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

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Indian Ocean Dipole (IOD) – SST and surface wind

Saji et al., 1999

The IOD intensification in the 20th century. (Abram et al., 2008)
IOD intensification: A result of global warming?

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

Shoaling thermocline

No intensification in coupled models (Du and Xie, 2008)

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

- **Shallow thermocline**
  - Strong thermocline feedback
  - Strong IOD intensity

- **Strong thermocline feedback**

- **Strong IOD intensity**
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:

\[ \omega' \left( \frac{\partial \overline{\theta}}{\partial p} \right) \sim Q' \ (\text{const}) \]

Atmospheric feedback is weakened.

Relative constant rainfall

Weakened zonal wind variability

Troposphere warming

\[ \Delta \theta \]

\[ \text{Pressure} \]

\[ \text{Troposphere warming} \]

\[ \text{Atmospheric feedback is weakened.} \]
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.
The weakened atmospheric feedback in the EEIO appears in most of the CMIP3 coupled models.
Other features of IOD change in global warming

- The ENSO-IOD correlation seems to decrease slightly in a warmer climate.
- The IOD asymmetry weakens significantly under global warming.
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.
Thank you