A carbon system model for the Barents sea

- Model description and preliminary results

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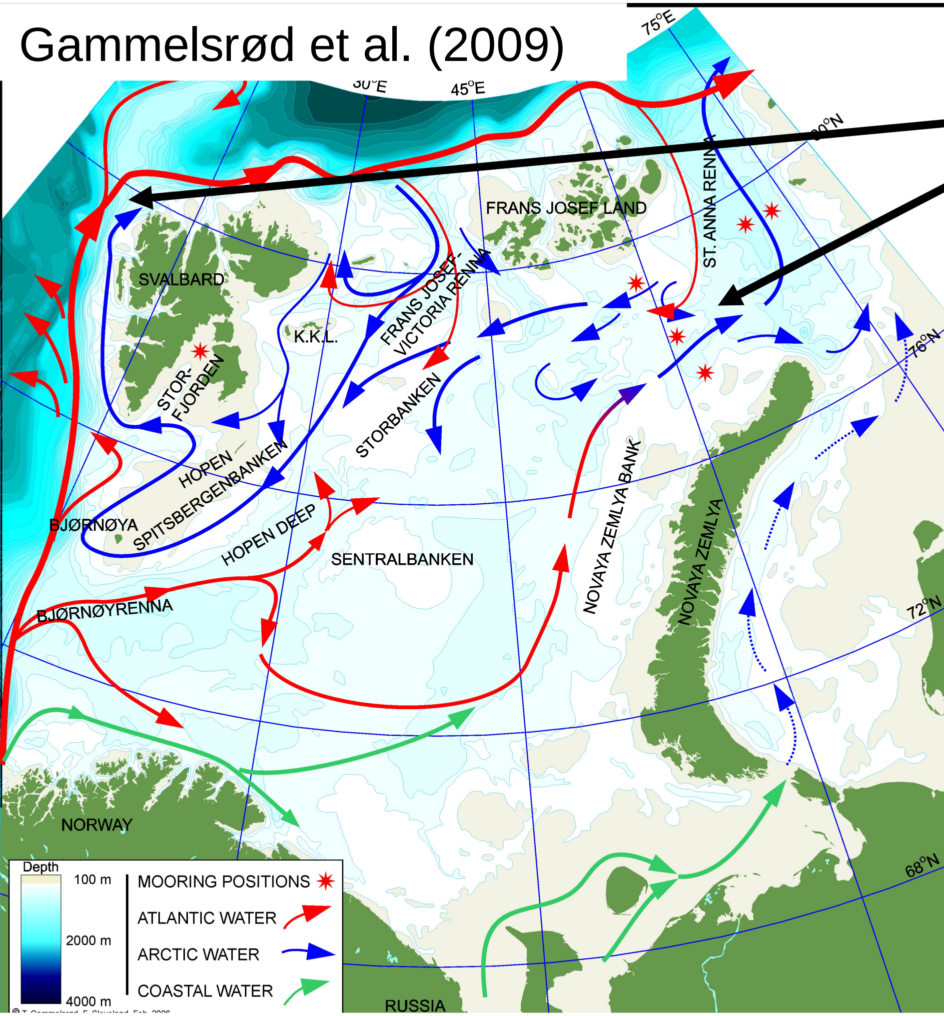
for Climate Research

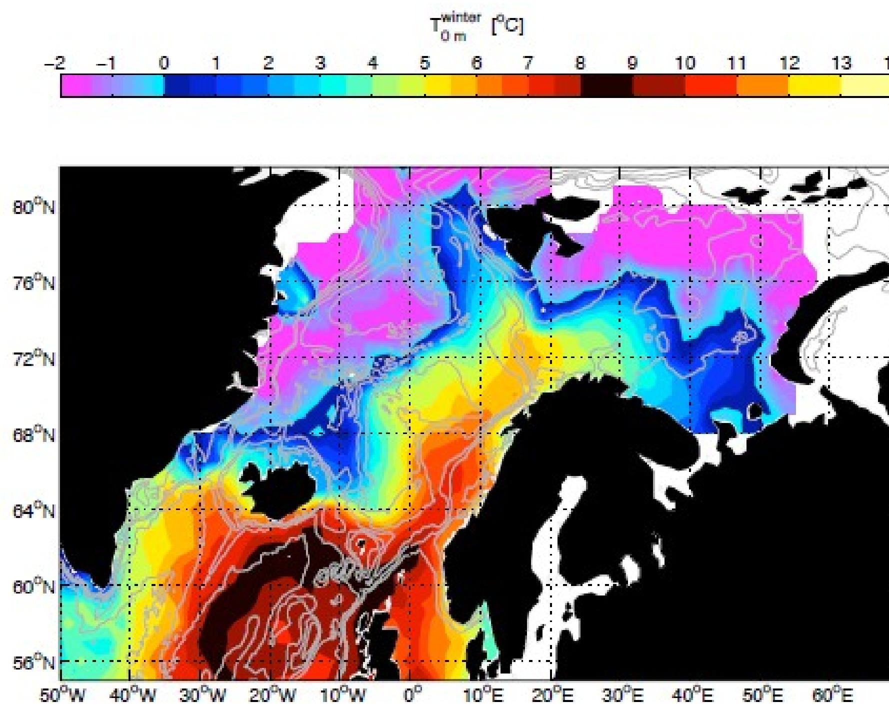
The Barents Sea

Gammelsrød et al. (2009)



