CLIMTAG

Climate Information Tool for Agriculture

Behind the scenes: agro-climate indicators and seasonal forecasts

9–11 oktober 2023

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Methods

- **Agro-climate indicators from reanalysis and climate projections**
- Agro-seasonal weather indicators from seasonal forecasts

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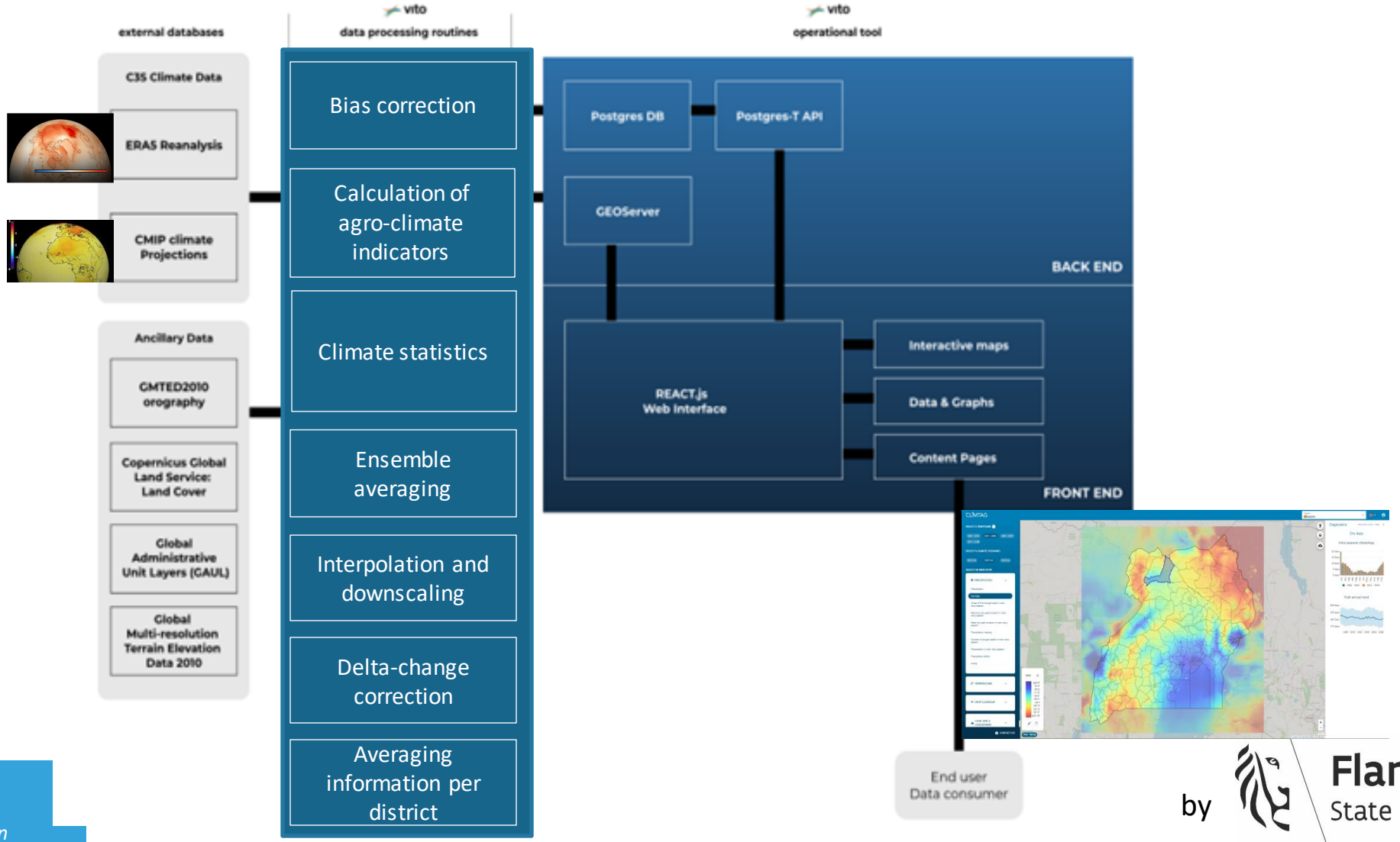
DATA PROCESSING AND VIZUALIZATION IN THE WEB TOOL

