Reducing the SST Bias to improve the Representation of Atlantic Niño Variability and Dynamics

Tina Dippe[1], Richard Greatbatch[1], Hui Ding[2]

GEOMAR

The Atlantic Niño

- Interannual **variability of the equatorial Atlantic cold tongue**[1] (Fig. 1). Impacts rainfall variability of the surrounding continents.
- Models struggle to simulate the Atlantic Niño. Suggested reasons: **Mean state biases**[2] (Figs. 2,3), **stochastic processes** dominating SST variability[3].

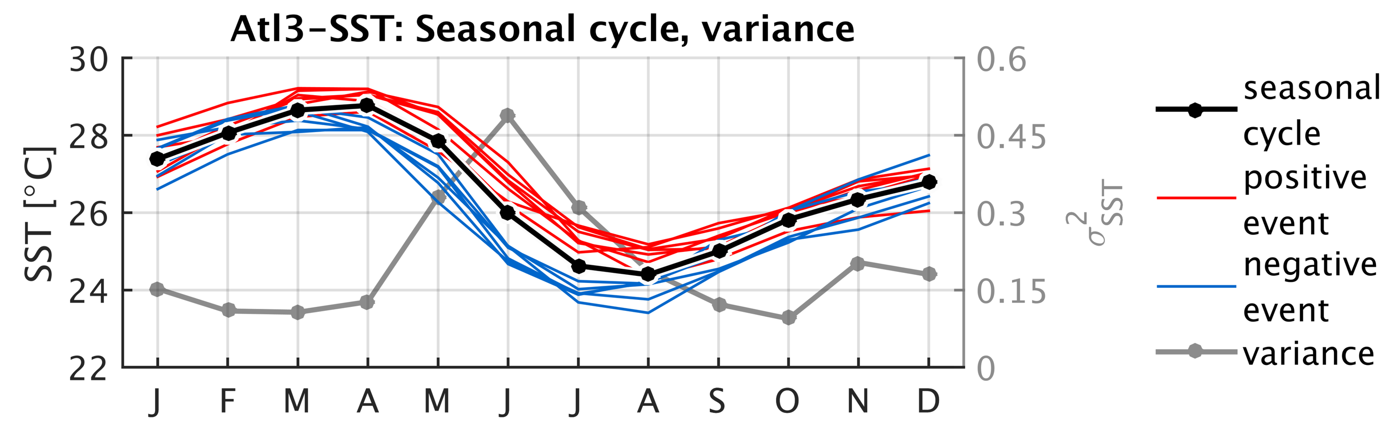

Fig. 1: Observed seasonal cycle and SST trajectories for Atlantic Niño events (black and colored lines, left y axis), and SST variance (right y axis, grey), 1981-2012. The Atlantic Niño index is the Atl3 (cf. Fig. 2) SST anomaly averaged for May-July. Events are based on the time series associated with the first principal component (PC1) of SST anomalies in the region [-10 10]°N, [-50 15]°E. If PC1 exceeds ± 1standard deviation during May-July, an event occurs.

Research Scope

Question 1: When do dynamical processes contribute to SST variability in the tropical Atlantic?

Question 2: How does the SST bias affect these processes in a coupled model?

