Front detection using wind turbine data

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EGU2020

Front detection

- Fronts are typically computed and visualized using weather prediction and satellite data
- Typical uncertainty: 2 hrs
- Topic of this talk:

  Can we detect fronts and determine their properties from wind turbine data?

- This may lead to improved front propagation forecasts
  - Decrease uncertainty of front arrival
  - Short-term prediction of “ramps”

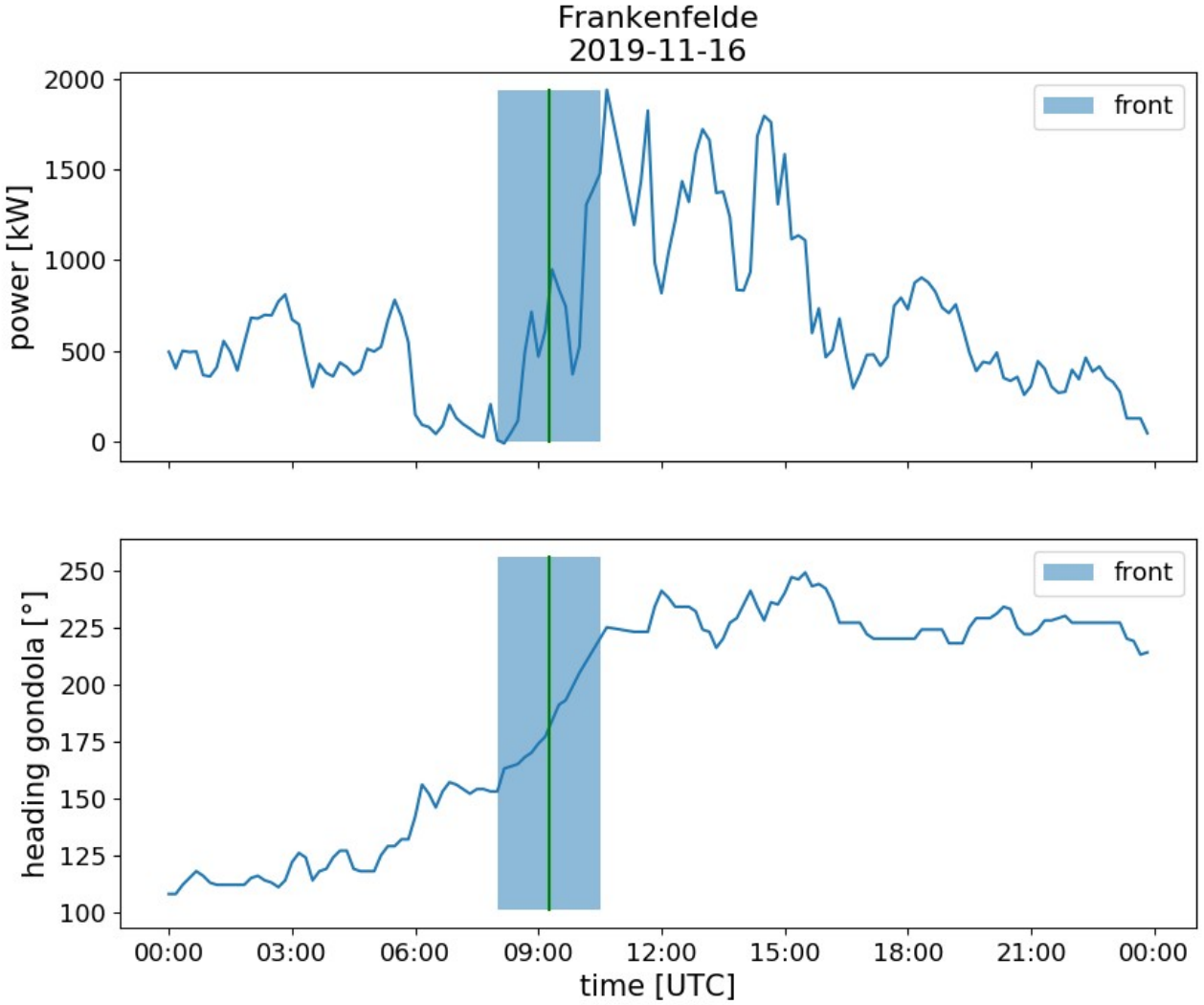
Wind Turbine Data

- Turbines provide production and gondola heading
- Often also: wind speed, wind direction, temperature, pressure
- Time resolution: typically 15mins or 10 mins, could be sec
- We use production and gondola heading in 10mins resolution
- Data with kind permission of the owner *Notus Energy Operations*

Finding Fronts in Wind Turbine Data

- Detect ramps using the abrupt change in wind direction
  - Smooth gondola heading using splines
  - Detect times with spline derivative above threshold
  - We define the front at the middle of this timespan
- Using the wind direction of two nearby turbines and the convection equation, we can estimate the local front speed projected on the axis between the two turbines.
  - We assume a homogeneous, straight front (which is incorrect since the two turbines are 173 km apart, but okay for a first proof of concept).