1981-2010

21st century



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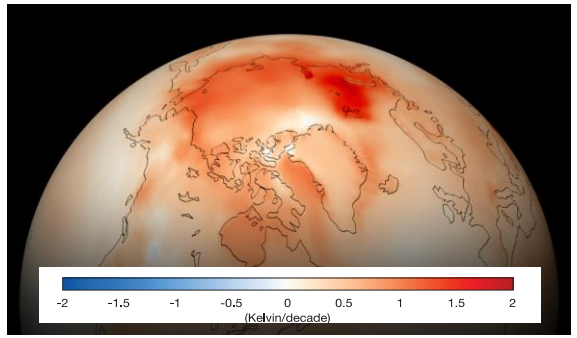
DAILY INPUT DATA

- Raw data
  - 2m temperature;
  - total precipitation;
  - 10m wind speed;
  - 2m specific humidity;
  - volumetric soil moisture at the upper surface layer (10 cm);
  - downward shortwave radiation;
  - surface sensible heat;
  - surface latent heat.
- Derived data (next slides)
  - Reference potential evaporation

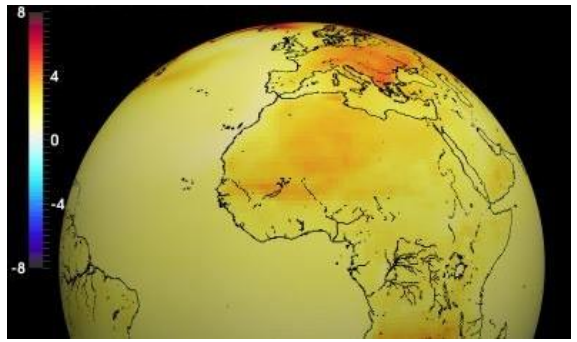
- Data from the Copernicus data store:
  - ERA5 reanalysis, a reconstruction of the historic gobal climate, based on ground-based observations, satellite imagery and atmospheric modelling at 0.25° x 0.25° resolution
  - CMIP5 projections to represent the future climate trends towards 2100, consisting of 15 climate models and 3 scenario's

Reanalysis: recent climate (ERA5)



1979-2018

Future climate: CMIP projections



21st century

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DAILY INPUT DATA

Table 3. Data description of ERA5 hourly data on single levels

Horizontal coverage	Global
Horizontal resolution	0.25° x 0.25°
Vertical resolution	Surface level
Temporal coverage	1979-present
Temporal resolution	Hourly
File format	GRIB

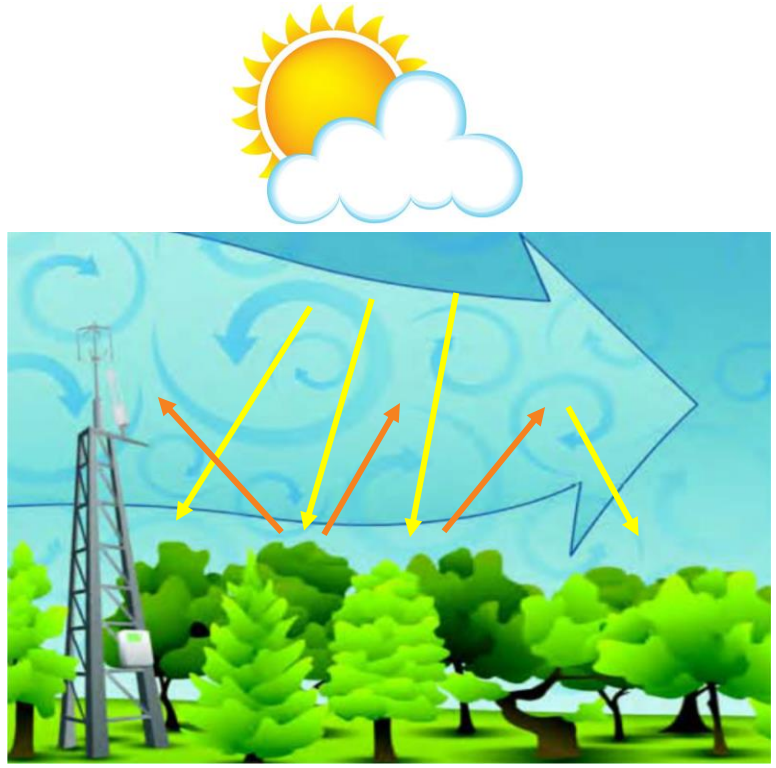
Table 4. Data description of CMIP5 daily data on single levels

Horizontal coverage	Global
Horizontal resolution	0.125°x0.125° to 5°x5° (depending on the model)
Vertical resolution	Surface level
Temporal coverage	1850-2100
Temporal resolution	Daily
File format	GRIB

