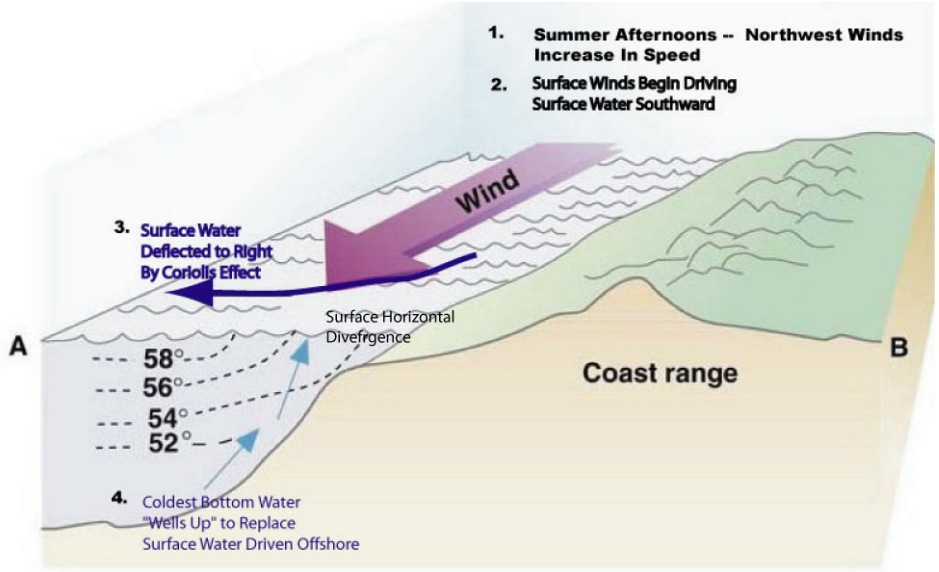
COASTAL UPWELLING: Movement of Energy Name: _____ EN___

Draw what occurs when warm fluid meets cold fluid. Is this effect due to density or displacement? How does this show the movement of energy?

INTRODUCTION

Coastal upwelling is the upward movement of water along a coast. This rising water is usually cooler and more nutrient rich than the surface water it replaces. The upwelling of nutrient rich water has made Monterey Bay, on the central coast of California, a favorite with fishermen. This information is presented in a form that provides students with a clear picture of upwelling concepts.



