GEOENGINEERING: TECHNICAL EVALUATION AND DISCUSSION OF IMPACTS

STUDY SPONSORED BY BOARD ON ATMOSPHERIC SCIENCES AND CLIMATE

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Statement of Task

An ad hoc committee will conduct a technical evaluation of a limited number of proposed **geoengineering techniques**, including examples of both **solar radiation management (SRM) and carbon dioxide removal (CDR)** techniques, and comment generally on the **potential impacts** of deploying these technologies, including possible **environmental, economic, and national security concerns**. The study will:

1. Evaluate what is currently known about the **science** of several (3-4) selected example techniques, including **potential risks and consequences (both intended and unintended)**,
2. Describe what is known about **the viability for implementation of the proposed techniques including technological and cost considerations**,
3. Briefly explain **other geoengineering technologies** that have been proposed (beyond the selected examples), and
4. **Identify future research** needed to provide a credible scientific underpinning for future discussions.

The study will also discuss historical examples of related technologies (e.g., cloud seeding and other weather modification) **for lessons that might be learned about societal reactions**, as well as examine what **international agreements** exist which may be relevant to the experimental testing or deployment of geoengineering technologies. This study is intended to provide careful a clear scientific foundation that informs ethical, legal, and political discussions surrounding geoengineering.

Sponsors

- NASA
- NOAA
- DOE
- Intelligence community
- NRC

Schedule

July 2013	**1st Meeting (Washington, DC):** Briefings from sponsors and speakers. Preliminary study planning including additional information needs. Plan approach for future meetings and other input.
	Conference calls as needed. Information gathering.
September 2013	**2nd Meeting – Workshop (Washington, DC):** Invite 20+ experts to two-day workshop; extra day for committee deliberations, report outlining, and begin writing assignments.
	Conference calls. Writing and editing draft report.
October 2013	**3rd Meeting (Irvine, CA):** Final information gathering as needed. Deliberations, writing, and dissemination planning.
	Conference calls. Writing and editing draft report.
December 2013	**4th Meeting (Irvine, CA)**: Final writing and deliberations. Finalize conclusions and recommendations. Plan response to review and dissemination strategy.
Jan – Feb 2014	Final revisions. Select and invite external reviewers. Preliminary copyedit. Committee approves report as ready for review.
Feb – March 2014	**Report Review Process:** Submit report for NRC institutional approval that it is ready for review; distribute report to external reviewers; review period.
April – May 2014	**Response to Review and Institutional Approvals:** Respond to review comments and revise final report. **5th meeting** may be held during this period, and/or conducted using. Submit revised draft to NRC Report Review Committee and DELS; final committee sign-off.
Summer 2014	**Report Delivery:** Deliver report (in prepublication format) and Report

Background

- 2009 Royal Society Report covered much of the science of different SRM and CDR techniques as well as governance issues
- We will update this, but the literature on techniques is still limited