Model	Origin	Atmospheric grid	
		Lat	Lon
inmcm4	INM, Russia	1.5	2
FGOALS-g2	IAP-THU, China	2.7906	2.8125
BNU-ESM	BCC, China	2.7906	2.8125
GFDL-ESM2G	NOAA, USA	2.0225	2.5
GFDL-ESM2M	NOAA, USA	2.0225	2.5
IPSL-CM5A-LR	IPSL, France	1.2676	2.5
IPSL-CM5A-MR	IPSL, France	1.2676	2.5
IPSL-CM5B-LR	IPSL, France	1.2676	2.5
NorESM1-M	NCC, Norway	1.8947	2.5
MPI-ESM-LR	MPI, Germany	1.87246	1.875
MPI-ESM-MR	MPI, Germany	1.87246	1.875
CSIRO-Mk3-6-0	CSIRO, Australia	1.87246	1.875
GFDL-CM3	NOAA, USA	2	2.5

DAILY REFERENCE POTENTIAL EVAPORATION

- **'Potential evaporation'**: a measure of **atmospheric water demand** that, combined with soil drought conditions, can put **crops** and **agriculture** activity under **water stress**
- **'Reference'**: considering a **reference hypothetical grass patch free from water stress**
  -> so **only depending on the atmospheric condition** (temperature, air humidity, radiation, pressure, and wind) **and available surface energy (net radiation – heat flux into the ground)**
  -> **Independent of the surface condition including** crop type or agricultural activity (at least when neglecting additional atmospheric feedbacks)
  -> **Different from the actual evaporation**, which also depends on the land-cover type (soil properties, crop type, vegetation, urbanization...) and conditions (soil moisture, soil temperature)
- In combination with precipitation and soil type/drought parameters, this parameter **can be used to select suitable crop types** for cultivation, cfr. precipitation deficit, aridity and soil moisture indicators



DAILY REFERENCE POTENTIAL EVAPORATION

Combination of 2 methods:

- Air humidity and available surface energy are not available on a daily basis for many climate models, so we start from the temperature-only definition by Hargreaves ($E_{p,H}$)
- They are still available on a monthly basis so we perform a correction to incorporate their effect on the long-term trend using the definition of Penmann-Montheith ($E_{p,PM}$)
- We combine the two definitions as follows:

$$E_{p,i} = E_{p,H,i} \times \sum_{j=i-15}^{i+15} E_{p,PM,j} / \sum_{j=i-15}^{i+15} E_{p,H,j}$$

with i and *j* a particular day in time

Daily values according to Hargreaves ($E_{p,H}$)

$$E_{p,H} = 0.0022 * R_A * \delta'_T{}^{0.5} * (T + 17.8) \quad (15)$$

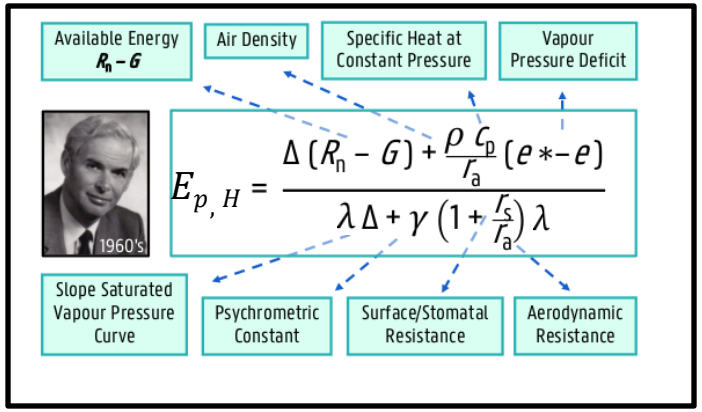
where:

R_A = mean extra-terrestrial radiation [mm/day], which is a function of the latitude f, (equation 8)

δ'_T = temperature difference = mean monthly maximum temperature - mean monthly minimum temperature for the month of interest [°C].

T = mean air temperature [°C].

