RESEARCH SPOTLIGHT

Highlighting exciting new research from AGU journals

New insight into substorm current wedges

Magnetic substorms, disruptions in the coupled magnetosphere-ionosphere system that cause brightening of the aurora, are driven by magnetic activity that starts in the Earth's magnetotail—the stretched-out region of Earth's magnetic field on the far side from the Sun—and are transmitted to the ionosphere through a phenomenon called a substorm current wedge. New findings from simulations provide insight into the nature of these current wedges.

In a substorm current wedge, a portion of the electric current that usually flows across the magnetotail (in a direction perpendicular to Earth's magnetic field in the plane of the equator) is instead diverted in the direction along Earth's magnetic field toward the ionosphere. In the traditional picture of the substorm current wedge, the current then travels westward through the ionosphere, then back out toward the magnetotail, forming a wedge-shaped loop of current.

Now *Birn and Hesse* show that the loop structure could be different than commonly thought. Building on their work in a previous paper, in which they used magnetohydrodynamic simulations to study the formation of current wedges following bursts of magnetic activity in the magnetotail, the authors further investigate the current wedges and accompanying changes in the magnetic field components.

In particular, their simulations show that in addition to the westward current flow in the ionosphere, substorm current wedges could include a north–south component of current flow in the ionosphere that is almost twice as large as the westward currents. The study could help scientists better understand the connection between magnetotail activity and disturbances observed in the ionosphere. (*Journal of Geophysical Research: Space Physics,* doi:10.1002/2014JA019863, 2014) —EB

What controls the relief of rocky headlands?

Rocky headlands are a common feature of coastlines but vary in their cross-shore "relief" (i.e., how far a headland extends offshore from the coastline), causing some coastlines to be more sinuous and others smoother. What controls headland relief? Most models of headland relief are qualitative and focus on the relationship between wave energy and rock strength but leave out other factors.

Now, in a pair of companion papers, *Limber et al.* describe a simple quantitative model that includes wave energy and rock strength as well as other factors such as the production and distribution of beach sediment, variable lithology, and buffering of cliff erosion by beach sediment.

The researchers used the model to explore the evolution of headland shape and found that headland amplitude is larger where there are greater alongshore variations in rock strength but smaller where there is more sediment or more focusing of waves. The authors also show how model results can be compared to field observations, providing a framework for studying natural coastline evolution. (*Journal of Geophysical Research: Earth Surface,* doi:10.1002/2013JF002950, 2014) —EB

Poul Christoffersen

Scientists working on the ice streams that feed into the Ross Sea.

Tracking the sources and sinks of Antarctica's subglacial waterways

Deep beneath Antarctica's kilometers-thick layer of glacial ice is a complex network of rivers and lakes. Research suggests that this water may affect the flows of the southern continent's massive ice streams, though the nature of its effect remains unclear. Adding to scientists' understanding of Antarctica's subglacial hydrology, *Christoffersen et al.* studied five ice streams that flow into the Ross Sea.

Ice streams' fast flow rates make them Antarctica's dominant contributors to sea level rise. Ice streams tend to overlay glacial till, loose sediments that create little frictional drag, driving their fast flows. Subglacial water is also thought to contribute, though how and by how much is uncertain.

Using observations of ice motion, bedrock topography, ice thickness, and sediment thickness and an ice sheet model, the researchers estimated the amount of water produced by the ice streams. Comparing these quantities with the amount that flows through pores in the underlying till layer and along the rock surface, they found that the quantity of water produced by each ice stream is surprisingly low and that external hydrological sources are needed to explain the ice streams' fast motion. For three of the ice streams—Whillans, Mercer, and Kamb—the researchers identified the external source as a large subglacial groundwater reservoir. For the two remaining ice streams, Bindschadler and MacAyeal, the extra water was produced in the ice sheet interior and moved to the ice streams through the regional hydrological network.

The authors found that the amount of water flowing from the ice sheet interior to the Whillans, Mercer, and Kamb ice streams is insufficient to provide sustained fast flows. The recent observed slowdown of these ice streams should be attributed to increasing friction between the ice and the rock bed caused by strengthening and compaction of the underlying glacial till, which is losing water. (*Geophysical Research Letters,* doi:10.1002/2014GL059250, 2013) —CS

Peering into the microphysics of the Madden-Julian Oscillation

The onset of the active phase of the Madden-Julian Oscillation (MJO) is marked by the formation of a region of deep convection and enhanced precipitation over the Indian Ocean. Generally persisting from 30 to 60 days as it progresses slowly eastward, the MJO consists of wet active phases alternating with suppressed periods of lower rainfall and reduced storm activity.

Although the Madden-Julian Oscillation is an important driver of intraseasonal weather variability, especially in the tropics, many competing hypotheses exist as to how or why it forms. Even less is known about the intricate details of what goes on inside the storm clouds, where and how the clouds form, and whether every active-phase storm is the same.

In October, November, and December 2011, researchers used radar to determine the type and arrangement of raindrops and ice particles within the precipitating clouds. Analyzing the radar output, *Rowe and Houze* determined the distributions of these different types of particles, identifying everything from wet and dry snow to graupel and drizzle. They found that while these distributions were generally similar, active-phase storm clouds reached farther into the atmosphere than clouds during inactive MJO phases.

