

# **Indian Ocean dipole response to global warming: Analysis of ocean-atmospheric feedbacks in a coupled model**

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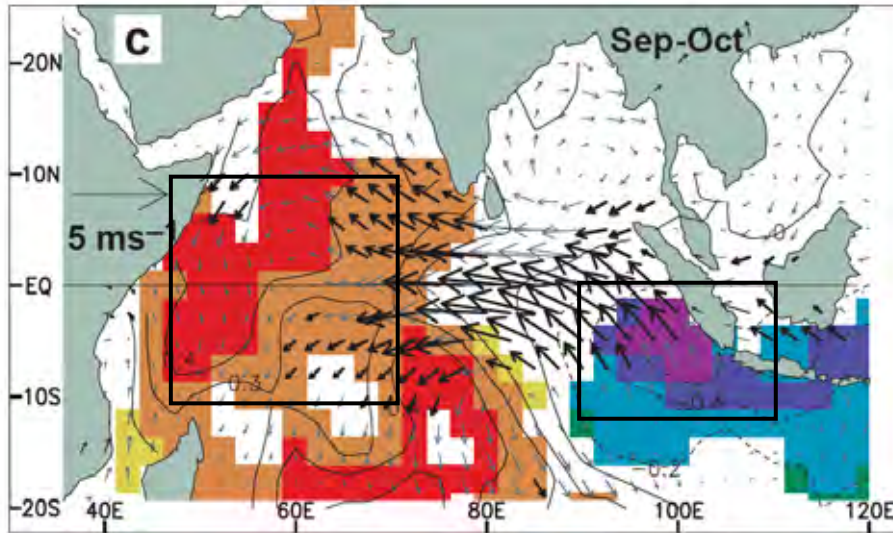
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**GREENHOUSE 2011  
4-8 April 2011, Cairns**

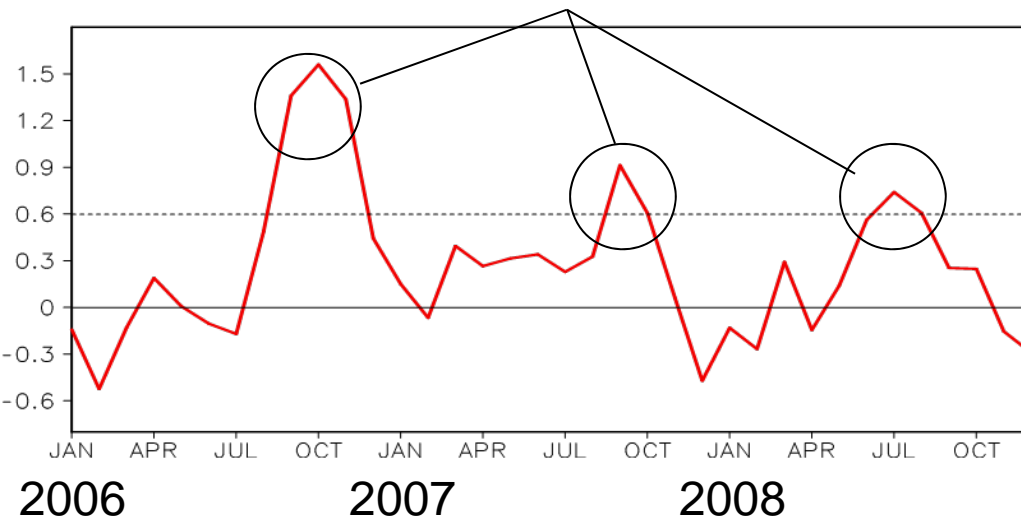
# IOD and its intensification



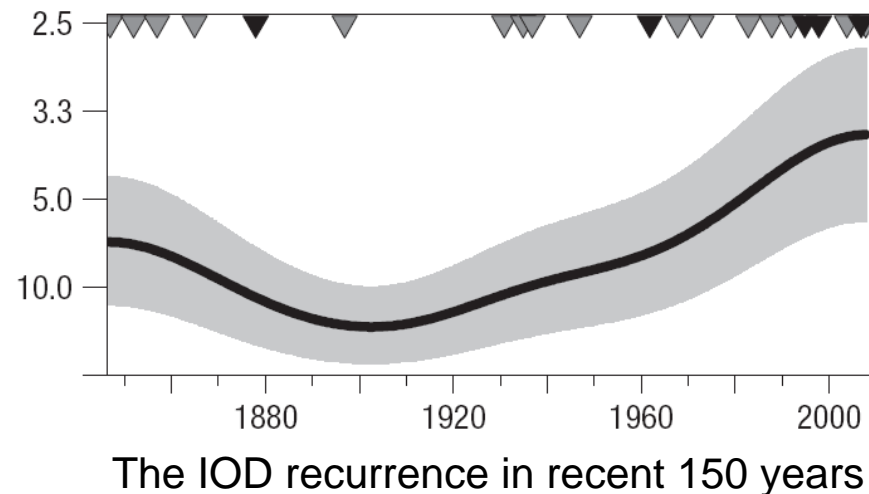
Indian Ocean Dipole (IOD) – SST and surface wind

