

The Benjamin Franklin and Timothy Folger Charts of the Gulf Stream

Philip L Richardson
Woods Hole Oceanographic Institution
Woods Hole, MA 02543
prichardson@whoi.edu
prichardson0981@gmail.com

1 Introduction

In September 1978 I found two prints of the first Franklin-Folger chart of the Gulf Stream in the Bibliothèque Nationale in Paris. Although this chart had been mentioned by Franklin in 1786, all copies of it had been “lost”¹ for many years. The Franklin-Folger chart was not only excellent for its time,² but it remains today a good summary of the general characteristics of the Gulf Stream. Because of its historical role in our understanding of the Stream and in the development of oceanography, I would like to discuss its depiction of the Gulf Stream relative to later charts and recent measurements.

There are three versions of the Franklin-Folger chart; the first was printed in 1769 by Mount and Page in London, the second was printed circa 1780-1783 by Le Rouge in Paris, and a third was published in 1786 by Franklin in Philadelphia. The last is the most widely known and reproduced of the three. However, its projection is different from the first two, and the Gulf Stream has been modified.

Since no copies of the first version had been located, some historians had doubted it had ever been printed (Brown 1938). Indeed, until a print of the first chart was discovered, the oldest known Gulf Stream chart was not by Franklin and Folger but one published by De Brahm in 1772.

¹ A note describing the discovery and showing a facsimile of the whole chart was published by Richardson (1980). A third print was subsequently discovered (1979) by Louis de Vorsey in the Naval Library, London.

² A description of the early ideas and charts of the Gulf Stream are given by Pillsbury (1891), Stommel (1958), and Deacon (1971). The following three papers describe the history and significance of the Franklin-Folger charts: Bache (1936), Brown (1951), and De Vorsey (1976).

2 Background

While Benjamin Franklin was in London as Deputy Postmaster General for the American colonies (1764-1775) he was consulted as to why mail packets sailing from Falmouth, England to New York were taking weeks longer than merchant ships traveling from London to Rhode Island. In October 1768 Franklin discussed this problem with his cousin Timothy Folger, a Nantucket ship captain with an intimate knowledge of the Gulf Stream then in London. Folger sketched the Stream on a chart and added written direction on how to avoid it when sailing from England to New England. Franklin then forwarded the chart to Anthony Todd, Postmaster General, with an accompanying letter dated “Craven Street, October 29, 1768” (Brown 1951).

Discoursing with Captain Folger a very intelligent Mariner of the Island of Nantuckett in New England concerning the long passages made by some Ships bound from England to New York I received from him the following Information Viz^t

That the island in which he lives is Inhabited Chiefly by people concerned in the Whale Fishery, in which they employ near 150 Sail of Vessels, that the Whales are found generally near the Edges of the *Gulph Stream*, a strong Current so called which comes out of the Gulph of Florida, passing Northeasterly along the Coast of America and turning off most Easterly running at the rate of 4, 3-1/2, 3 & 2-1/2 Miles an Hour; that the Whaling Business leading these people to Cruise along the Edges of the stream in quest of Whales, they are become better acquainted with the Course, Breadth, Strength and extent of the same, than those Navigators can well be who only cross it in their Voyages to and from America, that they have opportunities of discovering the strength of it when their Boats are out in pursuit of this Fish, and happen to get into the Stream while the Ship is out of it, or out of the stream while the ship is in it, for then they are separated very fast, and would soon lose sight of each other if care were not taken, that in Crossing the Stream to and Fro' they frequently in the same meet and speak with Ships bound from England to New York, Virginia & c^a, who have passages of 8, 9, & 10 weeks, and are still far from Land, and not likely to be in with it for some time, being engaged in that part of the stream that sets directly against them, and it is supposed that their fear of Cape Sable Shoals, Georges Banks or Nantuckett Shoals, hath induced them to

keep so far to the Southward as unavoidably to engage them in the said Gulph Stream, which occasions the length of their Voyage, since in a Calm it carrie's them directly back, and tho' they may have fair Winds, yet the Current being 60, 70 Miles a day, is so much subtracted from the way they make thro' the Water; At my request Captain Folger hath been so obliging as to mark for me on a Chart, the Dimensions Course and Swiftness of the Stream from its [sic] first coming out of the Gulph, where it is narrowest and strongest; till it turns away to go to the Southward of the Western Islands, where it is Broader and Weaker, and to give me withall some written directions whereby ships bound from the Banks of Newfoundland to New York may avoid the said Stream, and yet be free of danger from the Banks and Shoals abovementioned. As I apprehend that such a Chart and directions may be of use to our Packets in Shortening their Voyages, I send them to you that if their Lordships should think fit, so much of the Chart as is contain'd within the red Lines may be engraved and printed, together with the remarks at the Charge of the Office; or at least that Manuscript Copies may be made of the same for the use of the Packets. The expence of the former would not much exceed the latter, and would besides be of general service, with much esteem I am &c B. Franklin.

The Franklin-Folger chart was printed by Mount and Page in London in February 1769 (see Cohn 2000). In March 1775 Franklin left London and sailed for home. The next year he was sent as an envoy to Paris to negotiate a treaty with the French government. During his two transatlantic crossings in 1775 and 1776 Franklin measured the temperature of the Gulf Stream and discovered that it was warmer than the water on either side (Franklin 1786). The discovery rekindled his enthusiasm for the Gulf Stream chart, and he had it copied and printed by Le Rouge after he arrived in Paris. Franklin no doubt wanted to provide copies of the chart to ships sailing from France to the American colonies. Cohn (2000) has carefully studied Franklin's correspondence and concludes that the Le Rouge version was printed sometime between September 1780 and April 1783 and that it was produced for French merchant and packet captains in the months following the end of the American War of Independence.

