Climate Change Impacts on Air Quality: An Uncertainty Analysis

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Project Overview

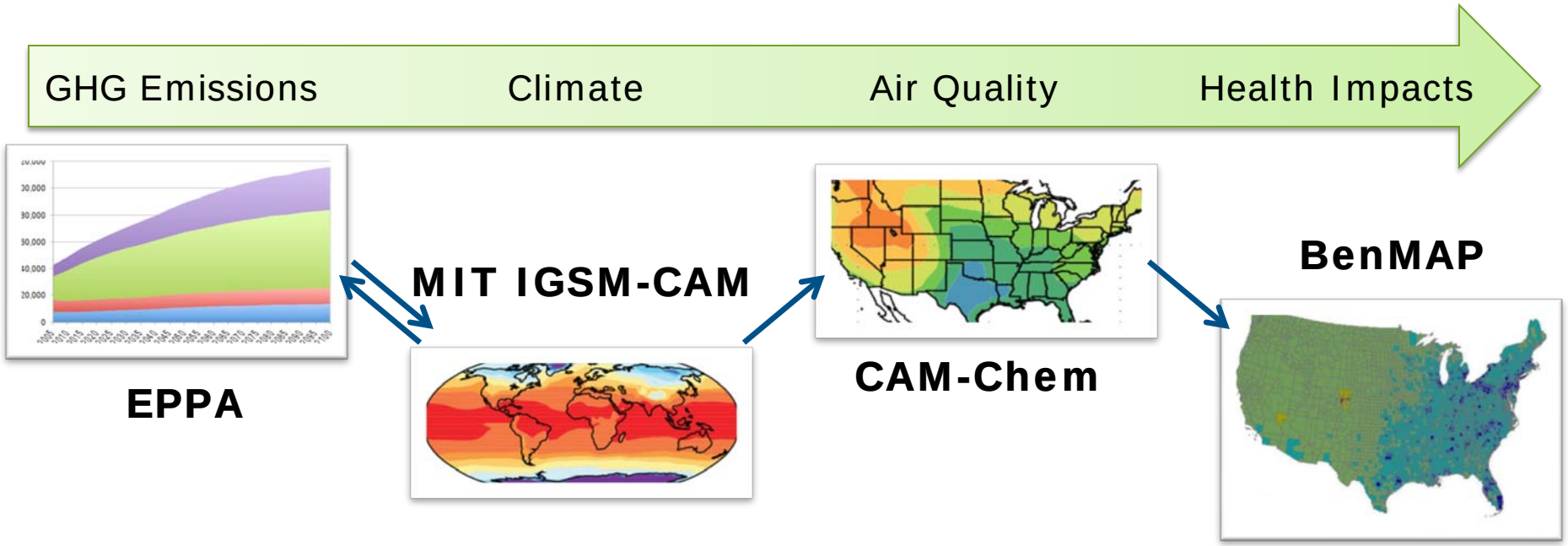
Climate Change Impacts and Risk Analysis (CIRA) Project:

- Project led by USEPA - Climate Change Division
- Analyze climate change impacts and risks in the U.S. under different global mitigation scenarios
- Includes multiple integrated assessment and sectoral impact models
- Investigate key sources of uncertainty

→ Infrastructure and Coastal Resources
→ Forestry and Agriculture
→ Water resources
→ Ecosystems
→ Energy
→ Health

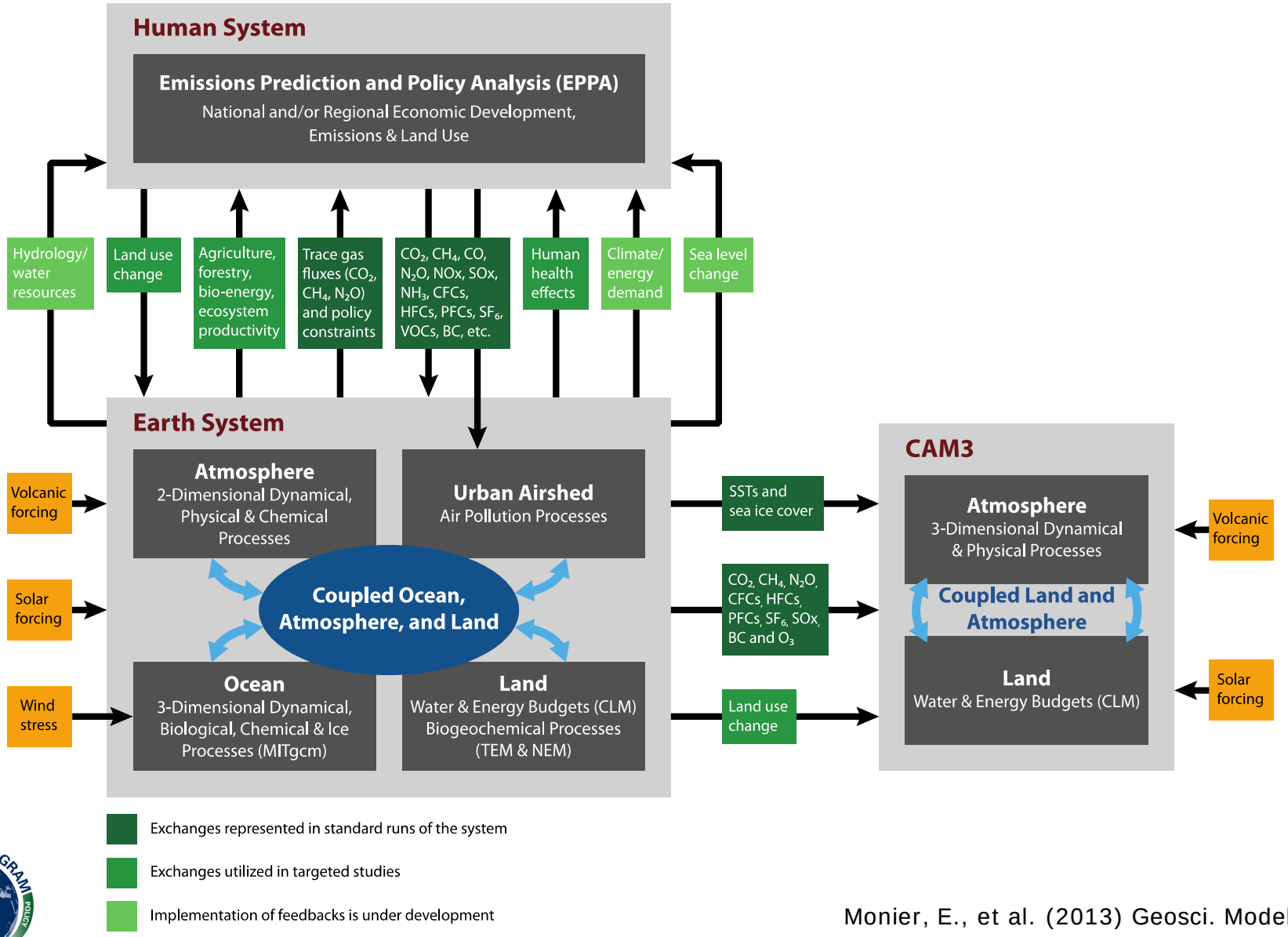
Project Overview

Climate - Air Quality Objectives:



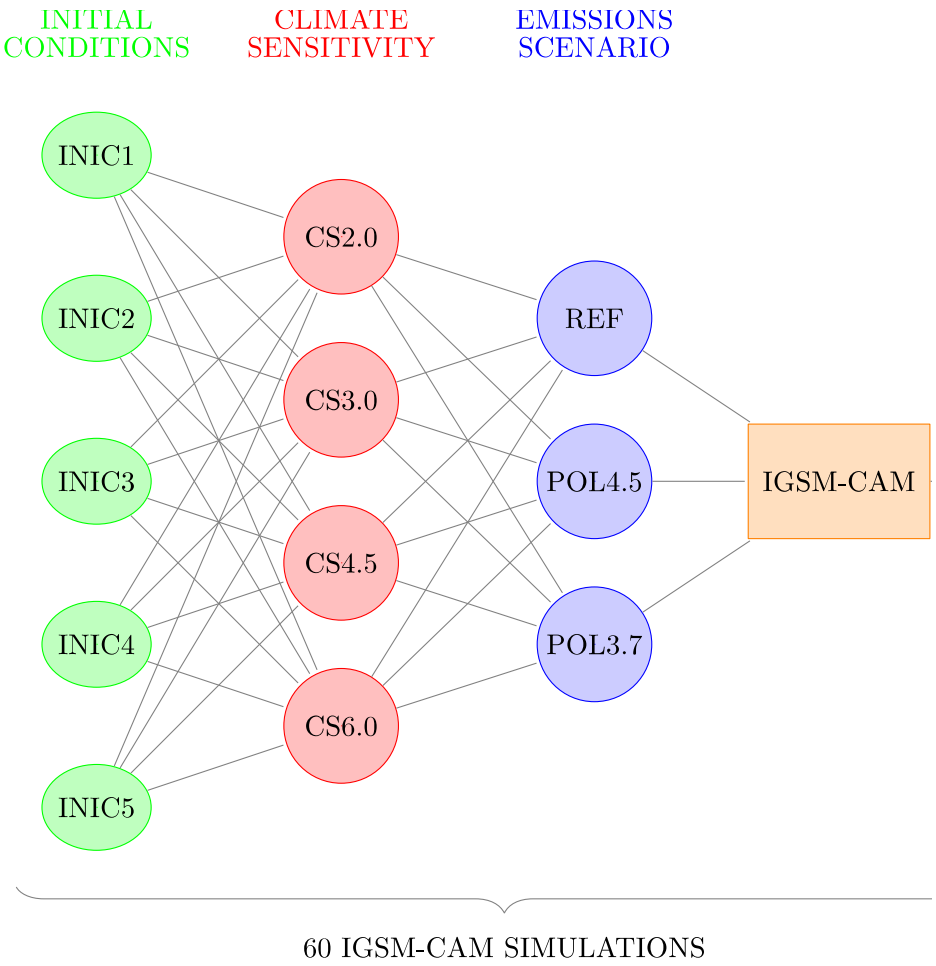
- Investigate the effects of uncertainty in climate projections on future U.S. air quality estimates.
- Weight uncertainty in climate penalty on U.S. air quality.

The MIT Integrated Global System Model



Monier, E., et al. (2013) Geosci. Model Dev.

Ensemble simulation of 21st century climate change



Focus on 3 sources of uncertainty in climate projections

12 core IGSM simulations :

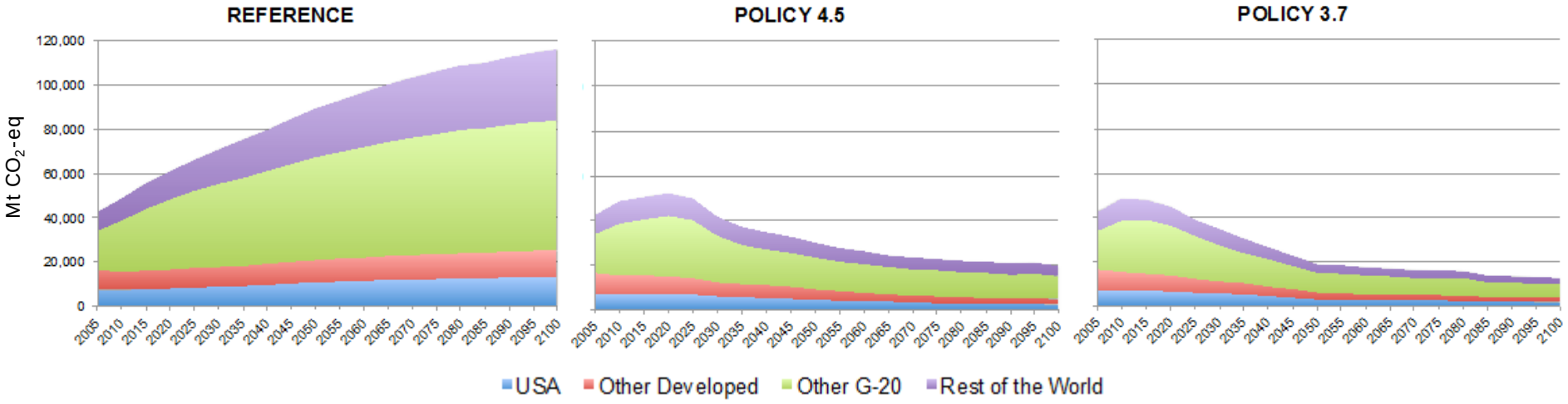
- 3 policy scenarios (reference, stabilization at 4.5 and 3.7 W/m²)
- 4 climate sensitivities (2.0, 3.0, 4.5 and 6.0°C)

60 IGSM-CAM simulations:

- 5 different representations of natural variability for each set of policy/climate parameters

