Decadal predictability of West African monsoon and impact of improved initial and boundary conditions: ocean and aerosols

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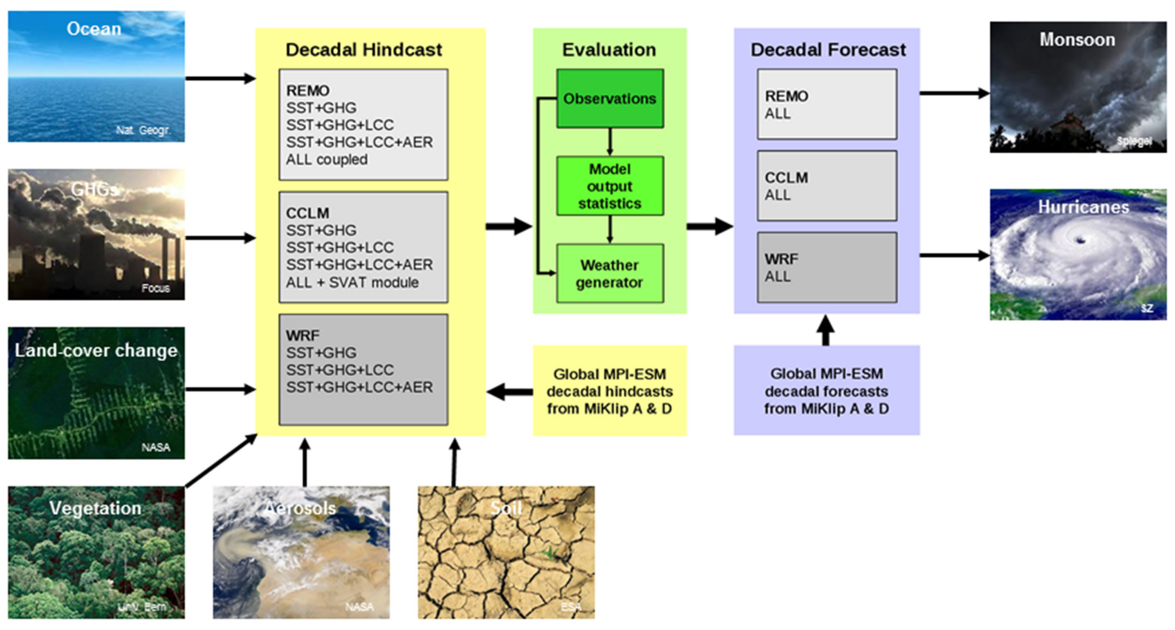
MiKlip DEPARTURE project

Project aim: Assessment of decadal predictability of West African monsoon rainfall and Atlantic hurricane activity

Project motivation:
- Socio-economic relevance of monsoon and hurricane events
- High potential decadal climate predictability in West Africa from realistic initial and boundary conditions

Project design:
- Hindcast: global MPI-ESM hindcasts downscaled by regional climate models REMO, CCLM and WRF with different boundary conditions (**SSTs**, greenhouse gases, land cover changes, **aerosols**), soil initialisation, **coupled ocean** and SVAT module
- Evaluation: multi-model ensemble forecast skill and uncertainty
- Forecast: global MPI-ESM forecasts downscaled by regional climate models REMO, CCLM and WRF

Project overview



Observation and model data

Observations: Gridded precipitation from Willmott & Matsuura (WMMA), University of Delaware, 0.5°

Model simulations:
- MPI-ESM LR Baseline1 (based on ECHAM6/MPI-OM): 10 decadal simulations initialised from a quasi-realisitic assimilation run for each hindcast decade with start years 1960-2013, T63/ GR15 with 47/ 40 vertical levels
- **REMO**/ **CCLM**/ WRF: 3 decadal simulations forced by selected MPI-ESM LR Baseline 1 simulations with best, middle and worst performance in global SST validation for selected hindcast decades 1966-1975, 1981-1990, 1991-2000 and 2001-2010, GHG forcing with RCP4.5 scenario, soil initialisation from spin-up simulations forced by ERA40 or ERAInterim reanalyses, model domain 59.4°W-59.4°E and 44°S-44°N, 0.44° with 31/ 35/ 38 vertical levels

CCLM with improved SST and aerosol boundary conditions: West African monsoon rainfall

- MPI-ESM and all considered RCMs strongly overestimate West African monsoon rainfall over the Gulf of Guinea and the Guinea Coast in all decades, probably due to overestimated SSTs in the South-East Atlantic.
- Therefore, we analyse two CCLM versions with improved boundary conditions: CCLM-AOD (Tanre to AeroCom AOD) and CCLM-AOD/SST (additionally MPI-ESM to ERAinterim SST).

