

# Wind Fluctuations at Horns Rev

## IEA workshop on Power Fluctuations

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(WEPROG ApS).

# Overview

Motivation

Approaches

Identification

Characterisation

Verification

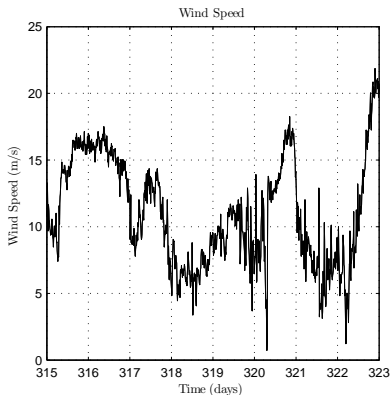
Modelling

The Future

Conclusions

# Motivation

- Severe variability is observed at Horns Rev
  - High concentration of turbines within a limited geographical area
  - Meteorological conditions associated with flow from the sea



# Approaches

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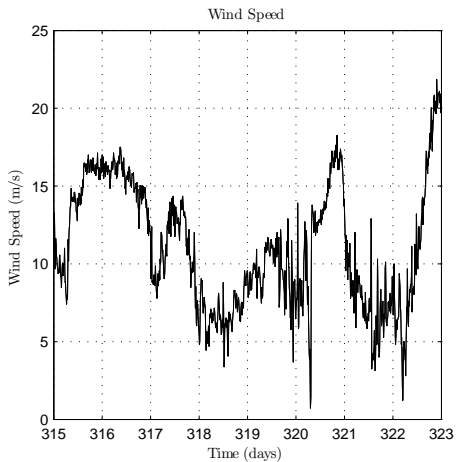
- Identification
  - Definition of variability and severe variability
- Characterisation
- Verification of existing models
  - How much of the total forecast variance is occurring on small scales?

# Approaches

- Identification
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  - How much of the total forecast variance is occurring on small scales?
- Modelling
  - Understand the physics
  - Make the forecasts as good as possible

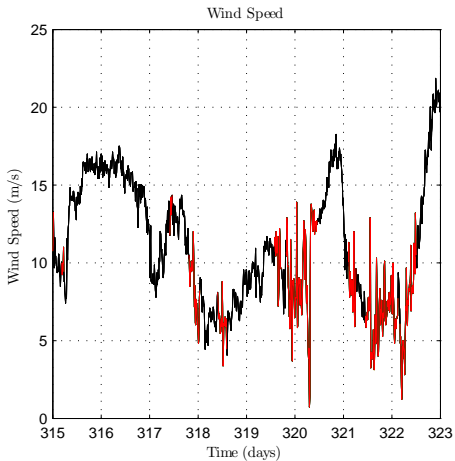
# Identification

- By eye?

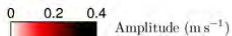
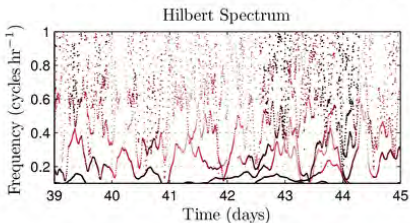
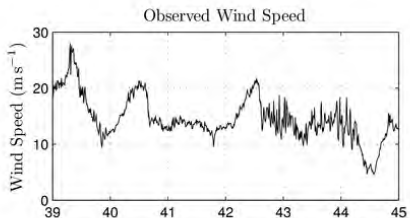


# Identification

- Variability: When is there enhanced spectral intensity?



# The Hilbert spectrum

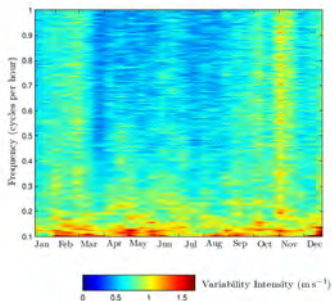


## Benefits and Draw-backs of the method

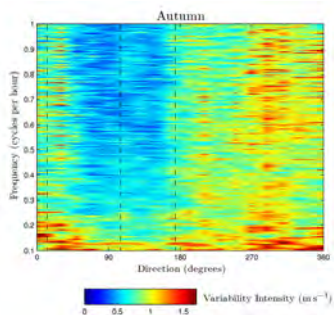
- ✗ Empirical decomposition: Lack of mathematical formulation
- ✗ Orthogonality and uniqueness of decomposition
- ✗ Need  $4\Delta t$  to resolve variance (compare with  $2\Delta t$  for Fourier transform)
- ✓ Local, non-parametric decomposition with no *a priori* decision about shape of basis functions
- ✓ Time evolving spectrum which responds quickly to non-stationarity
- ✓ Can create conditional spectra from non-consecutive parts of the time series

