WINDA-GALES
wind damage probability planning tool

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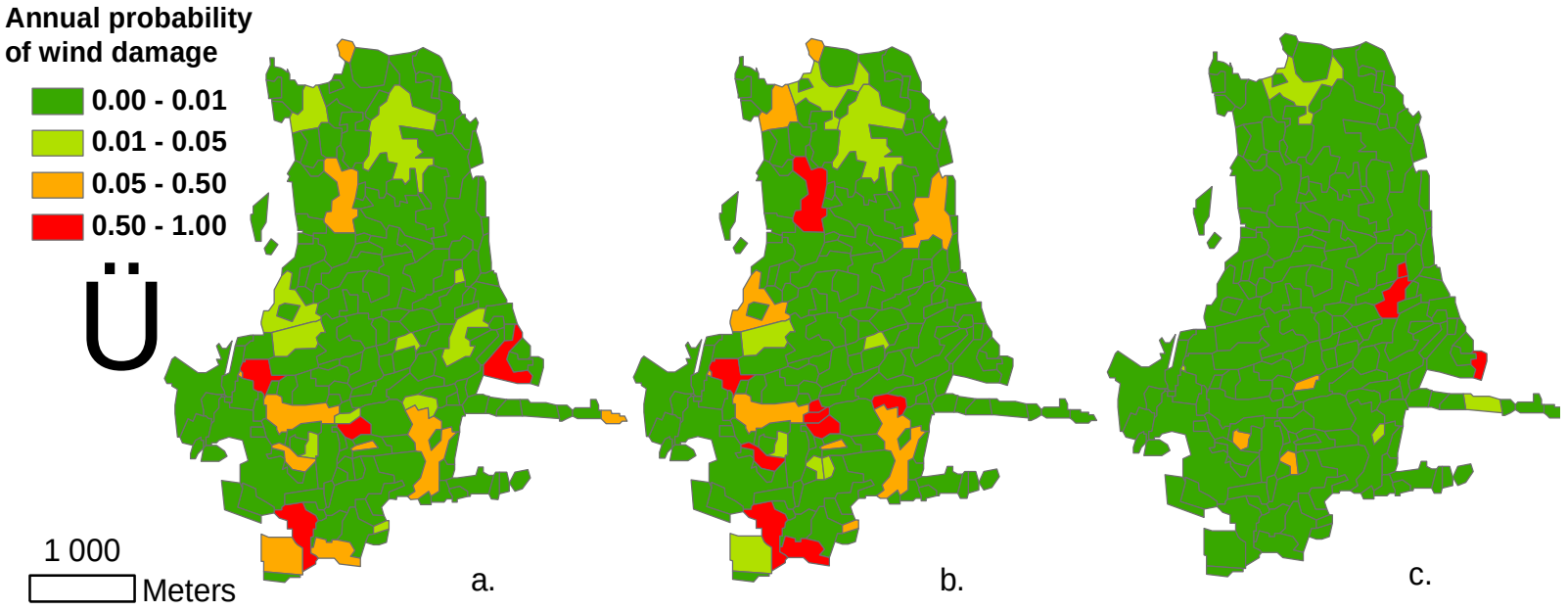
WINDA-GALES a tool to evaluate effects of climate change and adaptive forest management

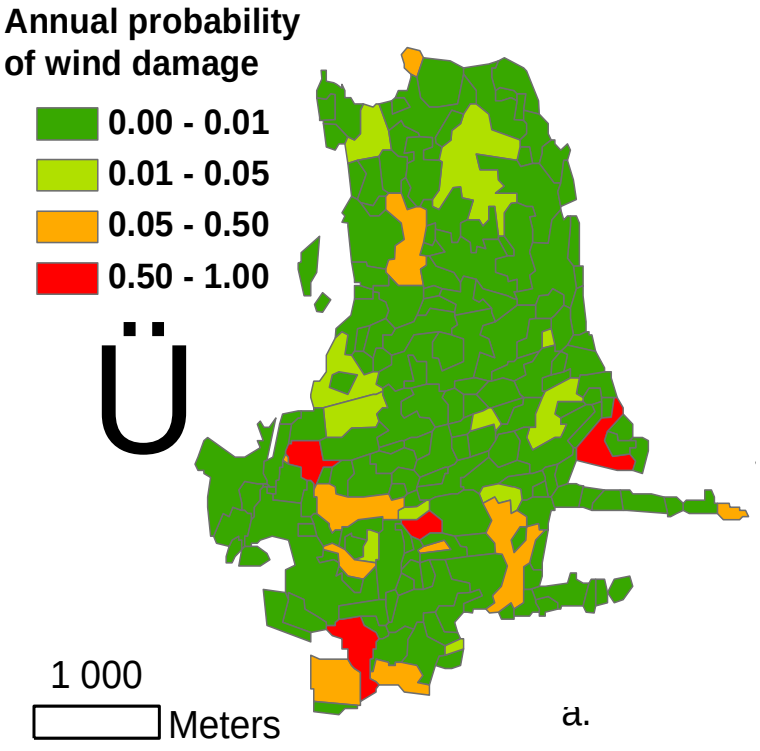


No climate change
Forest management
business as usual

Climate change
Forest management
business as usual

Climate change
Adaptive forest
management

WINDA and GALES



a.

Gardiner B, Peltola H, Kellomäki S (2000) Comparison of two models for predicting the critical wind speeds required to damage coniferous trees. *Ecological Modelling,* 129:1–23

Blennow, K. & Olofsson, E. (2008) The probability of wind damage in forestry under a changed wind climate. *Climatic Change*, 87:347-360

Blennow, K. & Sallnäs, O. (2004) WINDA – A system of models for assessing the probability of wind damage to forest stands within a landscape. *Ecological Modelling*, 175(1):87–99.