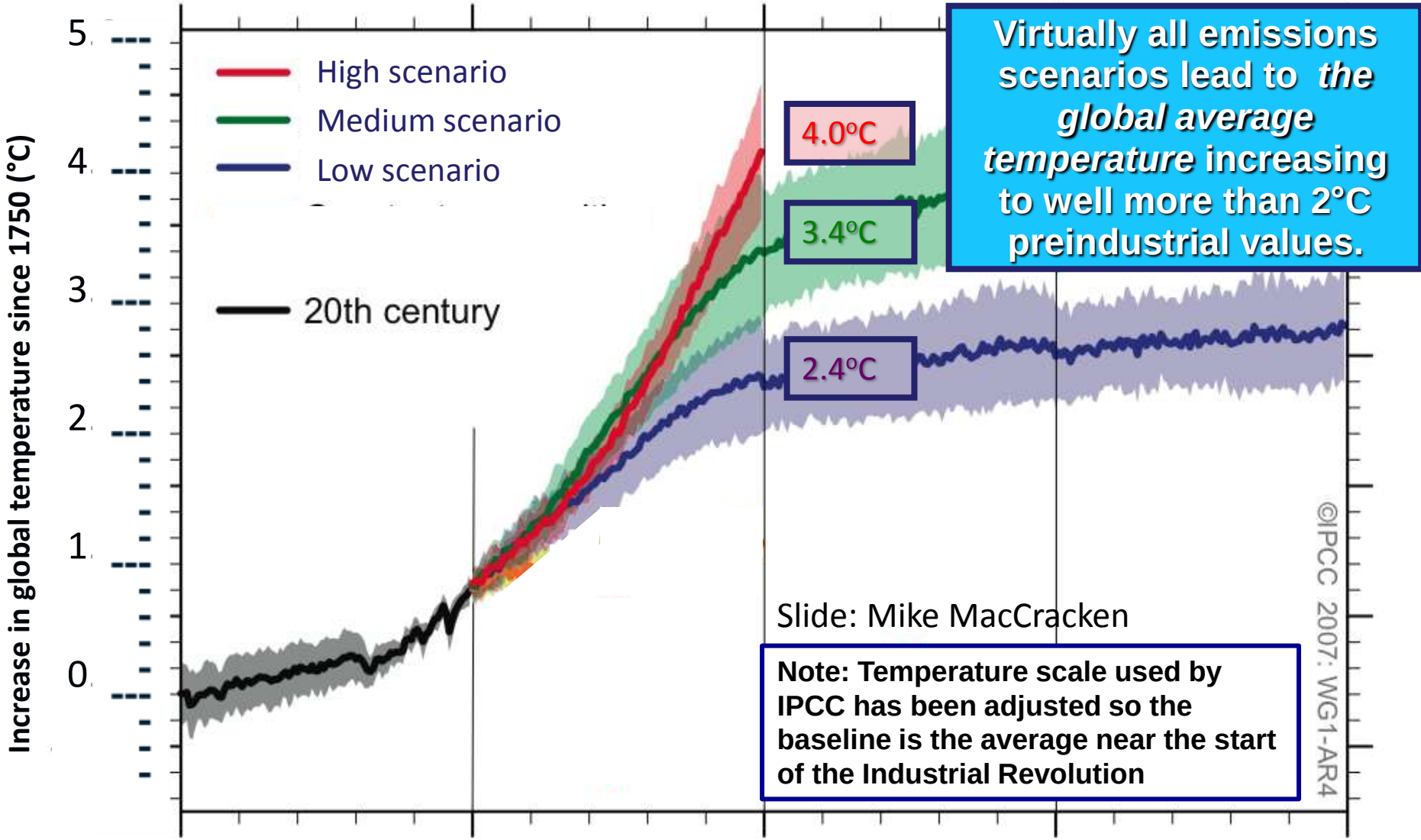
What is different now: (my view)

- 5 more years of emitting CO2 without any serious effort to mitigate emissions: it is cumulative emissions that matter
- Possible scenarios in which Geoengineering might be used are more clear and possibly impelling: we will attempt to outline these

Possible Scenarios

- CO2 mitigation is in place but not sufficient to avoid major consequences (e.g. 2° temperature rise)

The impetus for considering geoengineering is the prospect that there will be much greater warming in the future