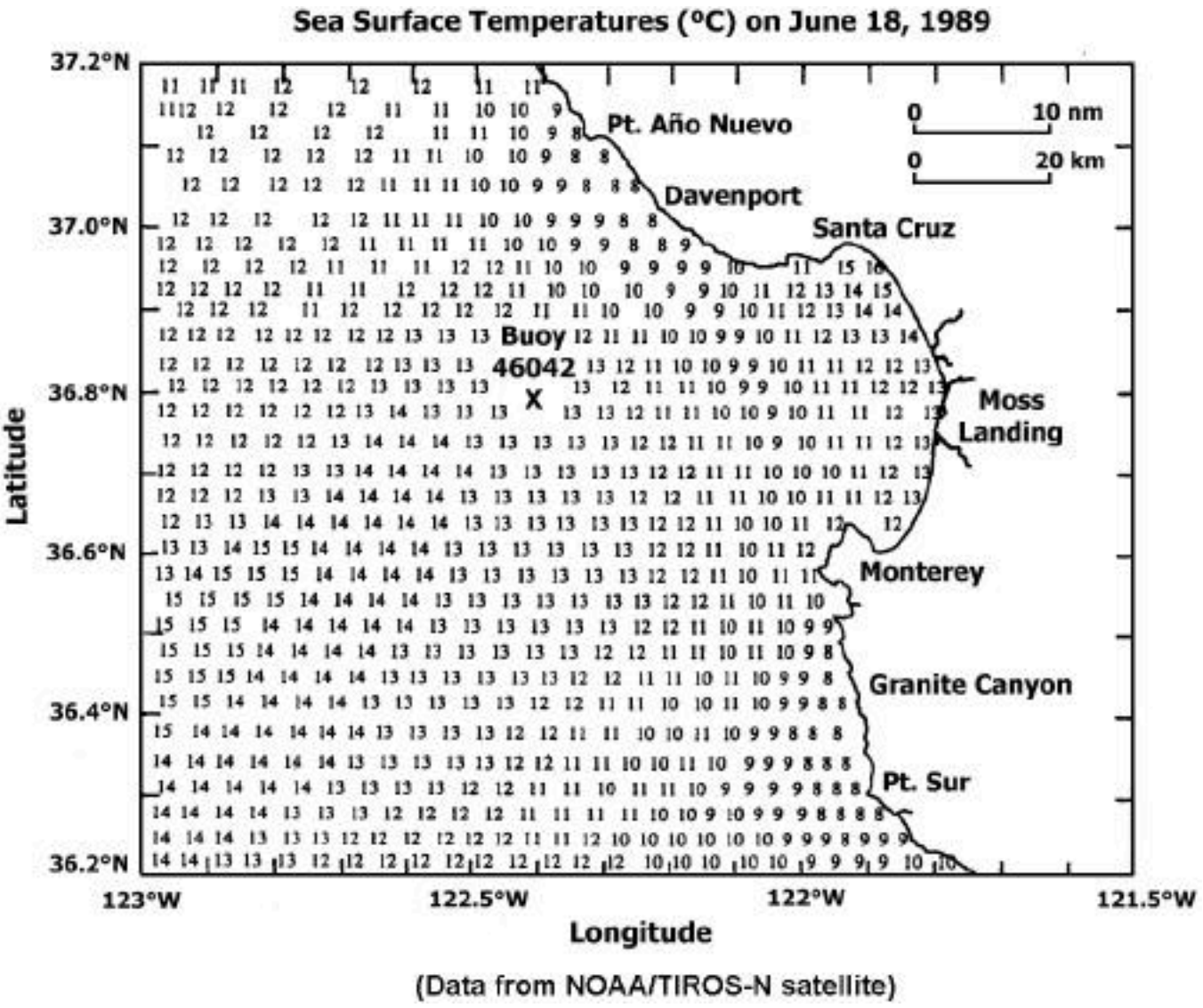
Northwest winds: The strongest upwelling occurs when the Monterey area is experiencing winds from the northwest which blow parallel to the coast of California. When these winds are weak or the winds are from the south, the upwelling tends to stop and the warmer waters of the California current move into Monterey Bay. The very large California Current travels southward along the California coast from the North Pacific.

Headlands: Observations of sea surface temperature from satellites show that upwelling is not uniform along the central California coast, but is strongest at the major headlands. The cold water of Monterey Bay comes primarily from the upwelling in the Point Año Nuevo area, and then progresses south across the mouth of Monterey Bay toward the Monterey Peninsula.

Coriolis effect: In the northern hemisphere the rotation of Earth causes surface water to move to the right of the wind. This movement to the right is known as the Coriolis effect. In the Monterey area, winds out of the northwest cause water to flow to the southwest, away from the coast. The water flowing offshore is replaced by the cool, nutrient rich water which rises up into the coastal area from below, resulting in the upwelling phenomena.

Bifurcated flow: When cool upwelling water rises to the surface at the headlands it departs in two directions, one tending offshore (to the west) and the other toward the equator (south). The upwelled water that flows westward, away from the coast, is immediately influenced by the Coriolis effect. The portion of the upwelled water that is traveling south is influenced by the Coriolis effect, the geography of the coastline, winds from the northwest and the California current.

The upwelling water can be tracked by measuring its cool 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.



PART I. MAPPING

Change the numerical sea surface temperature satellite data into a color image for ease of interpretation. Use the map of sea surface temperatures of the Monterey Bay area and a set of colored pencils to produce a more visually understood sequence of colors. Color in the areas of sea surface temperature using a different color for each temperature. Move through the "ROY G. BIV" (Red, Orange, Yellow, Green, Blue, Indigo, Violet) color sequence, with red being the warmest water. Start with the coldest water (lowest number) using violet. Place a key to the colors you have chosen and their matching temperatures in the margin. It may be easier if you first outline an area with a specific temperature and then fill it in with color.