In 1785 Franklin, then 79 years old, sailed back to America from France on the London packet and wrote his "Maritime Observations" published in 1786. Included in this paper is the third and best-known version of the Franklin-Folger charts and a review of its history:

About the year 1769 or 70, there was an application made by the board of customs at Boston, to the lords of the treasury in London, complaining that the packets between Falmouth and New-York were generally a fortnight longer in their passages, than merchant ships from London to Rhode-Island, and proposing that for the future they should be ordered to Rhode-Island instead of New-York. Being then concerned in the management of the American post-office, I happened to be consulted on the occasion; and it appearing strange to me that there should be such a difference between two places, scarce a day's run asunder, especially when the merchant ships are generally deeper laden, and more weakly manned than the packets, and had from London the whole length of the river and channel to run before they left the land of England, while the packets had only to go from Falmouth, I could not but think the fact misunderstood or misrepresented. There happened then to be in London, a Nantucket sea-captain of my acquaintance, to whom I communicated the affair. He told me he believed the fact might be true; but the difference was owing to this, that the Rhode-Island captains were acquainted with the gulf stream, which those of the English packets were not. We are well acquainted with the stream, says he, because in our pursuit of whales, which keep near the sides of it, but are not to be met with in it, we run down along the sides, and frequently cross it to change our side: and in crossing it have sometimes met and spoke with those packets who were in the middle of it, and stemming it. We have informed them that they were stemming a current, that was against them to the value of three miles an hour; and advised them to cross it and get out of it; but they were too wise to be counselled by simple American fishermen. When the winds are but light, he added, they are carried back by the current more than they are forwarded by the wind: and if the wind be good, the subtraction of 70 miles a day from their course is of some importance. I then observed that it was a pity no notice was taken of this current upon the charts, and requested him to mark it out for me, which he readily complied with, adding directions for avoiding it in sailing from Europe to North-America. I procured it to be engraved by order from the general post-office, on the old chart of the Atlantic, at Mount and Page's, Tower-Hill; and copies were sent down to Falmouth for the captains of the packets, who slighted it however; but it is since printed in France, of which edition I hereto annex a copy.

3 Observations of the Gulf Stream

Franklin, in his own hand, notes some of the data that went into the chart—the position of whales along the edges of the current and the drift of boats and ships in it. Each captain kept records of his whale catches, and because of the tendency of whales to keep to the sides of the Stream, a plot of the whale catch gave limits of the Stream. Franklin notes that the velocity in the Stream was determined when a ship was out of the Stream and boats pursuing whales happened into it. The rate of separation between the ship and boat gave the velocity of the current

Another method that might have been used to measure the speed of the Gulf Stream was to lower a weighted line from a whaleboat. The deep portion of the line acts as an anchor and the surface current flowing past the boat can be measured (Williams 1793, Truxtun 1794).

By 1768, captains like Timothy Folger accumulated considerable knowledge of the Gulf Stream. Of the nearly 150 Nantucket vessels employed in the whale fishery, nearly half were in the Gulf Stream region (Stackpole 1953). As their livelihood was strongly influenced by it, whalers were observant of ocean currents, and their observations were rapidly exchanged, both at sea and at home. The oceanographic knowledge of the Nantucket men was seldom written down and much of it has been lost. Fortunately, we have a rare summary of it in the Franklin-Folger charts of the Gulf Stream.

4 The Franklin-Folger Charts of the Gulf Stream

The 1769 Mount and Page Chart

Two prints of the Mount and Page chart, unknown for many years, were found by the author in the Department des Cartes et Plans of the Bibliothèque Nationale in Paris.³ An enlargement of the northwestern part of one is given in Fig. 1. The Stream is shown as a series of short dashed lines, perhaps the quick modification of an earlier plate. Superimposed on it are

³ Address of the Bibliothèque Nationale is: 58 rue Richelieu, 75084 Paris Cedex 02. The charts are identified on the photographic images as follows: 10922, Portefeuille 117, Division 0, Pièces 7 and 7': Mount and Page: A New and Exact Chart. One of these charts (7) was obtained in 1988 from the Bibliothèque Nationale by the United States Library of Congress.

arrows and speeds in agreement with those listed in Franklin's 1768 letter to Todd, except that the units in the letter to Todd are miles per hour: "4 minutes" off present South Carolina, "3-1/2" east of Cape Hatteras, "3" south of Cape Cod, "2-1/2" south of Nova Scotia and south of Newfoundland. Also superimposed on the Gulf Stream is a sailing vessel cleverly taking advantage of the favorable current.

