Currents and Watermasses

AOS 660

Fall 2013

Professor Galen A. McKinley

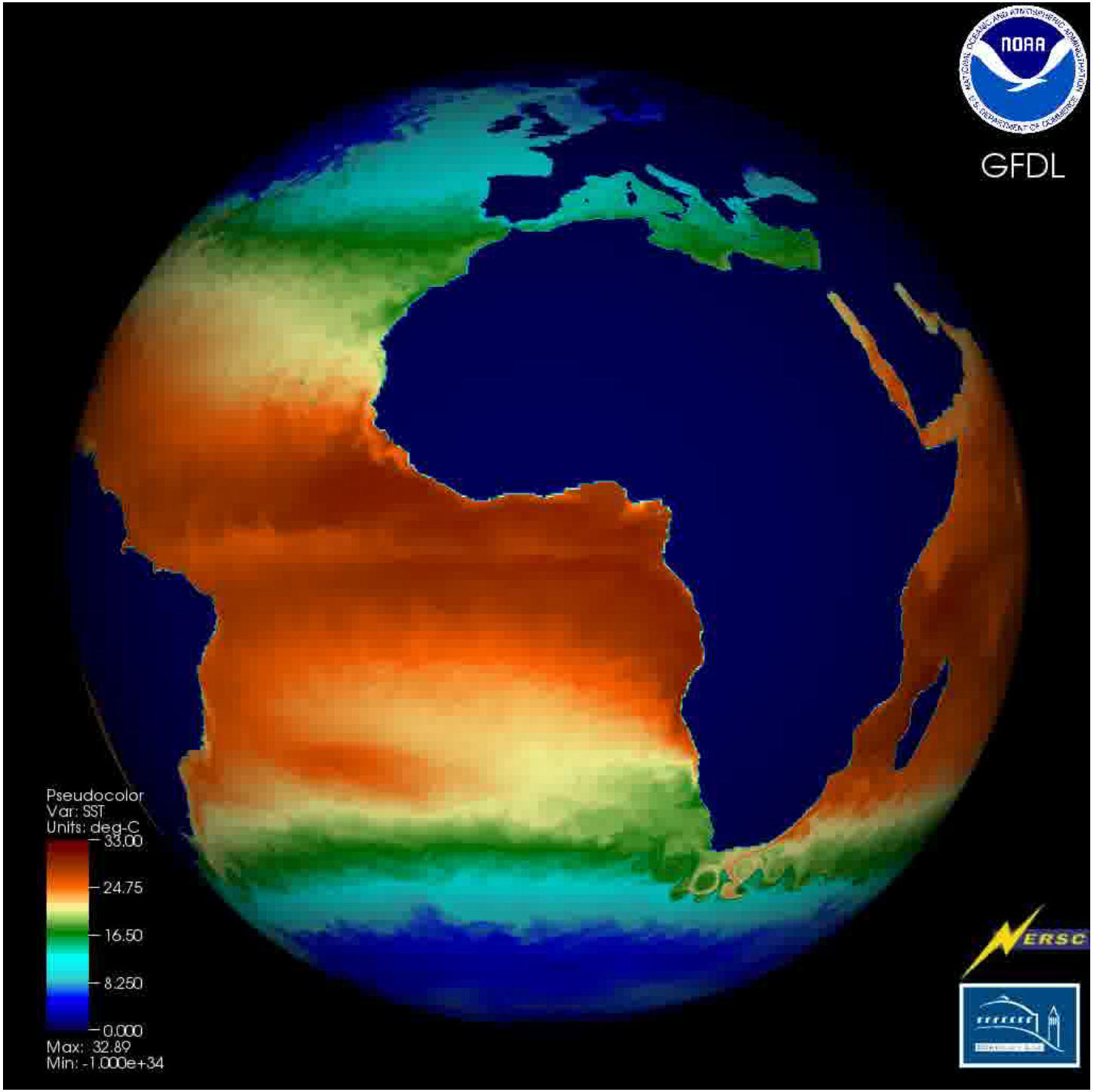
Currents

1 year coupled climate simulation

Ocean: 0.1° to 0.25°

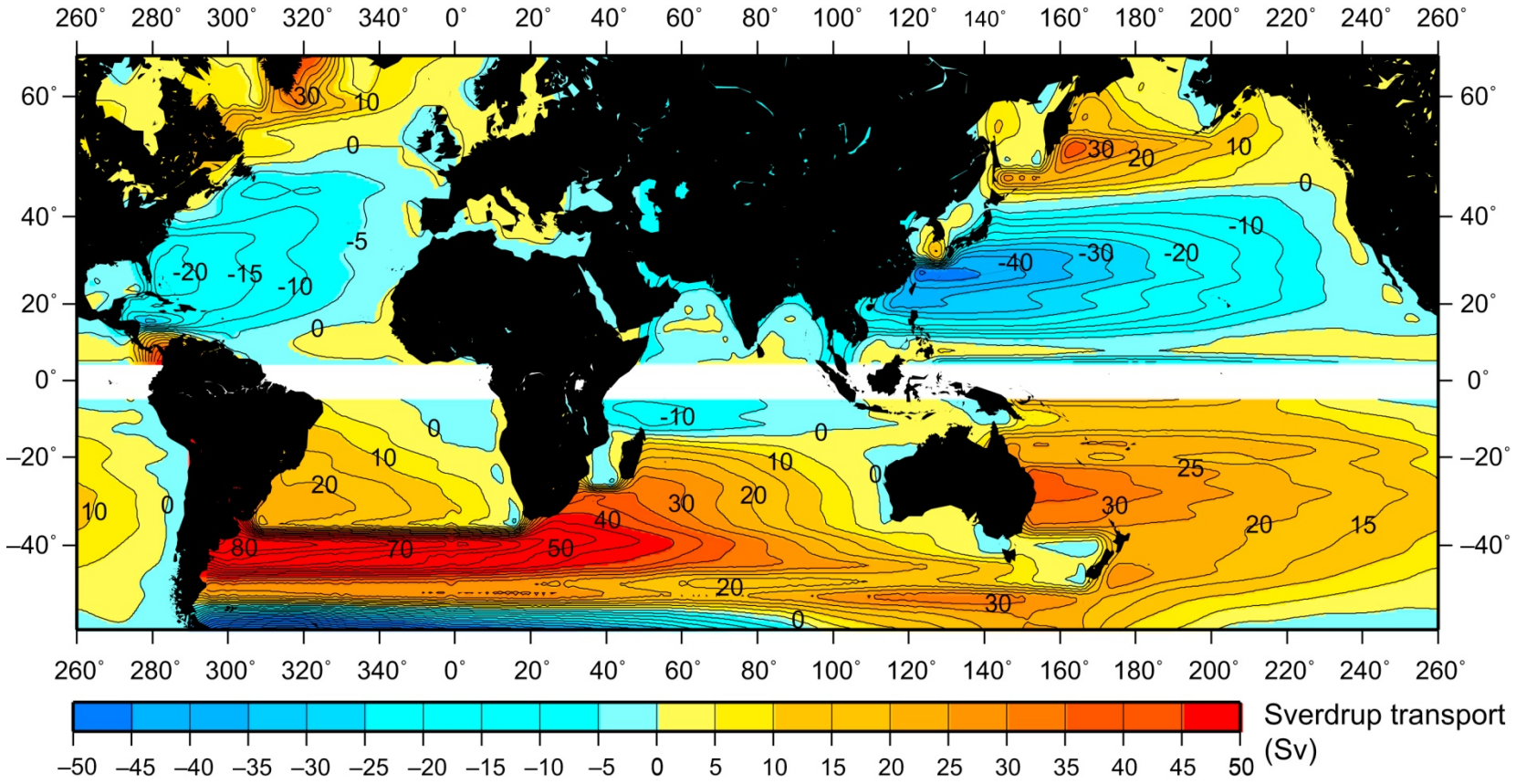
Atmosphere: 1°

NOAA GFDL



Estimate V from wind stress curl

$$\beta V = \frac{1}{\rho_o}\left(\frac{\partial \tau_{oy}}{\partial x} - \frac{\partial \tau_{ox}}{\partial y}\right)$$



Sverdrup transport (Sv), where blue is clockwise and positive is counterclockwise circulation. Wind stress data are from the NCEP reanalysis 1968–1996 (Kalnay et al., 1996). The mean annual wind stress and wind stress curl used in this Sverdrup transport calculation are shown in Figure 5.16a and in the online supplement, Figure S5.10.

FIGURE 5.17

North Pacific Surface Currents

Most purely wind-driven

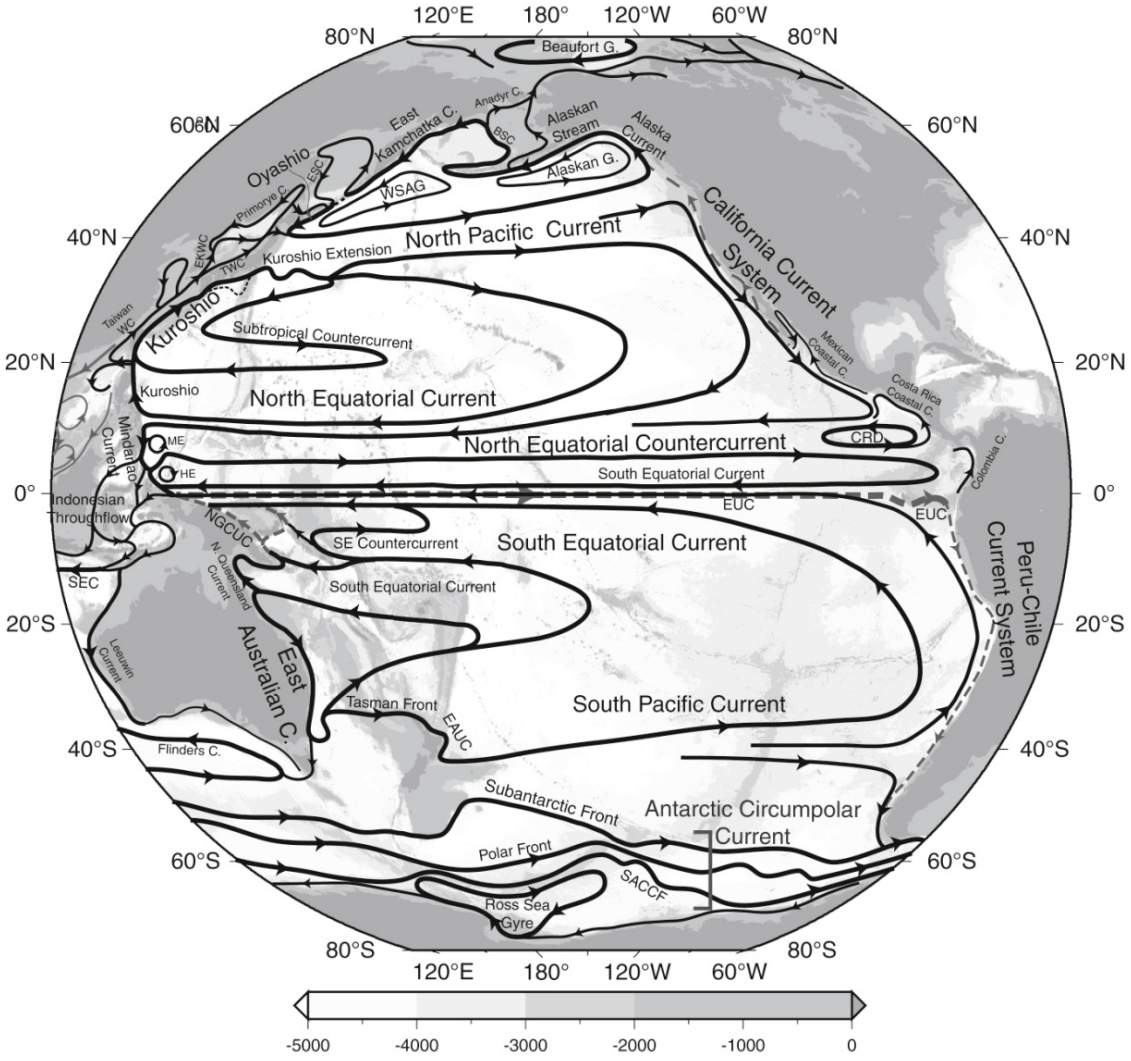


FIGURE 10.1

Pacific Ocean: surface circulation scheme. Major near-surface undercurrents at the equator and along the eastern boundary are also shown (dashed). The South China Sea circulation represents the winter monsoon. Acronyms: SACCF, Southern ACC Front; EAUC, East Auckland Current; NGCUC, New Guinea Coastal Undercurrent; EUC, Equatorial Undercurrent; CRD, Costa Rica Dome; ME, Mindanao Eddy; HE, Halmahera Eddy; TWC, Tsushima Warm Current; EKWC, East Korean Warm Current; WSAG, Western Subarctic Gyre; ESC, East Sakhalin Current; and BSC, Bering Slope Current.

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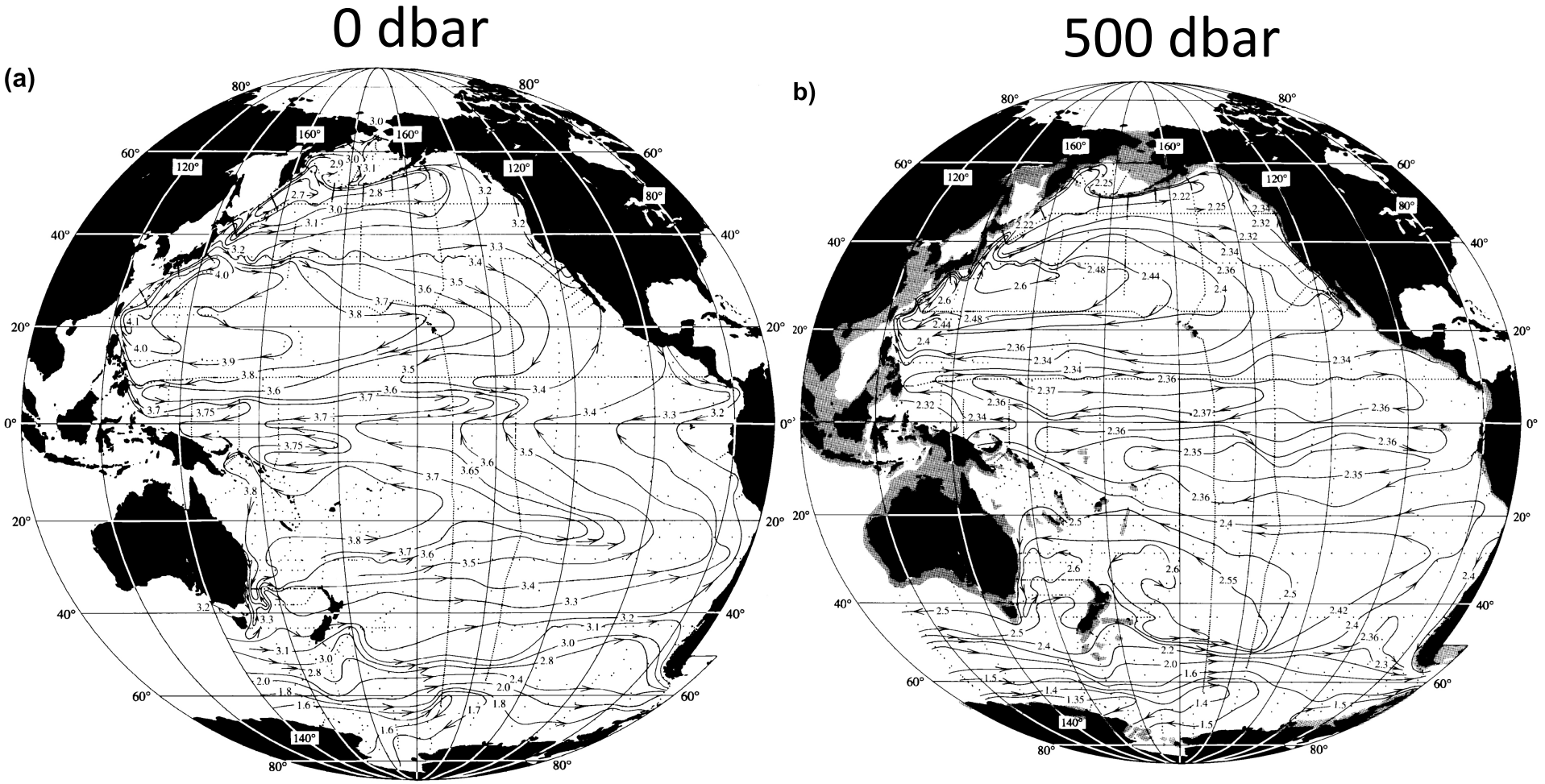

