Small agricultural impoundments affect pollutant transport

Reservoirs created by dams intercept runoff from upslope areas and thus are often sinks for fertilizers and other pollutants that would otherwise flow downstream. Most studies of solute transport through impoundments have focused on large, long-lived systems. However, small impoundments, such as those created for irrigation or livestock watering, are common in agricultural regions, and their total global surface area is comparable to that of large reservoirs. As these small systems mature, the impoundments fill with sediment, creating ecosystems with wetland-like characteristics. Because dams that create these small impoundments are more likely to be degraded, poorly maintained, or removed by their owners, it is important to understand how changes in such systems may affect pollutant transport. Powers et al. investigated solute transport through a mature, sediment-filled impoundment created by a small dam in an agricultural region of Wisconsin. Over a 6-year period, they took samples of water to measure a variety of solutes, including chloride, nitrate, ammonium, and sulfate. The dam was removed about 3 years into their study period.

Before the dam was removed, the researchers found that the impoundment was a net sink for sulfate year round and a sink for nitrate, ammonium, and soluble reactive phosphorus during the warm season. After the dam’s removal, the scientists found that mean water travel time through the impoundment decreased by 40%. As the authors expected, the reduced water travel time resulted in decreased retention of nitrate, sulfate, ammonium, and soluble reactive phosphorus. The authors emphasize the importance of considering these small agricultural impoundments in strategies to manage dams and surface water pollution. (Journal of Geophysical Research-Biogeosciences, doi:10.1029/2012JG002148, 2013) —EB

Mercury’s crust likely made of magnesium-rich basalt

With both X-ray and gamma-ray spectrometers, the MErcury Surface, Space ENVironment, GEochemistry and Ranging probe (MESSENGER), which entered orbit around Mercury in 2011, is well equipped for carrying out a detailed compositional analysis of Mercury’s crust, the understanding of which could help determine the nature of the planet’s formation and of its volcanic past.

Using spectrometric measurements and laboratory analyses of Mercury surface-analog samples, Stockstill-Cahill et al. determined that the upper layers of Mercury’s crust most closely resemble magnesium basalt terrestrial rocks, though with lower iron concentrations. To make their determination, the authors used a software package known as MELTS to simulate the cooling and crystallization of potential Mercurian lavas with different chemical compositions, estimating the temperatures at which minerals would crystallize out of the molten lava and the abundances of different mineral species. Similarly, the authors simulated the cooling of magnesium-rich terrestrial rocks and of meteoric samples.

Based on their chemical compositional analysis, the authors inferred a number of properties for early lava on Mercury. They suggest that the lava would have had a very low viscosity, streaming across the surface in widespread but thin layers. Further, they calculated that the temperatures required to produce the magnesium-rich lava would have been much higher than for terrestrial rocks not enriched in magnesium. The authors say that the low-viscosity lava would leave telltale marks on the planet’s surface that could be identified through further MESSENGER observations. (Journal of Geophysical Research-Planets, doi:10.1029/2012JE004140, 2012) —CS

How many lakes are there, and how big are they?

Because of the important role lakes play in regional and local biogeochemical cycling, including carbon storage and emissions, scientists need to know how many lakes of various sizes exist. However, determining the size distribution of lakes is more difficult than it may seem—the smallest lakes are often not recorded on maps. Some researchers have suggested that the number of small lakes is underestimated and have used size distributions to suggest that small lakes dominate the global lake surface area.

To help resolve the issue, Seekell et al. considered lake size distributions in a theoretical fractal geometry framework, focusing on how elevation might affect the lake area distribution. Their calculations indicate that the lake size distribution should

Lakes of a variety of sizes in the Adirondack Mountains in New York, one of the study sites Seekell et al. used to investigate the size distribution of lakes.

© 2013. American Geophysical Union. All Rights Reserved.
follow a power law in flat regions but could deviate from a power law in mountainous regions. They confirmed this empirically using data sets of lake sizes from the Adirondack Mountains in New York and the flat island of Gotland in Sweden. Their analysis suggests that small lakes probably do not dominate the total global lake surface area. (Geophysical Research Letters, doi:10.1002/grl.50139, 2013) —EB

Assessing black carbon's effects on climate

Black carbon aerosol, commonly known as soot, plays an important role in Earth’s climate system by absorbing solar radiation, affecting cloud processes, and influencing melting of snow and ice. In fact, after carbon dioxide, black carbon is the second most important individual climate forcing agent in the industrial era, a new study indicates. Large sources of black carbon emissions include burning of forests, industrial and residential burning of coal and biomass for fuel, and burning of diesel fuels for transportation.

Bond et al. present a comprehensive evaluation of the role of black carbon in Earth’s climate system. The authors use model results and observations to provide quantitative estimates of black carbon’s effects on climate through changes in absorption of solar radiation, influence on clouds, and deposition on snow and ice. As an assessment, the paper evaluates and provides context for a diverse array of previous climate forcing estimates.