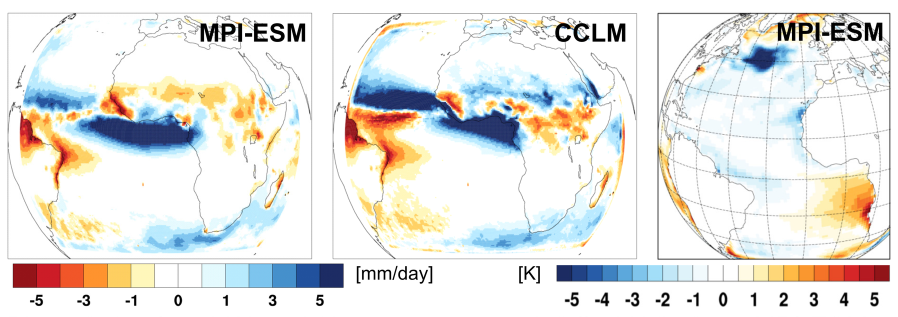


Fig. 1: Bias of simulated West African monsoon rainfall (JJAS) from MPI-ESM and CCLM decadal predictions compared to CRU/HOAPS observations during 1966-1975 (left and middle) and corresponding SST bias from MPI-ESM compared to ORAS4 (right).

- Improved SSTs induce decreased rainfall bias over the Guinea Coast and West Sahel and improved AODs cause decreased bias over the West Sahel but increased bias over the Guinea Coast.
- Concerning predictability, we find strongly improved correlations to observed rainfall for all regions and both improvements (except for improved AODs over the Central Sahel), especially over the Guinea Coast.

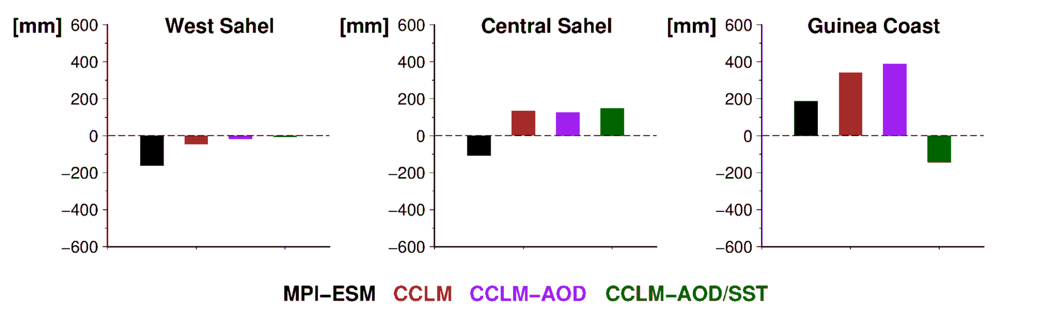


Fig. 2: Bias of simulated West African monsoon rainfall (JJAS) from MPI-ESM, CCLM, CCLM-AOD and CCLM-AOD/SST decadal predictions for selected regions compared to Wilmott-Matsuura observations during 2001-2010.