Saji et al., 1999

Three consecutive **positive** IOD in 2006-2008

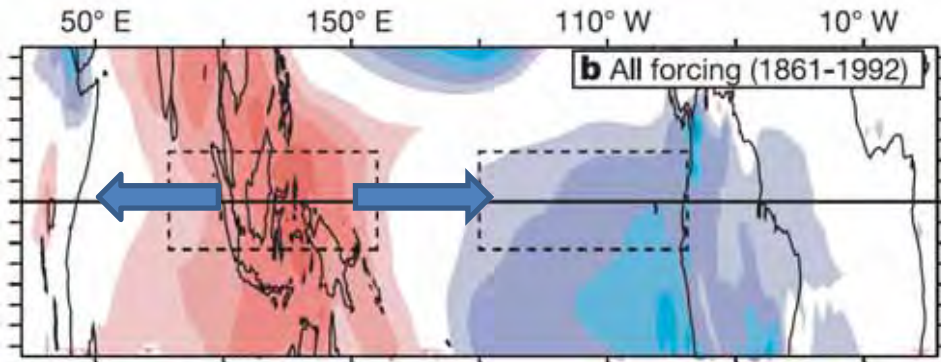


The IOD intensification in the 20<sup>th</sup> century. (Abram et al., 2008)

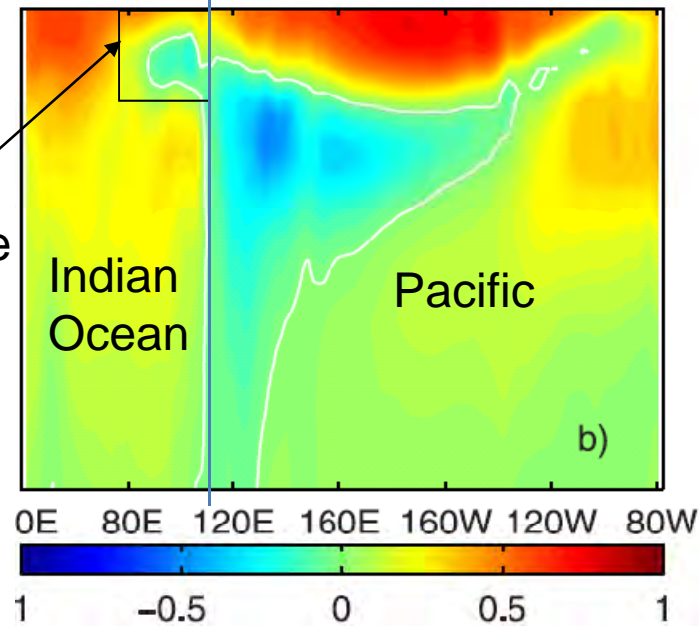


# IOD intensification : A result of global warming?

Sea level pressure



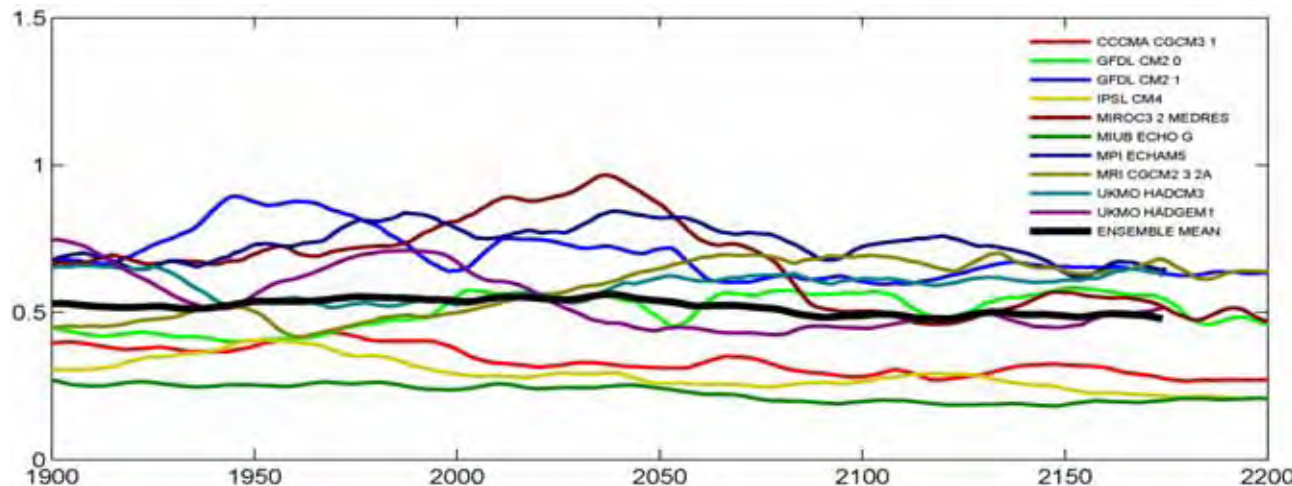
Shoaling thermocline



Walker circulation is weakened in global warming Vecchi et al., 2006

