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.

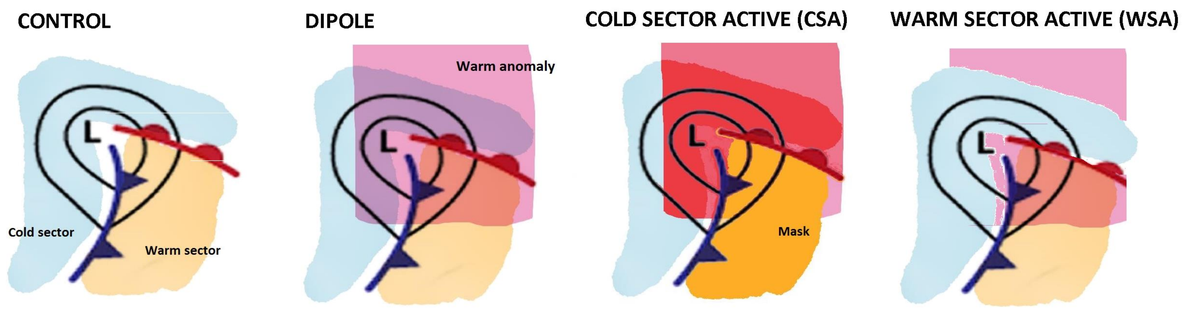
Need to identify the physical mechanism responsible for observed atmospheric response by separating the sectors.

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:

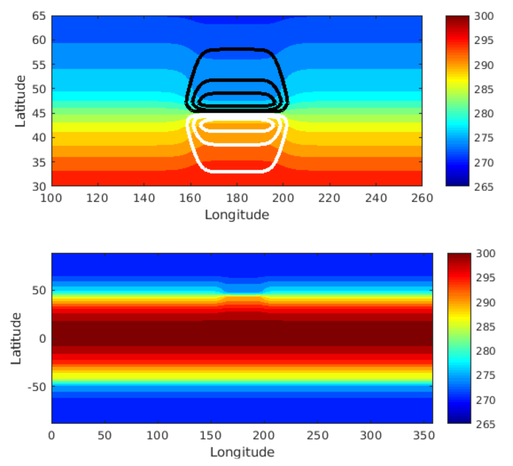


a) CONTROL: zonally averaged climatological SST is prescribed.
b) DIPOLE: atmosphere is forced with an SST anomaly comparable to WBC.
c) COLD SECTOR ACTIVE (CSA): at each model time-step the Warm sector is "masked", the same SST anomaly as DIPOLE is seen only in the Cold Sector.
d) WARM SECTOR ACTIVE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

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

3. Model

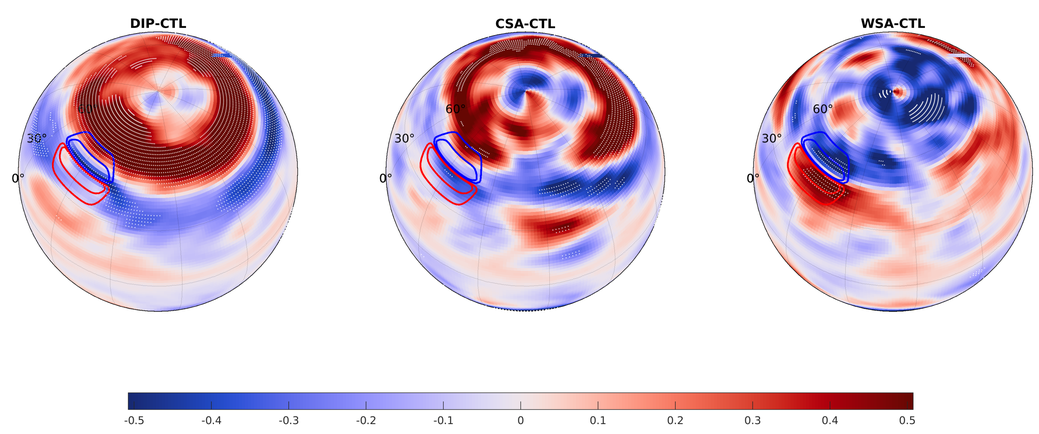
- AFES (Atmospheric Forcing Earth Simulator) aquaplanet simulation at T79 resolution with fixed SST.
- Intermediate complexity climate model with dynamical equations solved in full (with hydrostatic assumption).
- Simulations with higher resolution will be used to compare response at different resolutions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



Top: 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. Bottom: Prescribed SST field for the whole globe.