FIGURE 10.2

Adjusted geostrophic streamfunction (steric height, 10 m^2/sec^2) at (a) 0 dbar and (b) 500 dbar. *Source: From Reid (1997).*

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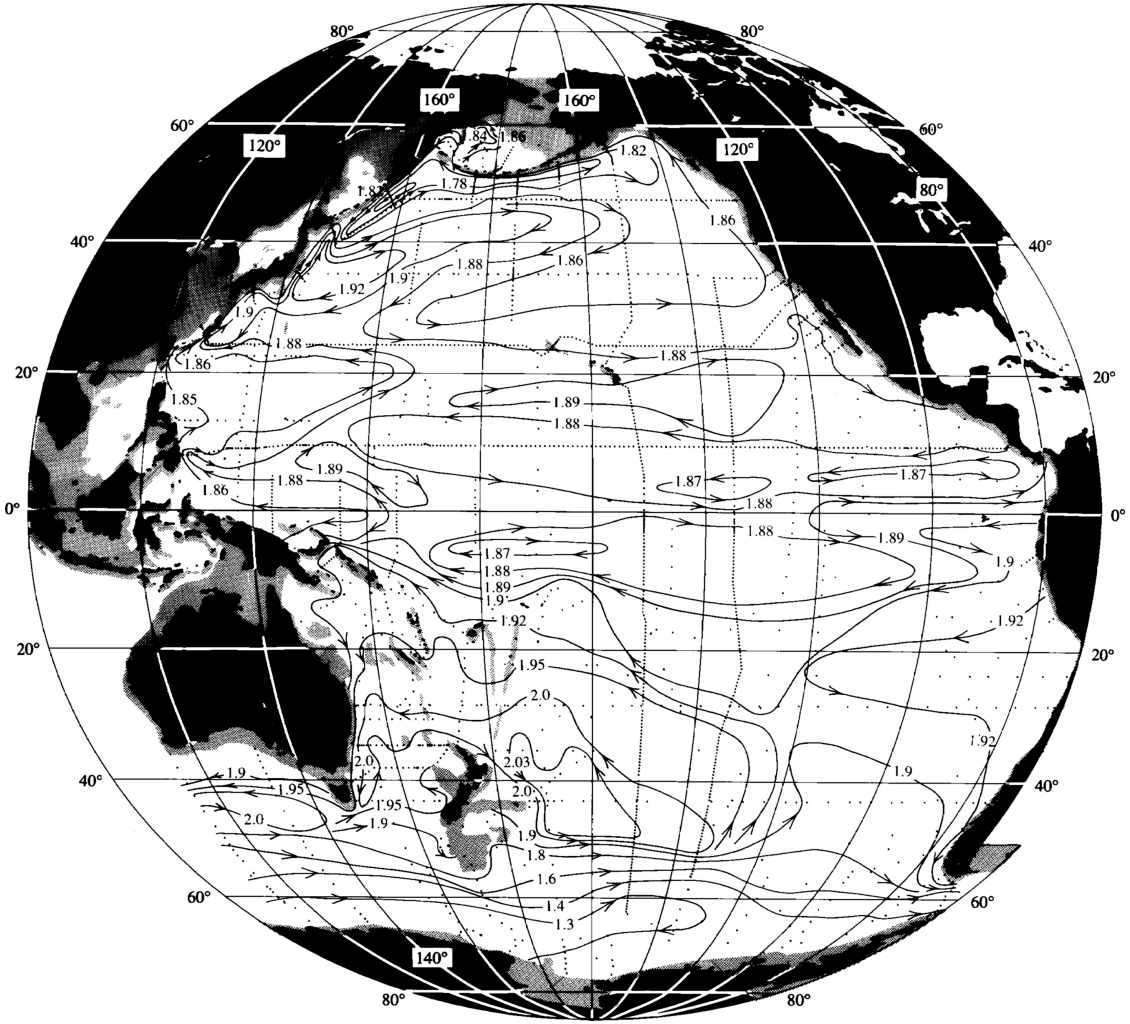
1000 dbar



Steric height (10 m^2/sec^2) at 1000 dbar based on hydrographic data and reference geostrophic velocities adjusted to provide absolute circulation at all depths. *Source: From Reid (1997).*

FIGURE 10.10

North Atlantic Surface Currents

Wind-driven, plus significant component of the Meridional Overturning

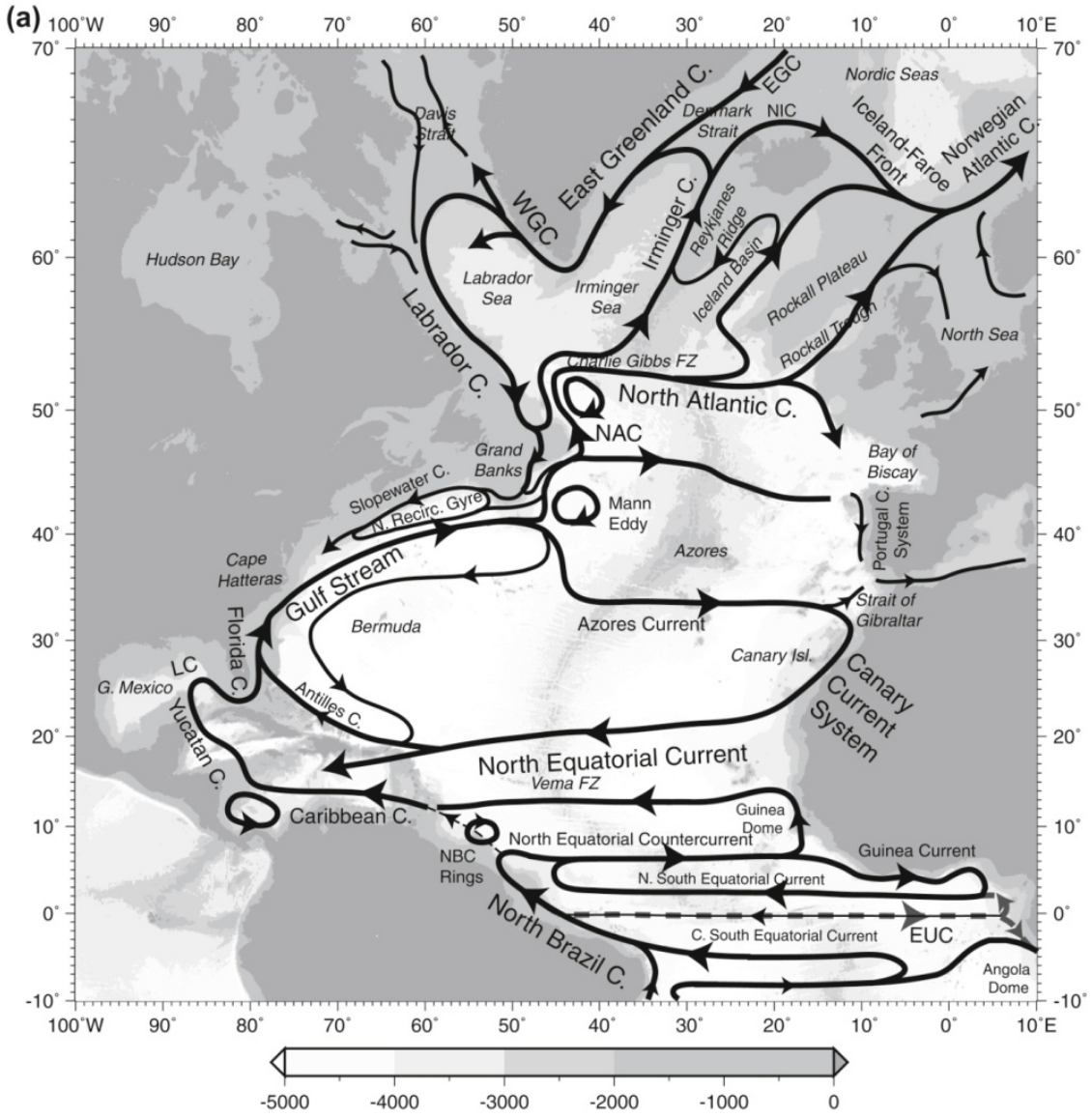
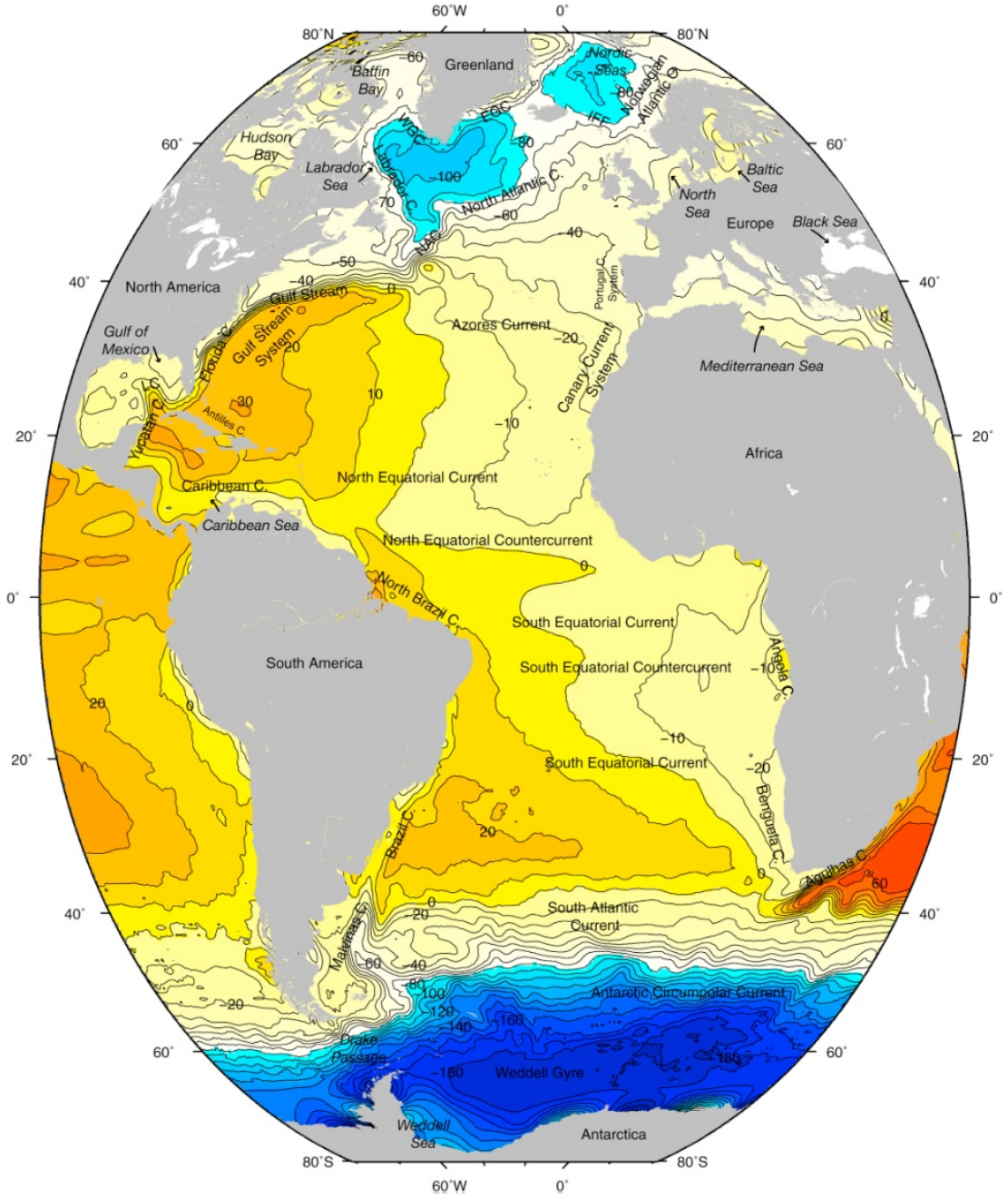


FIGURE 9.1

Atlantic Ocean surface circulation schematics. (a) North Atlantic and (b) South Atlantic; the eastward EUC along the equator just below the surface layer is also shown (gray dashed).



Atlantic Ocean surface height (cm) and surface current names (Table S9.1). *Data from Niiler, Maximenko, and McWilliams (2003).*

FIGURE S9.1

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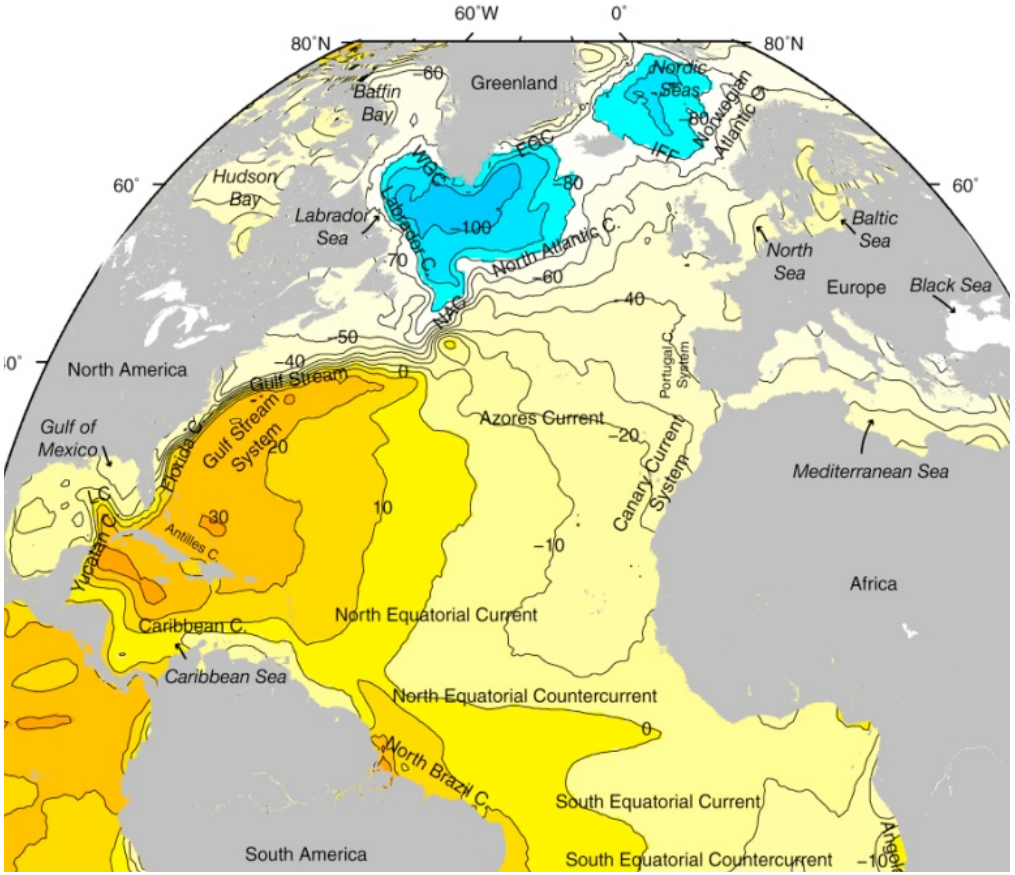

