



# Intra-ACP Climate Services and Related Applications Programme – ClimSA

## WORKSHOP - SADC Region

### WEFE NEXUS, Climate Variability, and Environmental Monitoring

South Africa, Johannesburg, June 10<sup>th</sup> – 13<sup>th</sup> 2024

Joint  
Research  
Centre





# Climate Variability module – Practical session

## Estimation of CV indicators

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South Africa, Johannesburg, June 11<sup>th</sup> 2024

# Climate Variability module – Practical session

- The following climate variability index can be calculated using E-Nexus tool – Climate Variability Module



## PRECIPITATION

### TEMPORAL AGGREGATION

Daily [ mm/d ]

Monthly Maximum[ mm/d ]

Monthly cumulative[ mm/m ]

Annual maximum[ mm/d ]

### INDEX

Drought

Return period (mm, yy, user defined)

Excess/Deficit (annual, monthly)

SPI

User defined Return periods

Annual return period



## TEMPERATURE

Daily

Monthly maximum

Annual maximum

Heat waves

Return period (monthly, annual, user defined)

Annual return period

# Heat waves

## Heat waves definition and analysis

The daily **Heat Wave Magnitude Index** (HWMId, Ceccherini, 2017; Russo et al. 2015) is used to detect heatwaves, being an indicator **based on both length and intensity of such phenomenon**, and more in detail, it aggregates temperatures above a defined threshold.

It is a metric that **quantifies the maximum magnitude of heat waves in a given year**

A “**heat wave**” is defined as a **sequence of three or more consecutive days** during which the daily maximum temperature **exceeds the 90<sup>th</sup> percentile of daily maximum temperatures** for a 31-day running window centered around that day, evaluated from a reference period (for example, 1981-2010)

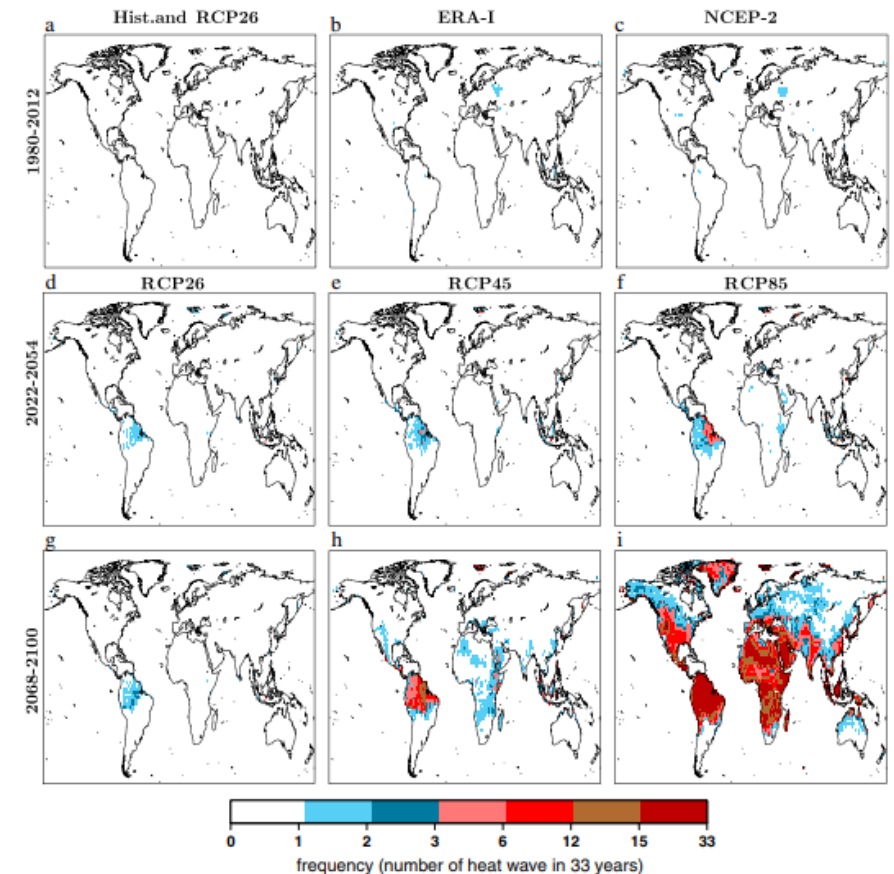
- Ceccherini, G., Russo, S., Ameztoy, I., Romero, C. P., and Carmona-Moreno, C.: Magnitude and frequency of heat and cold waves in recent decades: the case of South America, Nat. Hazards Earth Syst. Sci., 16, 821-831, <https://doi.org/10.5194/nhess-16-821-2016>, 2016.
- Ceccherini, G., Russo, S., Ameztoy, I., Marchese, A. F., and Carmona-Moreno, C.: Heat waves in Africa 1981–2015, observations and reanalysis, Nat. Hazards Earth Syst. Sci., 17, 115-125, <https://doi.org/10.5194/nhess-17-115-2017>, 2017.
- Russo, S., A. Dosio, R. G. Graversen, J. Sillmann, H. Carrao, M. B. Dunbar, A. Singleton, P. Montagna, P. Barbola, and J. V. Vogt (2014), Magnitude of extreme heat waves in present climate and their projection in a warming world, J. Geophys. Res. Atmos., 119, 12,500–12,512, doi:10.1002/2014JD022098.