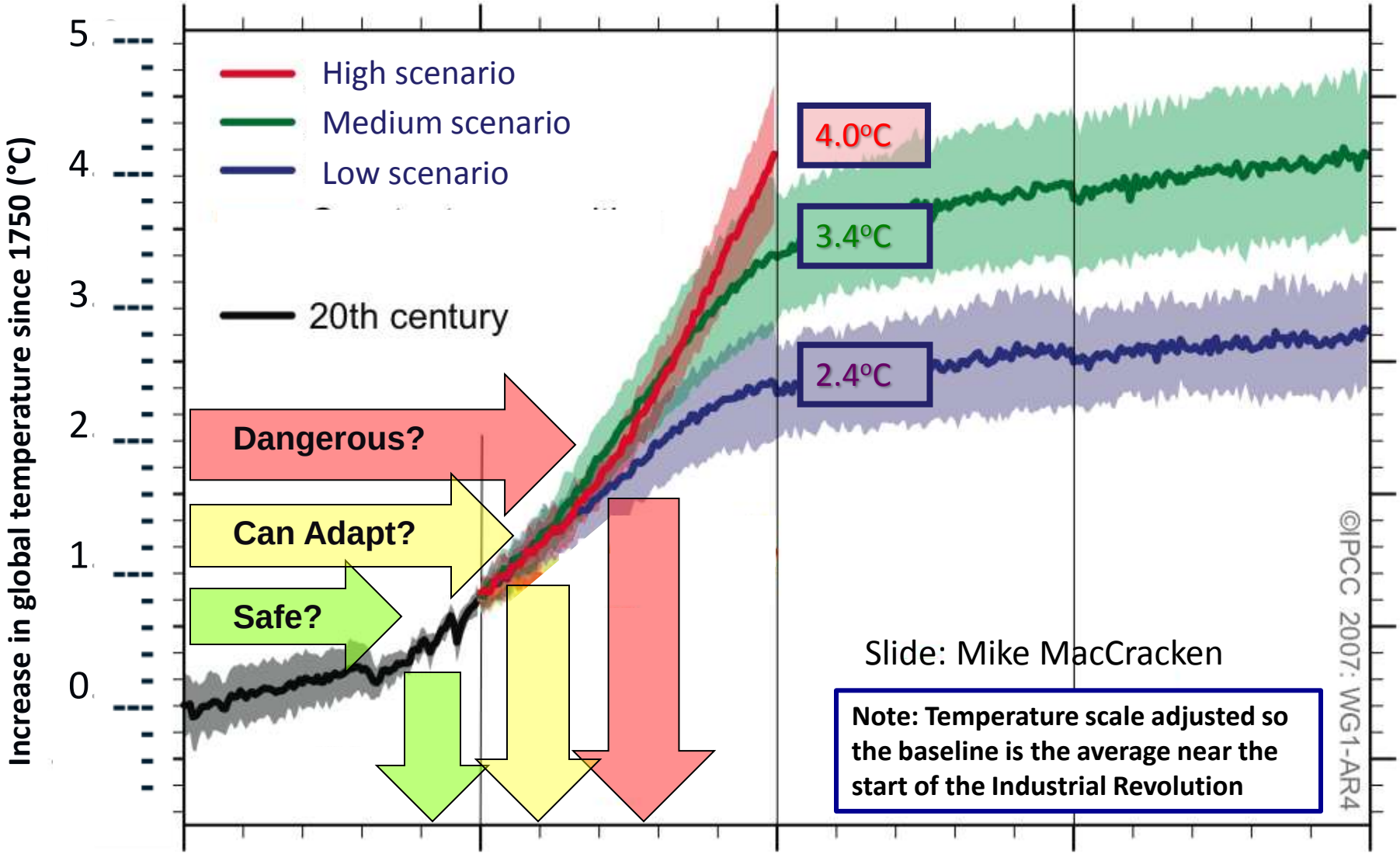


Virtually all emissions scenarios lead to *the global average temperature* increasing to well more than 2°C preindustrial values.

Slide: Mike MacCracken

Note: Temperature scale used by IPCC has been adjusted so the baseline is the average near the start of the Industrial Revolution

Based on projected emissions, warming will significantly exceed the 2° C goal for avoiding "dangerous anthropogenic interference with the climate system" (UNFCCC)



Slide: Mike MacCracken

Note: Temperature scale adjusted so the baseline is the average near the start of the Industrial Revolution

Possible Scenarios

- CO2 mitigation is in place but not sufficient to avoid major consequences (e.g. 2° temperature rise)
- A disaster occurs, and the world agrees on joint albedo modification action
- A nation or even a large corporation, deploys albedo modification hoping, perhaps, to ammeliorate local effects of climate change

Issues being discussed by the committee

- what observational capabilities are in place that the scientific community could bring to bear if a geoengineering technique – in particular so-called solar radiation management (SRM) techniques such as sulfates in the stratosphere or marine cloud brightening – were to be tested or deployed

  - if an experiment/test was run, how would we know that it worked?
  - If a technique were to be deployed, how would we know how effective it was?
  - If a natural event that were an analog to a technique were to occur (i.e., a volcanic eruption), what observational assets are in place to observe the effects?
  - Of particular note is the question of attribution – how well could the effects of a geoengineering technique be separated out from natural variability?

