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PHYSICAL PROPERTIES OF SEA WATER - TEMPERATURE AND SALINITY

I. Sea water temperatures

The distribution of surface temperatures for the major oceans is shown in Figure 1. The *isotherms* (lines of equal temperature) tend to deflect towards the equator on the eastern sides of the oceans and towards the poles on the western sides of the ocean. This is due to the major surface circulation pattern of the oceans. Warm water from low latitudes is transported towards the poles on the western sides of ocean basins and cold water from high latitudes is transported towards the equator on the eastern sides of ocean basins.

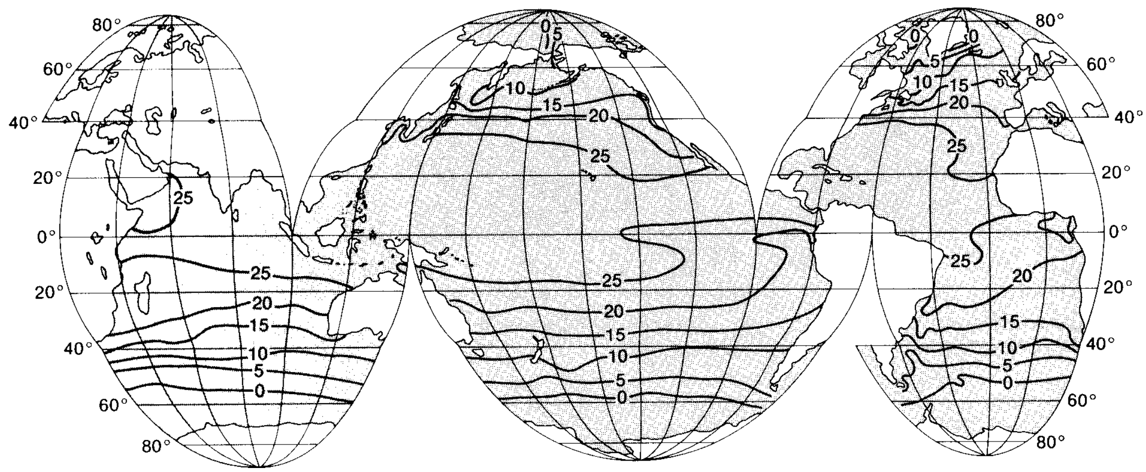

Figure 1. Distribution of surface ocean temperatures (°C) for the month of August. From Pipkin et al., 1987. *Laboratory Exercises in Oceanography, 2nd Ed.* New York: Freeman, p. 73.

Vertically the oceans can be divided into two reservoirs, a warm surface reservoir and a cold deep water reservoir. These two reservoirs are separated by a zone of rapidly changing temperature which is referred to as the *permanent (or main) thermocline* (Figure 2). The temperature of the top (mixed) layer varies seasonally in response to variations in solar heating. The solid curve shows the winter conditions in the mixed layer and the dotted curve shows the seasonal thermocline that exists during spring warming. Note that this seasonal thermocline is confined to the mixed layer. The dashed curve is the seasonal thermocline in extreme summer conditions. The permanent thermocline is not found at high latitudes where the surface waters are very cold and there is little variation in water temperature with depth. It is in these high latitude regions that cold surface waters can sink to depth. This process is responsible for the vertical circulation of ocean waters, called *thermohaline*

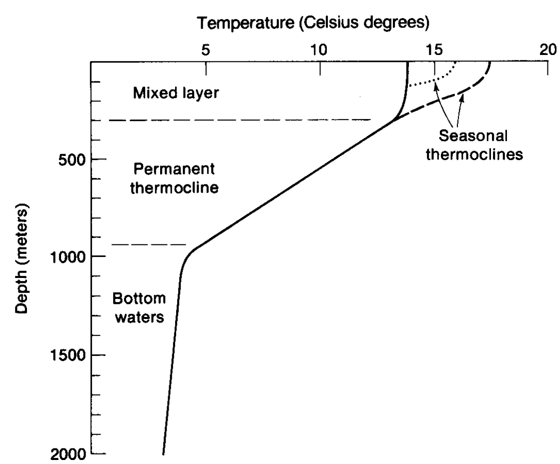

Figure 2. The main thermocline. Solid line shows the winter thermocline and the dashed and dotted lines show the summer thermocline. From Pipkin et al., 1987. *Laboratory Exercises in Oceanography, 2nd Ed.* New York: Freeman, p. 72.

