Intra-ACP Climate Services and Related Applications Programme – ClimSA

WORKSHOP - SADC Region

WEFE NEXUS, Climate Variability, and Environmental Monitoring

South Africa, Johannesburg, June 10th – 13th 2024

Climate Variability module – Practical session

Estimation of CV indicators

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South Africa, Johannesburg, June 11th 2024

European Commission

Joint Research Centre

Climate Variability module – Practical session

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

	TEMPORAL AGGREGATION	INDEX
PRECIPITATION	Daily [mm/d]	Drought
	Monthly Maximum[mm/d]	Return period (mm, yy, user defined)
	Monthly cumulative[mm/m]	Excess/Deficit (annual, monthly) SPI User defined Return periods
	Annual maximum[mm/d]	Annual return period
TEMPERATURE	Daily	Heat waves
	Monthly maximum	Return period (monthly, annual, user defined)
	Annual maximum	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 90th 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

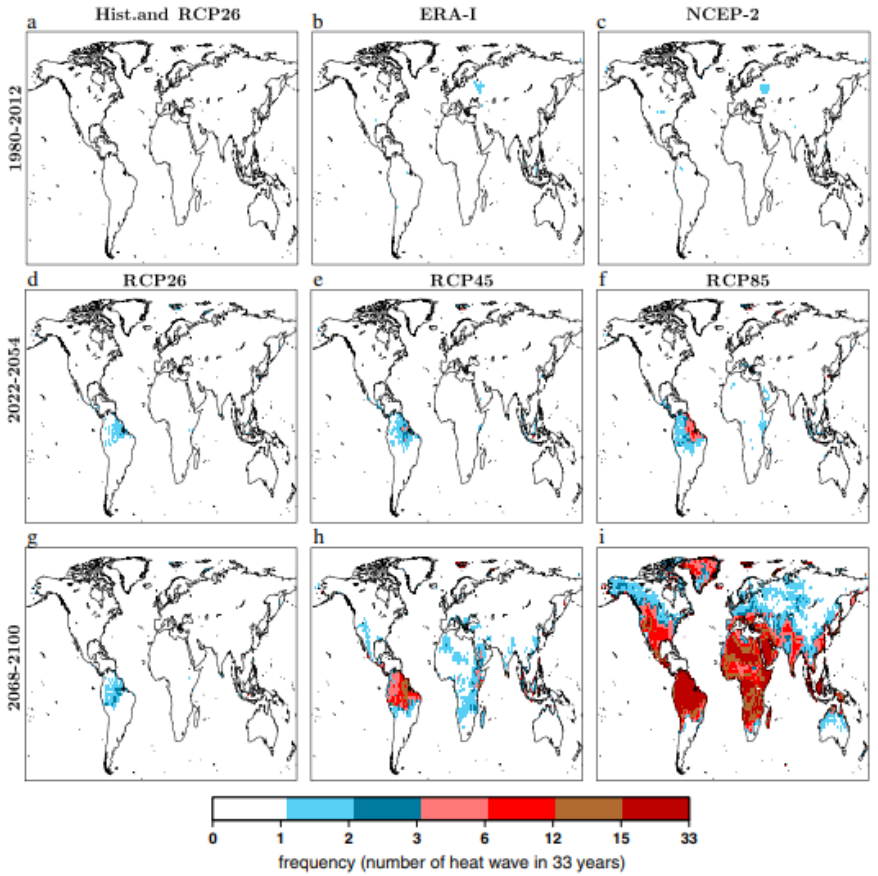

Figure 5. Number of very extreme heat waves (HWMI ≥ 8) in present and future climate. (a) Historical (1980–2005) and RCP2.6 scenario (2006–2012) for the multimodel CMIP5 ensemble, (b) NCEP-2, (c) ERA-Interim, and (d–f) median of the number of heat waves of the multimodel ensemble in the near future (2020–2052) 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)

