

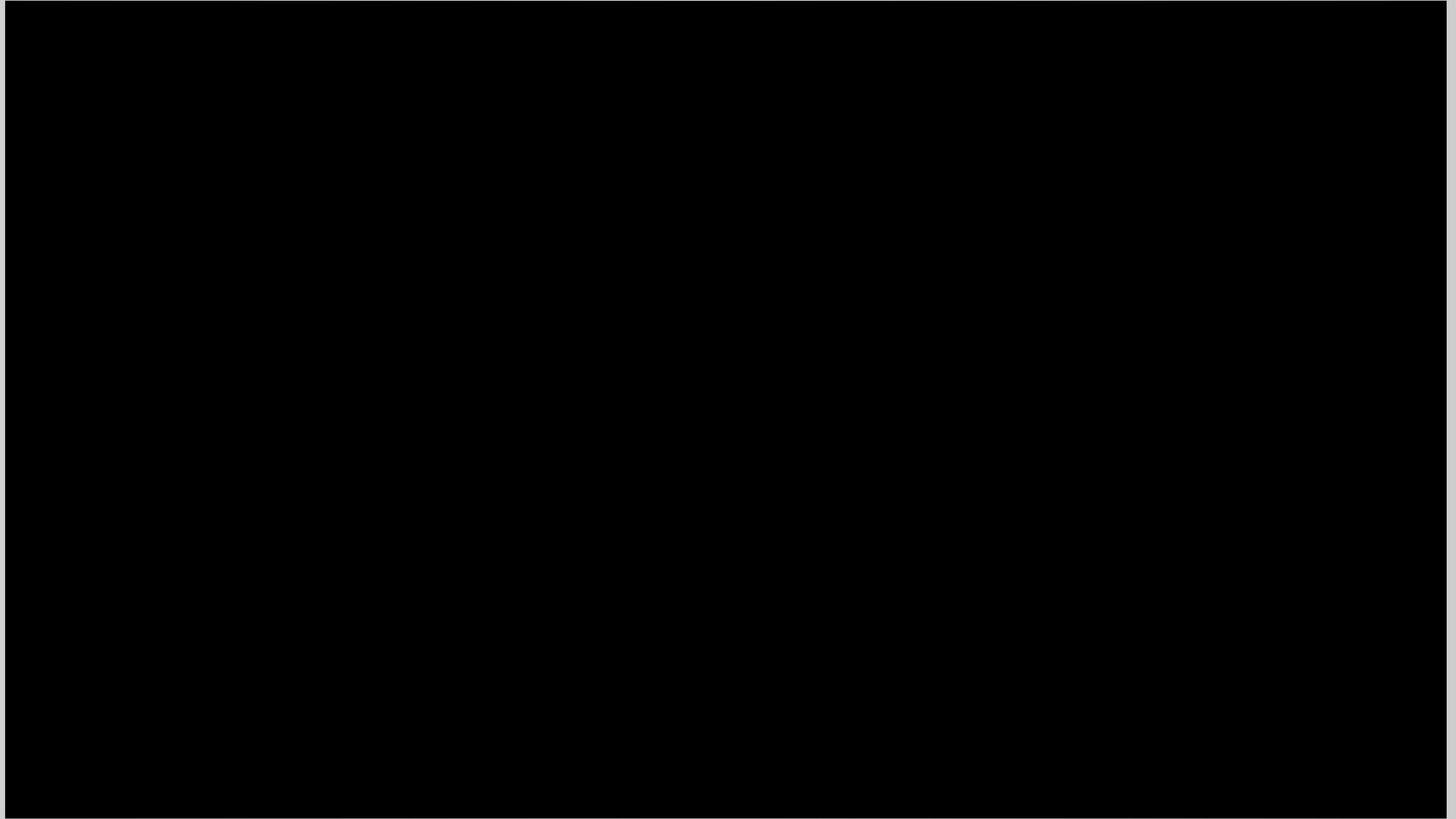
Oceanografia Física

parte 2: Circulação oceânica

PPG em Oceanografia Física, Química e Geológica
2015

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Instituto de Oceanografia, FURG

O Oceano em movimento...



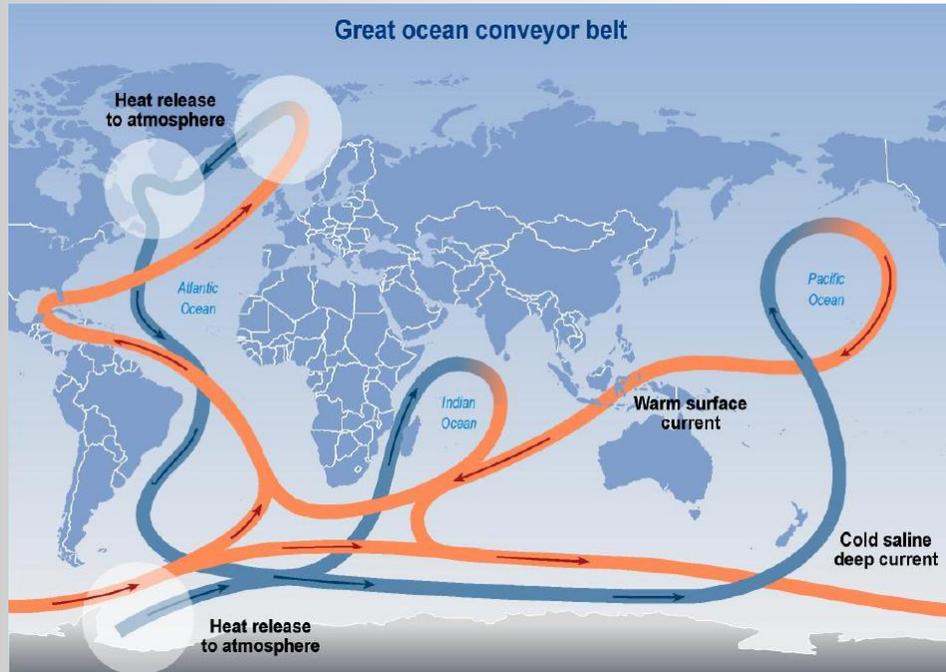
Tópicos a serem abordados

- As escalas envolvidas;
- A Radiação eletromagnética, cinturões de pressão atmosférica;
- As principais forçantes da circulação oceânica;
- Circulação termohalina e *Conveyor Belt*.
- Circulação do Oceano Atlântico

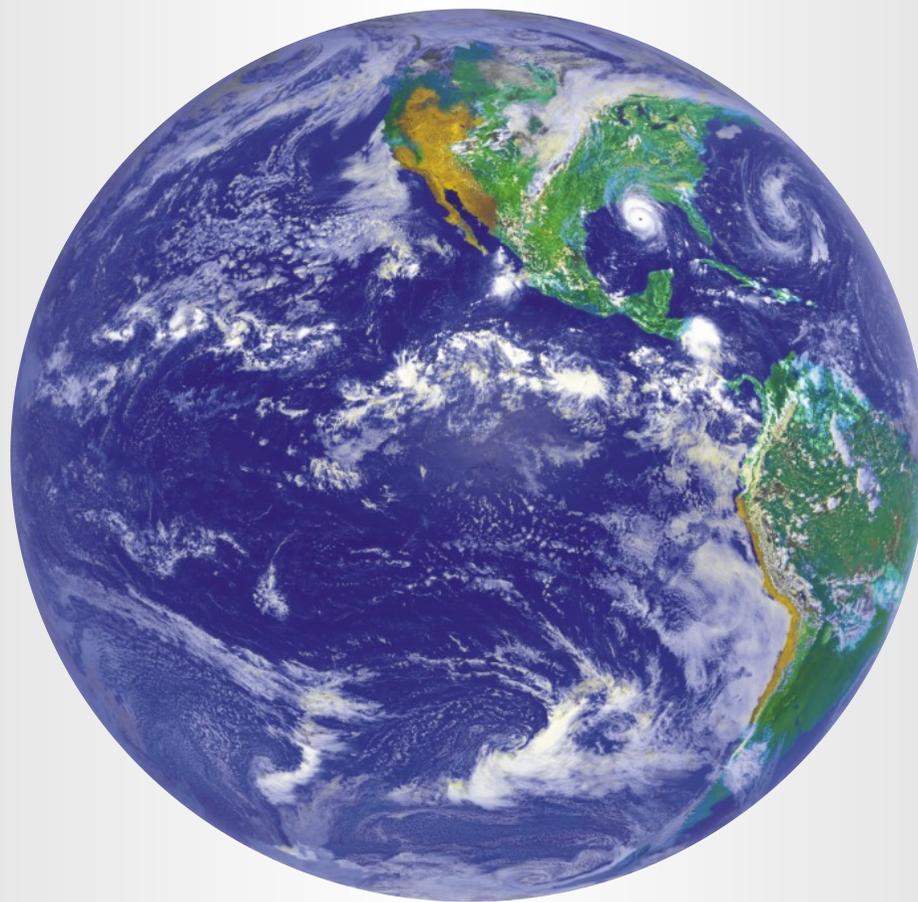
Introdução

- Os primeiros três metros dos oceanos armazenam a mesma quantidade de calor que toda a atmosfera. Este calor é liberado e reabsorvido regularmente em um ciclo do oceano para atmosfera e vice-versa. Conseqüentemente, é fundamental o conhecimento da circulação oceânica para o para que o regime climático dos nosso planeta (e suas mudanças) possa ser compreendido em escalas temporais da ordem de décadas. Em escalas menores, padrões atípicos na taxa e tamanho desta interação oceano-atmosfera pode causar eventos meteorológicos extremos (furacões, enchentes, secas, etc).

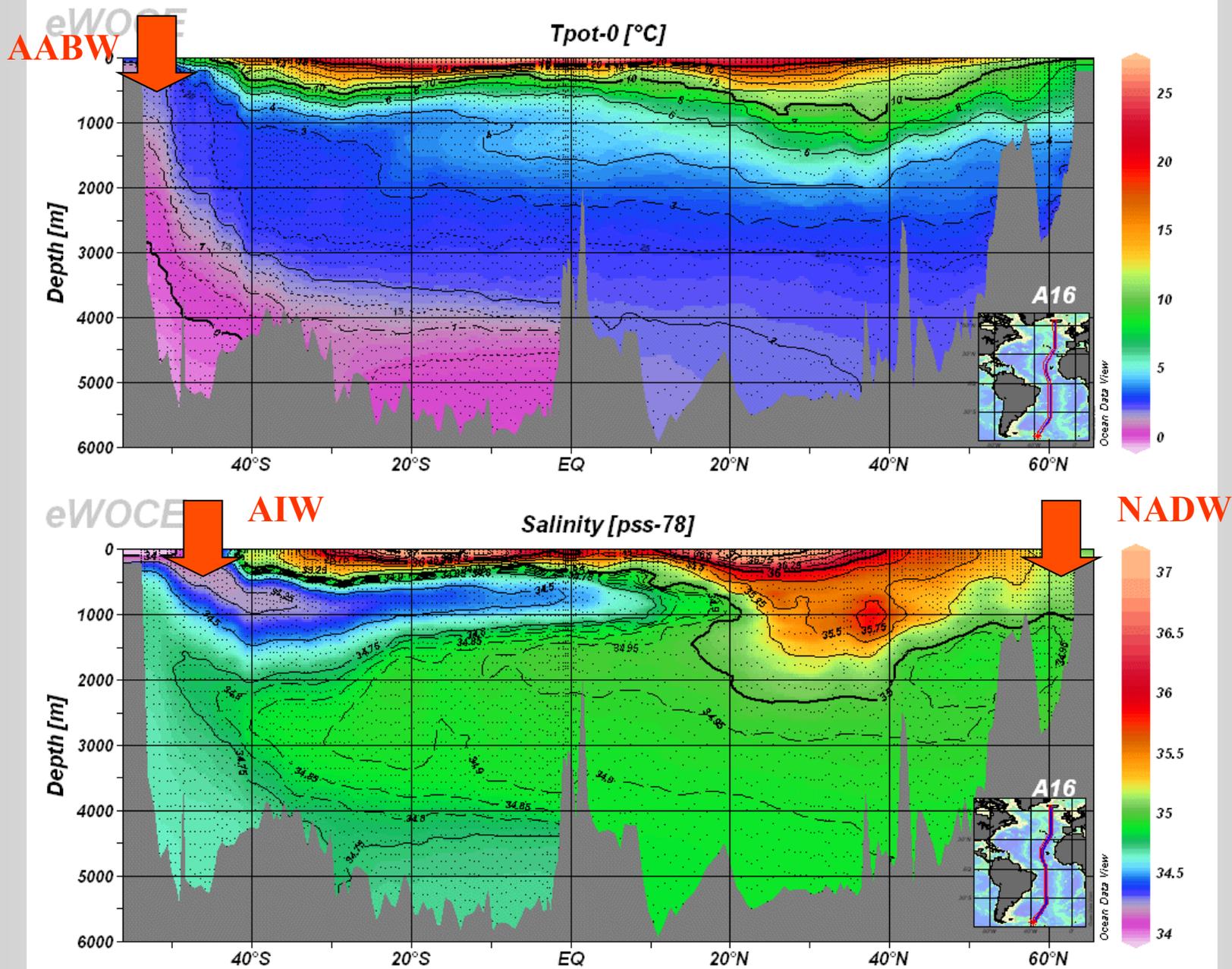
Great ocean conveyor belt

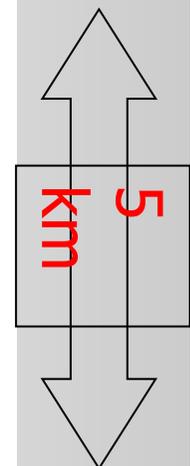
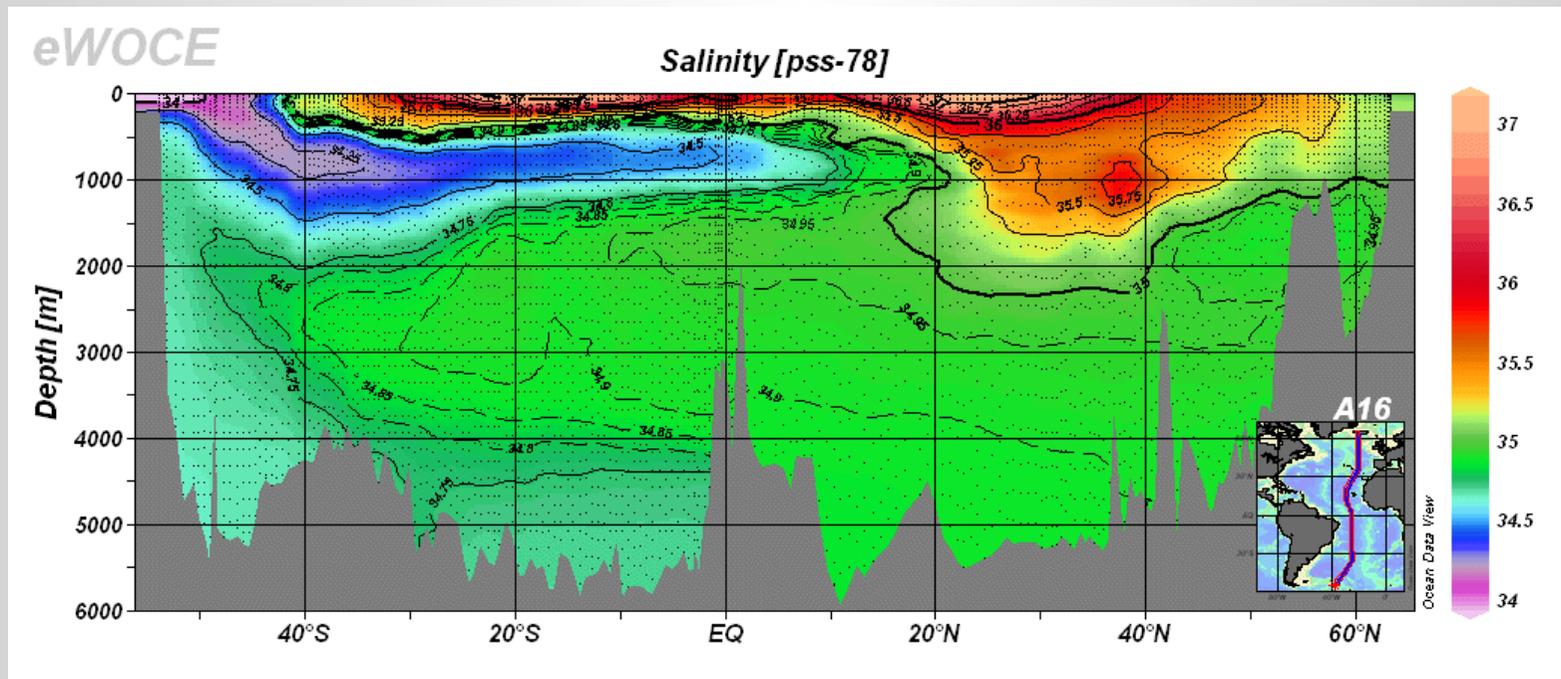


Escalas: “A Terra é uma bola de futebol molhada”. D. Olbers



Atlantic WOCE A16 Section – Theta e Salinidade





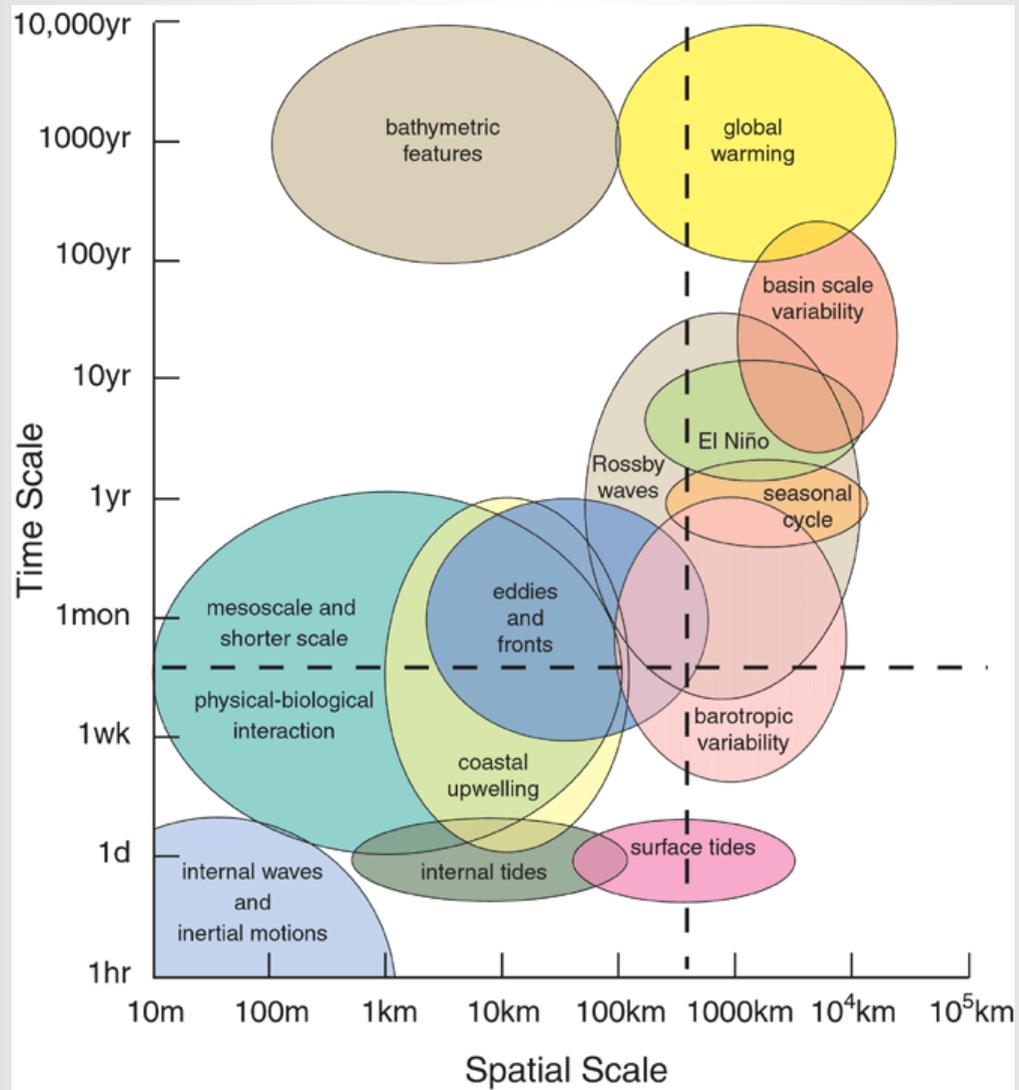


eWOCE

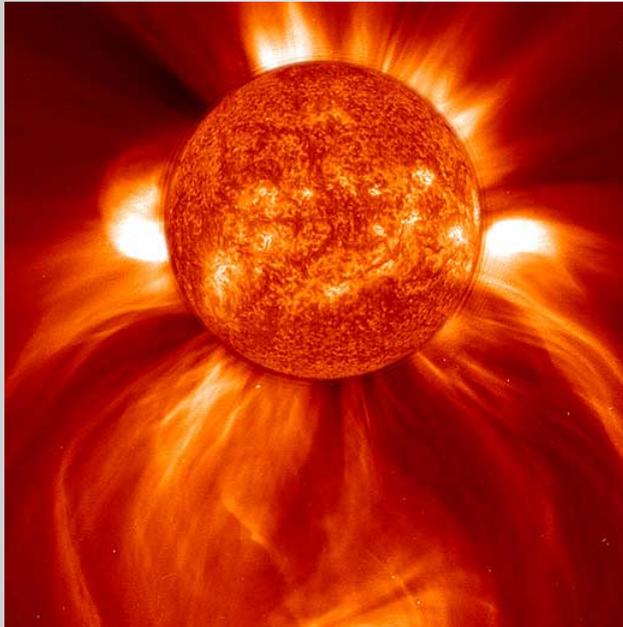
Salinity [pss-78]



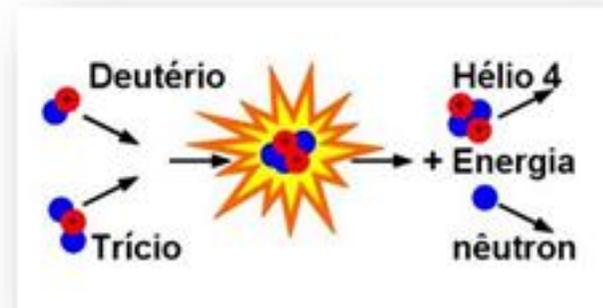
Escalas x Movimentos Oceânicos



A origem

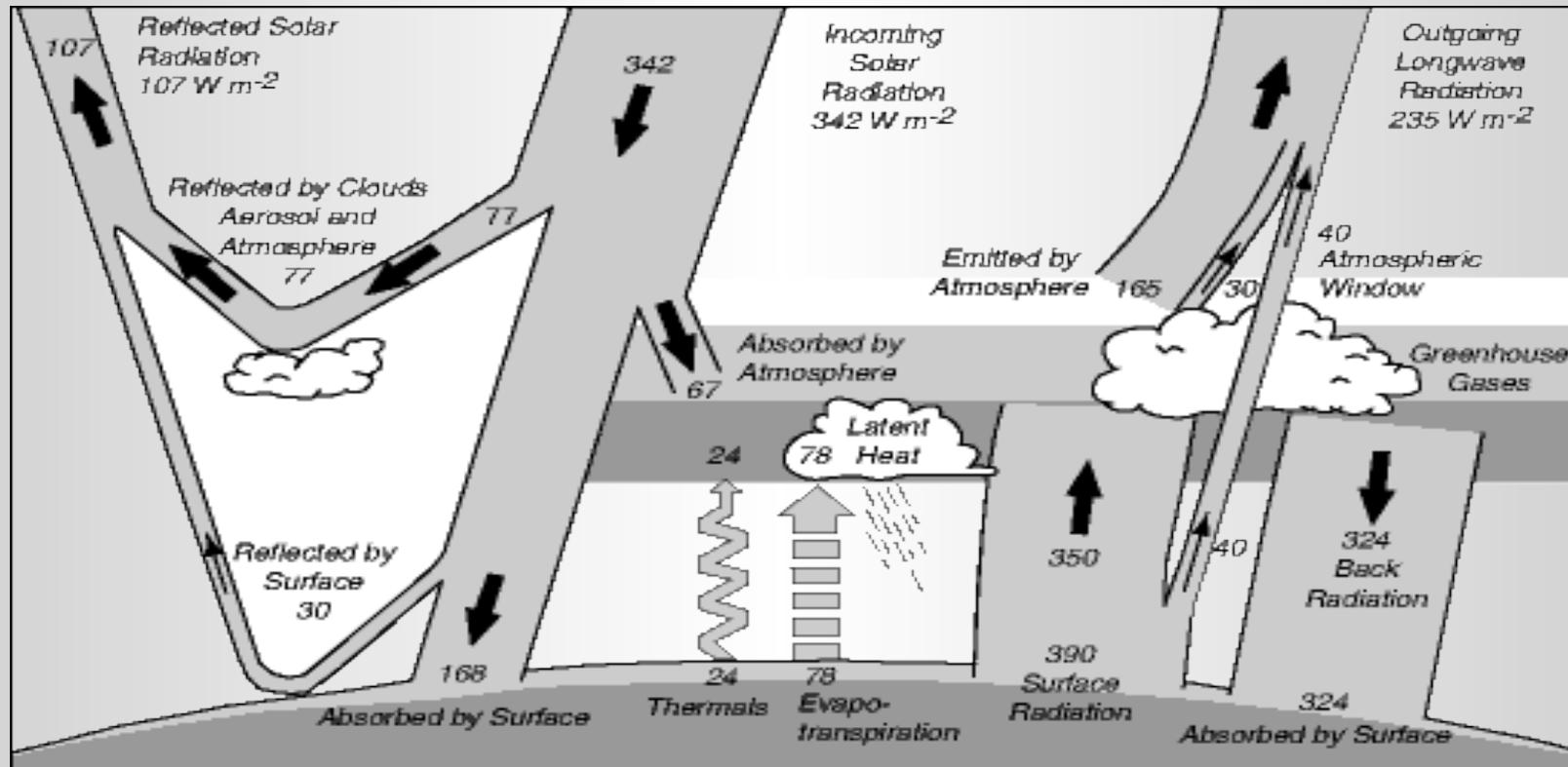


Fusão Solar



Os gases de hidrogênio (deutério e o trítio, isótopos do hidrogênio) se chocam e formam o hélio e uma partícula atômica chamada de nêutron. Como há uma pequena perda de massa no meio do processo, ela se torna uma quantidade de energia enorme e juntando com a alta temperatura do sol no núcleo, que é aproximadamente $15,7 \times 10^6$ K (Kelvin), ela continua o processo de fusão dos gases de hidrogênio formando o hélio até acabar a sua matéria-prima (este processo levará cerca de 7 bilhões de ano).

