Exploring the Adverse Weather Scenarios for Future Electricity Systems dataset

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CIREN MEETING

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Contents

1) Dataset details & structure
2) Visualising a single event
3) Polish wind farms
4) Data analysis of multiple events

The Dataset

- Contains gridded meteorological data associated with challenging periods of weather (adverse events)
- Focused on highly-renewable UK and European electricity systems of the future
- A collaboration project between the Met Office, the National Infrastructure Commission and the Climate Change Committee

Dawkins, L.; Rushby, I.; Pearce, M.; Wallace, E.; Butcher, T. (2021): Adverse Weather Scenarios for Future Electricity Systems. NERC EDS Centre for Environmental Data Analysis

Dataset Structure

- Long Duration (year-long “extreme” events) or Short Duration (week-long wind ramping events)
- Daily time series, 60 x 60 km spatial resolution, EU & UK
- Weather Variables: **100m Wind Speed, Surface Temperature, Net Surface Solar Radiation**
- Wind-drought-peak-demand events (Summer or Winter) or Summer surplus generation events
- Extremity levels: return period 1 in 2, 5, 10, 20, 50, 100 years *(or most extreme events)*
- Duration / Severity *(classified by)*
- Global Warming Level: 1.2 , 1.5, 2, 3, 4 ^{o}C above pre-Industrial
- Multiple events *(usually between 1-3 .nc files)*

*Red options were not used for this specific project

myClasses.py

- Event (event type, location, extremity, duration/severity, global warming level, event no)
- WeatherVariable (name, units, colour map)
  - View snapshot
  - View animation
  - Plot time series
  - Plot histogram
- WindTurbine (specs)

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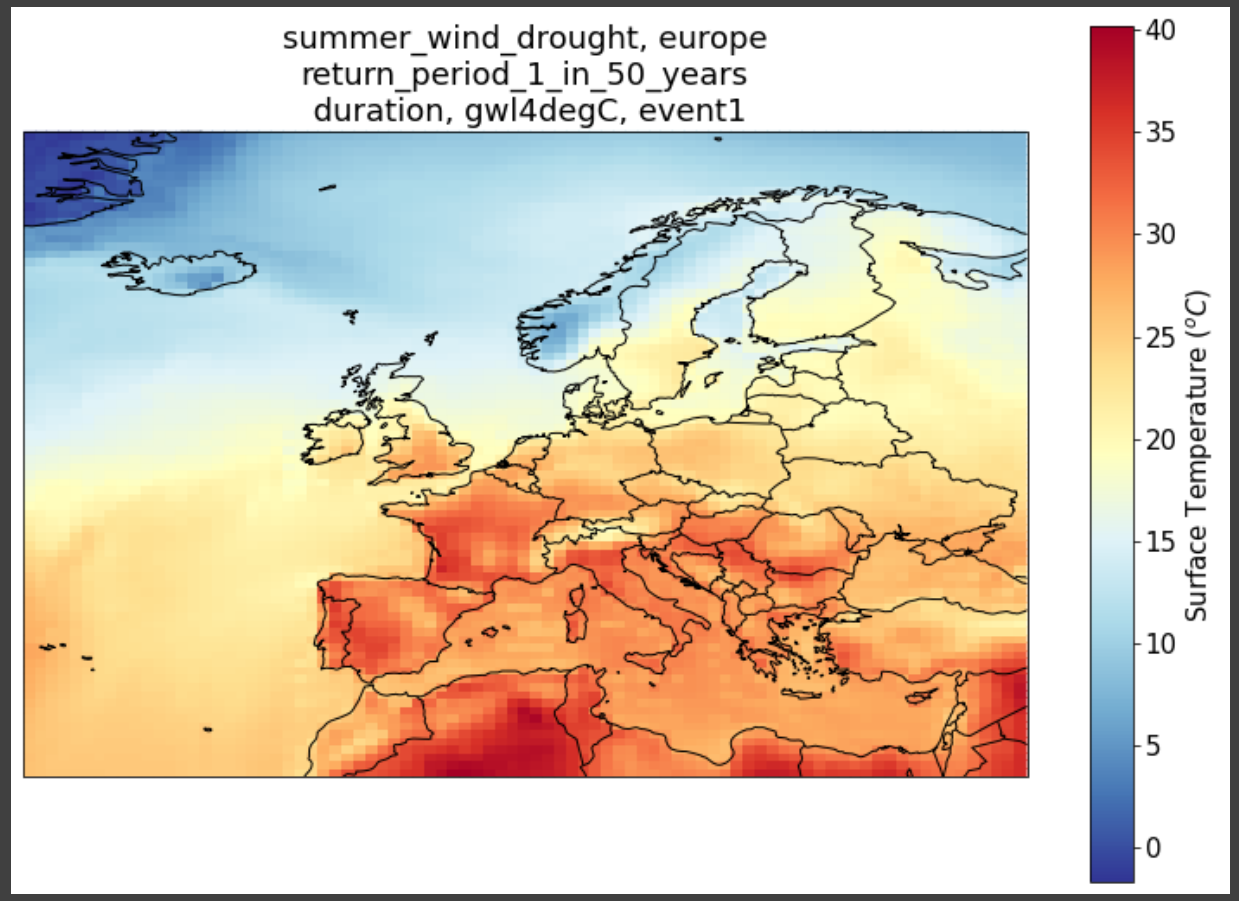
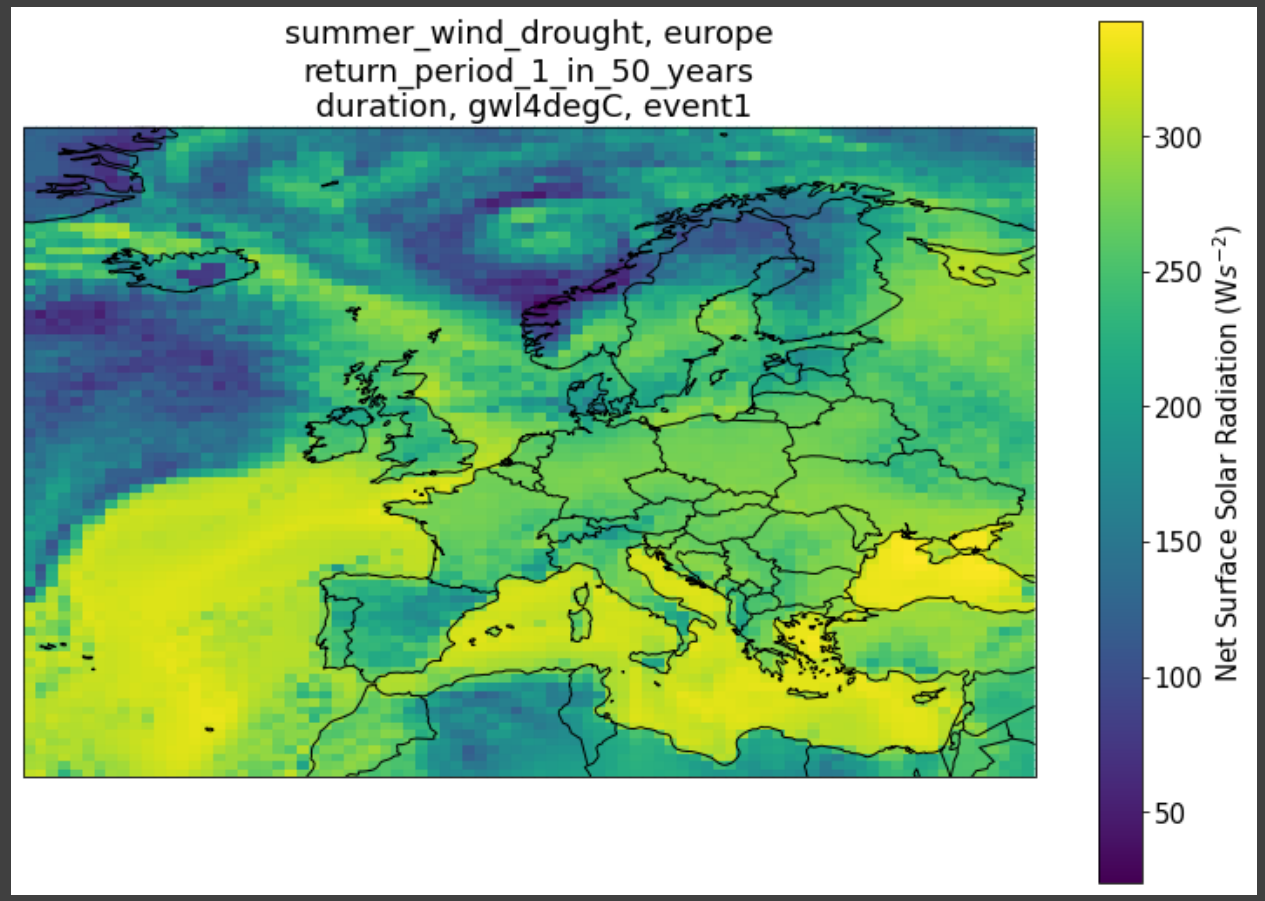
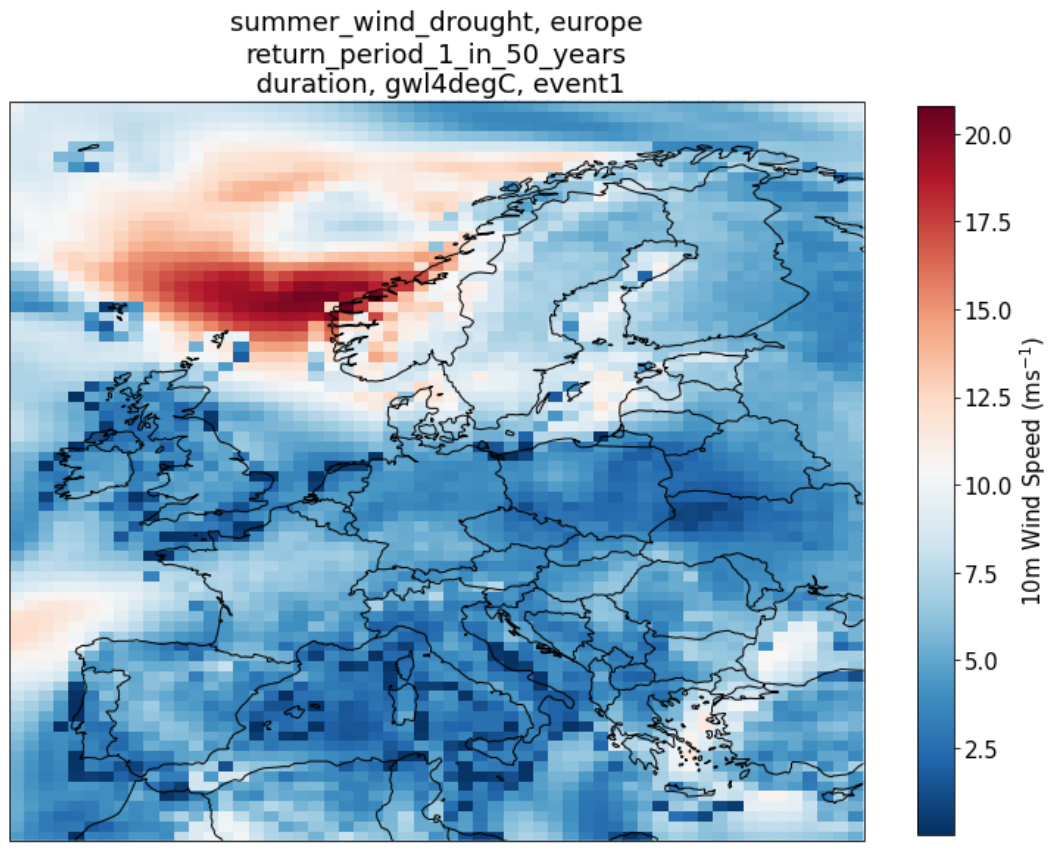
Visualise a Single Event

