Researchers discover Gulf Stream thermal fronts controlling North Atlantic subtropical mode water formation

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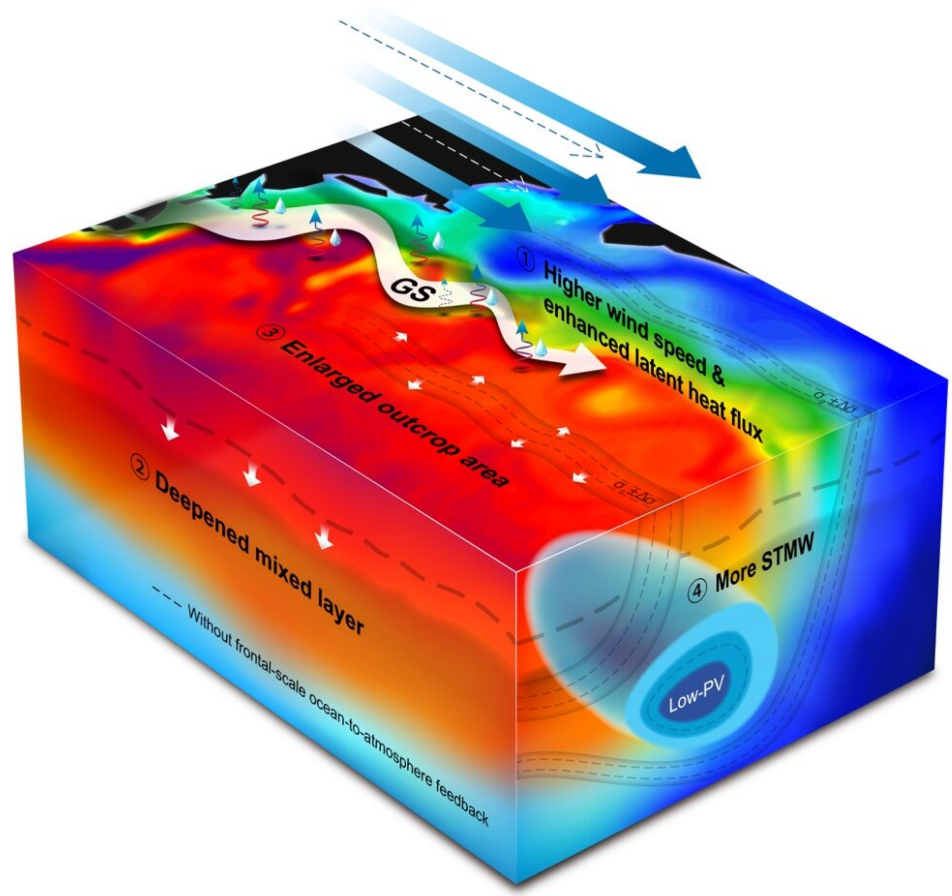

Figure 1. The Gulf Stream thermal front leads to excessive ocean latent heat release primarily due to higher surface wind speed and sharper air-sea humidity contrast over its warm flank. The cumulative extensive latent heat loss favors the

deepening of mixed layer, which gives rise to enlargement in the outcropping of corresponding isopycnals, leading to considerable transformation of lighter water masses into STMW. Credit: ©Science China Press

Subtropical mode water (STMW) is a vertically homogeneous thermocline water mass, serving as heat, carbon, and oxygen silos in the ocean interior and providing memory of climate variability for climate prediction. Understanding physics governing STMW formation is thus of broad scientific significance and has received much attention.

Traditionally, it has been considered that STMW is constructed by basin-scale atmospheric forcing. Due to the limitations resulting from sparse sampling of observations and coarse resolution of climate models, less knowledge is acquired about the role of oceanic thermal fronts in the STMW production.

With a focus on the North Atlantic Ocean, which contains the thickest and volumetrically largest STMW in the global ocean, the team found for the first time that the feedback of sharp surface thermal fronts shaped by the Gulf Stream to the overlying atmosphere is essential for the STMW formation. The paper is published in the journal *National Science Review*.

By comparing twin simulations conducted with a state-of-the-art eddy-resolving coupled global climate model, it is found that suppressing local frontal-scale ocean-to-atmosphere (FOA) feedback leads to STMW formation being reduced almost by half. This is attributable to a vast increase in surface outcropping associated with the cumulative excessive latent heat release primarily due to higher wind speeds and greater air-sea humidity contrast driven by the Gulf Stream fronts (Figure 1).

