Extension of regional river flow modeling to the continental scale of the Mississippi River Basin by using high resolution river data from NHDPlus dataset

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Main goal

This research explores the development of water flow computation in large scale river networks

Hydrologic science requires the integration of spatiotemporal data into an atmospheric model linked with a land surface model and a river model for long lead time forecasting and extreme events modeling

Research scope

Continental river routing

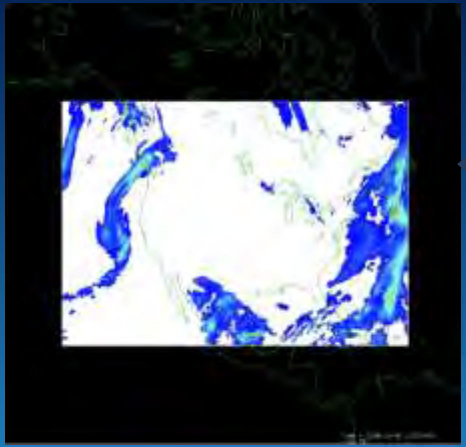
Improve modeling of **horizontal movement** of water through landscape

1.85 km average
NHD*Plus* river reach
3,144,162 km^2

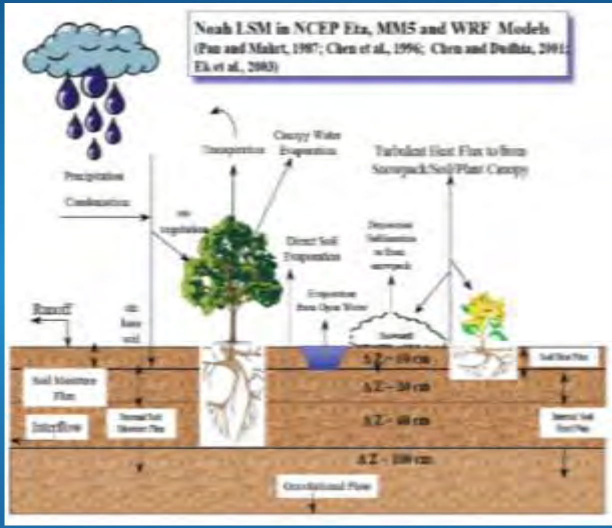
Mississippi: The largest river system in North America

Vector-based models more correctly follow the stream and watershed structure of the real landscape

Framework of Continental water dynamic modeling



Atmospheric model or dataset



Land surface model

Moving forward from regional scale river modeling to continental scale river modeling

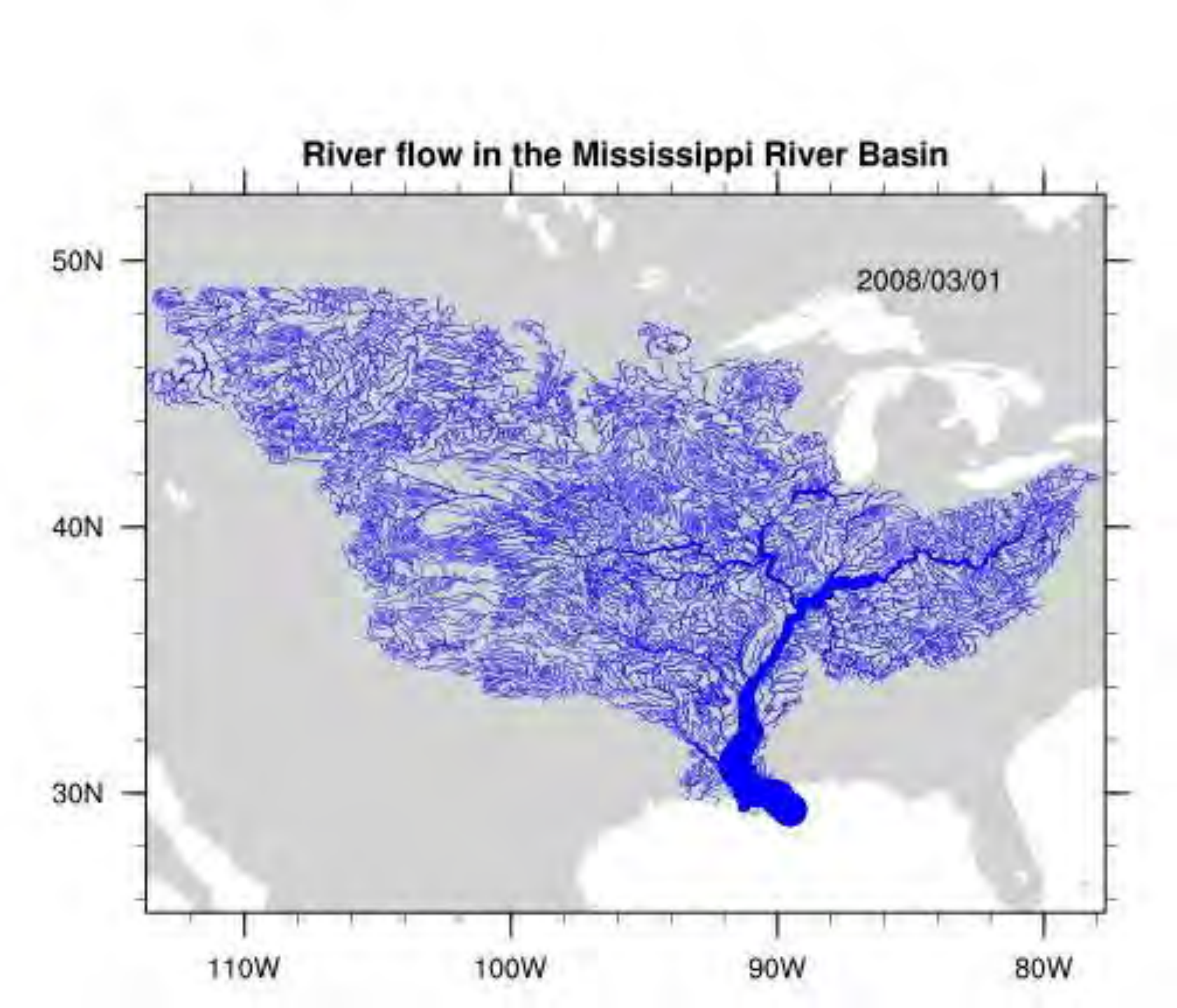
Regional scale river modeling
David et al. (2013)