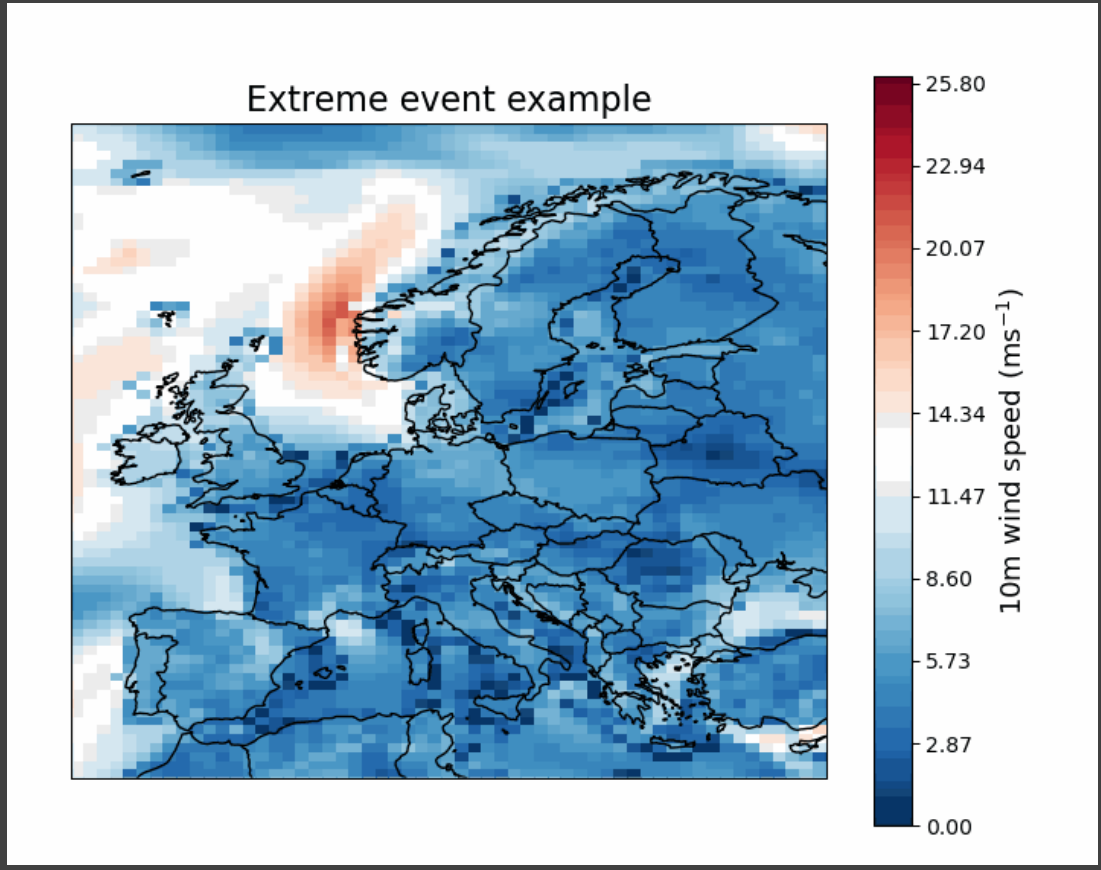
Snapshots on a Day (Europe map)