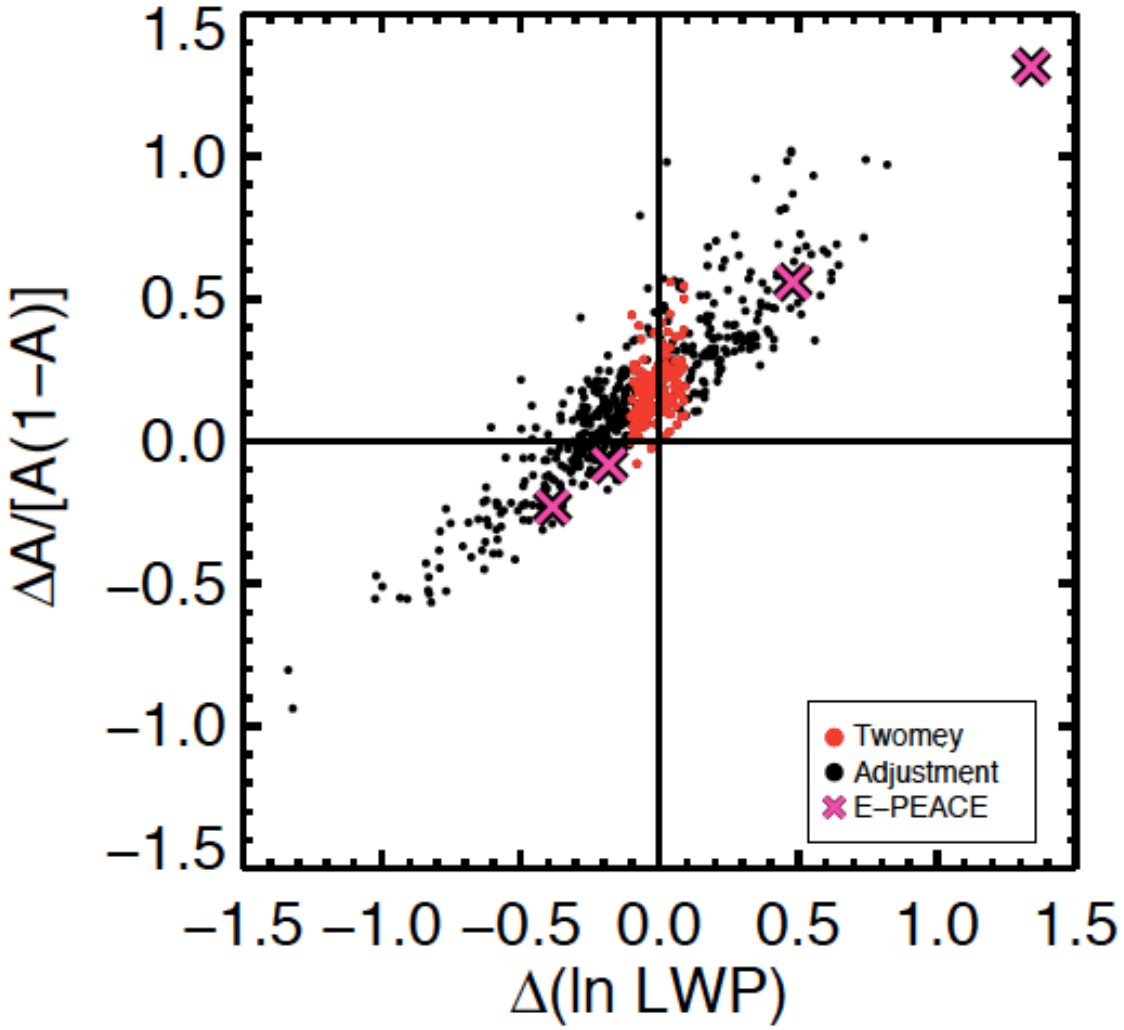
KISS findings: volcano analogs

Key uncertainties need to be addressed:

- a) The **connection between** the injection and evolution of **stratospheric sulfate aerosols and cirrus cloud formation** in the troposphere is poorly understood– and hence the significance of any warming effect/offset associated with large eruptions or geoengineering.
- b) The **connection between stratospheric sulfate aerosol injection and** water vapor is poorly understood; particularly in the tropics, where impacts on tropopause transition layer (TTL) heating and H2O transfer lead to **changes in stratospheric water vapor**.
- c) The **impacts of stratospheric sulfate injection impact on ozone**, including the convolved effects from other species, H2O, Br, Cl, and **also from climatic factors such as ENSO or QBO**, are not well understood for geoengineering scenarios.
- d) **Impacts on tropospheric chemistry** (including NOx, OH, etc.) in response to stratospheric geoengineering have not yet been assessed.
- e) The **relative sensitivity** of sulfate particle size distribution and its evolution **to microphysics vs stratospheric aerosol dynamics and transport** is poorly understood, in part because there are only sparse observations for the tropics.
- f) There remain major observational gaps for studying volcanic eruptions as an analog
- g) Attribution challenges – how representative are volcanic eruptions as analogues, given the presence of **confounding effects such as ash**, and the difference between one-time vs continual aerosol injection?