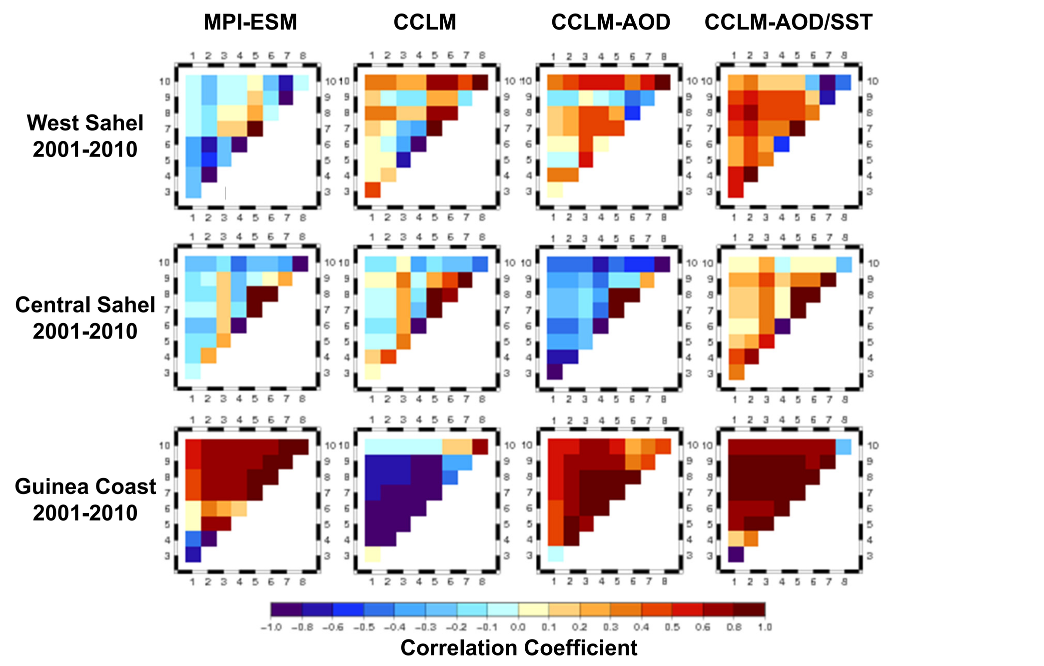


Fig. 3: Correlation between observed (Wilmott-Matsuura) and simulated West African monsoon rainfall (JJAS) from MPI-ESM, CCLM, CCLM-AOD and CCLM-AOD/SST for selected regions in 2001-2010. The x/y-axis denotes the first/last year within a decade considered for correlation.

REMO coupled to ocean model MPI-OM: West African monsoon rainfall

- A further improvement of RCM decadal predictions is the coupling of REMO to the ocean model MPI-OM with two different ocean initialisations (REMO-O1: equal to MPI-ESM, REMO-O2: combined ERA40 and coupled REMO forcing).
- Coupled REMO-O1 and REMO-O2 simulations strongly reduce the SST bias in the South-East Atlantic and thus, the rainfall bias over the Gulf of Guinea and the Guinea Coast.

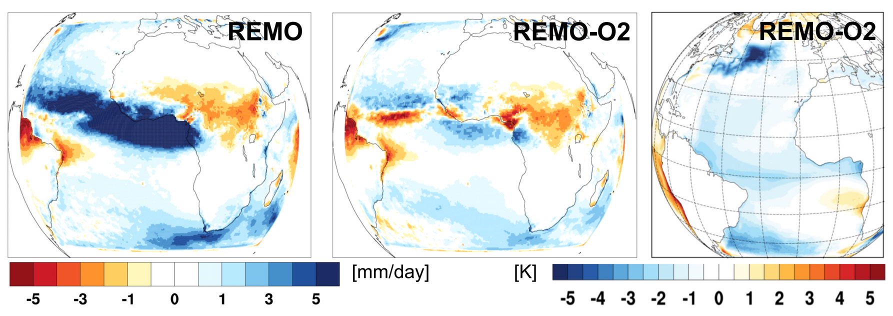


Fig. 4: Bias of simulated West African monsoon rainfall (JJAS) from REMO and REMO-O2 decadal predictions compared to CRU/HOAPS observations during 1966-1975 (left and middle) and corresponding SST bias from REMO-O2 compared to ORAS4 (right).

- Both coupled REMO versions strongly improve the rainfall bias over the Guinea Coast and Central Sahel but increase the bias over the West Sahel.
- Concerning rainfall predictability, we can state some improved correlations to observations for both coupled REMO versions, especially for REMO-O2 and over the Guinea Coast.

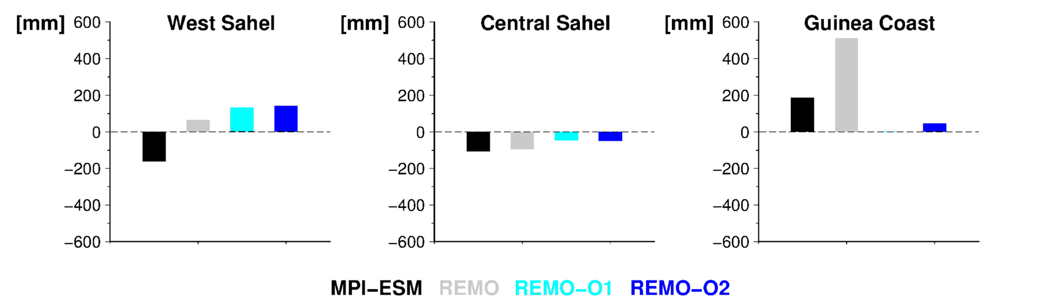


Fig. 5: Bias of simulated West African monsoon rainfall (JJAS) from MPI-ESM, REMO, REMO-O1 and REMO-O2 decadal predictions for selected regions compared to Wilmott-Matsuura observations during 2001-2010.