Color Key :

Part II. Graphing

Refer to **Figure 1** to answer the following questions:

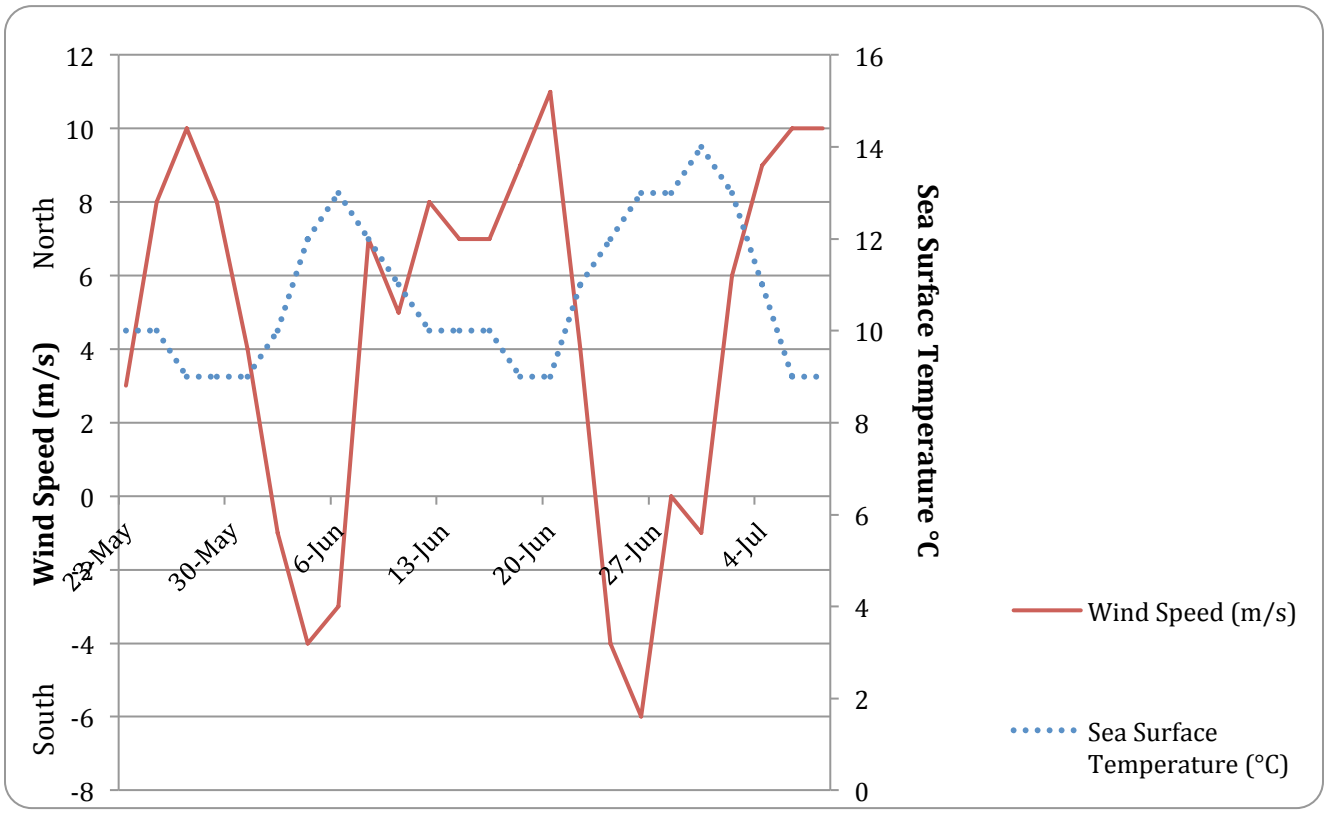
1. Which Wind direction is associated with upwelling- winds from the North or winds from the South? Why?

2. How can you tell when upwelling is occurring?

3. During which months does the strongest upwelling occur?

4. What could you measure to determine the best time of year to go fishing in Monterey Bay? Explain.

Figure 1: Upwelling- The Effect of Wind Speed on Sea Surface Temperature



PART III. AN ANALYSIS OF UPWELLING USING YOUR MAP AND GRAPH.

For the analysis you will need to choose one of the following options to complete. On a separate sheet of paper. Either use complete sentences in a paragraph format or make clear diagrams with accompanying explanations.

A) Answer the 4 questions in the top row.
B) Answer 2 questions from the top row and one from the middle row.
C) 2 questions in the middle row and one from the bottom row.
D) Answer 2 questions from the bottom row.

