The Use of WRF for Wind Resource Mapping in Norway

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ROGALAND FYLKESKOMMUNE

1. Introduction

The wind power potential for Norway has been calculated by Hofstad et al. (2005). By developing 0.5% of the land area of Norway an annual production of 250TWh from wind power could be generated. This amounts to more than twice the Norwegian consumption of electrical power. However to this date only a few wind farms are operational with a combined annual production of less than 1 TWh.

The WRF model is a promising tool for wind resource mapping. Combined with wind measurements at various locations, we can use this tool to locate good sites to develop wind power.

Moisture combined with temperature below freezing during large periods of winter makes icing on wind turbines a potential problem in Norway. Icing on wind turbines reduces the power output at any wind speed, and it is also associated with larger fatigue of the turbines. Ice that breaks off a wind turbine may also constitute a health risk for people and animals in the wind farm area.

2. Model setup

WRF v2.2 is set up with two 2-way nested model domains as shown in Figure 1. We use a horizontal resolution of 5 km for the outer domain and 1 km for the inner domain. We use 32 layers vertically, with the lowest 4 model levels at 20 m, 60 m, 115 m and 190 m above the ground. The model is run for the complete year 2005.

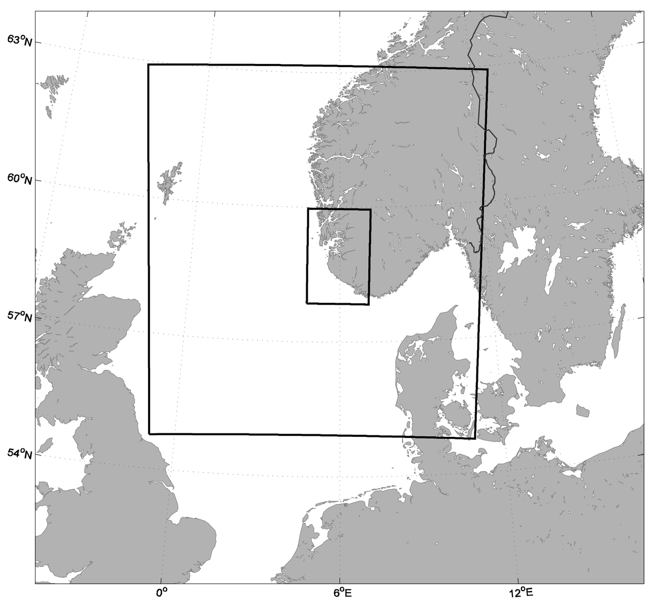


Figure 1 Setup of the domains

3. Wind climate

Model results from the nearest grid point to an observation site are used for validation purposes. Measurements at 10m height from 5 sites are openly available from the Norwegian Meteorological Institute (met.no). Additional 4 sites are operated by Kjeller Vindteknikk on behalf of Norwegian power companies. Our agreement with the power companies does not allow us to publish the wind speed nor the location of these sites. The sites are therefore kept anonymous and referred to as Site 1-4. The measuring height for these sites ranges from 50-100m.

The modeled wind speed generally correlates well with the observations and the model captures the wind direction quite well (Figure 2).

In general we find deviation in wind speed between WRF and observations within ±10%. For Haugesund we find larger deviations, this may partly be explained be sheltering effects at this site that are not captured by the model. Site 4 shows also a large deviation from model climate. A typical feature of the terrain at this site is sub-grid topographical variations that are smoothed by the model. This adds to the surface roughness and is not accounted for in the model.

By using WRF data as input to micro scale models we are able to adjust for finer variations in topography and surface roughness. By combining WRF with WAsP we generally accomplish to reduce the deviations in observed and modeled average wind speeds (Berge et al 2007).

