# Regional patterns of climate change: Dynamics and observations


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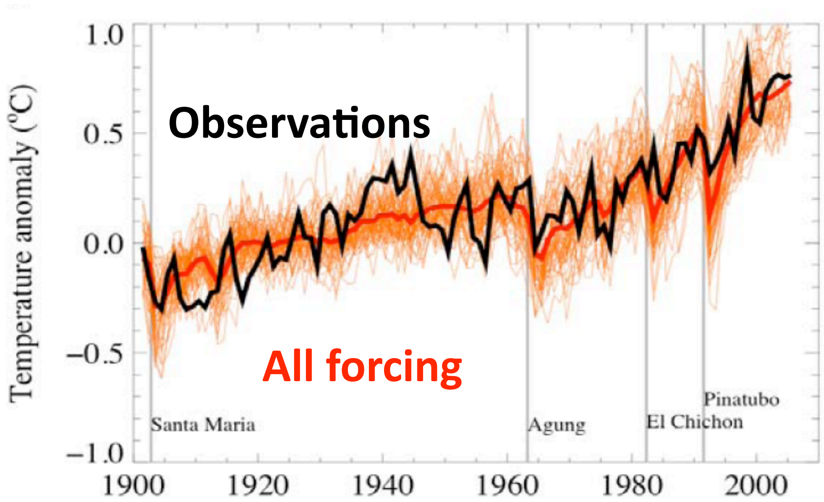
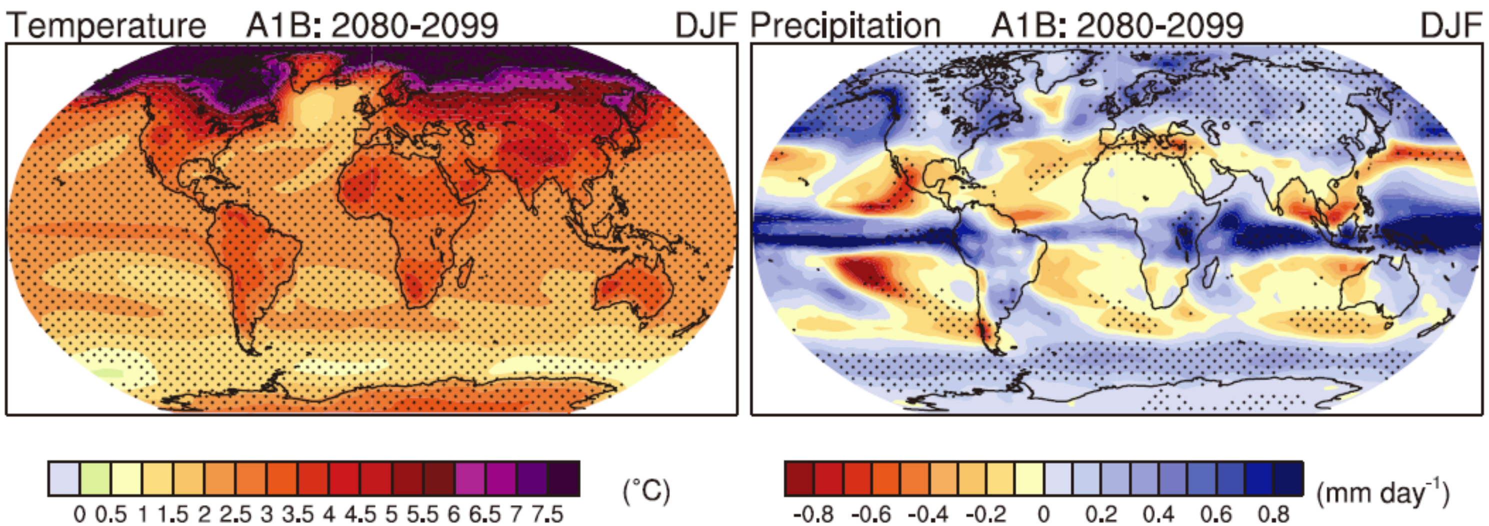



- SST patterns & rainfall change: simple principals
- Observed change in Eq. Atlantic: mean & Nino

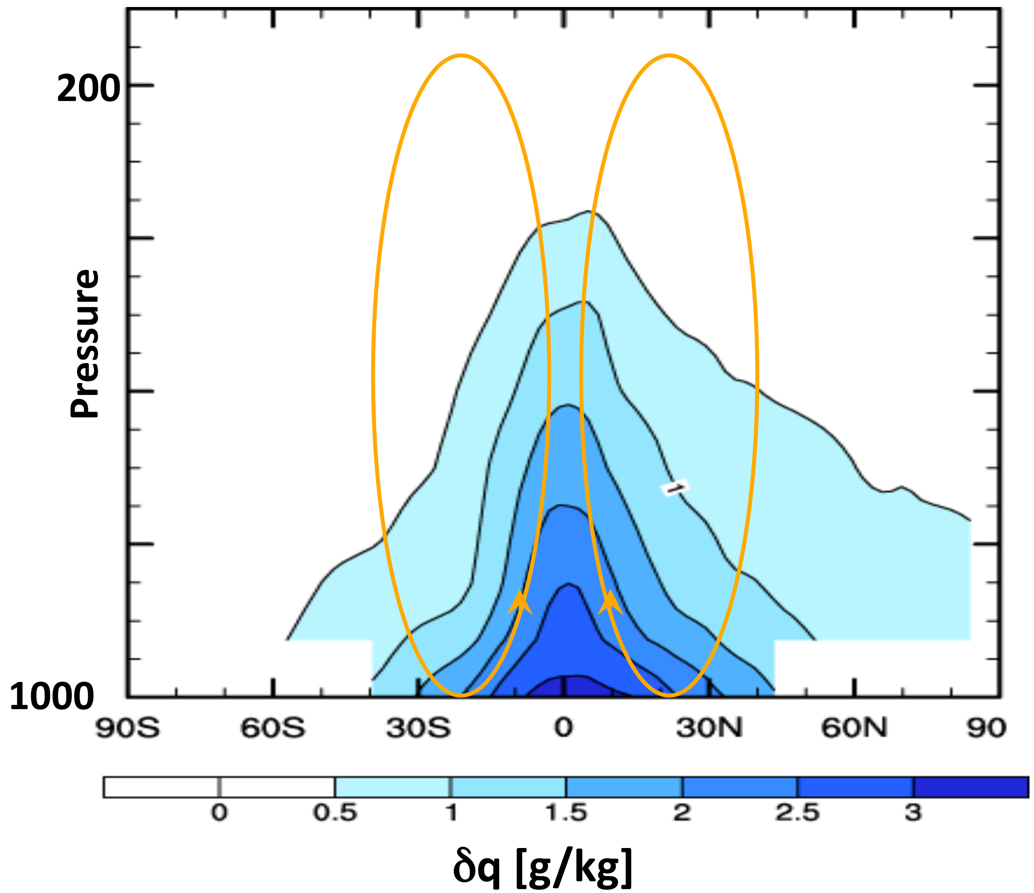
# Ocean warming is not uniform;
# precip change is even more variable in space.