Balanço de Calor



The mean annual radiation and heatbalance of the earth. From Houghton et al. (1996: 58), which used data from Kiehl and Trenberth (1996).

Forças que atuam nos oceanos

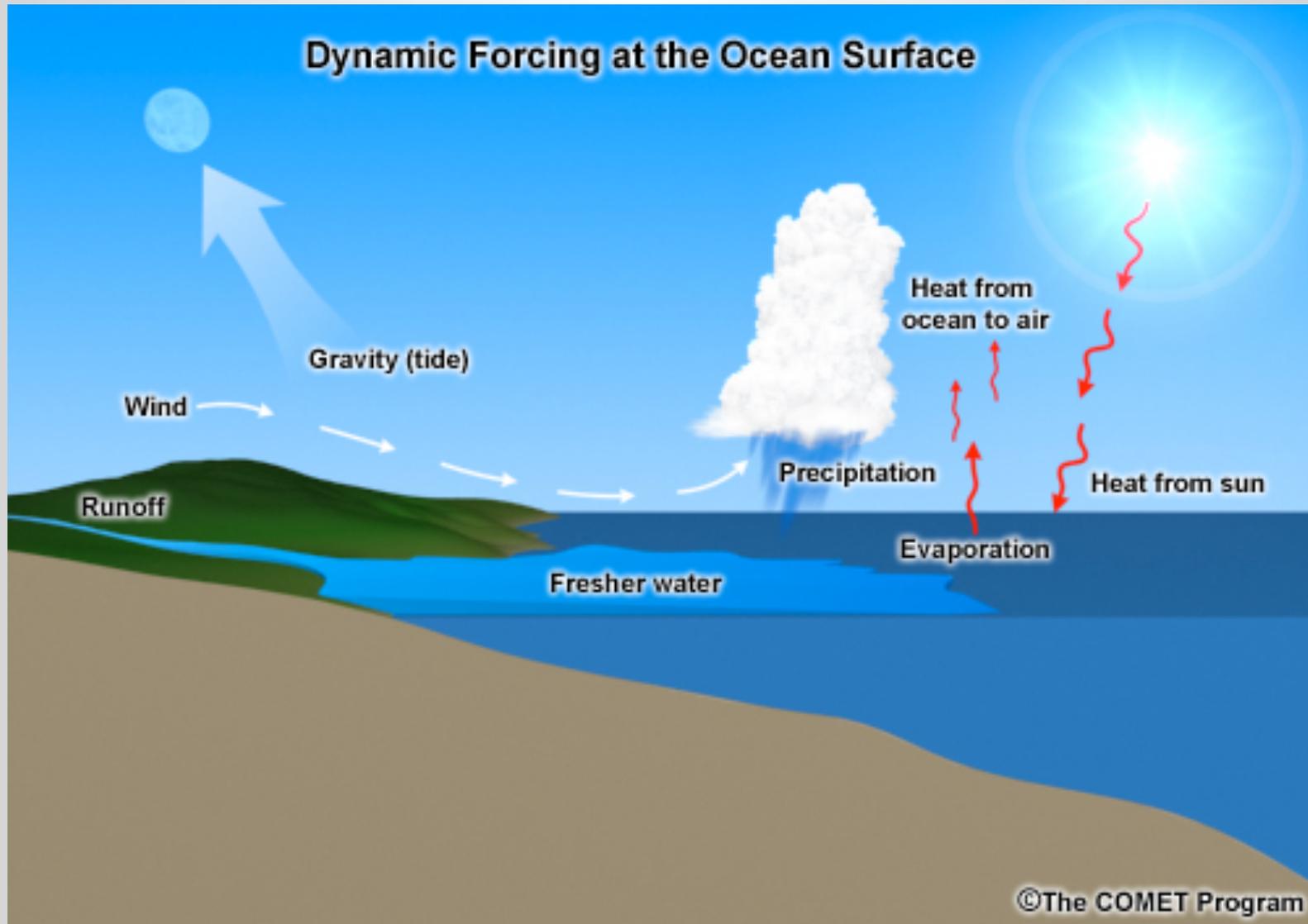
– PRIMÁRIAS

- Cisalhamento do Vento (wind stress)
- Gradiente de Pressão / Densidade
- Gravidade

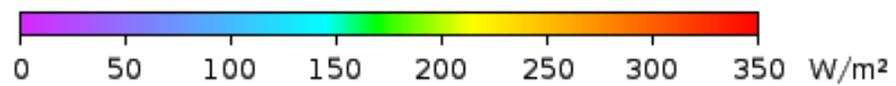
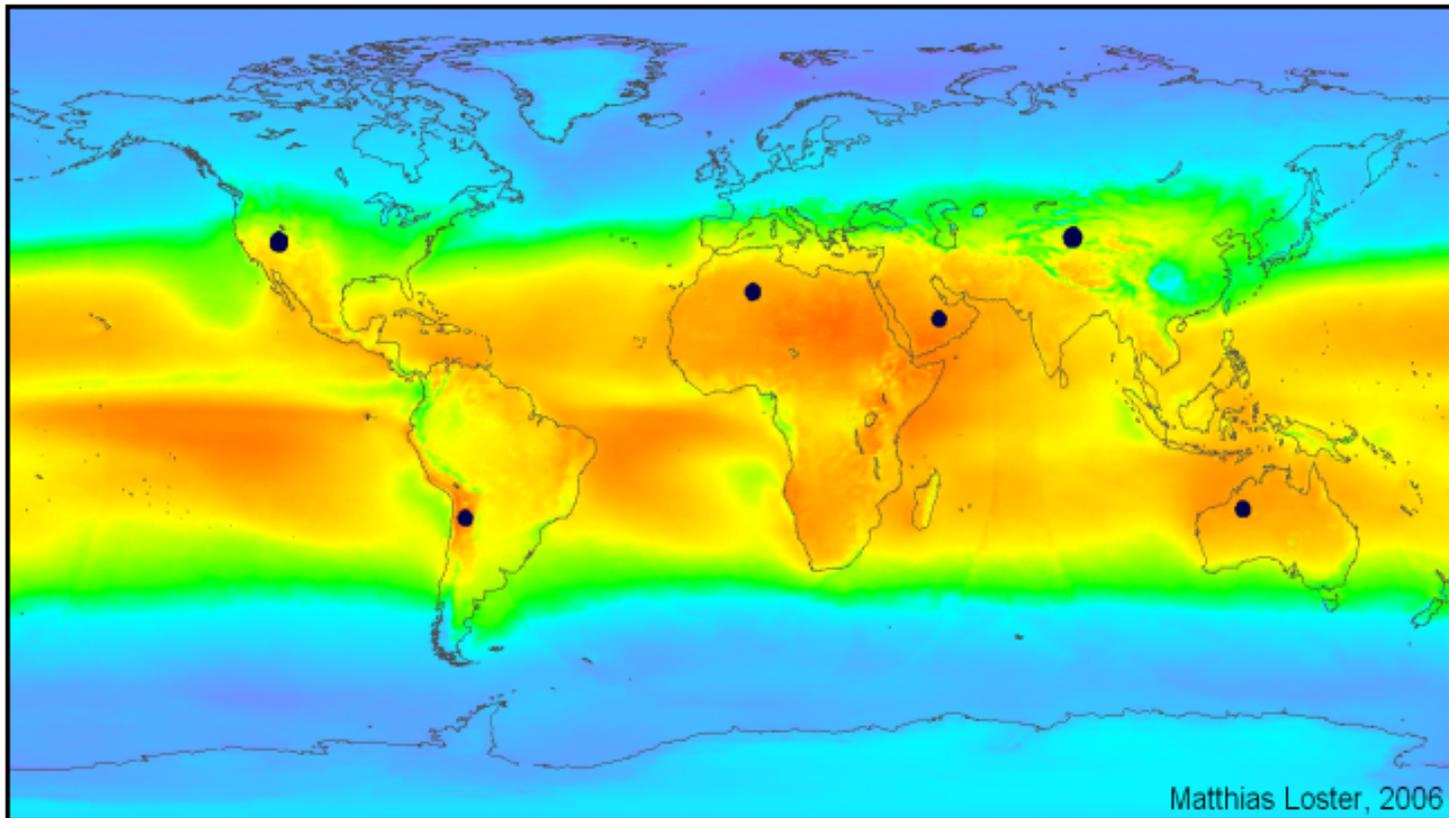
– SECUNDÁRIAS

- Coriolis
- Atrito / Fricção

Dynamic Forcing at the Ocean Surface

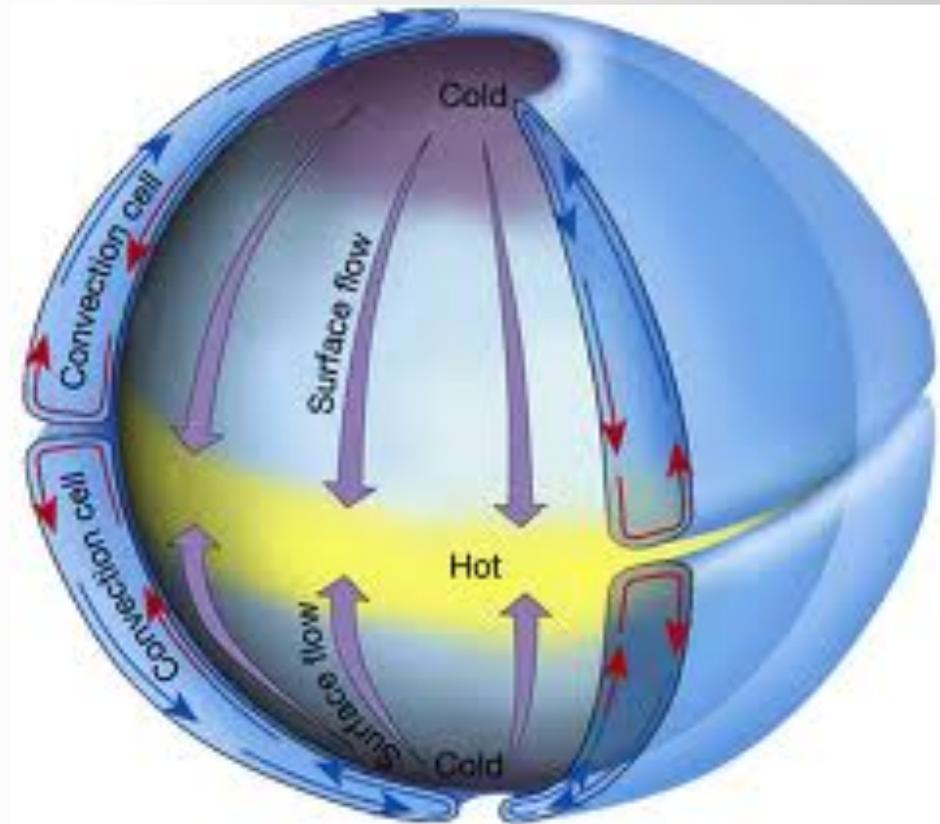
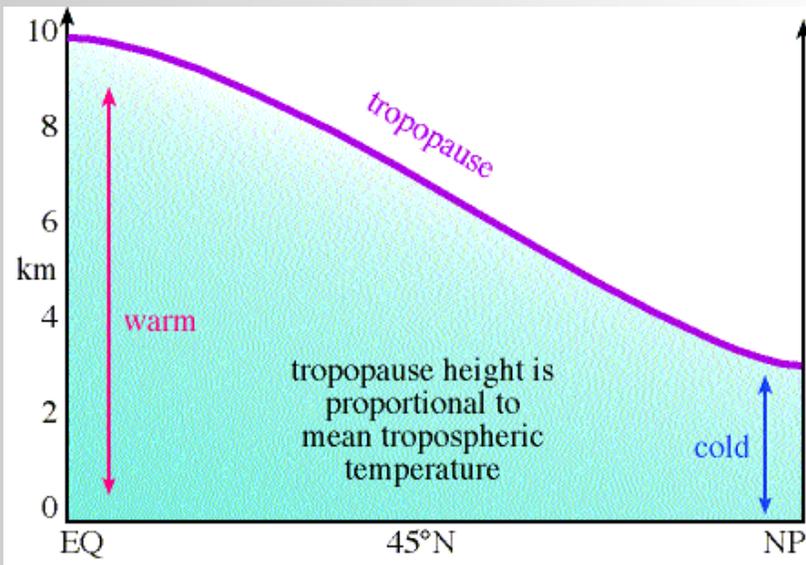


Insolação média (1991 -1993)



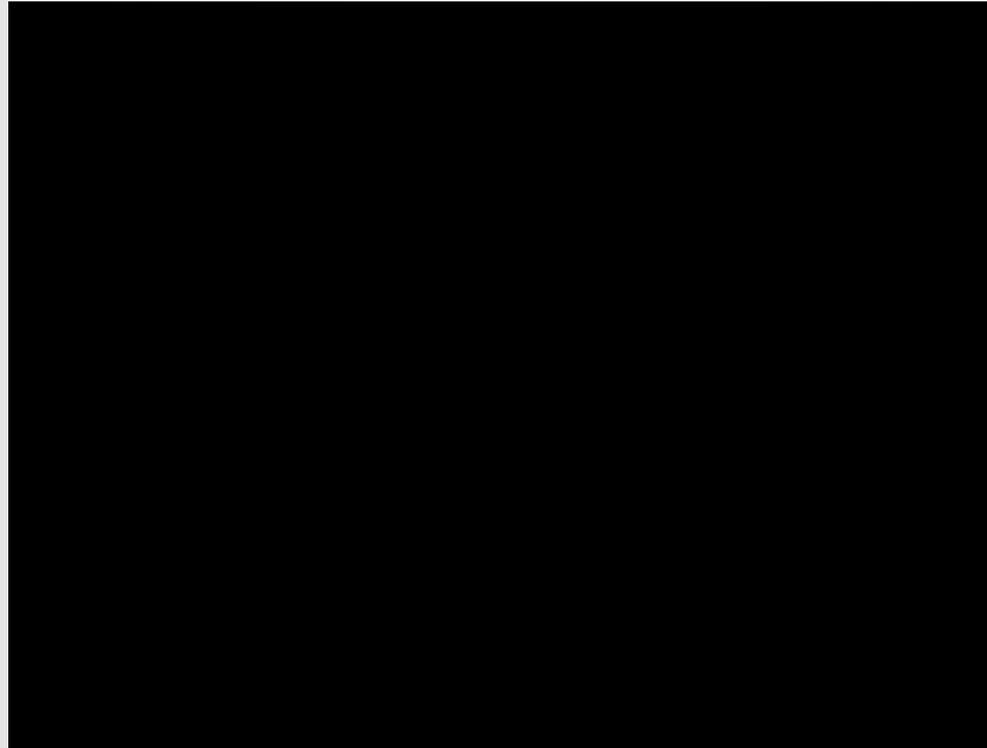
$\Sigma \bullet = 18 \text{ TWe}$

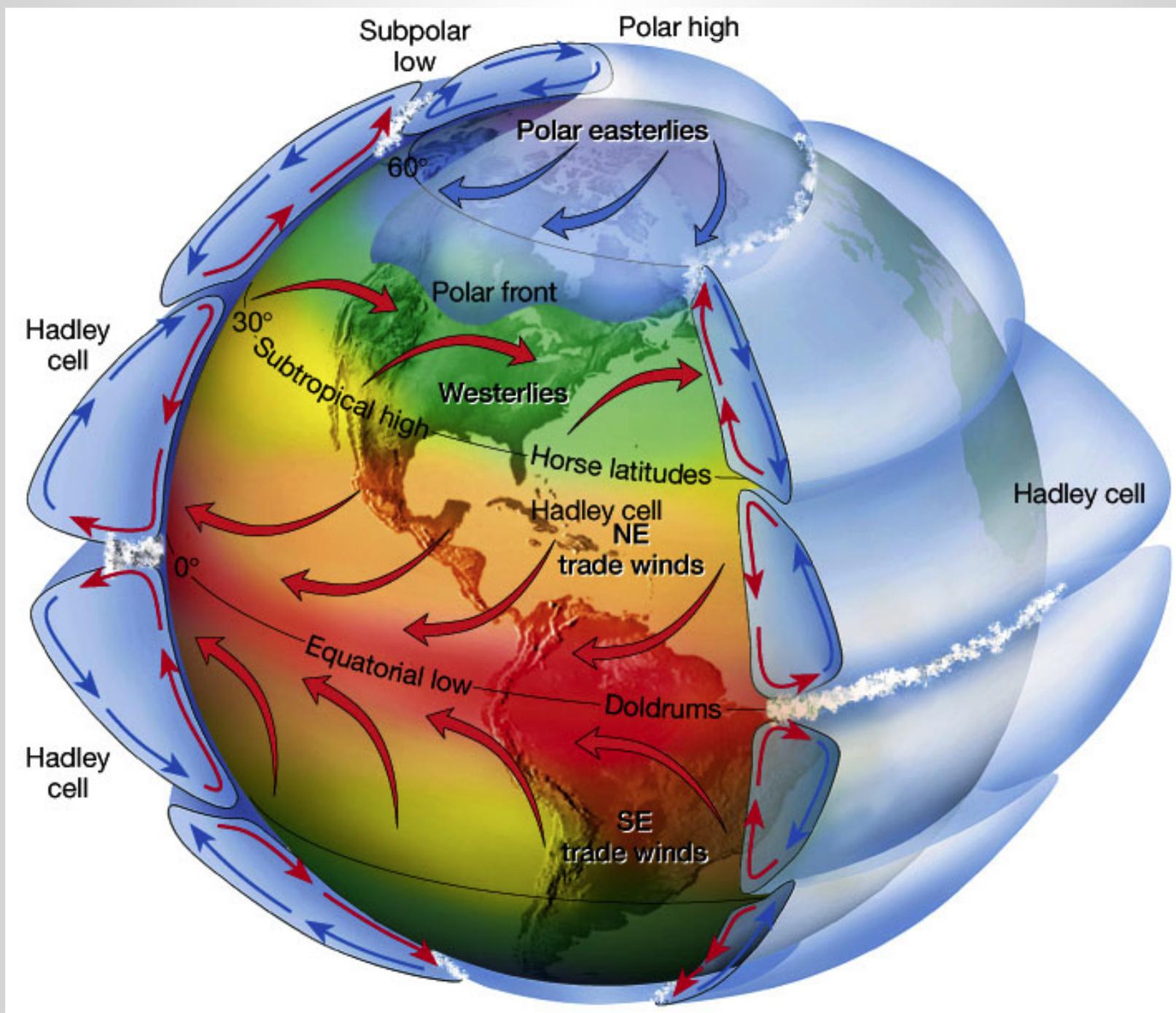
Altura da troposfera



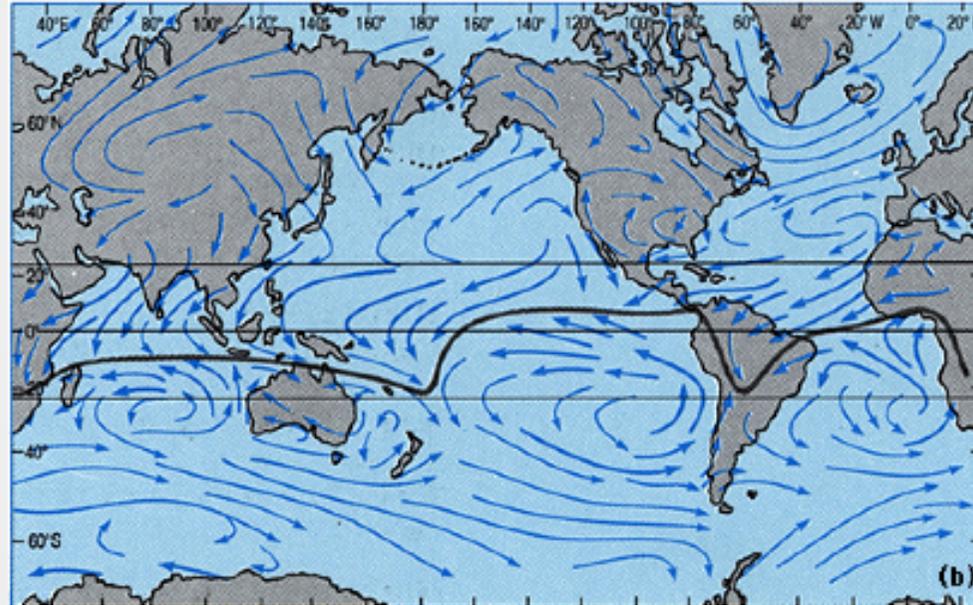
Circulação atmosférica (sem rotação)

