GEOENGINEERING

Hazy, cool and well fed?

Geoengineering that mimics volcanic activity to reflect incoming sunlight will not necessarily reduce crop yields.

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Volcanic eruptions can produce spectacular sunsets by ejecting fine particles (known as aerosols) that reflect incoming sunlight to outer space, thereby temporarily cooling the Earth's surface. Inspired by this phenomenon, various proposals — sometimes called solar-radiation management (SRM), but perhaps better labelled as geomimicry — have been suggested to 'fix' the greenhouse-gas problem. The basic idea is to engineer a system to inject particles into the upper atmosphere and thus cool the planet. By injecting just the right amount at the right time, one could, in principle at least, offset the globally averaged warming effect of anthropogenic greenhouse gases[1,2]. But is it really that simple, or is this a situation where the proposed solution might be worse than the perceived problem[3]?

Of great concern is the potential impact of such geomimicry on food and water security. Writing in *Nature Climate Change*, Pongratz *et al.* present an initial global-scale modelling assessment of the impacts of SRM on crop yields[4]. They investigate a scenario where atmospheric CO_2 increases to 800 ppmv over the next 100 years and use a global climate model to simulate the new climate. The simulated precipitation, temperature and other climate model outputs are then input into an empirical crop model to estimate crop yield. The procedure is then repeated, but this time including SRM sufficient to offset the radiative forcing due to greenhouse gases and thereby keep the surface temperature at present-day levels. The difference in the simulated crop yield is taken as an estimate of the overall impact of SRM. The changes in yield vary from region to region, but over latitudinal zones the results indicate a slight increase in crop yield that the authors in part attribute to the direct effects of increased CO_2 levels on photosynthesis without the penalty of increased temperature. As with any first estimate there are a lot of caveats. For example, the authors assume that the area of crop land remains fixed at current distributions. No account is taken of potential changes in disease, fertilizer application, agricultural varieties or technology, or any direct effects of air pollution. They also ignore the likely stimulation of photosynthesis in sunny areas caused by an increase in diffuse light (one effect of the hazier conditions illustrated in Fig. 1)[5–7], perhaps offset by decreases in areas that are already light limited. Nevertheless, the results suggest that a geomimicry approach may not reduce globally averaged crop yields and might even enhance them.

The ongoing human-induced accumulation of CO_2 in the atmosphere is expected to alter the radiation balance of the Earth. The aim of geoengineering is to intervene to restore the pre-industrial radiative balance. There are two main options — SRM and the better known CO_2 management (COM). COM addresses the original source of the problem by either reducing emissions or increasing withdrawals from the atmosphere. On the other hand, SRM manipulates a different part of the climate system in an attempt to cancel out the radiative impacts of increasing greenhouse gases. There are many obvious differences between COM and SRM, but some are not so obvious. For example, in their study, Pongratz *et al.*[4] assume that the additional aerosols used to reflect solar radiation are spread uniformly just like the well-mixed greenhouse gases that they are designed to offset. In reality, that would be very difficult to achieve. The issue here is that regional variations in aerosol concentrations are likely to change atmospheric circulation[8], and the resulting regional-scale changes in rainfall will be hard to predict as has been acknowledged[4].

A mere mention of the word 'geoengineering' at a conference is often sufficient to raise the blood pressure of many. Opinions are strong. So far, the tendency has been to look at geoengineering as some form of last-resort option. However, it is important to keep a sense of reality as the arguments rage. Central to the debate is the Earth's energy imbalance, which, for all practical purposes, is measured by changes in the oceanic energy balance[9]. Estimates of the energy absorbed by the oceans, forcing (mostly due to greenhouse gases), increases in outgoing thermal radiation (that is, increased temperature) and reflection of sunlight owing to volcanic eruptions leaves a substantial and unaccounted for energy gap of around half the greenhouse-gas forcing. In the absence of any credible alternative, this has been attributed to aerosols reflecting incoming sunlight to outer space[10]. If this is correct, we would be forced to conclude that we are already unintentionally geoengineering the climate, with effects akin to SRM.

Regardless of the uncertain degree of aerosol loading over time, it is clear that a great deal of unintentional SRM has already occurred[11]. In that context, the research reported by Pongratz *et al.*[4] provides added impetus to the need to estimate the impact of SRM on crop yields over the past 50 years. For example, in regions of large

Figure 1 | Haze to reduce over-heating of crops. Pongratz and colleagues[4] suggest that crop yields under geoengineered hazy skies (right) may not decrease.

aerosol increases, such as in China, one could in principle re-examine yield data in relation to aerosol loading to determine if an effect is detectable. In that sense, it is interesting that a study using a global climate model is leading us full circle back to empirical studies in the field and the laboratory. ❐

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BIOLOGY

Birds and butterflies in climatic debt

A European-wide analysis of changing species distributions shows that butterflies outrun birds in the race to move northwards in response to climate change, but that neither group keeps up with increasing temperatures.

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It took 1.5 million man-hours just to collect the data, but now there is a Europe-wide analysis on the impact of climate change on the shifts in distribution of butterflies and birds. Thousands of citizen scientists (skilled volunteers) have been getting up early on their days off to survey species of these two groups in seven European countries for two decades — a period over which Europe has been warming up. Writing in *Nature Climate Change*, Devictor *et al.*[1] use this unique dataset to estimate how fast birds and butterflies expand their ranges to the north. And the news is grim: despite the fact that birds and butterflies have shifted an average of 37 km and 114 km northward, respectively, they cannot keep up with the changes in temperature — their ranges should have shifted 249 km to do so. Birds and butterflies are thus building up their climatic debt quickly.

The world is warming, and because the Kyoto Protocol is running out and no binding emission targets were set at the recent climate talks in Durban, it will continue warming in the decades to come. Ecologists are faced with the question of what the consequences of this are for the planet's species. So far, two clear consequences of increasing temperatures have been shown across species groups: shifts in seasonal timing (or phenology) and shifts in the distribution of species by expanding their northern range limit[2]. These observed shifts can easily lead people to think that species are coping with their warming world. However, that conclusion would be premature without first assessing by how much species should shift their timing or range. In other words, we need a yardstick[3].

For range expansions, Devictor *et al.*[4] developed a simple yardstick to estimate how much species should shift. In their method, they first characterize each species by the temperature averaged over their entire distribution. This is what they termed

As a species found in bogs and pine forests, *Plebejus optilete* is a typical example of a 'cool' species with a low species temperature index. Image courtesy of Chris van Swaay, Dutch Butterfly Conservation.