Flow Modeling

Roughness The collective effect of the terrain surface and its roughness elements, leading to an overall retardation of the wind near the ground, is referred to as the roughness of the terrain. The point of interest must be 'far away' from the individual roughness elements, and the height usually much larger than the height of these.

Obstacles Close to an obstacle, such as a building or shelter belt, the wind is strongly influenced by the presence of the obstacle which may reduce the wind speed considerably. To be of any consequence, the point of interest must be 'close' to the individual obstacle, and the height comparable to the height of the obstacle.

Orography When the typical scale of the terrain features becomes much larger than the height of the point of interest, they act as orographic elements to the wind. Near the summit or the crest of hills, cliffs, ridges and escarpments, the wind will accelerate while near the foot and in valleys it will decelerate.

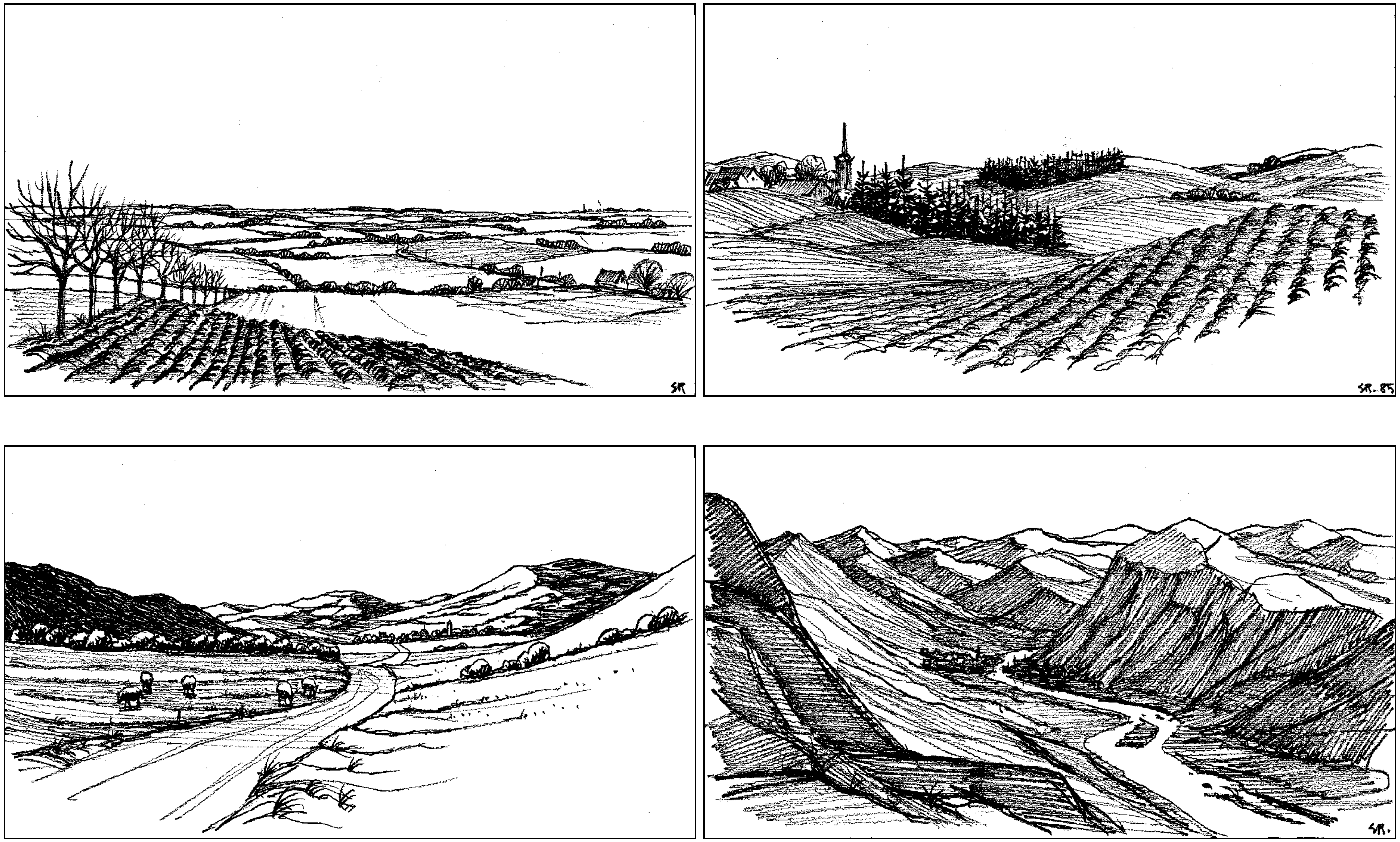


