River Routing for the Mississippi River Basin using Grid and Vector Based River Networks

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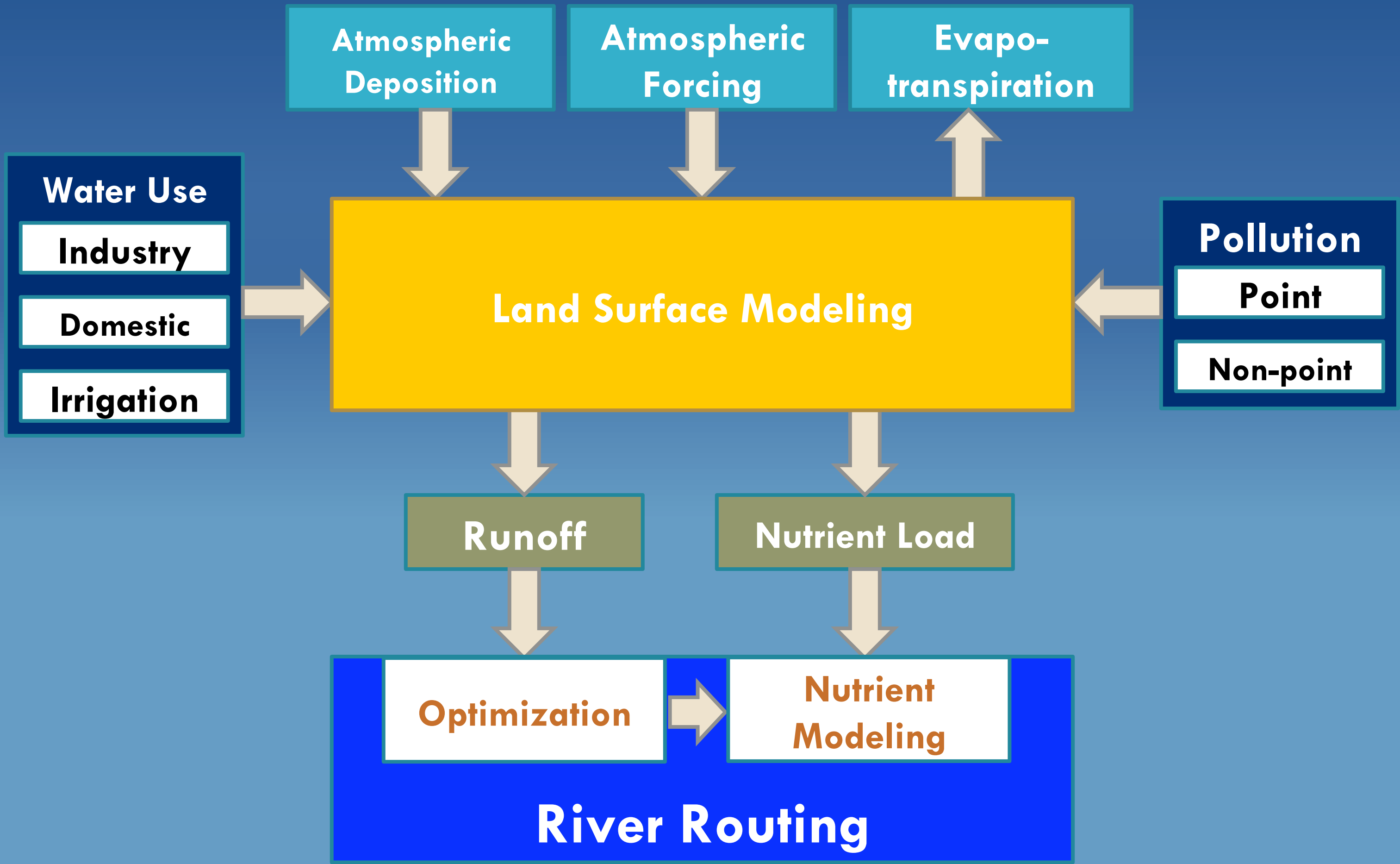
Tasks for NASA Interdisciplinary Science (IDS) Project

