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SECURES

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TU WIEN

BOKU MET Institute of Meteorology and Climatology

An European wide meteorological data set suitable for electricity modelling

supply and demand for actual climate and climate change projections

Formayer H.[1], Leidinger D.[1], Maier P.[1], Nadeem I.[1], Schöninger F.[2] Resch G.[2,3], Hasengst F.[2], Suna D.[3], Pardo Garcia N.[3], Totschnig G.[3]

[1]BOKU Vienna – Institute of Meteorology and Climatology
[2]TU Wien – Energy Economics Group (EEG)
[3]AIT – Center for Energy

IEWT 2023

An European wide meteorological data set
for electricity modelling

Motivation

- Europe faces great challanges regarding its energy system
- The energy system should be climate neutral by 2050
- Climate change could increase demands and threats to of the energy system (e.g. dark doldrums, cooling requirements, ...)
- The energy system is very complex and interlinked, thus models are required to understand the status quo and predict the future
- Many types of green energy production rely on the current or long-term weather
- A comprehensive but handleable meteorological data set for the past, present, and future is required as input to energy system models

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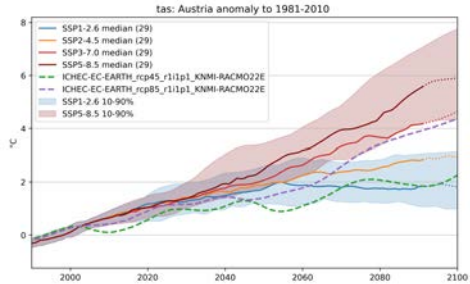
General specifications

input

- ERA5 and ERA5 Land
  $\rightarrow$ merged to one data set
- COSMO REA6 Reanalysis
  (150 m windspeed)
- 2 EURO-CORDEX climate scenarios:
  ICHEC-EC-EARTH - KNMI-RACCMO22E
  (RCP4.5, RCP8.5)
- eHYPE river discharge for ERA5 and scenarios
- Total $>$ 4TB input data



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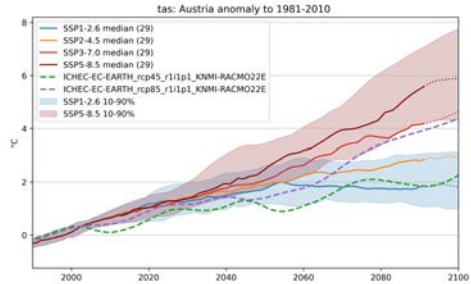

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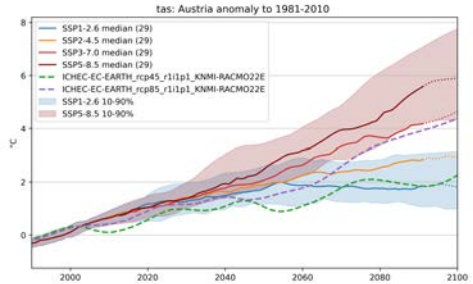

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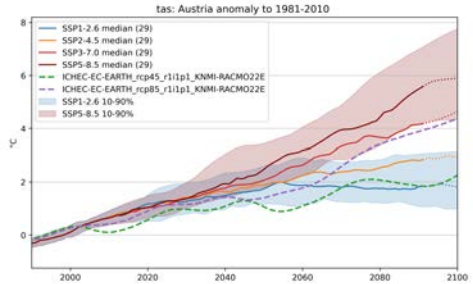

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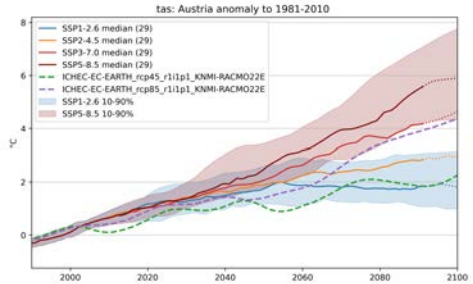

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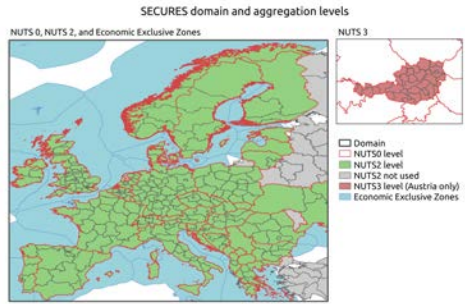

