Are channels standalone? The fan of influence of streams and the impacts of channel density on simulated water and carbon fluxes

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Motivations

Land surface models often assume channels are standalone, one-way conduits that conveys water from upstream to downstream. The dynamic, two-way interaction between the groundwater (GW) and surface water (SW) was often ignored. Using a physically-based model that explicitly represent the channel network and GW-SW exchange, we investigate the following questions:

1. Do channels exert influence on water and carbon fluxes?
2. How do channel geometries influence simulated fluxes?
3. Does simulated channel density matter?
4. Is it more efficient to simulate more channels or to refine grid?

Modeling Approach and methods

We employ the Process-based Adaptive Watershed Simulator (PAWS), a physically-based, well-tested, computationally efficient model that is coupled with CLM. PAWS adopts an explicit representation of channel network and resolves the sharp gradients in topography surrounding the channels. Our algorithm extracts the channel bed topography which is consistent with the observed groundwater.

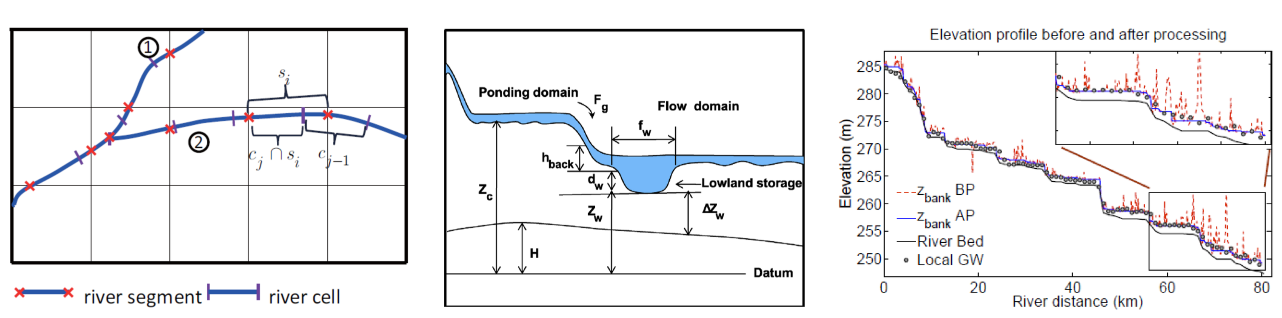


Figure: Left: explicit representation of channels and interaction with land cells; Center: conceptual diagram of overland flow ; Right: Extracted channel bed topography compared with groundwater observations.

We apply PAWS+CLM to the Upper Grand (UG) watershed in Michigan. The model compares well with observed streamflow, groundwater wells, soil moisture, MODIS-based ET and LAI.

