Sea Ice, Ice Shelves, and Polynyas

Online sea ice reading

Read Introduction on the web site, and information on all links to left, Ice formation through Dynamics

Sea Ice Formation

--in Antarctica, begins forming in late summer with winds from the continent, evaporative cooling at ocean surface reduces water temperature to ~-1.8 °C

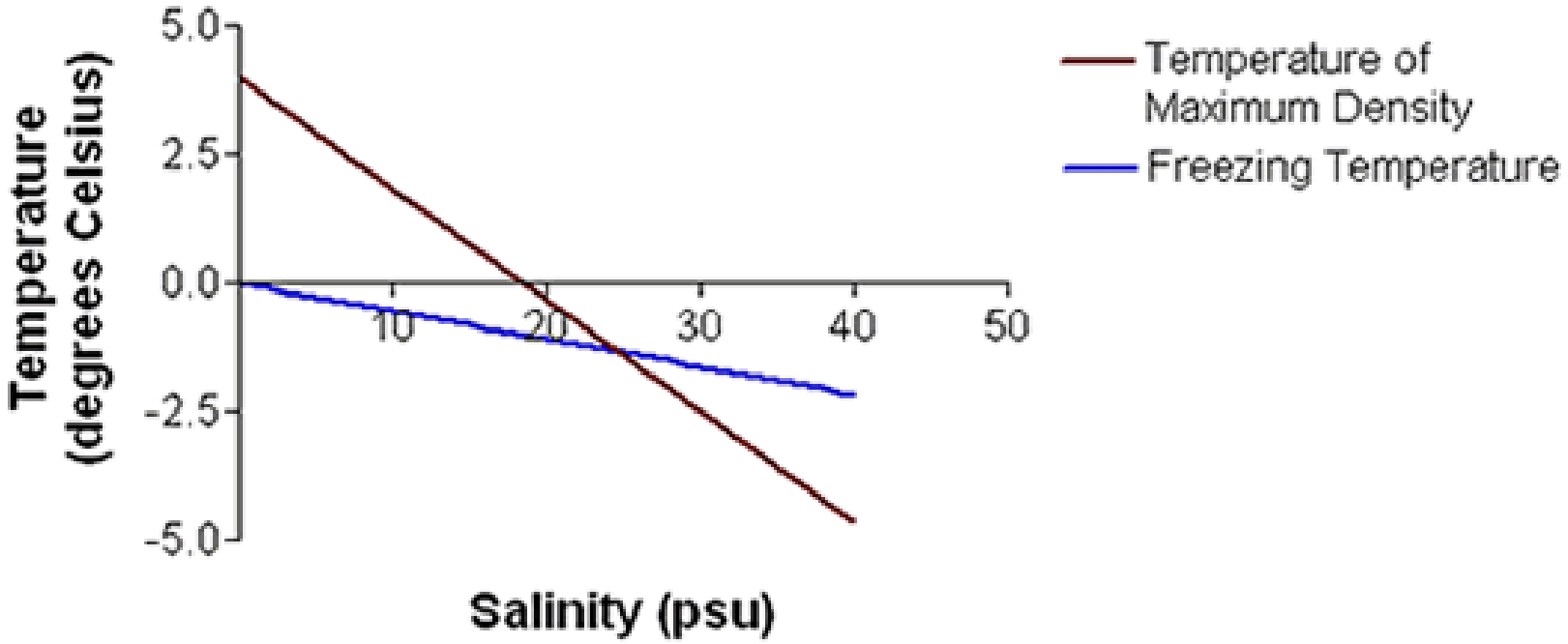
--as water temperature falls, ice crystals of fresh water begin to form (*frazil ice*) and move to surface

--may appear at first as *grease ice* or dark stains on surface that are similar to an oil slick; lightens with development

--grease ice forms sheets, or *nilas*, that cover the surface as a thin layer

--or frazil ice may form *pancake ice* if there is lots of motion in water from wind or currents

Ocean water begins freezing at -1.8 °C with average salinity at 35 ppt



https://nsidc.org/cryosphere/seaice/index.html

Ice Growth Process

https://nsidc.org/cryosphere/seaice/characteristics/formation.html

Frazil Ice


Grease Ice

Ice Growth Process

https://nsidc.org/cryosphere/seaice/characteristics/formation.html


Frazil and Pancake Ice in an advanced state of formation


As the ice congeals more, a solid sheet begins to form
Note algae trapped in ice

Newly formed sea ice, called *fast Ice* here as it is attached to land

Also get *drift ice* (not attached to land) and *pack ice* (ice drifts packed together from wind)

Ice floes are large pieces of drift ice

Sea ice is relatively thin when new or less than a year old

An icebreaker can easily clear a channel for ships to reach McMurdo Station

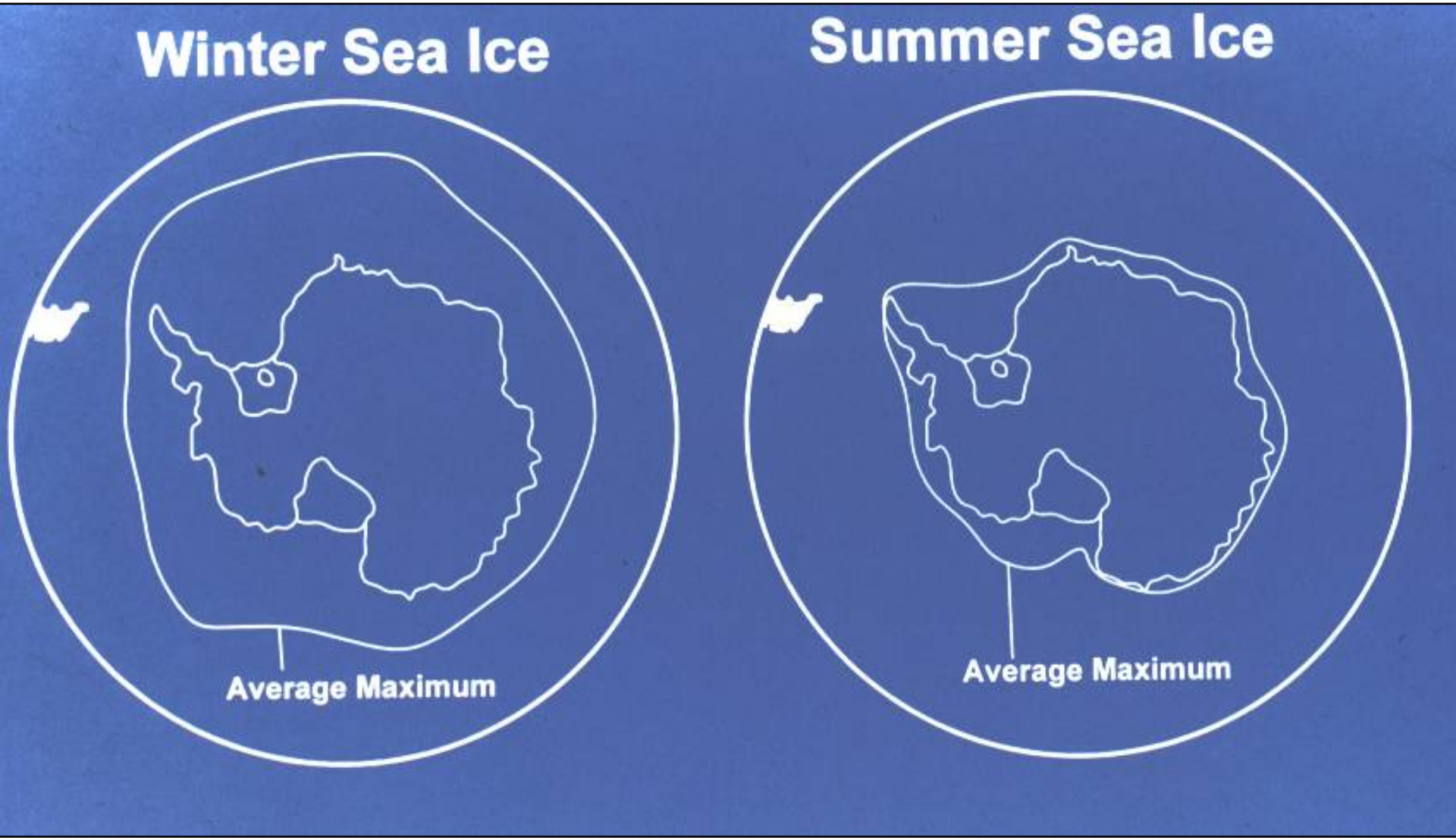

New ice forming between pieces of older sea ice
Note the rafting and ridges on the old ice that occurred during formation
Multiyear ice is one year or older, thicker from congelation on bottom

