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Probabilistic Forecasts of the Onset of the Rainy Season using Global Seasonal Forecasts

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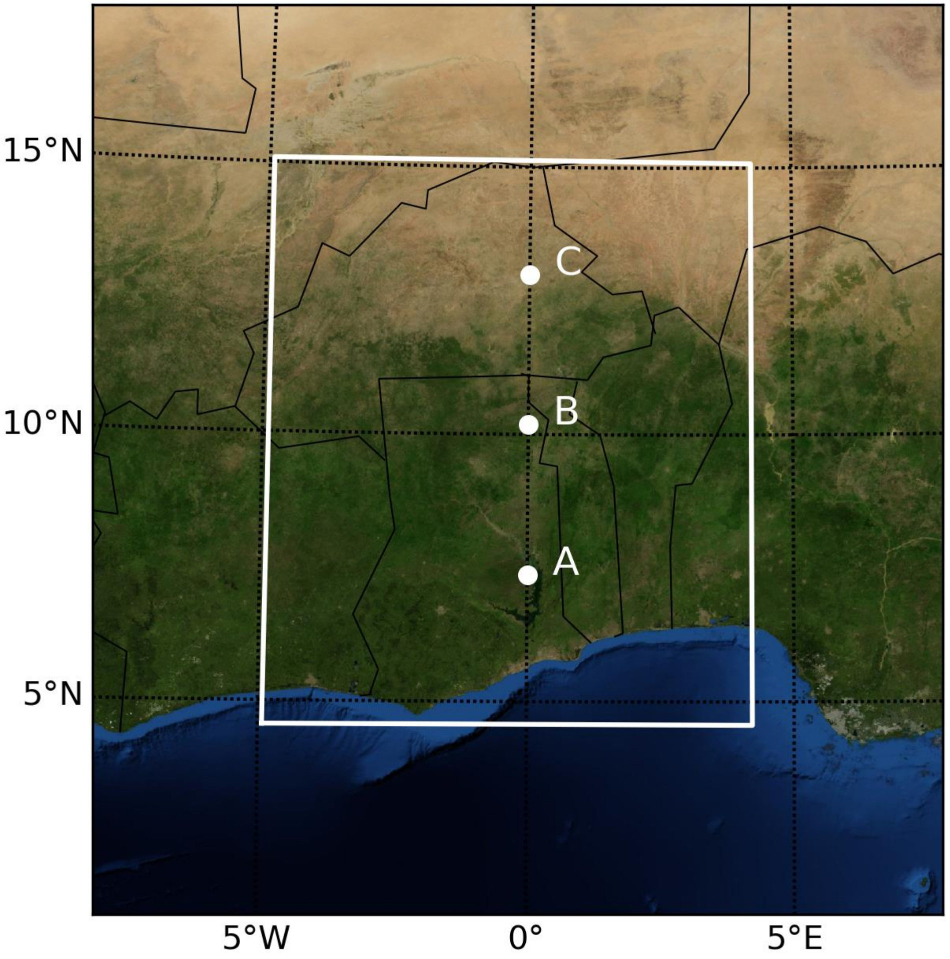
1. Introduction

Probabilistic Forecasts of the Onset of the Rainy Season (ORS) using Global Seasonal Forecasts

- Seasonal forecasts for monsoonal rainfall characteristics like the ORS are crucial in semi-arid regions to better support decision-making in water resources management, rain-fed agriculture and other socio-economic sectors.
- However, forecasts for these variables are rarely produced by weather services in a quantitative way.
- To overcome this problem, we developed an approach for seasonal forecasting of the ORS using global seasonal forecasts.
- The approach is not computationally intensive and is therefore operational applicable for forecasting centers in developing countries.
- It consists of a quantile-quantile-transformation for eliminating systematic differences between ensemble forecasts and observations, a fuzzy-rule based method for estimating the ORS date and a graphical method for an improved visualization of probabilistic ORS forecasts, called the onset of the rainy season index (ORSI).

2.1. Study Area

West Africa with a Focus on Burkina Faso, Ghana and Benin



Study Area “Burkina Faso, Ghana and Benin” (4.92°W–4.22° E, 4.56° N–15.08° N) and three grid points for the evaluation, each representative for Guinea Coast—A (7.37° N, 0.00° E), Sudan—B (10.18° N, 0.00° E) and Sahel—C (12.98° N, 0.00° W).

