Preliminary Hillslope River Routing (HRR) model results based on NLDAS runoff

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Hillslope River Routing (HRR) Model

- Combines hydrologic and hydraulic processes
- Topographic based, irregular computational grid (parallel processing)
- Vertical water/energy balance
- Lateral surface & subsurface routing
- Channel and floodplain routing
- Lake/reservoirs routing
- Model has ability to track **ALL** water stores

References

- Beighley, R.E., K. Eggert, T. Dunne, Y. He, and V. Gummadi, 2009. Simulating hydrologic and hydraulic processes throughout the Amazon River Basin, *Hydrological Processes* 23(8):1221-1235.
- Beighley, R.E. and V. Gummadi, 2011. Developing Channel and Floodplain Dimensions with Limited Data: A Case Study in the Amazon Basin, *Earth Surface Processes and Landforms* 36(8):1059-1071.
- Beighley, RE, R.L. Ray, Y. He, H. Lee, L. Schaller, M. Durand, K.M. Andreadis, D.E. Alsdorf, C.K. Shum, 2011. Comparing satellite derived precipitation datasets using the Hillslope River Routing (HRR) model in the Congo River Basin, *Hydrological Processes* 25(20):3216-3229.
- Beighley, R.E., K. Eggert, C.J. Wilson, J.C. Rowland, H. Lee., 2015. A hydrologic routing model suitable for climate scale simulations of arctic rivers: application to the Mackenzie River Basin, Hydrological Processes.

HRR (Surface & Subsurface) Runoff Generation & Routing

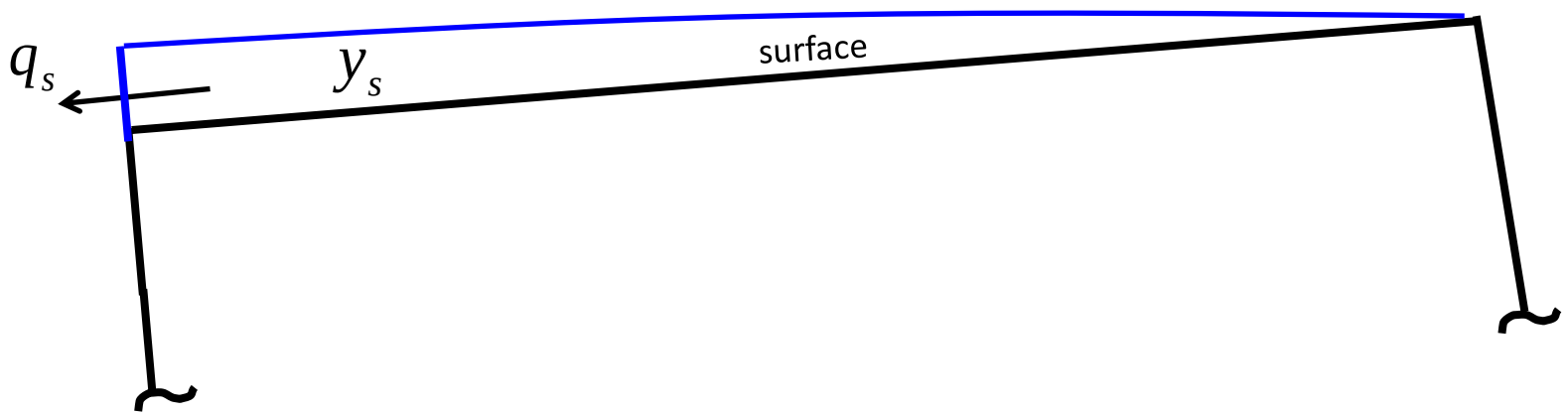
- **Surface runoff & routing**
  - Lateral routing → non-linear
  - e_s = (surface runoff and baseflow from NLDAS)
  - Kinematic wave w/ explicit solution
  - Based on Manning's eq. (wide rect. ch.)
  - Parameters:

    N = surface roughness; S = ground slope

    Lp = hillslope length (scale dependent)

$$\frac{\partial q_s}{\partial x} + \frac{\partial y_s}{\partial t} = e_S(t)$$

$$q_s = \left(\frac{1.49}{N} S^{1/2}\right) y_s^{5/3}$$

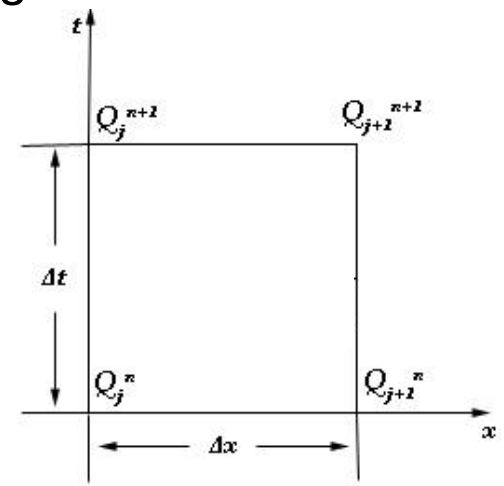


Channel and Floodplain Routing

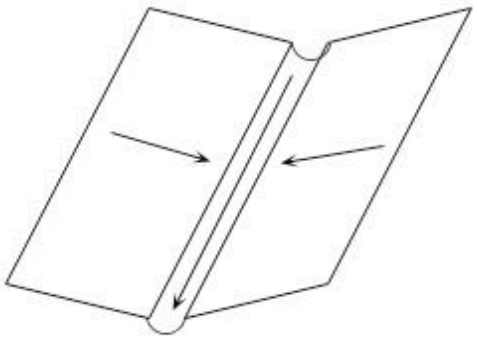
- Muskingum-Cunge (Diffusion Wave) channel routing
  - Finite difference over space and time
  - C's ~ f(Courant & Reynolds Nos., & Reference Q)

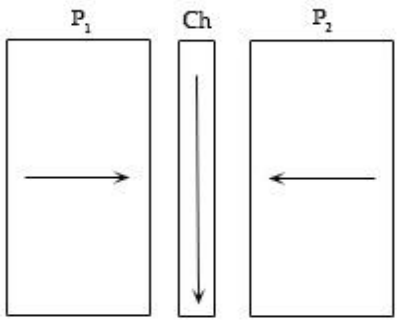
$$\frac{\partial Q}{\partial x} + \frac{\partial A}{\partial t} = q_s + q_{ss} = q_l \qquad Q = \frac{1}{n} A R^{2/3} S^{1/2}$$

$$Q_{j+1}^{n+1} = C_1 Q_j^{n+1} + C_2 Q_j^n + C_3 Q_{j+1}^n + C_4 Q_L$$



- Each model unit defined as "Open Book"
  - Channel receive lateral flow from 2 planes plus any upstream flow





n = channel roughness

A = cross-sectional area

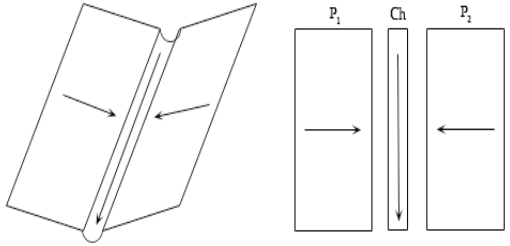
R = hydraulic radius (~A/w)