Força de Coriolis

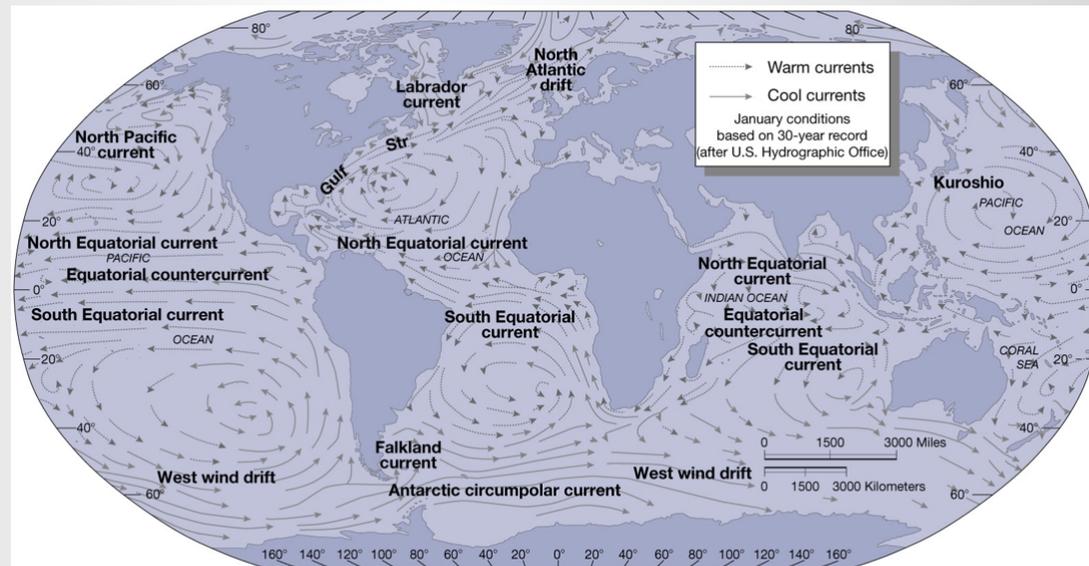




Padrão superficial de ventos - Janeiro



Correntes Oceânicas Superficiais



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Giros Oceânicos

- Giros Subtropicais
 - Centrados aprox. 30° N / S
- Sistema Equatorial de Correntes
- Corrente de Contorno Oeste
- Correntes Oceânicas em Latitudes Médias
- Correntes de Contorno Leste

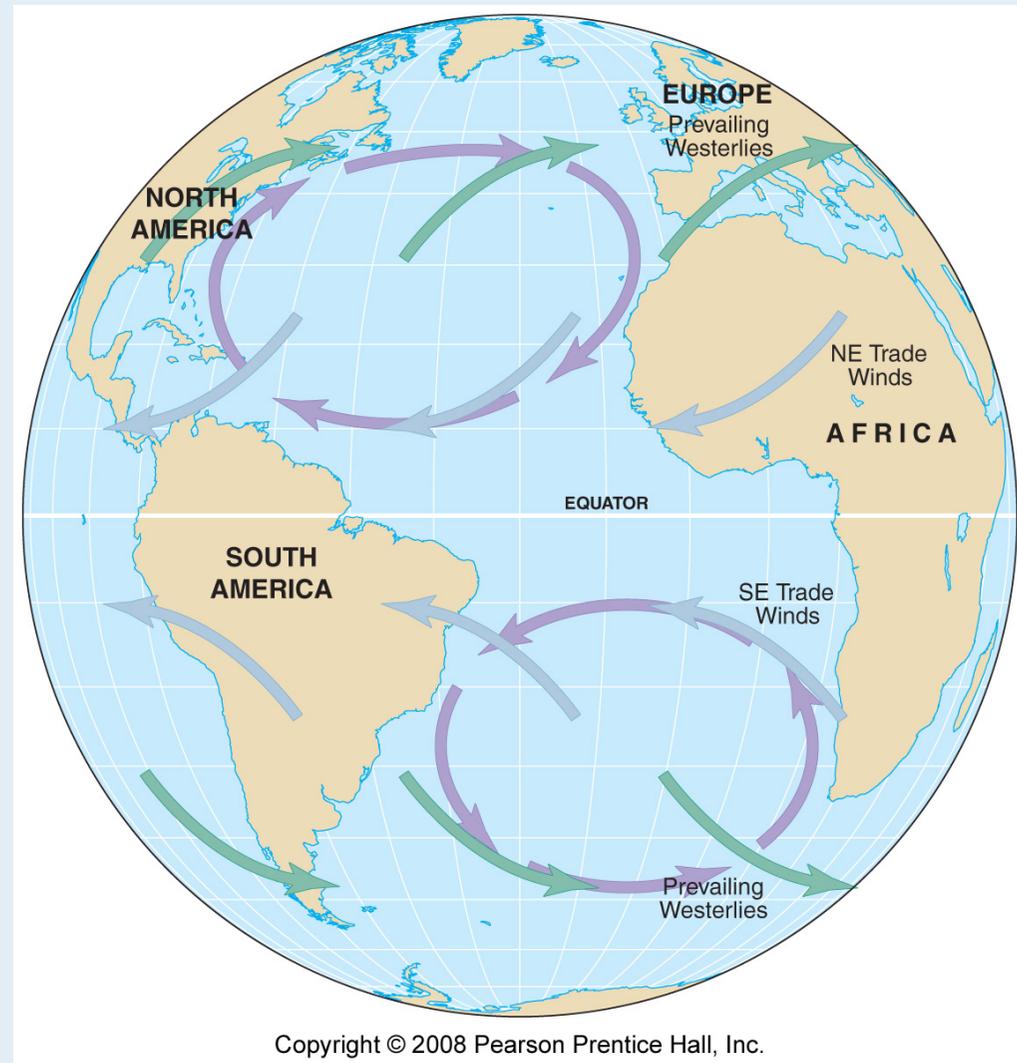
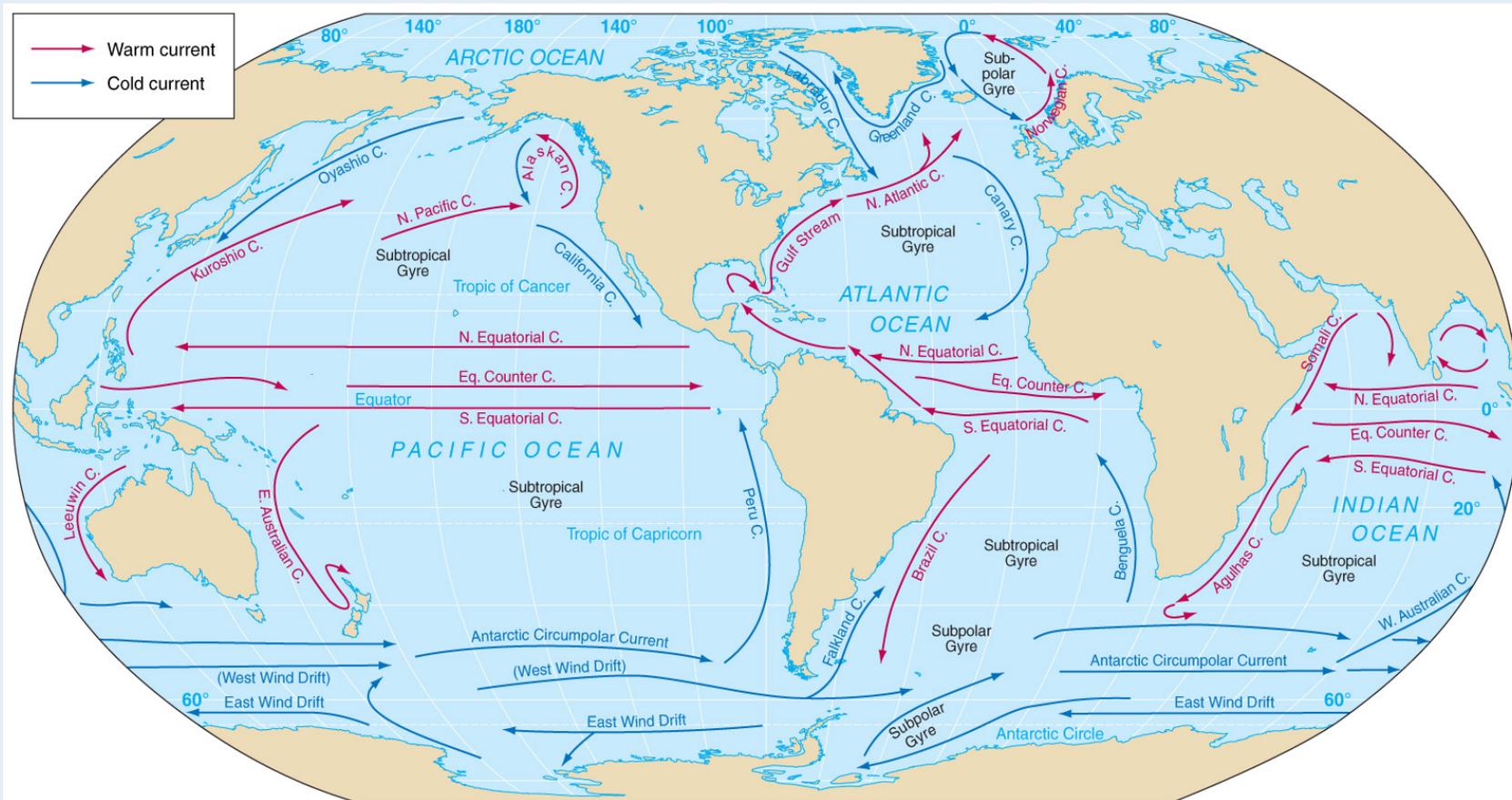


Fig. 7.4

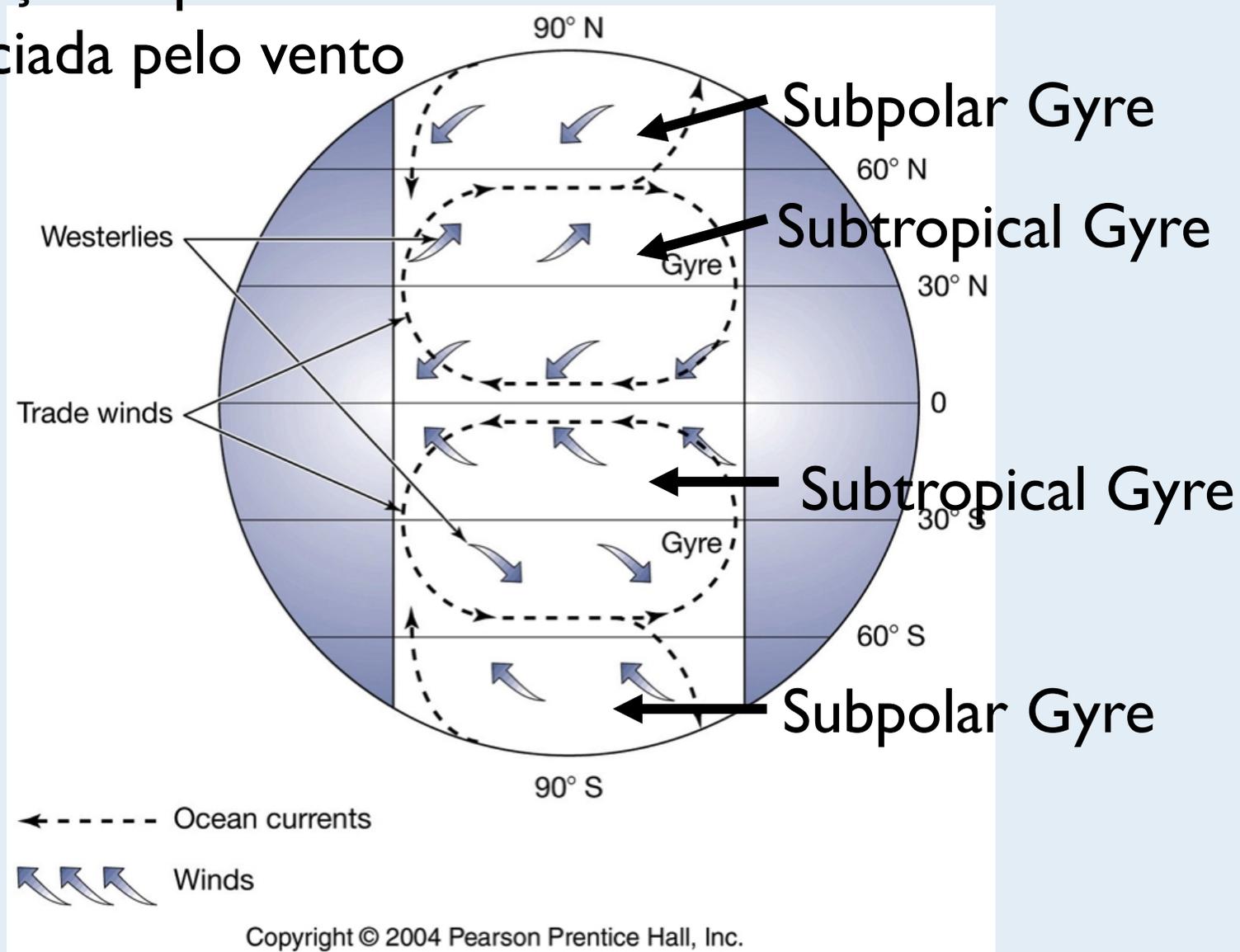
Outras Correntes de Superfície

- Contra-Correntes Equatoriais
- Giros Subpolares



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Esquema simplificado da Circulação superficial influenciada pelo vento

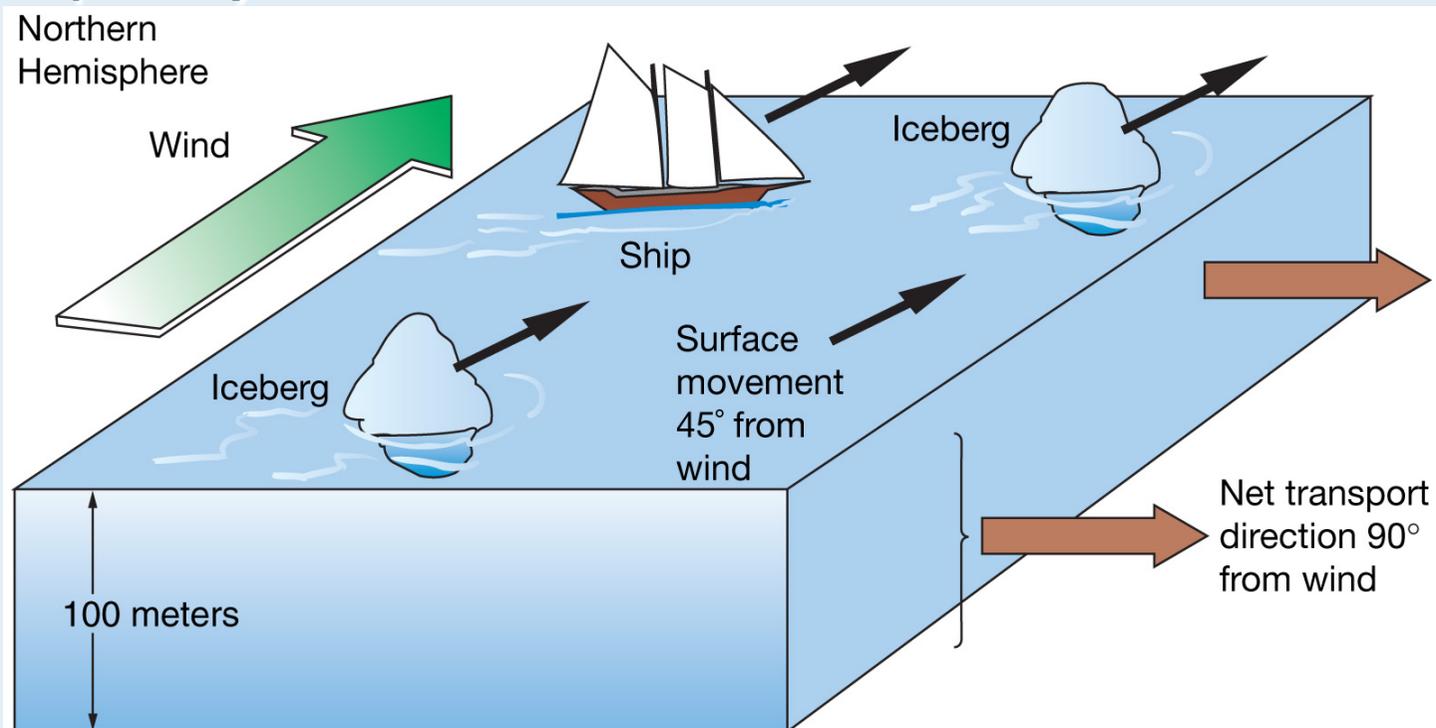


Como o oceano responde a ação dos ventos em superfície ?

- O Modelo de Ekman;
- Geostrofia

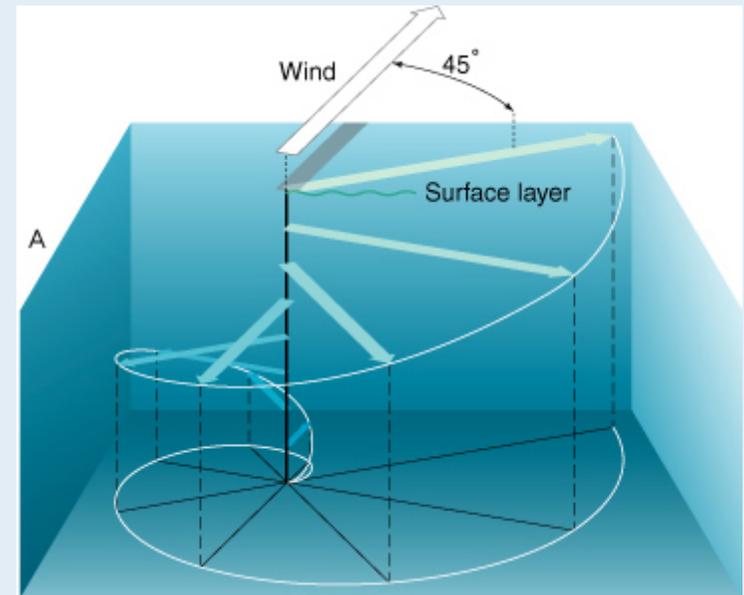
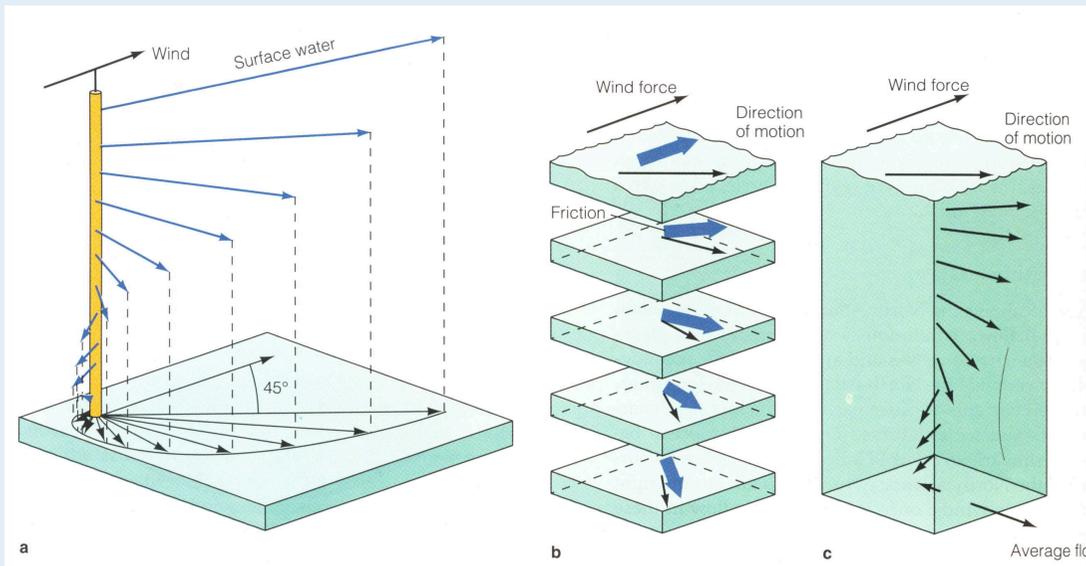
O Modelo de Ekman

- Observação: correntes superficiais movem-se em um ângulo em relação ao vento **local**.
- Ekman spiral describes speed and direction of seawater flow at different depths
- Each successive layer moves increasingly to right (N hemisphere)



Espiral de Ekman

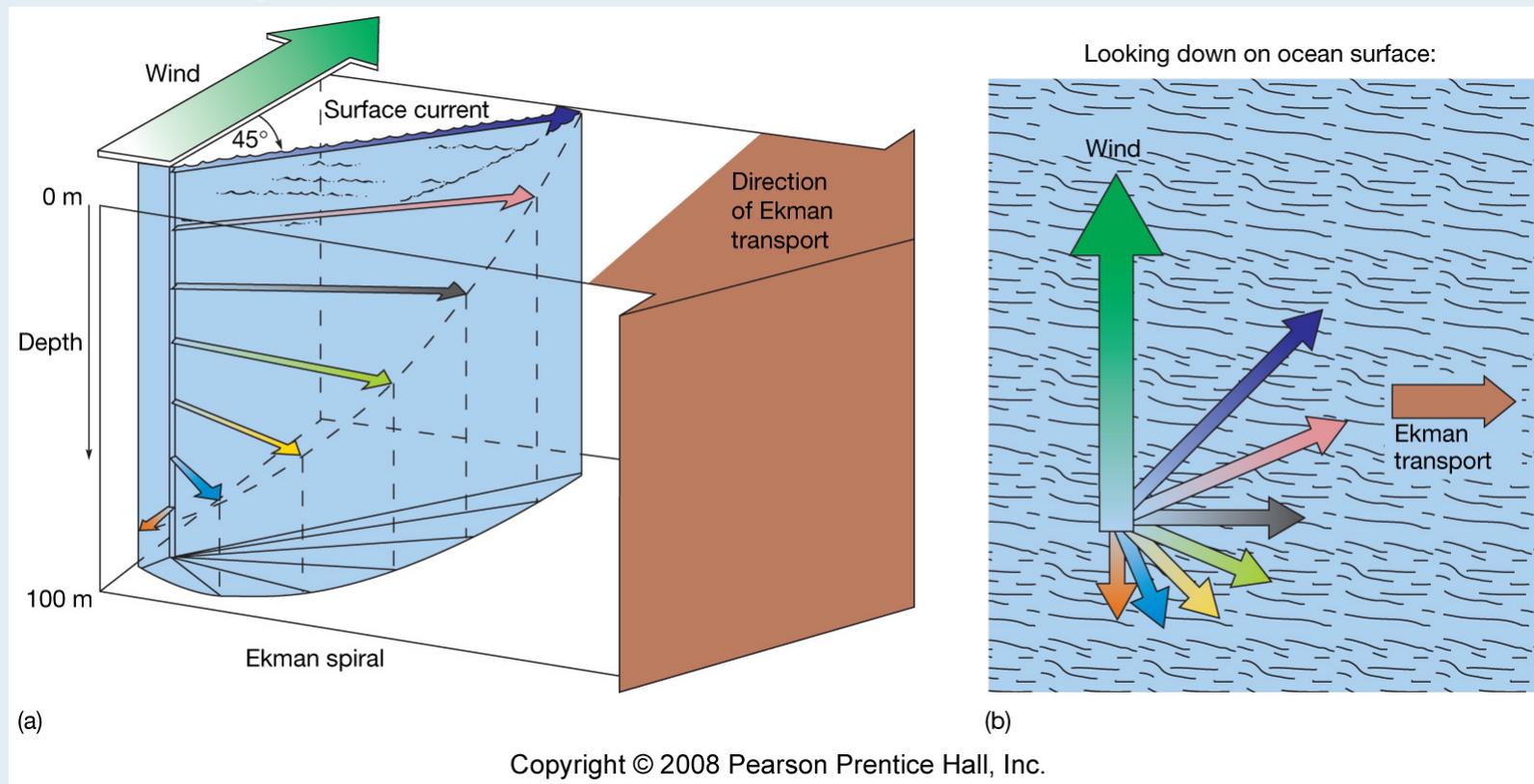
- Descreve a velocidade e direção da corrente forçada pelo vento em diferentes camadas;
- Cada camada gira mais à direita (esquerda) quando no Hemisfério Norte (Sul).