2.2. Data

ECMWF SYS4 Precipitation Hindcasts

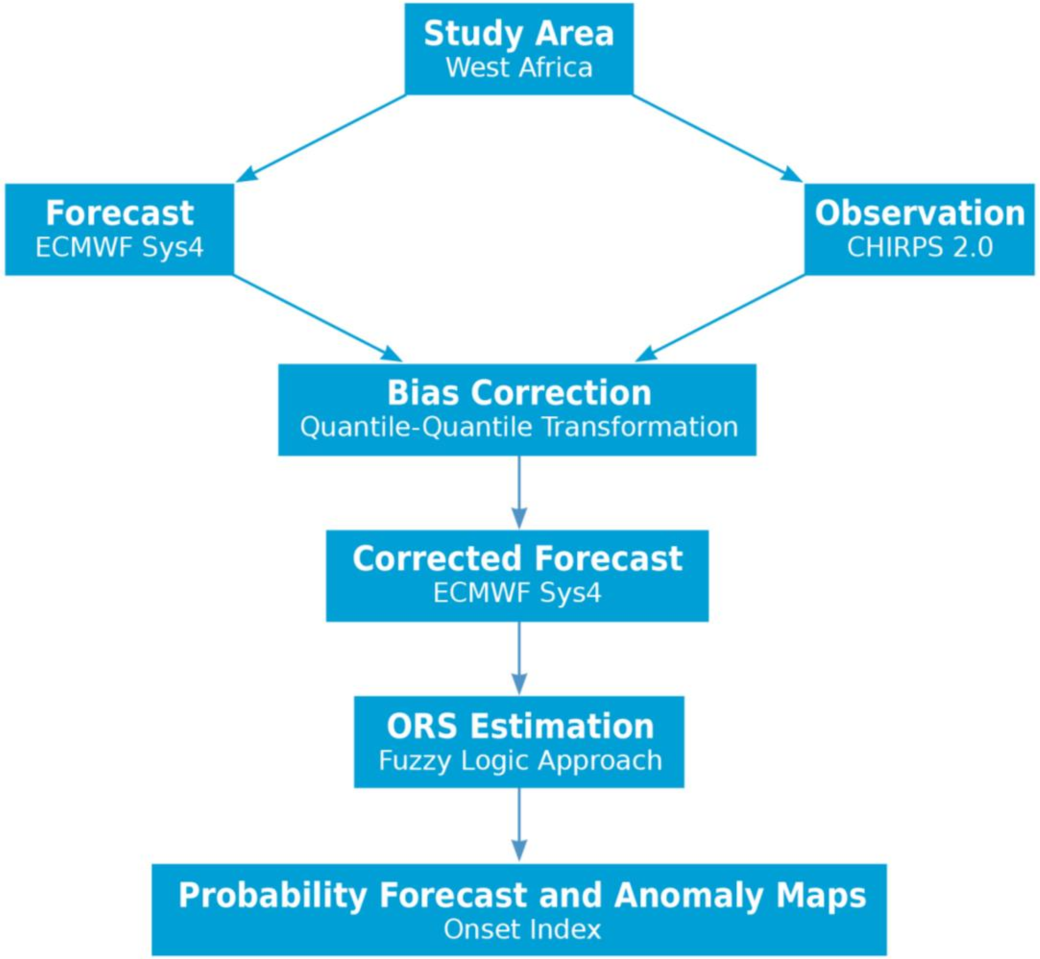
- 11 years (2000-2010) of precipitation hindcasts from the seasonal forecast system SYS4 of ECMWF (European Centre for Medium-Range Weather Forecasts)
- SYS4 comprises 15 ensemble members and consists of 7-month simulations initialized on the first day of each month

CHIRPS Observations

- CHIRPS (Climate Hazards Group InfraRed Precipitation with Station data) 2.0 was used as observational basis

3.1. Overview

Overview of the dataflow and the different components of the forecasting approach



Schematic overview of the different components of the forecasting procedure for the ORS. CHIRPS 2.0 = Climate Hazards Group Infrared Precipitation with Station data version 2, and ECMWF SYS4 = seasonal forecast system SYS4 of the European Centre of Medium Range Weather Forecasts. It is noted that the different components of the forecasting approach can be replaced by other methods or data products.

