Workpackage 2 – deliverables 2010:

No. 6: Seasonally resolved pCO_2 fields for the entire Baltic Sea

No. 8: CO_2 gas exchange balance

Results of the Gulf of Bothnia

Only few data about the CO_2 gas exchange in the Gulf of Bothnia have been published

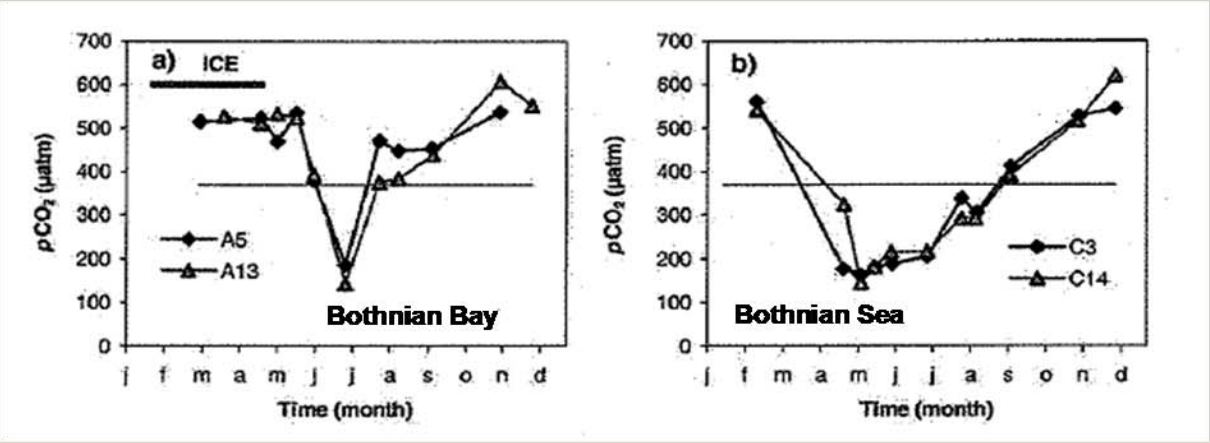
G. Algesten et al. (2004):

„The Gulf of Bothnia is a significant source of CO_2 to the atmosphere."

CO_2-emission [mmol C $m^{-2}a^{-1}$]:

Bothnian Bay: 3550

Bothnian Sea: 2600



Calculation of CO_2-fluxes

$$F_{CO2} = k_w \cdot K_0 \cdot \Delta pCO_2$$

Wanninkhof 1992

$$F_{CO2} = 0.31 \cdot u^2 \cdot (Sc/660)^{-0.5} \cdot K_0 \cdot \Delta pCO_2$$

F_{CO2} = CO_2 flux (water → atmosphere)

k_w = gas transfer velocity

K_0 = gas solubility constant = f(S, T)

$\Delta pCO_2 = pCO_2^w - pCO_2^a$

Sc = Schmidt number (interpolated for brackish water)

Parameters for the calculation:

pCO_2 (in water and atmosphere)

S, T

u (wind velocity in 10m)

ice coverage (duration and percentage)

$pCO_2^{water} – pCO_2^{atmosphere}$

Gulf of Bothnia – a source or a sink for CO_2 in the atmosphere?

Annekatrin Löffler, Bernd Schneider, Matti Perttilä

8 cruises with measurements of pCO_2

November 1999 (ARANDA)

March 2000 (ARANDA)

March 2006 (MERIAN)

June 2008 (MERIAN)

January 2009 (ARANDA)

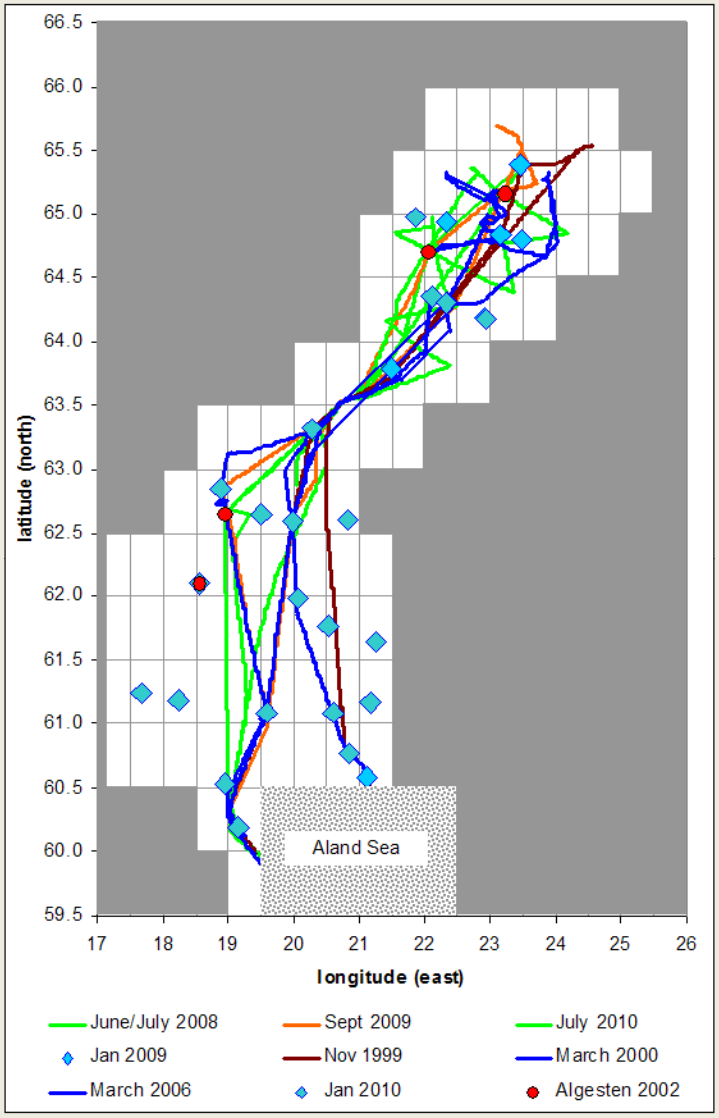
September 2009 (MERIAN)

January 2010 (ARANDA)

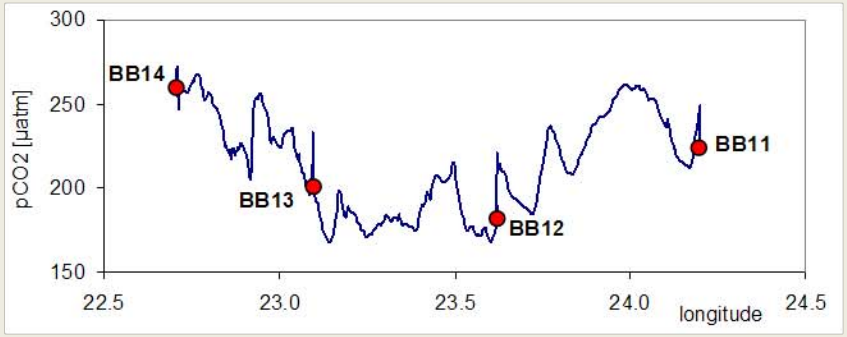
July 2010 (ALKOR)

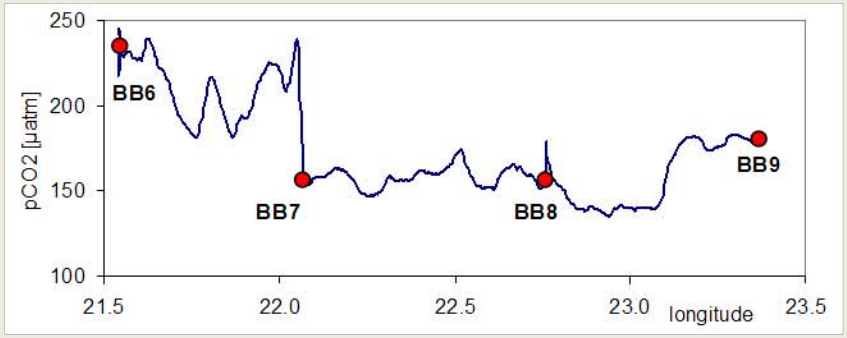
- continuously recording of surface water pCO_2
- seawater pumping system
- bubble type equilibrator
- CO_2 in equilibrated air was measured by IR-detection (LICOR CO2 analyzer)