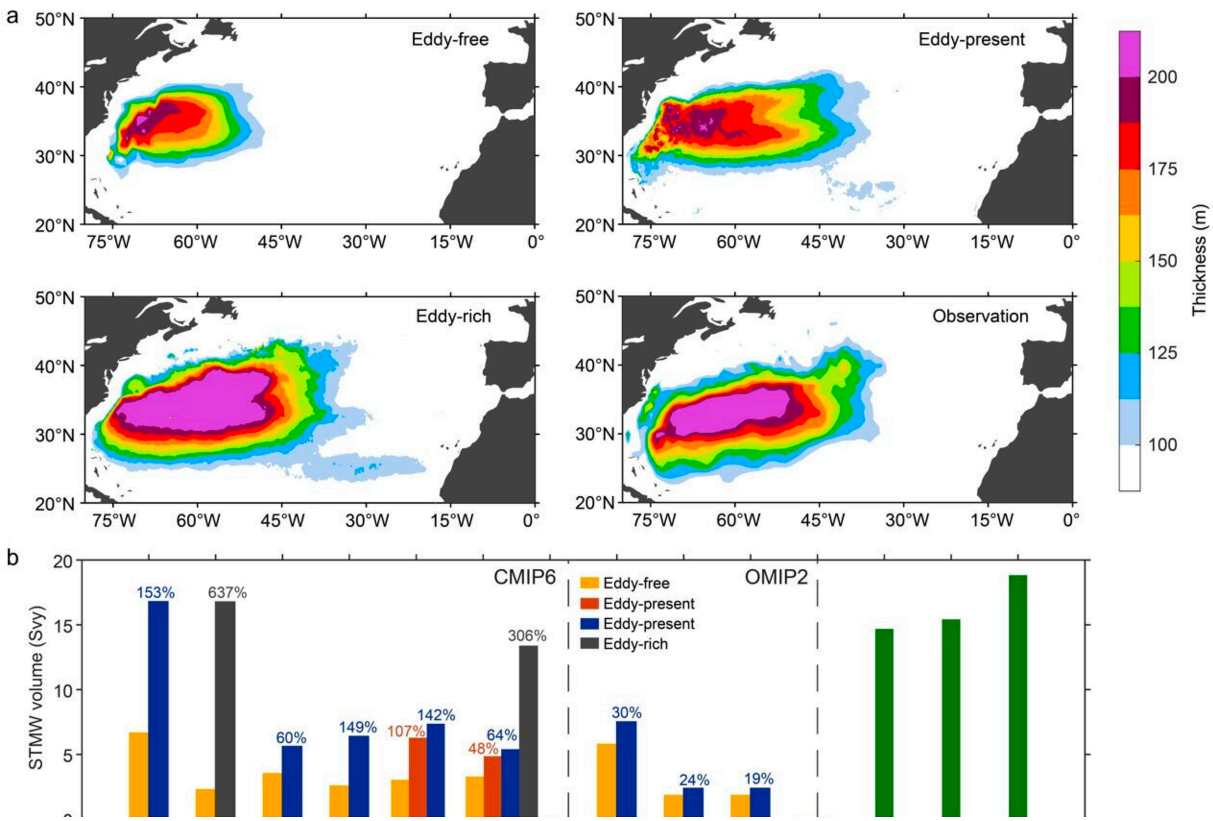

Figure 2. (a) Multimodel mean STMW thickness in the CGCMs classified into oceanic eddy-free (≥50 km), eddy-present (~25 km) and eddy-rich (~10 km) resolution regimes, as well as from the observationally based datasets. (b) Total volume of STMW in six CGCMs and three OGCMs at different resolutions as well as three observationally based data sets. (c) Taylor diagram for the STMW thickness pattern. Point marked "Reference" refers to the observational pattern in (a). (d) Inter-model relationship between the STMW volume and the wintertime-mean FOA feedback intensity. The linear regression (blue line) is displayed together with the inter-model correlation coefficient r and significance P value assessed by Student's t test. Dots, triangles and stars signify the eddy-free, eddy-present and eddy-rich configurations of CGCMs, respectively. Credit: Science China Press

Furthermore, the crucial role of the FOA feedback is attested by a multimodel and multi-resolution ensemble of latest global coupled models participating in CMIP6, in which with finer model resolution, the observed STMW is better reproduced due to more realistic representation of FOA feedback (Figure 2). "This is an important finding that incorporates the missing piece for the accurate STMW modeling and provides an effective solution to the common severe underestimation of STMW in earth system models," Dr. Gan says.

"This study lasted over two years since 2020 and I really enjoyed being part of it. It is a new exciting result that highlights the importance of frontal-scale air-sea interactions in climate system," Dr. Yu says.

More information: Bolan Gan et al, North Atlantic subtropical mode water formation controlled by Gulf Stream fronts, *National Science Review* (2023). DOI: 10.1093/nsr/nwad133

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