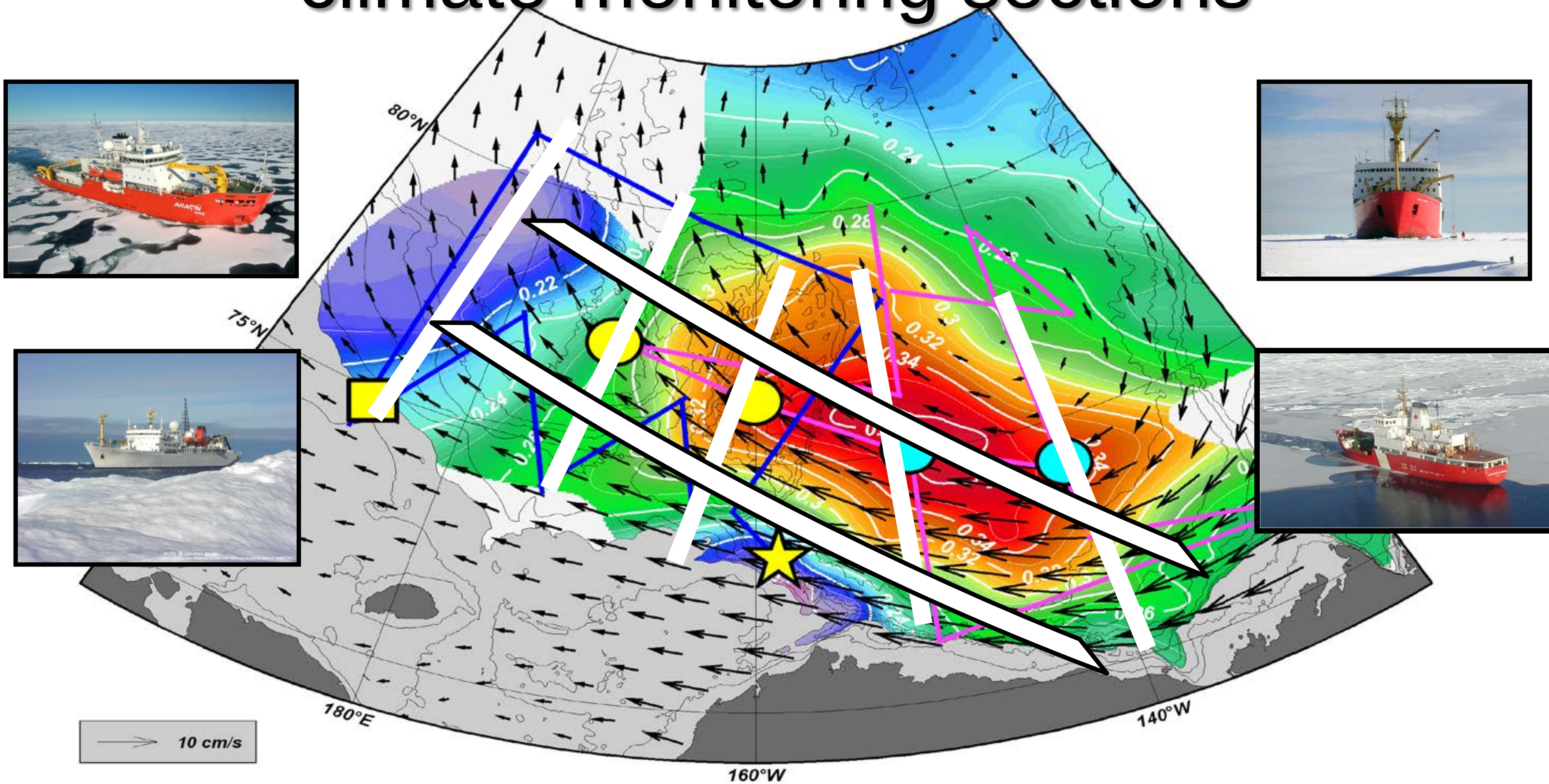
Presentation items for PAG meeting in KOPRI

Koji Shimada

Oct. 28-29

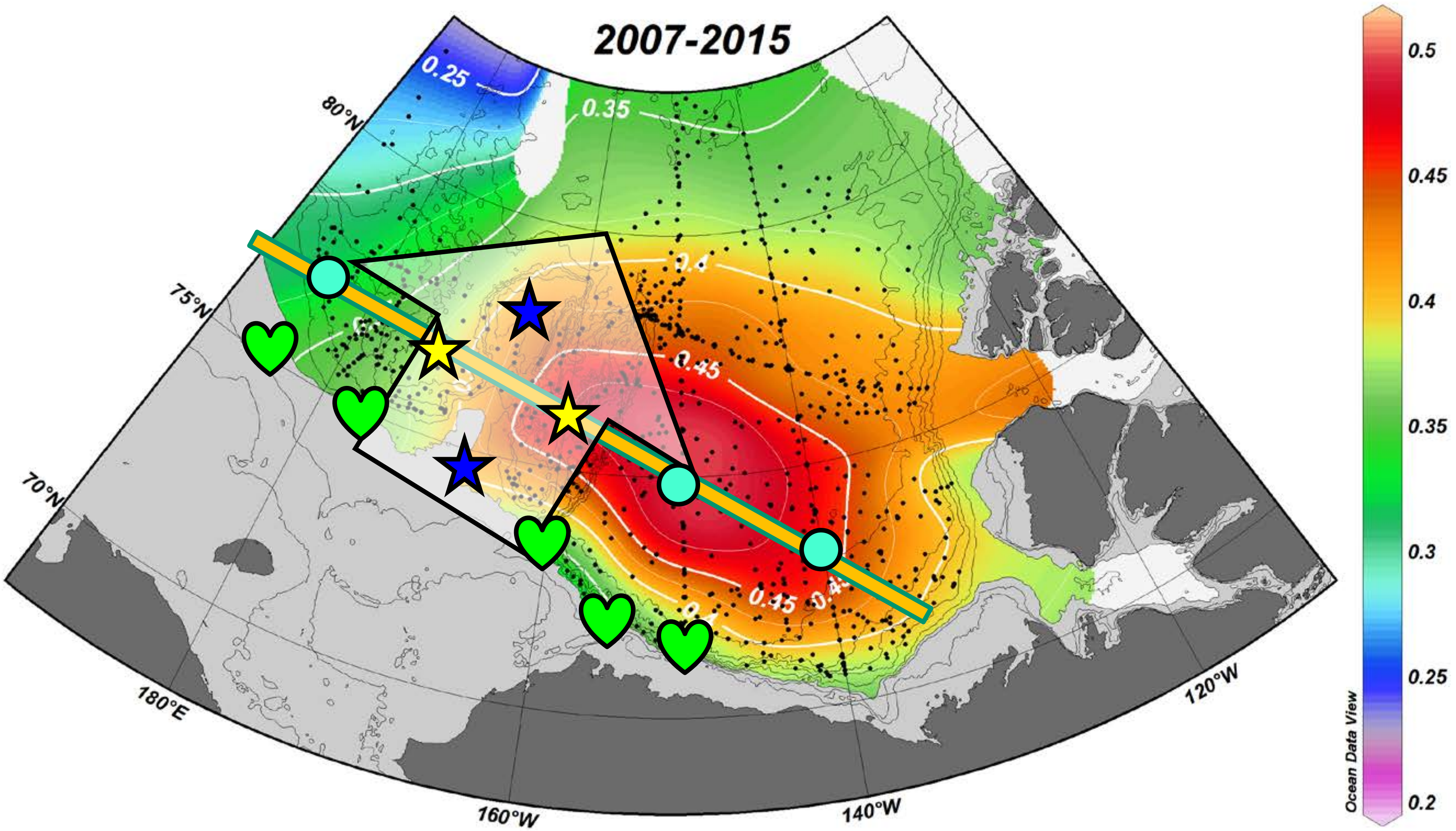
Proposed international Pacific Arctic climate monitoring sections



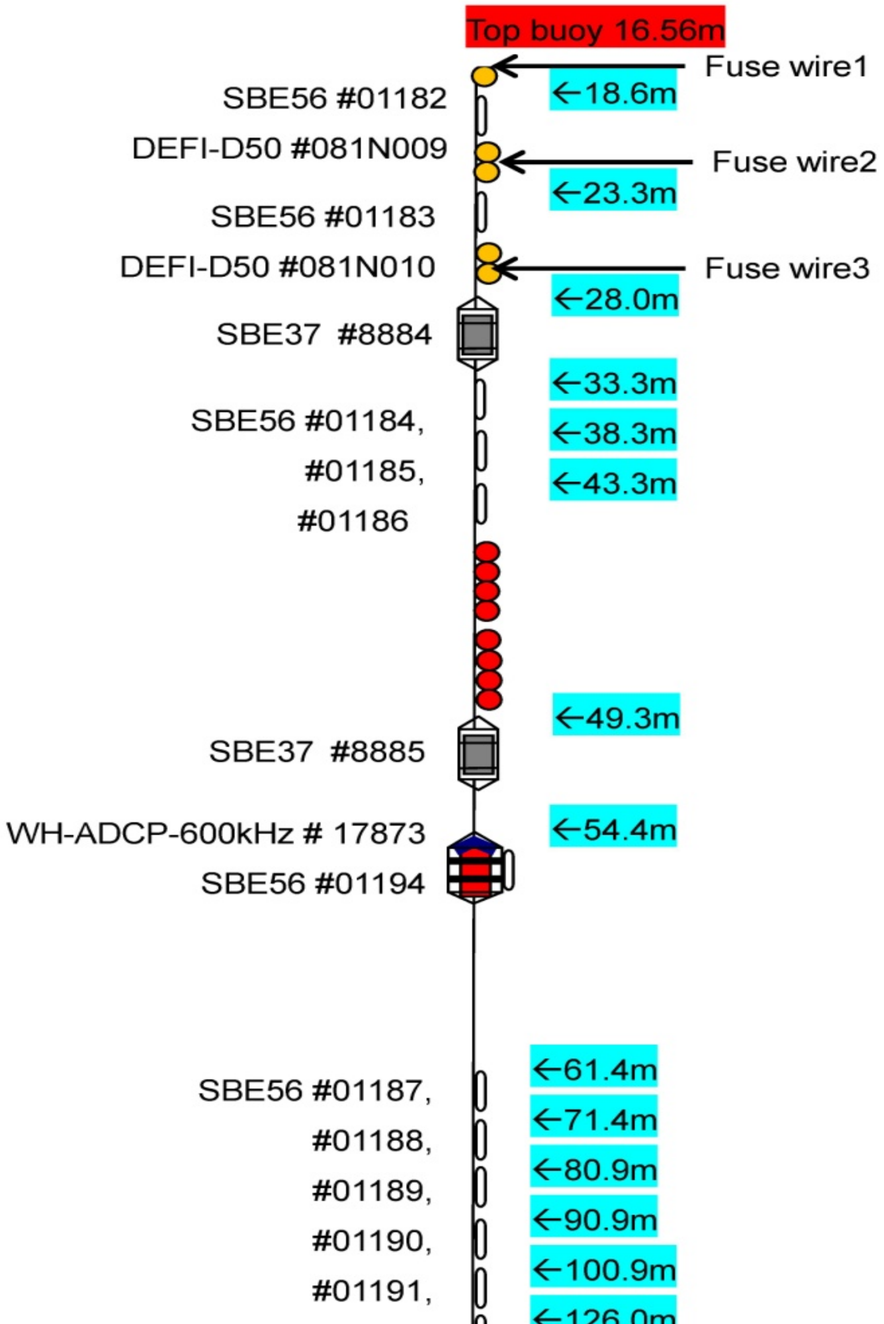
Background color: dynamic height at 100dar relative to 800bdar from Mirai and Louis S. St-Laurent 2008 cruises (Oceanic Beaufort Gyre)

Black vectors: average sea ice motion vectors for Nov. 2007- Apr. 2008 (Sea Ice Beaufort Gyre)

Simbols: Mooring array in 2012-2013 (TUMSAT/KOPRI/NIPR & WHOI)



2007-2015
0.25
0.35
0.4
0.45
0.45
80°N
75°N
70°N
180°E
160°W
140°W
120°W
0.5
0.45
0.4
0.35
0.3
0.25
0.2
Ocean Data View



Mooring CP13

Position:

(Anchor dropped position near the A frame)

77°28.331'N, 164°07.178'W

(Triangulation result)

77°28.3353'N, 164°07.0789'W

[77.47255°N, 164.11798°W]

Deployment time (Anchor):

August 26, 2013 23:42 (UTC)

Bottom depth: 277m

(272m[Multi beam depth] + 5m)

CTDs:

SBE37-SM S/No. 8884, 8885

Temperature loggers:

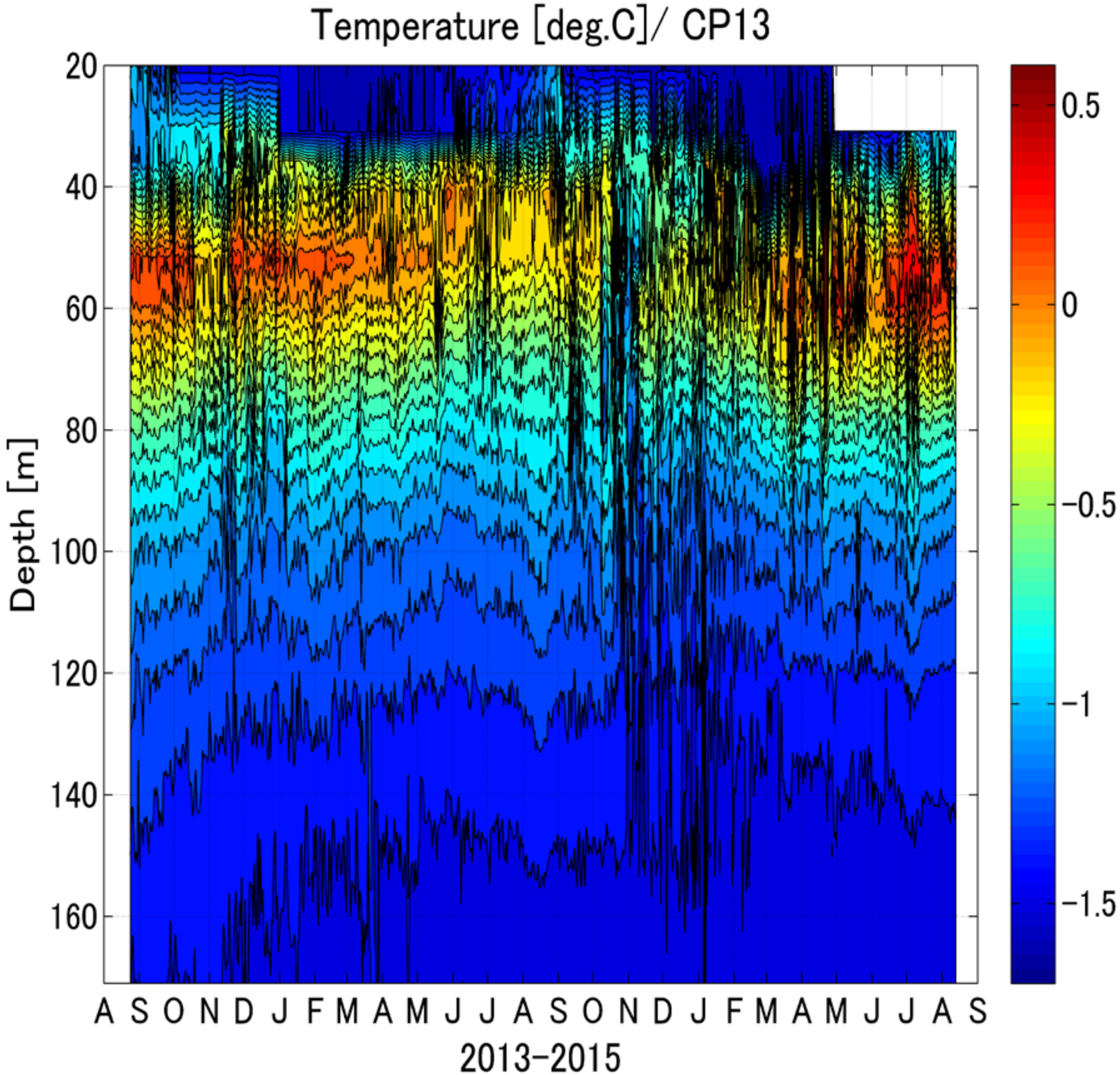
SBE56 S/No. 01182, 01183, 01184, 01185, 01186, 01187, 01188, 01189, 01190, 01191, 01192, 01193, 01194, 01195, 01196

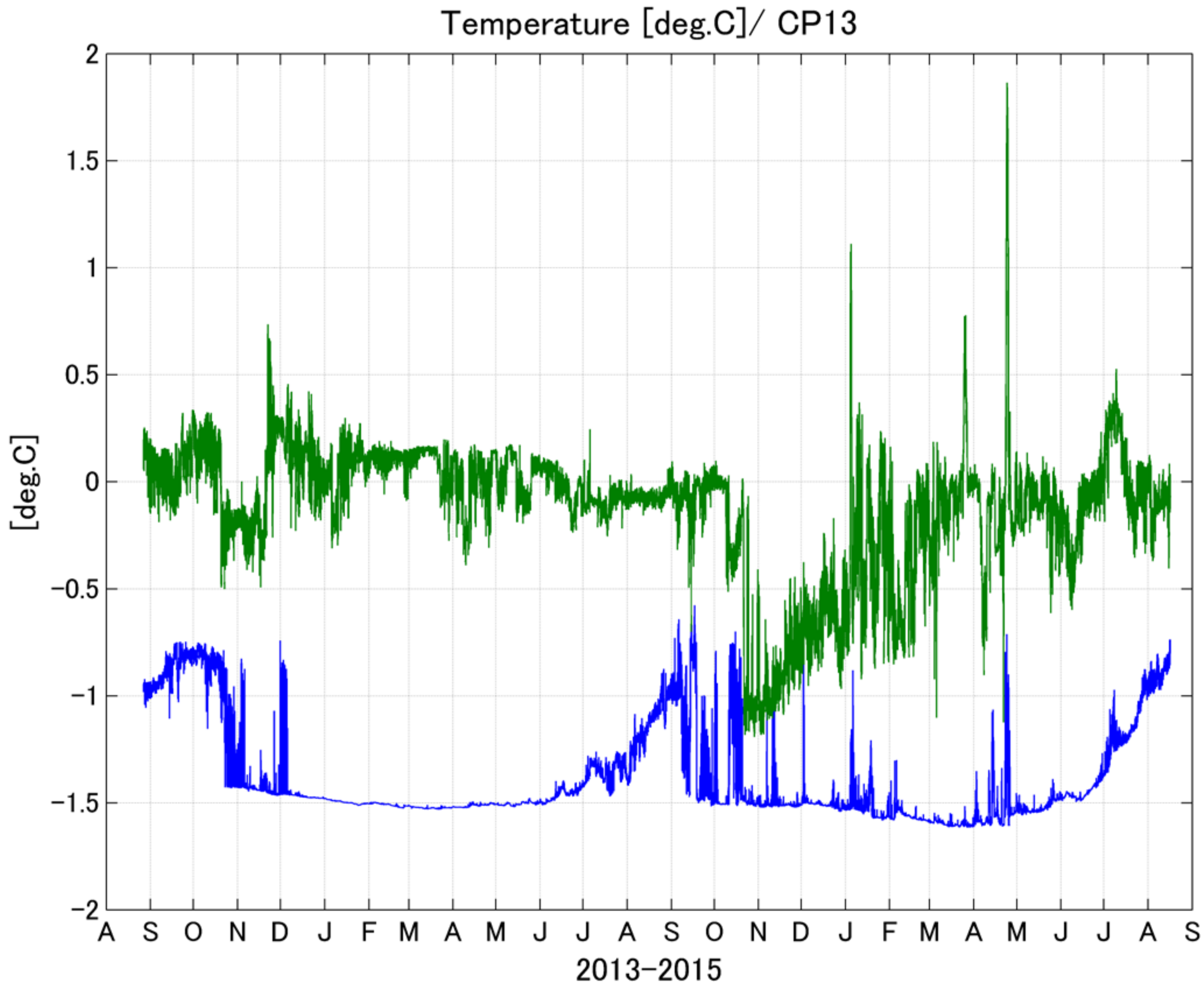
Pressure sensors:

DEFI-D50 S/No. 081N009, 081N010

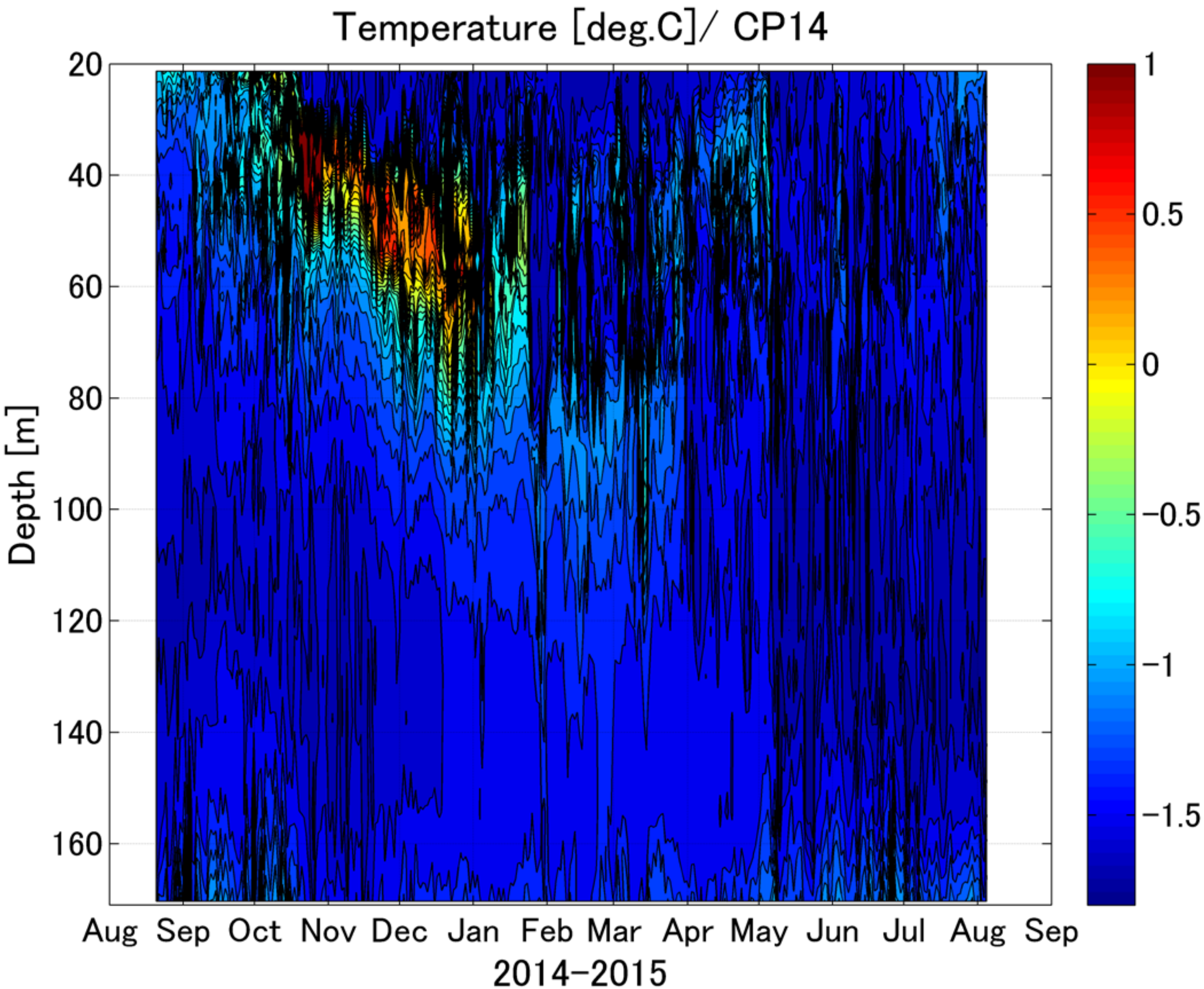
Current Meter:

WH-ADCP-600kHz Sentinel S/No. 17873


Temperature [deg.C]/ CP13
Depth [m]
20
40
60
80
100
120
140
160
A S O N D J F M A M J J A S O N D J F M A M J J A S
2013-2015
0.5
0
−0.5
−1
−1.5



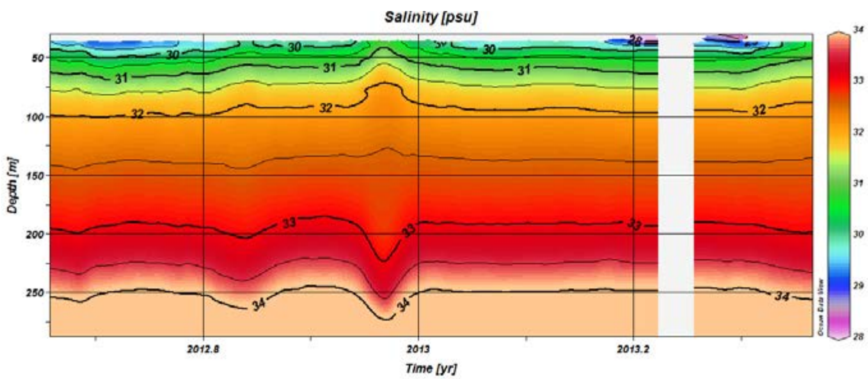
Temperature [deg.C]/ CP13
2
1.5
1
0.5
0
−0.5
−1
−1.5
−2
[deg.C]
A S O N D J F M A M J J A S O N D J F M A M J J A S
2013−2015

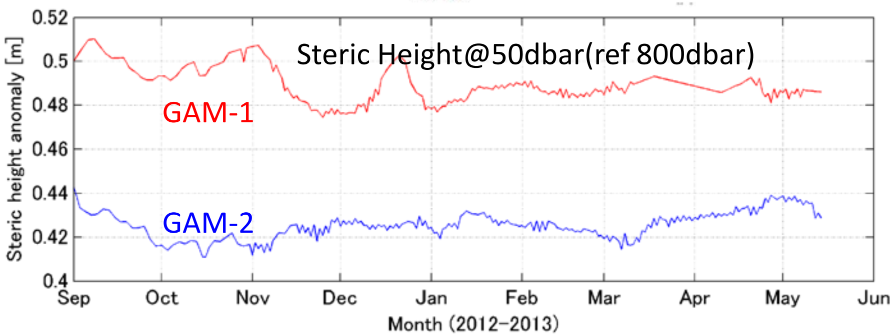


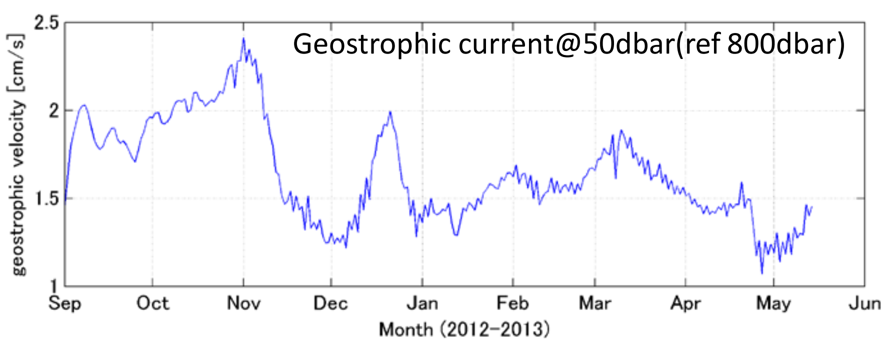
Temperature [deg.C]/ CP14
Depth [m]
20
40
60
80
100
120
140
160
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
2014−2015
1
0.5
0
−0.5
−1
−1.5

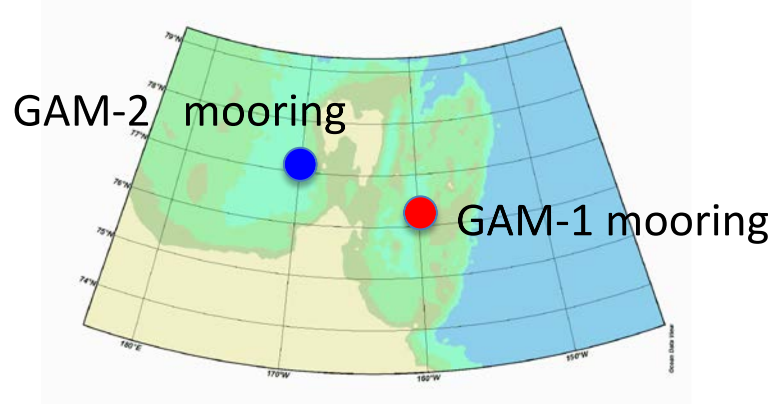
Strategy of monitoring for climate oriented studies

Variations of upper ocean circulation





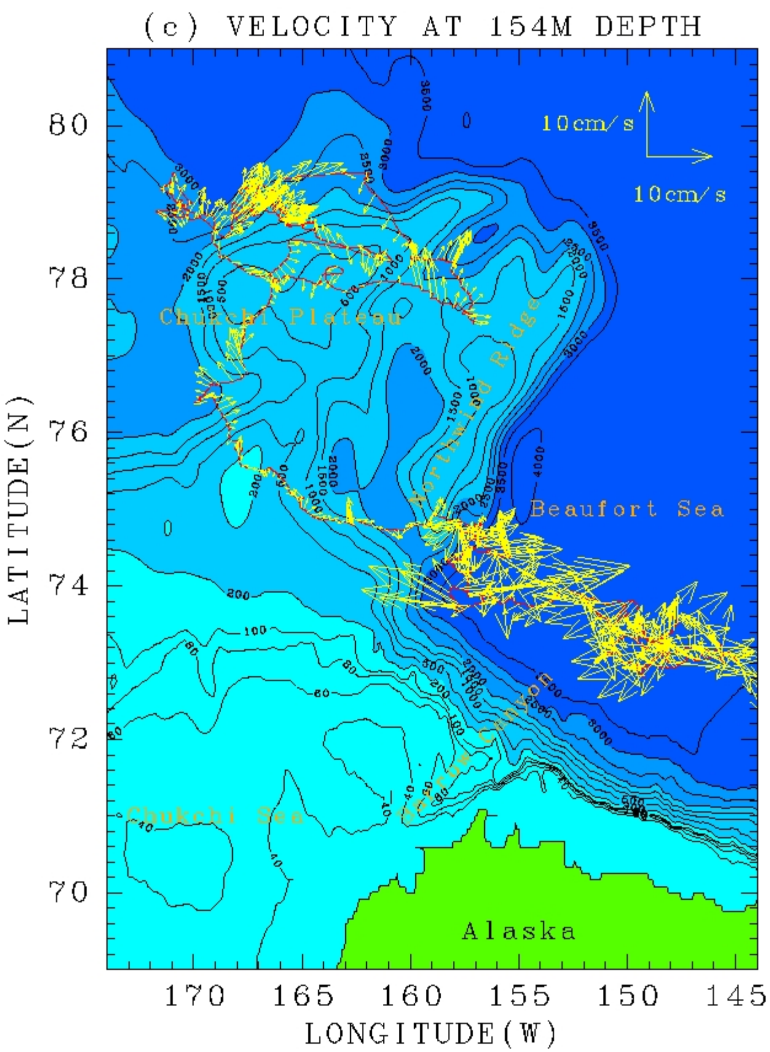


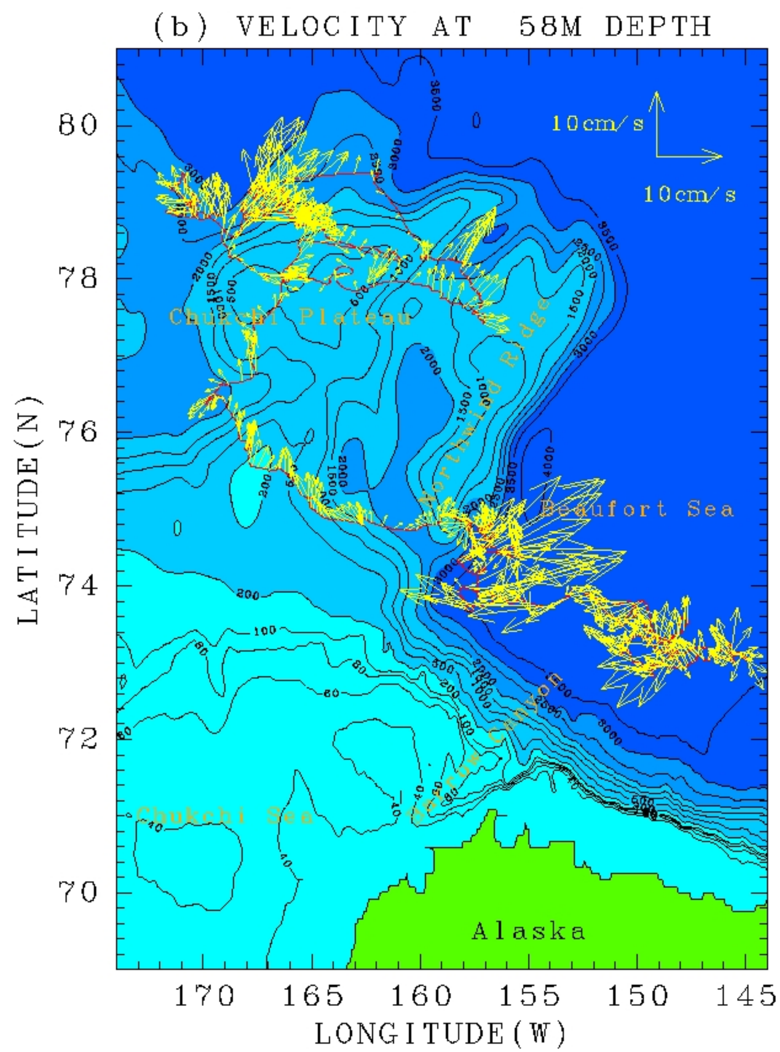


Mean northward current: 1.64cm/s
(500km/year)
STD of the mean current: 0.28cm/s
(including eddies)

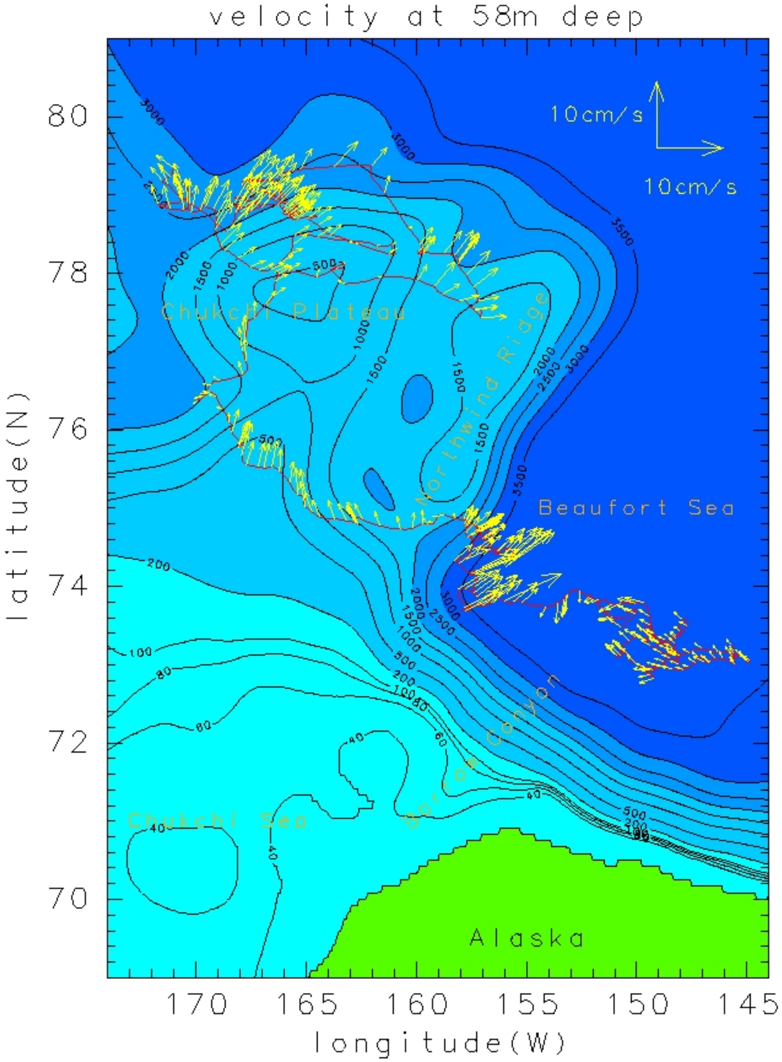
In the CBL area west of the Northwind Ridge, almost no seasonal variations, just inter-annual variations

