3rd ClimEd Online Training on "Digital Tools and Datasets for Climate Change Education"

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Hosts: University of Helsinki (UHEL, Helsinki, Finland) & Odessa State Environmental University (OSENU, Odessa, Ukraine)

Assessment the influence of meteorological conditions for safe operation of nuclear power plants in various climatic zones

Group A9

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Introduction

Existing problem of concern: Safe operation of nuclear power plants depends on the dangerous weather conditions which should be assessed considering climate change in the nearest future.

The project **aims** to analyse the influence of meteorological conditions and assess its changes in the nearest future by various climatic scenarios for the safe operation of nuclear power plants (NPP) located in different climatic zones.

Objectives

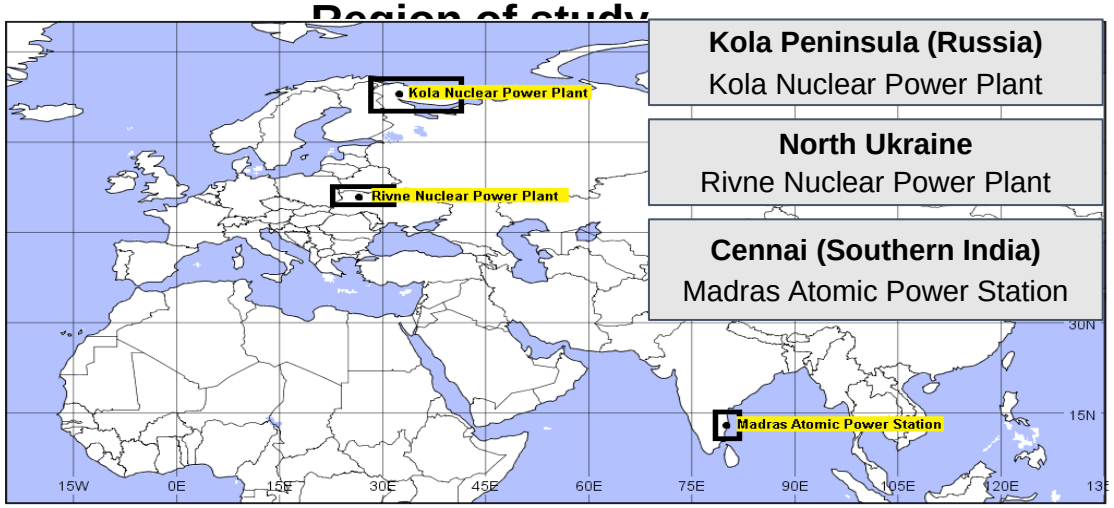
Estimate changes of key meteorological parameters which describe extreme precipitation; thermal and wind regimes which influence NPP

Obtain future projections of meteorological conditions in subpolar, temperate and tropical climatic zones which will help to describe possible changes of dangerous weather conditions for NPPs.

The expected results can be used for the following **sustainable development goals (UN SDGs)**:

Data and Methods

Region of study



Kola Peninsula (Russia)
Kola Nuclear Power Plant

North Ukraine
Rivne Nuclear Power Plant

Cennai (Southern India)
Madras Atomic Power Station

Research Period and Data

1991-2020 - climatological period
ERA5 hourly data on single levels from 1979 to present

2021-2099 - future scenarios
CORDEX regional climate model data on single levels (RCP-scenarios)
CMIP6 climate projections (SSP-scenarios)

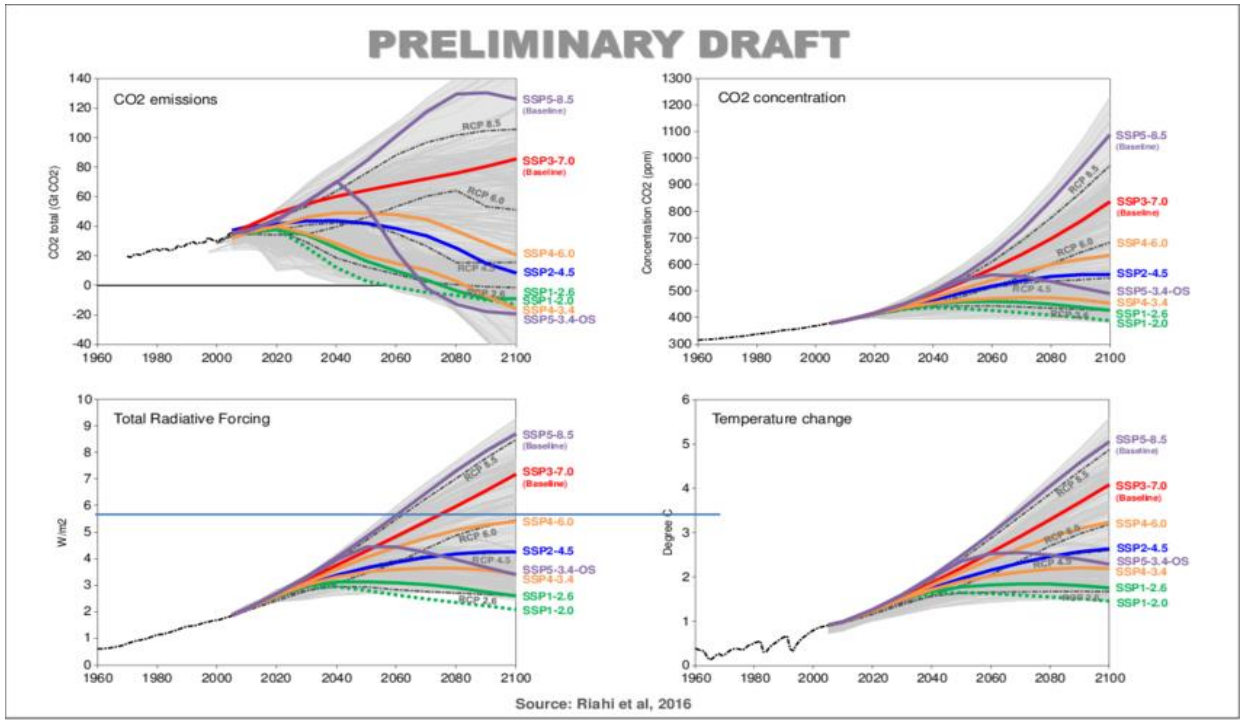
Data processing and tools

- CDS toolbox;
- CDO;
- Python; R
- Panoply

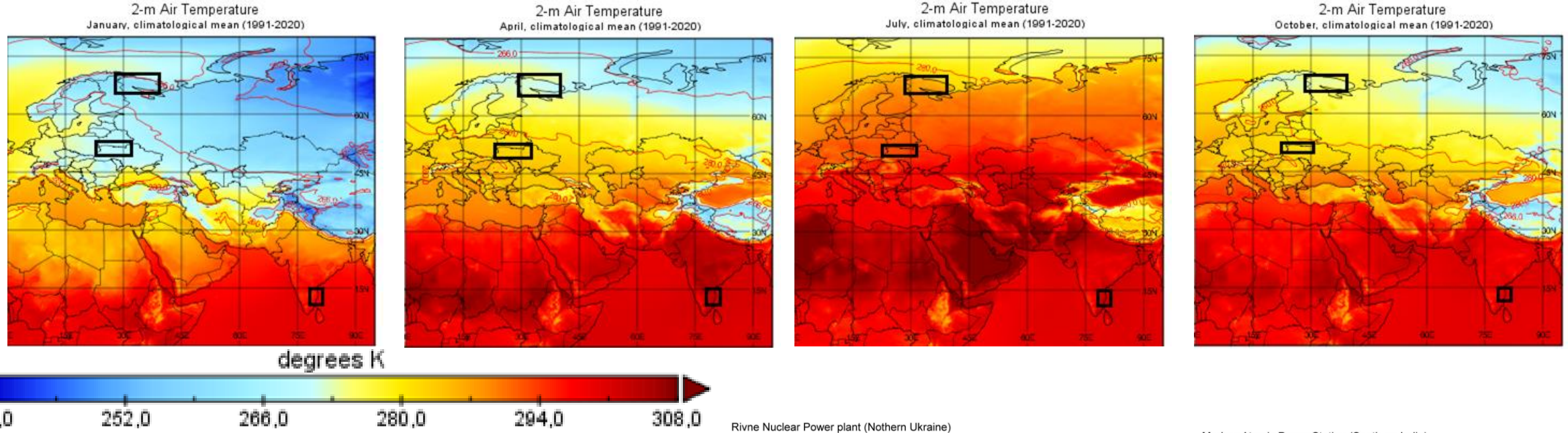
Meteorological parameters

- 2m air temperature (mean, max, min, extremes);
- 10m wind speed (mean);
- 10m wind gust (mean, max, extremes);
- Precipitation (mean totals, extremes);
- Snowfall (mean totals, extremes).

Scenarios describe possible future developments of anthropogenic drivers of climate change (i.e., greenhouse gases, chemically reactive gases, aerosols, and land-use).



