



ILMATIETEEN LAITOS
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FINNISH METEOROLOGICAL INSTITUTE

The Winds of North – Is It Always Windy Somewhere?

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Wind Finland 2019, Haltia, Nuksio, Espoo

Who are we?

- The FMI works for the safety and success of the Finnish society.
- The FMI provides high-quality services and scientific know-how on the weather, atmosphere and seas for the safety of the society and businesses.
- All services are based on high-quality research, observations and expertise.



FMI Wind services

For developing phase

- Preliminary study on wind potential
- Wind measurements
- Wind energy assessments
- Wind power index
- Icing
- Sea ice, sea level, wave assessments

For wind farm operations

- Short-term wind forecast
- Long range weather predictions
- Icing forecasts
- Lightning services
- Wind power index
- Sea ice and sea level forecast



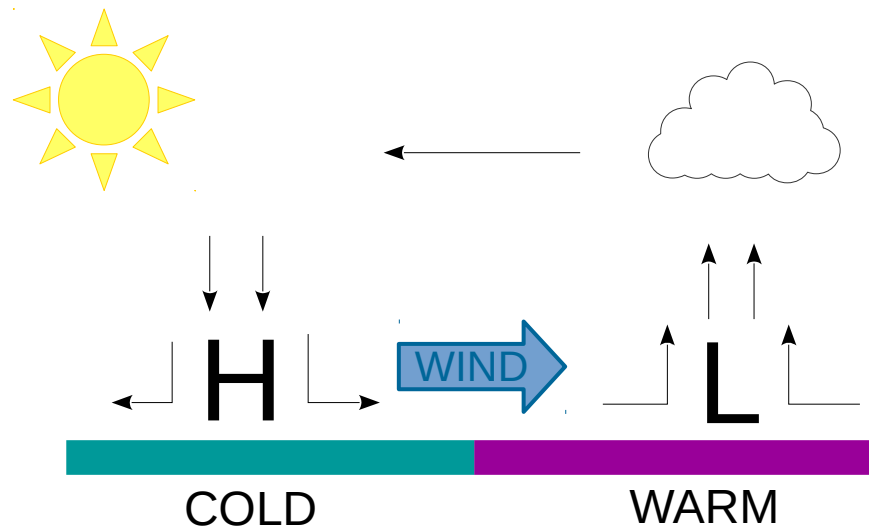
Outline

- Introduction to the winds in the Northern Europe
- Data: ERA5 climate reanalyses and the installed capacity in Finland
- First results on the frequency of weak winds
- Correlation analyses
- Summary: is it always windy somewhere in the North?
- Wind above a smooth surface and a forest – how do they differ?



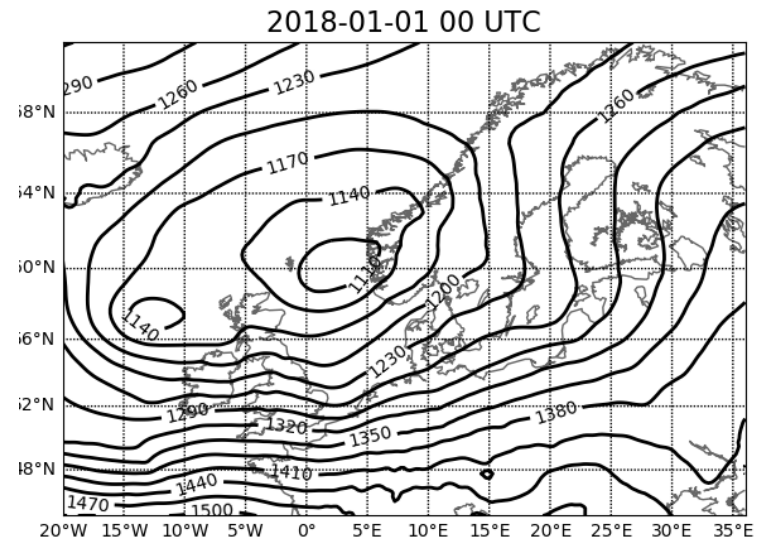
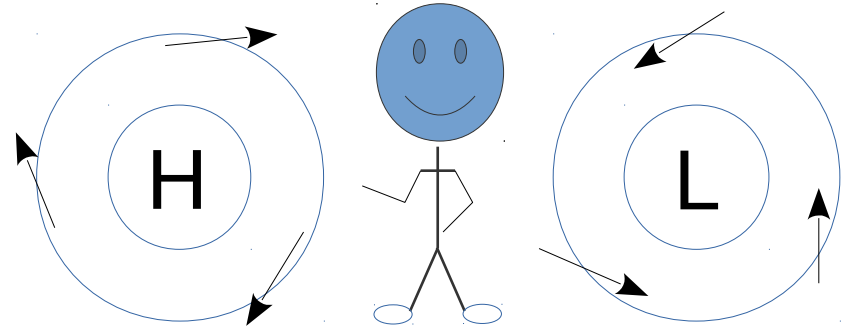
Wind – what is it?

- Wind is movement of air caused by uneven distribution of heat in the earth system causing horizontal pressure differences in the atmosphere
- The flow direction is usually from higher towards the lower pressure



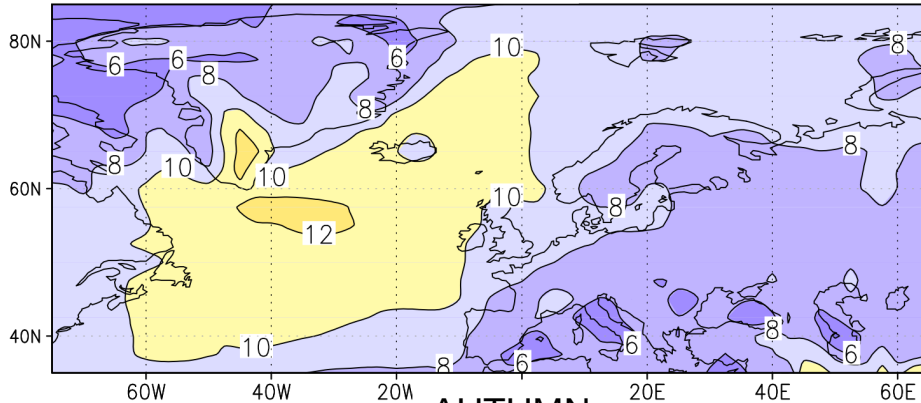
Wind in the large scales

- In the large scale (O~1000 km): the Coriolis force (due to Earth's rotation) affects, turning the wind parallel to isobars
- Near the surface, however, the flow is slightly towards the lower pressure because of friction
- The closer the isobars are to each other, the stronger the wind
- Cyclones = the low pressure systems (L) typically travel from southwest to northeast
- The path of cyclones is called the storm track