Extreme value theory by Gumbel

Probability of wind damage stand-wise

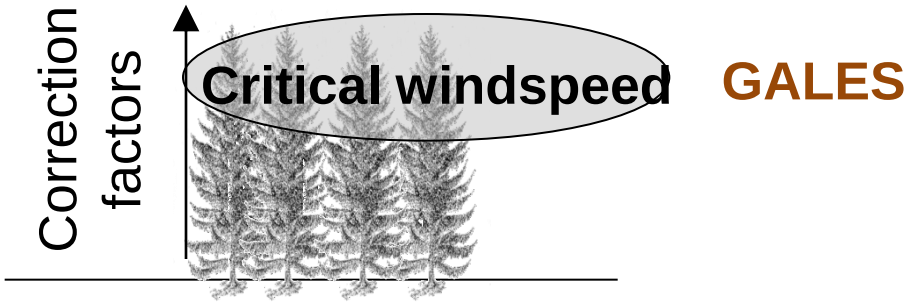
Probability of wind damage sector-wise

Geostrophic wind climatology

RCM output

Geostrophic windspeed corresponding to critical windspeed

Speed of free wind corresponding to critical windspeed



GALES

Extreme value theory by Gumbel

Probability of wind damage stand-wise

Probability of wind damage sector-wise

Geostrophic wind climatology

Free wind climatology

Correction factors

Wind mast

Geostrophic windspeed corresponding to critical windspeed

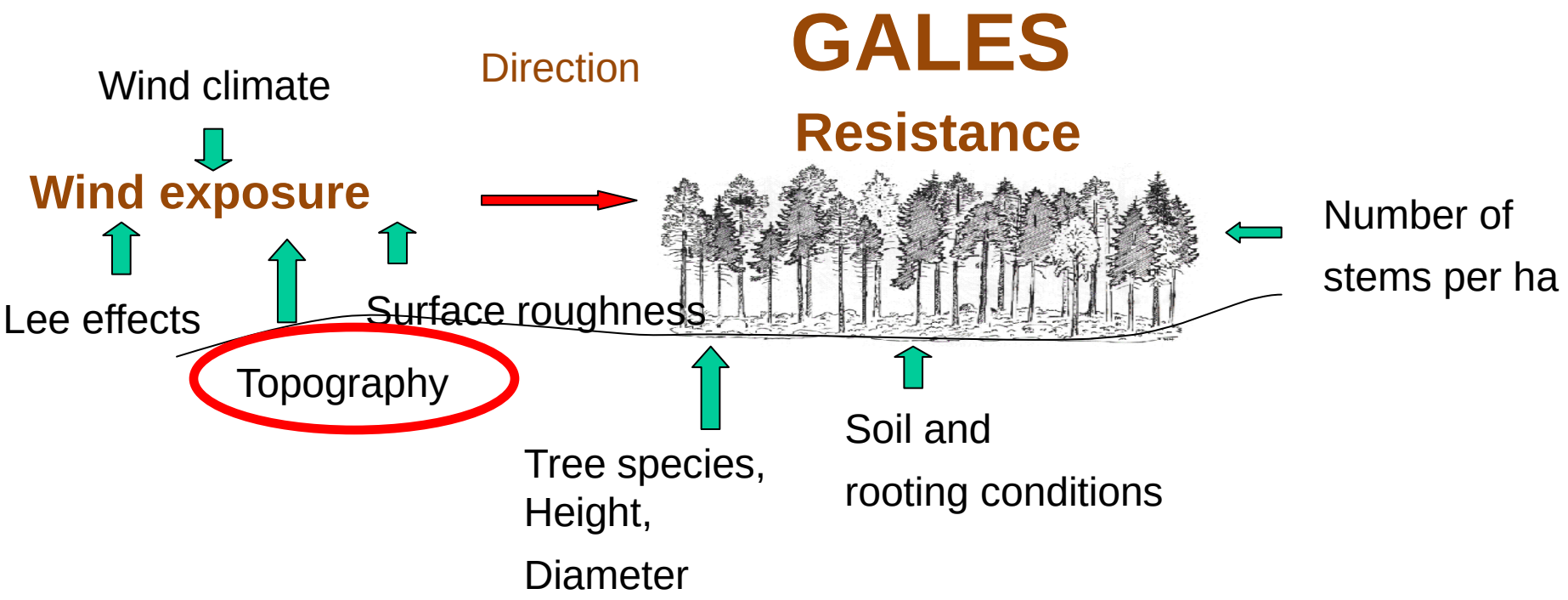
Speed of free wind corresponding to critical windspeed