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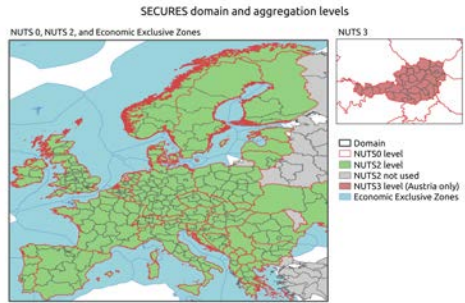

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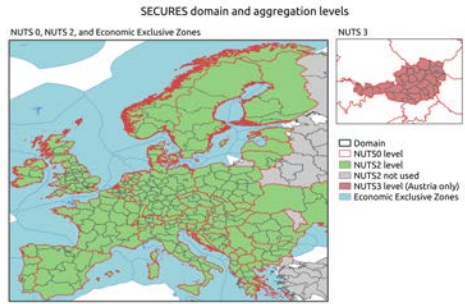

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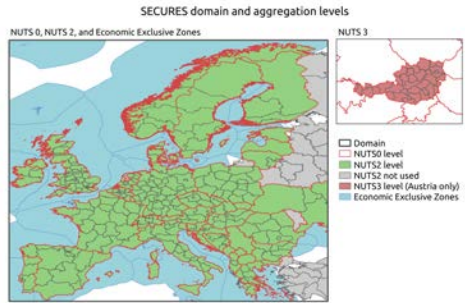

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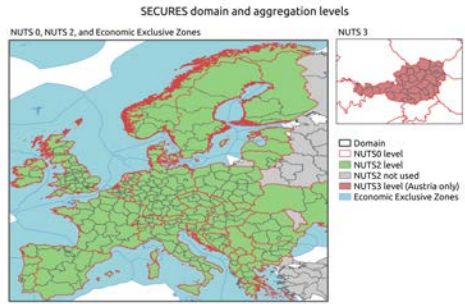

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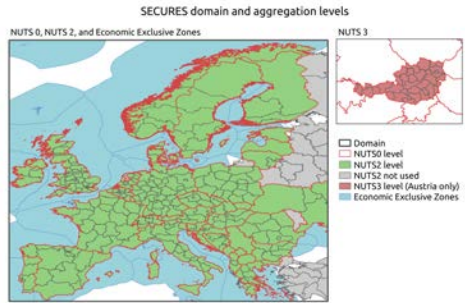

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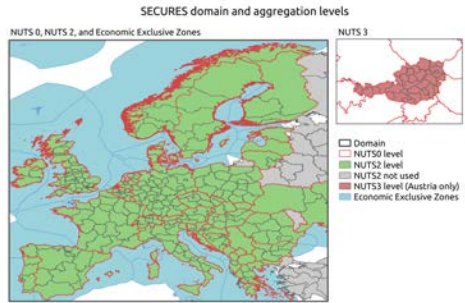


Processing CORDEX data

Workflow

Regrid to ERA5L

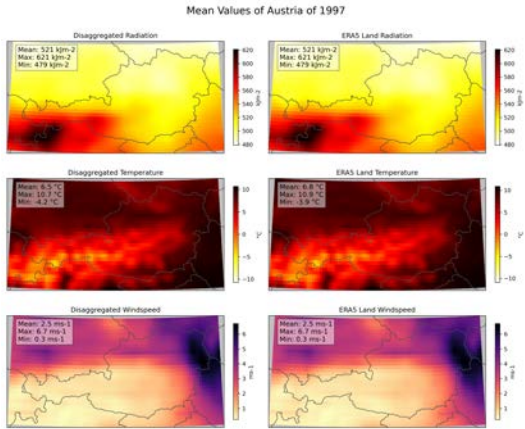
- Provide data on same grid
- CORDEX Data is projected curvilinear
- ERA5L is on Plate Carree (lat-lon)

Bias correction

- Get rid of inherent model biases
- Make data compareable

Temporal disaggregation

- Structure is preserved
- Daily temperature follows two cosine functions
- Surface wind is calculated via fractions of the historical ERA5L data
  Hourly wind divided by daily mean
- Solar radiation also uses statistics of historical ERA5L data



