Meso-to Planetary Scale Processes in a Global Ultra-High Resolution Climate Model

CESM1 total column integrated water vapor (TMQ) Visualization

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This visualization represents output from the Community Earth System Model (http://www2.cesm.ucar.edu/), a fully coupled, global climate model that provides state-of-the-art computer simulations of the Earth's past, present, and future climate states. This ultra-high resolution global model shows developing weather patterns in rich detail, and helps researchers understand the effect of smaller, more localized weather on the dynamics of climate at the planetary scale.

The research was enabled by the National Center for Atmospheric Research's (NCAR) Computational and Information Systems Laboratory (CISL) compute and storage resources, including Yellowstone, a 1.5-petaflops IBM iDataPlex supercomputer with 72,288 processor cores. The main computational objective was to perform and assess Community Earth System Model (CESM) simulations at high resolution with 1/4-degree atmosphere and land models and 1/10-degree ocean and ice models and to investigate influence of small (mesoscale) features in ocean, ice & atmosphere on basin and planetary scale climate.

The current generation of coupled general circulation models (CGCMs) is designed to be able to perform century and multi-century simulations, and ensembles. With existing computing power availability, this has restricted models to have grid spacings of around 1° (~100km). These models adequately resolve large scale modes of climate variability (such as ENSO, IOD, NAO) but do not capture smaller scale features such as tropical cyclones, mesoscale storms forced by steep orography, polar lows, ocean eddies and fronts, which have important local impacts and may feedback to the large scale climate.

In this ultra-high resolution experiment, the Community Earth System Model was used for a 60 year simulation under "present-day (year 2000)" greenhouse gas conditions. The resolution of this CESM experiment is 1/4deg. atmosphere (with Community Atmosphere Model CAM version 5) and land, and 1/10deg. ocean (Parallel Ocean Program POP2) and ice.

Some of the major climate science results of this research include that both Arctic and Antarctic sea ice extent and annual cycle compared well with observations and more-tuned low resolution runs. Annual mean SST in the

Equatorial Pacific and ENSO variability was also well simulated. Tropical and southern Atlantic sea surface temperature biases are reduced compared to most coarse resolution climate model simulations.

In addition, the high resolution of the model enabled small-scale features of the climate system to be represented, such as air-sea interaction over ocean frontal zones, mesoscale systems generated by the Rockies, the ocean response to strong wind jets and tropical cyclones, and, as shown in the accompanying visualization of water vapor, time evolving patterns of global circulation, seasonal changes, including proxies for small-scale transient features such as hurricanes, tropical cyclones, and typhoons.

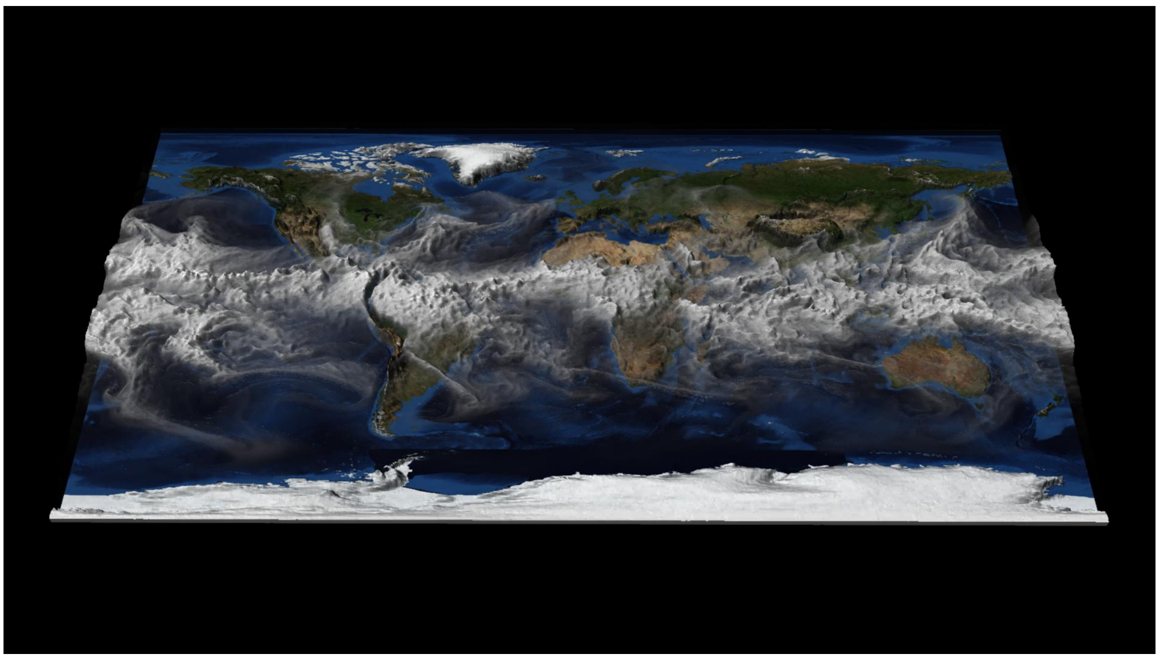

Figure 1 Shown here is a visualization (total runtime: 5m 14s) of CESM1 model output depicting hourly time steps of total column integrated water vapor (TMQ) across the globe for an entire year. The TMQ variable is represented by a 3D surface where the surface shape/height, color (black to white), and opacity (transparent to opaque) all redundantly represent the range of the variable's value from low to high.

The primary visualization tools used to produce this rendering include the NCAR Command Language (NCL version 6.1.1) and Autodesk Maya. The following HPC hardware resources were used to model and visualize the TMQ data: the NCAR-Wyoming Yellowstone Supercomputer, NCAR specialized data analysis and visualization cluster resources (Geyser and Caldera), and a multi-petabyte centralized Globally Accessible Date Environment (GLADE) file service.