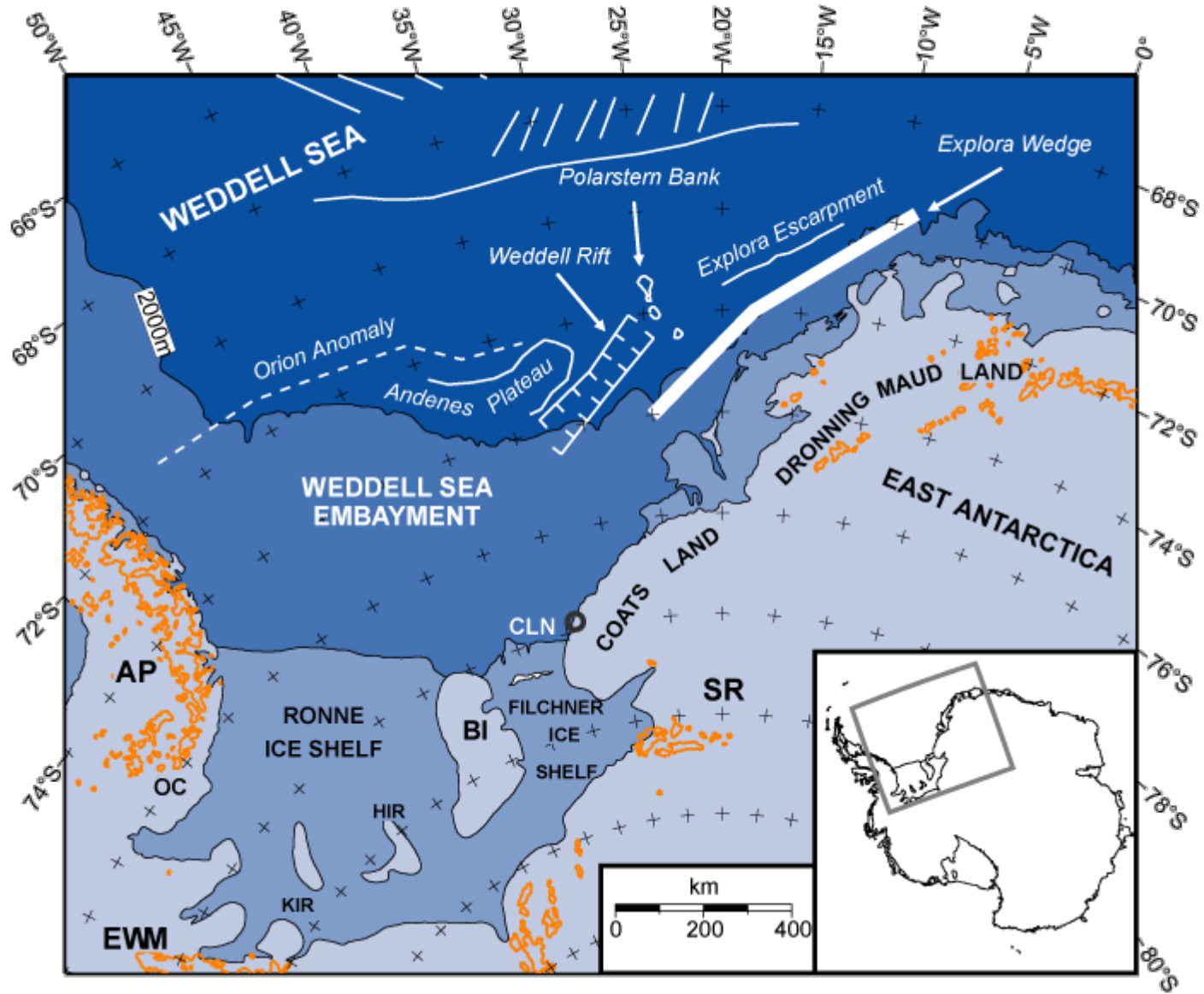
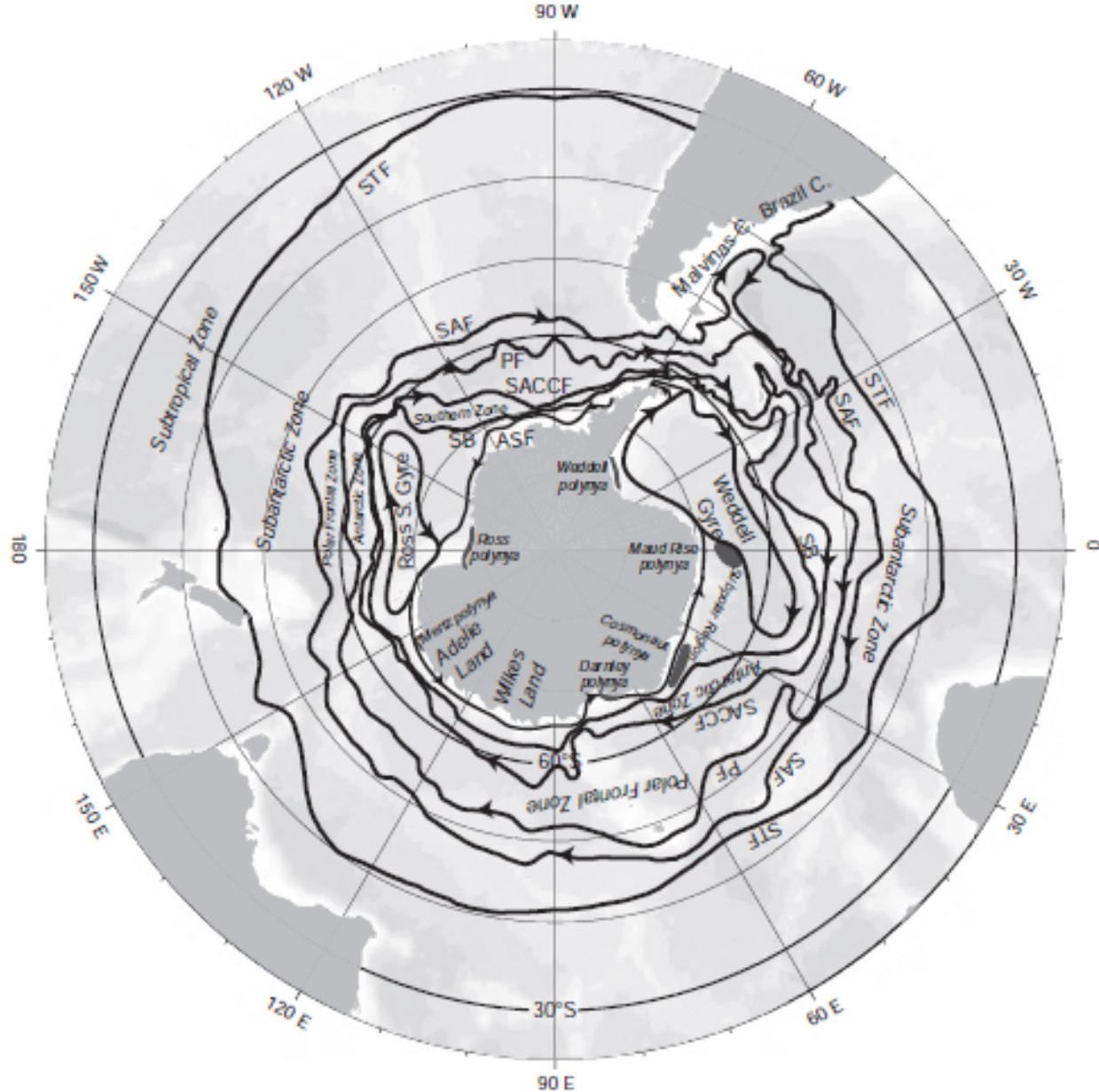


