Large ensemble simulations with a global climate system model reveal the role of internal climate variability

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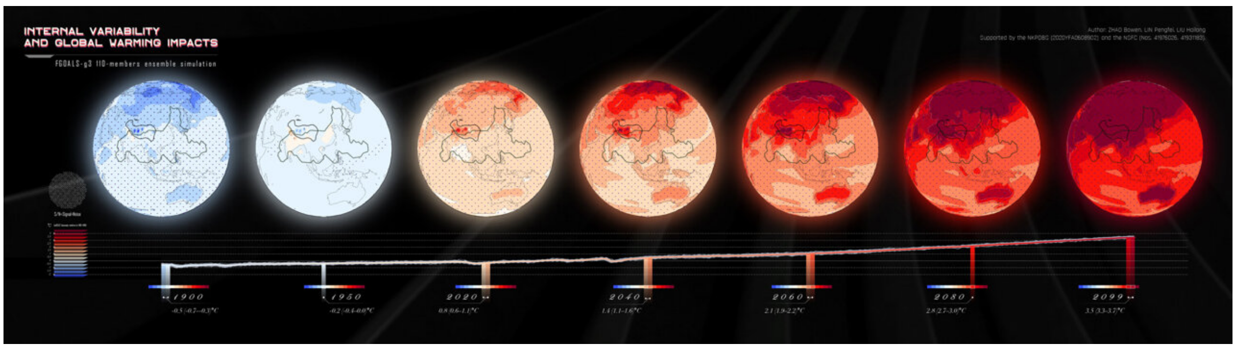

Change in surface air temperatures (SATs) at different time periods (relative to 1961-1990) and the internal variabilities (The dots identify signal strength and are significant to the study). The line is the globally averaged surface air temperature. Below the year, the SAT change and the range of IVs are denoted. Credit: Pengfei Lin

Since the Industrial Revolution era began, global warming, Arctic sea ice melting, and increasing sea-level rise are likely attributed to human activity, according to the IPCC AR6 report. The climate change response to external forces (including human activity) is non-linear and is affected by internal variabilities (IVs) generated mainly from internal processes in the climate or Earth system. Recently, scientists have found that IVs, such as the Pacific Decadal Oscillation or Inter-decadal Pacific

Oscillation, and the Atlantic Multi-decadal Oscillation, will greatly impact the Walker Circulation and Global Monsoon throughout the next three decades. IVs are also important sources of uncertainties in understanding historical climate change, especially at the regional scale. Put succinctly, IVs are useful for studying climate change, developing mitigation strategies, and providing guidance for policy makers.

Climate system models aid IV studies by providing simulations, especially when employing single-model initial-condition large ensemble simulations, which are an ensemble of simulations tied to a single climate model under a particular radiative forcing scenario. The large ensemble simulations apply perturbations, or deviations from normal input, to the initial conditions of each member to create diverging weather and climate trajectories. The ensemble sizes of large ensemble simulations are subject to computational and resource limits similar to those used in previous studies. Recently, several modeling center research groups have conducted single-model initial-condition large ensemble simulations that are now possible with rapidly increasing computer abilities.

Employing large ensemble simulations to study climate change has been a hotspot in climate research. For instance, the National Center for Atmospheric Research (NCAR) released a large ensemble simulation in 2015 that has been cited more than one thousand times. Until then, the ensemble sizes have featured no greater than 100 members and, even today, few of ensemble simulations have 100 ensemble sizes.

To study the impact of IVs on future global monsoon projections, the LASG ocean model team group from the Institute of Atmospheric Physics (IAP), Chinese Academy of Sciences (CAS) produced a super-large ensemble simulation with 110 members from their FGOALS-g3 climate system model. The full breadth of their research is available in a data description paper entitled "The Super-large Ensemble experiments of CAS FGOALS-g3" now published in *Advances in Atmospheric Sciences*.

"The Super-large Ensemble experiments of CAS FGOALS-g3 are the first set of large ensemble simulations from a global climate system model named FGOALS-g3 developed by IAP, CAS," said lead author Bowen Zhao. "The large ensemble simulation has the largest sample numbers in the world."

Each member contains a simulation for the climate system model, including ocean, atmosphere, sea ice, and land components. Researchers fully sampled the different phases of decadal ocean variability as the initial model states under the standard CMIP6 historical forcing conditions. They also included the Shared Socioeconomic Pathway scenario (SSP5-8.5), which suggests very high greenhouse gas emissions. These simulations cover a period between 1850 to 2099.

"Our assessment also shows that these ensembles are capable of accurately capturing surface air temperature response and land precipitation, including extreme climate events as well as external forcings, and we can quantify the internal variabilities," continued Zhao. "Having more than 100 simulations and their realizations helps us study rare events and improve our understanding of the impact of internal variability on forced climate changes."

More information: Pengfei Lin et al, The Super-large Ensemble Experiments of CAS FGOALS-g3, *Advances in Atmospheric Sciences* (2022). DOI: 10.1007/s00376-022-1439-1

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