Air-sea ice CO_2 fluxes measurement with eddy-covariance micrometeorological technique

B. Heinesch[1],
M. Aubinet[1], G. Carnat[3], N.-X. Geilfus[2], T. Goossens[5], H. Eicken[4], T. Papakyriakou[3],
C. Petrich[4], J-L. Tison[5], M. Yernaux[1], B. Delille[2]

[1] Gembloux Agricultural University, Physique des Bio-systèmes, Gembloux, Belgium (FUSAGx)

[2] University of Liège, Unité d'Océanographie Chimique, Interfacultary Centre for Marine Research, Liège, Belgium (ULG)

[3] University of Manitoba, Centre for Earth Observation Science, Winnipeg, Canada

[4] University of Alaska Fairbanks, Geophysical Institute, Fairbanks, USA

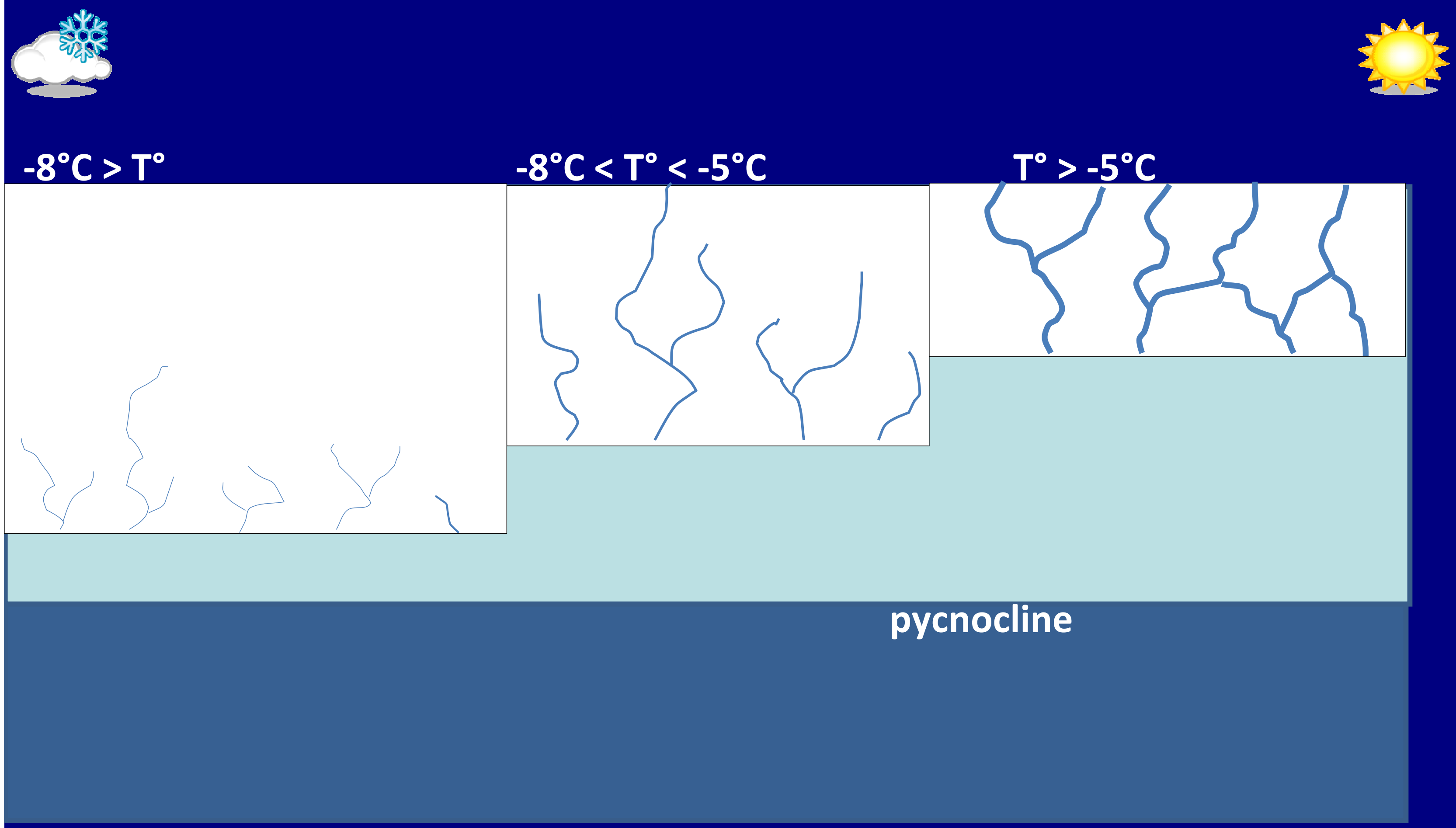
[5] Université Libre de Bruxelles, Glaciology Unit, Department of Earth and Environmental Science, Bruxelles, Belgium (ULB)

42nd International Liège Colloquium on Ocean Dynamics, Liège, Belgique , April 26-30 2010

- There are evidences that, in some conditions, sea-ice can be permeable for gas and that CO_2 gradients exist between the brines and the atmosphere.

- Ice-covered oceanic zones are not taken into account in the current ocean CO_2 budget estimations

