Real World Globes – Investigating Surface Currents around the Globe

Authored by Ryan Glaubke, Graduate Student at Old Dominion University, Norfolk, VA

Purpose:

- To practice basic plotting techniques using longitude and latitude coordinates.
- To illustrate the different patterns surface currents exhibit around the globe.
- To perform basic velocity calculations given information on distance and time.
- To demonstrate critical thinking by understanding the processes that govern ocean circulation and hypothesizing about what might happen if those processes were ceased or reversed.

Target Audience:

- High school science students

Materials:

- Mother Earth Globe^{TM}
- Clear 18” hemisphere
- Dry-erase markers, eraser, and calculator

Introduction:

For nearly a thousand years, sailors have known that the ocean is constantly on the move. This “motion of the ocean” (specifically the surface ocean) is primarily governed by the Earth’s winds. Because the Sun heats the Earth unevenly – the equator receives more of the Sun’s energy than the poles – winds blow to distribute this heat evenly across the surface of the planet. As the winds blow over the ocean, they exert a force on the surface, creating friction between the ocean and the atmosphere. In essence, the winds “drag” the ocean along with it, creating currents that reach nearly 400 meters (or 1,300 feet) deep!

But the winds are the not the only physical force that drives the surface ocean’s flow. Ocean currents tend to stray to the right in the Northern Hemisphere and to the left in the Southern Hemisphere. This “force” is due to the rotation of the Earth, known as the *Coriolis Effect*. Taking both the winds and the Coriolis Effect into account (along with a few other forces we’re not concerned with here), the surface currents of the global ocean display some spectacular patterns: deep underwater “rivers” known as *western boundary currents*, intensified by the Earth’s rotation; giant whirlpools kilometers across called *eddies*; enormous, circuitous *gyres* that nearly circle entire ocean basins!

Scientists are able to track the paths of these currents by using *drifters*, oceanographic instruments strapped to floats (see figure below) that relay GPS, temperature, salinity, and velocity measurements back to oceanographers on land. According to the National Oceanic and Atmospheric Administration (NOAA), there are over 1,000 of these drifters in the ocean today, gathering a treasure trove of information on the global ocean’s surface circulation. For our activities today, we’ll be using some of this data to investigate the different ocean circulation patterns exhibited on the Earth’s surface. We’ll touch briefly on why the patterns we see are important in a climatological context, and what would happen if these currents were to simply “turn off”.

Activity 1 – The Atlantic Ocean:

Months ago, a drifter was released off of the coast of Cape Cod, Massachusetts into the north Atlantic Ocean to catch a ride on the ocean currents. Over the course of the drifter's deployment, we've received a signal that tells us where in the Atlantic the drifter is. We want to plot these coordinates on the surface of a globe to see if we can find any of the patterns explained above.

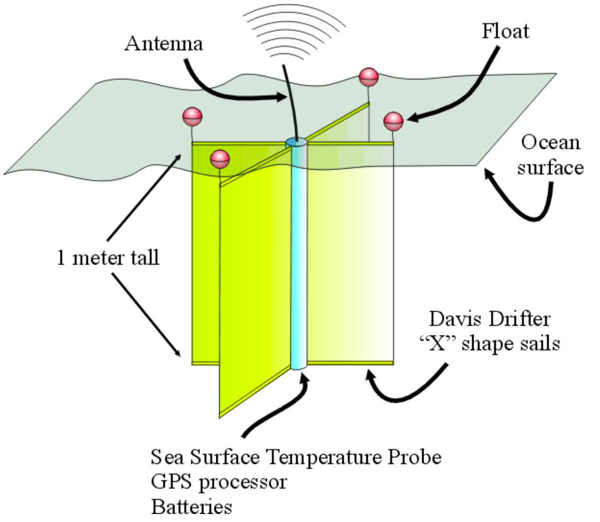

Figure 1: A picture of a drifter used by oceanographers to track the movement of the ocean.

1 – Assemble half of the Mother Earth Globe^{TM} so that the Atlantic Ocean is in the center. (Use the wedges that have the North American, South American and African continents on them.) Cover the globe with the 18" clear hemisphere.

2 – Before we start plotting GPS coordinates, we need to draw a couple of reference lines. First, using a dry erase marker, color red the latitudinal line (line that runs from horizontally from east to west) that separates the northern hemisphere from the southern hemisphere. Label this "EQUATOR (0°)".

Next, color red the longitudinal line (line that runs vertically from north to south) that runs through the eastern part of Great Britain. Label this "PRIME MERIDIAN (0°)". (Fun fact: the prime meridian was established by a British astronomer named Sir George Airy, who placed it in a position so that it would run straight through his observatory in Greenwich, England!)

