

NUMERICAL SIMULATIONS OF THE CLIMATOLOGY OF WINDS IN THE COMPLEX TERRAIN OF ICELAND

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Abstract: Flow over Iceland has been simulated over a fifteen year period using the PSU/NCAR MM5 mesoscale model. There is a considerable spatial variability in the mean annual wind speed as well as temporal variability between the four seasons (SON, DJF, MAM and JJA). This variability can to a large extent be explained by a combination of large scale seasonal effects and orographic processes that are theoretically fairly well known. However, theoretical knowledge of these processes is of limited use for producing quantitative maps of the wind climate as is done here. These maps can be used as a first step towards assessment of wind energy resources.

The simulations indicate that the mean winds are very strong over the largest glaciers and at their foothills. The simulations are in general in fairly good agreement with observed wind speeds. Observed discrepancies can be explained by the model resolution, i.e. the orography not being properly resolved and/or incorrect land use parameters as well as uncertainties in observations and sub-grid effects at individual observation sites.

Keywords – Wind climate, wind mapping, wind energy assessment, Iceland, numerical simulations, MM5

1. INTRODUCTION

The flow over Iceland has been simulated over a fifteen year period from September 1987 through August 2002. The flow was simulated using the PSU/NCAR MM5 mesoscale weather model (Grell et al., 1995) with a 8 km horizontal resolution and 23 levels in the vertical. The simulated mean wind is compared to observations at thirteen stations in Iceland (Fig. 1). The stations are both near the coast and at higher altitudes.

The simulated data is post-processed with a newly developed, open source, software suite named MM5IDL (Rögnvaldsson and Rögnvaldsson, 2004).

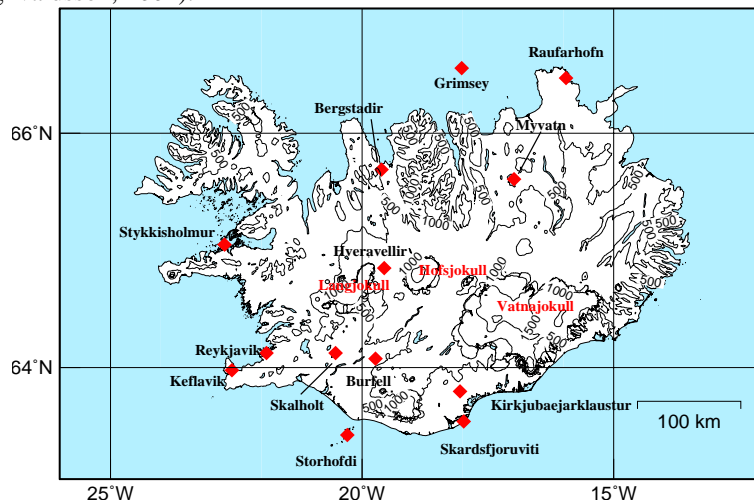


Figure 1. Observation stations (red diamonds) used for comparison with the MM5 simulations. The three red colored labels indicate the Langjökull, Hofsjökull and Vatnajökull glaciers.

2. EXPERIMENTAL SETUP

The model was forced using initial and boundary conditions from the European Centre for Medium range Weather Forecasts (ECMWF) in Reading. The boundary data were updated four times a day and each simulation was run over a period of six months. Model output was written every six hour. In this study, the turbulent boundary layer is parameterized according to Hong and Pan (1996) and cloud physics and precipitation processes according to Grell et al. (1995) and Thompson et al. (2004), respectively. The simulations were carried out with 8 km horizontal resolution, the domain size being 123×95 points with 23 vertical levels. Further discussions about the model setup and the observational network in Iceland can be found in Rögnvaldsson et al. (2004).

3. RESULTS

Fig. 2 shows the mean annual wind speed over the fifteen year period. There is a considerable spatial variability with a relatively strong coastal wind gradient and strong winds over the largest glaciers and at their foothills. The wind

