Winter-time precipitation response to North Atlantic SST changes in a RCP 8.5 scenario run

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1. Motivation - Response to the RCP 8.5 scenario in MPI-ESM

- Gulf Stream region is a key region for ocean atmosphere interactions (e.g. Minobe et al, 2008)
- Precipitation and SST variability are highly correlated in the Gulf Stream region in a model simulation driven by observed SST (Hand et al., 2014)
- RCP 8.5 scenario runs show strong changes in the oceanic circulation in the North Atlantic and related changes in the SST patterns, particulary in the Gulf Stream region.
- Atmosphere shows substantial changes in the North Atlantic as response to the RCP 8.5 scenario forcing (Fig.1).

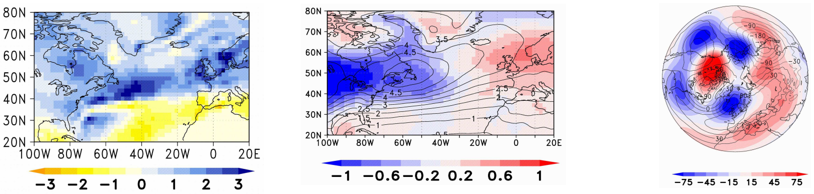

Figure 1: Winter-time (DJF) response to the RCP 8.5 scenario in MPI-ESM. Difference between the climatological mean in the RCP 8.5 scenario run (2200 to 2300) and the historical run (1850-2005) for (a) total preicitpitation (in mm/day), (b) the storm-track as indicated by the standard deviation of the 2-6day bandpass-filtered anomalies of SLP, and (c) the stationary waves, as indicated by the deviation of the 500 hPa geopotential height anomalies from their zonal mean (in m). Contours in (b) and (c) show the climatological patterns.

Key question: How large is the contribution of the Gulf Stream region SST changes to the Atmospheric signal in the CGCM?

Model

MPI-ESM-LR earth system model with

Atmospheric component:
ECHAM6 T63L47

Ocean component:
MPIOM GR15L40

Setup transient coupled runs

historical: historical atmospheric forcing, 1850 to 2005

RCP8.5: RCP 8.5 scenario, 2006 to 2300, our analysis here focusses on the period from 2200-2300

2. Experimental setup – Decomposition of the SST pattern from the CGCM to isolate the impact of North Atlantic SST pattern changes

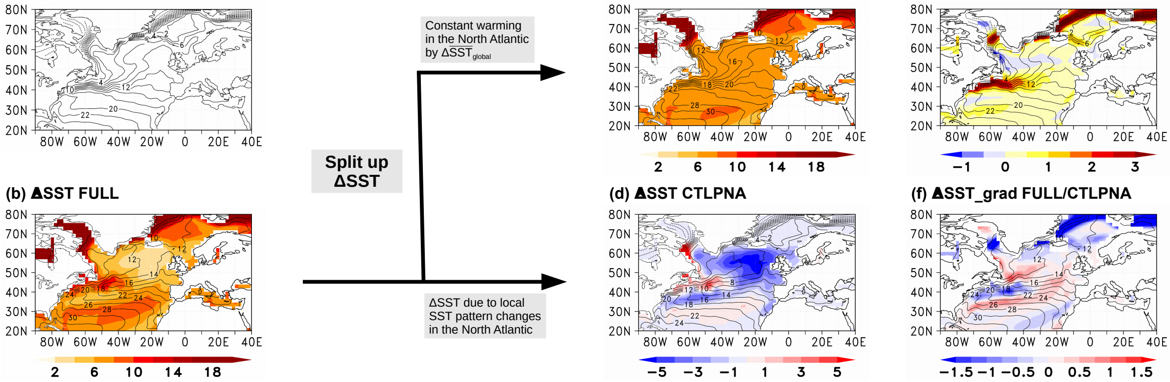

Figure 2: Winter-time (DJF) SST forcing for the sensitivity experiments. (a) SST for the control experiment, (b-d) SST (in °C, contours) and SST change with respect to CTL (shadings, in K) for (b) FULL, (c) FULLMNA and (d) CTLPNA. (e) meridional SST gradient in CTL/FULLMNA (in K/100km) ...