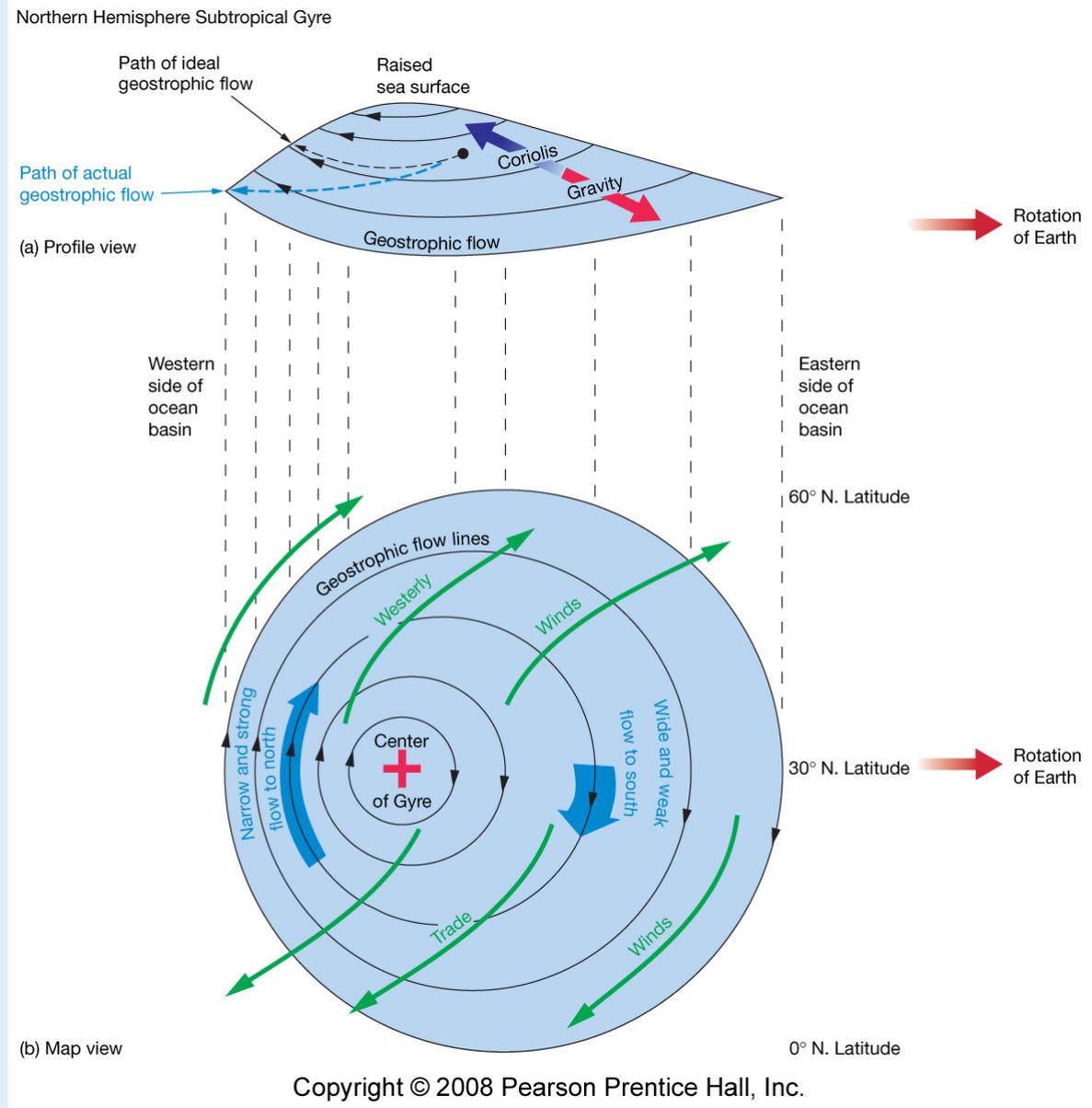
Transporte de Ekman

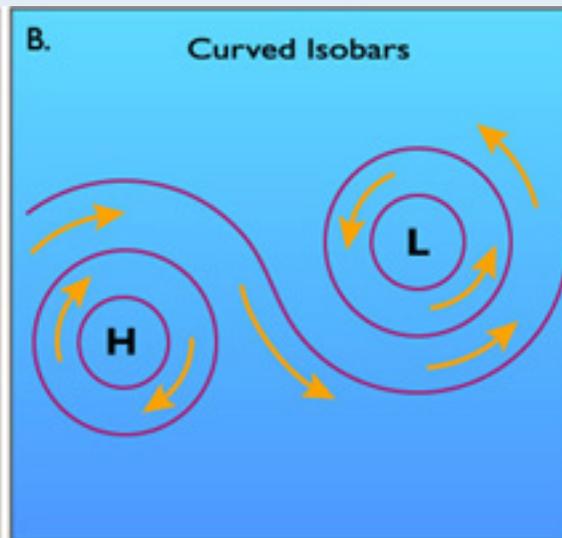
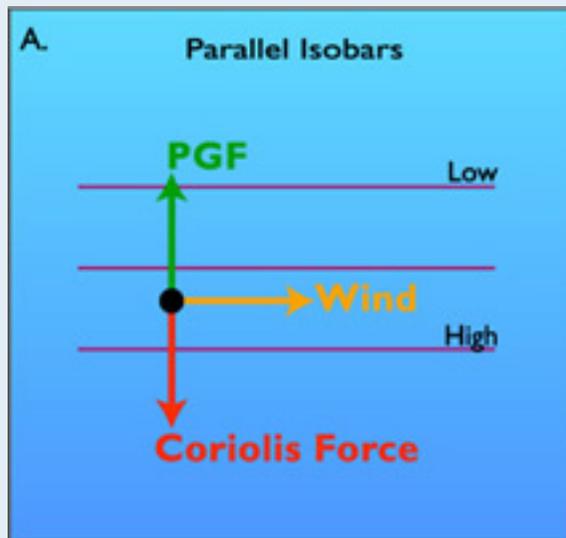
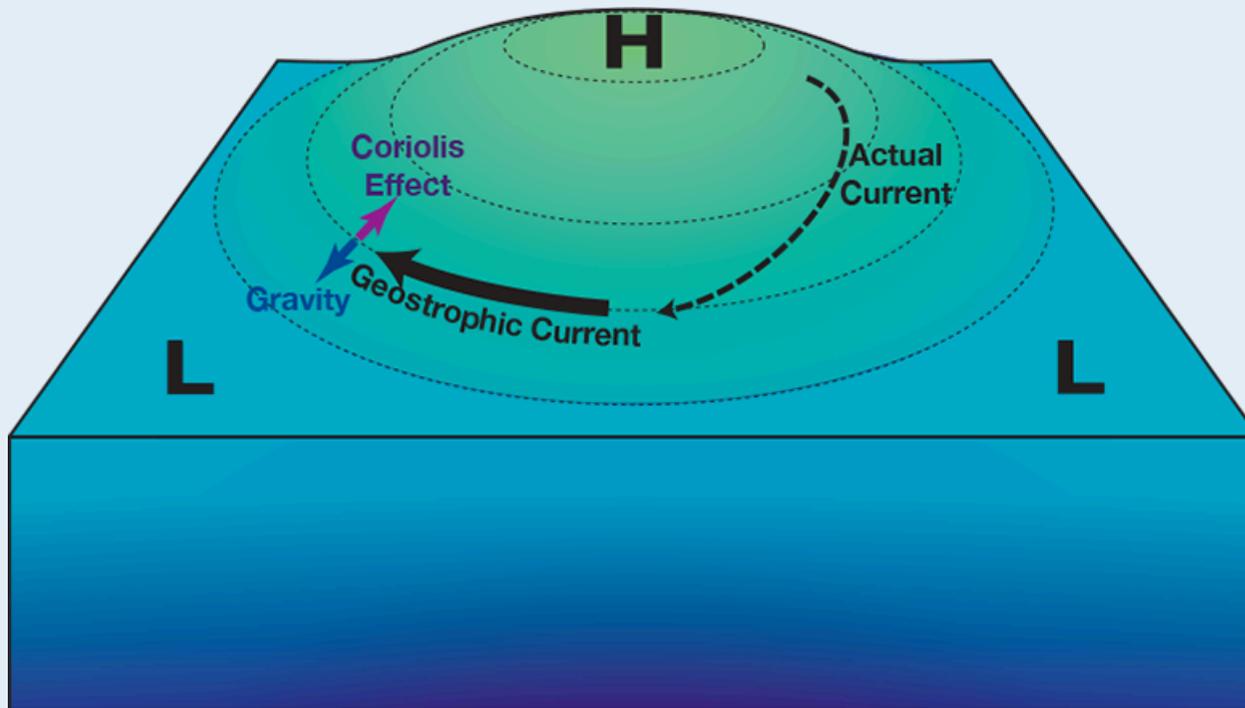
- Movimento resultante da coluna d'água sob a influencia do vento;
- 90° à direita do vento no HN
- 90° à esquerda do vento no HS



Geostrofia

- Através do mecanismos do Transporte de Ekman a água é empilhada no interior dos Giros subtropicais;
- A tendência, então, é que ela flua no sentido para fora dos giros (gravidade/Pressão);
- À medida que a água se movimenta sofre ação da rotação da Terra (Coriolis)
- O movimento resultante entre o balanço entre o GP e Coriolis gera o movimento **Geostrofico** em torno do centro do Giro subtropical.



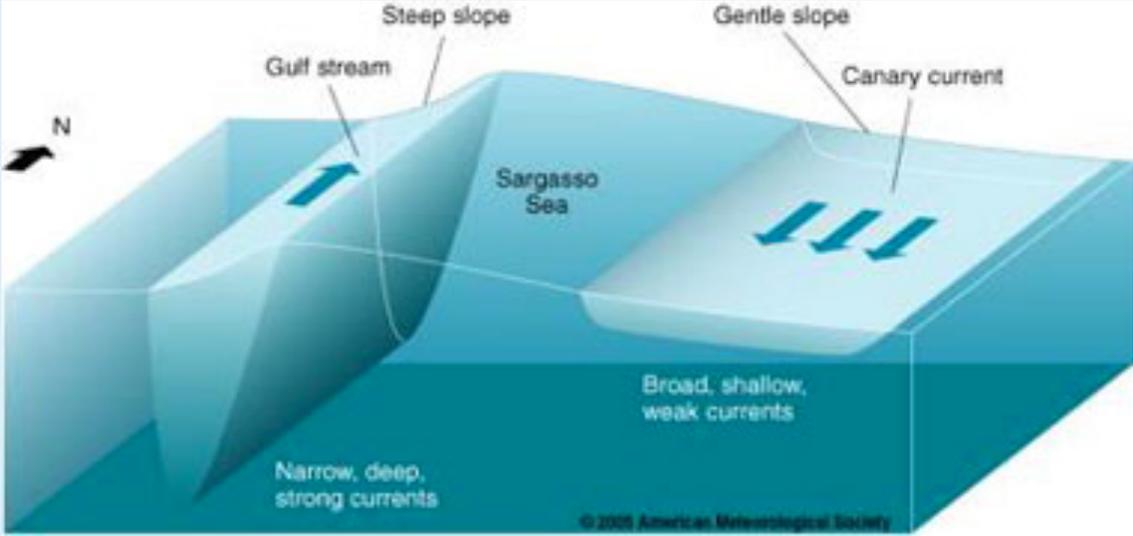
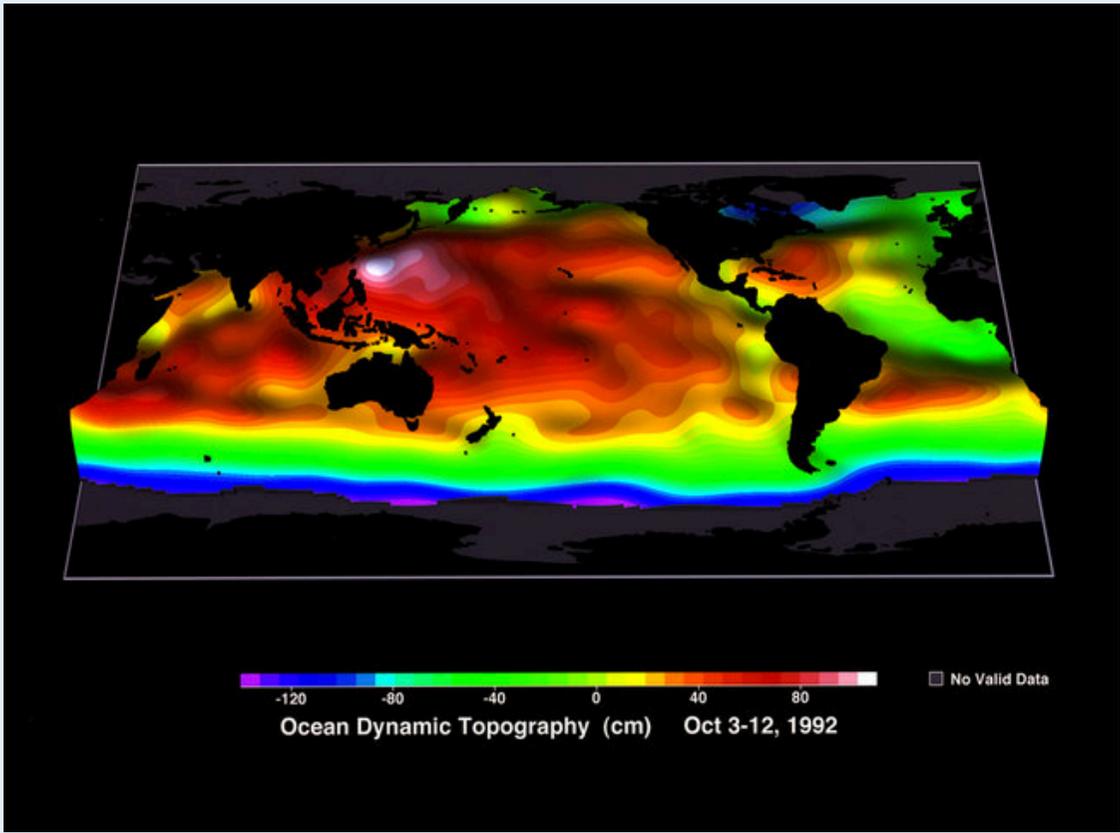


Intensificação das Correntes de Contorno Oeste

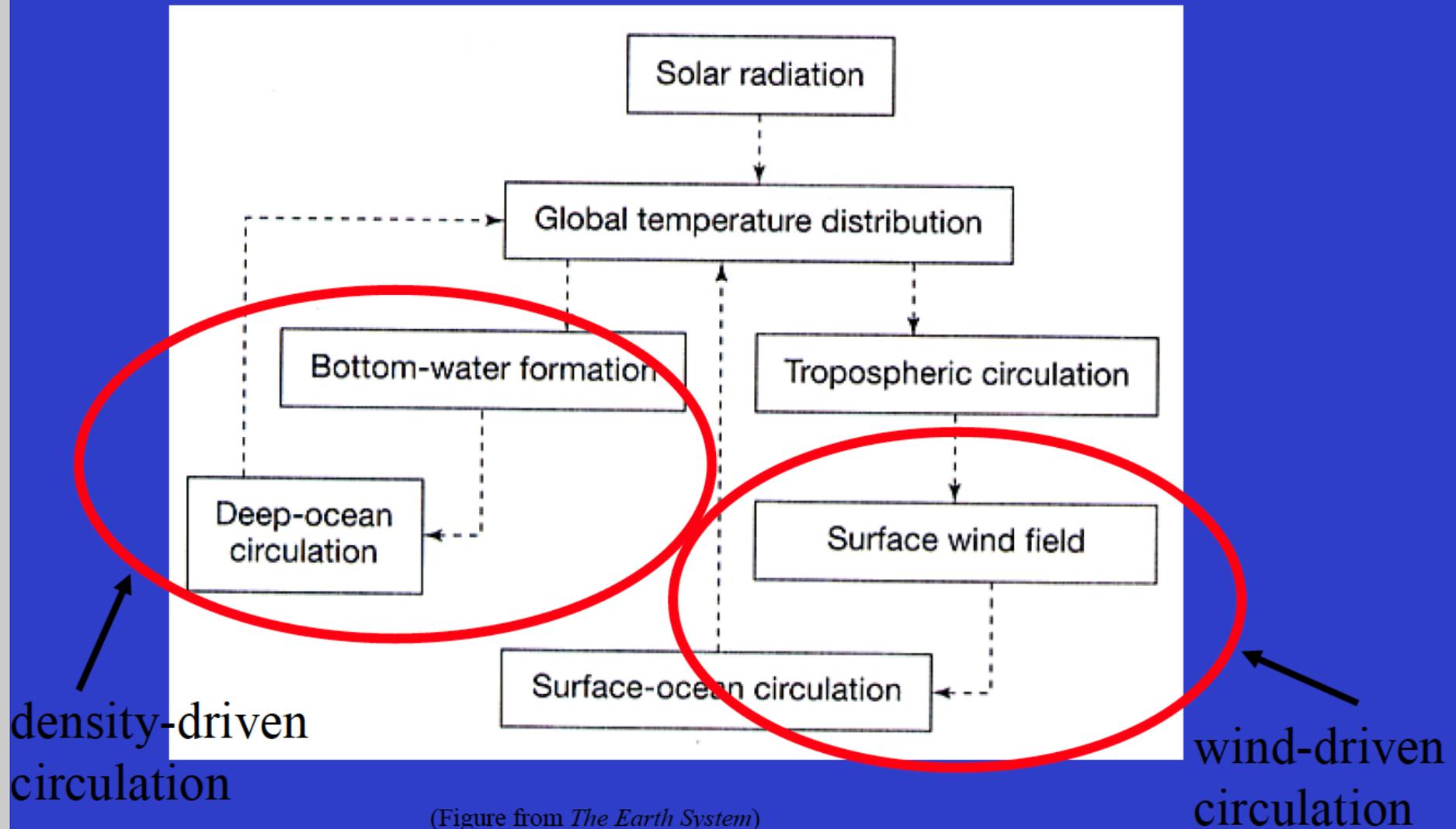
- Centro dos Giros Subtropicais deslocado para OESTE devido à influência da rotação da Terra;
- Como consequência as CCOeste são intensificadas:
 - Mais velozes;
 - Mais estreitas
 - Mais profundas
 - Mais quentes

Correntes de Contorno Leste

- Lado oriental das bacias oceânicas (com propriedades opostas as CCOs):
 - Frias
 - Mais lentas
 - Mais rasas
 - Mais largas



Two Circulation Systems

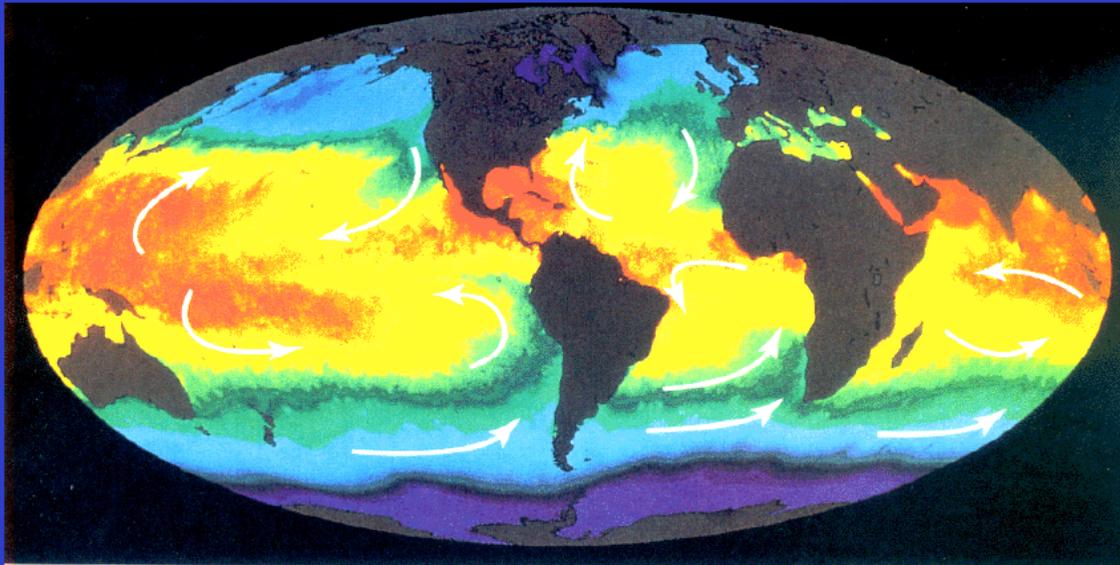


(Figure from *The Earth System*)



2a aula

Six Great Current Circuits in the World Ocean



□ 5 of them are geostrophic gyres:

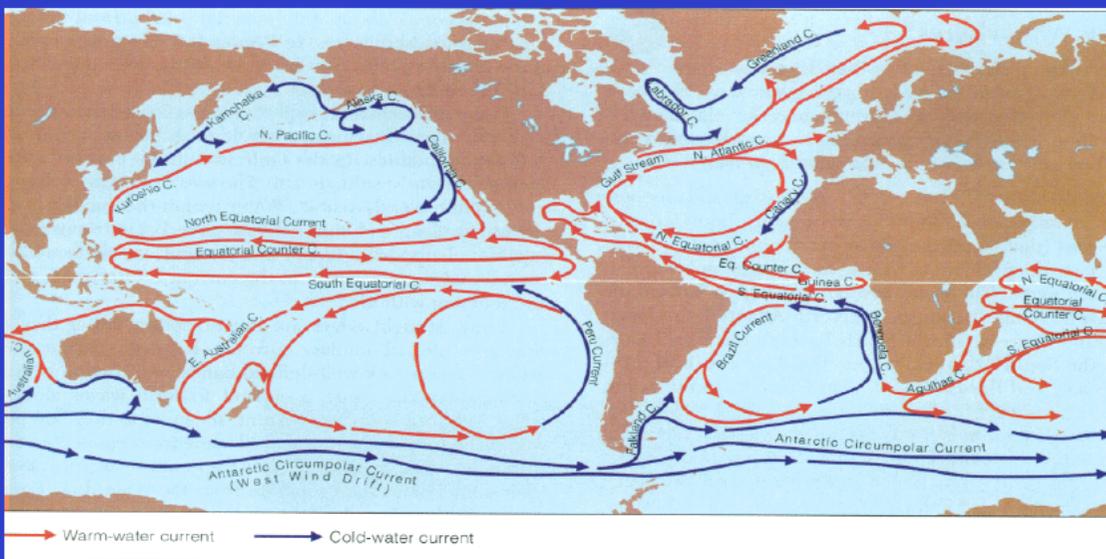
North Pacific Gyre

South Pacific Gyre

North Atlantic Gyre

South Atlantic Gyre

Indian Ocean Gyre



□ The 6th and the largest current:

Antarctic Circumpolar Current

(also called West Wind Drift)

