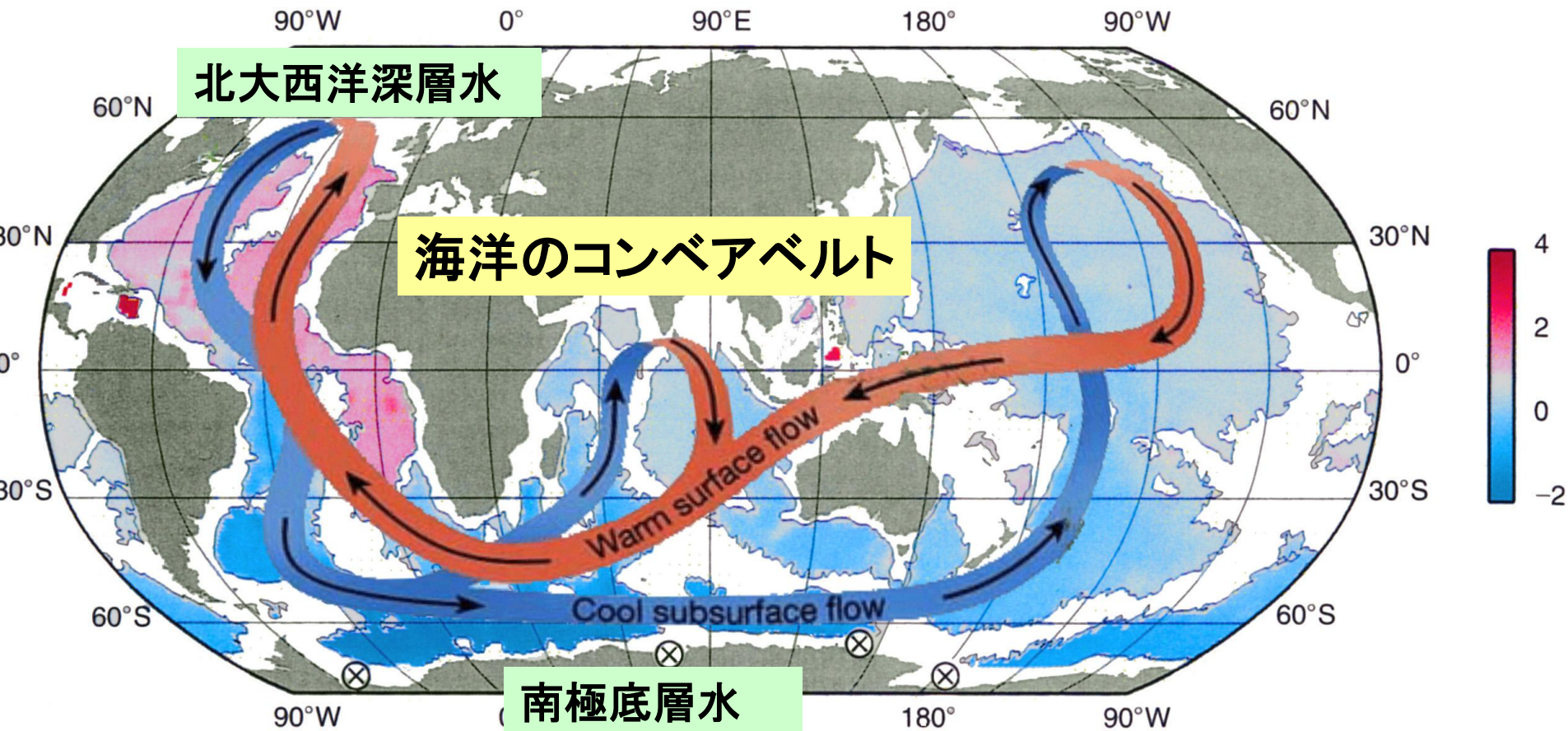


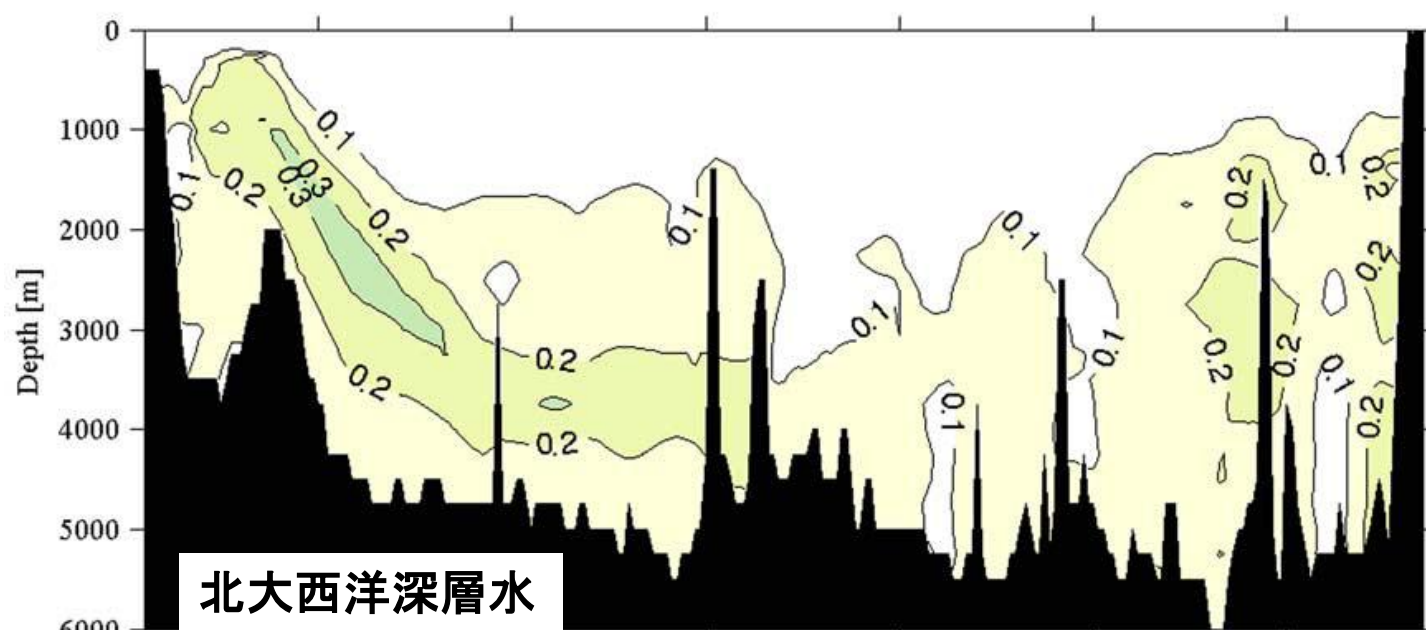
# ▪ 南極底層水研究の最新トピックス

# 世界の海洋の海底近くの水温分布

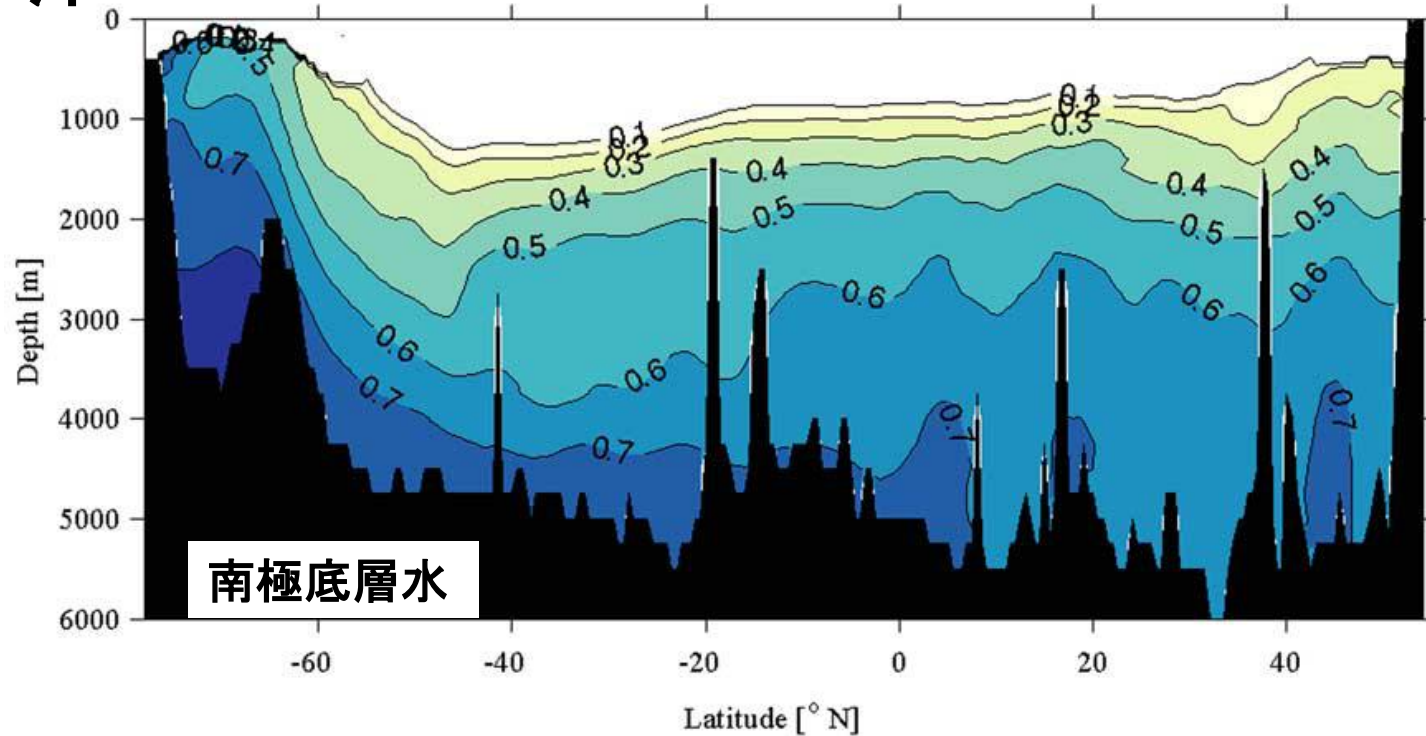


全海水の約75%は4°C以下。世界で一番**重い冷たい水**は南極海で作られ(南極底層水)、全世界の底層に広がっていく。深層循環(2000年の時間スケール)の源

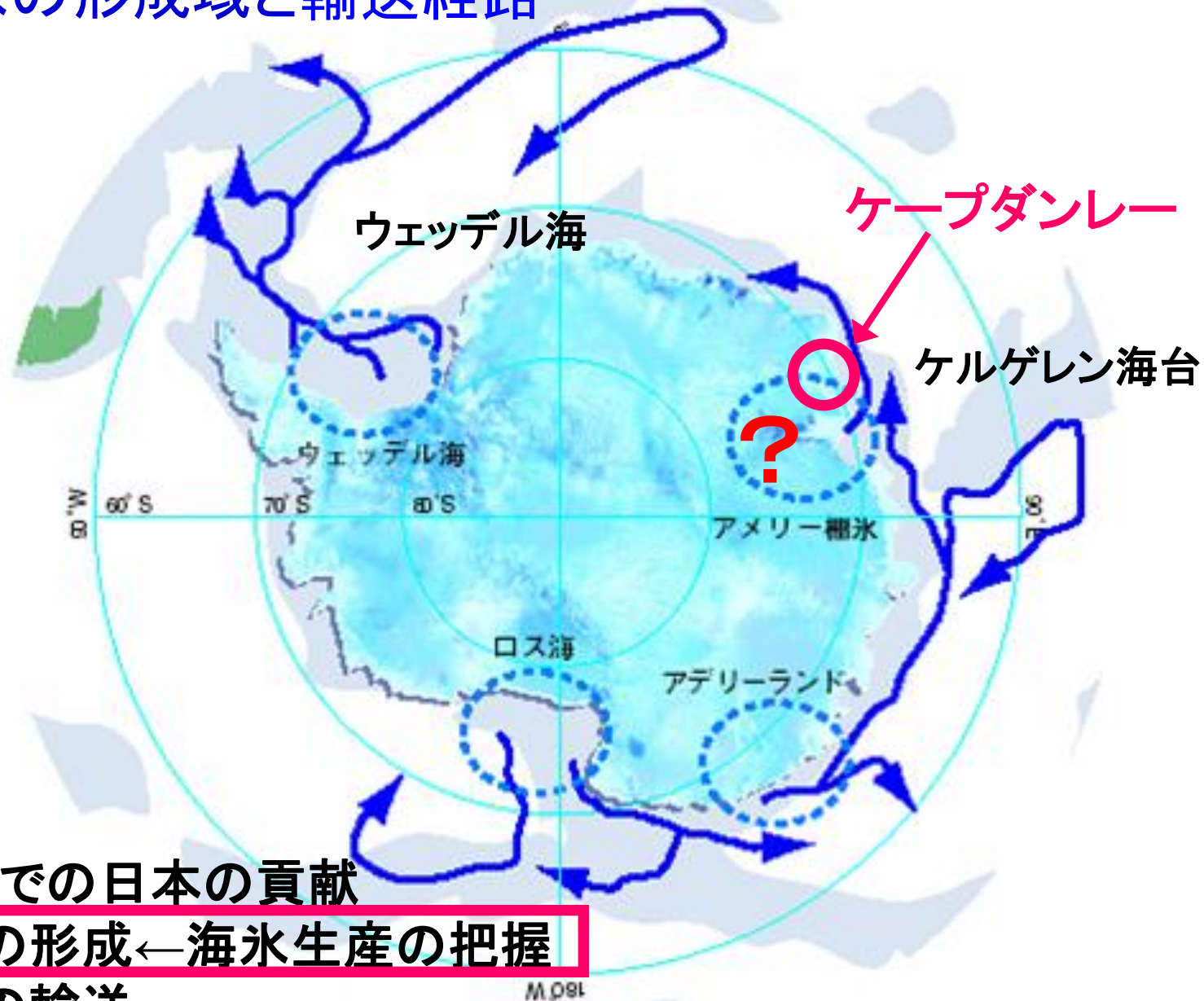
海洋の子午面循環 (MOC: Meridional Overturning Circulation )  
北大西洋深層水の南下; 南極底層水の北上



太平洋



# 南極底層水の形成域と輸送経路



## プレIPYとIPYでの日本の貢献

・南極底層水の形成 ← 海氷生産の把握

・南極底層水の輸送

・南極底層水の変質と原因

# 沿岸ポリニャとは？ →

- ・ 氷厚0~0.2mの薄氷域
- ・ 幅約数十km

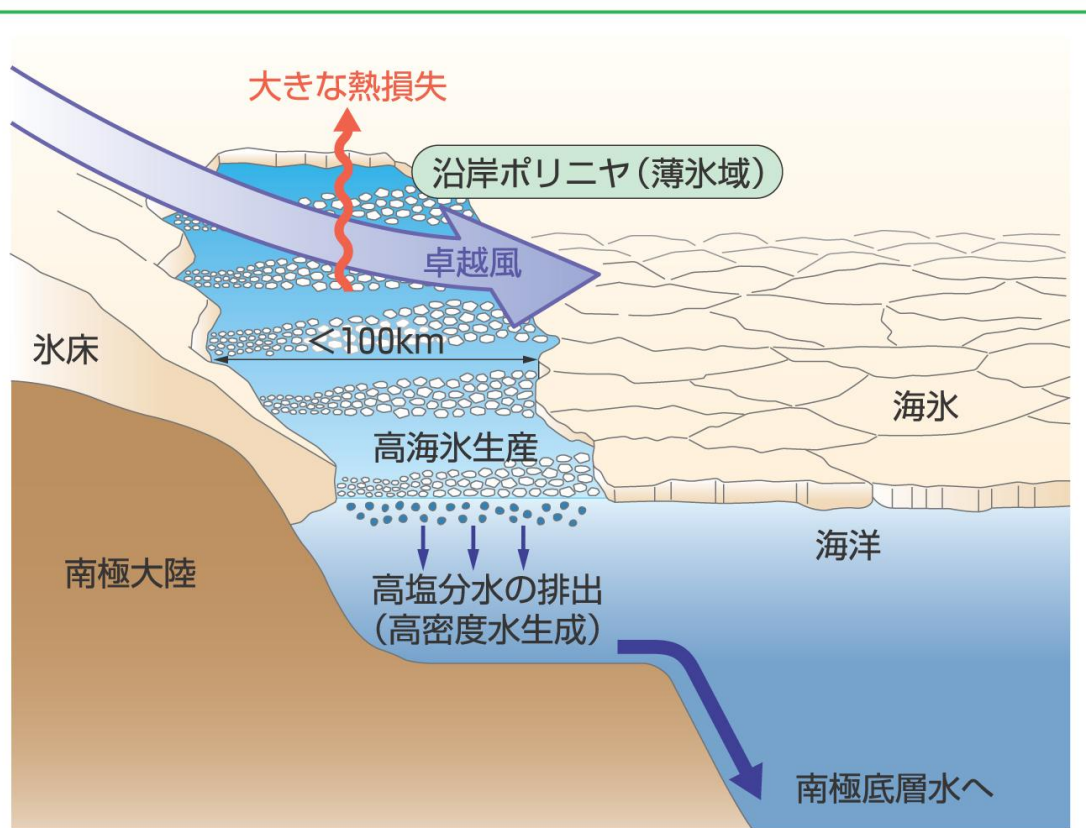
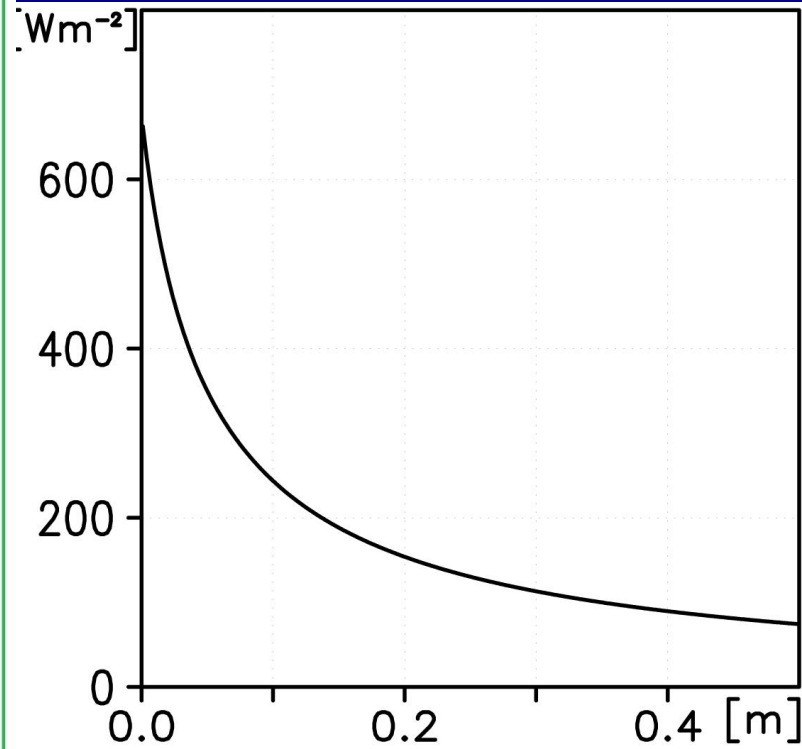


図3 南極海での沿岸ポリニャの模式図  
 (Morales Maqueda et al. (2004)<sup>4</sup>を参考に描画)

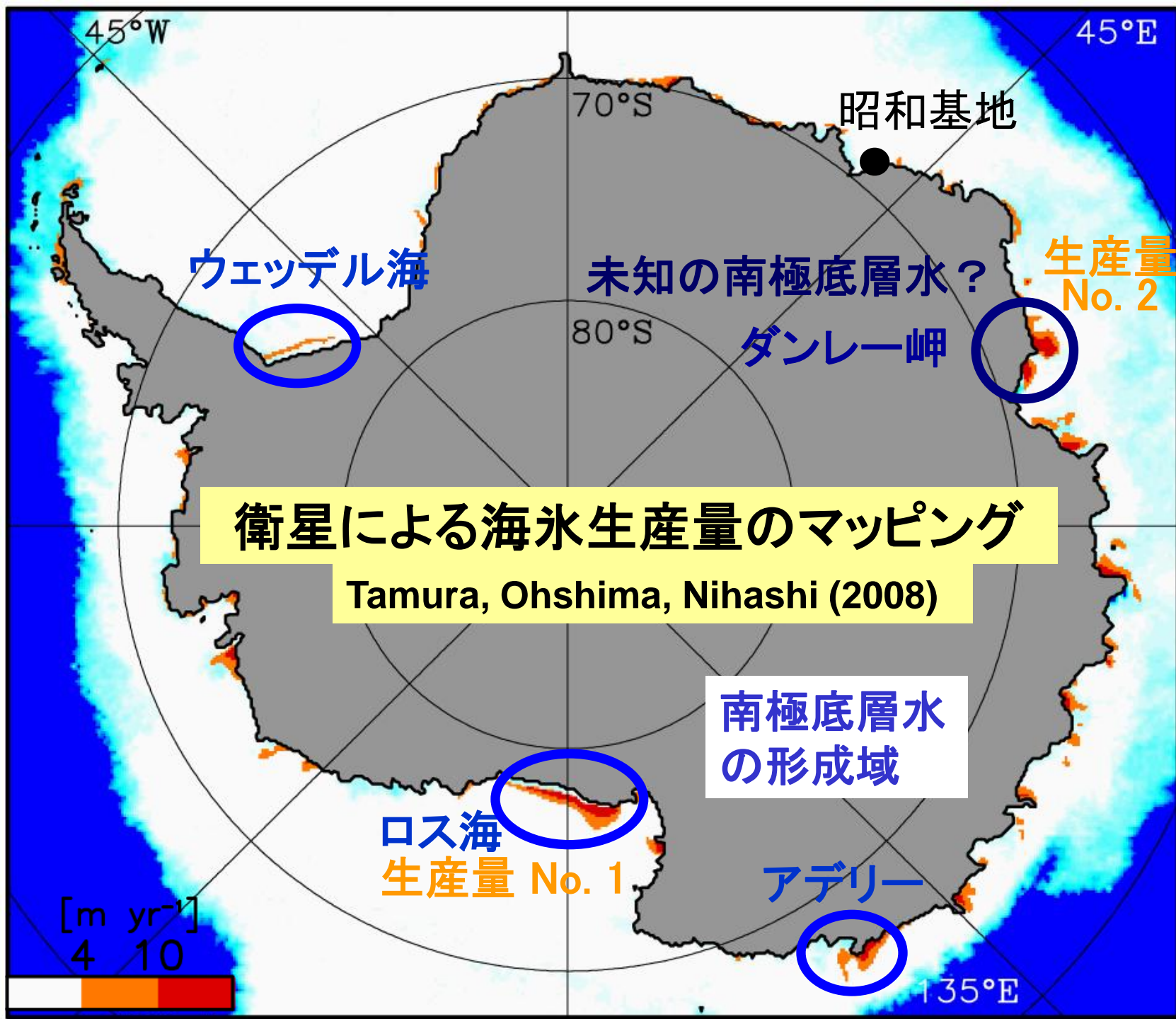


海氷厚と熱損失との関係



マイクロ波放射計

沿岸ポリニヤ＝薄氷域  
衛星(マイクロ波放射計)から薄氷厚推定  
熱収支計算: 奪われた熱量＝海氷生産量



45°W

45°E

昭和基地

ウェッデル海

未知の南極底層水?

