

LESSON 6

UNRAVELING THE GULF STREAM PUZZLE

On a Warm Current Running North

- 1 The way north
- 2 The Gulf Stream: a river in the sea?
- 3 The great merry-go-round
- 4 Winds good and bad
- 5 Variability in space and time
- 6 Currents of the abyss

A mighty ocean current runs north and east offshore from the East Coast, between the Florida Keys and Cape Hatteras (Fig. 6.01).

It moves warm water northward, from the Gulf of Mexico into the northern North Atlantic, on the way entraining warm water from the Sargasso Sea. It is one of the two most powerful warm currents on the planet (1). The heat it transports feeds the storms of the northern Atlantic, and helps maintain low air pressure in the vicinity of Iceland, stabilizing the "Iceland Low." In turn, the anti-clockwise winds running about the Iceland Low direct the heat-bearing marine air and associated rainstorms into northwestern Europe, from the British Isles and the Netherlands to Denmark and Norway.

The origin of this great weather-making current was a mystery well into the 20th century. In the 1940s, it was realized that the current represents the western boundary of the spinning wheel of warm water that is centered on the Sargasso Sea, in the desert belt of the North Atlantic. This wheel is made to spin by winds, but not any winds over the Gulf Stream itself. As long as there are trade winds and westerlies, the great wheel will spin, and the Gulf Stream will move warm water from low to temperate latitudes.

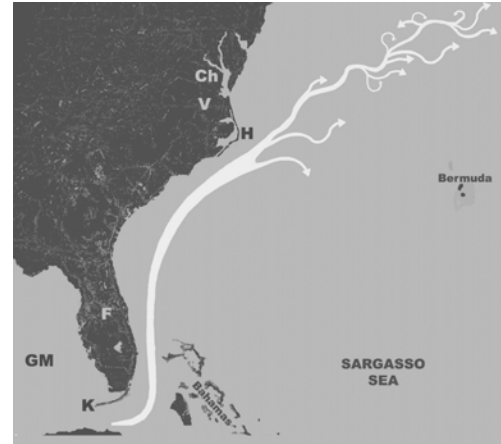


Fig. 6.01. Path of the "Gulf Stream." It starts in the Gulf of Mexico (GM), as the Florida Current south of the Florida Keys (F, K), and leaves the coast east of Cape Hatteras (H) (V, Virginia; Ch, Chesapeake Bay). On leaving the East Coast, the Gulf Stream becomes indistinct, making filaments and eddies.



Fig. 6.02. Flowers in Bergen's City Park, Spring 2002, at the same latitude as southern Greenland and Hudson Bay!

Notes and references

1. The other great warm current is its dynamic sibling, the Kuroshio, running northward from the Philippines to Japan.

Images



Fig. 6.03. Great temperature anomalies: much warmer than latitudinal averages in the North Atlantic, much colder off Peru and Namibia. (After G. Dietrich.)

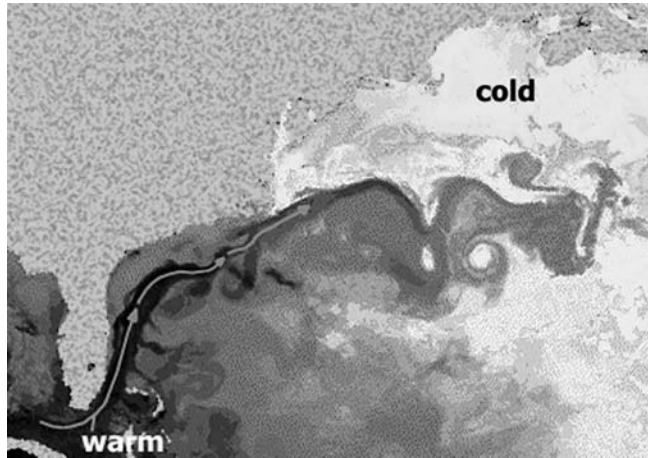


Fig. 6.06. Gulf Stream eddies south of Cape Cod, seen in temperature distributions, from space. Warm eddies are dark.

