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Interactive comment on "InMAP: a new model for air pollution interventions" *by* C. W. Tessum et al.

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Comment:

In regards to the approach the authors use to describe transport, it should be pointed out that their equation 3 can be rearranged to be made up of a purely diffusive term and one advection term, and this is what is numerically being solved (simplifying to one direction, letting fw,e=1): [equation omitted] The first term is a purely diffusive term with a diffusivity of [equation omitted], which shows that it is dependent on the grid size, which is not likely appropriate here for a few reasons, including:ÂăÂă1.ÂăÂă(It is likely more proper to use the average of the positive and negative components, instead of just Upos.ÂăÂă This leads to the second term being a centered difference, potentially adding more diffusion.)ÂăÂăDiffusion should not be dependent upon the grid size, and 2.ÂăÂăThis means that the effective transport distance, by diffusion,

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Interactive Discussion

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is also grid size dependent, 3. Effectively (discussed more below), exposures in a city are mainly determined by an effective horizontal diffusion, not net transport due to advection.ÂăÂăÂăIn terms of the dependence on grid size, material can be transported twice as far (or fast) just because of the choice of grid size doubling.ÂăÂăThe second term is also important in that it shows that the equation is asymptotically correct (e.g., the case where U is only positive or negative) only if FA=1 (they have set it to 2), and is likely not mass conservative without being set to 1.ÂăÂăFor the current solution approach, the actual equation they solve more closely resembles: [equation omitted]

Response:

We thank the reviewer for this comment, and also for the derivation that was subsequently provided. We are not able to entirely agree with the reviewer's interpretation of the derivation, however, because it seems clear to us from Equation 3 in the discussion manuscript that the rate of concentration transfer is depended on 1/dx rather than dx. We do agree that all upwind advection schemes are numerically diffusive and all numerical diffusion depends on grid cell size. In the case of InMAP, numerical diffusion is decreased in high population areas by the use of a higher-resolution grid. We have added text to the manuscript describing this point. Additionally, we have tested the advection algorithm that is discussed in this comment and have confirmed that it does conserve mass. However, in response to this comment and others, we have redesigned the advection scheme so that it no longer contains an empirical correction coefficient, and so that it is explicitly divided into advective and diffusive terms. We have also tested the new advection scheme to ensure that it conserves mass.

Changes:

We added the text: "The upwind advection scheme was chosen for its computational efficiency. A limitation of this scheme is that it is numerically diffusive, but this limitation is mitigated in InMAP because the variable resolution model grid uses smaller grid cells in high-population areas and thus limits numerical diffusion in the areas where accurate predictions are most important." We also redesigned the InMAP advection scheme to explicitly contain advective and diffusive components, and updated the "Advection" manuscript section (as well as other related parts of the manuscript and figures) to reflect the changes.

Comment:

The effective horizontal diffusion is likely about 300,000 m2 /s (U$\sim$5 m/s; dx$\sim$30,000m).ÂăÂăThis makes the effective Pe # (UL/D) about 0.002 (highly diffusion dominated) for transport in a city of size 100 km.ÂăÂăIn essence, they now take that the difference between the average positive and negative velocities to become a stochastic fluctuating quantity, and that the magnitude and direction is independent and uncorrelated to the other velocity components.ÂăÂăIt would be instructive to compare their solution with a few analytical solutions for simplified one dimensional transport cases (e.g., where the wind blows west at 5 m/s for 5 months and then east at 4 m/s for 7 months, with a source in the center, and chemical depletion of 0.1 per day), and maybe a two dimensional case as well (Upos=5, Uneg=2; Vpos=5, Vneg=4, each half the time; source in the center).ÂăÂăÂă Thus, at this point, the authors need to address the issues of the very large numerical diffusivity and the lack of asymptotic agreement with the governing equation, before this approach should be utilized.

Response:

We thank the reviewer for this comment. As one correction, within cities the typical grid cell size in InMAP is dx=1,000 m rather than 30,000 m. InMAP is designed to predict annual average changes in pollution concentrations under real-world conditions. Visual inspection of annual average PM2.5 concentrations as predicted by comprehensive chemical transport models (e.g., http://www.pnas.org/content/111/52/18490/F1.large.jpg) shows that changes in concentration at increasing distance from emissions sources tends to be somewhat symmetrical spatially, as is characteristic of a diffusion dominated process, rather than

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the highly asymmetric patterns characteristic of advection in one direction. This is because wind speed and direction is highly variable and quasi-random (e.g., https://youtu.be/3W_ClNKSBTM), at least within the boundary layer, which are the characteristics of a diffusive process. Therefore, representing annual average transport as a combination of advective and diffusive processes is not inappropriate. In response to this comment and others, we have redesigned the advection scheme to be explicitly divided into advective and diffusive components. We also redesigned the advection scheme to no longer use an empirical correction coefficient. We have added a description of a limitation of this approach in the case of highly bi-directional wind fields that are diagonal to the model axes. Finally, we have additionally added an evaluation of model performance for a single point source of non-reactive particle emissions to evaluate the performance of the advection scheme in real-world conditions.

Changes:

We added the text: “The upwind advection scheme was chosen for its computational efficiency. A limitation of this scheme is that it is numerically diffusive, but this limitation is mitigated in InMAP because the variable resolution model grid uses smaller grid cells in high-population areas and thus limits numerical diffusion in the areas where accurate predictions are most important.” We redesigned the InMAP advection scheme to explicitly contain advective and diffusive components, and updated the “Advection” manuscript section (as well as other related parts of the manuscript and figures) to reflect the changes. We added text: “As shown above, in order to represent temporally-variable advection in an annual average modelling framework, InMAP splits advective transport into three steps, one of which is advective in nature and two of which are diffusive in nature. One result of this is that in some cases information regarding transport direction may be lost. For instance, an extreme case were wind travels from the Northwest half of the time at 2 m/s and from the Southeast the other half of the time at 2 m/s would be represented by InMAP as advection at 0 m/s and diffusive mixing equally in all directions at $\sqrt{2}$ m/s.”

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Interactive Comment

Interactive comment on Geosci. Model Dev. Discuss., 8, 9281, 2015.

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