Eos, Vol. 94, No. 48, 26 November 2013

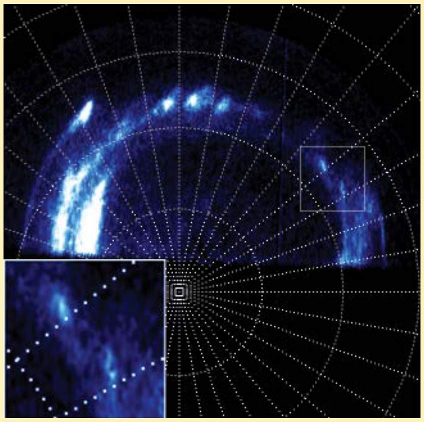
RESEARCH SPOTLIGHT

Highlighting exciting new research from AGU journals

Ganymede's auroral footprint has multiple spots

The moons of giant planets can create a phenomenon called an "auroral footprint," which is due to an interaction between the moon and the planet's magnetosphere. This phenomenon, which has been observed for Jupiter's moons Io, Europa, and Ganymede as well as Saturn's moon Enceladus, is usually seen as a single spot in the planet's aurora. However, Io has an auroral footprint that is known to be made up of at least three spots. Scientists wondered if a multispot auroral footprint is common or unique to Io.

Now *Bonfond et al.* report observations using far ultraviolet images from the Hubble Space Telescope showing that Ganymede also has an auroral footprint with two spots. They also found that the distance between the two spots varies with the location of Ganymede in the plasma sheet, the flat region of dense plasma near the equatorial plane in the planet's magnetosphere. The observations suggest that multispot auroral footprints are a common phenomenon resulting from the bidirectional acceleration of electrons by Alfvén waves. (*Geophysical Research Letters*, doi:10.1002/grl.50989, 2013) —EB



Polar projection of the southern aurora at Jupiter as observed by the Hubble Space Telescope, along with a zoom on the two spots of the Ganymede footprint.

Coastal radar observations reveal complex surface circulations

The behavior of nearshore ocean surface currents has important effects on the coastal ecosystem, with the alongshore propagating waves helping transport marine organisms and affecting how nutrients, salt, and heat are distributed. Using a network of 61 high-frequency radar stations off the U.S. West Coast, *Kim et al.* got a detailed look at the motion of the coastal ocean. They found that there are essentially two distinct sets of poleward propagating waves driving the nearshore flow.

Using the coastal radar observations, along with a simplified ocean circulation model and surface wind measurements, the authors determined that one set of waves moves northward at 100 to 300 kilometers per day, while the second set travels northward at around 10 kilometers per day. In agreement with previous studies, the authors concluded that the higher speed signals are likely coastally trapped waves. The cause of the slower speed signals, however, is less certain. The authors suggest that the slower signals may be the scattered or reflected remnants of the faster waves, or they may be caused by nearshore advection or pressure gradients. (*Journal of Geophysical Research-Oceans*, doi:10.1002/jgrc.20400, 2013) —CS

A plan to clear energetic protons from the radiation belt

The Earth's radiation belts have been a known hazard to satellites since at least 1962, when an American high-altitude nuclear weapons test named Starfish Prime produced an artificial belt that disabled the first commercial communications satellite, TelStar 1. In the years since the Cold War, thousands of satellites have been put into orbit, and surface charging, high-energy protons, high-energy electrons known as "killer electrons," and other hazards of the inner magnetosphere have continued to take their toll. Satellites can be hardened against these radiation hazards, but some researchers have recently floated a more radical idea: If specially designed transmitters are put into space and set to emit tightly tuned waves, known as electromagnetic ion cyclotron (EMIC) waves, they could potentially push the highly energetic protons out of the Earth's inner radiation belt, clearing the satellite's path.

The plan is theoretically possible and not without precedent. Researchers have previously used a different type of wave to scatter high-energy electrons out of the outer radiation belt. However, the specific details, such as which frequencies of waves would work best, are more elusive.

Researchers trying to calculate the wave-particle interaction are faced with a choice: They can model the interaction either nonlinearly or quasi-linearly. Quasi-linear solutions typically simplify the dynamics, whereas nonlinear computations are more difficult and take longer to perform. *Soria-Santacruz et al.* modeled the interaction between EMIC waves spread over a large area and high-energy protons using both techniques. They found that for all energies and interaction angles studied, the quasi-linear and nonlinear solutions generally agree. They suggest that researchers should be free to use the less computationally expensive quasi-linear approach in future work. (*Geophysical Research Letters*, doi:10.1002/grl.50925, 2013) —CS

Magnetic energy determines electron bulk heating

When magnetic field lines interact at the magnetopause—the boundary between the solar magnetic field and the Earth's magnetic field—a process known as magnetic reconnection causes magnetic energy to be converted into kinetic energy and heat. Magnetic reconnection is a collisionless process, and its dynamics are still not fully understood. Past studies of reconnection have produced conflicting findings as to whether, and, if so, how much, reconnection heats electrons. Although reconnection has been found to heat electrons to 10 million kelvins in the Earth's magnetotail, it does not appear to heat electrons in the solar wind.