生産量  
No. 2

80°S

ダンレー岬

# 衛星による海水生産量のマッピング

Tamura, Ohshima, Nihashi (2008)

南極底層水  
の形成域

ロス海  
生産量 No. 1

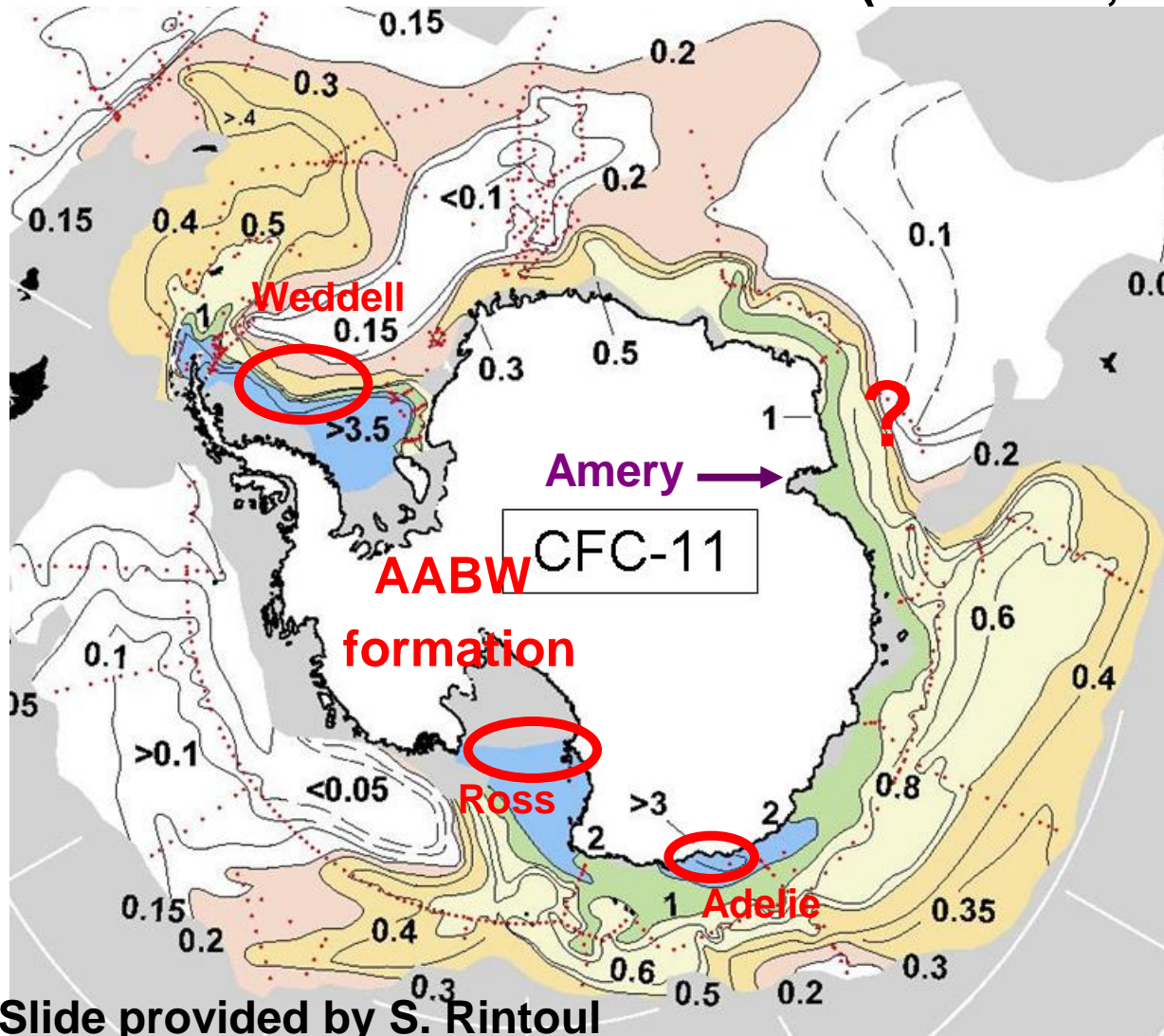
アデリー

135°E

[m yr<sup>-1</sup>]  
4 10



## CFC-11 Distribution near bottom (Orsi et al., 1999)



### Suggestion of AABW formation around 60-70E

- Jacobs and Georgi (1977)
- Middleton and Humphries (1989)
- Mantisi et al. (1991)
- Golovin et al. (2011)

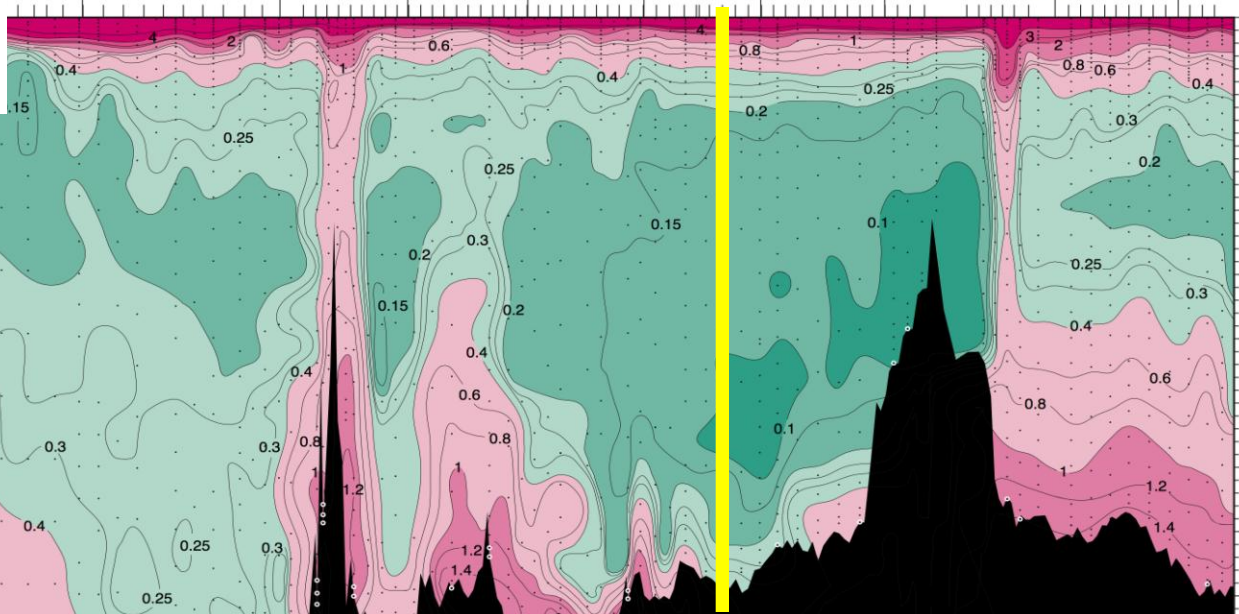
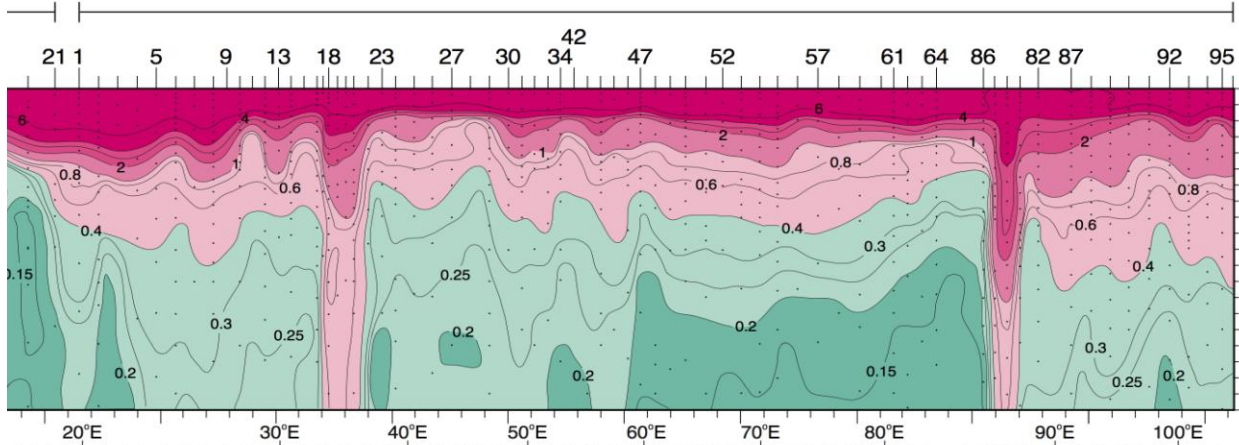
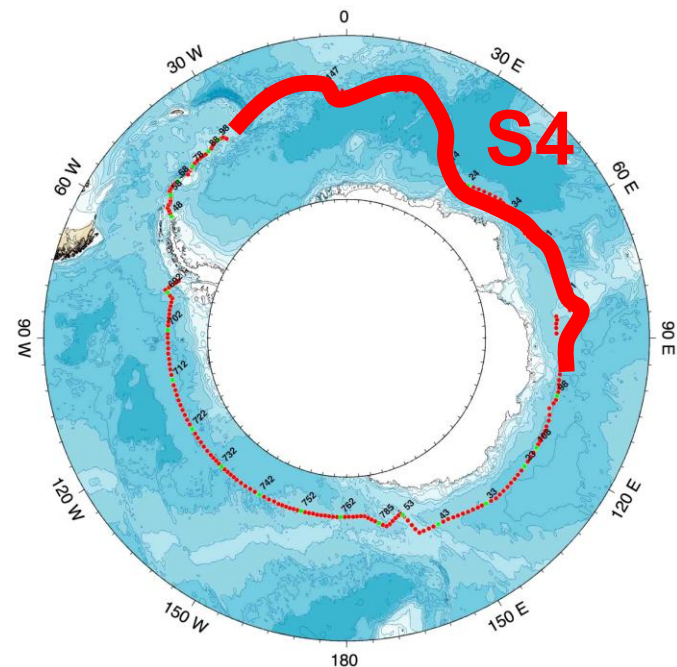
Slide provided by S. Rintoul

“CFC suggests that an important portion of the WADW in the southern Weddell Gyre originates outside the western Weddell Sea, probably near the Amery Basin and environs, around 75E.” from Meredith et al. (2000, JGR)

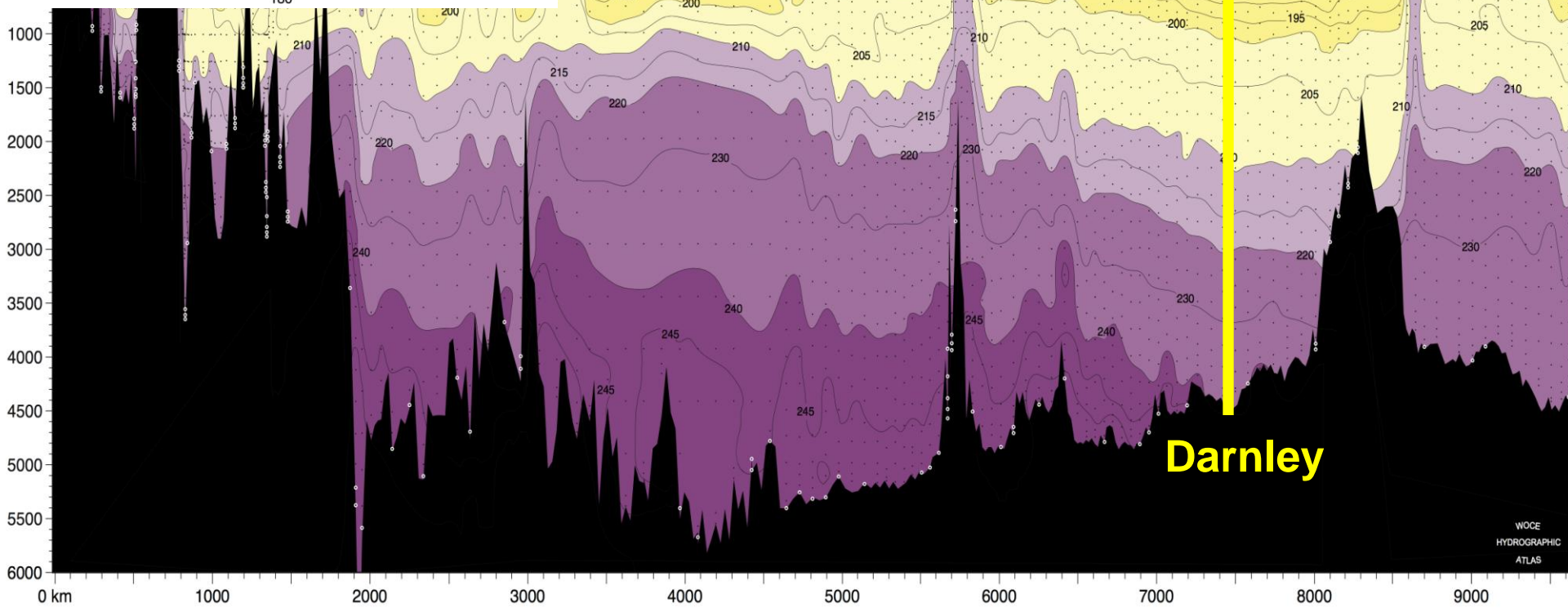
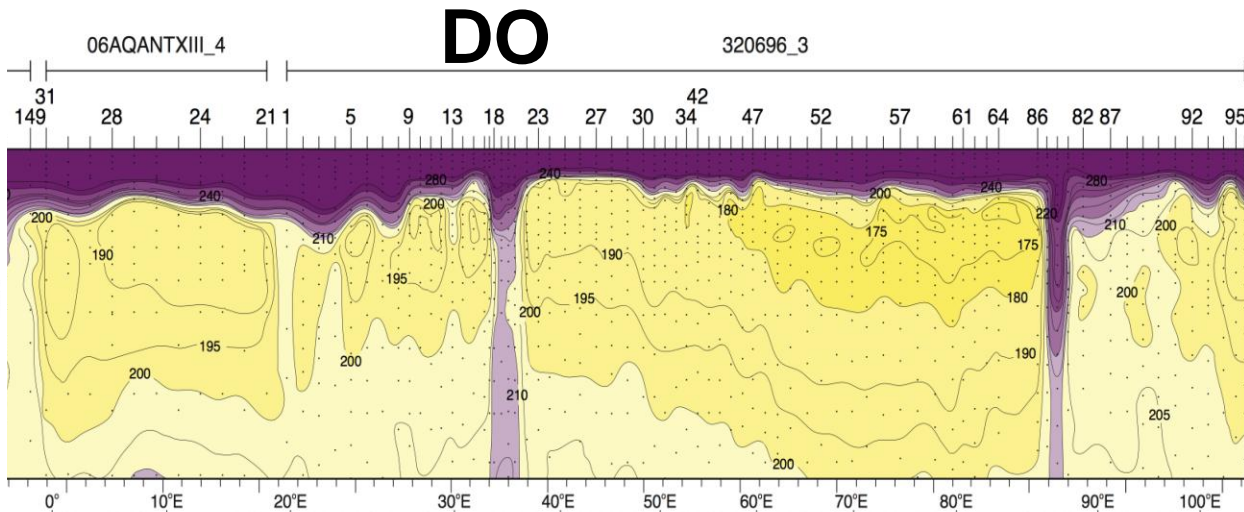
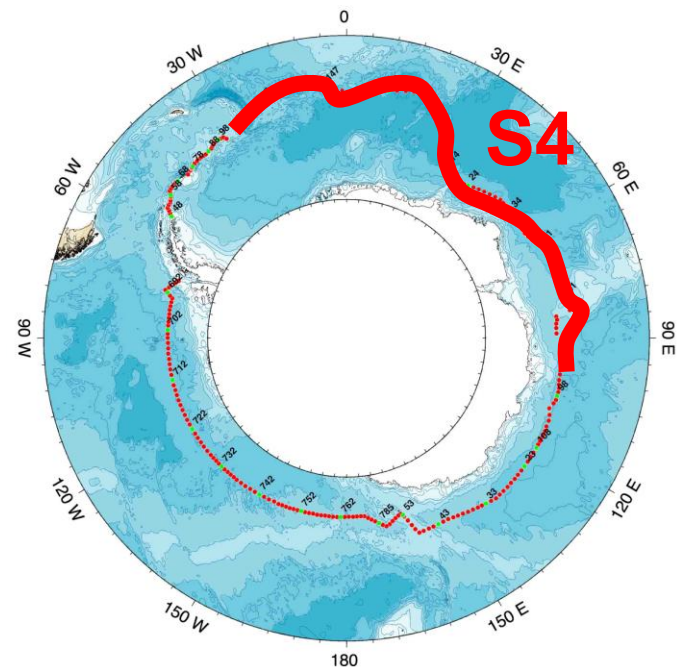


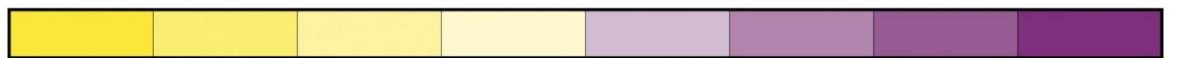
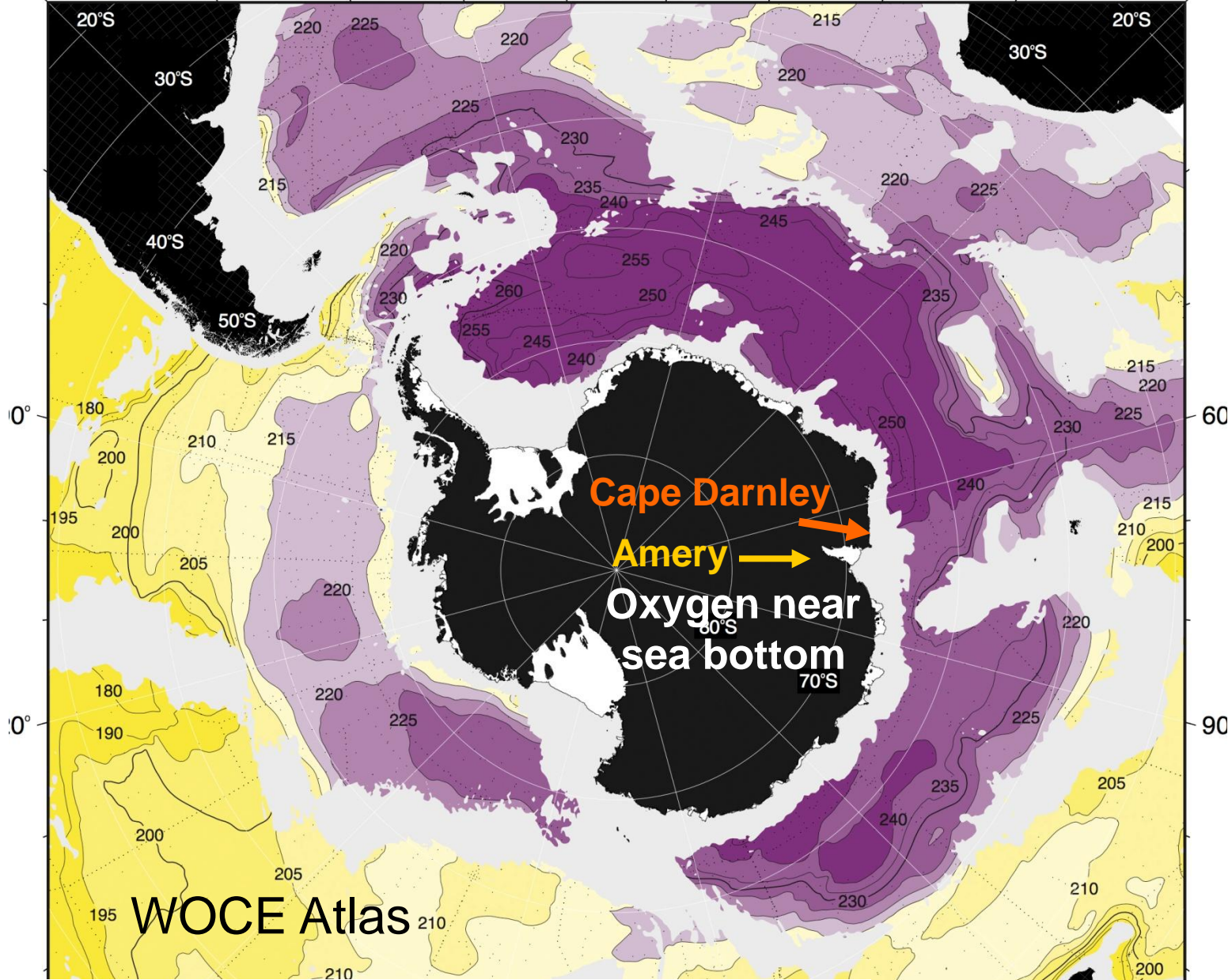
# CFC11

320696\_3



**Darnley**

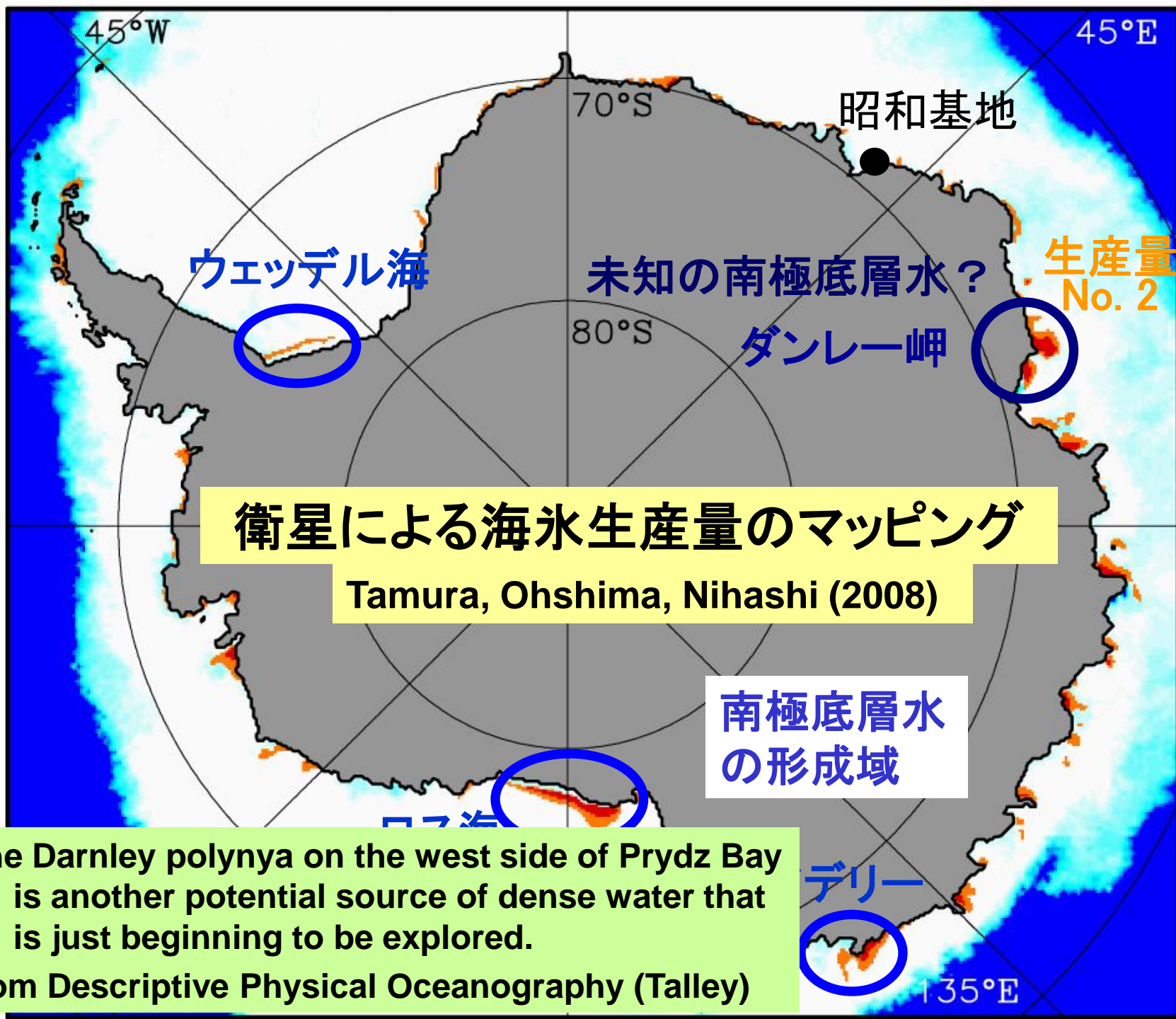




195 205 210 215 220 225 240

Oxygen ( $\mu\text{mol/kg}$ )