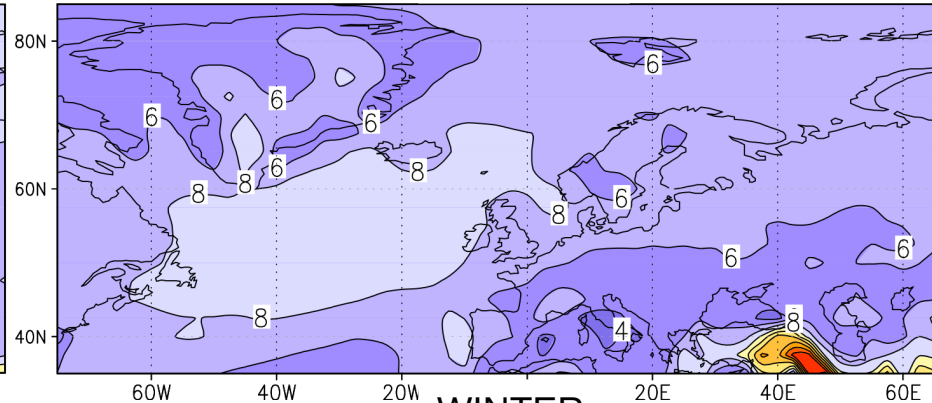


Winds in the free atmosphere

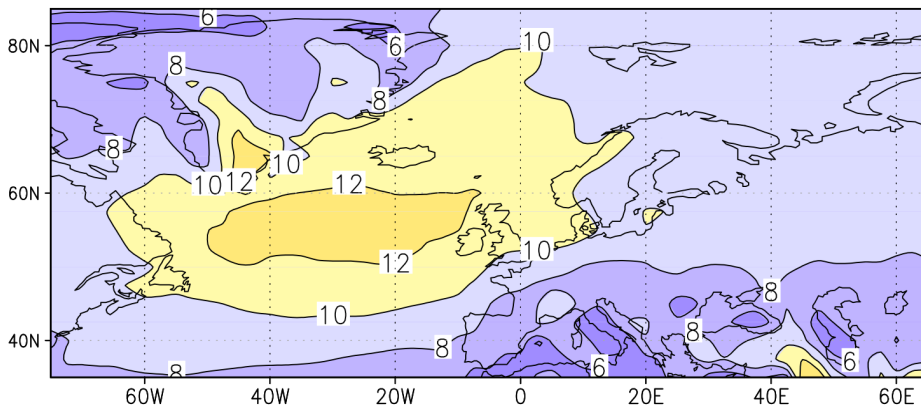
SPRING



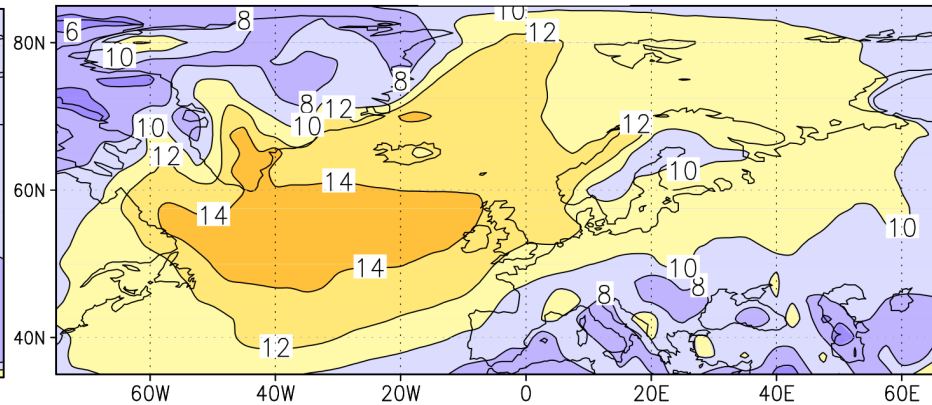
SUMMER



AUTUMN



WINTER



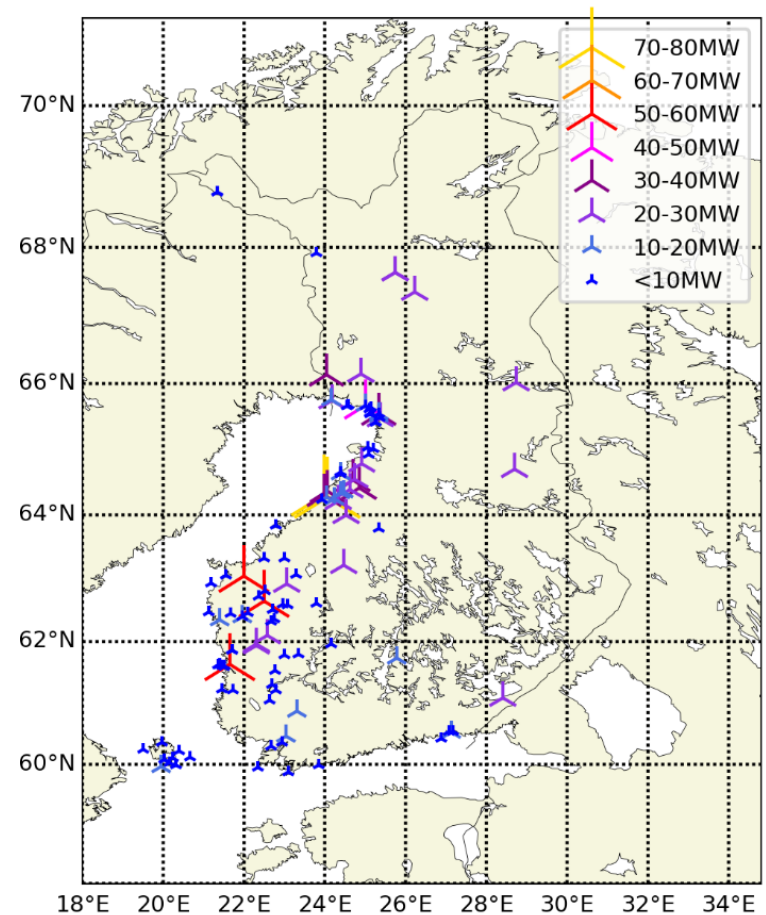
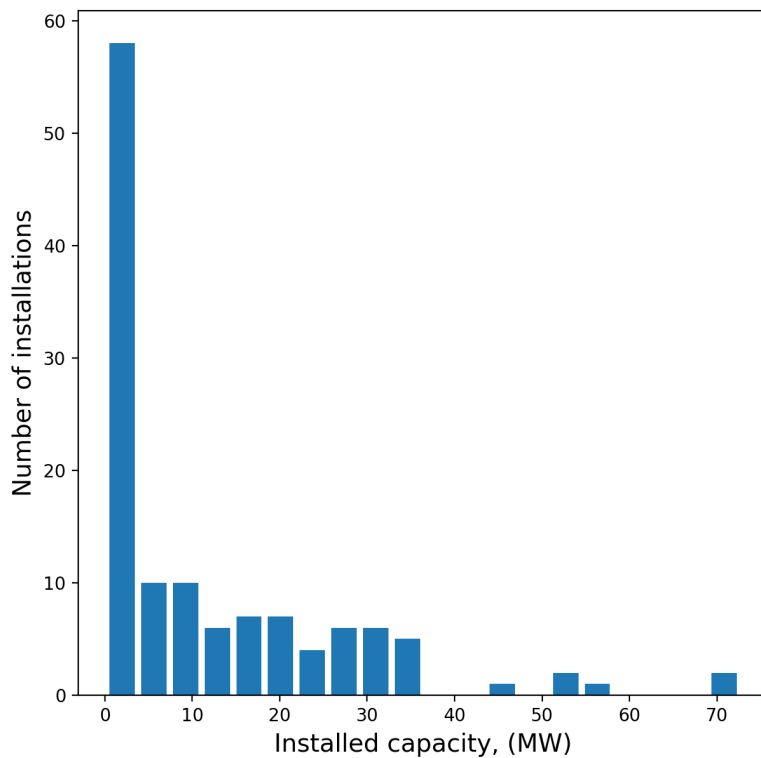
ERA40 reanalyses (ECMWF), period: 1971-2000
by Kimmo Ruosteenoja