3.2. Quantile-Quantile-Transformation

Observations

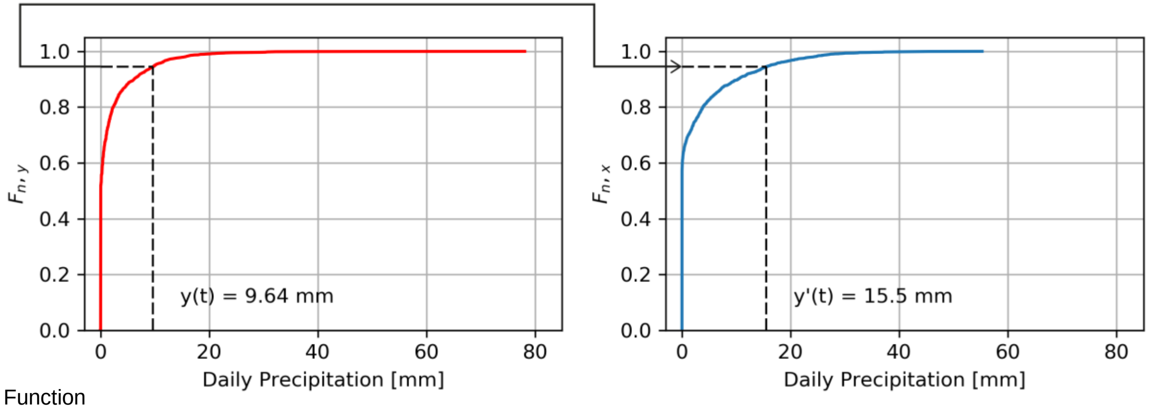
Forecast

Sort the daily values for the investigation period in an ascending order.

Determination of the rank for each observation/forecast with $i = 1,2,\ldots,n$ and $n =$ number of observations/forecast.

Determination of the ECDF[1] of the observations F_x and forecasts F_y

Determine the corrected prediction value $y_i^{'}(t)$ for each q_i (cumulative frequencies) with the inverse ECDF[1] of the observations $y_i^{'}(t) = F_x^{-1}(q_i)$.



Example of a quantile-quantile-transformation for correcting daily precipitation [mm] at grid point C (12.98°N, 0.00W°) of an ensemble member of SYS4 (left) using CHIRPS observations (right), y(t) = forecast value, y´(t) = corrected forecast value.

[1] Empirical Cumulative Distribution Function

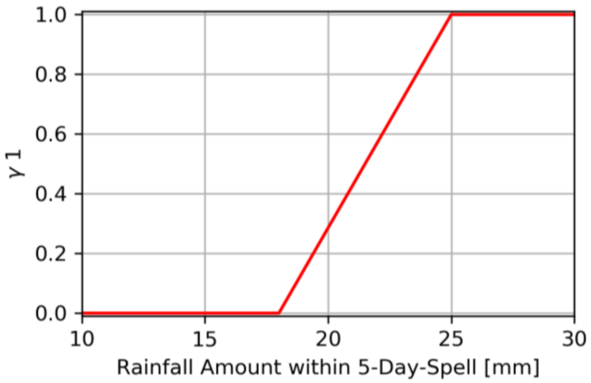
3.3. Calculation of the ORS Dates using Fuzzy Rules

ORS Definition according Laux et al. (2008)

Sum of precipitation in five consecutive days is at least 25 mm

Within this pentad, at least two more days must exceed a precipitation amount of 1 mm

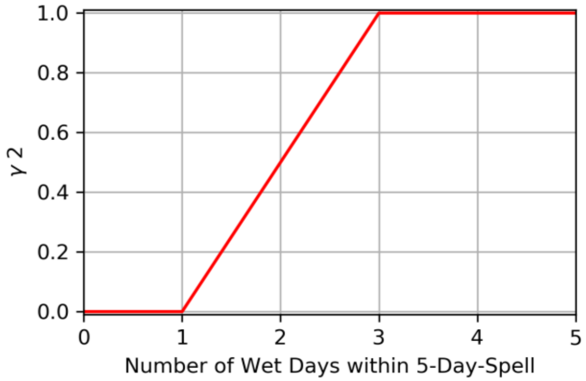
Smoothed transition of the applied conditions with fuzzy rules



Multiplication of membership functions

Threshold

ORS



Membership functions of the ORS definition for γ_1 (left) and γ_2 (right), obtained from Laux et al. (2008).

3.4. Calculation of the ORS Index (ORSI)

Calculation of the ORS index (ORSI)

In order to better interpret ensemble-based ORS forecasts, an index for the ORS dates is proposed. The calculation of the ORSI is based on the following formula:

$$ORSI = \sum_{k=1}^{K} g_k p_k$$

where p_k is the forecast probability of k-th category, g_k is the corresponding weight of k-th category, K is the number of climatologically equiprobable categories. The weights for the computation of the ORSI values for tercile-based forecast are $g_1 = {}^{1}/_{3}$, $g_2 = 0$ and $g_3 = -{}^{1}/_{3}$.

