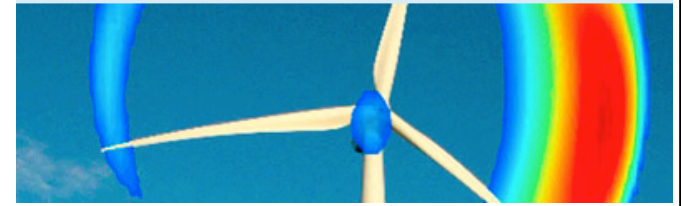




UPPSALA  
UNIVERSITET



# Amplitude modulation for different weather conditions

Conny Larsson  
Uppsala University, Sweden



EWEA Technology Workshop: Wind Turbine Sound 2014



UPPSALA  
UNIVERSITET

# Measurements

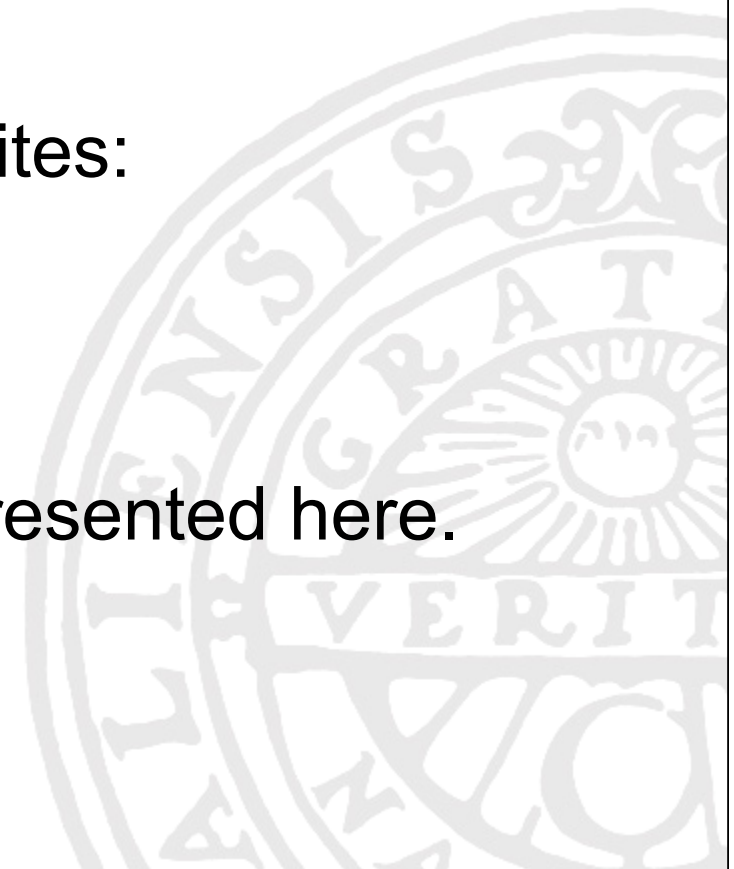
Economical support from Swedish Energy Agency  
2010-2014

Results from two Wind Turbine sites:

Forest, flat ground;

Forest, heterogeneous terrain

Special analyses of AM sound presented here.





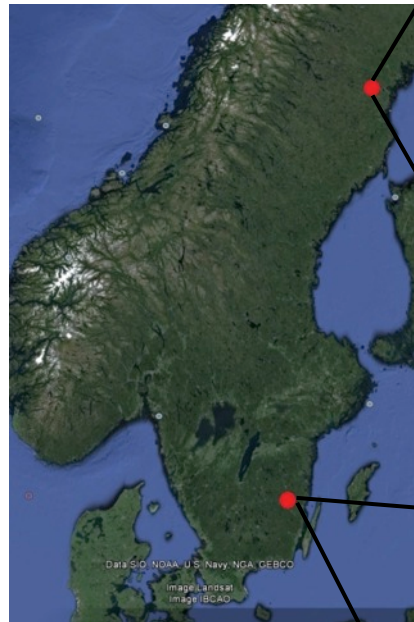
# Rythmic sound heard at distance

- Changes of the sound level occur due to the weather but does the weather also change the character of the sound at an immission point far away?
- *Oerlemans* demonstrated that mainly the downward movement of the turbine blades, as perceived on the ground, produces the swish sound.
- According to *van den Berg*, the synchronizing of sound between different WTs during propagation in a stable atmosphere could explain the thumping noise heard at greater distances from WTs.