3 – The GPS locations that have returned from one of our drifters (and the times these signals were received) are listed in Table 1. Plot these coordinates on the surface of the globe and connect them with a nice smooth line. Note that each latitudinal and longitudinal line are 10° apart.

IMPORTANT: GPS coordinates are reported as a pair, with both a latitudinal coordinate in degrees north/south (°N / °S) and a longitudinal coordinate in degrees east/west (°E / °W). Our coordinates are reported in °N (positive above the equator, negative below it) and °W (positive to the left of the prime meridian).

Question Set #1:

1) The drifter seems to have made a big circle around the north Atlantic Ocean. Knowing what you do about surface current features, what is this feature called?

2) Why are the currents moving clockwise? If we had the power to manipulate Nature, what would we have to do to make the currents flow counterclockwise?

The Gulf Stream, the surface current that flows north up the eastern coast of the United States, is considered one of the strongest currents on the planet. Let's calculate the velocity (or speed) of the Gulf Stream using our data.

Velocity is defined mathematically as the *distance traveled* divided by the *time it takes to cover that distance*. This makes sense, because speed is nothing more than how quickly (i.e. in how short a time) you can cover a certain distance. So, in order to calculate velocity, we need both parts of the equation.

3) Let's take two points on our globe that fall within the Gulf Stream: the last two points on our list in Table 1. How far apart *in degrees' latitude* are these two points?

4) Velocity is typically reported in meters per second (m/s), so we need to convert our distance in degrees to distance in meters. If 1° latitude = 111,000 meters, how far apart are the two points in meters? Make sure to show your work!

5) Now that we have our distance, we need our time. How many *hours* apart were these measurements received?

6) We need to convert time in hours to time in seconds. If one hour is 3,600 seconds long, how many seconds apart were these two measurements received? Show your work!

7) Now, divide the distance *in meters* (from question #4) by the time *in seconds* (from question #6) to calculate the velocity!

And THAT is one of the fastest ocean currents in the world! For comparison, people typically walk at approximately 5 meters per second. So keep in mind that when we talk about a parcel of water circling the globe, we are talking about a *long* time!

8) The Gulf Stream is important because it moves water from the equator – where it absorbs much of the heat coming from the Sun – to the higher latitudes in the north – where that heat is released to the atmosphere. What would happen to the average climate of Great Britain, whose mild winters depend on the heat being transported from the equator, if we were to turn off the Gulf Stream? How could we turn off the Gulf Stream in the first place?

Activity 2 – The Pacific Ocean:

A second data set has just come in from one of our drifters in the south Pacific! Let's plot the coordinates just as we did above and see if we find any similar patterns…

1 – Assemble half of the Mother Earth Globe^{TM} so that the Pacific Ocean is in the center. Cover the globe with the 18" clear hemisphere.

2 – We once again need to draw a couple of reference lines before we plot the drifter data. First, using a dry erase marker, color red the latitudinal line that separates the northern hemisphere from the southern hemisphere. Label this "EQUATOR (0°)".

Next, color red the longitudinal line that runs just east of New Zealand (the island to the southeast of Australia). Label this the "ANTI-MERIDIAN (180°)". The anti-meridian is the opposite of the prime meridian, marking the halfway-point around the globe. Again, longitudinal lines increase by 10° to the west (left) of the anti-meridian and decrease by 10° to the east (right) of the anti-meridian.

3 – The coordinates returned from the drifter in the Pacific Ocean are listed in Table 2. Plot these coordinates on the surface of the globe and connect them with a nice smooth line.

Question Set #2:

1) Do you see a similar feature to the one you plotted in the north Atlantic? If so, what is it? What is different about this feature than the one in the north Atlantic? Why?

Are the intensities of these ocean currents symmetrical on both sides of the gyre? Let's compare the velocity of a *western boundary current* and an *eastern boundary current* on opposite ends of the large south Pacific gyre: the East Australian Current (EAC) and the Peru Current (PC), respectively. For the EAC, we will use the two data points located at 200° longitude. For the PC, we will use the two data points located at 80° longitude.

2) What is the distance *in degrees' latitude* between the two points for the EAC and the PC?

3) If 1° latitude = 111,000 meters, how far apart are the two points for both currents in meters? Make sure to show your work!

4) Now that we have our distances, we need our times. How many *hours* apart were these measurements received for each current?

5) If one hour is 3,600 seconds long, how many seconds apart were these two measurements received for each current? Show your work!

6) Now, calculate the velocity for each current? Which is faster: the EAC or the PC?

Western boundary currents – so named because they typically exist on the western edge of ocean basins – tend to be much stronger than their counterparts in the east. This, ultimately, is caused by the rotation of the Earth, by the Coriolis Effect.

