MEERTALK

MARINE CLOUD BRIGHTENING: IS IT FEASIBLE?

MICHAEL DIAMOND

- CIRES (COOPERATIVE INSTITUTE FOR RESEARCH IN ENVIRONMENTAL SCIENCES AT UNIVERSITY OF COLORADO BOULDER)
- POSTDOCTORAL VISITING FELLOW AT NOAA'S CHEMICAL STUDIES LABORATORY

SUMMARY

Clouds exert an enormous influence on the global climate. Some clouds reflect shortwave radiation, eliciting a cooling effect, whereas others absorb longwave radiation and warm the climate. On balance, the cooling effect wins out, yielding a net global cloud radiative effect of -20W/m^2. For reference, an instantaneous doubling of CO2 would result in 4 W/m^2 of warming. Low altitude clouds have almost all of the cooling effect because they are relatively bright and their proximity to the earth's surface means that their greenhouse effect is negligible. In the 1960s, scientists observed a brightening effect of marine clouds above the shipping lanes of maritime cargo vessels, leading to the proposal that they could be purposefully brightened to increase the earth's reflectivity. This observation forms the basis of modern Marine Cloud Brightening (MCB) research.

All clouds need a seed or "cloud condensation nuclei" over which a cloud can condense. In the remote ocean, the primary aerosols that can perform this task are salt particles picked up by the wind. If a ship goes by and emits pollution, the increase in small particulate pollution can also lead to cloud enhancement and a change in cloud albedo through a process known as the Twomey Effect. Two other physical processes known as Drizzle Suppression and Enhanced Entrainment also take place. Drizzle Suppression leads to a cooling effect, which can enhance the Twomey Effect, while Enhanced Entrainment leads to the mixing in of warm dry air and can increase evaporation, counteracting the Twomey effect.

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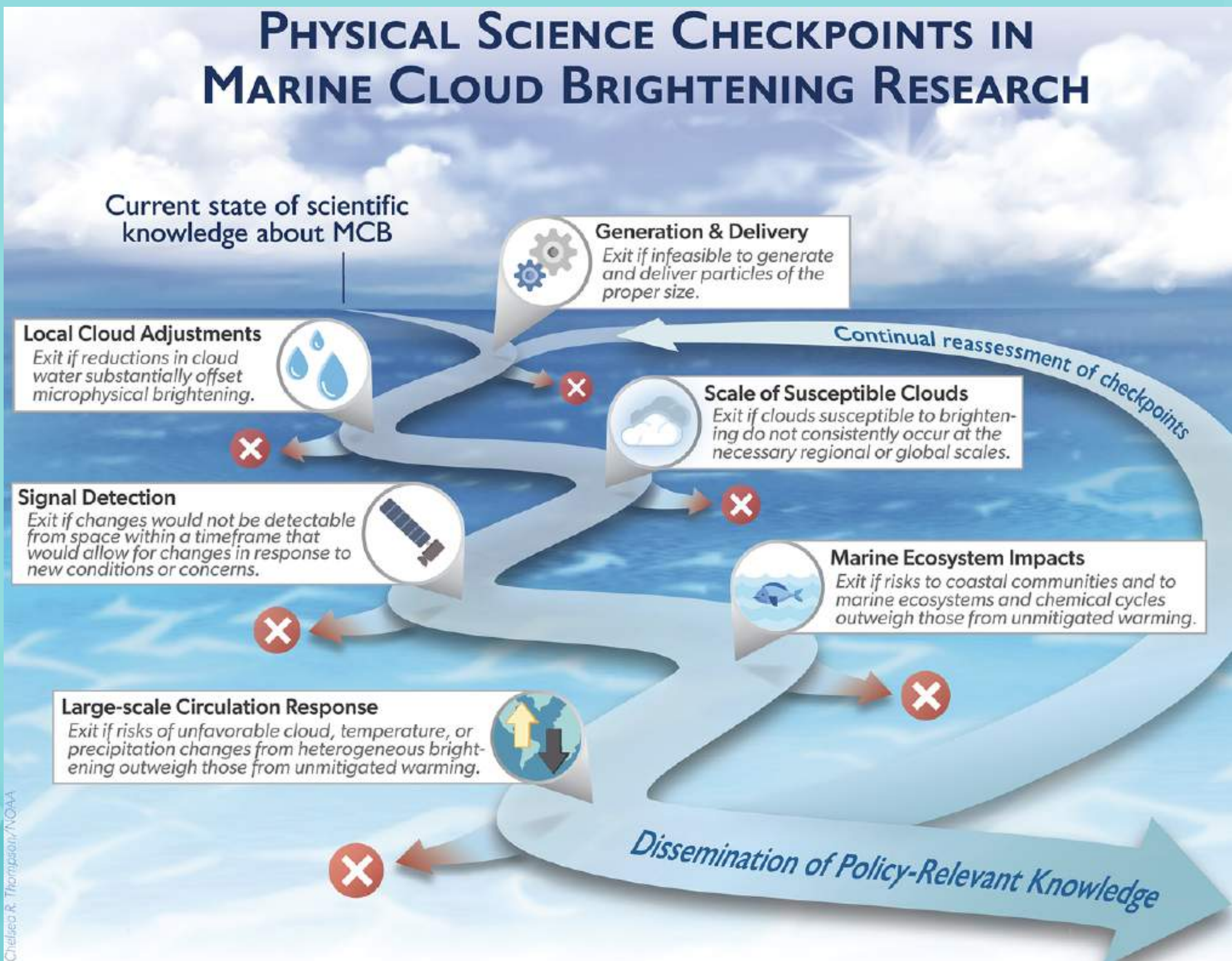
SUMMARY (CONT.)

