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Atmospheric response to Gulf Stream SST front shifting: impact of horizontal resolution in an ensemble of global climate models

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Western boundary currents transport a large amount of heat from the Tropics toward higher latitudes; furthermore they are characterized by a strong sea surface temperature (SST) gradient, which anchors zones of intense upward motion extending up to the upper-troposphere and shapes zones of intense baroclinic eddy activity (storm tracks). For such reasons they have been shown to be fundamental in influencing the climate of the Northern Hemisphere and its variability, and a potentially relevant source of atmospheric predictability.

General circulation models show deficiencies in simulating the observed atmospheric response to SST front variability. The atmospheric horizontal resolution has been recently proposed as a key element in understanding such differences. However, the number of studies on this subject is still limited. Furthermore, a multi-model analysis to systematically investigate differences between low-resolution and high-resolution atmospheric response to oceanic forcing is still lacking.

The present work has the objective to fill this gap, analysing the atmospheric response to Gulf Stream SST front shifting using data from recent High Resolution Model Intercomparison Project (HighResMIP). This project was designed with the specific objective of investigating the impact of increased model horizontal resolution on the representation of the observed climate. Ensembles of historical simulations performed with three atmospheric general circulation models (AGCMs) have been analysed, each conducted with a low-resolution (LR, about 1°) and a high-resolution (HR, about 0.25°) configuration. AGCMs have been forced with observed SSTs (HadISST2 dataset), available at daily frequency on a 0.25° grid, during 1950–2014.

Results show atmospheric responses to the SST-induced diabatic heating anomalies that are strongly resolution dependent. In LR simulations a low-pressure anomaly is present downstream of the SST anomaly, while the diabatic heating anomaly is mainly balanced by meridional advection of air coming from higher latitudes, as expected for an extra-tropical shallow heat source. In contrast, HR simulations generate a high-pressure anomaly downstream of the SST anomaly, thus driving positive temperature advection from lower latitudes (not balancing diabatic heating). Along the vertical direction, both in LR and HR simulation, the diabatic heating in the interior of the atmosphere is balanced by upward motion south of GS SST front and downward motion north and further south of the Gulf Stream. Finally, LR simulations show a reduction in storm-track activity over the North Atlantic, whereas HR simulations show a meridional displacement of the storm-track considerably larger (yet in the same direction) than that of the SST front. HR simulations reproduce the atmospheric response obtained from observations, albeit weaker. This is a hint for the existence of a positive feedback between ocean and atmosphere, as proposed in previous studies. These findings are qualitatively consistent with previous results in literature and, leveraging on recent coordinated modelling efforts, shed light on the effective role of atmospheric horizontal resolution in modelling the atmospheric response to extra-tropical oceanic forcing.