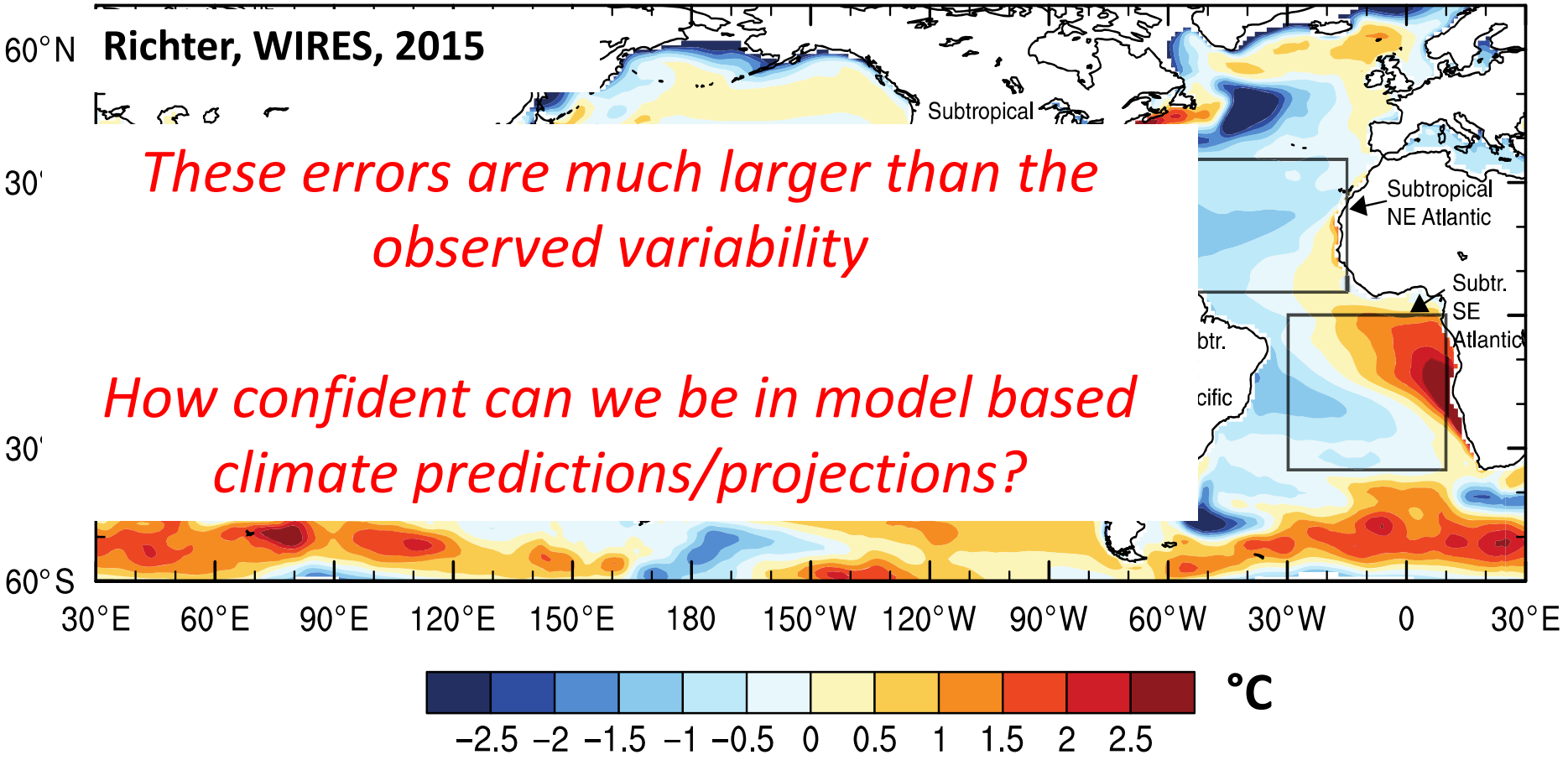
Impact of Tropical Atlantic biases in climate predictions/projections

Noel Keenlyside
Geophysical Institute, University of Bergen

Shunya Koseki, Teferi Demissie, Francois Counillon

Model biases in the South Eastern Tropical Atlantic among the most severe

CMIP5 multi-model mean sea surface temperature error



These errors are much larger than the observed variability

How confident can we be in model based climate predictions/projections?

Bjerknes Centre for Climate Research

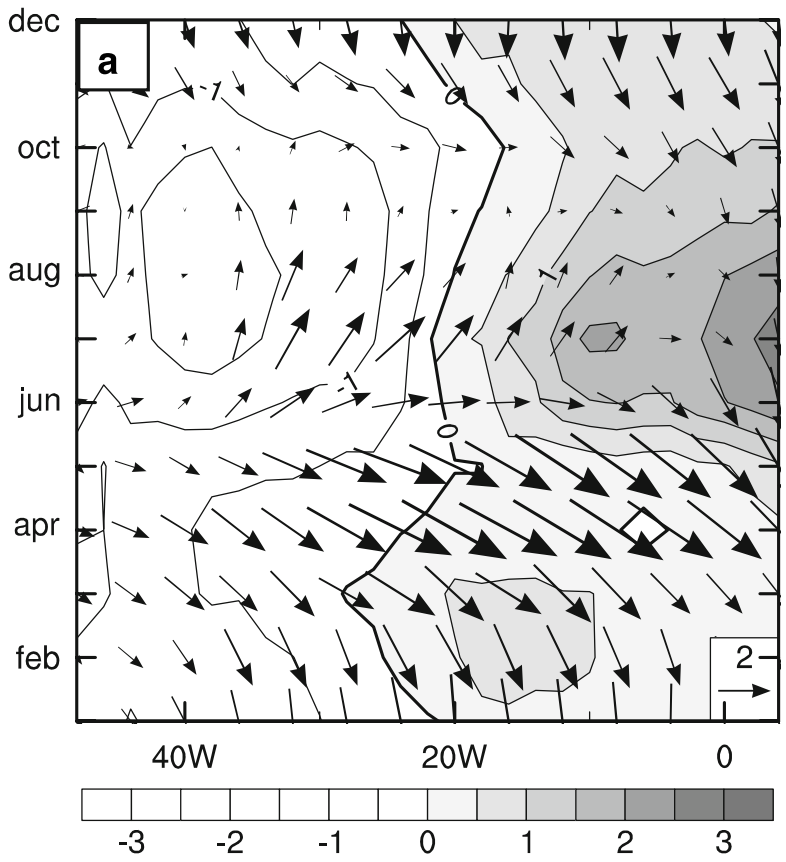
Origin of coupled model biases in the Tropical Atlantic

Bjerknes Centre for Climate Research

Equatorial Atlantic SST bias caused by too weak winds in boreal spring in atmospheric models

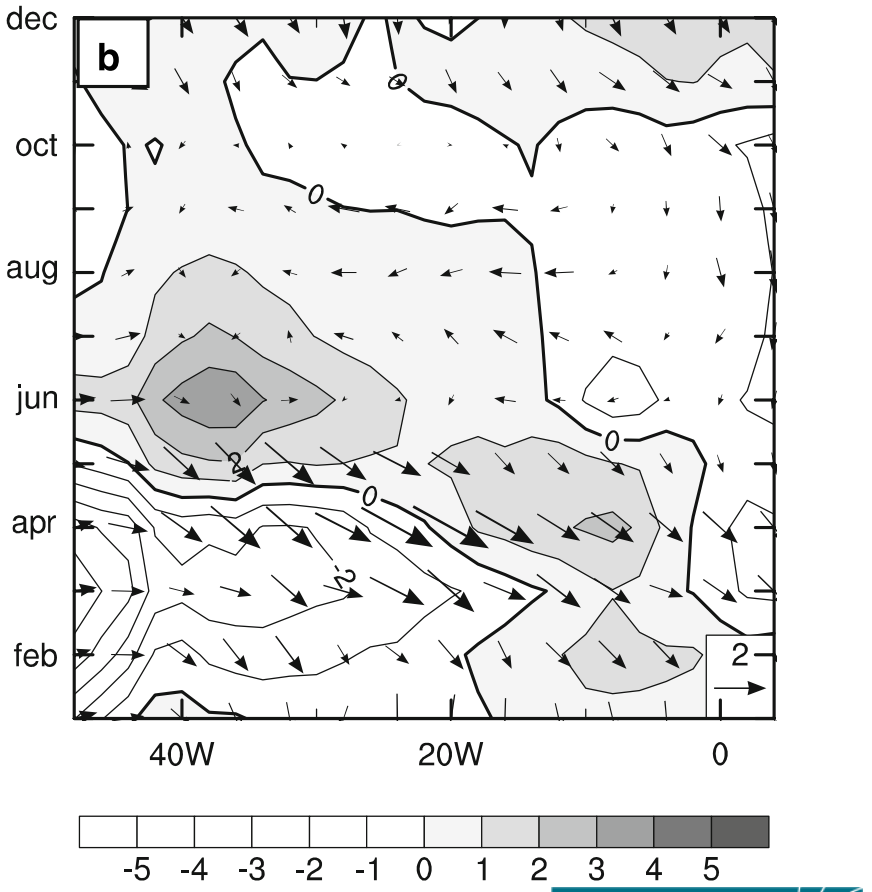
Seasonal biases along the equator from CMIP3

