Technical University of Denmark

Long-term (1-20 years) prediction of wind resources (WAsP)

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Wind Energy Department

Risø National Laboratory

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Overview

- WAsP
  - Problem
  - Solution
  - Models of WAsP
  - Complex terrain (RIX)
  - New WAsP
- Flow in and near forests
- Meso-scale modelling

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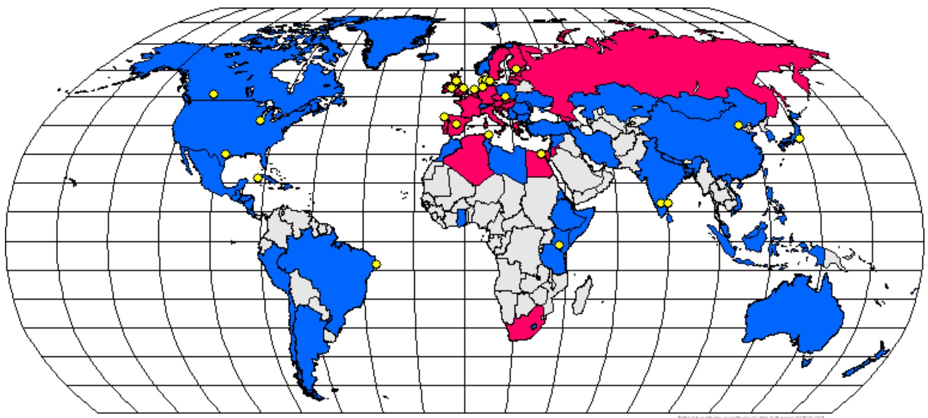
The World according to WAsP



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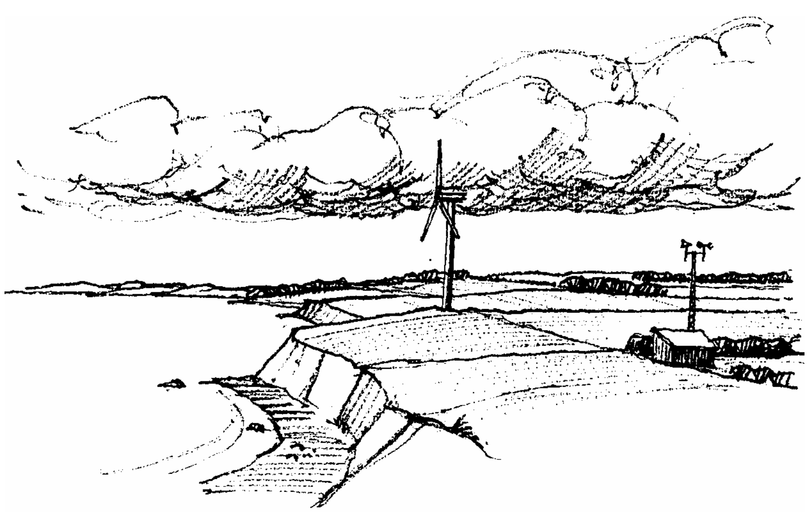
The problem



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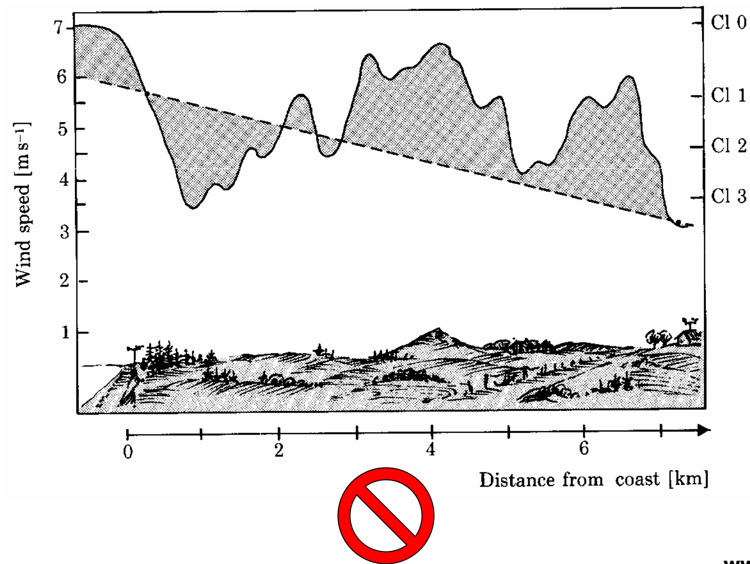
Linear interpolation



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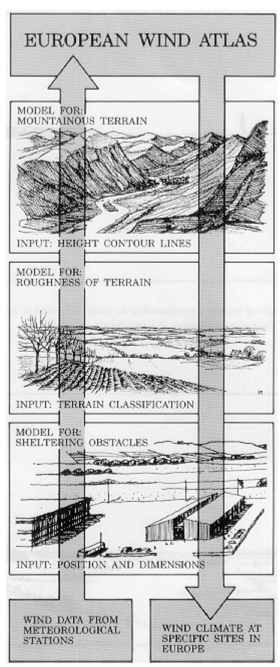

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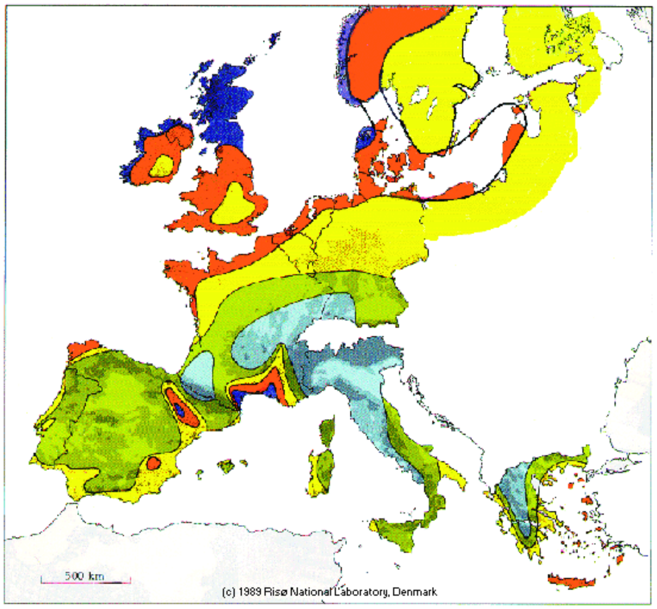
European Wind Atlas



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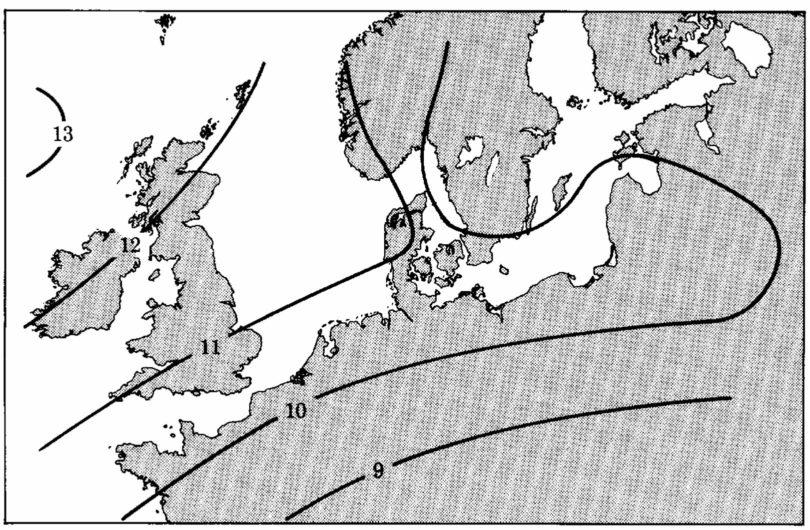
Geostrophic winds



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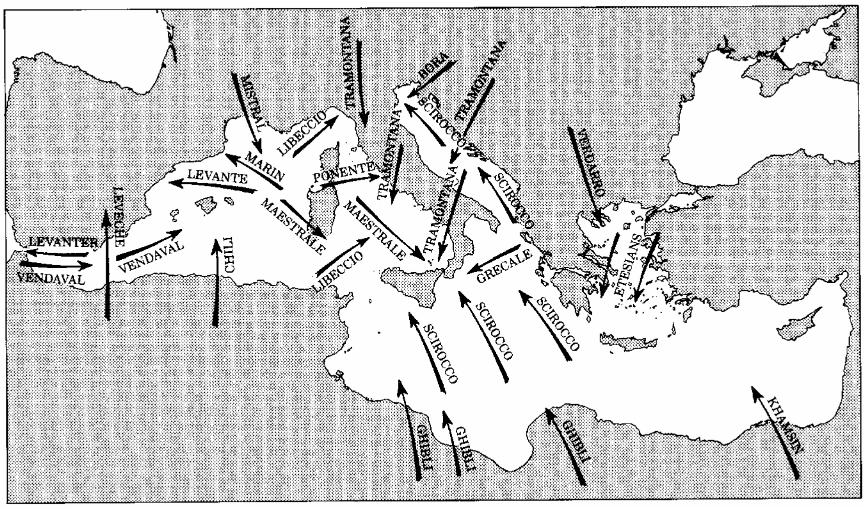
Thermal winds



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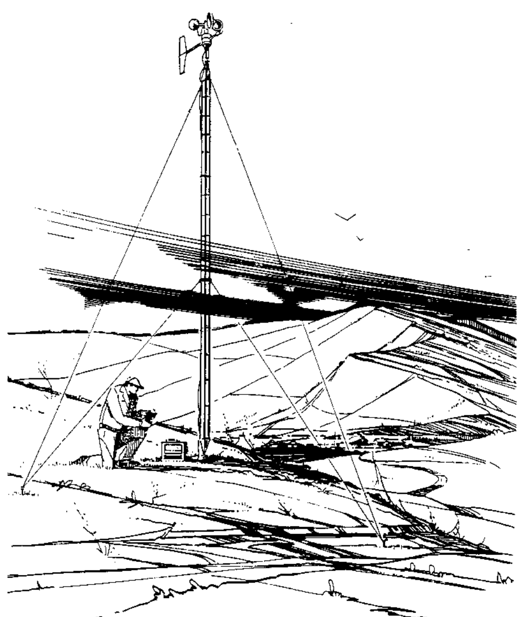

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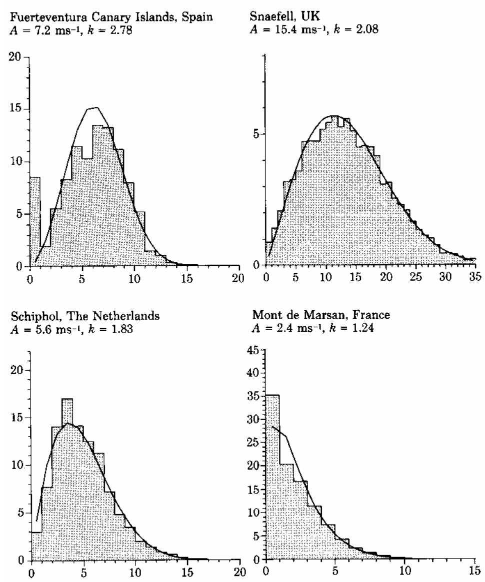
Weibull distributions



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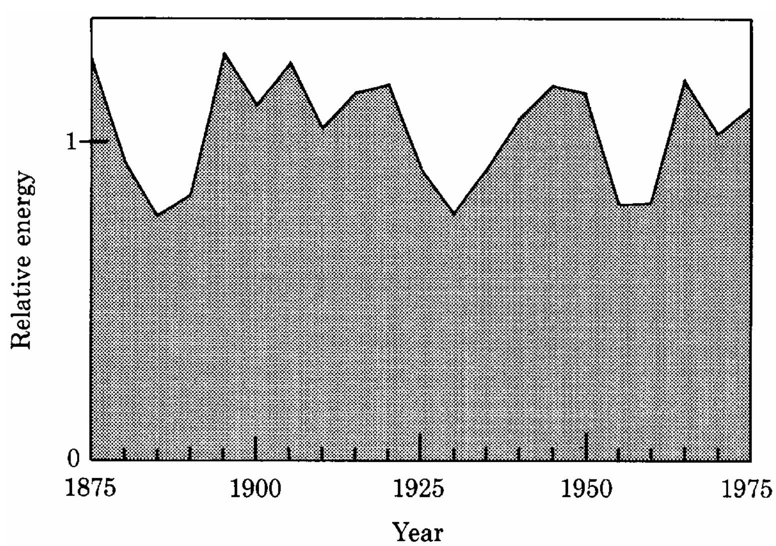
Annual variation



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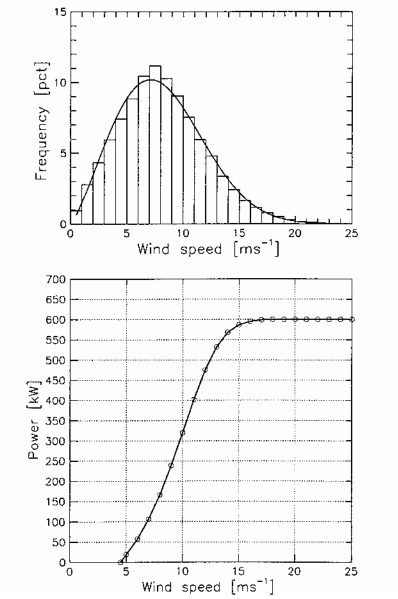
Power production basics