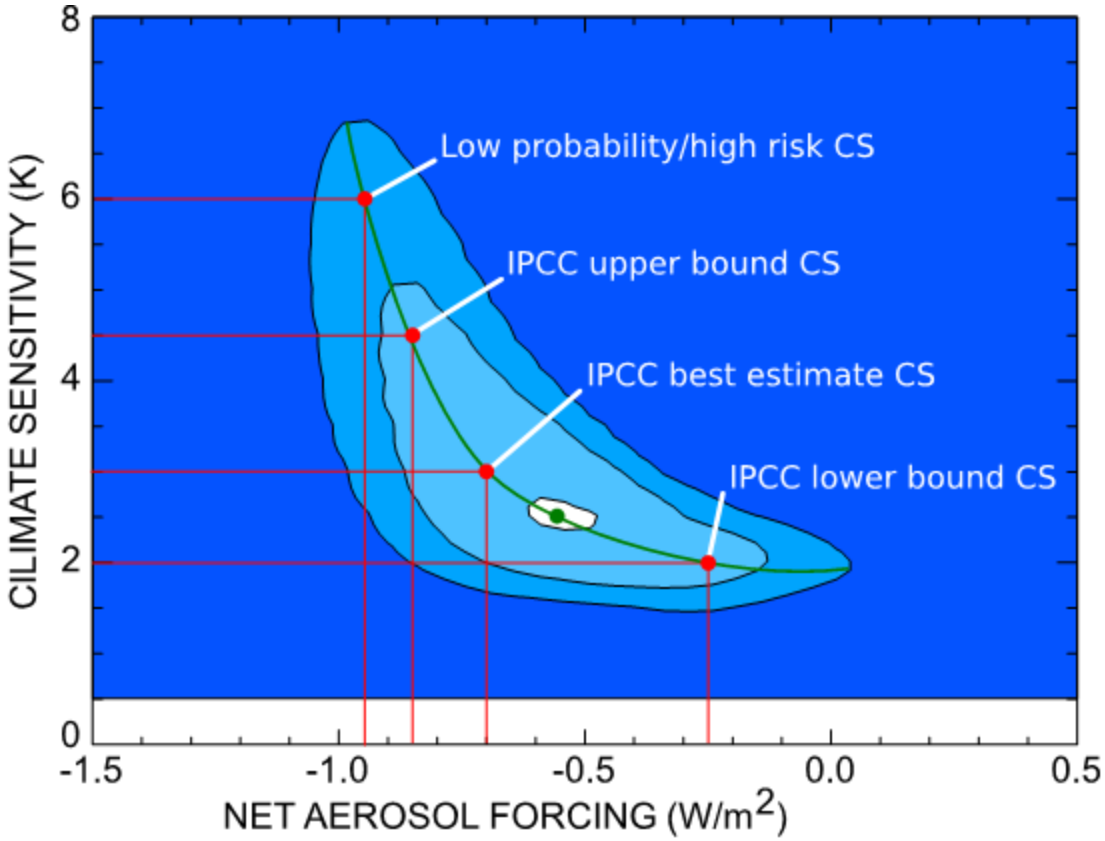
Climate policy scenarios

1. Reference scenario: - Unconstrained emissions after 2012
   - Total radiative forcing of 9.7 W/m^2 by 2100
2. Policy scenario I: - Stabilization scenario
   - Total radiative forcing of 4.5 W/m^2 by 2100
2. Policy scenario II: - Stringent stabilization scenario
   - Total radiative forcing of 3.7 W/m^2 by 2100



Paltsev, S., et al. (2013) Climatic Change

Climate system parameters

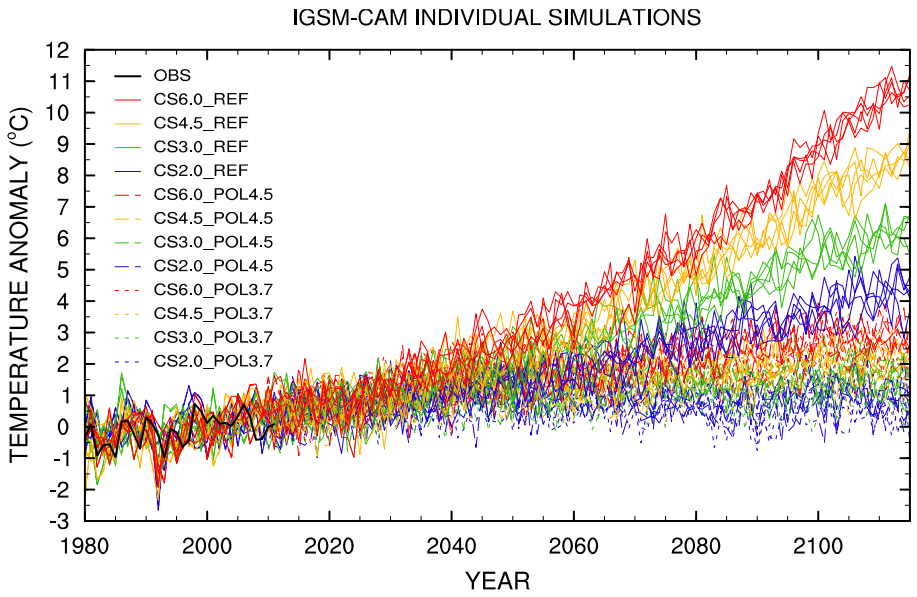


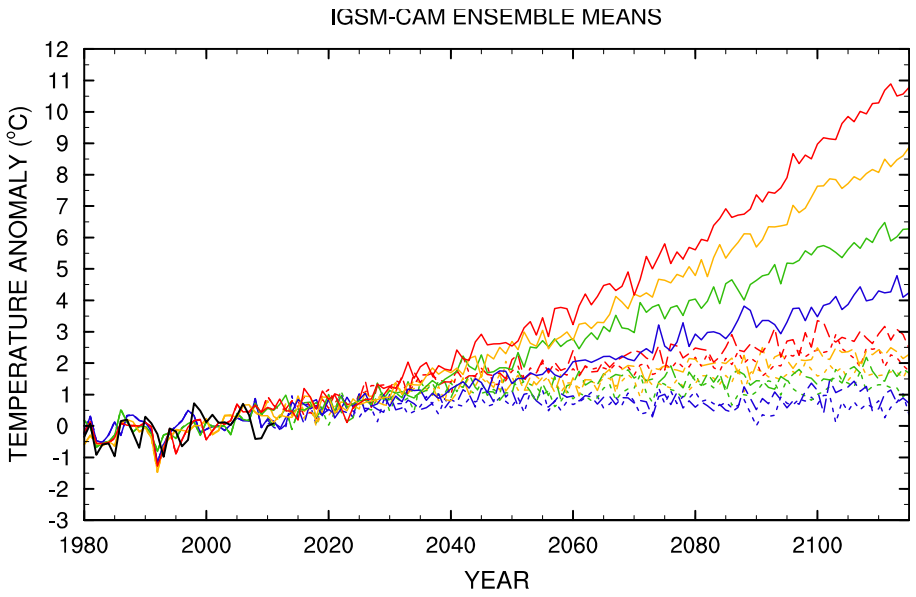
- Climate sensitivity changed through cloud radiative adjustment method
- *4 choices of climate sensitivity:*
  - → 2.0 °C
  - → 3.0 °C
  - → 4.5 °C
  - → 6.0 °C