Coupled: SST (con.), wind vectors



Richter et al. 2008

Atmos. only: Precipitation (con.) wind vectors



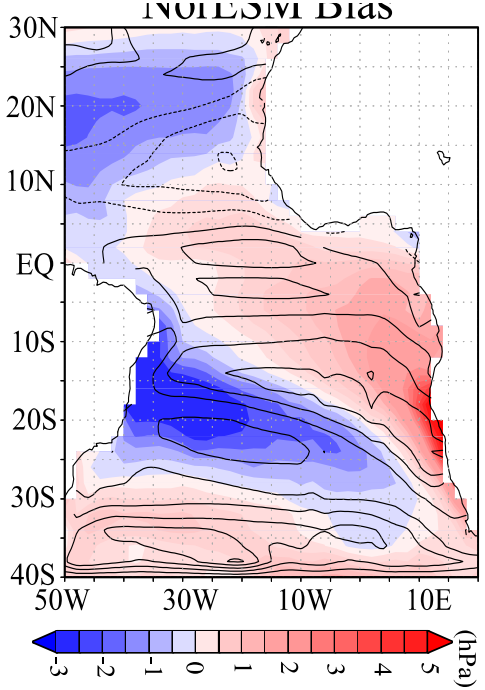
Bjerknes Centre for Climate Research

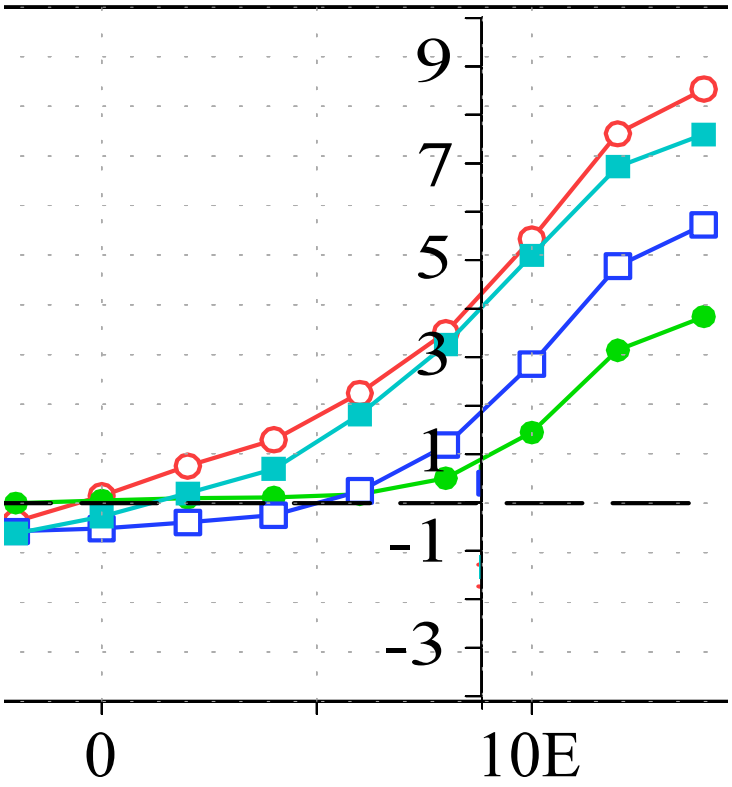
NorESM SST bias in Angola-Benguela Front Zone:

