ATMOS - Modelling air-sea interaction over the Gulf Stream and North Atlantic Current fronts

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Motivation

Previous studies (e.g. Minobe et al., 2008; 2010) indicate a significant **impact of the Gulf Stream on the climatological state of the atmosphere**. Strong SST gradients cause low level wind convergence, leading to strong upward motion and enhanced precipitation. In contrast, **this study** investigates the **atmospheric response to multi-annual to decadal SST variability**. Since ocean dynamics begin to control SST on the low frequencies, a better understanding of the coupling processes might lead to significant improvements of atmospheric predictability in the North Atlantic sector.

Models & Experiments

Model

- ECHAM5 atmospheric general circulation model
- Horizontal resolution: T106 (~1°)
- Vertical resolution: L31, top: 10 hPa

Transient Ensemble experiment

- 1870-2007, forced by monthly varying observed SST.
- 5 member ensemble

Fixed SST sensitivity exp.

- Control run: 60 years with climatological observed SST
- Sensitivity run: 60 years with fixed SST anomaly added to the climatological SST field in the Gulf Stream region

References

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Results (1) – Transient Ensemble Experiment

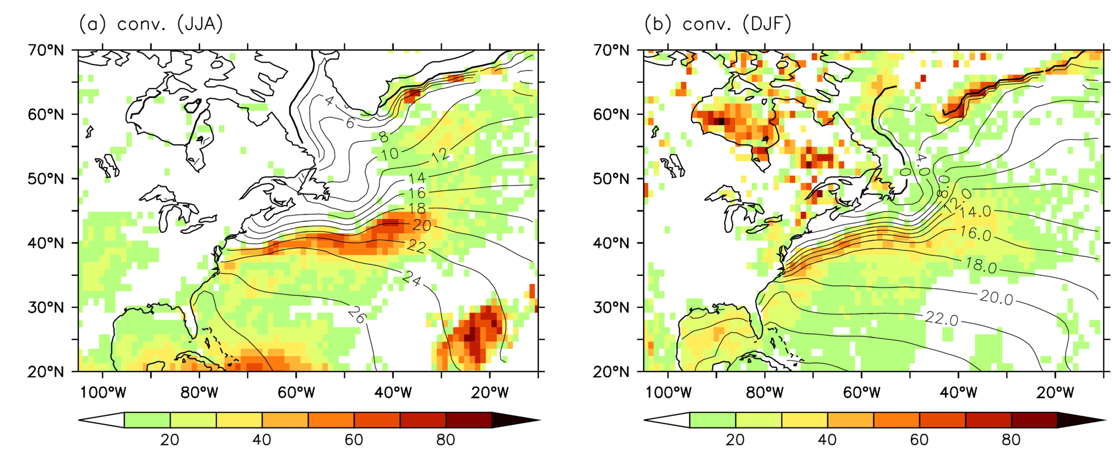

Figure 1: ANOVA explained variance (in %) due to the boundary forcing of convective precipitation for JJA (a) and DJF (b). Contours indicate climatological seasonal SSTs in °C.

- ANOVA: Up to 70% (50%) of low-frequent convective precipitation variability in summer (winter) can be explained by the boundary conditions (Fig. 1).

