The Southern Ocean

Small Window – Big Impact on Global Deep Ocean Circulation?

Michael Schodlok

© A.Friedrich

Emperor Penguins

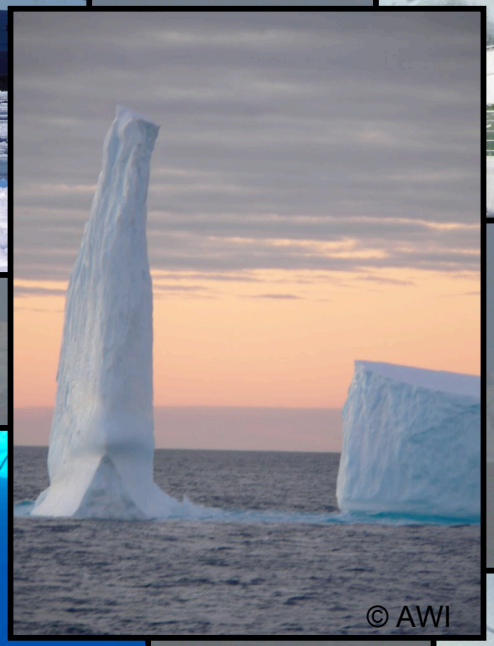
Calycopsis borchgrevinki

Crabeater Seal

Leopard Seal

© M.Schodlok

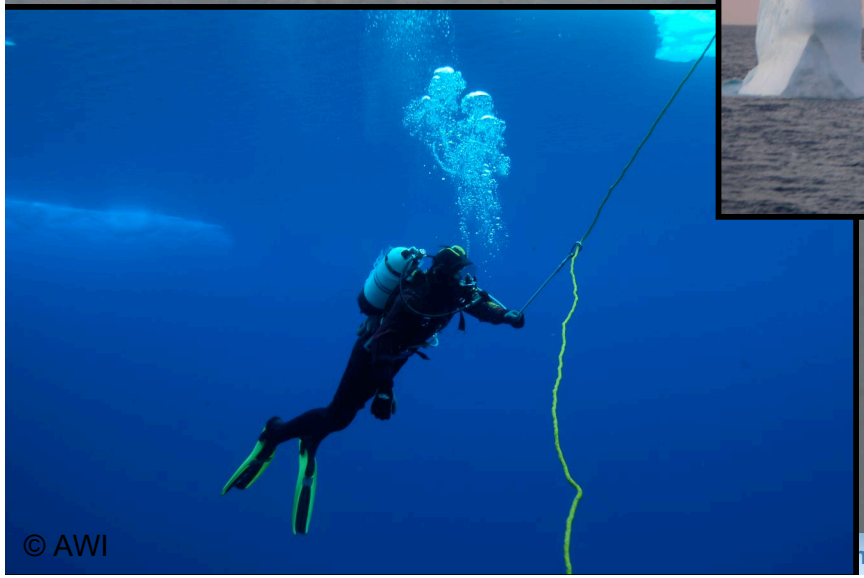
© M.Schodlok



© AWI

'Cricket'

© L.Norman



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Addresses “Archilles Heel*“:

Conversion of surface to deep waters, the variation of the meridional circulation and its impact on climate

Focus on Northern Hemisphere

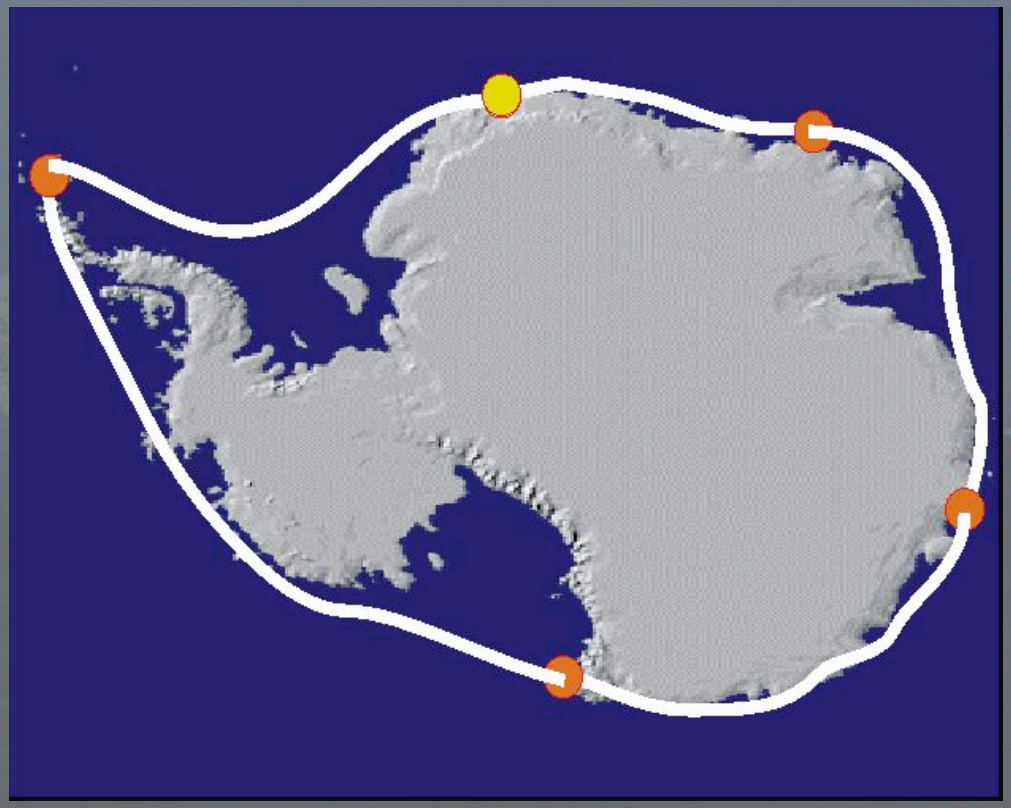
What happens in the Southern Hemisphere ?

What is the impact of ocean warming, ice sheet/shelf disintegration, seaice formation on this conversion?

* Wally Broecker

Tour d‘Antarctic - Outline

- The Ocean Conveyor
- Southern Ocean
- Sea Ice
- Ice Shelves
- Ocean modeling
- Outlook



www.ipy.org Chilenean Air Force

Roaring Forties: 40° -50°S

Furious Fifties: 50° -60°S

Shrieking/Screaming Sixties: below 60°S

MS Explorer sank 24-Nov-2007
near South Shetland Islands

- Iceberg?
- Navigation error?
- 154 people rescued

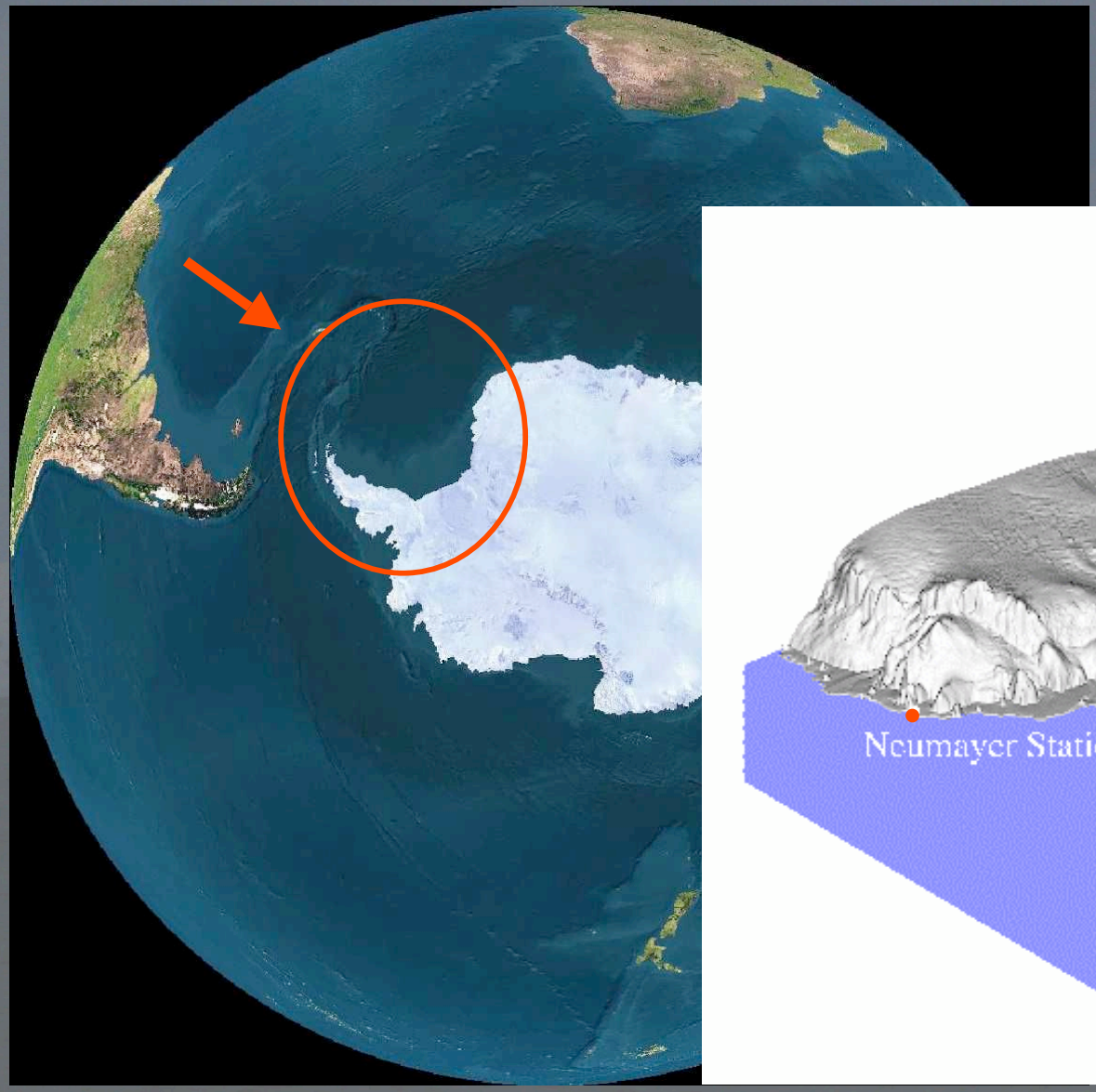
Flying P-Liner sailing around Cape Horn

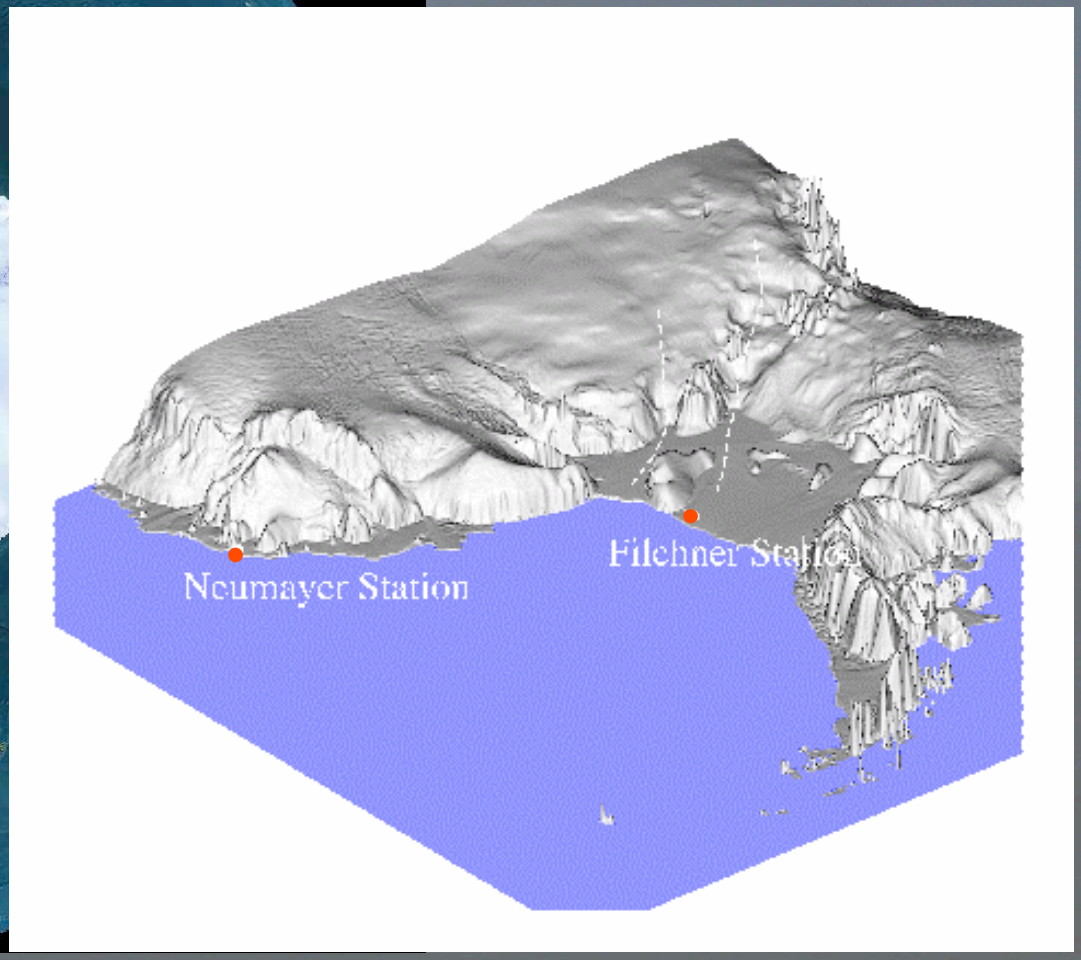
Antarctica – continent of extremes

- mean summer temperature: –30ºC / -22 F
- mean winter temperature: –60ºC / -76 F
- lowest temperature: –89.2ºC (Vostok) / –130 F

- ~80% of world‘s freshwater
- desert environment
- precipitation: ~20 mm/yr (0.8 in/yr) LA: 15 in/yr

- average ice thickness: ~2200 m / 7200 ft
- max ice thickness: ~4750 m / 15600 ft
- elevation up to: ~3000 m / 10000 ft (Mt San Antonio, San Gabriel Mtns)