# Il Mare di Weddell (MdW)

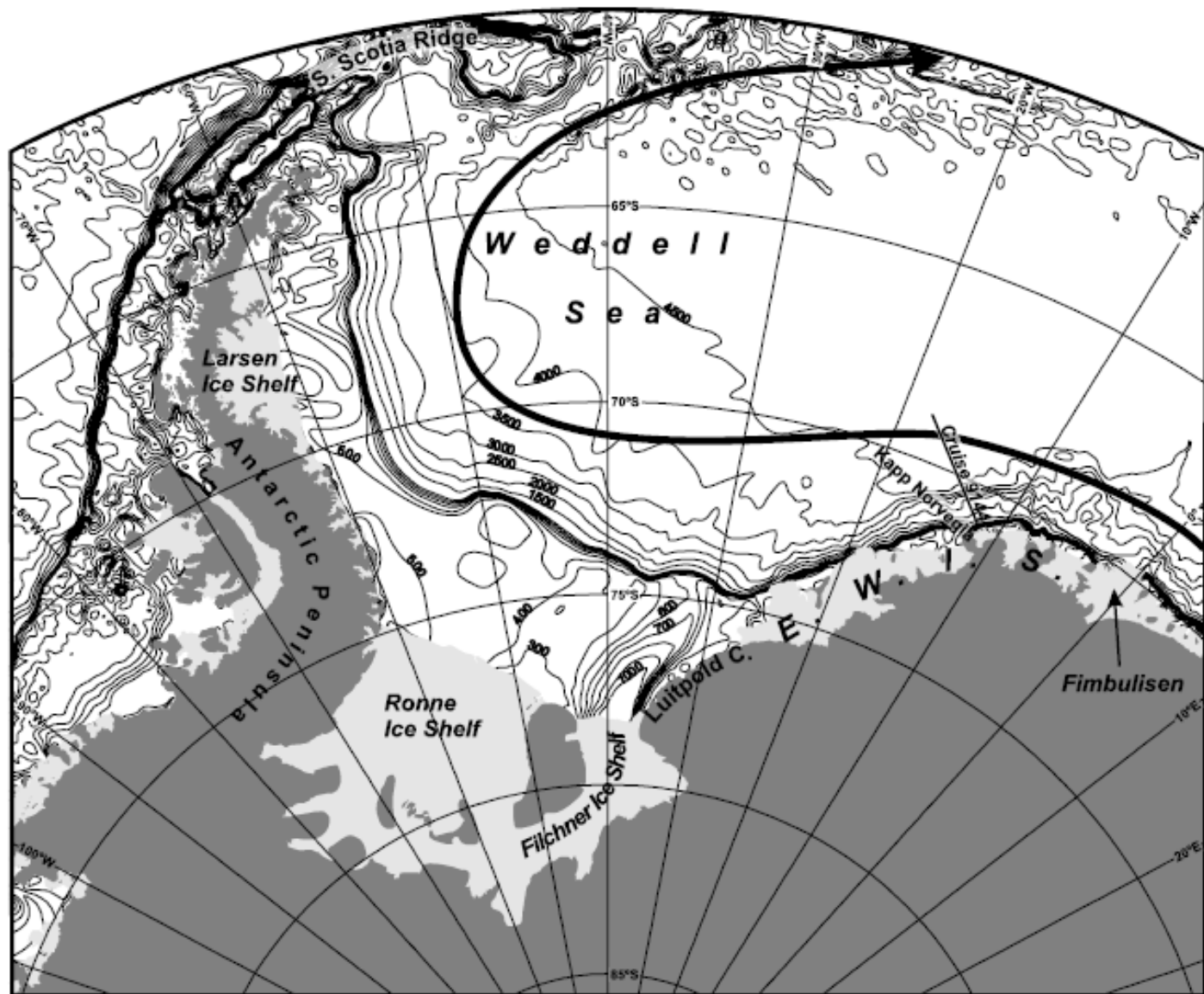


A mid-winter glow, Weddell Sea [showing The 'Endurance'], 1915



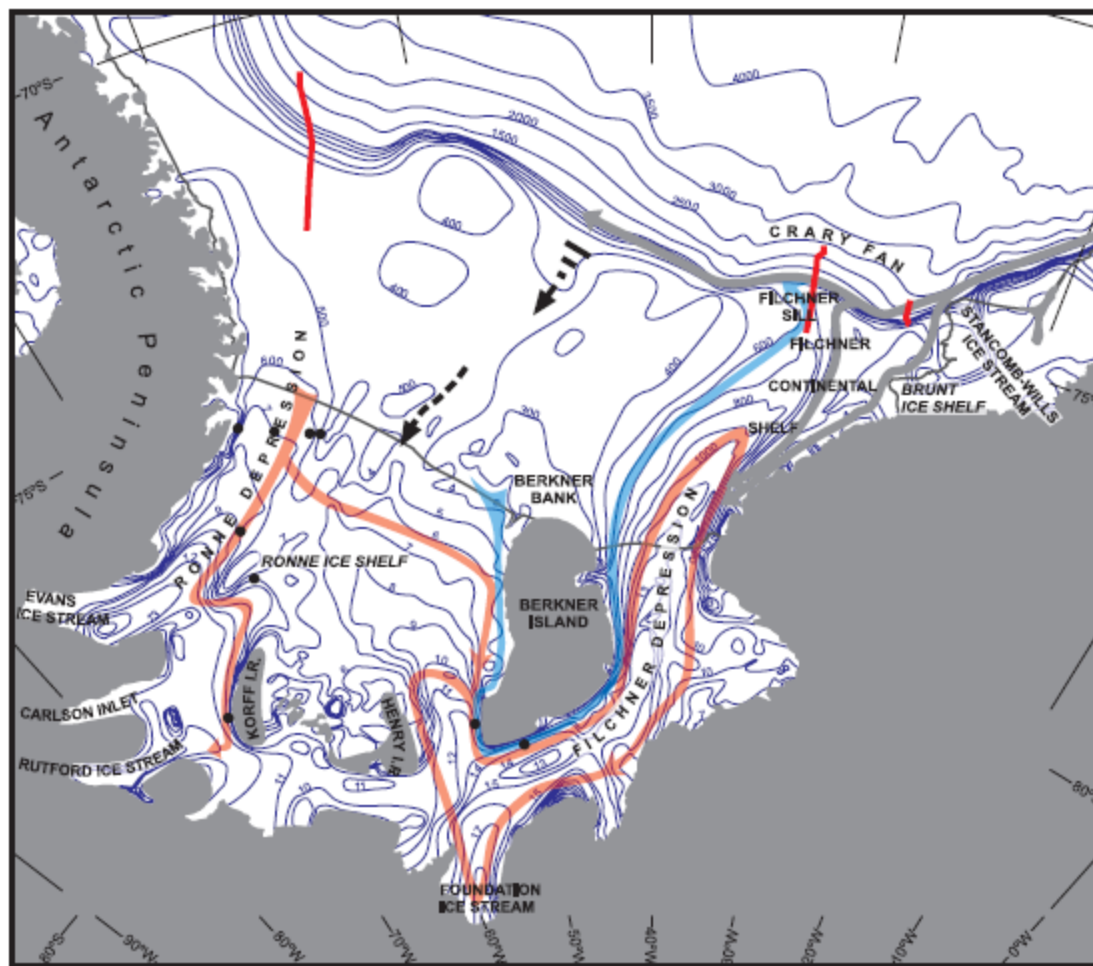


**FIGURE 13.1** The Southern Ocean geography, principal fronts, and oceanographic zones (see Table 13.1). The Subtropical Front (STF) is the oceanographic northern boundary for the region. The eastward Antarctic Circumpolar Current (ACC) includes these fronts: Subantarctic Front (SAF), Polar Front (PF), Southern ACC Front (SACCF), Southern Boundary (SB). Front locations from Orsi et al (1995). The westward Antarctic Slope Front (ASF) (thin) follows the continental slope. Circulation of the ocean basins north of the SAF is not represented; see the maps in Chapters 9, 10 and 11. Major polynyas (dark gray patches) are labeled; all polynyas are shown in Figure 13.20.



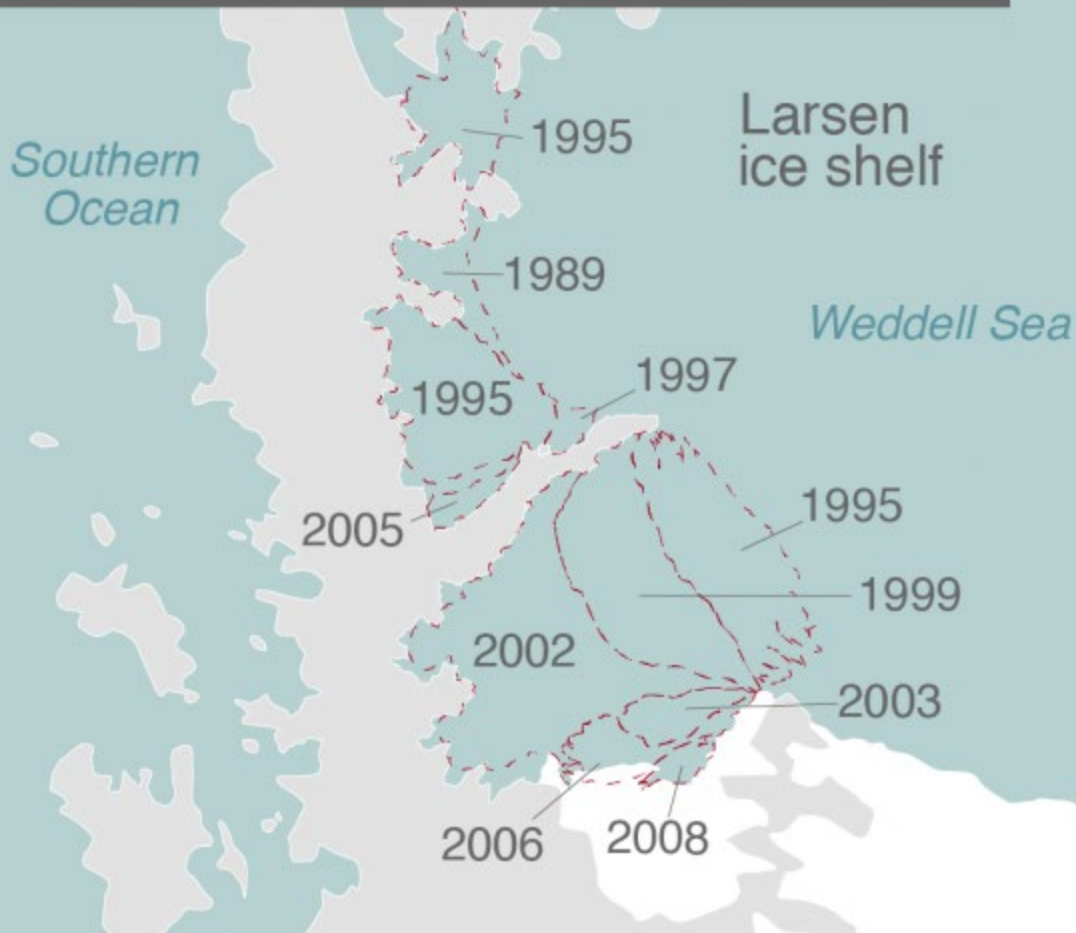
**Figure 2a.** Map of the western Weddell Sea. Contours are of bathymetry and are from BEDMAP [Lythe and Vaughan, 2001] and the *British Antarctic Survey* [2000]. Areas shaded in light gray are ice shelves; those in dark gray are land. The large arrow is a schematic representation of the western portion of the Weddell Gyre. The line labeled “Cruise 9144” from Kapp Norvegia shows the track of a hydrographic section discussed in the text.

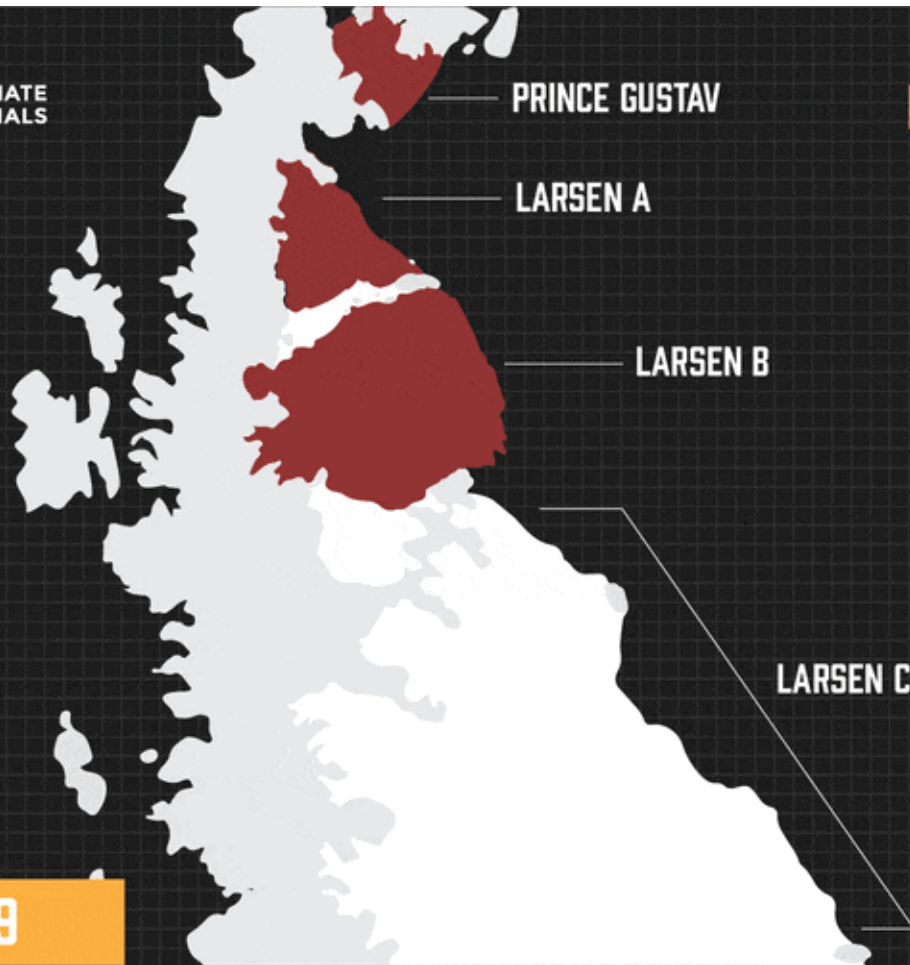




**Figure 2b.** Map showing the southwestern Weddell Sea. Bathymetric contours are labeled in hundreds of meters beneath the ice shelves. Ice fronts are shown by black lines. Black circles show drill hole locations. The gray arrows show the flow of the slope front and coastal currents. Blue and red arrows show the circulation beneath the ice shelf of waters originating from the eastern and western ends of the Ronne Ice Front, respectively. The top thick black broken arrow indicates the location of an MWDW inflow at the central trough in the Ronne continental shelf break, and the bottom thick black broken arrow indicates the location along the ice front where an MWDW core is observed. The three solid red lines at the shelf break show the position of the sections in Figure 8.

# YEAR OF SHELF LOSS





## ICE SHELF RETREAT AND COLLAPSE ON THE ANTARCTIC PENINSULA

Ice shelves on the Antarctic Peninsula have been retreating and collapsing in succession, each collapse closer than the last to the South Pole, as the northern climatic limit for ice shelves on the Peninsula recedes southward.