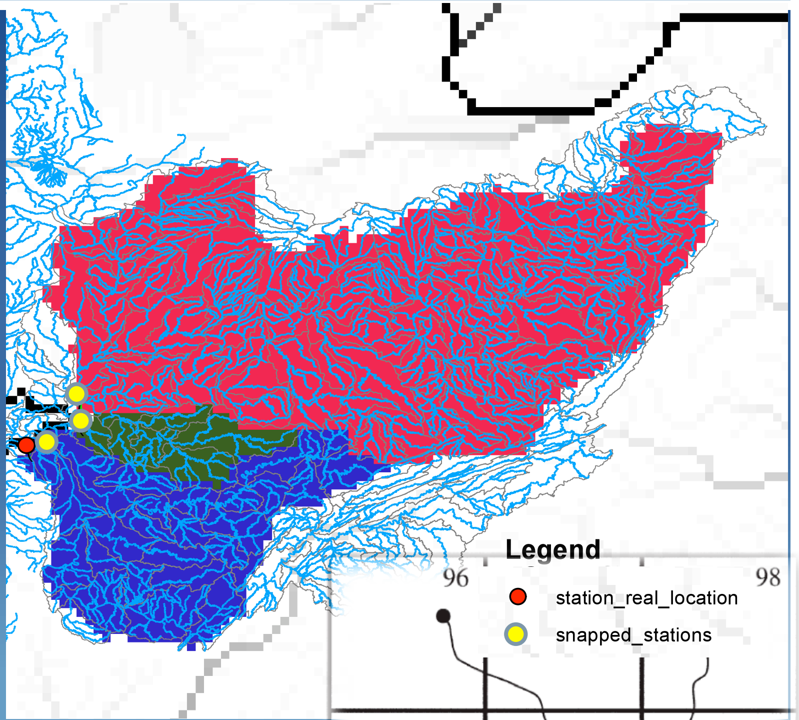


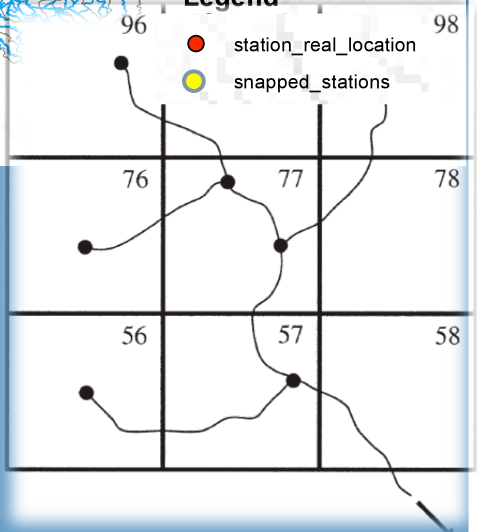
Funded by NASA NNX11AE42G

Two types of river networks

Research question: Can we use the blue lines from the map for river routing? Does it make a difference?

- Gridded river network
  - Traditional method
  - Requires GIS processing (sinks, flow direction, flow accumulation, etc.)
  - Requires careful placement of gauges where flow accumulation is high (snapping)
  - Approximate basin delineation
- Vector River Network or "mapped blue lines"
  - NHDPlus dataset provides a coherent description of topography and hydrographic features for the Unites States
  - Gauges located directly on NHDPlus