Monthly values according to Penmann-Monteith ($E_{p,PM}$)



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BIAS CORRECTION

- Monthly and daily raw data of CMIP5 is bias-corrected against ERA5 by a quantile-delta mapping of daily and monthly values (QDM; Cannon et al., 2017)
- Basic idea of QDM: subtract model bias that is associated to the percentile of the model values

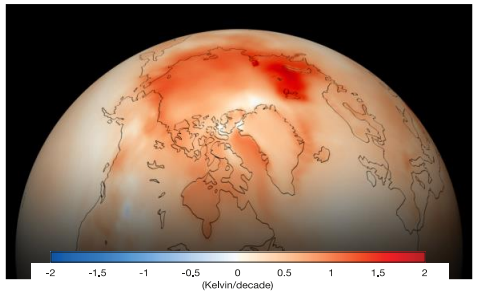
$$x_{m,corr}(t) = x_m(t) - B(p(x_m(t), t))$$

$x_m(t)$: model value for a particular time t

$p(x_m(t), t)$: Percentile of the model value $x_m(t)$ according to the time window around t

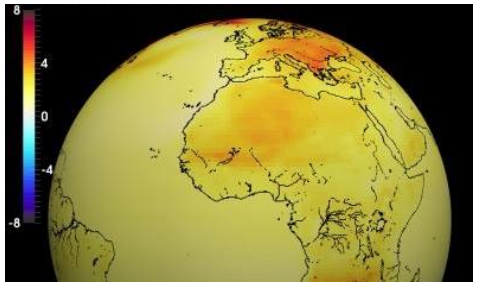
$B(p(x_m(t), t))$: Model bias associated to the percentile p

Reanalysis: recent climate (ERA5)



1979-2018

Future climate: CMIP5 projections



21st century

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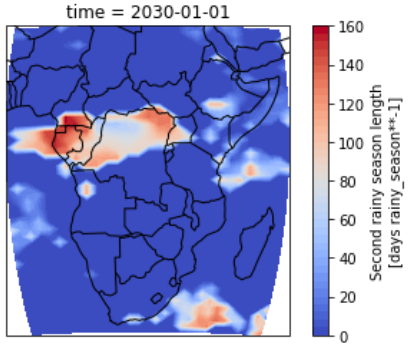
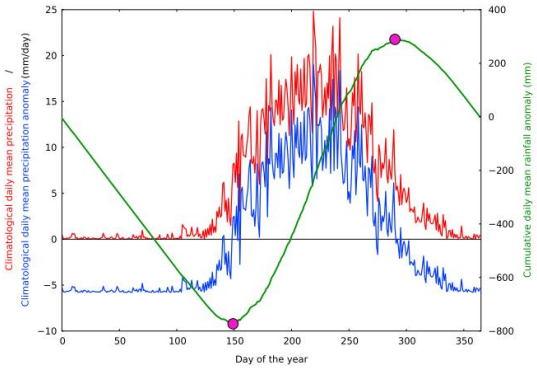
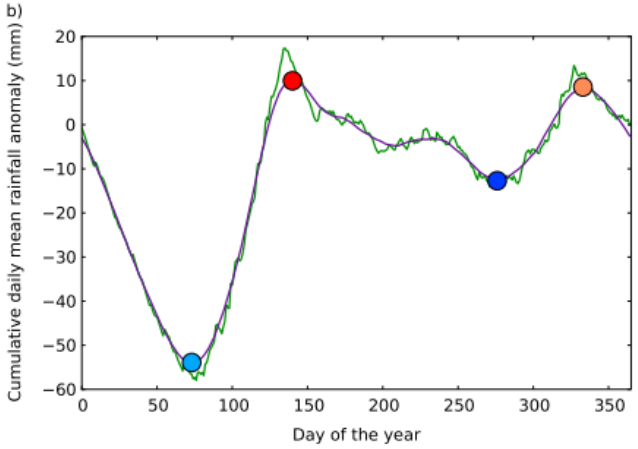
RAINY SEASON – CALCULATION WITH MULTIPLE DEFINITIONS

- **Universal** definition valid for the whole continent
- **STEP1:** identify **number** of rainy seasons (~ Dunning et al 2016: Fourier transformation)
- **STEP2:** identify search **window** (~ Dunning et al 2016: harmonic analysis)
- **STEP3: apply onset criteria** in the search window
  - ACMAD: 50 mm cumulative rainfall (ACMAD's reference)
  - Dunning et al., 2016: rainfall amount rel. to annual average (universal and peer-reviewed)
  - Ati et al., 2002: rainfall and ETo criteria (intuitive and known)
  - Sivakumar et al., 1988: first 3-day period with a cumulative precipitation of at least 20 mm and no dry spell longer than 7 days within 30 days following the determined onset.
- **Cessation:** last day of first 20-day period without rainfall







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POST-PROCESSING OF THE MODEL ENSEMBLE OF INDICATORS

- Climate statistics:
  - median and inter-quartile spread of the indicators for a 30-year moving window
- Ensemble averaging:
  - Averages of the medians and inter-quartile values are calculated to construct the final climatological spread
  - In case of rainy season indicators, we consider only the models for which the start of the rainy season start (median over 30 years) deviates less than 3 weeks than that from the climate reconstruction of the reference period (ERA5: 1981-2010). Otherwise, we keep them out of the ensemble.