Continental scale : 1,200,000 river reaches

Regional scale: 65,000 river reaches

Flow in the Mississippi River Basin

March to May 2008



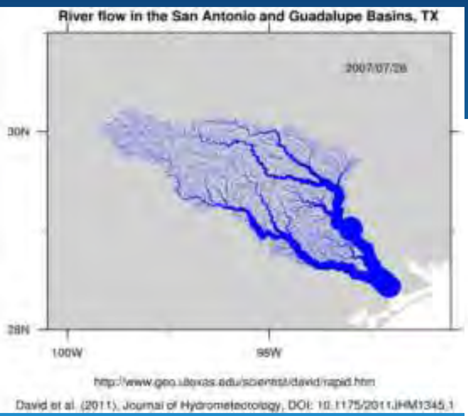
RAPID model

- RAPID (**R**outing **A**pplication for **P**arallel computat**I**on of **D**ischarge)
- Uses Muskingum method (k=time x=no dimension)
- Simultaneously computes discharge of water in many thousands of reaches of large river networks
- Actual parallel speedup
- Model code, input data and animations are available online

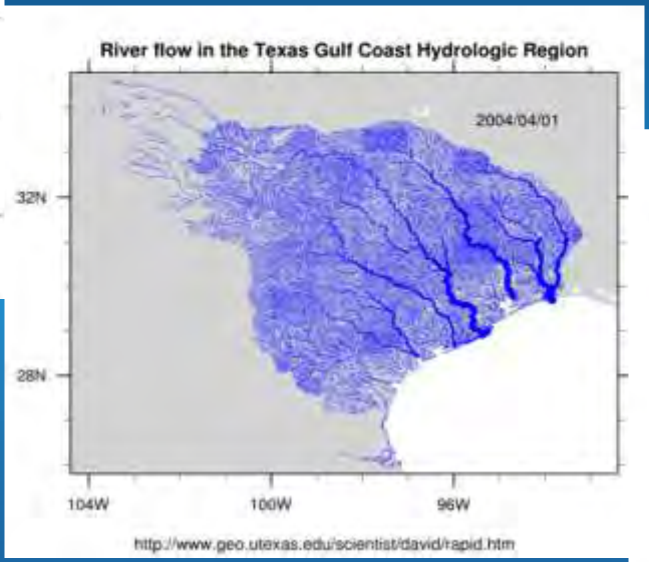
http://www.ucchm.org/david/rapid.htm

Towards continental river routing

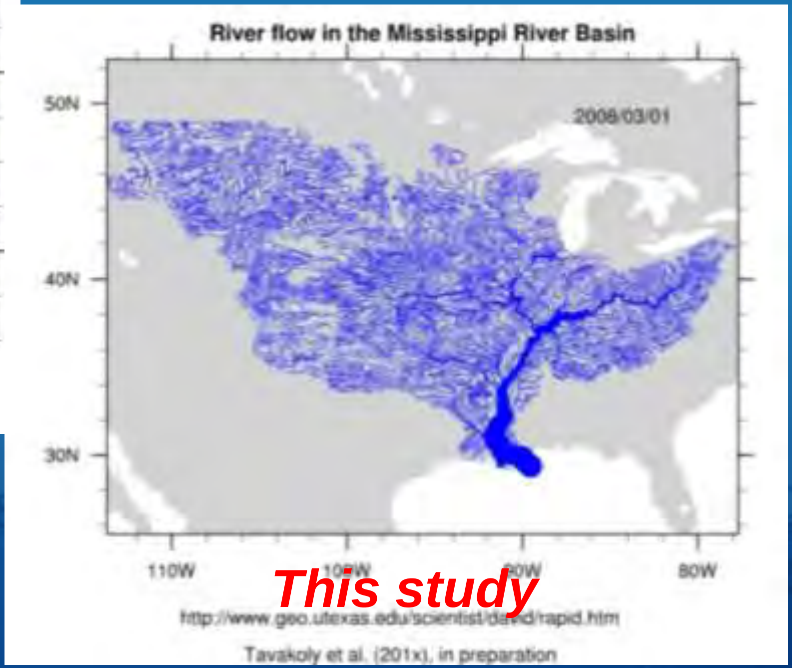
San Antonio and Guadalupe Basin: ~5,000 river reaches