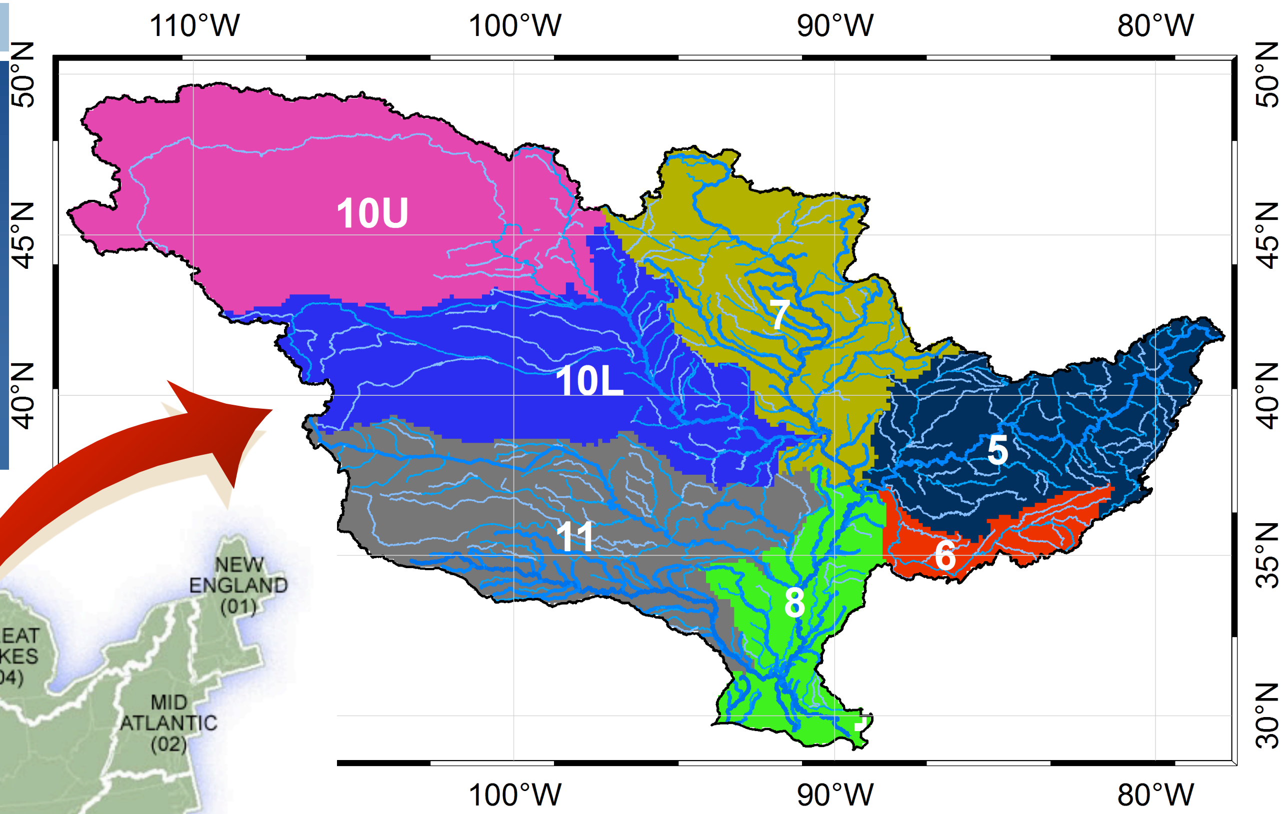


Ref.: *Olivera and Raina*, 2003

Study Area

Mississippi River Basin

- 6 HUC2 regions

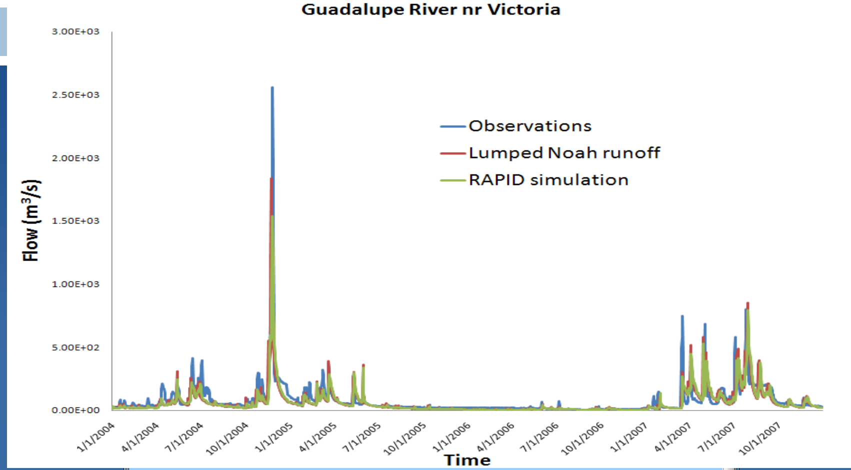


Mississippi River Basin

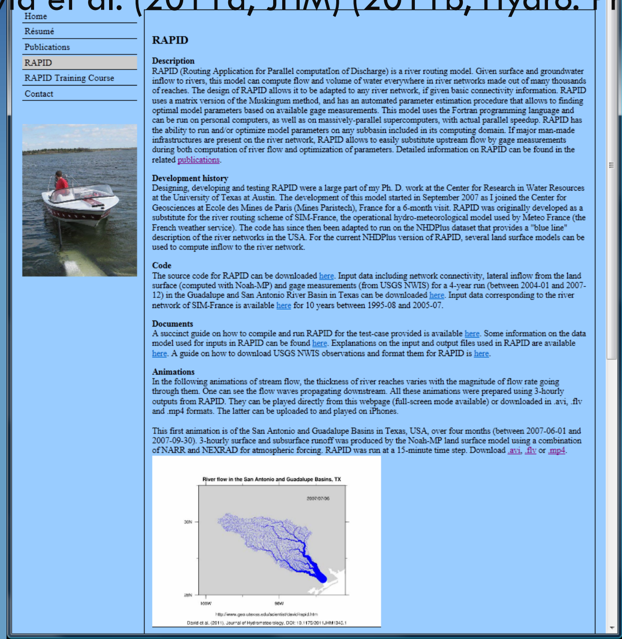
- ~3.3 million km^2
- Grid: 0.125° × 0.125°

River model

- RAPID (**R**outing **A**pplication for **P**arallel computat**I**on of **D**ischarge)
- Uses Muskingum method (k=time x=no dimension)
- Computes flow and automatically optimizes model parameters
- Actual parallel speedup
- Model code, input data and animations are available online



David et al. (2011a, JHM) (2011b, Hydro. Proc.)