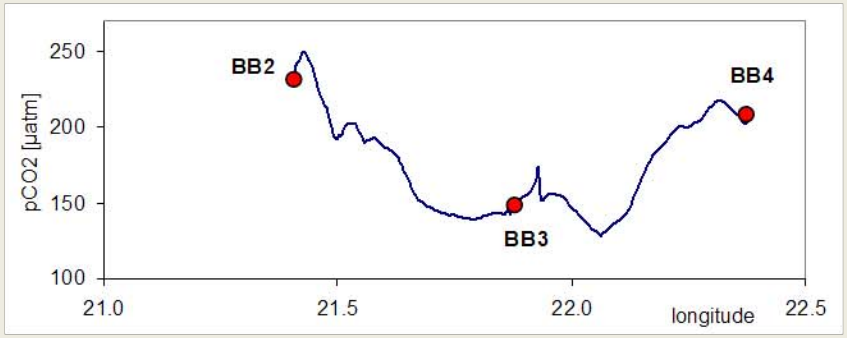
spatial resolution: 0.16 – 0.24 sm

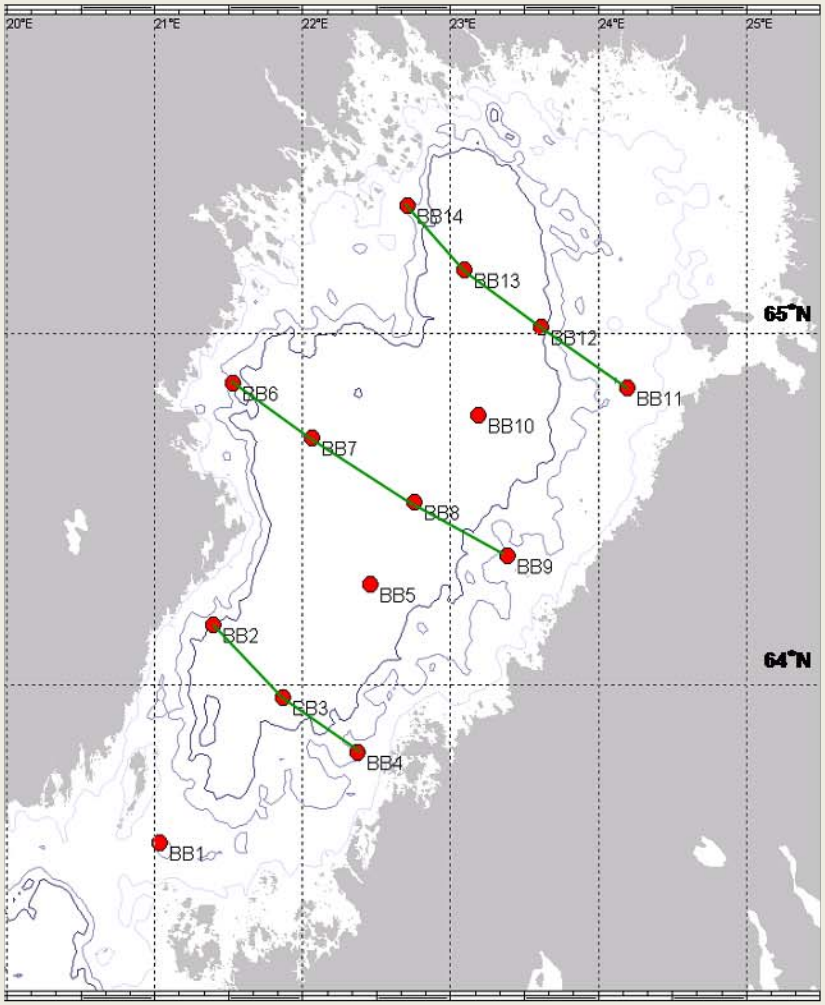


Patterns of pCO_2 distribution (Bothnian Bay, July 2010)



