SWOT Science Team Meeting
Toulouse, France June 26-29, 2017

River Model Inter-comparison Project for SWOT[1]

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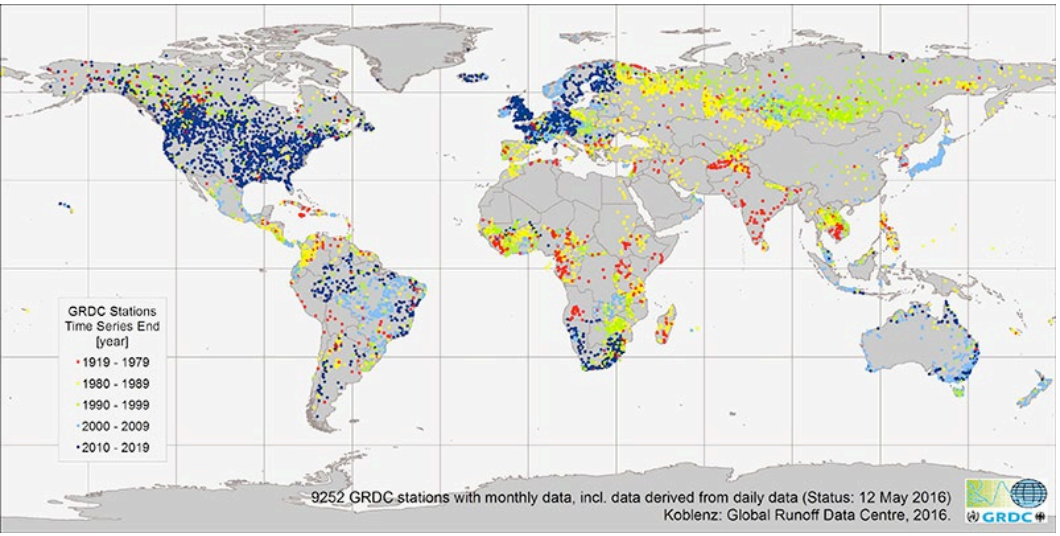
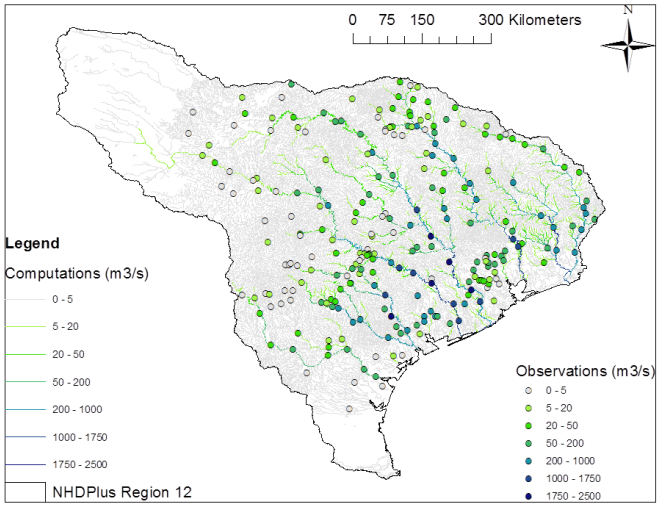
5. University of Tokyo, Tokyo, Tokyo, Japan
6. Environnement Canada, Montreal, Canada
7. LEGOS, Toulouse, France
8. Universidade Federal do Rio Grande do Sul, Porto Alegre, RS, Brazil
9. Princeton University, Princeton, NJ, United States

1. NASA's decision to proceed with the SWOT mission will not occur until completion of the National Environmental Policy Act (NEPA) compliance process. SWOT is a proposed NASA mission at this time and the information in this paper is pre-decisional, to be used for planning and discussion purposes only

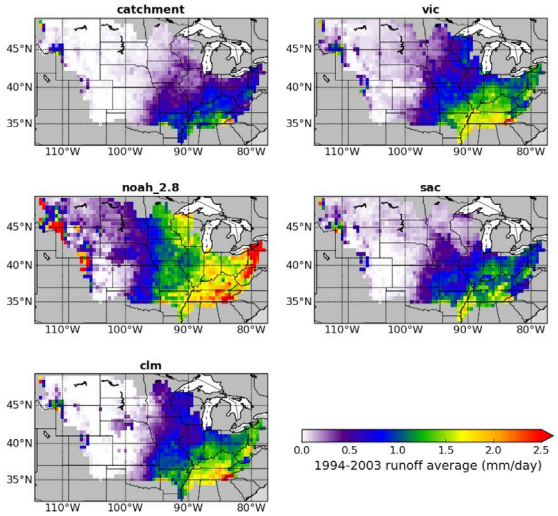
Motivation



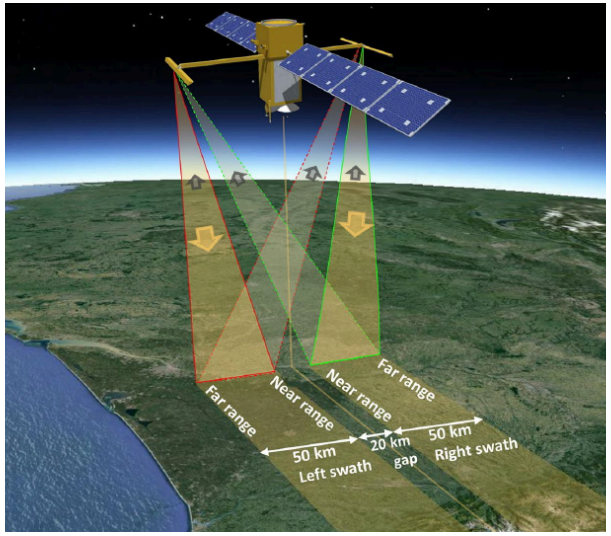
River gauges are disappearing (http://grdc.bafg.de)



Mystery between gauges (David et al. 2013)

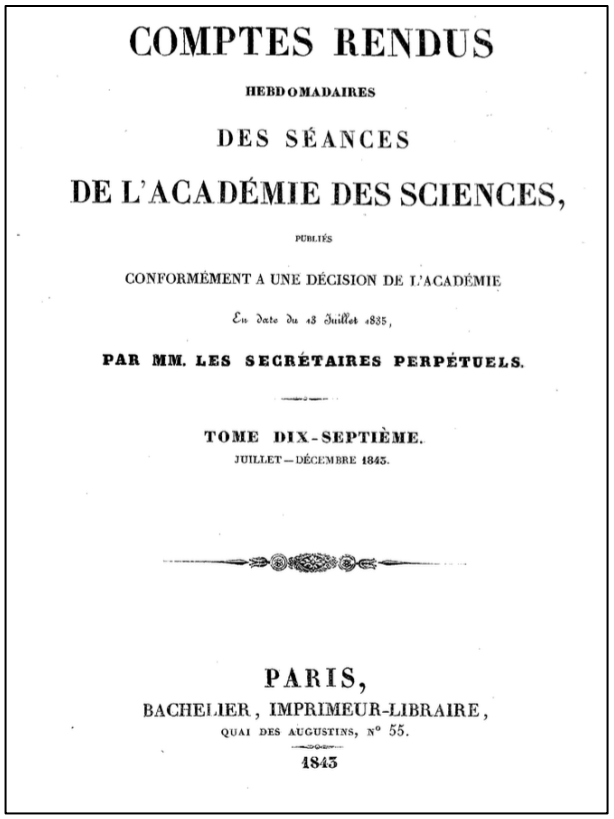


Runoff is uncertain (from D. Lettenmaier)



SWOT should help (Biancamaria et al. 2016)

Background (1/4)



COMPTES RENDUS

HEBDOMADAIRES

DES SÉANCES

DE L'ACADÉMIE DES SCIENCES,

PUBLIÉS

CONFORMÉMENT A UNE DÉCISION DE L'ACADÉMIE

En date du 18 Juillet 1835,

PAR MM. LES SECRÉTAIRES PERPÉTUELS.

TOME DIX-SEPTIÈME.

JUILLET — DÉCEMBRE 1843.

PARIS,

BACHELIER, IMPRIMEUR-LIBRAIRE,

QUAI DES AUGUSTINS, N° 55.

1843

Saint Venant (1843)

→ the golden equations

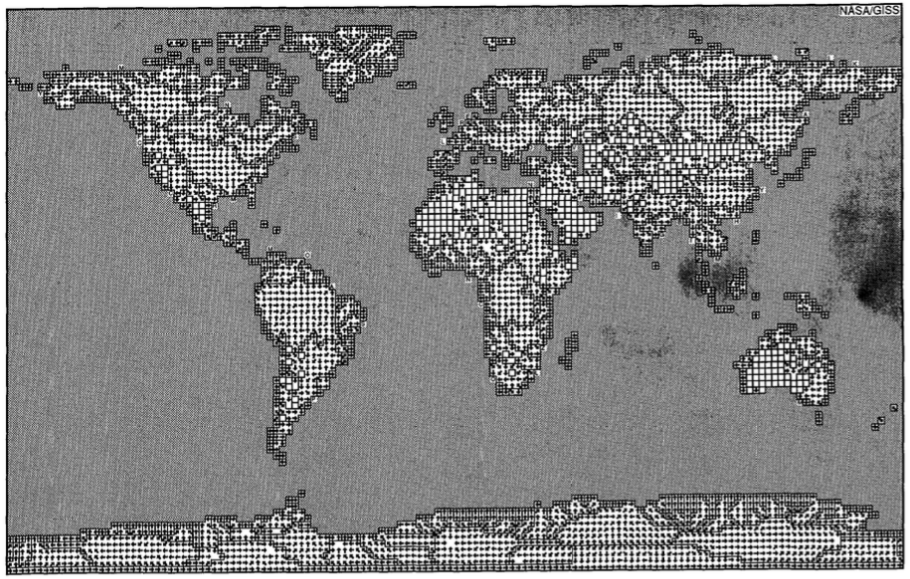


FIG. 1. Direction map for river flow for 2° × 2.5° horizontal grid resolution. Arrows indicate the direction of flow out of a grid box. Boxes without arrows drain internally. A letter corresponding to the first letter of each river's name is located at the river's mouth.