DOWNSCALING

- **Downscaling** of the **historical** (ERA5) **indicators** (ERA5) to 1km resolution using elevation height:

$$I_{HR,hist} = I_{CR} + \alpha_{CR}(h_{HR} - h_{CR})$$

I_{CR}: indicator on the coarse resolution interpolated to the 1km grid
h_{HR}: elevation height at 1km resolution
h_{CR}: elevation height aggregated to the coarse resolution (0.5deg) and re-interpolated to the 1km resolution.
α_{CR}: slope of the variable derived at coarse resolution with regression for the surround 250 km x 250 km and applied on the fine resolution

- **Superposition** of **future** change of the ensemble **coarse agro-climate indicators** on the downscaled historical indicators:

$$I_{HR}(t) = I_{HR,hist} + I_{CR,m}(t) - I_{CR,m}(t_0)$$

$I_{CR,m}(t)$: coarse ensemble agro-climate indicator for any time t in the future
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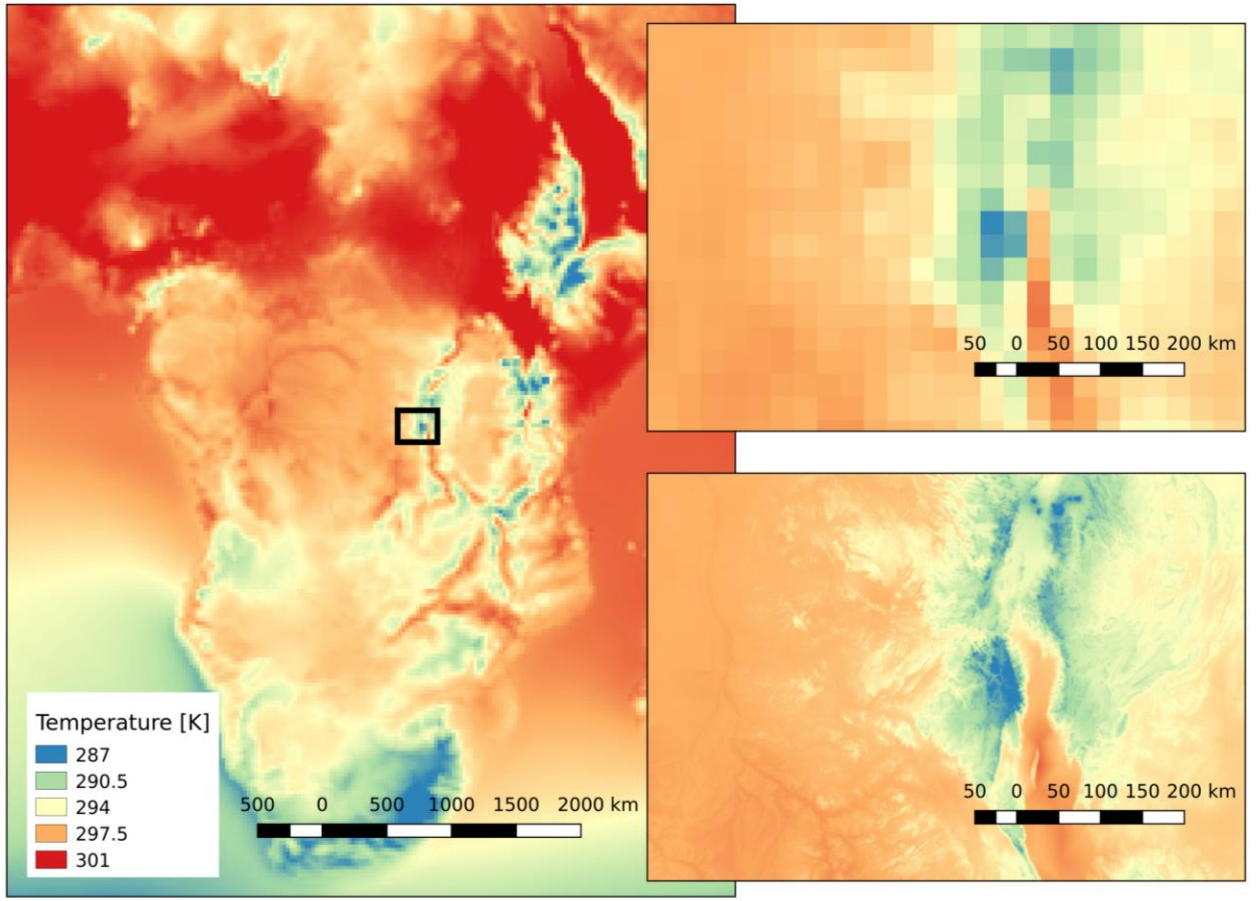

