POSSIBLE RESPONSES TO CLIMATE CHANGE

Edward Dunlea
National Academies of Sciences, Engineering, and Medicine

- The National Academies
- Climate Response Options
- Climate Intervention Reports
- My Opinion / Implications for university community

THE NATIONAL ACADEMIES

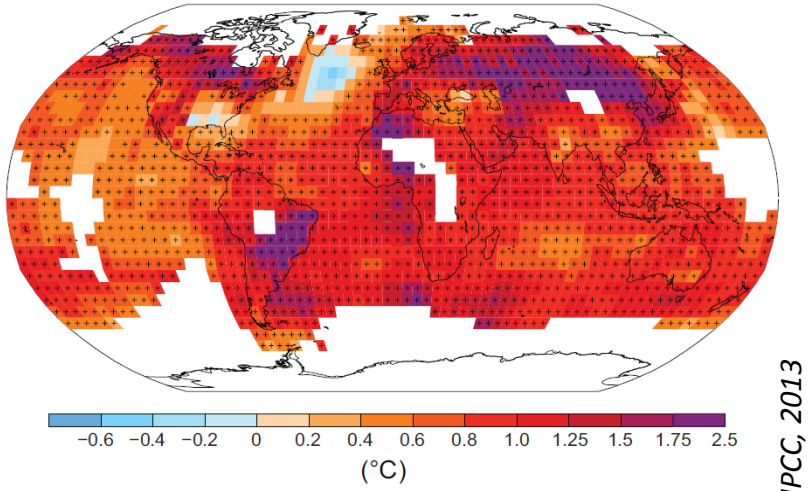
- Advisors to the Nation on science, engineering, and medicine.
- NAS created in 1863 under Lincoln Administration
- Independent non-profit with special relationship to the government
- Draw upon expertise in Academies (NAS, NAE, NAM) and more
- Rigorous review and quality control procedures
- Reports, workshops, roundtables
- **Independent, scientifically objective, and balanced advice**

BASC = Board on Atmospheric Sciences and Climate

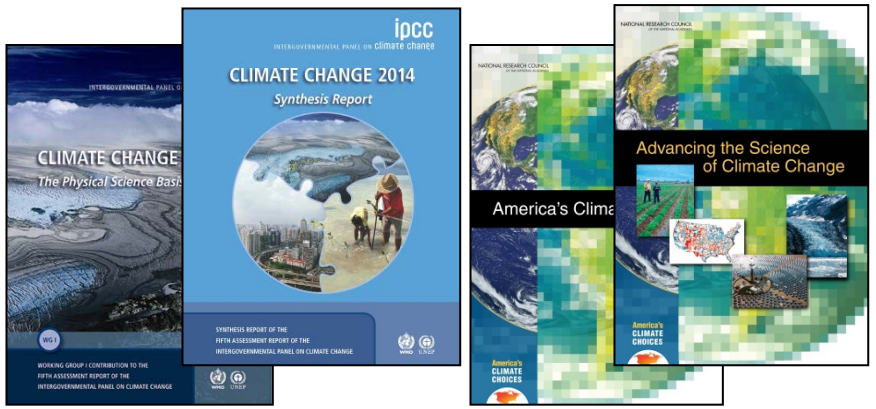
CLIMATE IS CHANGING

- The signs of changing climate are all around us:
  - Greenhouse gases are increasing
  - Sea level is rising
  - Ice sheets and glaciers are melting
  - Global temperatures are increasing
- Climate change impacts people, ecosystems, and the economy

Observed Change in Surface Temperature



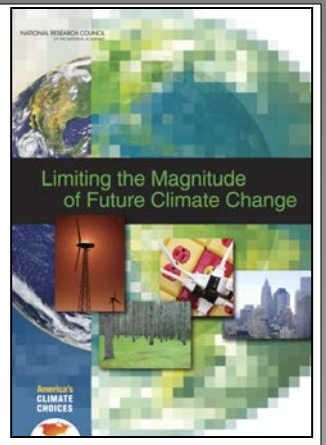
IPCC, 2013



POSSIBLE CLIMATE RESPONSE OPTIONS

- Reducing greenhouse gas emissions
  - "Mitigation"
- Adapting to the impacts of climate change
  - "Adaptation"
- Climate Intervention???

