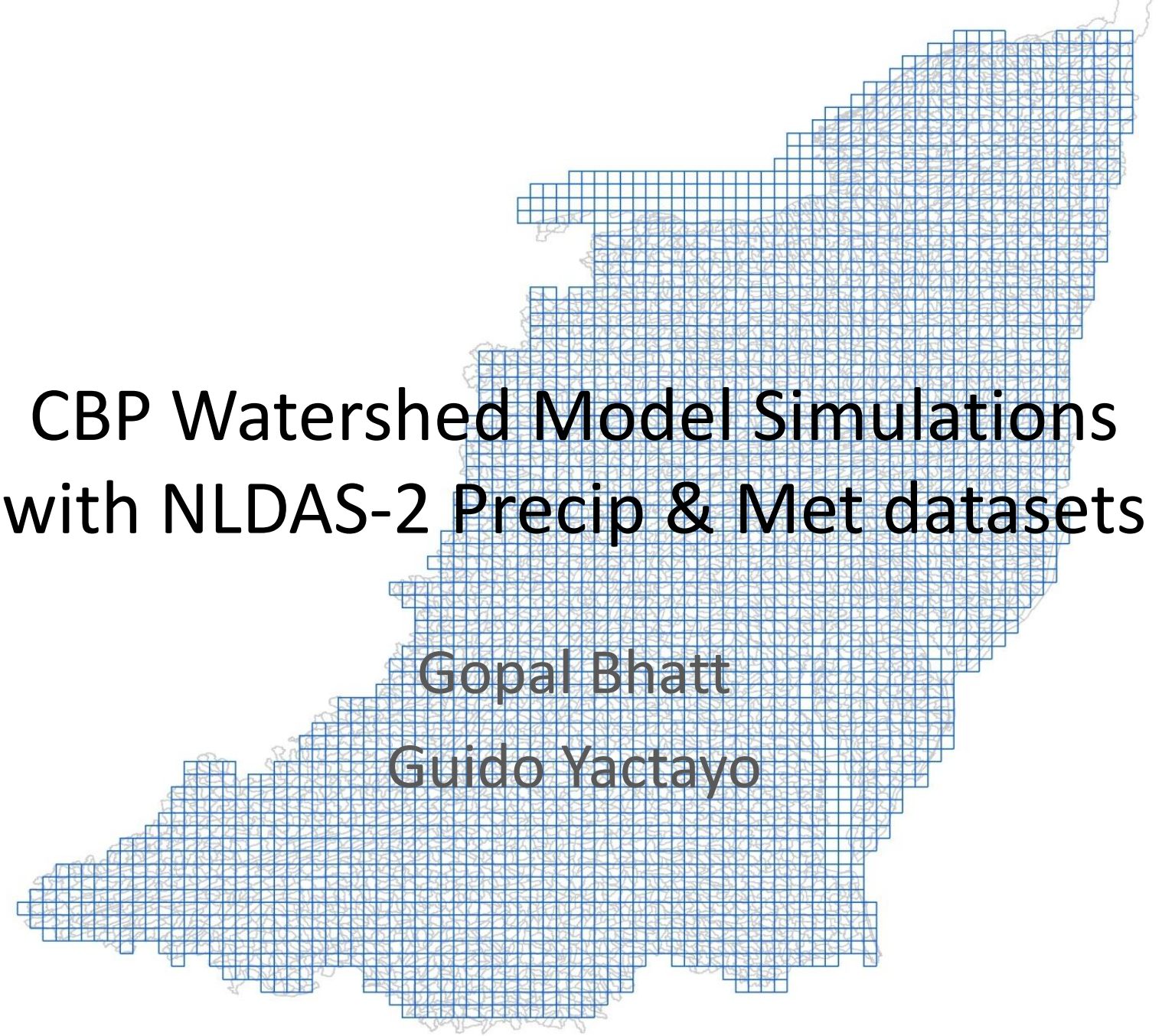
1. CBP Watershed Model Simulations with NLDAS-2 Precip & Met datasets