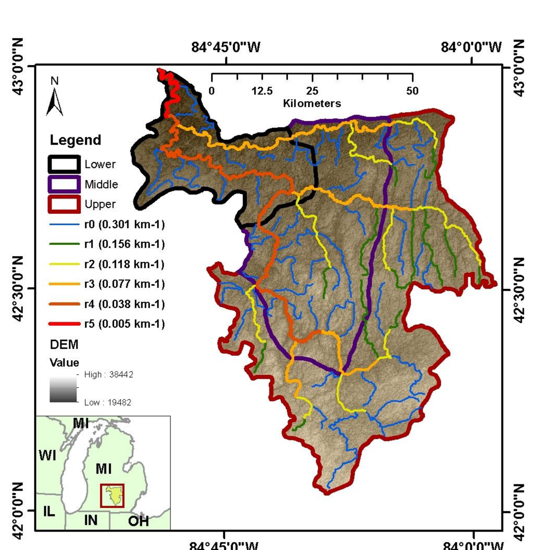
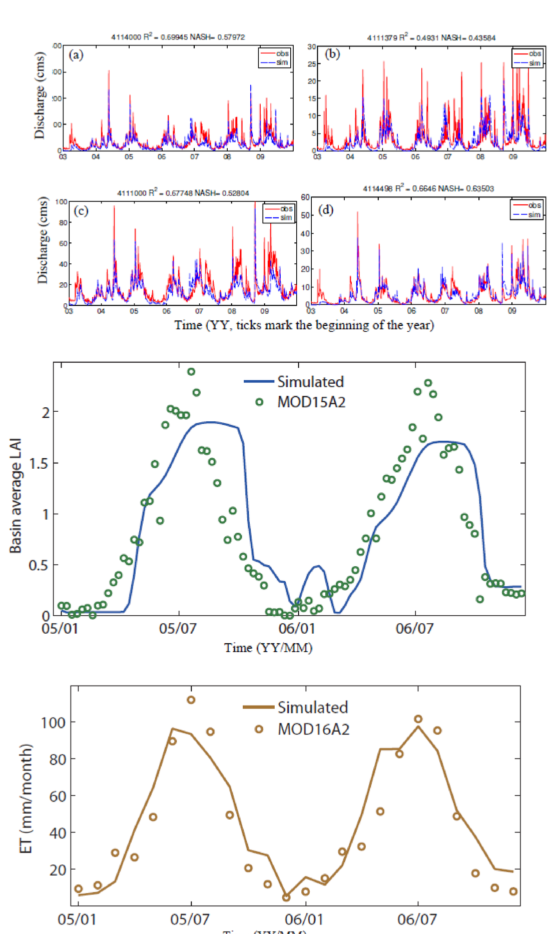


Figure: Upper Grand River and the systematically reduced channel density



Right Figures: Comparison with observations in the UG: Streamflow (top 4); ET (middle) and LAI (bottom)

Influence of simulated channel geometries and channel density

First, channel widths were adjusted to investigated the potential impacts of uncertainties with channel widths on outflow and land NPP. When channels are wider, the contacting face with groundwater is wider, which permits faster baseflow exchange.

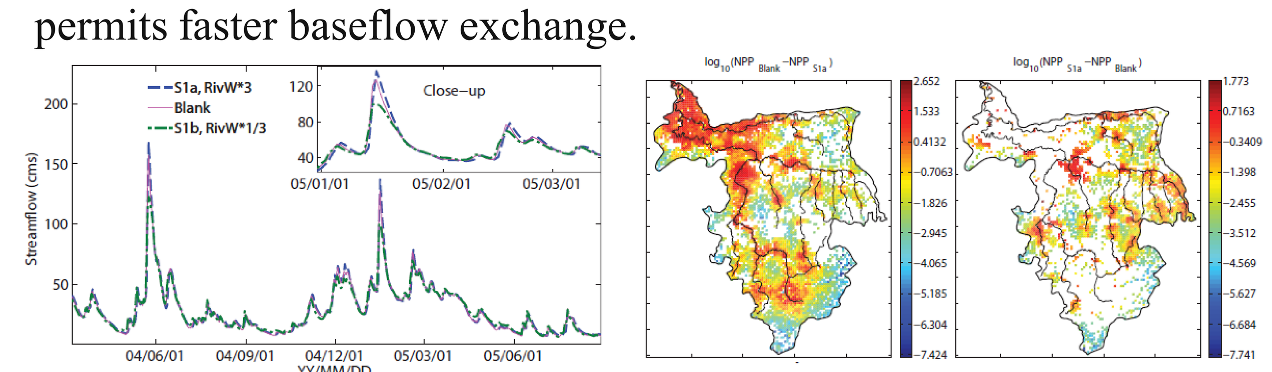
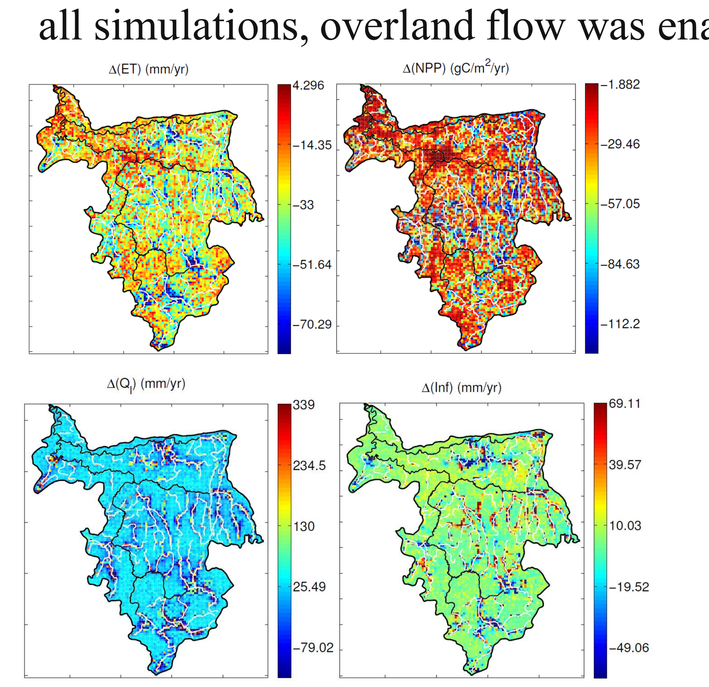
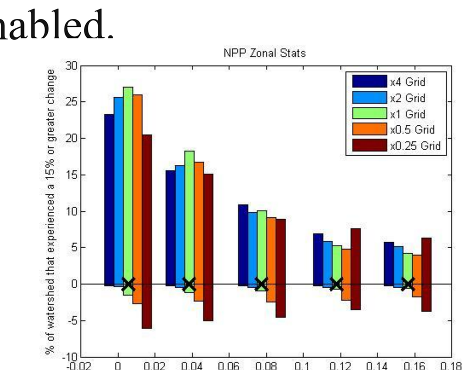