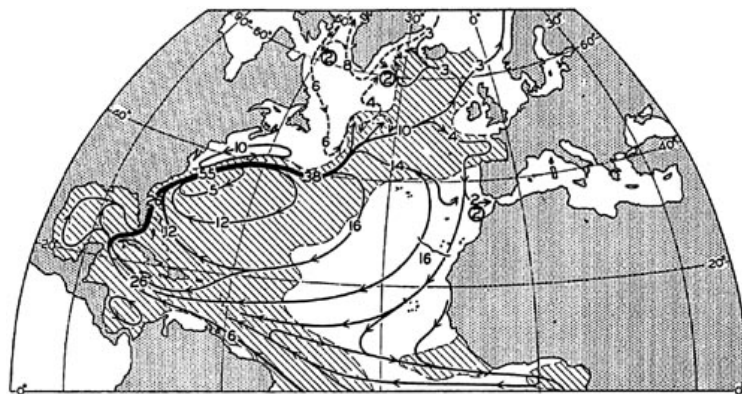


Fig. 6.07. Volume transport in the Gulf Stream System according to Sverdrup (1942), in million cbm per second. Note the asymmetry of the central wheel of currents in the subtropical Atlantic.

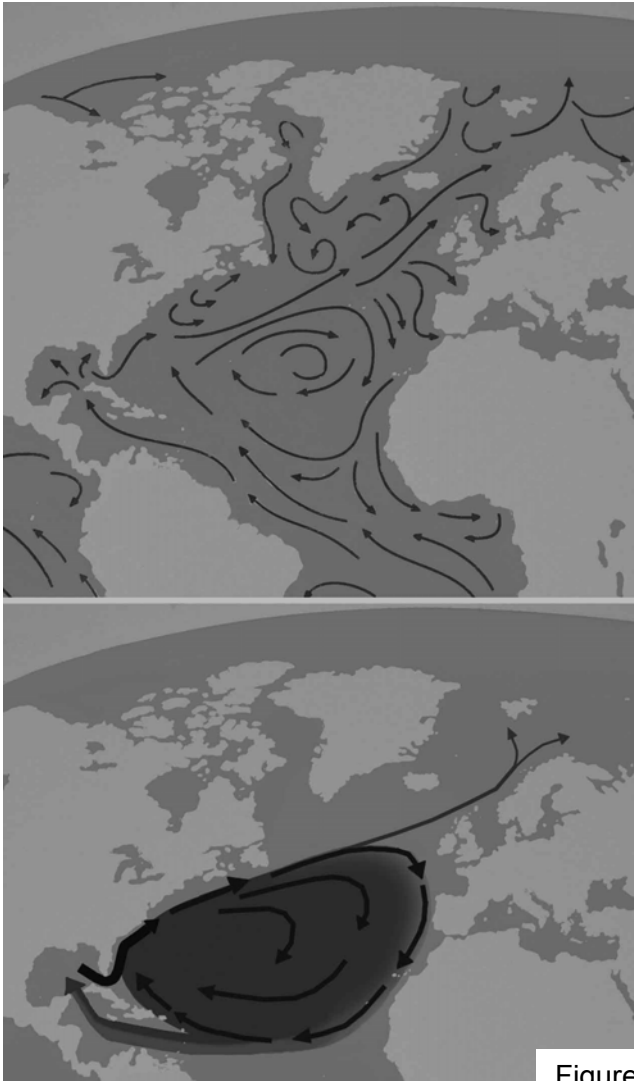


Figure 6.08. Two concepts of the Gulf Stream. Upper: Gulf Stream as part of the heat supply system for northern Europe (from a contemporary museum exhibit, in Europe). Lower: Gulf Stream as part of the great central gyre, with incidental outlier to the north.

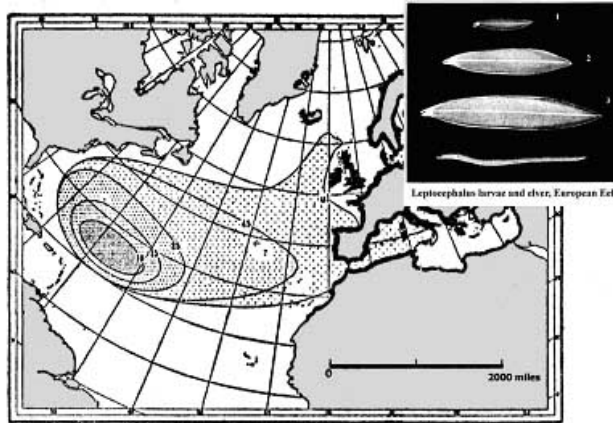


Fig. 6.09. Abundance of larvae of the common European eel in the central subtropical gyre of the North Atlantic.