# Heat waves

## Heat waves definition and analysis

- The HWMI considers both the **duration** (number of days) and **intensity** (how hot the heat waves are) of heat waves.
- It calculates the maximum magnitude of heat waves within a year, allowing for comparisons over space and time.
- The index may serve as a **benchmark for evaluating the impacts of future climate change**

In summary, the HWMI provides a comprehensive view of heat wave severity, considering both duration and intensity.  
→ It helps assess the impact of rising temperatures



**Figure 5.** Number of very extreme heat waves ( $\text{HWMI} \geq 8$ ) in present and future climate. (a) Historical (1980–2005) and RCP2.6 scenario (2006–2012) for the multimodel CMIP5 ensemble, (b) NCEP-2, (c) ERA-Interim, and (d–f) median of the number of heat waves of the multimodel ensemble in the near future (2020–2052) under the RCP2.6, RCP4.5, and RCP8.5 scenarios, respectively. (g–i) As Figures 5d–5f but for the future period (2068–2100).

[Magnitude of extreme heat waves in present climate and their projection in a warming world - Russo - 2014 - Journal of Geophysical Research: Atmospheres - Wiley Online Library](#)

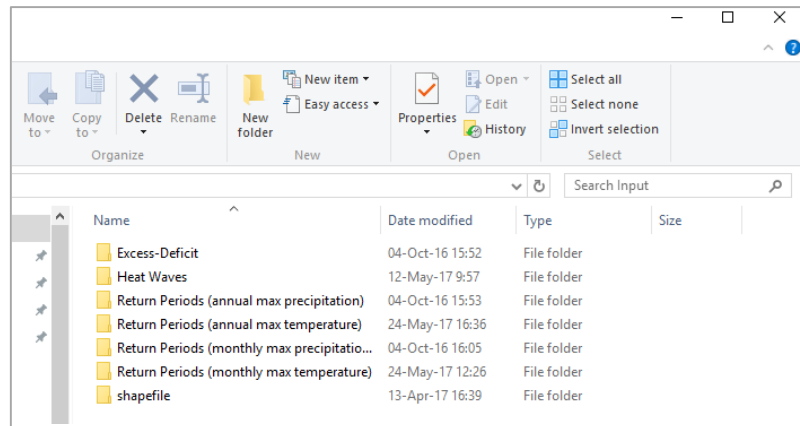
Heat waves are more than just uncomfortable: they can lead to illness and death, particularly among older adults, the very young, and other vulnerable populations ([ref](#))

# Heat waves



## Temperature indices

All required input data are stored into **Input** folder. More in detail, inputs are located in folders named after the specific process to execute. **Shapefile** folder contains .shp files related to available geographical domains.



Precipitation source: CHIRPS

<https://data.chc.ucsb.edu/products/CHIRPS-2.0/>

Temperature source : ERA5 re-analysis

<https://cds.climate.copernicus.eu/cdsapp#!/dataset/reanalysis-era5-single-levels?tab=form>

Process duration\*



Short (<1 minute)



Average (5:10 minutes)



Long (>10 minutes)

\* Performances affected by hardware specifics

# Heat waves



## Temperature indices

The aim is to assess the HWMI index of daily maximum temperatures in the period 1981-2023, using 1981-2010 interval as reference period. The final resume will consider all cases of HWMI with values of 4 and higher.