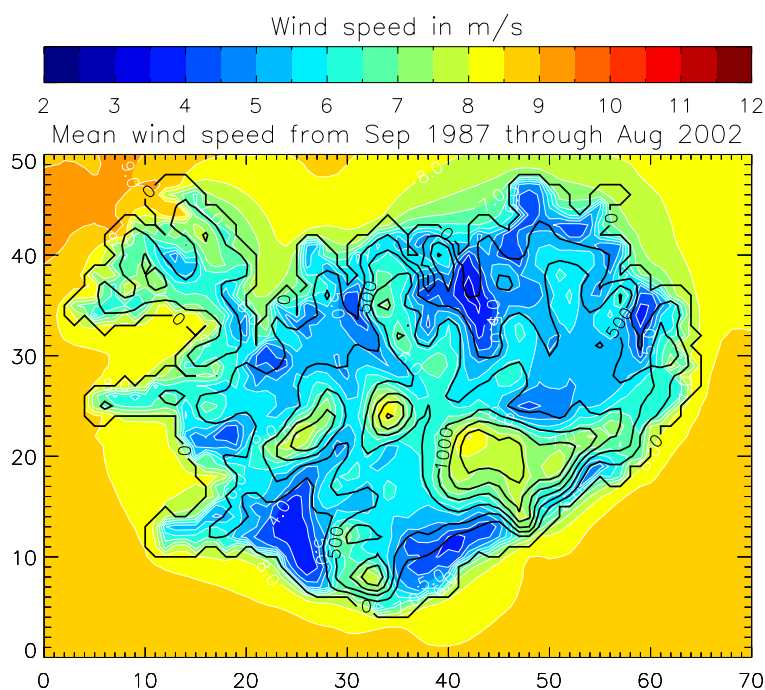


Figure 2. Simulated mean annual wind speed [m/s] from September 1987 through August 2002.

speed is not only a function of altitude as can be seen by the region of weak wind NE of Vatnajökull glacier and the relatively weak winds between Langjökull and Hofsjökull glaciers (station Hveravellir) in the Icelandic highlands. The high altitude area Mývatnsöræfi (station Mývatn) has also relatively weak mean winds. The relative difference in wind speed varies considerably between the four seasons, SON, DJF, MAM and JJA. The difference is greatest during winter (DJF) and summer (JJA) months (Fig. 3), the wind speed being on average 15–35% stronger than the annual mean during DJF and 15–40% weaker during JJA. The relative difference is less during the autumn (SON) and spring (MAM) months (not shown), the wind speeds deviating by only $\pm 5\%$ from the annual mean.

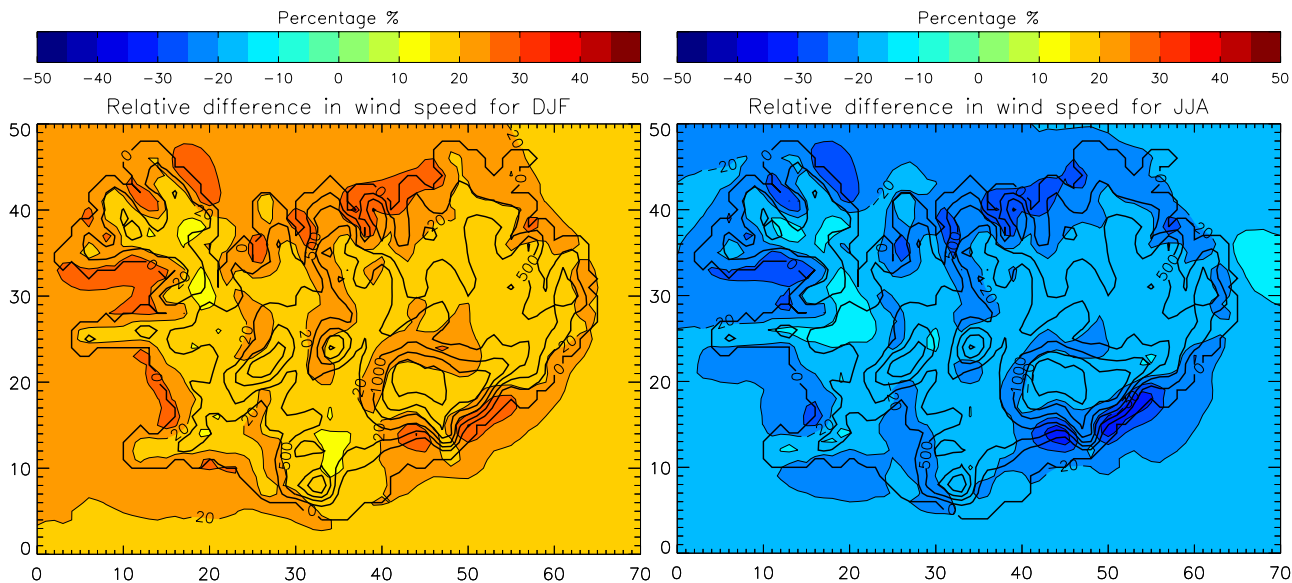


Figure 3. Relative difference [%] between seasonal and annual mean wind speeds for DJF (left) and JJA (right).