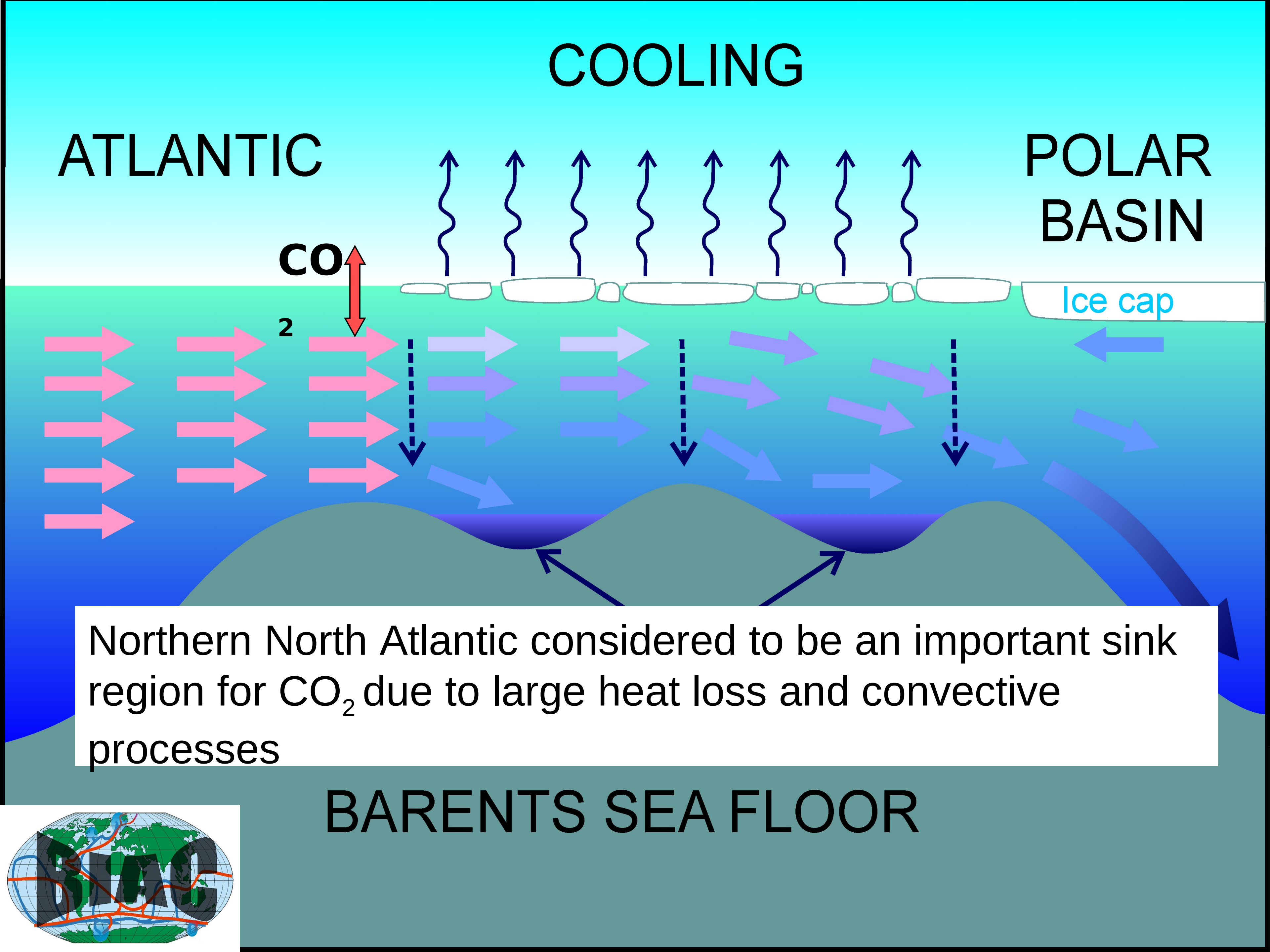
Two main branches of AW inflow to the Arctic: Fram Strait and Barents Sea

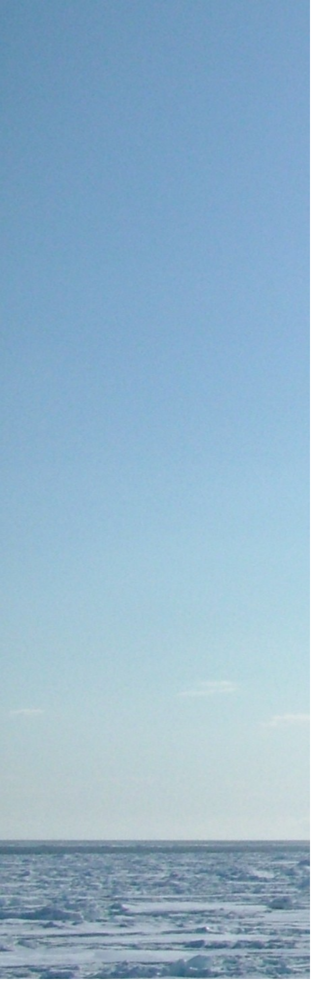
- Large heat loss
- Seasonal ice cover



NISE data: →

Nilsen et al (2008)


COOLING
ATLANTIC
POLAR
BASIN
CO_2
Ice cap
Northern North Atlantic considered to be an important sink region for CO_2 due to large heat loss and convective processes
BARENTS SEA FLOOR

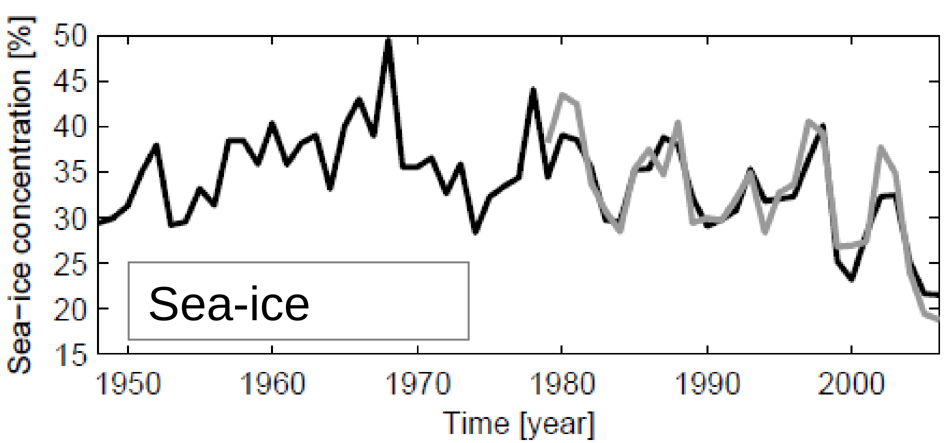


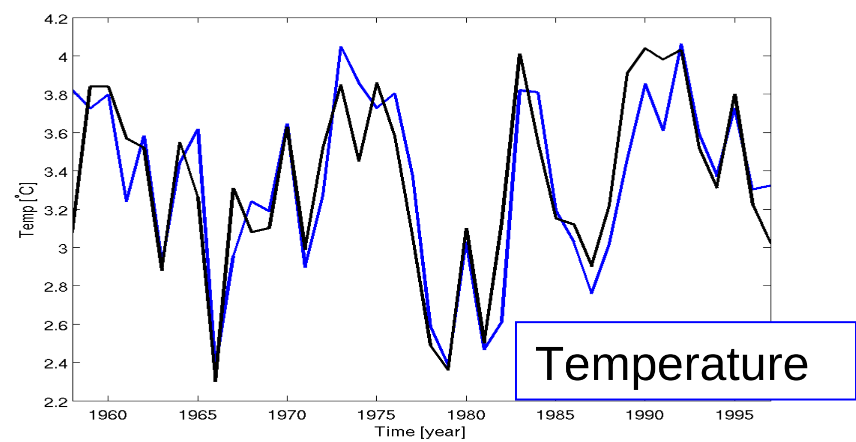
HAMSOM

- Hamburg Shelf Ocean Model
- 3D baroclinic, coupled ice-ocean model
- 7 km grid
- 16 z-levels
- NCEP atmospheric forcing
- T,S: BarKode
- M_2 tide included

Model

Obs.





