

Remote sensing images used for aggregation of the momentum roughness, z_0

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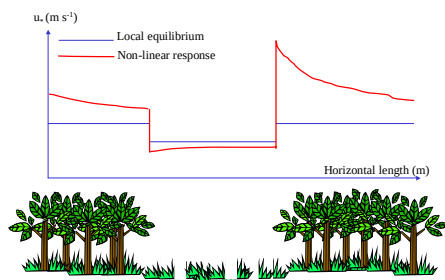


Fig. 1 The friction velocity (u_*) varies downstream as a function of local roughness and patch size. The equilibrium values (for very large patches) and the non-linear behaviour (for shorter patches) are shown.



Fig. 3 In the RS-model project, two years of observations of the effective roughness was observed at a 48 m tall mast. The local roughness was observed at 7 shorter masts, 2-10 m tall, during two crop years. View of the landscape in Foulum seen from the tall mast.

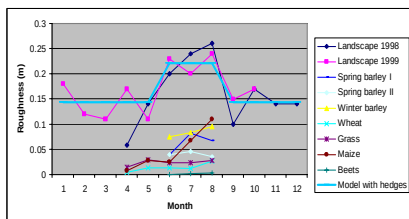


Fig. 4 Effective roughness (landscape level) measured from the tall mast and modelled with aggregation model including correction for hedge density. The local roughnesses in 7 crops are also shown. Note these are an order of magnitude smaller than the landscape roughness.

Background

In numerical weather prediction (NWP), climate and hydrological modelling, the grid cell size usually is larger than the typical horizontal length scale of variation in aerodynamic roughness. The roughness governs the local vertical surface flux of momentum and also partly the heat, water vapour and other scalar fluxes. Hence there is a basic need to parameterise the sub-grid scale variations, especially so because the atmospheric turbulent response to roughness changes is highly non-linear. In other words, a simple (logarithmic) area-average roughness value is significantly different from an aggregated value of effective roughnesses taking the non-linearities into explicit account.

Aggregation

The non-linear variations of friction velocity (u_*) (see fig. 1) is modelled in a horizontal 2-dimensional domain for arbitrary roughness variations in real terrain by a surface-flux aggregation model (see fig. 2). The effective roughness is calculated per HIRLAM grid cell at 15 km by 15 km for testing prior to an applied use in operational weather forecasting.

Results

Measurements of local roughness in Foulum is far smaller than the landscape roughness (fig. 4). The aggregation model is run based on the Landsat TM satellite map and the effective landscape roughness is sketched through the footprint (fig. 5). The aggregation model takes the non-linear responses into account that appears in the upwind direction of the mast. The effective roughness based only on land cover variations turned out to be underestimated. It was therefore necessary to include the additional roughness from hedges (fig. 6) and the method for this is described in detail in Hasager et al. (2002a) and the final result of additional roughness due to hedges is given in Fig. 6. The hedges are visible in Fig. 3 at the Foulum site.

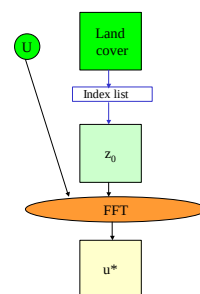


Fig. 2 Aggregation model with input of land cover type from satellite imagery assigned local roughness values from field experiments and literature. In the flow equation the advective term is balanced by the diffusion term (Hasager and Jensen, 1999)

$$U \frac{\partial u}{\partial x} = K \frac{\partial^2 u}{\partial z^2}$$

and calculated into friction velocity maps through linearized flow equations solved by Fast Fourier Transform (FFT).

