The observational events:

* Chapman and Walsh (1993):
  * The annual mean air temperature has increased by 2-3°C since 1950;
  * The winter mean air temperature has increased by ~4°C since 1950.

* Arctic Climate Impact Assessment (ACIA) (2005):
  * The annual mean air temperature has increased by 4-5°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
From D. K. Perovich and J. A. Richter-Menge
Arctic Sea ice in summer 2007, an animation downloaded from www.nsidc.org/

Images from NASA Earth Observing System Advanced Microwave 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
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.
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

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

Pabi et al. (2008)
Pabi et al. (2008): Total annual primary production (gray columns, given in Tg C a\(^{-1}\)), 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)
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)
Pabi et al. (2008)

Annual primary production anomalies (g C m$^{-2}$ yr$^{-1}$)

(relative to the mean of 1998-2006)
Pabi et al. (2008)
\( \Delta T / \text{Year} \sim 3.0^\circ C \)

Volume = \( 1.9 \times 10^{13} m^3 \)
Hydrographic sections selected to calculate the inter-annual patterns of water temperature and salinity as well as the water transport.
Geostrophic Water Transport on Sections 1, 2 and 6
Questions:

How does the climate change affect the coastal ecosystem?