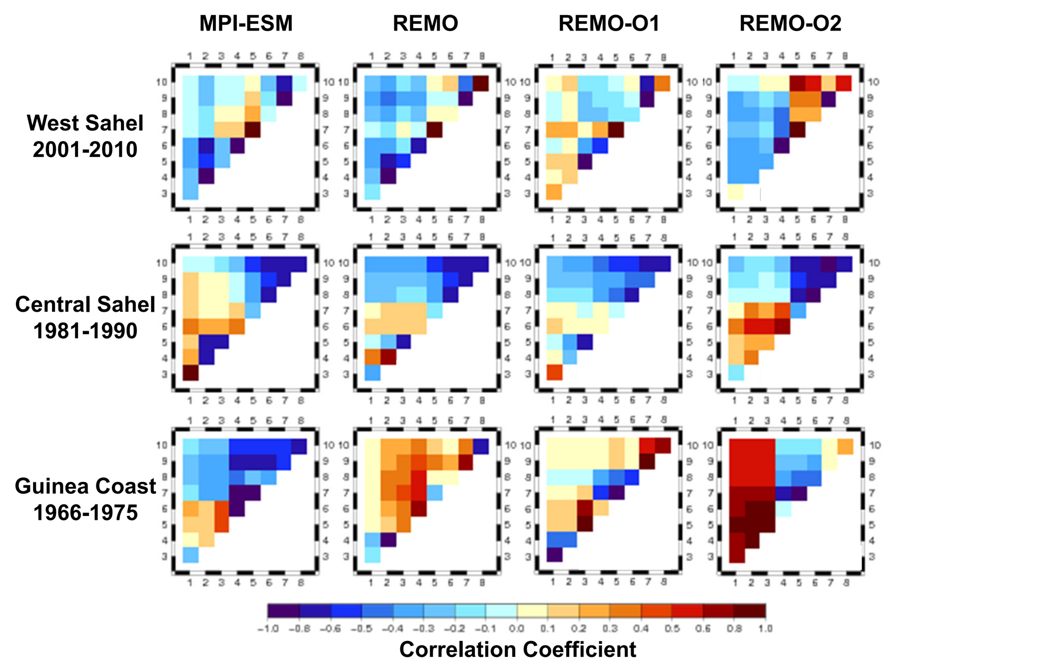


Fig. 6: Correlation between observed (Wilmott-Matsuura) and simulated West African monsoon rainfall (JJAS) from MPI-ESM, REMO, REMO-O1 and REMO-O2 for selected regions and decades. The x/y-axis denotes the first/last year within a decade considered for correlation.

REMO coupled to ocean model MPI-OM: Atlantic tropical storms and hurricanes

- Finally, we compare simulated Atlantic tropical storms and hurricanes (with wind speeds larger than 17 and 33 m/s) generated in the DEPARTURE domain from the uncoupled and coupled REMO decadal predictions with observations from the HURDAT2 reanalysis data base.
- We find that the generation area expands further southward for uncoupled REMO than for coupled REMO-O2 predictions.

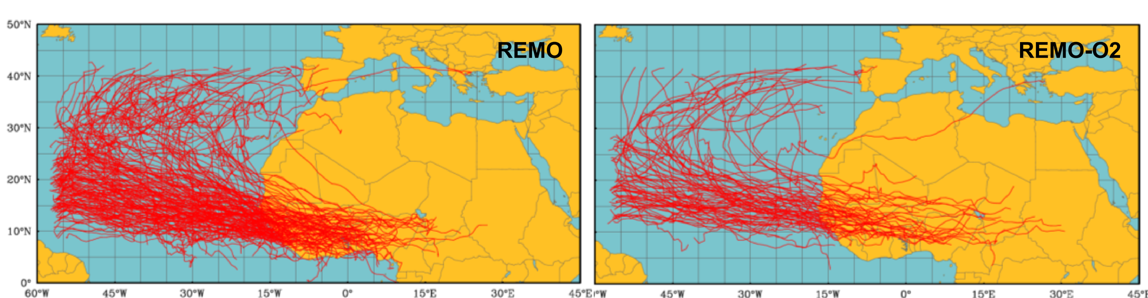


Fig. 7: Tracks of Atlantic tropical storms and hurricanes generated in the DEPARTURE domain from uncoupled REMO and coupled REMO-O2 predictions during 2001-2010.