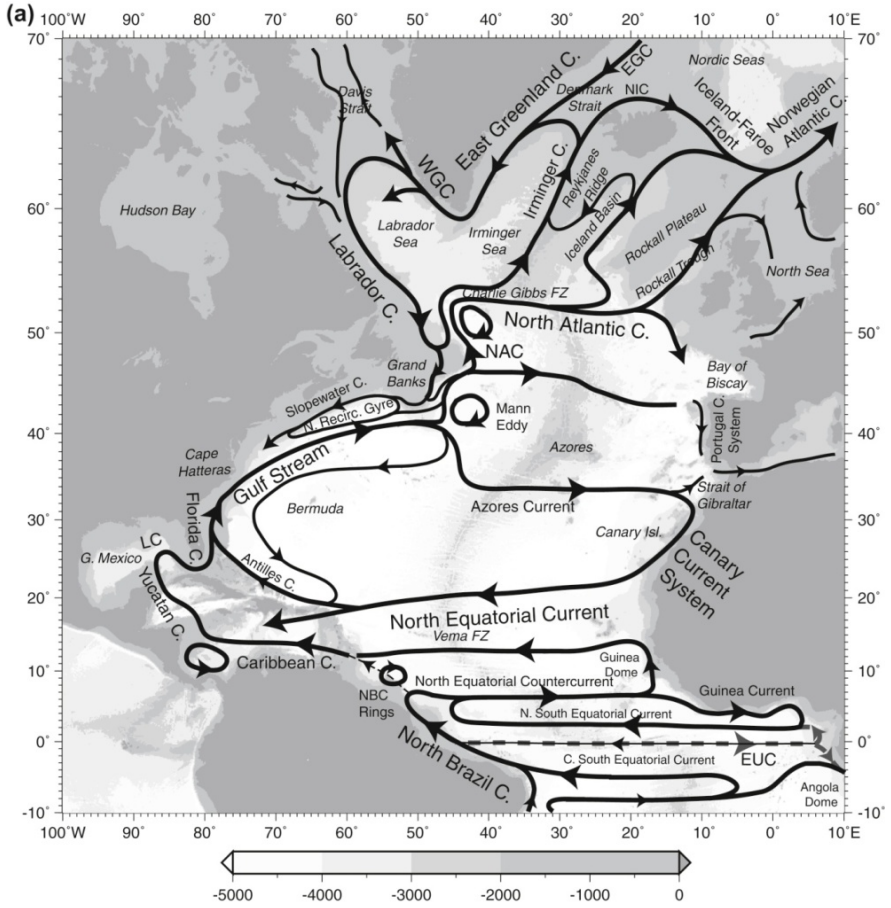

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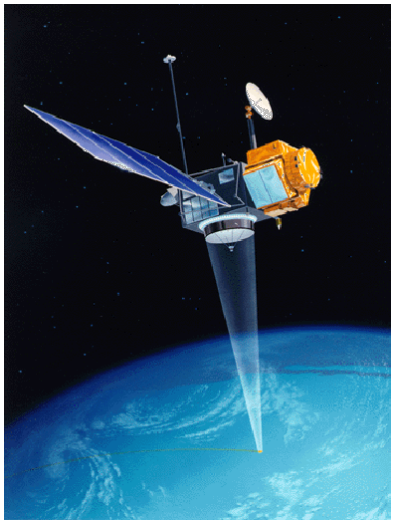
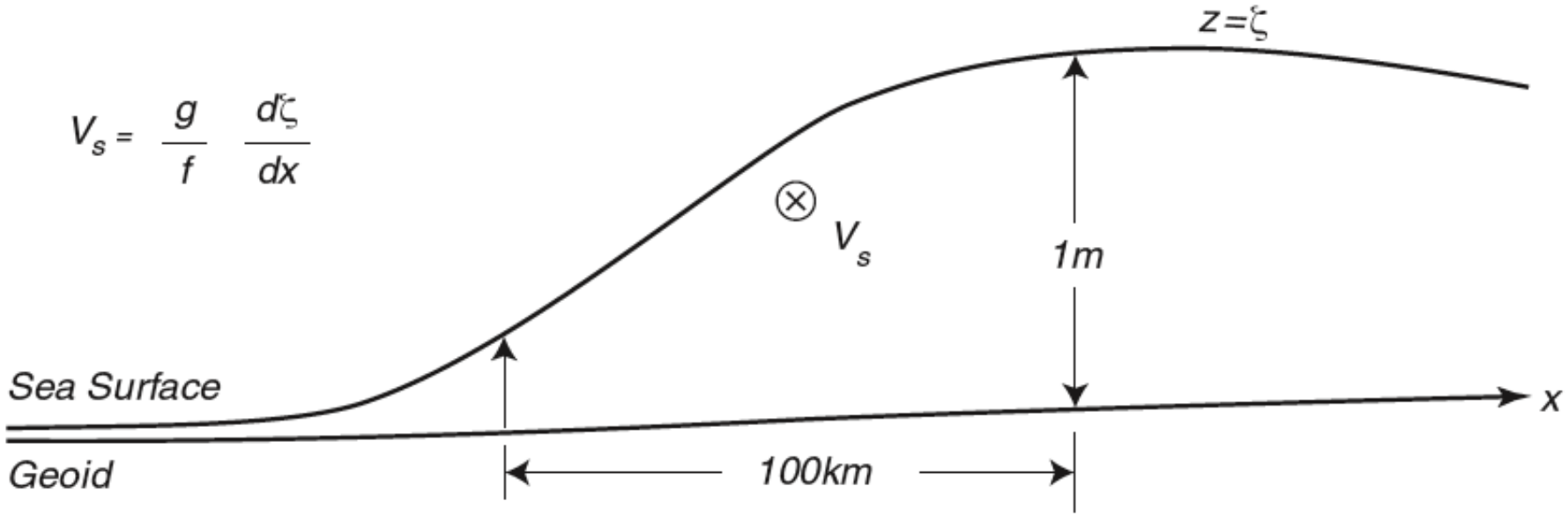
FIGURE S9.1



Dynamic Topography to get surface currents

$$V_s = \frac{g}{f}\frac{d\zeta}{dx}$$



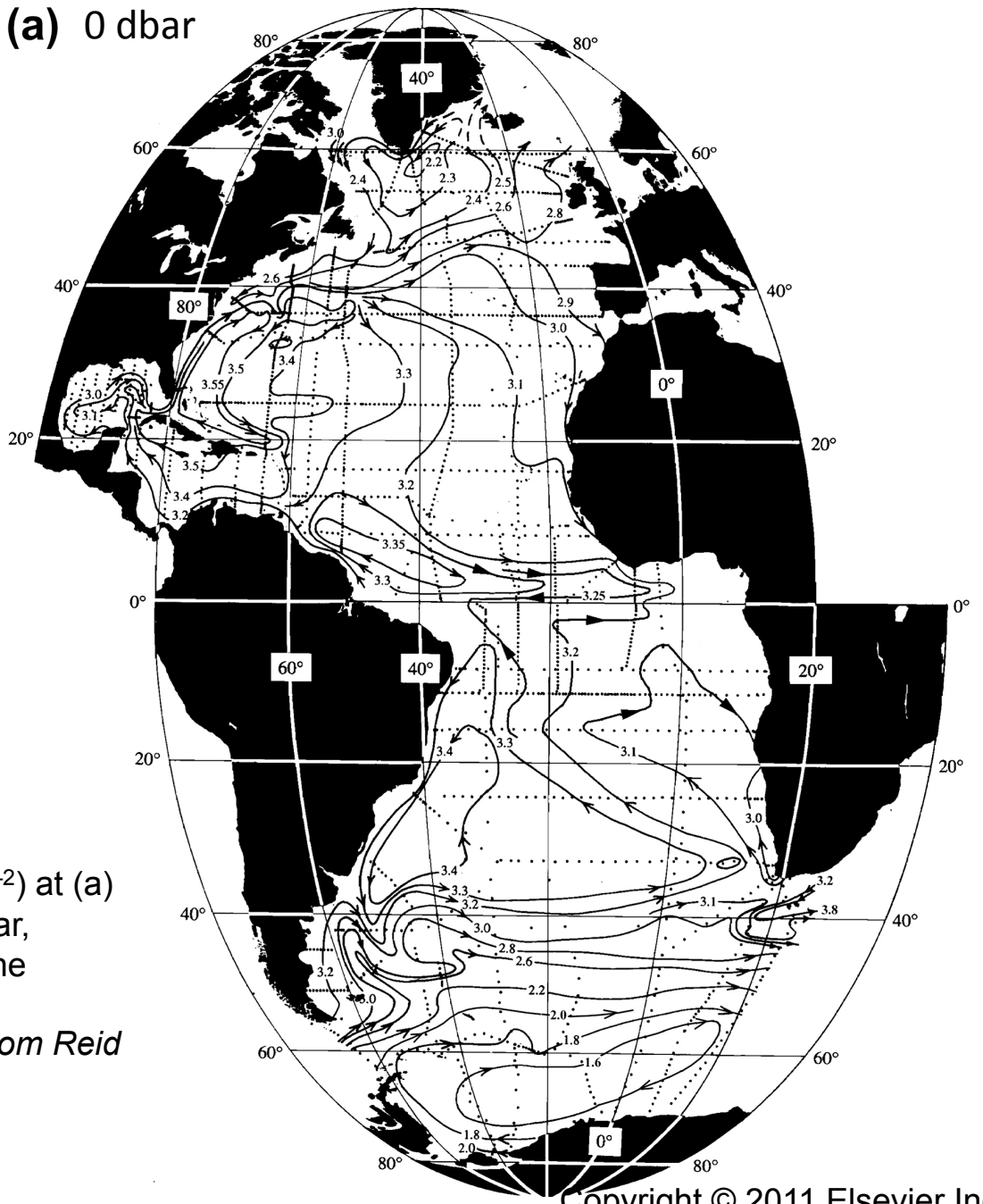
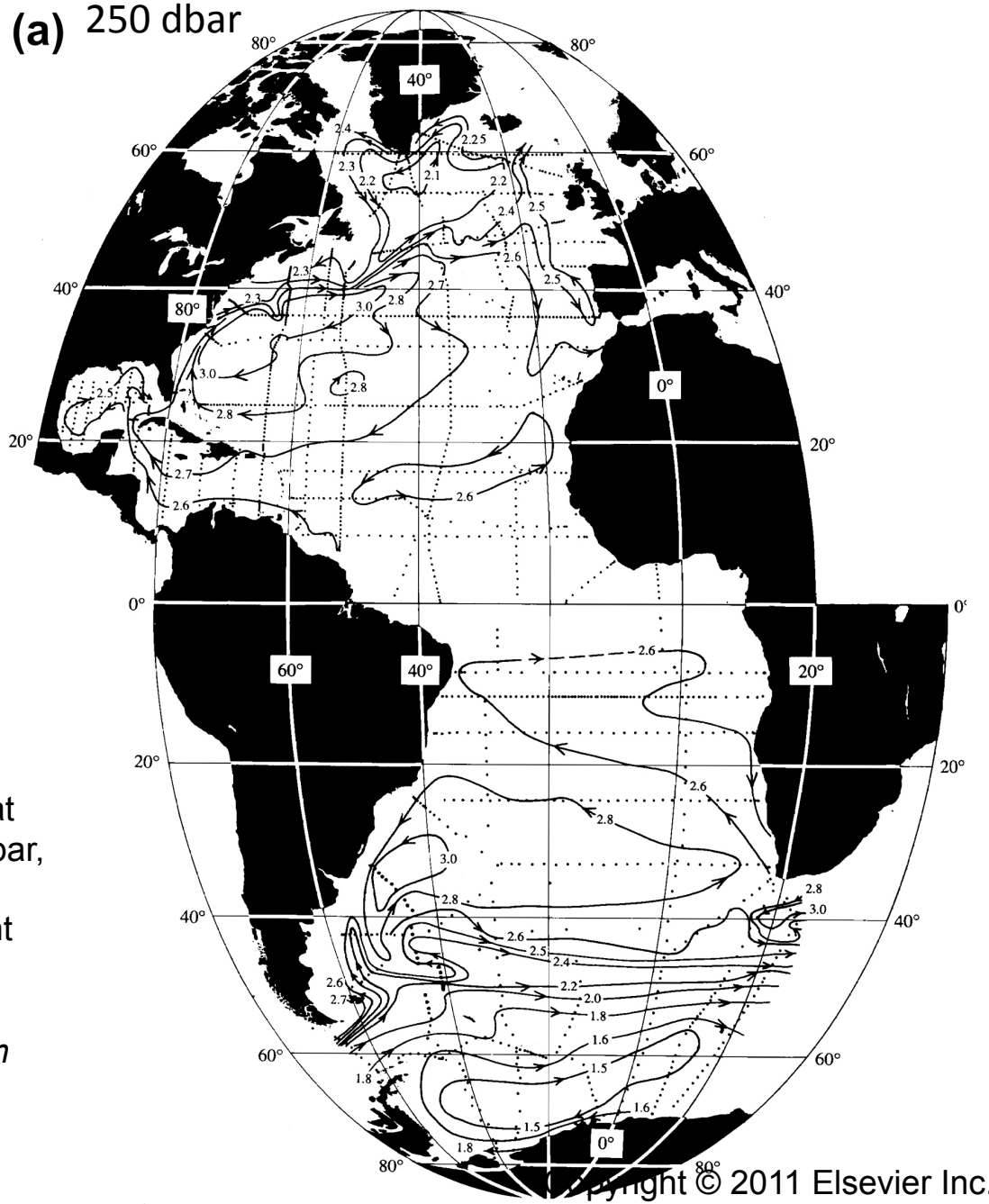


FIGURE 9.2

Steric height (10 m^2 s^{-2}) at (a) 0 dbar and (b) 500 dbar, adjusted to estimate the absolute geostrophic circulation. *Source: From Reid (1994).*



Geostrophic circulation at (a) 250 dbar, (b) 1000 dbar, and (c) 1500 dbar. The contours are steric height (10 $m^2 s^{-2}$), adjusted to represent the absolute circulation. *Source: From Reid (1994).*

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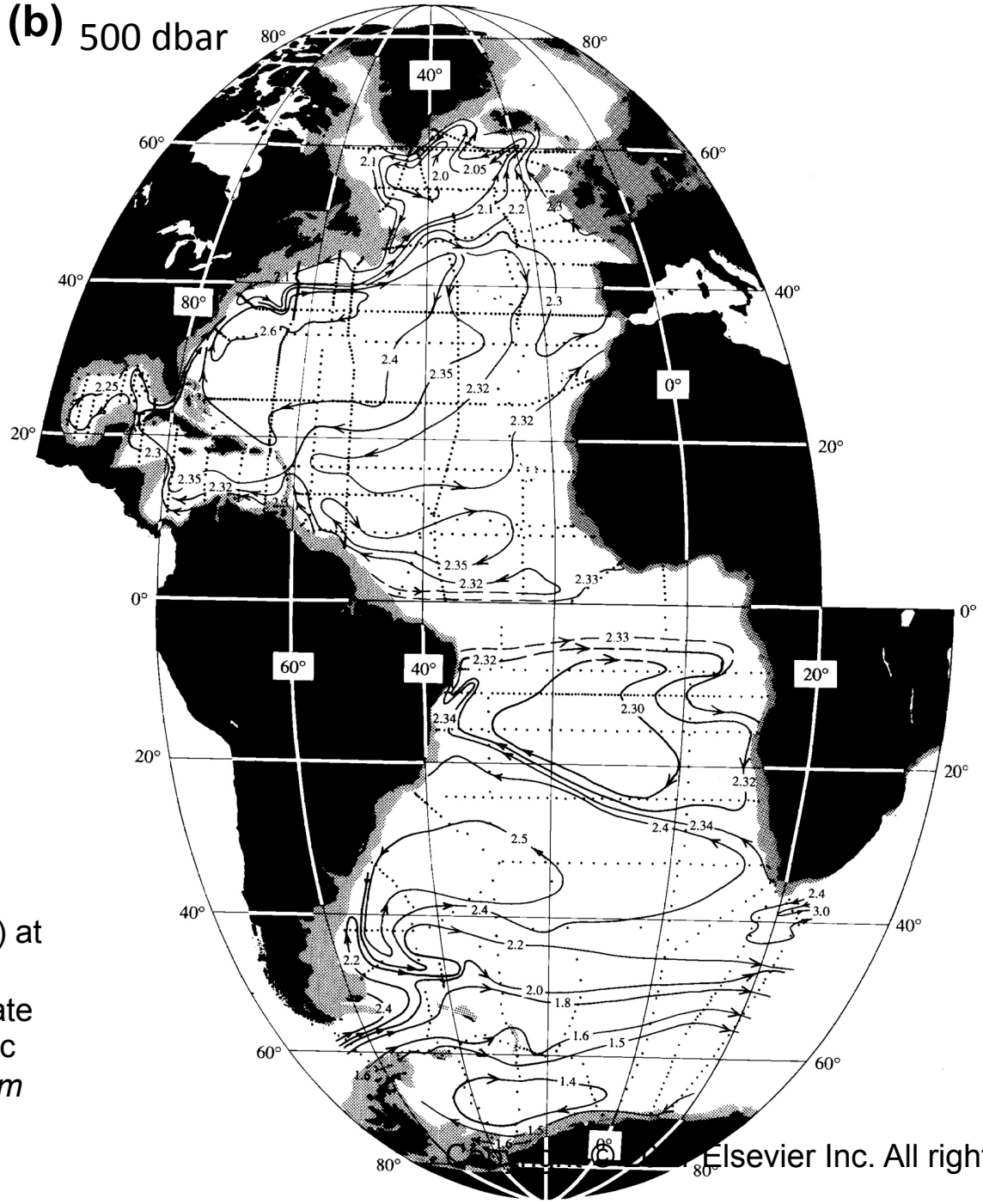