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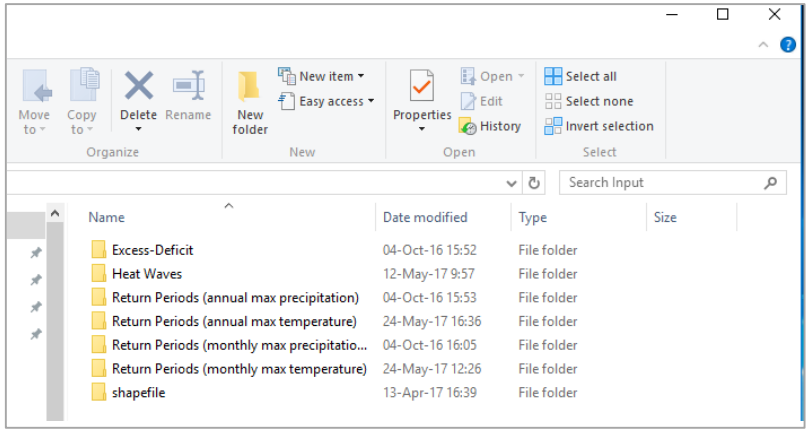
Heat waves

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.



* Performances affected by hardware specifics

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)

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Heat waves

Temperature indices

The aim is to assess the HWMId 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 HWMId 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
- **HWMId resume**: HWMId > 4