30°S  
WOCE  
HYDROGRAPHIC  
ATLAS



ウェッデル海

昭和基地

未知の南極底層水？

生産量  
No. 2

丹レー岬

衛星による海氷生産量のマッピング

Tamura, Ohshima, Nihashi (2008)

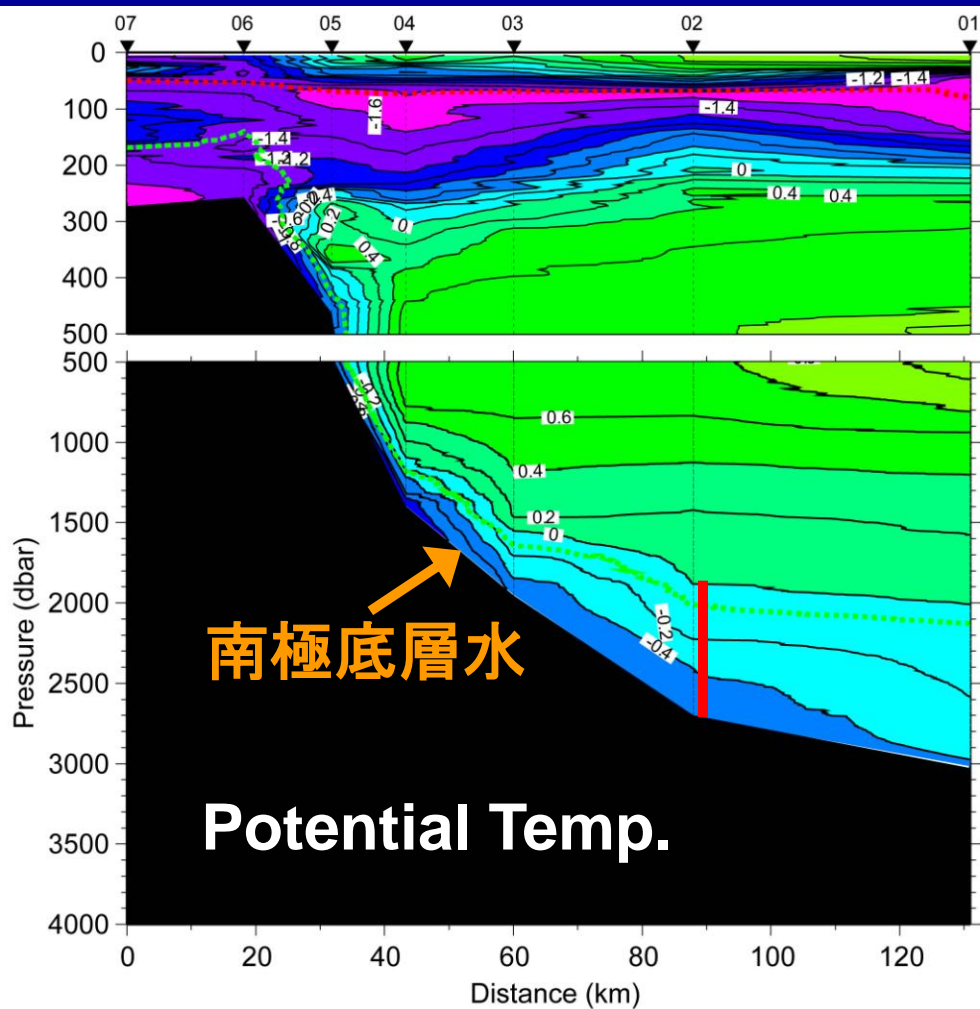
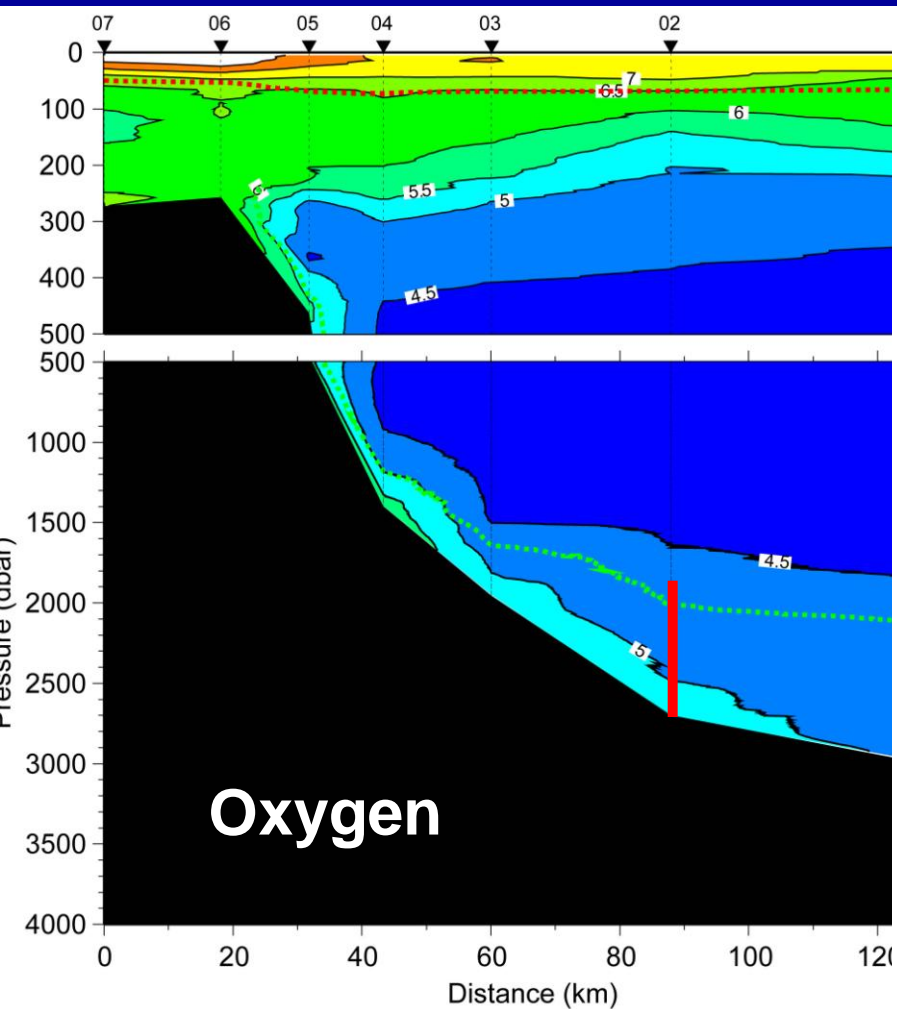
南極底層水の  
形成域

The Darnley polynya on the west side of Prydz Bay is another potential source of dense water that is just beginning to be explored.  
from Descriptive Physical Oceanography (Talley)

デリー

135°E

# ケーブダンレー沖：日本のIPYの集中観測海域



平野大輔氏  
作成

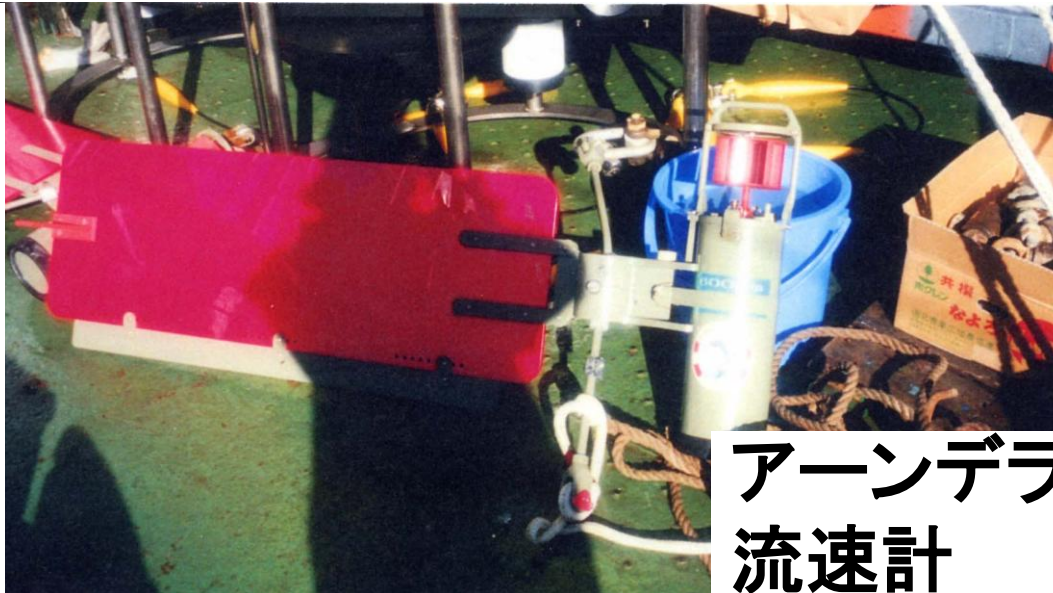


## 係留系観測

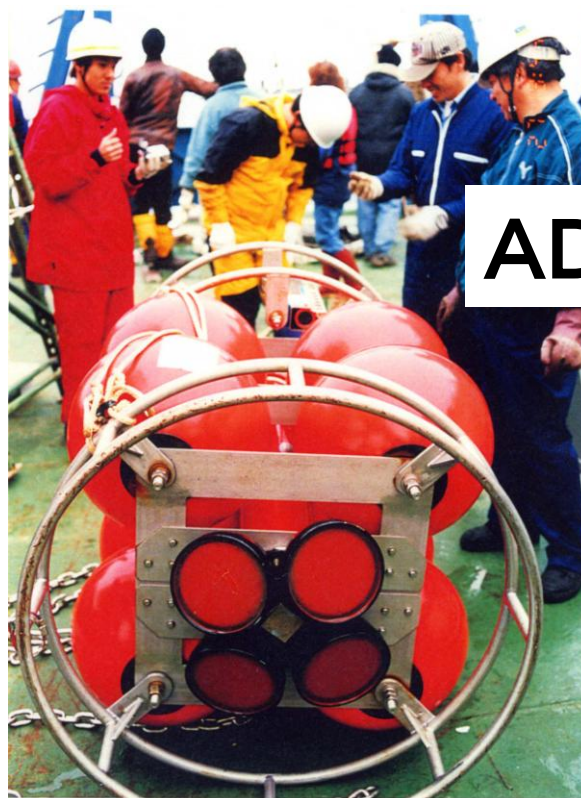
ダブルロープ 12 mm (70 m)



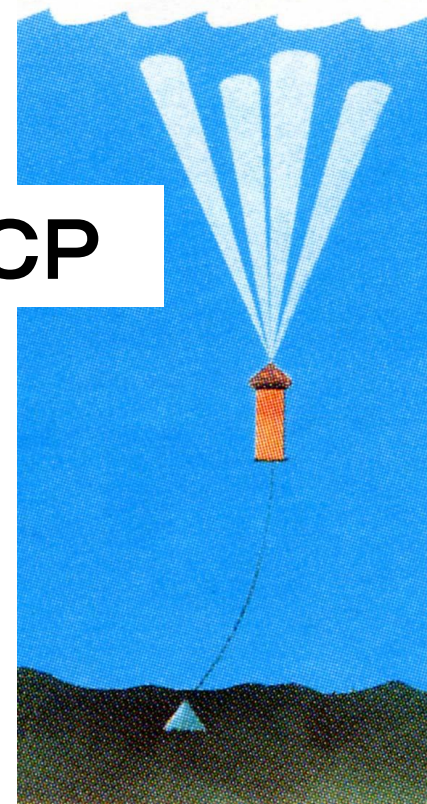
200 m深



アーンデラ  
流速計

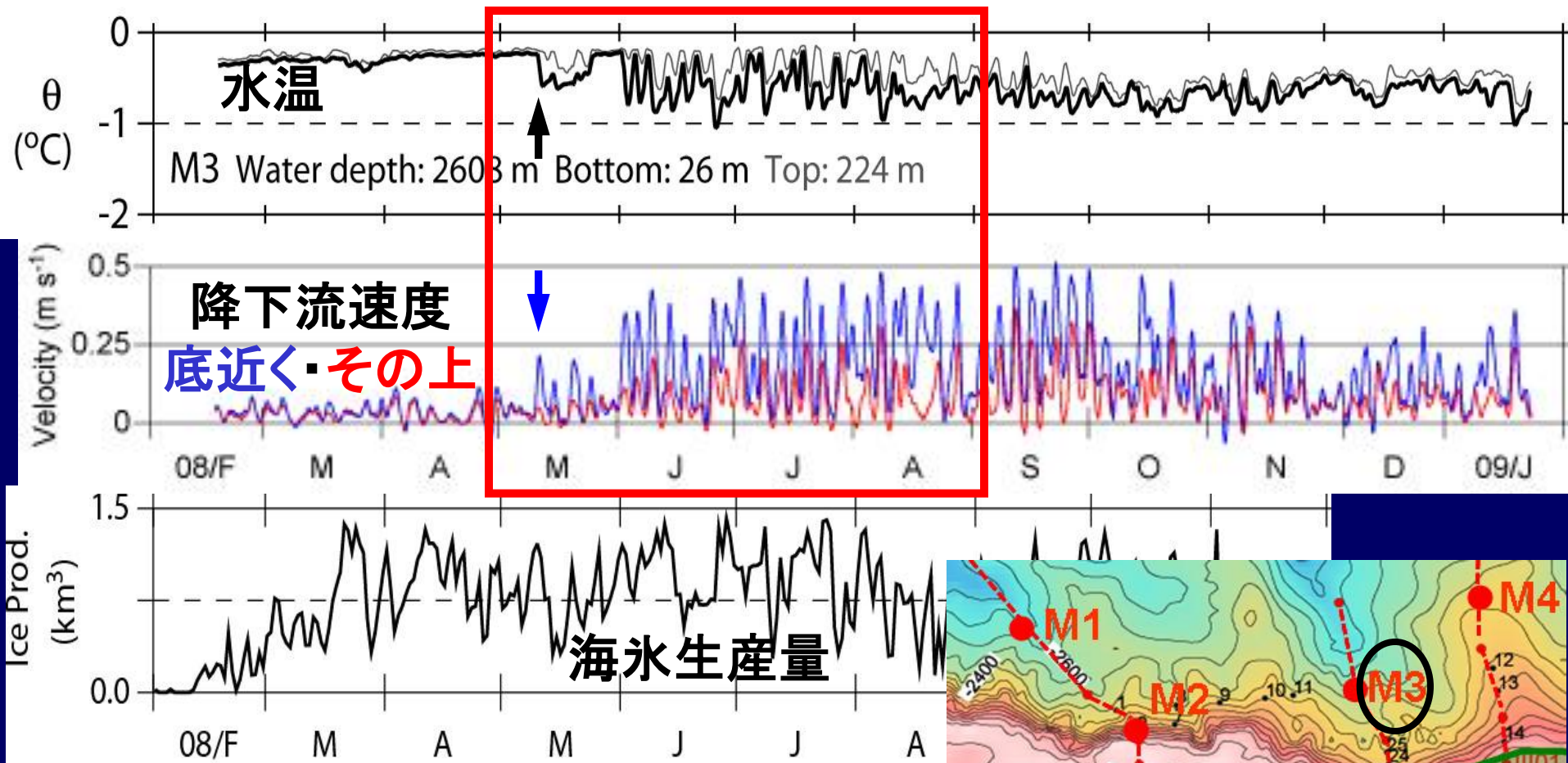


ADCP



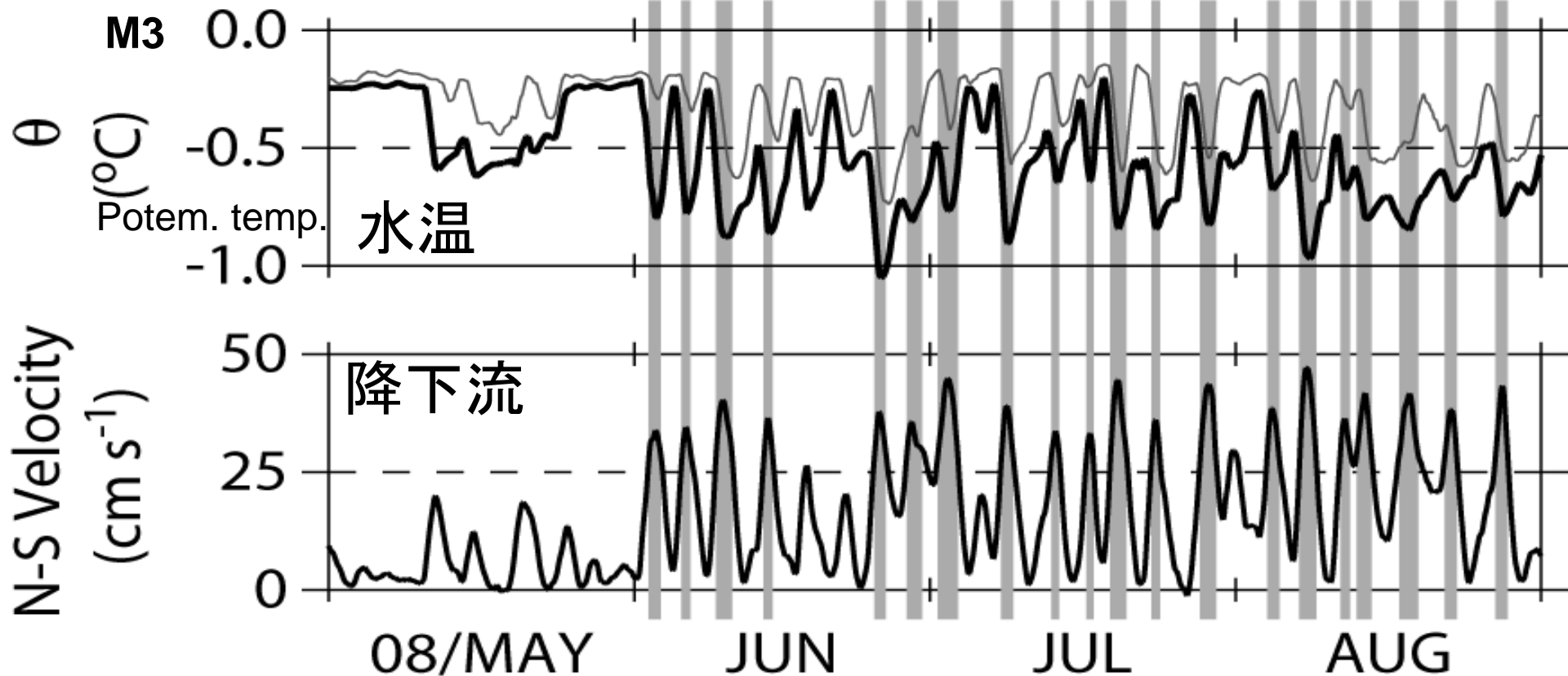


# 峡谷の底(M3)での水温と流速の1年間の時系列 (水深 2659 m)



- ・峡谷では、冷たい重い水の到来に同期して強い降下流
- ・流れは底近くほど強い





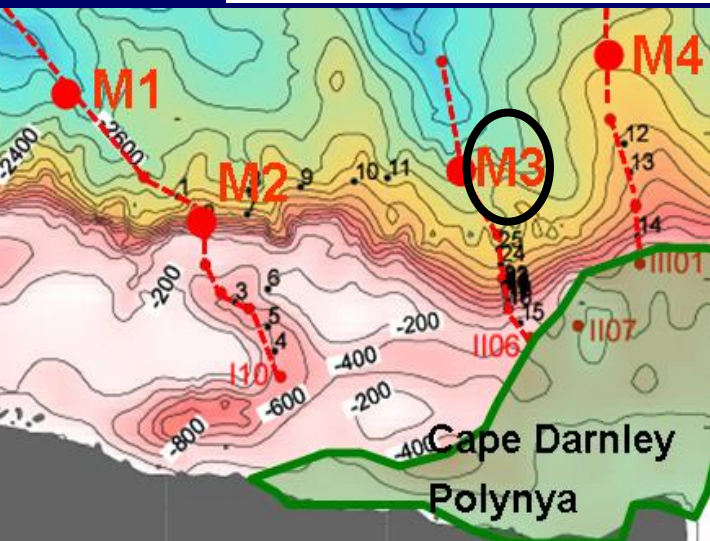
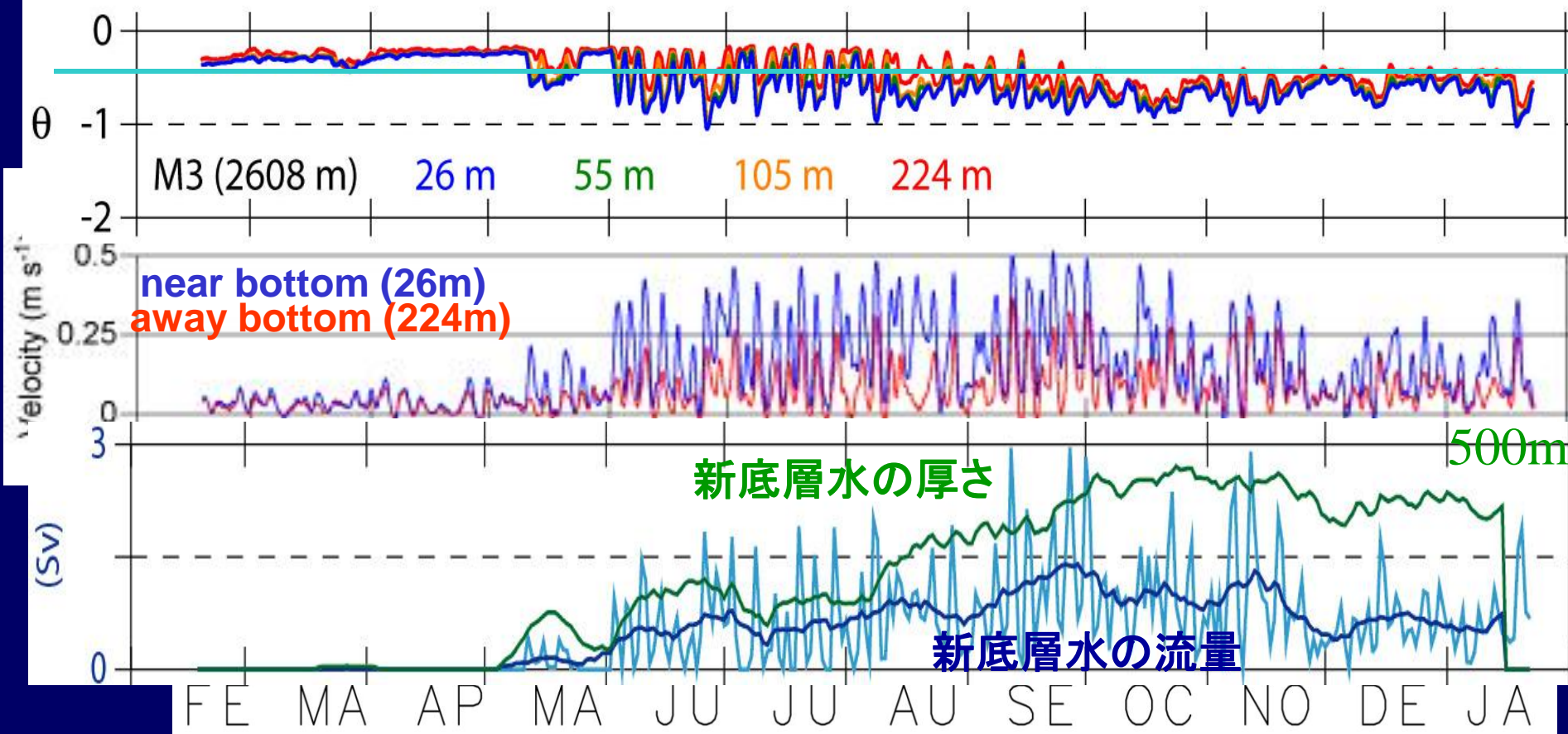
Thick lines: 20m from bottom

