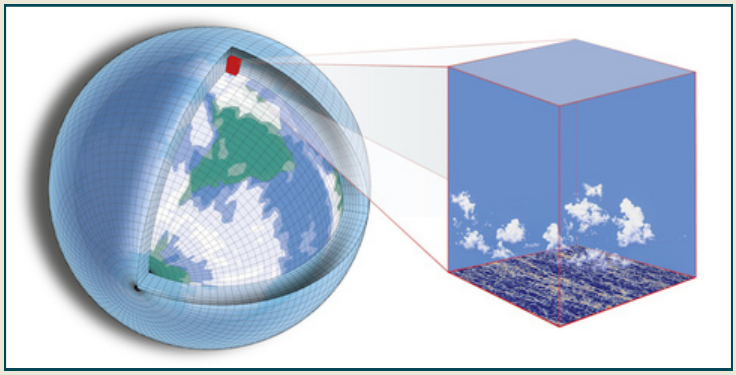
2 Global Climate Models and Land Management

Global Climate Models and Emissions Scenarios

What is a Global Climate Model?

Global climate models (GCMs) rely on mathematical equations that describe the processes of Earth's atmosphere, land, and ocean. Together, these mathematical equations create a model of the real-world conditions that are bound by the laws of physics. To conduct modeling experiments with GCMs, the Earth is divided into a grid of 3D cubes and the model is "run" by inputting an **emissions scenario**, which represents possible future human activities and levels of greenhouse gas emissions. The results, or outputs, of GCMs are projections of **climate metrics** like precipitation, temperature, humidity, and more, with one set of results for each of the Earth's 3D cubes. No climate model can create a perfect representation of Earth's systems, and regional climate processes are often simplified. There are more than 100 different climate models from 49 different research groups developed by research teams around the world and exactly how each model simplifies these processes differs, making the results of all models slightly different.

The first GCM was developed and run in 1956. While the model was not used to make future projections, it was able to accurately predict monthly weather patterns. Since then, models have been updated as scientists have improved their understanding of and ability to represent earth's physical processes, and the creation of emissions scenarios has allowed these models to make future projections.



(California Institute of Technology)

This figure shows how a climate model breaks down the Earth's surface into a 3D grid.

CMIP6

The Coupled Model Intercomparison Project (CMIP) is an international climate modeling experiment seeking to improve the accuracy of climate models. By comparing simulations of different models run with the same inputs, CMIP scientists are able to determine which climate projections are consistent between models, which differ between models, and the strengths of each model.[1] CMIP6 is the experiment's sixth iteration.

What are Emissions Scenarios?

Emissions scenarios are representations of possible futures with estimations of the rate at which humans will emit greenhouse gasses, and they provide scientists with shared inputs for climate modeling. CMIP6 models refer to these scenarios as **Shared Socioeconomic Pathways (SSPs)**.[2] SSPs use socioeconomic factors like population growth, technology change, and inequality to imagine the challenges that societies will face in changing their emissions habits and how those challenges will affect global climate change.

The Five Shared Socioeconomic Pathways

SSP1: Sustainability

- Global economic growth and cooperation lead to a prioritization of human well-being and a reduction in emissions.

SSP2: Middle of the Road
- The future does not shift significantly from the present.