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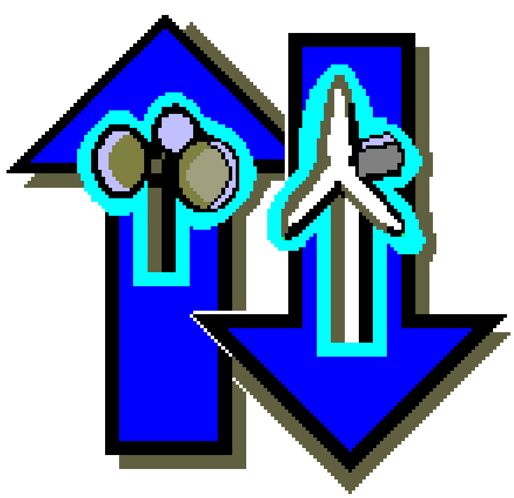
The WAsP Icon



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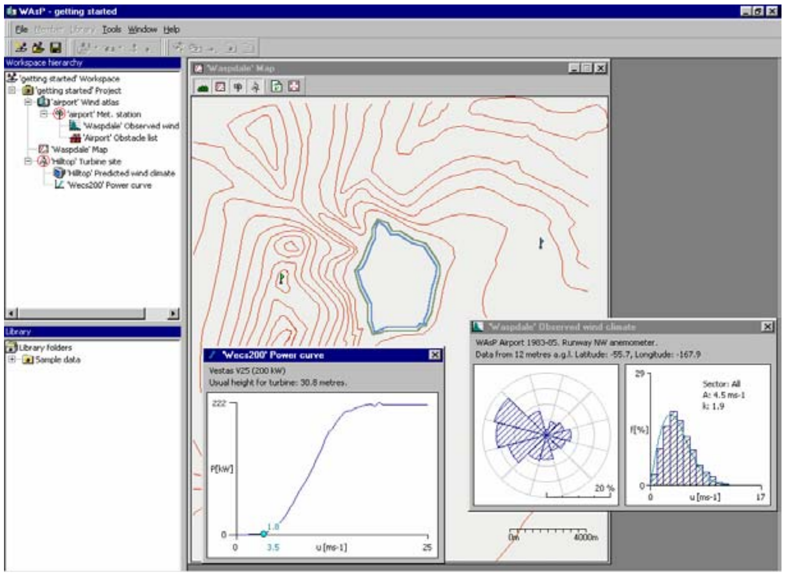
Screen lay-out



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WAsP-arithmetics

WAsP = OBS + ROU + ORO

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Obstacles

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What is an obstacle?

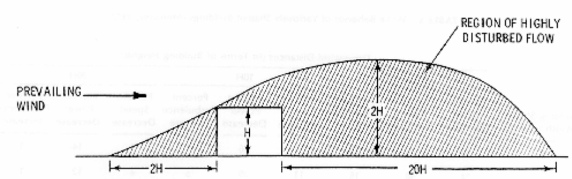
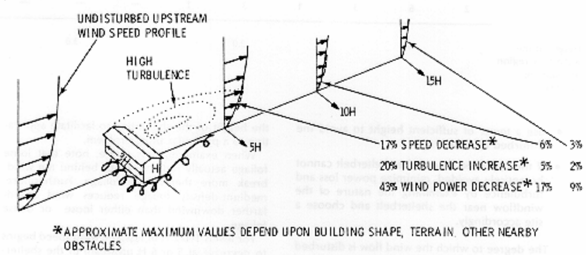


FIGURE 11. Zone of Disturbed Flow Over a Small Building (Frost and Nowak, 1977; Van Eimern et al., 1964)



After Meroney (1977)

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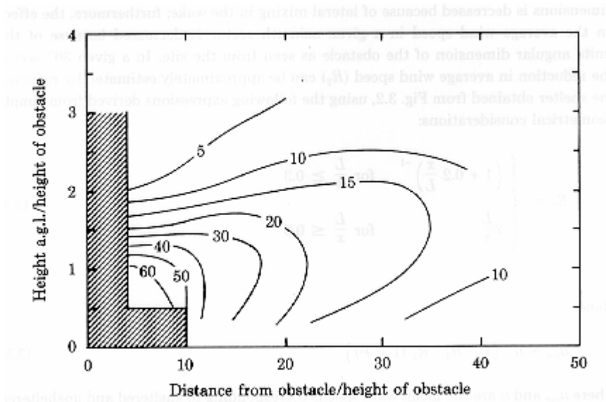
Effects of an obstacle



Reduction of wind speed in per cent due to shelter by a two-dimensional obstacle of zero porosity. Based on the expressions given by Perera (1981)

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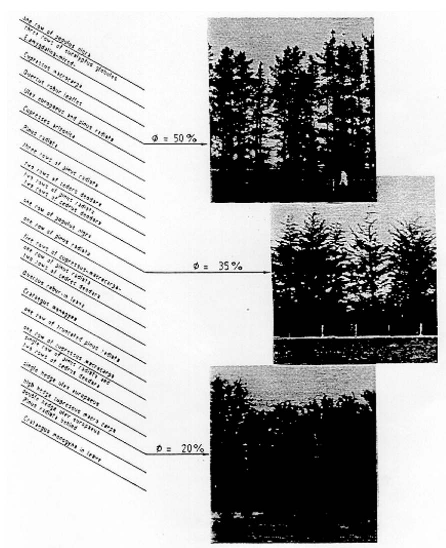
Trees and shelter belts



Porosity
in per cent or as a fraction

Open > 50%

Dense > 35%

Very dense < 35%

Solid = 0%

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Specifying obstacles in WAsP

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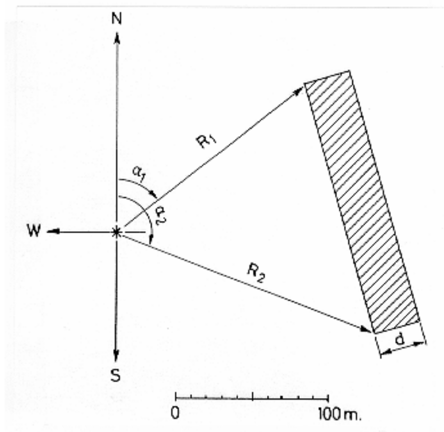

Obstacles are specified as rectangular boxes relative to the site: by two angles and two radii, their height, depth and porosity

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Obstacle viewed in WAsP

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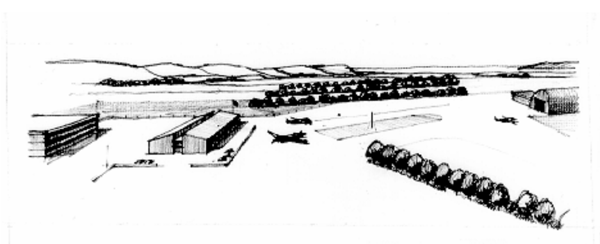

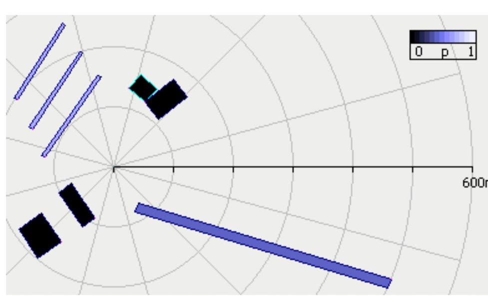

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Roughness

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Equations!

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$$u(z) = \frac{u_*}{\kappa} \ln\left(\frac{z}{z_0}\right)$$

$$G = \frac{u_*}{\kappa} \sqrt{\left[\ln\left(\frac{u_*}{f z_0}\right) - A\right]^2 + B^2}$$

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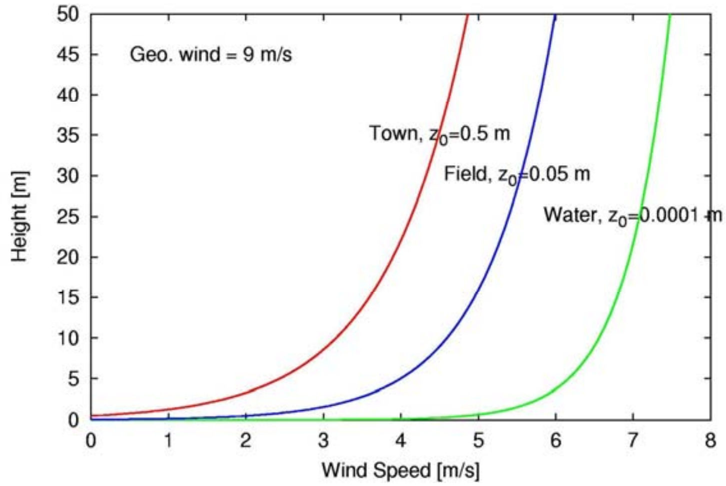
Logarithmic profile



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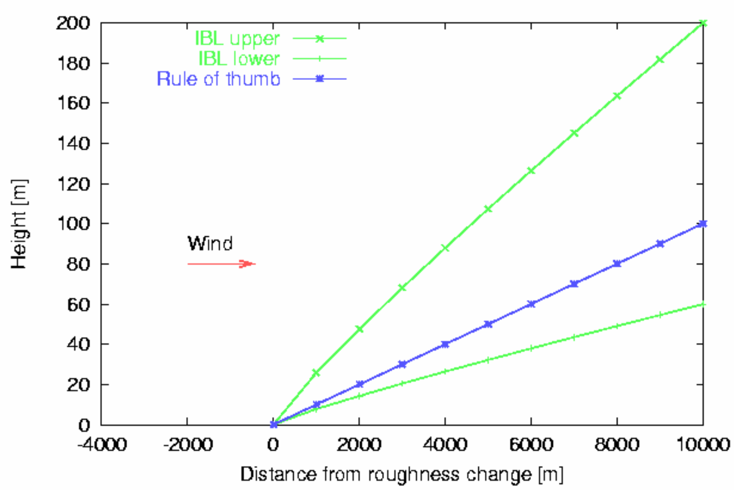
Internal Boundary Layer (IBL)



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Orography

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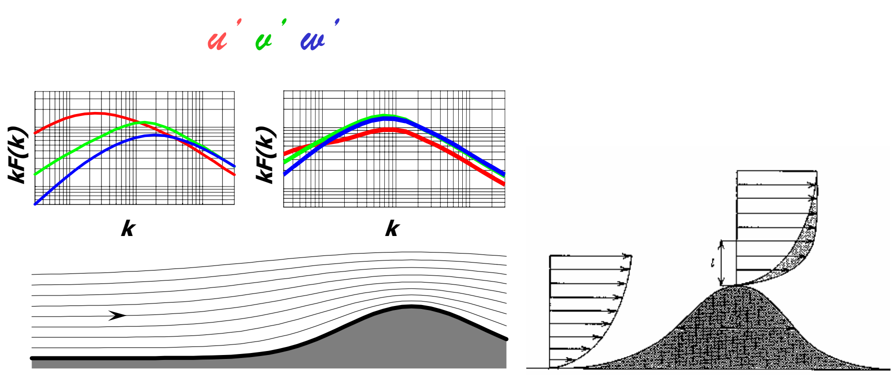
Stream lines and turbulence over a hill



Stream lines are compressed => wind speed-up!

Askervein Hill Field Experiment

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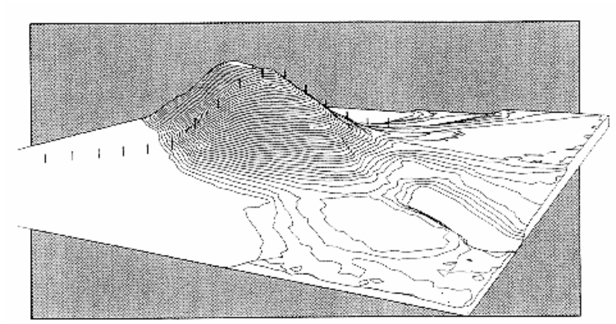
Mother of all flow-over-hill studies: The Askervein Hill field experiment

(Benbecula Island, Outer Hebrides, Scotland)



Wind measured on masts along a line across the hill
(mast distance 100 m)

Askervein Hill velocity profile

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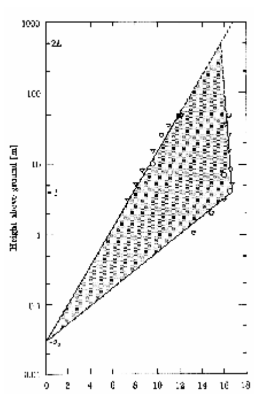
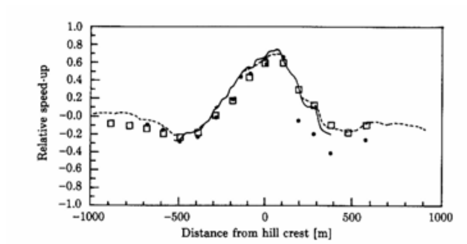
Orography effects on wind speed profile



Vertical profile

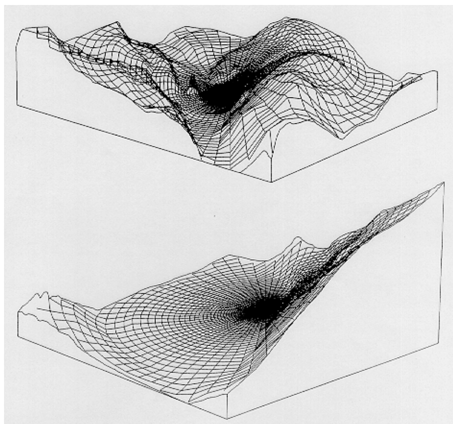


- • Measurement
- ▯ WAsP flow model
- -- Other flow model

Horizontal profile
of speed-up

BZ-model: Zooming Polar Grid

Inside the BZ-flow-model of WAsP the orography is represented by a zooming polar grid.



