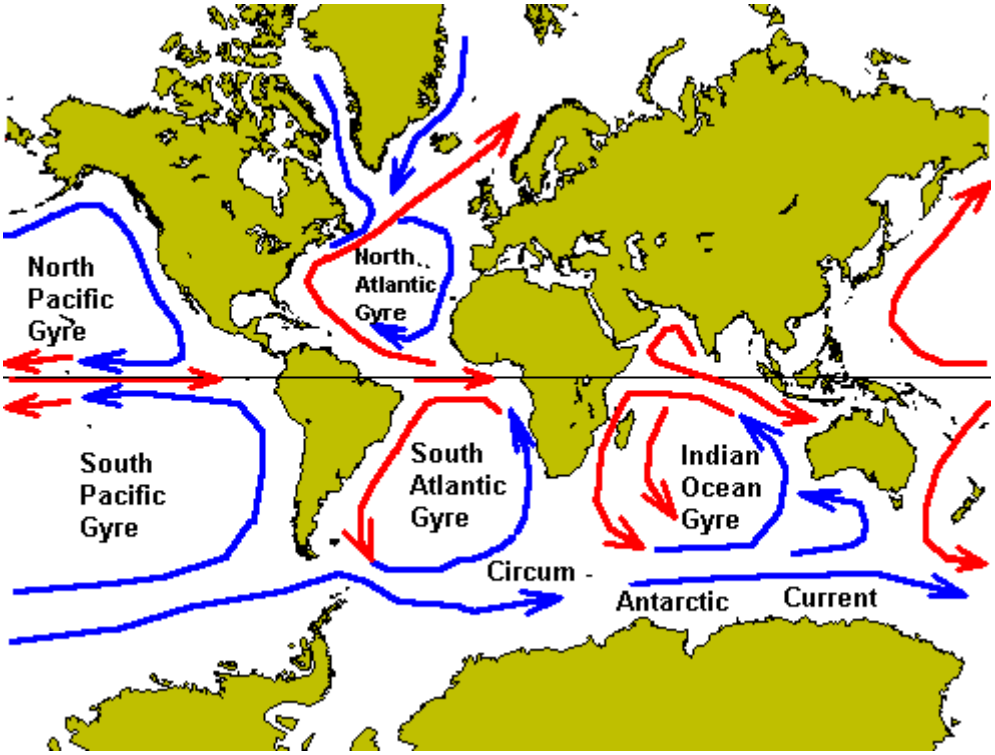
OCE-3014L
Lab 6

NAME_____

Surface Circulation & Upwelling

A closer look at the Gulf Stream Current & the California Current



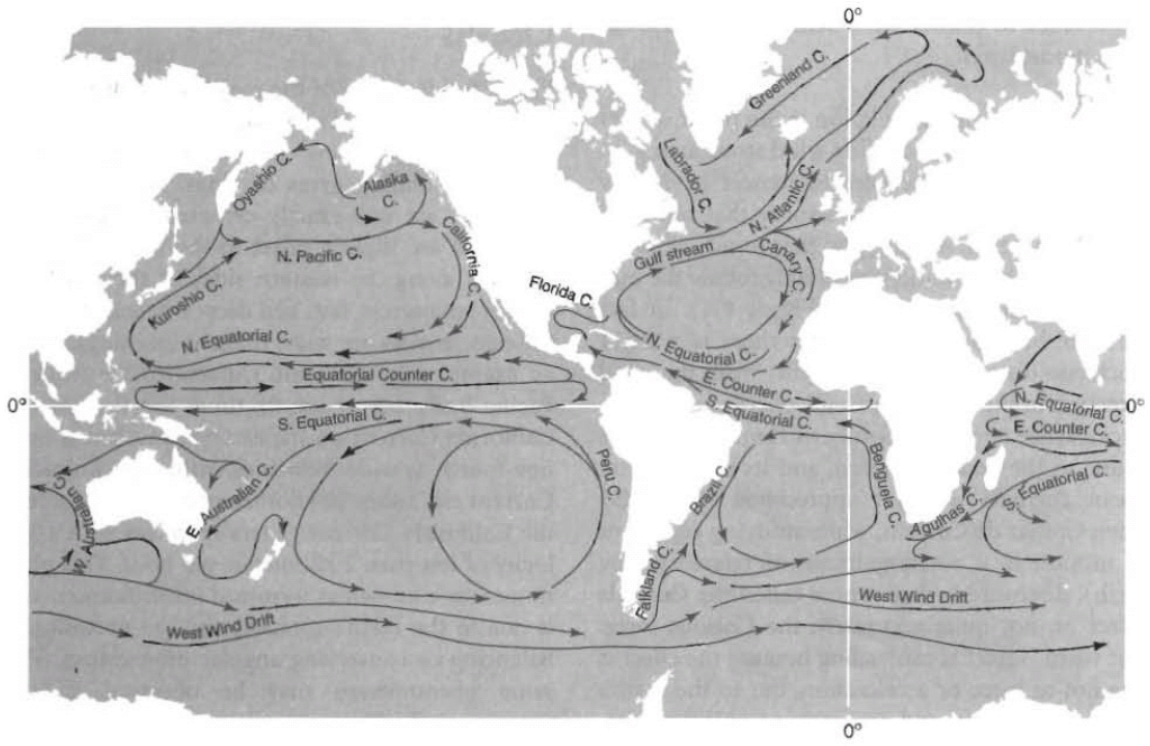
Part A. Global Surface Currents

Surface currents are in direct response to 1) wind, 2) Earth's rotation (the Coriolis Effect), and 3) land masses or continents which affect the location, speed, and direction of the currents.

Ocean currents follow a regular circular pattern in their respective ocean basins, called **gyres**. Gyres form north and south of the equator in Atlantic and Pacific Oceans. **Warm currents within gyres carry water from the equator toward the poles. Cold currents transport cooler water from the subarctic regions toward the equator**. *If you do not have a color printer, color code the currents in the above figure: red for warm currents; blue for cool currents.*

1. The North Atlantic Gyre circulates CW (clockwise) or CCW (counter-clockwise)?
2. The North Pacific Gyre circulates CW or CCW ?
3. The South Atlantic Gyre circulates CW or CCW?
4. The South Pacific Gyre circulates CW or CCW?
5. On which sides of the ocean basins are the warm currents? East or West ?
6. On which sides of the ocean basins are the cold currents? East or West ?