50% in ocean only runs+ 25% from atmosphere wind errors

Annual mean SST bias averaged between 17-22S

NorESM and uncoupled sensitivity experiments





NorESM =

Heat flux discrepancies +

Local atmospheric model error +

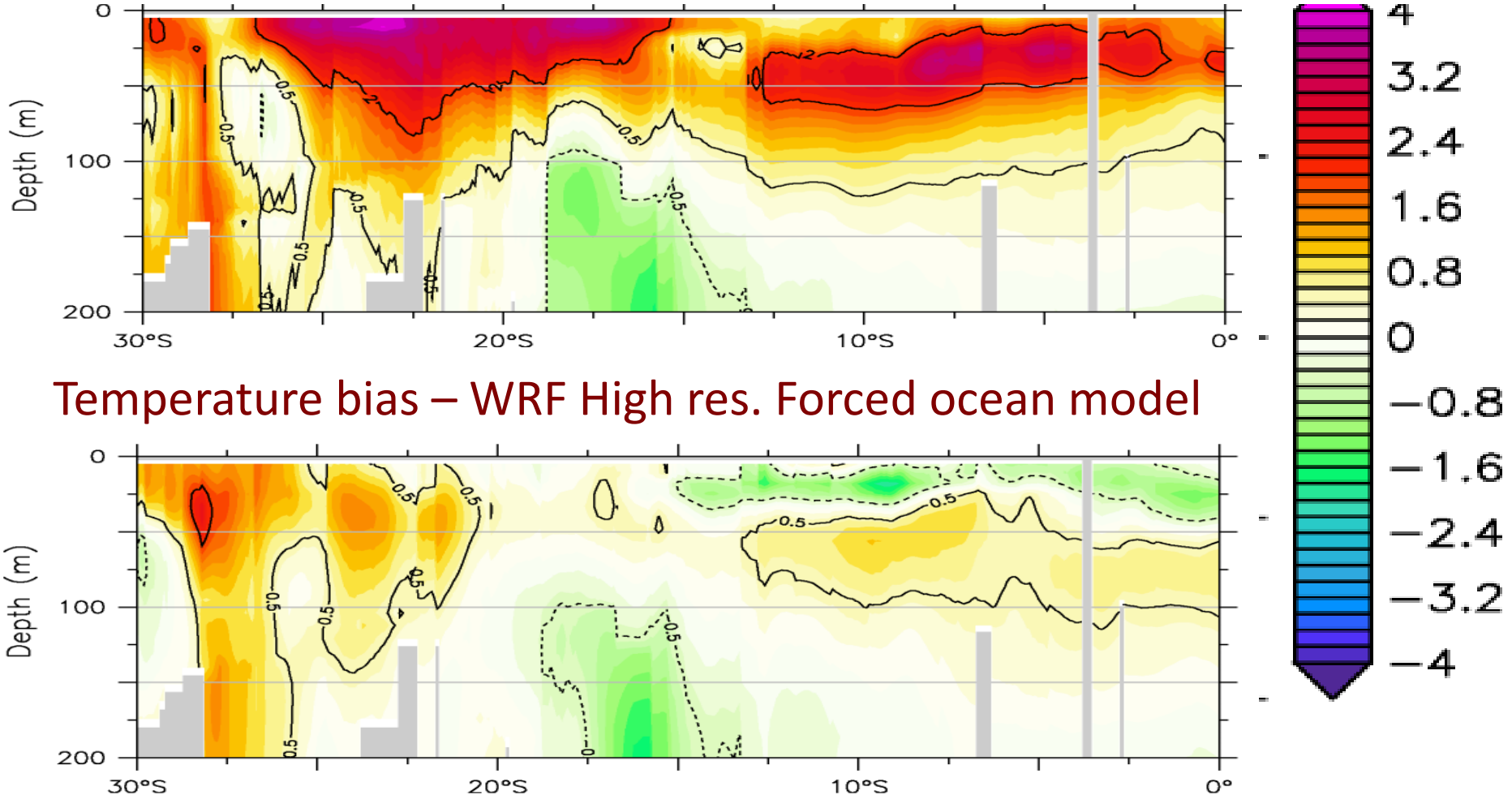
CORE-II MICOM,

Koseki et al. 2008

Bjerknes Centre for Climate Research

Weak Benguela Low-Level Jet causes Southeast Tropical Atlantic SST Bias

Temperature bias – CORE2 forced regional ocean model

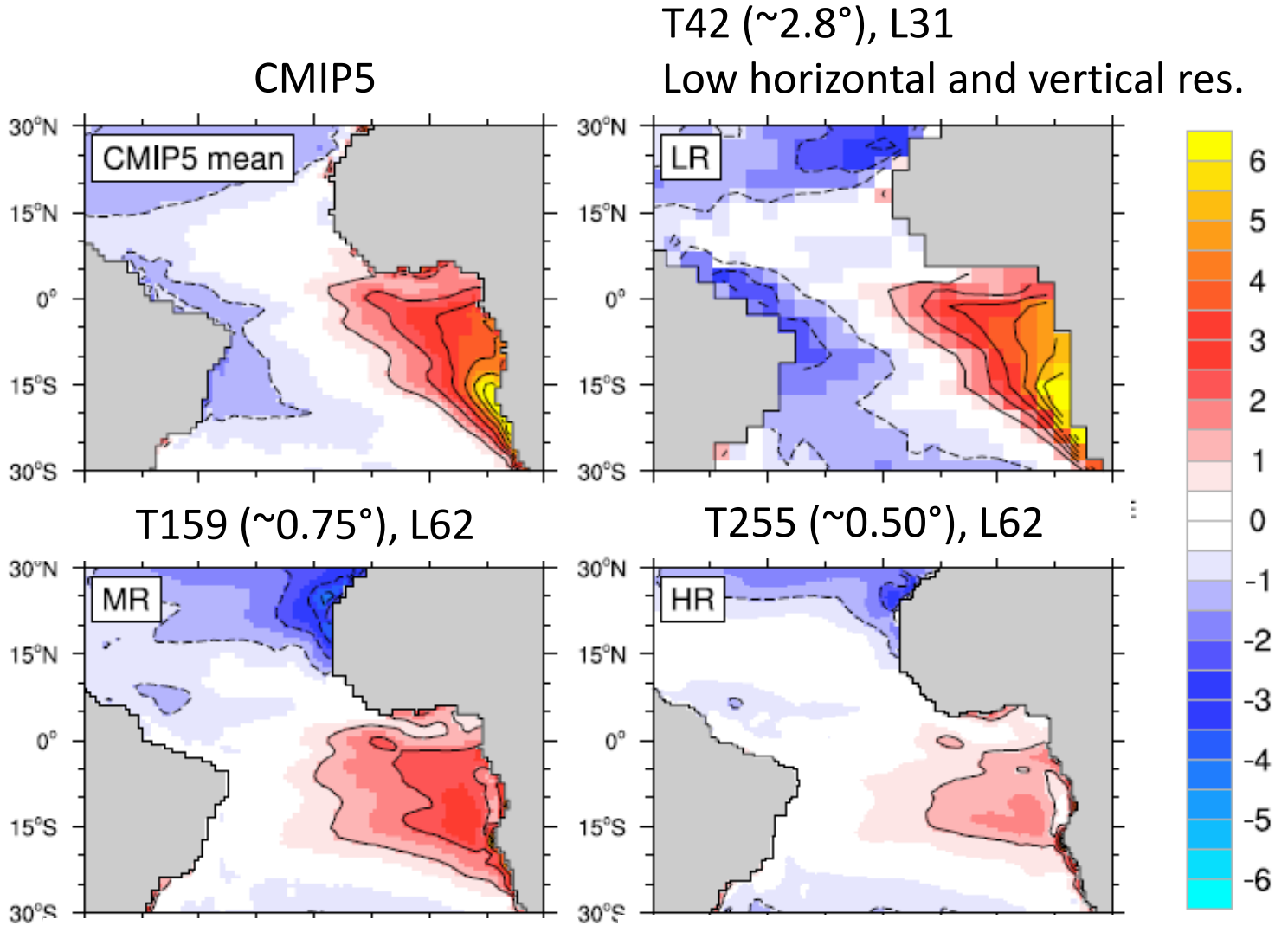


Temperature bias – WRF High res. Forced ocean model

Courtesy Ping Chang

Bjerknes Centre for Climate Research

Increasing resolution mitigates the JAS SST biases in KCM



Harlaß et al. 2016

Causes of Tropical Atlantic model biases

Equatorial SST errors

- To weak westerly winds in MAM, intrinsic to atmospheric models, and linked to precipitation
- Vertical momentum mixing in the lower atmosphere important
- Ocean stratification from insufficient vertical mixing or surface fresh water biases may contribute

South Eastern Tropical Atlantic SST errors

- Weak coastal winds and erroneous negative wind stress curl from (low res.) atmospheric model components
- High oceanic resolution (0.1 deg.) is required to further mitigate errors
- Shortwave flux errors can contribute to the large-scale error pattern

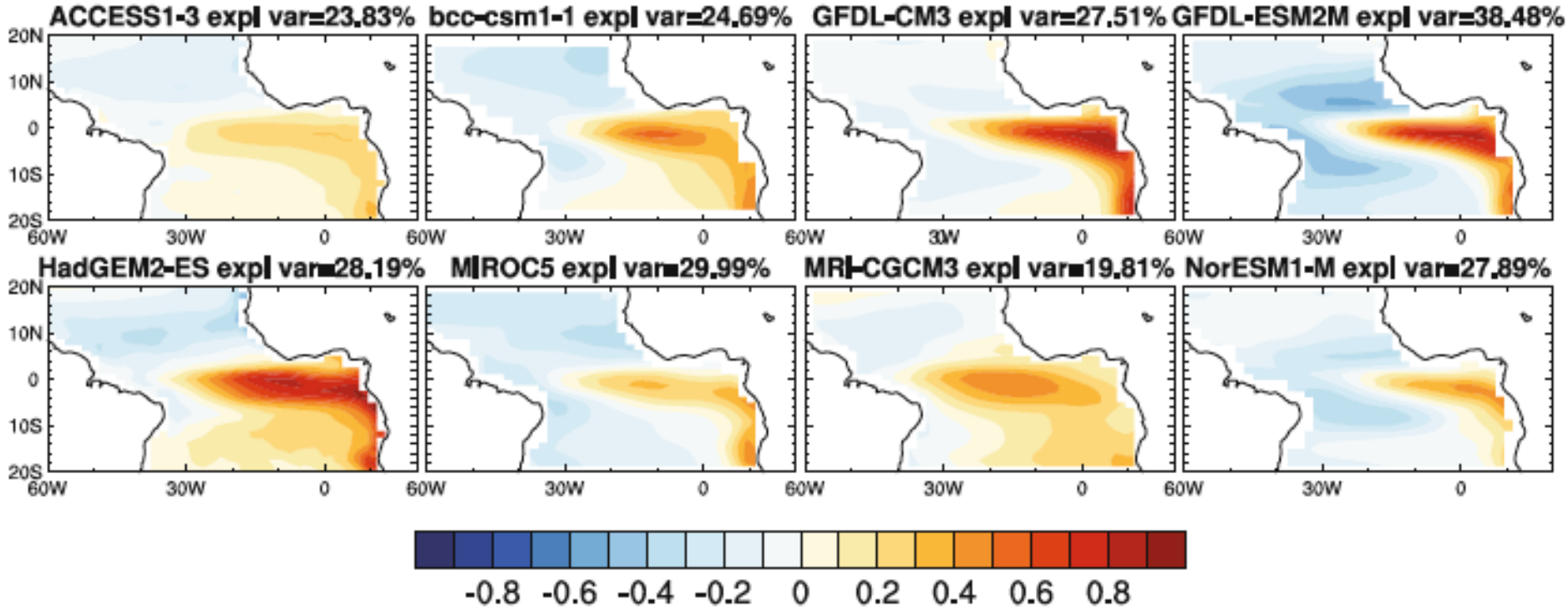
Bjerknes Centre for Climate Research

Consequences of coupled model biases for tropical Atlantic variability

Bjerknes Centre
for Climate Research

Despite large mean systematic errors, models still simulate Atlantic Nino variability

