A New Masking Technique to Investigate the Air–Sea Interaction Over the Western Boundary Currents

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1. Introduction

- Large ocean currents such as the Western Boundary Currents (WBCs) have a strong impact on the climate and is projected to change under climate change.
- WBCs influence the atmosphere via sustaining a strong gradient and high variability of Sea Surface Temperature (SST).
- Smirnov et al (2015) showed that identical experiments with varying model resolution produces different atmospheric responses to SST variability.

Better understanding of the mechanism of how SST variability impacts the atmosphere above is needed.

- Air-sea interactions over SST anomalies vary between the Warm sector (low turbulent flux, large ascent) and the Cold Sector (large heat exchange, confined layer) of a mid latitude cyclone.
- Recent study (Sheldon et al 2015) showed there were larger ascent over the warm sector when higher resolution was used; air-sea interaction over the warm sector may be misrepresented in models.

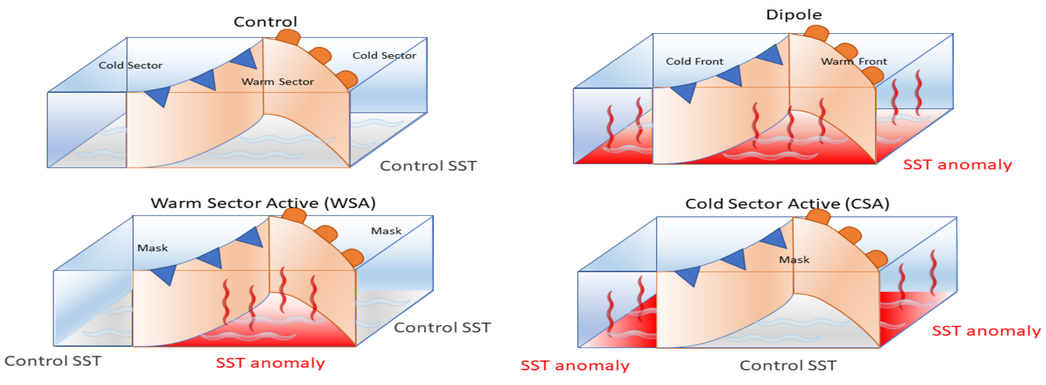
Need to identify the physical mechanism responsible for observed atmospheric response by separating the sectors.

HYPOTHESIS

A. At low resolution, the atmospheric response is dominated by the cold sector.
B. At high resolution, the atmospheric response is dominated by the warm sector

2. Masking Technique

- Sensitivity experiments are performed where the General Circulation Model is forced by prescribed SST anomaly with different configurations:

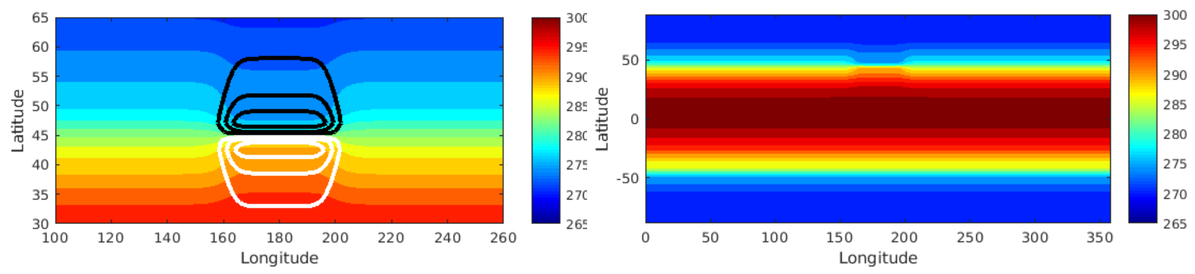


a) CONTROL: zonally averaged climatological SST is prescribed.
b) DIPOLE: atmosphere is forced with a SST anomaly comparable to WBC.
c) WARM SECTOR ACTIVE (WSA): opposite of CSA where only the Warm sector interacts with the SST anomaly and Cold sector "sees" the controlled SST.
d) COLD SECTOR ACTIVE (CSA): at each model time-step the Warm sector is "masked", the same SST anomaly as DIPOLE is "seen" only in the Cold Sector.

The sectors are diagnosed using sensible heat flux and meridional wind where Cold sector is the area with Q >10W/m^2 and v < -5m/s (Warm sector <-10W/m^2 >5m/s). The mask is used to alter the turbulent flux bulk formulae.