UPPSALA  
UNIVERSITET

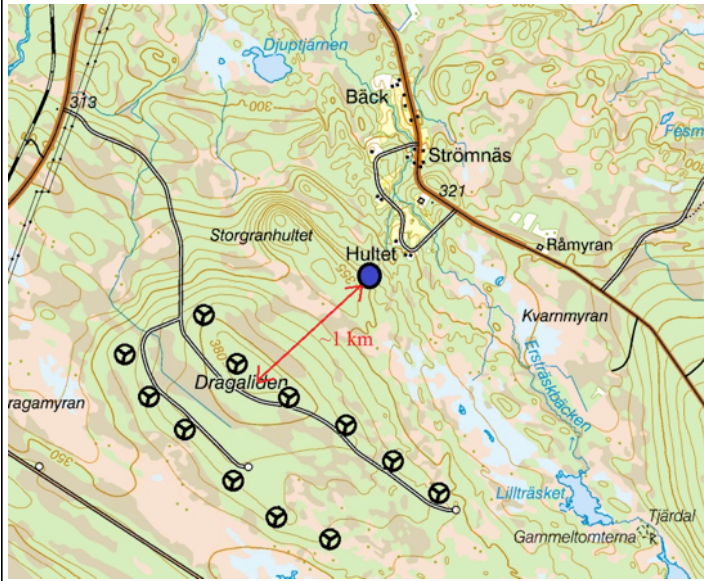
# Measurement sites





UPPSALA  
UNIVERSITET

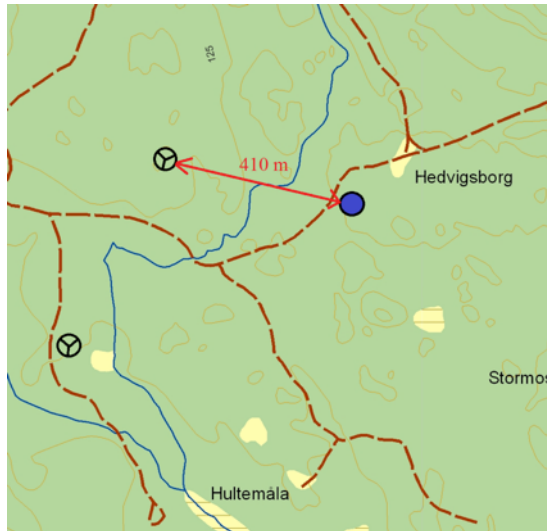
# Dragaliden, 1 km





UPPSALA  
UNIVERSITET

# Ryningsnäs, 400 m





UPPSALA  
UNIVERSITET

# AM study, 1 year at Ryningsnäs and Dragaliden

Lundmark, Measurement of swish noise, a new method, Fourth International Meeting of Wind Turbine Noise, INCE/Europe, Rome, Italy (2011).

- Measure 8 times/s (Fast)
- Divide into 15 s long periods and analyze.
- Observations at the sites and studies of different amplitude modulation spectra
- Our definition: **AM** if the AMS-value (periodicities between 0.6 – 1.0 Hz) is  **$\geq 0.4$**

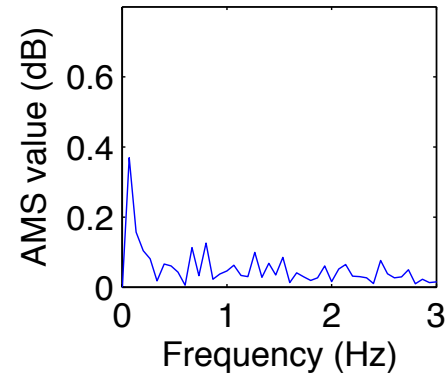
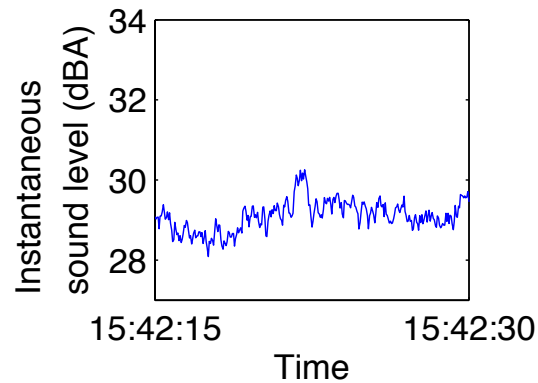
C. Larsson, and O. Öhlund, Amplitude modulation of sound from wind turbines under various meteorological conditions, *J. Acoust. Soc. Am.* 135(1), 2014, 67-73



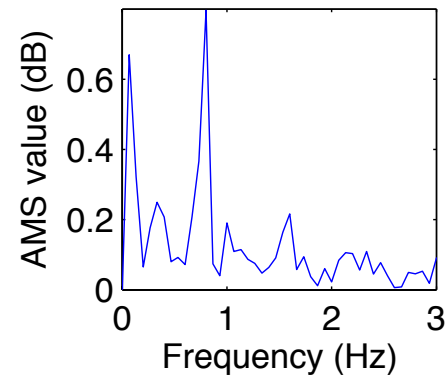
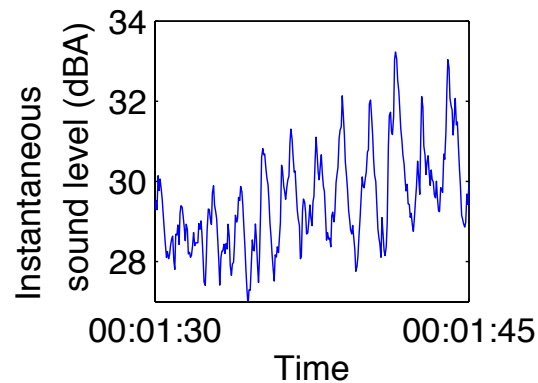
UPPSALA  
UNIVERSITET

# Amplitude modulation

Day



Night



Sound level recording from the Dragaliden site from 20 July 2011 at different clock hours. The measurements are taken 3 km from the closest WT. To the right is the amplitude modulation spectra with AMS value for a given 15 s period.