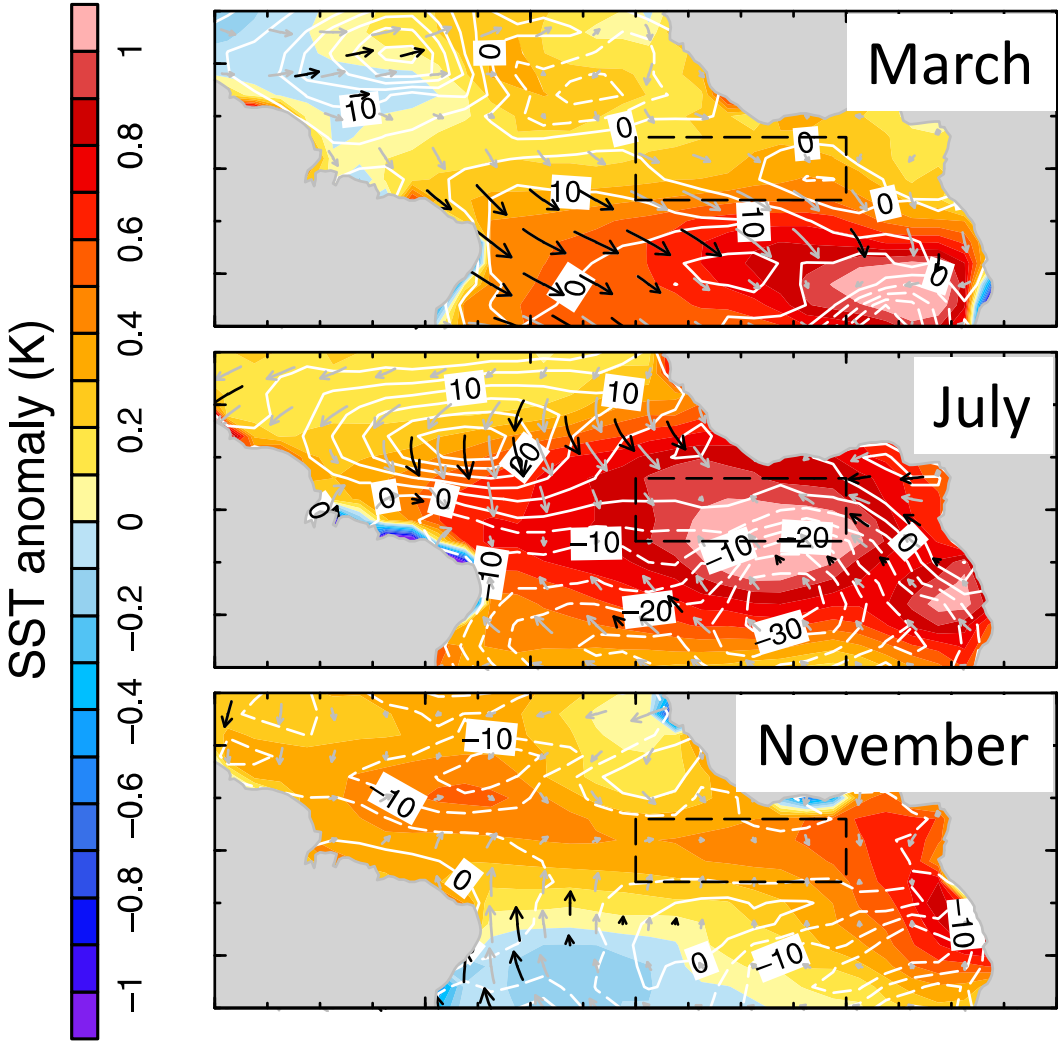
1st EOF of JJA SSTs (in K), CMIP5.



Richter et al. 2012

Bjerknes Centre for Climate Research

Thermodynamic Ocean-Atmosphere interactions are able to explain key Atlantic Nino features



Nnamchi et al. 2015

GFDL – CM2.0 AGCM-slab coupled model

Lag-regression:
Altantic 3 SST anomalies

with

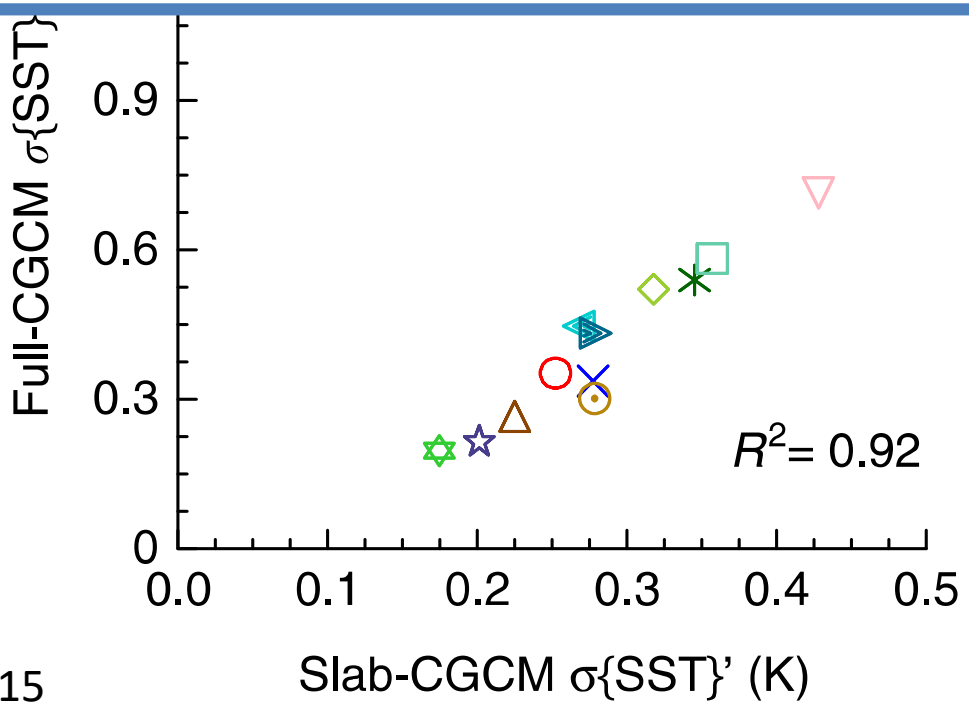
SST, surface windstress, and turbulent fluxes

Bjerknes Centre for Climate Research

Thermodynamic ocean-atmosphere interactions dominates equatorial Atlantic SST variability in climate models

