PHYSICS UPDATE

These items, with supplementary material, first appeared at www.physicstoday.org.

NEWFOUND ROCKS MAY BE PROGENY OF PRIMORDIAL CRUST

Within the first few hundred million years of our planet's formation, during the so-called Hadean eon, Earth's first rocks had frozen out of the molten surface to form a primordial crust. Chemical fractionation endowed those rocks with overabundances of the lighter rare-earth elements; they were richer in neodymium-144, for instance, than they were in heavier samarium-146. As a result, the few remaining rocks from that time carry a distinct isotopic signature: They are depleted in ^{142}Nd—the radioactive decay product of ^{146}Sm—relative to ^{144}Nd. Seemingly as a rule, rocks younger than about 3.3 billion years don't exhibit that depletion; the repeated cycling of material between the mantle and crust washed out the primordial ^{142}Nd signature.

Now Jonathan O'Neil (University of Ottawa) and Richard Carlson (Carnegie Institution for Science) have discovered more than a dozen counterexamples to that unwritten rule. Near the Nuvvuagittuq belt on the eastern shoreline of Canada's Hudson Bay, the researchers found 15 granitic rocks that exhibit Hadean-like ^{142}Nd deficits despite being just 2.7 billion years old. Based on the samples' isotopic profiles, O'Neil and Carlson effectively ruled out every possible explanation except one: Somehow, Hadean material survived for more than 1 billion years—many times a rock's life expectancy—before being recycled to form the granitic rocks. The discovery may help researchers pinpoint elusive events in the planet's geological time line, such as the emergence of tectonics and the formation of oceans. (J. O'Neil, R. W. Carlson, *Science* **355**, 1199, 2017.) —AGS

SEA TURTLES DON'T JUST GO WITH THE FLOW

When foraging, sea turtles presumably give little thought to the physics of ocean vortices. But scientists who study the reptiles want to know how mesoscale eddies, vortices 50–100 km in radius that transfer heat in the oceans, influence the distribution of turtle populations.

Now Peter Gaube at the University of Washington and colleagues have found that loggerhead sea turtles (*Caretta caretta*) modify their behavior to position themselves inside eddies. Colleagues from Uruguay and Brazil fixed satellite transmitters to juvenile turtles that journeyed to the confluence zone of the Brazil and Malvinas currents in the southwestern Atlantic Ocean. For five years the team tracked the turtles' positions and those of untethered buoys known as drifters that are administered by the National Oceanic and Atmospheric Administration. The researchers used satellite observations of sea-surface height to identify and track eddies.

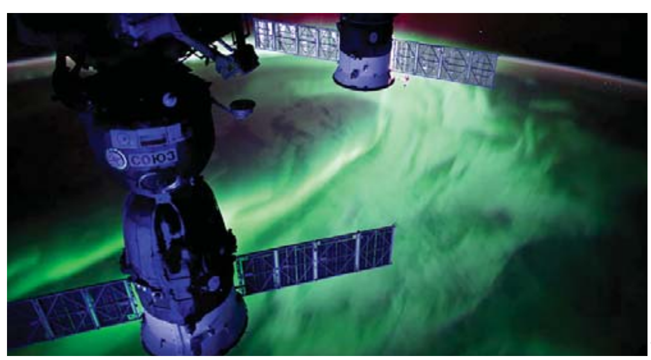
The data showed that turtles avoided the peripheries of anticyclonic eddies. They were 83% more likely to be found in the interior of the eddies than in the outermost regions, whereas the buoys were scattered about all regions. Once the turtles found the sweet spot of an eddy, they seemed to try to stay there: Relative to the local current, they swam more slowly in the interior (~17 cm/s) than they did when caught in the periphery (~29 cm/s). Gaube proposes that the turtles were seeking the gelatinous gastropods that favor the anomalously low chlorophyll concentrations and warm water in the interior. That hypothesis is bolstered by the fact that the turtles did not target the colder waters at the center of cyclonic eddies.

The study establishes a methodology for investigating how aquatic organisms make use of ocean currents, for identifying critical habitat in the open ocean, and for protecting endangered species. Such research is becoming increasingly important as ocean conditions change due to natural and anthropogenic factors. (P. Gaube et al., *PLOS ONE* **12**, e0172839, 2017.) —RB

A STEP TOWARD DECIPHERING AURORAS

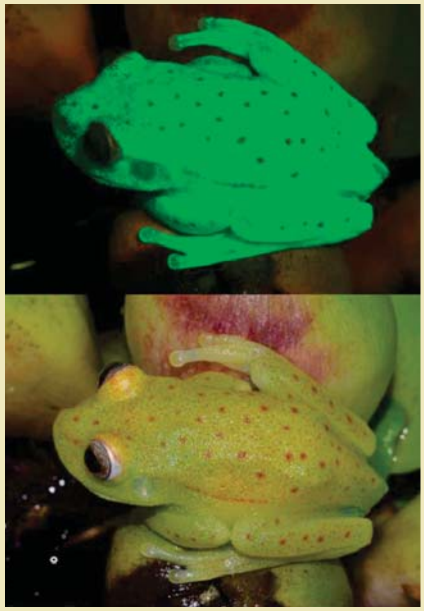
Auroras have long dazzled sky watchers but befuddled physicists. Via a mechanism that remains unclear, electrons get yanked away from the magnetosphere and slammed into the ionosphere, where their collisions with atoms and molecules engender green, red, and blue light. (See the Quick Study by Bob Strangeway, PHYSICS TODAY, July 2008, page 68.) The leading culprits for scooping up and accelerating auroral electrons are Alfvén waves, oscillations of the ions in a plasma that propagate along magnetic field lines. The oscillations can be triggered by magnetic storms, which often portend auroral displays. And at least in theory, the waves should be able to propel electrons in their path.