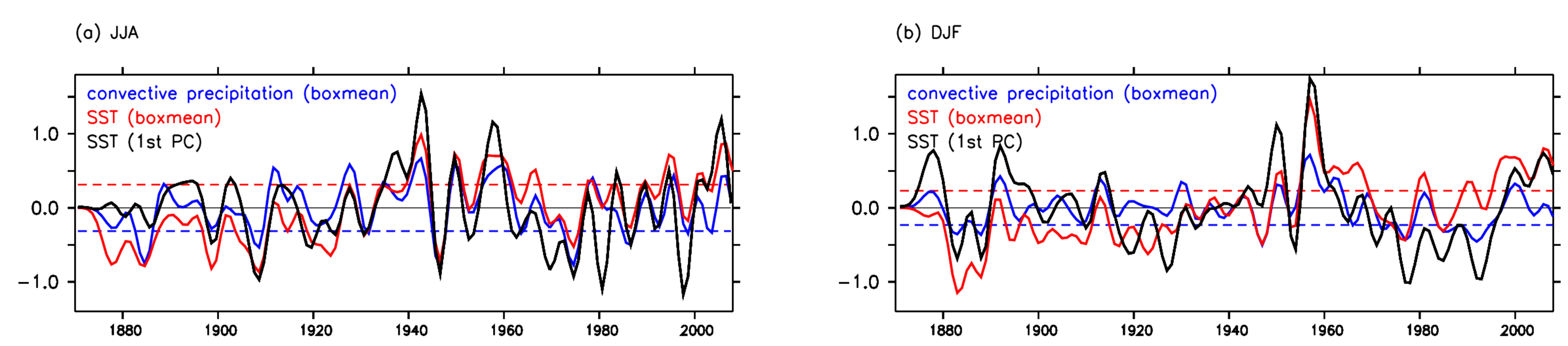

Figure 2: Time series of box means (65W:40W, 38N:40N) of 5 year low pass filtered seasonally averaged anomalies of ECHAM5 convective precipitation (in mm/day, blue), HadISST (in K, red) and first PC of the 5-year low-pass filtered Gulf Stream region SST Dashed lines: +/- 1 standard deviation of the convective precipitation time series, the treshold used to create SST composite for the forcing pattern for the sensitivity experiment.

- 5-year low-pass filtered timeseries of convective precipitation and SST are highly correlated (r=0.73 in summer and r=0.55 in winter for the box mean of 65°W-40°W/38°N-40°N) (Fig 2).

Results (2) – Sensitivity Experiment

summer response

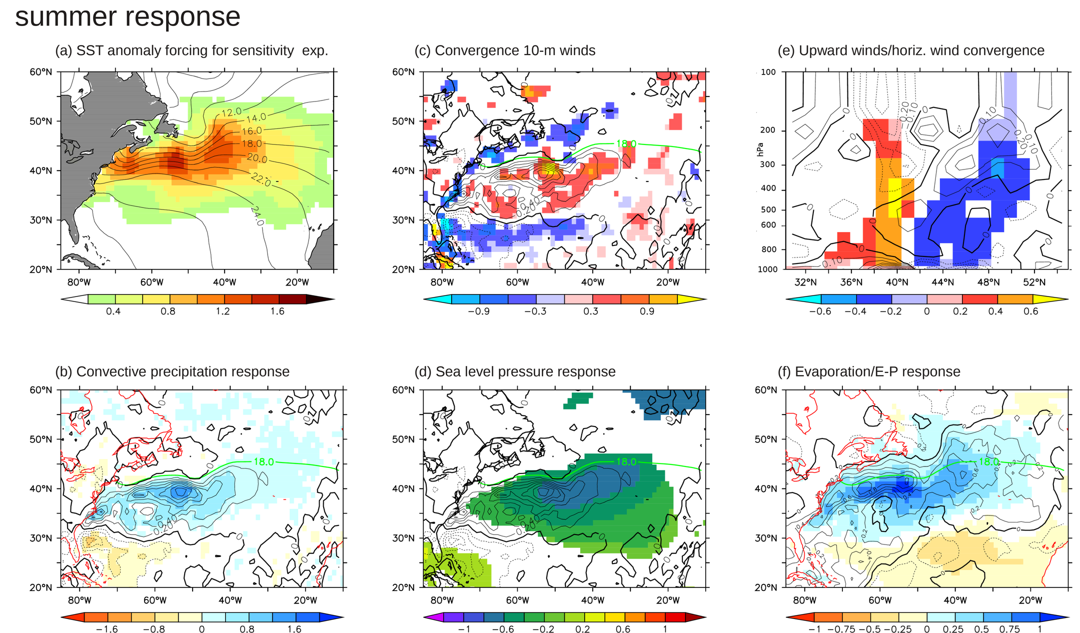

Figure 3: Summer (JJA) response in the sensitivity experiment. (a) Anomalous SST forcing (in K, shad.) and climatological SST (in K, cont.). (b) Convective precipitation response (in mm/d). (c) Convergence of 10m-winds response (in 10^{-6}m/s^2). (d) SLP response (in hPa). In (b-d) the contours are convective precip. Response (in mm/d). (e) Cross section of the zonally averaged (60°W-50°W) upward velocitiy resp. (in 10^{-2} Pa/s, shadings) and horizontal wind convergence (in 10^{-6}m/s^2 cont.). (f) Evaporation-precipitation response (in mm/d, shadings) and anomalous evaporation (in mm/d, cont.)