<table>
<tr>
<td>1. Referring to your graph:
a. Describe the wind direction and speed during the periods of coldest water (maximum upwelling).
b. Describe the wind direction and speed during the periods of warmest water (minimum upwelling).</td>
<td>2. Referring to your map:
a. Describe the location and shape of the area of cold surface water (9$_o$ - 11$_o$) off of Point Año Nuevo.
b. Explain why some of the cold upwelled water moves westward.
c. Explain why some of the cold upwelled water moves south across the bay toward Monterey.</td>
<td>3. Why do you think the cold upwelled water is concentrated at the Point Año Nuevo and Point Sur locations?</td>
<td>4. Explain why the Santa Cruz beach area is so much warmer than the rest of the bay?</td>
</tr>
<tr>
<td>5. Besides following water temperature, what other measurable items could you use to follow the
two paths of the upwelling water? Explain.</td>
<td></td>
<td colspan="2">6. Get together with two students and have each person explain upwelling to the two others. After all three of you have explained the idea twice, write an explanation for upwelling that a 10 year old could read and understand.</td>
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<tr>
<td>7. Fishing
a) Sardines. John Steinbeck wrote about the sardine canneries in Monterey in his book Cannery Row. The book describes the fishermen that netted these 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? (Take into account the growth rate of plankton.)
b) Squid are netted as they swarm in southern Monterey Bay to reproduce. Fishermen turn on bright lights to attract and net them from midnight to six a.m. T he squid prefer the water that is warmer than average. Based on your data which nights in June 1989 would you have picked to go squid fishing?</td>
<td>8. Tour boat operator
a. Suppose you were offering bay tours to the public and wanted your patrons to see the large, plankton-eating basking sharks that visit Monterey Bay. What area would be optimal for spotting these sharks close to Moss Landing?
Lat. _____°__ & Long._____°__
Why?
b. During the summer, there is often a small pod (group) of plankton-eating blue whales south of
Monterey. What area would be optimal for whale watching trips departing from Monterey?
Lat. _____°__ & Long. _____°__
Why?</td>
<td colspan="2">9. MBARI
The Monterey Bay Aquarium Research Institute (MBARI) has a new remotely operated vehicle (ROV) that can go down into the Monterey Submarine Canyon to a depth of 4,000 meters.
During most of the trip down to the bottom the video shows “marine snow” (tiny particles of decaying organisms, feces, and plankton) gently drifting to the bottom. Some of this material will be recycled by upwelling. If you sent MBARI’s ROV down at 37.0° N, 122.5° W, during which days in June 1989 would you have expected maximum marine snow? Why? Remember
to consider what the marine snow is composed of, that it drifts down slowly and the growth rate
of plankton.</td>
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PART IV. Making Connections with using high tech images of Earth.

Figure 2: Global Ocean Currents

http://upload.wikimedia.org/wikipedia/commons/c/cc/Ocean_surface_currents.jpg

Figure 3: Global Upwelling

http://oceanservice.noaa.gov/education/kits/currents/media/upwelling_image1.jpg

What inference can you make that explains the relationship between these two maps? Hint :think density or displacement.

Figure 4: Global Chlorophyll Concentration

http://upload.wikimedia.org/wikipedia/commons/thumb/4/44/Seawifs_global_biosphere.jpg/248px-Seawifs_global_biosphere.jpg

Explain the significance of the trends illustrated on the map below.

Wrap up:

Power Plant at Moss Landing

a. There is a large gas burning electrical power plant at Moss Landing that releases warm water, used for cooling its turbines, into Monterey Bay. Does this warm water show up on the satellite map? Why?

b. Would you expect to find this warm water near the surface or on the bottom? Why?

c. Explain whether or not you expect this to have an impact on fishing nearby.

PART V. Research and Application:

Pick one worldwide fishery or reef and research the annual temp and salinity. Compare this year's current data to data from 10, 20 and 50 years apart. Cite your source and give an explanation for the trends in the data. Lastly infer what effects these trends might have on the fishing industry.

Steve Clark, Monterey Academy of Oceanographic Science (MAOS) based on information that was compiled and evaluated by Leslie Rosenfeld and her colleagues from Monterey Bay Aquarium Research Institute (MBARI) in Moss Landing, CA.

Reference:
Bifurcated flow from an upwelling center: a cold water source for Monterey Bay, Rosenfeld et al., *Continental Shelf Research* Vol. 14, No. 9.

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SOURCE
Monterey Academy of Oceanographic Science.