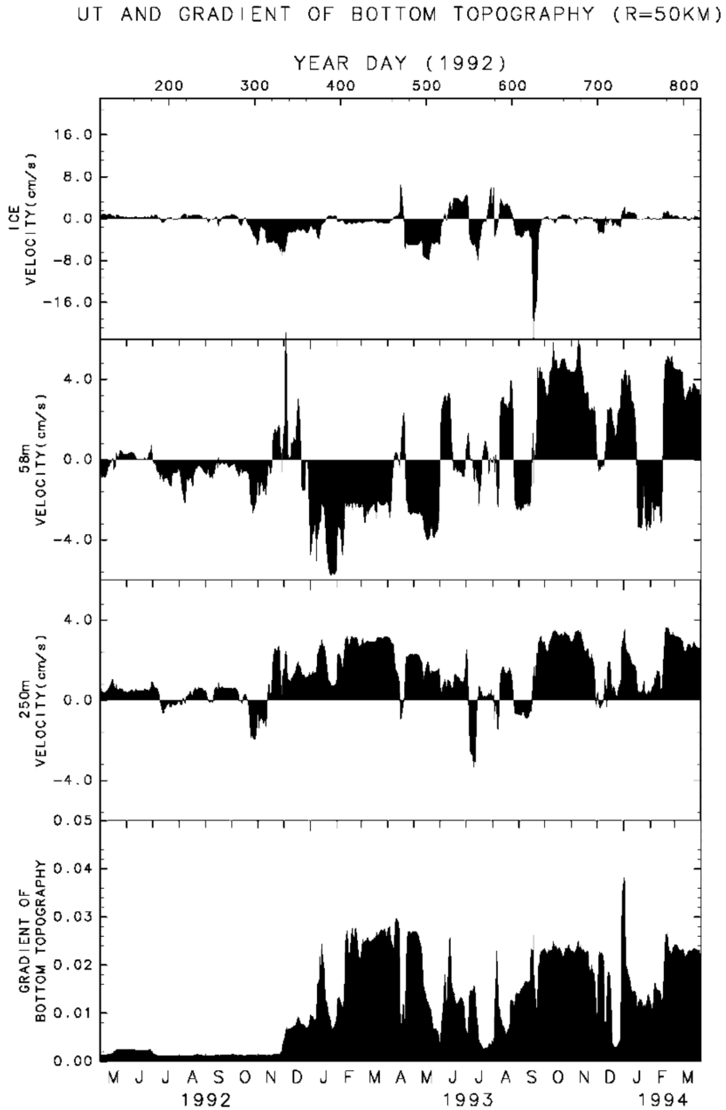
In the western Canada Basin, one section per year is enough to detect the change of large -scale ocean circulation

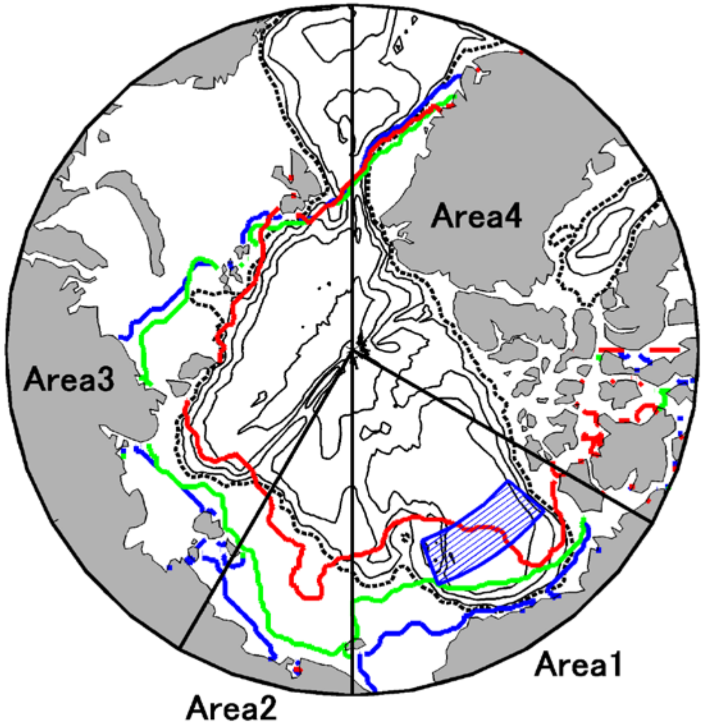

(c) VELOCITY AT 154M DEPTH
10cm/s
10cm/s
Chukchi Plateau
Northwind Ridge
Beaufort Sea
Barrow Canyon
Chukchi Sea
Alaska
LATITUDE(N)
LONGITUDE(W)

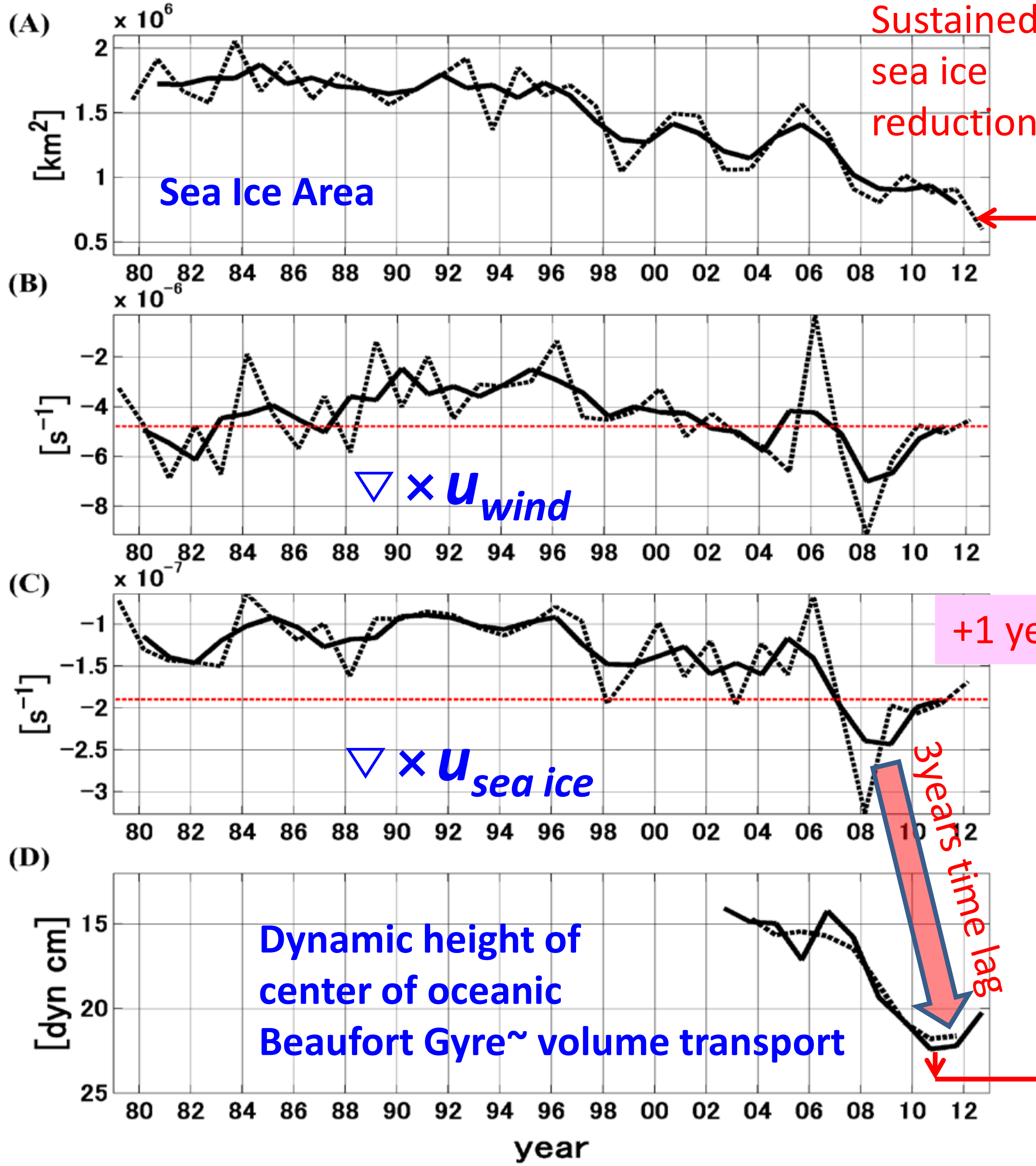

(b) VELOCITY AT 58M DEPTH
10cm/s
10cm/s
Chukchi Plateau
Northwind Ridge
Beaufort Sea
Barrow Canyon
Chukchi Sea
Alaska
LATITUDE(N)
LONGITUDE(W)

ノースウインド海嶺の重要性



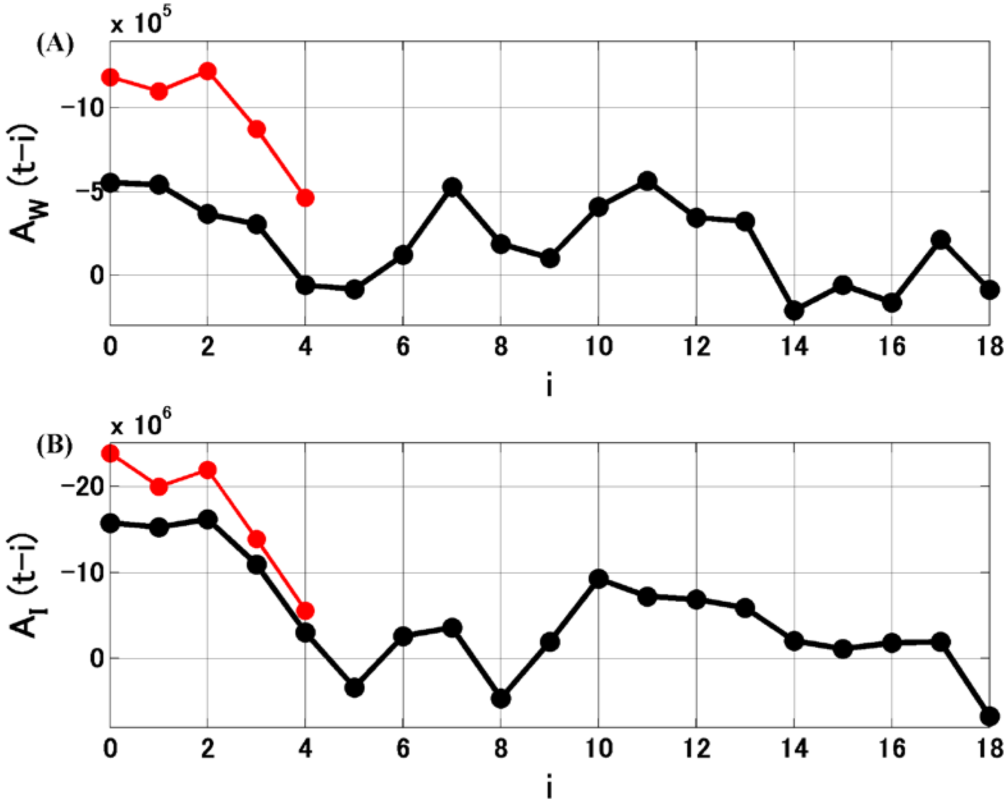






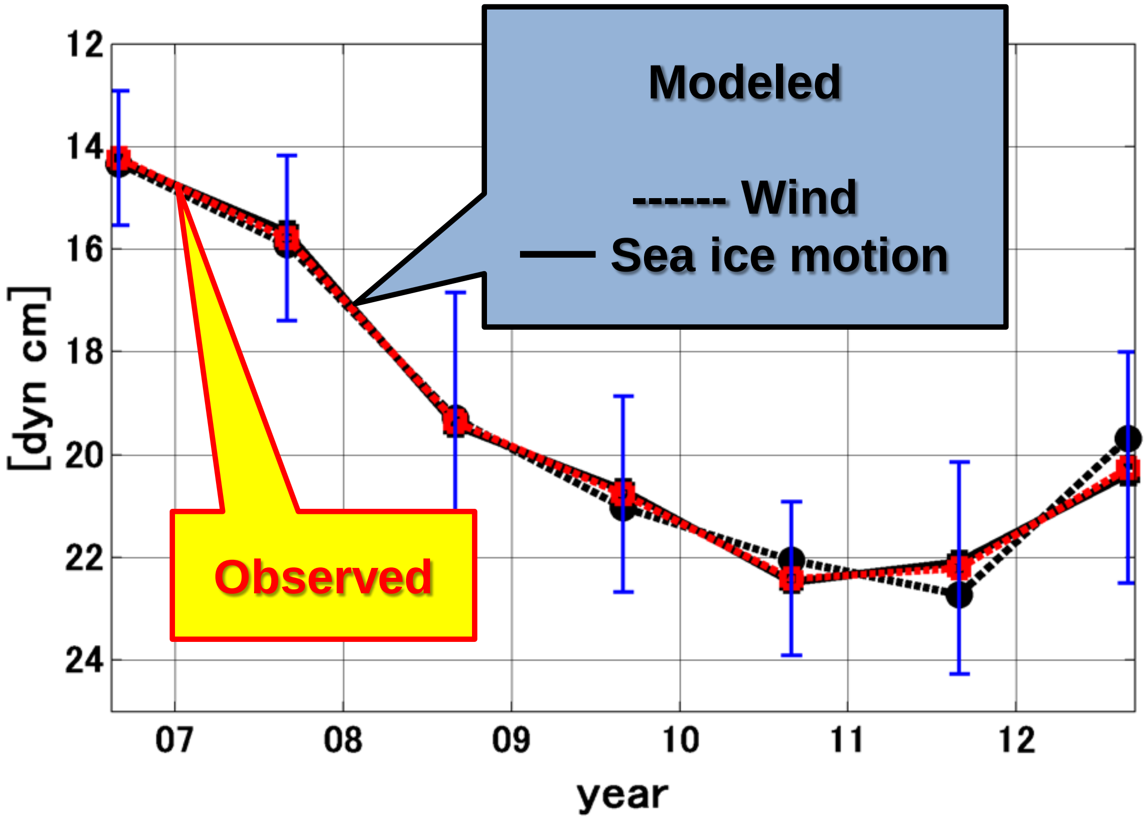
Upper ocean response delayed about 3 years relative to the surface forcings (wind or sea ice motion).

Yoshizawa et al., (2015)



$$D_{wind\ model}(t) = \sum_{i=0}^{\infty}\left[A_W(t-i)\cdot \nabla \times \overrightarrow{u_W}(t-i)\right] + B_W$$

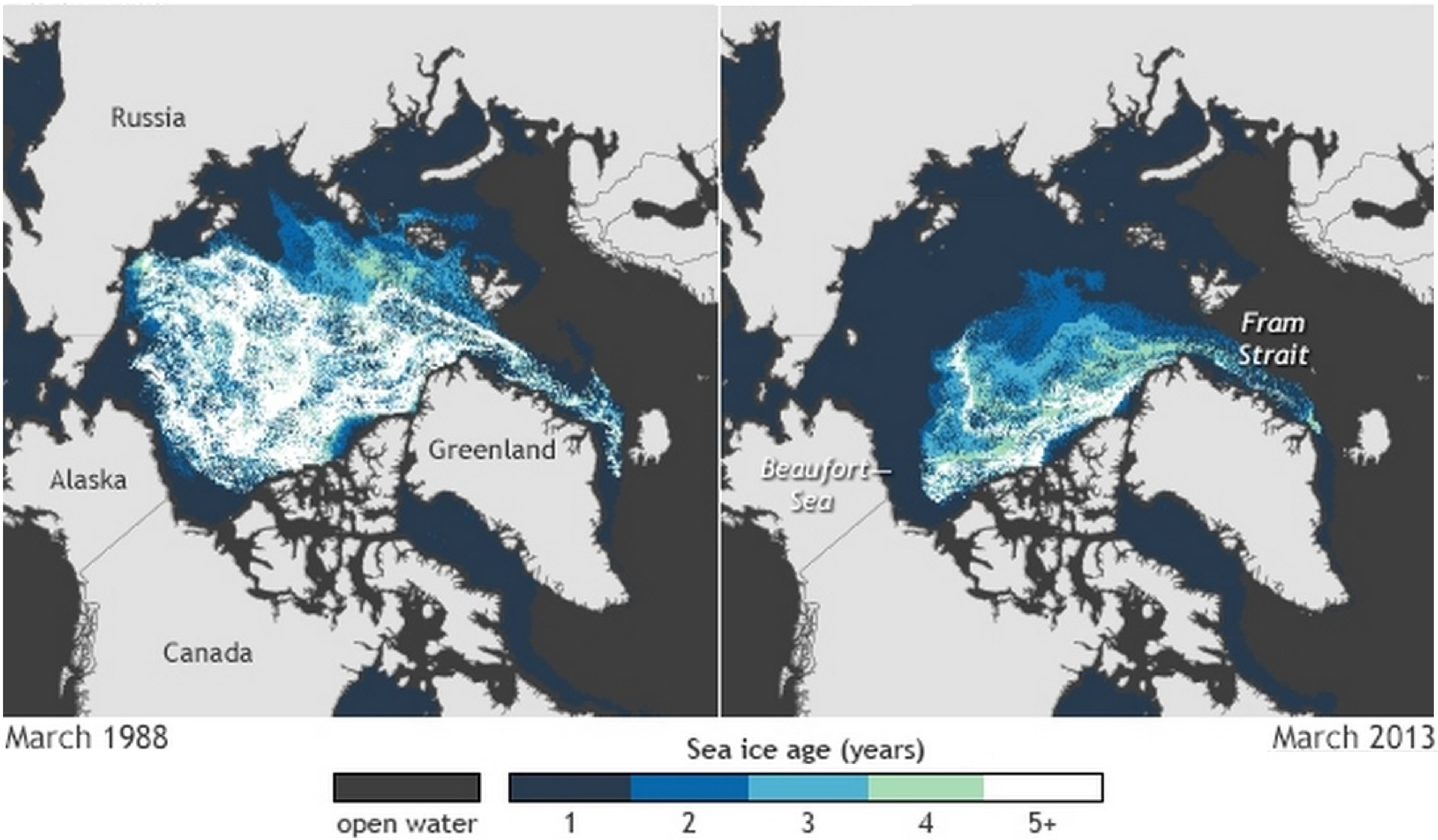
$$D_{sea\ ice\ model}(t) = \sum_{i=0}^{\infty}\left[A_I(t-i)\cdot \nabla \times \overrightarrow{u_I}(t-i)\right] + B_I$$



Accuracy ～ 0.2 dyn. cm
relative to 10 dyn.cm variation

$$D_{wind\,model}(t) = \sum_{i=0}^{4} [A_W(t-i) \cdot \nabla \times \overrightarrow{u_W}(t-i)] + B_W$$

$$D_{sea\,ice\;model}(t) = \sum_{i=0}^{4} [A_I(t-i) \cdot \nabla \times \overrightarrow{u_I}(t-i)] + B_I$$

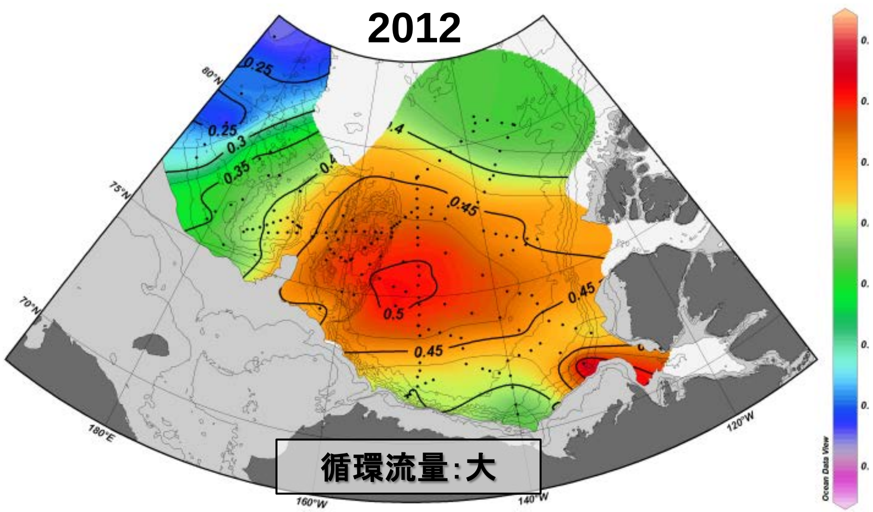


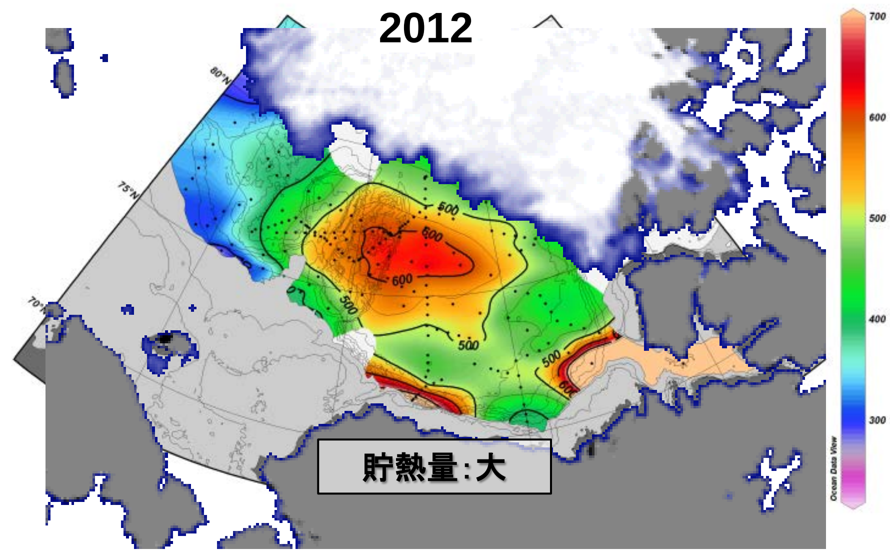
by Mark Tschudi, University of Colorado

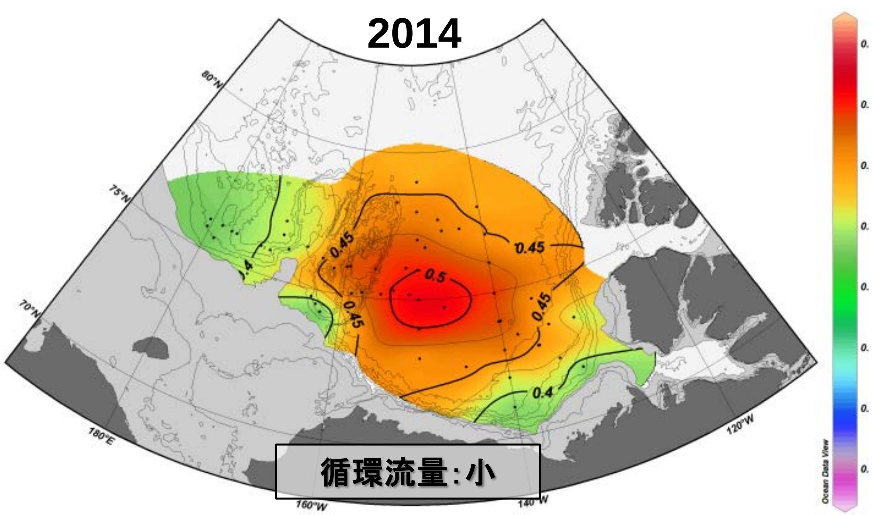
海洋循環・構造変動を海氷変動

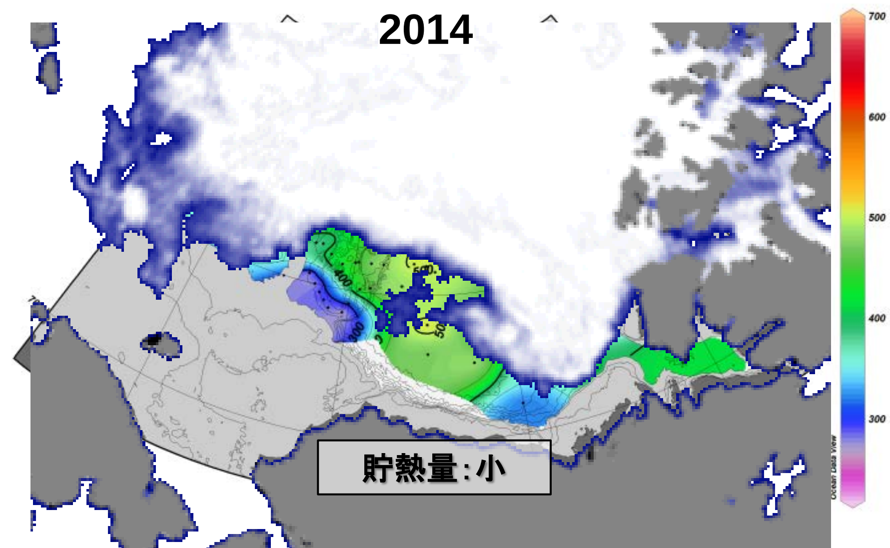
海洋循環
（800dbar基準50dbar面の力学高度偏差）

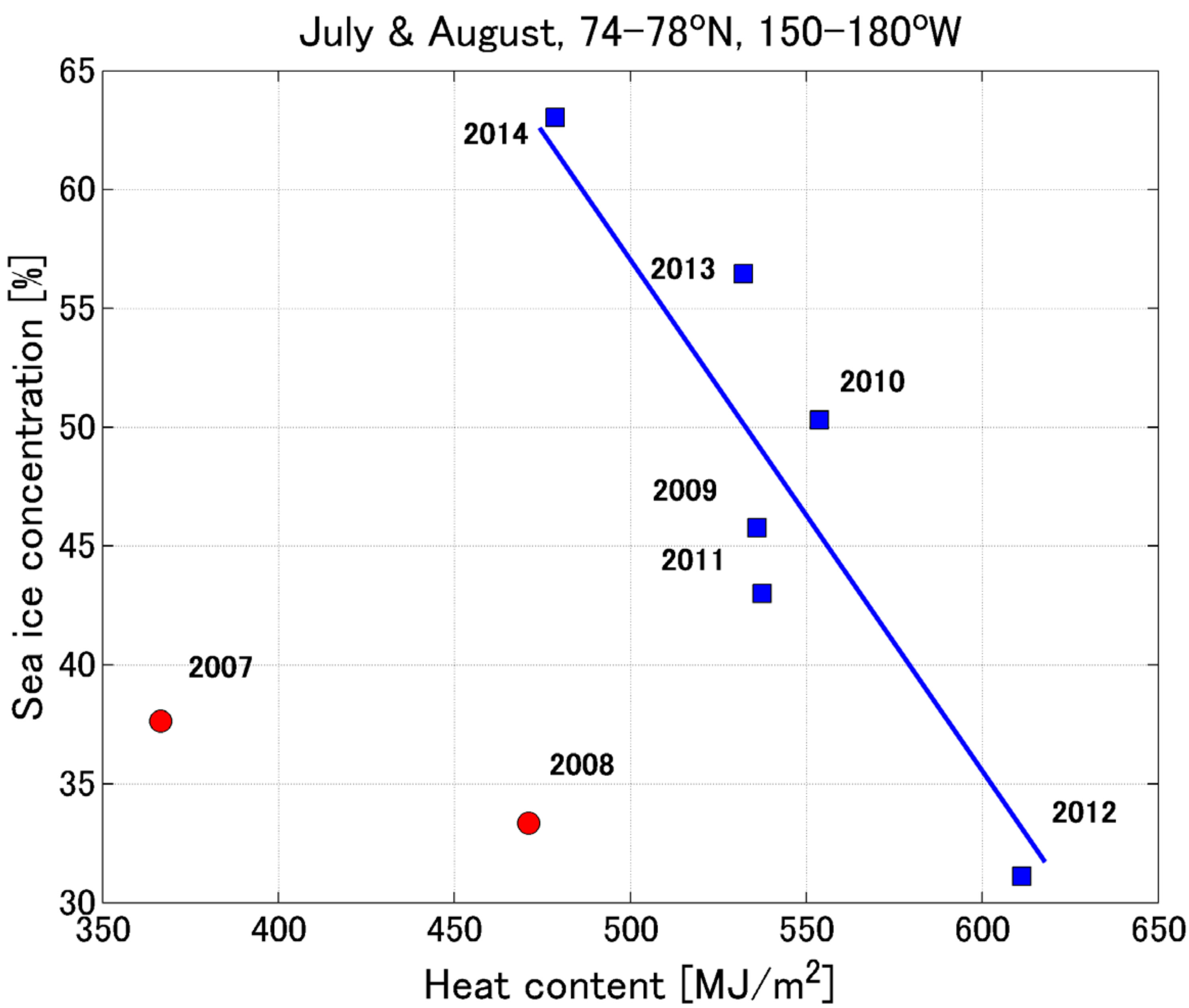
貯熱量
太平洋水層（20-150m）



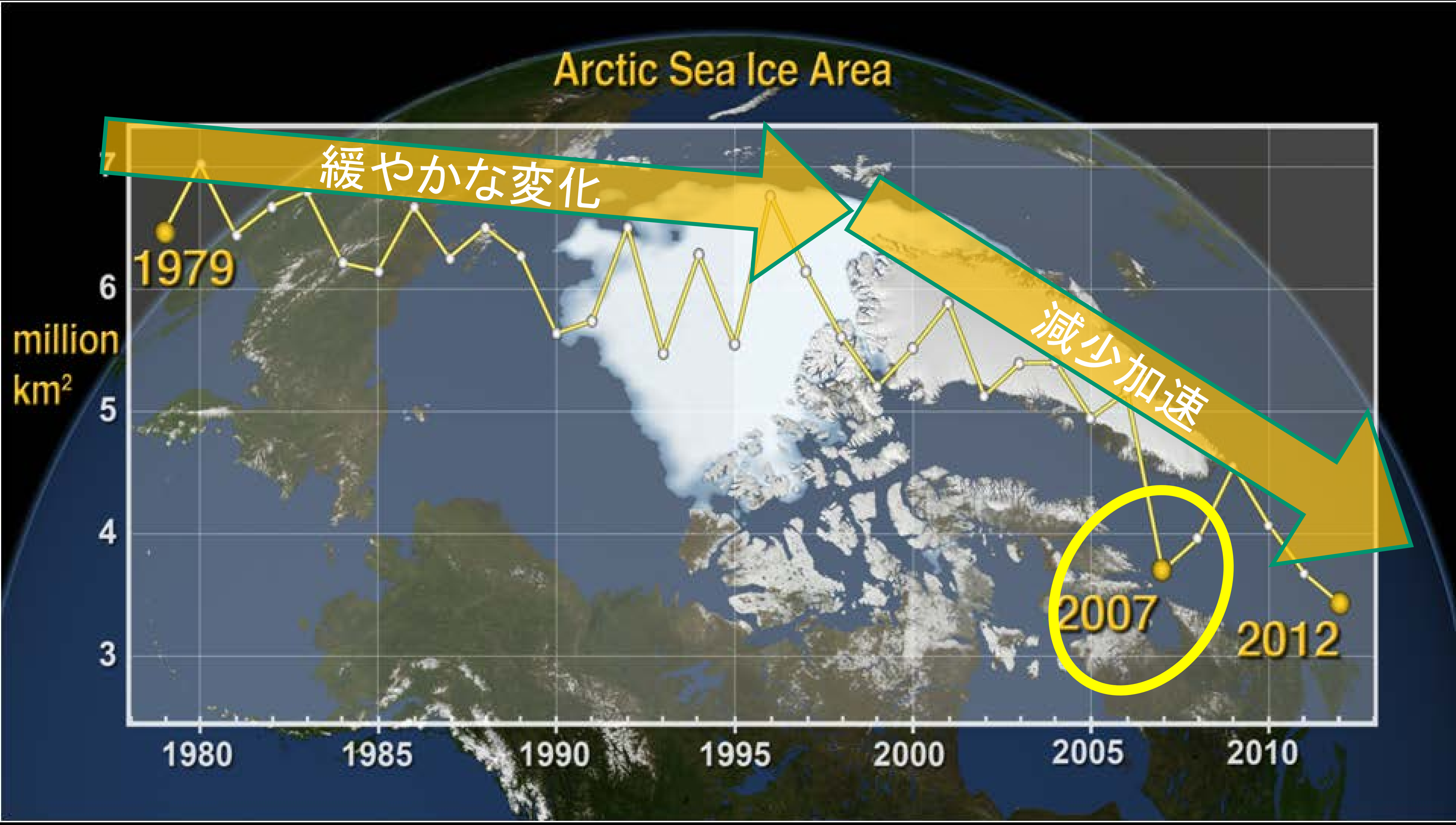




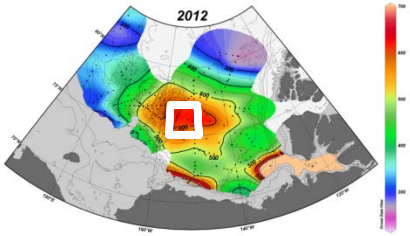



July & August, 74–78°N, 150–180°W
Sea ice concentration [%]
Heat content [MJ/m2]
65
60
55
50
45
40
35
30
350
400
450
500
550
600
650
2014
2013
2010
2009
2011
2007
2008
2012