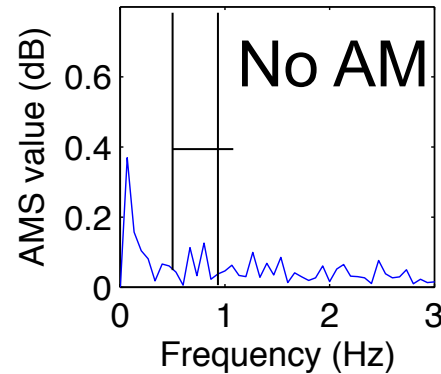
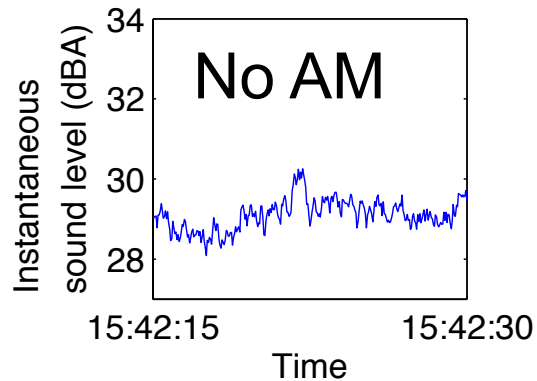




UPPSALA  
UNIVERSITET

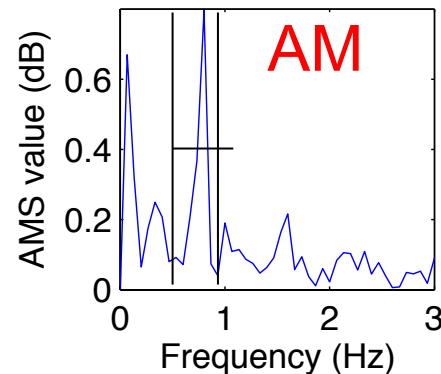
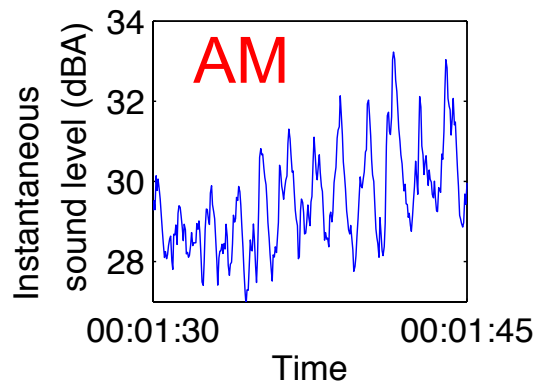
# Amplitude modulation

Day



$AMS < 0.4$

Night

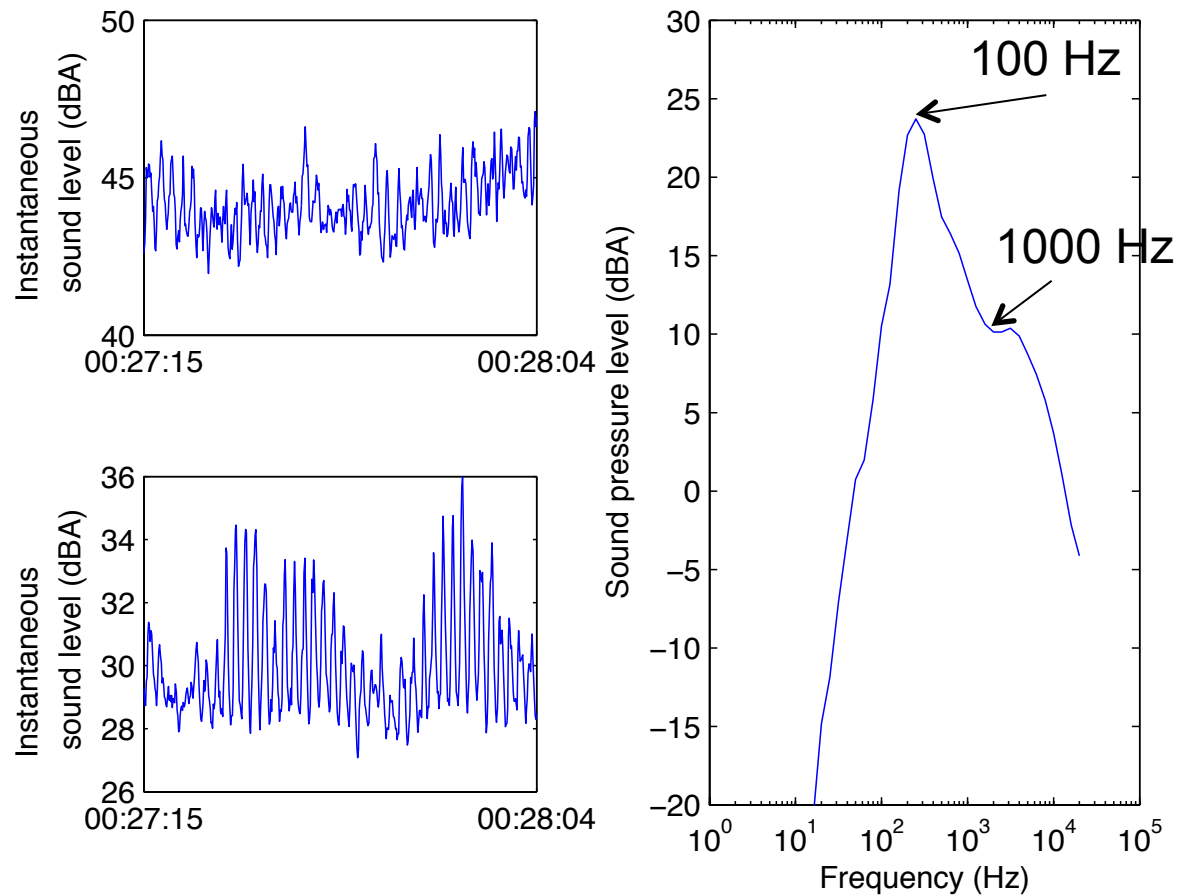


$AMS \geq 0.4$

Sound level recording from the Dragaliden site from 20 July 2011 at different clock hours. The measurements are taken 3 km from the closest WT. To the right is the amplitude modulation spectra with AMS value for a given 15 s period.