Correction factors

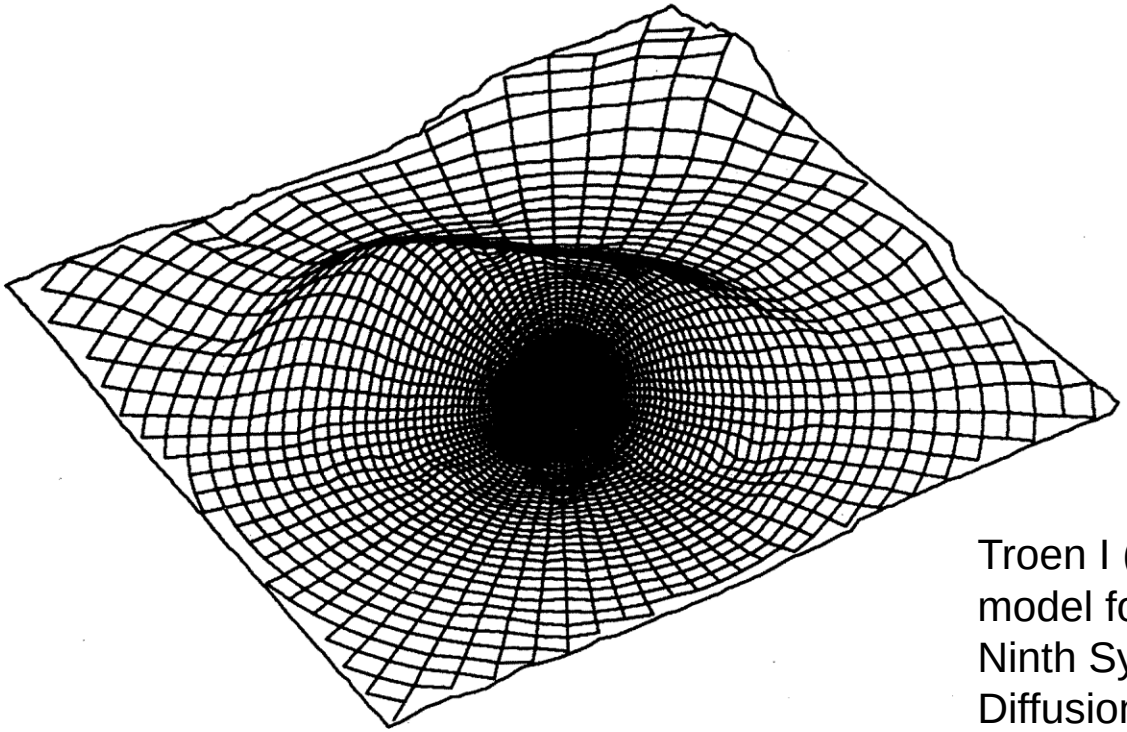
Critical windspeed

GALES

Geographically explicit environment



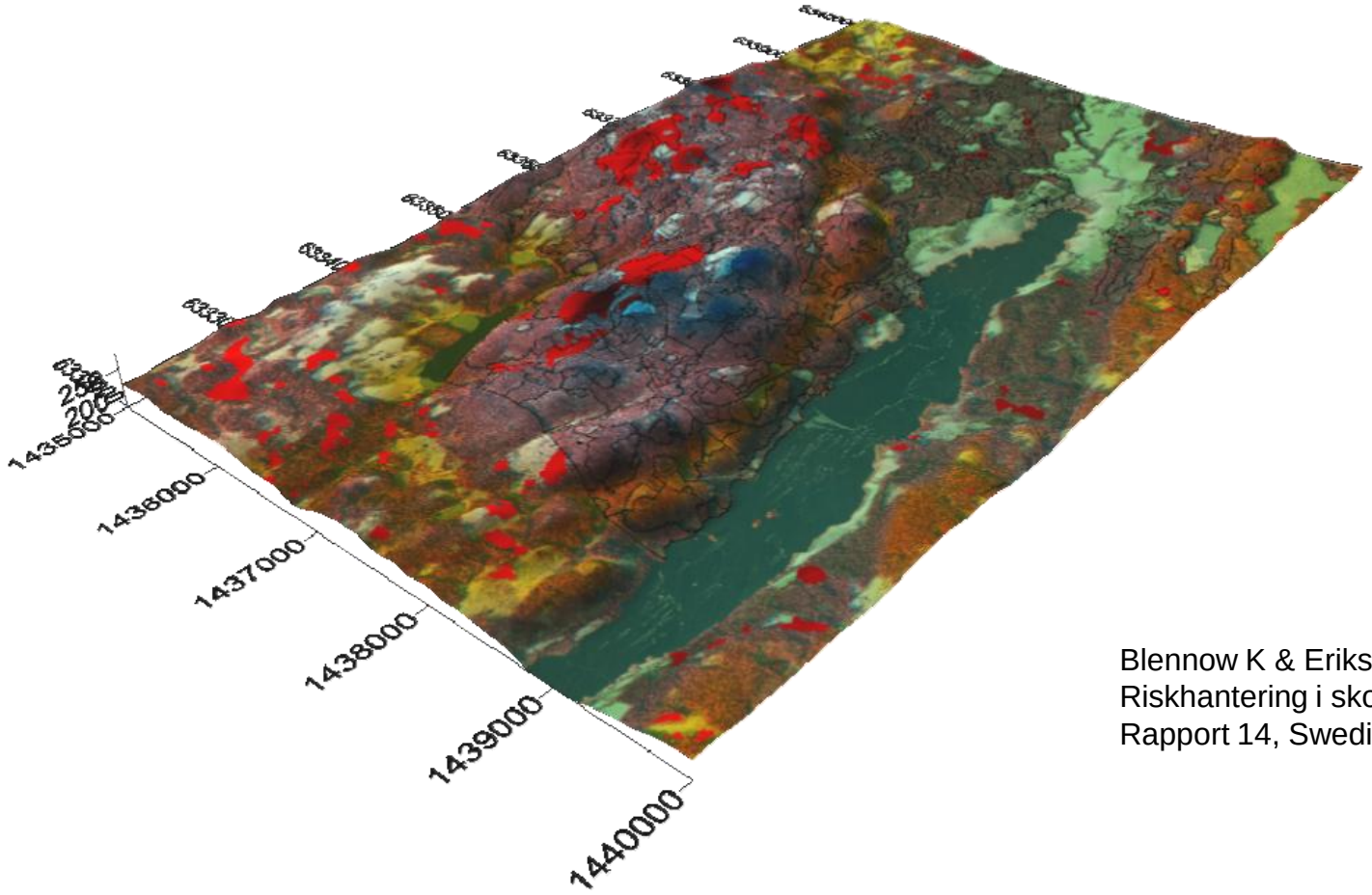
WASP airflow model



Orography factor, S_o

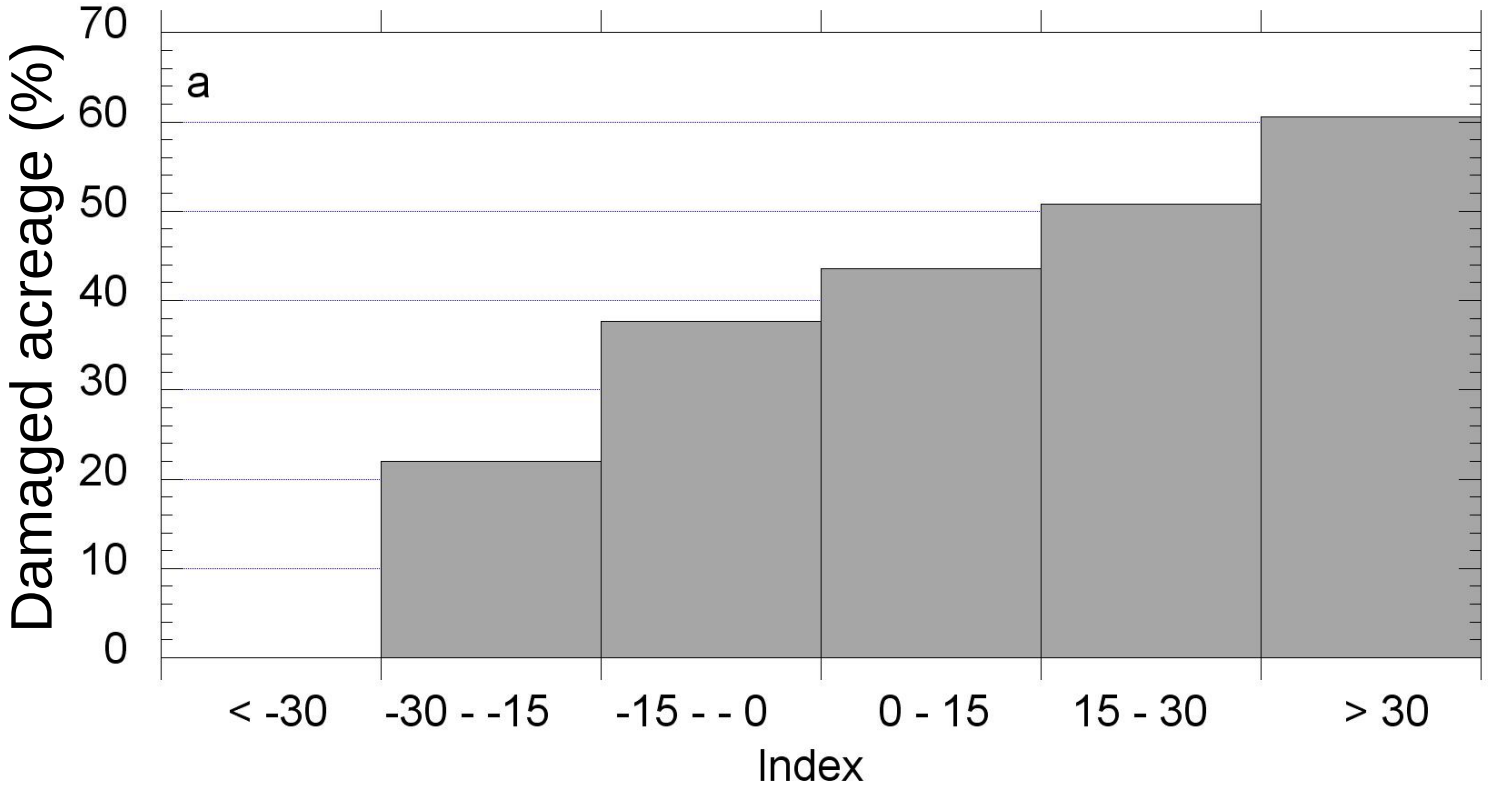
Troen I (1990) A high resolution spectral model for flow in complex terrain. In Ninth Symposium on Turbulence and Diffusion, Roskilde, Denmark. American Meteorological Society, Risø National Laboratory, Roskilde, Denmark. pp. 417-420.

Wind damage and orography



Blennow K & Eriksson H (2006)
Riskhantering i skogsbruket.
Rapport 14, Swedish Forest Agency

Wind damage in 2005 as a function of orographic effects on wind exposure



Blennow K & Eriksson H (2006)
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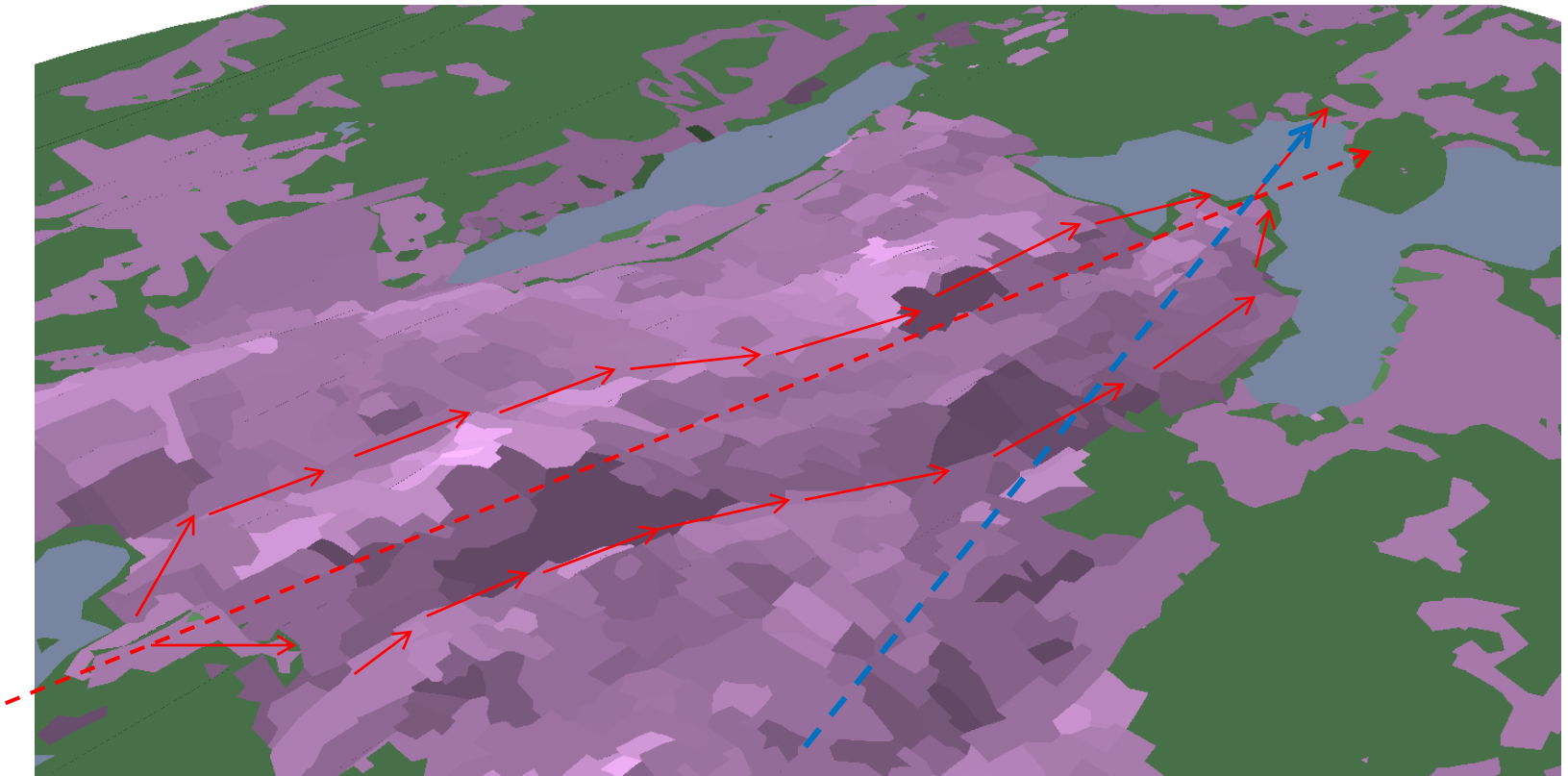
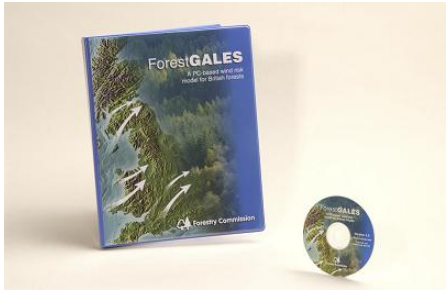
Tracing the path of the wind