Texas Gulf Region: 68,000 river reaches



Mississippi basin: 211,000 river reaches



Mississippi basin is the largest drainage system in North America

Data Sources

Inputs:

Surface and subsurface runoff data from the Mosaic and VIC land surface model available from the North American Land Data Assimilation System (NLDAS2).

The vector-based river network was extracted from the enhanced version of the National Hydrography Dataset (NHDPlus).

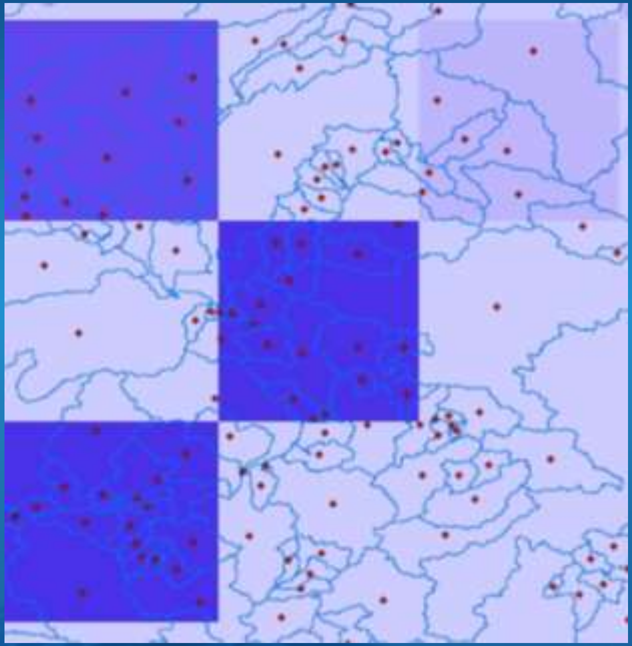
Observations:

Daily stream flow observations from the USGS were used to optimize RAPID parameters and to compare to observations.

