Review of manuscript number: doi:10.5194/bgd-11-16349-2014
Title: " Large eddy simulations of surface roughness parameter sensitivity to canopy-structure characteristics"
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General Comments

Representation of natural forest canopies within numerical models is an actual problem within the science community as it limits the accuracy and the applicability of their results.

The authors investigated the effect of changes in canopy structure using large-eddy simulations (LES). From the LES results they inferred statistical relationships between measurable canopy quantities and wind profile parameters (displacement height d and roughness length z_0). This approach is new and the well defined changes within the canopy characteristics allow insight in the dependencies of the wind profile parameters.

Further, existing approaches for d and z_0 from literature where applied to calculate the wind profile parameters from canopy quantities.

The different d and z_0 estimates where then used within the logarithmic wind profile equation for the calculation of friction velocity (i.e. the momentum transport between surface and atmosphere) using measured wind speeds and stability parameters.

These calculations where again validated with direct measurements of the momentum transport.

The authors found a dependence of the wind profile parameters on the maximum canopy height, leaf area index and gap fraction. However, changes of the vertical plant surface distribution resulted in an inconsistent variation of d and z_0 but also in incomprehensible changes of the simulated wind profiles.

As the authors state themselves, this is obviously caused by the interdependence between d and z_0. Unfortunately, they did no deeper investigation of this problem. This may be caused by their indifferent consideration of d and z_0. Both of the parameters were named 'roughness parameters'. However, only z_0 represents the roughness of the canopy, differently, d is introduced in the wind profile to reduce the height above the ground z, as z is used as a scale for the mixing length $l=\kappa(z-d)$.
In many case the fitting of d and z_0 at the same time leads to tradeoffs. The determination of one parameter first, with an independent method, and calculation the other afterwards on the basis of the wind profile circumvents the problem. For example estimating d based on the canopy structure (i.e. depending on the canopy height or the gap wide between the vegetation elements) would probably lead to a more reasonable behavior of z_0 within the presented work. If you want to use only wind measurements you can also use the methods described in Rotach (1994) or De Bruin and Verhoef (1997) to determine d.

The wind profiles in Figures 4-6 are not easy to compare, as they were not normalized with the wind speed at the top of the canopy or the wind speed at a reference height within the inertial sub-layer. Moreover, the figures indicate a different wind speeds within the inertial sub-layer far above the canopy. Thus, the different LES are probably not really comparable.

The conclusions of the authors are not very productive. The authors state ‘consistent relationships between roughness parameters and LAI, maximum height, and gap fraction’ (p16371L9). Which is, at least partly, contrary to statements within the document (p16368L3: However, the lack of any relationships between roughness parameters and gap fraction was surprising).
Despite the improvement of the correlation between *d* and canopy height by the use of the maximum tree height instead of the mean tree height, the general performance of the inferred statistical relationships was not better than the approaches from literature (Raupach 1994). The inclusion of the vertical plant area distribution seems to produce also no improvements. Thus, the main conclusion which remains is: It is very difficult to determine the influence of canopy structure on the wind profile parameter.

Some of the methods and the results are poorly described. For example it is not clear how the ‘Yearly Observed’ method works and how the results are gained. The calculated *d* and z_0 of the ‘Raupach 94’ and ‘Nakai 08’ approaches are not reported. The content of figure 5c, d, e and f can only be guessed by the reader.

The language of the manuscript could be improved by the use of shorter sentences, often different statements are linked together without break (e.g. P354L15-20, P360L20-23 and P363L3-10). Several parts need a revision with respect to concise and precise use of formulations (e.g. P16362L1, where the authors compare an improvement of something with a result of something).
The content of subsections 2.6 and 2.7 belong either to subsections “Theory” or “Results” (the statistical methods must not be listed explicitly as far as they are standard methods).

Specific comments and technical corrections

The following comments are indicated by page and line numbers of this manuscript, whereas for better readability the page number was reduced by 16000 (e.g. P350L21 indicates page 16350, line 21). Recommendations are leaded by an arrow ‘→’.