S = channel slope

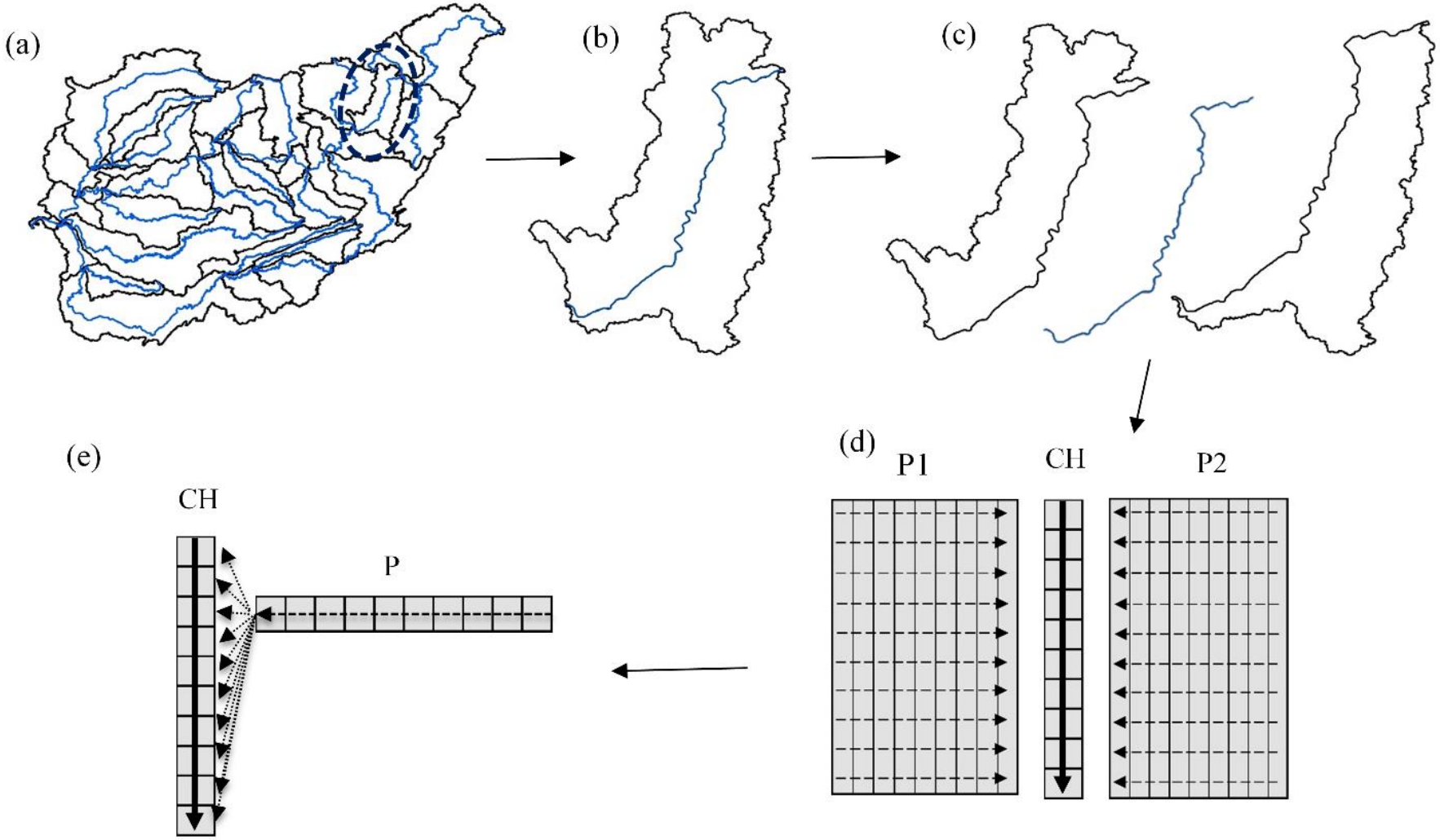
Q_{ref} = reference discharge

Characterizing flowpaths and scales

- Channel network
  - Defines model unit boundaries
  - Sets Hillslope Lengths & Slopes
  - Sets River Lengths & Slopes
- Model Scale vs. Real Scale
  - How to estimate parameters in model scale to capture physical process scale?
  - Depending on model scale, hillslope flowpaths represent hillslope and channel flowpaths



HRR model units → "open book"



Hillslope Parameters

- Runoff → NLDAS 2 (VIC Hourly) Dai's extremely awesome binary files for surface and subsurface runoff (http://hydro.iis.u-tokyo.ac.jp/~yamadai/tmp/SWOT-MIP/grads.tar.gz)
- NLDAS_VIC0125_H: NLDAS VIC Land Surface Model L4 Hourly 0.125 x 0.125 degree V002
- Hillslope Slope → mean pixel slope in catchment based on hydrosheds DEM
- Hillslope Length → based on river network resolution (Threshold area = 100 pixels; roughly 20.25 km^2), Lp = A/2/Lc
- Surface roughness → 0.8 x (1.5, sinuosity)

Channel Parameters

- Channel Slope → mean pixel slope along channel based on hydrosheds DEM
- Channel Length → based on river network resolution (Threshold area = 100 pixels; roughly 20.25 km^2), same as hydrosheds
- Channel roughness → 0.025 x (4.0, sinuosity)
- Channel width → Andreadis et al. (2013)
- Reference Discharge → Andreadis et al. (2013)

Andreadis, K. A., G. J.-P. Schumann, and T. Pavelsky (2013), A simple global river bankfull width and depth database, Water Resour. Res., 49, 7164–7168, doi:10.1002/wrcr.20440.

