# Wind conditions based on coupling between a mesoscale and microscale model

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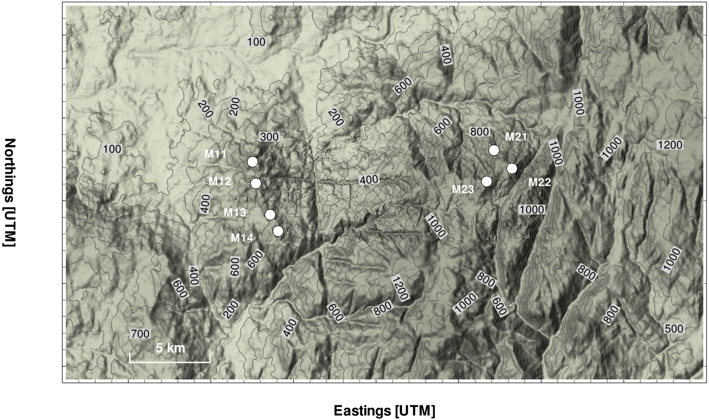
# Contents

1. Wind conditions for wind resource assessment and wind power forecasting
2. Model chain comprised of:
    - general circulation model ($\sim$ 100 km)
    - WRF, regional model (27 to 3 km)
    - VENTOS®/M, microscale model (300 $\sim$ 200 m)
3. Comparison with measurements at 2 complex sites (14 anemometers over 7 masts)
    - wind speed
    - wind direction
    - turbulence intensity
      IEC 61400-1: Wind turbines – Part 1: Design requirements
    - shear factor

# Sites 1 and 2




- 4 masts, 20 & 40 m, 30 & 60 m
- surface height: 30 to 1150 m

- 3 masts, 20 & 40 m, 30 & 60 m
- surface height: 120 to 1320 m

# Mesoscale: regional model WRF

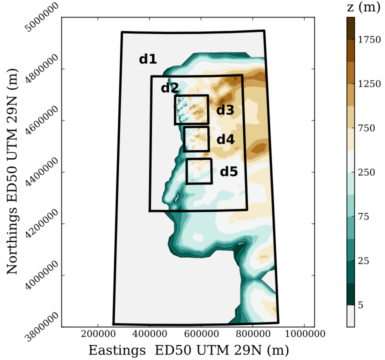
Weather Research and Forecasting model (version 3.2.1)

- ARW solver
- Initial/Boundary conditions:
  → NCEP GDAS operational analyses
  → NOAA RTG-SST

Parameterization schemes:

- Microphysics: WRF Single-Moment 6-class
- Atmospheric radiation: Dudhia scheme for SW, RRTM for LW
- Cumulus parameterization: Kain-Fritsch scheme
- Planetary Boundary layer: ACM2 non-local closure
- Surface Layer: Pleim-Xiu scheme
- Land-Surface Model: Pleim-Xiu (2 layers)

# Mesoscale: domains and nesting configuration




Domain, grid, resolution:

- d1: 24 × 44, 27 km
- d2: 43 × 61, 9 km
- d3: 46 × 40, 3 km
- d4: 34 × 34, 3 km
- d5: 34 × 34, 3 km

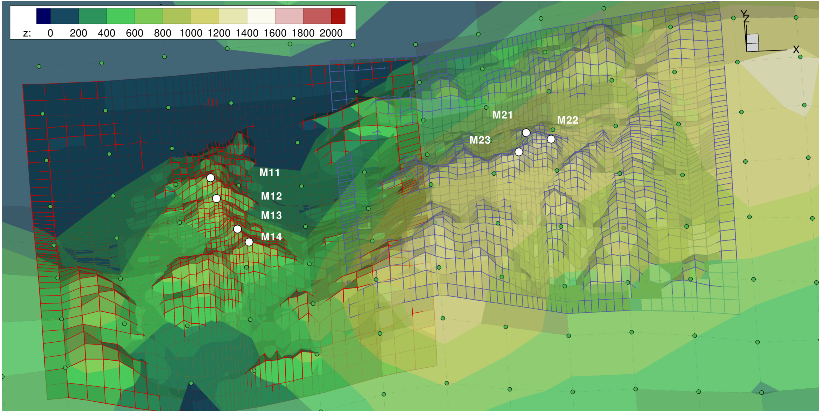
Vertical levels: 49

- Output: 30 minutes
- Time-step (seconds): 180, 60, 20

Time periods:

- 2005, July, 1st to 15th — Summer
- 2005, Nov. 19th to Dec. 3rd — Autumn

# Microscale: surface grid



# Microscale: VENTOS®/M

## SITE 1

- Grid: $47 \times 47 \times 44$
- Domain: $18 \times 18\,\mathrm{km} \times \approx 7$
- $\Delta x$ : 200 to 665 m
- $\Delta z$ : 3 to 922 m

- Time-step: 2 s
- Partitions: 6
- Speed-up: 4.0 / 3.8
- Resolution masts: 211–250 m

## SITE 2

- Grid: $42 \times 49 \times 44$
- Domain: $18 \times 21\,\mathrm{km} \times \approx 7$
- $\Delta x$ : 150 to 984 m
- $\Delta z$ : 3 to 919 m

- Time-step: 2 s
- Partitions: 4
- Speed-up: 3.1 / 5.2
- Resolution masts: 166–310 m

- VENTOS® is a software library (EC trade mark nº 4706438), used since 2002 by RES and 2004 by NPC.
- VENTOS®/M, part of the VENTOS® software library, is a new addition (2012), with the ability to mimic the whole range of atmospheric phenomena at a micro-scale level with a lower number of physical simplifications, compared to either meso- or microscale conventional approaches.