The grid is centered around the point in focus: met-station or wind turbine site.

The resolution is highest close to the point in focus, where high resolution matters.

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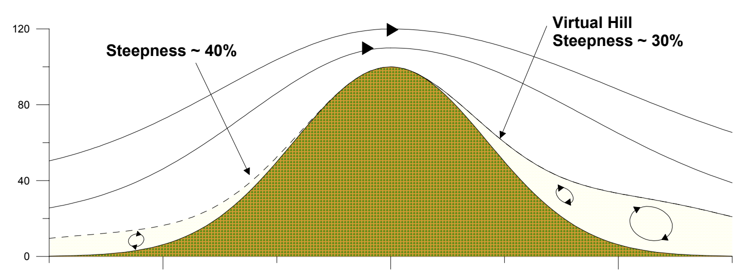
Effect of a steep hill

Flow Separation

Ex.#1: Steep but smooth hill



The flow behaves - to some extent - as if moving over a virtual hill with less steep sides =>

smaller speed-up than calculated by WAsP

Ref: N.Wood, "The onset of flow separation in neutral, turbulent flow over hills", Boundary-Layer Meteorology **76**, 137-164.

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Complex terrain
and
RIX

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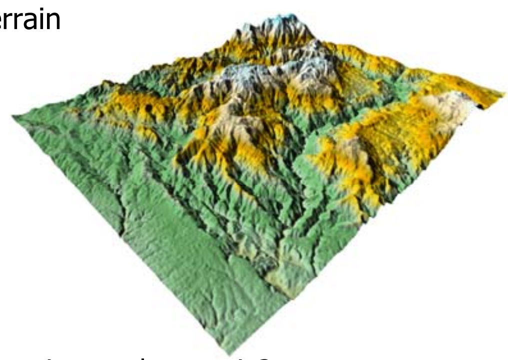
Outline

- Accumulation of orographic prediction errors
- WAsP basics in complex terrain
  - The similarity principle
- Case study in Portugal
  - Wind speed correlations
  - Flow separation
  - RIX and ΔRIX
  - WAsP prediction errors
  - RIX/ΔRIX configuration
  - Vertical wind profiles
  - Improving WAsP predictions in complex terrain?



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Background

- European Wind Atlas, Vol. II: *Measurements and Modelling in Complex Terrain*. Multi-partner EU project from 1990-95.
- Bowen, A.J. and N.G. Mortensen (1996/2005). WAsP prediction errors due to site orography. Risø-R-995(EN). Risø National Laboratory, Roskilde. 65 pp.
- Bowen, A.J. and N.G. Mortensen (1996). Exploring the limits of WAsP: the Wind Atlas Analysis and Application Program. Proc. *1996 European Union Wind Energy Conference*, Göteborg, 584-587.
- Rathmann, O., N.G. Mortensen, L. Landberg and A. Bowen (1996). Assessing the accuracy of WAsP in non-simple terrain. Proc. *8th British Wind Energy Association Conference*, Exeter, 413-418.
- Mortensen, N.G. and E.L. Petersen (1998). Influence of topographical input data on the accuracy of wind flow modelling in complex terrain. Proc. *1997 European Wind Energy Conference*, Dublin, 317-320.

Accumulation of orographic prediction errors

- Application procedure

  $U_A + (\Delta U_2 + E_2) = U_{Pe}$

- Analysis procedure

  $U_{Rm} - (\Delta U_1 + E_1) = U_A$

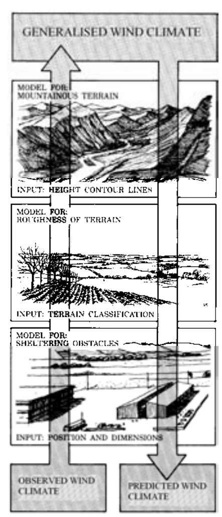
- Combined procedure, eliminating U_A

  $(U_{Rm} - \Delta U_1 + \Delta U_2) + (E_2 - E_1) = U_{Pe}$

- The correct estimation is then made up of

  $U_{Pm} = U_{Rm} - \Delta U_1 + \Delta U_2$ (perfect prediction)

  $U_{Pe} = U_{Pm} + (E_2 - E_1)$ (prediction error!)



The similarity principle

The predictor and the predicted site should be as similar as possible

- Topographical setting
  - Ruggedness index (RIX)
  - Elevation and exposure
  - Distance to significant roughness changes (coastline)
  - Background roughness lengths
- Climatic conditions
  - Same regional wind climate (synoptic and meso-scale)
  - General forcing effects
  - Atmospheric stability

This means that the basic input data should also be similar

- WAsP map
  - Map size
  - Contour interval
  - Accuracy and detail
  - Roughness classification
  - …

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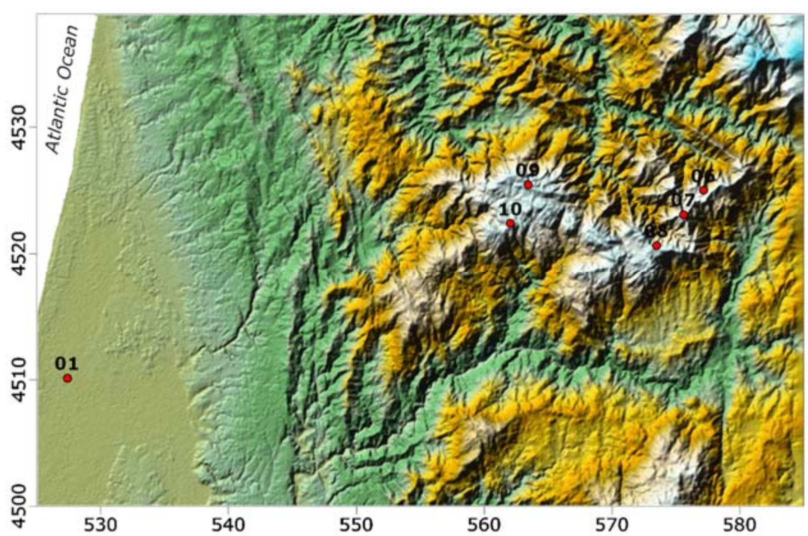
Case study in northern Portugal



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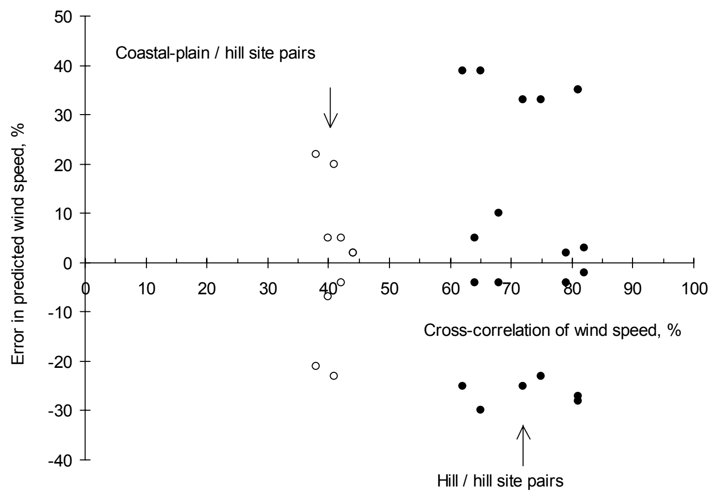
Cross-correlation of wind speeds



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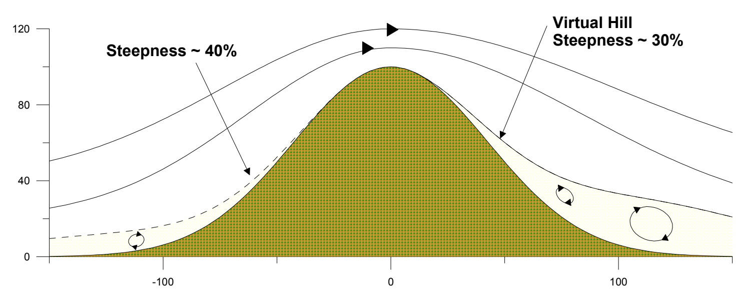
Effect of a steep hill – flow separation



The flow behaves – to some extent – as if moving over a virtual hill with less steep slopes than the actual hill =>

actual speed-up is smaller than calculated by WAsP

N. Wood (1995). “The onset of flow separation in neutral, turbulent flow over hills”, *Boundary-Layer Meteorology* **76**, 137-164.

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Complex terrain analysis

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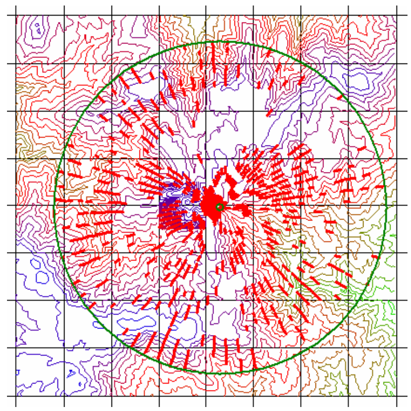

- Terrain steeper than θ_c is indicated by the thick red (radial) lines

- **Ruggedness index, RIX**
  - fraction of terrain surface which is steeper than a critical slope θ_c
  - Calculation radius ~ 3.5 km
  - Critical slope θ_c ~ 0.3-0.4
  - Onset of flow separation
  - Performance envelope for WAsP is when RIX = 0

- **Performance indicator, ΔRIX**
  - $\Delta RIX = RIX_{WTG} - RIX_{MET}$
  - $\Delta RIX < 0 \Rightarrow$ under-prediction
  - $\Delta RIX > 0 \Rightarrow$ over-prediction

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Prediction error vs. RIX difference

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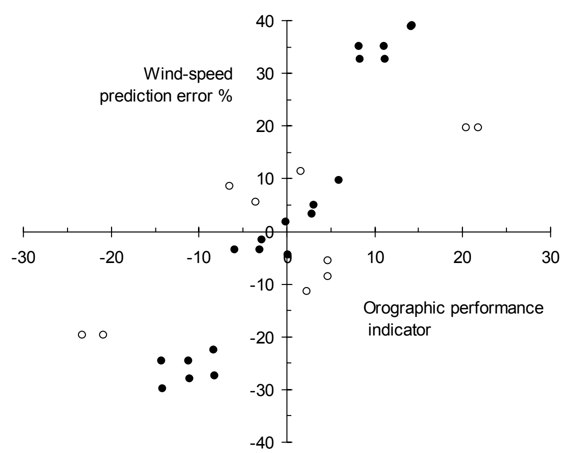

"This performance indicator provides encouraging results…"

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The Ruggedness Index – revisited

- Reanalyses of the Portuguese data set
  - Larger, more detailed and accurate maps (SRTM)
  - Improved RIX calculation (WAsP or ME)
  - More calculation radii: 72 rather than 12
  - RIX configuration corresponds to WAsP BZ-model grid
  - Both the prediction errors and ∆RIX change
- Data analysis and presentation
  - Asymmetry in plot of speed error vs. ∆RIX
    - speed error was defined as $(U_p/U_m - 1)$
    - not obvious which trend line(s) to fit…
  - Substitute $\log(U_p/U_m)$ for $(U_p/U_m - 1)$
  - Easier to fit a trend line…?

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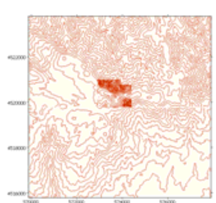
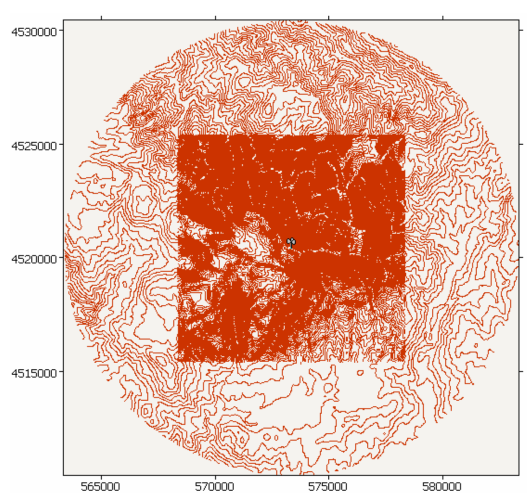
Maps for RIX calculation and test



- Hand-digitised map
  - 8 by 8 km²
  - 50- and 10-m cont.
- SRTM-derived map
  - 20 km diameter
  - 50-, 10- and 5-m height contours



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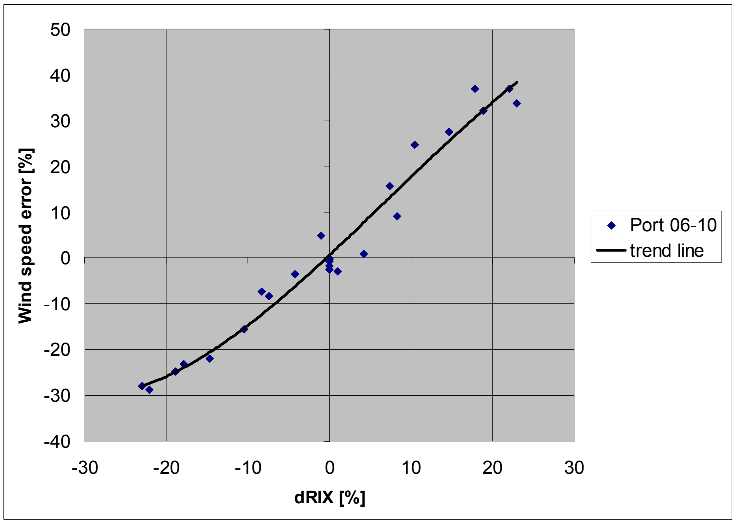
Wind speed error vs. ΔRIX



