Scientists develop Earth system models with clouds and ocean submesoscale eddies

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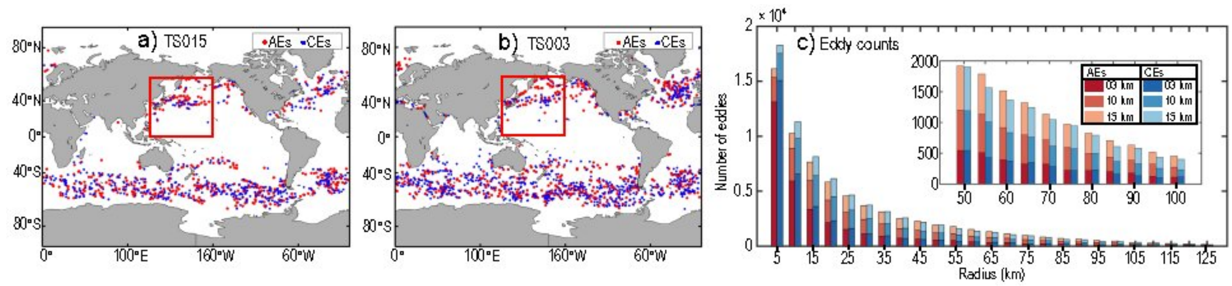


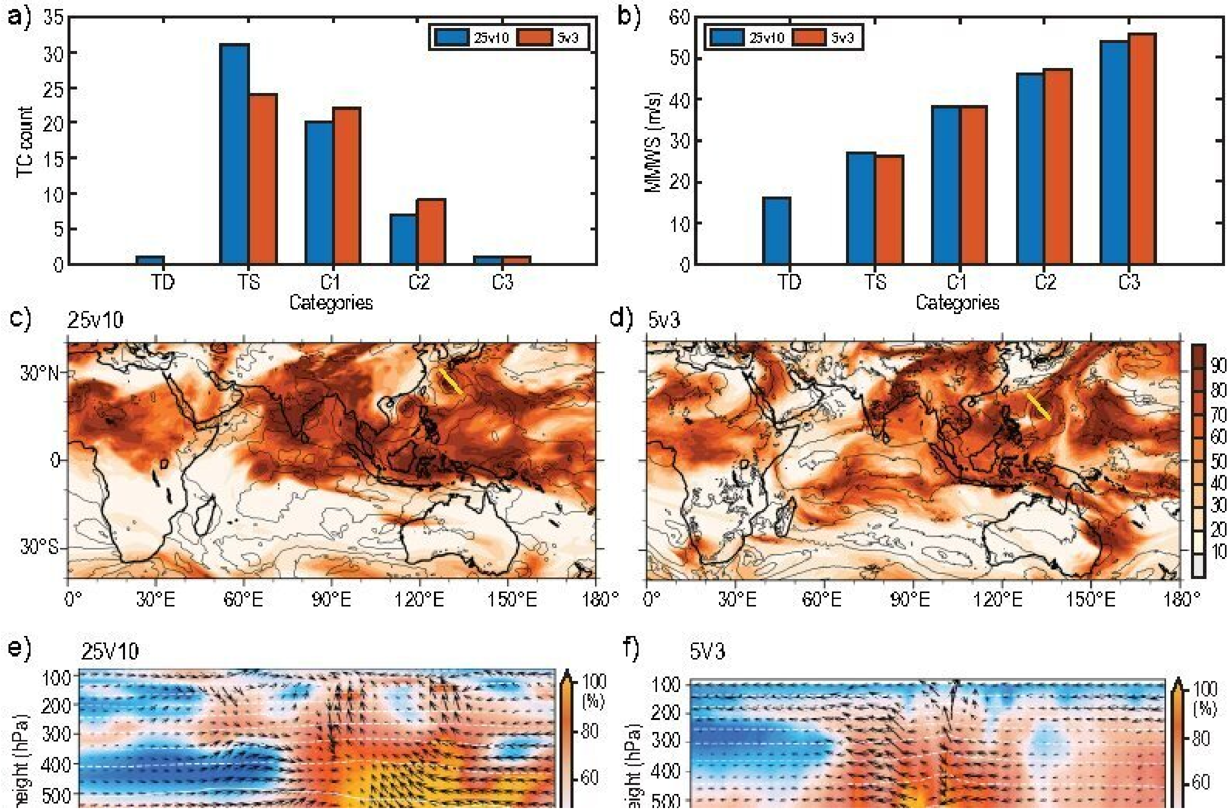
a and b) Spatial distributions of eddy centroids for Anticyclonic Eddies (AEs) (red) and Cyclonic Eddies (CEs) (blue) with amplitude > .05 m, detected from a) TS015 (panel a) and TS003 (panel b) models, and c) histogram of eddy radius constructed from TS015, TS010 and TS003 for the last year of 3-year model spinup. Red and blue bars stand for AEs and CEs, respectively. The radius range in 50-100 km (denoted by the red box) is zoomed-in the upper-right corner. Credit: Science China Press