# Error measures

## Mean square error

$$\text{MSE} = \frac{1}{\mathcal{N}} \sum_{n=1}^{\mathcal{N}} (\Phi_{pre} - \Phi_m)^2 \qquad (1)$$

where $\Phi$ is wind speed or wind direction

and pre and m refer to predicted and measured values

## Root mean square error

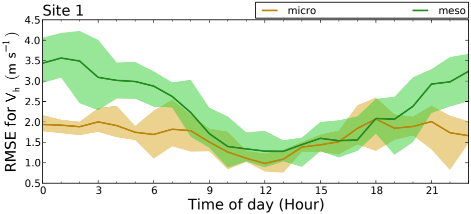
$$\text{RMSE} = \sqrt{\frac{1}{\mathcal{N}} \sum_{n=1}^{\mathcal{N}} (\Phi_{pre} - \Phi_m)^2} \qquad (2)$$

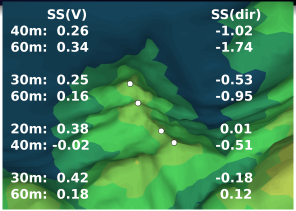
## Skill score

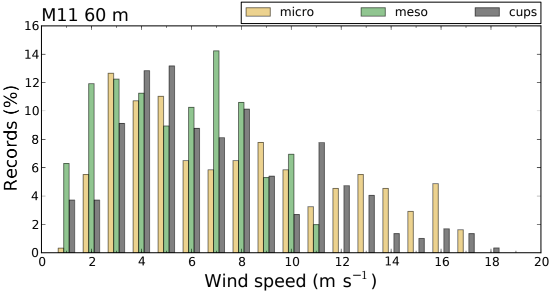
$$\text{SS} = 1 - \frac{\text{MSE}_{micro}}{\text{MSE}_{meso}} \qquad (3)$$

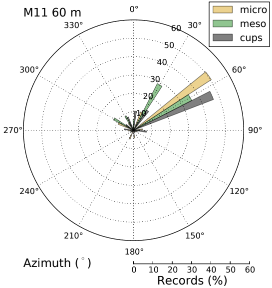
- $0 < SS \leq 1$, the coupled (micro) approach is superior to meso only.
- $SS < 0$, the coupled (micro) approach is worse than meso only.

# Summer period: results for site 1

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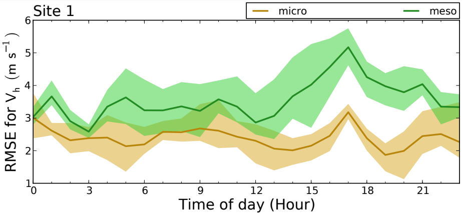
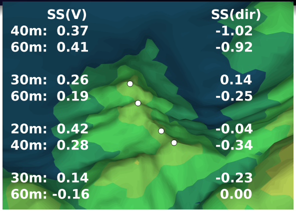
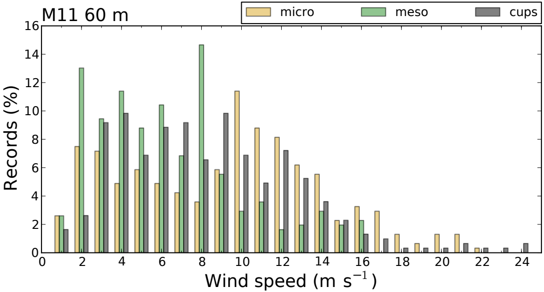
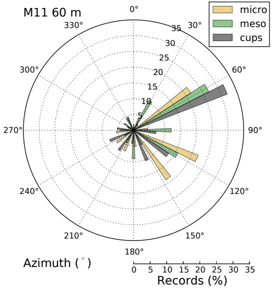
# Autumn period: results for site 1