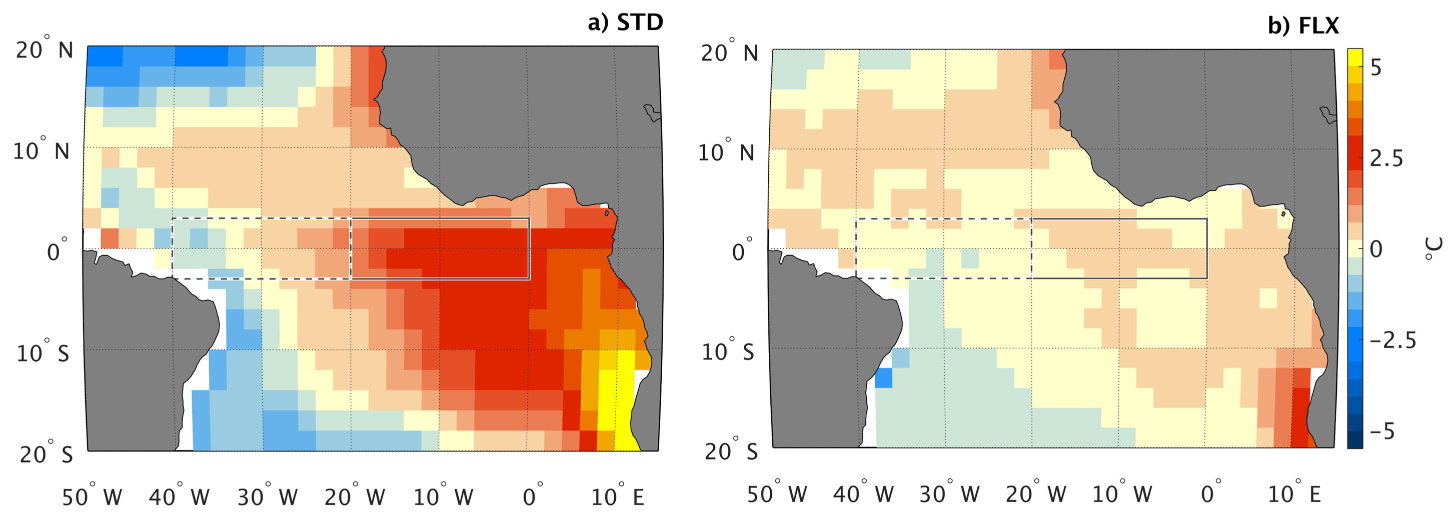

Fig. 2: Annual mean SST bias relative to ERA-Interim SST, 1981-2012, of (a) a standard simulation of the Kiel Climate Model, and (b) a heat flux corrected version. The solid (dashed) box is the Atl3 (WAtl) region.

Bias Reduction in the Kiel Climate Model

- Produce two **experiments** with the Kiel Climate Model (KCM):
  - **STD**: Standard run, strongly biased
  - **FLX**: Additional surface heat flux correction, i.e. strong SST bias-alleviation (Figs. 2,3)
- Wind stress forcing via **partial coupling**[4]: Force the ocean and sea ice components with wind stress anomalies that are added to the model wind stress climatology. SST and the atmospheric wind field are fully prognostic.

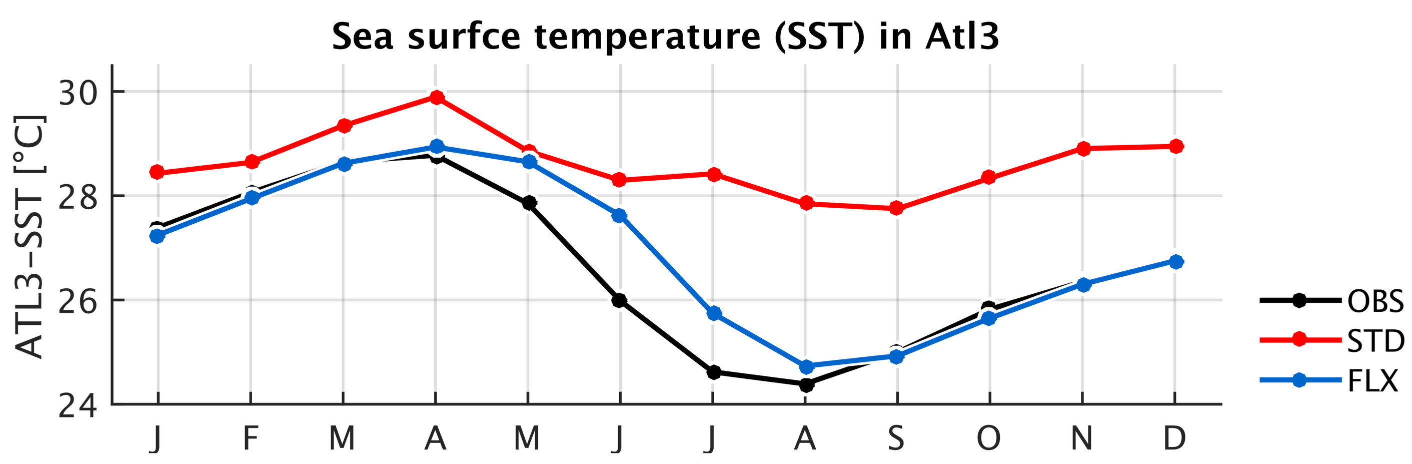

Fig. 3: Seasonal cycle of Atl3 SSTs in observations (black line, same as in Fig. 1), the heat-flux corrected experiment (blue, FLX), and the standard experiment (red, STD).