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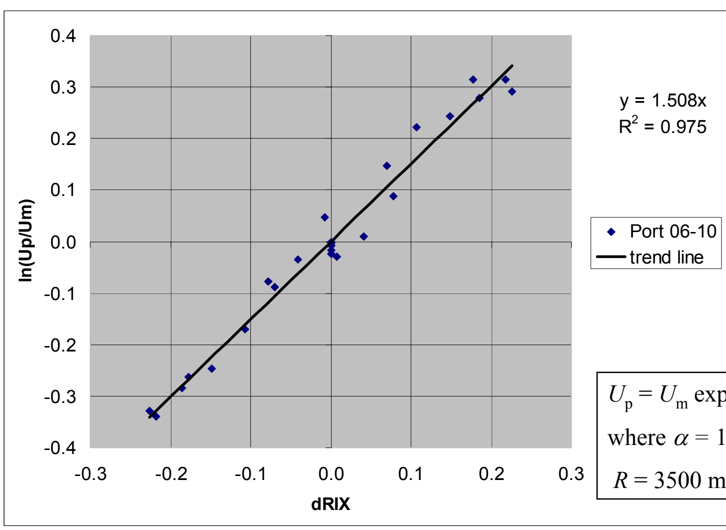
ln(U_p/U_m) vs. ΔRIX



$U_p = U_m \exp(\alpha\,\Delta\text{RIX})$
where $\alpha = 1.5$
$R = 3500$ m and $\theta_c = 0.3$

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Things to test…

- Wind speed prediction error is (almost) fixed…
  - Number of sectors
  - Modelling parameters
- RIX configuration can be varied easily
  - Original configuration somewhat arbitrary
  - Different calculation radii (3, 3.5, 4, and 5 km)
  - Calculation radius that provides max. RIX?
  - Different critical slopes (0.30, 0.35, 0.40, 0.45)
  - Matrix of R^2 (coefficient of determination) for different set-up's
- Weighting RIX with wind rose frequencies

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Influence of radius and critical slope

Radius *R* **[m]**	**Critical slope** θ_c			
	0.30	**0.35**	**0.40**	**0.45**
3000	0.960	0.967	0.978	0.973
3500	0.972	0.974	0.984	0.986
4000	0.971	0.978	0.982	0.979
5000	0.969	0.977	0.979	0.973

R^2 for different values of the calculation radius and critical slope.

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Recalculation – best fit values

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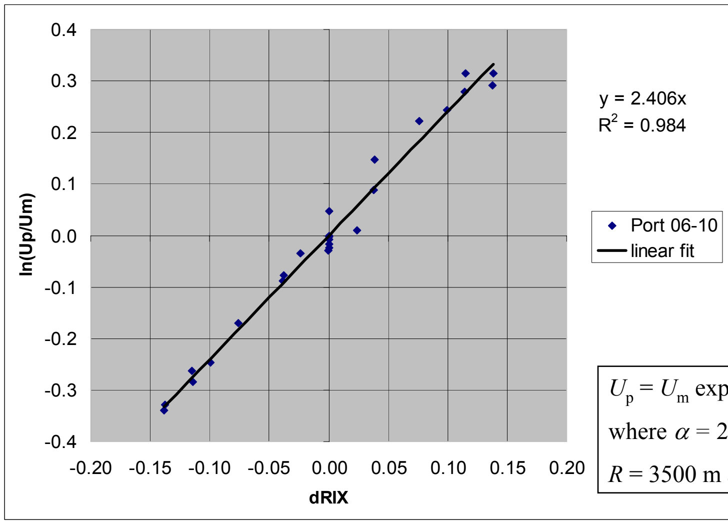

$U_p = U_m \exp(\alpha \Delta RIX)$

where $\alpha = 2.4$

$R = 3500$ m and $\theta_c = 0.4$

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Recalculation – weighted w. wind rose

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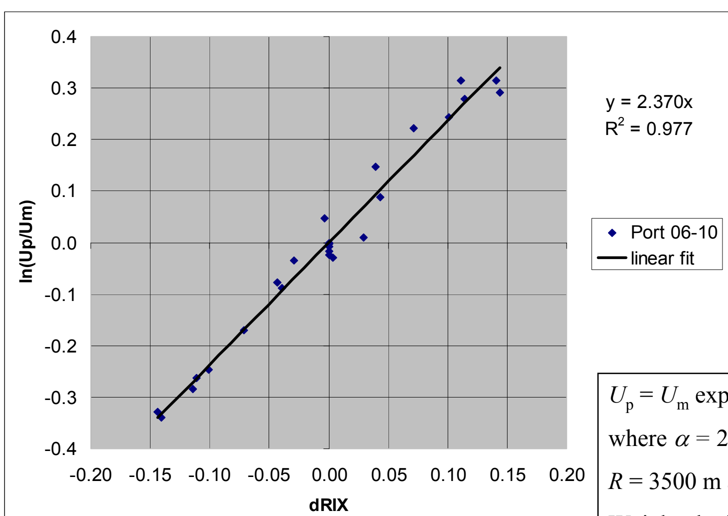

$U_p = U_m \exp(\alpha \Delta RIX)$

where $\alpha = 2.4$

$R = 3500$ m and $\theta_c = 0.4$

Weighted with wind rose

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Vertical profile in complex terrain

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Tetouan in northern Morocco, RIX = 16%

	Measured		Estimated			
z	$\langle U_m \rangle$	$\langle P_m \rangle$	$\langle U_e \rangle$	$\langle P_e \rangle$	P_e/P_m	
[m]	[m/s]	[MWh]	[m/s]	[MWh]		
10	9.8	2643	9.7	2532	0.97	
20	9.6	2518	9.5	2504	0.99	
30	9.8	2616	9.6	2529	0.97	
40	9.6	2565	9.6	2565	1.00	(predictor)

Vertical profile is predicted well because of the similarity in RIX:

$$\Delta RIX = RIX_{WTG} - RIX_{MET} = 0$$

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Improvement of AEP predictions

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Predictor/ predicted	Port 06	Port 07	Port 08	Port 09	Port 10
Port 06		**77%** (11%)	**85%** (53%)	**96%** (72%)	**90%** (89%)
Port 07	**96%** (12%)		**96%** (70%)	**89%** (75%)	**100%** (103%)
Port 08	**80%** (23%)	**91%** (39%)		**6%** (1%)	**86%** (23%)
Port 09	**89%** (38%)	**95%** (47%)	**-68%** (5%)		**3%** (0%)
Port 10	**97%** (42%)	**81%** (46%)	**82%** (13%)	**4%** (0%)	

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Conclusions

- The similarity principle
  - WAsP analysis and application errors tend to cancel out
  - The SP is the most important guiding principle for WAsP use
  - WAsP inputs (maps) should also be similar, of course
- Ruggedness index RIX and performance indicator ΔRIX
  - Concepts supported by new data and procedures
- Relation between WAsP prediction error and ΔRIX
  - Linear relation between $\log(U_p/U_m)$ and ΔRIX
  - Relation not very sensitive to calculation radius *R*, critical slope θ_c, or prediction height *h*
  - ΔRIX weighted with the wind rose does not improve the relation between $\log(U_p/U_m)$ and ΔRIX

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Conclusions (cont'd)

- Extension of WAsP procedures outside operational envelope
  - Requires two or more (non-similar) met. stations
  - Linear relation between $\ln(P_p/P_m)$ and ΔRIX
  - Case study AEP predictions improve significantly
  - Linear fit before extended procedure:
    - $AEP_P = -0.11\ AEP_M + 2.42$
    - $R^2 = 0.01$
  - Linear fit after extended procedure:
    - $AEP_P = 1.01\ AEP_M$
    - $R^2 = 0.92$
- Procedure can be applied with (2…*n*) met. stations
- Procedure should be tested with other data sets…

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AEP [GWh] = *F*(WAsP)

RISØ

Predictor/ predicted	Port 06	Port 07	Port 08	Port 09	Port 10
Port 06	1.398	1.197 -14%	2.271 +62%	2.444 +75%	2.771 +98%
Port 07	1.877 +12%	1.670	2.882 +73%	3.078 +84%	3.402 +104%
Port 08	1.818 -29%	1.467 -43%	2.552	2.810 +10%	3.229 +27%
Port 09	1.434 -42%	1.245 -50%	2.290 -7%	2.475	2.882 +16%
Port 10	1.427 -44%	1.113 -56%	2.145 -16%	2.351 -8%	2.546

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AEP [GWh] = *F*(WAsP, ΔRIX)

RISØ

Predictor/ predicted	Port 06	Port 07	Port 08	Port 09	Port 10
Port 06	1.398	1.352 -3%	1.532 +10%	1.355 -3%	1.531 +9%
Port 07	1.661 -1%	1.670	1.720 +3%	1.510 -10%	1.663 -0%
Port 08	2.695 +6%	2.458 -4%	2.552	2.310 -10%	2.644 +4%
Port 09	2.587 +5%	2.538 +3%	2.786 +13%	2.475	2.872 +16%
Port 10	2.584 +1%	2.277 -11%	2.619 +3%	2.360 -7%	2.546

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RISØ

The New WAsP flow model

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RISØ

Objective

- Micro-scale flow model better able to handle “steep” slopes
    - current WAsP performs poorly over steep slopes (>30%)
- To replace/complement the current WA^{S}P orography and roughness models
- Yet not too heavy computationally

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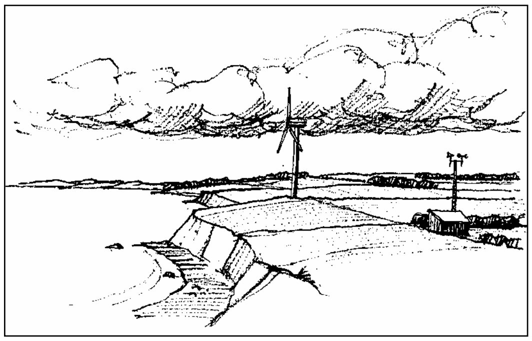
Ressource prediction

- Location of turbines ≠ location of met. Masts
- Different surroundings → different wind climates:
  - Obstacles, orography, roughness



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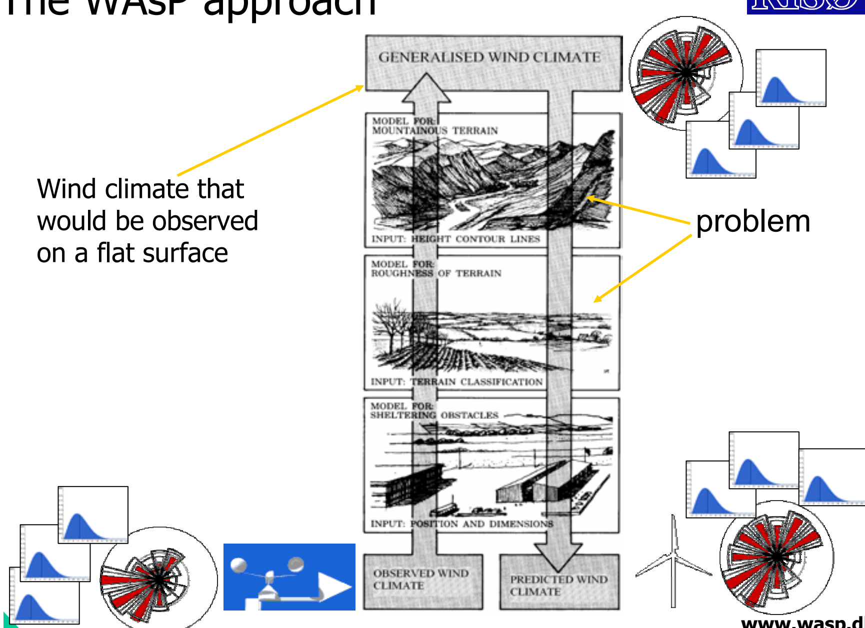
The WAsP approach



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Requirements

The new flow model must be:

- Quick:
  - A few hours on a PC for a predicted wind climate
- Easy to use:
  - Needs only limited user intervention
  - User expertise on numerical methods not required
  - Minimal number of user-input parameters
- Stable
  - Convergence takes place without extensive fine-tuning

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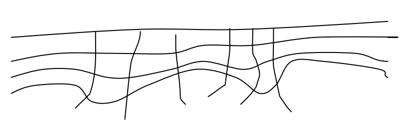
Description of the model

- Governing equations
  - RANS equations including Coriolis term, continuity
  - Turbulence closure: variant of k-ε model
  - Formulated in
    - General curvilinear coordinates
    - Strong conservation form
- Calculation domain
  - Vertically: entire boundary layer (~10^0 km)
  - Horizontally: ~ 20 km
  - Terrain-following grid



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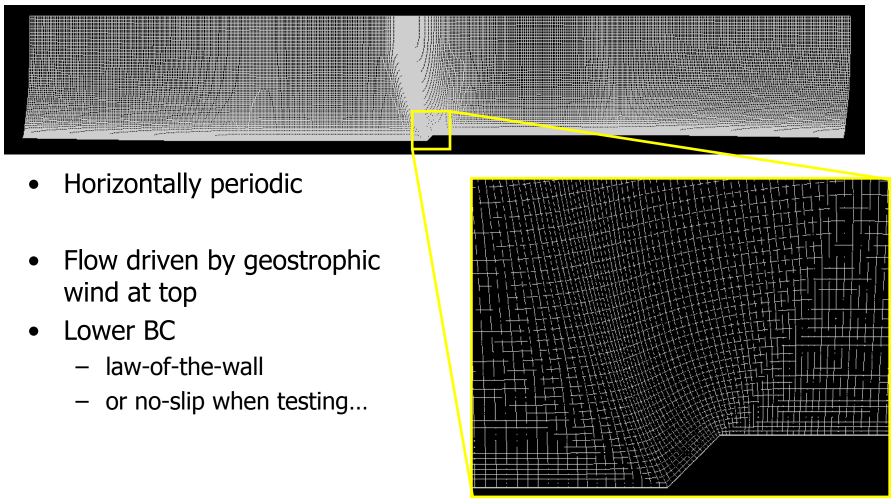
Example grid