The data in this study: ERA5 climate reanalysis

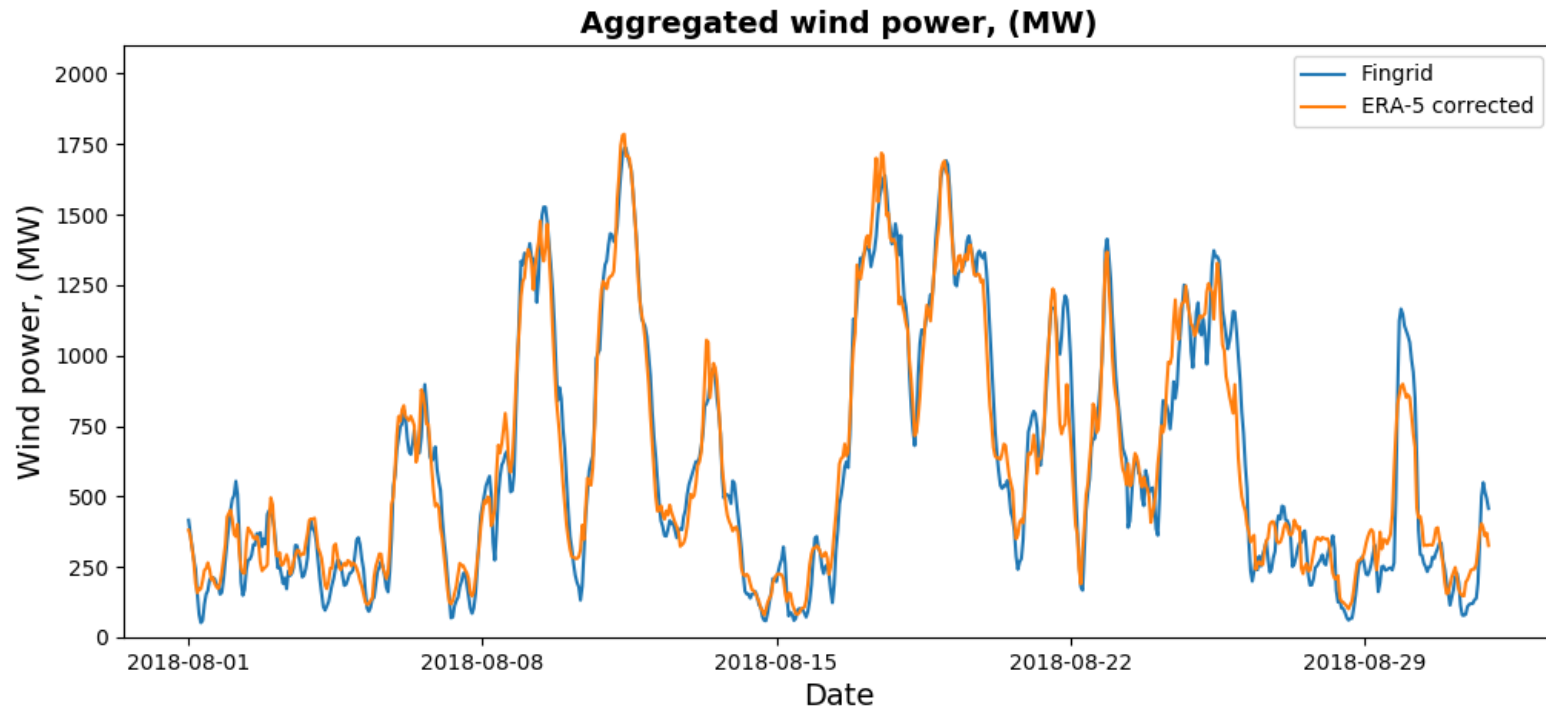
- A numerical description of the recent climate, produced by combining models with observations
- Contains estimates of atmospheric parameters such as wind, air temperature and pressure at different altitudes
- Covers all locations on earth with about 30 km horizontal resolution, and 137 vertical levels up to 80 km
- 1 hour temporal resolution
- Time period of this study 1979-2018 (20 years)
- This study is based on wind speed at 100 m level



Installed capacity by location (2018) used in calculations



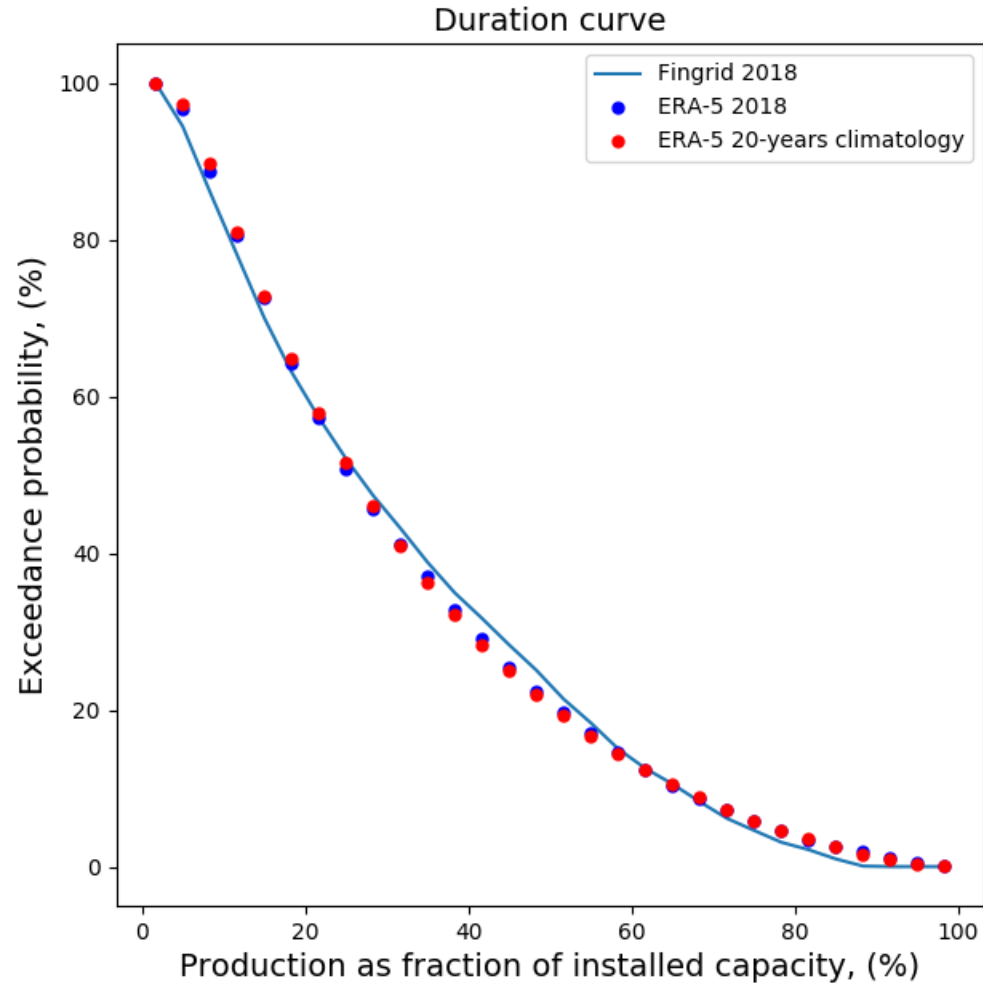
Validation of ERA5 based wind power production against Fingrid data



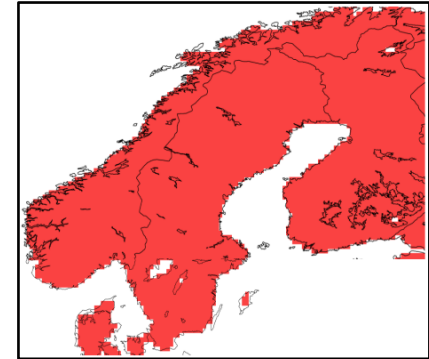
- aggregated wind power including all wind turbines
- wind power for each wind turbine was calculated using optimized theoretical power curve specific for that wind turbine
- results are based on ERA5 100 m winds
- the bias between ERA5 and Fingrid data has been removed on monthly basis