SST Decomposition: Linear Regression Models

- Build empirical models of **dynamical SST**.
- Stochastic SST = Total SST – dynamical SST
- Diagnose contribution of dynamical processes to SST variability.
- **Predictors**: Based on positive feedbacks in the tropical Atlantic:
  - Sea surface heigth (**SSH**) in Atl3: Thermocline feedback
  - Zonal surface wind anomalies (**u10**) in WAtl: Zonal advection feedback

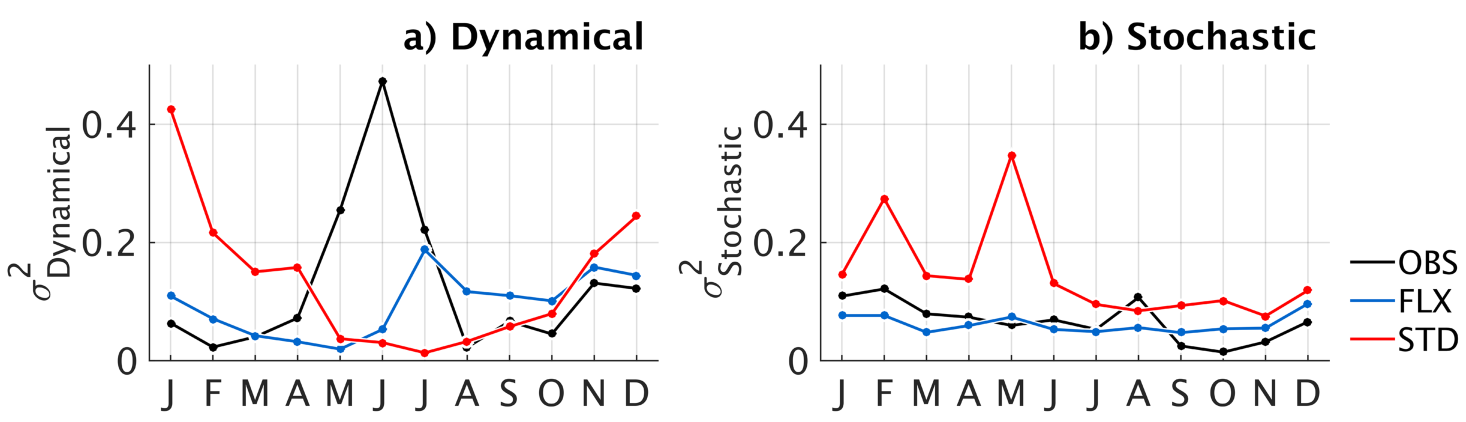

Fig. 4: SST variance decomposition into (a) dynamical and (b) stochastic components for (black, blue, red) observations, and the FLX and STD experiments. Observations are: SST, u10 (SSH) from ERA-Interim (AVISO).