circulation because density differences due to temperature and salinity differences are responsible for the circulation. Two other terms, parallel to the term themocline, are used in oceanography. The *halocline* is the zone of rapidly changing salinity between relatively low salinity surface waters and deeper more saline waters. The *pycnocline* marks a zone of rapidly changing density.

Upwelling, the movement of deeper water towards the surface and *downwelling*, movement of surface waters to greater depth, are important processes in the ocean. Upwelling and downwelling can occur locally in coastal waters or on a larger scale involving significant volumes of ocean water. During upwelling deeper cold water is brought towards the surface and isotherms deflect upwards. During downwelling warm surface water is moved to greater depths and isotherms are deflected downwards. There are five basic types of upwelling (Figure 3). Note that downwelling is simply the reverse of these processes. For example, if the wind is blowing onshore, rather than offshore (Figure 3b), downwelling will occur.

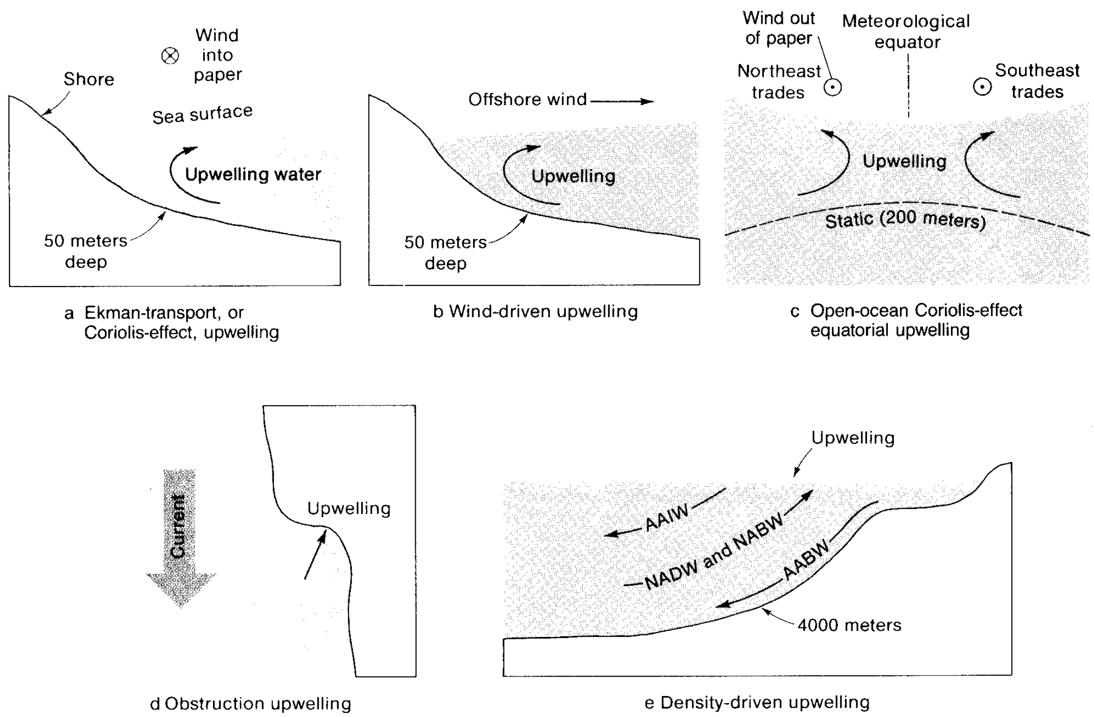

Figure 3. Diagrams of the various types of upwelling. From Pipkin et al., 1987. *Laboratory Exercises in Oceanography, 2nd Ed.* New York: Freeman, p. 74.