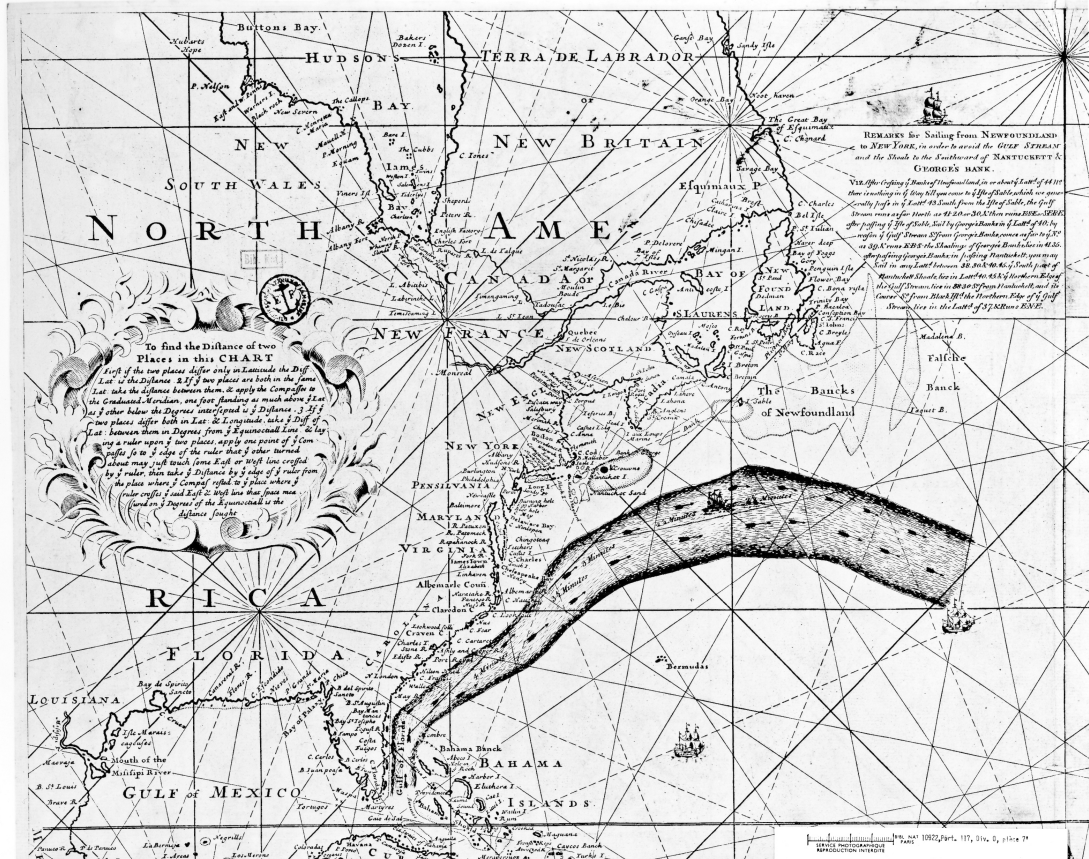


Figure 1. The Franklin-Folger chart of the Gulf Stream printed by Mount and Page in London in 1769. This illustration is the northwestern part of the much larger base chart.

The Gulf Stream begins in the Straits of Florida and runs northward with its left edge near the edge of the continental slope. After passing Cape Hatteras, it moves away from the coast, keeping a distance of 100 km from George's Banks and 120 km from the Grand Banks of Newfoundland. It reaches its northernmost latitude, $41^{\circ} 40' N$, south of Sable Island near

57°W⁴ and then runs southeastward. The width of the Stream increases from about 140 km off Florida to 475 km south of Sable Island, and then it narrows to about 420 km at its eastern end near 44°W.

On the chart to the east of Newfoundland are instructions on how to avoid both Stream and banks and shoals when sailing westward as mentioned in Franklin's 1768 letter to Todd.

The 1780-1783 Le Rouge Chart

The second version (Fig. 2) of the Franklin-Folger chart, printed by Le Rouge in Paris, is an exact copy of the northwestern part of the Mount and Page chart. The two are on the same scale, and when overlaid, the main features—land, islands, Gulf Stream—coincide exactly. The details are identical down to the placement of the current arrows, the speeds and the decorative ships.

A few minor differences between the charts are worth pointing out: (1) Le Rouge's is much the most attractive of the three Franklin-Folger versions. Numerous delicate lines run parallel to the current and new lines are added at the center where it widens. The edge of the Stream has been modified slightly and has small amplitude waves along it.

The "Remarks" on the Le Rouge chart are similar to those found on the Mount and Page chart, but they have been translated into French. The only significant change in text is the elimination of the words "Gulf Stream" and their replacement by the word "Courrant."

⁴ The prime meridian falls through Lizard Point, which is on the southwestern coast of England and 5.2° in longitude west of Greenwich. Hence it is necessary to add 5.2° longitude to the values of the chart to make them agree with present-day longitudes, and this has been done in this paper.