2. Development of a Large-scale Application of Physics-based Distributed Hydrologic Model



CBP Watershed Model Simulations with NLDAS-2 Precip & Met datasets

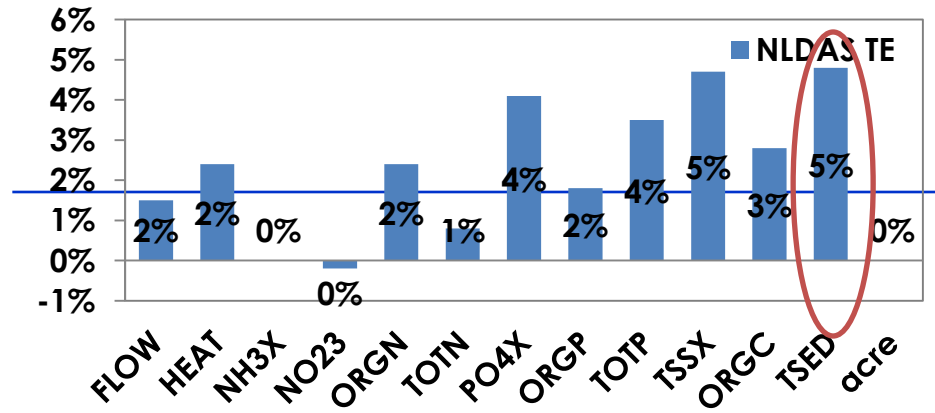
Gopal Bhatt

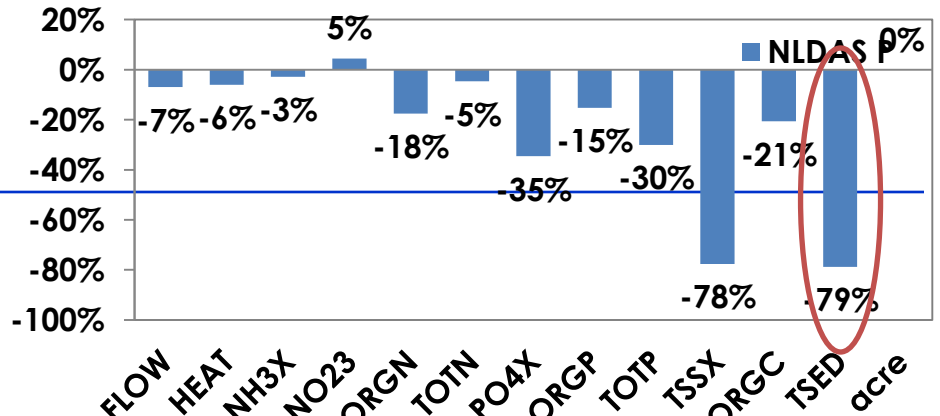
Guido Yactayo

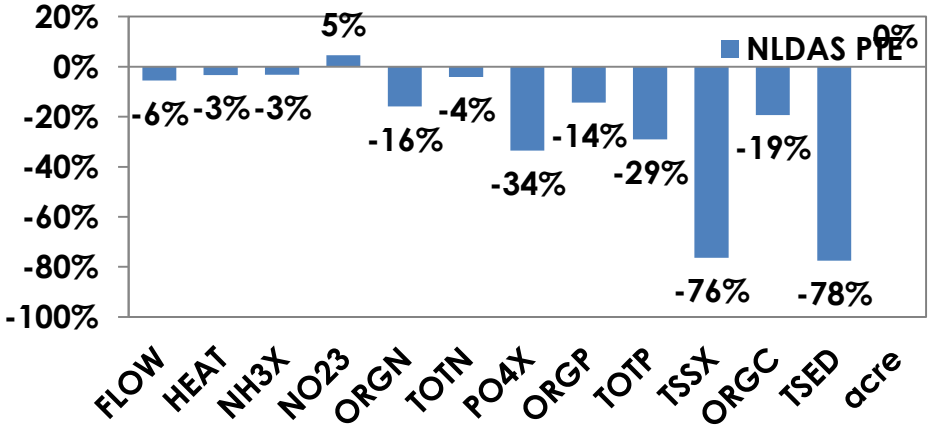
Simulation	Description
P532 Calib	Current generation using XYZ based space-time interpolation
NLDAS TE	P532 with NLDAS-2 **Temperature** & **PET *** estimates using Hamon Method
NLDAS P	P532 with NLDAS-2 Climate Reanalysis **Precipitation**
NLDAS PTE	P532 with NLDAS-2 **Precipitation**, **Temperature**, Pot. **Evapotranspiration ***
NLDAS PTERW	P532 with NLDAS-2 PTE + **Solar Radiation**, **Wind Speed**
NLDAS PTERWD	P532 with NLDAS-2 PTERW + **Dew Point Temperature ***
NLDAS PTERWDC	P532 with NLDAS-2 PTERWD + **Cloud Cover ***