Thin lines: 224m from bottom

Shaded periods: Northward (Downslope) velocity > 30cm/s

**約4日周期で0.4m/s程度の降下流: 冷たい重い水と同期  
 → 傾圧不安定? 地形性ロスビー波?**

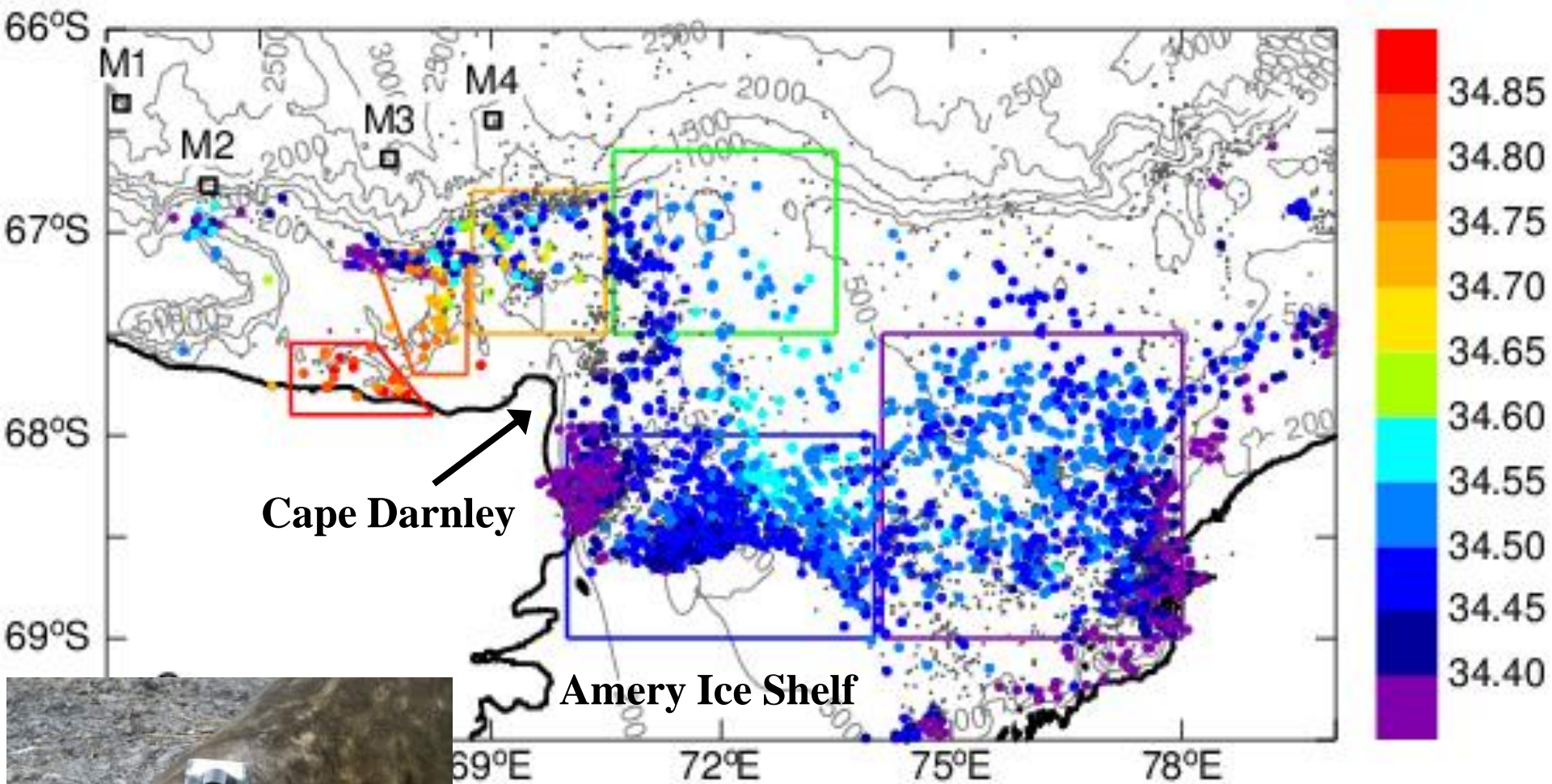
3-day 6-day oscillations occurs associated with dense plume  
 in the Filchner, Weddell Sea (Darelius et al., 2009)



流速・水温を内挿・外挿;  $-0.4^{\circ}\text{C}$ 以下を新底層水

新底層水の厚さは平均 300m:  
 170m(6月)  $\rightarrow$  420m(10月) (予想以上に厚い)

流れの幅を20kmと仮定: 新底層水の流量 0.52(Sv)

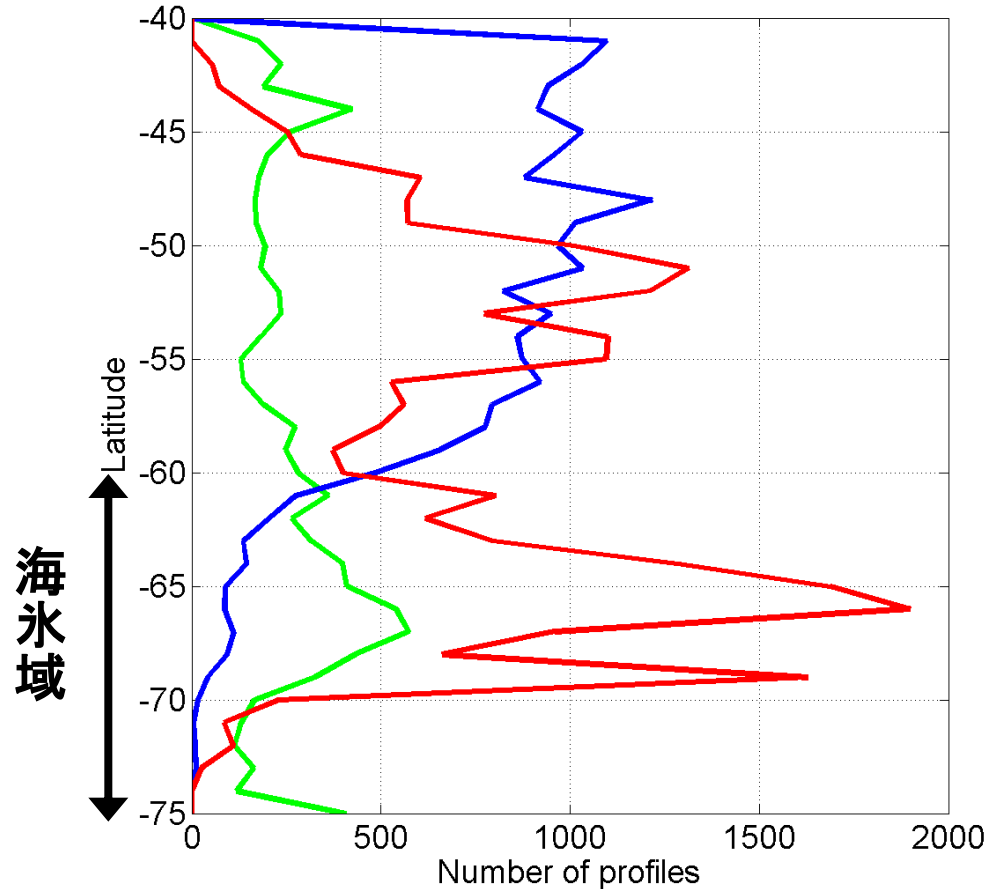


**Salinity of bottom water from instrumented seals**

**Collaborated with Drs. Williams, Roquet, Field, Hindell**

# SEaOS: Number of profiles: Southern Ocean

Number of profiles per degree Latitude (south of 40° S)



**SODB: 10513**

**Argo: 19463**

**SEaOS: 22230**

→ **150000**

Courtesy L. Boehme

**ゾウアザラシ (Elephant seals) の場合:**

**最大2000m まで潜る**

**底の餌を取りに行くので高密度陸棚水・底層水が観測できる**

# 高速非静水圧モデル(Matsumura & Hasumi)による数値simulation

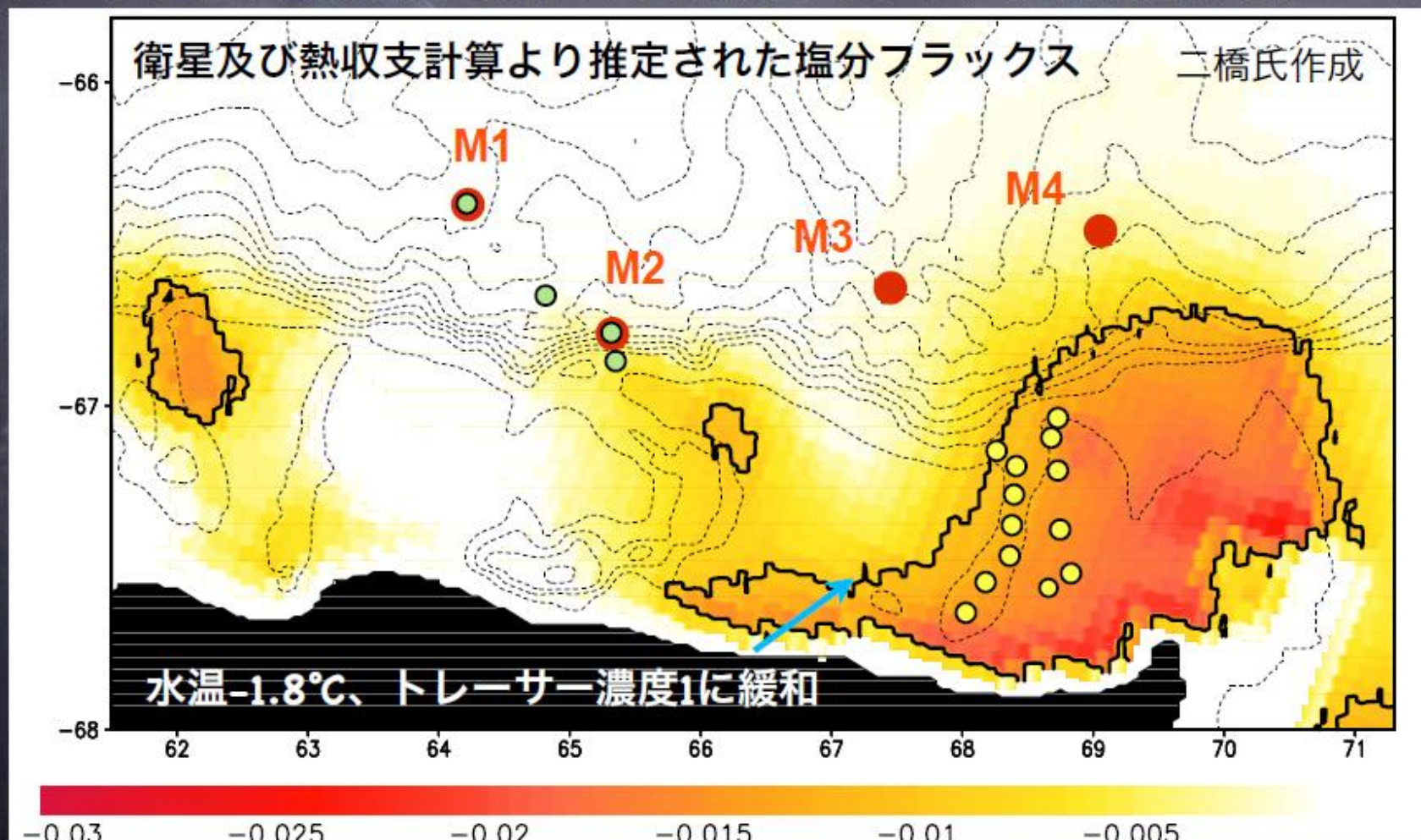
中山修士論文

解像度：1/20°(東西) × 1/80°(南北) 鉛直10m

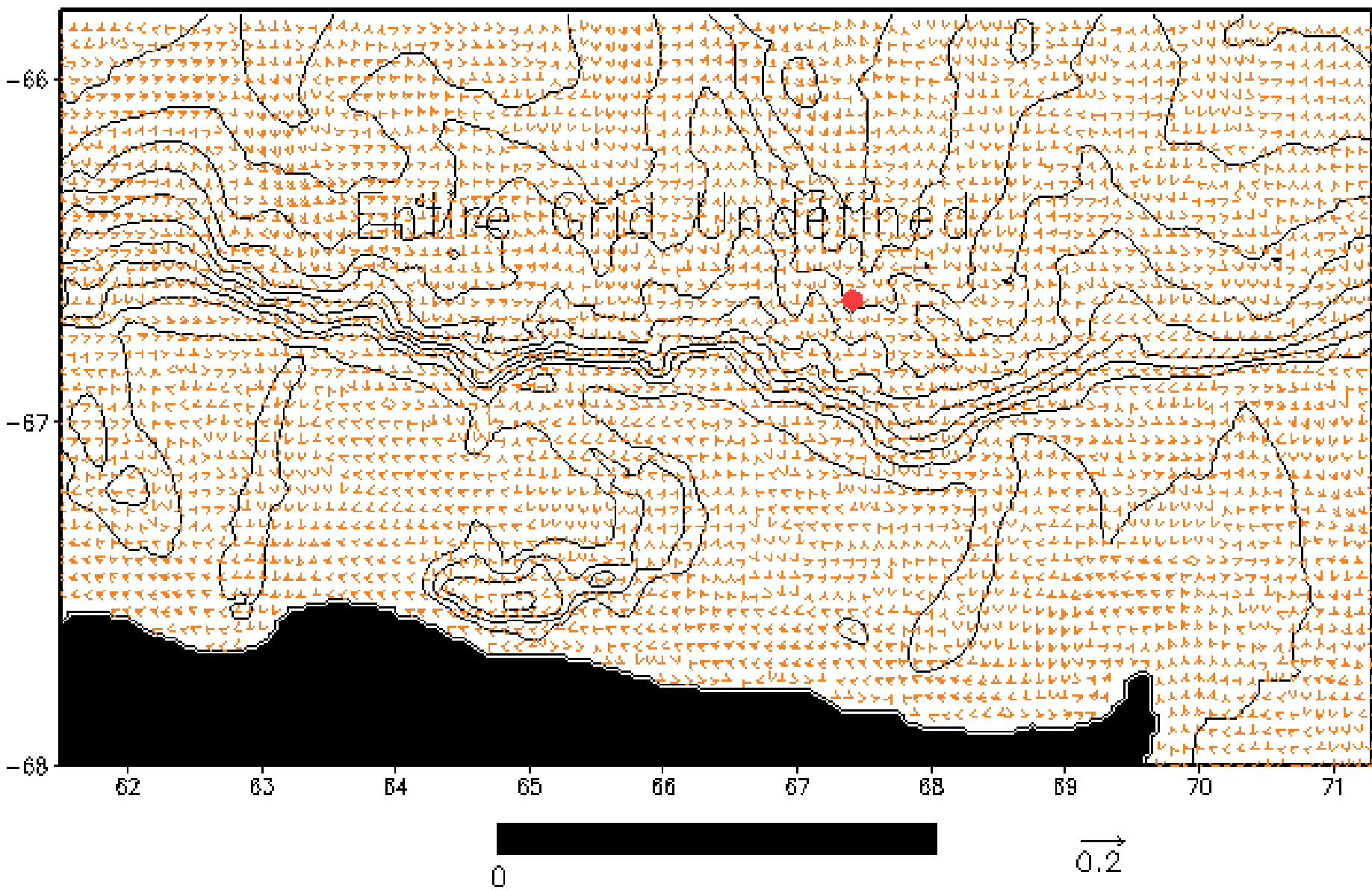
地形：GEBCO 1min 地形データ, AAD 0.005deg 地形データ

初期値：海鷹丸(緑)、しらせ(黄)の水温、塩分の観測値から補完。

フォーシング：2008年3-10月平均の塩分フラックス。風応力なし。

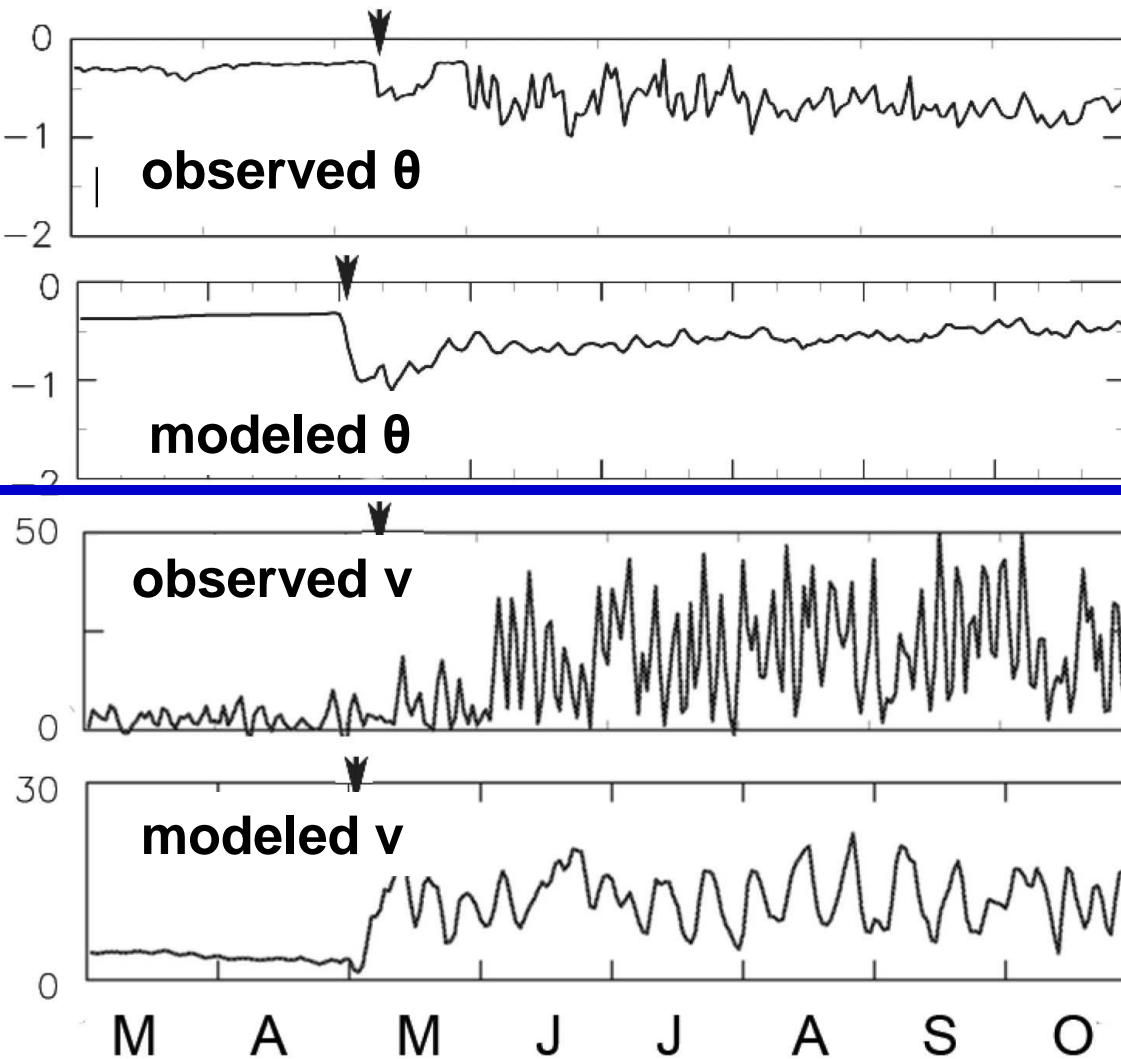


# 最下層トレーサー濃度 DAY 31

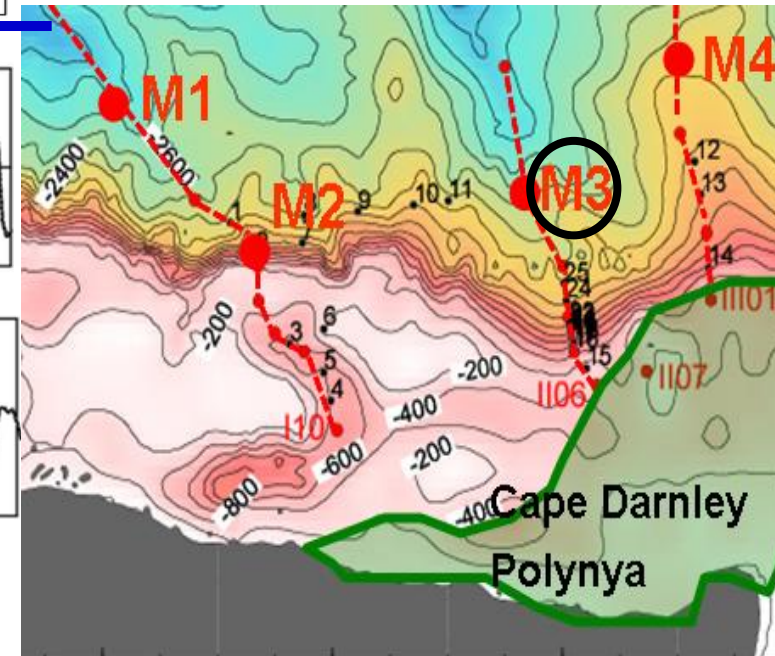


高密度水は窪地から間歇的に沈み込む。

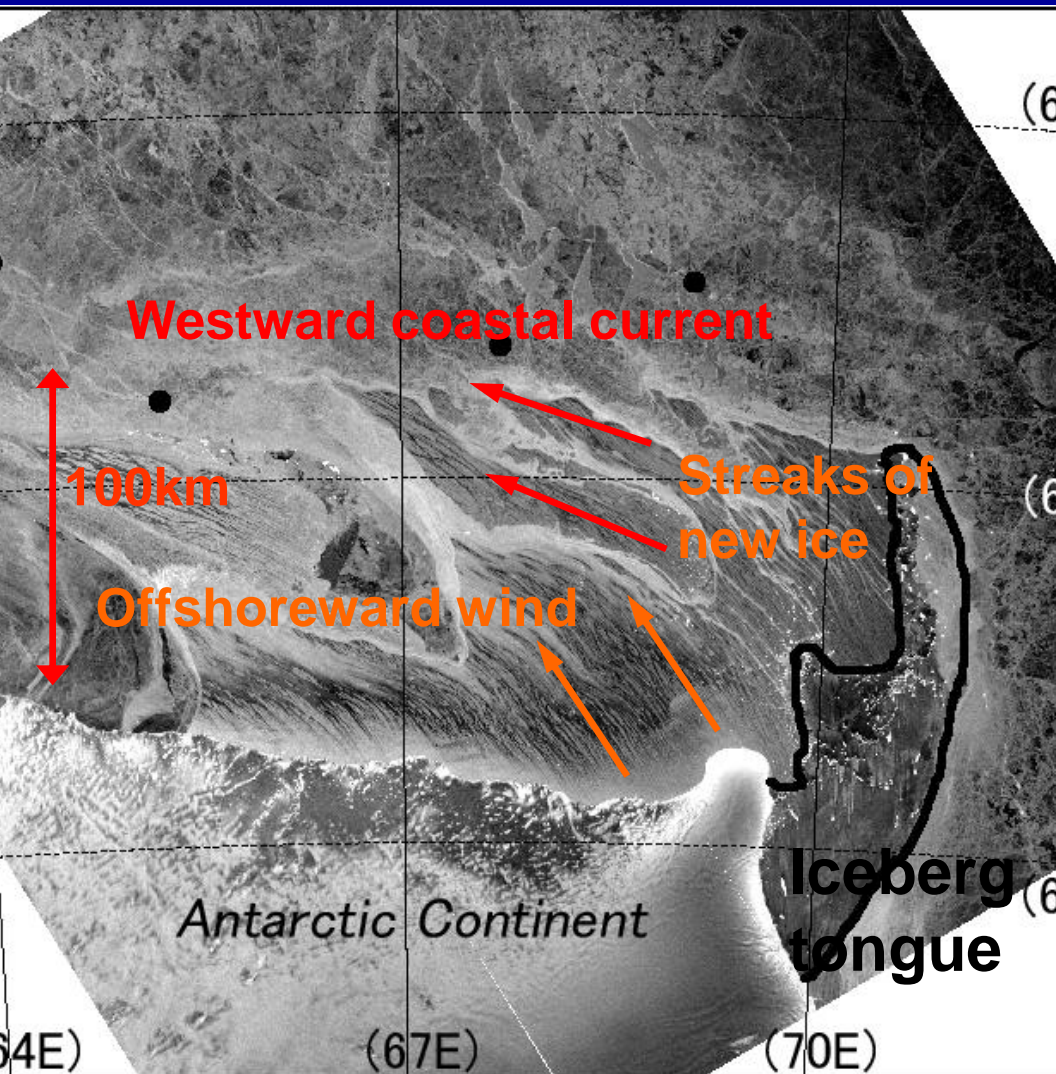
# Reproduction of arrival of dense water and periodic downslope current



