

PHYSICS UPDATE

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FISH CATCH AND OCEAN CURRENTS

The Kuroshio current starts off flowing west toward the Philippines. As it nears the archipelago, it veers northward past Taiwan. By the time it reaches the seas off Japan, it flows eastward. Taiwanese fishermen have long known that the current's western margins are rich in mackerel, even if they were unaware of the cause: The winds that pro-

pel the current also help to pull up deep, cold, nutrient-rich water that favors phytoplankton and, in turn, tiny crustaceans and other fish food. Leo Oey of Taiwan's National Central University and his collaborators have now added to that basic picture by examining how interannual fluctuations in the Kuroshio influence interannual fluctuations in fish catch. For their investigation, the researchers used remote-sensing measurements of ocean greenness—and therefore phytoplankton—as a proxy for surface nutrients. Satellite altimetry yielded Kuroshio's strength and location. And a hydrodynamical model characterized the three-dimensional flow in and around the current. As the Kuroshio makes its northward turn past Taiwan, it flows over the edge of the East Asian continental shelf. Oey and his collaborators found that the stronger the current, the further away from the shelf it flows, a condition that exposes more nutrient-rich deep water to the stronger upwelling. Roughly speaking, the Taiwanese mackerel catch fluctuates year to year by $\pm 15,000$ tons, or $\pm 35\%$. Fully 40% of those fluctuations, Oey and his colleagues found, can be accounted for by the changing current.



HIROSHIGE

Because larvae and juvenile fish benefit the most from the additional nutrients and phytoplankton, fluctuations in the catch of mature fish lag the fluctuations in current by about six months. As for what drives the changing current, the scientists' research implicates a monsoon-like interannual shift in the winds over the western North Pacific Ocean known as the Philippines–Taiwan Oscillation. (L. Oey, J. Wang, M.-A. Lee, *J. Phys. Oceanogr.*, in press, doi:10.1175/JPO-D-17-0041.1.) —CD

A PORTABLE OPTICAL CLOCK

Atomic clocks measure time by counting the oscillations of laser light tuned to an atomic transition of known frequency. Optical clocks, the most sophisticated variety of atomic clock, probe optical transitions in ultracold atoms and can measure time with an uncertainty approaching 1 part in 10^{18} . (Olympic athletes can be timed to the millionth of a second.)

Among their many applications, optical clocks can be used to measure Earth's gravitational potential: According to general relativity, clocks raised to higher potentials have their atomic transition frequency ν increased by $\Delta\nu = \nu \Delta U/c^2$, where ΔU is the change in potential and c the speed of light. Until recently the best optical clocks had always operated within the friendly confines of a controlled laboratory environment. Now an international group led by Christian Lisdat of the National Metrology Institute of Germany has developed an advanced, portable, strontium-based optical clock.

With that device, the researchers were able to measure frequencies with a precision of 2 parts in 10^{15} and determine the potential difference between the National Institute of Metrological Research (INRIM) in Turin,

based on cesium and ytterbium. For the first round of measurements, Lisdat and company brought their strontium clock to LSM. An optical fiber connecting the two labs enabled the Cs clock to measure the frequency of the Sr transition from afar. (Anticipated Yb-clock measurements were not possible.) Then the Sr clock was transported to INRIM, and the transition frequency was measured by both Cs and Yb clocks.

The 48 ± 1 Hz change in frequency determined by Lisdat's team indicates that LSM and INRIM differ in altitude by about 1000 m. That value is in good agreement with, but not nearly as precise as, those obtained with conventional ground-based and satellite methods, which can reach decimeter precision. To match that, an optical clock would need to be exact to 1 part in 10^{17} , a goal the Lisdat team expects to meet after their next round of improvements. (J. Grotti et al., *Nat. Phys.*, in press, doi:10.1038/s41567-017-0042-3.) —SKB [PT](#)



FLORIAN PÉPÉLIN

Italy, and the Modane Underground Laboratory (LSM), located 90 km away in the middle of the Fréjus Road Tunnel that runs through the Alps to connect France and Italy.

Turin's INRIM has its own atomic clocks