MAR 555
Introductory Physical Oceanography

CLASS NOTES

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 11 April 2012

FORWARD

Physical Oceanography in America

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(Edited by W. S. Brown)

Benjamin Franklin, the first postmaster general of the American colonies (circa 1740), tried to explain the longer westward sailing times of the England to New York mail ships. He collaborated with expert sailor (and cousin) **Timothy Folger** in attributing the delay to a “strong, adverse, warm current” near the New England coast. To avoid (find) the current on the England to American (American to England) trips, he instructed the ship’s captains to measure sea surface temperature regularly. Thus began the first scientific examination of the "Gulf Stream" in 1775 (Figure 1).

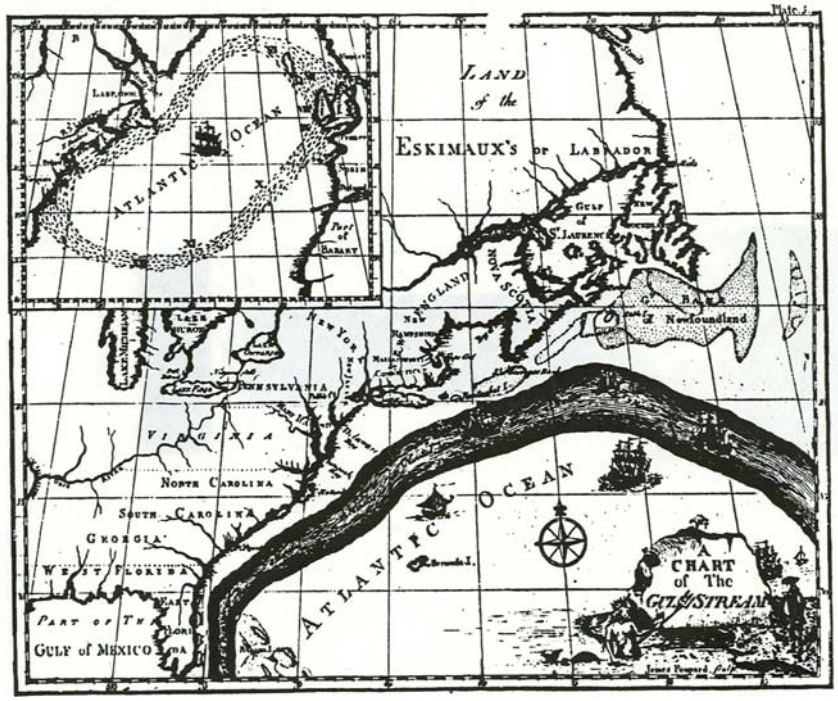

Figure 1. Benjamin Franklin’s map of the Gulf Steam based on his compilation of the sea surface temperatures.

Alexander Bache, the great grandson of B. Franklin and first Superintendent of the U.S. Coast Survey, committed the government to systematic study of the Gulf Stream and coastal currents and sea level, committed the government to systematic study of the Gulf Stream and coastal currents and sea level in the first half of the 19th century.

Matthew Fontaine Maury, a U.S. naval officer and first Superintendent of the U.S. Naval Observatory, organized information from ships logs from all around the world in an effort to infer the first global description of winds and currents.

This work inspired the curiosity of those who wanted to understand the physical basis of the currents in the ocean. However, the Civil War and changing political priorities undermined the American effort in physical oceanography and caused a decline during the latter half of the 19th century.

By the turn of the century, a group of Scandinavian meteorologists, namely **Vilhelm Bjerknes** – a theoretical physicist- and Norwegian **Bjorn Helland-Hansen**, **F. Nansen** and **V.W. Ekman** led the way in applying the principles of physics towards understanding the ocean circulation.

Figure 2. F. Nansen and the R.V. Fram stuck in the arctic ice.

In April 1912, the *Titanic* struck an iceberg and sank in the North Atlantic with great loss of life, including some of the wealthiest and most prominent people in the world. In response, the maritime nations of Europe and America established the *International Ice Patrol* in 1913.