3.5. Methodology for Probabilistic Forecasting of the ORS Dates

Observations

Calculation of observed ORS dates for a long-term period

Determination of the quantiles $Q_{\frac{1}{3}}$ and $Q_{\frac{2}{3}}$

Forecast

Calculation of the ORS dates from the bias-corrected precipitation hindcasts

Classification of the ensemble members into the tercile based categories

below average ($< Q_{\frac{1}{3}}$)

below average ($>= Q_{\frac{1}{3}}$, $<= Q_{\frac{2}{3}}$)

above average ($> Q_{\frac{2}{3}}$)

Calculation of forecast probabilities for each ORS category

Calculation of ORSI

3.6. Verification of the ORS Fields

Spatial Verification
(for each year over the entire study domain)

Temporal Verification
(for each grid cell over the entire study period)

Mean Absolute Error (MAE)[1]

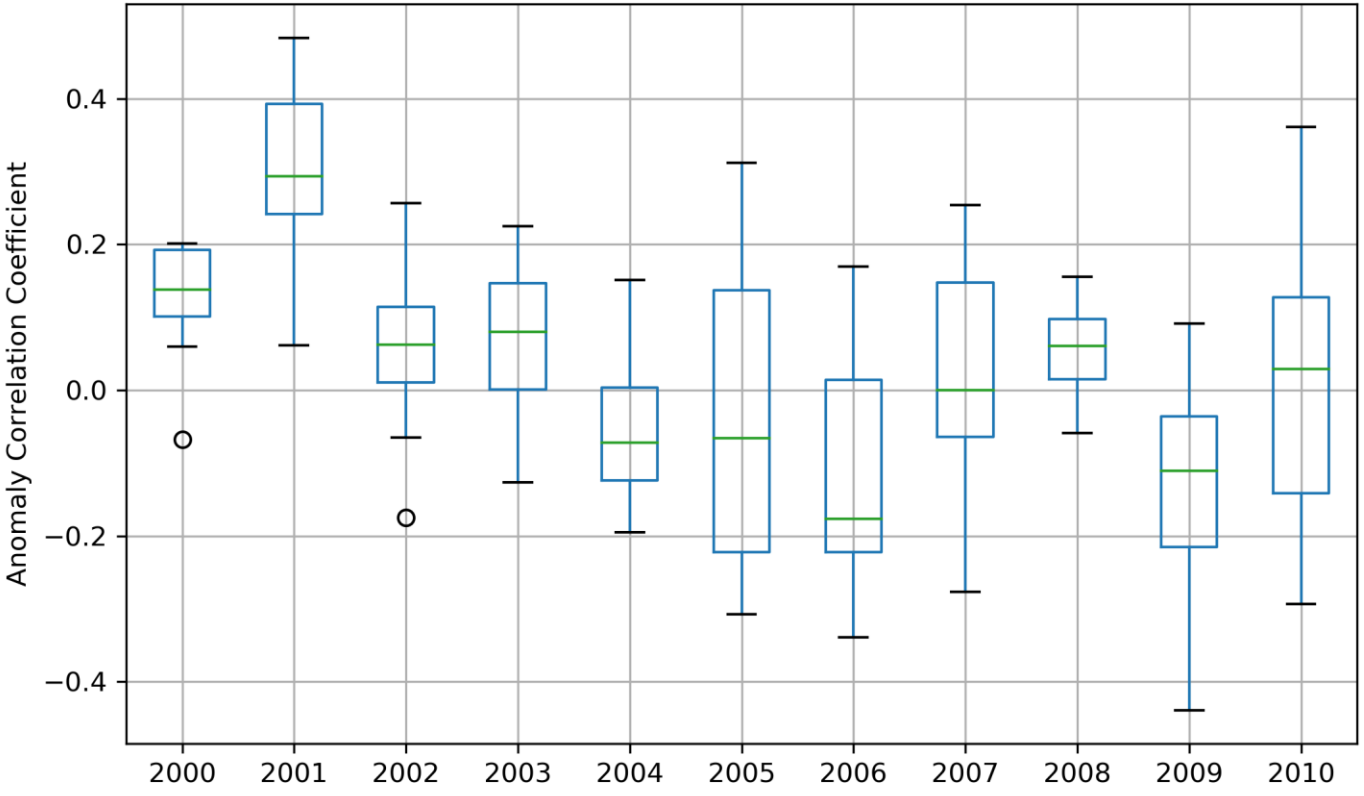
Pearson’s Correlation Coefficient (r)[1]

Anomaly Correlation Coefficient (ACC)[1]

[1] for detailed explanation see Rauch et al. (2019)

