4.3 THE HILLS AND VALLEYS OF THE OCEAN: SEA SURFACE HEIGHT AND OCEAN CIRCULATION FROM SATELLITE ALTIMETRY

VIDEO DURATION– 06:34

Satellite radar altimetry measurements provide vital data for oceanography and climate research. In particular Sea Surface Height, which has brought new insights into the variability of the Ocean Circulation.

In this lecture, you will learn what a satellite altimeter measures; how Sea Surface Height and ocean currents are obtained; and how these derived parameters can be powerful tools for monitoring and understanding our ever-changing oceans.

The success of the first experimental altimeters flown in space in the 70s and 80s paved the way for the development of modern satellite altimetry. Since then great progress has been made with the ERS-1 satellite mission launched in 1991 and further successive missions such as Topex/Poseidon, Jason 1 & 2 and Envisat.

Satellite radar altimeters have been continuously collecting ocean data globally for more than 25 years. In simple terms, the altimeter measures the height of the satellite above the sea surface.

A satellite radar altimeter flies at an altitude of about a thousand kilometres above the Earth's surface, but can measure Sea Surface Height with millimetric accuracy continuously; even when clouds, dust, smoke, snow and rain exist in the atmosphere. This is because radar altimeters operate in the microwave frequency range of the electromagnetic spectrum, which are largely unaffected by these atmospheric phenomena.

The most used frequency band is Ku and typically an altimeter emits a pulse of energy 20 times per second. These measurements are then averaged every second in order to reduce the effects of having a noisy signal. The spatial resolution obtained along the track of altimetry on the ocean surface for sea surface height and current velocities, is approximately ~ 7 km.

Using data from several satellite altimeters, along-track sea surface height measurements are mapped onto a regular grid in time and space, typically at 25 km resolution and on a daily basis.

Technically, the satellite radar altimeter emits a high-frequency signal that travels down towards Earth, bounces off the ocean surface, and returns to the satellite. Once the satellite detects the return signal, the altimeter calculates the round-trip travel time. From this two-way travel time and the known speed of the signal – the speed of light – we can derive the "satellite-ocean" distance (called the Range) from the relation: Range = speed times travel time, divided by 2.

However, this Range must be corrected for various instrumental and environmental effects. To finally obtain an accurate measure of sea surface height, additional geophysical corrections, such as the tide and atmospheric pressure, are applied. The tidal variation is stronger than the sea surface height variation, but it is well known and can be resolved by tidal models. A sea surface height corrected from all these effects can finally be obtained. This is an important parameter for the estimation of global sea level rise.

A synoptic view of the ocean's surface height reveals a changing sea surface height from one region to another and from year to year. Blue areas are lower than normal sea surface height, indicating cooler water, and red areas are higher than normal sea surface height, indicating warmer water. Notice also the swirling features – these are ocean eddies. Near the Equator, the eddies give way to fast moving features called Kelvin Waves.

In the Pacific Ocean, these waves play an important role in the dynamics of a large-scale phenomenon known as El Niño, which occurs when warm water and high sea levels move from the vicinity of Indonesia into the Eastern Pacific along the Equator. El Niño can have a big impact on marine ecosystems across the globe, bringing loss of commercially important fish species or affecting their migrating pattern as far the Peruvian and Californian coasts.

The sea surface height also defines the geostrophic current at the surface. The hills can be looked at as high pressure, and the valleys as low pressure. Similar to winds on weather maps, in geostrophic flow, water moves along isobars, with the higher pressure on the right in the northern hemisphere and to the left in the southern hemisphere.

On a nonrotating Earth, water would be accelerated by a horizontal pressure gradient and would flow from high to low pressure.

On a rotating Earth, however, the acceleration ceases when the current velocity is fast enough to produce a Coriolis force that balances the horizontal pressure-gradient force.

This geostrophic balance provides the basis for computing geostrophic currents from altimetry, using the proportional relation of the current velocity to the horizontal pressure gradient.

This movie of altimetric geostrophic currents shows the seasonal patterns of the major ocean currents, which displace water masses and deliver nutrients and biological constituents, such as plankton or larvae, to marine ecosystems. They also distribute heat globally, affecting the regulation of weather conditions, temperature extremes and cycling of gases.

For example, the Gulf Stream, as indicated by the Red jet, flows from the tip of Florida along the east coast of North America before deviating east into the Atlantic Ocean. Its western most branch is seen to accelerate from January to March along with associated meanders and eddies. Its presence can lead to the development of strong cyclones affecting the North Atlantic Ocean.

With this final lecture on Satellite oceanography, we have now seen how sea surface height and ocean surface currents are obtained from satellite radar altimetry measurements. We have also explored some of the most important uses of these variables in the understanding of the large-scale ocean circulation and some climate phenomena.