4. COMPARISON WITH OBSERVATIONS

Fig. 4 shows a scatter plot of the measured and simulated mean annual wind speed at the thirteen stations. Two points

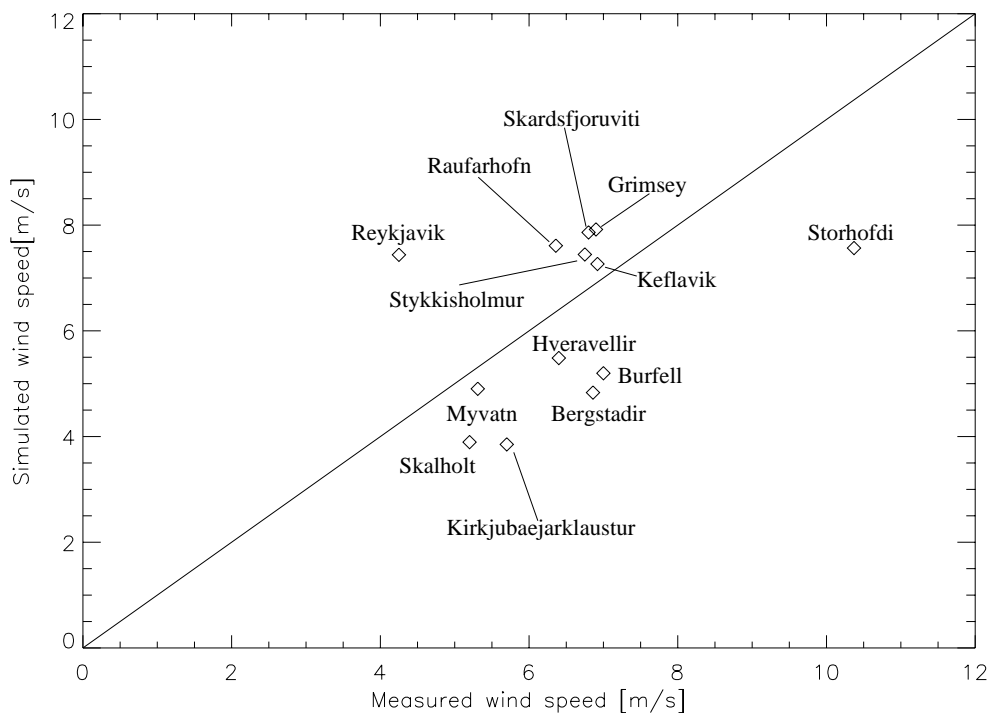


Figure 4. Comparison between measured (x-axis) and simulated (y-axis) annual mean wind speed at the thirteen observation sites shown in Fig. 1.

show the greatest discrepancies, stations Stórhöfði and Reykjavík. The anemometer at Stórhöfði is on a 120 m high cliff whilst the corresponding grid cell in MM5 is at sea level. This discrepancy between the topography in the model and reality explains the large difference between the measured (10.4 m/s) and simulated (7.6 m/s) wind speed. The Reykjavík weather station is at 50 m altitude but the nearest model grid cell is at 150 m altitude. There is further a strong coastal gradient in the wind field, the next inland grid cell having considerably less wind speed (5.7 m/s). This

can to some extent explain the difference between the measured (4.1 m/s) and simulated (7.4 m/s) wind speeds. It should further be noted that due to great urbanization and increase in vegetation in the capital area, measured winds in Reykjavík have been decreasing over the past decades. The model land use parameters do not capture the resulting high surface friction correctly, at least not at the current resolution.

Another source of difference between simulated and measured wind lies in the uncertainty of the observations themselves. Considerable differences have been noted between measurements made by different brands of anemometers in Iceland (P. Arason, personal communication). There are further local effects on a small sub-grid scale at the observation sites that the model can not be expected to resolve.

The MM5 grid cells for the following five stations are all over sea; Grímsey, Keflavík, Raufarhöfn, Skarðsfjöruviti and Stykkishólmur. The resulting reduction in surface friction is likely to explain to a large extent the overestimation (0.4 – 1.3 m/s) in the simulated wind speeds in addition to measurement uncertainties and sub-grid effects. The underestimation in simulated wind speeds at the remaining stations is probably caused by a mixture of erroneous surface parameters, describing friction and albedo, and to little mixing near the surface in the PBL scheme being used and the above mentioned issues regarding anemometers and local effects. These factors will be investigated further in the future.

5. CONCLUSIONS

We conclude that the simulated wind speeds agree fairly well with observations. The observed discrepancies can to a large extent be explained by the model coarse resolution and corresponding errors in land use parameters and orography. Another source of discrepancies is the inherited uncertainty of anemometers. It is further speculated that to little mixing near the surface in the PBL scheme used can contribute to low simulated wind speeds in the interior of Iceland.

As the ground network of wind observations is sparse in Iceland, these quantitative maps of wind speed can be used as a valuable first step towards assessment of wind energy resources in Iceland.

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