Miller et al. (1994)

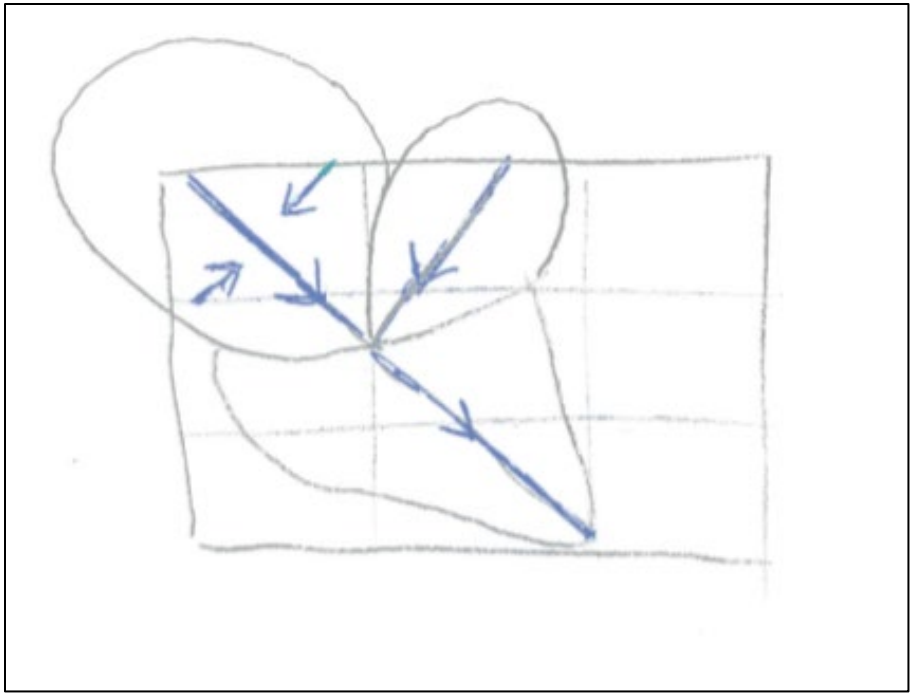
→ the first global scale river model

Modeling across scales involves a variety of simplifications

Background (2/4)

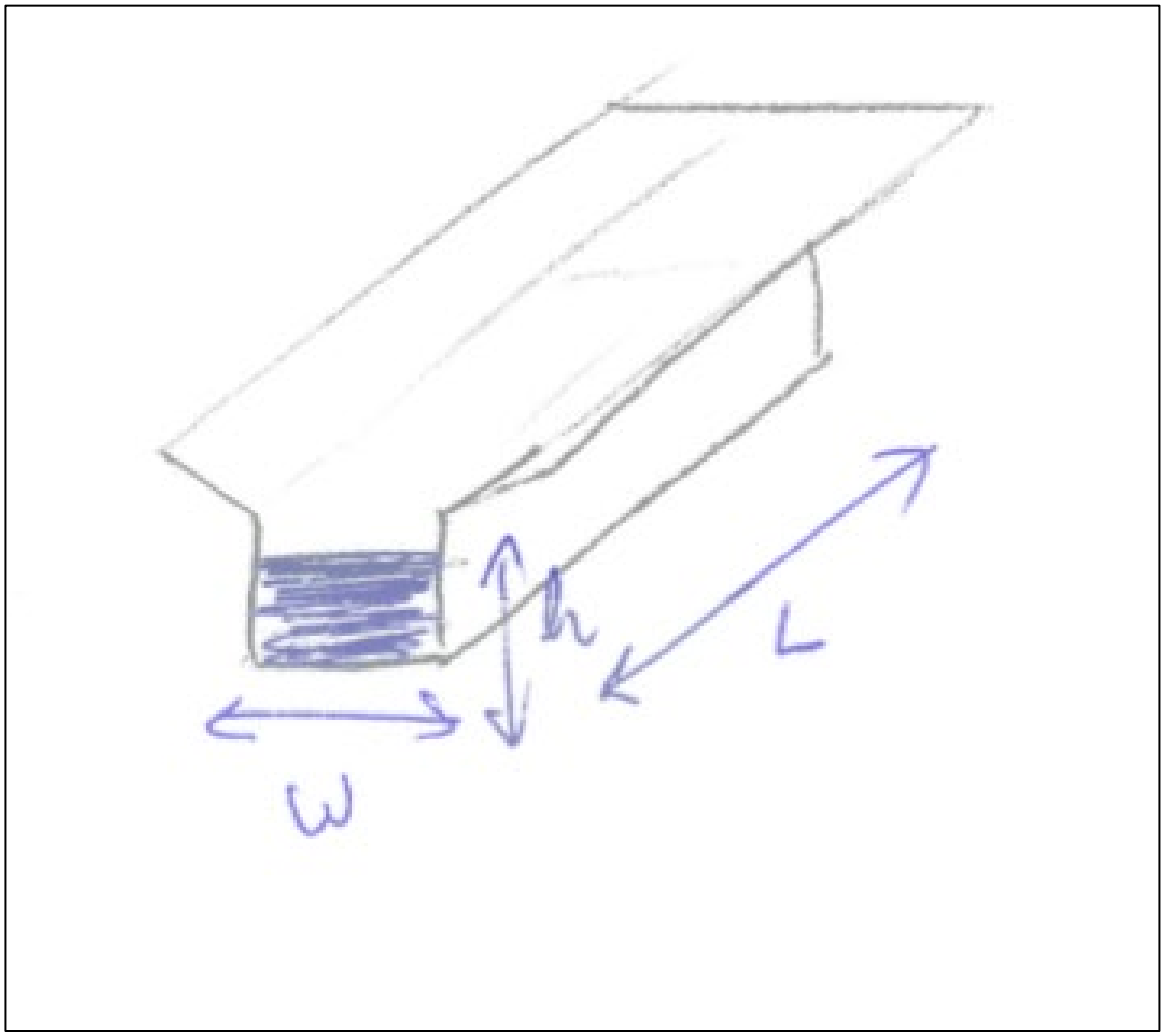
A world of grids

A world of features



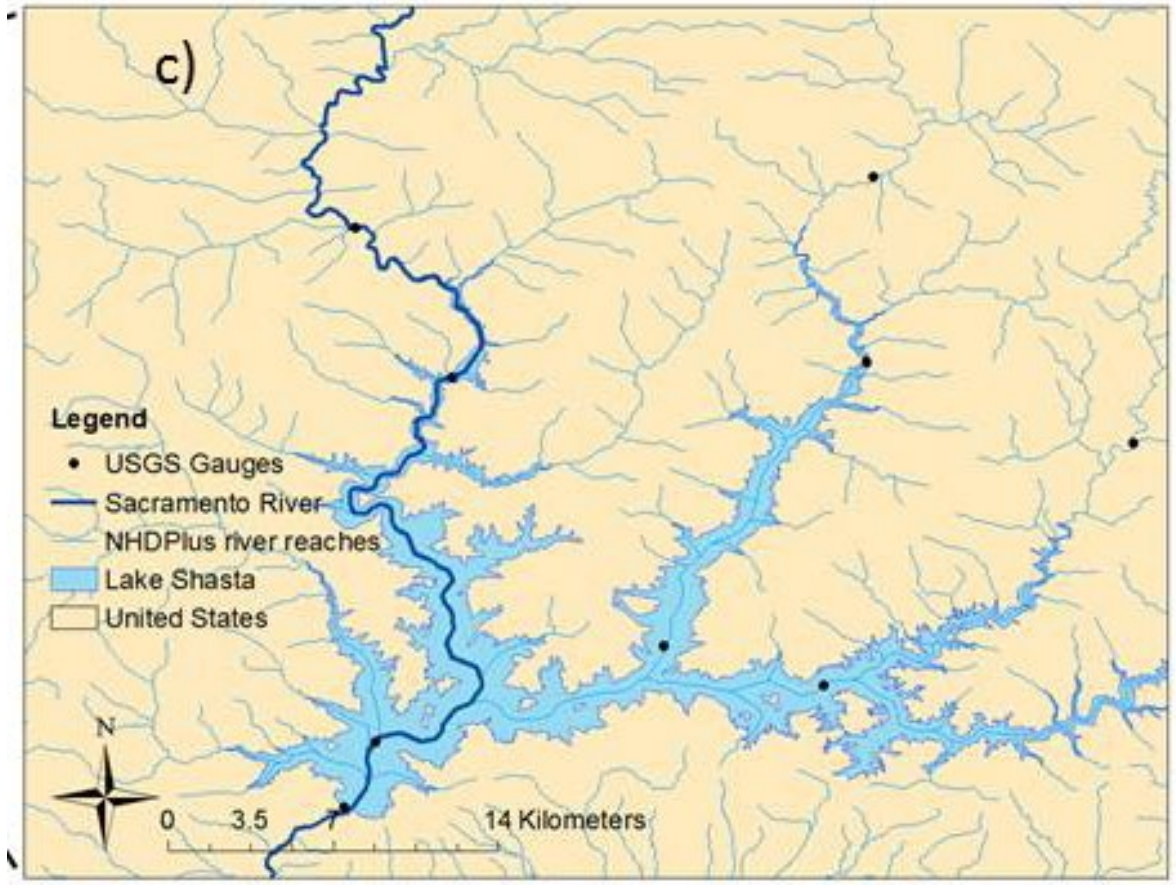
Both approaches are equally frequent

Background (3/4)



A variety of equations is used

Background (4/4)



Lake Shasta, CA

Anthropogenic effects are often not represented

Objectives

Understanding the best integration methods between expected SWOT terrestrial retrievals and existing global hydrologic/hydrodynamic models

1. How can we best **prepare for the expected SWOT continental to global measurements before SWOT even flies**? That is, how can we understand the relationships between existing **surface water variations and expected SWOT capabilities**?
2. What is the **added value of including SWOT terrestrial measurements into global hydro models** for enhancing our understanding of the terrestrial water cycle and the climate system? Are current global hydrologic models ready to ingest expected SWOT data? What SWOT variable(s) or SWOT-derived product(s) offer the best promise for integration and for data assimilation?