Temperature regime



During a year, 2-m air temperature varies within:

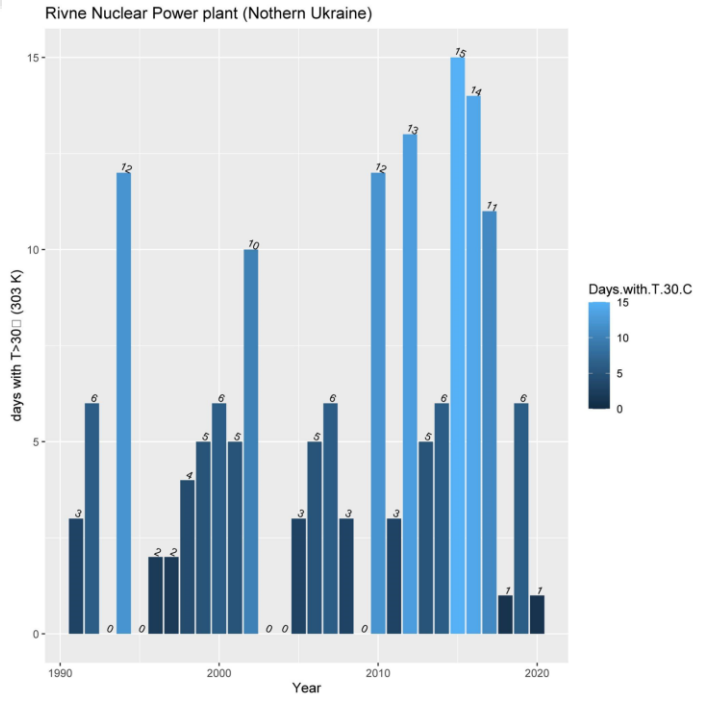
- 18 … 31 ℃ (292 … 302 K) in Southern India;
- -5 … 22 ℃ (268 … 295 K) in Northern Ukraine;
- -13 … 16 ℃ (260 … 289 K) on the Kola Peninsula.

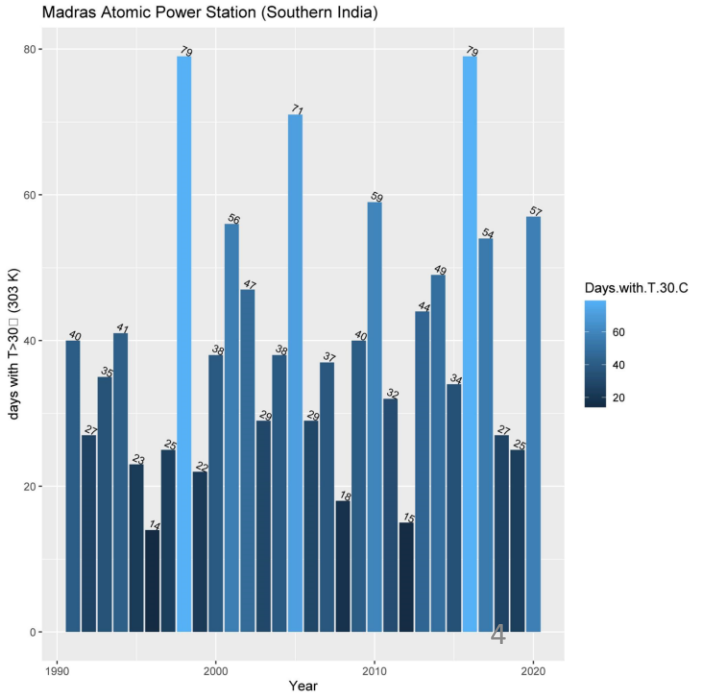
Average number of days with maximal 2-m Air Temperature >30℃ (>303 K)

- Madras Atomic Power Station - 39 days
- Rivne Nuclear Power Plant - 5 days
- Kola Nuclear Power Plant - 0 days

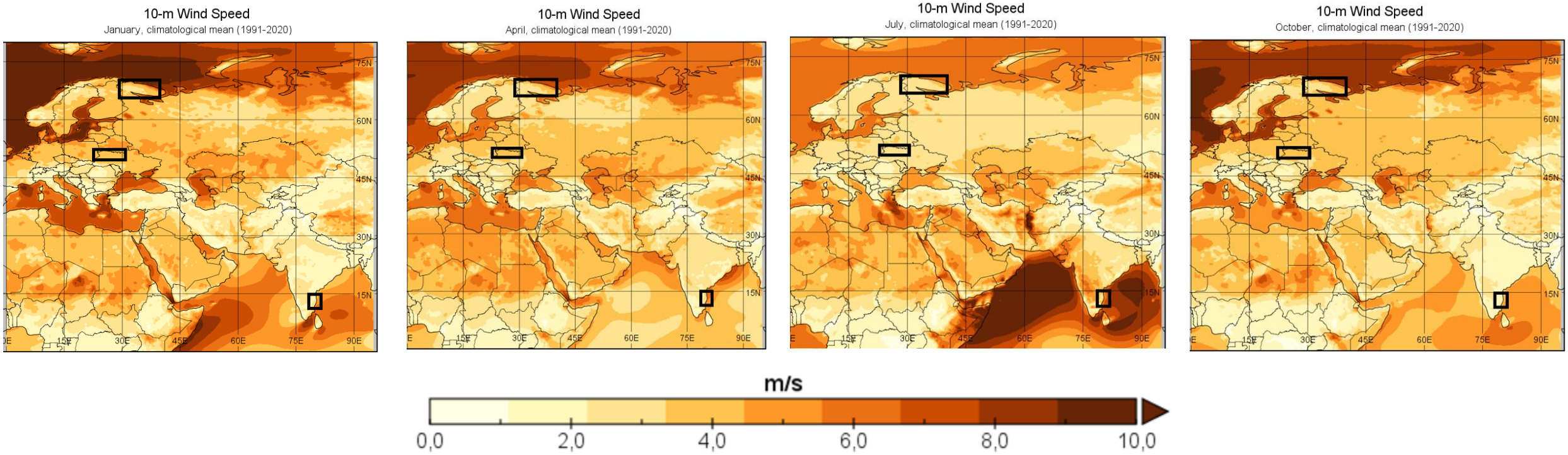
Average number of days with minimal 2-m Air Temperature <-30℃ (<243 K)

- Kola Nuclear Power Plant - 0.4 days





Wind regime: wind speed and wind gust



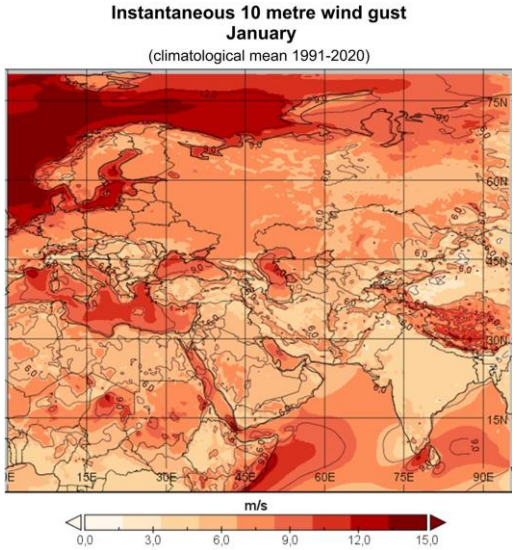
During a year, average wind speed varies within:

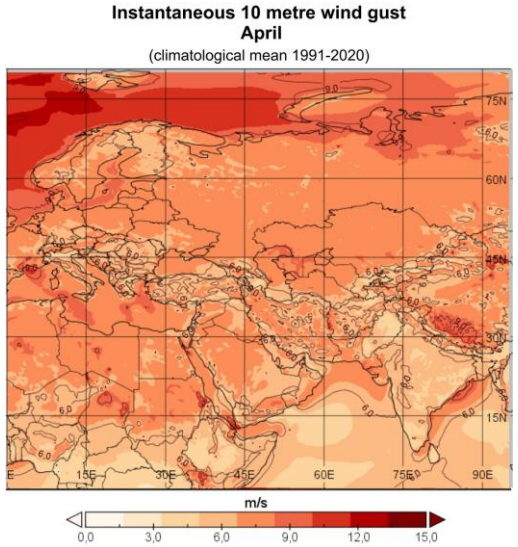
- 1 - 8 m/s in Southern India;
- 2 - 4 m/s in Northern Ukraine;
- 2 - 9 m/s on the Kola Peninsula.

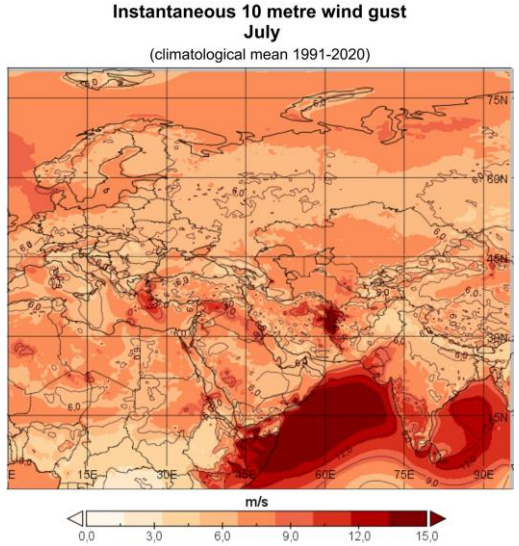
Average wind gust (m/s)