- Note the warm surface current in the Indian Ocean that crosses the equator to join the Indian Ocean's southern gyre, owing to the presence of the Asian land mass south of 0 degree latitude and atmosphere pressure extremes dominating wind patterns over Asia.



7. Indicate **warm** or **cool** beside the major ocean currents listed below.

Current	Relative temperature
California	_____
Kuroshio	_____
West Wind Drift	_____
Benguela	_____
Gulf Stream	_____
Canary	_____
Labrador	_____
Agulhas	_____

Circle the currents listed above that are **WESTERN BOUNDARY CURRENTS** (they travel along the western margin of an ocean)

Underline the currents listed above that are **EASTERN BOUNDARY CURRENTS**

- Currents on the west side of an ocean are faster, deeper, and narrower compared to the currents on the east side of an ocean which are shallower, more sluggish, and wider. This **Western Intensification** is due to Earth's rotation and the necessity of conserving and maintaining angular momentum.

Climate & Surface currents:

The distribution of surface temperatures in the major oceans is shown in Figure 3
Points of equal temperature are connected by isotherms. The isotherms tend to warp toward the equator on east sides of the oceans, and poleward on the west sides.

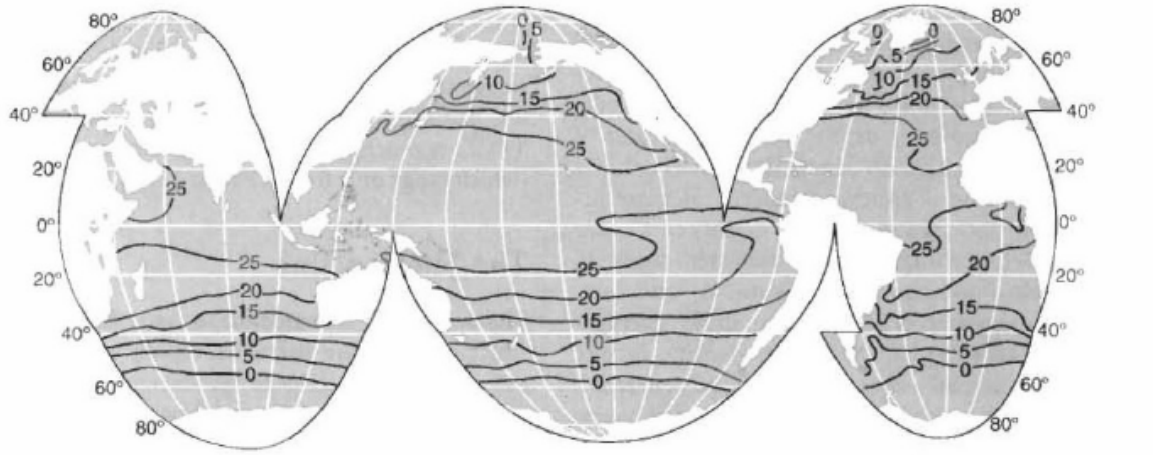


Figure 3: The distribution of surface ocean temperatures (in °C) for the month of August.