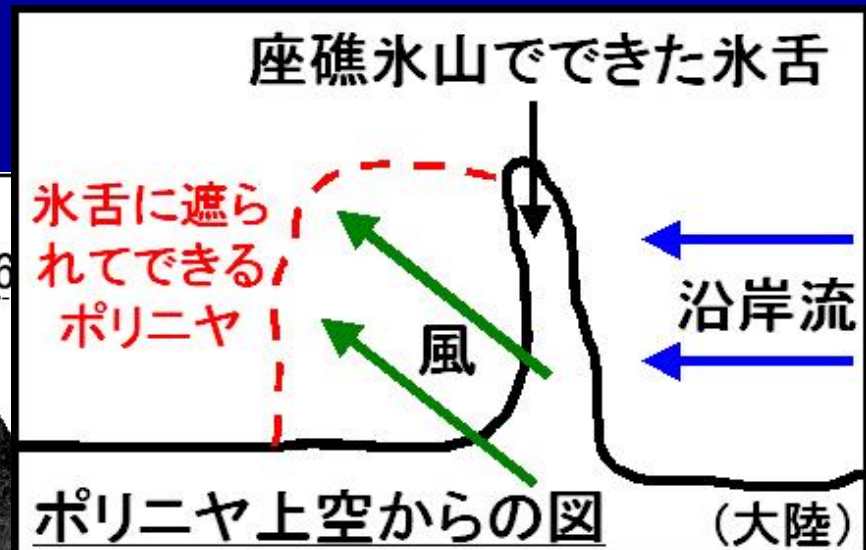
Comparison between observation and model at M3



# 大きな海氷生産量はなぜ？ なぜ巨大なポリニヤができるか？



合成開口レーダ

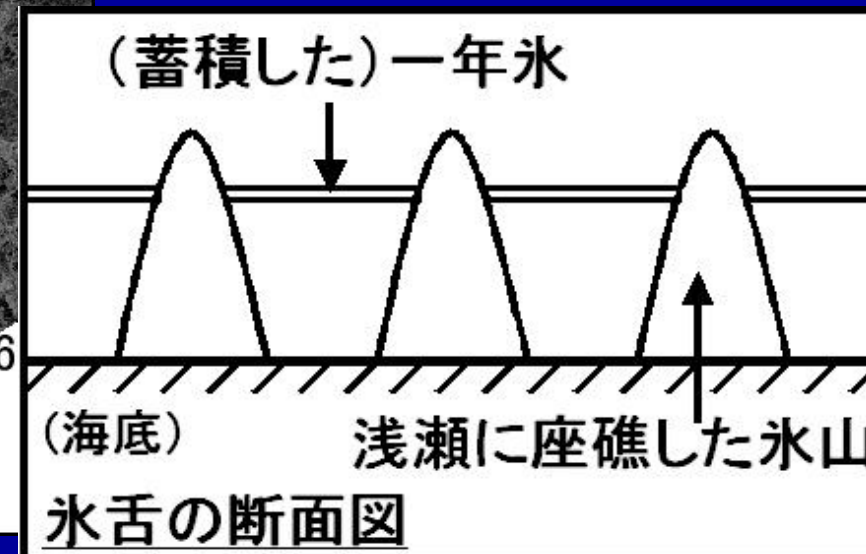


(6

(67S)

(6

## 氷山舌による フィルター効果



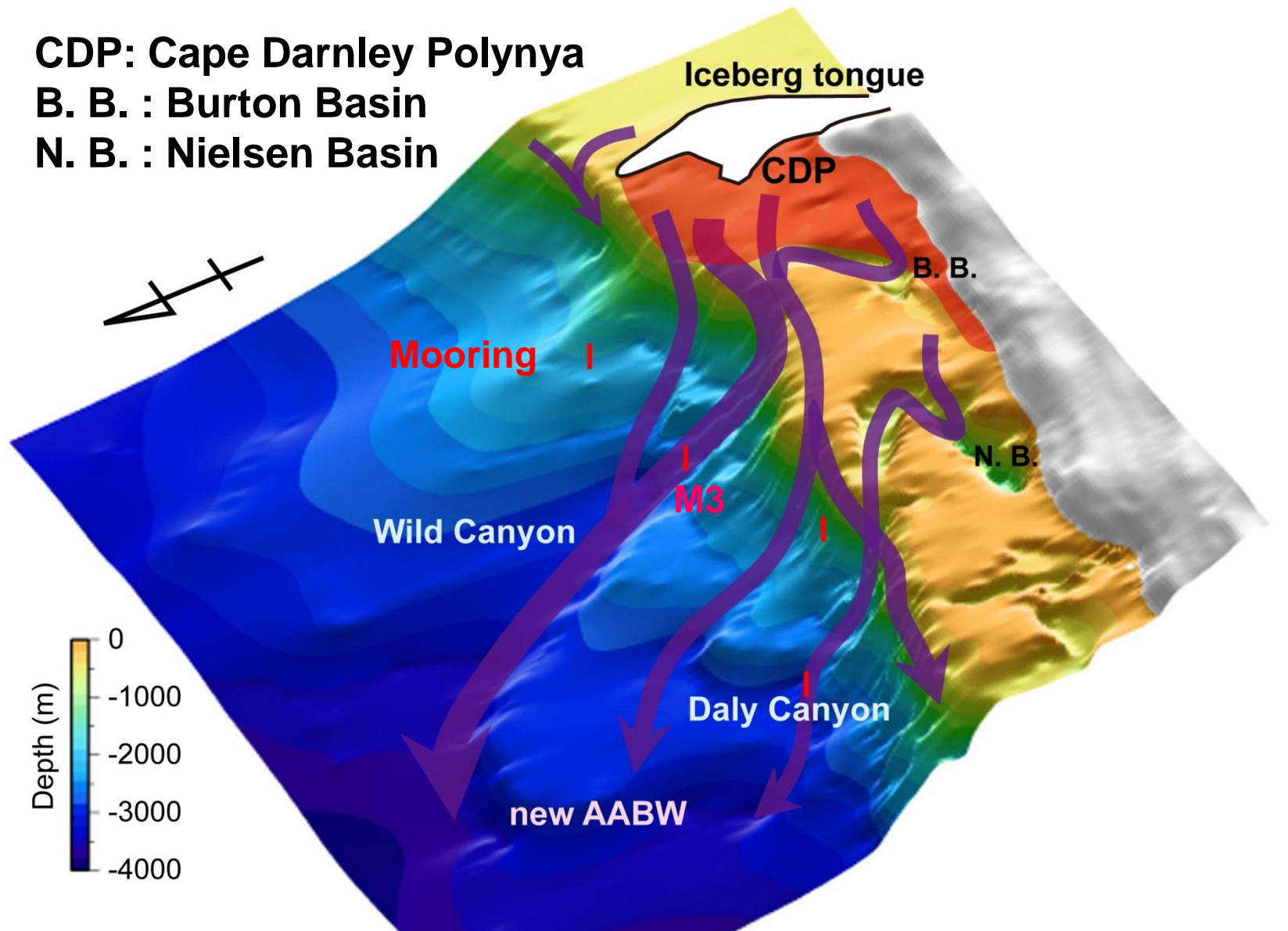


# DSW ventilation in Polynya and Subsequent AABW Transport

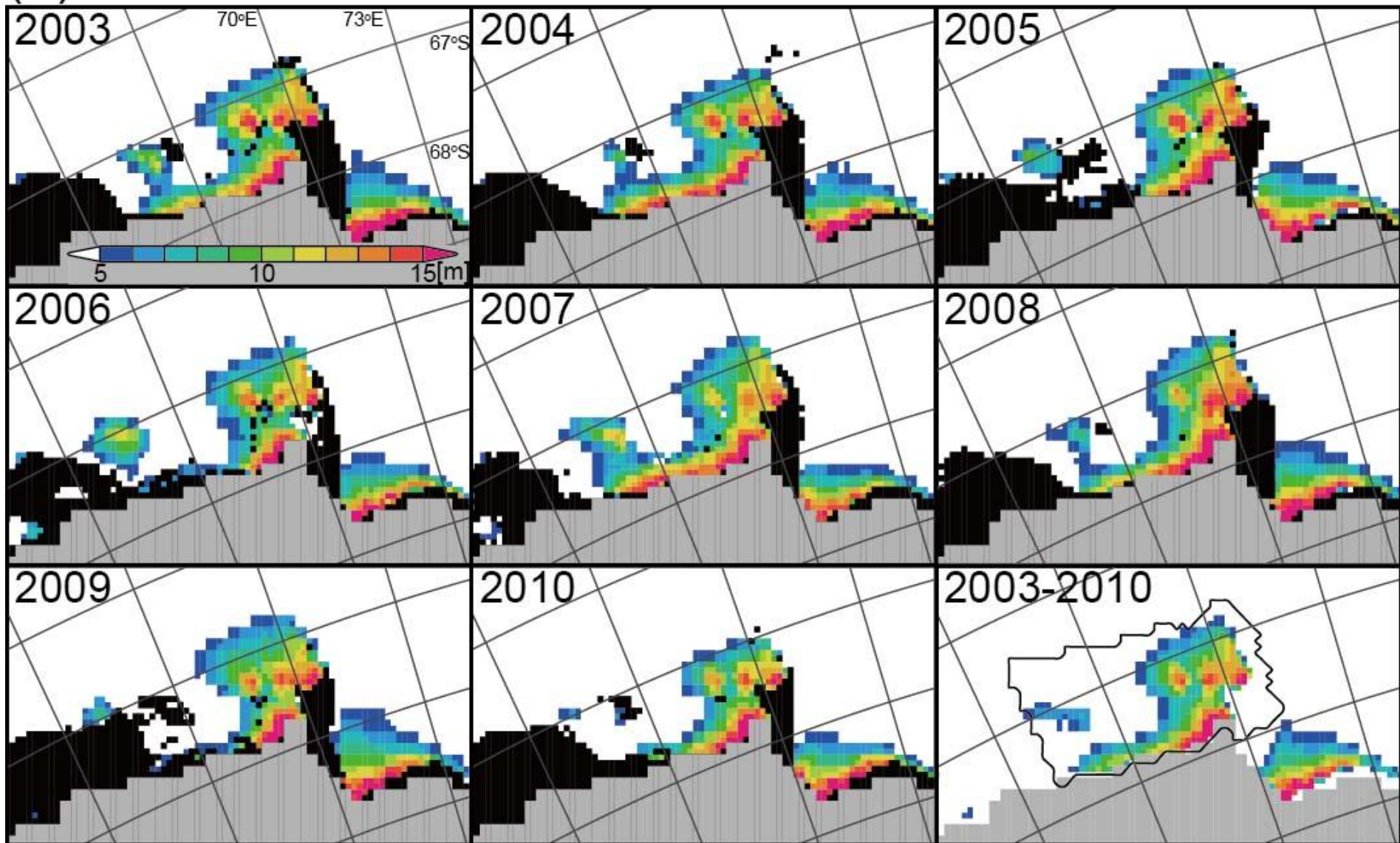
CDP: Cape Darnley Polynya

B. B. : Burton Basin

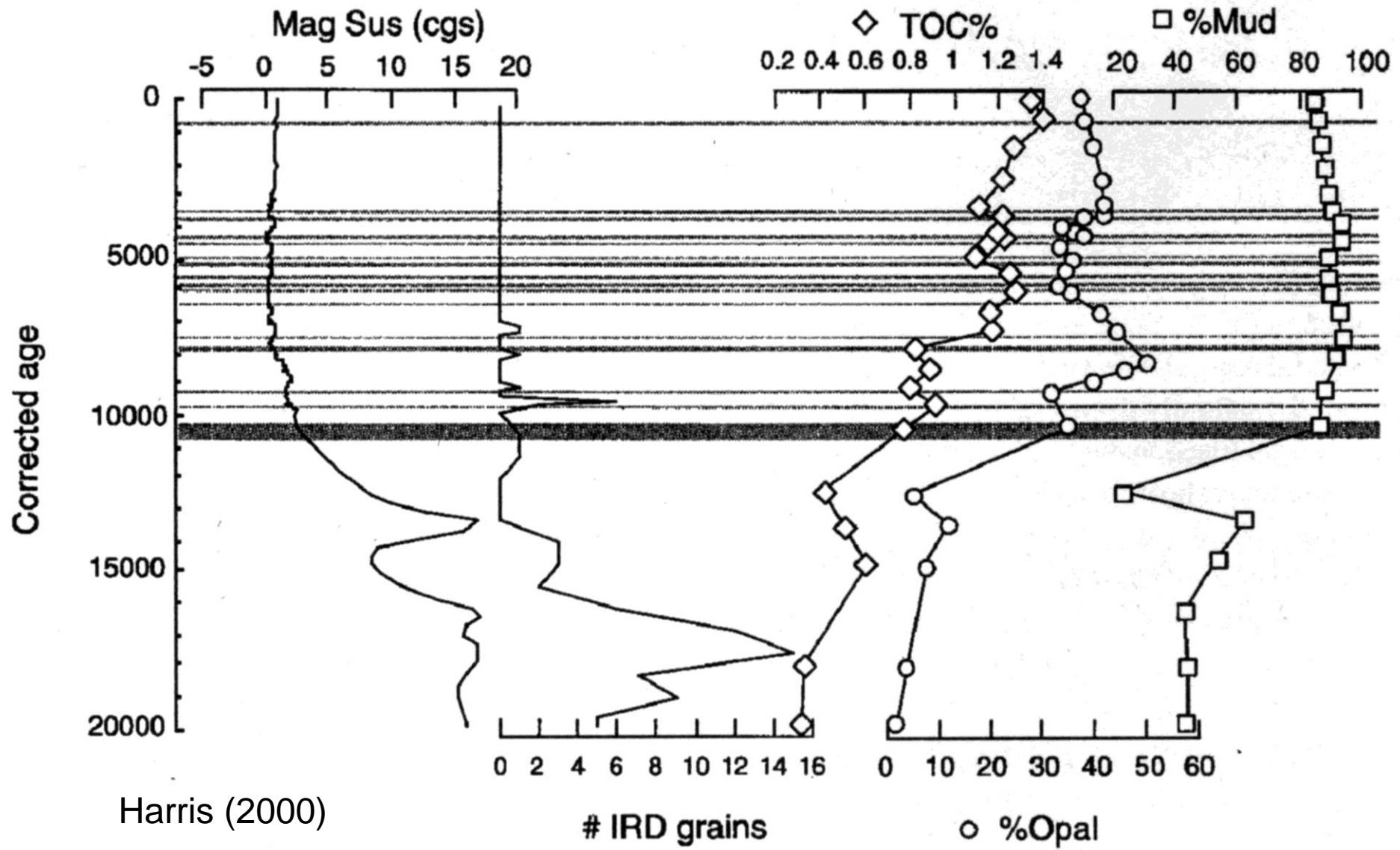
N. B. : Nielsen Basin



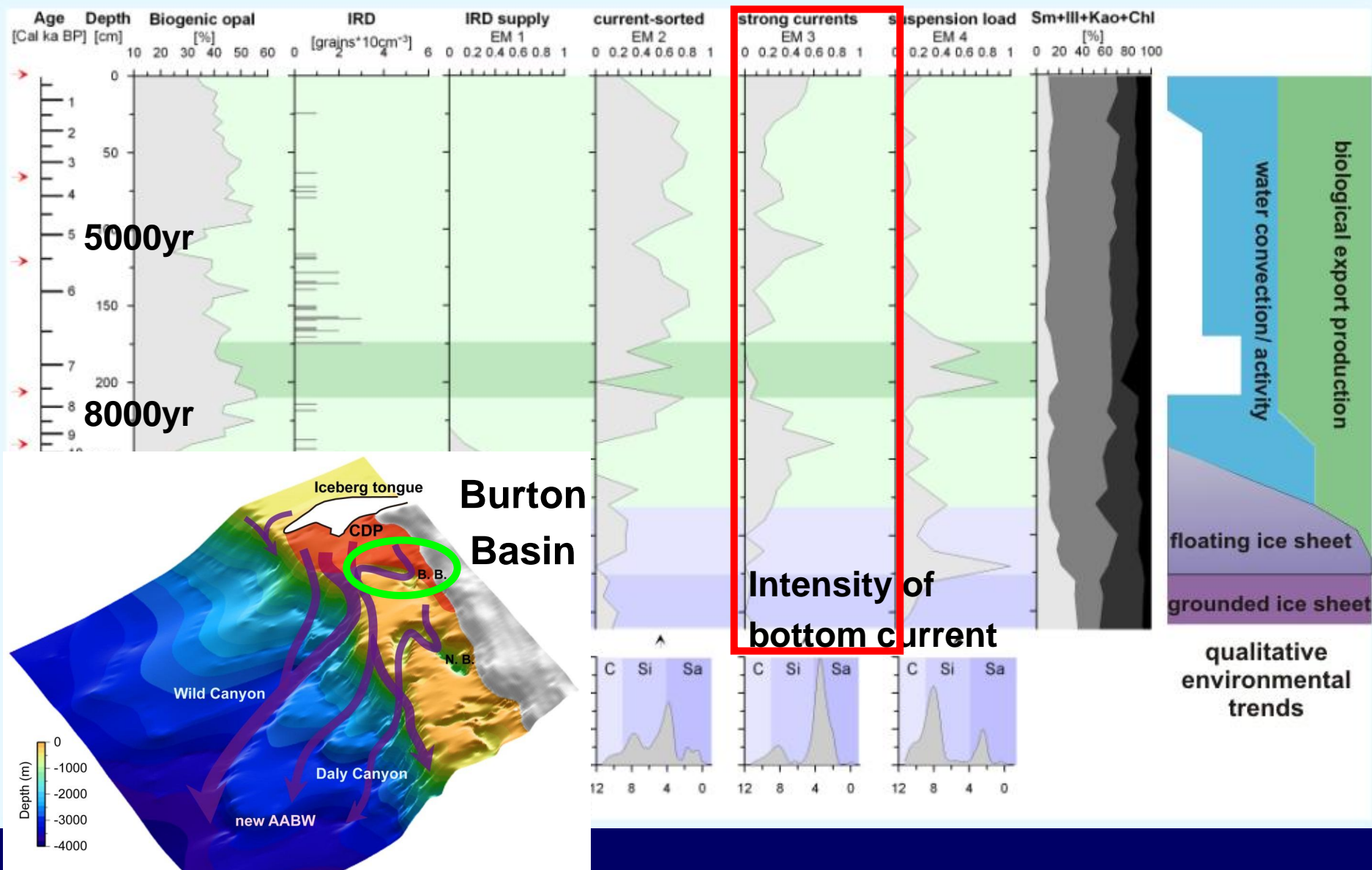
# Sea ice production (color shading) and iceberg tongue (black) during 2003-2010 (AMSR period)







**cross-laminated sediments → bottom water production**



Borchers, A. et al., (2010): **Bottom-water dynamics during the Holocene and the last interglacial stage (MIS 5) and its relation to sea-ice formation in East Antarctic shelf areas**, IPY Oslo Science Conference, Oslo,

# Cape Darnley Project (Cruises)

IPY



Year	2008	2009	2010	2011	2012	2013	2014	2015	2016
Cruise	↔ Hakuho- maru	↔ Umitaka- maru	↔ ↔ ↔ Shirase	↔ ↔ ↔ Shirase	↔ ↔ ↔ Shirase	↔ ↔ ↔ (Shirase)	↔ ↔ ↔ (Umitaka- maru)	↔ ↔ ↔ (Umitaka- maru)	↔ ↔ ↔ Hakuho- maru
Moored Region		↔ Slope	↔ Polynya	↔ ↔ ↔ Slope	↔ ↔ ↔ Slope	↔ ↔ ↔ (Polynya)	↔ ↔ ↔ (Polynya)		↔ ↔ ↔ or Canyon