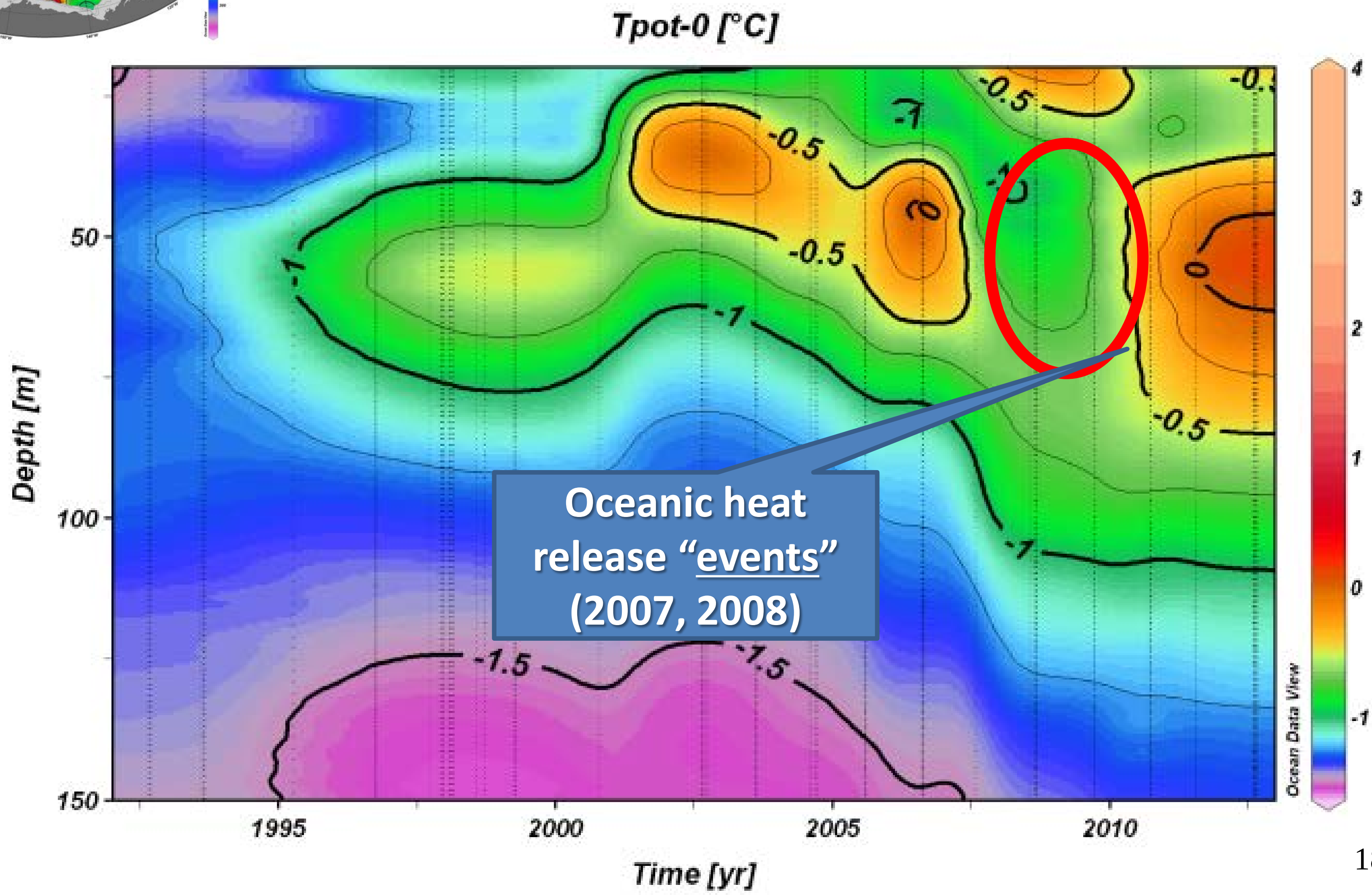
海氷面積の変化1979～2012



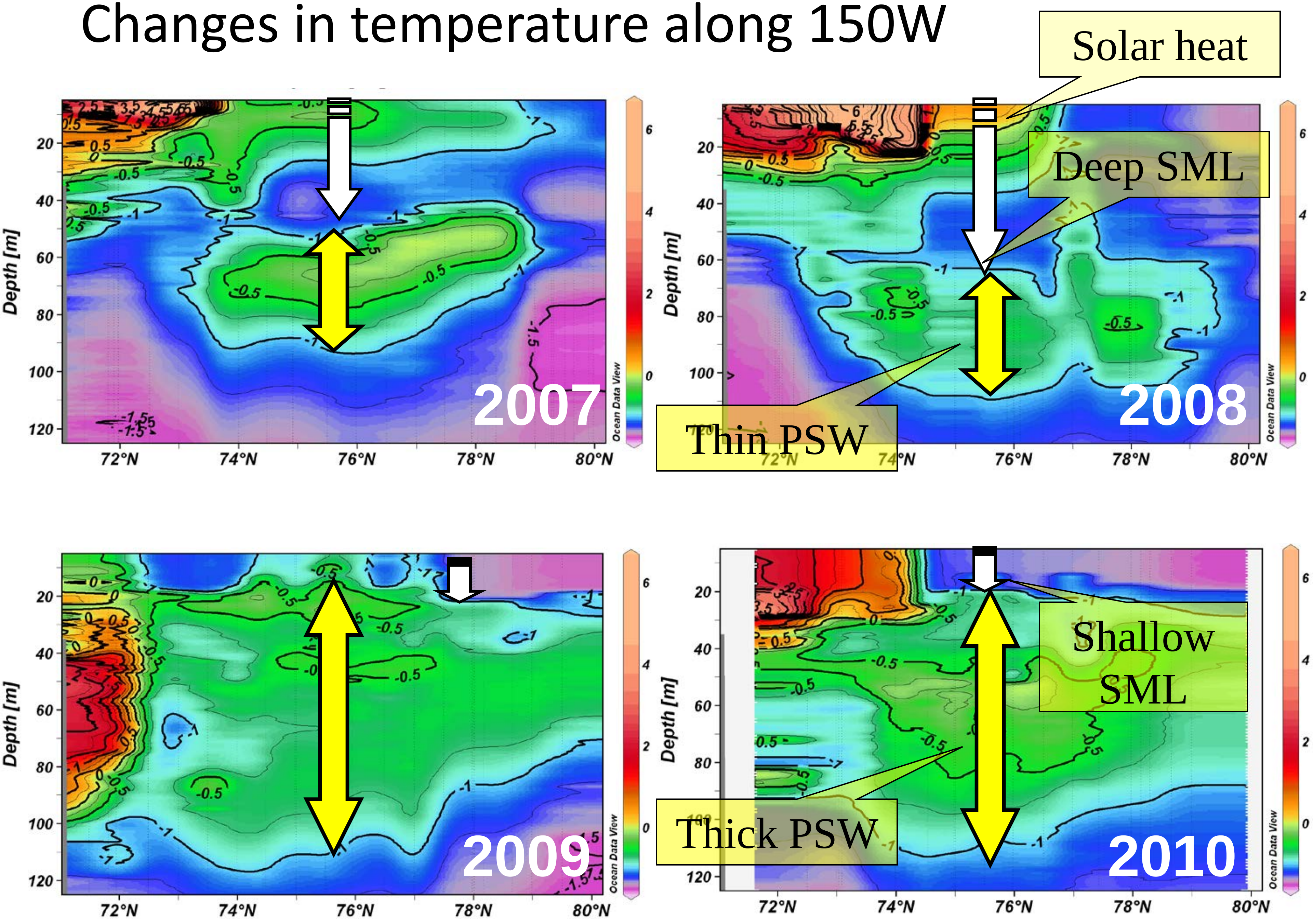
Time series of temperature on the Northwindridge



Heat release "event".

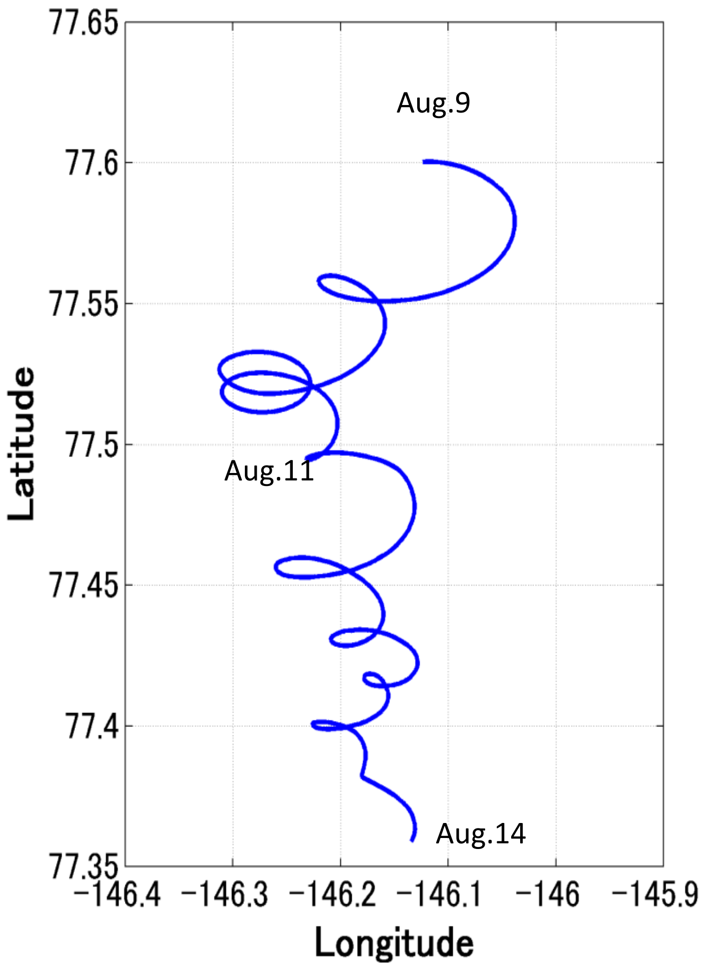


Changes in temperature along 150W

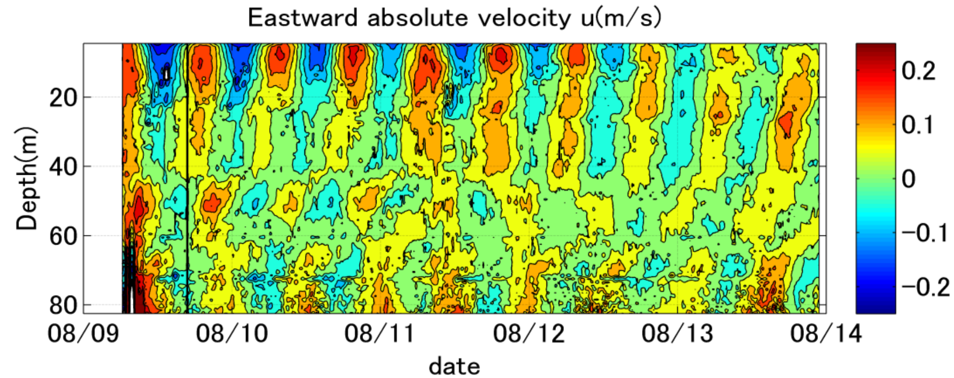


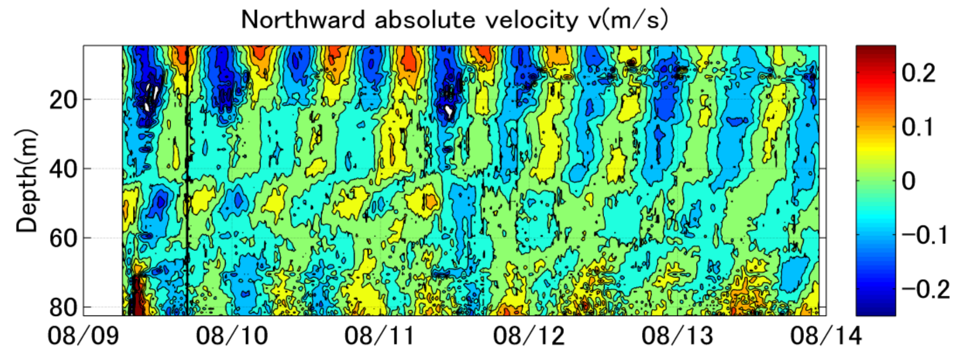
2.研究成果

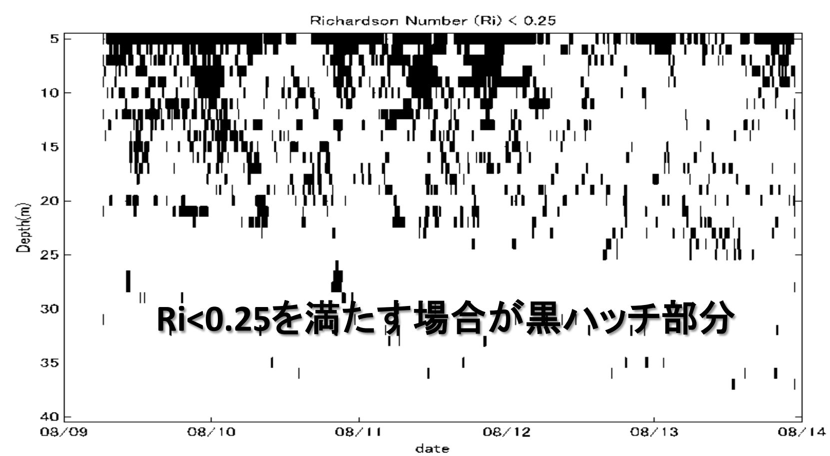
戦略研究目標に対して何を達成したのか、テーマごとに図表・数値を用いて分かりやすく示して下さい。
特に注目に値するチャンピオンデータや代表的研究成果については、冒頭に特出しで明記して下さい。



氷上観測ステーションの漂流軌跡

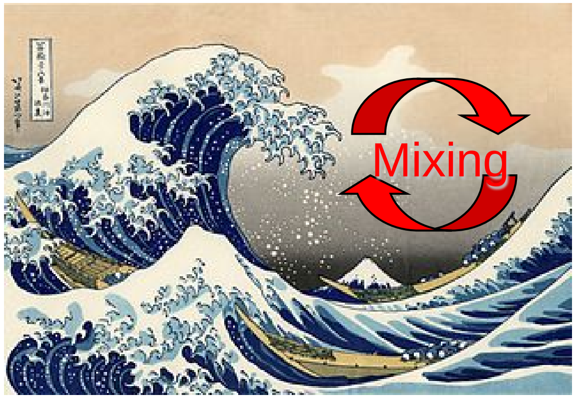


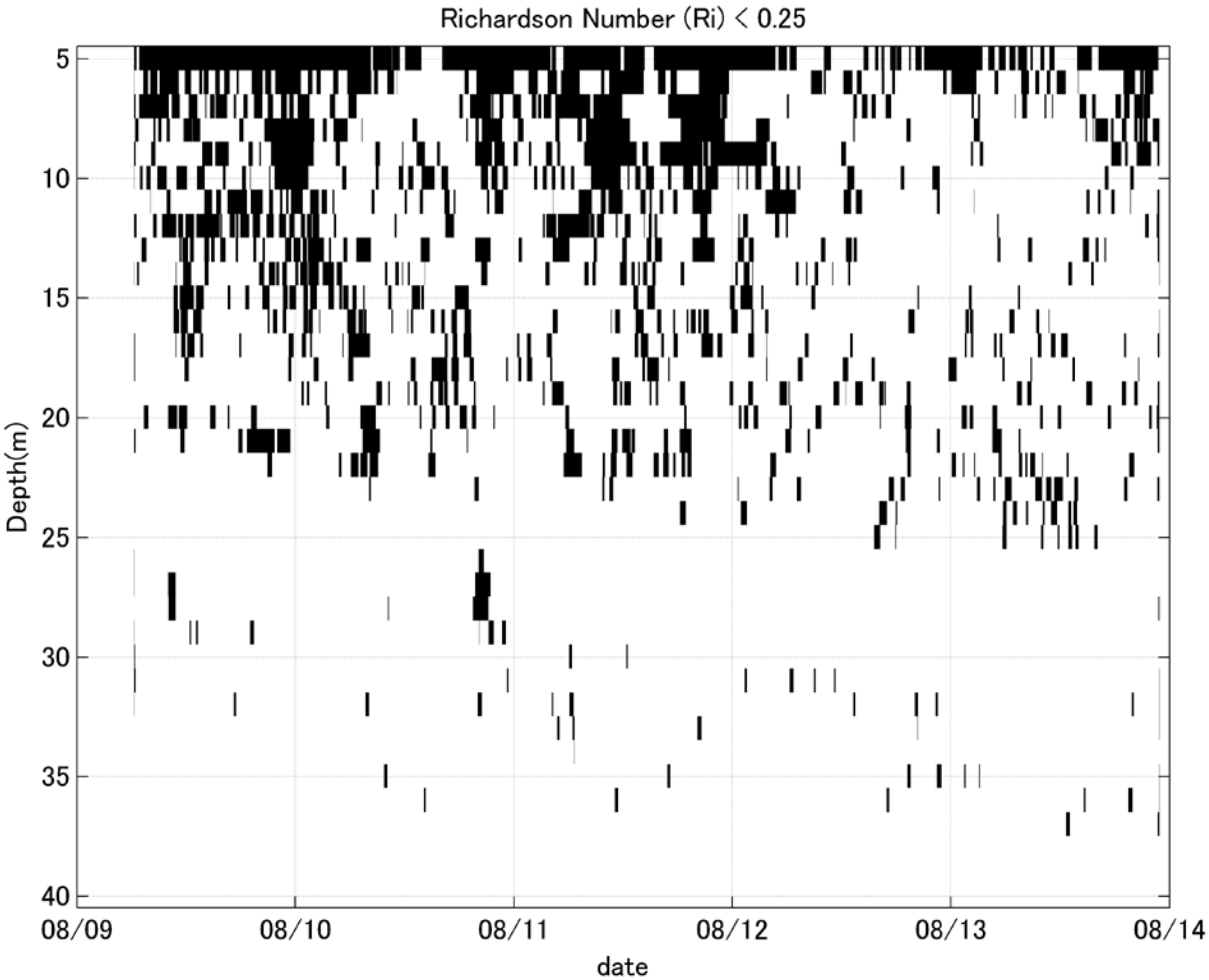




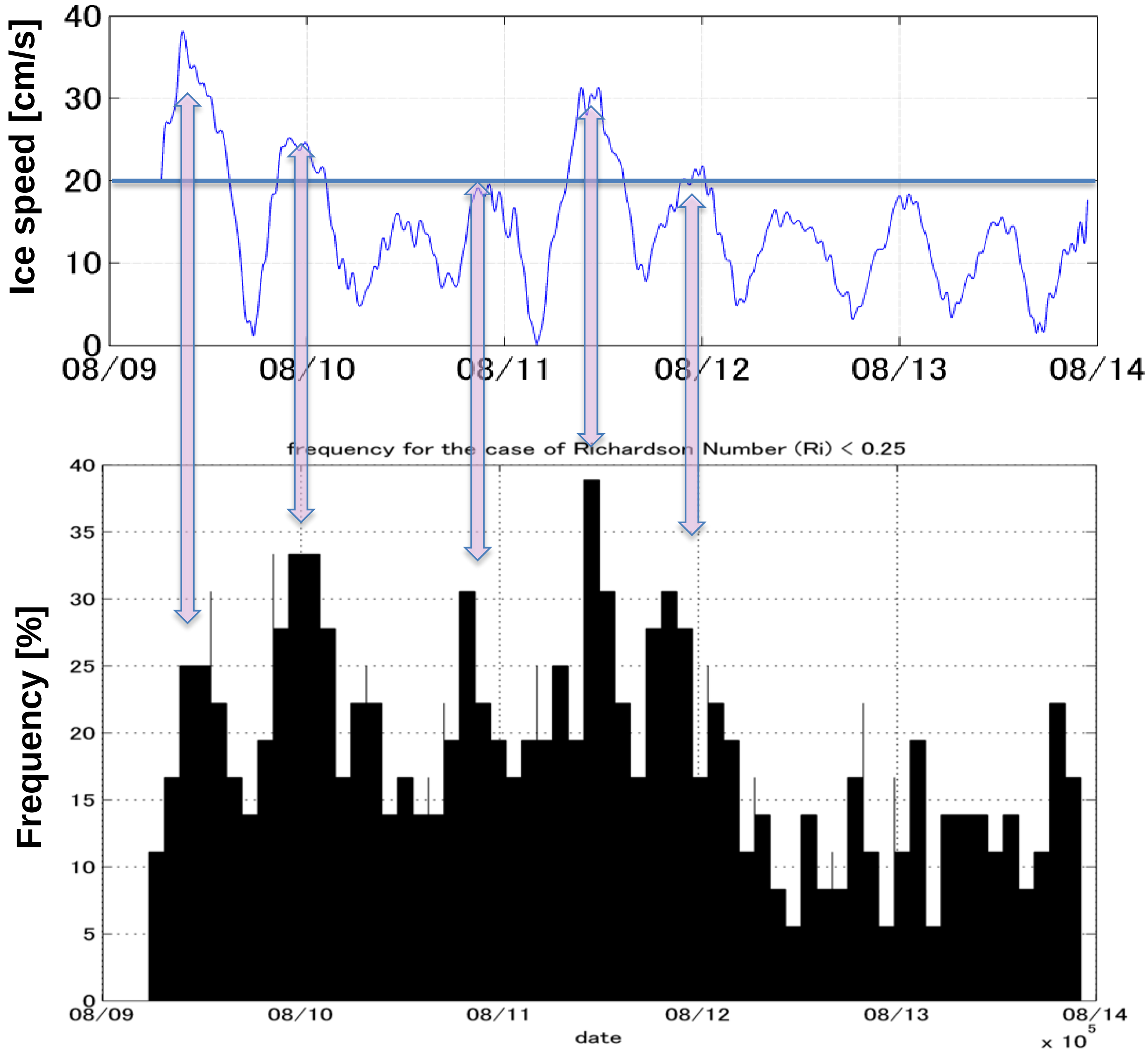
$$\boldsymbol{Ri = N^2/S^2}$$

$$N^2 = -\frac{1}{\rho}\frac{\partial \rho}{\partial z}, \quad S^2 = \left(\frac{\partial u}{\partial z}\right)^2$$





Sea ice speed and Frequency of the case satisfying Ri <0.25 (5-30m)

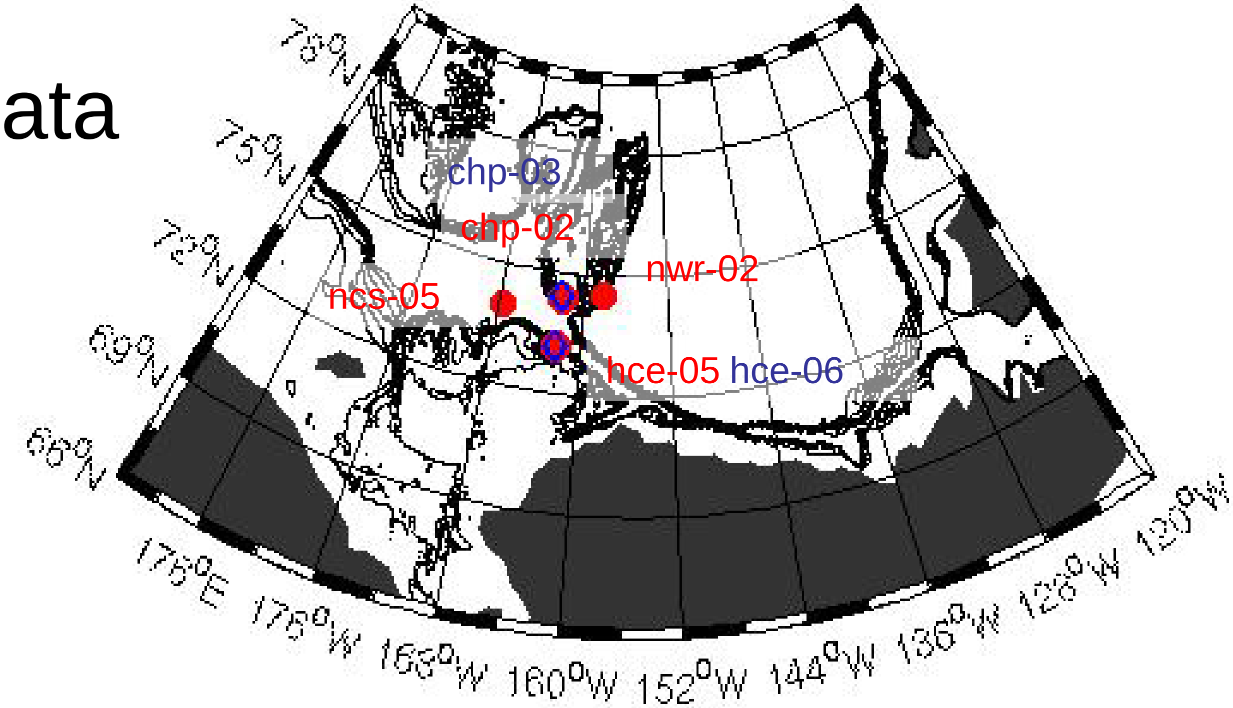


When sea ice speed is greater than 20cm/s, strong vertical mixing occurred.

The former study by Kawashima (2013) was meaningful.

Indirect evaluation of amplitude of inertial oscillation of sea ice from satellite data (AMSR-E)

Moored ADCP data



Chp-02　2002年　9月　3日　～ 2003年　9月17日

Chp-03　2003年　9月　3日　～ 2004年　8月17日

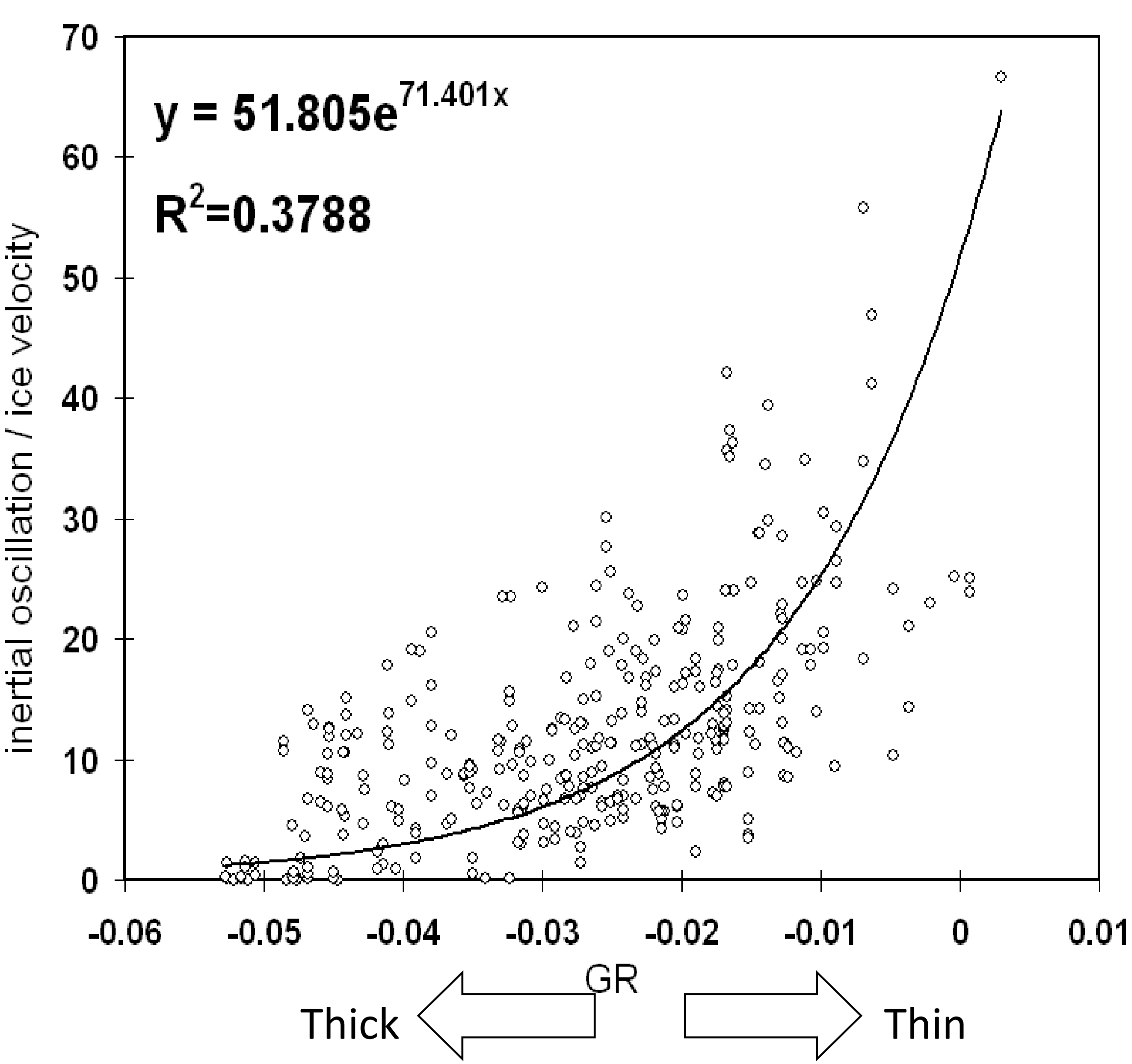
Hce-05　2005年10月　3日　～ 2006年10月　3日

Hce-06　2006年10月　6日　～ 2007年10月　6日

Ncs-05　2005年10月　5日　～ 2006年10月　5日

Nwr-03　2003年　8月16日　～ 2004年　9月　7日

[Amplitude of inertial oscillation] / [background low-passed sea ice velocity] depends on GR



Kawashima (Masters Thesis), 2013

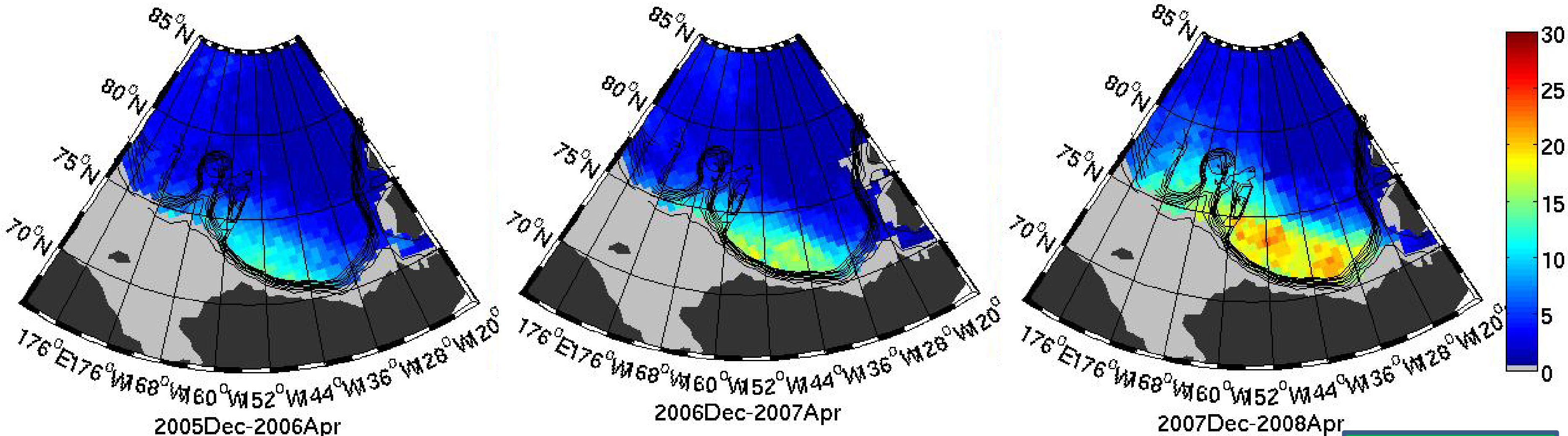
Plots for
Concentration > 95%
Wind speed > 6m/s
Ice speed > 20cm/s

- Thickness and sea ice type control amplitude of inertial oscillation
- This regression curve enable us to estimate absolute sea ice speed including inertial oscillation

Estimation of daily maximum absolute speed of sea ice

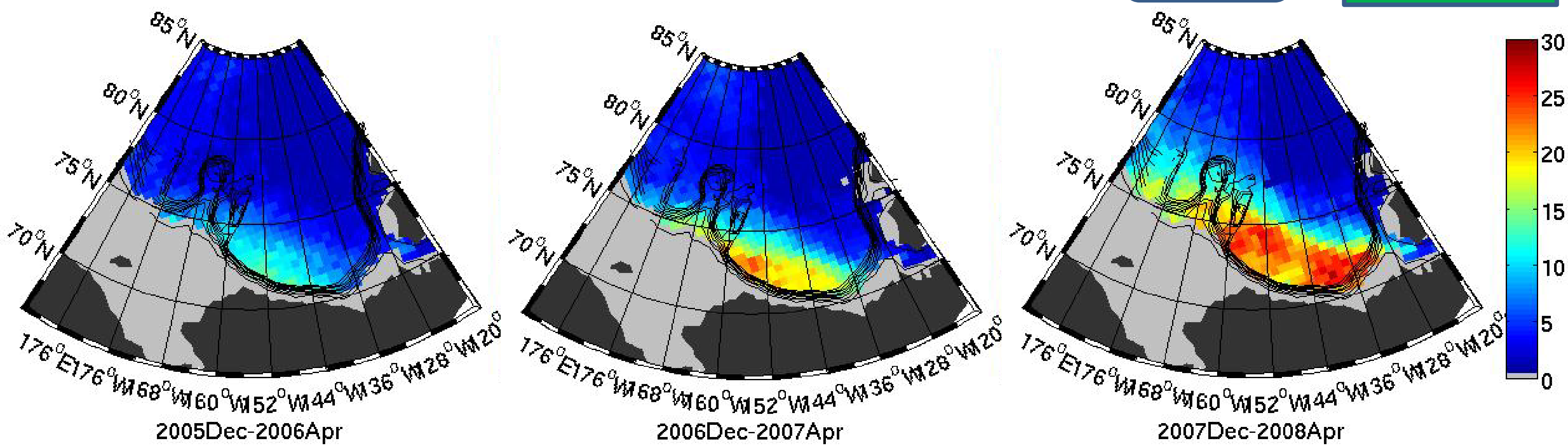
Kawashima (Masters Thesis), 2013

frequency (daily mean ice > 20cm/s)

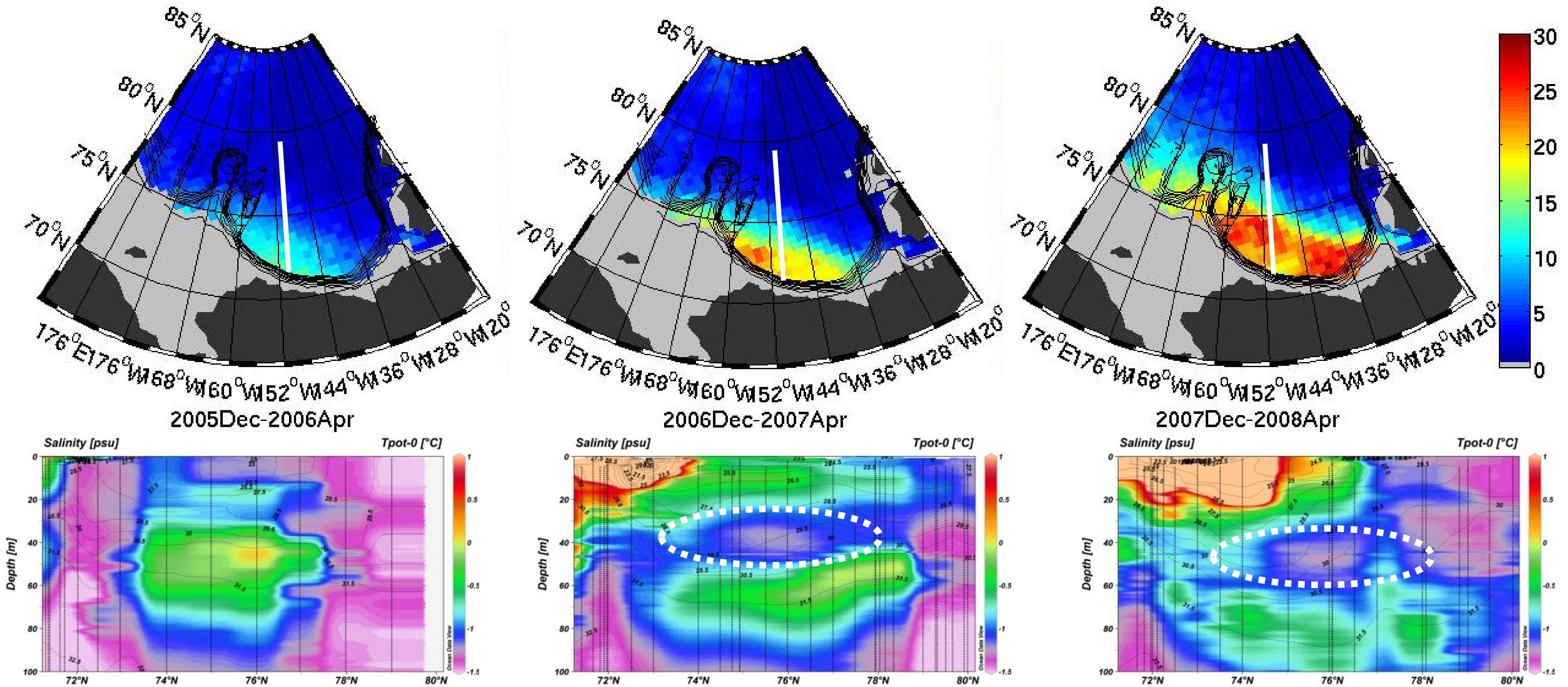


frequency (daily mean ice + inertial oscillation > 20cm/s)