Now, for the first time, scientists have confirmed that Alfvén waves can move electrons, an important first step toward linking the waves to auroras. Rather than probing plasmas at auroral altitudes, Jim Schroeder at the University of Iowa and his colleagues created Alfvén waves in the lab. Using a copper antenna placed inside the Large Plasma Device at UCLA, the researchers launched waves through a roughly 15-m-long column of magnet-



NASA

FROG FLUORESCENCE



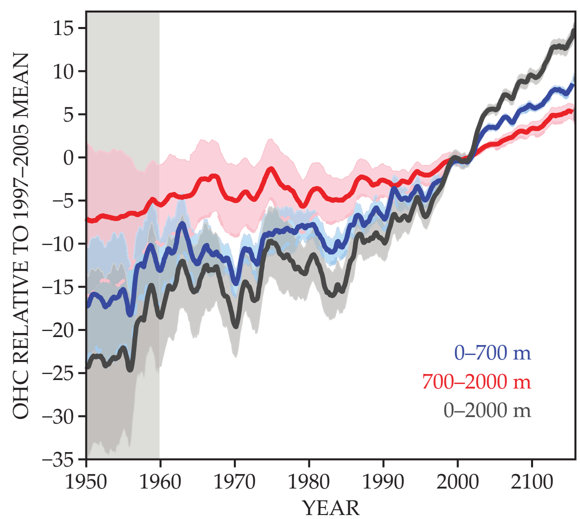
Biofluorescence, the re-emission of electromagnetic radiation at a wavelength longer than that at which an organism initially absorbed it, occurs widely in nature—in flora and fauna, on land and in the ocean. But among vertebrates, almost all known biofluorescent species—which include sharks, surgeonfish, and sea turtles—are aquatic; parrots had been the sole terrestrial exception. A team of researchers from Buenos Aires, Argentina, and São Paulo, Brazil, now report the first observation of naturally occurring fluorescence in an amphibian: the polka-dot tree frog, *Hypsiboas punctatus*. Under white light the frog's skin appears translucent (bottom photo), but when illuminated with 400 nm UV light, the frog gives off bright blue-green light (top). The team traced that glow to a class of fluorescent compounds located in the frog's lymph and skin glands, with the emission filtered by pigments in the translucent skin. The polka-dot frog is active primarily between dusk and dawn, so the researchers analyzed the relative contributions of fluorescence and reflection to the frog's visibility in low-light conditions. They estimate that at night under a full moon, fluorescence accounts for 18% of the light emerging from the frog; at twilight, the contribution approaches 30%. Moreover, the spectrum of the emitted fluorescence is well matched to the peak sensitivity of amphibian night vision, which suggests that the phenomenon plays an important role in the visual perception of fellow frogs in the chromatically complex terrestrial environment. (C. Taboada et al., *Proc. Natl. Acad. Sci. USA* **114**, 3672, 2017.) —RJF

ized plasma. As each wave zoomed through the column at more than 0.1*c*, a pair of detectors recorded pulses of high-frequency radiation that manifested the shifting distribution of electrons in the plasma. The measurements revealed that the Alfvén waves triggered oscillations of the highest-energy electrons.

The observed oscillations are fundamentally related to the mechanism that's thought to drive auroras: resonant electron acceleration. If electrons can be jolted by passing Alfvén waves, then they should be able to get picked up and boosted by the plasma disturbances as well. Schroeder and colleagues are designing follow-up experiments at UCLA to hunt for electrons surfing Alfvén waves. (J. W. R. Schroeder et al., *Phys. Plasmas* **24**, 032902, 2017.) —AG

RISING HEAT CONTENT OF EARTH'S OCEANS

Earth's Sun-warmed surface radiates heat into the atmosphere. As the concentration of carbon dioxide and other greenhouse gases increases, more of that extra heat fails to escape into space. Although the trapped heat warms Earth's lower atmosphere and land surface, more than 90% of it ends up in the ocean. How the ocean heat content (OHC) has changed over the past half century is the subject of a new study led by Lijing Cheng of the Institute of Atmospheric Physics in Beijing. Resolving OHC across time and space is challenging. Since 2005, a network of autonomous floats called Argo has continuously profiled the ocean's temperature at depths down to 2000 m with steadily increasing spatial coverage (see the article by Karim Sabra, Bruce Cornuelle, and Bill Kuperman, Physics Today, February 2016, page 32). Before then, and even in Argo's early years, measurements were less frequent, more sparse, and unevenly distributed. Cheng and his collaborators tackled the challenge through an interpolation scheme that took advantage of oceanographers' understanding of how the ocean's behavior is correlated through space and time. To validate the scheme, they demonstrated that they could reproduce data from recent, densely sampled observations by interpolating from a sparser sampling of those same observations. Among the findings: OHC remained fairly steady from 1960 through 1980; there-



after, it increased significantly. What's more, the study found that OHC is 13% higher than the value cited in the most recent (2014) report of the Intergovernmental Panel on Climate Change. As the figure shows, increases in OHC extended to lower depths mainly after 1990. The study by Cheng and colleagues also revealed that Earth's five oceans are sequestering heat at different rates. The Atlantic Ocean had the largest OHC increase from 1960 to 2015; it was 3.5 times as high as that of the Pacific Ocean, which covers twice the area. Circulation within and between oceans is the likely cause of the differences, which may themselves change if global warming alters circulation patterns. (L. Cheng et al., *Sci. Adv.* **3**, e1601545, 2017.) —CD PT