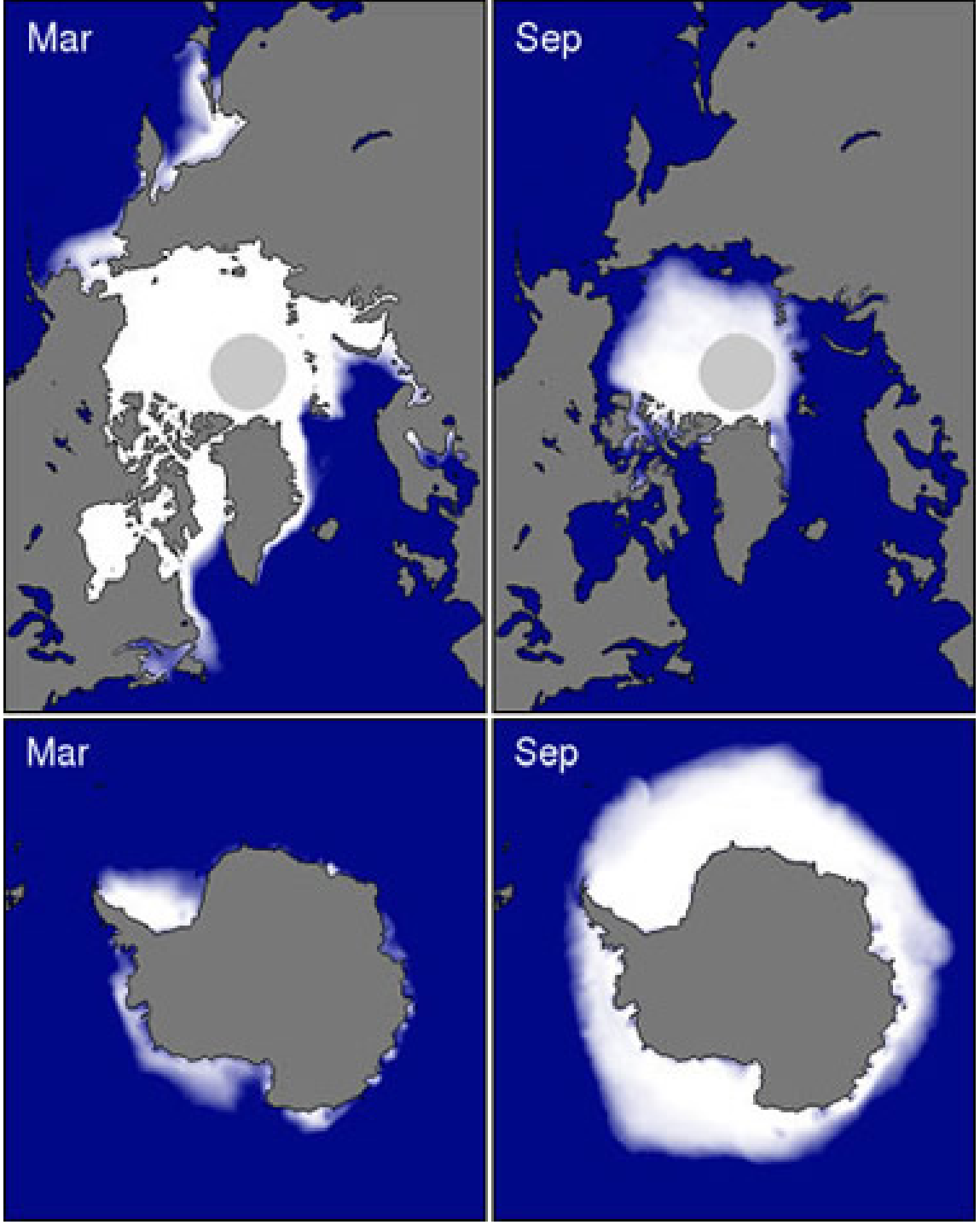
Multiyear ice with algae and congelation on bottom

Ice blink and water sky

Breaking ice for two months in Ross Sea

Heavy Ice Year: Sea Ice can double the size of Antarctica
Varies every year, heavier in ENSO years





Sea ice extent, summer vs. winter

Arctic vs. Antarctic

https://nsidc.org/cryosphere/seaice/characteristics/difference.html

Ocean Circulation

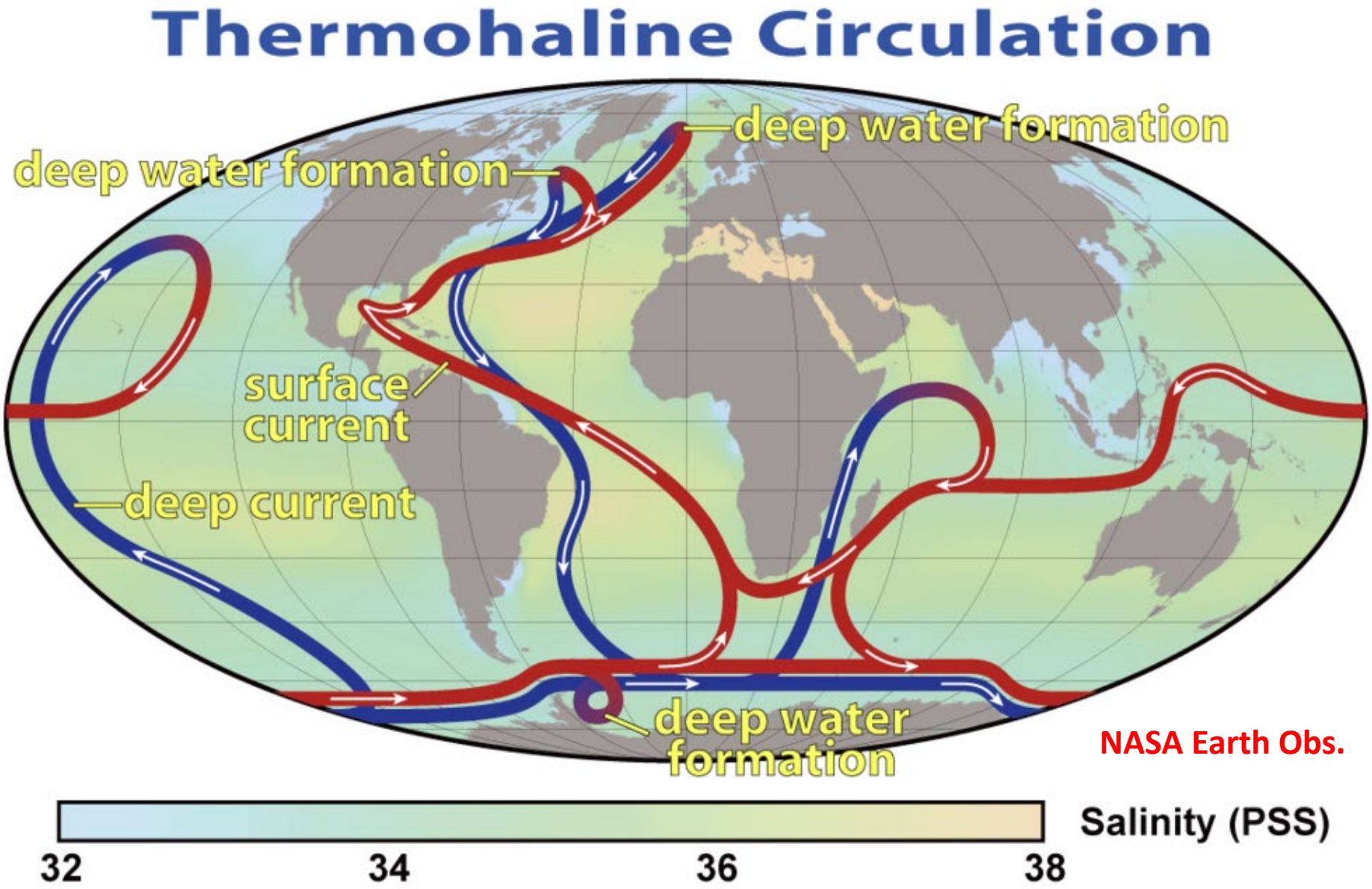
Sea ice is composed primarily of fresh water, with pockets of brine trapped inside