# AM heard at distance.



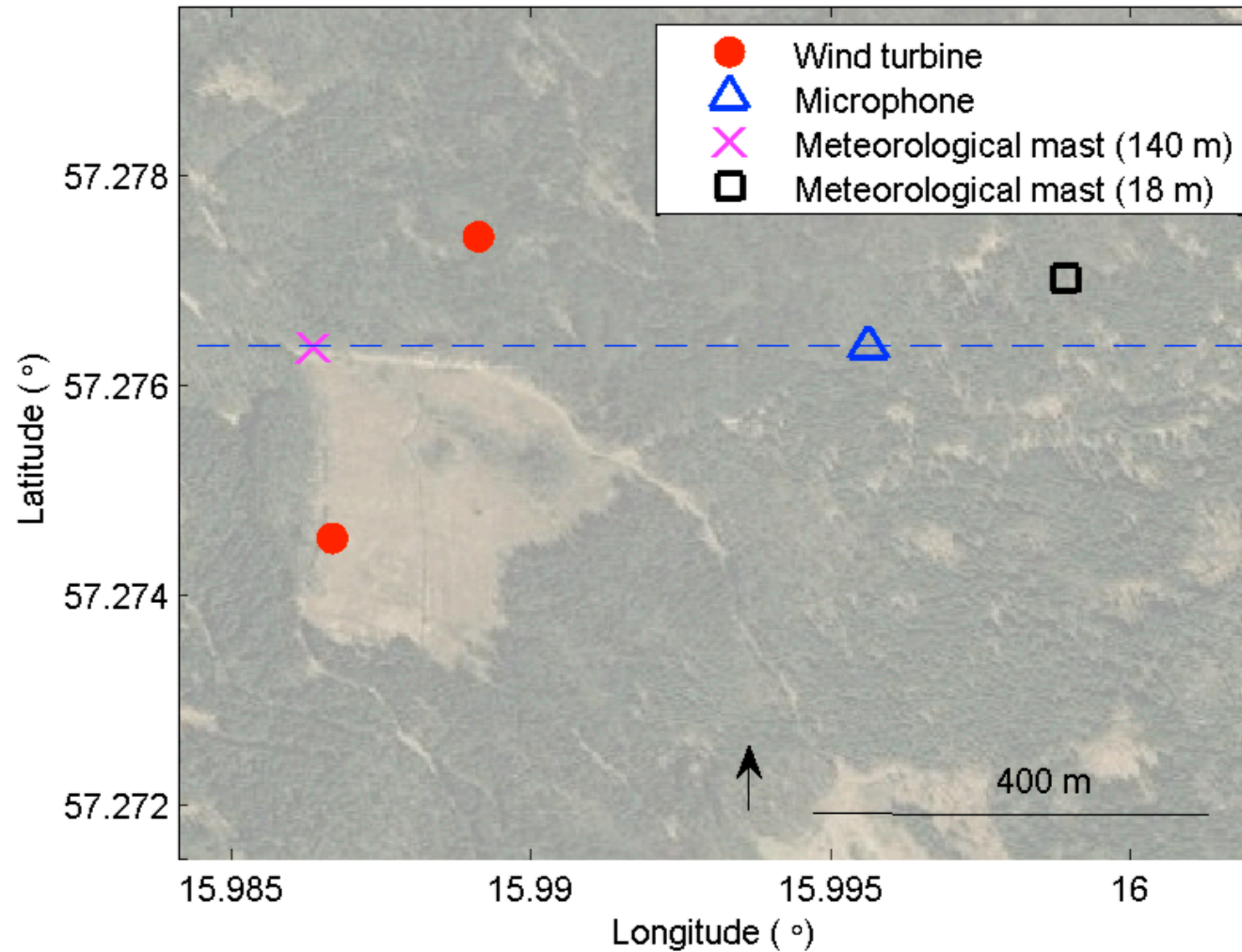
Emission (upper left) and immission (down left) sound level measurements and immission sound spectrum for the given time frame at Dragaliden site. Distance 2-4 km from the WT.