Geographically explicit environment



GALES

Direction

Wind climate

Resistance

Wind exposure

Number of stems per ha

Lee effects

Surface roughness

Topography

Tree species, Height, Diameter

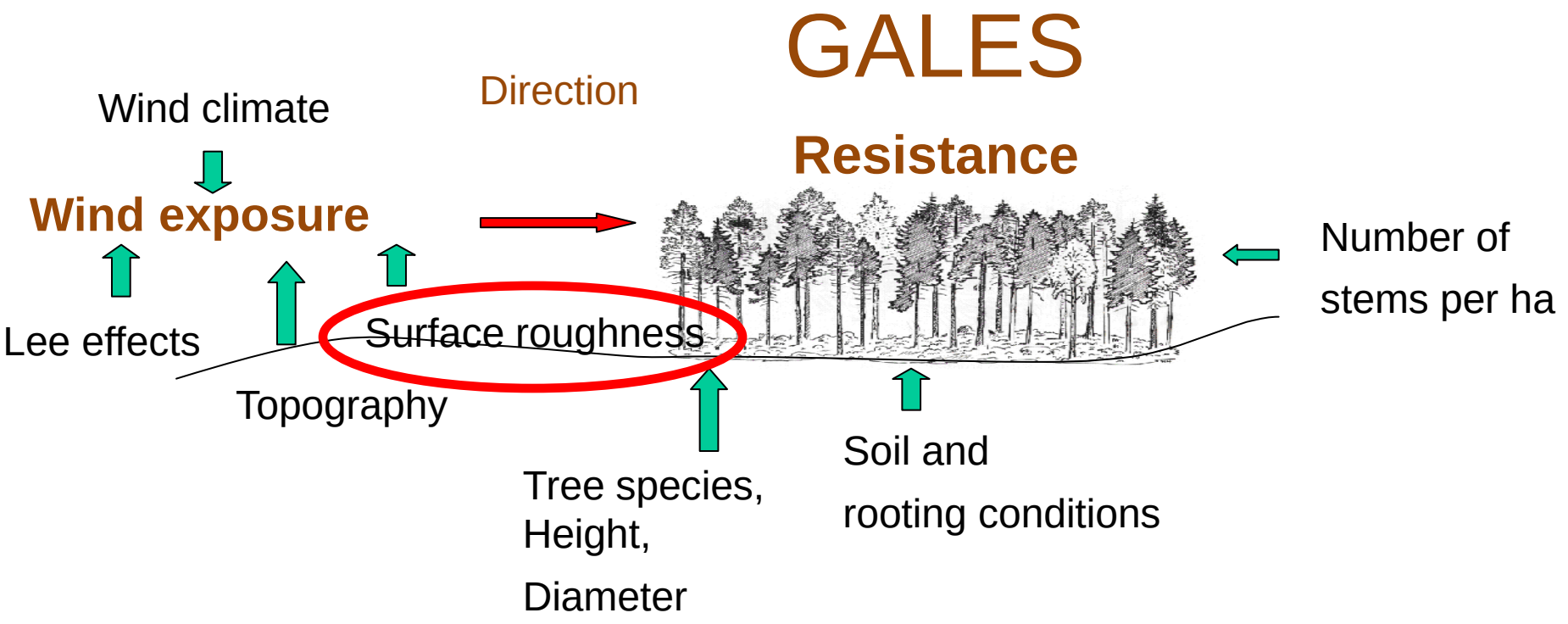
Soil and rooting conditions

Impact of Forest Edges and Gaps

Points along exposed edges and centre points

Size of gap

Geographically explicit environment



Roughness

Roughness change factor, S_r

Kaimal, J.C. and Finnigan, J.J., 1994: Atmospheric Boundary Layer Flows. Oxford University Press, 289 pp.

Average up-stream roughness length, z_{00}

Troen, I., Petersen, E.L., 1989: European Wind Atlas, Risø National Laboratory for Commission of the European Communities Directorate-General for Science and Development.

Wind Speed at Roughness Transition: ForestFLOW

$$\frac{\delta_i}{z_{02}} = A_1 \left(\frac{x}{z_{02}} \right)^{0.8}$$

$$A_1 = 0.75 + 0.03M$$

$$M = \ln\left(\frac{z_{01}}{z_{02}} \right)$$

$$\bar{u}(z) = \frac{u_{*2}}{k} \ln\left(\frac{z}{z_{02}} \right) + f\left(z/\delta_i \right)$$