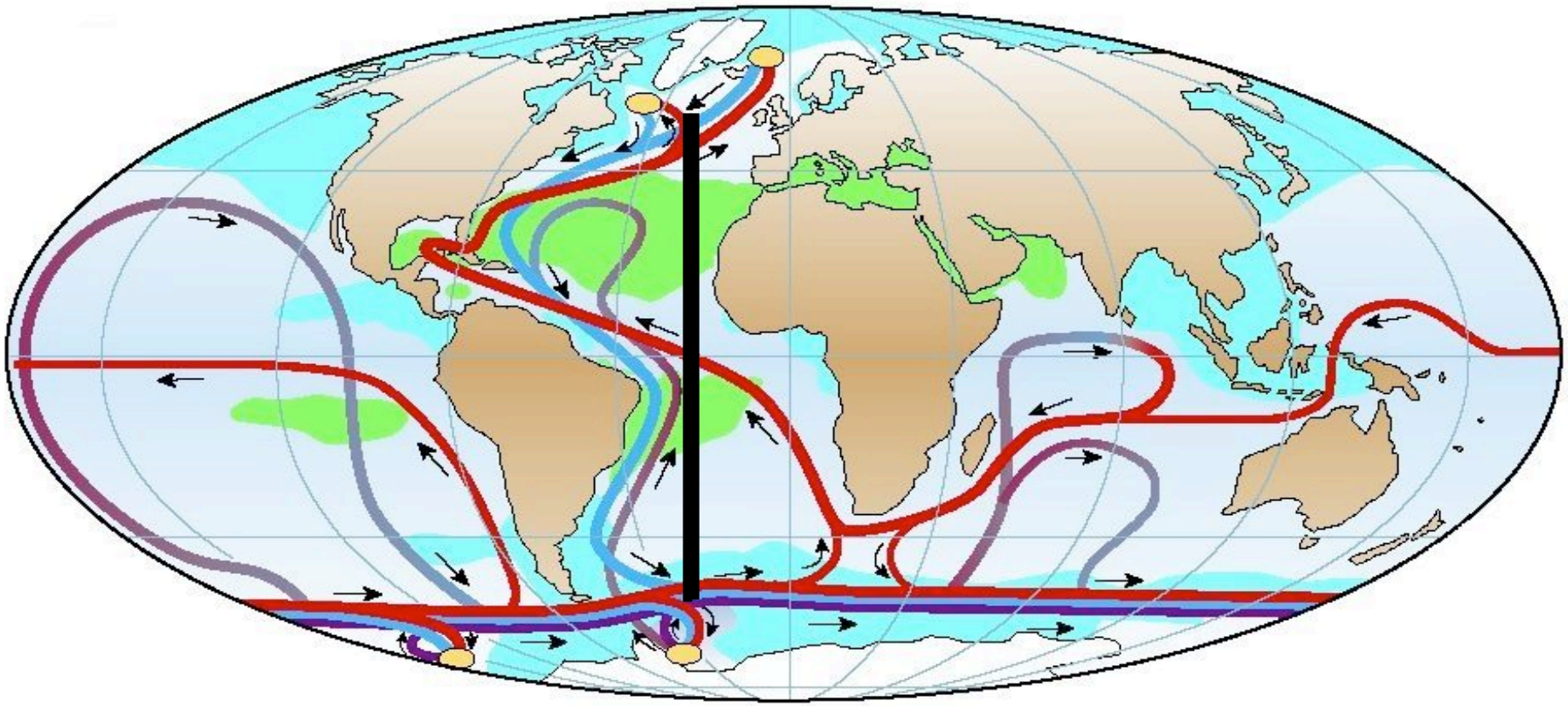



Neumayer Station
Filchner Station

- The Ocean Conveyor

Meridional Overturing Circulation: Video – 3 min

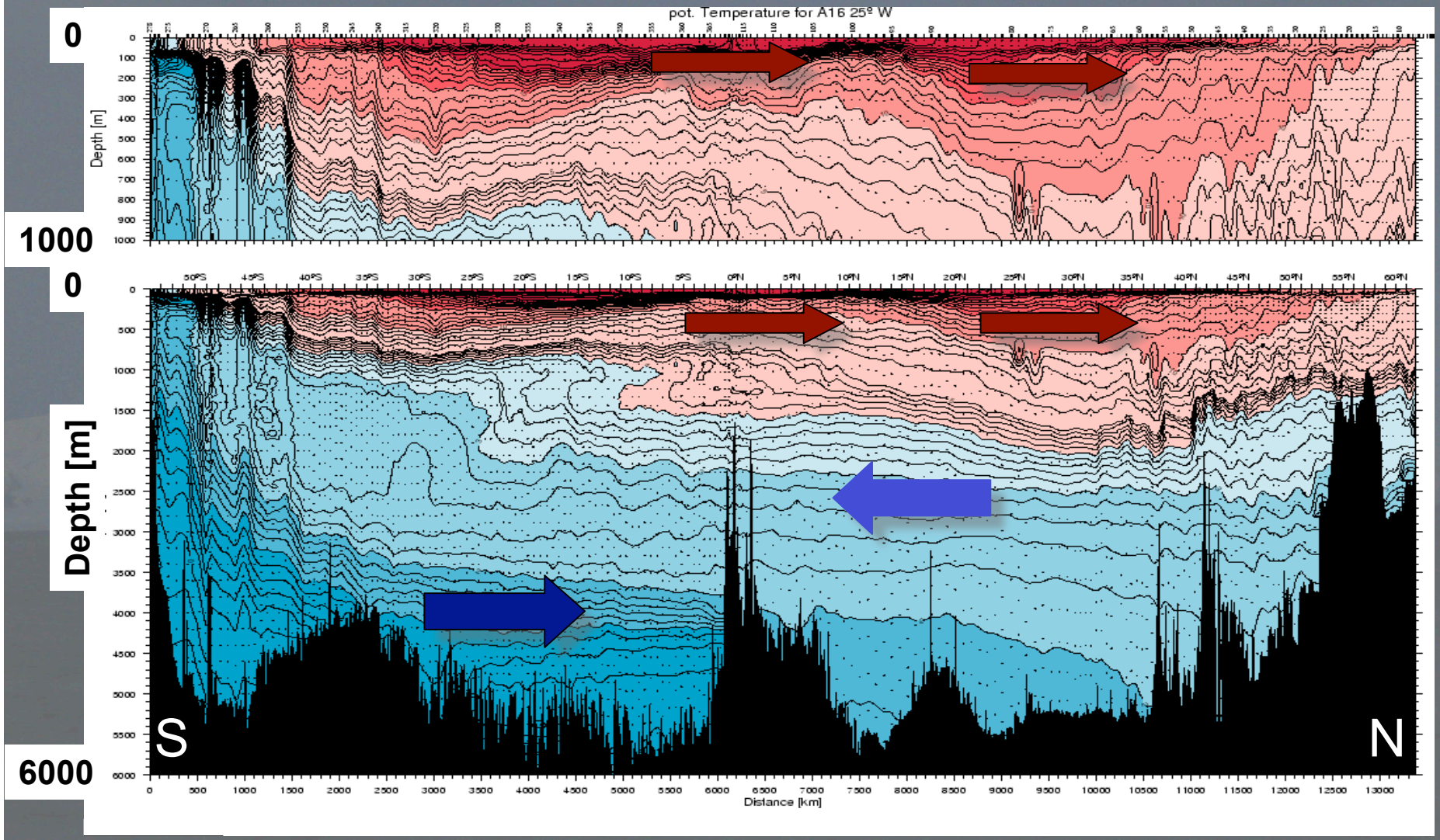
Thanks to Stephanie Simon and Susanne Gatti
Alfred Wegener Institute, Bremerhaven, Germany



The Global Ocean Conveyor Belt

(Rahmstorf, 2002)

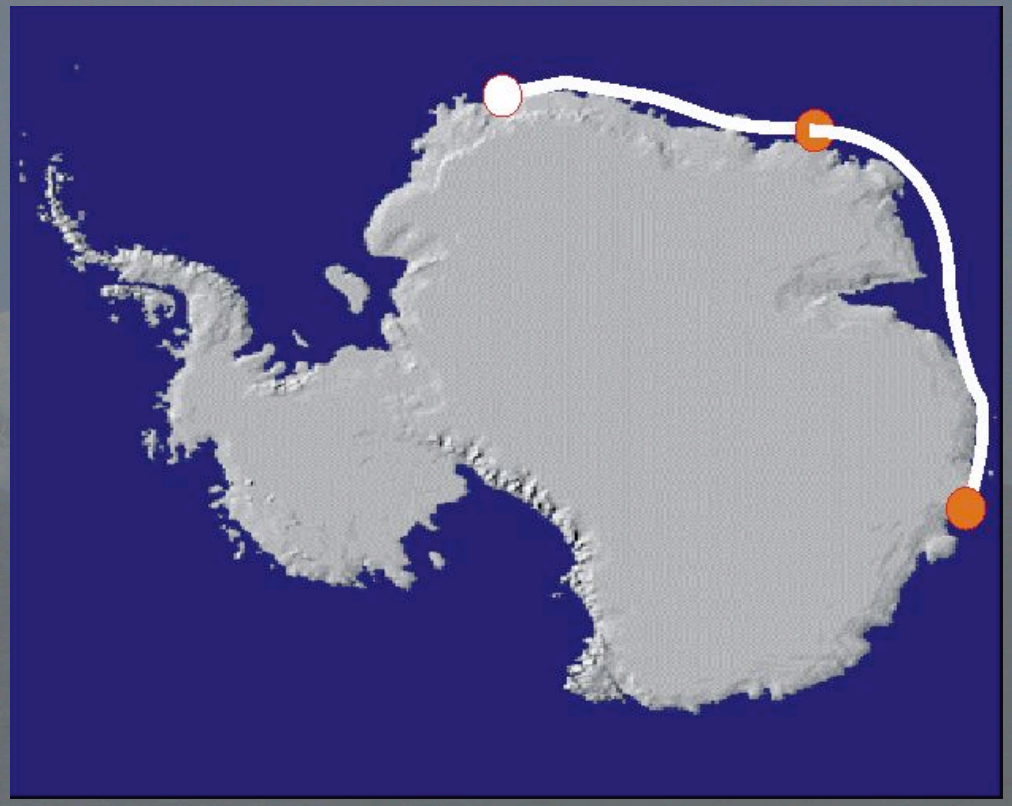
Meridional Overturing Circulation (MOC): Observation



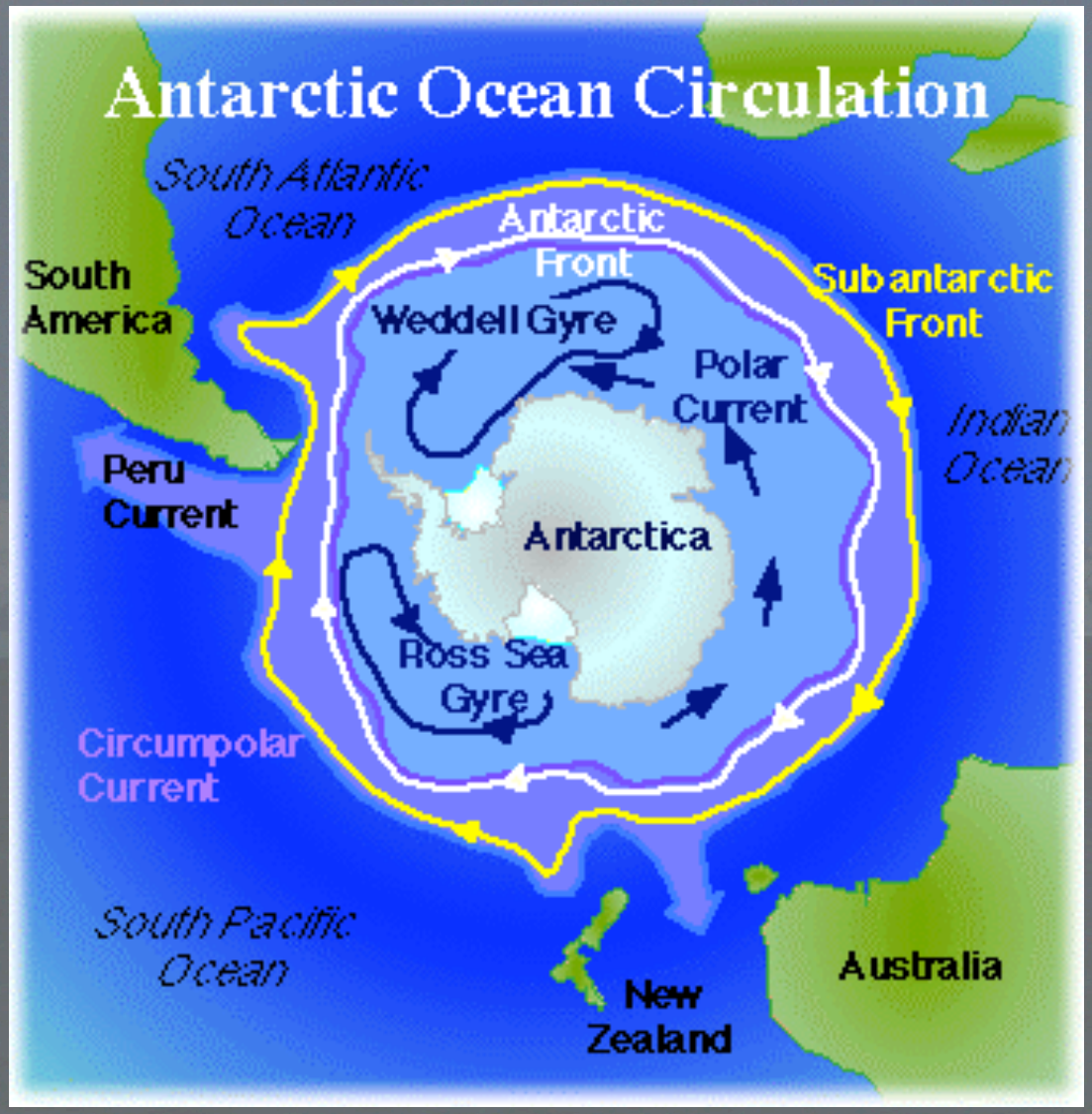
Dietrich et al, (1975)