4.1. Spatial Verification of the ORS Fields…

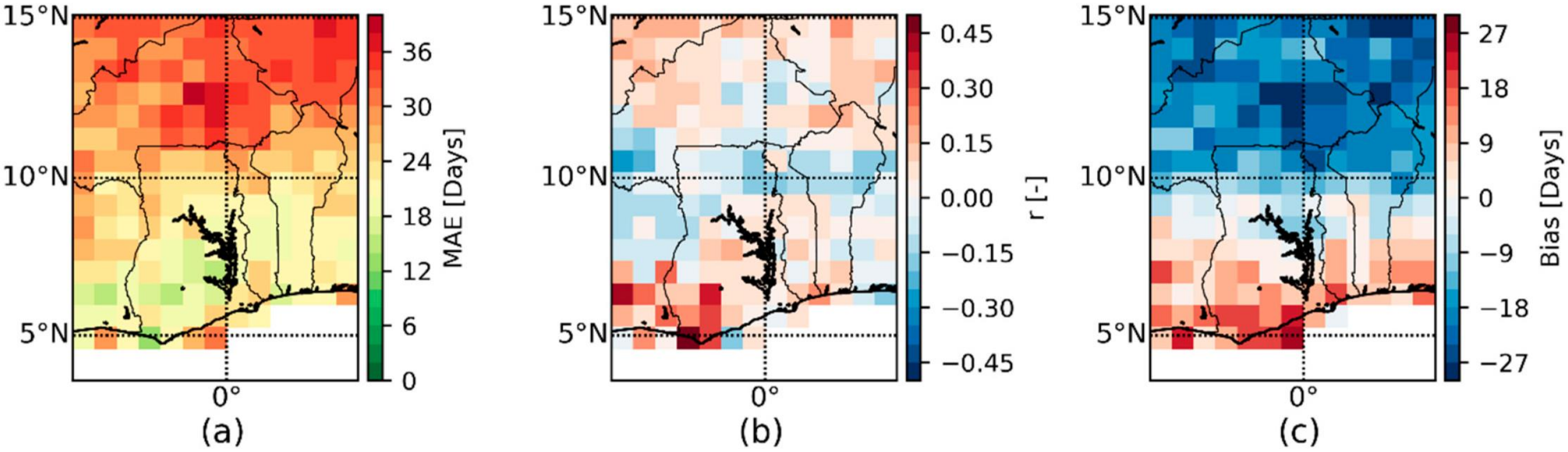
… based on the Anomaly Correlation Coefficient (ACC).



Spatial verification using the anomaly correlation coefficient. The calculation was done for each of the 15 SYS4 ensemble members (initialized in February) compared to CHIRPS for the entire study region. The statistics used for the visualization of the Box-Whiskers-Plots are the same as figure in slide 17.