Approach

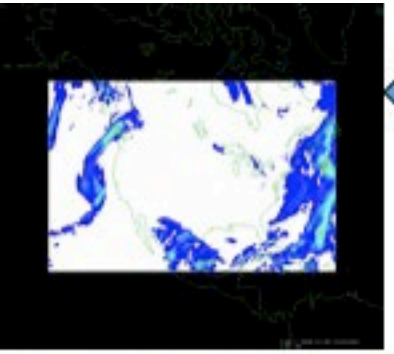
Justification

- Low barrier of entry to engage many
- Consistency among simulations despite model differences (apples/apples)
- Consistency among simulations despite basin differences
- Some expertise of the core team in study areas
- Walking before running

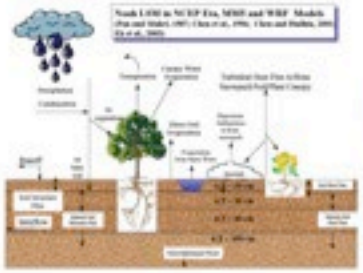
Consequence

- Datasets readily available online
- Same runoff forcing, related topography & river network, related hydraulic parameters
- Global availability of data products or modeling methods
- Start with river basins with existing team publications
- Increasing complexity

Modeling paradigm



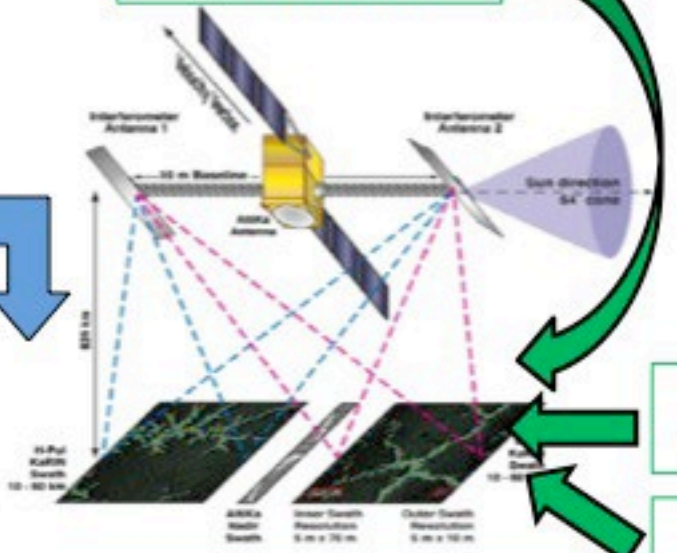
Atmospheric Model or Dataset



Land Surface Model

NASA's Land Data Assimilation System

Airborne Observations

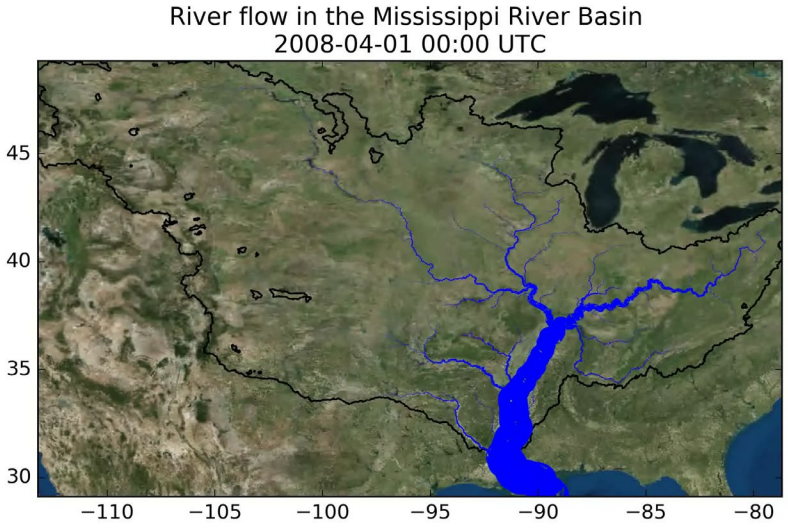


In situ Observations

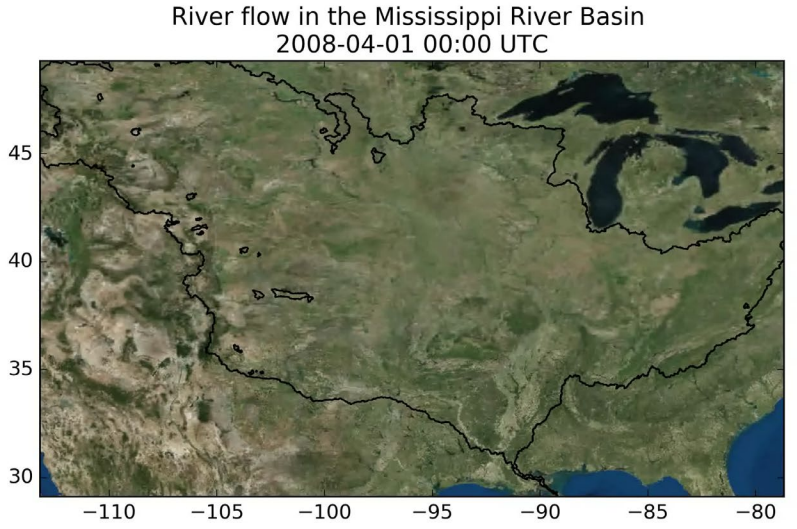
Mapped hydrography (HydroSHEDS, NARwidth)

Routing Models for Rivers and Reservoirs (CaMa-Flood, HRR, ISBA-TRIP, LISFLOOD, RAPID, WATFLOOD)

Such a system could be used to generate SWOT-like data before SWOT launches

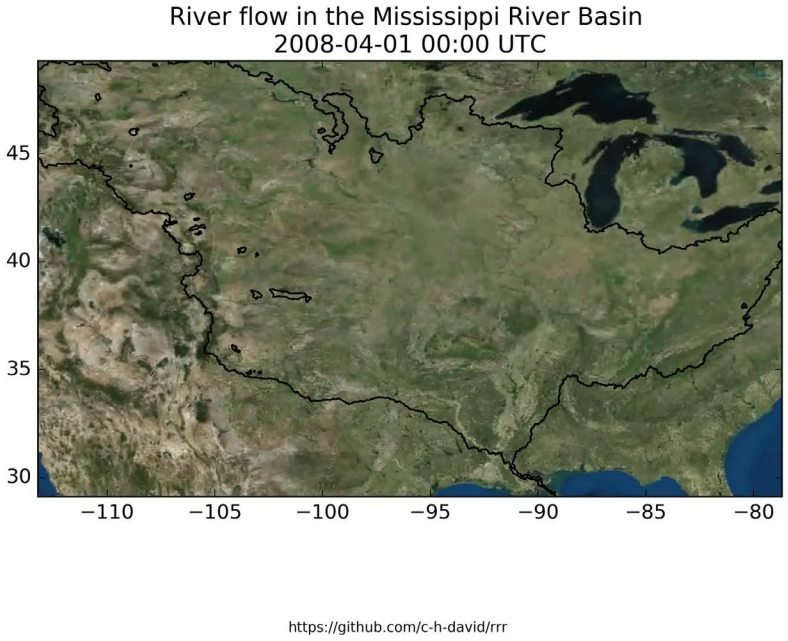


River model

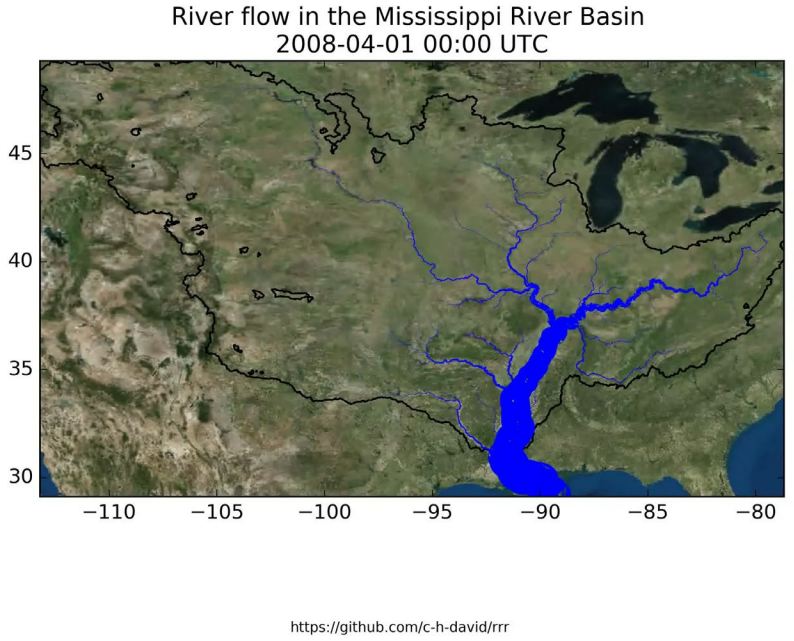


SWOT-like data

Such a system could be used to assimilate SWOT data when SWOT launches

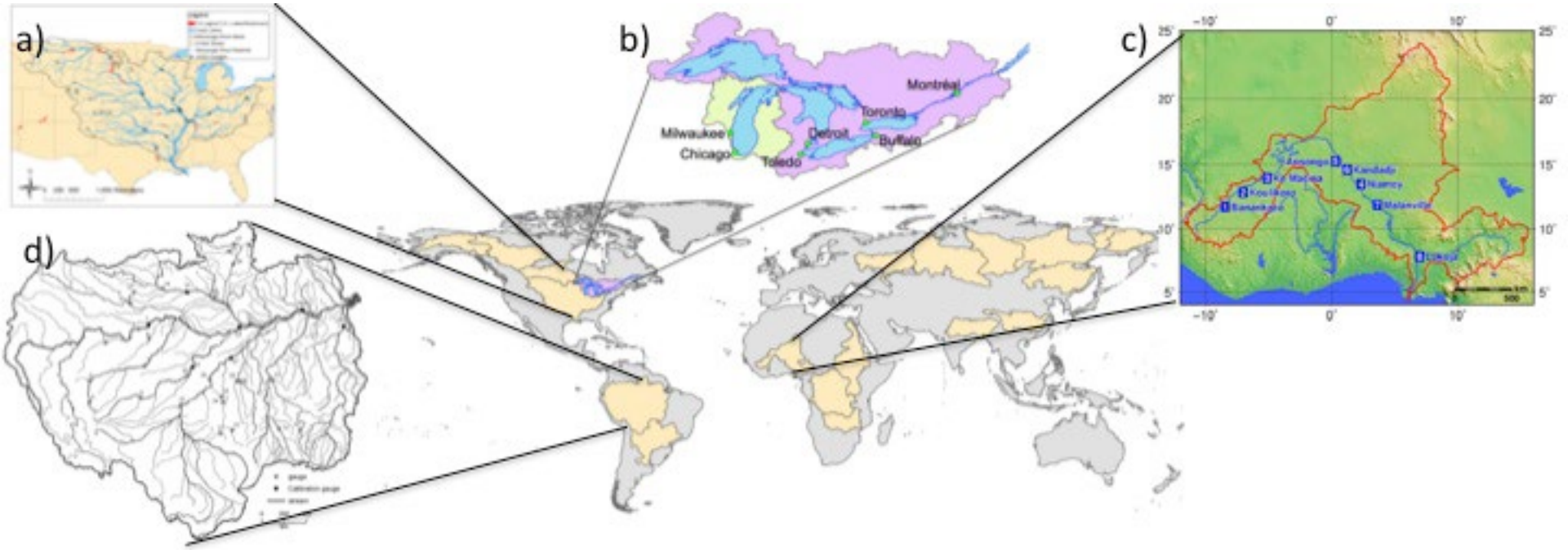


SWOT data



River model

Four basins in four years



The basins studied in this project benefit from existing studies:

a) the Mississippi [David et al., 2015],
b) Saint-Lawrence [Fry et al., 2014],
c) Niger [Pedinotti et al., 2014],
d) Amazon [Beighley et al., 2009].

Many models

- CaMaFLOOD (D. Yamazaki)
- HRR (E. Beighley)
- LISFLOOD (K. Andreadis)
- RAPID (C. David)
- MGB-IPH (R. Paiva)
- Lohman et al. (C. Fisher)
- TRIP (H. Kim)
- ISBA-TRIP (A. Boone)
- WATFLOOD (J. M. Fiset)
- Others?

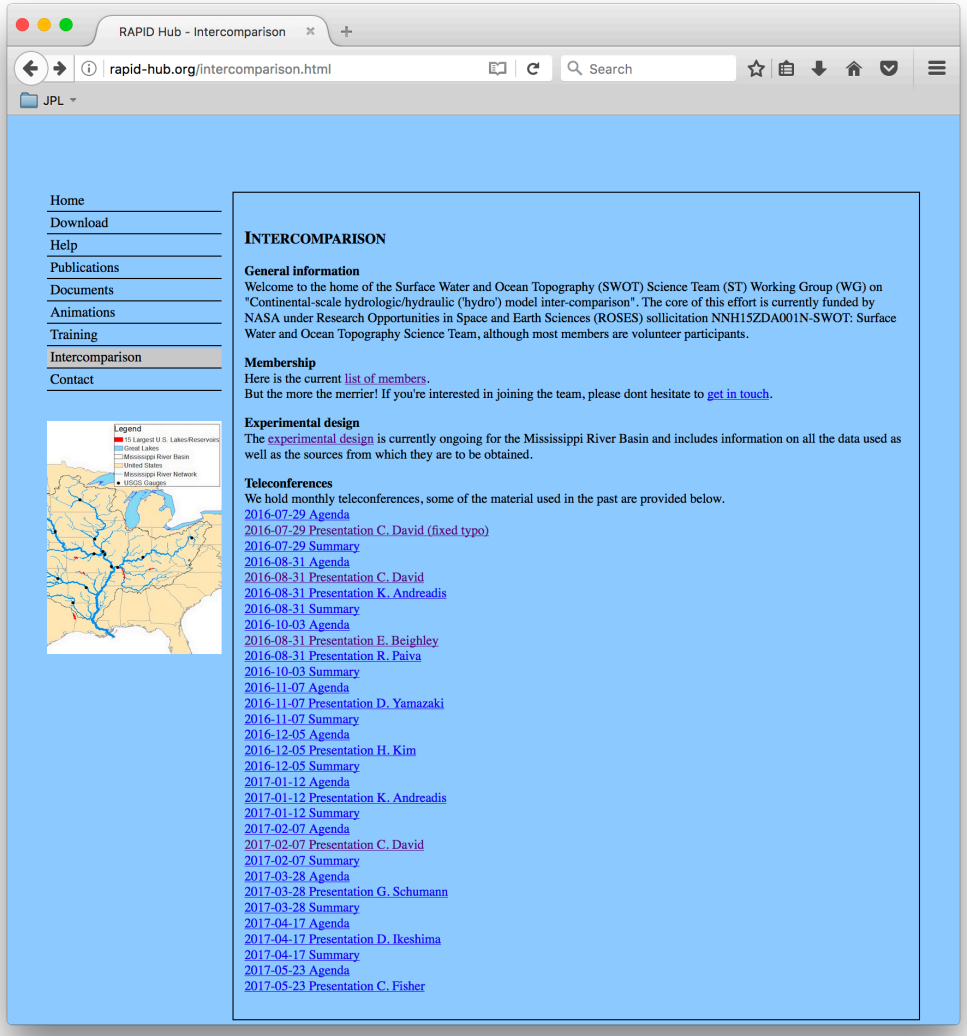
Experimental design

Tasks		2016 Q1	2016 Q2	2016 Q3	2016 Q4	2017 Q1	2017 Q2	2017 Q3	2017 Q4	2018 Q1	2018 Q2	2018 Q3	2018 Q4	2019 Q1	2019 Q2	2019 Q3	2019 Q4
Feasibility for applying the SWOT hydrology simulator at continental scale and alternatives	High resolution			1													
	Low resolution			1													
	Vector products			1													
	Method selected				1												
	Simulated truths				1			1				1				1	
Inter-comparison of hydro models	Design/prep.	1				1				1				1			
	Simulations	1				1				1				1			
	Multi-forcing variab.		1				1				1				1		
	Intra-model variab.		1				1				1				1		
	Inter-model variab.		1				1				1				1		
Investigating the integration of SWOT data into all hydro models	Flow				1				1				1				1
	Height				1				1				1				1
	Slope						1		1				1				1
	Width						1			1			1				1
Write scientific papers								1				1				1	1
Total number of tasks per year		12				12				12				12			

Legend
Mississippi
Niger
Saint-Lawrence
Amazon

We will combine an inter-comparison framework consisting of a series of six horizontal water transfer schemes: **CaMa-Flood** [Yamazaki et al., 2011], HRR [Beighley et al., 2009], **ISBA-TRIP** [Decharme et al., 2012], **LISFLOOD-FP** [Bates and de Roo, 2000], **RAPID** [David et al., 2011], and **WATFLOOD** [Kouwen et al., 1993]. These models will be fed by runoff produced by the four land surface models of NASA's **GLDAS** [Rodell et al., 2004].

RivMIP website



http://rapid-hub.org/intercomparison.html

Current membership

Experimental design

Agenda for monthly telecons

Presentations

Meeting minutes

Design table

Data sources

Type	Variable	Source	Spatial res.	Temp. res.	Download link
	Surface runoff	NASA NLDAS2 VIC	1/8°	1h	ftp://hydro1.sci.gsfc.nasa.gov/data/s4pa/NLDAS/NLDAS_VIC0125_H.002/
	Subsurface runoff	NASA NLDAS2 VIC	1/8°	1h	ftp://hydro1.sci.gsfc.nasa.gov/data/s4pa/NLDAS/NLDAS_VIC0125_H.002/
	Surface and subsurface only (grad files)	NASA NLDAS2 VIC	1/8°	1h	http://hydro.iis.u-tokyo.ac.jp/~yamadai/tmp/SWOT-MIP/grads.tar.gz
Runoff	Surface and subsurface only (geotiff files)	NASA NLDAS2 VIC	1/8°	1h	http://hydro.iis.u-tokyo.ac.jp/~yamadai/tmp/SWOT-MIP/gtiff.tar.gz
	Gridded DEM	HydroSHEDS	15 arcsec	-	http://hydrosheds.cr.usgs.gov/datadownload.php?reqdata=15demg
	Gridded Flow Accumulation	HydroSHEDS	15 arcsec	-	http://hydrosheds.cr.usgs.gov/datadownload.php?reqdata=15accg
	Gridded Flow Direction	HydroSHEDS	15 arcsec	-	http://hydrosheds.cr.usgs.gov/datadownload.php?reqdata=15dirg
	Gridded DEM (changed format)	Computed	15 arcsec	-	http://hydro.iis.u-tokyo.ac.jp/~yamadai/tmp/SWOT-MIP/mi1.condem.tif
Topography	Gridded DEM (adjusted for no negative ele	Computed	15 arcsec	-	http://hydro.iis.u-tokyo.ac.jp/~yamadai/tmp/SWOT-MIP/mi1.elevtn.tif
	Vector River Network	HydroSHEDS	15 arcsec	-	http://hydrosheds.cr.usgs.gov/datadownload.php?reqdata=15rivs
Hydrography	Vector River Basin	HydroSHEDS	15 arcsec	-	http://hydrosheds.cr.usgs.gov/datadownload.php?reqdata=15bass
	River reach length	Computed	15 arcsec (HydroSHEDS river network)	-	??? (to be computed after projection to North America Albers Equal Area Conic)
	Catchment area	Computed	15 arcsec (HydroSHEDS river network)	-	??? (to be computed from river reach centroid lon/lat, the number of upstream cells, and a spherical Earth of radius a-f/3 for WGS84 spheroid)
	Bankful Discharge	Computed	15 arcsec (HydroSHEDS river network)		http://doi.org/10.5281/zenodo.61758
	Bankful Width	Computed	15 arcsec (HydroSHEDS river network)	-	http://doi.org/10.5281/zenodo.61758
Hydrographic	Bankful Height	Computed	15 arcsec (HydroSHEDS river network)	-	http://doi.org/10.5281/zenodo.61758
geometry	Floodplain width	???	???	-	???
	Manning's n	Constant	15 arcsec (HydroSHEDS river network)	-	0.03
	Muskingum k	Computed	15 arcsec (HydroSHEDS river network)	-	??? (to be computed from river length, bankful width, bankful height using TBD equation)
River hydraulics	Muskingum x	Constant	15 arcsec (HydroSHEDS river network)	-	0.3
Land hydraulics	Manning's n	Constant	15 arcsec (HydroSHEDS river network)	-	0.1
Observations	River discharge	USGS NWIS DV	Irregularly spaced points	24h	http://waterdata.usgs.gov/nwis/dv & http://rapid-hub.org/docs/SWOT_ST_WG_Example_Outputs.csv & http://rapid-hub.org/docs/SWOT_ST_WG_O
Model outputs	River discharge	All of us	Irregularly spaced points	24h	See example given above