Important number



Interpretation of heat release event (=anomalous huge sea ice reduction event away from reduction trend) in 2007 and 2008



2006　　　　2007　　　　2008

Shallow winter mixed layer (20m)

Base depth of mixed layer is deeper than the general core depth of the warm Pacific Summer Water

Gentle heat release

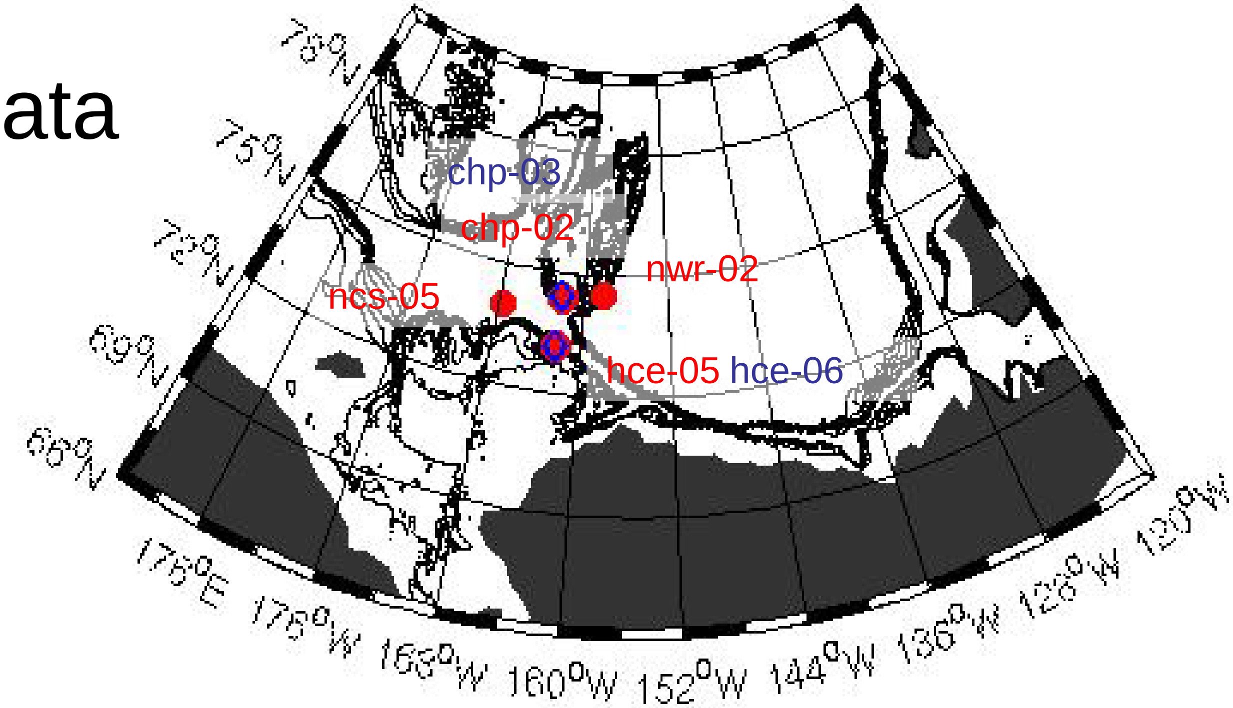
Deep winter mixed layer (50-70m)

Base depth of mixed layer is deeper than the general core depth of the warm Pacific Summer Water

Active heat release ⇒ anomalous event-like reduction of sea ice

Kawashima (Masters Thesis), 2013

Moored ADCP data



Chp-02 2002年 9月 3日 ～ 2003年 9月17日

Chp-03 2003年 9月 3日 ～ 2004年 8月17日

Hce-05 2005年10月 3日 ～ 2006年10月 3日

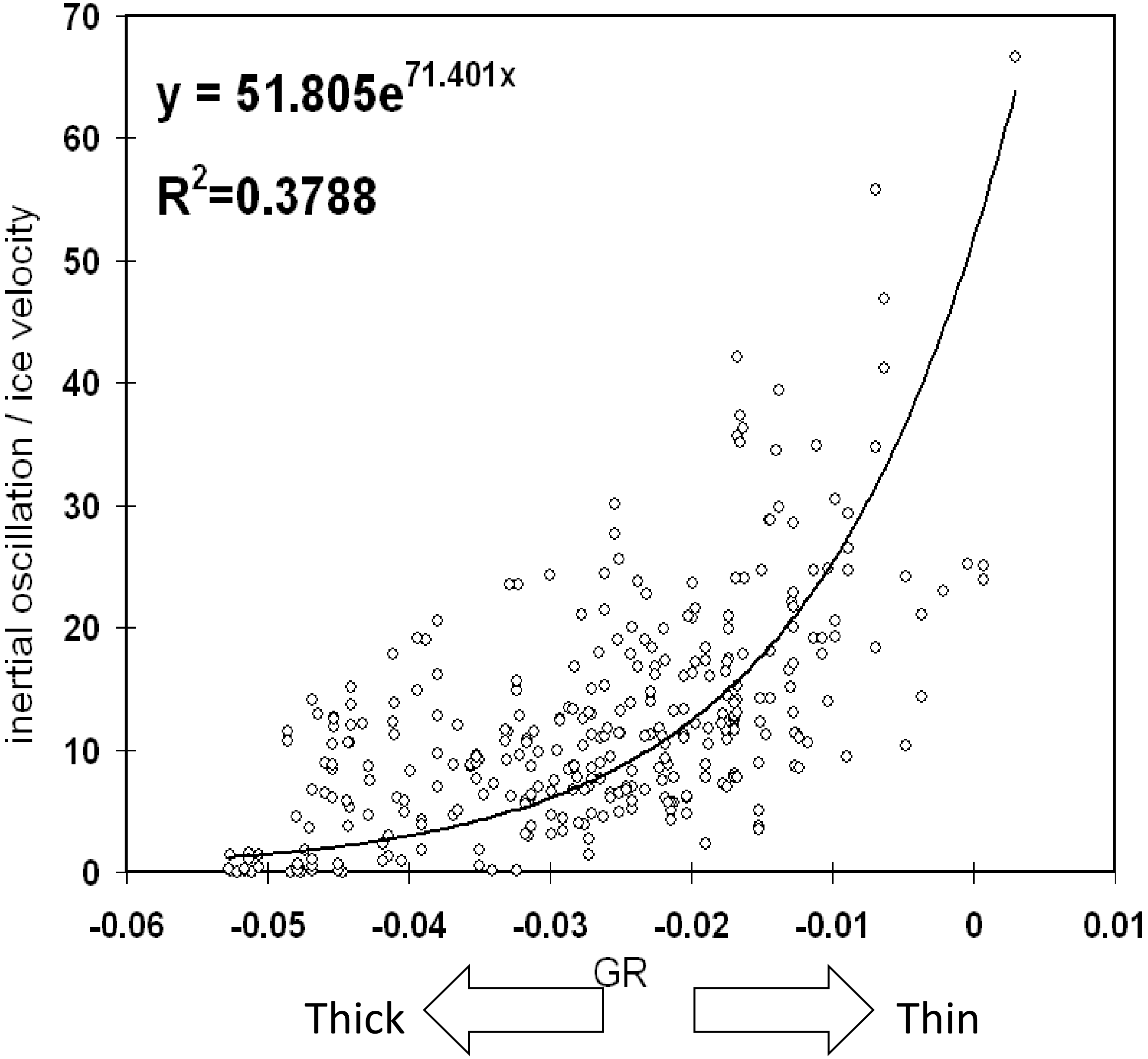
Hce-06 2006年10月 6日 ～ 2007年10月 6日

Ncs-05 2005年10月 5日 ～ 2006年10月 5日

Nwr-03 2003年 8月16日 ～ 2004年 9月 7日

Kawashima (Masters Thesis), 2013

[Amplitude of inertial oscillation] / [background low-passed sea ice velocity] depends on GR



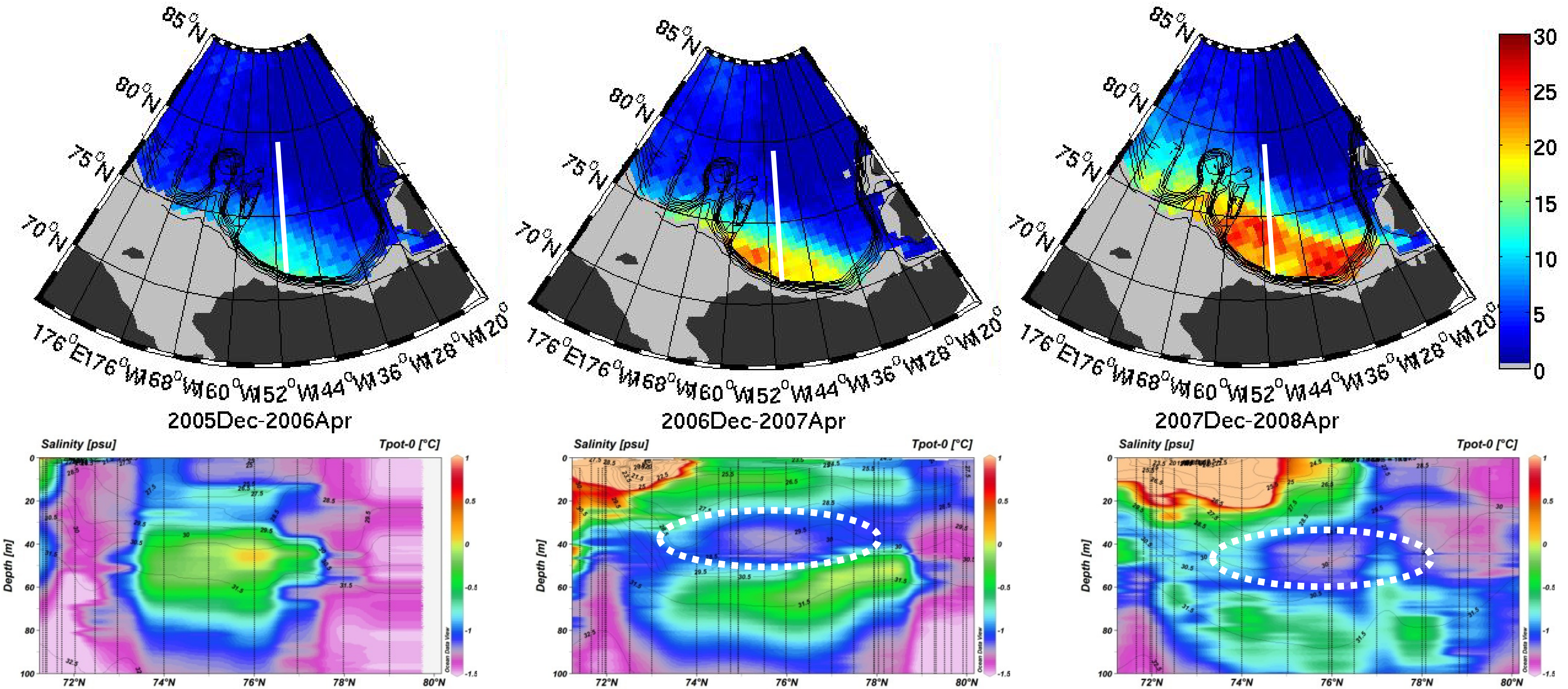
$$GR = \frac{[36V] - [18V]}{[36V] + [18V]}.$$

Plots for
Concentration > 95%
Wind speed > 6m/s
Ice speed > 20cm/s

- Thickness and sea ice type control amplitude of inertial oscillation
- This regression curve enable us to estimate absolute sea ice speed including inertial oscillation

Kawashima (Masters Thesis), 2013

Interpretation of heat release event (=anomalous huge sea ice reduction event away from reduction trend) in 2007 and 2008



2006 | 2007 | 2008

Shallow winter mixed layer (20m)

Base depth of mixed layer is deeper than the general core depth of the warm Pacific Summer Water

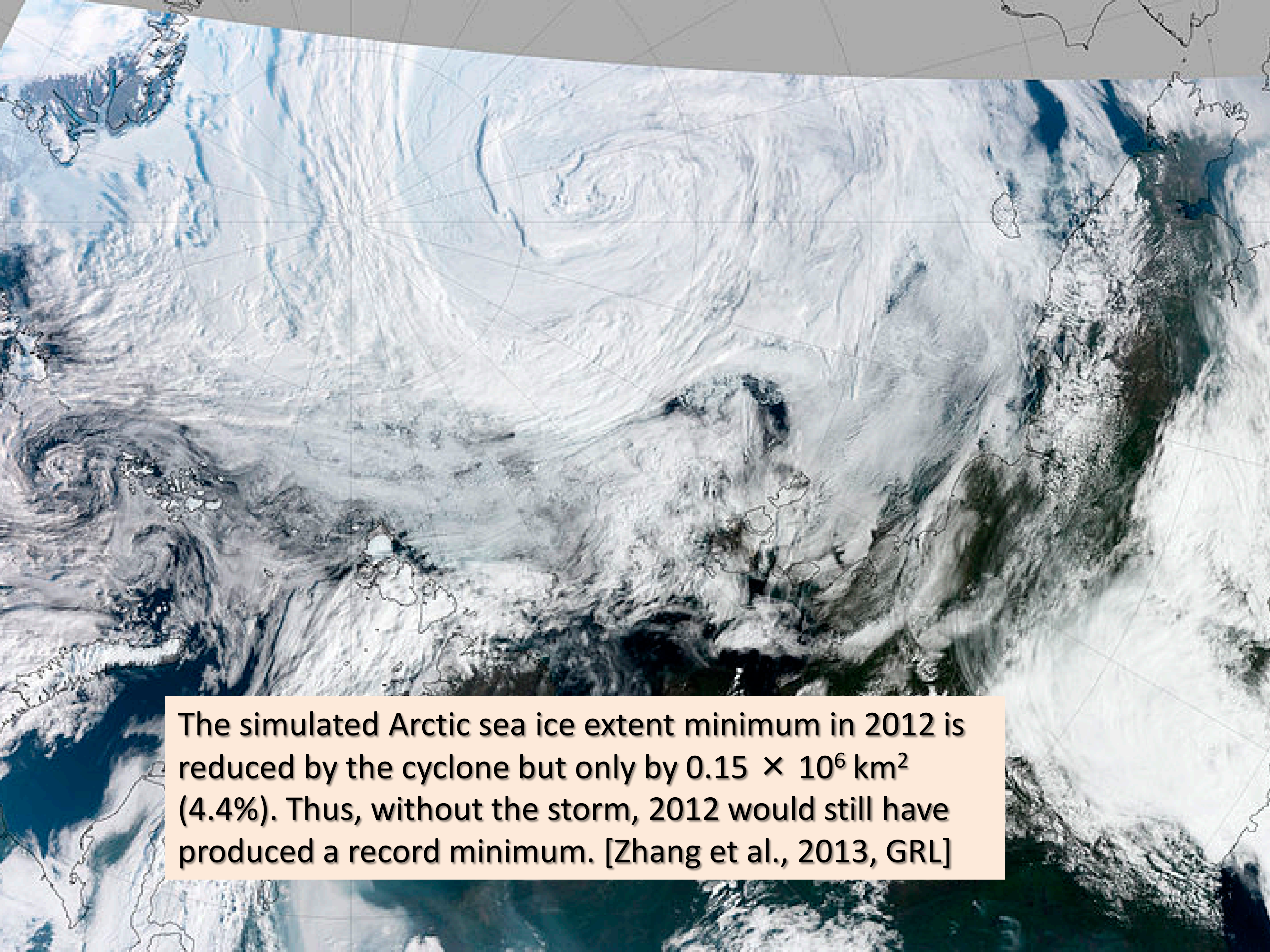
Gentle heat release

Deep winter mixed layer (50-70m)

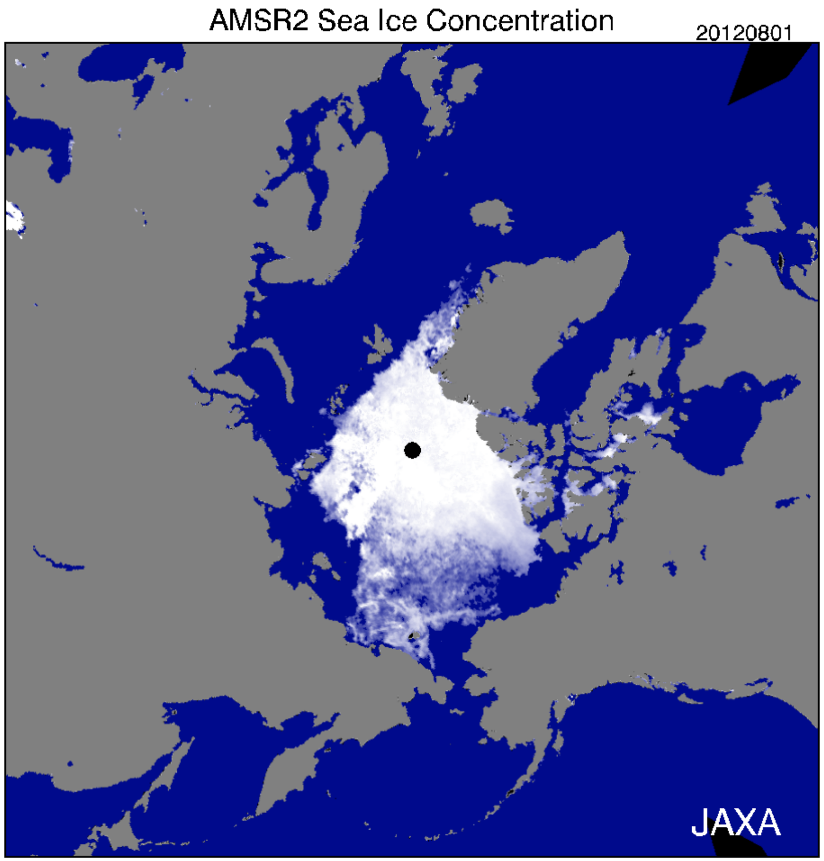
Base depth of mixed layer is deeper than the general core depth of the warm Pacific Summer Water

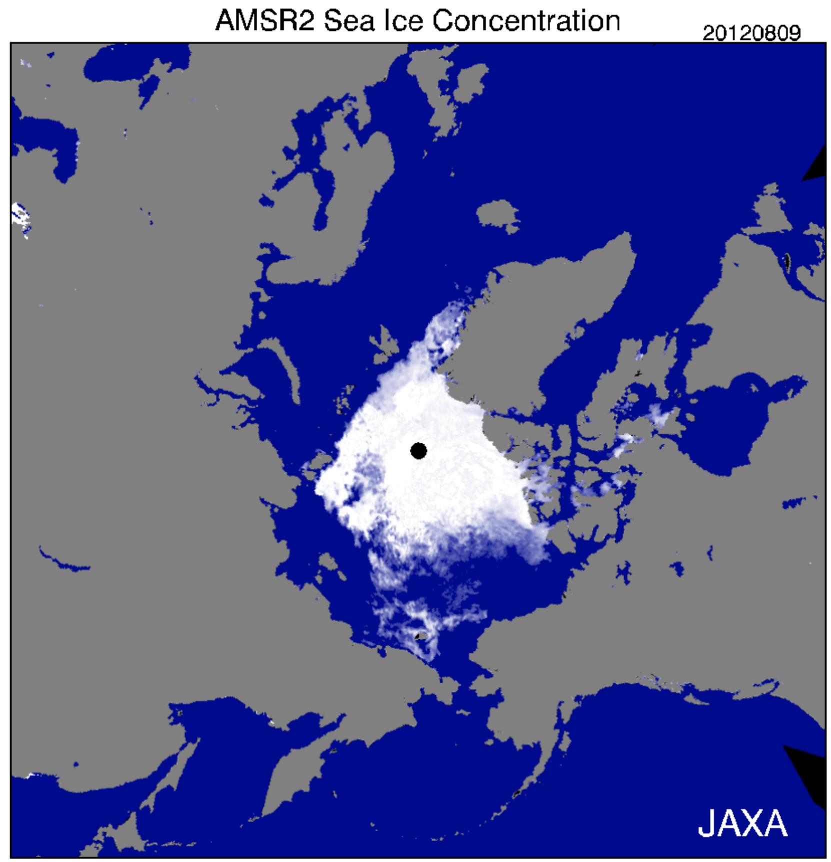
Active heat release ⇒ anomalous event-like reduction of sea ice

Kawashima (Masters Thesis), 2013

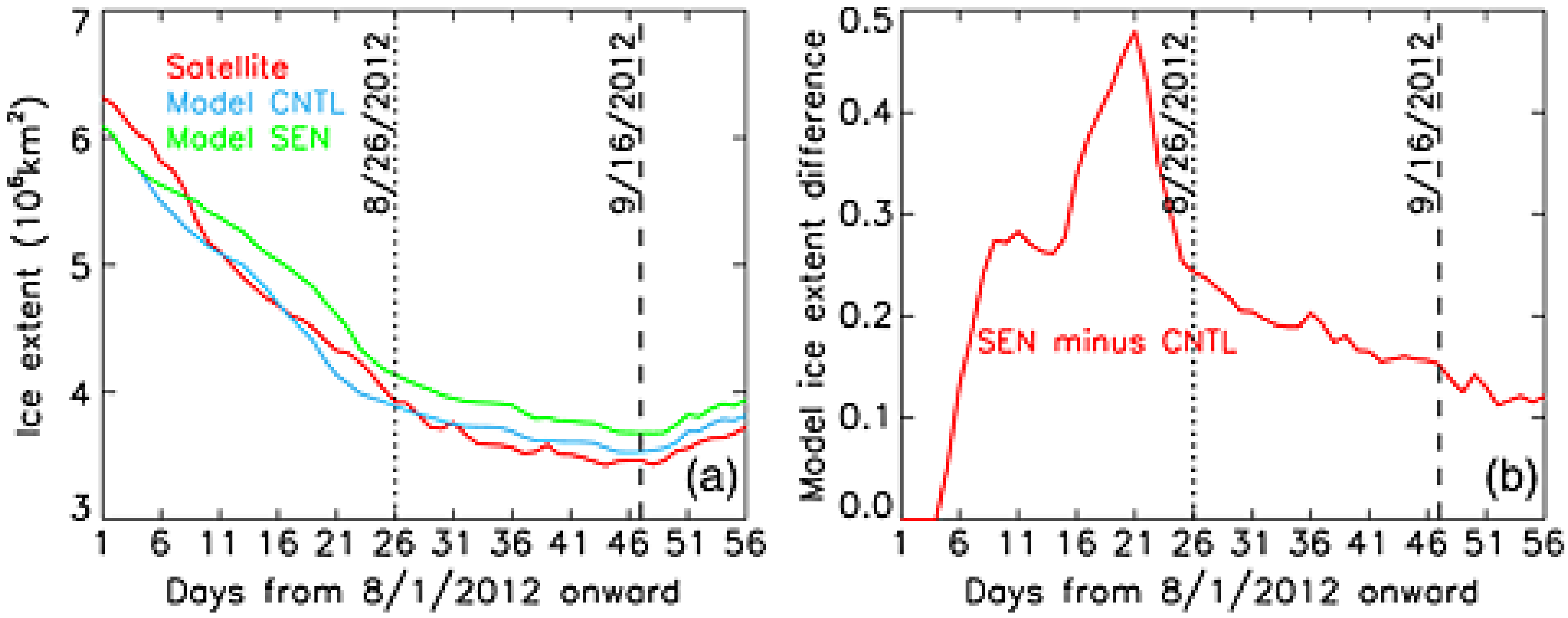


The simulated Arctic sea ice extent minimum in 2012 is reduced by the cyclone but only by 0.15×10^6 km^2 (4.4%). Thus, without the storm, 2012 would still have produced a record minimum. [Zhang et al., 2013, GRL]


AMSR2 Sea Ice Concentration
20120801
JAXA


AMSR2 Sea Ice Concentration
20120809
JAXA

[Zhang et al., 2013, GRL]

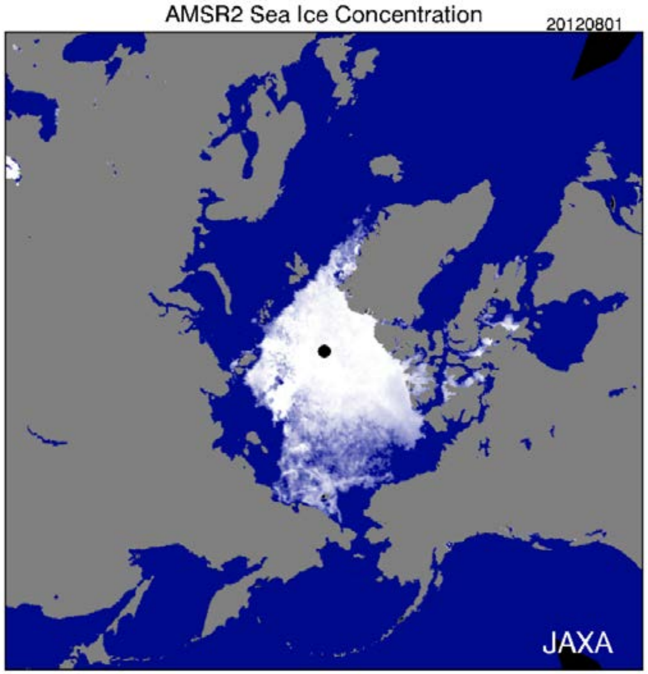


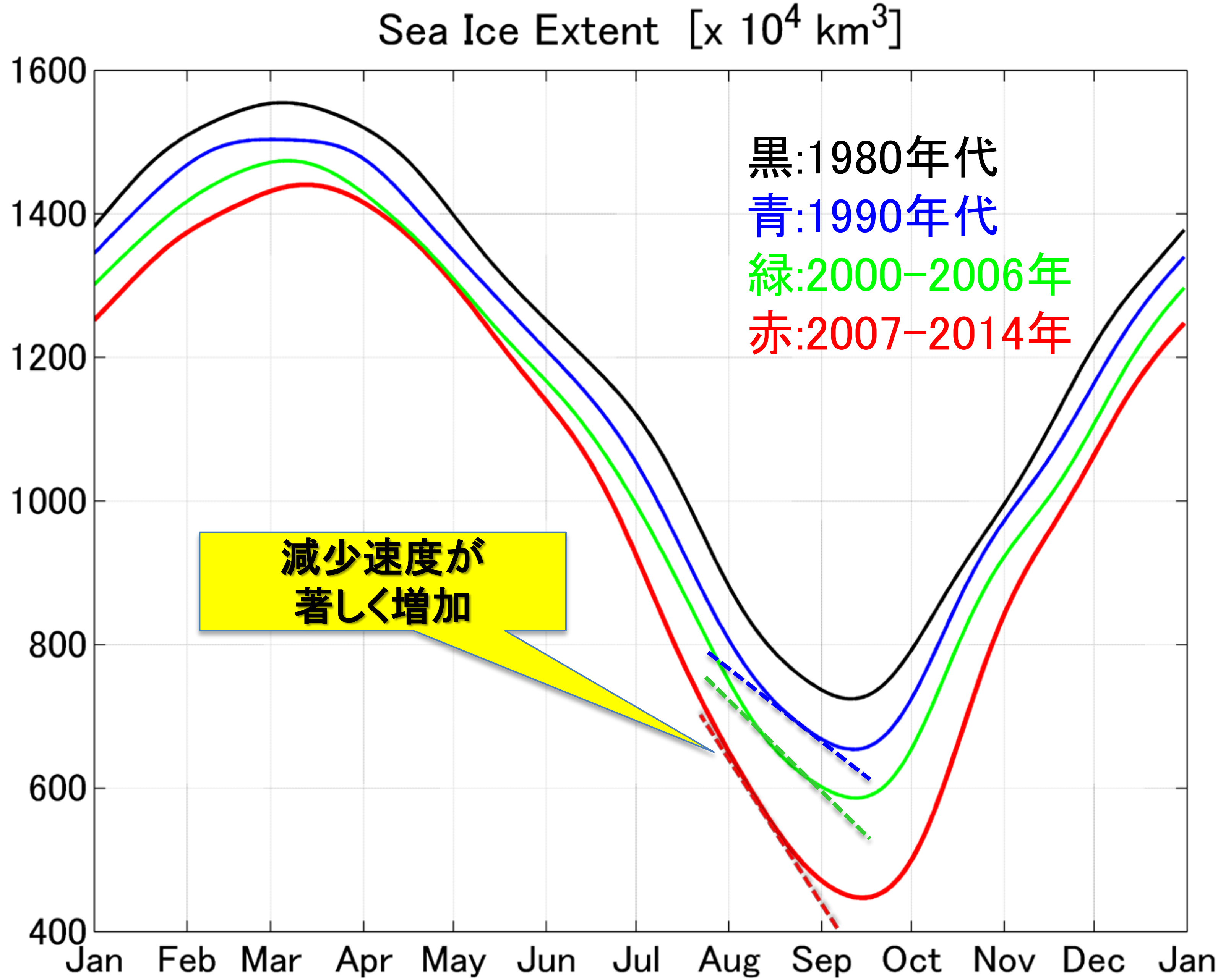
At a glance, cyclone seems to be important impression, but the influence is not so large.

Another processes is much significant to understand the sea ice decline and spatial pattern of sea ice distribution.

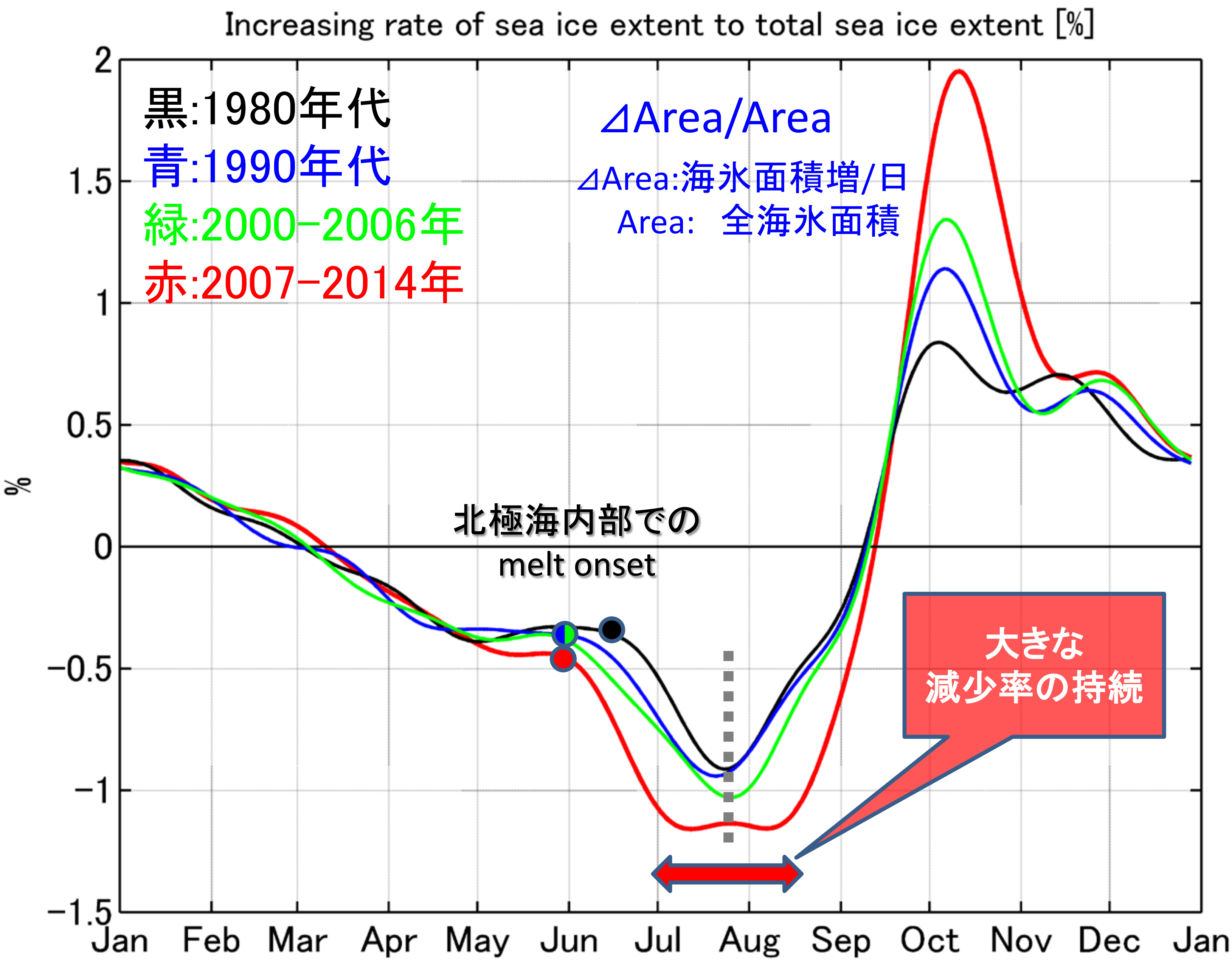

KOPRI

Precondition Changes in melt pond

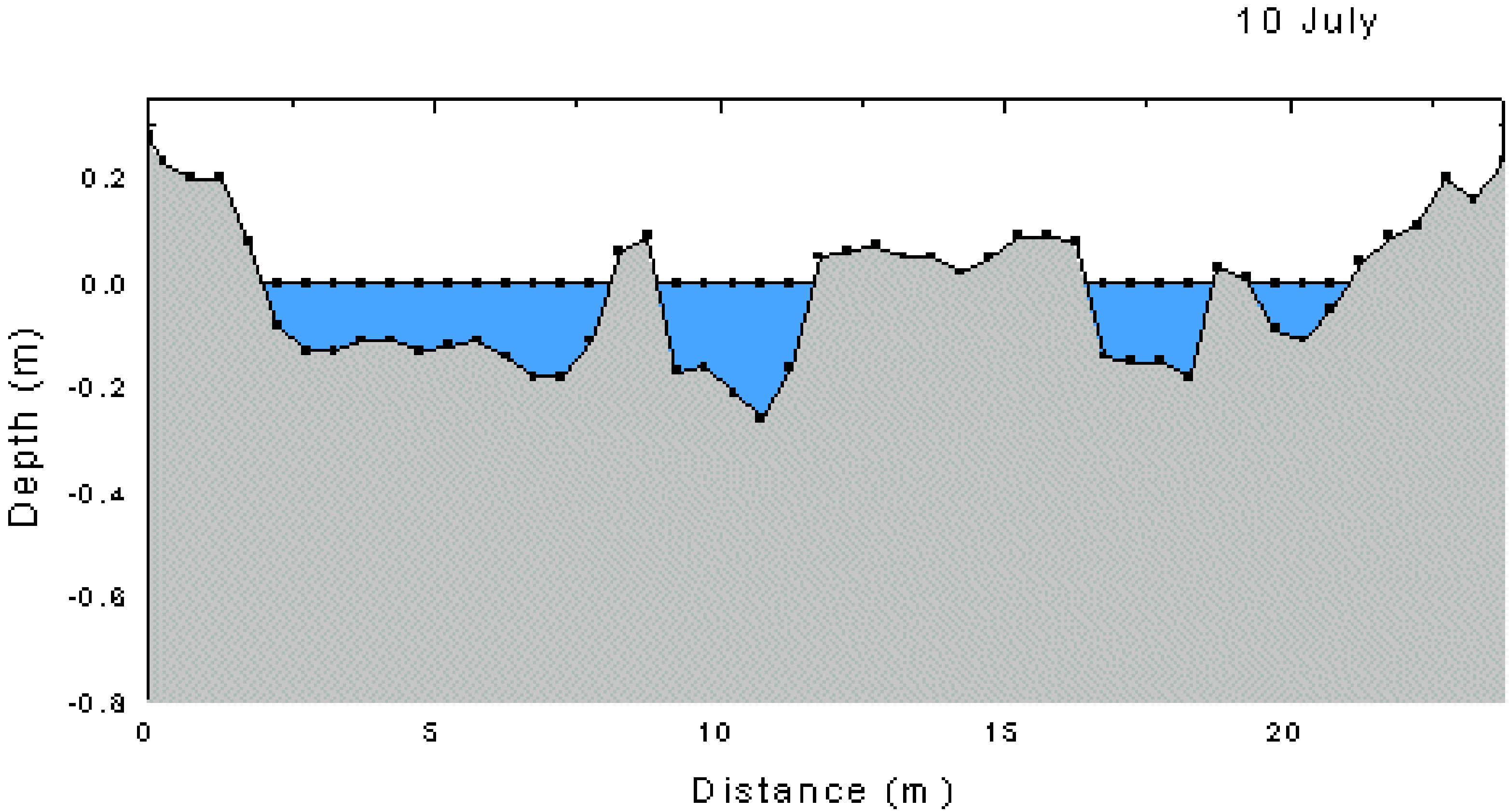




Sea Ice Extent [x 10^4 km^3]
1600
1400
1200
1000
800
600
400
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
黒:1980年代
青:1990年代
緑:2000-2006年
赤:2007-2014年
減少速度が
著しく増加