Figure 16. Different landscape types [7]: flat (upper left) and hilly (upper right) terrain is generally within the performance limits of linearized flow models. As the terrain gets steeper and more complex (lower left) the modelling uncertainties become larger and present-day engineering models must be applied with utmost care. The flow in mountains cut by deep valleys (lower right) may be investigated using more advanced flow models and/or by measurements. (S. Rasmussen del.)

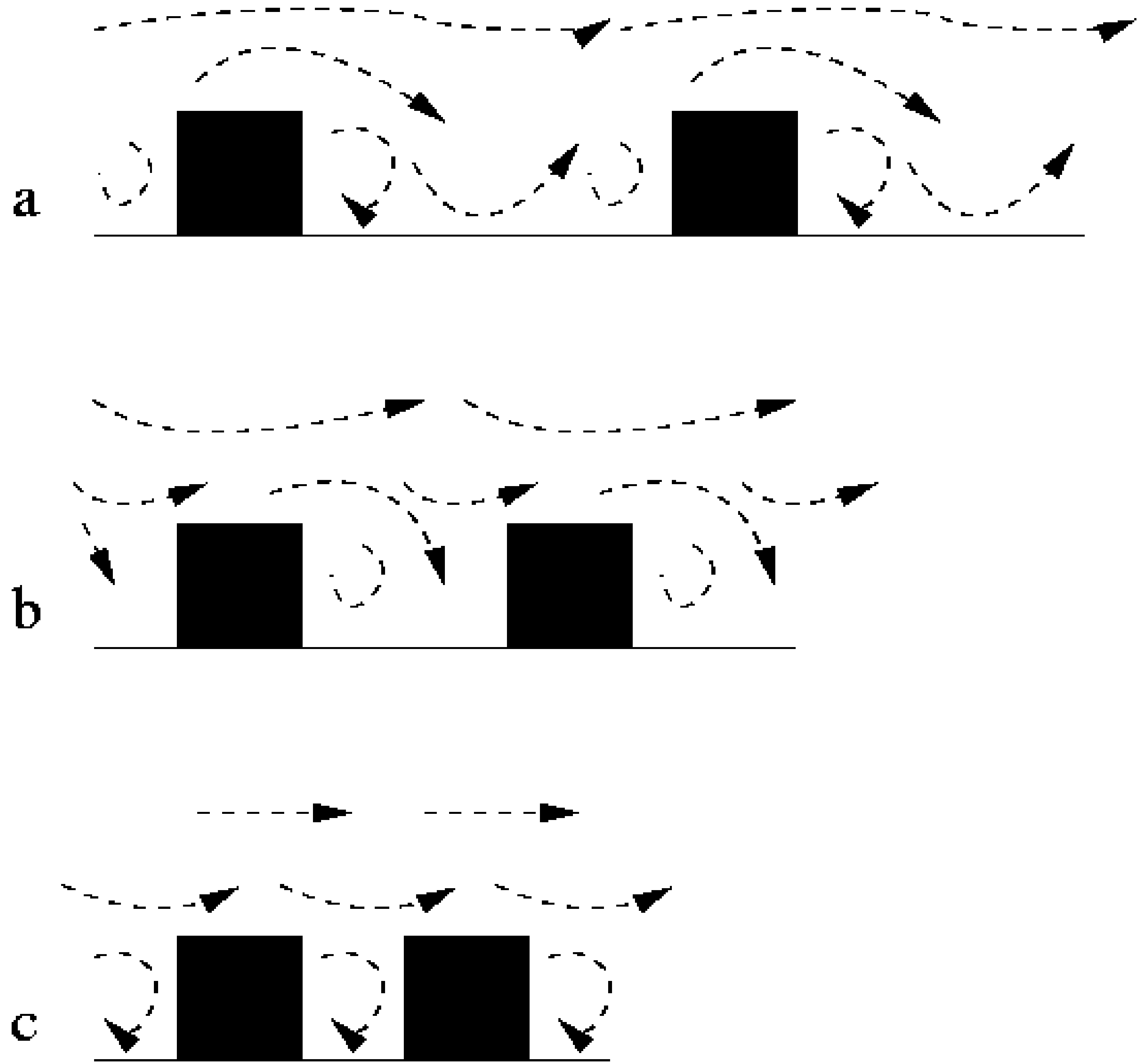
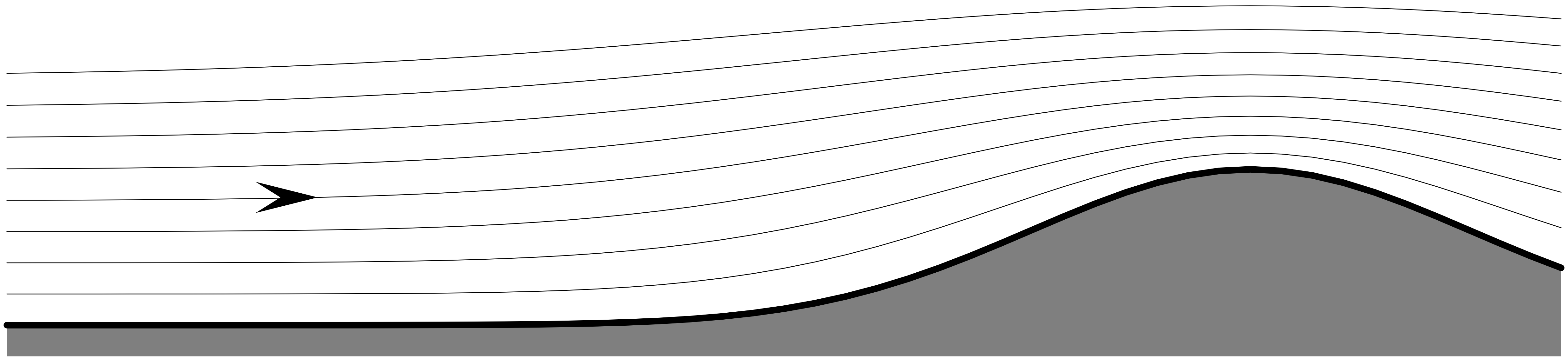