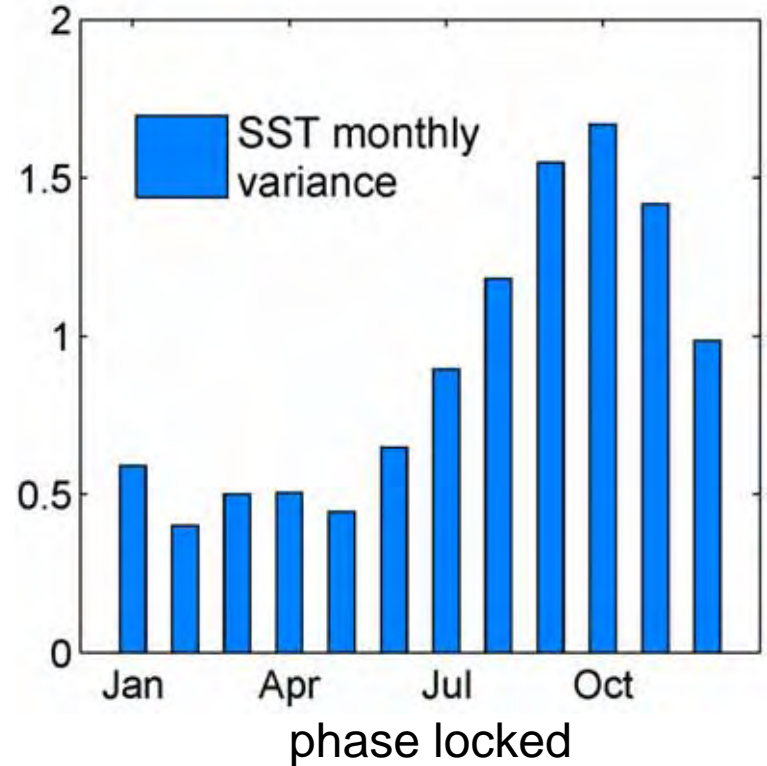
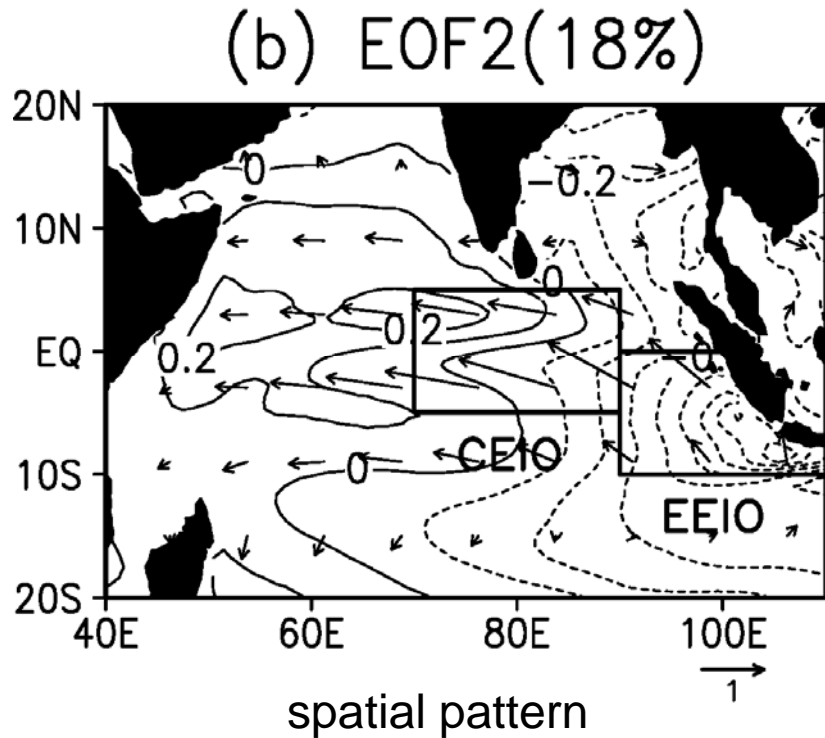
Du and Xie, 2008

No intensification in coupled models



50-year running IOD variance in IPCC global warming simulations.

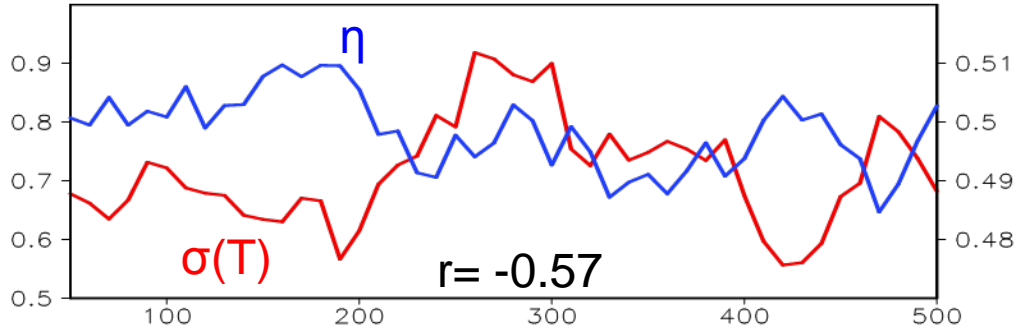
# Our work: investigating the IOD response to global warming in GFDL CM2.1



Question:

- Does IOD intensify in global warming following the thermocline shoaling? Why?

