Ahoy aquaplanet: Identifying model resolution shortcomings

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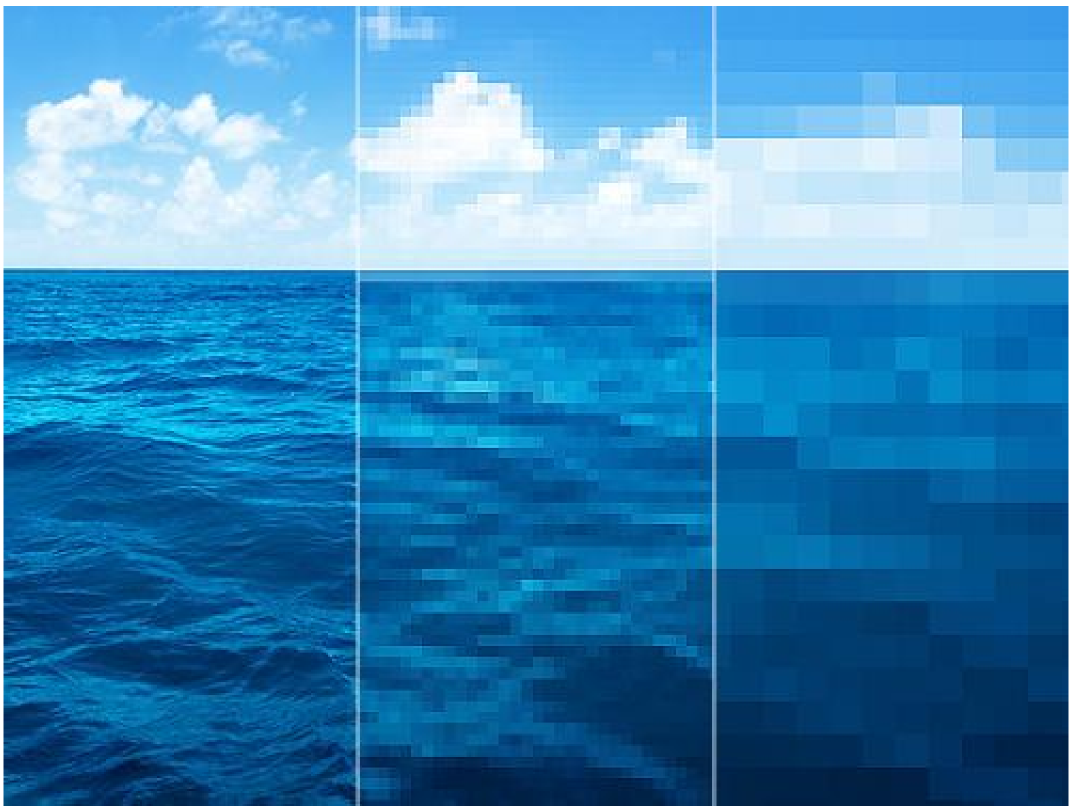

Using an all-ocean "aquaplanet," scientists can study many aspects of the climate system in an idealized setting that facilitates interpretations. High-resolution climate modeling represents processes with more details and accuracy, but comes with a high computational cost. So, scientists are developing approaches which can be tested without distracting and competing land-surface or topography interactions.

By putting models through their paces in an all-water world, scientists at Pacific Northwest National Laboratory found highly scale-sensitive issues in regional climate modeling. In the first of two studies, two approaches for high-resolution modeling produced uncertainties in circulation patterns due to the sensitivity of precipitation representations to model resolution. In the second study, they found that key model components that are supposed to simulate the upward transport of moisture important for modeling precipitation underestimate moisture transport across all scales.

"By simulating climate processes in a hypothetical 'all-ocean' planet," said Dr. Samson Hagos, lead researcher and climate scientist at PNNL, "we are able to analyze the models without the complications of distracting and competing processes, such as land-surface interactions or topography."

Although climate change is global, information on climate adaptation and mitigation are required by the local and regional decision-makers. High-resolution regional climate modeling can help inform that need, but it comes with a high computational cost. More computer resources are required to deliver these detailed accounts. So, scientists have developed different approaches to enable high-resolution simulations more efficiently. Although these techniques deliver the benefit of much smaller computing resources, the studies highlighted here show that certain cloud and precipitation processes are distorted. To support an informed assessment of climate change mitigation and adaptation strategies, model results for regional climate simulations must be robust at reasonable computational cost.

In the first study, the research team from PNNL and Los Alamos National Laboratory used idealized global model simulations of the aquaplanet with Model for Prediction Across Scales-Atmosphere (MPAS-A) and Weather Research and Forecasting Model (WRF) to run at low, high and variable resolutions. The team examined the impacts of changing model resolution and using two techniques on the simulated tropical precipitation and circulations: variable resolution and nesting.

In the idealized aquaplanet setting, where the simulated climate should be zonally symmetric, their results showed that by introducing a high-resolution region in the tropics embedded in a global or very large domain with coarse resolution elsewhere produces zonal asymmetry in the simulated climate. This is due to amplified precipitation in the high-resolution region compared to the coarse-resolution region. Because the model parameterizations are not scale aware, increased precipitation produces zonally asymmetric climate circulation patterns that characterize the "errors" in the model simulations.

In the second study by PNNL researchers, they used two simulations with nested domains of higher spatial resolution to directly compare the moist processes in the nested domains with those in the low-resolution parent domains that are explicitly resolved instead of parameterized. Their analyses show that upward moisture transport by eddy fluxes dries the boundary layer and enhances evaporation and precipitation. This effect is better resolved with increasing spatial resolution. However, model physics process representations that are supposed to account for the eddy moisture transport effects on convection significantly underestimate them compared to simulations that explicitly resolved eddy moisture transport without using convective representations.

Both studies are part of a model improvement plan to compare different high-resolution climate modeling approaches and find the impacts of model resolution on results. In subsequent studies, the team will compare real-world simulations that include realistic topography and land cover with the observed climate. Using variable resolution global models, their analyses will take into account the sensitivity of water cycle processes such as atmospheric rivers and monsoons to model resolution.

More information: Hagos S, LR Leung, S Rauscher and T Ringler. 2013. Errors Characteristics of Two Grid Refinement Approaches in Aqua-planet Simulations: MPAS-A and WRF, *Monthly Weather Review*. DOI:10.1175/MWR-D-12-00338.1, early online.

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