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Steric height (10 m^2 s^{-2}) at (a) 0 dbar and (b) 500 dbar, adjusted to estimate the absolute geostrophic circulation. *Source: From Reid (1994).*

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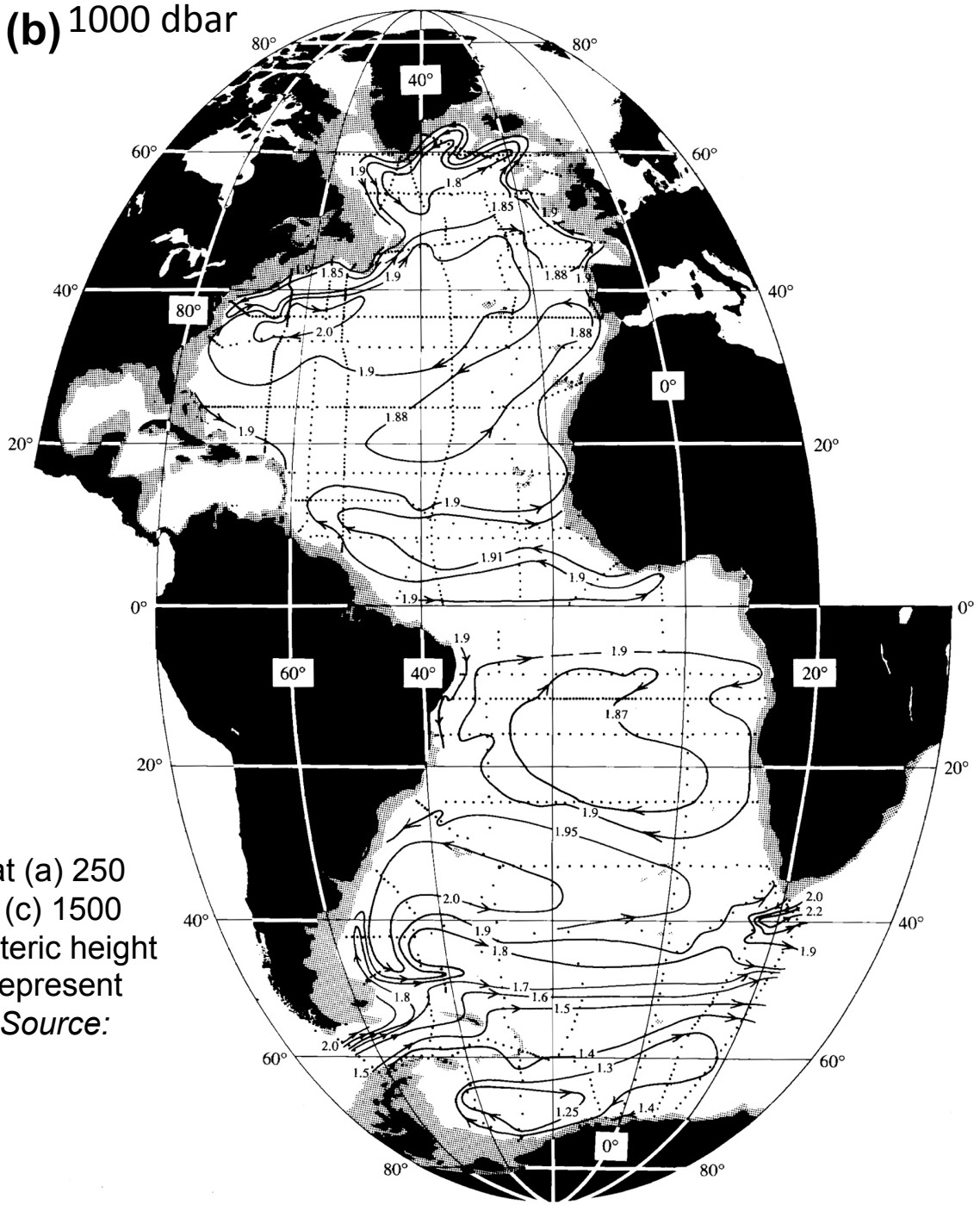

FIGURE S9.2ab

Geostrophic circulation at (a) 250 dbar, (b) 1000 dbar, and (c) 1500 dbar. The contours are steric height (10 $m^2 s^{-2}$), adjusted to represent the absolute circulation. *Source: From Reid (1994).*

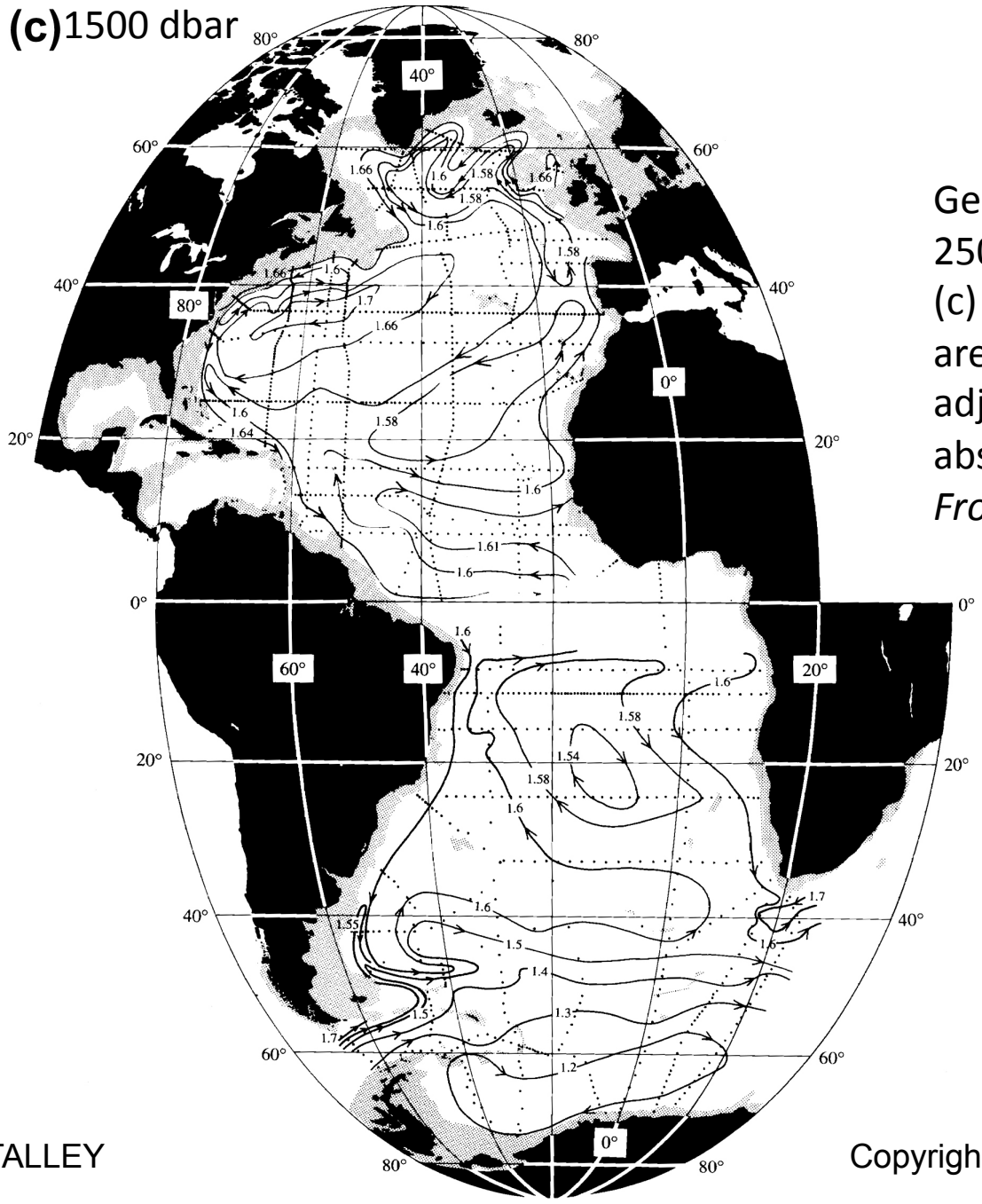

FIGURE S9.2c

Geostrophic circulation at (a) 250 dbar, (b) 1000 dbar, and (c) 1500 dbar. The contours are steric height (10 $m^2\ s^{-2}$), adjusted to represent the absolute circulation. *Source: From Reid (1994).*

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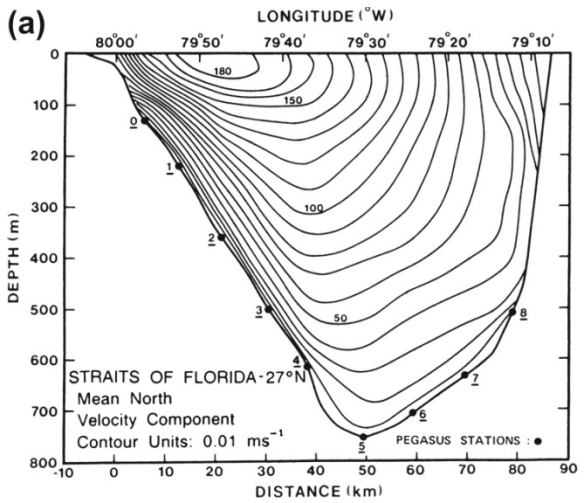
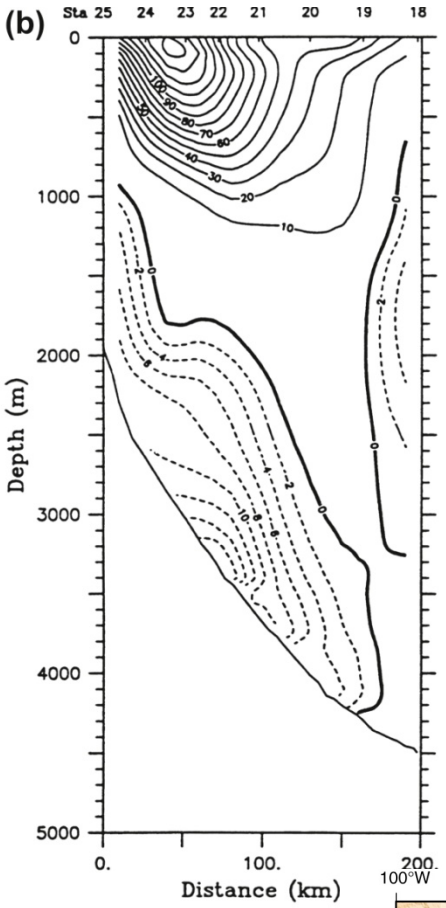
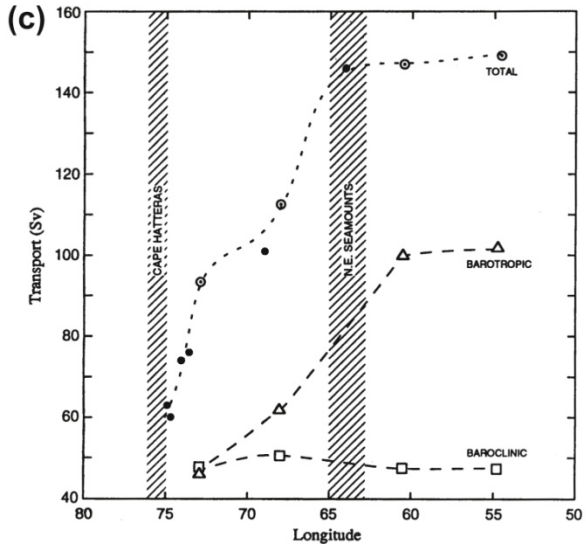
Gulf Stream and North Atlantic Current







Gulf Stream velocity sections and transports. (a) Mean velocity of the Florida Current at the Straits of Florida at 27°N. *Source: From Leaman, Johns, and Rossby (1989).* (b) Smoothed geostrophic velocity at Cape Hatteras. *Source: From Pickart and Smethie (1993).* (c) Gulf Stream transport (Sv) at different longitudes; Cape Hatteras and the New England Seamounts are indicated by hatching. Barotropic and baroclinic transports are indicated. *Source: From Johns et al. (1995).*

