Meteotest

Le vent: la complexité de ce système fascinant

Enjeux pour la production d'énergie éolienne

Conférence Université de Genève

Sara Koller

19 février 2026

Meteotest

Outline

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Challenges for wind energy in Switzerland – complex terrain

Flat terrain

Complex terrain

…according to Measnet 2022*

*Measnet: Evaluation of Site specific Wind conditions, Version 3, September 2022

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Challenges for wind energy in Switzerland – complex terrain

Complex terrain in Switzerland

KEYSTONE/Olivier Maire
Nufenen Wind Park

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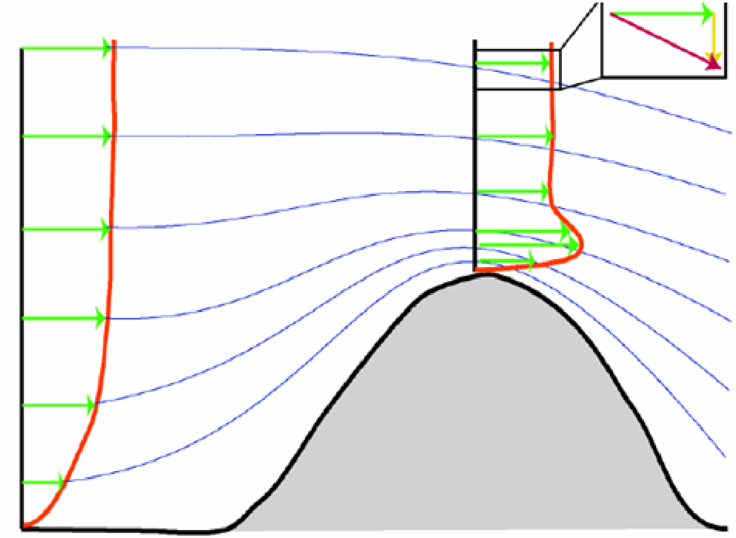
Challenges for wind energy in Switzerland – complex terrain



Wind profile in flat terrain

Wind profile in complex terrain

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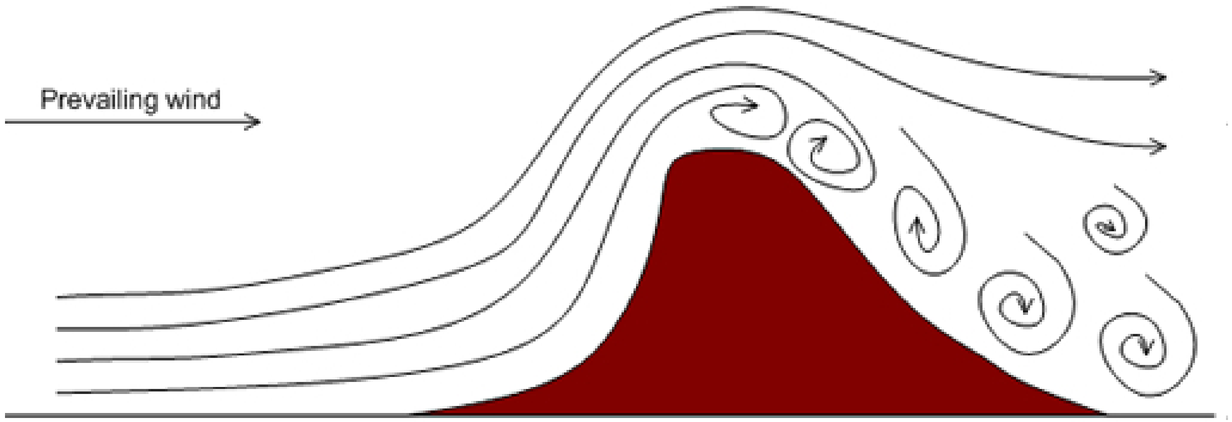
Challenges for wind energy in Switzerland – complex terrain