Figure: Left: Influence of channel width on discharge. Right: channel width influence upland vegetation NPP.

We noticed a "fan of influence" extending from the channels into the upland. In this fan, land surface fluxes respond to changes in channel geometries. Because in the Amazon basin, channel hydrography datasets are often missing, to investigate the impacts of simulated channel density on water and carbon fluxes, we run simulations with systematically varied channel densities and grid resolution. In doing so, we quantify the sizes of the fans (defined as the area showing >10% change due to the existence of simulated channels) for each variable. In all simulations, overland flow was enabled.





Top figure: The fan of influence of channels (areal percentage in the basin) for NPP.
Left 4 figures: Comparing simulated fluxes (Q: GW lateral inflow, Inf: infiltration)

Conclusions: Channels and upland areas are a tightly connected system. The changes to the channel network induce significant alteration to water and carbon fluxes, through strong modifications of the flow net. Although each variable have different fan of influence, the channel network always tend to control a large portion of the basin. Adding channel density is more efficient way of resolving the dynamics, as compared to adding resolution. Therefore, we should make every effort to better characterize the flow network in the Amazon. These results are currently being prepared for publication in Shen *et al.* [2014b].

Amazon project progress: Basin identification and data compilation

We have identified a cluster of basins for testing upland dynamics of PAWS+CLM in the Amazon. The basins has been determined based on the size, location in the forest, availability of flow gage, and proximity with climatic stations. The Upper Rio Preta de Eva (URPE) basin (#1 in the figure) will be our starting point.