UPPSALA  
UNIVERSITET

# Ryningsnäs, Småland

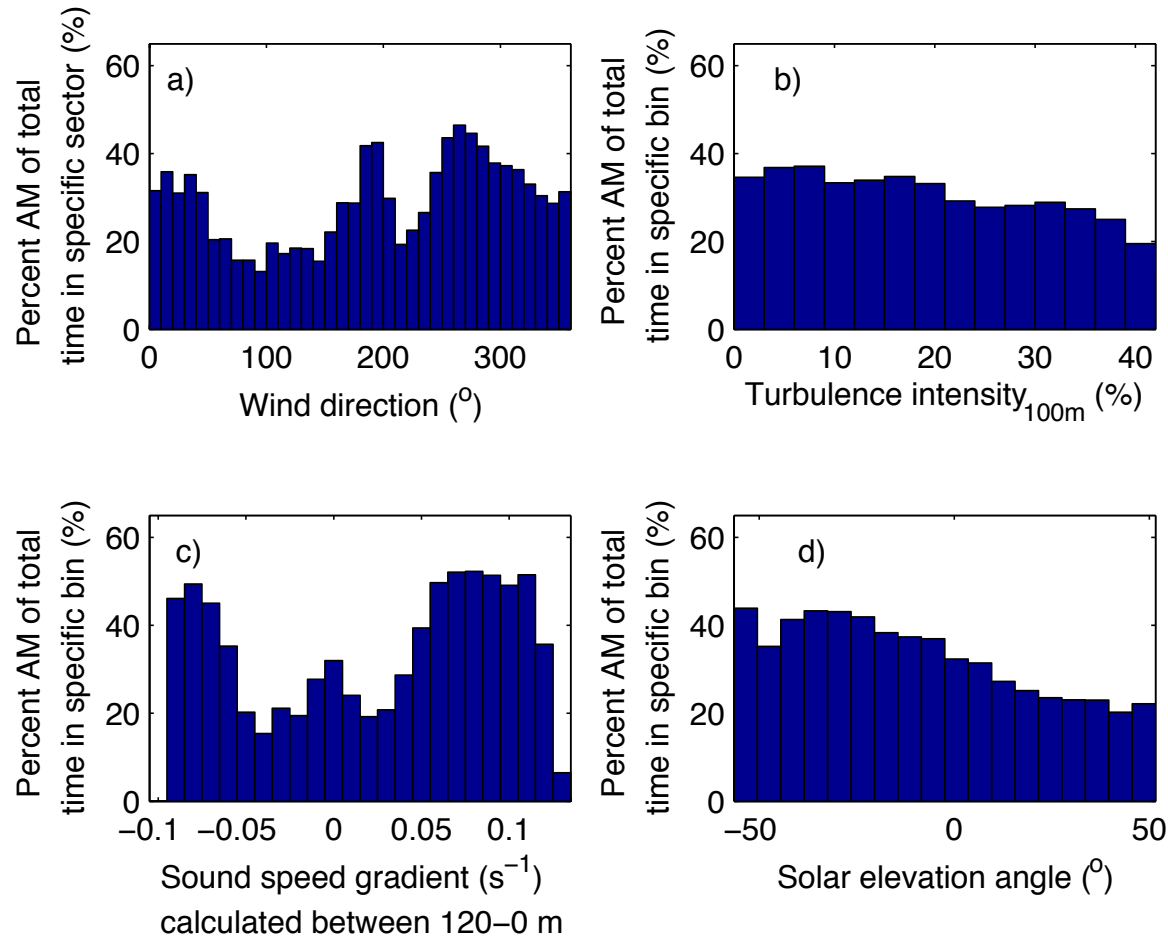
Nordex 2500 LS (2,5 MW) hub height 80 and 100 m





