# Climate Science Models

Climate science models have evolved significantly, from early simplistic representations to today's sophisticated simulations. These models are indispensable tools for comprehending Earth's complex climate system, incorporating advancements in scientific knowledge, computational capabilities, and data availability.

Models encompass the atmosphere, oceans, land surfaces, ice, and biogeochemistry. They simulate interactions between these components, considering factors like greenhouse gas concentrations, sea surface temperatures, land use, and biological processes. Once we understand *what* climate models project, we can look at *how* they create these projections. Climate models calculate the physical interactions between four components: atmosphere, land, ocean, and sea ice. The calculations are based on several inputs: air temperature, pressure, density, water vapor content, and wind magnitude.

The size and complexity of the Earth make it challenging to represent in a model. This is in part because different places on the planet have different responses to energy and materials (e.g., land warms up and cools down faster than oceans). It is also because different parts of the planet have different climate influences (e.g., jet streams are typically stronger at the poles than they are at the equator). To make this task more manageable, climate models divide the Earth into a 3D grid with cubes extending across the surface of the Earth, up into the atmosphere, and down into the ocean. Each cube is analyzed individually over time while receiving information (inputs) from and passing information (outputs) to neighboring cubes. The size of the cubes varies among models, but each cube is approximately 100 km^3 (24 miles^3, about 2.8 miles on every side of each cube). How high and how deep the cubes extend also varies among models and depends on what information is of most interest to modelers. Like pixels in a photograph, a higher resolution model has more, smaller cubes and provides a more accurate picture of how changes to the climate impact an

area. A 3D grid helps reduce errors because each grid cell can have different inputs, outputs, and calculations for different terrains (i.e., rainforests versus deserts, or open ocean versus coastal ocean) and atmospheric layers. Some variables and processes, such as snow, rain, and clouds, only exist and/or function in areas smaller than the typical climate model cube (100 km^3), and must be simplified, or parameterized. Parameterization includes other mathematical equations that mimic real-world impacts. Parameterization may be used to estimate how much sunlight is reflected or absorbed by clouds, and how much heat is radiated by them, what types of clouds exist in each cube, and when and which type of precipitation forms.
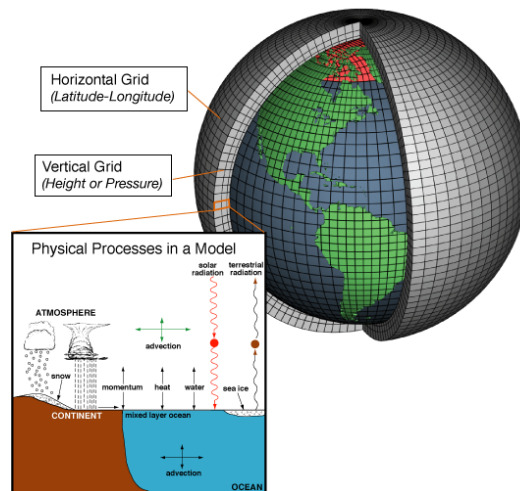
The evolution spans from early models in the 1950s to the present, with a progression from basic atmospheric simulations to today's high-resolution, coupled models. The inclusion of biogeochemistry in the 2000s marked a crucial step, addressing the human impact on the carbon cycle. Climate models serve multiple purposes, including understanding complex systems, predicting future conditions, informing policy decisions, and facilitating scientific research. They provide a holistic view of Earth's climate, helping us explore feedback mechanisms, identify drivers of climate change, and make informed decisions. Predicting climate change is crucial for assessing risks, planning adaptation strategies, and fostering international collaboration. It allows for the evaluation of impacts on ecosystems, economies, and societies, guiding the development of resilient infrastructure and sustainable policies.

As climate models continue to advance, they play a pivotal role in shaping our understanding of climate dynamics. From basic atmospheric representations to intricate simulations, these models empower scientists, policymakers, and communities to address the urgent global challenge of climate change proactively.