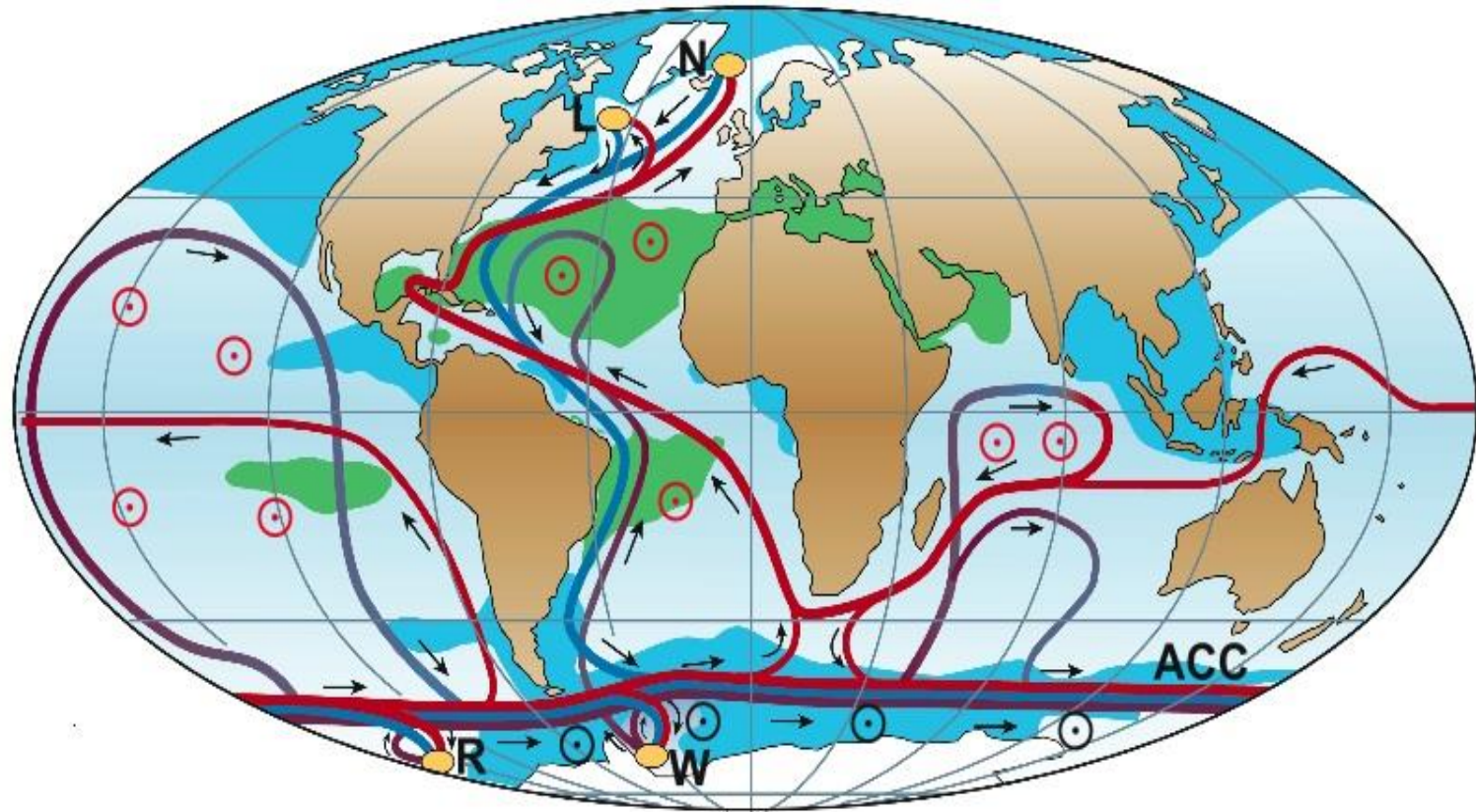




Il mare di Ross

Meridional Overturning Circulation (MOC)



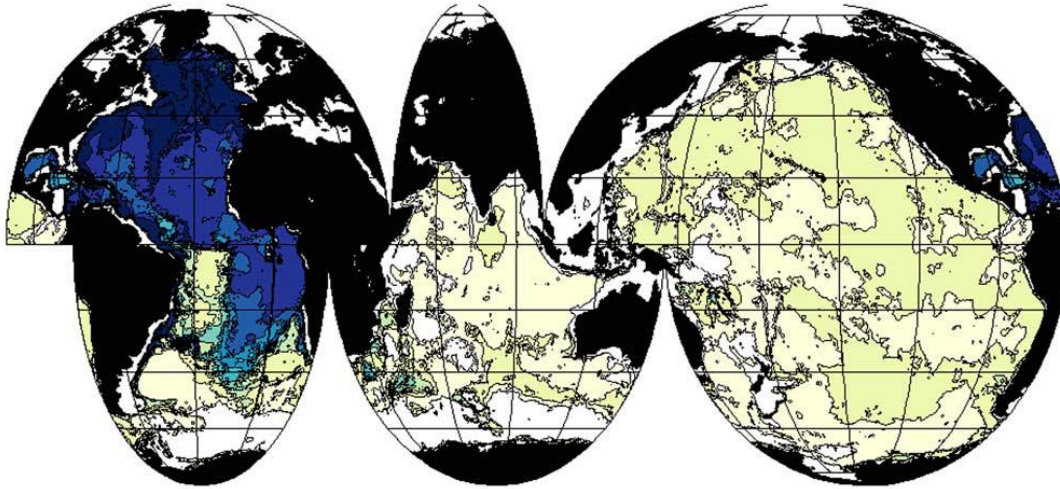
- Surface flow
- Deep flow
- Bottom flow
- Deep Water Formation

- ⊙ Wind-driven upwelling
- ⊙ Mixing-driven upwelling
- Salinity > 36 ‰
- Salinity < 34 ‰

- L Labrador Sea
- N Nordic Seas
- W Weddell Sea
- R Ross Sea

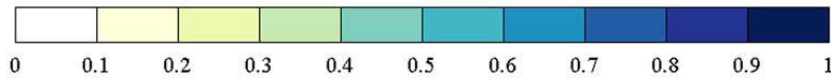
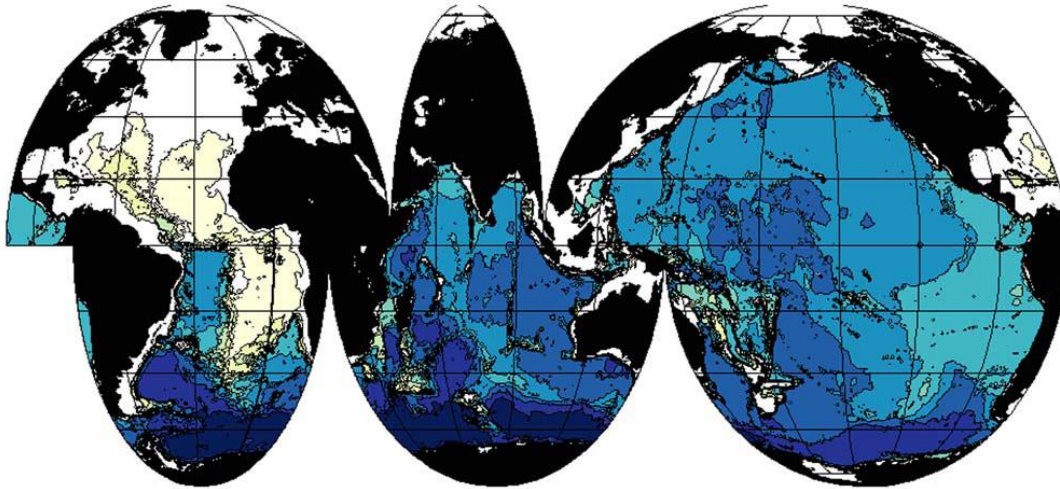
80% of the world ocean bottom water is too cold to be derived from North Atlantic processes

NADW



$$\frac{\text{AABW}}{\text{NADW}} \sim 2$$

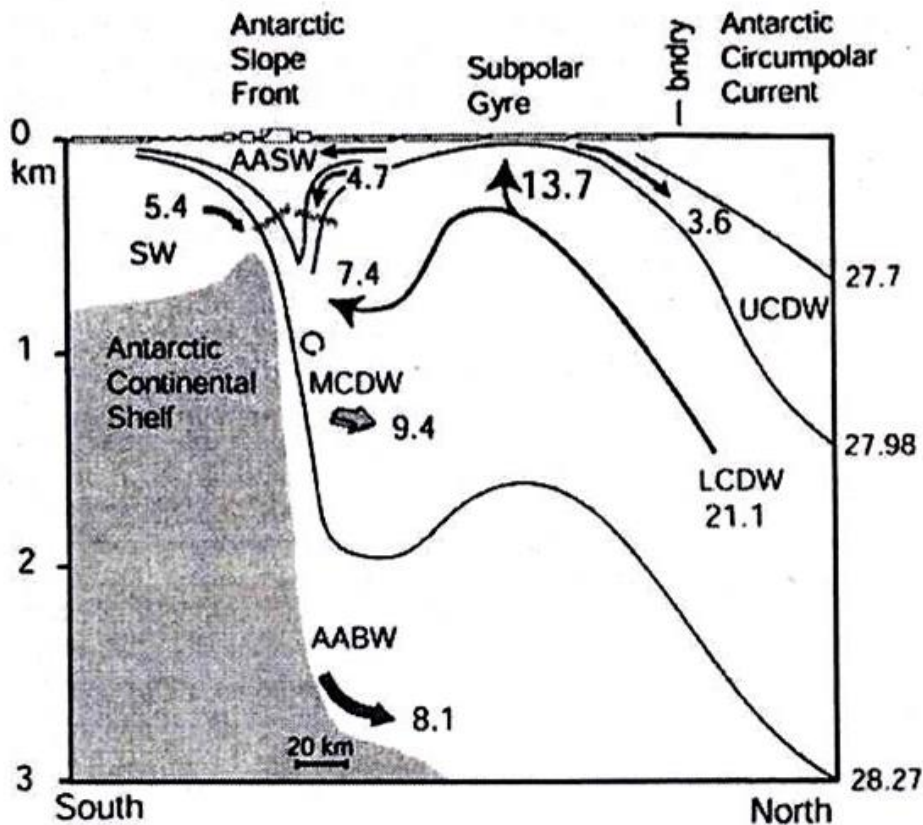
AABW



Bottom Fraction

Fraction of (top) NADW and (bottom) AABW at the deepest sample in the climatology contoured (color bar) at 0.1 intervals.

Johnson (2008)



5.4 Sv Antarctic Shelf water exported is combined [entrainment] with 4.7 offshore surface water + 7.4(CDW) to produce 17.5 Sv of Antarctic deep and bottom water (9.4 Sv of AADW + 8.1 Sv of AABW)

Southern Ocean *circumpolar* continental margin water type budgets from CFC Orsi et al. 2001; 2002

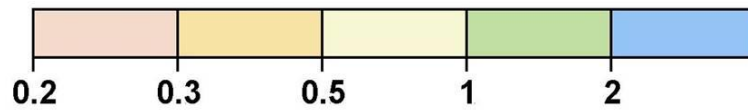
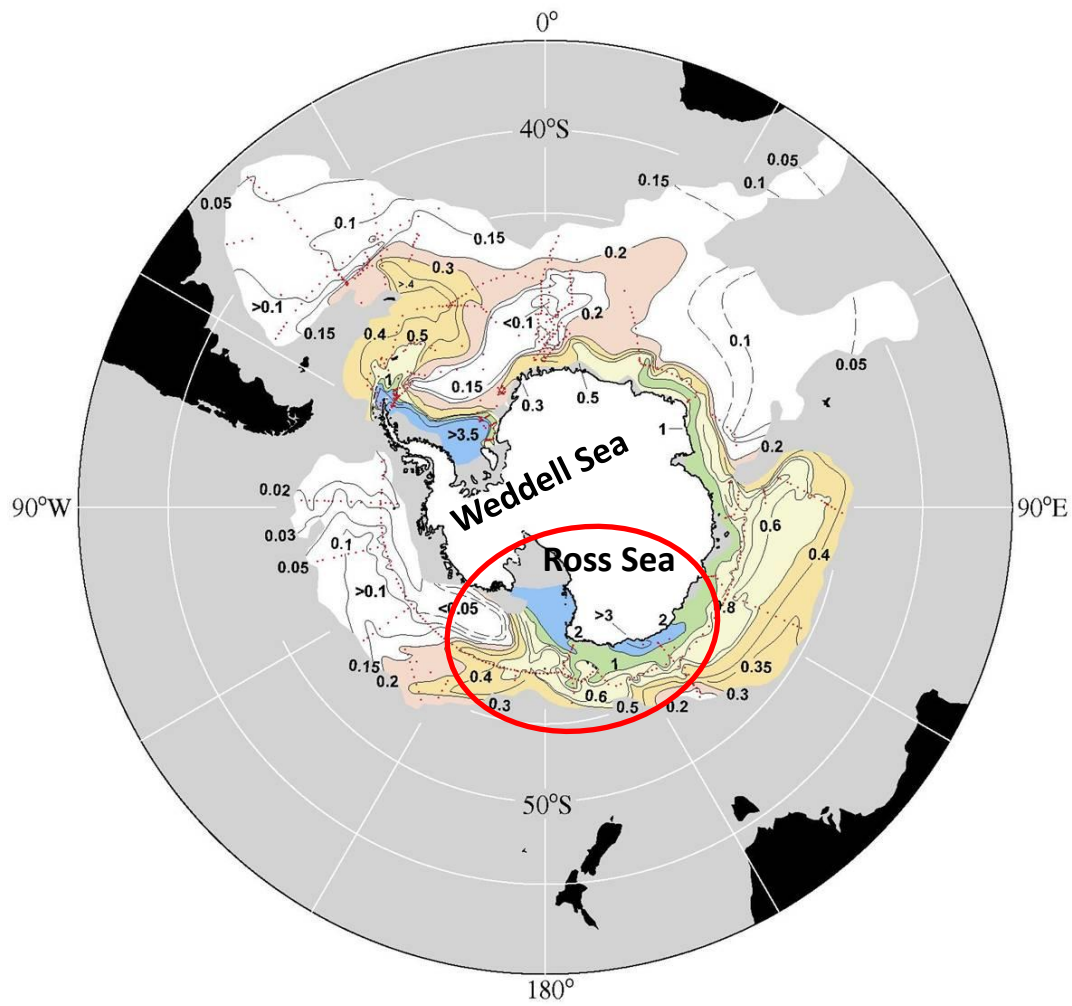
8.1 Sv of AABW:

50% Weddel Sea

30% Ross Sea

20% Adelie Land, Prydz Bay.....

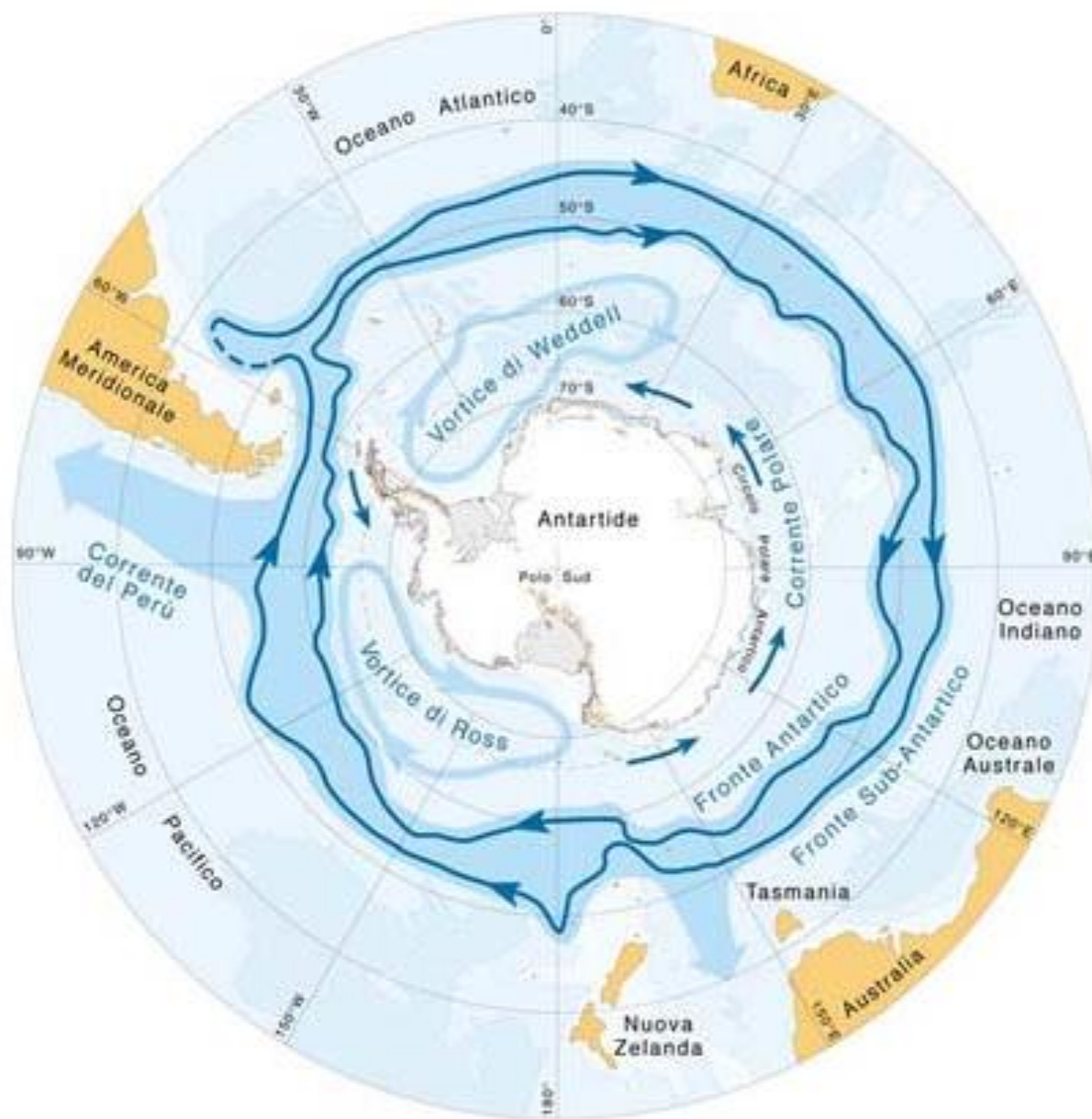
AABW LAYER

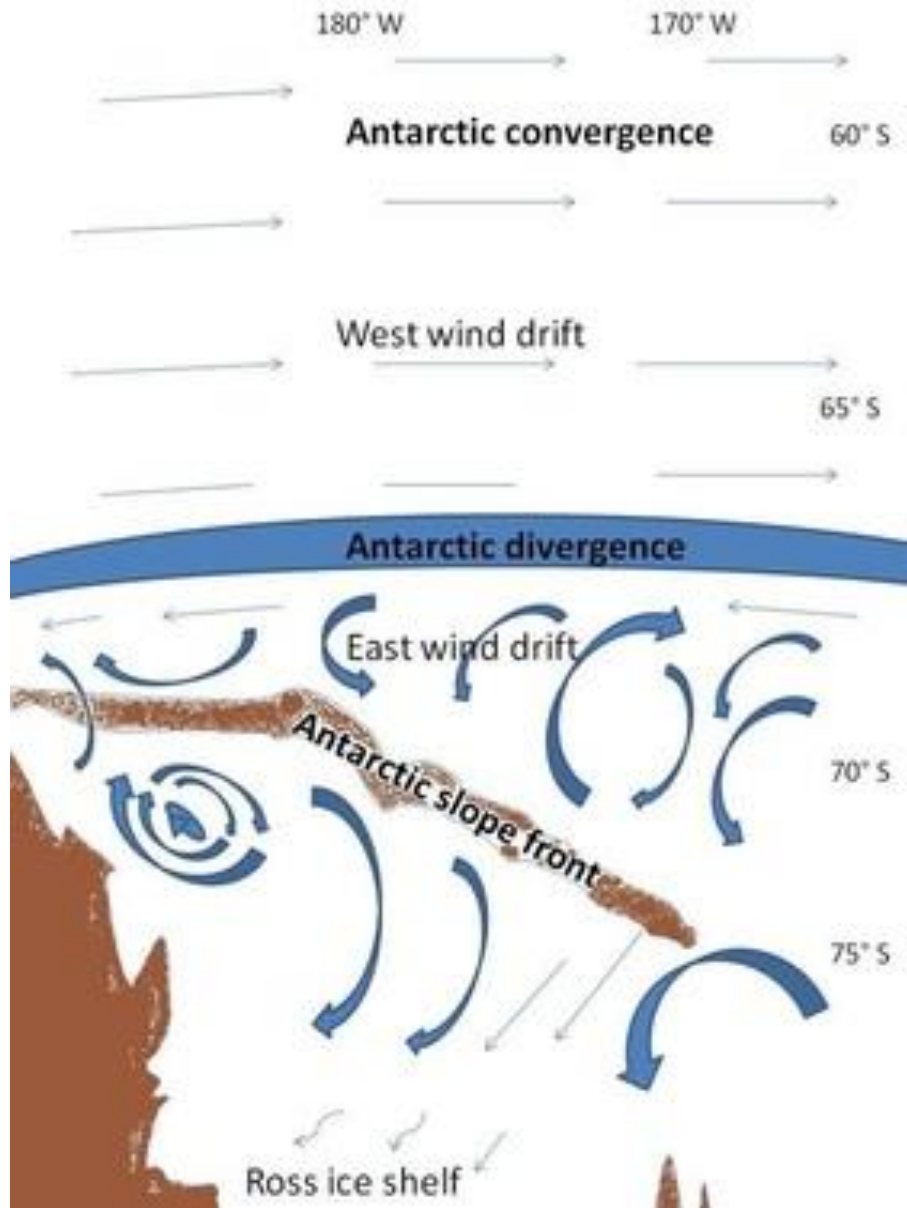


Mean CFC-11 (pmol/kg)

Orsi et al., 1999

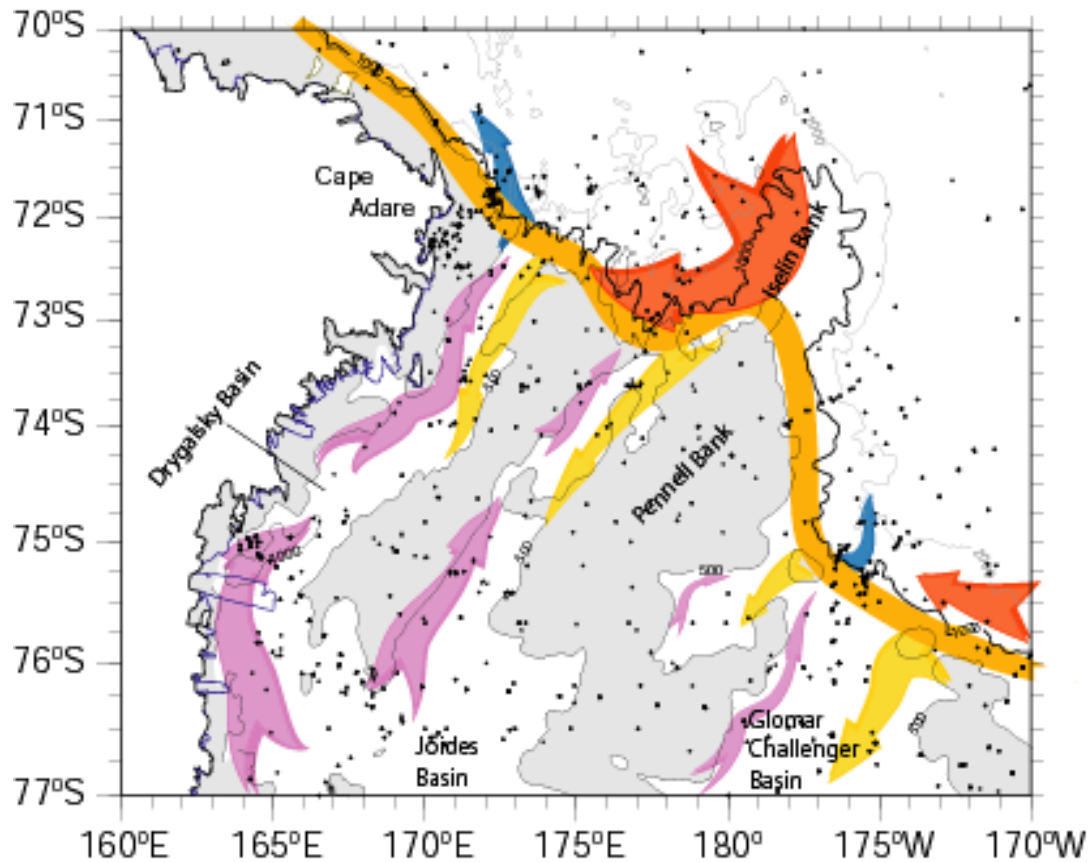
Schema della circolazione orizzontale nell'Oceano Meridionale





- La **CDW** che procede verso Sud, entra nella circolazione ciclonica del **Ross Gyre**
- La sua densità è tale da posizionarla sotto la **AASW (acque superficiali antartiche)** e sopra le AABW
- La risalita in superficie della CDW avviene seguendo approssimativamente la batimetria dei 700 m
- Processi diapirnici nella zona del Antarctic Slope Front determinano, più a sud, una massa d'acqua nota come Modified CDW (MCDW)

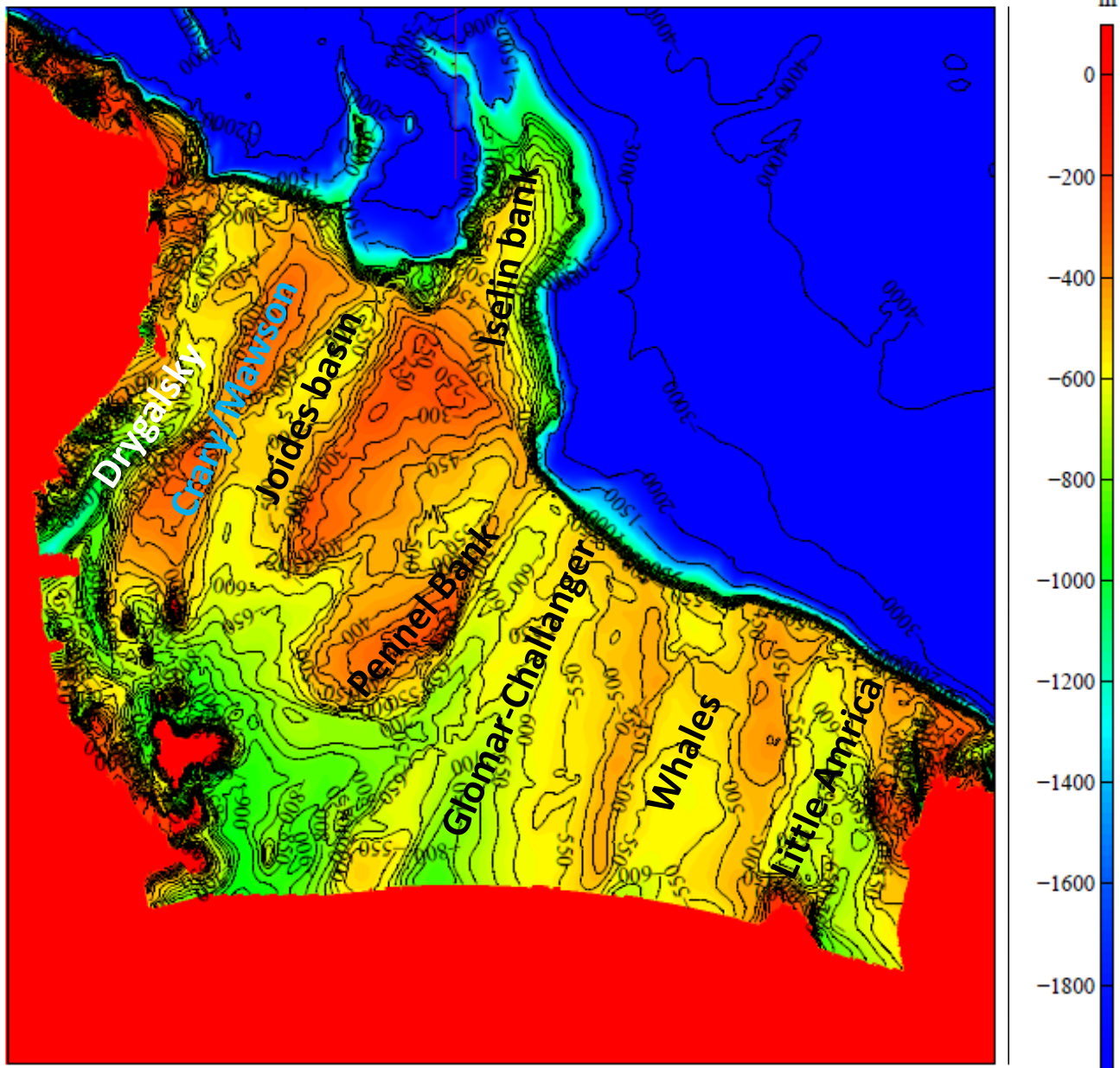
Ross Sea oceanography, in a nutshell



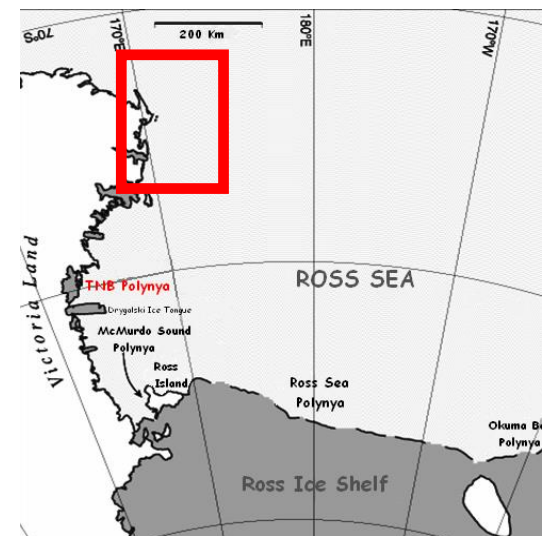
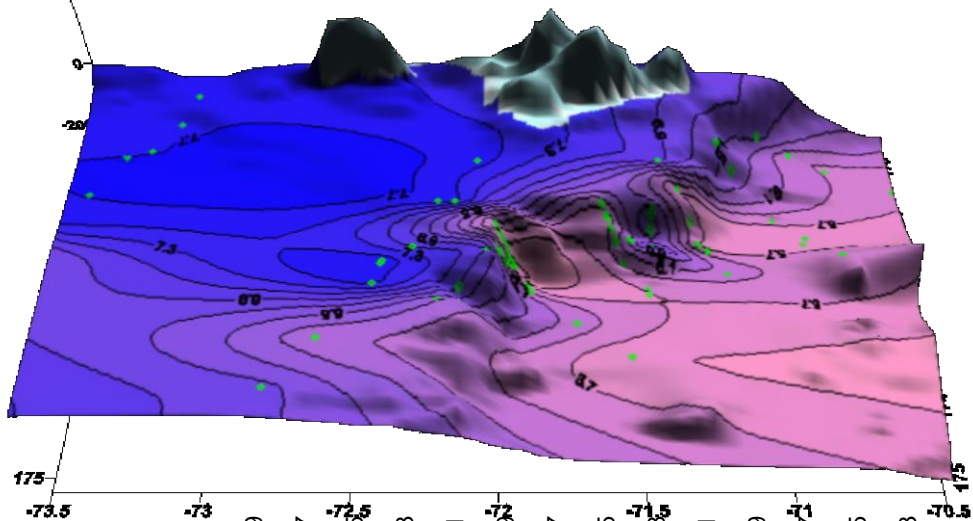
Warm oceanic inflows