Simulation

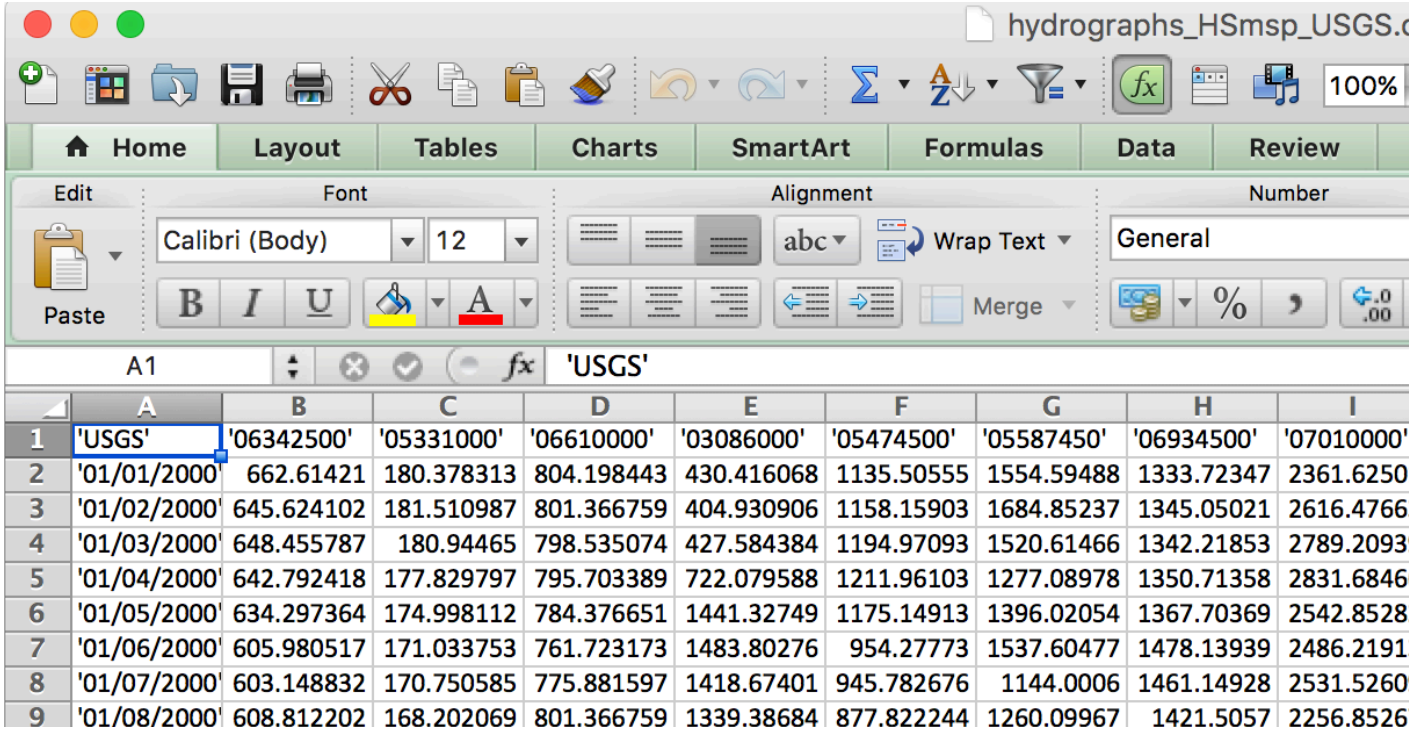
Domain	Start time	End time	Output temp res.	Variable
Mississippi	1/1/00	12/31/09	hourly to daily	Q (m^3/s)

Last update	12/6/16

Analysis

Locations	Start time (CST)	End time (CST)	Resolution
14 gauges of Dav	1/1/00	12/31/09	daily

File formats

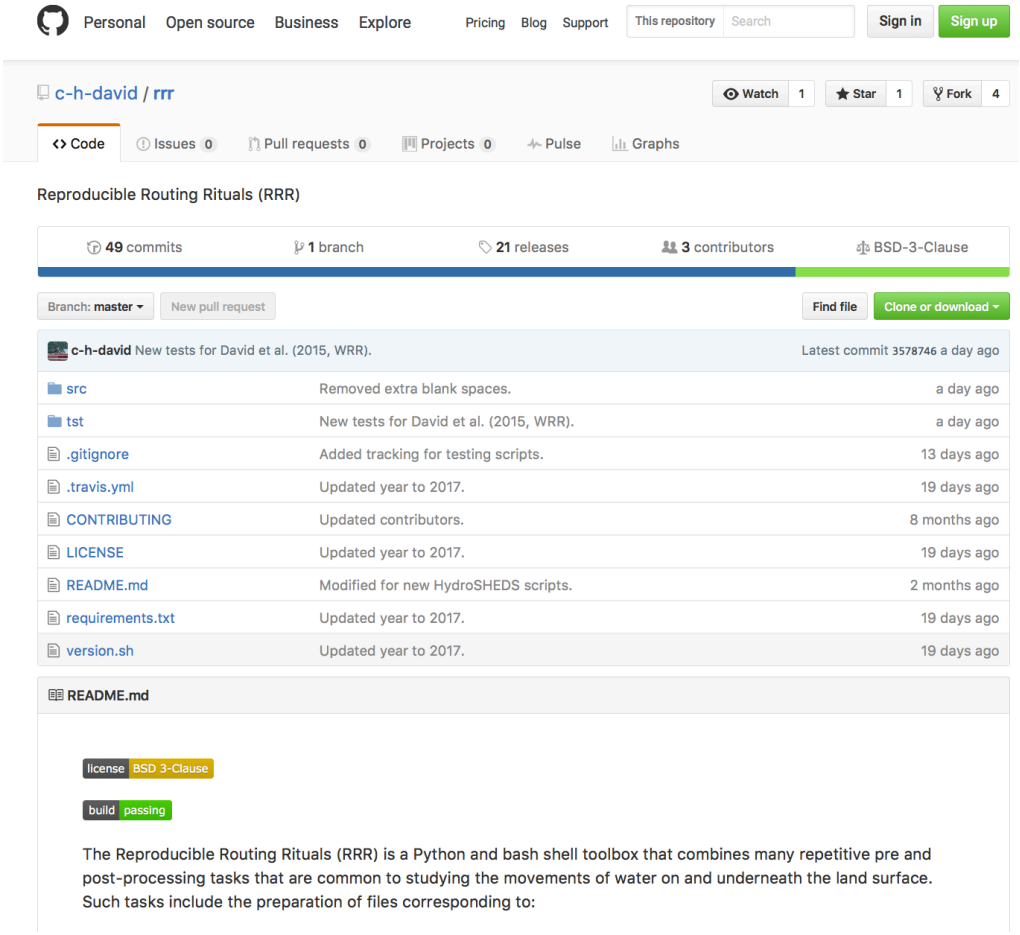


	A	B	C	D	E	F	G	H	I
1	'USGS'	'06342500'	'05331000'	'06610000'	'03086000'	'05474500'	'05587450'	'06934500'	'07010000'
2	'01/01/2000'	662.61421	180.378313	804.198443	430.416068	1135.50555	1554.59488	1333.72347	2361.6250
3	'01/02/2000'	645.624102	181.510987	801.366759	404.930906	1158.15903	1684.85237	1345.05021	2616.4766
4	'01/03/2000'	648.455787	180.94465	798.535074	427.584384	1194.97093	1520.61466	1342.21853	2789.2093
5	'01/04/2000'	642.792418	177.829797	795.703389	722.079588	1211.96103	1277.08978	1350.71358	2831.6846
6	'01/05/2000'	634.297364	174.998112	784.376651	1441.32749	1175.14913	1396.02054	1367.70369	2542.8528
7	'01/06/2000'	605.980517	171.033753	761.723173	1483.80276	954.27773	1537.60477	1478.13939	2486.2191
8	'01/07/2000'	603.148832	170.750585	775.881597	1418.67401	945.782676	1144.0006	1461.14928	2531.5260
9	'01/08/2000'	608.812202	168.202069	801.366759	1339.38684	877.822244	1260.09967	1421.5057	2256.8526

