Biogeochemistry: Impacts of Ocean Heat Flux, Surface Flooding and Fluid Transport

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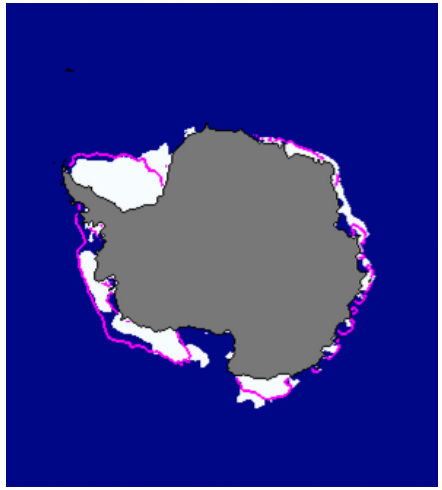
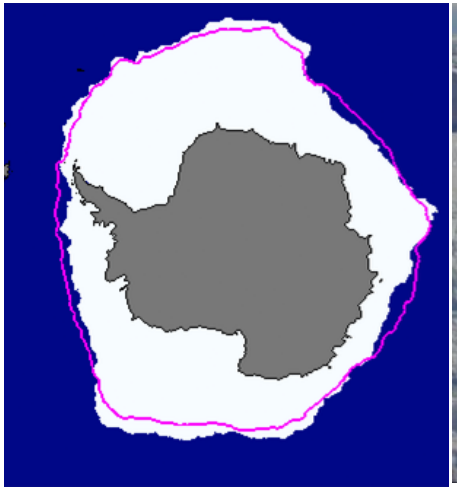
(Presented at June 2012 Ice at the Interface Workshop, Boulder Co

Challenges: Antarctic sea ice

- High winds
- Broken up ice cover
- Deep snow
- Thin ice
- Surface flooding
- Large ocean heat flux
- Large seasonal changes

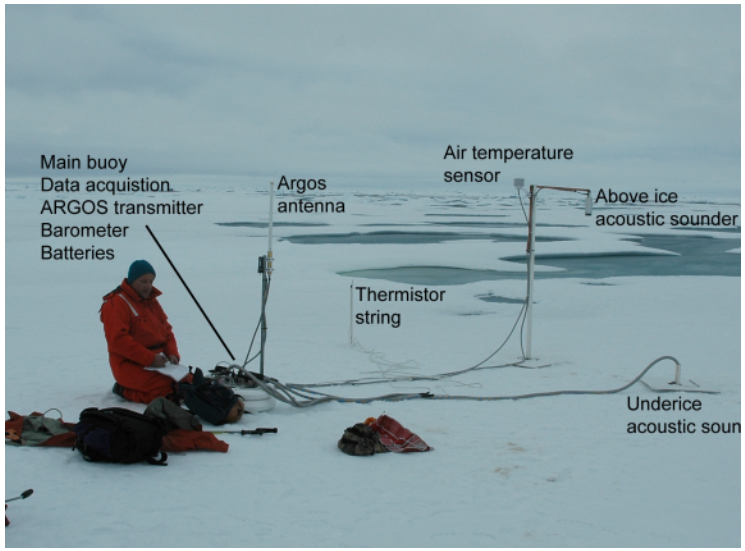


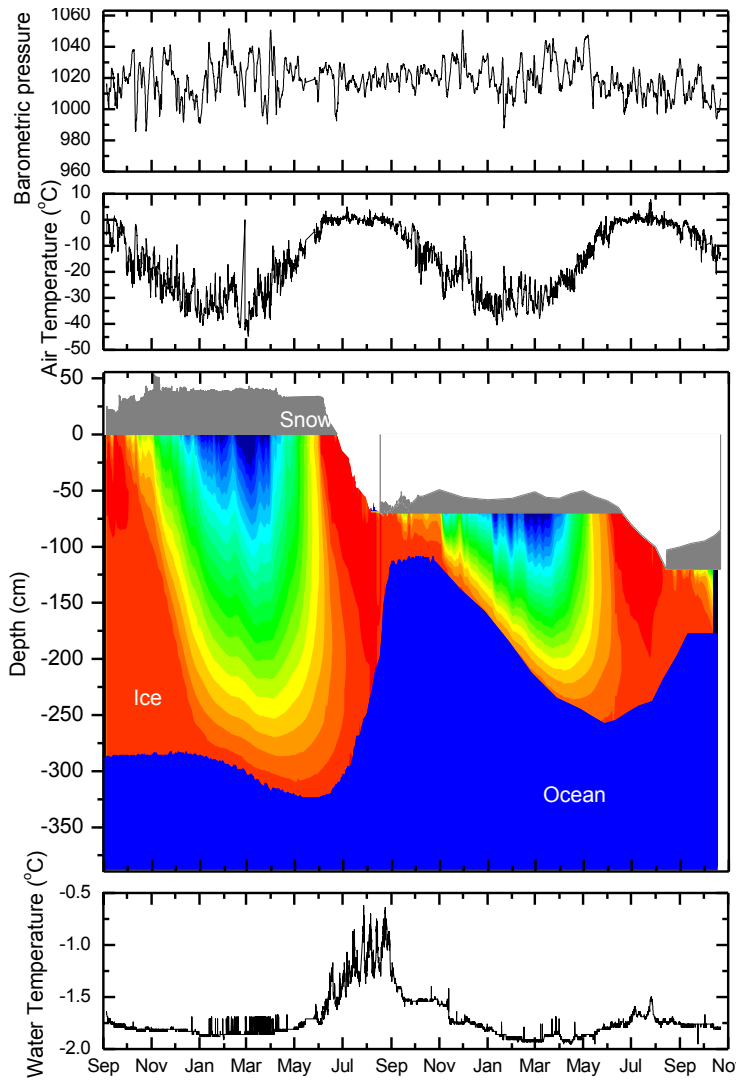


Not the best long term platform

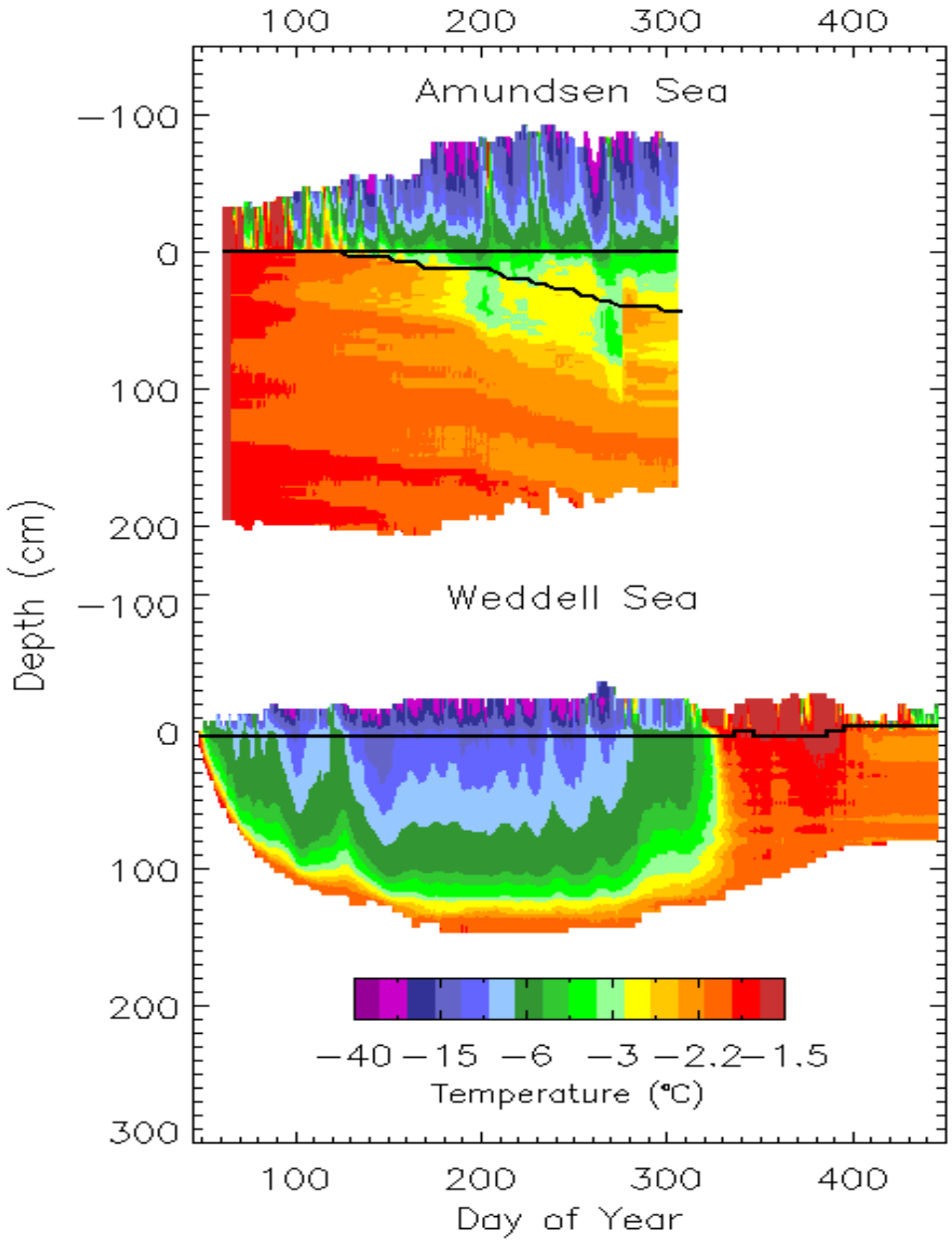
Sea ice mass balance

- Position
- Air temperature
- Barometric pressure
- Ice temperatures
- Upper ocean temperatures
- Snow accumulation and ablation
- Ice growth
- Surface and bottom ice melt



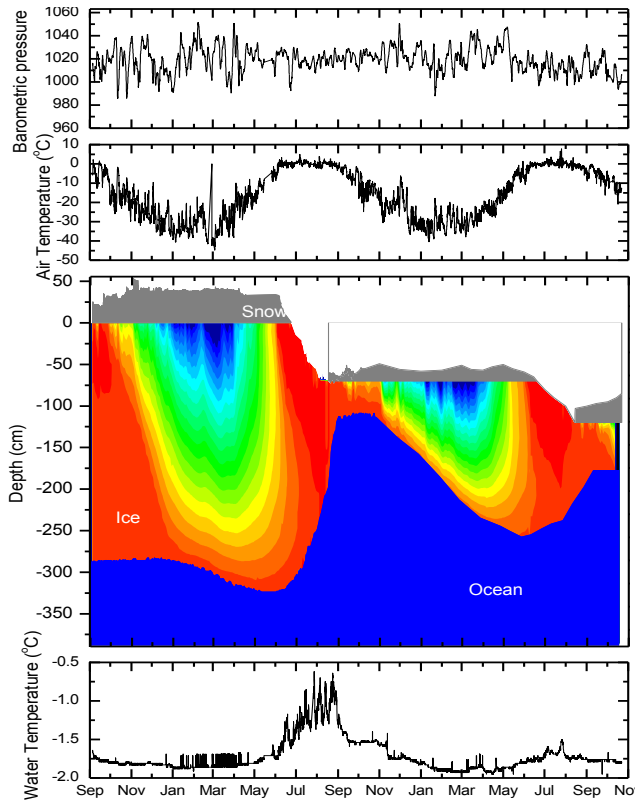


A way to attribute change

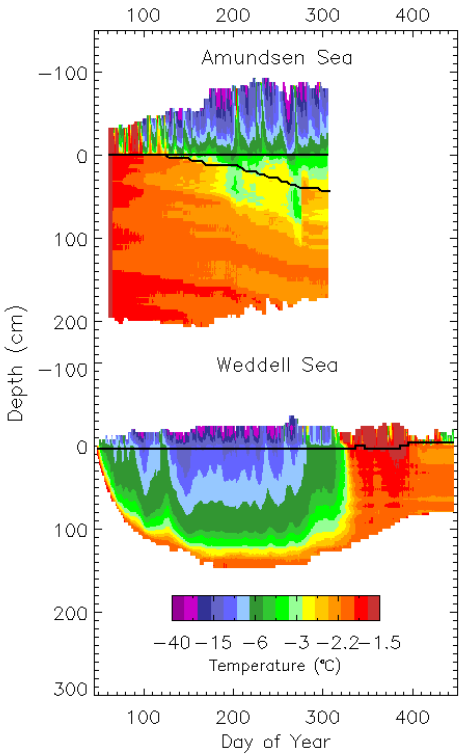

Amundsen Sea
Weddell Sea
Depth (cm)
Day of Year
Temperature (°C)
−40 −15 −6 −3 −2.2 −1.5
100
200
300
400
−100
0
100
200
−100
0
100
200
300