Title/Abstract

P350L21: ‘We compared it with three other semi-empirical models …’. Is LES a semi-empirical model?
P350L23: ‘fixed representations of roughness’ please clarify what is meant by that phrase, or better reformulate the last two sentences.

1 Introduction

The introduction could be written more concise and focused.
P352L4: The displacement height *d* is not a ‘surface roughness parameter for momentum’
P354L15-20: Split the sentence.

2 Materials and methods

2.1 Theory

P356L21-22: Up to this line it is not clear how ha, d and z0 will be determined. The reader does not know what is ‘simulation-specific’. “the horizontal wind profile”: presumably the “vertical profile of the horizontal wind speed” is meant (see also P360L21, …).

P356L3: Check the indices (uw = 0.1 * uw_ha ?)

2.2 Site description

2.3 Large eddy simulations

2.4 Virtual experiment setup: sensitivity analysis to quantify the effects of specific canopy-structure characteristics on roughness parameters

P359L24: '**these** structural characteristics' Which? Please describe or name them.
P359L24: 'surface-aerodynamic properties' → 'aerodynamic properties of the surface'
P359L27: 'that describe such canopy structure.' → delete or exchange with 'that characterize such canopy structure'
P360L1-6: Combine both of the lists (maybe as table)
P360L15: 'Changes along the four canopy-structure axes yielded twenty permutation cases.' - The permutation gives 400 cases!

2.5 Empirical determination of roughness parameters from simulations results

P360L20-23: split sentence in two or shorten to: 'To find this point we compiled a domain averaged wind-speed profile using Eq 2.'
P360L22: 'h_r'→'u_r'
P360L22: 'vertical layer' - layer or column?
P360L20-23: 'As RAFLES was able to estimate wind statistics across a large domain,' - delete or explain the function within this sentence.
P360L24: 'we fit the wind profile in space' - delete 'in space'
P360L26: How did you interpolate between the profile functions? Did you use linear interpolation, spline or … (that is important for the position of inflection point.
P360L27: 'found the height above the ground' → 'determined h_a'
P361L6: 'vertical layer' - layer or column?

2.6 Surface roughness parameters: forest structure effects → Sources of variation of wind profile parameter

P361L6: 'LAD position' → 'LAD distribution'
P361L6: 'chaotic' → 'not explainable'
P361L17-20: These are results which do not belong in 'Materials and methods'

2.7 Testing empirical models linking roughness parameters to biometric measurements

Please write clearly and in an easy accessible manner which models and methods did you apply.
P361L25: How did you evaluate the potential improvement of the surface flux estimates? The '(a)' belongs presumably to a 'not easy to follow' list which is continued at P362L5. Please use a clearer structure. Reformulate and split the sentence. One cannot compare an improvement of something with a result of something.
P362L5-18: This part shout be shifted to subsection 'Theory'.
P363L0-10: Reformulate and split the sentences into shorter ones.
P363L4: What are the "**four** other direct empirical methods"?
P363L7: Describe the "Yearly Observed" method.
P363L11: Did you force the regression trough zero? Otherwise report the offset values.

P363L17: I assume you did apply the yearly parameterizations of the “Yearly Observed” on the whole data set (all 10 years). Why did you use the parameters of structure-driven methods only for one year (P363L20)? This is inconsistent. Further, it would be interesting how long the parameters, which are gained from biometric measurements, can be used.
P363L19: Delete ‘Sect. 2.7,’ as this is Section 2.7.

3 Results

3.1 Virtual experiment to explore canopy-roughness relationships

P364L9: write ‘$d = 0.69h_{max}$’ in Equation stile, thus you can refer on this result later on.
P364L12: ‘There was little change to d with increasing gap fraction’? Table A1 showed an decrease of d of almost 30 % (from 20.1 m to 14.4 m) as a result of the 50 % increase of the gab fraction.