For sources and more information see:  
[climatesignals.org/headlines/events/larsen-c-ice-shelf-calving-and-retreat-2017](https://climatesignals.org/headlines/events/larsen-c-ice-shelf-calving-and-retreat-2017)

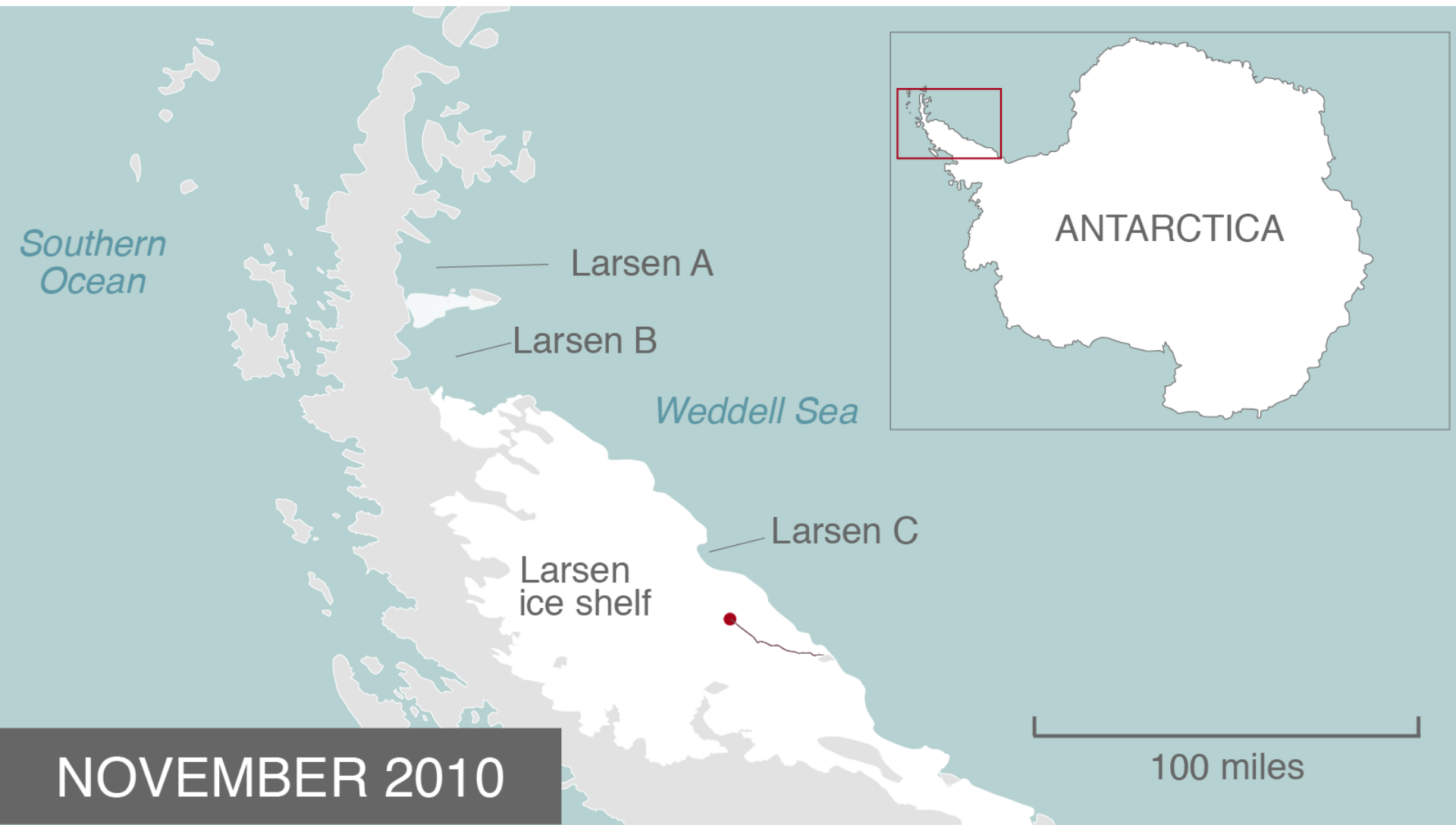


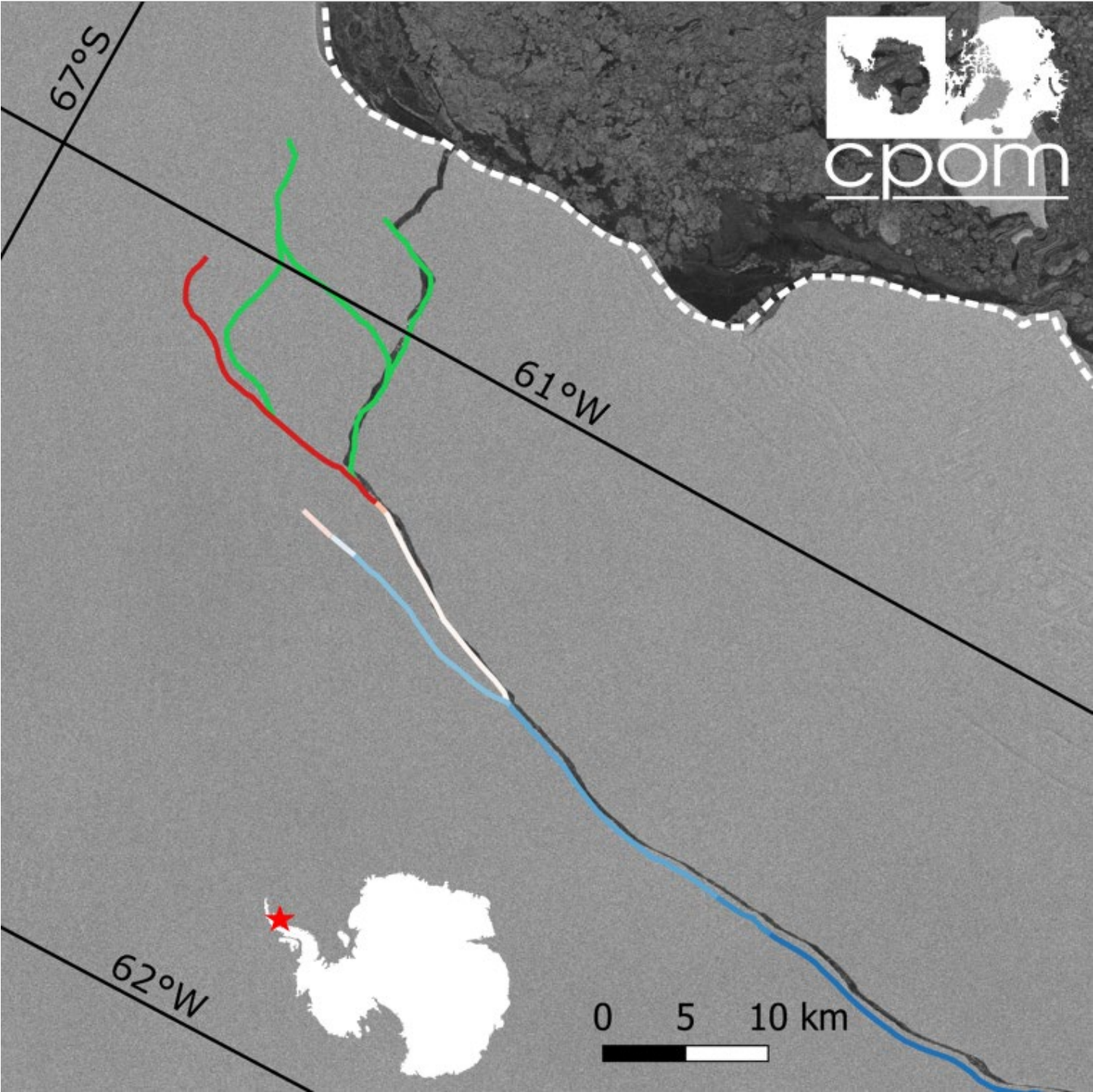


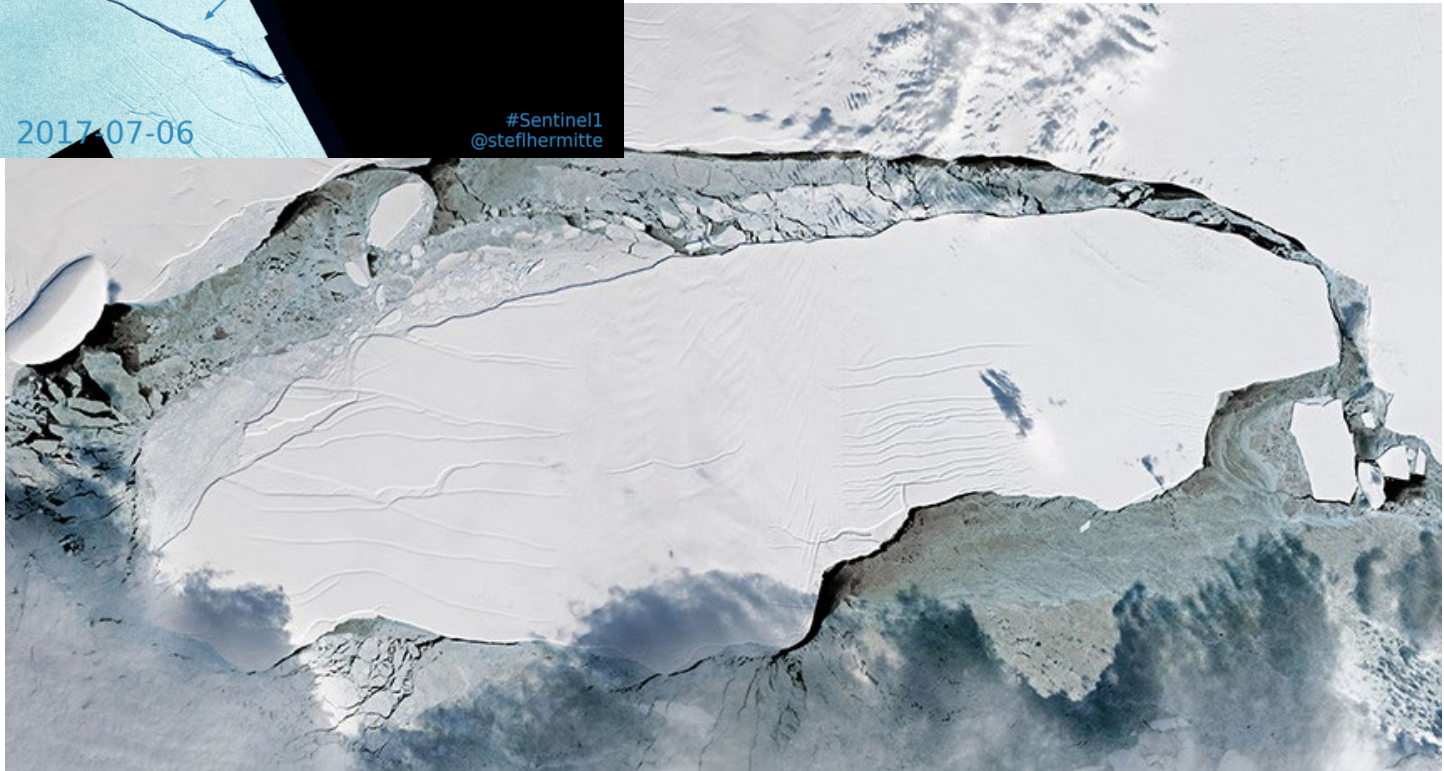
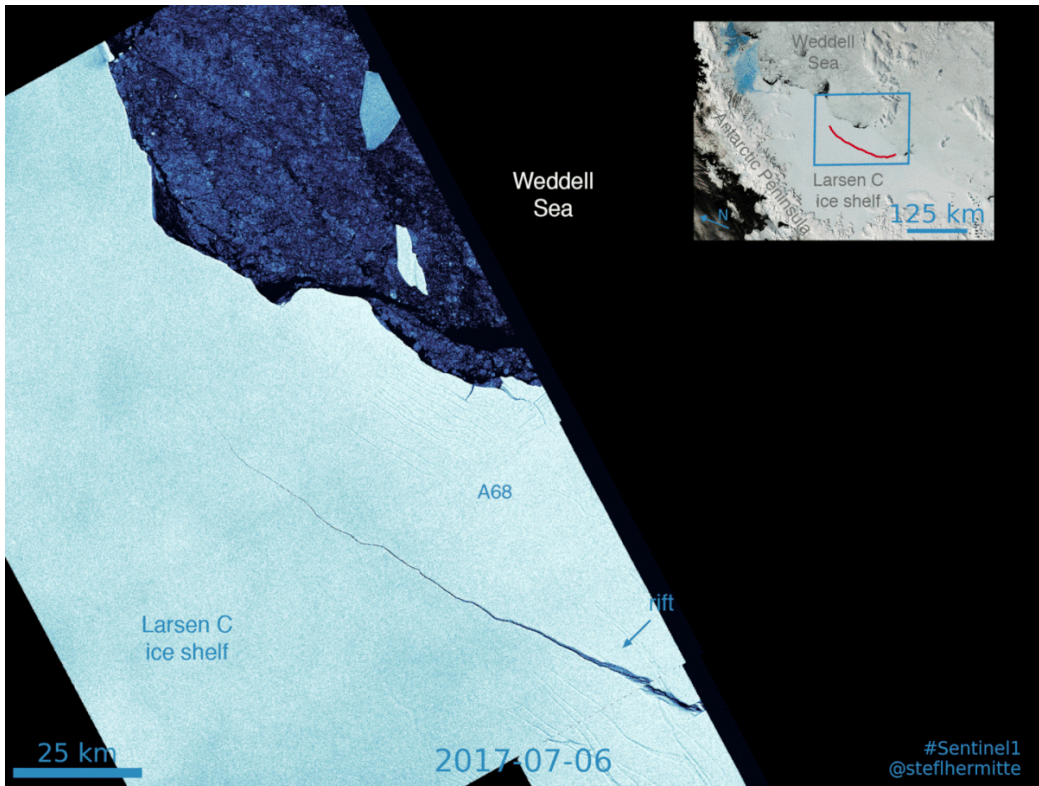