Cold shelf outflows

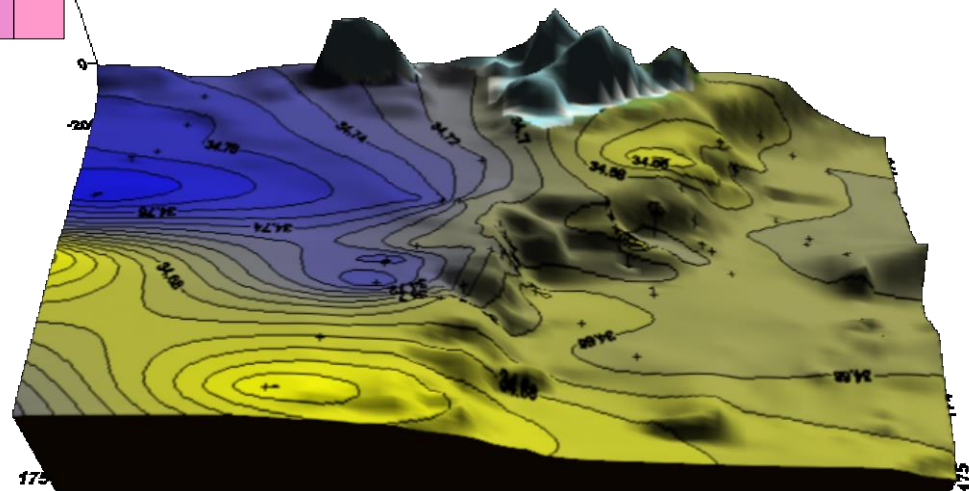
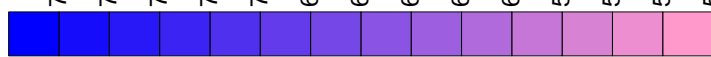
Antarctic Slope Current



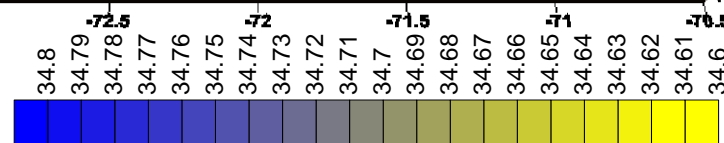
Bathymetry from Fred Davey
region: ross_large



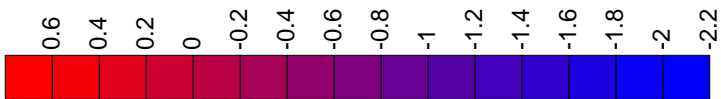
O_2 [$mg\ l^{-1}$]



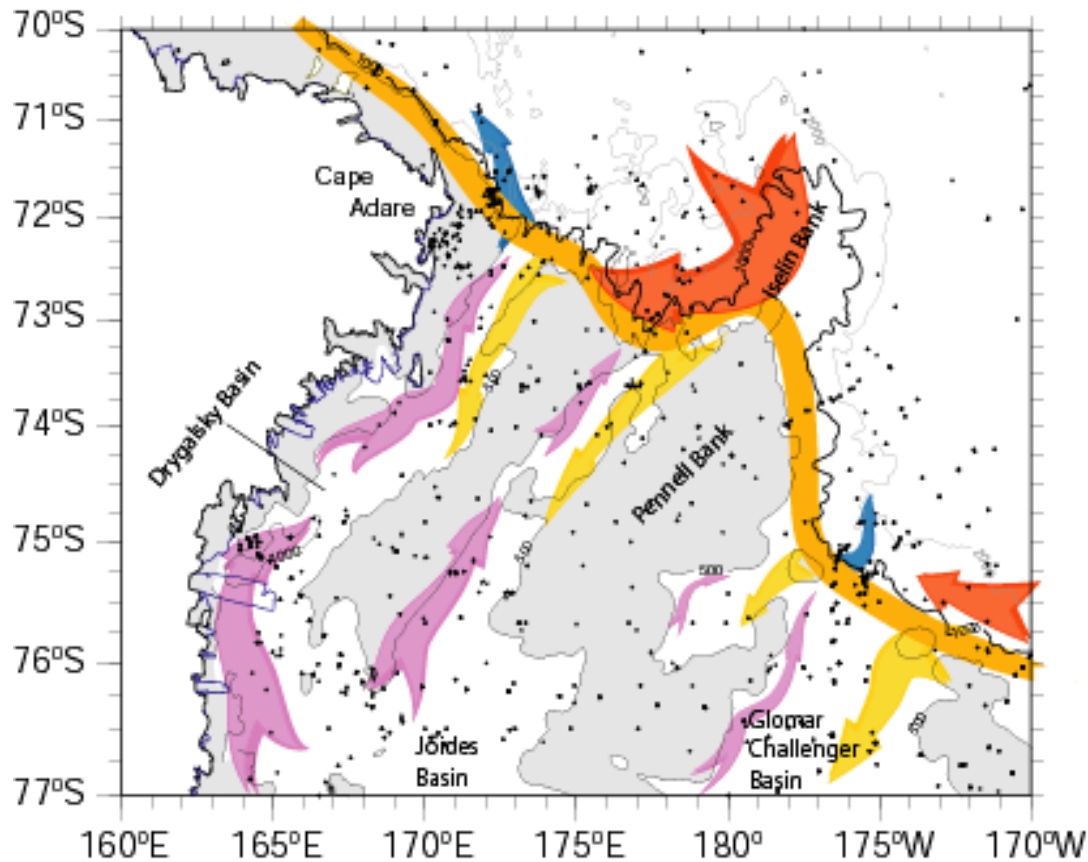
S



θ [$^{\circ}C$]



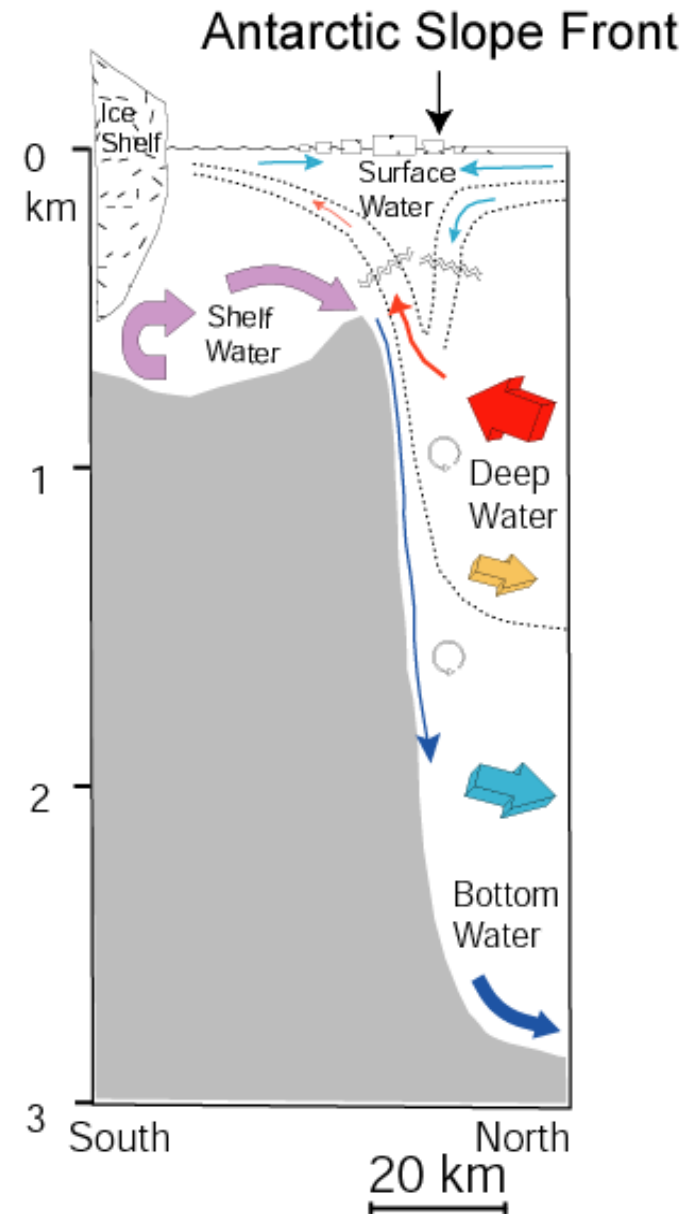
Ross Sea oceanography, in a nutshell



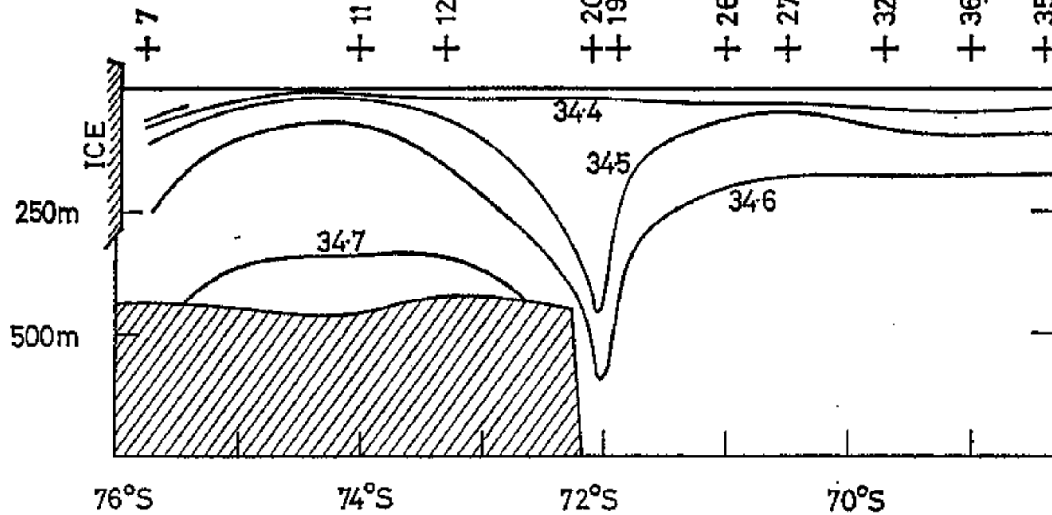
Warm oceanic inflows

Cold shelf outflows

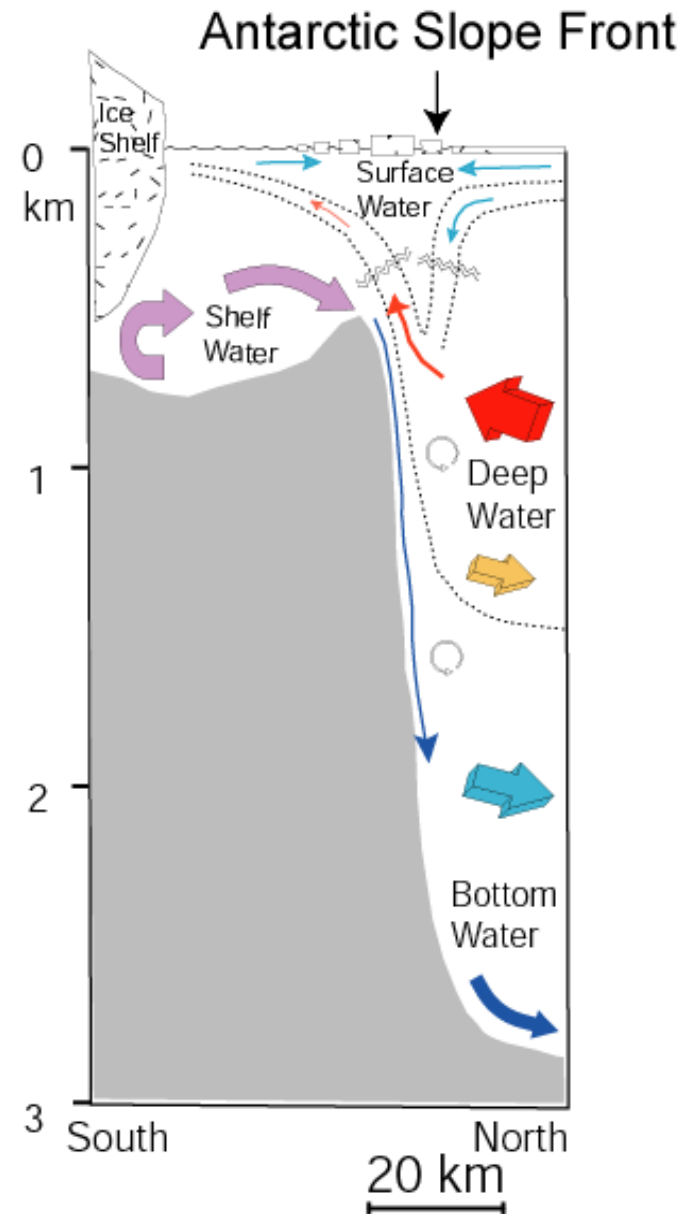
Antarctic Slope Current

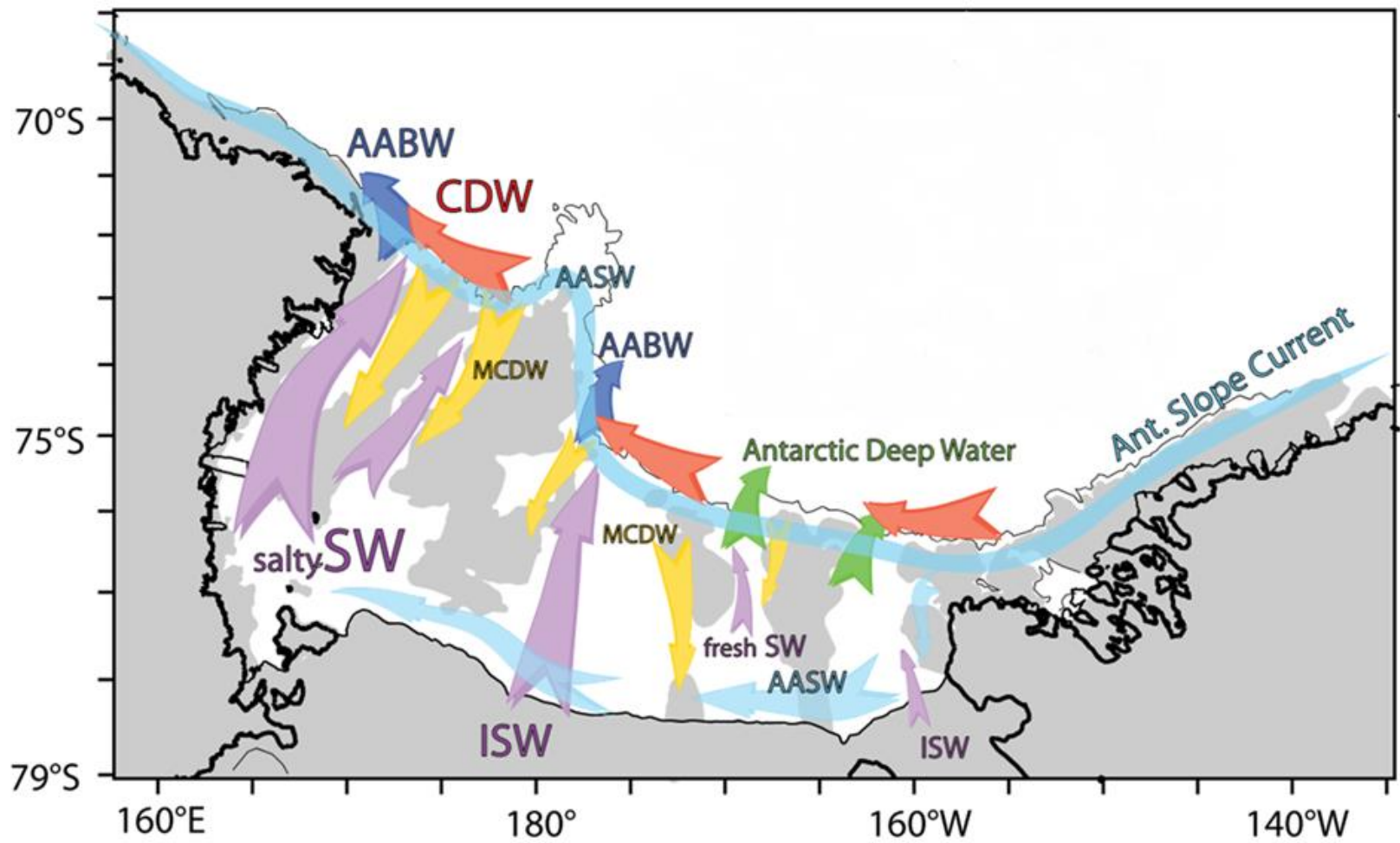


Antarctic Slope Front

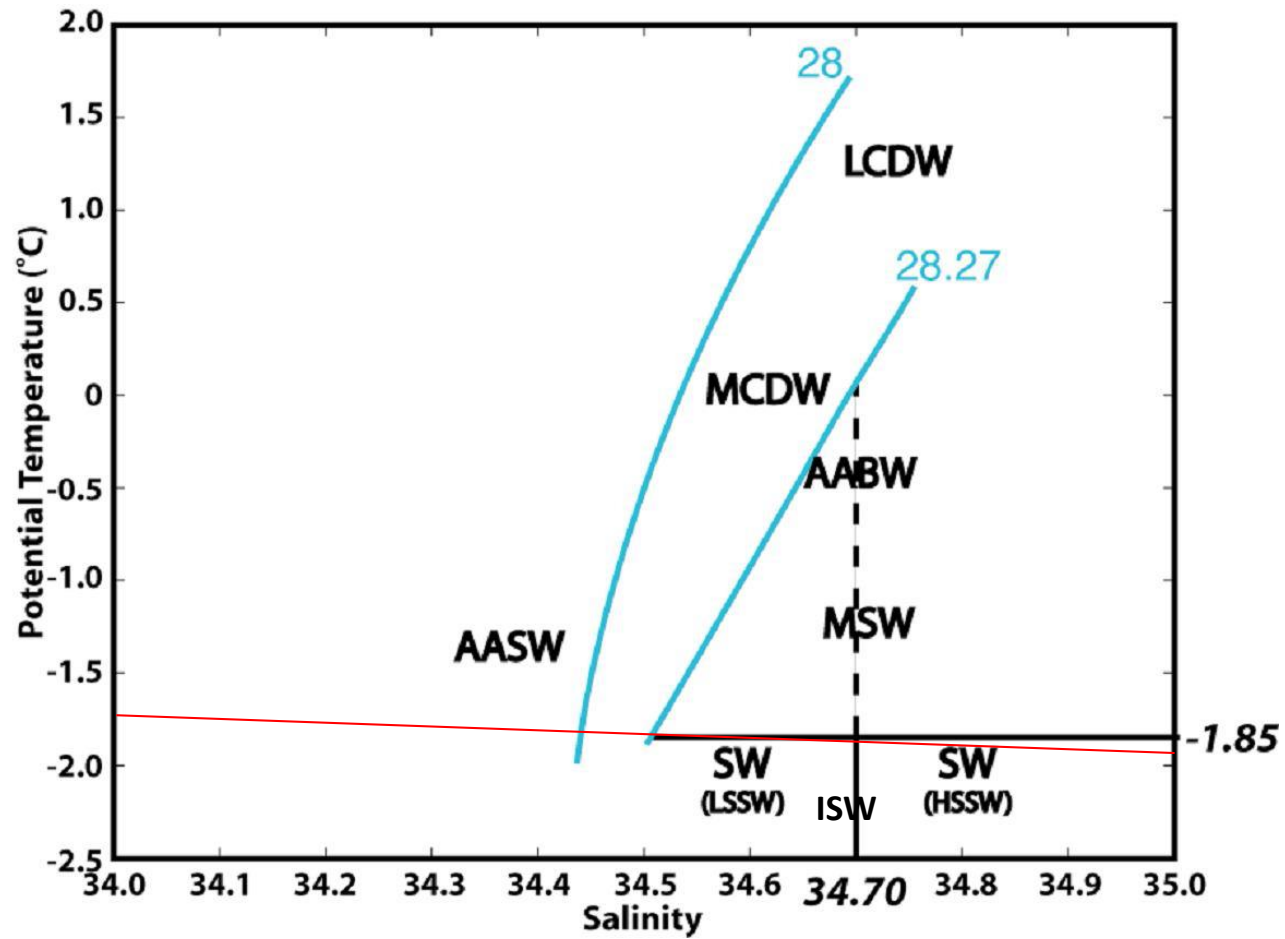


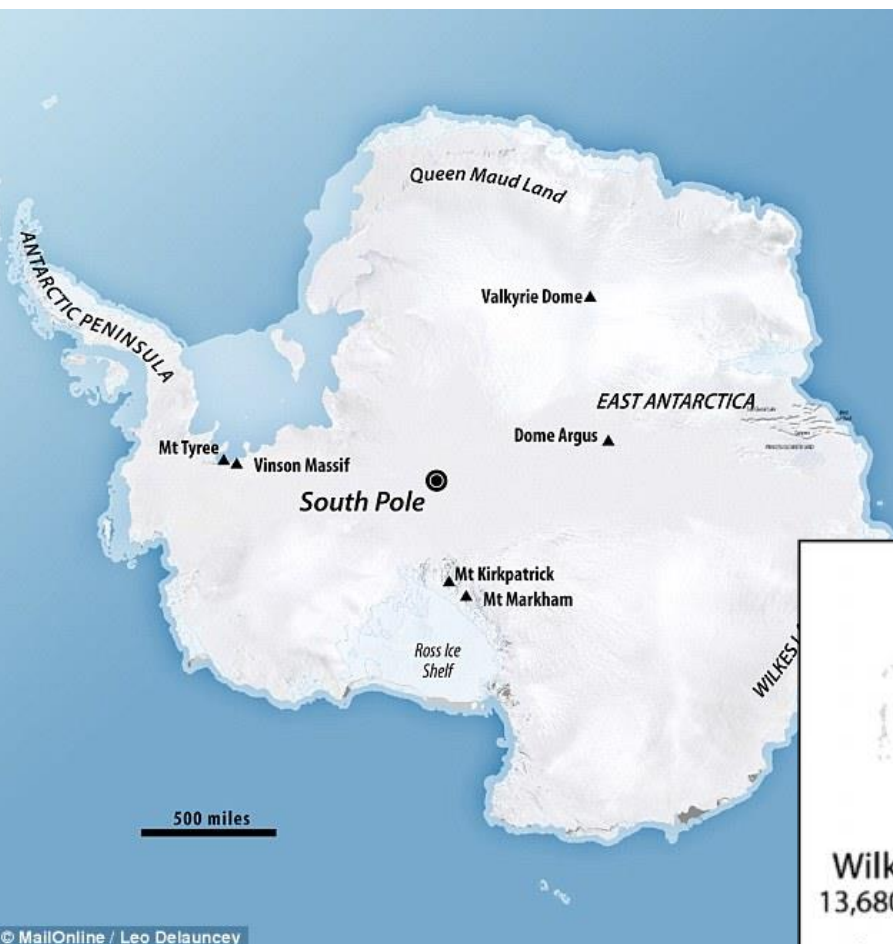
- Barriera, dinamica e permeabile sulla scarpata continentale, tra le acque calde circumpolari e le acque fredde di piattaforma
- Caratterizzato dalla forma a "V" del campo di densità



