Mesoscale ocean eddies impact weather, study shows

July 7 2013

Not only large-scale ocean currents impact weather but also relatively small eddies, as a new study by scientists at ETH Zurich reveals. The researchers therefore recommend to account for these eddies in weather prediction models.

Ocean currents have a big impact on weather and climate. Without the Gulf Stream, the climate of Northern and Western Europe would be cooler. Scientists at ETH Zurich now uncovered that also relatively small swirling motions in the ocean, so called eddies, impact weather. A large number of such eddies exists in all oceans at any time, featuring diameters of about one hundred kilometers.

Eddies arise because ocean currents are generally turbulent, affected for instance by the topography of the ocean bottom, explains Ivy Frenger, a postdoc in the group of ETH-professor Nicolas Gruber at the Institute of Biogeochemistry and Pollutant Dynamics. "An analogy to this topographic effect are the swirls that occur downstream of a rock in a creek", says Frenger. In the ocean, eddies can be carried along by large-scale currents over vast distances, and also move around independently.

Precise satellite measurements

The ETH scientists analysed comprehensive satellite data to determine the impact of these eddies on the overlying atmosphere. Their focus is the Southern hemisphere where such eddies are especially frequent. They detected the eddies based on precise measurements of sea surface topography. "Eddies appear as bumps or dips on the sea surface as the density of water within the eddies differs from that of the surrounding ambient water", explains Frenger.

The scientists investigated data collected over nearly a decade allowing them to extract information for more than 600'000 transient eddies. They compiled these eddy-data, and compared them to the corresponding overlying wind, cloud and precipitation data which had been retrieved by means of satellites as well. The scientists found that so-called anticyclonic (meaning they rotate counter clockwise in the southern hemisphere) eddies cause on average a local increase of near-surface wind speed, cloud cover and rain probability. In contrast, the clockwise rotating (so-called cyclonic) eddies reduce near-surface wind speed, clouds and rainfall.

Increased variability

Surface water in anticyclonic eddies is warmer than in their surroundings, for cyclonic eddies it is the opposite. These temperature differences mainly reflect the origin of the eddies, meaning they originate from either warmer or cooler waters relative to their current position. Frenger and colleagues computed that wind speed increases by roughly 5 percent, cloud cover by 3 percent and rain probability by 8 percent for each degree Celsius that an eddy is warmer than its ambient water.

According to Frenger, the number of warm and cold eddies is similar in most of the ocean, so that their opposite signals in the atmosphere tend to neutralize themselves, likely leading to only a small change on average. However, the oceanic eddies increase atmospheric variability and hence may influence extreme events. If a storm blows over such an eddy, peaks in the wind speed may be diminished or amplified depending on the sense of rotation of the underlying eddy. Possibly, eddies may also influence the intensity or course of such a storm. "It is important to know the variability caused by ocean eddies and account for it in weather and climate models", concludes Frenger. In addition, in areas where either warm or cold eddies dominate, they may also have larger-scale effects.

Indications for the mechanism

This study is the first examining such eddies systematically with regard to their impacts not only on wind and clouds but also on rainfall. Further, the ETH scientists inferred the mechanism of this phenomenon based on the spatial pattern of the local changes of the weather above the eddies. Two main hypotheses have been discussed in the literature: the first argues that the anomalous sea surface temperatures of the eddies cause a change in the overlying temperature of the atmosphere, which in turn results in changes in surface pressure. This leads to a compensating air flow, more specifically wind. If this hypothesis was true, one would expect wind speed changes at the edge of eddies.

However, the data evaluated by the ETH scientists reveal that the wind speed changes not at the edge of eddies, but rather at the centre. This points to another mechanism to be dominant, one where the anomalous ocean surface temperature modifies primarily the level of turbulence in the overlying atmosphere: the warmer the eddy, the greater the disturbance in the atmosphere above and the greater the altitude to which the eddy affects the lower atmosphere, which subsequently may change wind, clouds and rain.

In this project, the scientists so far only examined the impact of ocean eddies on weather, neglecting the possibility that the resulting changes in the atmosphere influence the ocean, leading to a fully coupled atmosphere ocean system at scales of 100 kilometres and less. In an on-going study, the researchers are investigating this effect with computer simulations.

More information: Frenger I, Gruber N, Knutti R, Münnich M: Imprint of Southern Ocean eddies on winds, clouds and rainfall. *Nature Geoscience*, 2013, Advance Online Publication, doi: 10.38/ngeo1863

Provided by ETH Zurich