Analysing the occurrence and duration of periods with low wind speeds and high cloud cover in the Baltic Sea area: Insights from a renewable energy perspective

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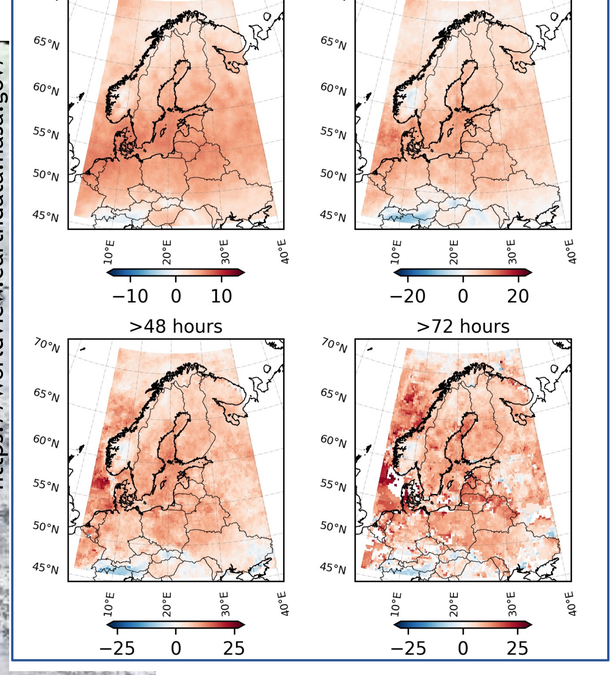
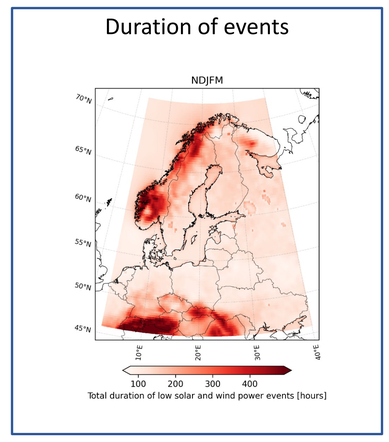
INTRODUCTION

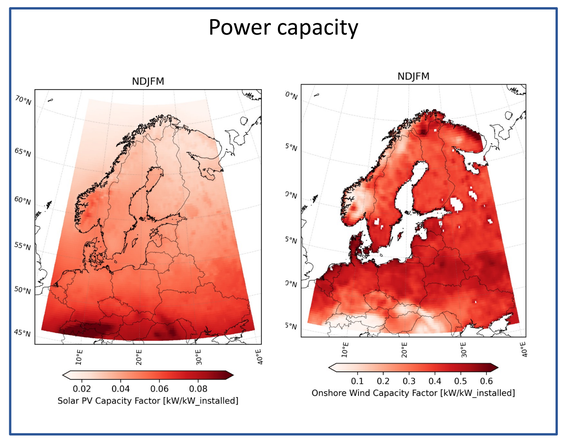
In the upcoming years, wind and solar energy are expected to play a more prominent role in Europe's energy mix. European Renewable Energy Directive raises the EU's binding renewable target for 2030 to a minimum of 42.5% of the region's total energy demand by 2030 (European Commission, 2023). The North and Baltic Sea regions have been pivotal in driving this expansion of renewable energy.

However, regarding energy security, the frequency and duration of concurrent low wind speed and surface solar radiation levels are crucial considerations. Nevertheless, the increasing dependence on variable wind and solar generation presents challenges for power production, particularly during adverse weather conditions. We specifically focus on a meteorological phenomenon called 'Dunkelflaute,' characterised by calm winds and overcast skies (Li et al., 2021). Understanding and predicting such extreme weather events is essential for effective power production planning.

These 'Dunkelflaute' events are common in the cold season from November to March. Copernicus Climate Change Service (2020) offers new Energy Service data. We aim to check the feasibility of these data to understand better the frequency of occurrence of these events and the possible atmospheric circulation patterns leading to them.