Turbulence in flat terrain

Turbulence in complex terrain

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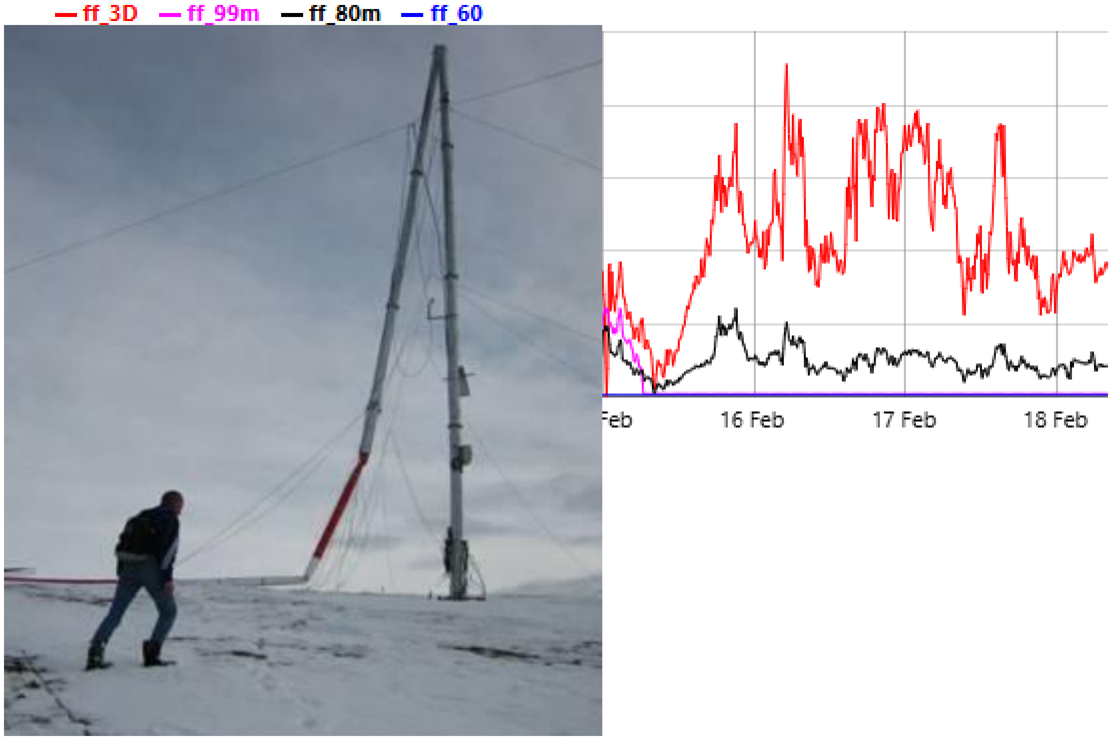
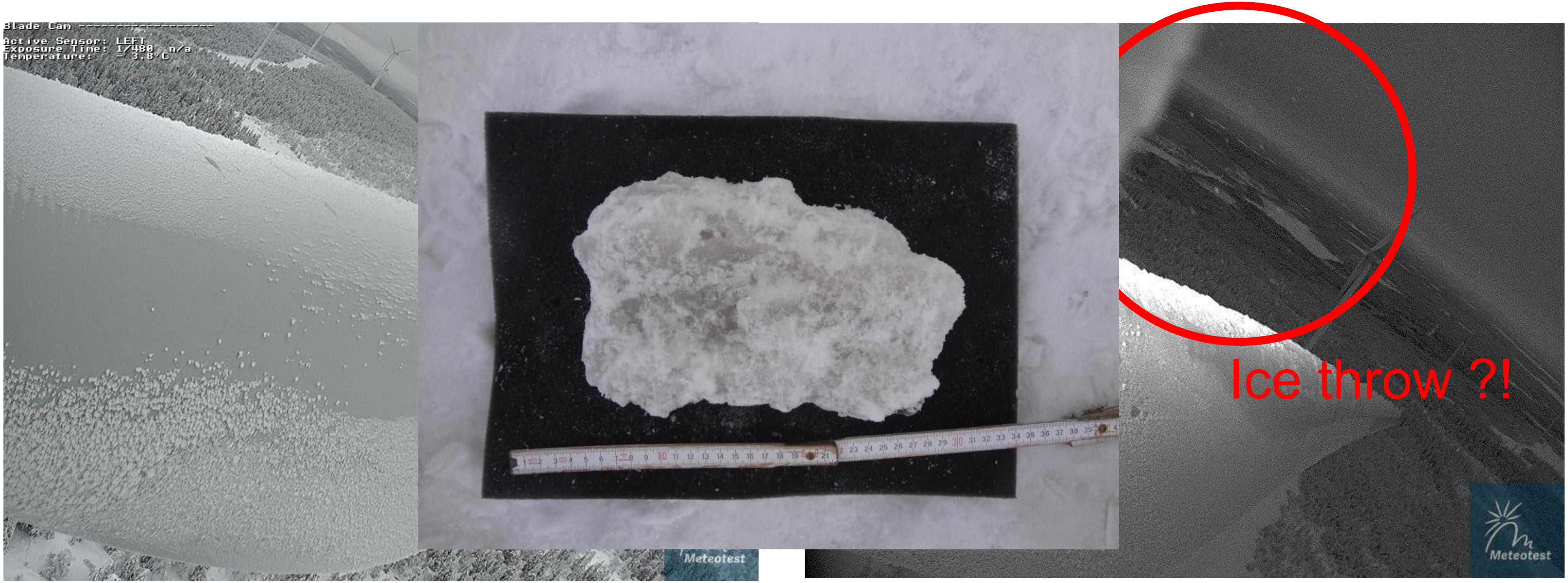
Challenges for wind energy in Switzerland – cold climate



Challenges for wind energy in Switzerland – cold climate



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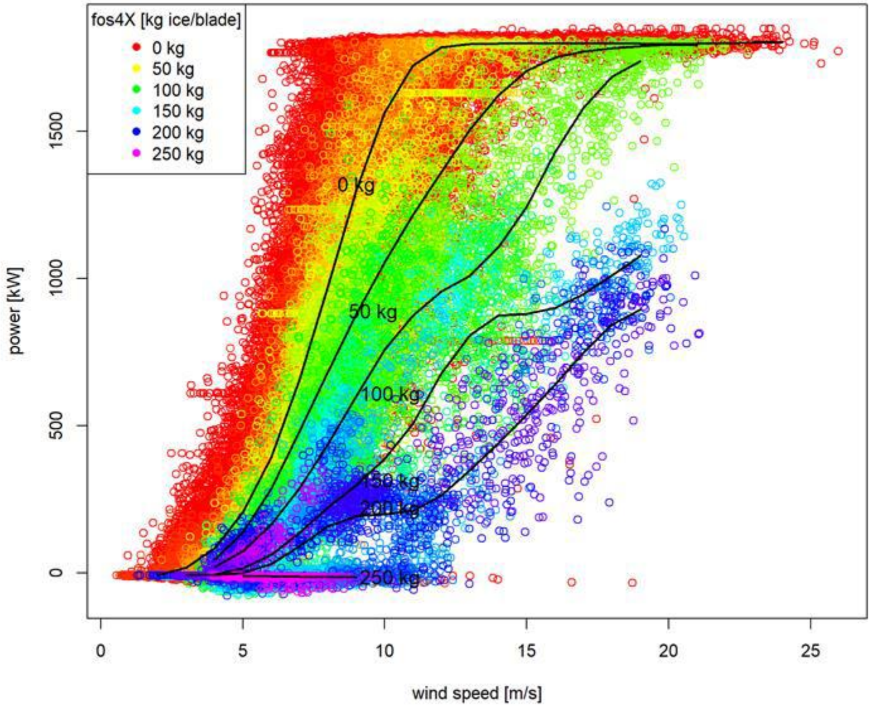
Challenges for wind energy in Switzerland – cold climate