Arctic-Antarctic Comparison

Arctic Seasonal Cycle



Antarctic Seasonal Cycle



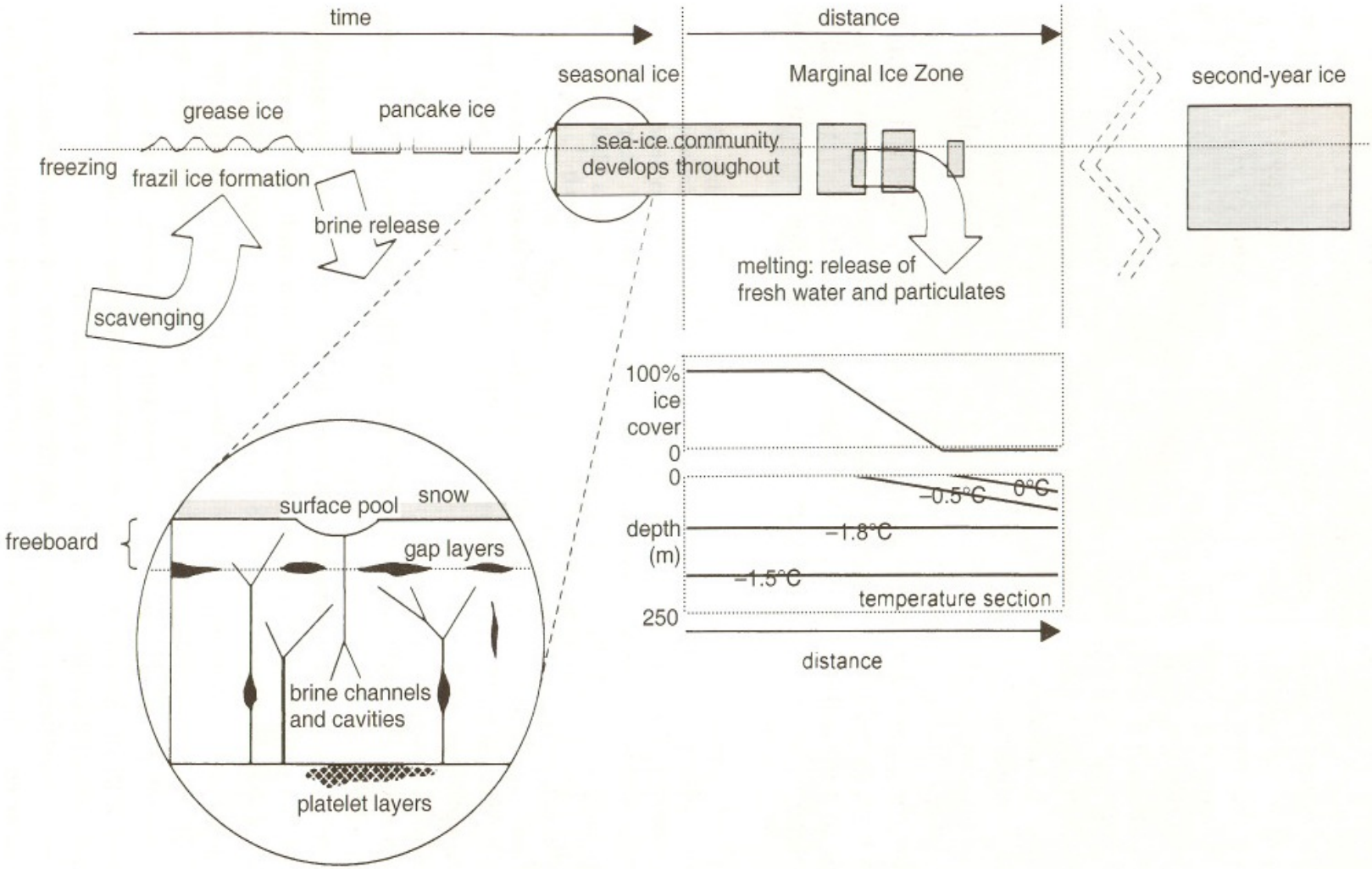
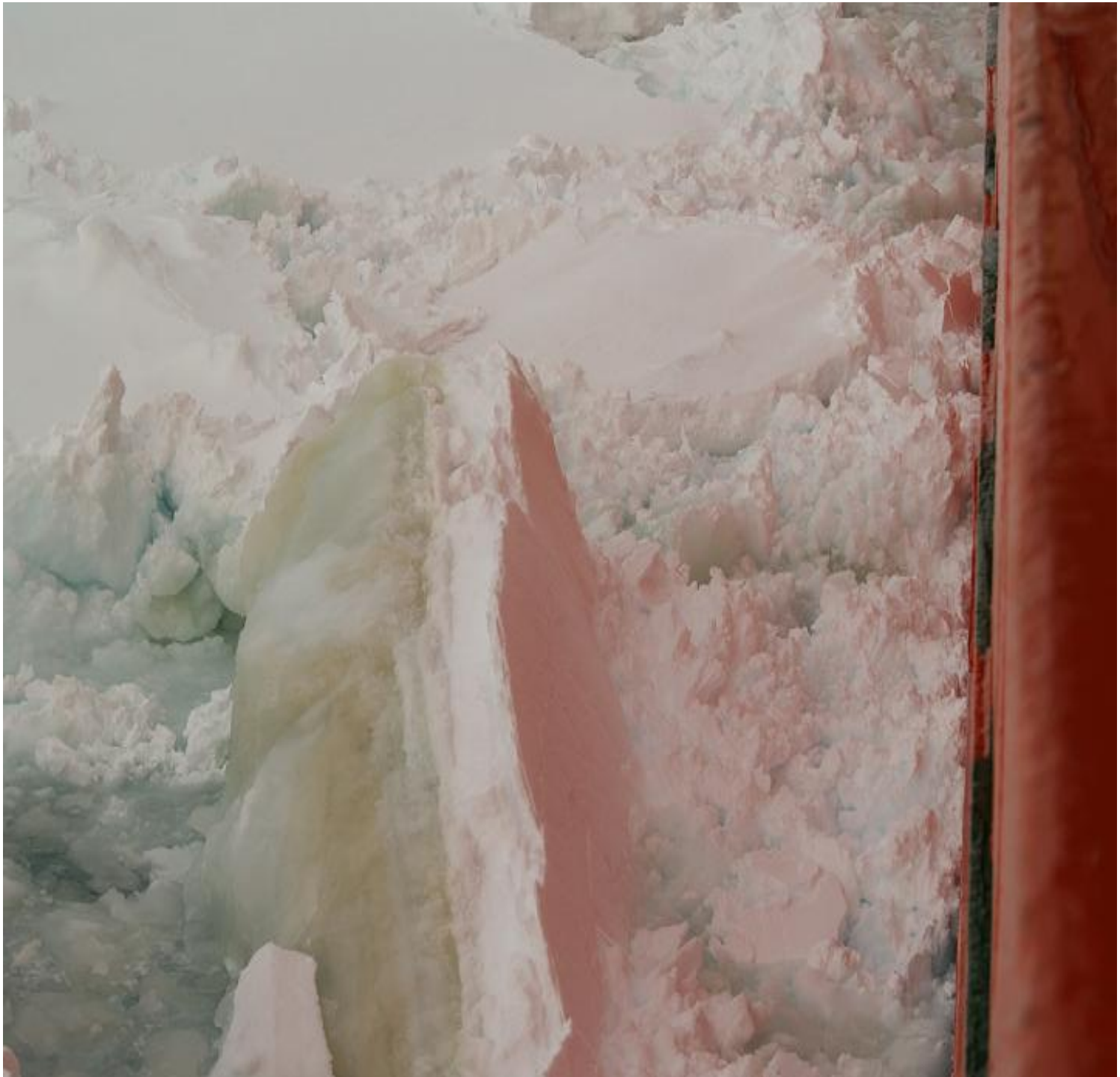
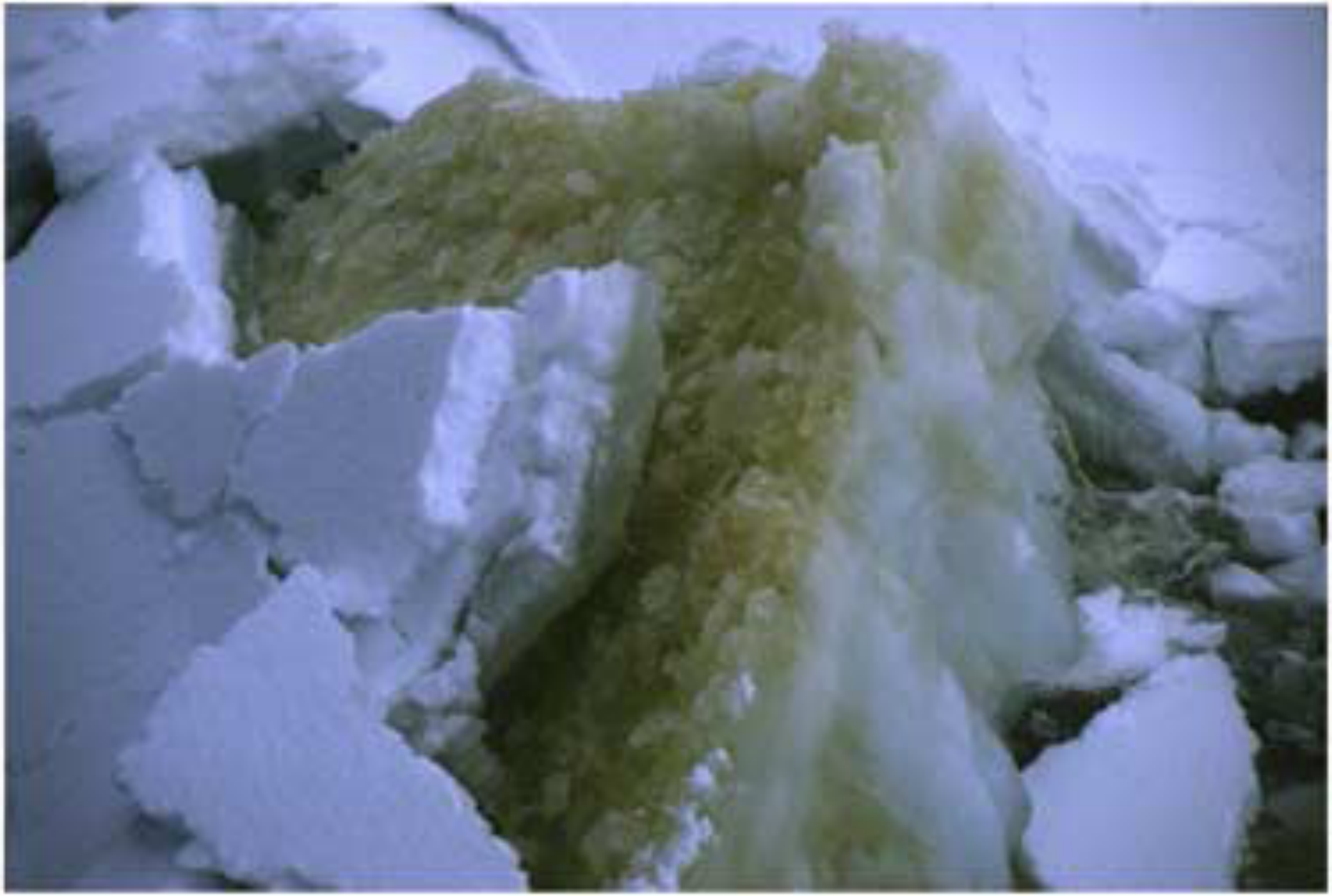