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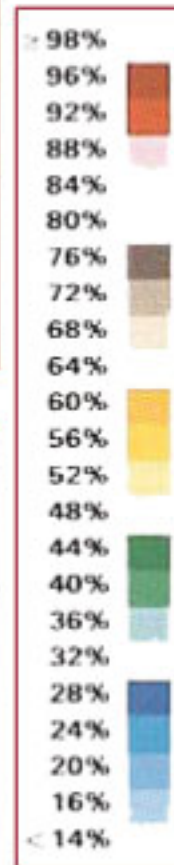
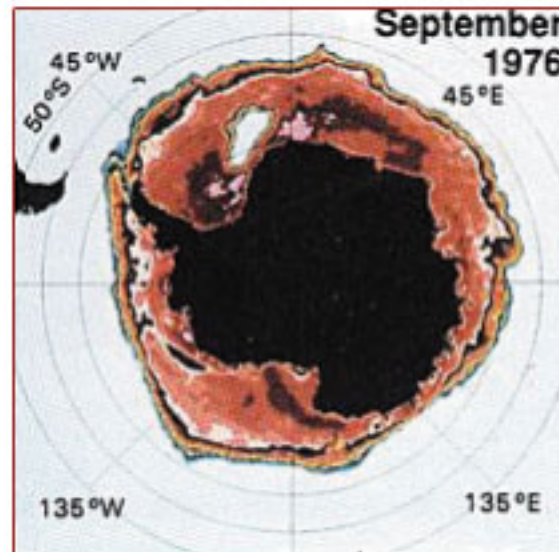
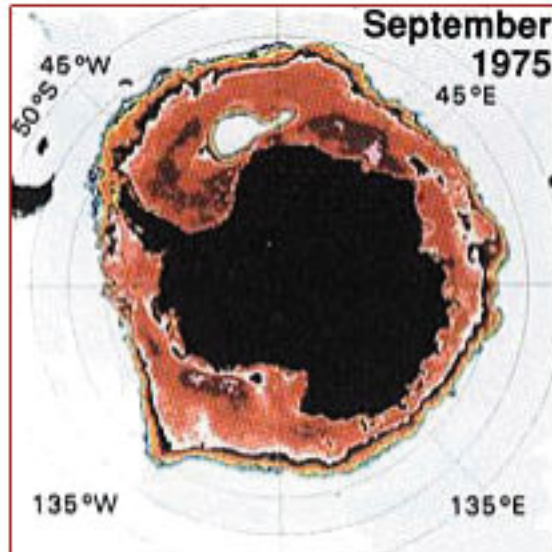
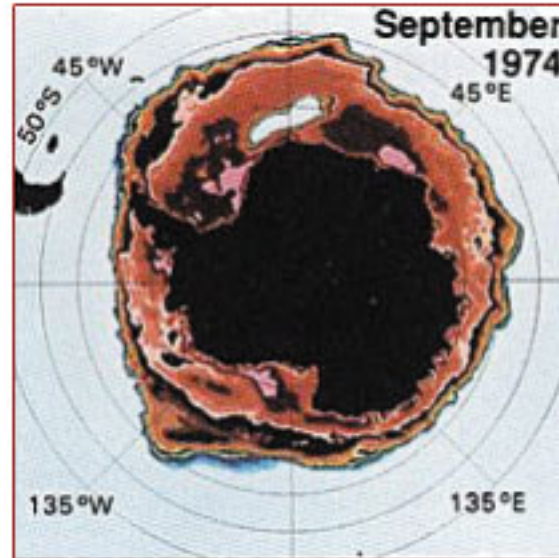
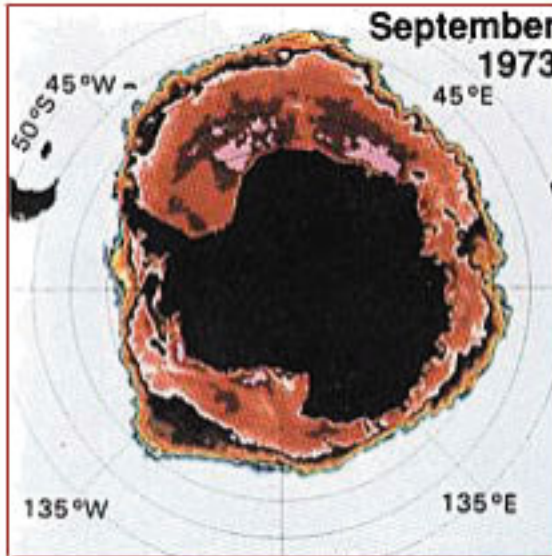


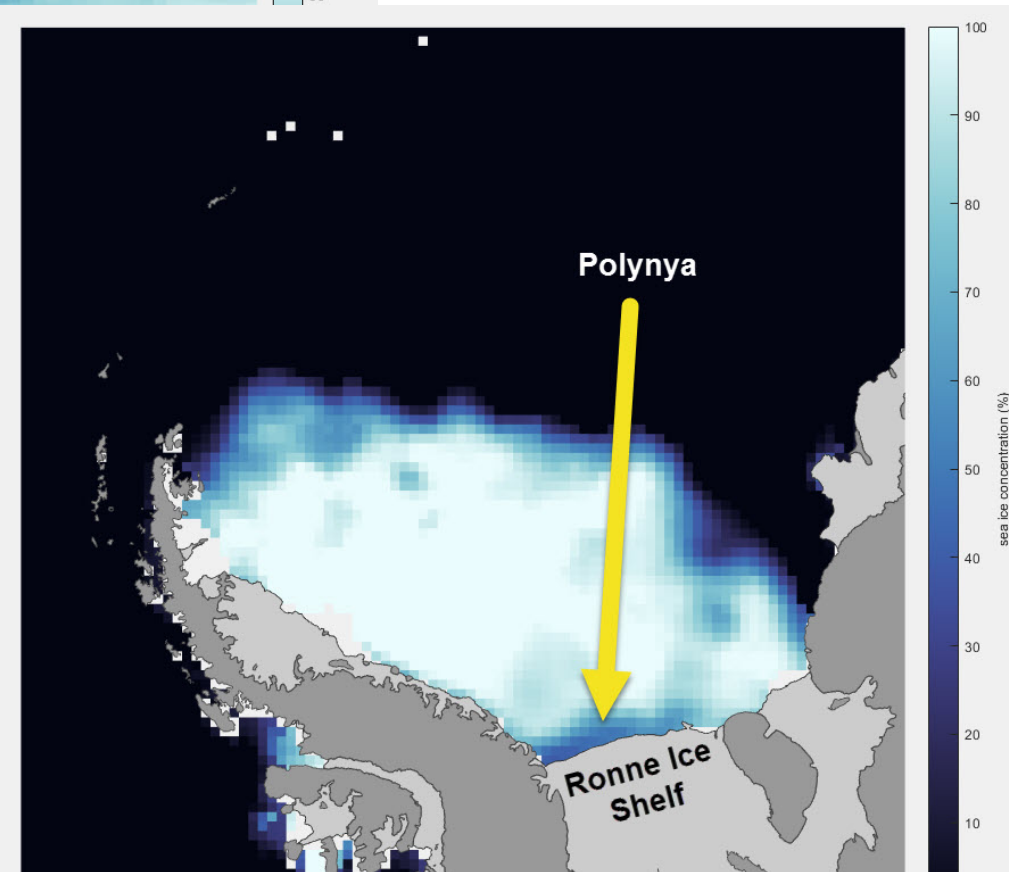
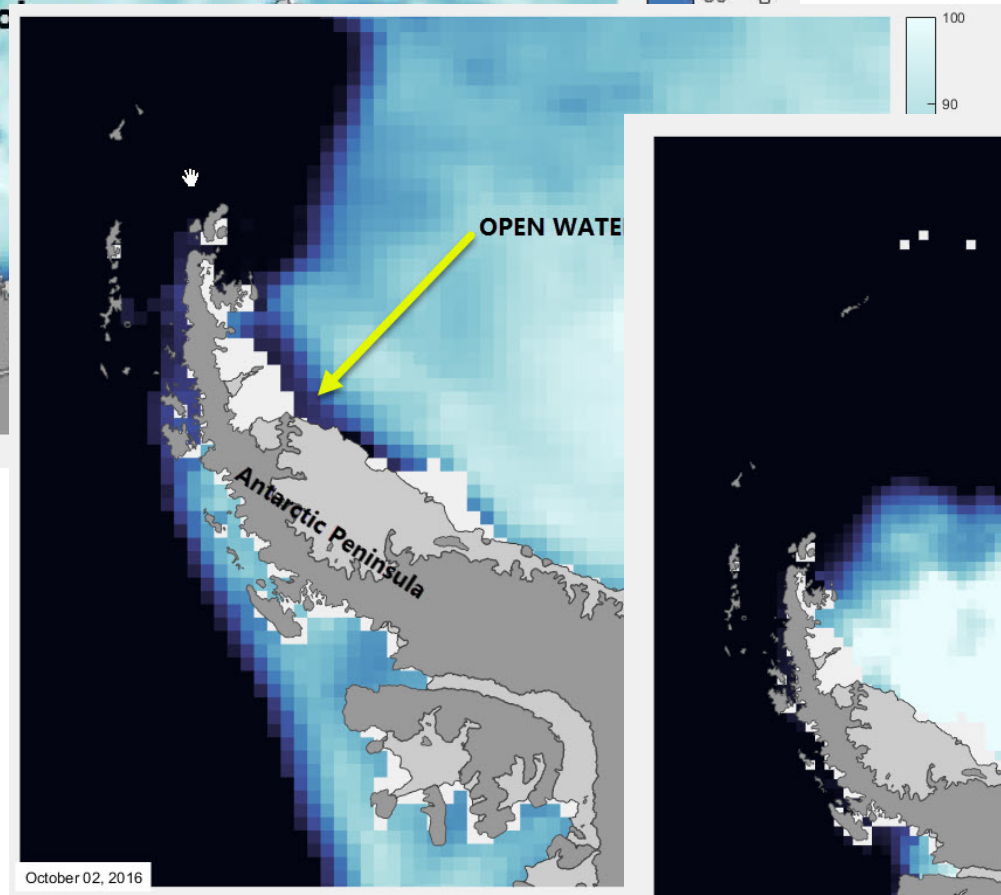
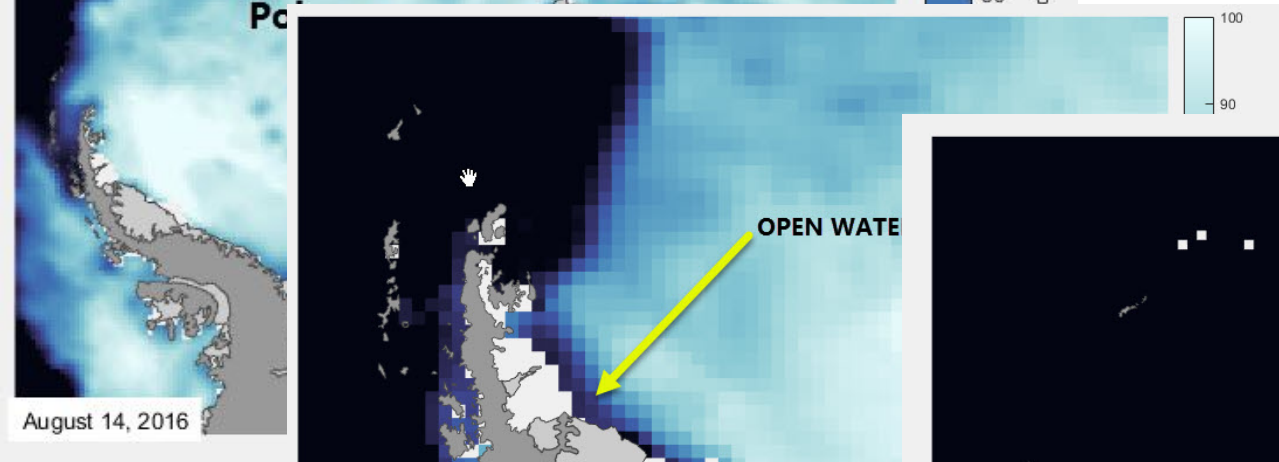
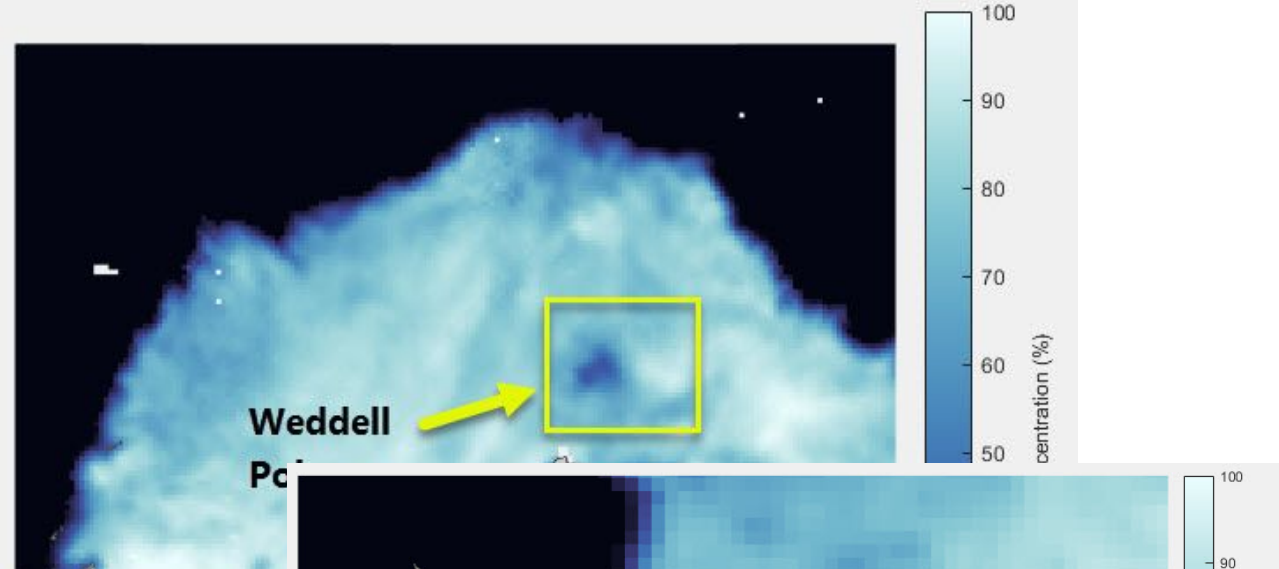