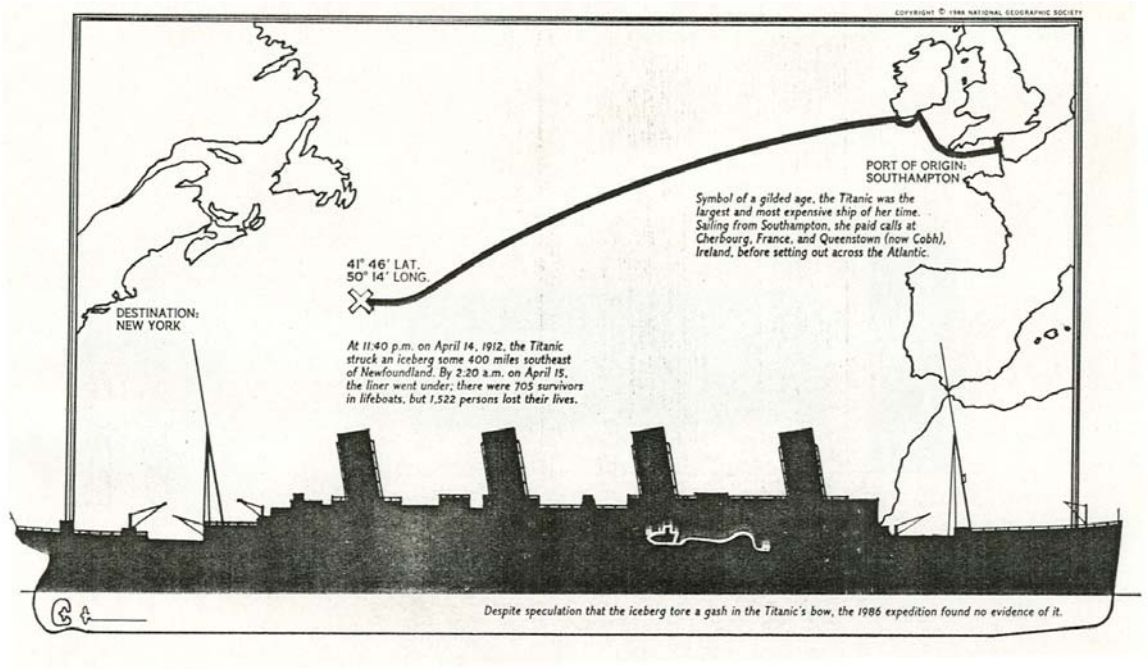

Figure 3. The Titanic –"the unsinkable ship"- hit an iceberg in the North Atlantic in April 1912 and sank with great loss of life.

The mission of the Patrol, operated by the United States Coast Guard, was to keep track of the hundreds of icebergs that endangered shipping in the sea lanes of the North Atlantic in the spring of each year. The problem was that direct observations of the ice were hampered by the fog. Thus the Coast Guard officers soon became convinced that they needed to employ modern scientific techniques for calculating ocean currents indirectly through the measurement of water properties.

During the early part of the 20th century, Scandinavia had become the world center for physical oceanography. Scientists from Sweden, Norway and Denmark had developed the methods for measuring temperature and salinity in the open ocean and using these measurements to compute the direction and strength of open ocean currents. In Scandinavia, the perceived decline of the North Sea fisheries led to intensive study, and the scientists who did the research were quick to see that biological productivity had to

depend on the physical conditions of the marine environment. These they began to measure and their work received a considerable boost from the immensely popular activities of the noted Arctic explorer, **Fritjof Nansen**. Nansen soon interested the most distinguished mathematical physicist in Scandinavia, **Vilhelm Bjerknes**, in the problem of ocean currents, and Bjerknes' students - **J.W. Sanstrom** and **Bjorn Helland-Hansen** worked out the techniques for calculating currents from the temperature and salinity data which was now routinely collected. A method existed by 1905 for the determination of currents indirectly.

Thus in 1924, a young Coast Guard officer **Edward H. Smith**, was sent to the Geophysical Institute at Bergen, Norway, to work with Bjorn Helland-Hansen, the developer of the formula for computing what we now call geostrophic ocean currents. It is interesting that Smith had to leave the US, which had been on the forefront of physical oceanography during the mid-1800s, and go to Scandinavia learn the most modern physical oceanographic techniques in the early 1900s. How had the United States lost its dominance of the study of ocean?

American dominance of the science of physical oceanography in the first half of the 19th century derived from the way in which the American economy developed. Before the Civil War, US commerce was mainly the exchange of its vast natural resources for finished goods. This type of commerce depended almost entirely upon water transportation; river steamboats on the western rivers and sailing ships on the ocean. Thus from 1815 to 1860 the American merchant marine quadrupled in size and North Atlantic shipping routes became the world's busiest.

The importance of seaborne commerce meant that there was compelling need for safer and faster sea travel. By 1850 three federal agencies had been founded to furnish what we now call research and development service to maritime commerce. Further the employees of these American agencies raised the science of physical oceanography to a dominant position in world.