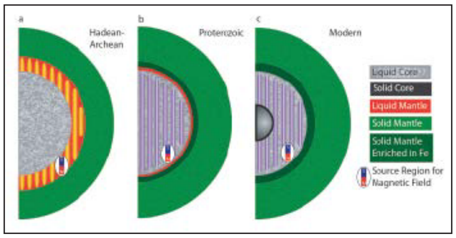
Drawing on observations of 79 instances of magnetic reconnection as recorded by NASA's Time History of Events and Macroscale Interactions during Substorms (THEMIS) satellites, *Phan et al.* studied the extent to which various physical properties affect the magnitude and occurrence of electron bulk heating. The authors found that bulk electron heating depends primarily on the amount of available magnetic energy in the solar wind.

From their observations the authors empirically determined that around 2% of the magnetic energy in the solar wind is converted to bulk electron heating. This finding, they suggest, may be universal for plasmas in space as well as in the laboratory. It could help explain why there is strong electron heating in the Earth's magnetotail but essentially no heating in the solar wind during reconnection. They suggest that it could also be used to investigate the role of magnetic reconnection in heating the solar corona. (*Geophysical Research Letters,* doi:10.1002/grl.50917, 2013) —CS

Early geodynamo could have been driven by magma in lower mantle

A new study suggesting that early in Earth's history the magnetic field may have been generated not in the core but by a magma ocean at the base of the lower mantle could change scientists' understanding of the magnetic history of Earth.

Earth's magnetic field is currently generated by convecting, electrically conductive fluid in the core. However, recent estimates of the properties of Earth's core suggest that the core may not have been able to sustain a geodynamo early in Earth's history.



Ziegler and Stegman suggest that Earth may have gone through three phases of geodynamo generation. (a) Earliest Earth until circa 2.5 billion years ago: A basal magma ocean in the mantle hosts a thin-shell dynamo. (b) Second stage, characterized by an almost fully solidified mantle. (c) Third stage: As core cools, solid inner core initiates and grows. Geodynamo is powered by thermal and compositional convection enhanced by core solidification.

Ziegler and Stegman propose that Earth's early geomagnetic field could instead have been generated by a magma ocean at the base of the solid lower mantle. Such an ocean has been hypothesized to have existed for billions of years, from very early in Earth's history, about 4.5 billion years ago, through at least about 2.5 billion years ago.

At the high temperatures and pressures of the lower mantle, the properties of the silicate melts that could have existed in such an ocean are uncertain. Therefore, the authors modeled a range of possible electrical and magnetic properties of a magma ocean and considered paleomagnetic evidence. They conclude that electrical conductivity could have been high enough for a magma ocean at the base of the lower mantle to have been a main driver of a geodynamo early in Earth's history. (*Geochemistry, Geophysics, Geosystems,* doi:10.1002/2013GC005001 —EB)

High-resolution model captures global atmospheric deep convection

When moist air is mixed high into the atmosphere, a process known as deep convection, the motion can give rise to towering storm clouds. Deep convection is also an important process for balancing momentum and energy within the atmosphere. Atmospheric deep convection is a relatively small-scale physical process, with the motion spanning anywhere from 1 to 10 kilometers. Its effects, though, are globally relevant, dictating storm patterns and climatological changes. Modeling deep convection in a global simulation, then, is challenging because these small-scale processes need to be represented and tracked across the whole planet.

Typically, global climate models use parameterizations to represent deep convection. More recently, researchers have tried to calculate deep convection directly but have been hindered by models that are not fine-grained enough to accurately capture the process. For the first time, a global atmospheric model has been designed that represents deep convection with a spatial resolution of just 0.87 kilometer. The model, described by *Miyamoto et al.,* is of sufficiently high resolution to accurately represent deep convection on a global scale.

The high resolution, however, also makes running the model incredibly expensive computationally. The authors experimented with a number of spatial resolutions, from 0.87-kilometer grid cells to 14-kilometer ones, to find how such changes affect the representation of deep convection. They found that there is a sharp improvement in the model's skill when the spatial resolution of the model drops below approximately 2 kilometers per cell. (*Geophysical Research Letters,* doi:10.1002/grl.50944, 2013) —CS

—ERNIE BALCERAK, Staff Writer, and COLIN SCHULTZ, Writer