Activity: Sea-Surface Temperatures

Introduction

In some near-shore areas of the ocean, coastal orientation, prevailing winds, and rotation of Earth combine to influence vertical ocean circulation. In these regions, the wind sometimes transports the upper 10 to 100 meters of water away from a coast, to be replaced by cooler water welling up from below. This process, called coastal upwelling, brings to the surface relatively cold bottom water which can chill the air immediately above the ocean surface. At other times and places, the prevailing wind transports near-surface water towards a coast, causing warm surface waters to pile up and sink. This process, called coastal downwelling, produces relatively warm ocean surface-water near the coast.

This activity investigates coastal upwelling and downwelling by looking at the combinations of coastline orientation, prevailing wind direction, and Earth rotation that produce them. From this, you can predict the general sea-surface temperature pattern and possible influences on weather and climate.

Materials

Photocopies of Model Ocean Basin page and Global Ocean Basin Chart, scissors, paper brad.

Objectives

After completing this investigation, you should be able to:

- Demonstrate the causes of coastal upwelling and downwelling.
- Describe the influence of the prevailing wind and the Coriolis effect on upwelling and downwelling.
- Describe the influence of upwelling and downwelling on sea-surface temperatures.

Investigations

Use the scissors to separate the top and bottom diagrams along the dashed line and cut out the windows from the top diagram as indicated. The top block diagram represents the ocean surface with a vertical cross-section through a model ocean basin. If desired, this can be better seen by folding the diagram along the intersection of the ocean surface and the vertical cross-section and placing it so the vertical cross-section is hanging off the edge of a table.

Use a pencil point to poke a small hole through the rotational centers (each marked with a ⌖) of the two diagrams. Lay the top diagram (Model Ocean Basin) directly over the bottom diagram (arrows) so the rotational centers of the two coincide. To hold the two together, place a paper brad down through the holes you punched in the diagrams.

The global Basin Chart is provided for reference as you proceed through the following investigations.

1. According to the cardinal direction arrows in the upper left hand corner of the top block diagram, the west boundary of any ocean basin is the land's **[(*eastern*)(*western*)]** coast and the east boundary of any ocean basin is the land's **[(*eastern*)(*western*)]** coast.

2. On Earth, away from the equator, surface water set in motion by the wind will be deflected by Earth's rotation. This deflection is called the Coriolis effect. Turn the bottom diagram until a Northern Hemisphere combination appears, that is, an “N” appears in the upper right window. Compare the wind direction and the direction of the near-surface water motion. If desired, this can be better seen by orienting yourself so that you are on the tail of the wind arrow facing its head. The near-surface water motion is about 90 degrees to the **[(*right*)(*left*)]** of the wind direction.

3. Predict the direction of the near-surface water motion produced by winds blowing from the opposite direction in the same hemisphere. Your prediction is that the near-surface water motion will be about 90 degrees to the **[(*right*)(*left*)]** of the wind direction.

4. To check your prediction, rotate the bottom diagram until the other “N” appears in the window. From what you have learned so far in this activity, wind-driven near-surface water motion in the Northern Hemisphere is about 90 degrees to the **[(*right*)(*left*)]** of the wind direction.

5. Repeat the last three steps, but this time for the Southern Hemisphere. Again predict and note the direction of the near-surface water motion relative to the wind direction. The wind-driven near-surface water motion in the Southern Hemisphere is about 90 degrees to the **[(*right*)(*left*)]** of the wind direction.

6. When wind transports near-surface water away from a coast, it tends to be replaced by cooler water from below in a process called upwelling. Rotate the bottom diagram to a position showing the wind blowing from south to north in the Northern Hemisphere. This combination will produce upwelling along the land's **[(*eastern*)(*western*)]** coast.

7. Upwelling of colder ocean water would tend to produce relatively **[(*high*)(*low*)]** sea-surface temperatures compared to regions not affected by the upwelling. Warmer air moving over this ocean surface would be **[(*chilled*)(*heated*)]** from below.