Compacted ice loses these pockets over time, so that the ice could be used as a source of fresh water

Removal of water from the ocean surface as sea ice forms, though, increases the salinity of the surface waters below the ice

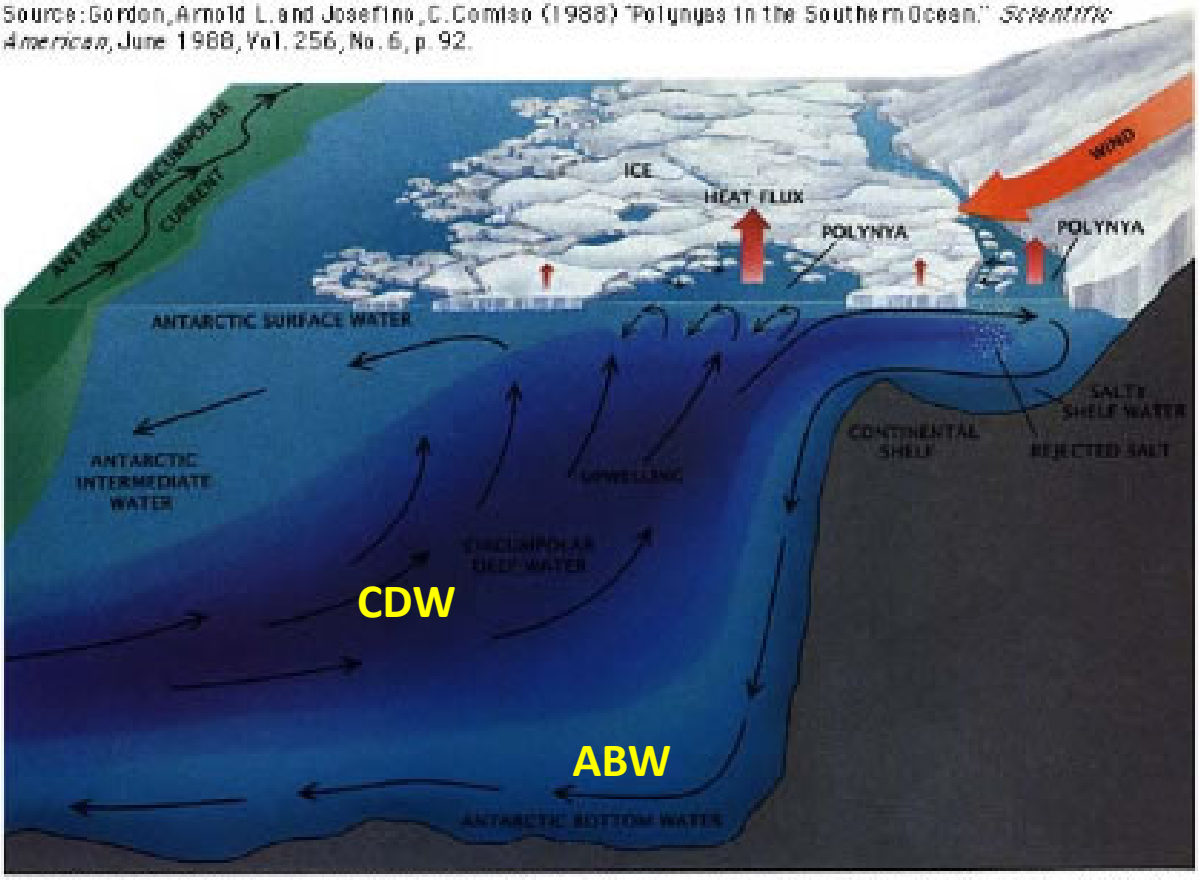
The cold temperature, with increased salinity, causes this water to become very dense and it begins to sink: *Antarctic Bottom Water*

***Thermohaline circulation* is a major process in ocean circulation every year in Antarctica**

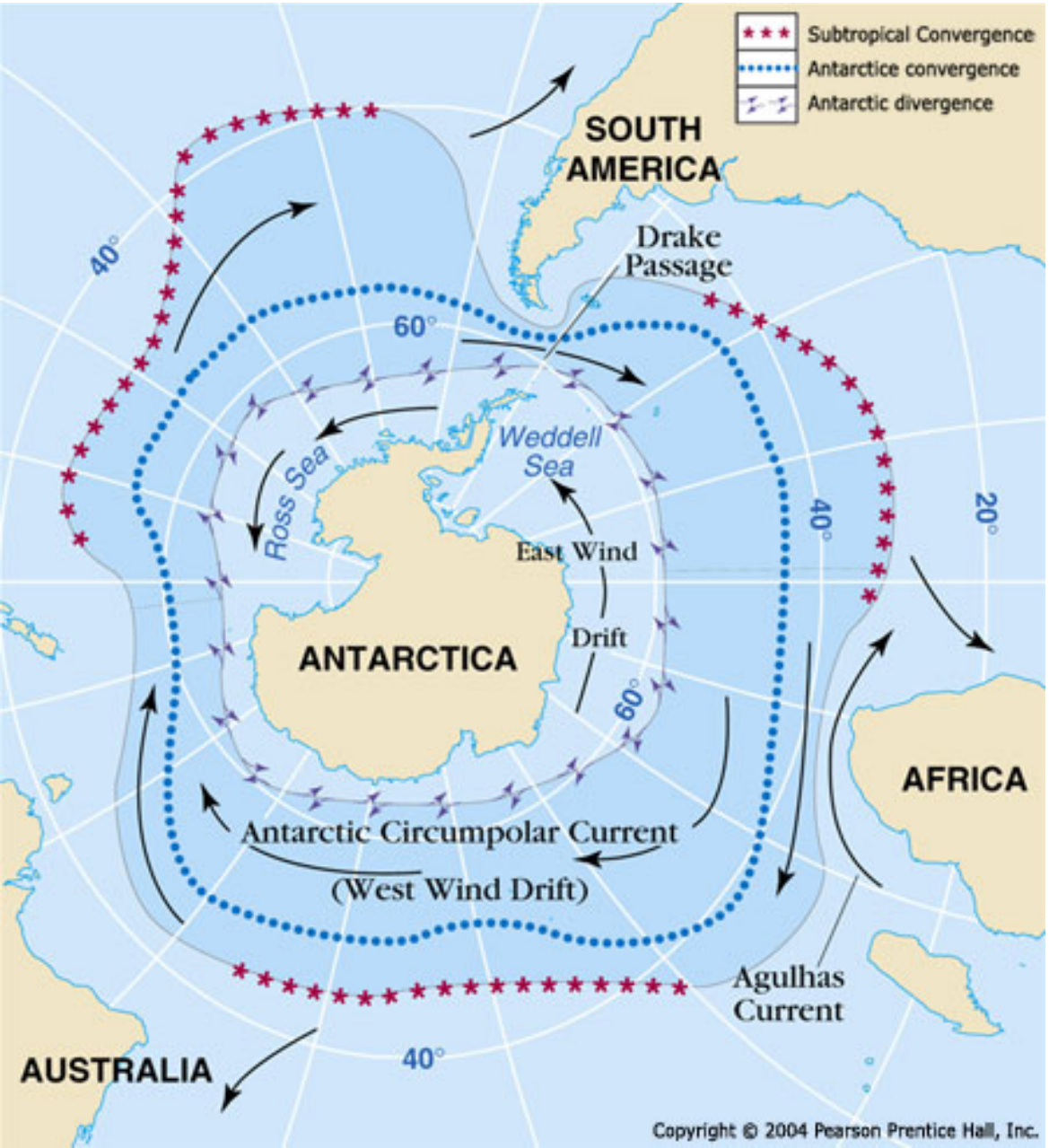


Circumpolar deep water (CDW)

Source: Gordon, Arnold L. and Josefino, C. Comiso (1988) "Polynyas in the Southern Ocean." *Scientific American*, June 1988, Vol. 256, No. 6, p. 92.



