

## Monitoring and characterizing offshore wind variability with weather radars for wind energy applications

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# Monitoring and characterizing offshore wind variability with weather radars for wind energy applications

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# Google search: “wind energy + weather radar”

<https://www.google.com/#sclient=psy-ab&q=wind+energy+%2B+weather+radar&oq=wind+energy+%2B+weather>

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Environ 26 300 000 résultats (0,29 secondes)

[PDF\] Doppler Weather Radars and Wind Turbines - InTech](#)  
[www.intechopen.com/download/pdf/35119](http://www.intechopen.com/download/pdf/35119) - Traduire cette page  
 0. Doppler **Weather Radars** and **Wind Turbines**. Lars Norin and Günther Haase. Swedish Meteorological and Hydrological Institute. Sweden. 1. Introduction. Vous avez consulté cette page 2 fois. Dernière visite : 12/06/13

[Wind Turbine Interference with Weather Radar](#)  
[www.ec.gc.ca/meteo-weather/default.asp?lang=En...](http://www.ec.gc.ca/meteo-weather/default.asp?lang=En...) - Traduire cette page  
 30 avr. 2013 – Information for **wind farm** developers and the general public on the interference between **wind turbines** and **weather radar** in Canada.

[Weather radar - Wikipedia, the free encyclopedia](#)  
[https://en.wikipedia.org/wiki/Weather\\_radar](https://en.wikipedia.org/wiki/Weather_radar)  
 Aller à [Wind farms](#) – [edit]. Reflectivity (left) and radial velocities (right) southeast of a NEXRAD **weather radar**. Echoes in circles are from a **wind farm**.

[IEEE Xplore - Wind Turbine Clutter mitigation for weather radar by ...](#)  
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**Wind Turbine** Clutter (WTC) is the **radar** clutter caused by strong backscatter from large **wind turbines** within the **radar** vicinity. Due to the rotation of the rotor ...

[Concerns Grand Bend wind turbines could affect weather radar](#)  
[london.ctvnews.ca/concerns-grand-bend-wind-turbine...](http://london.ctvnews.ca/concerns-grand-bend-wind-turbine...) - Traduire cette page  
 21 févr. 2013 – Tests on the proposed Grand Bend **Wind Farm** indicate it could cause problems for Environment Canada's **weather radar** station in Exeter, Ont.

[Wind Farm Interference Showing Up on Doppler Radar - National ...](#)  
[www.erh.noaa.gov/buf/windfarm.htm](http://www.erh.noaa.gov/buf/windfarm.htm) - Traduire cette page  
 6 juin 2009 - The National Weather Service in Buffalo, NY, serves the Western and

# Building wind power forecasts – The Danish offshore experience



## (summarized) DIALOGUE

- **wind farm operator (wfo):** "I observe significant differences in wind power variability onshore and offshore. How come such differences?"

- **meteorologist:** "This is because of large offshore wind farm layout concentrating many wind turbines within a small geographical area. There is no smoothing effect!"

- **meteorologist:** "But not only. Offshore wind dynamics are also very different owing to enhanced convection over waters."

- **wfo:** "It is true. I often observe very intense rain showers during episodes of large wind (power) fluctuations."

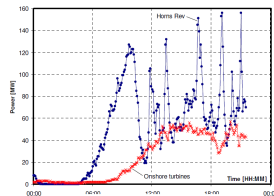
- **statistician:** "I don't understand the causes but wind time series show very sudden changes in variability."

- **meteorologist:** "I performed a mesoscale analysis of the weather and I also noticed that enhanced wind fluctuations are often correlated with the occurrence of heavy precipitation in the vicinity of the wind farm."

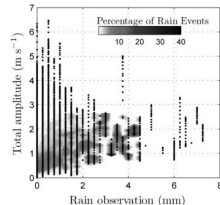
- **wfo:** "Can you provide me with new/specific wind power forecasts so that I can better handle these situations?"