| 50-yr change | Air Temp | Precip |
|---|---|---|
| Global mean | 1.16 | 1.48 |
| Spatial $\sigma$ | 0.46 | 7.17 |




A1B multi-model ensemble mean (IPCC AR4, 2007)

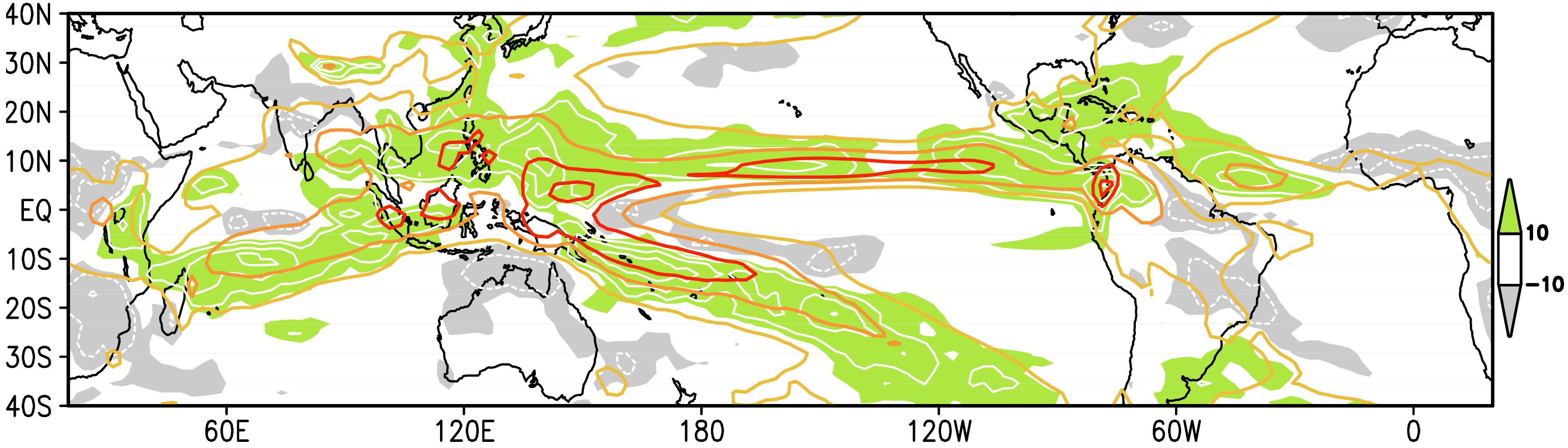
**Hypothesis 1: The wet gets wetter** (e.g., Held & Soden 2006, JC)
(Precipitation increases in equatorial rain bands; decreases in subtropics; and increases in high-latitudes due to increase in moisture transport)




Zonal-mean change in specific humidity

The wet-get-wetter pattern is realized in atmospheric response to a uniform SST warming in so-called Cess runs.

But what about in coupled simulations with δSST patterns?