- Icing disturbs production
- Risk of ice throw
- Icing reduces turbine life time



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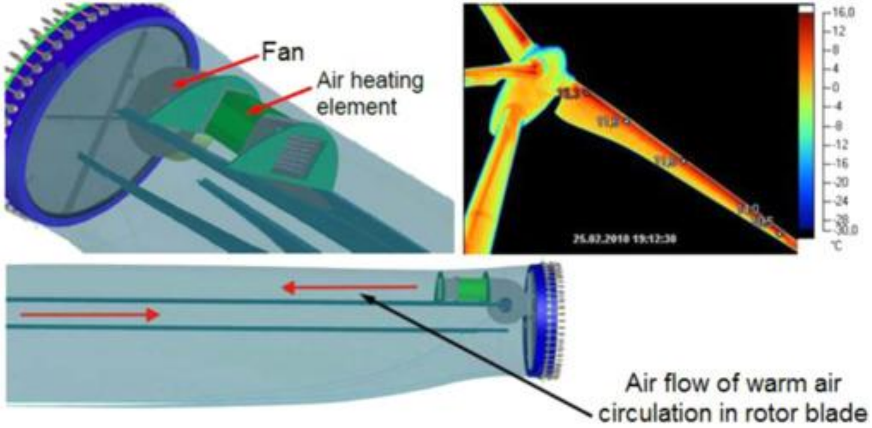
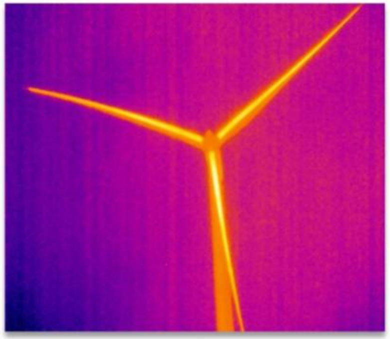
Challenges for wind energy in Switzerland – cold climate

What can we do ?
- Stopping the turbine and waiting

And/or
- **Heating** the turbine (two mature technologies):
    - Hot air blown inside the blade
    - Heating mats inside the blade wall



