Outline & motivation

• Require: mean wind speed estimates and distributions over periods of 10-20 years, 50-100 m above the surface at sites
• Use archived and rerun Met Office weather forecast models
• Local downscaling adjustments
• “Virtual Met Mast”
• Extension to long term climatology
• Verification
• Wind atlas
• High resolution modelling to improve adjustment
• Conclusions/ Improvements
Primary Operational NWP Forecast Systems

UK 4km/1.5km
- 36 hour forecast
- 70 levels up to 40km
- 4 times per day

Regional 12km
- 60 hour forecast
- 38 levels (70L now)
- 4 times per day
- +EPS 18km, 24member

Global 25km
- 60 hour forecast twice/day
- 144 hour forecast twice/day
- +EPS 24member, 90km
Model levels – focusing on the near surface

LEFT: Global and 12 km model levels
RIGHT: 4 km and 1.5 km model levels

Lowest 1000m
Global +12km L70: 11 levels
4km + 1.5km L70: 16 levels

Lowest levels at 10m, 37m, 77m, 130m
Lowest 5 levels at 2.5 m, 13 m, 32m, 60 m and 93 m
Example: orography over the COLPEX (Cold Air Pooling Expt) region
Model=box mean from 100m data

- Orographic Roughness scheme in NWP models accounts for drag due to unresolved terrain.
- Local wind predictions need to correct for this.
Impact of Orographic roughness in UK 4km model

(4 year) Average wind speed (ms⁻¹)

30 m above ground level

100 m above ground level
Impact of Orographic roughness in UK 4km model

wind speed (ms\(^{-1}\))

30 m above ground level

Mean 25m Wind speed (1970–2000), from Met office gridded 10m observations
• $h_{\text{ref}}$ is the height above which perturbations due to sub-grid hills have decayed to some small value
• Derive wind at mast height from $u_M(h_{\text{ref}})$
• In VMM, only apply this correction if $h_{\text{ref}} > z_{\text{hub}}$
• Determination of $h_{\text{ref}}$ is therefore important
• $h_{\text{ref}} = \{\ln(kh) - \ln(\varepsilon)\}k^{-1}$
  • $k =$ characteristic wavelength
  • $h =$ amplitude orography
  • $\varepsilon =$ adjustable tuning
The ‘Virtual Met Mast’ - VMM

• Downscaling required
  • Orographic roughness known to reduce low-level winds
  • Effect of unresolved orography can be considerable
  • Local roughness variability
  • Adjustment of boundary layer at coasts (roughness change)
  • Further Offshore - no adjustments

• “High”-resolution NWP archives are relatively short
  • 4km, 12km 2006 → today
  • Techniques to extend NWP climatology to cover longer periods
  • Extending high resolution period by hindcasts - downscaling re-analyses (ERA Interim)
Climatology Extension

Probability matrix=

probability of downscaled wind \( u \) with speed (\& direction) in bin \( k \) when “climate” wind \( u_c \) has speed (\& direction) in bin \( l \)

\[ P \cdot u_{\text{climate}} = u_{\text{mast}} \]
Climatology Extension

All directions

Weibull shape, scale = 2.04, 7.80

All speeds

47m derived model distribution

Mean wind speed = 6.914 m/s
Height adjustment for local orography - Linear model

- Based on Mason & King ‘model D’
- 100 m DTED orography centred on site
- Orography tapered at edges of domain (typically 25x25 km²)
- Orography filtered to remove larger scales represented in UK4
- Run for all wind directions e.g. with 5° resolution
Local wind map at location

- Combine
  - mean wind distribution
  - Fractional speed-up by direction

- Show local orographic influence
Verification

Monthly Mean Wind Speeds - 70m

Obs Mean: 6.68 m/s  VMM Mean: 6.74 m/s

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Flat terrain
Verification

Monthly Mean Wind Speed - 50m Height, Gentle Hills

Observation mean: 5.50 m/s \ VMM mean: 5.78 m/s
Verification

Monthly Mean Wind Speed - 70m height

Observation Mean: 9.38 m/s VMM Mean: 9.24 m/s

Offshore
Wind Atlas maps

70m mean speed 2010 height and orographic drag corrected

70m mean speed 2010 uncorrected
High Resolution modelling - Colpex – Met Office masts

- COLPEX
  - Cold Air Pooling Experiment
  - Valley in Shropshire
- Chose windy period in COLPEX observational period to run UK4, 1 km, 333 m and 100 m models
  - 4km model provides LBCs for 1km model which provides LBCs for 333m model….through to the 100m model.
- All nested models (1km and finer) are free running and fixed resolution.
- 17/12/09 to 31/12/09
## Configuration of each of the models