From talk of Manizza, 8th ICDC, Jena

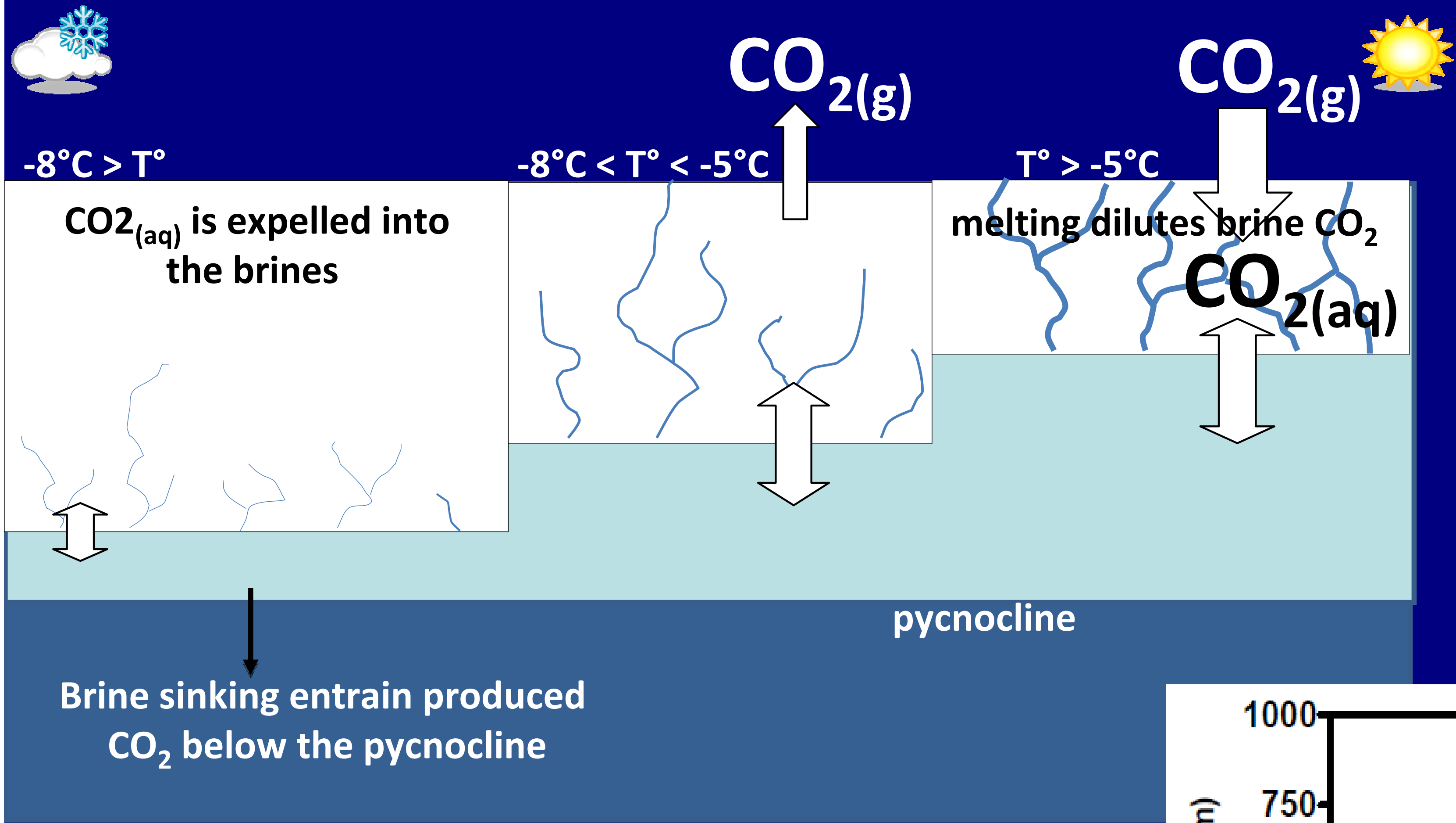


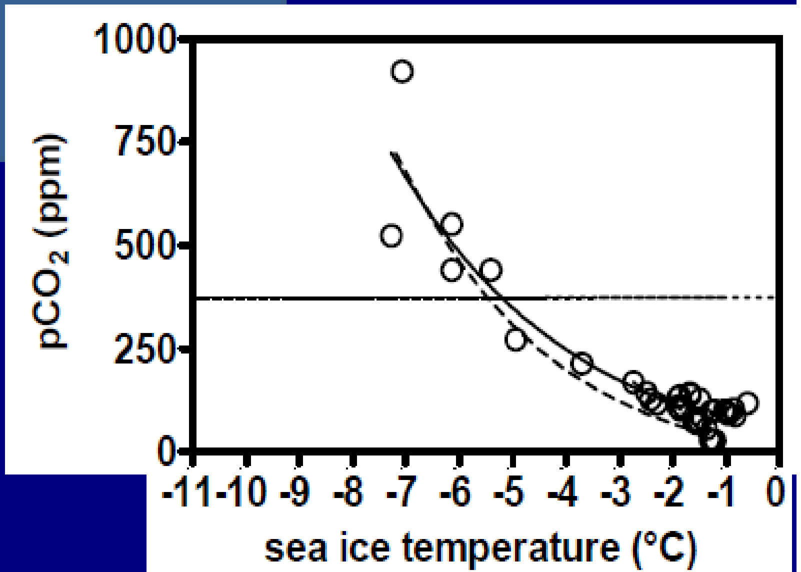
Key processes governing CO_2 exchanges

-

-

-

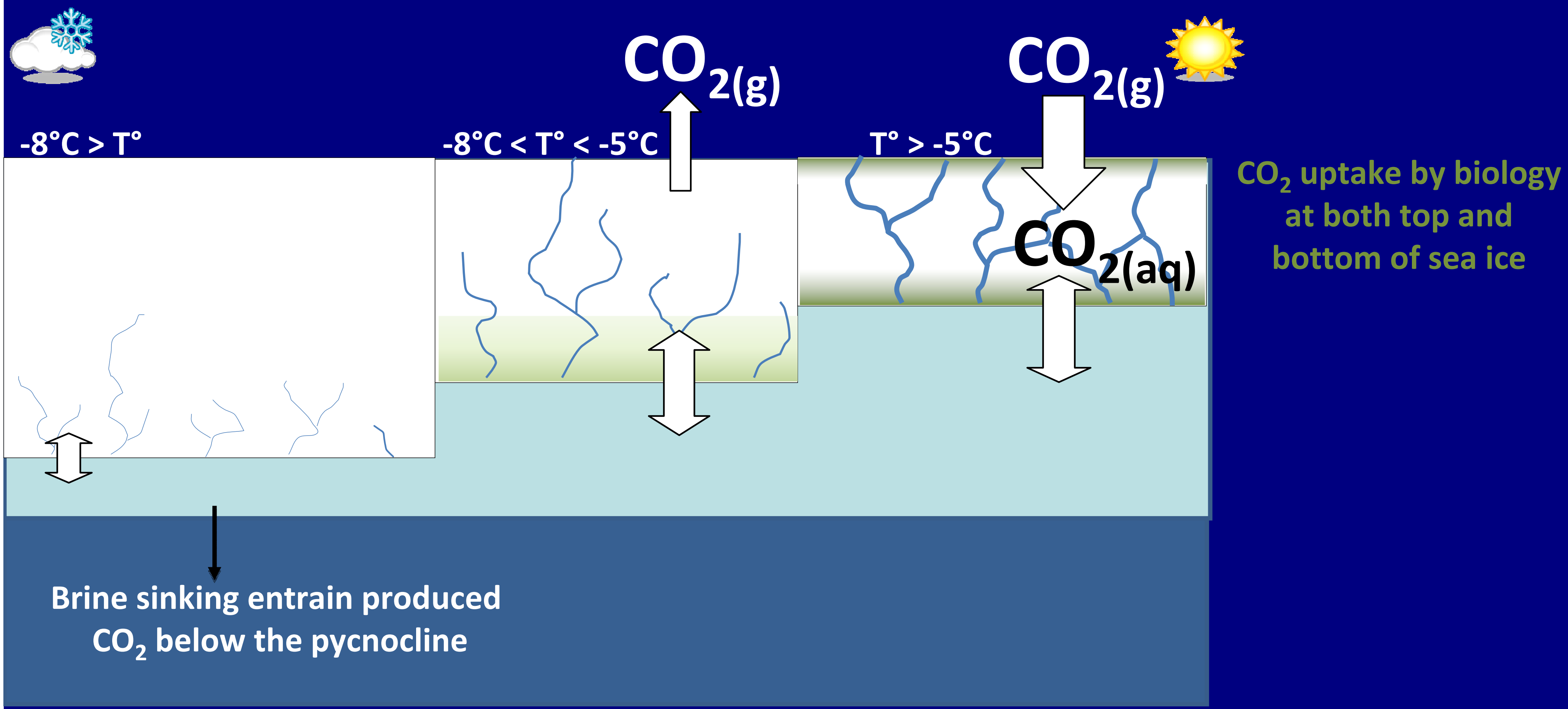




Delille B. (pers. com.)