Carbon in seawater

CO_2 hydration 1^{st} 2^{nd}

solution

dissociation step dissociation step

pCO_2 K_h K_1 K_2

$$CO_2^{gas} + H_2O \leftrightarrow H_2CO_3^{aq} \leftrightarrow HCO_3^- + H^+ \leftrightarrow CO_3^{2-} + 2H^+$$

carbonic bicarbonate proton carbonate

acid ion

ion

total alkalinity, seawater property determining dissociation of weak acids

$$A_T = [HCO_3^-] + 2[CO_3^{2-}] + [B(OH)_4^-] + [OH^-] - [H^+] + \text{small terms}$$

$$C_T = [CO_2 + H_2CO_3] + [HCO_3^-] + [CO_3^{2-}]$$

total carbon /

dissolved inorganic carbon

If 2 of the variables are known, all the others can be computed

HAMSOM

T, S

K_1, K_2, K_h, K_w, K_b

pCO_2(sw), A_T

$S_0 = pCO_2 \cdot K_h$

$C_{T0} = s_0(1+K+/h+K+\cdot K_2/h/h)$

- Use empirical relationships to estimate alkalinity, seawater CO_2 partial pressure, and dissociation constants

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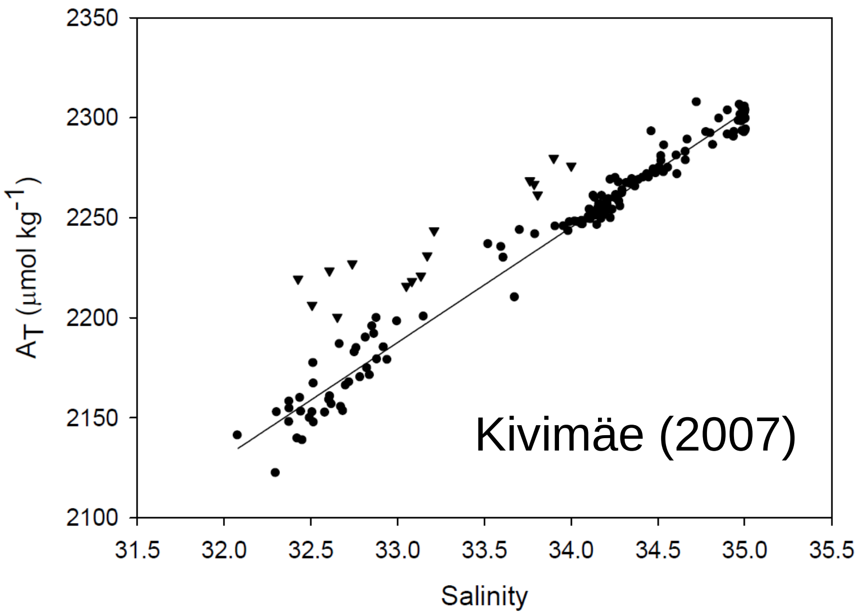
Carbon system model

- *Use empirical relationships to estimate alkalinity, seawater CO_2 partial pressure, and dissociation constants*



Barents Sea:

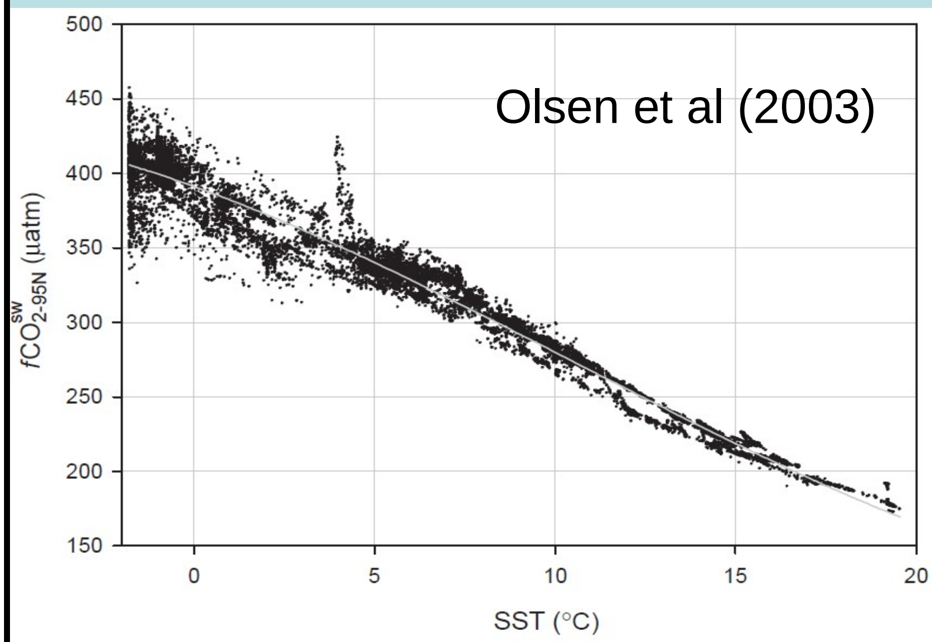
TAlk = 57.6·S + 288

R^2 = 0.98

Northern North Atlantic:

$fCO_2 = 391.13 - 8.71 \cdot T - 0.36 \cdot T^2 + 0.011 \cdot T^3$

R^2 = 0.97



Carbon system model

$$
\begin{aligned}
K_0 &= [CO_2]/pCO_2^w \\
lnK_0 &= 9345.17/T - 60.2409 + 23.3585 \cdot log(T/100) \\
&\quad + S \cdot \left(0.023517 - 0.00023656 \cdot T + 0.0047036(T/100)^2\right) \\
K_1 &= [H^+][HCO_3^-]/[CO_2] \\
pK1 &= 3633.86/T - 61.2172 + 9.6777 \cdot log(T) - 0.011555 \cdot S + 0.0001152 \cdot S^2 \\
K_2 &= [H^+][CO_3^{2-}]/[HCO_3^-] \\
pK2 &= 471.78/T + 25.9290 - 3.16967 \cdot log(T) - 0.01781 \cdot S + 0.0001122 \cdot S^2 \\
K_b &= [H^+][B(OH)_4^-]/[B(OH)_3] \\
lnK_b &= (-8966.90 - 2890.53 \cdot S^{1/2} - 77.942 \cdot S + 1.728 \cdot S^{3/2} - 0.0996 \cdot S^2)/T \\
&\quad + 148.0248 + 137.1942 \cdot S^{1/2} + 1.62142 \cdot S + (-24.4344 - 25.085 \cdot S^{1/2} - 0.2474 \cdot S) \\
&\quad \cdot log(T) + 0.053105 \cdot S^{1/2} \cdot T \\
K_w &= [H^+][OH^-] \\
lnK_w &= -13847.26/T + 148.96502 - 23.6521 \cdot log(T) \\
&\quad + (118.67/T - 5.977 + 1.0495 \cdot log(T)) \cdot S^{1/2} - 0.01615 \cdot S
\end{aligned}
$$

Mehrbach et al (1973), Lueker et al (2000), Dickson (1990), Millero (1995), Weiss (1974)