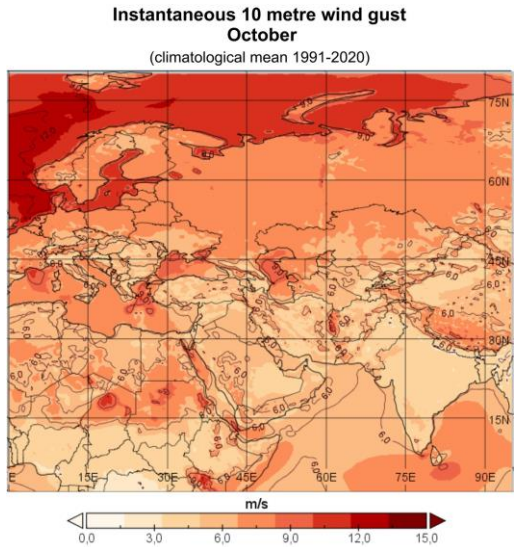
	winter	spring	summer	fall
South. India	3.1-9.9	3.2-11.1	4.1-12.3	2.9-9.9
North. Ukraine	6.5-8.6	5.6-8.2	4.9-6.8	5.5-8.1
Kola Peninsula	5.7-13.2	4.4-12.2	3.8-8.7	4.6-12.4

