SPECIAL PROJECT PROGRESS REPORT

All the following mandatory information needs to be provided. The length should *reflect the complexity and duration* of the project.

Reporting year	10/2022-06/2023
Project Title:	Agricultural decision-tailored (sub)seasonal drought forecasting for Sub-Saharan Africa (AGENDA-SSA)
Computer Project Account:	de4l
Principal Investigator(s):	Dr. Patrick Laux
Affiliation:	Karlsruhe Institute of Technology (KIT) Institute of Meteorology and Climate Research Department of Atmospheric Environmental Research (IMK-IFU)
Name of ECMWF scientist(s) collaborating to the project (if applicable)	
Start date of the project:	27.09.2022
Expected end date:	31.12.2024

Computer resources allocated/used for the current year and the previous one

(if applicable)

Please answer for all project resources

		Previous year		Current year	
		Allocated	Used	Allocated	Used
High Performance Computing Facility	(units)	4 M	4 M	35 M	21.5 M
Data storage capacity	(Gbytes)	default		default	

Summary of project objectives (10 lines max)

Agricultural productivity and food security in sub-Saharan Africa (SSA) heavily depend on uncertain rainfall. The exposure to climate risk characterizes the livelihood of the majority of the region's population: high rainfall variability impedes the farmers' efforts to intensify agricultural production and negatively affects the level of food security. The overall goal of this Special Project (SP) is to contribute to improving agricultural management strategies with sufficient lead time by optimizing water usage for agriculture. To achieve this goal, two different approaches are pursued: i) Development of improved regionally adapted and optimized seasonal drought forecast products that integrate technical and climatological limitations and farmers' needs, ii) assessment of optimized (intra-)seasonal agricultural management rules by coupling the improved (i.e., downscaled) seasonal forecasts with process-based and more simplified mechanistic agricultural sectoral models.

Summary of problems encountered (10 lines max)

- Technical problems to write monthly WRF restart files using I/O quilting due to their large size → namelist setting "IO_form for the restart files = 102" finally solved the problem by writing (smaller) restart files for each CPU.
- Initial problems to compile the WPS on ATOS. This problem was solved by the help to technical support of ECMWF.
- MARS archive for retrieving SEAS5 data did not work continuously. Not all the required SEAS5 hindcasts and operational forecasts (e.g., the 2023 forecasts initiated in June) could be retrieved until now (`“AccessError: The tape on which the data reside is unavailable. Please visit ECMWF Support Portal and raise a ticket: http://support.ecmwf.int [marsod]”`).

Summary of plans for the continuation of the project (10 lines max)

The following activities are planned for the remaining project period:

- Assessing the added-value of downscaling compared to the raw SEAS5 data (based on reforecasts and observations).
- First publication of selection of ensemble members suitable for dynamical downscaling and assessment of the added-value of the downscaled WRF-SEAS5 products.
- Application of PIC member selection for downscaling the forthcoming OND season based on operational SEAS5 products. Timely publication of data in open-access repositories for testing the performance by climate impact modelers.
- Assessment of optimized (intra-)seasonal agricultural management rules by coupling the improved (i.e., downscaled) seasonal forecasts with process-based and more simplified mechanistic agricultural models and other sectoral models including hydrological models, and water- and vector-borne health models (to be achieved towards the end of the project period).
- Check whether or not CP-simulation require further bias correction (Laux et al., 2021a)

List of publications/reports from the project with complete references

None

Summary of results

The first step comprised the review of drivers of rainfall variability in selected African regions. During this first phase of the project, the focus has been set to the Greater Horn of Africa (GHAF) as well as the short rainy season (OND) in East. Based on the SEAS5 retroforecasts (1986-2015) and observational data, an Indian Ocean Diploe (IOD) and East African Rainfall (EAR)-related approach has been developed to select most promising perturbed initial conditions (PICs) members of the SEAS5 retroforecast ensemble. IOD is considered on the basis of the Dipole Mode Index (DMI), introduced by Saji et al (1999). It depicts the SST anomaly difference between the western pole of East Africa (WEA) and the eastern pole of Sumatra (EPS), see Figure 1 (left). The EAR anomaly is calculated as deviation of the mean field precipitation of the 2021 OND season (black box, Fig. 1 right) and the SEAS5 retroforecasts (1986-2015, PIC member #0) in the same region.