Temperature distribution in the Atlantic Ocean, ~25°W

- The Ocean Conveyor
- Southern Ocean



Simplified View of Southern Hemisphere Ocean Circulation



Features:

deep basins

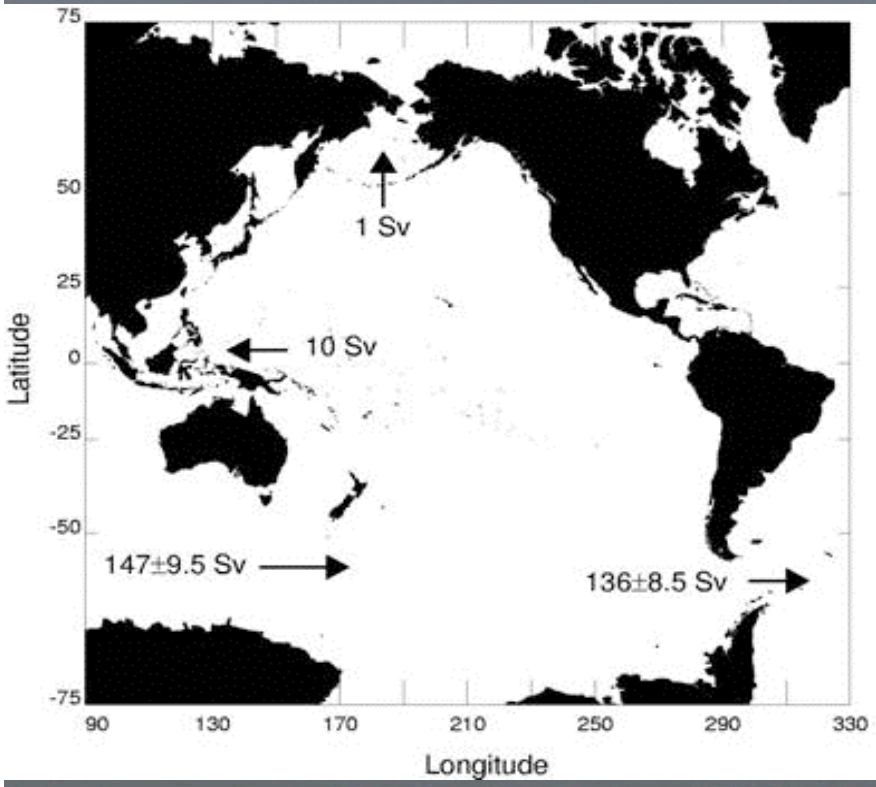
narrow shallow shelf area

free circumpolar flow

ocean basin communication

Antarctic Circumpolar Current

Real Beer



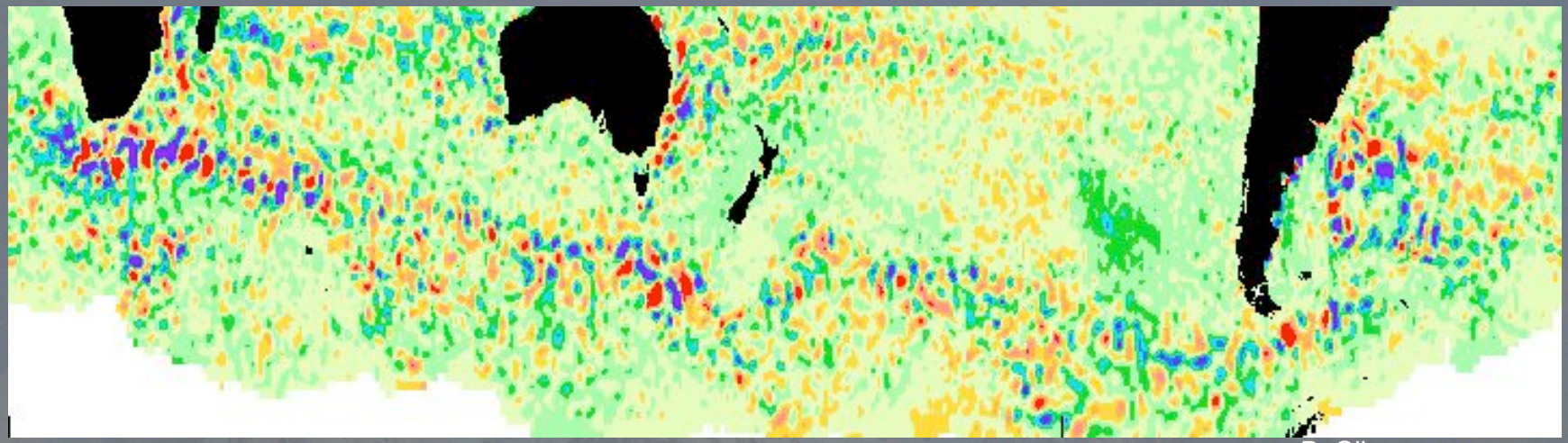
Bering Strait throughflow = 1 Sv, Coachman and Aagaard, 1988

Indonesian thoughflow, av = 10 Sv, Vresswell et al., 1993 and Meyers et al., 1995

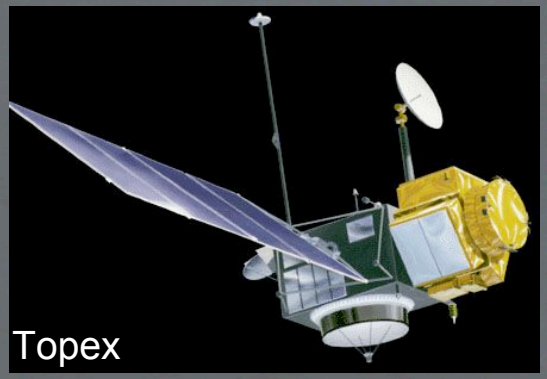
Rintoul et al., 2001

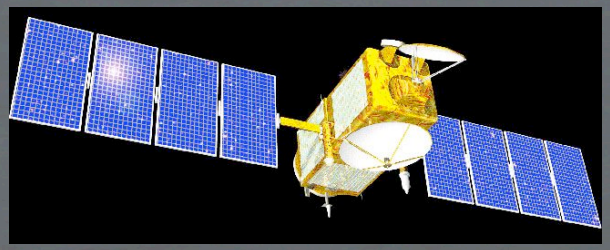
~ 410 billion beers/sec

Eddy Activity from Topex/Poseidon Satellite Altimetry



D. Olbers, pers. comm.

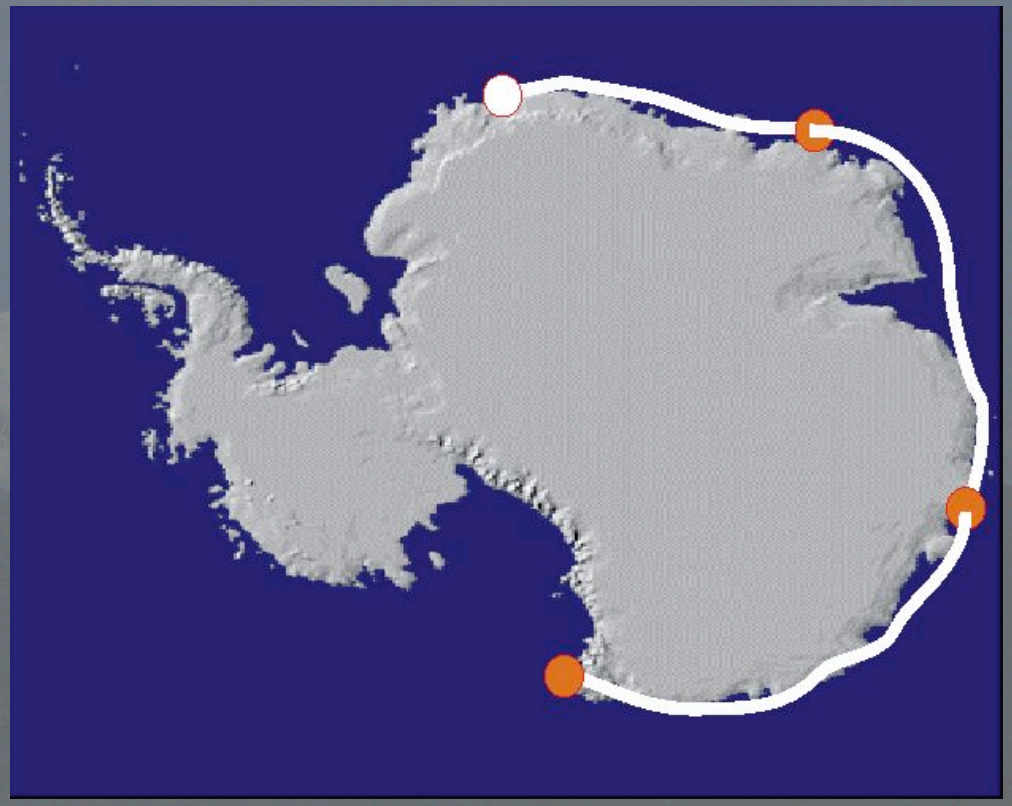




Jason

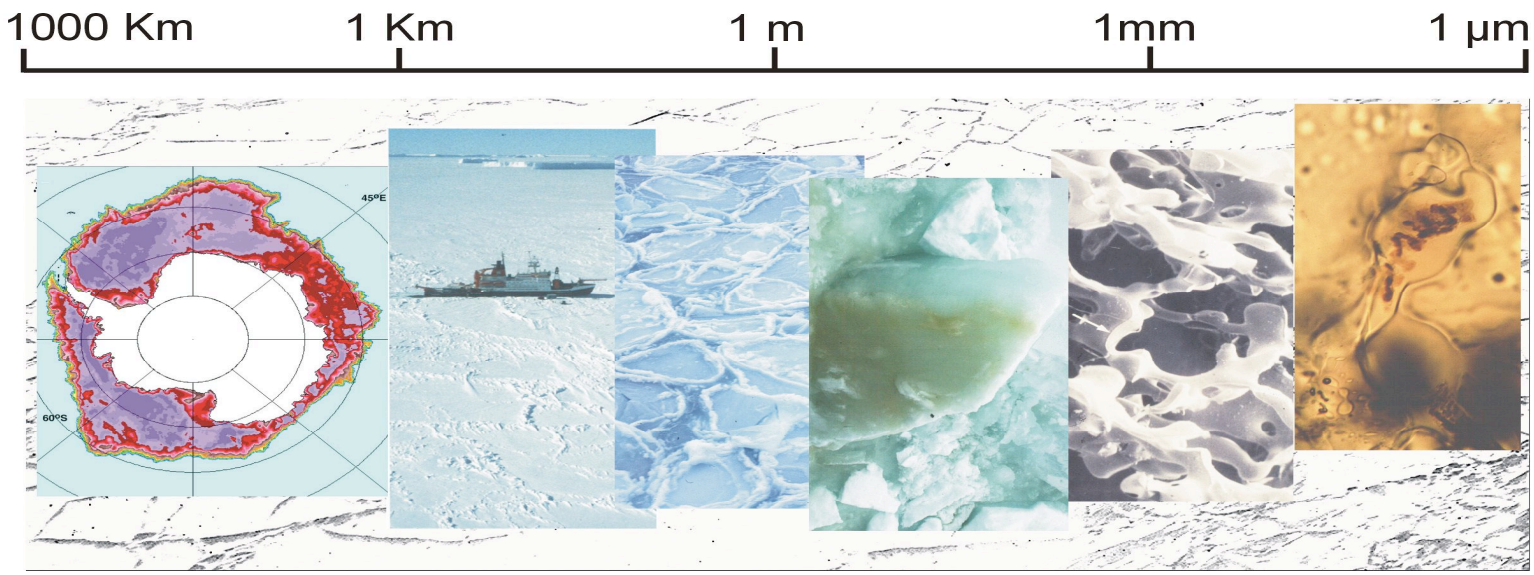
Launch in June

- The Ocean Conveyor
- Southern Ocean
- Sea Ice

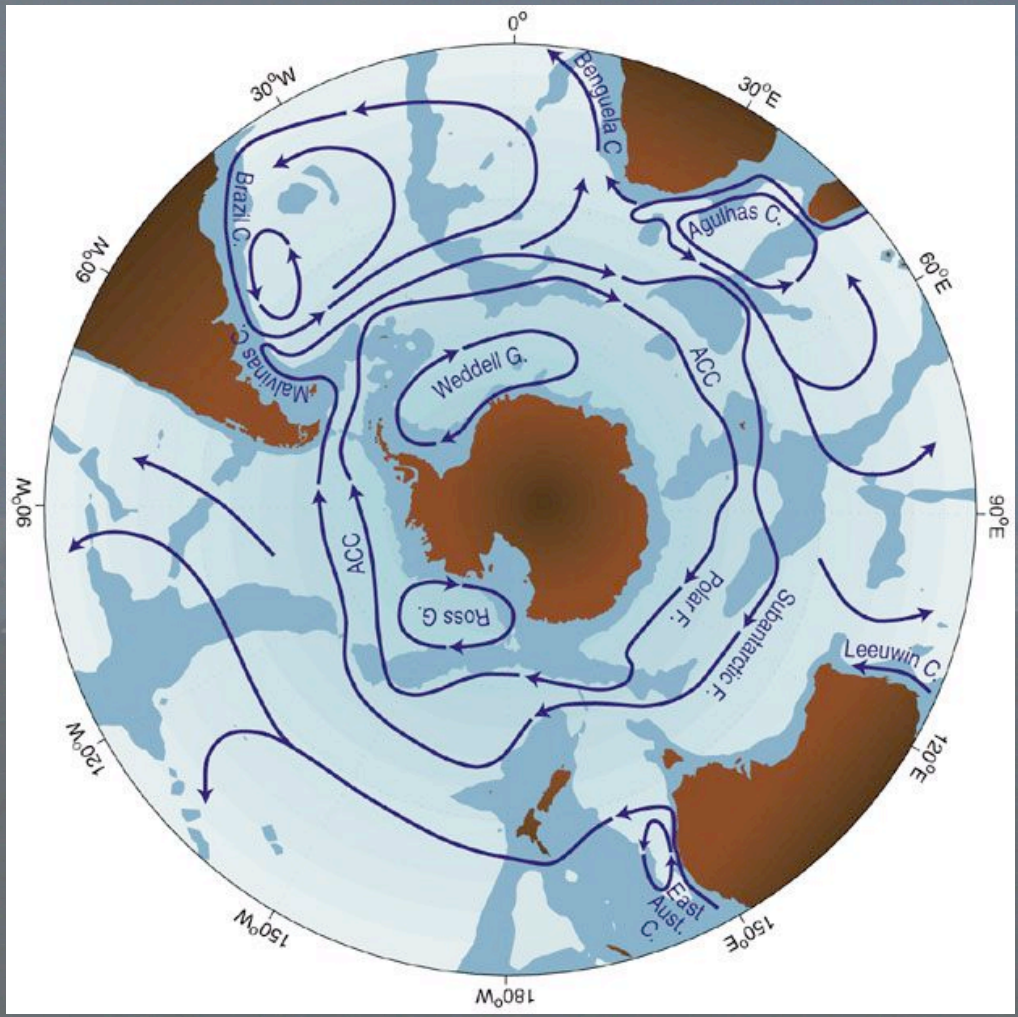


Cryosphere

Scales



Simplified View of Southern Hemisphere Ocean Circulation



Features:

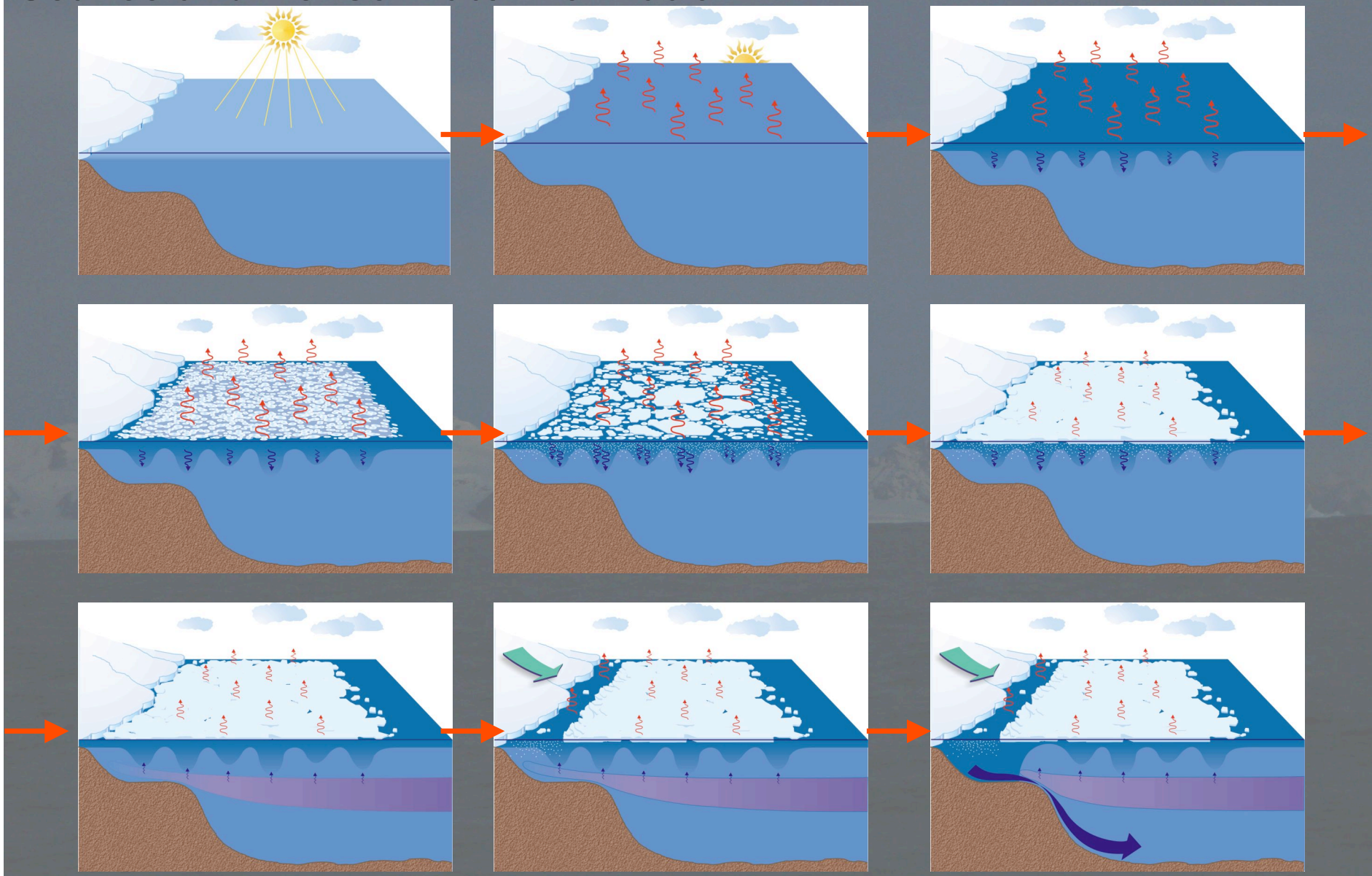
deep basins (light blue)

narrow shallow shelves (dark blue)

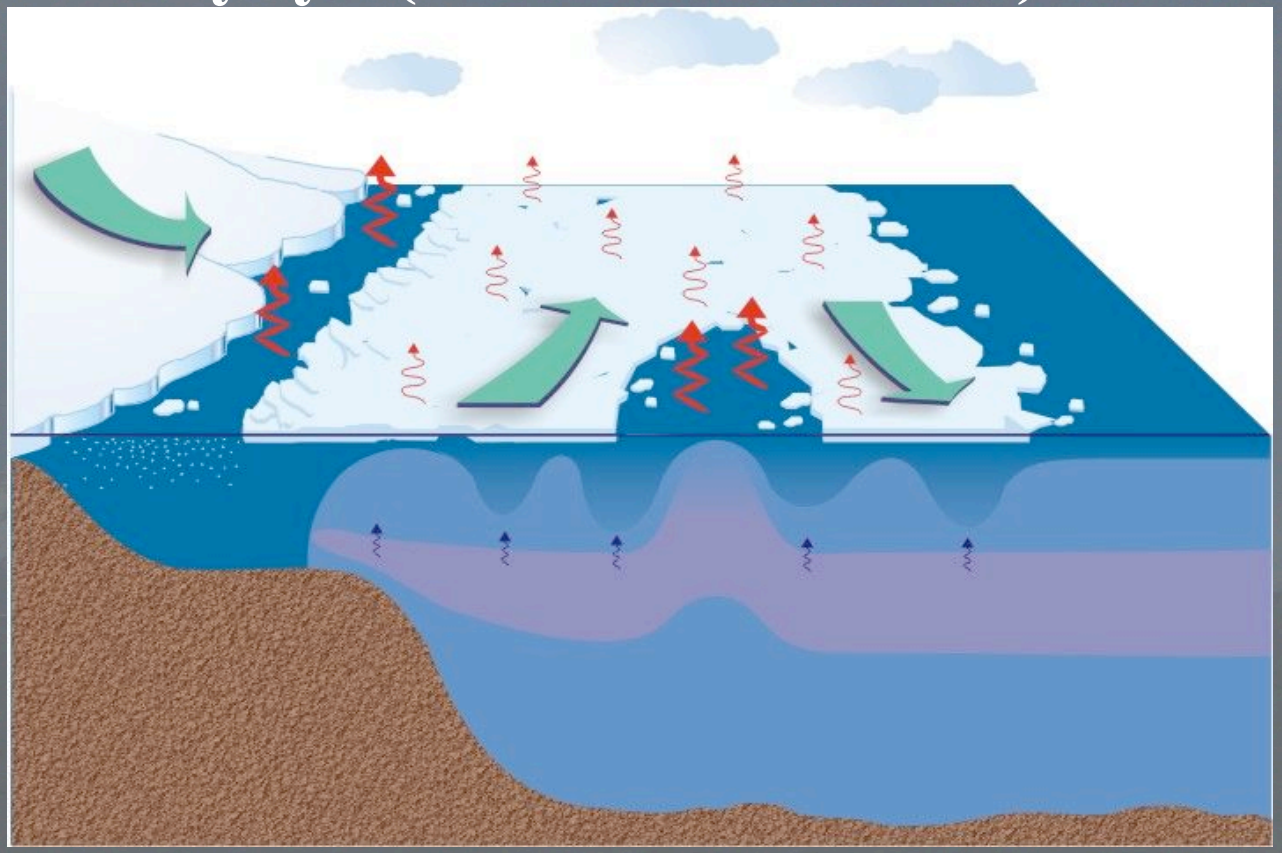
free circumpolar flow

ocean basin communication

Sea Ice and Dense Water Formation



Polynya (Russian: Полыня)

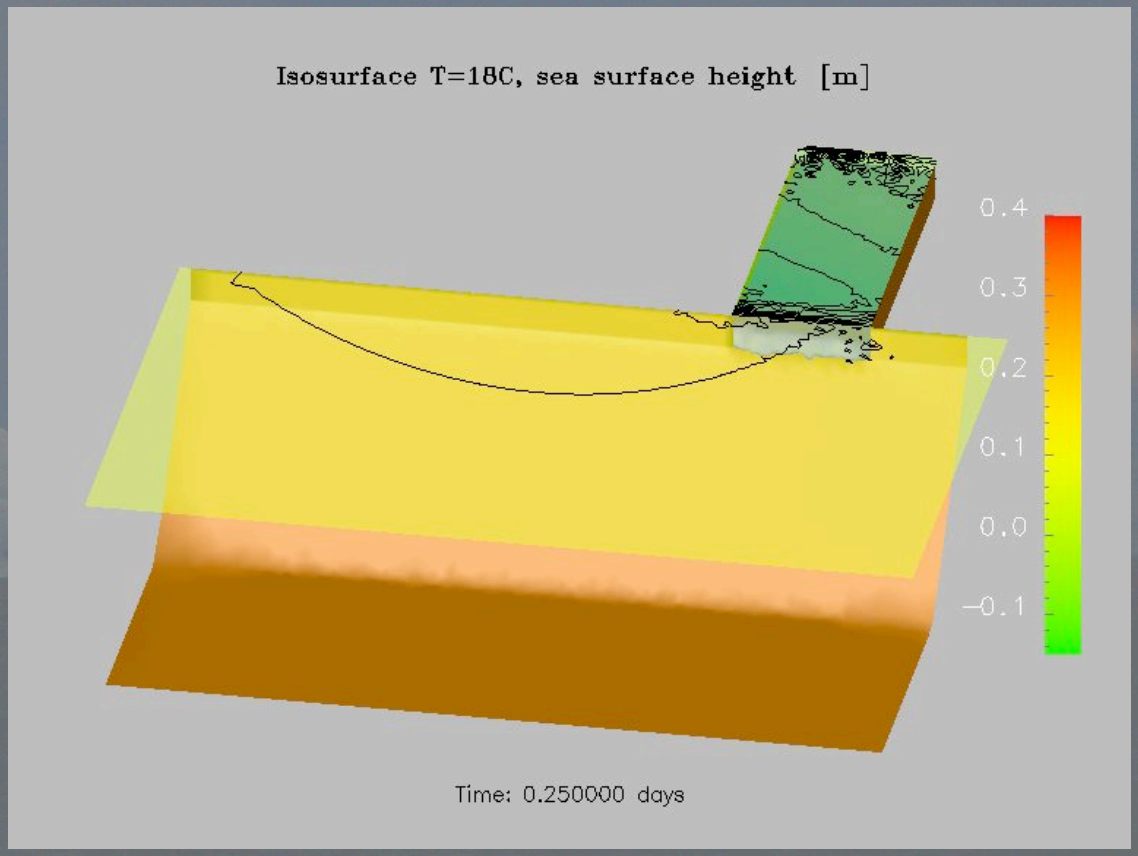


Coastal Polynya: Wind Forcing

Open Ocean Polynya: Currents, Convection

Downslope flow

- accumulation of dense water masses (bath tub)
- spilling and descending into deep ocean