FIGURE 9.5

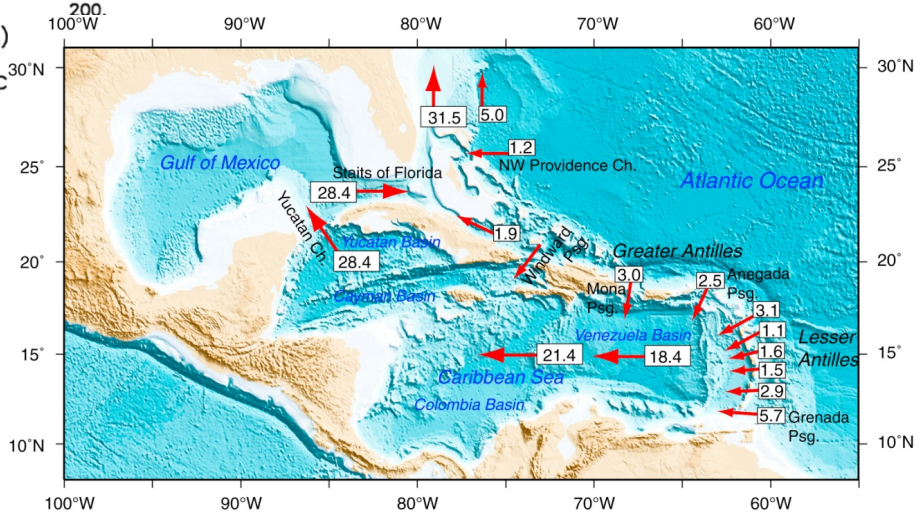


FIGURE 9.3

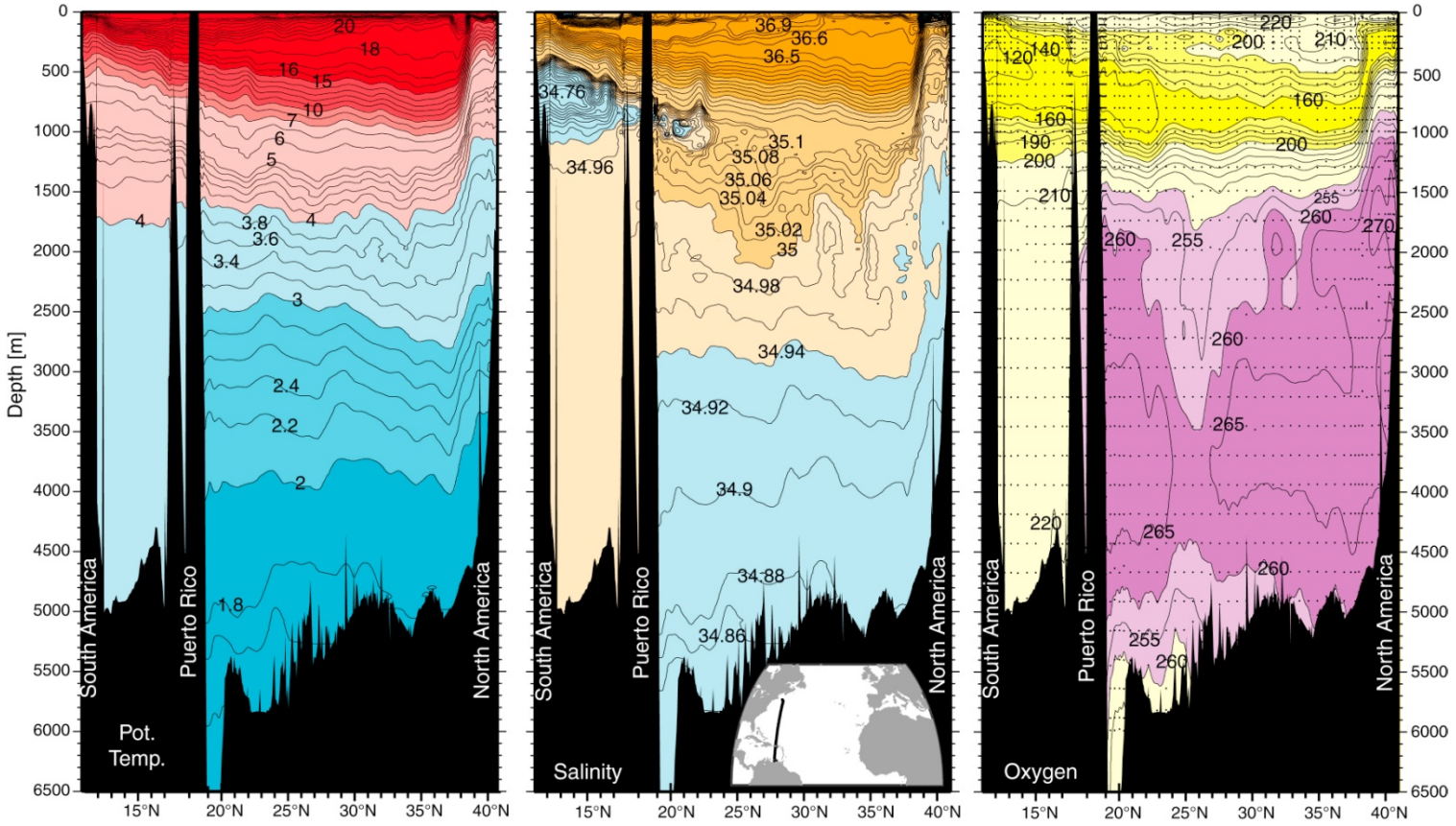
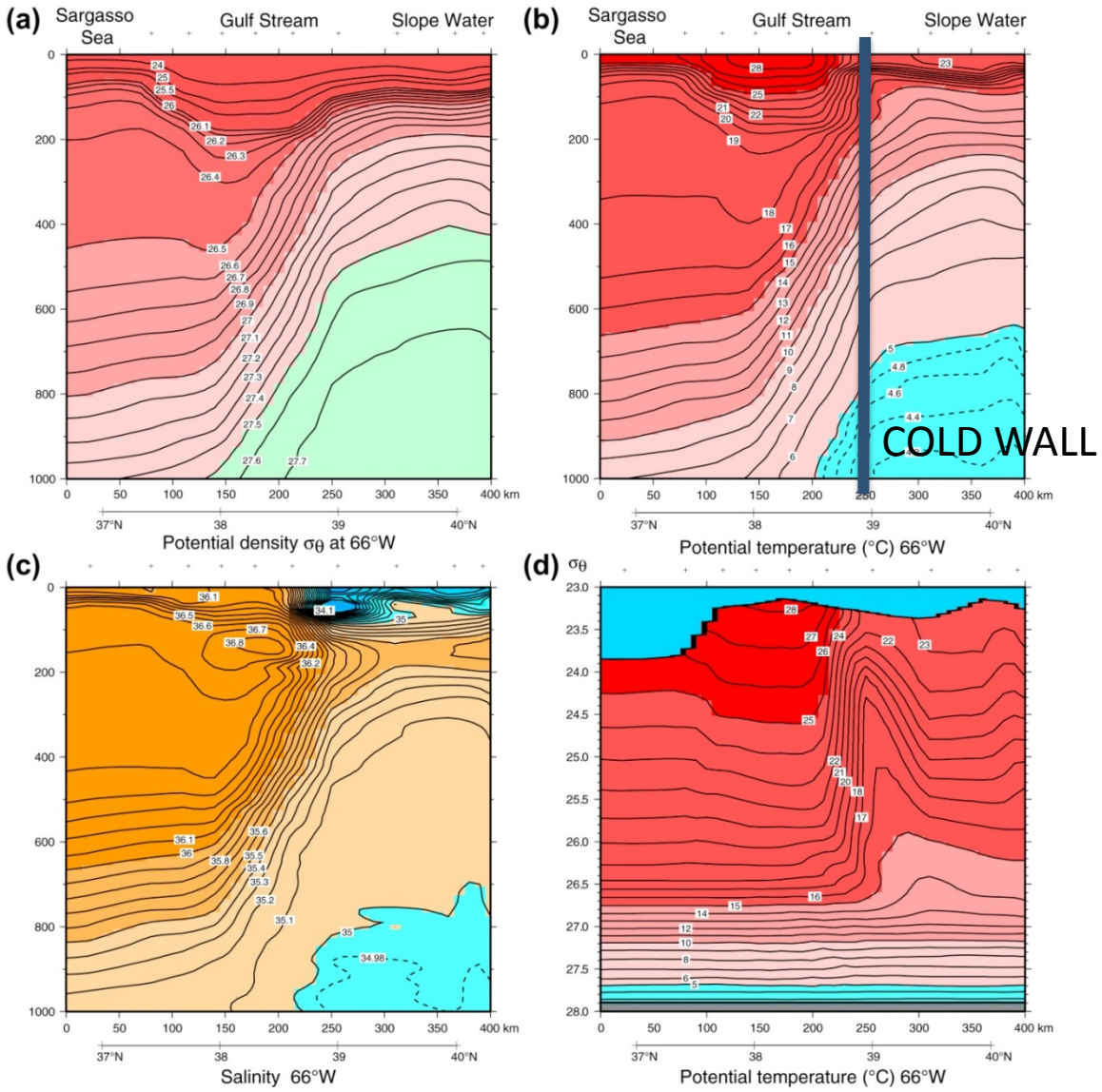


FIGURE 9.7

Subtropical North Atlantic at 66°W in August 1997. (a) Potential temperature (°C), (b) salinity, and (c) oxygen (μmol/kg). This figure can also be found in the color insert. *(World Ocean Circulation Experiment section A22.)*



Gulf Stream properties at 66° W (World Ocean Circulation Experiment section A22 in August, 1997). (a) Potential density σ_θ, (b) potential temperature (°C), (c) salinity, (d) potential temperature with potential density σ_θ as the vertical coordinate.

FIGURE S9.9

TALLEY

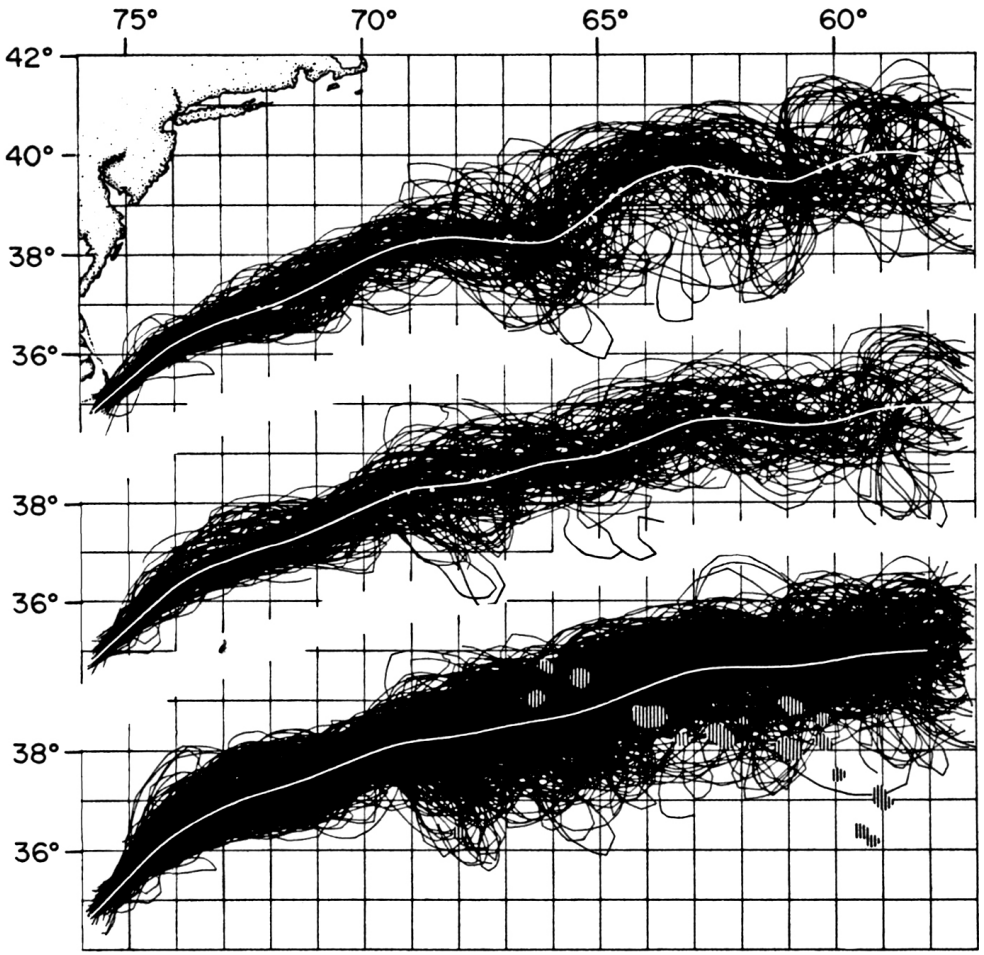


FIGURE 9.6

Gulf Stream northern edges every two days from infrared surface temperature for (top) April to December 1982, (middle) all of 1983, and (bottom) April 1982 to September 1984. The faint white curves are the mean tracks. *Source: From Cornillon (1986).*

Significant variation in location of the cold wall

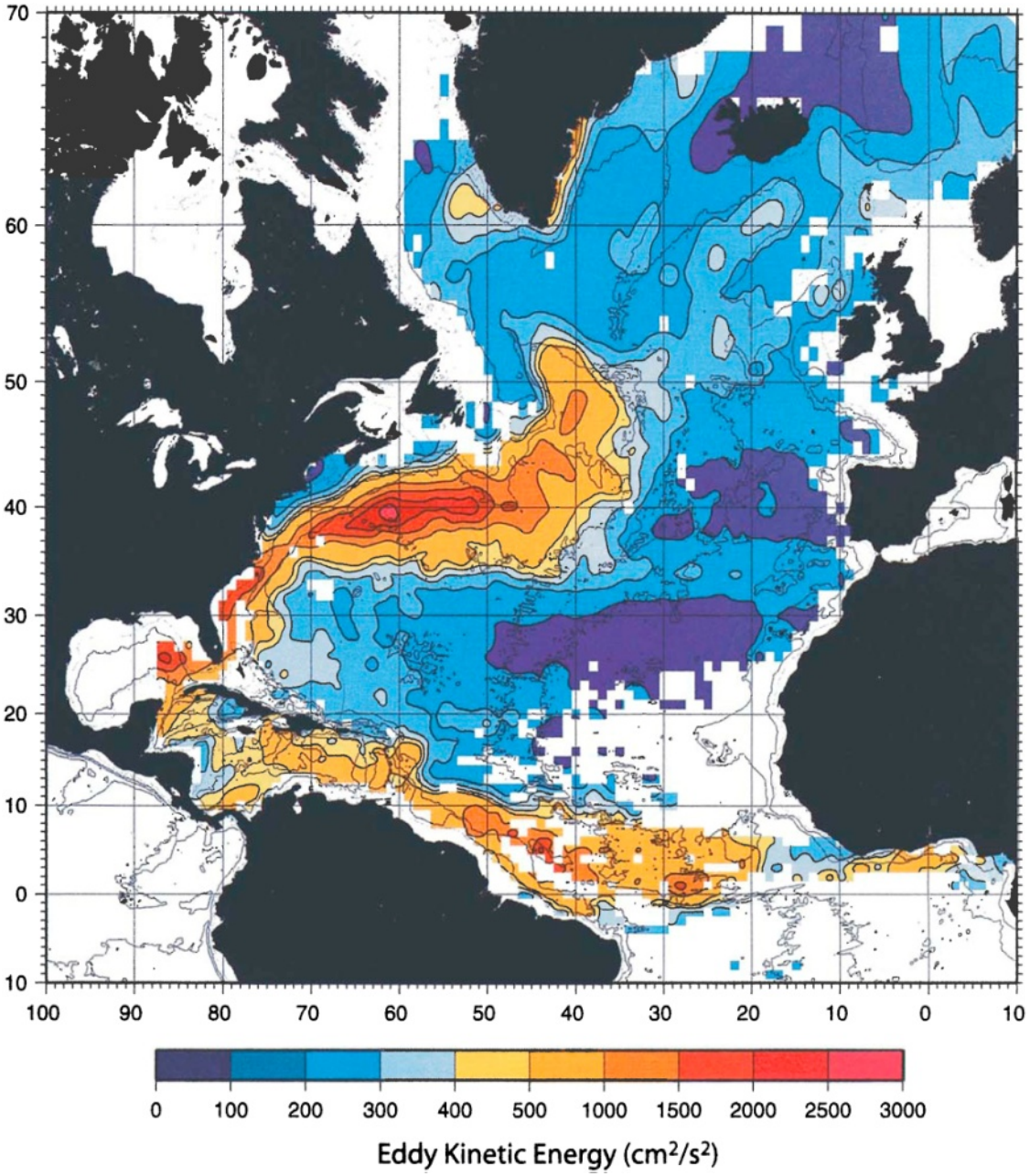


FIGURE S9.11

Eddy kinetic energy of the North Atlantic Ocean (cm^2/s^2) from surface drifter observations from 1990 to 1999. *Source: From Fratantoni (2001).*

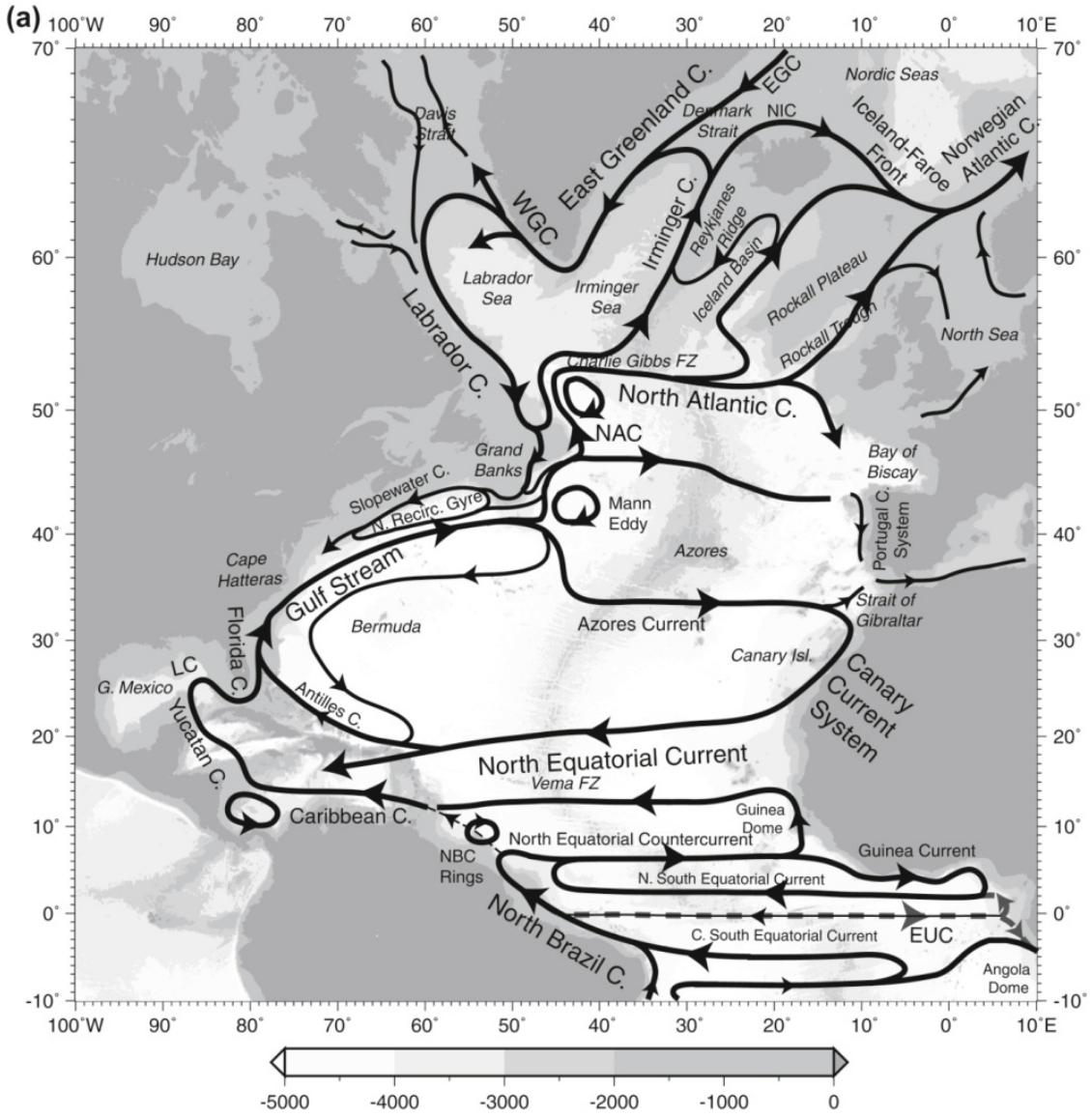


FIGURE 9.1

Atlantic Ocean surface circulation schematics. (a) North Atlantic and (b) South Atlantic; the eastward EUC along the equator just below the surface layer is also shown (gray dashed).