Duration:



General parameters



- **Folder:** *Input\era5\_daily\_19812023.nc*
- **Input Shapefile :** *Shapefiles\Gadm36\_L4\_SampleArea\_Box1.shp*
- **Output folder:** free choiche
- **Start time:** 01 Jan 1981
- **End time:** 31 Dec 2023

Specific parameters  
(tab **Temperature**)



- Select **Tmax**
- **Temporal aggregation:** daily
- **Temp. unit:** K
- **Index:** Heat waves
- **Reference period -> Start:** 1981 **End:** 2010
- **HWMI resume:** HWMI > 4



# Heat waves



## Temperature indices

Specific parameters  
(tab **Temperature**)

1. Variable = Temperature
2. Aggregation = Daily
3. Temp. unit = K
4. Index = Heat Waves
5. Select Tmax
6. Reference period = 1981-2010
7. HWMIId > 4
8. Start the tool

The screenshot shows the E-Nexus Climate Variability software interface. The 'Settings' tab is active, and the 'Climate' section is selected. The 'Input Pre-Processing' section shows 'CHIRPS' and 'ERA Interim' options. The 'Select File' field contains the path 'C:\Users\Msi-pc\Desktop\JRC\E-Nexus\Zambezi\Input\Temperature\DailyMax 1981\_2017.nc'. The 'Climate data source' is set to 'NetCDF file'. A table lists the data tables and their variables:

Table	Field	Variable	Unit	Start date	End date	Time step
mekrou_monsum	Precipitation	precip	mm/month	01/01/1981	01/12/2015	Monthly
mekrou_tmax	Temperature	temp	°C	01/01/1981	31/03/2016	Daily
moekrou_monmax	Precipitation	date	mm/day	01/01/1981	01/12/2015	Monthly
prova_temp	Temperature	temp	°C	01/01/2021	01/01/2023	Annual

The 'Settings' section includes a search bar, field and time step dropdowns, and an 'Import' button. The 'Start date' is '01/01/1981' and the 'End date' is '01/01/2015'. The 'Input shapefile' and 'Output folder' are both 'C:\Users\Msi-pc\Desktop\JRC\E-Nexus\Zambezi\'. The 'Shapefile' section has 'View geom. file' and 'Ref. field' set to 'name'. The 'Clip by extent' and 'Clip by boundaries' options are present. The 'Temperature' tab is selected, showing 'Time aggregation' set to 'Daily', 'Temp. unit' set to 'K', and 'Index' set to 'Heat waves' and 'Tmax'. The 'Return period (years)' section has '2', '5', and '10' selected. The 'Reference period' is '1981-2010', and the 'HWMIId resume' is 'n° years with HWMIId > 4'. The 'Ann. threshold (°C)' is '40'. The 'Distribution' is 'Pearson type III'. The 'Start' button is highlighted.



# Heat Waves- OUTPUTS



## *Temperature indices*

For every process, outcomes are created into selected output folder in the following formats:

- 1) images (.png)
- 2) Vector files(.tif) to be displayed in GIS environments.

The output is arranged in multiple subfolders. For instance, results for monthly indices are placed into folders named after specific months (from JAN to DEC).

All created files will be placed in the following folders:

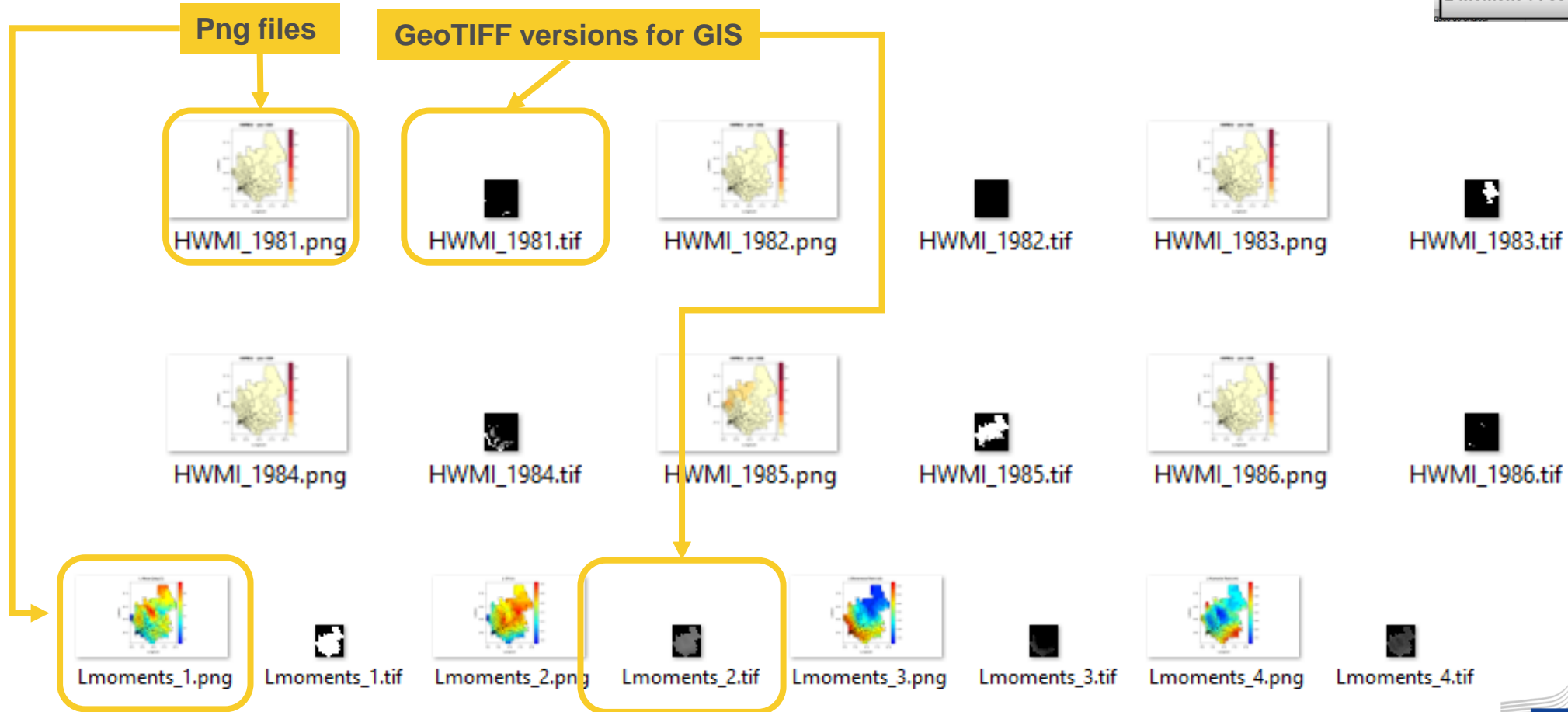
- **Annual Maps:** HWMId evaluated for all the years between 1981 and 2023 (86 files)
- **L-Moments:** the 4 main L-Moments (8 files)
- **Resume\_HWMI.png:** image showing the number of years with HWMId equal 4.

# Heat Waves - OUTPUTS



## Temperature indices

Les 4 principaux L-Moments  
L-moment 1 : moyenne  
L-moment 2 : variation (L-CV)  
L-moment 3 : coefficient de skew (L-Skewness)  
L-moment 4 : coefficient de Kurtosis (L-Kurtosis)

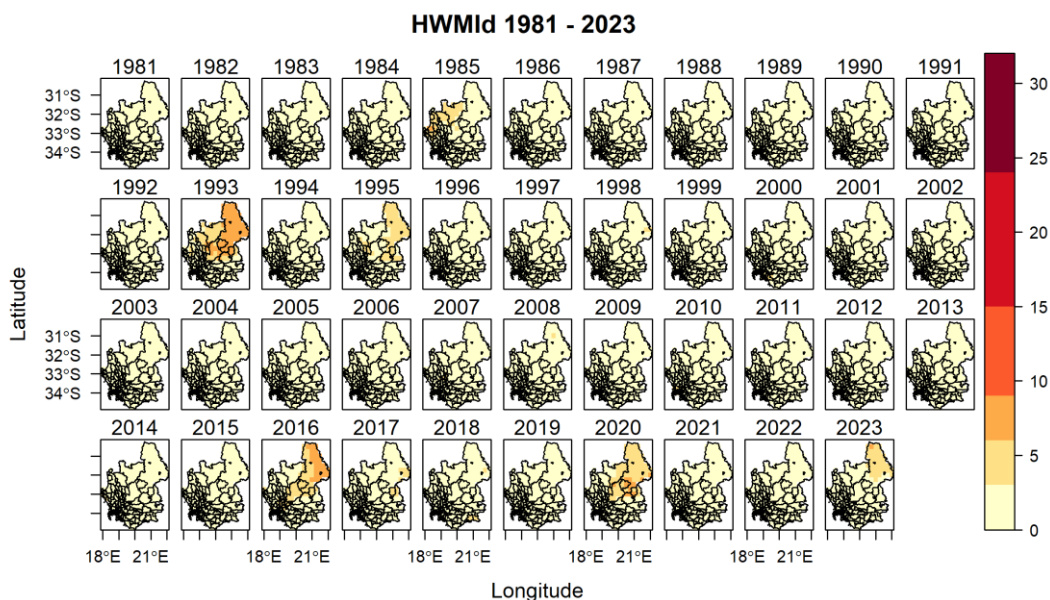




# Heat Waves - OUTPUTS

## OUTPUTS - INTERPRETATION

### Summary of all analysed years



Most of the values over the period studied are in line with normal temperature behaviour. **However, the years 1993, 1995, 2016 and 2020 and 2023 were impacted by more significant heat waves: 1993 and 2016 saw an extreme event, especially in the North-East part.**

Generally speaking, the last 10 years have been characterised by a higher frequency of heat waves.