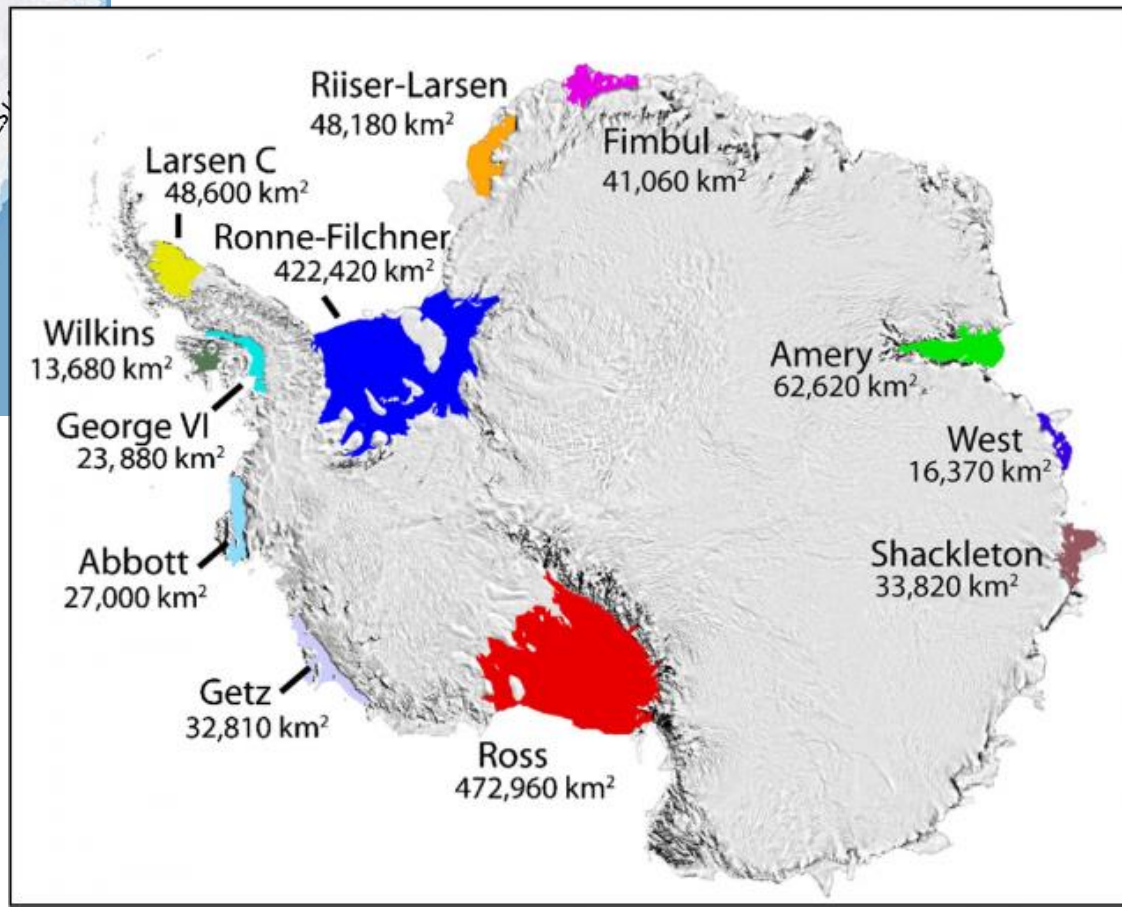


Ross Sea Water masses





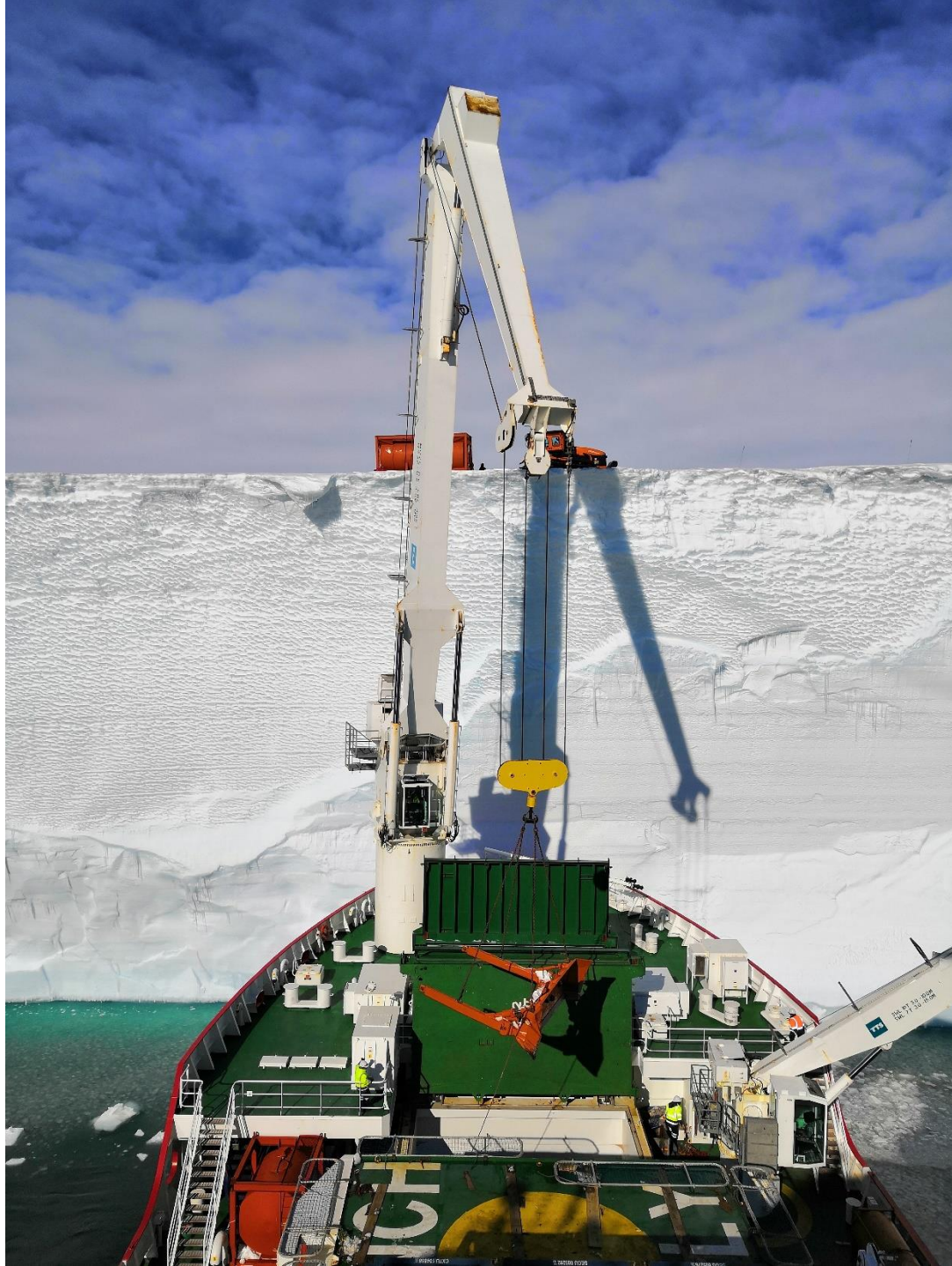
© MallOnline / Leo Delauney



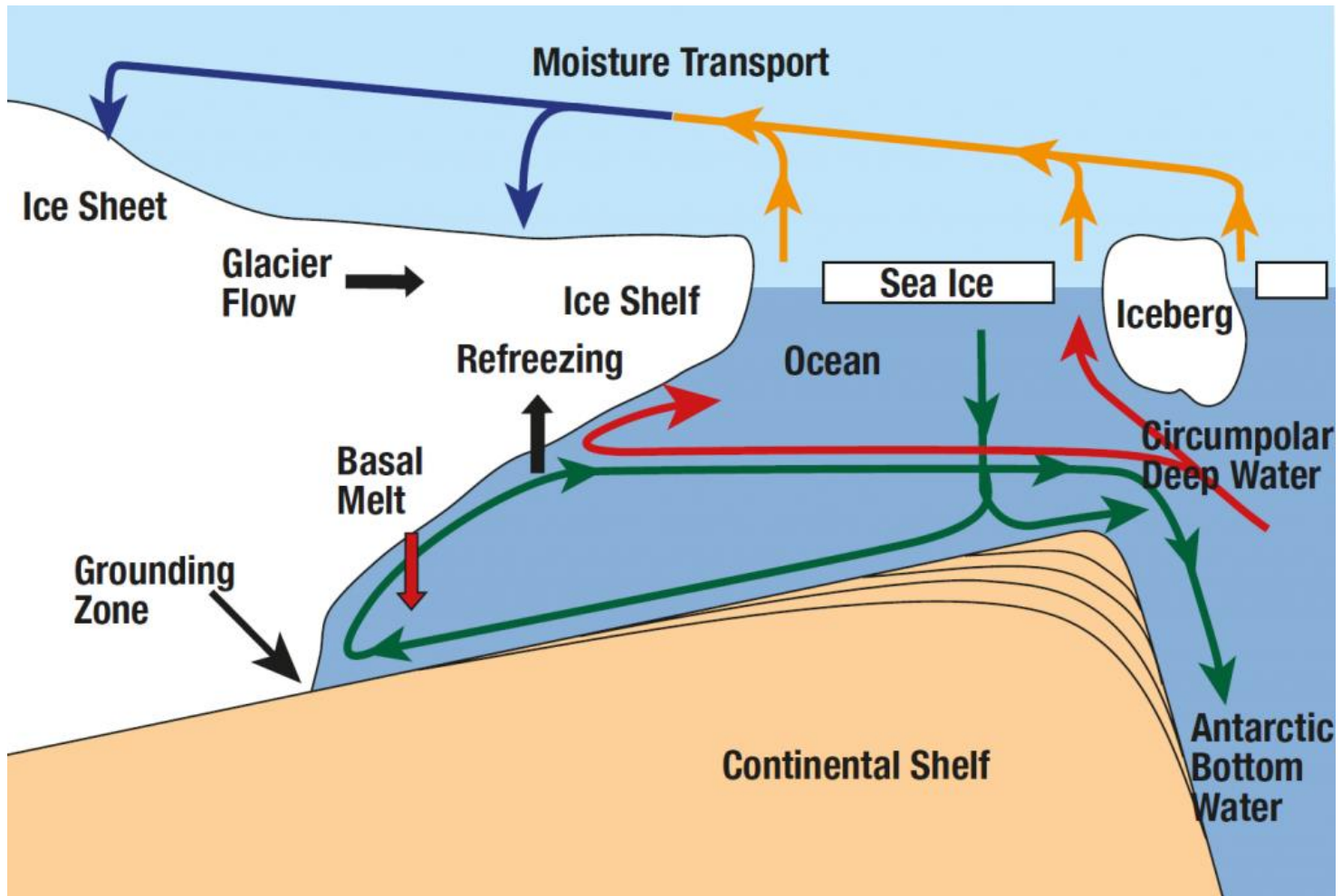






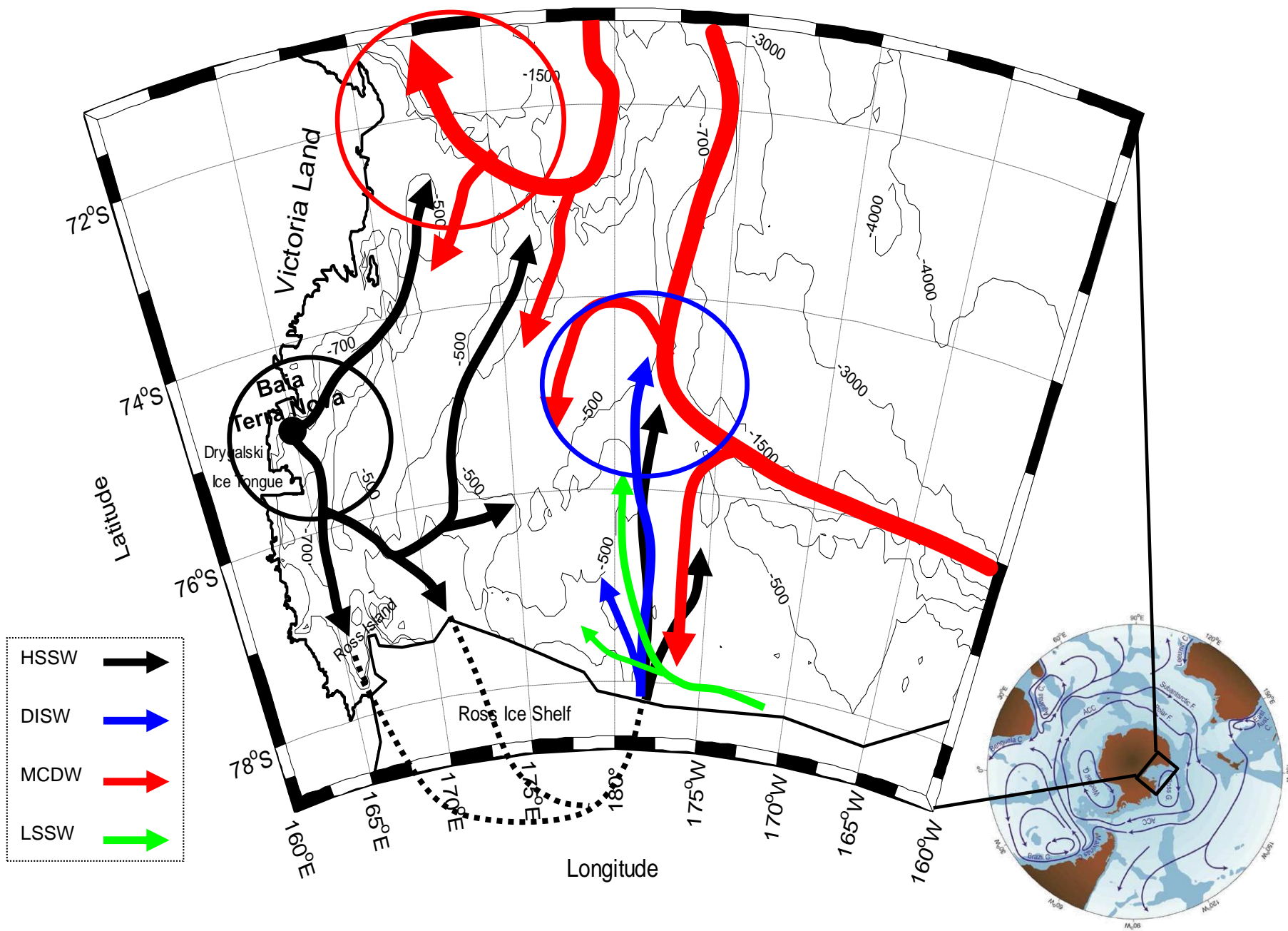


Formazione delle AABW

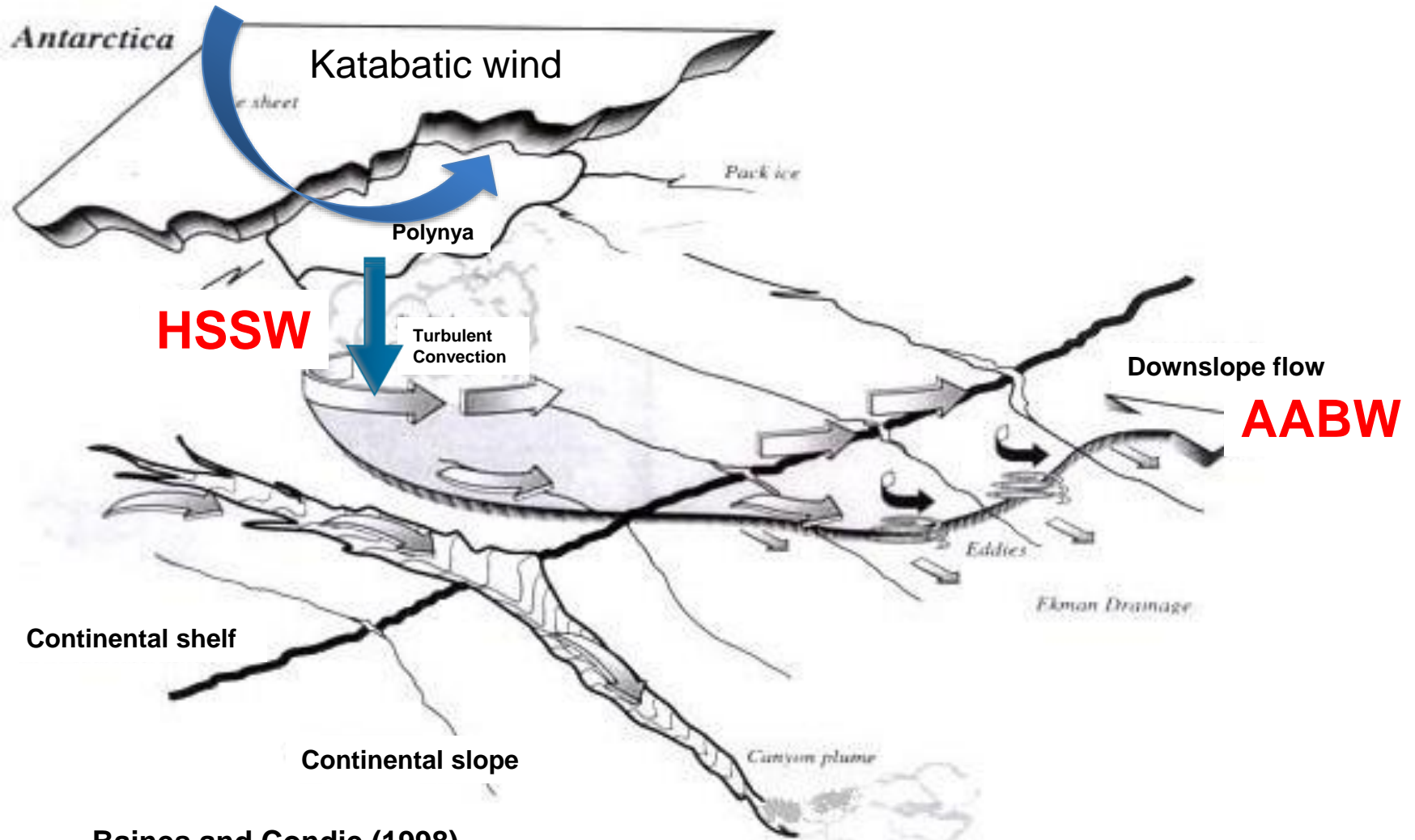


Jacobs et al., 1992

Schema di circolazione sub-superficiale



HSSW & AABW water formation process



Baines and Condie (1998)

Ross Sea Polynyas

Terra
Nova Bay
Polynya
(TNB)

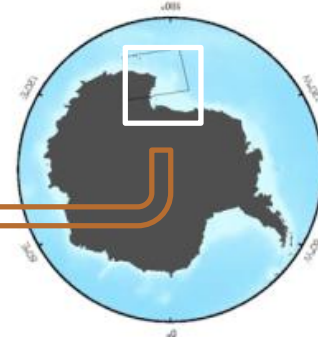
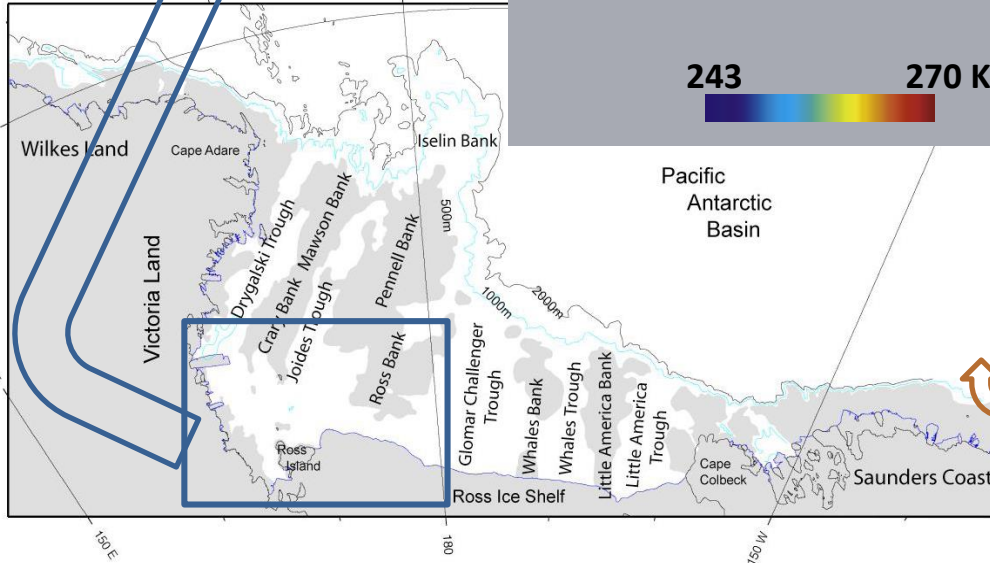
Terra Nova Bay Polynya (TNB)

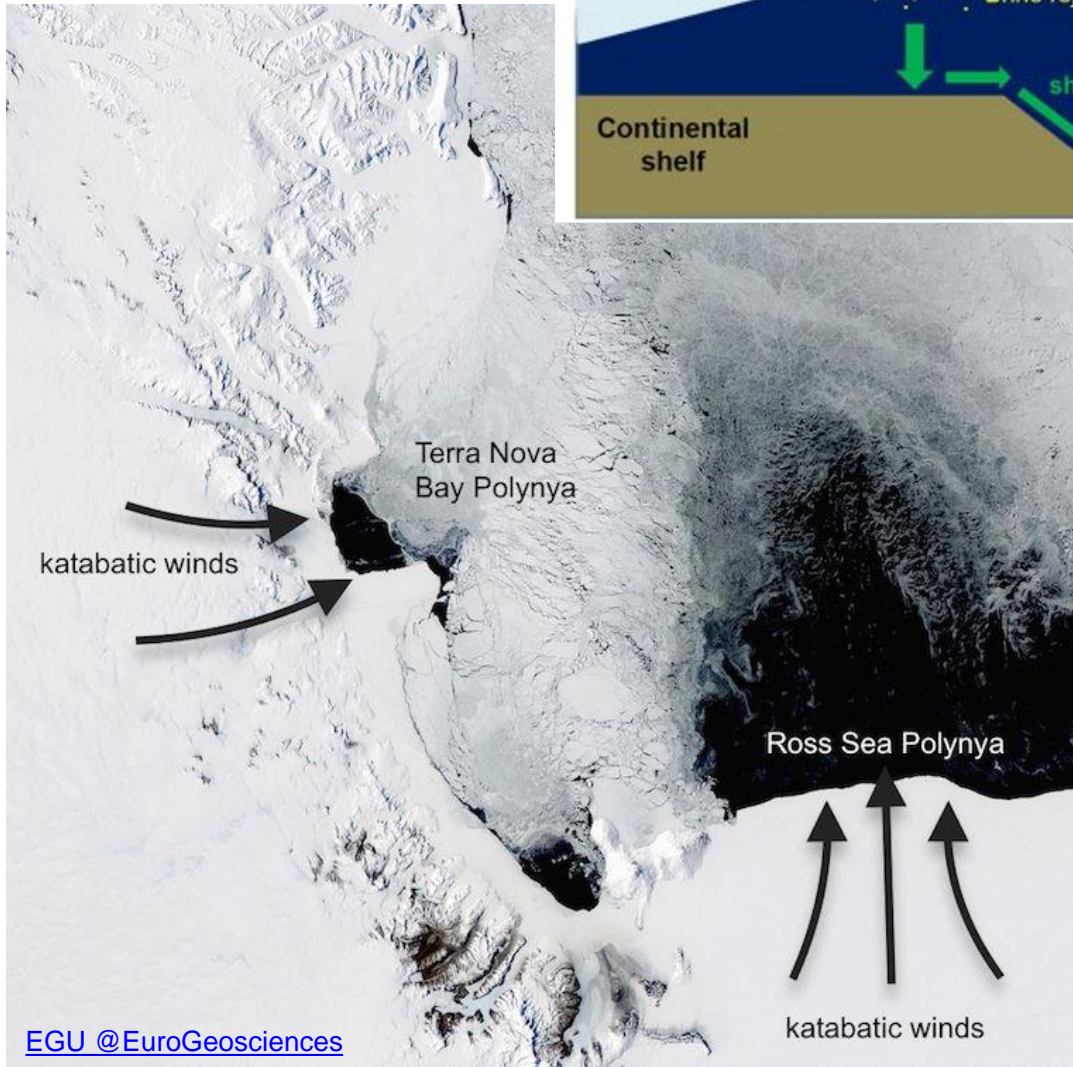
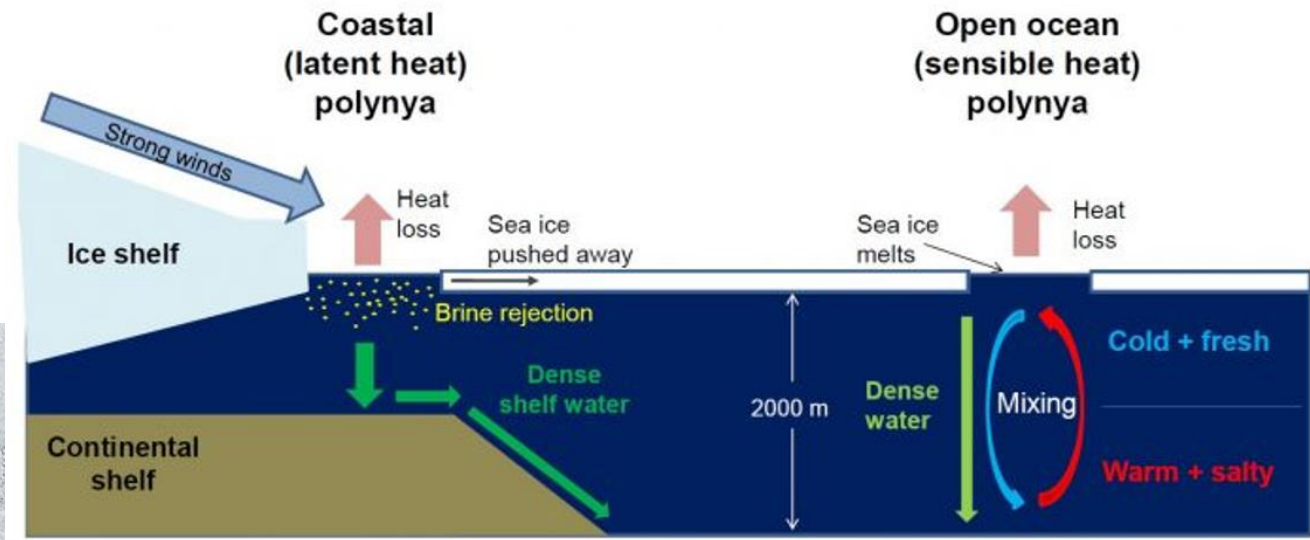
Jun 23

Ross Sea Polynya (RSP)