# In constant GHG control run: Thermocline depth plays a key role on IOD intensity

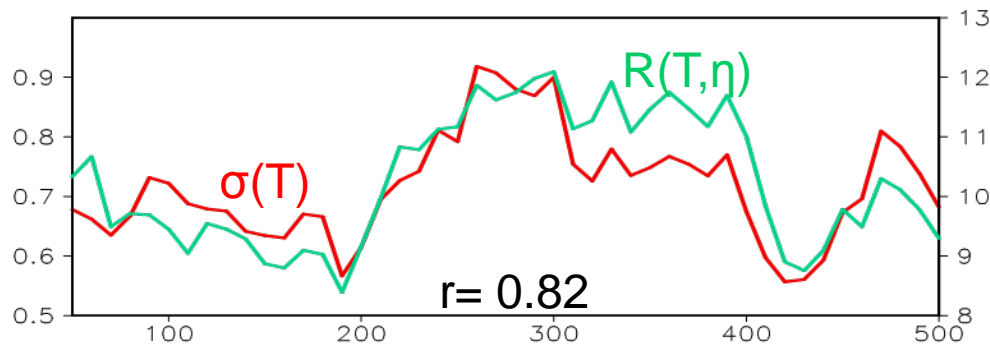


IOD intensity VS thermocline depth

Shallow thermocline



Strong thermocline feedback



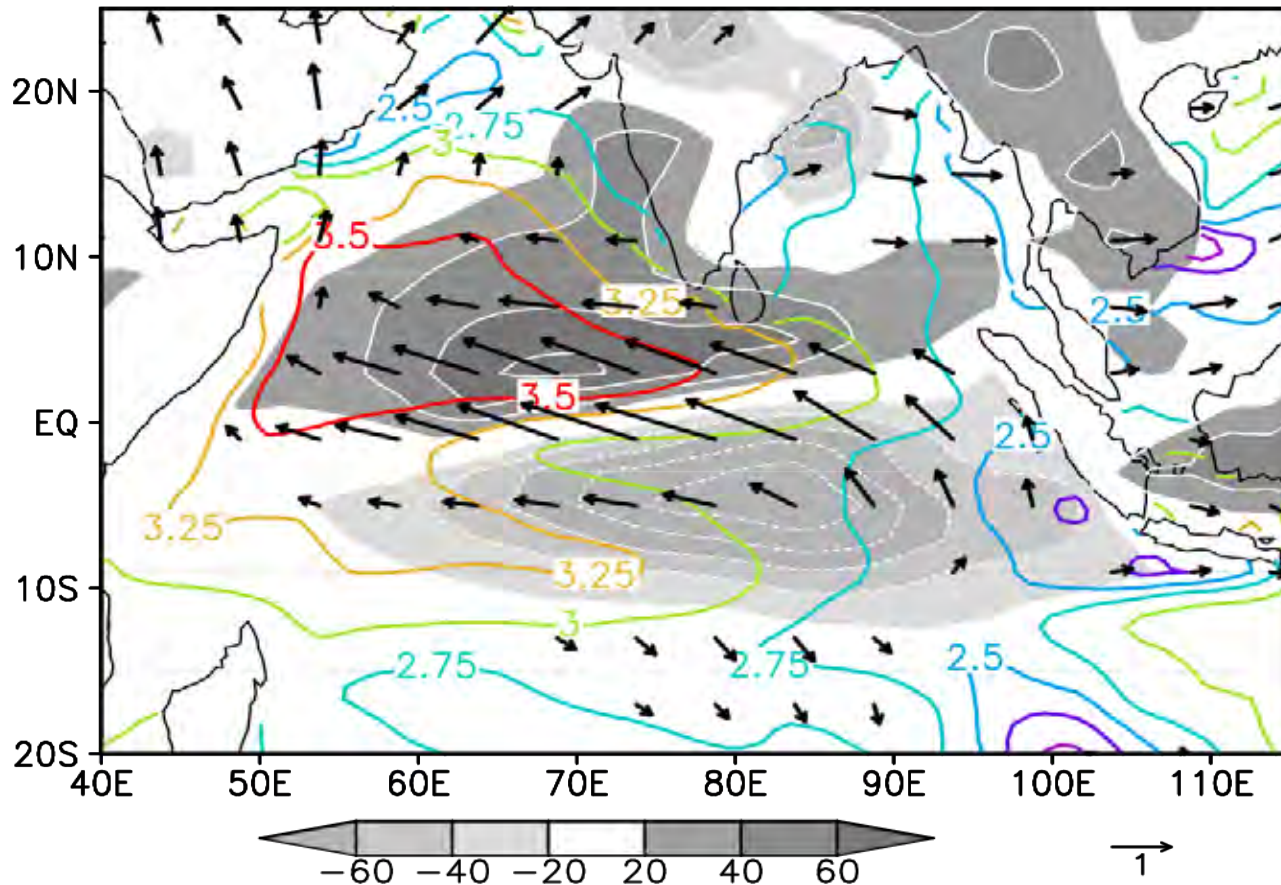
IOD intensity VS thermocline feedback



Strong IOD intensity

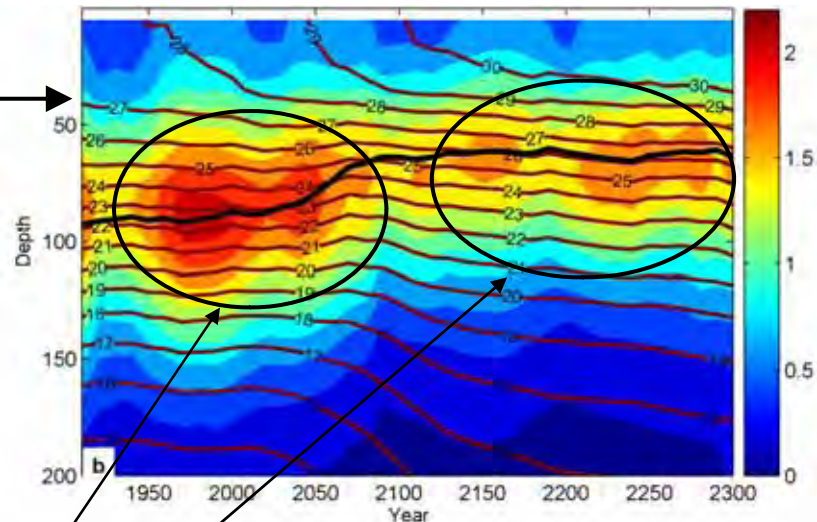
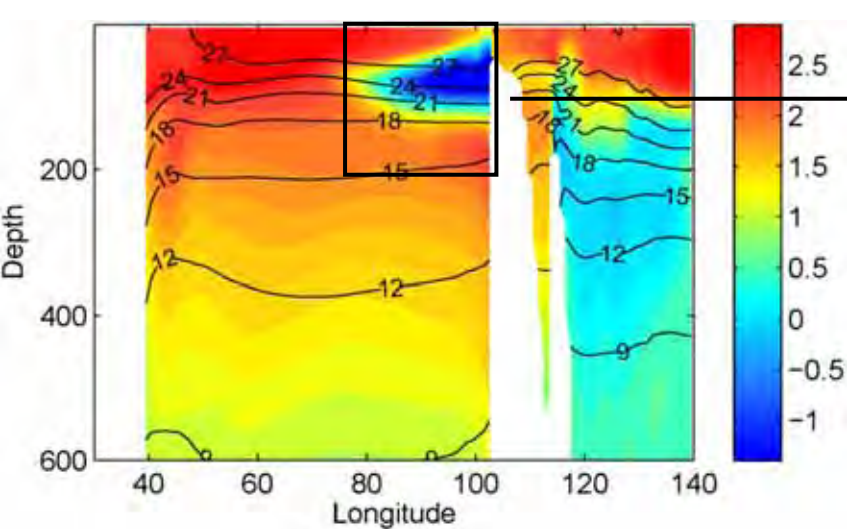
# Mean states change in global warming

## Weakened Walker circulation and dipole-like pattern



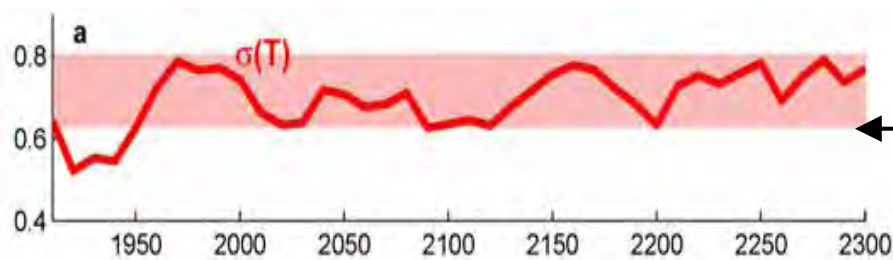
