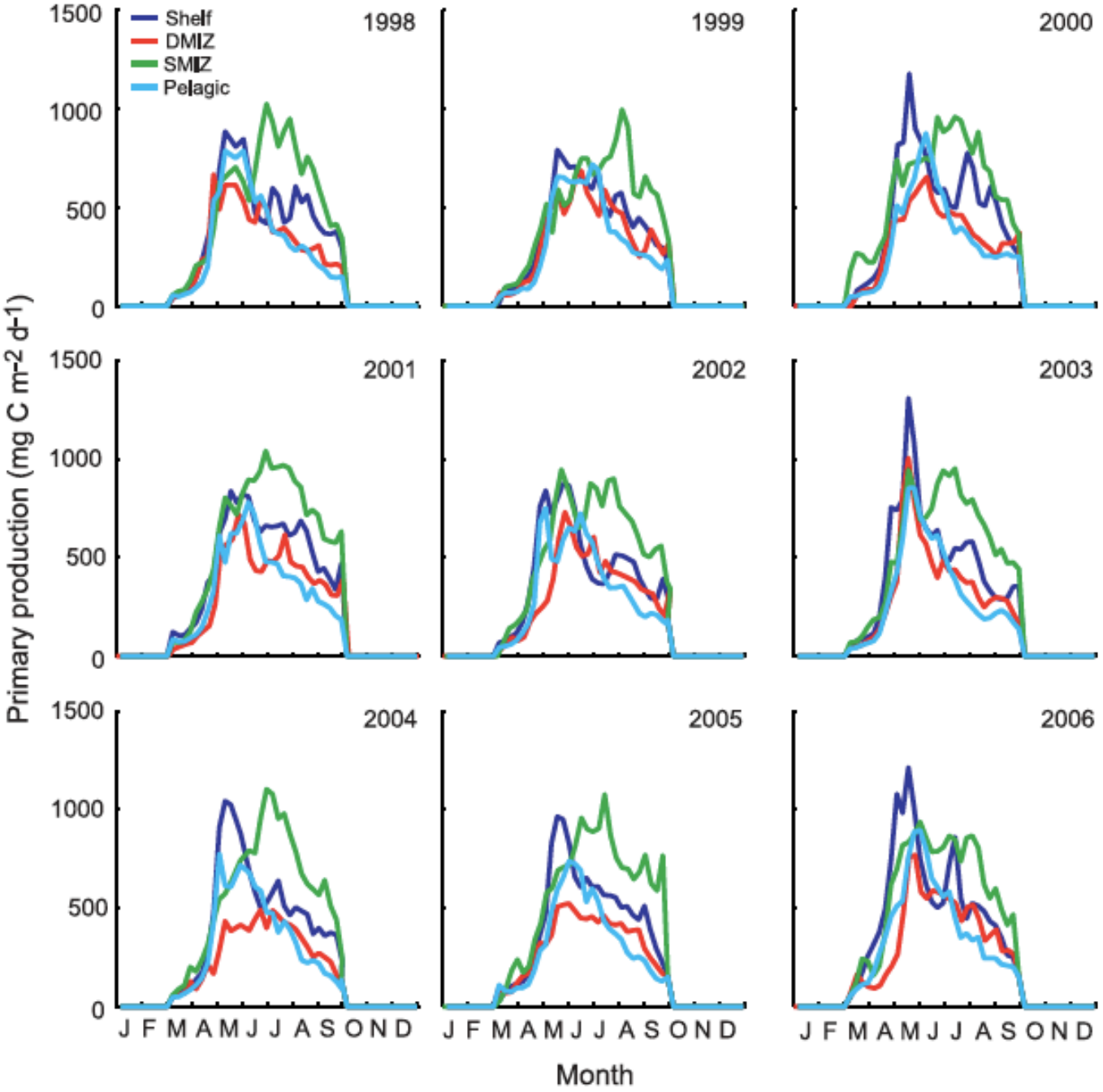
b: May-June

c: August-September



Pabi et al. (2008)

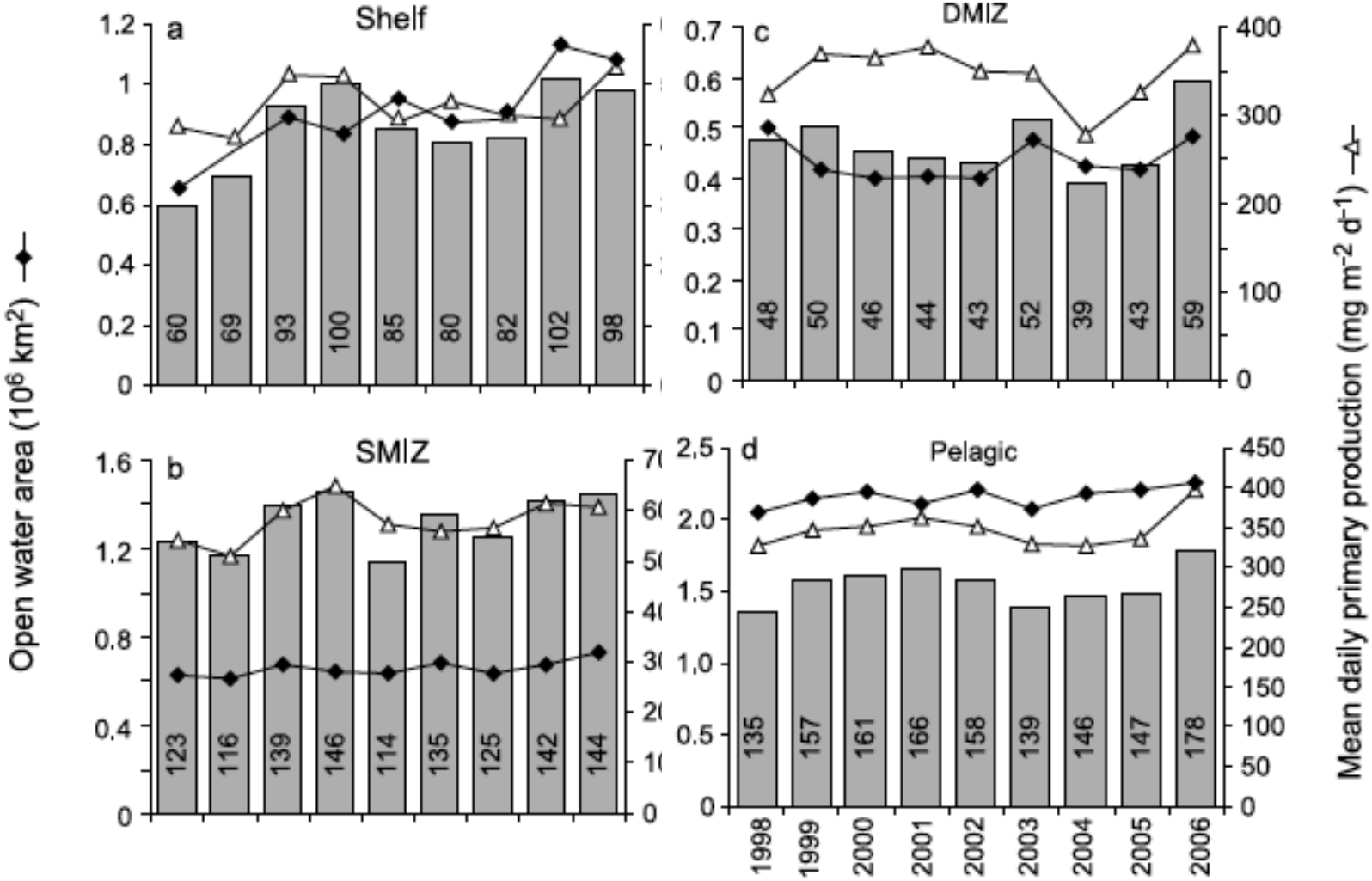
Annual primary production in the Arctic Ocean for each ecological province and geographical sector during 1998–2006.



