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Hydrology and Earth System Sciences Discussions

Interactive comment on "A framework to utilize turbulent flux measurements for mesoscale models and remote sensing applications" *by* W. Babel et al.

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We thank the anonymous referee #2 for his comments. These comments made us realize that our manuscript has some potential for misunderstanding in the modelling community. We start with a general reply in order to clarify the major misinterpretations. After that we give specific replies to the raised concerns and comments.

Scale considerations and aim of the paper

We believe that there is a misunderstanding regarding the aim of the manuscript and

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the applied methods. The overall aim is an upscaling of flux measurements with the eddy-covariance method on a pixel or grid size of remote sensing data and mesoscale models, which is recognized at least from the referee. The upscaled flux, representative for one pixel (typically 1 km^2 when using MODIS data for e.g. land surface temperature), can be used to validate mesoscale flux simulations, driven by remote sensing data.

But the referees seem to underestimate the substantial gap in the scale of eddy-covariance data and the typical pixel or grid scale. The spatial scale of eddy-covariance data is highly variable depending on friction velocity and stratification which is for low measuring heights (up to 10 m) in the micro-β and micro-γ scale according to the classification by Orlanski (1975), while the pixel and grid scale is micro-α or even meso-γ. An overlapping in the stable case is possible (Foken and Leclerc, 2004), but in the unstable and neutral case the overlapping is small. All relevant references for the footprint problem are given in the manuscript, which are mainly Schmid (1997, 2002); Vesala et al. (2008). To overcome this problem of highly variable footprint areas in the paper a combination of footprint method and tile approach (Avissar and Pielke, 1989; Beyrich et al., 2006) was developed. From this point of view it should be clear that an upscaling on a 25 km^2 scale or catchments etc. cannot be the aim of the paper. For such a purpose mesoscale models, subgrid models or even Large-Eddy-Simulations must be applied.

The flux parameterisation in remote sensing or mesoscale models is based on the Monin-Obukhov similarity theory or a simplification like a bulk approach. Therefore data from two levels are necessary to determine the vertical gradient. The determination of the flux is a highly non-linear calculation due to the gradient approach and the influence of stratification. Therefore, it makes no sense to validate this approach against directly measured flux data when the input information (like surface temperature) is a mixed signal from a highly heterogeneous surface. This is the reason why we reduced the discussion of the upscaling mainly on two surfaces and introduced the multi-surface case only as theoretical approach. Furthermore we applied the method to an area without dramatic changes in the surface characteristics, otherwise the averaging of the surface parameters by remote sensing techniques is questionable due to the non-linear problem.

In summary, our aim is to provide high quality flux data for validation purposes of grid-based applications. The developed scheme combines the already existing features of QA/QC and gapfilling with considerations about heterogeneity and footprint and provides flux estimates including uncertainty ranges for each value (final flagging, Table 7). In the light of this target, the spatial integration via modelling of adjacent land-use types serves to estimate the uncertainty related to heterogeneity and it limits the error in case of substantial heterogeneity. We show, that it is possible to apply this feature, when a certain extent of heterogeneity is reached. But of course, it will be always preferable, if the measurements can be used directly. **We will point this out more clearly in the revised manuscript**.

Reply to the comments

"Concerning the required data: Given that, '... validation of model performance for adjacent land-use types, where typically no flux measurements are available, remains a major issue ...', points out that without flux measurements for each land cover the scaling approach has major shortcomings."

Of course, validation of a model, when no measurements exist, is in principle not possible. Thus we cannot solve this problem in general and therefore it remains an issue. Nevertheless, in most situations it is not true, that really nothing is known about the adjacent land use. We already discussed some strategies on page 5199, lines 20 ff., but this depends too much on the types of land-use involved to give a general solution. Possibilities are: (i) Measurements over a short period of time on the adjacent land-use. (ii) If the surface it well-known in literature, error estimates can be deduced from comparable studies. (iii) Derivation of surface and soil properties from additional measurements to narrow the range of model parameter and (iv), to use the footprint method according to Foken and Leclerc (2004); Göckede et al. (2005), in case that the eddy-covariance signal is mainly influenced by another land use type under certain conditions. Given this opportunities we think, that meaningful error ranges can be derived for most sites, which are suitable for model validation. Thus, our approach can be applied. **We will elaborate more precisely, what can be done to minimize this problem**

"Concerning the homogeneous test case: The authors have chosen an extremely homogeneous EC site composition to prove their concept. For the majority of EC sites, being much more heterogeneous within and around their footprints, the validity upscaling method still requires to be demonstrated. For an applicable upscaling framework the authors would require to show that the method works for land cover with significantly different fluxes. Basically, I would expect that section 3.2.2. 'Mixed case' is further included."

It makes no sense to demonstrate the concept for an extremely heterogeneous site due to the problem of non-linearity: As mentioned above, calibration and validation of a mesoscale model is not suitable in an area, where the surface characteristics by remote sensing are averaged from extremely different surfaces. **We will add information about these contraints in the manuscript**.

"The manuscript as such, offering too little applicability for mesoscale hydrology or remote sensing studies considering the initial motivation, is in my opinion not covering the scope of HESS and I can only reject it."

We cannot believe, that this manuscript is not covering the scope of HESS. But the criticism regarding the applicability is based on a misunderstanding from our point of view. Please see our general reply.

"Minor changes: The paper is written in a very detailed, but also convoluted man-

ner. The quite elaborate methods section should be focussing on the actual upscaling approach and not so much on describing every model component in great detail. Whereas section 3 highlights the actual upscaling, section 2 should be shortened in most parts. I also suggest to refer to both, section 2 and 3, as methods. Shortening sentences, such as '...corrected following Twine et al.(2002) as suggested in Foken(2008)...' or '... developed by Mengelkamp et al. (1999) in the former GKSS Research Center, Geesthacht, Germany, ...' and less crossreferences to the different sections would immensely enhance the clarity of the manuscript."

We agree, that the manuscript can be improved regarding readability. **We will revise the manuscript in order to rephrase the most complicated sentences and to reduce the number of crossreferences**

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