14 locations throughout the Mississippi River Basin

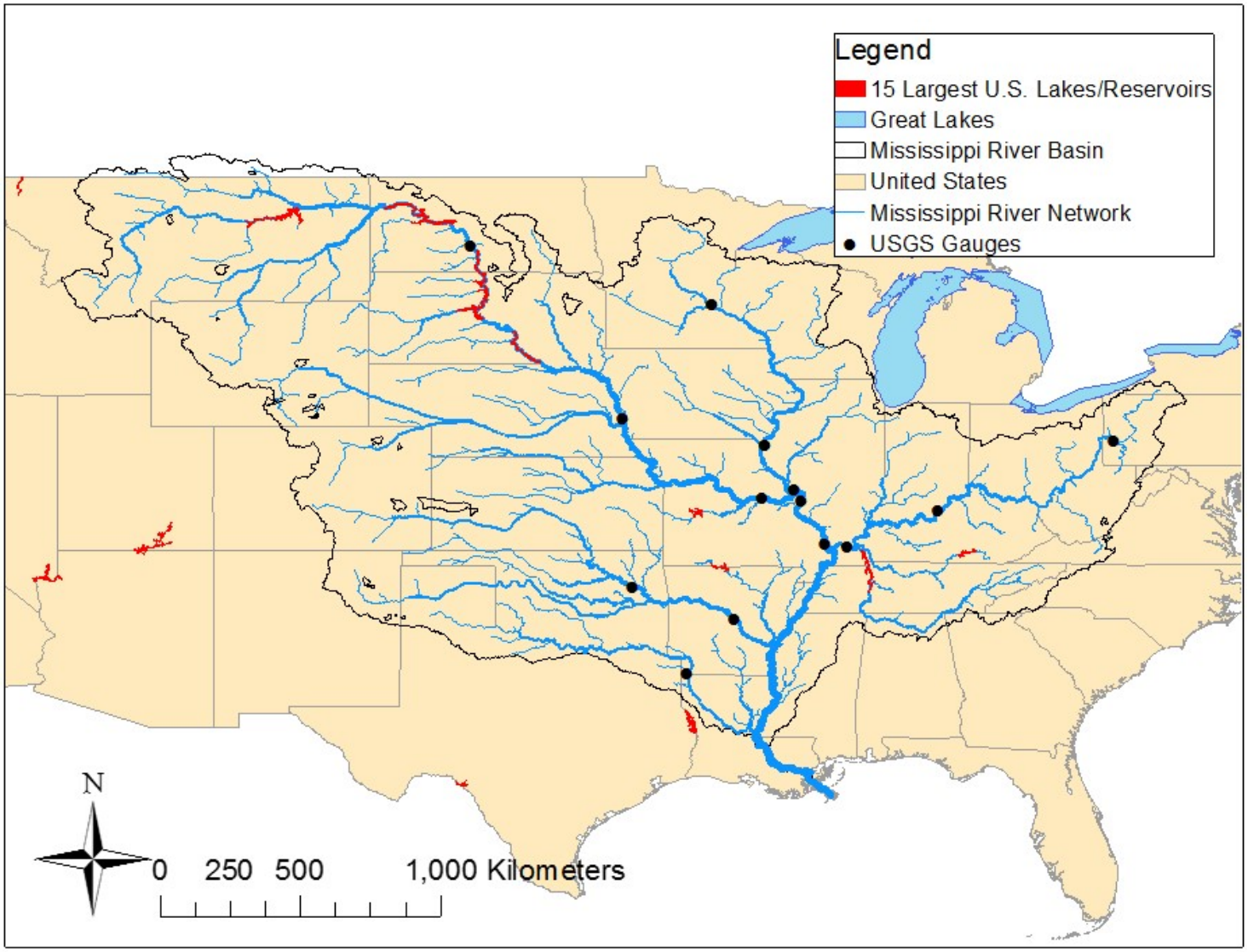
As specified in experimental design table:
http://rapid-hub.org/docs/SWOT_ST_WG_Mississippi_Experimental_Design.pdf

Processing toolbox

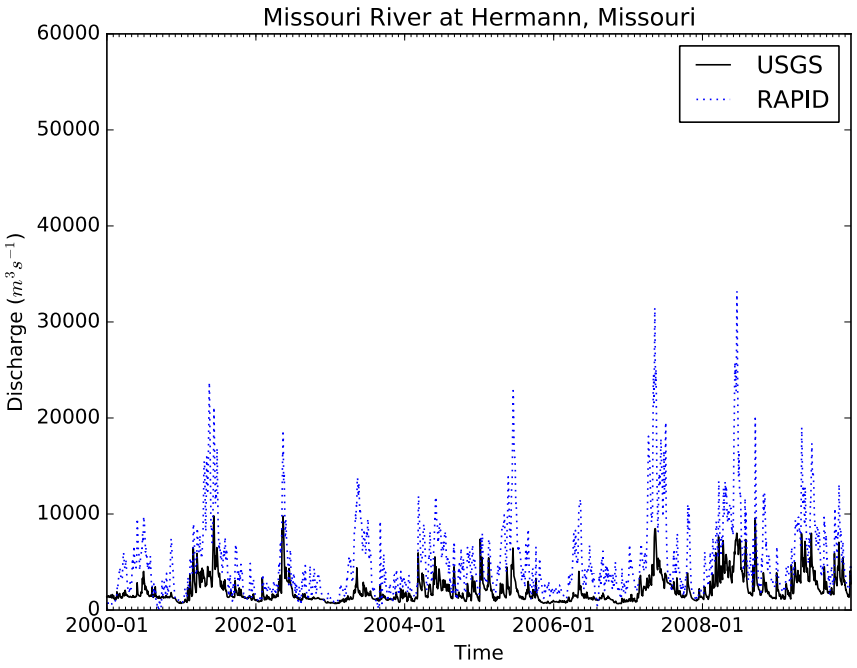


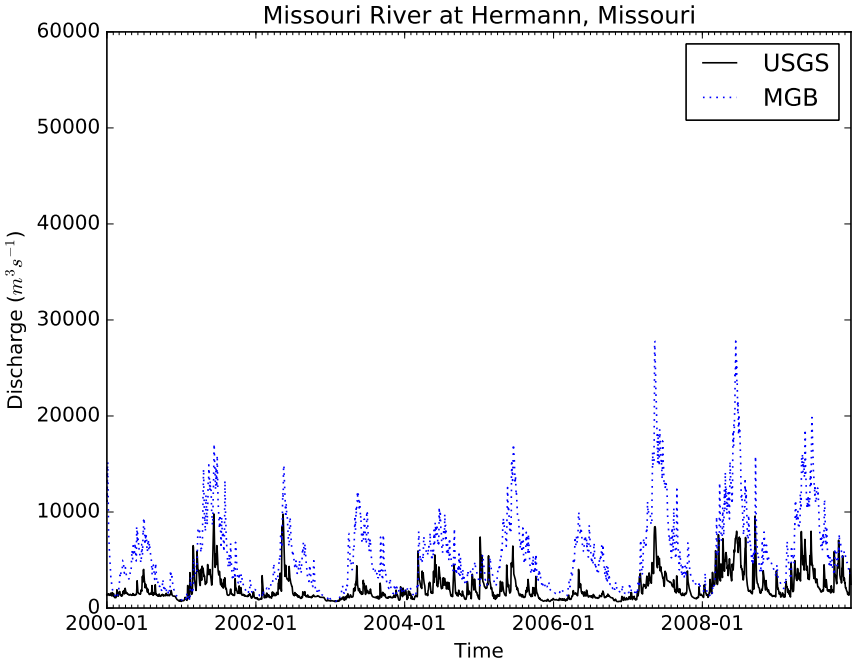
https://github.com/c-h-david/rrr
Currently being updated with the Python scripts for analysis