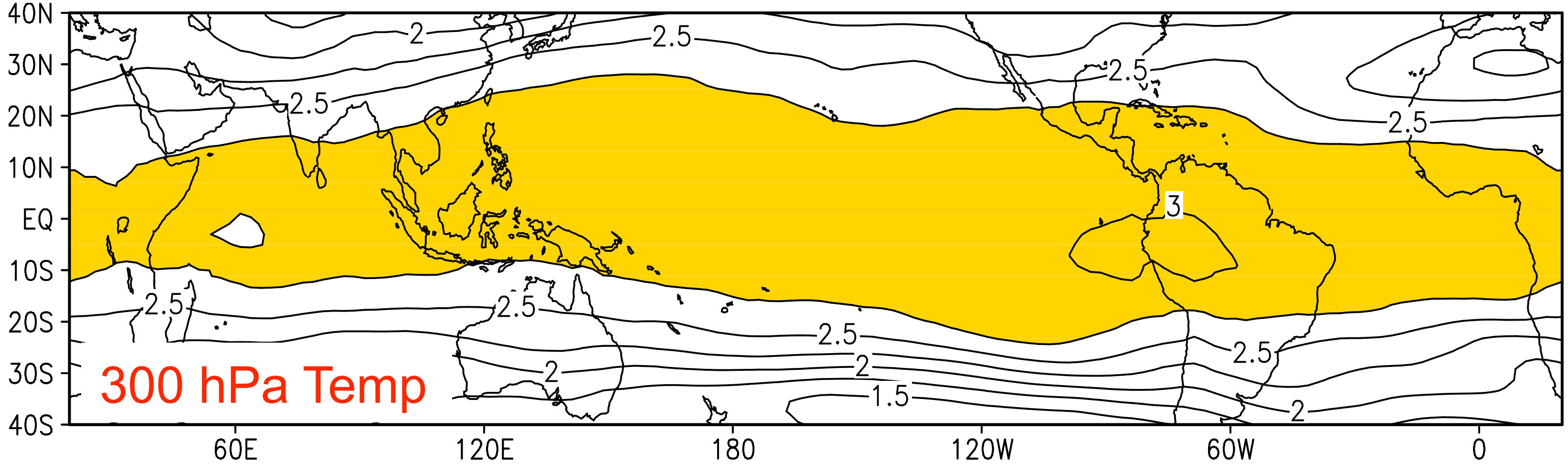

2K uniform SST warming: mean (contour) and change of precipitation

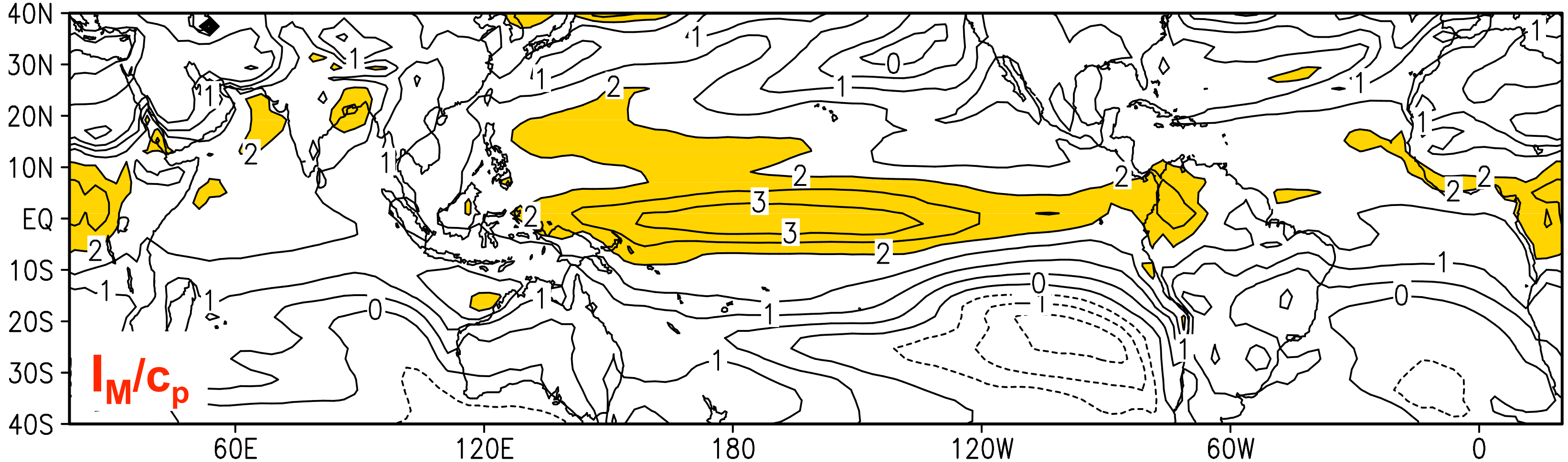
→ Wet-get-wetter pattern

# Hypothesis 2: Warmer get wetter (Xie et al. 2010, JC)

Convective Instability: $I_M = (c_pT+Lq)_{sfc} - (c_pT+Lq)_{300\ hPa}$

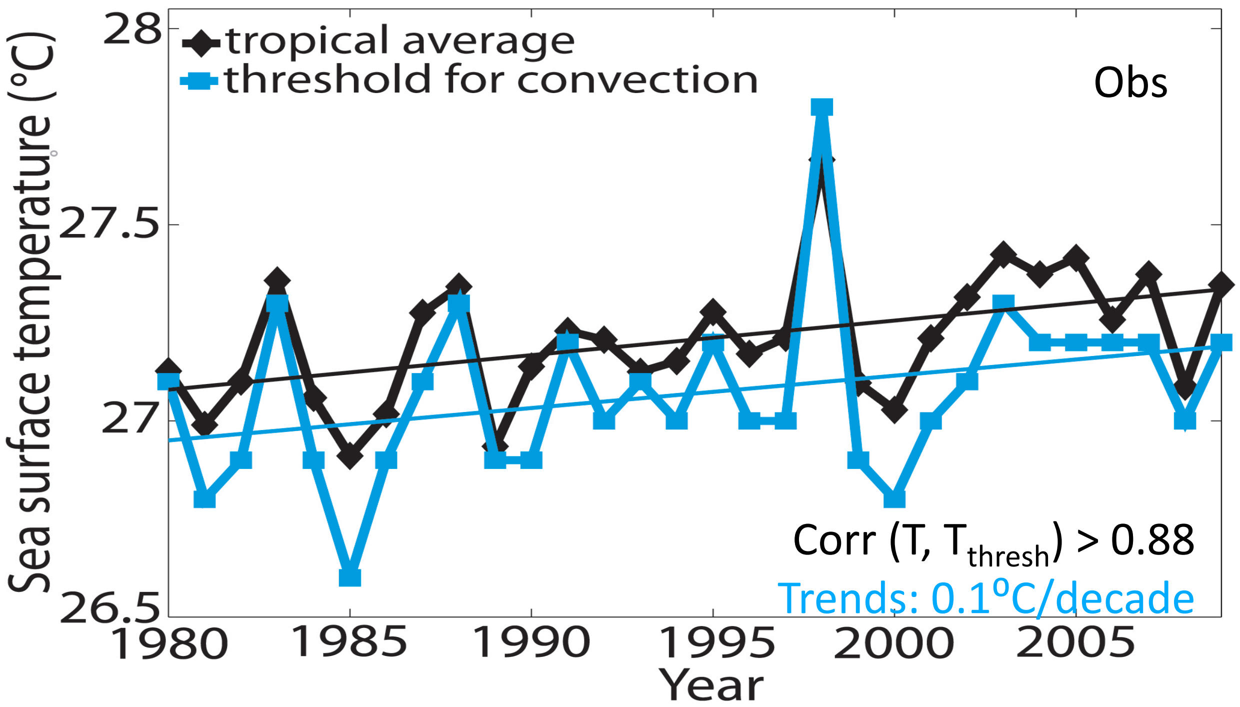
- Flat warming in upper troposphere ← equatorial waves
- $I_M$ follows closely SST patterns



# Rising Sea Surface Temperature Threshold for Tropical Convection

N. Johnson and S.-P. Xie (2010, *Nature Geosc.*)



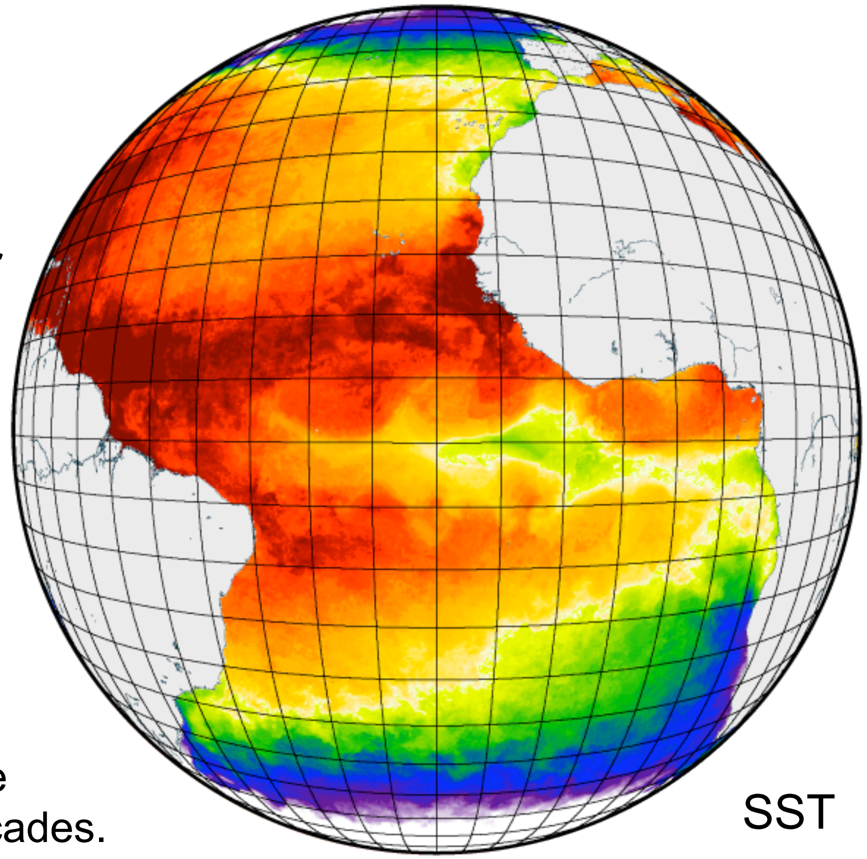


- Over the past 30 years, the convective threshold has risen in parallel with the tropical mean SST
- Consistent with the moist adiabatic lapse rate (MALR) adjustment of the tropical troposphere