Figure 2 Schematic representation of sea-ice structure, showing ice formation in autumn, melt at the sea-ice edge in spring, and the underlying water column. Adapted from data in Eicken (1992), Horner *et al.* (1992), Ackley and Sullivan (1994) and Priddle *et al.* (1996).

http://www.arctic.noaa.gov/essay_krembsdeming.html

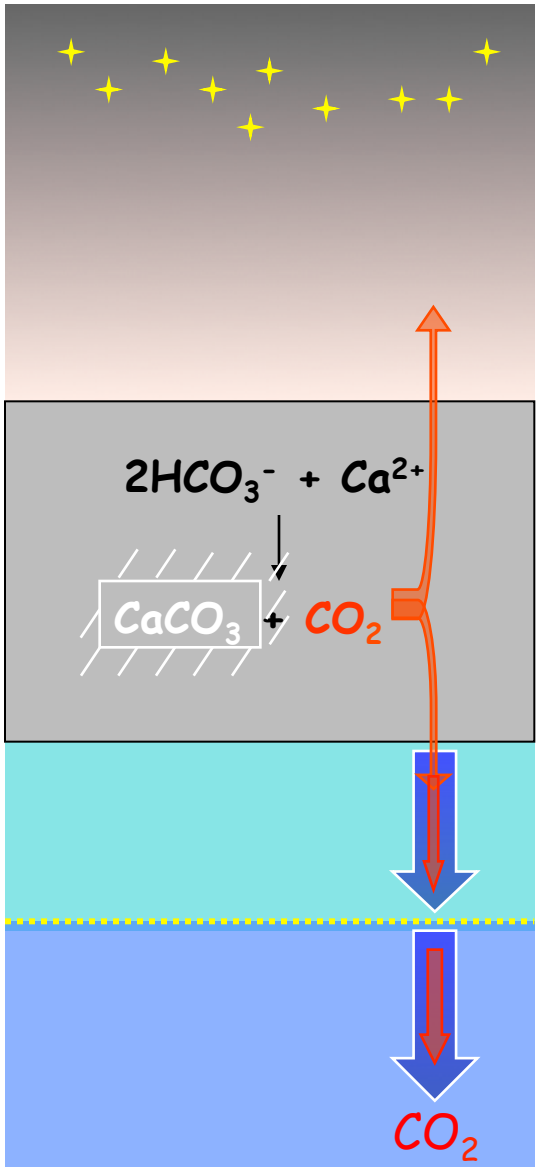




SEA ICE PUMP

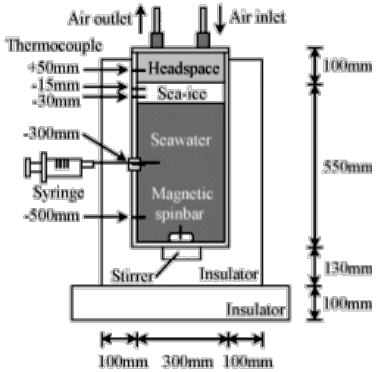
A potential abiotic $CaCO_3$ Carbon source

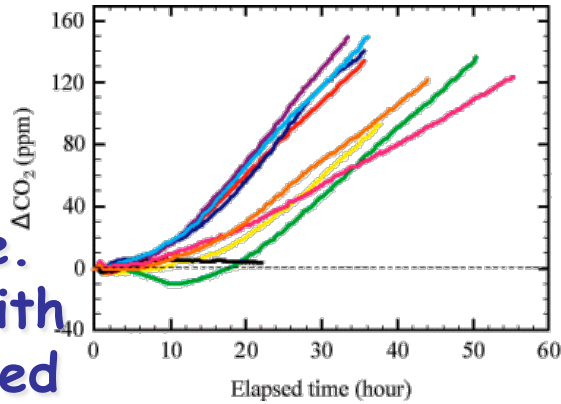
fall/winter



Is CO_2 released to the atmosphere anytime new ice forms?
(Answer on Next Slide)

In winter, precipitation of $CaCO_3$ occurs within sea ice. Produced CO_2 is expelled with brine, while $CaCO_3$ is trapped within brine channels





D. Nomura, 2006

Brine sink rapidly carrying CO_2 (see Brine Drainage Slide)

Part of CO_2 which passes below the pycnocline is « removed » from the system.

Rysgaard et al., 2007, Delille et al., in prep.

Implications of High Biology

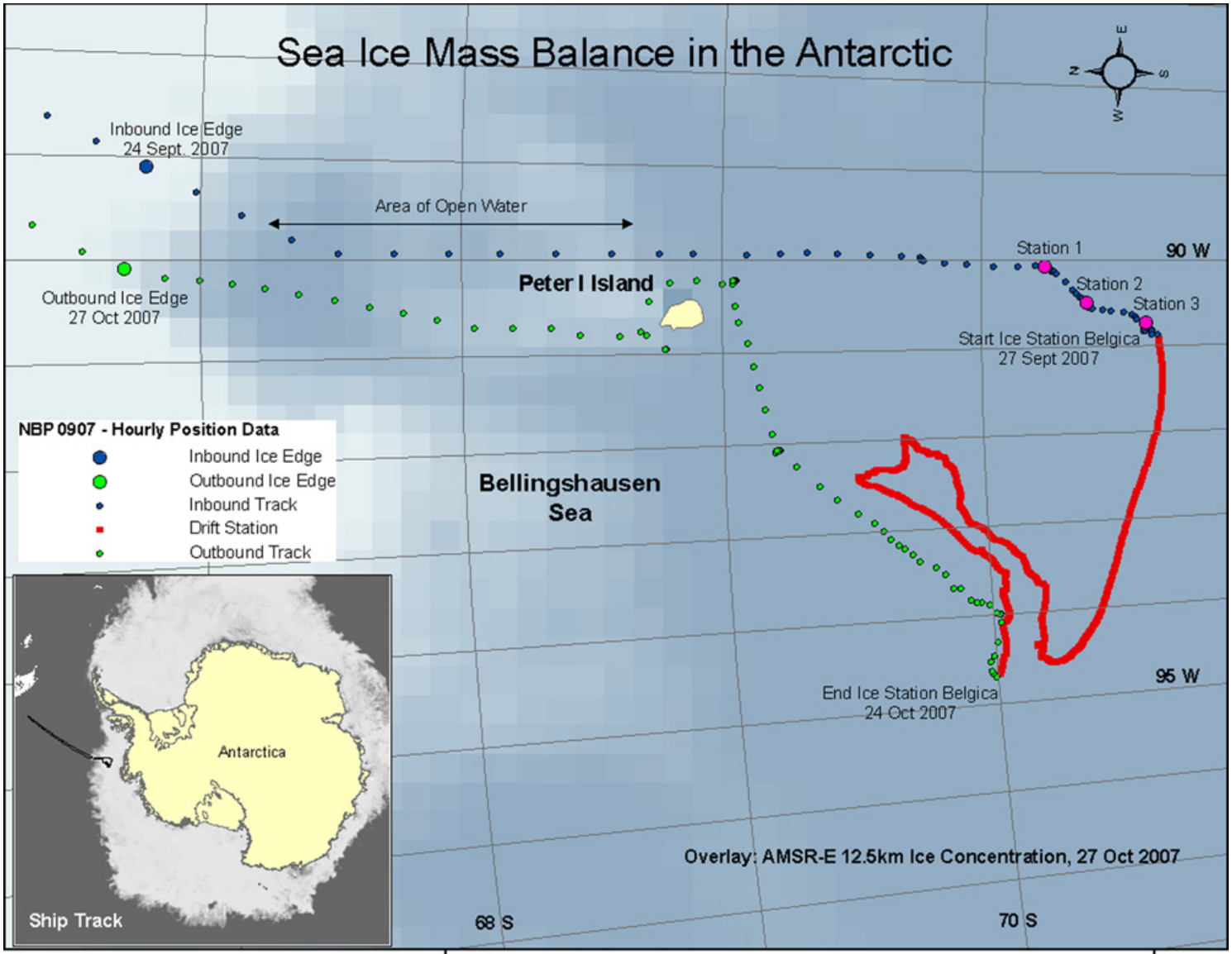
- Initially, need mechanism such as Wave Pumping to deposit particulates in new frazil
- Subsequently, Need for Fluid Transport to maintain high Nutrient Fluxes for growth (Vancoppenolle, Saenz have discussed modeling with freezing conditions, after Lytle and Ackley 1996; Fritsen et al 1994