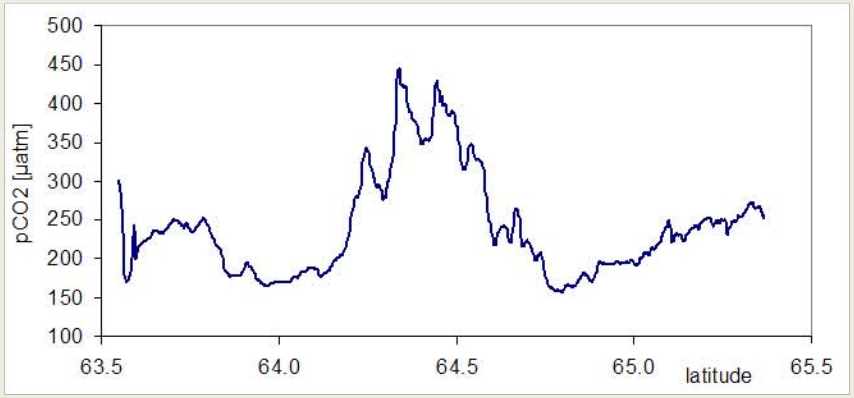


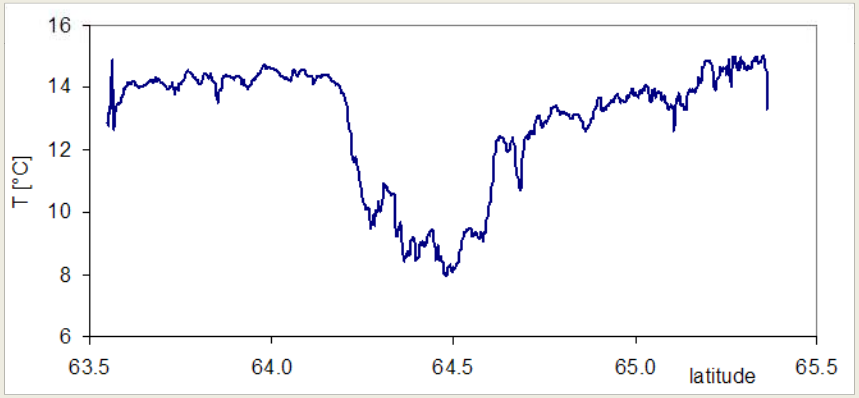




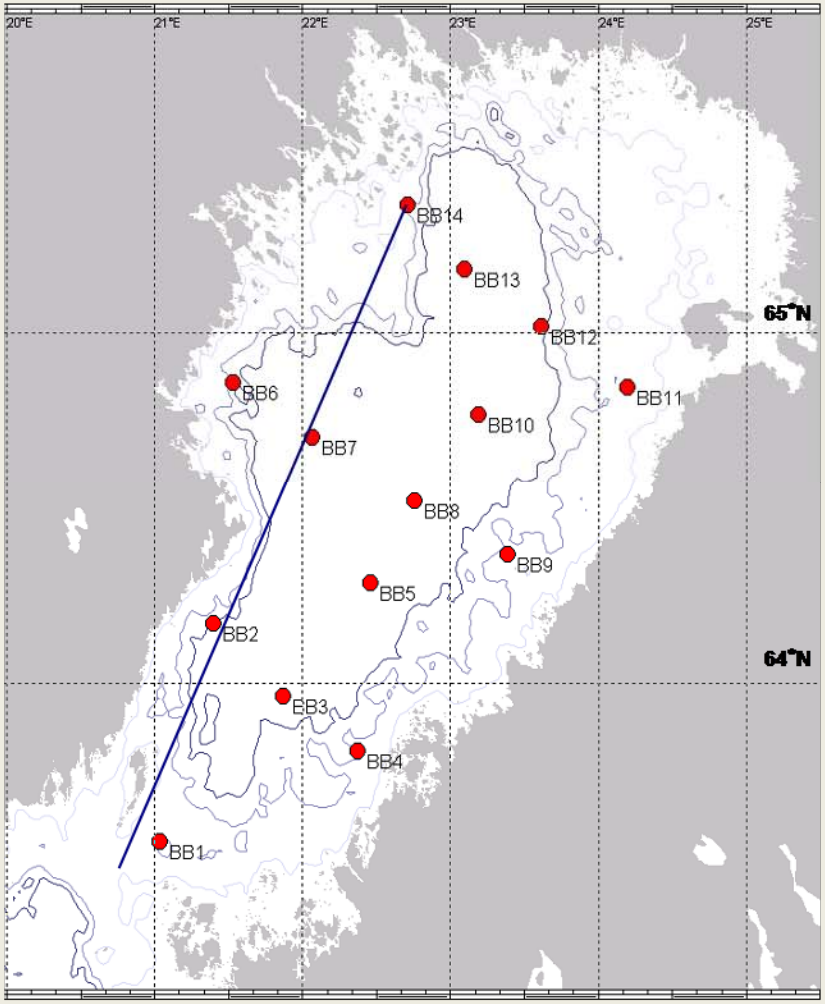
Isolines at 10m, 30m, 50m

Upwelling near the coast (Bothnian Bay, July 2010)



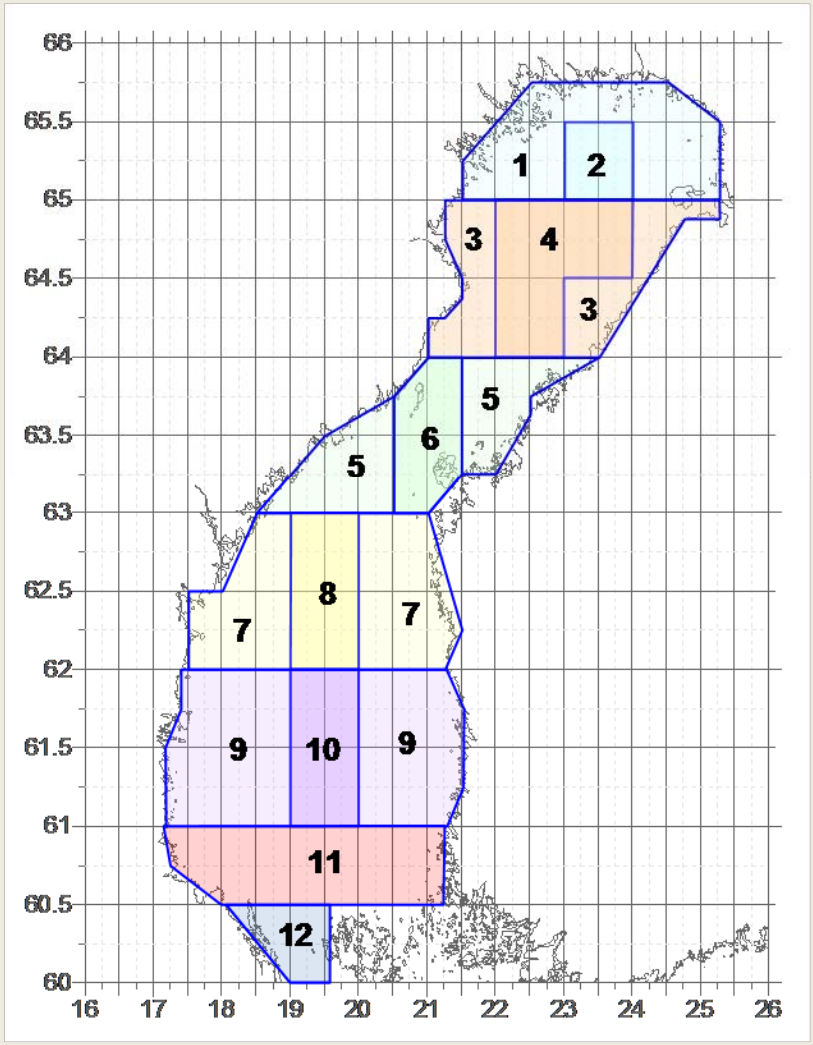


enhanced pCO_2 in the vicinity of the coast
(wind speed 8-10 m/s)