Increasing rate of sea ice extent to total sea ice extent [%]
黒:1980年代
青:1990年代
緑:2000-2006年
赤:2007-2014年
⊿Area/Area
⊿Area:海氷面積増/日
Area:　全海氷面積
北極海内部での
melt onset
大きな
減少率の持続
%
2
1.5
1
0.5
0
−0.5
−1
−1.5
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

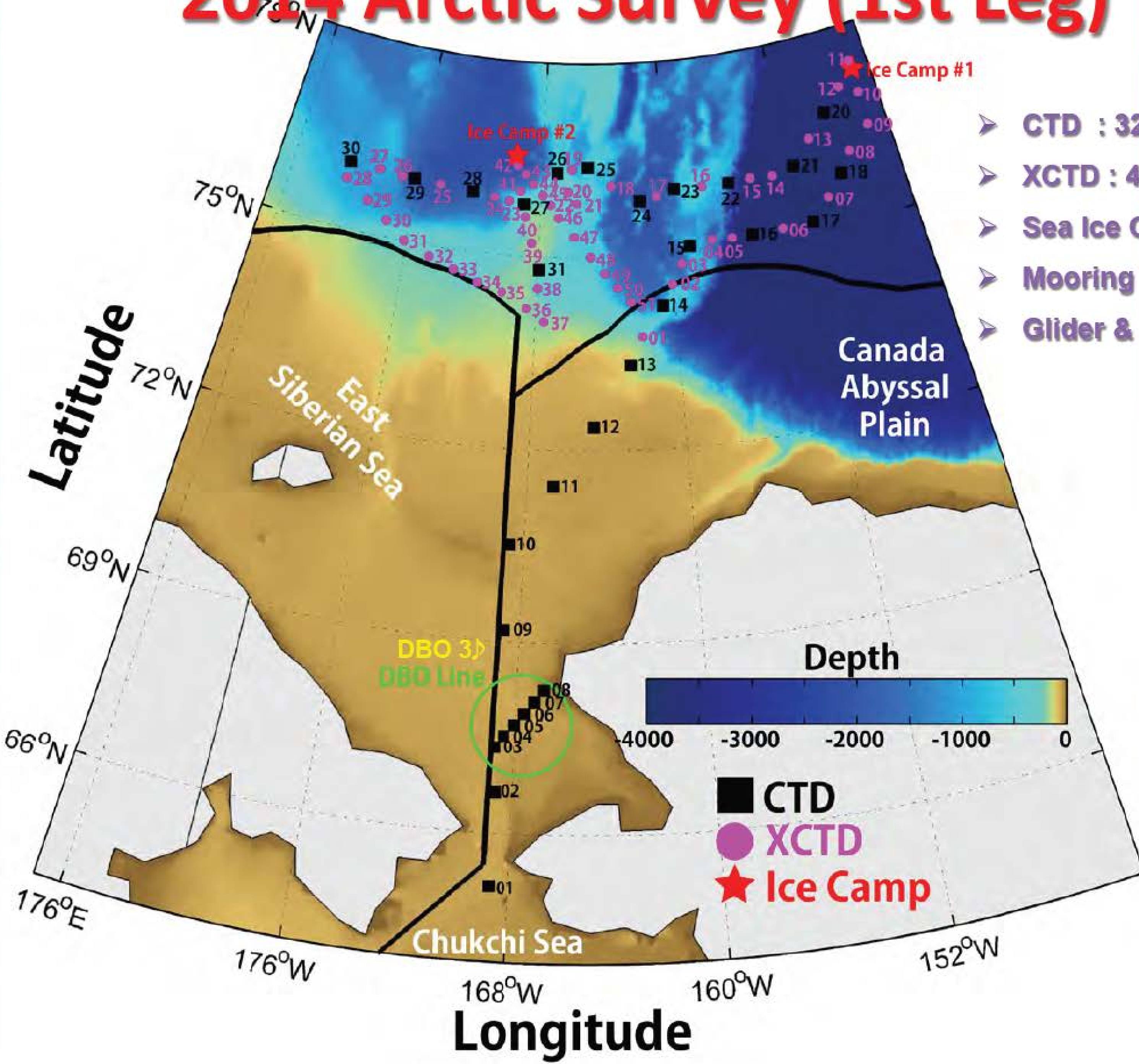


SHEBA 1998
多年氷上のmeltpond の発展

SHEBA HP より

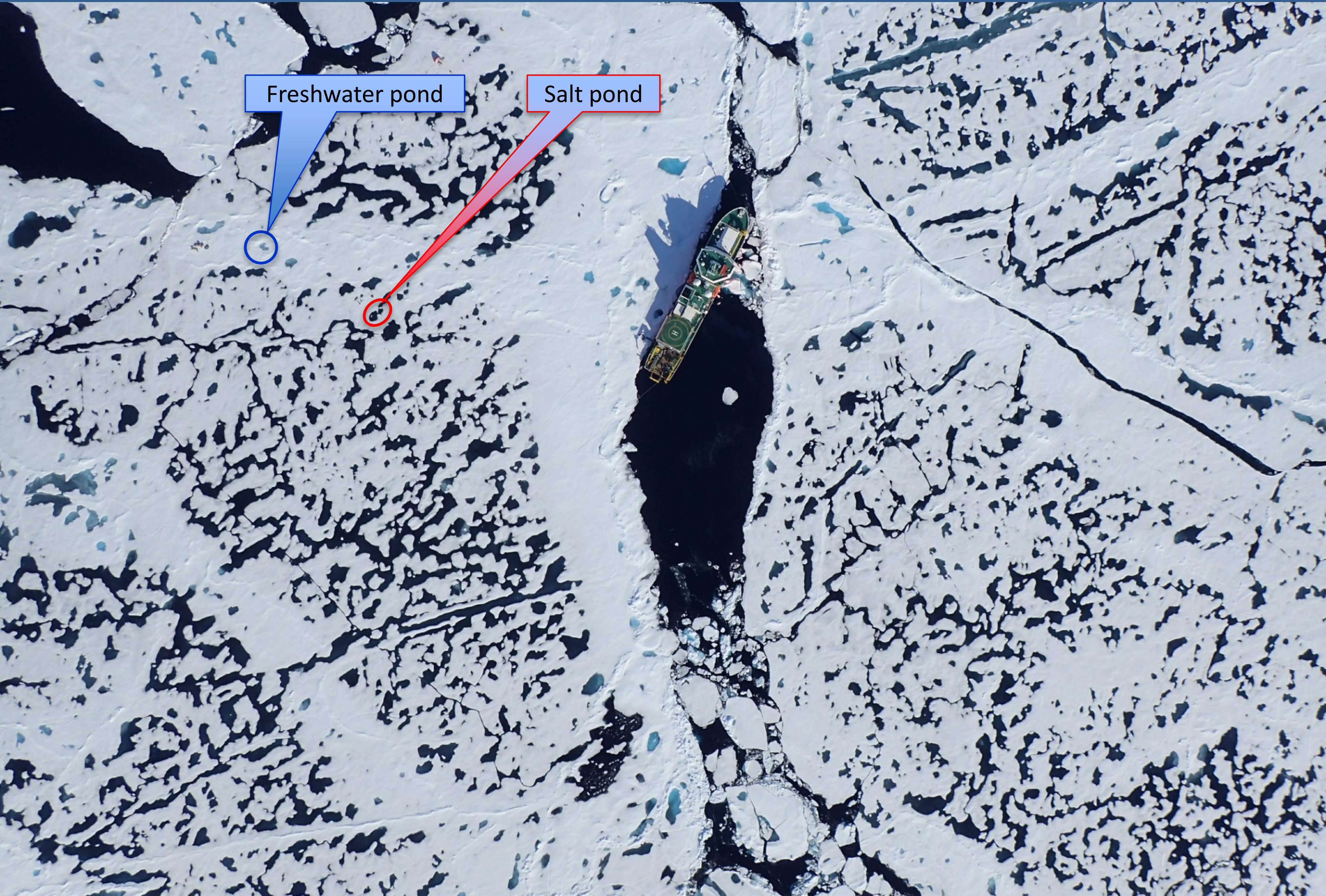
面積変化が無い
⇒　底融解が卓越

2014 Arctic Survey (1st Leg)



- CTD : 32 stations
- XCTD : 46 stations
- Sea Ice Camp : 2 sites
- Mooring : 2 sites
- Glider & SWFT array

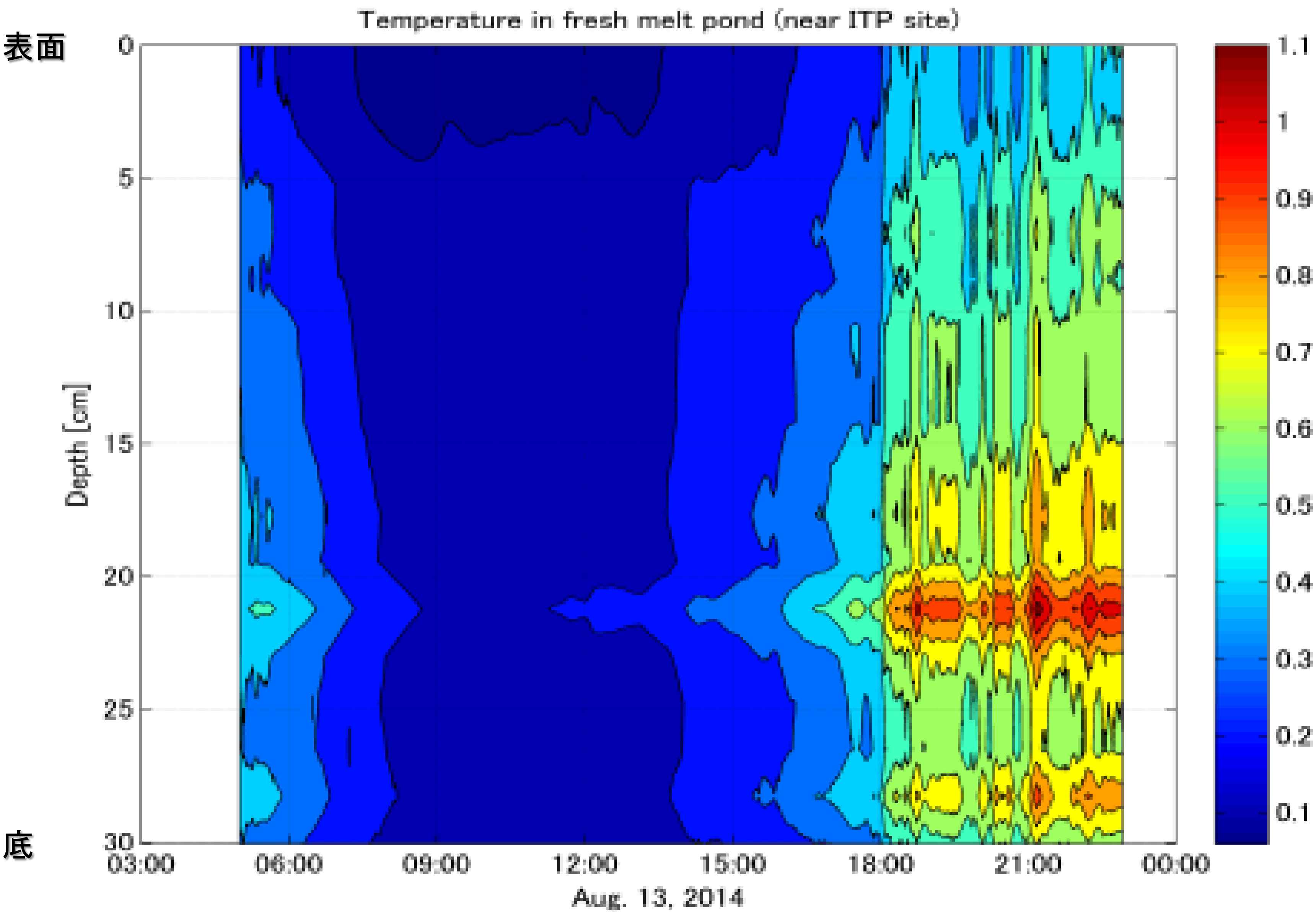
メルトポンドの再考【氷上観測】: 一年氷のメルトポンドは何故拡大、融解が速いのか？



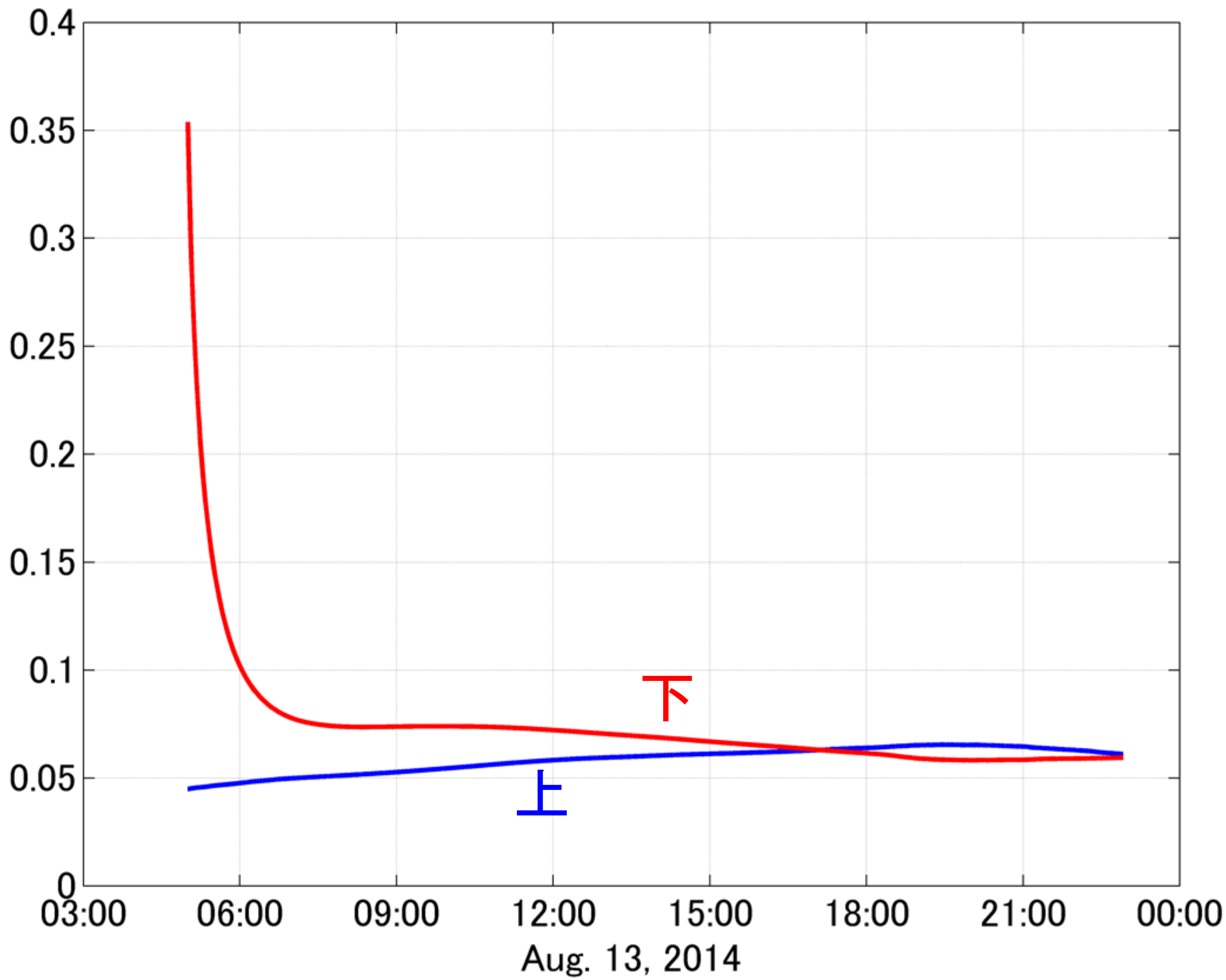

SBE
SEA-BIRD


ARAON

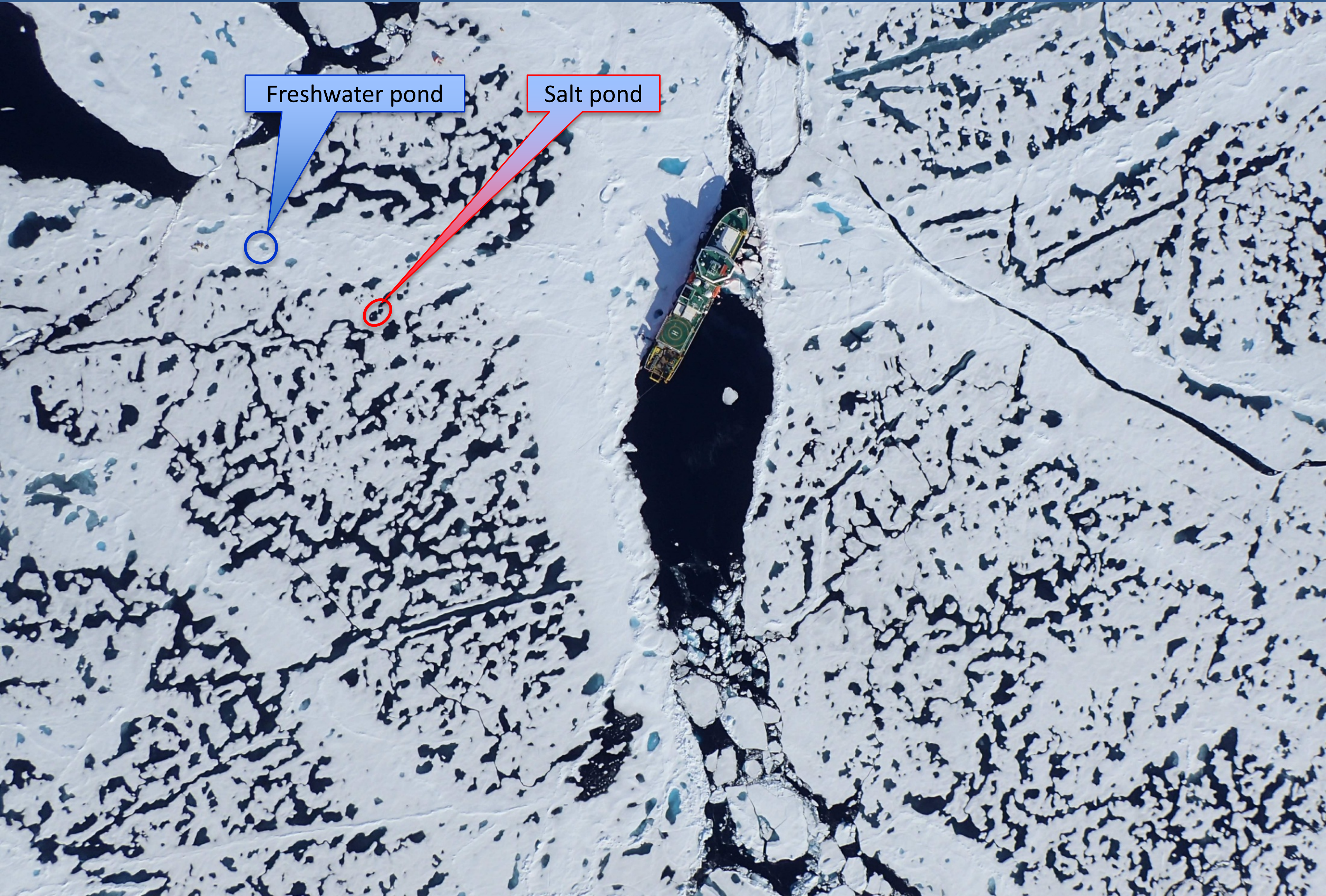
淡水ポンド



Temperature in fresh melt pond (near ITP site)
表面
底
Depth [cm]
0
5
10
15
20
25
30
03:00
06:00
09:00
12:00
15:00
18:00
21:00
00:00
Aug. 13, 2014
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1


0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
03:00
06:00
09:00
12:00
15:00
18:00
21:00
00:00
Aug. 13, 2014
下
上

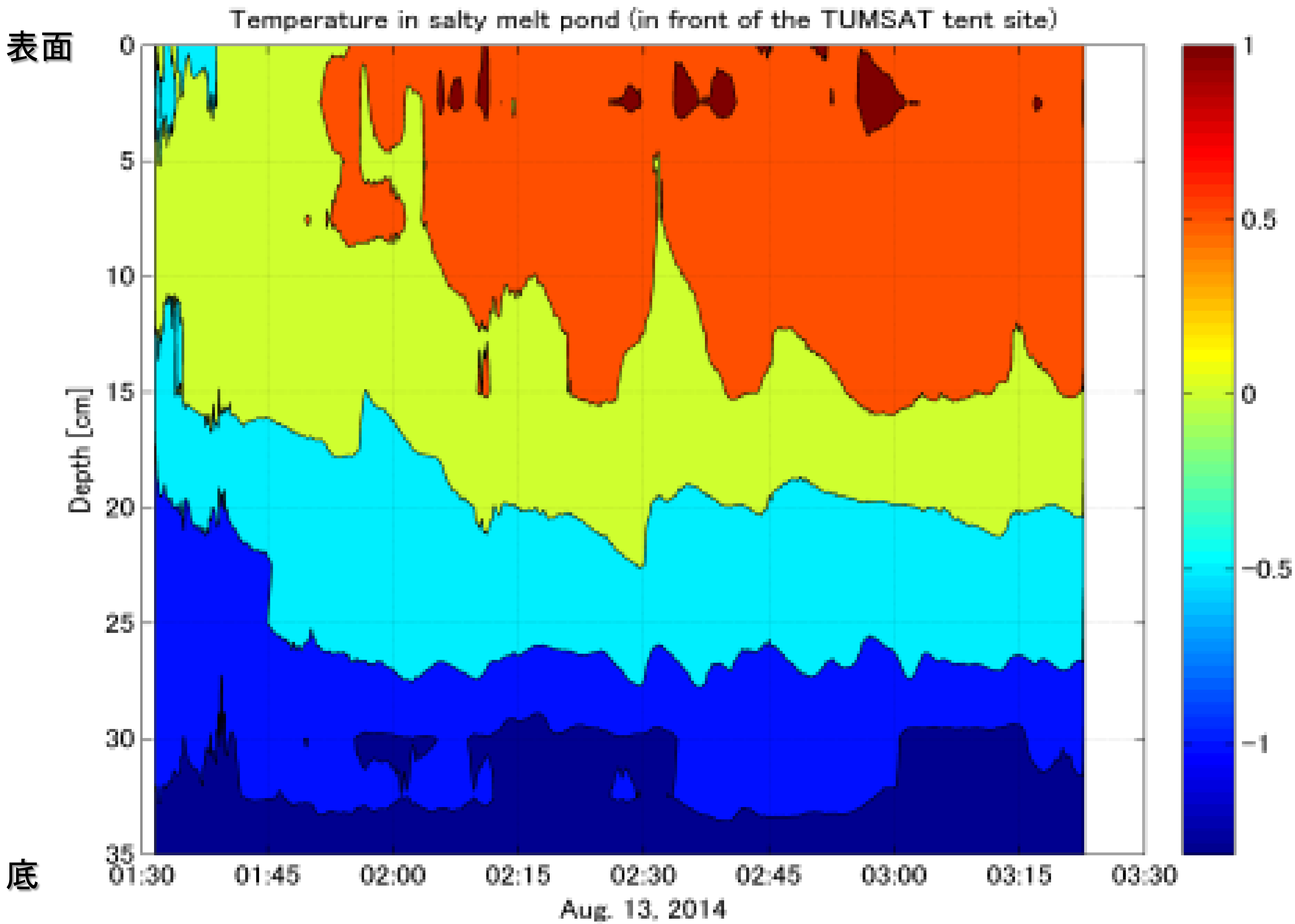
メルトポンドの再考【氷上観測】: 一年氷のメルトポンドは何故拡大、融解が速いのか？

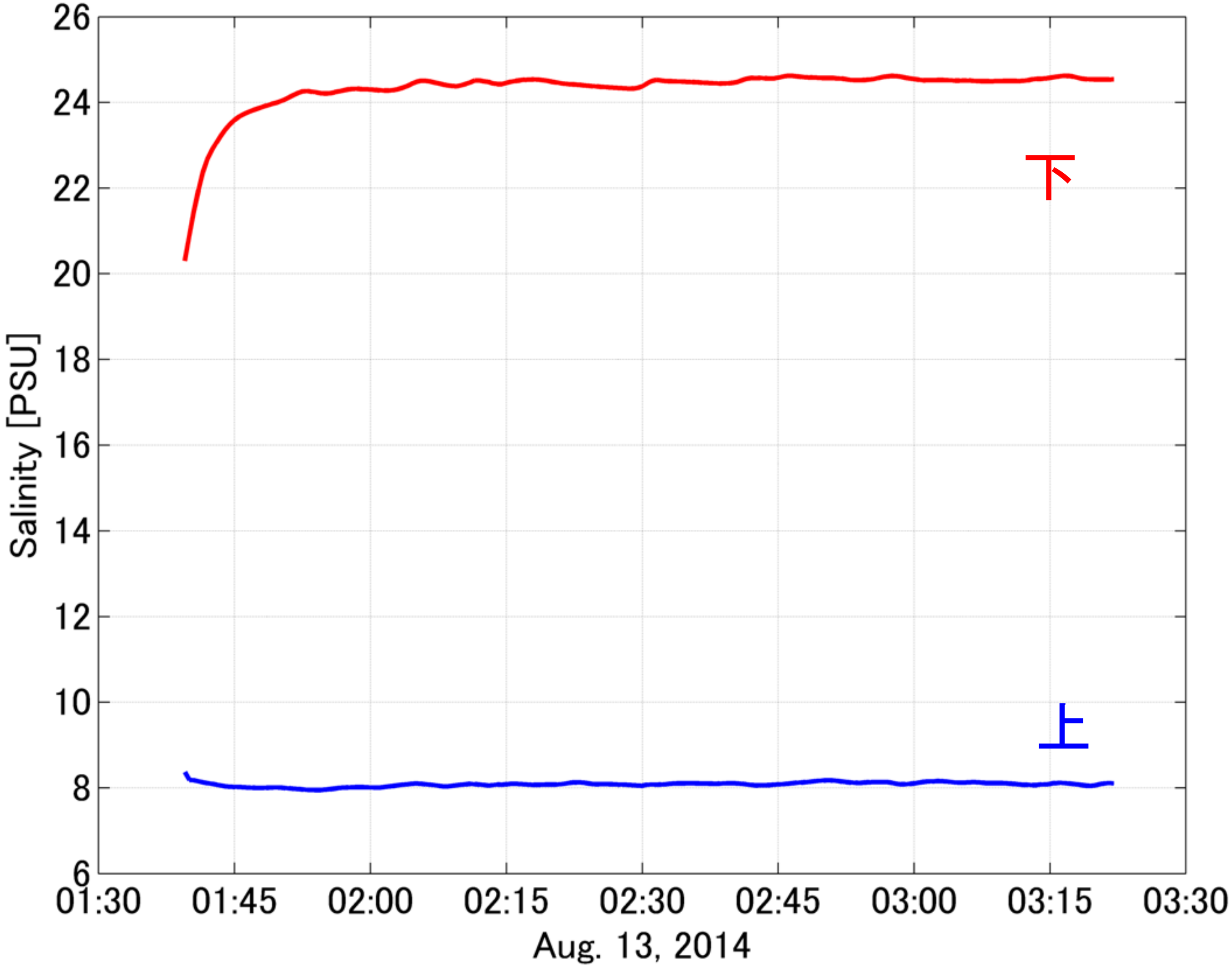



ARAON
아라온
KOPRI


SBE
SEA-BIRD

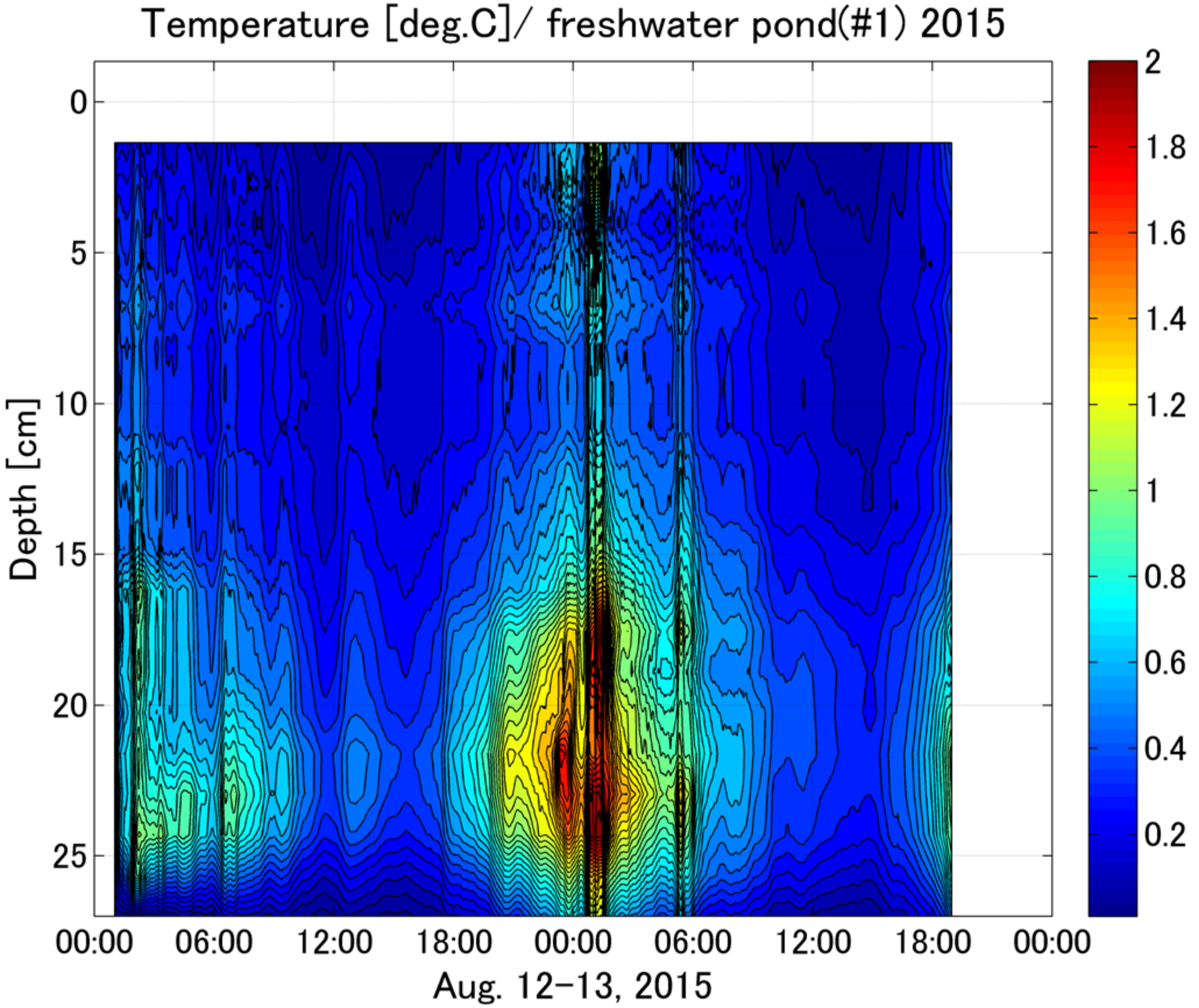
塩ポンド


Temperature in salty melt pond (in front of the TUMSAT tent site)
表面
底
Depth [cm]
0
5
10
15
20
25
30
35
01:30
01:45
02:00
02:15
02:30
02:45
03:00
03:15
03:30
Aug. 13, 2014
1
0.5
0
−0.5
−1

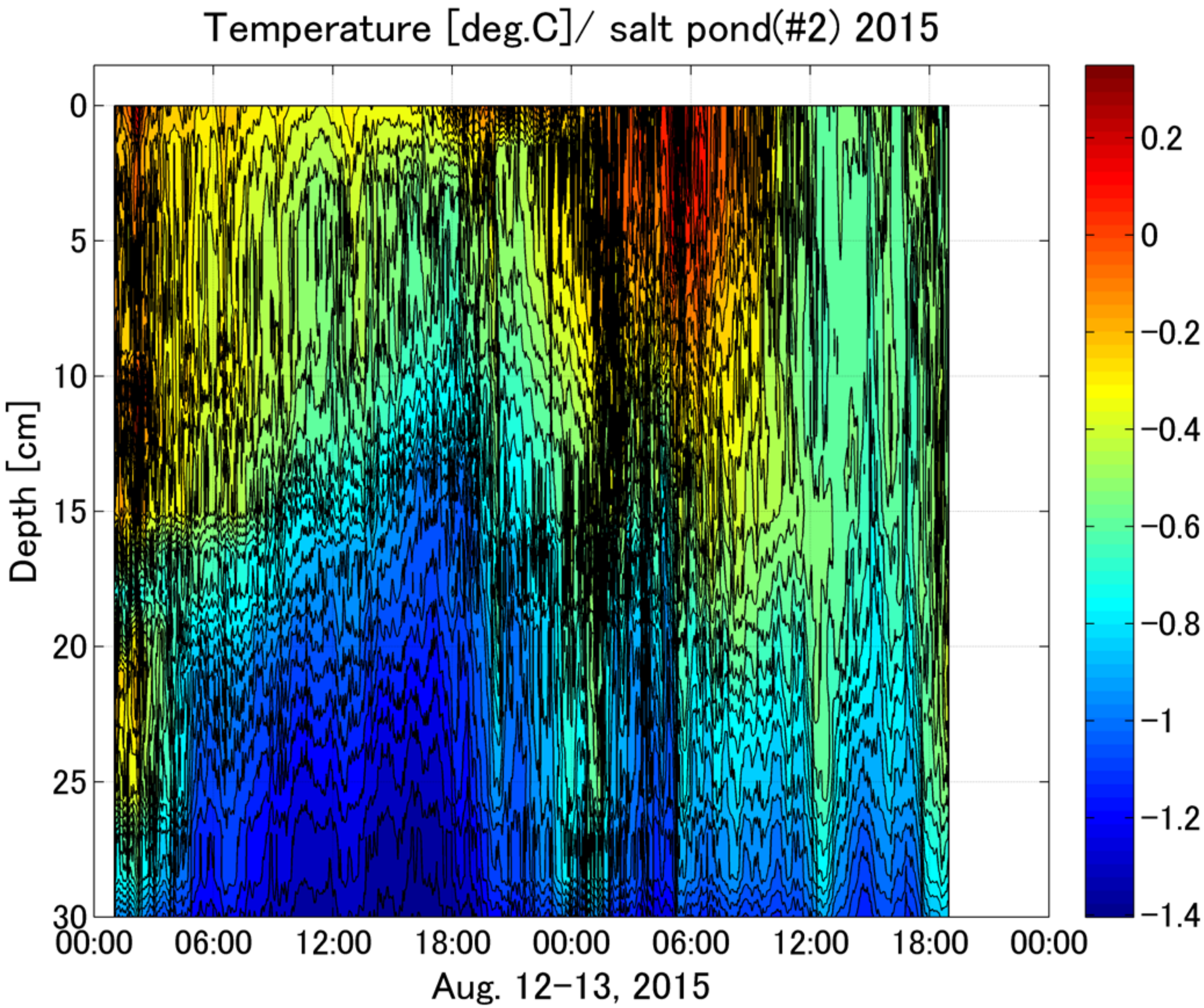


26
24
22
20
18
16
14
12
10
8
6
Salinity [PSU]
下
上
01:30
01:45
02:00
02:15
02:30
02:45
03:00
03:15
03:30
Aug. 13, 2014