Station	Observed 2005	WRF 2005		ρ
Lista	6.6 m/s	6.4 m/s	- 3 %	0.80
Obrestad	7.2 m/s	7.9 m/s	+ 10 %	0.83
Utsira	8.8 m/s	8.7 m/s	- 1 %	0.87
Haugesund	6.0 m/s	7.5 m/s	+ 25%	0.83
Sola	4.8 m/s	4.5 m/s	- 7%	0.81
Site 1			+ 5%	0.89
Site 2			- 8%	0.91
Site 3			- 6%	0.80
Site 4			+ 22%	0.78

***Table 1** Average wind speed (2005) for 5 observation sites and the nearest WRF point. Percentage deviation of the WRF model compared to observations at 9 sites. Correlation coefficient (ρ) between hourly data from WRF and observations.*

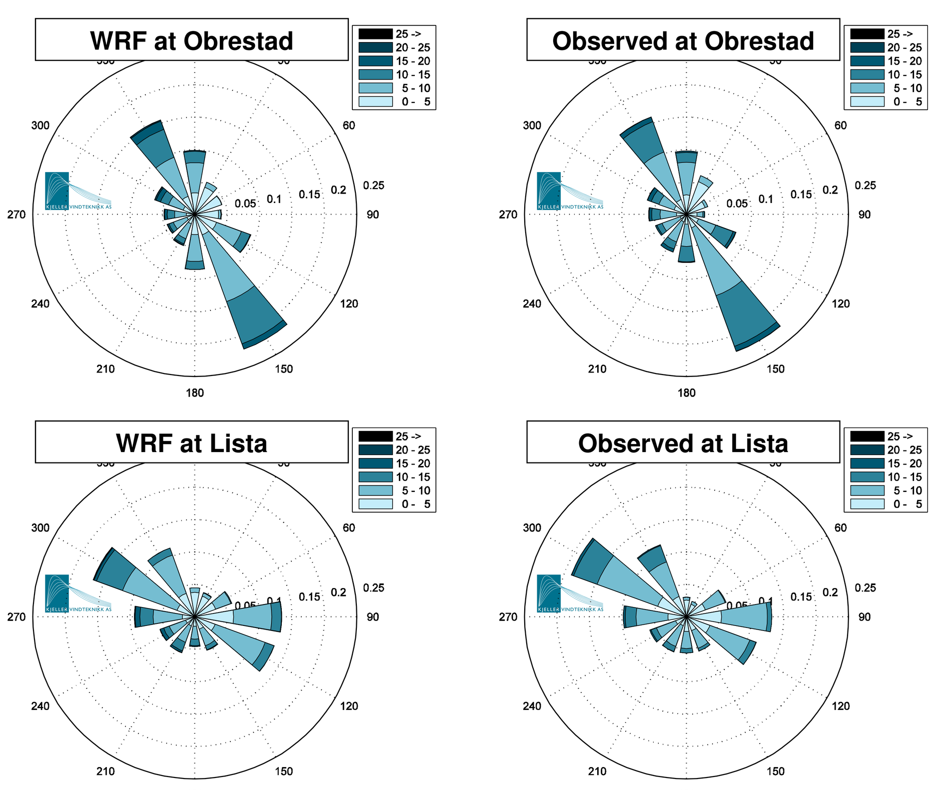
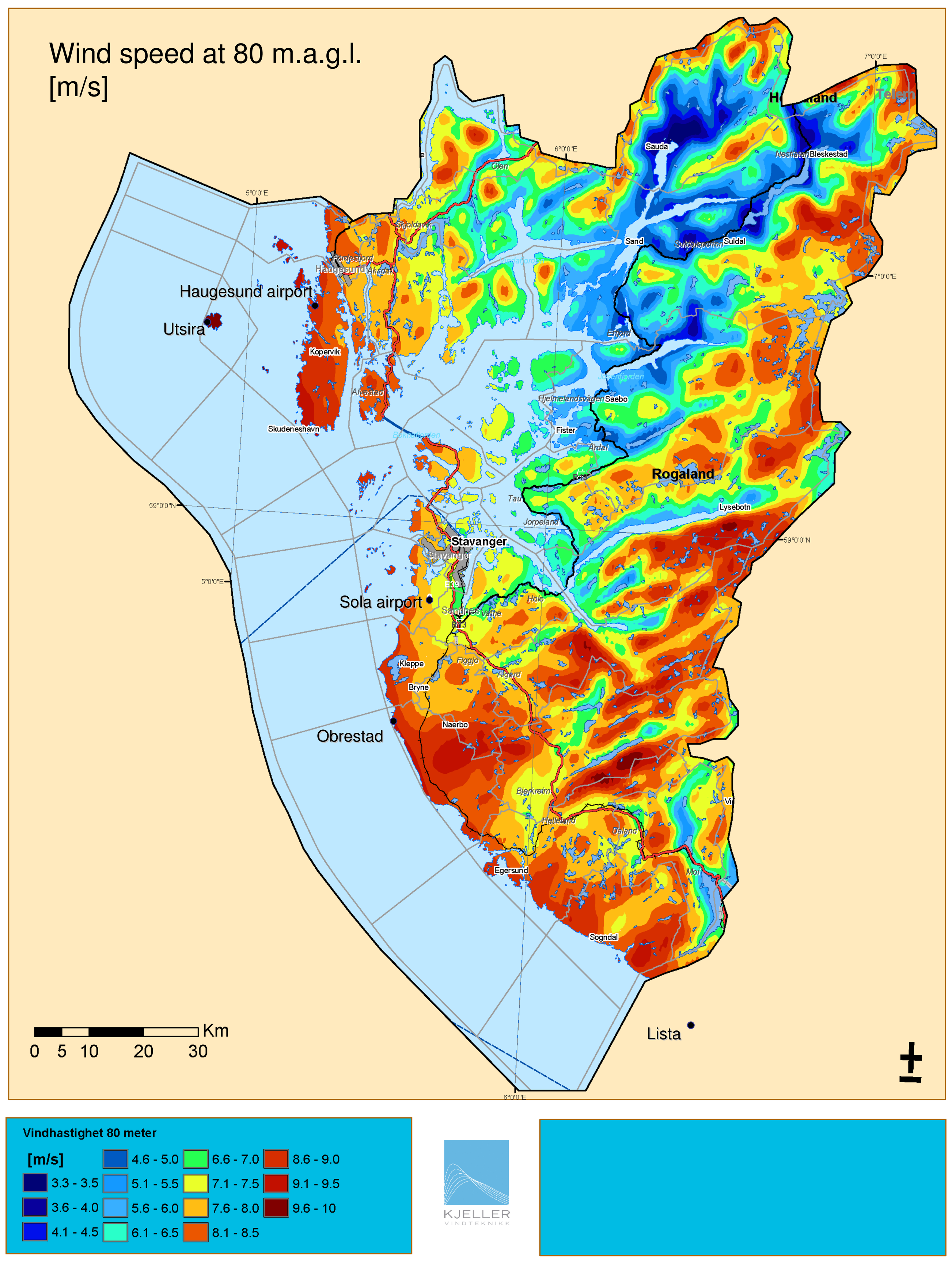