# Patterns of tropical Atlantic climate change

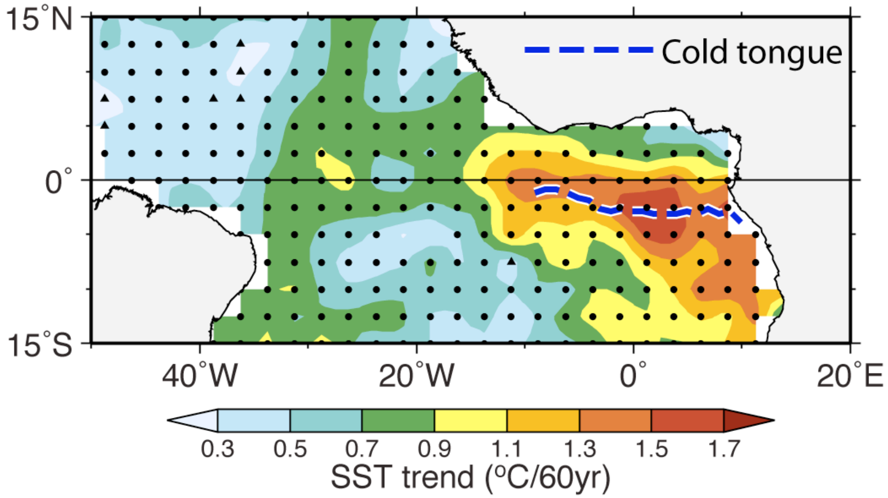
## Multi-variable synthesis

- WASWind (corrected with windwave obs)
- SST, SLP, marine cloud cover from ICOADS
- Bias-corrected XBT temp.
- Land precipitation
- 1950 – 2009 (60 years)

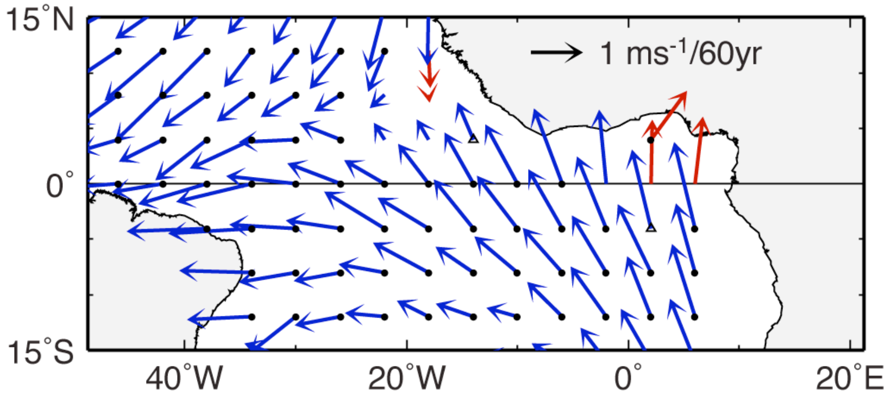



Tokinaga, H., and S.-P. Xie, 2011: Weakening of the equatorial Atlantic cold tongue over the past six decades. *Nature Geosci*., 4, 222-226.