where

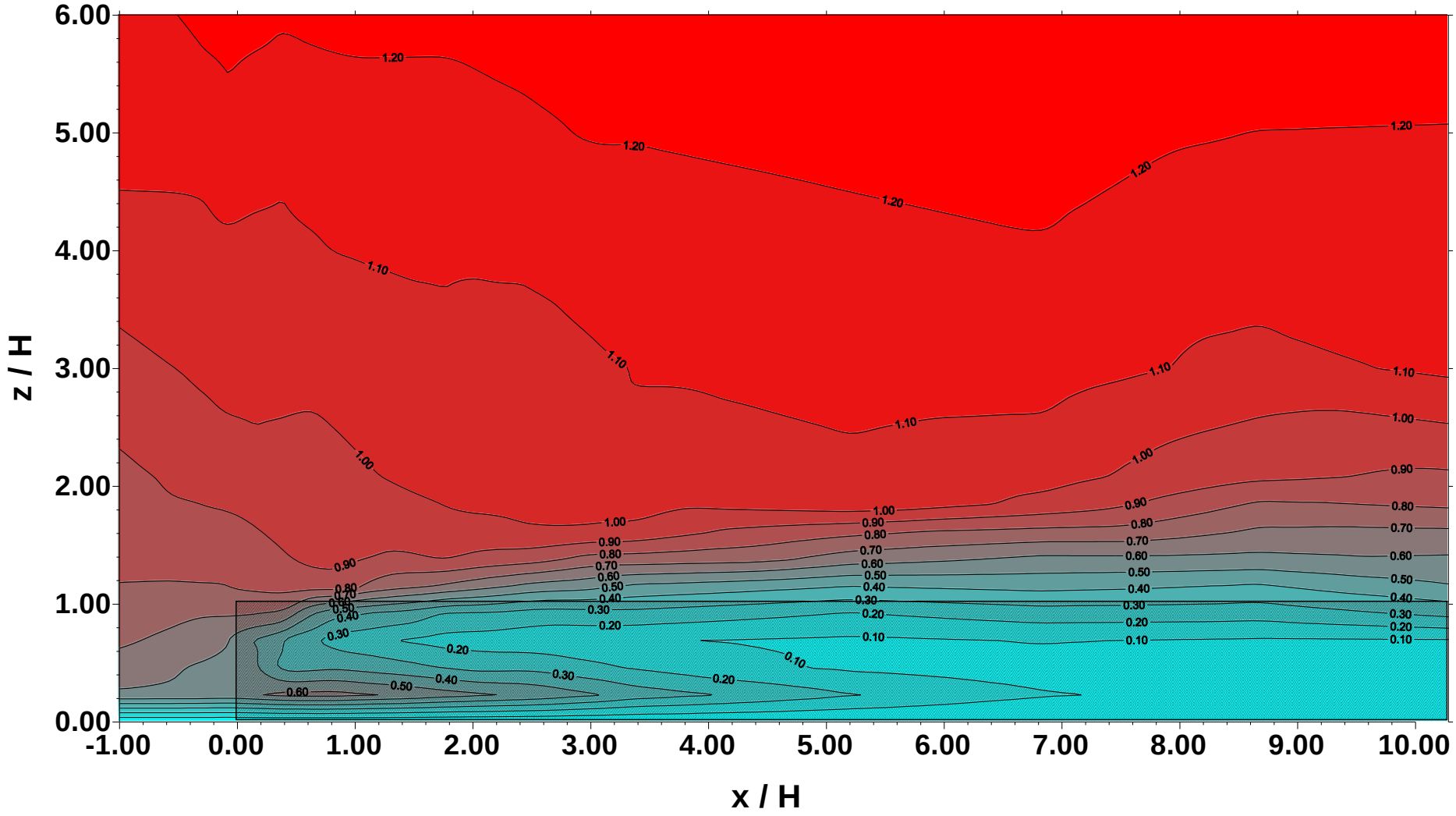
$$f\left(z/\delta_i \right) = \frac{u_{*1}}{k} \ln\left(\frac{z}{z_{01}} \right) - \frac{u_{*2}}{k} \ln\left(\frac{z}{z_{02}} \right), \qquad z/\delta_i > 1,$$

$$f\left(z/\delta_i \right) = 0, \qquad z/\delta_i \leq 1$$

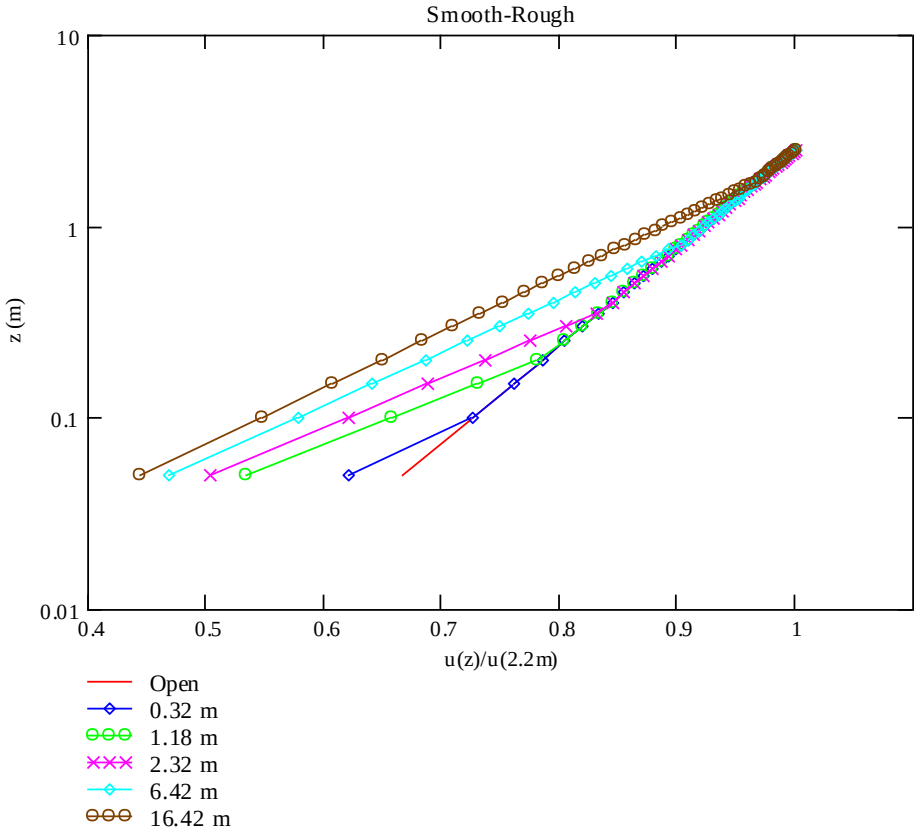
Roughness factor, S_R

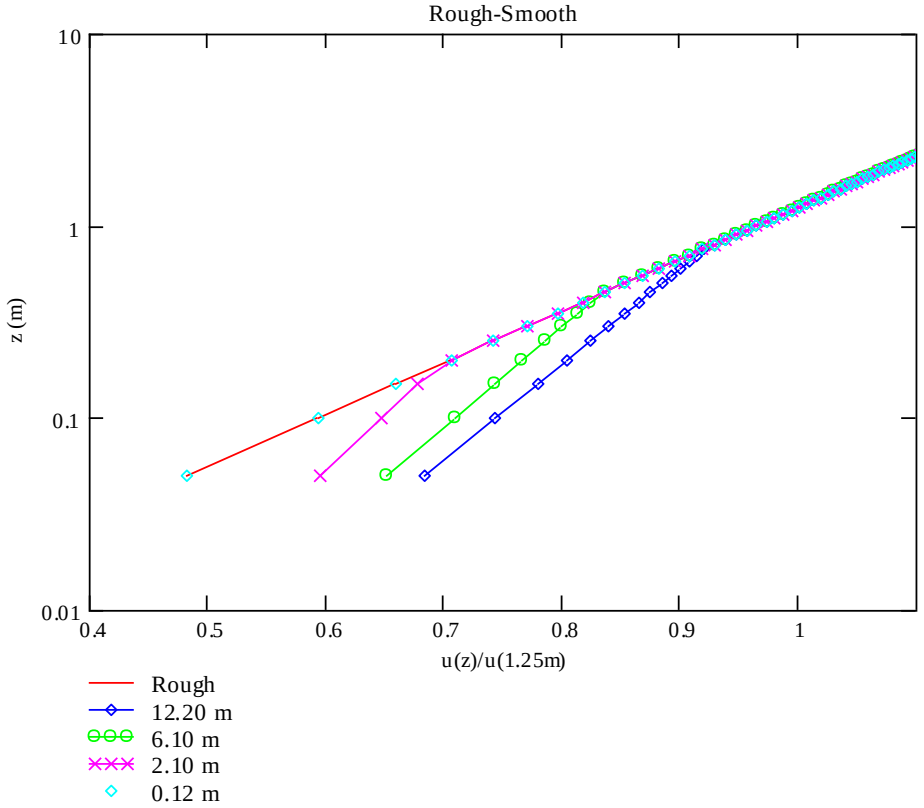
Kaimal, J. C. and Finnigan, J. J. (1994). *Atmospheric Boundary Layer Flows*. Oxford University Press.