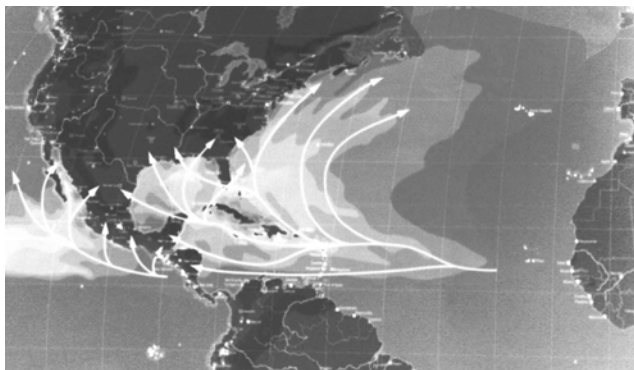


Fig. 6.10. Common paths of tropical storms (after Munich Re, 1998). Light shades of gray indicate high frequency of strong storms. Tropical storms feed on vapor from a warm sea surface. The Gulf Stream provides a warm water path.

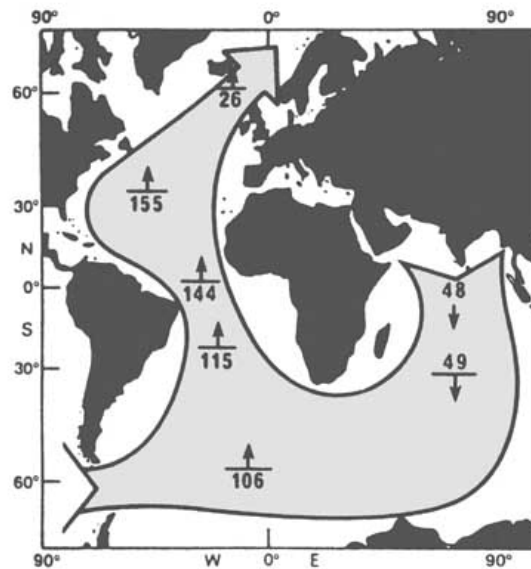


Fig. 6.11. Heat piracy of the North Atlantic, as envisaged by Henry Stommel (in 1980). Shown is the heat transport across latitudes in deca-trillion watts (10^{13} W).

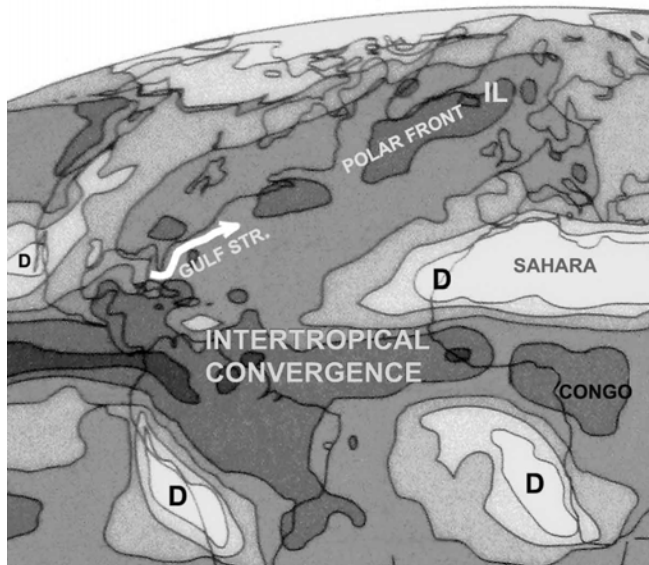


Fig. 6.12. High (dark) and low (white) precipitation regions in and around the North Atlantic (after Schneider). Note that anomalously warm regions (Fig. 6.03) are wet, and cold regions are dry (D).

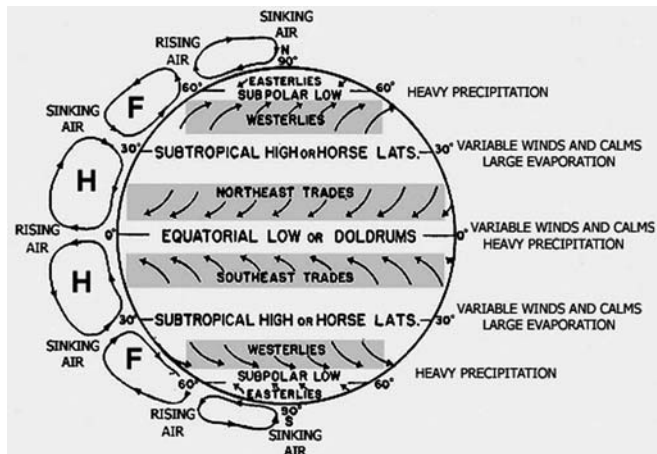


Fig. 6.13. A traditional representation of the global wind system, emphasizing symmetry about the equator: Hadley cells (H), Ferrel cells (F), trades and westerlies. (After Fleming, 1957.)