UPPSALA  
UNIVERSITET

# Ryningsnäs, 400 m

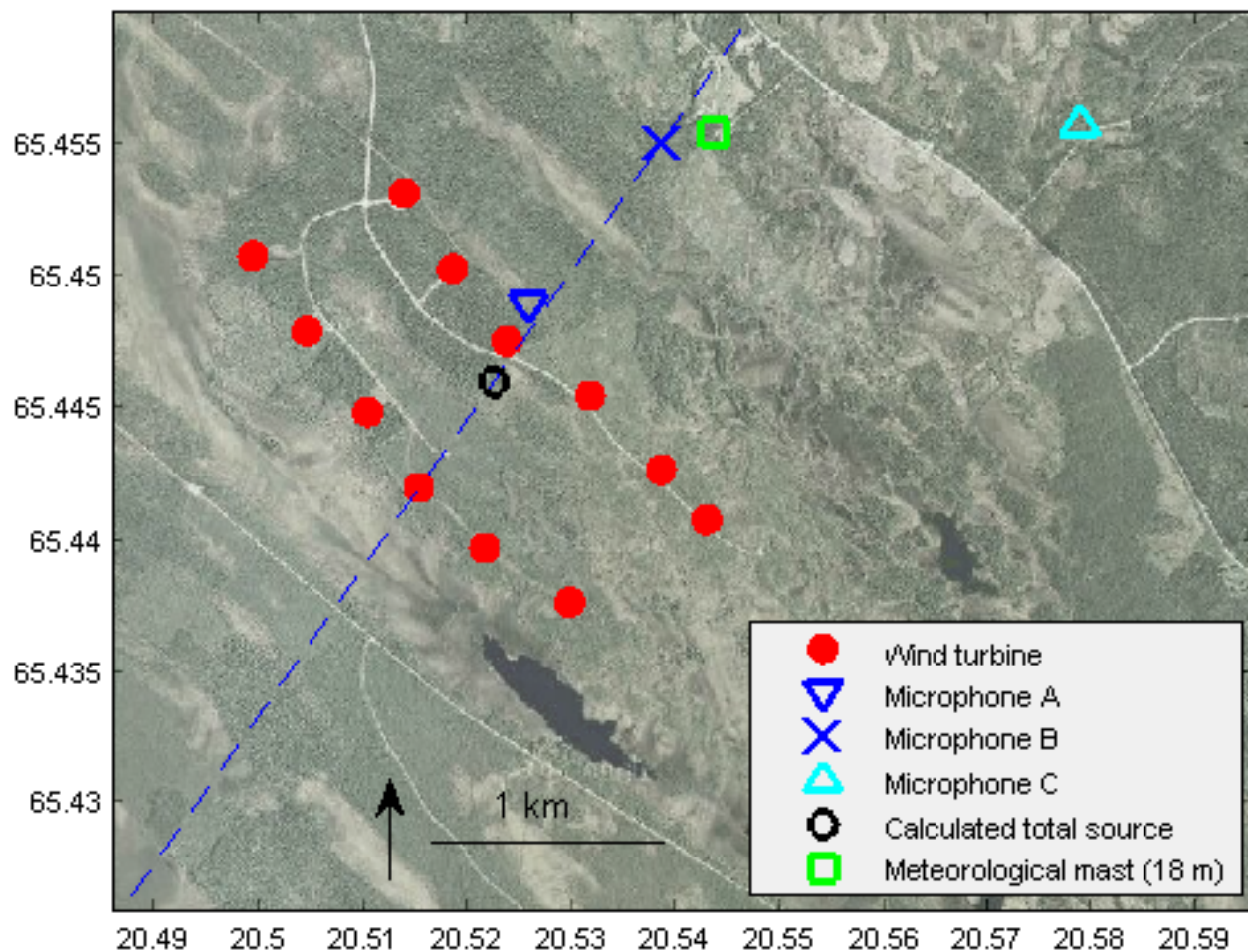


Percentage of AM in a specific bin for the Ryningsnäs site.



UPPSALA  
UNIVERSITET

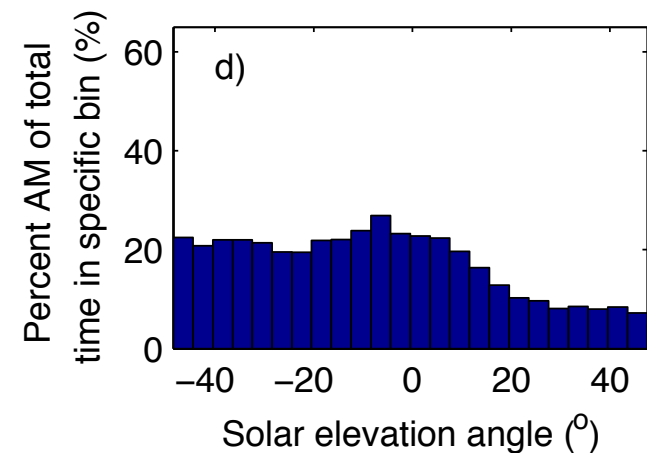
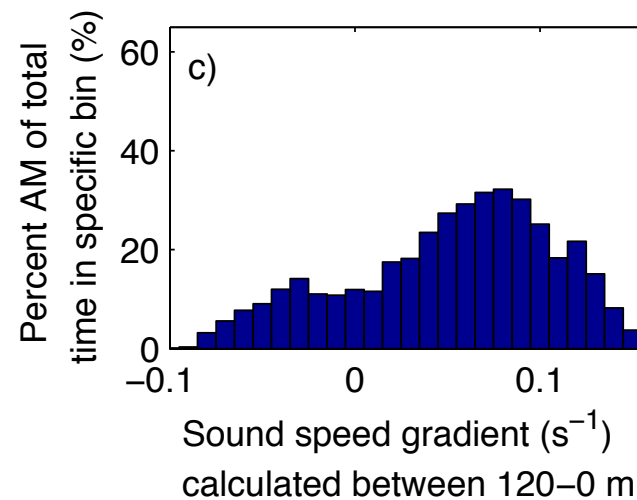
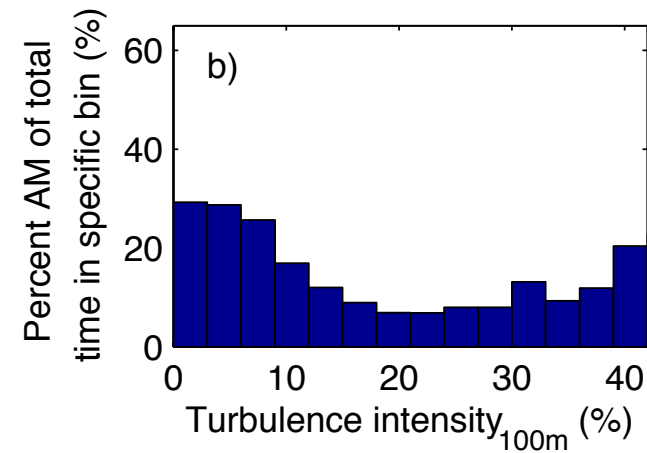
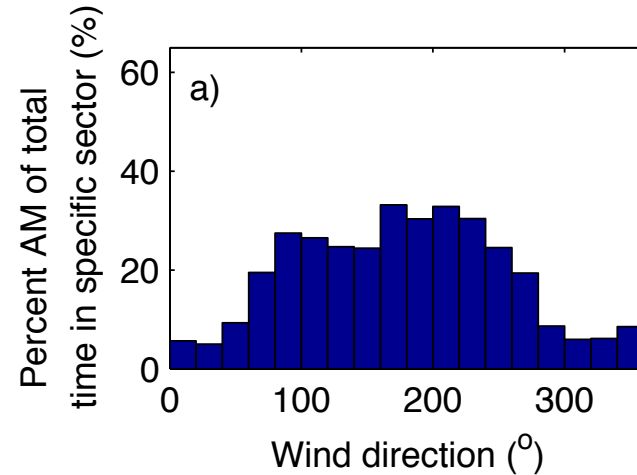
# Dragaliden, Enercon-E82 (2 MW) WTs hub height 108 och 138 m