243 270 K

Kwok et al., 2007

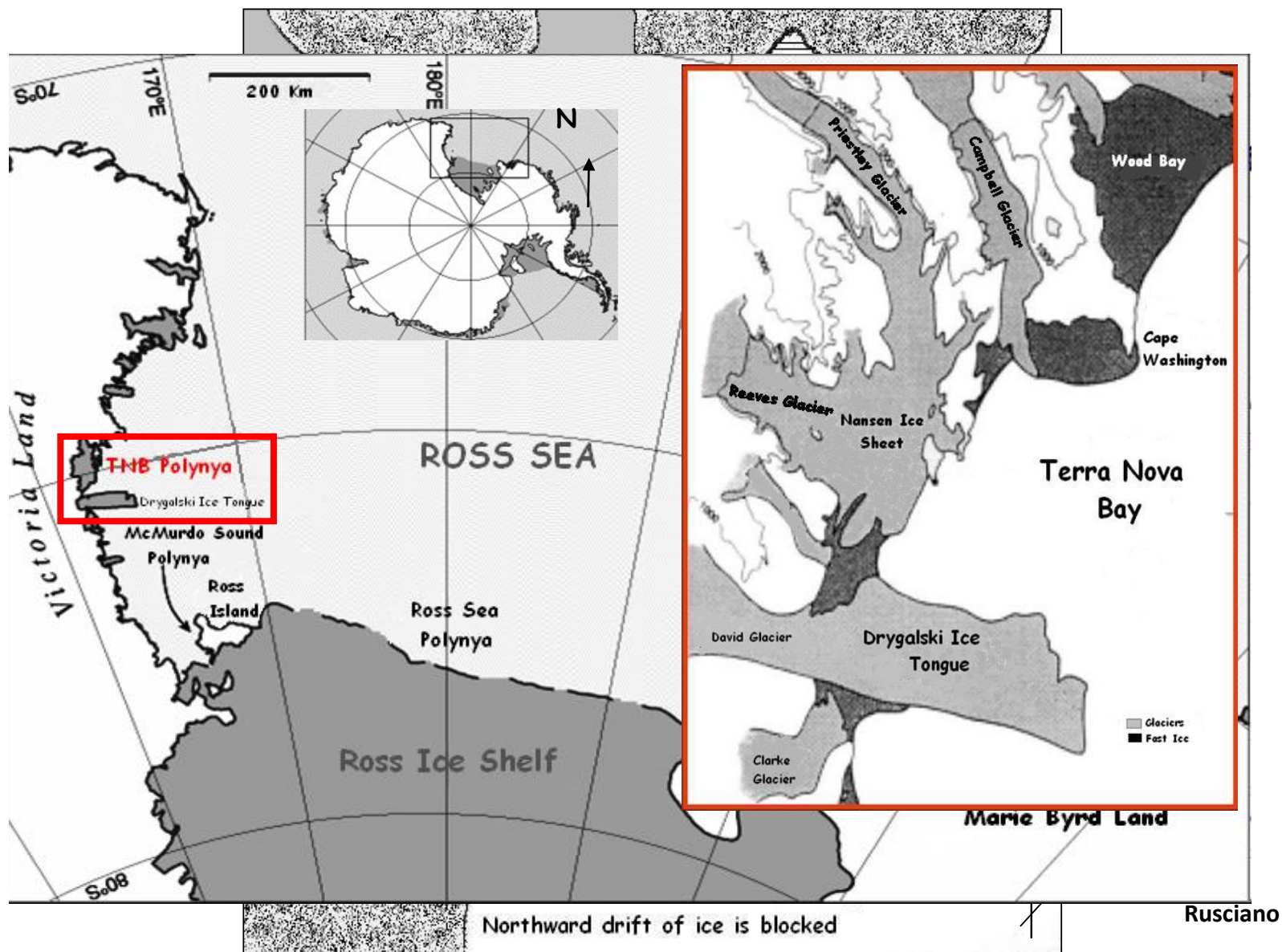




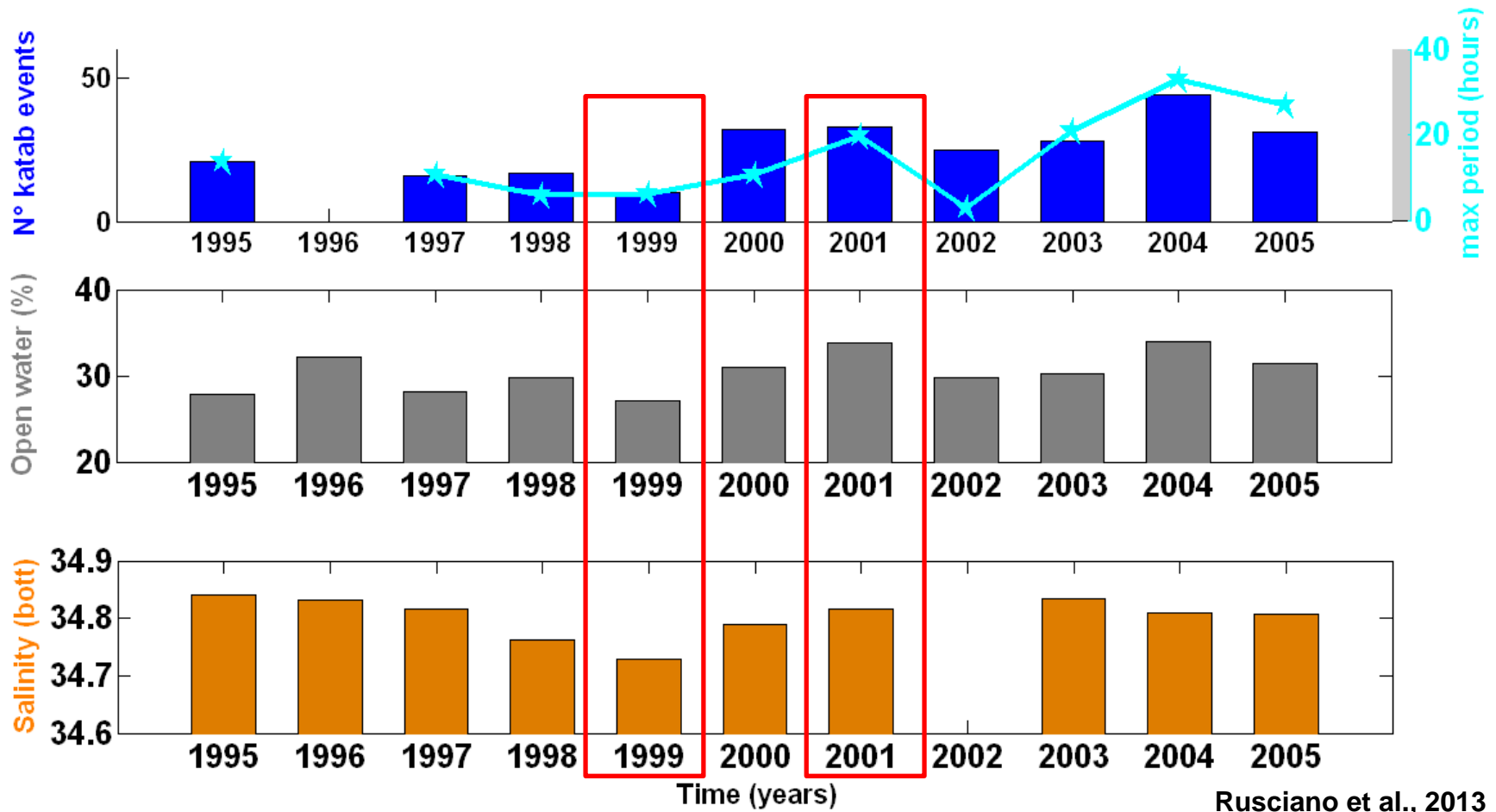
Terra Nova Bay

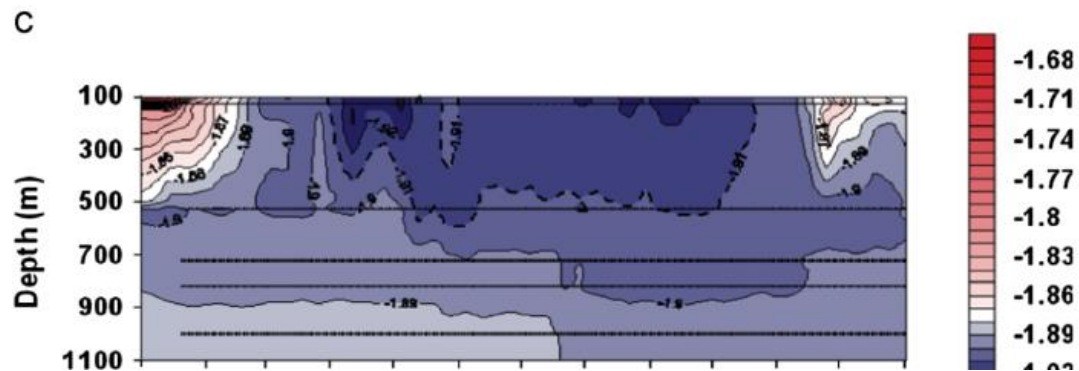
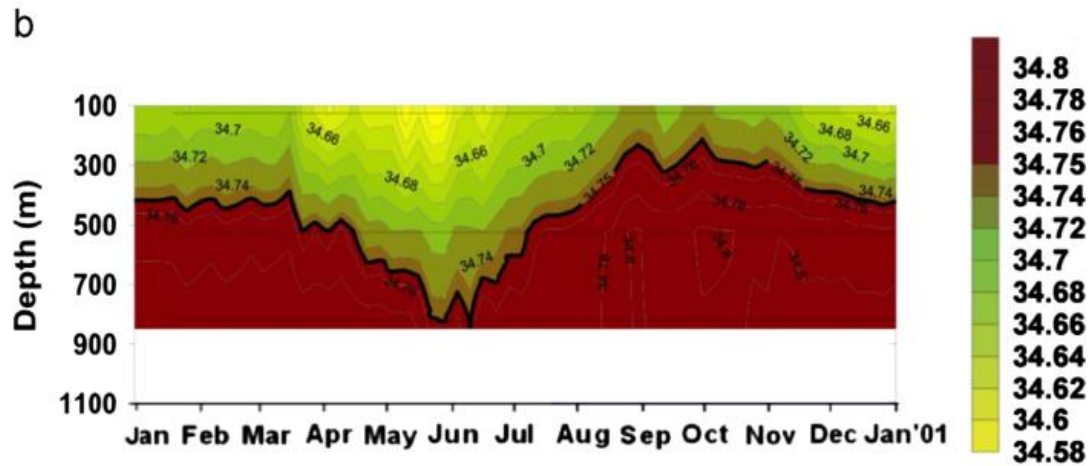
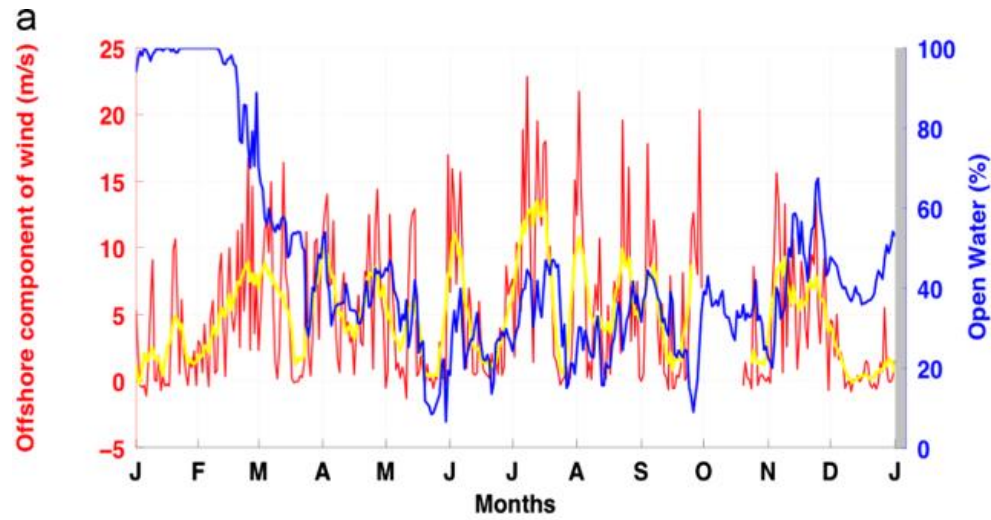


COSTAL POLYNYA

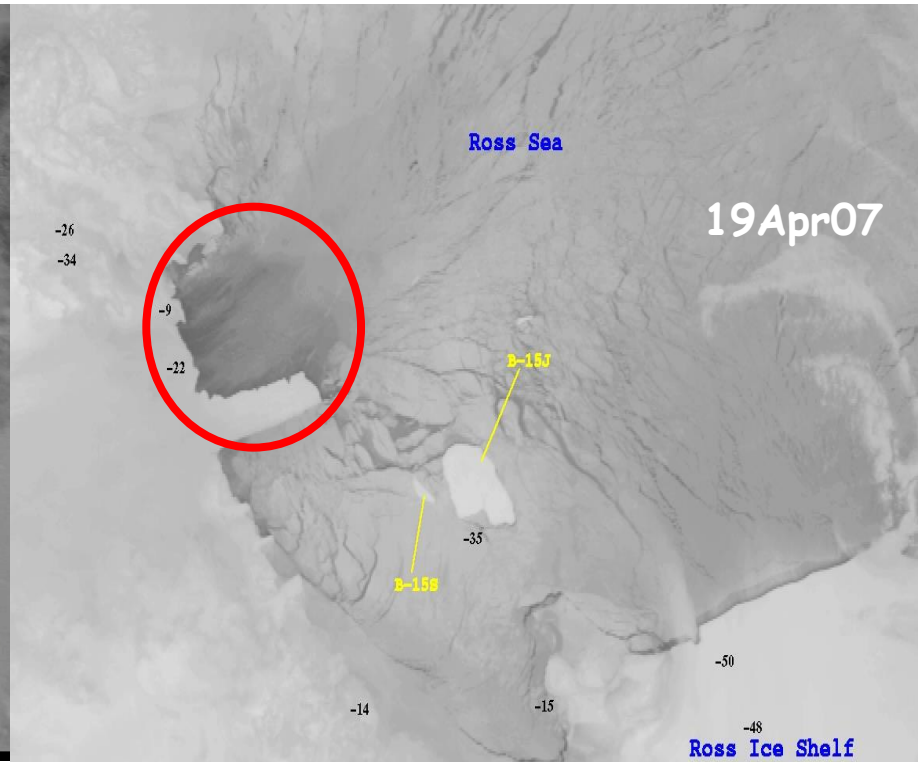
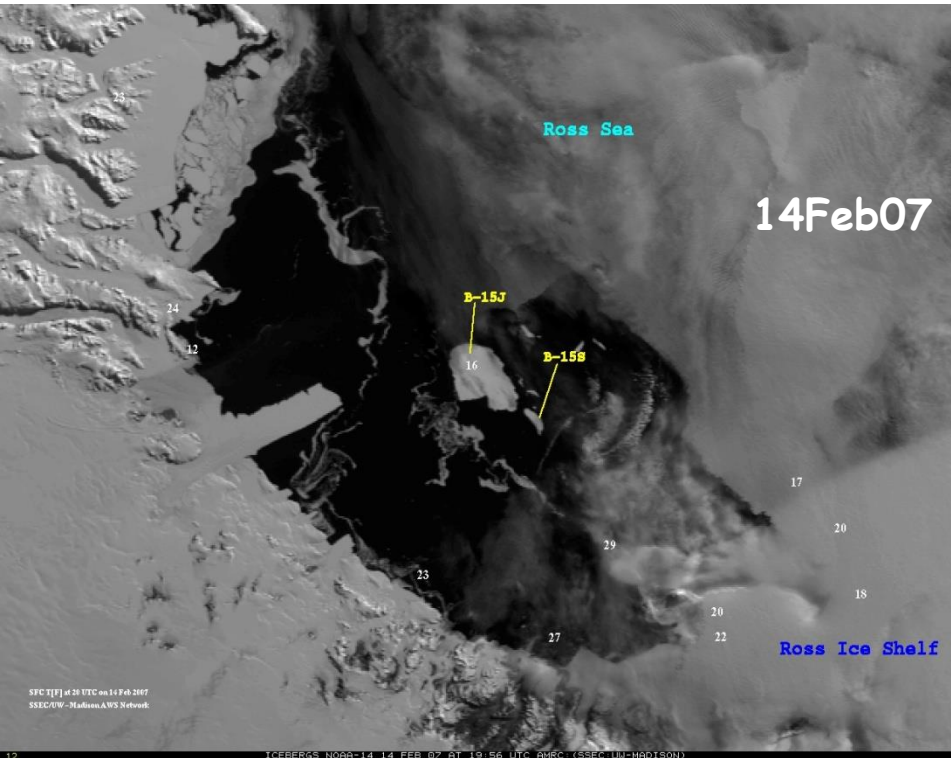


Terra Nova Bay polynya





Terra Nova Bay



Rusciano

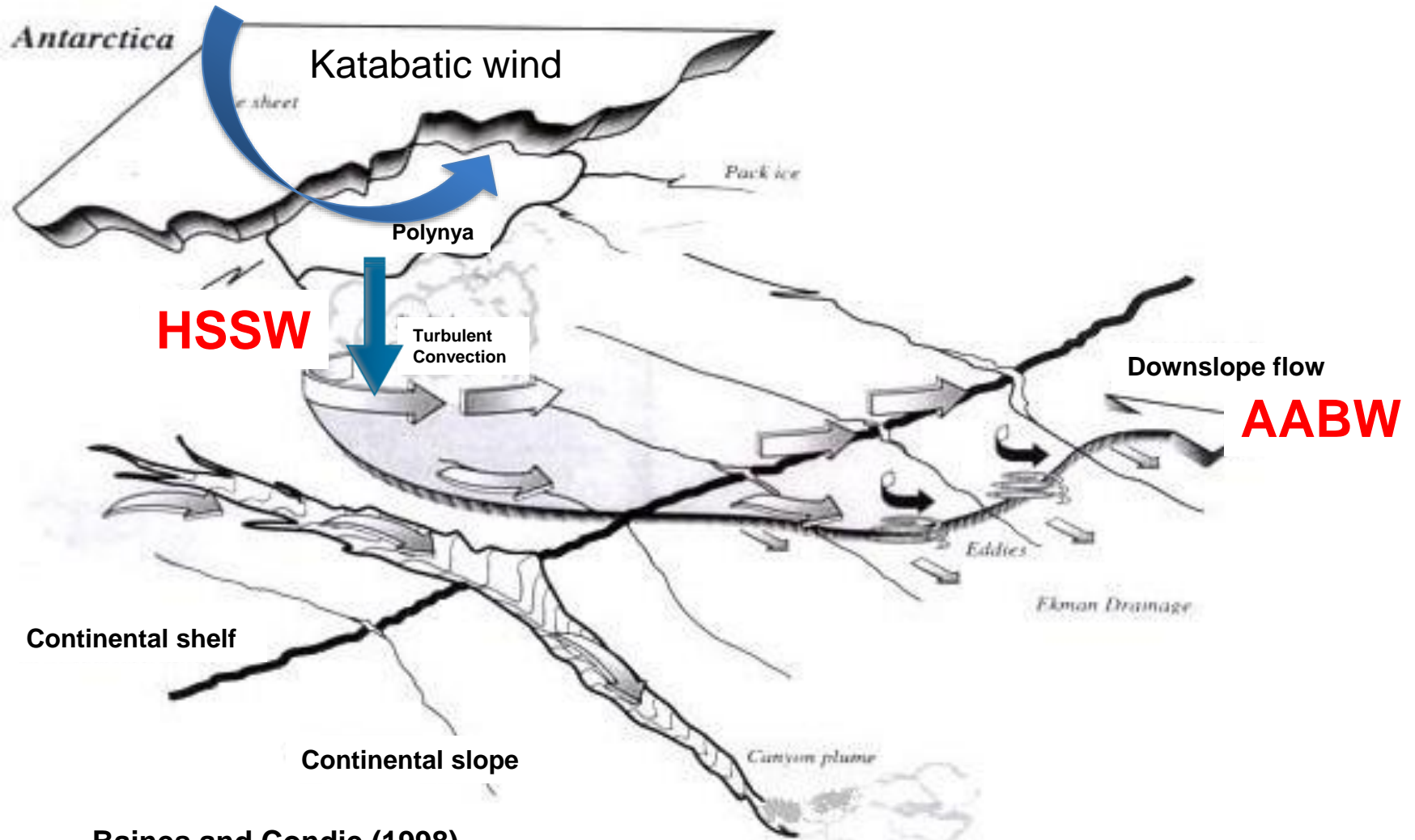
Terra Nova Bay: Ice formation in Terra Nova Bay Polynya



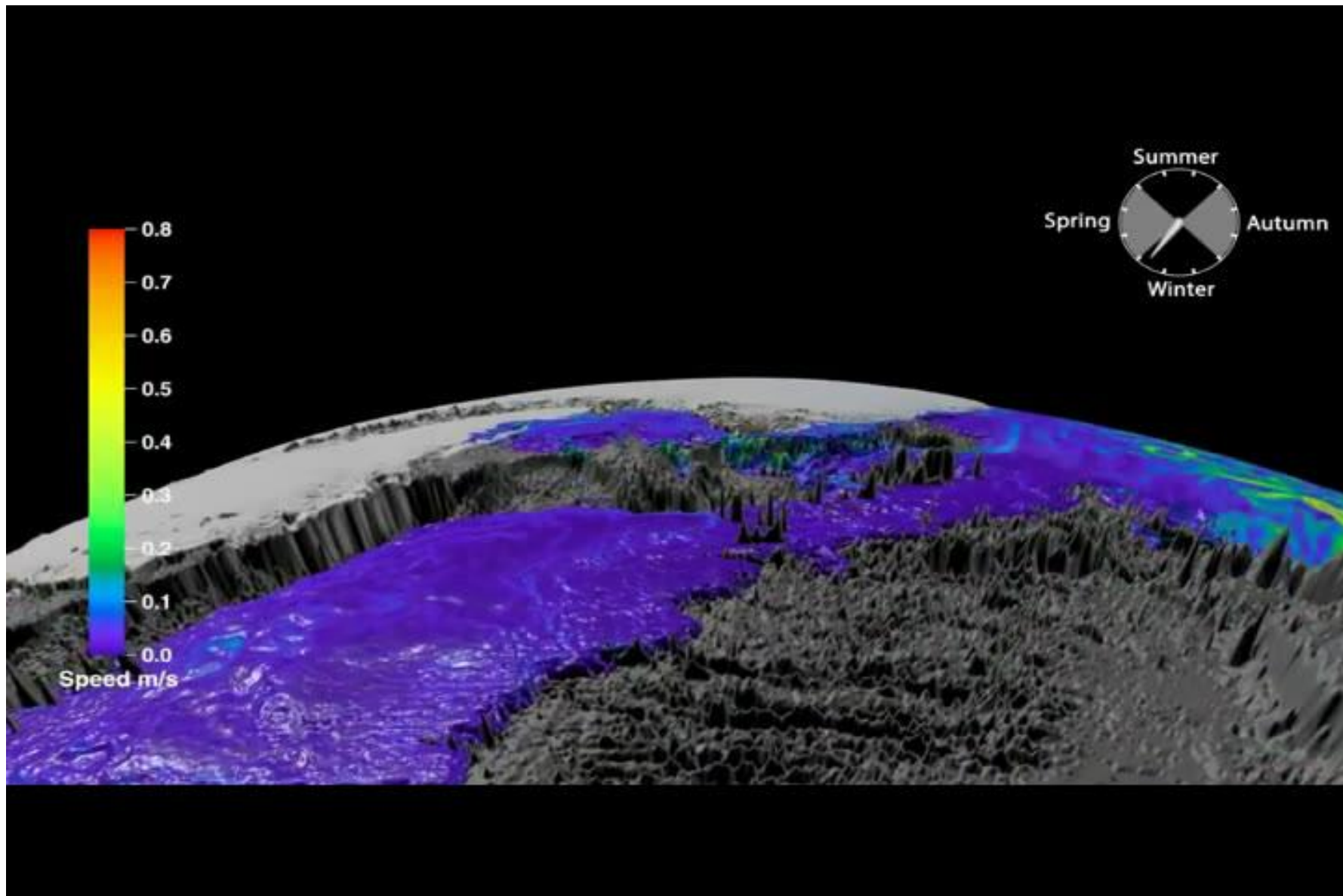
Terra Nova Bay: Ice formation in Terra Nova Bay Polynya



HSSW & AABW water formation process

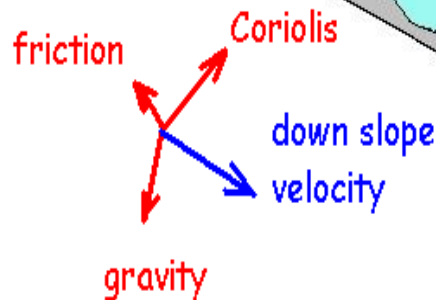
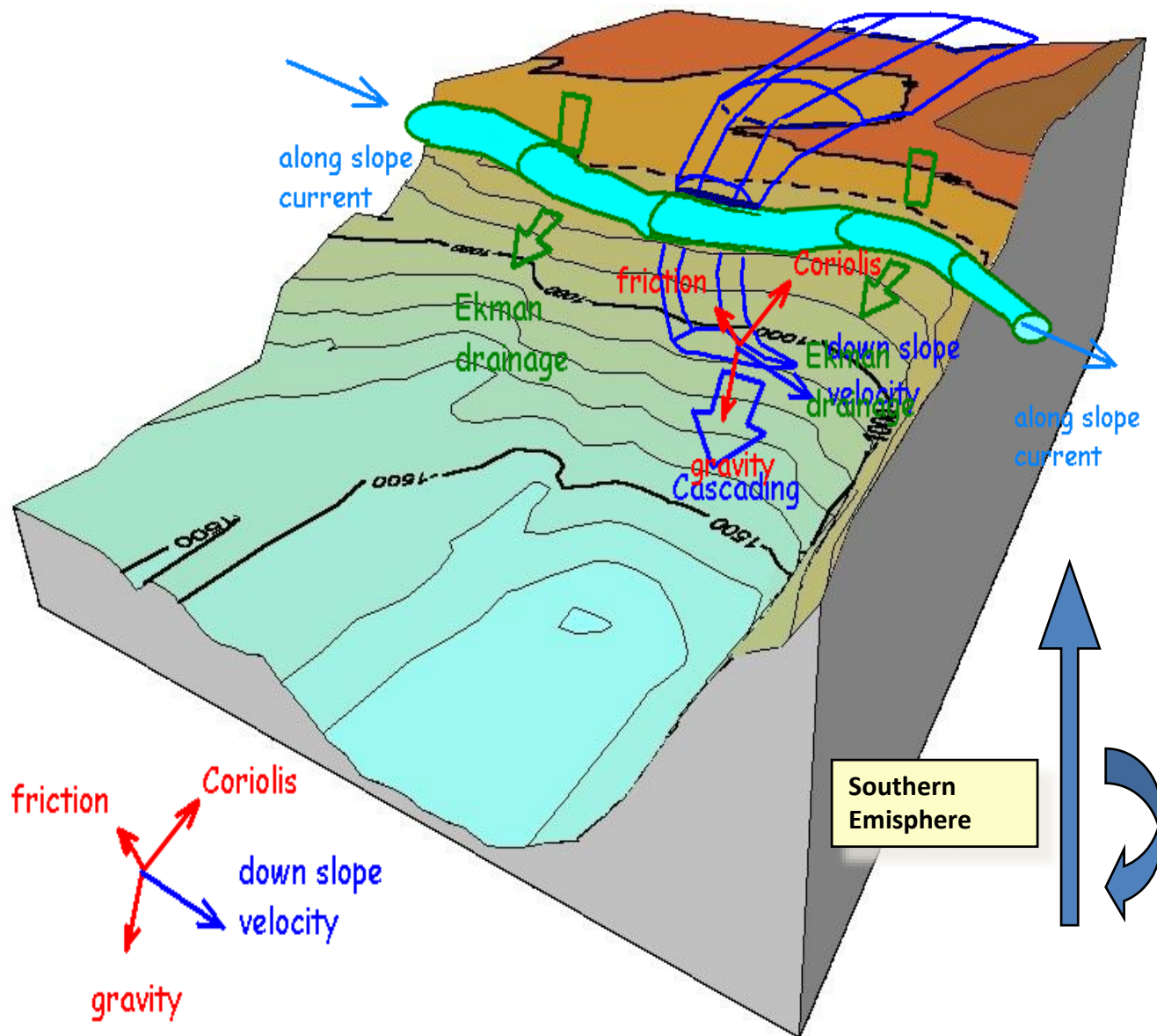


Baines and Condie (1998)

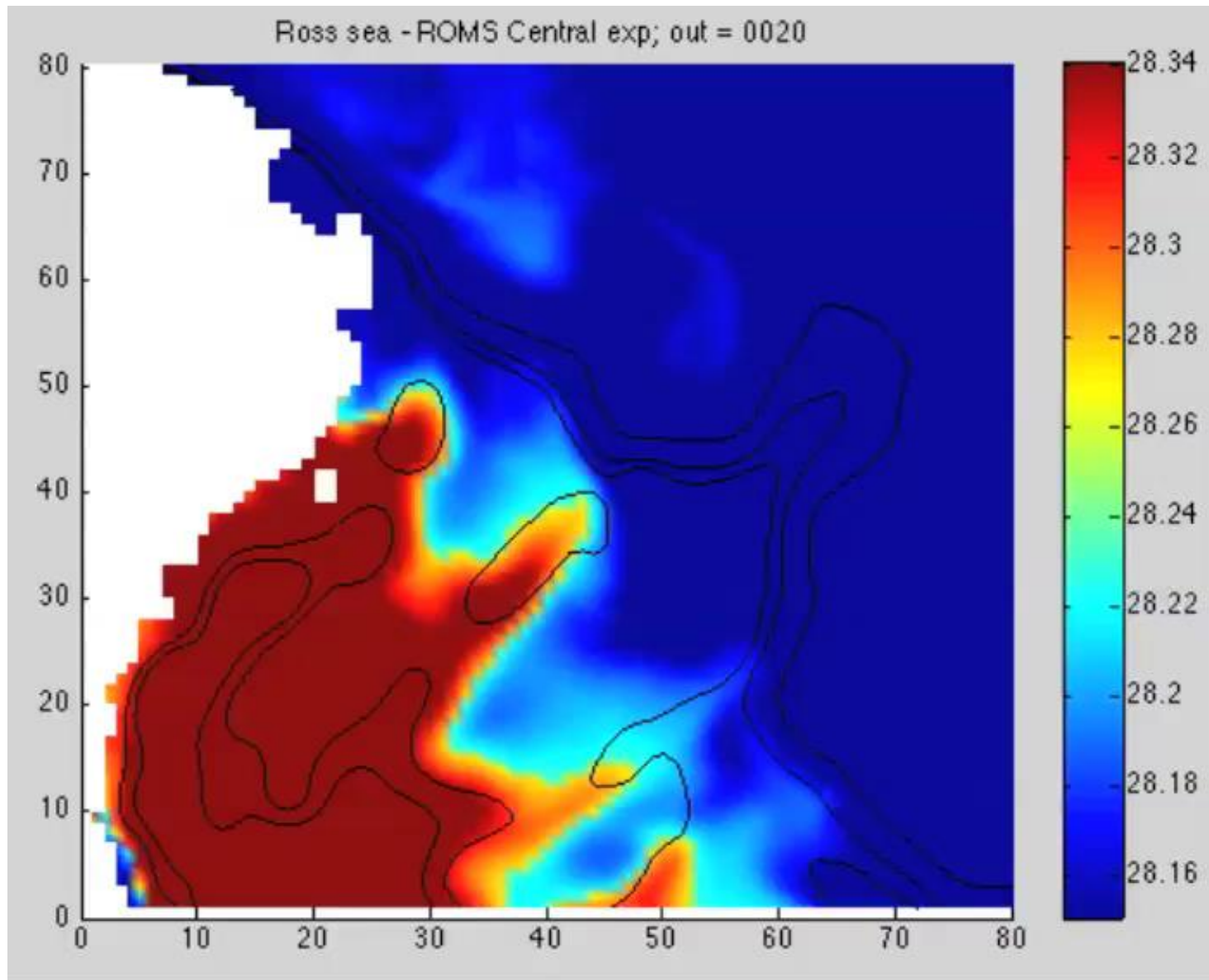


Processes involved in Downslope motion

- **Gravity current cascading**
- **Ekman drainage (bottom Ekman layer transport induced by along slope currents)**
- **All mechanisms that can break the Potential Vorticity Constraint**