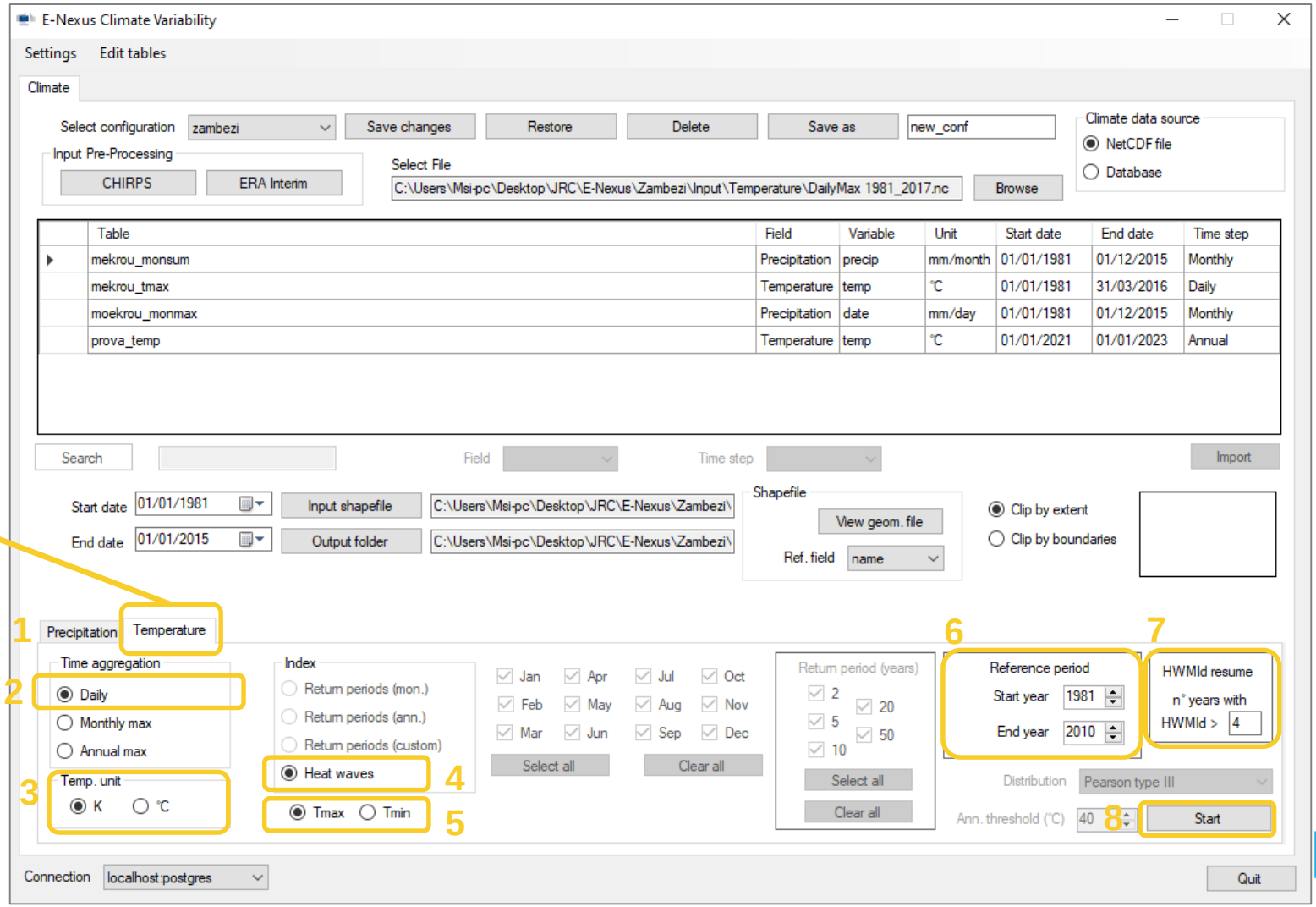
→ **Start** ←

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. HWMId > 4
8. Start the tool



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:

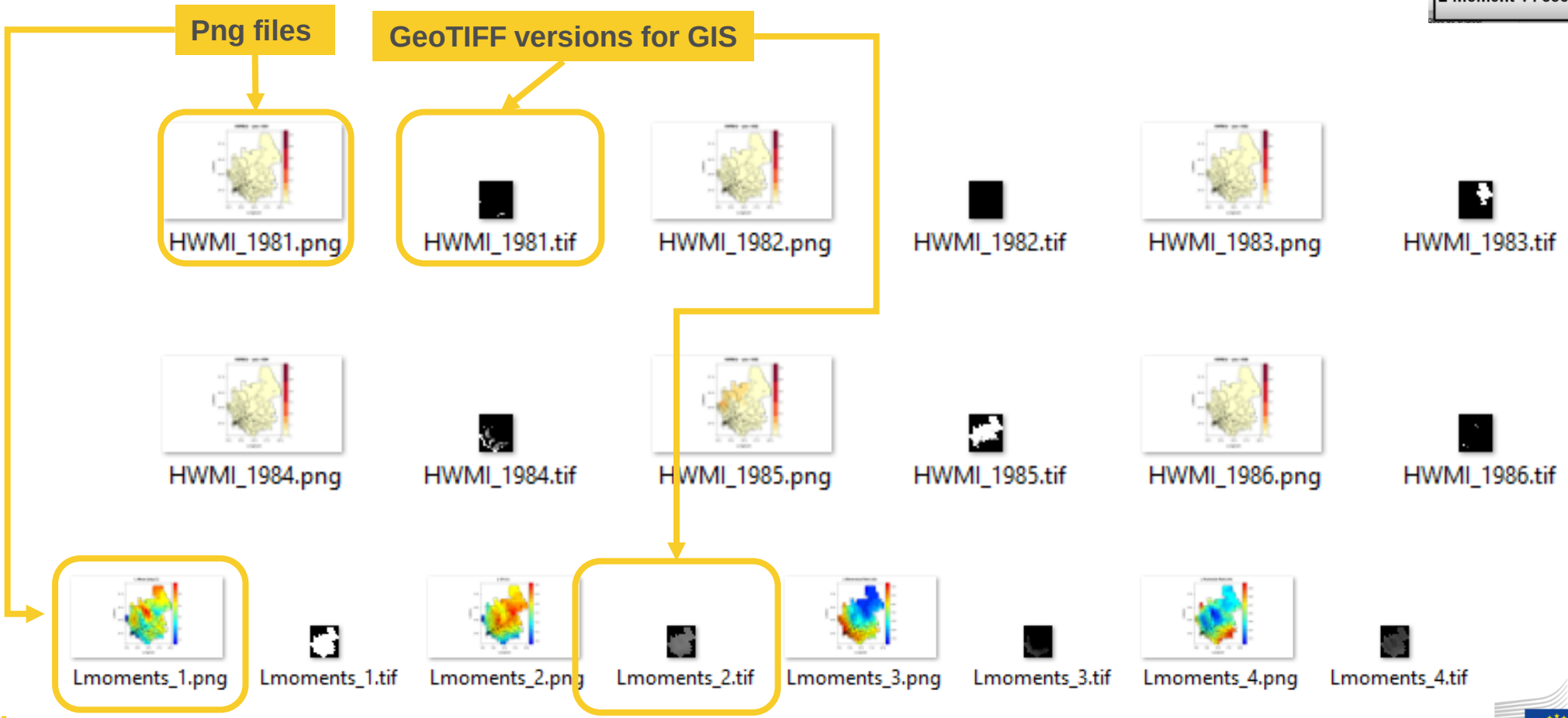
- ***Annual Maps***: HWMId evaluated for all the years between 1981 and 2023 (86 files)
- ***L-Moments***: the 4 main L-Moments (8 files)
- ***Resume_HWMI.png***: image showing the number of years with HWMId equal 4.