# Trend for 1950 - 2009

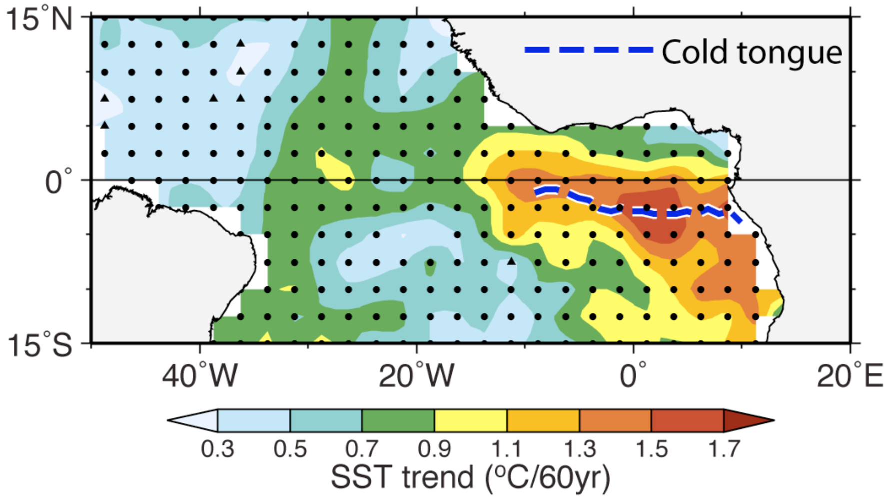



## SST
(°C/60yr)



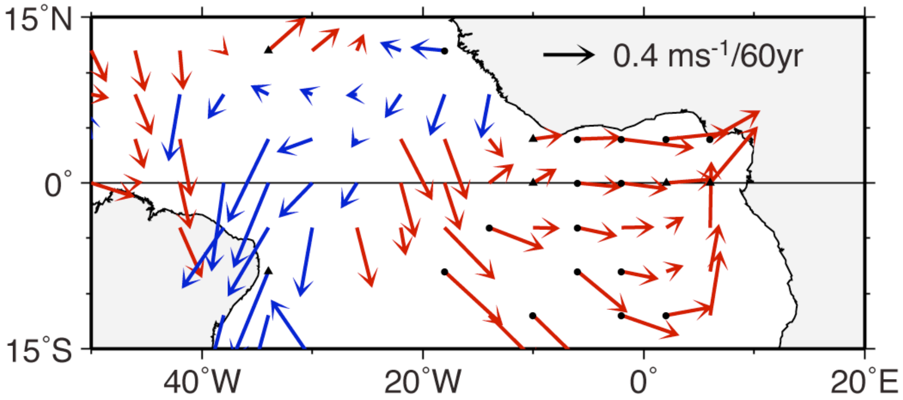

## Uncorrected ICOADS wind
(ms$^{-1}$/60yr)

# Trend for 1950 - 2009




SST

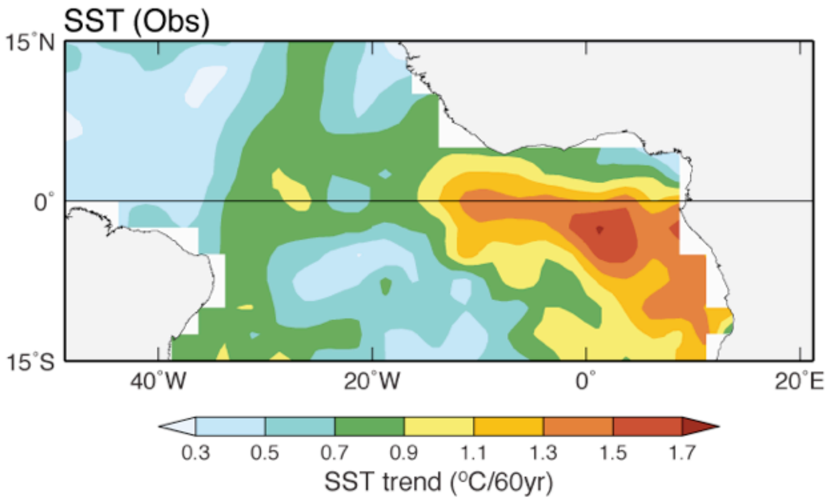
(°C/60yr)

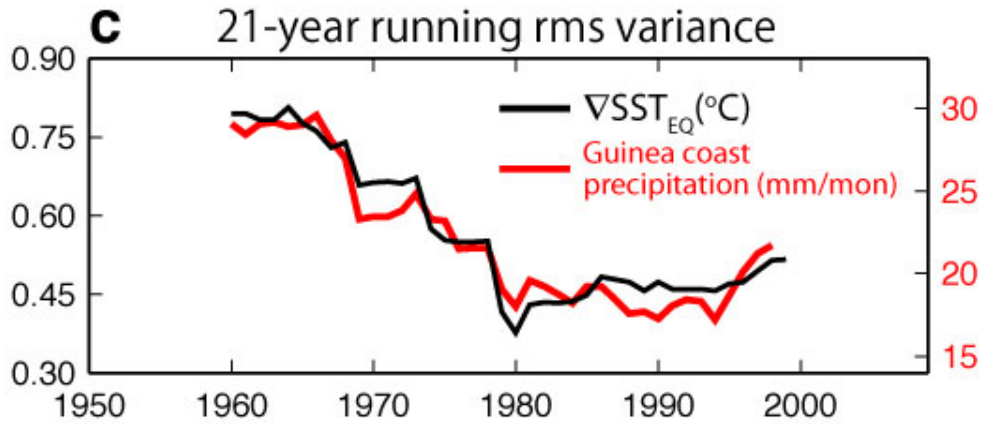



WASWind

($ms^{-1}$/60yr)