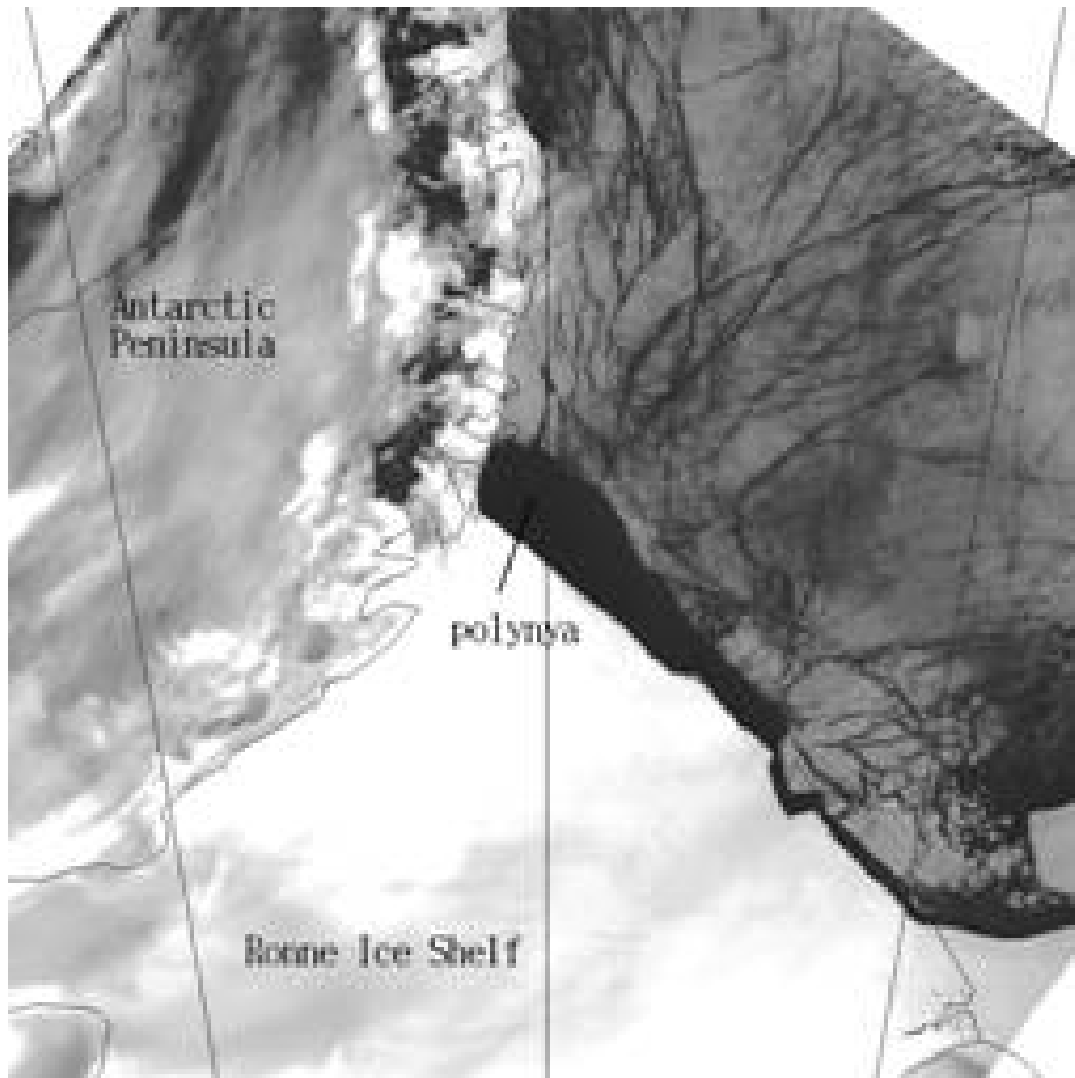


# Polynya del MdW in mare aperto

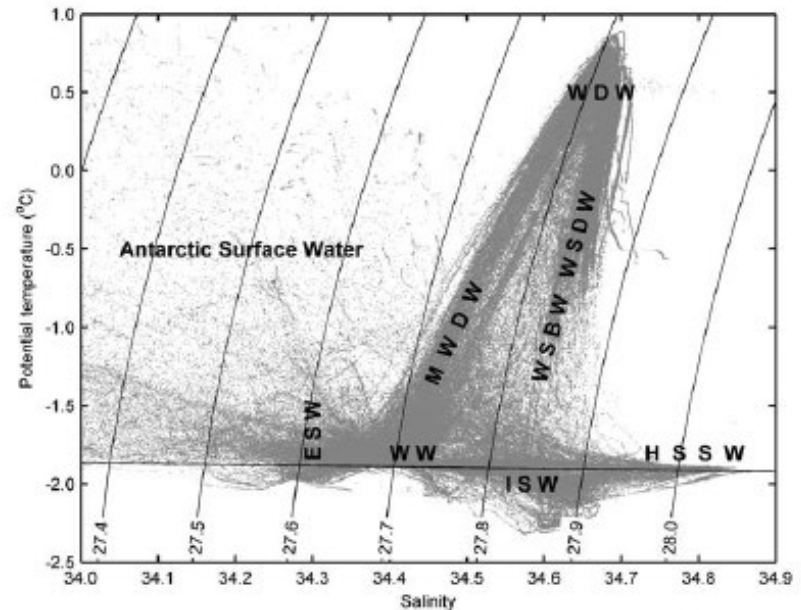




# Ice front polynya - shore lead



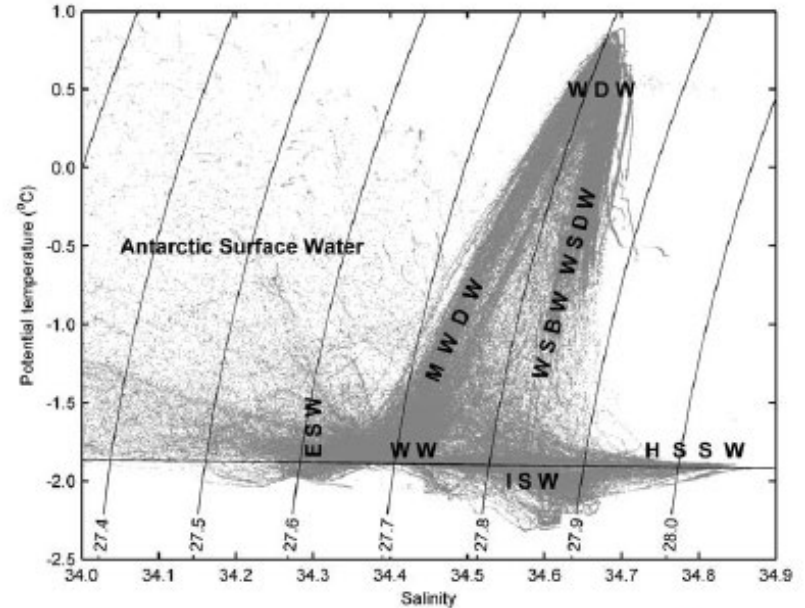
- **Warm Deep Water (WDW)** deriva dalla CDW quando, entrata nel Weddell Gyre (WG), si raffredda e diventa meno salata
- **Weddell Sea Bottom Water (WSBW)** si trova sotto la WSDW si forma per processi lungo la scarpata. Si trasforma in WSDW dopo aver stazionato nel WG e dopo essersi mescolata con **Weddell Sea Deep Water (WSDW)** è la manifestazione di AABW nel MdW. Il maggior volume entra da est ma vi è anche formazione locale negli strati superiori .