***Figure 2:** Wind roses for 2 locations, from WRF (left) and observations (right)*



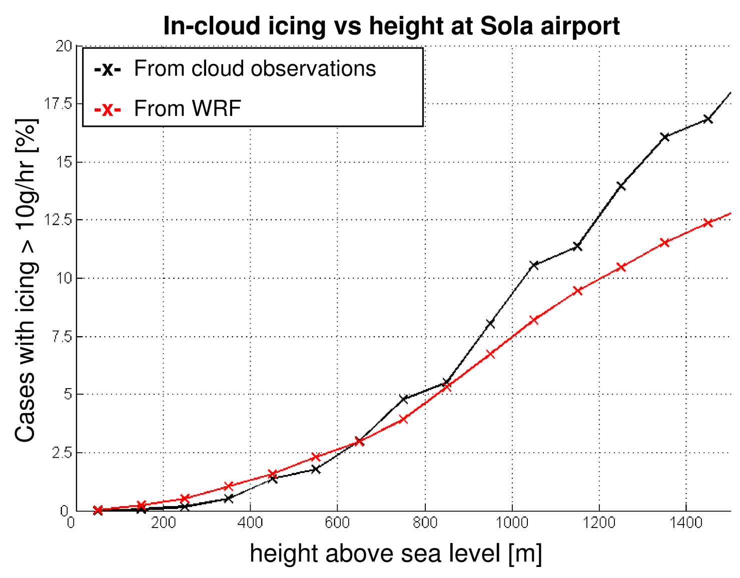
4. Icing

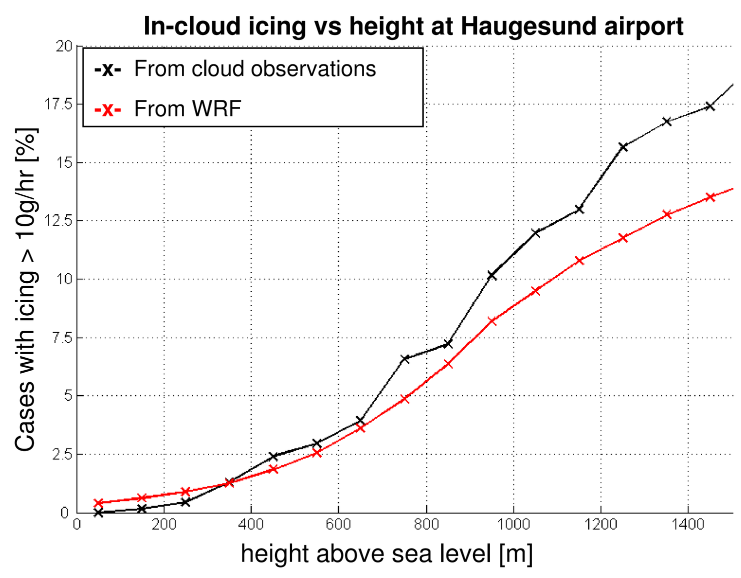
In-cloud icing is a challenge for wind power in Norway. In-cloud icing describes the process where liquid supercooled droplets (typically cloud droplets) collide with structures and momentarily freezes to the structure. In-cloud icing is known to accumulate thick layers of ice. Icing has been calculated from:

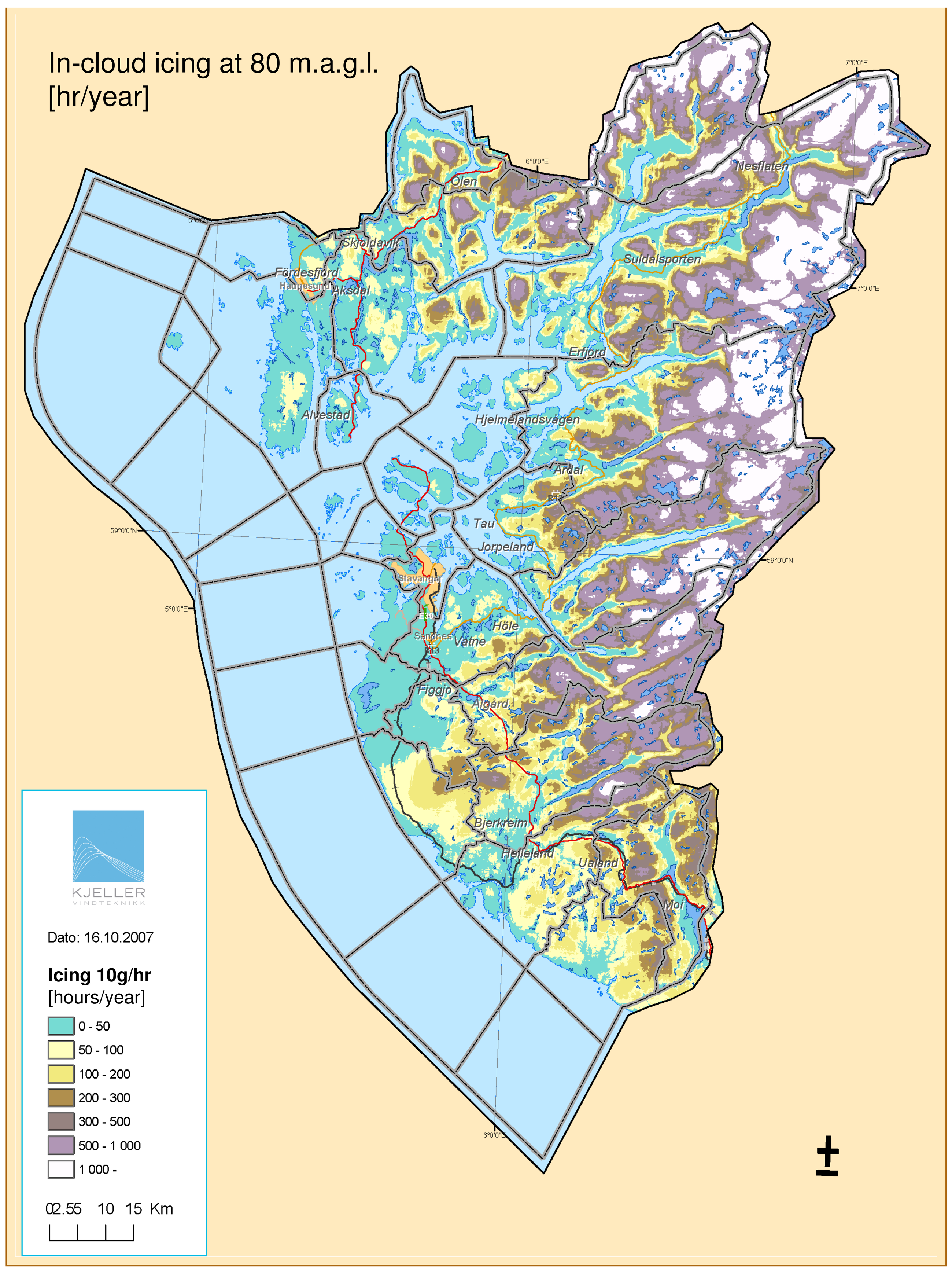
$$\frac{dM}{dt} = \alpha_1 \alpha_2 \alpha_3 \cdot w \cdot A \cdot V$$

Here dM/dt is the icing rate on a standard object (defined by ISO 12494, 2001, as a cylinder of 1m length and diameter 30mm). w is the liquid water content, A is the collision area perpendicular to the flow of air. V is the collision speed. α_1, α_2 and α_3 are the collision efficiency, sticking efficiency and accretion efficiency.

In-cloud icing calculated from WRF data is compared to icing calculated from observations of cloud height from the airports at Sola and Haugesund (using the method by Harstveit 2002). The model tends to overpredict number of hours of icing for heights 200-500 m.a.s.l and underpredict icing at heights above 1000 m.







5. Conclusions

We find good correlation between observations and the WRF model. But the absolute wind climate and the vertical wind speed profile at a certain height is very sensitive to local surface roughness and topography of sub-grid scale. The model thus seems to overestimate wind speed in areas with large sub-grid topographic variations. While the smoothed model-terrain often leads to underestimated wind speed at hilltops. The uncertainty of predicting the absolute wind speed for the lowest 100m of the atmosphere is in the order of 10%. But for areas with smoother terrain, the uncertainty is in general less than this. The largest uncertainties are typically found for measurements at 10m height. We have experienced that the uncertainty in the predicted wind climate can be further reduced by combining WRF with microscale models.

Icing can be calculated by the model, but icing is typically overestimated in the lower 200-400m of the atmosphere. This is probably related to biases in the vertical mixing processes and the relatively simple microphysical parameterization scheme (Ferrier) used in this simulation.

References

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