Considering all of the mechanisms through which black carbon affects the climate, the study estimates that black carbon has a total warming effect of about 1.1 watts per square meter (with an uncertainty range of 0.17 to 2.1 watts per square meter).

Because black carbon is short-lived in the atmosphere, the authors conclude that mitigating some emissions—especially those from diesel engines—could help slow climate warming in the short term. The paper also examines the effects of coemissions, particles such as sulfur dioxide and organic aerosol that are often emitted along with black carbon, which can either cool or warm. The net effect of short-lived species is warming from some sources and cooling from others, so the paper sets up a framework for targeting emission reductions. (Journal of Geophysical Research-Atmospheres, doi:10.1002/jgr.50171, 2013) —EB

Modeling complex systems in the geosciences

Many geophysical phenomena can be described as complex systems, involving phenomena such as extreme or “wild” events that often do not follow the Gaussian distribution that would be expected if the events were simply random and uncorrelated. For instance, some geophysical phenomena like earthquakes show a much higher occurrence of relatively large values than would a Gaussian distribution and so are examples of the “Noah effect” (named by Benoit Mandelbrot for the exceptionally heavy rain in the biblical flood). Other geophysical phenomena are examples of the “Joseph effect,” in which a state is especially persistent, such as a spell of multiple consecutive hot days (heat waves) or several dry summers in a row. The Joseph effect was named after the biblical story in which Joseph’s dream of seven fat cows and seven thin ones predicted 7 years of plenty followed by 7 years of drought.

Watkins provides an overview of some of the mathematical models that have been used to study complex geophysical systems, from Mandelbrot’s early contributions beginning in the 1960s to more recent stochastic approaches to extreme events. The author concludes that such complex stochastic models are needed to more fully capture the wide range of extreme events that occur in nature and that for complex systems, there are typically several possible explanations for observed scaling properties. To help tackle this ambiguity, the author advocates the wider use of statistical model testing methods. (Geophysical Research Letters, doi:10.1002/grl.50103, 2013) —EB

For U.S. biomes, climate change will decrease vegetative productivity

One recurrently forecast effect of global climate change is that, in general, precipitation patterns will become more extreme, with fewer, larger storms and longer dry spells in between. The aftermath of this shift, borne out by the effect the changing water availability will have on vegetative productivity, however, is less well known. Previous research showed that productivity changes with the total annual precipitation, but the measured effect of a shift to a more extreme distribution is less consistent. Research seeking to understand this aspect of the changing precipitation pattern question has typically been conducted through small-scale or short-duration intervention experiments, where the availability of rainwater is artificially manipulated. This makes extrapolating the research to other climates or biomes difficult.

To overcome this difficulty, Zhang et al. conducted an investigation into the observed effect of precipitation variability from 2000 to 2009 on 11 different sites within the continental United States—experimental plots that represented a range of climate and ecological conditions. Using satellite observations of canopy photosynthetic capacity, the authors estimated the aboveground net primary productivity for the experimental sites. Long-term precipitation and temperature records enabled the authors to calculate the occurrence of extreme events. Using these records, the authors could then compare the effect of more or less extreme precipitation patterns for a single site and also compare across experimental sites.

The authors found that for all biomes tested, a more extreme precipitation pattern had either a neutral or negative effect on vegetative productivity. In addition, extreme rainfall distributions were related to, on average, a 20% reduction in rain use efficiency. The decreases were more pronounced for arid grasslands and Mediterranean forests, while mesic grasslands and temperate forests were less affected. (Journal of Geophysical Research-Biogeosciences, doi:10.1029/2012JG002136, 2013) —CS

Projected U.S. water use likely to increase as climate warms

Despite increases in efficiency, water demand in the United States is likely to increase substantially in the future if climate continues to warm, new projections indicate. Brown et al. project future water use to 2090 based on past trends from U.S. Geological Survey water use data from 1960 to 2005 and trends in efficiency. They projected U.S. water demand under climate change scenarios using three different global circulation models, and they ran each model for three different global socioeconomic scenarios adapted from the scenarios used by the Intergovernmental Panel on Climate Change (IPCC).

The scientists projected that with no climate change, because of increasing efficiency, water demand in the United States over the next 50 years would stay within 3% of current demand, even with an expected 50% increase in population. The projections varied between the different climate models and emissions scenarios, but most show that if there is climate warming, projected water demand would rise substantially. This increased demand would be mainly due to
increases in the need for water for irrigation as rising temperatures increase evapotranspiration. Electricity generation for additional air conditioning as temperatures rise would also contribute to increased water demand, though to a much lesser extent. The authors caution that projected increased demand under climate warming may lead to unsustainable water use even if available water supplies do not diminish as climate warms. (Water Resources Research, doi:10.1002/wrcr.20076, 2013) —EB

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