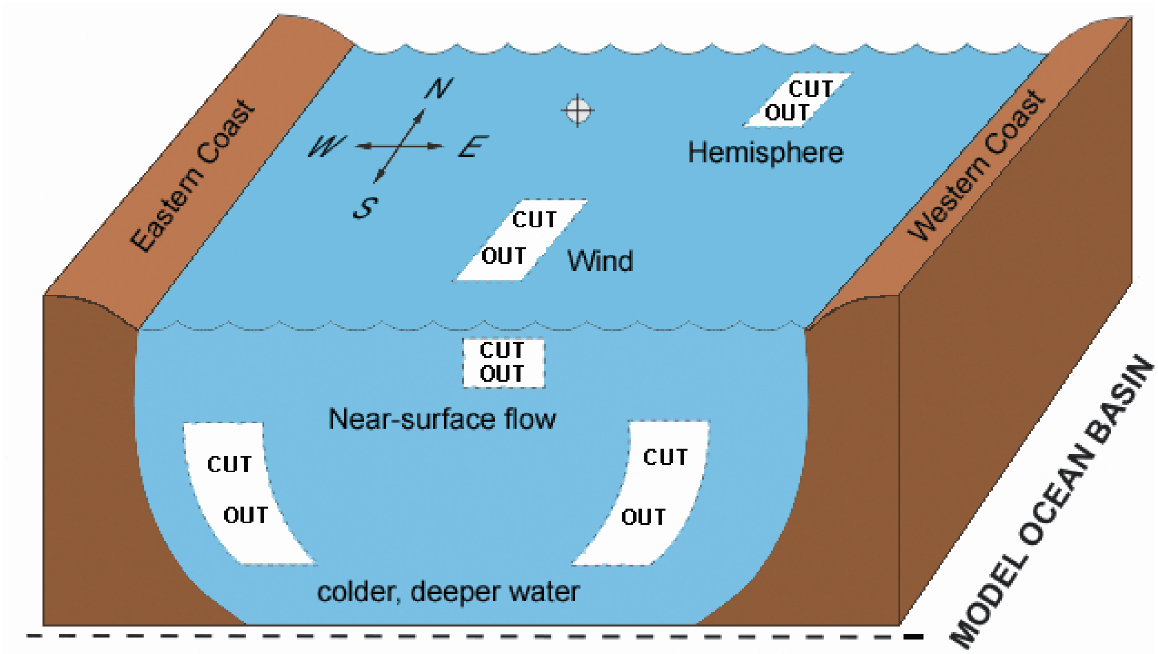
8. Chilling of air by a relatively cold ocean surface would likely **[(*enhance*)(*inhibit*)]** development of clouds, showers, and thunderstorms. Also sea fog **[(*would likely*)(*would be unlikely to*)]** form.

9. When wind transports near-surface water towards a coast, the warm surface layer thickens and water is forced downward. This process is called downwelling. Rotate the underlay to a position showing the wind blowing from south to north in the Northern Hemisphere. This combination will produce downwelling along the land's **[(*eastern*)(*western*)]** coast.

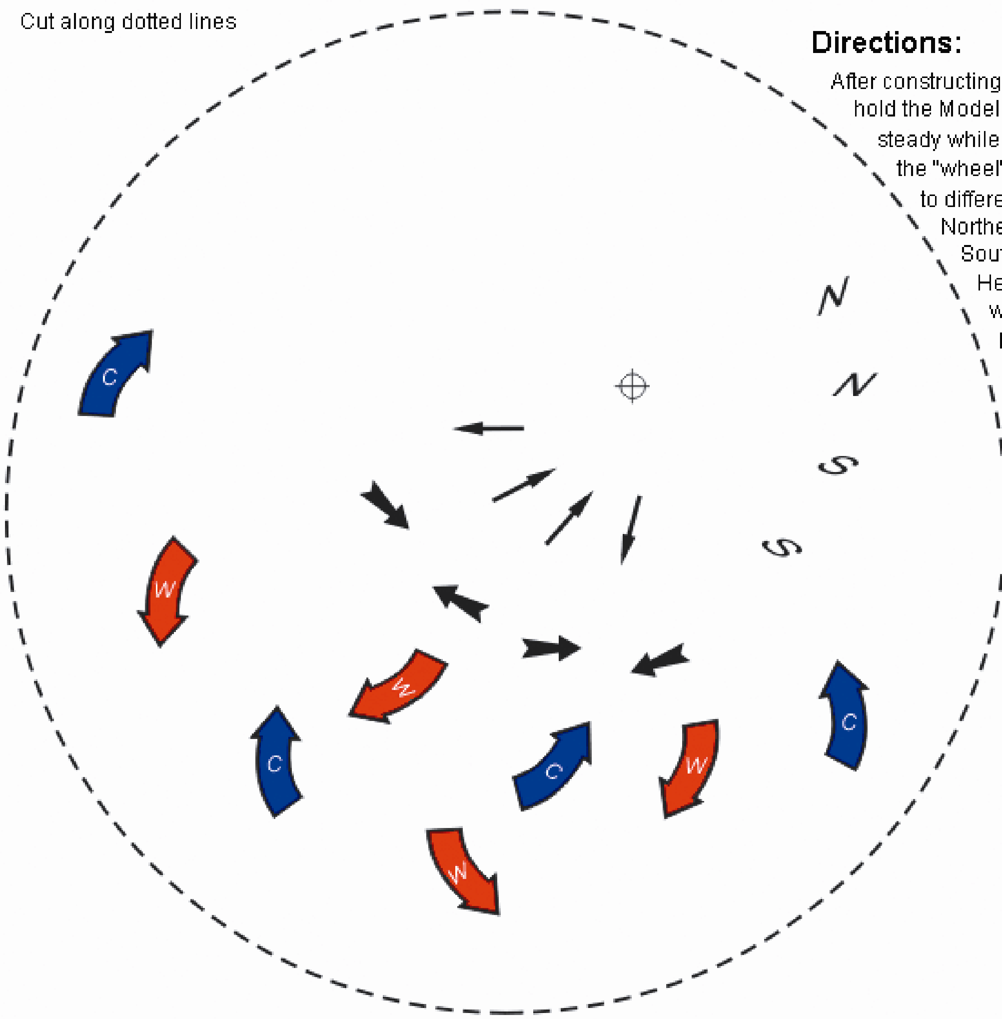
10. Along the coast of central and northern California, prevailing surface winds blow from north to south in the summer and from south to north in the winter. The season of warm water movement towards the coast and downwelling for this region is **[(*summer*)(*winter*)]**. The season for cold-water upwelling and frequent fog is **[(*summer*)(*winter*)]**.

