Long-term climate variability and climate change

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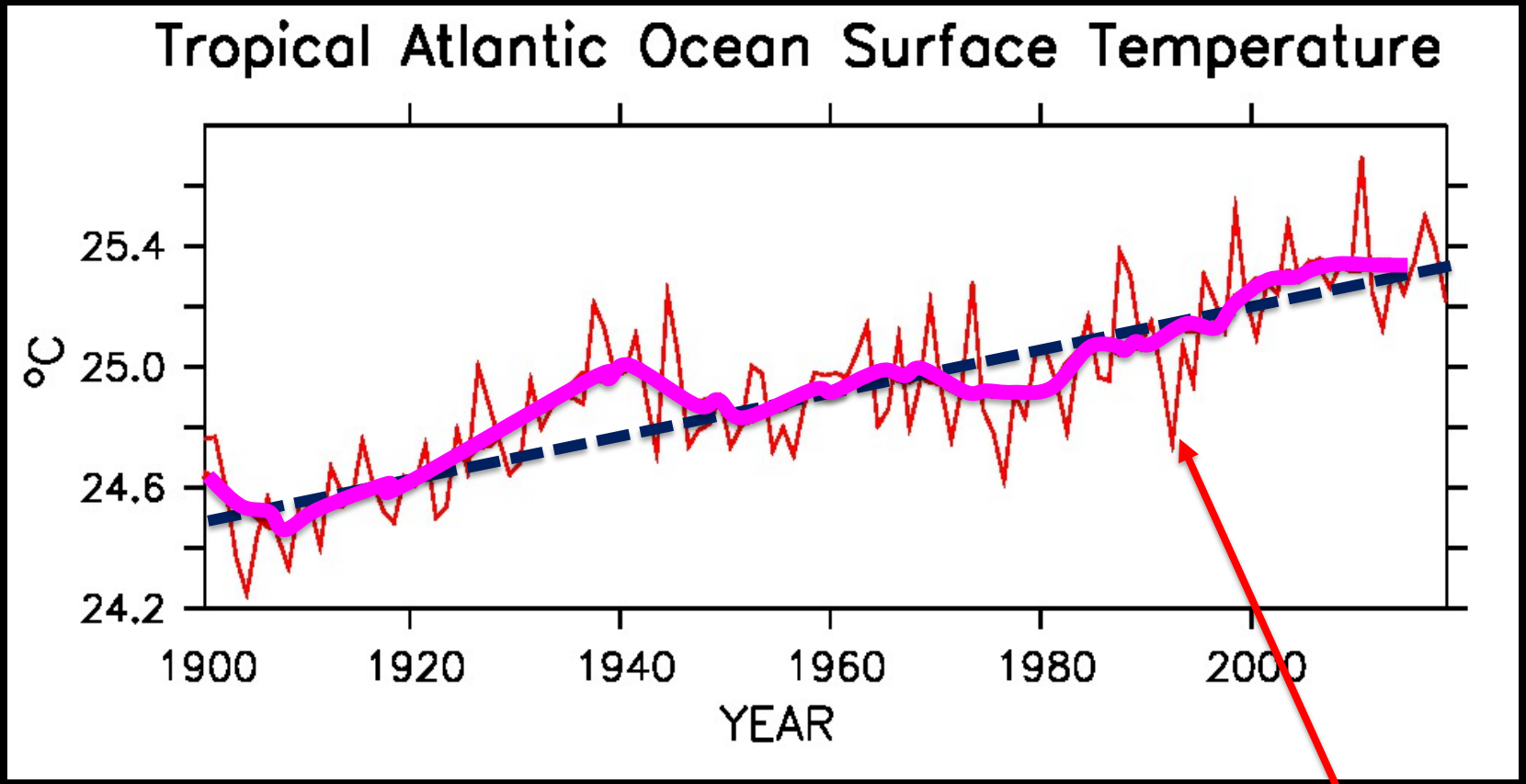
Topics covered

- Internal variability versus external forced variability
- What is model (response) uncertainty
- Atlantic multi-decadal variability
- Future changes in tropical Atlantic climate

Causes of short and long-term changes in climate



Long-term trend caused mainly by global warming

Decade to decade changes caused by both natural and anthropogenic factors

Year to year fluctuations caused by natural processes in the climate system

Example of internal climate variability: El Niño Southern Oscillation, events occur every 2-7 years

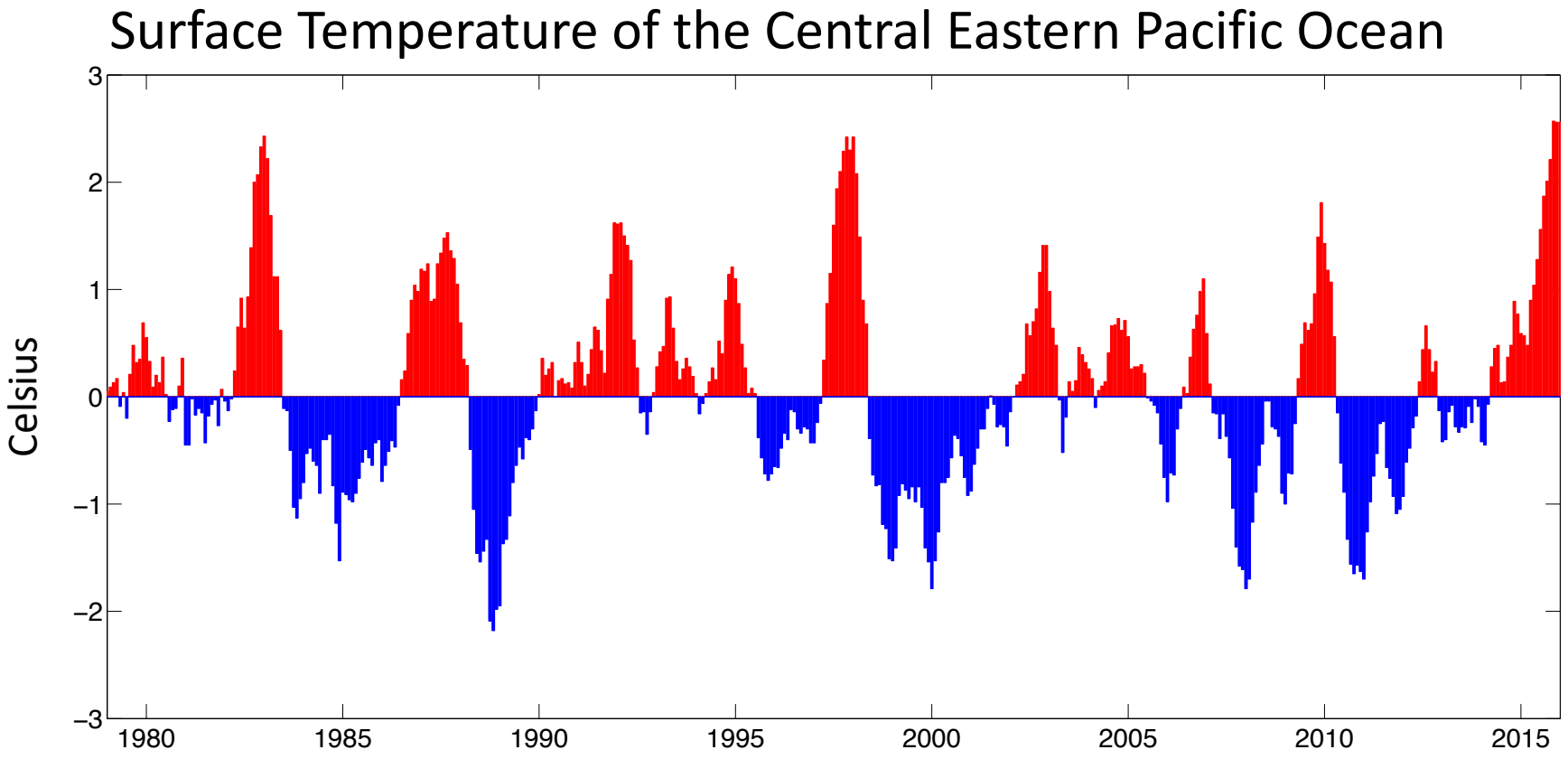
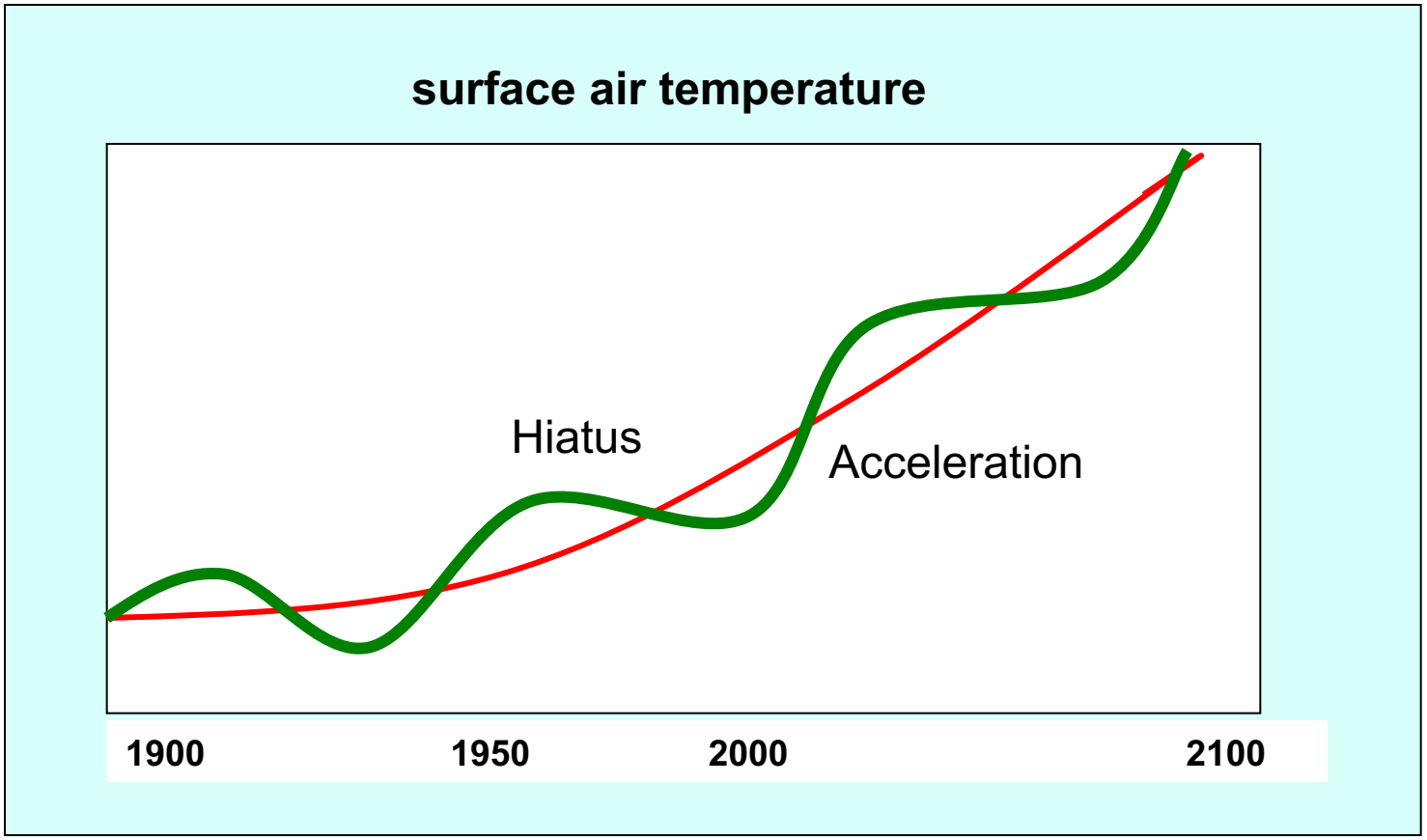