8. San Diego, California, and Savannah, Georgia, have different temperatures and humidities, even though they are both at 32° north latitude. In August Savannah is hot and humid; San Diego is mild with cool nights and low humidity.

a. What side of the Pacific Basin is San Diego? _____

b. What side of the Atlantic Basin is Savannah? _____

c. Might we conclude that the California Current off the coast of San Diego is considerably

warmer or **colder**

than the Gulf Stream Current off the coast of Savannah and that surface currents have considerable local effect on coastal climate? YES NO

Part B. Tracking Ocean Currents – *what happened to all those shoes?*

Each year more than 10,000 containers fall overboard and spill their cargo into the ocean. Storms are often to blame. Items like shoes, plastic turtles, rubber ducks, 3 million Lego pieces, and 34,000 hockey gloves have been spilt. Shoes may stay afloat for 10 years, and be wearable even after 3 years at sea!

On January 10, 1992, severe storm conditions were encountered by a container vessel crossing the North Pacific on a route from Hong Kong to Tacoma, Washington.

Twelve huge containers holding thousands of Nike sneakers were knocked overboard, rupturing as they collided, spilling tens of thousands of tennis shoes into the ocean at 44.7 °N, 178°E.

Ten months after the spill in November 1992, Nike's began showing up in the North Pacific waters and on beaches near Alaska. This spill provided new data for ocean current pathways and rates.

Below is a chart indicating when and where the Nike spill occurred and when and where Nikes were recovered. You have also been given a map of the Northern Pacific with a star indicating the site of the Nike spill.

Site	Date	Latitude (degrees)	Longitude (degrees)	Name
Spill Site	1 Jan 1992	44.7 N	178.1 E	
Recovery Site 1	1 Nov 1992	50 N	145 W	Weather Station Papa
Recovery Site 2	1 Dec 1992	57 N	135 W	Coronation Island
Recovery Site 3	1 Jan 1993	60 N	148 W	Cordova Island
Recovery Site 4	1 July 1993	58 N	160 W	Bristol Bay
Recovery Site 5	1 Jan 1994	60 N	164 W	Kinak Bay

9 a. On your map of the North Pacific (page 5), plot the five stations using information above.

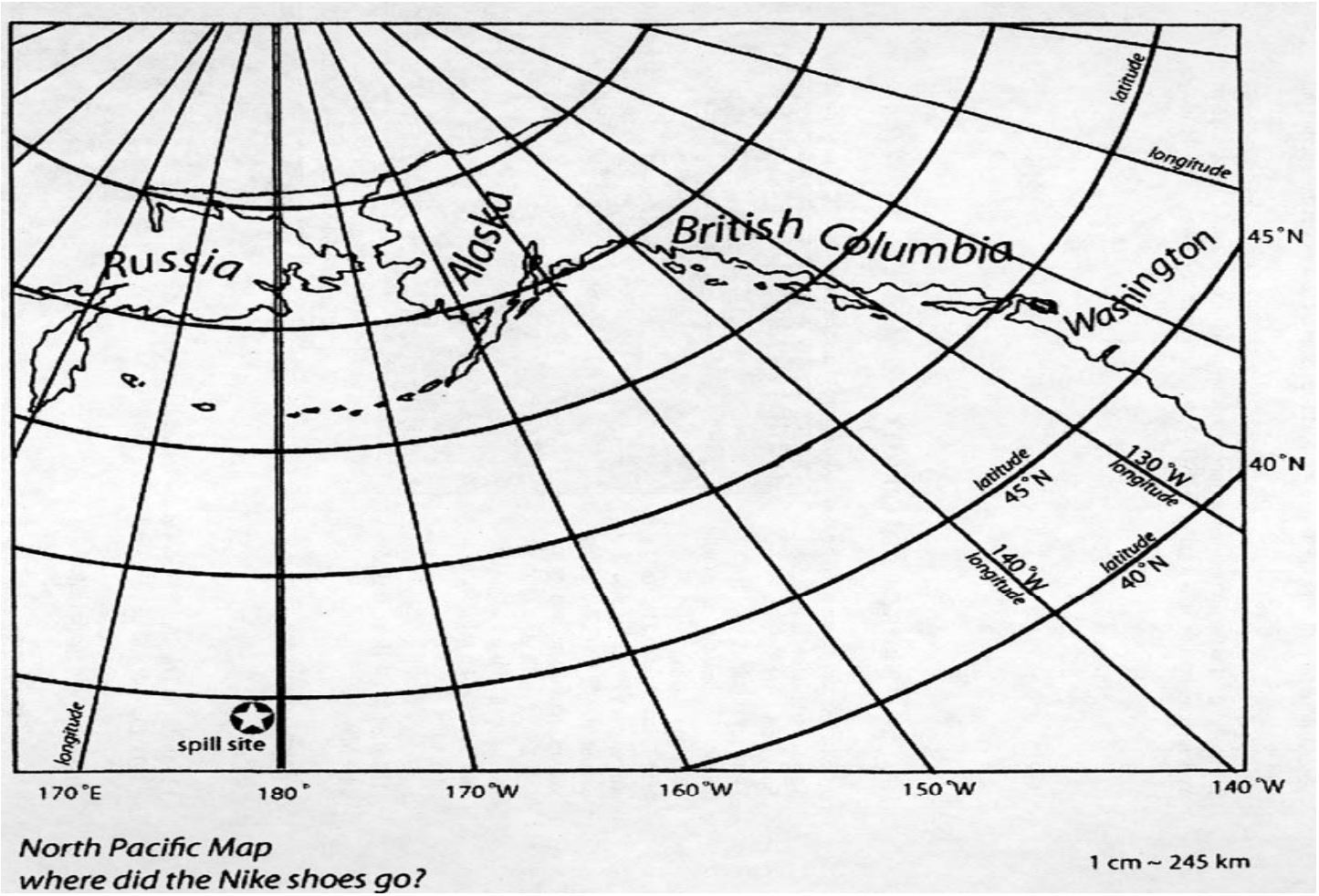
b. Based on dates the sneakers were found, use arrows to indicate the direction of currents carrying the shoes to these locations.