Time period: from 2000 to 2008 and 3-hourly runoff file

Vector river networks

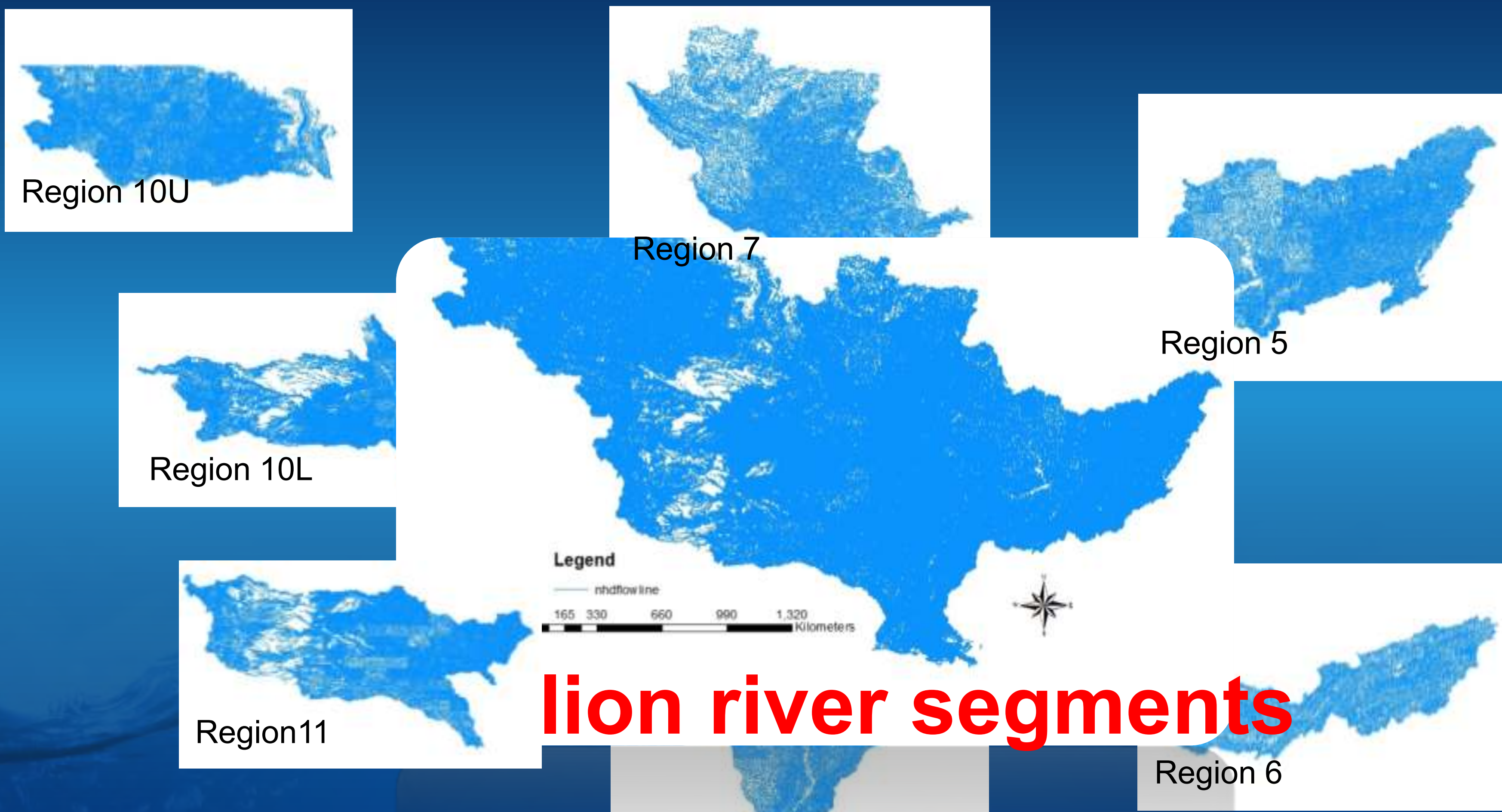
- Vector River Network or “mapped blue lines”
  - NHDPlus dataset provides a coherent description of topography and hydrographic features for the Unites States



The centroid of each NHDPlus catchment is superimposed with the NLDAS grid and the unique grid cell where each centroid is located is selected

Gauges located directly on NHDPlus

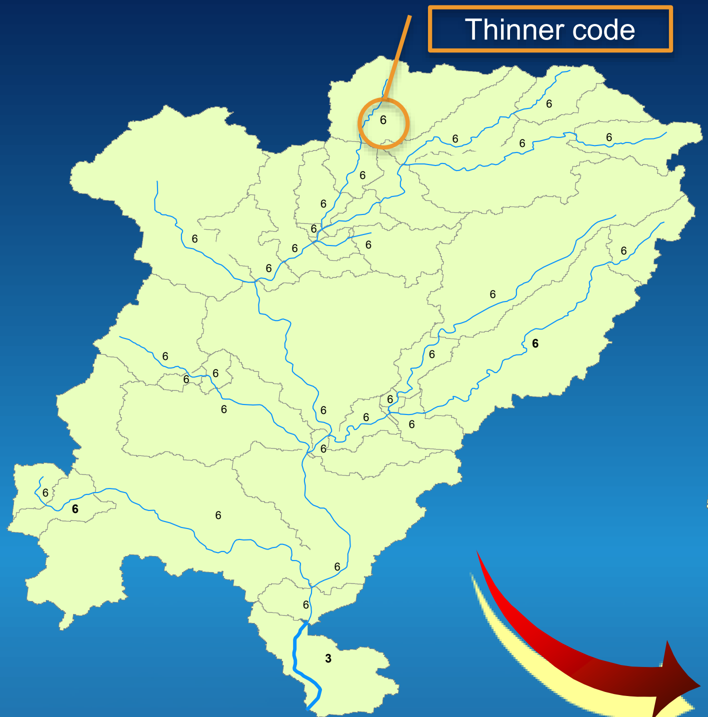
Vector river network



lion river segments

Inflow of surface and subsurface water file is 118 GB
One processor to read this file