Methods

- Agro-climate indicators from reanalysis and climate projections
- **Agro-seasonal weather indicators from seasonal forecasts**

Methods

Agro-seasonal weather indicators

- 3-monthly precipitation statistics indicating the overall wetness or dryness of the season ahead, particularly for 1 to 3 months ahead and for 4 to 6 months ahead.
  - median and inter-quartile range of 3-monthly precipitation over the different seasonal forecast model members.
  - 'tercile summary' is provided, that indicates the chance of being wetter (that is, >40% of the forecast members are above second tercile value, ie., the 66.7th percentile; orange color) or drier (that is, >40% of the forecast members are below the first tercile value, ie., the 33.3th percentile; green color) than usual.
  - Median and interquartile ranges are also provided for 10-daily (decadal) precipitation to show the overall evolution of precipitation for the season ahead.

Methods

Agro-seasonal weather indicators

- Prior to calculating the seasonal weather indicators, daily values of the seasonal forecasts are bias-corrected with the quantile-delta mapping approach similar as for the climate models. Quantile values and their associated biases are determined for a reference period 1993 until 2022. The bias is determined by the difference between the seasonal forecast and ERA5 and subtracted from the daily values of the forecasts.
  - To account for a possible intra-seasonal variation of the model bias. This is done by performing the bias correction of each month separately, in which quantile values are determined from the month before, the month itself and the month after.
  - the bias-correction accounts for a possible change in bias of the seasonal forecasts over time. For that, biases associated with the quantile values are determined separately for the months that are 0, 1 ,…, 5 months ahead of the initialization of the forecast.
  - In the same way as the climate projections, the seasonal forecasts for precipitation are downscaled by overlaying a (ERA5-based) high resolution map over the seasonal forecasts interpolated to the 1km grid.
- Finally, CLIMTAG also includes the same seasonal weather indicators (ie., 3-monthly and 10-daily statistics) based on the ERA5 climate reconstruction (from 1961 until the same season of the previous year) and the future (bias-corrected) climate model scenarios (from 1950 until 2100). Thanks to the bias-correction on the seasonal forecasts, the seasonal weather indicators of the upcoming season are directly comparable, hence CLIMTAG shows at a glance how the upcoming season is similar to—or exceptional with respect to— the past climate record and future climate scenarios.

https://klimpala.marvintest.vito.be/country/ghana/2?it=seasonal&i=seasonalPrecipitation_10&timeframe=2056