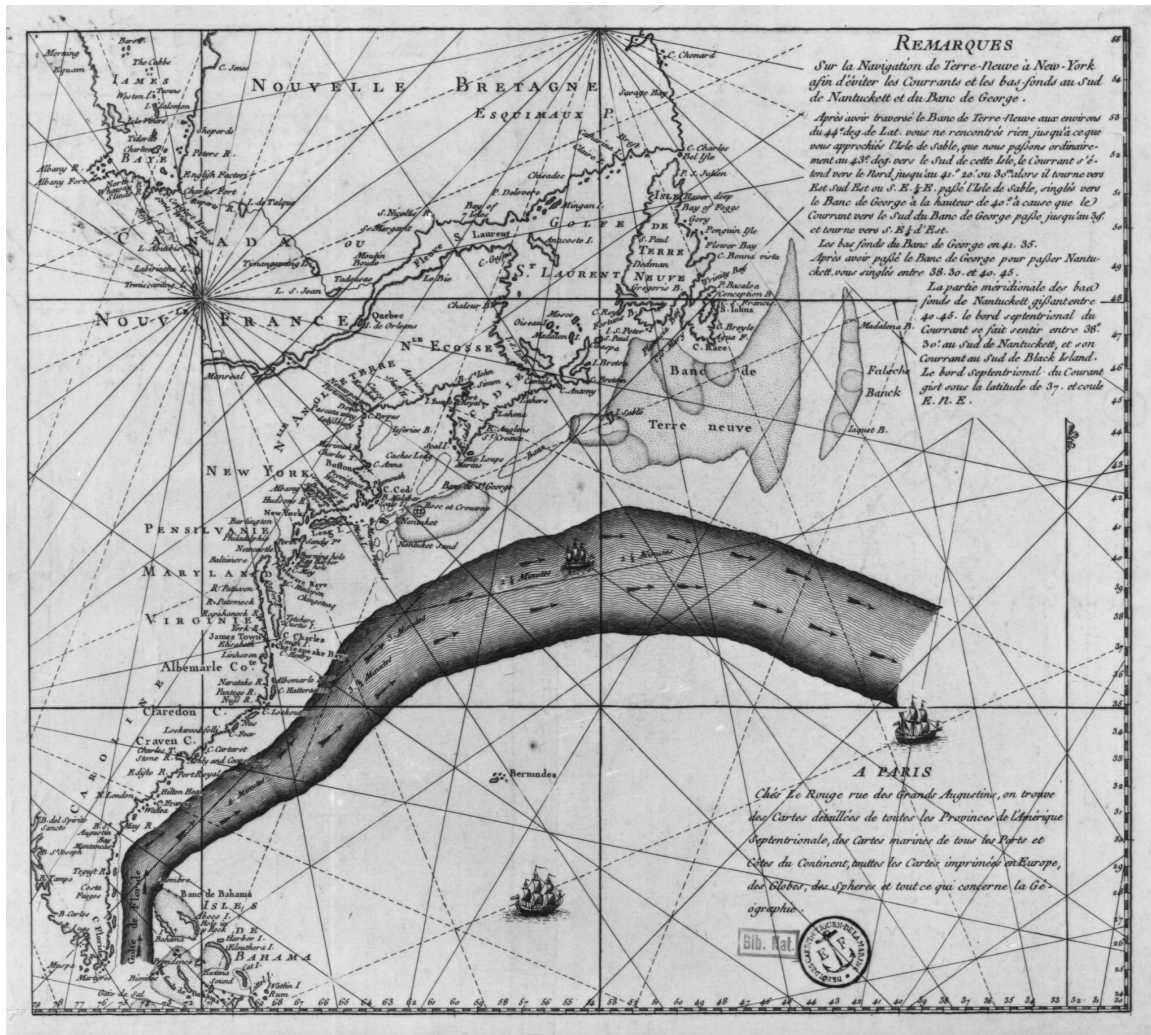


Figure 2. The Le Rouge version of the Franklin-Folger Gulf Stream chart printed in Paris circa 1780-1783.

The 1786 Poupard Chart

The third version (Fig. 3) of the Franklin-Folger chart, engraved by James Poupard, was published in Philadelphia as a figure in Franklin's 1786 article. On this chart the Gulf Stream has much the same character as on the earlier versions, but a close look reveals some important differences. The chart has a different projection; meridians are not parallel, and in many places in North America they are several degrees in error even after adding the 5.2° longitude effect. Bermuda is shown south of Long Island rather than south of Nova Scotia. Because he used a different projection, Poupard was not able to trace the Le Rouge chart. In transferring the Gulf Stream he made several changes. The Stream is 400 km at its widest point, narrower than

shown on the earlier charts, and it flows within 20-25 km of George's Banks. This small passage between shoals and Stream must have discouraged navigators. The current arrows and speeds were drawn at roughly the same location but "2 minutes" has been added south of Newfoundland.

R E M A R K S

Upon the Navigation from

NEWFOUNDLAND to NEW-YORK,

In order to avoid the

GULPH STREAM

On one hand, and on the other the Shoals that lie to the Southward of

Nantucket and of St. George's Banks.

AFTER you have passed the Banks of Newfoundland in about the 44th degree of latitude, you will meet with nothing, till you draw near the Isle of Sable, which we commonly put in latitude 43°. Southward of this Isle, the current is found to extend still as far North as 42° or 35', then it turns towards the E. S. E. or S. E. ½ E.

Having passed the Isle of Sable, shape your course for the St. George's Banks, so as to put them in about latitude 40°. Beside the current Southward of those banks reaches as far North as 39°. The Banks of those banks lie in 44° 35'.

After having passed St. George's Banks, you must, to clear Nantucket, form your course so as to pass between the latitudes 38° 30' and 40° 45'.

The most Southern part of the Banks of Nantucket lie in about 40° 45'. The Northern part of the current directly to the South of Nantucket is felt in about latitude 38° 30'.

By observing these directions and keeping between the Stream and the Banks, the passage from the Banks of Newfoundland to New-York, Delaware, or Virginia, may be considerably shortened; for so you will have the advantage of the eddy current, which moves contrary to the Gulf Stream. Whereas if to avoid the Banks you keep too far to the Southward, and get into that Stream, you will be retarded by it at the rate of 60 or 70 miles a day.

The Nantucket whaler-men being extremely well acquainted with the Gulf Stream, its course, strength and extent, by their constant practice of whaling on the edges of it, from their Island quite down to the Bahamas, this draft of that Stream was obtained from one of them, Capt. Folger, and caused to be engraved on the old chart in London, for the benefit of navigators, by

B. FRANKLIN.

Note, The Nantucket captain who is acquainted with this Stream, makes their voyage from England to Boston in as short a time generally as others who are going from Boston to England, viz. from 20 to 30 days.

A Stranger may know when he is in the Gulf Stream, by the warmth of the water, which is much greater than that of the water on each side of it. If then he is bound to the westward, he should cross the Stream to get out of it as soon as possible.