11. Rotate the underlay to a position showing the wind blowing from north to south in the Northern Hemisphere. Along the land's eastern coast, this combination will produce **[(*upwelling*)(*downwelling*)]** and relatively **[(*cool*)(*warm*)]** surface waters. This surface temperature pattern would tend to **[(*enhance*)(*suppress*)]** cloud formation.

12. In view of the latent heat requirements of tropical storms and hurricanes, those weather systems are not likely to develop over a(n) **[(*upwelling*)(*downwelling*)]** zone. A hurricane that moves over an upwelling area of a tropical ocean is likely to **[(*intensify*)(*weaken*)]**.



Cut along dotted lines



Directions:

After constructing this device, hold the Model Ocean Basin steady while turning the "wheel" underneath to different Northern and Southern Hemisphere wind-direction positions.

Note changes in water flow.

Real World Applications

The U.S. West Coast shows the effects of these wind and water interactions and their influences on the coast areas. **Figure 1** is the comparison of the annual average air pressure patterns off the U.S. West Coast. Note that, although there is north-south movement of the center of highest pressure seasonally, the clockwise and outward atmospheric flow about the center of a High means that there would generally be a fairly steady wind directed toward the southeast the majority of the year.

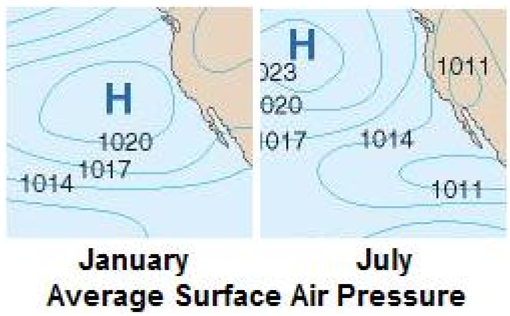


Figure 1. Atmospheric pressure patterns off the U.S. West Coast. (Adapted from *AMS Weather Studies*.)

Figure 2 is a composite of three California regional weather maps for the twenty-four hour period from 00Z 11 October to 00Z 12 October 2011. The maps show the persistent wind flow toward the southeast along the California coast over that period.

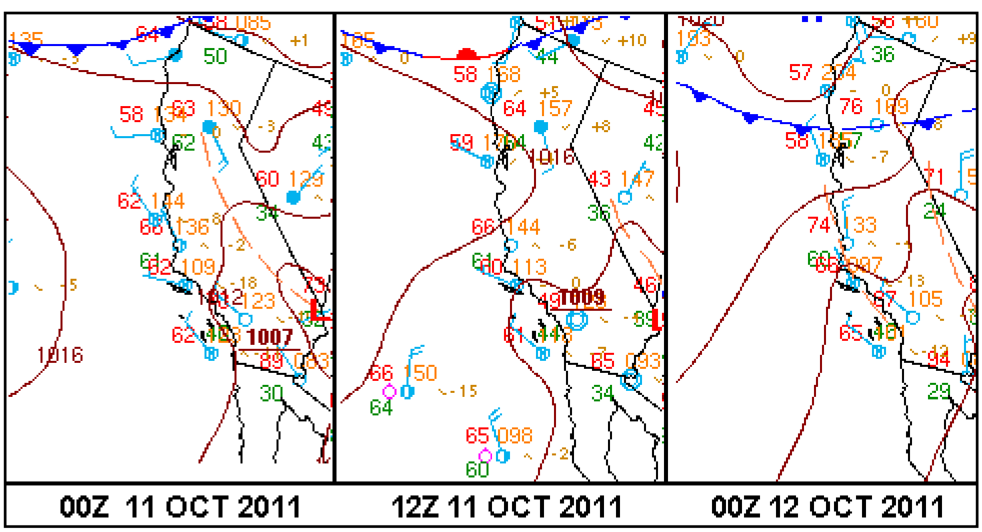


Figure 2. California regional weather maps for the twenty-four hour period of 11 October 2011. [HPC – NCEP, NOAA]