UPPSALA  
UNIVERSITET

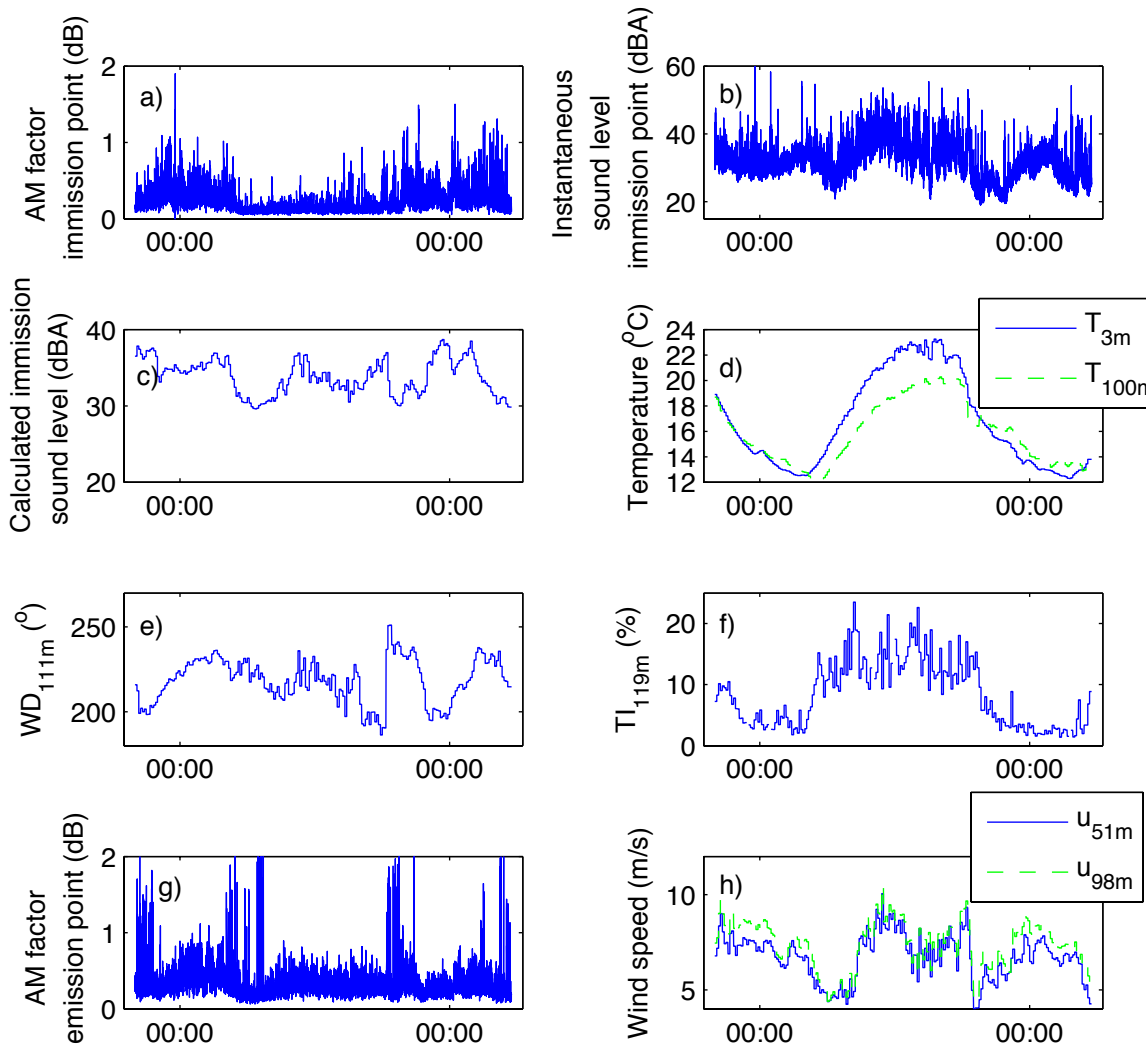
# Dragaliden, Enercon-E82 (2 MW) WTs hub height 108 och 138 m