Consistently, coupled models are found to underestimate the thermocline feedback

Deppenmeier et al. 2015, Ding et al. 2015a,b



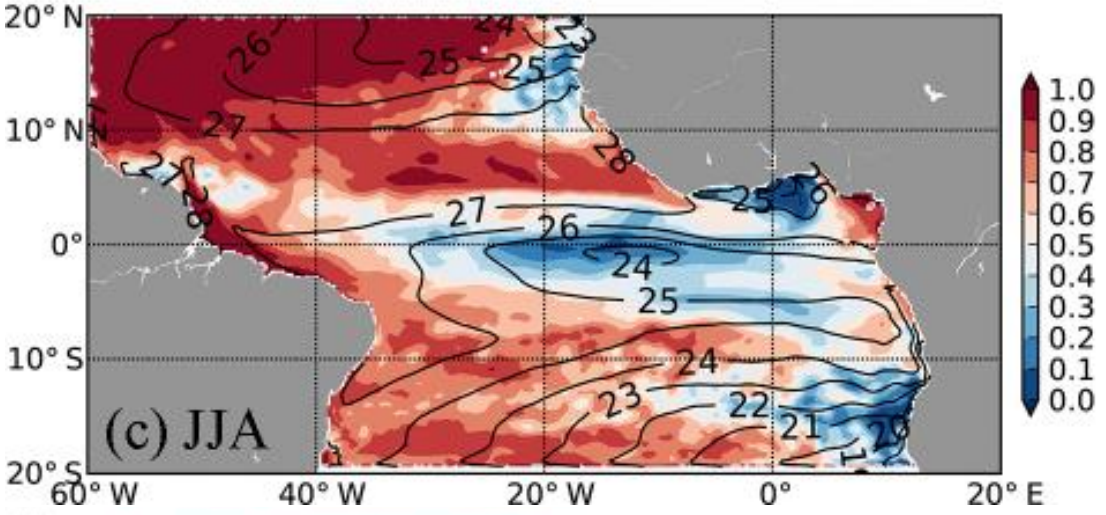
Nnamchi et al. 2015

Bjerknes Centre for Climate Research

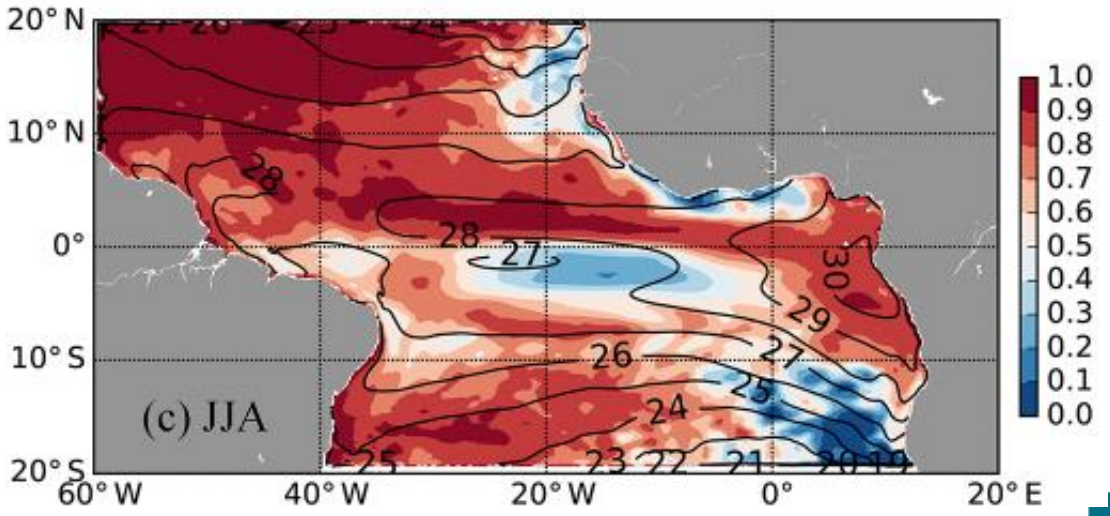
Model bias impact on dynamical versus thermodynamical driven SST variations

Explained variance of thermodynamic driven SST in ocean model experiments

Observed climatological forcing



Biased coupled model climatological forcing



Jouanno et al. 2017

Bjerknes Centre for Climate Research

Atlantic Niño: mechanisms and simulation

1. Driven by the Bjerknes feedback, but weaker than in the Pacific *(Zebiak 1993, Keenlyside & Latif 2007)*

2. Climate models simulate Atlantic Niño like variability, despite large biases *(Richter et al. 2012)*

3. Thermodynamics ocean-atmosphere interaction can explain key aspects of the Atlantic Niño *(Nnamchi et al 2015, 2016)*

4. Model biases in state-of-the-art models lead weak thermocline feedback *(Deppenmeier et al. 2015, Dippe et al. 2016, Nnamchi et al 2015)*

5. Evidence that reducing model biases enhances dynamical ocean-atmosphere interaction, and improves Atlantic Niño simulation

(Ding et al. 2016, Harlass et al. 2016, Juanno et al. 2017)

Bjerknes Centre for Climate Research

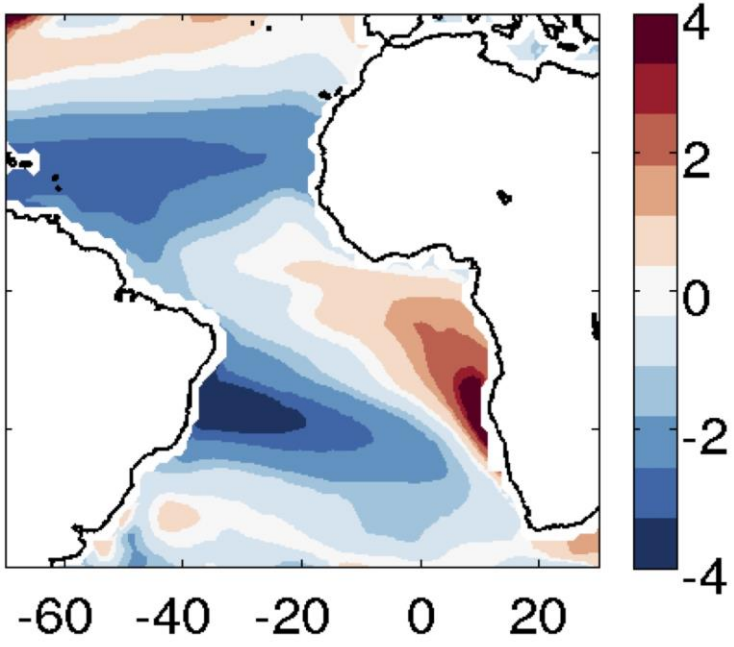
Consequences of coupled model biases for seasonal prediction

Bjerknes Centre
for Climate Research

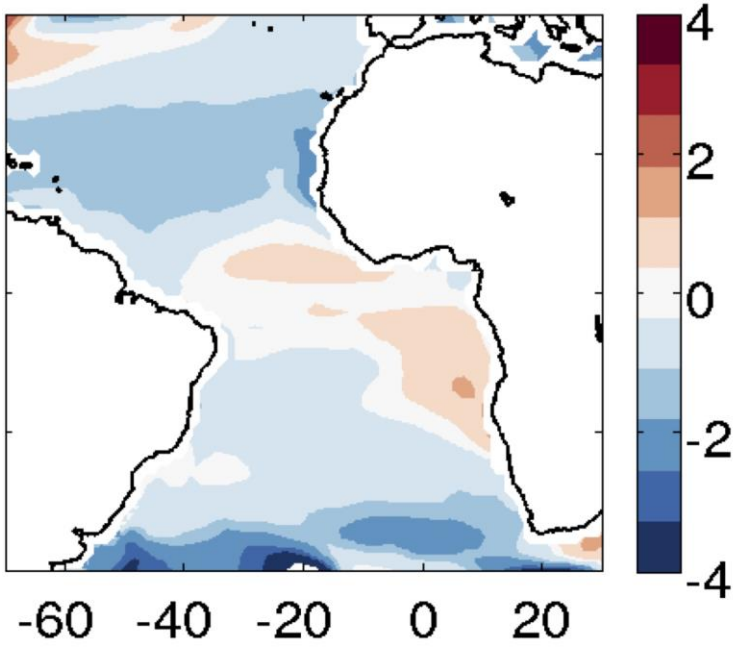
Tool to assess impact of mean model errors: Anomaly coupling captures Atlantic cold tongue