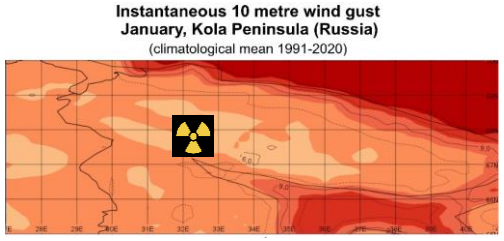
Wind regime. Wind gust

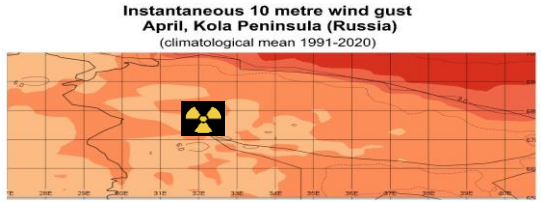


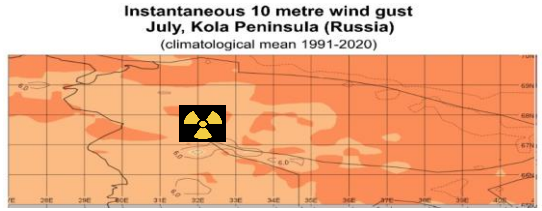


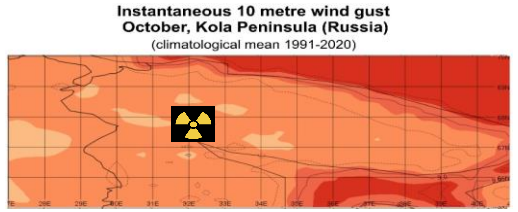


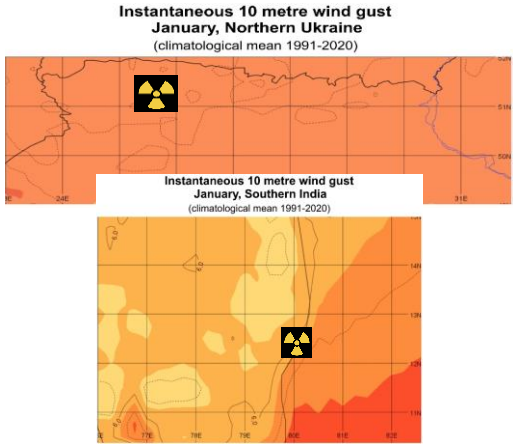


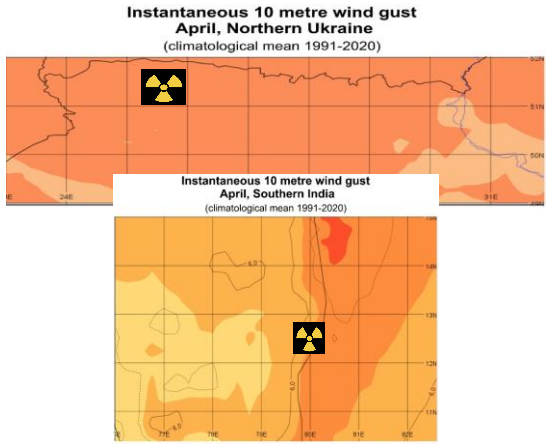


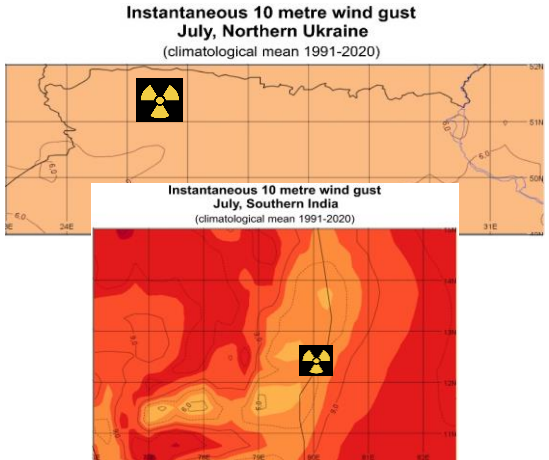


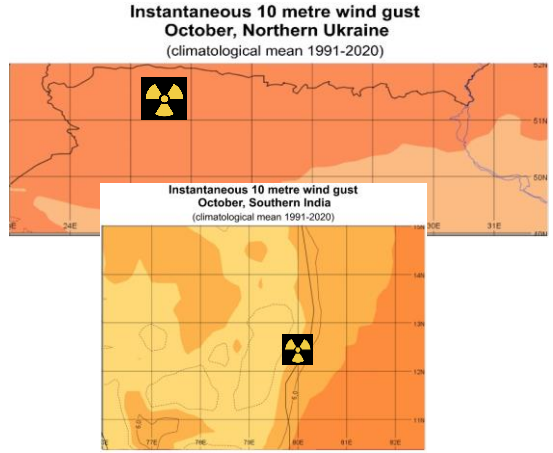




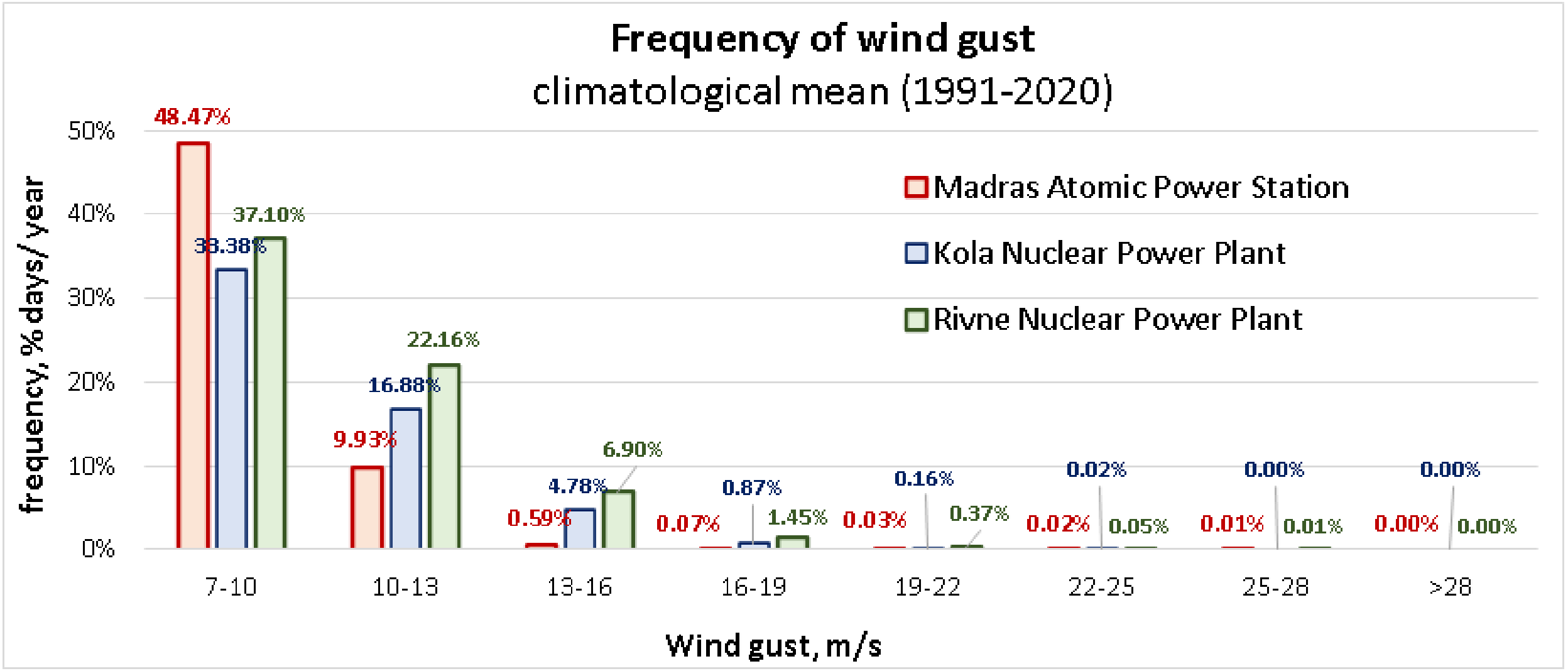




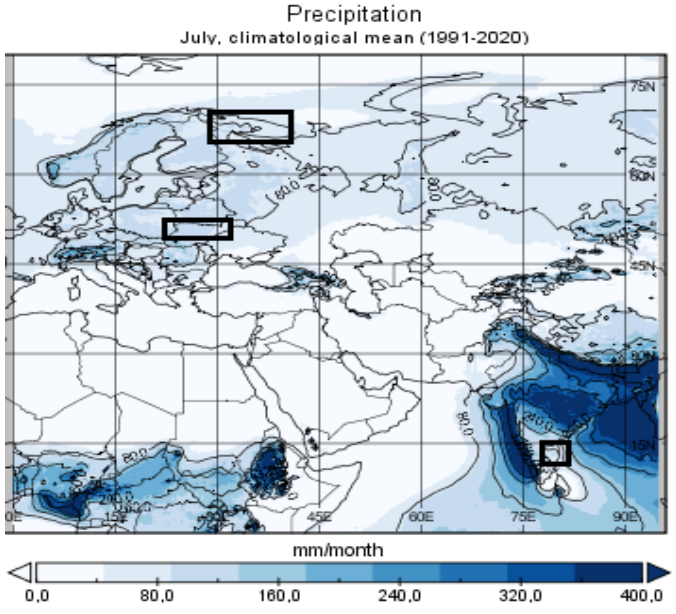


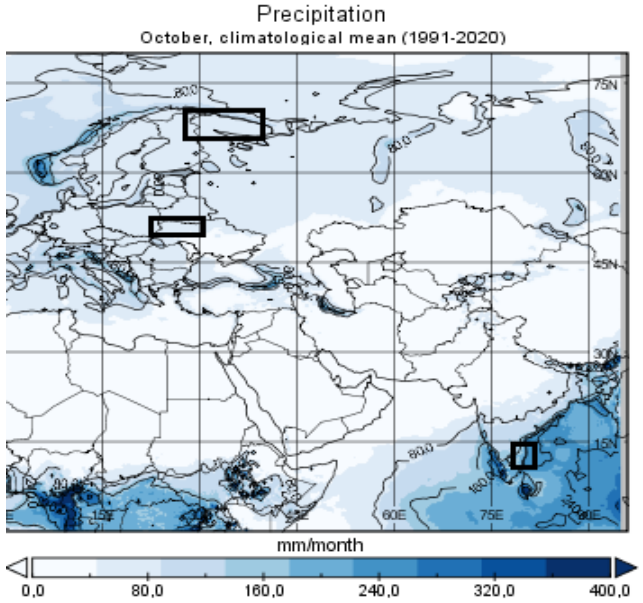


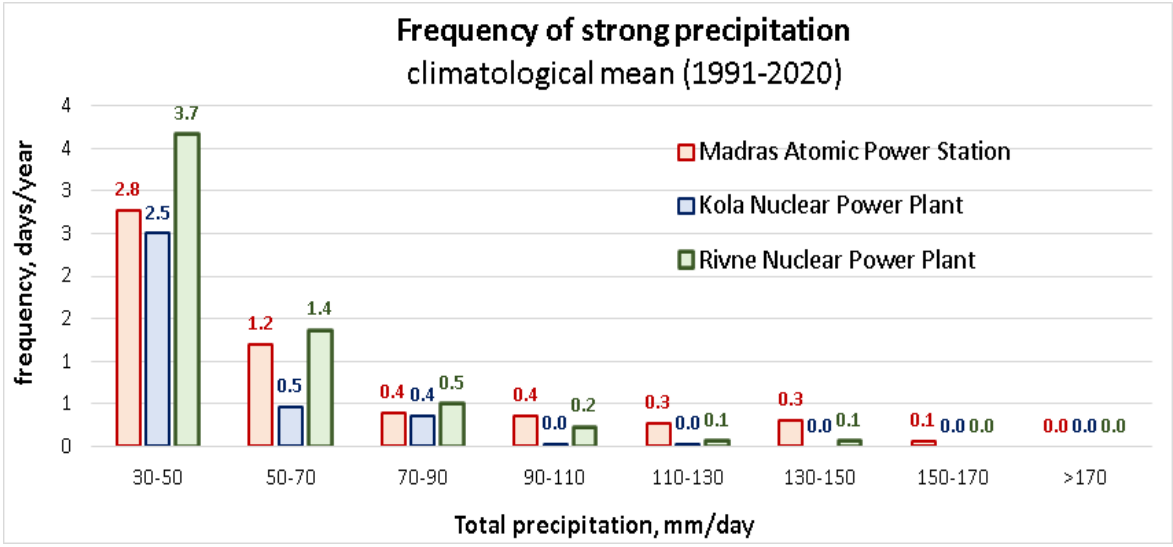
Wind regime. Extremes

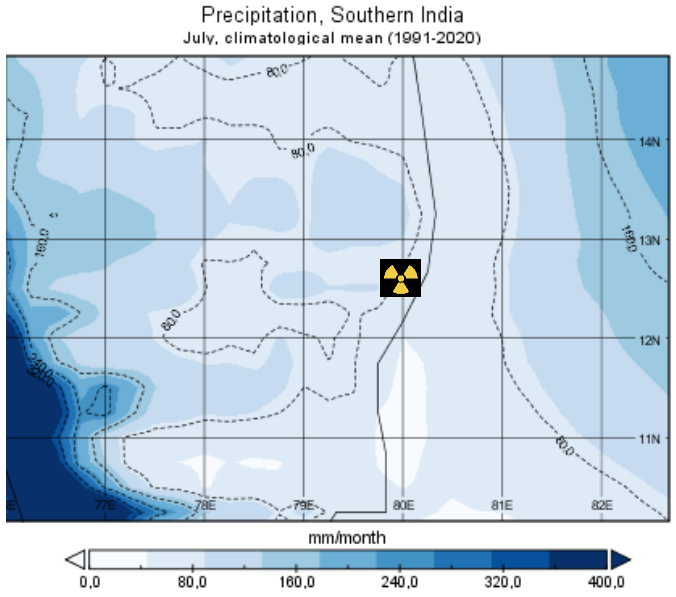


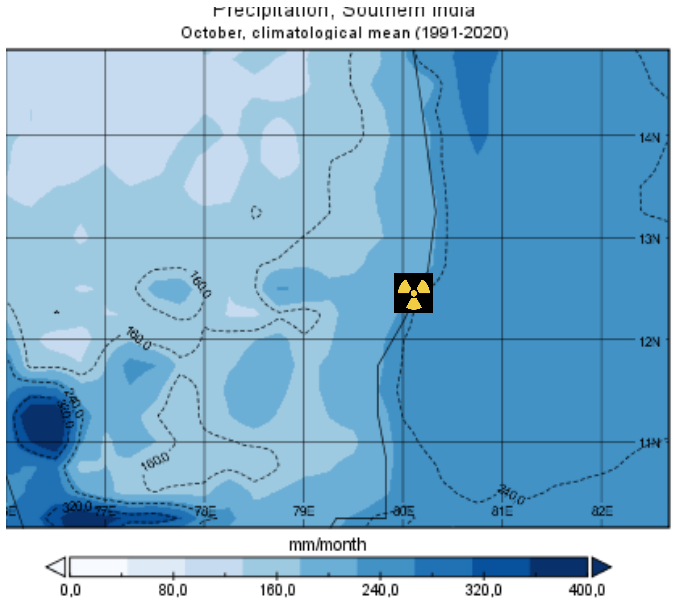