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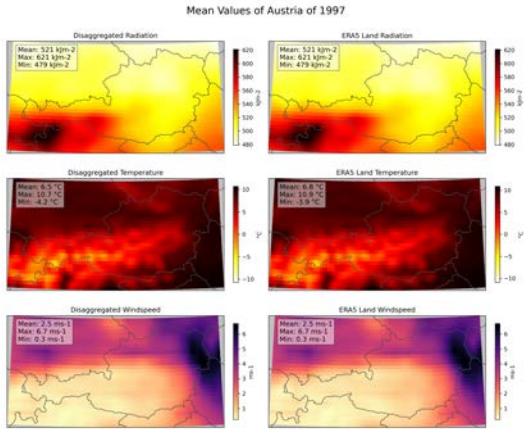

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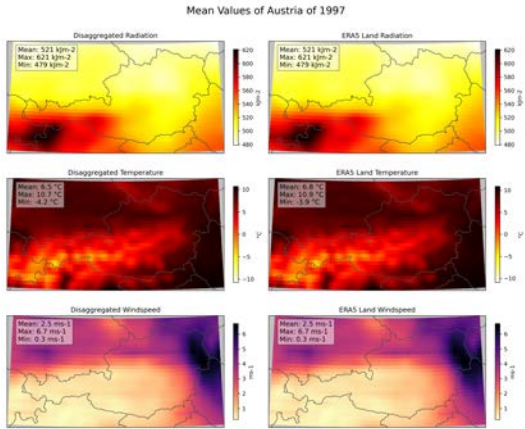
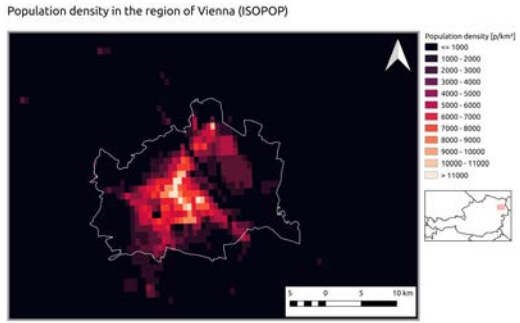


Population weighting
Temperature and radiation

motivation and methods

- electricity demands increase with population density
- solar panels are more likely on roofs
- people tend to live in the valleys, where the temperatures are higher
- thus temperature and radiation were additionally weighted with population
- temperature was regridded using an elevation correction to the 1 km ISOPOP raster before aggregating



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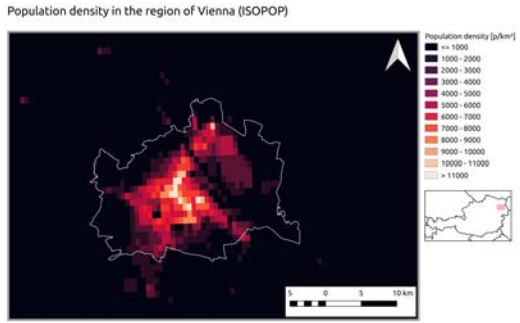

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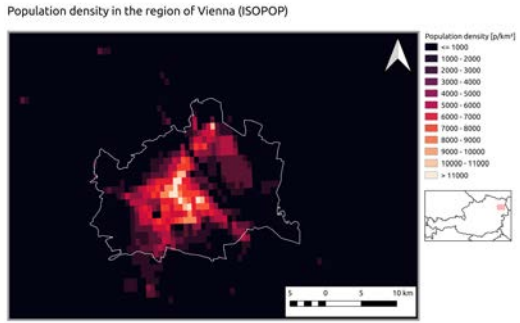

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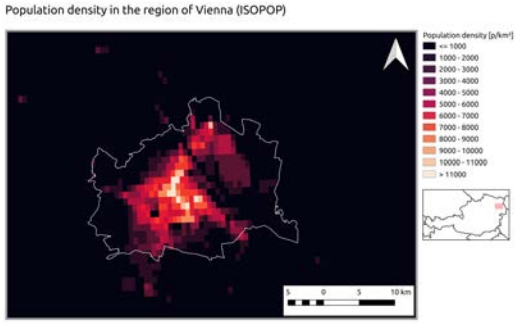