Sea Surface Temperature Bias

NorESM - Standard



NorESM Anom. Coupled



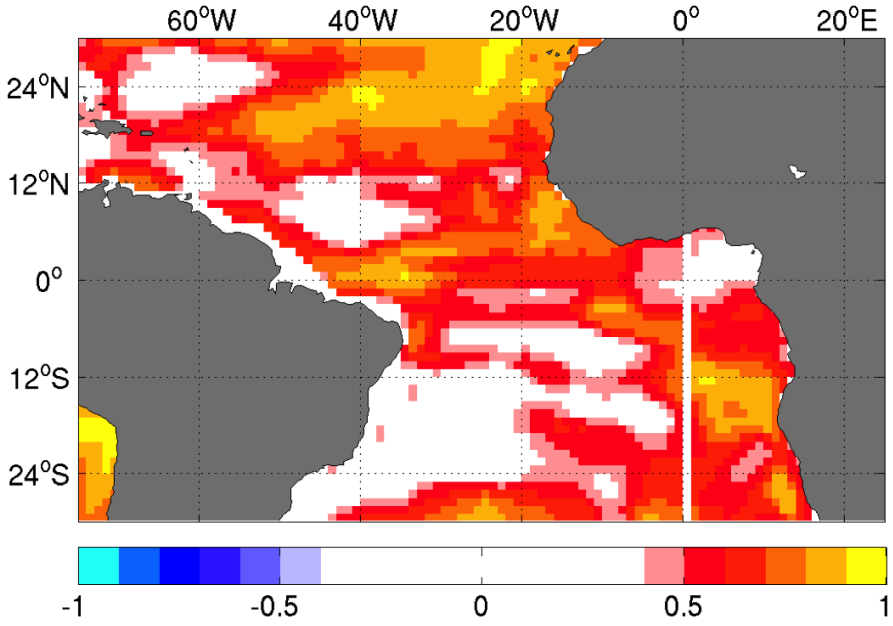
Courtesy: Teferi Demissie

Bjerknes Centre for Climate Research

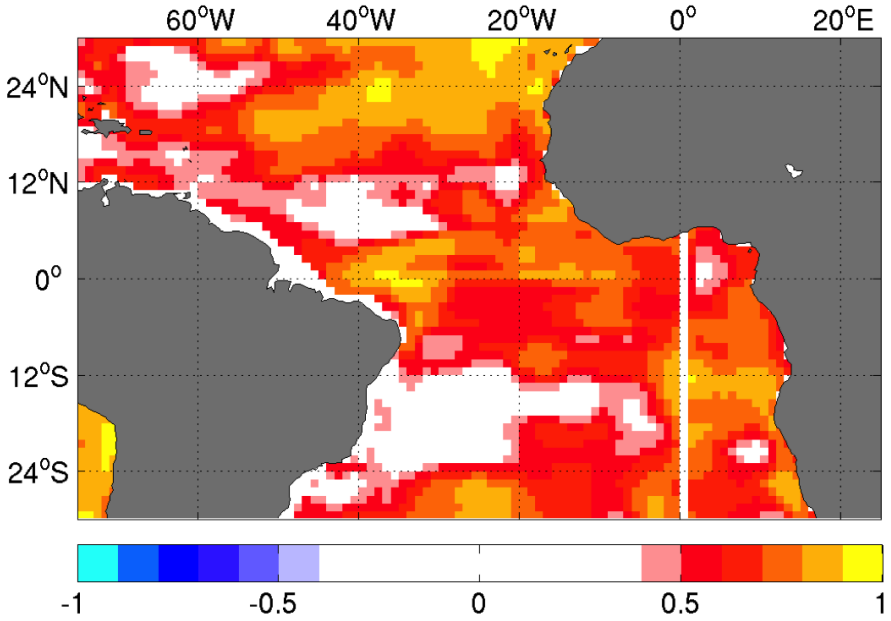
Reducing mean biases enhances ocean analysis

Correlation (1980-2010), 200m heat content
EN4 objective analysis with
Norwegian Climate Prediction Model ocean reanalysis

Standard (biased) model



Anomaly coupled model

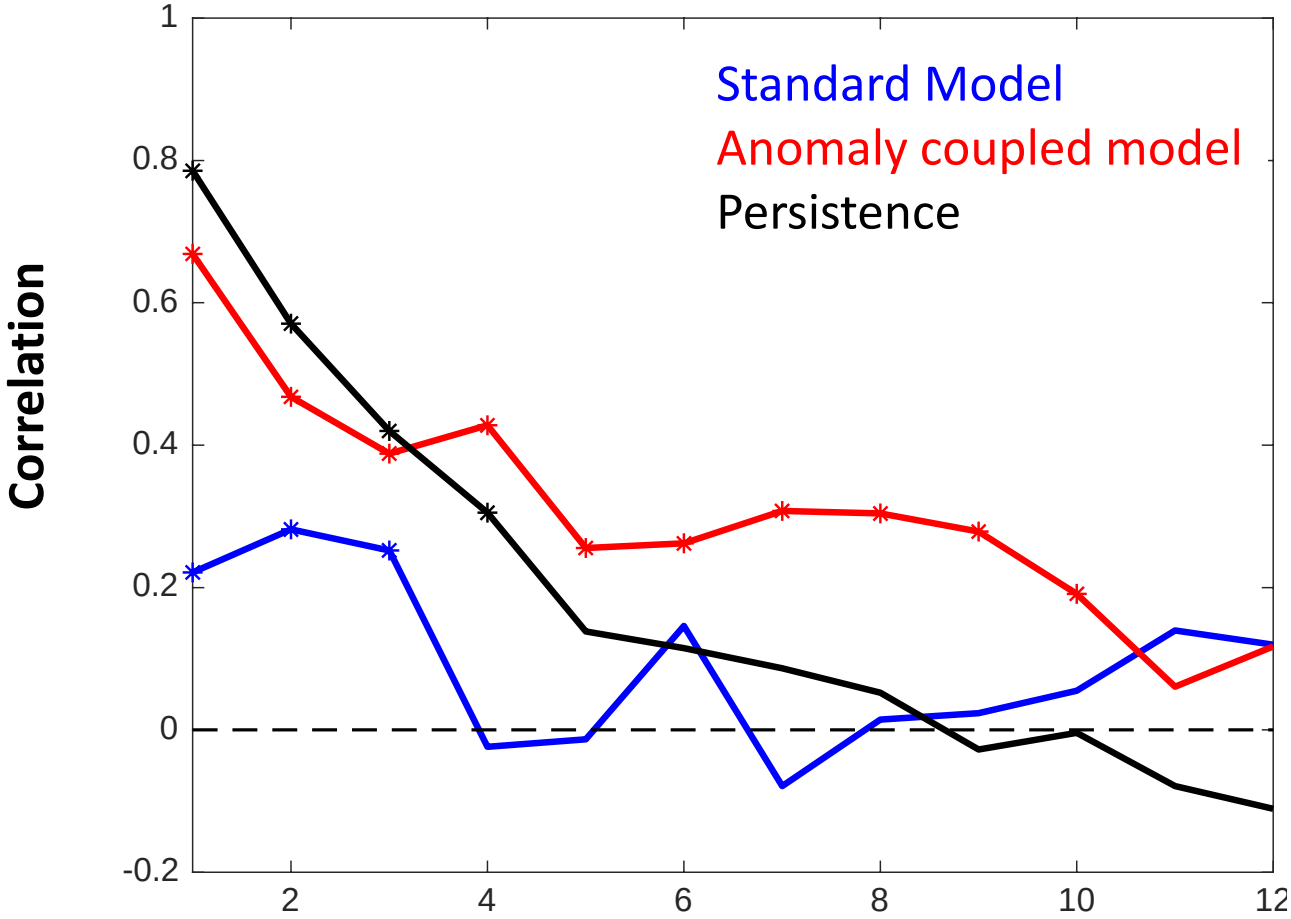


Courtesy: Francois Counillon

Bjerknes Centre for Climate Research

Reducing mean biases enhances seasonal prediction skill for the Atlantic Niño

Norwegian Climate prediction Model, Correlation skill for ATL3 region
1980-2010, 4 starts per year (Feb. May, Aug. Nov.), 9 ensemble members