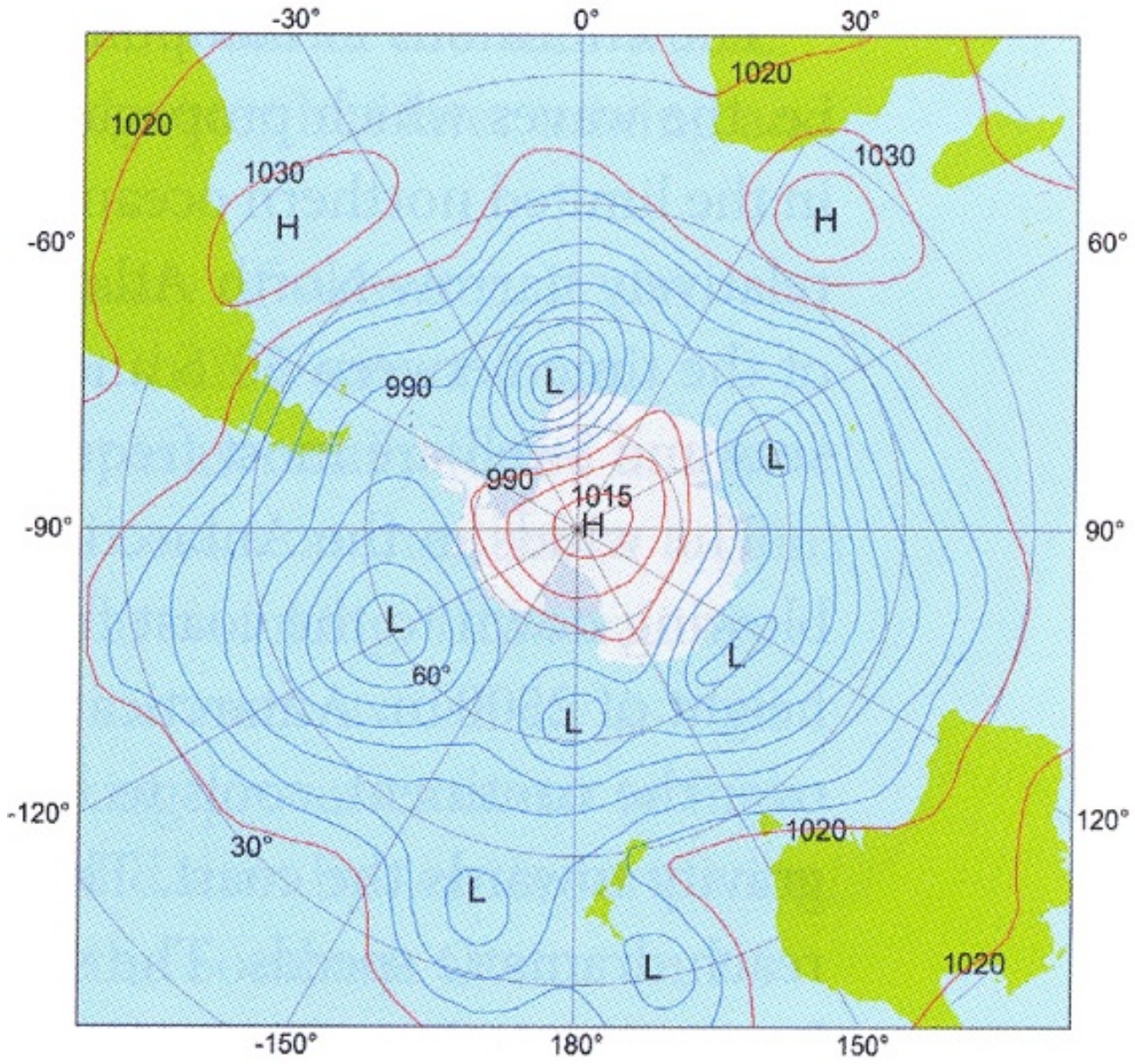
Meridional circulation pattern of the Southern Ocean (the ocean surrounding Antarctica) is dominated by the upwelling of a warm, salty water mass called the Circumpolar Deep Water and its transformation into Antarctic Surface Water, which ultimately sinks to become Antarctic Intermediate Water and Antarctic Bottom Water. The circulation is driven by wind and the exchange of heat and fresh water between the ocean and the atmosphere.



In summer, sea ice melts and surface waters stop sinking, move northward until meeting warm waters from lower latitudes.

Antarctic waters colder, so sink below at **Antarctic Convergence**

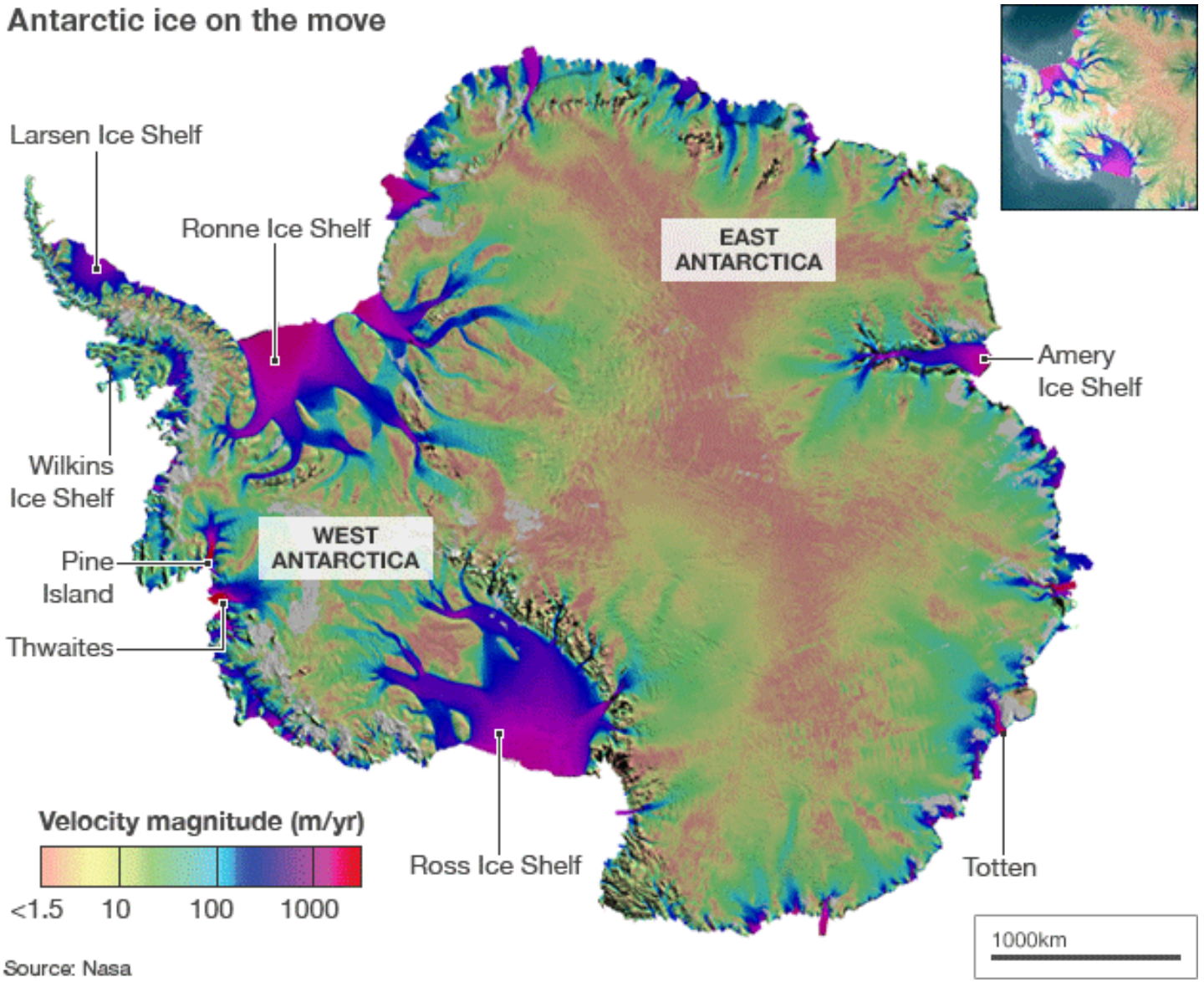
Crossing the convergence by ship shows how dramatic the air temperature changes as ocean temperatures strongly influence air temperatures