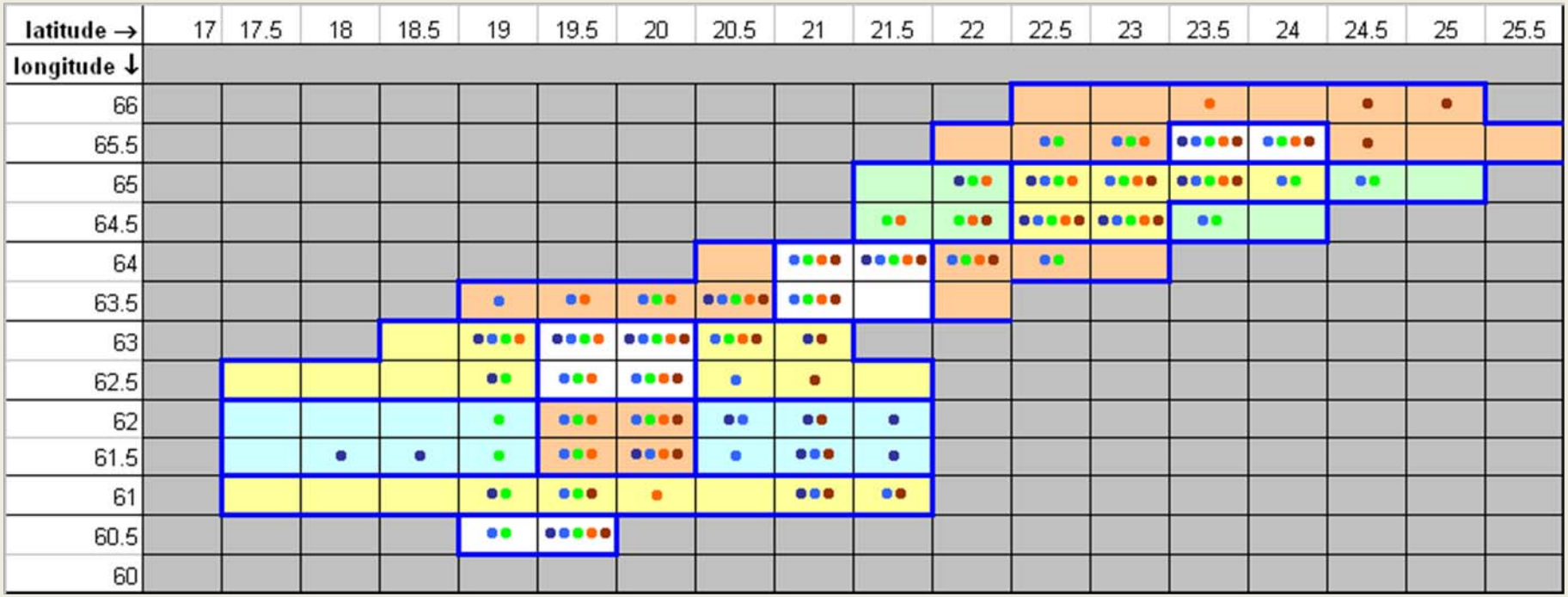
Isolines at 10m, 30m, 50m

Grid elements



Area	grid elements
Bothnian Bay:	1 - 4
Quark:	5, 6
Bothnian Sea:	7 - 12

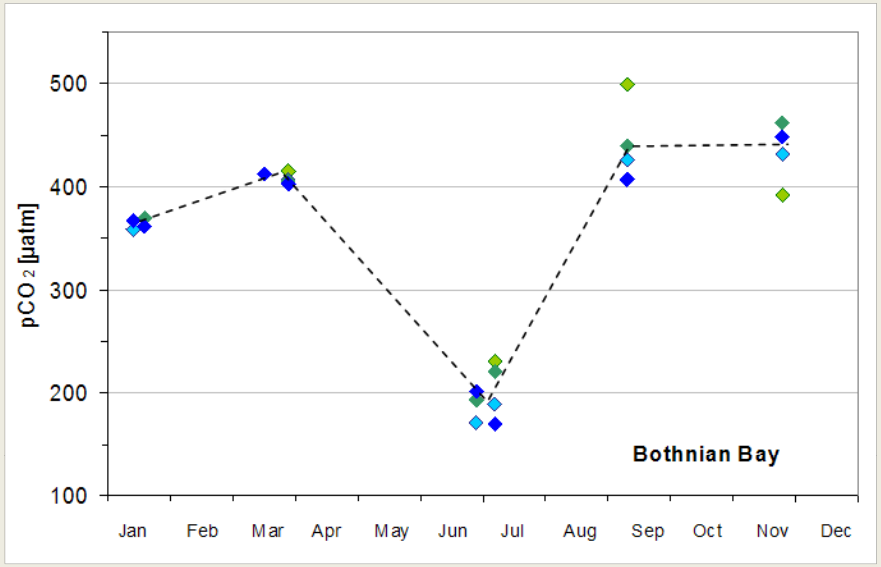
Available data for several seasons in the matrix areas

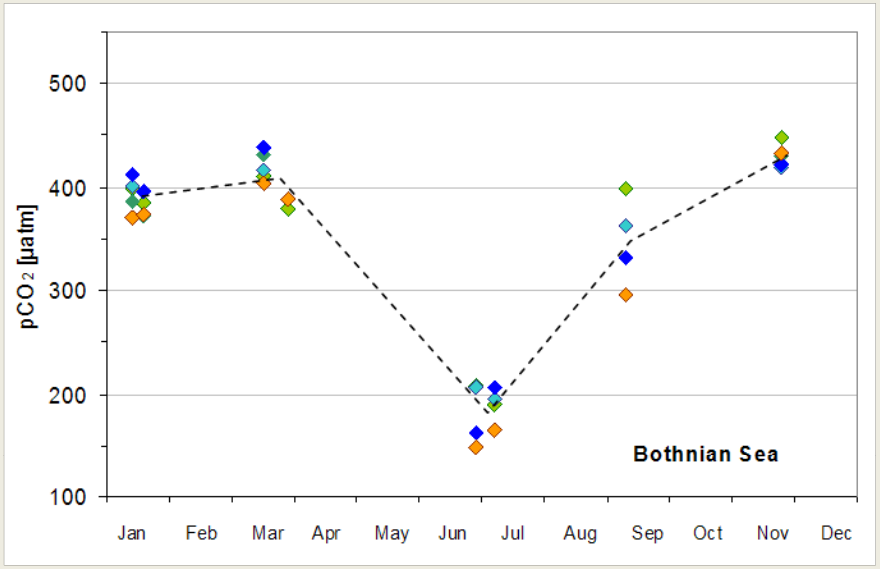


pCO_2 average was calculated for each grid element and for each cruise

●	January 2009/2010
●	March 2000/2006
●	June/July 2008/2010
●	September 2009
●	November 1999

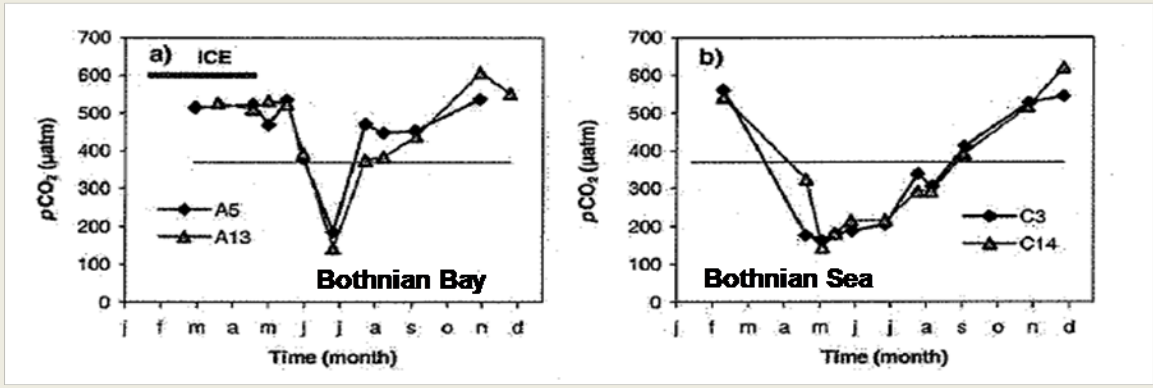
Mean pCO_2 in the grid elements



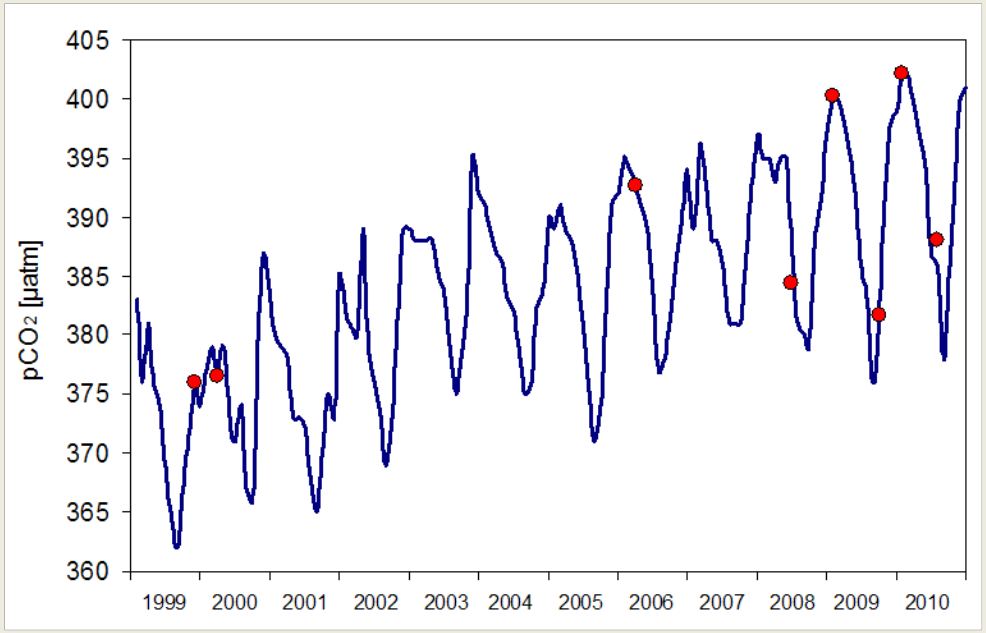


G. Algesten et al. (2004)

(data from 2002)