3.2 Canopy-roughness improvements to surface flux models

What are ‘Canopy-roughness improvements’?
P365L7: ‘fit’ → ‘fitted
P365L13: As far as I understood the setup, the h-h_{max} relationship is not ‘found from the virtual experiment’ it is given by the virtual canopies with h_{max} and GF.
P365L13: ‘we empirically fit’→ ‘we calculated’
P365L13: ‘Eq. (11)’ → ‘Eq. (12)’
P365L13-17: These lines are not comprehensible.
P365L20: Regard comment on P365L9, delete Eq. 14 and refer to ‘d = 0.69hmax’ as well as to Eq. 7 for z_0.
P365L21: How did you exactly determine λ.
P366L3: SD is not introduced.
P366L9: ‘Eqs. 11, …’ →‘Eqs. 12, …’. What influence has Eq. 13?

4 Discussion

4.1 Response of roughness parameters to canopy structure change

P366L15-16: Emphasize that this are model results gained by the use of artificial canopies. Different relationships of h_a are possible for real canopies. Contrary to your statement, Table A1 shows that h_a is rarely sensitive to canopy structure, i.e. LAD profile variation (lower: h_a=20.7 m to upper: h_a=21.2 m).
P367L10: d and z_0 are canopy parameters; they do not change with meteorological conditions, at least as long as the properties of the canopy are not influenced. However, the estimation of d and z_0 might depend on the meteorological conditions.
P367L22: ‘roughness-height’? Did you mean ‘roughness-canopy height’ (i.e. z_0-h)?
P367L28: How does the eddy-penetration depth influence the determination of d?
P368L3-4: Table A1 shows a clear relationship between GF and d or d+z_0 (see comment on P364L12)
P368L15-18: Repetition of P367L1..
P368L21: I cannot identify a ‘weaker above-canopy turbulence and horizontal wind speed’ within Fig. 5a and b. This might be caused by different wind speeds within the higher model layers.
P368L24-27: This statement is very general, i.e. trivial.
P368L18-21: Please, reformulate this sentence.
P368L18-24: This is a conclusion, which is not so clearly stated within section ‘conclusions’ (shift it).

4.2 Integrating canopy-structure characteristics into flux models

P370L1-9: As the ‘‘Yearly Observed’ model’ is not described these statements cannot be evaluated.

P370L12: What is meant by ‘surface height, complexity, and density’(especially by the last to terms)

P370L10-19: What do you want to say exactly within this paragraph? Especially by the sentence: ‘In their urban study of building heterogeneity, Grimmond and Oke (1999) suggested the method of Raupach (1994) for random building arrangements, which may provide insight towards its success in this study over our heterogeneous forest canopy.’

P370L25: ‘used’ → ‘taken’

P370L26: ‘each’ → ‘any’

5 Conclusions

P371L11-22: Those are general statements but not unique conclusions from your work.

Tables

Table 1 is not necessary, it is part of Table A1.

Table 3: Why has the coefficient of determination always the value 0.8?

Figures

The axis labels of the kind ‘*d* [m]’ are common but mathematical incorrect. Please write ‘*d* in m’ or ‘*d* /m’ or ‘d m^{-1}’. Variables should be written in the same style as in the text (kursiv, …)

Fig. 1: Please add a 1:1 line

Fig. 2: Please add a 1:1 line in Fig. 2b

Fig. 3: y-axis label: ‘d_e‘, use the Greek letter or write ‘eddy-penetration depth’, please add a 1:1 line in Fig. 3b

Fig. 4: Use the same order of the colours in Fig. 4 and Fig. 5

Fig. 5: Explain in the figure caption, what is exactly shown in 5c, d, e and f? If 5d shows the case with GF = 0 % then use the same colour as in 5a and 5b or better leave it out. SD is not introduced. The x-labels of 5b are not readable

Fig. 6: Use the same colours like in Fig A1.

References

De Bruin H, Verhoef A (1997) A new method to determine the zero-plane displacement. Boundary-Layer Meteorology 82:159–164

Raupach MR (1994) Simplified expressions for vegetation roughness length and zero-plane displacement as functions of canopy height and area index. Boundary-Layer Meteorol 71:211–216

Rotach MW (1994) Determination of the zero plane displacement in an urban environment. Boundary-Layer Meteorology 67:187–193