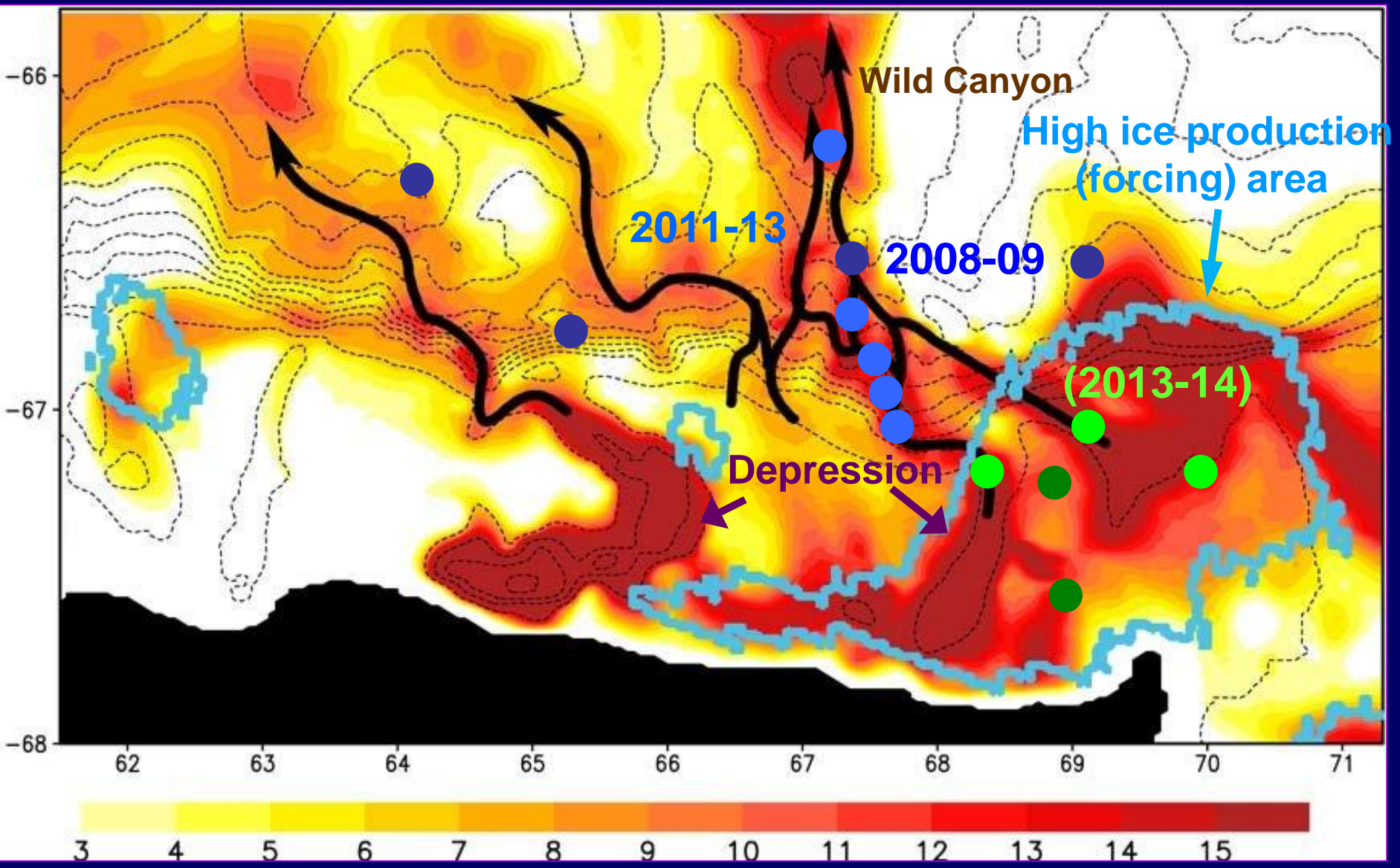
Aqua AMSR-E

present

GCOM-W1 AMSR2

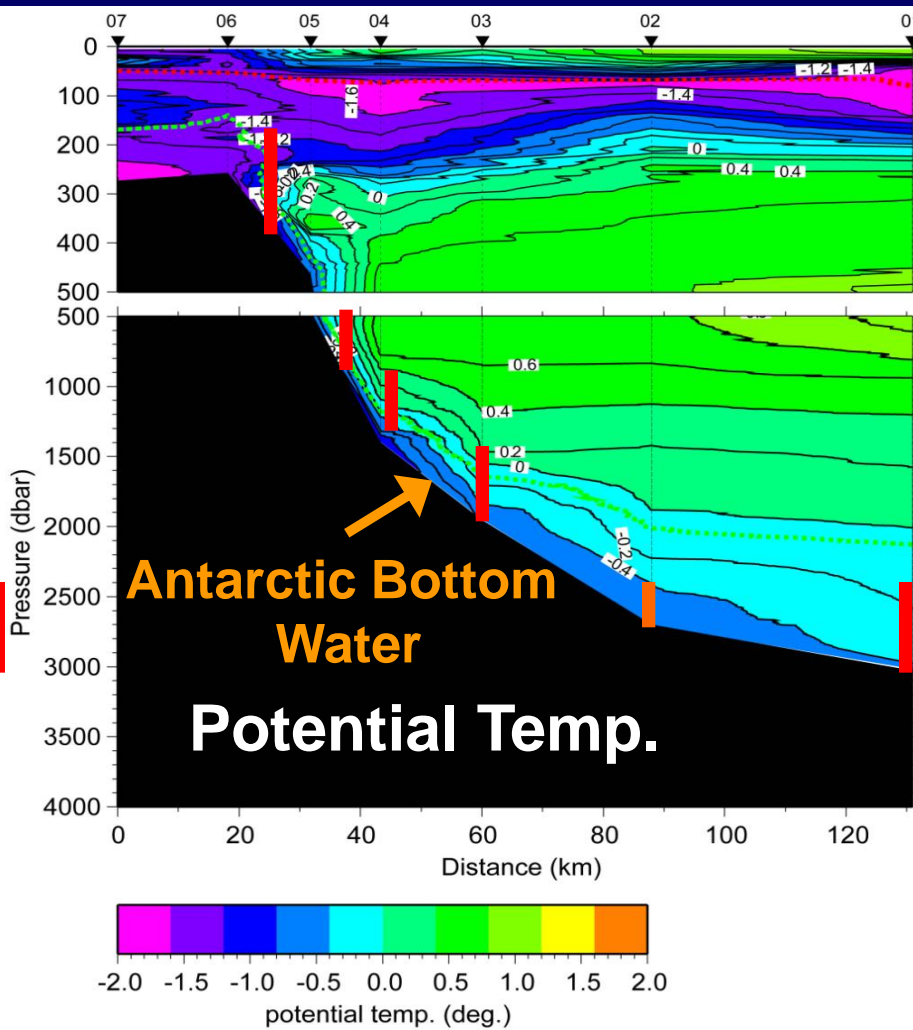
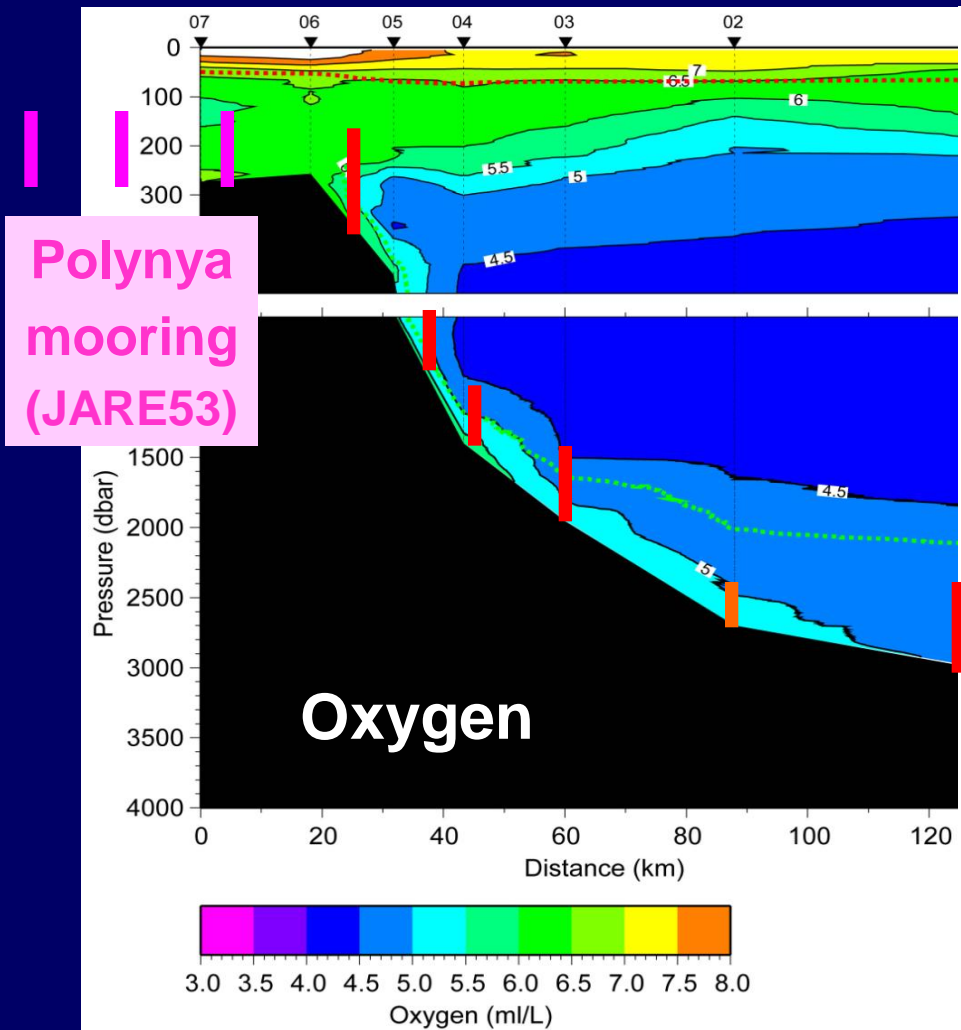
# AABW Pathways in Model Forced by Polynya Salt Flux (Nakayama, in pre.)

**Integrated tracer concentration** DW: Polynya → Depression → Canyon



# Mooring array off Cape Darnley

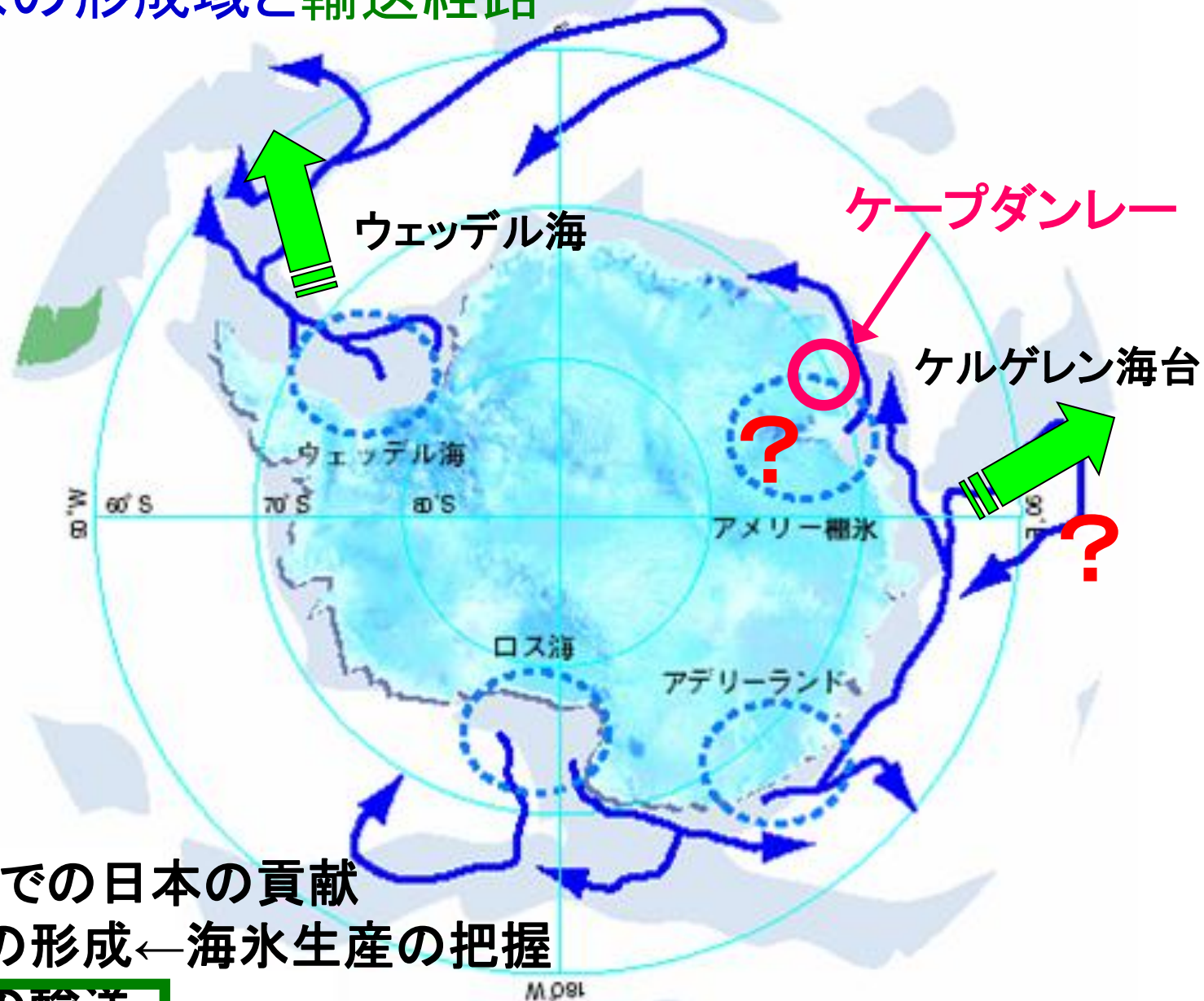
Deploy: Feb. 2011 (JARE52) → Recover: Feb. 2013 (JARE54)



JARE51 → JARE54: 未知の南極底層水を探る



# 南極底層水の形成域と輸送経路



## プレIPYとIPYでの日本の貢献

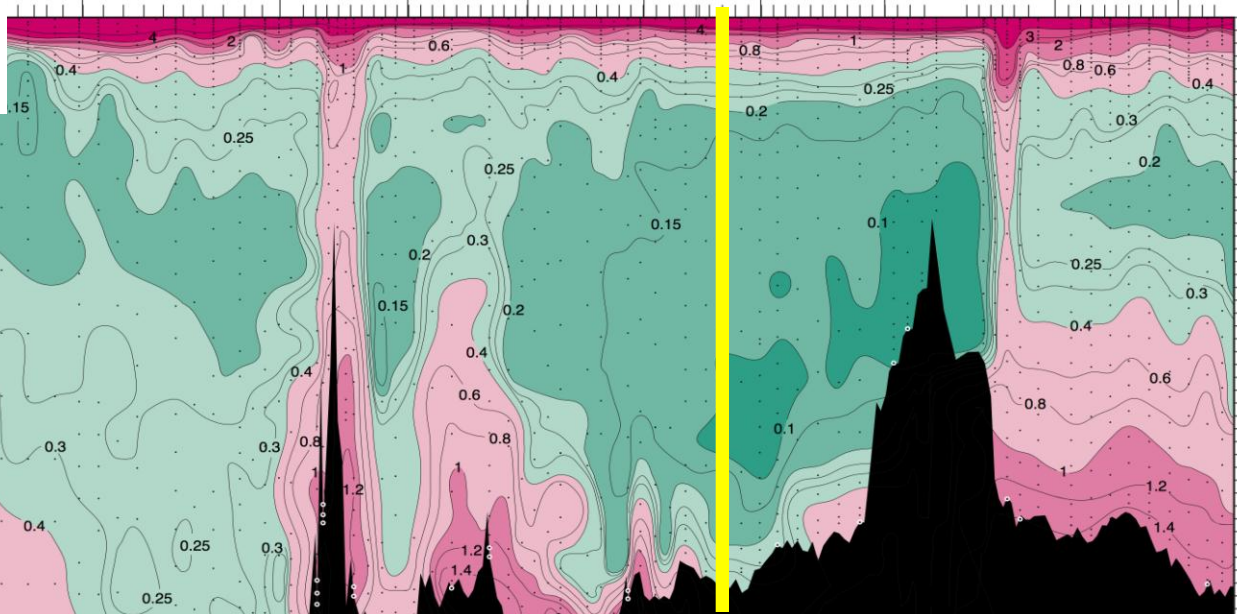
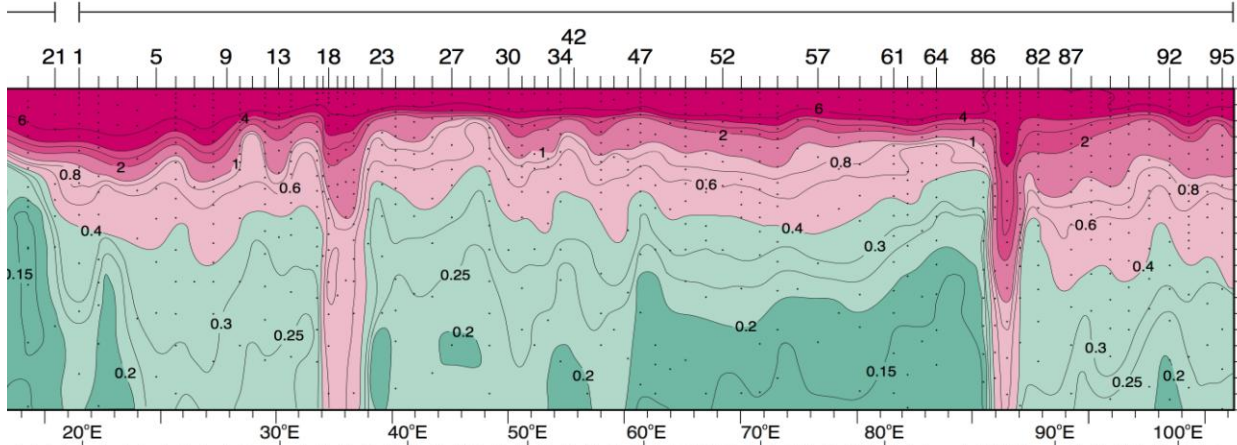
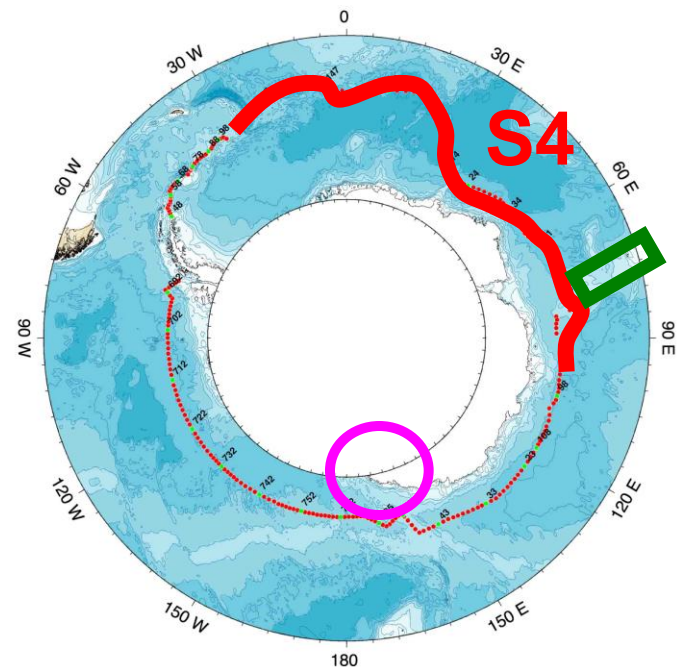
・南極底層水の形成 ← 海氷生産の把握

・南極底層水の輸送

・南極底層水の変質と原因

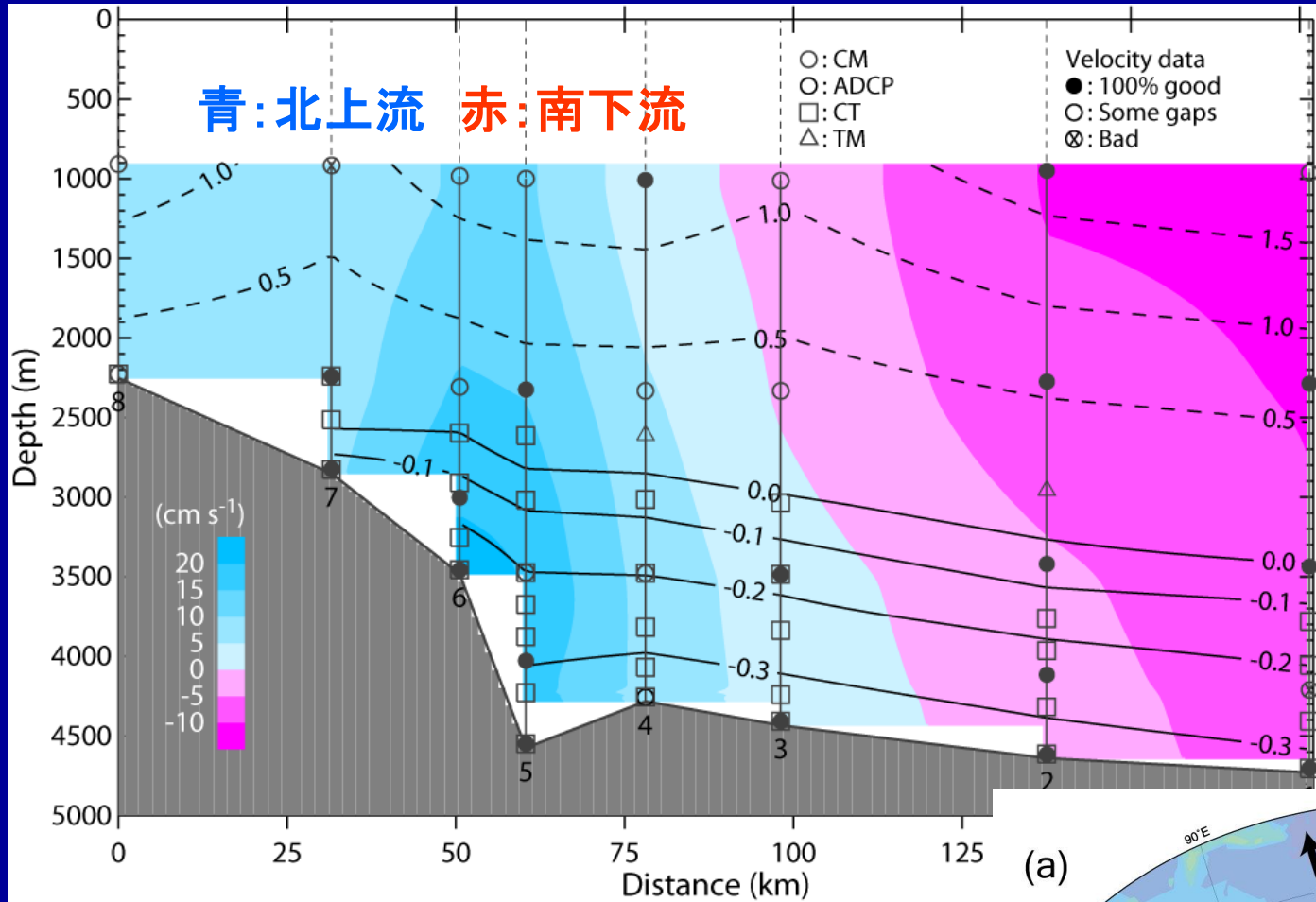
# CFC11

320696\_3



**Darnley**

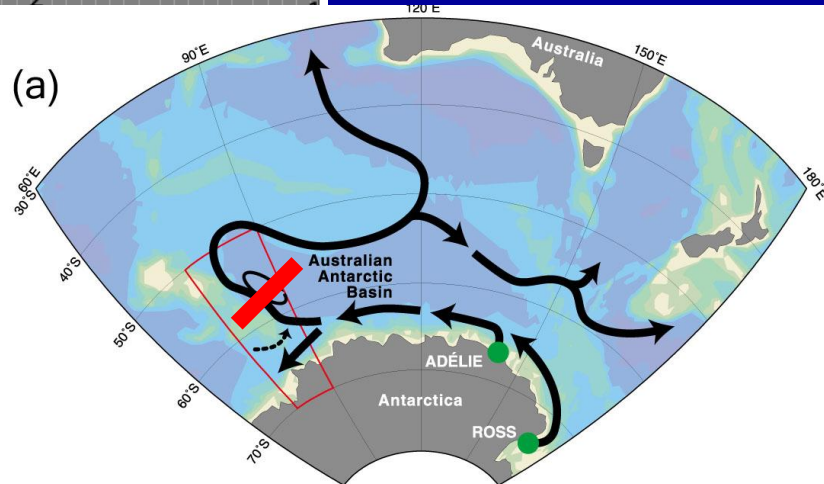
# プレIPY観測(2003-2005): ケルゲレン海台東斜面での北上流と水温