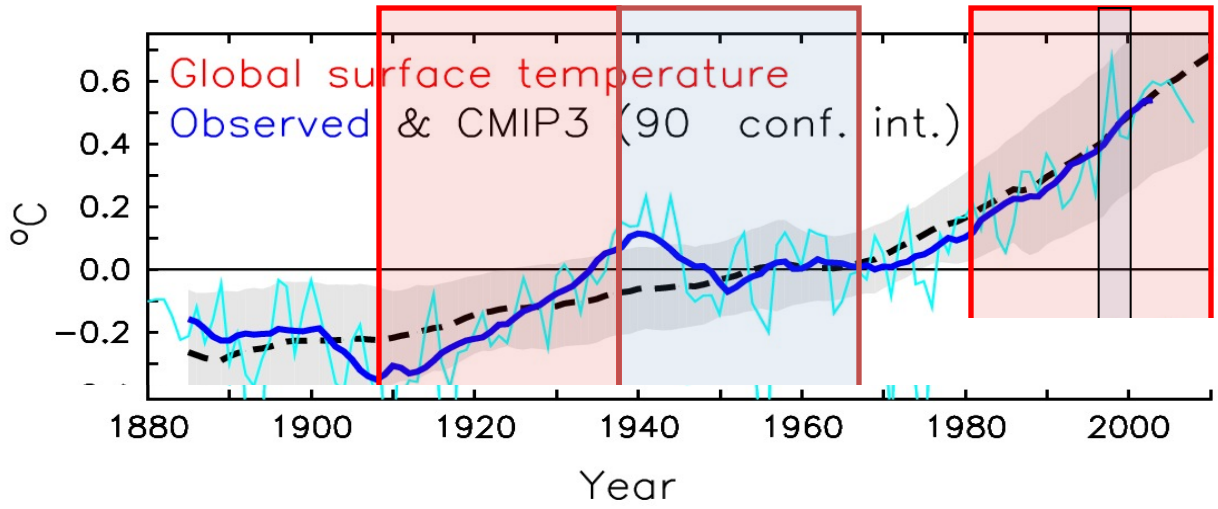
Figure 3 Monthly Niño 3.4 time series from 1979 to 2016 (data from NOAA 2017).

Courtesy Stephanie Gleixner

External forcing + internal variability
Short and long-term climate variations



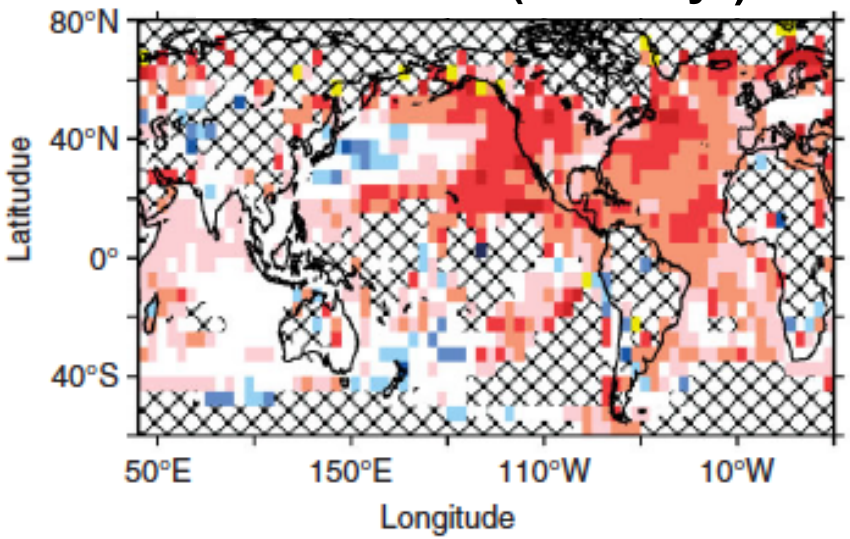
Multidecadal temperature fluctuations: Internal versus externally driven



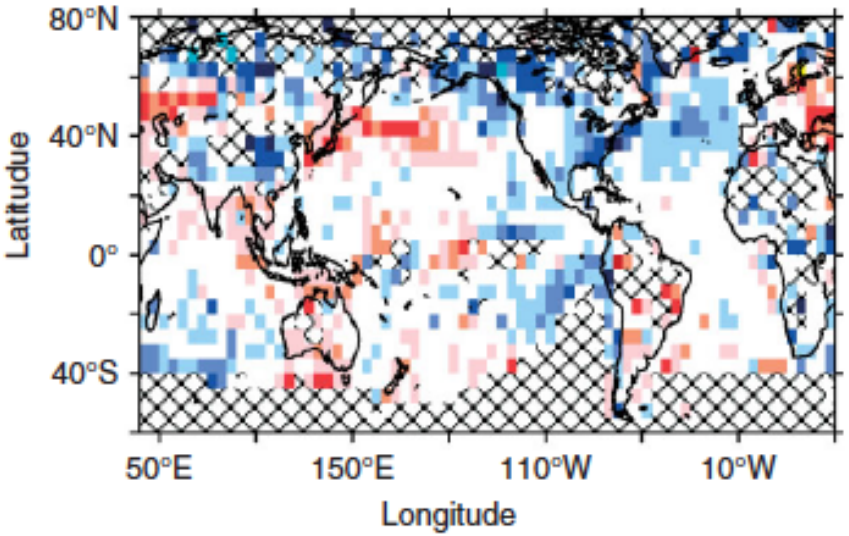
El Nino 97/98

Observed surface temperature trends

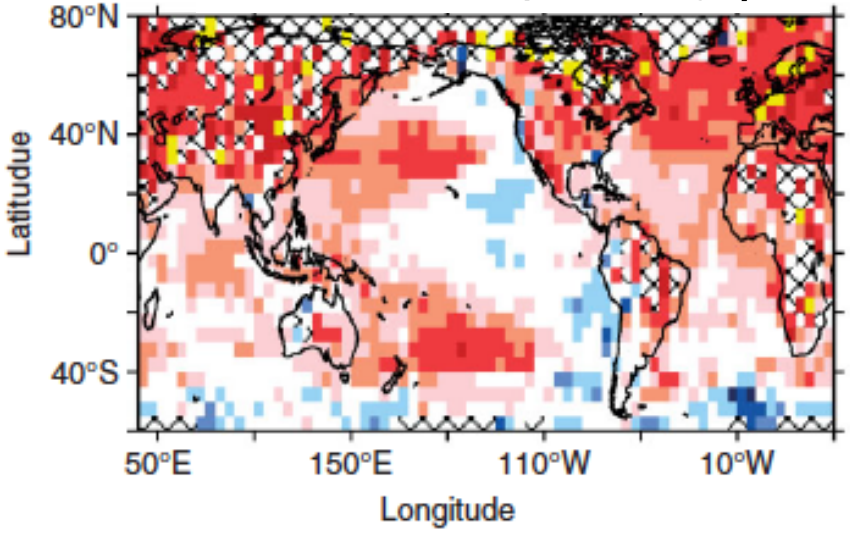
1910-1940 (° C/10 yr)

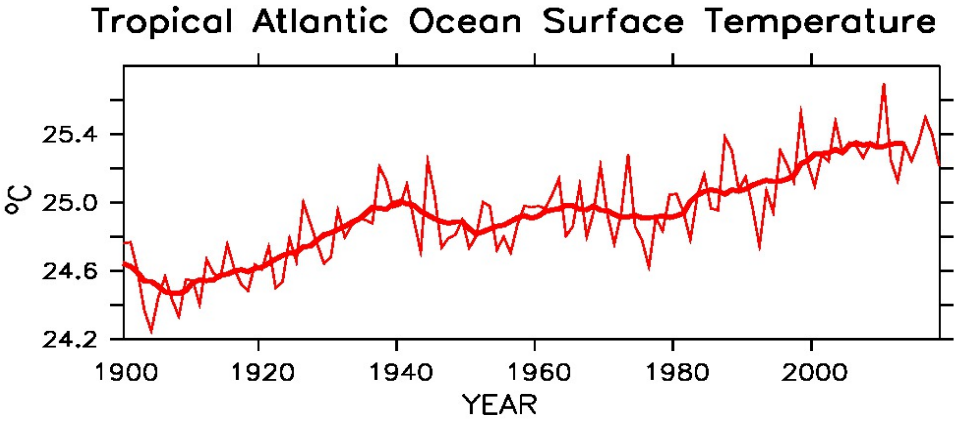


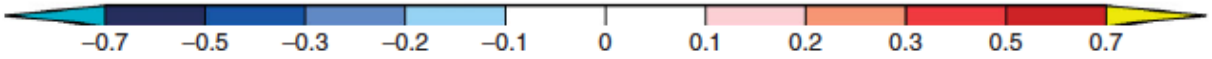
1940-1970 (° C/10 yr)



1978-2008 (° C/10 yr)







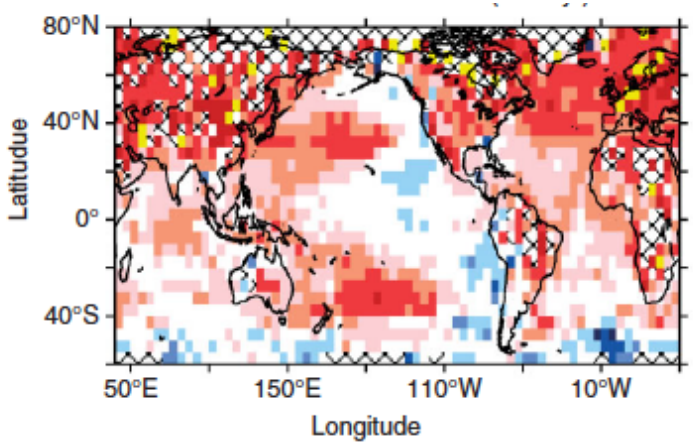
Keenlyside and Ba (2010)

Internal variability large at decadal/regional scales
External dominates on centennial

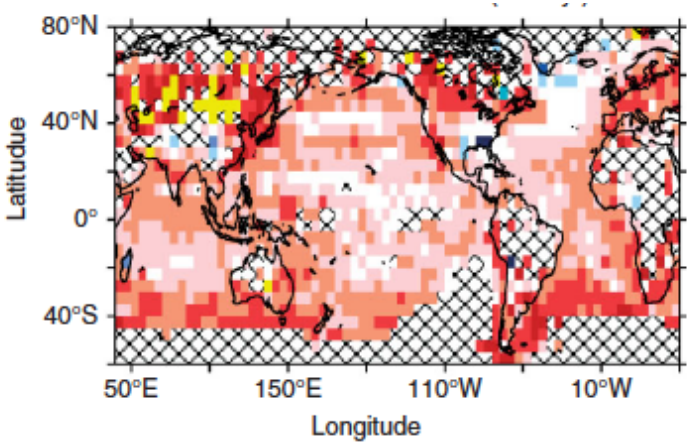
Surface temperature trends

Observed

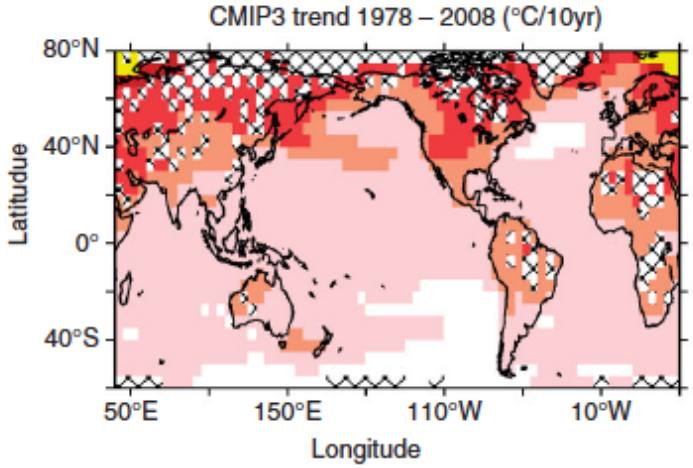
1978-2008 (° C/10 yr)