Total Precipitation







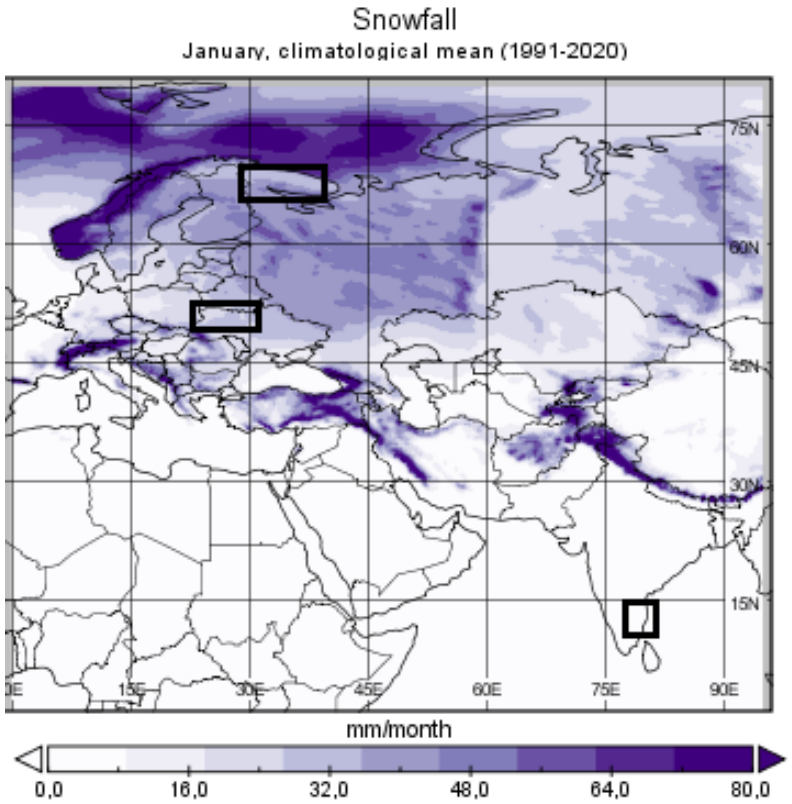


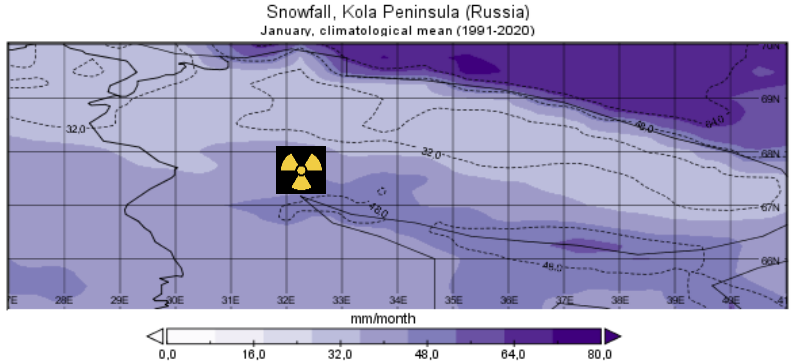


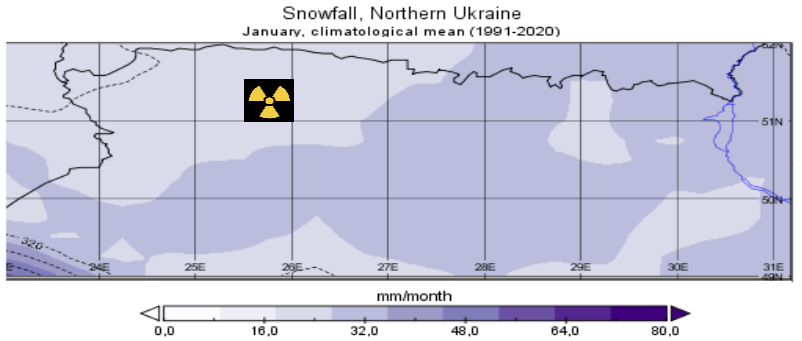
Average number of days with total precipitation >30 mm/ day

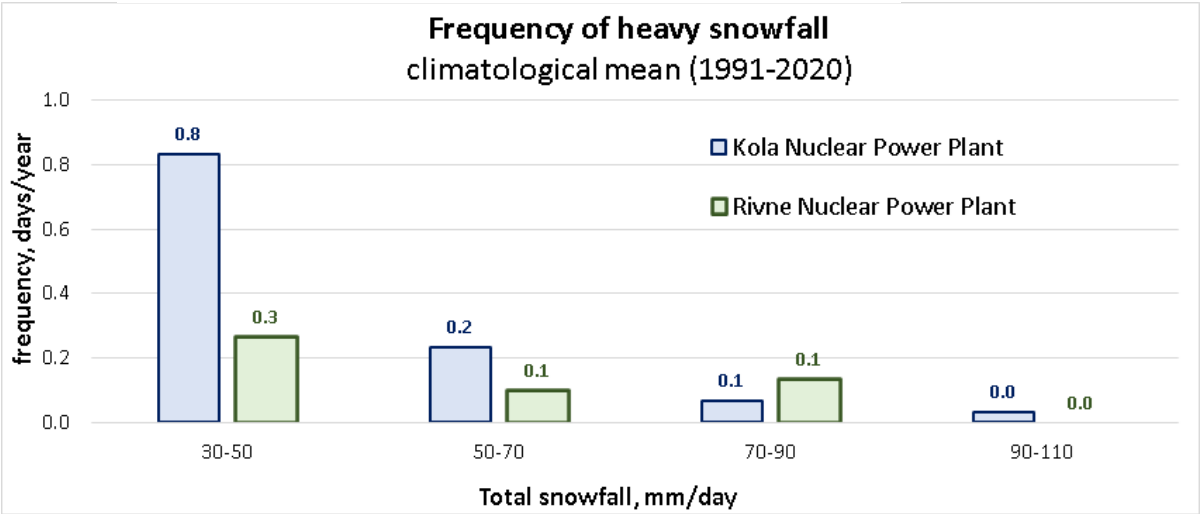
Madras Atomic Power Station - 5 days;
Rivne Nuclear Power Plant - 6 days;
Kola Nuclear Power Plant - 3 days

Snowfall







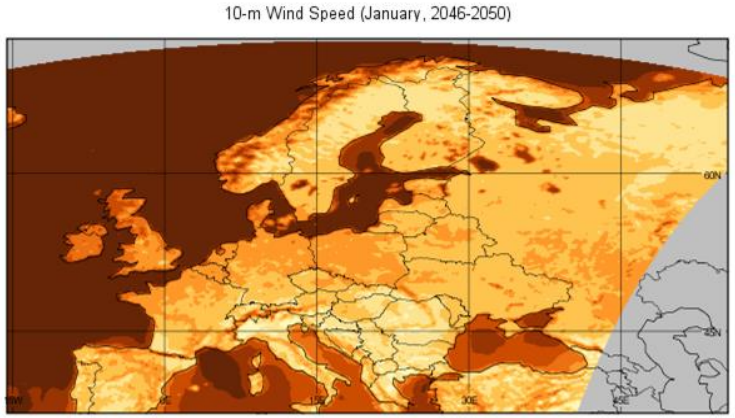


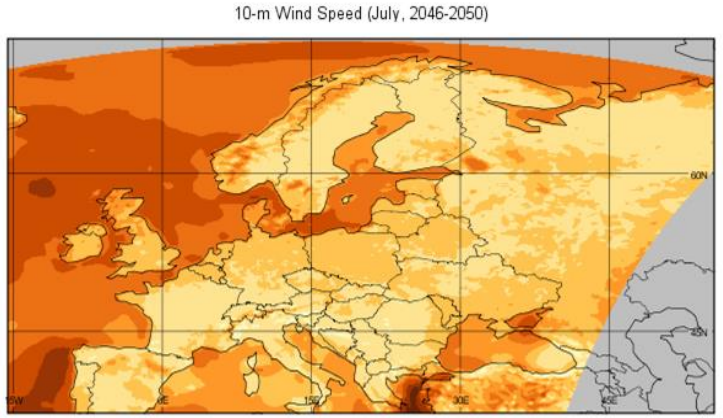
Average number of days with total snowfall >20 mm/ day

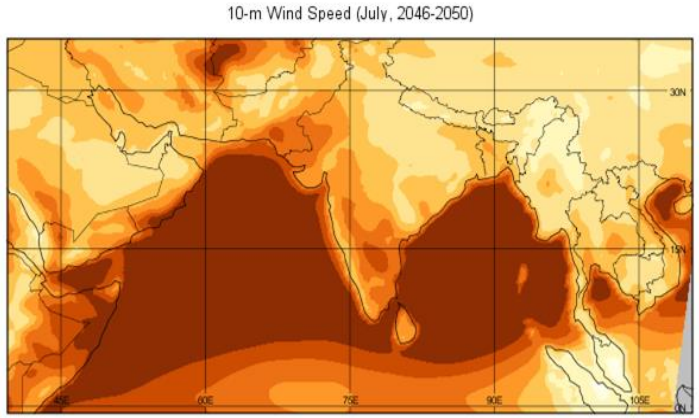
Rivne Nuclear Power Plant - 0.5 days;
Kola Nuclear Power Plant - 1.2 days

Future projections. Wind speed.