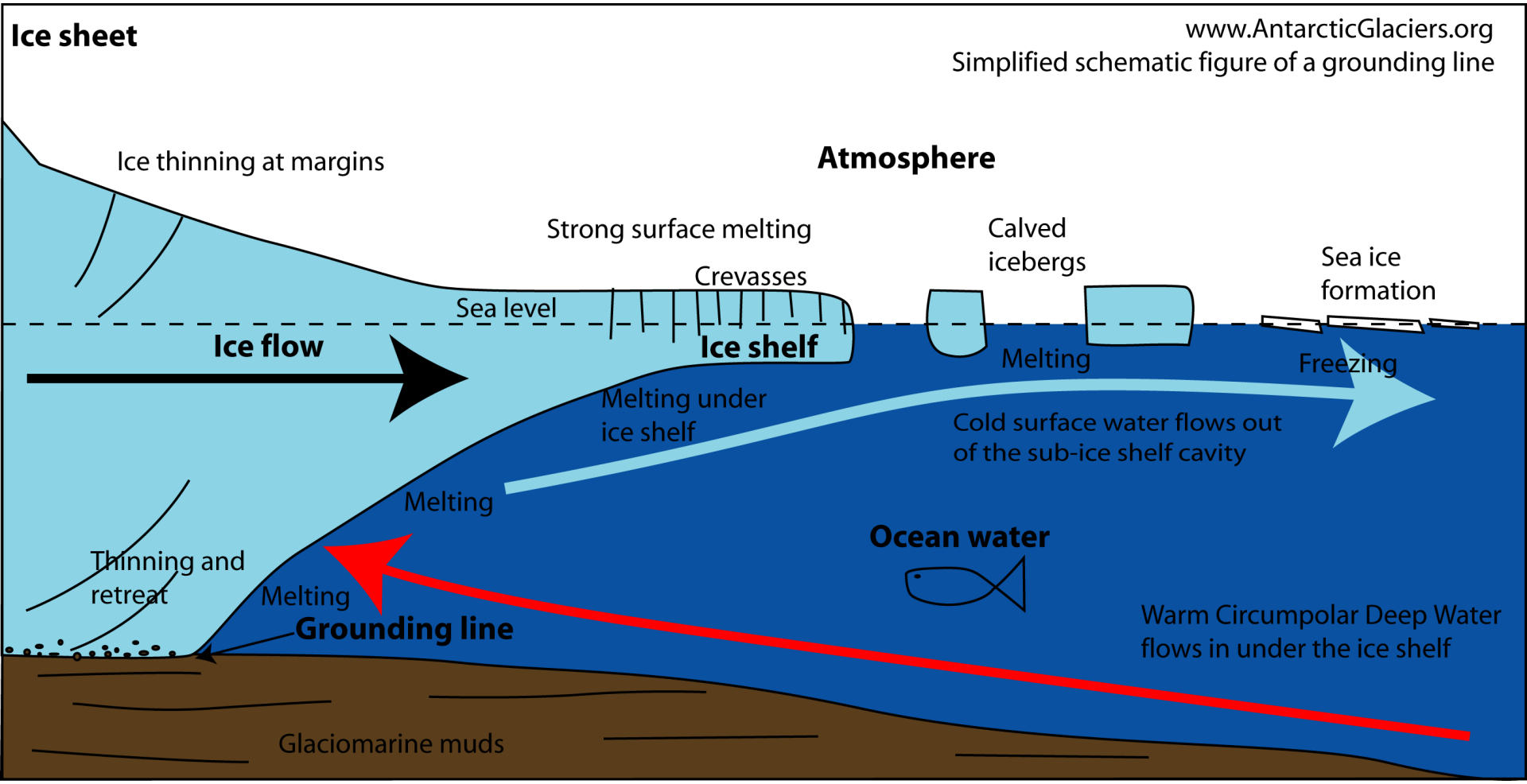


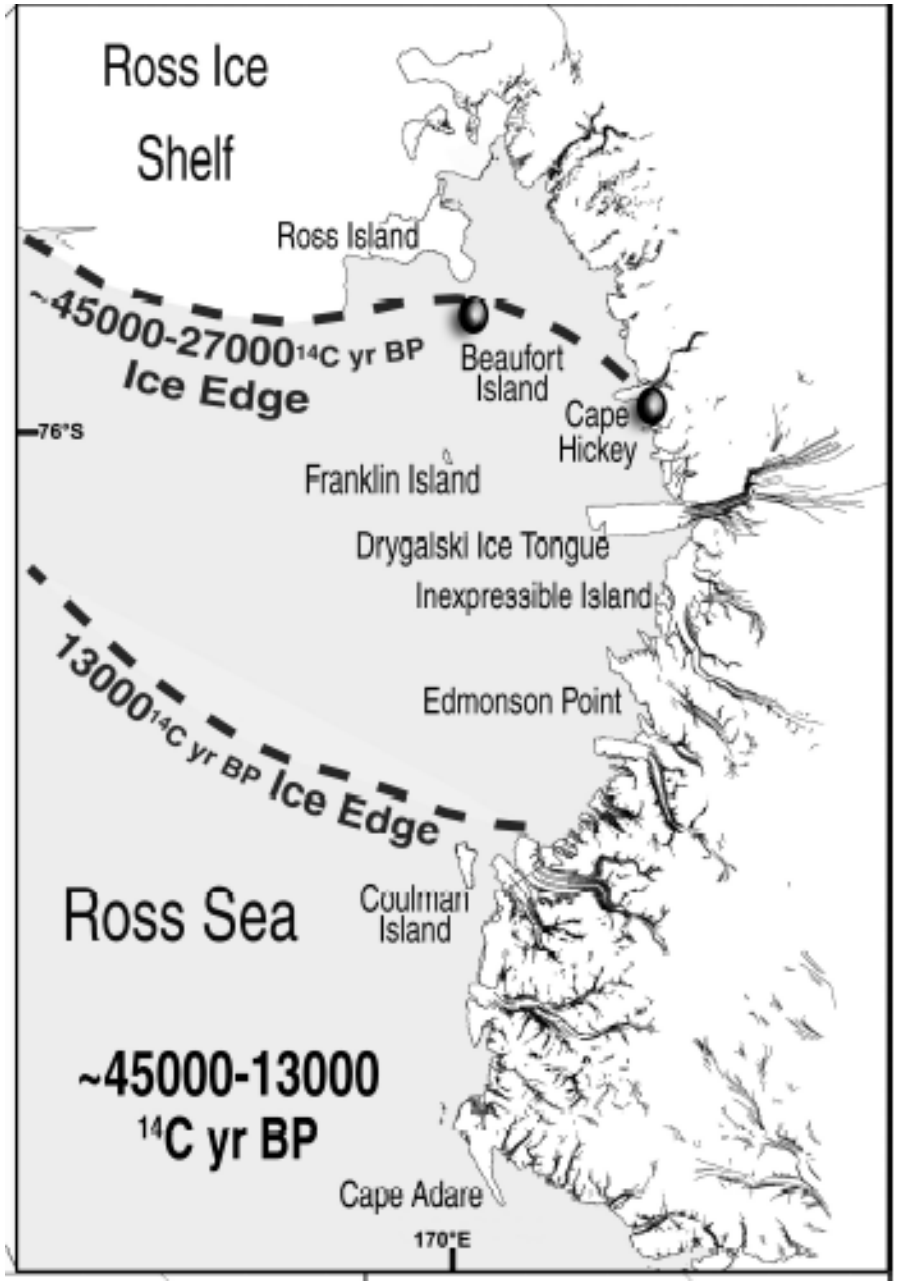
https://earth.nullschool.net/

Fig. 5.2 in Walton (2013)

Ice Shelves


Antarctic ice on the move
Larsen Ice Shelf
Ronne Ice Shelf
EAST ANTARCTICA
Amery Ice Shelf
Wilkins Ice Shelf
WEST ANTARCTICA
Pine Island
Thwaites
Ross Ice Shelf
Totten
Velocity magnitude (m/yr)
<1.5
10
100
1000
Source: Nasa
1000km


Ice sheet
www.AntarcticGlaciers.org
Simplified schematic figure of a grounding line
Ice thinning at margins
Atmosphere
Strong surface melting
Calved icebergs
Sea ice formation
Crevasses
Sea level
Ice flow
Ice shelf
Melting
Freezing
Melting under ice shelf
Cold surface water flows out of the sub-ice shelf cavity
Melting
Ocean water
Thinning and retreat
Melting
Grounding line
Warm Circumpolar Deep Water flows in under the ice shelf
Glaciomarine muds

