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Geoscientific Model Development Discussions

Interactive comment on "Sensitivity analysis of the meteorological pre-processor MPP-FMI 3.0 using algorithmic differentiation" *by* John Backman et al.

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The authors would like to thank the reviewer for the constructive comments on how to improve the manuscript.

Comments and questions

Comment: The article is limited to the sensitivity of the meteorological pre-processor, and deliberately avoids investigating the dispersion model itself. As such, the relevance of the results is somewhat limited, and the present article should be considered as a methodological proof of concept, which constitutes in itself an important building block,

but leaves the reader expecting that the authors will pursue the efforts and include the dispersion model in the approach.

Reply: The choice to limit the study was indeed deliberate. The ultimate goal of, not only the presented meteorological pre-processor, but other meteorological pre-processors that are based on the Van Ulden and Holtslag (1985) publication, is indeed to provide parameters relevant for dispersion models. In the authors' opinion, the wide use of the method warrants restricting the study to meteorological pre-processing. The message that the manuscript focus on a meteorological pre-processor, and not in conjunction with a dispersion model, was clarified throughout the paper where needed, in light of the referee's comment.

Comment: Extending the sensitivity analysis to dispersion modelling will undoubtedly raise the issue of the relative importance of drivers of mixing height in addition to Obukhov length and friction velocity. In the design of the meteorological preprocessor MPP-FMI, the mixing height is computed independently from the Obukhov length. It would be good to recall in Section 2.1 the rationale for this choice, and more specifically the consequences for the findings of the study. Mixing height is at least as important as Obukhov length and friction velocity in driving atmospheric dispersion in the surface layer and the matter should be discussed in more details. This comment regards both the methodological section, but also the results for instance in Section 3.3. on Cross Sensitivity, where the key findings should be put in perspective with the qualitative sensitivity that one might expected regarding mixing height (even if the quantitative sensitivity analysis is left outside of the scope of the paper).

Reply: The mixing height is indeed computed separately from the Obukhov length, since the radiosonde routine uses the standard technique of potential temperature data from radiosondes to estimate the mixing height. The comparison of this profile method to methods where both friction velocity and Obukhov length are used in the mixing-height estimations is already available in literature (Karppinen et al. 2001). Indeed a future interesting study would certainly be on the relative importance of mixing

height, friction velocity, and Obukhov length to the dispersion of pollutants in a dispersion model, and the inter-relationship between them would not be so trivial, so we preferred to keep the manuscript concise without too much speculation. Nonetheless, in the revised manuscript mixing height is also highlighted as an important dispersion parameter. The end of the first paragraph of Section 2.1 now reads:
"However, we have not addressed the routines within the MPP-FMI model that deal with the vertical temperature gradient and hence mixing height which are obtained from temperature profiles provided by radiosondes (Karppinen et al. 2001). Mixing height is another key parameter for the modelling of dispersion of pollutants because it determines the spread of pollutants particularly vertically, and so any future dispersion-model sensitivity study, based on the present work, would naturally also use mixing height as an input."
It would surely be warranted to include mixing height to the discussion in Seciton 3.3 if mixing height was calculated in the fluxes routine (Fig. 1 in the manuscript). Since this is not the case, we refrained from adding speculation on the intricate nature of boundary layer evolution and stability to section 3.3, and instead kept text about mixing height more general.

Comment: L54: is it possible to assess the sensitivity to internal model parameters rather than input data using the AD approach?

Reply: Yes it is possible. One can rewrite the code so that the internal model parameters are inputs to the model. This will enable AD to add this model parameter to the Jacobian and thus enable the user to assess its impact on model output. This was in fact what is explained at the beginning of Results section when e.g. precipitation and state-of-the-ground inputs were replaced with the Priestley-Taylor moisture parameter.

Comment: L55: Further background information should be added regarding the fact that Tapenade proposes analytical derivatives for differentiable functions.

Reply: This was also raised by the other referee and the paragraph was rewritten to

provide more background information. The paragraph now reads:
"Other source transformation AD tools for Fortran are also available (e.g. OpenAD) and a representative list can be found from the community driven portal for algorithmic differentiation (http://www.autodiff.org). A source transformation tool approaches the differentiation by analysing the source code of a given computer program and generating an augmented source code which contains, in addition to the original operations, instructions that carry out their chain rule differentiated versions. As these differentiated statements accompany each relevant mathematical operation in the source code, they propagate the derivative information across the entire program, providing exact sensitivity information (to machine precision) on how the inputs of the program influence its results."

Comment: L148-150: There are computer programs that deal with non-derivable functions, how are those handled by AD? Isn't that the reason why in Section 3 (L192-194) the outcome of the outlook table is used instead of the (non-derivable) table itself?

Reply: The reason for omitting the table lookups was scientific and not technical. It is more informative to assess e.g. how the moisture parameter (that ranges from dry=0.5 to moist=1.0) affects the stability, than having the input as surface synoptic observations (SYNOP) codes (http://weather.unisys.com/wxp/Appendices/Formats/SYNOP.html). However, when using AD, keep in mind that partial derivatives of the output need not change when an input is changed if there is a table lookup (or rounding of real values) before a threshold is reached which results in a different value being returned from the table lookup (or rounding to a different value).

Comment: L157: please explain what is meant by "forward" or "reverse", and why the reverse mode should be favoured in some cases (L182)

Reply: The reverse mode will give one row of the Jacobian at a time. Thus, the reverse mode is much more effective if the number of inputs is much higher than the number

of outputs (rows). This is now also stated in the revised manuscript as:
"The reverse mode should be favoured when $n \gg m$ because the reverse mode constructs the Jacobian one row at a time and is therefore more efficient."
A more in-depth description of the difference between the two modes of AD does not seem motivated given the extent to which the description would have to be extended. Thus, the interested reader is referred to Griewank and Walther (2008) as cited in the manuscript.

Technical comments

Comment: L40-44: provide the range of spatial scale for application of the mentioned models

Reply: The spatial scale is urban, which is now mentioned in the revised manuscript.

Comment: L92: two occurrences of "the"

Reply: Corrected.

Comment: L149: a sequence "of" arithmetic

Reply: Corrected.

Comment: L185: provide the link for the web interface

Reply: The link is now provided.

Comment: L187-189: unclear sentence, rephrase

Reply: The sentence was rephrased to "In this work, if an input variable to the model was solely used in a table lookup, that input was replaced by the parameter that results from the table lookup".

References

Karppinen, A., Joffre, S. M., Kukkonen, J., and Bremer P.: Evaluation of inversion strengths and mixing heights during extremely stable atmospheric stratification, Int. J.

Environ. Pollut., 16, 1–6, doi:10.1504/IJEP.2001.000653, 2001.

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