Impact of WRF PBL schemes for wind energy forecasting in Ireland.

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Introduction

Weather forecasts are widely used by transmission system operators and energy market traders for predicting wind energy production. Physics schemes in forecast models, especially planetary boundary layer (PBL) schemes, have been shown to influence the skill of wind speed forecasts at wind turbine hub-heights [1,2].

Six PBL schemes within the Weather Research and Forecasting (WRF) model have been compared for wind energy forecasting in Ireland. The overall forecast skill is examined to determine the most accurate PBL scheme for the forecasting of wind energy output.

Data

NWP data:
- WRF v4.0 used to downscale ECMWF IFS forecast data to 2.25km, 51 vertical levels.
- Time period Oct 2017 - Sept 2018.
- Six PBL schemes analysed: YSU [3], MYJ [4], QNSE [5], MYNN2.5 [6], ACM2 [7] and Shin-Hong [8].

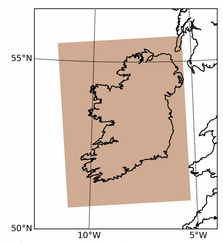

Figure 1: Inner-most WRF domain at 2.25km grid spacing.

Observations:
- Mast observations from three Irish wind farms. Referred to as Farm A, B and C here.
- 10m wind speed at closest three synop weather stations are used for comparison, which are within 35km of the wind farm.

Results

1. Station Comparisons

- **ACM2** scheme has best overall RMSE for each of the three wind farms, table 1.
- Meanwhile **MYNN2.5** has best overall RMSE for 10m wind speed at the three synop stations.

PBL	Synop A	Synop B	Synop C	Farm A	Farm B	Farm C
YSU	1.604	1.965	1.763	2.350	2.259	2.525
MYJ	1.902	2.210	1.939	2.049	2.157	2.249
QNSE	1.656	2.087	1.695	2.126	2.258	2.296
MYNN2.5	**1.237**	**1.669**	**1.356**	2.058	2.097	2.310
ACM2	1.275	1.674	1.495	**1.933**	**2.042**	**2.184**
Shin-Hong	1.471	1.822	1.562	1.992	2.104	2.20

Table 1: Overall RMSE for wind speed at synop and wind farms. Synop wind speeds are at 10m. Wind speeds at farms are at 40, 50 and 75m respectively.

2. Wind Ramp Verification

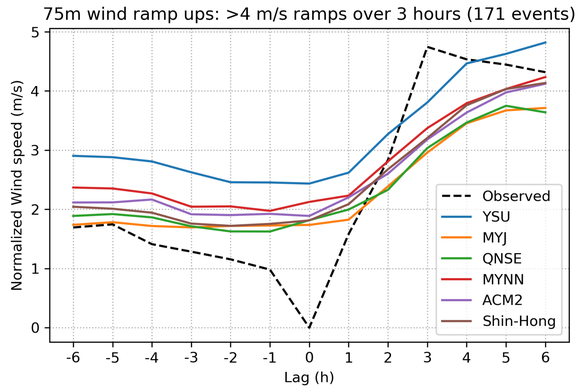

Figure 2: Average of observed 3 hour ramp up events (black-dashed) greater than 4m/s at Farm C. The corresponding forecast values for each PBL scheme are also shown.

- Composite of observed ramp up events at Farm C and the corresponding forecast values show that WRF forecasts tend to underestimate the strength of ramps, fig 2.
- The **YSU** scheme has the lowest bias in terms of ramp magnitude and maximum wind speed, table 2, (using metrics defined in [9]). It also has the highest hit rate.
- All PBL schemes have large false alarm rates, but YSU has the highest, table 2.

PBL	Mag (m/s)	Delay (h)	w_max (m/s)	HR (%)	FAR (%)
YSU	**-1.219**	1.120	**0.056**	**20.3**	69.0
MYJ	-1.977	0.829	-1.216	16.4	62.1
QNSE	-1.715	0.819	-1.069	17.9	67.6
MYNN2.5	-1.765	0.804	-0.643	16.8	66.5
ACM2	-1.969	0.995	-0.917	17.7	**57.9**
Shin-Hong	-1.824	**0.769**	-0.925	17.5	62.2

Table 2: Mean errors in ramp magnitude, ramp delay and max wind speed, Hit Rate (HR) and False Alarm Rate (FAR) for each PBL scheme at wind farm C at 75m.

3. Influence of Stability

- Skill of different PBLs for modelling wind speed has been shown to depend on stability [1].
- Bulk Richardson number is calculated from forecast output using θ_V and wind speed at 10m and 100m.
- Wind speeds at Farm B are better represented by **YSU/ACM2** for unstable conditions and **MYJ/MYNN2.5** for strongly stable conditions.

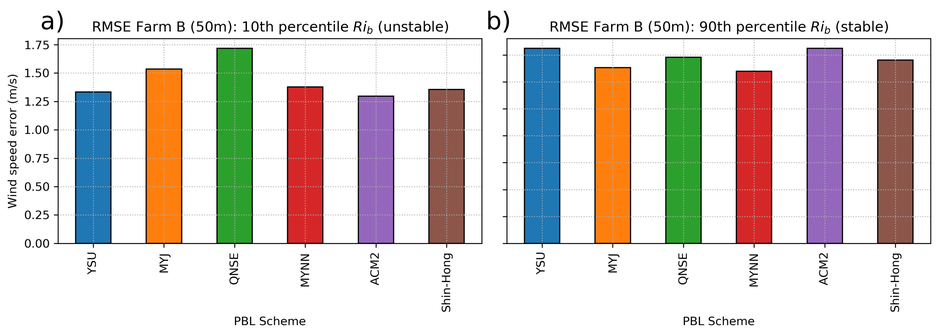

Figure 3: RMSE of 50m wind speed for each PBL scheme at Farm B for different tails of the distribution of Bulk Richardson Number; (a) less than 10th percentile and (b) greater than 90th percentile.

Conclusions

- Best PBL scheme for 10m wind speed is not the best for hub-height wind speeds at nearby wind farm.
- ACM2 has best overall skill at hub-height at three Irish wind farms
- Magnitude of wind ramps are underestimated by all schemes. YSU represents the magnitude of ramps best but also suffers from a high false alarm rate.
- Stability has an impact on the relative performance of different PBLs for hub-height wind speed forecasts.

Future Work

- Consider forecast performance in the context of wind power capacity factor.
- Analyse factors affecting forecast performance (e.g. stability) to investigate if the best PBL scheme can be adaptively determined prior to running the forecast.
- Run some shorter case study events at higher resolution (750m) to assess the impact of going to sub-km resolution.
- Extend work to examine the skill of NWP for solar resource forecasting and prediction of ramping events.

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