Sokolov, A.P. and E. Monier (2012) *J. Climate*

Change in U.S. mean temperature

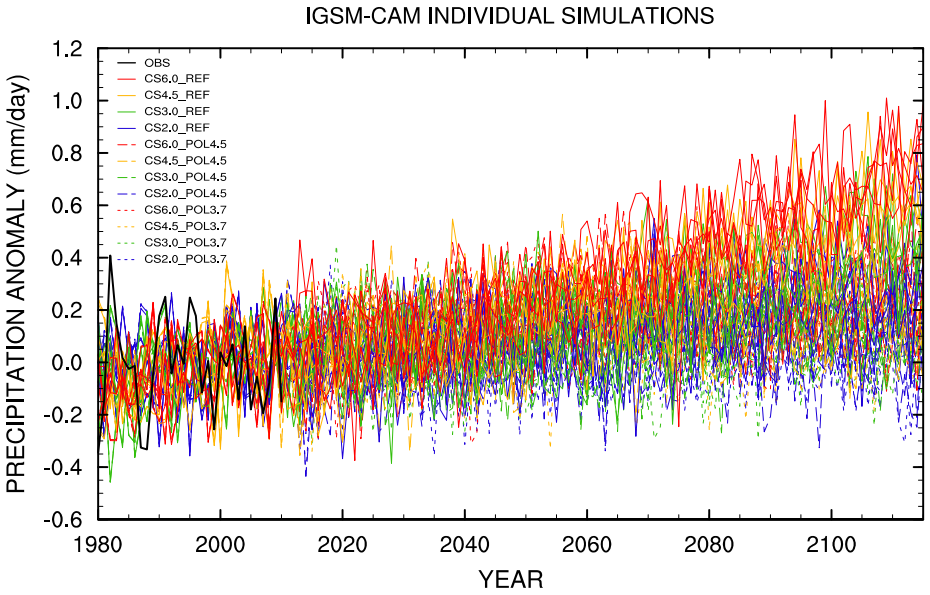
Anomalies from present day (1991–2010 mean)

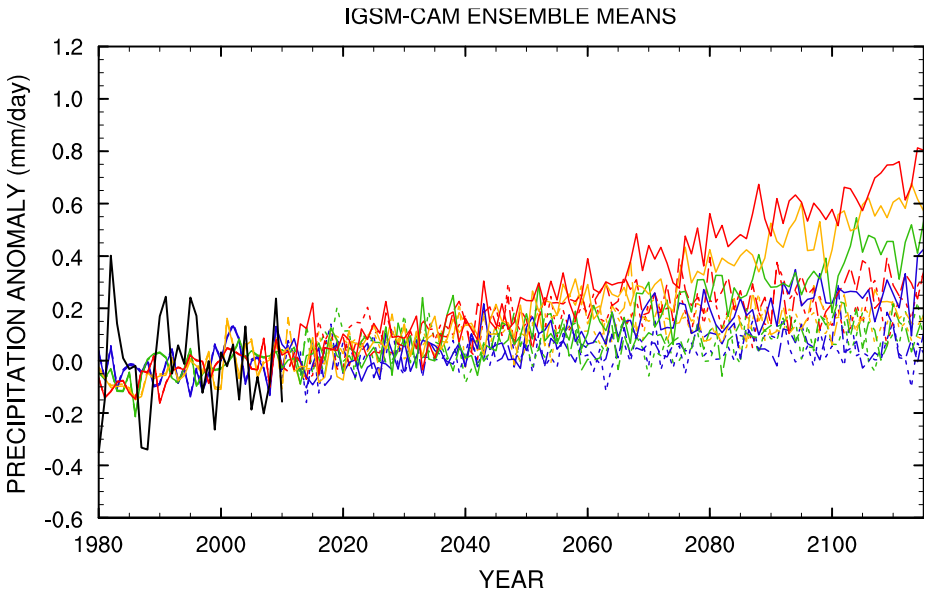




Change in U.S. mean precipitation

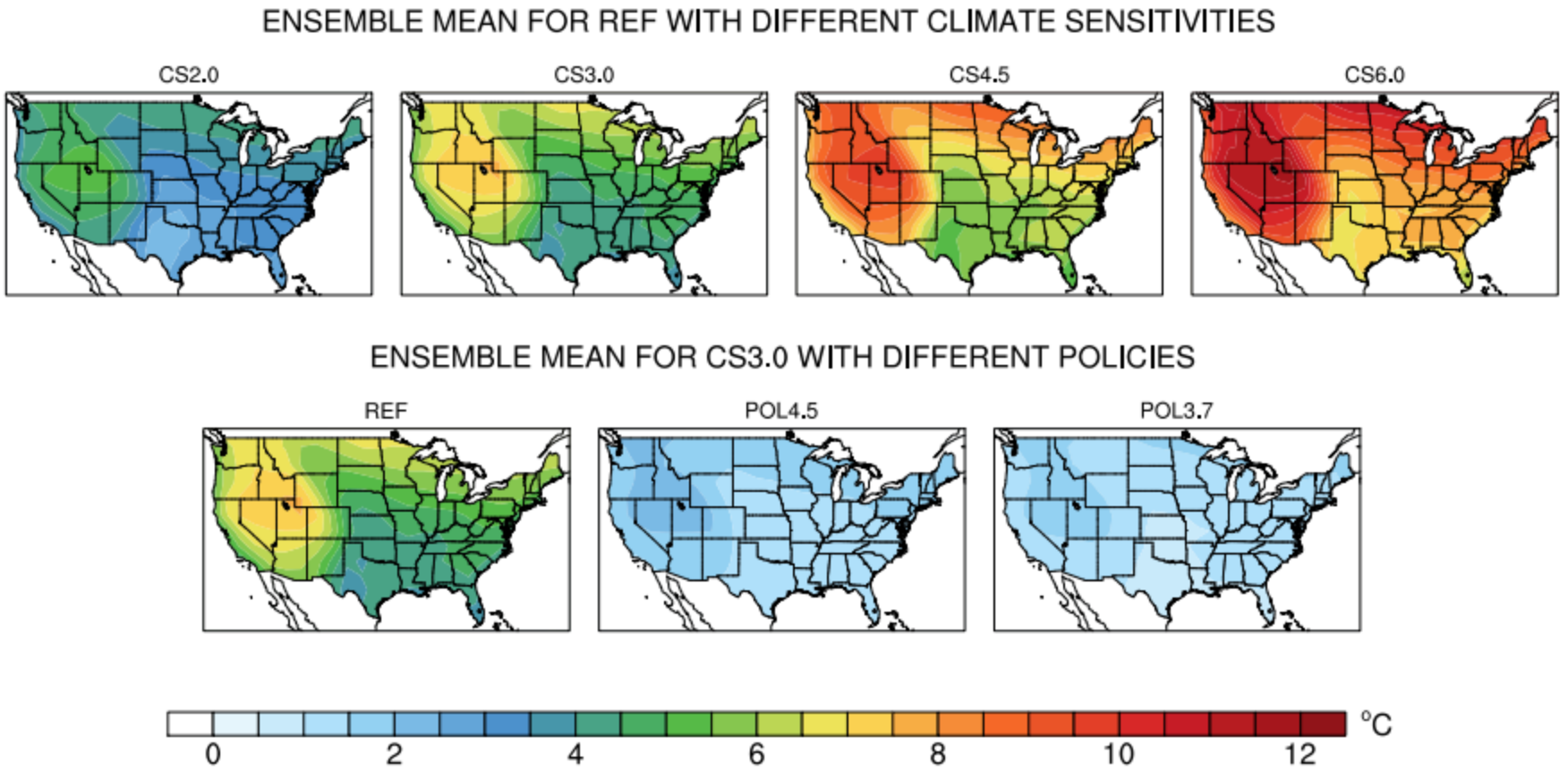
Anomalies from present day (1991–2010 mean)