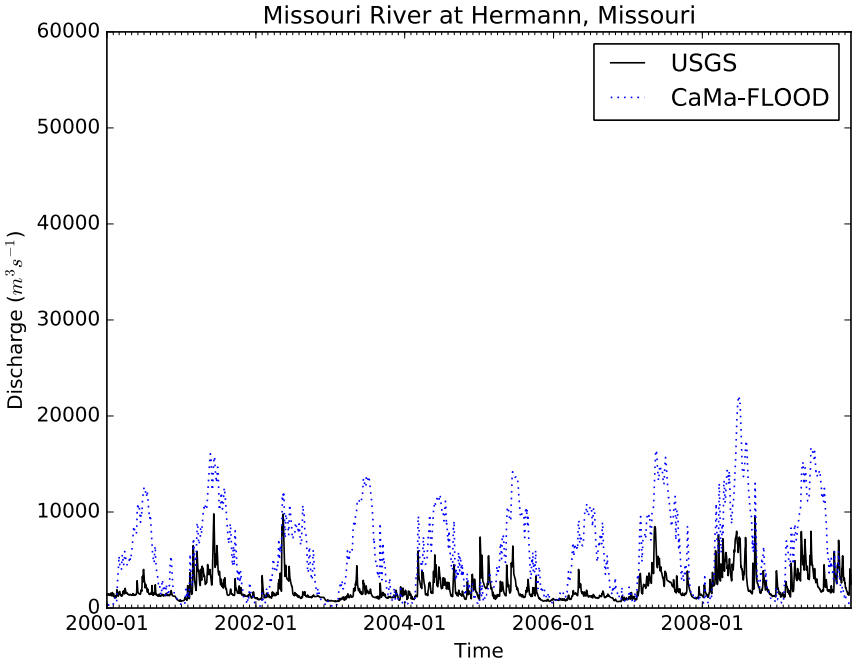
Preliminary results



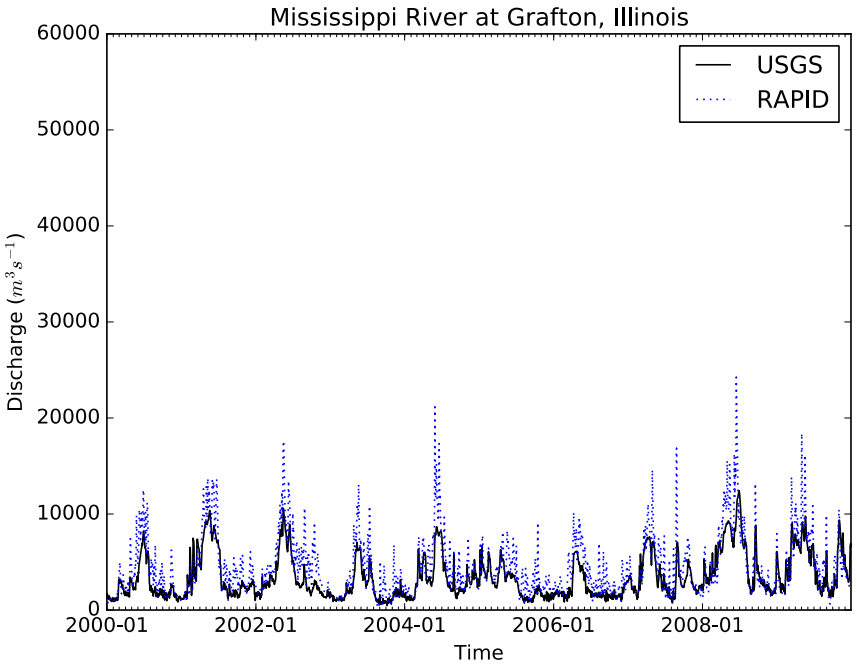
Outlet of Missouri River

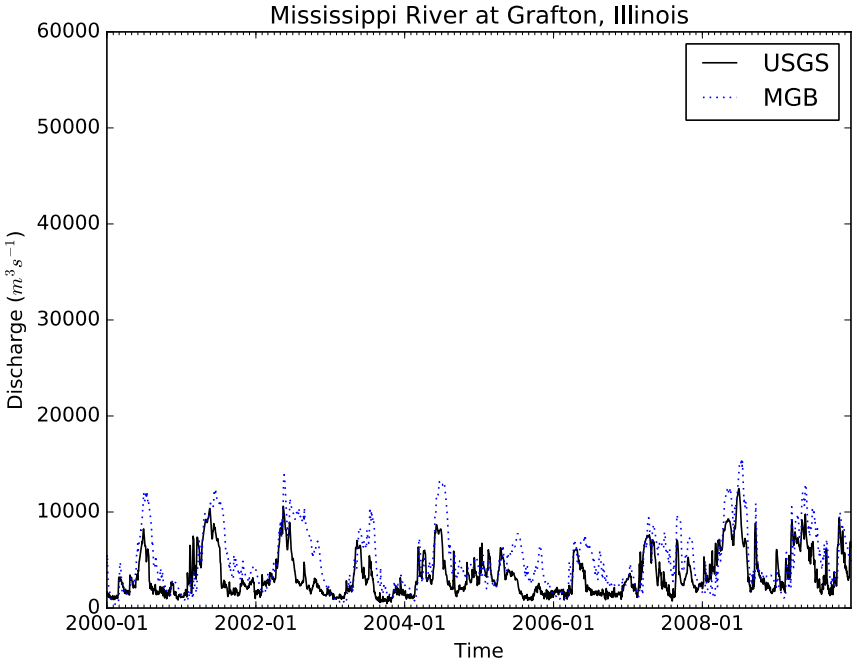


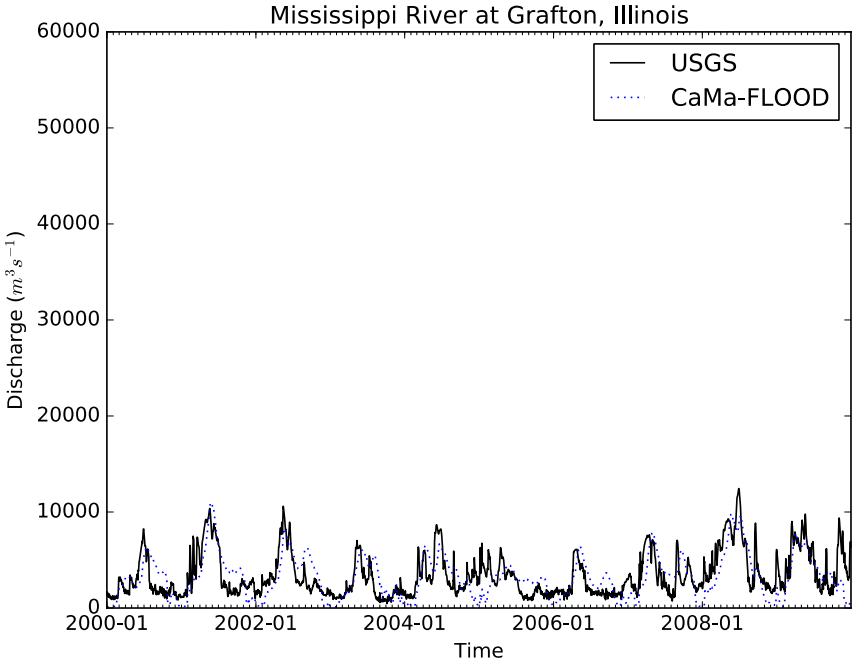




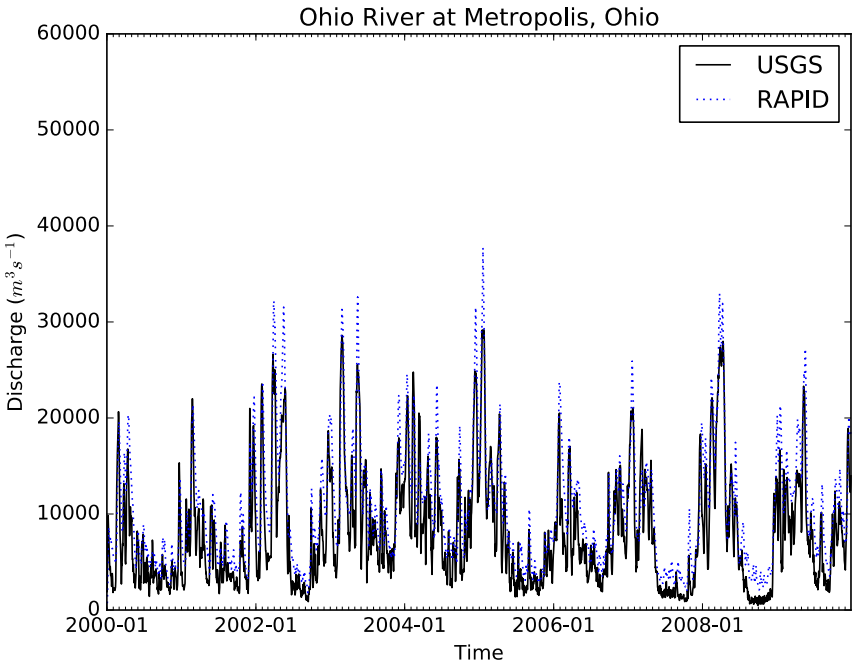
Outlet of Upper Mississippi River

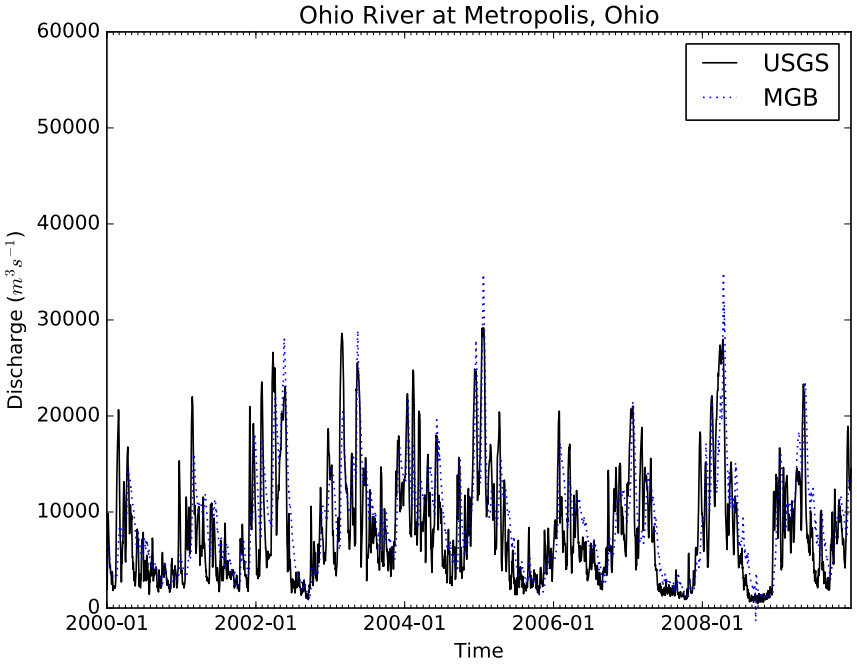


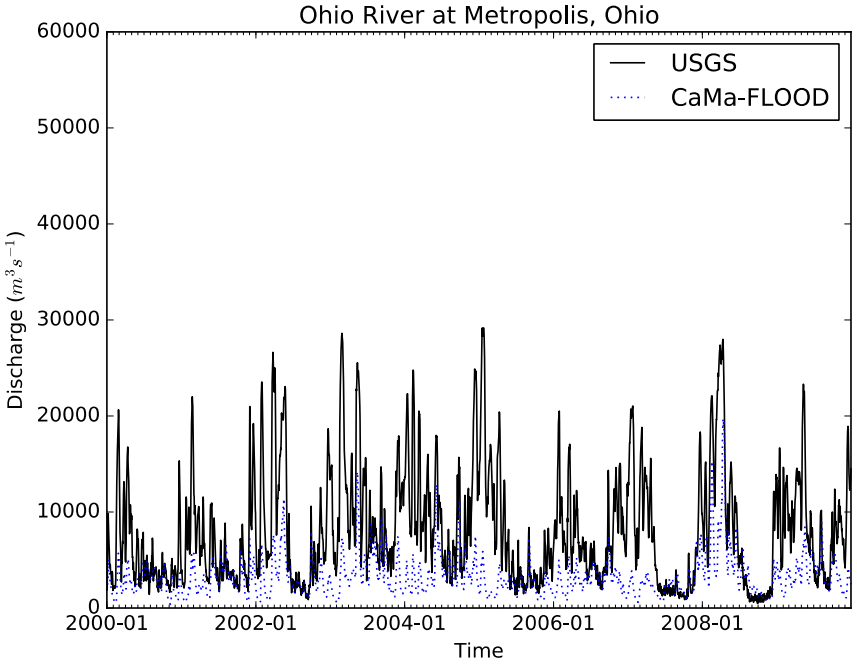




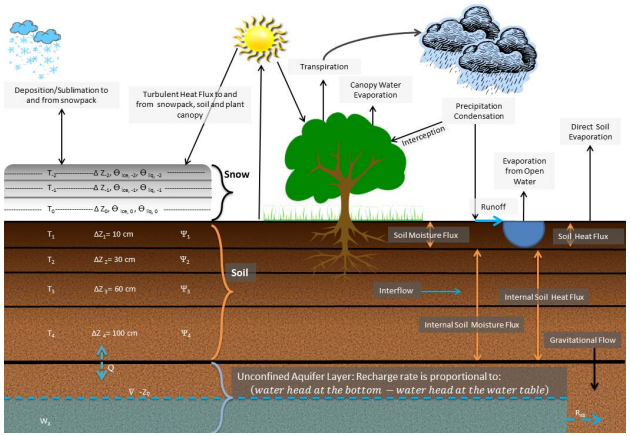
Outlet of Ohio River





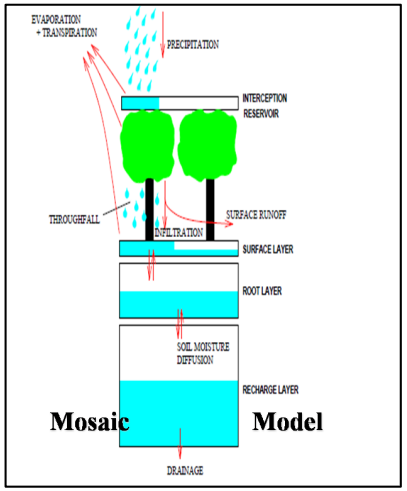


Parallel: the variety of Land Surface Models

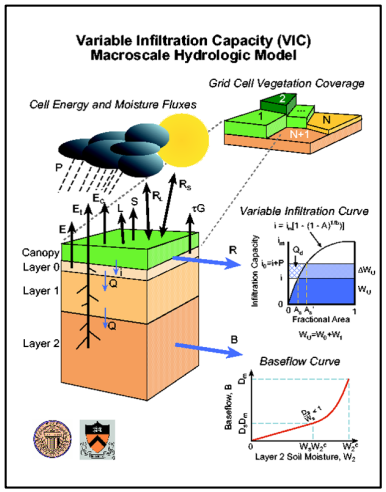


Noah MP

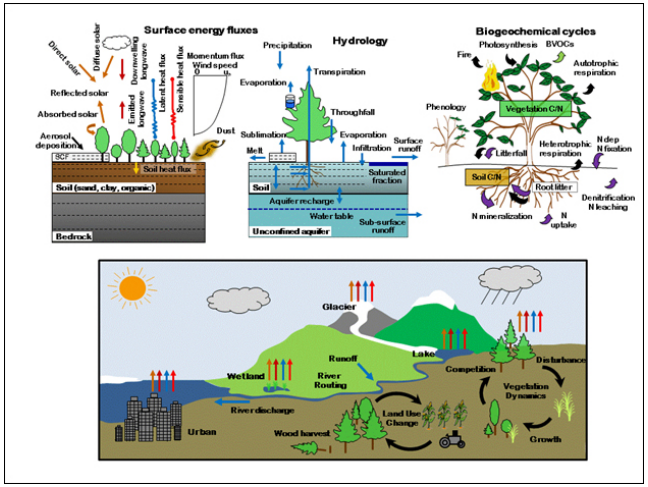
We have a similar variety in the river modeling world



Mosaic

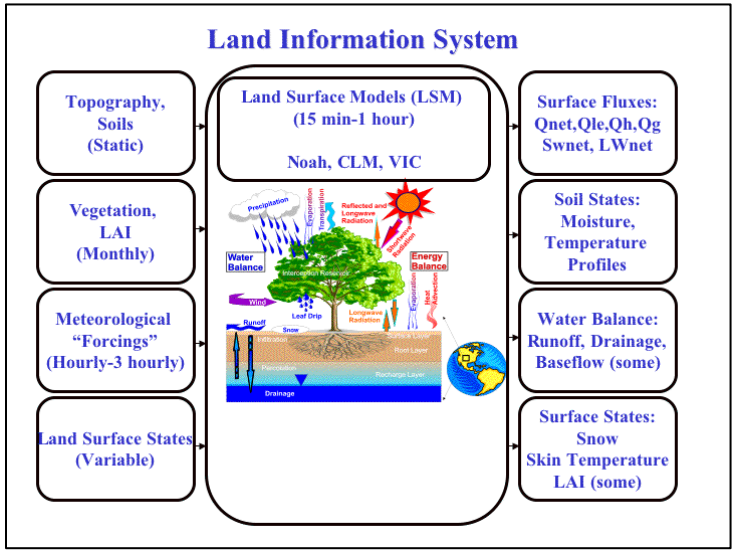


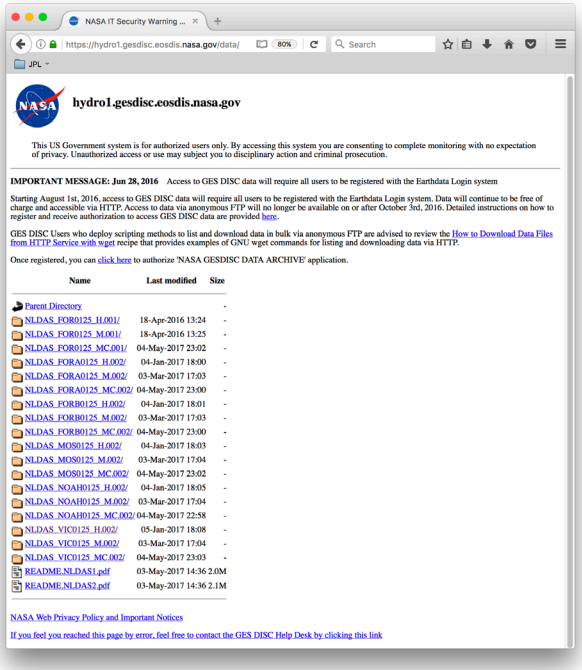