The first of these agencies was the civilian *United States Coast Survey*, founded in 1807 under the aegis of President Thomas Jefferson. Under its first director, the Swiss immigrant **F.R. Hassler**, the Survey established high standards. However, the Survey operations were suspended between 1818 and 1832 because of the financial after-effects of the War of 1812; and a growing role of the navy employing the war's surplus naval officers. After Hassler's death, **Alexander Dallas Bache** became superintendent of the Coast Survey. Bache led the Survey through a period of rapid expansion, sending vessels to sea to chart currents as well as surveying the land, and he found employment for a number of American scientists. The Coast Survey under Bache became the principal center of the American scientific community, in part because he developed alliances with professors in the leading colleges and with scientists in Europe. Despite its rise to prominence, the future of the Survey was not secure because of its competition with the US Navy.

The US Navy's role in supporting commerce was expressed through the establishment of the *Depot of Charts and Instruments* in 1830. The initial reason for its establishment of the Depot was to provide a shore billet for Lieutenant **Charles Wilkes**, who was organized and led the U.S. Navy Exploring Expedition - America's principal contribution to the geographical reconnaissance of the ocean world. Unfortunately, few physical oceanographic measurements were made during his four-year cruise. Around 1840, the federal government built a world-class astronomical observatory; and relocated the Depot there under the leadership of Lt. **Matthew Fontaine Maury**.

Thus for almost two decades thereafter, Maury and Bache were great rivals on the scientific scene, both in the United States and abroad. This rivalry arose from their differing views on the relative value of basic and applied sciences. Maury, first and foremost a self-educated naval officer, perceived no difference between them. Bache, who graduated West Point at the head of his class when only 19, stood for science as a profession in its own right.

Bache and his friends collaborated in persuading the government to establish the Nautical Almanac Office with a mission to serve shipping through its scientific research. Part of the Navy, the Almanac Office was located by its founder, Navy Lieutenant **Charles Henry Davis**, in Cambridge, Massachusetts. There it could make use of the *Harvard College Observatory* (rather than Maury's National Observatory). Since its job could never be finished, the Almanac Office was more secure than the Survey and thus was able to build its staff of skilled scientists and mathematicians.

About this time, the Coast Survey under Bache inaugurated a highly sophisticated investigation of the Gulf Stream, the most intense of the currents of the North Atlantic. From 1844 to 1860 Coast Survey ships ran fourteen lines of temperature measurements across the Gulf Stream between New Jersey and Florida, setting the pattern of research on the world's most studied ocean current.

In the early years of the Depot, Maury led the painstaking analysis of ships' logs, from which he compiled charts that showed prevailing winds and currents over the worlds' oceans. However, by 1849 he also wanted to direct research at sea. Ironically, the same appropriations bill (passed by a lame-duck Congress) that funded the establishment of the Almanac Office also funded the construction of two naval vessels that Maury wanted to do oceanography at sea. Maury's ideas about the physics of the ocean currents that his charts revealed were first published as part of the Sailing Directions that accompanied his charts. Maury's theories were later collected into one of the all-time best-sellers of science, his *Physical Oceanography of the Sea* (1855). Although Maury's ideas were generally rejected by those who understood best the problems that he considered, they did motivate others with alternate ideas.

In particular they stimulated a self-taught schoolteacher, **William Ferrel** of Nashville, Tennessee, to develop and advance his own. Thus began the career in dynamical meteorology and physical oceanography of the leading American practitioner of both. Ferrel's first paper, his pioneering "Essay of the Winds and Currents of the Ocean," was published in Nashville in 1856. In it he presented for the first time anywhere the

principle that the earth's rotation accounts for the general circulation of the atmosphere and ocean. When this and other papers came to the attention of Bache and his circle, Ferrel was invited to Cambridge to join the staff of the *Nautical Almanac Office*. There he remained until 1867, when Bache's successor and close friend, the Harvard mathematician **Benjamin Pierce**, took Ferrel to Washington and the Coast Survey. Fifteen years later in 1886, Ferrel left the Coast Survey to close out his distinguished career there for the Signal Service -predecessor of the Weather Bureau. During this long and fruitful career, Ferrel worked on the theory of winds, ocean currents, and tides, and in the process built one of the earliest tide-predicting machines. While Ferrel was probably the world's most distinguished physical oceanographer of his day, he left no successors. Thus the period of American dominance in physical oceanography ended.