Heat wave amplitude index (HWMId) for the period from 1981 to 2023.

In the table below, you will find an example of HWMId classification (Ceccherini et al.,2016)

**Table 1.** Classification of heat and cold wave (i.e. HWMI and CWMI) scale categories.

Classification	Heat Wave Magnitude Index	Cold Wave Magnitude Index
Normal	$1 \leq \text{HWMI} < 2$	$-1 \geq \text{CWMI} > -2$
Moderate	$2 \leq \text{HWMI} < 3$	$-2 \geq \text{CWMI} > -3$
Severe	$3 \leq \text{HWMI} < 4$	$-3 \geq \text{CWMI} > -4$
Extreme	$4 \leq \text{HWMI} < 8$	$-4 \geq \text{CWMI} > -8$
Very extreme	$8 \leq \text{HWMI} < 16$	$-8 \geq \text{CWMI} > -16$
Super extreme	$16 \leq \text{HWMI} < 32$	$-16 \geq \text{CWMI} > -32$
Ultra extreme	$\text{HWMI} \geq 32$	$\text{CWMI} \leq -32$



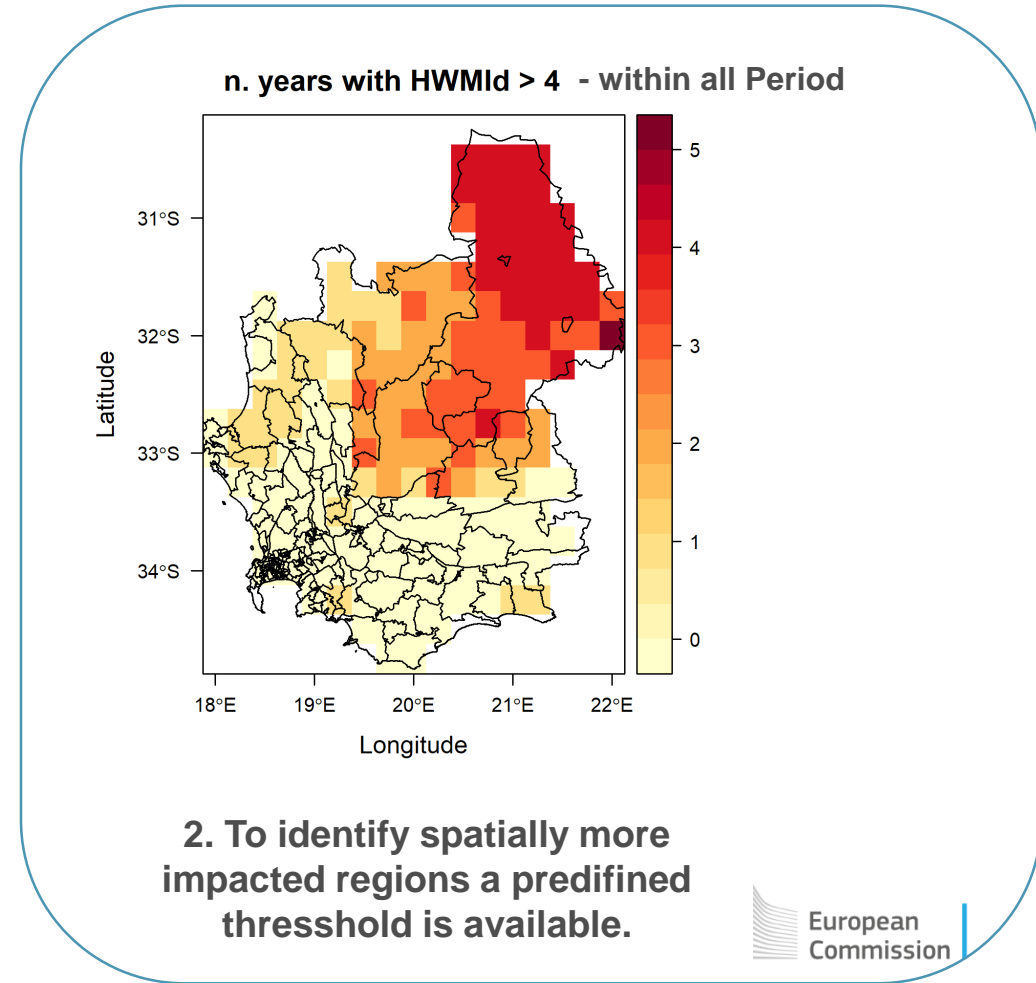
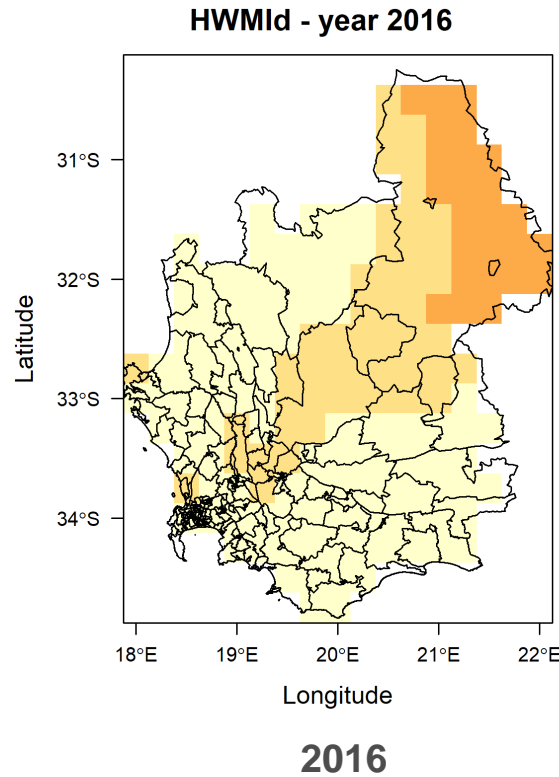