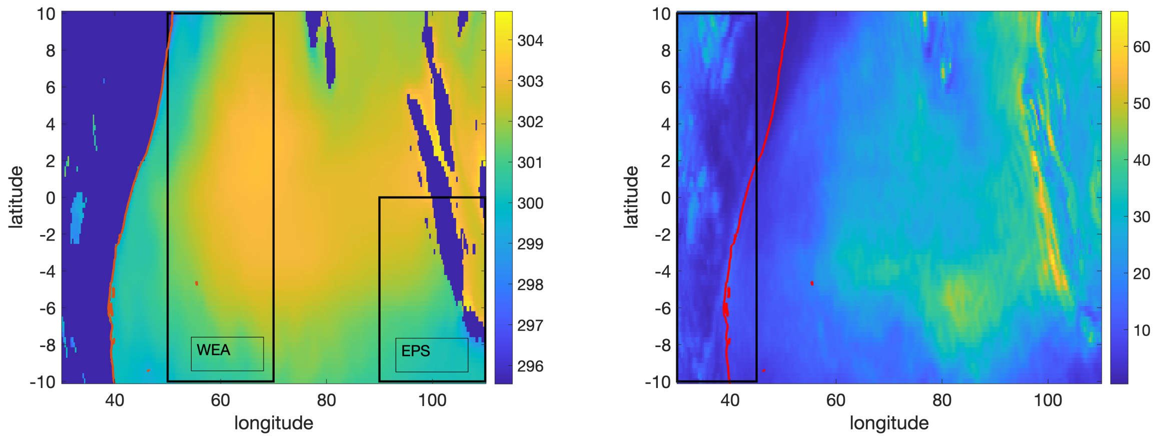

Fig.2: Left: schematic illustration of the Dipole Mode Index (DMI), calculated as SST anomaly difference between the western pole of East Africa (WEA, left big black box) and the eastern pole of Sumatra (EPS, right big black box), i.e., WEA minus EPS. Right: East African Rainfall (EAR) anomaly [mm d^{-1}] is calculated for the Greater Horn of Africa region (black box). Red line represents the coastline. Both indices represent the forecasted average 2021 OND season using a lead time of 4 months (i.e., forecasts issued in June).

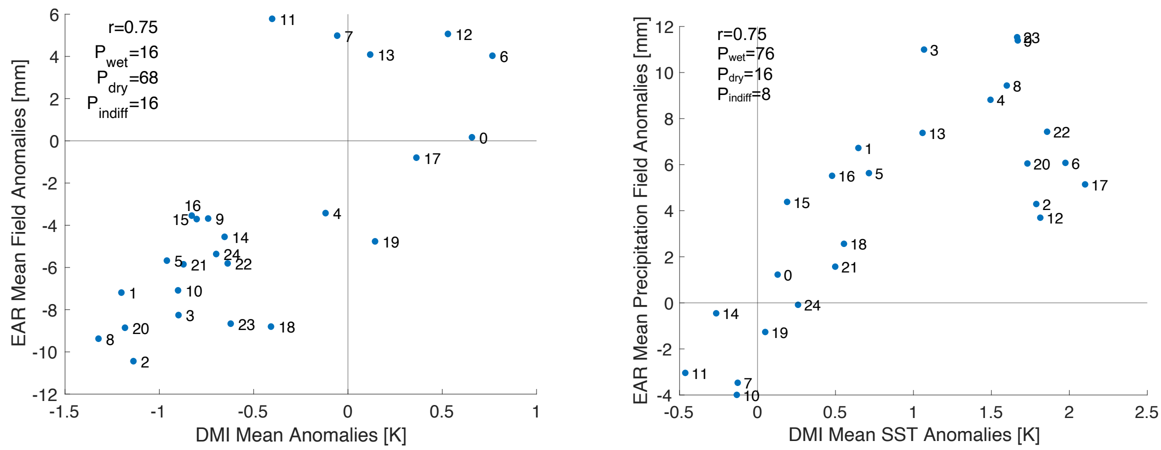

Fig.2: Left: Scatter plot of 25-members ensemble predictions by the SEAS5 reforecasts between the Dipole Mode Index (DMI) (x-direction, K) and the East African rainfall (EAR) index (y-direction, mm day −1) for the 2021 October-December (OND) average issued on early June (blue dots). Right: same as for the left figure, but for the 'wet year' 2019. Based on the long-term retroforecast statistics (1986-2015), the inter-ensemble scatter plot can be split into 4 quadrants, whereas the lower left represents anomalously dry and the upper right anomalously wet conditions.