4.2. Temporal Verification of the ORS Fields…

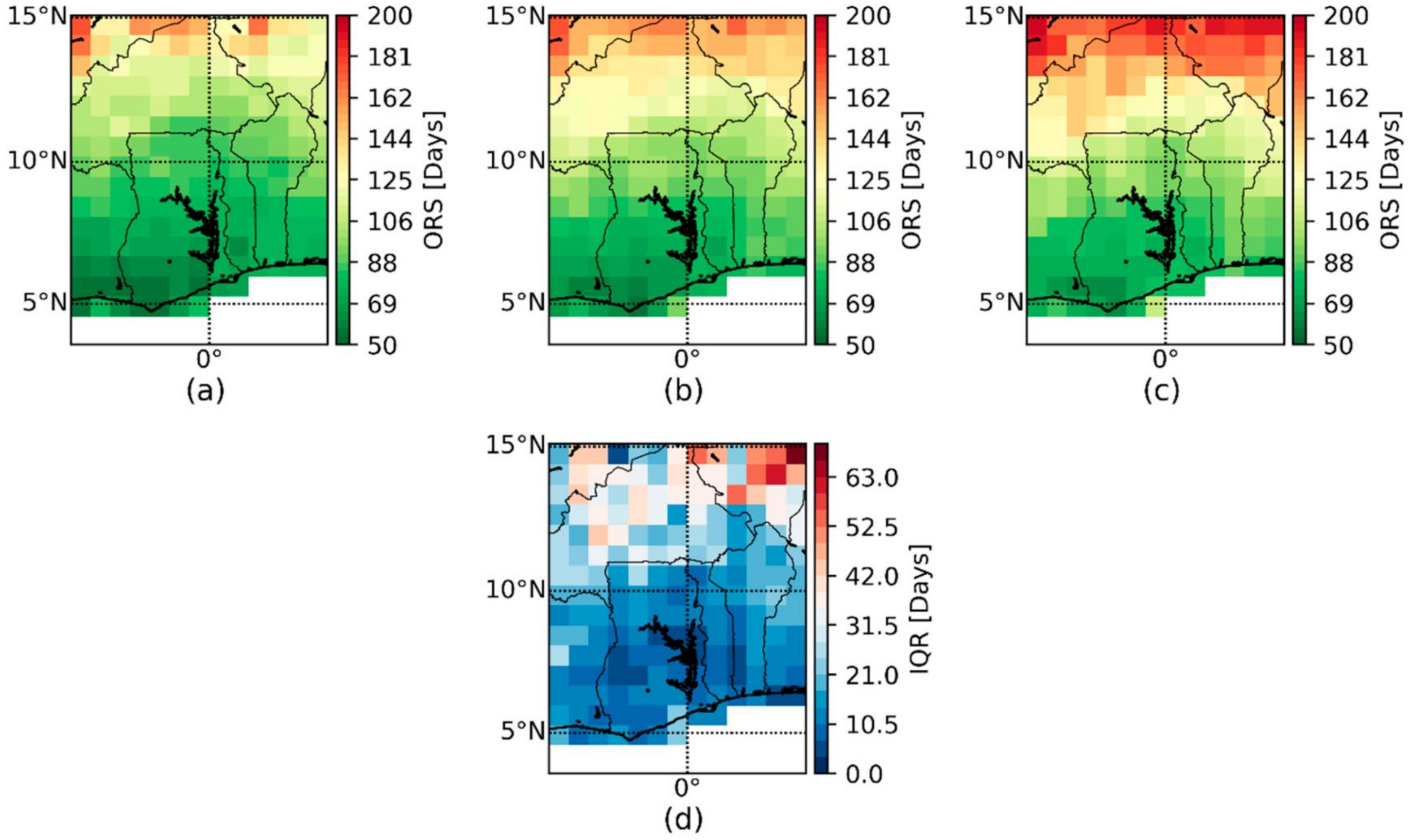
… based on MAE, r and Bias.



Forecast accuracy, skill and bias for ORS dates for each grid cell based on (a) MAE; (b) Pearson's correlation r; (c) bias. Mean of 15 ensemble members of SYS4 (initialized in February) in comparison to CHIRPS, 2000 - 2010.

4.3. Visualization of the ORS fields with…

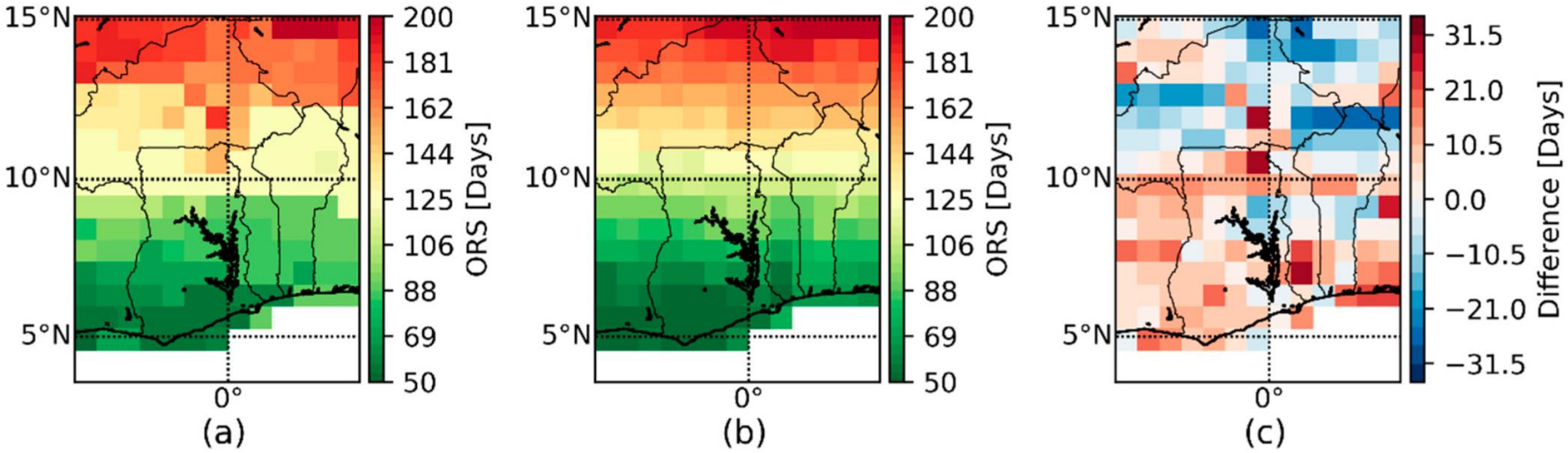
…quantile-based maps from SYS4.