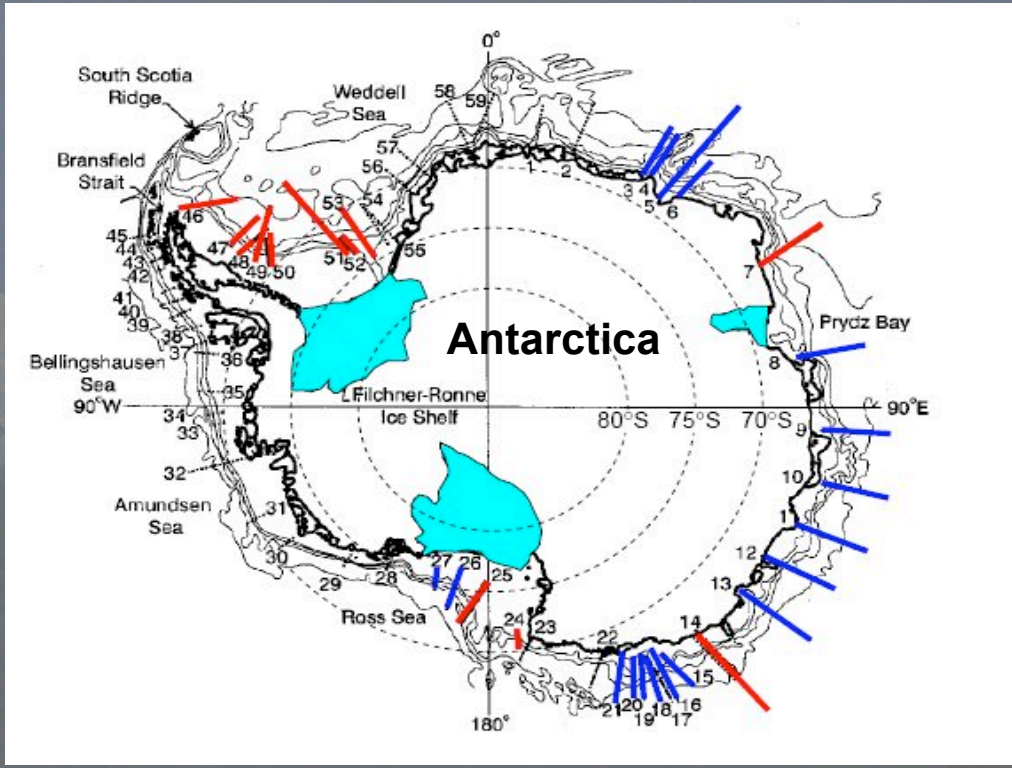


S. Harig

Small windows into the deep

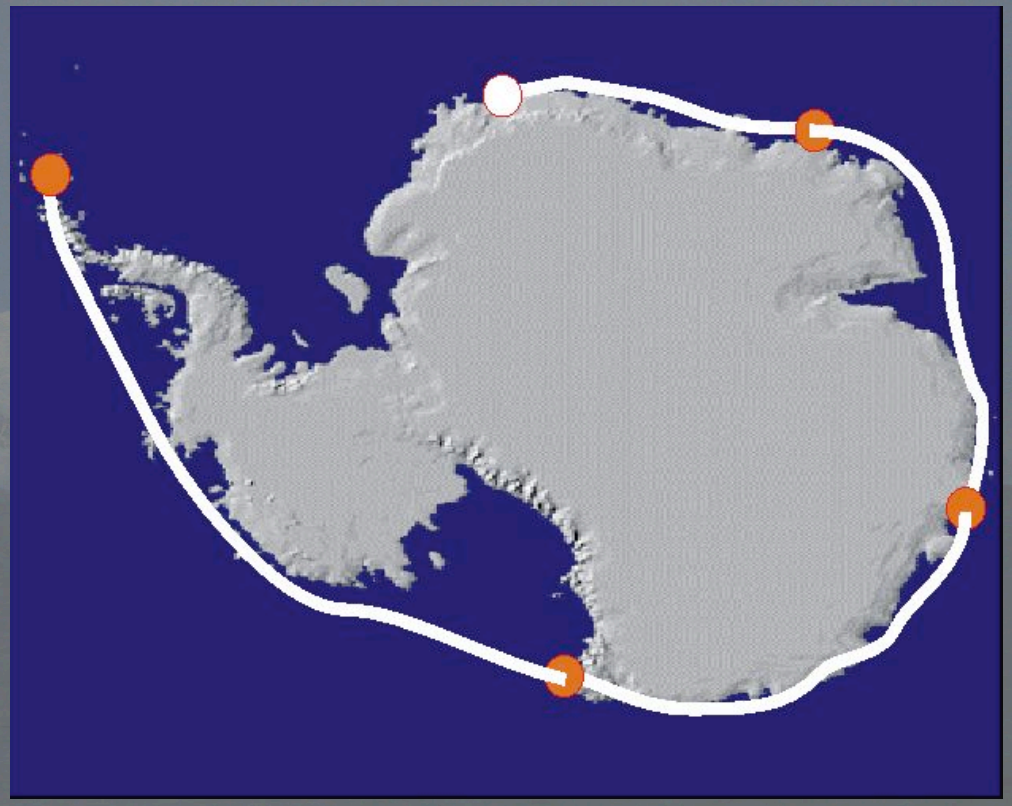
Convection on Continental Shelf

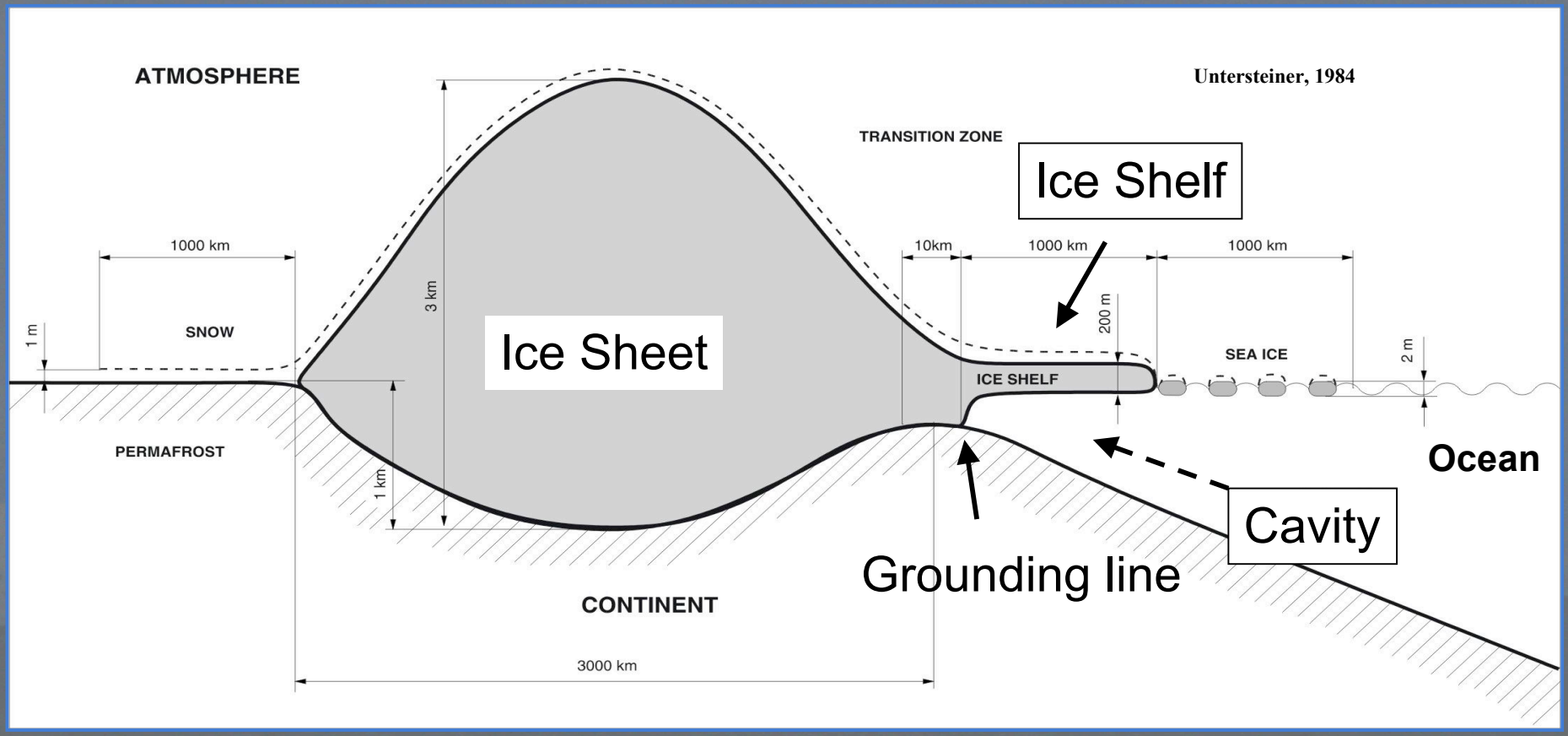
- katabatic winds form polynyas
  - latent heat loss → sea ice
- brine rejection during freezing over shelves forms a cold dense water mass
- major sites:
  - Weddell Sea (~70%)
  - Ross Sea
  - Prydz Bay
  - Adelie Coast



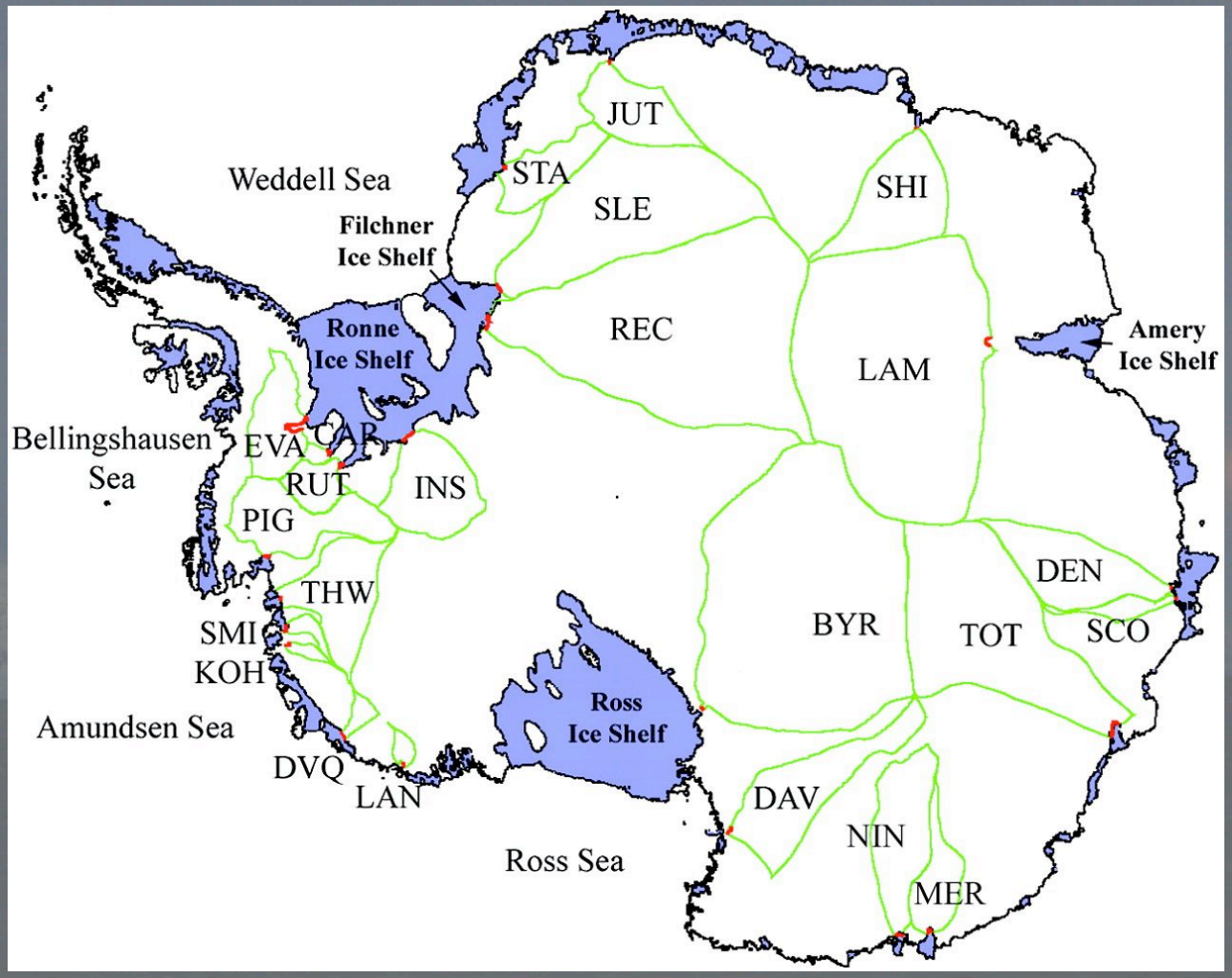
after Baines & Condie, 1998

- The Ocean Conveyor
- Southern Ocean
- Sea Ice
- Ice Shelves



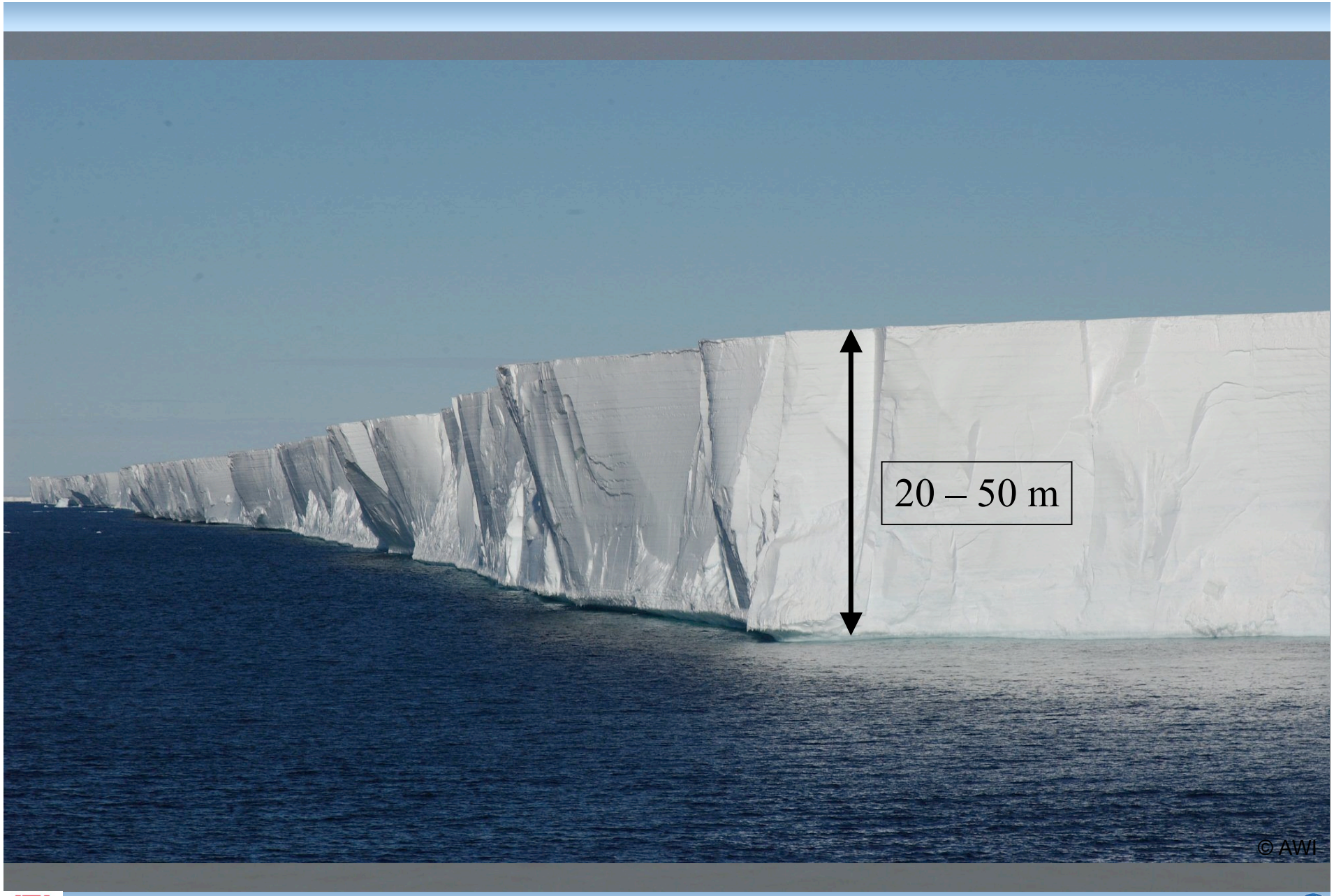


- Slow accumulation of snow with little melt
- Snow transformed to ice by pressure
- Thickness up to +4000 meters!
- Age up to 120,000 - 500, 000 years!
- Moves by gravity and basal slipping