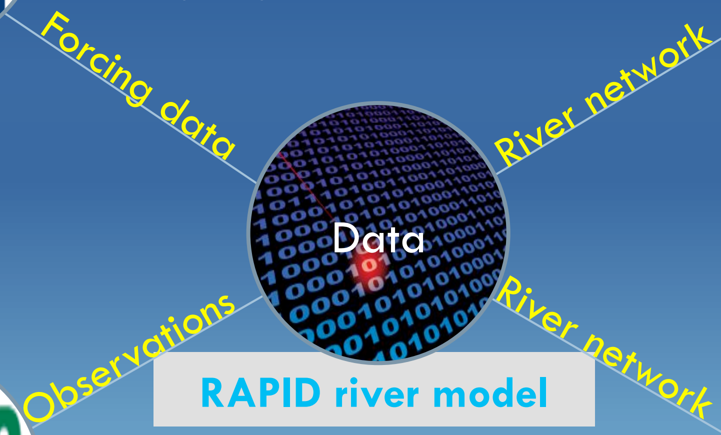


http://www.geo.utexas.edu/scientist/david/rapid.htm

Data Sources

- **Mosaic** surface and subsurface runoff
- Convert data
- Ongoing Noah-MP

- Grid-based river network
- Delineate watershed

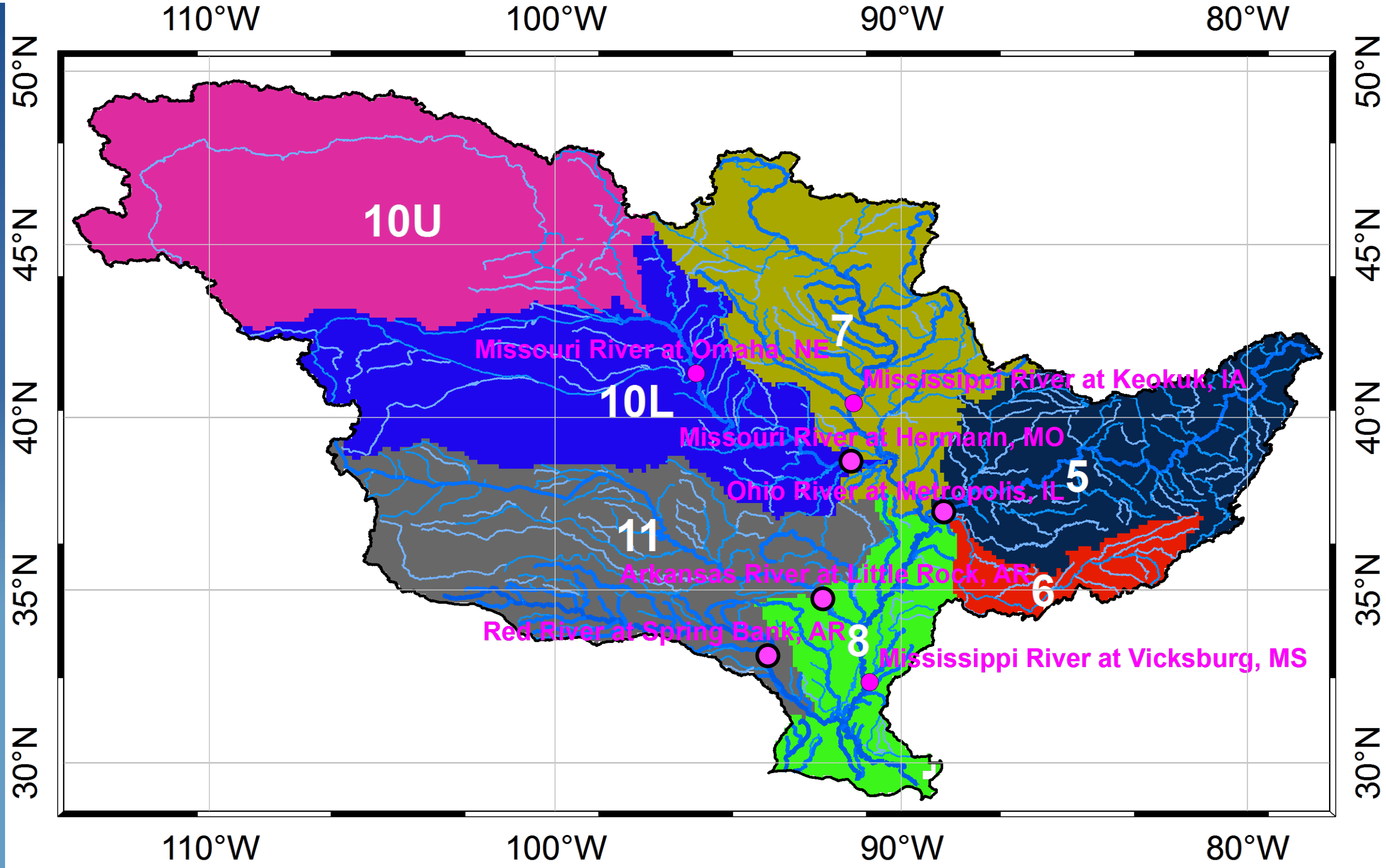


- Daily data
- Stream Gauges

- Vector-based River Network
- Catchment data
- Vector networks are increasingly becoming available for the globe (HydroSHEDs, CarTHAgE)

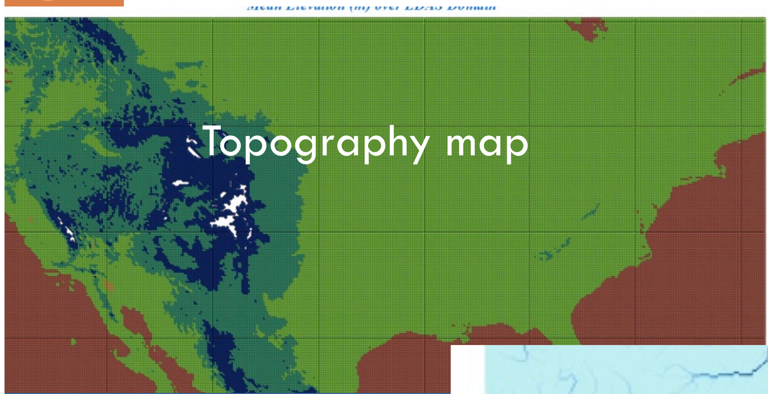
- 10-year data, 2000-09 and 3-hourly input file