c. Using your North Pacific map, calculate the ocean current speed (distance/time) in centimeters per second from the spill site to recovery site #1. THEN calculate from recovery site #1 to recovery site #2.

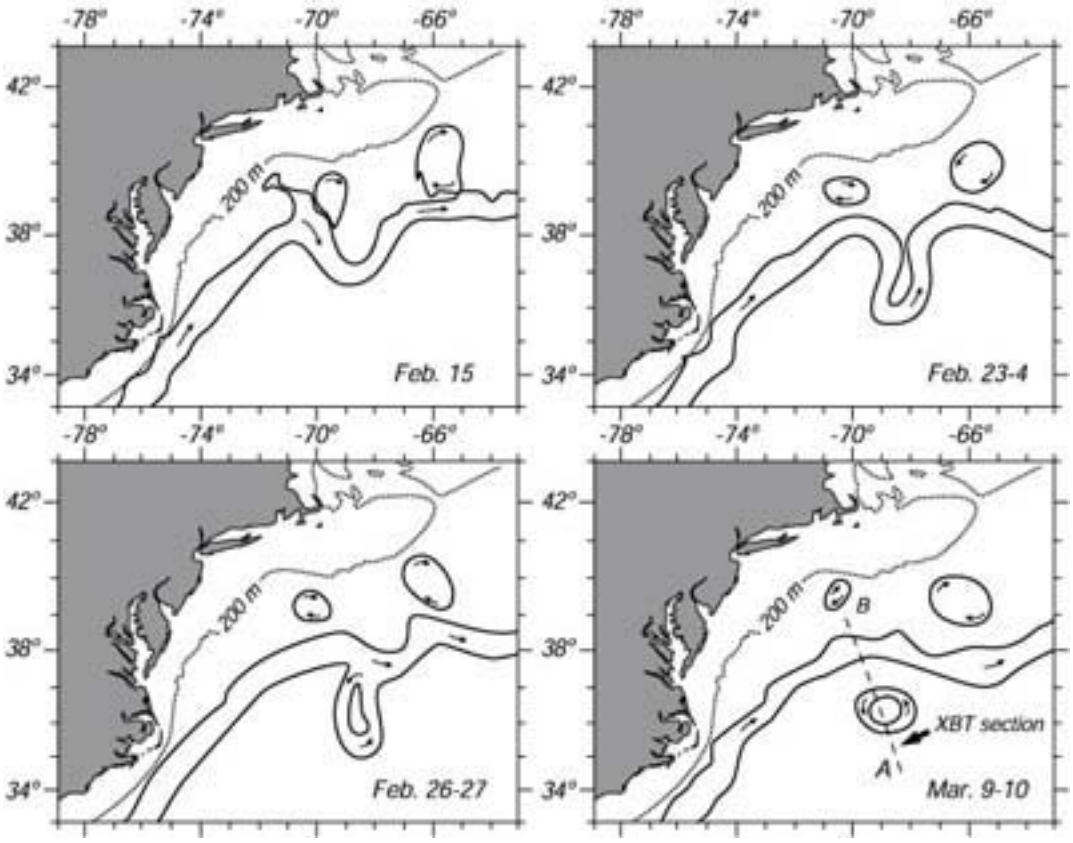
FYI – To determine how many seconds are in one month (let's use 30 days in a month) you will multiply 30 days/month x 24 hours/day x 60 minutes/hour x 60 seconds/minute.