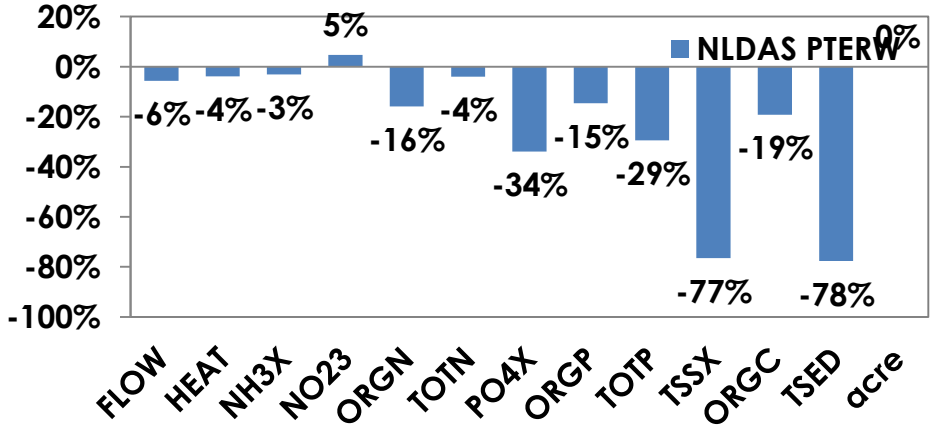
* Derived data products computed using appropriate equations

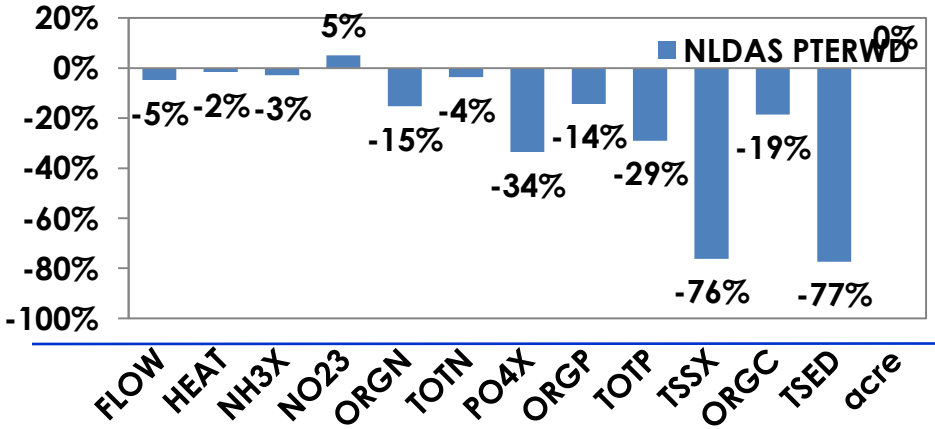
Delivered Loads

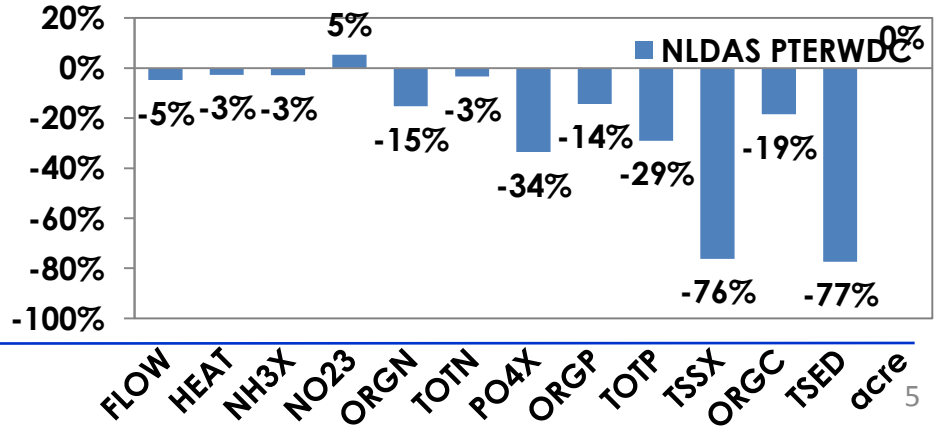

NLDAS TE
6%
5%
4%
3%
2%
1%
0%
-1%
2% 2% 0% 0% 2% 1% 4% 2% 4% 5% 3% 5% 0%
FLOW HEAT NH3X NO23 ORGN TOTN PO4X ORGP TOTP TSSX ORGC TSED acre