What had happened to the structure erected by Bache, Maury, and their contemporaries had erected? The Civil war was probably single most significant event that led to the decline of American marine science in the late 1800s. The War removed the Virginian Maury from the scene, and it drove Bache into war work so strenuous that he suffered a stroke and died soon after Appomattox. After the war, America turned inward as the vast interior was opened to exploitation by the spread of the railroad. The American merchant marine and navy almost vanished from the ocean. Seaborne commerce gave way to mining as the theme of the American quest for riches.

Whatever reputation the Coast Survey had around the turn of the twentieth century came from the tidal work of **Rollin A. Harris**. Here, American physical oceanography suffered directly from the low prestige of Federal science as of American theoretical science generally. Harris' outstanding work ran counter to the theories of G.H. Darwin, a professor at Cambridge University in England. As a result, Harris' efforts did not receive the acclaim they deserved, and the Survey suffered with him.

Despite this downturn in American interests, oceanographic research continued. A key contributor was **Alexander Agassiz**, despite being a zoologist and geologist, helped to link the 19th and 20th century periods of highly active American physical oceanography.

Agassiz sustained his efforts in marine science (mainly at Harvard) through the fortune that he built from the Michigan copper mines. This enabled him to make a series of cruises on the steamer *Blake* for the Coast Survey beginning in 1877. The Coast Survey's *Blake* was later used by Lieutenant **John E. Pillsbury** for a systematic study of the Gulf Stream with his newly invented current meter. From 1884 to 1890 the Survey's vessel spent part of each year moored along six sections that crossed the Gulf Stream between Cape Hatteras and the southern tip of Florida. Pillsbury published these measurements in the Survey's 1890 annual report. Unfortunately, they made little impact at the time.

Alexander Agassiz was associated through much of his life with *Harvard University,* though his income came from copper mining. As a result, he had a number of students who learned from him the ways of the sea and used the library he collected at the *Museum of Comparative Zoology* to learn about these new developments in Scandinavia. One of these students was **William E. Ritter**, who left Harvard to become chairman of the *Department of Zoology at the University of California* in Berkeley.

Each summer, Ritter studied organisms at the seaside from a portable tent that moved up and down the California coast. Finally in about 1905, he settled north of San Diego at a permanent site acquired through the generosity of E.W. Scripps and his sister and founded the *Scripps Institution for Biological Research*. His Berkeley colleague **Charles A. Kofoid** went to Europe on sabbatical in 1907-1908 and returned to Scripps with the Scandinavian message that a study of the physical conditions, especially the currents, was necessary for understanding the biology of the oceans. When Ritter came to La Jolla and the Scripps Institution in 1911, he brought a graduate student in mathematics, **G.F. McEwen**, who immediately began to introduce the new Scandinavian methods to Scripps.

If McEwen was doing Scandinavian-style physical oceanography in the in California, then why did Edward Smith of the Ice Patrol choose to go to Europe? While there are no clear answers to this question, we have some suggestions. First, McEwen, like his predecessor William Ferrel, was a shy and solitary man, whose efforts he could be

understood by few and these few remained working at Berkeley with other mathematicians rather than go to La Jolla. Second, it seems to be true that the most successful theoreticians pursue problems that can be tested experimentally. The problems of ocean currents were not very high on the lists of US mathematicians. This was due in part to the lack of a dynamic leader like Bjerknes, Harold **Sverdrup**, Henry Stommel, or Walter Munk to attract students and colleagues. Neither McEwen nor Ferrel were able to establish groups to carry on the tradition in American physical oceanography. Thirdly, the American workers of the time may not have been convinced of the validity of the new Scandinavian techniques before they were decisively demonstrated in 1924. In that year, the German physical oceanographer **Georg Wust** compared the currents in the Florida Strait calculated from Pillsbury's measured temperature and salinity data. The general agreement between the measured and estimated currents confirmed the soundness of the Scandinavian methods. Fourthly, his advisor on oceanographic matters probably thought of Scripps Institution as a rival.

In any case, Edward Smith went to Scandinavia for his studies. His return marked a rejuvenation of American physical oceanography. Shortly thereafter in 1930, the Rockefeller Foundation played a crucial role in the establishment of *Woods Hole Oceanographic Institution*, whose first director was **Henry Bryant Bigelow**. At the same time the Foundation built a new building at Scripps Institution and at the behest of T. **Wayland Vaughan**, Ritter's successor as director, the name was changed to *Scripps Institution of Oceanography*.

Therefore, in spite of America's turning inward after the Civil War, in spite of the decline in the scientific stature of the Coast Survey, in spite of the loss of American dominance in physical oceanography, Alexander Agassiz and his students were able to link the two periods of American preeminence in physical oceanography: that of the mid-nineteenth century and that of today.