(a) Early ORS (0.33th quantile), (b) Mean ORS and (c) Late ORS (0.66th quantile) in 2001 for SYS4 [Julian Day] over 15 ensemble members (initialized in February) and (d) Inter-Quantile-Range (IQR) [Julian Days] between Early ORS (0.33th Quantile) and Late ORS (0.66th Quantile) in 2001 for SYS4 over 15 ensemble members (initialized in February).

4.3. Visualization of the ORS fields based…

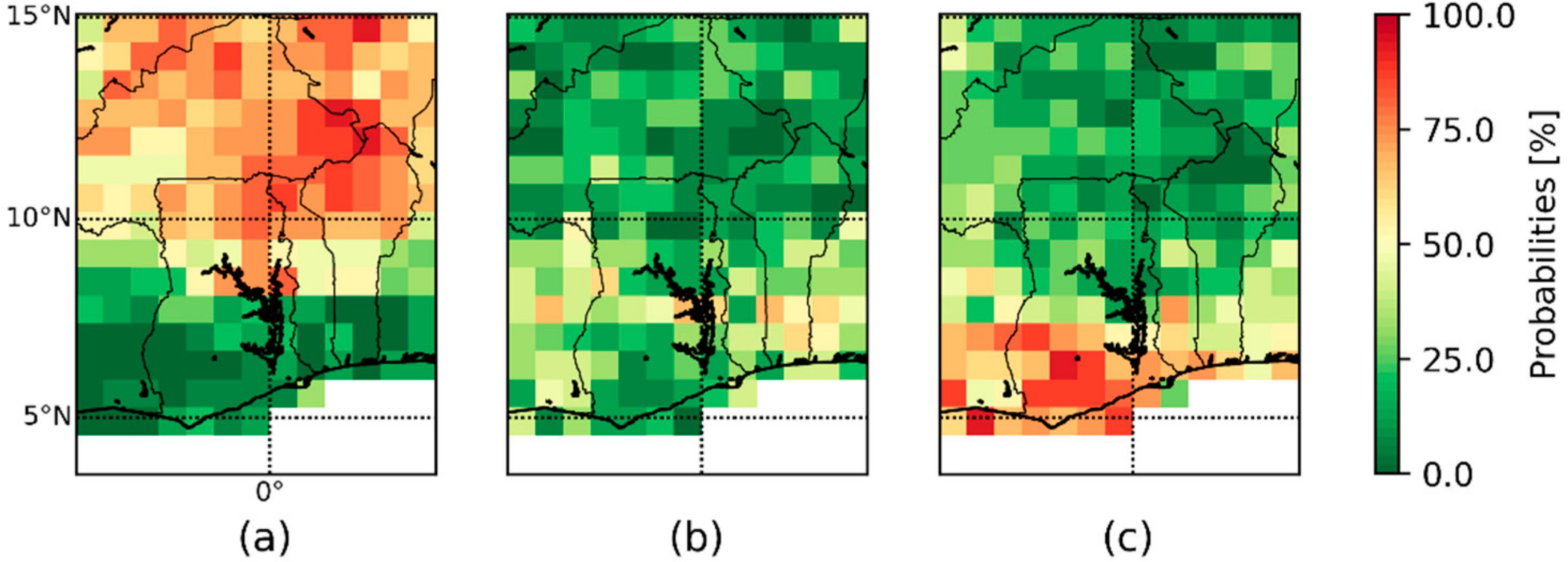
… on observational data from CHIRPS.



(a) ORS from CHIRPS [Julian Day] in 2001, (b) ORS Climatological mean from CHIRPS (1981-2010), (c) Difference between (a) and (b).