Figure 8: Flow regimes for different roughness element densities: (a) isolated elements, (b) wake interference, (c) skimming.



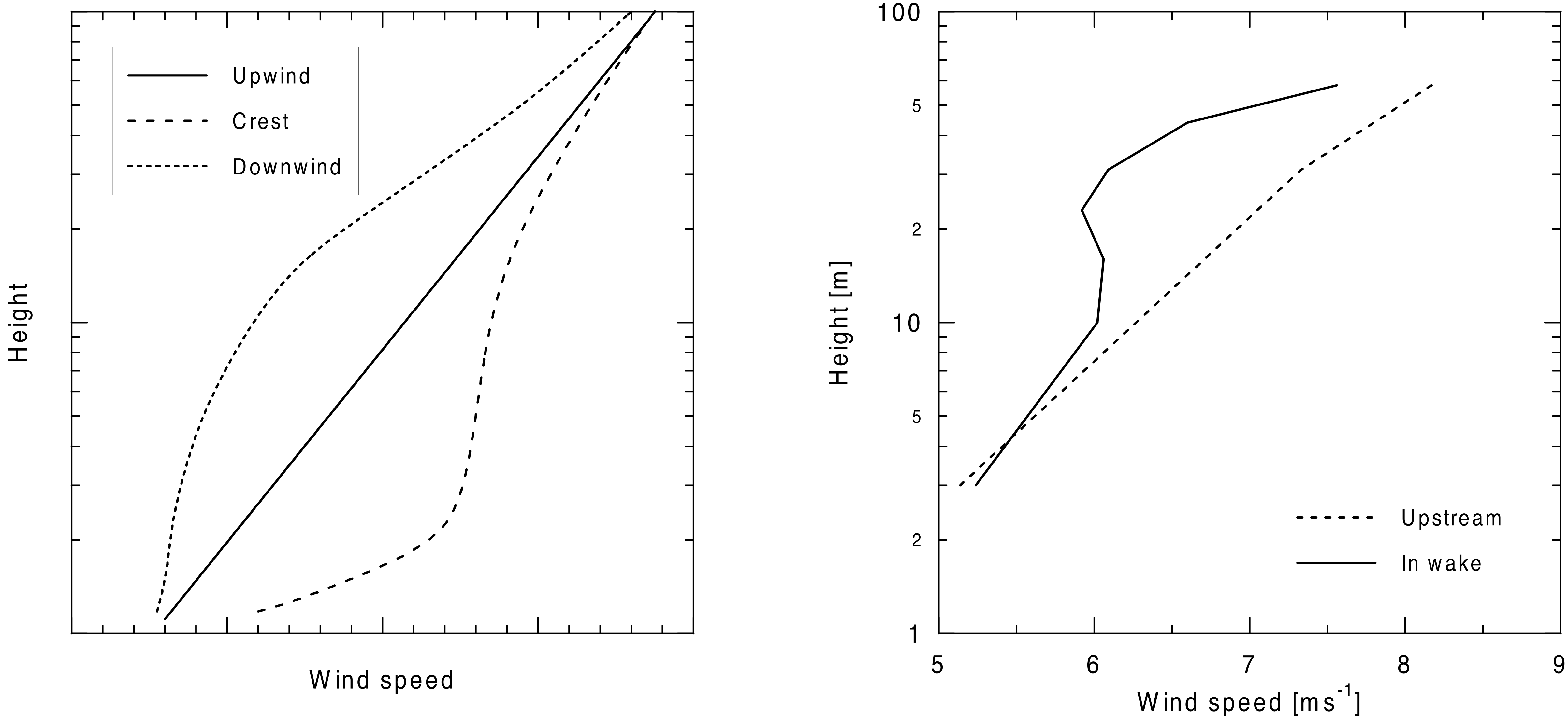


Figure 7. (a) Normalized wind profiles observed upwind, at the crest, and at the foot downwind of a two-dimensional ridge [27]. (b) Wind profiles upwind and 5.3 rotor diameters downwind of an operating wind turbine [26]. Seventeen time-series of 30-minute duration, with hub-height wind speeds in the range from 6 to 8 $m\,s^{-1}$ *and near-neutral conditions, were selected for calculation of this average wind profile.*

Table 2. Validation of the modeled mean wind speeds at 80 m a.g.l. using the RMSE calculation from equation (2).

	Site				
	1	**2**	**3**	**4**	**Combined**
Terrain	Flat	Complex	Complex	Complex	
Land Cover	Mixed	Open	Forested	Forested	
Number of Masts	8	6	3*	9	26
Mean Distance Between Masts	7.3 km	5.0 km	5.7 km	6.0 km	
	RMSE (m/s)				
Linear Jackson-Hunt model	0.26	0.34	1.15	0.74	0.62
CFD model	0.50	0.46	1.07	0.95	0.76
Mass-consistent model	0.32	0.26	0.75	0.76	0.56
Coupled NWP and mass-consistent model	0.10	0.39	0.56	0.67	0.48
Coupled high-res NWP and mass-consistent model	0.24	0.30	0.59	0.63	0.46
NWP/LES model	0.28	0.49	0.57	0.49	0.45

*For Site 3, the simulation domain was too small to include mast 2.

- Overall, the more sophisticated models do perform better at the four sites studied:
    - The coupled mesoscale NWP-mass-consistent model, SiteWind, performed about as well as the coupled NWP-LES model, ARPS. However, the NWP-LES model was run at a significantly lower resolution than the others (90 m compared to 50 m). It is possible that improved accuracy could be obtained at a higher resolution and with further refinements in the turbulence closure and other aspects of this model.
    - The linear microscale model and non-linear CFD model assuming neutral atmospheric conditions produce significantly higher errors. Those models were not designed to fully capture temperature (and moisture) gradient effects. The high performance of the coupled mesoscale NWP-mass-consistent model, SiteWind, suggests that coupling a mesoscale NWP model with the linear microscale model or the CFD model would yield more accurate wind flow estimates than using these two models in a stand-alone mode.

- On-site met mast measurements show that thermal effects have a significant impact on the diurnal cycle and distribution of wind speeds and wind shears:
    - The PBL is rarely in near-neutral conditions except when the winds are moderate to strong with a cloudy sky or around sunrise and sunset.
    - The PBL is rarely in equilibrium
- Pay attention to the local wind climate and mesoscale circulations.
- Know the advantages and limitations of your numerical model.