- REMO predictions strongly overestimate observed numbers, which is clearly improved by coupled REMO-O1 and REMO-O2.

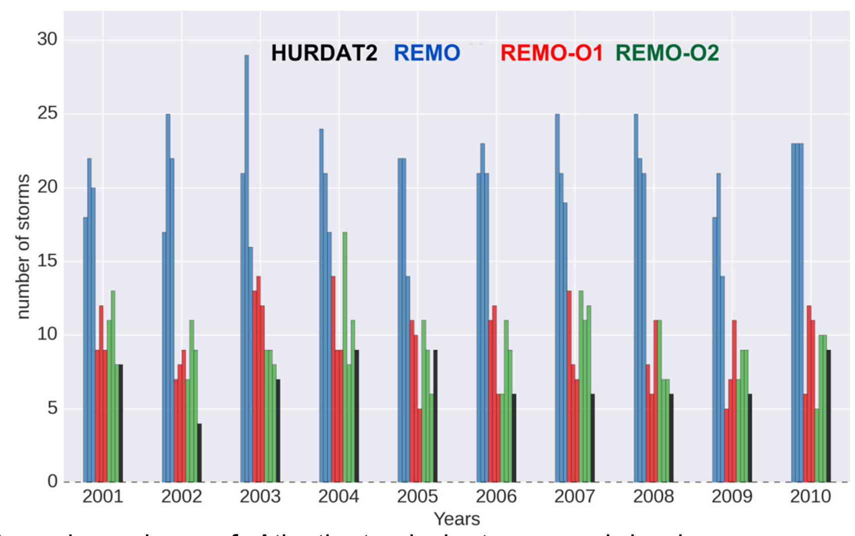


Fig. 8: Annual numbers of Atlantic tropical storms and hurricanes generated in the DEPARTURE domain for three ensemble members each of REMO, REMO-O1 and REMO-O2 compared to HURDAT2 observations during 2001-2010.

- This can be caused by a southward shift of the ITCZ position in uncoupled REMO (and MPI-ESM), whereas REMO-O1 and REMO-O2 clearly reproduce the observed ITCZ position.

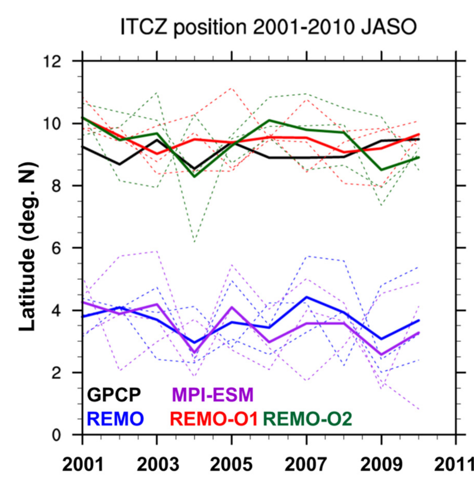


Fig. 9: Annual ITCZ position as geographical latitude over West Africa for three ensemble members and corresponding means (dashed and continuous lines) each of MPI-ESM, REMO, REMO-O1 and REMO-O2 compared to GPCP observations during 2001-2010.

Summary of major results

- Both applying ERAinterim SSTs in CCLM and coupling REMO to MPIOM reduce the SST bias over the South-East Atlantic and the rainfall bias over the Guinea Coast. We further find improved rainfall predictability for both RCM modifications, especially over the Guinea Coast.
- Using AeroCom AOD in CCLM improves rainfall bias over West Sahel and predictability over Guinea Coast and West Sahel.
- REMO coupled to MPIOM produces more realistic numbers and tracks of Atlantic tropical storms and hurricanes due to an improved position of the ITCZ compared to both uncoupled REMO and MPI-ESM.

Outlook

- Analysis of Atlantic tropical storms and hurricanes for MPI-ESM, CCLM, WRF and all applied RCM modifications, including the analysis of predictability (correlation)
- Further sensitivity studies with improved SST and aerosol boundary conditions for CCLM, REMO and WRF