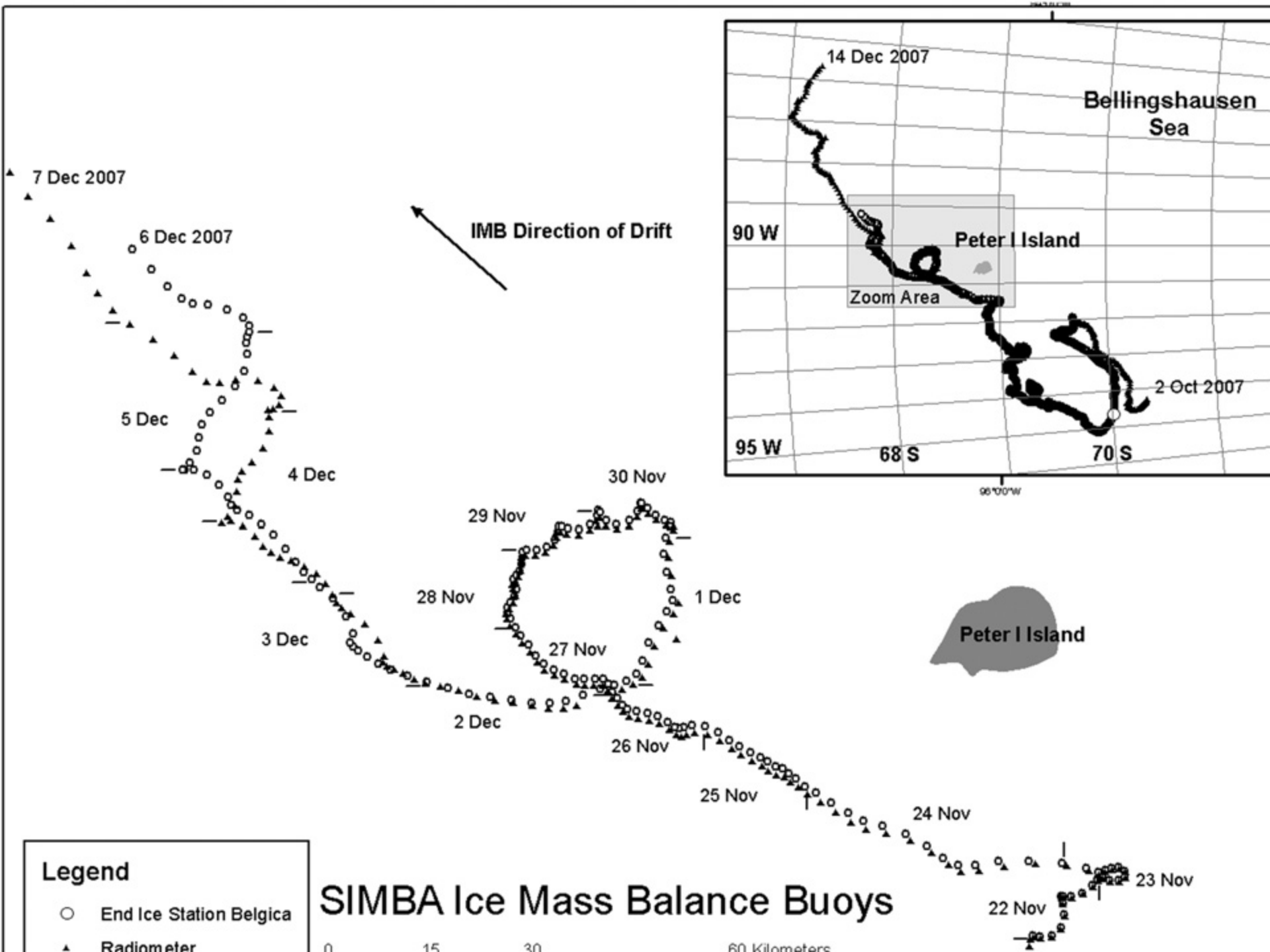
Two Effects of Ocean Heat Flux

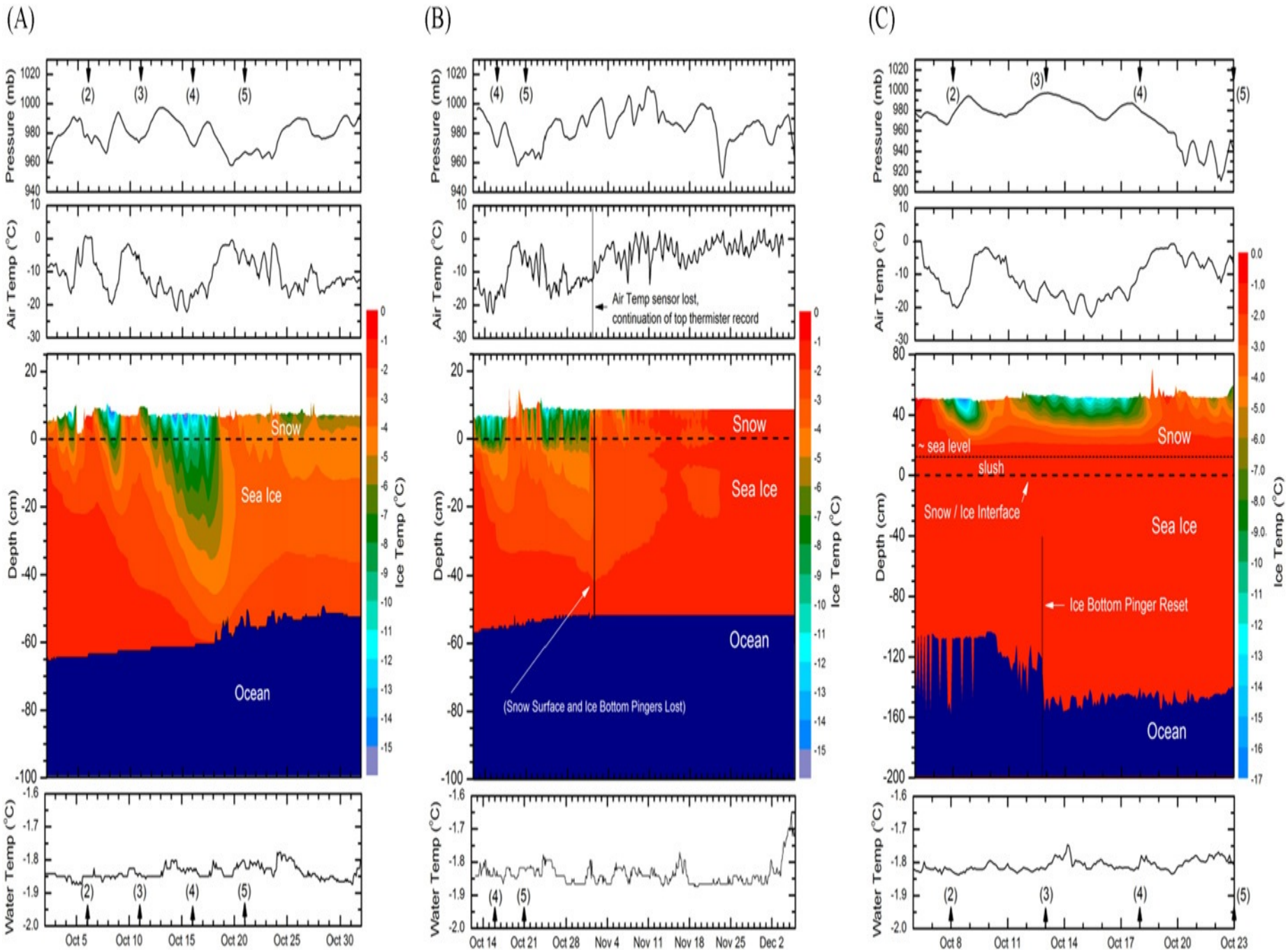
- 1. Release of Ice Algae during Winter and Spring by Bottom Melting

- 2. Development of Surface Flooding Communities in Summer

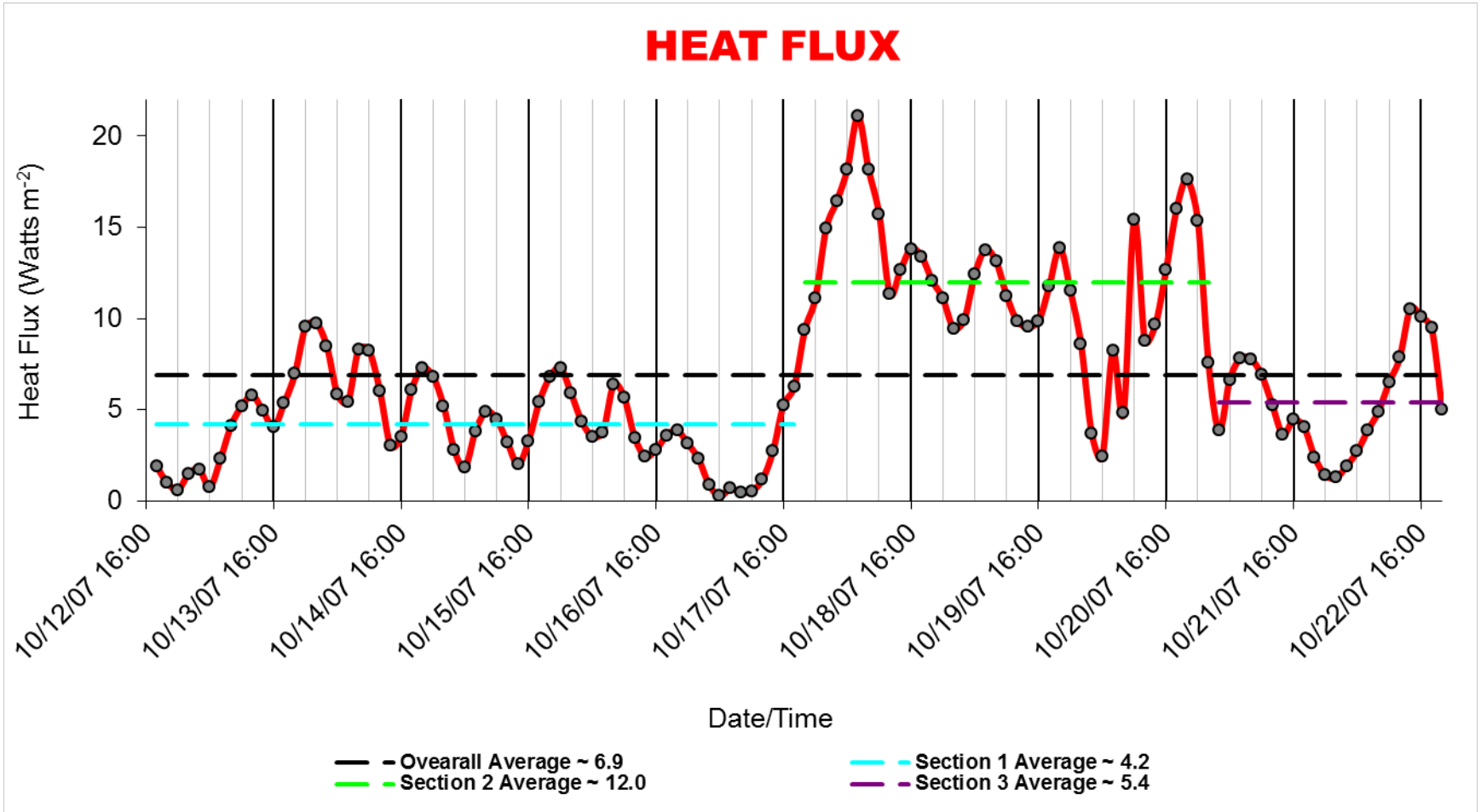
SIMBA Cruise and Drift




14 Dec 2007
Bellingshausen Sea
90 W
Peter I Island
Zoom Area
2 Oct 2007
95 W
68 S
70 S
7 Dec 2007
6 Dec 2007
IMB Direction of Drift
5 Dec
4 Dec
30 Nov
29 Nov
28 Nov
1 Dec
3 Dec
27 Nov
Peter I Island
2 Dec
26 Nov
25 Nov
24 Nov
23 Nov
22 Nov
Legend
End Ice Station Belgica
Radiometer
SIMBA Ice Mass Balance Buoys
0
15
30
60 Kilometers

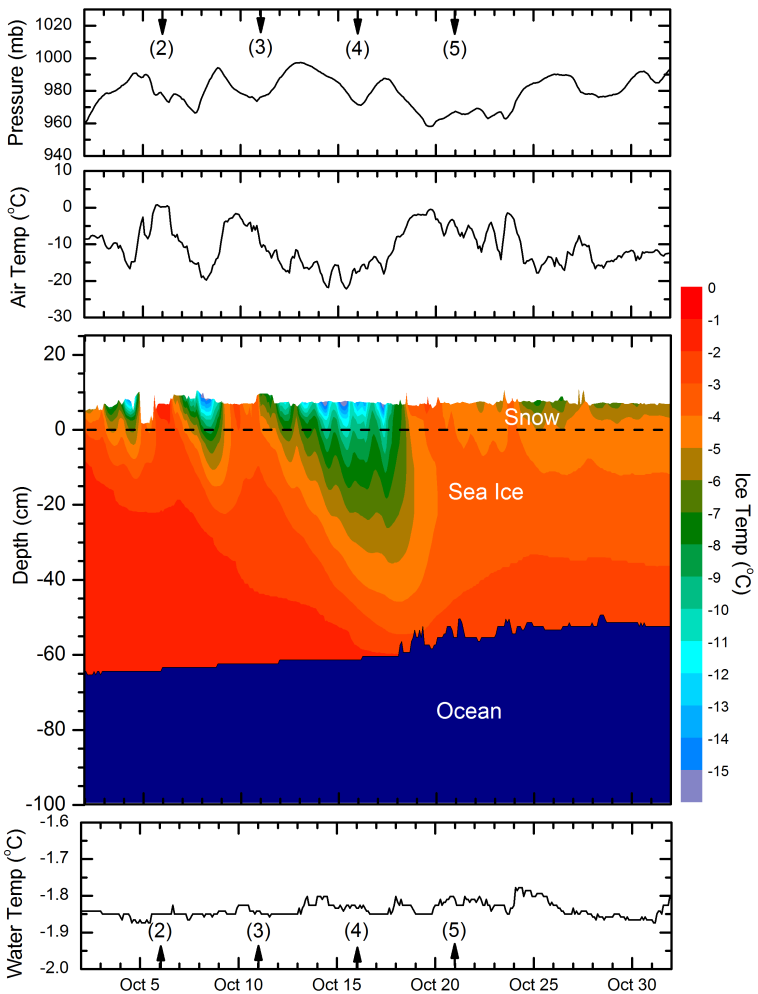

(A)
(B)
(C)
Pressure (mb)
Air Temp (°C)
Depth (cm)
Water Temp (°C)
Ice Temp (°C)
Snow
Sea Ice
Ocean
Air Temp sensor lost,
continuation of top thermister record
(Snow Surface and Ice Bottom Pingers Lost)
~ sea level
slush
Snow / Ice Interface
Ice Bottom Pinger Reset
Oct 5
Oct 10
Oct 15
Oct 20
Oct 25
Oct 30
Oct 14
Oct 21
Oct 28
Nov 4
Nov 11
Nov 18
Nov 25
Dec 2
Oct 8
Oct 11
Oct 14
Oct 17
Oct 20
Oct 23