The interaction of these phenomena create uncertainties and are the object of current MCB research.

MCB researchers, led by Diamond, have created a road map to generate policy-relevant knowledge. Based on recommendations from the National Academies, each of the 6 stages delineated in this roadmap has an exit ramp based on what would need to be true to terminate the research program. The identification and acceptance of exit ramps can guard against lock in of an unnecessary research program, if MCB proves to be infeasible, or unwarranted development, if the risks of MCB outweigh the risks of unmitigated warming. The importance of transdisciplinary research across Physical Science, Technology, Ecology, Social Science, and Ethics was stressed. MCB has the potential to help limit global warming to below 1.5 degrees Celsius of warming, but only as a complement to climate mitigation efforts.



STUDENT QUESTIONS

Q What percentage and portion of the ocean's surface is suitable for this operation?

A: This is currently the topic of a lot of research, and it is hard to answer now, as there will be some areas with little response or a counteracting response. For a baseline, low altitude clouds cover roughly a quarter of the oceans.

Q How much do we need to increase the cloud cover to maintain global warming within 1.5 degrees Celsius?

A: This depends on the baseline of warming that MCB deployment is initiated against. It will take a greater increase to recover from greater levels of warming.

Q Are we able to get a measurable signal to detect global average temperatures, and how many years of continuous data collection would it take to see a response to MCB?

A: If experiments were done for 1 year with 10-20% brightening, it would be hard to detect on less than a couple of year timescale. Regional tests would essentially be indistinguishable from deployment. Hopefully in the future, large ensemble climate models would be able to help answer this.

Q In the case that national programs find conflicting results, who makes the ultimate decision?

A: That question would need input from social science experts, although it would likely be very thorny.

Q Is there any effort to set up ecological impact studies with rigorous background control measurements to test for the effects of clouds moving over large distances?

A: This question needs more study. The question will be how to get better understanding over time, as we will never be able to do enough studies to resolve all scenarios or all possible impacts.

Q What changes would we expect to see in primary productivity levels in regions with a significant and uniform reduction of sunlight?

A: It is not clear how direct the linkage will be, as some vegetation respond better to more diffuse light and it is uncertain if this will hold true in the ocean.

Q Given the short lifespan of clouds, how feasible is it to replace cloud condensation nuclei every 3-4 days over such vast areas?

A: This question would need to be posed to someone with expertise in engineering.

STUDENT QUESTIONS (CONT.)

Q Could the direct CO_2 emissions from MCB deployment eventually cancel out the climate benefits?

A: Technically yes, although if shipping vessels are still running on fossil fuels, that would suggest that the global economy still is as well, which would be more significant.

Q How does the recent decrease in sulfur content as a result of policy decisions factor into this research program?

A: It has little to no impact. While it does result in more warming, the lack of air pollution also improves public health and reduces overall environmental impact.

Q What should the deployment timeframe be?

A: This depends on how much warming there is. Less warming would necessitate less aggressive of a timeline.

Q Should there be a global research equivalent of the IPCC for technological, engineering, and ecological experimentation?

A: This is a great idea, but it is unclear how it would be created. It is more likely that national research bodies will eventually be combined internationally.

Q What checkpoints would be necessary to add for a global framework?

- A: It isn't necessarily required to add a check point, but more detail would be needed on the scale of susceptible clouds on a regional basis to determine how they interact with one another.

AUDIENCE QUESTIONS

Q Is the estimated albedo regional or global? Is the albedo increase of 20% relative to earth's current albedo or absolute?

A: This is a relative albedo increase. For large scale experimentation, only a year would be needed to detect the microphysics effect. About 3-6 years would be needed to determine the brightening effect.

Q Wouldn't the top of the atmosphere energy balance offer a more direct measurement than surface temperatures?

A: Yes. Surface temperature would be very difficult to detect. In any case, it would be surprising if detection of these effects would be able to be conducted on an annual or sub annual basis.

AUDIENCE QUESTIONS CONTD

Q What model or models and lateral grid spaces are being used to create the precipitation impacts figure?

A: Different climate models have done different configurations.

Q Is there a mechanism to burn off clouds if it gets too cold?

A: Far simpler would be to see less and have less cooling rather than introducing offsetting warming.

Q What thoughts do you have on those in the social sciences jumping to claims of moral hazard and banning research outright, without regard to the existential risks created by unmitigated warming?

A: It is important to have multiple different communities and perspectives at the table in a democratic and transparent way for these decisions going forward. We wouldn't want to overly preference social scientists, physical scientists, or either for that matter, since both groups are relatively self-selected and don't necessarily represent the population writ large.

Q How does increasing the number of cloud droplets affect infrared transmission?

A: The effect is negligible.

Q Is there evidence from the Mt. Pinatubo eruption of a termination shock? Is that something that we should worry about?

A: Termination shock isn't something that we would have to worry about at low levels of MCB: only higher levels of Solar Radiation Management, for which there is no analog in recent history.