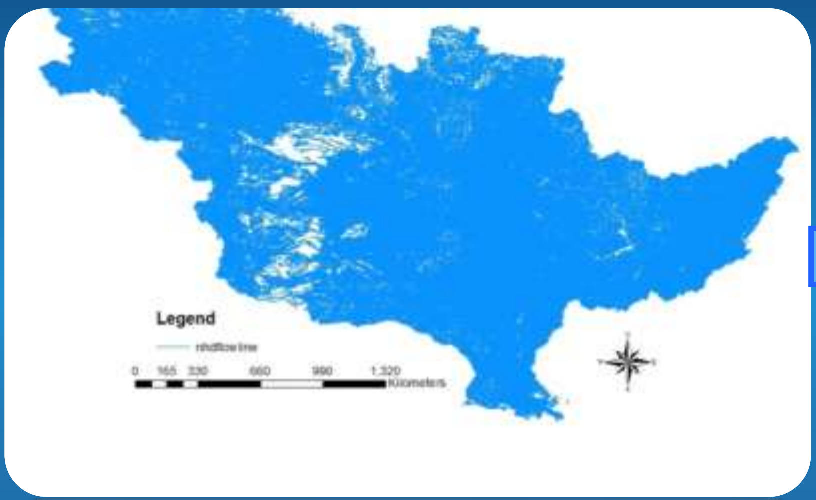
Upscaling process



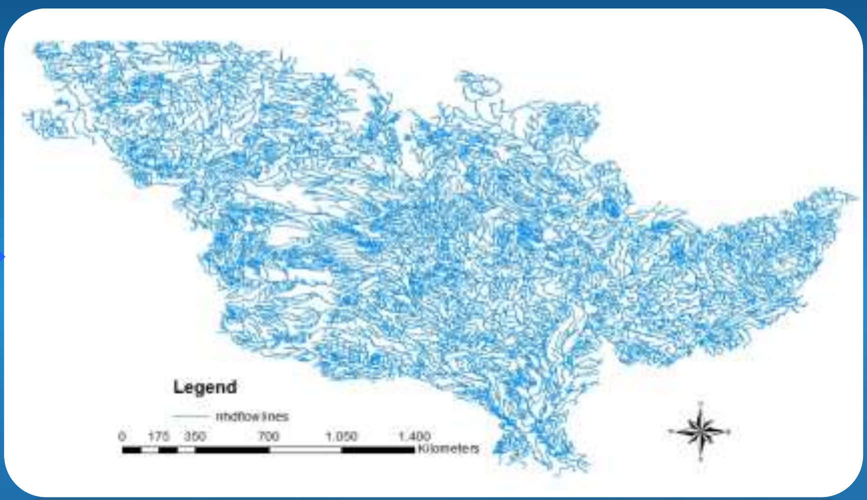
"ThinnerCod", is an ordinal number that displays the density of the river network with six levels, denoting an increasing density of the river network

Condensed all the level six streams down and accounted for river reaches only for the first 5 levels of the ThinnerCod

