Using supervised machine learning and global datasets (ERA5-Land, CMIP6) to predict climate indices from monthly data

Supervisor: Marianne Bügelmayer (AIT), Herbert Formayer (BOKU)
Beratungsteam:
Marianne Bügelmayer-Blaschek
Herbert Formayer
Harald Rieder (BOKU)

Kristofer Hasel, Marianne Bügelmayer-Blaschek, Herbert Formayer
kristofer.hasel@ait.ac.at, kristofer.hasel@boku.ac.at
AIT: Giefinggasse 6, 1210 Vienna, BOKU: Gregor-Mendel-Straße 33, 1180 Vienna

Background

- Climate change indices describe the **extremes in climate** while climate itself is mainly described by its mean.
- To estimate possible **future climate states,** climate change indices **are computed from computationally intensive climate models**, which demand considerable computational resources resulting in a high energy demand.
- Climate models are complex systems needing a great amount of background knowledge while **climate change indices** are able to **display the impact of a changing climate** in an **easy to understand** way.

Energy consumption **VSC-3** under full load (596.01 TFlop/s)[1]	450 kW
Average energy consumption of a **household** in Austria in 2016[2]	0.41 kW
Energy consumption of a usual **notebook**[3]	60 W

[1] Source: Top500 Liste - https://www.top500.org/
[2] Source: Strom- und Gastagebuch – Statistik Austria, www.statistik.at
[3] Source: My notebook

Aim

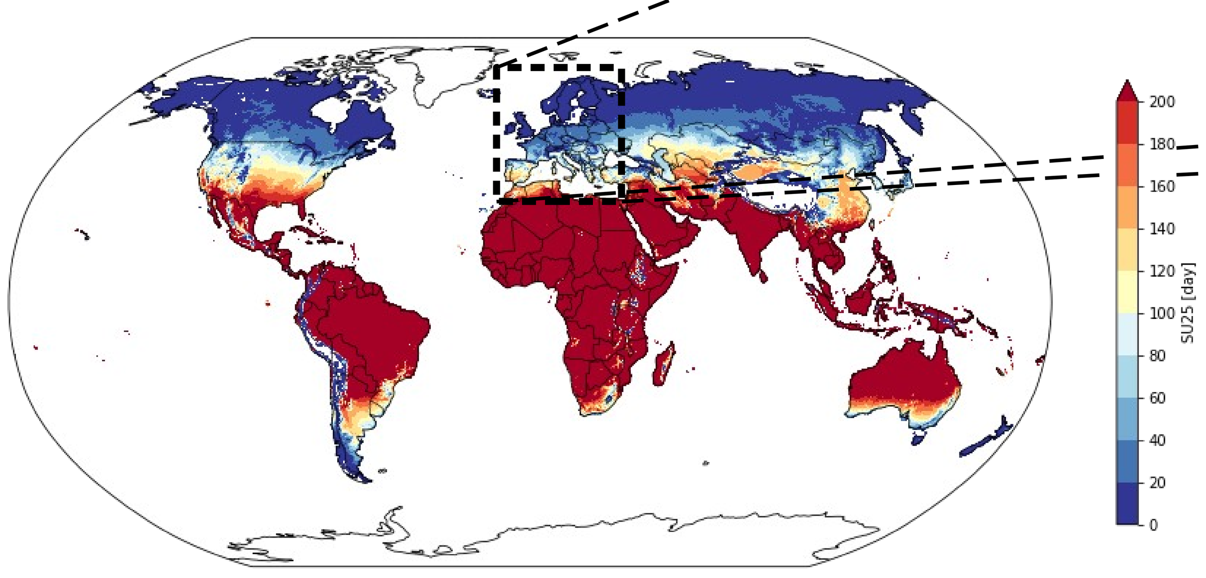
- Derive a **mathematical expression** connecting the peak over threshold climate indices with the monthly mean temperature or monthly precipitation sum.
- The mathematical expression should fullfill the following needs:
  - **Simplicity:** One should be able to use it with a calculator.
  - **Reproduction of climatologys:** For the comparison of different climate models, the index climatology should be reproduced well.
- The method therefore has the following goals:
  - **Prediction of climate change indices** based on monthly means and sums
  - **Easy and efficient comparison** of climate model ensembles