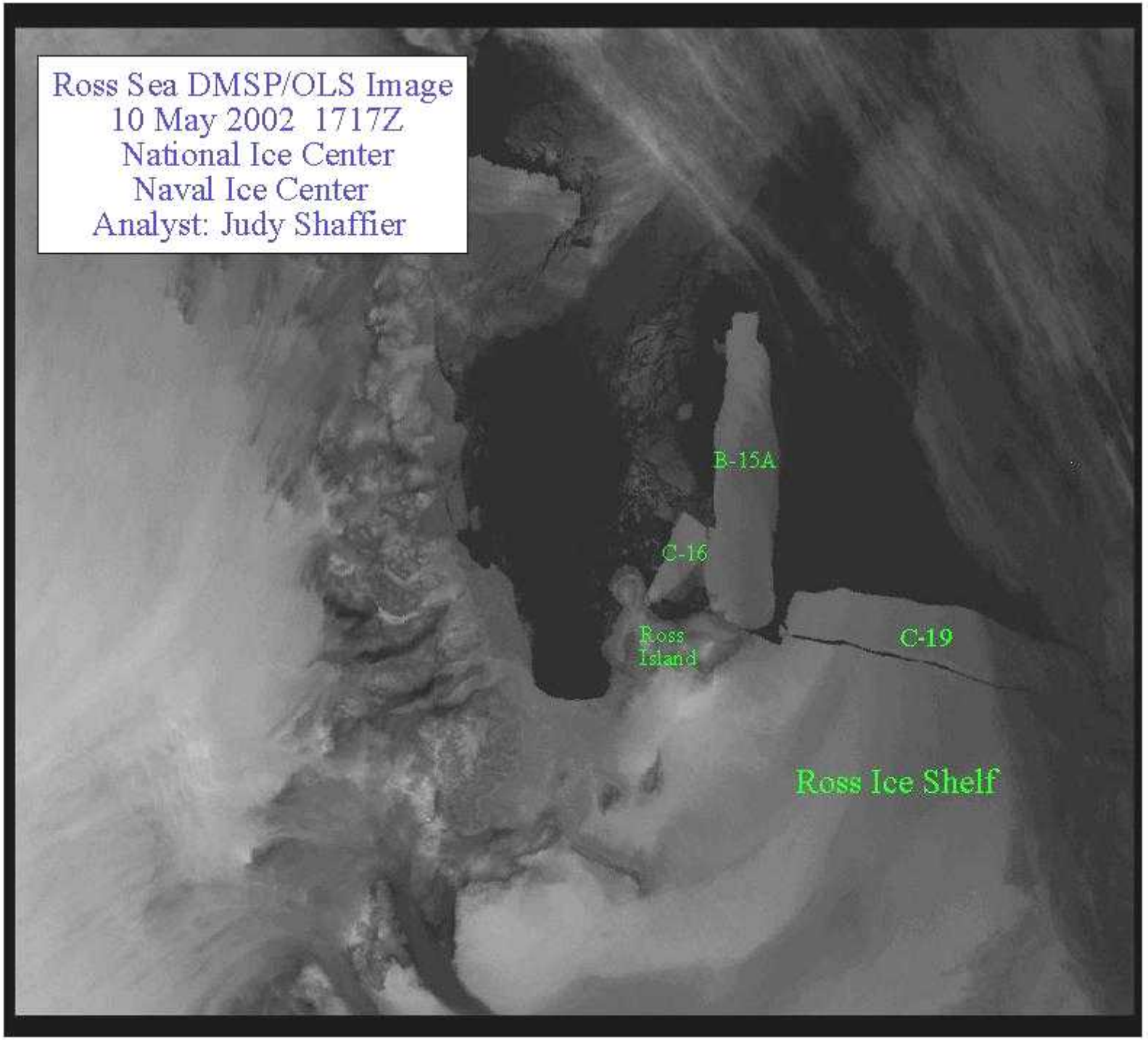


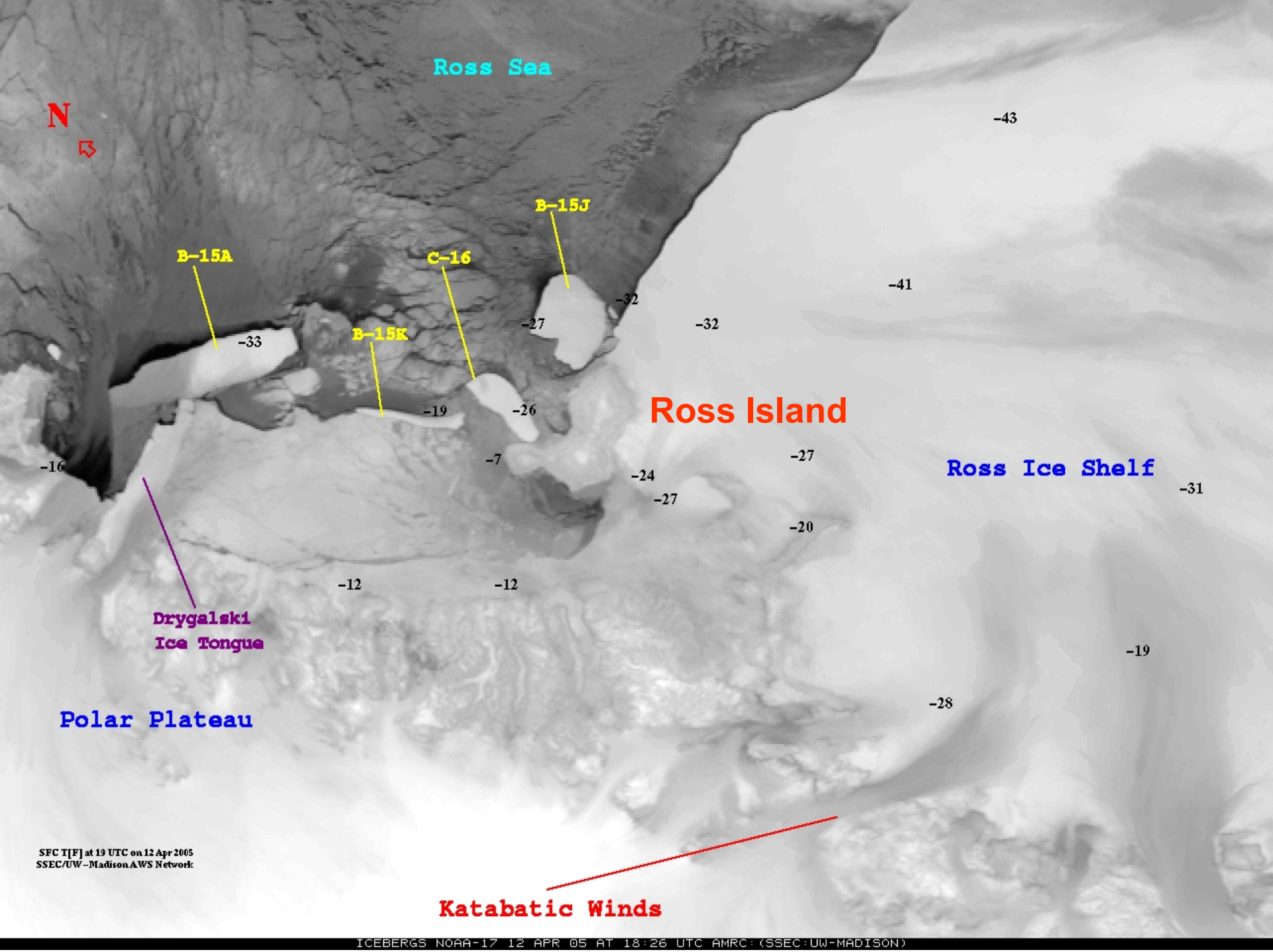
The last advance of the RIS was in the last ice age.