<table>
<thead>
<tr>
<th>Horizontal Resolution (km)</th>
<th>Horizontal Grid-size (columns × rows)</th>
<th>Timestep (s)</th>
<th>Convection Param.</th>
<th>Orographic Form Drag</th>
<th>Sub-grid Turbulence (S-L=Smag’sky-Lilly)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>288x360</td>
<td>100</td>
<td>Shallow</td>
<td>Effective Roughness</td>
<td>1DBL + 2D S-L</td>
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<tr>
<td>1</td>
<td>100x100</td>
<td>30</td>
<td>None</td>
<td>None</td>
<td>As 4km + drainage</td>
</tr>
<tr>
<td>0.333</td>
<td>150x150</td>
<td>10</td>
<td>None</td>
<td>None</td>
<td>3D S-L + drainage</td>
</tr>
<tr>
<td>0.1</td>
<td>200x200</td>
<td>3</td>
<td>None</td>
<td>None</td>
<td>3D S-L + drainage</td>
</tr>
</tbody>
</table>
100 m model domain and orography

- Area = 20km x 20km centred on Springhill
- Masts at:
  - Duffryn (main valley)
    - 50m
  - Springhill (valley rim)
    - 30m
  - Burfield (adjacent valley)
    - 30m

Height in metres
Time averaged wind speed at 30m above ground level

- Area = 10km x 10km centred on Springhill
- Orography contours from 200m (white lines) to 600m (black lines).
- Increased detail and larger range of winds in finer resolution simulations.
- Not surprisingly, windier over the hill tops (including Springhill) and calmer in the valleys (including Duffryn).
- Hill top location

- 4 km model consistently 2-3m/s slower than wind mast observations.

- Mean errors for 1 km, 333 m and 100m models all within 0.3 m/s of observations

  - 1km resolution sufficient to get winds right at this location
Duffryn 14 day timeseries

- Located in main valley
- 4 km model consistently 2-3 m/s faster than wind mast observations.
- 1 km model consistently ~2 m/s faster than wind mast observations.
- Mean errors for 333 m and 100m models within 0.2 m/s of observations
  - 333 m resolution sufficient to get winds right at both locations
Mean Wind Errors at the two sites:-

Summary

• Remarkable agreement between finest resolution model simulations and mast observations

• Using corrections to 4km winds based on these 100m (or 333m) simulations should yield small errors in the VMM timeseries.

<table>
<thead>
<tr>
<th>Model</th>
<th>Springhill</th>
<th>Dyffryn</th>
</tr>
</thead>
<tbody>
<tr>
<td>4km</td>
<td>-2.28</td>
<td>+2.25</td>
</tr>
<tr>
<td>1km</td>
<td>-0.01</td>
<td>+1.82</td>
</tr>
<tr>
<td>333m</td>
<td>-0.23</td>
<td>-0.05</td>
</tr>
<tr>
<td>100m</td>
<td>+0.06</td>
<td>+0.19</td>
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</tbody>
</table>

14 day averaged Wind Speed Error (m/s)

Observed Speed       6.31    3.42
Correction techniques tested rely on relating high-resolution UM timeseries (i.e. $\Delta x=100\text{m or 333m}$) to 4km resolution timeseries.

1) Ratio of time average winds ($U_{100\text{m}}/U_{4\text{km}}$)
2) Linear regression
3) Linear regression with forced zero intercept
4-6) Directionally dependent versions of 1-3
## Summary of results – 14 locations

### $\Delta x=100m$

<table>
<thead>
<tr>
<th></th>
<th>VMM</th>
<th>Linear regression</th>
<th>Directional linear regression</th>
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</thead>
<tbody>
<tr>
<td>Mean $</td>
<td>bias</td>
<td>$</td>
<td>1.05</td>
</tr>
<tr>
<td>St. dev $</td>
<td>bias</td>
<td>$</td>
<td>0.60</td>
</tr>
<tr>
<td>Mean $bias$</td>
<td>0.054</td>
<td>-0.017</td>
<td>-0.045</td>
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<tr>
<td>St. dev $bias$</td>
<td>1.26</td>
<td>1.03</td>
<td>1.18</td>
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</table>

### $\Delta x=333m$

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<td>-0.05</td>
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<td>1.07</td>
<td>1.05</td>
</tr>
</tbody>
</table>

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Conclusions

- Cost Effective site screening
- Wind maps/atlas in preparation
- Extension to long term climatology
- High resolution modelling for more local accuracy – especially in complex terrain
- Improvements
  - Ability to ingest limited period site mast observations (MCP)
  - Better orographic drag correction by scaling 1.5km/4km winds