The changes of SST (contour), rainfall (shading) and surface wind (vector) during global warming in boreal summertime.

# EEIO: Thermocline shoaling, Unchanged SST variance

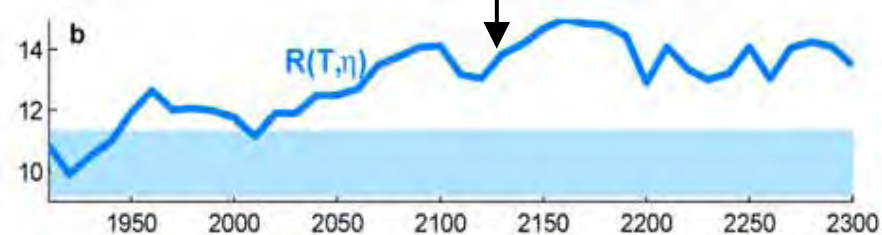


Warming trend (color) along the equator

Thermocline depth (Black line)  
Temperature variance (color)



Unchanged IOD variance

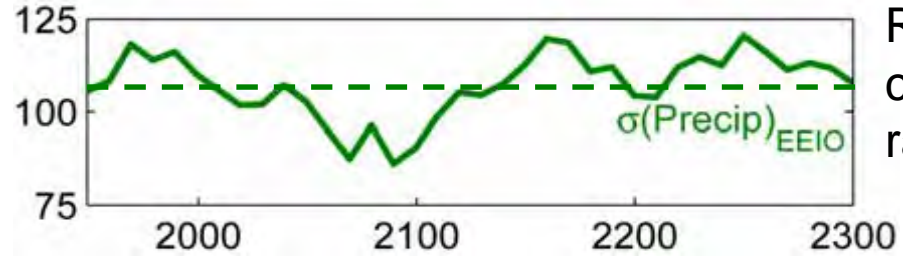
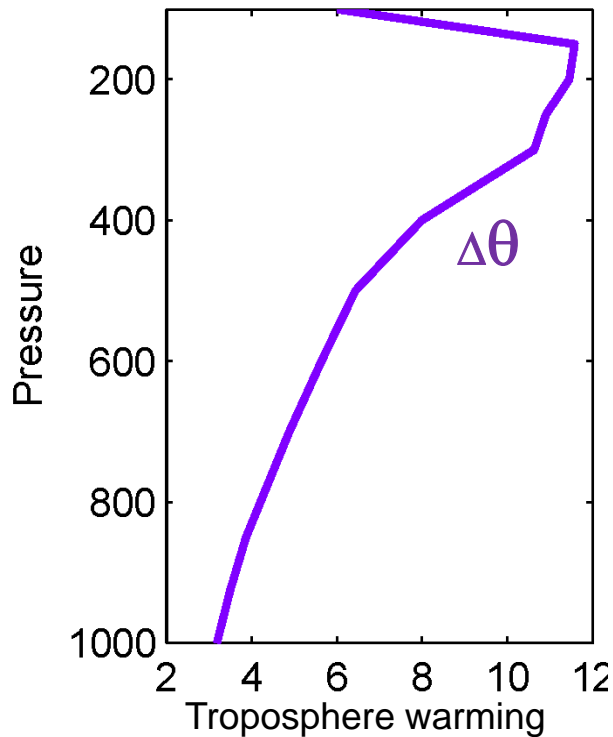