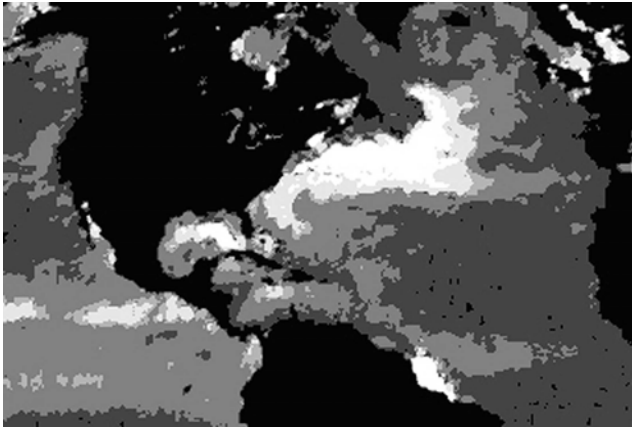
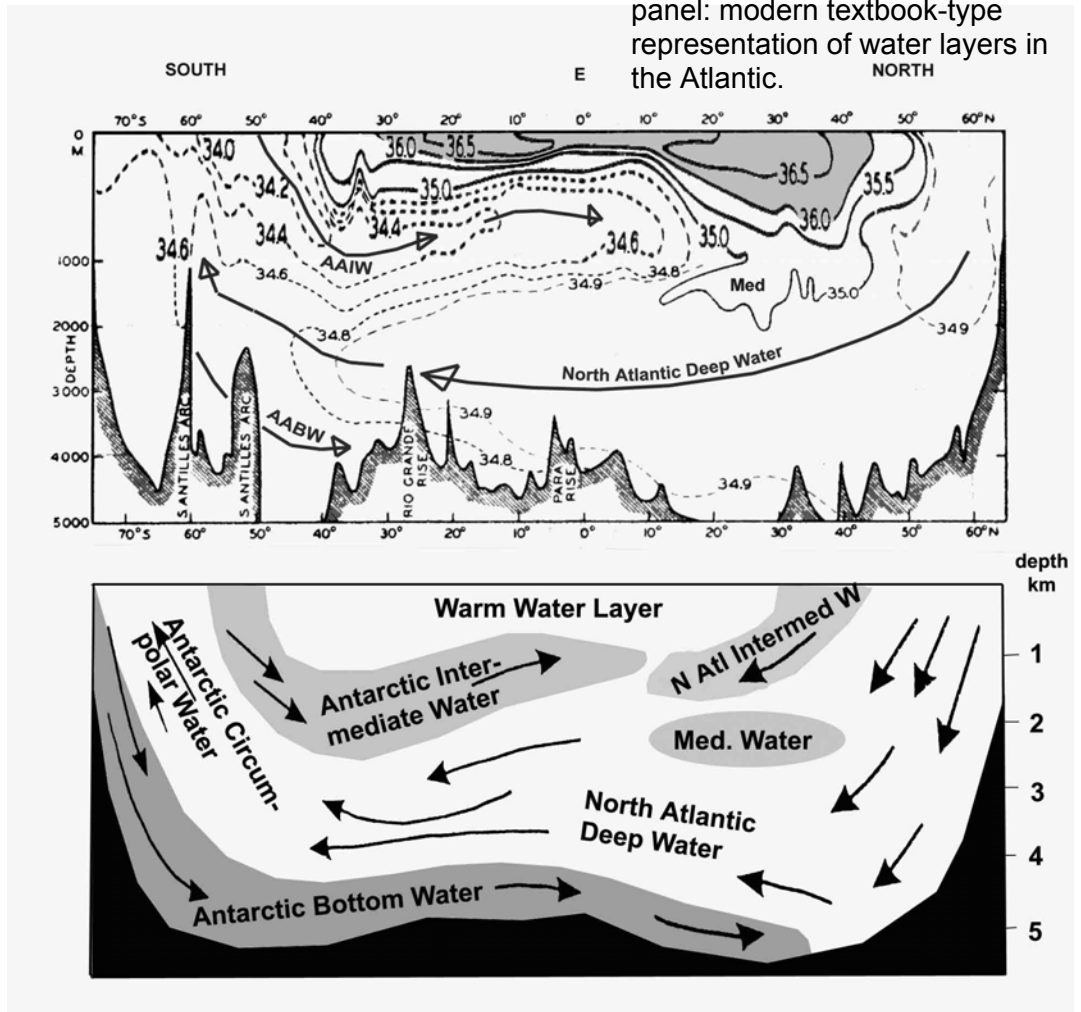


