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Interactive comment on “Improving terrestrial CO₂ flux diagnosis using spatial structure in land surface model residuals” by T. W. Hilton et al.

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Author responses to Anonymous Referee #3
Referee comments in boldface, author responses in normal typeface.

VPRM is a very simple model, which may cast doubt on the generalization of these results to other land surface models with higher levels of complexity, especially regarding the challenge on the parametric prescription by PFT. Although other studies have shown intra-PFT variations in parameters [e.g. Groenendijk et al., 2011] and some associated it to local environmental conditions [e.g. Carvalhais et al., 2010]; see for example how Kuppel et al. [2012] showed that despite parametric differences between site-level optimizations for the same PFT a com-

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mon parameter vector would be attained to explain most of the observational variability.

We agree with Reviewer 3 that VPRM's simplicity and our method's lack of probability density functions for our parameter estimates limit this result's applicability toward more complex models, and also dictate that we be careful not to over-interpret this result.

However, there is literature suggesting that land surface model residuals are essentially uncorrelated in space (Chevallier et al., 2006). That result would make the problem of estimating regional surface fluxes far more difficult. We believe that VPRM, despite its simplicity, is a useful model for evaluating the question of spatial structure in model residuals.

Additionally, we do not view the similarity of our optimized VPRM parameters across PFTs as one of the central points we wish to make in this article, but rather as an interesting result that we found mildly surprising, and wished to include in reporting our results. We will revise the text to better reflect this and note the studies mentioned above.

The conclusion that the “North American flux tower observation network is adequate for determining a land surface model residual covariance matrix” implicitly embeds assumptions on the representativeness of the network to the main factors controlling NEE fluxes and model errors. Given the significant dependence of site history in adequately simulating ecosystem fluxes [e.g. Kuppel et al., 2012] and the network representativeness being dependent of multiple factors [e.g. Sulkava et al., 2011], isn't this a strong assumption worthwhile discussing?

By fitting a semivariogram model to observed NEE residuals, we are able to completely and quantitatively express the model's error covariance structure in terms of known quantities (eq 7). Because they are the difference between eddy covariance-observed NEE and VPRM-modeled NEE, the VPRM errors that we fit with parametric semivariograms include the structural error that VPRM incurs by not considering site

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history. Thus, the robust semivariogram fits we report here demonstrate that the North American network of eddy covariance towers is minimally sufficient to determine an error covariance matrix for VPRM.

Having said this, site disturbance history is undoubtedly a first-order driver of NEE and its inclusion in model structure (through carbon pools) could only improve the results. However, other players such as climate (precipitation, temperature, solar radiation) are certainly first-order drivers as well (e.g. Mahadevan et al 2008). On those grounds we believe that a climate-driven approach can yield useful results in this arena.

A strong relevance to the characterization of spatial correlations in NEE fluxes is given in the introduction. Given that the range found in this study for North America is much smaller than the considered in previous studies could something be said about implications in terms of regional estimates and associated uncertainties?

This is a an excellent point. We have developed some results in this area and plan to submit them to Biogeosciences soon in a separate manuscript.

Some more detailed comments concern:

The large range in the length scale between 100km and 900km: these results could be shown before the conclusions and addressed in the discussion, especially the reasons behind the wide range.

We will revise the results section to emphasize in the text that there is considerable spread within our semivariogram range estimates.

Given the dependence of model and region to the current results, shouldn't this be more explicitly addressed in the conclusions and also reflected it in the title?

We have revised the title to 'Improving North American terrestrial CO₂ flux diagnosis using spatial structure in land surface model residuals'.

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We have also revised the last paragraph of the caveats section (p. 20, lines 1-6) to read:

It is possible that VPRM residuals covary differently in the East-West direction than North-South or in different regions of the world, or that plant functional types, site disturbance history, or some other land surface descriptor is of first-order importance. The present spatial density of eddy covariance observations limits our ability to test these ideas. The residual spatial covariance of a more complex model structure may also be different. Computational limitations at this time preclude the rigorous optimization of more than a handful of parameters, so we have chosen to focus our attention on VPRM, whose relatively small number of parameters may be rigorously estimated in their entirety.

Some changes in the abstract to make it more quantitative would be appreciated.

We have edited the abstract to include more detailed quantitative descriptions of the main findings (edits in italics):

We evaluate spatial structure in North American CO₂ flux observations using a simple diagnostic land surface model. The Vegetation Photosynthesis Respiration Model (VPRM) calculates net ecosystem exchange (NEE) using locally observed temperature and photosynthetically active radiation (PAR) along with satellite-derived phenology and moisture. We use observed NEE from a group of 65 North American eddy covariance tower sites spanning North America to estimate VPRM parameters for these sites. We investigate spatial coherence in regional CO₂ fluxes at several different time scales by using geostatistical methods to examine the spatial structure of model data–model residuals. We find that persistent spatial structure does exist in the data-model residuals at a length scale of approximately 400 km (*median 402 km, mean 712 km, standard deviation 931 km*). This spatial structure defines a flux-tower-based VPRM residual covariance matrix. The residual covariance matrix is useful in constructing prior fluxes for atmospheric CO₂ concentration inversion calculations, as well as for

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constructing a VPRM North American CO₂ flux map optimized to eddy covariance observations. Finally, the estimated VPRM parameter values do not separate clearly by plant functional type (PFT). This calls into question whether PFTs can successfully partition ecosystems' fundamental ecological drivers when the viewing lens is a simple model.

We are happy to make additional edits to the abstract if Reviewer 3 could provide more information about what additional quantitative information would be helpful.

In table 3, 2003 is shown as a very coherent year: the exponential variogram model is always better than the pure nugget model. Could the authors postulate reasons behind such singularity when compared to other years?

We considered the years 2000 (launch of the MODIS instrument) to 2006 (end of the Fluxnet synthesis dataset). The Fluxnet synthesis dataset contains data from more sites in 2003 and 2004 than the other years of the study period. We hypothesize that spatial structure in model residuals exists but the spatial density of the North American eddy covariance tower network is minimally adequate to detect it. If this hypothesis is valid, it makes sense that the years from the study period with the most data would also display the most spatial coherence.

We have edited the discussion to include this point.

In page 4, line 124: “splace”.

Thank you for noting this error - it is corrected.

BGD

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