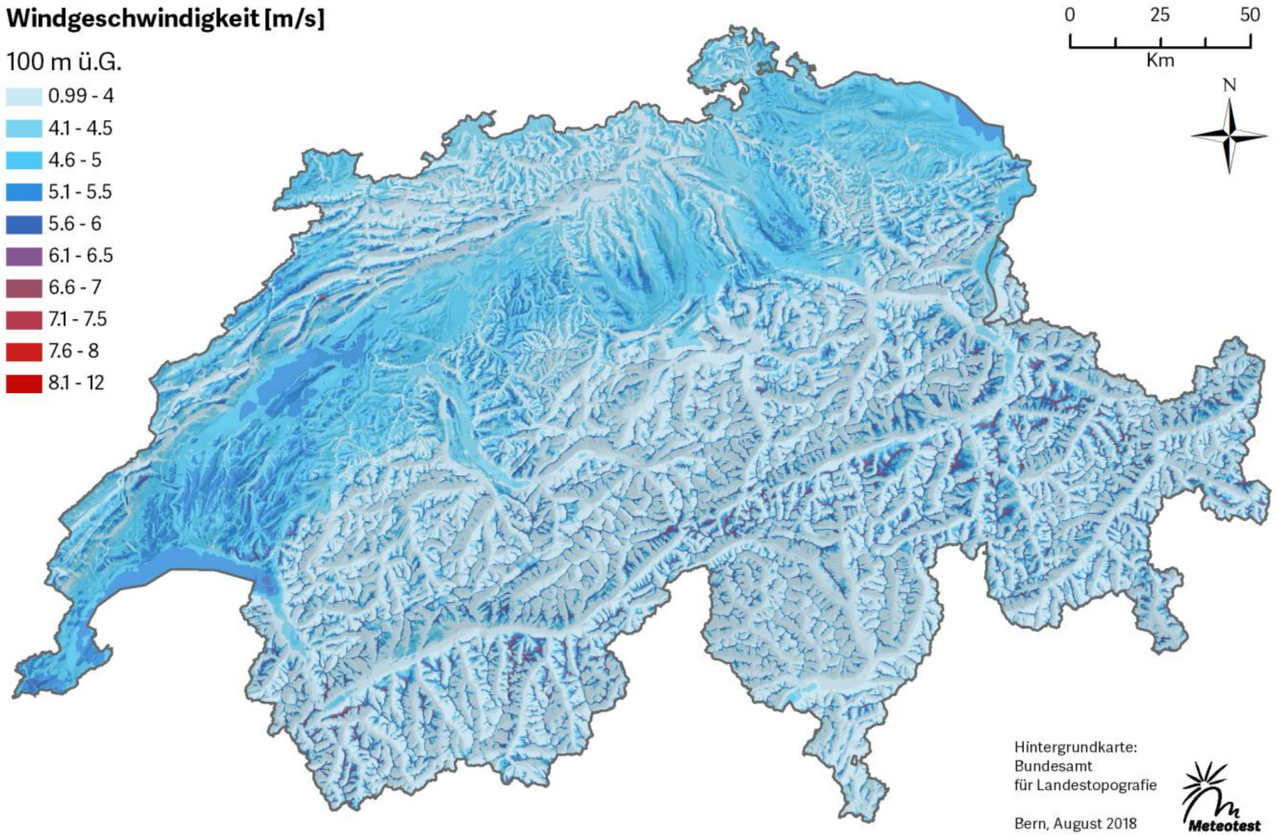
IR validation



SWT-2.3-101 de-icing activated

SWT-2.3-101 de-icing activated

Wind atlas for Switzerland (2019)



https://www.uvek-gis.admin.ch/BFE/storymaps/EE_Windatlas/

Key question for wind energy development

What is the long-term wind speed distribution at hub height?

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Wind measurements

➢ wind measurements with calibrated anemometer for at least 12 consecutive months at 2/3 of the future hub height

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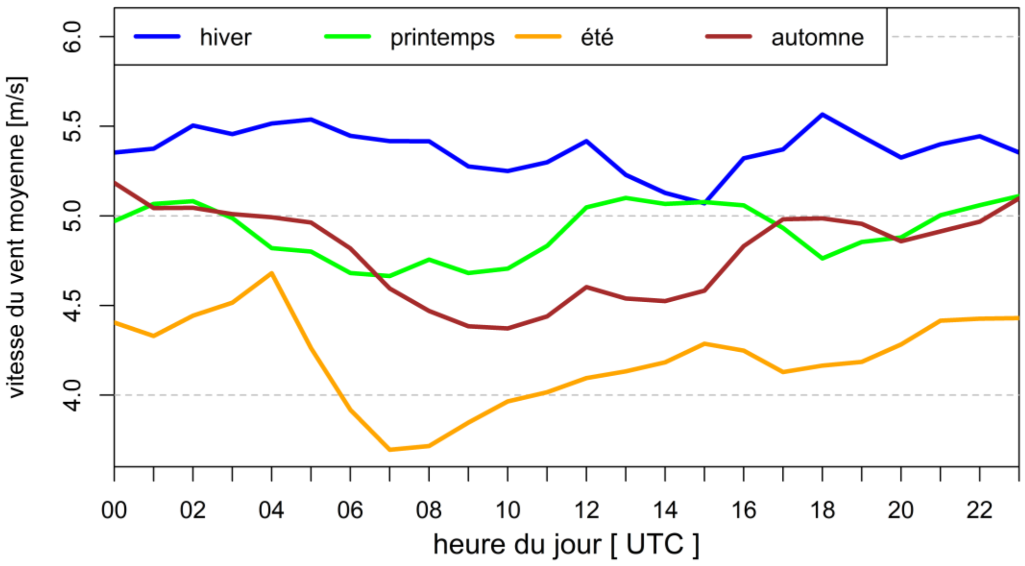
Wind measurements



- ➢ seasonality of the wind

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Wind measurements

- wind profile up to 300m a.g.l.

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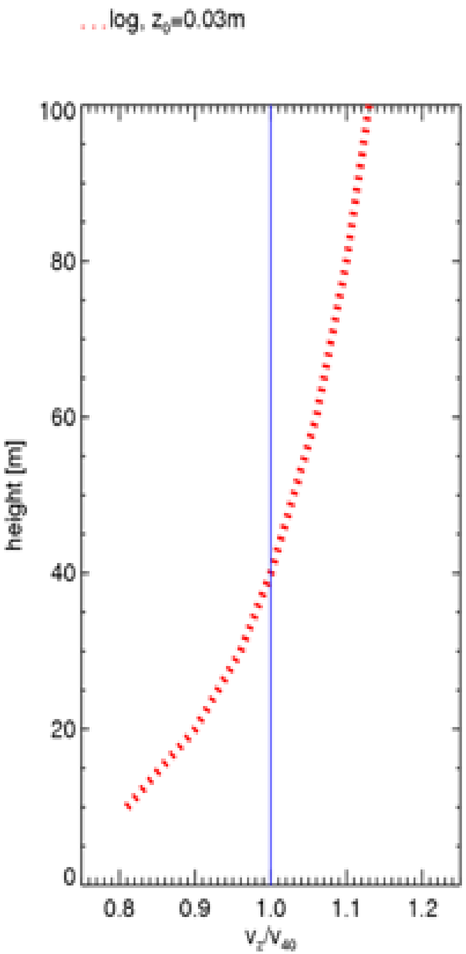
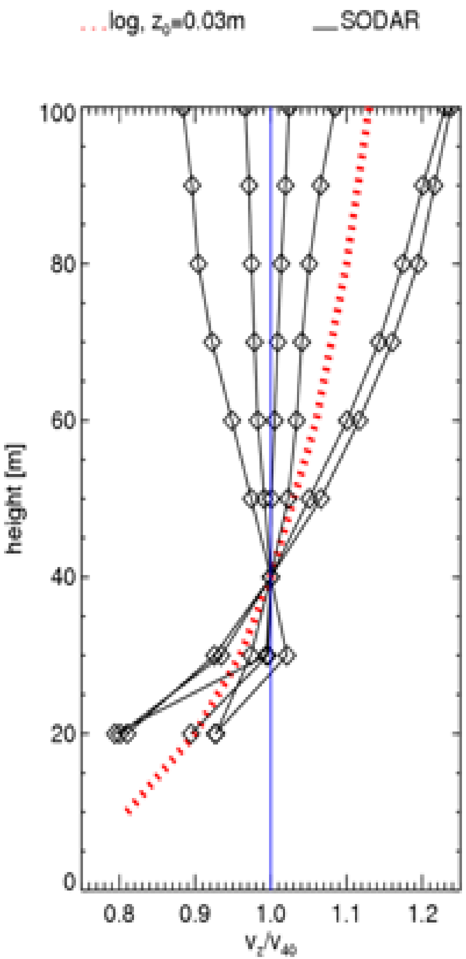
Wind speed extrapolation