B. F.

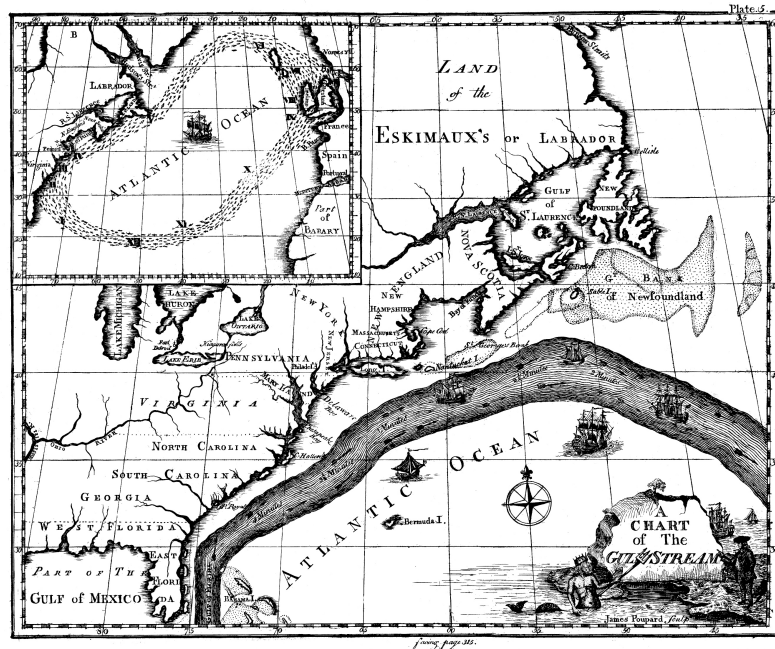


Figure 3. The Poupard version of the Franklin-Folger Gulf Stream chart published in Philadelphia in 1786 with Franklin's "Maritime Observations."

Poupard added several decorative ships, one of which is stemming the Gulf Stream. Franklin must have been amused by this and by the inset in the lower right corner showing himself in discussion with Neptune. The inset in the upper left hand corner is a chart of the migration of herring, an illustration for a paper by John Gilpin (1786). Some viewers of the inset chart mistakenly interpret the herring migration as a large-scale current system in the North Atlantic.

The familiar "Remarks" on the left side of the chart on how to avoid the Gulph Stream have been clarified and the words "Gulf Stream" appear in the title. Franklin added several comments that were not present earlier: (1) he repeats his description of how the map came into existence, much as in the letter to Todd and in his 1786 paper, and (2) he mentions an "eddy current, which moves contrary to the Gulf Stream" located between the Stream on

the south and the shoals to the north, which is in agreement with recent observations of the currents there.

Two Bizarre Reproductions of the 1786 Chart

Franklin's 1786 paper and the accompanying Gulf Stream chart were very popular and were reprinted many times. Usually the chart was carefully and accurately copied, but there are some exceptions. These differ markedly

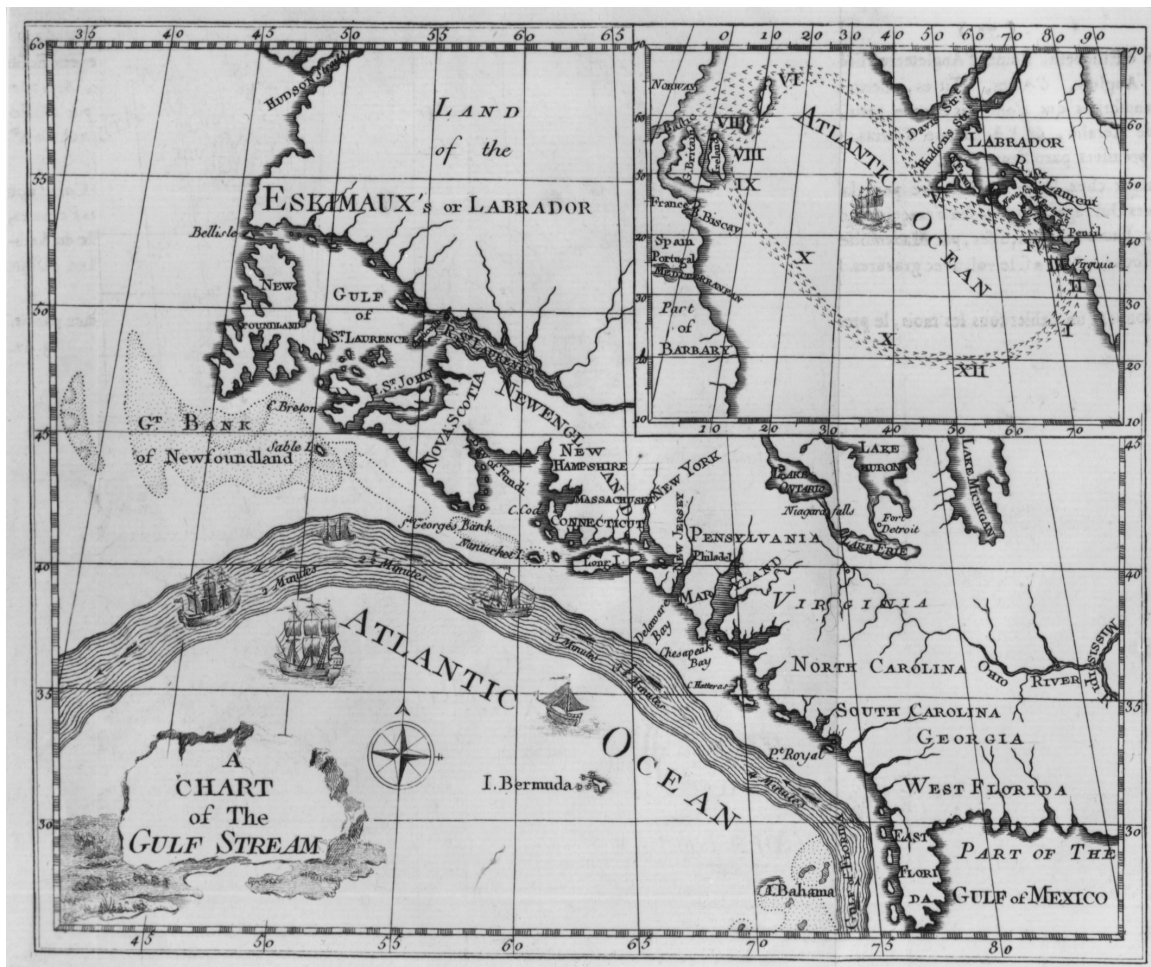


Figure 4. A chart included with a French reprint (Franklin 1787) of Franklin's Maritimes Observations paper.