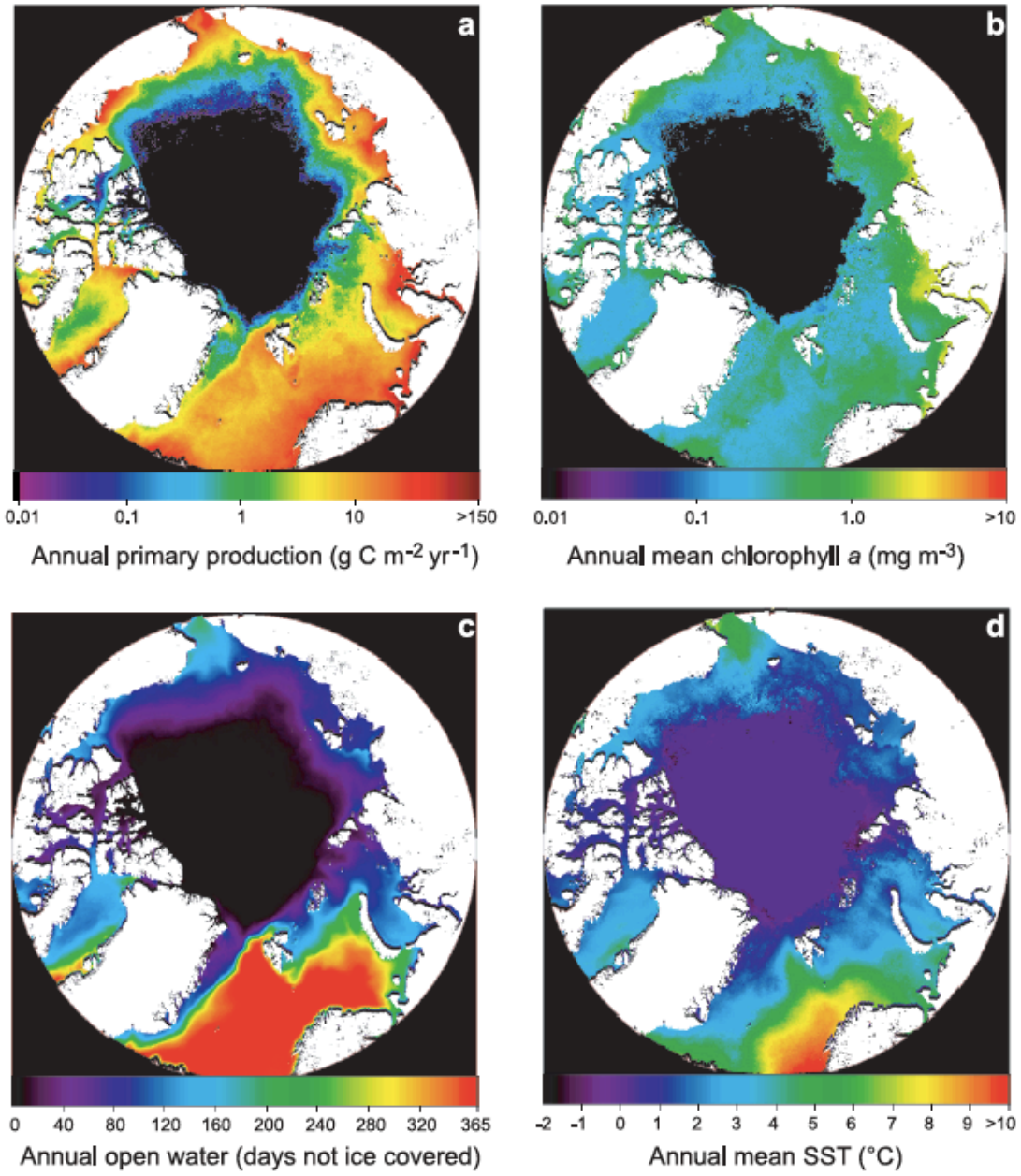
Pabi et al. (2008)

Weekly changes in daily area-normalized primary production in each ecological province of the Arctic Ocean during 1998–2006.

Pabi et al. (2008): Total annual primary production (gray columns, given in Tg C a1), annual mean open water area and annual mean area-normalized primary production in the (a) shelf, (b) SMIZ, (c) DMIZ, and (d) pelagic provinces of the Arctic Ocean during 1998–2006.



Pabi et al. (2008)

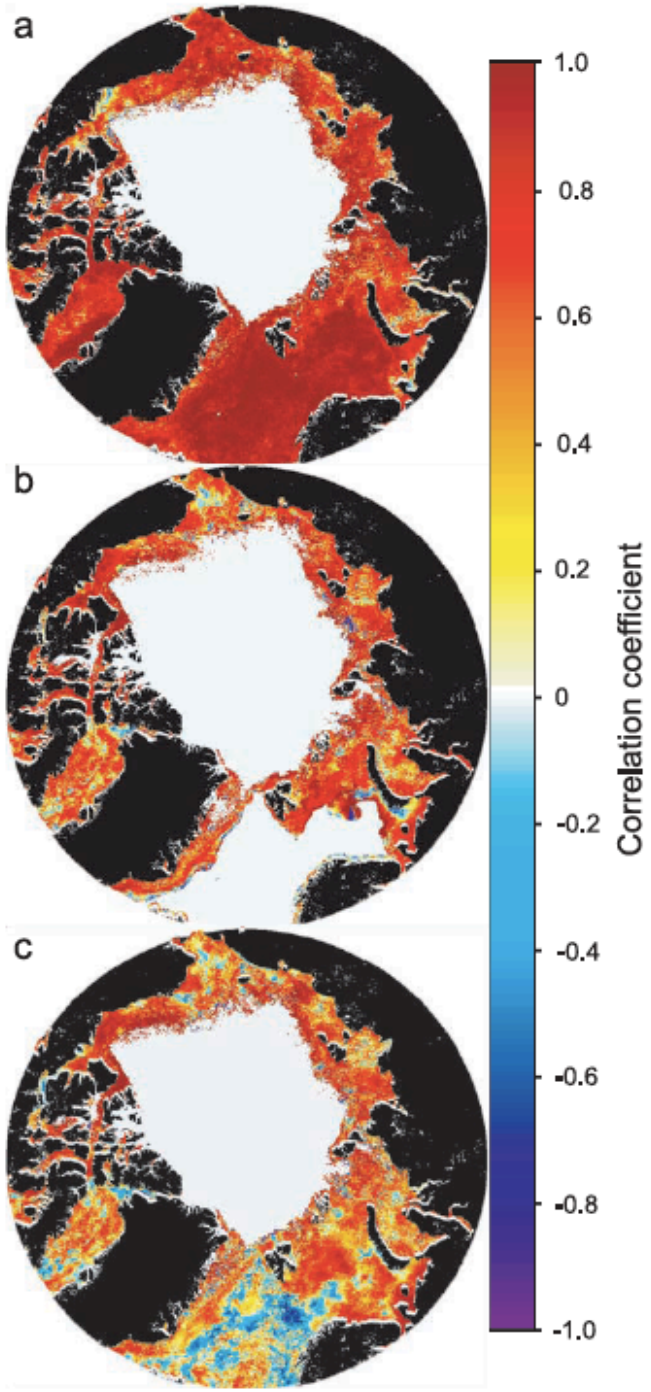


Pabi et al. (2008)

