Environment Canada Environnement Canada

Canada

Marine Geoengineering on the Canadian Horizon

A survey of the future of marine geoengineering

Dr. John Cullen & Ms. Suzanne Agius

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Project Objectives

- Identify the types of marine geoengineering that might be expected in Canada or to be conducted by Canadians in the next 10 years

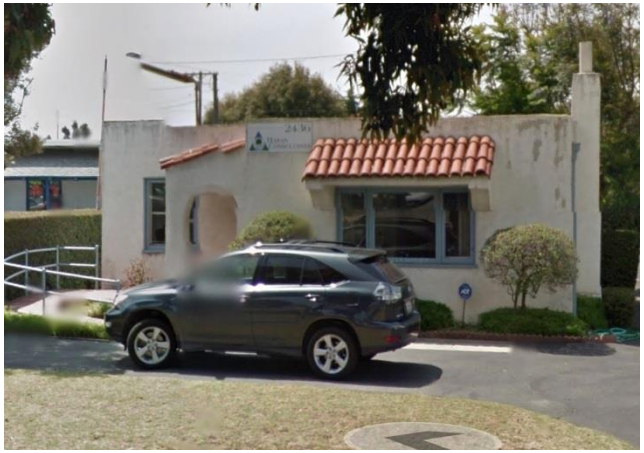
- For each activity, assess its:
  - Likeliness to achieve intended purpose
  - Potential activity in next decade
  - Relative risk

- Organize the information in an overview table with links to text and extensive background material, suitable for updates and enhancements

Methodology

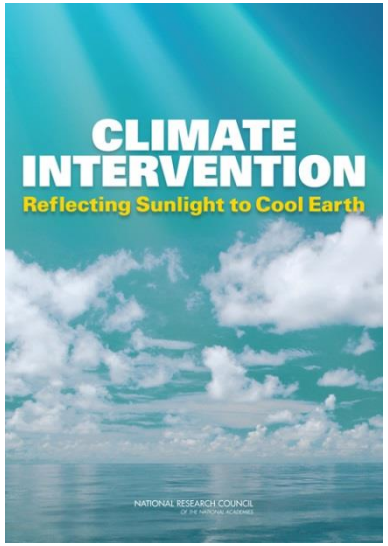
- To identify MGE ideas being actively developed (vs. just ‘ideas’), relied on informal interviews or email exchanges with knowledgeable parties from:
  - Universities
  - government laboratories
  - a nongovernmental organization
  - the private sector

- Reported only on publically available information (vs. hearsay) gained through further investigation of:
  - peer-reviewed literature
  - commissioned reports
  - media stories
  - promotional web sites
  - other publicly available material



Methodology

- Two important documents released by the U.S. National Research Council during this project
- Each provided a thorough and potent assessment of selected climate intervention activities, complementary to a report from the Royal Society (Shepherd 2009)
- Project assessment incorporated information from these new in-depth NRC reports, although by necessity, superficially



Definitions

- Used the definition of ‘marine geoengineering’ found in the 2013 London Protocol amendment
  - “a deliberate intervention in the marine environment to manipulate natural processes, including to counteract anthropogenic climate change and/or its impacts, and that has the potential to result in deleterious effects, especially where those effects may be widespread, long-lasting or severe”

Limitations / Notes

- Recognized that assessment could only be representative, and in some cases, topics could only be treated selectively
  - table-based structure, could be updated and enhanced into a more comprehensive assessment
- Expressing interest in marine geoengineering research does not necessarily imply support for large-scale implementation
- Financial status of several companies proposing geoengineering activities could not always be determined, so likelihood of proposed next steps could not be assessed with confidence
- Consequently, projections about what activities are likely to occur in the next decade are highly speculative

Limitations / Notes

- Difficult to determine Canadian connections to many activities in the absence of self-identification, but did manage to get a more global perspective with some indications of what might be feasible in Canadian waters

- We included some activities that are on the boundary of the LP definition of marine geoengineering (i.e. activities that might be regarded as marine geoengineering depending on scale and details of deployment)