1. *Ekman-transport upwelling.* Wind blowing across the surface water sets the water into motion. Because of the Coriolis effect water in the Northern Hemisphere is deflected to the right of the wind direction and water in the Southern Hemisphere is deflected to the left. Some of the momentum of the moving surface waters is transferred to the deeper waters setting them in motion. As we go down in the water column the momentum transfer decreases and at some depth the water motion is zero. At all the depths above this the water is deflected to the right (NH) or left (SH), the slower the water movement the greater the amount of deflection. This variation in direction of water movement with depth is referred to as the *Ekman spiral* (Figure 4). If we sum up the total water movement throughout the Ekman spiral the net movement is at 90° to the surface wind. Referring to Figure 3a, you are in the Northern Hemisphere and the wind is blowing to the north (a southerly wind since winds are named for the direction from which they come). The net movement of water is to the right away from

the shore. The offshore movement of the surface water is offset by the movement of deeper waters to the surface, i. e., upwelling.

2. *Wind-driven upwelling*. In this case an offshore wind causes water to move away from the coastline. This water is replaced by deeper water moving to the surface (Figure 3b).

3. *Open-ocean Coriolis-effect upwelling*. The divergence of surface currents causes deeper waters to move to the surface replacing surface waters that move away from the zone of divergence (Figure 3c).

4. *Obstruction upwelling*. A current moving past a headland or other obstruction will draw water away from the obstacle and upwelling will occur (Figure 3d).

5. *Density-driven upwelling*. Cold denser surface waters sinking to depth force less dense waters to the surface (Figure 3e).

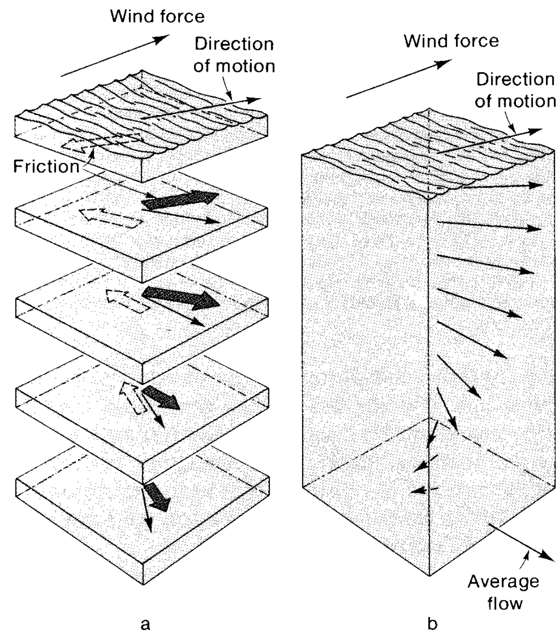

Figure 4. Diagram illustrating the Ekman spiral. (a) A body of water can be thought of as a set of slabs, the top one driven by the wind and each one below set in motion by momentum transfer. With depth each layer moves at a slower speed. (b) Vectors showing water motion as a function of depth. Average waver movement is at 90º to the surface wind direction. The example is set in the Northern Hemisphere. From Pipkin et al., 1987. *Laboratory Exercises in Oceanography, 2nd Ed.* New York: Freeman, p. 73.

1. Figure 5 shows a number of surface temperatures taken as part of a program known as the Organization of Persistent Upwelling Structures (OPUS). The investigation centers on a region of intensified upwelling between Point Conception and Point Arguello, California.

   a. Contour the surface temperatures at a 0.5 ºC contour interval. It is suggested that you contour whole degrees to start, then fill in half-degree intervals by interpolation.

   b. Explain the temperature pattern found off Point Conception.