MITIGATION: EMISSIONS BUDGET NEEDED

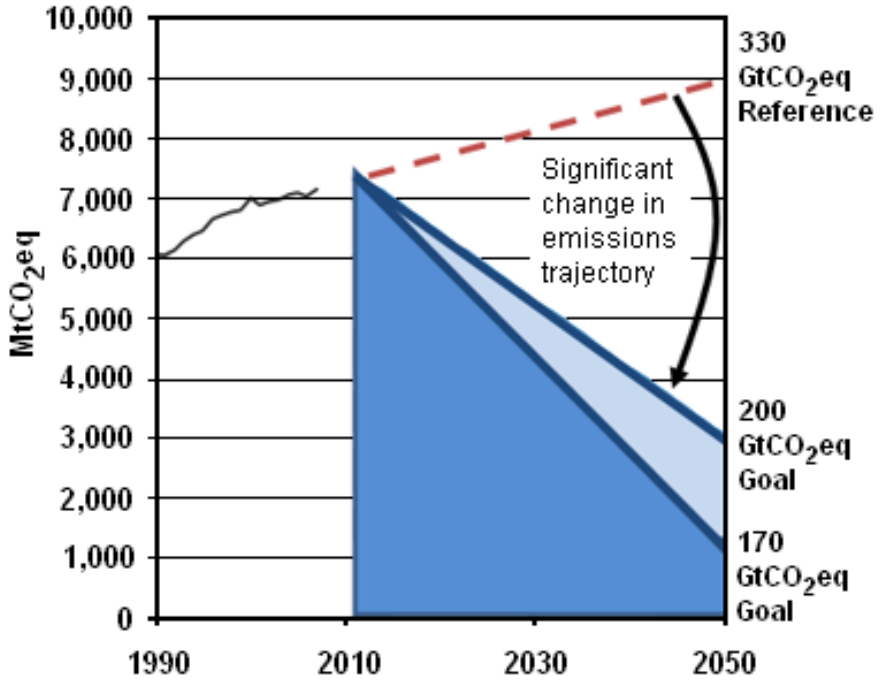


In order to limits impacts of climate change, need to limit cumulative carbon in atmosphere

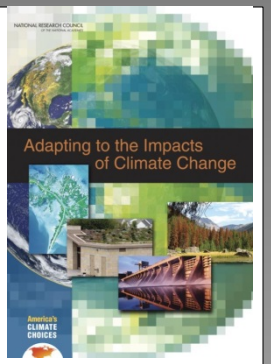
Recommendation for U.S. to establish a 'budget' for cumulative GHG emissions over a set period of time

Set an example budget based on limiting climate change

Business-as-usual emissions would consume budget well before 2050



ADAPTATION: EXAMPLES OF IMPACTS



IMPACTS OF CLIMATE CHANGE

Across the United States, climate change impacts are already evident and more severe impacts are expected in the future. Some impacts are beneficial, especially over the short run, but negative impacts are and will be pervasive. Examples of the diverse range of impacts across key sectors are displayed.

HEALTH

Increases in the frequency, intensity, and/or duration of extreme weather events, will directly affect human health.

COASTAL AREAS

Coastal areas - among the most densely populated areas - are at increasing risk from sea-level rise and storm surge.

TRANSPORTATION

Sea-level rise and increased storm surges, permafrost thaw, and more frequent extreme weather will affect transportation systems.

ENERGY

Energy demand will decrease in the winter and increase in the summer, other impacts include extreme weather events, sea-level rise, and reduced water availability.