Three general categories

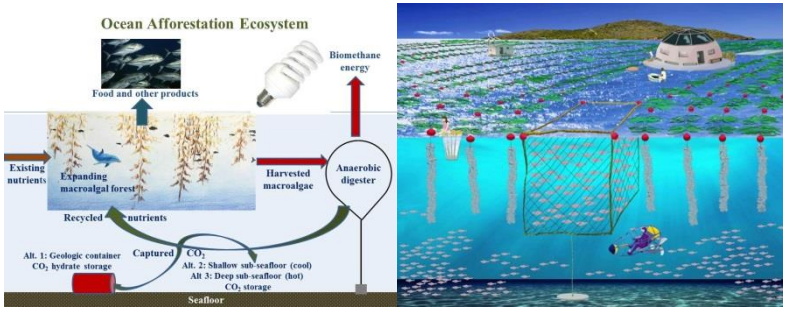
- Carbon dioxide removal and sequestration
- Albedo modification
- Ocean pumping (thermal geoengineering?)

Ocean Fertilisation

- Likely to work for intended purpose?
  - NRC Committee excluded ocean iron fertilization from their overview table, pointing out that nearly all previous studies agree that “deploying ocean iron fertilization at climatically relevant levels poses risks that outweigh potential benefits”

Macroalgae Culture

- Likely to work for intended purpose?
  - Bio-energy with carbon capture and storage (BECCS), if implemented on a scale large enough to significantly reduce concentrations of atmospheric CO_2, would require new forms of offshore aquaculture and offshore infrastructure on unprecedented scales
  - Considerable practical obstacles to the technology, amplified as operations move offshore, leading to skepticism among stakeholders that an offshore industry could develop
- Potential Activity in next 10 years?
  - Not likely on scale that would be considered marine geoengineering



Enhancing Ocean Alkalinity

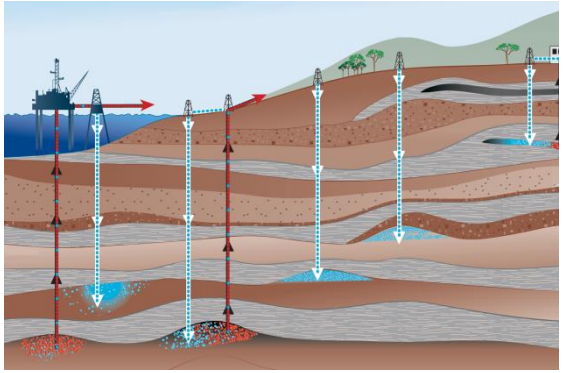
- Likely to work for intended purpose?
  - No demonstration- or pilot plants exist to date
  - Would involve the mining and crushing of hundreds of cubic kilometers of minerals, much more than worldwide coal production
  - NRC Committee identified some promise in ocean alkalinity enhancement based on potential benefits vs. risk and costs
- Potential activity in next decade?
  - Implementation well over a decade away
  - NRC identified several areas for additional research
  - Any research expected to be on a small scale, accelerating over 10 years (e.g. tests proposed by the *Olivine Foundation)*
  - Might also be employed to mitigate effects of low-alkalinity waters on shellfish aquaculture (west coast of North America)

Enhancing Ocean Alkalinity

- Relative Risk?
  - Many ecological effects of altered ocean chemistry are untested
  - Possible ecological consequences of adding inanimate particles (olivine) to the ocean at concentrations similar to the most abundant phytoplankton have not been evaluated