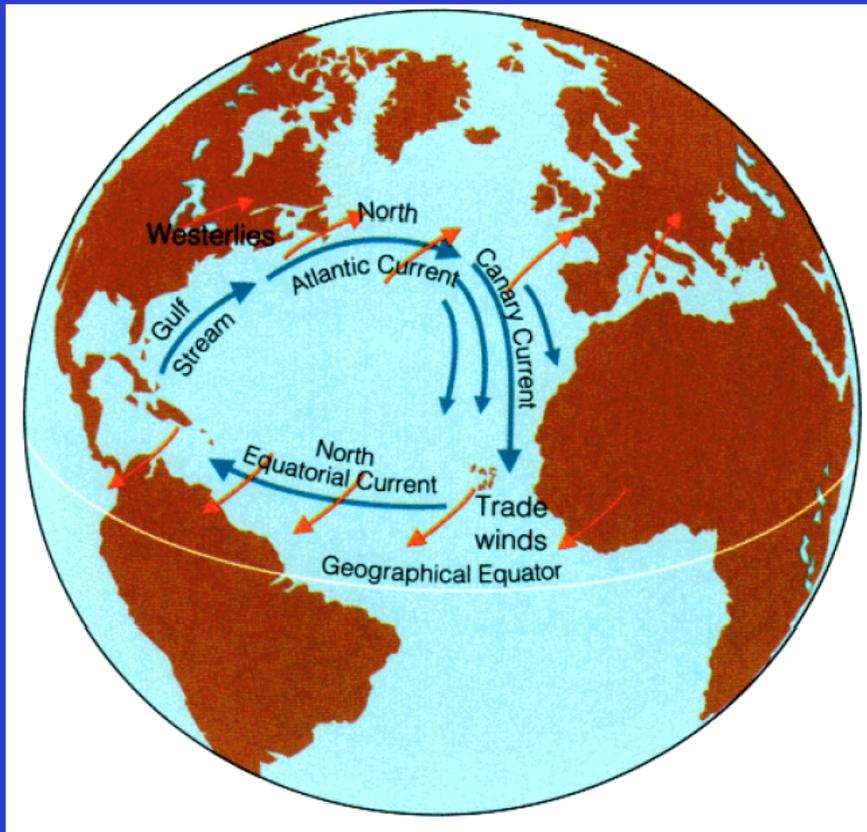
(Figure from *Oceanography* by Tom Garrison)



ESS228
Prof. Jin-Yi Yu

Characteristics of the Gyres

(Figure from *Oceanography* by Tom Garrison)



Volume transport unit:

1 sv = 1 Sverdrup = 1 million m^3/sec

(the Amazon river has a transport of ~ 0.17 Sv)

- ❑ Currents are in geostrophic balance
- ❑ Each gyre includes 4 current components:
 - two boundary currents: western and eastern
 - two transverse currents: eastward and westward

Western boundary current (jet stream of ocean)

the fast, deep, and narrow current moves warm water polarward (transport ~ 50 Sv or greater)

Eastern boundary current

the slow, shallow, and broad current moves cold water equatorward (transport $\sim 10-15$ Sv)

Trade wind-driven current

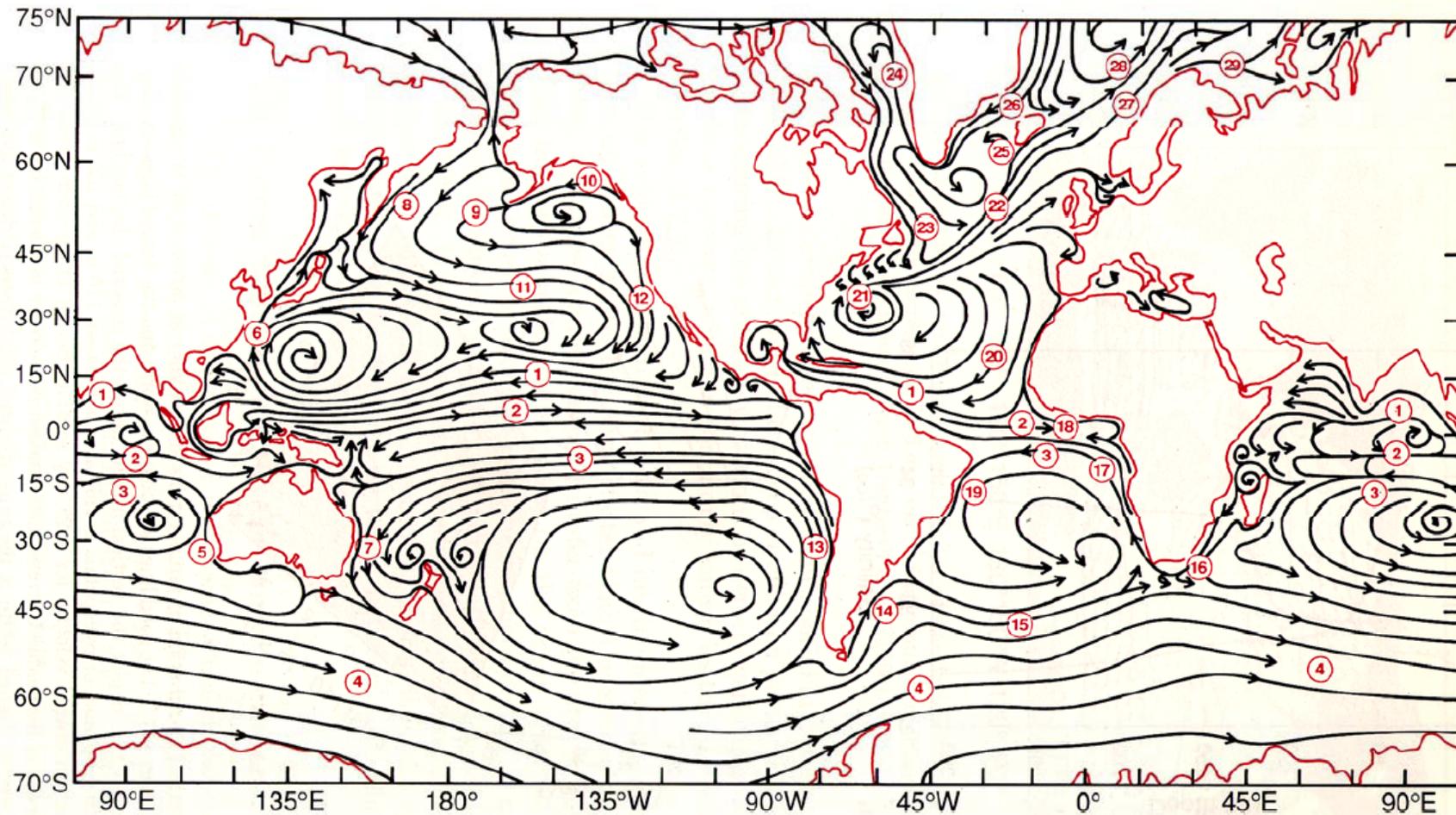
the moderately shallow and broad westward current (transport ~ 30 Sv)

Westerly-driven current

the wider and slower (than the trade wind-driven current) eastward current

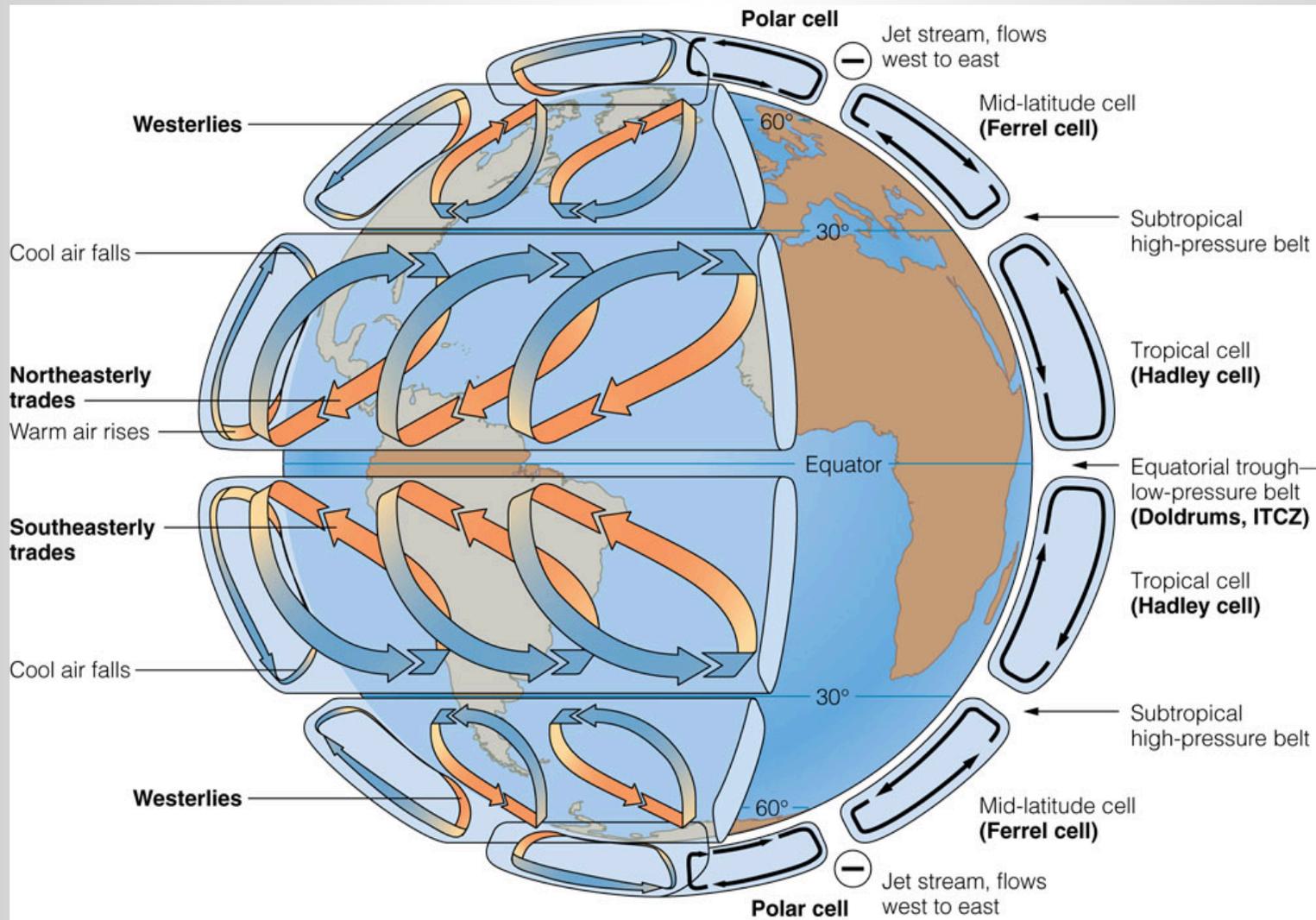


Global Surface Currents



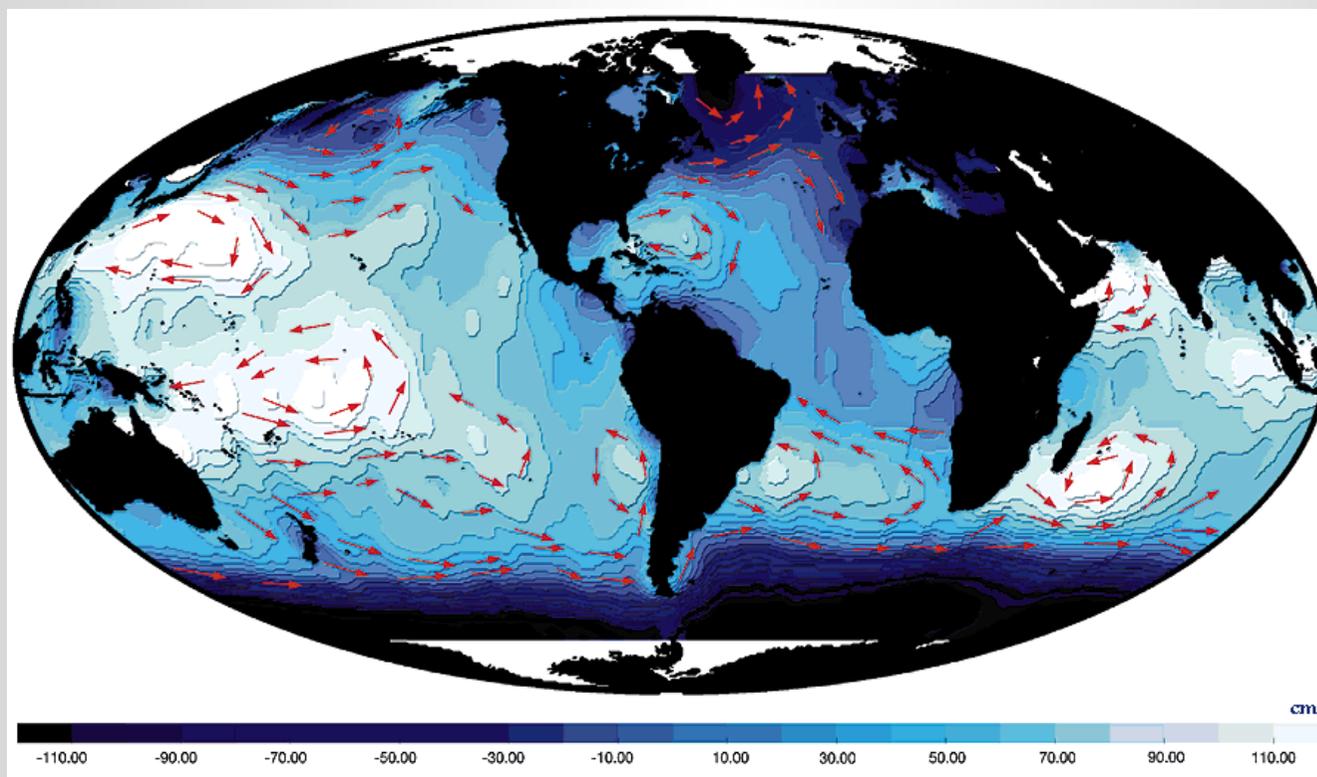
- | | | | | | |
|-----------------------------|---------------------------|---------------------------|---------------------|---------------------------|---------------------------|
| 1 North Equatorial Current | 6 Kuroshio Current | 11 North Pacific Current | 16 Agulhas Current | 21 Gulf Stream | 26 East Greenland Current |
| 2 Equatorial Countercurrent | 7 East Australian Current | 12 California Current | 17 Benguela Current | 22 North Atlantic Current | 27 Norway Current |
| 3 South Equatorial Current | 8 Oyashio Current | 13 Peru Current | 18 Guinea Current | 23 Labrador Current | 28 Spitsbergen Current |
| 4 West Wind Drift | 9 Aleutian Current | 14 Falkland Current | 19 Brazil Current | 24 West Greenland Current | 29 North Cape Current |
| 5 West Australian Current | 10 Alaska Current | 15 South Atlantic Current | 20 Canary Current | 25 Irminger Current | |

Circulação Atmosférica



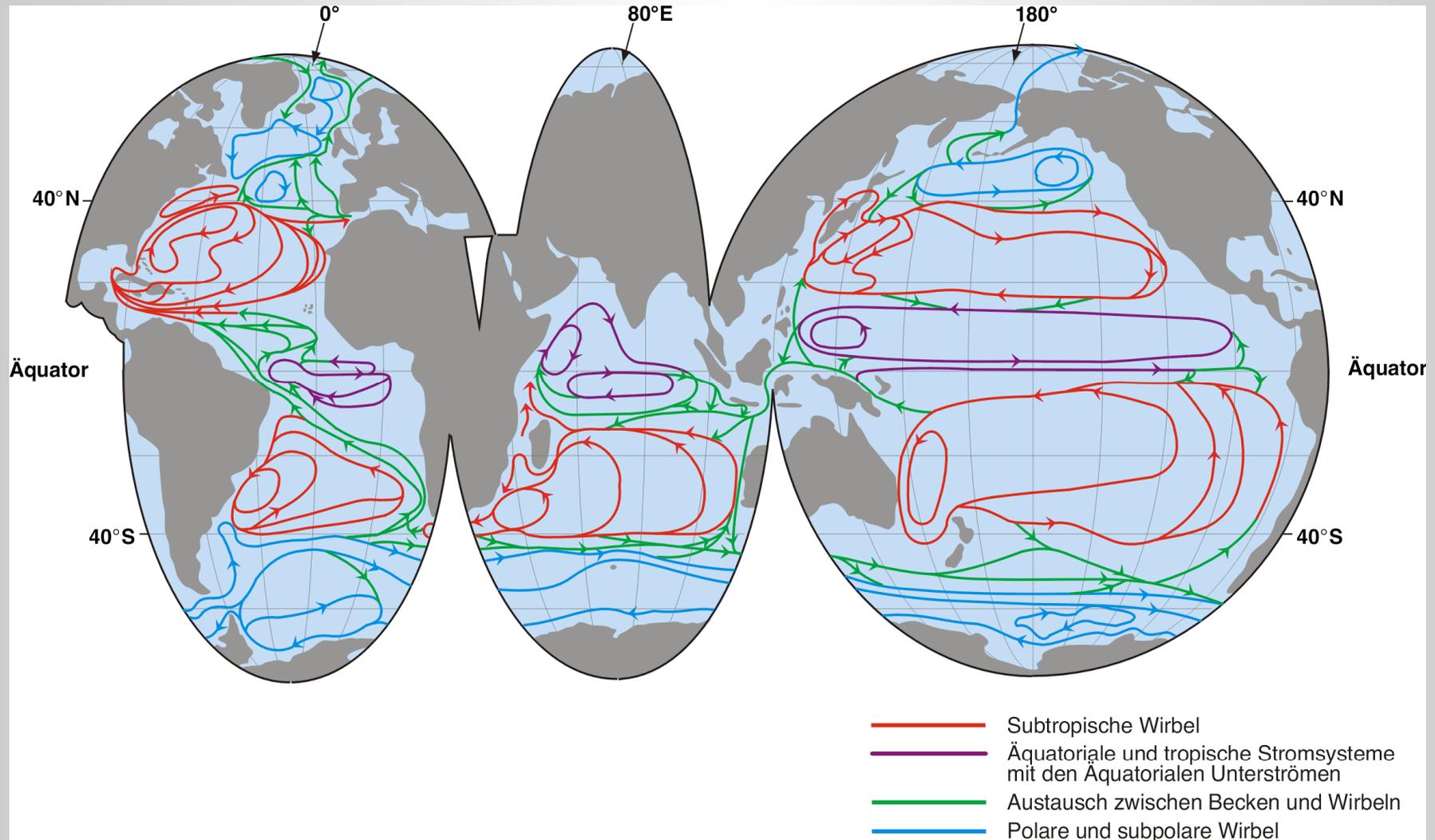
CIRCULAÇÃO DE LARGA ESCALA:

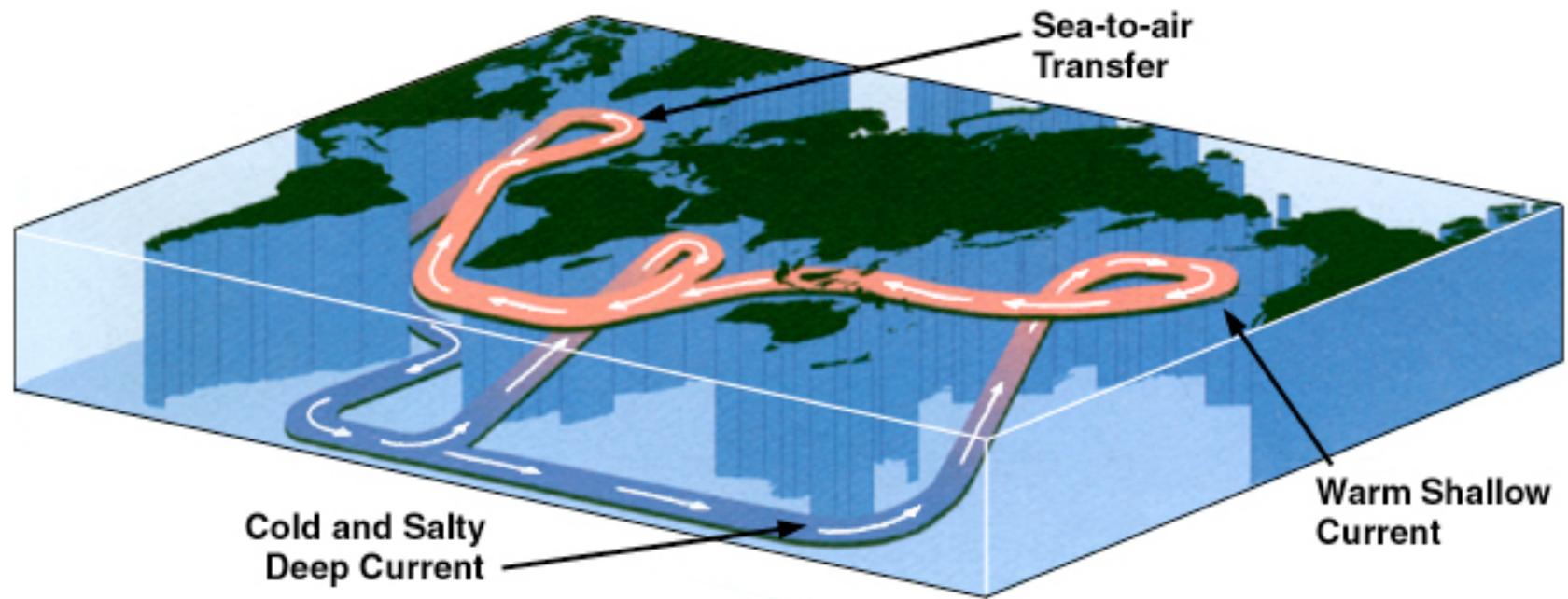
- Dominada pelos Giros Anticiclônicos



Fonte: www.noaa.gov

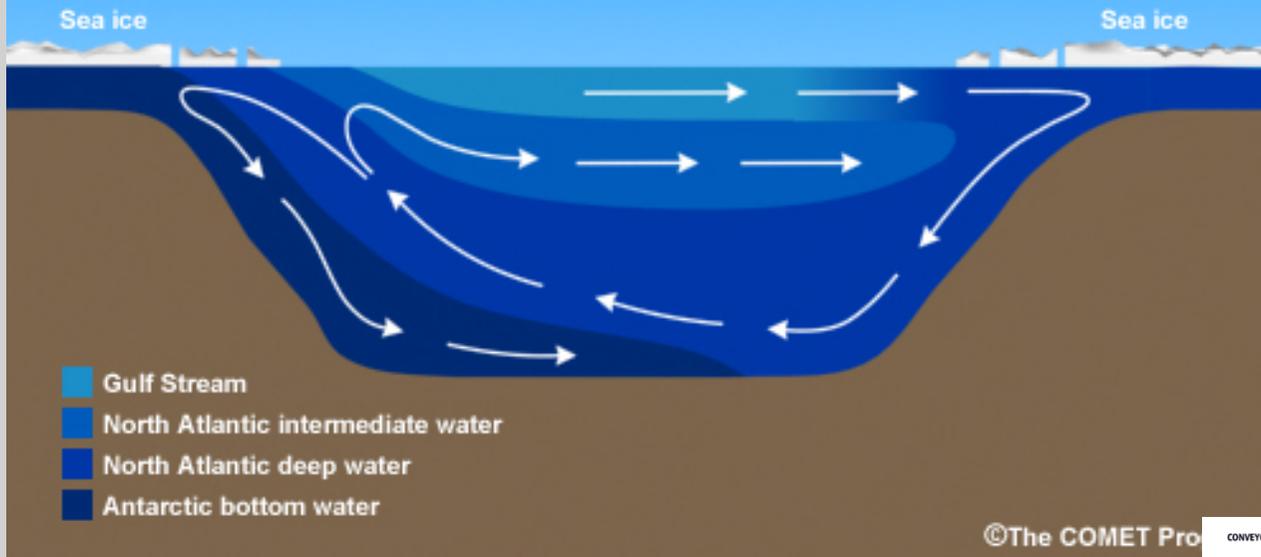
Circulação Superficial



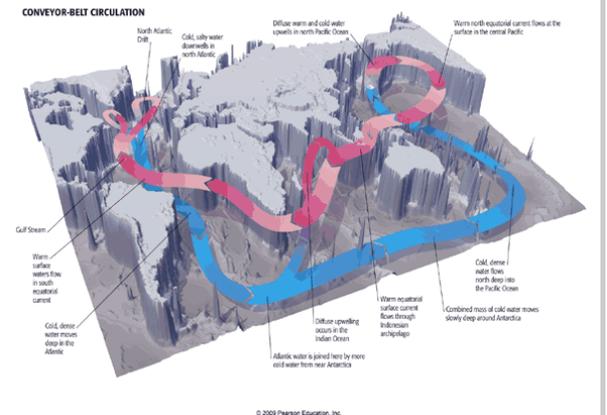


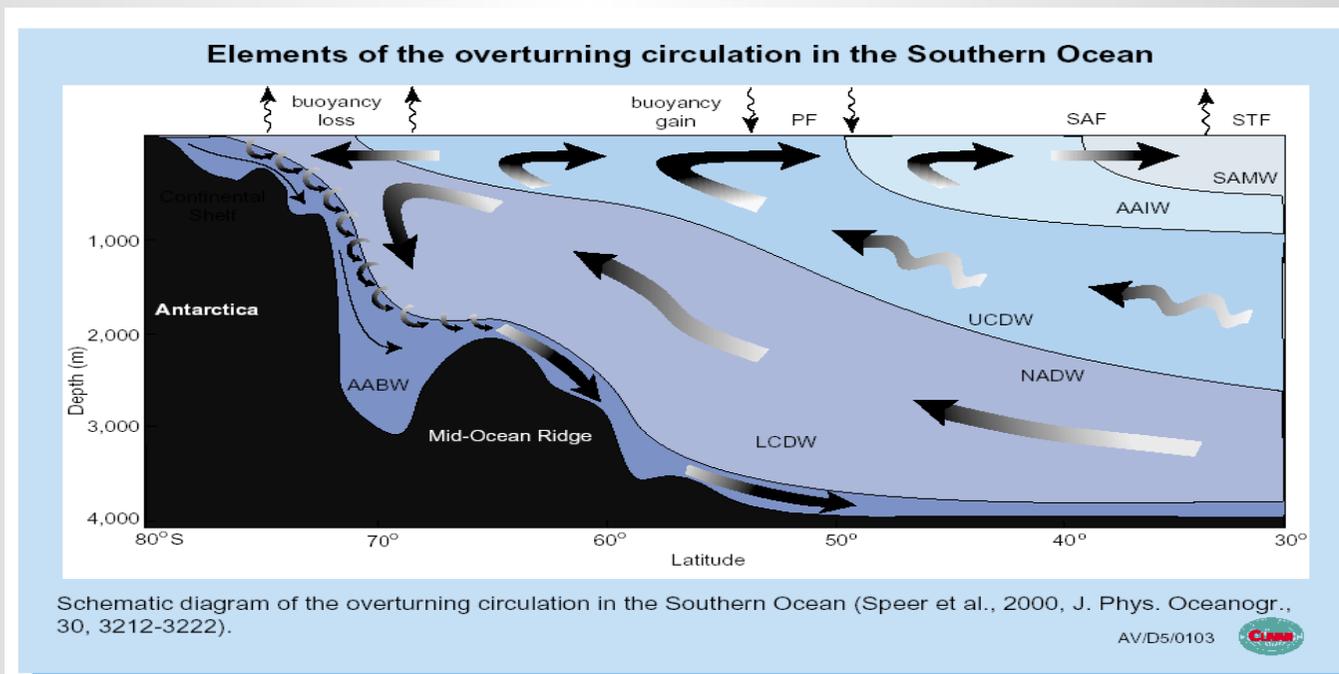
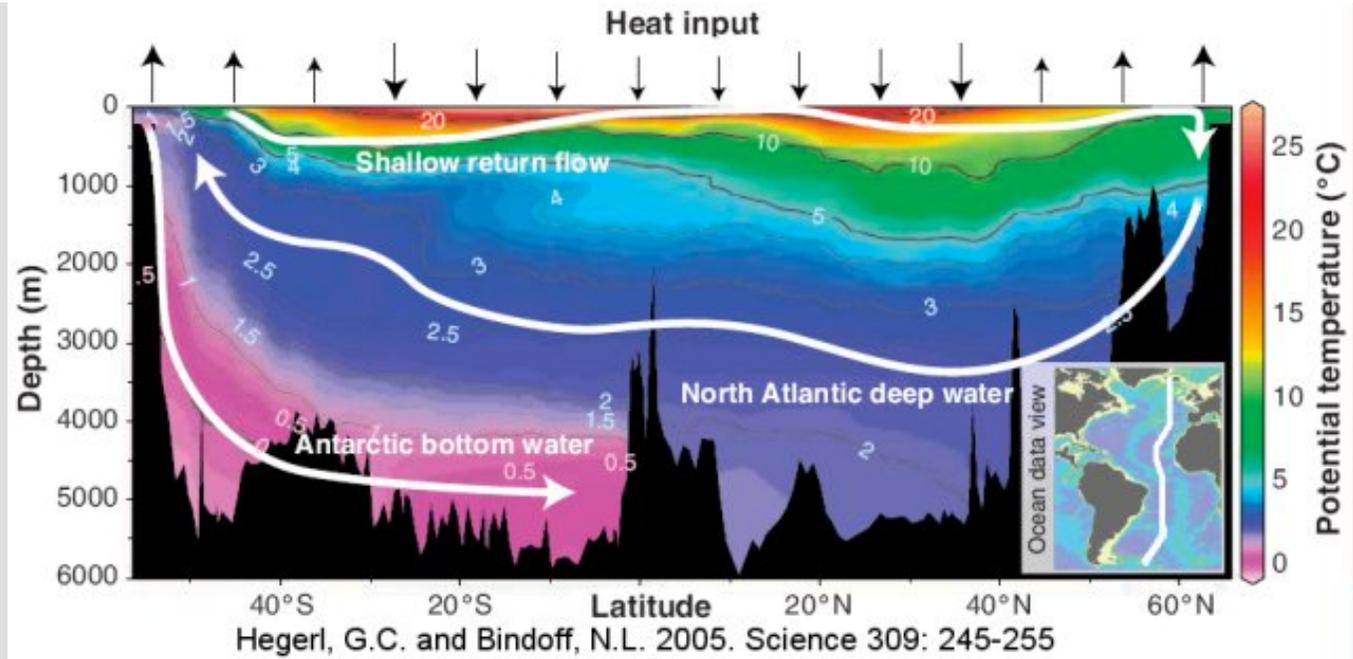
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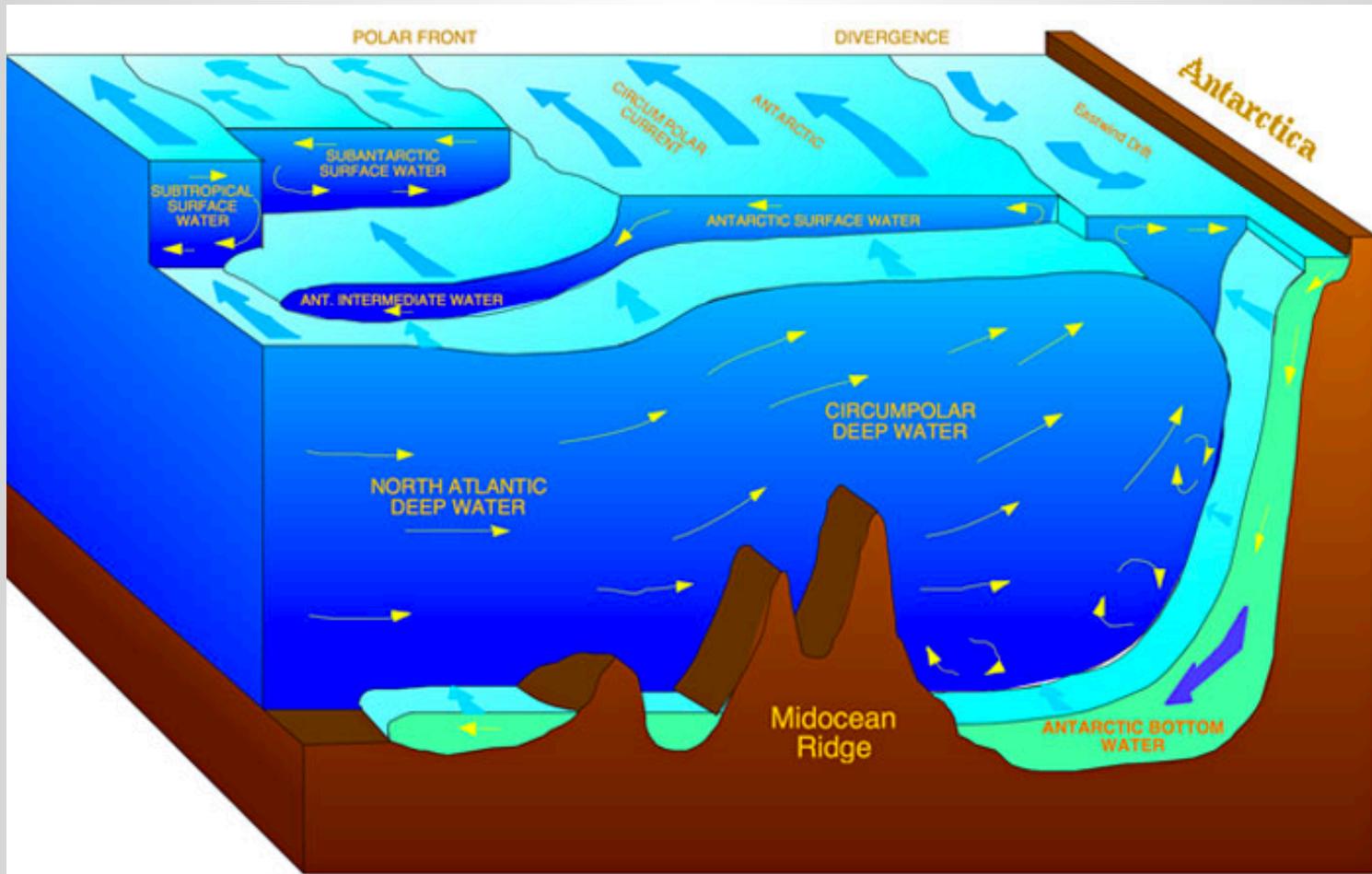
Atlantic Meridional Overturning Circulation

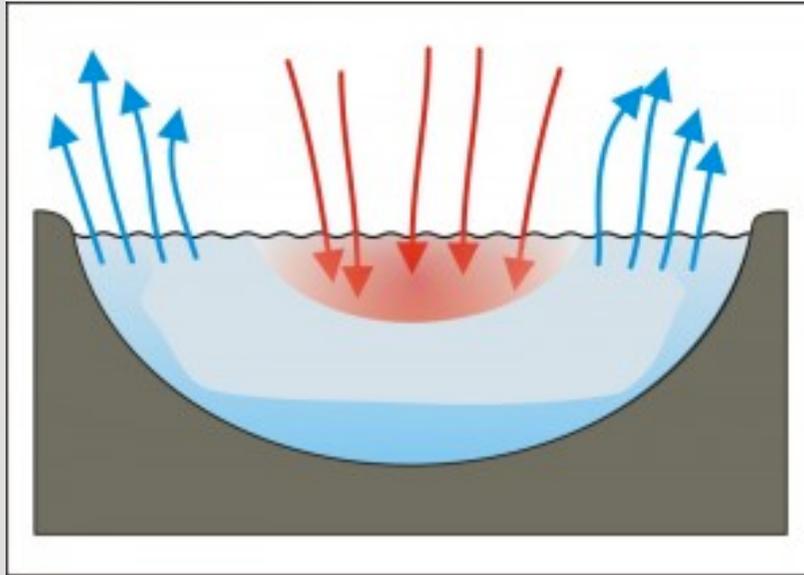


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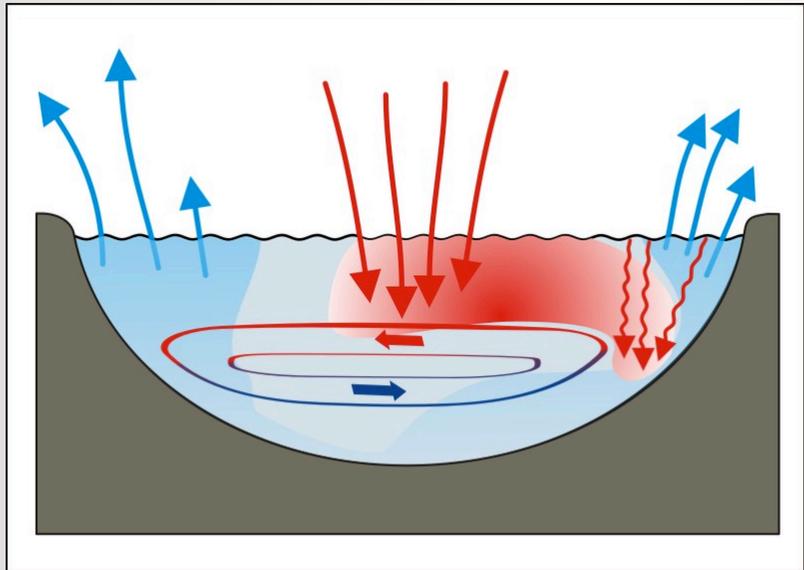






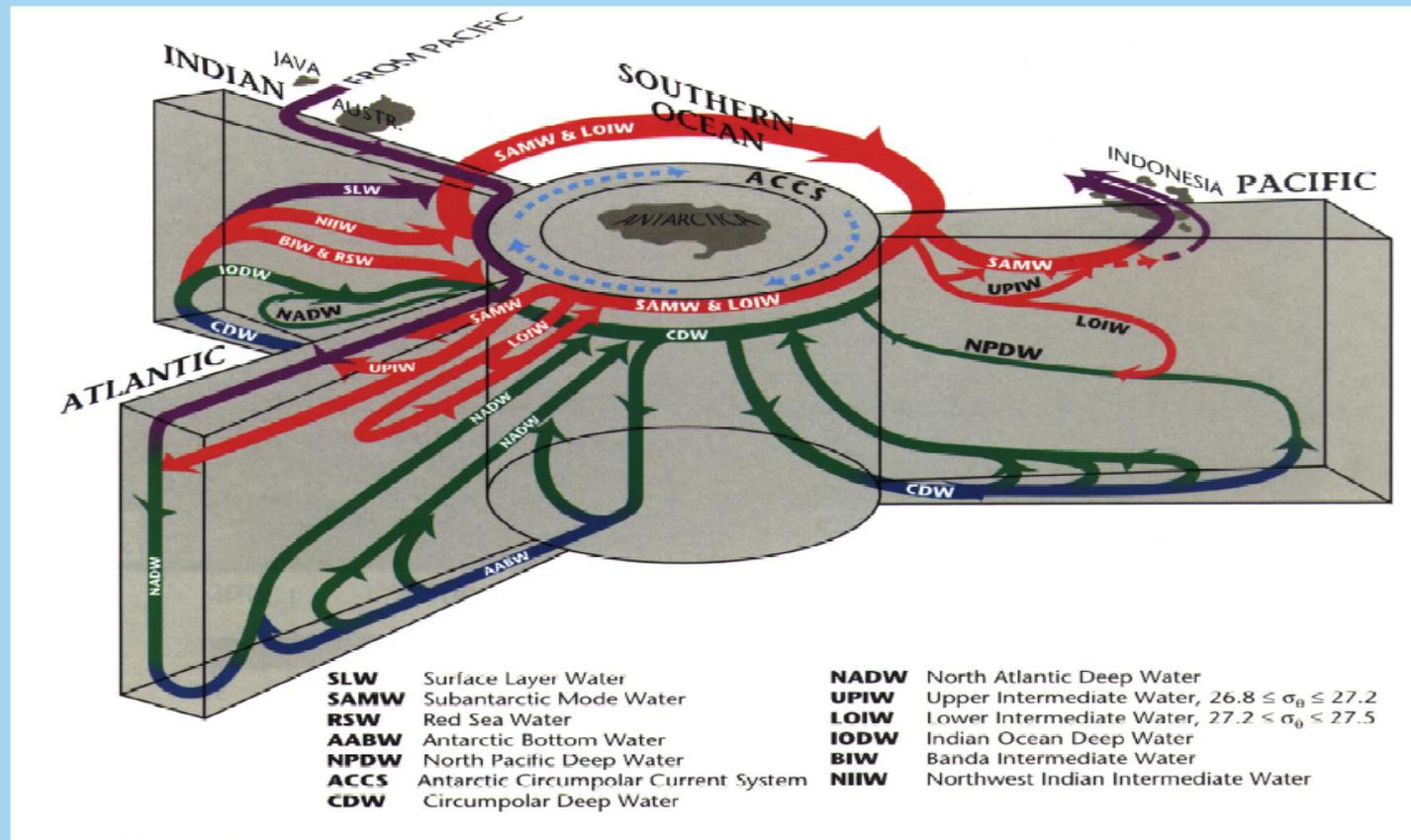


THC – Modelo 1



THC – Modelo 2

Key Role of the Southern Ocean

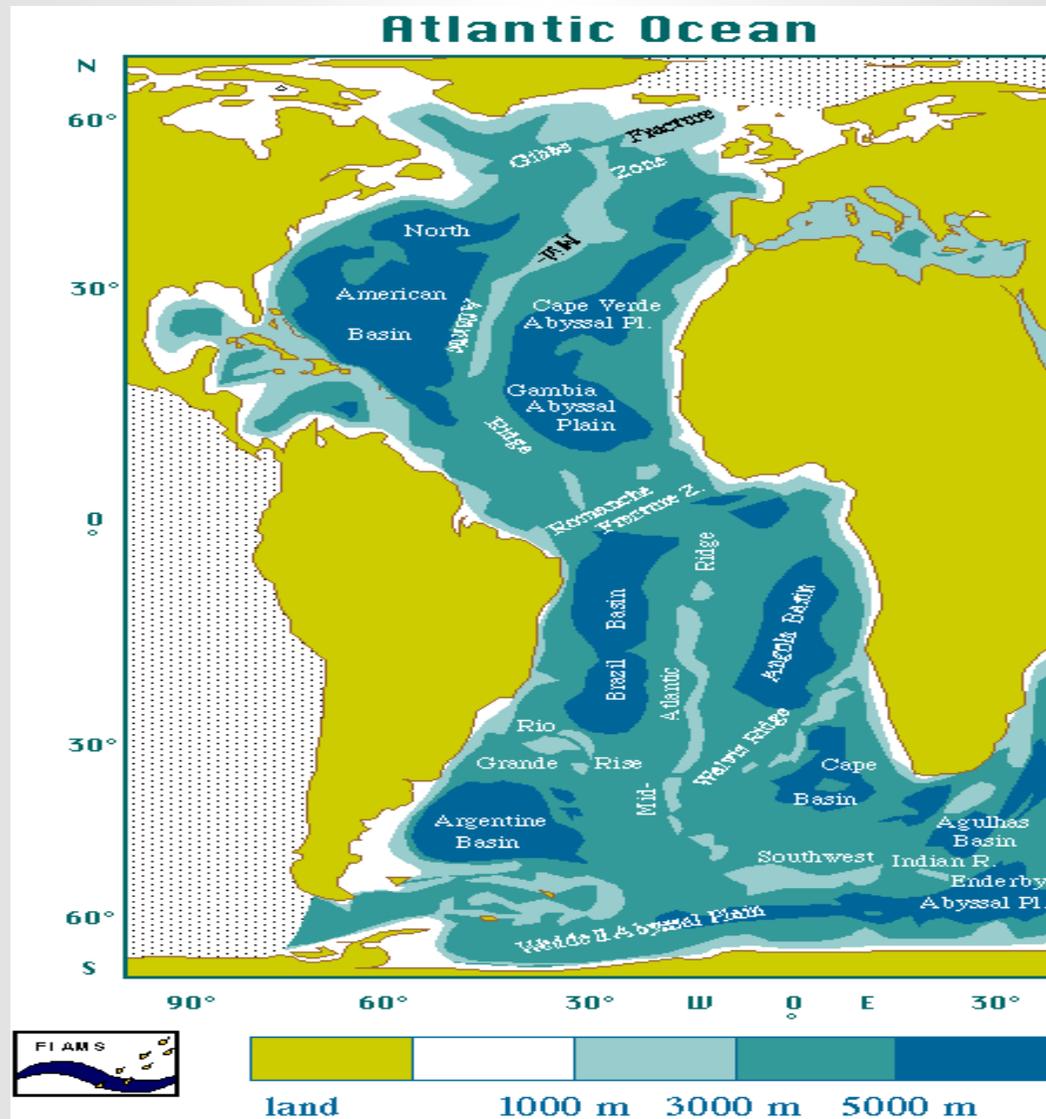


3-D global overturning diagram, from Schmitz (1996)

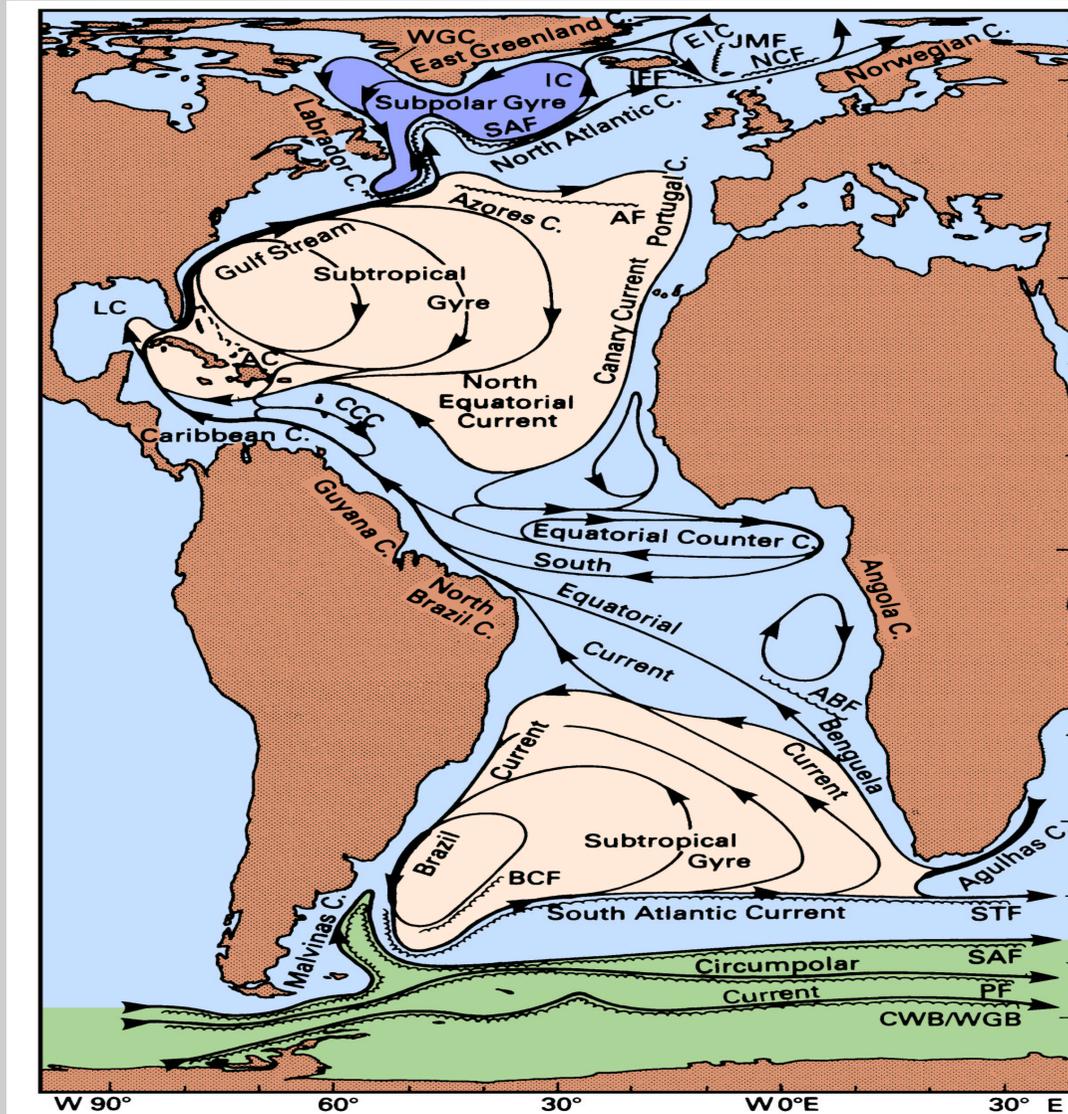
The figure illustrates two of the key roles the Southern Ocean plays in the climate system:

- Water mass transformations in the SO “close” the overturning circulations by converting deep water which upwells at high latitude into lighter intermediate waters and denser bottom waters.
- The Antarctic Circumpolar Current connects the ocean basins, allowing a global overturning circulation to exist, and allowing anomalies to propagate between basins and influence the climate “downstream”.