- **meteorologist:** "I could use a weather radar to monitor weather conditions in the vicinity of the wind farm and assimilate precipitation data into a local NWP models."

- **statistician:** "I could ultimately develop regime-switching models based on the NWP forecasts and the information provided by the weather radar."



(Source: Kristoffersen (2005))



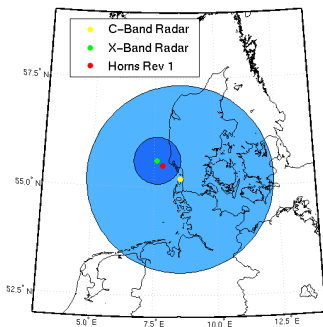
(Source: Vincent et al. (2011))

# Radar@Sea (2009-2012) – Partners



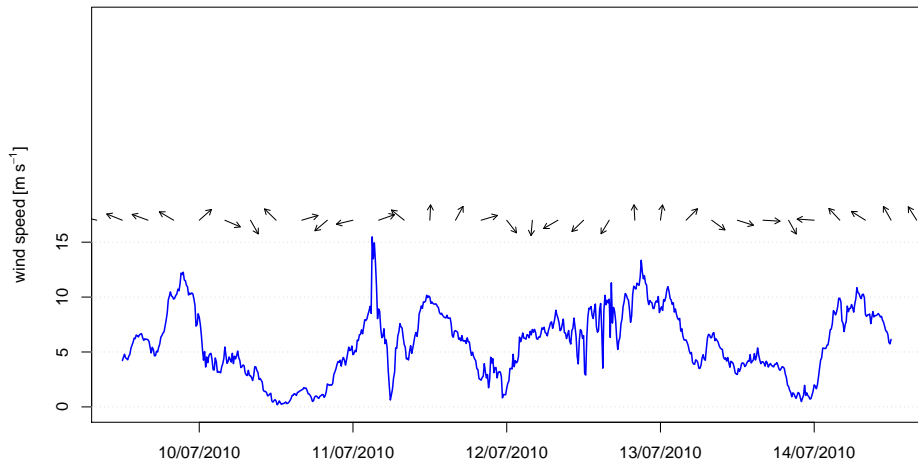
# Experimental design

	● LAWR (X-Band)	● Doppler (C-Band)
Location	Offshore (~15 km from HR1 ●)	Onshore (~70 km from HR1 ●)
Range	small	long
Spatial resolution	fine	coarse
Temporal resolution	high	low



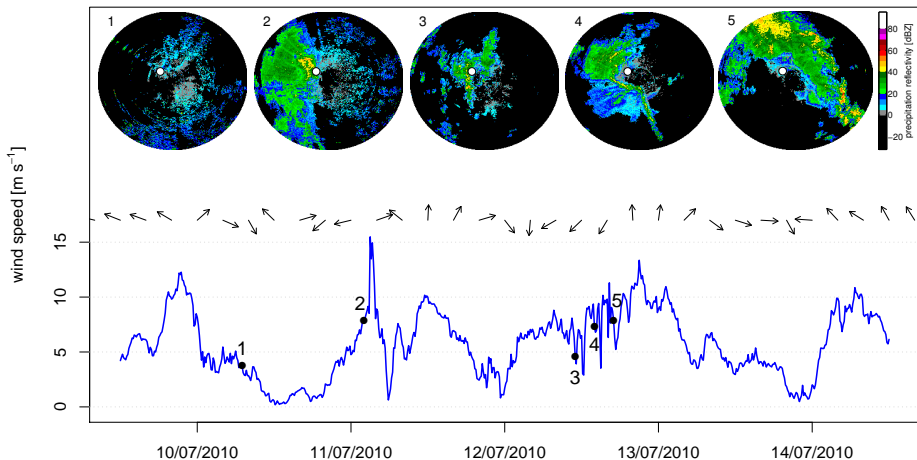
X-Band radar at Horns Rev

# Data example: Summer season



[[video \(click here\)](#)]