1. The coastal wind directions seen in the Figure 2 map segments **[(*__are__*)(*__are not__*)]** consistent with the southerly flow to the east side of the persistent High seen in Figure 1.

Set your Model Ocean Basin device to the combination of the ***Northern Hemisphere*** position with a wind directed toward the ***south***. Consider the water movements in the ocean in relation to the "Western Coast".

2. This Model Ocean Basin configuration **[(*__is__*)(*__is not__*)]** the same as the California weather map configuration seen in Figure 2.

3. The Model Ocean Basin device indicates that the Near-surface flow of water along the California coastal region would be directed **[(*__onshore__*)(*__offshore__*)]**.

4. The Model Ocean Basin device also indicates that the flow of colder, deeper water would be **[(*__upwards__*)(*__downwards__*)]**.

5. This condition would be a case of **[(*__upwelling__*)(*__downwelling__*)]**.

6. With this vertical movement of the deeper water, surface water temperatures in the region affected would be relatively **[(*__lower__*)(*__higher__*)]** than surrounding temperatures.

Figure 3 is a composite of MODIS satellite views on 12 October 2011 showing the California region in visible conditions where clouds are to the west and north in the left image. The center image displays ocean "color", a measure of chlorophyll concentration in surface waters. Higher biological productivity produces more chlorophyll as shown by the yellow and red shadings. The image on the right shows sea surface temperatures as shades of green. Black is where the clouds caused missing data. Darker shades of green are warmer temperatures. Blues and light greens represent cooler temperatures.

7. The color shadings of sea surface temperatures along the Southern California coast **[(*__are__*)(*__are not__*)]** consistent with your answer to Question 6.

8. The associated existence of upwelling in coastal waters **[(*__would__*)(*__would not__*)]** bring nutrients to surface layers to enhance biological productivity.

9. The likelihood of upwelling and increased biological productivity in the Southern California coastal waters **[(*__is__*)(*__is not__*)]** consistent with the center image in Figure 3 of chlorophyll concentrations.

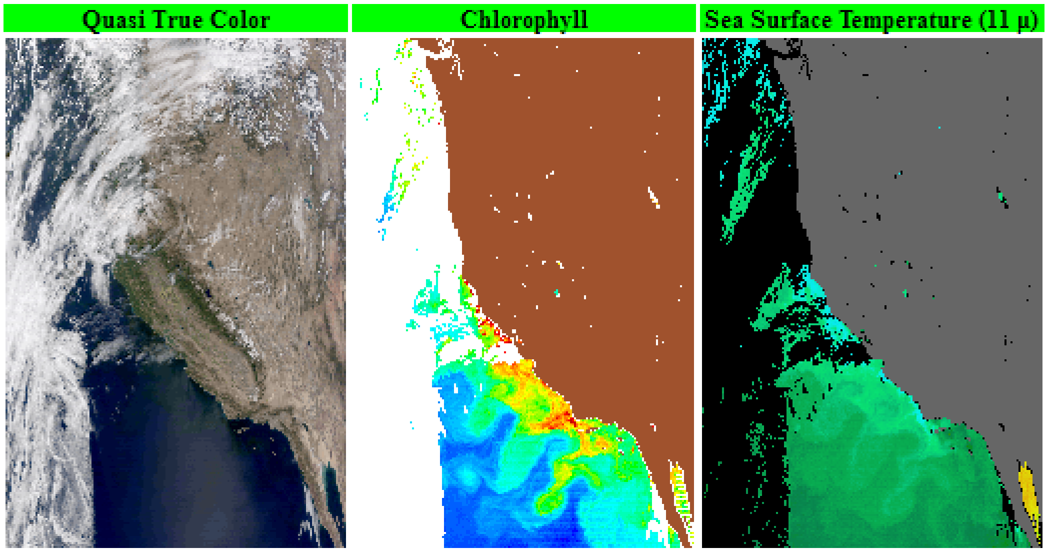


Figure 3. MODIS images of visible, chlorophyll, and sea surface temperature from left to right, respectively, on 12 October 2011. [SeaWiFS]