SIMBA Ocean Heat Flux



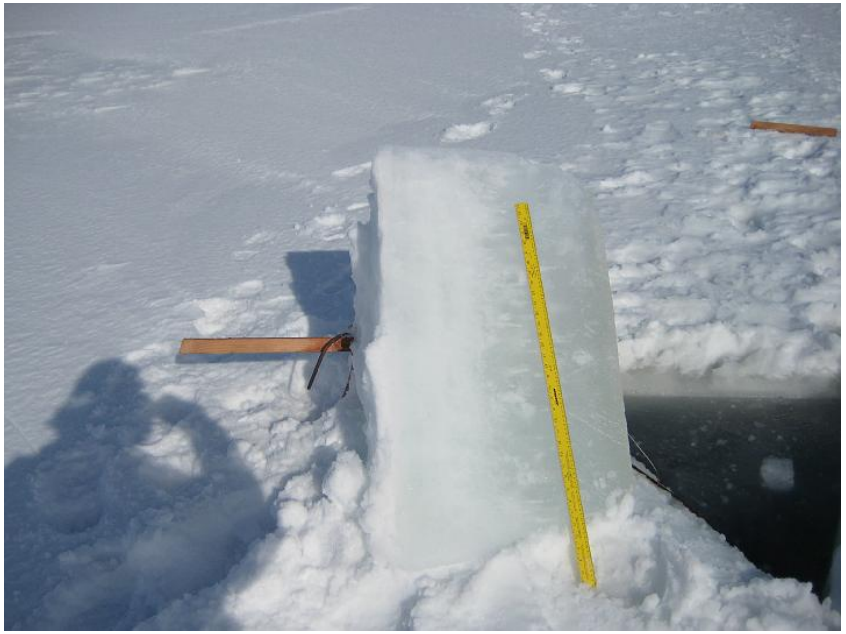
Brussels Site IMB

Radiometer Buoy (Brussels 1)

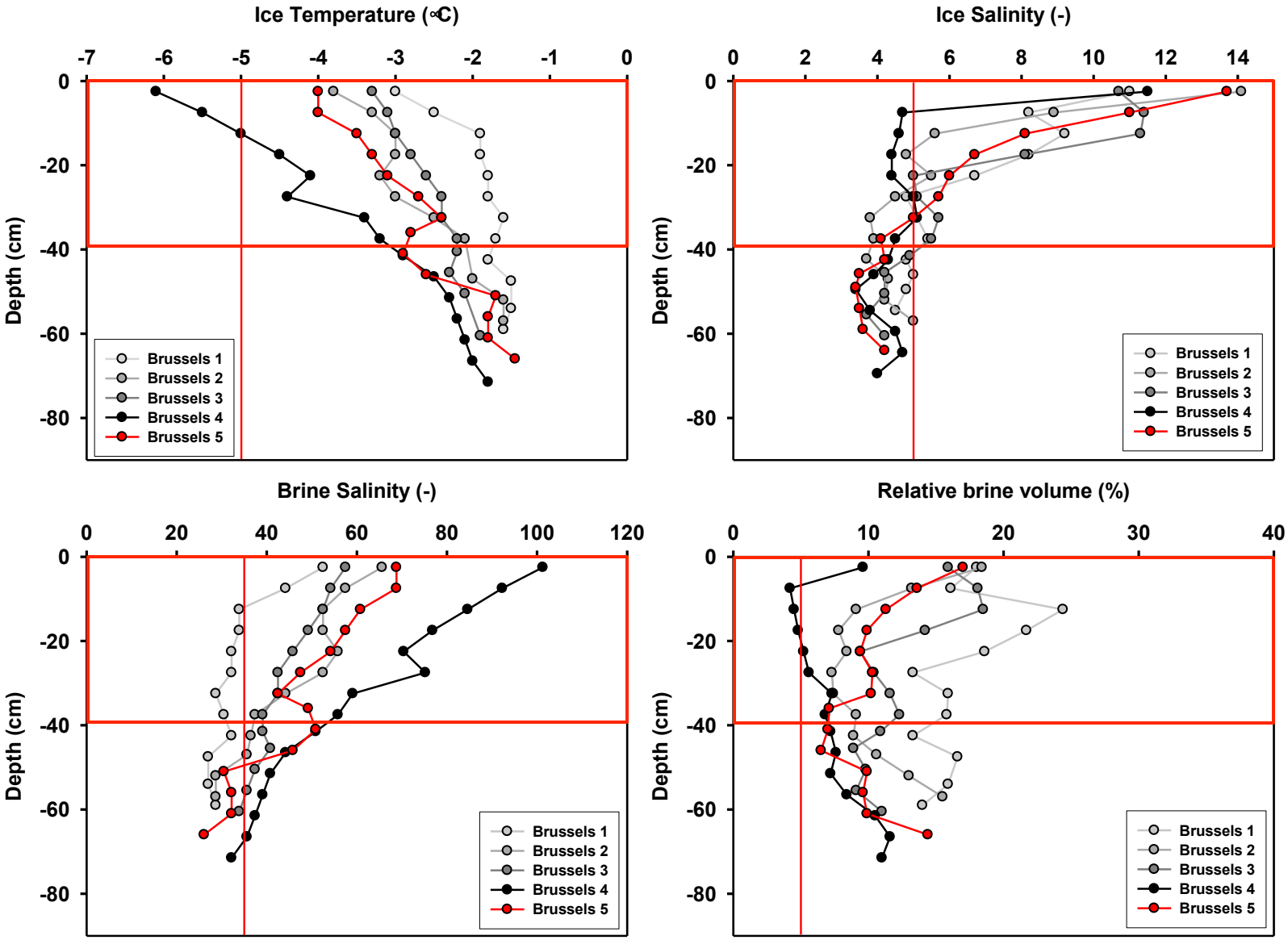


Thinner snow cover allows cold pulse to penetrate sea ice

No flooding at snow/ice interface



Thermodynamics at Brussels Site (unflooded)



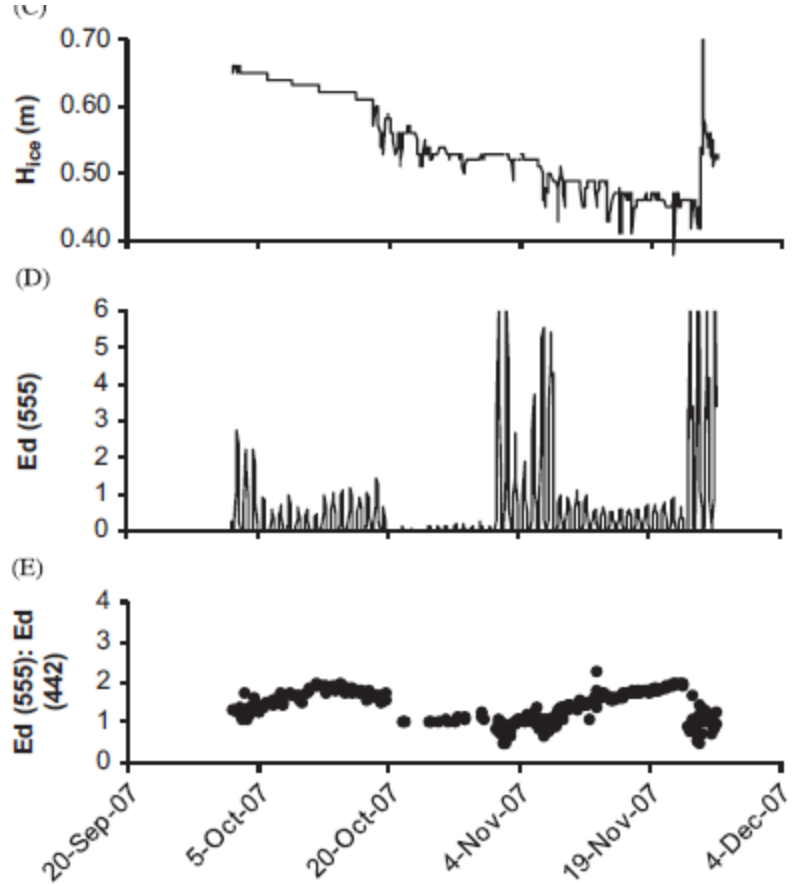
• SIMBA Brussels IMB

UnderIce Radiometer

Ice Thickness Changes

Transmission 555 nm

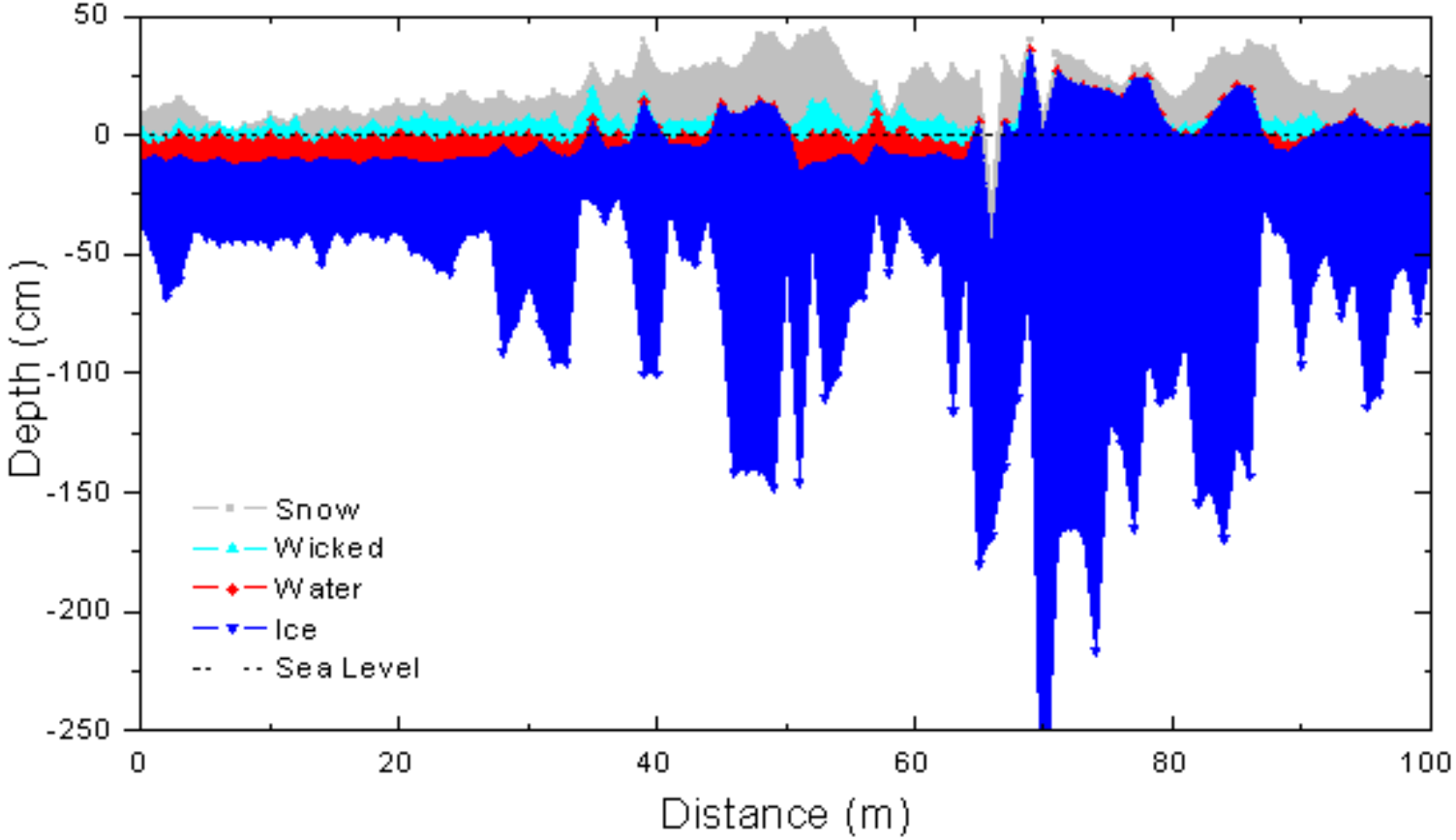
Integrated Chl Proxy (Ratio of 555nm: 442nm)