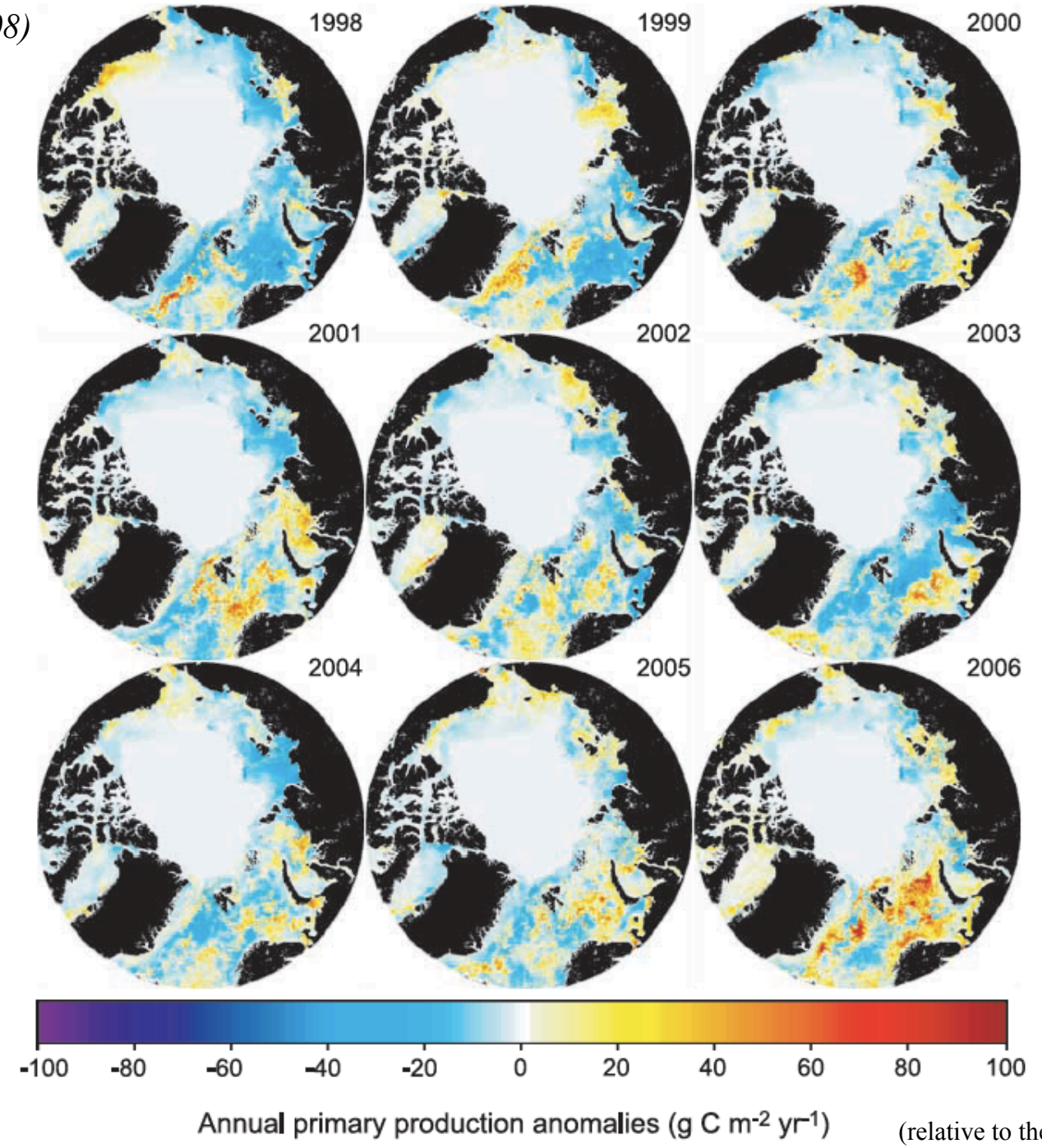
Annual Mean Primary production via annual mean surface Chl-a

Annual Mean Primary production via annual mean open water area (only in regions where the open water last for 350 days)