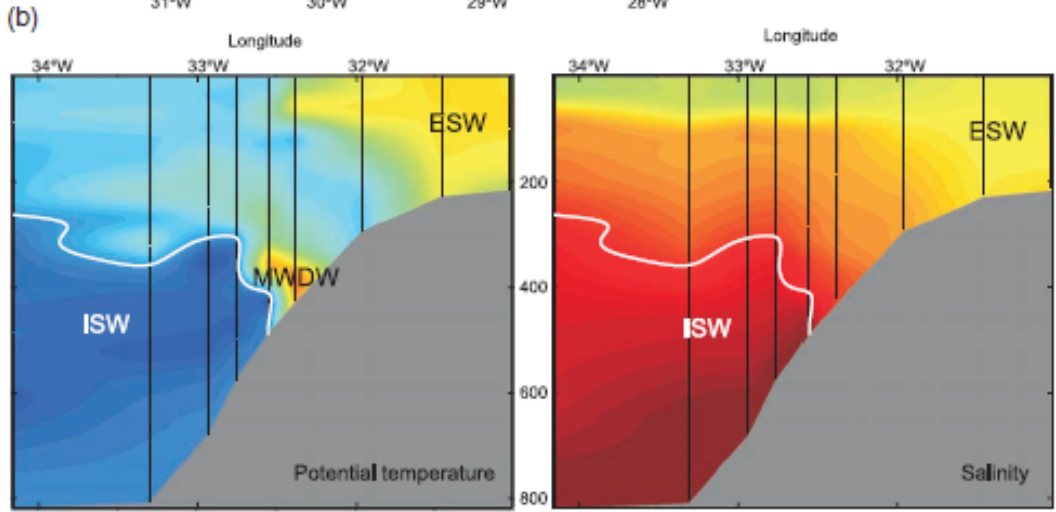
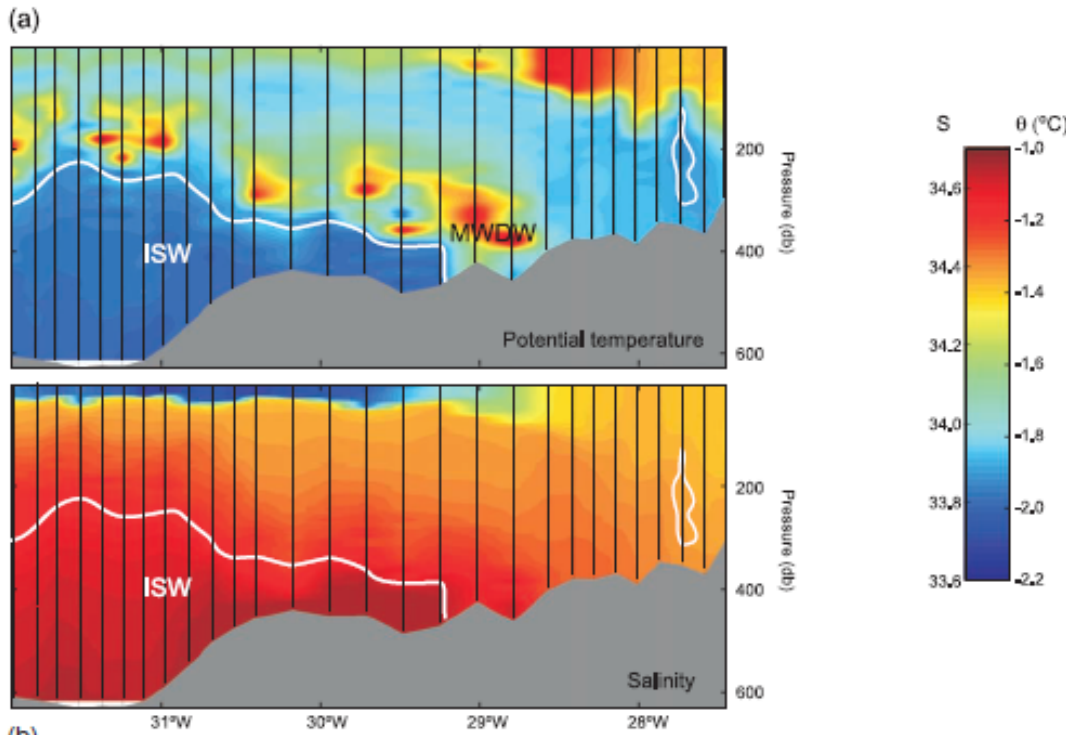
**Figure 3.** A  $\theta$ - $S$  diagram showing data from 554 CTD profiles from the Weddell Sea south of 70°S and west of 0°. The diagram shows approximate  $\theta$ - $S$  characteristics for the water mass types mentioned in the text. Isopycnals are referenced to surface pressure, and the near-horizontal line shows the surface pressure freezing temperature [Fofonoff and Millard, 1983]; all data below that line are from Ice Shelf Water.



- **Strato superficiale occupato da ASW** che si trasforma per raffreddamento invernale e aumento di salinità (scioglimento ghiaccio) in **Winter Water (WW)**
- **WW** è caratterizzata da temperatura bassa e salinità "alta" per effetto della formazione di ghiaccio marino e mescolamento con la WDW (più salata) posta sotto le WW
- **Modified Warm Deep Water** è un'acqua di transizione tra WW e WDW che partecipa ai processi di formazione di WSBW e delle acque di shelf
- Le **Eastern Shelf Water (ESW)** si formano per diluizione delle WW con le acque glaciale proveniente dall'eastern Weddel ice shelves



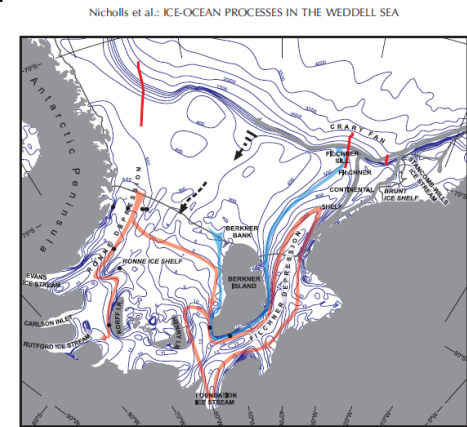
**Figure 3.** A  $\theta$ - $S$  diagram showing data from 554 CTD profiles from the Weddell Sea south of  $70^{\circ}\text{S}$  and west of  $0^{\circ}$ . The diagram shows approximate  $\theta$ - $S$  characteristics for the water mass types mentioned in the text. Isopycnals are referenced to surface pressure, and the near-horizontal line shows the surface pressure freezing temperature [Fofonoff and Millard, 1983]; all data below that line are from Ice Shelf Water.



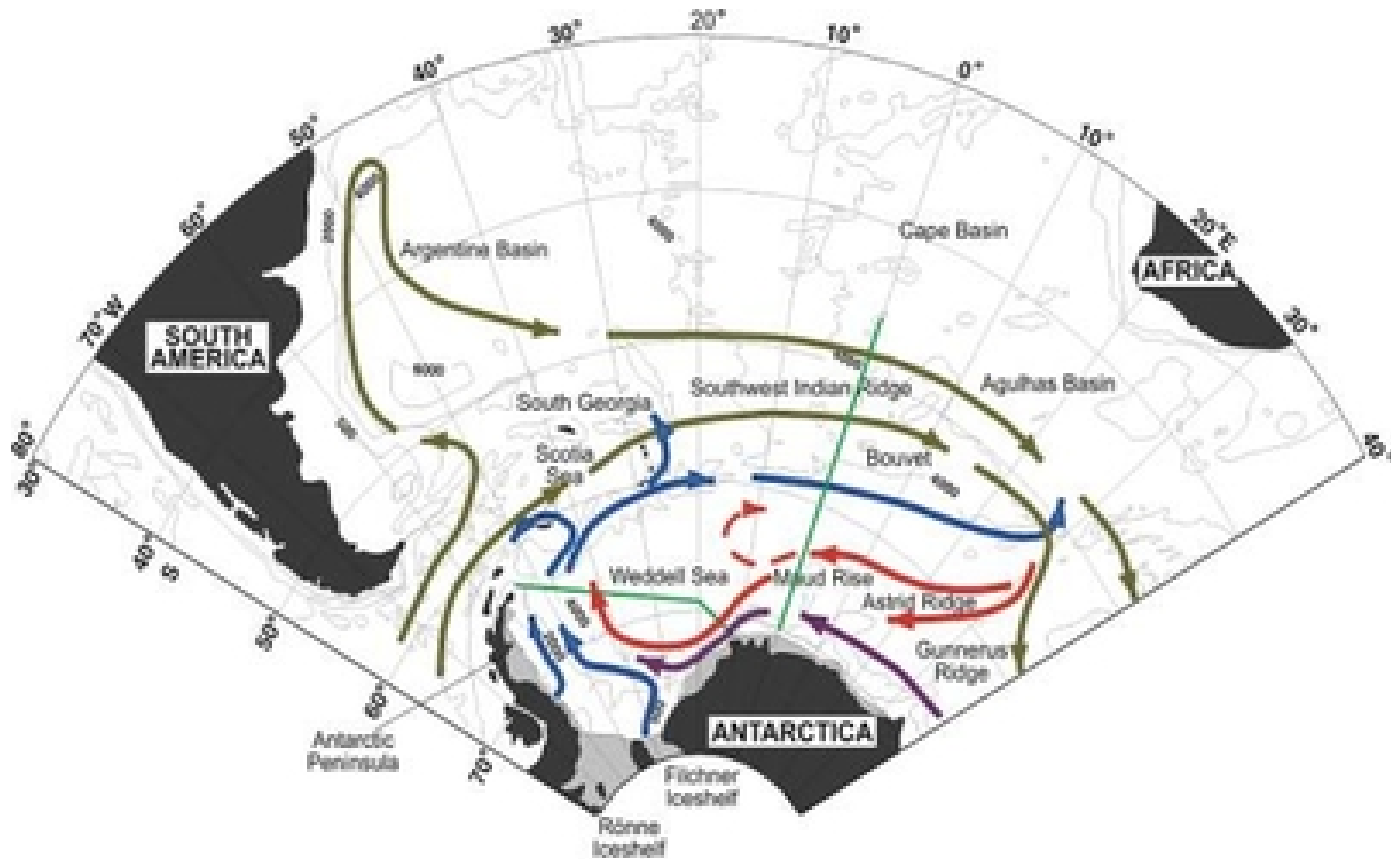
**Figure 7.** Potential temperature and salinity sections from (a) RISOC (2003(1)) and (b) JR97 (2005) cruises. The tracks for the sections are shown in Figure 6. The white contours indicate the position of the isotherm for the surface freezing point; all colder water is Ice Shelf Water.

-Eastern Shelf Water (ESF) si forma sulla piattaforma per effetto dell'interazione delle WW con l'estremità della piattaforma per cui ESF sarà meno salata di WW.