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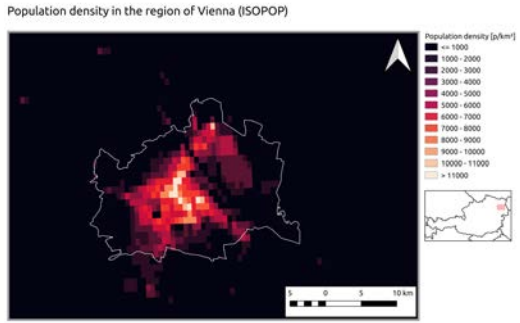
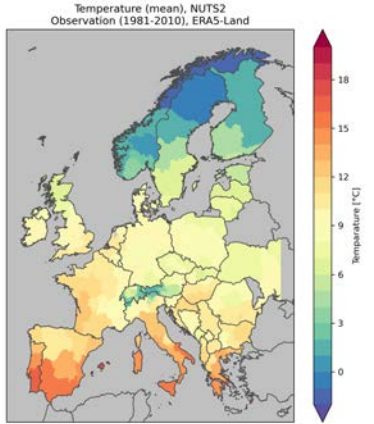
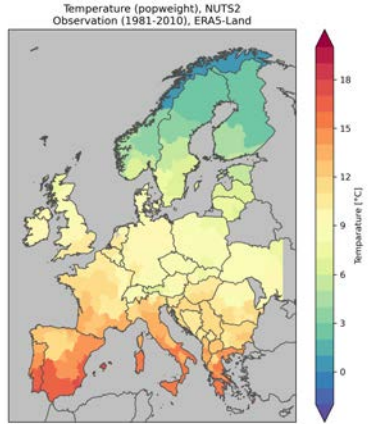


Population weighting

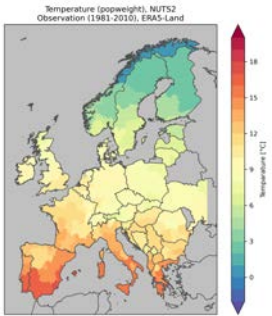
arithmetic mean vs. population weighting

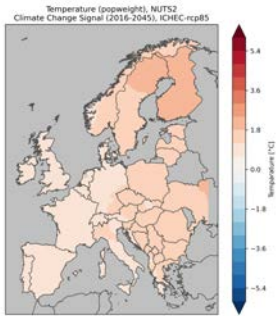


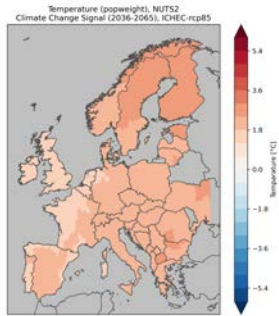


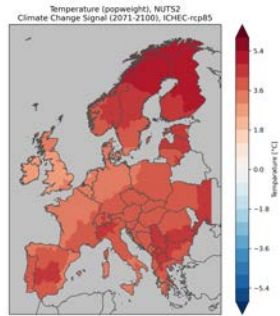
Temperature

RCP 8.5 - population weighted









Global radiation

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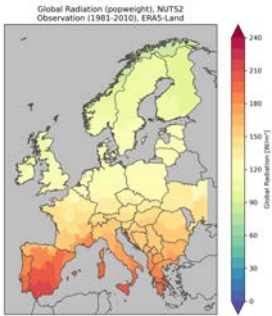
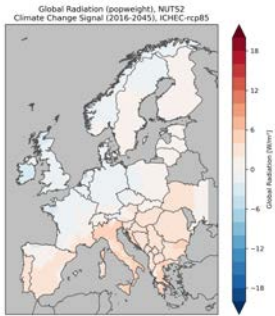
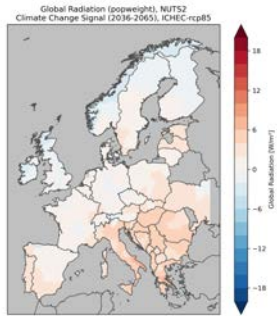
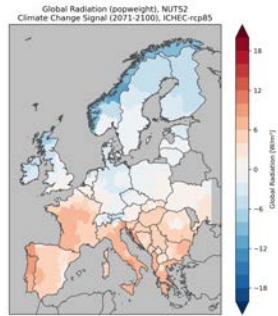


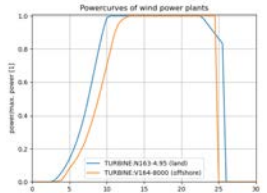


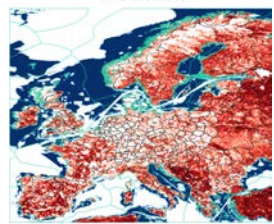




Wind power
methods

- COSMO REA6 was regridded to the target grid (ERA5-Land)
- ERA5(Land) and EURO-Cordex surface wind was adjusted with QM to match the 150 m wind from COSMO REA6
- for onshore and offshore representative turbine types were choosen
- the normalized power was calculated by applying the power curves
- weights for aggegating are the fraction of suitable area for wind power plants