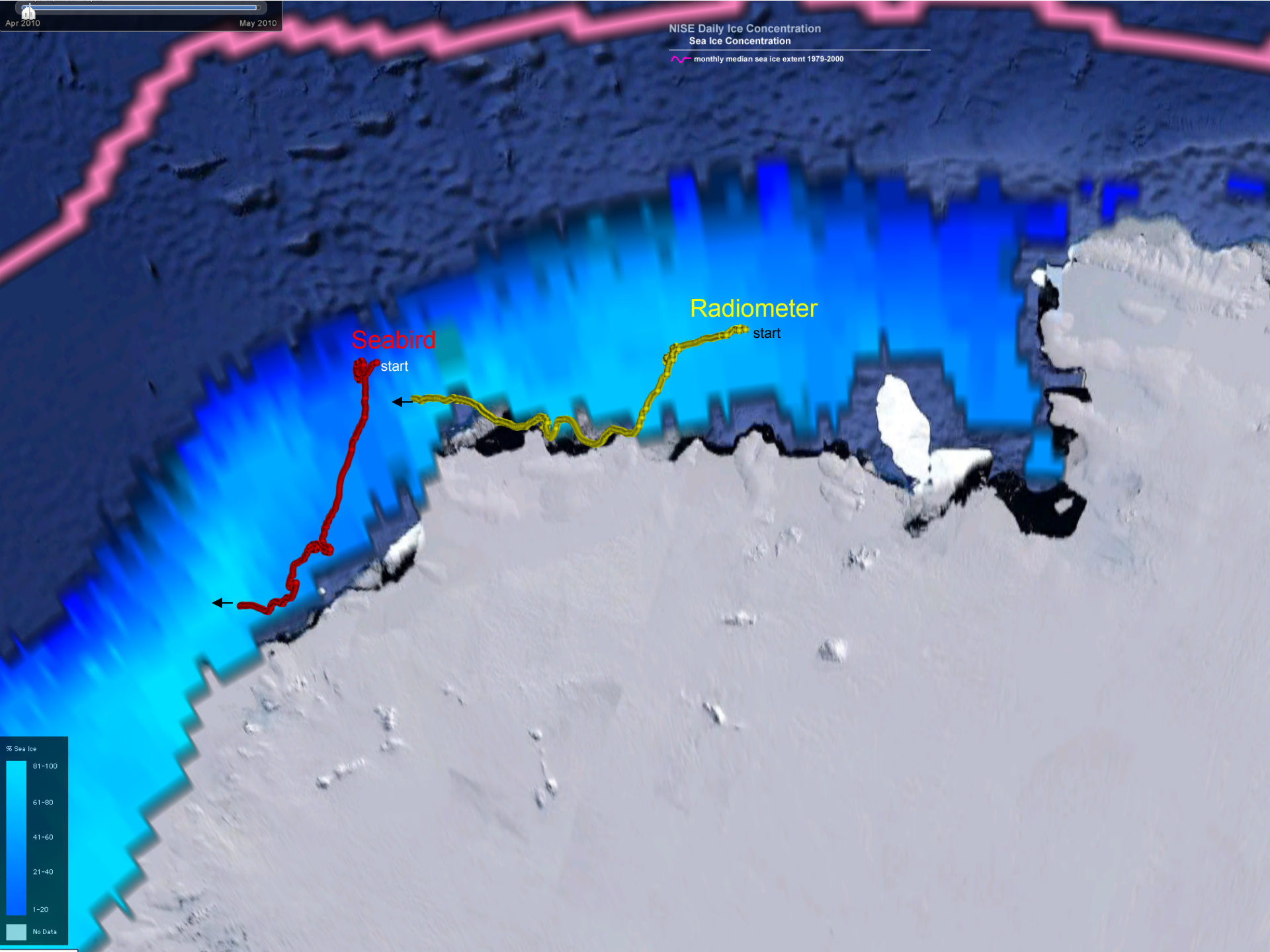


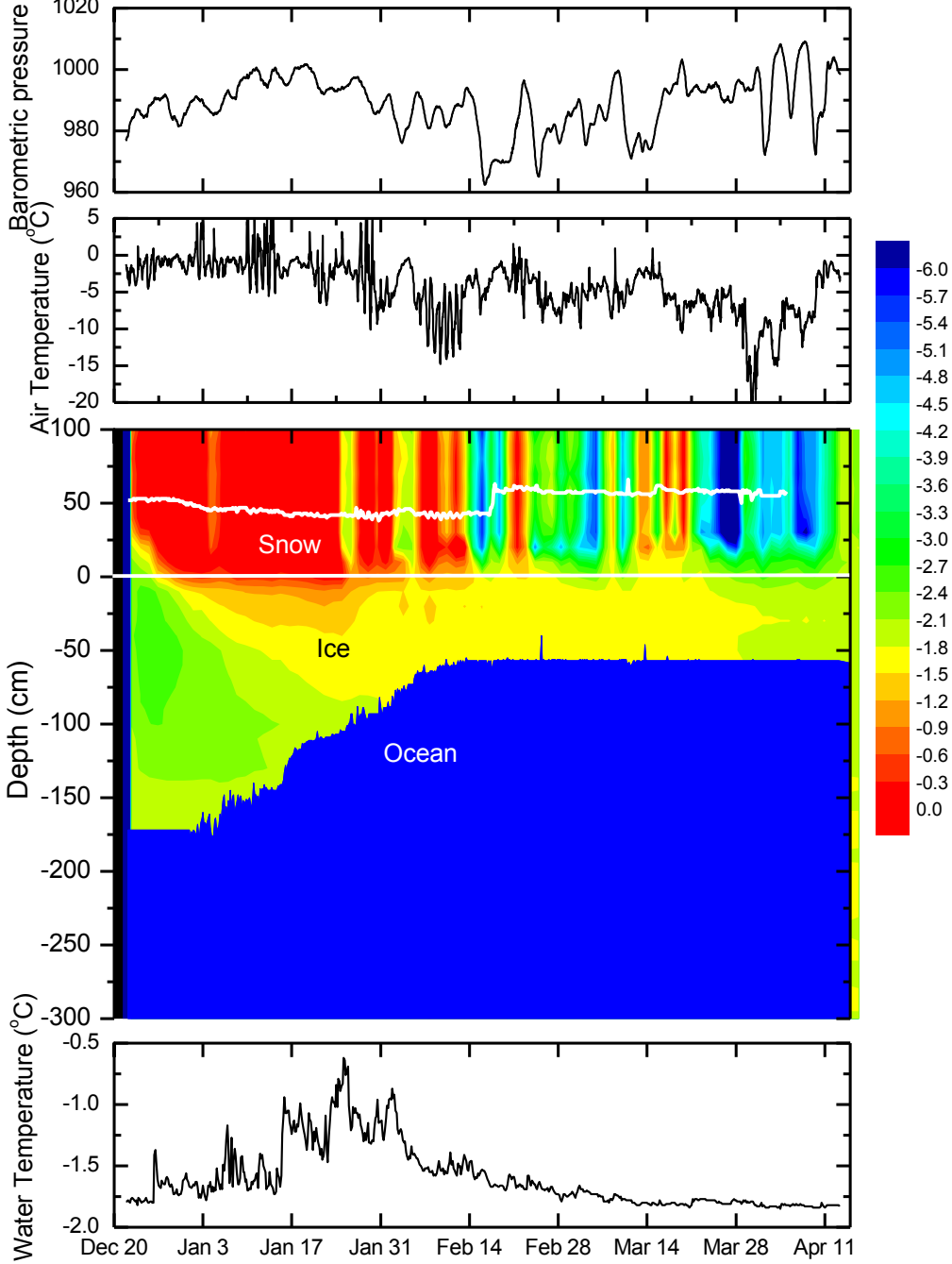
DMS(P) and Chla evolution at Brussels Site

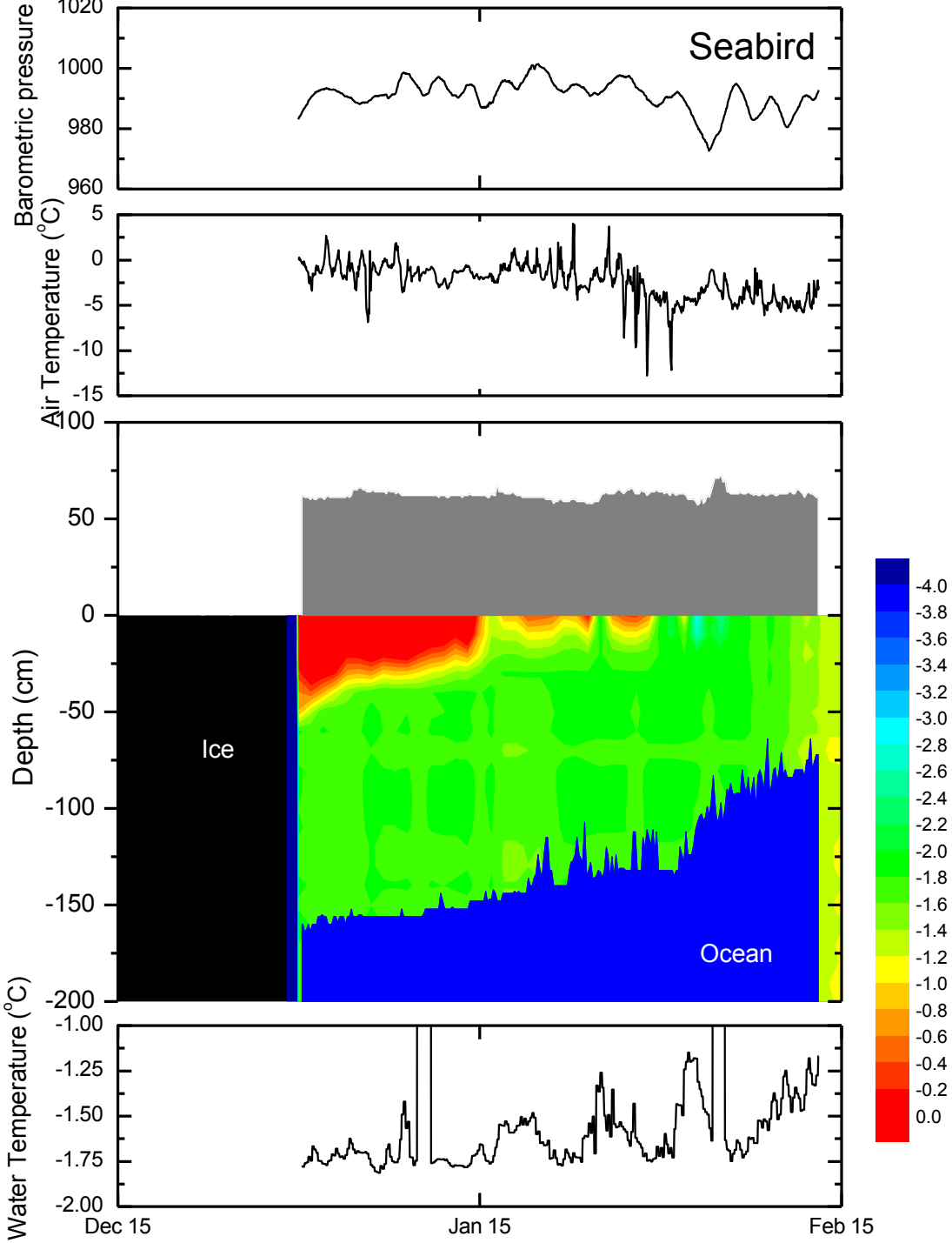
REFERENCE	LOCATION	ICE TYPE	SEASON	DMS + DMSP (nM) Mean	DMS + DMSP (nM) Range
Kirst et al., 1991	Weddell Sea	Pack ice	Spring	322	4 - 1664
Turner et al., 1995	Bellingshausen Sea	Pack ice	Spring-Summer	200	17- 546
Curran et al., 1998	Prydz Bay	Pack ice	Spring	144	8 - 725
Curran et al., 1998	Dumont Durville Sea	Pack ice	Winter	40	nd - 193
Di Tullio et al., 1998	Ross Sea	Pack ice	Spring-Summer	212	5 - 980
Di Tullio et al., 1998	Ross Sea	Fast ice	Spring	150	81 - 219
Trevena et al., 2000	Offshore Prydz Bay	Pack ice	Spring	107	6 - 787
Trevena et al., 2003	Prydz Bay	Fast ice	Spring-Summer	112	9 - 1478
V1, AA03, pers. comm., 2003	Australian sector of S.O. (Wilkes Land)	Pack ice	Early spring	267	1.3 - 4736
ISPOL, pers. comm., 2004	Western Weddell Sea	Pack ice	Summer	229	6 - 3340
THIS STUDY			**BRUSSELS Site**	**1338**	**99 - 8435**