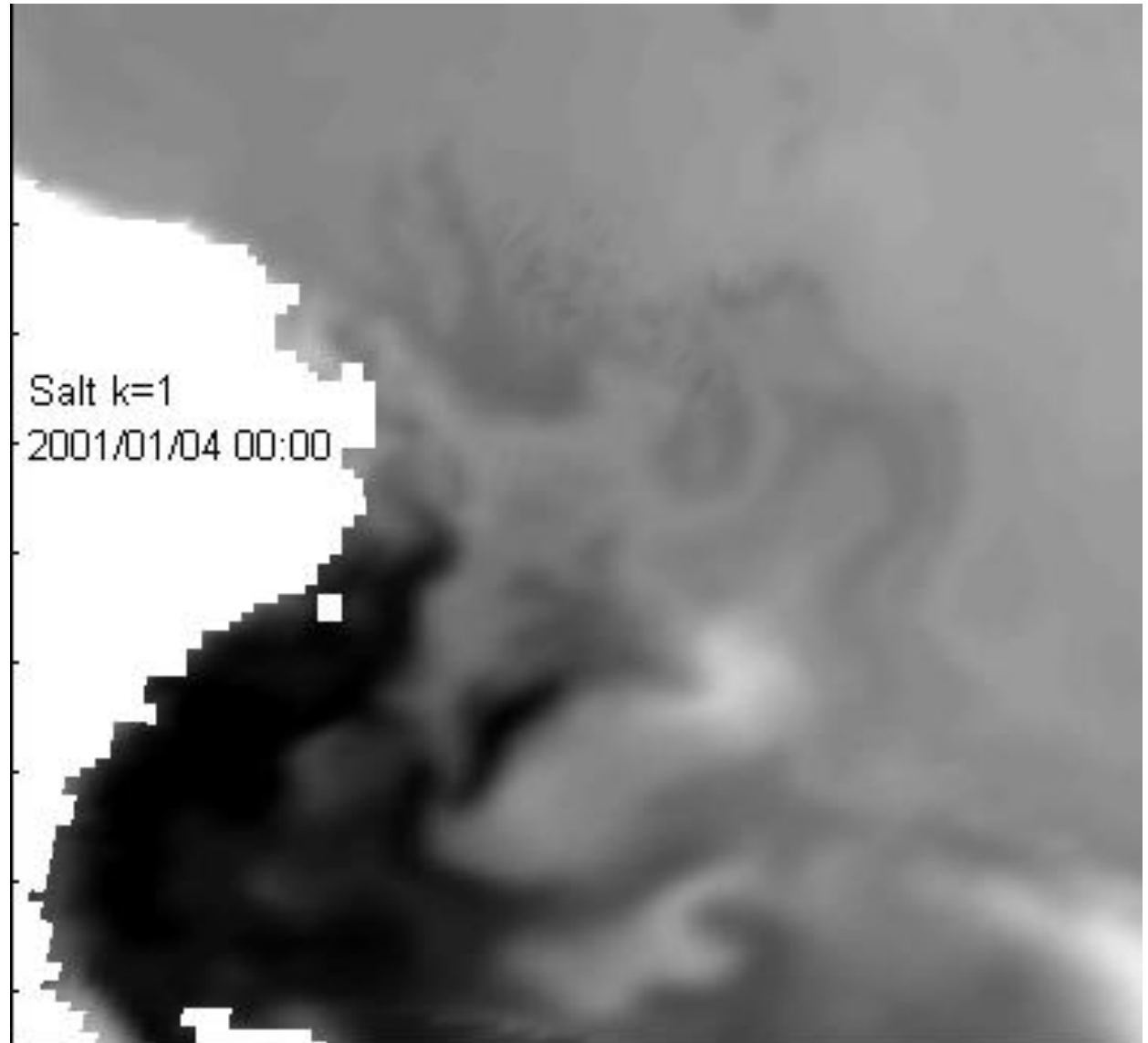


Bottom layer density

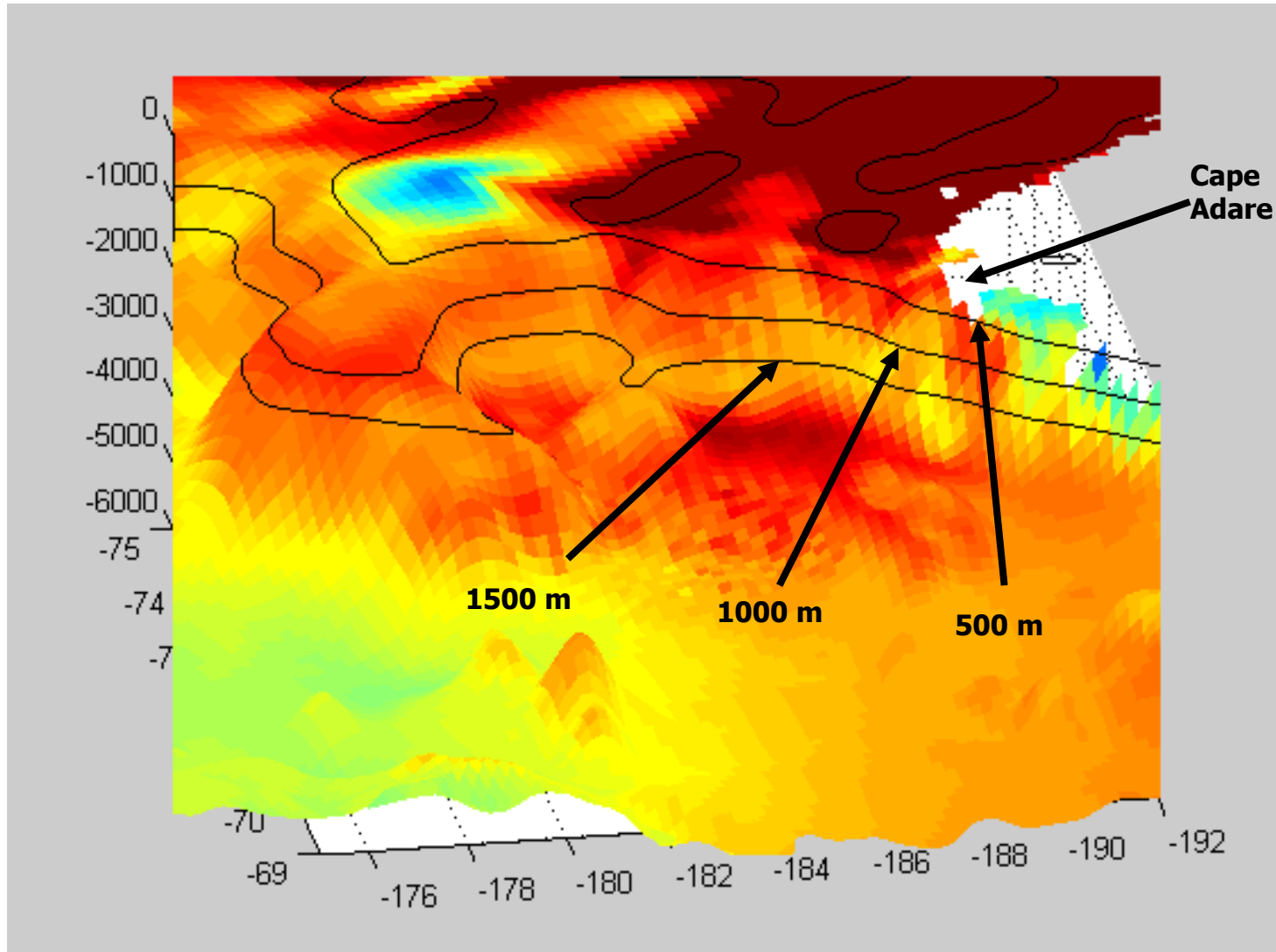


bottom layer salinity

From: 04-01-2001
To: 27-01-2001



3D view 04-01-2001 : 27-01-2001



Climatologia del mare di Ross

A.H. Orsi, C.L. Wiederwohl / *Deep-Sea Research II* 56 (2009) 778–795

779

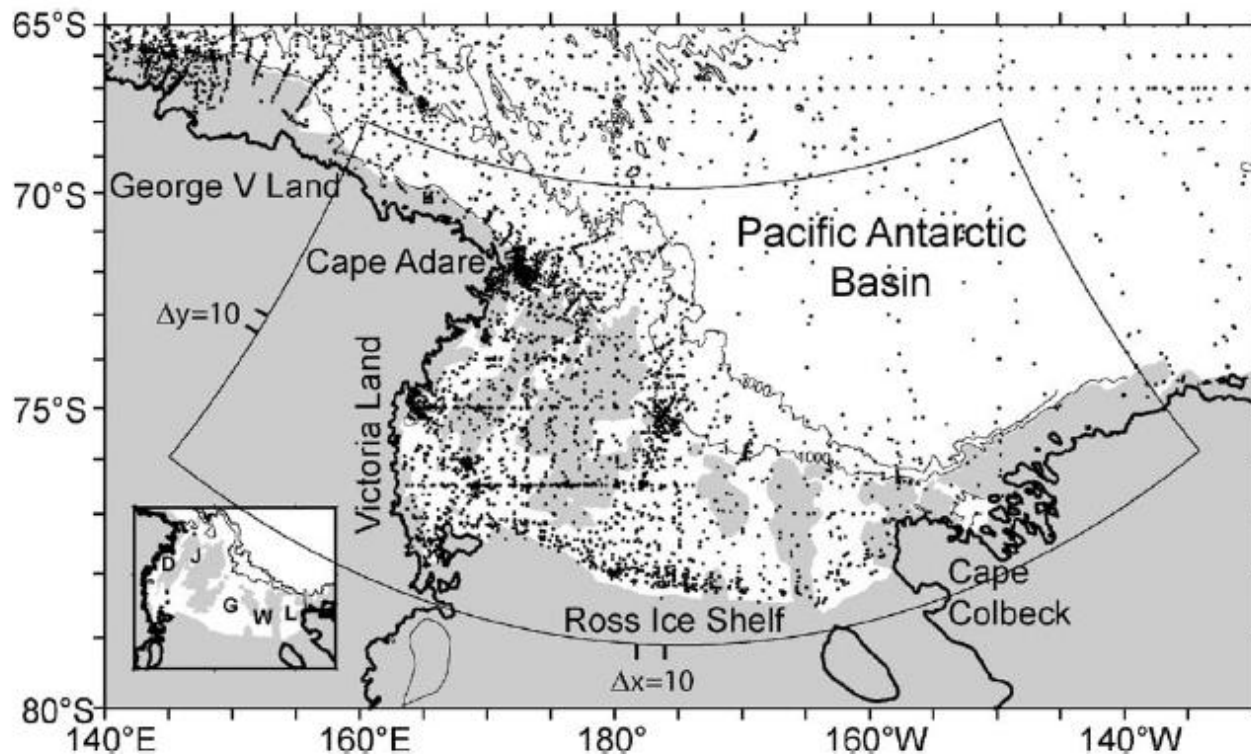


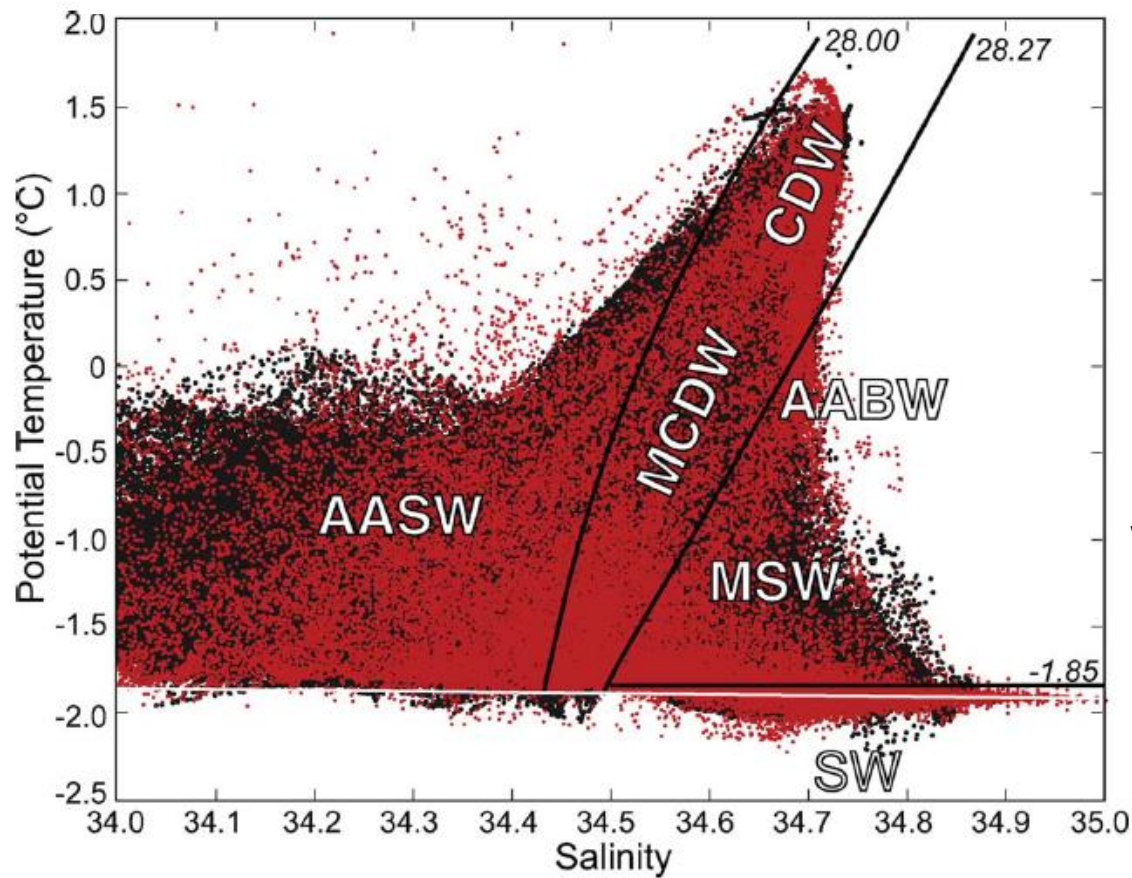
Fig. 1. Base map of the study area. Depths less than 500 m are lightly shaded, and the thin lines show the 1000 and 3000 m isobaths. Small dots show all stations (4364; mostly from the austral summer) used in this study. Meridional (zonal) grid spacing is indicated for 10 adjacent grid points aligned at the western (southern) edge of the grid. Major troughs are labeled in the inset: (D) Drygalski, (J) Joides, (G) Glomar Challenger, (W) Whales, and (L) Little America, separated by the Cary/Mawson, Ross/Pennell/Iselin, Whales, and Little America banks. Bathymetry derived from satellite radar altimetry data (Smith and Sandwell, 1997) and GEBCO-1997 digital isobaths (IOC et al., 1997).

Classificazione della masse d'acqua

- Suddividiamo la verticale in tre livelli individuati da due isopiche di densità neutrale γ_N
- Strato superficiale (L1), ovvero lo strato occupato dalla AASW, limite inferiore $\gamma_N = 28.00 \text{ Kgm}^{-3}$
- Strato di fondo (L3) al di sotto di $\gamma_N = 28.27 \text{ Kgm}^{-3}$ che separa la AABW dalla soprastante CDW
- Lo strato (L2) compreso tra $28.00 \text{ Kgm}^{-3} < \gamma_N < 28.27 \text{ Kgm}^{-3}$ è dove si posiziona la CDW e la MCDW che si trovano a nord e a sud della scarpata continentale

Water mass definitions. Shelf/slope 700 m demarcation refers to water depth.

γ^n layer (kg m^{-3})	Slope (> 700 m)	Shelf (< 700 m)	Properties
Top (L1: < 28.0)	AASW	AASW	
Middle (L2: $28 < \gamma^n < 28.27$)	CDW	MCDW	
Bottom (L3: > 28.27)	AABW	MSW	$\theta > -1.85^\circ\text{C}$
		SW	$\theta < -1.85^\circ\text{C}$
		HSSW	$S > 34.62$
		LSSW	$S < 34.62$
		ISW	$\theta < -1.95^\circ\text{C}$



Da Orsi e
Wiederwohl, 2009

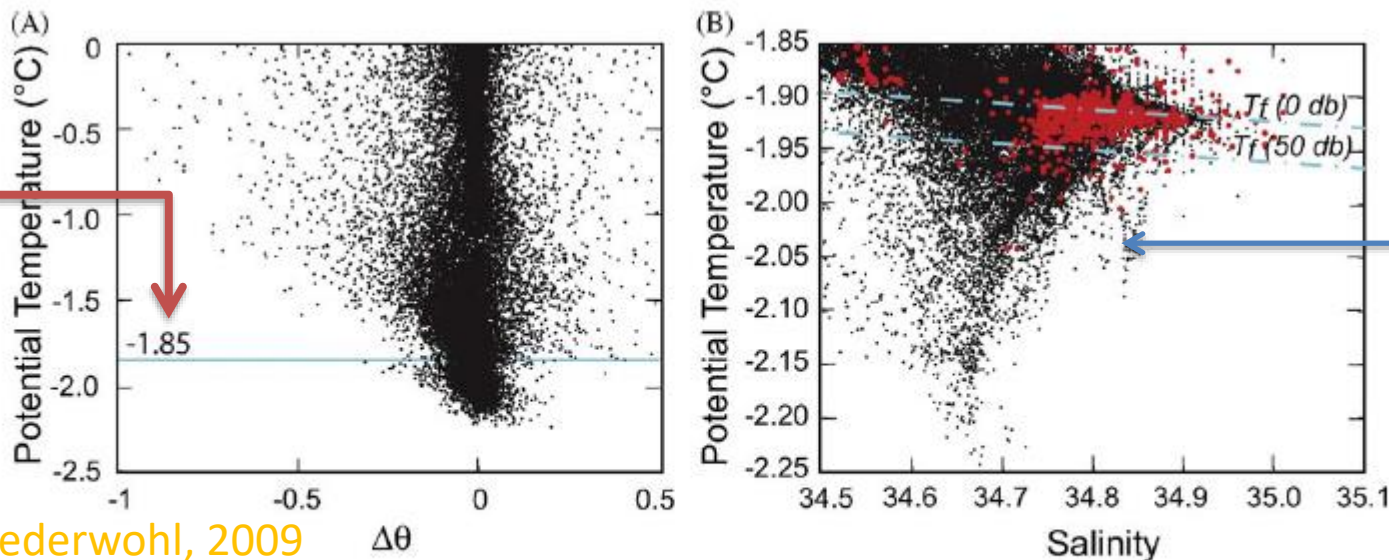


Fig. 2. θ - S scatter plot for Ross Sea stations (red) and climatology (black) at water depths shallower than 2000 m. Solid traces show the 28.00 and 28.27 kg m^{-3} neutral density γ^n surfaces. The white horizontal line shows the surface freezing point of seawater. Major water masses are labeled: Antarctic Surface Water (AASW), Modified Circumpolar Deep Water (MCDW/CDW), Modified Shelf Water (MSW/SW), and Antarctic Bottom Water (AABW). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Shelf Water(SW) e Modified SW

- **Le SW hanno origine** quando il ghiaccio formandosi, converte le acque superficiali (sia le fredde AASW che le più calde MCDW) nelle acque più dense che si trovano in Antartide
- **Le MSW nascono dalla continuo** mescolamento che subiscono le SW nel loro percorso all'interno del mare di Ross
- Forzanti che favoriscono il mescolamento (come le correnti di marea) determinano la transizione tra SW in MSW con caratteristiche intermedie tra le masse acqua che partecipano al processo di formazione

- Limite superiore (isoterma) delle SW : $\theta = -1.85^{\circ}\text{C}$
- \Rightarrow SW si hanno quando $\theta < -1.85^{\circ}\text{C}$ con salinità che compresa in un range abbastanza ampio ($S > 34.50$ psu)
- Se $\theta > -1.85^{\circ}\text{C}$ (nello strato di fondo) \Rightarrow MSW
- Acque superfredde che non derivano da interazioni superficiali (sono sotto la temp di cong a 50 db) sono effetto di interazioni con il ghiaccio
- $\theta < -1.95^{\circ}\text{C}$ è il limite dell Ice Shelf Water (ISW)



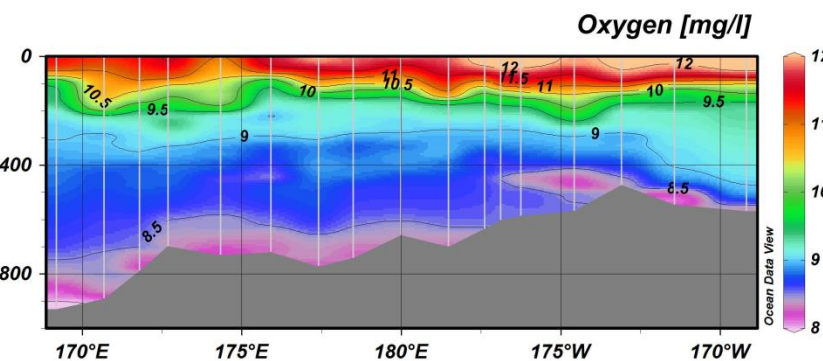
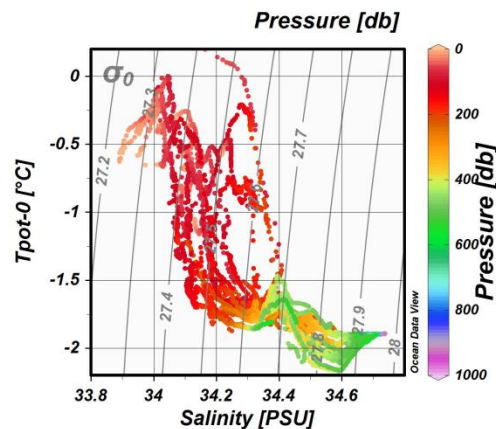
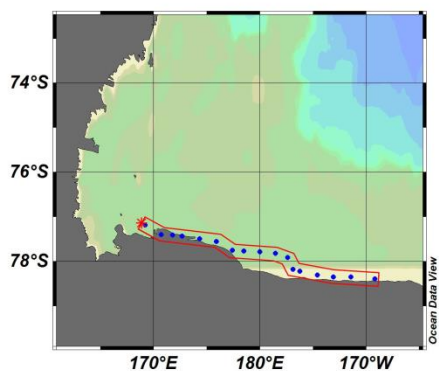
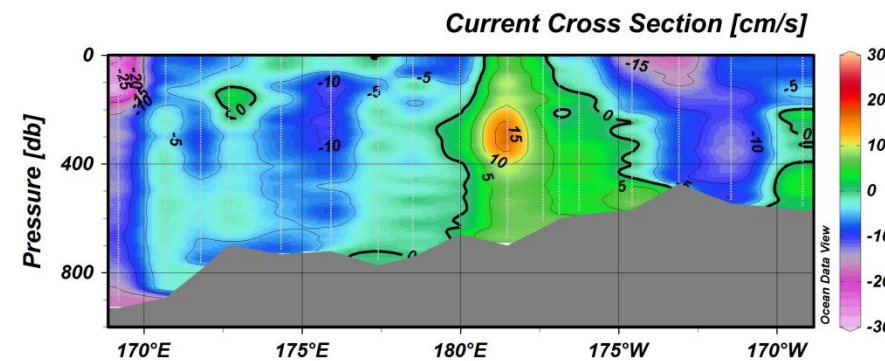
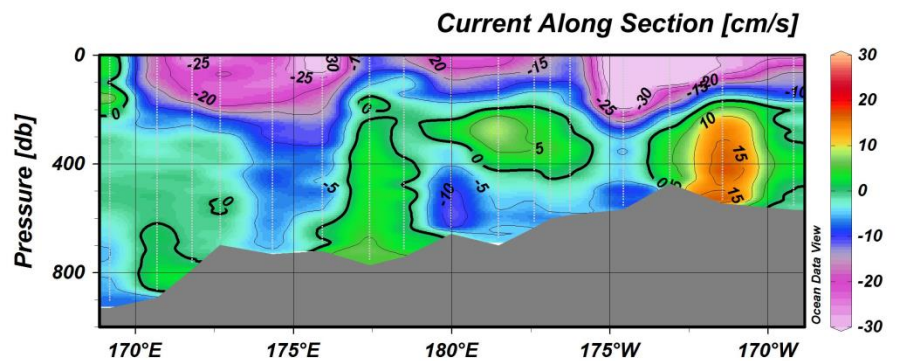
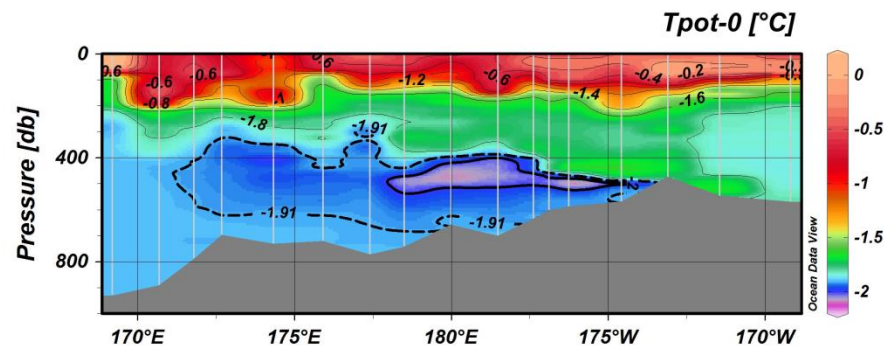
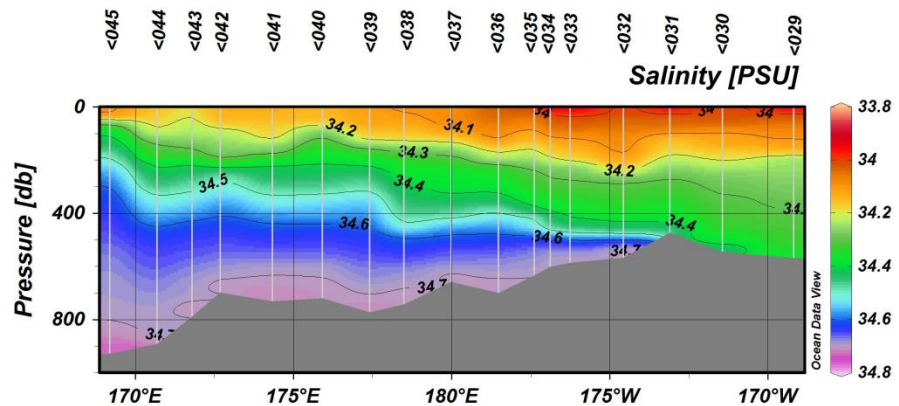
Da Orsi e Wiederwohl, 2009

Fig. 3. (A) Scatter plot of 10 m vertical thermal gradient at $\gamma^n > 28.10 \text{ kg m}^{-3}$ against temperature from CTD data in the Ross Sea. (B) θ -S Scatter for SW with red dots showing bottom values deeper than 500 m. Dashed lines show freezing temperatures at the sea surface and at 50 db. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

High Salinity Shelf Water (HSSW)

- Il ghiaccio marino è meno salato rispetto all'acqua che lo genera
- Nella fase di formazione, la parte in “eccedenza” rimane in acqua aumentando la salinità degli strati superficiali
- **Si forma così la HSSW.**
- La produzione di ghiaccio durante l'inverno è maggiore nelle aree di polynya
- Questo crea un gradiente di salinità E-W

- Si distinguono pertanto una HSSW ed una Low SSW (LSSW)
- La prima è presente nel settore occidentale del mare di Ross, si diffonde in profondità seguendo l'asse del Drygalsky basin sia verso nord che verso sud.
- Verso nord, raggiunge la shelf break dove, per mescolamento, crea con CDW acque dense e di fondo
- Verso Sud si ha “ragionevole” convinzione che fluisca sotto il Ross Ice Shelf dal quale (per interazione con la base del ghiaccio) uscirà più fredda, meno salata e densa come ISW.
- Il segnale di ISW si osserva a quote intermedie (300-500m)

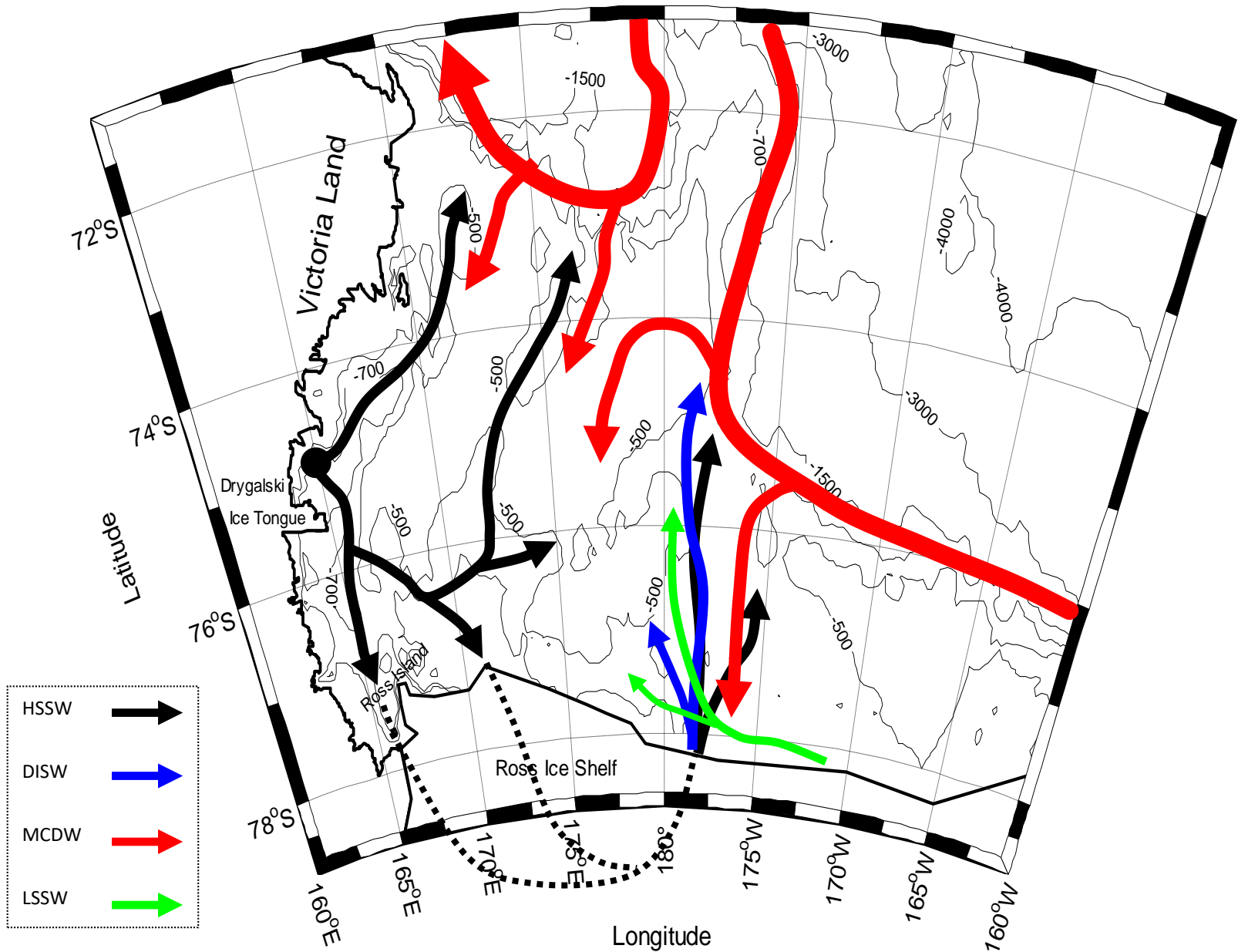


PNRA – XXVII sped – Dal report di campagna - Spezie et al., 2012

- La ISW procede verso lo shelf break dove per mescolamento con la MCDW contribuirà a produrre ancora acqua densa e di fondo
- **La LSSW, si osserva** nel settore centro- orientale del mare di Ross ed è il prodotto di processi di modifica della AASW
- I continui cicli di raffreddamento, scioglimento e congelamento della superficie determinano valori relativamente variabili della AASW con conseguente impatto sulla LSSW.