RISØ



- Horizontally periodic
- Flow driven by geostrophic wind at top
- Lower BC
  - law-of-the-wall
  - or no-slip when testing…

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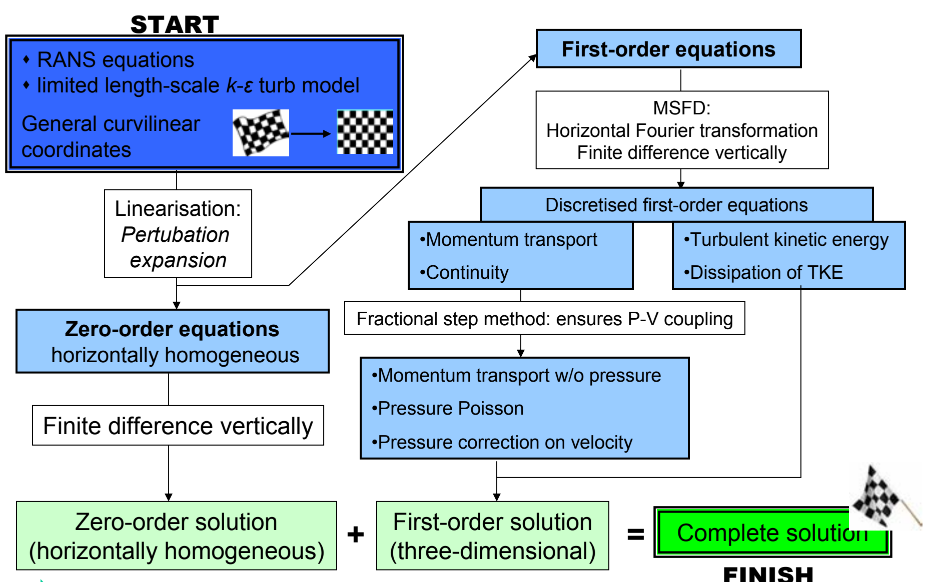
New flow model for complex terrain

RISØ



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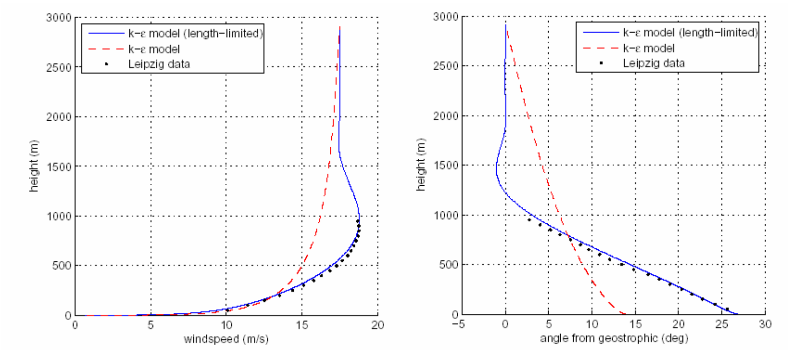
Results: flat terrain

- Comparison of turbulence models :



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Results – non-flat terrain

- First-order turbulence equations are not ready yet
- Still debugging first-order momentum solver

- Results presented are for "laminar" flow
  - i.e. a uniform eddy viscosity is provided artificially
  - lower boundary condition: no-slip
- In direction perpendicular to the screen:
  - Grid is uniform, no driving
  - 2D problem solved in 3D

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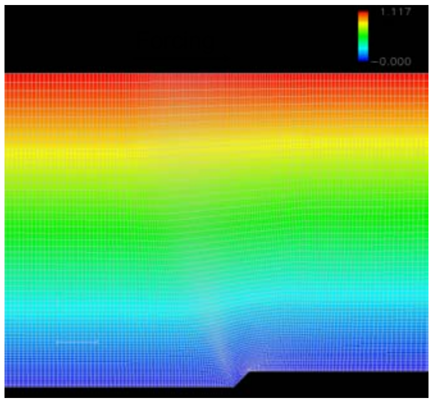
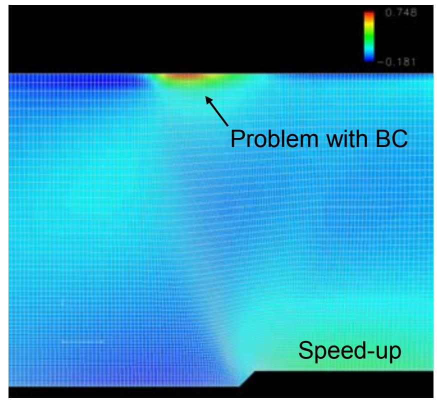
Streamwise velocity

RISØ

Zero-order solution



First-order solution



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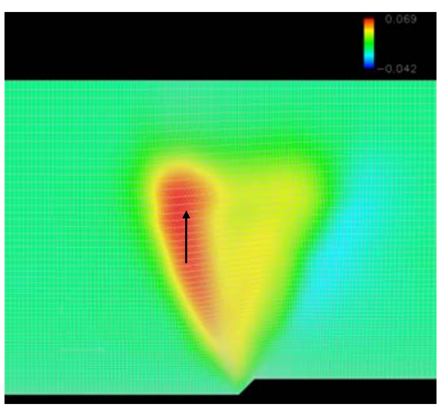
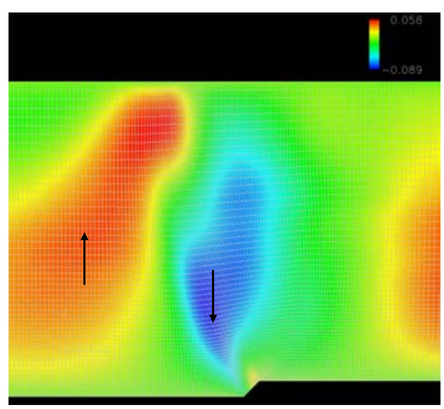
Vertical velocity

RISØ

Zero-order solution



First-order solution



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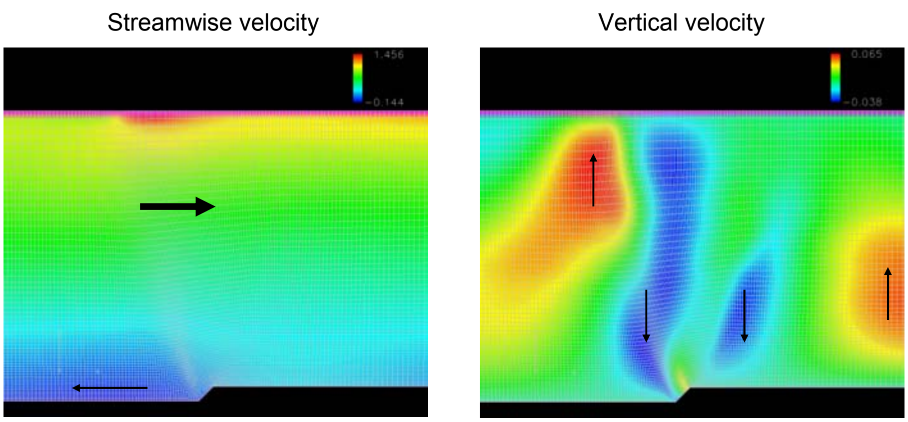
Final solution

RISØ



• Lean, mean, and, well… "room for improvement" in the accuracy department
• 512 (L) x 64 (H) x 4 (W) grid : calculation takes a few minutes

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Work ahead

RISØ

- Debugging and testing of the first-order momentum solver
  - Newly-discovered error in the upper/lower boundary conditions of the Poisson and projection equations
  - Re-writing terms of the first equation to include previously neglected geometry terms
  - And more…
- Debugging and testing of the turbulence closure
- Test cases, calculations, fine-tuning and analysis

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Forest and wind turbines

…. is generally a bad combination…

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Outline

- How is a forest different?
- Forest model parameters
- Turbine/mast close to forest
- Turbine/mast not so close to forest

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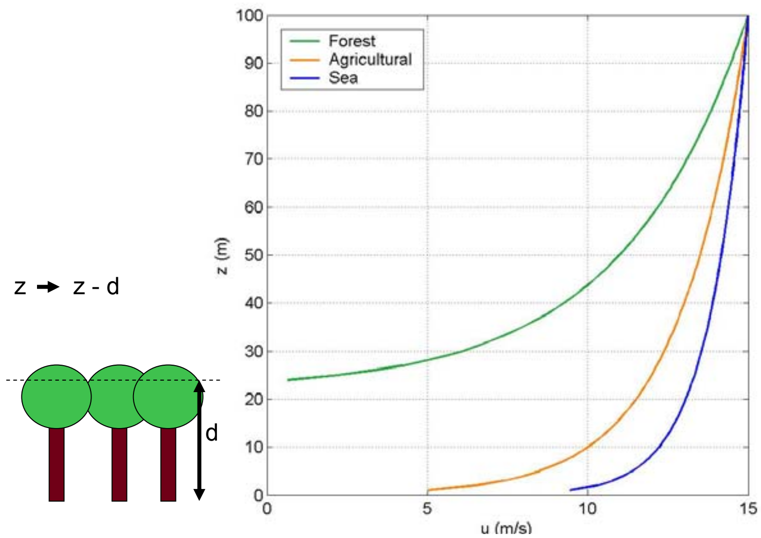
How is a forest different 1?



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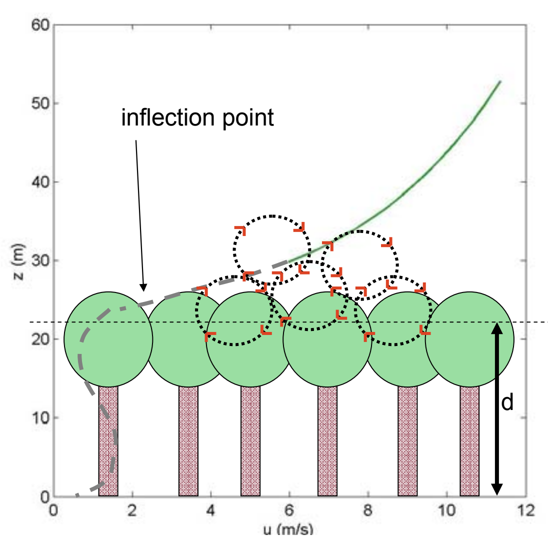
How is a forest different?



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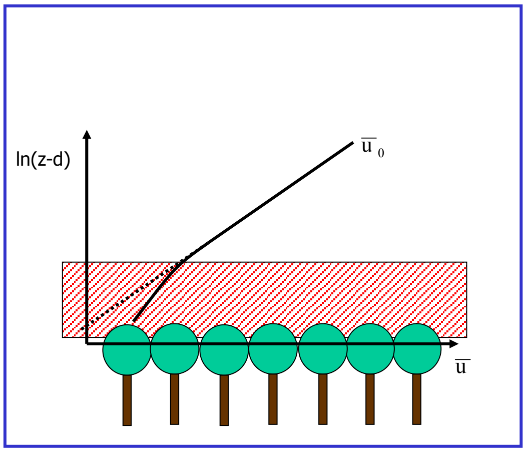
How is a forest different?

The roughness sublayer effect



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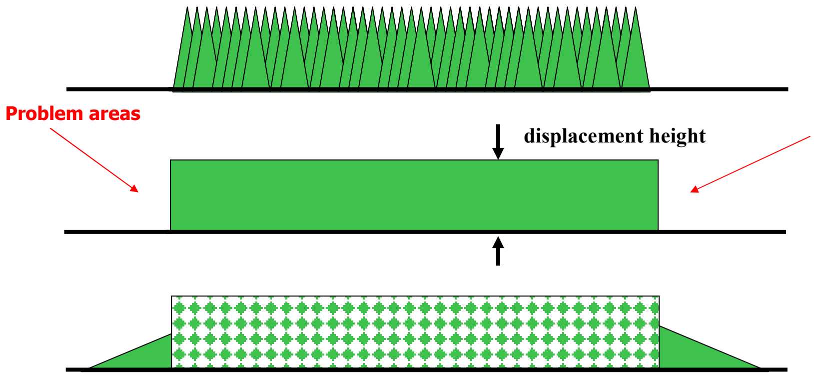
How is a forest different?

Displacement height => Forest edge effects



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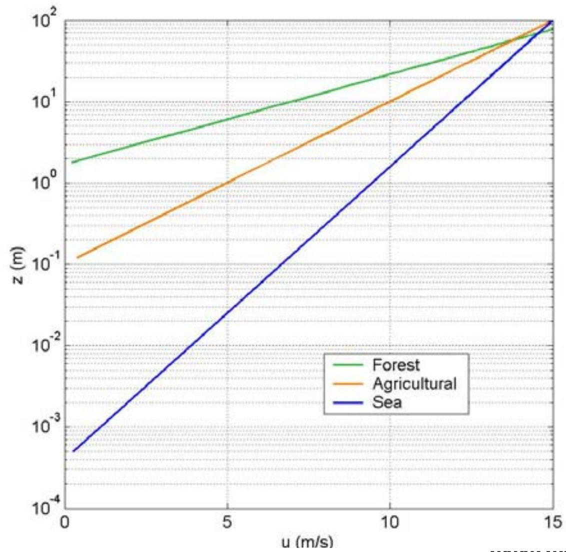
How is a forest different?

$$0.5m < z_{0,forest} < 2.5m$$
$$0.01m < z_{0,agric} < 0.15m$$
$$10^{-5}m < z_{0,sea} < 10^{-2}m$$



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How is a forest different, summary?