AGRICULTURE & FORESTRY

Agriculture & Forestry production in some regions will benefit from better growing conditions under moderate climate change, while other regions will be negatively affected by increased heat, water stress, and weather extremes.

ECOSYSTEMS

Multiple stresses, including climate change, affect ecosystems by altering productivity, abundance, and species/habitat interactions.

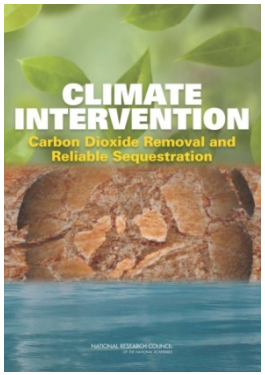
WATER

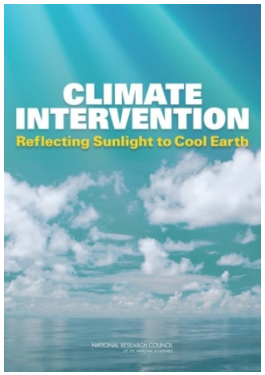
Climate change will likely place additional burdens on already stressed water resources and increases the risk for flooding.

Adaptation

Adaptation to climate change impacts will require examination of practices to adapt to current climate variability and weather extremes as well as identification of novel adaptation approaches to climate conditions that will be outside the range of past human experiences. As this report demonstrates, adaptation will require a flexible process to adjust to new information and climate conditions.

CLIMATE INTERVENTION





Background

- Otherwise called "geoengineering"
- Proposed large-scale projects to reduce climate impacts
- Two separate classes
  - Carbon dioxide removal
  - Albedo modification (reflecting sunlight)

This Study

- DOE, NASA, NOAA, U.S. intelligence community, and National Academy of Sciences supported study
- Study goal = technical assessment of proposed approaches
- What is currently known about risks, consequences, and viability for implementation

COMMITTEE ON GEOENGINEERING CLIMATE: TECHNICAL EVALUATION AND DISCUSSION OF IMPACTS

Marcia K. McNutt (Chair)
Science / AAAS
Waleed Abdalati
University of Colorado, Boulder
Ken Caldeira
Carnegie Institution for Science
Scott C. Doney
Woods Hole Oceanographic Institution
Paul G. Falkowski
Rutgers, The State University of New Jersey
Steve Fetter
University of Maryland
James R. Fleming
Colby College
Steven P. Hamburg
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Carnegie Mellon University
Joyce E. Penner
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Philip J. Rasch
Pacific Northwest National Laboratory
Lynn M. Russell
Scripps Institution of Oceanography
John T. Snow
University of Oklahoma
David W. Titley
Penn State University
Jennifer Wilcox
Stanford University

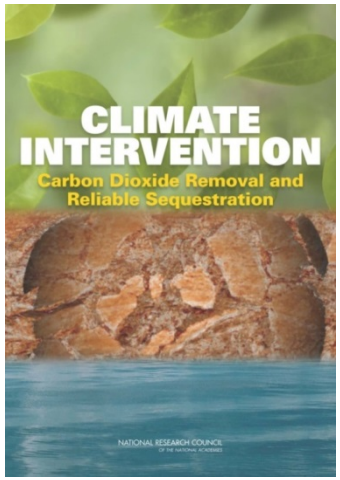
- The Committee held four meetings and interacted with dozens of scientists
- Reports were reviewed by 16 outside experts

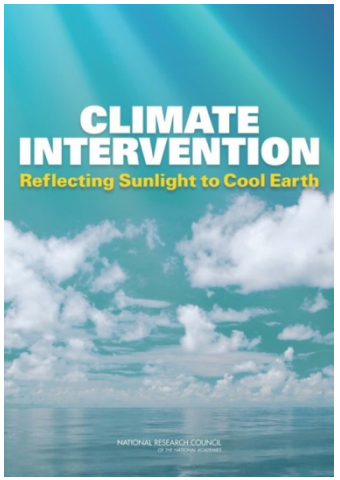
TERMINOLOGY CHANGE AND TWO REPORTS

"Climate Intervention" more appropriate than "geoengineering"