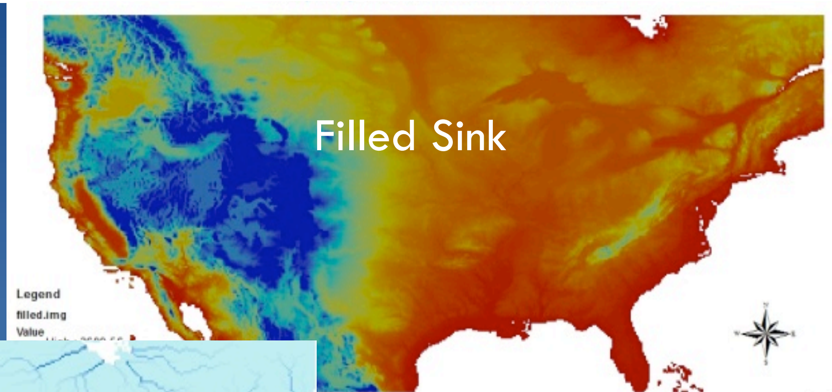
USGS Gauges

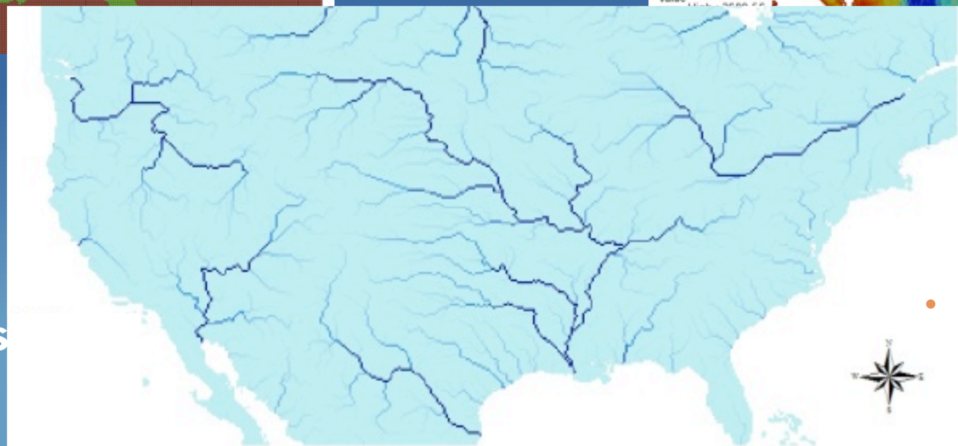


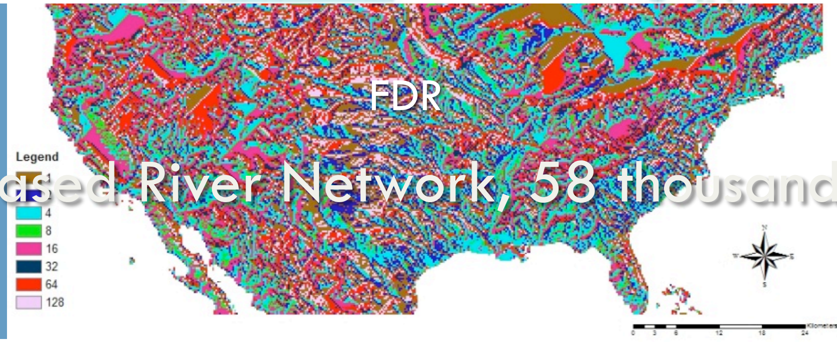
So many gauges available, most studies only use between 4-10 stations

Gridded River Network









GIS Process

- Hydrology Tools

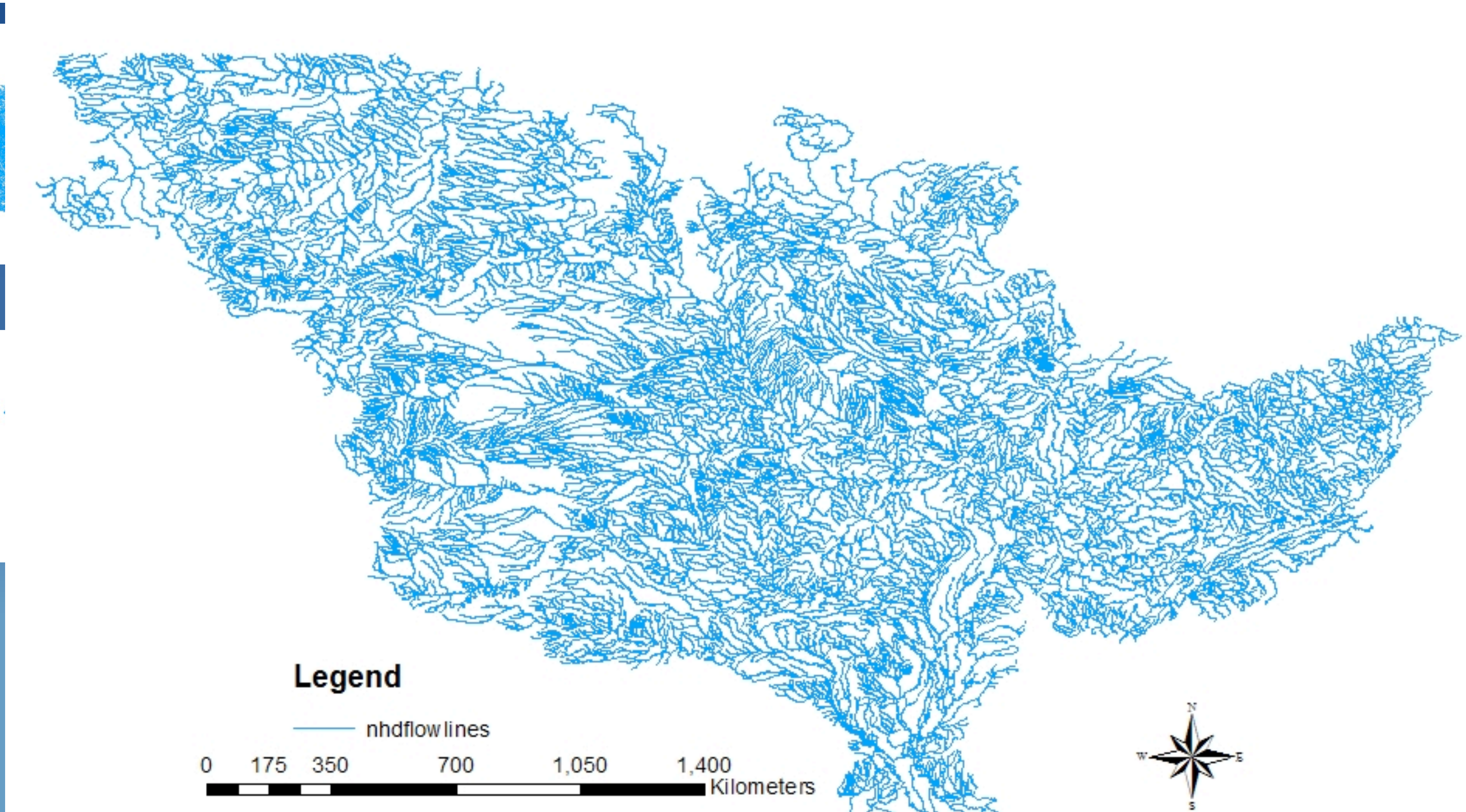
IS Process

- Spatial Analyst

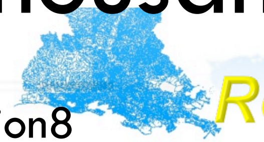
Grid Based River Network, 58 thousand grids