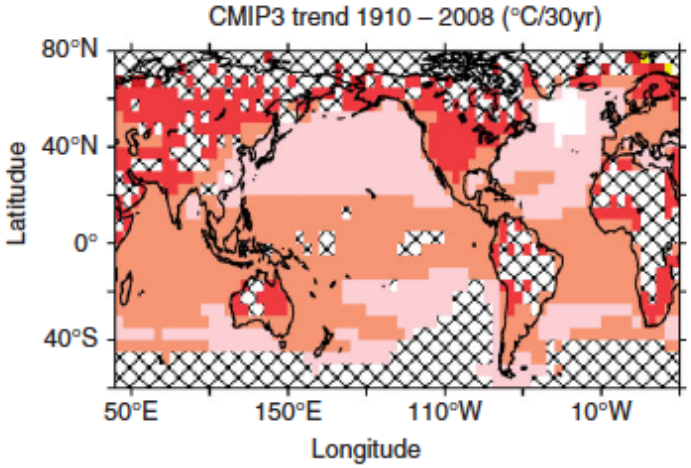


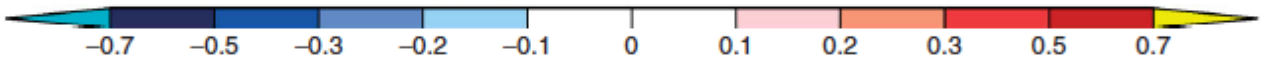
1910-2008 (° C/30 yr)



IPCC AR4 (CMIP3)





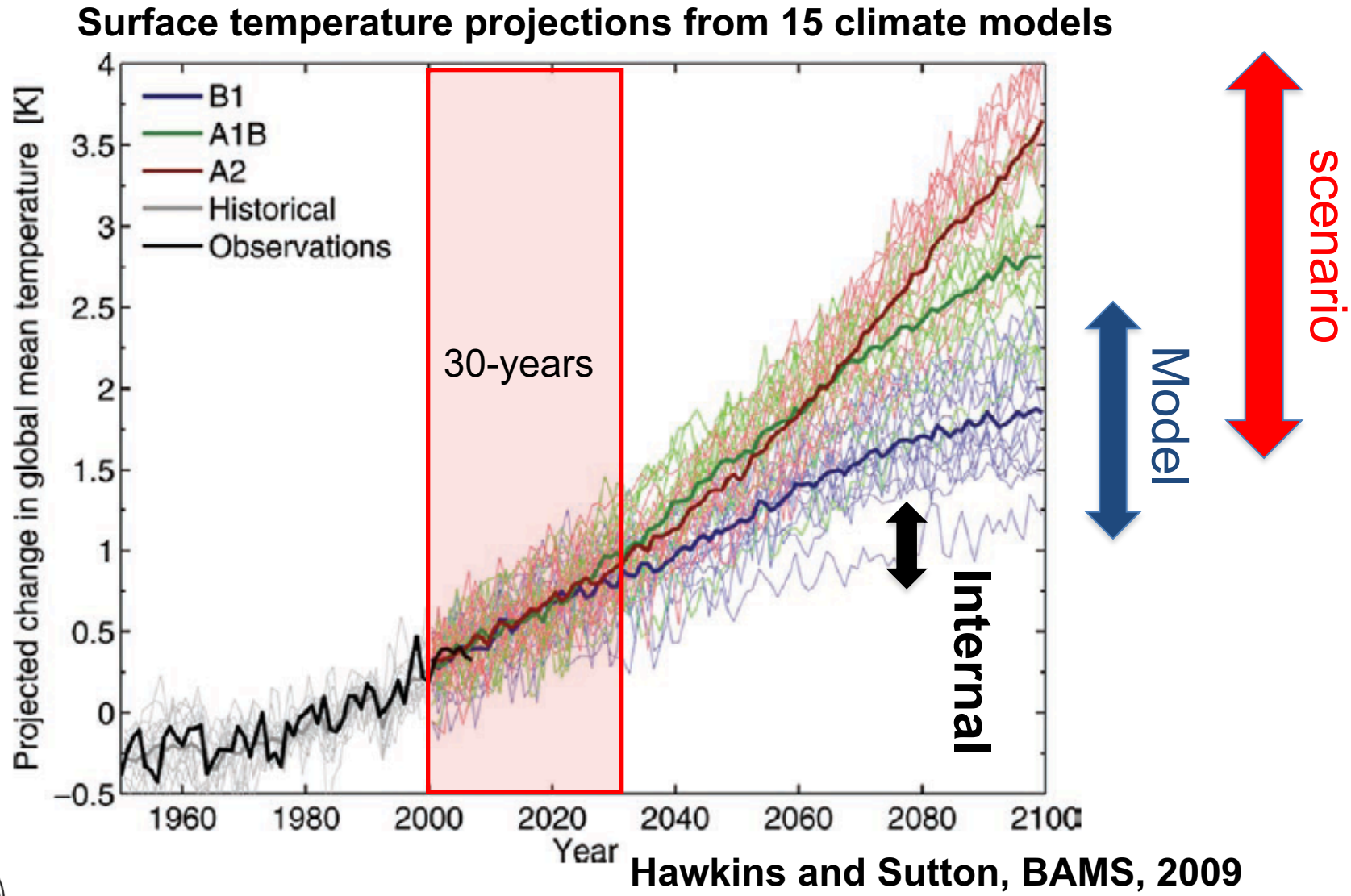


Keenlyside and Ba (2010)

Uncertainties in future projections

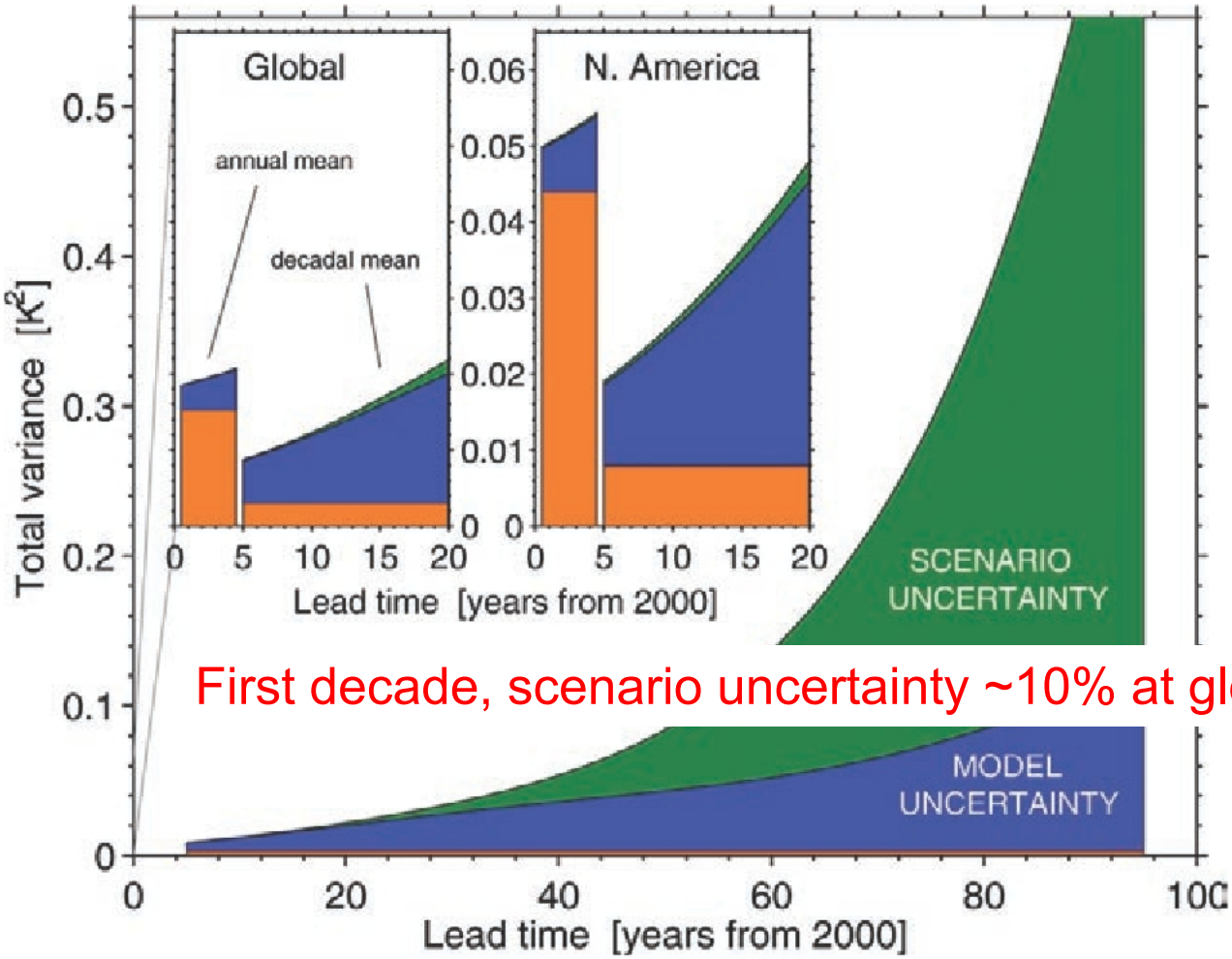
Externally driven climate projections

Prediction uncertainty: scenario, model, and internal



Near-term surface temperature prediction: model and initial condition uncertainty large