Separated into two reports because of vast differences between two classes of climate intervention approaches:

- research needs,
- environmental risks, and
- social and political issues





THERE IS NO SUBSTITUTE FOR MITIGATION AND ADAPTATION

Recommendation 1:

Efforts to address climate change should continue to focus most heavily on

- **mitigating greenhouse gas emissions**
- **in combination with adapting to the impacts of climate change**

because these approaches

- **do not present poorly defined and poorly quantified risks and**
- **are at a greater state of technological readiness**

CARBON DIOXIDE REMOVAL AND RELIABLE SEQUESTRATION

Enhancing natural carbon sinks

- Changes in land use management
  - Reforestation / afforestation
  - Agricultural practices
- Accelerated weathering
  - Chemical reactions to form carbonate or silicate minerals
- Ocean iron fertilization
  - Adding iron to the ocean to boost the growth of phytoplankton

CARBON DIOXIDE REMOVAL AND RELIABLE SEQUESTRATION

Other technologies

- Direct Air Capture and Sequestration (DACS)
  - Chemical scrubbing processes
- Bioenergy with Carbon Capture and Sequestration (BECCS)
  - Use plants (biomass) to produce energy
  - Capture carbon dioxide from power plant and sequester underground

CARBON DIOXIDE REMOVAL READY FOR INCREASED RESEARCH AND DEVELOPMENT

Recommendation 2:

The Committee recommends research and development investment to

- **improve methods of carbon dioxide removal and disposal at scales that matter**

in particular to

- **minimize energy and materials consumption**
- **identify and quantify risks**
- **lower costs, and**
- **develop reliable sequestration and monitoring**

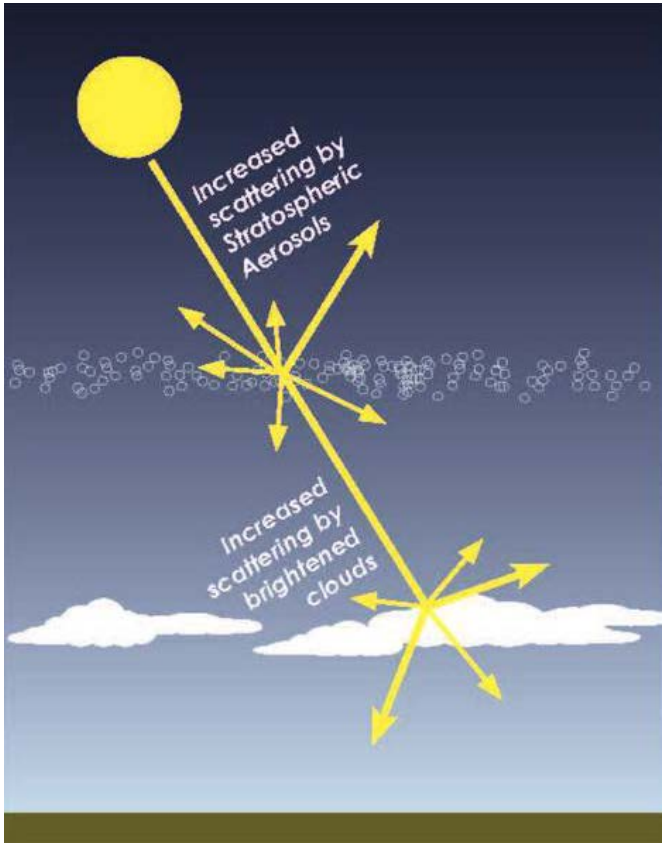
ALBEDO MODIFICATION

Albedo modification could reduce amount of sunlight absorbed by Earth in order to cool planet's surface quickly