Vector River Network

Region



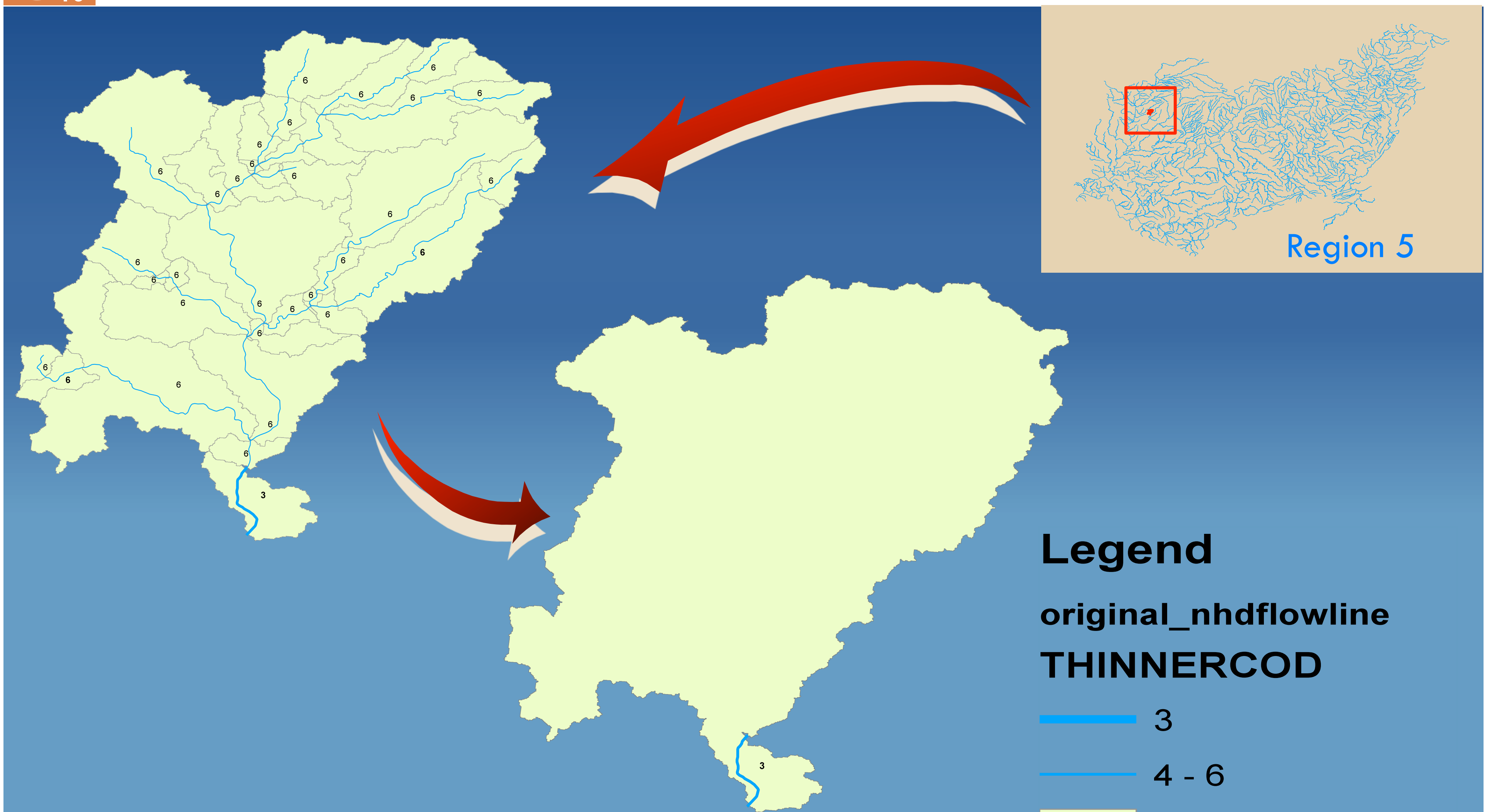
200 thousand rivers



Region8

Reduce Simulation Time …

Upscaling of Catchment



Finding the correct upstreams is Challenge …

Experimental design

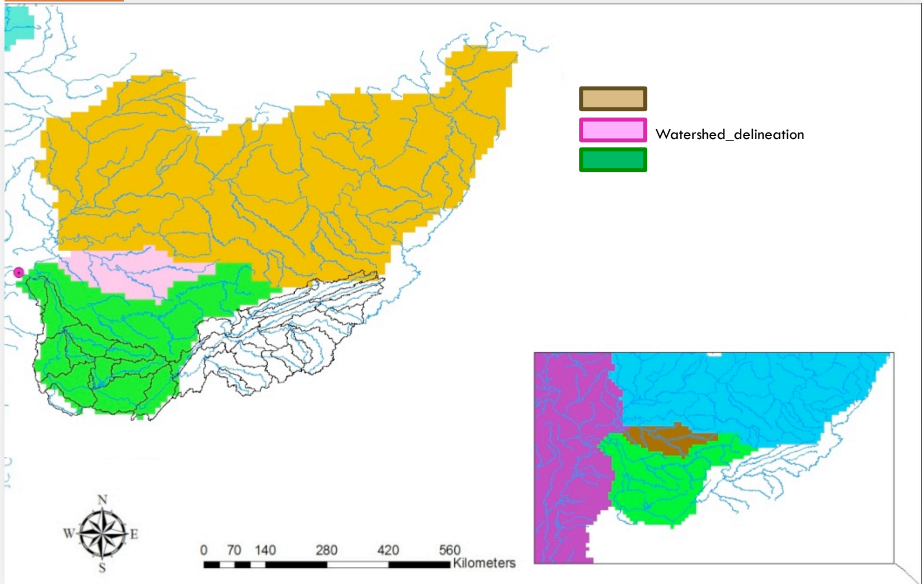
- Two optimization cost function (ϕ1 and ϕ2), both taking several gauging stations into account
- Four types of spatial variability of Muskingum k