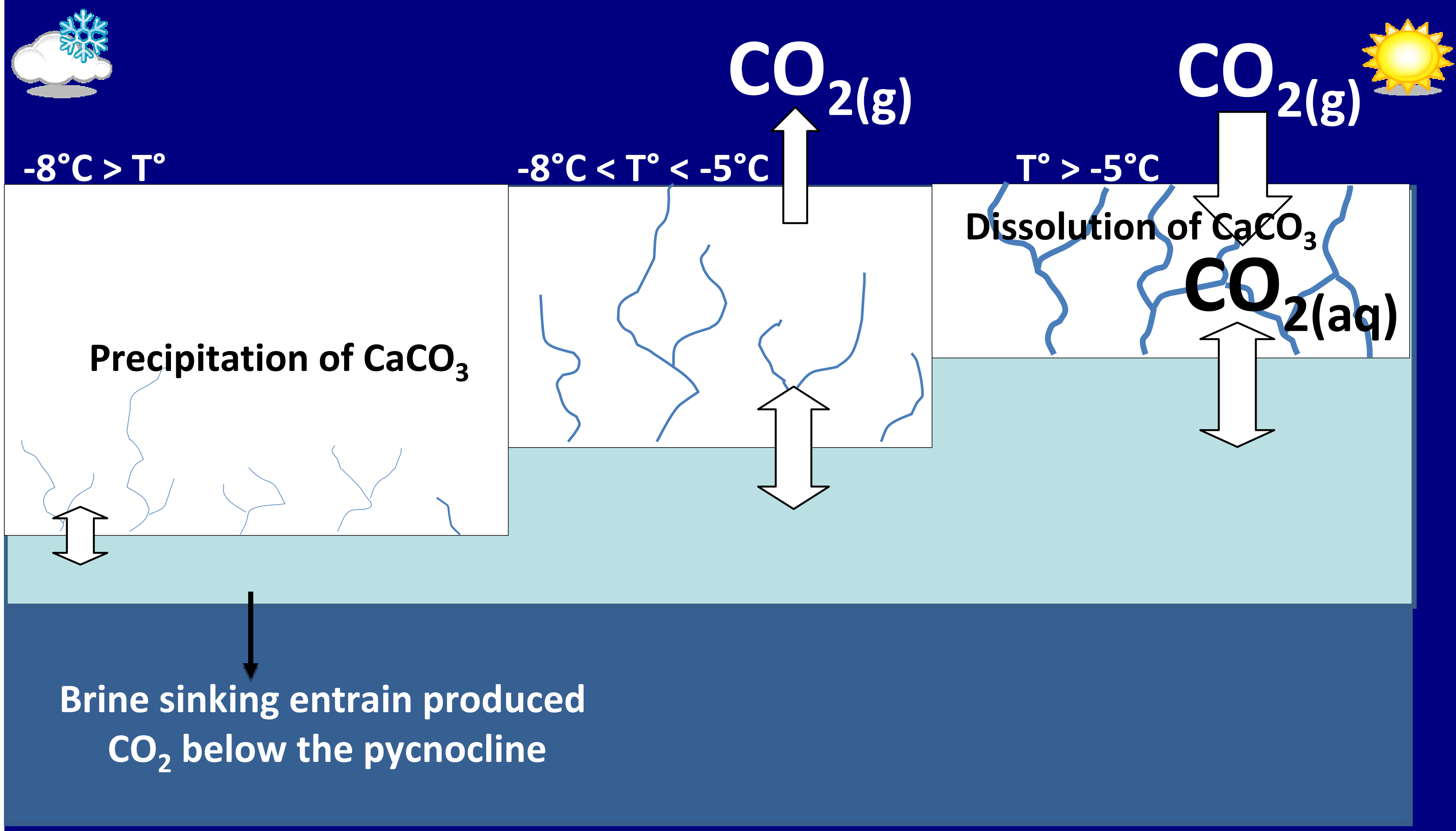
Key processes governing CO_2 exchanges

- physical: concentration/dilution effect
-
-



Key processes governing CO_2 exchanges

- physical: concentration/dilution effect
- biological: primary production
-



Key processes governing CO_2 exchanges

- physical: concentration/dilution effect
- biological: primary production
- chemical: precipitation/dissolution of CaCO3

Overview of published field work on CO_2 fluxes above sea-ice

- Previous direct estimates of CO_2 fluxes above sea-ice are rare, sparse and incomplete

Reference	Duration (days)	Sea-ice type	CO2 flux (mgCO2 m-2 s-1)	Method	Date	location
Semiletov et al., 2004	18	Fast-land, melt-ponds?	-0.03 to +0.02	EC, OP	June 2002	Barrow, Alaska
Zemelink et al., 2006	23	Multi-year flooded	-0.01 to +0.002	EC, OP	Dece mber 2004	Weddell Sea
Delille et al., 2007	-	First-year, unflooded	-0.002 to +0.001	Chambers		Weddell Sea