NLDAS P
20%
0%
-20%
-40%
-60%
-80%
-100%
-7% -6% -3% 5% -18% -5% -35% -15% -30% -78% -21% -79% 0%
FLOW HEAT NH3X NO23 ORGN TOTN PO4X ORGP TOTP TSSX ORGC TSED acre

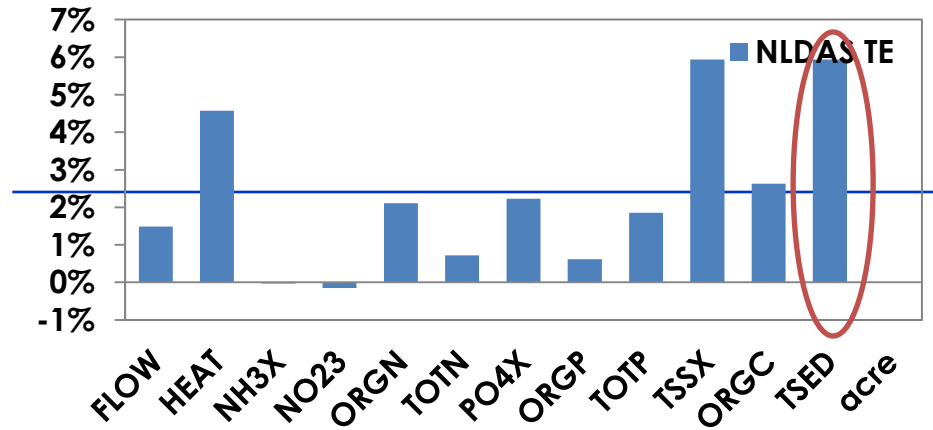

NLDAS PTE
20%
0%
-20%
-40%
-60%
-80%
-100%
-6% -3% -3% 5% -16% -4% -34% -14% -29% -76% -19% -78% 0%
FLOW HEAT NH3X NO23 ORGN TOTN PO4X ORGP TOTP TSSX ORGC TSED acre

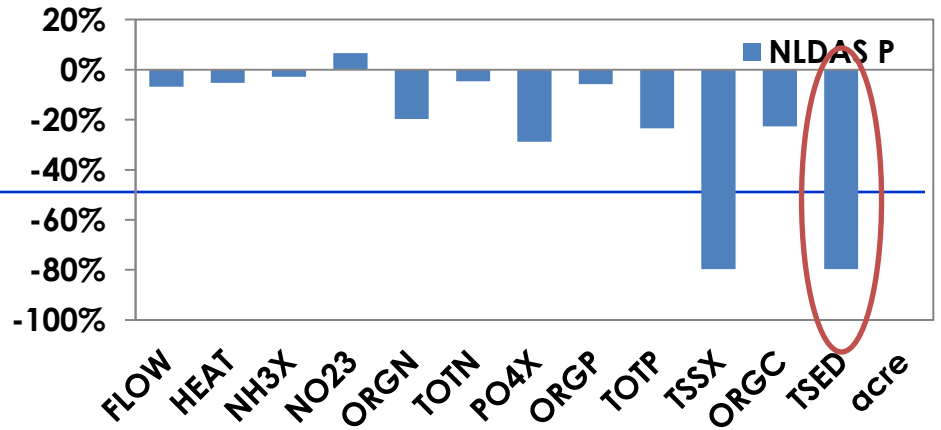

NLDAS PTERW
20%
0%
-20%
-40%
-60%
-80%
-100%
-6% -4% -3% 5% -16% -4% -34% -15% -29% -77% -19% -78% 0%
FLOW HEAT NH3X NO23 ORGN TOTN PO4X ORGP TOTP TSSX ORGC TSED acre