Sea water type	LSSW	HSSW
Parameter		
Potential Temperature (°C)	-1.80	-1.92
Salinity	34.47	34.88
Oxygen ($\mu\text{mol dm}^{-3}$)	300	298
Phosphate ($\mu\text{mol dm}^{-3}$)	2.1	2.2
Nitrate ($\mu\text{mol dm}^{-3}$)	29.0	31.0
Silicate ($\mu\text{mol dm}^{-3}$)	76.0	80.0
Potential vorticity ($\text{m}^{-1} \text{sec}^{-1}$) x 10^8	0.075	0.001
Mass conservation	-	-

Circolazione in L2 e L3 (intermedia e profonda)



From Budillon et al., Antarctic Science 2003

Circolazione in L1 (AASW)

Circolazione ciclonica nell'area del mare di Ross

- Flusso verso W allo shelf break come **Antarctic Slope Current**

- Fronte alino (**Antarctic Slope Front**)

- Oltre al flusso verso W si osserva una deflessione verso S, passato capo Colbeck, Tale flusso si osserva anche a 300 m e rappresenta la **Antarctic Coastal Current**.

- Ancora più a Sud la AASW si incunea sotto il RIS, dove per interazione con la base del ghiaccio, si "osserva" una riduzione della sua T fino a quella di congelamento.

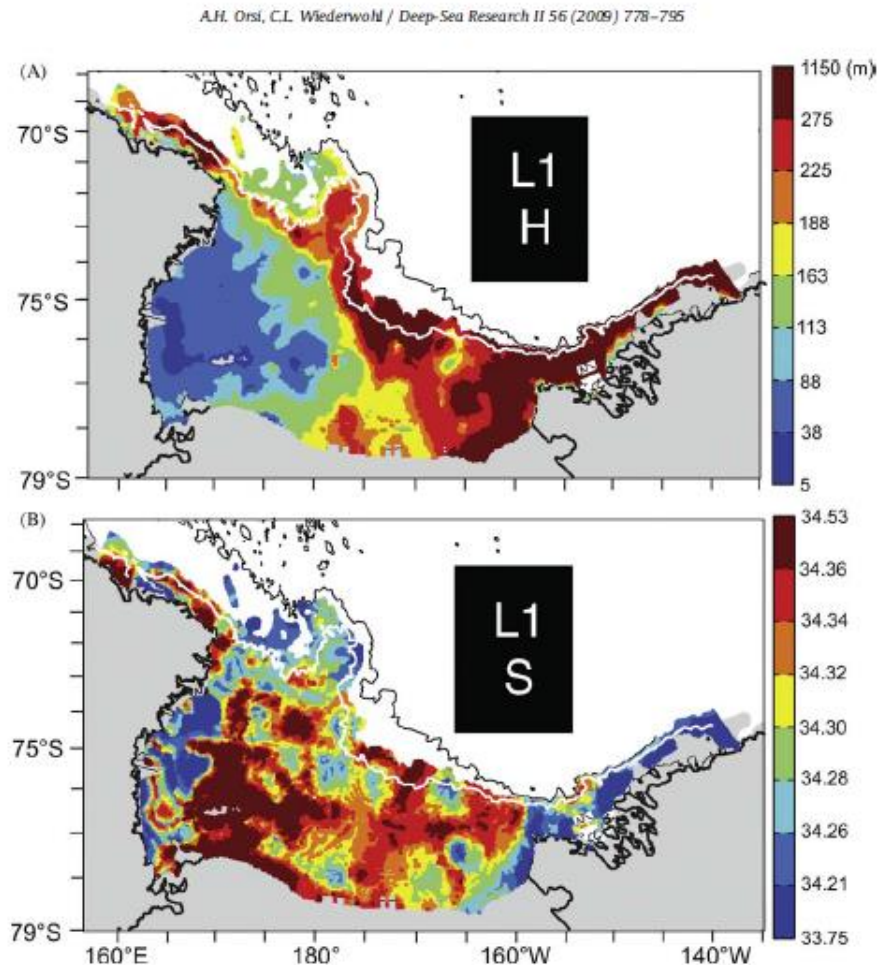
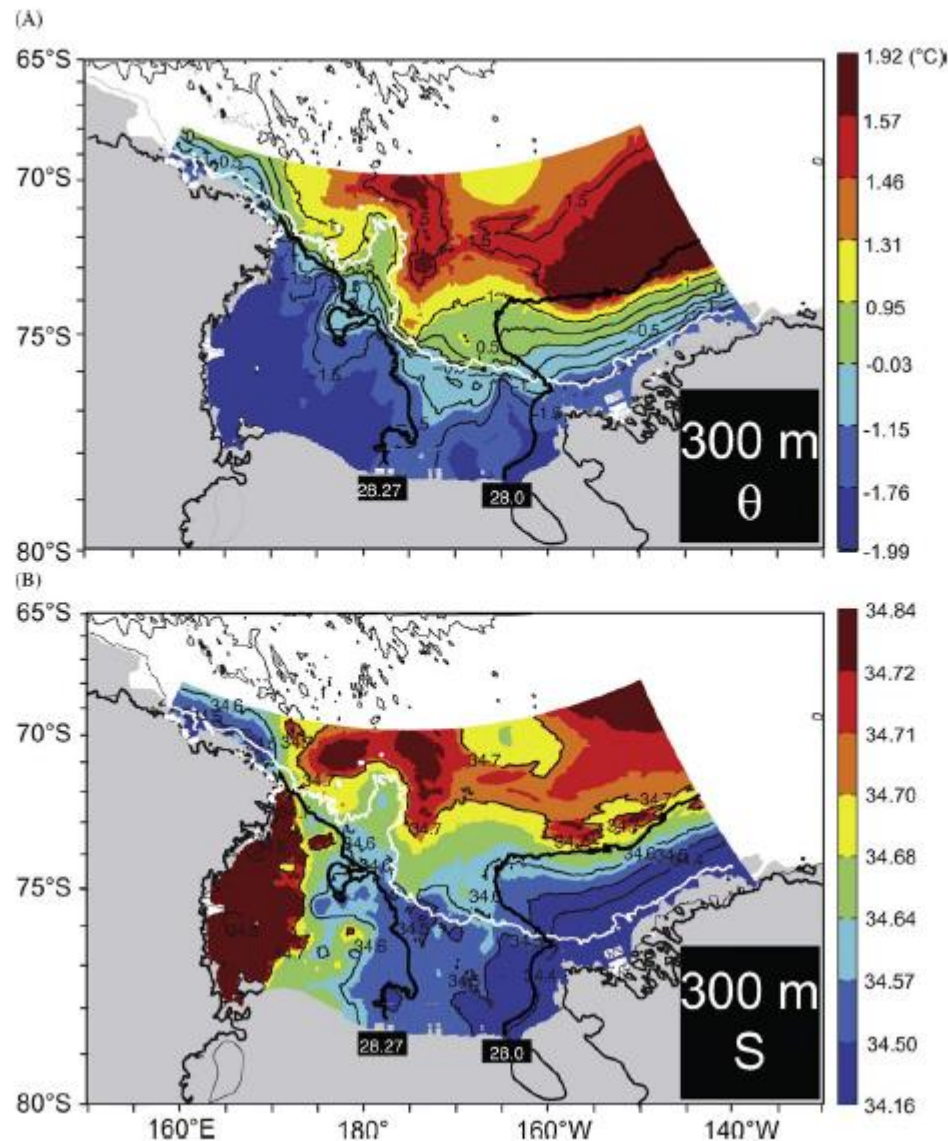


Fig. 5. (A) Thickness (m) and (B) salinity average for the top density layer (L1: $\sigma^t < 28.00 \text{ kgm}^{-3}$) spanning AASW. The white (black) line shows the 1000 m (3000 m) isobath. Areas shown with the same color extend over 1/8 of the total spatial domain mapped at water depths shallower than 2000 m.

Input oceanico

A.H. Orsi, C.L. Wiederwohl / Deep-Sea Research II 56 (2009) 778–795

783

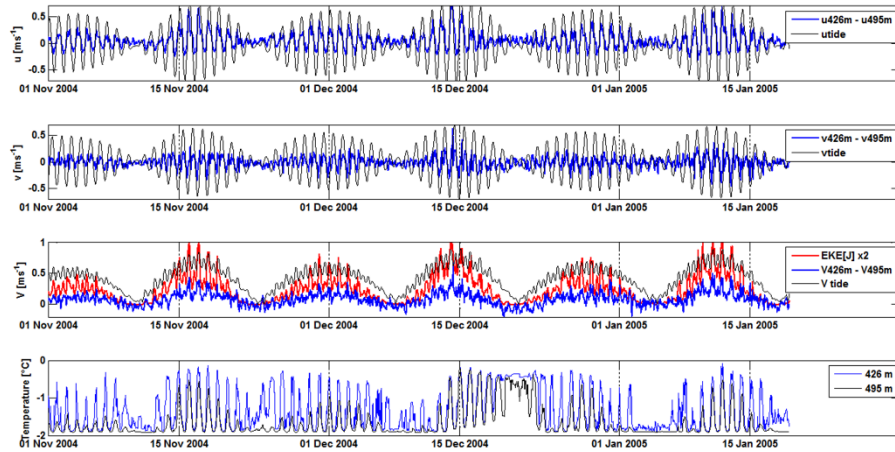


- La CDW entra nel Ross gyre dal margine orientale
- Come la AASW anche la MCDW allo shelf break è trasportata verso W con caratteristiche che si attenuano lungo il tragitto
- Lungo lo shelf break a prof > 700 m si osserva una stato spesso circa 1000 metri di CDW con $T \cong 0.6^\circ\text{C}$

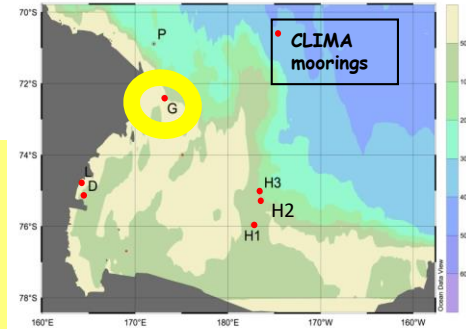
Fig. 6. (A) Potential temperature (°C) and (B) salinity at 300 m. The white line shows the 1000 m isobath; black contours show the traces of the $\sigma^T = 28.00$ and 28.27 kg m^{-3} isopycnals at 300 m. Areas shown with the same color extend over 1/8 of the total spatial domain mapped.

Ruolo marea nell'intrusion di CDW inflow sulla piattaforma

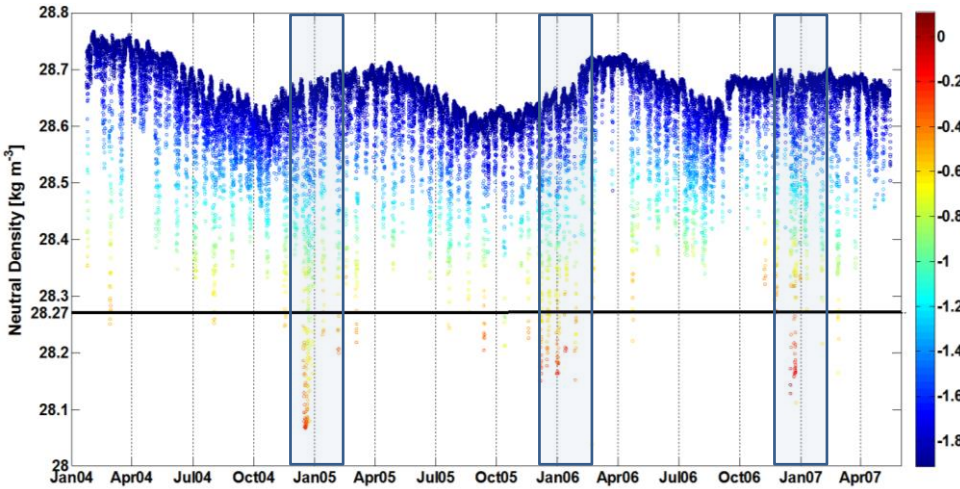
Daily and fortnightly



The variability of the MCDW inflow is related to the tidal forcing at all time scales

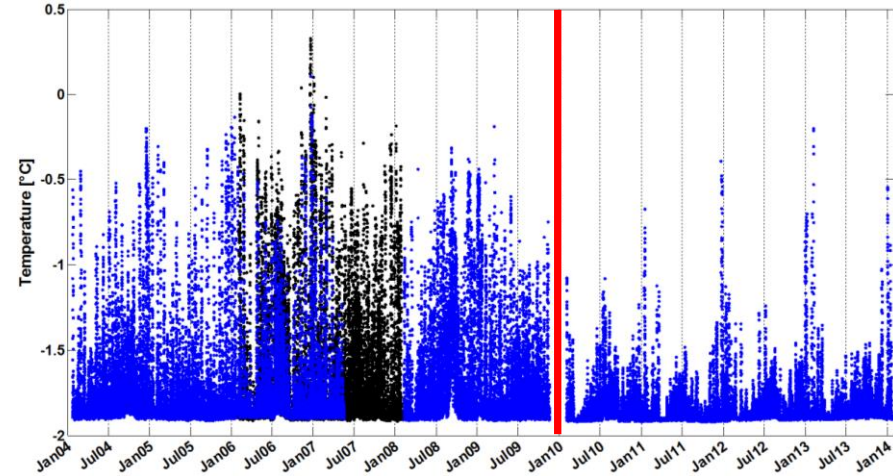


Seasonal

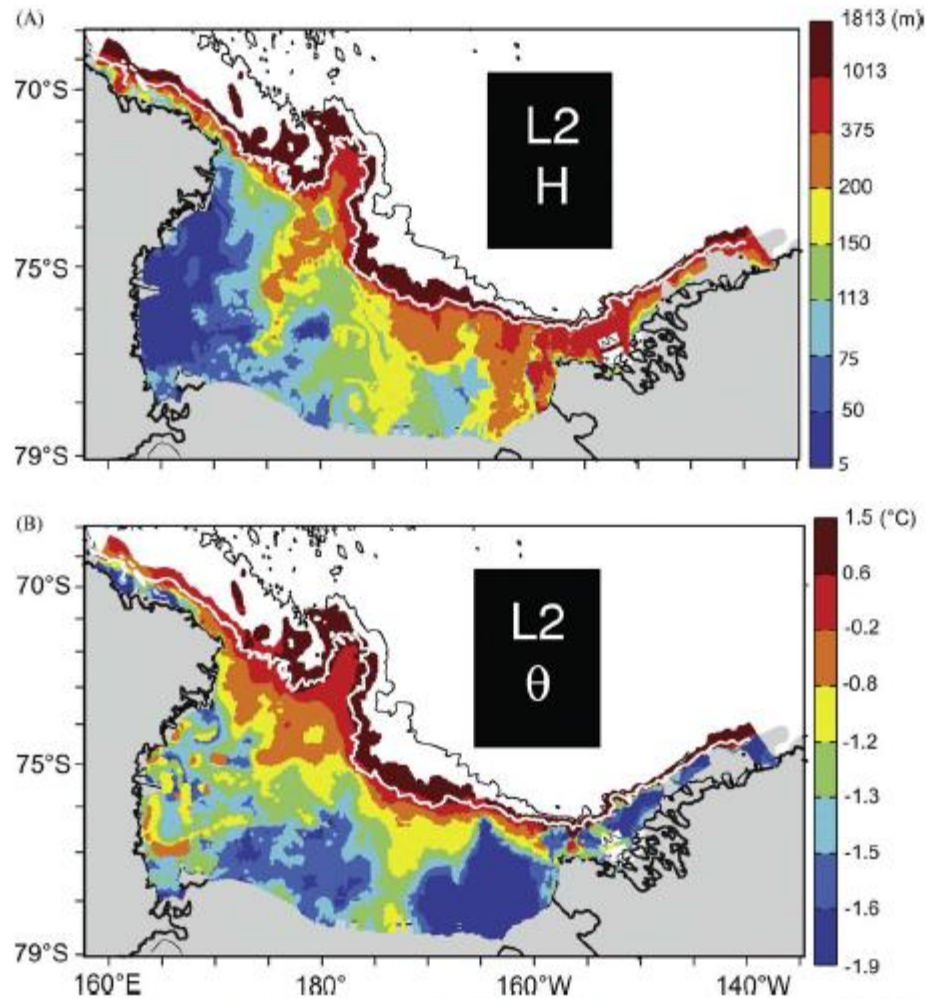


A high presence of CDW is observed each austral summer around the end of December beginning of January.

Interannual



A change in the temperature signal fluctuations is observed before and after 2010. Strong daily fluctuations are present from 2004 to 2010, while they are much less evident after 2010

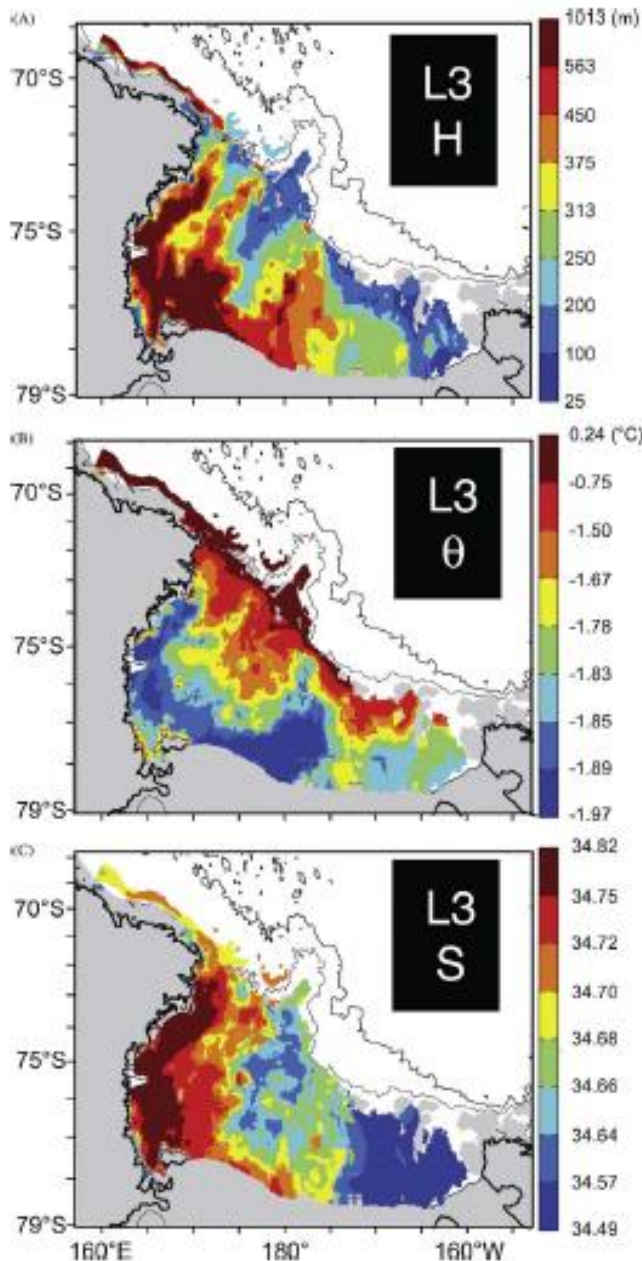


-Intorno ai 170 W nel Glomar basin si osserva l'intrusione di acqua oceanica : MCDW con $\theta > -1.2^{\circ}\text{C}$ e $S > 34.5$

-Dal Drygalsky e dal Joides basin giungono input relativamente calda che si estendono verso il RIS.

Fig. 7. (A) Thickness (m) and (B) potential temperature ($^{\circ}\text{C}$) for the middle density layer (L2: $28.00\text{ kg m}^{-3} < \gamma^{\ast} < 28.27\text{ kg m}^{-3}$) spanning MCDW and CDW. The white line shows the 1000m isobath. Areas shown with the same color extend over 1/8 of the total spatial domain mapped at water depths shallower than 2000m.

Shelf outflow



- Lo strato di fondo è occupato da AABW a profondità >700 m e da SW e MSW sulla piattaforma
- Nessuna di queste masse d'acqua si osserva a E di 160 °W (topografia)
- Il segnale di O₂ può essere utilizzato per individuare le regioni di formazione ed il percorso successivo

Fig. 8. (A) Thickness (m), (B) potential temperature (°C), and (C) salinity averages for the bottom density layer (L3: $\sigma^*_t > 28.27 \text{ kg m}^{-3}$) spanning SW, MSW, and AABW. Depths less than 500 m are lightly shaded, and the thin lines show the 1000 and 3000 m isobaths. Areas shown with the same color extend over 1/3 of the total spatial domain mapped at water depths shallower than 2000 m.

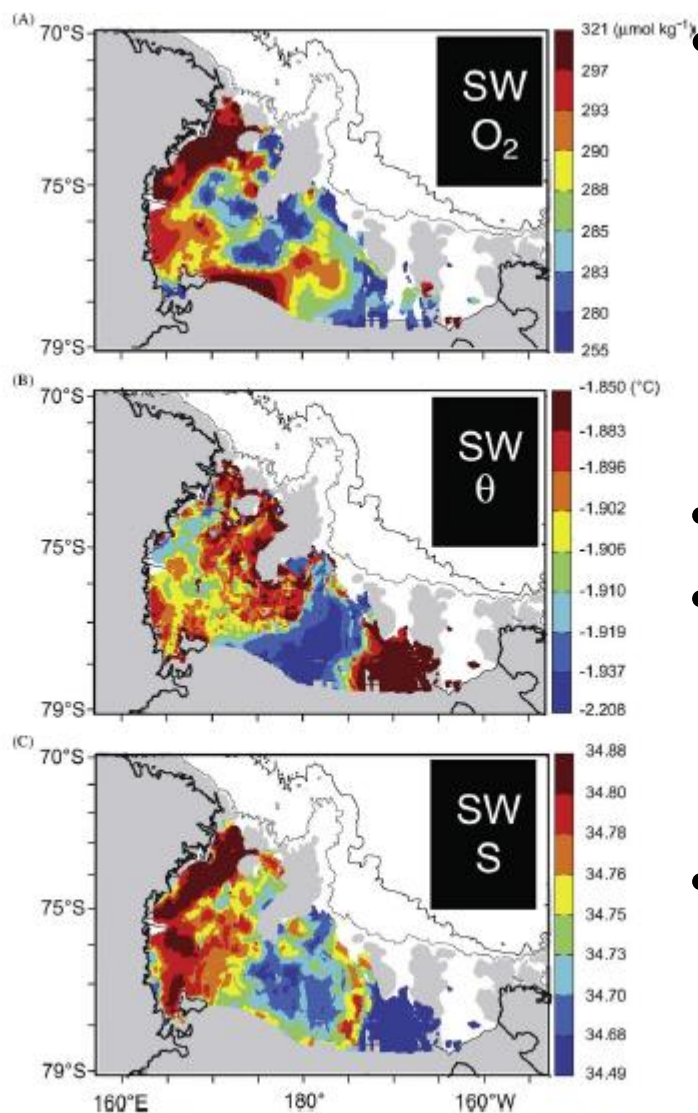
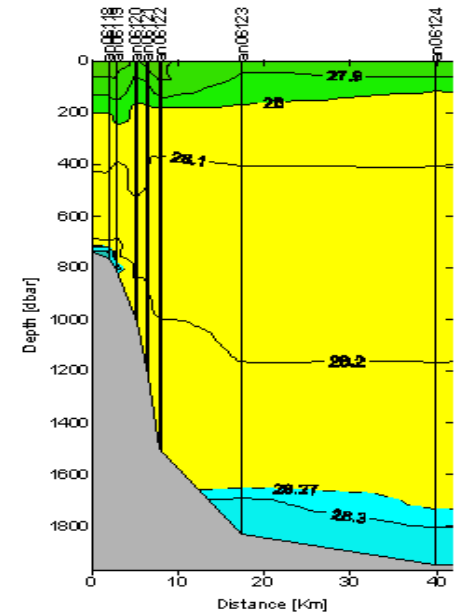
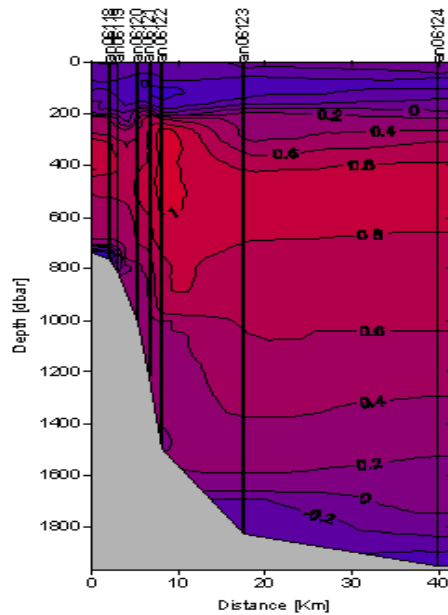
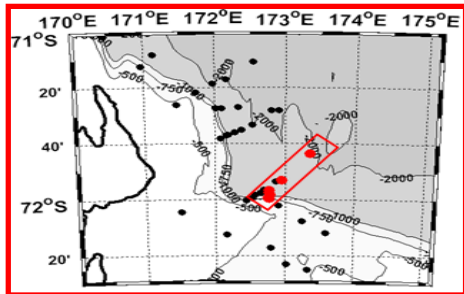


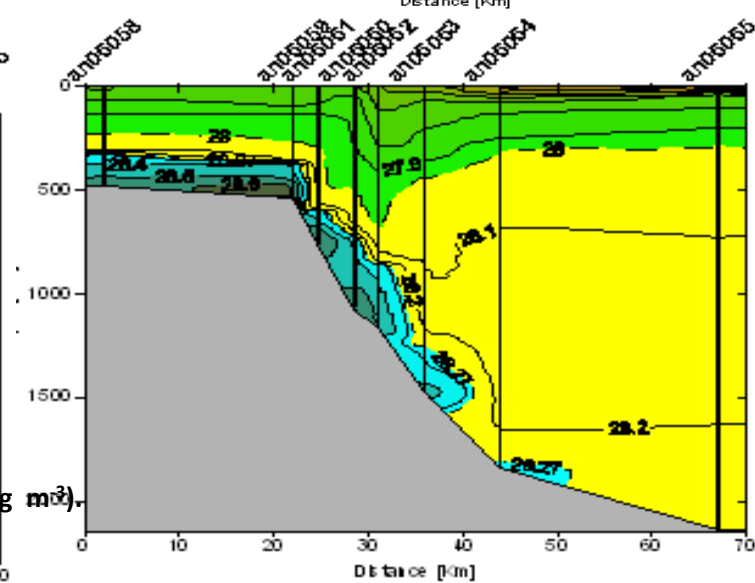
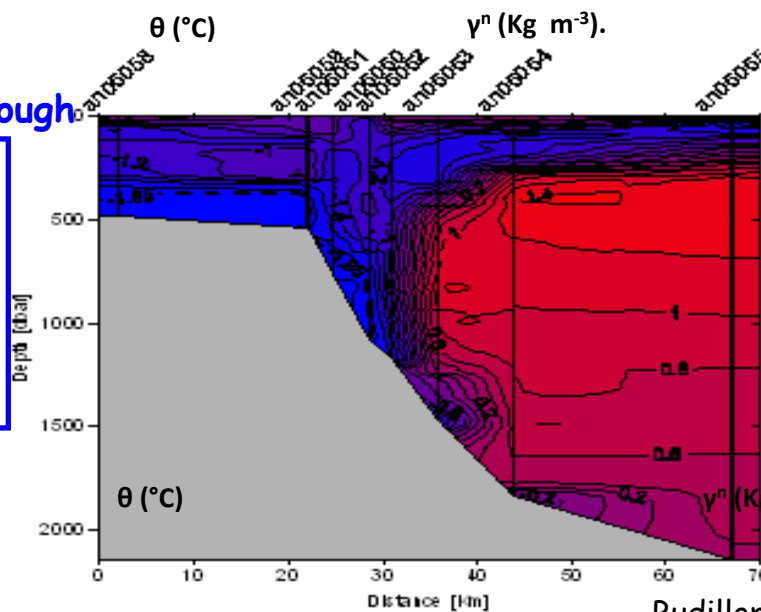
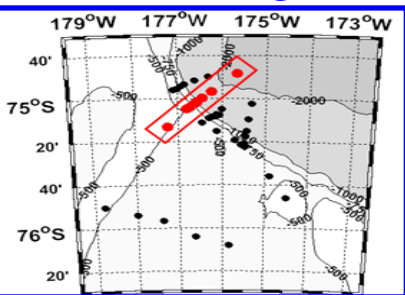
Fig. 9. (A) Dissolved oxygen ($\mu\text{mol kg}^{-1}$), (B) potential temperature ($^{\circ}\text{C}$), and (C) salinity averages for the bottom layer of SW ($\rho^{\theta} > 28.27 \text{ kg m}^{-3}$ and $\theta < -1.85^{\circ}\text{C}$). Depths less than 500 m are lightly shaded, and the thin lines show the 3000 and 3000 m isobaths. Areas shown with the same color extend over 1/8 of the total spatial domain mapped at water depths shallower than 2000 m.