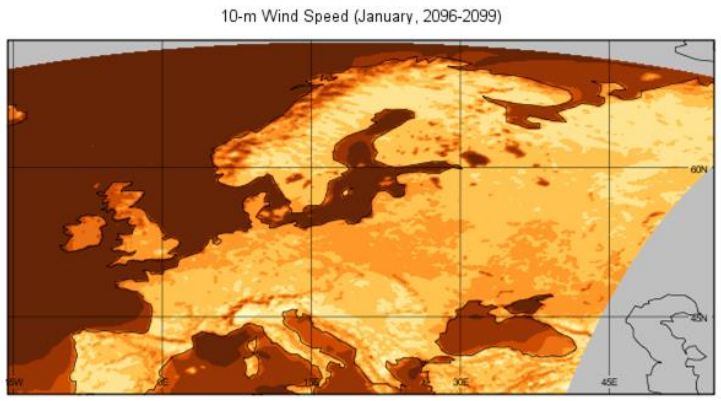
2046-2050
RCP2.6

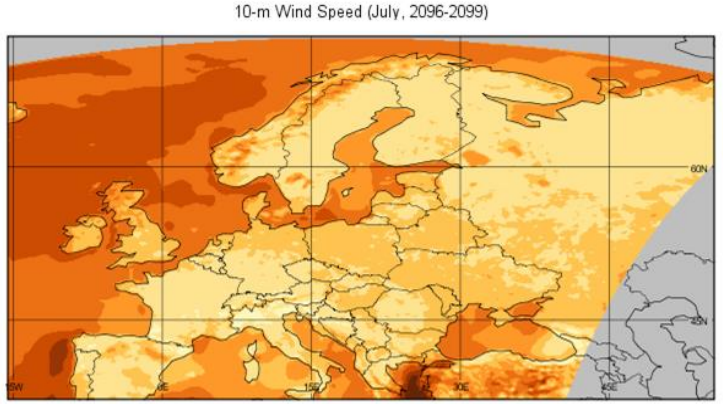


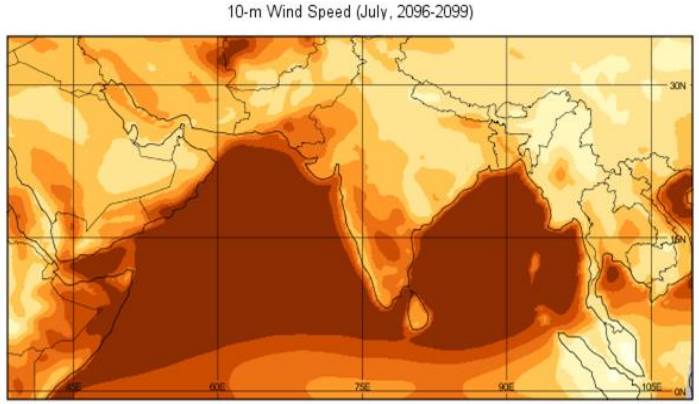


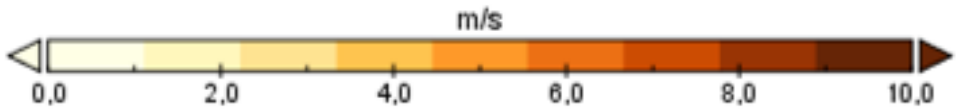


2096-2099
RCP2.6

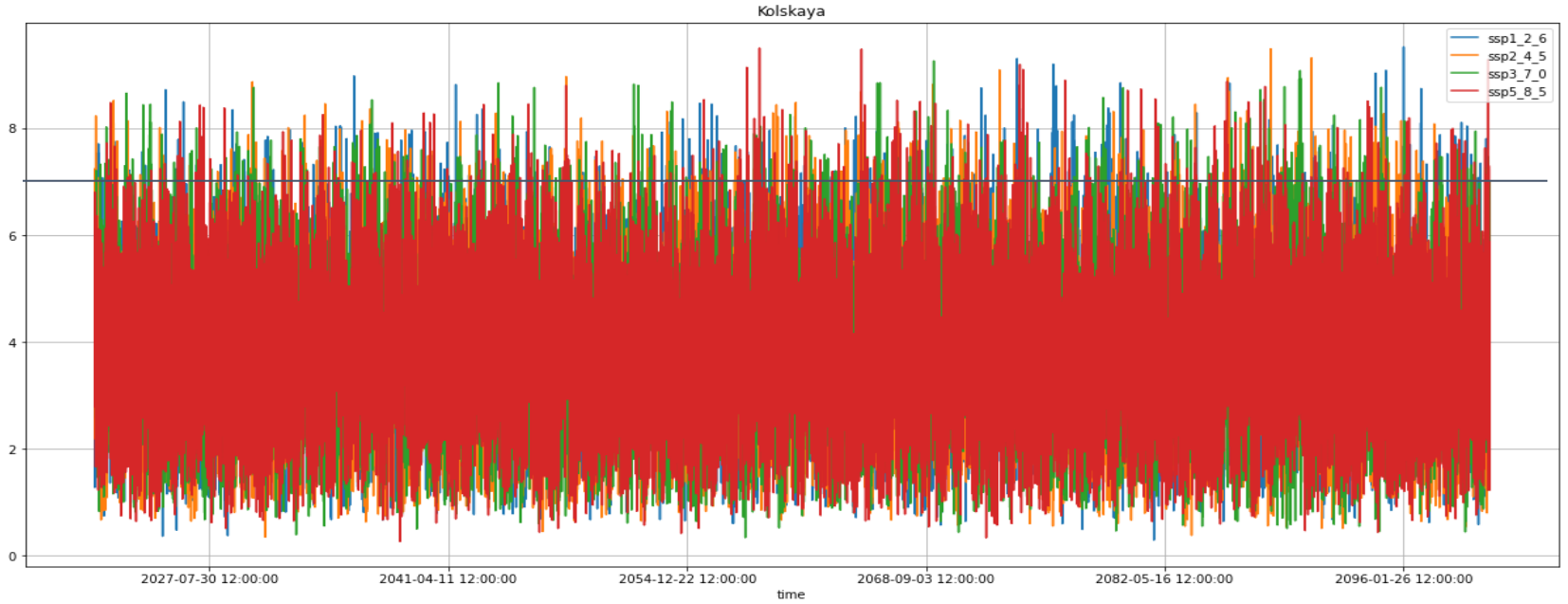


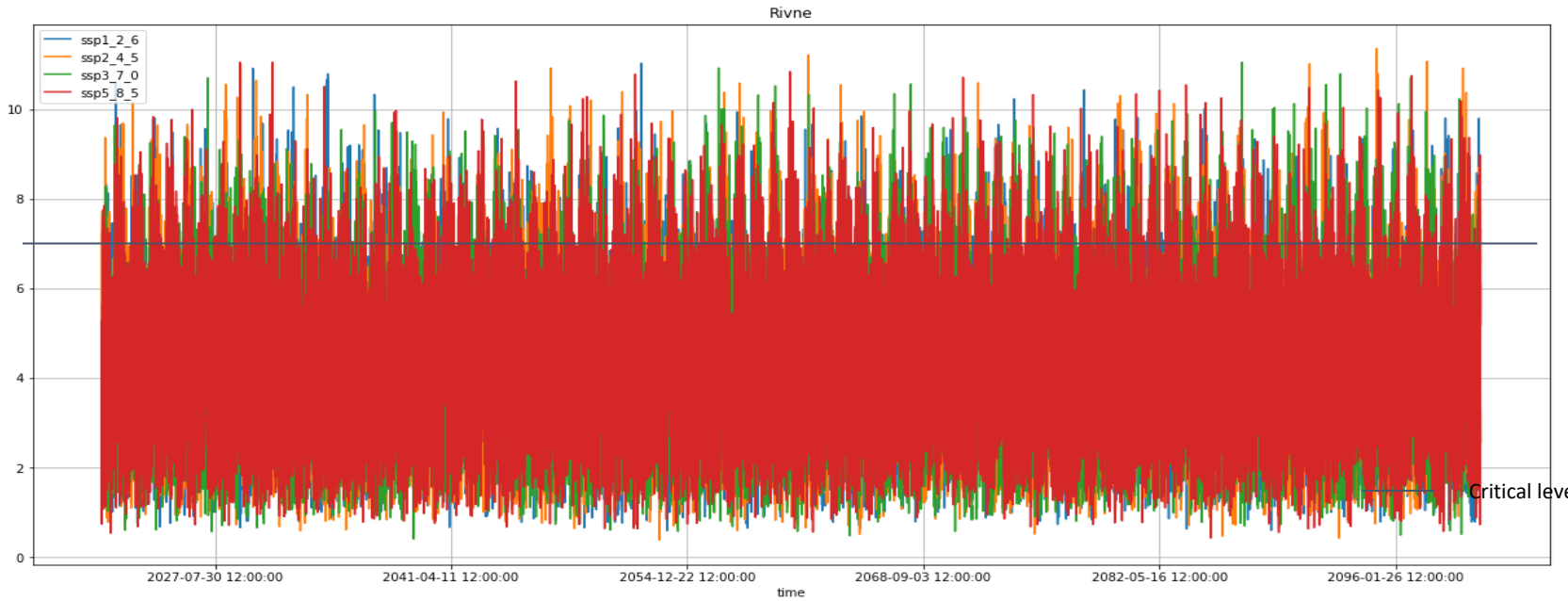






Future projections. Wind speed.





The maximum wind speed varies according to scenarios within 0.5 m / s.

For the Kola NPP, the average value of the maximum speed is 9.4 m / s.

Rivne NPP the average value of the maximum speed is 11.2 m / s.

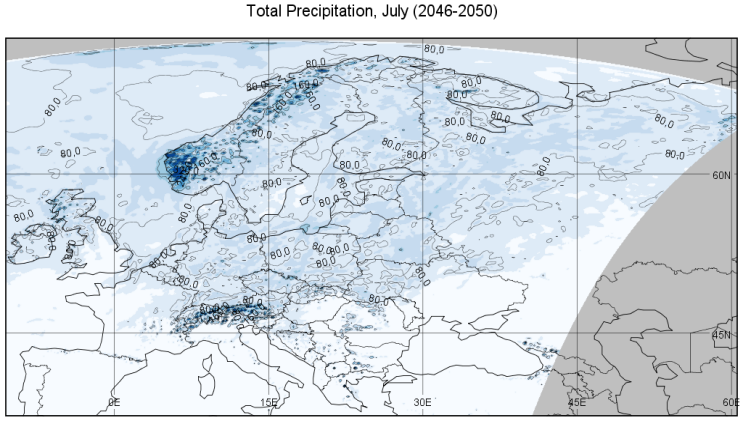
Madras NPP average maximum speed is 15.5 m / s.

The most unstable to wind load (including thermal power plants) are cooling towers, domes and pipes.