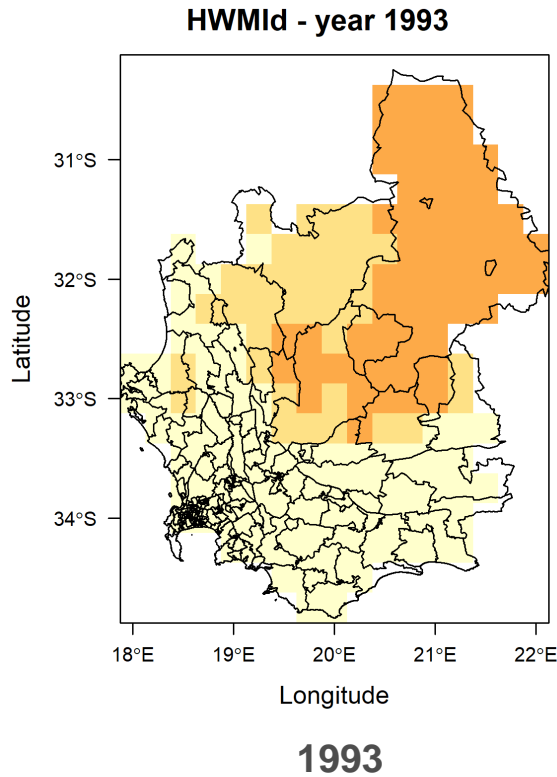
# Heat Waves - OUTPUTS

## OUTPUTS - INTERPRETATION

1. Annual maps ensure a more focused analysis.

**Table 1.** Classification of heat and cold wave (i.e. HWMI and CWMI) scale categories.

Classification	Heat Wave Magnitude Index	Cold Wave Magnitude Index
Normal	$1 \leq \text{HWMI} < 2$	$-1 \geq \text{CWMI} > -2$
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Extreme	$4 \leq \text{HWMI} < 8$	$-4 \geq \text{CWMI} > -8$
Very extreme	$8 \leq \text{HWMI} < 16$	$-8 \geq \text{CWMI} > -16$
Super extreme	$16 \leq \text{HWMI} < 32$	$-16 \geq \text{CWMI} > -32$
Ultra extreme	$\text{HWMI} \geq 32$	$\text{CWMI} \leq -32$



# Return periods



## Temperature indices

The aim is to assess the values of annual maximum temperatures with return periods of 5 and 20 years in the period 1981-2023.