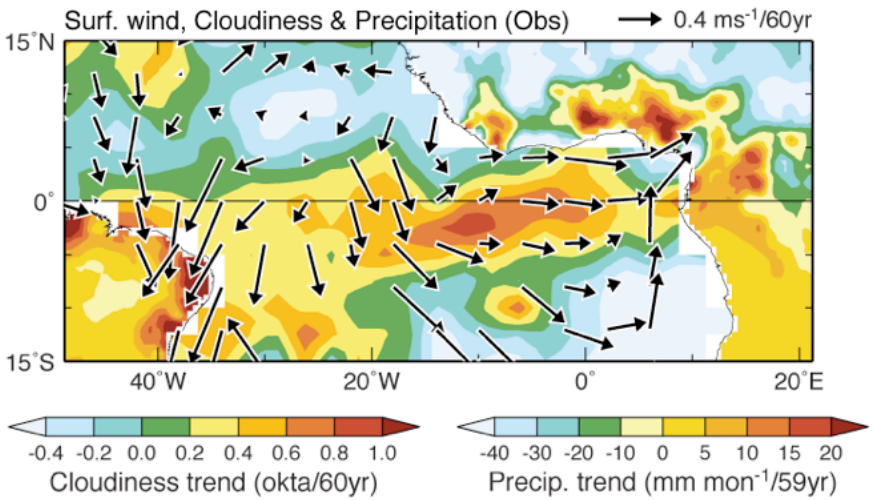
# Atlantic change: Ship obs 1950-2009

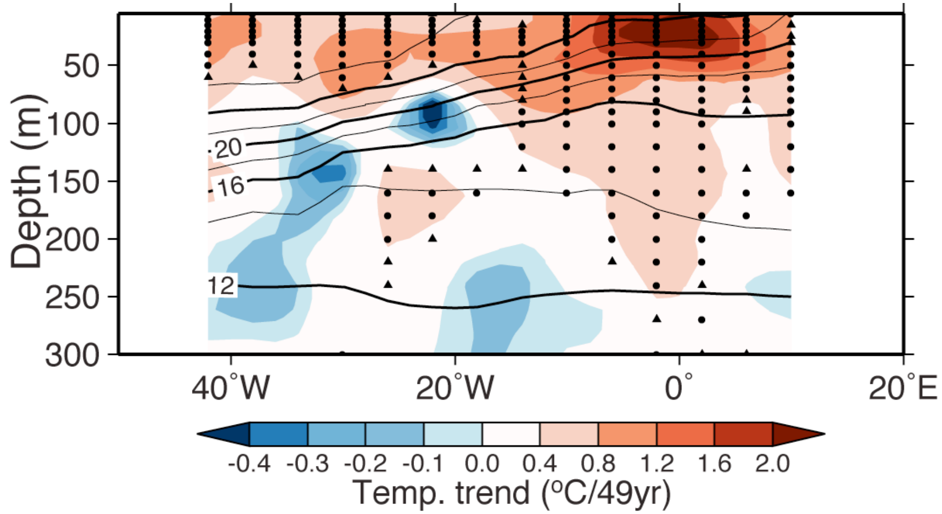



Weakened Atlantic Nino

Flattened thermocline



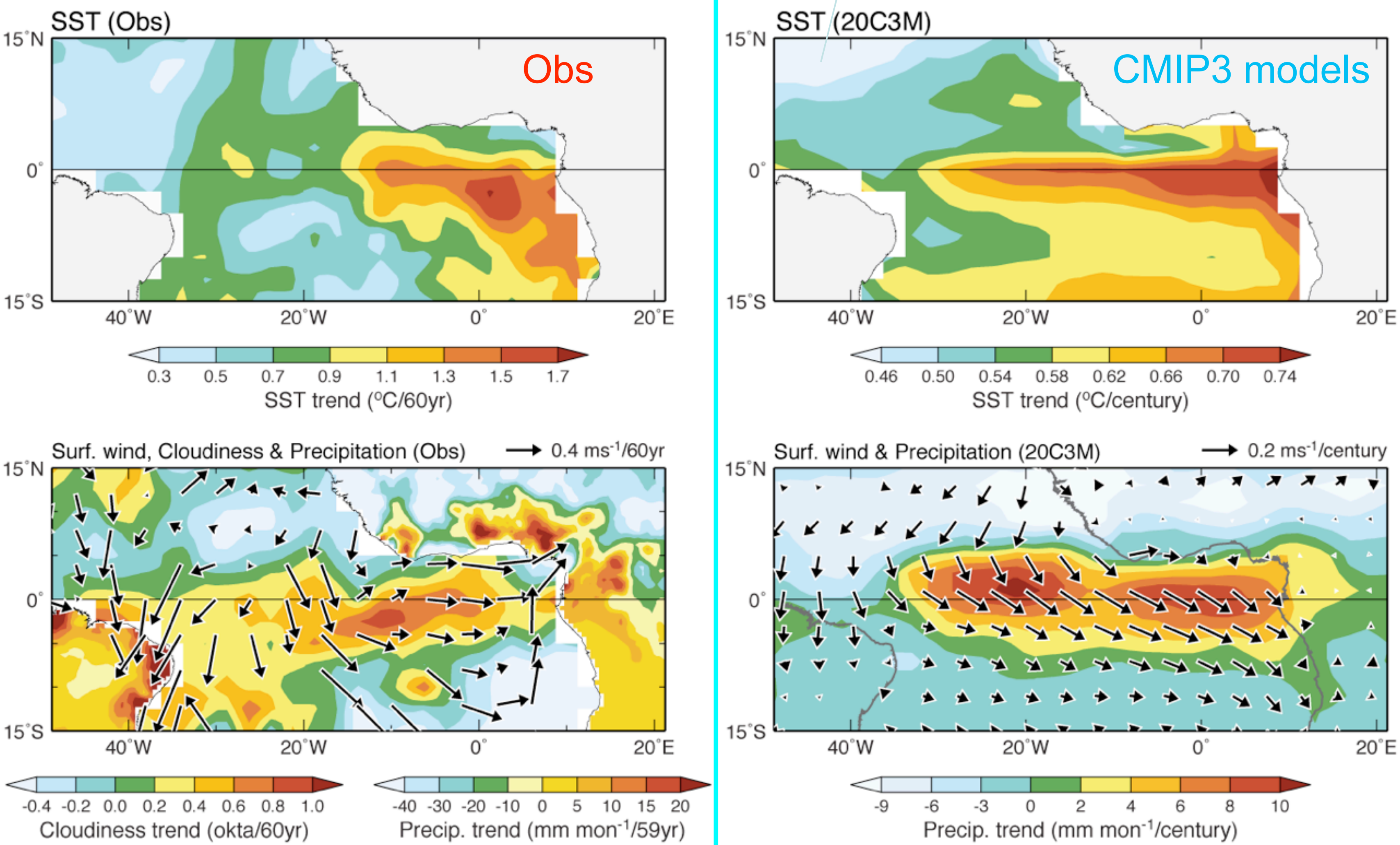



Tropical Atlantic climate might undergo major shifts as GHG forcing becomes more dominant.

Aerosol cooling

↓ ?

Reduced warming north of equator



# Summary

- Patterns of SST warming determine tropical rainfall change
  → Warmer get wetter.
- Reduced spatio-temporal variations in equatorial Atlantic
  -- Weakened cold tongue & reduced annual cycle (Bjerknes feedback)

  -- Reduced interannual variability (Atlantic Nino)

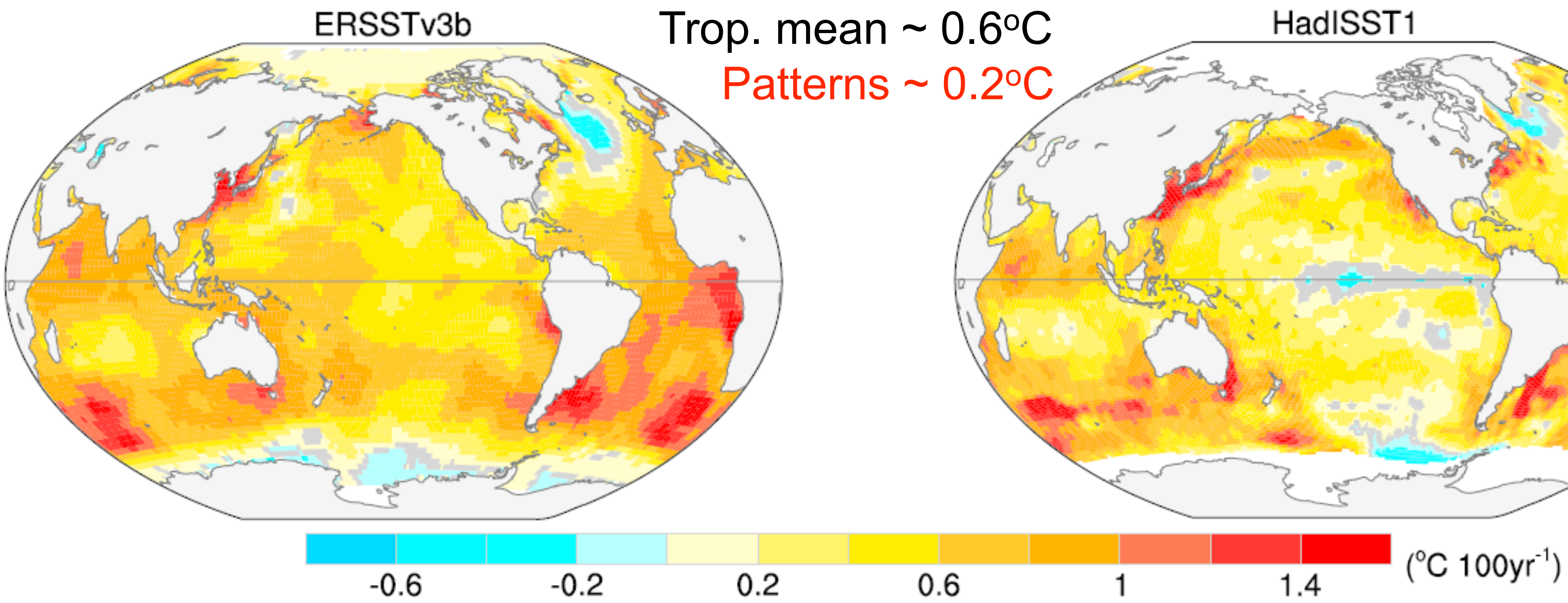
  -- Possibly triggered by NH aerosol forcing

- Regional patterns are large and important.
- Past SST patterns are poorly described and understood.
- Ocean-atmosphere interaction is important.

