Transient development of the double-ITCZ bias in CESM1 and its sensitivity to convective parameterization

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Intertropical Convergence Zone (ITCZ)

GPCP (observations)

CMIP5 (models)

Hwang and Frierson (2013)
Double-ITCZ Bias in CESM1

- Excess precipitation in southern tropics
- Too cool SSTs over equator

Wang et al. (2015)
Theories for the double-ITCZ bias

• Extratropical controls
  - e.g. Hwang and Frierson (2013)

• Inadequate convective parameterization
  - e.g. Song and Zhang (2009), Oueslati and Bellon (2015)

• Coupled ocean-atmosphere feedbacks
  - e.g. Zhang et al. (2007), Liu et al. (2012)
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If convection plays a key role in coupled tropical feedbacks related to the double-ITCZ bias,
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If convection plays a key role in coupled tropical feedbacks related to the double-ITCZ bias, perturbations to convective parameterization should influence the development of the double-ITCZ bias.
Experimental Design
Experimental Design

[1] Spin up model components

Ocean/Sea Ice (CORE2 Forced; Large and Yeager, 2009)

Atmosphere IC (ERA Interim)

Land (CAS Atmo. Forcing; Qian et al., 2006)
Experimental Design

[1] Spin up model components

[2] Run stand alone models forward

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[1] Spin up model components
[2] Run stand alone models forward
[3] Initialize fully coupled simulations from stand alone simulations

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1981-01

Initial conditions for coupled run taken from this point
Experimental Design

[1] Spin up model components

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Initial conditions for coupled run taken from this point

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Atmosphere IC
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Land
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1981-01
1986-01
1991-01
Experimental Design

[1] Spin up model components
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Ocean/Sea Ice
(CORE2 Forced; Large and Yeager, 2009)

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Land
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Initial conditions for coupled run taken from this point

Convective parameterizations

**CTRL & NOSP**
- UW shallow convection (Park and Bretherton, 2009)
- ZM deep convection (Zhang and McFarlane, 1995)

**NODC**
- UW shallow convection (Park and Bretherton, 2009)
  - ZM deep convection (Zhang and McFarlane, 1995)

**SP**
- Embedded 2D cloud-resolving model (Grabowski, 2001)
Other model details

- CTRL and NODC use CESM1.2.2
- NOSP and SP built from CESM1.1

Diagram:

- **Atmosphere (2°)**
  - CAM5, Finite Volume
  - Prescribe Aerosols

- **Sea Ice (1°)**
  - CICE4

- **Ocean (1°)**
  - POP2

- **Land (2°)**
  - CLM4.0
  - Satellite Phenology
Comparison datasets

**SODA** – Carton and Geiss (2008)
Sea surface temperature (SST)
Surface wind stress ($\tau$)
Ocean velocities

**GPCP** – Huffman et al. (2009)
Precipitation
Precipitation
Feb. 1981
Precipitation
Feb. 1981

• Dry bias over equator in all simulations
Precipitation Feb. 1981

- Dry bias over equator in all simulations
- Excess precipitation in SE Pacific
Precipitation
Feb. 1981

- Dry bias over equator in all simulations
- Excess precipitation in SE Pacific

Take zonal mean over central Pacific (180-220°E)
Precipitation Hovmoller (180-220°E)
• SP able to produce precipitation over the equator
Precipitation Hovmoller (180-220°E)

- SP able to produce precipitation over the equator

- ITCZ shifts: poleward in NODC and equatorward in SP
Effect of $\Delta$Conv. Parameterization

$\Delta$Precipitation

- $NODC, mean-CTRL, mean$  
  $\theta=[180, 220]$  
  $\beta=-20$ to $20$

- $SP, mean-NOSP, mean$

Latitude vs. Time (mon)

$PRECT$ (mm/d)
Effect of ΔConv. Parameterization

ΔZonal wind stress

ΔZonal wind stress

Latitude

Time (mon)

TAUX (N/m²)
SST-Obs
Hovmoller (180-220°E)

Carton and Geiss (2008)
SST-Obs

Hovmoller (180-220°E)

Cold tongue bias:

• Develops rapidly with amplitude of 1.5 K by month 2 in CTRL
SST-Obs
Hovmoller (180-220°E)

Cold tongue bias:
• Develops rapidly with amplitude of 1.5 K by month 2 in CTRL
• Amplified in NODC
• Reduced in SP

Carton and Geiss (2008)
Effect of $\Delta$Conv. Parameterization

Cyclonic vorticity shifts
- Poleward in NODC
- Equatorward in SP
Effect of $\Delta$Conv. Parameterization

Cyclonic vorticity shifts
- Poleward in NODC
- Equatorward in SP
Effect of $\Delta$Conv. Parameterization

Cyclonic vorticity shifts

- Poleward in NODC
- Equatorward in SP

which affects surface currents
Effect of $\Delta$Conv. Parameterization

Cyclonic vorticity shifts

- Poleward in NODC
- Equatorward in SP

which affects surface currents
But what about the SE Pacific?
But what about the SE Pacific?
But what about the SE Pacific?

Little change in SE Pacific double-ITCZ
Conclusions

Varying convective parameterization can improve cold tongue bias.

• At the cost of degrading near-equatorial wind stress field
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Meridional shift in wind stress curl may play an overarching role in tropical response.
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Double-ITCZ develops regardless of convective parameterization employed.
Conclusions

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  • At the cost of degrading near-equatorial wind stress field

Meridional shift in wind stress curl may play an overarching role in tropical response.

Double-ITCZ develops regardless of convective parameterization employed.