Duration:



General parameters



- **Folder:** *Input\era5\_annmax\_19812023.nc*
- **Input Shapefile :** *Shapefiles\Gadm36\_L4\_SampleArea\_Box1.shp*
- **Output folder:** free choice
- **Start time:** 01 Jan 1981
- **End time:** 01 Jan 2023

Specific parameters  
(tab **Temperature**)



- Select **Tmax**
- **Temporal aggregation:** Annual max
- **Temp. unit:** K
- **Index:** Return period (ann.)
- **Return periods (years):** check 5 and 20



# Heat waves



## Temperature indices

Specific parameters  
(tab **Temperature**)

1. Variable = Temperature
2. Aggregation = Annual max
3. Temp. unit = K
4. Index = Return periods (ann.)
5. Select Tmax
6. Return periods (years) = select 5, 20
7. Start the tool

The screenshot shows the 'E-Nexus Climate Variability' software interface. The 'Settings' tab is active, and the 'Climate' section is selected. The 'zambezi' configuration is chosen. The 'Input Pre-Processing' section shows 'CHIRPS' and 'ERA Interim' options. The 'Select File' field contains the path 'C:\Users\Msi-pc\Desktop\JRC\E-Nexus\Zambezi\Input\Temperature\DailyMax 1981\_2017.nc'. The 'Climate data source' is set to 'NetCDF file'. A table lists the data tables and their variables:

Table	Field	Variable	Unit	Start date	End date	Time step
mekrou_monsum	Precipitation	precip	mm/month	01/01/1981	01/12/2015	Monthly
mekrou_tmax	Temperature	temp	°C	01/01/1981	31/03/2016	Daily
moekrou_monmax	Precipitation	date	mm/day	01/01/1981	01/12/2015	Monthly
prova_temp	Temperature	temp	°C	01/01/2021	01/01/2023	Annual

The 'Settings' section includes 'Start date' (01/01/1981) and 'End date' (01/01/2015). The 'Input shapefile' and 'Output folder' are both set to 'C:\Users\Msi-pc\Desktop\JRC\E-Nexus\Zambezi\'. The 'Shapefile' section has 'View geom. file' and 'Ref. field' (name) options. The 'Clip by extent' and 'Clip by boundaries' options are present. The 'Index' section has 'Return periods (ann.)' selected, and 'Heat waves' is the chosen index type. The 'Return period (years)' section has '5' and '20' selected. The 'Reference period' section has 'Start year' (1981) and 'End year' (2010). The 'HWMid resume' section has 'n° years with HWMid >' set to 4. The 'Temp. unit' is set to 'K'. The 'Ann. threshold (°C)' is set to 40. The 'Start' button is highlighted.

# Return periods - OUTPUTS

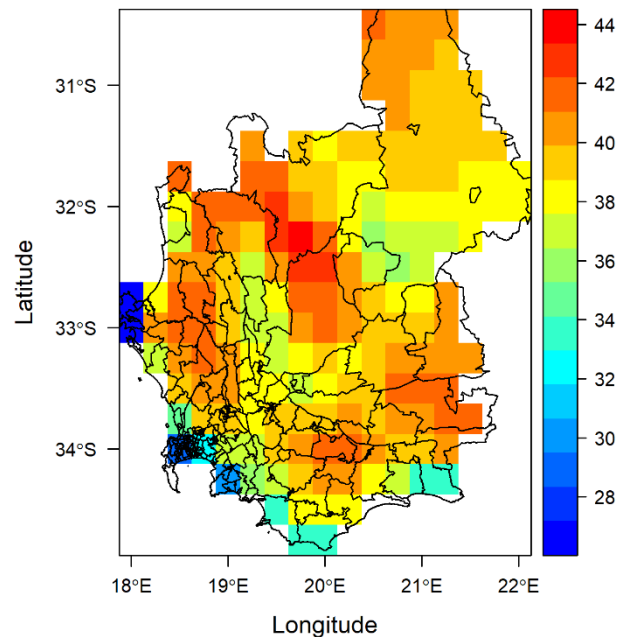


## Temperature indices

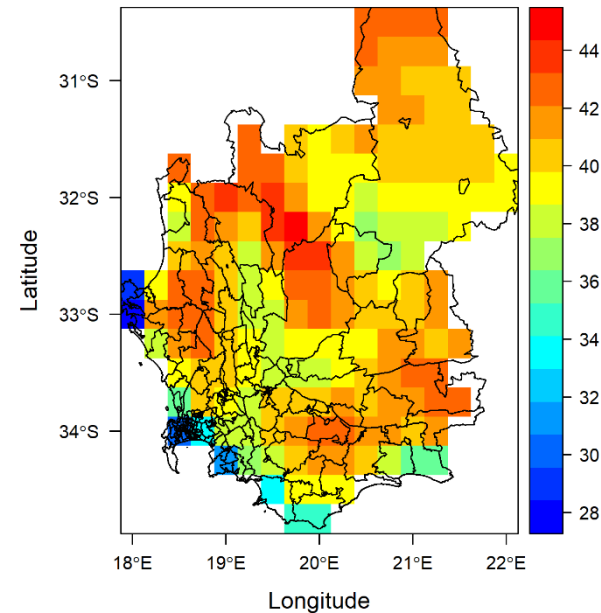
All created files will be placed in the following folders:

- **Annual Return Periods:** annual maximum temperatures with return periods of 5 and 20 years
- **L-Moments:** the 4 main L-Moments (8 files)

Daily Max. Temperature [deg C] (RP = 5 years)



Daily Max. Temperature [deg C] (RP = 20 years)

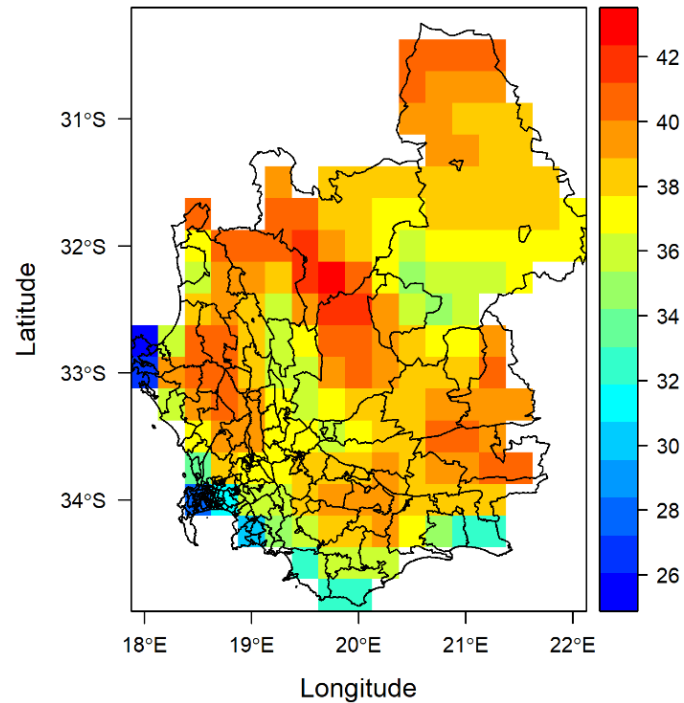


# Return periods - OUTPUTS

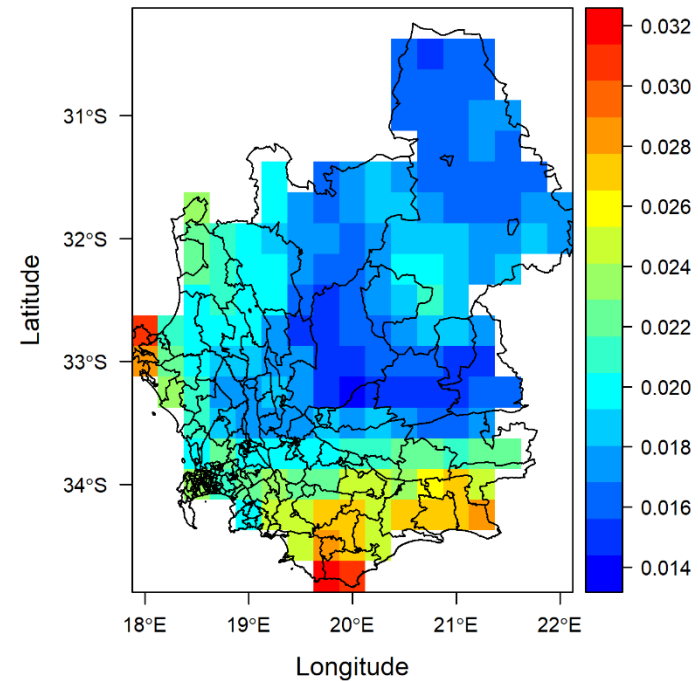


## Temperature indices

L-Mean of Daily Max. Temperature [deg C]



L-CV (t) of Daily Max. Temperature



1. 1<sup>st</sup> L-moment (mean) of annual maximum temperature for period 1981-2023
2. 2<sup>nd</sup> L-moment (standard deviation) of annual maximum temperature for period 1981-2023



# Thank you



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