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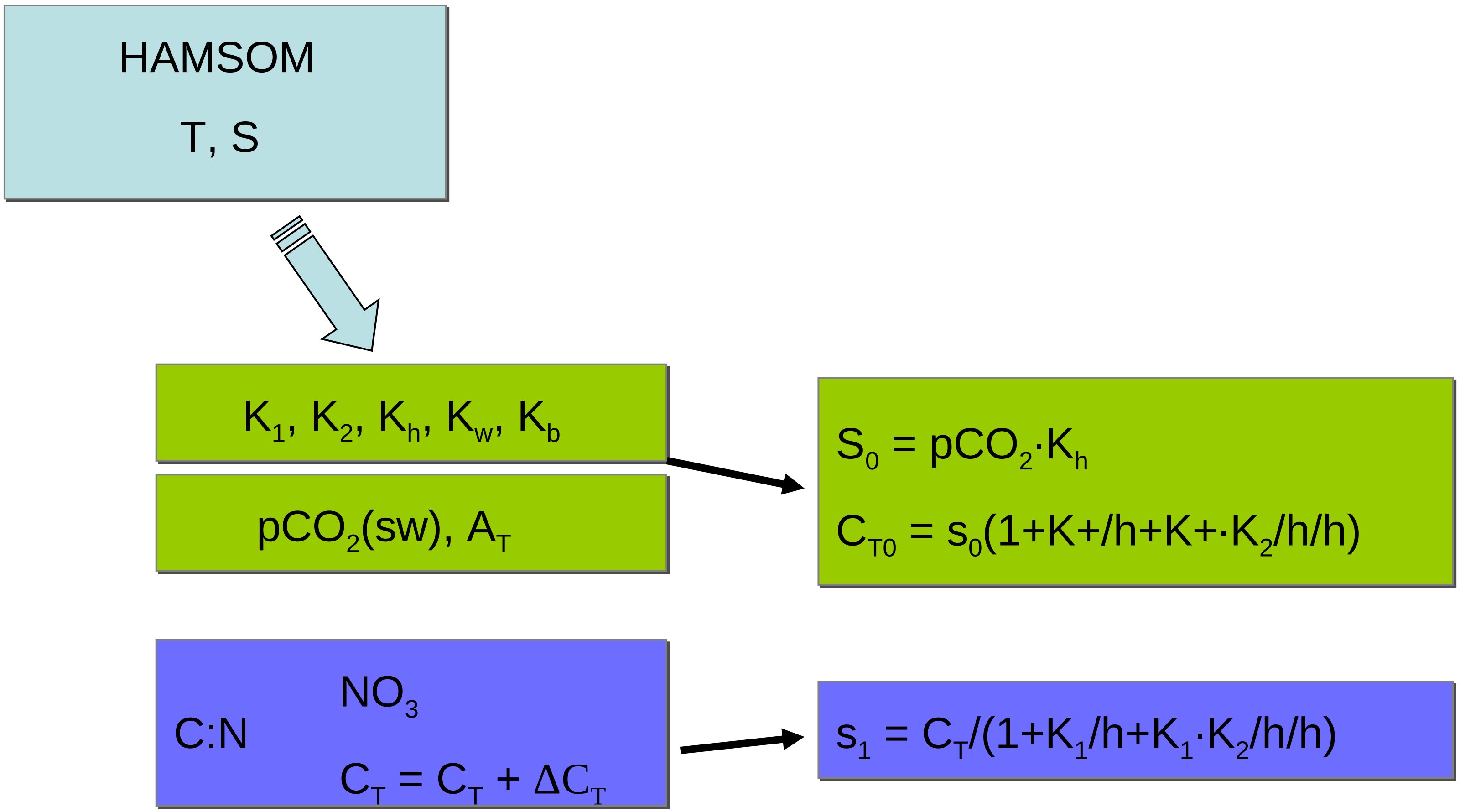


Photosynthesis => consumption of carbon

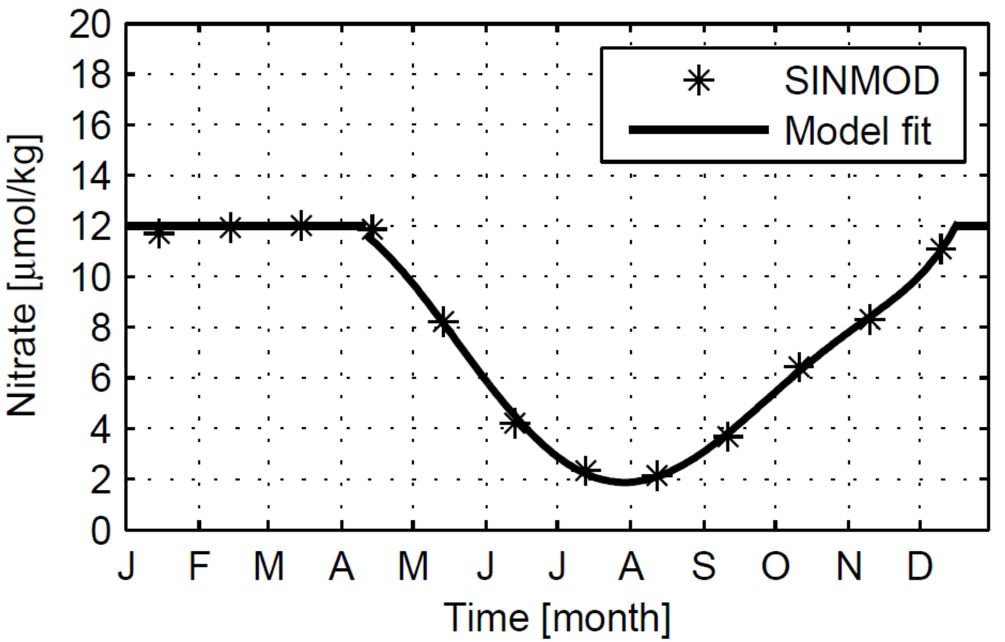
Nutrients (nitrate) important to biological activity