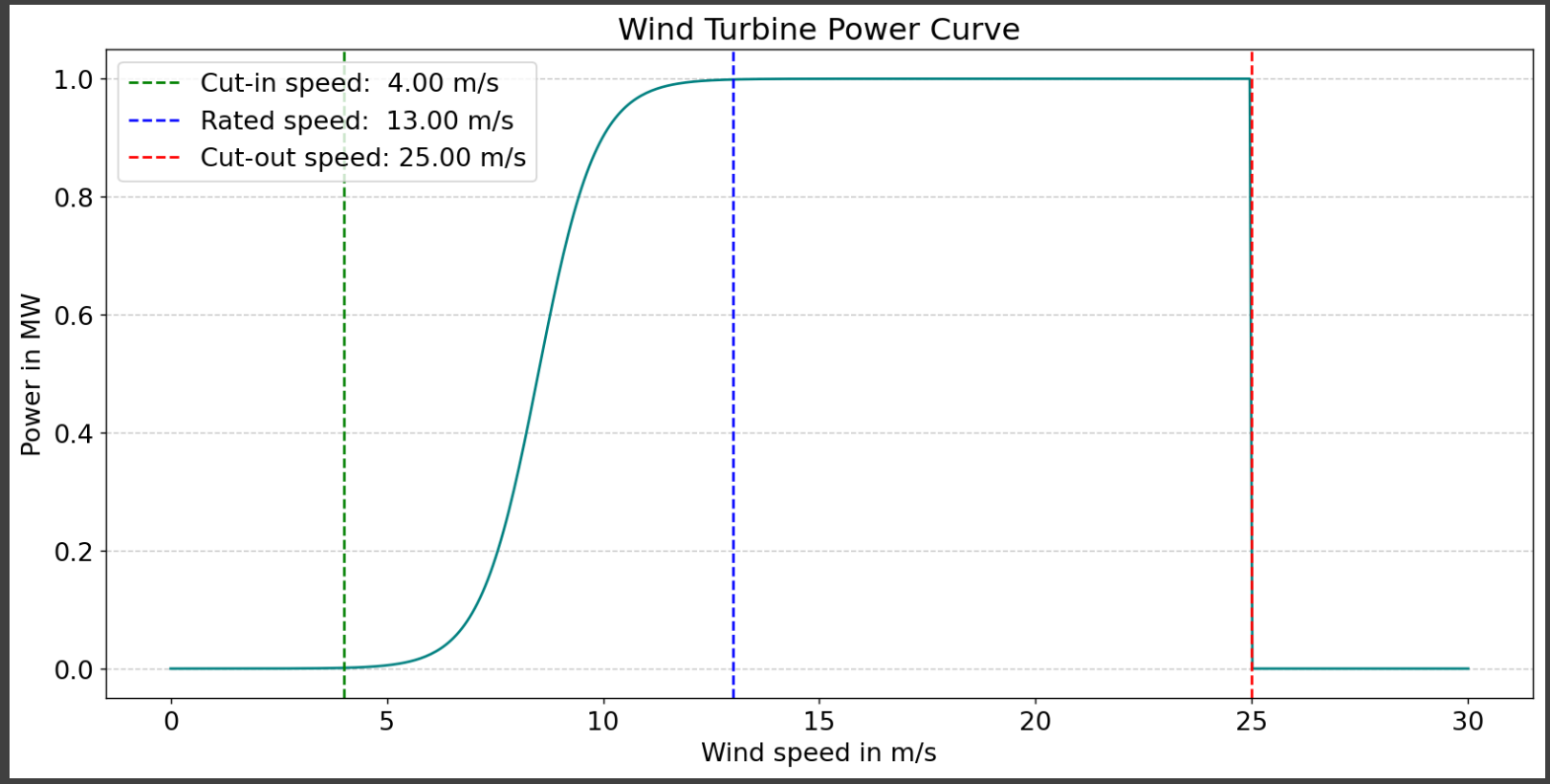
Animation (over the year)