It is found that the correlation among the different PIC SEAS5 reforecasts members between the DMI and the EAR index for mean 2021 OND season is highest for a lead time of 4 months (i.e., forecasts issued in June). The relative high correlation (r=0.75) enables a statistical linear regression model to estimate the OND EAR anomaly based on the OND DMI anomaly with a lead time of 4 months (Fig. 2). Similar observations have been made for the 'wet' OND 2019 season.
This approach does not only provide opportunities to assess the quality of the raw SEAS5 retroforecast product (compared to observation), but will facilitate the HPC intensive dynamical downscaling of suitable PIC members for high-impact climate extreme events (droughts and floods) using the operational SEAS5 data with sufficient lead time. Depending on the strategies of the users, suitable candidates for downscaling could be from the anomalously dry quadrant (based on the high

drought probability), such as #8 or #2 to simulate the most extreme droughts, candidates around the centre of the dry PIK could be e.g., #10 or #21, or #8 or #2 to reflect the range of a possible drought. As such, the decision on the selection is still subjective and more objective solutions will be explored in the future.

It has been found that the correlation between OND EAR and the OND DMI anomaly decreases with decreasing lead time. However, the probability of getting a dry 2021 OND season is increasing at the same time (Table 1, left). While the probability to get a dry season was 68% (16% probability of a wet and an indifferent season, respectively) based on the forecasts issued in June, it increased to 94% for August and September (probabilities of indifferent season is 4%). Similar observations have been made for the 'wet' OND 2019 season (Table 1, right). Table 1 suggests that the predictability for high-impact events based on raw SEAS5 works well. Further analyses for dry and wet years supported this conclusion.

Table 1: Summary statistics of 25-members ensemble SEAS5 reforecasts for the year 2021 (top) and 2019 (bottom). The Pearson correlation coefficient (r) is demonstrating the linear dependency between the OND EAR anomaly and the OND DMI anomaly.

Lead time [month]	r	Probability Wet OND	Probability Dry OND	Probability Indifferent OND
June (lead 4)	0.75	16	68	16
July (lead 3)	0.4	0	68	32
August (lead 2)	0.54	0	96	4
September (lead 1)	0.33	0	96	4

Lead time [month]	r	Probability Wet OND	Probability Dry OND	Probability Indifferent OND
June (lead 4)	0.75	76	16	8
July (lead 3)	0.56	88	0	12
August (lead 2)	0.65	96	0	4
September (lead 1)	0.39	100	0	0

During the reporting period, the WRF test simulation phase on Atos HPC has been finished. Based on conducted speedup performance tests using different compiler settings, i.e., different domain settings (nested vs single nest simulations) as well as different number of nodes, a reasonable WRF setup has been identified. Scalability on Atos is found to be much higher for a single nest and a big domain and using OpenMPI. Next will be the sensitivity analyses based on predefined parameterization schemes (e.g., Laux et al., 2021b) for microphysics (MP) and planetary boundary layer (PBL).

Not only due to identified technical (scalability) but also due to scientific reasons, the original working plan has been adapted to increase the (scientific) impact of the AGENDA-SSA project. The regional focus for the downscaling has been changed from SSA to whole Africa, and this using high-resolution (4 km) and convection-permitting (CP) simulations. While there exist only a few studies of downscaled seasonal predictions for different regions across Africa, e.g., Mori et al. (2020) for East Africa and Siegmund et al. (2013) for West Africa, to the best of the PI's knowledge, it is the first time that seasonal CP simulations are being performed for whole Africa. It is expected that the new CP simulations will clearly outperform the simulations based on Cumulus parameterization and that they will raise significant scientific awareness in various sectors besides agriculture (e.g., health, energy). Therefore, it is planned the CP simulations will be published with sufficient lead time to serve the needs of sectoral impact modelers.

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