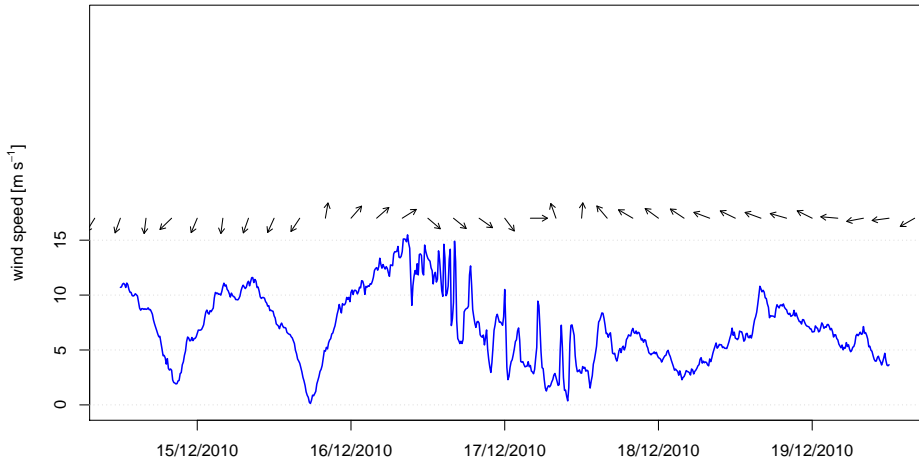
# Data example: Summer season



[video (click here)]

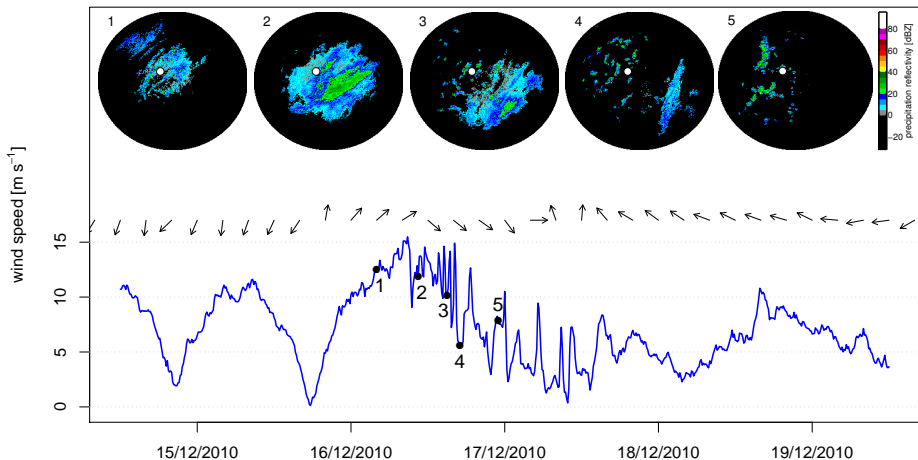


# Data example: Winter season



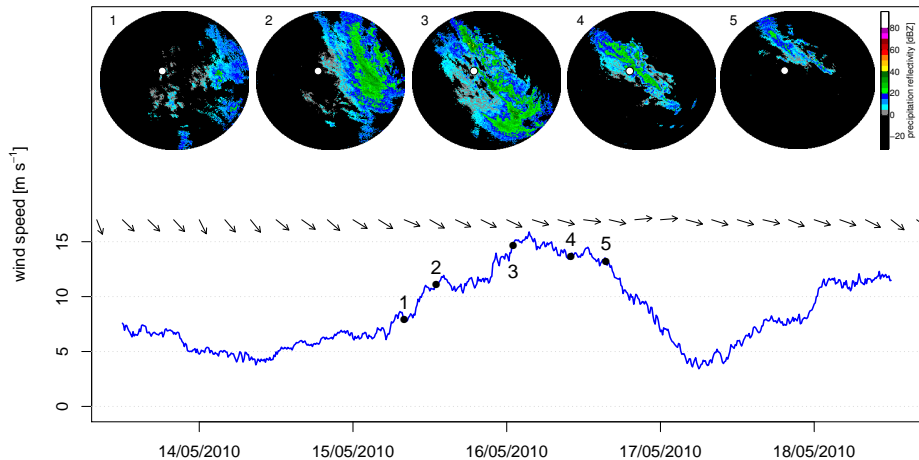
[video (click here)]

