The Near-Term Increase in the Rate of Climate Change

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This work will examine the rate of climate change as proxied by the change in global-mean temperature.

Context: The last 1000 years
- Drivers of climate change
- What is the level of variation to which human and natural systems are adapted

Future Rates of Change
- GCAM reference scenario
- The impact of recent trends in SO₂ control in China and elsewhere

Uncertainty
- Impact of uncertainty in climate sensitivity and aerosol forcing

Thanks to DoE SC for Funding Support
**Drivers of Climate Change**

*Top of the atmosphere radiative forcing measures the radiative imbalance that drives global climate changes.*

<table>
<thead>
<tr>
<th>Radiative Forcing (GCAM Ref)</th>
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</thead>
<tbody>
<tr>
<td>Year</td>
</tr>
<tr>
<td>1800</td>
</tr>
<tr>
<td>1850</td>
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<tr>
<td>1900</td>
</tr>
<tr>
<td>1950</td>
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<td>2000</td>
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<tr>
<td>2050</td>
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<tr>
<td>2100</td>
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**Long-term drivers of climate**
- Greenhouse gases, particularly carbon dioxide
- Anthropogenic aerosols
- Volcanic and solar forcing
- Internal modes (ENSO, NAO, etc.)
- Feedbacks

**Dominant Influences**

<table>
<thead>
<tr>
<th>Last Millennium</th>
<th>20th Century</th>
<th>21st Century</th>
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<tbody>
<tr>
<td>Solar, Volcanoes, Internal Modes, Feedbacks</td>
<td>Increasing Aerosol and GHGs</td>
<td>GHGs Will Eventually Dominate</td>
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Temperature change observed over the past half century is unprecedented for the last 500-1000 years.
Last 1000 Years: Rate of Temperature Change

Global rates of change are 10-20% smaller due to spatial averaging.

Sustained rates of change (over 40-years) are generally within ±0.1 °C/decade over the last millennium.

Particularly for the positive excursions.
The anthropogenic influence is seen in recent decades as the long-term rate of change is moving toward 0.2 °C/decade.

• Rate of change over land is larger than global (land + ocean) rate in recent decades.
Future Rates of Climate Change and the Impact of Recent Trends in SO$_2$ Emissions
Global SO$_2$ emissions have been decreasing faster than projected in GCAM ref scenario.

- China is already using SO$_2$ scrubbers at power plants.

*Historical Emissions: Smith et al. (2011), Klimont, Smith, and Cofala (2012)*
A New SO₂ Emissions Scenario

Anthropogenic SO₂ Emissions

Will use a new near-term SO₂ emissions scenario that assumes:
- China continues to install SO₂ controls on all power plants
- North American and European SO₂ controls continue on current trajectory
- MAROPOL limits on bunker fuel sulfur contents are implemented as planned
21st Century Rate of Climate Change

Examined the consequences of both scenarios using the GCAM version of MAGICC

With more realistic SO₂ emission assumptions, the rate of global climate change increases even faster.

- For a central parameters, the rate of climate change increases above 0.3 °C/decade by 2020.
- By 2040, the global rate of temperature change will have been greater than 0.1°C/decade for 40 years, > 0.2 for 30 years, and > 0.3 for 20 years.
A Simple Uncertainty Analysis
Uncertainty Analysis

A number of factors impact the past and future rate of climate change.

- Climate Sensitivity
- Aerosol Forcing Strength
- Rate of Ocean Heat Uptake
- Natural Variability

Will conduct a simple uncertainty analysis to examine the sensitivity of these results to two key assumptions:

- Aerosol Forcing Strength
- Climate Sensitivity

Aerosols played an important role historically

However, this role is uncertain.

Year 2000 aerosol forcing estimates range from -0.4 to -1.6 W/m².
Sensitivity to Aerosol Forcing

Graph shows sensitivity to uncertain aerosol forcing and climate sensitivity.

Aerosol forcing assumptions have a significant impact on the historical rate of climate change.
- While the strength of aerosol forcing has a significant impact on historical climate changes.
- **Future changes depend largely on climate sensitivity**
Sensitivity to Aerosol Forcing

We are heading into a time of sustained, rates of climate change that do not appear to have been experienced for a millennium.

- Under mid to high climate sensitivity rates of change are above 0.3 °C/decade for over half a century.
Under a 2.6 scenario rates of change will still be larger than historical values over at least half of the 21st century.

- The probability (and duration) of very large rates of change (> 0.3 °C/decade) are greatly reduced.
The rate of climate change is thought to be a key driver of climate impacts.

- We are almost certainty entering a time period where the sustained rate of climate change will be far larger than historical rates.
  - If the climate sensitivity is moderate to high, rates of change without mitigation could exceed 0.3 °C per decade over many decades.

- Current scenarios appear to have underestimated the rate at which the world is controlling SO$_2$ emissions.
  - This will result in a near-term increase in the rate of climate change.
Thank You
Extra Slides
Sustained rates of change over 20-years are generally within ±0.2 °C/decade, perhaps with some higher values at times.
Counter-Factual: no China SO$_2$ control

If China did not ever control SO$_2$ from power plants, then the global rate of temperature change will be lower in the near-term.

- The long-term rate is determined by GHGs.

China is, however, already controlling SO$_2$ to reduce health and ecosystem impacts.