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)



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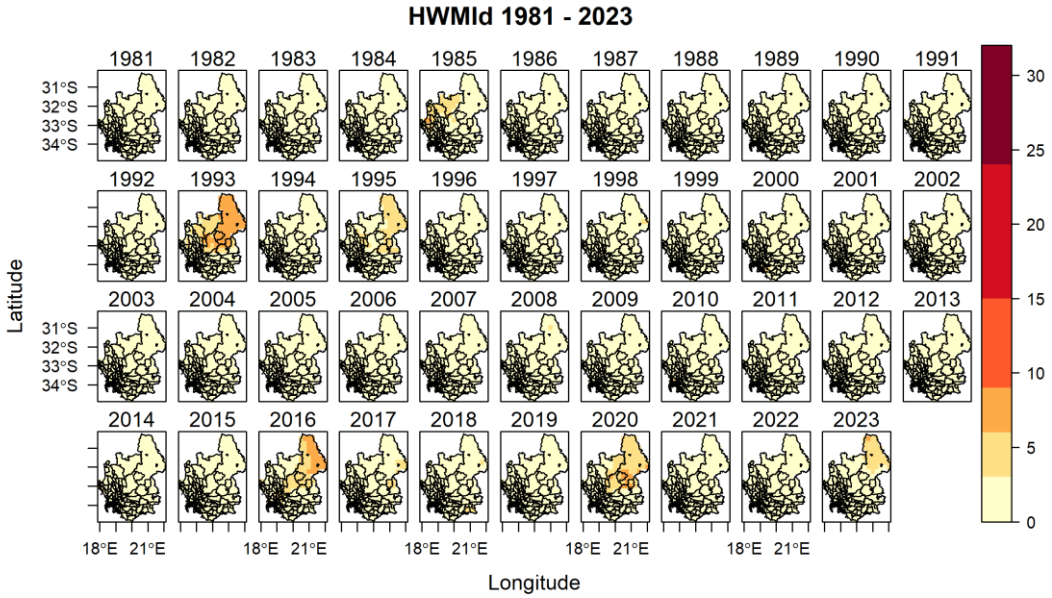
Heat Waves - OUTPUTS

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 (HMWId) for the period from 1981 to 2023.
In the table below, you will find an example of HMWId 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	$1 \leq HWMI < 2$	$-1 \geq CWMI > -2$
Moderate	$2 \leq HWMI < 3$	$-2 \geq CWMI > -3$
Severe	$3 \leq HWMI < 4$	$-3 \geq CWMI > -4$
Extreme	$4 \leq HWMI < 8$	$-4 \geq CWMI > -8$
Very extreme	$8 \leq HWMI < 16$	$-8 \geq CWMI > -16$
Super extreme	$16 \leq HWMI < 32$	$-16 \geq CWMI > -32$
Ultra extreme	$HWMI \geq 32$	$CWMI \leq -32$