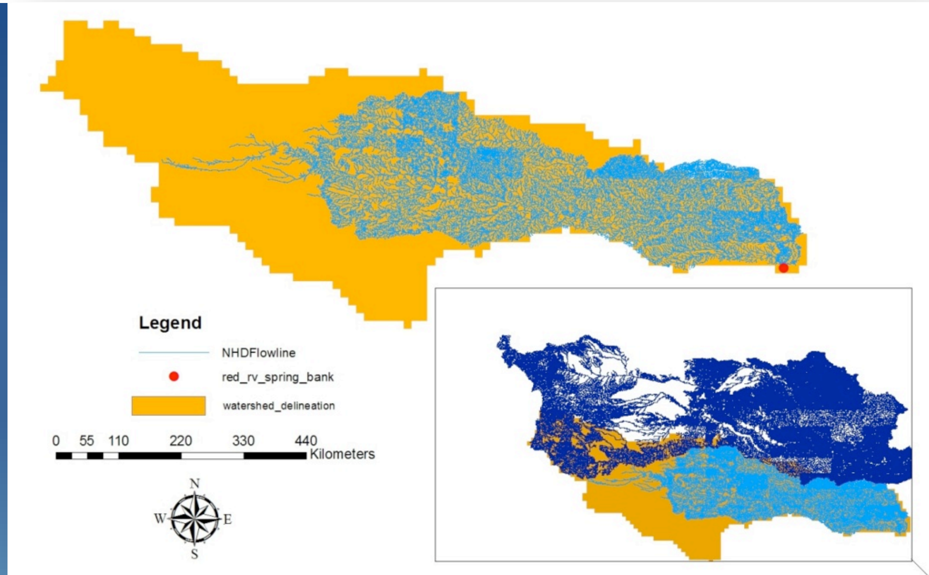
$$K^1_{ini} = \frac{\bar{L}}{C_0} \qquad K^2_{ini} = \frac{L_i}{C_0} \qquad K^3_{ini} = \alpha \frac{L_i}{\sqrt{S_i}}$$

$$K^4_{ini} = \alpha \frac{L_i}{\left(\sqrt{S_i}\right)'}; \qquad \left(\sqrt{S_i}\right)' \in P[0.05, 0.95]$$

where: $\bar{L}$ is the mean of the river length, C_0 is the reference water wave celerity; L_i is the river length; S_i is the river slope and α is the inverse of the velocity.

Influence of basin delineation on 10-year Average Flow





Ohio River at Metropolis

	Average Flow (m^3)	Drainage Area(km^2)
grid	3,084	401,383
Vector	3,913	523,498

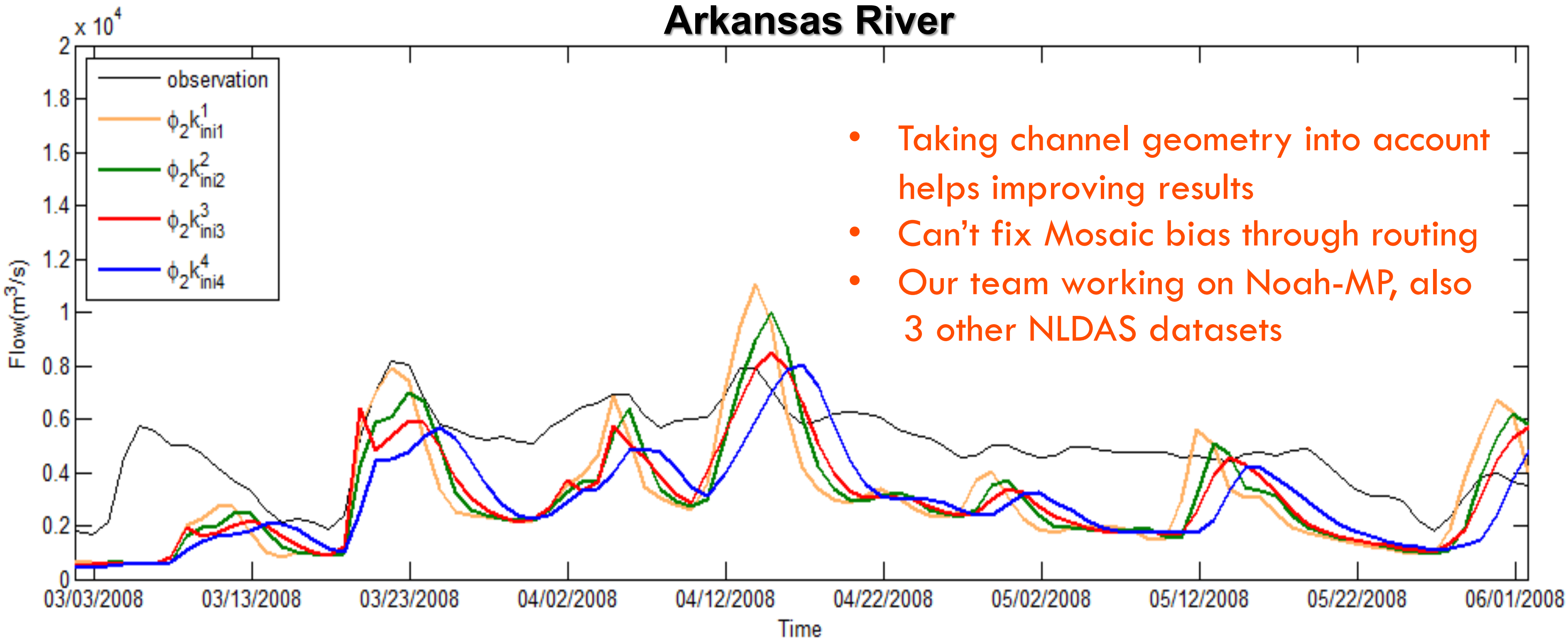
%30 bigger area produces %26 more flow …