Annual Mean Primary production Via annual mean sear surface temperature

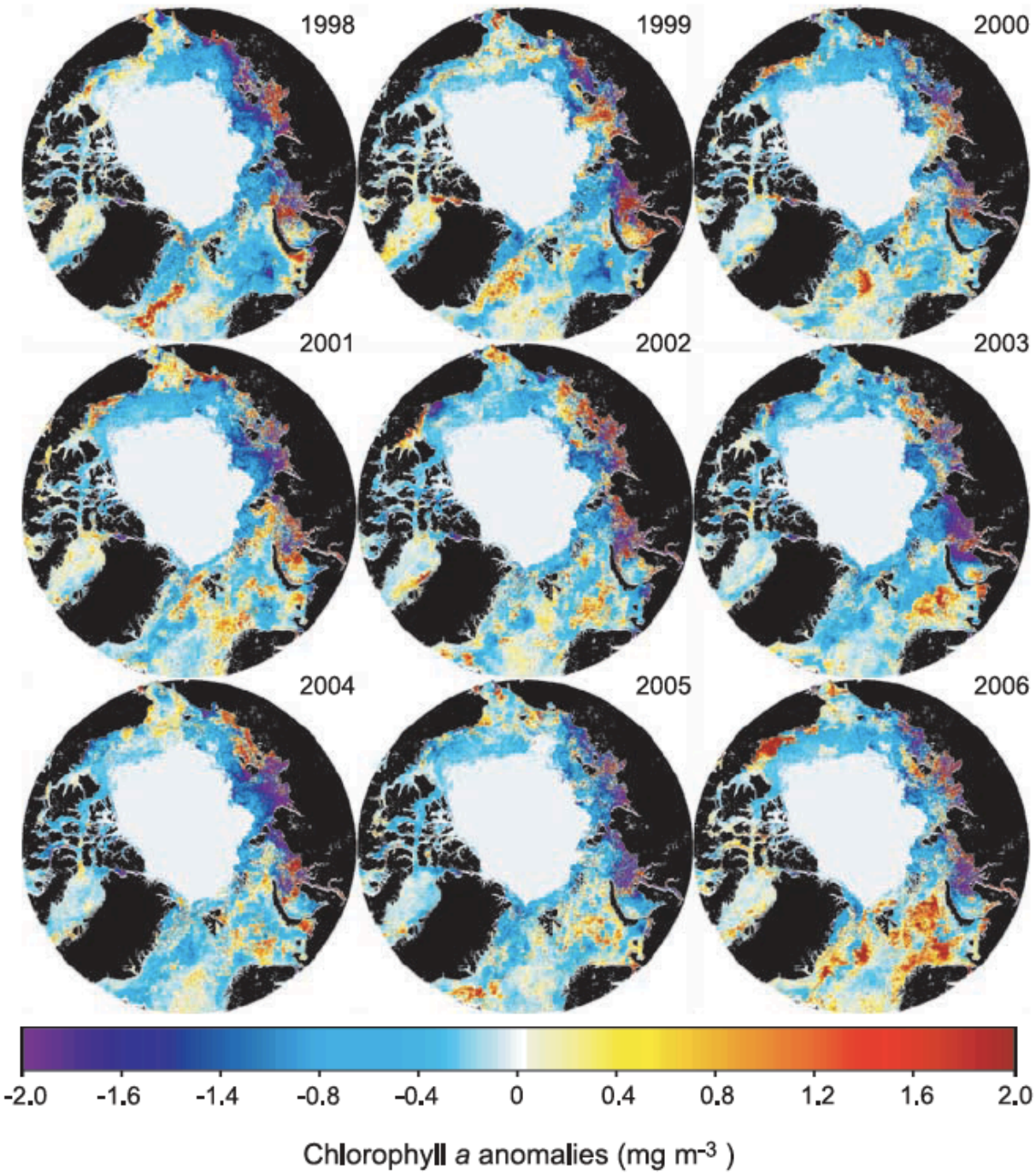


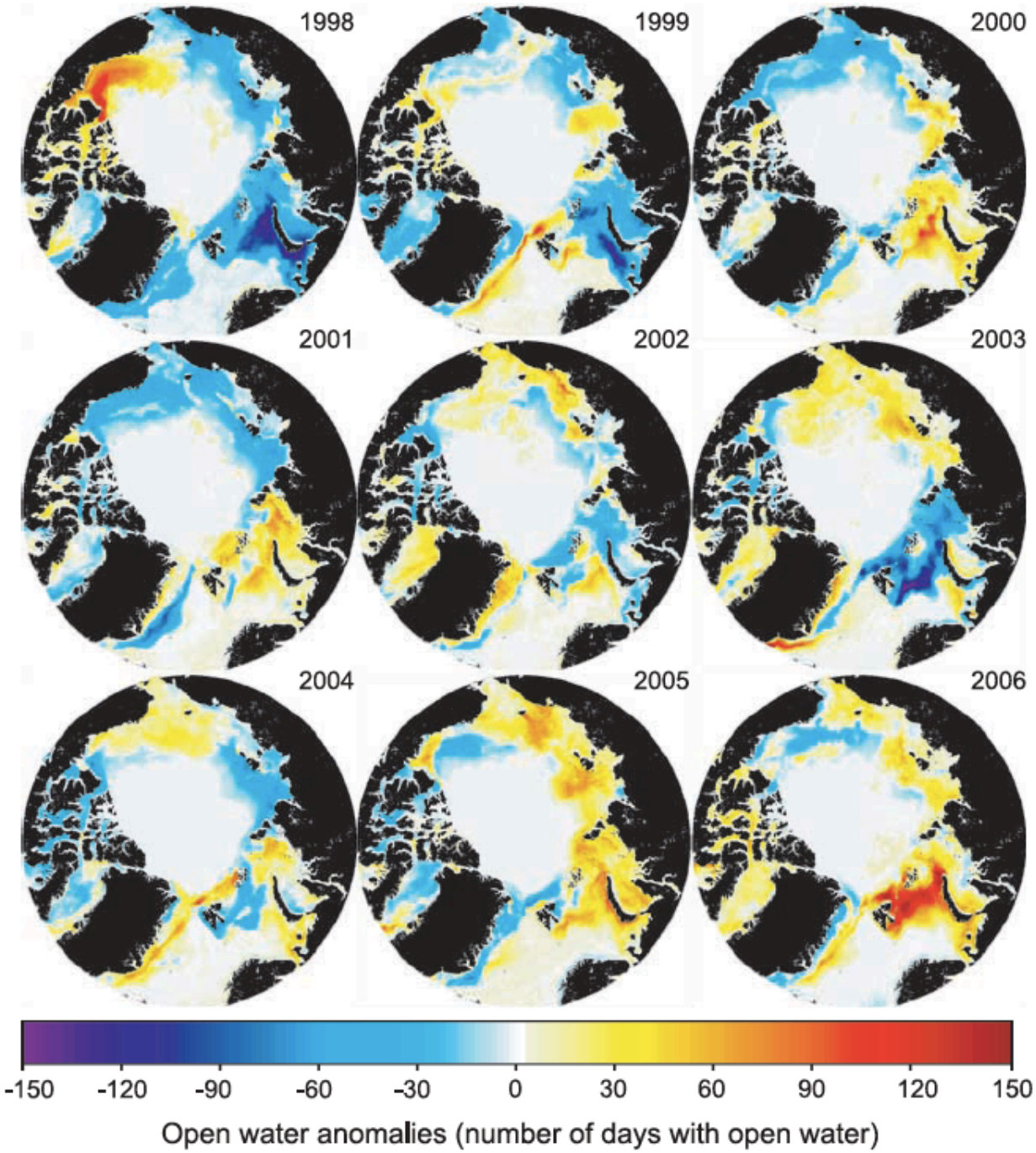
Pabi et al. (2008)