⇒ **Main goals of this survey**

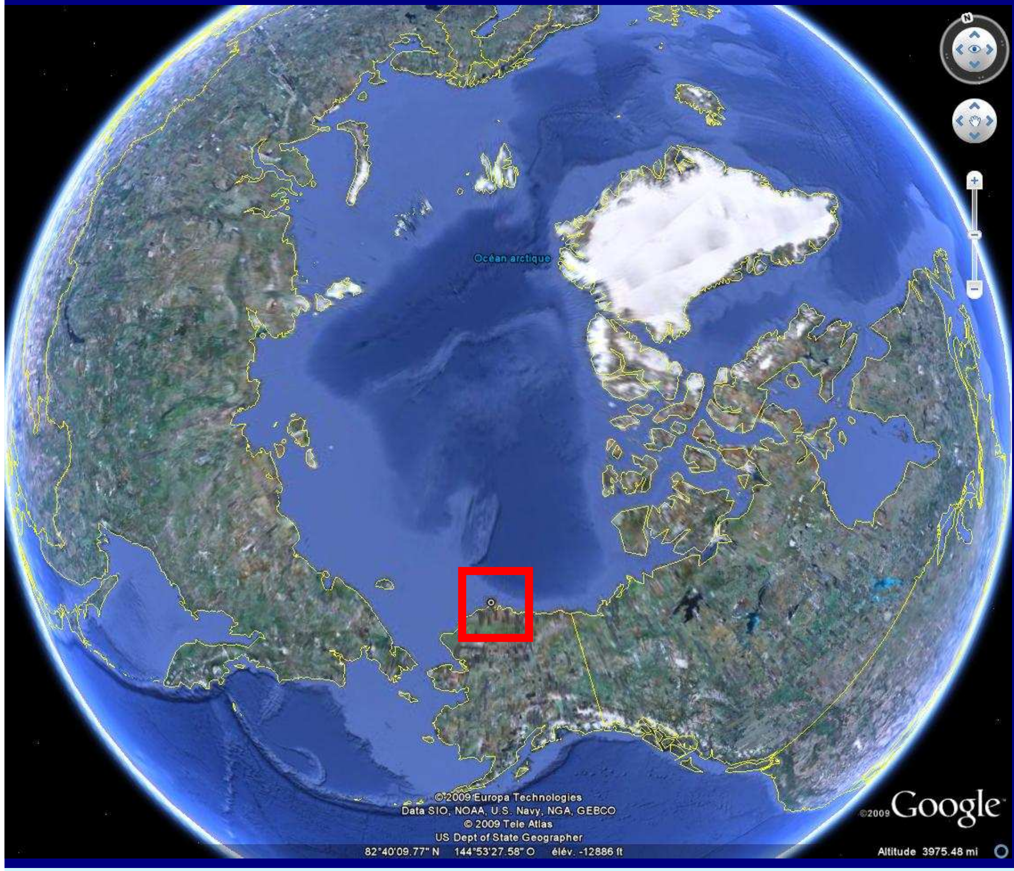
- to robustly track CO_2 exchange between land-fast sea-ice and the atmosphere during the winter and spring season
- to analyse these fluxes in respect with physical and biochemical properties of sea-ice
- to produce a CO_2 budget for sea-ice

Site

Flat first-year land-fast sea-ice near Barrow (Alaska), 1 km off the coast.

The source area for EC measurements at 2.8 m was well within the boundaries of the floe.

Duration: from the end of January 2009 to the beginning of June 2009, before ice break-up.

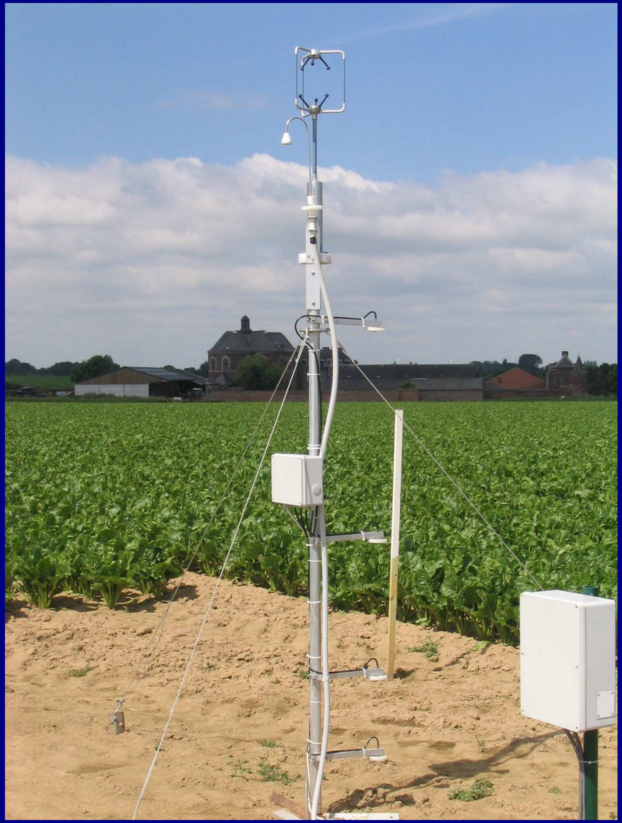


Experimental setup: main characteristics

Micro-meteorological mast (eddycovariance)

CO_2 sampling	: 10Hz
IRGA	: 1 LiCor 7000
Sonics	: 1 Csat3
Measurement height	: 2.8 m
Data acquisition	: CR3000

Standard methodology
for flux computation
- closed path CO_2 analyser
- detection limit



Time resolution : ½ hour

Spatial resolution : 1 km^2

Number of flux towers : > 300

Experimental setup: main characteristics

Micro-meteorological mast (eddycovariance)

CO_2 sampling	: 10Hz	Standard methodology for flux computation
IRGA	: 1 LiCor 7000	- closed path CO_2 analyser
Sonics	: 1 Csat3	- detection limit
Measurement height	: 2.8 m	
Data acquisition	: CR3000	