*Current speed from spill to site 1*_____

*Current speed from spill to site 2*_____


Russia
Alaska
British Columbia
Washington
latitude
longitude
45°N
40°N
130°W
longitude
latitude
45°N
140°W
longitude
latitude
40°N
spill site
longitude
170°E
180°
170°W
160°W
150°W
140°W
North Pacific Map
where did the Nike shoes go?
1 cm ~ 245 km

Part C. The Gulf Stream Current



In the above figures the Gulf Stream Current develops a meander which necks-off (closes the loop forming an eddy. A meander is a bend in a stream or current that gives it a sinuous snake-like path. An eddy is a circular current released from the main current when its meander doubles back on itself closing the loop.

10. The Gulf Stream Current's Temperature and Eddies

To answer the questions below go to the following website and work through steps 1-10.
http://www.classzone.com/books/earth_science/terc/content/investigations/es2403/es2403page01.cfm

a. The Gulf Stream Current leaves the U.S. coast and starts to veer eastward at approximately what latitude? Offshore what state?

_____ _____

b. Steps 2 & 4. Click the red dots at Cork and Winnipeg to see average winter conditions at each location during the month of January. Where are the palm trees? Why?

_____ _____

c. Complete the SST (sea surface temperature) table below.

(To convert to Fahrenheit: Multiply degrees Celsius by 9; divide by 5; add 32)

City	Degrees North Latitude	Average SST (° C)	Average SST (° F)
Cork, Ireland			
London, England			
Amsterdam, Holland			
Halifax, Nova Scotia			

d. Steps 6 & 7 Click on the red eddy dots to see animation. Then proceed to step 7. Where are the two warm core eddies located in relation to the main Gulf Stream Current? North or South

_____

What is the water temperature within the eddies?_____

What is the temperature of the surrounding water?_____

Do the eddies rotate clockwise (CW) or counterclockwise (CCW)? _____

e. Work through Steps 8-10. In Step 10 describe the concentration of phytoplankton in these eddies. Based on concentration of phytoplankton what can you infer about the abundance of fish in the eddies and why? Be sure to compare temperature of eddies to that of surrounding water.

11. Velocities of the Gulf Stream Current. Go to the website: Current Velocities of the Gulf Stream: http://rads.tudelft.nl/gulfstream/

Examine the three or four images on this web page.

a. What are the highest velocities? (notice the units)_____

b. What is the highest velocity of a meander?_____

c. What is the highest velocity of an eddy?_____

d. Are these eddies warm or cool? How do you know?

e. What is the average velocity of the sea to either side of the Gulf Stream Current?

_____

Before leaving the website be sure to click on *Animations* and look at the dynamics of the current over several months.

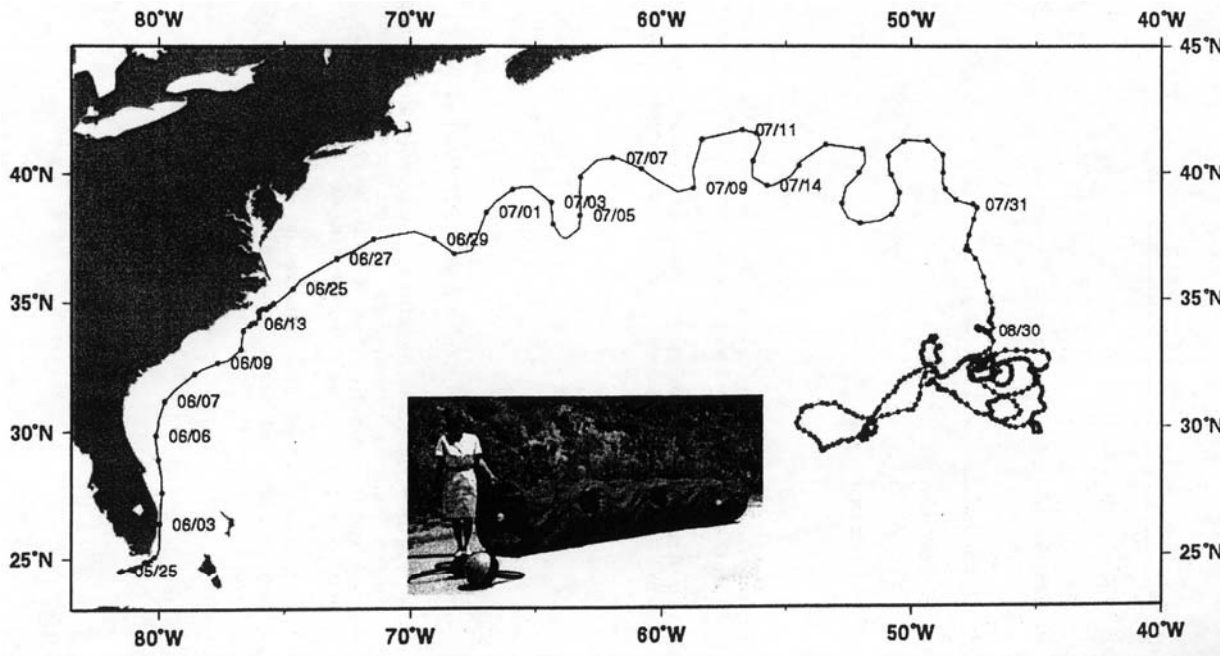
f. You are in a 30-foot sailboat off the coast of Miami, Florida. The light winds die and you find yourself caught up in the Gulf Stream Current at 25 ° N latitude and 80° W longitude. The Gulf Stream Current is moving northerly at the rate of 1 meter/second. How many days (or hours) will it take you to get to a Coast Guard ship located offshore of St. Augustine, Florida at approximately 30° N latitude and 80° W longitude? Show work.