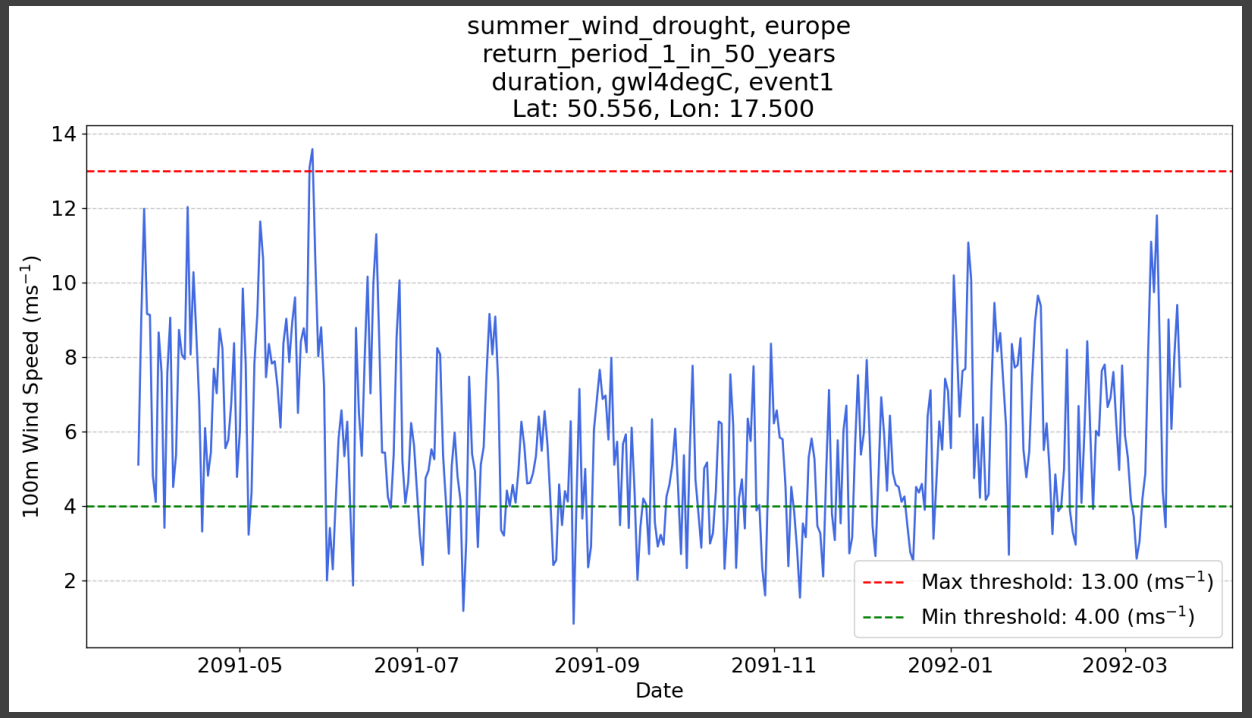


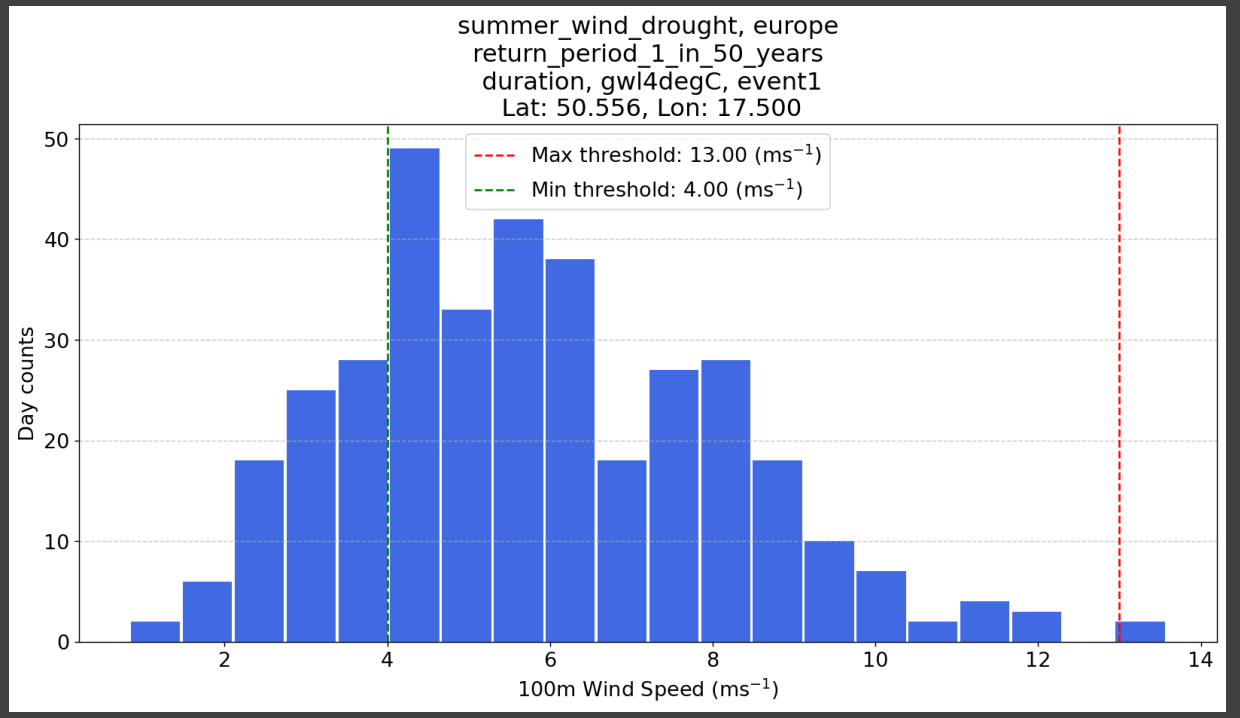
Wind Turbine class

- Specs of the wind turbine are given as arguments when creating an instance of this class:
  - Cut-in speed in m/s *(e.g. 4)*
  - Cut-out speed in m/s *(e.g. 25)*
  - Rated output speed in m/s *(e.g. 13)*
  - Rated output power in W *(e.g. 1 MW)*
- Power curve is modelled as a rescaled sigmoid / logistic function

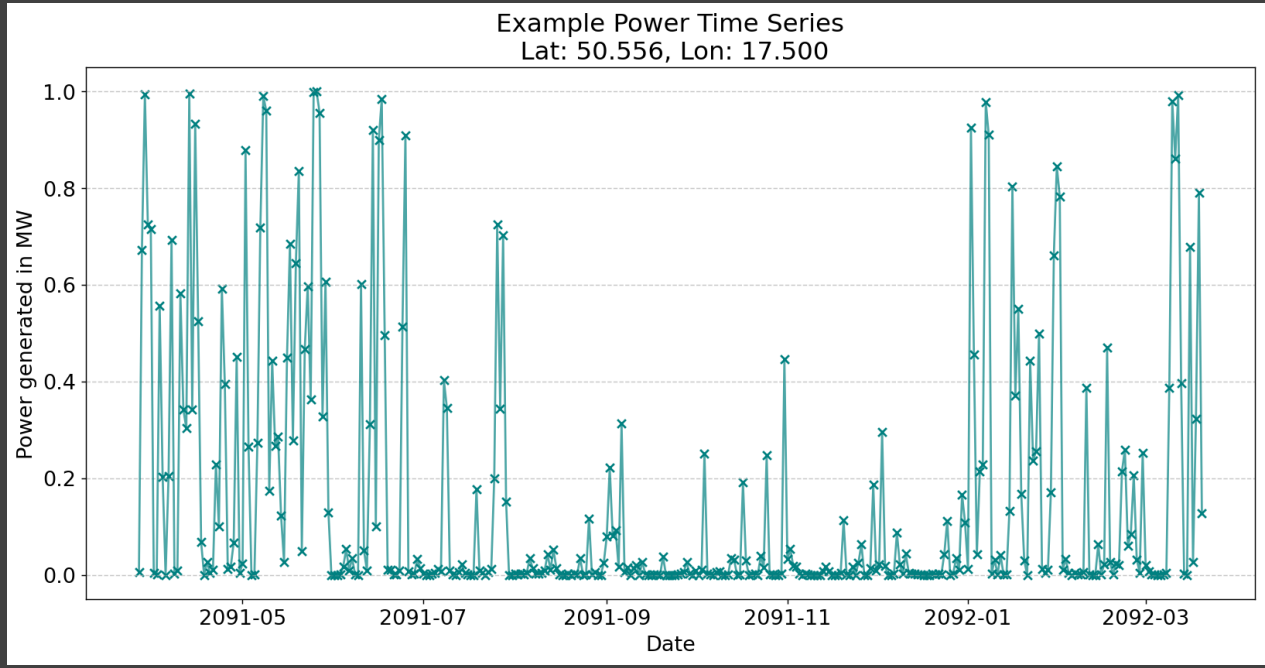


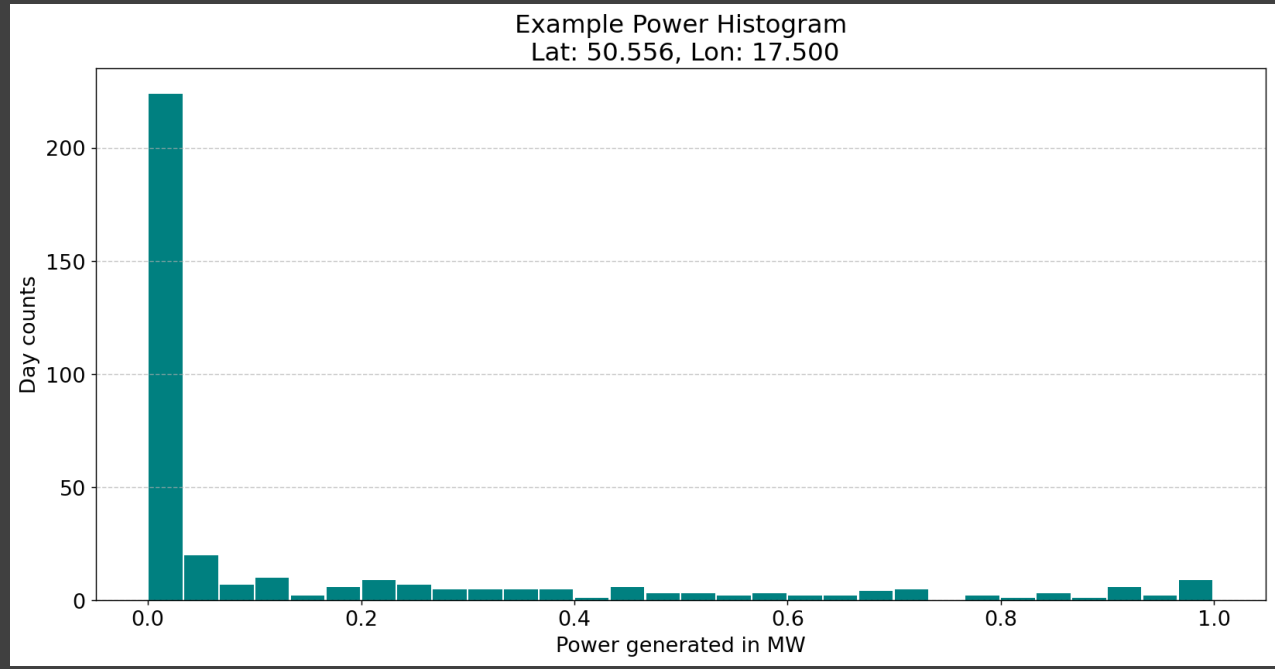
Wind Data (at a Polish wind farm)