from the original and illustrate the evolution of charts that were successively copied. These also serve as a reminder that it is important to use original sources. The first (Fig. 4) which appeared in a French translation of Franklin's article (Franklin 1787) is a mirror image of the 1786 chart, a

bottom view of the Gulf Stream in which its width has been decreased, continuing the trend begun by Poupard. The second (Fig. 5) is included in

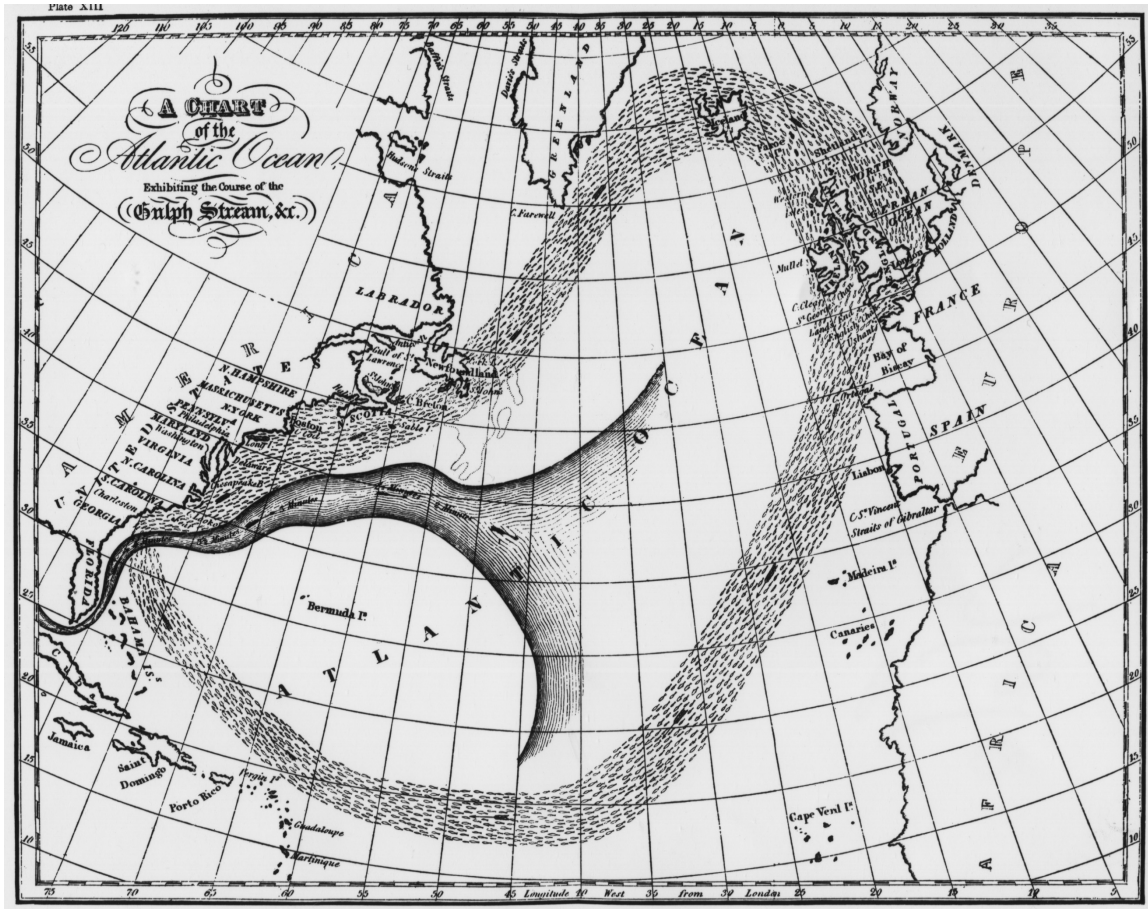


Figure 5. A chart included with Smyth's (1906) reprint of Franklin's Maritime Observations paper.

Smyth's (1906, Vol. IX) copy of Franklin's article, and combines the Gulf Stream path and Gilpin's herring migration pattern on the same chart. A fish tail has been added to the Gulf Stream which continues eastward from the longitude where the Franklin-Folger chart stops and divides into two nearly equal branches, one flowing northeastward toward 49°N 30°W, the other southwestward toward 23°N 45°W. Since Franklin wrote that the Gulf Stream flowed south of the Azores, Smyth certainly did not get his ideas from Franklin.

The origin of the fish tail can be traced to Duane (1808) who constructed it based on the suggestions of Volney (1804) who cites Strickland (1802). Strickland measured warm surface temperatures northeast of the Grand Banks and concluded that a branch of the Gulf Stream flows northeastward and that it probably continues entirely across the Atlantic until it ultimately strikes the coast of Ireland and the Hebrides. Evidently Smyth (1906) copied the chart given by Sparks (1838) who had copied Duane's (1808) chart.

5 Comparison with Other Early Charts of the Gulf Stream

Before 1769 charts of the Atlantic indicated only the most rudimentary and bizarre features such as major surface currents crossing in mid-ocean or ending abruptly at sea coasts. The Franklin-Folger chart was a major improvement and it served as a basis for all but one subsequent 18th century chart of the Stream. Pownall (1787) clearly acknowledges Franklin, and incorporated several of Franklin's notes and corrections in his paper and chart. The Gulf Stream is similar to Franklin and Folger's but it continues southeastward, extending entirely across the Atlantic and intersecting Africa. Current arrows show the main circulation of the Atlantic so as to almost vanish as it approaches the African coast.