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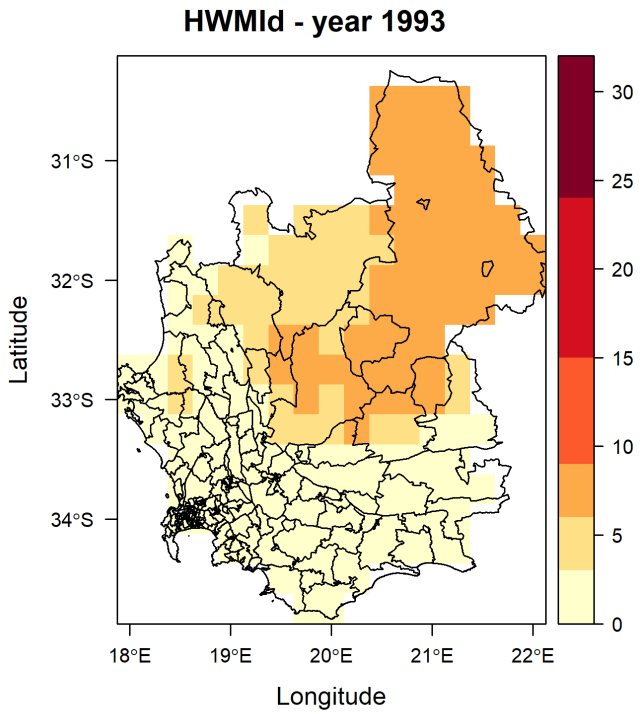
Heat Waves - OUTPUTS

OUTPUTS - INTERPRETATION

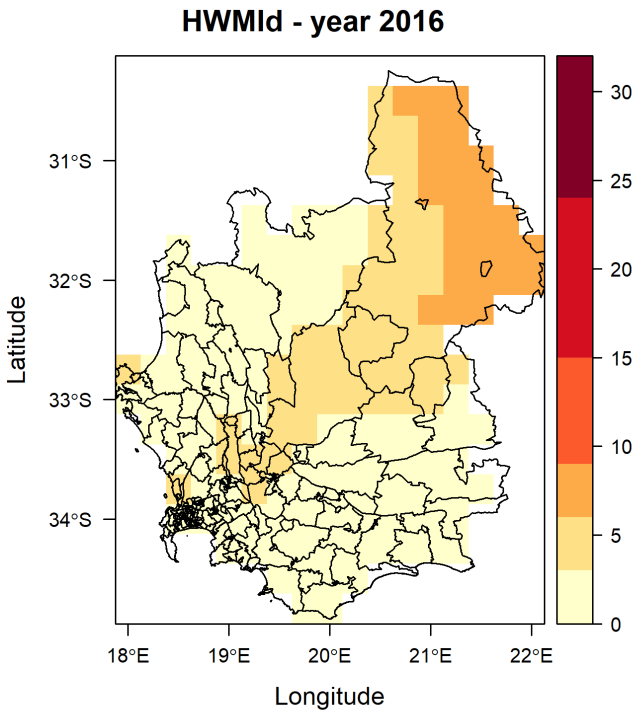
1. Annual maps ensure a more focused analysis.