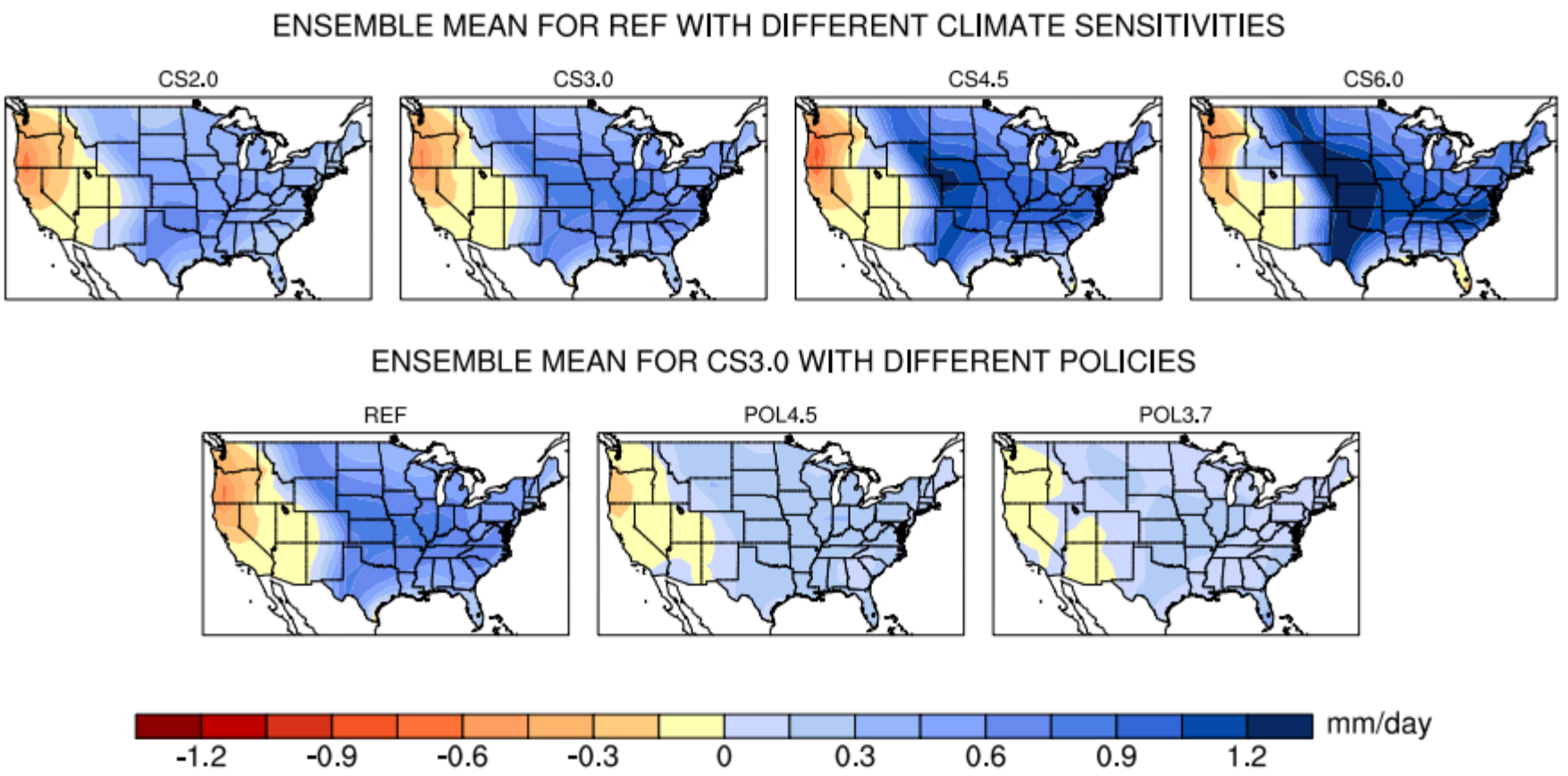
Impact of policy scenario and climate sensitivity

Change in future surface air temperature (2091–2110 mean) relative to present (1991–2010 mean)



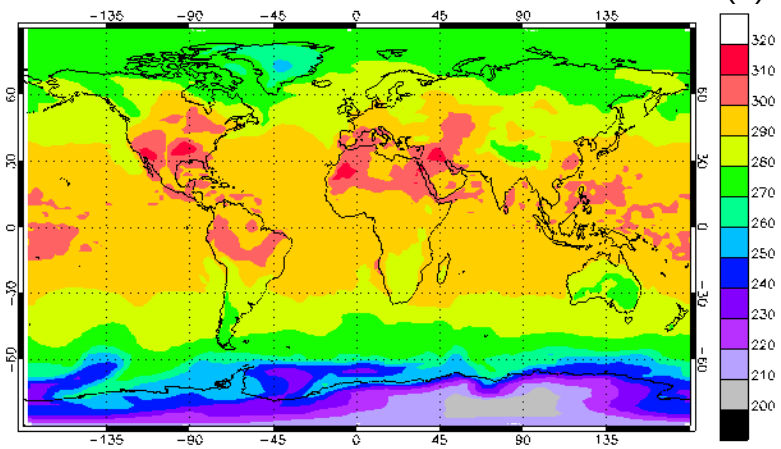
Impact of policy scenario and climate sensitivity