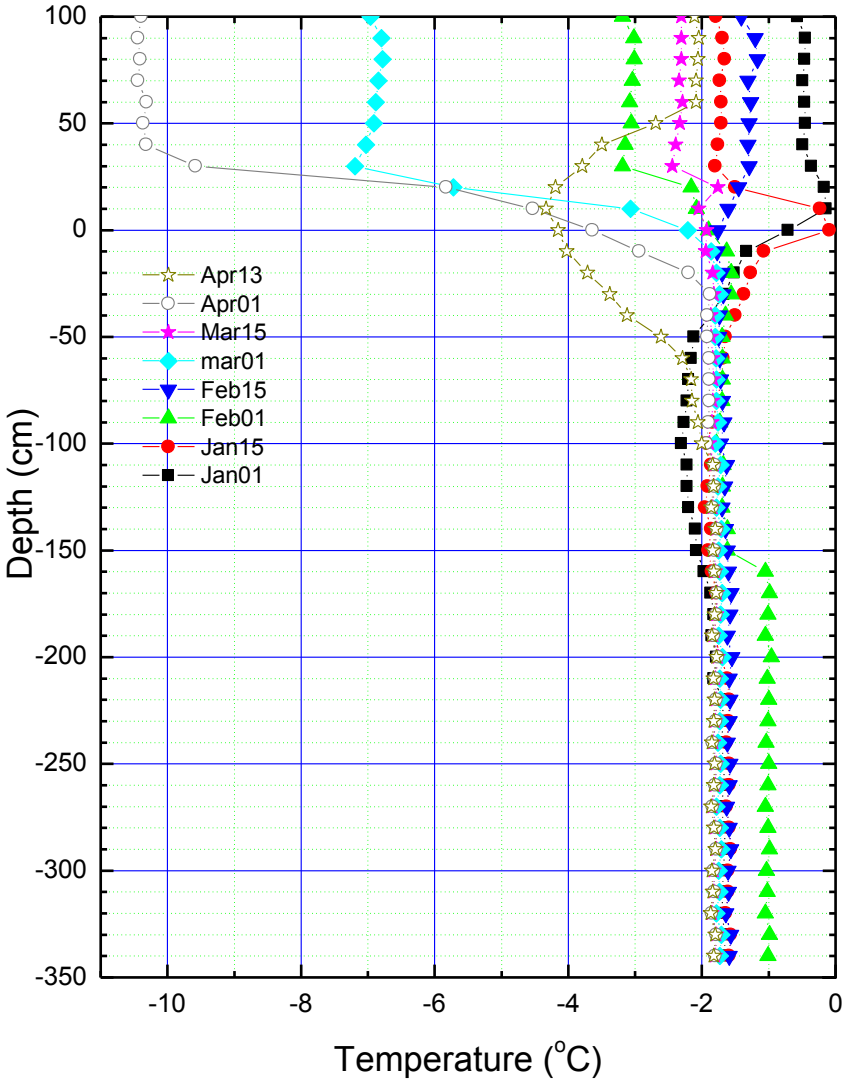
Antarctic Sea Ice Profile

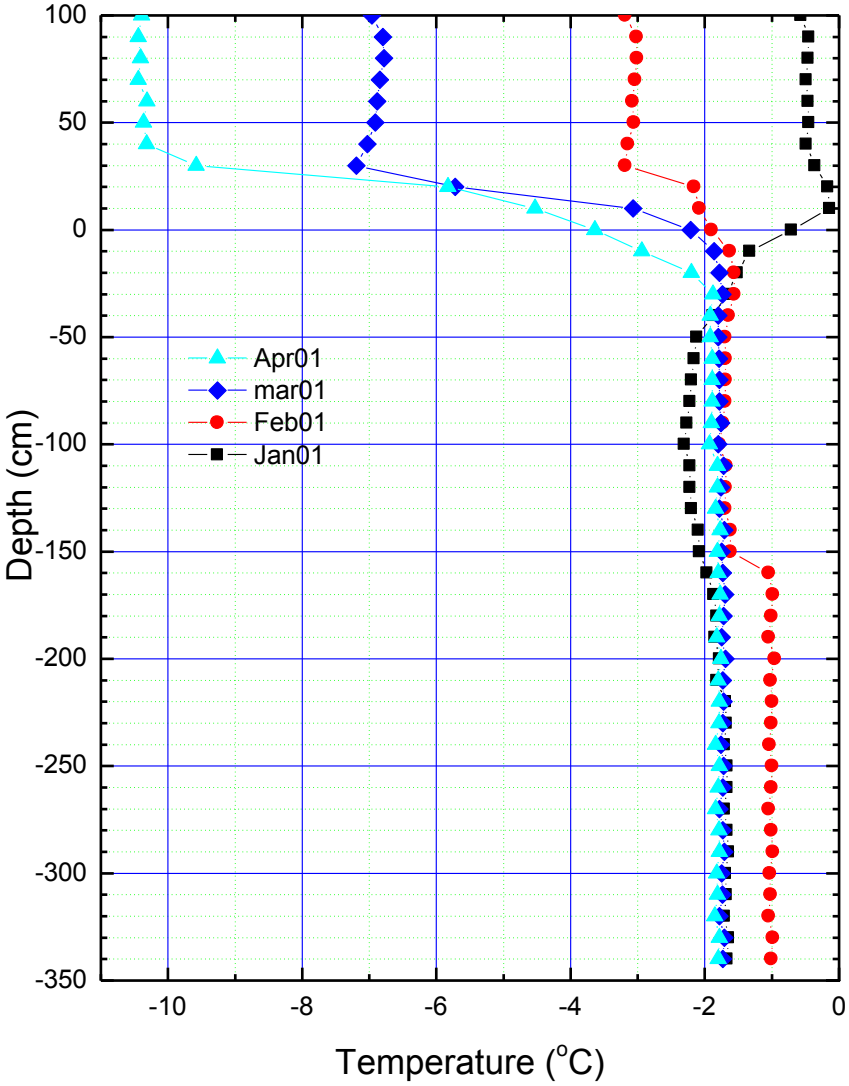



Apr 2010
May 2010
NISE Daily Ice Concentration
Sea Ice Concentration
monthly median sea ice extent 1979-2000
Radiometer
start
Seabird
start
% Sea Ice
81-100
61-80
41-60
21-40
1-20
No Data

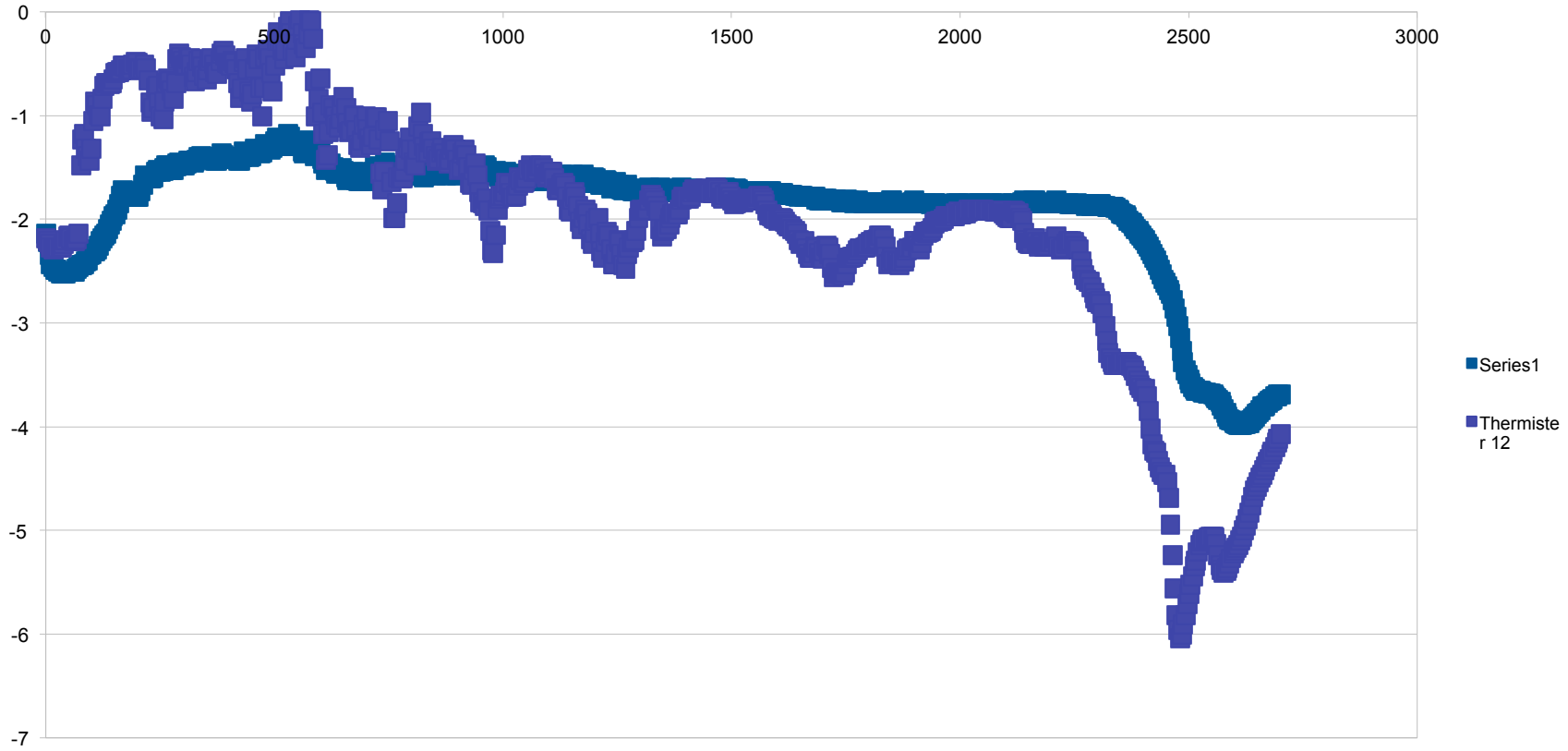

Barometric pressure
1020
1000
980
960
Air Temperature (°C)
5
0
-5
-10
-15
-20
Depth (cm)
100
50
0
-50
-100
-150
-200
-250
-300
Snow
Ice
Ocean
Water Temperature (°C)
-0.5
-1.0
-1.5
-2.0
Dec 20
Jan 3
Jan 17
Jan 31
Feb 14
Feb 28
Mar 14
Mar 28
Apr 11
-6.0
-5.7
-5.4
-5.1
-4.8
-4.5
-4.2
-3.9
-3.6
-3.3
-3.0
-2.7
-2.4
-2.1
-1.8
-1.5
-1.2
-0.9
-0.6
-0.3
0.0


Seabird
Barometric pressure
1020
1000
980
960
Air Temperature (°C)
5
0
-5
-10
-15
100
50
0
-50
-100
-150
-200
Depth (cm)
Ice
Ocean
Water Temperature (°C)
-1.00
-1.25
-1.50
-1.75
-2.00
Dec 15
Jan 15
Feb 15
-4.0
-3.8
-3.6
-3.4
-3.2
-3.0
-2.8
-2.6
-2.4
-2.2
-2.0
-1.8
-1.6
-1.4
-1.2
-1.0
-0.8
-0.6
-0.4
-0.2
0.0