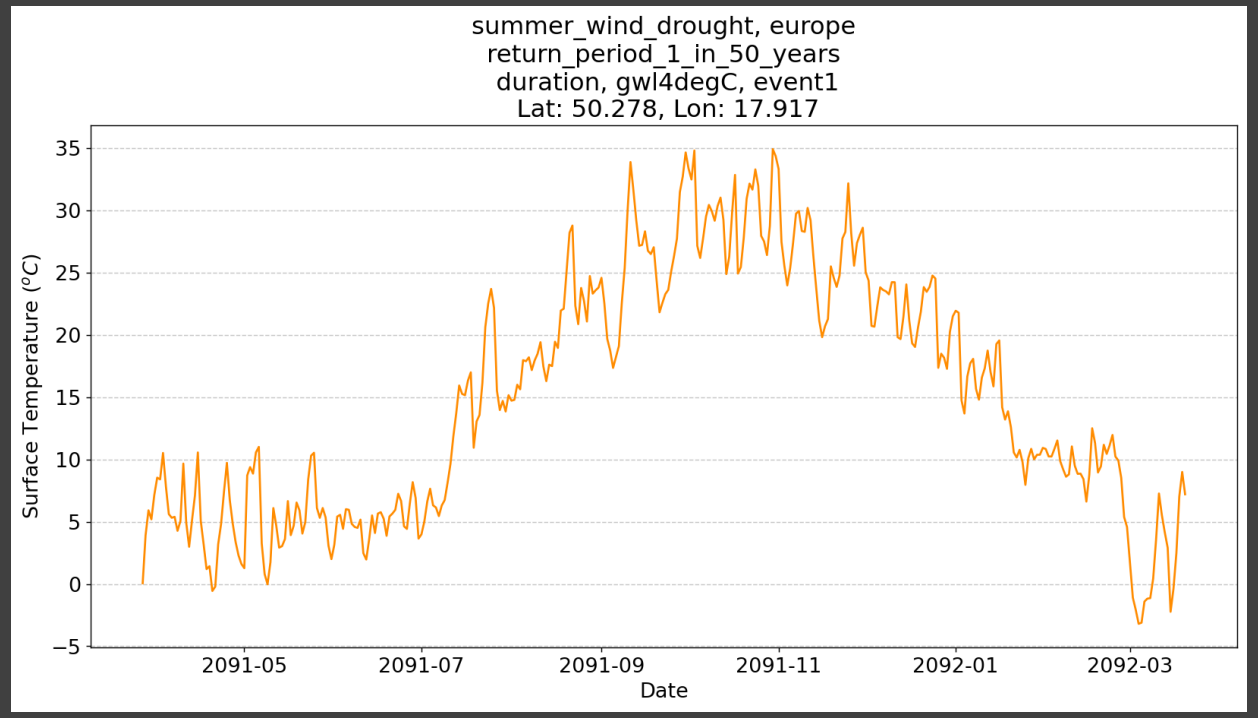
Converted to Power Output

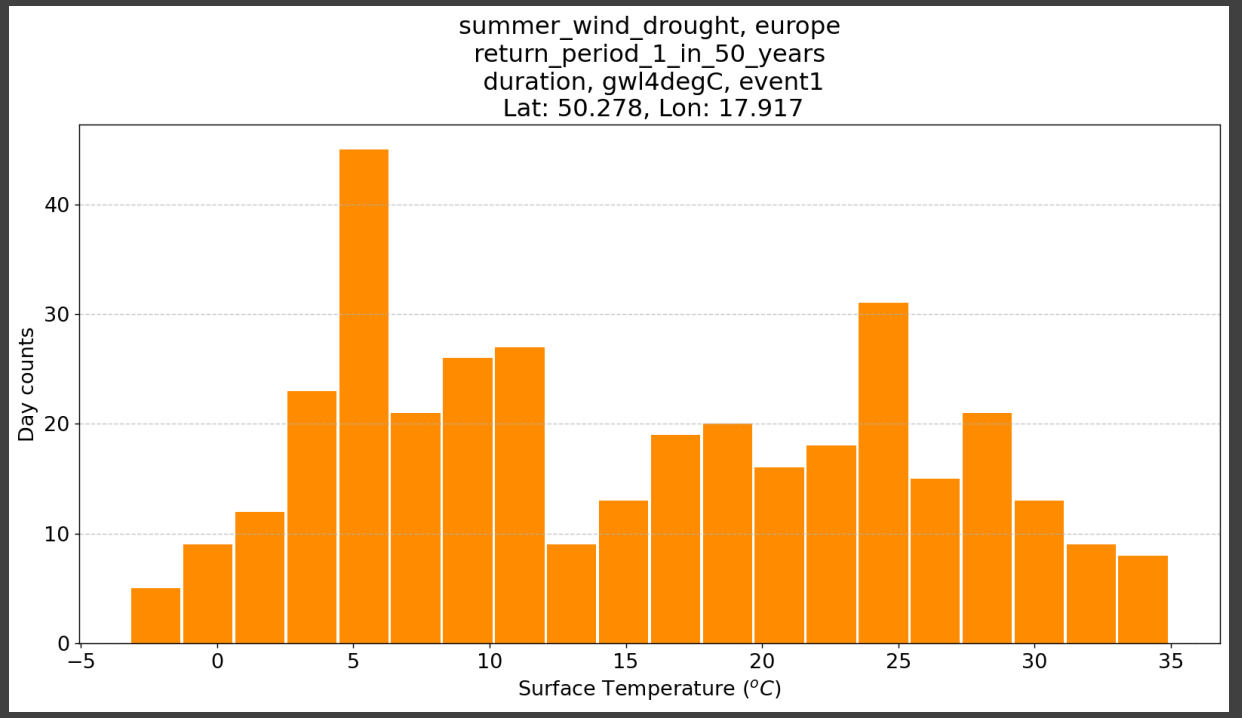




- Anything close to min threshold (green line) is converted to min power output (~ 0 W ; **most days of the year!)**
- Anything close to max threshold (red line) is converted to max power output (~ 1 MW for 1 turbine)

Surface Temperature Data





Polish Wind Farms

Cumulative wind capacity in Poland

Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2019	2020	2021	2022
Installed capacity (MW)[7][8][9]	0	27	63	63	83	153	276	544	725	1,180	1,616	2,497	3,390	3,834 [10]	5,100[11]	5,782[11]	5,917[12]	6,294[6]	7,306[6]	8,256[6]
Generation (GWh)[13]					132	234	506	796	1,051	1,843	2,745	4,435	5,822	7,184 [14]	10,858[11]	11,623[11]	14,685[1]	15,800[15]		
% of electricity production					0.1%	0.2%	0.3%	0.6%	0.8%	1.3%	1.8%	2.74%	3.53%	4.59%[14]	*6.6%[16]	7.1%[17]	9.8%[1]	10.0%[15]		

*Provisional estimate

- According to this data, Polish wind farms produced around 63 MW in 2004 (year of MATPOWER network*)
- Total power capacity of the network *(case2736sp)* is 18.4 GW – wind % was negligible at the time
- But since we are focused on future highly-renewable power systems, we will **assume** around 11% of that is wind (~ 2 GW)