Data

- Era5-Land global reanalysis dataset with spatial resolution of 9 km and hourly data from 1981 – 2020
- SSP5-8.5 scenario from the CMIP6 global climate model MPI-M MPI-ESM1.2-50 HR with a spatial resolution of 100 km and daily data from 1981 – 2100

Methodology

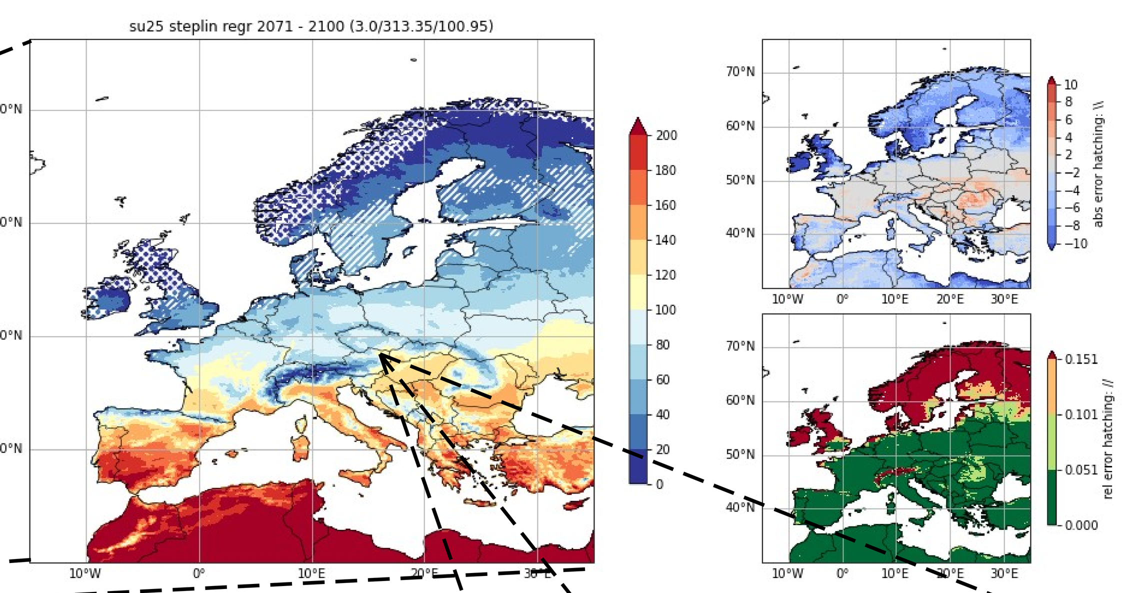
- **Calculate monthly peak over threshold indices** for the global Era5-Land dataset.
- **Add anomalys calculated from CMIP6** global climate model SSP5-8.5 pathway to cover the impacts of a possible future climate.
- **Produce regression model** for every gridpoint on the dataset for 3 different mathematical expressions:
  - Linear function: $f(x) = b_1 * x + b_2$
  - Stepwise linear function $f(x) = b_1 * x + b_2 * (x - z_i)_+ + b_3$
  - Exponential function $f(x) = b_1 * \exp(b_2 * x)$
- **Find the best fitting regression function** by R^2, RMSE, relative and absolute error in climatologys.



Climatology of summer days SU25 derived from Era5-Land for the period 1981-2020.