VIC



CLM

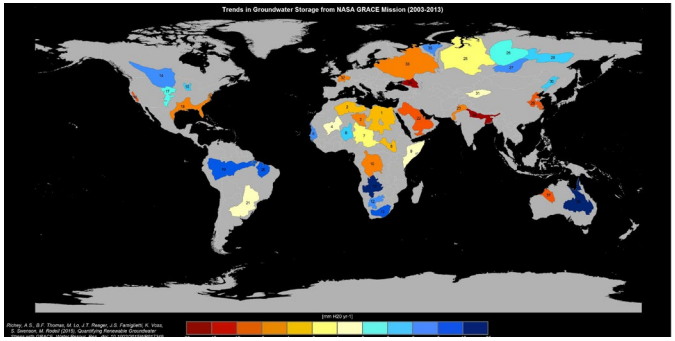
NASA's Land Information System (GSFC)

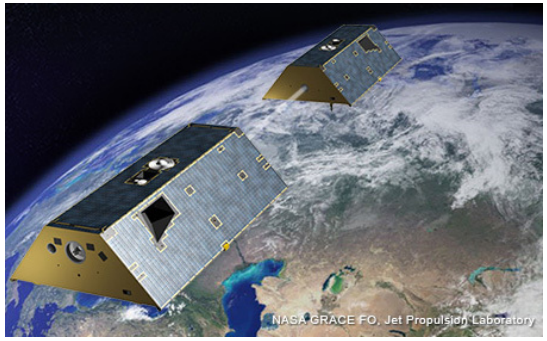


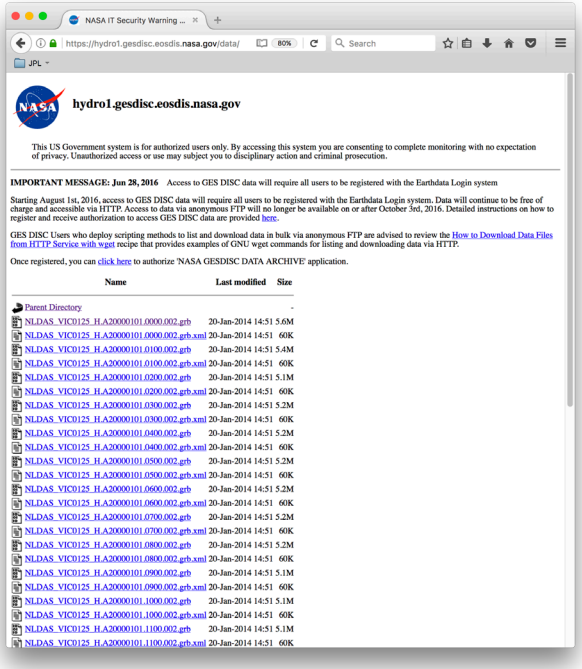


Available on Goddard's DAAC (GES DISC)

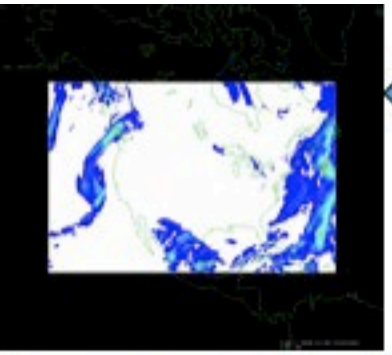
… is a crucial component of GRACE studies



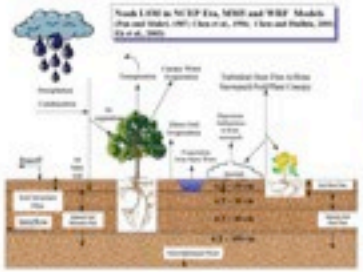




A similar system can be built with multiple river/lake models for SWOT…



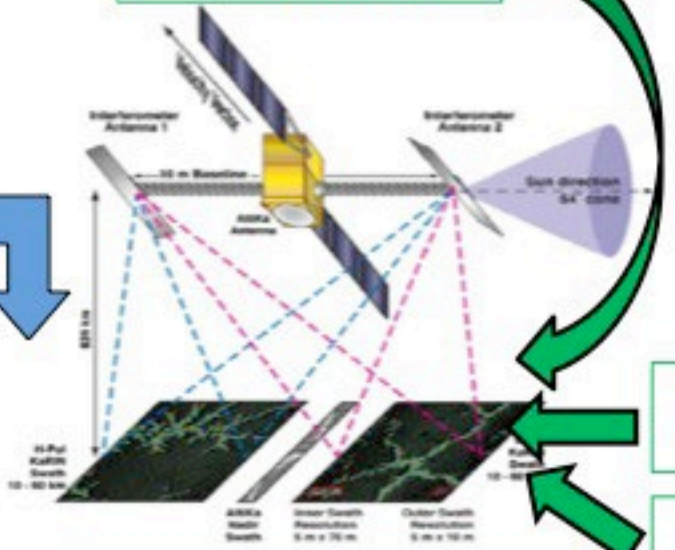
Atmospheric Model or Dataset



Land Surface Model

NASA's Land Data Assimilation System

Airborne Observations



In situ Observations

Mapped hydrography (HydroSHEDS, NARwidth)

Routing Models for Rivers and Reservoirs (CaMa-Flood, HRR, ISBA-TRIP, LISFLOOD, RAPID, WATFLOOD)

Thanks!
Questions?