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**Geoscientific
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Discussions**

Interactive comment on "Semi-Lagrangian methods in air pollution models" *by* A. B. Hansen et al.

Anonymous Referee #1

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The scope of this paper is impressive and it undoubtly stems from a considerable effort behind the implementation of the numerical schemes that the authors compare. The content is appropriate for publication in GMD.

As the ordering of the numerical schemes is based on a rank, I would expect some discussion of its relevance. For the rotating cone results with rural chemistry (Table 1) one genereally notices (and the authors state it 5.3.1) that the higher the spatial resolution, the higher the rank. For a given spatial resolution, the larger the time step, the higher the rank. For a given spatio-temporal resolution, filtered SL schemes pefrom better than the non-filtered ones. Generally, with a couple of exceptions, all three norms associate similar ranks to the schemes. For the slotted cylinder (Table 2) this resolution-wise and filter presence-wise ordering is less of the case. But if you take a

closer look, it turns out that it is rank(l_∞) which considerably lowers the rank of the test cases with the spatial resolution $\triangle x = 0.5$, for the filtered schemes. To a lesser degree this is also the case in Table 4 where it lifts the position of the non-filtered schemes. It is clear that l_∞ is crucial from some applications of the air pollution modeling. I would therefore suggest the authors go beyond a simple description which scheme is ranked higher according to each of the norms and discuss the approriatness of the numerical schemes for some applications rather than for for others.

On a technical side, I would recommend that the authors have the article read with a focus on the logical coherence of the sentences, on matching the nouns and verbs and put them either in singular or plural, on the correct prepositions and on the usage of articles. This suggestion refers in particular to section 5 of the paper, 5.3 (and especially 5.3.1 and 5.3.2) being really difficult to follow.

Below, specific somments are followed by the minor ones and the suggested edits.

1 Specific comments

It is very valuable that the authors present the numerical schemes they implement and compare. The task of finding a balance between a concise description of a numerical scheme (which avoids rewriting the original paper) on the one hand and an understandable presentation on the other hand is very difficult. I would, therefore, suggest the authors take a refreshed look on the presentation of the numerical schemes addressing the following items:

1. Section 3.2

   I am disturbed by the way $consistency$ is used here. I am aware that the authors follow Machenhauer et al. (2008) but 'consistency' in the studies of the numerical schemes refers to a property that a discrepancy between an operator and its

discretized version, applied to a reasonable solution, tends to 0 when $\triangle x$ and $\triangle t$ tend to zero. I would only suggest considering using $consistency$ enriched with some descriptive addition like, for example, $consistency\ of\ the\ discretization$ or something of this sort.

2. Section 3.3.3

   The description of the cascade interpolation is somewhat difficult to follow even if I have Fig.1 of Nair et al. in front of me. It is obvious that understanding how the scheme works requires an effort from a reader. I would suggest, nevertheless, chopping the description into a larger number of small paragraphs. Also the sentence on p 2380, l 10 on piecewise parabolic profiles of the vertical columns leaves me perplexed. I suggest skipping 'vertical' at least and, even better, talk about i-th and j-th or λ and μ directions instead of horizontal and vertical as it is very confusing, especially without Nair et al. Fig.1.

3. Section 3.3.5

   There is a sentence in the second paragraph of this section which gives a general idea behind this scheme. Maybe the authors could, nevertheless, intertwine the sequence of formulas which follow with some explanations making them more digestible.

4. Section 5.3.1

   I suggest rewriting this section using full sentences and structuring the presentation. In your description, do you initially analyze the spatial resolution of $\triangle x = 1$ and only afterwards at $\triangle x = 0.5$? If so, please state clearly. If not, please also state clearly according to which criteria you structure the analysis of the results. You mention 'traditional', 'fine' and 'finest' resolution which suggest there are three resolutions at least, while I can only see two in Table 1.

5. Section 5.3.1

   If I understand correctly you consider LMCSL with filter to be the main challenger of the ASD. Did you actually check if they perform better than the ASD if you increased the time step for the spatial resolution of 0.5?

6. Section 5.3.2

   I also suggest rewriting this section.

2 Minor comments

1. Section 2.2.1 I find it valuable to remind the readers the reasons behind the choice of a particular advection scheme for DEHM. But the reader's appetite is not satiated as the authors remind four schemes of Brandt et al. (1996a) but briefly discuss only two of them. I would suggest adding a three-sentence paragraph on the Holm's algorithm at least. Also, a link between those schemes and the scheme finally selected for the current implementation of DEHM is not very clear to the reader.

2. Section 2.3.1 Could the authors remind the reader what σ and $\dot{\sigma}$ stand for?

3. I would suggest adding an ordering column to the tables analyzed in the text. In this way you could actually state in the text which entry in a table you mean while describing it. It is not always necessary but in some circumstances it could help the readers.

4. Table 1 p 2414 has four identical bottom entries on this page. Is this correct? This also occurs in Table 5 in both p 2422 and 2423 for non-filtered SL schemes.