Recall: distance = rate x time

1° of latitude = 60 nautical miles; 1 nautical mile = 1,852 meters

g. Below is the 3-month plot of a satellite-tracked drifter. How does your progress compare to that made of the drifter between Miami and St. Augustine?

About the same Faster Slower



h. Indicate in the figure above where the drifter goes off course, leaving the Gulf Stream.

The Sunday Times
May 08, 2005

Britain faces big chill as ocean current slows

JONATHAN LEAKE, SCIENCE EDITOR

CLIMATE change researchers have detected the first signs of a slowdown in the Gulf Stream—the mighty ocean current that keeps Britain and Europe from freezing. They have found that one of the "engines" driving the Gulf Stream – the sinking of supercooled water in the Greenland Sea – has weakened to less than a quarter of its former strength.

The weakening, apparently caused by global warming, could herald big changes in the current over the next few decades that could lead to Britain and northwester Europe undergoing a sharp drop in temperatures. Such a change has long been predicted by scientists but the new research shows clear evidence of the phenomenon.

Peter Waldham, professor of ocean physics at Cambridge University, hitched rides under the Arctic ice cap in Royal Navy submarines and used ships to take measurements across the Greenland Sea. Waldham reports, "Until recently we would find giant 'chimneys' in the sea where columns of cold, dense water were sinking from the surface to the sea bed 3,000 meters below, but now they have almost disappeared. As the water sank it was replaced by warm water flowing in from the south, which kept the circulation going. If that mechanism is slowing, it will mean less heat reaching Europe."

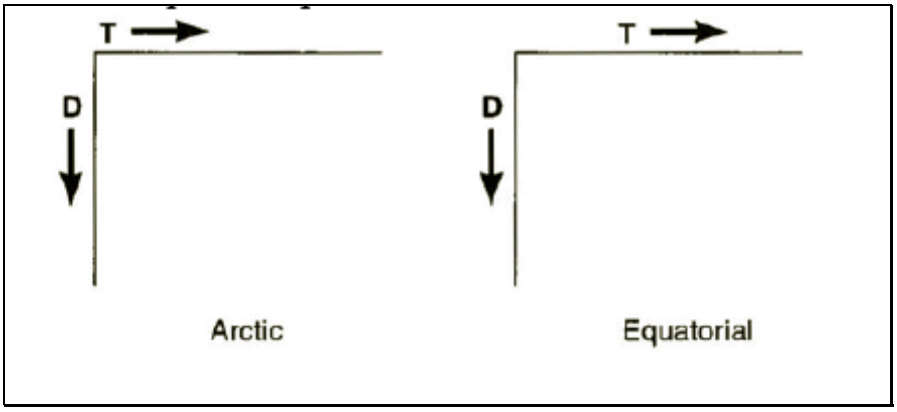
Such a change could have a severe impact on Britain, which lies on the same latitude as Siberia and ought to be much colder. The Gulf Stream transports 27,000 times more heat to British shores than all the nation's power supplies could provide warming Britain by 5-8 °…Waldham and his colleagues believe that such changes could be well under way predicting that the slowing of the Gulf Stream is likely to be accompanied by other effects, such as the complete summer melting of the Arctic ice cap by as early as 2020 and most certainly by 2080. This would spell disaster for Arctic wildlife such as the polar bear, which would face extinction.

Waldham's submarine took him under the North Polar ice cap. Using sonar to survey the ice from underneath, he has measured how the ice has become 46% thinner over the past 20 years. This has prompted him to focus on a feature called the Odden ice shelf, which should grow out into the Greenland Sea every winter and recede in summer. The growth of this shelf should trigger the annual formation of the sinking water columns. As sea water freezes to form the shelf, ice crystals expel their salt into the surrounding water, making it heavier than the water below.

However, the Odden ice shelf has stopped forming. It last appeared in full in 1997. "In the past we could see nine to 12 giant columns forming under the shelf each year. In our latest cruise, we found only two and they were so weak that the sinking water could not reach the sea bed," said Waldham….One possibility is that Europe will freeze; another is that the slowing of the Gulf Stream may keep Europe cool as global warming heats the rest of the world—but with more extremes of weather.

