SPEAKER: Let's have a look at how the ocean moves. It might be useful to begin by talking about the time-mean circulation at the surface of the ocean, which is where we observe it best. Here is a diagram that you might find in a typical undergraduate textbook on physical oceanography, showing the time-mean currents around the world. Basically, the ocean basins are filled with these anticyclonic gyres-- that is, clockwise in the Northern Hemisphere, counterclockwise in the Southern Hemisphere.

So we have this clockwise flow around the Atlantic here, also around the North Pacific, counterclockwise in the Southern Hemisphere. These are slow currents. Their typical speeds are in the order of a centimeter per second, several orders of magnitude smaller than atmospheric winds. But remember, the ocean has much more mass and heat capacity, so these currents transport a lot of heat.

Well, here is another way of looking at the time-mean state of the ocean. This is made possible by a fantastic set of instruments that are put on satellites, called sea surface altimeters. What these instruments do is to send pulses of laser radiation down to the sea surface. They're scattered back to the receiver on the satellite. The time of transit is very carefully measured. And by comparing to previous measurements, one can get a remarkably accurate estimate of the absolute altitude of the sea surface.

So here is a chart showing sea surface altitude anomalies, averaged over the period 1993 to 2001, with reds being positive anomalies, greens and blues being negative anomalies. These are heights in centimeters, relative to a gravitational equipotential surface. So one sees that you have relatively high ocean heights in the western part of the Pacific in both hemispheres, in the southern Indian Ocean, in the western South Atlantic, and the western North Atlantic.

Now, ocean currents that are geostrophically balanced tend to have a relationship to this height field which is parallel to the relationship that atmospheric winds have to the pressure field. That is, we expect to see clockwise circulations around high pressure-- or high altitude in this case-- in the Northern Hemisphere, and counterclockwise circulation in the Southern Hemisphere. And that's actually what we saw in the previous chart. We have eastward flow of the ocean in the North Pacific here, southward flow, a return flow toward the west in the tropics, and then a very strong northward flow along the western flank of the North Pacific. A very similar circulation in the Southern Hemisphere, for example-- westward flow here, strong poleward flow, eastward flow, and then the return flow following along these height fields.

Well, this would be the simple if the actual ocean looks like the time-mean ocean, but it doesn't. And to have a look at that, I'm going to show you a film of the ocean circulation as simulated by a state-of-the-art ocean model. It's worth watching this film in your own time, and in this slide I'm giving you a link to that film. It has been created from an ocean general circulation model developed at my institution, Massachusetts Institute of Technology. And the film itself was made by NASA. So let's have a look at this film now.

Here is a video showing the evolution with time of surface currents on the ocean, as simulated by the Massachusetts Institute of Technology ocean general circulation model. These currents don't look very much like the time-mean currents we saw in the previous slide. We have these narrow ribbons, like the Gulf Stream that you see here, bending around Florida and traveling up along the East Coast of the United States. We see an overwhelming tendency for the strongest currents to be on the western periphery of ocean basins, and an overall impression that the ocean is a very turbulent place, with lots of eddies whose typical scales are a few hundred kilometers across.

So here we see strong currents in the tropical Indian Ocean, and traveling up and down along the east coast of Africa, lots of eddies along the western periphery of the Arabian Sea, strong currents along and near the equator in the Indian Ocean, flow through the Indonesian archipelago, very strong flows along the western periphery of the North Pacific Ocean, including the Kuroshio current from the

Philippines to off of Japan. Much weaker flows on the eastern sides of ocean basins, such as the eastern extra-topical North Pacific Ocean. But here again, we see very strong eddy activity in the eastern tropical North Pacific and strong flows near and along the equator. Traveling south, we notice very strong west-to-east flows in the southern Ocean, but again with lots of turbulent eddies. We see strong flows along the western periphery of the South Pacific Ocean where it's bounded by Australia. These are poleward flows with mesoscale eddies again.