It has long been a dream for Earth scientists to have a numerical model that can better represent compound multiple-scale processes in the real-world Earth system. Apart from requiring deep understanding on physics of geo-fluid motions, developing such a model demands interdisciplinary advancement in the Earth sciences and high-performance supercomputing as well as software engineering.

"The successful development of Earth system models with clouds and ocean submesoscale eddies permitted is a milestone in the advancement of understanding the earth system," said Dr. Lixin Wu.

Based on the newly-developed "Sunway" heterogeneous architecture supercomputer which has a world-leading high-performance computing capability, Shaoqing Zhang, Lixin Wu and Yang Gao, a group of scientists at Ocean University of China, together with Shiming Xu, Haohuan Fu and Zhao Liu, a group of professors and engineers at Tsinghua University and National Wuxi Supercomputing Center, organized a large cross-field group of scientists and engineers to take on the challenges and develop new high-resolution Earth system models.

After resolving plenty of physical and engineering issues, the large group successfully developed a series of high-resolution coupled Earth system models consisting of 12, 9 and 5 km resolution atmosphere-land models and 15, 10, 5 and 3 km resolution ocean-ice models. "These models can meet the needs of multiscale interaction studies with different computational costs," said Dr. Shaoqing Zhang.



a and b) Distributions of TC counts (panel a) and mean maximum wind speed (MMWS) (panel b) in different categories produced by the 5v3 (red) model in Jan.-Oct. as the model are initialized from the 25v10 state on Jan. 1, 0646-year, compared with the results of 25v10 model in the same period. cd) Distributions of 850 hPa relative humidity (shaded) and wind speed (contours) in the 25v10 model (panel c) at 00UTC of Sep. 3 and 5v3 model at 06UTC of Aug. 31 as the C3 category TC (marked by the green segment in each panel) in both models reaches its maximum wind speed. e and f) The atmosphere and ocean conditions on the air-sea interface in the vertical section of the TC marked by the thick green segment in panels c (for 25v10) and d (for 5v3). The dashed red vertical line represents the center of TC; the atmosphere (ocean) relative humidity (%) (temperature: oC) is color shaded, while the atmosphere (ocean) temperature (unit: oC) (salinity: psu) is contoured, and the vector arrows always represent the atmospheric (u,w×102) (unit: m/s) (ocean currents: 0.04 m/s). The white-bold line represents the mixing layer depth. Credit: Science China Press

These high-resolution models can simulate cloud cells and ocean submesoscale vortex filaments by some degree (see below). Therefore, they can bring new understanding on weather-climate mechanisms from the perspective of cross-scale interactions.

"The most exciting results from these new high-resolution models are that the major weather-climate extremes in the atmosphere and ocean are captured, stressing the importance of permitted clouds and ocean submesoscale eddies in modeling tropical cyclones and eddy-mean flow interactions," said Drs. Shiming Xu and Yang Gao.

"The new heterogeneous many-core architecture high-performance supercomputer brings new opportunities for climate modeling once the optimization of heterogeneous architecture computing is efficiently implemented. The low work consumption of heterogeneous architecture computing complies with the 'green' future of the world," said Drs. Haohuan Fu and Zhao Liu.

The new high-resolution Earth system models lay the foundation for future efforts to sustain the advancement of the Earth sciences through modeling more complex biogeochemical processes and carbon cycling. "These models pave [the way] for further model development to resolve finer-scales with even higher resolution and more realistic physics. For example, based on these results, development of a nonhydrostatic, cloud and ocean submesoscale resolving Earth system model has been undergoing," said Drs. Shaoqing Zhang and Yang Gao.

The research is published in the journal *National Science Review*.

More information: Shaoqing Zhang et al, Toward Earth system modeling with resolved clouds and ocean submesoscales on heterogeneous many-core HPCs, *National Science Review* (2023). DOI: 10.1093/nsr/nwad069

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