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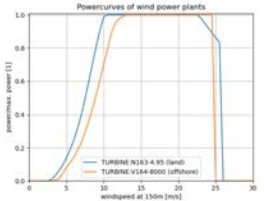

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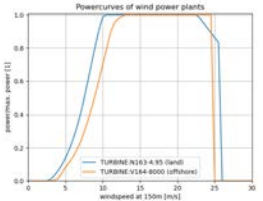

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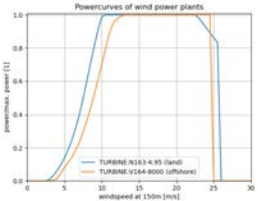
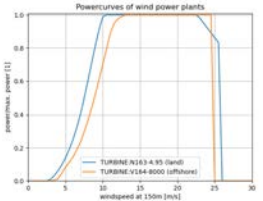


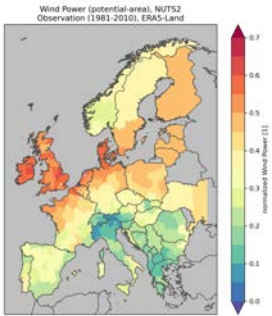
Wind power
methods

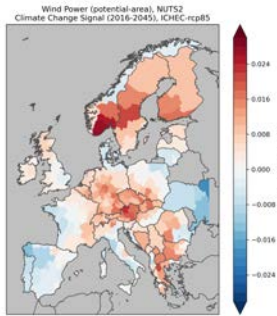
- COSMO REA6 was regridded to the target grid (ERA5-Land)
- ERA5(Land) and EURO-Cordex surface wind was adjusted with QM to match the 150 m wind from COSMO REA6
- for onshore and offshore representative turbine types were choosen
- the normalized power was calculated by applying the power curves
- weights for aggegating are the fraction of suitable area for wind power plants

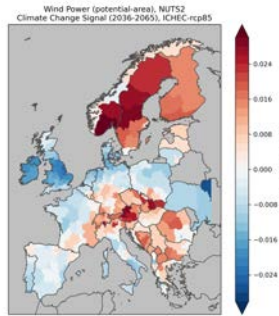


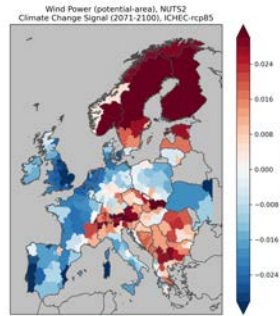
Wind power onshore

RCP 8.5 - potential area



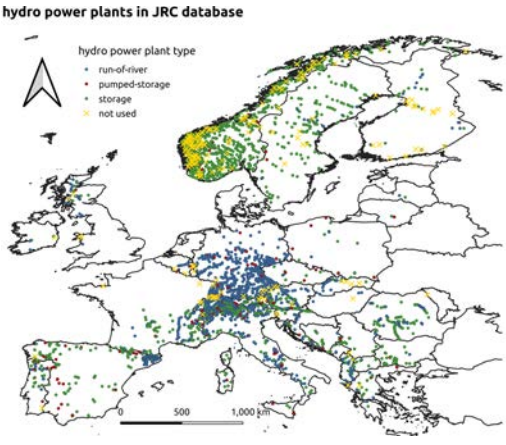






Hydro power
methods

- hydro power plant data: JRC data base
- river discharge data (Q): SMHI eHYPE (ERA5 and ICHEC-RACMO22E driven)
- assumption: $P = s_0 Q$
- however hydro plants have got limited capacity P_{max} and cut-off runoff $Q_{max=}Q(P_{max})$ is unknown
- Q_{max} can be estimated in an iterative process
- if annual production is unknown, representative full load hours for each country are assumed