winter response

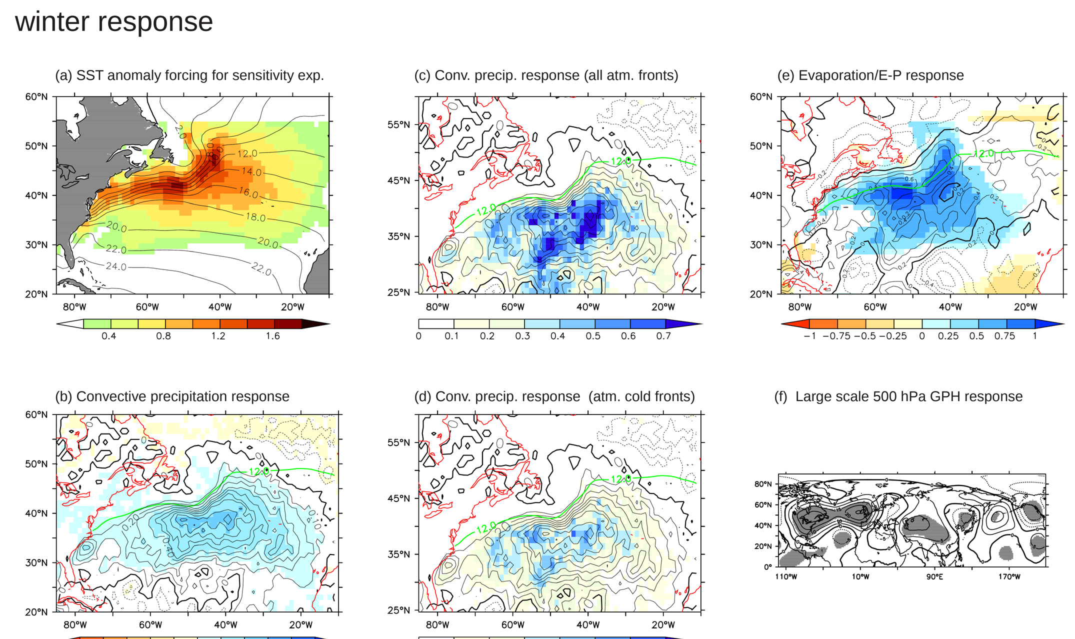

Figure 4: Winter (DJF) response in the sensitivity experiment. (a) Anomalous SST forcing (in K, shad.) and climatological SST (in K, cont.). (b) Convective precipitation response (in mm/d). (c) Convective precipitation response, only that part considered, which falls within a radius of 200 km of atmospheric fronts. (d) As (c), but for cold fronts only. (e) Evaporation-precipitation response (in mm/d, shadings) and anomalous evaporation (in mm/d, cont.). (f) Large scale response of 500 hPa geopotential height (in m). Values passing a bootstrapping test at the 95% conficence level are shaded in grey.

Both seasons:

- consistent to ANOVA enhanced convective precipitation signal (Fig. 3b and 4b).

Summer:

- convective-like response, enhanced climatological state (Minobe et al, 2008; 2010) (Fig. 3c-e):
  - low level converg.
  - enhanced anomalous low pressure
  - deep upward wind

Winter:

- no deep signal found.
- Large part of the convective precipitation connected to atmospheric cold fronts in the control run. → consistent with observations (Catto et al.) (Fig. 4c-d)
- Potential large scale influence. (Fig. 4f)

Conclusions

As most recent coupled climate models, ECHAM5 shows a cold bias in the North Atlantic due to problems with the correct placement of the Gulf Stream and the North Atlantic Current in the ocean components. Results from ATMOS and the recent paper by Keeley et al. (2012) indicate that on low-frequency time scales the cold bias does impact the atmospheric circulation in coupled models, particularly over the Euro-Atlantic sector of importance for MiKlip. We therefore recommend to put effort in **reducing the North Atlantic cold bias in the MiKlip forecast system.**

Take Home Messages

On multi-annual to decadal time scales in ECHAM5:

- Convective precipitation is linked to boundary forcing in the Gulf Stream region.
- Local SST explains the atmospheric variability (with possible large scale influence at least in winter)
- Enhanced local evaporation due to warmer SST is sufficient to supply enhanced local precipitation.

Mechanisms:

- Summer: convective-like response, enhancement of the climatological state
- Winter: interaction with atmospheric fronts, indications for large scale response.

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