Ross: 490,000 km2 - about the size of France

Filchner/Ronne: 450,000 km2

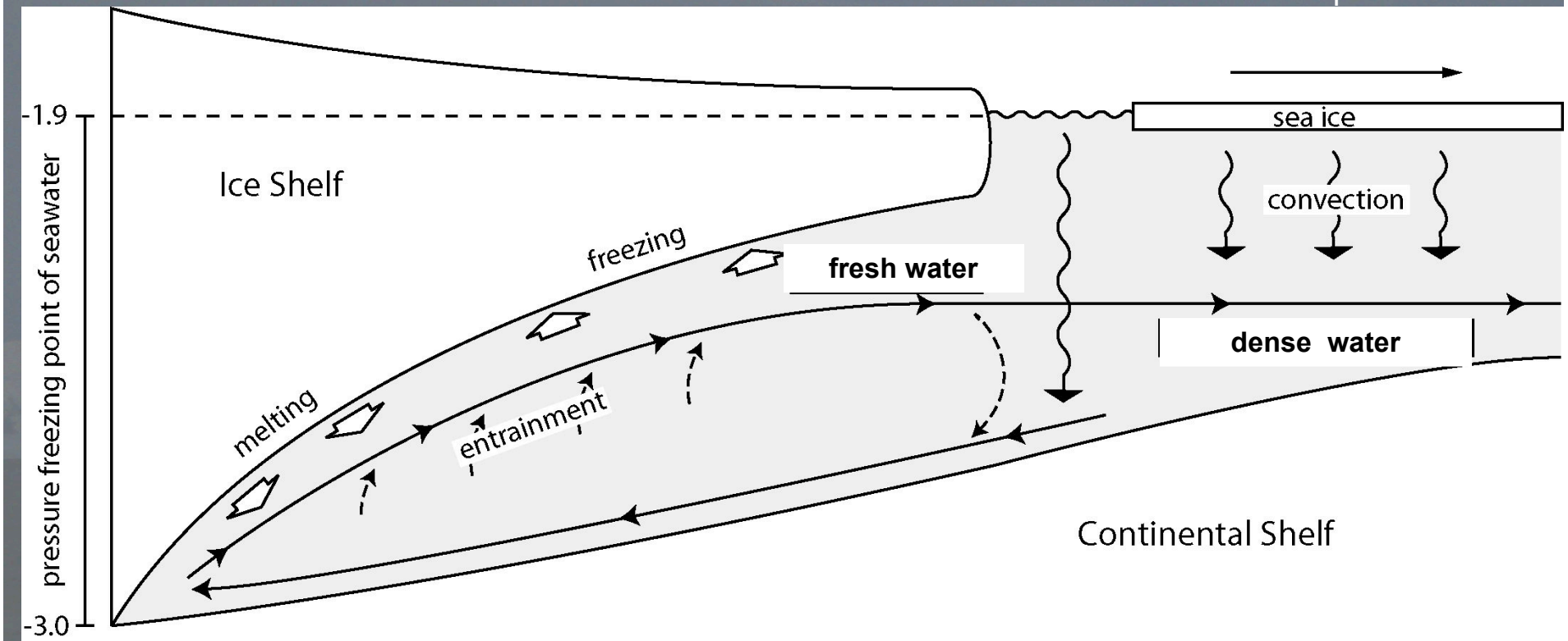

20 – 50 m
© AWI

~6 ft
POLARSTERN
© AWI

Ice Shelf Ocean Interaction

$T_f = f(T,S,P)$

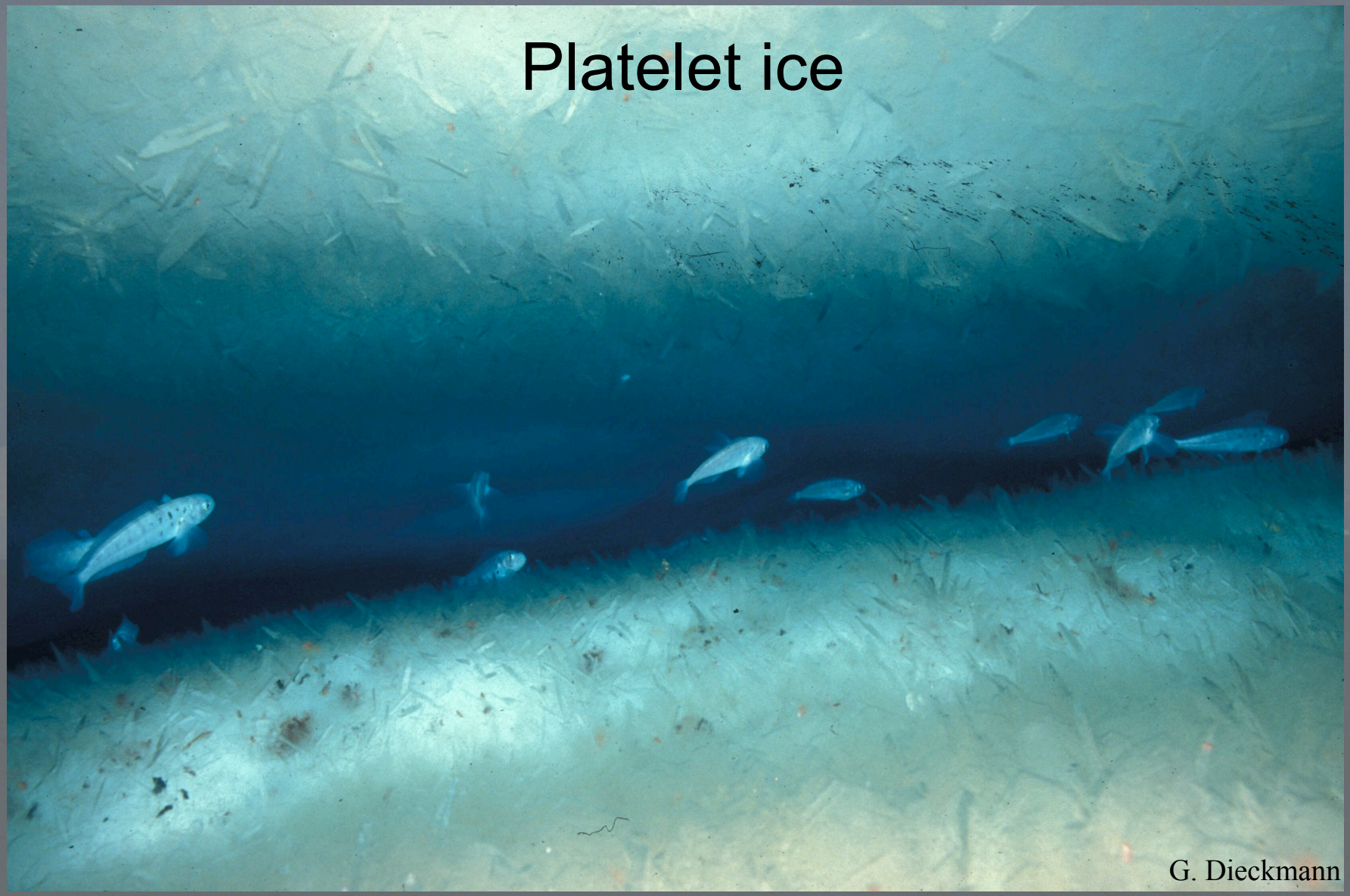
$T_f = -1.86°C$



$T_f \approx -2.4°C$

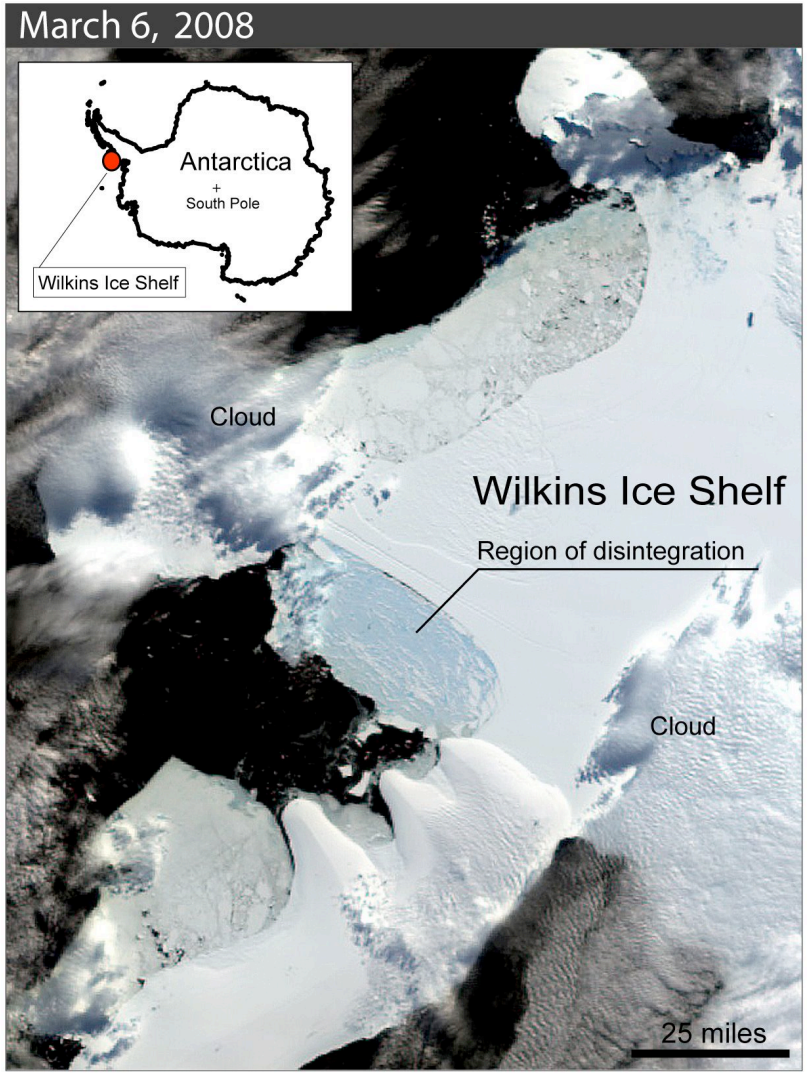
- Ice Shelf Water
  - fresh and cold
  (supercooled to form ice platelets)

