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RESEARCH SPOTLIGHT

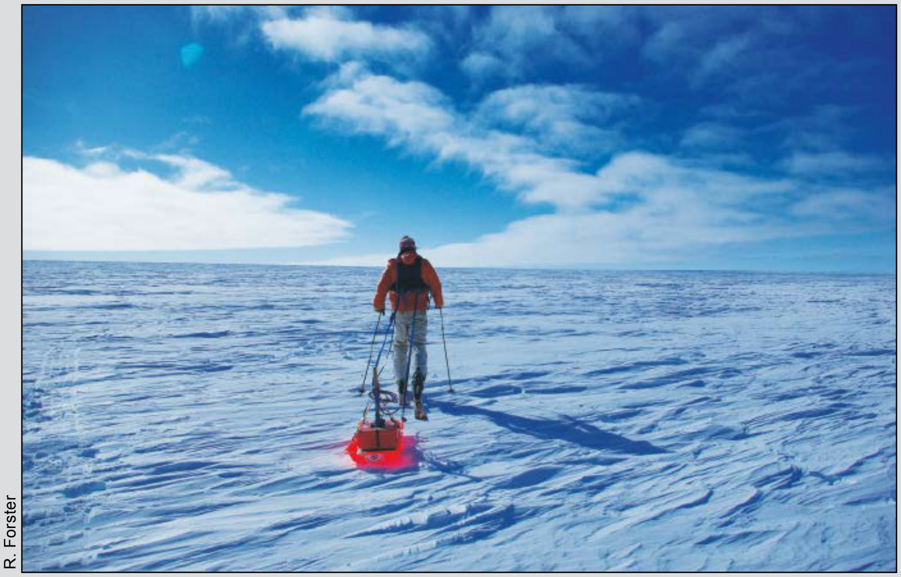
Highlighting exciting new research from AGU journals

Greenland aquifer properties measured for the first time

A dozen meters beneath the surface of the southeastern Greenland Ice Sheet is an aquifer that holds roughly as much water as Israel's Dead Sea. The unconfined aquifer occupies about 980 cubic kilometers of Greenland's porous firn, snow that is more than a year old but has not yet compacted to ice. Were the aquifer to drain into the ocean, the water could cause as much as 0.4 millimeter of global sea level rise. *Koenig et al.* build on their 2011 discovery of the aquifer and report the first attempts to directly measure its properties.

During previous research, the authors collected two core samples from the firn beside and above the aquifer but could not drill into and sample the aquifer itself. For the present research, the authors drilled into the reservoir for the first time, measuring the density and studying how the temperature of the stored water and the depth of the water table changed over the course of a year or more.

Their data shows that the aquifer is fed by meltwater percolating down from the surface of the ice sheet. The water is insulated by high annual snowfall and stays in the liquid phase despite the sub-freezing surface temperatures. Though the presence of liquid water beneath the glacier's surface is not uncommon in mountain glaciers, the Greenland aquifer is larger and seemingly more stable. (*Geophysical Research Letters*, doi:10.1002/2013GL058083, 2013) —CS



R. Forster

A scientist takes radar measurements to detect liquid water stored within the Greenland Ice Sheet in April 2013.

Mountain forests' root growth stabilize atmospheric CO_2

Throughout Earth's history, carbon dioxide (CO_2) has been released and sequestered from the atmosphere in cycles that profoundly influence global climate. One of the processes depleting the atmosphere of CO_2 is silicate rock weathering—chemical reactions that eventually combine atmospheric CO_2 with calcium or magnesium and remove it from the atmosphere.

Tree roots and their symbiotic relationship with fungi are thought to play a role in such weathering and thus can influence CO_2 concentrations and climate. Previous research has studied this phe-nomenon in temperate forests, but until now, no one has quantified how root systems in montane tropical forests influence weathering.

Doughty et al. present the first evidence of a feedback relationship between temperature and biotic weathering in which the warmer the climate, the more prone rocks are to being broken down by root systems. The researchers believe this process is mediated by the depth of the top—or organic—layer of soil. Montane tropical root systems are especially important: Given the abundance of silicate minerals in montane systems and the high temperatures found in tropical forests, they may contribute significantly to buffering changing CO_2 concentrations in the atmosphere.

