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Geoscientific Model Development Discussions

Interactive comment on "Linkage between an advanced air quality model and a mechanistic watershed model" *by* K. Vijayaraghavan et al.

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General Comments

Multimedia simulation is an important approach to analyzing some complex classes of environmental problems, such as atmospheric emissions that are transported to watersheds, causing water quality deterioration, with attendant human and ecological risk. Broadly speaking, two simulation approaches can be pursued – integrated multimedia modeling, and linked single media modeling. Each approach offers advantages, and proponents have developed both over the past decade or two. Both approaches require a software framework to handle a variety of observational data and internally simulated data.

For large domains, I am encouraged to see the use of advanced "legacy" models, which can be run independently for many problems. Linkage of two or more legacy models, however, often requires some modification to the component models, particularly the input and output routines, in order to maintain mass balance through intermedia transport at the proper scale. The linked modeling approach puts more demand on crafting flexible, robust linkage software and on developing proper application strategies. This approach also requires more attention on representing intermedia transfer consistently within each of the component models. Consistency involves both process elucidation and parameterization.

Technical linkage issues and application strategies are not often addressed in the scientific and engineering literature, which preferes to focus more on issues of process representation – equations and parameterization. This paper helpfully addresses this imbalance in the literature. The linkage technology described here represents incremental progress in the mechanics of transferring data from one modeling domain to another. I believe that the meteorological linkage described is an innovative, useful approach, but some pollutant mass balance flaws at the subbasin scale can best be resolved by modifying WARMF (see specific comments below).

Proper model linkage is a prerequisit to analyzing difficult multimedia problems through simulation. This linkage of AMSTERDAM with WARMF (as well as other similar efforts) represents a start, but many scientific and application issues remain. For some problems, feedback from the landscape to the atmosphere could be significant, posing additional difficulties in one-way linkage of legacy models. The authors conclude correctly that, despite the advantages in spatial coverage, caution should be taken when linking atmospheric and watershed models. It is premature to conclude, however, that these linked models can be used to connect individual atmospheric point sources to water quality consequences. At present the uncertainties are quite large, and mass balance discrepancies must be better resolved at the subbasin scale. I endorse the authors' recommendation that the atmospheric models be used as a supplement to conventional measurement data when applying the watershed model. Results must be qualified.

Specific Comments

Temporal and Spatial Scale: Atmospheric and watershed models differ significantly in temporal and spatial scales and resolution. The general differences are summarized in this paper, particularly with regard to linkage mechanics (i.e., mapping grid elements, matching output/input times), but otherwise are not pursued in depth.

For many multimedia problems of interest, atmospheric models must be run over large spatial domains, usually continental in scale. As pointed out in this paper, large scale atmospheric models are practically limited to runs of a year or two due to availability of data and computational resources. Watershed and ecosystem models often require small to medium spatial domains, but use relatively fine scale spatial grids and often must be run for years to decades to properly address some water quality issues. Depending on characteristics of the water bodies, the pollutants, and the management questions, it can be important to capture water quality dynamics down to the subbasin level. Intermedia transfer can differ significantly with land use and vegetative cover, which often varies in finer scale than many watershed grid elements, and much finer scale than atmospheric grid elements. These fine scale processes are, by computational necessity, lumped and parameterized. The practical impact of the resulting process representations needs to be explored more fully. Furthermore, to fully realize the objectives of linking large models with diverse time scales, application strategies need to be developed and explored. These practical research questions are beyond the scope of this particular paper, but they do need to be highlighted.

Dry deposition: This section did not explain clearly why dry deposition velocities from the atmospheric model grid elements are averaged over the entire watershed and over an entire month. It seems more straightforward to simply apply the deposition velocities to the underlying watershed elements on an hourly basis. Averaging over time

and space may be justified if the calculated atmospheric dry deposition velocities are relatively constant in time and space, or if watershed elements are relatively insensitive to these loadings. This linkage simplification should be explained and justified briefly.

In the later case study section, discussion reveals that "WARMF requires monthly average dry deposition velocities that are constant over the entire Catawba watershed and hence an average value over the Catawba watershed is provided by AMSTERDAM to WARMF via the linkage." This averaging is a significant problem, I believe, which could be resolved best by modifying WARMF to accept dry deposition velocities by subwatershed, or even by land use within the subwatersheds. Instead of monthly averaging, some pollutants might require daily or even hourly resolution. Future improvements to this linkage should allow for finer time and space scales. As the case study demonstrates, the present linkage leads to mass balance discrepancies at the subbasin scale.

Case Study Results: The case study shows interesting differences between calibrated WARMF results and linked AMSTERDAM-WARMF results for select subwatersheds in the Catawba River Basin. These results are a useful demonstration of the practical calibration issues that must be resolved in any application. The deposition results comparing AMSTERDAM output and WARMF input for the air-model linkage scenario presented in Tables 10, 12, and 14, however, are problematic. If the models are properly linked at the subwatershed scale, then for the simulated pollutants WARMF input should equal AMSTERDAM output. Significant differences between AMSTERDAM and WARMF occur by subwatershed for dry deposition, and smaller differences for wet deposition. These tables show that constituent mass balance is not maintained at the subwatershed scale. It would be helpful if the authors calculated the wet and dry deposition totals basinwide to assure that mass balance is indeed enforced at the watershed scale. in any case, because mass balance between the models is not enforced at the subwatershed scale, it would be difficult to justify the use of this linkage in any regulatory application involving water quality within the watershed.

Nevertheless, as a research project, the case study can provide useful information to better inform future refinements in multimedia software. It reinforces the need for proper calibration of watershed models, and it highlights discrepancies in using observed data versus atmospheric simulation to drive watershed models.

Summary: The linkage outlined in this paper allows the separate simulation of two large legacy models, AMSTERDAM and WARMF, to investigate some multimedia issues. Because intermedia mass balance is not enforced within the watershed, I believe the authors overstate how the linked models can be useful in tracking the path of pollutants emitted to the atmosphere through the complicated set of transport and transformation pathways to downstream water bodies: âĂć "The AMSTERDAM-WARMF linkage also can be used to connect individual atmospheric point sources to water quality consequences." âĂć "...they are particularly useful in estimating the effect of atmospheric emissions on water quality after the proposed implementation of controls or due to climate change." Until the intermedia mass balance scaling issues are resolved, the first statement above should be deleted and the second softened by changing "particularly" to "potentially."

Technical Corrections

p. 1512, line 20 delete "are converted" p. 1513, lines 11-12: change "error of simulated flow" to "errors in simulated flow"

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