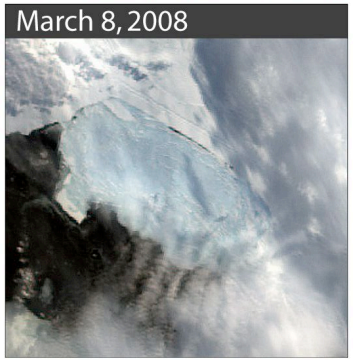
Platelet ice



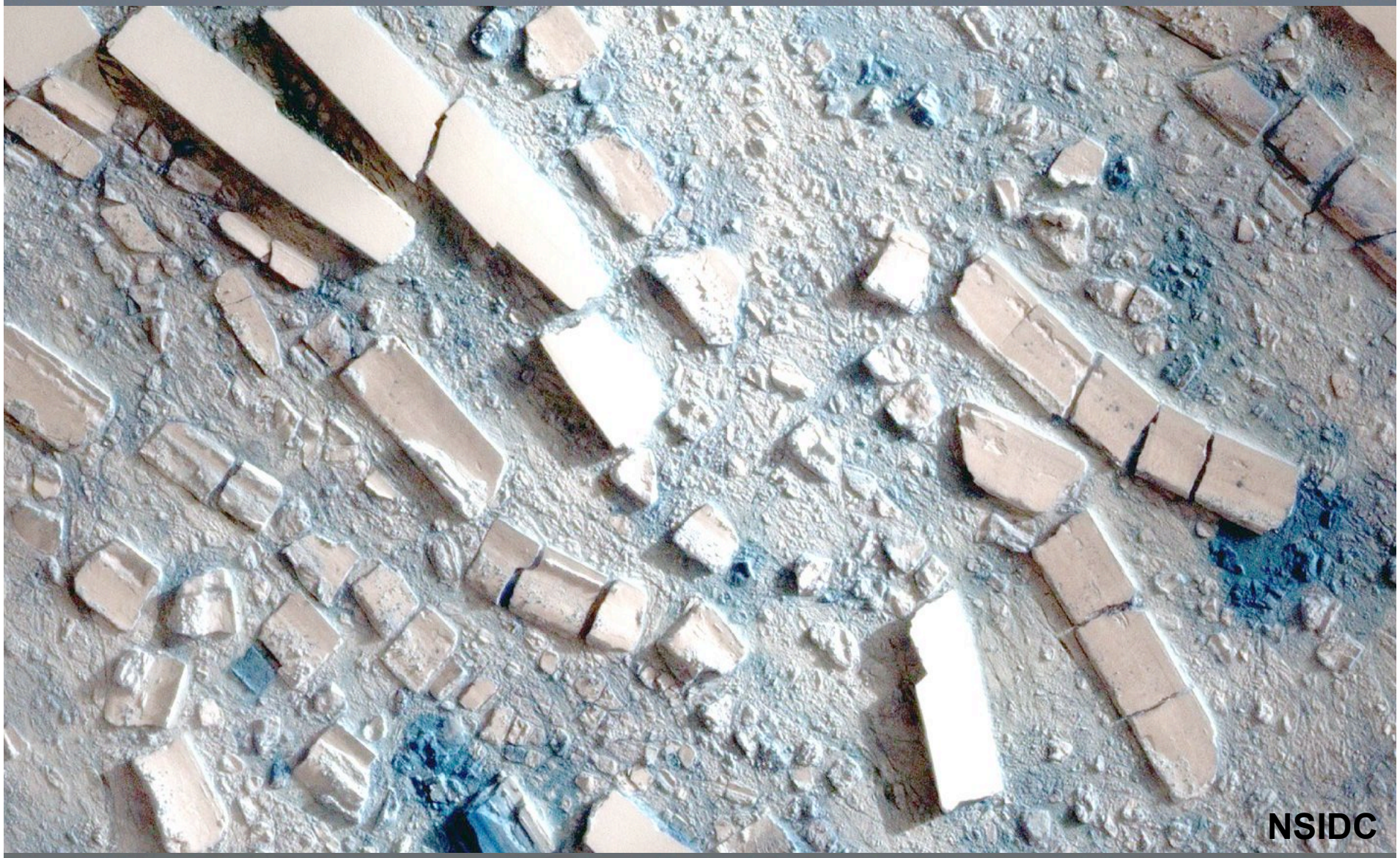
Green Iceberg

G. Dieckmann

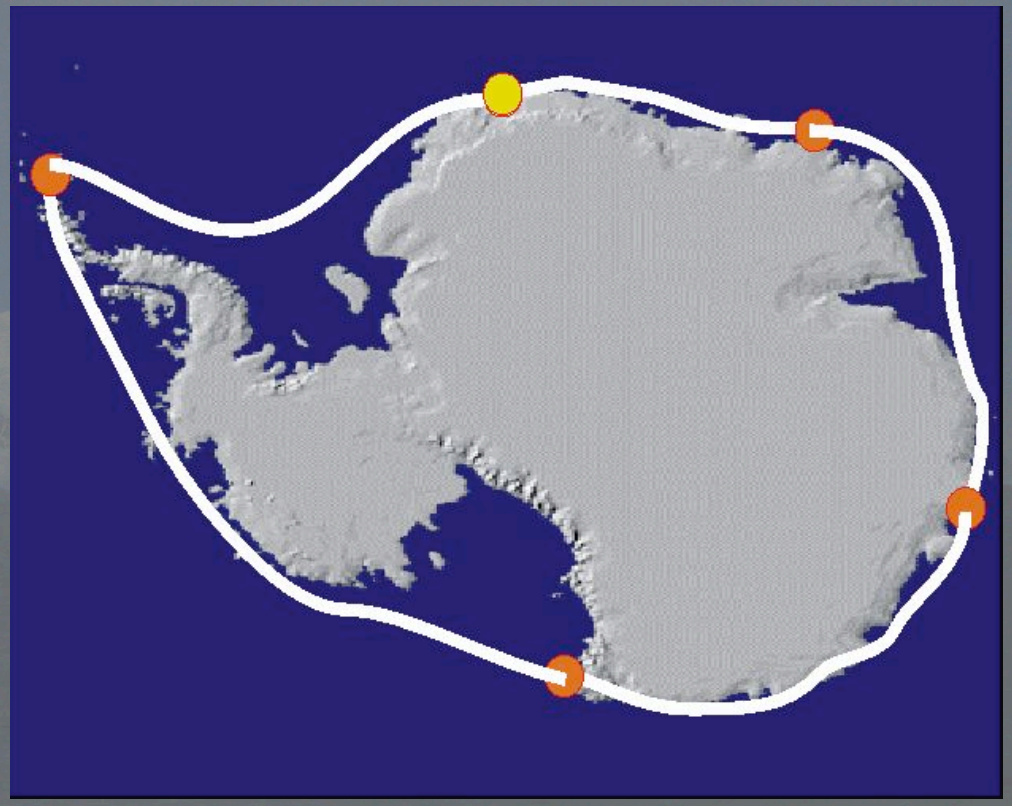




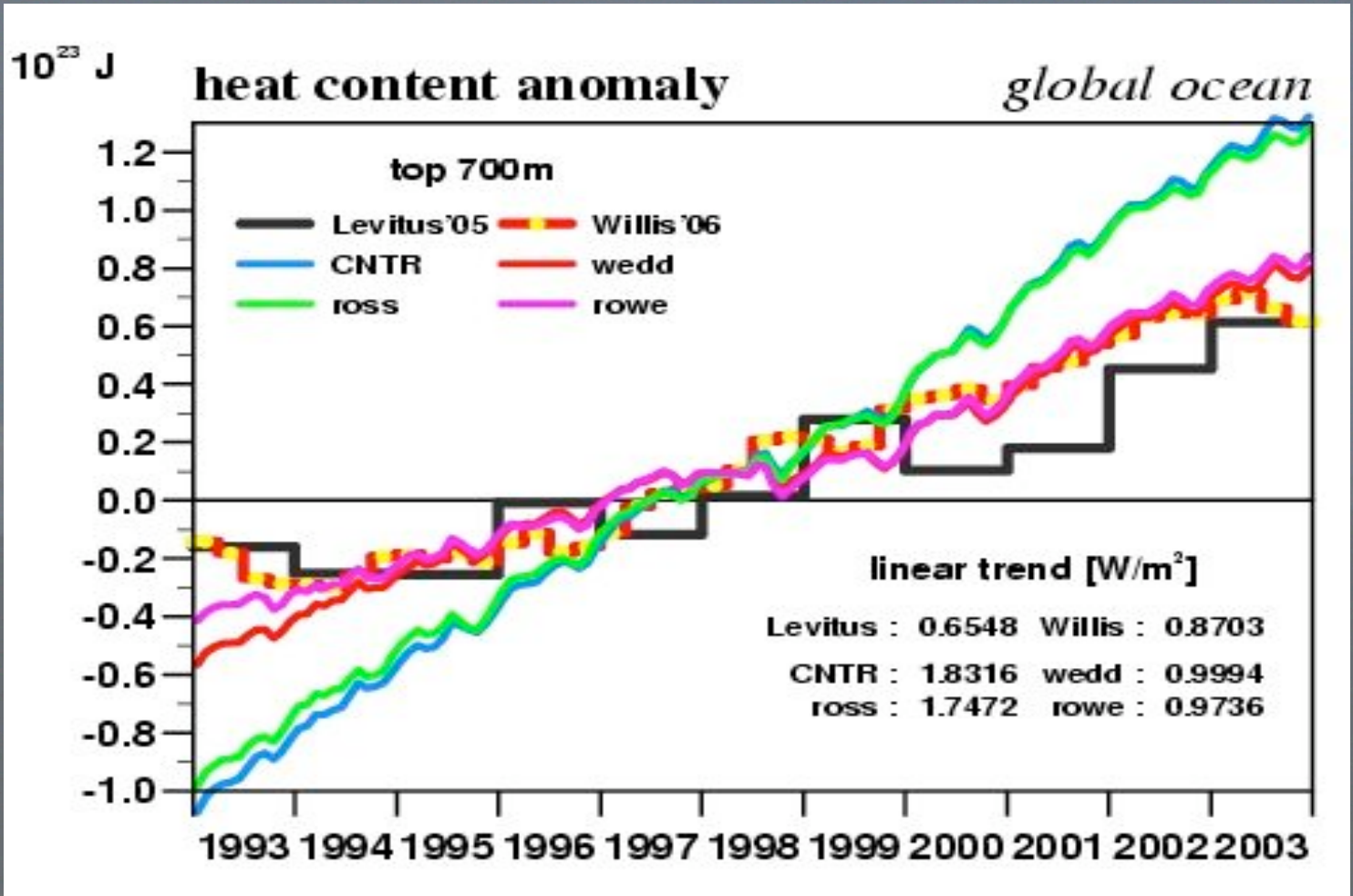
National Snow and Ice Data Center, Boulder, CO