SMART STONES
The Olivine Foundation

Direct Air Capture and Ocean Storage



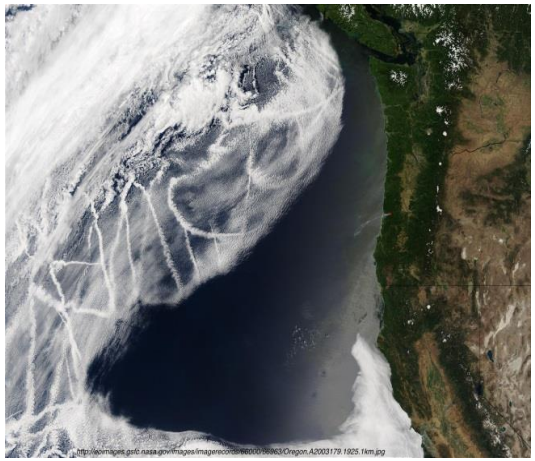
- Likely to work for intended purpose?
  - There are a few potential Direct Air Capture methods in development
- Potential activity in next decade?
  - Canadian company Carbon Engineering as broken ground on a DAC pilot demonstration project, but no mention of ocean CO_2 storage (rather, enhanced oil recovery)
- Relative Risk?
  - NRC report concludes that CO_2 storage in ocean waters, either injected at mid-depths or in deep “lakes”, is no longer the subject of active research due to “the potential biological impacts, high cost, sequestration reversibility, and public concerns.”

Marine Cloud Brightening

- Jurisdiction?
- Likely to work for intended purpose?
  - Already well established that stack emissions from cargo ships can lead to MCB under suitable atmospheric conditions
  - Potentially more effective mechanisms for MCB have been proposed (e.g. cloud brightening from seawater droplets, production of chemical particles as used for skywriting or military applications)
  - Uncertainties about efficacy, scalability, regional effects on climate around the globe, influences on ocean temperature their consequences, and ecological effects

Marine Cloud Brightening

- Potential activity in next decade?
  - Interventions would occur where cloud conditions are suitable (e.g., off the west coasts of North and South America, and Southern Africa)
  - E-PEACE experiment (L.M. Russell et al. 2012) used synthetic particles
  - Numerous field experiments of increasing scale have been proposed
  - High-profile funding (including by FICER), but unclear to what extent, for how long



Marine Cloud Brightening

- Relative Risk?
  - “Poorly Understood and Regionally Heterogeneous Consequences for the Climate System”
  - “Timescale Mismatch, Risks of Millenial Dependence, and Constraints on Strategies for Limiting the Duration of Reliance on Albedo Modification”
  - continuous emissions of such oils in aerosols over hundreds of thousands of square kilometers of ocean (though in small quantities) was not considered in the assessment of product safety
  - possible ecological consequences of decreased irradiance and altered vertical structure of the water column due to reduced thermal stratification
  - will not reduce ocean acidification

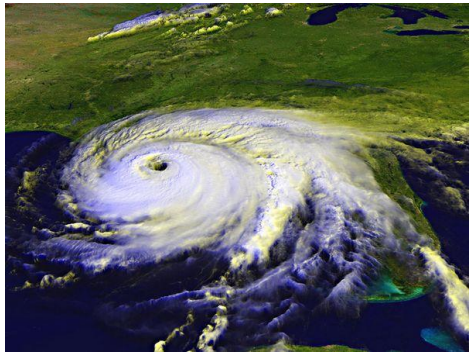
Artificial Upwelling

- Likely to work for intended purpose?
  - Early claims of carbon benefits have been tempered because deeper water is enriched in dissolved inorganic carbon which can escape to the atmosphere
  - Also been promoted as a means to suppress hurricane formation

- Potential activity in next decade?
  - Failed to find evidence of active, well-funded programs of artificial upwelling for geoengineering
  - NRC: “a tool to study marine ecosystem responses to nutrient perturbations and changes in mixing regimes…, rather than a cost-effective measure to significantly counteract climate change”

Artificial Down-welling

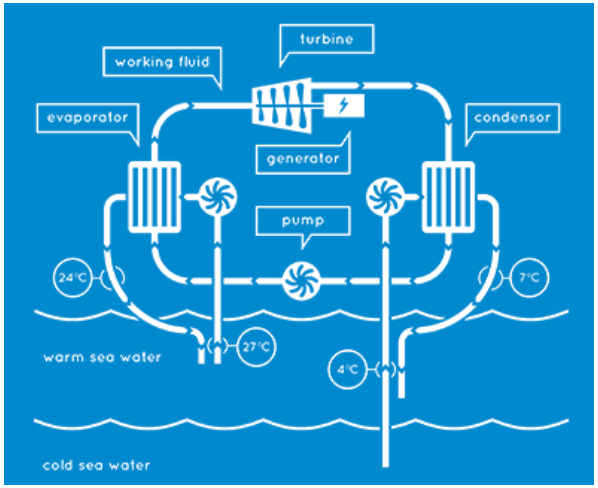
- Likely to work for intended purpose?
  - research to support conjectures that technique can purpose is to suppress hurricanes, remove atmospheric CO_2, and enhance fish stocks without any environmental or ecological problems has not been done
- Potential activity in next decade?
  - Difficult to determine, but several patents for the 'Salter Sink' have been issued and some proponents have access to significant financial resources
- Relative Risk?
  - Litigation (hurricanes being diverted elsewhere, rather than stopped)