Logarithmic wind profile:

$$v_2 = v_1 \frac{\ln\left(\frac{h_2}{z_0}\right)}{\ln\left(\frac{h_1}{z_0}\right)}$$





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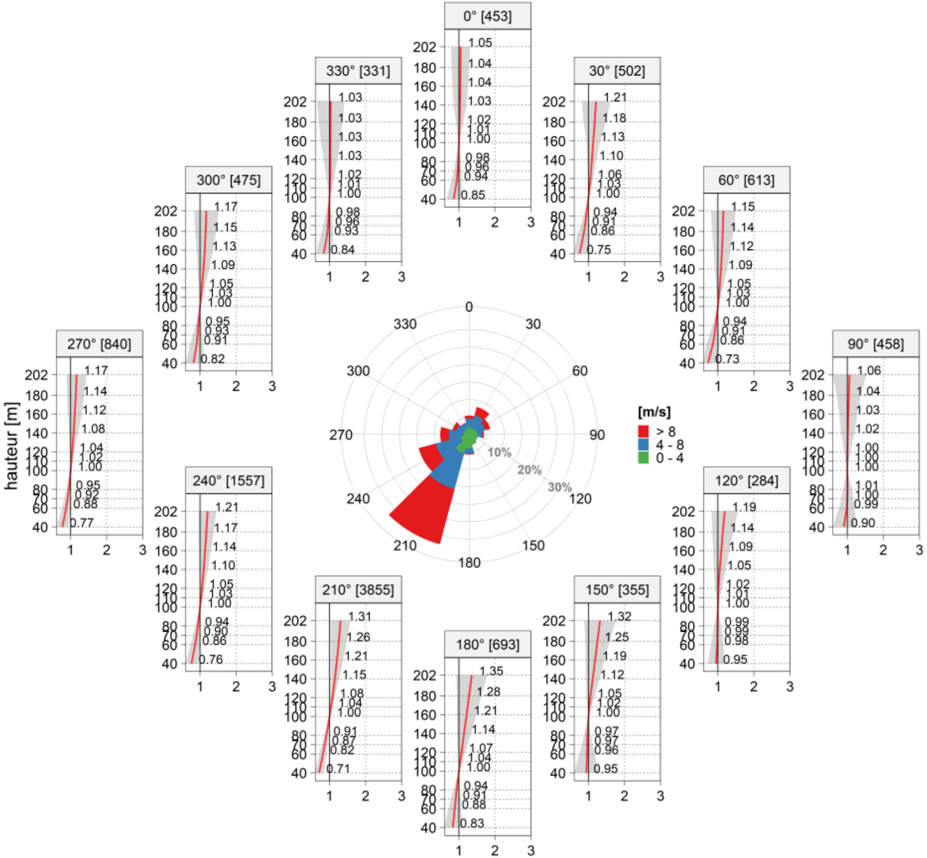
Wind speed extrapolation