*case2736sp : Power flow data for Polish system - summer 2004 peak

Data Analysis of Multiple Events

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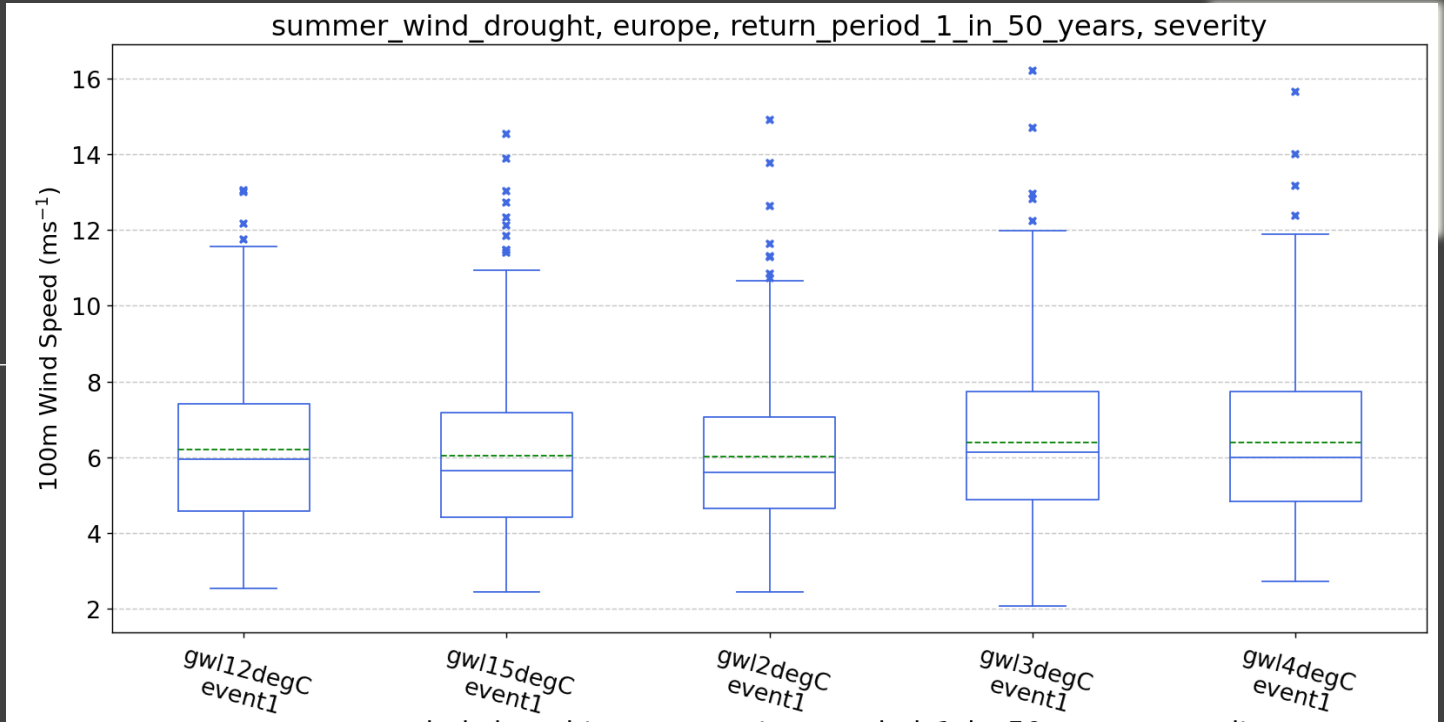
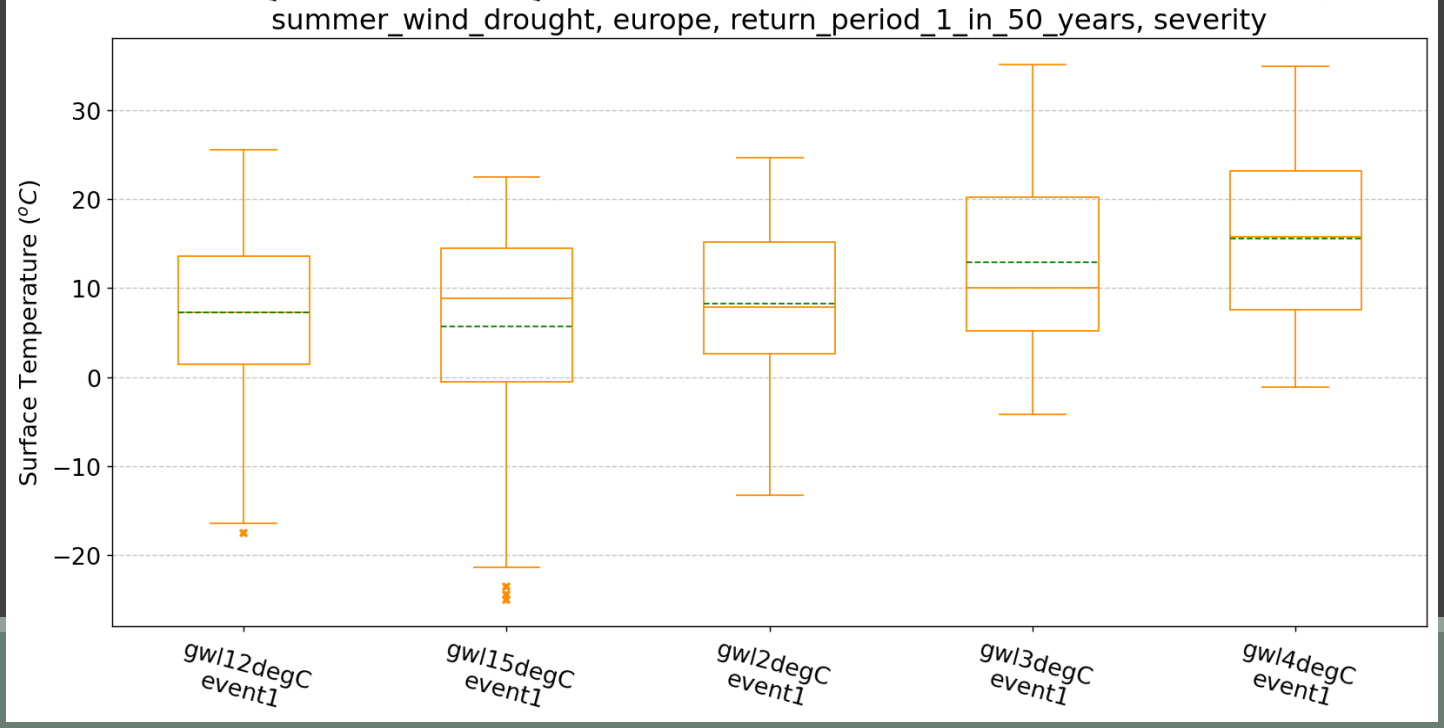
Box Plots

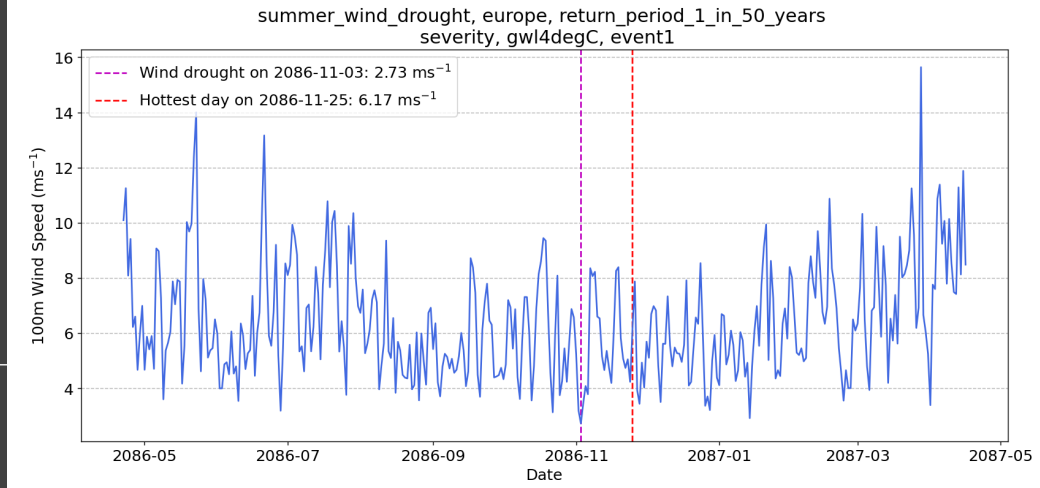
- Box Plots are a nice way to summarise sets of data:
  - Minimum, 1st quartile, median, 3rd quartile and maximum
  - Outliers → crosses , Mean → green dashed line
- Averaged over all Polish wind farms, to highlight the effect over Poland
- As expected, mean temperatures (& their extremities) increase as global warming levels rise
- It is also observed that wind speeds become increasingly extreme as global warming levels rise