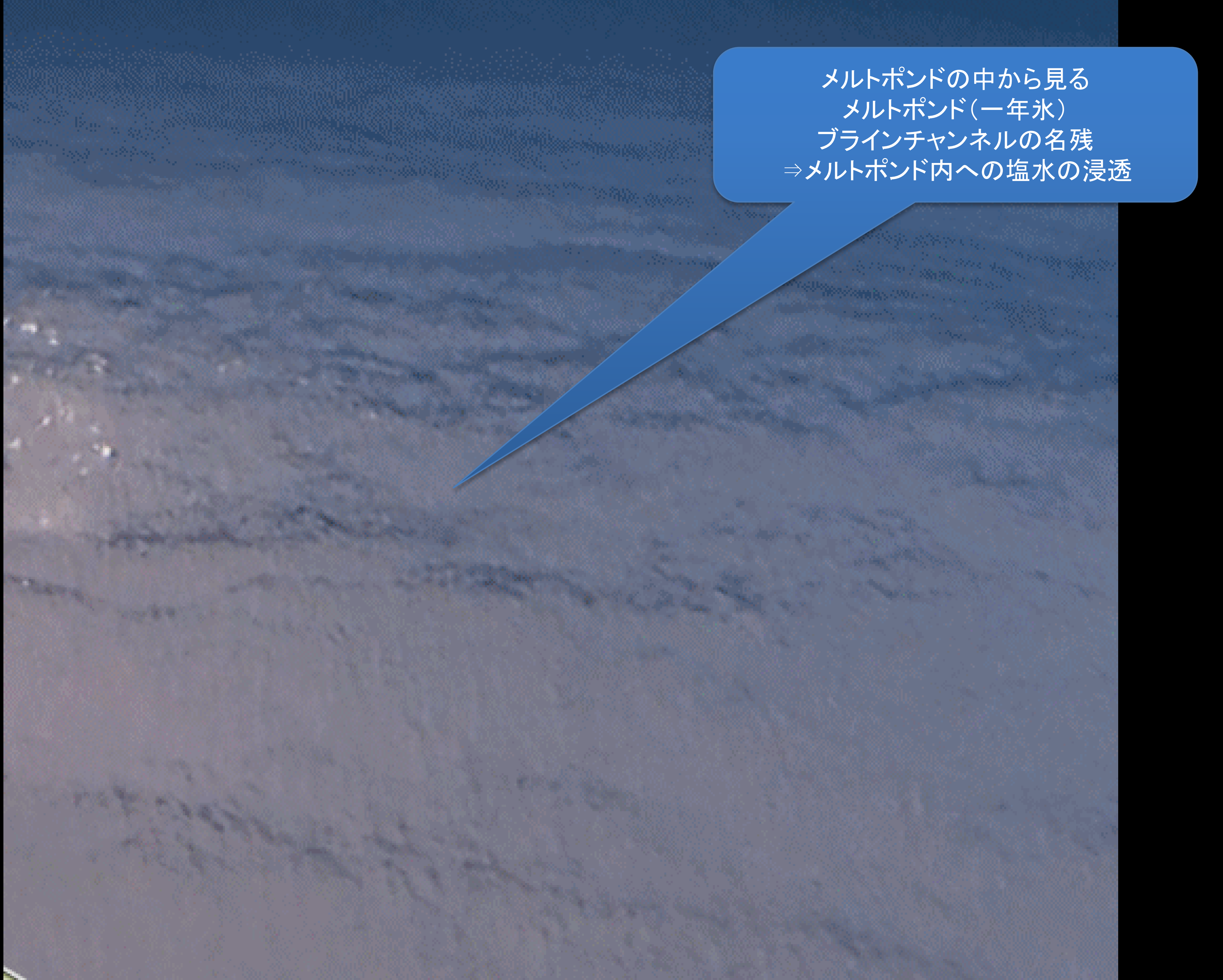

ARAON

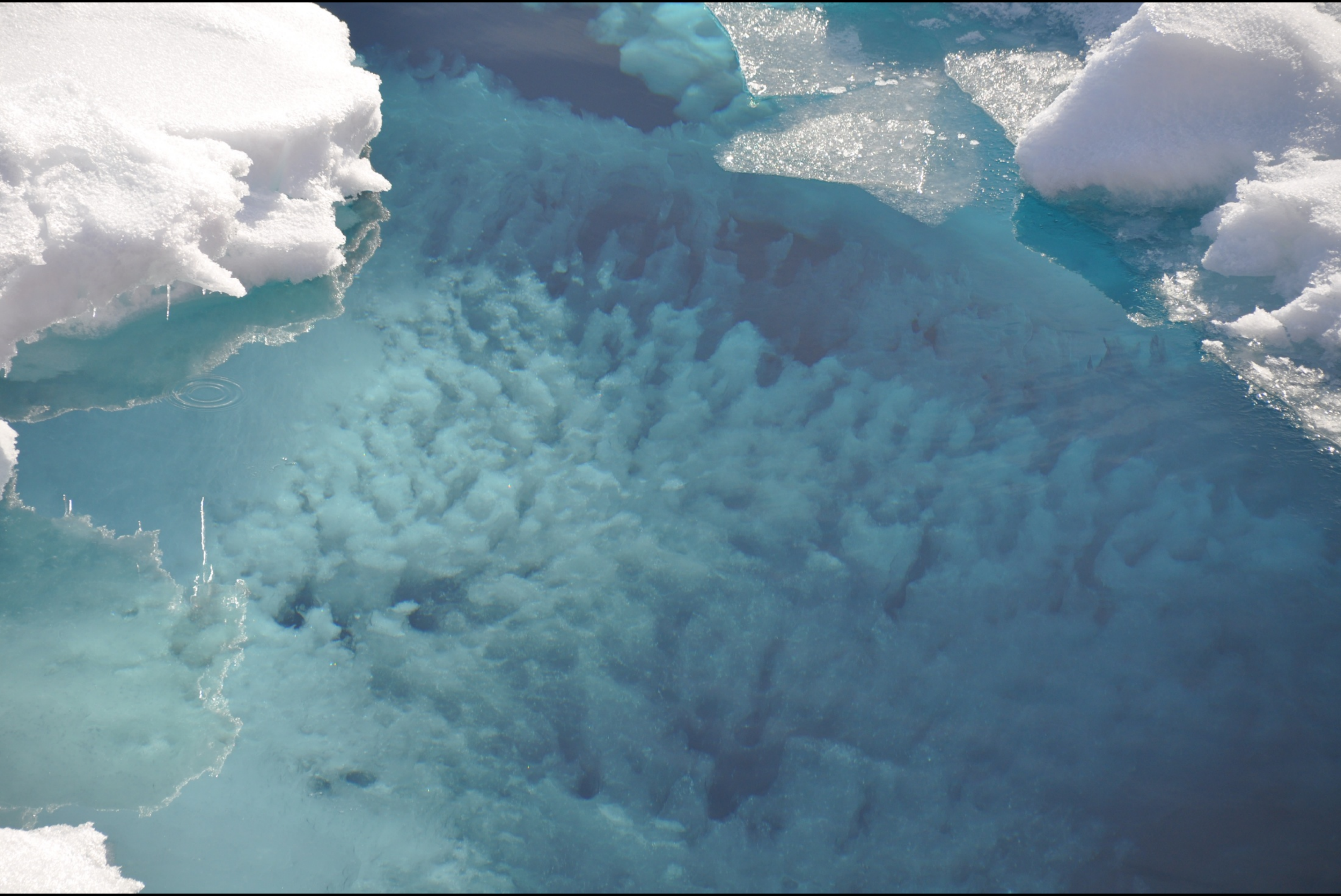


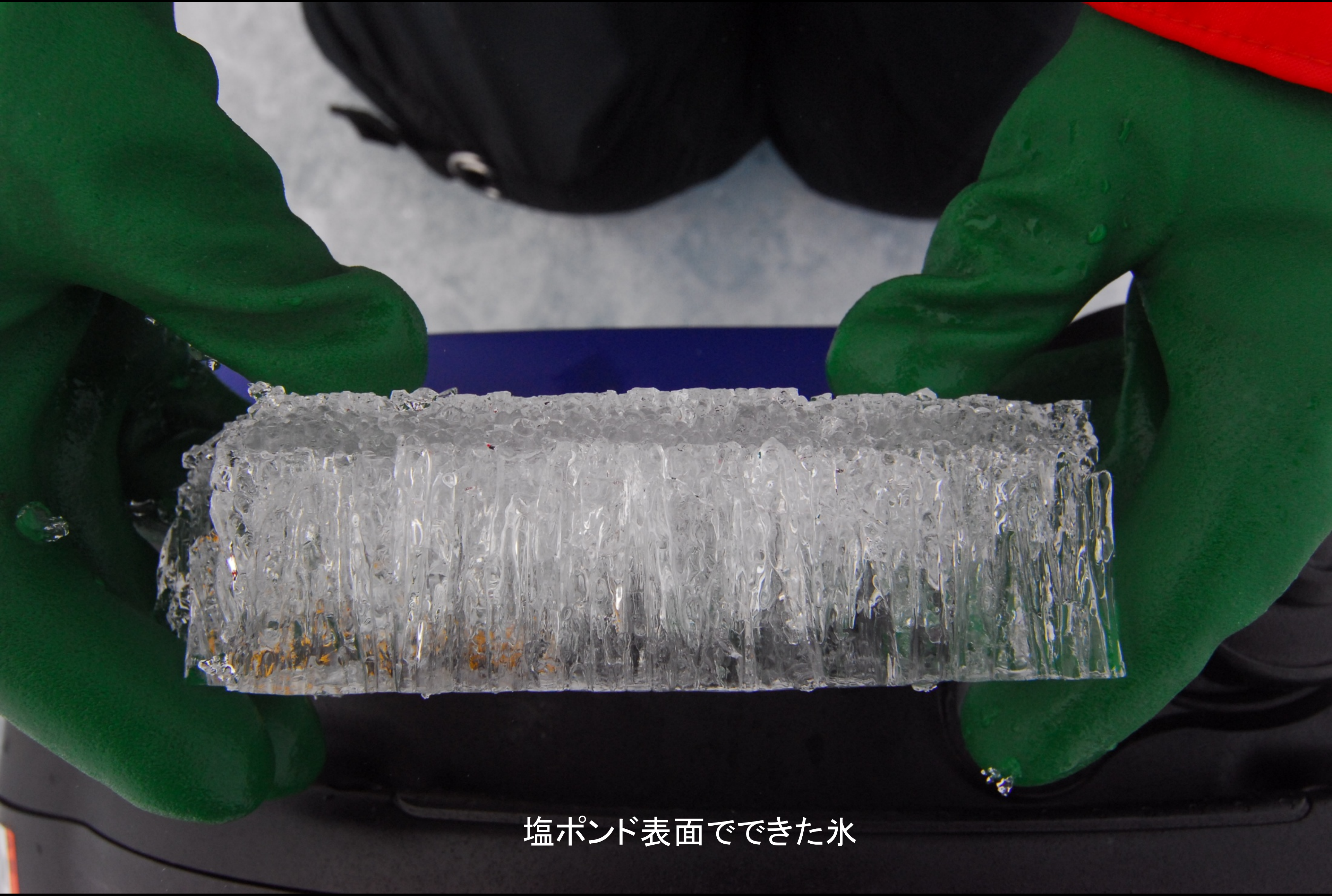
Temperature [deg.C]/ freshwater pond(#1) 2015
Depth [cm]
0
5
10
15
20
25
00:00
06:00
12:00
18:00
00:00
06:00
12:00
18:00
00:00
Aug. 12-13, 2015
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2



Temperature [deg.C]/ salt pond(#2) 2015
Depth [cm]
0
5
10
15
20
25
30
00:00
06:00
12:00
18:00
00:00
06:00
12:00
18:00
00:00
Aug. 12−13, 2015
0.2
0
−0.2
−0.4
−0.6
−0.8
−1
−1.2
−1.4

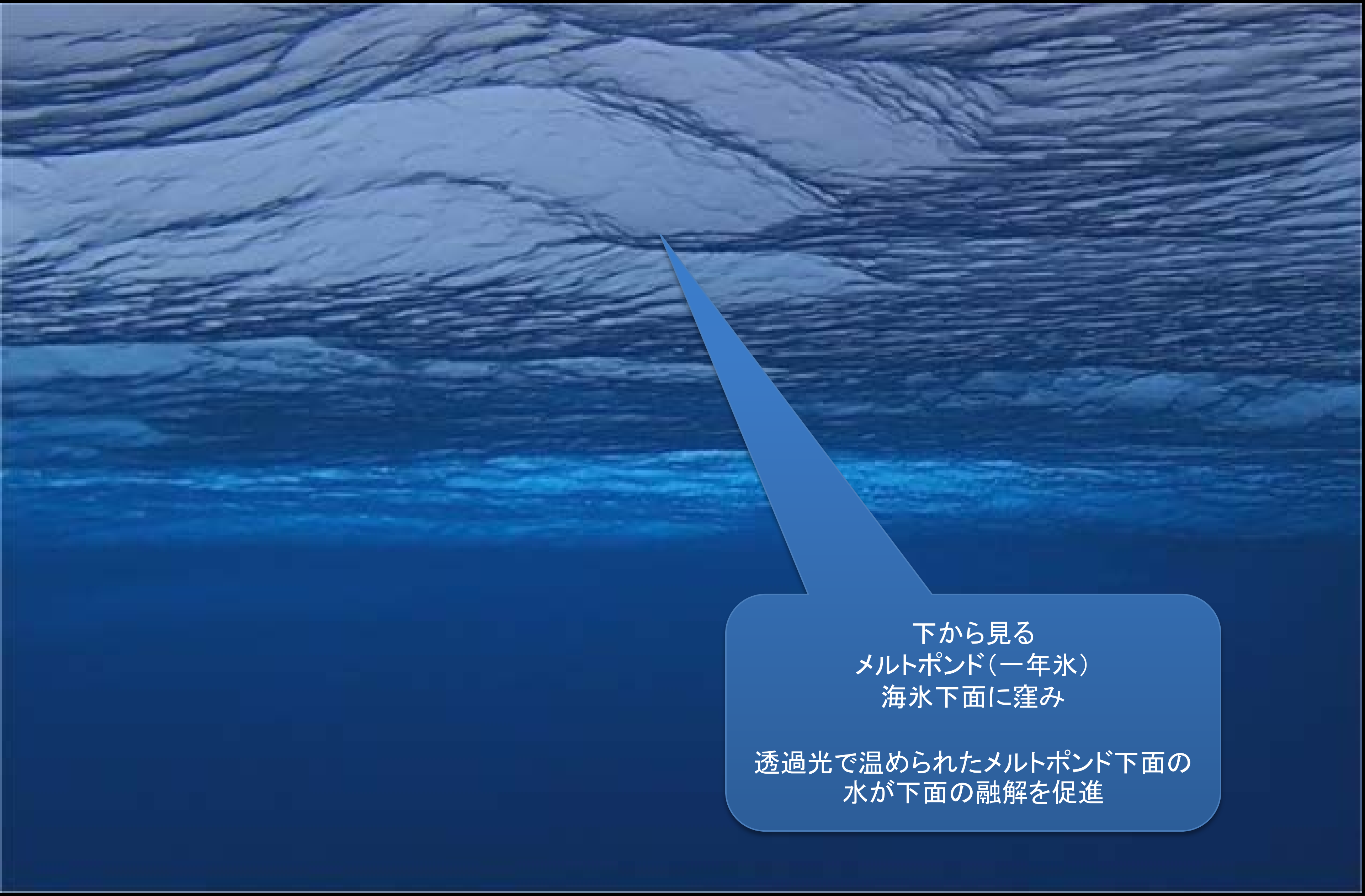

メルトポンドの中から見る
メルトポンド（一年氷）
ブラインチャンネルの名残
⇒メルトポンド内への塩水の浸透





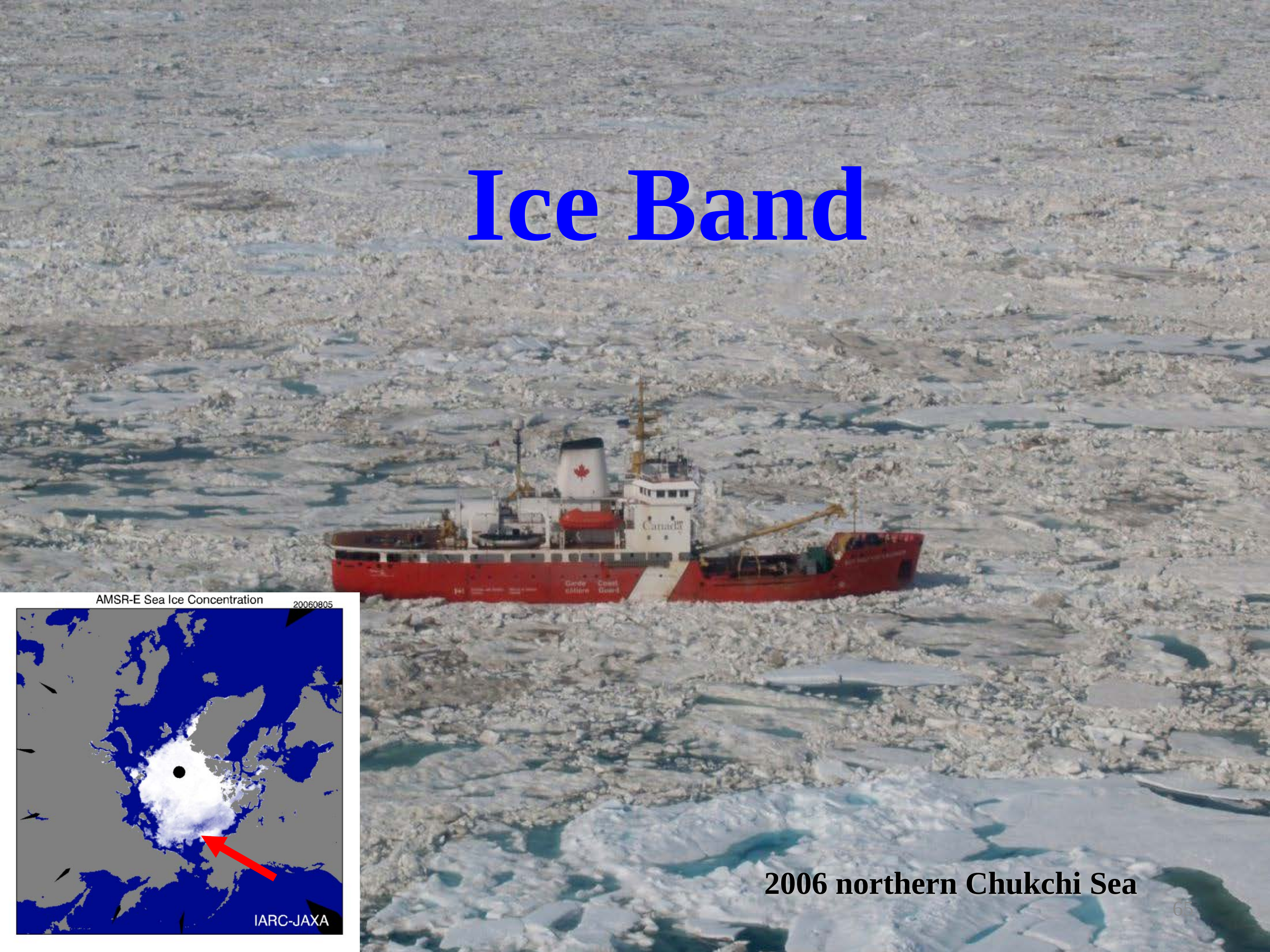
塩ポンド表面でできた氷


MUSTANG SURVIVAL
警告
東京海洋大学 TUMSAT
YAMAHA

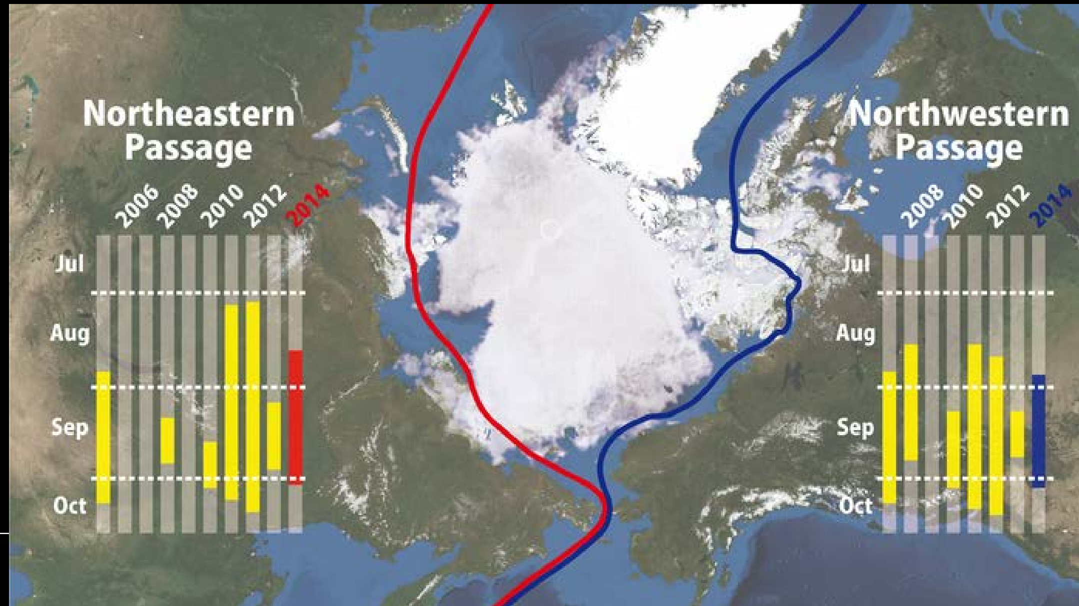

下から見る
メルトポンド（一年氷）
海氷下面に窪み

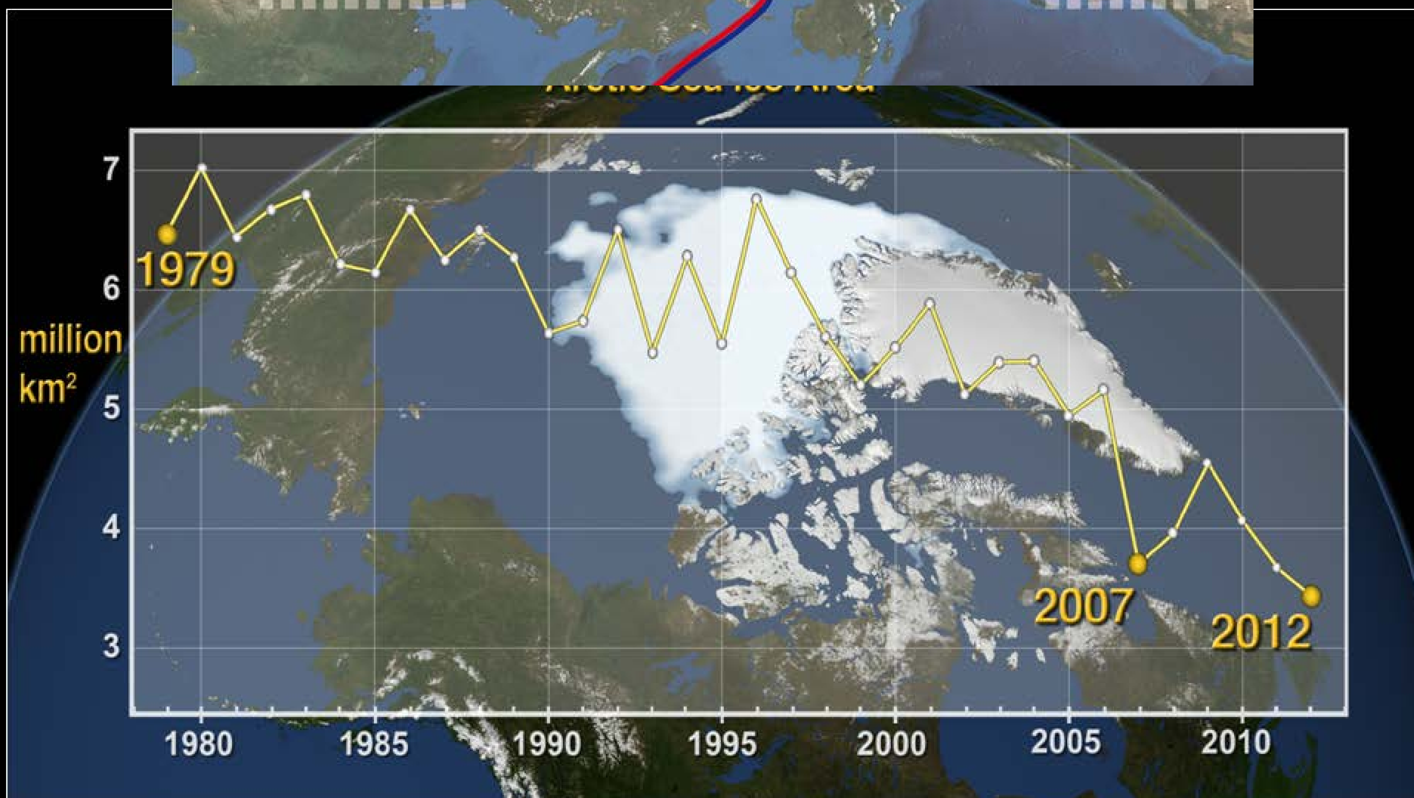
透過光で温められたメルトポンド下面の
水が下面の融解を促進

Ice Band

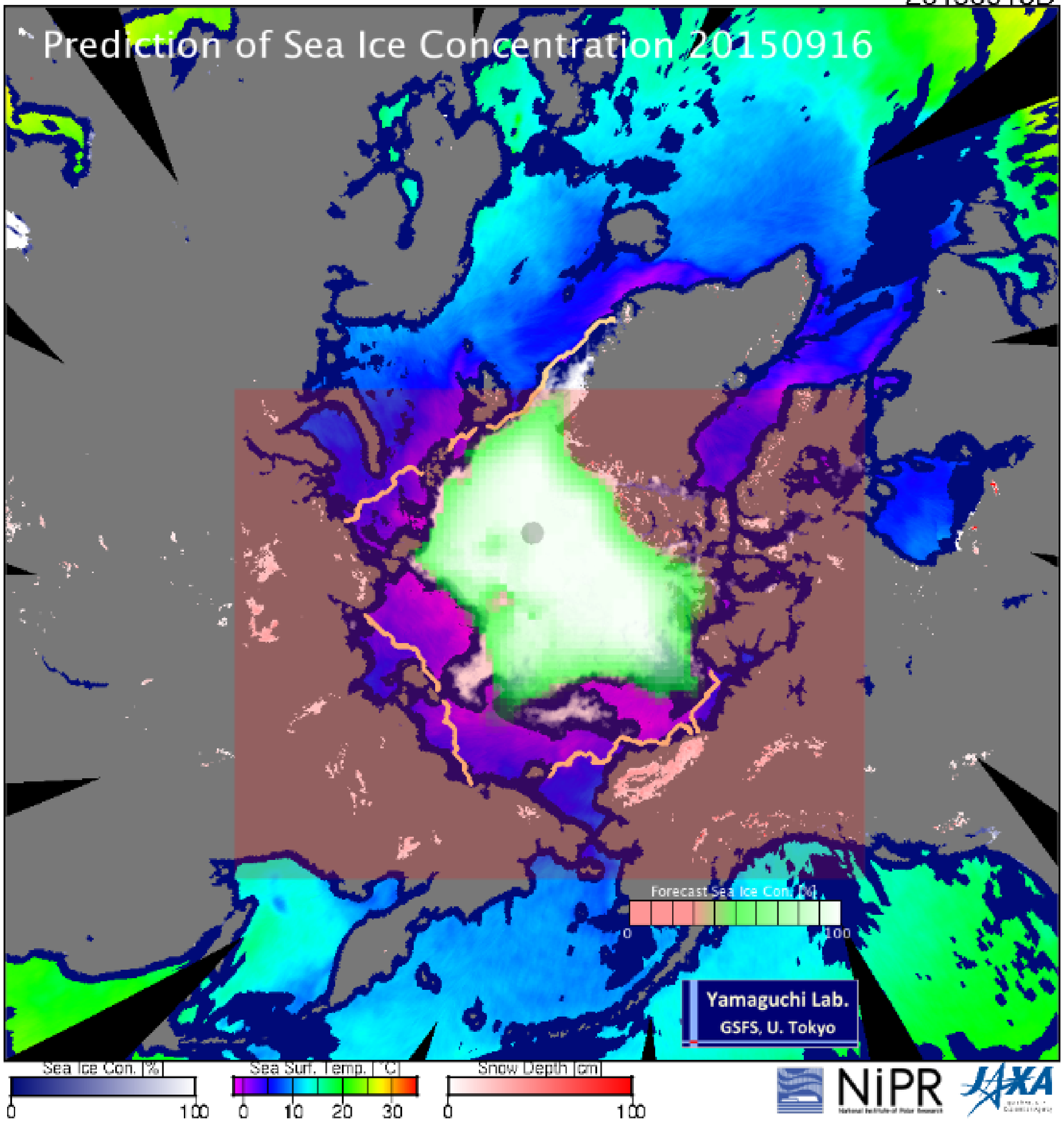


2006 northern Chukchi Sea


Northeastern Passage
2006
2008
2010
2012
2014
Jul
Aug
Sep
Oct
Northwestern Passage
2008
2010
2012
2014
Jul
Aug
Sep
Oct

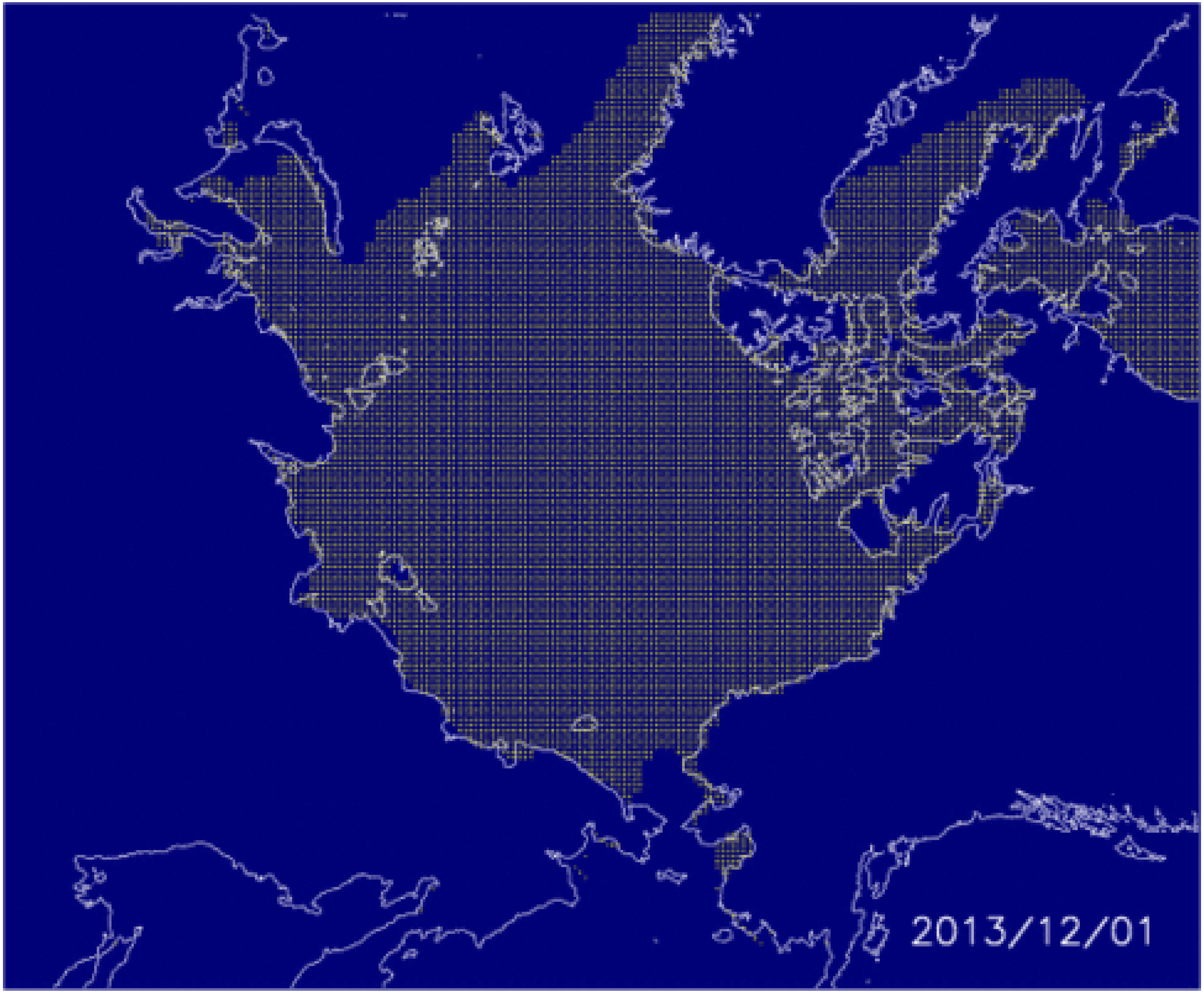

7
6
5
4
3
million km²
1979
2007
2012
1980
1985
1990
1995
2000
2005
2010

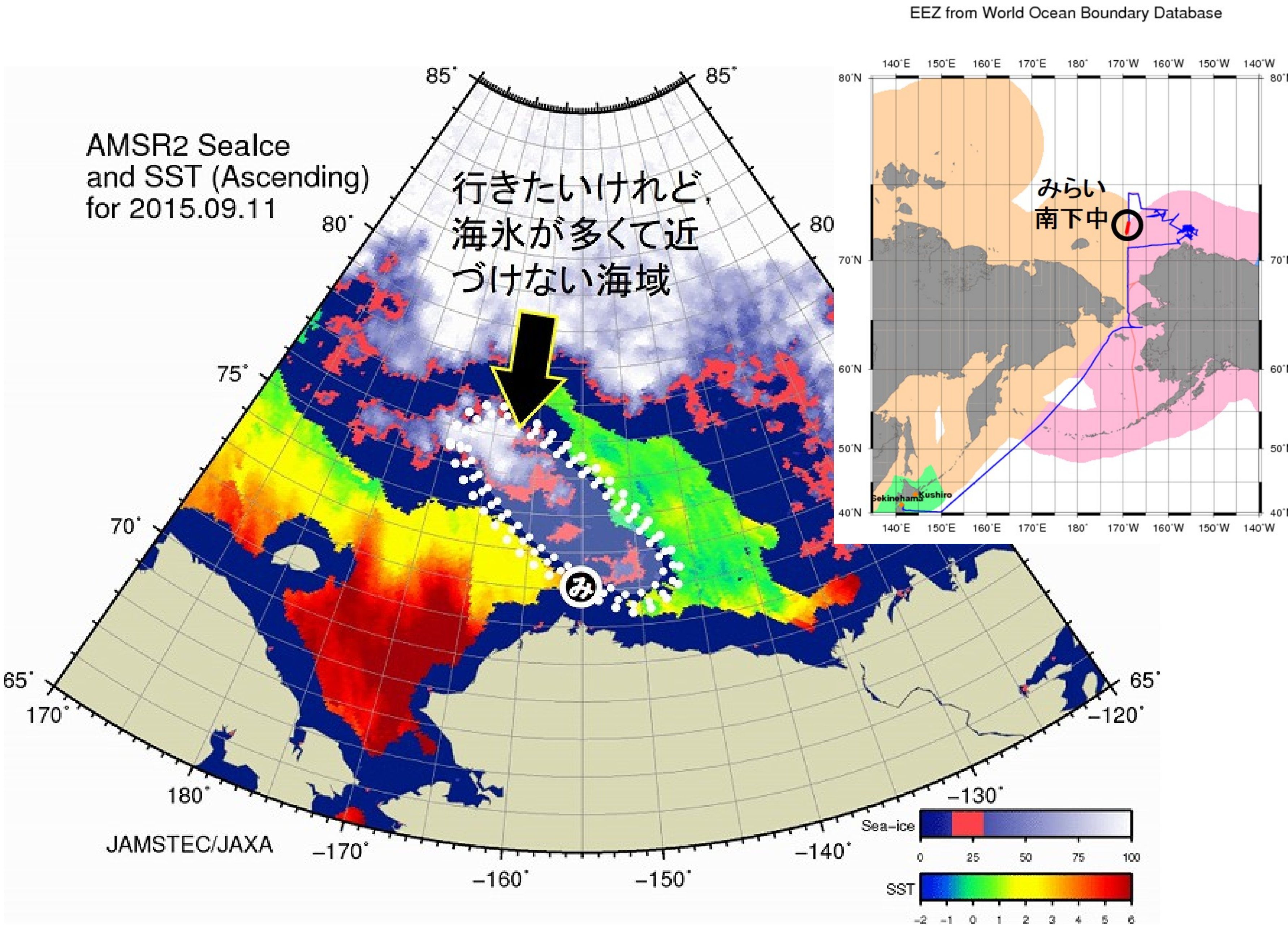
AMSR2 Sea Ice con.+Sea Surf. Temp.+Snow Depth 20150916D



※ change date of image by scrolling mouse-wheel.