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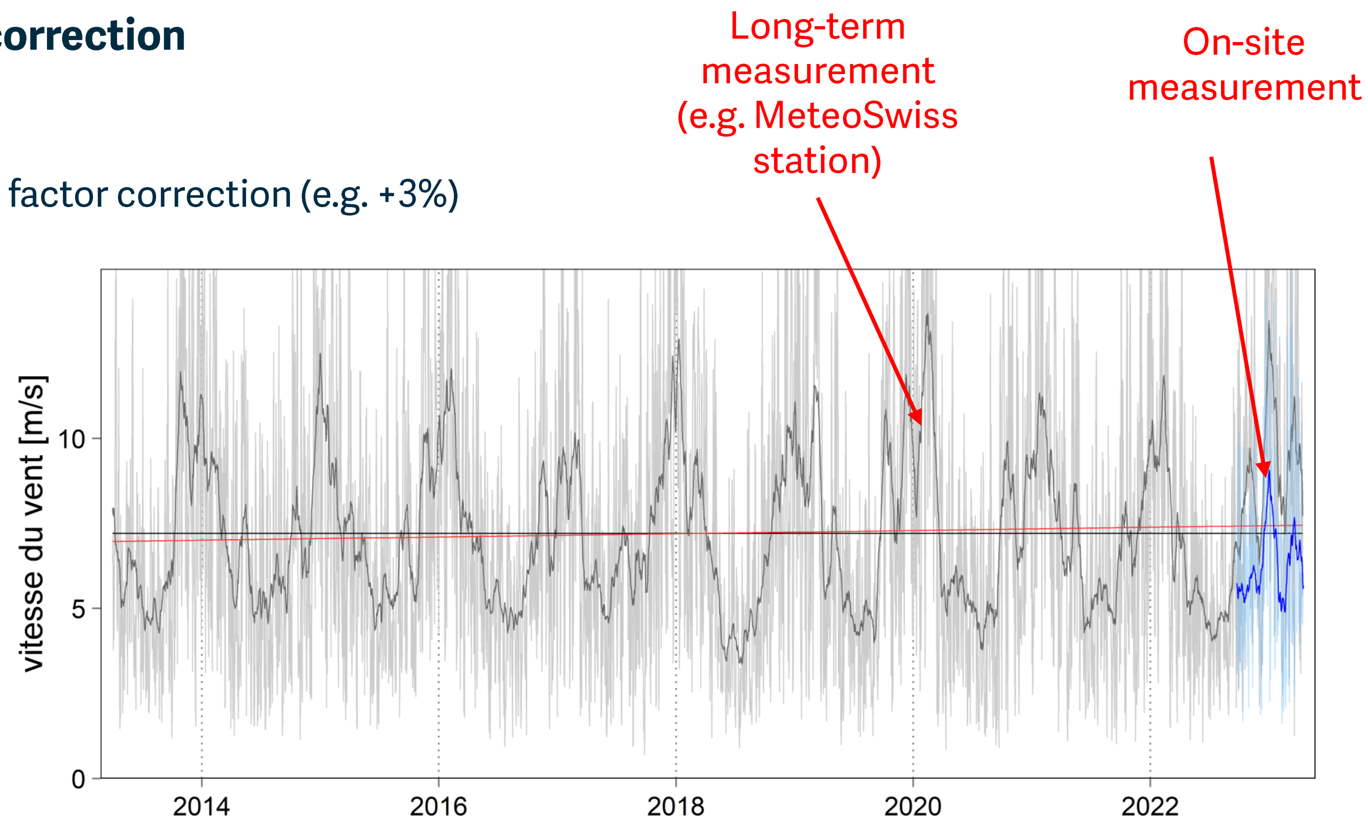
Long term correction

Single factor correction (e.g. +3%)



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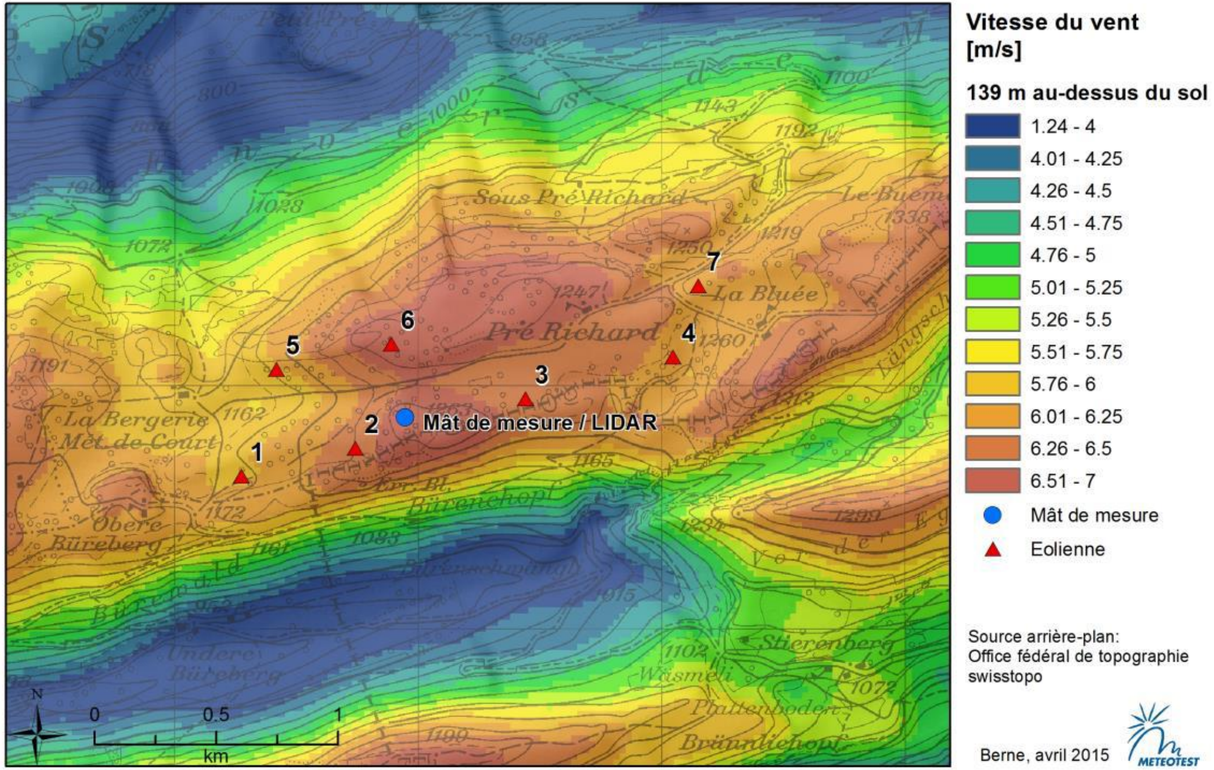
Wind modelling

- CFD (Computational Fluid Dynamics)
- Reynolds-Averaged Navier-Stokes Equations (RANS, steady-state) is a good compromise for this application
- Input data:
  - digital elevation model
  - model of surface roughness
  - **long term climatology**
- Output:
  - wind resource maps on different heights above ground
  - energy yield and wake effects