O Oceano Atlântico



Fonte: Tomczak and Godfrey, 1994



Correntes de superfície do Oceano Atlântico

Abreviações usadas para correntes:

EIC (Leste da Islândia)

IC (Irminger)

Oeste da Groelândia (WGC)

Loop/Giro (LC)

Antilhas (AC)

Contra corrente do Caribe (CCC)

Abreviações usadas para frentes:

Frente Jan Mayen (JMF)

Frente da Corrente da Noruega (NCF)

Frente da Islândia-Faroe (IFF)

Frente Subártica (SAF)

Frente de Açores (AF)

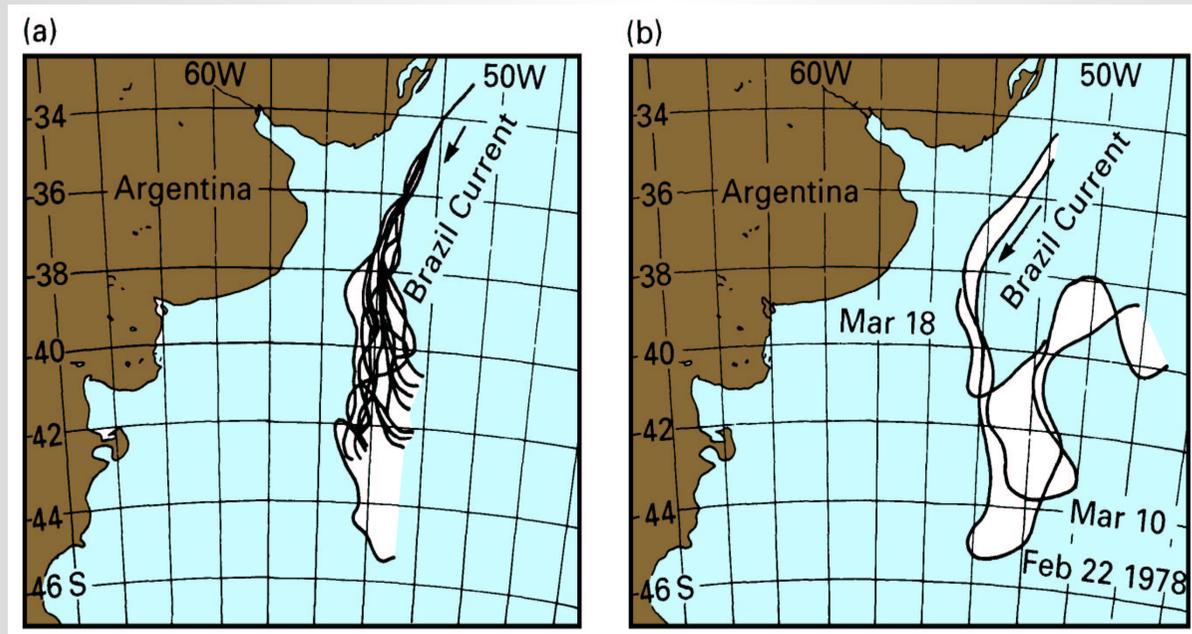
Frente de Angola-Benguela (ABF)

Frente da Corrente do Brasil (BCF)

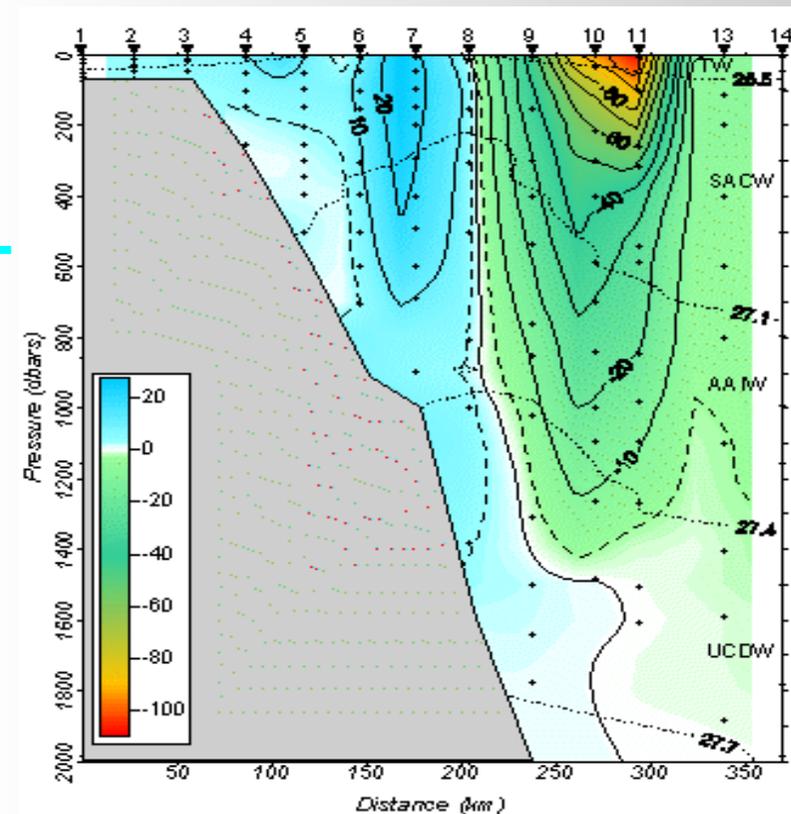
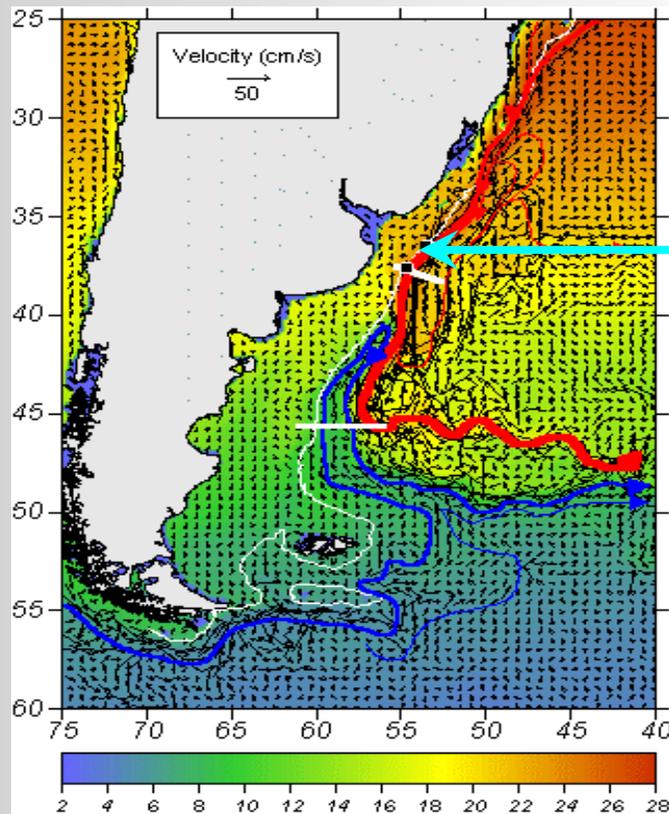
Frente SubTropical (STF)

Frente Polar (PF)

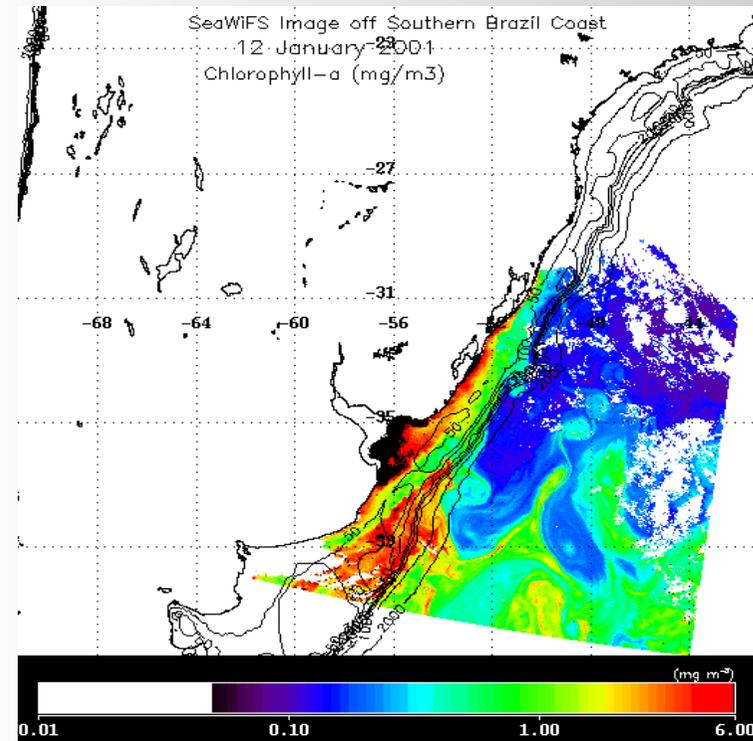
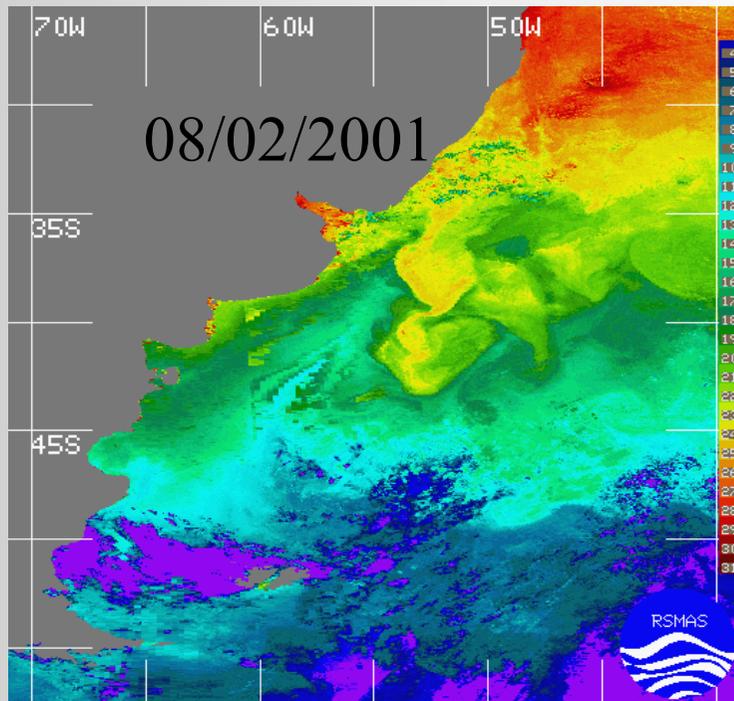
Borda do Giro de Weddell (CWB/WGB)



(a) A separação da corrente do Brasil da costa Sul Americana indicada pelas TSM entre Setembro 1975-Abril 1976; (b) A migração da posição de separação da CB entre fevereiro e março de 1978. Durante este último período dois vórtices foram formados (Legeckis e Gordon, 1982).

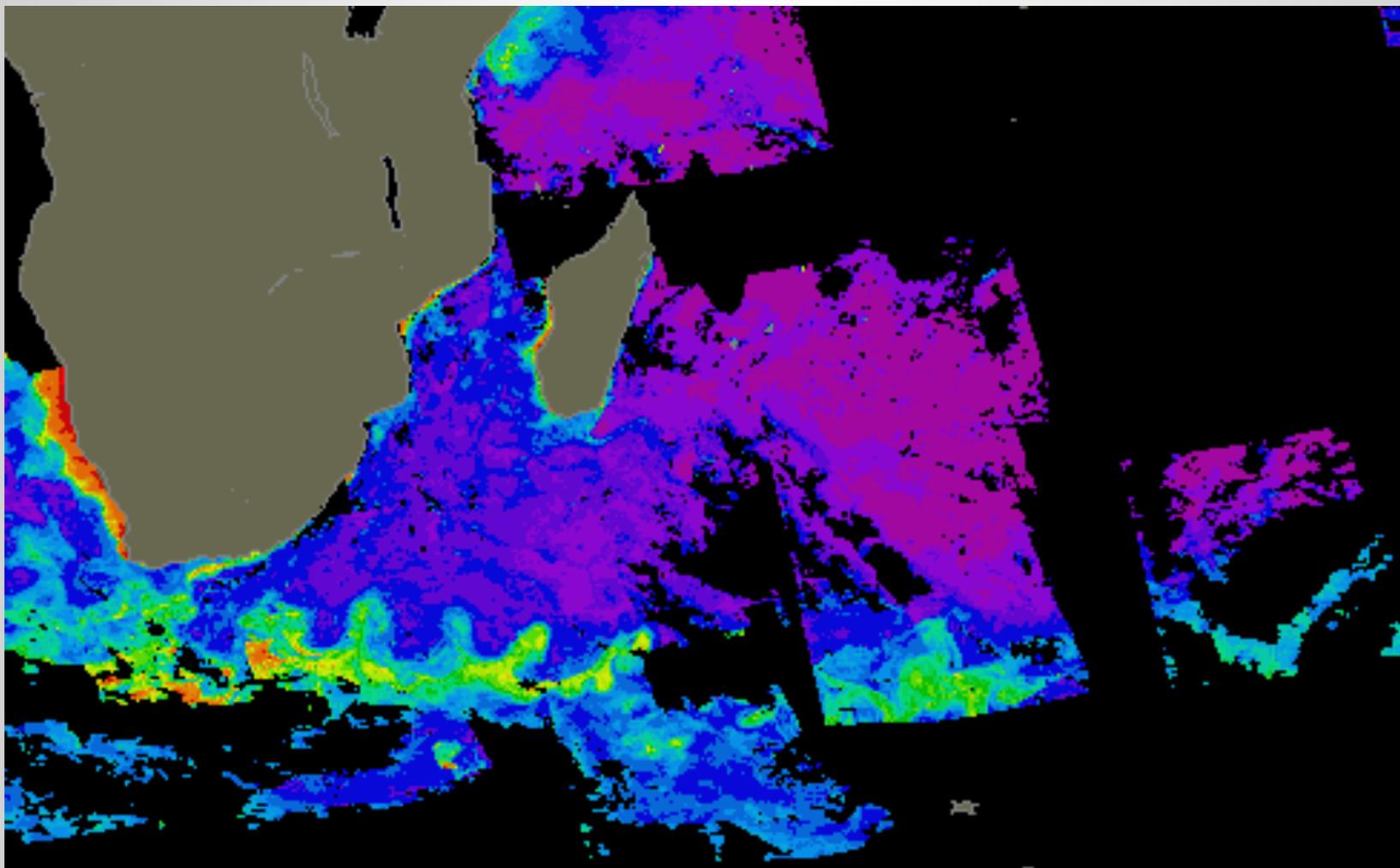


Circulação simulada por modelo numérico na região SW do Atlântico Sul (esquerda) e uma seção hidrográfica mostrando a interface CB/CM (direita).

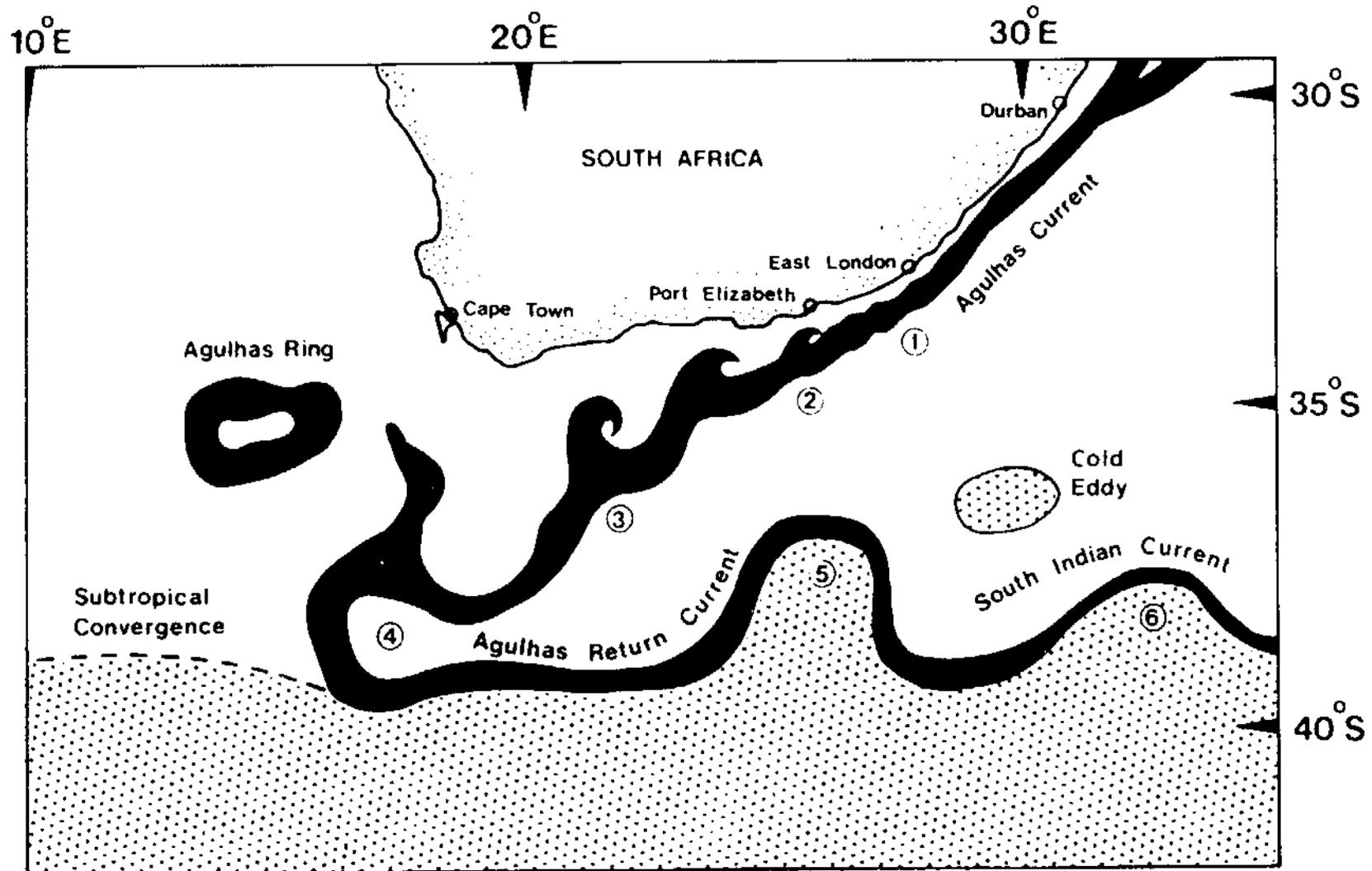


Variabilidade de mesoescala na confluência Brasil/Malvinas observada a partir de dados de TSM (AVHRR/NOAA, a esquerda) e de cor do oceano ([] clorofila-a pelo SeaWIFS, a direita).

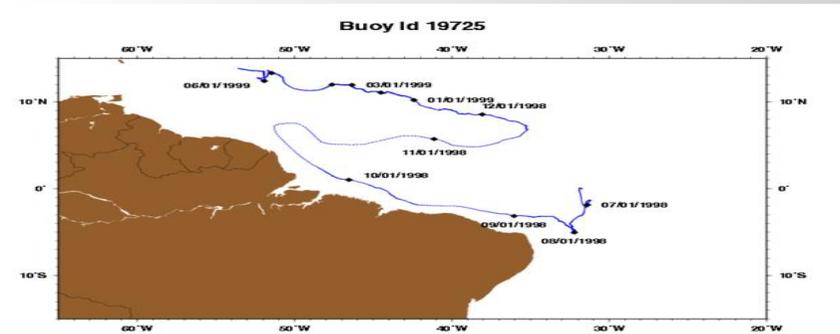
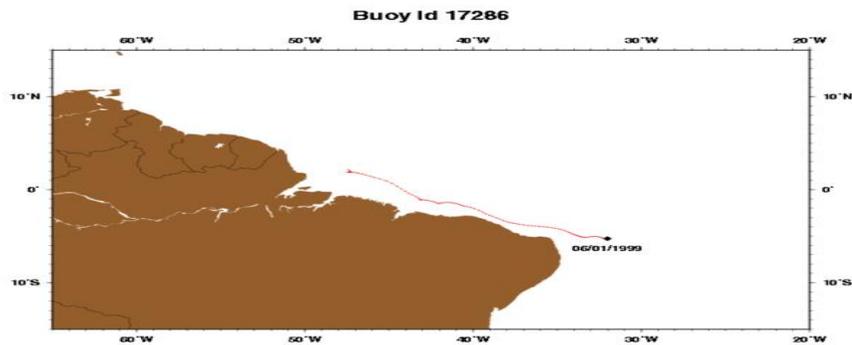
Fonte: Garcia, et al 2004



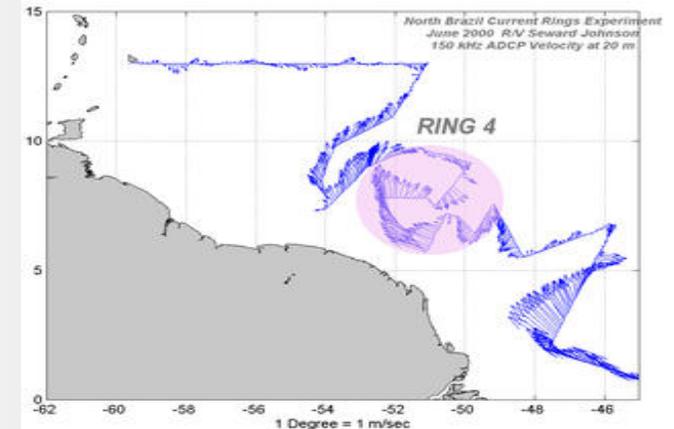
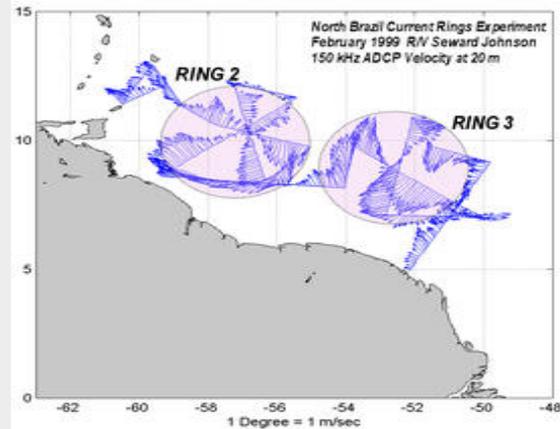
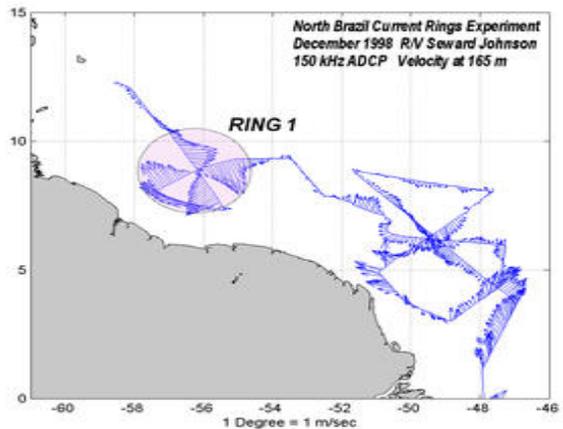
Mosaico de imagens do CZCS (Coastal Zone Colour Scanner) de 1983. Maiores concentrações de clorofila podem ser observados em tons vermelhos. Note a ressurgência na costa da Namíbia/Angola.