# Data example: Winter season



[video (click here)]

# Data example: Spring season



[video (click here)]

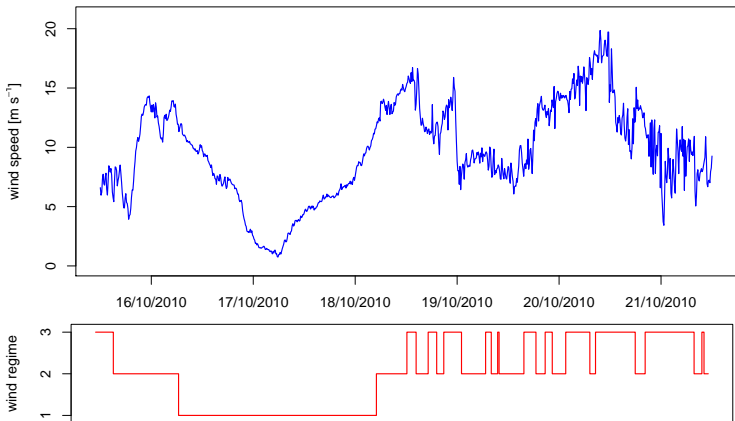
# Status & Goals

- The assimilation of weather radar data (Doppler C-Band) into a local NWP models has just started,
- So far, most work consisted of data mining (i.e, explorative analysis of the data with statistical tools):
  - objective: improve the understanding of offshore wind speed variability with the information extracted from weather radar observations,
  - initial focus on the observations produced by the Doppler C-Band,
  - develop automatic procedure (with very little knowledge expert)
- Present results in a easy-to-interpret manner:
  - graphic based,
  - low dimensional outputs.