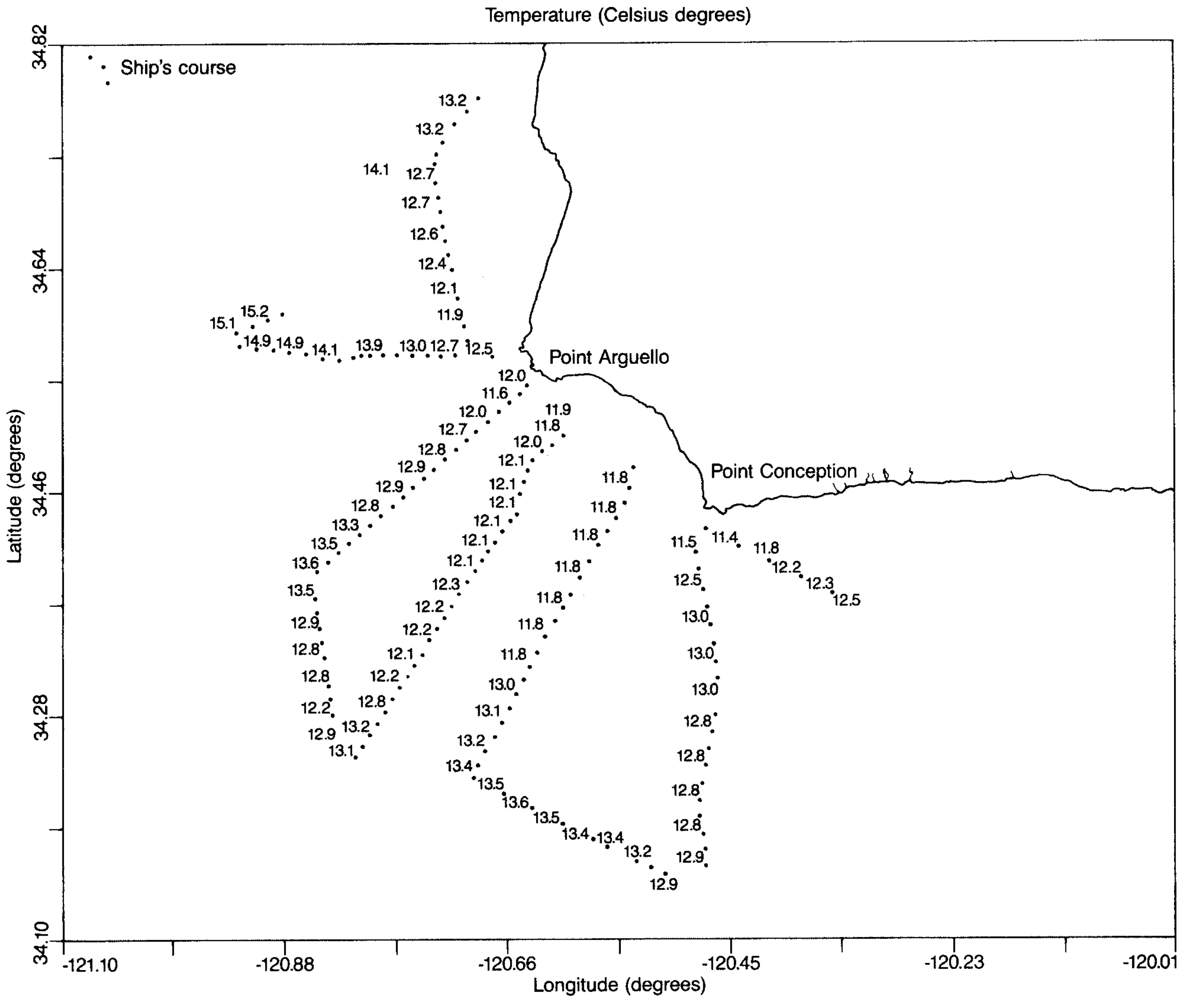

Figure 5. Surface temperature pattern off Point Conception, California, taken on April 14 - 15, 1983. From Pipkin et al., 1987. *Laboratory Exercises in Oceanography, 2nd Ed.* New York: Freeman, p. 77.