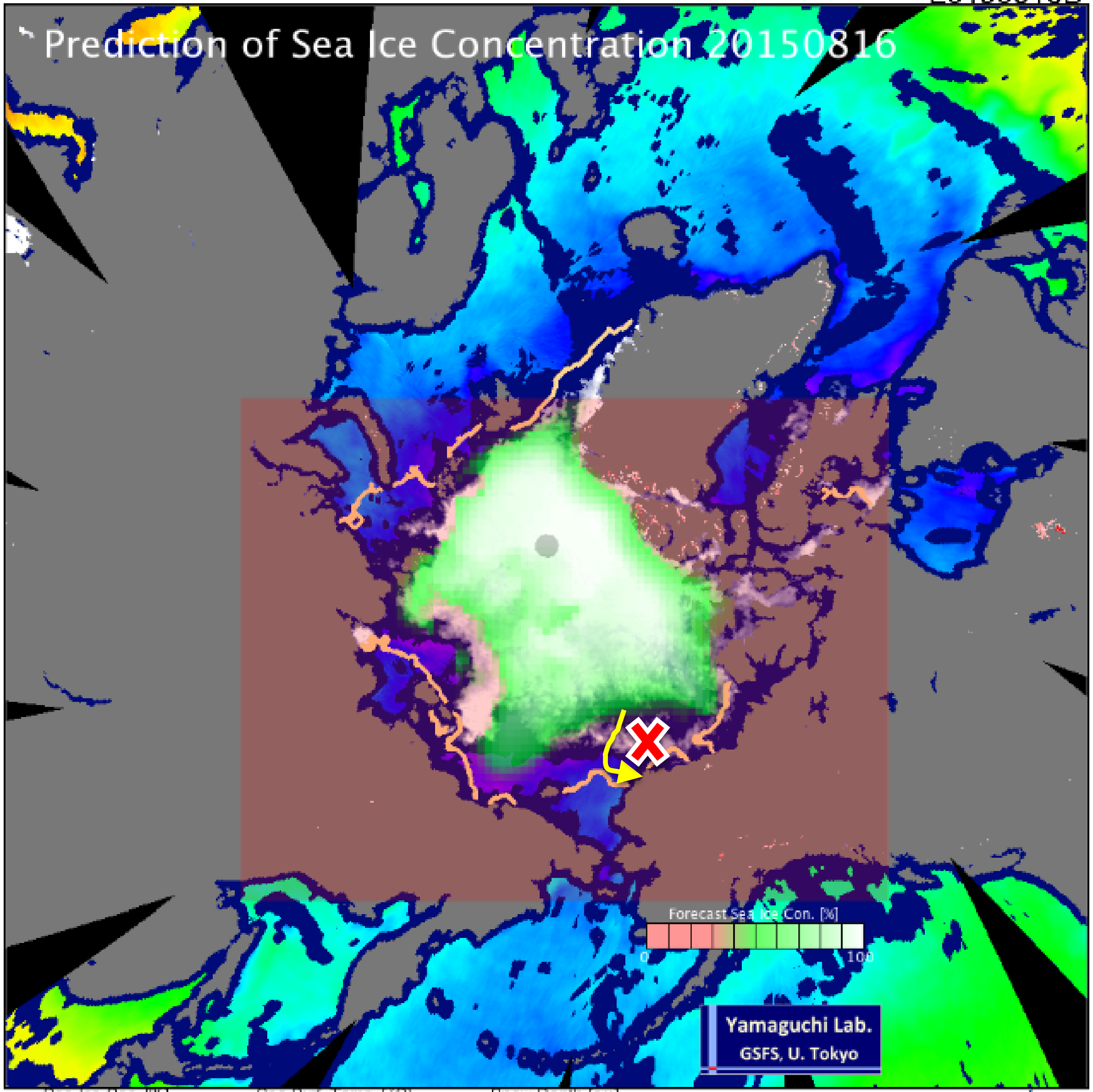
※ zoom/move image area by mouse click (left-drag:zoom, right-drag:move, double-click:reset)


2013/12/01



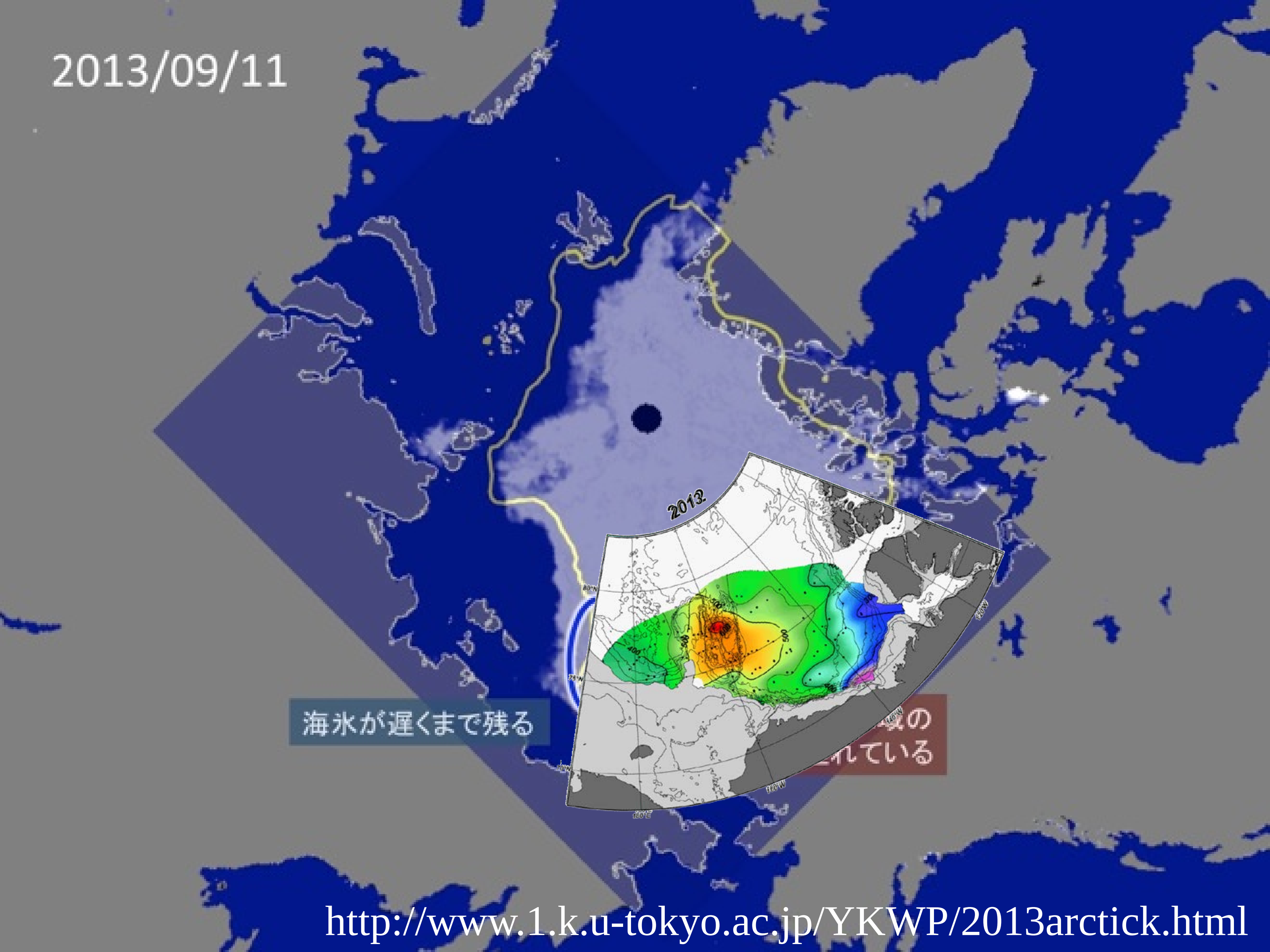
AMSR2 SeaIce
and SST (Ascending)
for 2015.09.11
行きたいけれど、
海氷が多くて近
づけない海域
み
JAMSTEC/JAXA
Sea-ice
SST
EEZ from World Ocean Boundary Database
みらい
南下中
Sekinehama
Kushiro

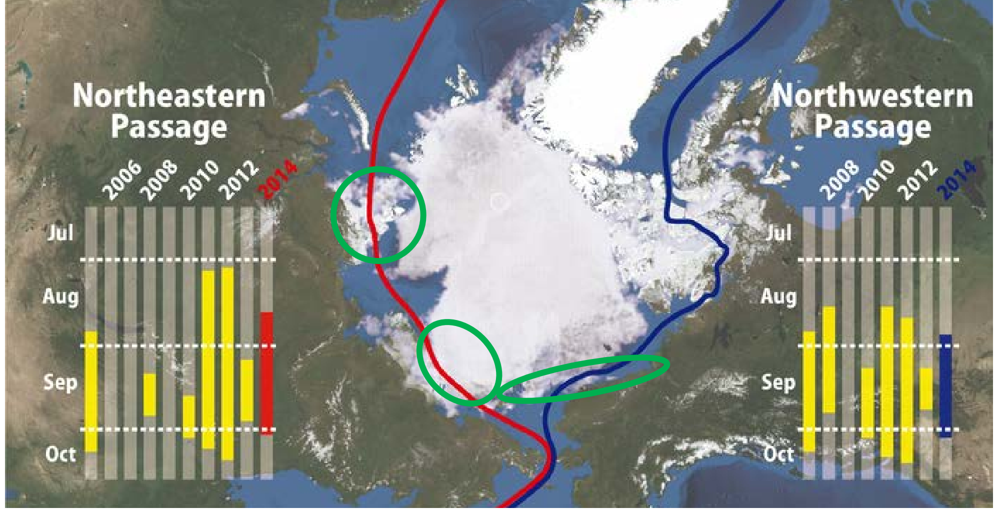
AMSR2 Sea Ice con.+Sea Surf. Temp.+Snow Depth 20150816D



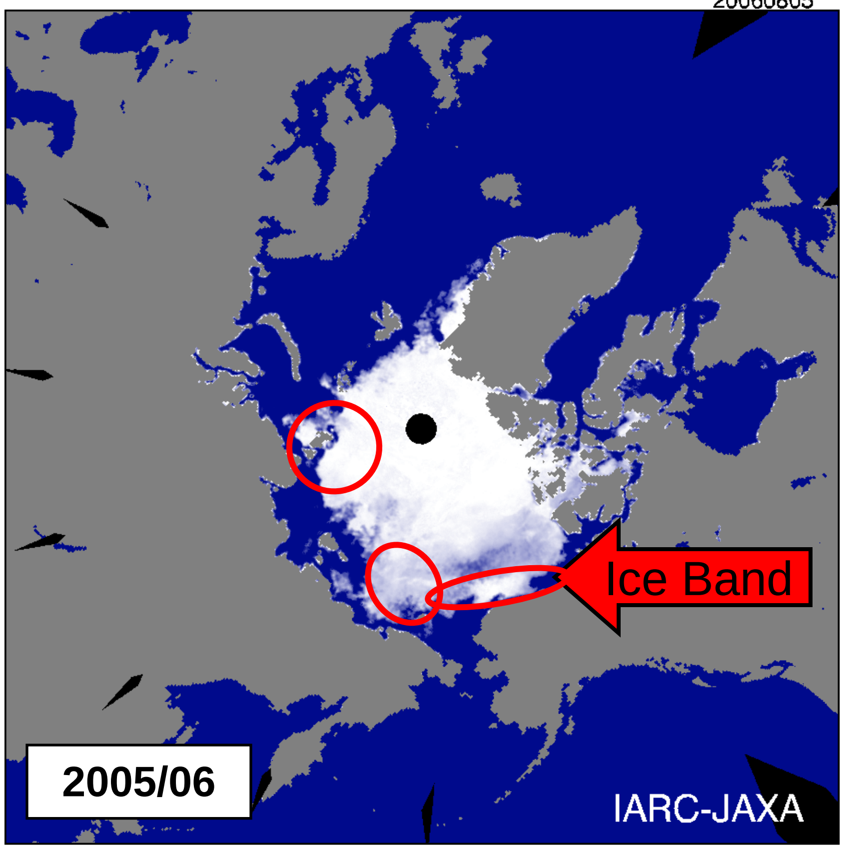
※ change date of image by scrolling mouse-wheel.

※ zoom/move image area by mouse click (left-drag:zoom, right-drag:move, double-click:reset)

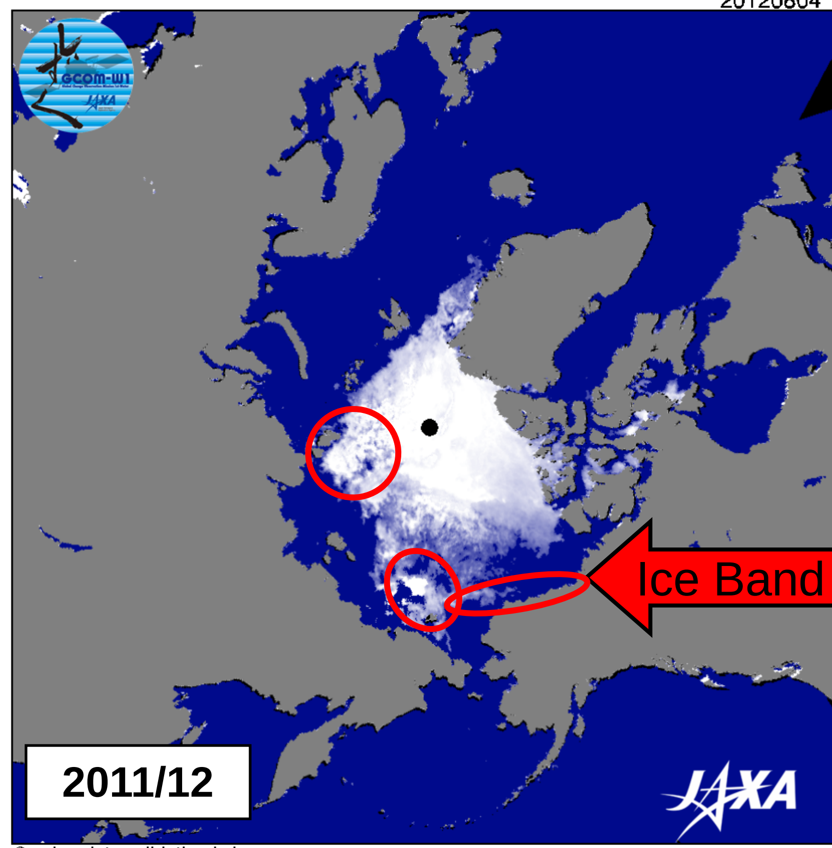

2013/09/11
2013
海氷が遅くまで残る
http://www.1.k.u-tokyo.ac.jp/YKWP/2013arctick.html



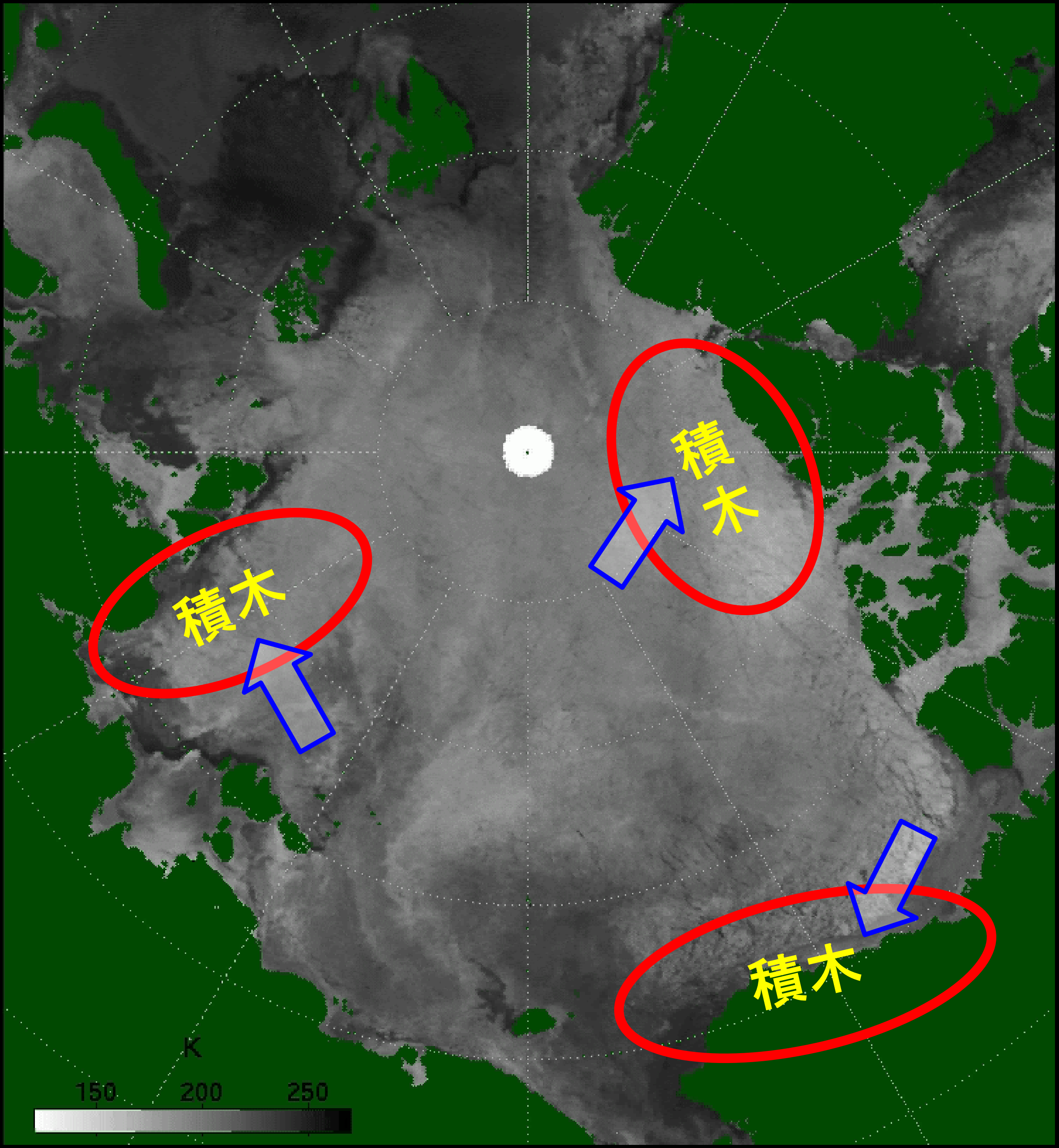
AMSR-E Sea Ice Concentration 20060805



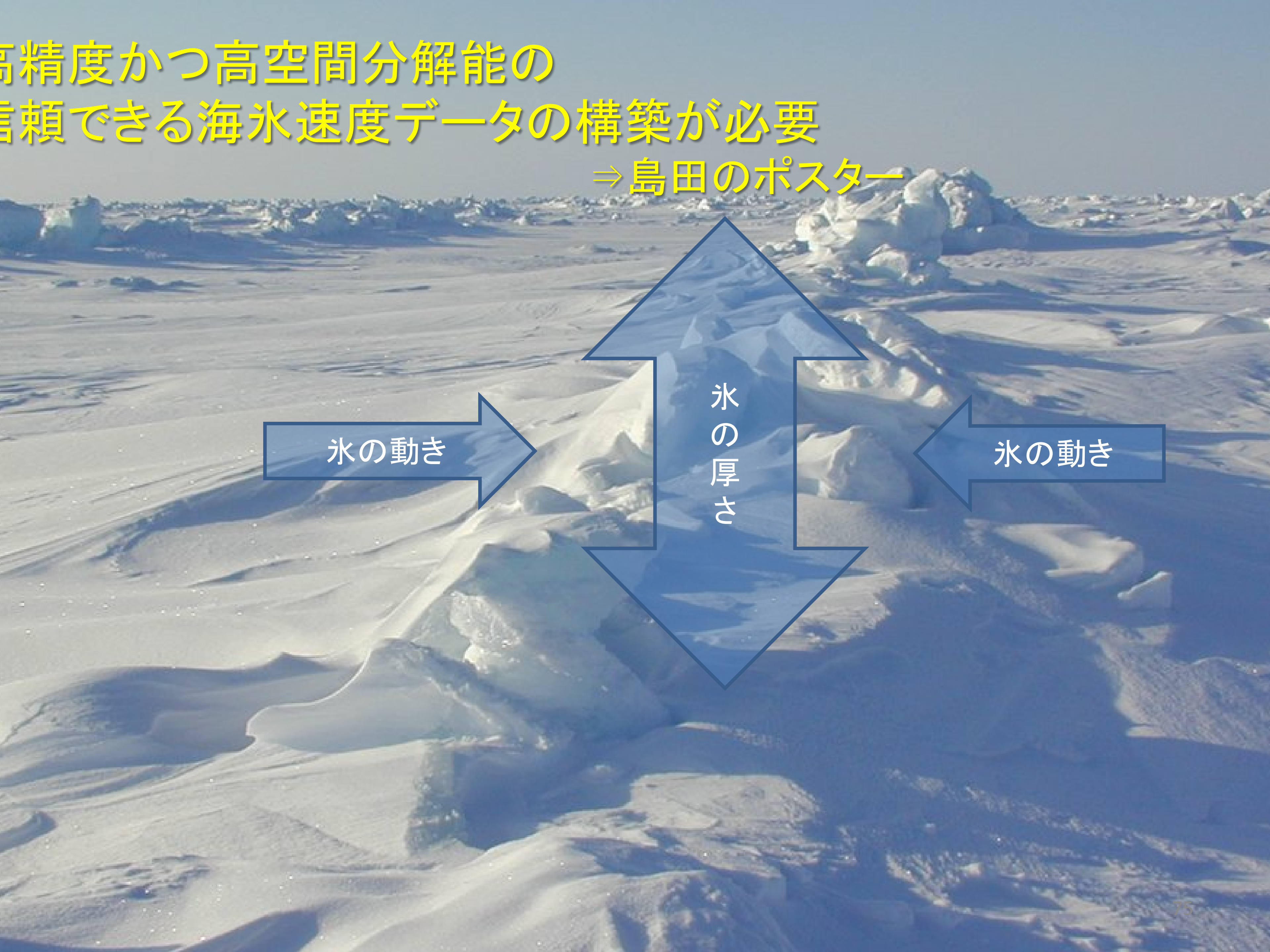
AMSR2 Sea Ice Concentration 20120804



Sea ice data validation is in progress.
The value of sea ice concentration may change after the validation process in future.



積木
積木
積木
K
150
200
250

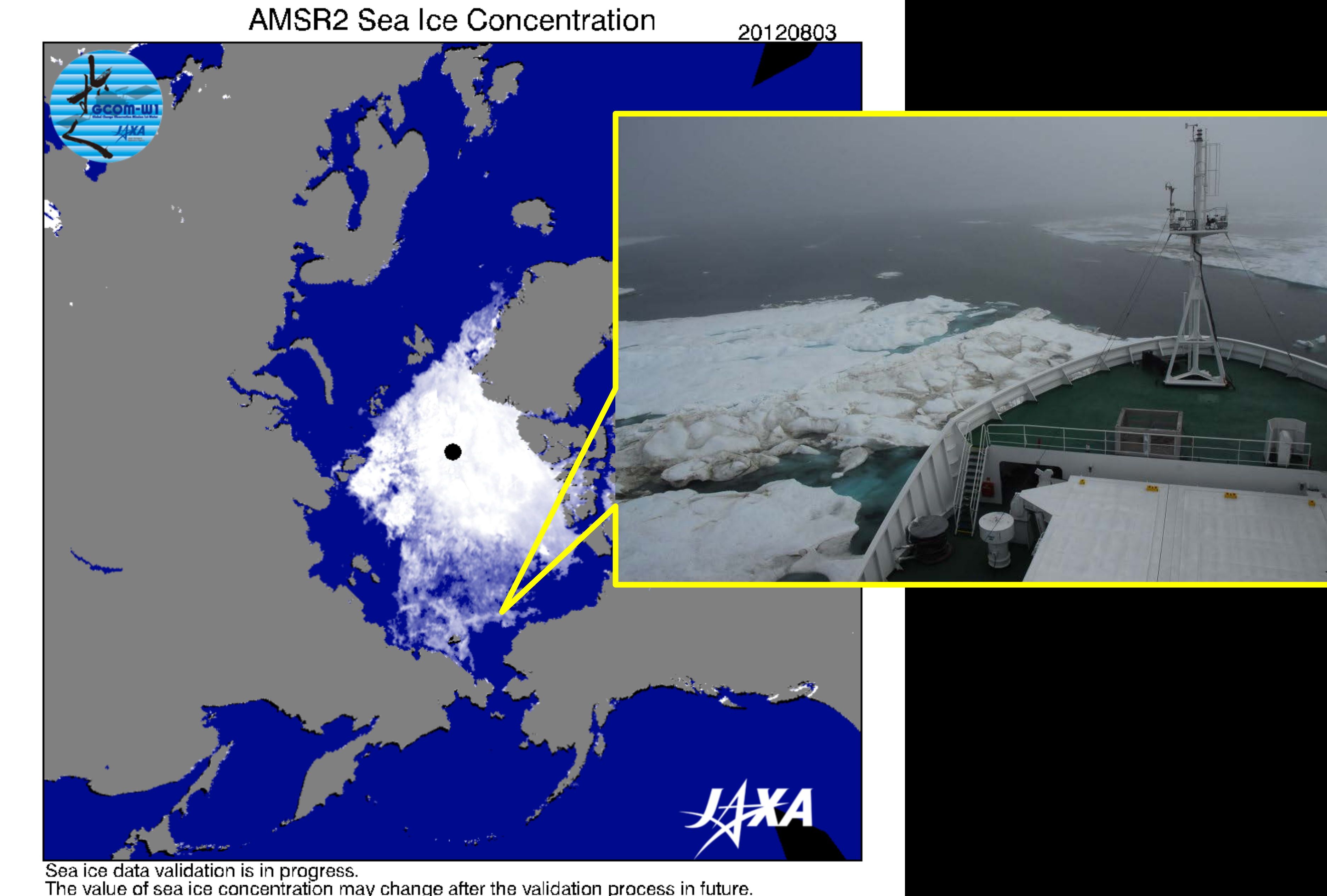


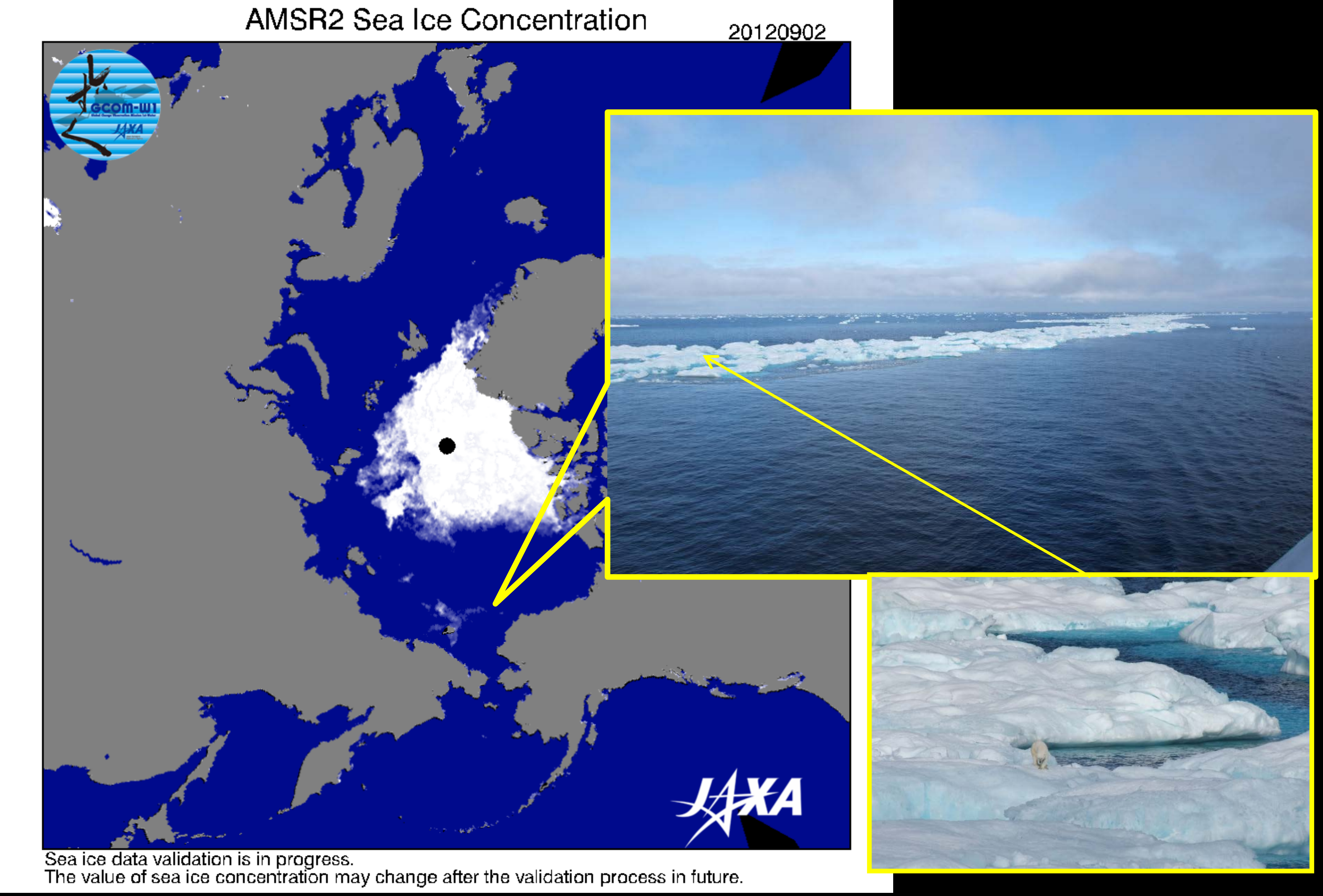
高精度かつ高空間分解能の
信頼できる海氷速度データの構築が必要
⇒島田のポスター
氷の動き
氷の厚さ
氷の動き

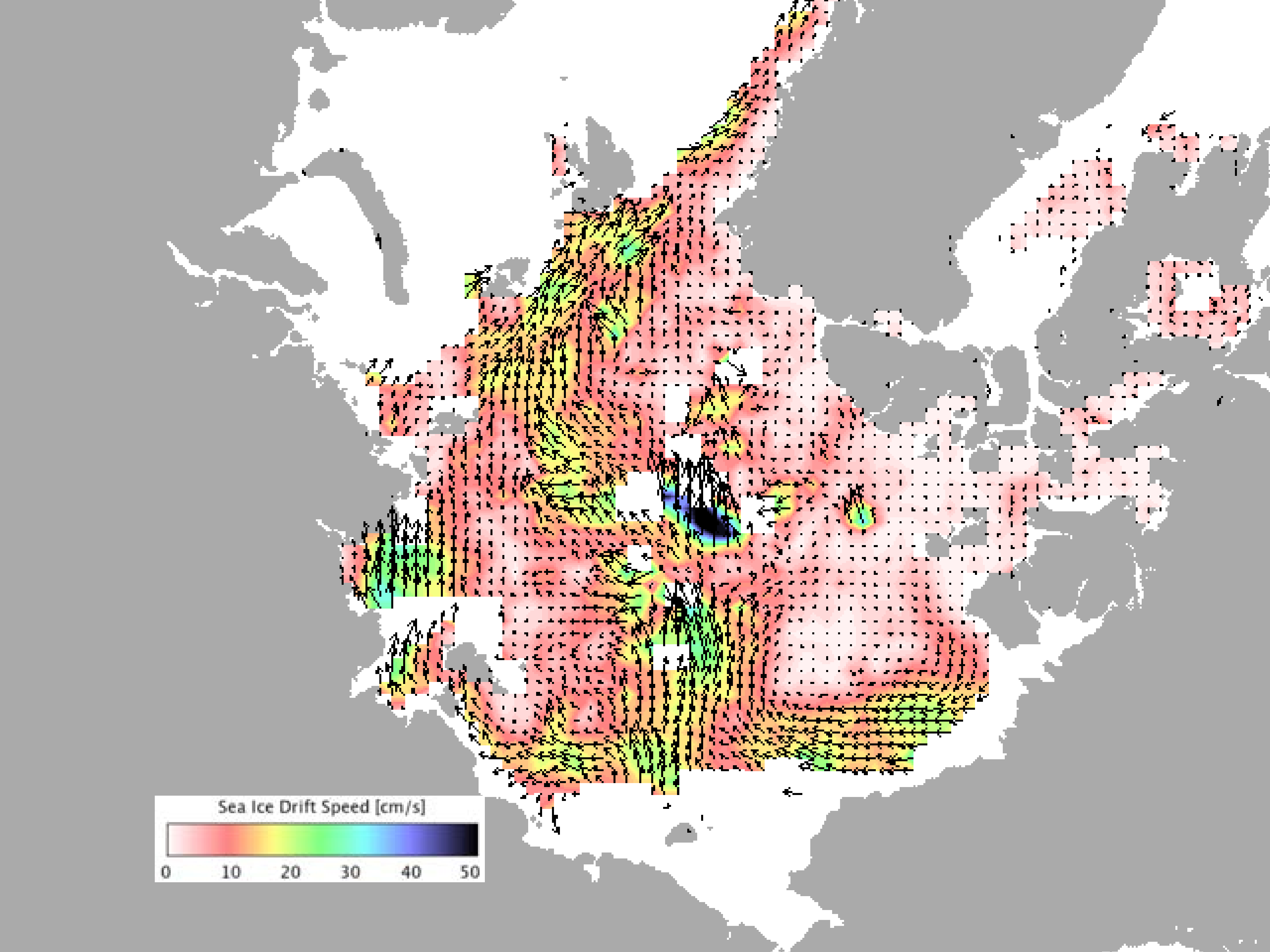
Application for availability of Arctic Sea routes

2006 northern Chukchi Sea

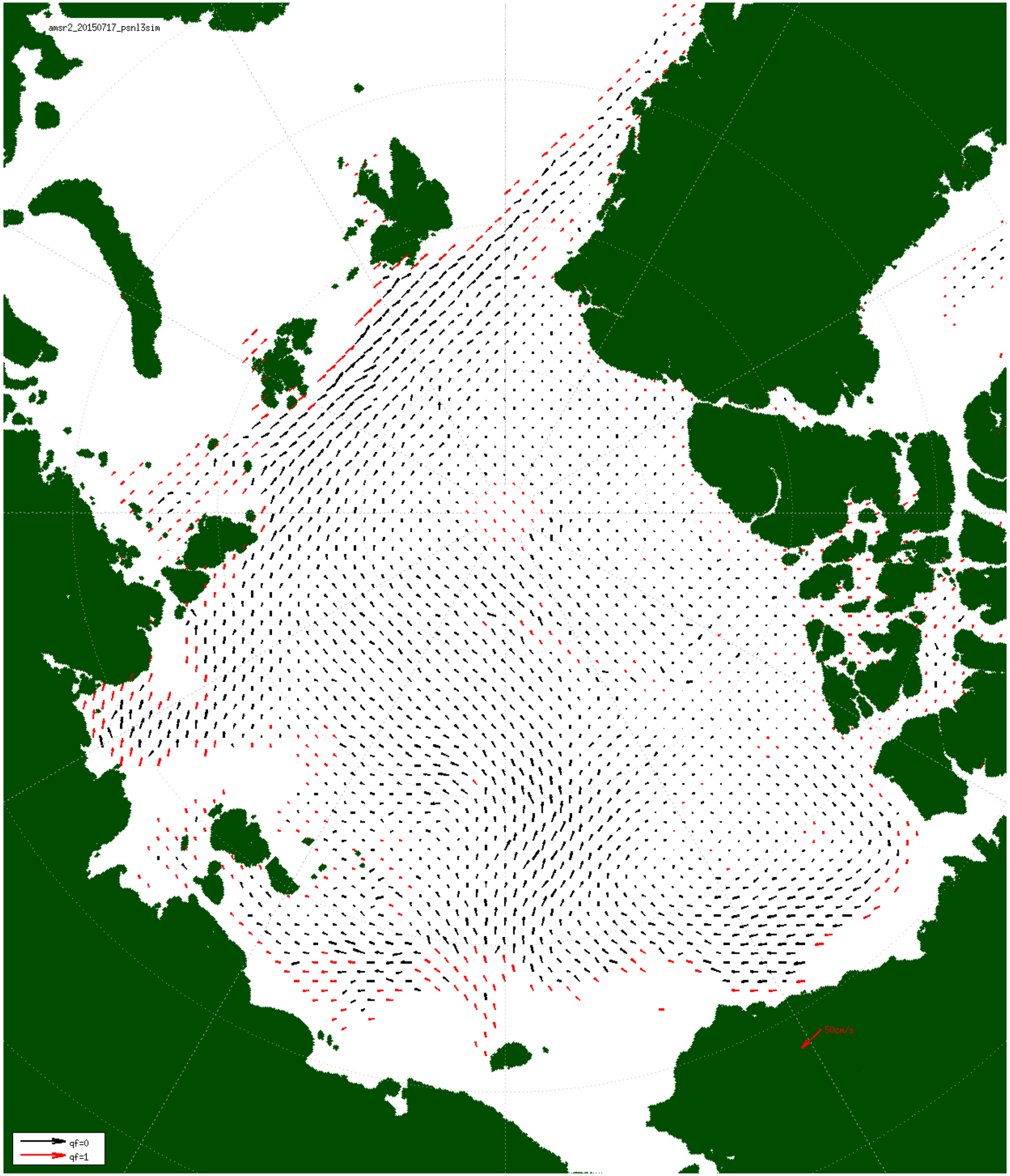

2006 northern Chukchi Sea
Photo by Koji Shimada


AMSR2 Sea Ice Concentration
20120803
GCOM-W1
JAXA
Sea ice data validation is in progress.
The value of sea ice concentration may change after the validation process in future.