Wind Speeds Across Forest Edge in Wind Tunnel

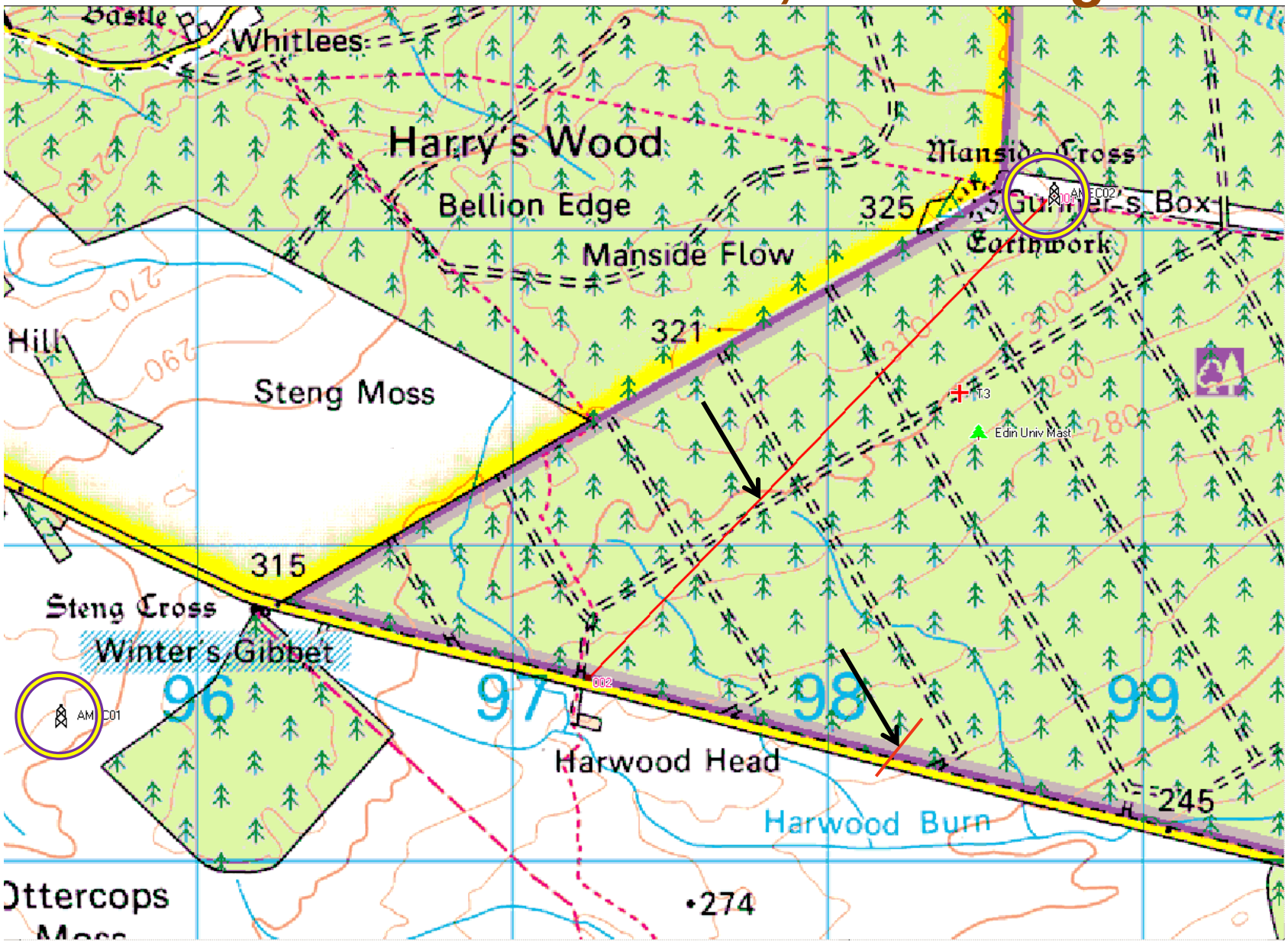


Wind Speed Change At Roughness Transition

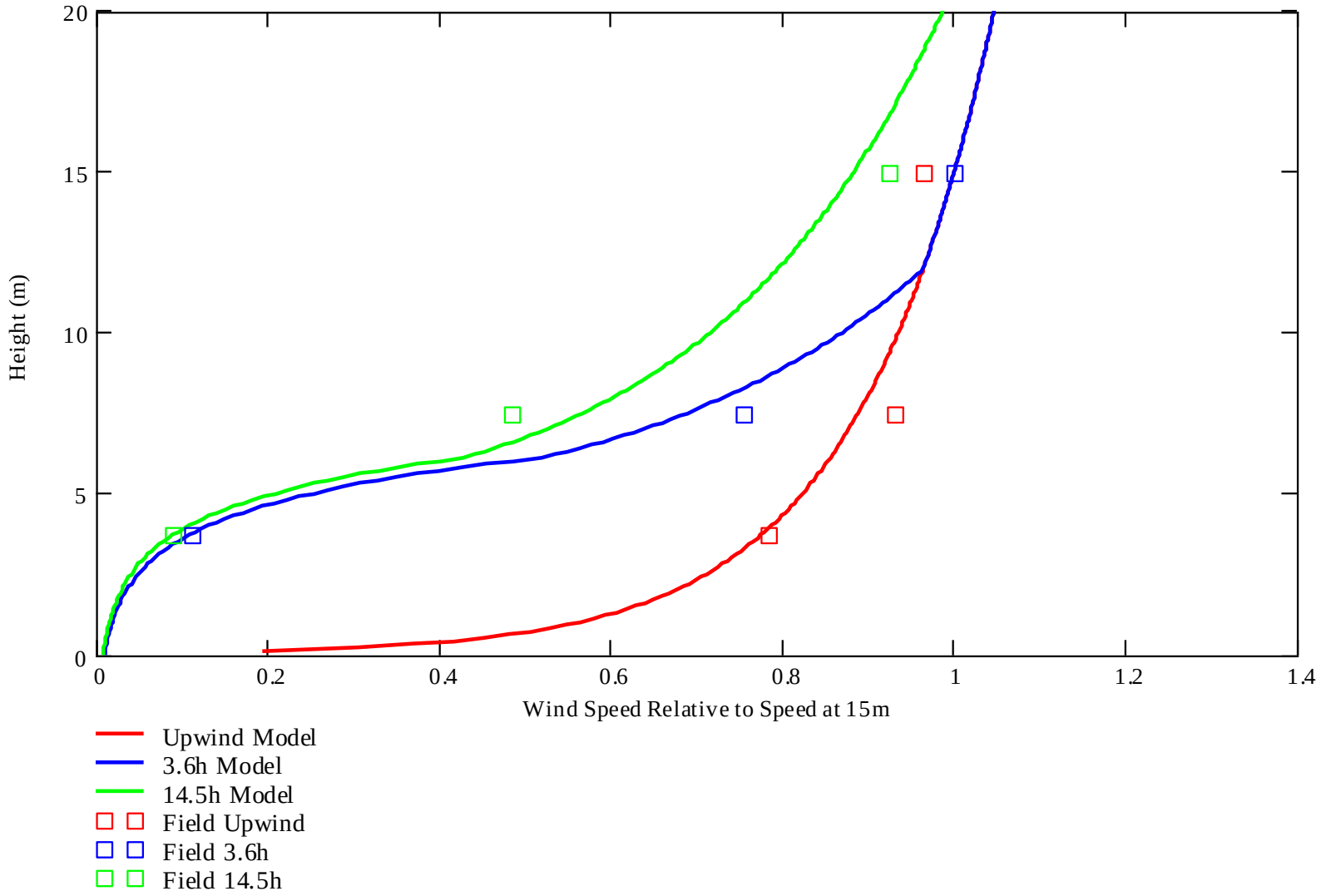


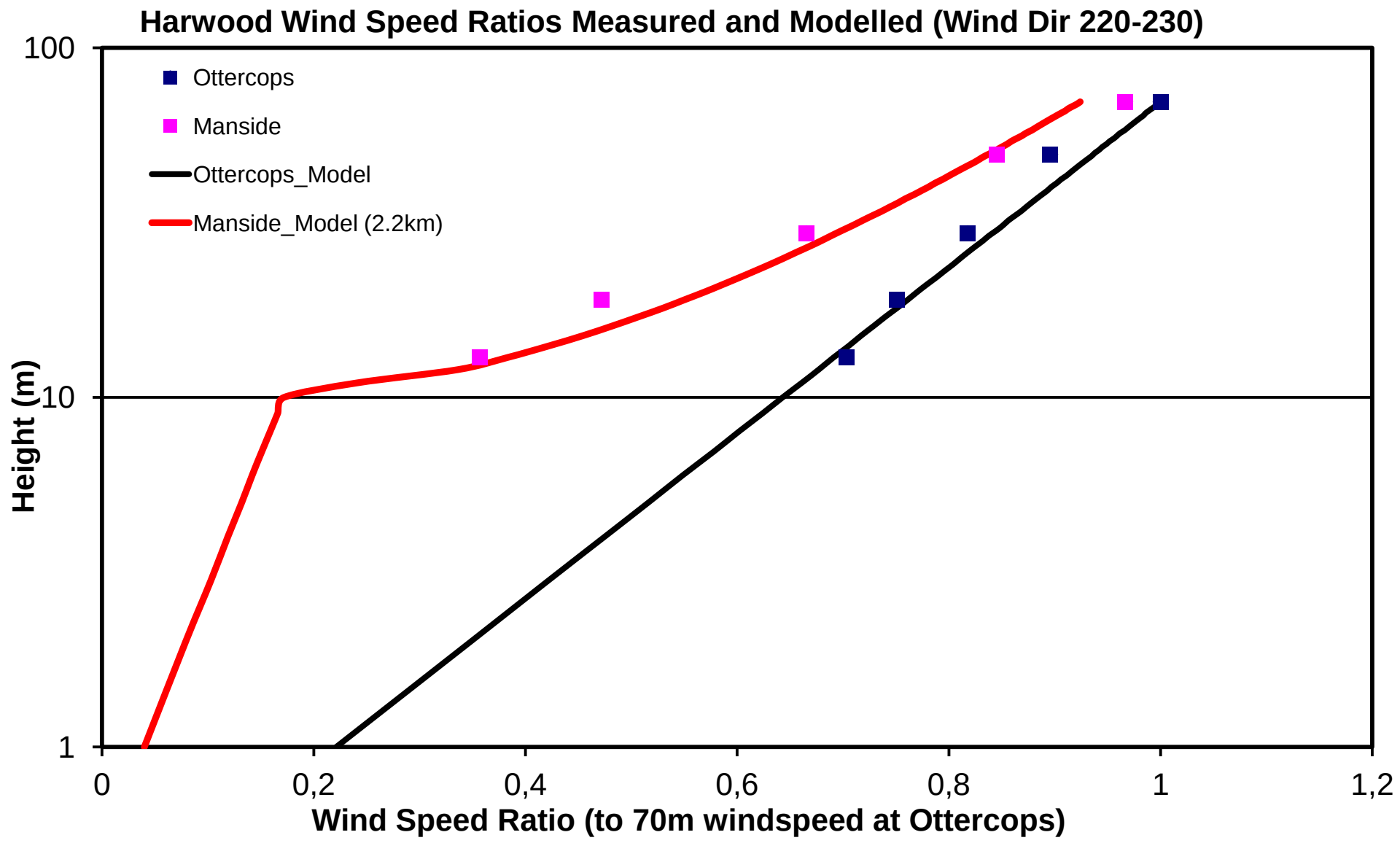