2. Figure 6 is a temperature cross section off Point Conception. Contour the profile down to the 8°C isotherm using a 0.5°C contour interval. It is suggested that you begin contouring at the bottom (8°C isotherm) and work upward.

   a. What process is indicated by the shape of the contours at shallower depths?

   b. Based on the appearance of the contours, what seems to be the motion of the deeper water?

   c. Compare the temperature map and cross section to the upwelling processes shown on Figure 3. What type of upwelling best describes what is taking place at Point Conception? Why?

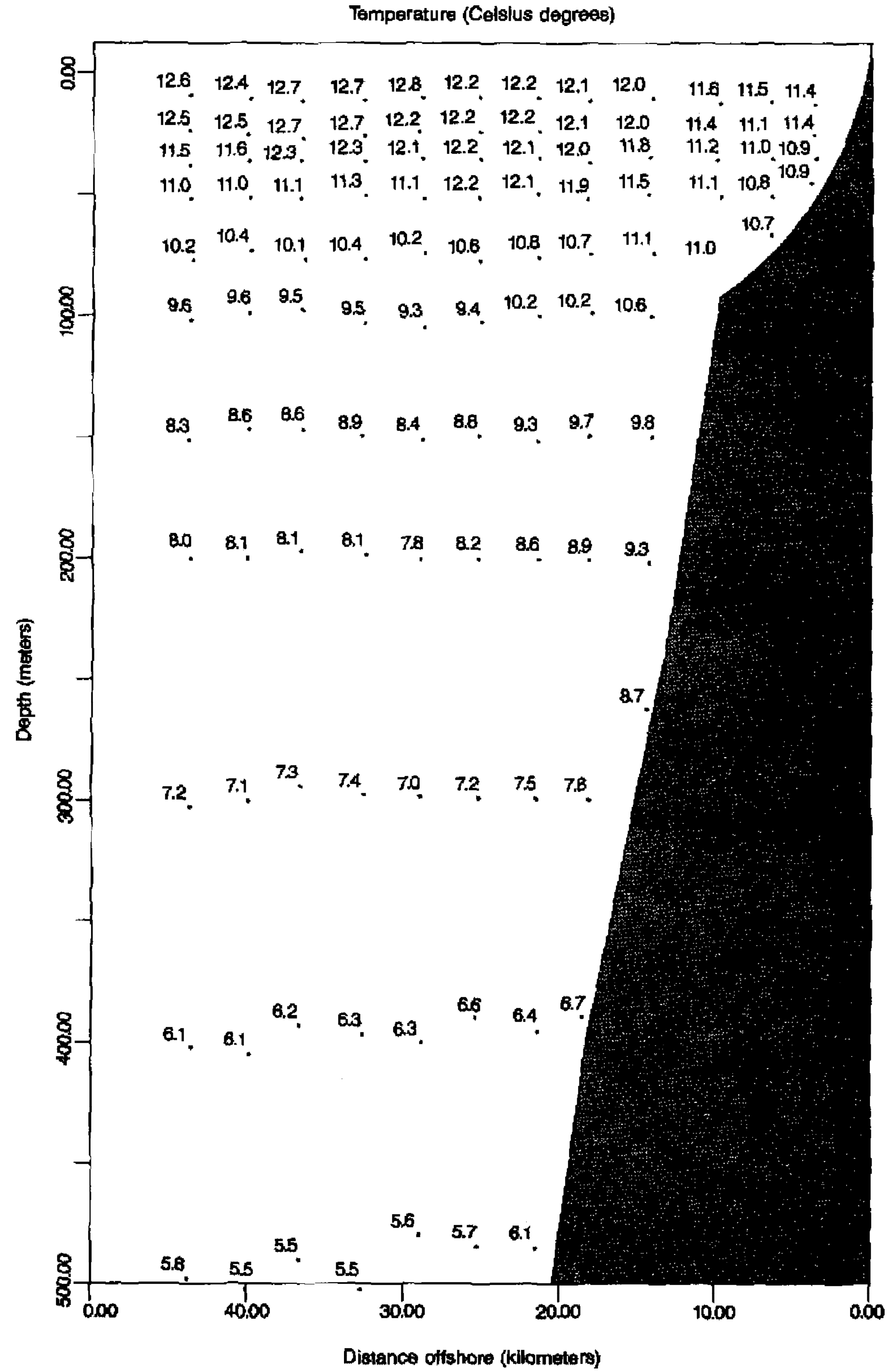

Figure 6. Vertical temperature profile off Point Conception. From Pipkin et al., 1987. *Laboratory Exercises in Oceanography, 2nd Ed.* New York: Freeman, p. 79.