Relative importance computed from CMIP3 models



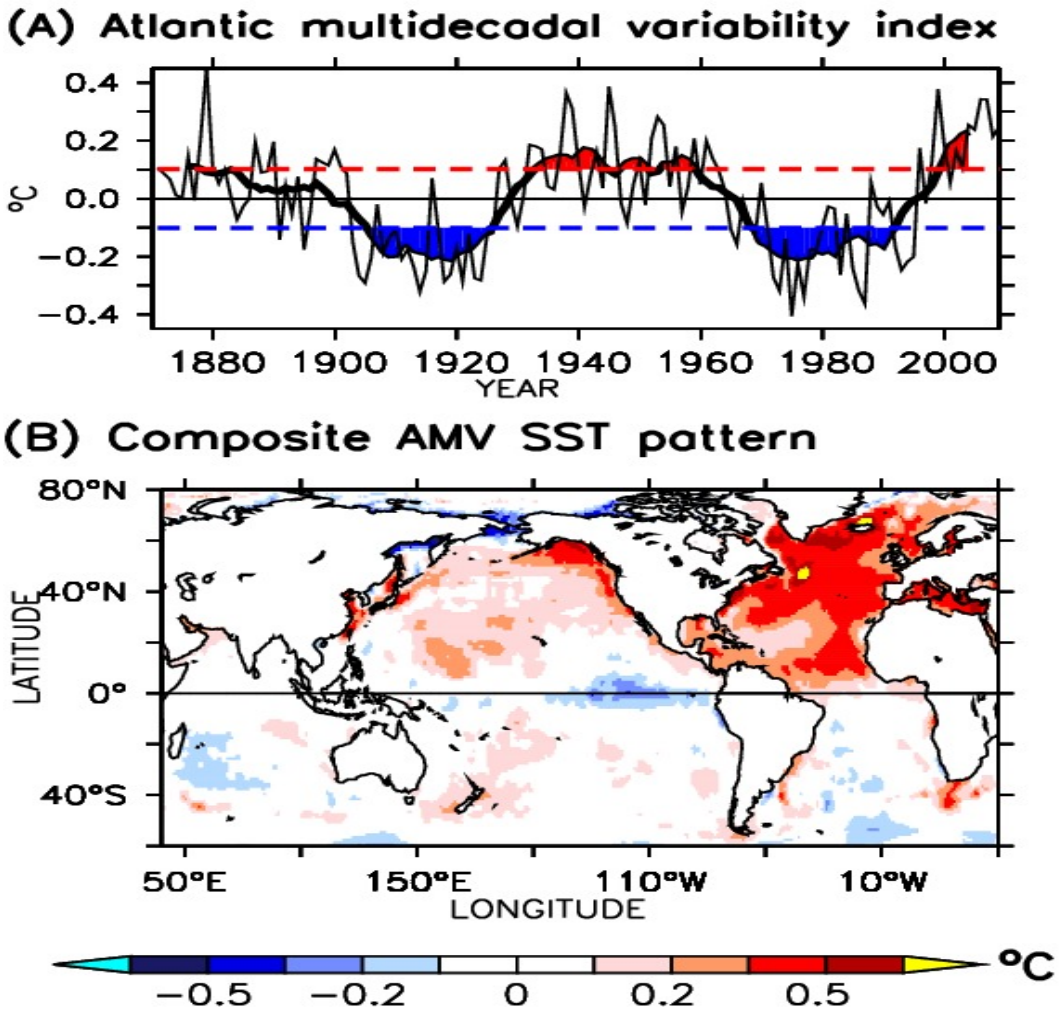
First decade, scenario uncertainty ~10% at global scale

Hawkins and Sutton, BAMS, 2009

Atlantic multi-decadal variability

Atlantic Multi-decadal variability (AMV)

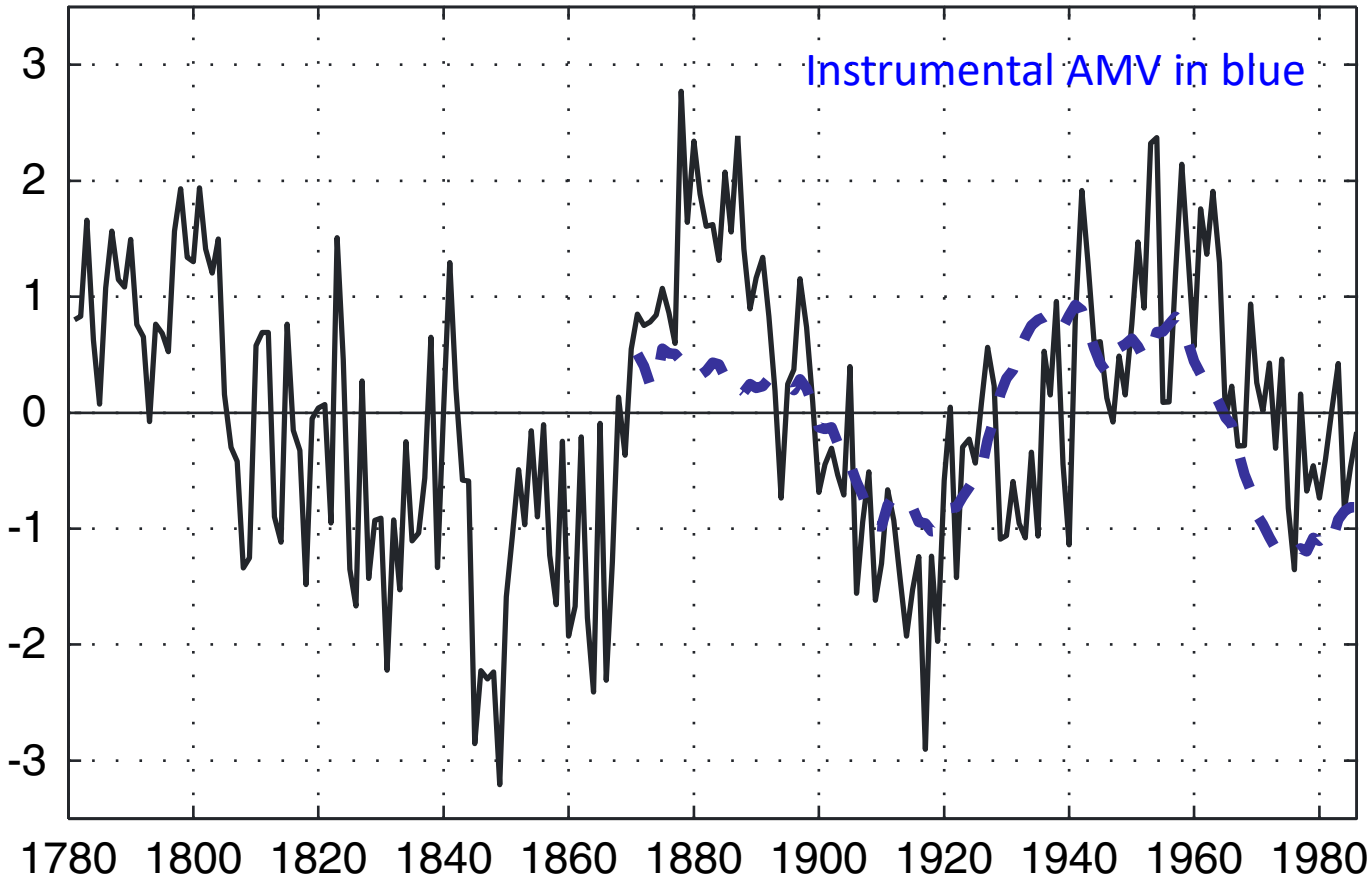
- Commonly defined as detrend SST anomalies averaged over the North Atlantic (0-60N), with a decadal low-pass filter
- Index shows pronounced 70-80 year variations, even without filtering
- Also known as the Atlantic multi-decadal Oscillation (AMO)



HadISST observations

Atlantic multi-decadal variability existed before the instrumental record

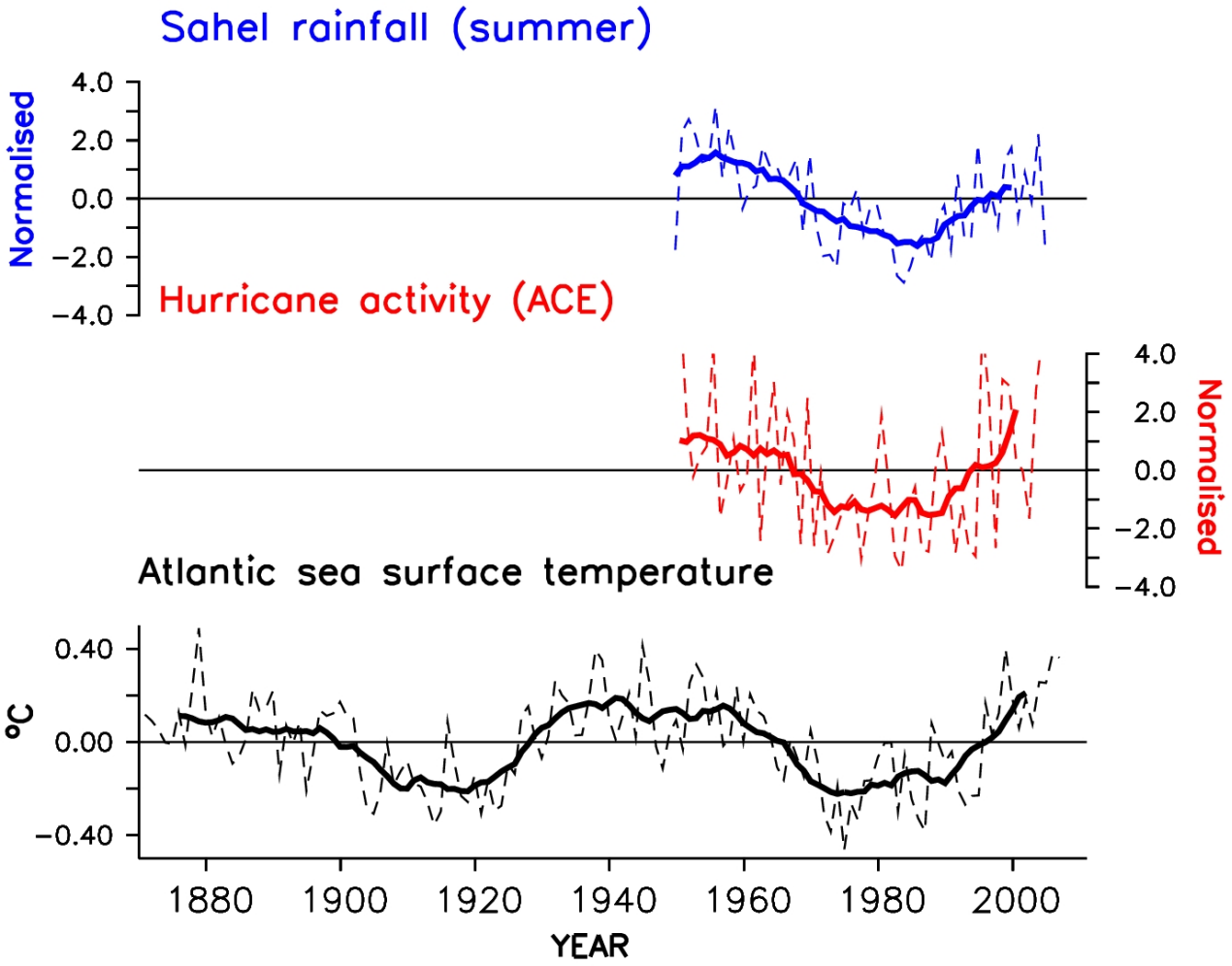
Principle component analysis of five coral records from the tropical Atlantic