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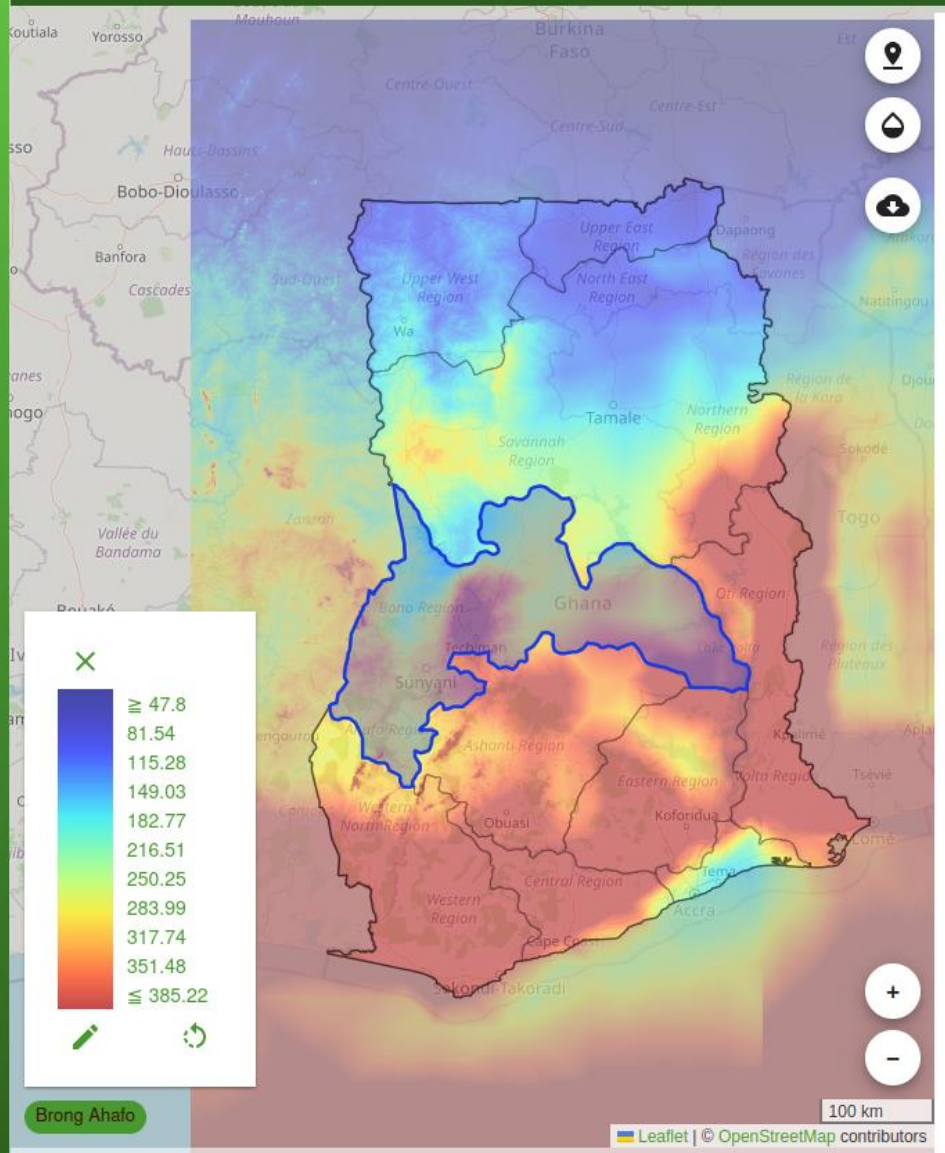
CLIMATE | SEASONAL WEATHER

Country: Ghana

- Precipitation & Drought
  - Precipitation
    - July August September
    - October November December

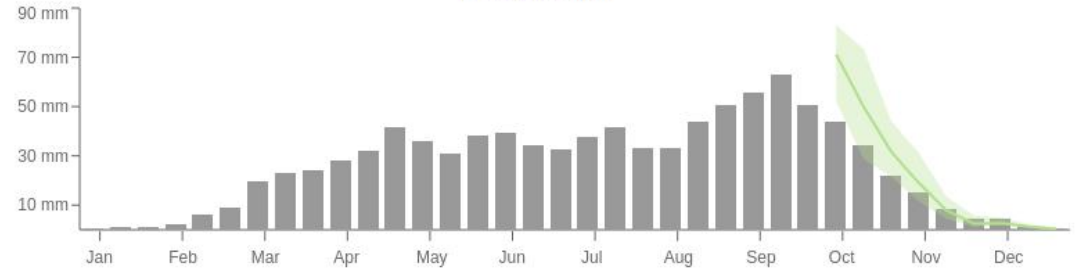


seasonal weather forecast versus
past climate reconstruction and future climate scenarios