Results



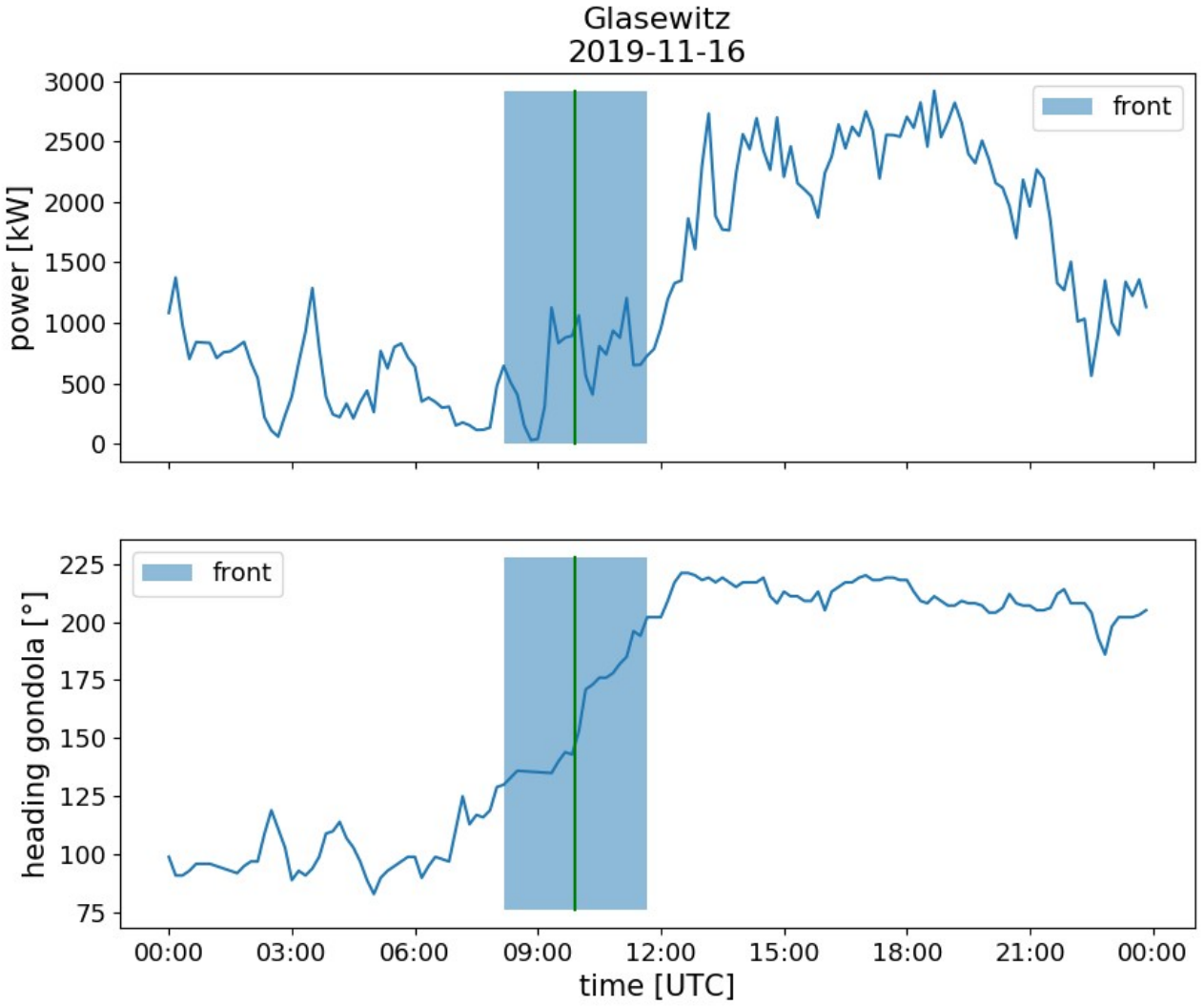
Turbine 1

Coordinates:
(52.683°, 14.072°)