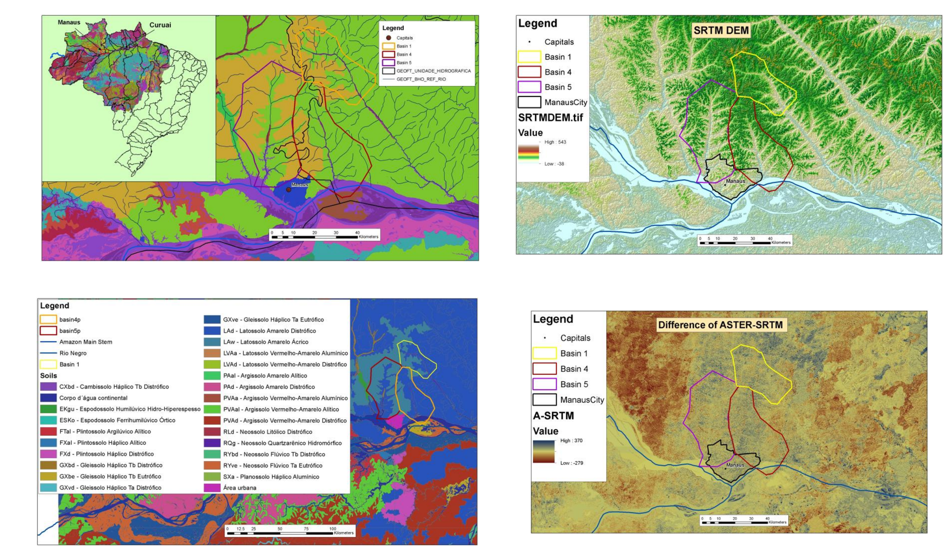
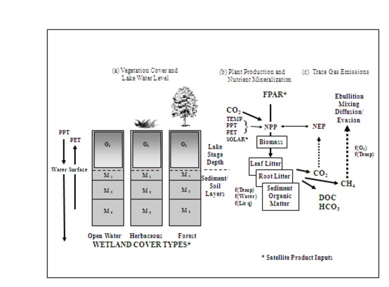


Figure: Identified basins for modeling, DEM and soils data

We have obtained SRTM and ASTER DEM data. We have obtained soils, geomorphology and geology maps from Brazilian Institute of Geography and Statistics. We obtained discharges and rainfall data from Brazilian national water agency. We have also obtained simulated groundwater table data from Fan and Miguez-Macho [2013].

Our plan is to infer soil properties from soil taxonomy. We will obtain the Hydrosheds channel network from USGS. We will attempt to combine information from SRTM and ASTER to create a high resolution DEM. We will parameterize the subsurface conductivity using the formulation in Fan and Miguez-Macho [2013]. We will compare our results to the measured streamflow and water table results in Fan and Miguez-Macho [2013].

In addition, a new process-based simulation model to estimate methane emissions from Amazon floodplain ecosystems is described and evaluated in comparison to independent measurements of methane fluxes in Potter, Melack and Engle (in press).



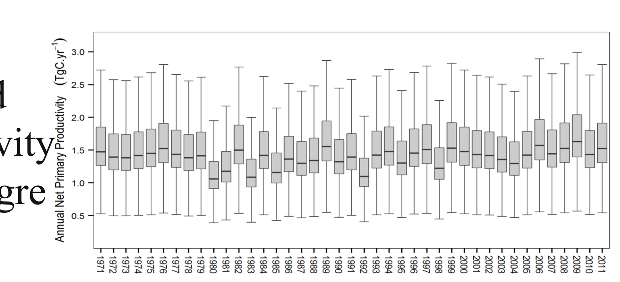


Figure: Box and whisker plot of simulated annual aboveground net primary productivity for macrophytes at Curuai and Monte Alegre regions, lower Amazon floodplain, Brazil

Summary

Progresses:

- We found river geometries and channel densities had strong influence on simulated water and carbon fluxes.
- Resolving high resolution channel density if more efficient than adding grid resolution.
- We've made progress in Amazon data compilation, and modeling effort will soon be underway.

References

Shen, CP., J. Niu and K. Fang, Quantifying the Effects of Data Integration Algorithms on the Outcomes of a Subsurface - Land Surface Processes Model, Environmental Modeling & Software., doi: 10.1016/j.envsoft.2014.05.006 (2014)

Shen, CP. and Kurt M. Smithgall, The fan of influence of streams and the impacts of channel density on simulated water and carbon fluxes (2014b, Under preparation)

Potter, C., J.M. Melack and D. Engle. Modeling carbon dynamics and methane emissions from Amazon floodplain ecosystems. Wetlands, (2014, in press)

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