...and (f) change of the meridional SST gradient in FULL/CTLPNA (in K/100km) with respect to CTL/FULLMNA. In (e) and (f) contours show the SSTs (in °C) from CTL (e) resp. FULL (f).

Precipitation change is likely influenced by absolute SST changes AND by the change of the position and strength of SST fronts.

Idea of this sensitivity experiment: Isolate the effects of local SST pattern changes in the North Atlantic from the direct impact of changes in the radiative forcing and large-scale SST changes:

CTL 60 years, forced with SST climatology 1850-2005 from coupled historical run.

FULL 60 years, forced with SST climatology 2200-2300 from coupled RCP 8.5 run.

FULLMNA 30 years, like FULL, but only with constant warming (historical SST gradients maintained) in the North Atlantic

CTLPNA 30 years, like CTL, but with the SST effect of North Atlantic Ocean circulation changes as found in RCP 8.5 added.

3. Results – Atmospheric Response in the sensitivity experiments

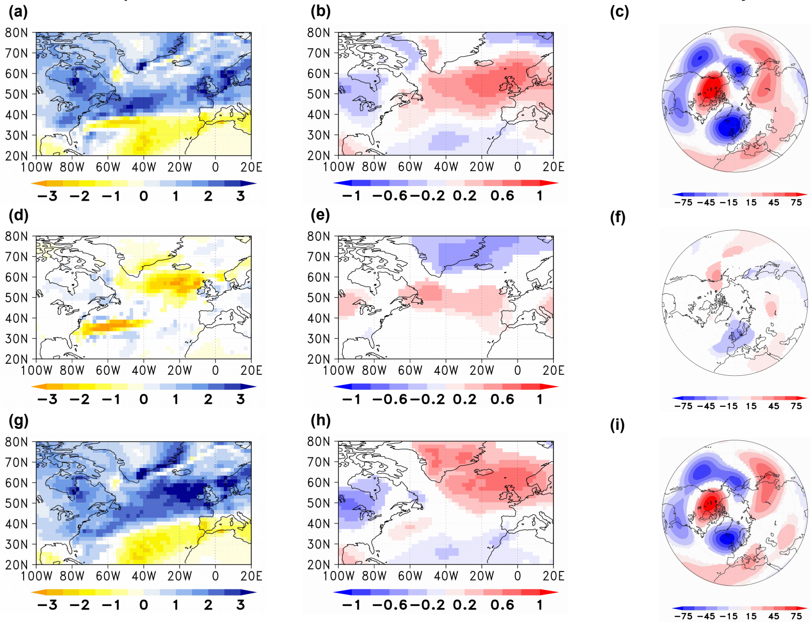

Figure 3: Atmospheric response in the sensitivity experiment: (a-c) Response to all forcing factors (i.e. FULL-CTL), (d-f) the effect from local SST pattern changes in the North Atlantic only (i.e. FULL-FULLMNA), and (g-i) the effect from all other changes than the local SST pattern changes (i.e. The effect of changed radiative forcing, remote SST pattern changes and large-scale SST warming, FULLMNA-CTL) for total precipitation (a, d & g, in mm/day), ...

... the North Atlantic storm track, as indicated by the standard deviation of the 2-6day bandpass-filtered anomalies of SLP (b, e & h, in hPa) and the stationary waves, as indicated by the deviation of the 500 hPa geopotential height anomalies from their zonal mean (c, f & i, in m). Only significant values passing a bootstrapping test at 95% confidence level are shown.

4. Take home messages

- Atmospheric response to RCP 8.5 scenario can be reproduced in atmosphere-only setup with prescribed SSTs from the coupled run (Fig. 3A-c)
- Local precipitation response in the Gulf Stream region is mainly controlled by North Atlantic SST pattern changes (Fig. 3d,g)
- Large-scale atmospheric response is mainly controlled by other factors than local SST pattern changes (i.e. changes in radiative forcing, large-scale ocean warming, remote SST changes, Fig. 3g-i)

References

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Hand R et al., to be submitted. The role of ocean-atmosphere interaction in shaping climate change in the North Atlantic sector

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FONA Decadal Climate Prediction BMBF
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