Canary Current System

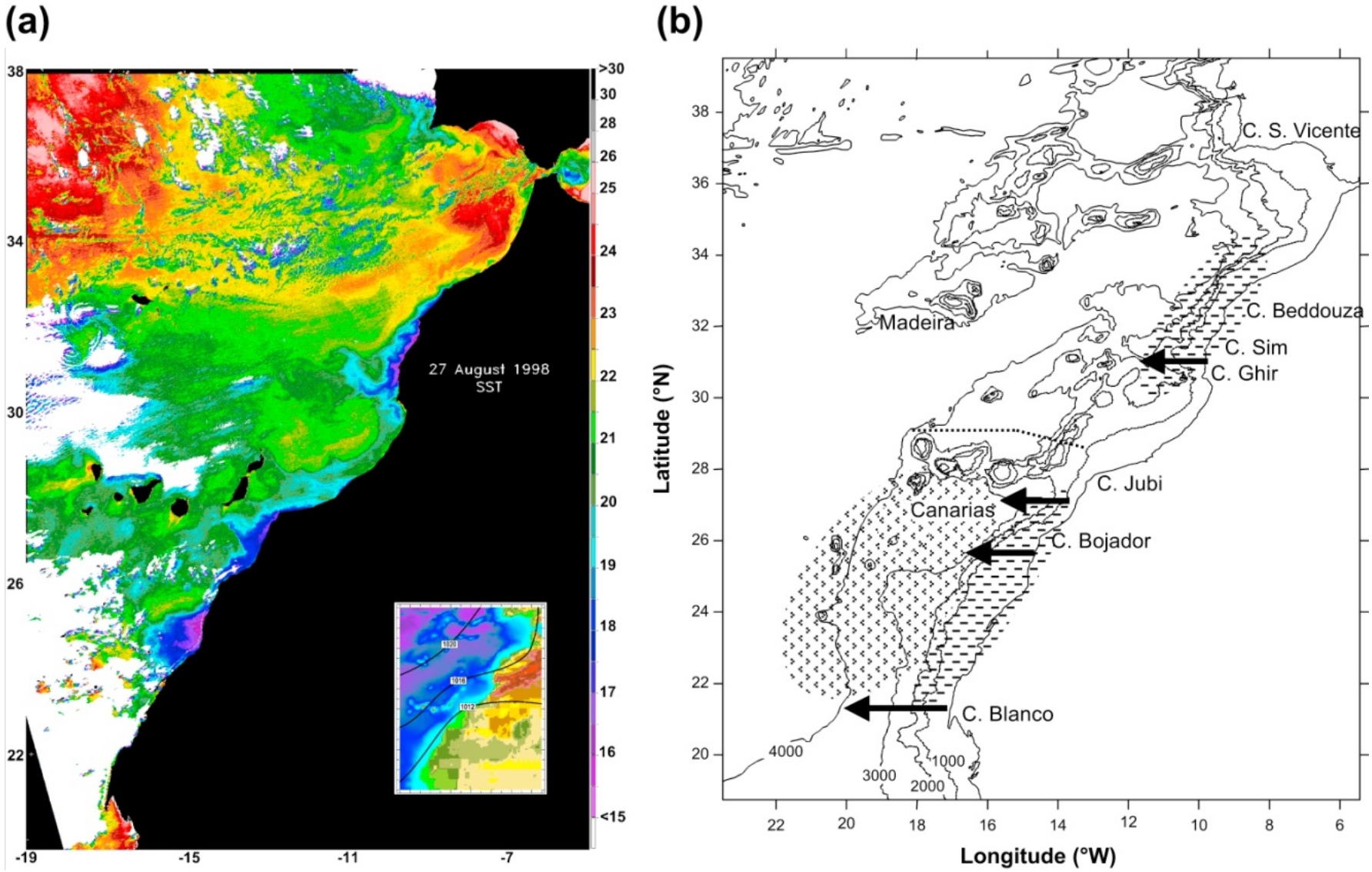
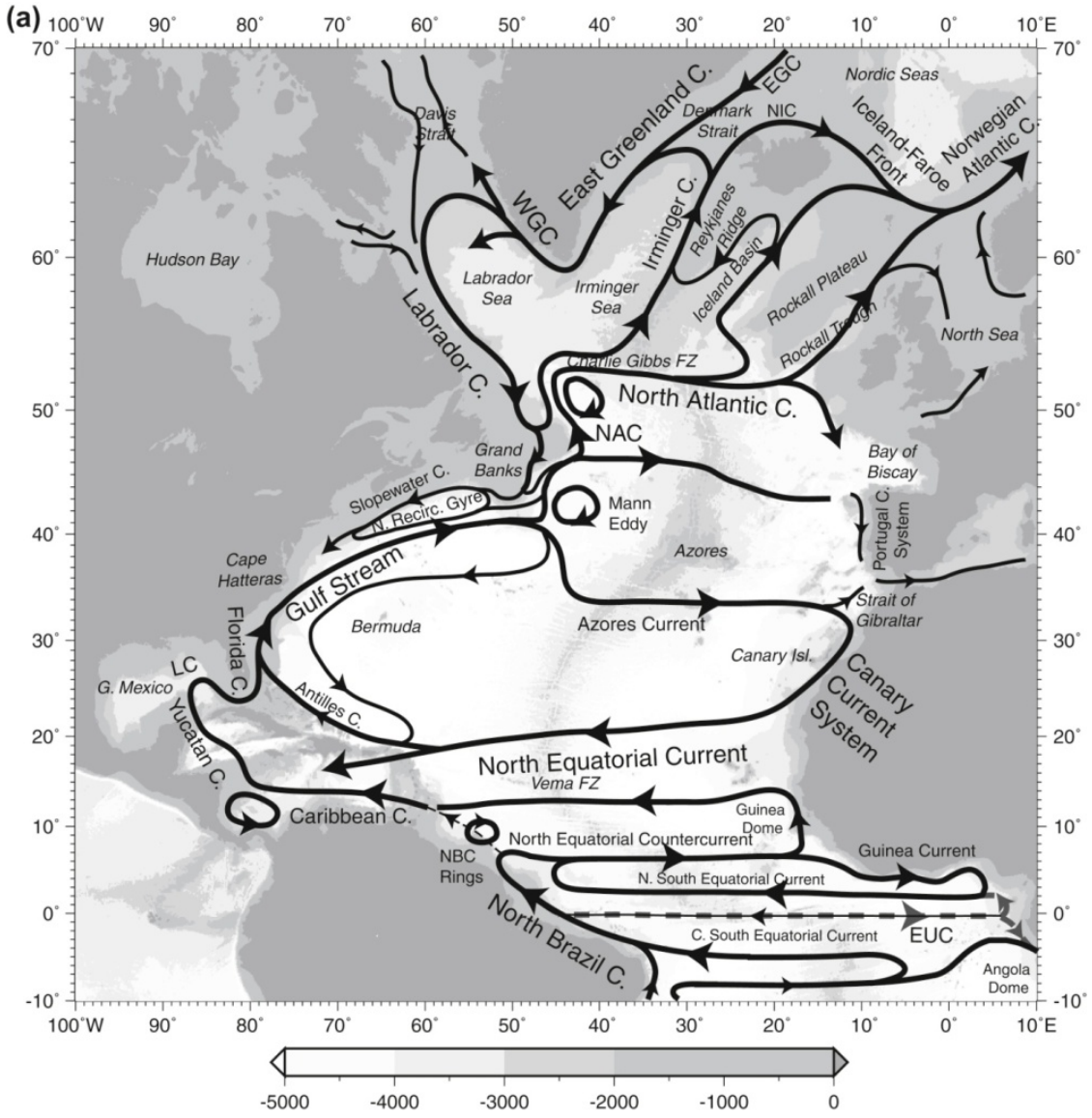


FIGURE 9.8

Canary Current System. (a) SST (satellite AVHRR image) on August 27, 1998. This figure can also be found in the color insert. (b) Schematic of upwelling (horizontal bars), eddy fields (dots), and preferred filaments (arrows). *Source: From Pelegrı´ et al. (2005).*

Subpolar Gyre



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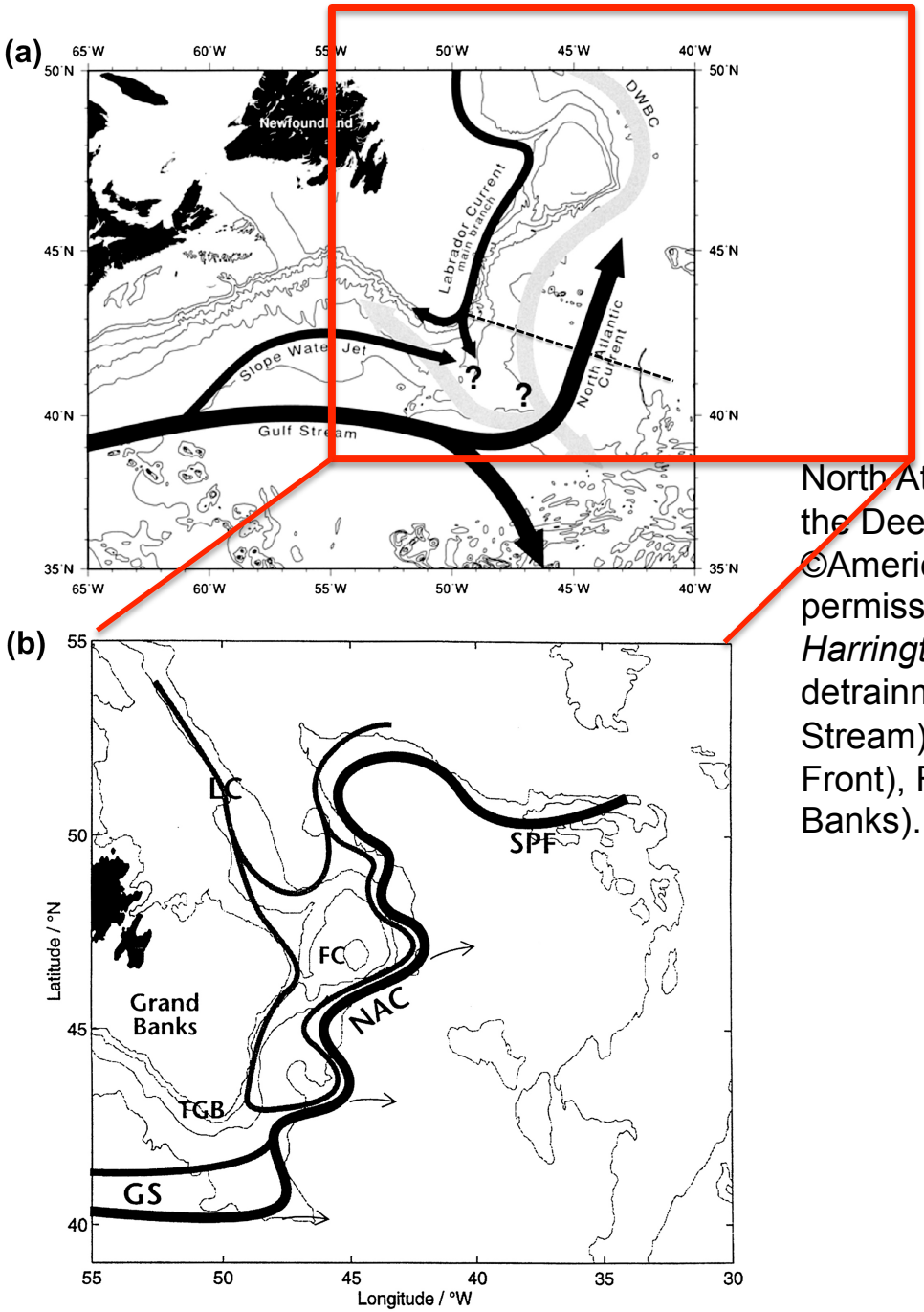
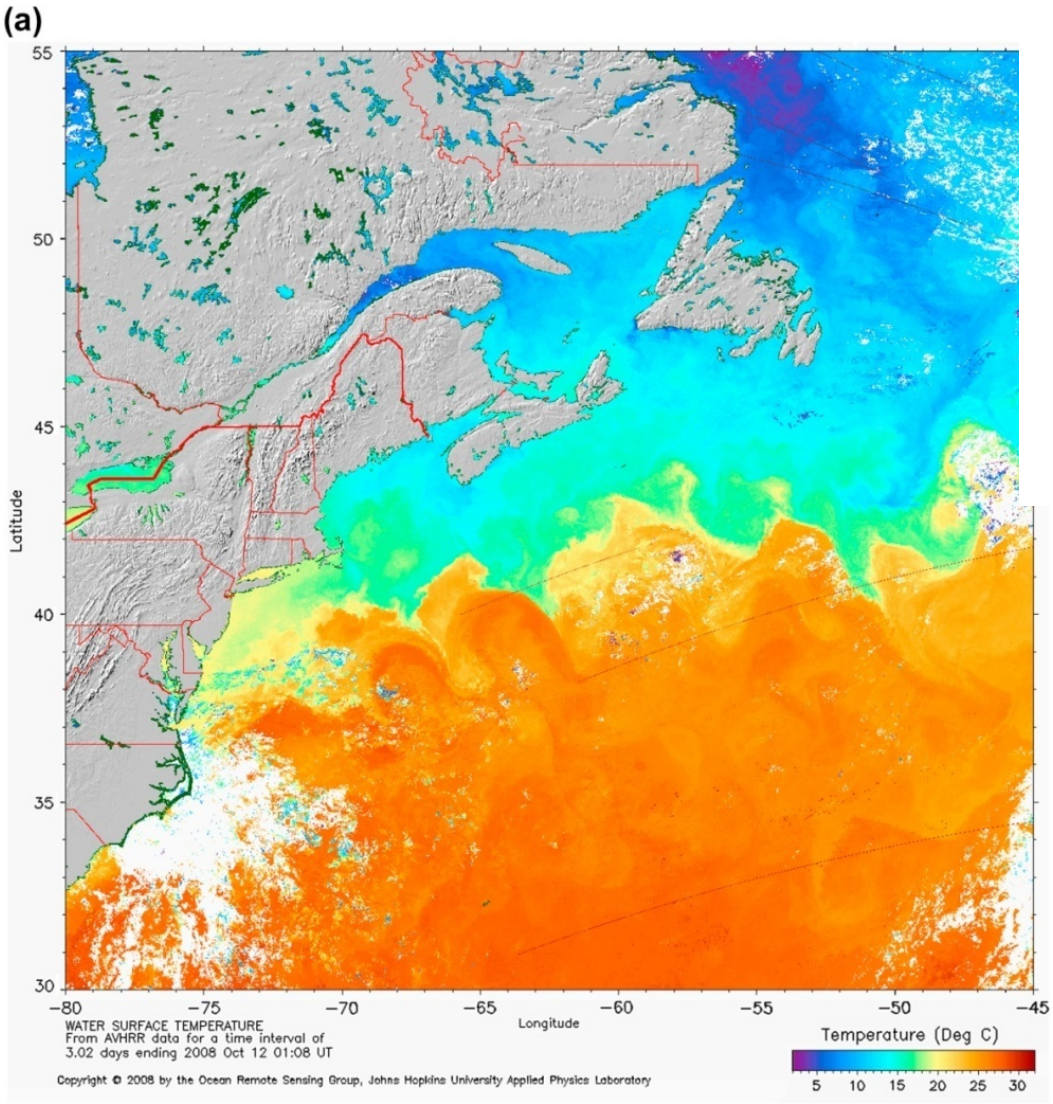


North Atlantic Current formation region: (a) including the Deep Western Boundary Current (DWBC) ©American Meteorological Society. Reprinted with permission. *Source: From Pickart, McKee, Torres, and Harrington (1999),* and (b) including eastward detrainments. NAC (North Atlantic Current), GS (Gulf Stream), LC (Labrador Current), SPF (Subpolar Front), FC (Flemish Cap), TGB (Tail of the Grand Banks). *Source: From Rossby (1999).*



North Atlantic Current and Labrador Current at the Grand Banks. (a) SST (AVHRR) on October 12, 2008, showing cold Labrador Current moving southward along the edge of the Grand Banks. *Source: From Johns Hopkins APL Ocean Remote Sensing (1996).* This figure can also be found in the color insert. (b) North Atlantic Current and DWBC velocity section (solid contours and numbers) with temperature contours, from August 1993 to January 1994, from about 48°W to 41°W at about 42°N. Velocity contours are 10 cm/sec. *Source: From Meinen and Watts (2000).*