Wind resource map



https://www.court.ch/documents/PDF-contenu/2018/B1-4a_Etude_des_vents_-_Meteotest.pdf

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Wake effect

https://www.researchgate.net/figure/Wake-effect-on-a-real-wind-farm-Horns-Rev-1-regular-layouts-like-the-one-in-the_fig1_353171725

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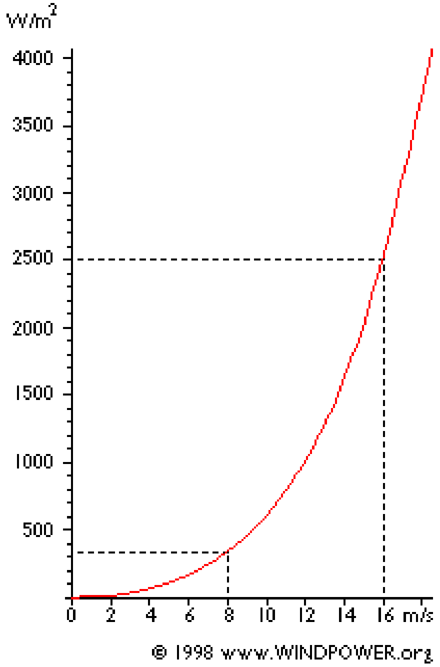
Energy yield

Site A:
- January 1 to December 31: constant wind speed of 5 m/s
→ Average wind speed **5 m/s**
~ 1'500'000 kWh/a (with typical 2 MW turbine)

Site B:
- January 1 to June 30: constant wind speed of 10 m/s
- July 1 to December 31: no wind at all
→ Average wind speed **5 m/s**
~ 7'000'000 kWh/a (with typical 2 MW turbine)



$$E_{kin} = \frac{1}{2}\rho A v^3 t$$

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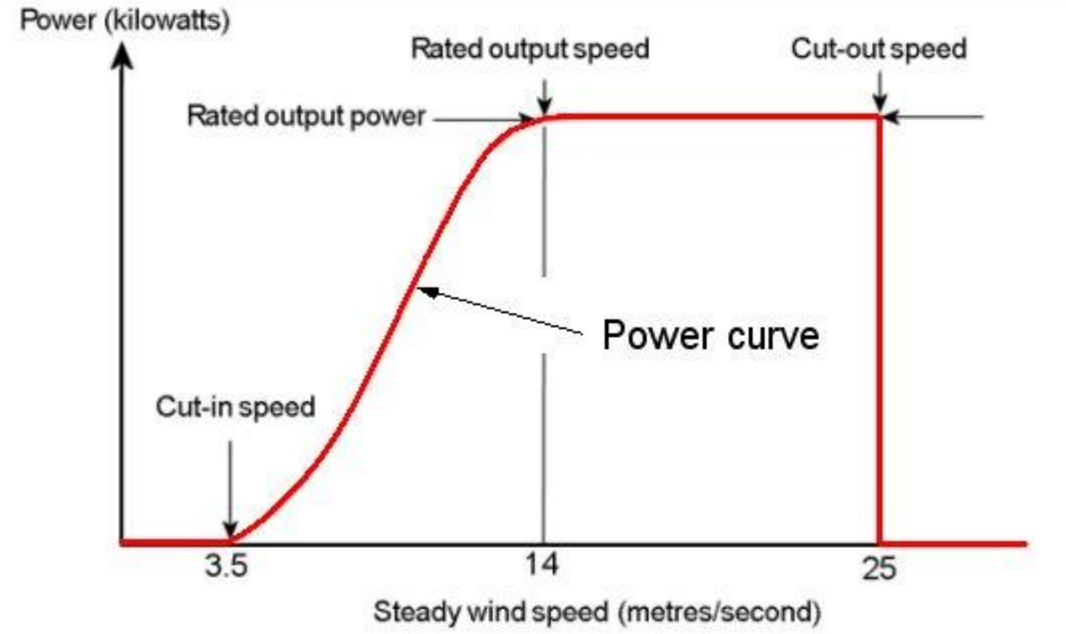
Power curve



Typical wind turbine power output with steady wind speed.

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Quantifying uncertainty

Errors in:

- A. Anemometry measurement
- B. Extrapolation using LIDAR
- C. Long term correction
- D. Transfer to turbines locations (CFD)
- E. On-site power curve