UPPSALA  
UNIVERSITET

# Dragaliden, 19 - 21 July 2011, 2-4 km distance



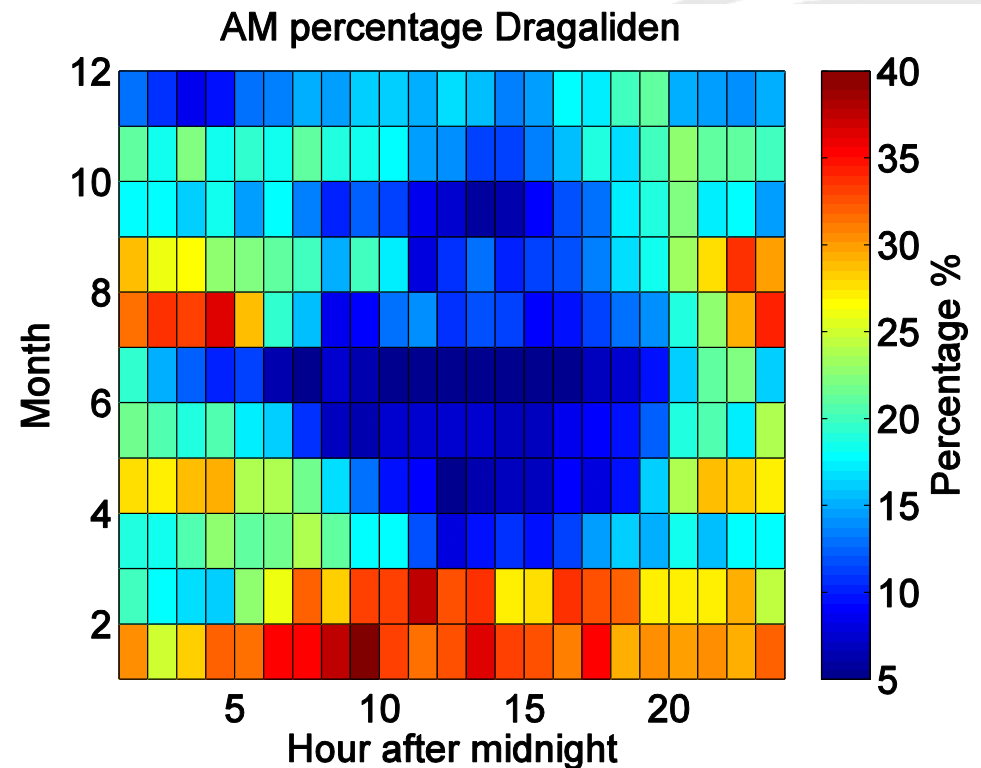


Amplitude modulation  
(percentage of selected  
measurements)

Evening-night-morning

Ryningsnäs (400 m) 33 %

Dragaliden (1 km) 19 %

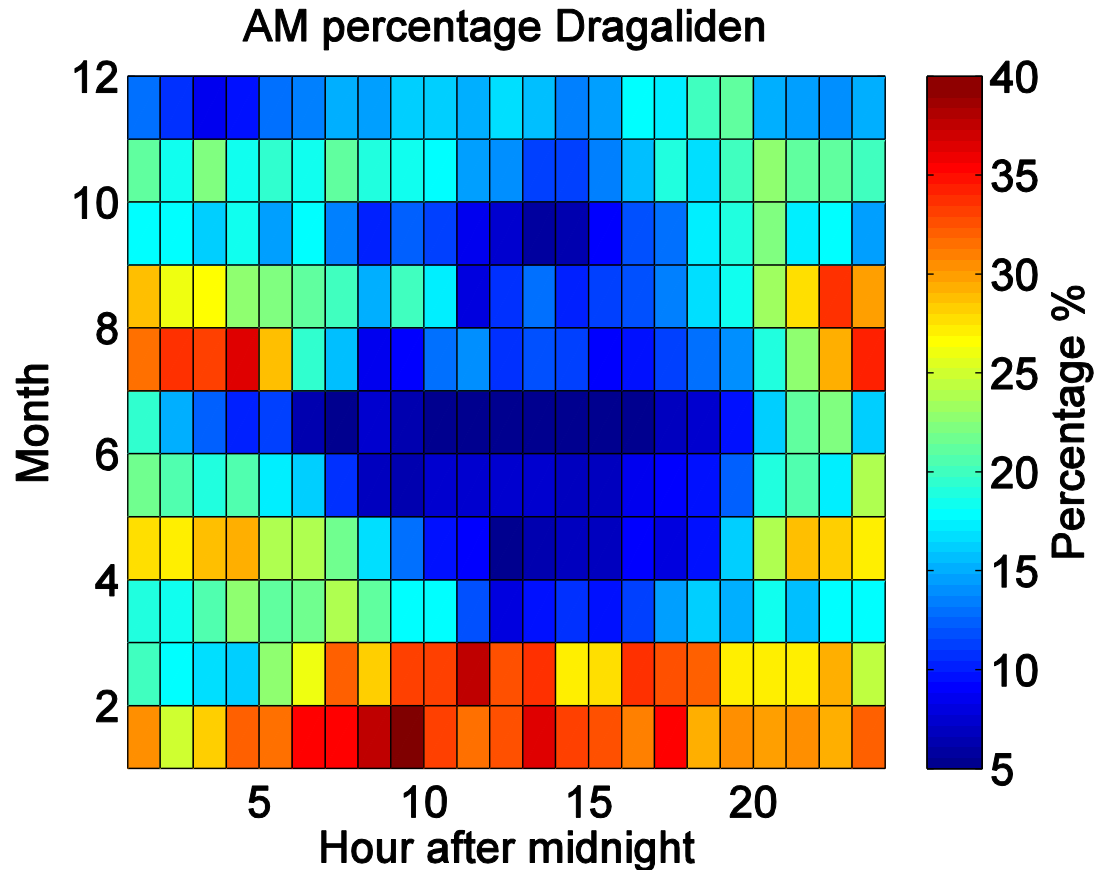






UPPSALA  
UNIVERSITET

# Results – AM during 1 year



AM more common during specific meteorological conditions



UPPSALA  
UNIVERSITET

# Conclusions

- The weather governs the immission sound level even for high elevated sources (WT).
- The weather governs the character of sound from WTs – Amplitude modulation.
- Amplitude modulation 20 - 30 % of time.
- Most frequent at evening-night-morning at stable stratification.