Carbon system model

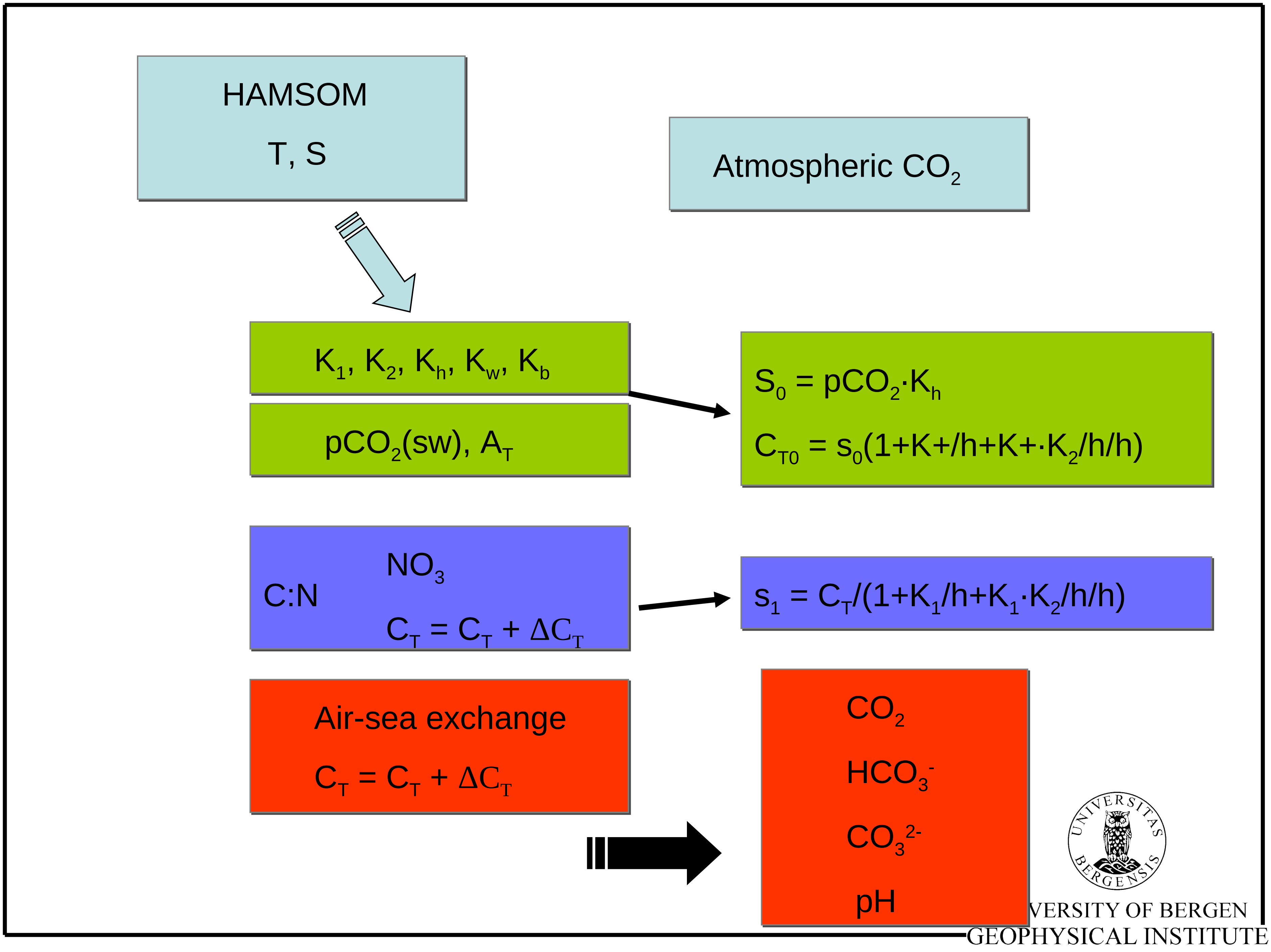
- *Biology/nutrients considered using a mean seasonal cycle of nitrate (NO_3).*

C:N = 8.75

Takahashi et al (1985), Kaltin et al (2002), Kivimäe (2007), Findlay et al (2008)



Seasonal cycle based on data from SINMOD, 2002-2006.