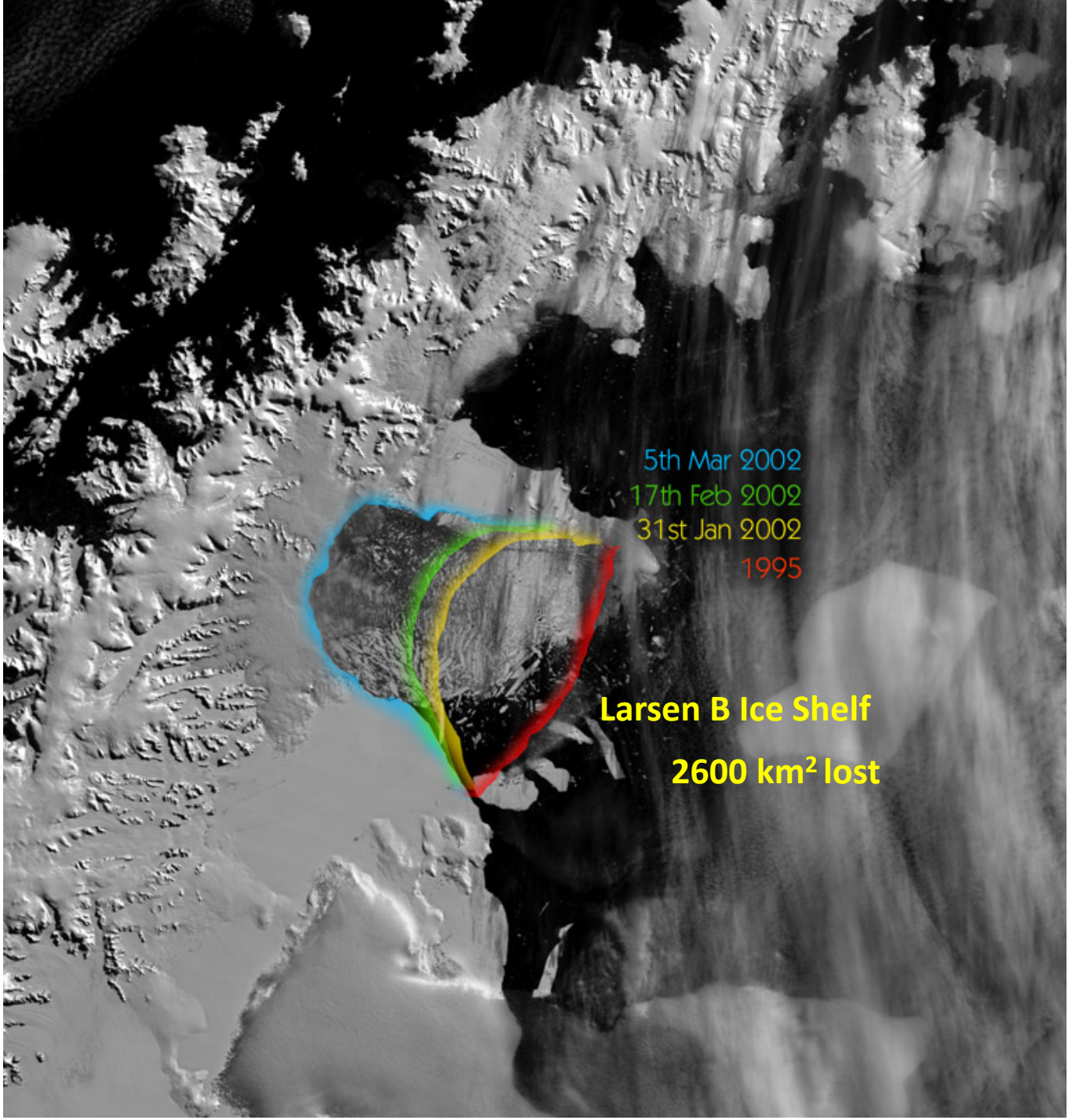
Grounding lines on the ocean floor show how far it advanced by 13000 BP

The penguin record indicates open water in the Ross Sea up to 27,000 BP, so this helps date when the RIS began its last advance


Ross Ice Shelf
Cape Crozier


Ross Sea DMSP/OLS Image
10 May 2002 1717Z
National Ice Center
Naval Ice Center
Analyst: Judy Shaffier
B-15A
C-16
Ross Island
C-19
Ross Ice Shelf


Ross Sea
N
B-15J
B-15A
C-16
B-15K
Ross Island
Ross Ice Shelf
Drygalski
Ice Tongue
Polar Plateau
Katabatic Winds
-43
-41
-32
-27
-32
-33
-19
-26
-7
-16
-24
-27
-27
-31
-20
-12
-12
-19
-28
SFC T[F] at 19 UTC on 12 Apr 2005
SSEC/UW-Madison AWS Network


5th Mar 2002
17th Feb 2002
31st Jan 2002
1995
Larsen B Ice Shelf
2600 km² lost

Tabular ice bergs have calved from ice shelves from ablation, or natural growth and movement of the glacier

Polynyas

Defined as areas of open water surrounded by sea ice

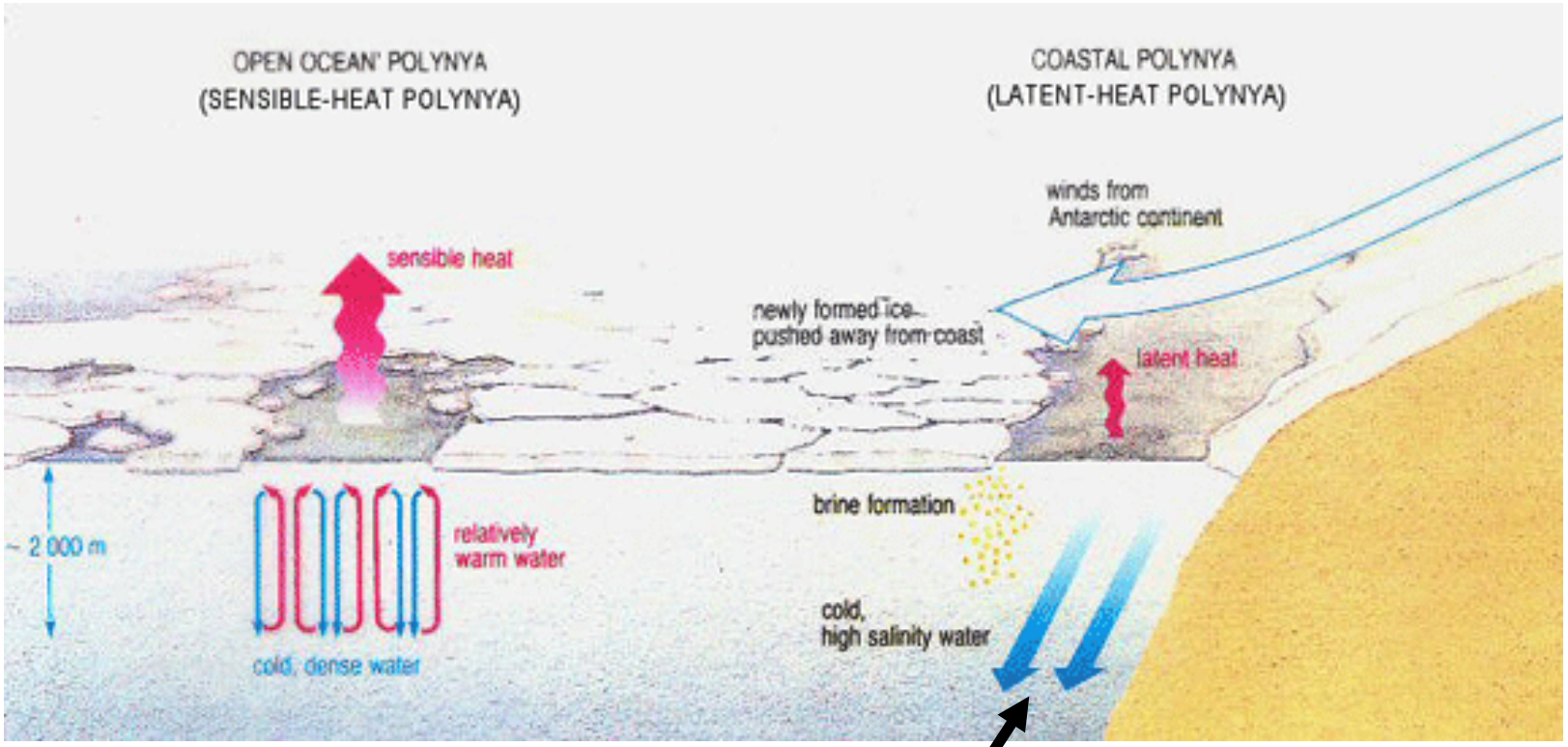
Develop as a result of either strong katabatic winds that constantly blow newly formed sea ice farther out to see

Or from warmer waters upwelling from below in a localized area

Areas of open water can be highly productive and provide winter habitat for species that need open water and access above the sea ice