The micro-met. final dataset consisted 45 days of reliable CO_2 flux data

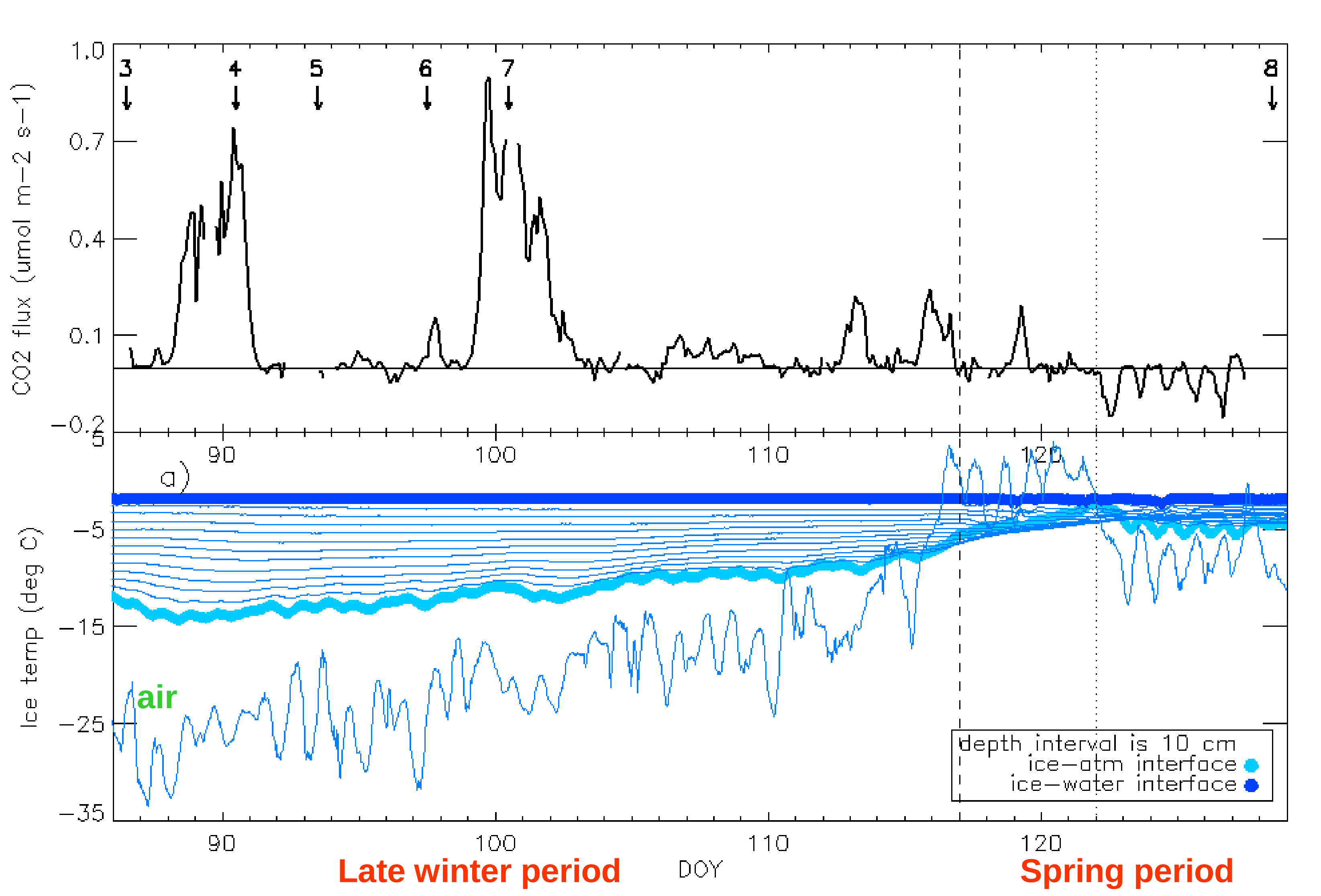
Automatic mass balance station

Ice temperature and thickness
Air temperature and humidity
Snow depth
Water temperature and depth

Ice coring (10 stations)

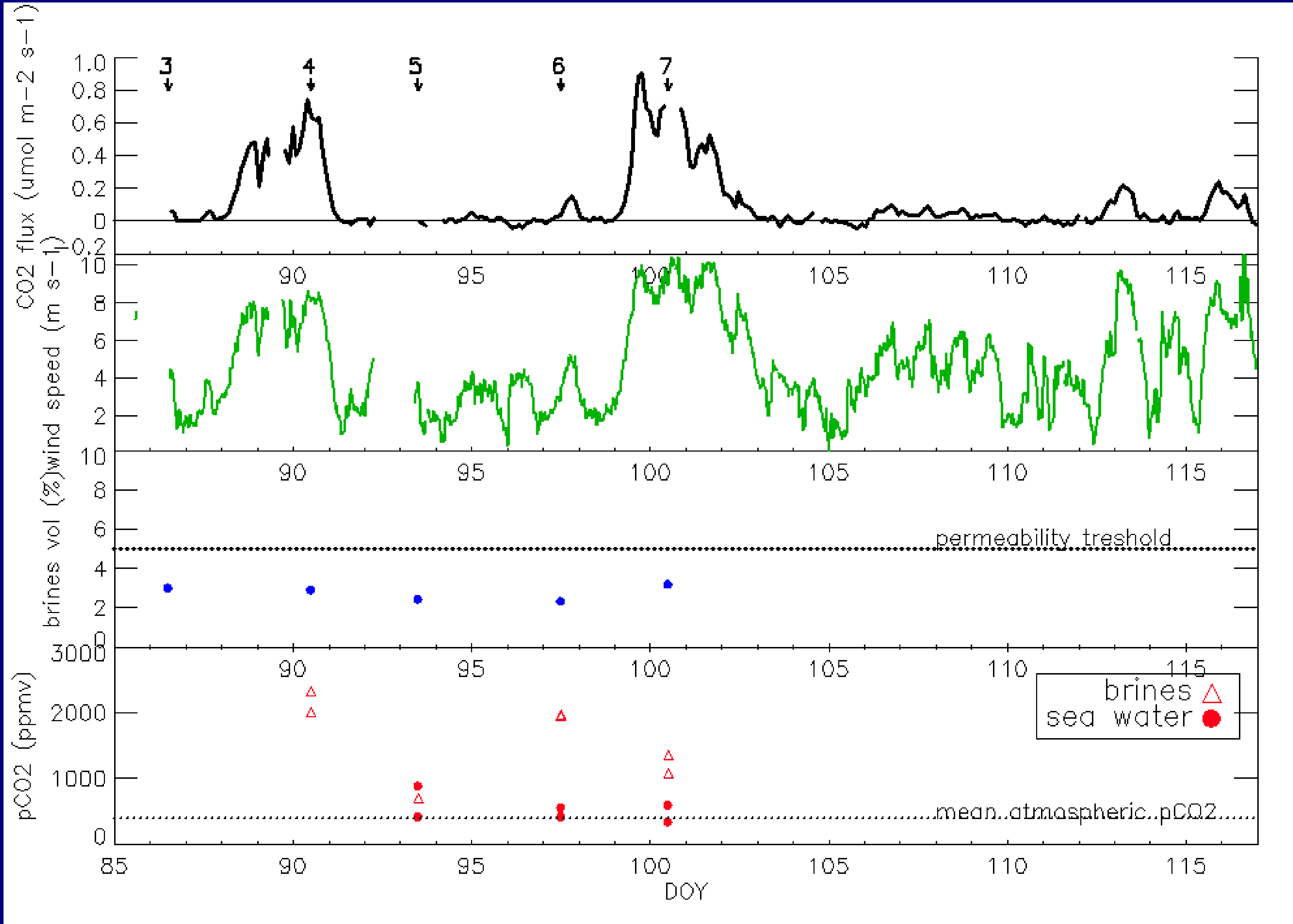
Brines pCO_2
Brines POC
DIC, Alkalinity
Chlorophyll a
Ice texture

CO_2 flux and ice temperature profile



Around day 117, onset of substantial convection throughout much of the ice column as the ice warms and allows forced convection (due to the hydraulic head of the brine above freeboard level) to occur.