HAMSOM
T, S
Atmospheric CO_2
K_1, K_2, K_h, K_w, K_b
$pCO_2(sw)$, A_T
$S_0 = pCO_2 \cdot K_h$
$C_{T0} = s_0(1+K+/h+K+ \cdot K_2/h/h)$
C:N
NO_3
$C_T = C_T + \Delta C_T$
$s_1 = C_T/(1+K_1/h+K_1 \cdot K_2/h/h)$
Air-sea exchange
$C_T = C_T + \Delta C_T$
CO_2
HCO_3^-
CO_3^{2-}
pH
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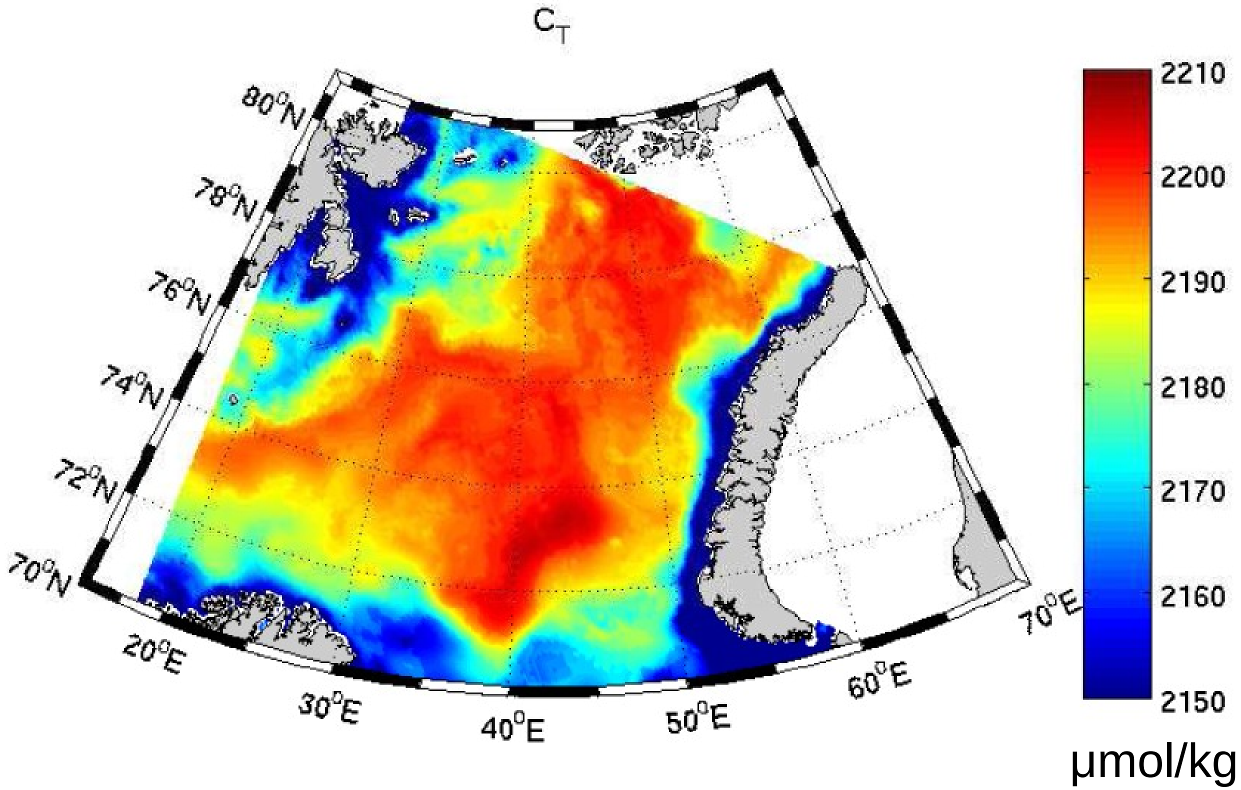
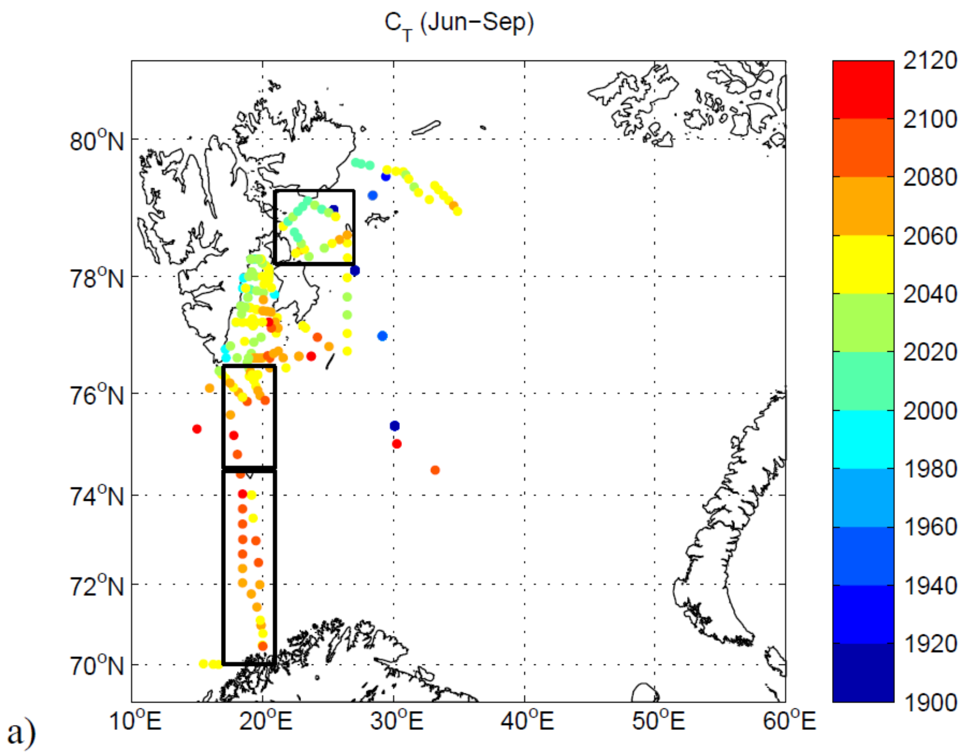
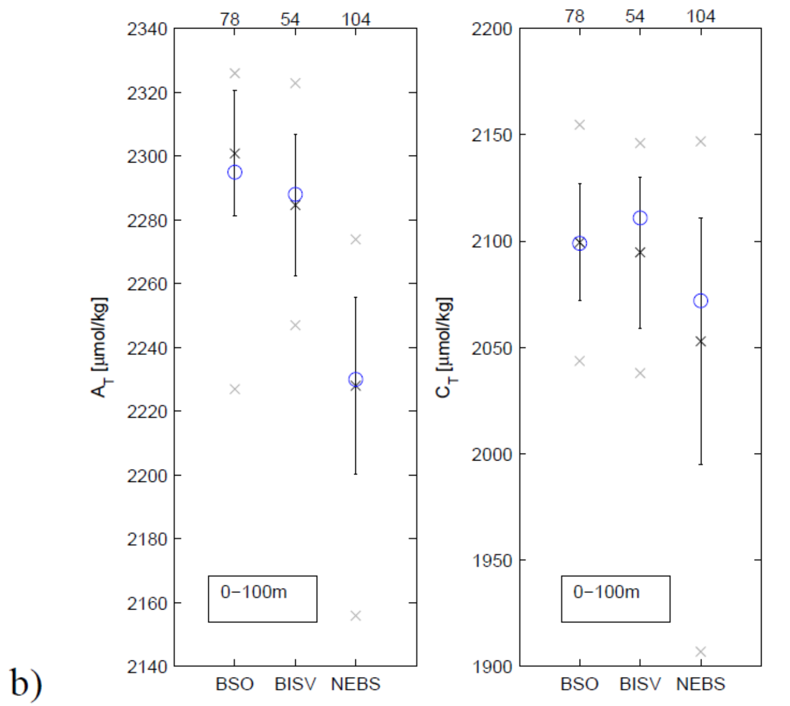
Results – C_T



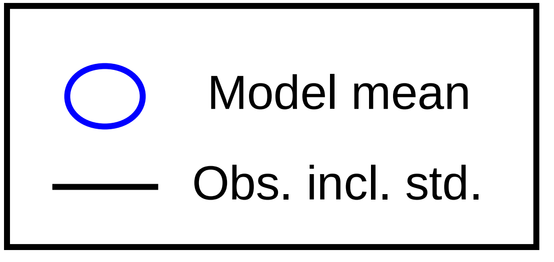
- Influenced by warm, saline Atlantic Water, fresher coastal water and cold Arctic Water
- Annual mean CT ~ 2150-2200 µmol/kg

