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Oceanography Findings Make Waves [1]

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Two new Rossby wave observations enhance prediction possibilities.

"No one has ever observed a Rossby wave, but we know they exist," Dudley Chelton's oceanography professor said in 1974. Now, Chelton and other investigators are not only seeing intraseasonal, seasonal and interannual Rossby waves in DAAC-distributed data, they are studying the waves' relationship to our weather and rethinking our theoretical understanding of them.

Rossby waves are a natural result of the Earth's rotation and a key feature of large-scale ocean and atmospheric circulation that were theoretically conceived in the 1930s by C. G. Rossby. Though they can be thousands of kilometers long, they have amplitudes smaller than 10 cm and travel slowly, requiring years to decades to cross the Pacific Ocean. Thus, they do not show up clearly in ocean views provided by conventional measurements.

Oceanic Rossby waves were first detected from upper ocean thermal measurements in the late 1970s. However, because these measurements are sparse over most of the world's oceans, it was not possible to observe Rossby waves globally until the TOPEX/Poseidon altimeter began providing high quality sea level data in late 1992.

"A great range of currents, eddies, and waves exists in the ocean, and there are no roads or traffic lights to keep them separated. At any one time, all these different and interacting ocean events add together to form a very complex system which is difficult to interpret from sporadic and sparse in situ measurements," oceanographer Gregg Jacobs says. "If however, you have well-distributed altimeter data that you can view over a longer time, you are able to separate some of the phenomena."

Working from the Naval Research Laboratory (NRL) at Stennis Space Center, Jacobs surprised the oceanography community when he spotted an interannual Rossby wave using TOPEX/Poseidon altimeter data in late 1994. In TOPEX/Poseidon data combined with data from two earlier altimeters (ERS-1 and Geosat), Jacobs saw evidence of a single Rossby wave lingering in the Pacific Ocean 10 years after its origin.

Identifying a wave with Rossby characteristics was only the first step for Jacobs. To trace the origins of the wave, he performed a series of numerical model experiments using the NRL layered global ocean model. The model simulations corroborated his data observations and only reproduced the wave under the expected conditions.

Since Jacobs first reported evidence of the lingering wave (Nature, August 1994), his findings have generated widespread debate. "It's definitely not a settled issue. This is a large change in how we view ocean dynamics, and there are many aspects about this wave which remain to be studied. At times I still think that it's pretty incredible that such a feature would remain coherent in the middle of the ocean for so long," he says.

Perhaps more important than Jacobs' pioneering observation of an interannual Rossby wave is his explanation of its origin. When he altered the wind stresses forcing the model, Jacobs found that the 1982-83 El Niño event generated the Rossby wave he observed in 1992-93 data. Moreover, he argues from an analysis of sea surface temperature data that the wave could have influenced weather patterns in the North Pacific a decade later.

"Ten years after its origin, the Rossby wave appears to have moved through the Kuroshio Extension and shifted it northward," he says. The Kuroshio is the Pacific equivalent of the Atlantic's Gulf Stream.

By shifting currents and their corresponding sea surface temperatures, the waves could influence the way the oceans release heat to the atmosphere and thus be able to affect weather patterns. "Significant correlations exist between Pacific Ocean temperatures and weather patterns across North America," Jacobs says. "Because sea surface temperatures drive atmospheric circulation, shifts in one small area can conceivably affect weather on the other side of the globe."

The potential of an interannual Rossby wave to affect weather patterns a decade after its origin presents interesting possibilities. With a better understanding of the relationship between Rossby waves and weather patterns, improved forecasts could result from our new ability to track the waves through the years.

"However, in order to forecast their effects, we still need to know how fast the waves propagate," Dudley Chelton says.

Chelton is an Oregon State University oceanographer and a co-investigator on an Interdisciplinary Science (IDS) Team investigating physical and biogeochemical processes in the Southern Ocean. A few years ago, the team was trying to characterize the variability of circulation in the South Indian Ocean when Chelton first saw evidence of Rossby waves.

"I was a little shocked to see it initially because I really didn't believe Rossby waves were going to show up clearly in Geosat altimeter data," Chelton says. After seeing evidence of Rossby waves in the Southern Ocean, he began looking for them in other oceans.

In recently published work (Science, April 12, 1996), Chelton reports his findings about intraseasonal Rossby waves. He first saw the waves in animations of the altimeter data as alternating positive and negative sea level features traveling west across the Pacific. By mapping them in time-longitude sections of the entire world ocean, he was able to identify the features unmistakably as Rossby waves. Chelton then objectively estimated the speed of each wave that traveled 30 degrees of longitude in a section.

Analyzing three years of TOPEX/Poseidon data this way, Chelton found a surprising discrepancy between observed Rossby wave speeds and those predicted by theory. The standard theory about Rossby waves holds that their speed decreases with latitude. When Chelton compared his estimates with the latitudinal variation of the propagation speed of the Rossby waves predicted by the standard theory it became clear that the theory underestimated Rossby wave speeds by as much as a factor of two at midlatitudes.

Because Rossby waves play a role in the way the oceans adjust to changes in the atmosphere, Chelton's wave-speed finding is important. "If our notions about the wave speeds are incorrect," he says, "then the waves get from one side of the ocean to the other twice as fast, which means that the ocean evidently adjusts more rapidly that we previously thought."

With Chelton's wave speed finding, oceanographers can now more accurately predict the position of an El Niño-generated Rossby wave. More accurate predictions of Rossby wave locations will facilitate the long-term forecast of large scale ocean circulation that Jacobs' work suggests is now possible. Though more quantitative conclusions are presently limited by the three-year duration of TOPEX/Poseidon data, the statistical reliability of these interannual variability studies will improve as the data record grows.

Reference(s)

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