Thermocline feedback increasing

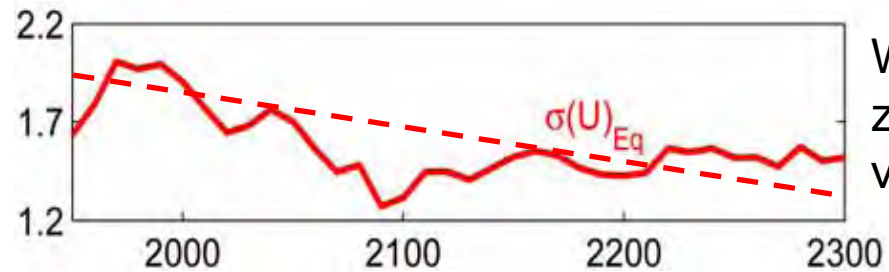
# Weakened zonal wind feedback

Our hypothesis:

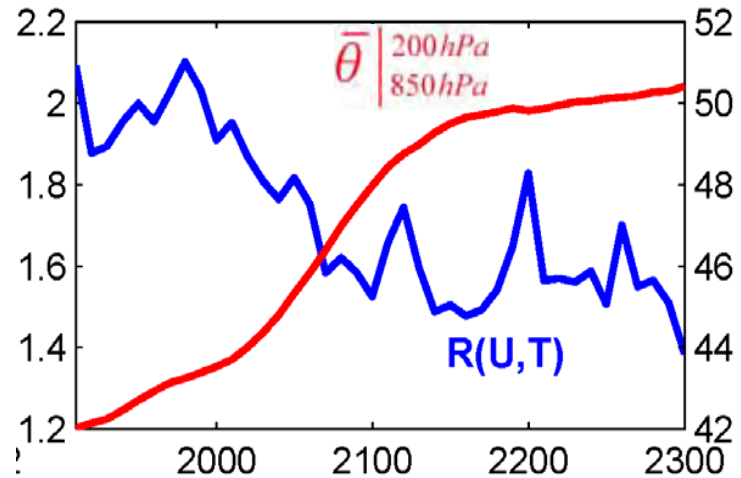
$$\omega'(\downarrow) \frac{\partial \bar{\theta}}{\partial p}(\uparrow) \sim Q' \text{ (const)}$$



Relative constant rainfall



Weakened zonal wind variability

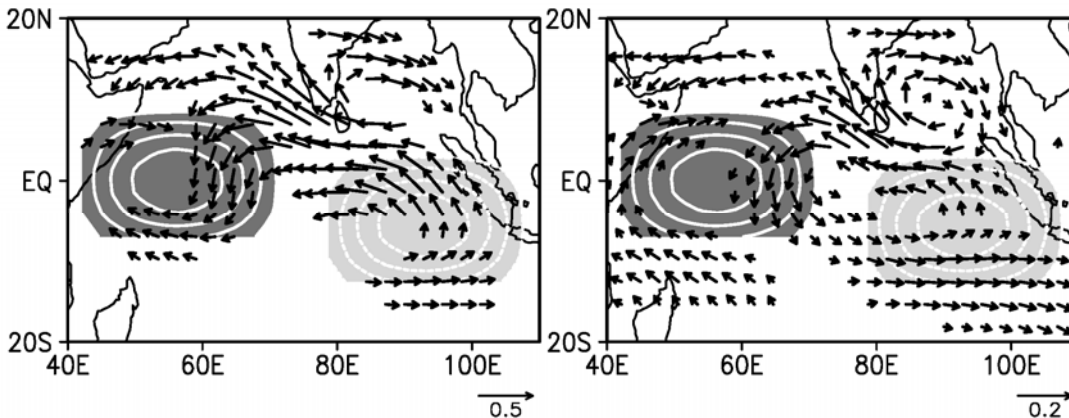
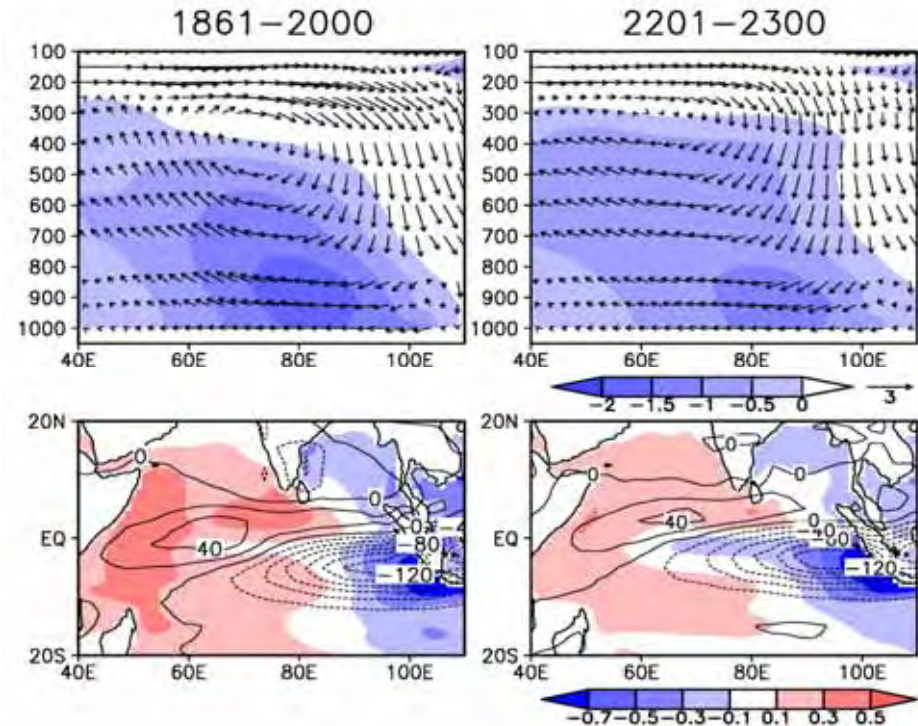