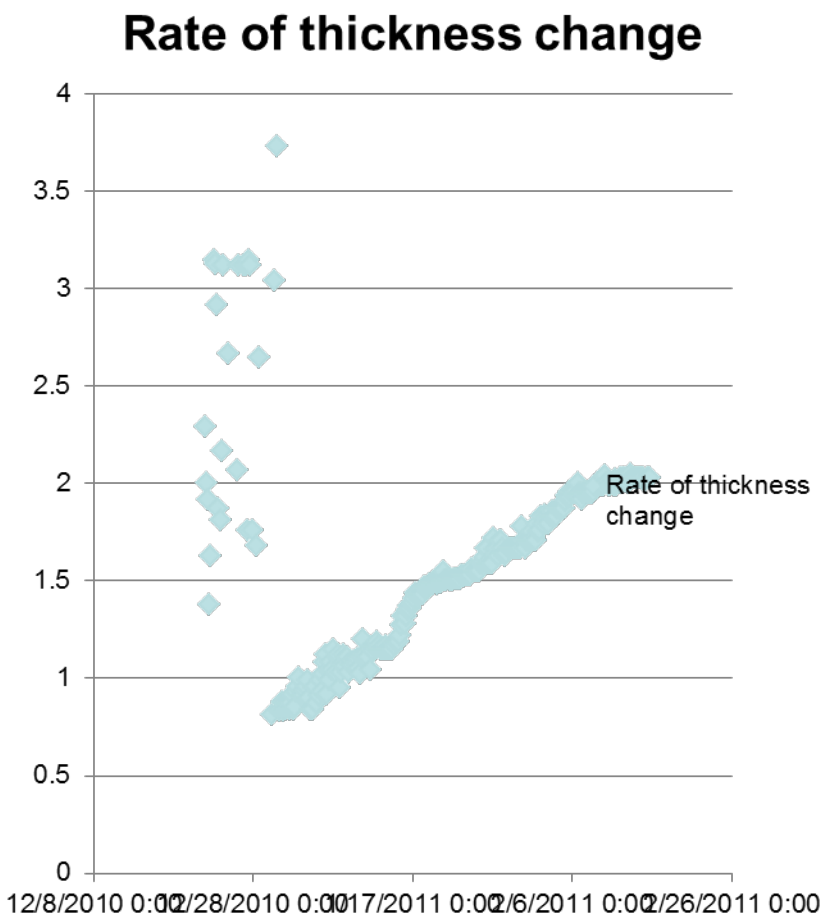

Depth (cm)
Temperature (°C)
Apr13
Apr01
Mar15
mar01
Feb15
Feb01
Jan15
Jan01

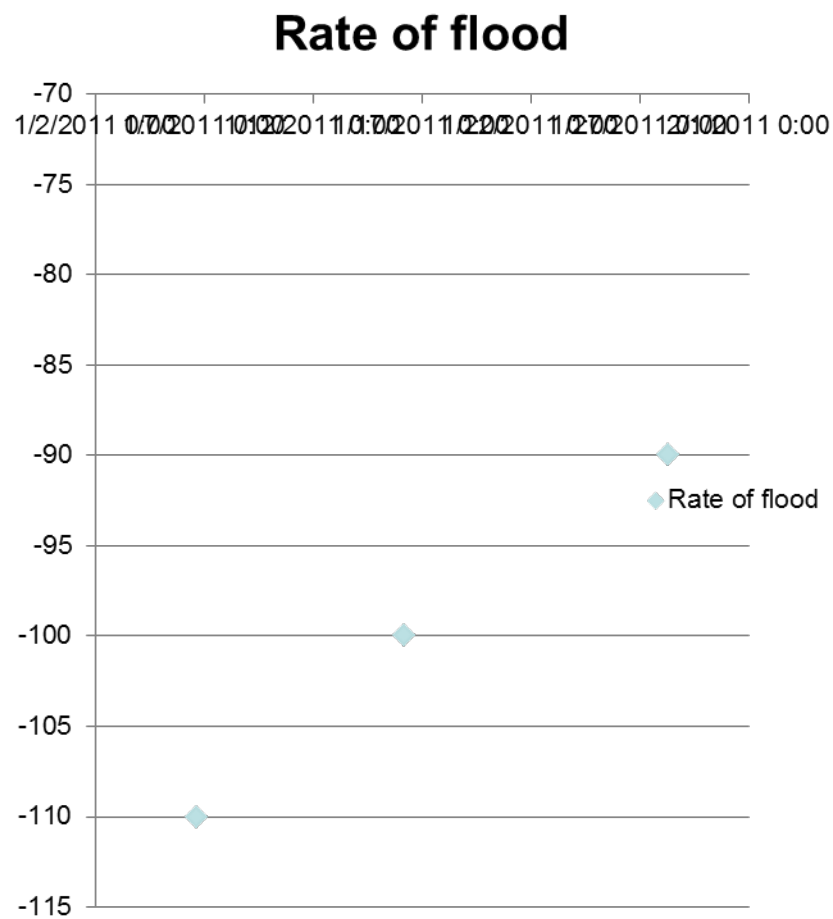

Depth (cm)
Temperature (°C)
Apr01
mar01
Feb01
Jan01

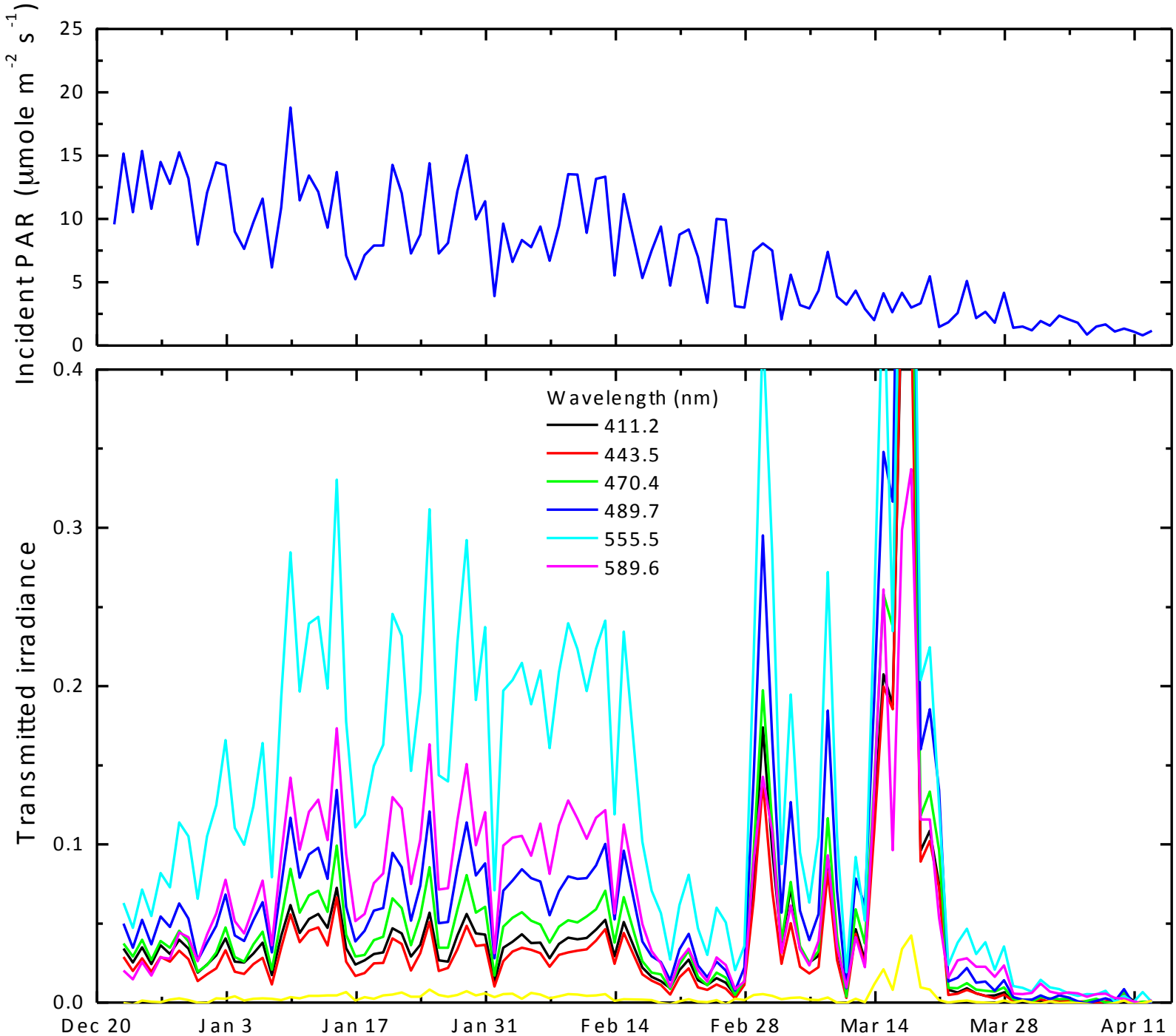
Radiometer-Thermisters 12&13

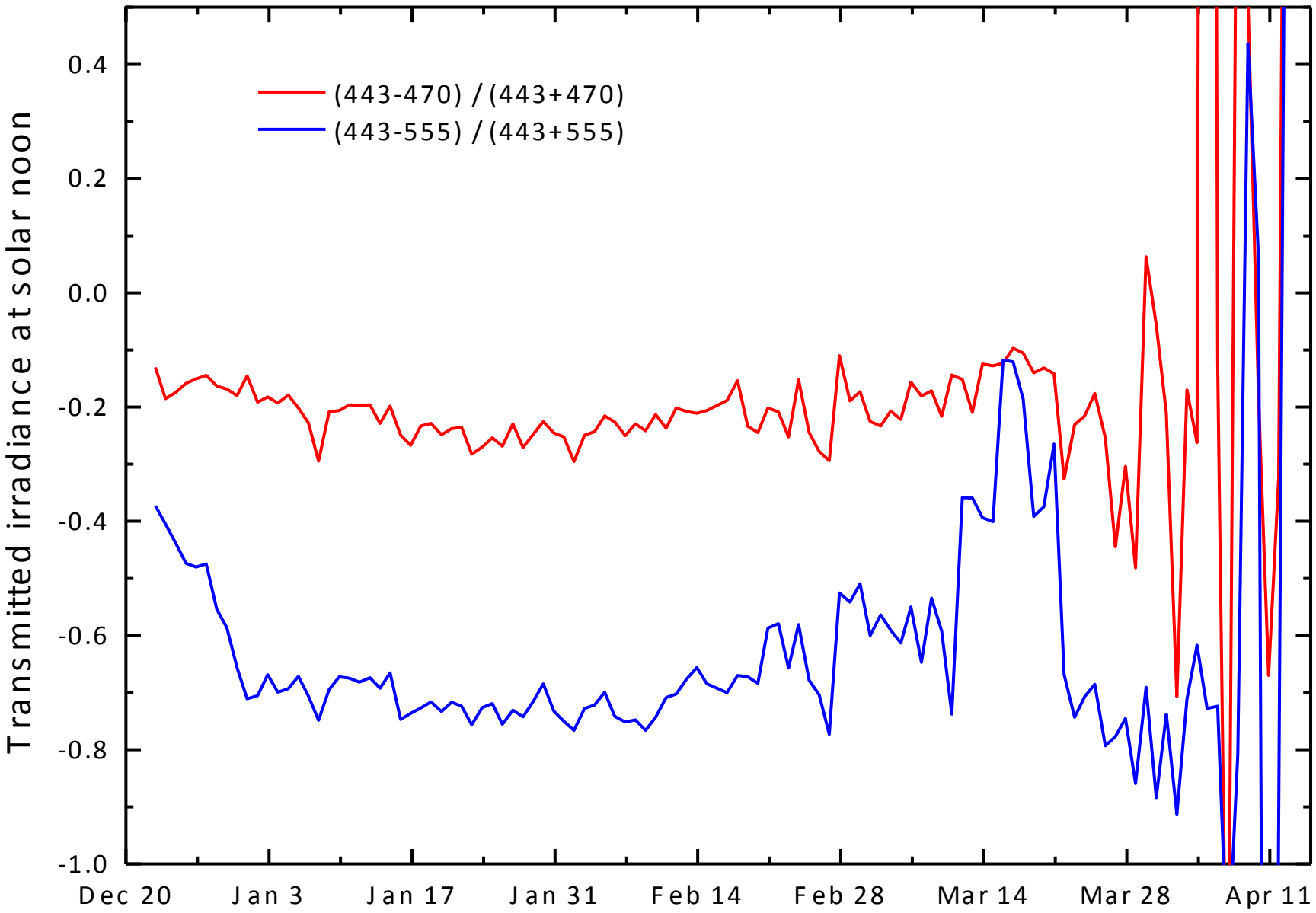


Thinning and Flooding






Incident PAR (µmole m-2 s-1)
25
20
15
10
5
0
Transmitted irradiance
0.4
0.3
0.2
0.1
0.0
Wavelength (nm)
411.2
443.5
470.4
489.7
555.5
589.6
Dec 20
Jan 3
Jan 17
Jan 31
Feb 14
Feb 28
Mar 14
Mar 28
Apr 11


(443-470) / (443+470)
(443-555) / (443+555)
Transmitted irradiance at solar noon
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
Dec 20
Jan 3
Jan 17
Jan 31
Feb 14
Feb 28
Mar 14
Mar 28
Apr 11