NSIDC

- The Ocean Conveyor
- Southern Ocean
- Sea Ice
- Ice Shelves
- Ocean modeling

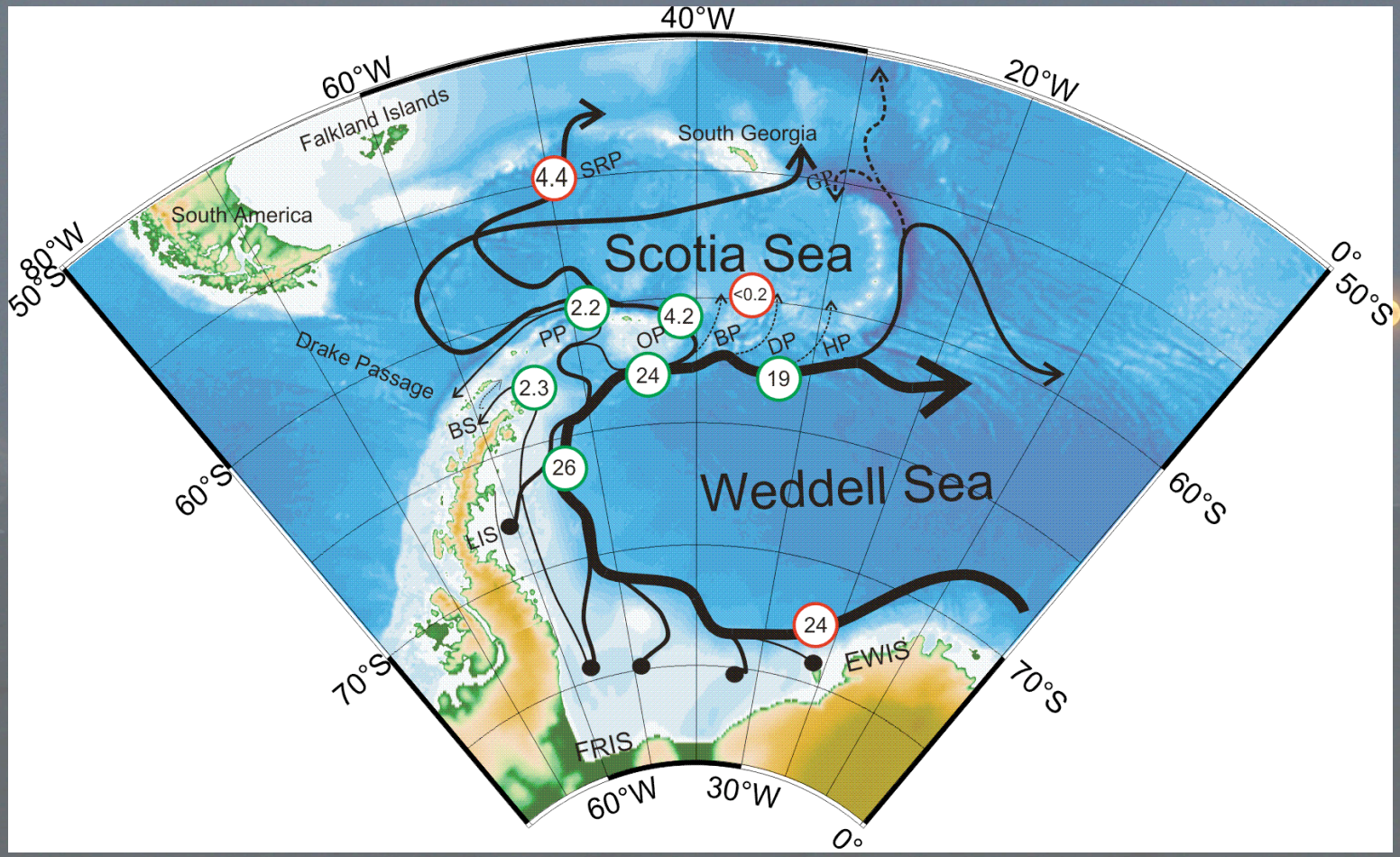


Global Modeling



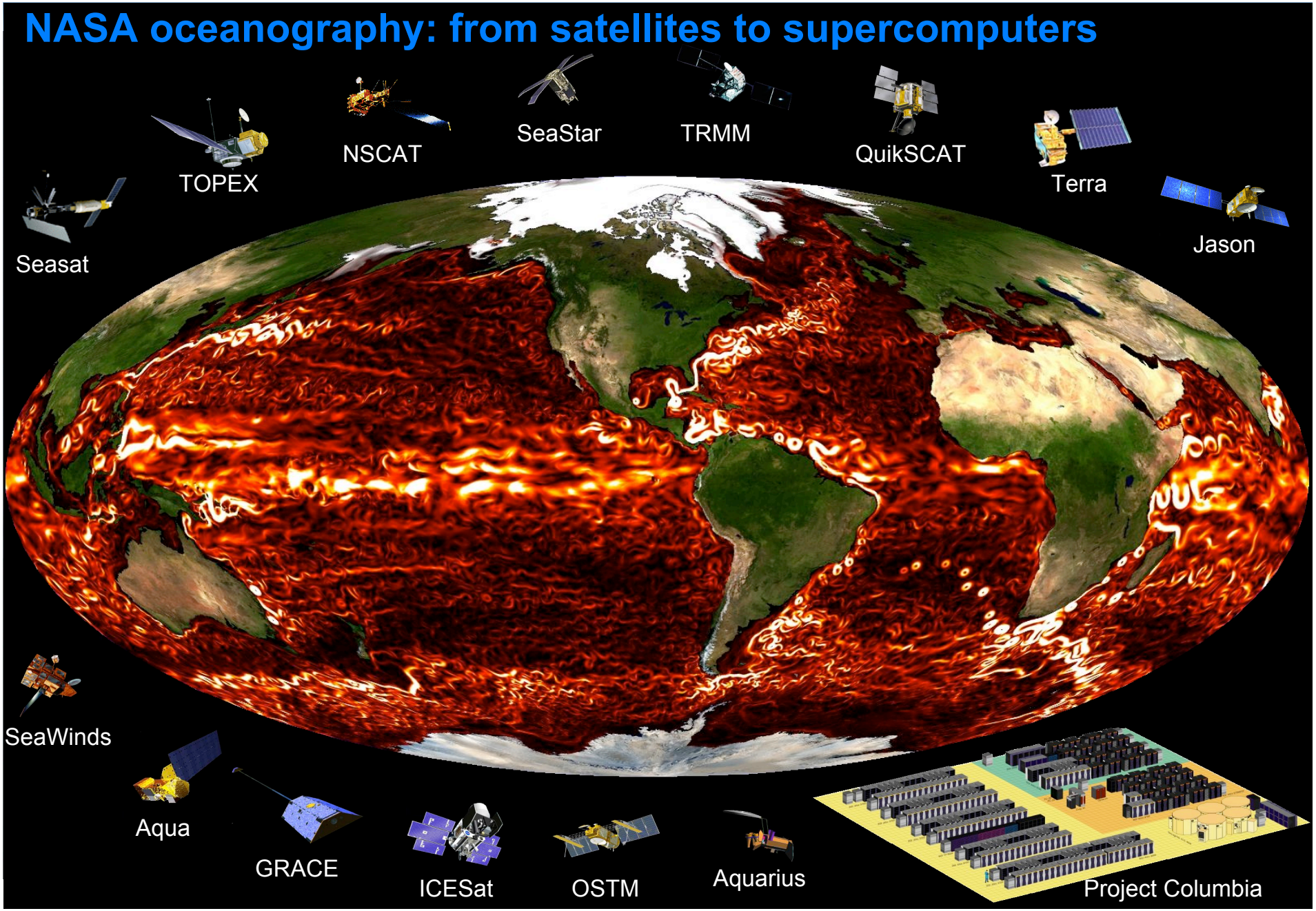
Schodlok et al., in press

Regional Modeling



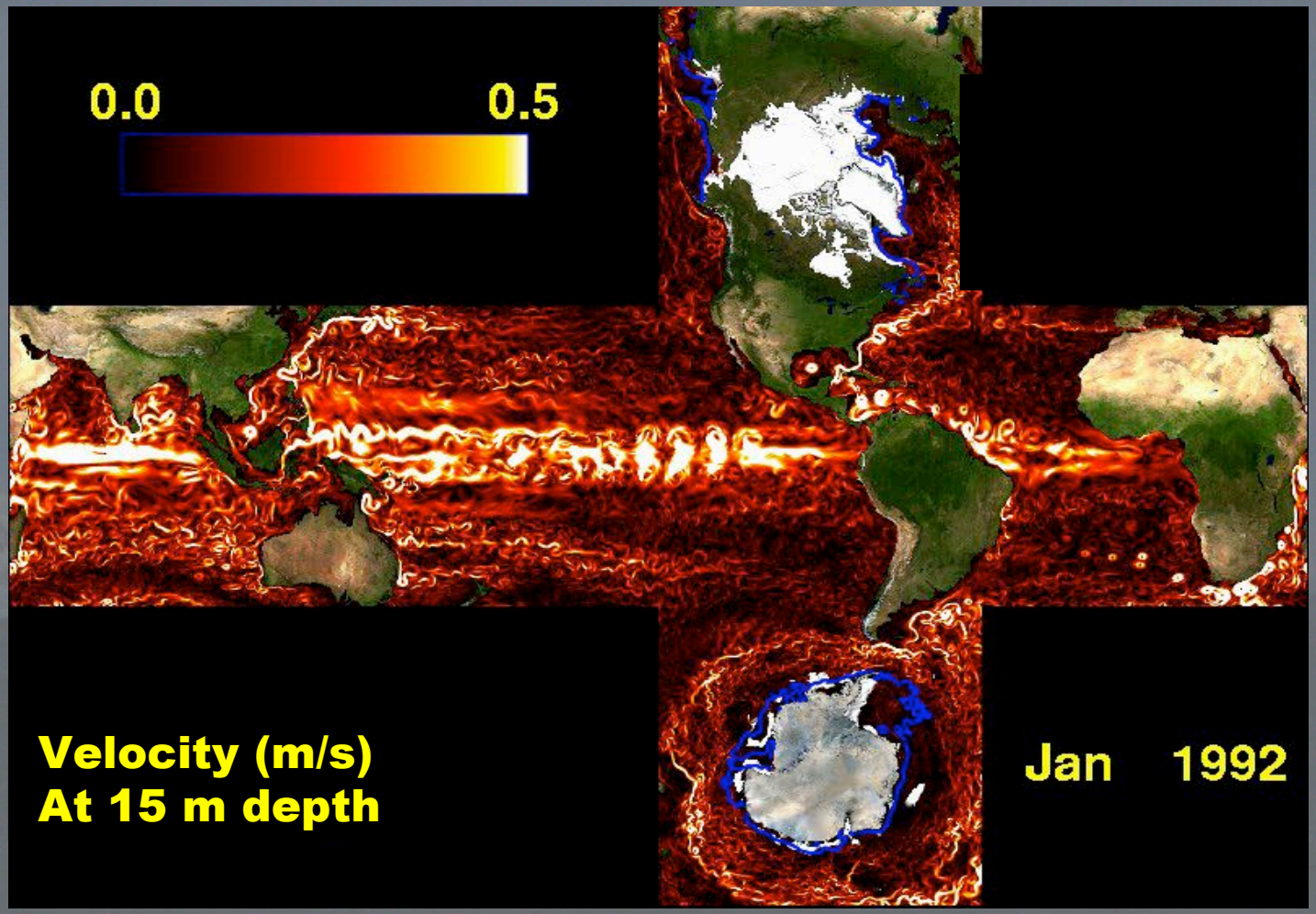
Schodlok 2002, Schodlok et al. 2006

NASA oceanography: from satellites to supercomputers

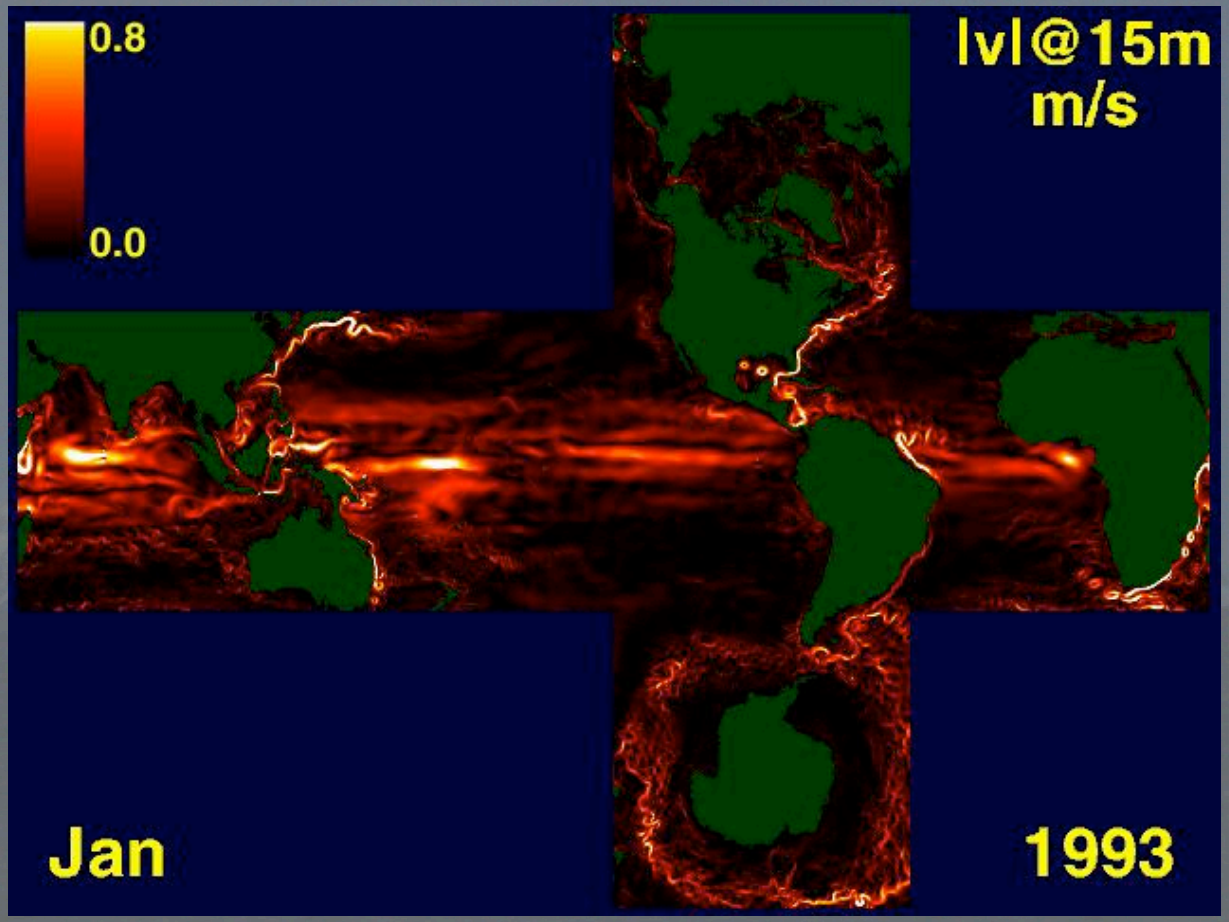


ECCO2: High-Resolution Global-Ocean and Sea-Ice Data Synthesis

JPL
Fu, Kwok, Lee, Menemenlis, Nguyen Zlotnicki, Zhang, Volkov
MIT
Marshall, Heimbach, Hill Wunsch
GSFC
Rienecker Suarez
ARC
Henze, Taft
HARVARD
Tziperman
GFDL
Adcroft
ARGONNE
Hovland, Utke
AWI
Losch



Objective: synthesis of global-ocean and sea-ice data that covers the full ocean depth and that permits eddies.
Motivation: improved estimates and models of ocean carbon cycle, understand recent evolution of polar oceans, monitor time-evolving term balances within and between different components of Earth system, etc.



ECCO2 – cube sphere http://ecco2.jpl.nasa.gov

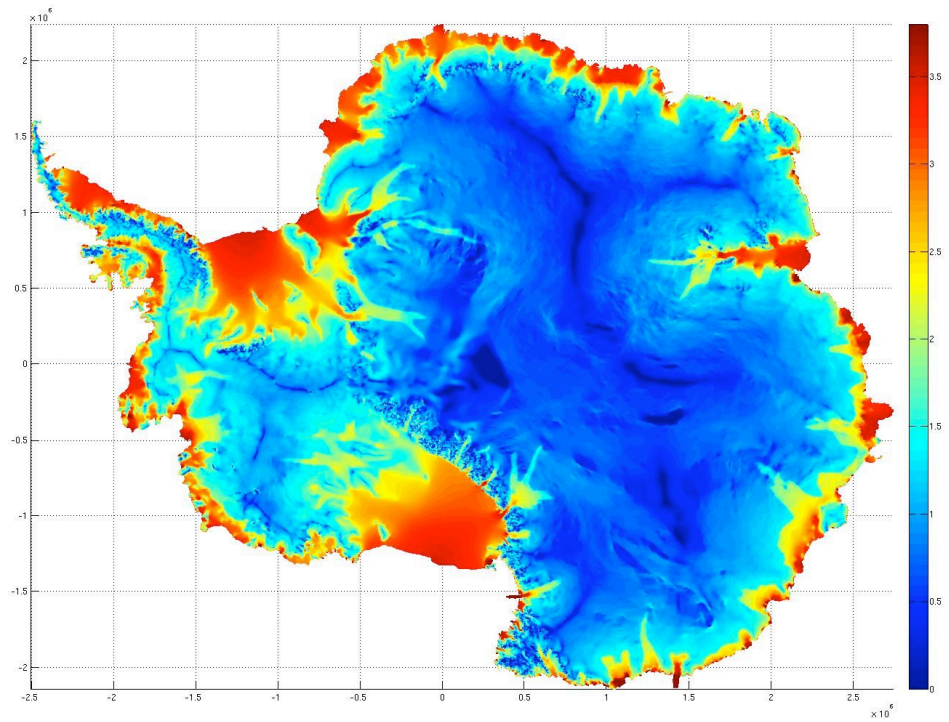
Conclusions

- Important physical processes for water mass conversion
  - sea ice, ice shelf ocean interaction
- Narrow Shelves provide window into the deep ocean
- Dense water masses found in the global abyss
- ECCO2 – implementing ice-shelf ocean interaction
- Senior scientists are as tall as emperor penguins

OUTLOOK

Present day ice flow simulation for Antarctica,using Cielo.

Eric Larour, JPL



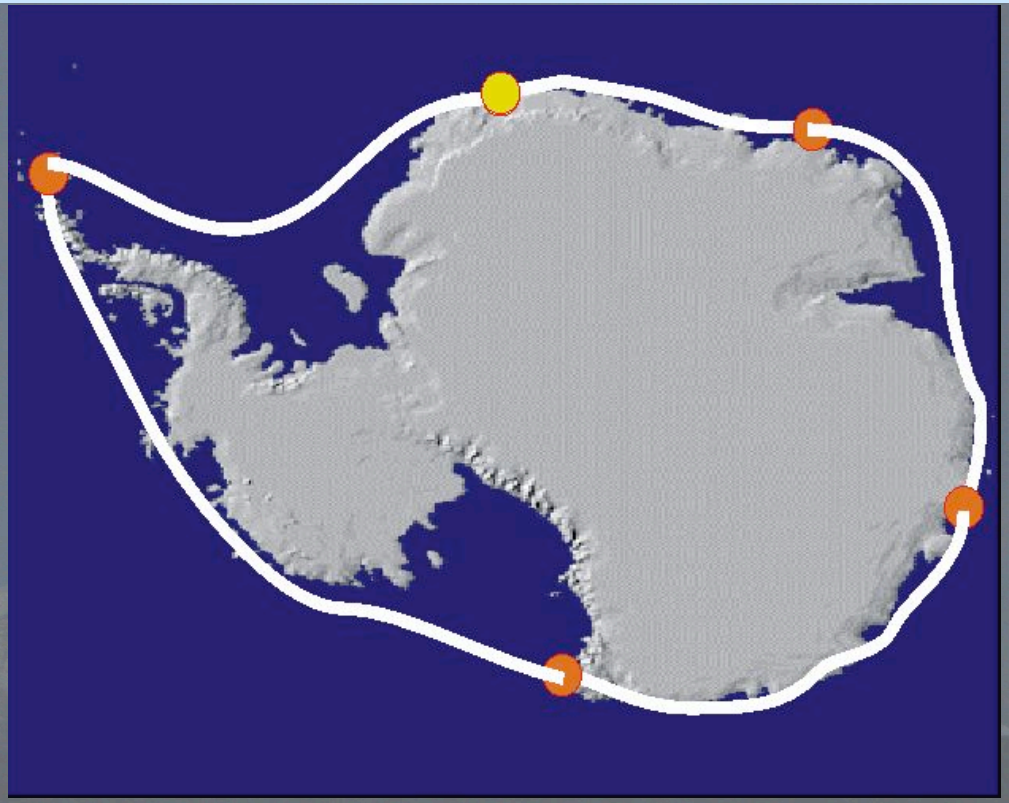
Surface velocity magnitude (m/yr). Logarithmic scale.

Fast flowing ice shelves appear in red (~1000 m/yr). Fast moving ice streams appear in yellow (~400 m/yr). Ice moving on frozen bedrock appears in blue (~1 m/yr).

Motivation:

- Decadal survey from NRC/NASA: " Will there be catastrophic collapse of the major ice sheets, including Greenland and West Antarctic and, if so, how rapidly will this occur? What will be the time patters of sea level rise as a result?"
- Strong need for a large scale model of ice flow in Antarctica to assess future mass balance of the continent.

Thank You !!



Questions?

Thanks to the ECCO2 team: Dimitris, An, Hong, Denis, Victor, Tony, Ron, Lee

Thanks for great Fotos:
Title - D. Olbers; Penguin - A. Friedrich; Background - O. Klatt; ISPOL - I. Arndt