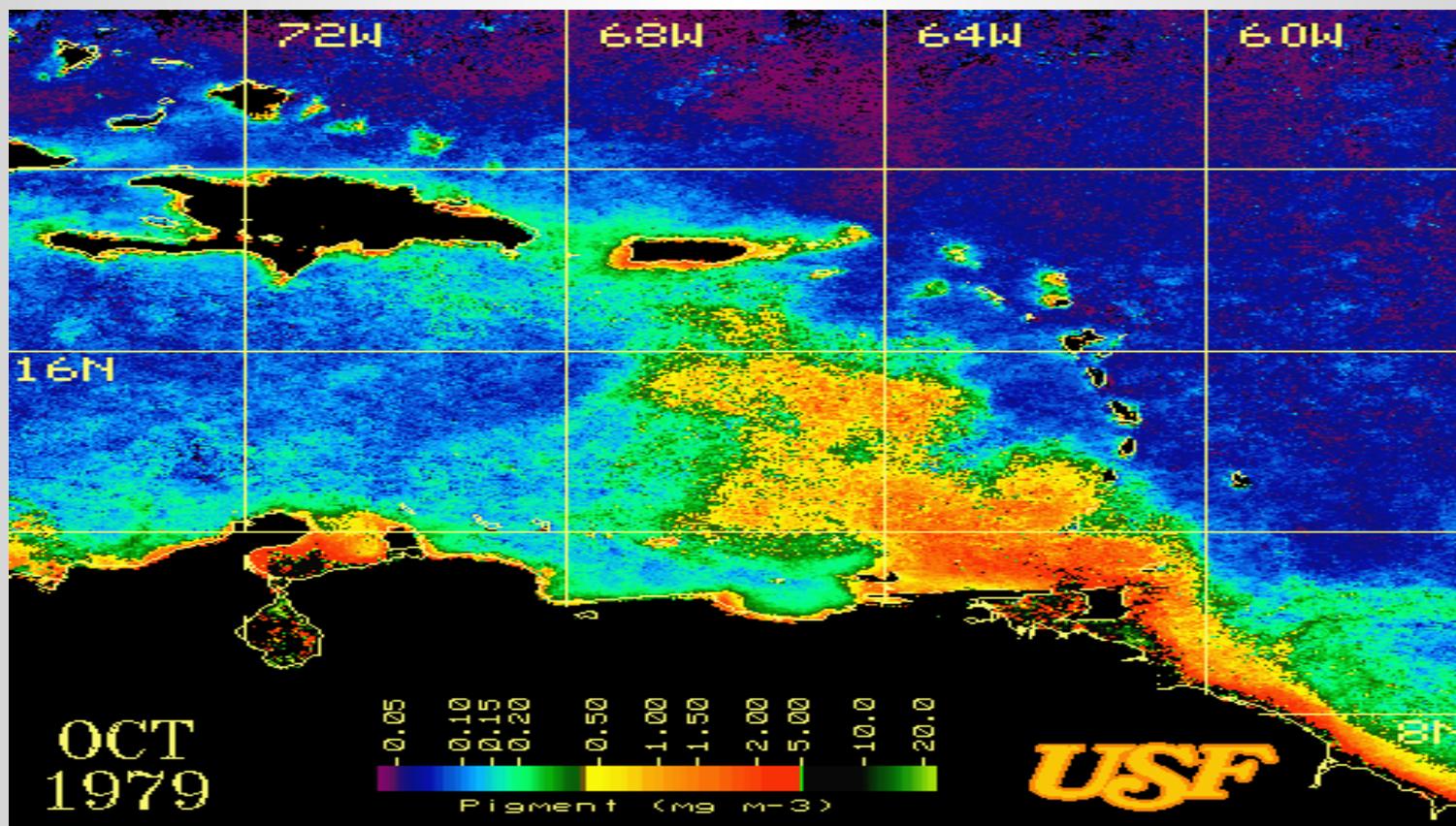
Fonte: Tomczak and Godfrey, 1994



Buoys ID 17286 (red) and 19725 (blue) both move quickly along just offshore of the North Brazil Coast. Buoy 19725 also exhibits the well-known retroflexion of the North Brazil Current during October of 1998. It is then advected by the North Equatorial Current into the source region for the Antilles Current.

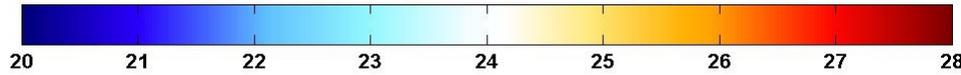
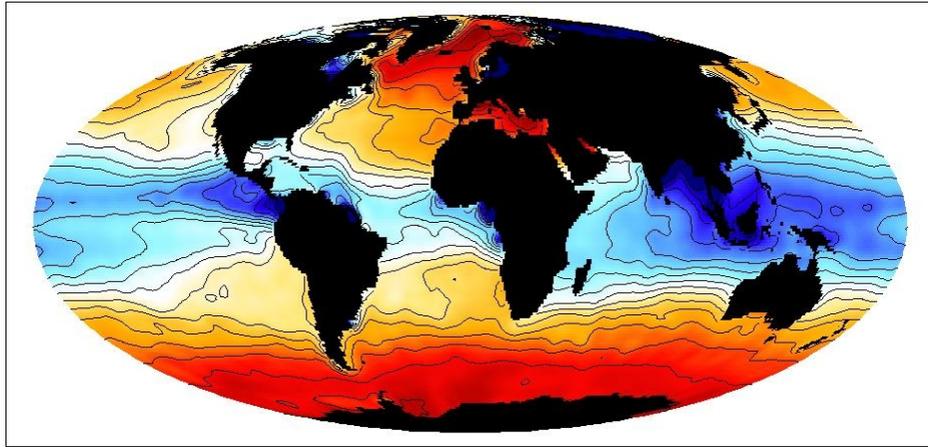


Maps of the SADCPC current vectors obtained for each of the four rings surveyed during three cruises: NBC1: December 1988, NBC2: February 1999, NBC4: June 2000.



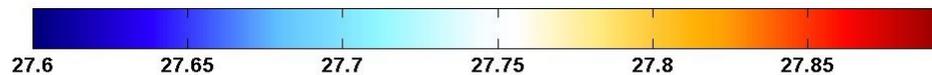
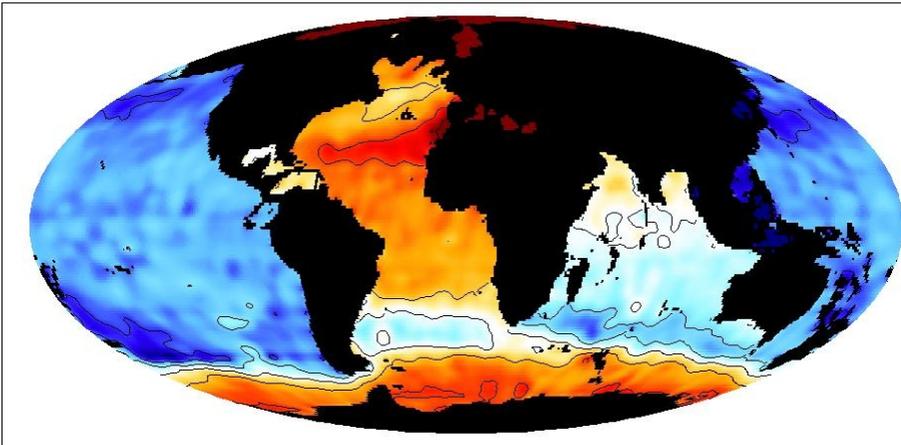
CZCS composite image of the eastern Caribbean Sea for October 1979, showing the spatial extent of the Orinoco River plume of induced high productivity that occurs during the summer rainy season. (Image courtesy of Dr. Frank Muller-Karger, University of South Florida Remote Sensing Laboratory.)

Levitus surface density

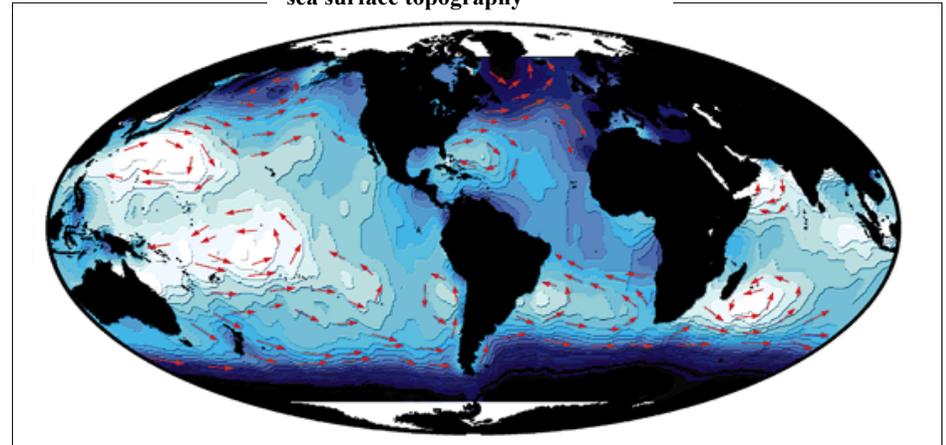


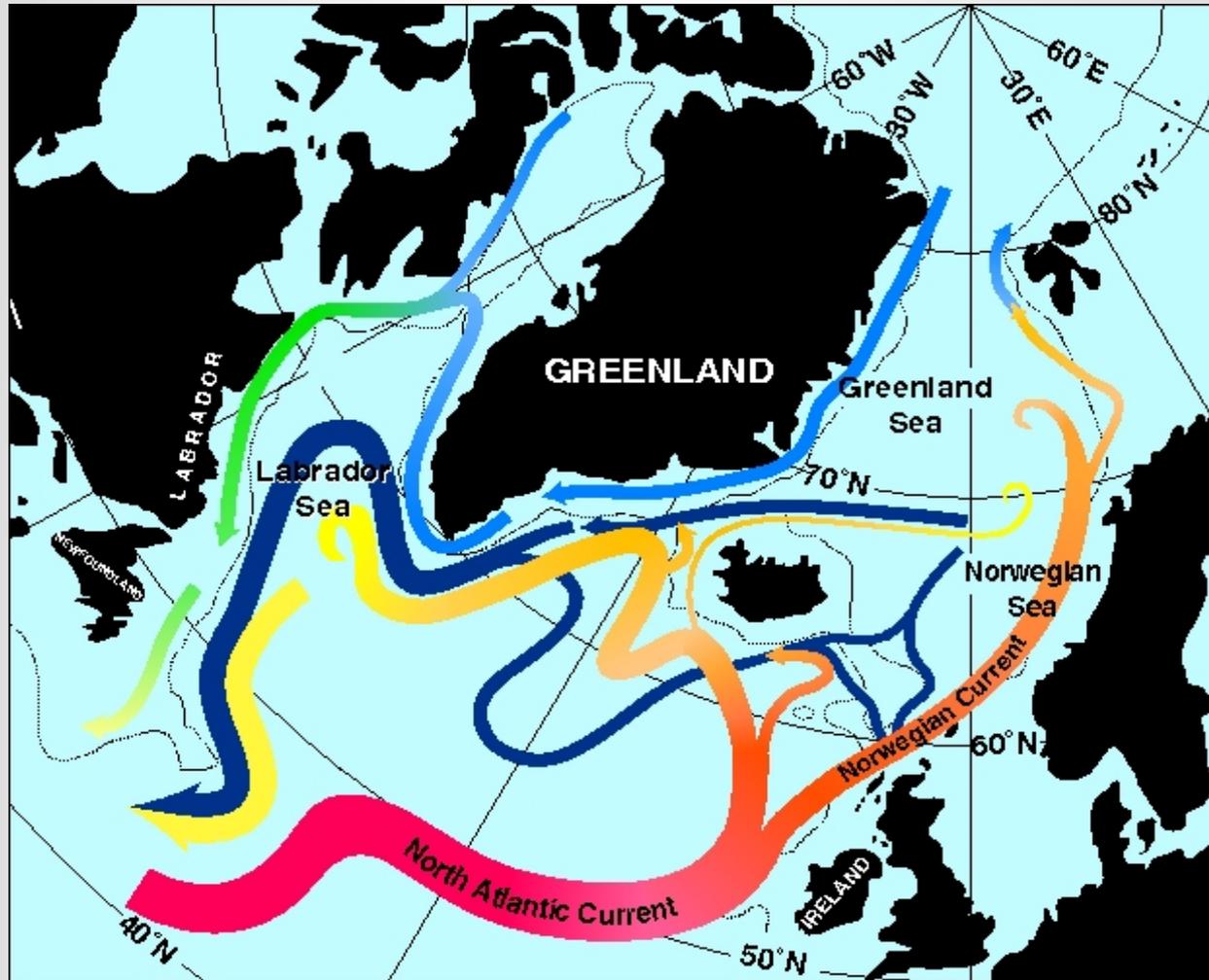
the Atlantic is exceptional !

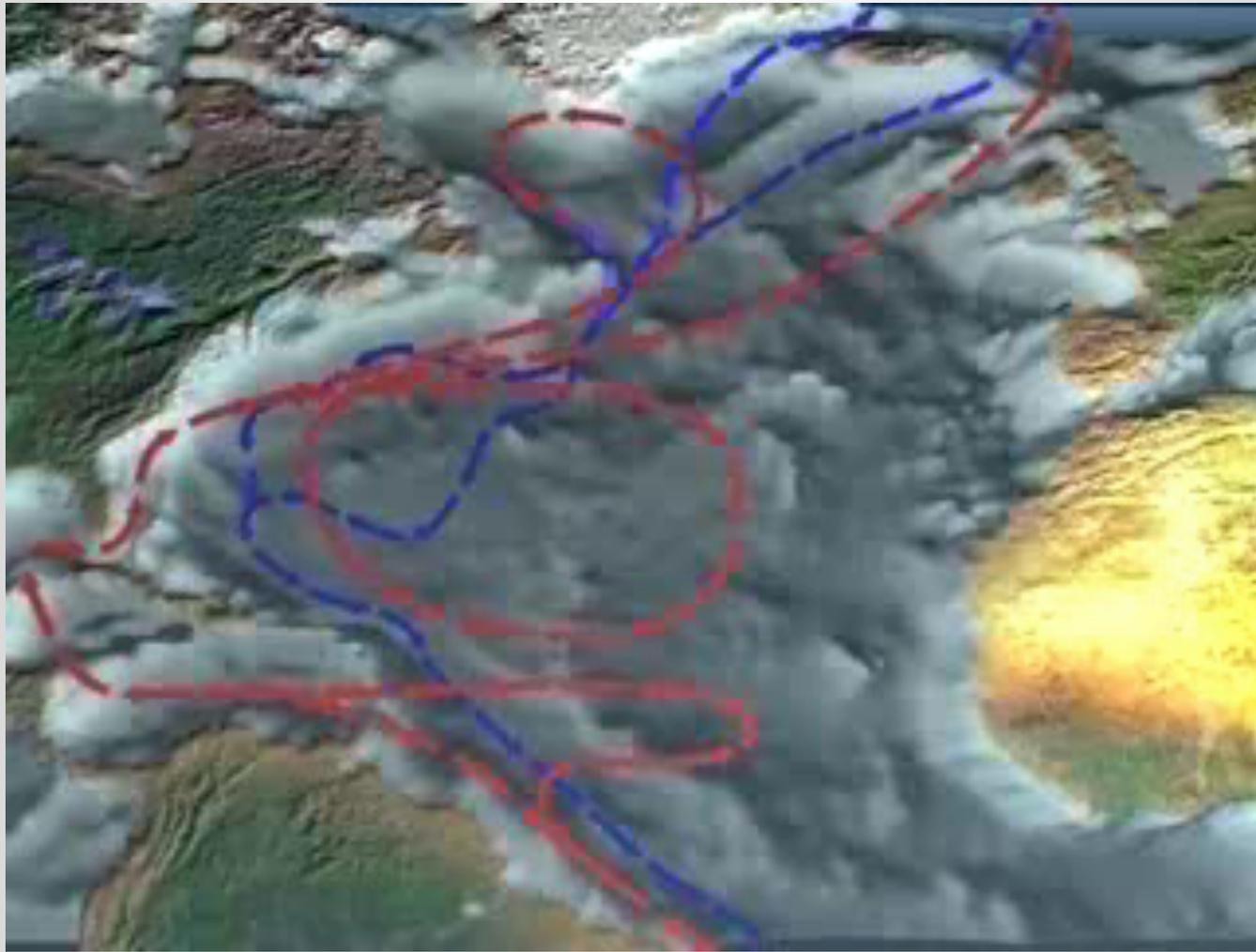
Levitus density 2000 m

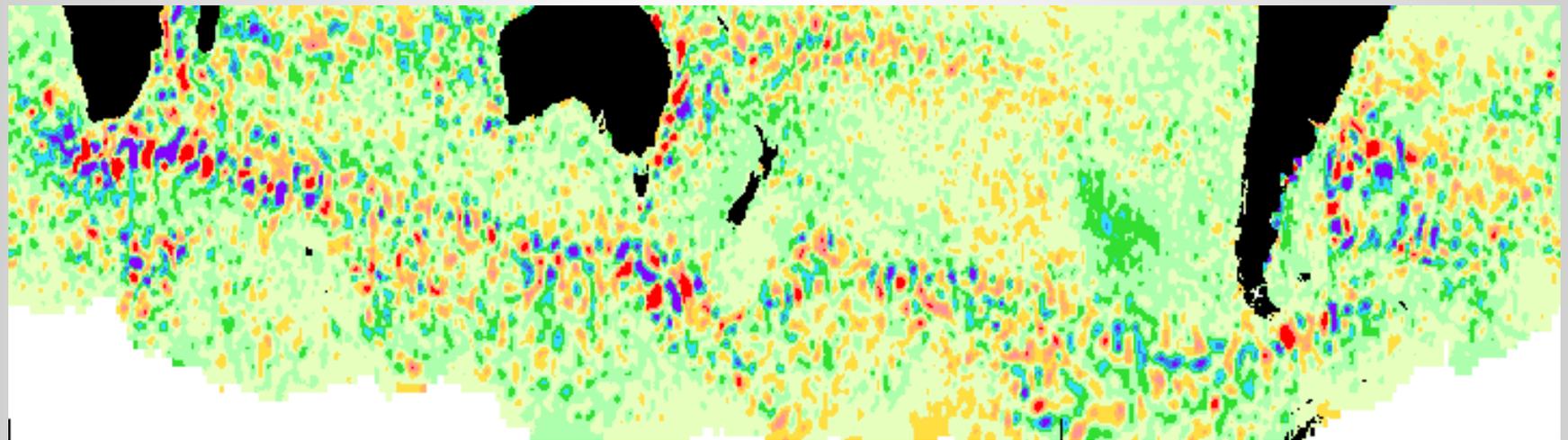


sea surface topography

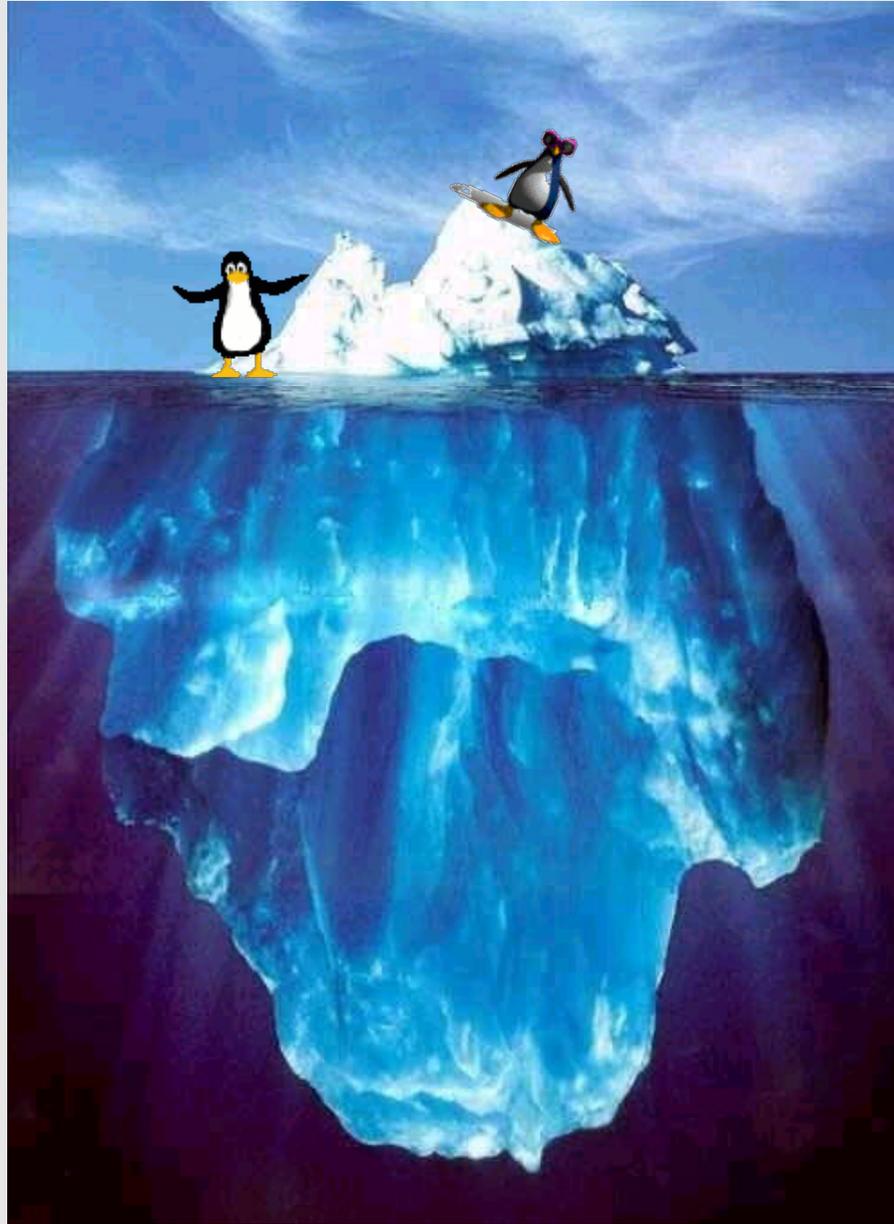








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agora!