Enhanced vertical atmosphere resolution improves climate model simulation of tropical Atlantic SST and interannual variability

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OS1.7: Tropical & Subtropical Ocean Circulation, Equatorial to Mid-Latitude Air-Sea Interactions

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Enhanced Vertical Atmosphere Resolution Improves Climate Model Simulation

Jan Harlaß

Motivation

Model
SST
Precipitation
Equator
Benguela Region
Variability
Summary

Tropical Atlantic SST bias in CMIP 3 & 5

(a) CMIP5-Reynolds
(b) CMIP3-Reynolds
(c) CMIP3-CMIP5
(d) [Xu et al. 2014]
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Subsurface temperature bias
1° wide band along the coast

[Figure showing temperature variations across latitude and longitude, labeled CMIP5, CFSR, and CMIP5 - CFSR]

[Xu et al. 2014]
Contours: precipitation bias (mm/day), Vectors: surface wind bias (m/s)

[Richter & Xie 2008]
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Higher model resolution
Annual mean SST bias

CM 2.1, ATM: 200 km L24, Ocean: 100km L50

CM 2.5, ATM: 50 km L32, Ocean: 28km L50

[Delworth et al. 2014]
ORCA2

- $2^\circ \times 2^\circ$
- Latitudinal refinement
- 31 levels
- No changes

KIEL CLIMATE MODEL SYSTEM (KCMS)

**Atmosphere**

ECHAM5

**Coupler**

OASIS3/4

**Ocean circulation**

OPA9

**Sea ice**

LIM2/3

**Biogeochemistry**

Nucleus for European Modelling of the Ocean (NEMO):

ORCA2 / ORCA05 / ORCA025 / ORCA12 / AGRIF

[Park et al. 2009]
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Motivation

Kiel Climate Model (KCM)

Model design

Kiel Climate Model (KCM)

ORCA2

- 2° x 2°
- latitudinal refinement
- 31 levels
- No changes

ECHAM5

- T42 (2.8°, ~300km)
- L31 / L62
- LR / LR_V

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[Park et al. 2009]
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Model design
Kiel Climate Model (KCM)

**ORCA2**

- 2° x 2°
- Latitudinal refinement
- 31 levels
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**ECHAM5**

- T42 (2.8°, ~300km) L31 / L62 LR / LR_V
- T159 (0.75°, ~80km) L31 / L62 HR / HR_V

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[Park et al. 2009]
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SST bias
July-September [JAS]
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Total Precipitation bias
JAS

(a) LR
(b) HR
(c) LR-V
(d) HR-V

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Zonal section along the equator
3° S-3° N, JAS

(a) SST

(c) Zonal wind stress

HadISST
LR
LR_V
HR
HR_V
Temperature bias
5° S-5° N, annual average

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Meridional velocity
Zonally averaged over 3 gridpoints from the coast, annual average

[Xu et al. 2014]
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Interannual variability
Standard deviation of SST in ATL3 (20°W-0°E, 3°S-3°N)

HadISST  LR  LR_V  HR  HR_V
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Regression ATL3 index on SST
JAS, Contours: HadISST, Shading: bias
Summary

- Increased atmospheric **horizontal** resolution reduces Tropical Atlantic SST bias (T42->T159)
- Spatial bias pattern remains
**Summary**

- Increased atmospheric **horizontal** resolution reduces Tropical Atlantic SST bias (T42->T159)
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- **High** resolution in both the **horizontal** and **vertical** strongly reduced biases in the Tropical Atlantic (T159 L62)
- Improved mean state in the ocean and the atmosphere
- Improved interannual variability
Summary

- Increased atmospheric **horizontal** resolution reduces Tropical Atlantic SST bias (T42->T159)
- Spatial bias pattern remains

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- Consistent choice of horizontal and vertical resolution!
Thank you for your attention!


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Delworth, T. L., Rosati, A., Anderson, ... (2012). Simulated Climate and Climate Change in the GFDL CM2.5 High-Resolution Coupled Climate Model. Journal of Climate, 25(8), 2755–2781. doi:10.1175/JCLI-D-11-00316.1


Xu, Z., Chang, P., Richter, I., ... (2014). Diagnosing southeast tropical Atlantic SST and ocean circulation biases in the CMIP5 ensemble. Climate Dynamics, 43(11), 3123–3145. doi:10.1007/s00382-014-2247-9