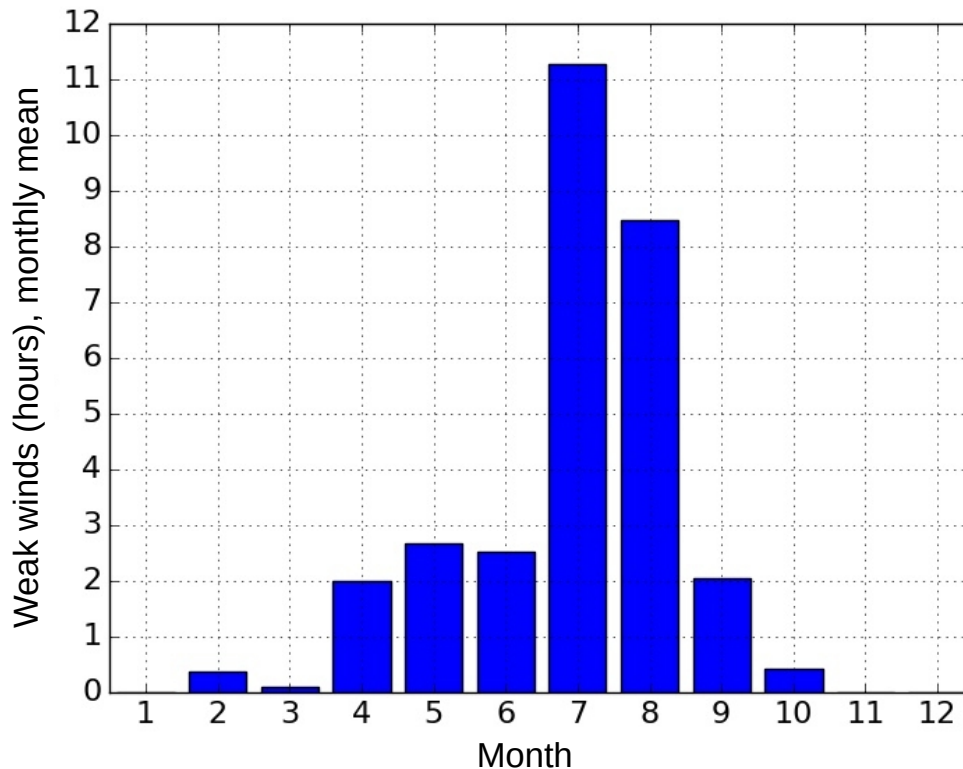
Validation of ERA5 against Fingrid data: wind power in Finland in 2018



The first results on the frequency of weak winds



Average number of calm hours per month:



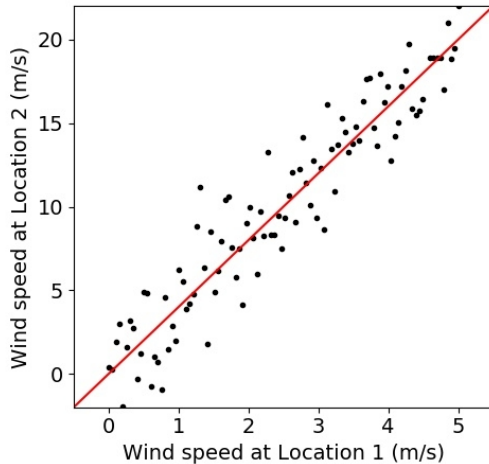
- Statistics have been calculated for the land areas shown in red
- Data: ERA5 reanalysis (ECMWF)
- Period: 2000-2018 (19 years)
- Criteria for a weak wind condition:
 - Wind speed at 100 m height less than 4 m/s
 - Criterion is fulfilled at least over 90% of the land areas simultaneously
 - Temporal resolution of data: 1 h



Correlation analysis: examples

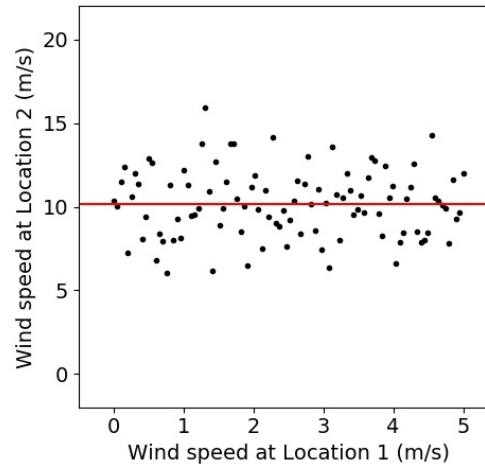
High correlation

$r = 0.94$



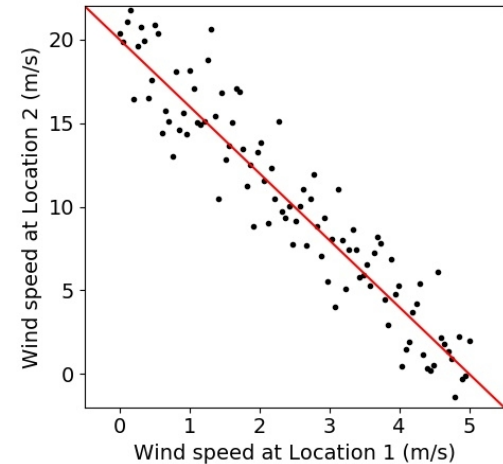
Low correlation

$r = -0.02$



Negative correlation

$r = -0.95$



High correlation: weak wind at location 1 → weak wind at location 2

Negative correlation: weak wind at location 1 → strong wind at location 2

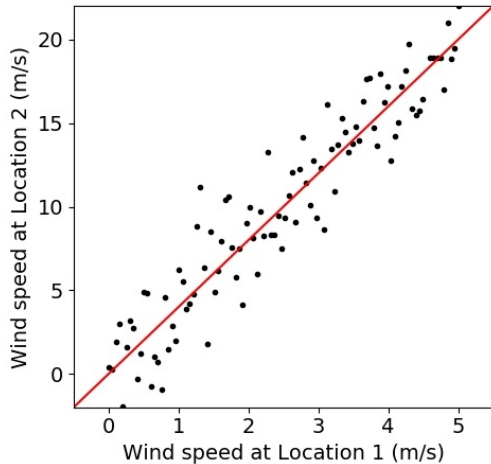
No correlation: weak wind at location 1 → weak or strong wind at location 2