Changing atmospheric concentrations of CO_2

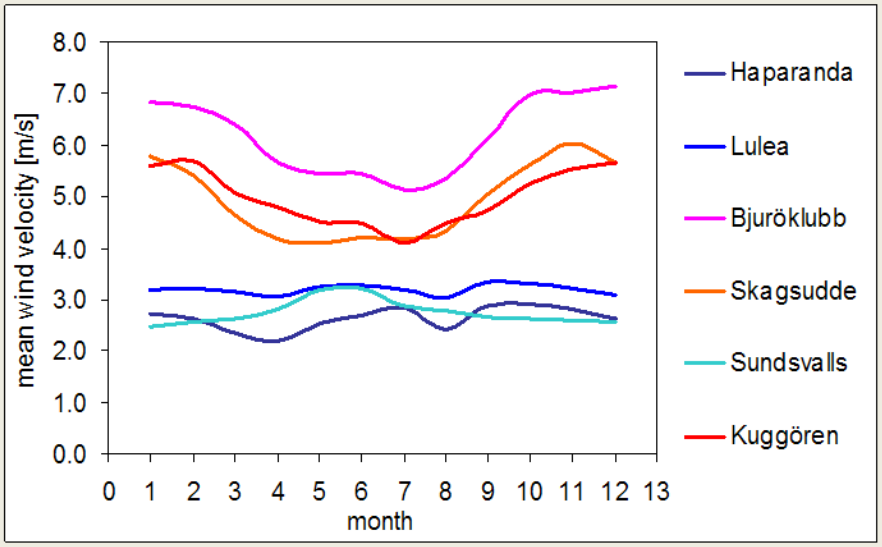


cruises

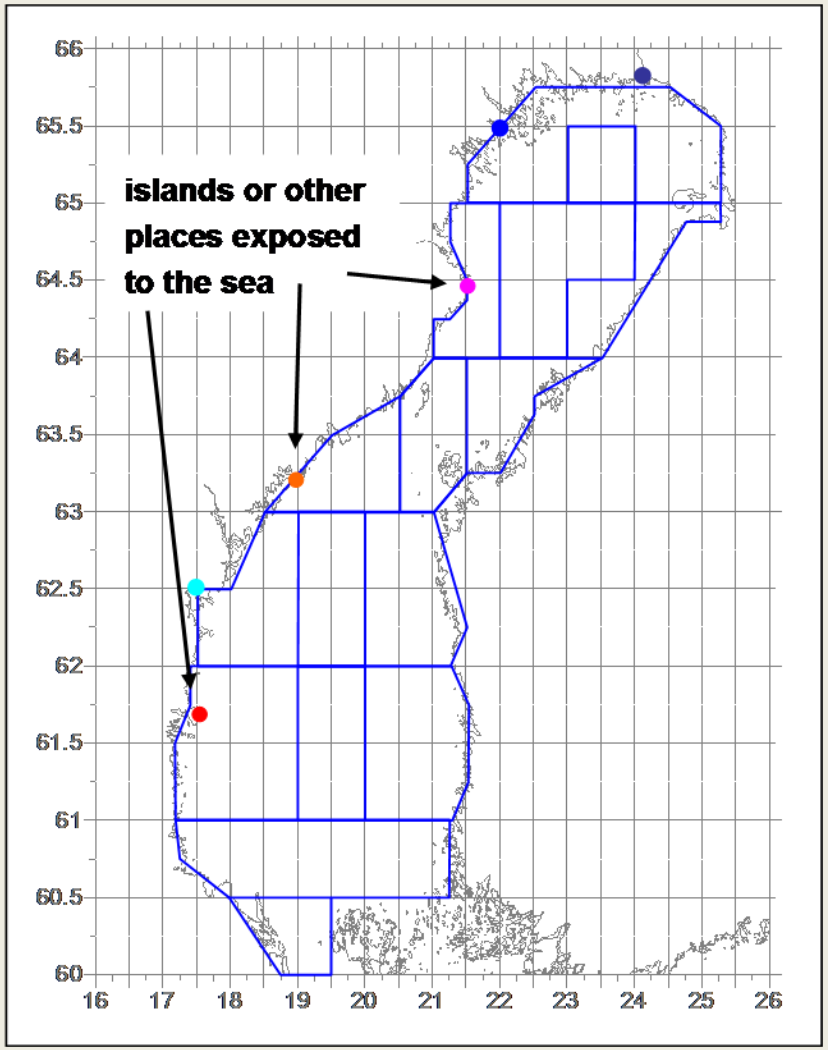
atmosheric pCO_2 (monthly mean; Morski Instytut Rybacki, Poland)