Results – C_T & A_T





CARINA data 2000-2003



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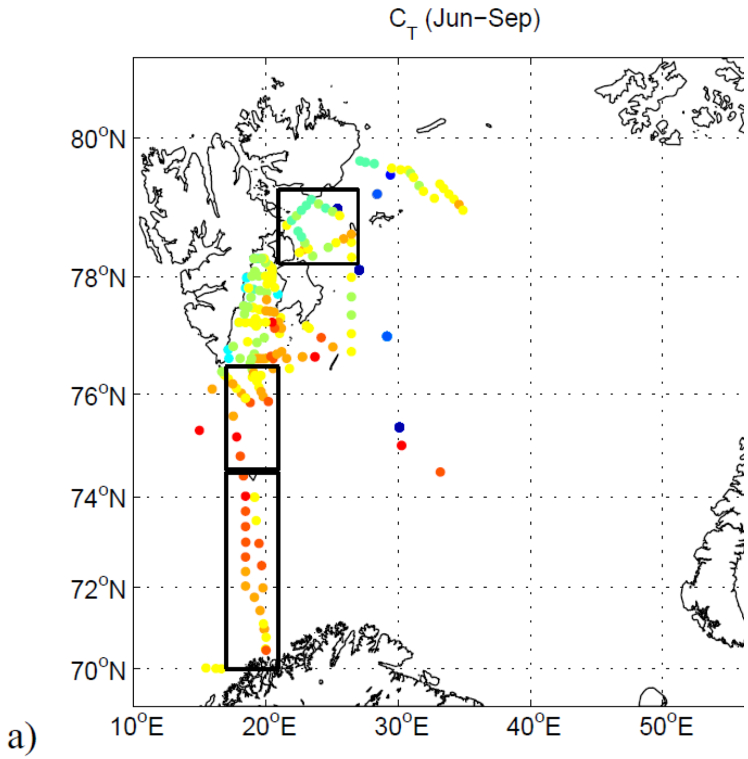
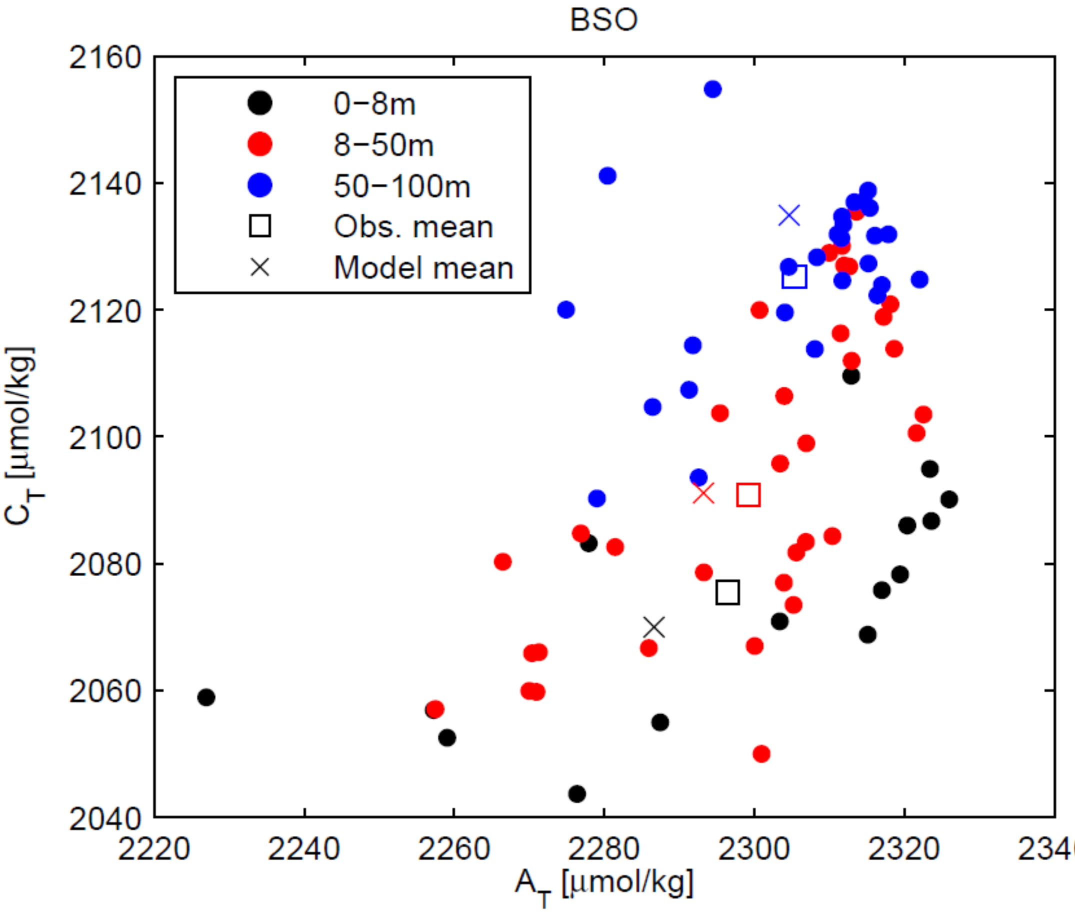
Results – C_T & A_T





CARINA data 2000-2003

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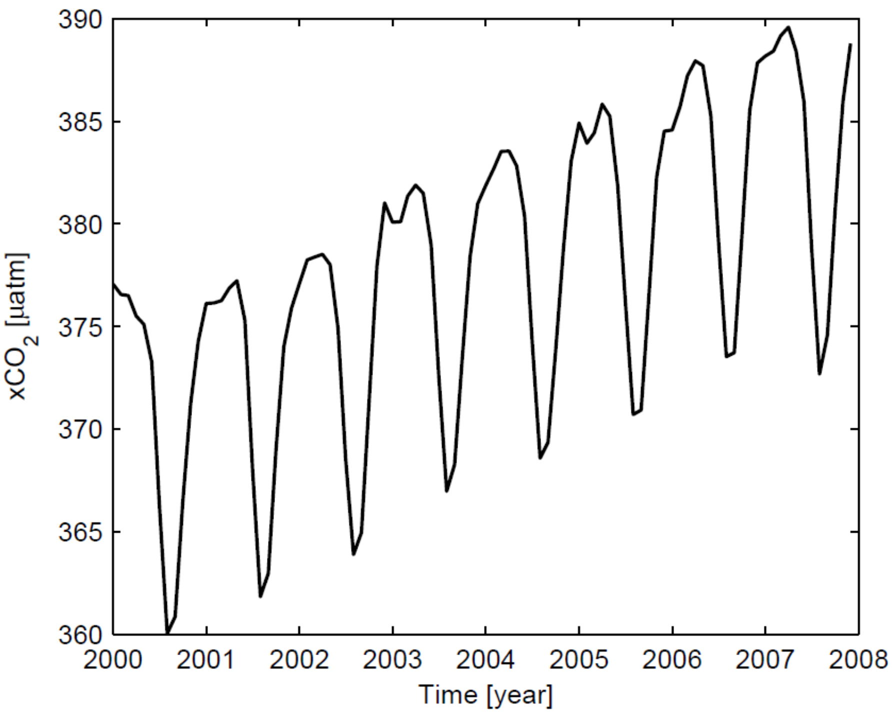
Air-sea CO_2 flux

$$F = K_0 \cdot k \cdot (pCO_2^a - pCO_2^w)$$

$$k = 0.26(Sc/660)^{-1/2} W^2$$



K_0: solubility of CO_2 in seawater

k: gas transfer velocity (Wanninkhof)

pCO2w: calculated (Zeebe & Wolf-Gladrow, 2001)

pCO2a: prescribed (Ny-Ålesund)

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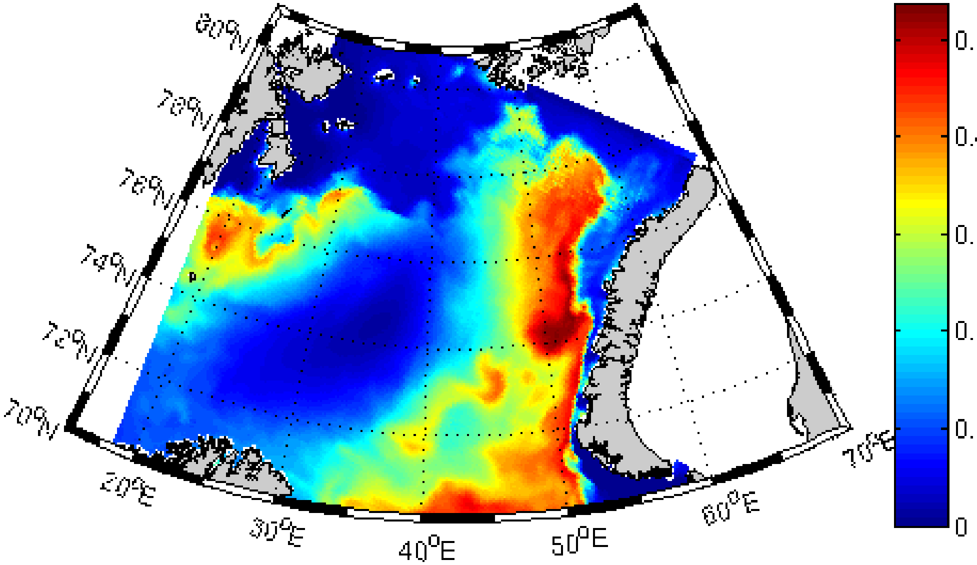
The Barents Sea is a sink of atmospheric CO_2