Slide from Riley Duren

Ship track analogues for marine cloud brightening show response of clouds is mixed

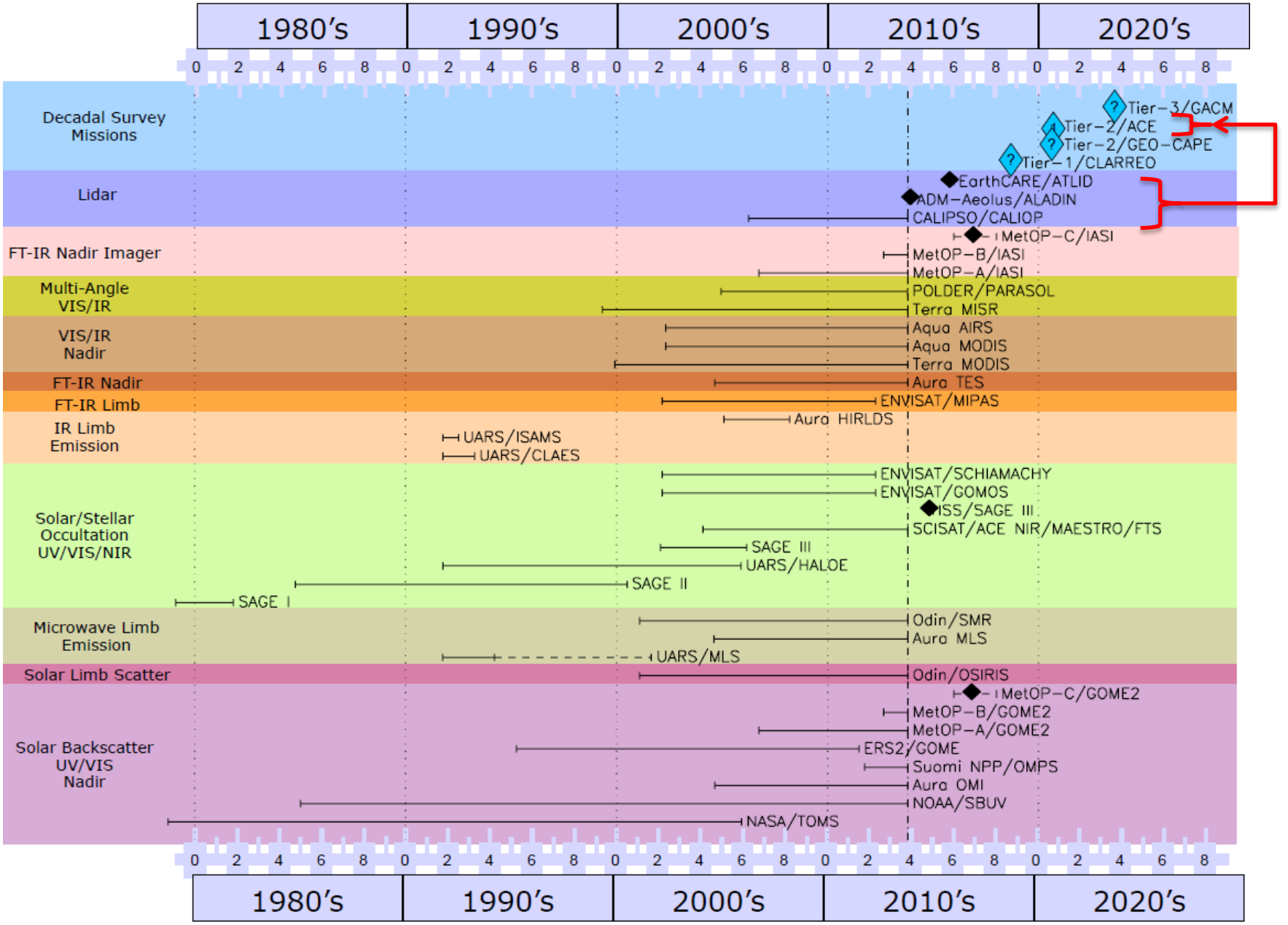


May be hard to detect and attribute changes

Note: both volcanoes and ship tracks are imperfect analogues, so field experiments that can be scaled up in size to an eventual full scale test will be needed.

Chen et al., 2012

Complication: observational continuity



The instruments here are "well-known" for aerosols/SO2/O3, but the tables in back-up cover only current and future instruments. Also does not include current Geostationary instruments e.g. MSG-SEVERI.

Slide from Riley Duren

Observational needs

- Need satellite capabilities to be able to make scientific use of the next volcanic analogue (or even ongoing small volcanoes)
- Need capabilities to sort out attribution if a rogue actor deploys SRM

- Could consider adding “dual use” criteria to whatever other criteria go into shaping the prioritization of continuity of satellite observations

Questions/Discussion?