https://zenodo.org/record/61758#.V_IoR_ArJaS (Zenodo Link, IDs match Hydrosheds)

Compare to data sources

- HRR Rivers = 102,229
- Hydrosheds Rivers = 102,229
- Andreadis et al. (2013) Rivers = 102,229

- HRR max pixels = 19,595,996
- Hydrosheds max pixels = 19,595,996
- Andreadis et al. (2013) max pixels = 19,595,996

Compare to data sources

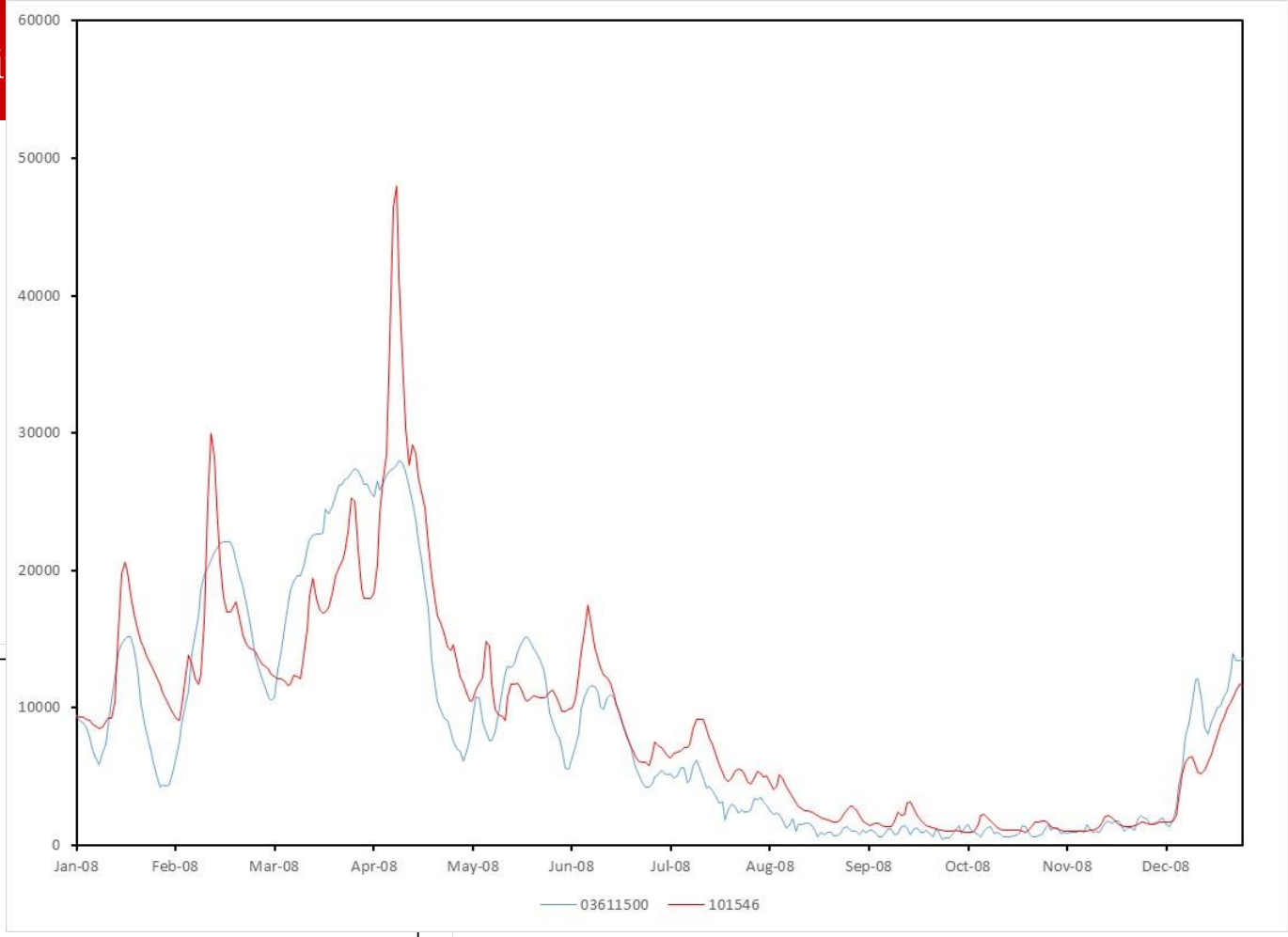
- HRR Area = 3,183,250 km^2
- Hydrosheds Area = 3,179,517 km^2
- Andreadis et al. (2013) Area = 4,201,681 km^2