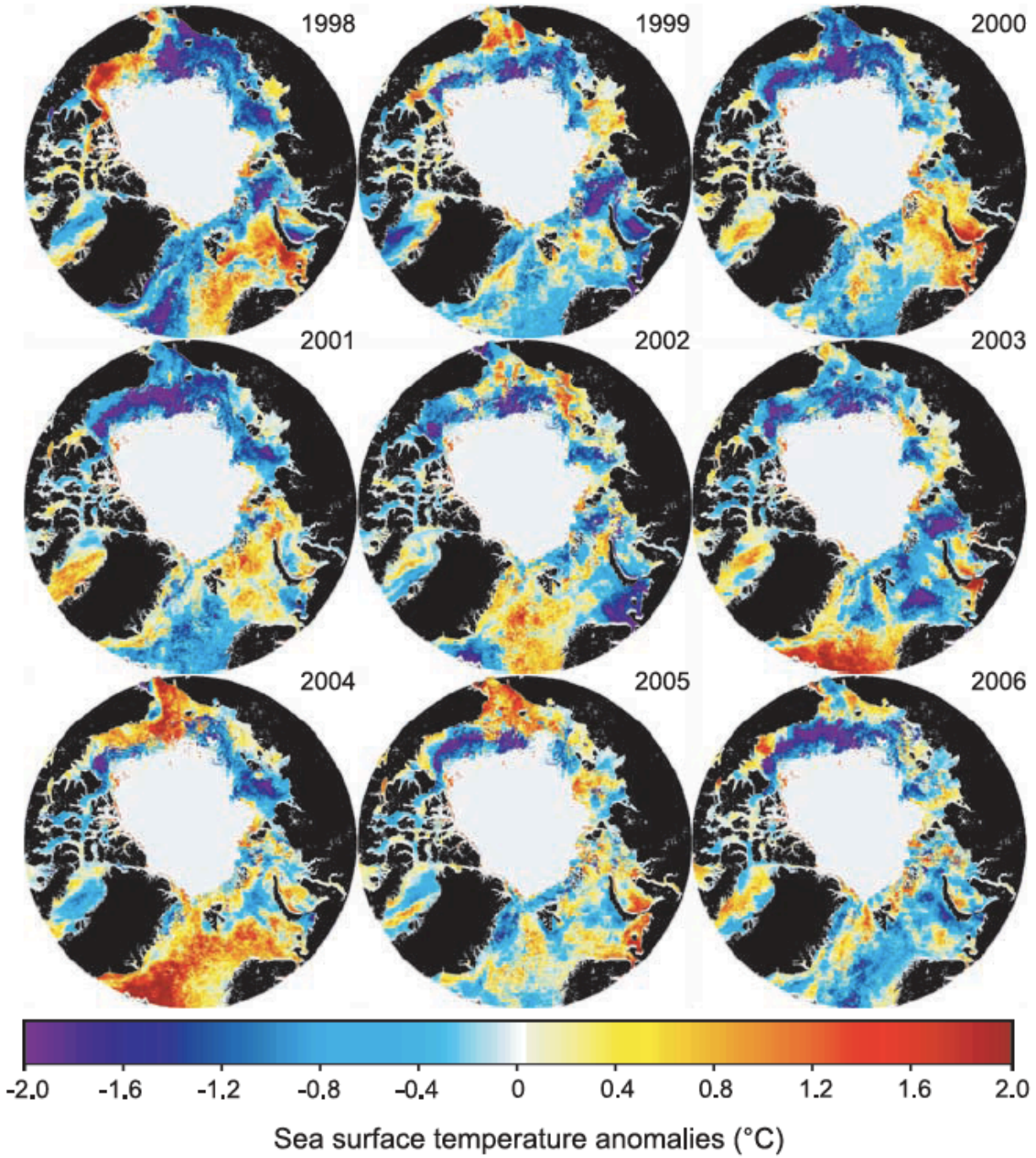


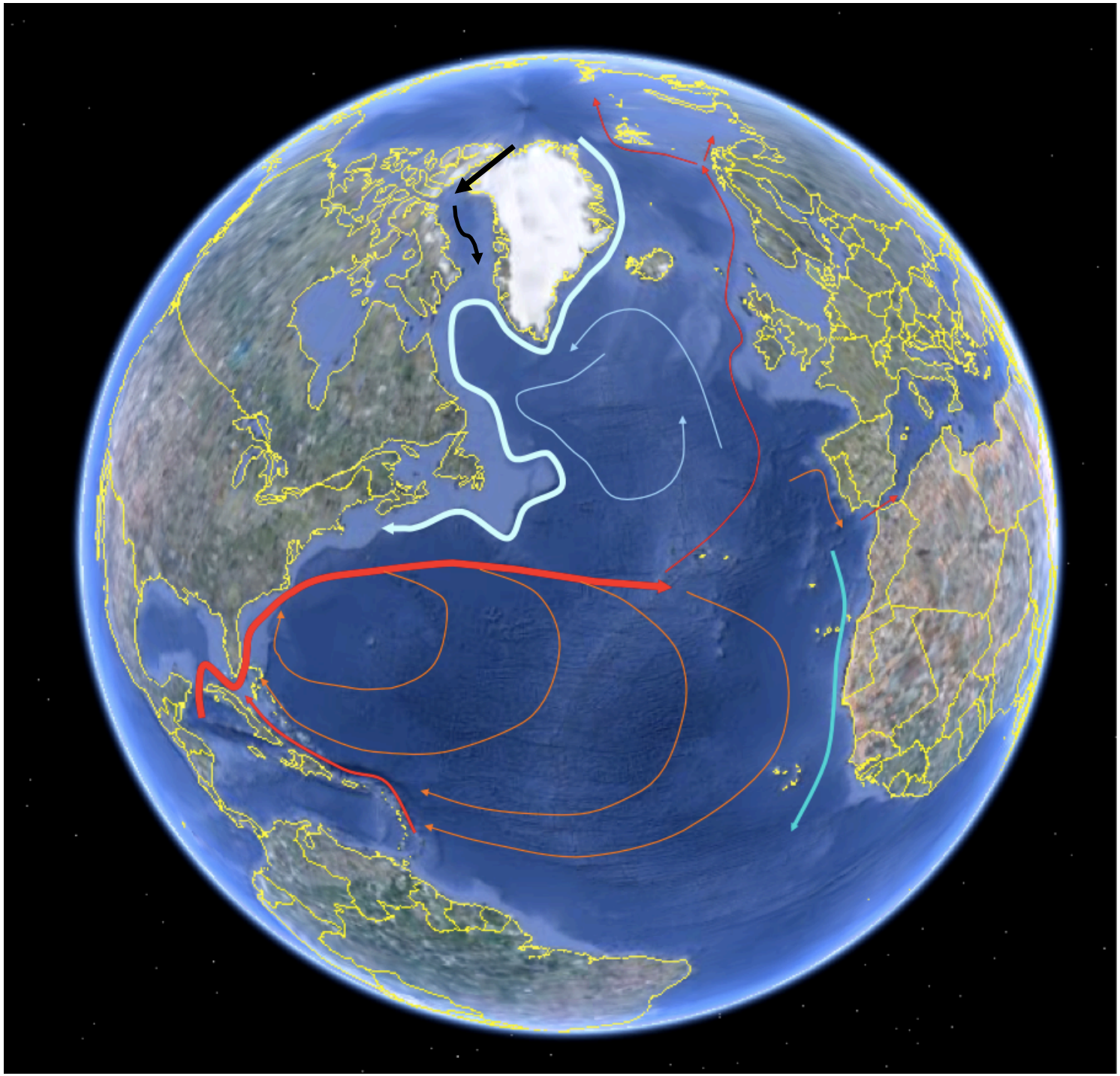
(relative to the mean of 1998-2006

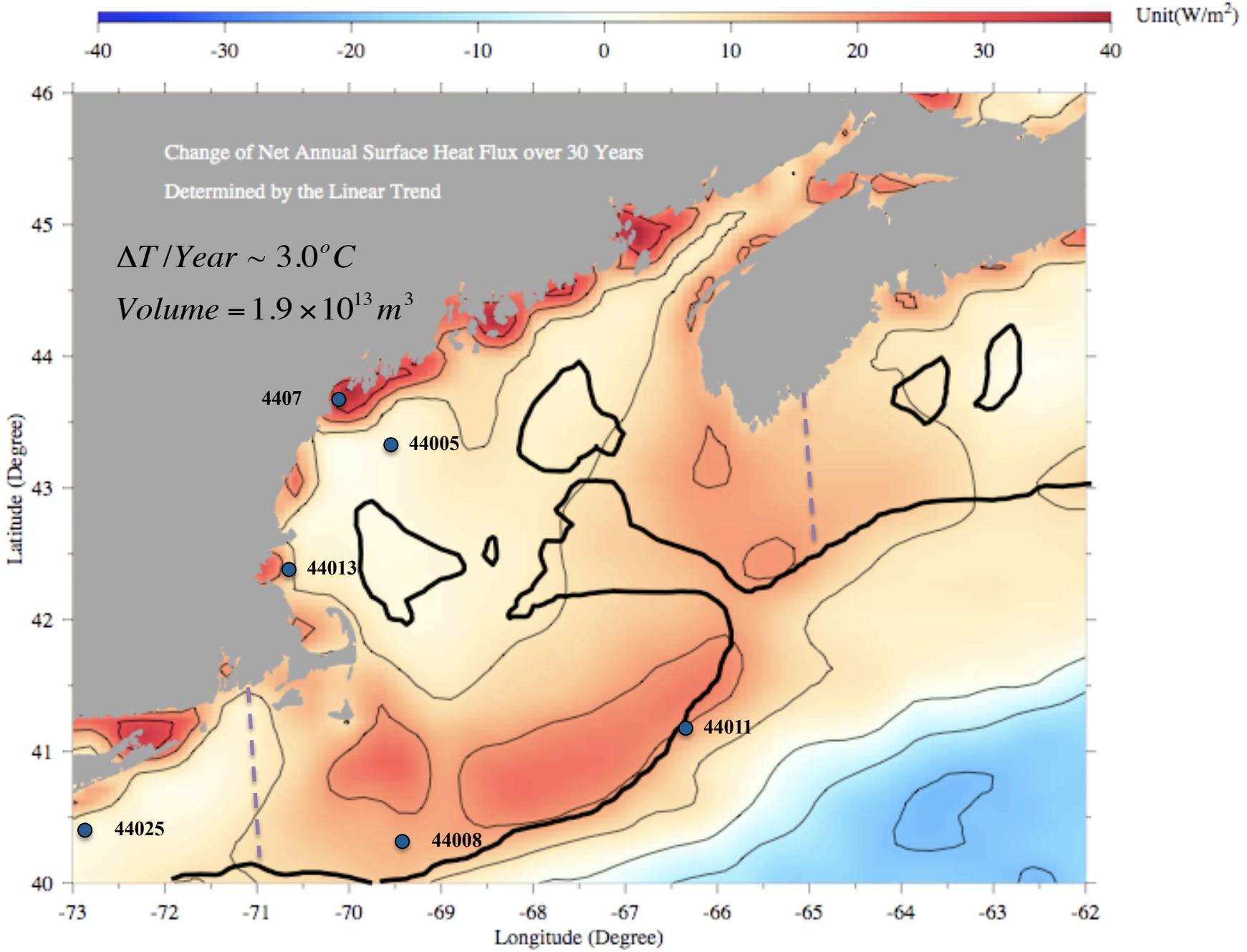
Pabi et al. (2008)

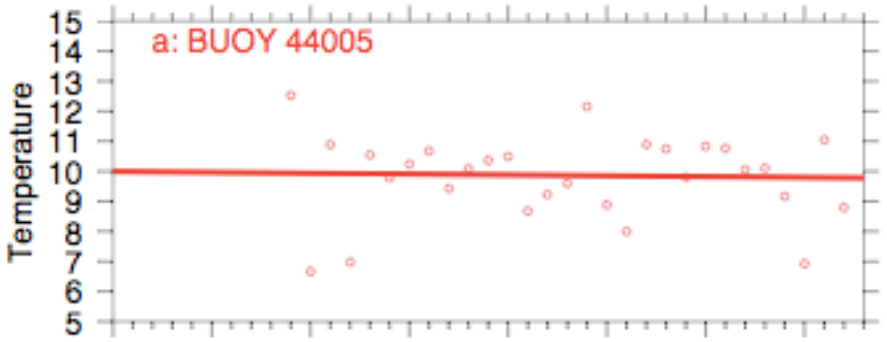


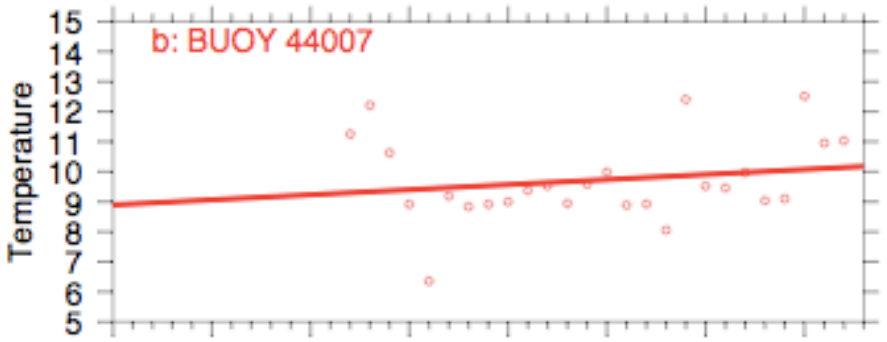

1998
1999
2000
2001
2002
2003
2004
2005
2006
-150
-120
-90
-60
-30
0
30
60
90
120
150
Open water anomalies (number of days with open water)

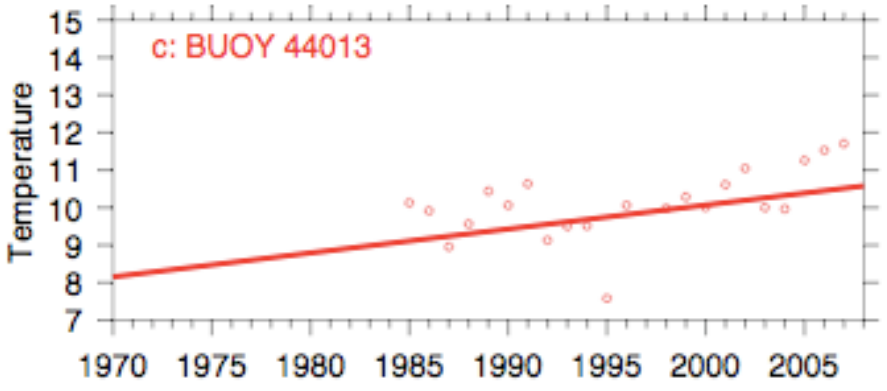

1998
1999
2000
2001
2002
2003
2004
2005
2006
-2.0