Jonathan Williams (1793, 1799) and Captain Thomas Truxtun (1794), both on Franklin's last cruise in 1785, published charts with the familiar Franklin-Folger Gulf Stream. Williams included sea surface temperatures that he had measured and added arrows indicating countercurrents measured by ship drift on both sides of the Gulf Stream (Williams 1799).

The only Gulf Stream chart made independently of Franklin and Folger during this period was published by De Brahm in 1772 (see Brown 1938, De Vorse 1976). During a trip to England in 1771 De Brahm tracked the Gulf Stream from off Charleston, South Carolina to 39° N, a distance around 1000 km. From 39°N he extrapolated the Gulf Stream northeastward until it joined near 46°N 35°W another current setting southeastward. The two currents continued southeastward, passed north of the Azores and made a large clockwise turn first southward then southwestward. De Brahm's chart was the first recorded attempt to follow and plot the path of the Gulf Stream; it also shows the width of the Stream to be about 100 km, very close to the generally accepted instantaneous width today. However, De Brahm's Gulf Stream is plotted too far north and crosses Georges Bank and the Grand Banks of Newfoundland. On his chart De Brahm shows the Stream to run

along the southern edge of the Newfoundland Banks which he incorrectly plotted nearly 9° west and 1° north of its real position. The incorrect location of the Stream flowing over or against the banks could have mislead mariners and might have caused those sailing westward to deviate their course southward and into the real position of the Stream.

The next two significant improvements in charting the Gulf Stream were by Rennell (1832) and Iselin (1936). Rennell plotted and analyzed a great many ship drift observations of currents. These were based on accurate navigation made possible with chronometers. As can be seen in Rennell's charts and in his description, the Gulf Stream's complex structure such as meanders, eddies, and countercurrents began to be recognized.

During the 19th century the subsurface temperature structure of the Stream began to be measured; the strong temperature gradient across the Stream gave its position. Because these observations were difficult and time consuming it was only quite recently that Iselin (1936) accumulated a sufficient number to make a good chart of the Stream.

6 Comparison with Recent Charts of the Gulf Stream

The Franklin-Folger 1769 chart shows a combination of mean and instantaneous measurements of the Gulf Stream that agrees well with modern measurements. The current vectors superimposed on the Stream are typical instantaneous speeds found in the high velocity part of the current. These high speeds are much greater than the mean speed of the surface currents, which is on the order of one-half knot because the Stream meanders and an average includes low speeds as well as high speeds. All but one of the speeds are written where the high speed axis exists north of the Stream's centerline. The chart also shows the mean limits of the Gulf Stream, the region covered by its meanders. Modern observations of the meanders (Niiler and Robinson 1967, Hansen 1970) indicate that they increase in amplitude towards the east as shown by Franklin and Folger; south of Sable Island where the Stream crosses the New England Seamounts, particularly large meanders are formed (Fuglister 1963, Richardson, Wheat and Bennett 1979).

Franklin and Folger show the Gulf Stream reaching its northern limit at the longitude of Sable Island and from here flowing southeastward to 44°W, where the drawing of the Stream stops. What happens to the Gulf Stream

after it reaches 44°W was apparently not well known to Folger or too difficult to draw. In his 1768 letter to Todd, Franklin wrote that the Gulf Stream flows “to the southward of the Western Islands [Azores], where it is Broader and Weaker.” Even today the circulation at the eastern terminus of the Gulf Stream and the pathways of its recirculation are poorly understood and subject to considerable debate. Does the Gulf Stream sweep around the North Atlantic in a broad, sluggish gyre with a major part of the Stream flowing northeastward into the Newfoundland Basin (Iselin 1936, Sverdrup, Johnson and Fleming 1942, Stommel 1958), or is all the Gulf Stream water recirculated to the southwest in a tight gyre (Worthington 1976)?

At least three modern, independent, circulation schemes exist that look very similar to the eastern part of the Franklin-Folger Gulf Stream: (1) Worthington (1976) shows the Stream gradually decreasing in transport as it flows southeastward toward 35°N 42°W, flow lines of the Stream peel off from the main current and circulate toward the southwest; (2) Mann (1967) shows the Gulf Stream flowing toward 38°N 44°W where it splits, approximately half the water flowing northeastward and half southward; (3) paths of numerous free-drifting buoys moving eastward in the Stream rapidly fan out near 44°W, some buoys moving northeastward, some continuing southeastward and others moving southward and westward (Kirwan, McNally and Coehlo 1976, Richardson, Wheat and Bennett 1979). In short, we can say that the Franklin-Folger chart of the Gulf Stream is in agreement with modern oceanographic measurements.

Acknowledgements

This paper was presented at the Third International Congress on the History of Oceanography held September 22-26, 1980, at the Woods Hole Oceanography Institution, Woods Hole, Massachusetts, on the occasion of the fiftieth Anniversary of the founding of the Institution. The paper was published in *Oceanography: The Past*, 1980, Sears, M. and Merriman, D. (Editors) Springer-Verlag, New York, pp. 703-717, and is Contribution No. 4263 from the Woods Hole Oceanographic Institution. The present version was modified from the original in 2016 and includes a few corrections, additions, and more accurate dates of the first two Franklin-Folger charts as described by Ellen R. Cohn (2000).