Upscaling process



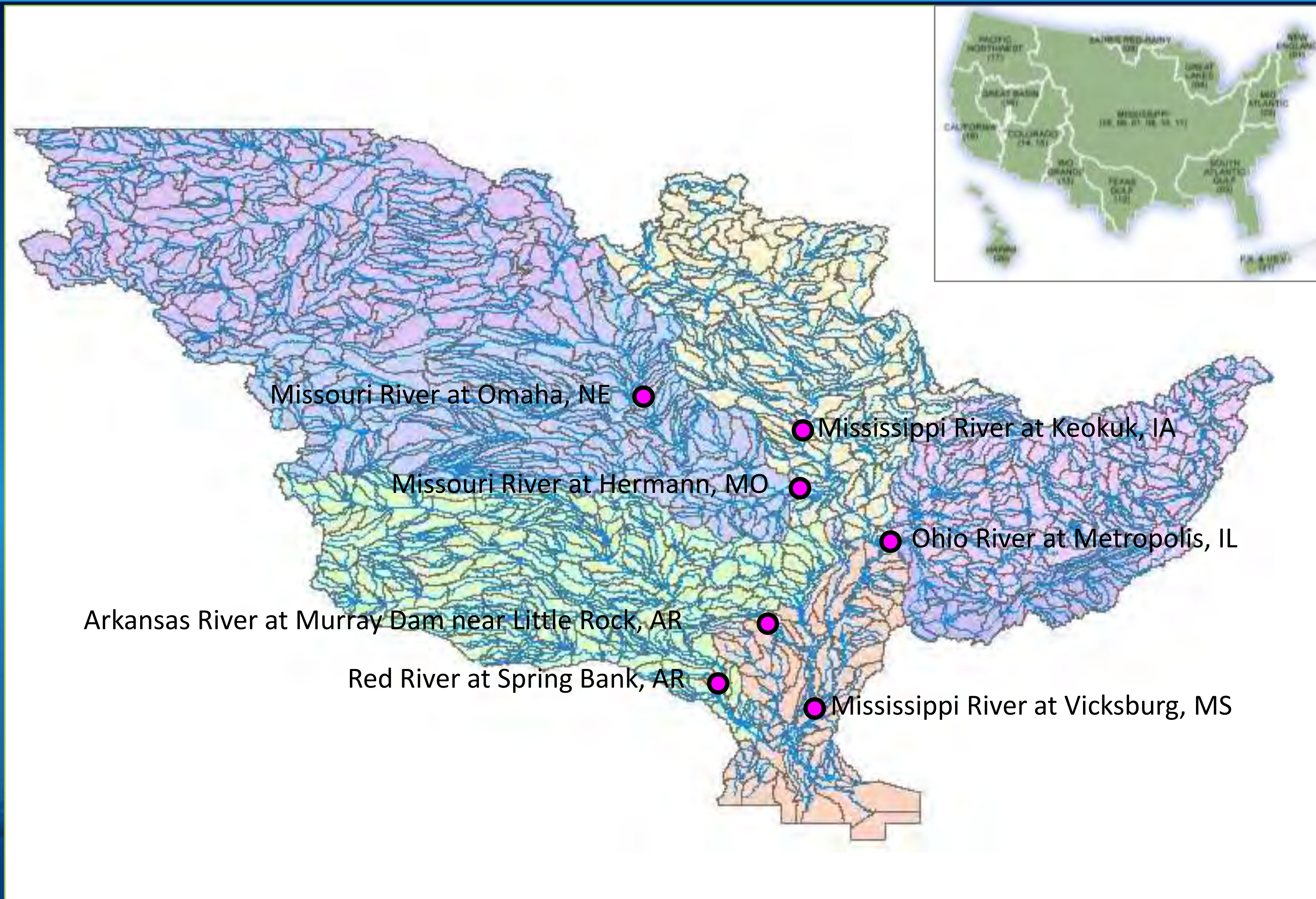
1.2 Million rivers



200 thousand rivers

The size of the inflow is reduced to 20 GB

USGS Gauges



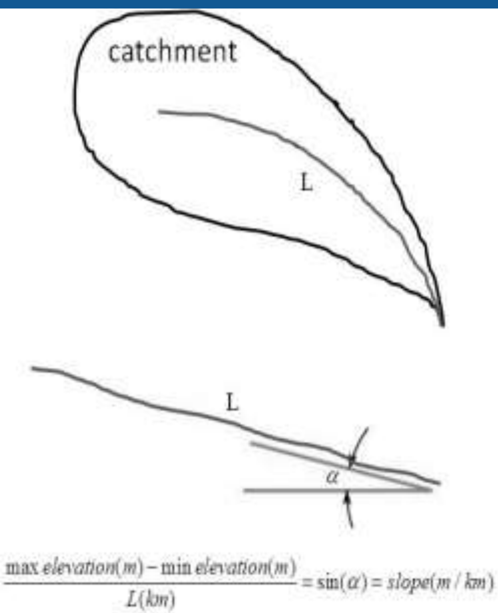
Missouri River at Omaha, NE
Mississippi River at Keokuk, IA
Missouri River at Hermann, MO
Ohio River at Metropolis, IL
Arkansas River at Murray Dam near Little Rock, AR
Red River at Spring Bank, AR
Mississippi River at Vicksburg, MS