# Wind speed variability index

- **Time series segmentation**

Markov-Switching model + Global Decoding algorithm = categorical index

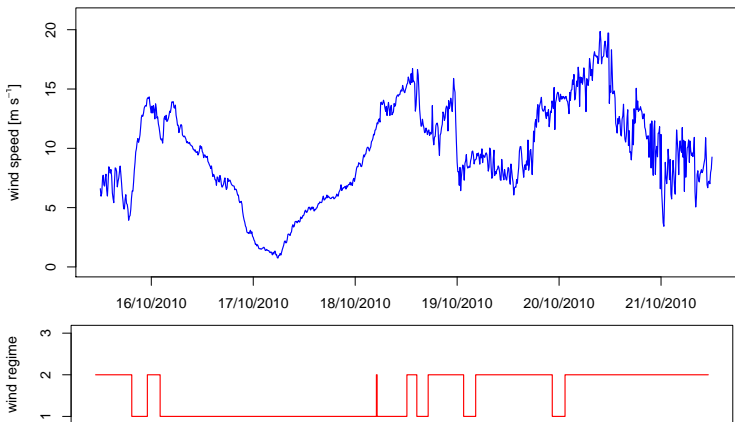


**Figure:** Segmenting into 3 regimes

# Wind speed variability index

- **Time series segmentation**

Markov-Switching model + Global Decoding algorithm = categorical index

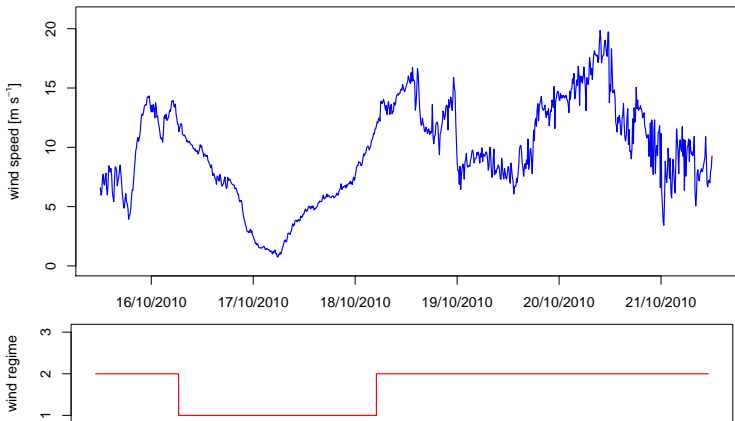


**Figure:** segmenting into 2 regimes

# Wind speed variability index

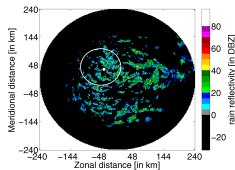
- **Time series segmentation**

Markov-Switching model + Global Decoding algorithm = categorical index

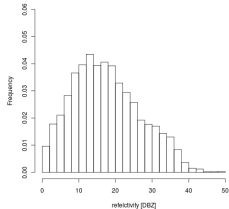


**Figure:** Segmenting into 3 regimes initially but merging regimes #2 and #3

# Global attributes from weather radar images

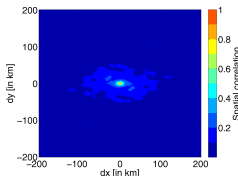


Reflectivity distr.



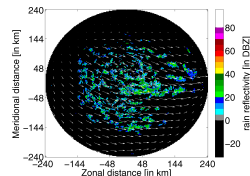
median, quantile 99%  
(robust estimator of  
maximum value), ...

Spatial Continuity



Area & Ellipticity

Motion

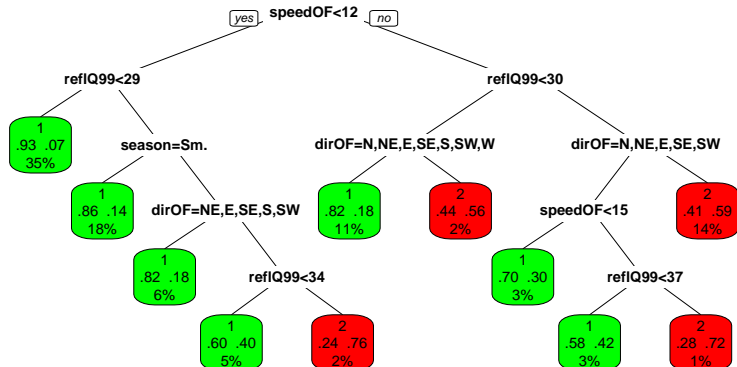


Speed & Direction



# Wind variability classification

- Method: Classification and Regression Trees (CART)



- learning #1: importance of particular attributes (speed, direction and max reflectivity),
- learning #2: we cannot go global, need for local attributes.

# Conclusion

- There is a mutual interest for weather radar and wind energy communities to collaborate,
- Methodological proposal for mining offshore wind farm and weather radar data (with focus on visual representation of the results),
- Confirmation of previous results [*Vincent et al. (2011)*],
- Statistical and data mining tools can help revealing interesting insights on meteorological data for energy applications,
- Future work:
  - consider 3D weather radar observations + radial winds
  - time series analysis over multi-scale,
  - object identification on weather radar images (e.g, small convective cells and storms)
  - consider other meteorological inputs (e.g. met. forecasts from NWP models, satellite images),
  - integrate weather radar data into a prediction system.

# Thank you for your attention!

## References and further reading:

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