FIGURE 9.9

TALLEY

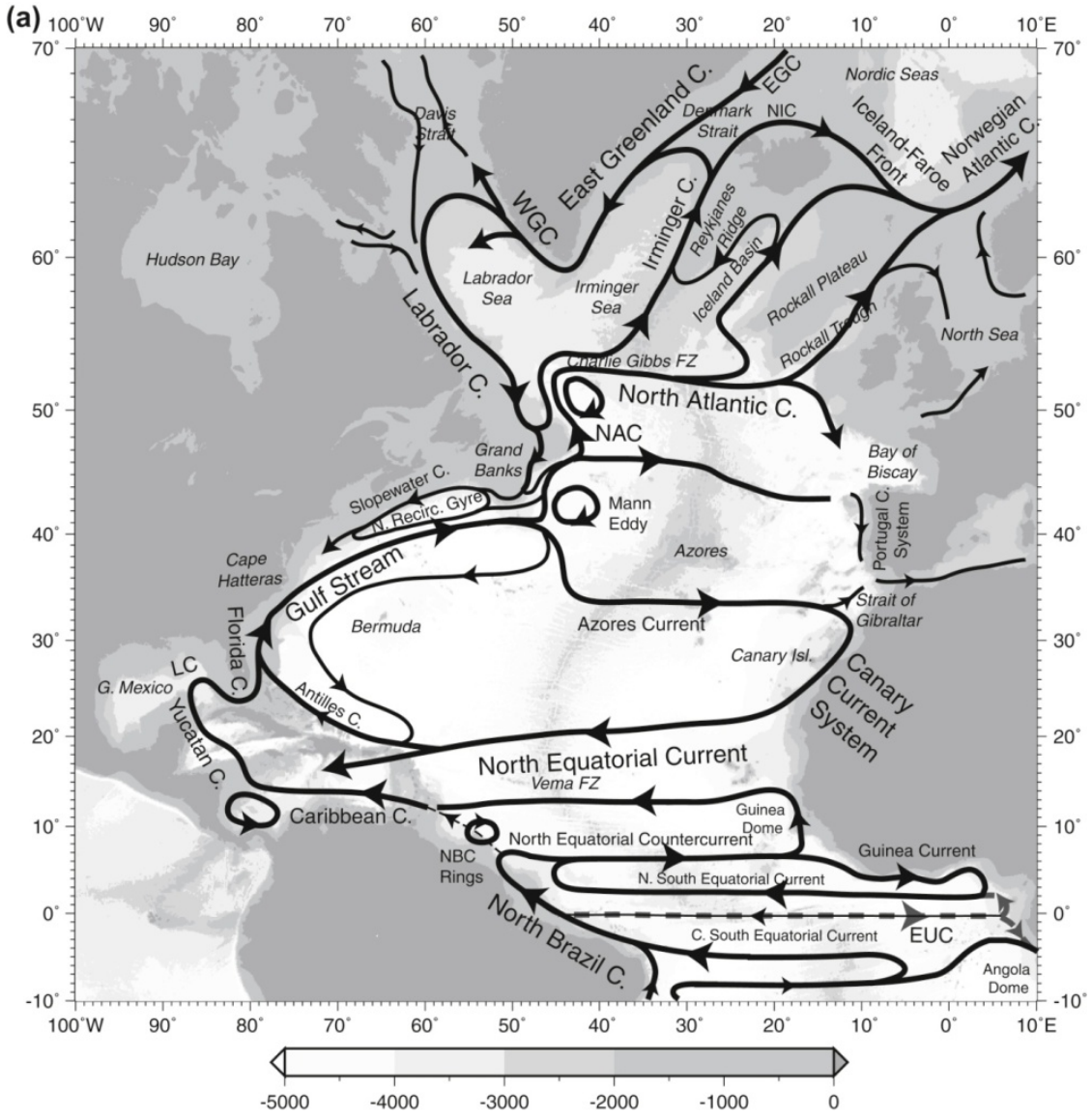
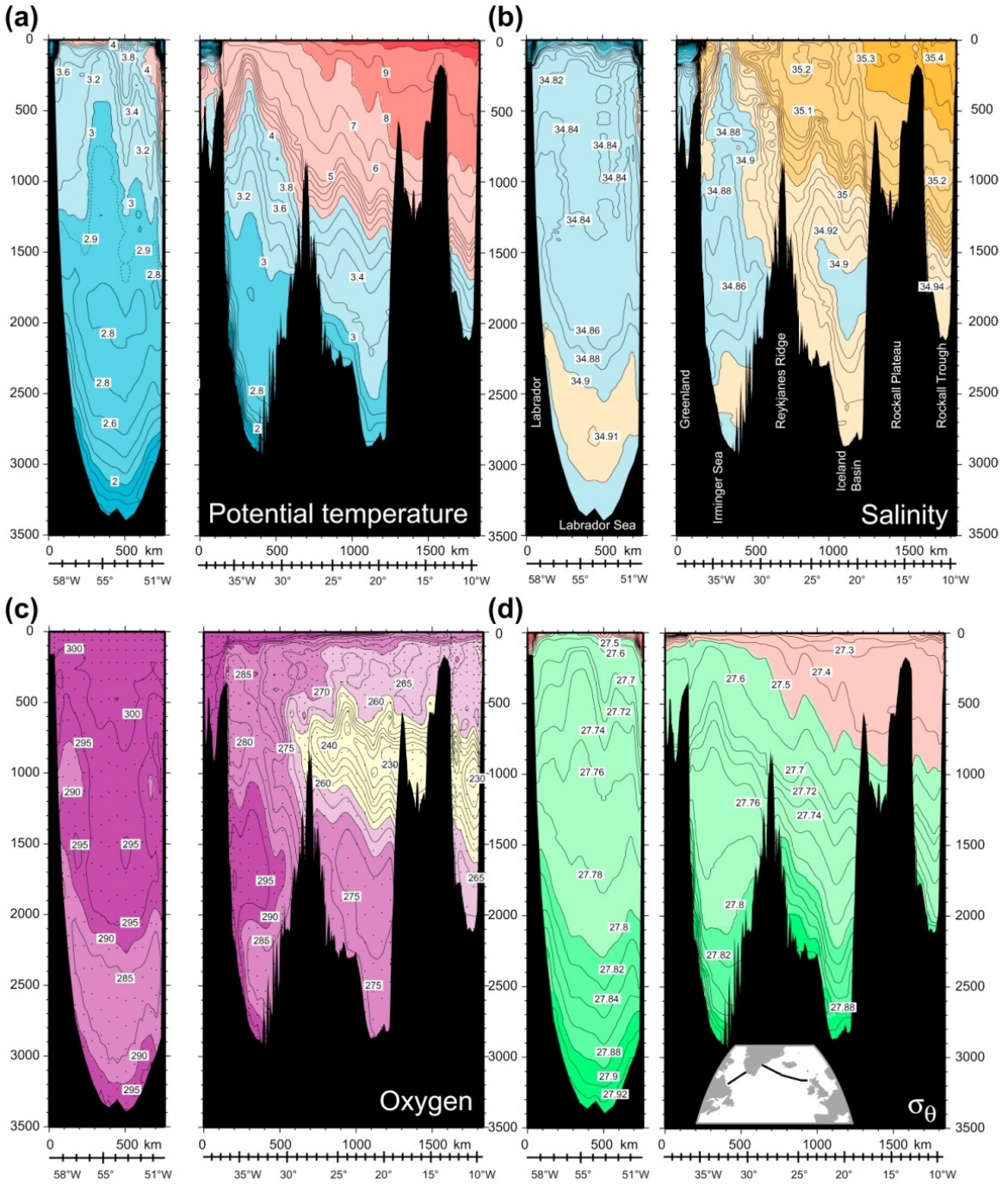


FIGURE 9.1

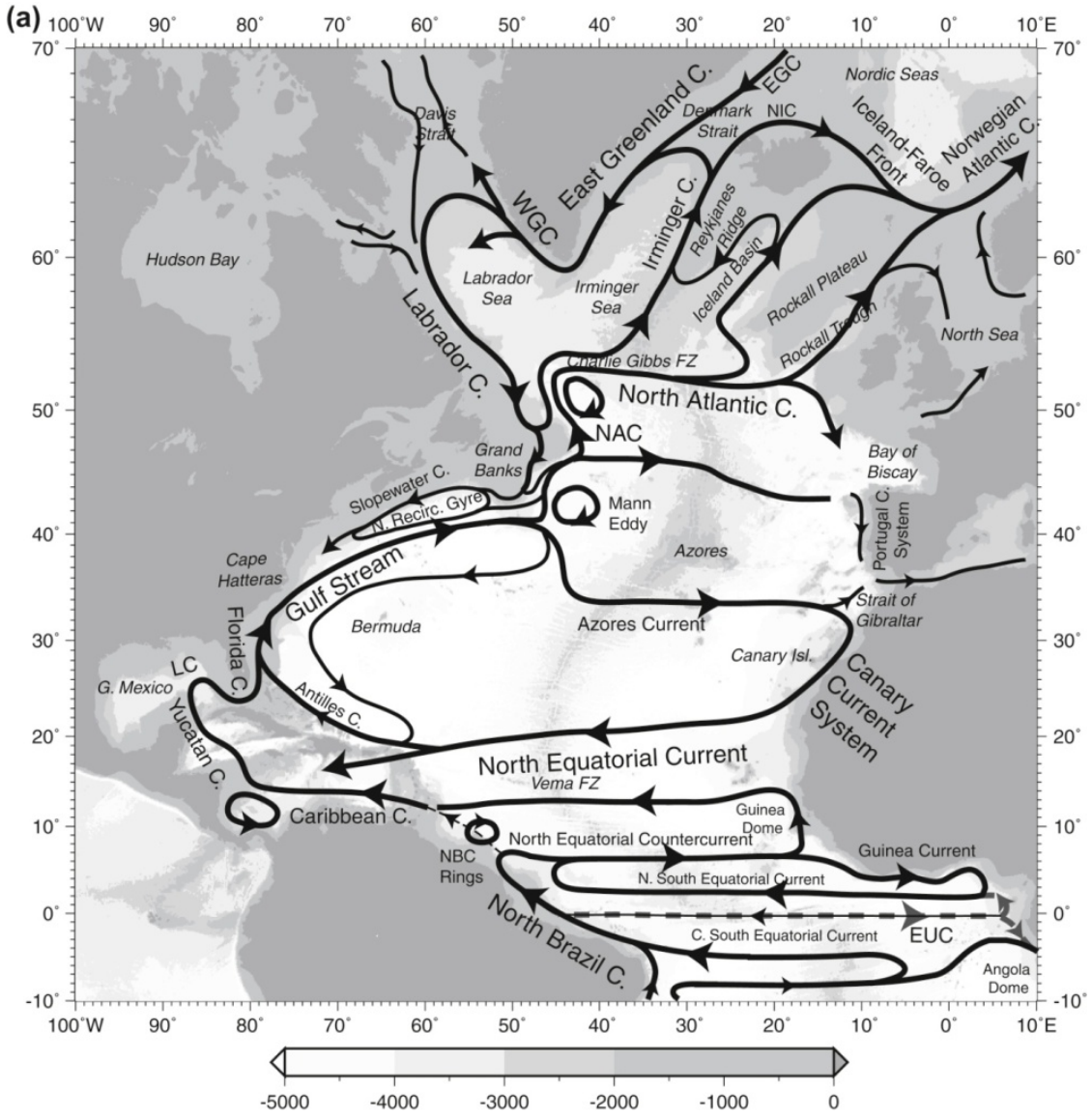
Atlantic Ocean surface circulation schematics. (a) North Atlantic and (b) South Atlantic; the eastward EUC along the equator just below the surface layer is also shown (gray dashed).



Subpolar North Atlantic at about 55°N from May to June, 1997. (a) Potential temperature (°C), (b) salinity, (c) oxygen, and (d) potential density (σ_θ) in the Labrador Sea (left side) and from Greenland to Ireland (right side). This figure can also be found in the color insert. (World Ocean Circulation Experiment sections AR7W and A24.)

FIGURE 9.20

Equatorial



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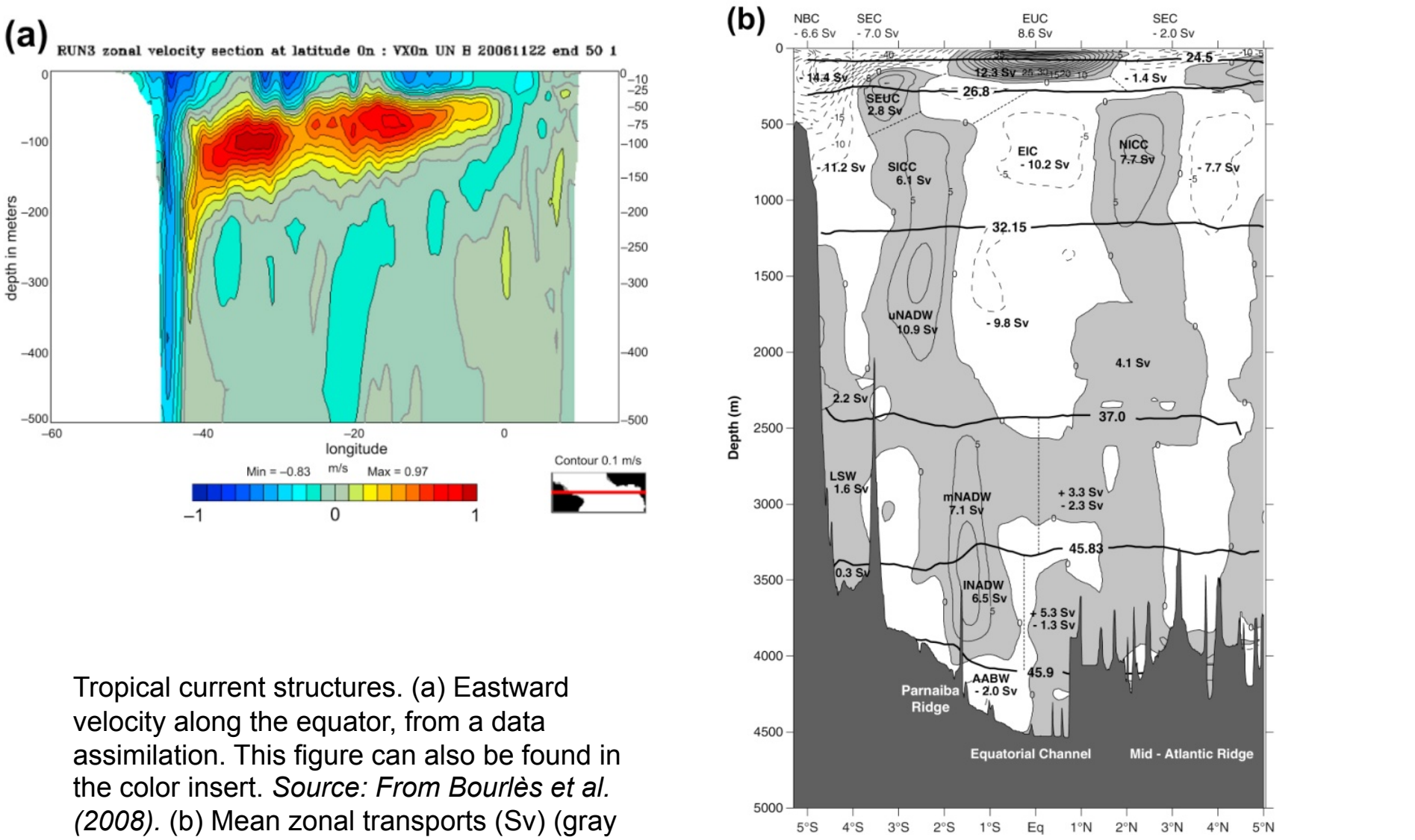
Atlantic Ocean surface circulation schematics. (a) North Atlantic and (b) South Atlantic; the eastward EUC along the equator just below the surface layer is also shown (gray dashed).