-1.6
-1.2
-0.8
-0.4
0
0.4
0.8
1.2
1.6
2.0
Sea surface temperature anomalies (°C)

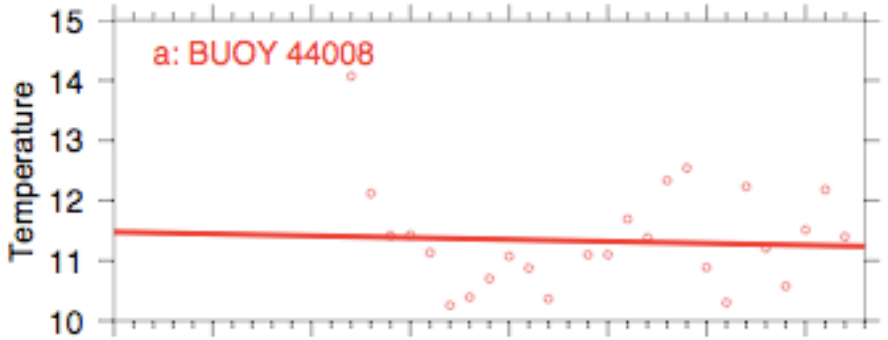


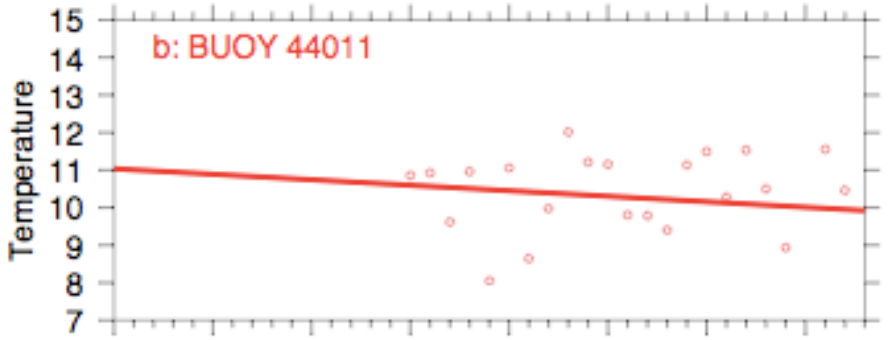

Unit(W/m²)
-40
-30
-20
-10
0
10
20
30
40
Change of Net Annual Surface Heat Flux over 30 Years
Determined by the Linear Trend
$\Delta T / Year \sim 3.0^{o} C$
$Volume = 1.9 \times 10^{13} m^{3}$
4407
44005
44013
44011
44025
44008
Latitude (Degree)
Longitude (Degree)
46
45
44
43
42
41
40
-73
-72
-71
-70
-69
-68
-67
-66
-65
-64
-63
-62