●日豪の測器を結集した係留系アレイ

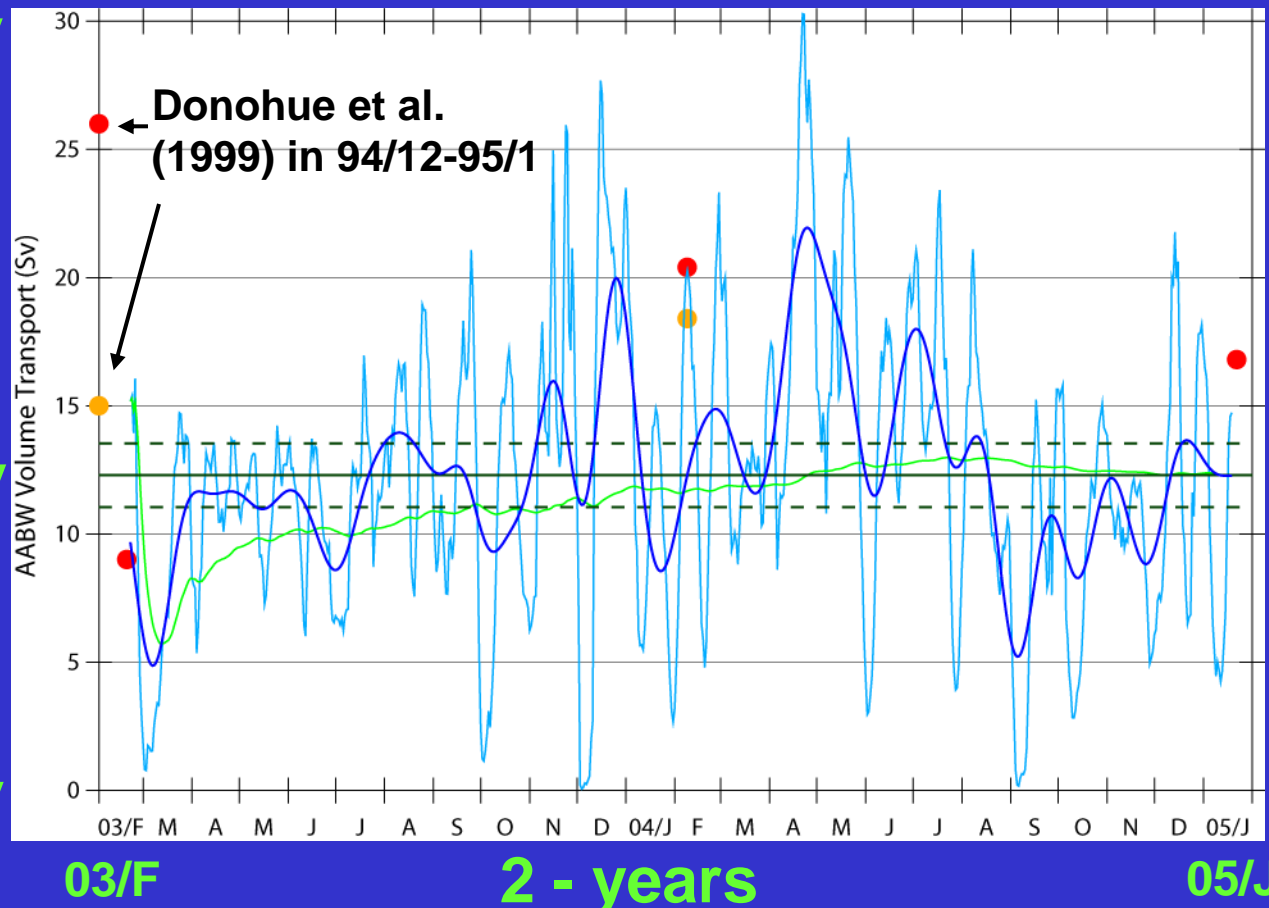
Fukamachi et al.,  
Nature Geoscience,  
in press

- 底層強化: 世界最強の深層流
- 南極底層水の厚さは1500 m



# ケルゲレン海台での南極底層水の北上流量

30 Sv  
12 Sv  
0 Sv



● LADCP  
● SADCP  
とCTD観測を  
合わせた流量  
の見積り

Fukamachi et al.,  
Nature Geoscience,  
in press

- 2年間の平均流量は12.3 Sv → ウェッデルより大、大西洋の循環量に匹敵
- 但し、再循環の部分の評価は今後の課題
- 変動が極めて大 → スナップショット(過去研究)の見積もりではダメ
- 季節変動は不明瞭、季節内変動が顕著

# 南極底層水の形成域と輸送経路



## プレIPYとIPYでの日本の貢献

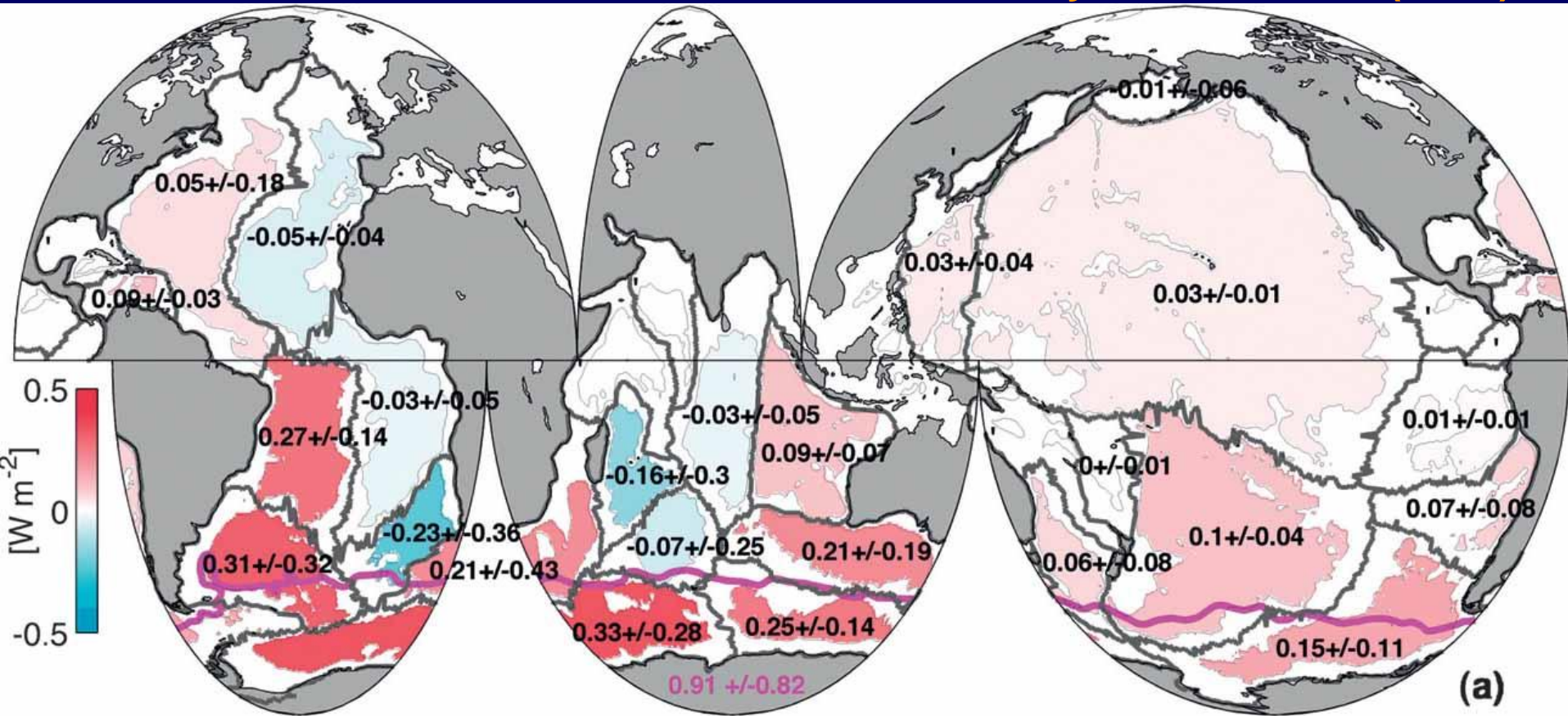
- ・南極底層水の形成 ← 海氷生産の把握
- ・南極底層水の輸送
- ・南極底層水の変質と原因

# Ongoing warming / freshening of Antarctic Bottom Water (AABW)

- Brief review and new results -

# Abyssal warming below 4000m from 1990s to 2000s

Purkey and Johnson (2010)

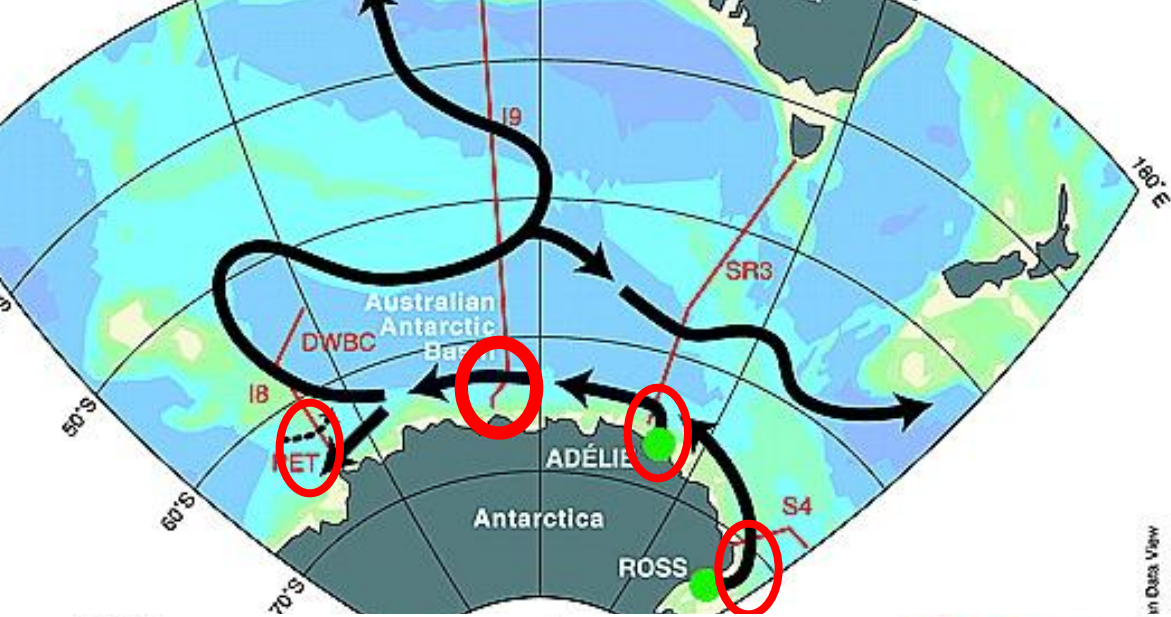


Warming trend of bottom water (AABW)

Weddell Sea: Fahrbach et al.(2004)

Ross Sea: Ozaki et al. (2009), Jacobs and Giulivi (2010)

Adelie Coast: Aoki et al. (2005), Rintoul (2007)

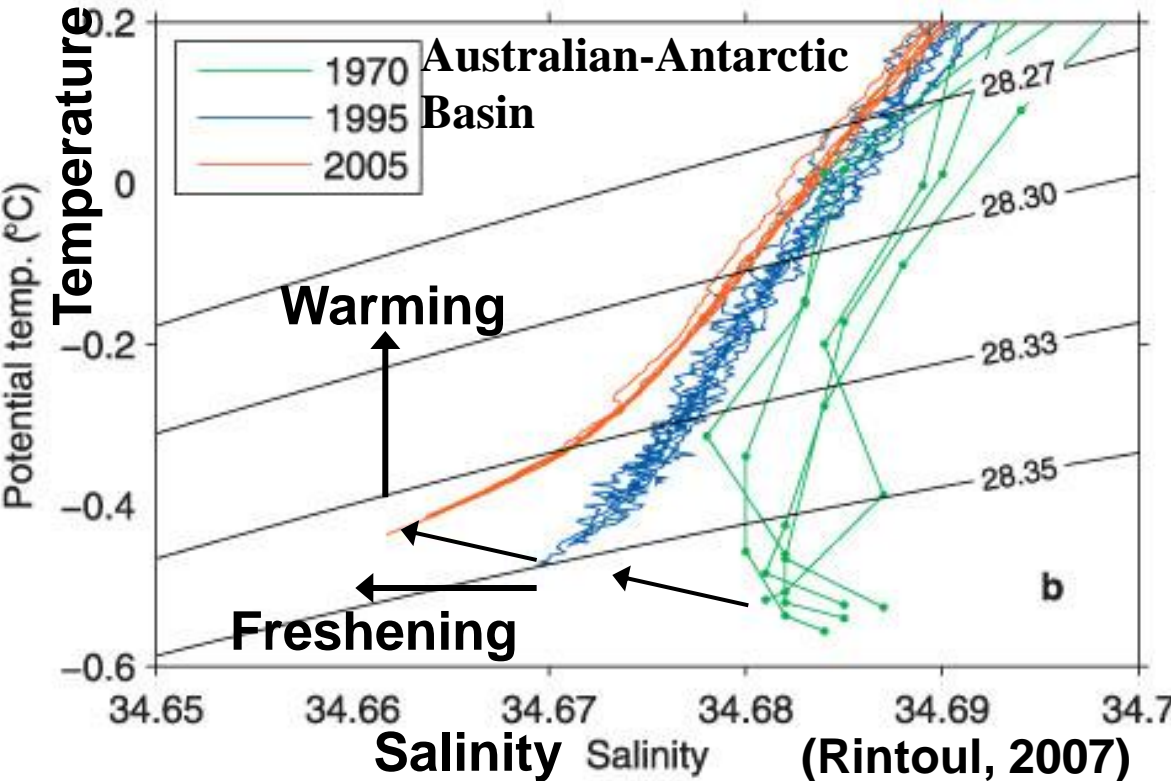


## Freshening of AABW

Ross Sea: Jacobs (2004)

Australian-Antarctic Basin : Rintoul (2007)

Adelie Coast: Aoki et al (2005)

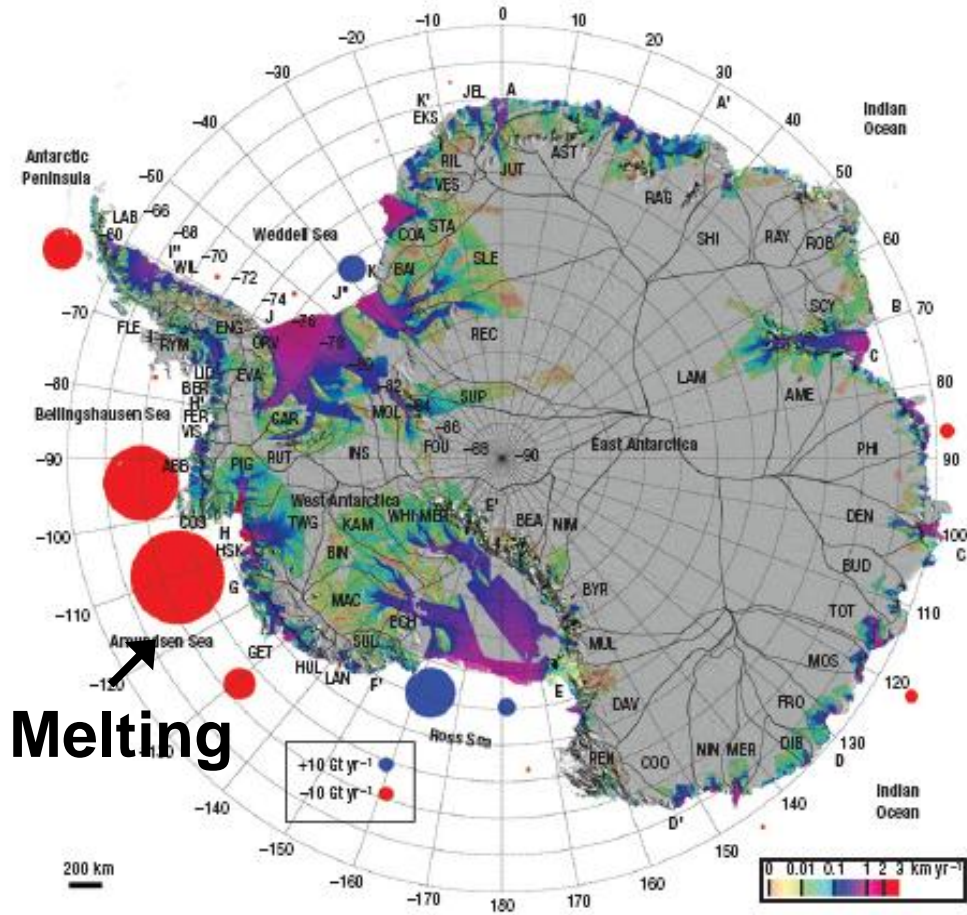


## Cause of Freshening

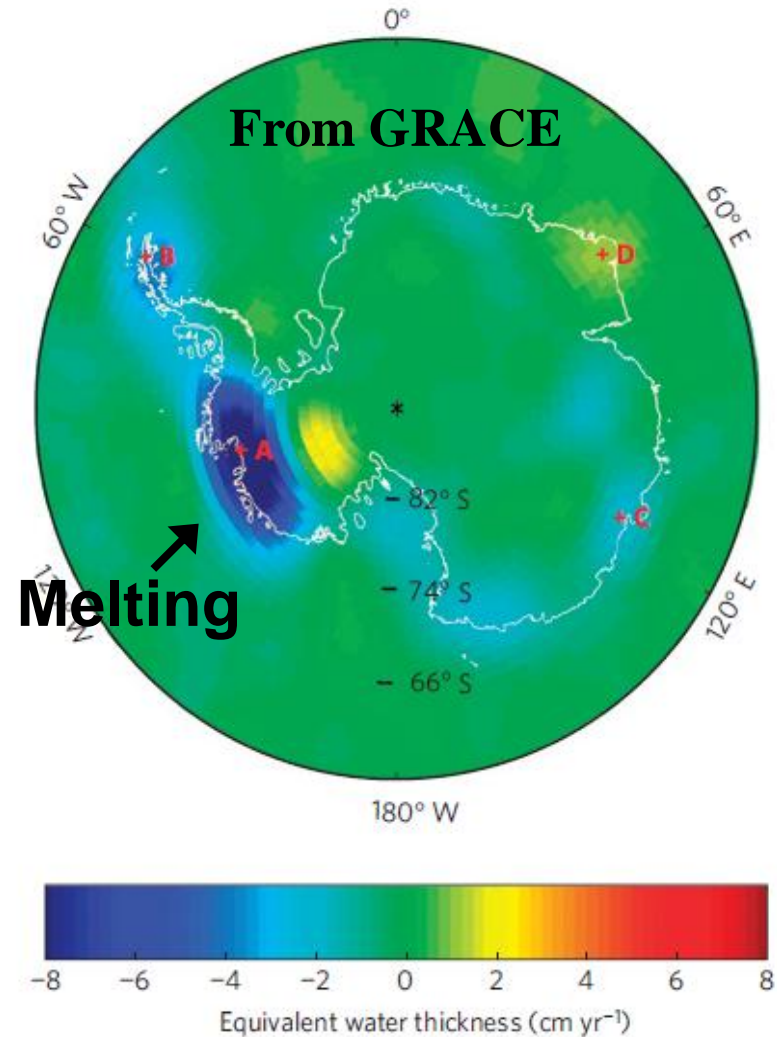
- Enhanced melting of Ice Shelf
- Increase of P-E (Precipitation-Evaporation)
- Deduced sea ice prod. in the polynya



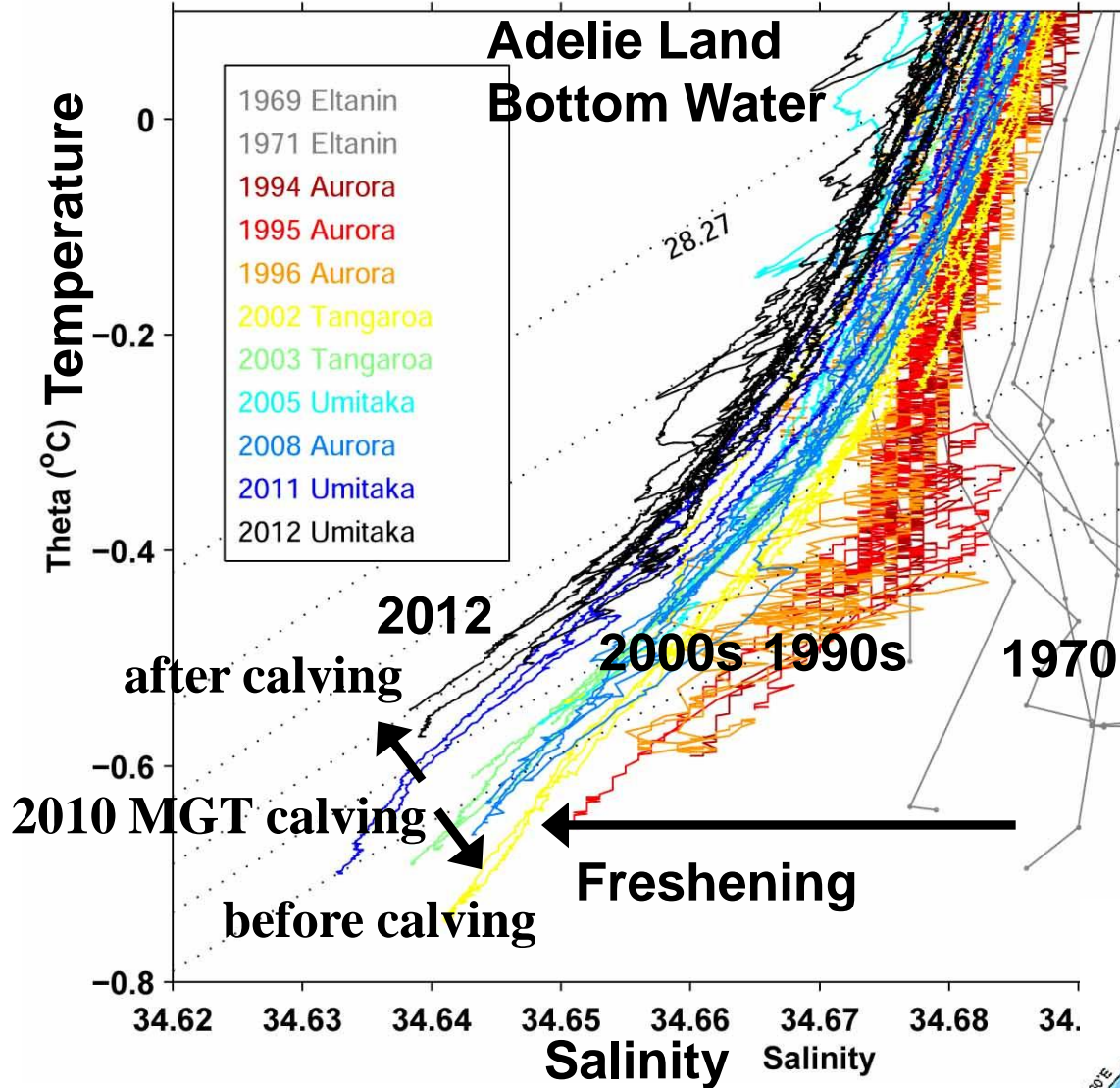
# Increase/Decreased rate of Ice Shelf, Ice Sheet



(Rignot et al. 2008)

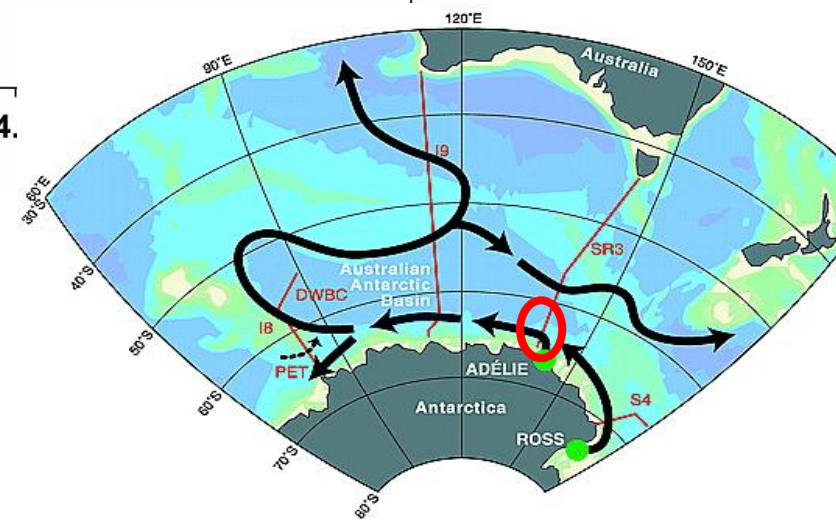


(Chen et al., 2008)