Change in future precipitation (2091–2110 mean)
relative to present (1991–2010 mean)

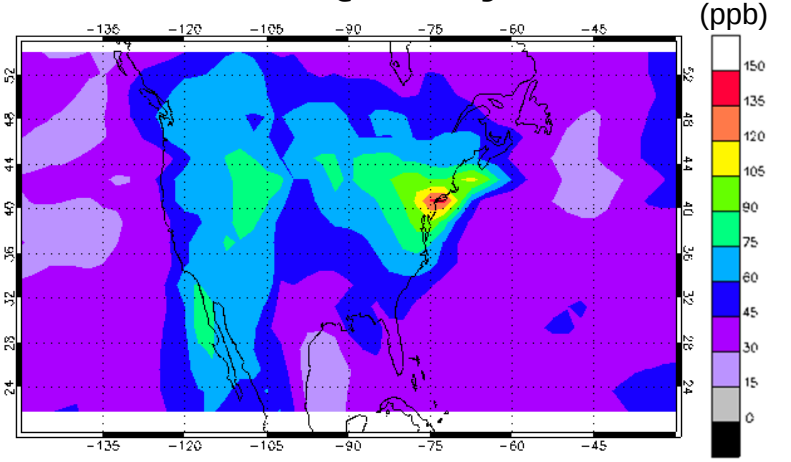


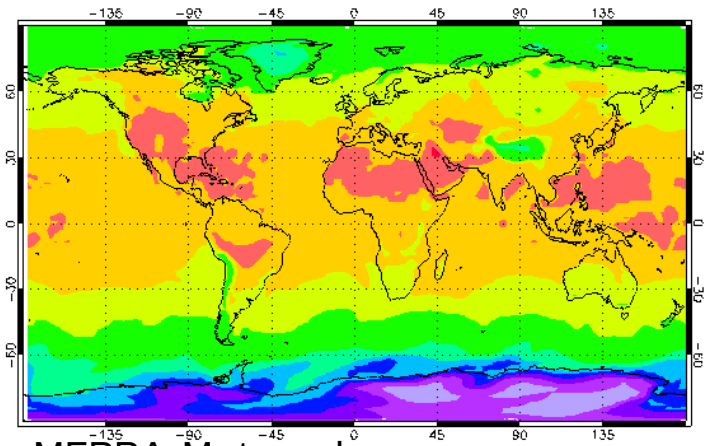
Air Quality Modeling

Meteorology

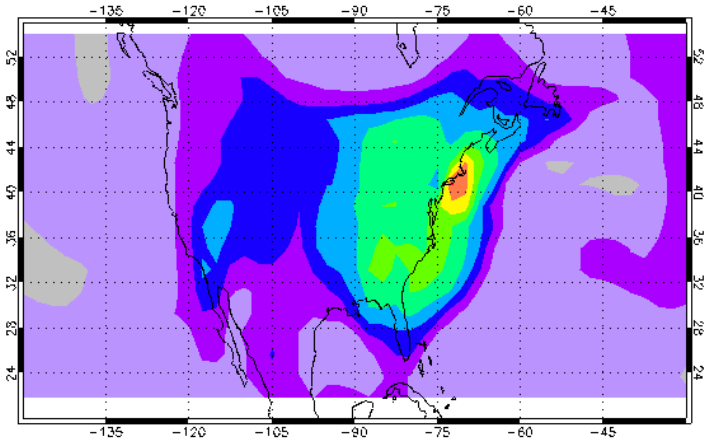


Air Quality





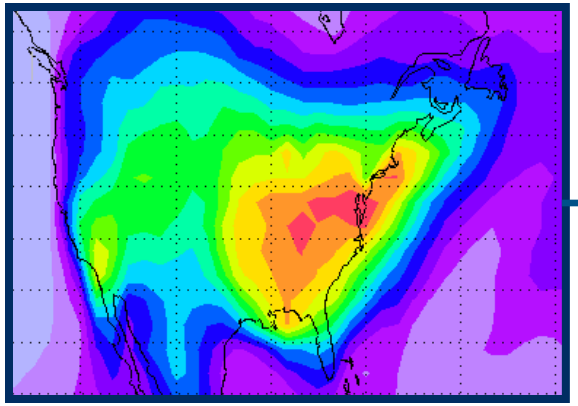
MERRA-Meteorology



Air Quality Modeling

- Objective function => Air-quality related health impacts
- Systematically assess uncertainty in future health impacts

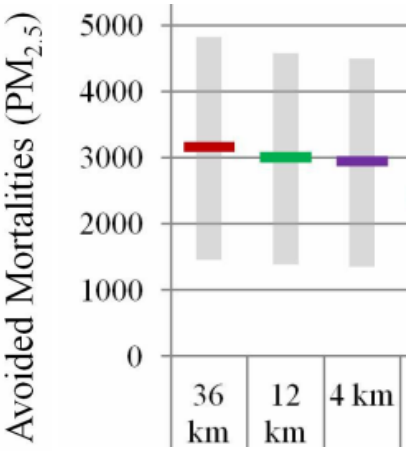
Air quality:
8-hr max. O_3
24-hr avg. $PM_{2.5}$



Exposure:
Population-weighted concentrations

$$M_{\text{pop}} = \frac{\sum_g (p_g \times \{c_g\})}{\sum_g p_g}$$

Health Impacts:
Mortality & Morbidity



Thompson, T., et al. (2014) Atmos. Chem. Phys.

Ongoing work

I. 30-year reference simulation - present climate:
   - Pollutant emissions at fixed level

II. Reference simulation - future climate
   - Reference policy scenario; best estimate climate sensitivity

III. Systematic test simulations
   - Climate policies, climate parameters, initial conditions

...