Atmospheric feedback is weakened.



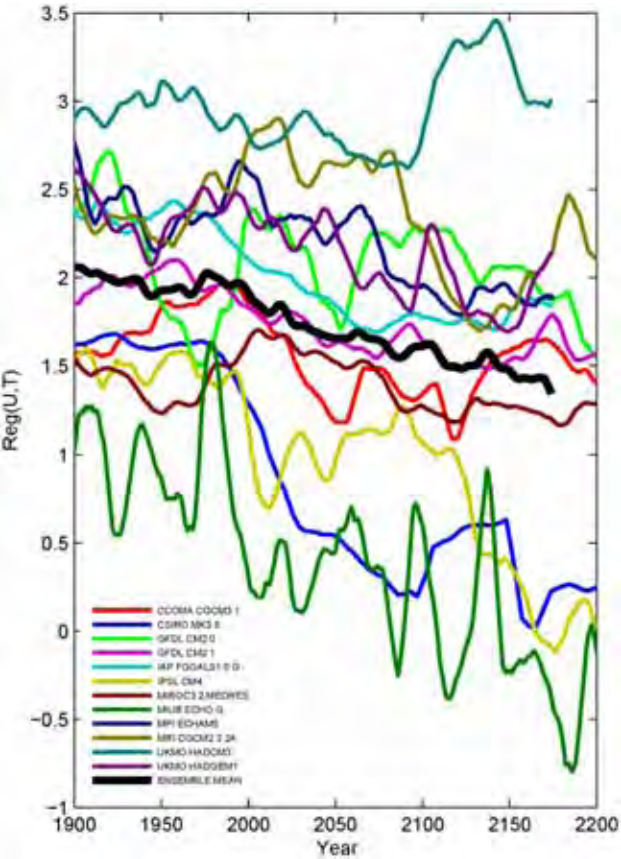
# The evidence of the weakened zonal wind feedback

The SVD results in different epochs support the weakened atmospheric feedback in global warming simulation.

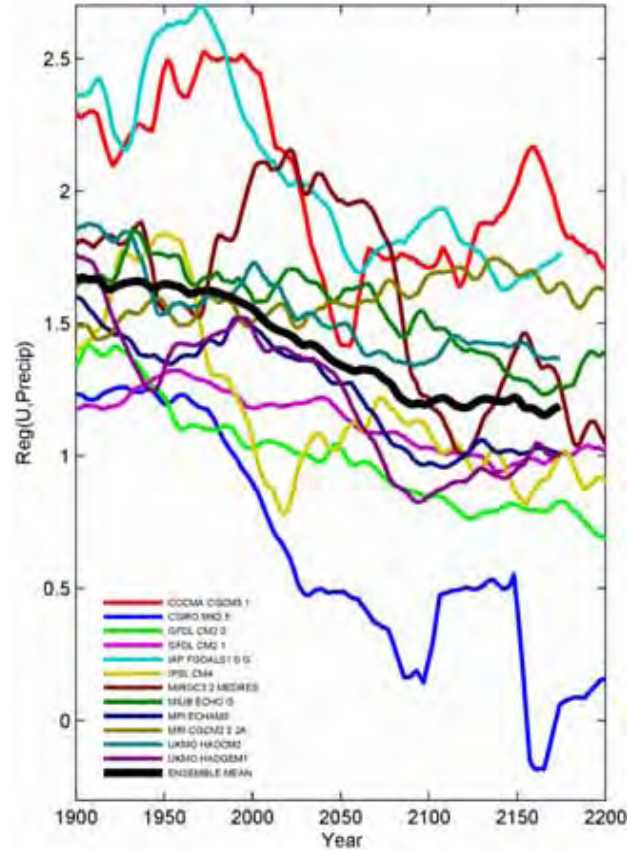


A simple LBM experiment is applied to test this hypothesis of the weakened feedback.