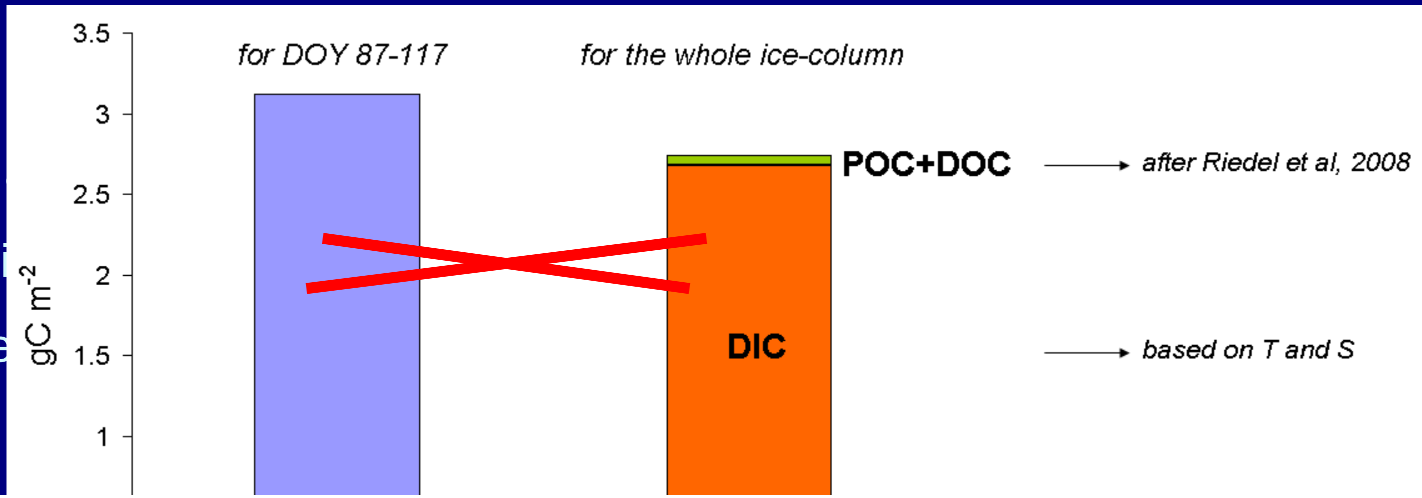
“Late winter” regime

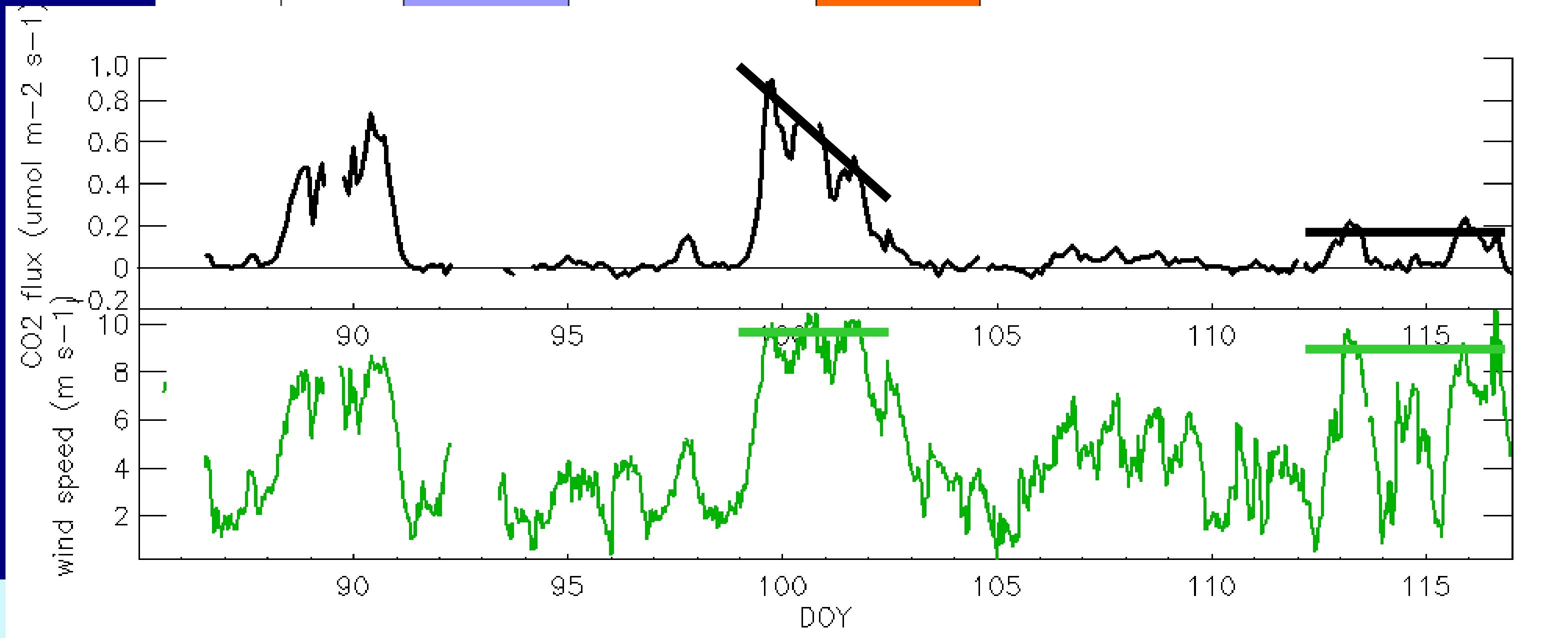


“Late winter” regime

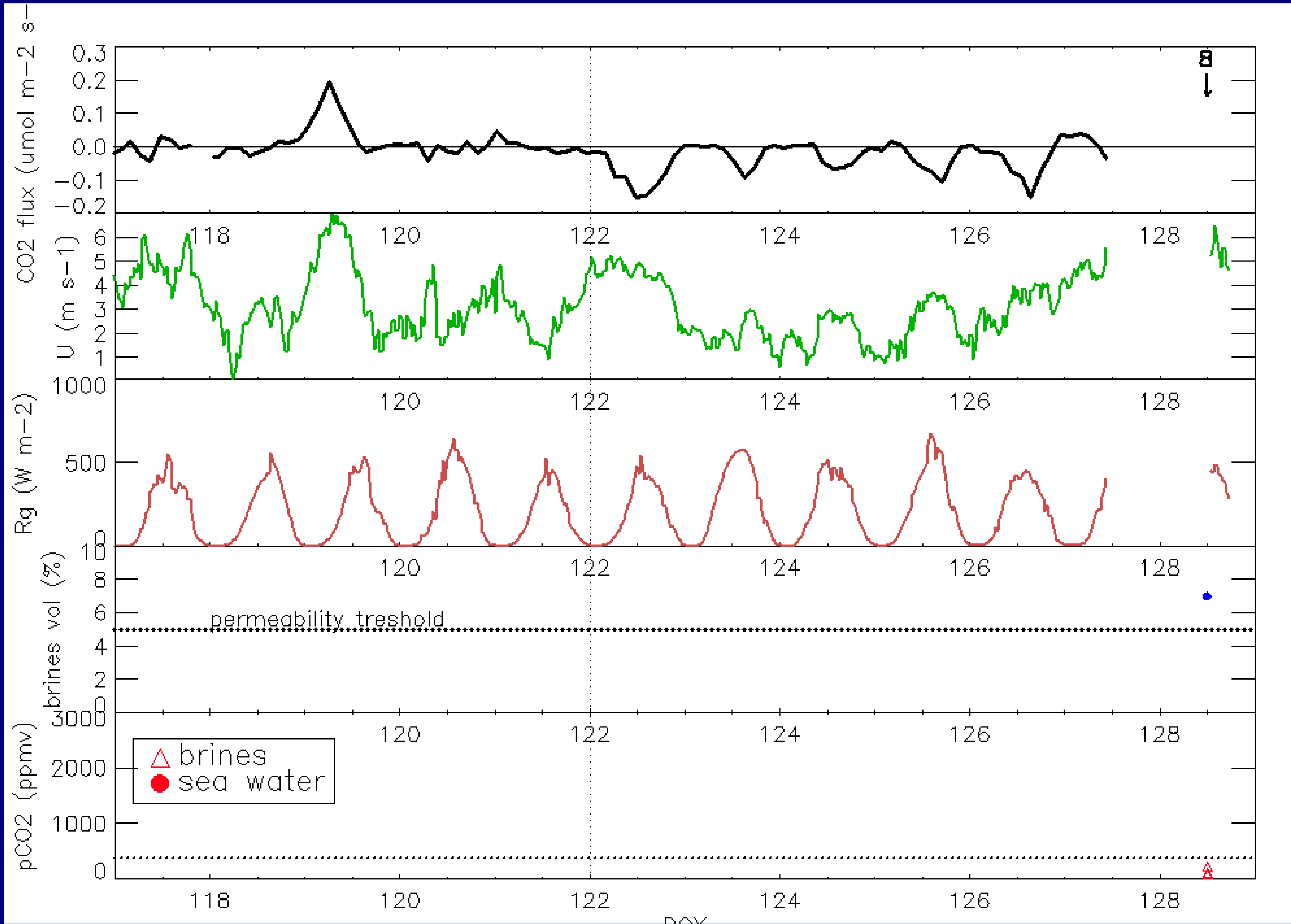
- Late winter fluxes are surprising because
  - Sea-ice brine volume is **below** the commonly accepted treshold for permeability
  - The amount of emitted carbon seems too large compared to the available stock