Wind data

Wind velocity from different stations along the Swedish coast

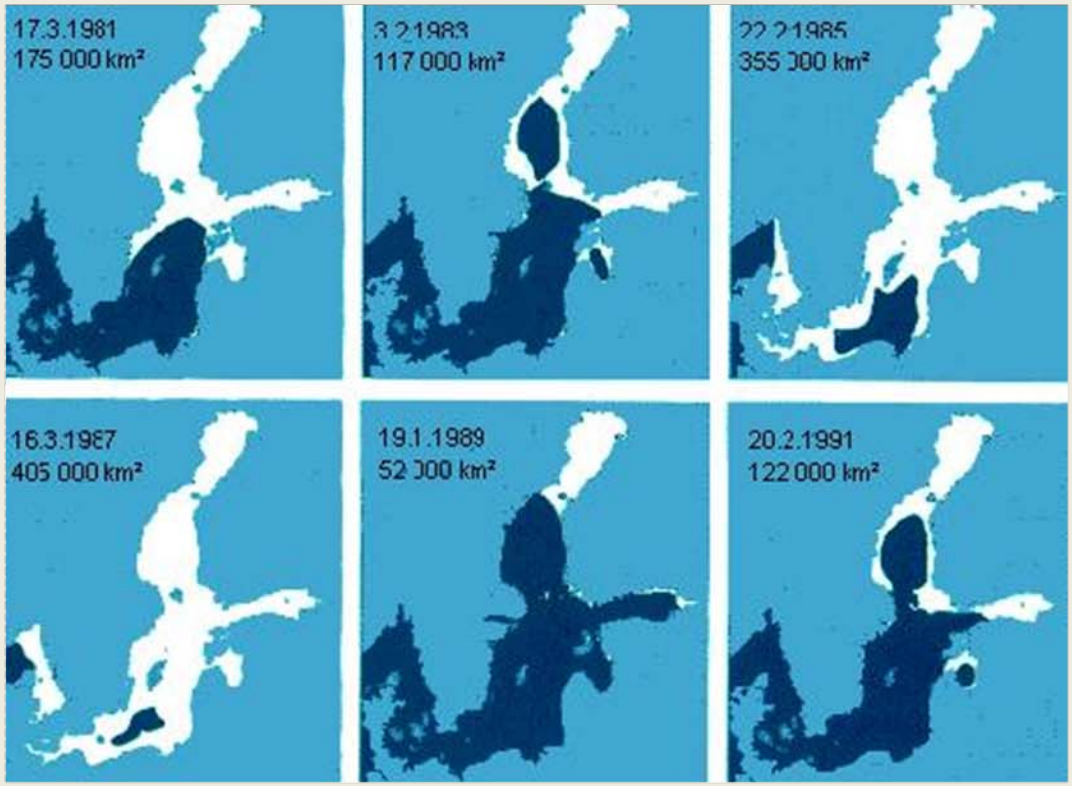


wind data 1999-2008 from SMHI Norrköping



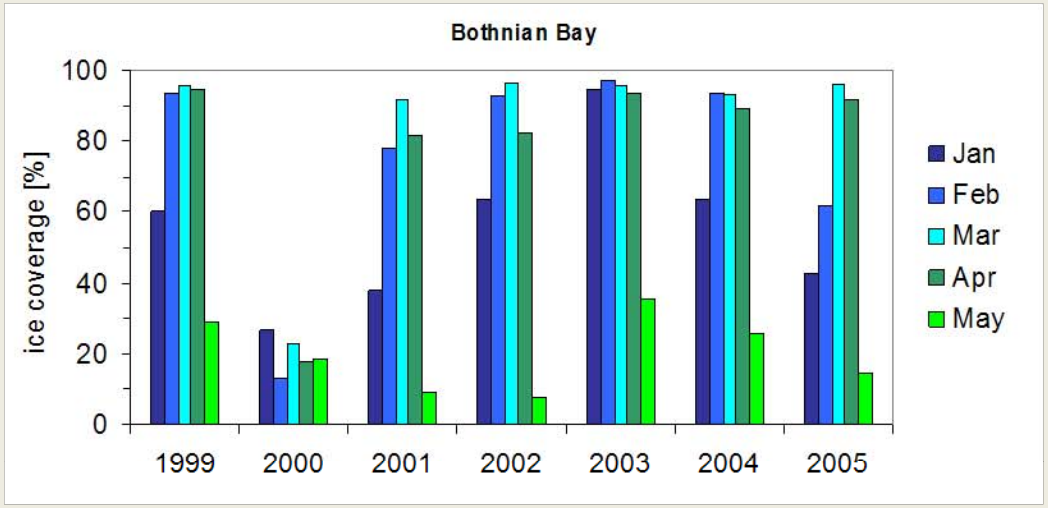
Ice coverage

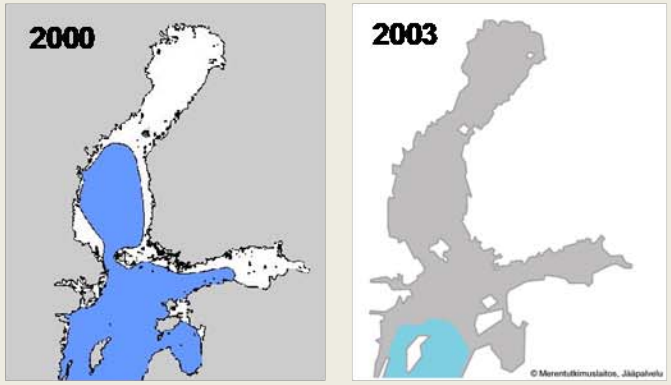
Strong variations in the Sea ice conditions in different years



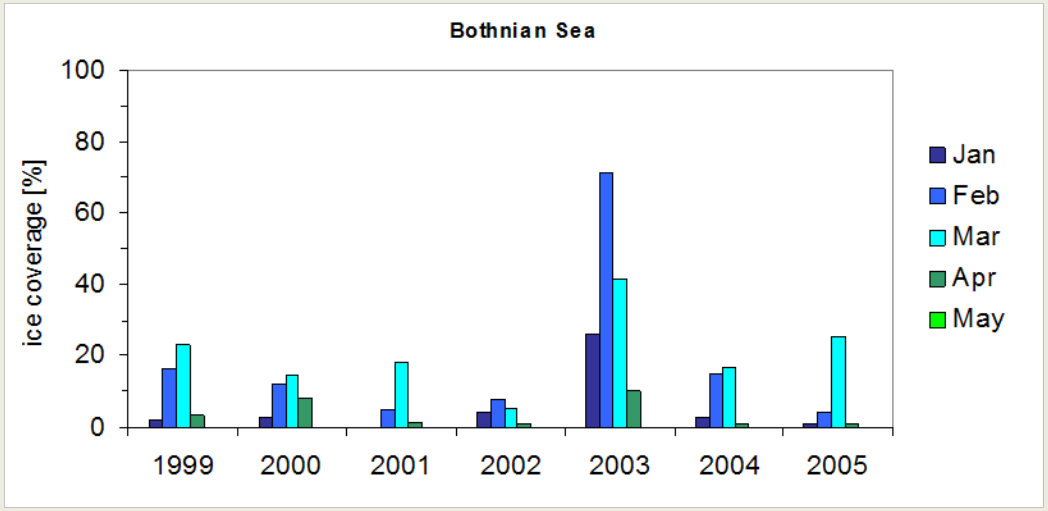
picture from the Finnish Institute of Marine Research

Ice coverage in the Gulf of Bothnia





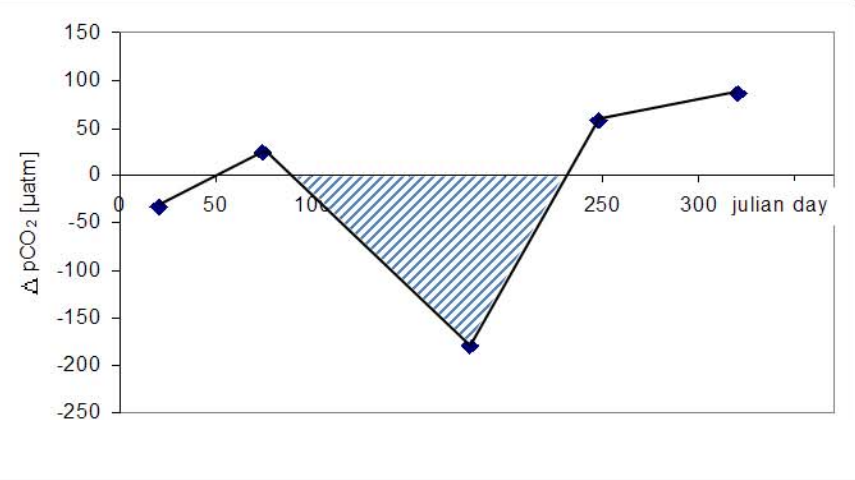
maximum ice cover



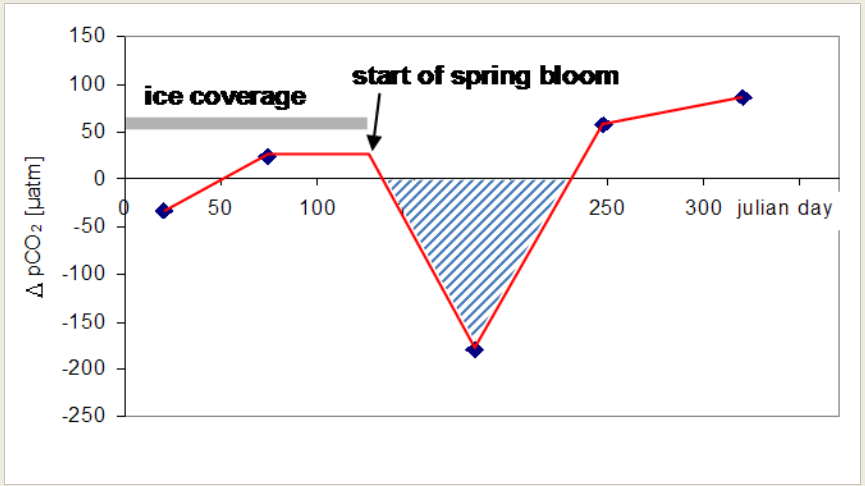
no air-sea gas exchange during ice-coverage