- Introduction of displacement height – porous surface in tree crown level
  - ⇨ 1. Roughness sublayer
  - ⇨ 2. Flow effects at forest edge
- Forests are aerodynamically **much** rougher than for example the sea surface

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Roughness and zero displacement height

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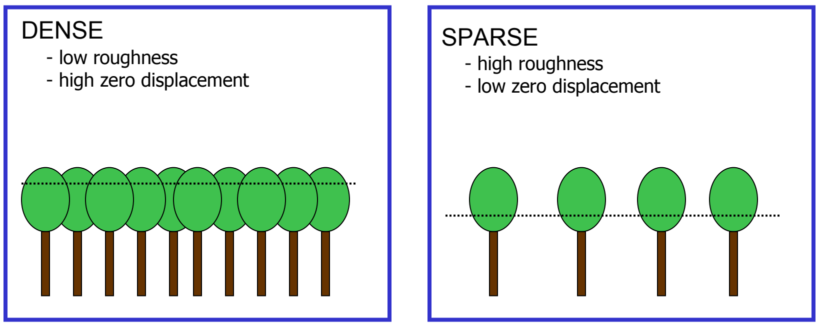
Depends on

1. The mean height of the roughness elements (trees)
2. The density of the forest



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The roughness sub-layer effect

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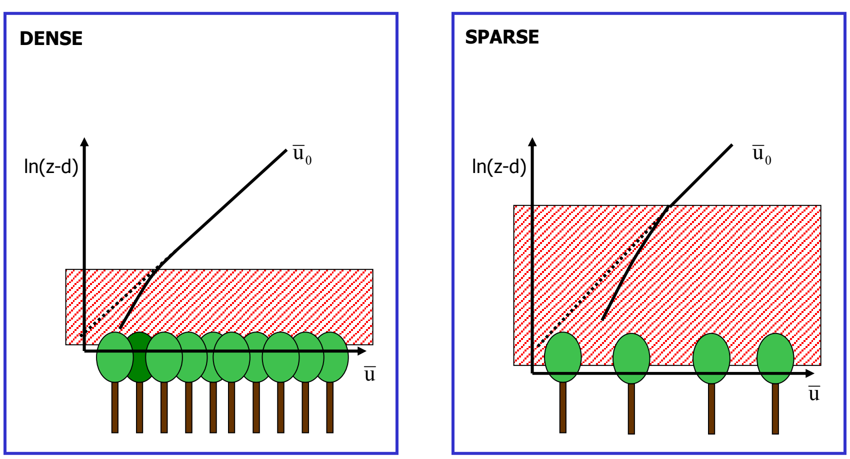

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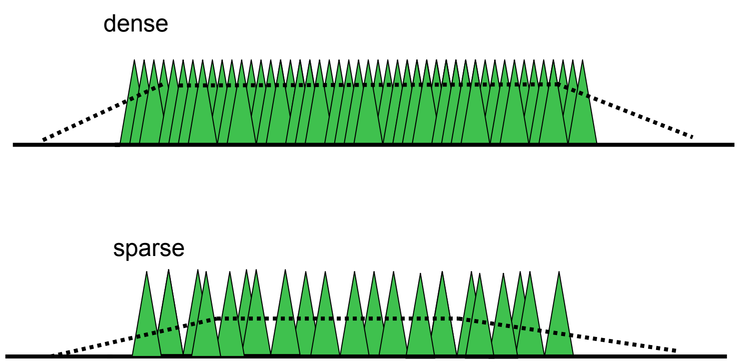
Forest edge effects

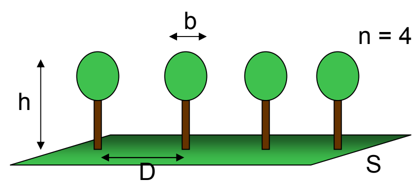


Forest density 1

How is it parameterised?

Raupach (1992):

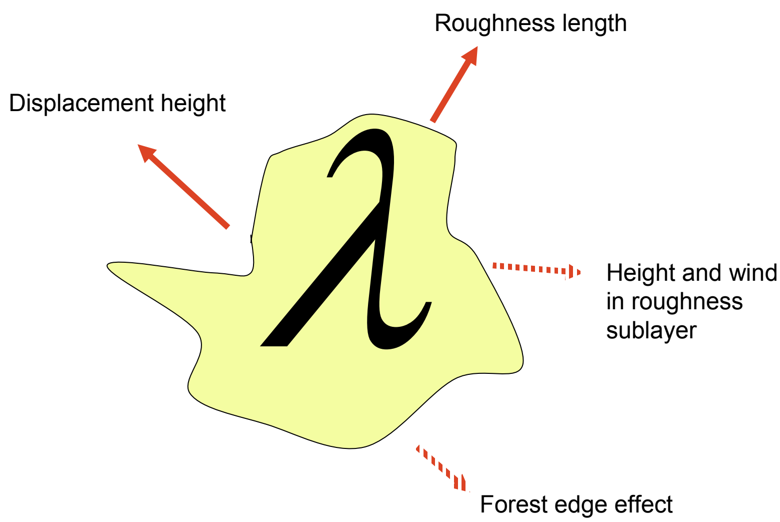
$$\lambda = \frac{bh}{D^2} = bh\left(\frac{n}{S}\right)$$



$$\lambda \approx \frac{LAI}{2}$$

LAI leaf area index

Forest density 2



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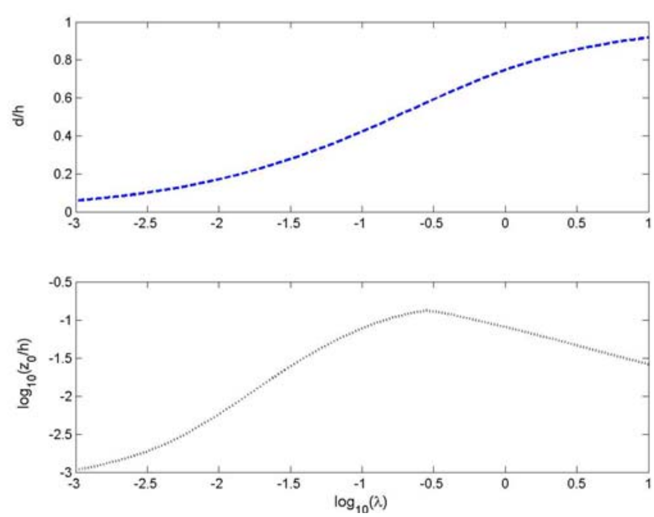
How is forest flow parameterised ?

Model by Raupach (1992, 1994, 1995)



$$\lambda = \frac{bh}{D^2}$$

b Tree breadth

h Tree height

D Distance between trees

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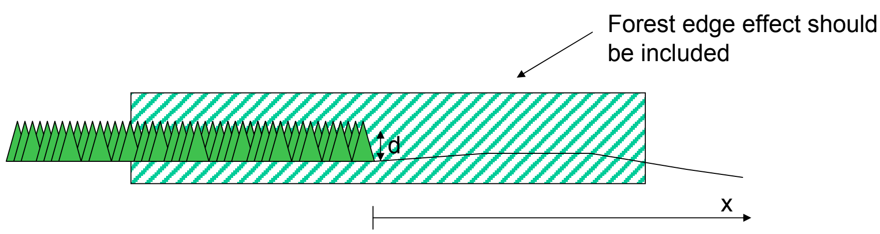
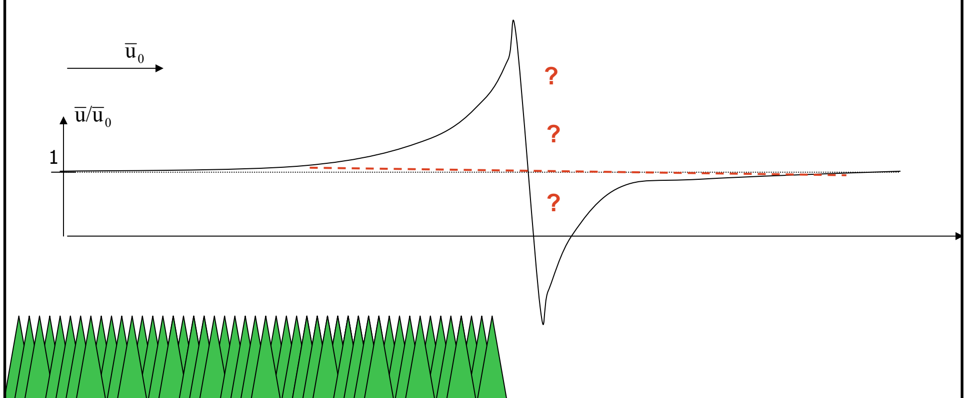
What is close?

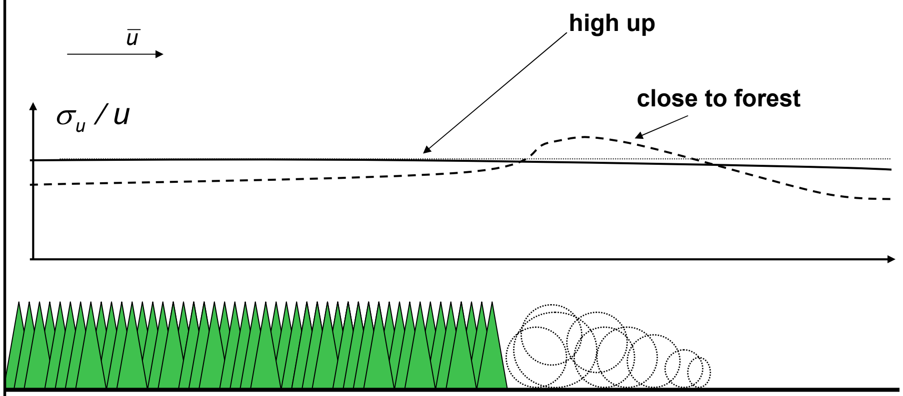
Close	x < 20d
Not so close	x > 20d



Orographic effects of forest edge, mean wind



Turbulent effects of forest edge



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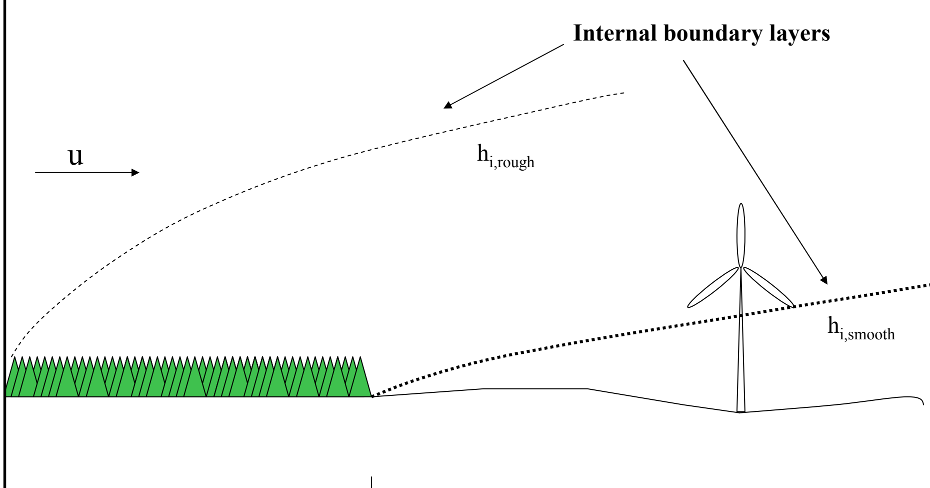
Wind turbine not so close to a forest, x > 20d



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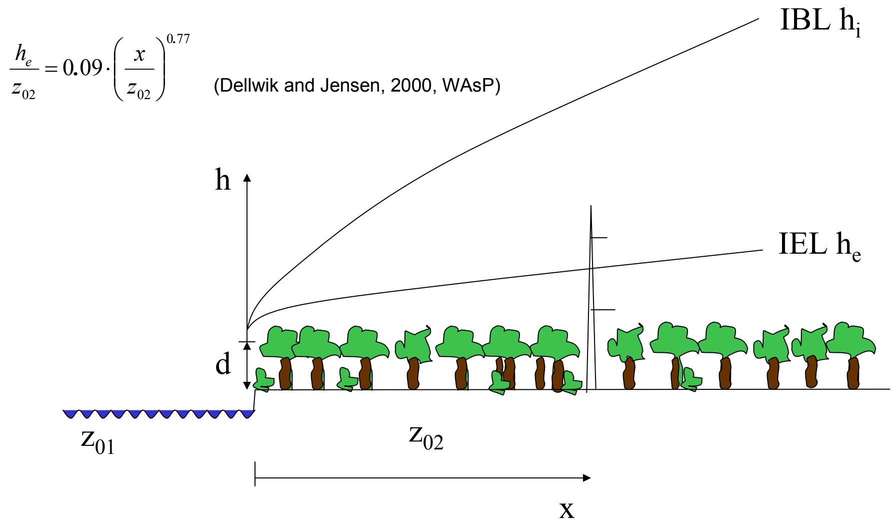
IBL structure

$$\frac{h_e}{z_{02}} = 0.09 \cdot \left(\frac{x}{z_{02}}\right)^{0.77}$$

(Dellwik and Jensen, 2000, WAsP)



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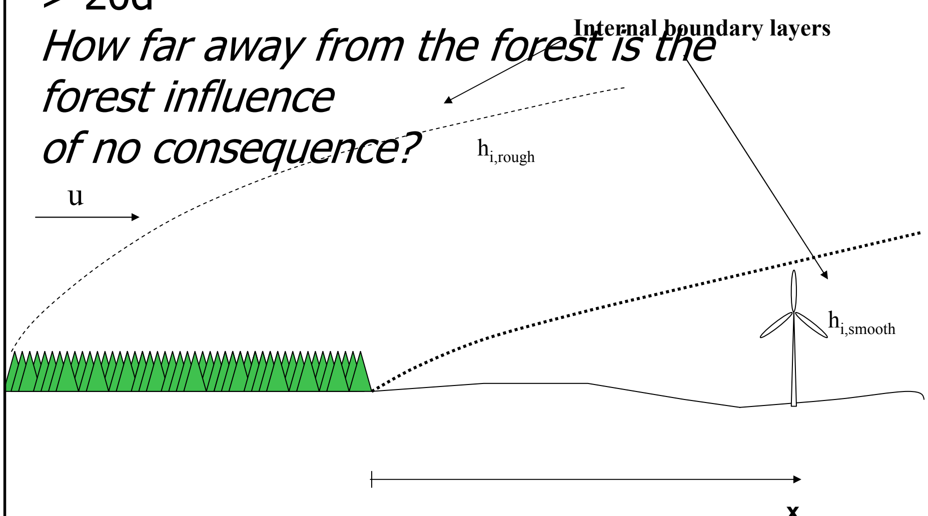
Wind turbine not so close to a forest, x > 20d

How far away from the forest is the forest influence
of no consequence?