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

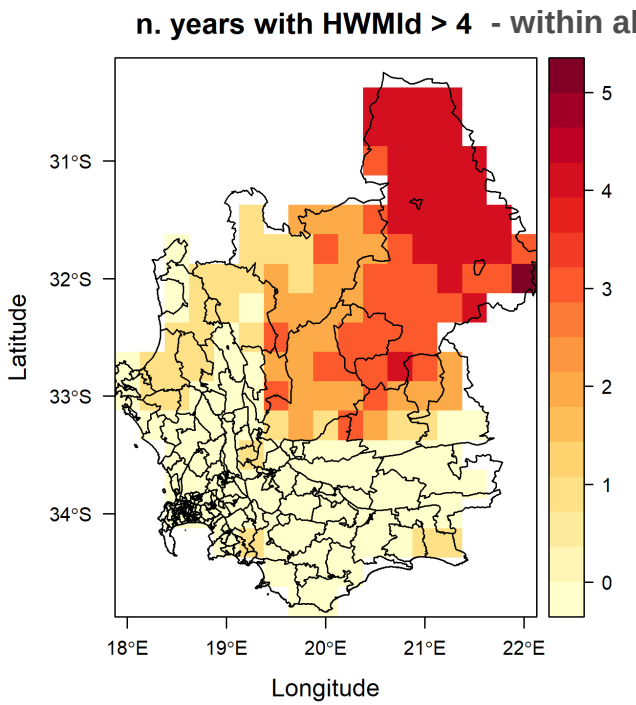
Classification	Heat Wave Magnitude Index	Cold Wave Magnitude Index
Normal	$1 \leq HWMI < 2$	$-1 \geq CWMI > -2$
Moderate	$2 \leq HWMI < 3$	$-2 \geq CWMI > -3$
Severe	$3 \leq HWMI < 4$	$-3 \geq CWMI > -4$
Extreme	$4 \leq HWMI < 8$	$-4 \geq CWMI > -8$
Very extreme	$8 \leq HWMI < 16$	$-8 \geq CWMI > -16$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



1993



2016



2. To identify spatially more impacted regions a predifined thresshold is available.

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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