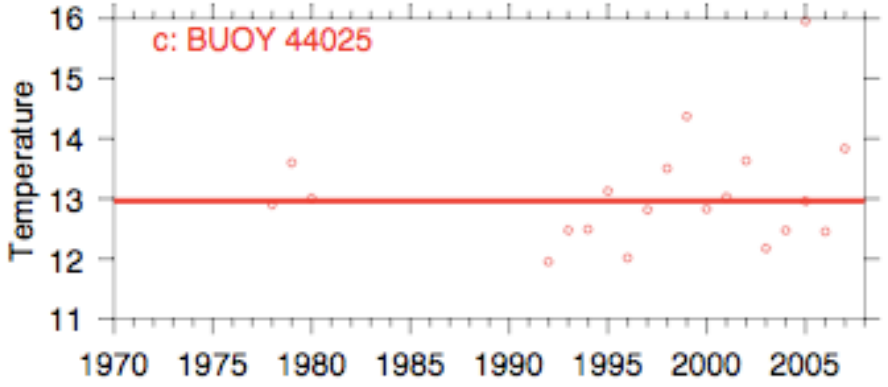

a: BUOY 44005
Temperature
15
14
13
12
11
10
9
8
7
6
5

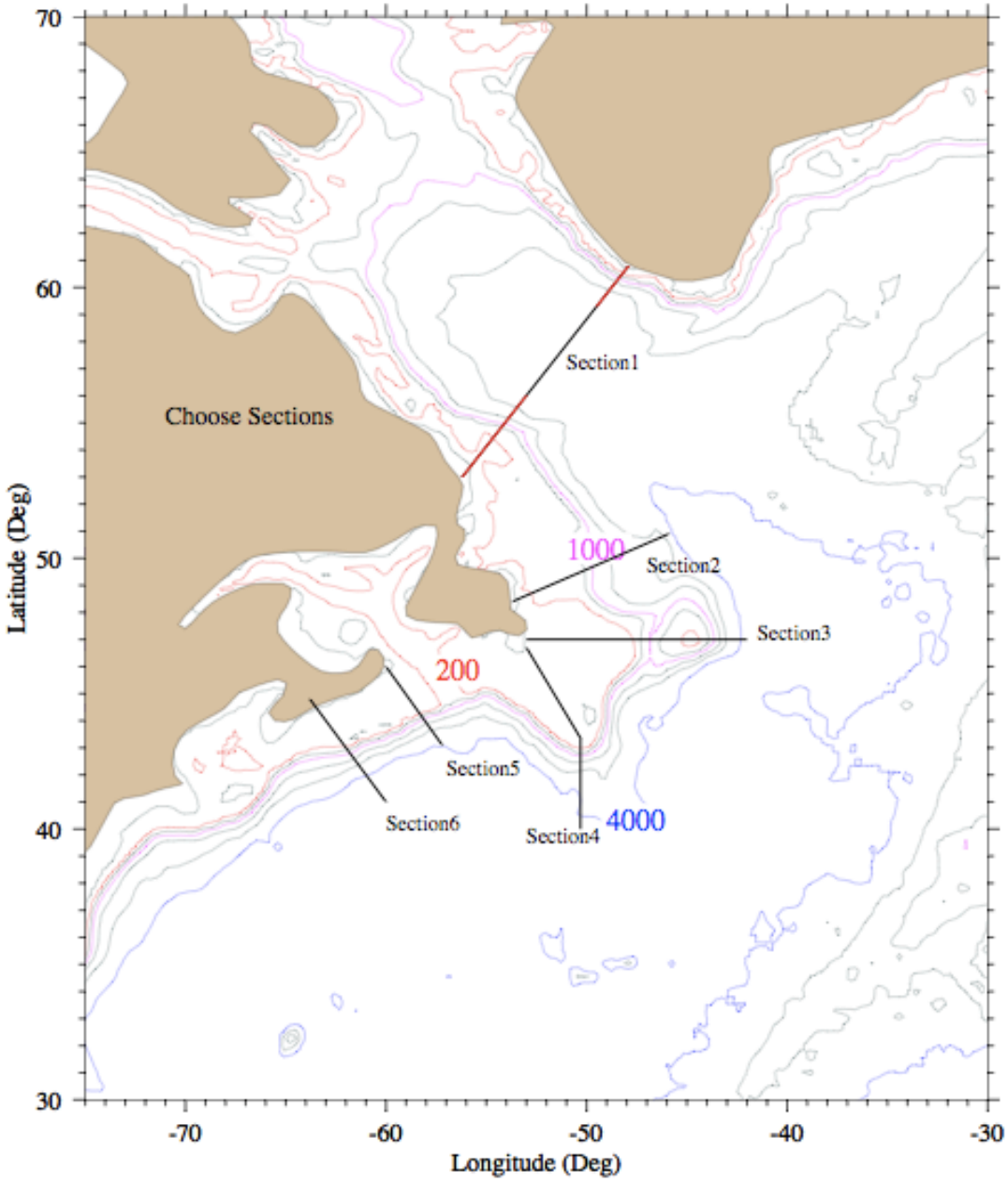

b: BUOY 44007
Temperature
15
14
13
12
11
10
9
8
7
6
5


c: BUOY 44013
Temperature
15
14
13
12
11
10
9
8
7
1970
1975
1980
1985
1990
1995
2000
2005

