in it and in the subsequent projections of Arctic sea-ice extent in September. In a complementary approach[4], Wang and Overland sift out those six models in the CMIP3 archive that accurately simulate the seasonal cycle of Arctic sea ice, in the hope that the models give the most reliable estimate for future sea-ice decline. They arrive at a considerably earlier date of 2037 for an end-summer Arctic Ocean without ice. However, the assumption that an accurate simulation of the seasonal cycle is a useful indicator of a model's ability to estimate future trends is not obviously true. There is some logic to their reasoning because the seasonal cycle has been used to good effect in other studies in which albedo feedbacks dominate[5], but if I had to put money on one or the other approach I would choose the one used by Boé and colleagues.

For other climate variables whose future evolution we would like to know, such simple reasoning may not be possible. For example, in similar studies that seek to constrain projections of the global climate sensitivity (the magnitude of the temperature change for a doubling of atmospheric carbon dioxide), other authors[6] have had to resort to using such complex techniques as multivariate empirical orthogonal functions to render the model and observed variables into reduced dimension spaces. By contrast, Boé *et al*. were able to reduce the myriad component processes involved in sea-ice decline, such as winds, surface heat fluxes and ocean currents, to the correlation between past and future decline. The model simulations for phase 5 of the Coupled Model Intercomparison Project, which will form part of the basis for the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, are currently being prepared. Techniques for calibrating and observationally constraining those simulations will undoubtedly come to the fore.

The bottom line of the two studies[1,4] is stark. Both sets of authors conclude that the Arctic Ocean will probably be ice-free in September before the end of the twenty-first century if we follow the current trajectory of greenhouse-gas emission[7]. Of course, there are ways in which such predictions might go wrong. Improvements in the modelling of sea ice and related physical processes might reveal feedbacks that either arrest or accelerate the rate of decline in some nonlinear way. We will not know until we produce new models and perform new future-scenario experiments. Yet the simplicity and elegance of the relationship between present-day and future climate change that is exploited by Boé and colleagues[1] leaves me with a sinking feeling that this is one prediction that we have to believe in. ❒

Mat Collins is at the Met Office Hadley Centre, Exeter EX1 3PB, UK
e-mail: matthew.collins@metoffice.gov.uk

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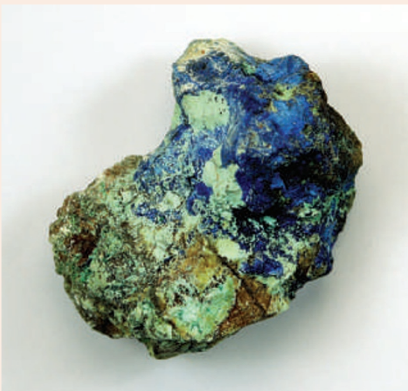
BIOGEOCHEMISTY

Meddling with metals

The human love affair with metals began in earnest at the end of the Stone Age, when our ancestors stumbled on a material that was far more amenable than rocks for making tools, weapons and jewellery. Metals continue to be central to human civilization and they have pervaded practically every aspect of our lives. In addition to the perennially useful iron and copper, we are exploiting a plethora of metals as exotic as niobium and tantalum. No wonder then, that the extraction, purification and use of metals by humans have had a profound effect on their biogeochemical cycling.

Human modifications of the carbon and nitrogen cycles have been the focus of considerable research, because of their importance to ecosystems and climate. Global cycles of metals have, by contrast, received much less attention. Now, Jason Rauch and Jozef Pacyna have taken stock of the key reservoirs for a range of important metals from silver to zinc, and analysed their global flows (*Glob. Biogeochem. Cycles*, **23,** GB2001; 2009). The analysis reveals that the movement



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of metals due to human activities is a substantial fraction of the total flow.

The researchers quantified natural cycles and reservoirs as well as the human ones. Natural reservoirs include the solid Earth and the biosphere, and natural mobilization occurs mainly through water movement, biosphere growth and decay, and by winds. In contrast, anthropogenic reservoirs include, for example, metal stocks held by governments and scrap metal. As robust estimates are available for only some countries, Rauch and Pacyna scaled up and interpolated their data.

The end result is a series of flow charts for each metal showing that, compared with only a few thousand years ago, twice as much metal flows in the global cycles because of human activities. In particular anthropogenic mobilization of copper is much greater than that induced by natural agents. Sediments on continental margins are accumulating metals as agricultural activity and urban run-off sweep discarded metals into the rivers and eventually the oceans. At the same time, the amount of metal in human-made objects is increasing at the expense of that in natural ores.

In light of the rapidity and extent to which humans have modified metal cycles in the recent past, we would do well to monitor the anthropogenic alterations of these cycles on a continuous basis — and recycle where we can.

NINAD BONDRE