balloons and aeroplane flights. No satellite has directly measured winds, although scientists can infer wind speed and direction from satellite measurements of cloud movement, for instance.

CHALLENGES

ESA selected the mission in 1999. It is reaching the launch pad only now because of the difficulties of building a powerful enough laser. Fifty times each second, the satellite's laser will zap Earth's atmosphere with a beam of billions of ultraviolet photons (see 'World's first wind-mapper'). A few hundred of those photons will bounce off air molecules and particles and reflect back to the spacecraft's 1.5-metre primary telescope. Aeolus will measure not only the distance to the reflection — giving the altitude of the winds — but also the tiny change in wavelength created as the molecules move back and forth.

That 'Doppler shift' allows scientists to calculate the winds' speed and direction. "It's much more challenging than just measuring the signal coming back," says Oliver Reitebuch, an atmospheric physicist at the German Aerospace Center in Oberpfaffenhofen, who led aeroplane flights to test the satellite's technology. The information will, for instance, allow scientists to track winds of different velocities and at different altitudes in the atmosphere — information that is important for understanding developing storms, but that cannot be obtained globally in any other way.

The data from Aeolus will feed into numerical weather predictions, in which national weather services incorporate atmospheric conditions such as temperature, pressure and humidity to generate forecasts for the coming days[3]. Not incorporating winds can lead to errors: in one study, the ECMWF analysed a rainstorm in Europe in March 2014, and found that better data on winds above the Pacific Ocean in the days before the storm would have allowed a more accurate prediction of the heavy rains to come[4].

If Aeolus launches successfully, mission controllers plan to switch on the laser system in September, with initial data arriving by the end of January 2019 and inserted into forecasting systems by April. And if the technology proves solid, it could help pave the way for future wind-mapping satellites, says Lars Peter Riishojgaard, head of the World Meteorological Organization's Integrated Global Observing System in Geneva, Switzerland. ■

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H. RUIZ

ECOLOGY

Hurricane Maria's coral-reef clues

Scientists struggle to predict future of deep-water reefs.

BY SARA REARDON IN LA PARGUERA, PUERTO RICO

Dark skies hint at the hurricane that is moving quickly across the Caribbean on this early July morning, but the sea off Puerto Rico's southwest coast is glassy. Marine scientists Ernesto Weil and Juan Cruz Motta of the University of Puerto Rico–Mayagüez (UPRM) swim along the La Parguera reef, stopping to examine a fan coral marred by black patches of disease and a staghorn coral bleached white.

For decades, ecologists had thought that La Parguera and other reefs in the dimly lit 'mesophotic zone', 30–150 metres below the ocean surface, were sheltered from storms and temperature fluctuations — unlike corals in shallow waters. But several recent studies suggest that deep-water reefs are susceptible to the increasingly powerful hurricanes and ocean warming caused by climate change. And that casts doubt on the long-standing idea that deep-water corals could serve as refuges for marine life displaced from increasingly vulnerable shallow reefs.

In Puerto Rico, such questions are more than academic. In September 2017, Hurricane Maria — a deadly category-4 storm — devastated the island and many of its surrounding reefs. Weil, Cruz Motta and their colleagues are tracking the health of deep-water corals at La Parguera, which escaped significant damage, and that of deep reefs that were directly in the storm's path. This natural experiment could help to reveal the extent to which turbulence from the more frequent and extreme hurricanes predicted by climate models could endanger deep reefs in the coming decades.

"If we're going to have one of these or two of these per year, it's going to be very hard for reefs and other coastal communities to recover," Weil says.

The UPRM researchers expected to see devastation at offshore reefs after Maria hit. "We pretty much thought it was the end of the world," says Nikolaos Schizas, a marine biologist at the university. But when the ▶

Hurricanes and ocean warming are thought to present a growing threat to deep coral reefs.

team ventured out to La Parguera reef a few months after the storm, its deep-water corals seemed surprisingly healthy. Schizas suspects that this is because Maria travelled east to west across Puerto Rico, and lost strength over land.

TWILIGHT ZONE

The scientists are now analysing data collected by sensors that they studded on the reef's 80-metre-tall face before the hurricane. These continuously record information on water temperature, turbidity and other factors at various depths. The team's preliminary analysis suggests that Hurricane Maria sent waves crashing into the reef with unusual frequency and pushed a swell of cold water from the ocean bottom up to the reef.

It could take years to understand whether the changes observed during Maria affected the La Parguera reef ecosystem. But the data are intriguing because most previous measurements of hurricanes' hydrological impacts have come from continents, not islands, says Curt Storlazzi, an oceanographer at the US Geological Survey in Santa Cruz, California, who analysed the UPRM data.

Now the UPRM team is gearing up to visit a reef near Vieques, an island 13 kilometres off Puerto Rico's eastern coast that suffered severe storm damage. The researchers plan to survey corals at depths of 30 metres or more, and to compare their data with photos and samples collected before the storm.

That contrast may reveal the hurricane's impact on shallow and deep-water corals. Reefs evolved to adapt to storms — even the occasional monster hurricane. But today, many corals face a variety of other threats, including ocean acidification and invasive sargassum algae. And warming waters have created a more hospitable environment for pathogens.

"We pretty much thought it was the end of the world."

The UPRM team's surveys might also help researchers to understand whether deep-water reefs could serve as a refuge for species fleeing damaged or destroyed corals in shallow waters. A study published last month in *Science* has cast doubt on that idea: survey data from four reefs in the Atlantic and Pacific oceans revealed little overlap between the species found on shallow and deep reefs (L. A. Rocha *et al. Science* **361**, 281–284; 2018). That makes it unlikely that residents of one type of reef could 'reseed' the other. The study also reported evidence of storm damage to some of the deep-water reefs, parts of which seem to have been buried by sediment stirred up by hurricanes.

And research by Tyler Smith, a coral-reef biologist at the University of the Virgin Islands in St Thomas, has found that hurricanes can scramble ocean temperature gradients, which could make deep-water reefs inhospitable to native species (T. B. Smith *et al. Glob. Change Biol.* **22**, 2756–2765; 2016).

Smith says that scientists will need more data to verify, or discard, the deep-refuge-reef idea. He and his colleagues are surveying reefs around the Virgin Islands that were hit by Hurricane Maria. Their early data suggest that visible hurricane damage stopped about 10 metres below the ocean surface.

But reefs' luck may not hold. More-frequent major storms and other threats could wear these ecosystems down over time. "To lose structural complexity here would be unbelievable," Schizas says. "But it's a little by little process." ■

CORRECTION

The News story 'Trove of exotic matter thrills physicists' (*Nature* **560**, 151–152; 2018) stated that the properties of a topological insulator were first seen experimentally in bismuth antimony in 2008. In fact, the property was first observed in mercury telluride in 2007.