Fig. 6.14. Variability of the sea surface topography, North Atlantic, from TOPEX satellite data (1992-1998). White: most variable.

Fig. 6.15. Stratification of the deep Atlantic, reflecting the various deepwater sources. Top panel: Stratification as seen in salinity, according to Georg Wüst, as given in Sverdrup et al. (1942). Arrows (here added) denote flow direction according to “core method” of Wüst. Labels (here added): AABW, Antarctic Bottom Water, AAIW, Antarctic Intermediate Water. High salinity (>36 permil): dark shade. Note asymmetric distribution of highly saline surface waters. Note change of scale at 1000 m (factor of two, here redrawn). Bottom panel: modern textbook-type representation of water layers in the Atlantic.



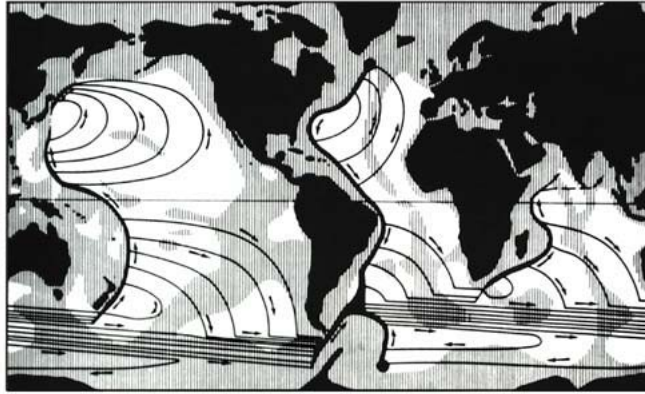


Fig. 6.16. Stommel's solution for deep circulation (1958), based on fixed deepwater sources and including effects from the Earth's rotation. The water sinking at the two equal sources (off Greenland and in the Weddell Sea) is assumed to rise evenly over the entire ocean.

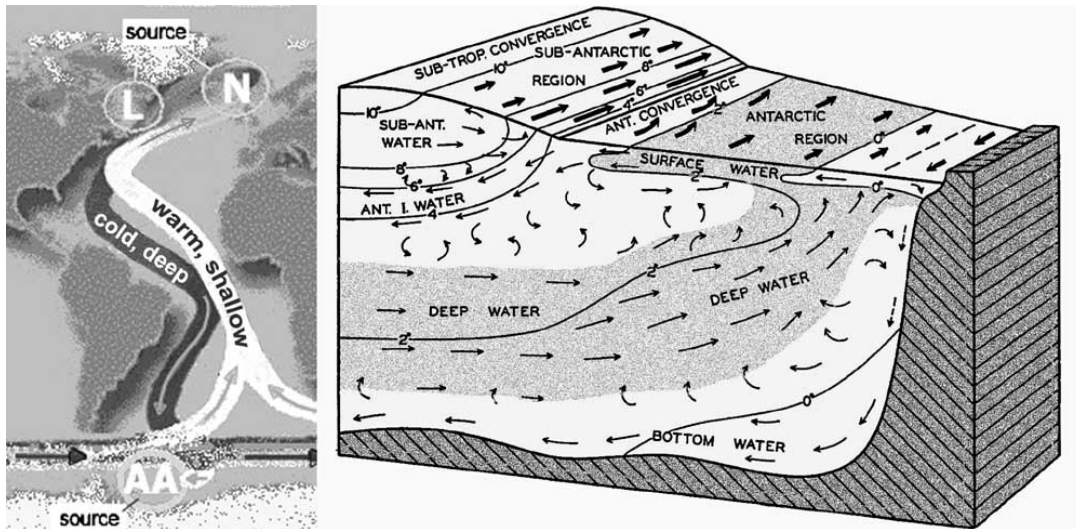


Fig. 6.17. The Atlantic portion of the global deepwater circulation and its link to the Antarctic circumpolar circulation. Left: schematic representation of the North Atlantic heat piracy (shallow water in, deep water out). L, Labrador Sea. N, Nordic Seas. Right: the rise of deep water around the Antarctic continent, as drawn in Sverdrup et al. (1942). The rising of the deep water acts as a long-distance pump on the vertical circulation, and hence for production of North Atlantic Deep Water.