Correlation analysis: examples

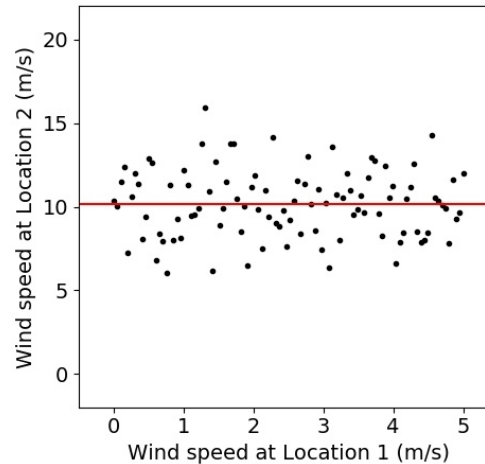
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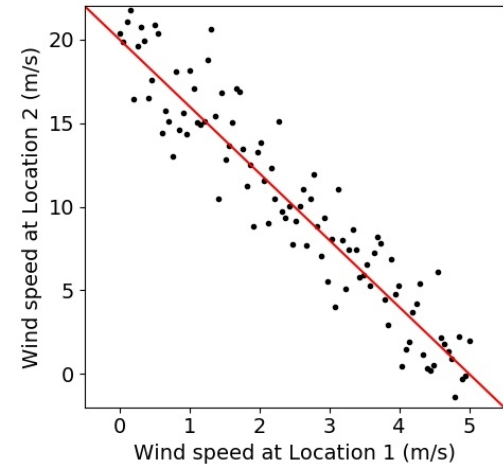
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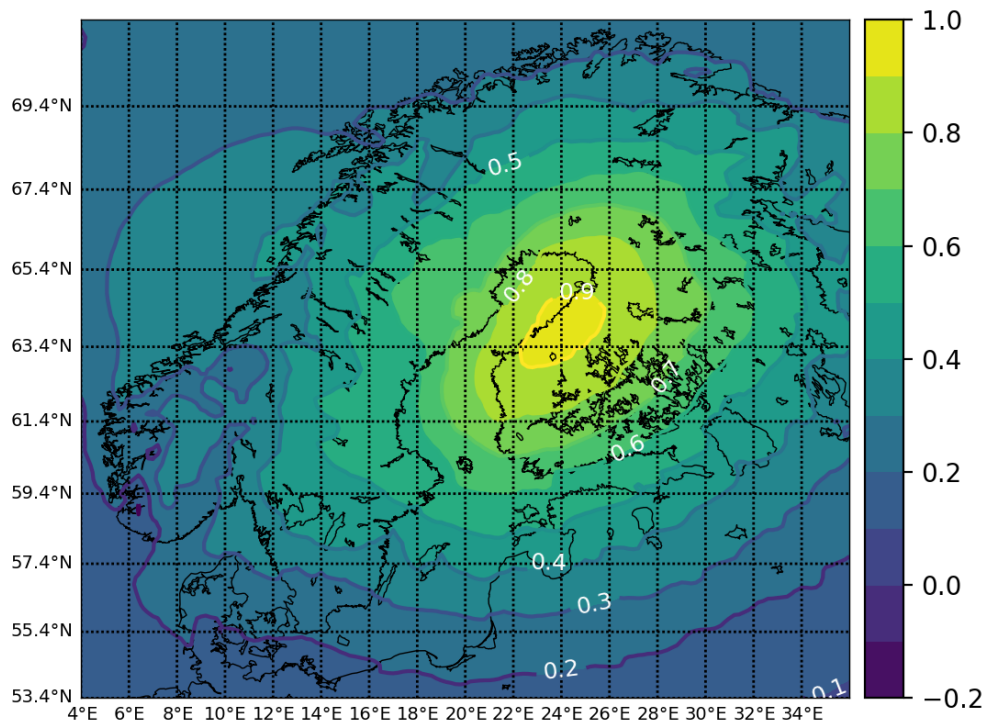
Negative correlation: weak wind at location 1 → strong wind at location 2

No correlation: weak wind at location 1 → weak or strong wind at location 2

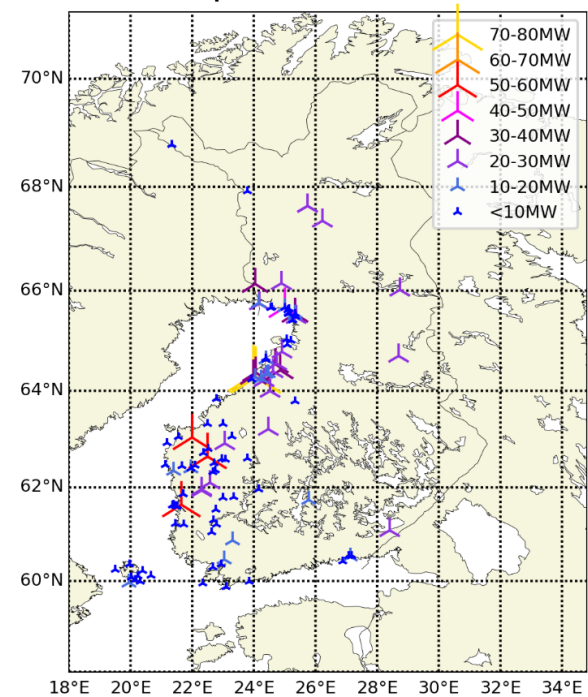


Correlation analysis

Correlation between the aggregated wind power density of the Finnish wind power fleet ($WPD_{aggregated}$) and the wind power density from ERA5 at all grid points (Pd_{grid}) during 1999-2018 (20 years)



Wind power installations:



Wind power density:

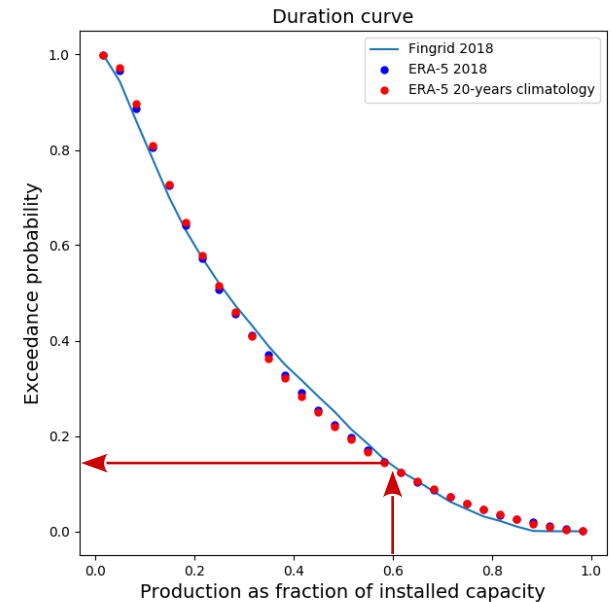
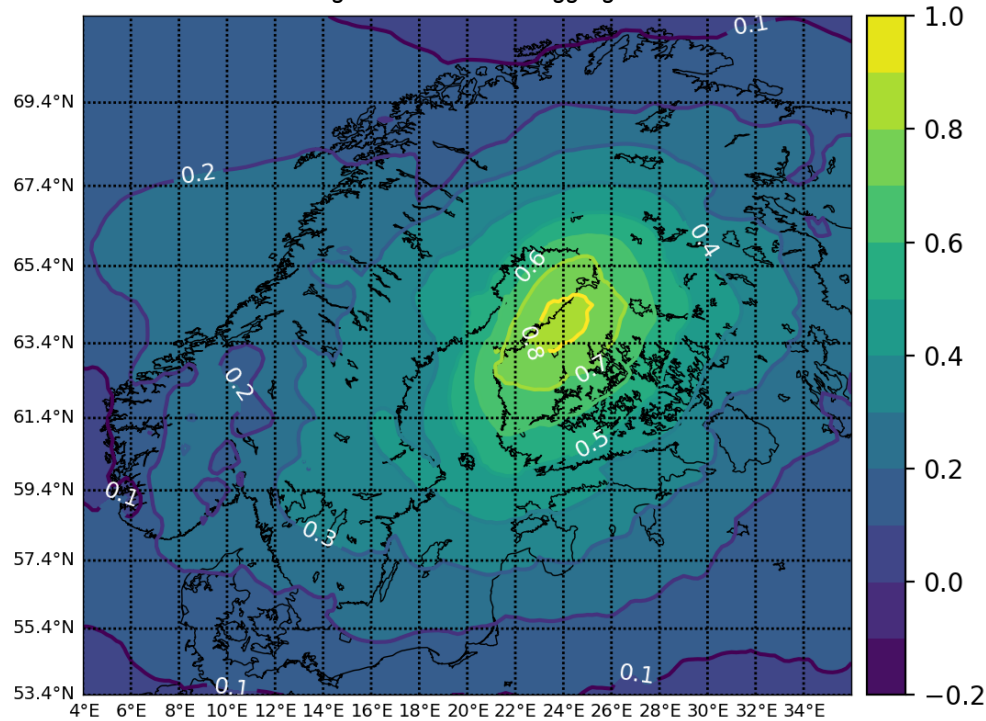
$$PD = 0.5 \rho_{air} U^3$$