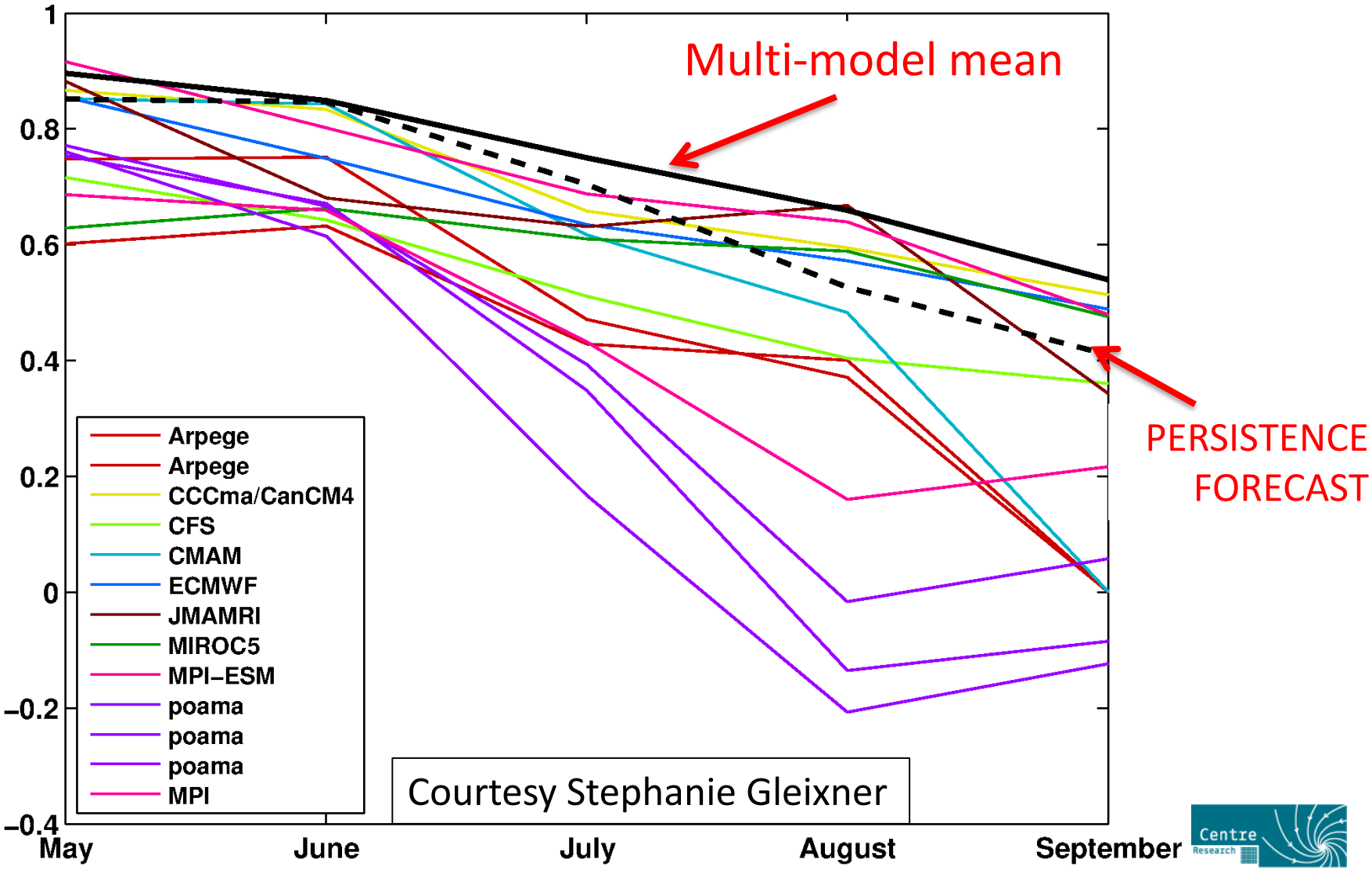


Courtesy: Francois Counillon

Bjerknes Centre for Climate Research

Multi-model seasonal forecasts initialised in May show useful skill in Equatorial Atlantic beyond persistence

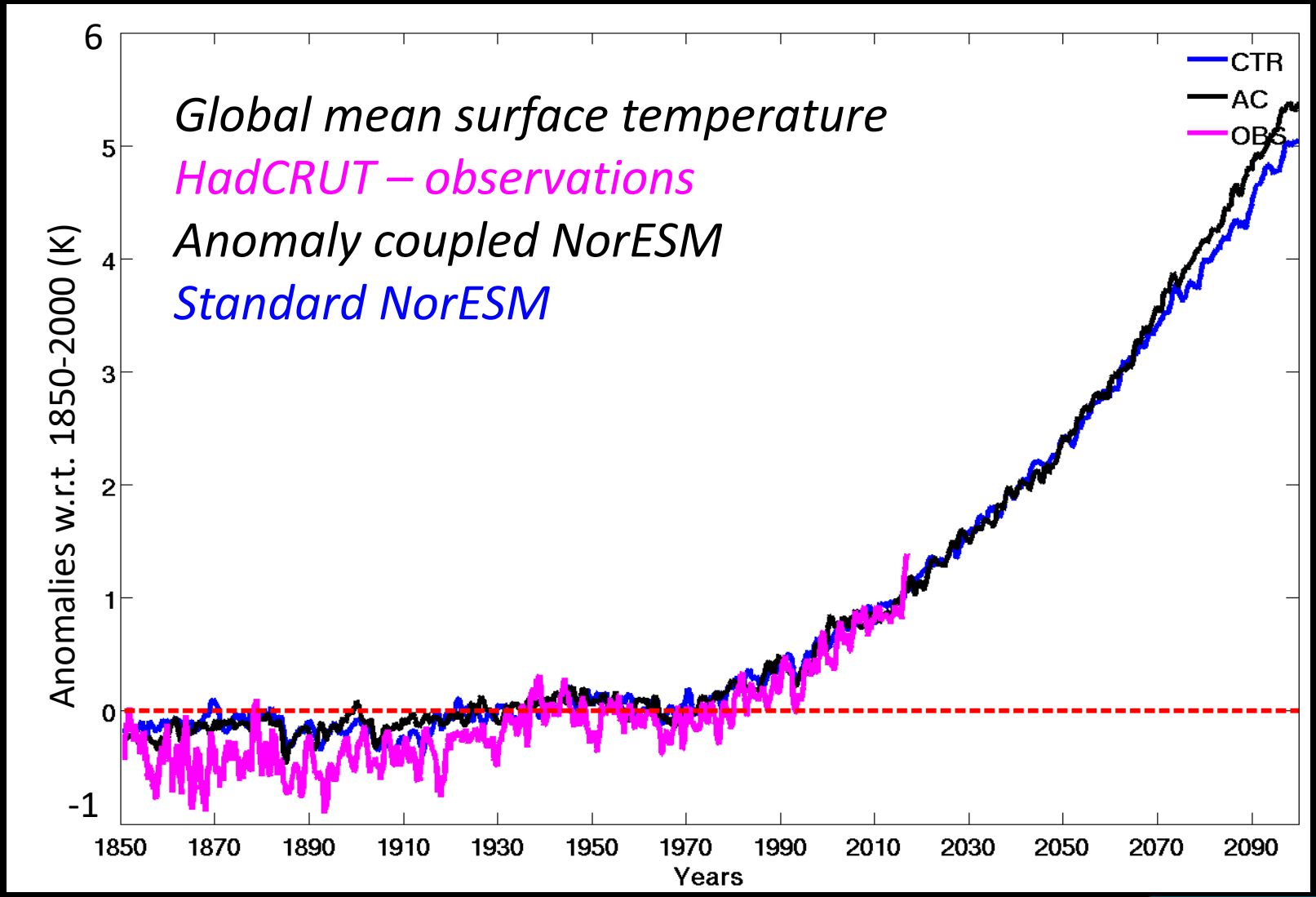
Correlation skill Atlantic 3 SST anomalies, 13 models, WGSIP CHFP