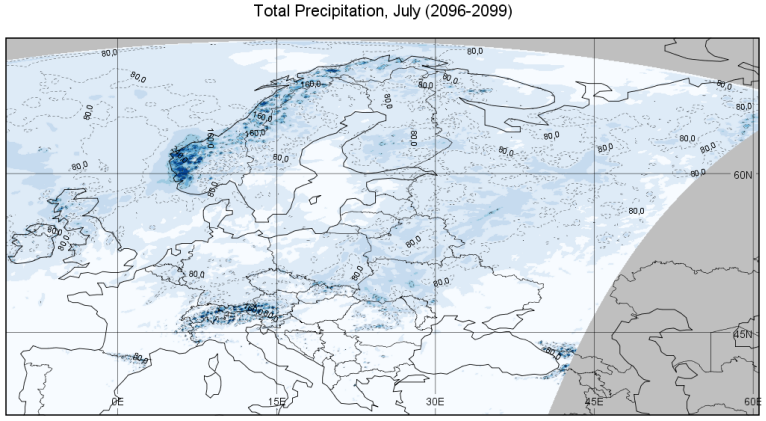
Critical levels of 10-m wind speed

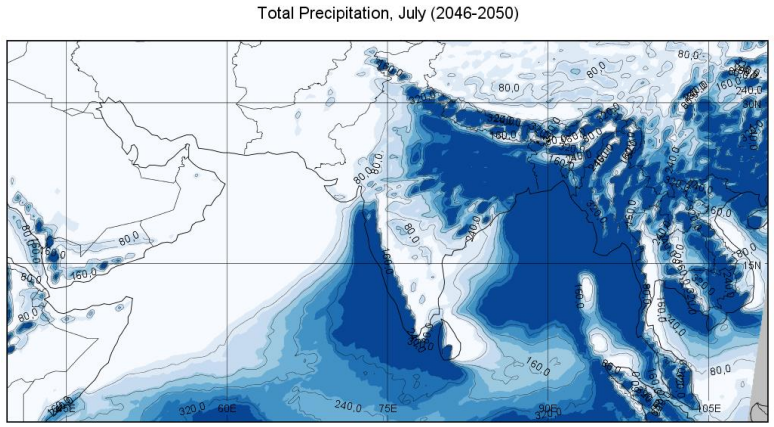
Future projections. Precipitation.

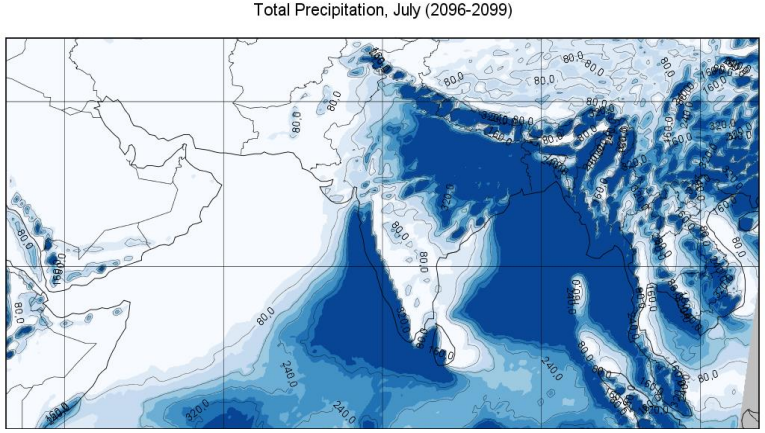
2046-2050, RCP2.6

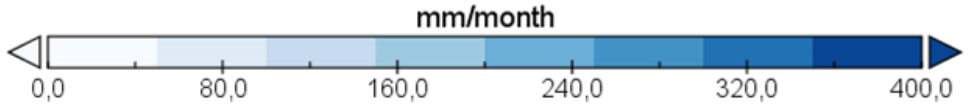


2096-2099, RCP2.6

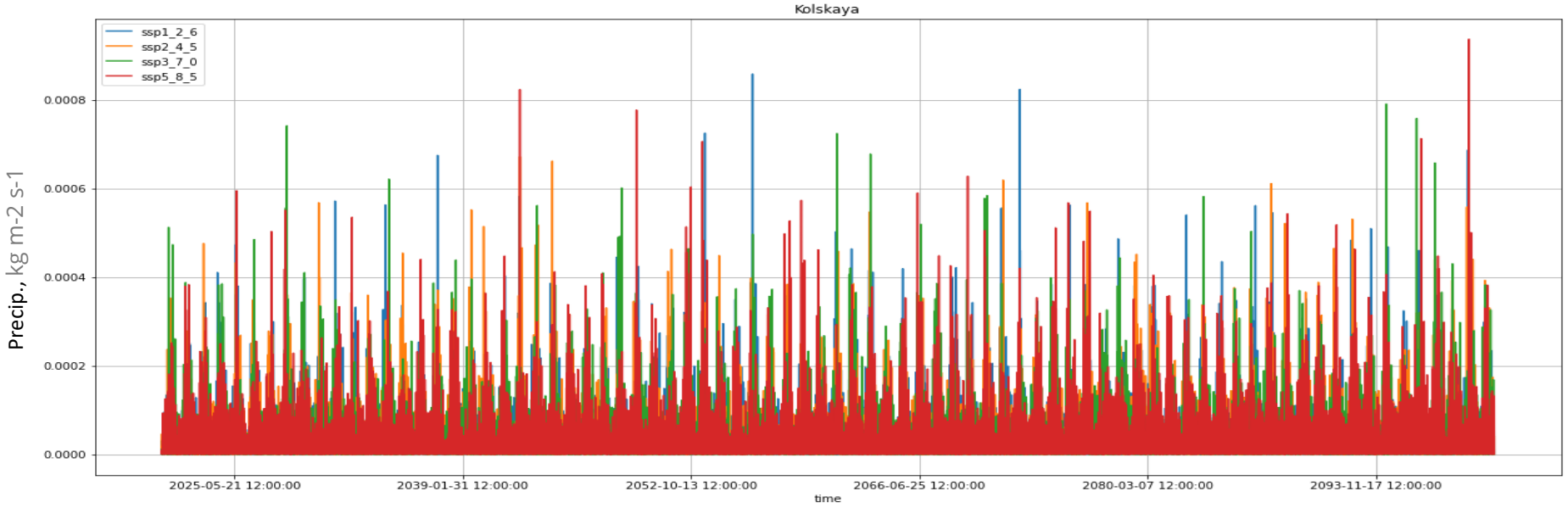


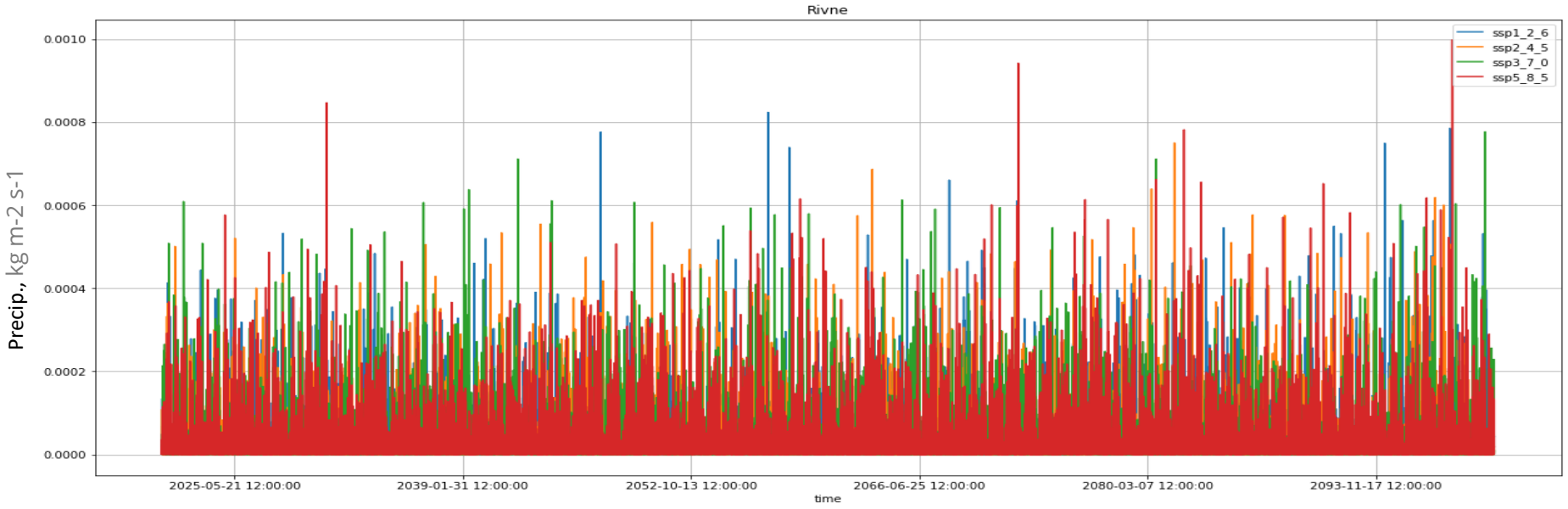






Future projections. Precipitation.