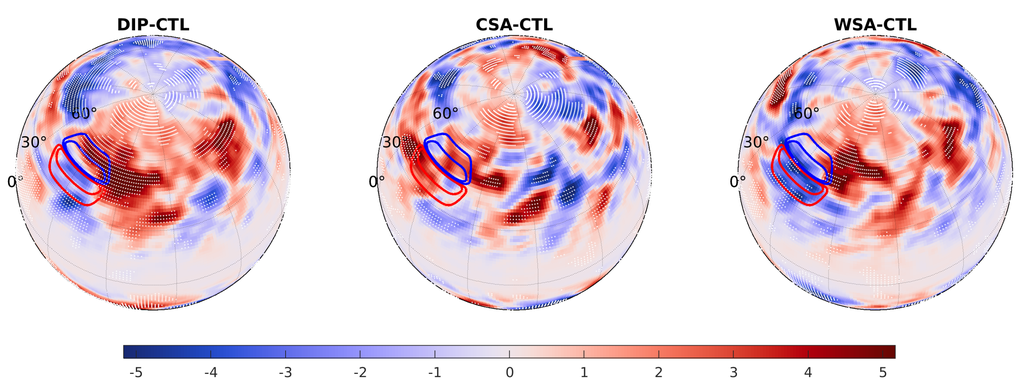
4. Atmospheric Response to SST perturbation

- The zonal response pattern is more comparable between Dipole and Cold Sector Active simulations than with Warm sector only.



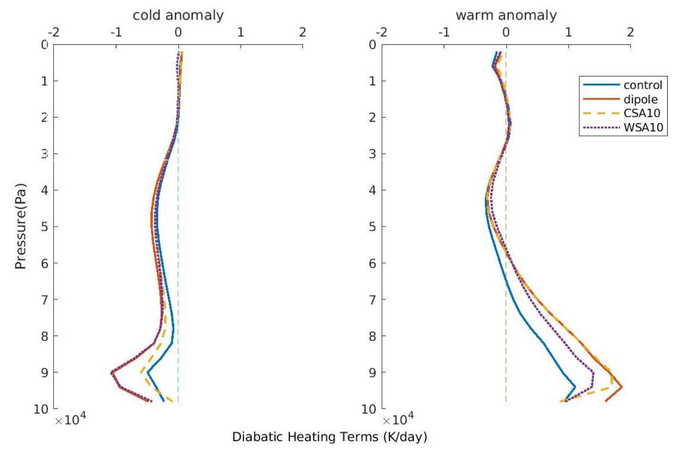
[shadings] Zonal wind U response at 990 hPa (m/s)
[contour] SST anomaly (1K gradient) [stippling] points with significance p < 0.05

- EKE response show that eddy activity is enhanced not only locally but further downstream. This response however is better represented in WSA case



[shadings] EKE* (Eddy Kinetic Energy, deviation from zonal mean) at 300hPa (m^2/s^2)

5. Discussion



Total diabatic heating rate averaged over the warm and cold anomaly (K/day)
[blue] control, [red] dipole, [yellow] CSA, [purple] WSA

- the CSA case closely follows the heating response of DIPOLE over the warm anomaly. Opposite is true over the cold anomaly.
- Need for further analysis of which physical processes is important in each sector and the reasons behind the difference.
- Future work: explore the change in response when using higher resolution model and investigate the physical mechanism responsible for it.

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.

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