4.3. Visualization of the ORS fields with…

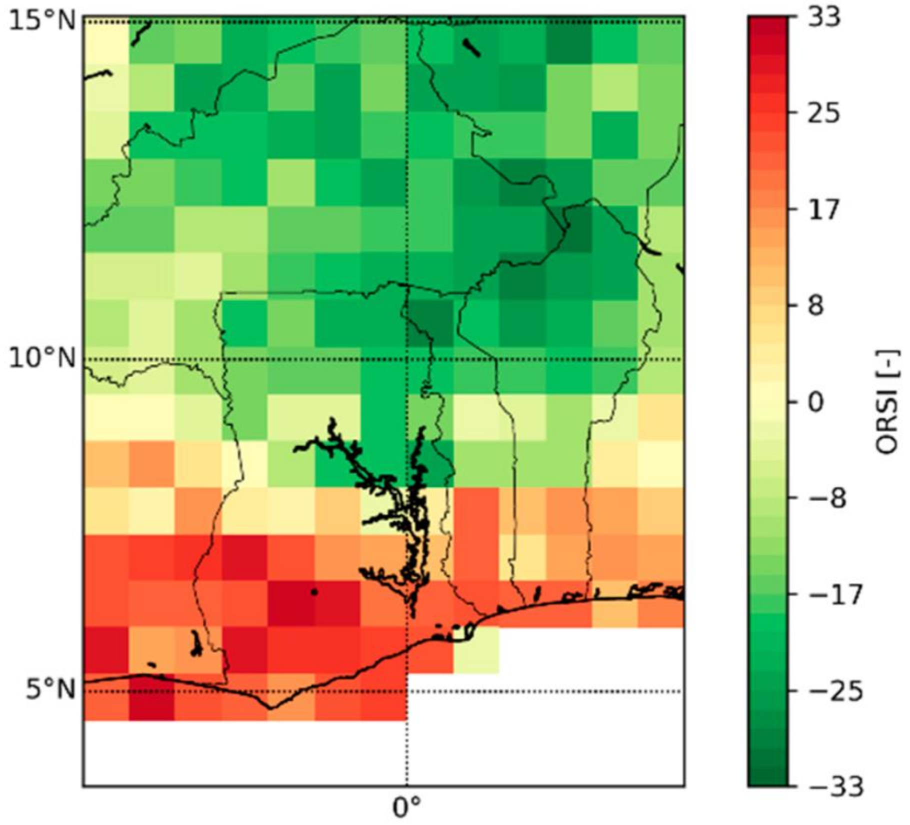
… forecast probabilities of climatologically equiprobable categories.



Relative frequency in percent (%) of the 15 ensemble members for the year 2001 of SYS4 by the classification into the categories: (a) "Below Average" (p_1), (b) "Near Average"(p_2) and (c) "Above Average"(p_3).

4.3. Visualization of the ORS fields using…

… using an index-based method (ORSI).



Seasonal forecast of the onset of the rainy season using an index-based method (ORSI) for the year 2001. An early, normal, and late onset of the rainy season is indicated by green (ORSI > 0), yellow (ORSI ~ 0), and red (ORSI < 0) values.

5.1. Conclusion

Probabilistic Forecasts of the Onset of the Rainy Season using Global Seasonal Forecasts

- Statistical approach for seasonal forecasting of the onset of the rainy season using precipitation forecasts of a global seasonal ensemble prediction system
- The basis of this approach is:
  - a quantile-quantile transformation for removing biases from the precipitation ensemble,
  - a fuzzy-rule based approach for calculation of the ORS date and
  - several graphical methods for an improved visualization of ensemble-based ORS forecasts.
- The different components of the approach are modular and can therefore be replaced by other methods (i.e., downscaling or ORS approaches) and datasets (i.e., GSEPS forecasts and observations).
- Moreover, the approach can be relatively easily transferred to other geographical regions of the world and extended to crucial rainfall characteristics like the cessation and the length of the rainy season.
- The presented approach has also the advantage that it is not very CPU demanding and requires only a single variable for the downscaling process. Unlike many other downscaling approaches, it might be better operationally applicable to forecasting centers in development countries where bandwidth and computing power are often limited.

5.2. Outlook for Further Work

Classification of Circulation Patterns

- The forthcoming work aims to enhance the scientific understanding of the complex relationships between atmospheric features and regional precipitation in West Africa by an objective classification of daily circulation patterns.
- The capability of global dynamic models to forecast local precipitation is usually restricted, but the simulation of global models for large-scale atmospheric patterns has normally a higher quality.
- The identified daily circulation patterns can therefore be used as an intermediate step for downscaling, statistical-post-processing of global climate models and pre-selection of ensemble members for regional climate modelling.

References

Laux, P.; Kunstmann, H.; Bárdossy, A. Predicting the regional onset of the rainy season in West Africa. *International Journal of Climatology: A Journal of the Royal Meteorological Society* **2008**, *28*, 329–342.

Rauch, M.; Bliefernicht, J.; Laux, P.; Salack, S.; Waongo, M.; Kunstmann, H. Seasonal Forecasting of the Onset of the Rainy Season in West Africa. *Atmosphere* **2019**, *10*, 528.

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Thanks for your attention.