- ESW ha una densità minore della WW offshore determinando una pendenza delle isopiche e quindi un gradiente di pressione che alimenta la corrente lungo la scarpata

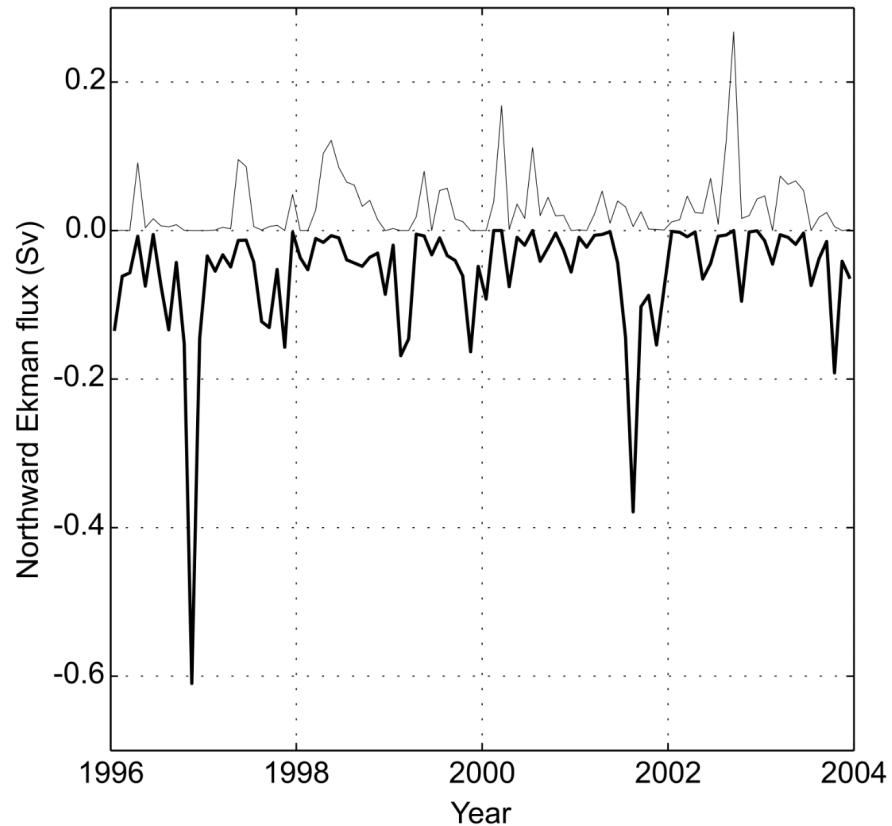


**Figure 2b.** Map showing the southwestern Weddell Sea. Bathymetric contours are labeled in hundreds of meters beneath the ice shelves. Ice fronts are shown by black lines. Black circles show drill hole locations. The gray arrows show the flow of the slope front and coastal currents. Blue and red arrows show the circulation beneath the ice shelf of waters originating from the eastern and western ends of the Ronne Ice Front, respectively. The top thick black broken arrow indicates the location of an MWDW inflow at the central trough in the Ronne continental shelf break, and the bottom thick black broken arrow indicates the location along the ice front where an MWDW core is observed. The three solid red lines at the shelf break show the position of the sections in Figure 8.



Circumpolar Deep Water enters into the Weddell gyre. There, it is then called **Warm Deep Water (WDW; red arrows)**. WDW is transported in the southern limb of the gyre and contributes to the formation of **Western Shelf Water (WSW)** which can sink along the Antarctic continental slope to form **Weddell Sea Bottom Water (WSBW)** by mixing with WDW. WSBW flows to the northwest (blue arrows) and mixes again to form **Weddell Sea Deep Water (WSDW)** which then can leave the Weddell Sea. The Antarctic Coastal Current (magenta arrows) surrounds Antarctica flowing westwards. In the Atlantic sector of the Southern Ocean it is the major transport way to carry the WDW in the deep and bottom water formation area in the south-western Weddell Sea.

# Ruolo del vento e trasporto di Ekman



**Figure 5.** Ekman transport across  $73^{\circ}5.5'S$  using ECMWF winds. The southward (thick line) and northward (thin line) contributions were integrated separately.



L'accesso delle acque più calde alla parte più meridionale del MdW è fortemente condizionato dalla forma del picnoclino che separa lo strato sup mescolato dalla WW poste sotto.

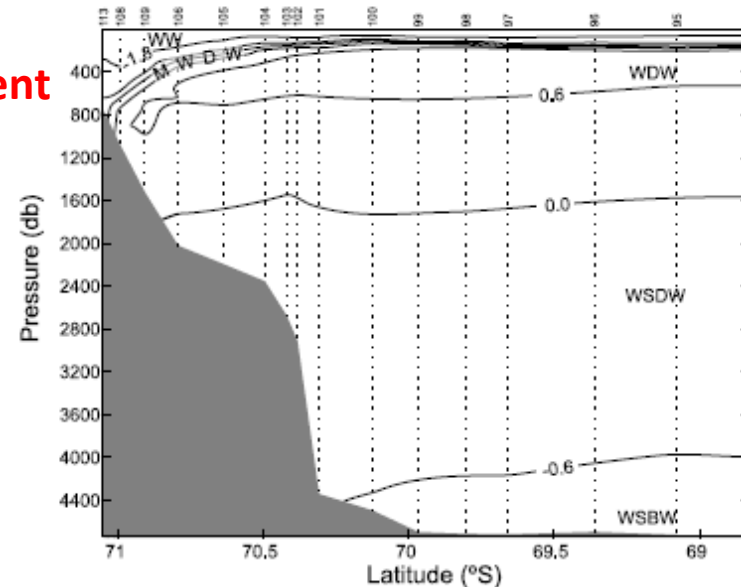
**Centro del gyre** : upwelling, convezione determina l'intensificazione e l'affioramento del picnoclino e riduzione della prof del mixed layer

**I venti orientali** determinano trasporto di Ekman verso la costa

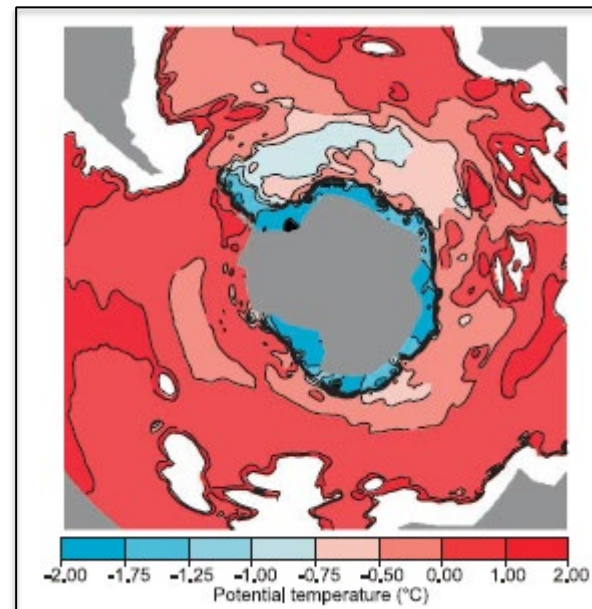
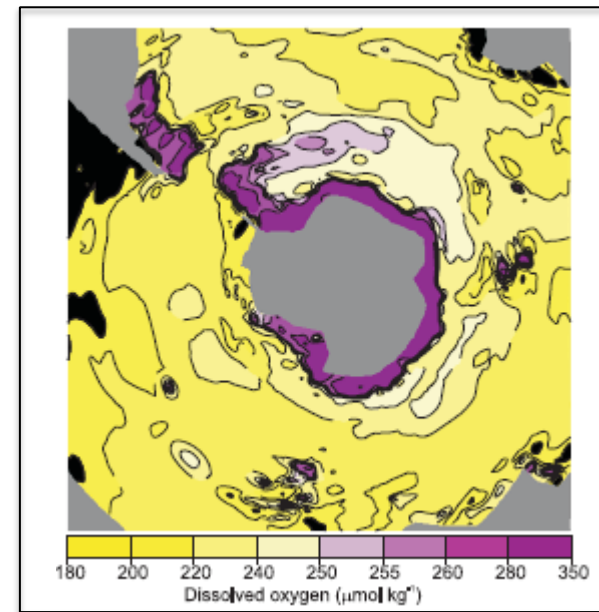
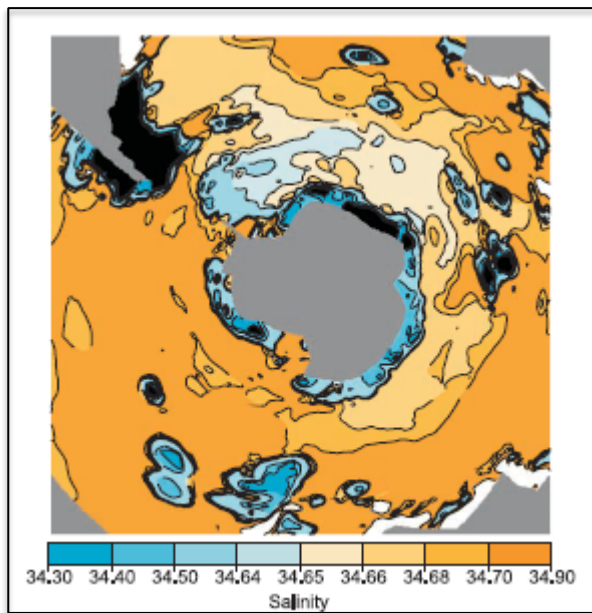
**Come conseguenza** : abbassamento del picnoclino e aumento d prof dello strato mescolato dove si trova MWDW. A tale processo contribuiscono anche le polynye

### Slope front e slope front current

La massa d'acqua di transizione tra WW e WDW, ovvero le MWDW, svolge un ruolo importante sia come sorgente per la formazione delle SW sia come principale costituente delle WSBW e quindi anche per le AABW



**Figure 4.** Potential temperature section from the central Weddell Sea to the southern Weddell Sea coast, obtained during cruise ANTARKTIS IX/2 of R/V *Polarstern* [Bathmann *et al.*, 1992]. The track for the section is shown in Figure 2a (as cruise 9144).



Il MdW produce il maggior volume di AABW, la più fredda e ricca di O<sub>2</sub> dell'Oceano Meridionale.

**Figure 1.** Bottom salinity, potential temperature, and dissolved oxygen for the Southern Ocean. Note the nonlinear color scales.

# Formazione di acqua profonda

- La massa d'acqua fondamentale per la produzione di BWs è la HSSW
- Le HSSW hanno tre potenziali “sorgenti” :
  - Acqua dello strato mescolato trasportata, nello strato di Ekman, verso sud attraverso lo shelf break
  - Acqua proveniente da est, che scorre sulla piattaforma continentale prima di piegare verso sud (verso il Filchner-Ronne Ice Shelf – FRIS)
  - MWDW è la più accreditata, in termini volumetrici, “*source water*” per HSSW. Come entra la MWDW in piattaforma ?

# Trasporto di MWDW sulla piattaforma

- Il meccanismo attraverso il quale la MWDW entra in piattaforma cont. Può essere determinato dalla struttura del campo di densità
- Il percorso che segue la MWDW per entrare in piattaforma segue una traiettoria che attraversa la scarpata.
- Un approccio usato in questo caso è considerare isolinee di galleggiamento neutro che consentono di capire se è necessario che l'energia potenziale cresca per sollevare la MWDW

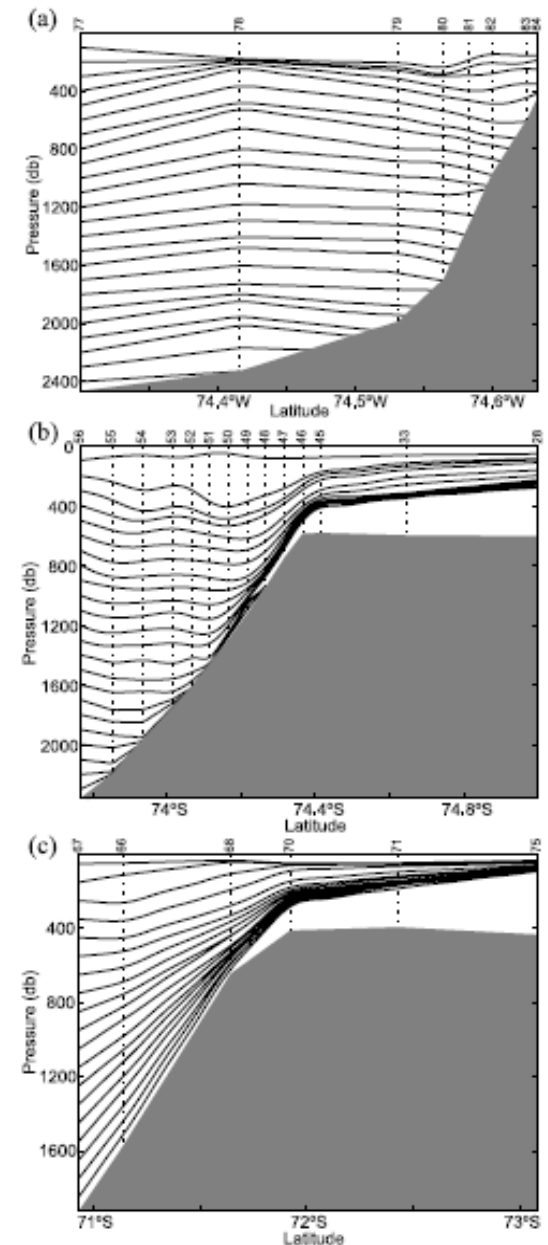


Figure 8. Neutral paths for sections across the southern Weddell Sea slope at longitudes (a) 27°W, (b) 32°W, and (c) 55°W. The positions of the sections are shown as red lines in Figure 2b.