IV. Integrate uncertainty for pollutant emissions

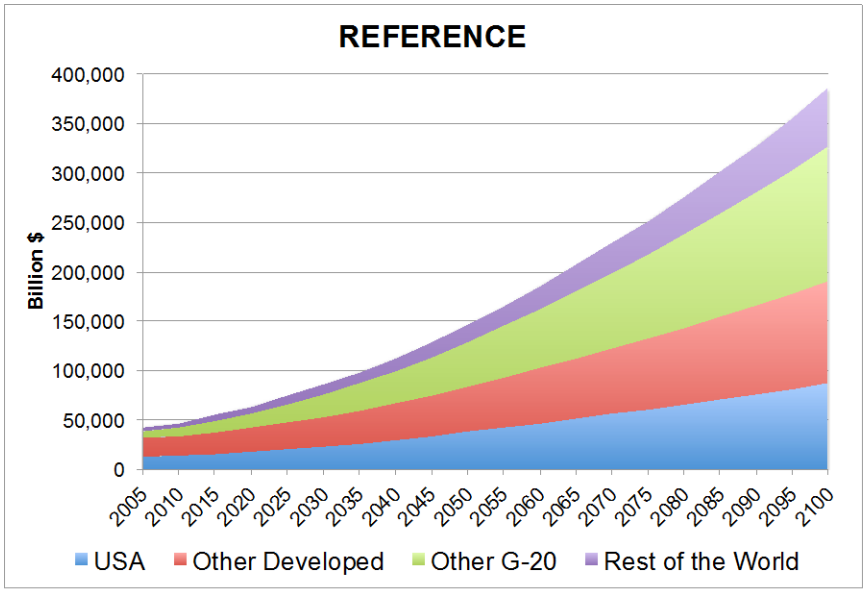
Some initial questions we hope to address:

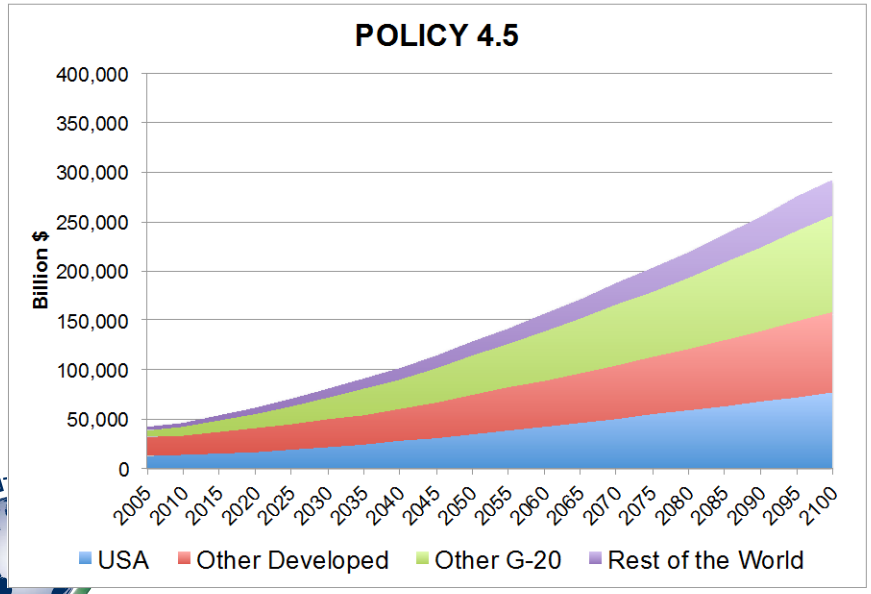
- How long must simulation periods be to characterize climate?
- How sensitive are air quality/health impacts to meteorology?
- How significant is the climate change signal in projected changes to air quality?

Thank you

This work is funded by the US EPA Climate Change Division and is part of the Climate Change Impacts and Risk Analysis (CIRA) project.

GDP


REFERENCE
Billion $
400,000
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070 2075 2080 2085 2090 2095 2100
USA
Other Developed
Other G-20
Rest of the World


POLICY 4.5
Billion $
400,000
350,000
300,000
250,000
200,000
150,000
100,000
50,000
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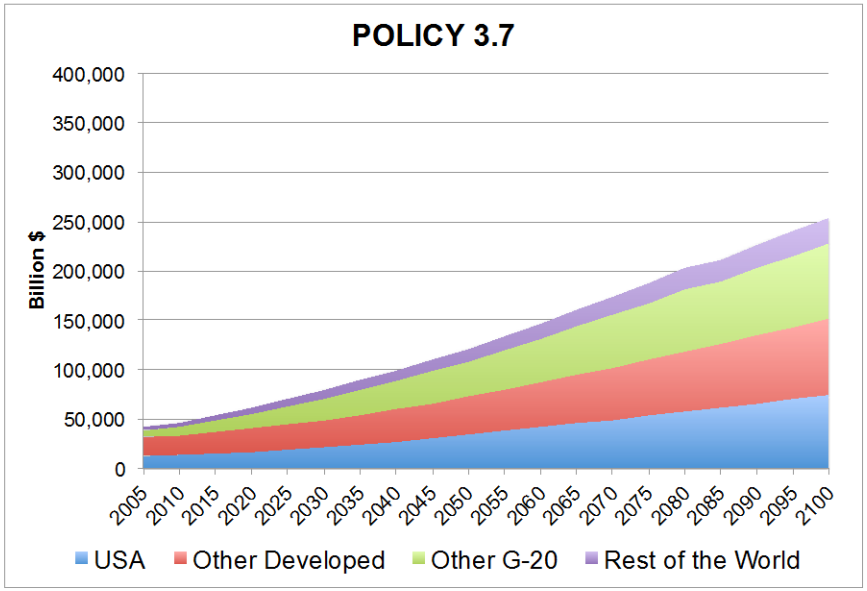
2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070 2075 2080 2085 2090 2095 2100
USA
Other Developed
Other G-20
Rest of the World