(ρ_{air} = air density, U = wind speed)

Correlation analysis

Cases with **high production**: > 60% of installed capacity

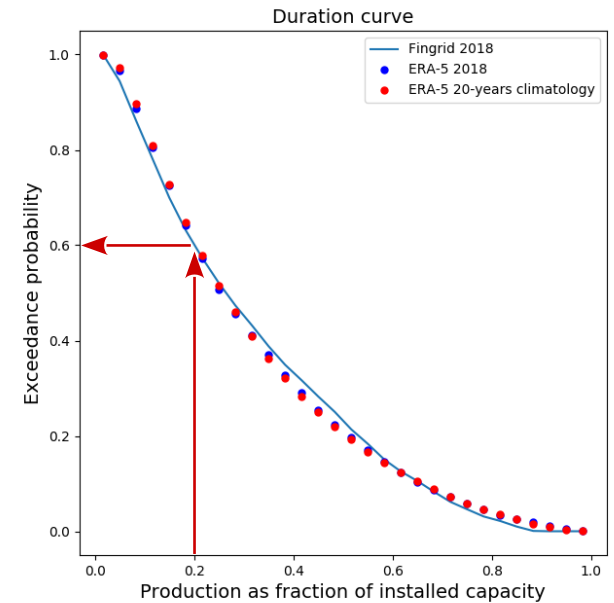
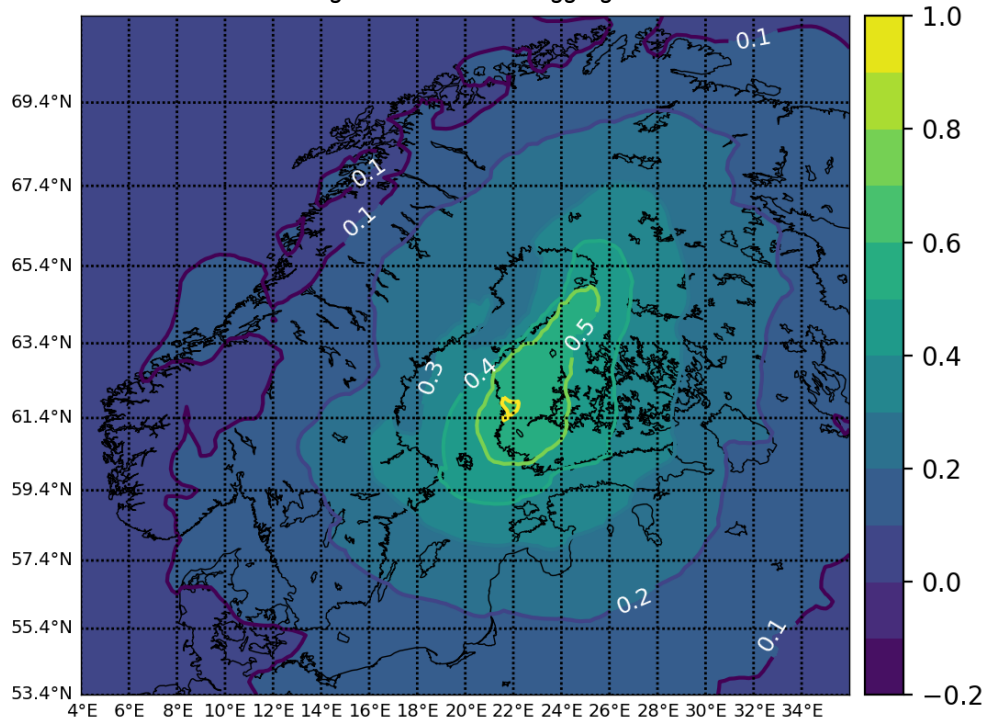
Correlation:
 PD_{grid} vs $WPD_{aggregated}$



Correlation analysis

Cases with **low production**: < 20% of installed capacity

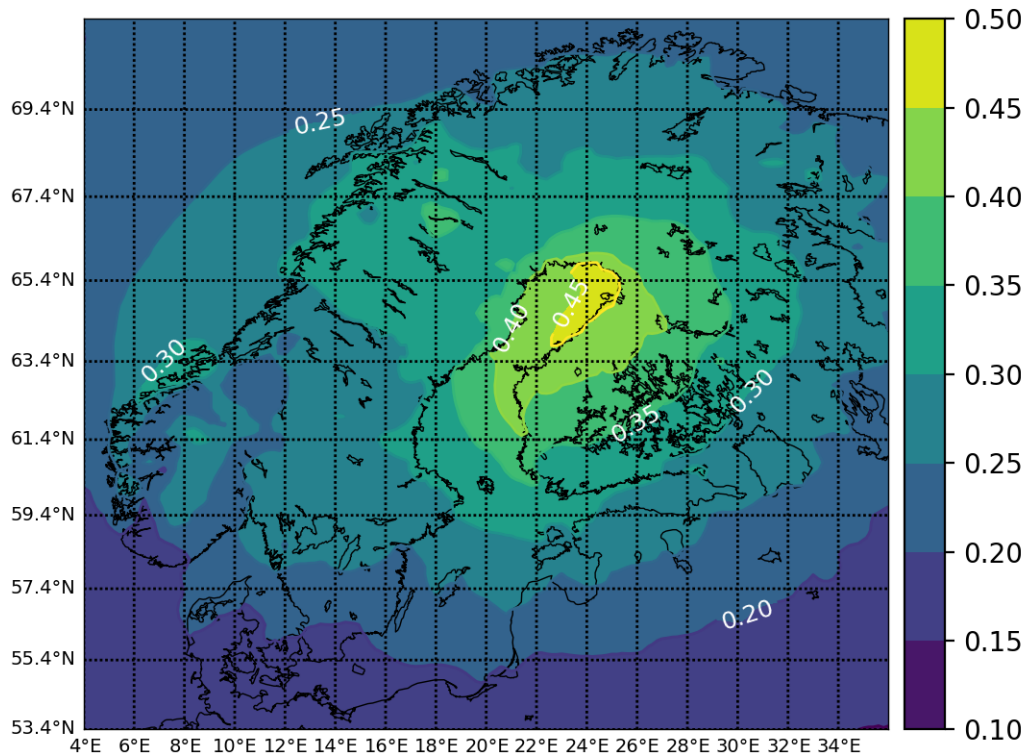
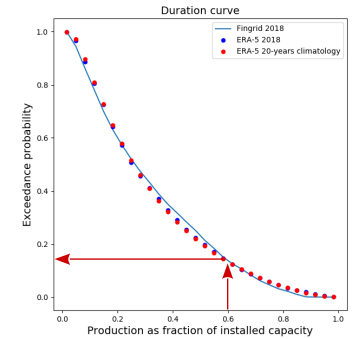
Correlation:
 PD_{grid} vs $WPD_{aggregated}$