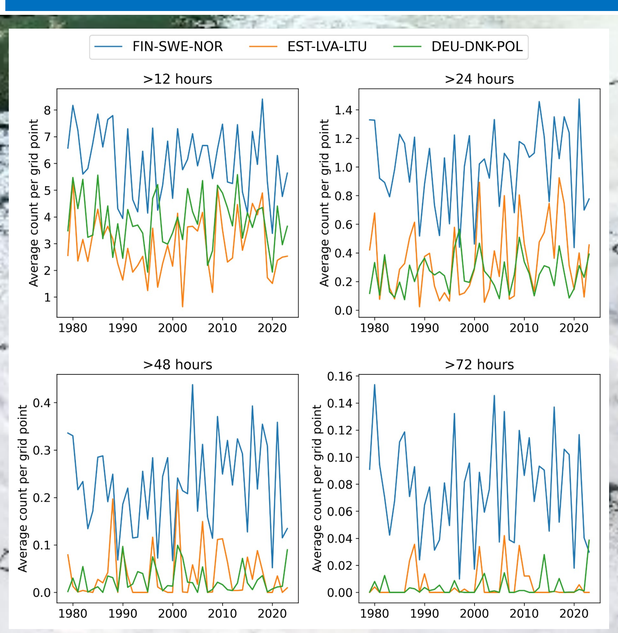


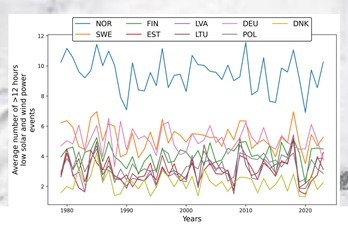


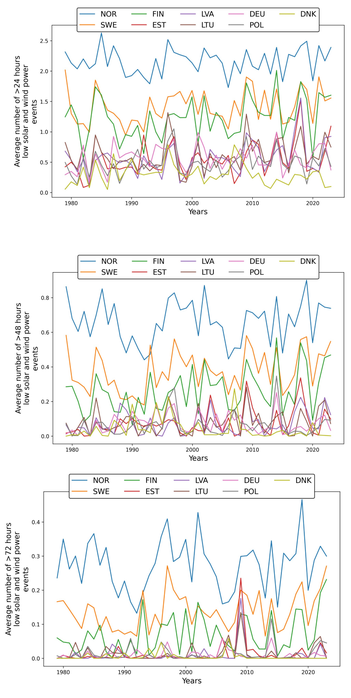


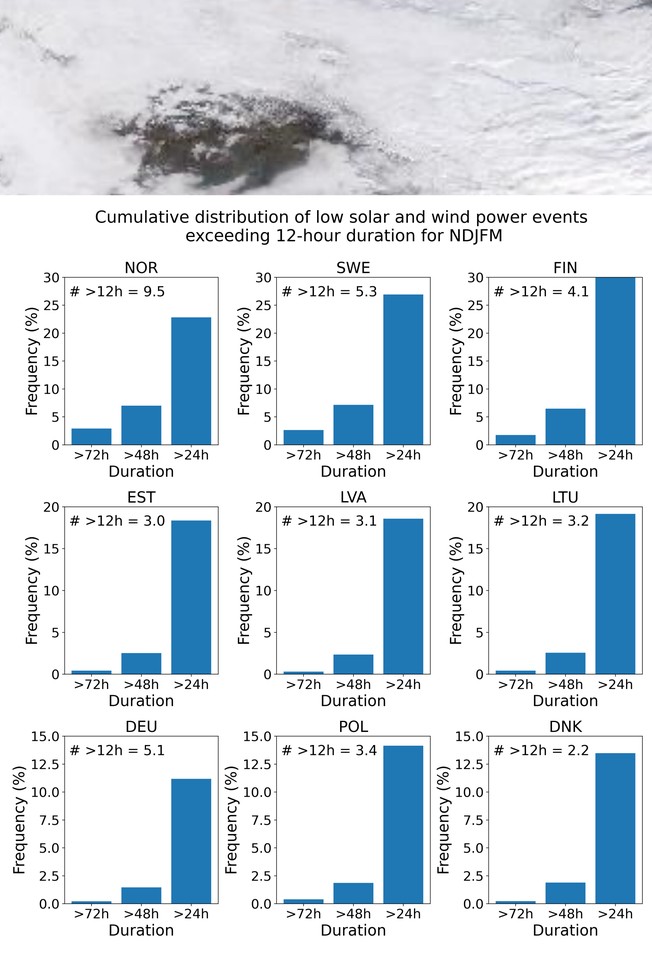
DATA AND METHOD

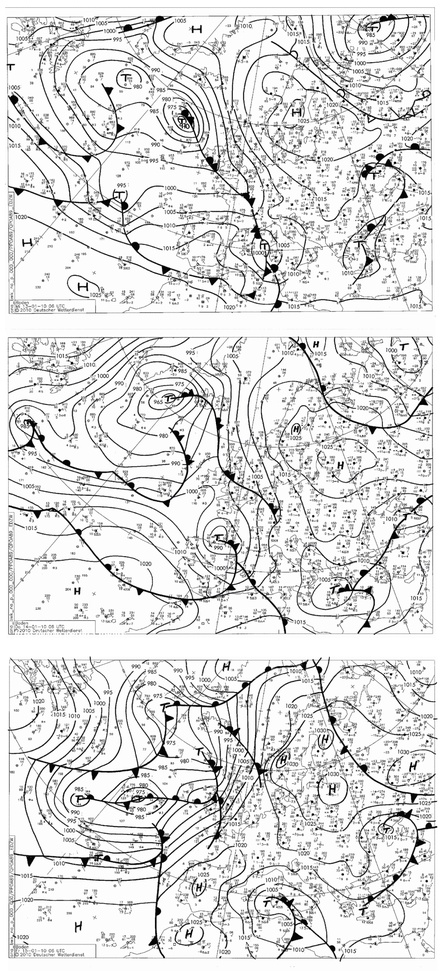
- The energy indicators utilized in this study are sourced from the Copernicus Climate Change Service (C3S) dataset, covering the period from 1979 to the present. This dataset relies on ERA5 reanalysis data to estimate climate variables. Energy indicators for the European energy sector are generated by converting climate variables using statistical models and physically based data.
- To determine capacity factors (the ratio of actual generation to installed capacity) for both wind and solar power, we assume a uniform distribution of wind turbines and photovoltaic plants across Europe. Hourly capacity factors from 1979 to 2023 for onshore wind power generation (WON) and solar photovoltaic power generation (SPV) are used at the model grid level (approximately 30x30 km). Events where capacity factors for wind and solar photovoltaic energy production drop below 10% are categorised as "Dunkelflaute" events.
- We specifically analyse events lasting more than 12, 24, 48, and 72 hours, providing estimates of occurrence frequencies within these duration brackets across each month and grid cell. Aggregated results at the country level only include data from WON and SPV. Additionally, we calculate the anomaly in mean sea level pressure (MSLP) during Dunkelflaute events for each duration group to elucidate the relationship between the events and the large-scale meteorological situation. The special long-lasting periods are also characterised by synoptic maps and circulation patterns.











CONCLUSIONS

The main pattern of events is linked to extensive cloud cover in Scandinavia, where event counts can reach up to 500 hours per NDJFM period of the year.

Norway records notably high event counts compared to eight other countries. Moreover, there's a direct correlation between the frequency of events lasting over 12 hours and the proportion of those lasting over 72 hours.

Interannual variability of events is significant, with maximums and minimums coinciding in subregions: NOR+FI+SWE and EST+LVA+LTU.

In the Baltic Sea region, events coincide with above-average mean sea level pressure periods.

The longest recorded event for Estonia occurred from January 12th to 16th, 2010, during a period of anticyclonic weather that persisted in the area.

Dunkelflaute events are associated with blocking high-pressure systems, which reduce winds and can result in prolonged periods of thick cloud cover over vast areas during the cold season.

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