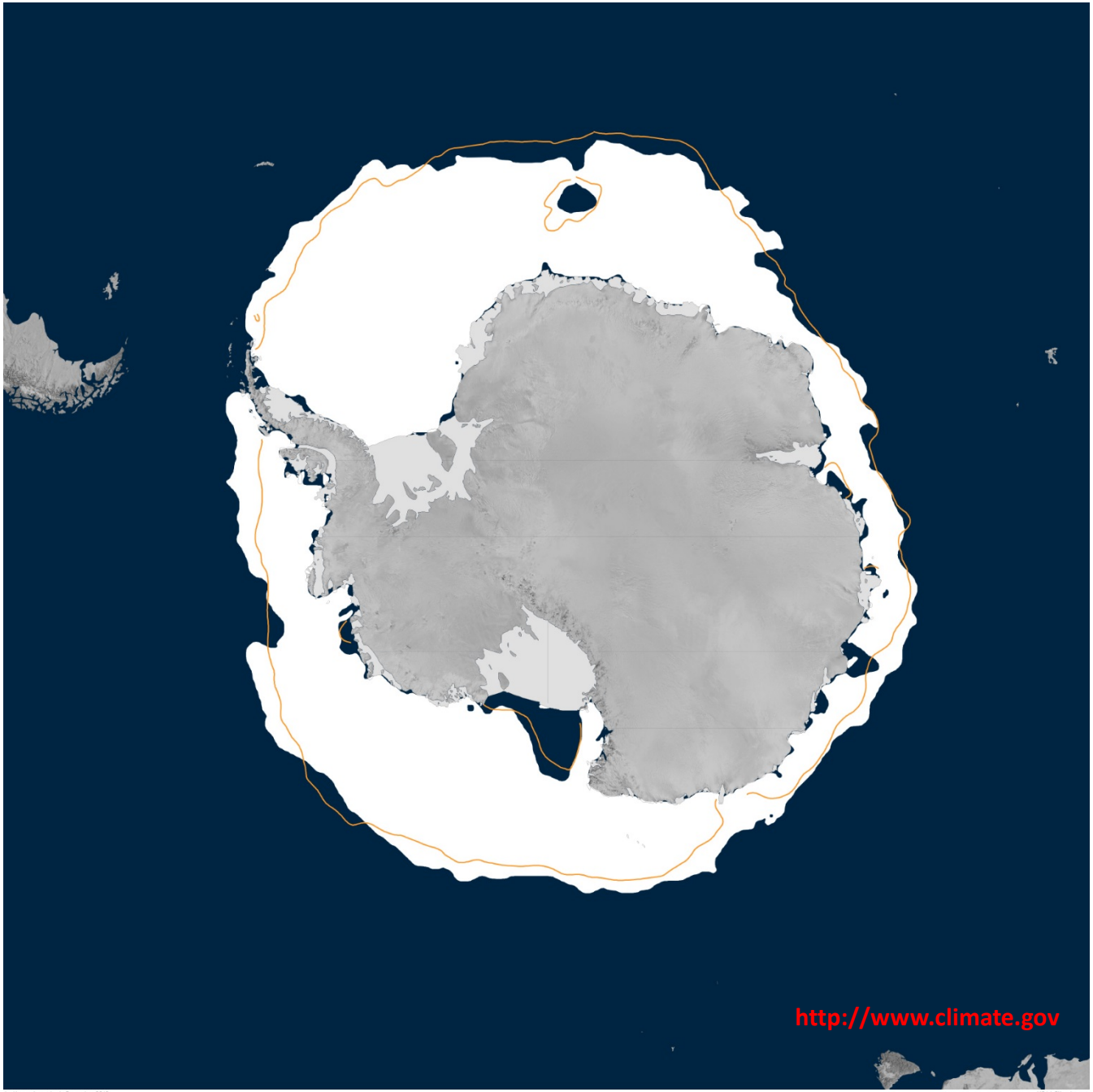
Open ocean polynyas develop from warm water upwelling

Coastal polynyas develop from katabatic winds. The winds constantly cool the ocean surface, enhancing ice formation. The ice blows away from this 'sea ice factory' leaving highly saline water behind



https://nsidc.org/cryosphere/seaice/characteristics/polynyas.html

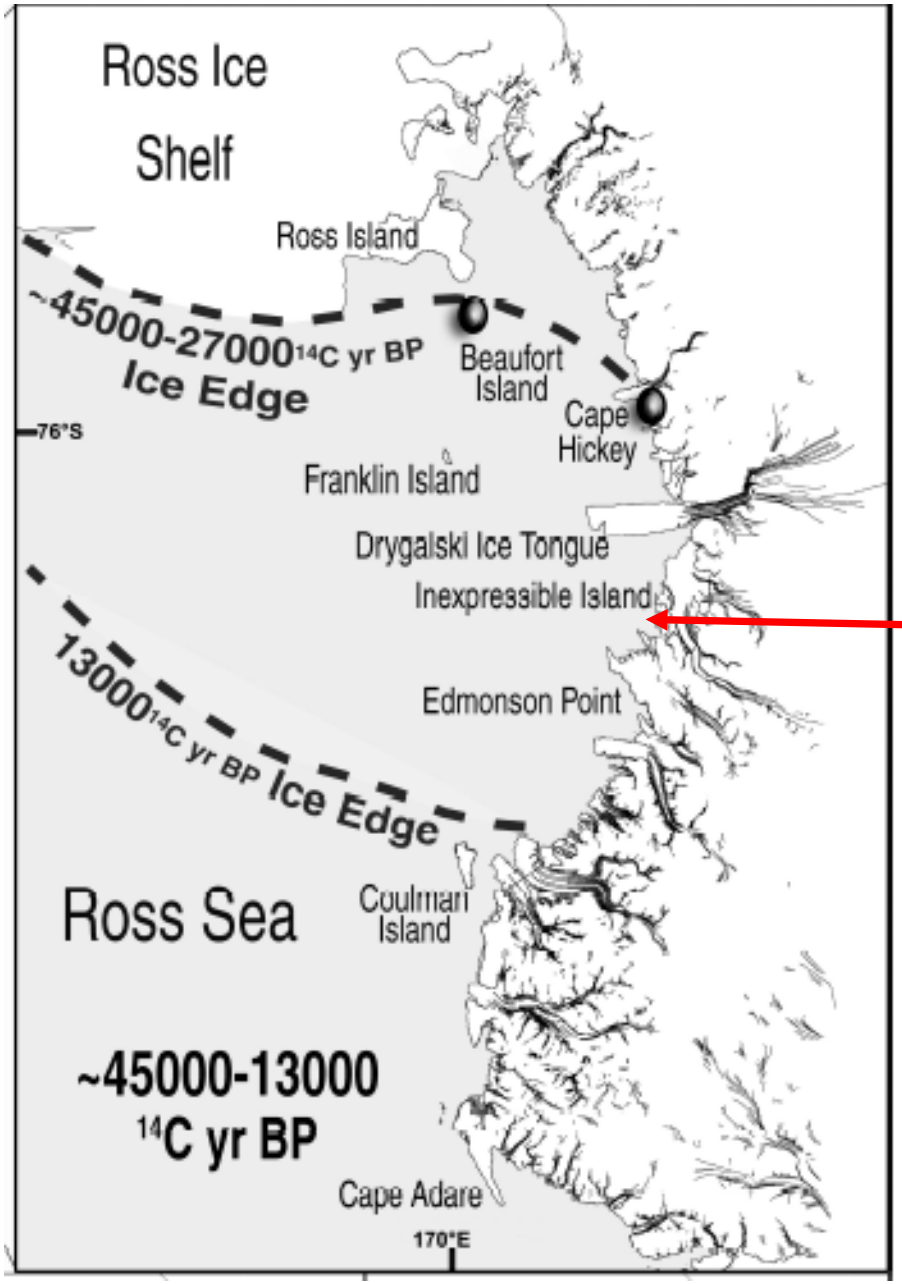
Important source of Antarctic Bottom Water



Arctic sea ice extent, December 2013

NOAA Climate.gov

Satellite view of polynyas (dark areas) near Oates Coast, Antarctica (solid white area at bottom of photo). *—Image courtesy of NASA.*



Terra Nova Bay Polynya

Quiz

1. What is pancake ice?

2. What causes East Wind and West Wind Drift?

3. What is the Antarctic convergence and divergence?

4. What is the difference between sensible heat and latent heat polynyas?

5. What is thermohaline circulation?

Reading for next time:

http://earthobservatory.nasa.gov/Features/Paleoclimatology CloseUp/

Read introduction and section on The Ice Core Record