7) What would happen to the currents that make up the south Pacific gyre if the Earth were to stop spinning? (Remember: the winds are still blowing!)

Activity 3 – The Indian Ocean:

Finally, our last data set (listed in Table 3) has come from a drifter we released in the Indian Ocean. The circulation within the Indian Ocean has been known to be rather odd – sometimes reversing directions completely during the monsoon season! – so it's important we take a close look.

1 – Assemble half of the Mother Earth Globe^{TM} so that the African continent is in the center. Cover the globe with the 18" clear hemisphere.

2 – We once again need to draw a couple of reference lines before we plot the drifter data. First, using a dry erase marker, color red the latitudinal line that separates the northern hemisphere from the southern hemisphere. Label this "EQUATOR (0°)".

Find the prime meridian once again and color it red. Remember that the prime meridian marks the starting point around the globe (i.e. 0°) but it *also* marks the end of the trip around the globe (i.e. 360°). When labeling the prime meridian this time, label it "PRIME MERIDIAN (360°)".

3 – The coordinates returned from the drifter in the Indian Ocean are listed in Table 3. Plot these coordinates on the surface of the globe and connect them with a nice smooth line.

Question Set #3:

1) After being jettisoned from the Indian Ocean, our drifter begins to behave rather oddly. What is this feature?

Ocean currents certainly flow like rivers, but they don't have "banks" to keep the currents flowing straight. Ocean currents will meander as they flow and, sometimes, break off a chunk that spins away from its source.

2) Take a close look at the path the drifter left behind in the south Atlantic. Does anything seem odd to you? (Hint: we're in the southern hemisphere! Think about the Coriolis Effect…)

There are two kinds of these "whirlpools" defined by the temperature of the water in the center – *warm-core eddies* and *cold-core eddies* – which rotate clockwise and counterclockwise, respectively, no matter which hemisphere they reside in!

3) Without having data on the water temperature from this drifter, do you think the water on the inside of the eddy would be colder or warmer based on its circulation?

4) The Indian Ocean waters trapped within the eddy are much saltier than the surrounding waters of the south Atlantic. If we were to turn off the Agulhas Current (the current our drifter hitched a ride in to the southern tip of Africa) and stop the eddies from leaking Indian Ocean water into the Atlantic, what would happen to the salinity of the Atlantic Ocean? What about the salinity of the Indian Ocean?

Table 1 – *Drifter data from the Atlantic Ocean*

Date Received	Latitude (°N)	Longitude (°W)
Jan 1 @ 0900	40	65
Jan 15 @ 1215	45	55
Feb 2 @ 1730	50	40
Feb 10 @ 0445	50	30
Mar 13 @ 1315	40	15
Mar 29 @ 1420	30	18
Apr 16 @ 0230	20	20
May 19 @ 1630	5	30
Jun 22 @ 1845	5	50
Jul 4 @ 1730	10	60
Jul 12 @ 0525	15	65
Jul 18 @ 1200	20	70
Jul 22 @ 0930	25	75
Jul 26 @ 2130	32	75

Table 2 – *Drifter data from the Pacific Ocean*

Date Received	Latitude (°N)	Longitude (°W)
Aug 12 @ 1100	-10	90
Sep 11 @ 1930	-5	100
Sep 30 @ 2200	-5	120
Oct 12 @ 1130	-8	140
Oct 31 @ 2345	-10	160
Nov 10 @ 0245	-15	175
Dec 2 @ 1450	-20	190
Dec 24 @ 1630	-30	200
Jan 3 @ 0430	-45	200
Jan 13 @ 1000	-32	180
Mar 12 @ 1345	-60	170
June 20 @ 1440	-60	120
Sep 15 @ 1230	-40	80
Jan 20 @ 1330	-20	80

Table 3 – *Drifter data from the Indian Ocean*

Date Received	Latitude (°N)	Longitude (°W)
Mar 11 @ 1600	10	290
Mar 30 @ 0200	15	295
Apr 6 @ 1745	10	305
Apr 18 @ 0530	0	310
May 1 @ 0440	-10	315
May 10 @ 1544	-20	320
Jun 2 @ 1925	-35	330
Jun 19 @ 1200	-40	340
Jul 2 @ 0300	-35	350
Jul 12 @ 1830	-30	350
Jul 25 @ 1900	-30	345
Aug 9 @ 0230	-30	355
Aug 20 @ 0945	-25	355
Sep 4 @ 1800	-30	350
Sep 16 @ 1050	-25	360
Sep 30 @ 0100	-20	355
Oct 6 @ 2300	-25	355
Oct 12 @ 1230	-20	5