Ocean Thermal Energy Conversion

- Likely to work for intended purpose?
  - a technology that has been explored and implemented at relatively small scales for decades

- Potential activity in next decade?
  - Interest in the technology continues, with largest project to date in design phase funded by Lockheed Martin



Sediment Remediation

- When done on a large scale (e.g. using activated carbon to remediate *in situ* sediments along a coastal region impacted by aquaculture), would this meet the definition of marine geoengineering?

Flocculants for Harmful Algae Blooms

- If done on a large scale (e.g. to manage HAGs along an entire coastline), would this be marine geoengineering)?

Conclusions

- Research into lower-risk CDR activities is likely to accelerate
- There do not appear to be any marine geoengineering activities that are ‘imminent’ in terms of field research or deployment for commercial purposes, but activity and interest will likely increase over the next ten years
- Most likely activities to be tested in the field in the next ten years (highly speculative)
  - Ocean alkalinity enhancement (most active area of research)
  - Artificial downwelling (high profile and secure research funding)
  - Marine cloud brightening (marine geoengineering? A very active area of research with some high profile funding)

Thank you!

Terrestrial Biomass Storage

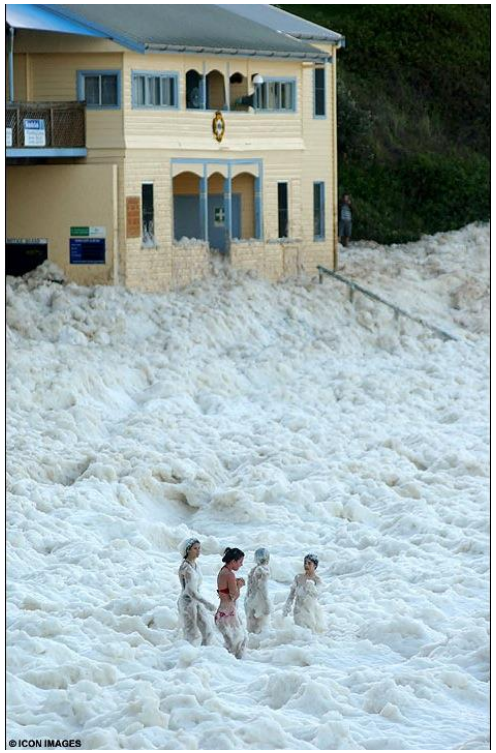
- Likely to work for intended purpose?
  - "This idea, while unsavory, might represent a viable tool in the fight against the rise of atmospheric CO_2." (R.G. Keil et al., 2010, *Marine Chemistry*)
- Potential activity in next decade?
  - We found no indications that large-scale placements will occur any time soon

Bubble Production

- Likely to work for intended purpose?
  - many uncertainties about the effectiveness of this intervention have been identified
- Potential activity in next decade?
  - the idea has not gained a great deal of traction
  - implementation would be many years off

Foam Production

- Likely to work for intended purpose?
  - Many practical challenges - expected aggregation of foams at ocean convergences and biochemical effects of added substances
  - Noteworthy that persistent foams are a well recognized nuisance generated by blooms of the alga *Phaeocystis* (transport to coastal areas may not be welcome)

Foam Production

- Potential activity in next decade?
  - Difficult to find evidence of widespread support for increasing ocean albedo through the production of persistent foams.
- Relative Risk?
  - Ecological effects of reflecting away the sunlight that fuels marine food webs