UNIVERSITY of WASHINGTON
COLLEGE OF THE ENVIRONMENT

MARINE CLOUD BRIGHTENING

A RESEARCH PROGRAM TO STUDY INTERVENTIONS TO REDUCE ENVIRONMENTAL IMPACTS OF WARMING CLIMATE BY INCREASING THE SUNLIGHT REFLECTED BY CLOUDS

The Marine Cloud Brightening (MCB) Project is an academic research program studying interventions to cool climate through increasing the reflection of sunlight from clouds and the effects of aerosol particles on clouds and climate. Led by a prominent cloud-aerosol scientist, Robert Wood, the MCB Project is a collaboration of over 25 distinguished experts from the University of Washington, Palo Alto Research Center, Pacific Northwest National Laboratory and other institutions.

THE PROBLEM

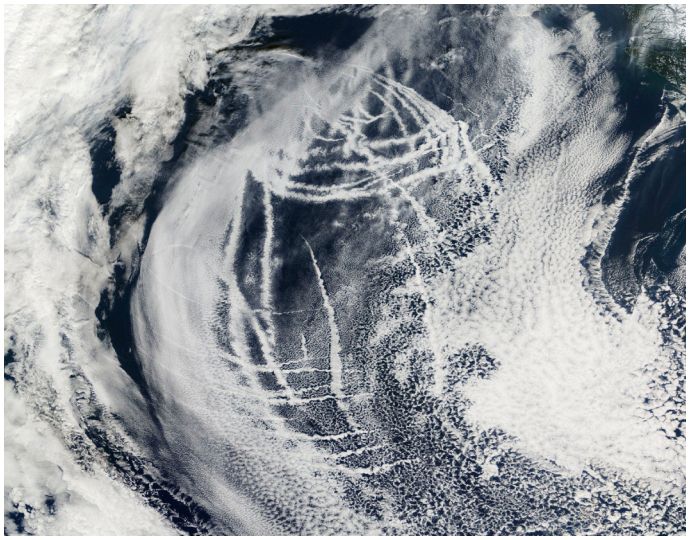
A LACK OF FAST-ACTING RESPONSES TO CLIMATE RISKS

Environmental changes from greenhouse gas warming are among the greatest threats of our time, and strategies to mitigate their effects are essential. Current projections indicate that achieving the emissions reductions required to ensure safety are unlikely, and that heat, extreme weather, biodiversity losses and other impacts may have devastating effects in the next 10-30 years. In light of this, policymakers have begun to consider technological interventions to counter climate change, including methods for removing greenhouse gases from the atmosphere or reflecting sunlight to reduce warming. Scientific analysis suggests it will take many decades to remove or significantly reduce greenhouse gases.

A 2015 National Academy of Sciences study determined that the most promising approaches to reducing warming rapidly (within a decade) involve slightly increasing the amount of sunlight reflected from clouds and particles in the in the Earth's atmosphere, known as "solar climate intervention", "solar radiation management" or "solar geoengineering".

CLOUD-AEROSOL COOLING

Particles (aerosols) in the atmosphere, from both natural and anthropogenic sources, are catalysts for the formation of clouds and affect their properties in ways that drive weather and climate. Some mix with clouds in ways that increase the amount of sunlight they reflect back to space, producing a cooling effect. Atmospheric scientists generally agree that particles from anthropogenic emissions (industrial, energy, and shipping), such as SO2, influence clouds to reflect sunlight and generate significant cooling (0.5-1.1°C) in the climate today. This "cloud-aerosol" effect is uncertain, but is likely to result in near-term warming as emissions fall and has been designated by the U.N. Intergovernmental Panel on Climate Change (IPCC) as one of the highest priorities in climate research. The effect may be particularly strong when emissions are introduced into unpolluted clouds over the ocean, a phenomenon that can be observed in satellite images of clouds brightened by ship emissions ("ship tracks").



Particles from commercial shipping create "ship tracks" of increased reflected sunlight in marine clouds off the west coast of the United States

MARINE CLOUD BRIGHTENING

- SEA SALT SPRAY FROM OCEAN WATER DELIVERED BY SHIPS
- MAY BRIGHTEN LOW-LYING MARINE CLOUDS BY 5-7%
- APPLYING TO 10-25% OF CLOUDS MAY OFFSET 2°C WARMING

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Observation of this effect led British scientist John Latham to propose using an analogue from nature - particles of salt from sea water - to brighten clouds over parts of the ocean to cool climate. In this approach, optimized particles of sea salt are dispersed from ships drawing in sea water to create an aerosol spray and deliver it into low lying clouds. The particles persist for a few days with their reach limited to localized areas. Dispersal is continuous and targeted to the most susceptible areas of clouds.

Marine clouds occurring over cool oceans (known as "stratocumulus") appear particularly susceptible to additions of aerosol, with large stratocumulus cloud decks present off the west coasts of California, Chile and south-central Africa. Early climate modeling studies suggest that using ships to deliver optimized sea salt particles into 10-25% of the Earth's marine clouds could provide enough cooling to offset a doubling of CO2, extending the time available to reduce greenhouse gases. Scientists have also proposed possible applications for mitigating local or regional impacts of warming, such as reducing heat stress on coral reefs or coastal redwood forests.

MCB RESEARCH PROGRAM

Led by University of Washington scientists, a team of researchers designed a program to explore marine cloud brightening as a mechanism for cooling climate while simultaneously providing insight about cloud-aerosol effects and their influence on climate. The program develops tools and technologies; studies primary effects of sea-salt aerosols on marine clouds, including via small-scale field experiments; and researches local, regional and global climate effects and impacts of marine cloud brightening.

- **Develop technology for generating aerosol**
- **Improve the understanding of cloud-aerosol effects and their impact on climate**
- **Explore the feasibility and risks of marine cloud brightening to reduce global and regional temperatures**
- **Explore the feasibility and risks of localized marine cloud brightening to reduce impacts (coral reefs, redwood forests, hurricanes)**
- **Serve as a model for governance pf experimental research in atmospheric science and solar climate intervention**

THE MCB PROJECT

The MCB Project is an interdisciplinary collaboration of engineers, physicists, atmospheric scientists and other experts executed in multiple phases whose classification is related to physical experiments, but where each phase includes computer modeling, technology development and (lab or field) experimental activities and related data analytics.

Phase 1: Aerosol spray development and testing

Phase 2: Aerosol process experiments

Phase 3: Cloud-brightening experiments

Each phase is only undertaken if earlier phases are successful, and studies indicate the planned work will be scientifically fruitful. Later phases also require review by independent authorities to validate that they are justified, safe and operating at a scale with negligible environmental and health impacts.

The Project includes standard procedures for governance for research activity led by a public university alongside new initiatives including cooperation with NOAA for experimental oversight and open research licensing for climate intervention technologies. As a groundbreaking and controversial effort, the program engages with government, media, civil society and the public to educate and respond to concerns.

MCB Project partners include Palo Alto Research Center (PARC), the Department of Energy (DOE) Pacific Northwest National Laboratory (PNNL) and the NGO SilverLining. UW is the lead institution and its team coordinates the overall project and leads scientific and field work, collaborating with researchers at PNNL on global, regional and near-field modeling. Building on the work of physicist Armand Neukermans, aerosol technology development is undertaken at PARC. Non-profit SilverLining provides policy, communications and government relations support.

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