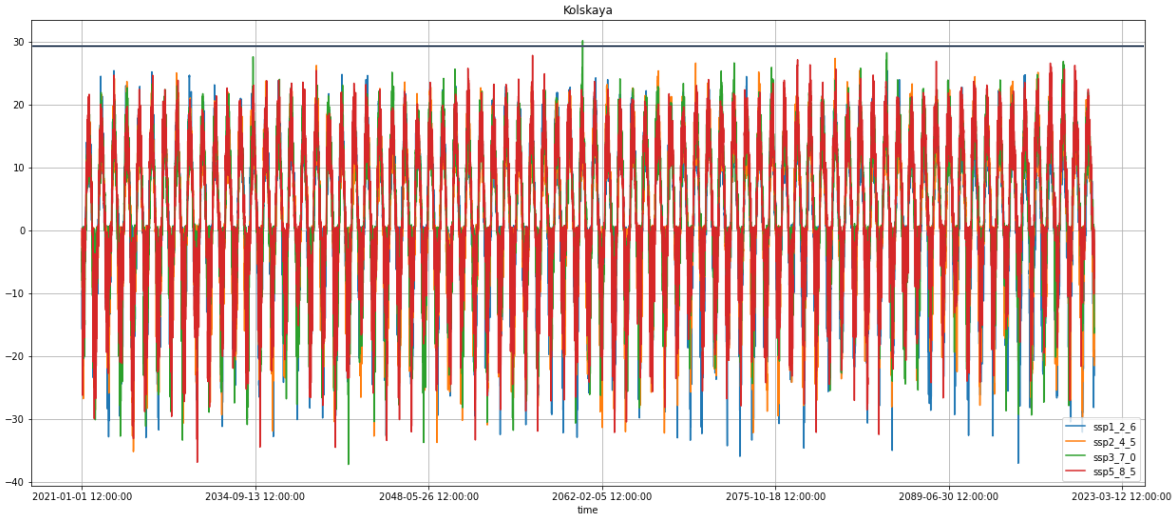


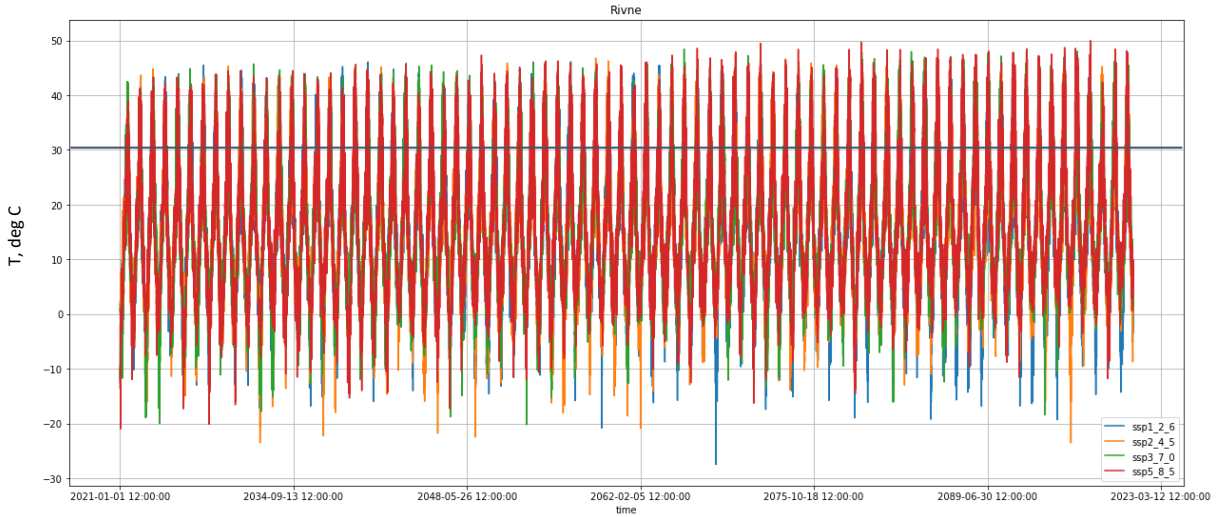
Scenario SSP2_4.5 shows the minimum precipitation delta for both NPPs. Scenario SSP4_8.5 - maximum delta.

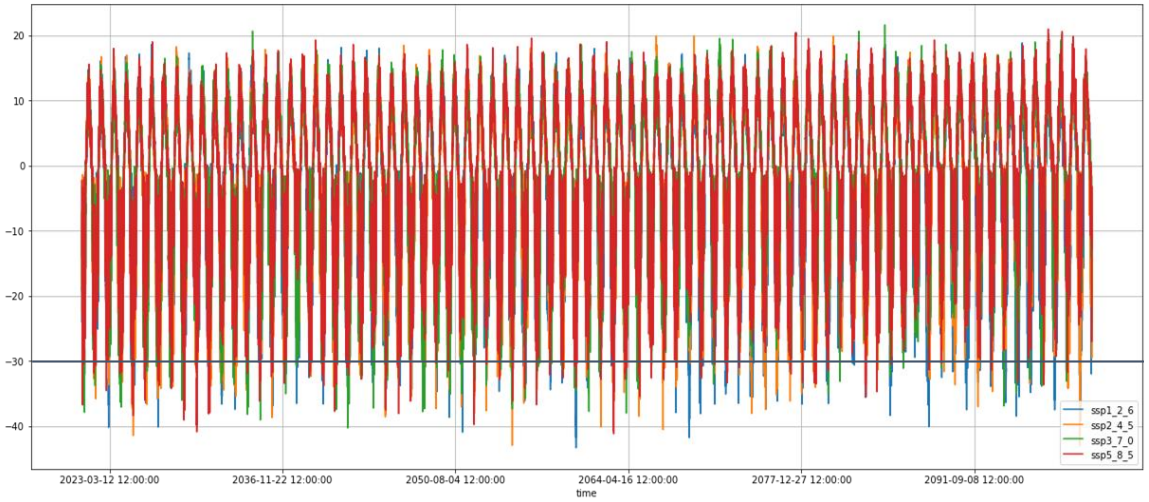
Kola NPP - the frequency of exceeding total precipitation >30 mm/ day steadily increases along the series SSP1_2.6> SSP2_4.5> SSP3_7.0> SSP4_8.5

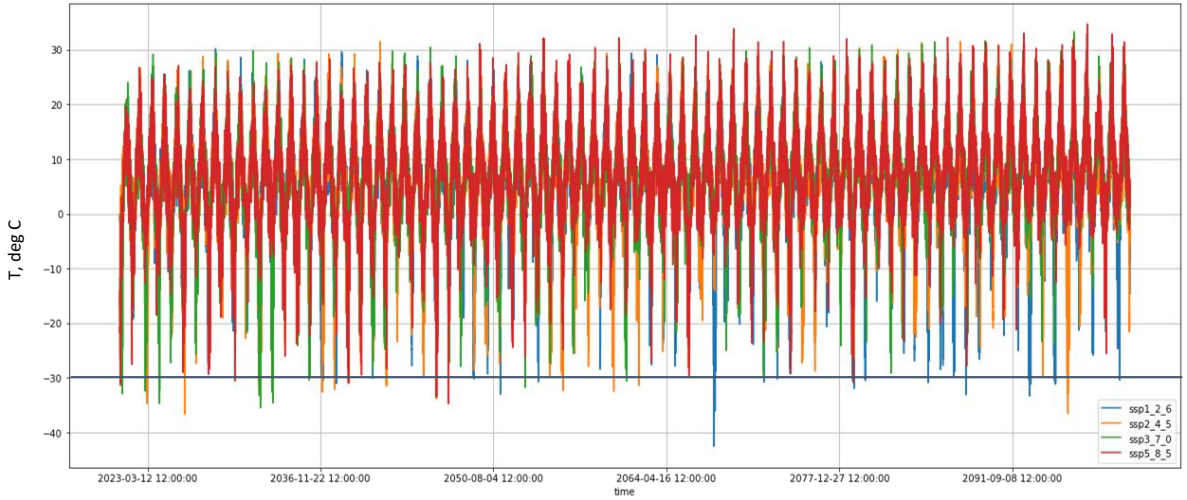
Rivne NPP - the frequency of exceeding total precipitation >30 mm/ day is minimal for the scenarios SSP2_4.5 and SSP3_7.0. Frequency is maximum for SSP4_8.5 scenario

Future projections.
2-m Tmin and Tmax









——— Critical levels of 2-m temperature

Conclusions

- Nuclear power plants face unsafe meteorological conditions in all regions arising from extreme air temperature, strong wind, heavy precipitation and snowfall.
- The most unfavorable thermal regime for NPP operation observed in the Southern India where air temperature exceeds dangerous thresholds (>30℃) on average 39 days per year in comparison to 5 days per year in Ukraine. In contrast, NPP on the Kola Peninsula faced extremely cold air temperature (<-30℃) with the frequency of 1 day per 2 years.
- Dangerous wind (>7 m/s) for safe NPP operations observed in all seasons with the summer maximal in tropical and winter maximals in temperate and subpolar climatic zones. Depending on the region, the wind gust of 7-10 m/s observed in 33% to 49% days. In India and Ukraine, there were cases with wind of about 25-28 m/s being close to the most dangerous threshold (33 m/s) for NPP.
- Kola Peninsula and Northern Ukraine face heavy snowfall with the frequency of about 1 day per year in the subpolar zone and 1 day per 2 years in the temperate zone. Heavy precipitation observed 3-6 times per year in all regions with the maximal rainfall during summer-fall in the Southern India that could reach 150 mm/ day.
- According to the scenarios, the maximum increase in the absolute precipitation value corresponds to the SSP 4_8.5 scenario for both NPPs, the minimum absolute precipitation value corresponds to the SSP 2_4.5 scenario.
- For the Kola NPP, the excess of the critical temperature of 30℃ for the period 2021-2100 is achieved only according to the SSP 3_7.0 scenario, isolated cases, since this is not typical for the climatic zone as a whole. At the same time, for all scenarios, there is a high frequency of extremely low air temperatures (<-30 ℃). Minimum temperatures (<-40 ℃) are most often achieved for SSP 1_2.6 and SSP 2_4.5 scenarios.
- For Rivne NPP, the max temperature rise up to 40℃ for the period 2021-2100. achieved in all scenarios. In this case, most often for the SSP scenario 4_8.5. For the same scenario, an increase in absolute temperature maximums by 7 ℃ by 2100 was noted. The frequency of temperature rise up to 30 ℃ for the period 2021-2100 is high, but this is generally typical for the climatic zone. For the SSP 1_2.6 scenario, there were isolated cases of critically low temperatures (<-40 ℃), which may require additional thermal insulation and measures against glaciation of buildings.


Thank you for attention!