- The report considered two strategies:
  - Stratospheric aerosols
  - Marine cloud brightening

Elsewhere referred to as "Solar Radiation Management"

"Albedo" is the proportion of incoming sunlight that is reflected back to space



ALBEDO MODIFICATION POSES SIGNIFICANT RISKS

Environmental risks – both known and poorly known

- Decreases in stratospheric ozone
- Changes in the amount and patterns of precipitation
- No reduction of root cause of climate change (greenhouse gases)
- Poorly understood regional variability
- Potential risk of millennial dependence

Significant potential for unanticipated, unmanageable, and regrettable consequences

- Including political, social, legal, economic, and ethical dimensions

Recommendation 3: Albedo modification at scales sufficient to alter climate should not be deployed at this time

ALBEDO MODIFICATION RESEARCH

Research needed to determine if albedo modification could be viable climate response

- If there were a climate emergency
- Could it be key part of a portfolio of responses?

Better understanding of consequences needed if there were an action by a unilateral / uncoordinated actor

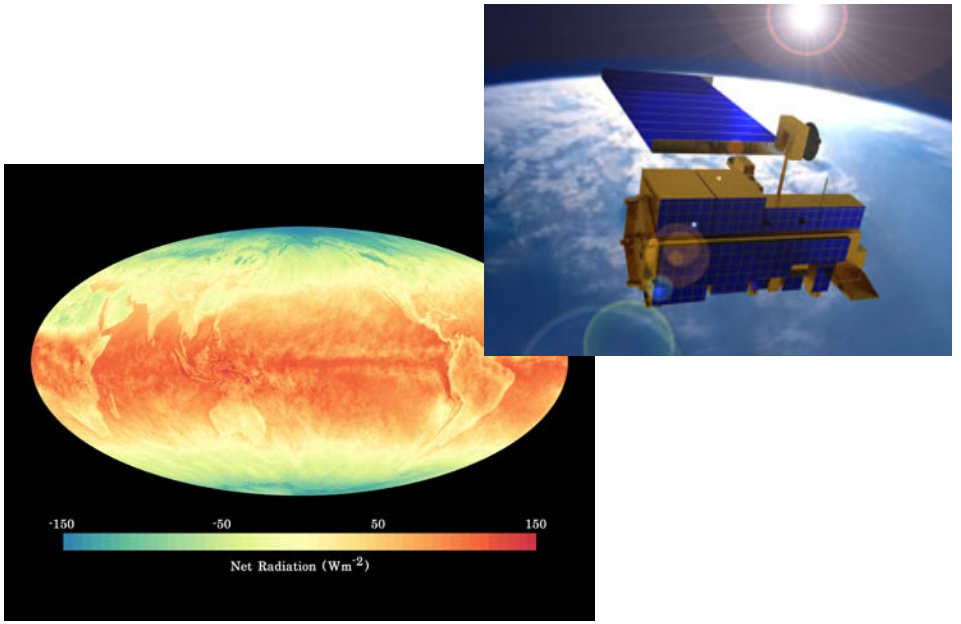
Recommendation 4:

The Committee recommends an albedo modification research program be developed and implemented that emphasizes multiple benefit research that furthers

- **basic understanding of the climate system**
- **and its human dimensions**

ALBEDO MODIFICATION RESEARCH

Current observational capabilities lack sufficient capacity to detect and monitor environmental effects of albedo modification deployment



Recommendation 5: The Committee recommends that the United States improve its capacity to detect and measure changes in radiative forcing and associated changes in climate

GOVERNANCE CONSIDERATIONS

More than just science involved in decisions on research and deployment

- Governance
- Ethical & legal considerations

Albedo modification research is not specifically addressed by any federal laws or regulations

Need for transparent and inclusive conversations

Goal of governance should be to maximize benefits of research while minimizing risks

GOVERNANCE CONSIDERATIONS

Recommendation 6:

The Committee recommends the initiation of a serious deliberative process to examine:

(a) what types of research governance, beyond those that already exist, may be needed for albedo modification research, and

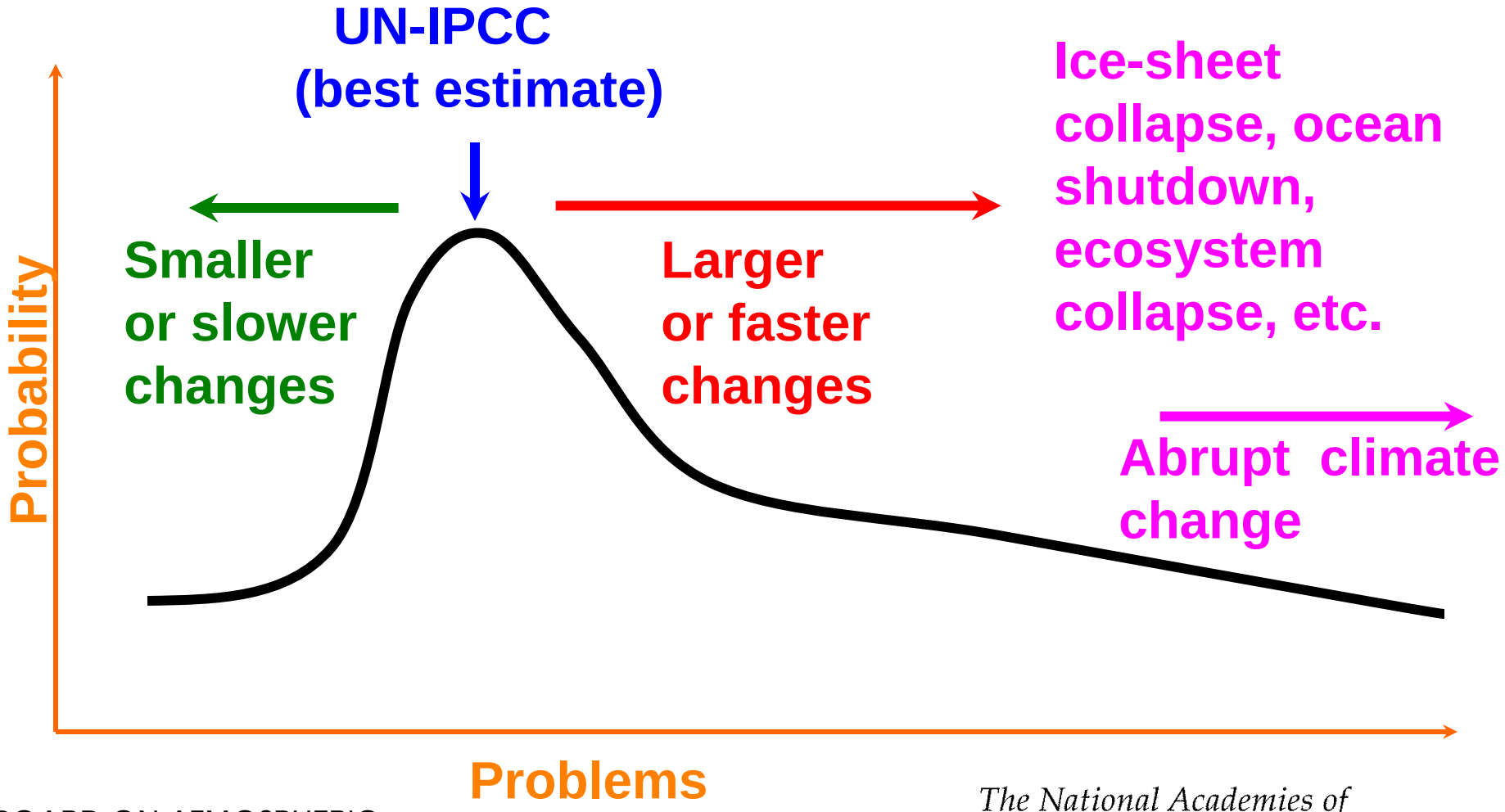
(b) the types of research that would require such governance, potentially based on the magnitude of their expected impact on radiative forcing, their potential for detrimental direct and indirect effects, and other considerations