Svendsen et al. 2014

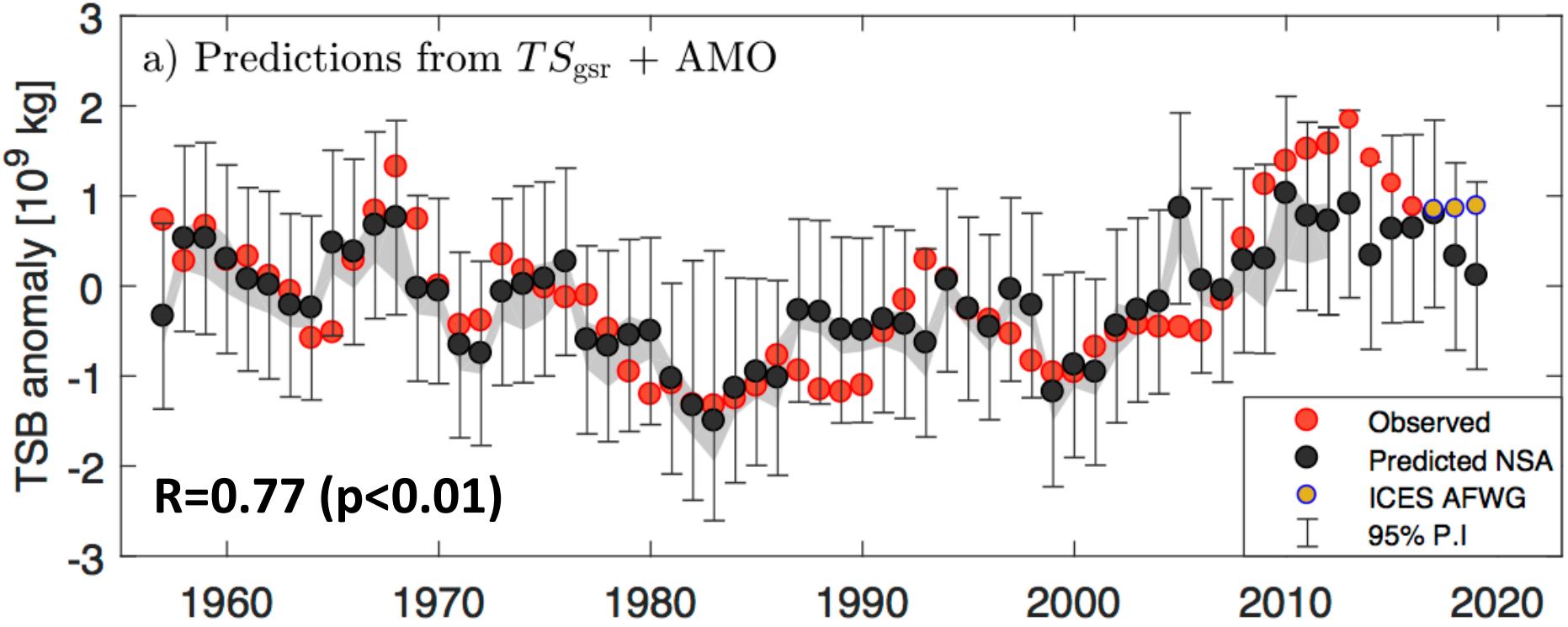
AMV is associated with climatic impacts of strong socio-economic importance

Detrended observed timeseries



AMV impacts on marine ecosystems allow prediction of Barents Sea Cod Total Stock Biomass

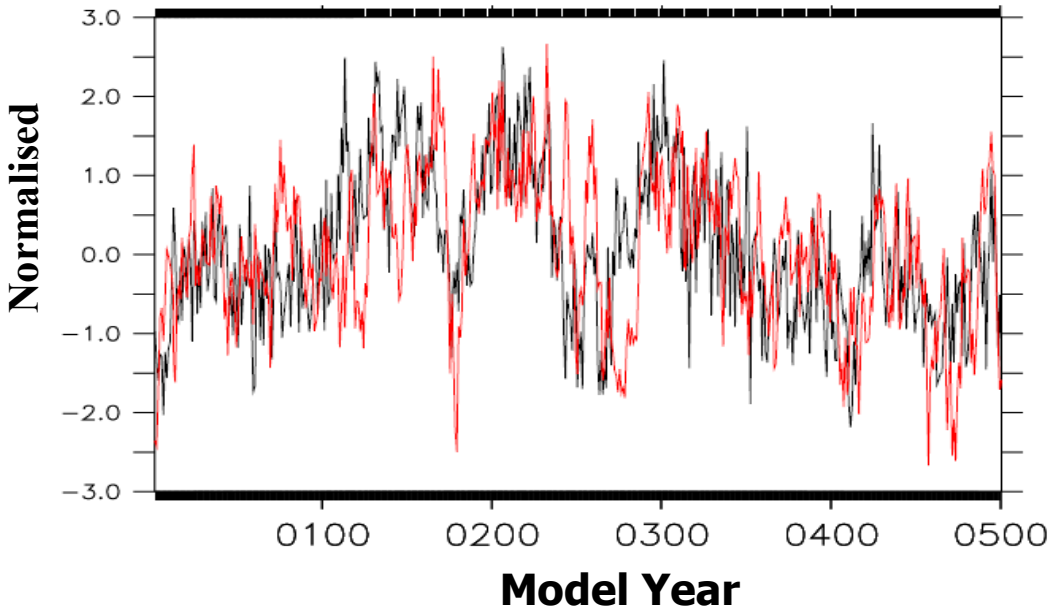
Observed and predictions based on Atlantic inflow temperature and AMO seven years in advance



Årthun et al. 2018

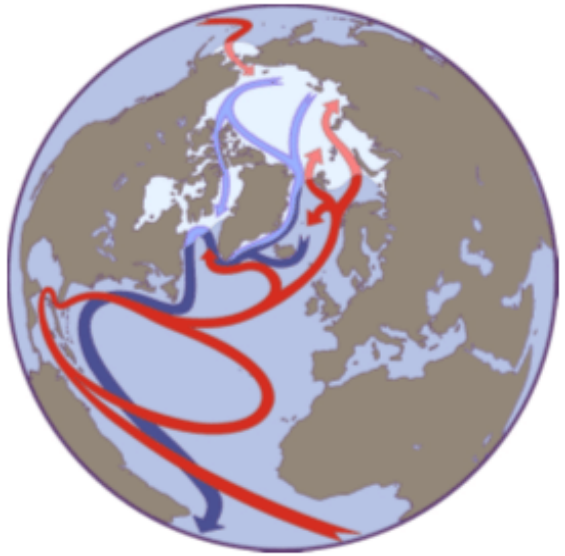
Mechanisms for AMV involves poleward heat transport associated with Meridional Overturning Circulation

Kiel Climate Model – MOC (black), Atlantic sea surface temperature (red)



[Latif et al. 2009]

Meridional overturning circulation (MOC)

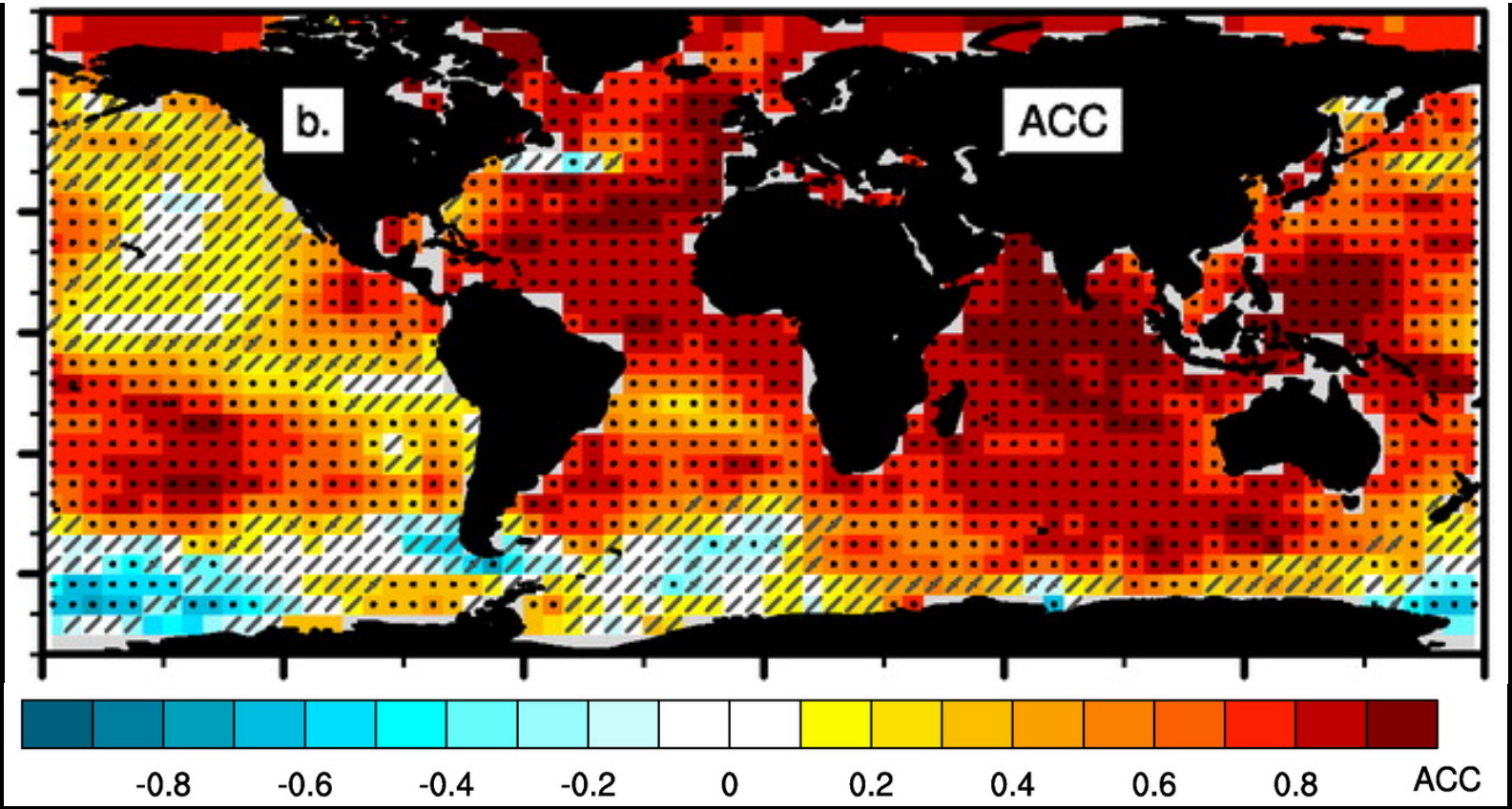


Additional considerations

- Models do show disagreement in the mechanisms, timescales, and patterns for Atlantic multidecadal variability (Keenlyside and Ba 2010, Zhang et al. 2018)
- Role of ocean dynamics has been questioned (Clements 2015)
- Role of external forcing also highlighted (Otterå et al. 2010, Booth et al. 2012)

Climate prediction on multi-year timescales reaching useful skill levels in the Atlantic

Anomaly correlation skill in predicting sea surface temperature 3-7 years ahead
Model: CESM-DPLE, yearly reforecasts 1954-2015, 40 ensemble members



Yeager et al. 2018

Historical and future changes in tropical Atlantic climate

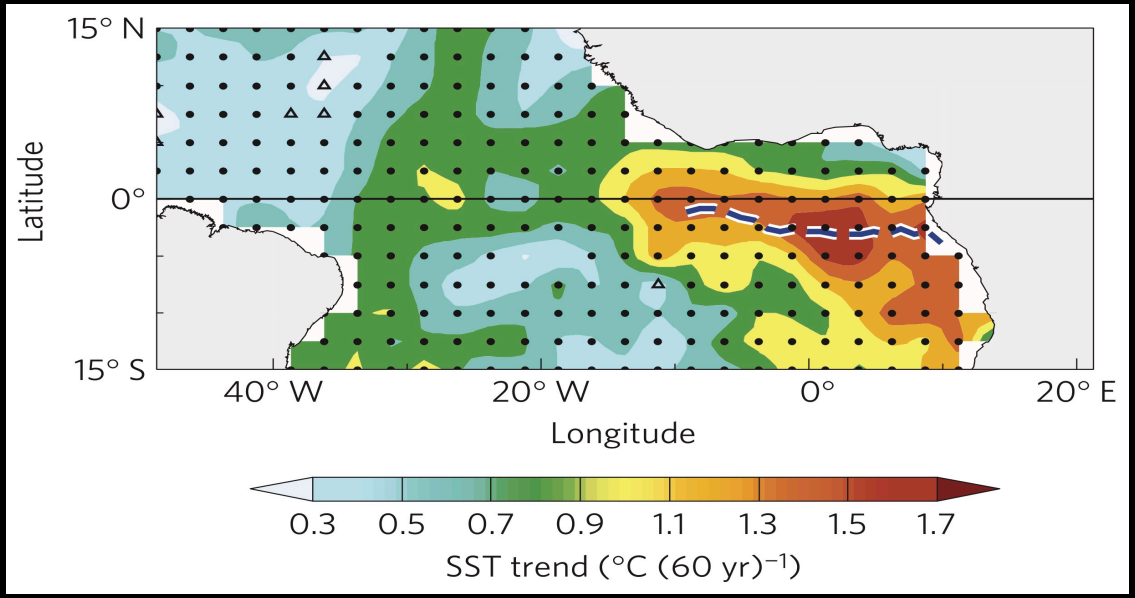
Analysis of CMIP5 models by Lander Crespo