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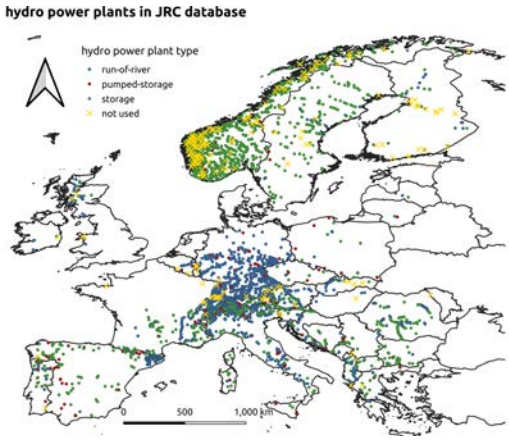

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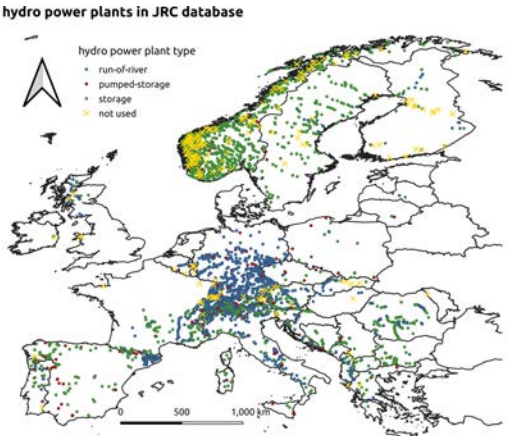

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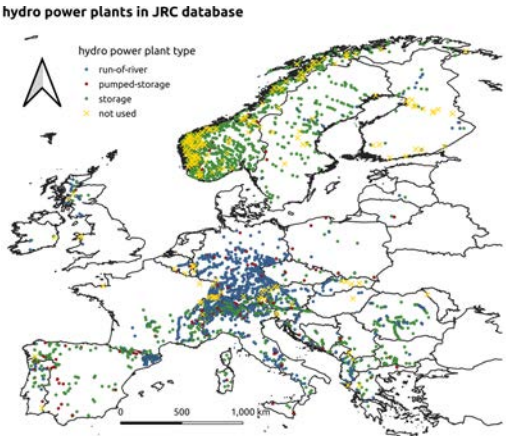

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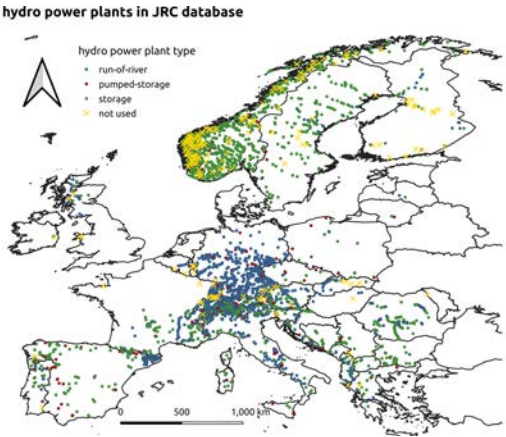

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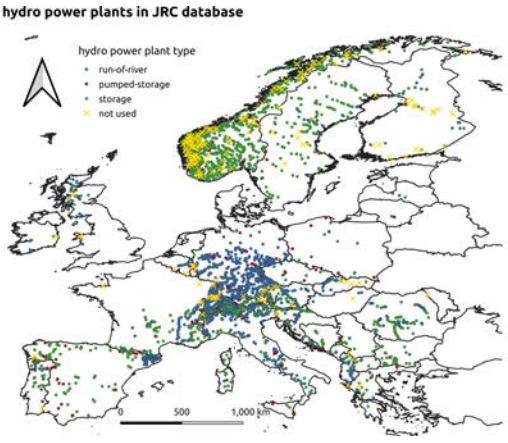
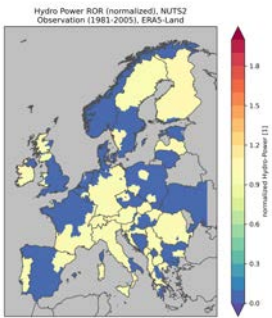
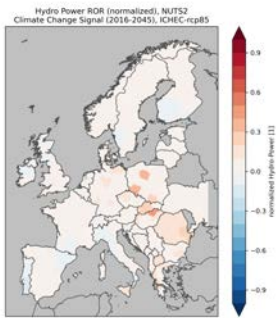
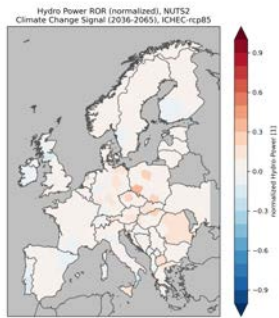