I thank F. C. Fuglister, who suggested to me that the Franklin-Folger map of the Gulf Stream was a very good summary of the Stream, and who spent many hours discussing various aspect of the Stream with me. The librarians at the Bibliothèque Nationale in Paris were very helpful in my search for the Mount and Page and Le Rouge charts. Funds for this work were provided by the Office of Naval Research under contract N00014-74-C-0262, NR 083-004 and the United States-France Exchange of Scientists Program, which is funded by the National Science Foundation and Centre National de la Recherche Scientifique. This paper was written during a year I spent at the Muséum National d'Histoire Naturelle in Paris. I thank H. Lacombe and J. Gonella who helped arrange my visit and all the members of the Laboratoire d'Océanographie Physique who made my stay a pleasant one.

References

- Bache, F. 1936. Where is Franklin's first chart of the Gulf Stream? *Proc. Am. Philos. Soc.*, 76, 731-741.
- Brown, L. 1951. The river in the ocean. In: *Essays honoring Lawrence C. Wroth*. Anthoensen Press, Portland, Maine, 69-84.
- Brown, R. H. 1938. The De Brahm charts of the Atlantic Ocean, 1772-1776. *Geogr. Rev.*, 124-132.
- Cohn, E. R., 2000. Benjamin Franklin, Georges-Louis Le Rouge and the Franklin/Folger chart of the Gulf Stream. *Imago Mundi*, 52, 124-142.
- Deacon, M. B. 1971. *Scientists and the sea, 1650-1900, a study of marine sciences*. Academic Press, New York, 445 pp.
- De Brahm, W. G. 1772. *The Atlantic Pilot*. T. Spilsbury, London, 25 pp.
- De Vorsey, L. 1976. Pioneer charting of the Gulf Stream. The contributions of Benjamin Franklin and William Gérard De Brahm. *Imago Mundi*, 28, 105-120.
- Duane, W. 1808. *The works of Dr. Benjamin Franklin, in Philosophy, Politics, and Morals, Vol. 3*. W. Duane, Philadelphia.

Franklin, B. 1786. A letter from Dr. Benjamin Franklin to Mr. Alphonsus le Roy, Member of Several Academies, at Paris. Containing sundry maritime observations. Trans. Am. Philos. Soc., 2, 294-329.

Franklin, B. 1787. Lettre de Monsieur Benjamin Franklin à Monsieur David LeRoy, member de Plusiers Académies, Contenant différents observations sur la marine. Lagrange, Paris, 72 pp.

Fuglister, F. C. 1963. Gulf Stream '60. In: Progress in Oceanography. Pergamon Press, London, 1, 265-383.

Gilpin, J. 1786. Observations on the annual passage of herrings. Trans. Am. Philos. Soc., 2, 236-239.

Hansen, D. V. 1970. Gulf Stream meanders between Cape Hatteras and the Grand Banks. Deep-Sea Res., 17, 495-511.

Iselin, C. O'D. 1936. A study of the circulation of the western North Atlantic. Pap. Phys. Oceanogr. Meteorol., 4, 101 pp.

Kirwan, A. D., Jr., McNally, G. and Coehlo, J. 1976. Gulf Stream kinetics inferred from a satellite-tracked drifter. J. Phys. Oceanogr., 6, 750-755.

Mann, C. R. 1967. The termination of the Gulf Stream and the beginning of the North Atlantic Current. Deep-Sea Res., 14, 337-360.

Niiler, P. P. and Robinson, A. R. 1967. The theory of free inertial jets II. Tellus, 19, 601-619.

Pillsbury, J. 1891. The Gulf Stream: Methods of the investigation and results of the research. Appendix No. 10—Report for 1890, United States Coast and Geodetic Survey, Washington, D. C., 461-620.

Pownall, T. 1787. Hydraulic and nautical observations. Printed for Robert Sayer, London, 17 pp.

Rennell, J. 1832. An investigation of the currents of the Atlantic Ocean and those which prevail between the Indian Ocean and the Atlantic. Publ. for Lady Rodd by J. G. and F. Rivington, London, 359 pp.

- Richardson, P. L. 1980. Benjamin Franklin and Timothy Folger's first printed chart of the Gulf Stream. *Science*, 207, 643-645.
- Richardson, P. L., Wheat, J. J. and Bennett, D. 1979. Free-drifting buoy trajectories in the Gulf Stream System (1975-1978), a data report. Woods Hole Oceanogr. Inst. Techn. Rept. No. WHOI-79-4. Unpublished manuscript.
- Smyth, A. H. 1906. The writings of Benjamin Franklin. The Macmillan Co., New York, 10 vols.
- Sparks, J. 1838. The works of Benjamin Franklin, Vol. 6. Hilliard, Gray and Co., Boston.
- Stackpole, E. A. 1953. Sea-hunters; the New England whalers during the two centuries 1635-1835. J. B. Lippincott Co., New York, 510 pp.
- Stommel, H. 1958. The Gulf Stream: a physical and dynamical description. University of California Press, Berkeley, 202 pp.
- Strickland, W. 1802. On the use of the thermometer in navigation. *Trans. Am. Philos. Soc.*, 5, 90-103.
- Sverdrup, H. U., Johnson, M. W. and Fleming, R. H. 1942. The oceans, their physics, chemistry, and general biology. Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1087 pp.
- Truxtun, T. 1794. Remarks, instructions and examples relating to the latitude and longitude. T. Dobson, Philadelphia, 105 pp.
- Volney, C. F. 1804. A view of the soil and climate of the United States of America. J. Conrad and Co., Philadelphia, 446 pp.
- Williams, J. 1793. Memoir of Jonathan Williams on the use of the thermometer in discovering banks, soundings, etc. *Trans. Am. Philos. Soc.*, 3, 82-96.
- Williams, J. 1799. Thermometrical navigation. R. Atkin, Philadelphia, 98 pp.

Worthington, L. V. 1976. On the North Atlantic circulation. The Johns Hopkins Oceanographic Studies. The Johns Hopkins University Press, Baltimore, Maryland, 6, 110 pp.