→ **Dynamics of regional climate change is an emerging topic bridging CLIVAR and IPCC.**

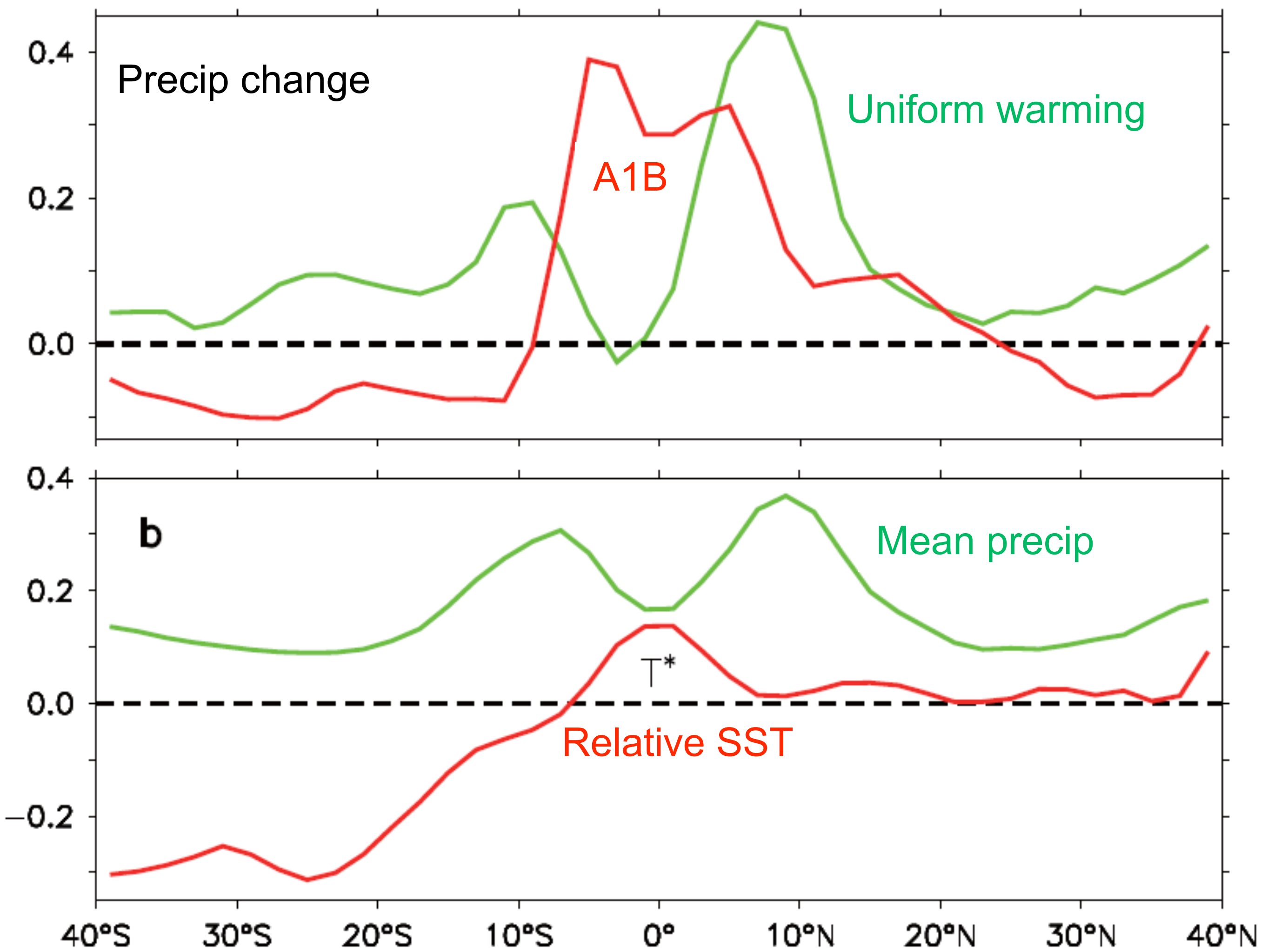
# Connect pieces of observations and with models

- What are the major patterns of observed change since 1950 when iCOADS ship observations are abundant?
- Are changes in ocean and atmosphere mutually consistent? Use physical considerations to constrain data uncertainties (measurement, sampling, mapping …)
- Are observed changes consistent with 20C simulations, and future projections?

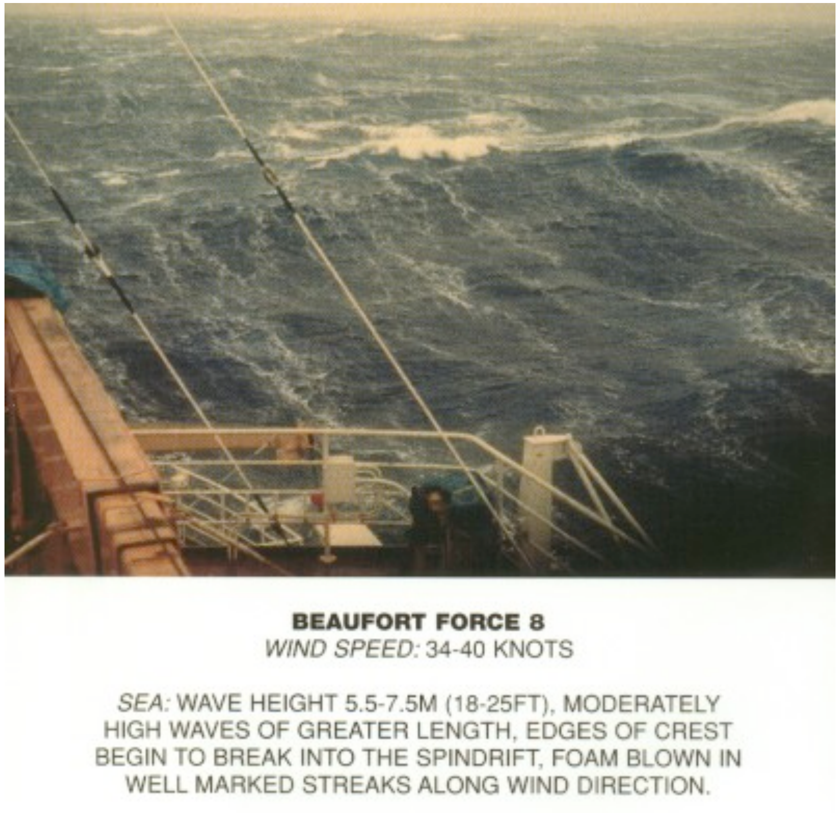



20th century SST trends (°C ) (Deser et al. 2010, *GRL*)