- La distribuzione di O_2 mette in evidenza due siti di formazione : 1) la polynya di Baia Terranova (più salata $S > 34.8$) e 2) la polynya del RIS ($S < 34.76$)
- RIS-SW \Rightarrow ISW (non di fondo)
- Anche nei θ -S si osserva un modo di acqua più fredda ($\theta < -2^{\circ}\text{C}$) e meno salata ($34.6 < S < 34.75$)
- “Nuova” AABW ($-0.75 < \theta < 0.24^{\circ}\text{C}$ e $34.68 < S < 34.25$) si osserva in corrispondenza di capo Adare

Drygalski Trough



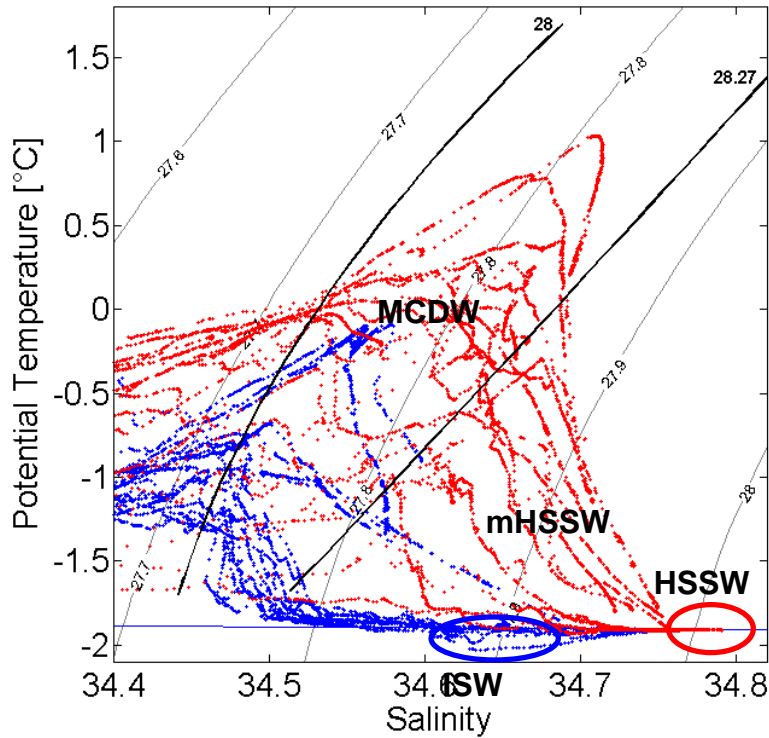
Glomar Challenger Trough



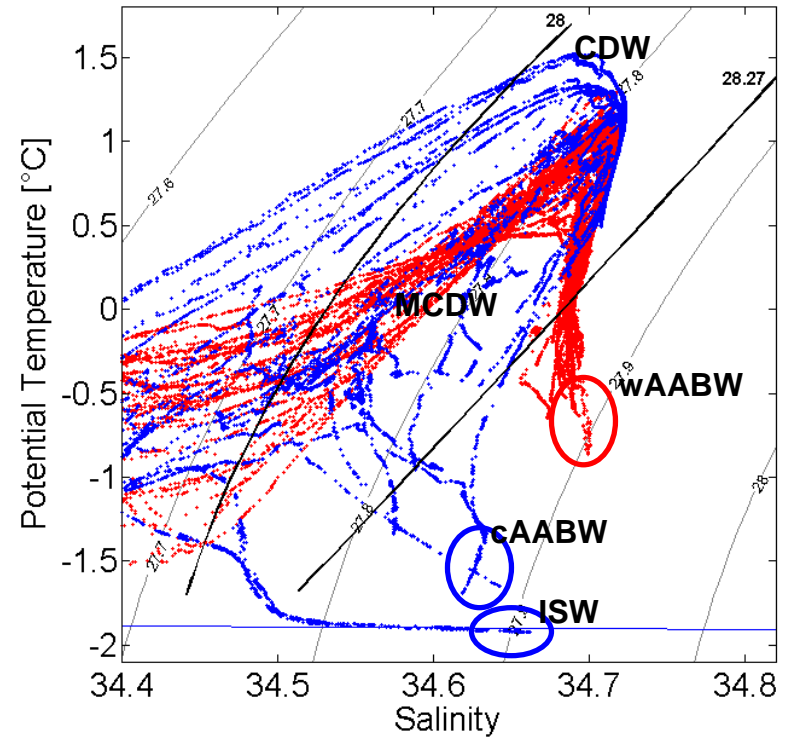
2006

Formazione delle AABW

Shelf



Outer shelf



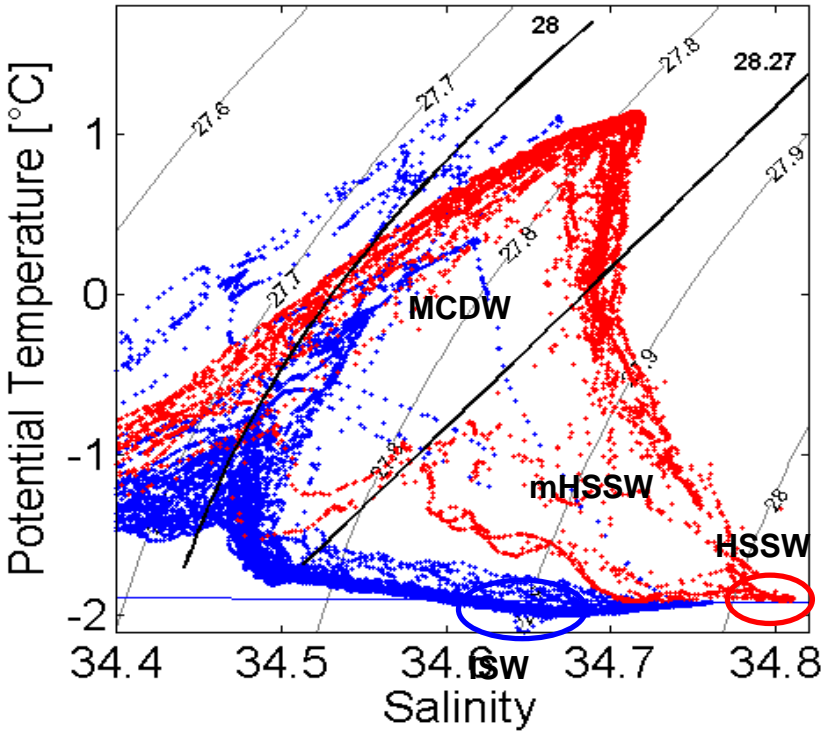
Rosso = settore occidentale

Blu = settore centrale

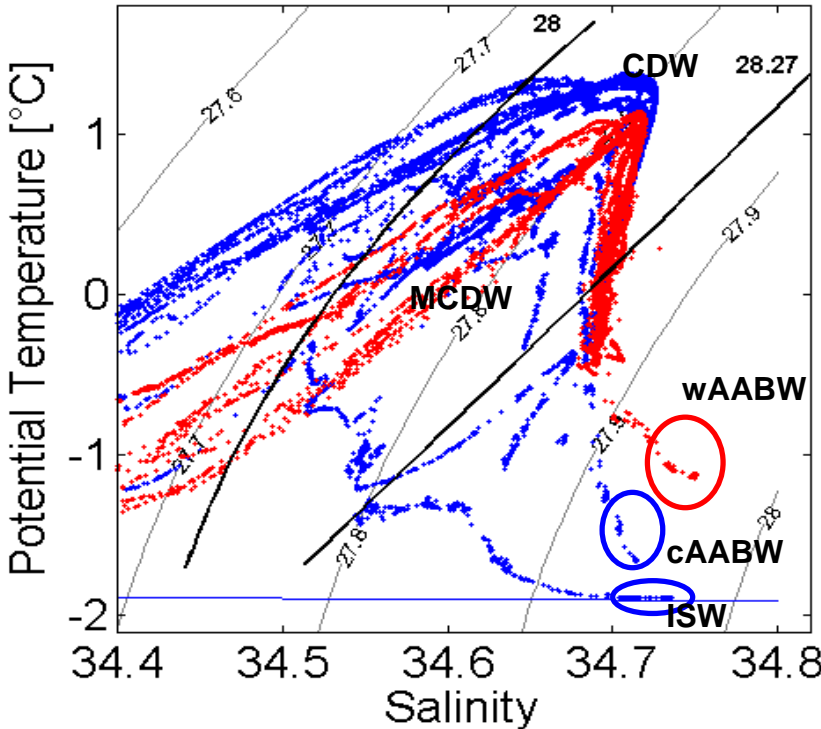
1998

Formazione delle AABW

Shelf



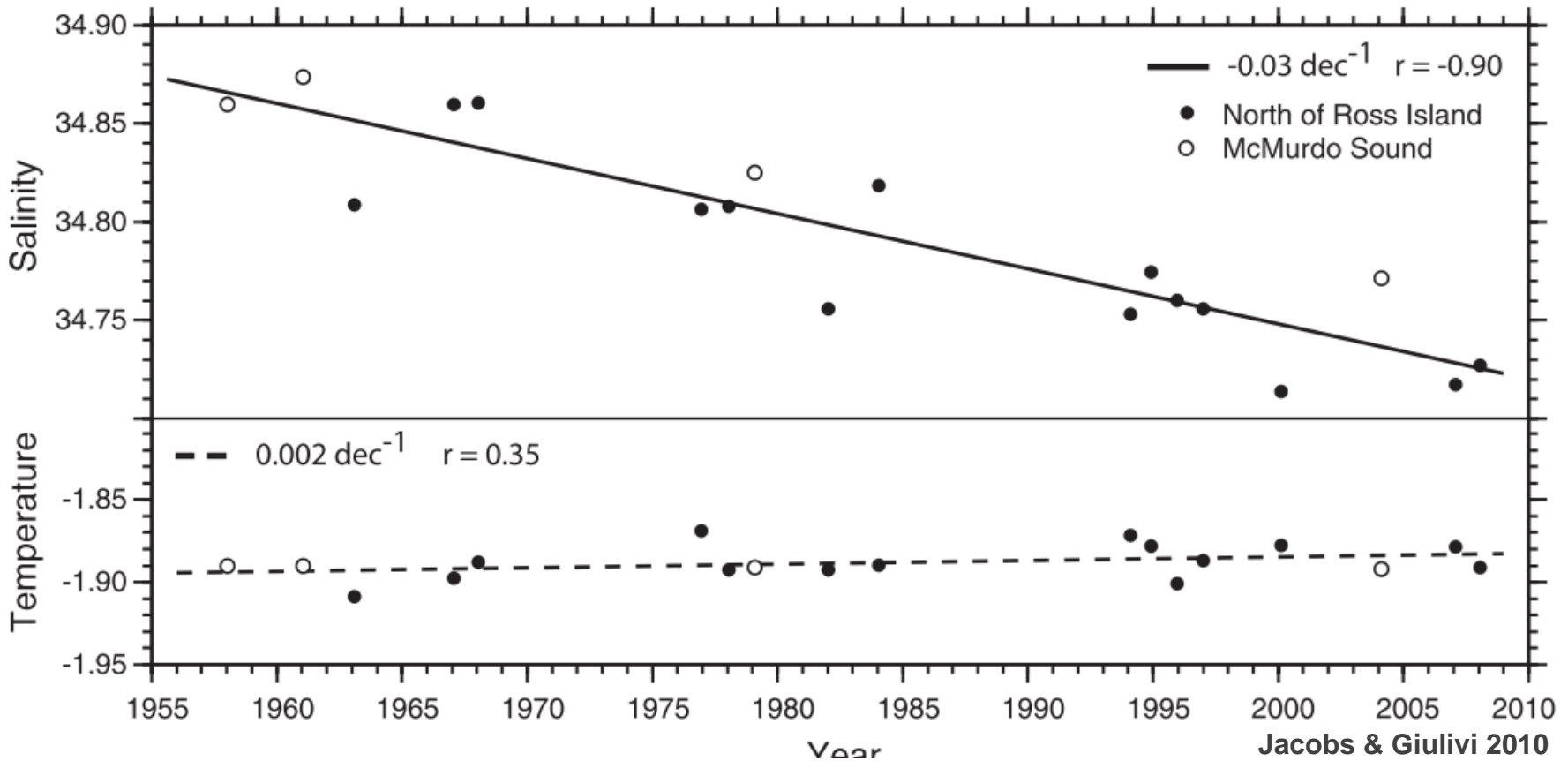
Outer shelf



Rosso = settore occidentale

Blu = settore centrale

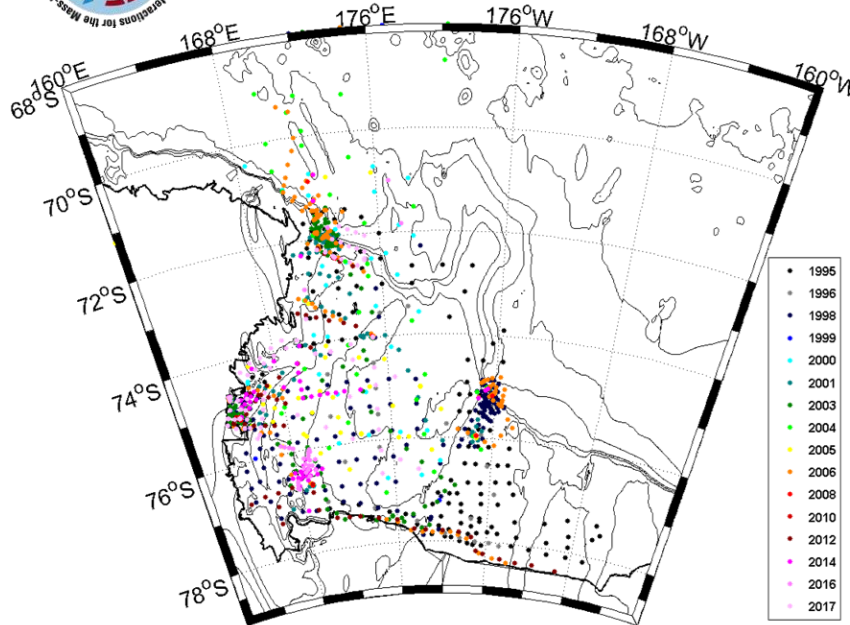
Variabilità della Antarctic Bottom Water



In recent decades AABW has warmed freshened and decreased in volume and density



Data Set: 19 summer cruises over 23 years



CTD (SeaBird SBE 911 + system):

- pressure
- Temperature
- Salinity
-

Hydrographic surveys (Dec-Feb):

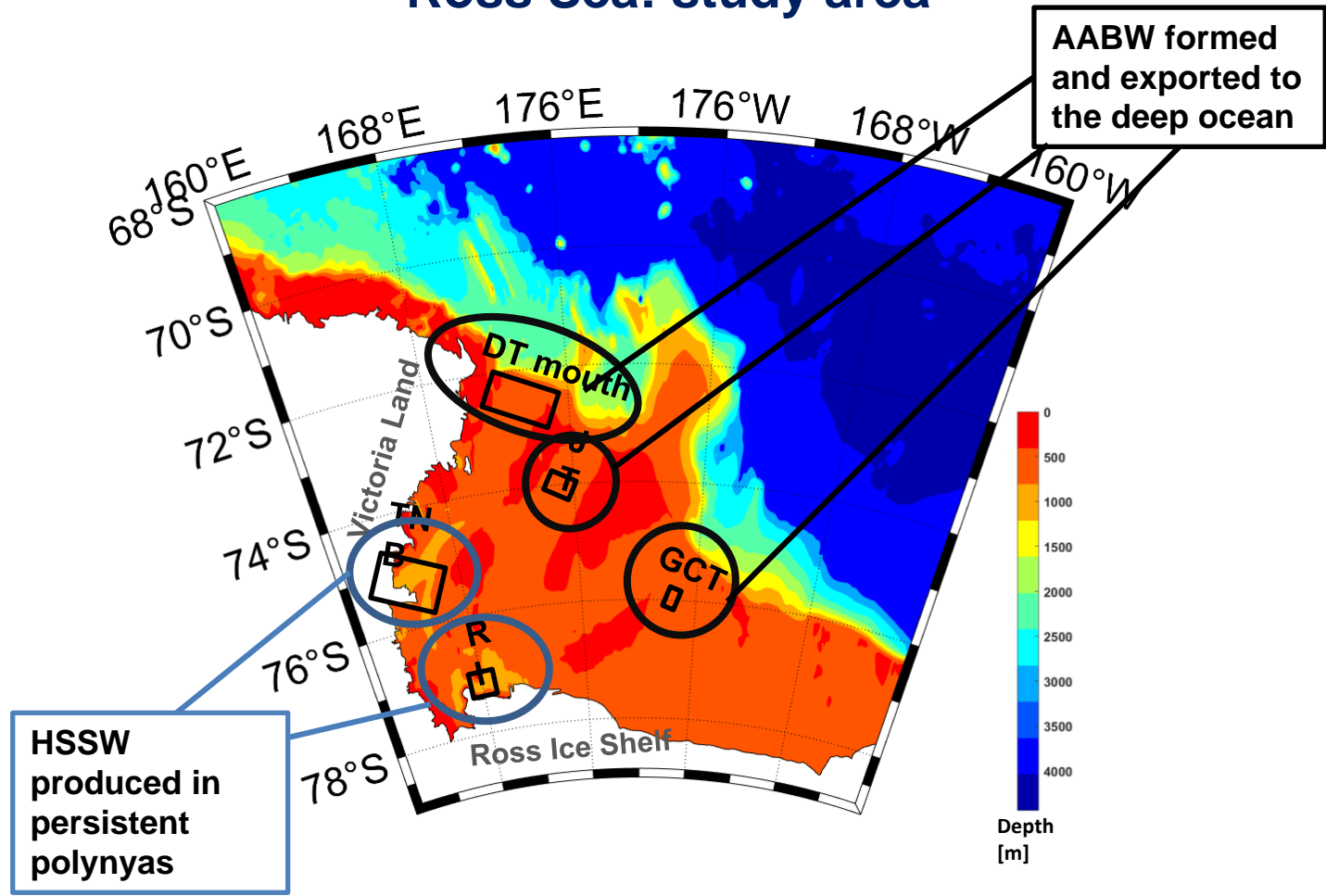
Italica (PNRA):

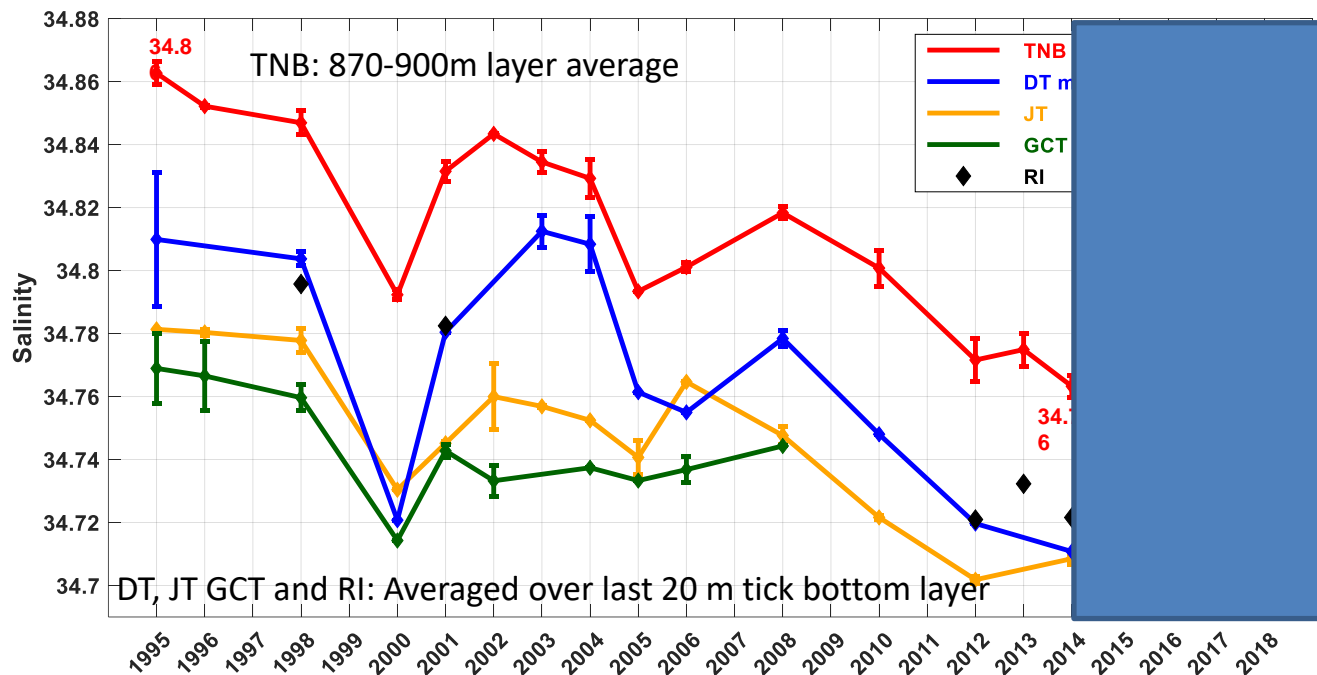
1995
 1996
 1998
 1999
 2000
 2001
 2003
 2004
 2005
 2006
 2008
 2010
 2012
 2014
 2016
 2017

Palmer (NSF):

2005
 2013
 2018
 ANSLOPE,
 TRACERS and
 CICLOPS
 projects.

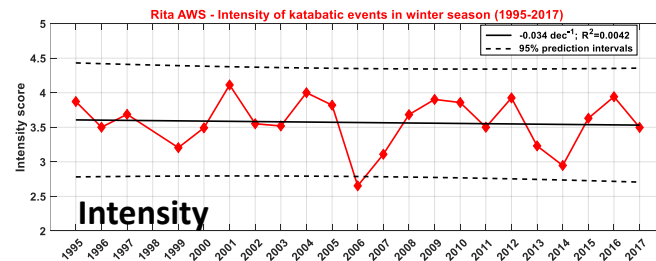
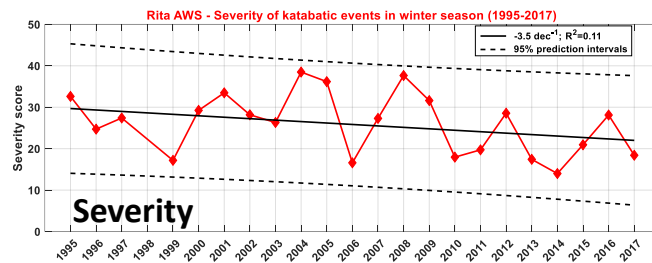
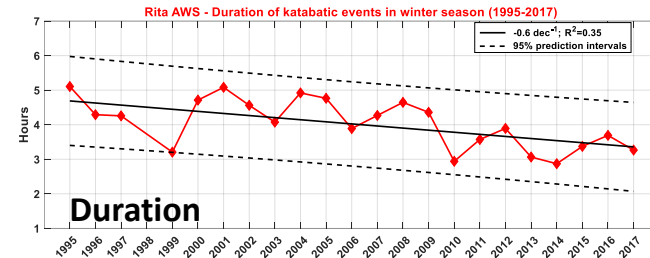
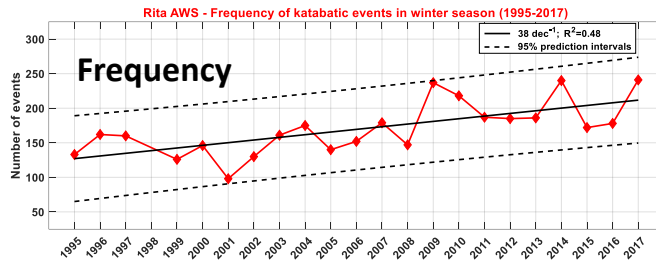
Ross Sea: study area





- **Between 1995 and 2014 HSSW salinity decreased at similar rate (-0.04 dec^{-1} in TNB, -0.03 dec^{-1} at DT and -0.04 dec^{-1} at JT) of previous observed freshening (Jacobs & Giulivi 2010 and Budillon et al., 2011).**
- **After 2014 HSSW salinity rebounded sharply, with values in 2018 similar to those observed in the mid-1990s.**

Variability of the TNB polynya activity



- Changes in the intensity, duration or frequency of katabatic wind events cannot explain the observed changes in salinity.
- Sea ice production in the TNB polynya has changed little with time (Tamura et al., 2016)
- Near-synchronous variability at five locations on the shelf also suggests that local factors in TNB cannot explain the observed salinity variability

Trends and fluctuations can't be explained by local changes in Terra Nova Bay polynya, suggesting "preconditioning" influences the salinity of dense water formed on the shelf.