Red River at Spring Bank

	Average Flow (m^3)	Drainage Area(km^2)
grid	469	270822
Vector	376	146785

%85 bigger area produces %25 more flow …

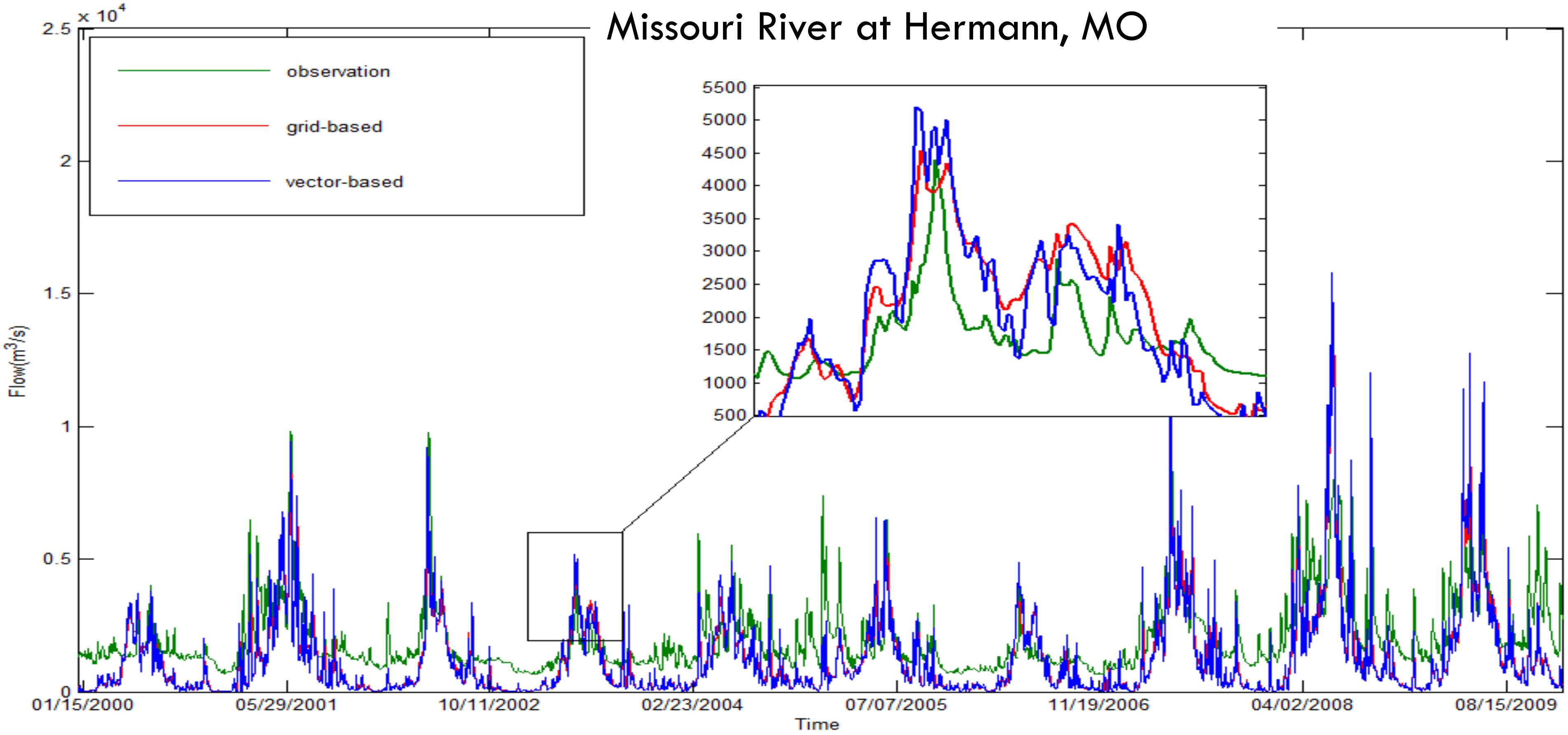
Results: ϕ_2 and 4 types of k, gridded network



- Taking channel geometry into account helps improving results
- Can't fix Mosaic bias through routing
- Our team working on Noah-MP, also 3 other NLDAS datasets

Gauging station		Observation	Lumped Model	Grid river network ϕ_1 K^1_{ini}	ϕ_1 K^2_{ini}	ϕ_1 K^3_{ini}	ϕ_1 K^4_{ini}	Grid river network ϕ_2 K^1_{ini}	ϕ_2 K^2_{ini}	ϕ_2 K^3_{ini}	ϕ_2 K^4_{ini}
Arkansas River at Murray Dam near Little Rock, AR	Average	1281	771	771	771	771	771	771	771	771	771
	ρ	-	0.41	0.61	0.61	0.61	0.67	0.73	0.75	0.78	0.78
	NSE	-	-0.34	0.16	0.16	0.16	0.28	0.39	0.43	0.46	0.46
	RMSE	-	1640	1298	1299	1294	1203	1102	1072	1040	1037

Results: Gridded vs. Vector Network



Select the K_{ini}^{3} as a best experiment …

Flow Animation, 3 months

Conclusions

- Drainage area is a key factor affecting the mean flow, particularly wetter climates
  - In the wet zone vector networks can reproduce drainage areas better than gridded networks can unless using very fine grids
  - The differences between the gridded and vector approach are small when watershed areas are comparable
  - The location of river gauges is more easily determined with vector river networks (no need for snapping), one can hence use as many gauges as possible
- The influence of optimization cost functions and spatial variability of parameters confirm previously published work

Thank You !

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Data Sources

More info on Mosaic being used alone

Mosaic Model

Surface-Vegetation-atmosphere transfer scheme (SVATS)

Heterogeneity of soil moisture and vegetation