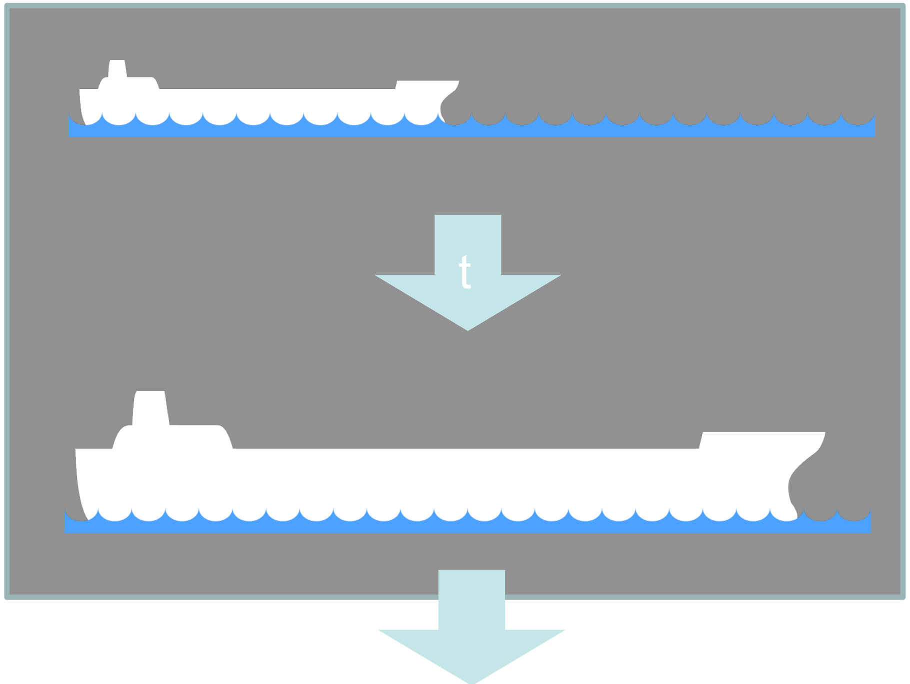
# **Four-model mean** (GFDL CM2.1, INM CM3.0, MPI, CCSM3)



# Surface wind trend based on ship obs.




Increased ship size & anemometer height



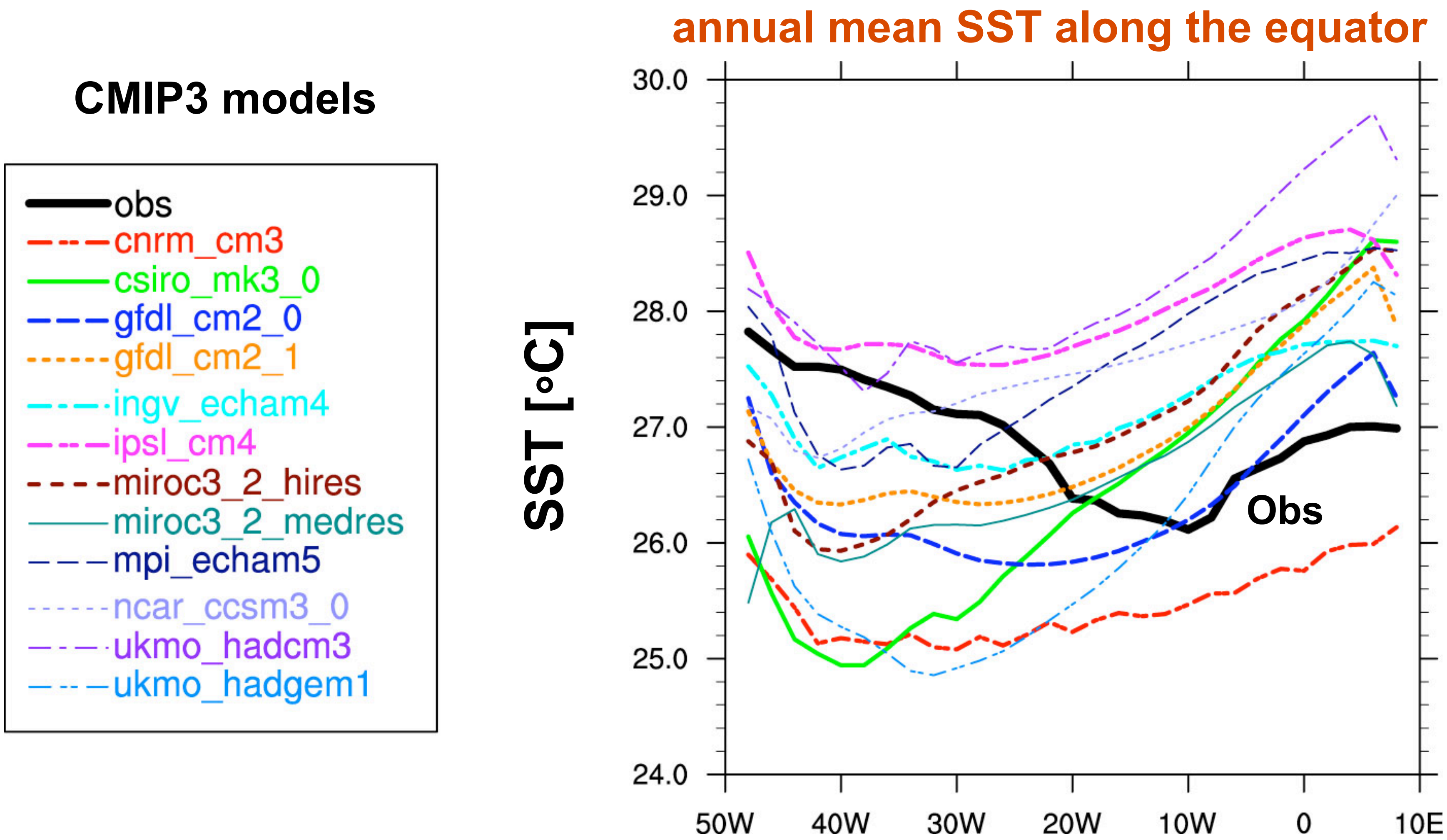

Spurious increase in measured wind

Visual observations of wind wave height → correct wind biases

Tokinaga, H., and S.-P. Xie, 2011: Wave and Anemometer-based Sea-surface Wind (WASWind) for climate change analysis. *J. Climate*, 24, 267-285.

Coupled models suffer large biases in the equatorial Atlantic.

## What can observations tell us about change there?




Richter, I. and S.-P. Xie, 2008: On the origin of equatorial Atlantic biases in coupled general circulation models. *Clim. Dyn.*, 31, 587-598.