Enhanced atmospheric response to Gulf Stream SST anomalies in CAM6 simulations with 1/8-degree regional grid refinement over the North Atlantic

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Abstract

North Atlantic sea-surface temperatures (SSTs) exhibit variability on seasonal to decadal timescales, providing a potential source of predictability for the atmospheric circulation and regional climate on these timescales. Recent work has shown that initialized climate models have skill in predicting the decadal evolution of North Atlantic SSTs [1], but this will only help to predict regional climate in the surrounding continents if models can correctly simulate the atmospheric response to these SST anomalies. There is growing evidence that models systematically underestimate the atmospheric response to extratropical SST anomalies [2], and that this may be rectified by increasing the atmospheric resolution to resolve mesoscale processes over ocean frontal zones [3]. Here, we investigate the large-scale atmospheric circulation response to idealized Gulf Stream SST anomalies in two configurations of the Community Atmospheric Model (CAM6), one with 1-degree resolution globally and one with regional grid refinement of 1/8-degree over the North Atlantic. The variable resolution configuration, which resolves mesoscale atmospheric processes, shows a large negative response of the wintertime North Atlantic Oscillation (NAO) to a strengthening of the SST gradient across the Gulf Stream (a 2-standard-deviation NAO anomaly for SST anomalies that vary between ±2°C). The response is substantially weaker and has a different spatial structure in the lower resolution simulations. The large-scale atmospheric circulation response in the variable resolution simulations results from mesoscale processes that enhance convection over the Gulf Stream and lead to latent-heating and divergence anomalies in the upper troposphere. These results suggest that the atmospheric circulation response to extratropical SST anomalies may be fundamentally different at higher resolution. Regional refinement in key regions offers a potential pathway towards improving simulation of the atmospheric response to extratropical SST anomalies and thus improving multi-year regional climate predictions. [1] Yeager, S.G., et al., 2018, https://doi.org/10.1175/BAMS-D-17-0098.1. [2] Simpson, I.R., et al., 2018, https://doi.org/10.1175/JCLI-D-18-0168.1. [3] Czaja, A., et al., 2019, https://doi.org/10.1007/s40641-019-00148-5.

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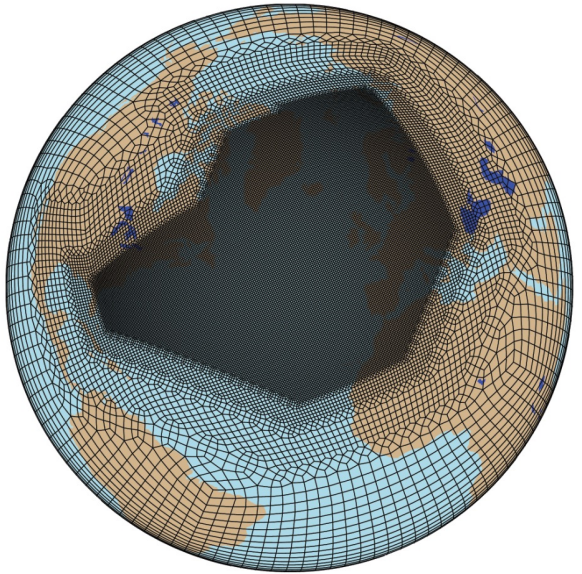
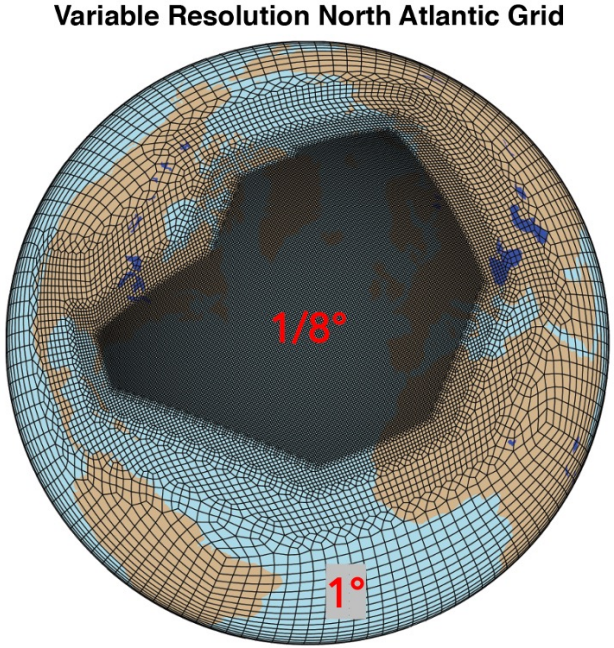
Motivation:

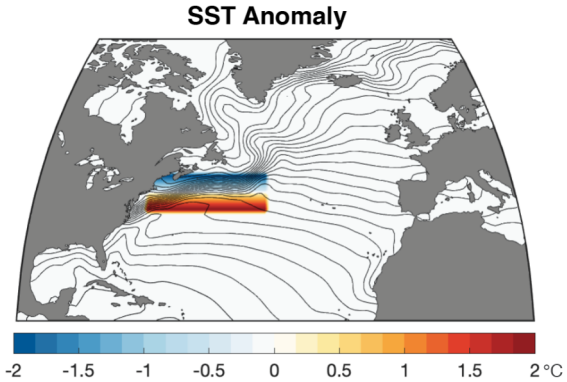
- Models underestimate the atmospheric response to extratropical SST anomalies and the associated multi-decadal variability of atmospheric circulations *(Simpson et al. 2018; 2019; O'Reilly et al. 2021)*
- Resolving atmospheric mesoscale processes over ocean frontal zones may help to simulate the full atmospheric response to extratropical SST anomalies *(Smirnov et al. 2015; Czaja et al. 2019)*

Variable Resolution North Atlantic Grid



Idealized experiments with Gulf Stream SST anomalies in a variable resolution version of CAM-SE



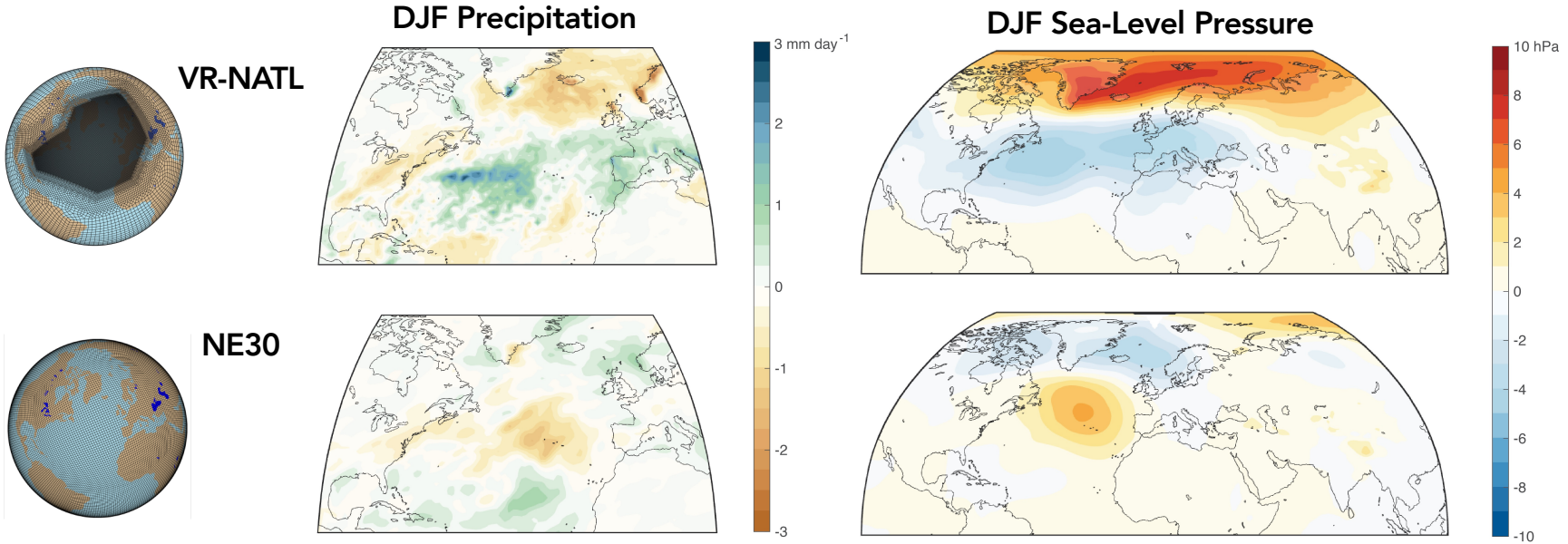


Reference: Atmosphere-only (CAM6-SE) simulations with specified seasonally varying climatological SSTs (1° res.)

Experiment: Added SST anomaly pattern in the Gulf Stream, strengthened SST gradient

- Both simulations run with the VR-NATL grid and with a 1° reference grid (NE30), each simulation run for 8 years
- Cost of VR-NATL is ~35x cost of NE30
- Other planned experiments include full AMIP run, uniform SST anomaly in Gulf Stream, response to realistic modes of decadal SST variability

Enhanced precipitation over warm Gulf Stream SSTs leads to NAO-like large-scale circulation response



- Large wintertime NAO-like response to Gulf Stream SST anomalies
- Mesoscale atmospheric processes increase precipitation over anomalously warm SSTs, leading to a large-scale circulation response through influence on free tropospheric latent heating (work in progress to characterize influence on individual storms)