Validation: Harwood Forest, North England

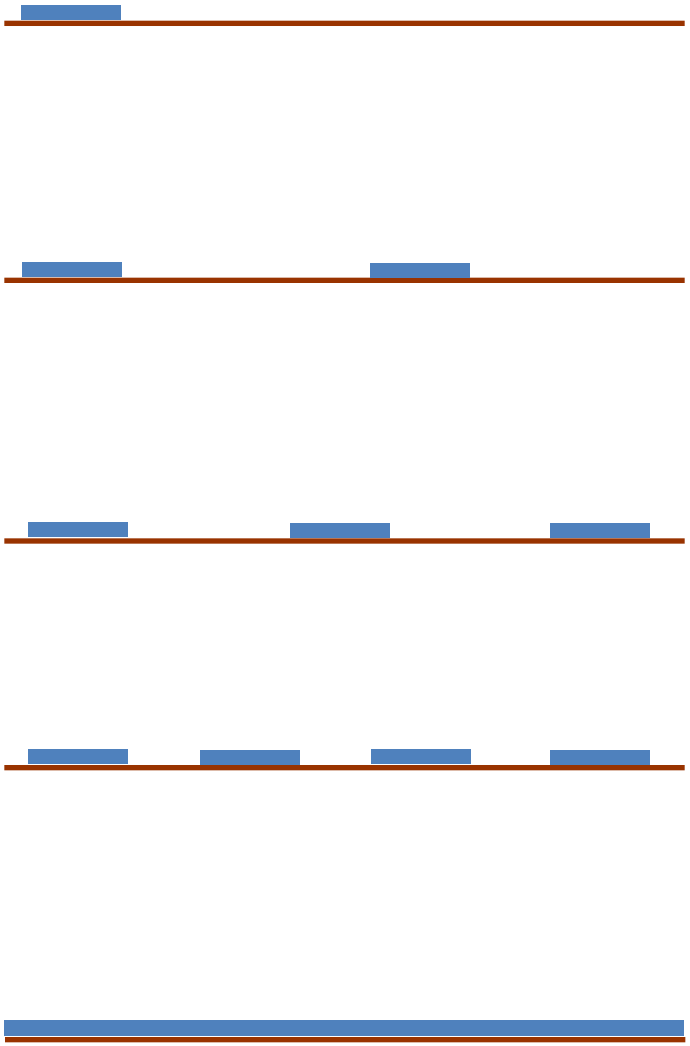


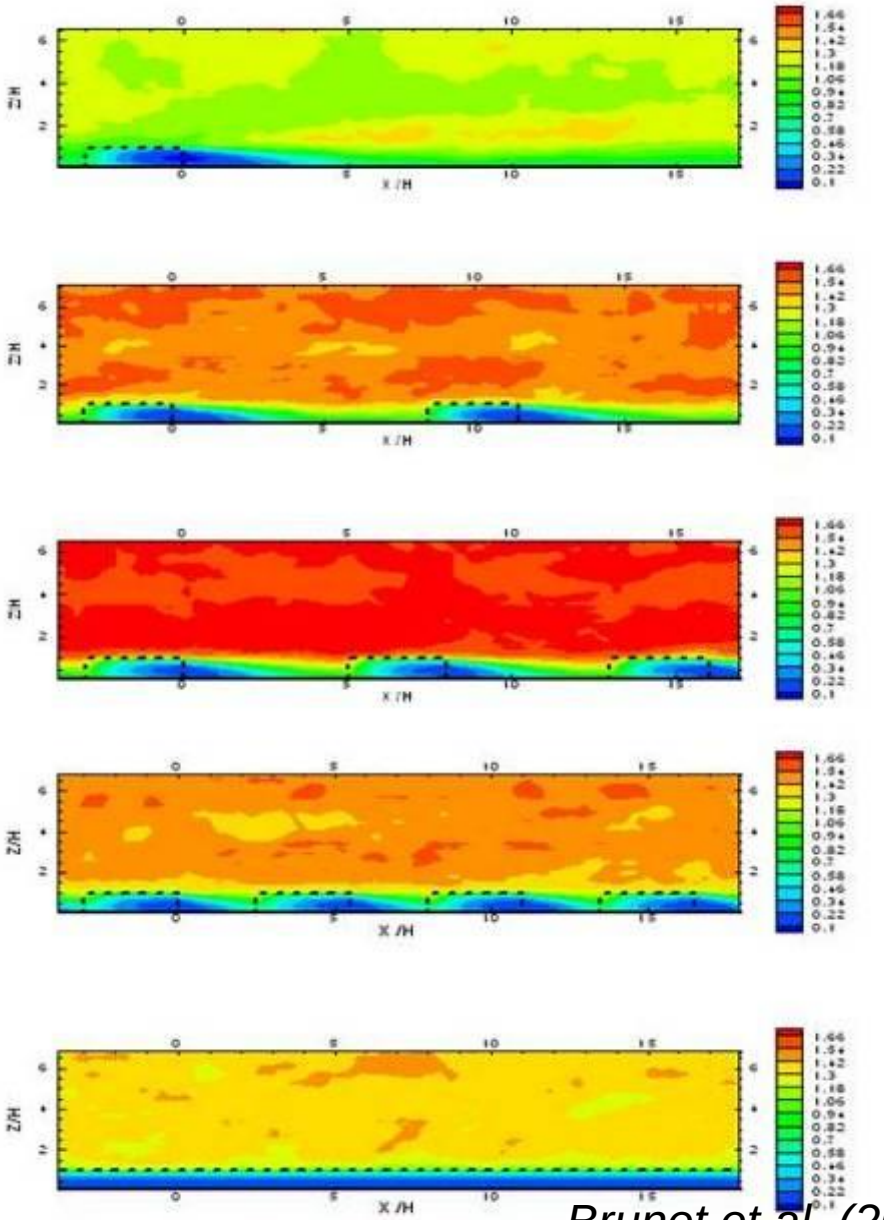
Validation of Wind Profile Calculations over Forests