Consequences of coupled model biases for climate projections

Bjerknes Centre
for Climate Research

Two versions of NorESM have very similar climate sensitivity



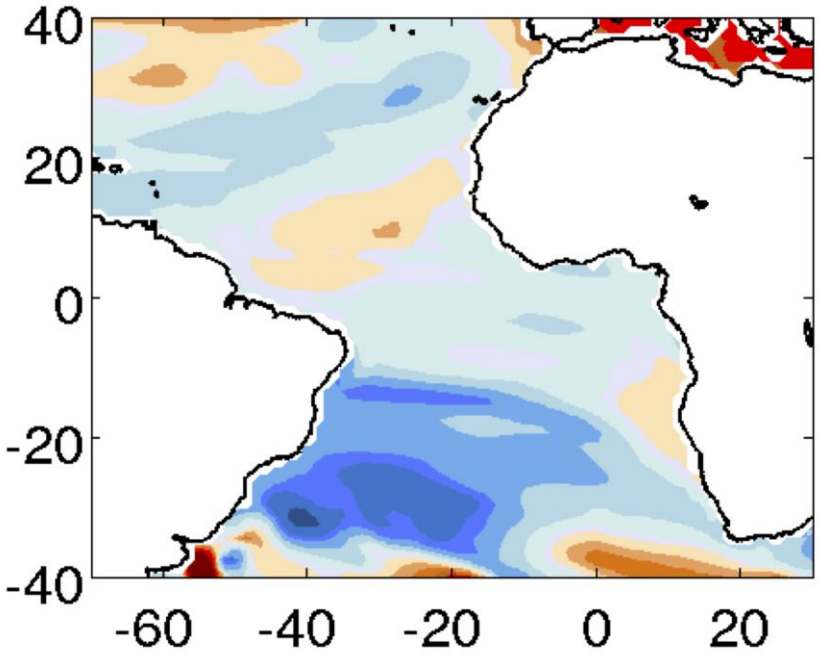
Courtesy: Teferi Demissie

Bjerknes Centre for Climate Research

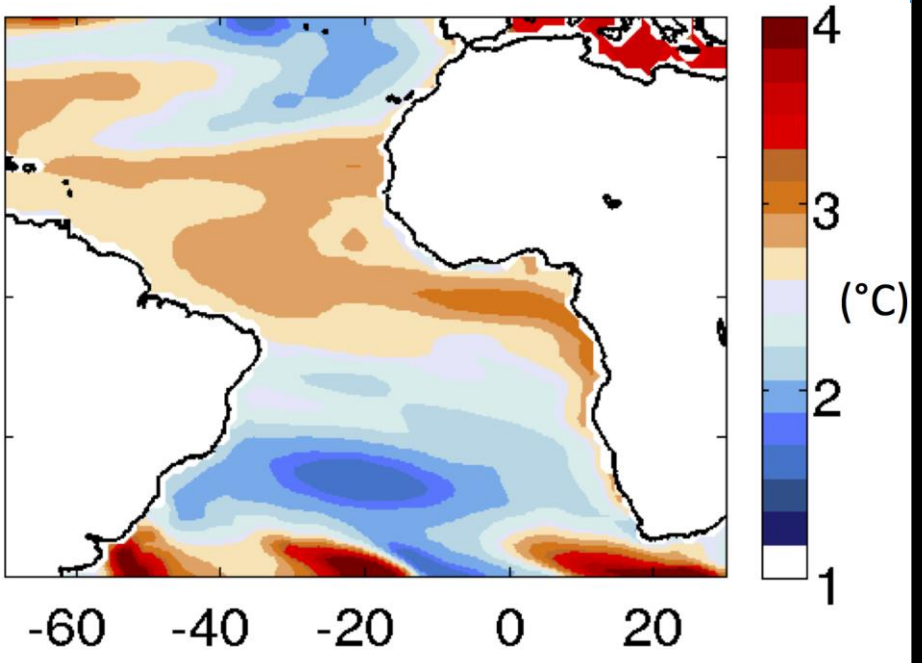
Climate change: Reducing model error causes different warming pattern

Ocean surface temperature change: 2080-2100 minus 1980-2000

Standard Norwegian Model



Corrected Norwegian Model



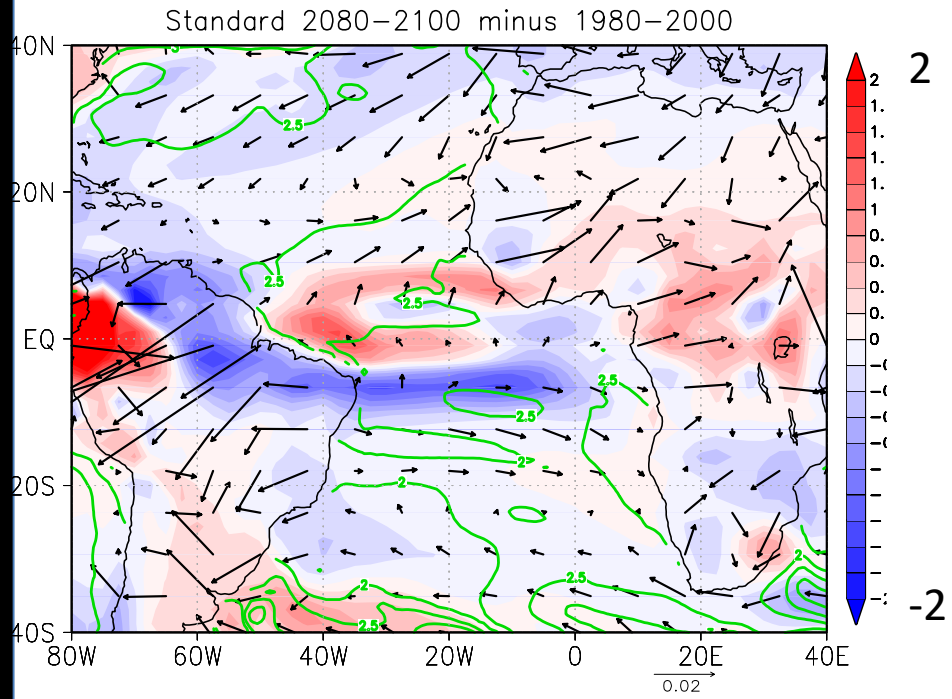
Courtesy: Teferi Demissie

Bjerknes Centre for Climate Research

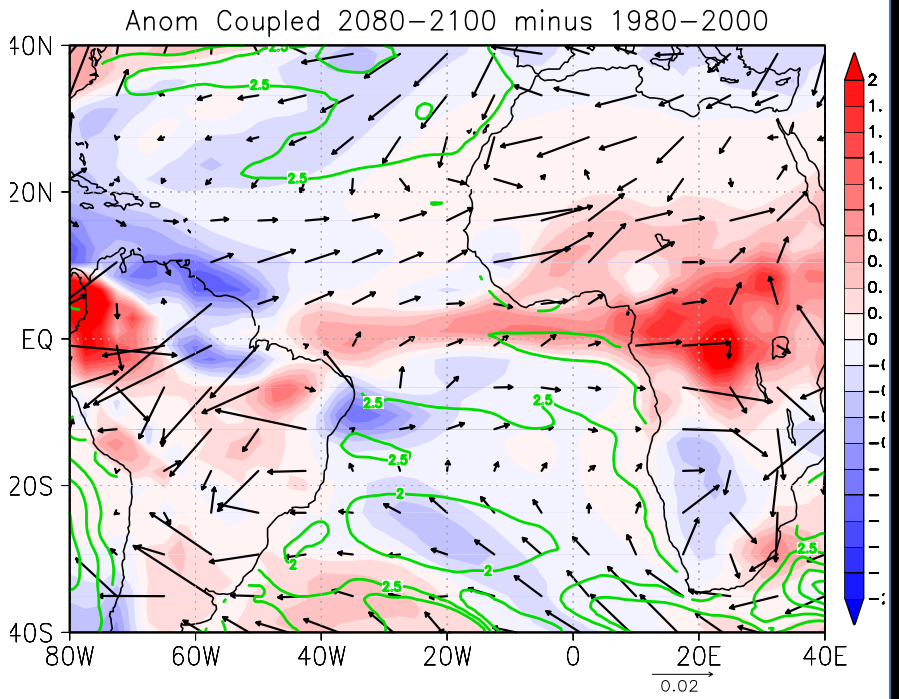
Climate change: Atlantic Niño warming when warm bias reduced

Precipitation change: 2080-2100 minus 1980-2000

Standard NorESM



Anom. Coupled NorESM



Courtesy: Teferi Demissie

Bjerknes Centre for Climate Research

Improving prediction/projection of Tropical Atlantic climate and its impacts

1. Large model biases are linked to Atlantic Niño variability and patterns of long-term climate change
2. Reducing biases is a high-priority to improve predictions and reduce uncertainties in climate change projections

Thank you

Input for TAOS review – Climate Prediction

- Observations to close the momentum in the ocean and atmospheric boundary layer can help reduce model biases
- Observations to constrain heat and freshwater ocean mixed-layer budgets (including surface fluxes) can help reduce biases, and enhance ocean reanalysis
- Ocean current observations important for equatorial and coastal variability

Bjerknes Centre
for Climate Research