STUDY CONCLUSIONS

- The challenges of climate change require a portfolio of actions with varying degrees of risk and efficacy
- There is no substitute for mitigation and adaptation
- Carbon dioxide removal strategies offer potential to decrease carbon dioxide concentrations in the atmosphere
- Albedo modification strategies currently limited by unfamiliar and unquantifiable risks and governance issues
- Any intervention in Earth's climate should be informed by a far more substantive body of scientific research than is available at present

MY OPINION

(Richard Alley's) Interpretation of probability of various levels of future problems

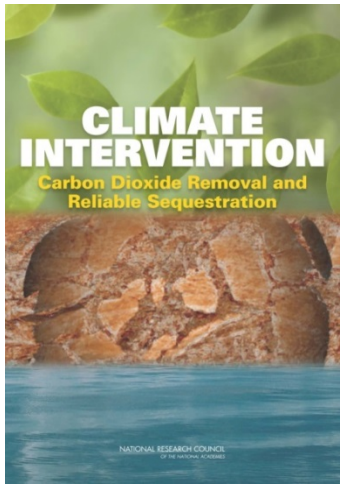


MY OPINION

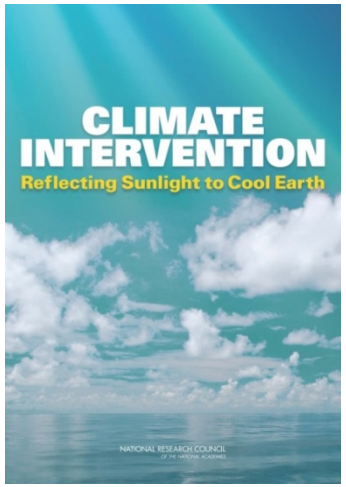
- Probability distribution is against us
- Impacts are already upon us
  - E.g., sea level rise in Miami
- We need CDR
  - Need breakthrough(s)
- It will be hard to resist albedo modification without really good reason

- Research needed
  - Knowledge is better than ignorance
  - We are already doing research
  - Need to be aware of controversy

ACKNOWLEDGMENTS



Sponsors
Committee
Reviewers
NRC Staff
Numerous colleagues consulted during study



Please visit **americasclimatechoices.org** to find:

- Complete reports available for free PDF download
- Report in Brief (4-page lay summary)
- Press release
- Information about upcoming events, such as webinar Feb 26
- Briefing slides and archived public release webcast

Join the conversation : #ClimateIntervention

Carbon Dioxide Removal proposals…	Albedo Modification proposals…
… address the cause of human-induced climate change (high atmospheric GHG concentrations).	…do not address cause of human-induced climate change (high atmospheric GHG concentrations).
…do not introduce novel global risks.	… introduce novel global risks.
…are currently expensive (or comparable to the cost of emission reduction).	…are inexpensive to deploy (relative to cost of emissions reduction).
…may produce only modest climate effects within decades.	…can produce substantial climate effects within years.
…raise fewer and less difficult issues with respect to global governance.	…raise difficult issues with respect to global governance.
…will be judged largely on questions related to cost.	…will be judged largely on questions related to risk.
…may be implemented incrementally with limited effects as society becomes more serious about reducing GHG concentrations or slowing their growth.	…could be implemented suddenly, with large-scale impacts before enough research is available to understand their risks relative to inaction.
…require cooperation by major carbon emitters to have a significant effect.	…could be done unilaterally.
…for likely future emissions scenarios, abrupt termination would have limited consequences	…for likely future emissions scenarios, abrupt termination would produce significant consequences

americasclimatechoices.org **#ClimateIntervention**