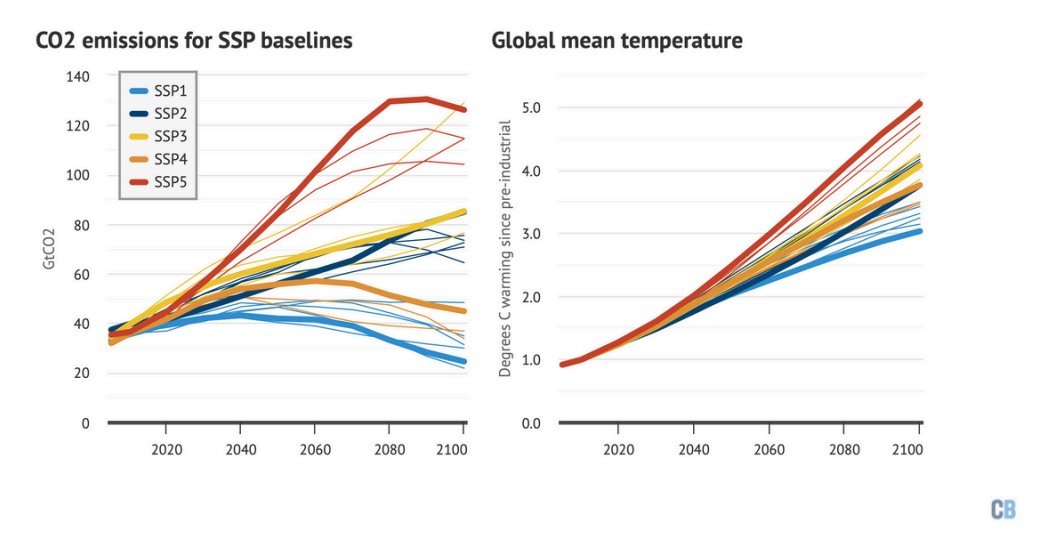
SSP3: Regional Rivalry
- Nationalism leads to isolated improvements in technology and reductions in emissions, making global improvement extremely challenging.

SSP4: Inequality
- Growing economic disparities will lead to disparities in technology development and emissions reductions, making global improvement challenging.

SSP5: Fossil Fuel Development
- While technology will improve overall, a doubling-down on fossil fuels will lead to extreme increases in global temperatures.

The scientific team behind the scenarios have made no claims about the likelihood of each scenario becoming a reality, but SSP2 is the scenario most closely associated with current socioeconomic trends.[3]

Global mean temperature is tied to greenhouse gas concentrations, with more greenhouse gasses leading to warmer temperatures. The highest CO2 emissions under SSP5 (red line, left) are associated with the greatest global mean temperature increases (red line, right). By comparison, SSP1, which shows declining emissions in the second half of the 21st century (light blue line) is associated with the least amount of temperature increase.



(Carbon Brief)

Representative Concentration Pathways

Since SSPs are a relatively recent development in climate modeling, it is common to see older emissions scenarios referenced, especially in interactive online tools developed using GCM data. **Representative Concentration Pathways (RCPs)** are the emissions scenarios used for the fifth iteration of CMIP (CMIP5). These scenarios represent four pathways where anthropogenic forcing has increased Earth's energy budget in 2100 by 2.6, 4.5, 6.0, and 8.5 watts of thermal energy per meter squared, respectively, and are named according to their forcing amount. RCP8.5 describes a high emissions scenario with continually increasing greenhouse gas concentrations and no climate mitigation policy. RCP4.5 is generally used as a "middle-of-the-road" scenario where some changes to human activity lower emissions.[4]

1. Hausfather. (2019) CMIP6: the next generation of climate models explained. Carbon Brief. https://www.carbonbrief.org/cmip6-the-next-generation-of-climate-models-explained/
2. Harrisson. (2021) Explainer: How "shared socioeconomic pathways" explore future climate change. Carbon Brief. https://www.carbonbrief.org/explainer-how-shared-socioeconomic-pathways-explore-future-climate-change/
3. Riahi et al. (2017) The shared socioeconomic pathways and their energy, land use, and greenhouse gas emissions implications: An overview. Global Environmental Change.
4. Hausfather. (2019) Explainer: The high-emissions 'RCP8.5' global warming scenario. Carbon Brief.. https://www.carbonbrief.org/explainer-the-high-emissions-rcp8-5-global-warming-scenario/

Recommended Citation: Oxarart, A. Parker, L. USDA California Climate Hub (2024). Global Climate Models and Land Management: Global Climate Models and Emissions Scenarios [Fact sheet].