Potential impacts on variability

Weakening of equatorial cold tongue

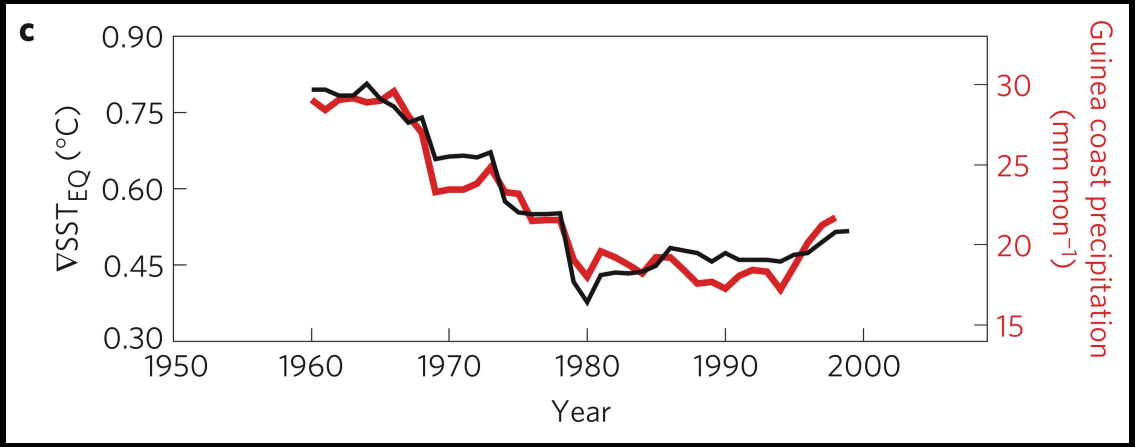
1950-2009 SST trend in JJA

Tokinaga and Xie 2011



Weakening SST and rainfall variability

21-year running variance, equatorial zonal SST gradient and Guinea coast rainfall



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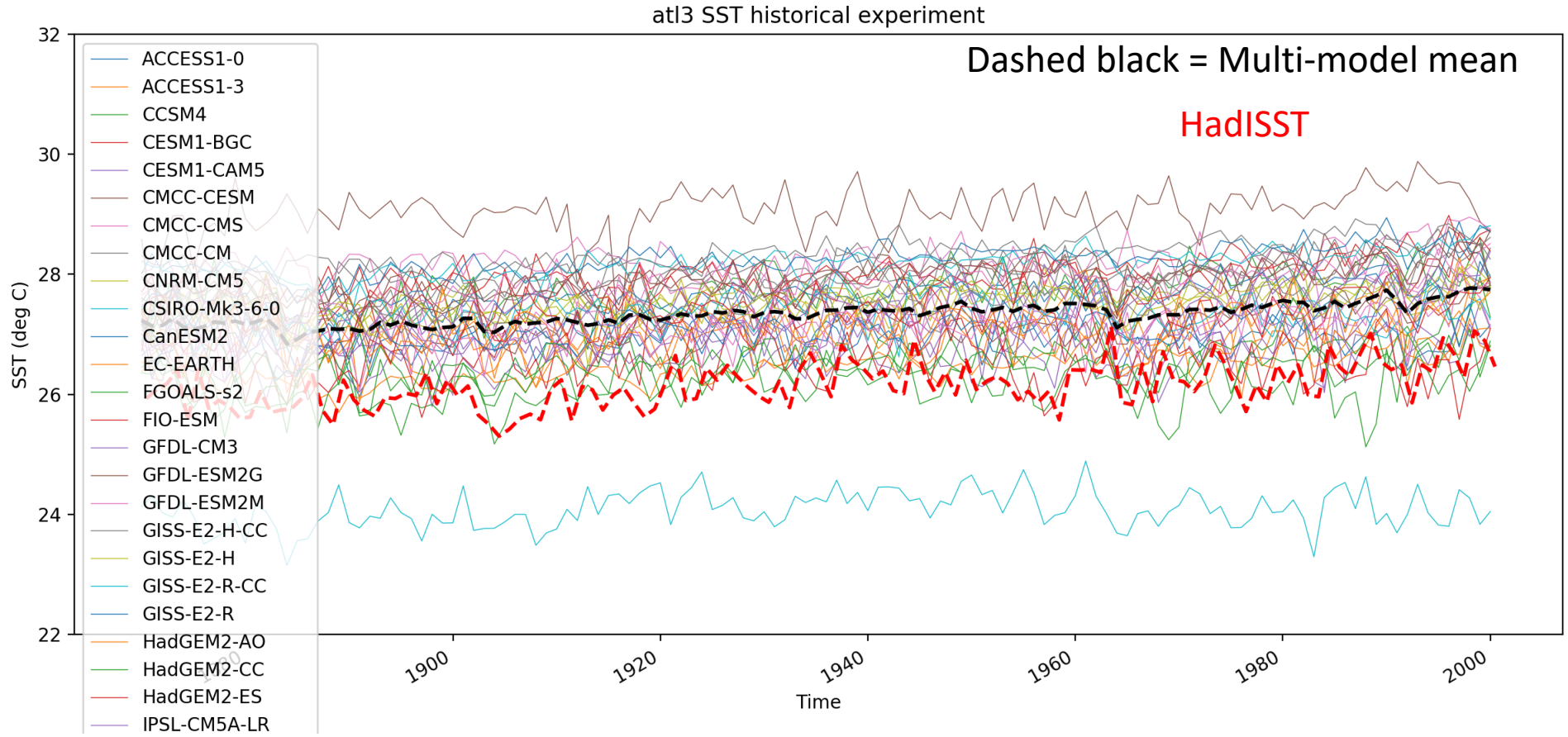
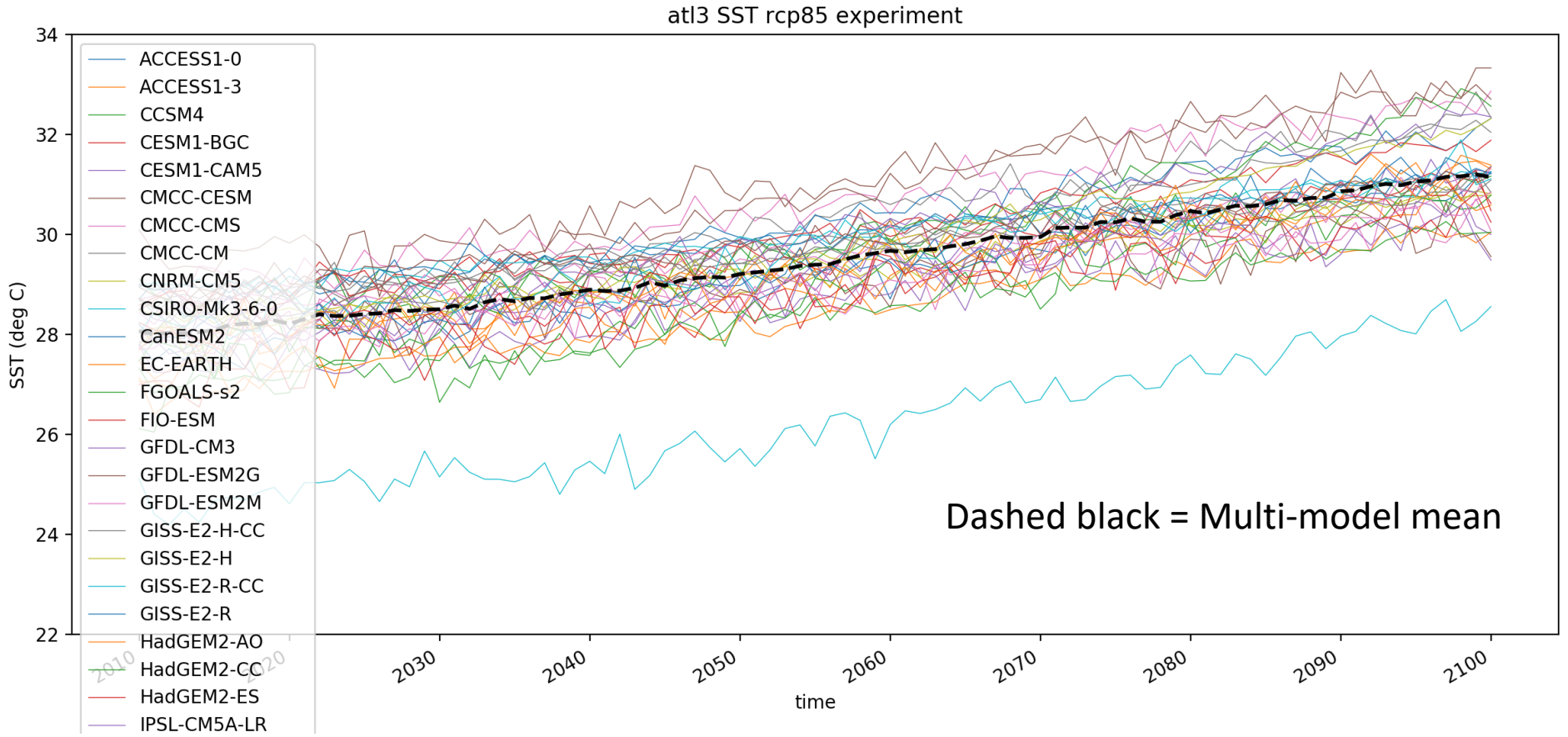
Historical period: observed and simulated SST

Sea surface temperature in the equatorial Atlantic cold tongue (ATL3 index)