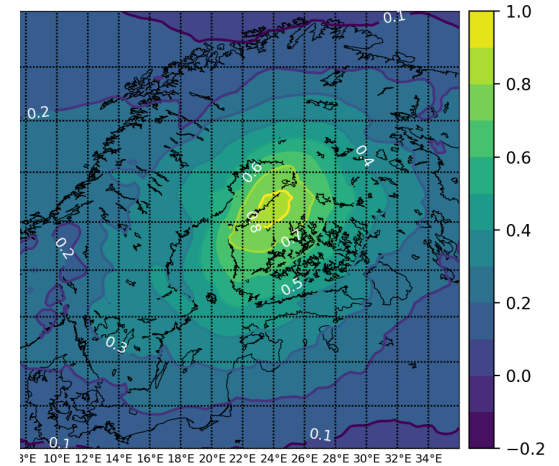
Correlation analysis

Cases with **high production**: > 60% of installed capacity

Fraction of the total power density:



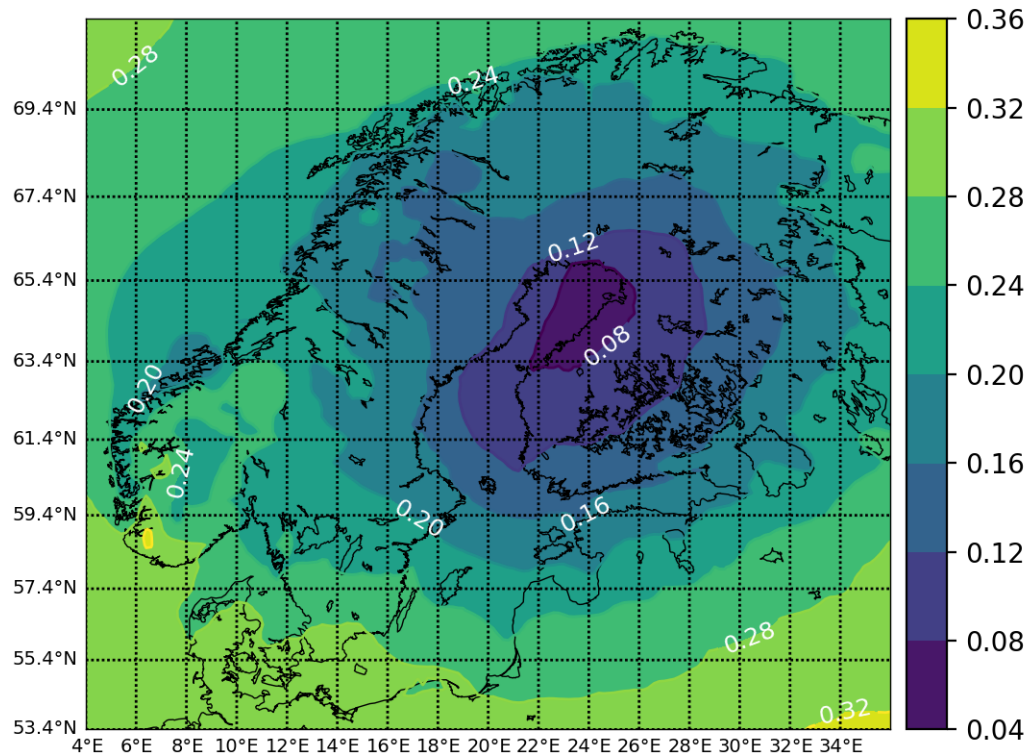
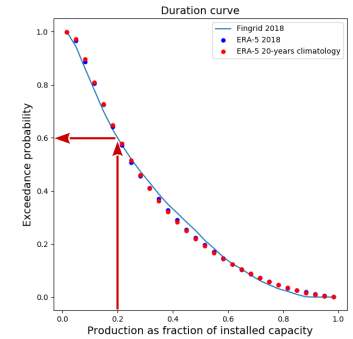
Correlation:
 PD_{grid} vs $WPD_{aggregated}$



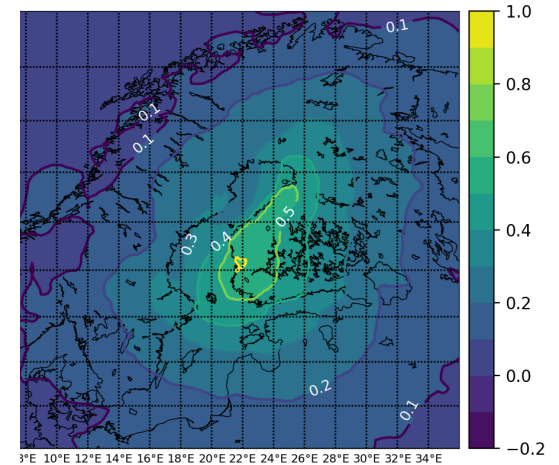
Correlation analysis

Cases with **low production**: < 20% of installed capacity

Fraction of the total power density:



Correlation:
 PD_{grid} vs $WPD_{aggregated}$



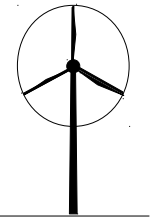
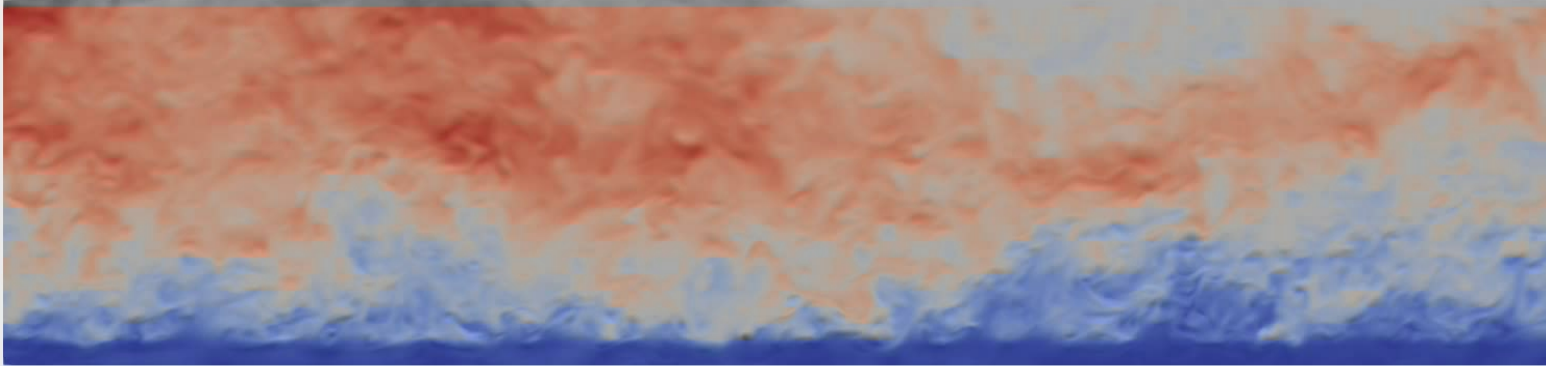
The Winds of North: Is It Always Windy Somewhere?

- **Yes** - there is wind always somewhere in the study region
- Correlation analyses were applied to detect areas that could potentially support the existing wind power installations in Finland when their production is low.
- The results show that the aggregated wind power production in Finland is centered over the western Finland, and the correlation decreases fairly uniform in all directions.
- Minimum correlations within the study area were close to zero, which means that no other location alone can compensate Finnish wind power production at low production conditions
- The fraction of total wind power density in low production situations was up to about 16-20% higher in Denmark and coastal regions of Norway than in Finland. In Finnish Lapland, the fraction was about 10% higher than in the western Finland.
- The research is still ongoing. Further investigations are needed, for example, to understand the seasonal variability of the results. We could also include wind power installations from other countries in the area.
- In this study, we did not take into account the environmental conditions special for Northern Europe, for example, icing conditions in the cold climate (<http://www.tuuliatlas.fi/icingatlas/>)
- The rough forest surface is also an important factor when planning new onshore wind energy...