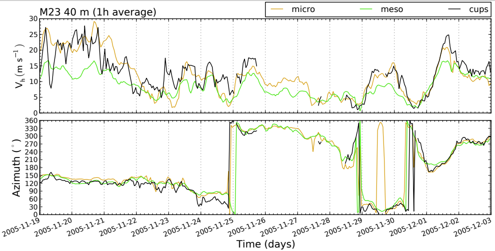


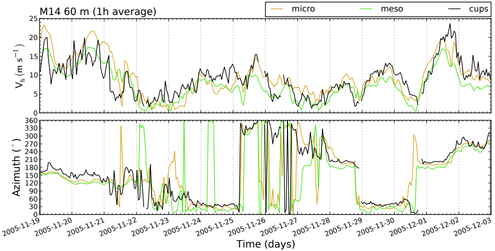



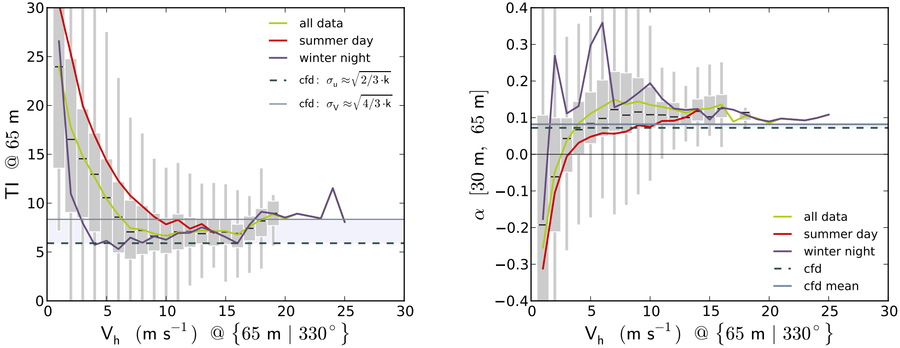
# High wind speeds (14 days: 19 Nov – 3 Dec 2005)



# Turbulence intensity and shear factor (IEC 61400-1)

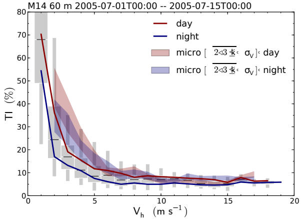
**Neutral flow simulations:** *TI* and $\alpha$ nearly independent of wind speed
(Results presented at EWEC 2010)



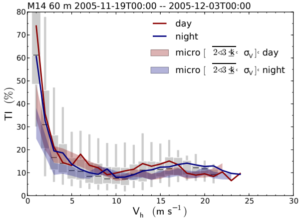

Turbulence intensity and shear factor have become two indicators of increasing importance, given their impact of WT lifetime and operational costs.

# Turbulence intensity: effects due to stratification

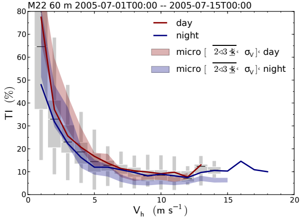
## Summer — Site 1



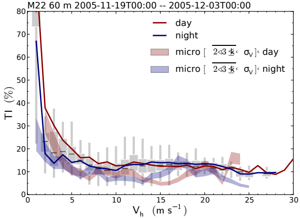

## Autumn — Site 1



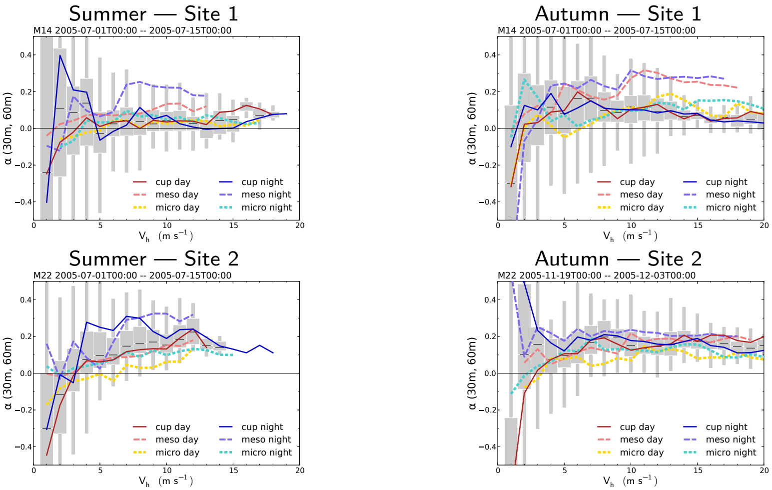

## Summer — Site 2




## Autumn — Site 2



# Shear factor: effects due to stratification



# Conclusions

## Wind speed

- $SS > 0$ for 10 out of 14 masts
- Autumn has higher RMSE (3.4 against 2.3 $\mathrm{m\,s^{-1}}$)
- Histograms: microscale captures high velocities and shows good agreement

## Wind direction

- Microscale performs worse on overall: mostly $SS = -0.2 \sim -1.7$, higher variability, higher bias and phase error.
- Wind roses: microscale captures most frequent sector
- Results are better in Autumn than Summer

## Turbulence intensity and shear factor

- Stratified flow: simulations able to capture increase of $TI$ with decrease of $V_h$
- Diurnal $TI$ agreement is better than in nocturnal period
- Microscale shows better agreement than mesoscale and capture nocturnal negative shear factor trend