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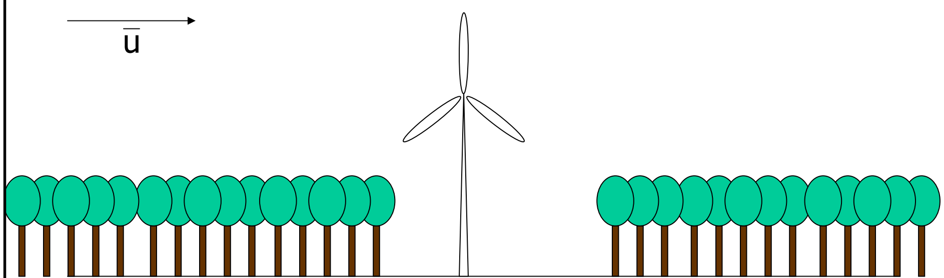
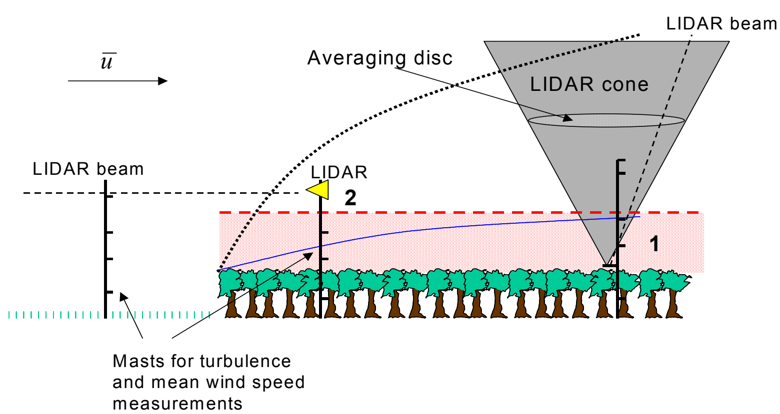
Scary story – low turbine in small clearing

- high roughness, no effect of clearing
- orographic effect leads to a reduction in wind
- edge effects may cause a very turbulent environment



New project: *Wind Profiles and Forest*



Use in WAsP

- Estimate λ
- Calculate z_0
- Calculate *d*
- Input z_0 in WAsP map
  - effect of high roughness taken into account
  - effect of IBL growth taken into account
- Subtract *d* from all heights (mast and turbine)

- Turbines in forest do not necessarily ”see” a forest.
- Turbines outside a forest are likely to be influenced by the forest if the forest is not very far away (take care at edge!)

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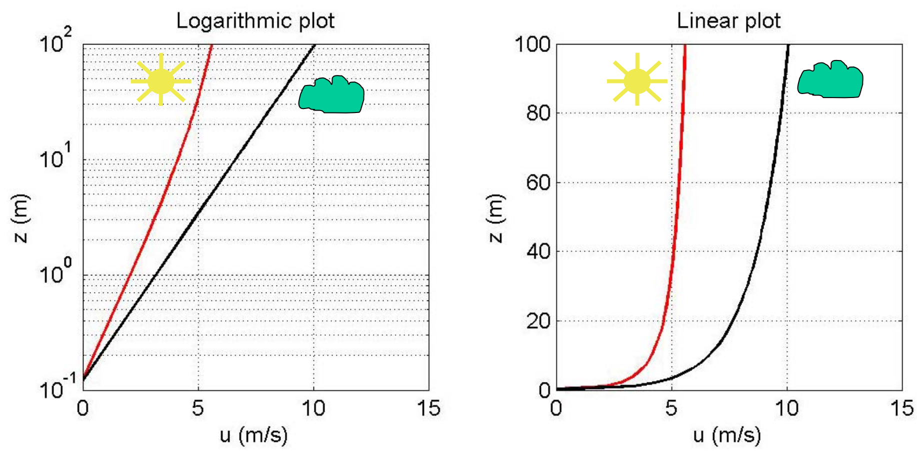
The logarithmic profile



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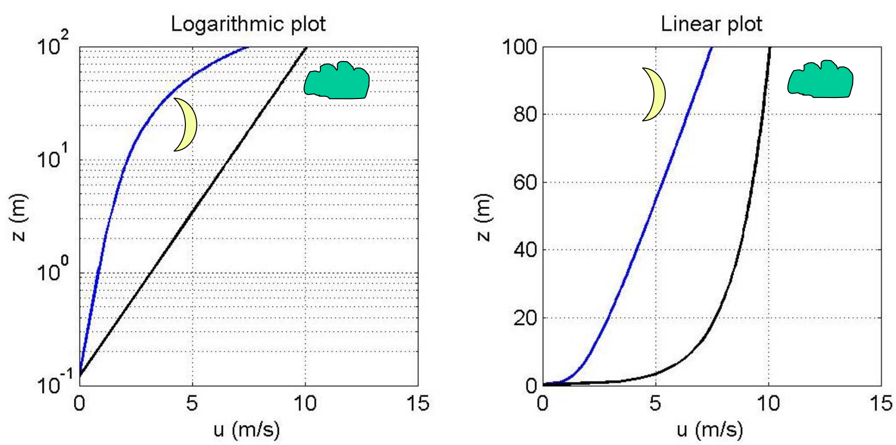
The logarithmic profile



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KAMM/WAsP Methodology - meso-scale modelling

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Numerical Wind Atlas Methodology

- useful when long-term measurement data unavailable
- uses the principle of statistical dynamical downscaling

large-scale *meteorological conditions*

⇩

small-scale *meteorological conditions*

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Numerical Wind Atlas Methodology

Need :

- tool to calculate how atmospheric flow modified by terrain
  - mesoscale model

⇩

- information about large-scale meteorological conditions
- information about terrain
  - surface elevation (orography)
  - surface roughness

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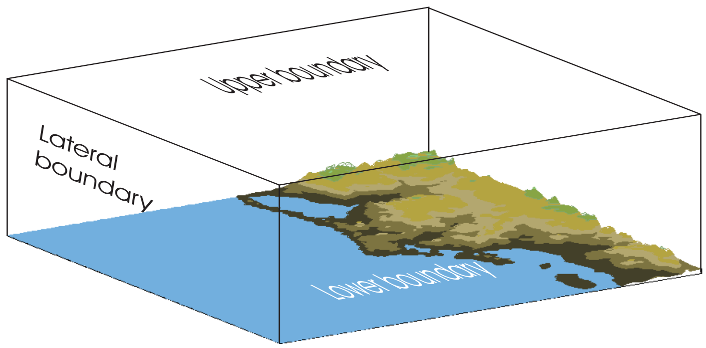
KAMM – Mesoscale model

Karlsruhe Atmospheric Mesoscale Model

non-hydrostatic, regular horizontal grid, stretched vertical coordinate (terrain following)



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Large-scale meteorological conditions

- NCEP/NCAR reanalysis data provides large-scale, long-term atmospheric forcing.
  - 2.5 x 2.5 degree resolution
  - 4 times daily
  - 1948 to present

Calculate profiles of
- geostrophic wind
- potential temperature

at 0, 1500, 3000, 5500 m (1965-1998)

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Terrain description

Orography

- United States Geological Survey (USGS), GTOPO30 data – approx. 1km resolution.

Surface roughness

- USGS Global Land Cover Classification – approx. 1km resolution.
- Land use → surface roughness (via look-up table)

Statistical-dynamical downscaling

- We could run KAMM using 30 years of 4 times daily data as large-scale forcing conditions

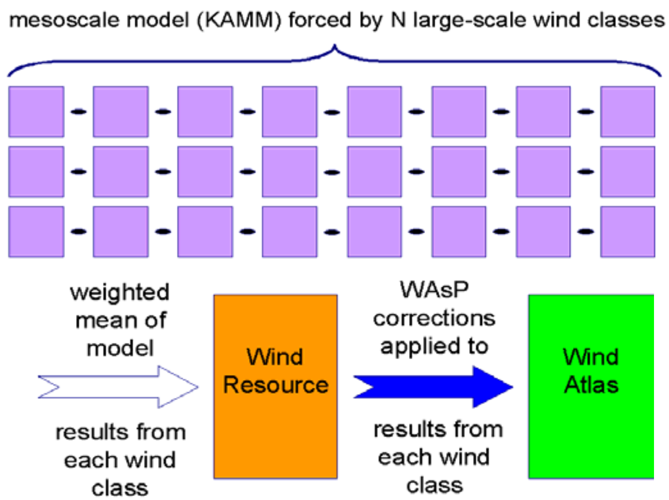
  30*365*4 = 43800 integrations

  A lot of work! …and also repetition.

- Instead we select around 100 representative conditions, called wind classes profiles.

- ***Statistical-dynamical downscaling***

KAMM / WAsP



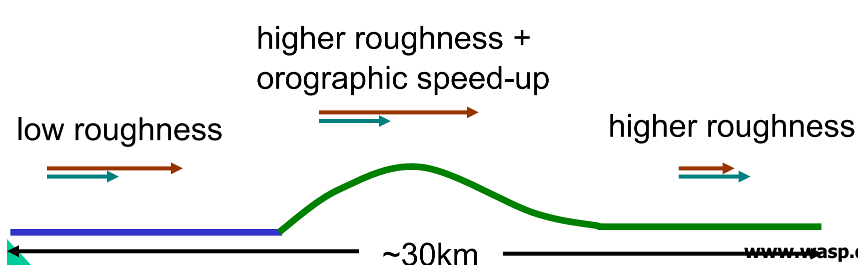
The WAsP part in KAMM/WAsP

Example:

simulated wind

wind corrected to standard conditions

flat terrain** with **homogeneous roughness



Egypt – case study

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Egypt calculation domains

Large domains

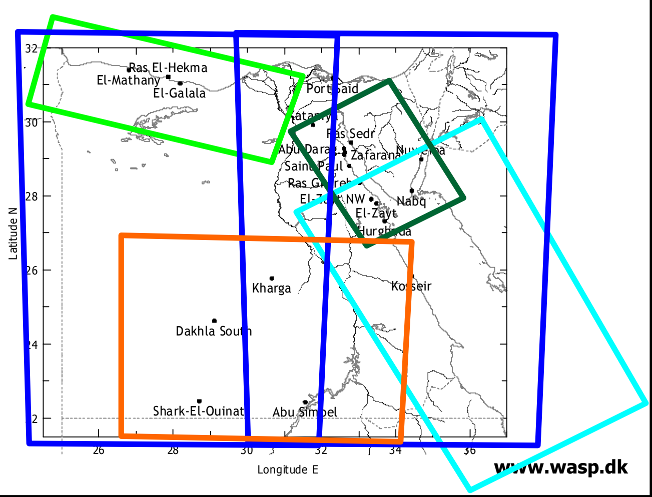
•7.5 km resolution

•generalized wind class profiles

Smaller domains

•5 km resolution

•location specific wind class profiles



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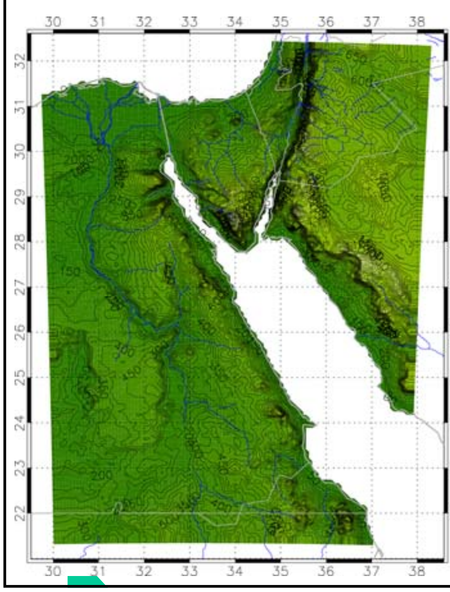
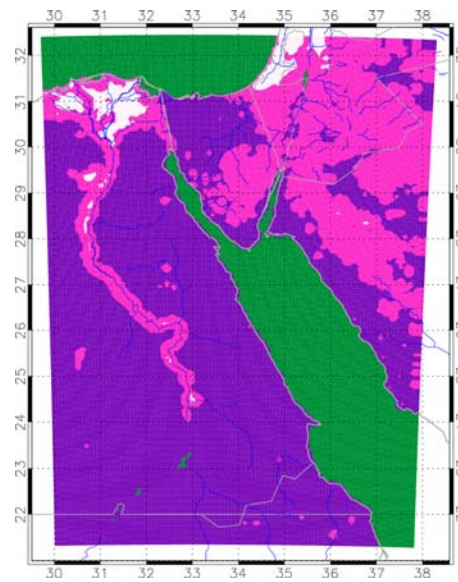
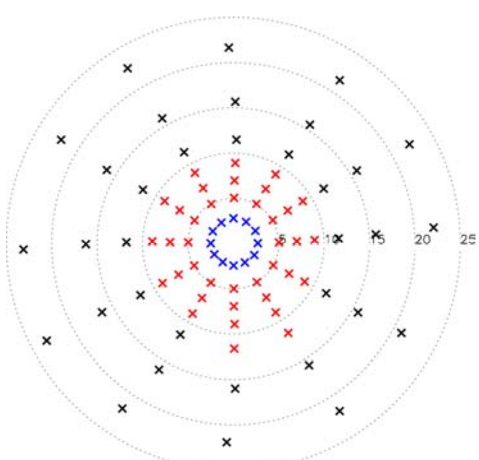
Eastern Egypt: orography & roughness