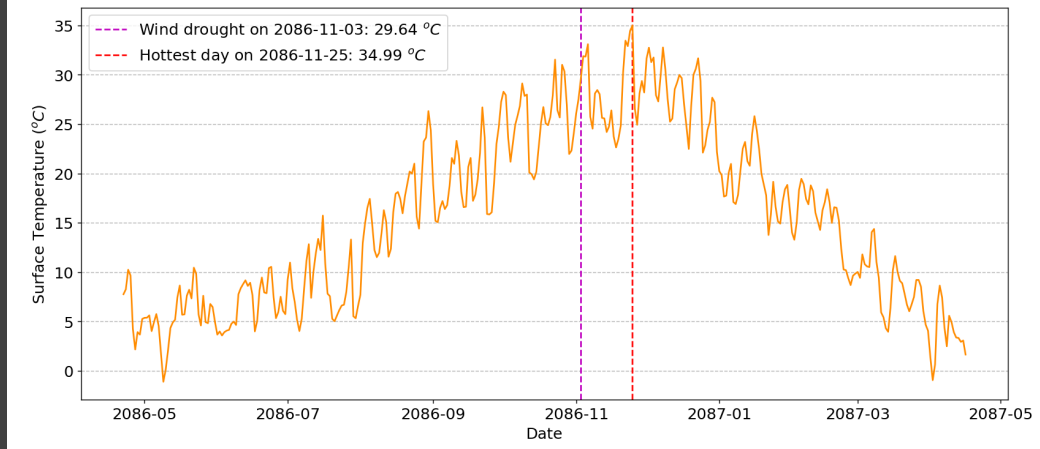


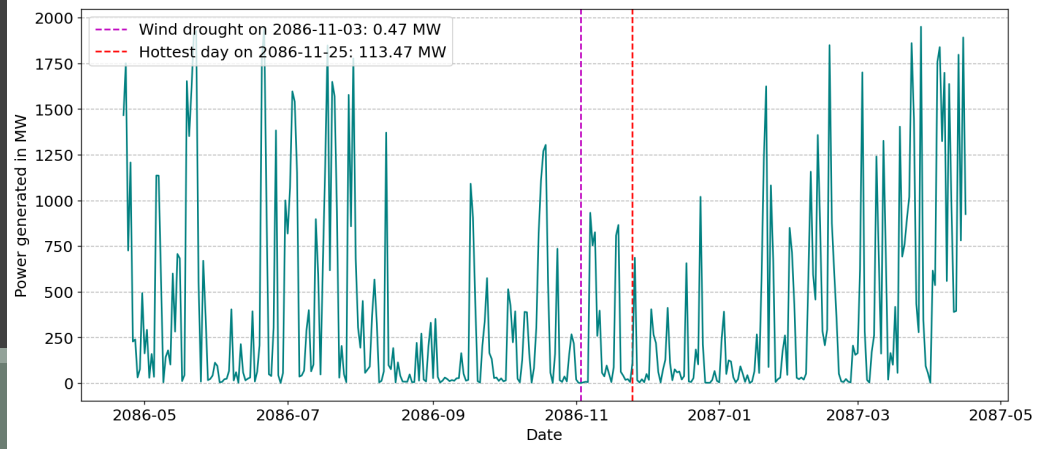


Wind Drought - Peak Demand

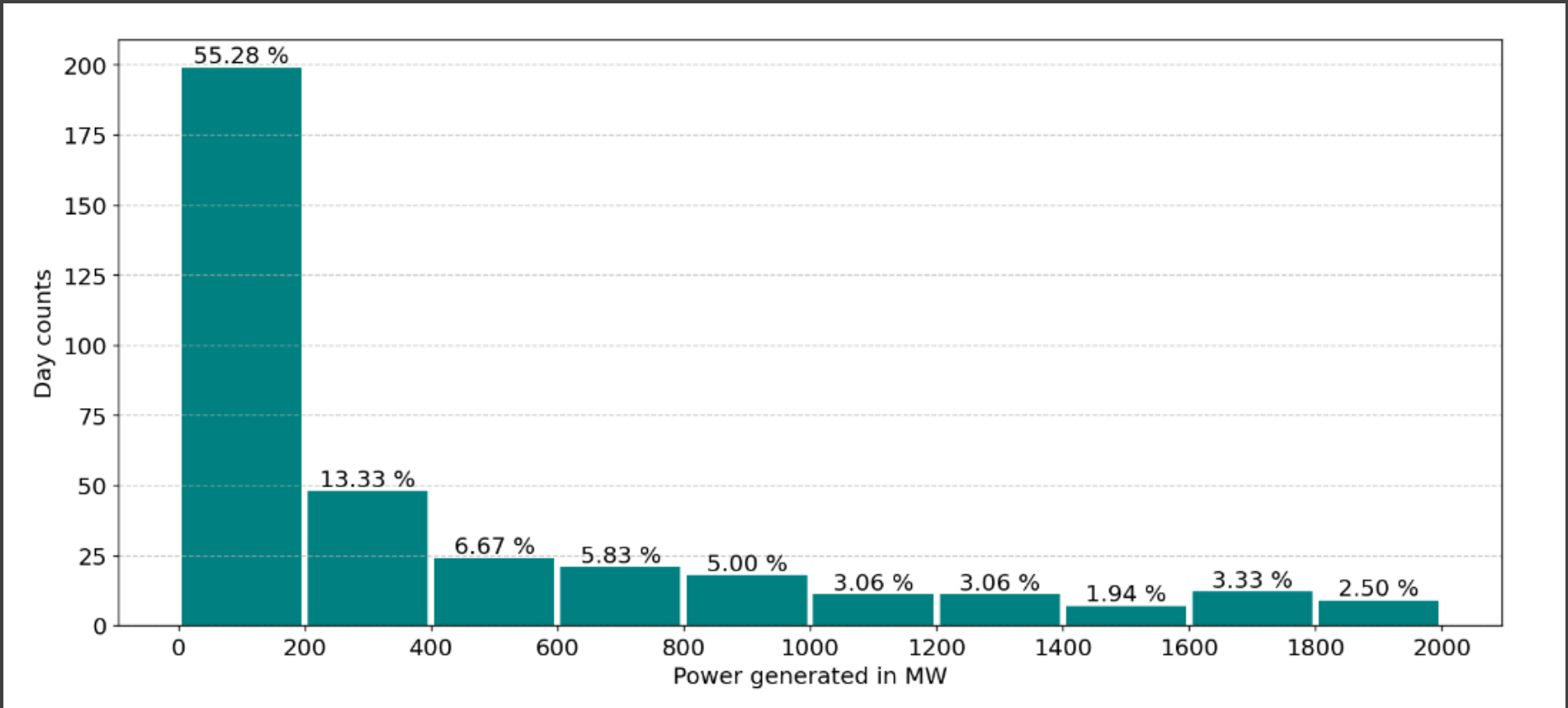
- Data averaged over all Polish wind farms
- Indicates the worst wind drought & hottest day
- In both cases, the power produced **over all farms** is close to 0 (remember the whole network is 18.4 GW …)
- Trigger a cascade under these circumstances (using AC-CFM model)
- Network is under immense stress (due to hotter days = high demand) & no wind-power production, so cascades will be worse