3. Figure 1 shows the distribution of surface temperatures in August in the major ocean basins. With reference to this figure

   a. Where is water of the greatest density formed? Explain your answer.

   b. How would a depth-temperature (BT) curve from the Arctic regions differ from one at mid-latitude or one from the equatorial regions? Explain your answer.

   c. Why is water so much cooler along the west coast of North America than at equivalent latitudes on the opposite side of the Pacific Ocean?

II. Sea water salinity

Salinity is defined as the amount of dissolved material in grams per kilogram of sea water when all the iodine and bromine have been replaced by chlorine, the carbonates have been converted to oxides and all the organic matter has been oxidized. Salinity varies with latitude (Figure 7). The major processes responsible for these variations are evaporation, precipitation and mixing. Where evaporation exceeds precipitation salinity values are high. Where precipitation exceeds evaporation salinity values are low. *Isohalines* are lines of equal salinity.

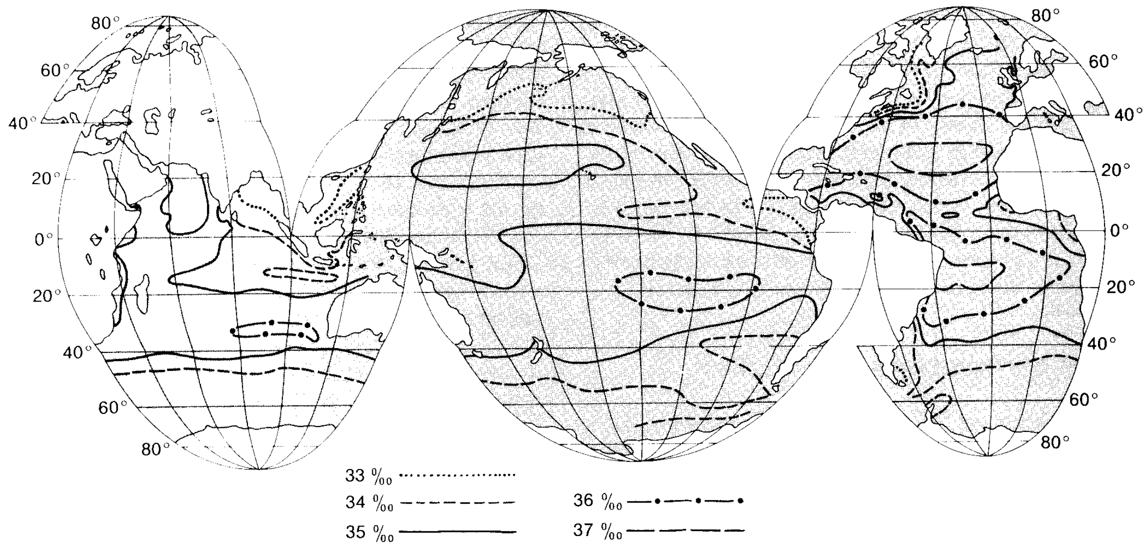

Figure 7. Salinity distribution in the surface waters of the oceans in August. From Pipkin et al., 1987. *Laboratory Exercises in Oceanography, 2nd Ed.* New York: Freeman, p. 82.

4. Study the isohalines on Figure 7 and answer the following questions.

   a. How does salinity vary from the equator to polar regions in the Pacific Ocean? Give exact values and general latitudinal zones.

   b. Which of the two oceans shown is saltier and by what amount? How might you explain this? (Hint: Relate to the major wind belts.)

   c. Explain the tongue of low-salinity water extending from Baffin Bay west of Greenland to the eastern coast of Canada. (Remember that it is summertime in the Northern Hemisphere.)