Ocean Mixing & Pollution – Tutorial Script

Let's return to the concept of mixing – which happens for ocean waters over 1000 years. How does this mixing happen? Through a combination of surface currents and thermohaline currents. But how do we mix between the two? In the poles, there's no pycnocline, so surface and deep water can mix easily, but what about elsewhere? We can break through the pycnocline if we allow surface water to pile up in an area. That will cause **downwelling** – surface water pushed down and mixed with deeper water. Or we can pull surface water away, which will cause **upwelling** – deep water rises up and brings its cold temperatures and high nutrient contents to the surface. But what causes water to pile up in an area or be pulled away? Where surface currents converge, water will pile up, and downwelling will occur. This happens around 55°S and generates the Antarctic Intermediate Water as discussed in the thermohaline currents video tutorial. Water also piles up in the western equatorial oceans where the equatorial currents converge with the land as was discussed in the surface currents video tutorial. The opposite – surface currents diverging – happens where the North Atlantic Deep Water rises around Antarctica – just south of the zones of convergence. And along the eastern equatorial Pacific, the equatorial currents diverge and leave a hole in the surface water, creating upwelling.

More localized coastal upwelling or downwelling is also found throughout the oceans and is an important aspect of California coastal dynamics. To understand coastal upwelling better, let's study this picture of a coastline in the southern hemisphere. When winds are moving from the south, the leftward coriolis deflection causes water to be pulled away from shoreline. Deep water wells up to take its place. The reverse happens when the wind changes direction. When the wind comes from the north, the leftward coriolis deflection pushes water up onto the beach and causes downwelling.

The California Current and other eastern boundary currents can also cause upwelling when the coastline bends inland. Water is pulled south in this picture, away from the downcurrent side of the bend, creating a zone where deep water can well up and take its place. Everywhere there's a bend along the California Coastline, we get increased upwelling on the downcurrent side because of this phenomenon. Finally, when we have currents colliding with underwater seamounts, the seamounts will shove the water upward, and also create a zone of upwelling on the surface nearby. These are especially interesting upwelling zones, because they attract lots of marine life to the area, but there doesn't have to be any nearby land. An oasis in the center of the ocean.

So what? How does upwelling affect the coastline? The upwelled water is both cold and rich in nutrients. The nutrients mean that it can support a high abundance of marine autotrophs that then also support large fisheries and bird populations. The cold water cools the air, thus reducing its water capacity and increasing its relative humidity, usually causing fog banks to develop or rain. Early marine navigators used the currents to help them identify their location and increase their speed. Zones of upwelling, which they identified by the high bird and fish life and by changes in relative humidity, alerted them to underwater seamounts and chains of islands. Currents, upwelling, and other clues such as wave patterns and night-time stars were used to find their way day or night through the middle of the vast Pacific Ocean.

This image shows parallel lines of white foam atop a shallow lagoon behind Rodeo Beach in the Marin Headlands. Why is it here? What causes these? When strong winds blow across this body of water in the same direction for a long time, they whip the water up, much like an egg beater. The top 10 meters of the water are pushed away from each other along lines of divergence, creating local limited upwelling. These zones collide with each other creating zones of convergence, and local limited downwelling. Floating material, such as sea foam and garbage, will collect along the zones of convergence, and hence you get these white parallel lines. We call these circulation cells **Langmuir cells** and they help to quickly mix the surface waters on windy days.

Between thermohaline currents, surface currents, upwelling, downwelling, and langmuir circulation, the world's ocean water mixes on average every 1,000 years. That means that pollutants will mix over that same time frame. And whatever is dumped in any one part of the world ocean will be delivered, ultimately to the shores of all the others within 1000 years – even sooner if you're closer to the source of pollution. International cooperation on pollution standards and regulation of ocean dumping is essential if we all want to share a healthy ocean. How would dumping of chemicals off of California's coast reach the rest of the world? First they'd get caught up in the California Current and mixed through the North Pacific through the North Pacific gyre. Some would get caught up in the western equatorial Pacific dome or pile and some might end up migrating southward to the southern gyre, where they'd get mixed up with the nearby West Wind Drift and carried all around Antarctica, where they'd get incorporated into bottom currents and intermediate currents that would migrate northward through the three major ocean until they get caught up in upwelling zones and carried into the surface gyres. After 1,000 years they would have been thoroughly mixed.

Some pollutants float – others sink. The floating ones are useful for showing surface current mixing. Common floating pollutants include oil and plastics and, yes, rubber duckies and tennis shoes. Container ships that cross the ocean sometimes lose containers, and the materials within them act as ocean drifters clocking current speeds and directions. This map shows the location of a Nike shoe spill off of the Aleutian Islands and the path they took as they drifted with the currents and eventually washed up on the shores of Northern Vancouver Island in British Columbia.

There are a number of large areas of convergence in the world ocean where floating pollutants, primarily plastics, collect in still waters. This image shows two large zones of convergence in the center of the North Pacific Gyre. These areas are called garbage patches. Ships that have traveled through these waters can see floating debris on the surface and plankton nets towed just underneath bring back large amounts of very tiny plastic fragments – in fact there is more disseminated bits of floating plastic there than there is plankton. Plankton ingest the plastic, as do fish, marine mammals, and birds. It is now highly unlikely that you can catch any fish from the ocean and technically call it organic, since they all now carry small bits of ingested plastic in their bodies. This image shows the plastic bottle caps found in the body of a dead albatross on Kure Atoll – a remote island in the North Pacific. Here is a close up of what that pristine, uninhabited ocean island looks like today. Although not many footprints have been left here by humans, we've shared our garbage – our fishing debris, our plastic containers, and our lighters, and left our mark. To understand better how to be proper stewards to the world's oceans and keep it healthy for ourselves and future generations, we must continue to learn more about how ocean waters move and mix, so that ultimately we can better understand the long-term impact of our actions.

Pause now.

For more information and more detail, continue on to the next video in the series.

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Ocean Circulation Series:
Part 1: Thermohaline Currents
Part 2: Surface Currents
Part 3: Ocean Mixing and Pollution
Part 4: ENSO

Ocean Mixing and Pollution
Geoscience Video Tutorial
Produced by Katryn Wiese
City College of San Francisco

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