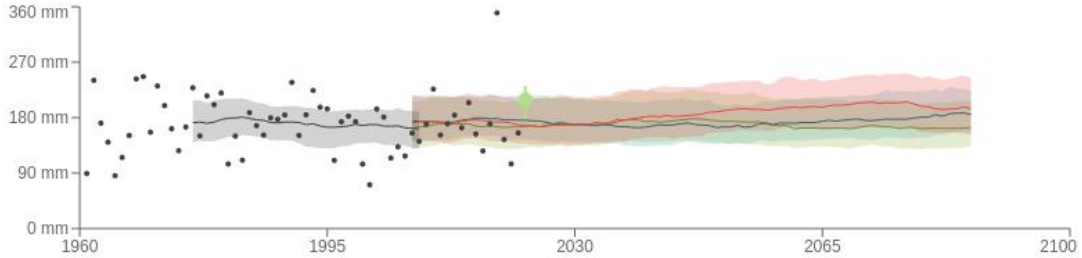
Diagnostics for Brong Ahafo

Precipitation October November December

Intra-seasonal



Total



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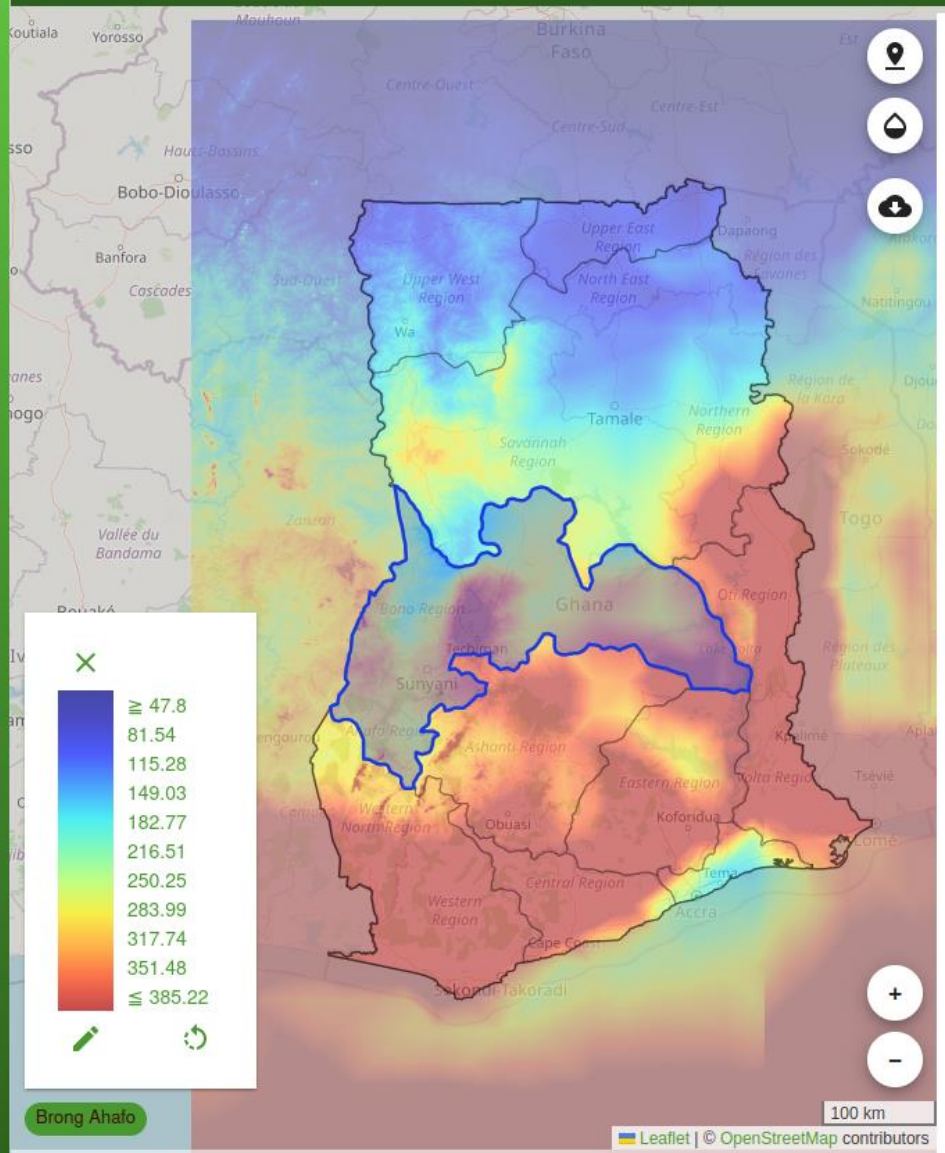
CLIMTAG

CLIMATE | SEASONAL WEATHER

Country: Ghana

- Precipitation & Drought
  - Precipitation
    - July August September
    - October November December



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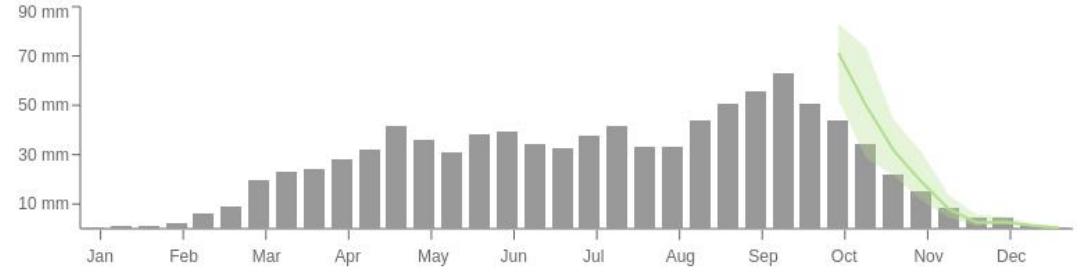

Total