Spatial variability of parameters

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

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

Vector-based river network

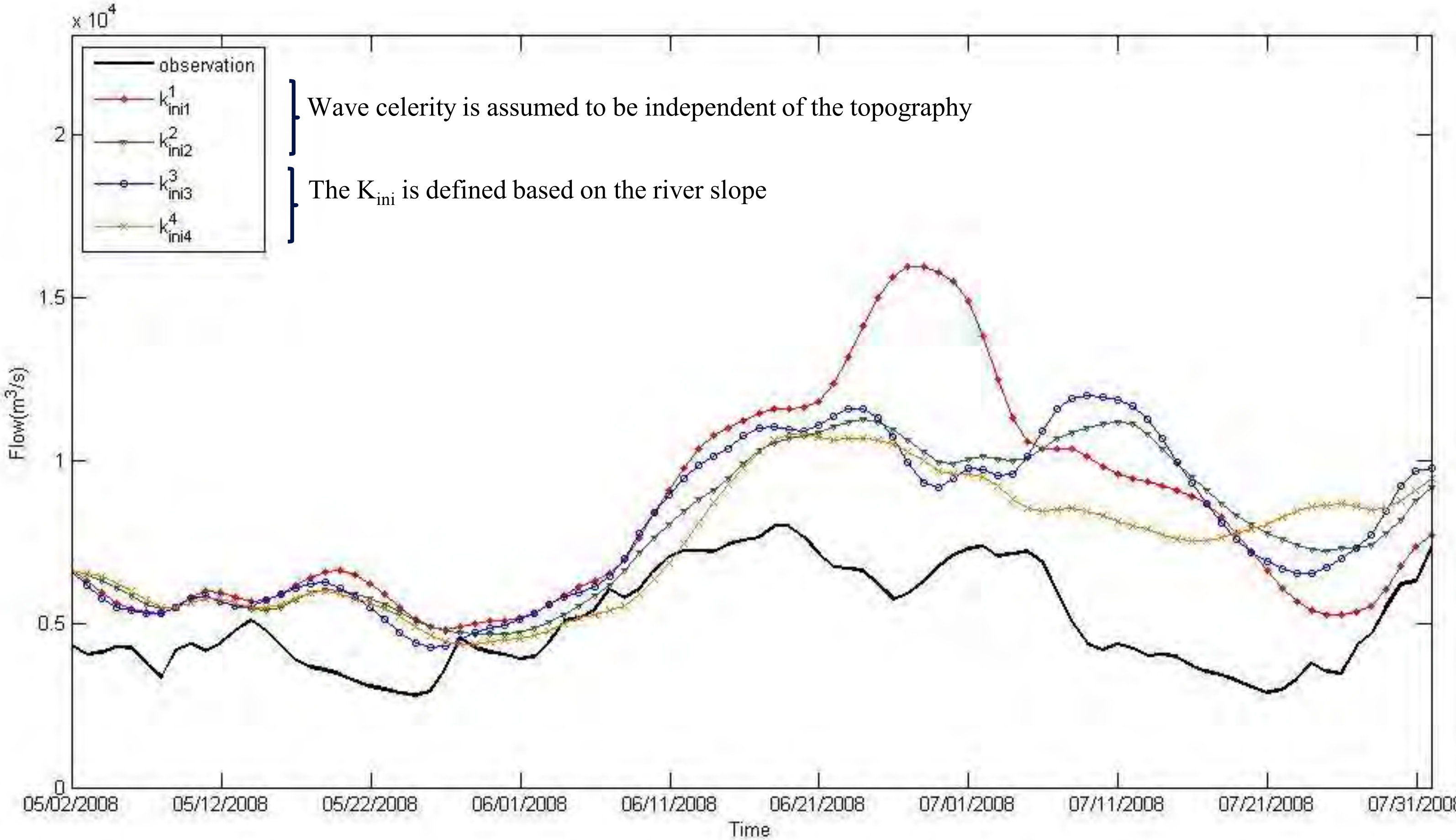


$\overline{L}$ is the mean of the river length, C_0 is the reference water wave celerity, S_i is a river slope, α the inverse of a velocity and L_i is the river length

$$\alpha = \frac{K^2_{ini}}{L_i \sqrt{S_i}}$$

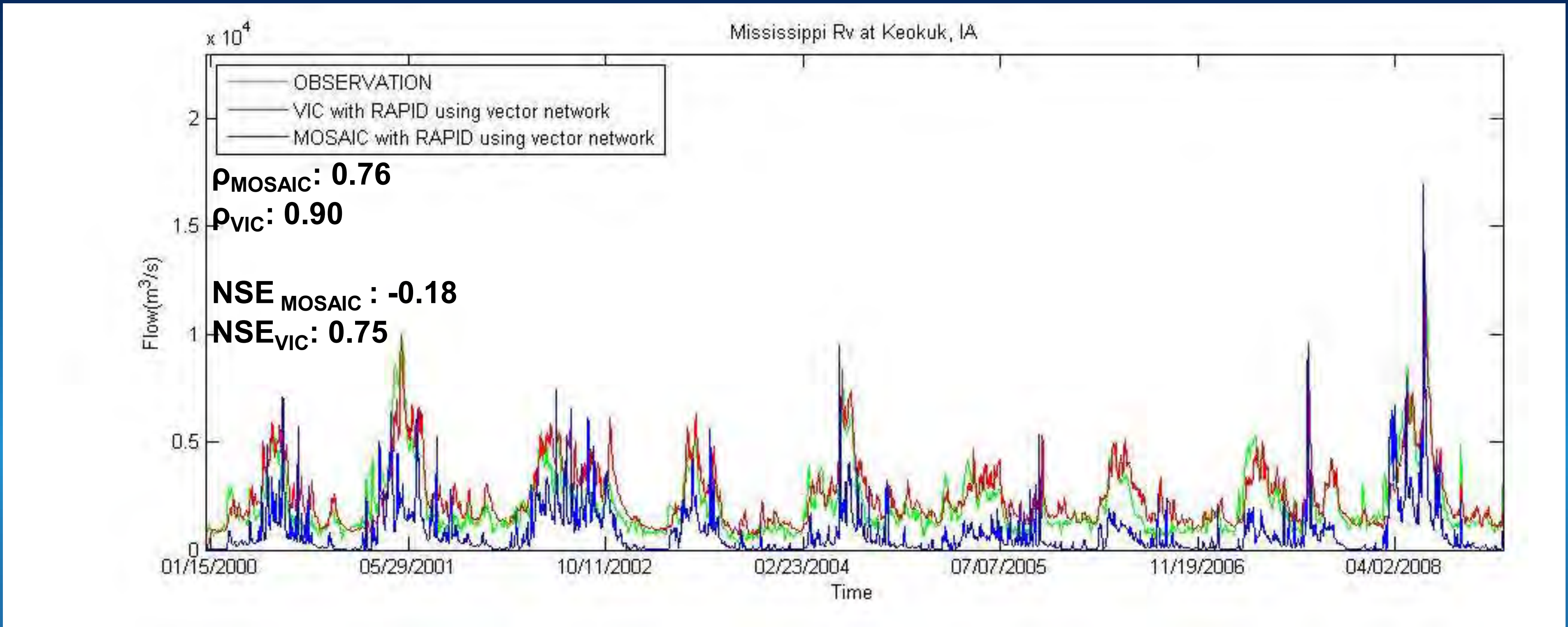
Length and slope of river segments can be obtained from the NHDPlus dataset