- Explan
  - Possi
  - Syste
  - …





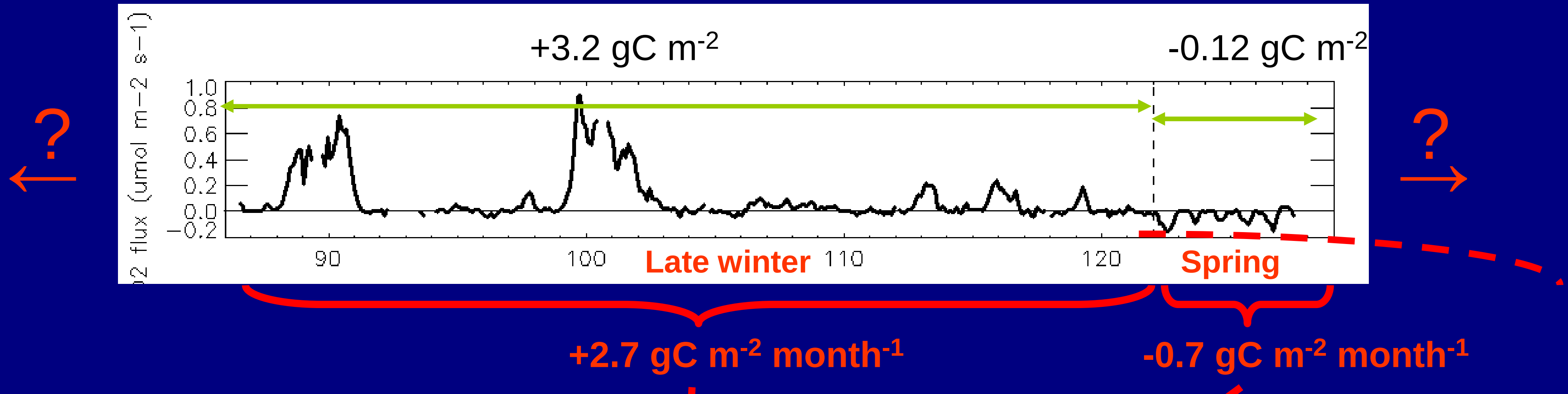
"Spring" regime

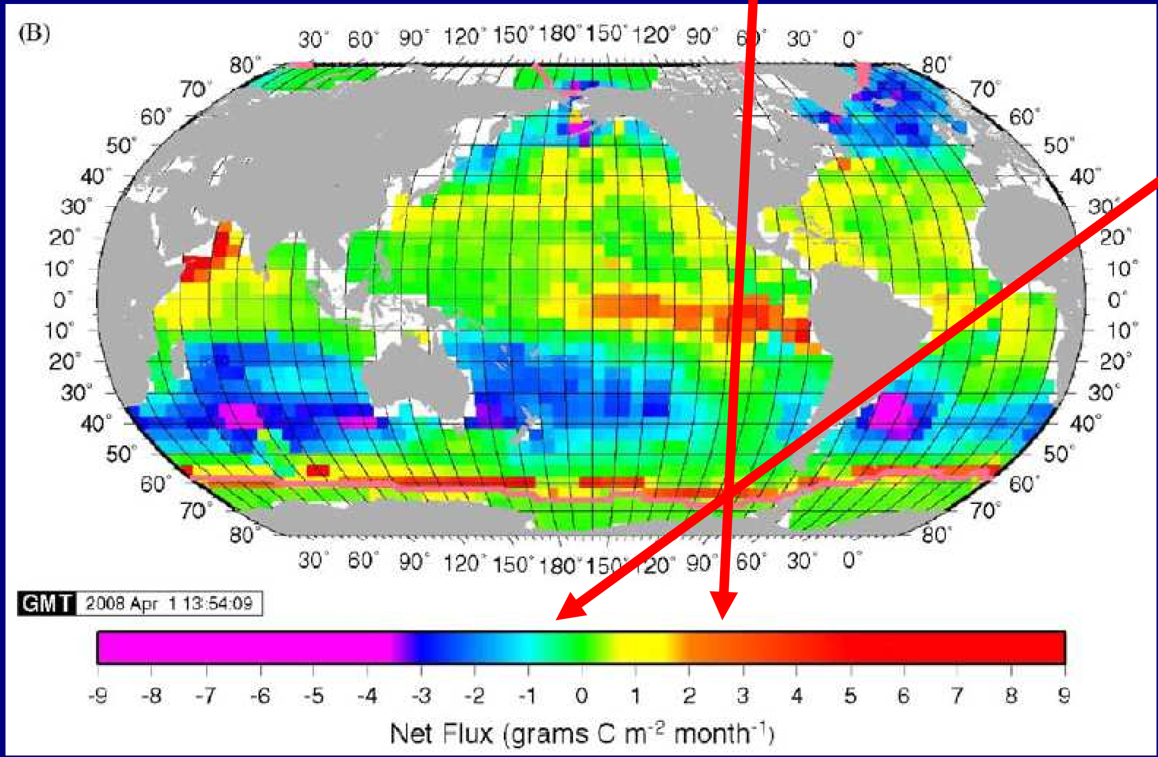


“Spring” regime

- Sea-ice mainly behaves as a sink
  - Sea-ice brine volume is **above** the commonly accepted treshold for permeability
  - Brines are undersaturated in CO_2 compared to the atmosphere
- CO_2 fluxes follow a diurnal pattern
  - Both physical (concentration/dilution of the brines) and biological (primary production) processes can explain the diurnal pattern of the fluxes