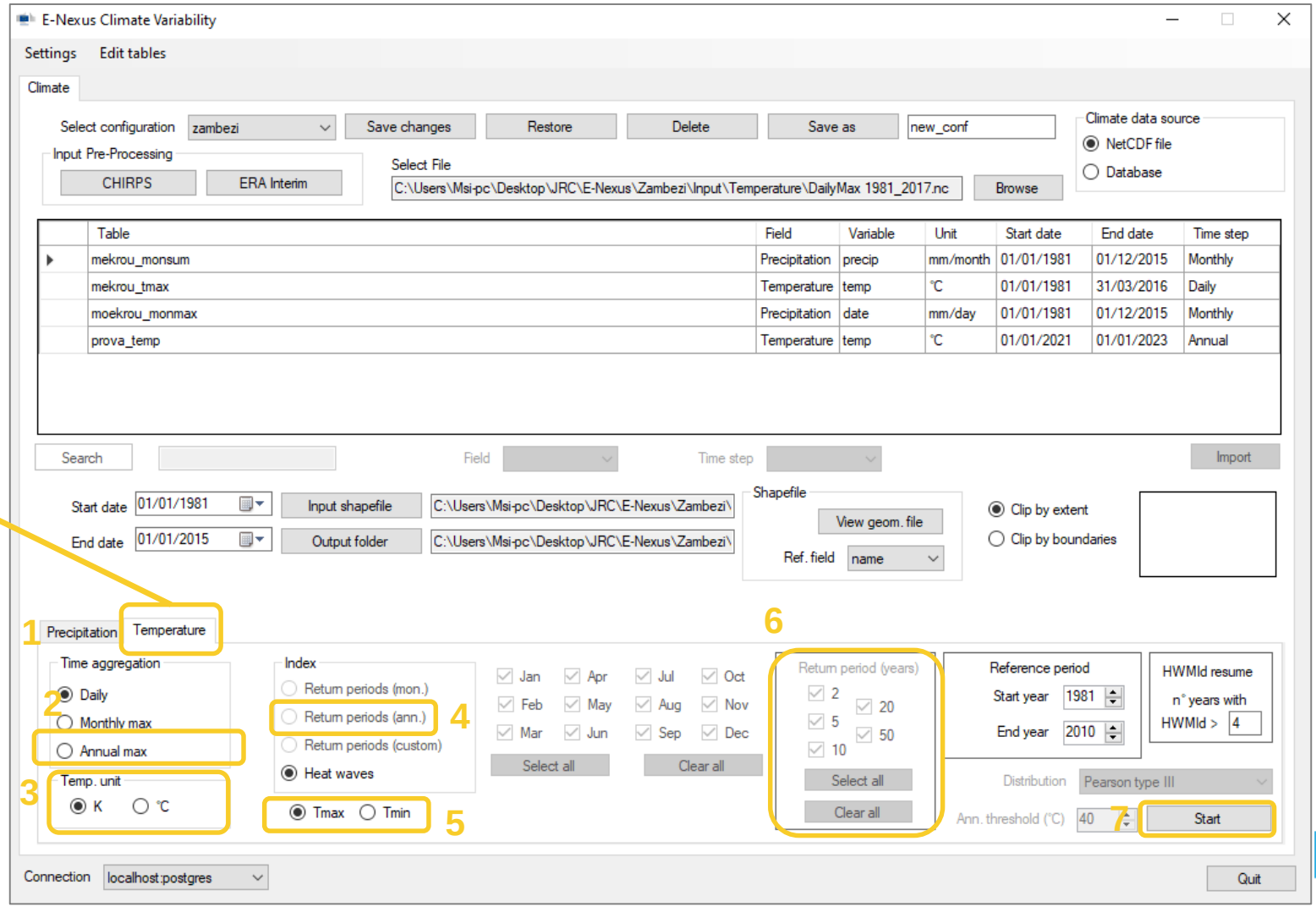
→ **Start** ←

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

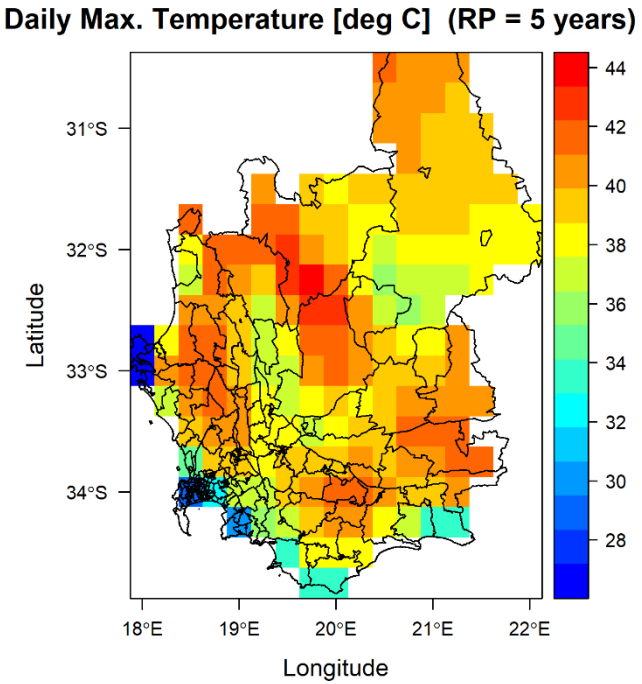


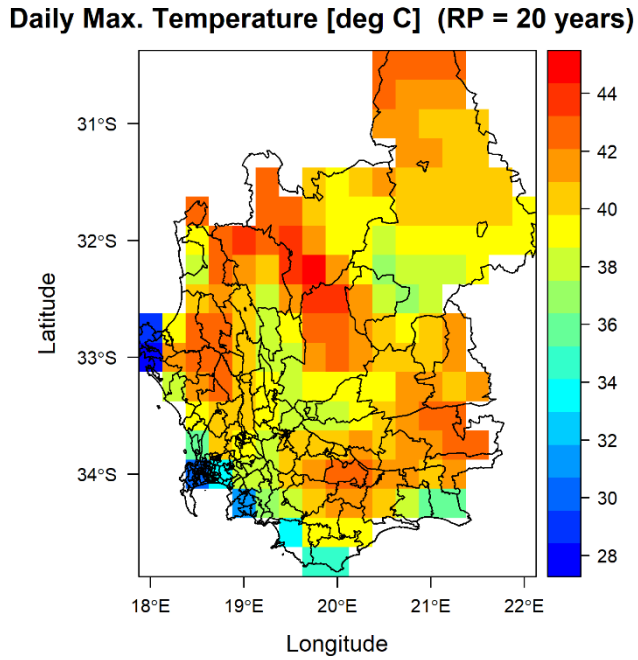
Return periods - OUTPUTS

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)