3 Edits

- p 2364 l 24 The authors mean 'implement' and not 'develop', I believe. To my view 'develop' suggests the schemes are proposed in the paper. As mentioned at the bottom of p 2363 it is the case for one of them but not all.
- p 2366 l 20 Just 'mixing ratios' and not 'mixing ratios concentrations'
- p 2367 l 5 Skip 'the' before both
- p 2370 l 7-8 'longer alkenes lump' are mentioned twice
- p 2371 l 9 Should be 'is' instead of 'are'
- p 2379 l 19 I believe the authors mean 'Eulerian' latitudes
- p 2380 l 25 'should sum to one' appears twice
- p 2381 l 7 'k-th'
- p 2381 second line of the formula (21) - skip the hat above $\hat{w}_{k,l}$
- p 2382 and 2383 Could you please state clearly what k and K stand for?
- p 2383 In the formulas (29) and (30) you could maybe replace '[]' with '' and the first interval with a colon or semi-colon
- p 2386 formula (37) Similarly, I would suggest replacing '[]' with ''
- p 2387 l 7 Looks like you are back to one dimension here. Please, state it.
- p 2387 - 2388 formula (44) Do you mean here upper- or lower-case c?
- p 2389 l 9 Skip 'In'

- p 2390 l 22-23 grid cells
- p 2391 l 20 Split the sentence after 'Sect.5.1'.
- p 2391 l 23 A comma after 'and last', please.
- p 2391 l 26 Remove one of the 'only's.
- p 2392 l 7-9 Please, rewrite the sentence as: 'semi-Lagrangian schemes are compared to ASD'. IC being common to all of the schemes, there is no need to mention it.
- p 2392 l 24 Make up your mind id you want to use 'plots' or 'shows'
- p 2392 l 25 'as a cone', I believe
- p 2394 l 1 I believe it should be 'what' instead of 'this' and 'In' instead of 'On'. Check with a native speaker.
- p 2393 l 2 'axes' or 'is'; 'in the top plots'
- p 2393 l 4 Consider splitting into three sentences instead of commas.
- p 2394 paragraph 5.1.3 Could you, please, state clearly the name of the analyzed scheme in agreement with Section 4.1 (and Fig.2).
- p 2394 paragraph 5.1.4 Same remark as above. Also the way the first sentence of the paragraph is written suggests that each of the plots in Fig.3 shows a cone for each of the numerical schemes. In reality it is one numerical scheme combining all those characteristics and, therefore, it would be better to just use the name introduced in Section 4.1.
- p 2394 l 23 'species'

- p 2394 l 24 'From a comparison', I believe
- p 2394 l 25 I believe the authors want to say 'bottom right plot of Figs. 1-3'
- p 2395 l 2 But the bulk occurred for a different scheme, didn't it.
- p 2395 l 5 'than for the other'
- p 2395 l 5 'worse', please
- p 2395 l 8-9 I would propose: 'The maximum value is again closer to that of the initial condition than for the semi-Lagrangian schemes using 1_1 resolution but not as close as for the ASD', or something of the sort.
- p 2395 l 15-16 'solutions' or 'performs'
- p 2396 l 4 'throughout'
- p 2396 l 12 Do you mean 'cylinder' or 'cone'?
- p 2397 l 5 'smaller' instead of 'less'
- p 2397 l 13 'scheme' or 'smooth'
- p 2398 l 4 I believe it should be 'The scales in the four plots vary'
- p 2398 l 6 I am not sure how to understand 'and the lowest value of the shown plots as well'
- p 2399 l 6 I think it should read 'and giving points to the methods relative to their results' or something of that sort
- p 2399 l 20 Please check it with a native speaker but I think it should be 'the better the performance'

- p 2399 l 21 I tend to think that an error could be 'smaller' but I would not use 'better' in this context
- p 2399 l 22 'than for the'
- p 2399 l 24 Remove 'The semi-Lagrangian schemes the'
- p 2399 l 26 Do you really mean '3_1'? Or '10_1'?
- p 2399 l 26 - p 2400 l 1 I simply do not understand how do the results from Table 1 support this statement.
- p 2400 l 9 To me, 'the second resolution is 10_1' does not really mean much. It would be enough to insert 'The second best performing resolution' and the sentence would be so much smoother.
- p 2400 l 7 - 11 You mix the spatial and temporal resolution here which is perturbing. In 5.3.1 you talk about 'coarser time step' which is more informative.
- p 2400 l 18 Maybe 'The second class of the filtered'
- p 2400 l 20 - 21 Could you please reformulate this sentence and avoid the phrase 'worst resolution'. Also how do you see that the resolution currently used in DEHM gives inferior results to all the other tested spatial and temporal resolutions. Are you only comparing the performance of the ASP schemes? I mean, it is hard to realize which entries in Table 2 you actually analyze.
- p 2400 l 23 Skip the comma after l_1
- p 2401 l 21 It is not easily understandable what you mean starting from the words 'as well, the filtered ...'
- p 2401 l 22 Maybe you could insert 'resolution 05_05, third according to the l_2 error, is the best ...'

- p 2401 l 25 - 26 Please reformulate the last sentence on this page. Something of the sort: After the filtered high resolution ASD, LMC cascade scores second and the (pure? bare?) cascade comes third.
- p 2402 l 5 'overall'
- p 2402 l 10-11 It is not clear to me what 'with the filtered schemes first and he filtered resolution 3_1'. By the way is it 3_1 or 10_1?
- p 2408 l 8 Should be 'compares'. I would also start a sentence with an 'A ranking'
- p 2408 l 14 I would merge it with the previous paragraph.
- p 2409 l 16 Should be 'improves'.
- p 2409 l 25 - 29 There is something missing in this sentence. I would also suggest splitting it into two sentences after 'steps'.
- p 2410 l 7 'straightforward'
- p 2410 l 14 Should be 'computational'
- p 2412 l 23 'Meteorology'

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