Tracing the origins of tropical SST biases in CESM through a hindcast approach

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Mean SST biases in CMIP5 models

- CMIP5 models suffer from biases in SST over the tropics such as:
  1. reversed SST gradient in the equatorial Atlantic
  2. too cold equatorial Pacific SST
  3. anomalous warm SST at southeastern Atlantic and Pacific coasts

- **Hypothesis:** Biases in SST represent the average effects of biases in fast processes (e.g. clouds, precipitation, wind stress) and are visible within simulations of a few months.
Research Questions

Question 1: Is there a correspondence between short and long-term tropical SST errors?

Question 2: What are the relative contributions of the atmospheric and oceanic component of the model to the SST biases?
Modeling Evaluation Framework

Question 1

T-CMIP/C-CAPT

Question 2

Bias correspondence

T-AMIP/CAPT

GCMs

AMIP

CORE

CMIP

Bias correspondence
Datasets

- **CESM1 LENS** Historical simulation ensemble mean (1980-2005)
- **2005 CCAPT** CESM run in 6-month long hindcast mode for 2005
- **AMIP CAM5.1** Simulations with prescribed SSTs (1997-2012)
- **Long-term AMIP CAPT CAM 5.1** run in 3-day long hindcast mode (1997-2012)
Does CESM have similar mean SST biases to the CMIP5 MMM?

- CESM1 (LENS) shows similar tropical SST bias patterns, although weaker in magnitude.
Question 1: What is the correspondence of short and long-term tropical SST errors?
SST bias growth through 1-6 months hindcast lead time

ANN mean bias

Ref: OISST
SST bias growth: case of the tropical Atlantic

ANN mean bias

Ref: OISST
Annual cycle of the equatorial Atlantic (5°S-5°N) SST bias

OBS monthly climatology

MON mean bias

lead time = 1 month

CESM1

5 months

6 months
Annual cycle of the southeastern tropical Atlantic (10°S-20°S) SST bias

OBS monthly climatology

MON mean bias

OISST

lead time = 1 month

MON mean bias

CESM1

6 months
Possible reasons for the SST biases

\[ \frac{\partial T_m}{\partial t} = \frac{Q_{net}}{\rho C_p h_m} - \nabla \cdot \mathbf{T} \]

- Too strong westerly winds (Chang, 2007; Richter and Xie, 2008)
- Southward Atlantic ITCZ (Richter et al., 2013)
- Underestimated stratus cloud cover/overestimated SW flux (Huang, 2007)
- Coupling with the equatorial Atlantic bias (Toniozzo et al., 2013)
- Resolution of topography (Milinksi, 2016)
Question 2: What are the relative contributions of the atmospheric and oceanic component of the model to the SST biases?
Biases in surface radiative and turbulent fluxes

JJA bias

- LW
- SW
- Turbulent Fluxes
- Net Flux
- SST

- CESM1 LENS
- CCAPT 6 months lead time
- CAM5.1
- ACAPT Day3

Ref: NOCSv2

heat loss by ocean  heat gain by ocean
The coupled CAPT framework is used to diagnose the sources of tropical SST biases in CESM

Preliminary analysis of the coupled CAPT runs indicate that SST biases along the southeastern tropical Atlantic emerge within 1 month lead time, and after 1 month lead time for the equatorial Atlantic

The CCAPT framework will be used together with AMIP/ACAPT and CORE analysis to identify the atmospheric and oceanic contributions

Next steps: sea surface/mixed-layer heat budget analysis of CCAPT