Effect of topography on flow rate computation



Taking channel geometry into account helps improve results

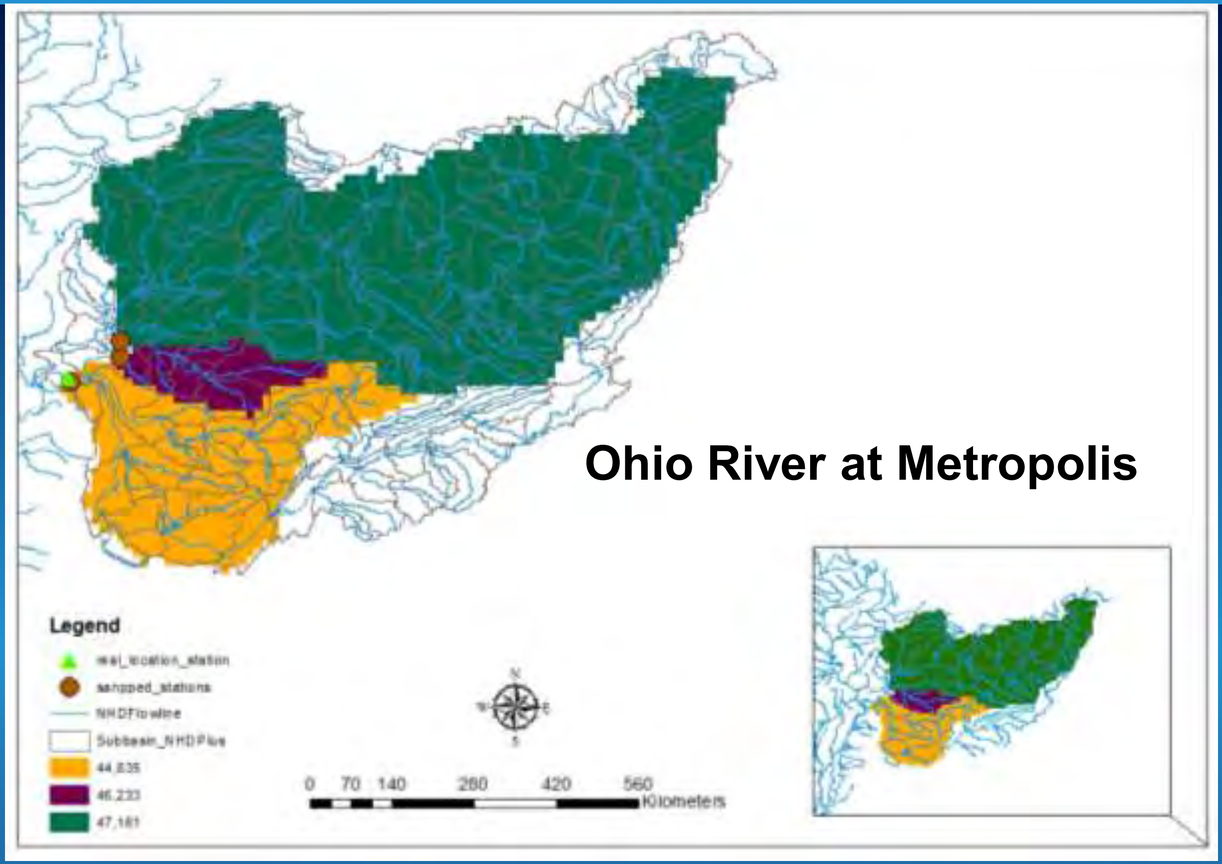
Simulated streamflow using the VIC and Mosaic land surface models



Mean Flow 9yrs VIC=2450 (m^3/s)
Mean Flow 9yrs mosaic=818 (m^3/s)
Mean Flow 9yrs observation=2147 (m^3/s)

Model results are underestimated using Mosaic LSM. The VIC runoff data gives better results.

The effect of drainage area on the 9-year mean flow



Grid-based networks with 12x12 km cells can give very misleading drainage areas

30% bigger area produces 30% more flow

	Average Flow (m^3)	Drainage Area(km^2)
Observation	8,051	525,768
grid	6,397	401,383
Vector	8,331	523,498

VIC land surface model

Results

- ✓ This study showed an extension of regional river flow modeling to the *Mississippi River basin scale* by using high resolution river data
- ✓ The upscale procedure can be extended to the national level for modeling river flow for entire Unites states using vector river network
- ✓ Drainage areas for smaller basins *cannot be calculated* accurately with 12x12 km cells
- ✓ River gauges are more easily associated with the correct points on the drainage network with the vector based models

Questions

Thank you!

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