start of the spring bloom after ice melting

Start of the spring bloom



CO_2 - undersaturation

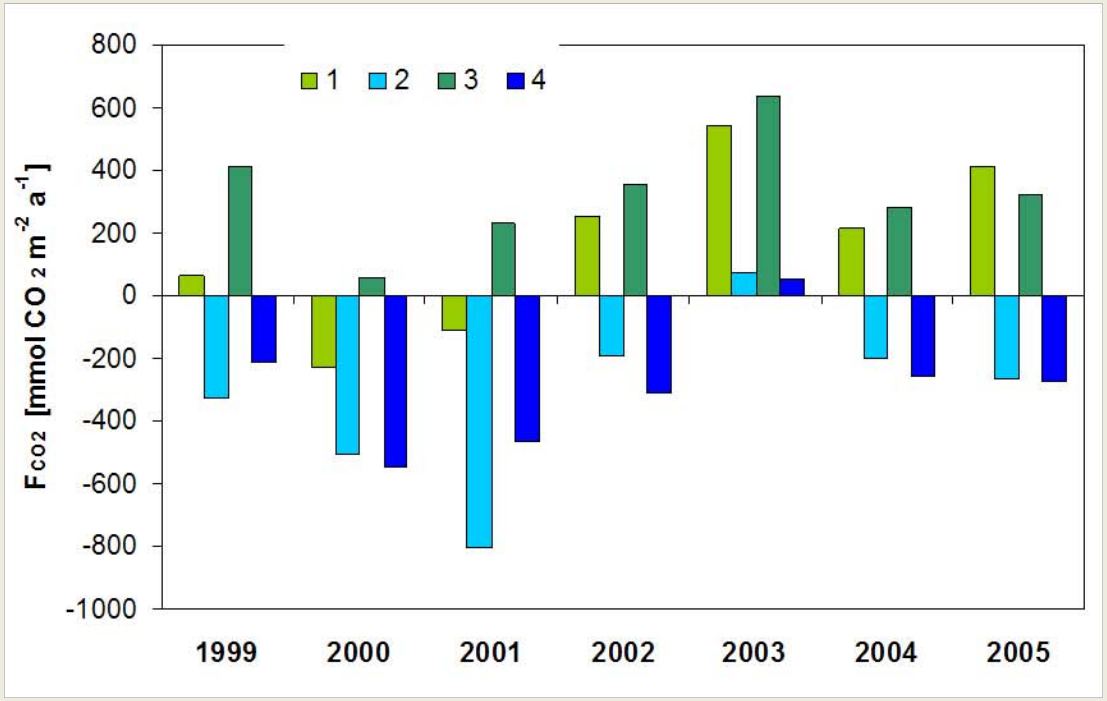


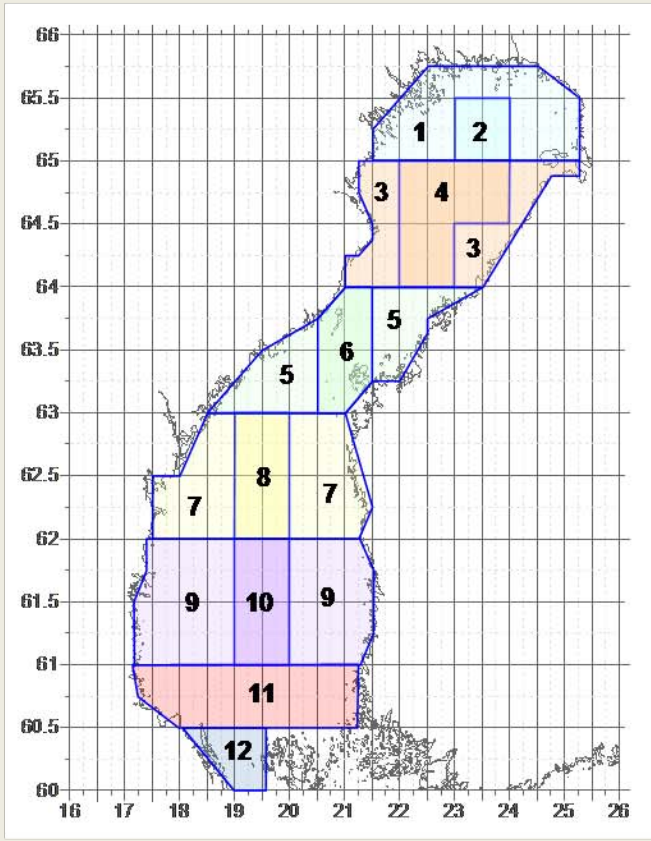
usually spring bloom starts immediately after melting of sea ice

grid element 3 from the Bothnian Bay

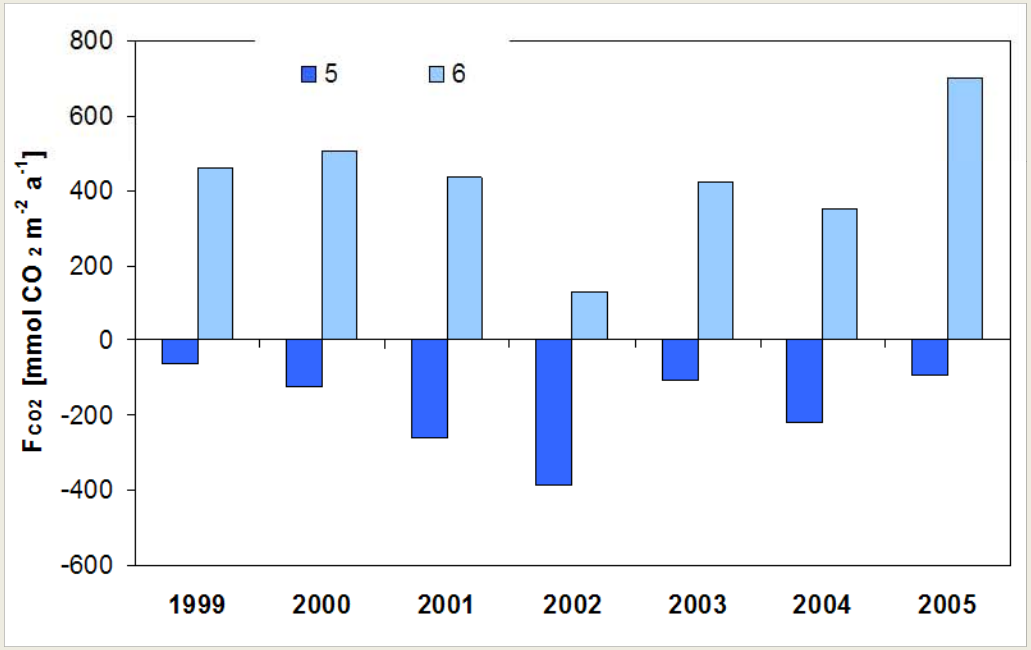
CO_2 - fluxes

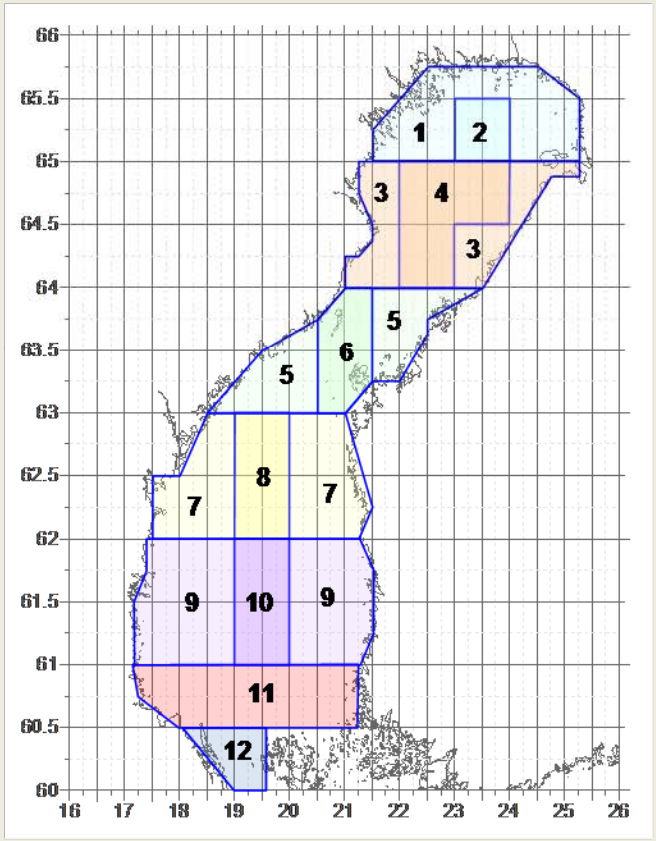
Annual fluxes of CO_2 in the grid elements of the Bothnian Bay