Fig. 6.18. The floating seaweed that gives its name to the Sargasso Sea.

Figure sources (where based on sources in the literature, on the web or in museum exhibits: figures are considerably modified and adapted for present purposes, using Adobe Photoshop; drawings and photographs by the author are marked “orig.”): 1, orig. sketch based, in a general way, on Iselin (1936), Iselin and Fuglister (1948), Sverdrup et al. (1942) (see Ch. 2 for reference), and various satellite images (infrared, NOAA); 2, orig.; 3, Dietrich 1957; 4, Krümmel 1907; 5, Sverdrup et al. 1942; 6, NOAA infrared image; 7, Sverdrup et al. 1942; 8, Universum Museum Bremen (upper) (orig.), and orig.; 9, Russell and Yonge, 1936; 10, Munich Re 1998; 11, Stommel 1980; 12, Legates 1996; 13, Fleming 1957; 14, TOPEX/Poseidon, ERS-1, ERS-2, Space Oceanography Division CLS Toulouse, France; 15, G. Wüst 1935, and orig.; 16, Stommel 1958; 17, NOAA (loop) and Sverdrup et al. 1942; 18, Larousse Dictionary. **References:** C.O'D. Iselin, 1936, *A study of the circulation of the western North Atlantic*, Papers in Physical Oceanography and Meteorology, 4 (4) 1-101; C.O'D. Iselin, F. C. Fuglister, 1948, *Some recent developments in the study of the Gulf Stream*, J. Mar. Res., 7, 317-329; G. Dietrich, 1957, *Allgemeine Meereskunde*. Bornträger, Berlin, 492pp., cited in G. Dietrich, K. Kalle, W. Krauss, G. Siedler, 1975. *Allgemeine Meereskunde, Eine Einführung in die Ozeanographie*. Gebrüder Bornträger, Stuttgart, 593 pp.; O. Krümmel, 1907, *Handbuch der Ozeanographie*, Bd. 1, J. Engelhorn, Stuttgart, 526pp; F.S. Russell and C.M. Yonge, 1936. *The seas, our knowledge of life in the sea and how it is gained*. Frederick Warne, London, 379pp.; H. Stommel, 1980. *Asymmetry of interoceanic fresh-water and heat fluxes*. Proc. Natl. Acad. Sci. USA, Geophysics, 77(5), 2377-2381, cited in J. Woods, 1981. The memory of the ocean. In: A. Berger (ed.), *Climatic Variations and Variability: Facts and Theories*. D. Reidel, Dordrecht, pp. 63-83; D.R. Legates, 1996. *Precipitation*. In: S.H. Schneider (ed.) *Encyclopedia of Climate and Weather*, Oxford Univ. Press, New York & Oxford, pp. 608-612; R.H. Fleming, 1957. *General features of the oceans*. In: J.W. Hedgpeth (ed.) *Treatise on Marine Ecology and Paleoecology* vol. 1, Geol. Soc. America Memoir 67 (1) 87-107; Space Oceanography Division, CLS, in R.E. Cheney, 2001, *Satellite altimetry*, in J.H. Steele, S.A. Thorpe, K.K. Turekian (eds) *Encyclopedia of Ocean Sciences*, v. 5, Academic Press, San Diego, 2504-2510; G. Wüst and A. Defant, 1936. *Atlas zur Schichtung und Zirkulation des Atlantischen Ozeans*. Meteor. Ergebn., 1925-1927, Wissenschaftl. Ergebn. Bd. 6 – Atlas (103 pls.). Berlin, Walter de Gruyter & Co., cited in Sverdrup et al., 1942 (see Ch. 2 for reference); H. Stommel, 1958. *The abyssal circulation*. Deep-Sea Research, 5, 80-82; National Oceanic and Atmospheric Administration, U.S. Department of Commerce; Claude Augé, 1926, *Nouveau Petit Larousse Illustré, Dictionnaire Encyclopédique*, Paris, Librairie Larousse, 1760pp.