# Conditional Spectra

## Time of year

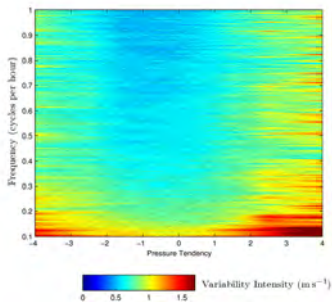


## Wind direction

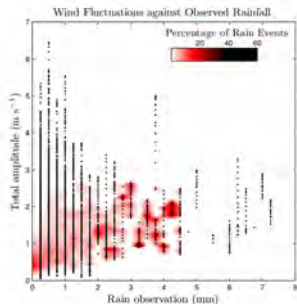


# Conditional Spectra

## Pressure Tendency



## Rain



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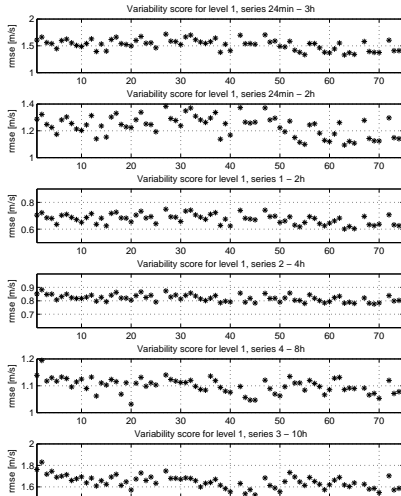
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- Combining these facts, high risk conditions seem to be unstable, post-frontal, and showery, with flow coming from the North Sea.

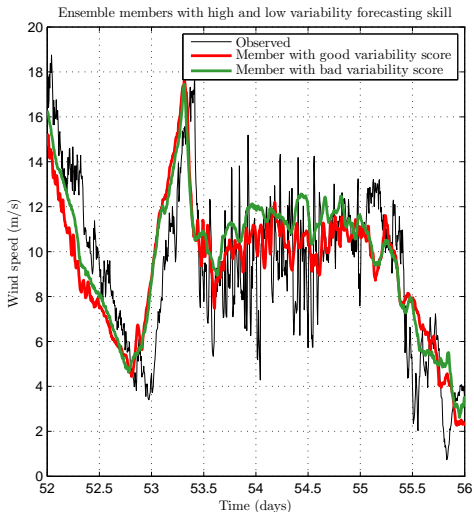
# Verification

- The model
    - 75 member Mesoscale Ensemble Prediction System (MSEPS)
    - Run by Danish company WEPROG
    - 10 month timeseries at Horns Rev with temporal resolution of about 6 minutes for this study
  - Verification
    - Hilbert-Huang transform all the forecasts
    - Calculate scalar time series of variability on several different time scales
    - Compare with the analagous observed variability time series
- ⇒ An interesting way of doing spectral verification!

# Verification Results

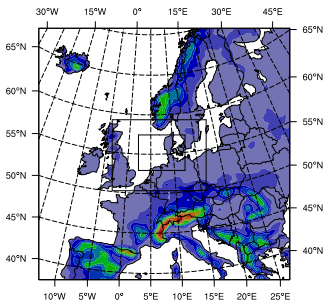


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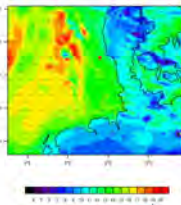
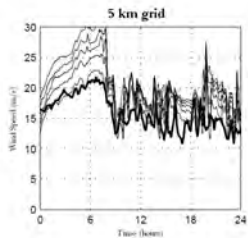
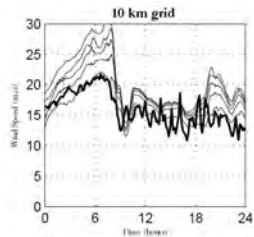
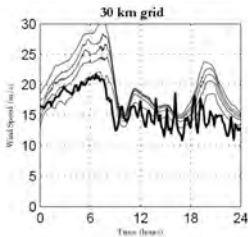


# WRF

- Open-source numerical weather prediction model
- Can run on different scales, from global model to Large Eddy Simulation model
- Initial conditions and boundary conditions freely downloadable from NCEP (US)
- Nested domain over Horns Rev: First stages!



# WRF: (very) preliminary results



# Future

- Understand the model
- Use the model to understand the physics
- Use the model to suggest forecasting tools

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- Complex problem to define “FLUCTUATIONS”
- We define it as spectral energy within a certain frequency range
- Some climatological trends have been uncovered
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Horns Rev Mast 2 data was provided by Vattenfall as part of the Danish PSO project ‘HRESNSEMBLE - High Resolution ENSEMBLEs for Horns Rev, under contract PSO-6392’. Precipitation data from the meteorological station at Blåvandshuk was also provided by DMI. MSEPS model data was kindly provided by WEPROG ApS.