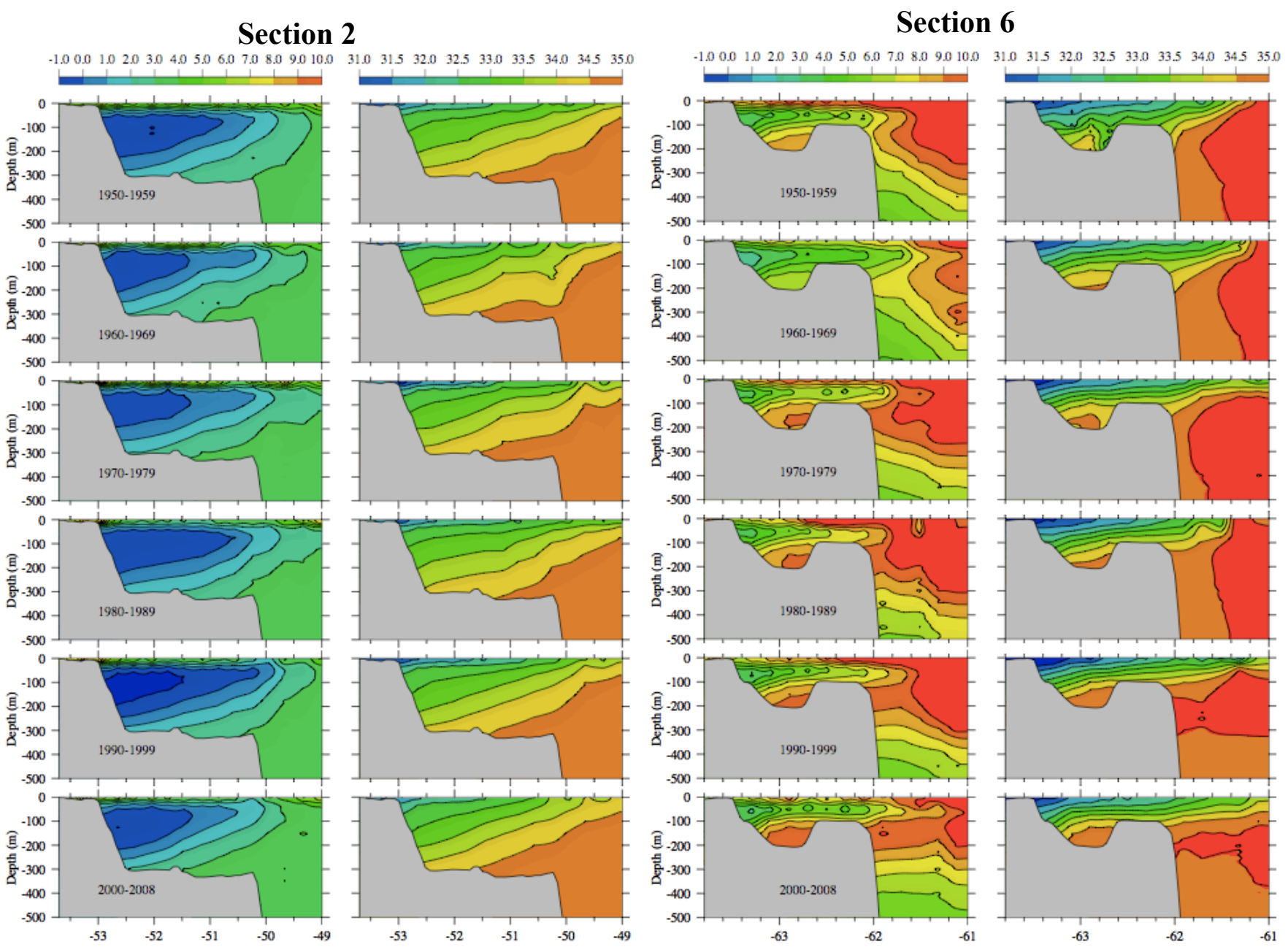

a: BUOY 44008
Temperature
15
14
13
12
11
10


b: BUOY 44011
Temperature
15
14
13
12
11
10
9
8
7

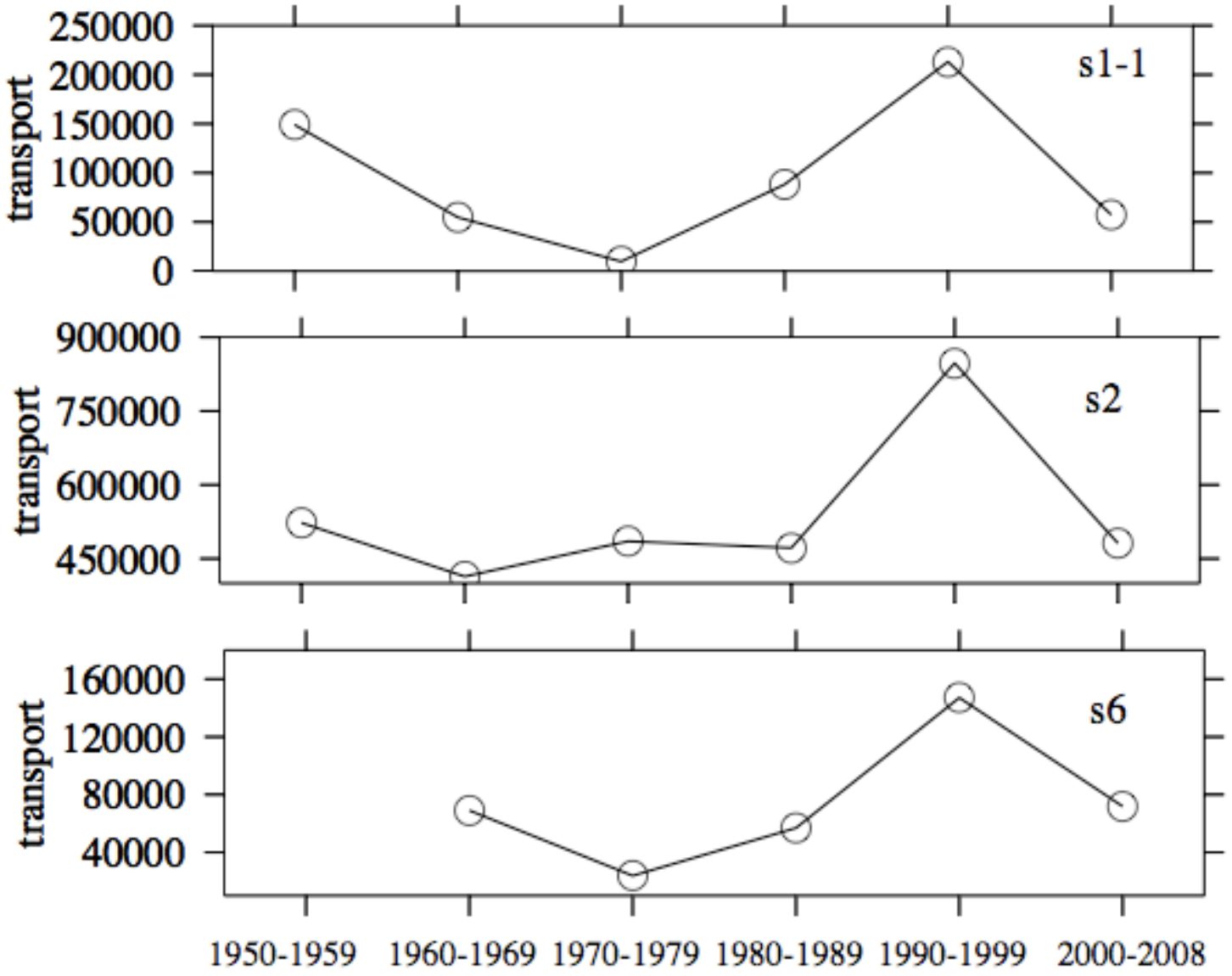

c: BUOY 44025
Temperature
16
15
14
13
12
11
1970
1975
1980
1985
1990
1995
2000
2005



Hydrographic sections selected to calculate the inter-annual patterns of water temperature and salinity as well as the water transport


Section 2
Section 6
-1.0 0.0 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.0
31.0 31.5 32.0 32.5 33.0 33.5 34.0 34.5 35.0
Depth (m)
0
-100
-200
-300
-400
-500
1950-1959
1960-1969
1970-1979
1980-1989
1990-1999
2000-2008
-53
-52
-51
-50
-49
-63
-62
-61

Geostrophic Water Transport on Sections 1, 2 and 6



Questions:

How does the climate change affect the coastal ecosystem?