To be investigated:

- regional variability
- seasonal cycle
- interannual variability

10.02.2000



mol·m^{-2}·month^{-1}

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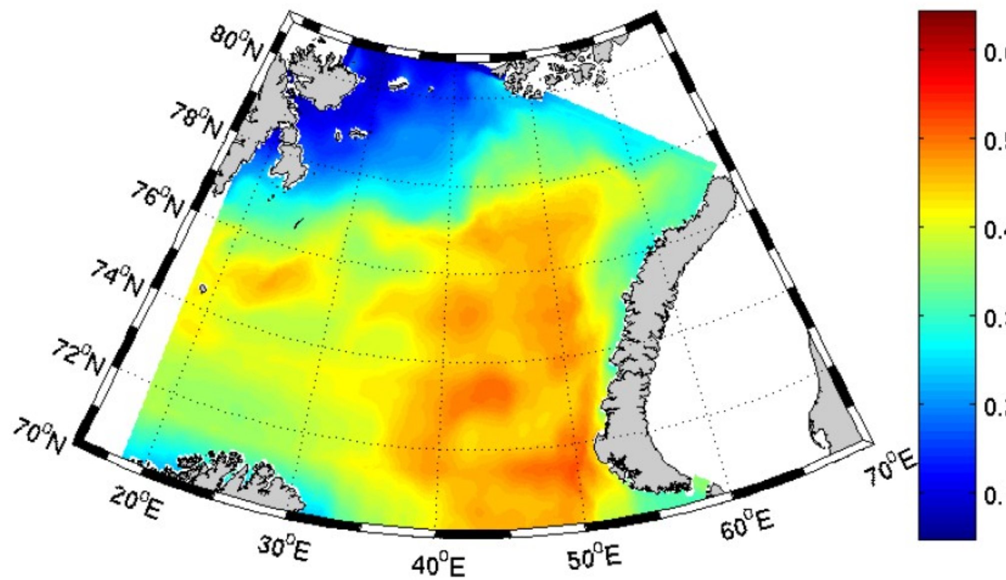
Annual mean



$mol \cdot m^{-2} \cdot month^{-1}$

Air-sea CO_2 flux

$$F = K_0 \cdot k \cdot (pCO_2^a - pCO_2^w)$$

K_0: solubility of CO_2 in seawater

k: gas transfer velocity (wind speed)

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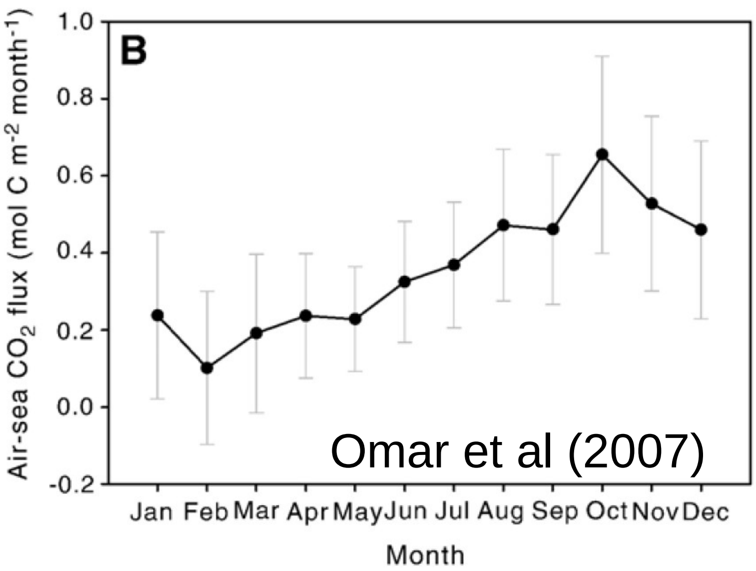

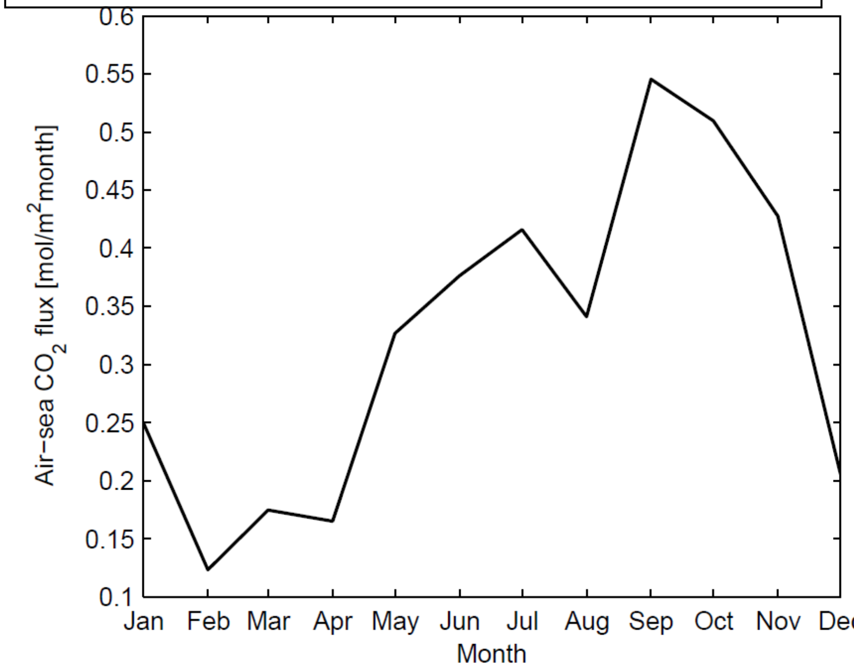

$mol \cdot m^{-2} \cdot month^{-1}$

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Summary

- *An idealized carbon system model is successfully applied to the Barents Sea*
- *Dissolved inorganic carbon (C_T) and total alkalinity close to observed values*
- *The Barents Sea acts as a sink for atmospheric CO_2*

- *Evaluation of empirical relationships*
- *Investigate interannual variability*
- *Processes important to CO_2 fluxes, including C_T release during sea-ice formation*

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Thank you

Questions??

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