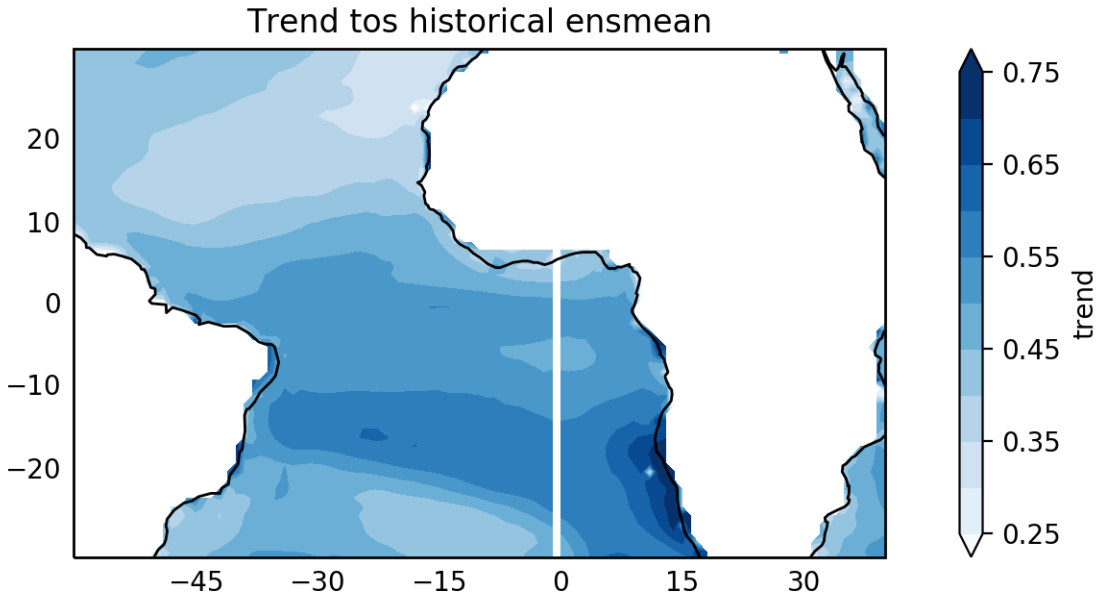


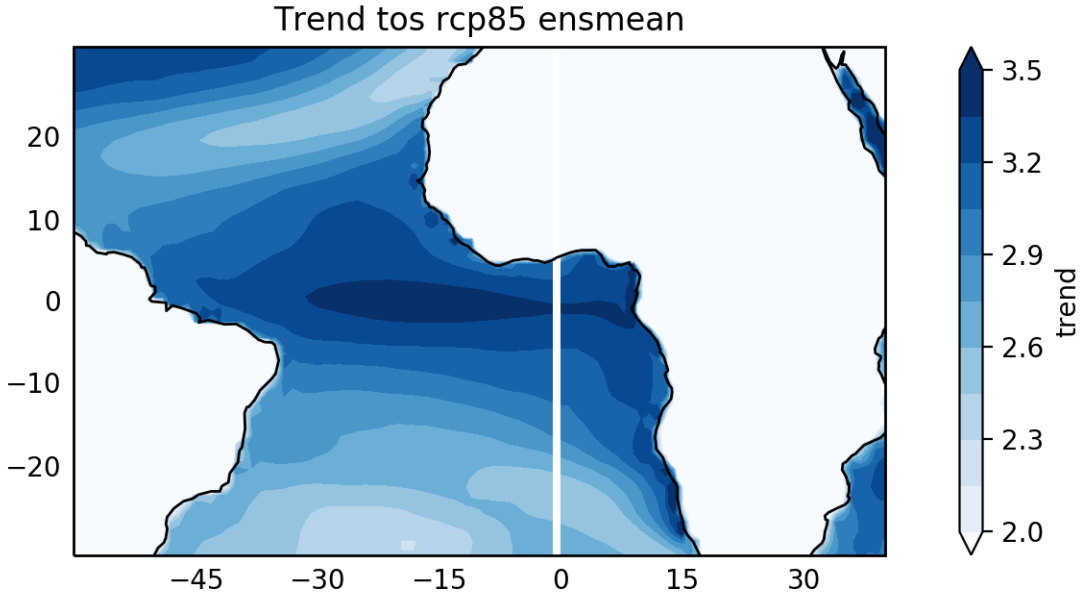
Future changes in Atlantic SST

Sea surface temperature in the equatorial Atlantic cold tongue (ATL3 index)

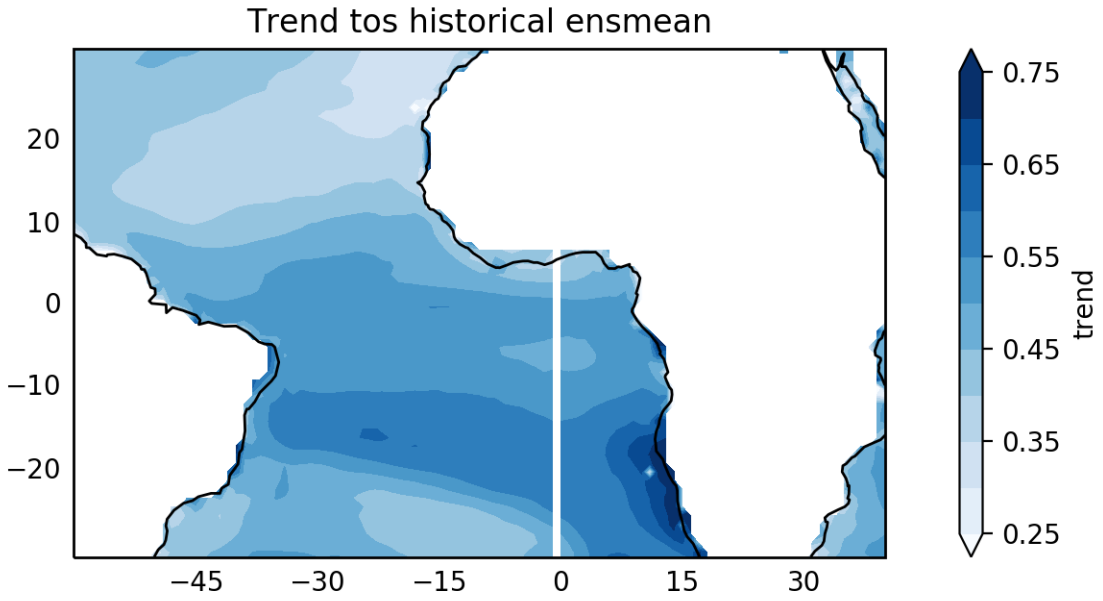


SST trends tropical Atlantic (MME)

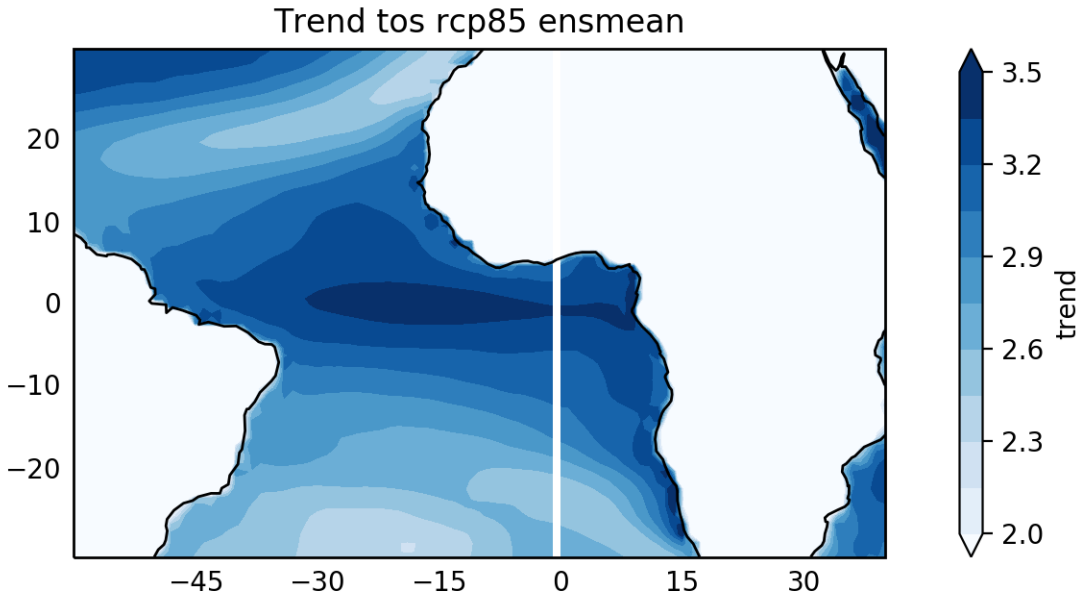




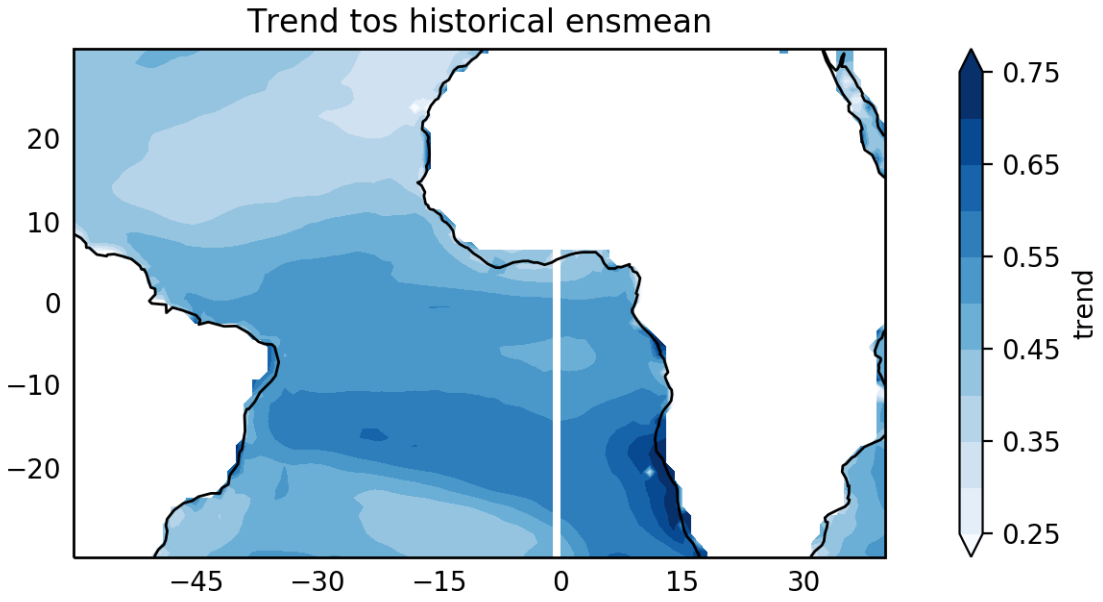
SST trends tropical Atlantic (MME)



- The observed warming rate is zonally homogeneous in the tropical Atlantic.
- Angola-Benguela region has warmed more.

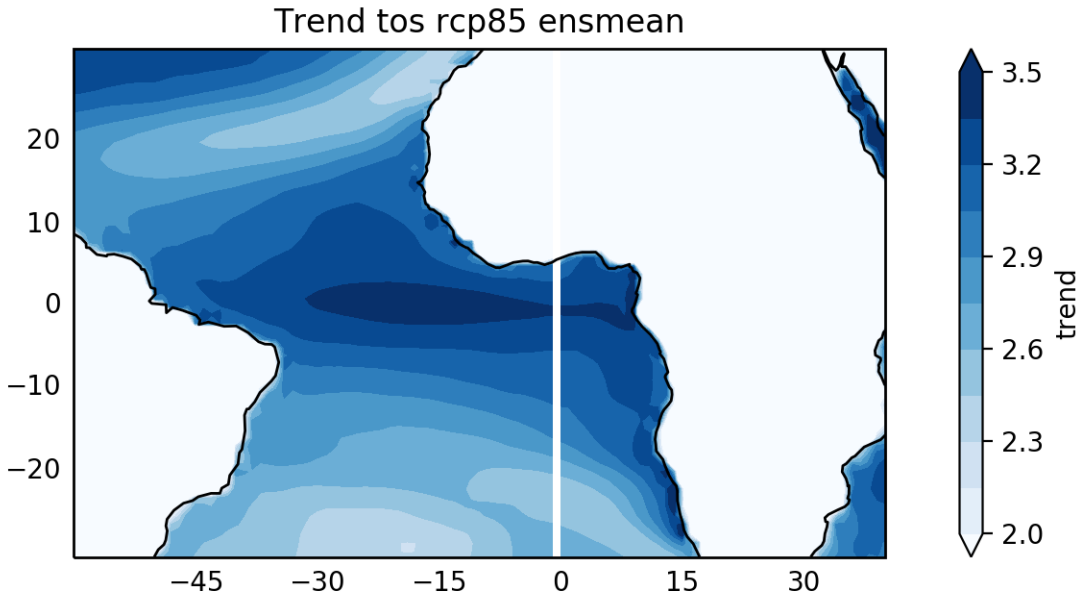


SST trends tropical Atlantic (MME)