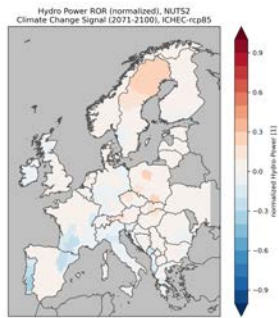
Hydro power from run-of-river plants

RCP 8.5 - normalized



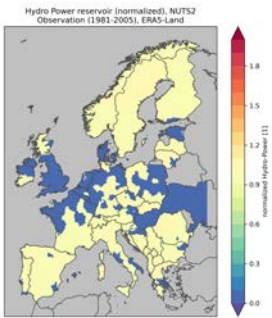


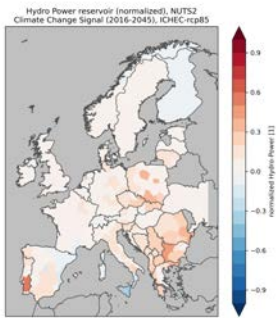


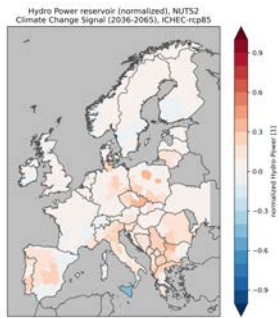


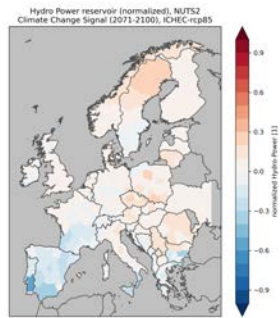
Hydro power from reservoirs

RCP 8.5 - normalized





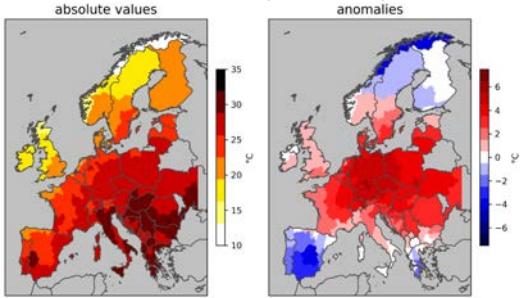




Extreme heat

Maximum temperature

Monthly mean maximum temperature
June 2039 (RCP 8.5)

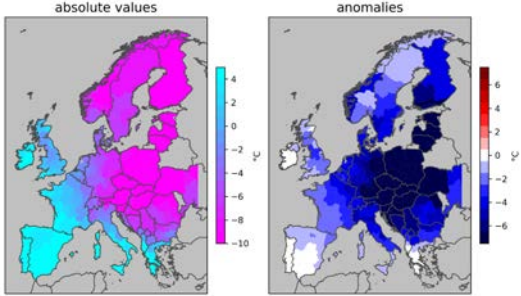


Anomalies	Austria	Europe
T [℃]	5.3	4.0
Tmax [℃]	6.3	4.4
Tmin [℃]	4.0	3.4
WP [%]	56.3	95.5
WP offshore [%]	-	92.1
Radiation [%]	120.1	110.6
HP [%]	58.2	107.5

Dark doldrum (extreme cold)

Minimum temperature

Monthly mean minimum temperature
December 2047 (RCP 8.5)



Anomalies	Austria	Europe
T [℃]	-5.1	-3.3
Tmax [℃]	-5.0	-3.6
Tmin [℃]	-5.5	-2.9
WP [%]	117.1	90.0
WP offshore [%]	-	94.3
Radiation [%]	98.3	93.7
HP [%]	78.8	142.7

Conclusions

- For modelling the energy system of Europe long-term, high quality climate data for the past and future is required
- We created a comprehensive data set specifically designed for this purpose
- Variables include temperature, radiation, wind power, and hydro power and cover 1981 - 2100
- the data was aggregated to NUTS3 (Austria only), NUTS2, NUTS0 and EEZ
- 4 TB of input data were used to create 1 PB of intermediate data and condensed to 45 GB of final data
- The data will be made available to the community in 2023

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Thank you!
Any questions?

Herbert Formayer

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Department of Water, Atmosphere and Environment (WAU)
Institute of Meteorology and Climatology

✉ herbert.formayer@boku.ac.at
☎ +43/1/47654-81415

Image: https://pixabay.com/