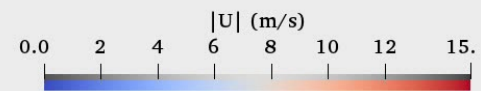
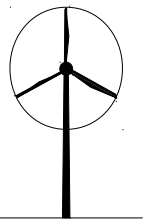
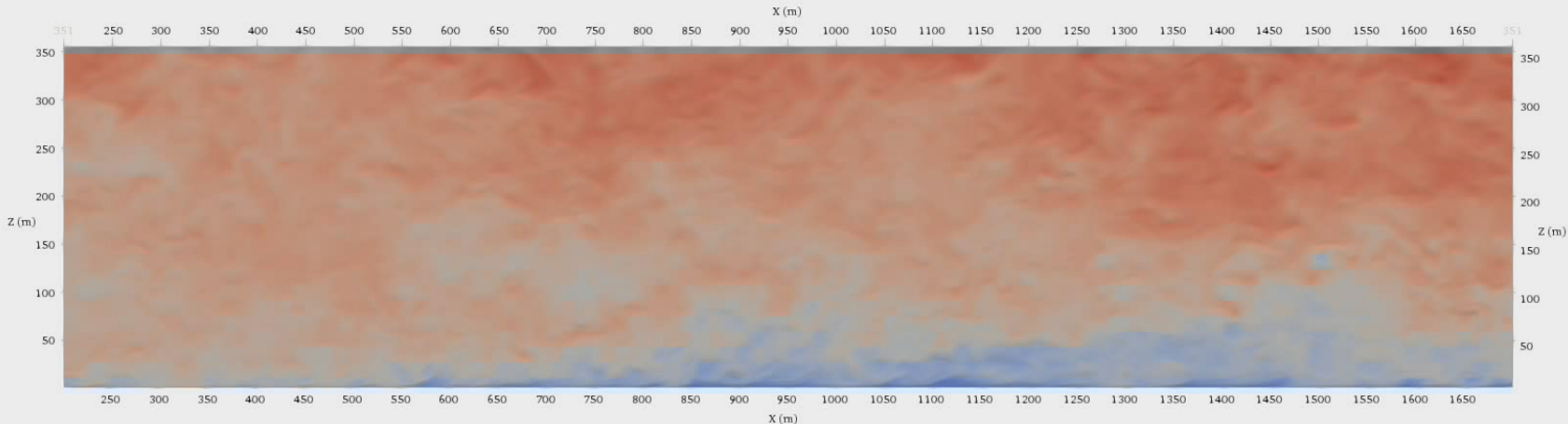


Wind above a forest – how does it differ from that over a flat surface?

Wind over forest canopy. Mean height of trees $H=25$ m.

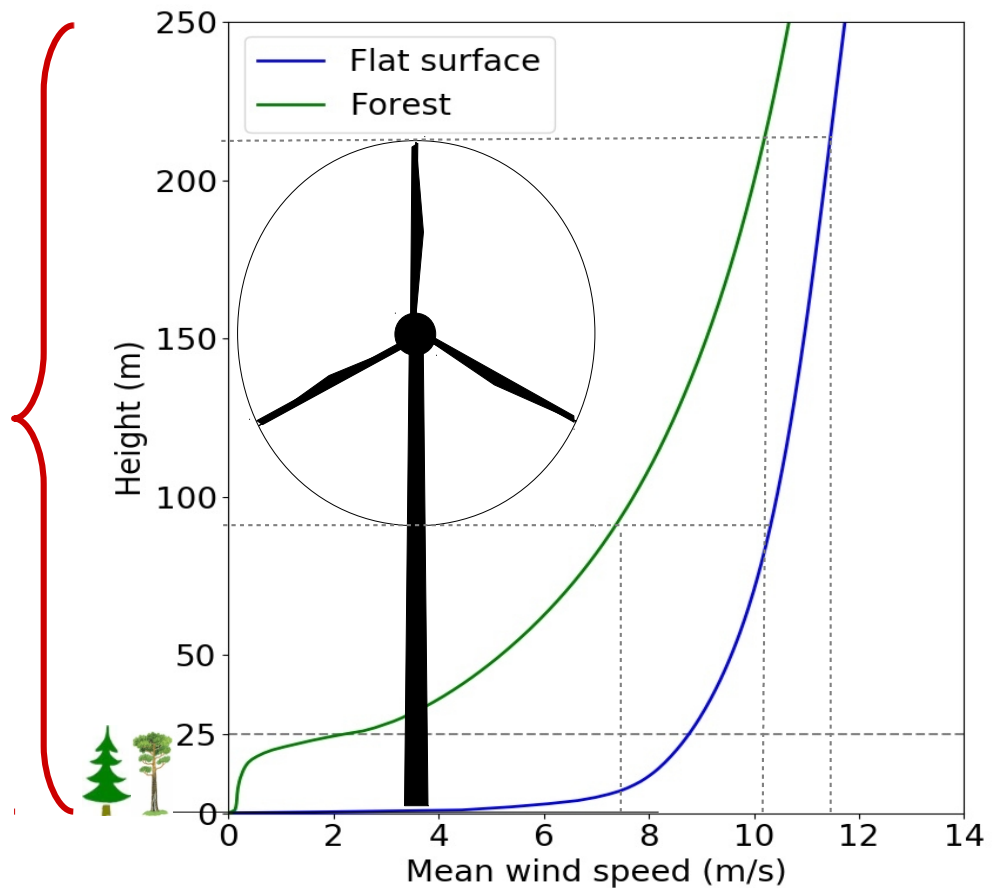
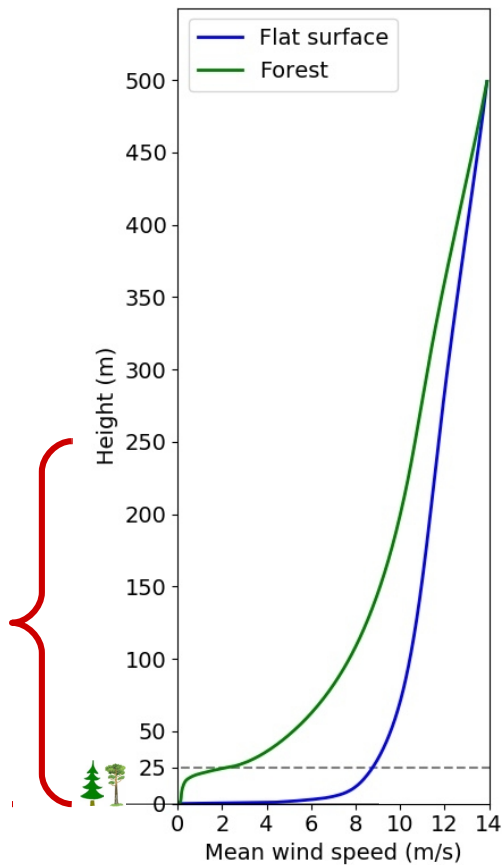
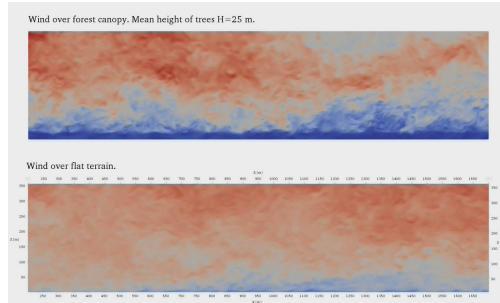


Wind over flat terrain.



Time: 2 min

Wind profile over the forest and the flat surface





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Thank You!

We are here for your questions:



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