Eastern Egypt: wind classes



Wind class rose

- each x indicates a different forcing of the mesoscale model
- frequency of occurrence of each wind varies within domain

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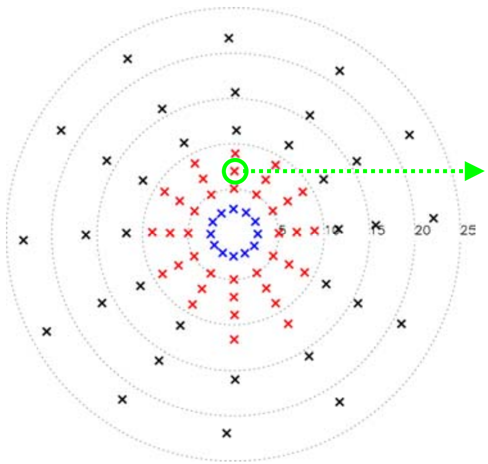
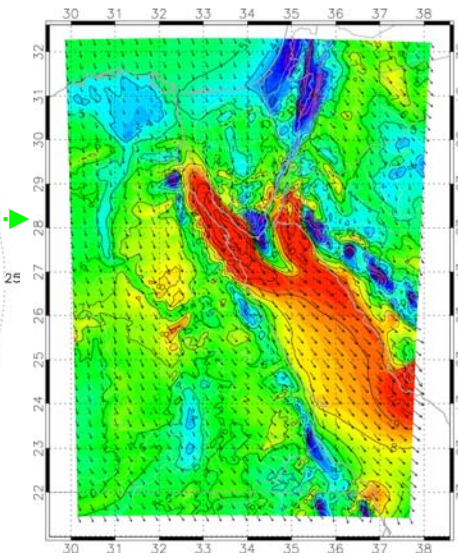
Eastern Egypt: example wind class



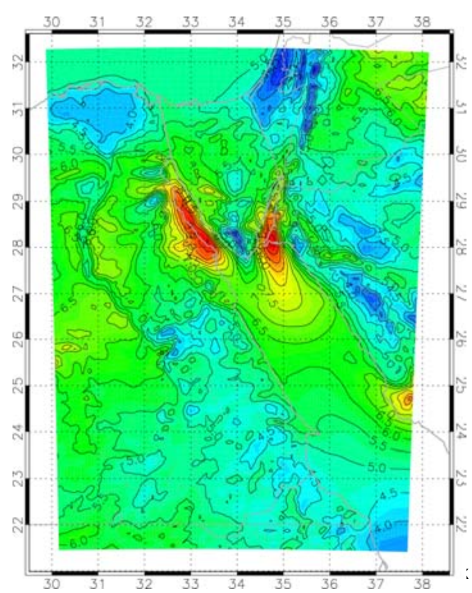


Eastern Egypt: wind resource map

Mean simulated wind speed at 50 m a.g.l.

Weighting of each wind class varies within domain.

Remember: resolution is 7.5 km

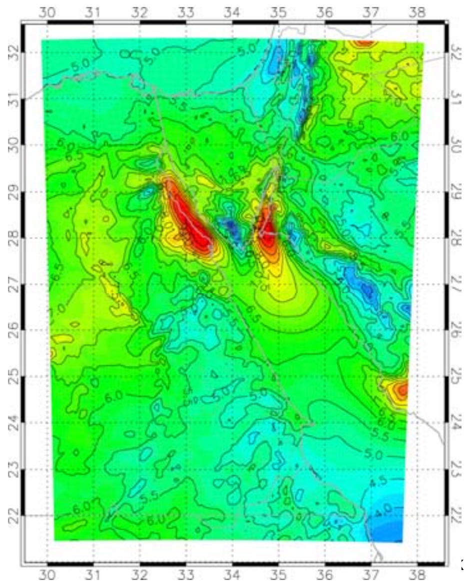


Eastern Egypt: wind atlas map

RISØ

Mean generalized wind speed at 50 m a.g.l. above flat terrain with 0.0002 m surface roughness

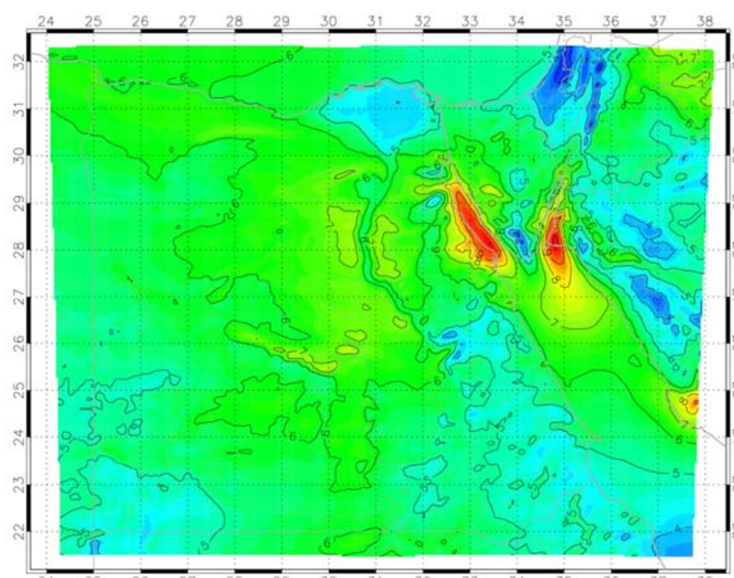
- channelling
- orographic barriers



Egypt: wind resource map

RISØ

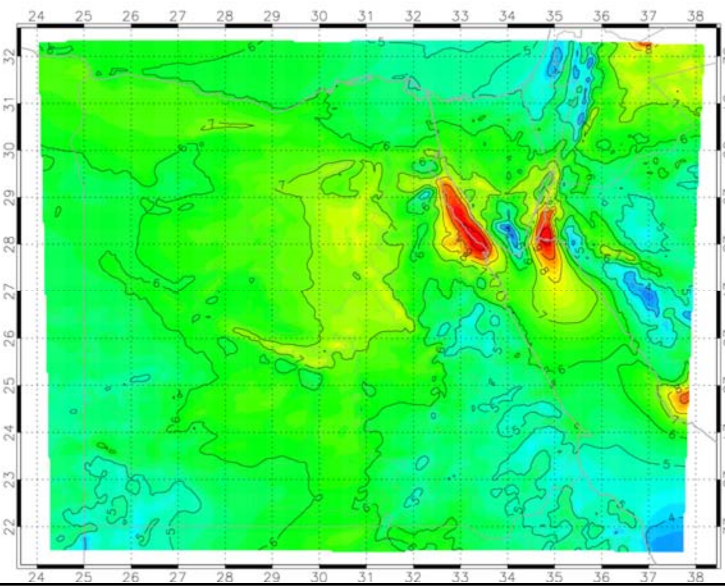
Combine East and West Egypt domains



Egypt: wind atlas map

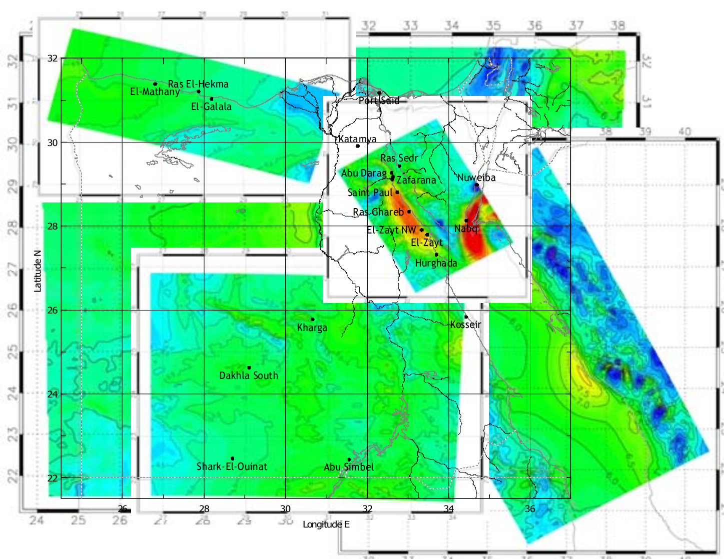
RISØ

Combine East and West Egypt domains



Other domains

RISØ



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KAMM / WAsP Numerical Wind Atlas

- many maps can be produced, i.e.
  - wind speed and wind speed at different heights
  - Weibull A and k parameters at different heights
- output can also be used in WAsP
  - WAsP .lib files can be generated
  - for any location within domain

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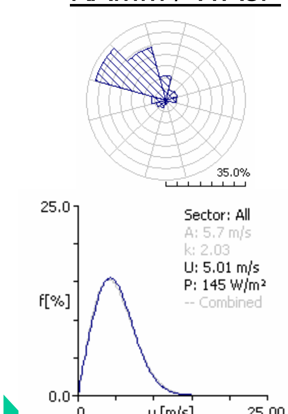
KAMM / WAsP Numerical Wind Atlas

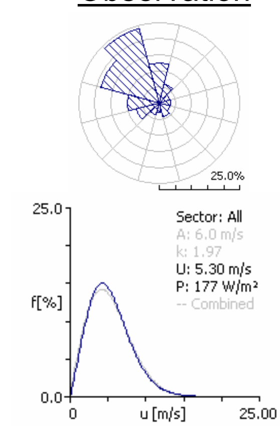
El-Hekma

WAsP display of generalized wind atlas

KAMM / WAsP



Observation



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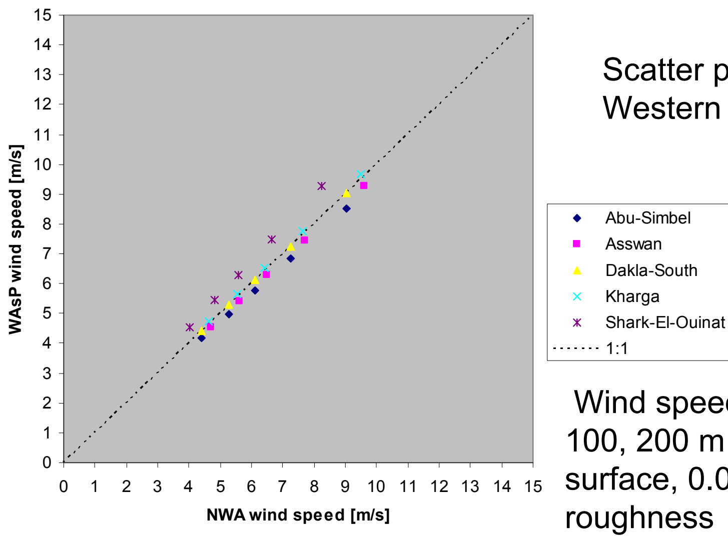
Verification

RISØ



Scatter plot for Western Desert

Wind speed at 25, 50, 100, 200 m above flat surface, 0.03 m roughness

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Verification

RISØ

Domain	mean absolute error on 50 m wind speed	
Eastern Egypt	9.7 %	
Western Egypt	12.9 %	
North-eastern coast		5.5 %
(Western Egypt	13.6 %)	
Western Desert	4.5 %	4.6 %
(W and E Egypt	9.7 %	6.2 %)
Gulf of Suez		7.5 %
(Eastern Egypt	6.4 %)	
Red Sea		5.9 %
(Eastern Egypt	6.8 %)	

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Conclusions

RISØ

The KAMM / WAsP method has been used to create numerical wind atlases for Egypt.

- 2 large domains cover all of Egypt
  - 7.5 km resolution
- 4 smaller domains cover specific regions of interest in more detail
  - 5 km resolution
  - location specific wind profiles

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Conclusions

RISØ

- colour maps produced are just a graphical "slice" of the data generated by the method.
- .lib files are also generated
- WAsP can then be used to determine local effects
  - orographic speed up
  - roughness change
- Verification shows error to be around 5-10 % on wind speed.

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Summary

- Wind Atlas Methodology: industry-standard (rou, oro, obs)
- Complex terrain: RIX, new WAsP
- Forest (λ)
- KAMM/WAsP (Egypt case)

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Web-sites

- www.risoe.dk

- www.wasp.dk
- www.windatlas.dk
- www.prediktor.dk
- www.waspengineering.dk
- www.cleverfarm.com
- www.mesoscale.dk

- www.windpower.org

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