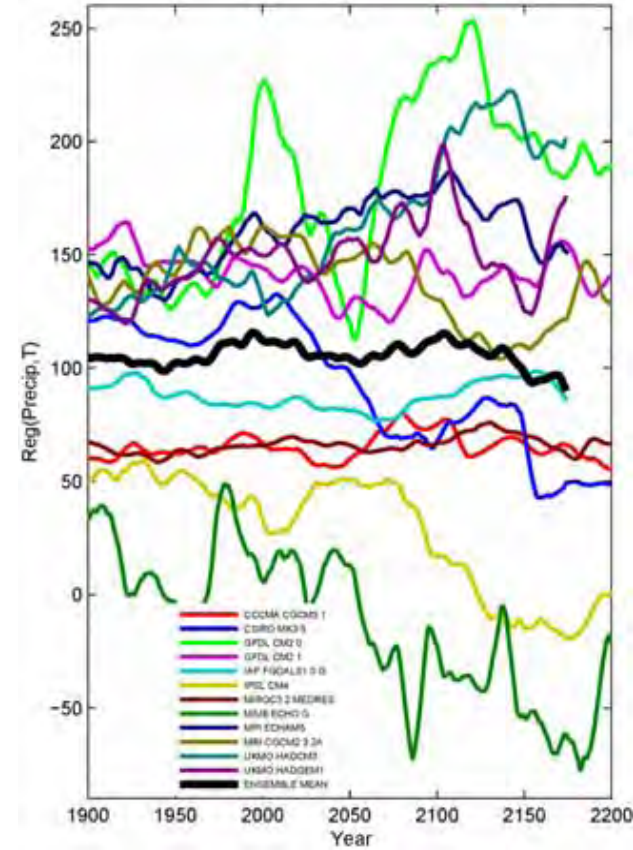
# Weakened atmospheric feedback: In multi-model



$R(U, SST)$



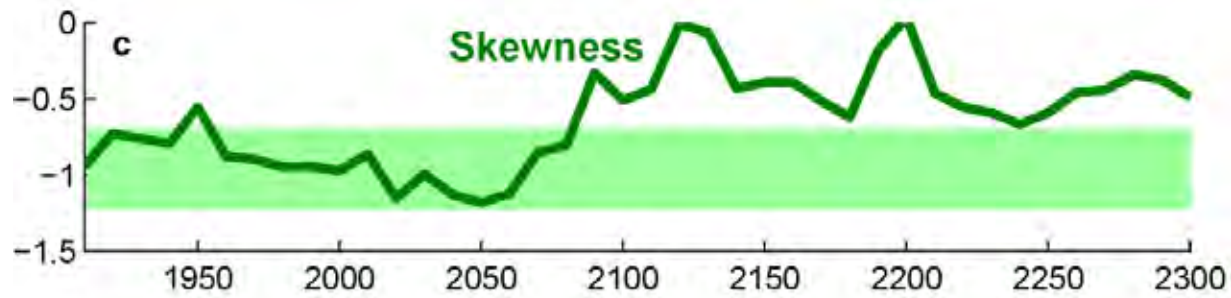
$R(U, Precip)$



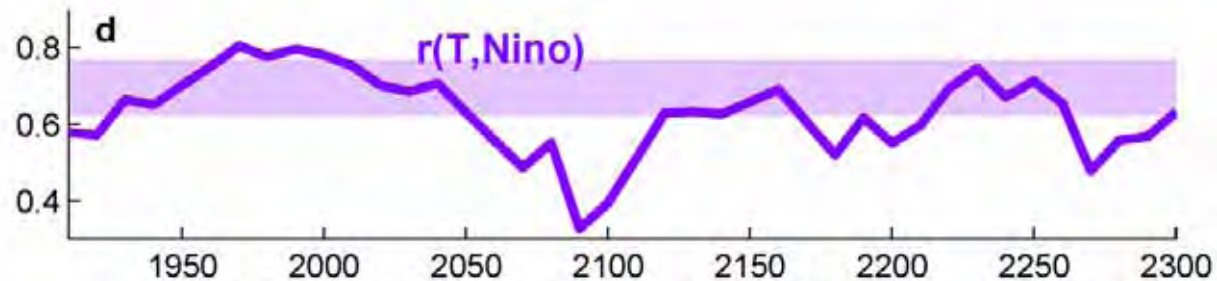
$R(Precip, SST)$

The weakened atmospheric feedback in the EEIO appears in most of the CMIP3 coupled models.

# Other features of IOD change in global warming



The IOD asymmetry weakens significantly under global warming.



The ENSO-IOD correlation seems to decrease slightly in a warmer climate.

# Summary

- The thermocline feedback associated with the thermocline depth in the EEIO during the boreal summer is very important for the intensity of IOD in the interdecadal timescale.
- In the global warming simulation, the thermocline in the EEIO is shoaling and thermocline feedback is enhanced.
- Opposing oceanic feedback, atmospheric stability is increased and zonal wind feedback is weakened.

# Summary

- The variance of IOD does not change much. Our results suggest that the recent IOD intensification might be likely part of natural low-frequency modulation instead of global warming.
- Other features change:
  - Asymmetry weakens significantly.
  - ENSO-IOD relationship decreases slightly.

The background is a smooth blue gradient. On the left side, there is a bright, glowing area that resembles a sun or a light source, with a vertical reflection of light extending downwards. The overall color palette is various shades of blue, from a deep, dark blue at the bottom to a lighter, almost white-blue at the top.

Thank you