Carbon budget





Takahashi, T. et al., in press

Summary

➢ We observed conspicuous CO_2 flux events qualitatively linked to pCO_2 of the brines

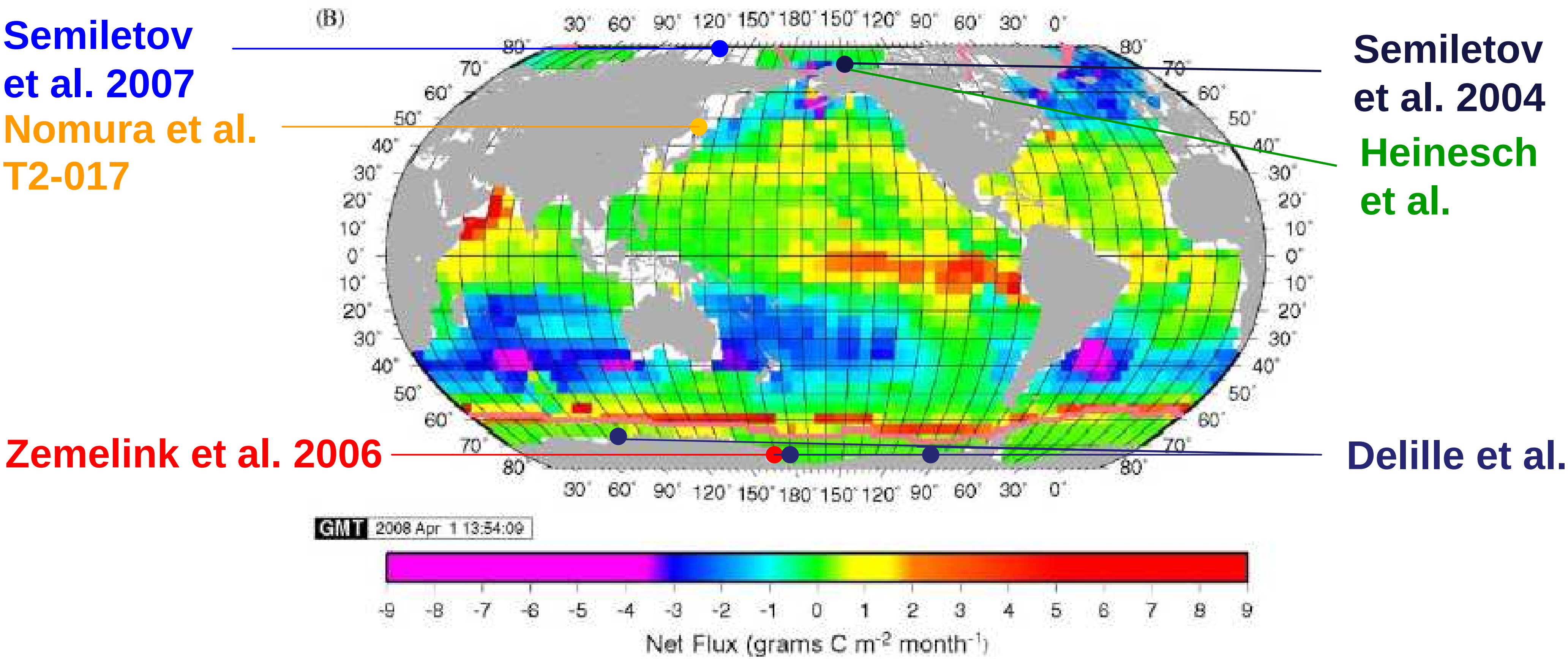
- in late winter, prior to the start of the internal processes that can lead to brines pCO_2 reduction, sea-ice was a source
- in the beginning of spring, sea-ice shifted to a sink 5 days after the warming period started

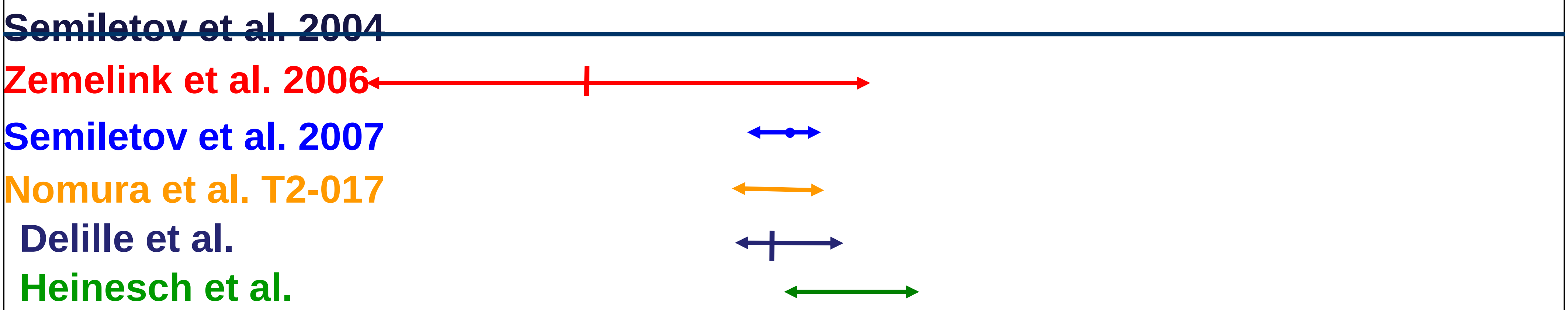
Are these fluxes significant in the carbon budget of the polar oceans ?

The order of magnitude of the measured fluxes, integrated on the whole sea-ice cover of Arctic ocean would lead to a significant contribution but we catched only a short part of the year and so it's difficult to make a budget on the sea-ice life cycle.

Thank you for your attention

heinesch.b@fsagx.ac.be


Semiletov
et al. 2007
Nomura et al.
T2-017
Zemelink et al. 2006
Semiletov
et al. 2004
Heinesch
et al.
Delille et al.
(B)
30° 60° 90° 120° 150° 180° 150° 120° 90° 60° 30° 0°
80° 70° 60° 50° 40° 30° 20° 10° 0° 10° 20° 30° 40° 50° 60° 70° 80°
GMT 2008 Apr 1 13:54:09
-9 -8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8 9
Net Flux (grams C m-2 month-1)


Semiletov et al. 2004
Zemelink et al. 2006
Semiletov et al. 2007
Nomura et al. T2-017
Delille et al.
Heinesch et al.