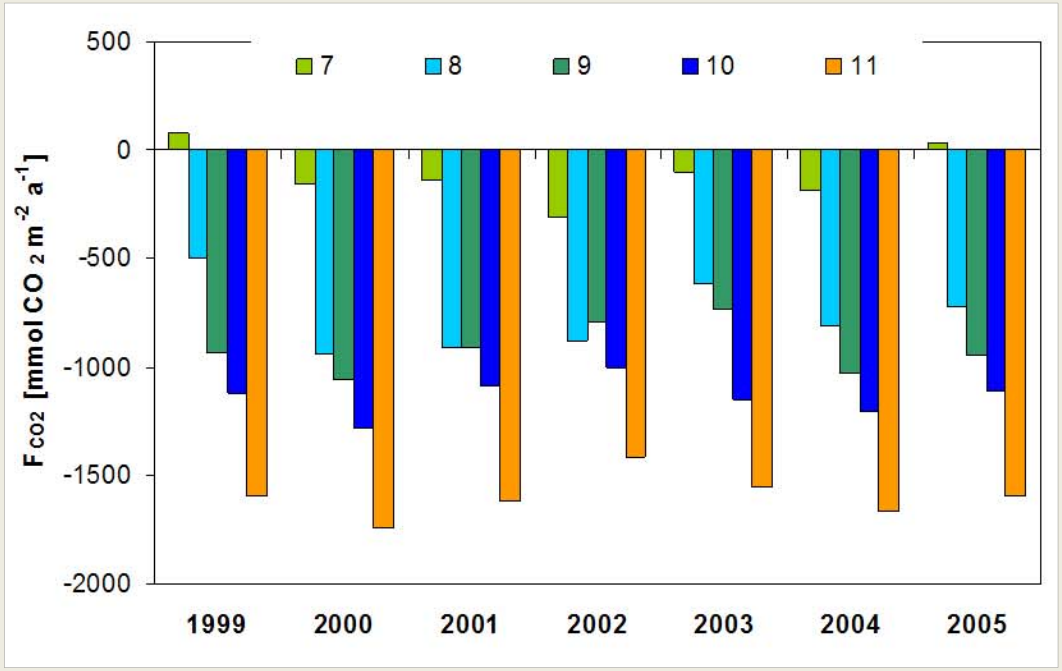


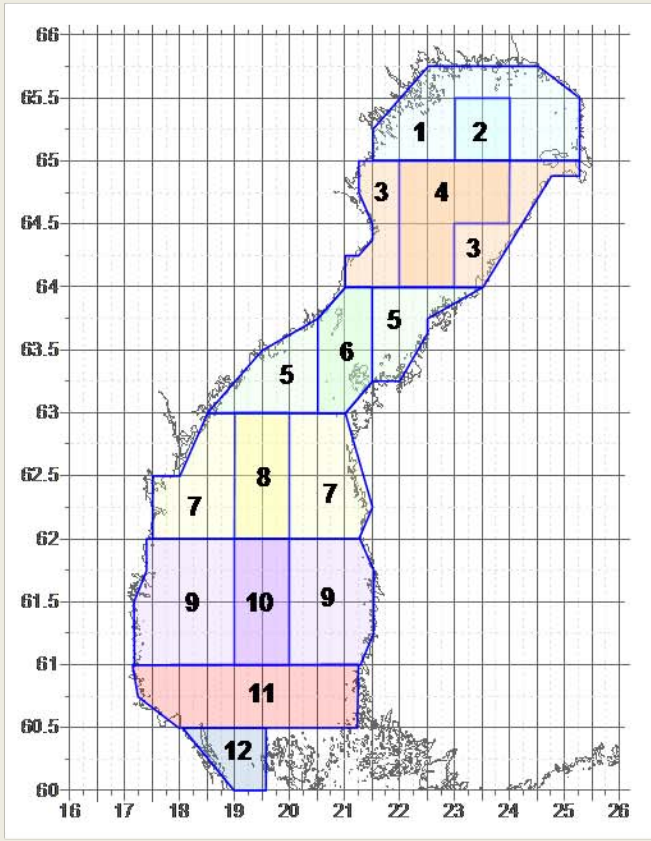
Annual fluxes of CO_2 in the grid elements of the Quark area



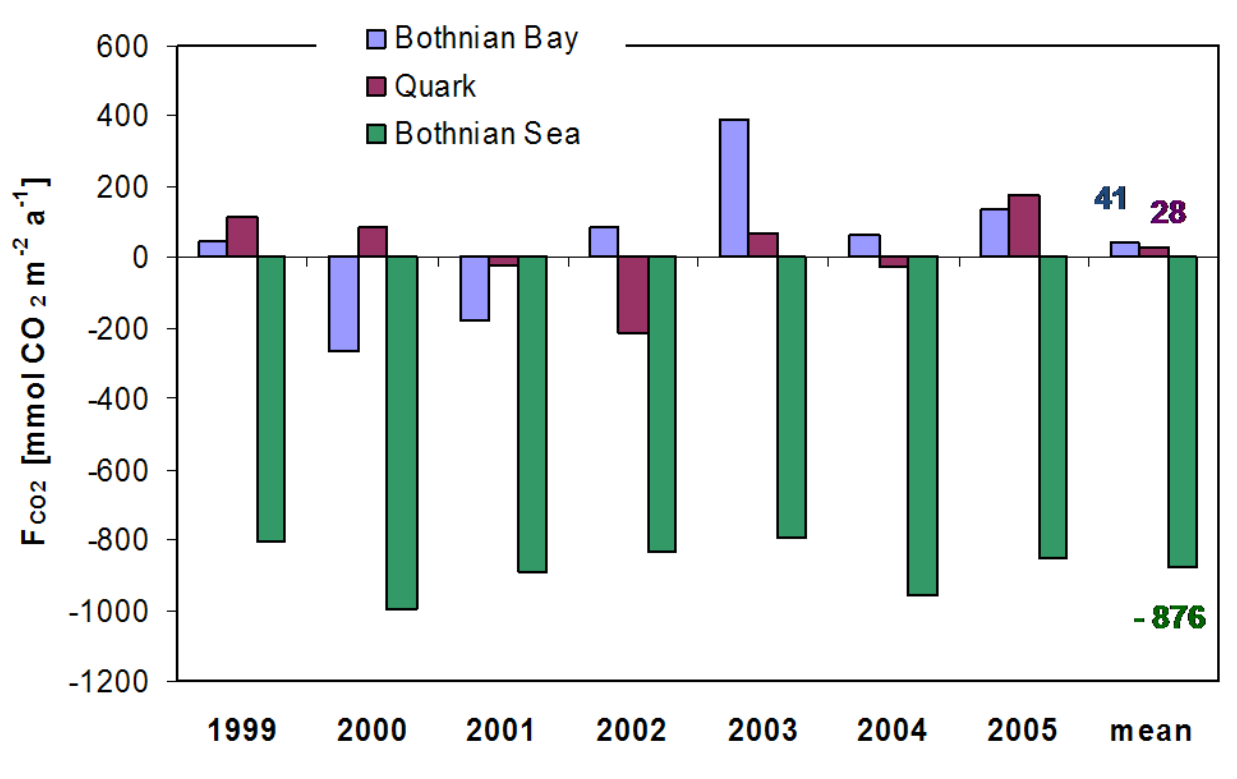


Annual fluxes of CO_2 in the grid elements of the Bothnian Sea





Annual fluxes of CO_2 in the Gulf of Bothnia



Gulf of Bothnia – a source or a sink for CO_2 in the atmosphere?

		Bothnian Bay	Bothnian Sea
F_{CO2} [mmol CO_2 m^{-2} a^{-1}]	**mean**	**41**	**-876**
		(-260 ... +390)	(-1000 ... -800)
	2002	86	-836
	Algesten 2002	3550	2600
Total annual emission [Gg C]	**mean**	**18**	**-694**
	2002	38	-662
	Algesten 2002	1132	2282

- depending on the meteorological conditions the Bothnian Bay can act as a sink or a source of CO_2
- central areas of the Bothnian Bay show a tendency to be a sink for CO_2
- coastal and shallow waters show a tendency to be a source for CO_2 (upwelling)
- in average the CO_2 in the surface waters of the Bothnian Bay is balanced with the atmosphere
- the Bothnian Sea is a significant sink for CO_2