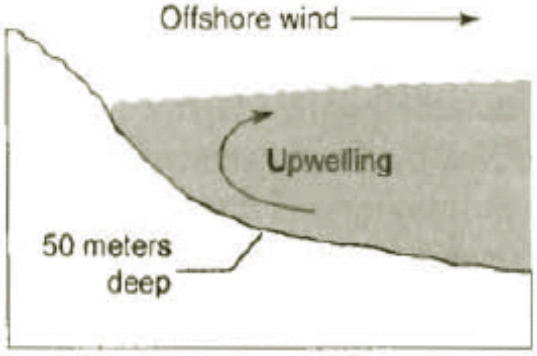
i. If ice caps melt at an increasing rate, what would the affect of this release of **freshwater** have on the down-welling off the coast of Greenland. Would it accelerate the sinking of cold water or diminish it further? Explain

j. As depicted in the futuristic disaster movie, *The Day After Tomorrow*, this trend can be formulated into a worse-case scenario that disrupts the global Thermohaline Circulation (Lab 5). Draw worse-case scenario global warming temperature depth profiles.



Part D. The California Current and coastal upwelling – Monterey Bay

Introduction: There are only a few major coastal upwelling regions worldwide. They make up about 1/10 of a percent of the ocean's surface area, yet 95% of the global marine biomass is produced in these regions. Upwelling waters support many of the world's most important fisheries. In areas of coastal upwelling, cooler, nutrient-rich waters rise from greater ocean depths to replace the surface water that prevailing winds (combined with the Coriolis Effect) pushes off shore. Coastal upwelling occurs off the western margins of continents.



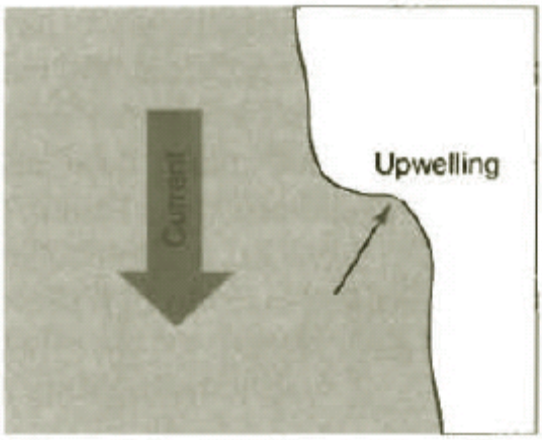
a Wind-driven upwelling

Along California's Monterey coast intense upwelling occurs due to the complex interactions of wind, currents, and topographic features of the coastline. Plumes of upwelled water enter Monterey Bay from the north, from an upwelling center off Point Año Nuevo.

The strongest upwelling occurs when the Monterey area is experiencing winds from the northwest which blow parallel to the coast of California. When these winds are weak or the winds are from the south, the upwelling tends to stop and the relatively warmer surface waters of the California current move into Monterey Bay.

Observations of sea surface temperatures from satellites show that upwelling is not uniform along the central California coast, but is strongest at the major headlands. See below how the obstruction of the

headland contributes to the upwelling in the bay on the south side.

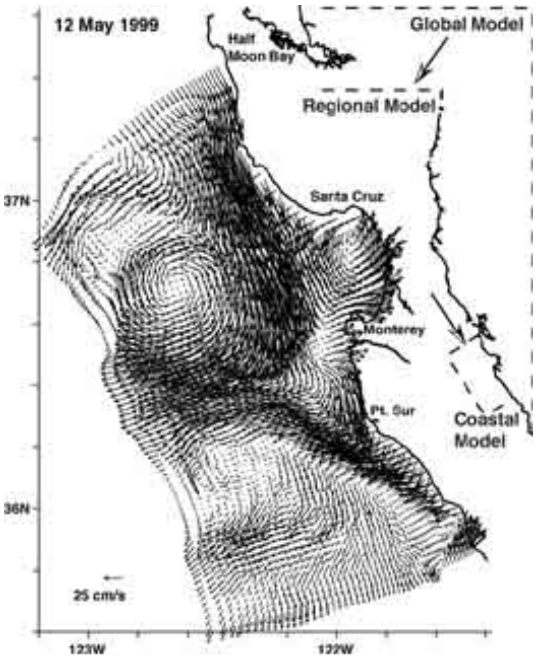


b Obstruction upwelling

The upwelling water can be tracked by measuring the temperature, high nutrient content, high salinity, and high density. The nutrients brought to the surface encourage the high plankton productivity of the Monterey Bay area, which is why it is an excellent fishing locality.

The nutrient (e.g. nitrogen for production of proteins and nucleic acids; phosphorous for production of teeth/bones/shells) rich waters produce phytoplankton which in turn support krill, a tiny shrimp-like crustacean. Blue whales feed almost entirely on krill. A single blue whale can consume more than two tons of krill a day.