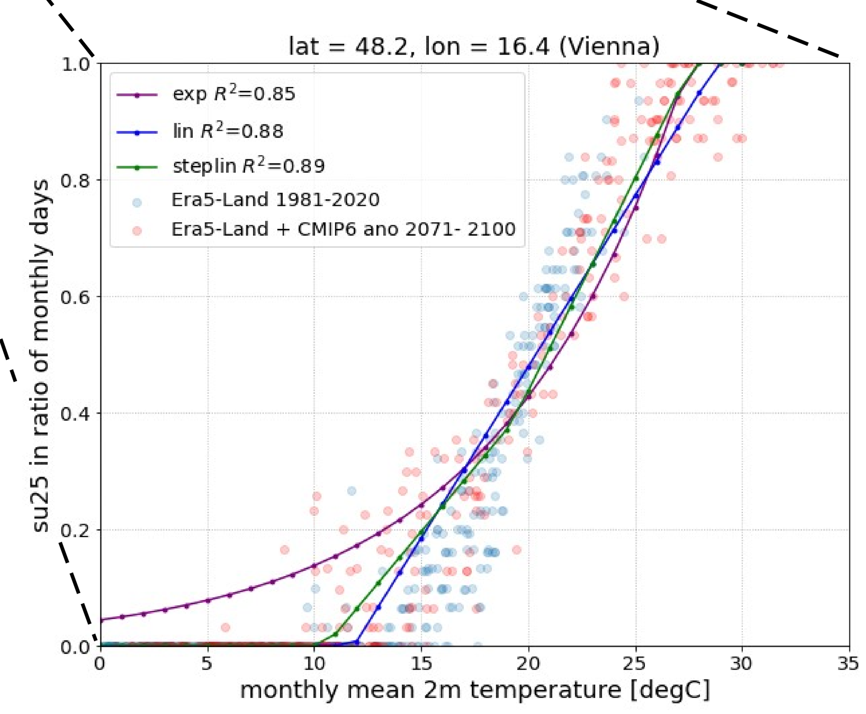
Preliminary results

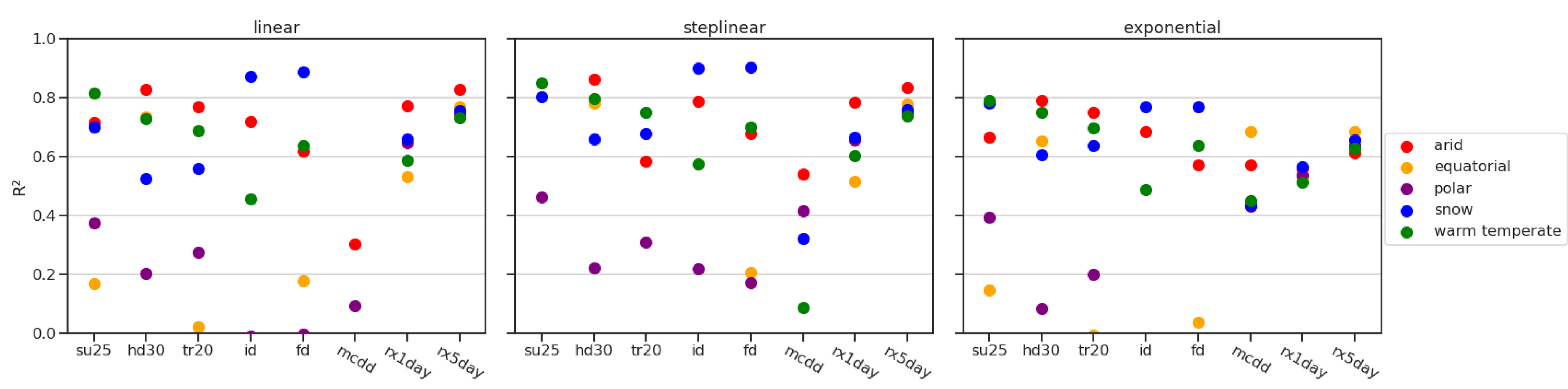
- From the three regression functions the **linear and stepwise linear function works best for temperature indices** like summer days, tropical nights, heat days, ice and frost days.
- The precipitation indices **rx1day, rx5day are reproduced well with linear regression function** while the **maximum consecutive dry days are best displayed by the exponential function**.
- The indices **climatology can be reproduced almost globally**. In areas where a index is allways present, like summer days in the tropics, the regression can not resolve the data's variance.
- Areas where the index occurs rarely, the regression has a big relative error, but usually a small absolute error.



Summer days SU25 climatology for the future ssp5-8.5 scenario from 2071 – 2100 produced by the regression model with stepwise linear function (left). Absolute error top right and relative error lower right. Areas with hatching are not performing well enough. Areas with a R^2 lower than 0.5 are hatched with 'x', Areas with an relative error greater than 0.15 are hatched with '\\' and areas with a climatology bellow 20 days and an absolute error greater than 3 are hatched with '//'.

The figure to the right presents the different regression functions for the climate index summer days SU25 in Vienna. The x axis displayes the monthly mean temperature, the y axis the index summer days SU25. The blue and orange points show the Era5-Land data and the Era5-Land data with added anomalies from the CMIP6 ssp5-8.5 model scenario. The purple, blue and green lines represent the different regression functions.





Evaluation of regression model metrics (R^2) based on the 5 basic Köppen-Geiger climate zones for the calculated climate indices.

Literature

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