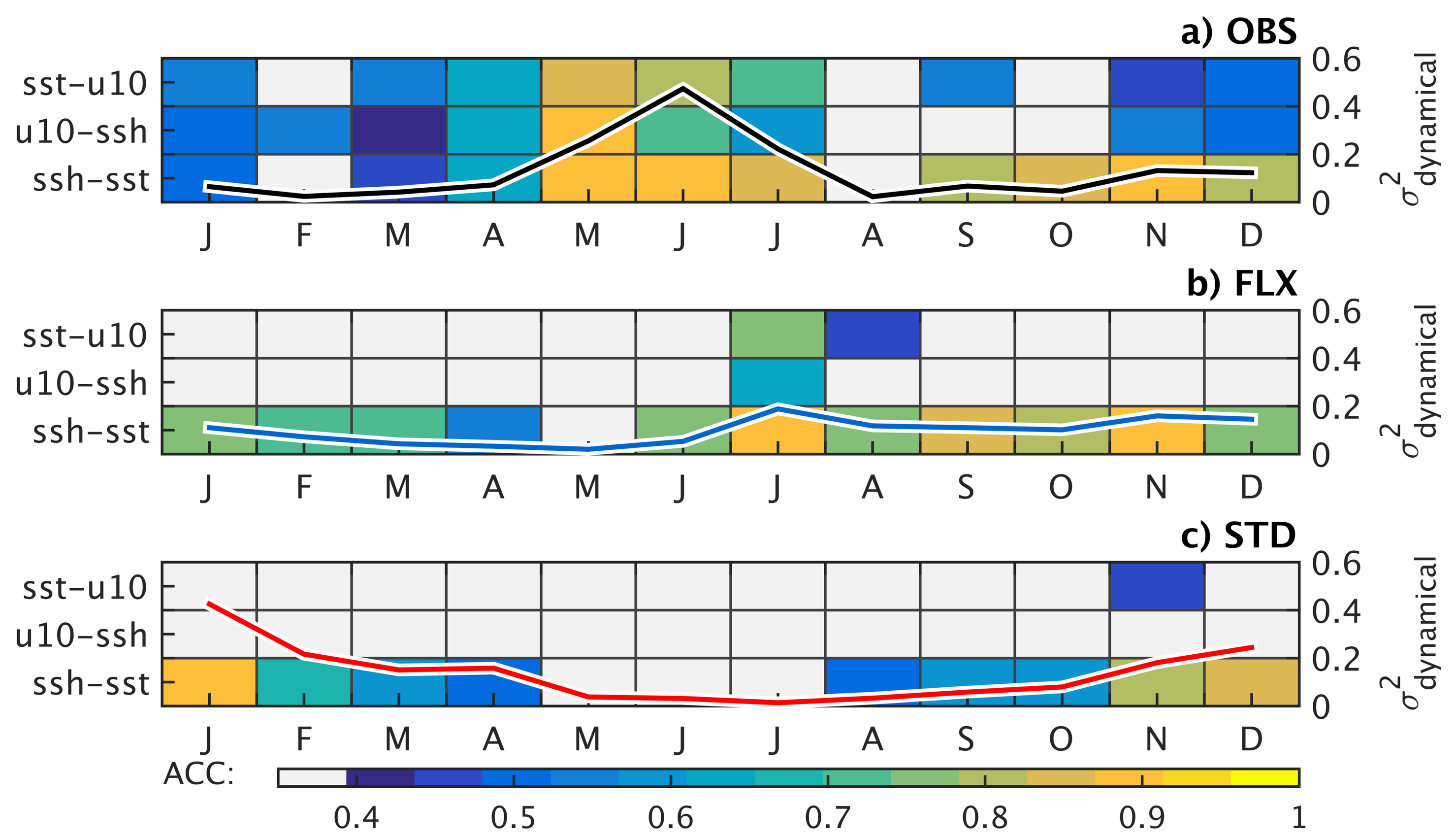

Fig 5: Instantaneous relationships between SST, u10, and SSH in the tropical Atlantic (shading, left y axis) and dynamical SST variance from the empirical model (right y axis, same as in Fig. 4a) for (a, b, c) observations, FLX, and STD. The relationship strength is measured via the anomaly correlation coefficient (ACC). ACC values that are not significantly different from 0 at the 95% level according to a Student t test are shown in grey.

The Atlantic Cold Tongue: Key to realistic SST Dynamics

- **Dynamical processes clearly contribute to observed SST variability** in May-July (Figs. 4a)
- Need a closed Bjerknes feedback loop to establish dynamical SST variability. (Fig. 5a)
- **Bias alleviation improves dynamical SST variability** (cf. FLX and STD experiments in Fig. 4a).
- However, FLX dynamical SST variance, too, peaks one month late (Fig. 4a). This is because the FLX **cold tongue** peaks one month late (Fig. 3). The feedbacks on the other hand depend on the cold tongue and can only work correctly in July (Fig. 5b).
- The STD experiment fails to produce the cold tongue (Fig. 3). Hence, the feedbacks are not established (Fig. 5c), and dynamical SST is unrealistic (Fig. 4a).

Contact: Tina Dippe (tdippe@geomar.de)
Affiliations: [1] GEOMAR Helmholtz Centre for Ocean Research, Kiel – [2] Cooperative Institute for Research in Environmental Sciences, NOAA Earth Systems Research Laboratory, Boulder, U.S.A.

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[1] Xie & Carton, 2004: Tropical Atlantic Variability: Patterns, Mechanisms, and Impacts. *Pages 121-142 of: Earth's climate. American Geophysical Union.* **[2] Richter et al., 2012**: Tropical Atlantic biases and their relation to surface wind stress and terrestrial precipitation. *ClimDyn.* **[3] Nnamchi et al., 2015**: Thermodynamic Controls of the Atlantic Nino. *Nat comm.* **[4] Ding et al., 2013a**: Hindcast of the 1976/77 and 1998/99 Climate Shifts in the Pacific. *JClim.*