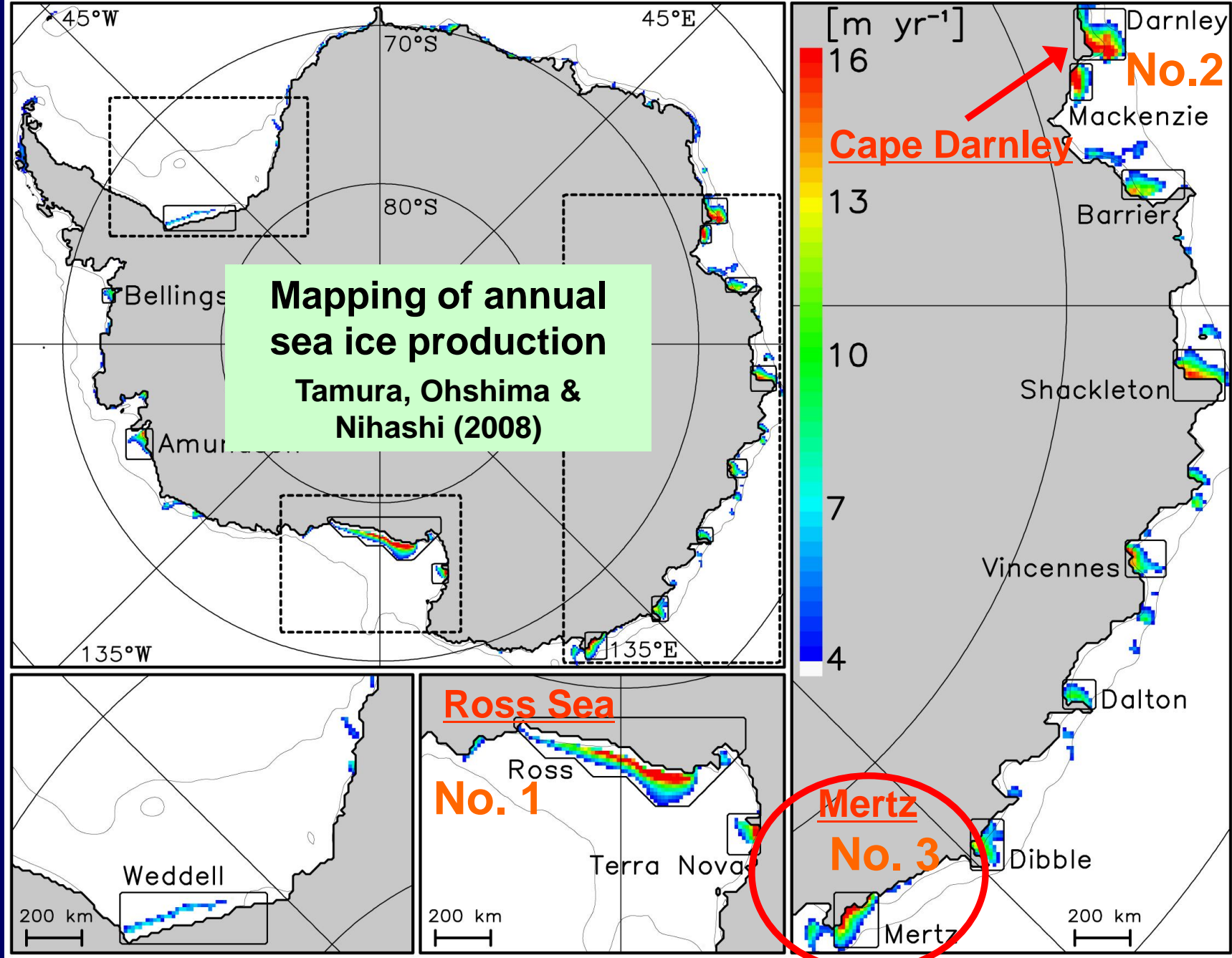


- ### Cause of Freshening
- Enhanced melting of Ice Shelf
  - Increase of P-E (Precipitation-Evaporation)
  - Deduced sea ice prod. in the polynya

Aoki et al., in preparation

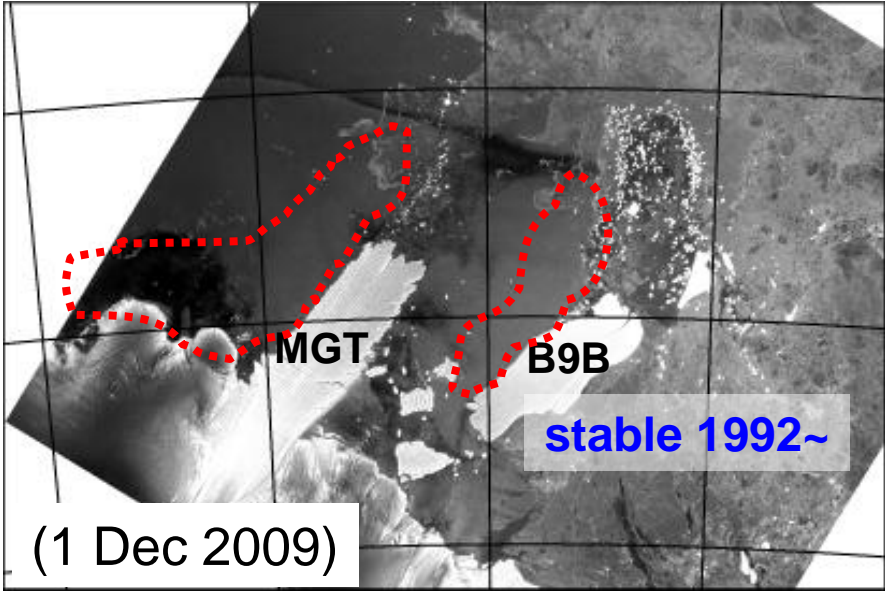


**Mapping of annual  
sea ice production**  
Tamura, Ohshima &  
Nihashi (2008)

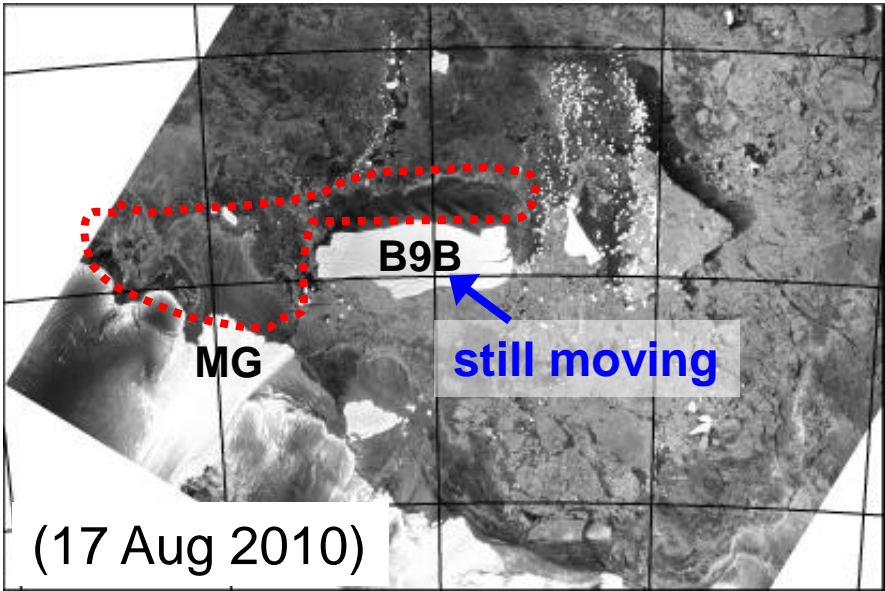
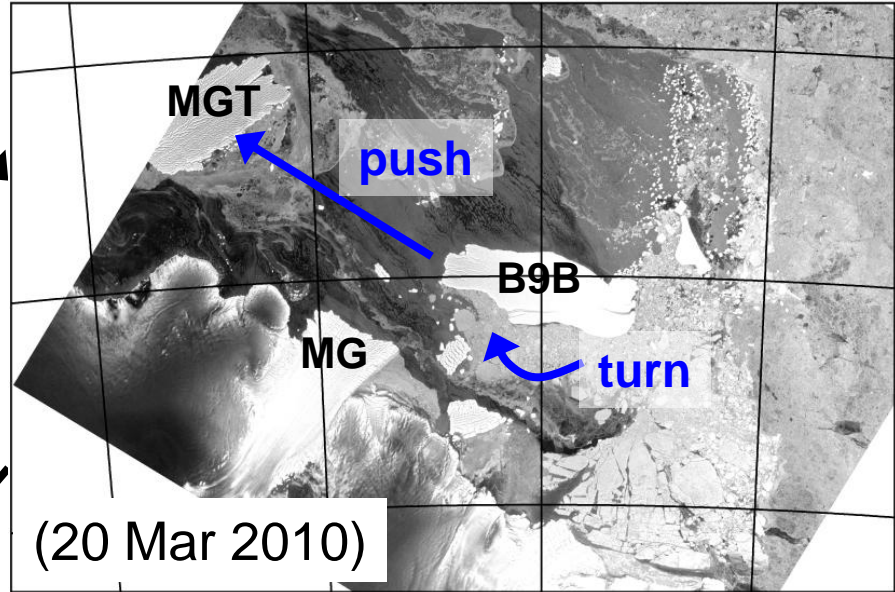


# Breaking and outflow of MGT and B9B grounded iceberg from ALOS imageries

(Breaking of MGT: Feb 2010)

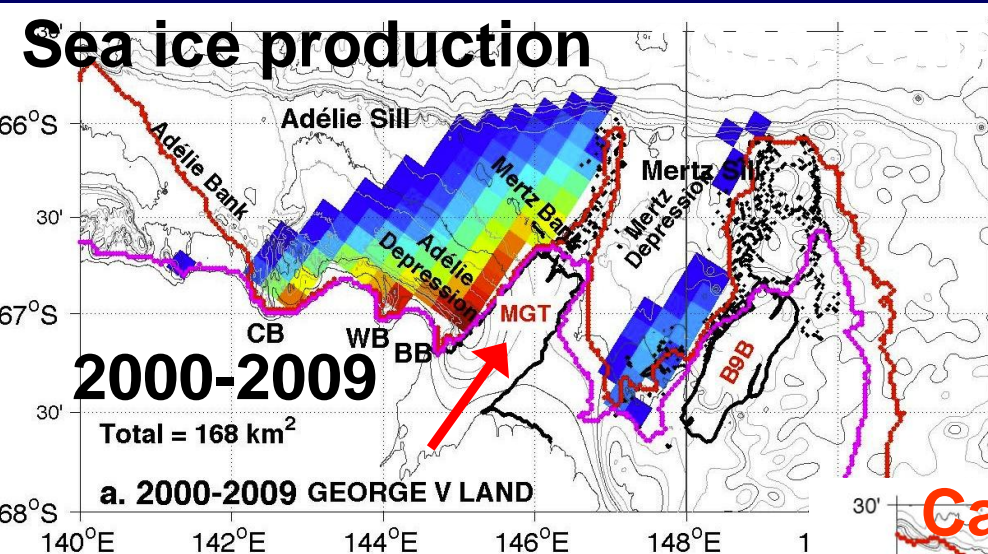


Old regime of Mertz and Ninnis Glacier polynyas by MGT and B9B



**Change of ice production?**  
**Change of AABW formation?**

New regime of Mertz Glacier polynya by B9B and MG (Mertz Glacier)



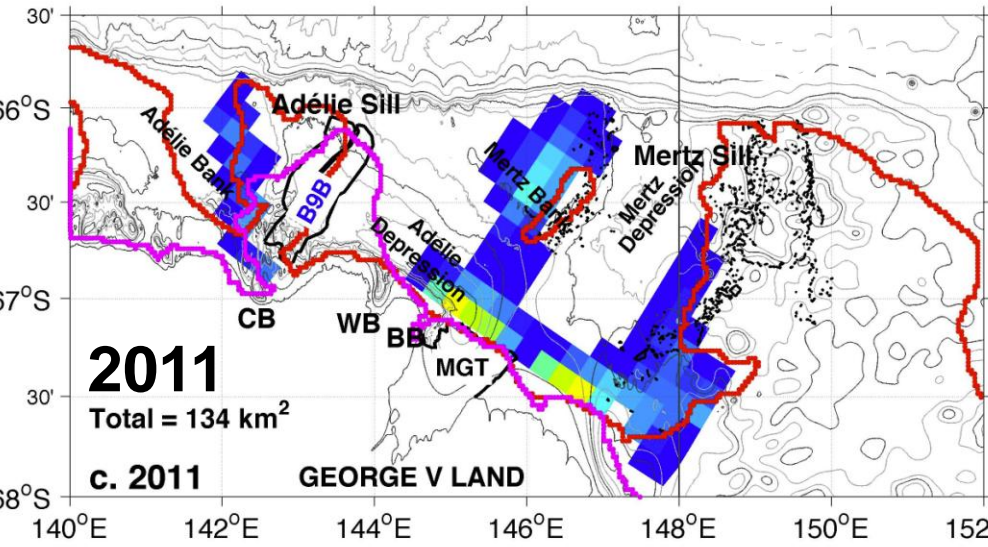
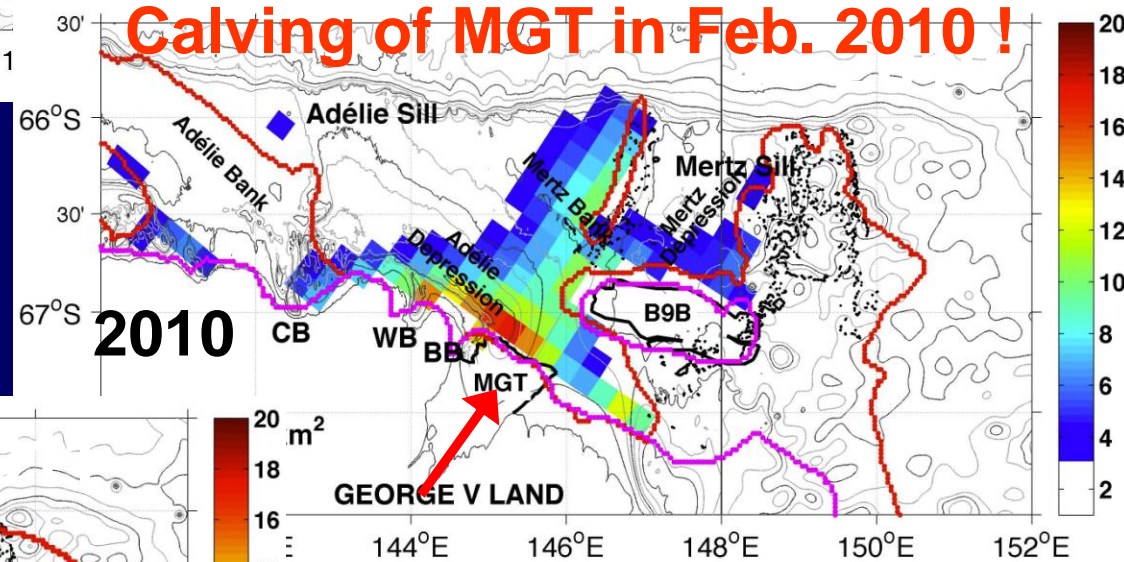
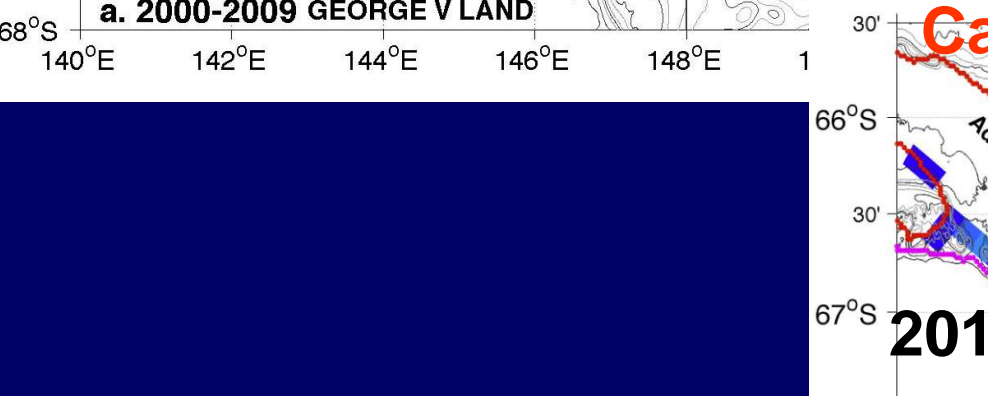
**Calving of Mertz Glacier Tongue (MGT)**

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**Decreased sea ice production**

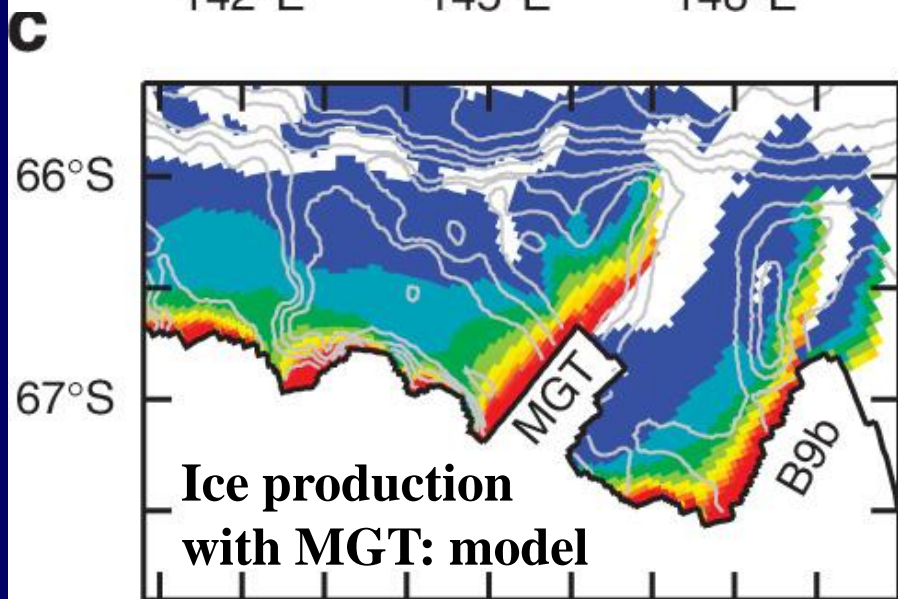
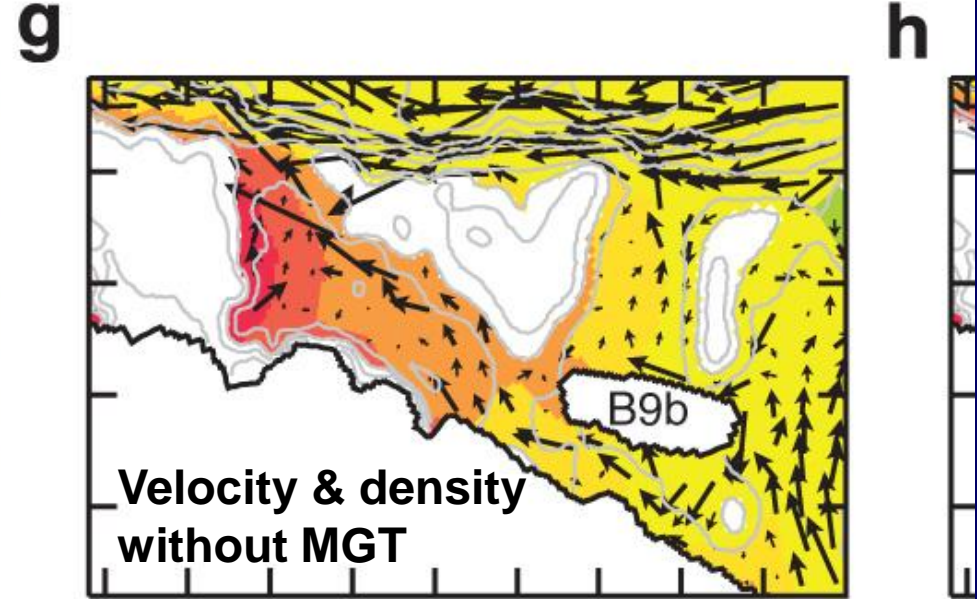
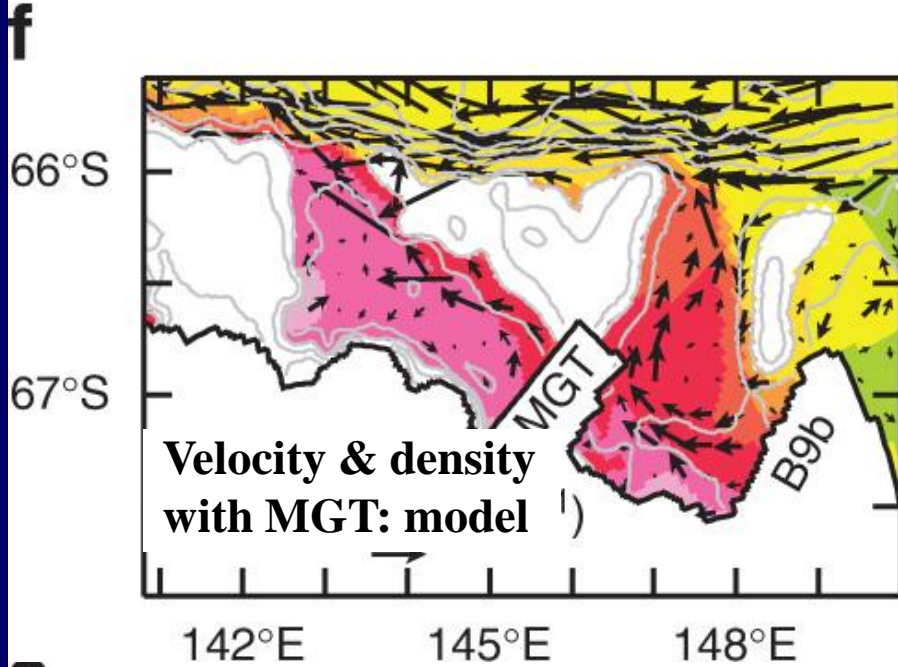
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**Decreased AABW ?**

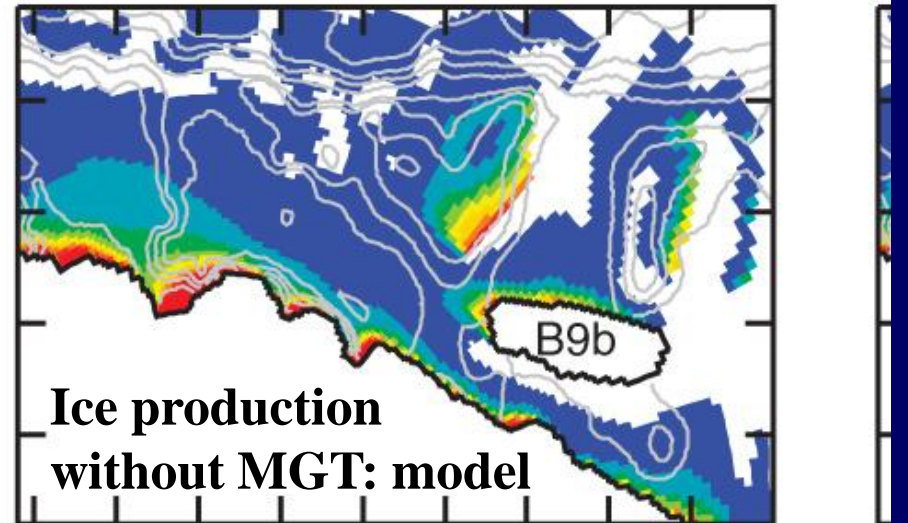


Tamura and Williams, et al., 2012,  
Nature Communications

# Impact of the Mertz Glacier Tongue calving on dense water formation and export; Kusahara et al. (2011, Nature Comm.)



**d** Decreased DSW by 23%



# Ongoing warming / freshening of Antarctic Bottom Water (AABW)

→ **Contraction of AABW ?**

→ **Global-scale slowdown of  
lower limb of MOC ??**