Front passes at:
9:15 UTC

Projected local front speed:
119.5 km/h

Results



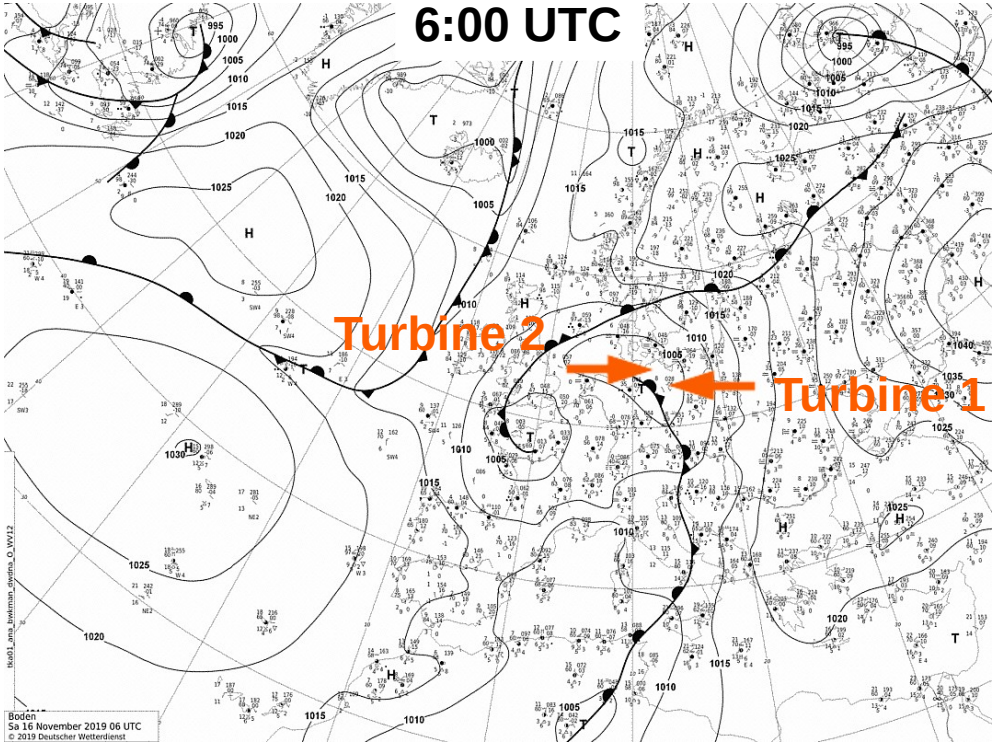
Turbine 2

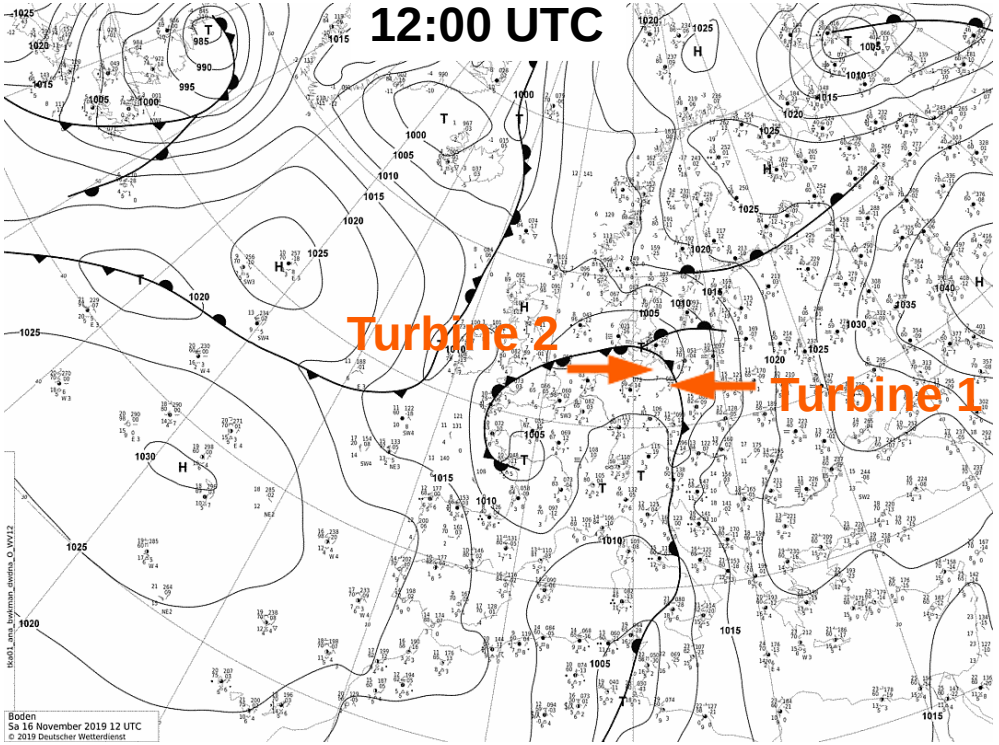
Coordinates:
(53.834°, 12.314°)

Front passes at:
9:55 UTC

Projected local front speed:
167.1 km/h

Verification





Mean Sea Level Pressure analysis charts from the DWD

A front passed both turbines between 6:00 and 12:00

Verification

Estimation of the front speed from the DWD charts:

- At Turbine 1: ~ 50 km/h
- At Turbine 2: ~ 70 km/h

Estimation of the angle between front velocity and axis between the two turbines from the DWD charts:

- At Turbine 1: ~ 70°
- At Turbine 2: ~ 80°

Using those angles on the projected front speed determined by the turbine data yields:

- Turbine 1: ~ 40 km/h
- Turbine 2: ~ 30 km/h

For turbine 1 we get a comparable result. The result of Turbine 2 is more off. Using more turbines with smaller distances should improve accuracy. Also, the front may have turned or slowed down (compare with reanalysis data instead of charts).

Conclusion and Outlook

- Proof of concept for front detection and front speed determination using turbine data
- Using more turbines with smaller distances should improve accuracy and additionally enable the determination of front direction and front curvature
- Especially in regions with many turbines (e.g. northern germany) this could make significant short time corrections of front propagation predictions possible.
- Full automation based on NWP prior and turbine data posterior planned
- Extension with meteorological measurement data possible
- Statistics needed: wind atlas data, other inputs are searched for.