3. Model Set Up

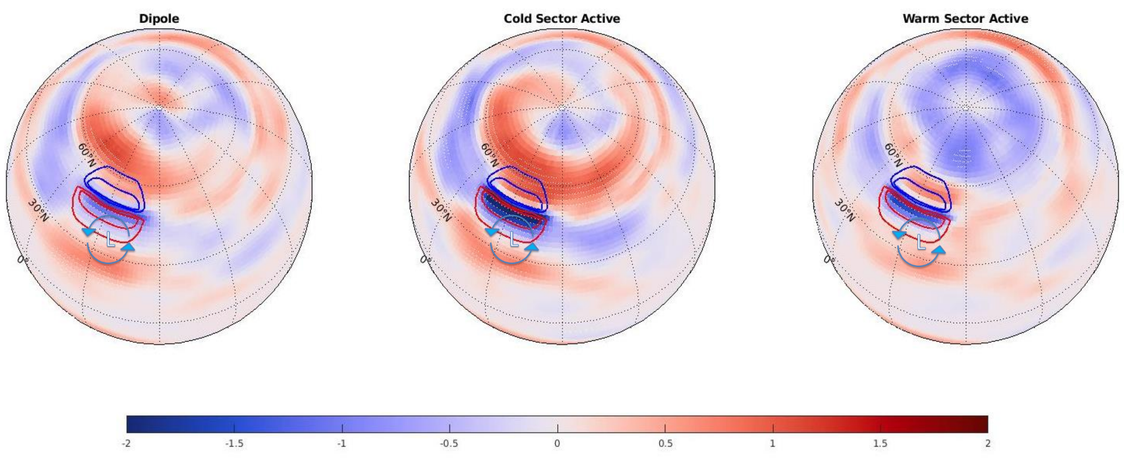
- AFES (Atmospheric Forcing Earth Simulator) aqua-planet simulation at T79 (~150km) resolution.
- Pre-scribed fixed SST configuration.
- Intermediate complexity climate model with dynamical equations solved in full (with hydrostatic assumption).
- Simulations with higher resolution will be used to compare response at different resolutions (~50, ~100, ~300km)



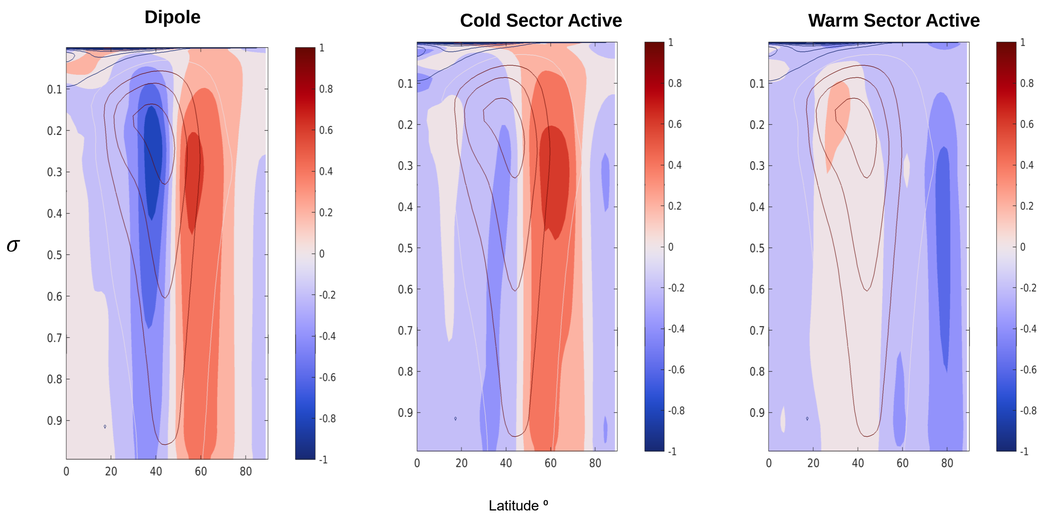
Left: prescribed SST field in the midlatitudes with a tightening of gradient. Black/White contour represent the negative/positive temperature anomaly compared to CTL experiment in 1K interval. Right: Prescribed SST field for the whole globe.

4. Atmospheric Response to SST perturbation

- Local response pattern is more comparable between Dipole and Cold Sector Active simulations than with Warm Sector Active case.



[shadings] Time mean zonal wind response at 980 hPa (m/s)
[contour] SST anomaly (1K gradient)



[shadings] Zonal mean zonal wind response (m/s)
[contour] Zonal mean zonal wind profile in the control experiment (10 m/s)

5. Discussion

- Prescribed SST anomaly on aquaplanet simulation produced a cyclonic response near surface consistent with the Low Resolution experiment in Smirnov et al (2015), also consistent with the Linear Response Theory (Hoskins and Karoly 1981). The anomaly appears to shift the jet polewards, wind response at upper level indicates excitation of wave train (not shown).
- All experiments reproduce a cyclonic response, however CSA resembles more closely the full atmospheric response compared to the WSA. This result is in agreement with the hypothesis that in a low resolution case, the atmospheric response is dominated by atmosphere-ocean interaction in the cold sector.
- Future work: explore the change in response when using higher resolution model and investigate the physical mechanism responsible..

Sheldon et al (2017),'A 'warm path' for Gulf Stream–troposphere interactions', Tellus A: Dynamic Meteorology and Oceanography 69(1), 1299397.
Smirnov et al (2015), 'Investigating the local atmospheric response to a realistic shift in the Oyashio sea surface temperature front', Journal of Climate 28(3), 1126–1147.
Hoskins, B. J. & Karoly, D. J. (1981), 'The Steady Linear Response of a Spherical Atmosphere to Thermal and Orographic Forcing'

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