The result is high-resolution maps of friction velocity (e.g. 20 m by 20 m cells) and from these the effective roughness ($\langle z_0 \rangle$) is calculated into larger cells (e.g. 15 km by 15 km) from

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

$$\langle u_* \rangle = \sqrt{\frac{1}{n_1 n_2} \sum_{x=1}^{n_1} \sum_{y=1}^{n_2} u_*^2(x, y)}$$

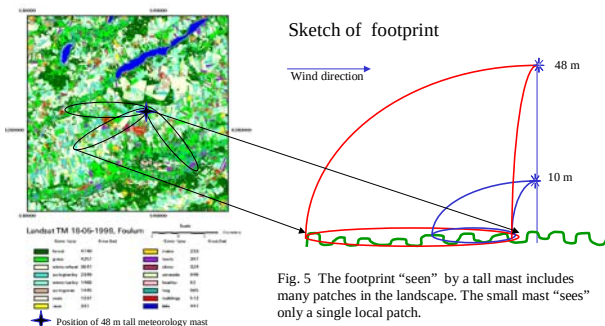


Fig. 5 The footprint "seen" by a tall mast includes many patches in the landscape. The small mast "sees" only a single local patch.

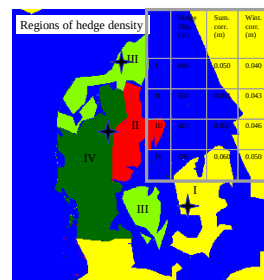


Fig. 6 Roughness corrections due to hedge density.

Application

New roughness maps for winter and summer including the additional effect from hedges are calculated for a 15 km by 15 km grid and used in the HIRLAM (High Resolution Limited Area Model) operational weather forecast model at DMI. The area investigated is Denmark. The results found are

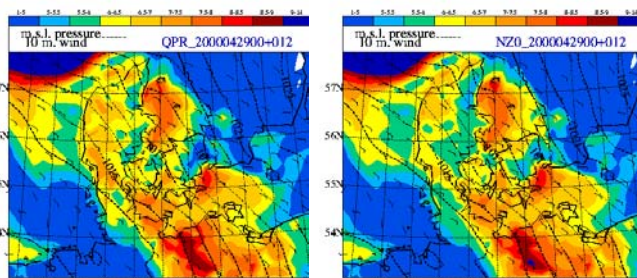
- 1) that the new roughness maps are more rough than the operational map in many areas, especially in Jutland where the hedge density is high
- 2) the 10m wind speed is reduced over the land area in the spring time cases investigated.
- 3) the roughness over cities (Copenhagen, Odense and Aarhus) had to be used from the operational roughness map as the new map was not correct

Furthermore it was found that a directional effect on the roughness does exist. It is not very significant at a 15 km by 15 km grid size but only for higher resolution.

References:

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Hasager, C.B. Nielsen, N.W., Jensen, N.O., Christensen, J.H and Dellwik, E. Soegaard, H., Boegh, E. 2002 Effective roughness calculated from satellite-derived land cover maps and hedge information used in a weather forecasting model. *Boundary-Layer Meteorology* (submitted, 2002a)
Hasager, C.B., Nielsen, N.W., Soegaard, H., Boegh, E., Christensen, J.H., Jensen, N.O., Rasmussen, M.S., Astrup, P. and Dellwik, E. 2002b SAT-MAP-CLIMATE project results. Risø-R-1350(EN), Roskilde, Denmark. Available at <http://www.risoe.dk/rispub/VEA/ris-r-1350.htm>

HIRLAM weather forecasting



HIRLAM 12 hour forecast of wind speed based on the operational roughness map

HIRLAM 12 hour forecast of wind speed based on new effective roughness map from the aggregation model

Conclusions

The roughness maps based on land use maps from Landsat TM and vector-based map of hedges, calculated into effective roughness maps by the microscale aggregation model, are generally more rough than the roughness maps operationally used in HIRLAM. The HIRLAM forecasting of wind speeds in April shows a decrease in wind speed over land with the new roughness map. This is a positive result as the operational seasonal bias on wind speed over land is $+0.5 \text{ m s}^{-1}$ and over sea is -0.2 m s^{-1} . For further detail see Hasager et al. (2002b).

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