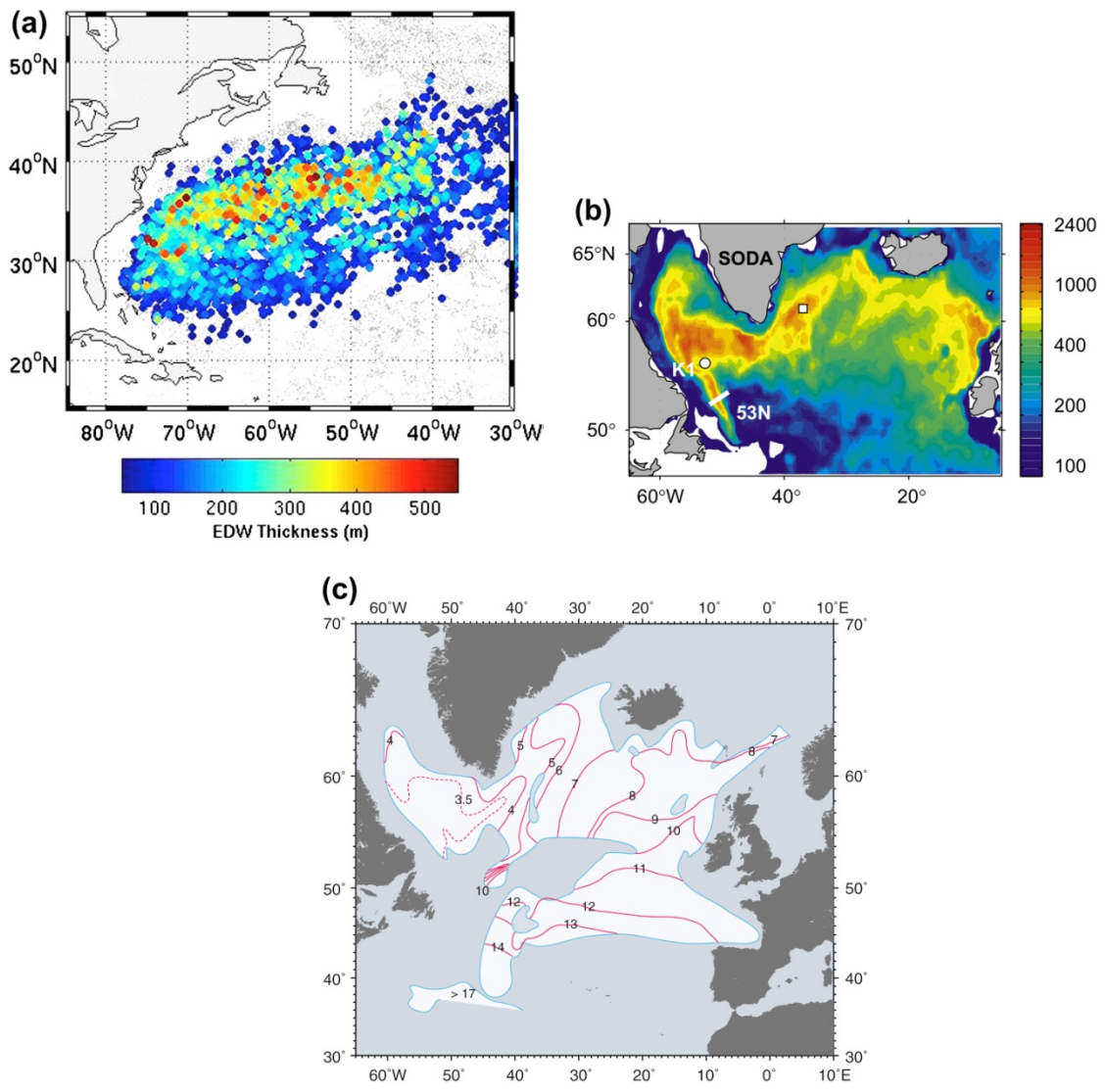


Tropical current structures. (a) Eastward velocity along the equator, from a data assimilation. This figure can also be found in the color insert. *Source: From Bourlès et al. (2008).* (b) Mean zonal transports (Sv) (gray eastward) and water masses at 35°W. *Source: From Schott et al. (2003).*

FIGURE 9.11

TALLEY

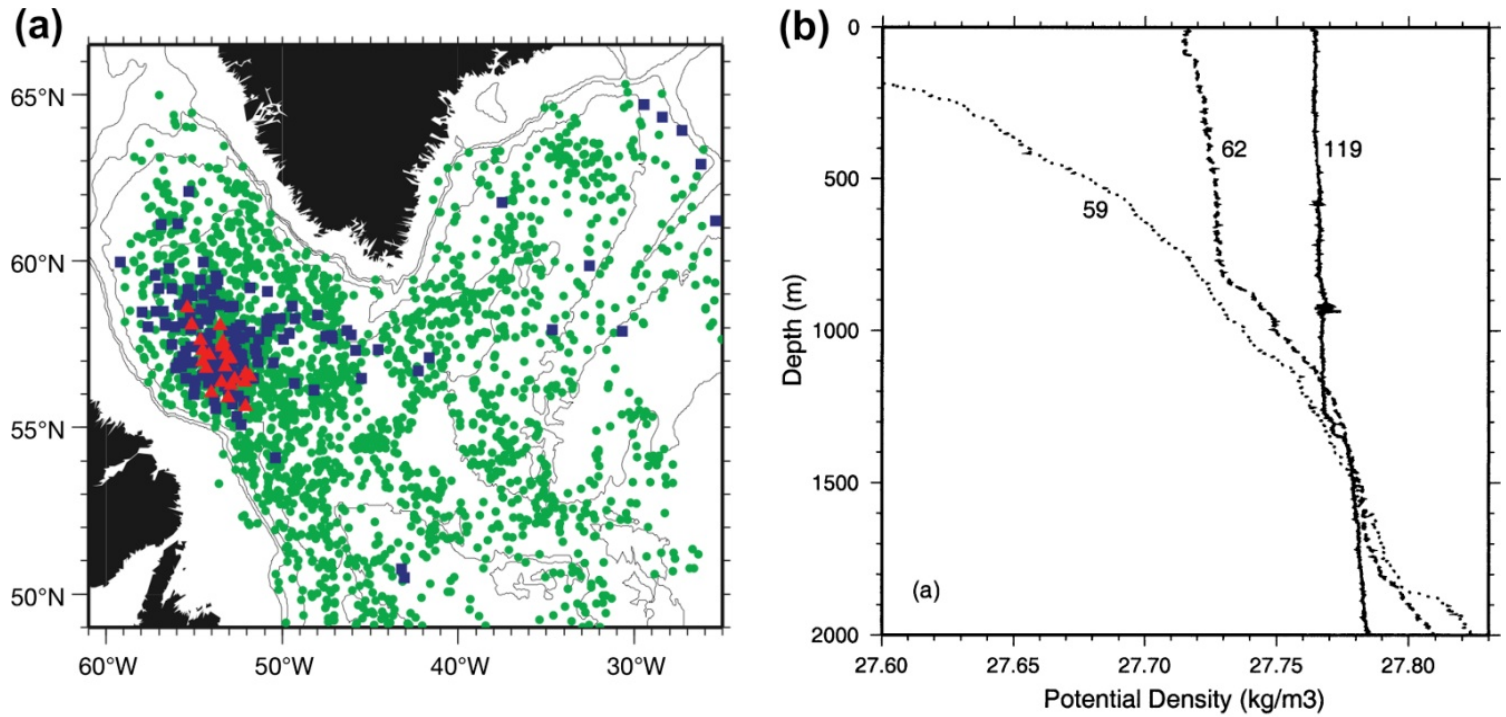
Intermediate Atlantic



Mode waters. (a) EDW thickness from all Argo profiles from 1998–2008. The EDW is defined here by 17ºC ≤ T ≤ 19ºC and dT/dZ ≤ 0.006 ºC/m. The small gray dots in the background indicate profiles without EDW. (*Young-Oh Kwon, personal communication, 2009.*) (b) March mixed layer depth from a data-assimilating model (SODA). *Source: From Schott et al. (2009).* (c) Potential temperature (ºC) of the late winter mixed layer, shown only where the mixed layer is more than 200 m thick. This is the SPMW. *Source: From McCartney and Talley (1982).*

FIGURE 9.19

TALLEY



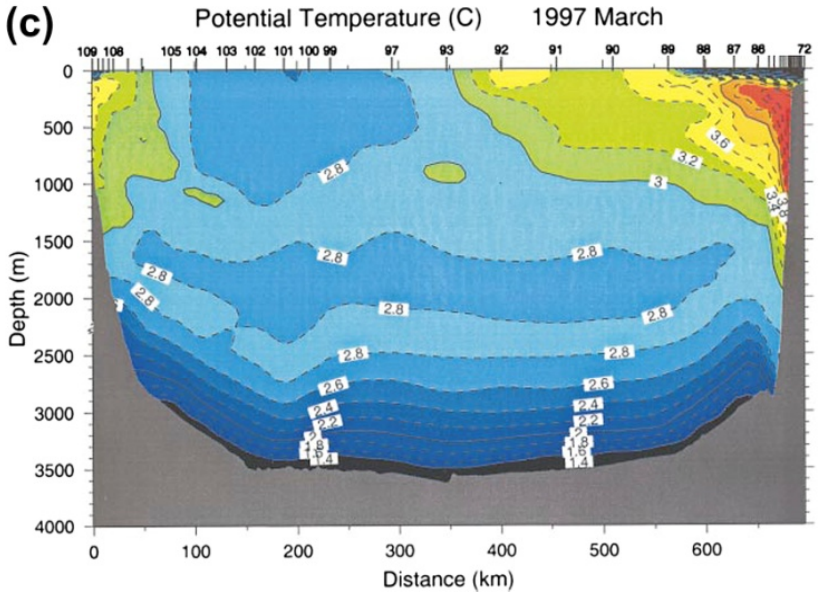
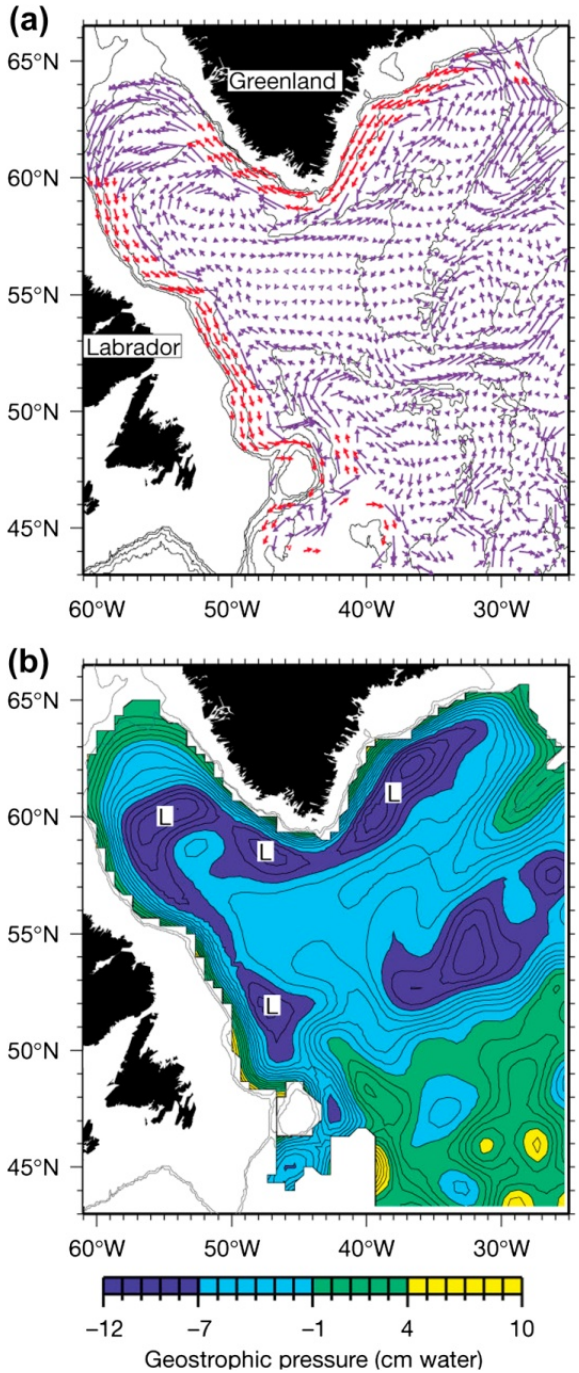


FIGURE S9.31

Labrador Sea Water. (a) Mixed layer depths in winter (1996–1998) from profiling floats. Red: >800 m. Blue: 400 to 800 m. Green: <400 m. *Source: From Lavender et al. (2000).* (b) Potential density profiles from a deep convection region in the Labrador Sea in late winter of 1997 (“119” in the deep convection patch, “62” in a western boundary convection regime, “59” typical of stratified water). (c) Vertical section through the Labrador Sea in late winter 1997 that includes deep convection stations. *Source: From Pickart, Torres, and Clarke (2002).*



Mid-depth Labrador Sea circulation. (a) Velocity (cm/sec) and (b) geostrophic pressure (cm) at 700 m from profiling float observations. *Source: From Lavender, Davis, and Owens. (2000).*

FIGURE S9.18

TALLEY

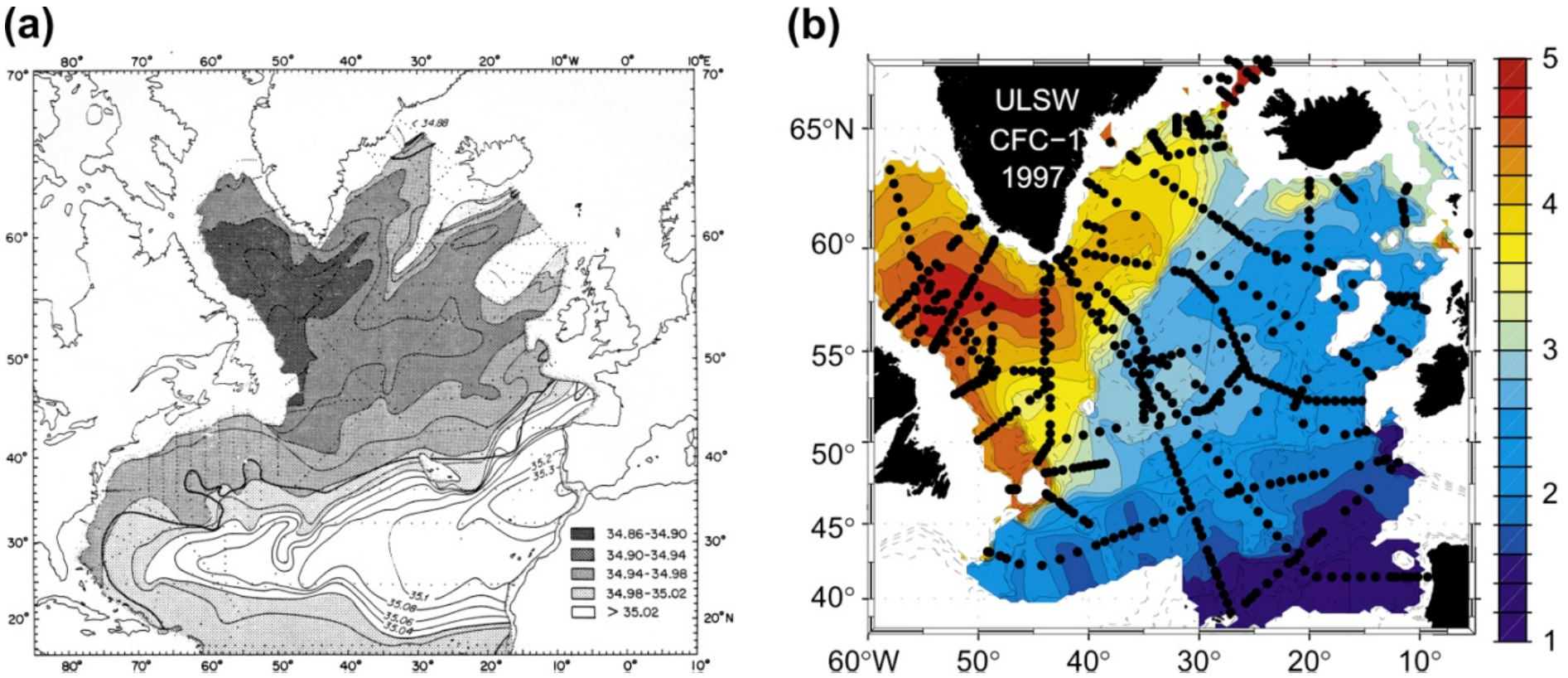


FIGURE 9.21

LSW. (a) Salinity at the LSW potential vorticity minimum. Dark curve is the limit of the PV minimum; salinity on an intersecting isopycnal is shown south and east of this limit. *Source: From Talley and McCartney (1982).* (b) Chlorofluorocarbon-11 (pmol/kg) in the upper LSW layer, at $\sigma_\theta \sim 27.71$ kg/m^3. Figure 9.21b can be found in the color insert. *Source: From Schott et al. (2009) and from Kieke et al. (2006).*