Harwood Wind Speed Ratios Measured and Modelled (Wind Dir 220-230)
Ottercops
Manside
Ottercops_Model
Manside_Model (2.2km)
Height (m)
100
10
1
0
0,2
0,4
0,6
0,8
1
1,2
Wind Speed Ratio (to 70m windspeed at Ottercops)

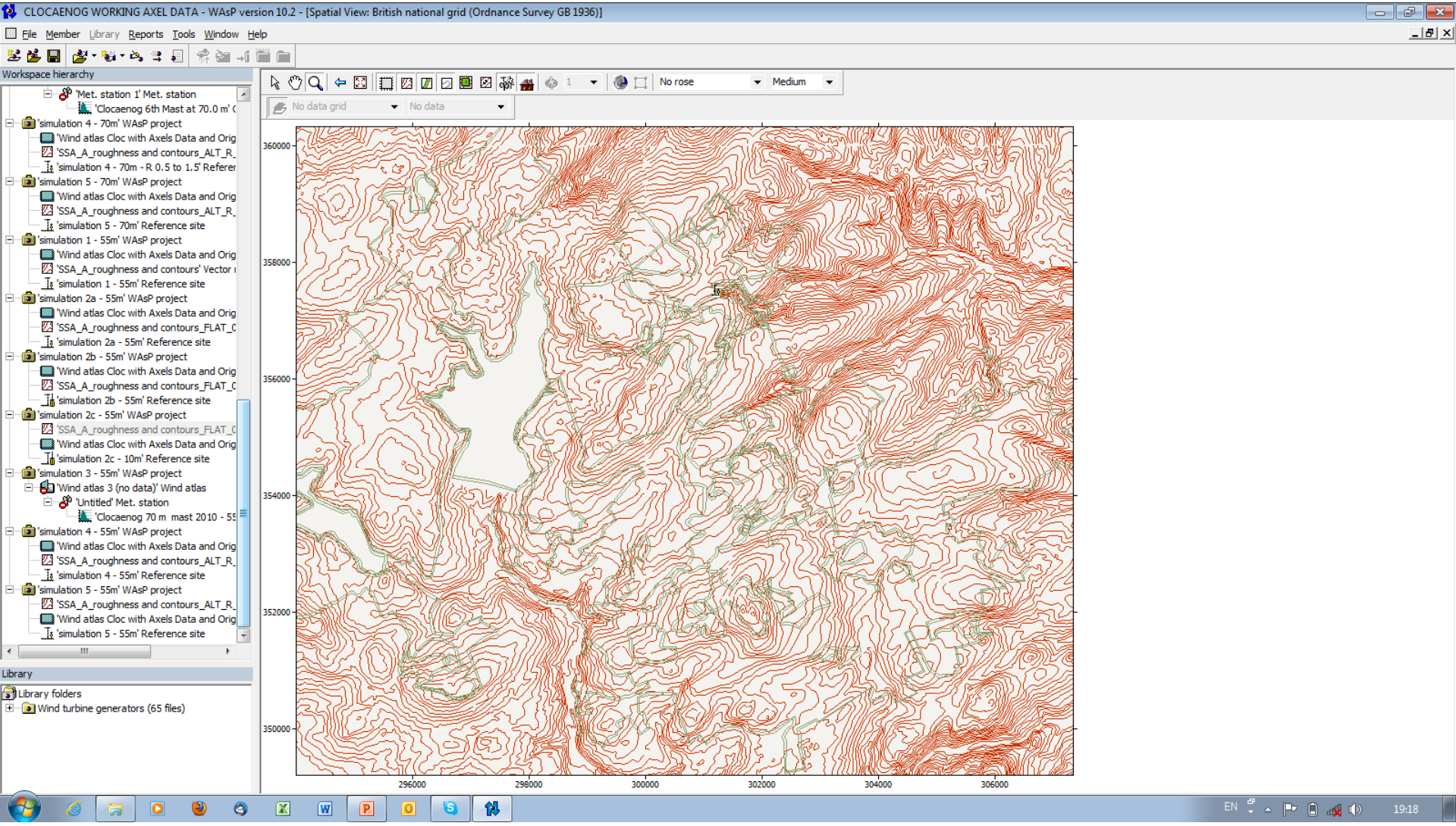
Computer Simulation: LES modeling





Brunet et al. (2009)

Integrating WAsP and ForestFLOW



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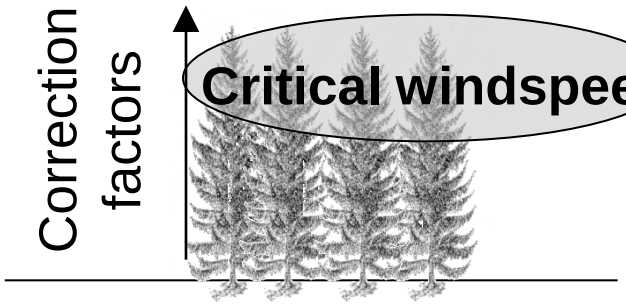

GALES

Free wind

$$U(z) = \frac{U_0(z)}{\left(1 + S_o(D_0)\right)\left(1 + S_r(D_0)\right)}$$

Geostrophic wind, G

$$u_{*0}(D_0) = \frac{\kappa U(z)}{\ln(z/z_{00}(D_0))}$$

$$G = \frac{u_{*0}}{\kappa}\sqrt{\left\{\ln\left(\frac{u_{*0}}{f z_{00}}\right) - A\right\}^2 + B^2}$$

f=2*(the earth's rate of rotation in rad/s)*sin(latitude)
A and *B* are dimensionless constants

Kristensen, L. Rathmann, O., Hansen, S.O., 2000: Extreme winds in Denmark. Journal of Wind Engineering and Industrial Aerodynamics 87, 147–166.

Summary

- We are linking models of wind damage vulnerability, wind flow and wind climate in forested complex terrain
- Effect of terrain and the roughness of the forest can be calculated separately and then combined.
- The calculation of the surface roughness impact on wind speeds is replaced in WAsP with a new empirical model (ForestFLOW)
- Able to include the effects of future wind climates
- System integrated within GIS
- Provides a tool for assessing the impacts of management on forest wind damage risk under a changing climate.

Thank you!