POLICY 3.7
Billion $
400,000
350,000
300,000
250,000
200,000
150,000
100,000
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2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070 2075 2080 2085 2090 2095 2100
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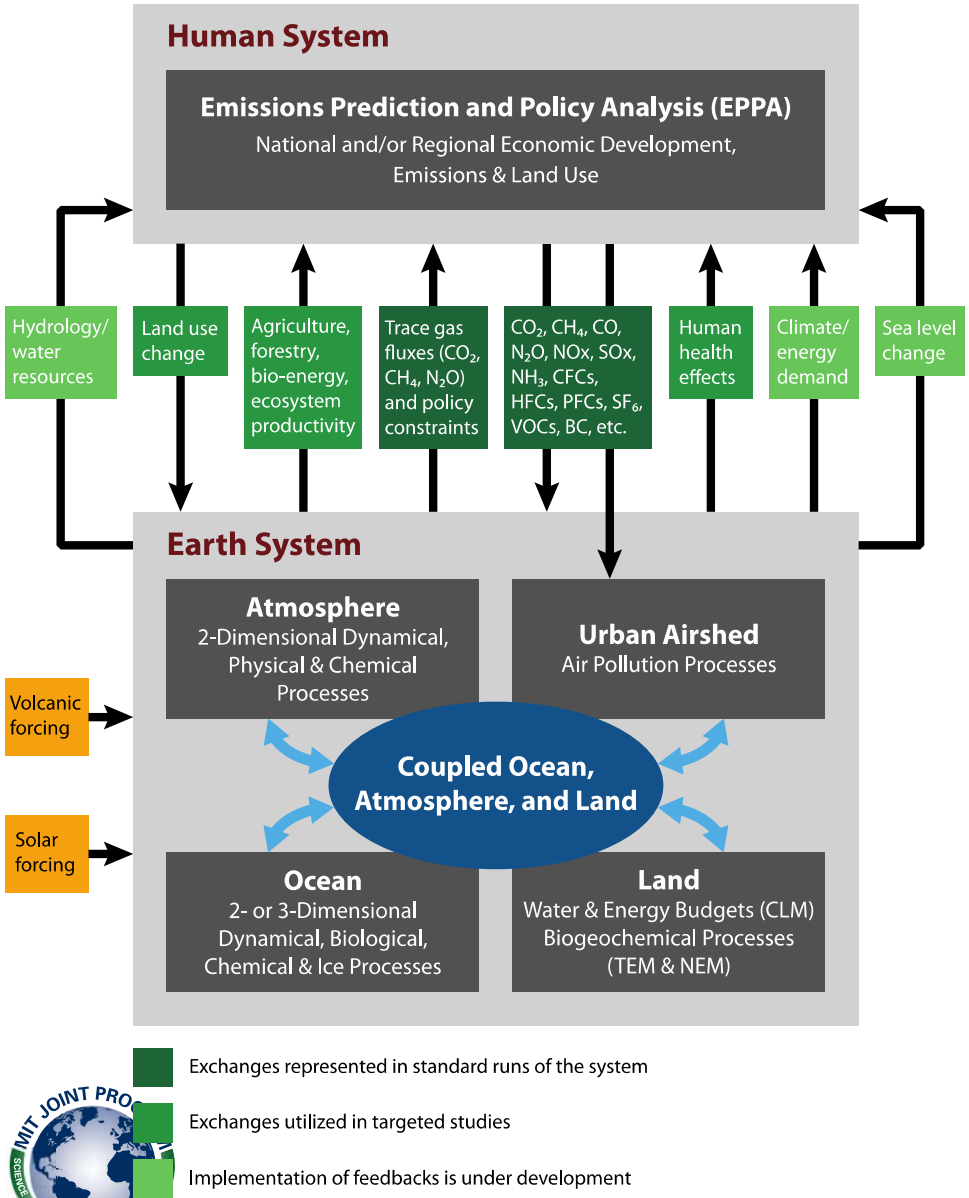
The MIT Integrated Global System Model



The IGSM is an integrated assessment model that couples an earth system model of intermediate complexity to a human activity model.

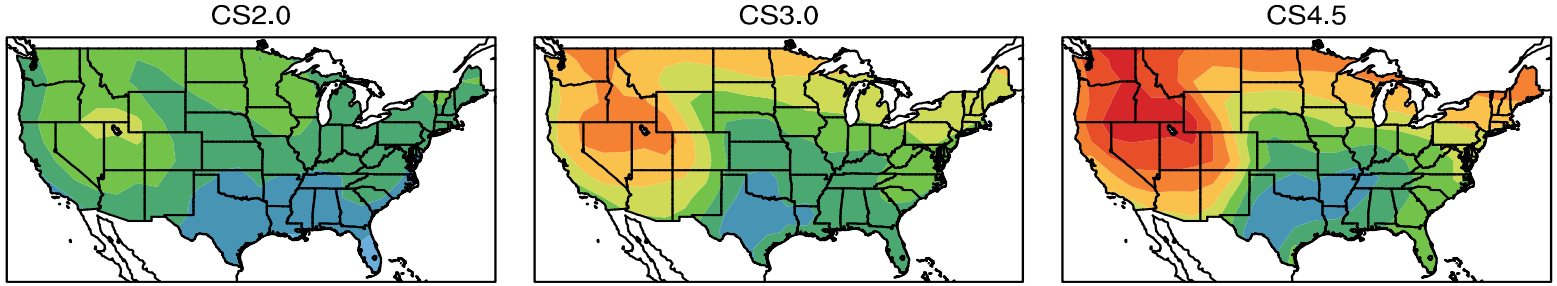
Major advantages of the IGSM:

- Flexibility to change the climate system response
  - -climate sensitivity
  - -strength of aerosol forcing
  - -ocean heat uptake rate
- Flexibility to test different climate policies
- High computational efficiency, allowing large ensemble simulations to estimate PDFs of climate parameters

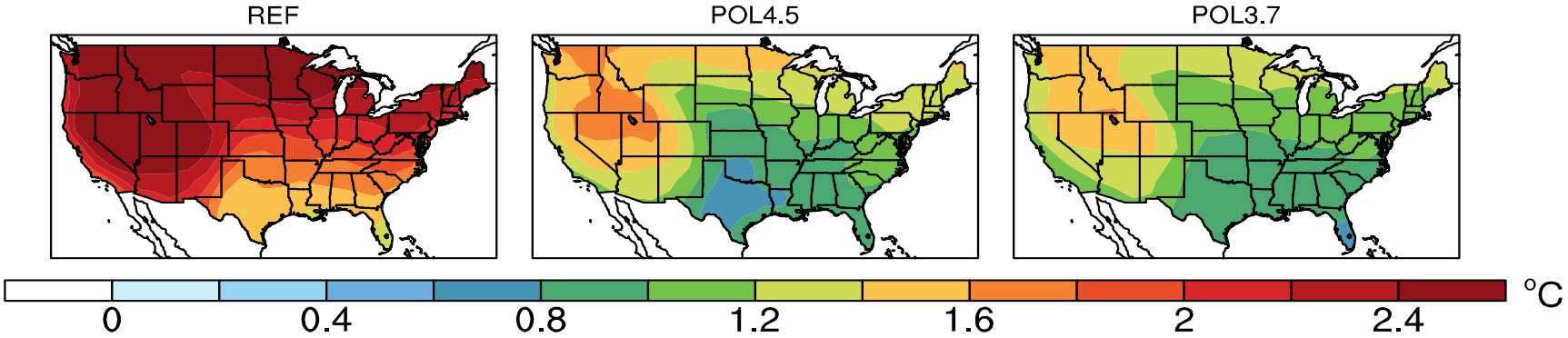
Impact of choice of policy and climate response

2041-2060 mean minus 1991-2010 mean

a) IGSM-CAM ENSEMBLE MEAN FOR POL4.5 WITH DIFFERENT CLIMATE SENSITIVITIES



b) IGSM-CAM ENSEMBLE MEAN FOR CS3.0 WITH DIFFERENT POLICIES



Impact of natural variability and choice of model

2041-2060 mean minus 1991-2010 mean