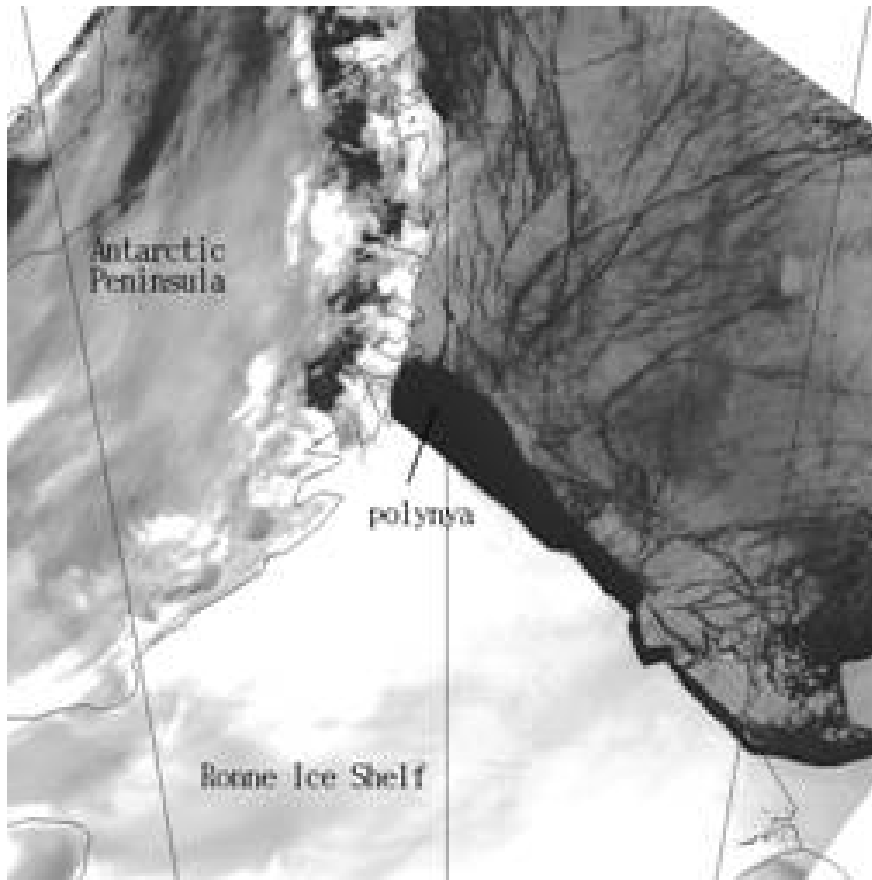
# Produzione di HSSW

- E' legata al budget di ghiaccio della piattaforma continentale
- L'analisi dei movimenti del ghiaccio ha messo in evidenza che l'import di ghiaccio gioca un ruolo secondario nel bilancio e che la produzione più abbondante si ha localmente
- Per formare HSSW , deve essere sottratto calore prima per formare ghiaccio ma ulteriore calore deve essere ceduto affinché una quantità sufficiente di ghiaccio si formi per aumentare la salinità degli strati "superficiali"

# Produzione di HSSW (da Nicholls et al., 2009)

- Una stima realistica (limite inferiore) del tasso di conversione di MWDW in HSSW è data dal flusso di HSSW attraverso il Ronne Ice Front nelle cavità sotto il ghiaccio
- Si stima un flusso che va da c.a.  $1.4-1.6 \pm 0.5$  Sv
- In termini invece di flusso di calore necessario per formare HSSW si ottiene: 1) valore di T e S della MWDW sono  $-1.76$  °C e 34.50 psu; 2) i valori di T ed S della HSSW sono  $-1.9$ °C e 34.75 psu; 3) su un anno la perdita di calore totale deve essere  $\sim 3 \cdot 10^{20}$  J
- Si stima che l' 80% di tale energia è necessaria per incrementare la salinità
- A tale scopo il ghiaccio deve raggiungere uno spessore minimo di 2.2m su un'area di 370.000 Km<sup>2</sup> della piattaforma continentale

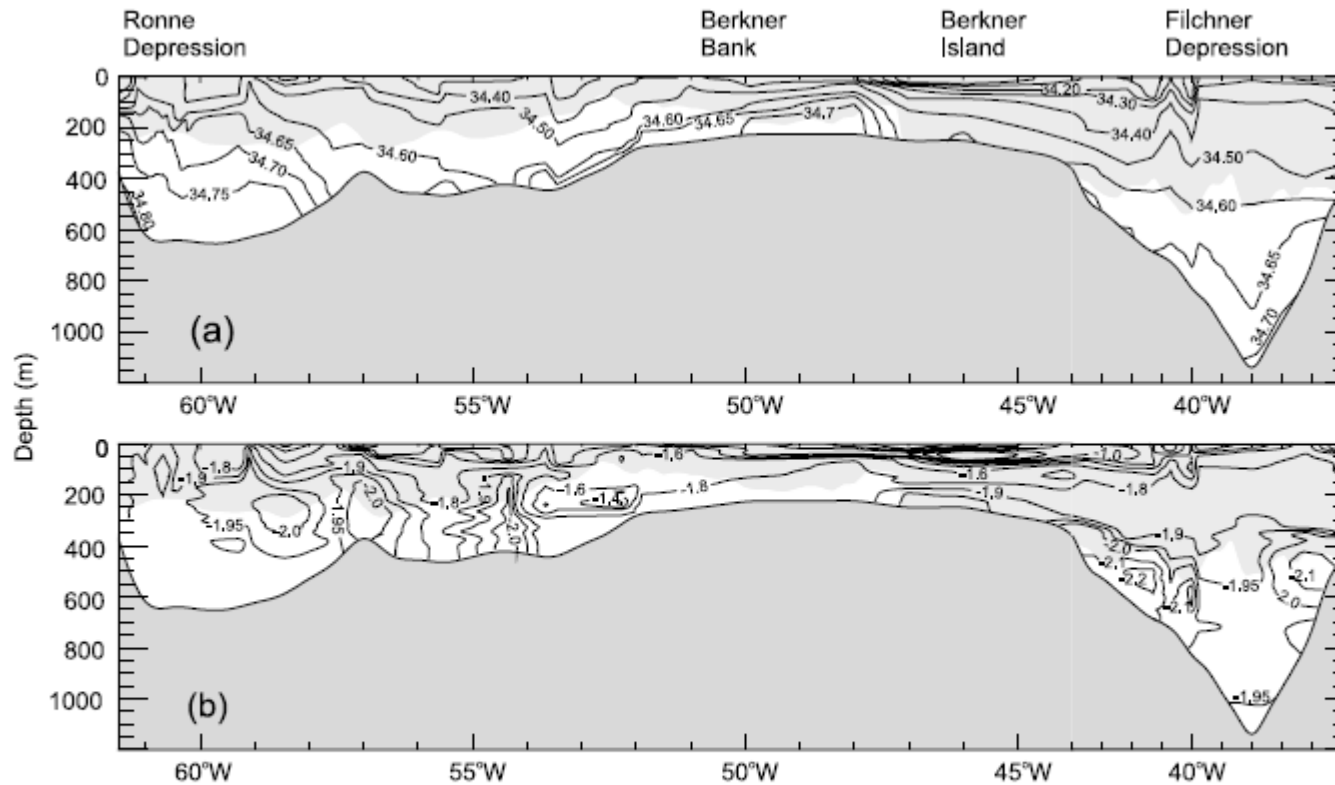
# Ice front polynya - shore lead



.... According to our foregoing discussion about the amount of heat that needs to be extracted from the continental shelf waters to make up the required HSSW production rate, the majority of HSSW production must take place over the sea ice-covered region....

... The scenario in which convection takes place over a large area but with a smaller zone of more intense heat loss has not been covered by numerical experiments to date, and the shelf circulation and distribution of salinity that would result is unclear.

# Distribuzione di HSSW

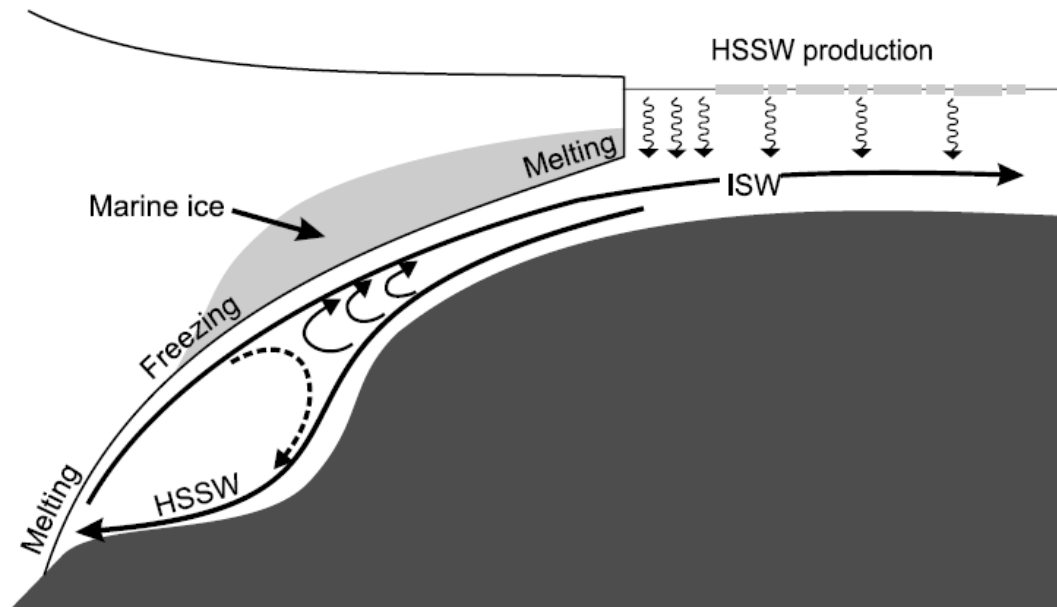


**Figure 11.** (a) Salinity and (b) potential temperature sections along the Filchner and Ronne ice fronts obtained in February 1993 by the Nordic Antarctic Research Programme 1992–1993 [Gammelsrød *et al.*, 1994]. The light shading indicates the draft of the ice shelf at the ice front.

- Dall'analisi dei dati misurati durante diverse campagne oceanografiche, si è osservato un gradiente di salinità E-W



# Processi nella cavità



**Figure 12.** Two-dimensional schematic of the melting and freezing processes beneath FRIS.

- ISW sono prodotte dalle interazione della HSSW sotto la base del ghiaccio. Le acque a  $T < -1.9^{\circ}$  sono considerate ISW
- Nelle cavità le HSSW sono influenzata dal mescolamento mareale, le interazioni dirette con la base del ghiaccio e la produzione di cristalli di ghiacci a temperature superfredde