Processing of HRR length/area using:

North America Albers Equal Area Conic.prj

(per comparison study table)

USGS Gauge Name	USGS ID	Area_sqkm	USGS (cms)	HRR (cms)	R
Missouri River at Bismarck, North Dakota	06342500	476,589	467	1543	0.00
Missouri River at Omaha, Nebraska	06610000	813,613	756	2484	0.60
Missouri River at Hermann, Missouri	06934500	1,325,160	2083	5423	0.78
Arkansas River near Haskell, Oklahoma	07165570	189,470	303	815	0.77
Arkansas River at Murray Dam near Little Rock, Arkansas	07263450	402,573	1294	2445	0.79
Red River at Spring Bank, Arkansas	07344370	146,889	589	1078	0.79
Ohio River at Sewickley, Pennsylvania	03086000	50,323	990	973	0.60
Ohio River at Louisville, Kentucky	03294500	235,990	3623	3877	0.73
Ohio River at Metropolis, Illinois	03611500	525,399	8130	8898	0.87
Mississippi River at Saint Paul, Minnesota	05331000	95,543	401	742	0.50
Mississippi River at Keokuk, Iowa	05474500	309,388	2189	3645	0.70
Mississippi River at Grafton, Illinois	05587450	445,580	3418	5027	0.76
Mississippi River at Saint Louis, Missouri	07010000	1,776,970	5547	10526	0.81
Mississippi River at Thebes, Illinois	07022000	1,818,740	6080	11060	0.80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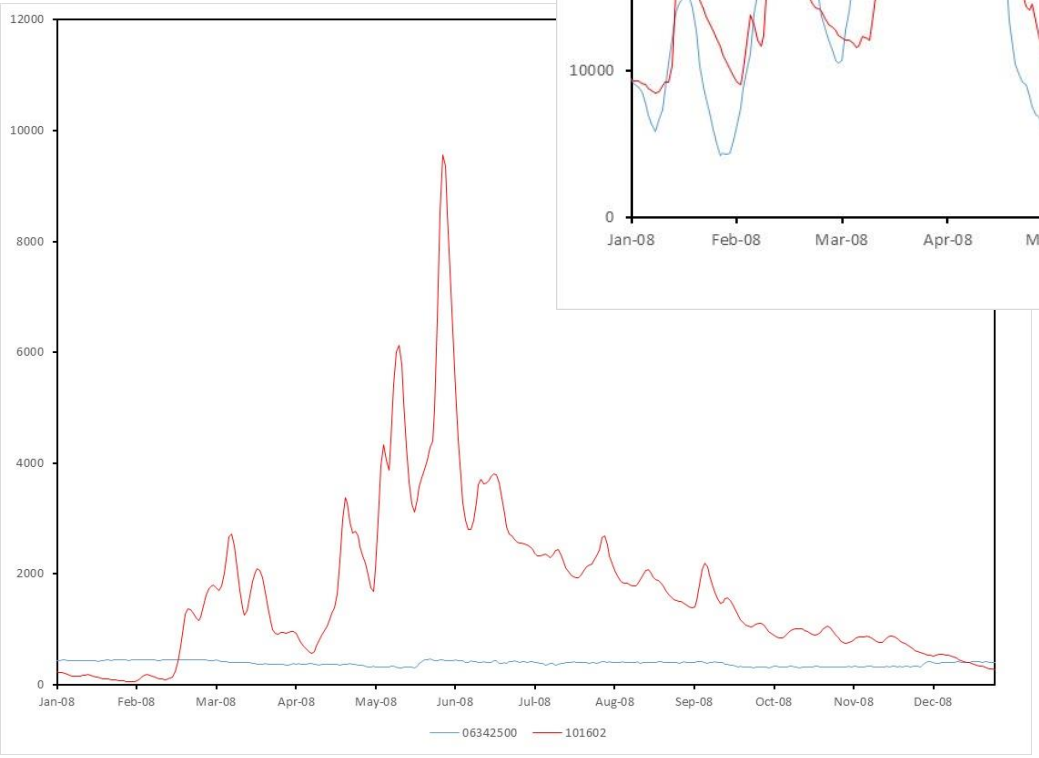
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