The authors combined field data from test plots in the Peruvian Andes with known weathering models and found that globally, as temperatures rise and the organic layer of soil shrinks, weathering by mountain root systems is greatly enhanced. They applied their models to simulations of past climates during the Cenozoic when CO_2 concentrations changed rapidly, either because of volcanic eruptions or continental uplift, and found that mountain root systems could have exerted a significant stabilizing force on atmospheric CO_2. The authors note that this research highlights a previously overlooked role that the organic layer of soil could play in influencing climate. (*Geophysical Research Letters*, doi:10.1002/2013GL058737, 2014) —JW

Cecile Girardin

Researchers measured fine root growth and organic layer thickness over several years in this valley in the southern Peruvian Andes.

Verifying intercalibration of solar proton sensors

Energetic protons emitted in bursts from the Sun pose a potential hazard for spacecraft, satellites, humans in space, and aircraft at high latitudes. Researchers have now verified that a set of sensors used to measure solar proton events are correctly intercalibrated to provide early warning of the events.

Since the 1970s, the Geostationary Operational Environmental Satellites (GOES) have measured solar protons using energetic particle sensors (EPS). Starting with GOES 4 (launched in 1980), the EPS devices on the GOES series of satellites have all used the same design and have become a standard tool for providing alerts of radiation hazards.

On the basis of solar wind pressure, *Rodriguez et al.* identified environmental conditions during which the solar proton detectors could be expected to measure the same flux, creating suitable conditions for intercalibrating the devices. They analyzed data from particle sensors from GOES 8 through GOES 15 and found that the relative responses of the detectors all agree within 20%—and sometimes better than 1%—indicating that the sensors are correctly intercalibrated.

The authors note that the results "affirm the long-held confidence in the consistency of the long series of EPS solar proton measurements, including the current (and final) GOES-13–15 series [of EPS], for real-time space weather alerts issued in the interest of human and spacecraft safety." This method will be used for intercalibrating the GOES-R successor to EPS. (*Space Weather*, doi:10.1002/2013SW000996, 2014) —EB

New algorithm to improve earthquake early warning systems

When a fault line ruptures, seismic waves race out from the earthquake epicenter. Compressional seismic waves, known as primary (*P*) waves, travel fastest. Shear waves—secondary (*S*) waves—travel more slowly but are the source of the bulk of earthquake-induced damage. Using the opportunity afforded by the difference in travel times between these two types of waves, researchers have begun to design and implement earthquake early warning systems.

To calculate the properties of an earthquake that is just seconds old, these early warning systems analyze the first few seconds of *P* waves arriving at seismic monitoring stations. Pulling observations from multiple monitoring stations enables the calculation of the earthquake's location, and analyzing the *P* waves' properties gives a way to estimate the earthquake's magnitude. Exactly which properties of a *P* wave to measure to best derive a magnitude estimate, however, is a matter of ongoing research.

For the California Integrated Seismic Network's warning system, magnitude estimation is done three different ways, using three different algorithms and three sets of input variables. These approaches each use measures of the *P* waves' amplitude and frequency. In a new study, however, *Kuyuk and Allen* found that in this case, less is more: A new algorithm that relies solely on the *P* waves' vertical amplitude can estimate earthquake magnitude with strong statistical reliability, outperforming the other techniques. (*Geophysical Research Letters*, doi:10.1002/2013GL058580, 2013) —CS

Quartz-in-garnet samples reveal conditions within subduction zones

In subduction zones, seismic activity is dictated, to some extent, by the specific dynamics of the subsurface, including the depths to which rocks dove during subduction, the path that brought them back to the surface, and the mineral reactions they experienced along the way. The way to best understand these details requires either directly or indirectly measuring the depth of subduction and the mechanisms and rates of both subduction and exhumation.

Geothermometers are minerals that through changes in their properties, record the temperature at which they were formed. When exhumed rocks are studied, geothermometers can provide a reliable measure of metamorphic temperatures at depth. Similarly, geobarometers track pressure, but few good geobarometer candidates are known for studying depths below 50 kilometers—depths often reached during subduction.

