Climate-altering approaches & the Arctic: Carbon-dioxide removal (CDR) & Solar Radiation Modification (SRM)

Douglas MacMartin
Mechanical & Aerospace Engineering, Cornell University
What is the role for CDR & SRM?

- **Business as usual**
- Cut emissions aggressively
- CO₂ removal ("CDR")
- Solar Radiation Mod.? (SRM)
1.5°C and CO₂ removal

• To stay below 1.5°C, need to rapidly ramp down CO₂... *and then go negative*

• Lots of ideas for how, but
  – Typically either
    • Expensive
    • Hard to scale
    • Significant local impacts

IPCC SR1.5 SPM
Carbon dioxide removal (CDR)

- Ocean iron fertilization
- Enhanced weathering
- Sequestration in soils (e.g., biochar)
- Etc...

- Doesn’t matter where the CDR is done
- For most, not likely to take place in the Arctic
- Relevant question on reversibility?

Bioenergy with Carbon-Capture and Storage (“BECCS”)

Afforestation

Direct air capture

Climeworks plant in Switzerland
Captures 900 tons CO₂/year
(Need ~25,000,000 such plants)
Solar Radiation Modification

- Reflecting sunlight would cool the climate
- Two questions:
  - Arctic impacts of SRM applied globally?
  - Can one specifically target the Arctic?

Stratospheric Aerosol Injection (SAI)

Marine cloud brightening (MCB)

Surface albedo modification
What is the role for CDR & SRM?

- Business as usual
- Cut emissions aggressively
- CO₂ removal ("CDR")
- Solar Radiation Mod.?
Climate Model Simulations (of global SAI)

1° warming from CO₂ offset by 1° cooling from strat. aer.

Temperature (per degree)

Precipitation (per degree)

MacMartin et al, JGR 2019
How would SRM affect the Arctic?

- Reduce incoming sunlight $\rightarrow$ cools the climate $\rightarrow$ increase sea ice extent, etc.
- With Arctic-only SRM, changes in heat transport $\rightarrow$ effects at lower latitudes
- Changes to precipitation patterns and clouds
  - While sign of effect on Greenland ice sheet is clear, details aren’t
- Changes to seasonal cycle; relative to no CO$_2$ and no SRM, there could be a warmer winter and cooler summer (probably irrelevant compared to high CO$_2$ only)
  - Could influence snow depth, insulation over permafrost...
- Changes to ocean circulation
- SAI: Ozone loss (with sulfate aerosols); increased UV
- SAI: Deposition – overall quantities are small compared with industrial pollution, but industrial pollution falls not far from where it is emitted
- Possible surprises?

NEEDS MORE RESEARCH!
Governance

• A “globally-focused” strategy (with SAI, MCB) introduces a number of concerns
  – Who decides; whose voices are at the table
  – What happens if some people or places are harmed
  – How do you ensure that this isn’t taken as an excuse not to mitigate
  – How do you manage deployment for centuries

• Arctic-focused strategies share some of these concerns
  – Potential for action by a small set of nations / actors
  – Technically feasible: Arctic-focused SAI, for example could be deployed almost immediately
    • We don’t have the scientific research to inform responsible decisions
    • We don’t have the capacity to make responsible decisions

• CDR: ensure Arctic impacts are considered
SAI is not “one thing”: Impacts depend on how it is deployed

- This makes it hard to talk about “the” impacts of SAI
- Decisions aren’t just yes/no
Questions

• How confident do we need to be?
  – Some uncertainty will not be resolvable

• Who gets to decide?
  – Everyone is affected... whose voices are at the table?

• What happens if some people/places are harmed?
  – Or are perceived to be harmed?

• How do you ensure that this isn’t taken as an excuse not to mitigate?

• How do you manage deployment for centuries?
  – Without any interruption...