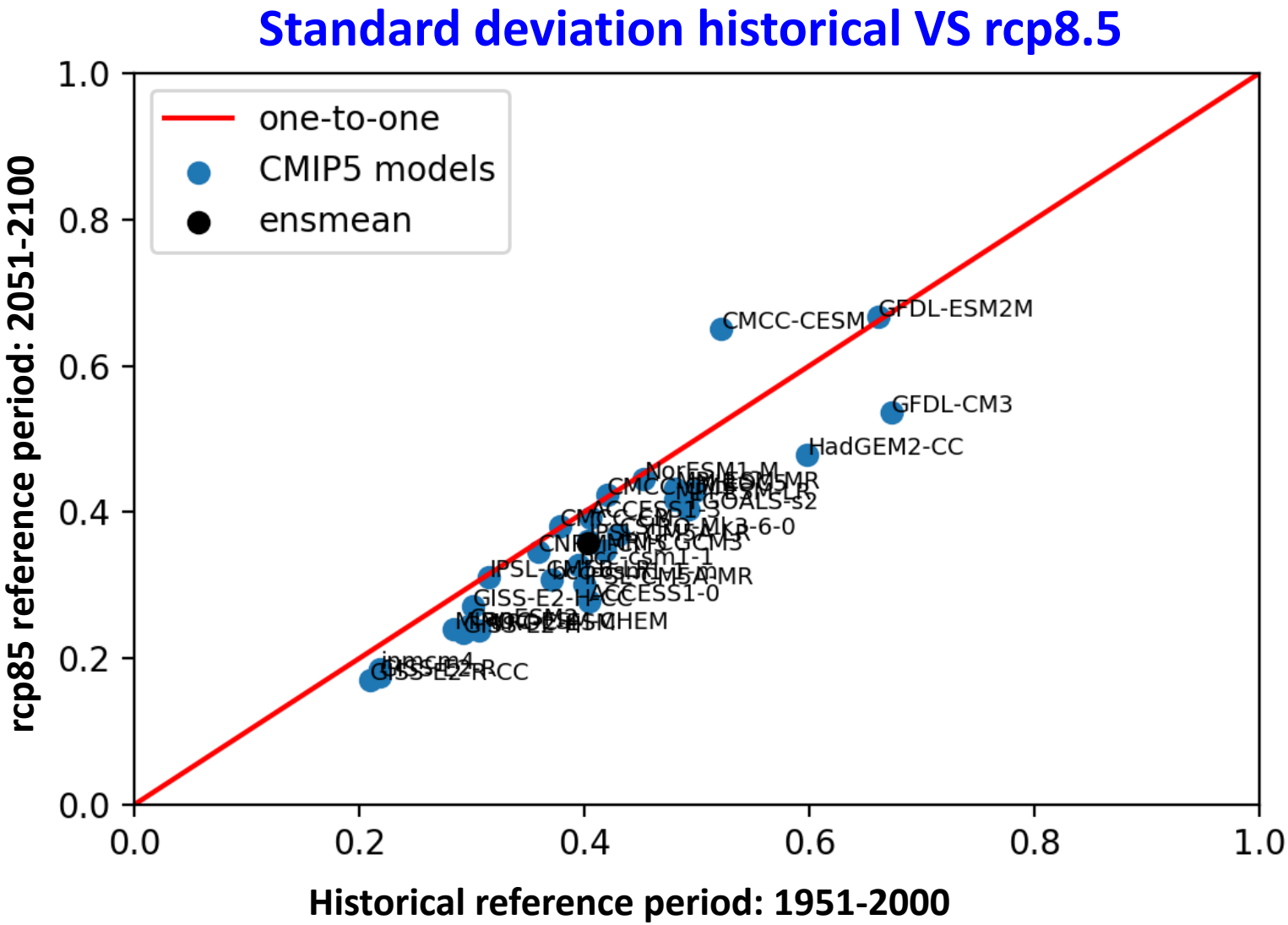


- The observed warming rate is zonally homogeneous in the tropical Atlantic.
- Angola-Benguela region has warmed more.

- The equatorial Atlantic and Angola-Benguela region larger warming rate.

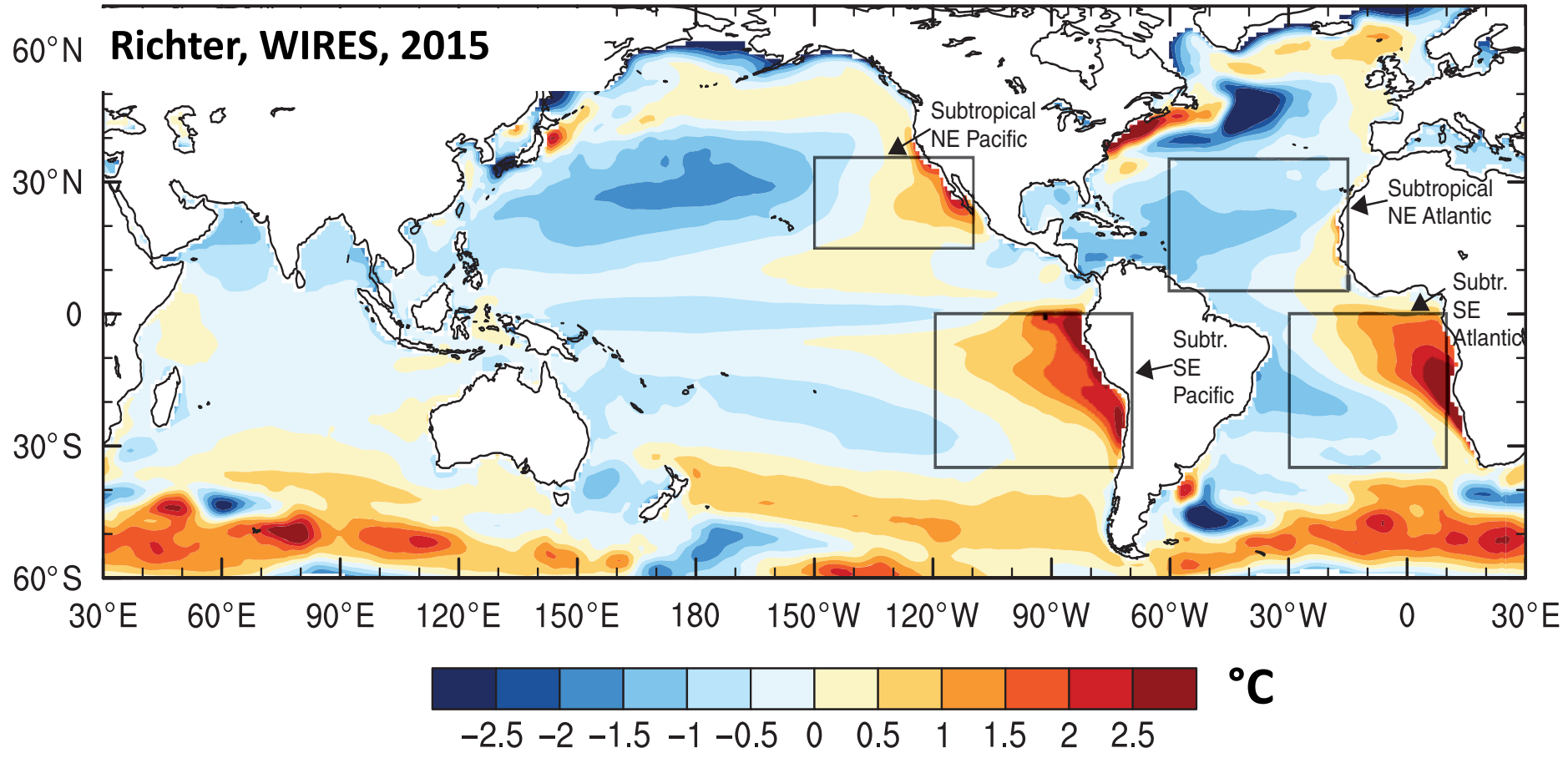


Models indicate reduction in future SST variability



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

CMIP5 multi-model mean sea surface temperature error

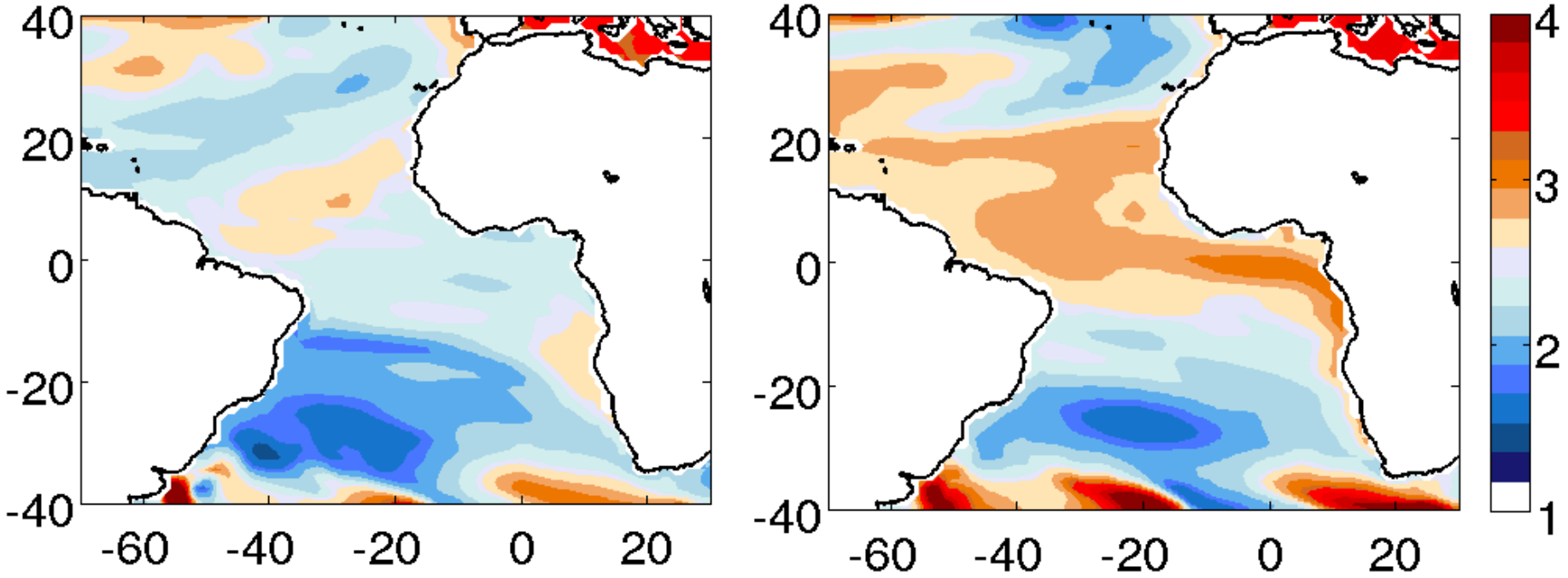


Climate change: Atlantic Niño warming when warm bias reduced

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

Standard NorESM

Anom. Coupled NorESM



Courtesy: Teferi Demissie

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Long-term climate variability and climate change in the tropical Atlantic

- Tropical Atlantic shows long-term warming with multi-decadal changes
- Internal variability and external forcing may explain the multi-decadal changes
- Observations show recent weakening of the Atlantic cold tongue strength and variability
- Model with historical forcing tend to fail to simulate the historical weakening of the cold tongue
- Large uncertainties in future changes in the tropical Atlantic

Thank you for your attention

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PREFACE