$$\text{Total uncertainty} = \sqrt{A^2 + B^2 + C^2 + D^2 + E^2}$$

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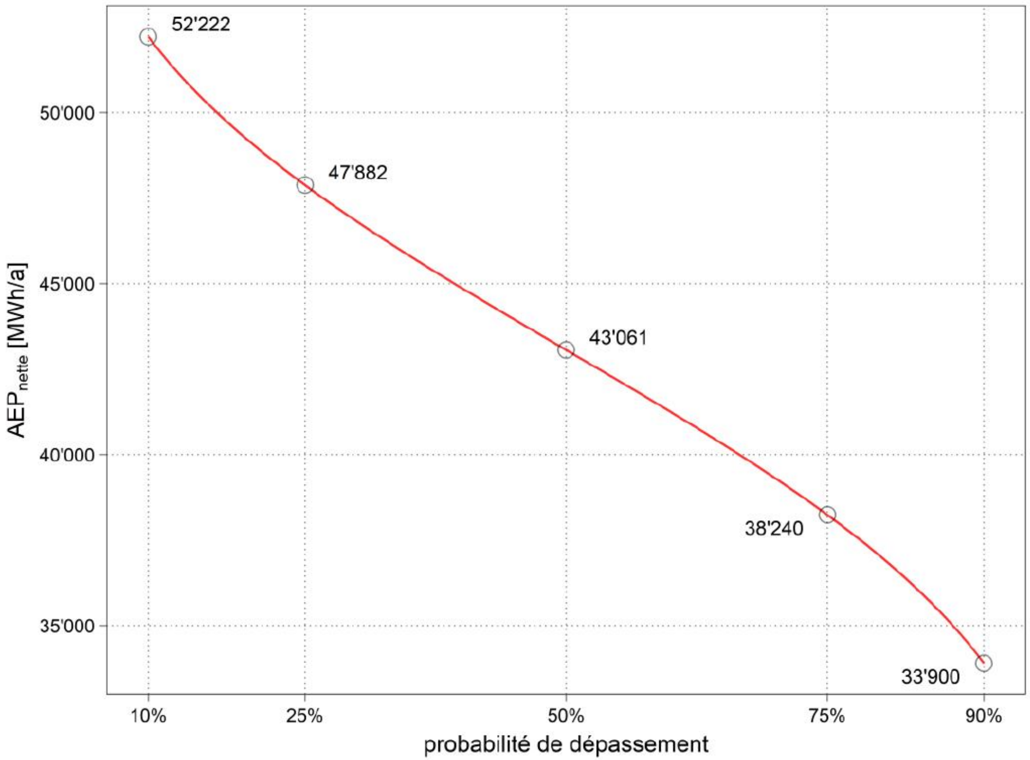
Quantifying uncertainty



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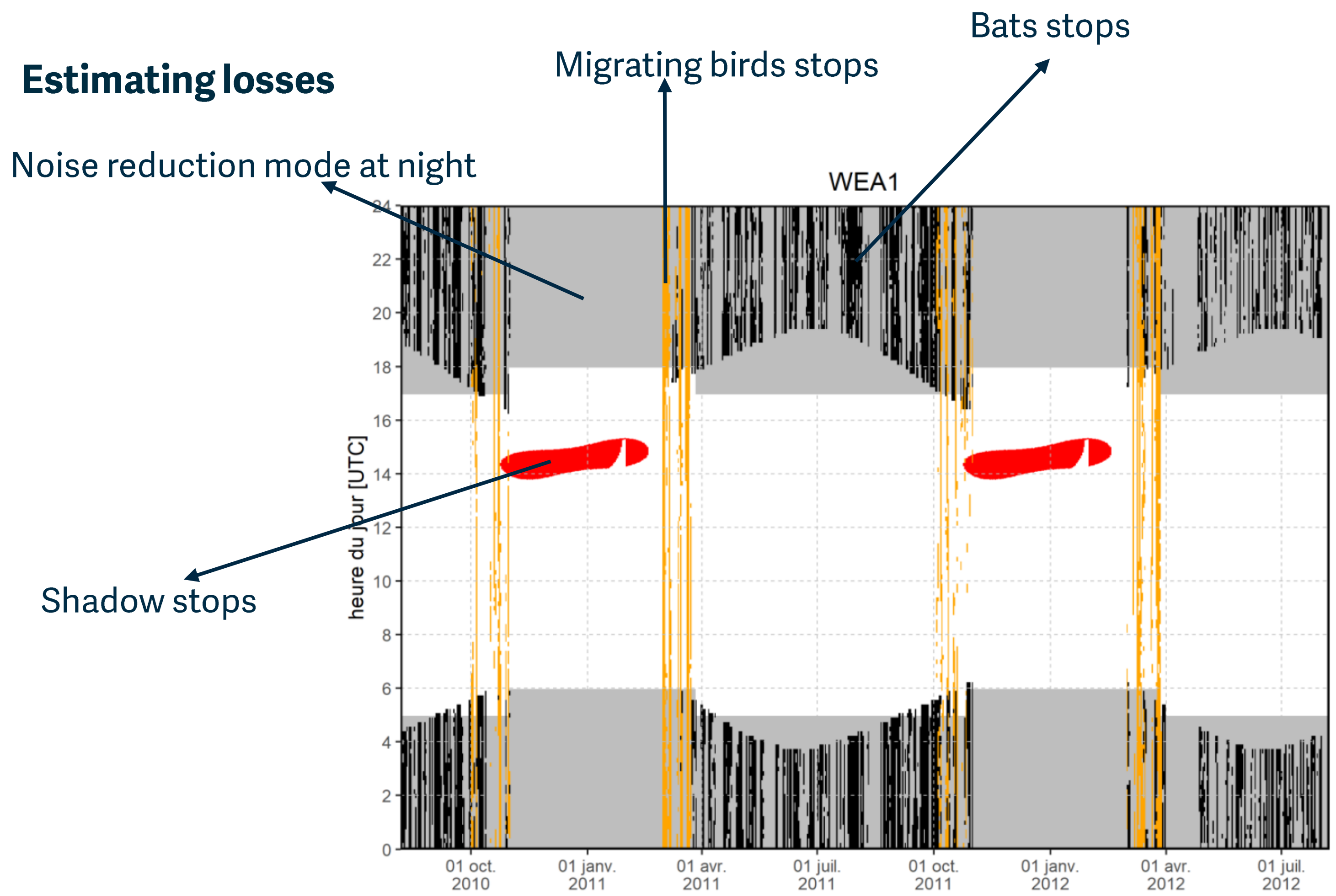
Estimating losses



Thank you for your attention!