They found that during MJO active phases, precipitating clouds not only extend to greater altitudes but organize into large storm clusters known as mesoscale convective systems. Each stage of this process brings different distributions of the different types of precipitation. The authors note that the October, November, and December storms were not all the same. The December active-phase storms consisted of shallower mesoscale convection and a lower concentration of melting snow than the storms during the other active periods. The authors suggest that different wind, humidity, and temperature profiles prevailed during the December active phase, accounting for the differences. (*Journal of Geophysical Research: Atmospheres,* doi:10.1002/2013JD020799, 2014) —CS

How should flood risk assessments be done in a changing climate?

Growing consensus on climate and land use change means that it is reasonable to assume, at the very least, that flood levels in a region may change. Then why, ask *Rosner et al.* in a new study, do the dominant risk assessment techniques used to decide whether to build new flood protection infrastructure nearly always start with an assumption of "no trend" in flood behavior?

Marilee Caliendo/FEMA

An example of Hurricane Sandy's destruction along the Connecticut coast. Hurricane Sandy reinforced the lesson that the costs of flood damage often dramatically outpace the costs of flood protection infrastructure

In an argument grounded in an analysis of the inherent limitations of statistical analyses, the authors suggest that researchers' typical starting assumption that flood behavior is not changing—even in the face of suspected trends in extreme events and knowledge of how difficult such trends are to detect—causes water managers to undervalue flood protection benefits, opening the door to unnecessary losses down the line.

When researchers assume no trend, statistical errors could cause them to overlook the risks of underpreparing for changing flood conditions. Often, potential flood damage due to underpreparedness far exceeds the potential cost of overinvesting in flood protection infrastructure. Flipping the process, starting with an assumption that a change in flood conditions is occurring rather than only considering the risk of wasting money on unneeded infrastructure, would give critical attention to the risk of underestimating future floods.

The authors propose a method of risk assessment that starts with the null hypothesis of no trend but that explicitly assesses the effect of statistical uncertainties that may cause it to misidentify real trends and the damages those trends might produce. (*Water Resources Research,* doi:10.1002/2013WR014561, 2014) —CS

A new earthquake model may explain discrepancies in San Andreas fault slip

Investigating the earthquake hazards of the San Andreas fault system requires an accurate understanding of accumulating stresses and the history of past earthquakes. Faults tend to go through an "earthquake cycle"—locking and accumulating stress, rupturing in an earthquake, and locking again in a well-accepted process known as "elastic rebound." One of the key factors in preparing for California's next "big one" is estimating the fault slip rate, the speed at which one side of the San Andreas fault is moving past the other.

Broadly speaking, there are two ways geoscientists study fault slip. Geologists formulate estimates by studying geologic features at key locations to study slip rates through time. Geodesists, scientists who measure the size and shape of the planet, use technologies like GPS and satellite radar interferometry to estimate the slip rate, estimates which often differ from the geologists' estimations.

In a recent study, *Tong et al.* developed a new three-dimensional viscoelastic earthquake cycle model that represents 41 major fault segments of the San Andreas fault system. While previous research has suggested that there are discrepancies between the fault slip rates along the San Andreas as measured by geologic and geodetic means, the authors found that there are no significant differences between the two measures if the thickness of the tectonic plate and viscoelasticity are taken into account. The authors found that the geodetic slip rate depends on the plate thickness over the San Andreas, a variable lacking in previous research.

The team notes that of the 41 studied faults within the San Andreas system, a small number do, in fact, have disagreements between the geologic and geodetic slip rates. These differences could be attributed to inadequate data coverage or to incomplete knowledge of the fault structures or the chronological sequence of past events. (*Journal of Geophysical Research: Solid Earth,* doi:10.1002/2013JB010765, 2014) —CS

Proposed satellite would improve study of cloud physics

Aerosols can have a profound impact on cloud formation and thus an impact on the global climate. Cloud droplets forming around aerosols tend to be smaller, increasing the cloud's ability to reflect radiation back into space, thus shading the Earth. However, how much light is scattered by different types of aerosols and how that relates to climate change still represent the largest uncertainty in climate change research.

In the past few years, some climate scientists have suggested that a new satellite capable of taking sensitive and complex measurements of cloud microphysics could improve understanding of aerosol-cloud interactions by leaps and bounds. But is building such an instrument even possible?

Rosenfeld et al. provide new research demonstrating that one of the main components of the proposed satellite—simultaneous measurement, from space, of the way cloud droplets form around aerosol particles and cloud microstructure—is possible. The authors extrapolated the needed data from satellite-based measurements and then compared them to ground-based measurements, which are traditionally used to study cloud-aerosol interactions, and found that the satellite's measurements were accurate.

NOAA/NWS/Jerry Penry

Could detailed measurements of cloud microphysics improve scientific understanding of aerosol-cloud interactions?

The next step, the authors note, is to assess whether collecting other required measurements from space, such as wind updraft speeds on the base of clouds, is technically possible by satellite. (*Geophysical Research Letters,* doi:10.1002/2014GL059453, 2014) —JW

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