From samples collected on the Greek island of Sifnos, *Ashley et al.* have applied a novel geothermobarometer, a mineral system that can record the temperature and pressure of formation at the depths of the now-exhumed Sifnos subduction zone.

The key to the authors' goethermobarometer is that it requires two minerals with contrasting properties. At depth, quartz can become enclosed within garnet, essentially sealing it off from the outside environment. As the complex is exhumed, most quartz crystals begin to expand under the dropping pressure, losing all record of their former high-pressure history.

The quartz trapped inside garnet, however, cannot so easily expand and thus records something close to the pressure at which it was included in the garnet. Spectroscopic analysis of the quartz inclusion and calculations to compensate for some slight relaxation of the garnet shell provide a way to measure both the temperature and the pressure at the depth at which the quartz was enclosed in the garnet. (*Geochemistry, Geophysics, Geosystems*, doi:10.1002/2013GC005106, 2013) —CS

New method to estimate variability in groundwater volumes

As the warming climate and increasing population put stress on the world's water supply, it has become increasingly important to have a global understanding of how groundwater volumes vary from season to season and from year to year. Current global hydrological models do not include lateral groundwater flow, which plays a significant role in providing water to plants and in recharging lakes, rivers, and streams.

Using an existing hydrological model that includes lateral groundwater flow, *Sutanudjaja et al.* show that remotely sensed soil moisture data can be valuable for predicting groundwater dynamics. The researchers found that at a local level such combined models predicted groundwater dynamics with acceptable accuracy. They note that this method could be scaled up to provide more accurate information about groundwater variability, availability, and reserves across the globe. (*Water Resources Research*, doi:10.1002/2013WR013807, 2014) —JW

Insight into overturning circulation measurements from southern Atlantic

The Atlantic Meridional Overturning Circulation (AMOC) is a major component of global ocean circulation and thus has a profound effect on global climate. The AMOC transports warm, salty water from tropical regions northward on the surface and cool, fresher water southward as deep water. Although much effort has concentrated on examining AMOC dynamics in the easily accessible north, few studies have ventured south.

Meinen et al. present the first continuous observations of AMOC from the southern Atlantic at a latitude of 34.5°S. The authors measured density, temperature, salinity, and other characteristics of AMOC to determine the volume of water transported daily. Although the time period of approximately 20 months was relatively short for this type of data collection, the authors were able to determine factors that caused variability of volume of transport at that latitude.

For periods shorter than 20 days, the authors found that variability depended on wind forcing, whereas periods between 20 and 90 days were affected more by geostrophic forces—the balance between water's tendency to flow to low-pressure areas and forces from Earth's rotation pushing back. With the collected data, scientists will be able to build a more complete picture of AMOC, both at this latitude and as a whole. (*Journal of Geophysical Research: Oceans*, doi:10.1002/2013JC009228, 2013) —JW

Hot Pliocene climate explained by ozone and aerosol emissions

The Pliocene (5.3 to 2.5 million years ago) is an extensively studied epoch because its hot, wet climate can serve as a possible analog for what might happen if today's atmospheric carbon dioxide (CO_2) concentrations rise unchecked. During the Pliocene, the two main factors believed to influence the climate—atmospheric CO_2 concentrations and the geographic position of the continents—were nearly identical to modern times. But climate scientists have long puzzled over why the Pliocene's global temperatures were so much warmer than Earth's preindustrial climate.

Unger and Yue present the first evidence that ozone (O_3) and carbon aerosols contributed to the high temperatures of the Pliocene. The authors used an Earth system model to simulate the release of volatile organic compounds from Earth's forests and smoke from wildfires 3 million years ago and found that the O_3 and aerosols produced from these emissions may have had a far greater impact on global warming than ancient atmospheric levels of CO_2. According to their findings, the higher level of global vegetation cover during the Pliocene compared to the preindustrial period was the dominant driver of the higher forest and fire emissions during the Pliocene—and of the subsequent effects on climate.

The research provides evidence that dynamic atmospheric chemistry played an important role in past warm climates, underscoring the complexity of climate change and the relevance of natural chemical emissions. (*Geophysical Research Letters*, doi:10.1002/2013GL058773, 2014) —JW

—Ernie Balcerak, Staff Writer, Colin Schultz, Writer, and JoAnna Wendel, Staff Writer