

# Bubble, bubble, toil and trouble

## An editorial comment

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Seitz (2011) has proposed using micron-size bubbles in water to increase albedo and cool the water as an alternative to geoengineering in the stratosphere using sulfate aerosols. The slogan “Don’t dim the Sun; Brighten the water” appears twice in the paper. Seitz suggests that cooling oceanic regions this way would be a safer way to address the problem of global warming.

The problem of global warming is real and potentially very dangerous (IPCC 2007). Society has various options for responding to this problem, nothing (the response so far), mitigation (reducing or eliminating emissions of greenhouse gases that are causing the warming—the far preferable option), adaptation and suffering in response to the warming and other climate impacts that are already happening and will grow in the future, and geoengineering. Geoengineering here will refer to “solar radiation management” attempts to reduce absorbed solar radiation to counteract the warming. Carbon capture and storage is also sometimes called geoengineering, but it has completely different ethical, risk, governance, and cost issues and will not be addressed here.

Robock (2008a) and Robock et al. (2009) point out that while production of a stratospheric aerosol cloud would indeed cool the climate and prevent or reverse ice melting and sea level rise, it would also bring a large number of potential risks (Table 1). While Seitz correctly states that his bubble method would remove some of these risks, it would bring its own list of risks. These include impacts on convection in the ocean once you cool the ocean surface, which would remove the bubbles. A cooler ocean will also absorb CO<sub>2</sub> more efficiently, enhancing ocean acidification. As artificial surfactants would be needed in some situations, the costs and environmental impacts of these chemicals may present problems. And what would be the effects of bubble clouds on oceanic life, through their effects on temperature and amount of sunlight? Bubble clouds would also induce changes in oceanic circulation and anom-

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**Table 1** Benefits and risks of stratospheric geoengineering

Benefits	Risks
Cool planet	Drought in Africa and Asia
Reduce or reverse sea ice melting	Perturb ecology with more diffuse radiation
Reduce or reverse land ice sheet melting	Ozone depletion
Reduce or reverse sea level rise	Whiter skies
Increase plant productivity	Less solar energy generation
Increase terrestrial CO <sub>2</sub> sink	Degrade passive solar heating of buildings
Beautiful red and yellow sunsets	Environmental impact of implementation
Unexpected benefits	Rapid warming if stopped
	Cannot stop effects quickly
	Human error
	Unexpected consequences
	Commercial control
	Military use of technology
	Conflicts with current treaties
	Whose hand on the thermostat?
	Degrade terrestrial optical astronomy
	Affect stargazing
	Affect satellite remote sensing
	Moral hazard—the prospect of it working would reduce drive for mitigation
	Moral authority—do we have the right to do this?

Updated from Robock et al. (2009)

alous evaporation, which would in turn affect atmospheric heating and atmospheric circulation. Would the bubble patterns allow regional climate control, with potential benefits, but also potential for use as a weapon?

As discussed by Robock (2008b), a research program is needed to evaluate all the potential benefits, risks, and costs of different proposed geoengineering schemes, so that society can in the future be able to make informed decisions about implementation. This research program should include Seitz's bubbles and initially be focused on computer simulations and laboratory studies. However, when scientists propose small-scale in situ field experiments, they will be confronted with unsolved ethical and governance issues. What if the field trials prove dangerous to marine life or the regional climate? Up to what temporal and spatial scales, and what amount of emissions or disturbance should be allowed? And how will this decision be made? By ethical panels associated with funding agencies? By international conventions, such as the London Convention? And what criteria will be used for the allowed impact? Less than the disturbance of current ocean waves, or of a tanker traversing an ocean? But does intention matter? Is additional disturbance OK, even if it adds on to current disturbance? Do two wrongs make a right?

Bubble generation in the ocean should be added to the list of solar radiation management options being considered as part of geoengineering, but it needs to be rigorously evaluated, along with marine cloud brightening and stratospheric aerosol generation, in terms of its costs, benefits, and risks. If society can develop ethical and governance responses to the idea that we advertently control the climate, then at some time in the future we will be able to decide whether bubbles are a useful addition to the geoengineering toolbox.

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