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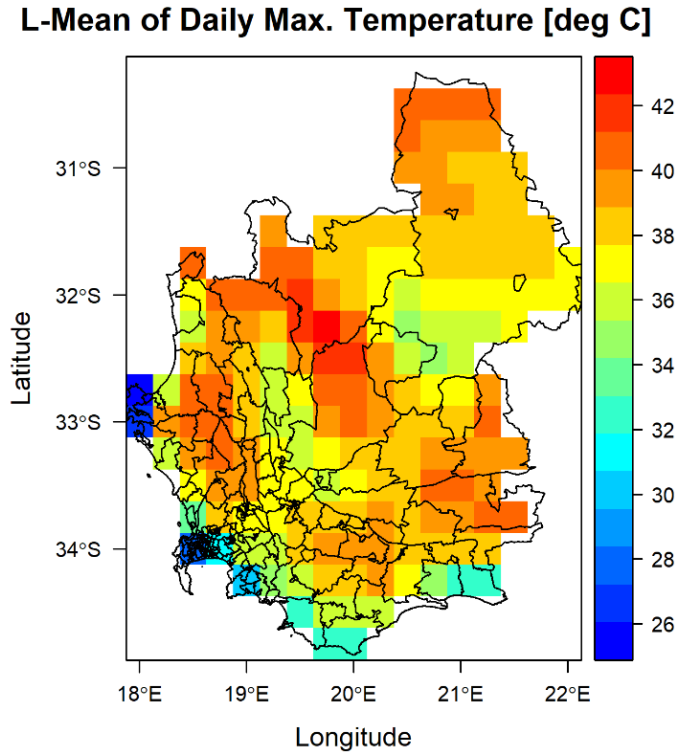
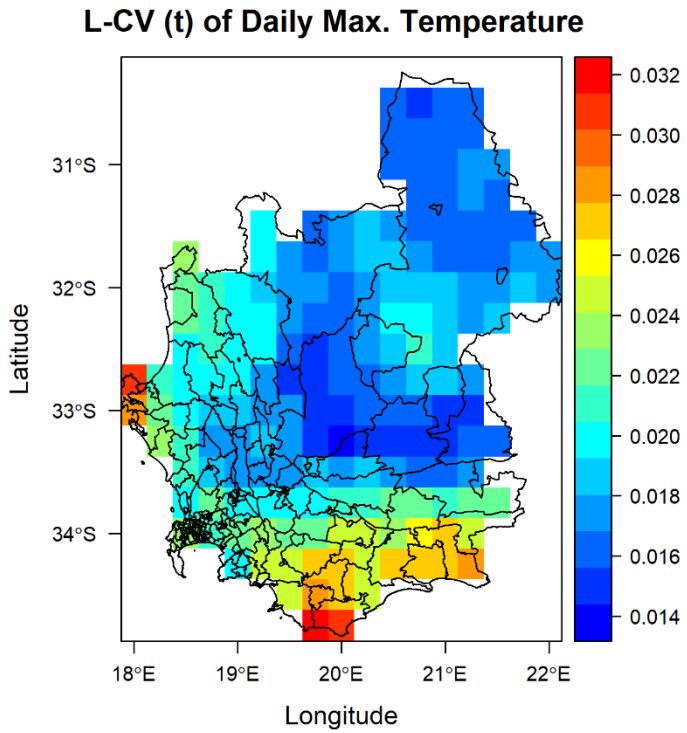
Return periods - OUTPUTS

Temperature indices





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

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Thank you

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