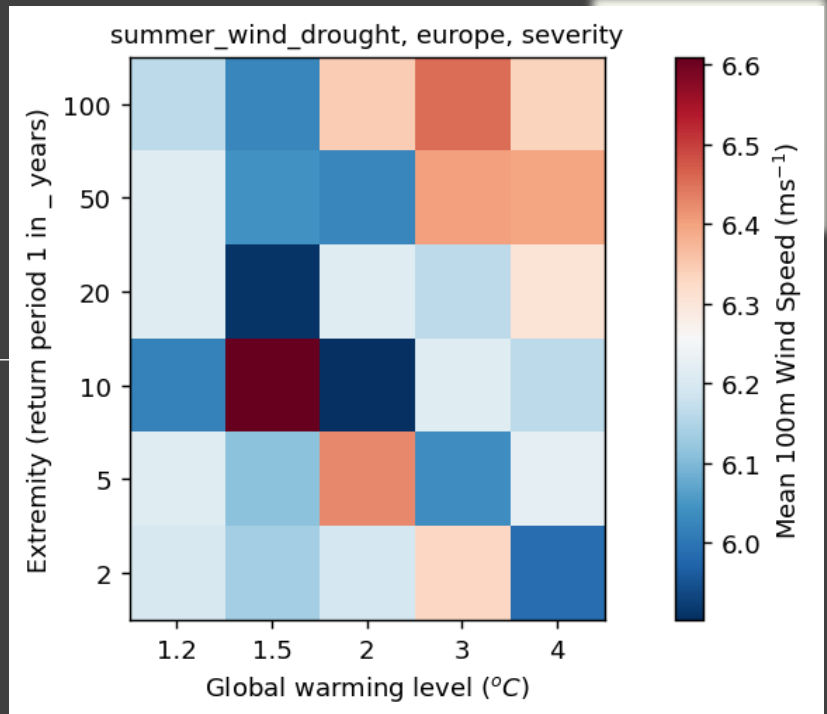
Power Histogram Sampling

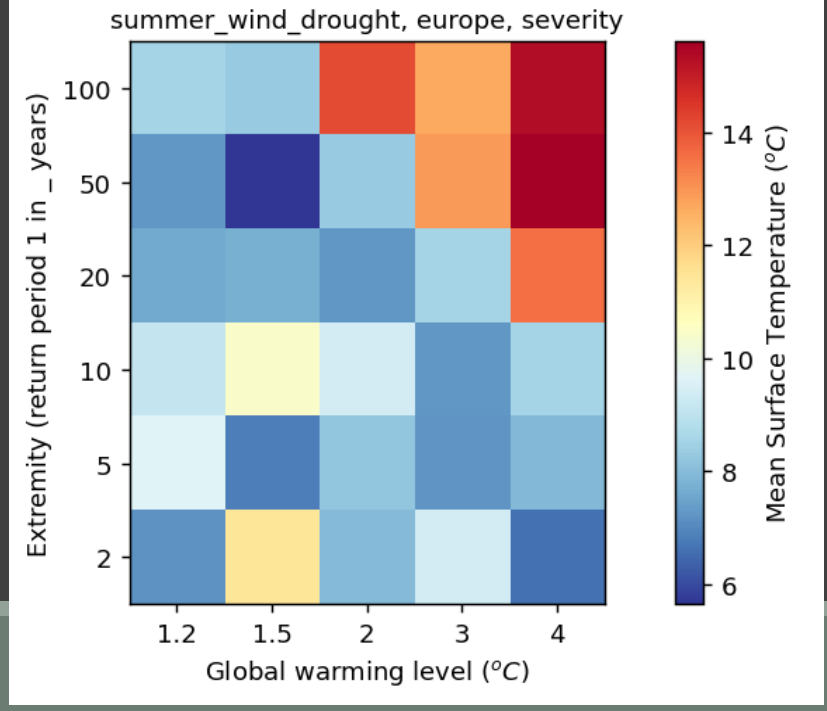


- Quantifies the probability of being in different power-generation scenarios in the Polish network

Bulk Analysis

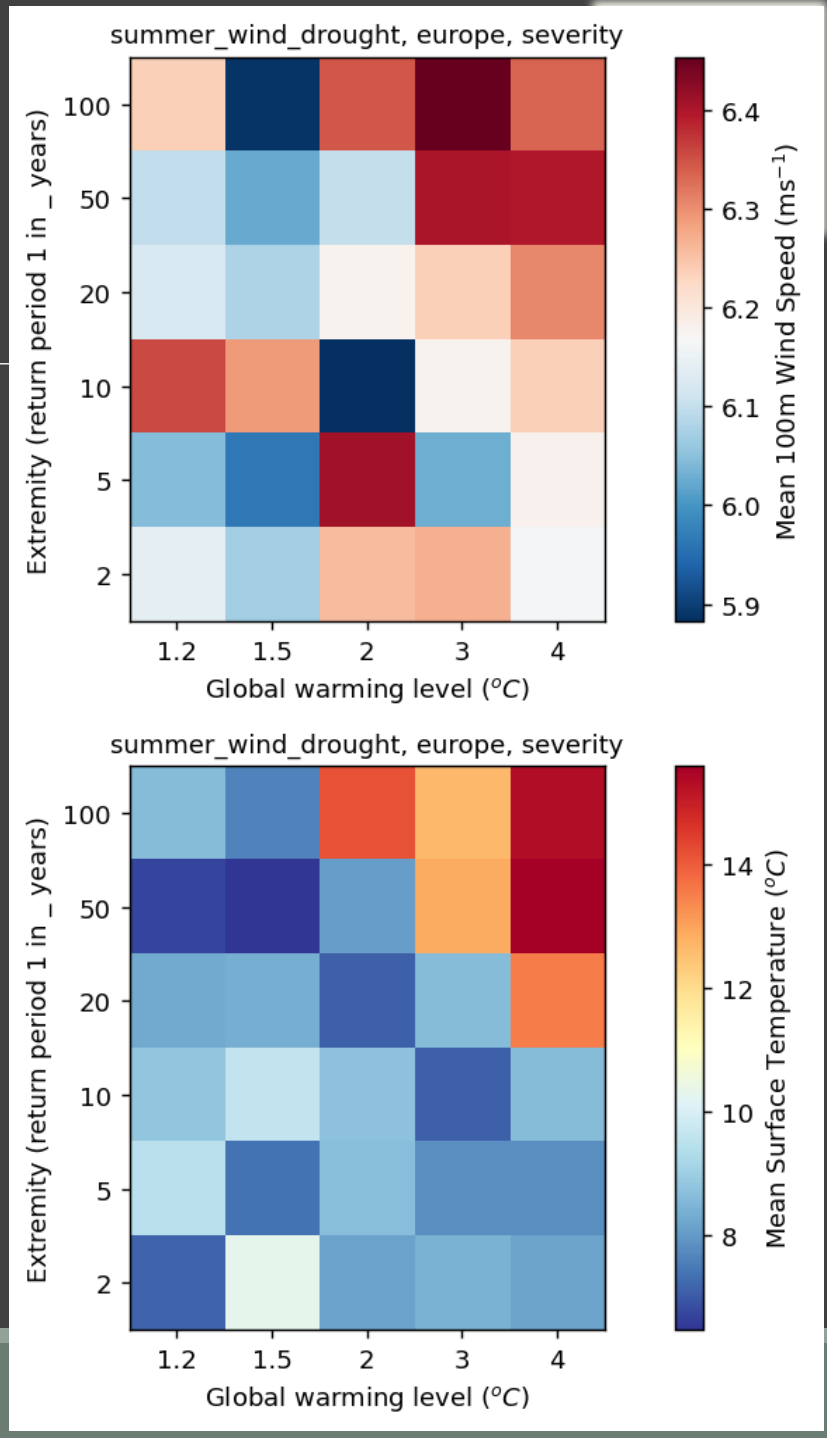
- Total of 30 events (6 extremities * 5 global warming levels)
- Averaged over all Polish wind farms
- Trend is as expected: higher **average** temperature as the extremity and g.w.l. rise
- Wind speeds also show similar trend: higher **average** wind speed as extremity and g.w.l. rise
  - But, with some outliers *(e.g. 1 in 10 years – 1.5 g.w.l)*





Bulk Analysis

- Same plot as last slide, but averaged over multiplicities of events where applicable *(e.g. event 1, event 2, event 3)*
- Helps smoothen out some irregularities in the average temperature data
- But “creates” some irregularities in the average wind speed data
- Overall, the trends remain the same



Bulk Analysis (of power generation)

- Wind speed converted to **power generation, s**ummed over Polish wind farms
- Measured days of the year where the total power is < 100 MW
  - This basically means no power from the wind farms == strained network
- Converted that to an annual %
- Plots look very similar to the **average wind speed** plots
  - Top is only *event1* of each category; bottom is averaged over *events 1-3*
- It looks like as g.w.l. and extremities increase, there are **fewer days of the year** with wind droughts