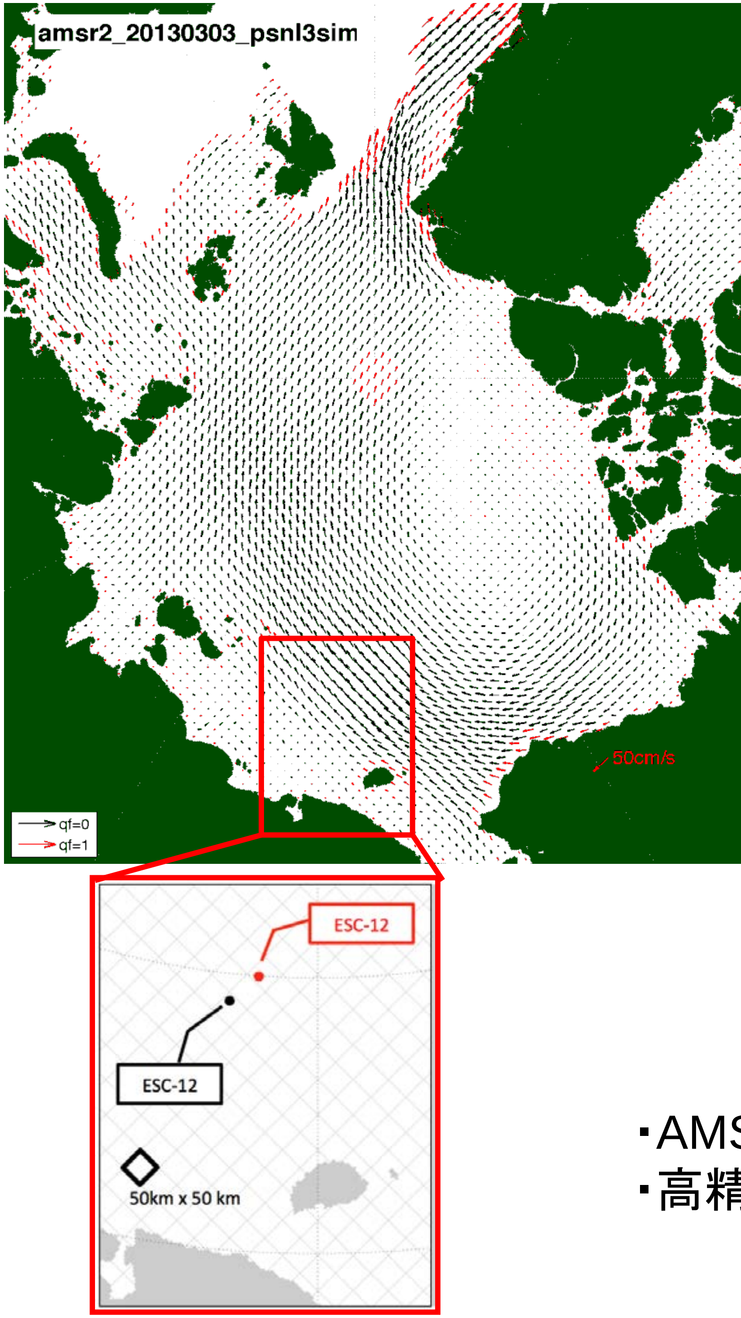

AMSR2 Sea Ice Concentration
20120902
GCOM-W1
JAXA
Sea ice data validation is in progress.
The value of sea ice concentration may change after the validation process in future.

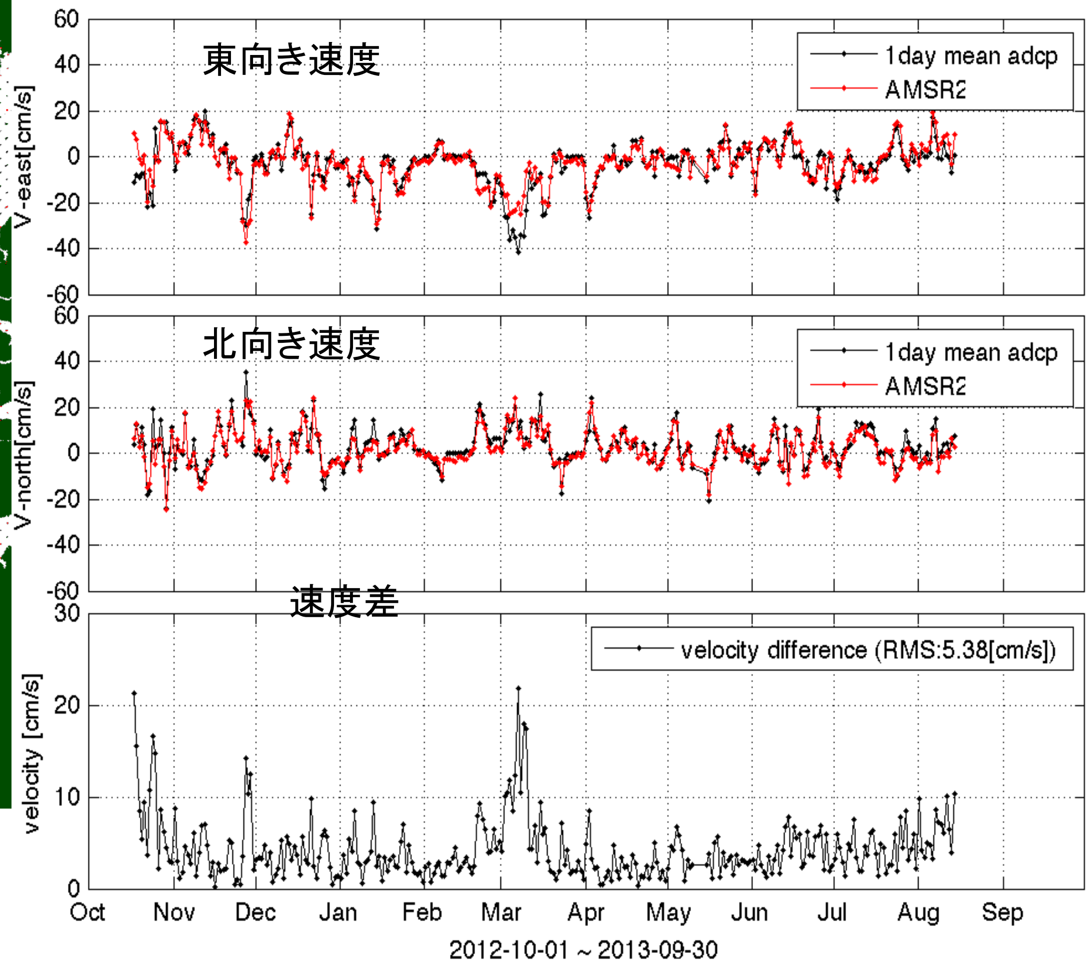


Sea Ice Drift Speed [cm/s]
0
10
20
30
40
50


amsr2_20150717_psnl3sim
50cm/s
qf=0
qf=1

係留系観測(2012-2013)⇒AMSR-2ベースの海氷速度ベクトルアルゴリズム

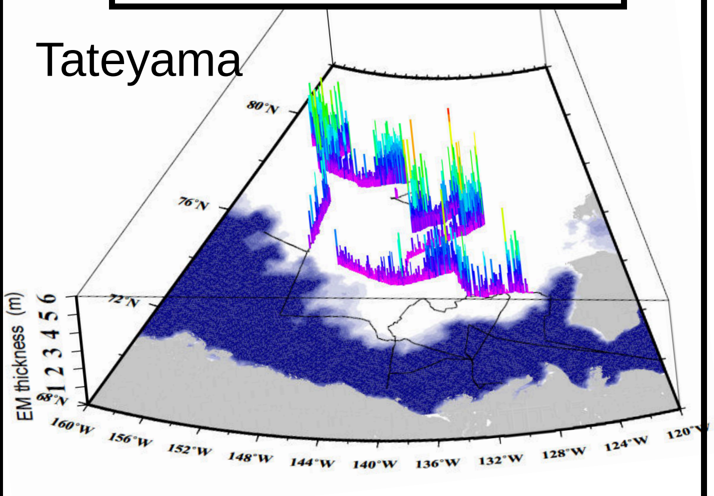


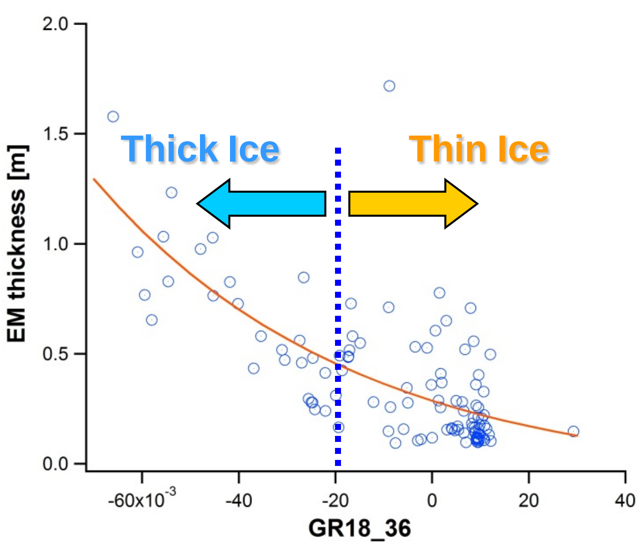


・AMSR-2ベースの海氷速度算出アルゴリズムに利用
・高精度リアルタイム海氷速度データ提供計画(from JAXA)

Ice Thickness Group

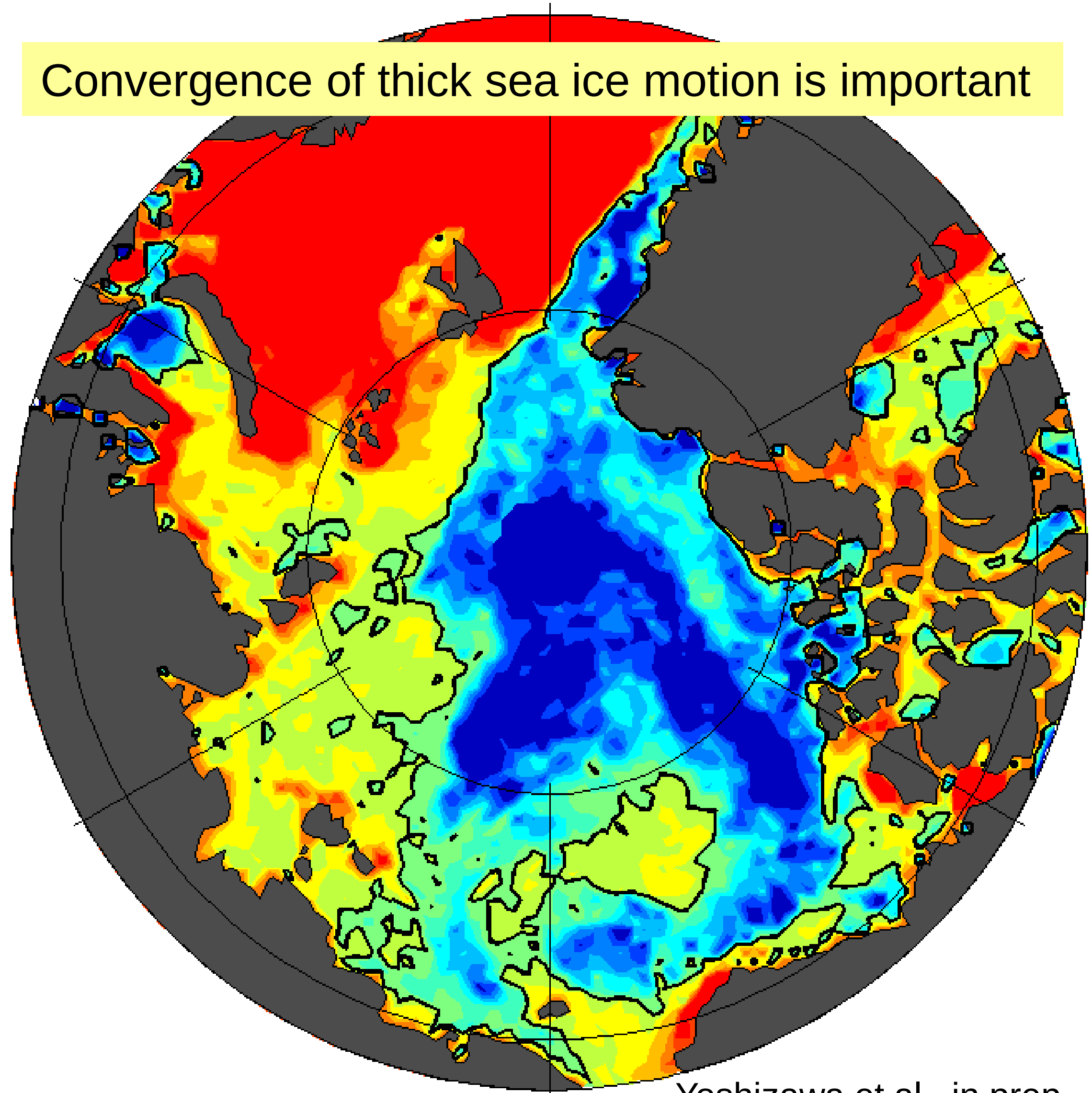
Tateyama



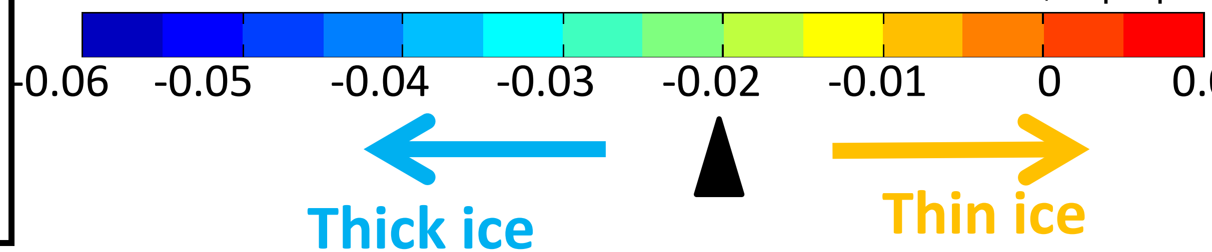


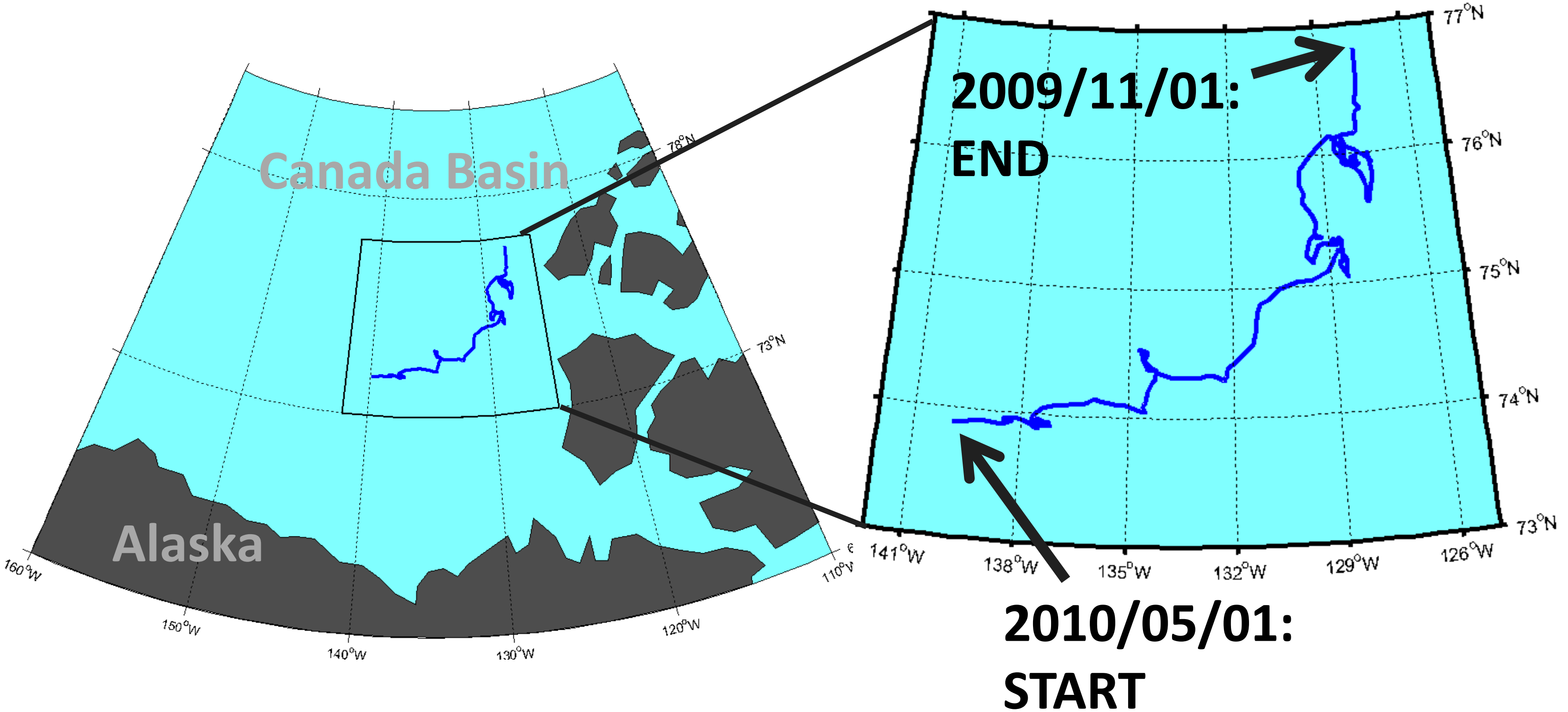
$$GR = \frac{[36V]-[18V]}{[36V]+[18V]}.$$

Convergence of thick sea ice motion is important



Yoshizawa et al., in prep.

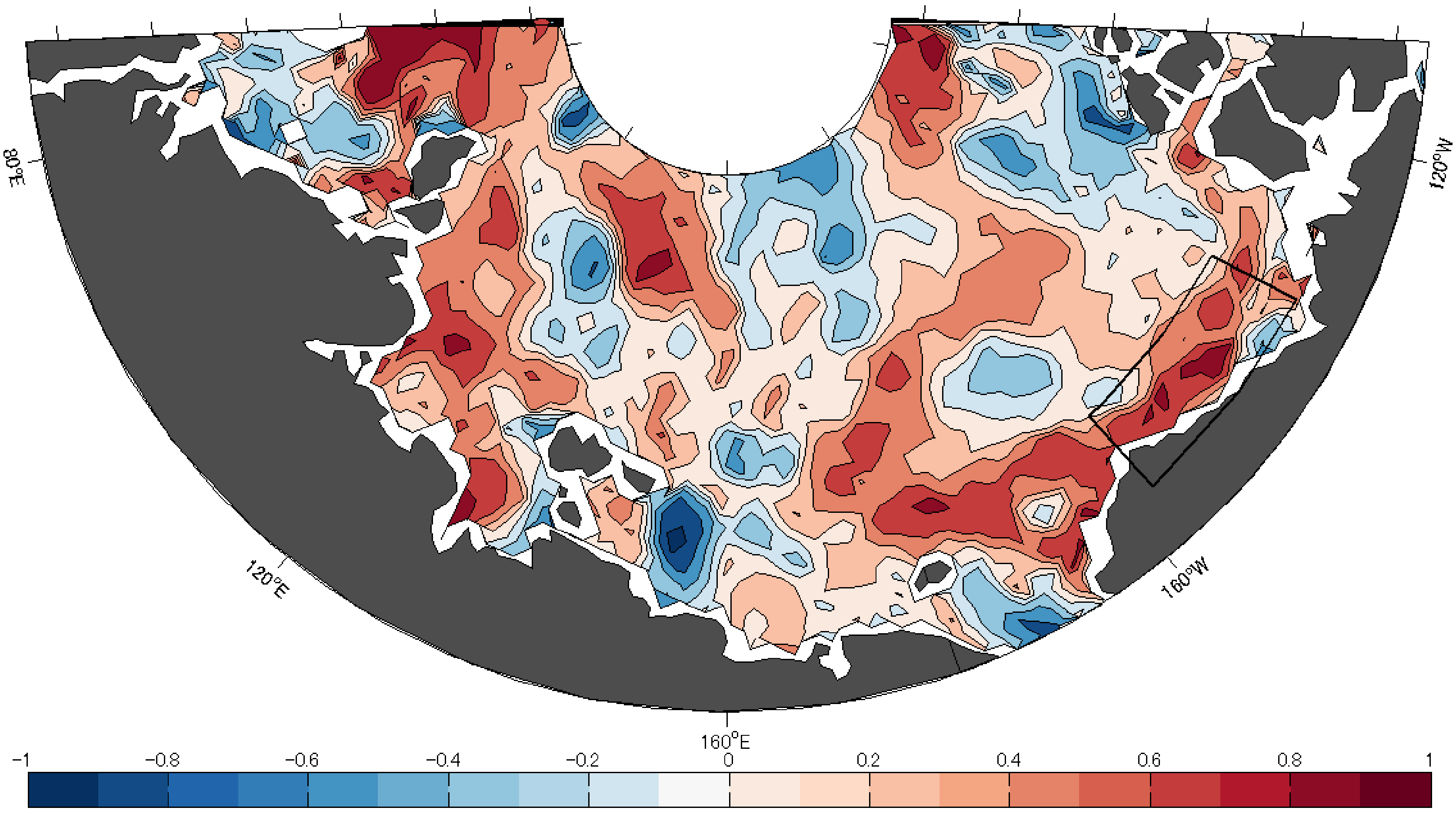




- Calculate convergence if GR is less than critical value (-0.02) and sea ice concentration is greater than 98%.

  $\Rightarrow$ effective convergence for rafting: ECR

- Integrate ECR along drift track of sea ice from November to April.



Correlation between “integrated effective convergence of sea Ice along drift track (Nov.～Apr.)” and “sea ice concentration in the following summer (Jun.～Sep.)”. Box shows a key area of the Northwest passage area (70 - 74°N, 135 - 157°W).

regression

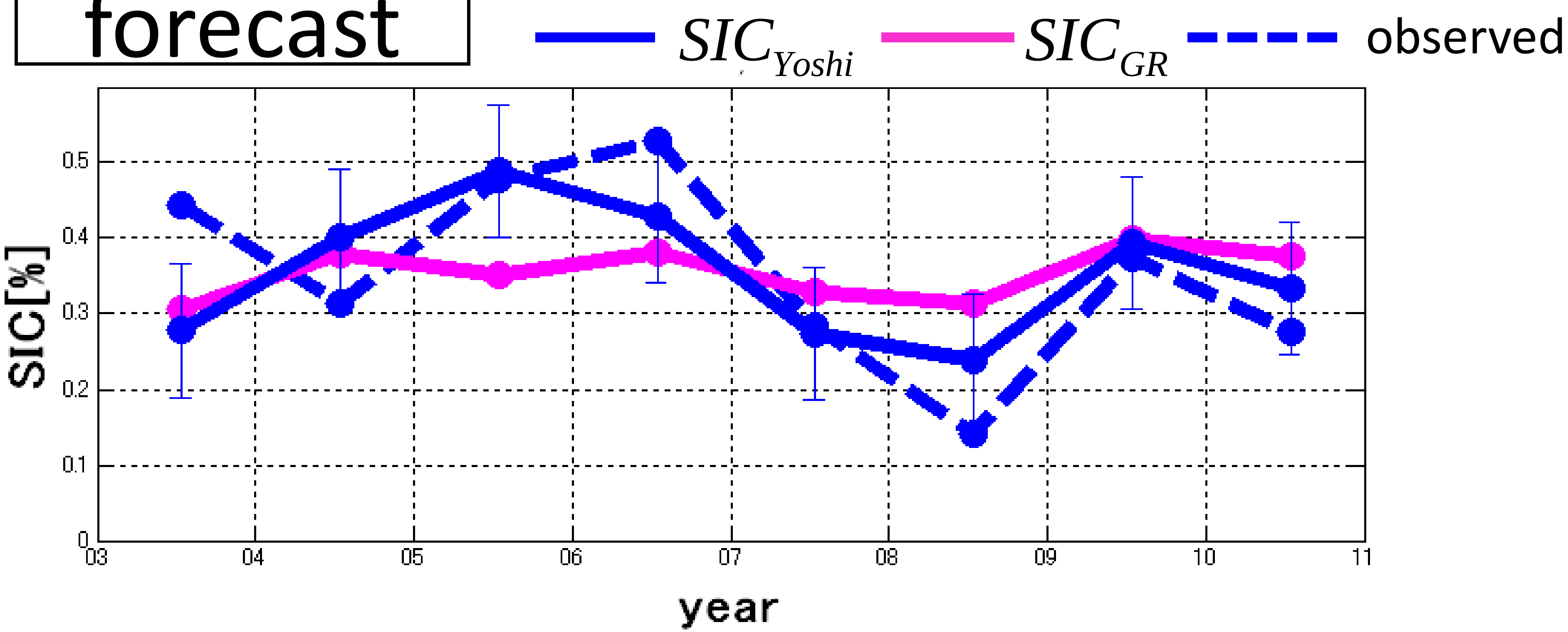
Spring GR only (using just thickness in spring, without sea ice motion)

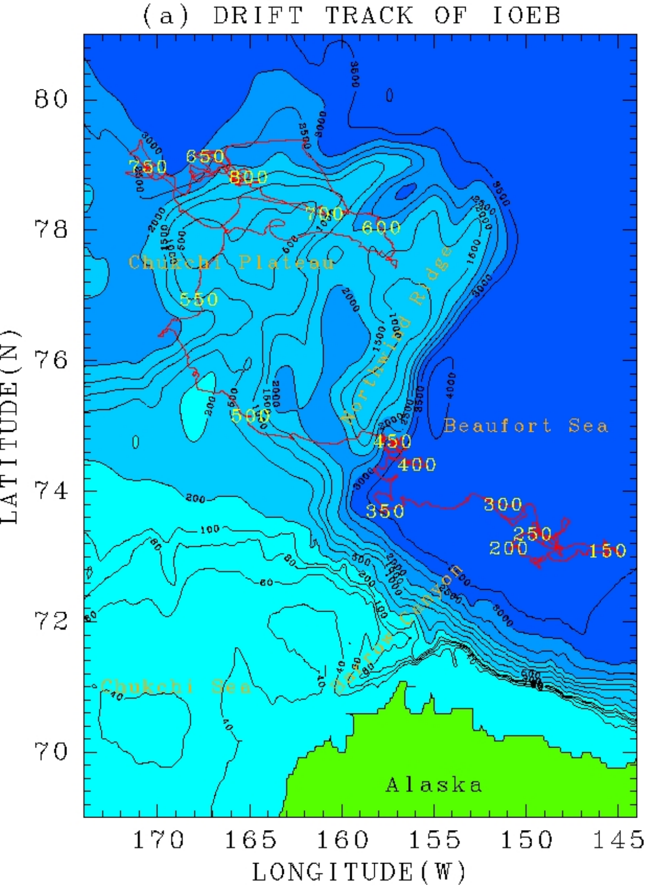
$$SIC_{GR} = 4.3542 \times \mathrm{GR} + 0.2556. \qquad (r = 0.2717)$$

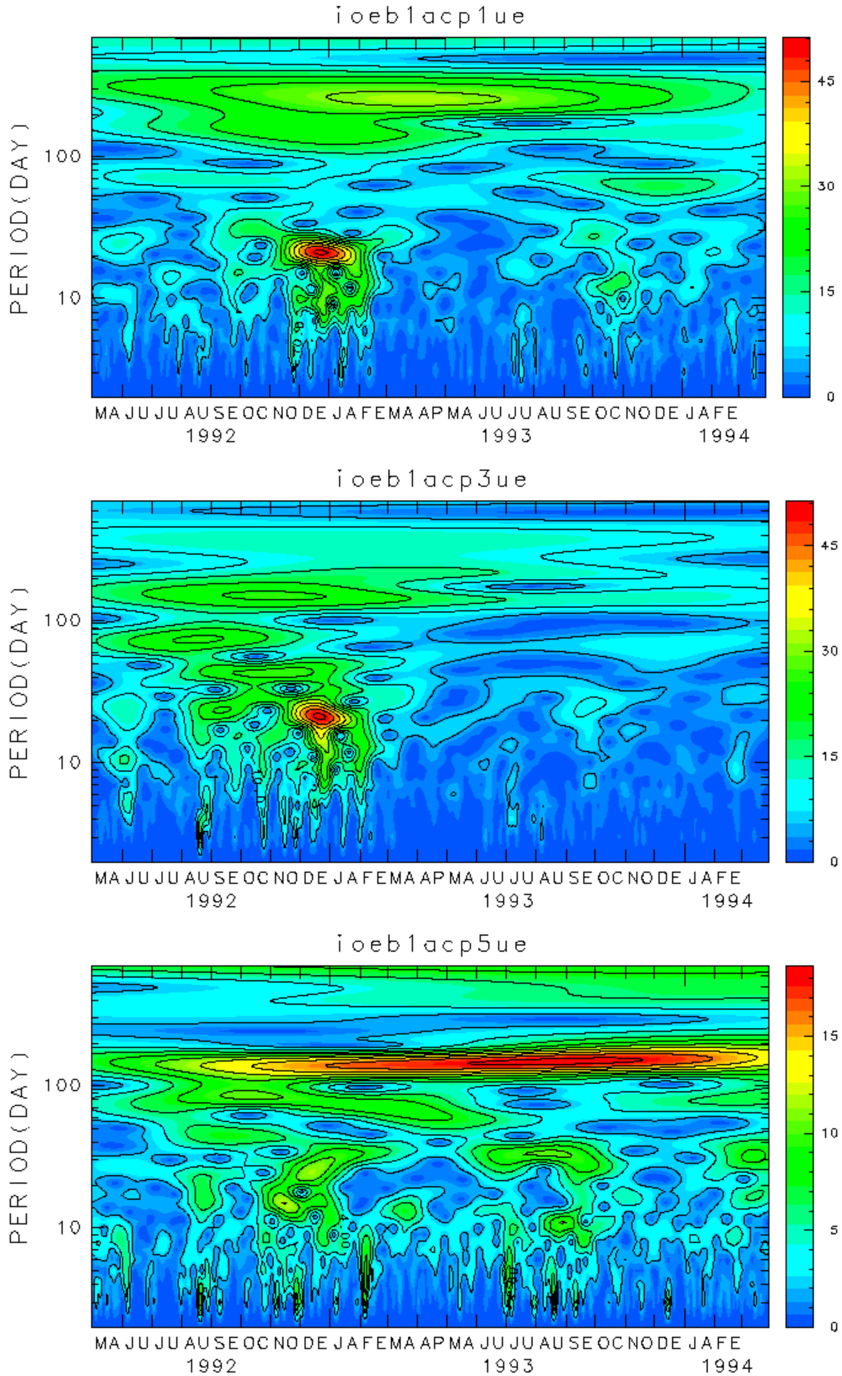
GR and integration of effective convergence for rafting (iECR)

$$SIC_{Yoshi} = 0.6924 \times \mathrm{iECR} + 0.1547 \qquad (r = 0.6924)$$

forecast







T=5.4d: R=15km,U=20cm/s

T=22d: R=30km, U=10cm/s