Upwelling conditions in Monterey Bay, California



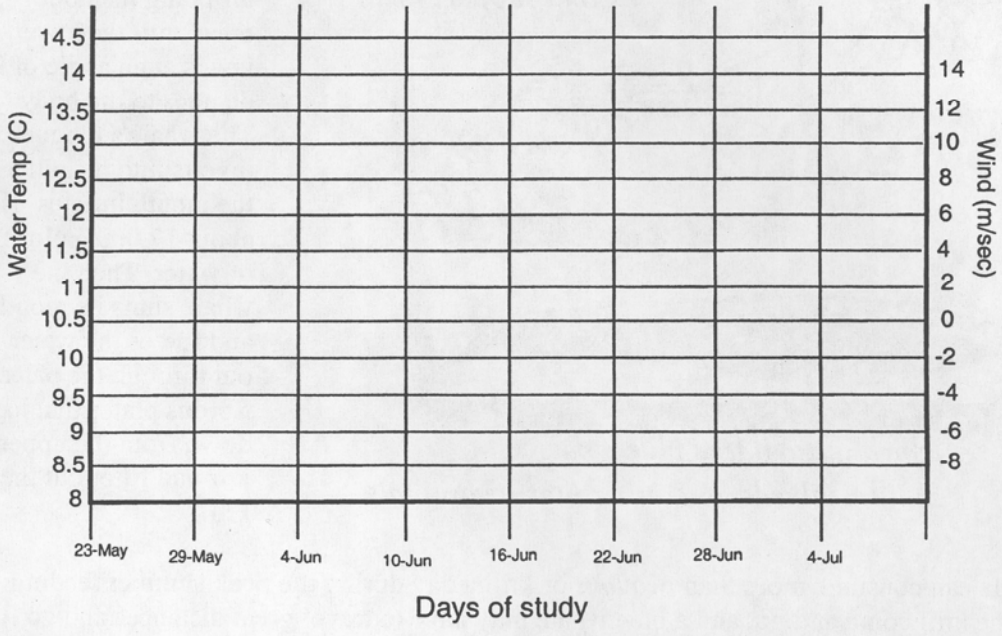
ICON model surface velocities during an upwelling event (courtesy I. Shulman).

12. Upwelling conditions in Monterey Bay, California

1989 Sea Surface Temperature and Wind

DATE	TEMP °C	WIND direction	Speed (m/sec)
May 23	10	N	3
25	10	N	8
27	9	N	10
29	9	N	8
31	9	N	4
June 2	10	S	-1
4	12	S	-4
6	13	S	-3
8	12	N	7
10	11	N	5
12	10	N	8
14	10	N	7
16	10	N	7
18	9	N	9
20	9	N	11
22	11	N	4
24	12	S	-4
26	13	S	-6
28	13	-	0
30	14	S	-1
July 2	13	N	6
4	11	N	9
6	9	N	10
8	9	N	10

1. Plot the sea surface temperature and wind speed with time (data collected from Monterey Bay about 50 km southwest of Santa Cruz). Use a different color for temperature and for wind. Notice that the negative numbers indicate winds **from** the south.



a. On page 12 plot the sea surface temperatures and wind speed with time from the wind and surface temperature data collected from Monterey Bay about 50 km southwest of Santa Cruz. Use one color for temperature and a different color for wind. Note that the negative numbers indicate winds from the south.

b. Describe wind direction and speed during the periods of coldest water (Maximum upwelling).

_____ _____

c. Describe wind direction and speed during periods of warmest water (minimum upwelling).

_____ _____

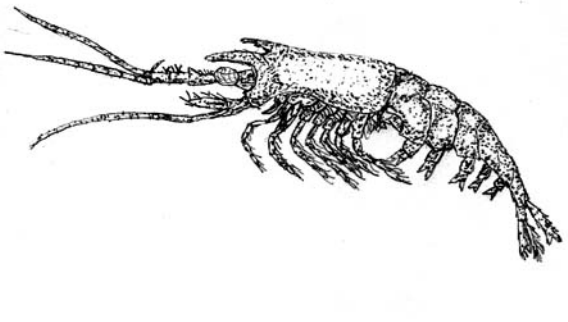
d. John Steinbeck wrote about the sardine canneries in Monterey in his book Cannery Row. Fisherman netted this small plankton-eating fish by the hundreds of tons yearly until they were almost fished out. If they were still plentiful, how would wind direction influence your choice of days to take your boat and crew out sardine fishing?

_____

e. Suppose you are a tour boat operator based in the town of Monterey. During the summer there is often a small pod of plankton-eating whales south of Monterey. Based on the Sea Surface Wind and Temperature Table, what days didn't you bother to look for whales? Why?

_____

Whales lunge feeding on krill in Monterey Bay



Krill