Factors influencing the salt budget of Ross Sea shelf waters

- Inflow of relatively fresh water from the Amundsen Sea (reducing salinity)
- Net export of sea ice (increasing salinity)
- Inflow of CDW
- Precipitation
- Basal melt of the Ross Ice Shelf

Salinity field pre-conditioning

Salinity anomalies at each site extend throughout the water column, with fresh (salty) HSSW associated with fresh (salty) upper ocean waters and a deeper (shallower) halocline

Salinity from sea ice formation

- A crude estimate of the change in salt or freshwater input needed to account for the salinity increase between 2014 and 2018 can be used to assess possible drivers.
- The salinity increase between 2014 and 2018 requires an addition of

$$\rho V \Delta S = 6.322 \times 10^{15} \text{ kg of salt}$$

$\rho = 1027 \text{ kg m}^{-3}$, $\Delta S = 0.086$, $V = 7.158 \times 10^4 \text{ km}^3$ is the mean volume of HSSW (Orsi and Wiederwohl, 2009)

- The mass of salt added to the water column during sea ice formation is

$$\rho_{\text{ice}} V_{\text{ice}} f S_{\text{surf}}$$

$\rho_{\text{ice}} = 920 \text{ kg m}^{-3}$, V_{ice} is the volume of sea ice formed, $f = 0.79$ (Skogseth et al, 2004) is the fraction of salt released during freezing, $S_{\text{surf}} = 34.0$ is the SSS

Salinity from sea ice formation

• If the salinity change reflected only a change in sea ice formation, the observed increase in salt content would require formation of an additional

255 km³ of sea ice

or an average annual anomaly of about

64 km³ yr⁻¹

- The mean (1992-2013) cumulative sea-ice production of the Ross and TNB polynyas is $438 \pm 64 \text{ km}^3 \text{ yr}^{-1}$ (Tamura et al., 2016)
- The **increase in salinity of HSSW between 2014 and 2018 could therefore be accounted for by an increase in annual sea ice formation by the Ross and TNB polynyas of about 15% of the 1992-2013 mean value, sustained over four years.**

Role of the Fresh water Inflow from West Antartica

- **Upstream preconditioning:** Jacobs and Giulivi (2010) observed that the **freshening of the westward coastal and slope front current (entrained in the formation of MCDW) from 1964-2007, was sufficient to account for the HSSW salinity decline and was consistent with the increased melting of the continental ice upstream in the Amundsen Sea.**

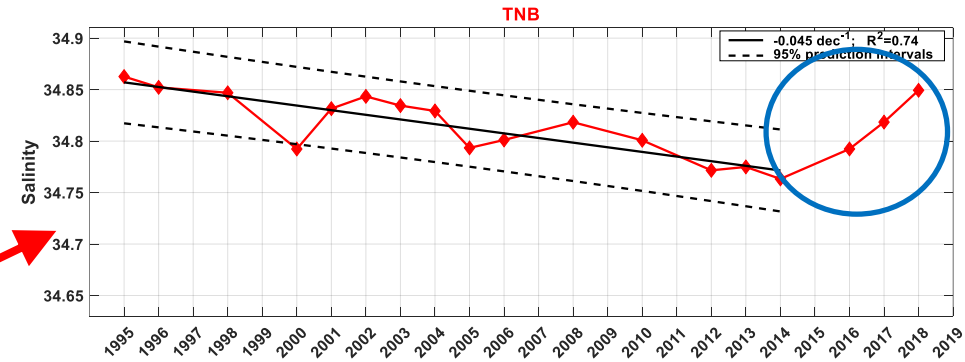
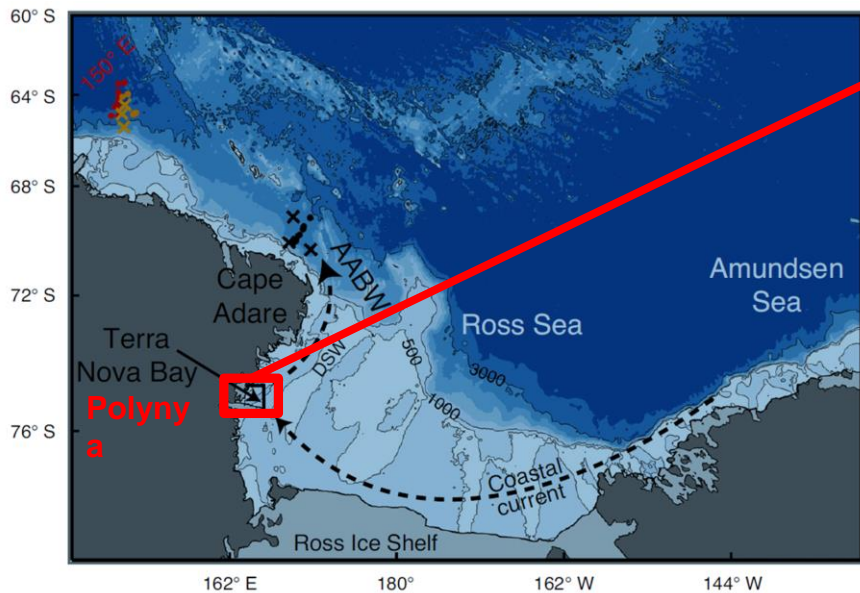
- **A decrease in freshwater input to the HSSW layer could also contribute to the observed increase in salinity.**
- Assuming the salt content of the HSSW remains unchanged

$$\rho_o V_o S_o = \rho_o V_f S_f,$$

where the subscripts refer to initial (2014) and final values (2018)

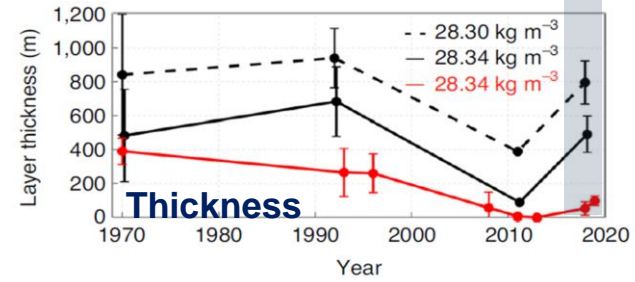
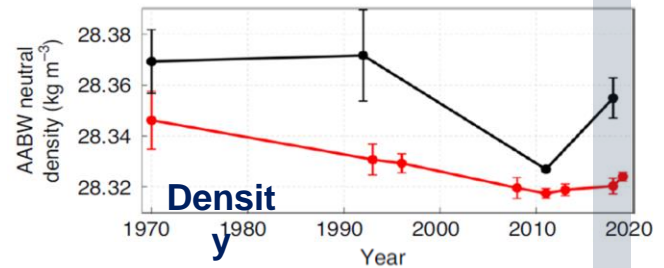
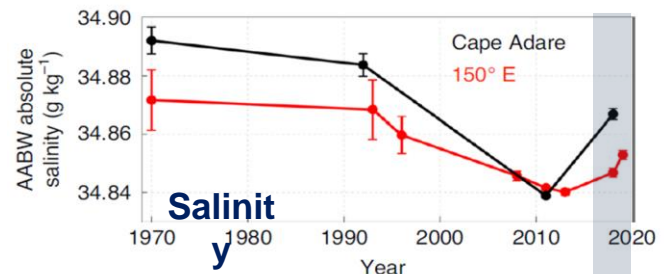
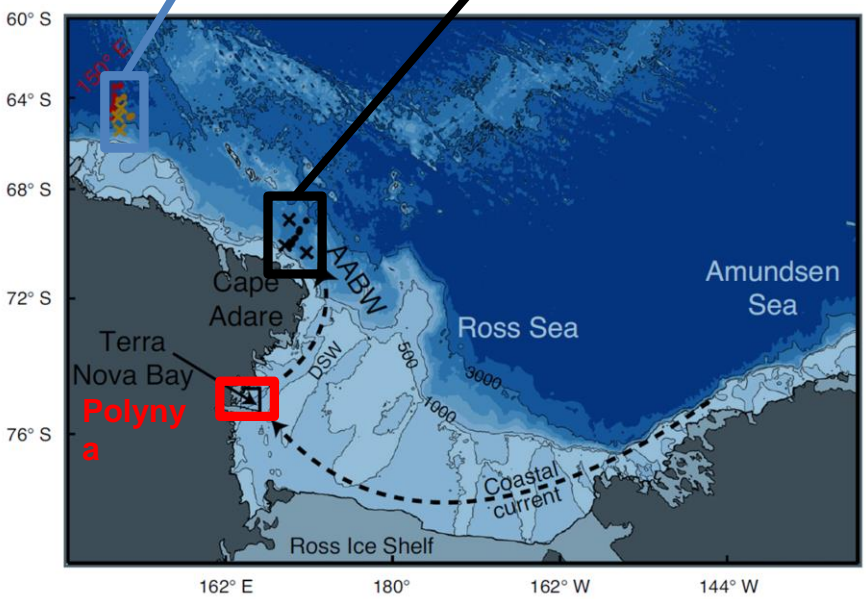
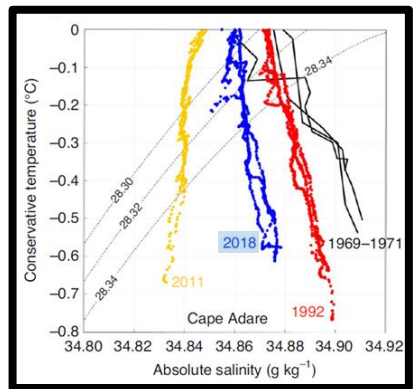
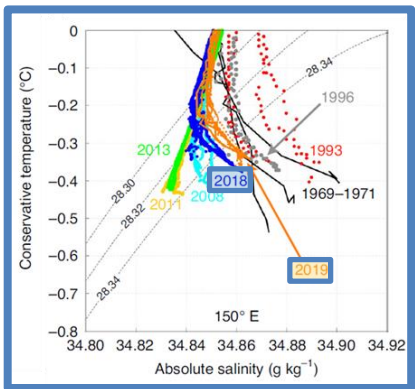
- **A reduction in volume of $0.018 \times 10^4 \text{ km}^3$ would be needed to explain the observed increase in salinity.**
- This corresponds to a **reduction in freshwater input of 180 km^3 between 2014 and 2018, or about 45 Gt yr^{-1} sustained over four years.**
- **However, freshwater input to the ocean from West Antarctica has generally increased in recent decades (Rignot et al., 2019), counter to the recent trend of increased HSSW salinity***

Quindi cosa causa il Recupero salinità delle acque di piattaforma?



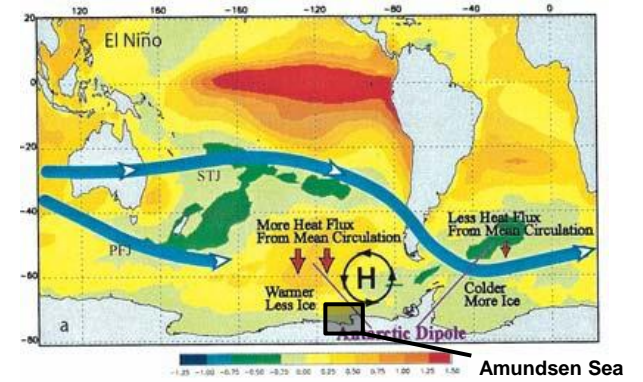
From Castagno et al., 2019 - Nat. Comm.

Evidente anche nel Recupero salinit  Antarctic Bottom Water

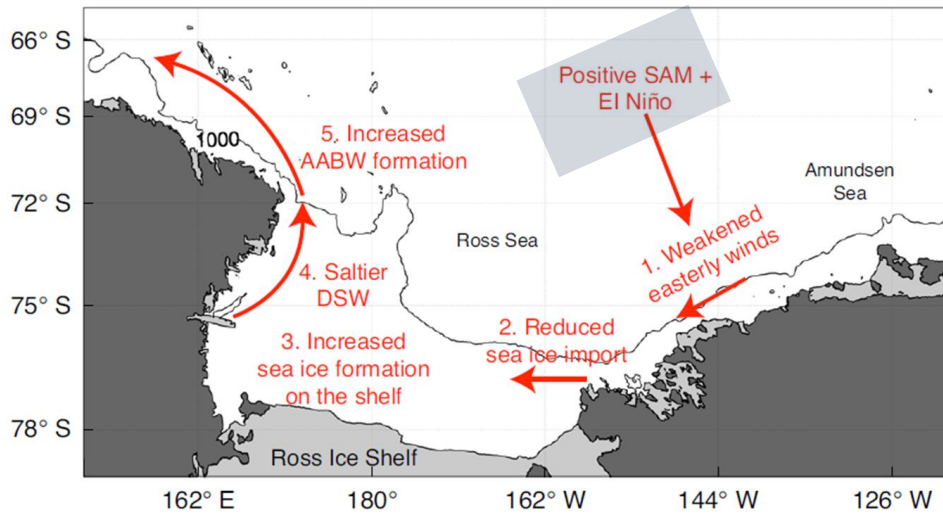


From Silvano et al., 2020 - Nat. Geoscience

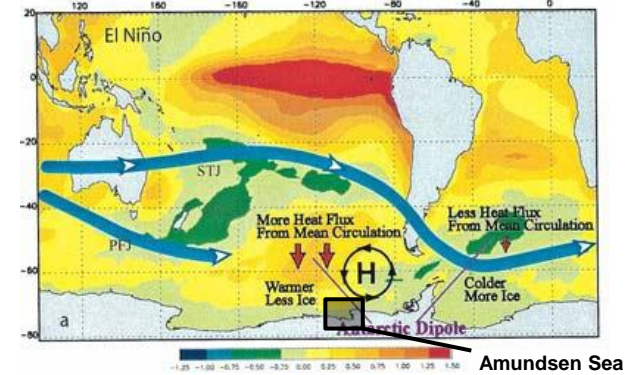
Teleconnessioni



El Niño causa un indebolimento della Bassa di Amundsen



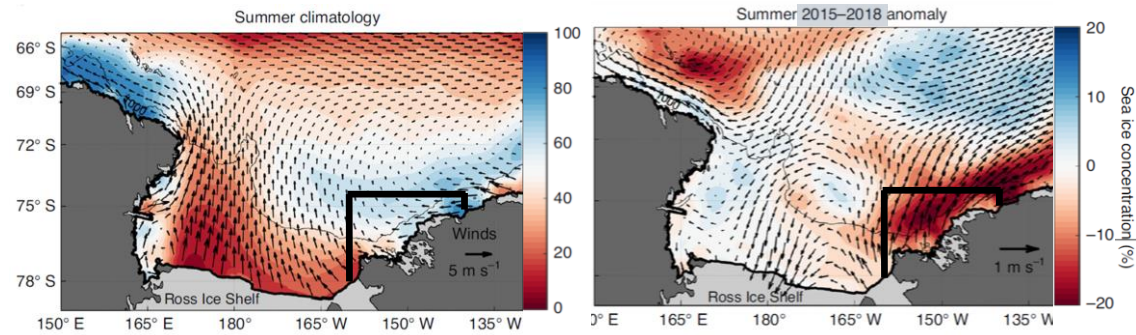
Teleconnessioni



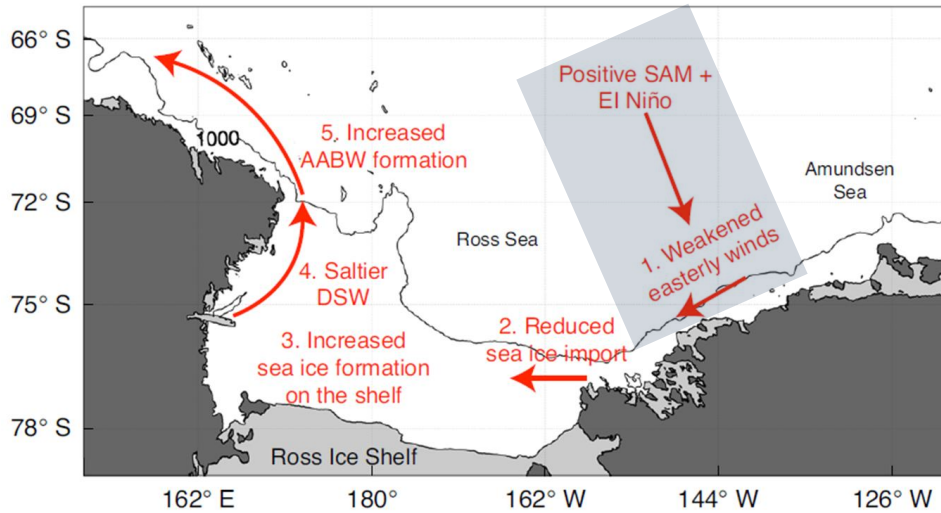
El Niño causa un indebolimento della Bassa di Amundsen



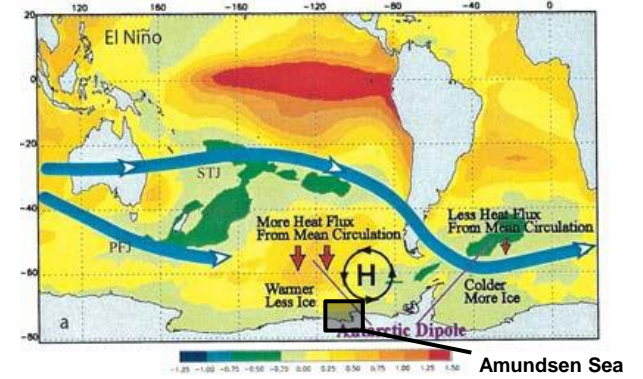
(1) Indebolimento dei venti orientali e bassa concentrazione di ghiaccio marino nel Mare di Amundsen occidentale



From Silvano et al., 2020 - Nat. Geoscience



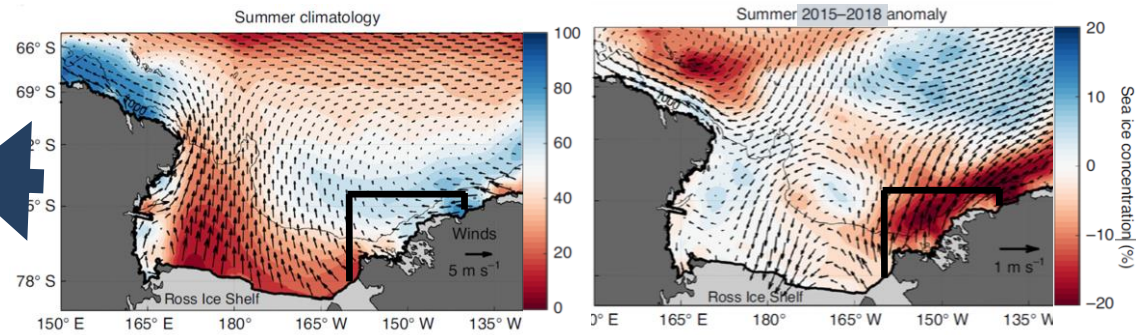
Teleconnessioni



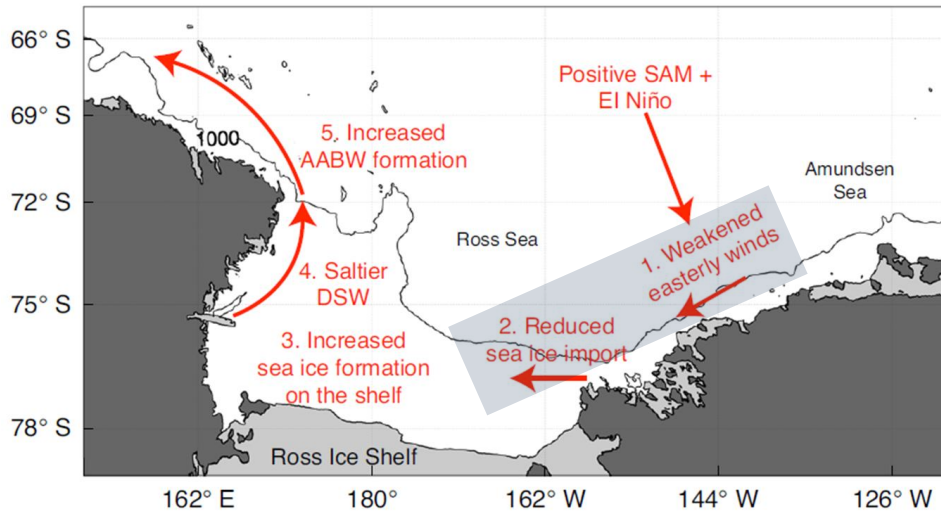
El Niño causa un indebolimento della Bassa di Amundsen



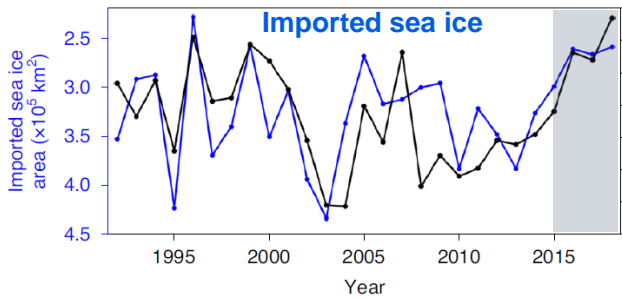
(1) Indebolimento dei venti orientali e bassa concentrazione di ghiaccio marino nel Mare di Amundsen occidentale



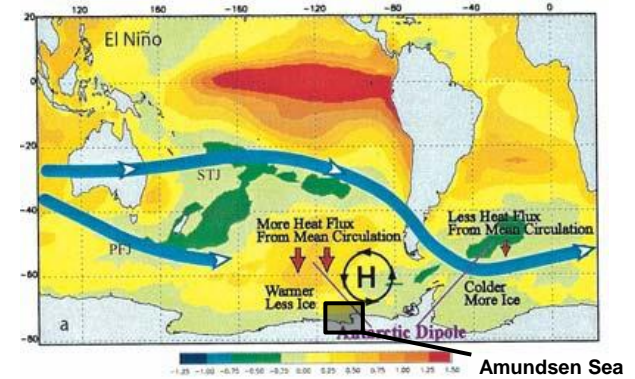
From Silvano et al., 2020 - Nat. Geoscience



(2) Riduzione del flusso di ghiaccio verso il Mare di Ross



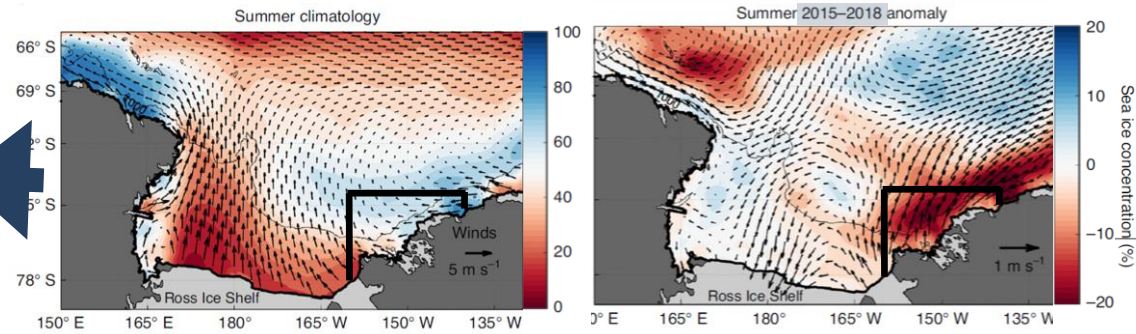
Teleconnessioni



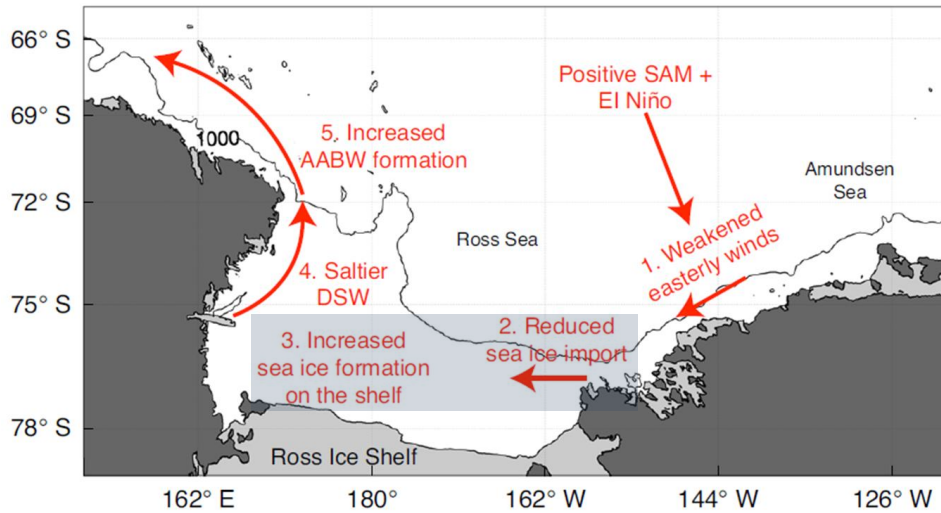
El Niño causa un indebolimento della Bassa di Amundsen



(1) Indebolimento dei venti orientali e bassa concentrazione di ghiaccio marino nel Mare di Amundsen occidentale

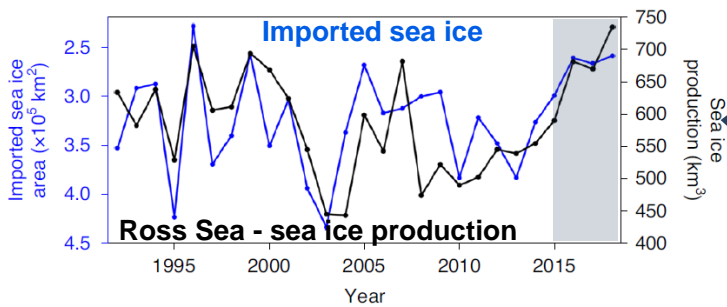


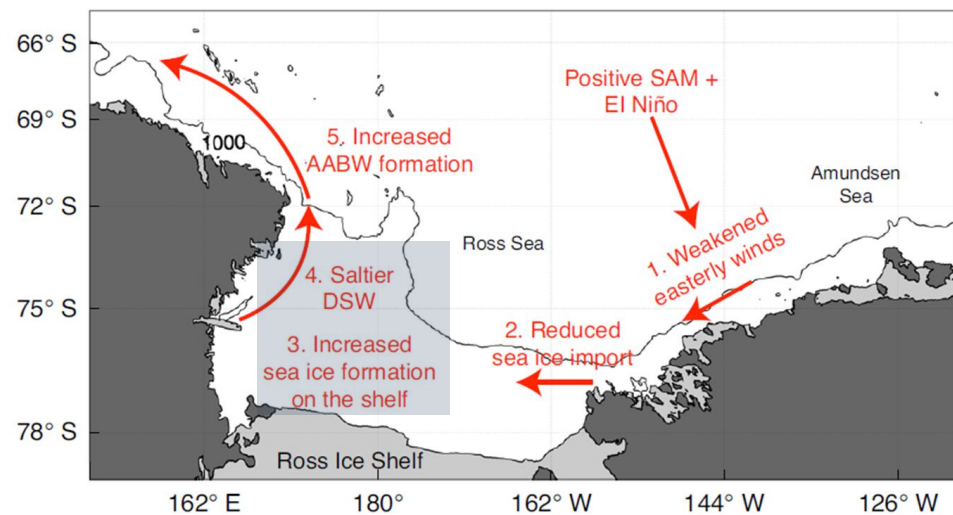
From Silvano et al., 2020 - Nat. Geoscience



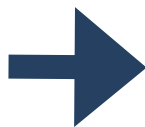
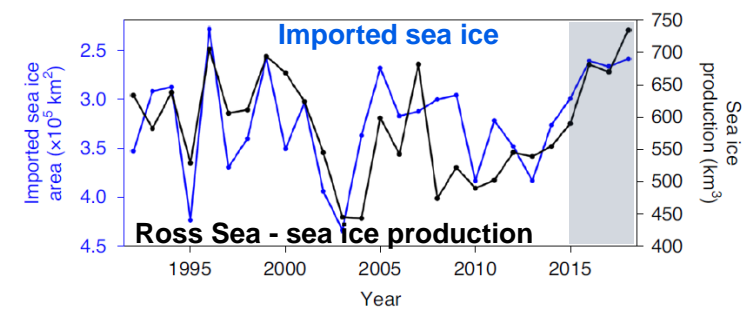
(3) Aumento della produzione di ghiaccio marino nel Mare di Ross

(2) Riduzione del flusso di ghiaccio verso il Mare di Ross

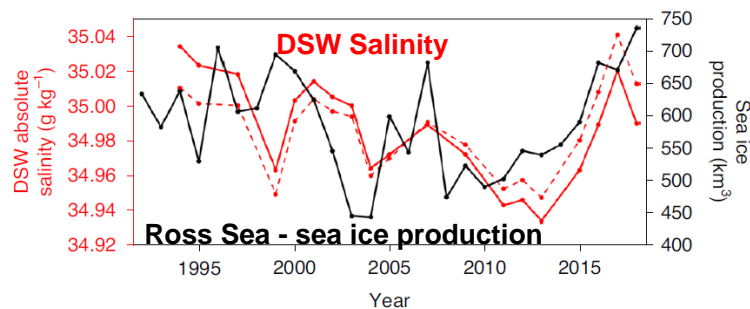




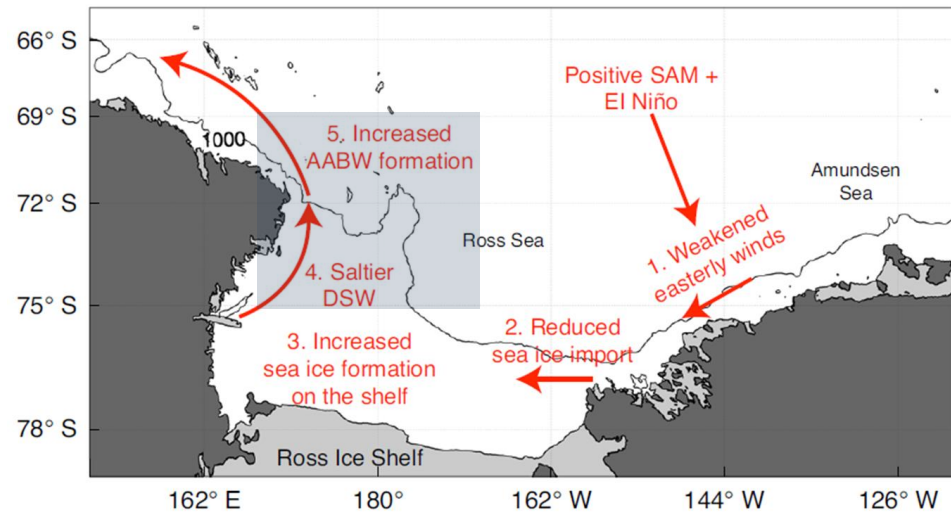
(3) Aumento della produzione di ghiaccio marino nel Mare di Ross



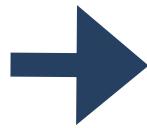
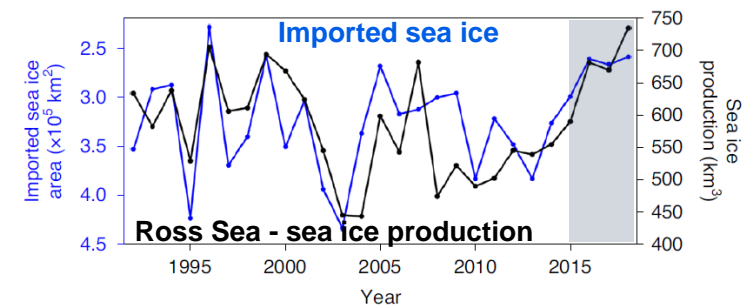
(4) Aumento della salinità delle acque dense sulla piattaforma continentale del Mare di Ross



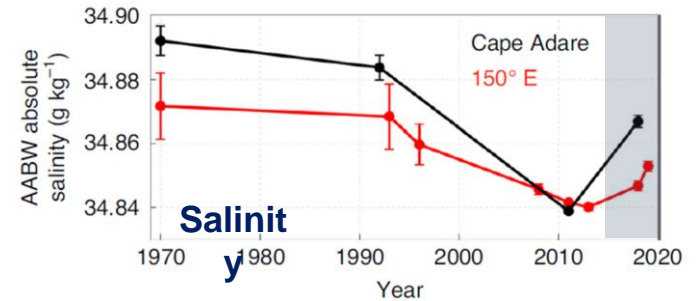
From Silvano et al., 2020 - Nat. Geoscience



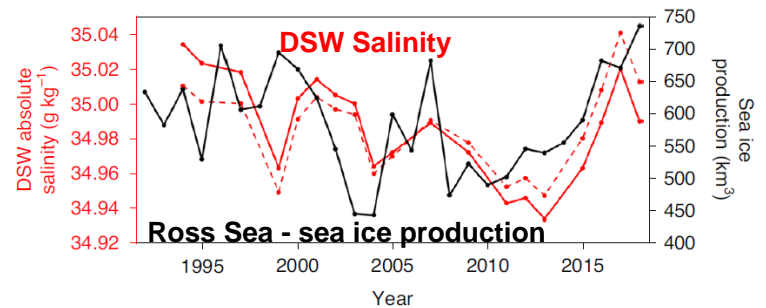
(3) Aumento della produzione di ghiaccio marino nel Mare di Ross



(5) Recupero salinità AABW



(4) Aumento della salinità delle acque dense sulla piattaforma continentale del Mare di Ross



From Silvano et al., 2020 - Nat. Geoscience