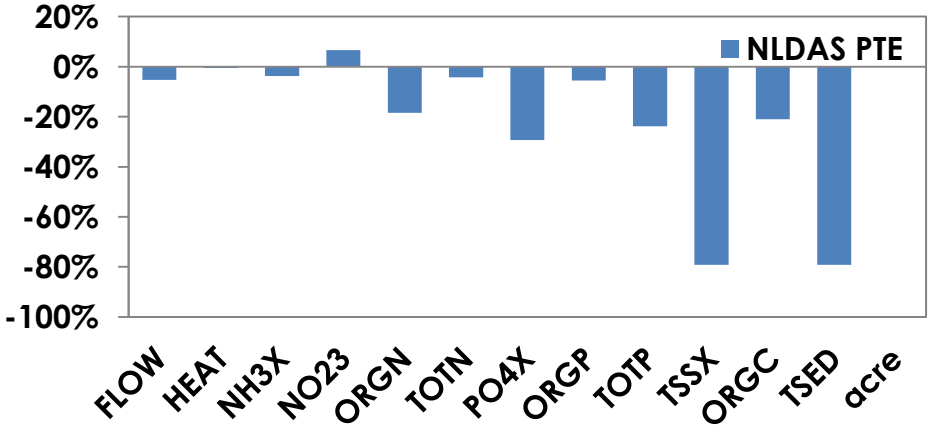

NLDAS PTERWD
20%
0%
-20%
-40%
-60%
-80%
-100%
-5% -2% -3% 5% -15% -4% -34% -14% -29% -76% -19% -77% 0%
FLOW HEAT NH3X NO23 ORGN TOTN PO4X ORGP TOTP TSSX ORGC TSED acre

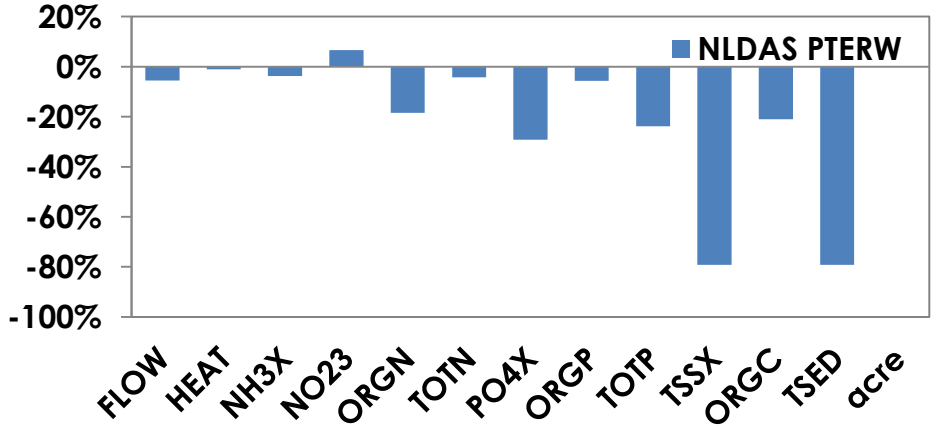

NLDAS PTERWDC
20%
0%
-20%
-40%
-60%
-80%
-100%
-5% -3% -3% 5% -15% -3% -34% -14% -29% -76% -19% -77% 0%
FLOW HEAT NH3X NO23 ORGN TOTN PO4X ORGP TOTP TSSX ORGC TSED acre

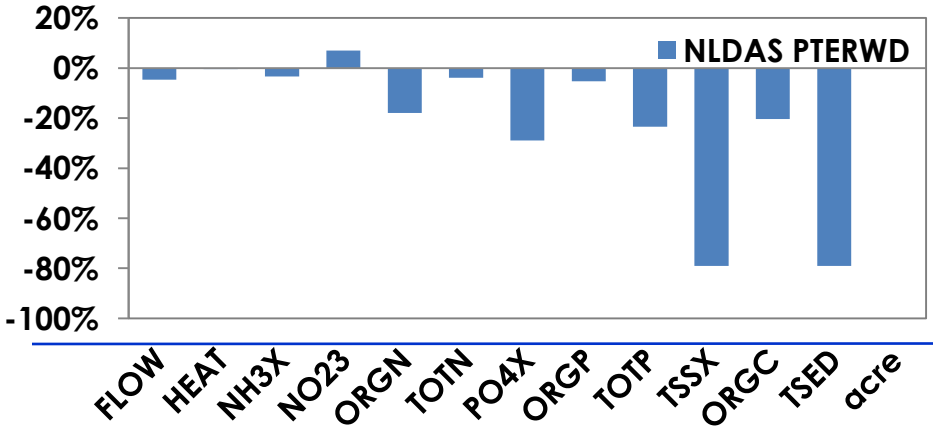
Edge of Stream Loads

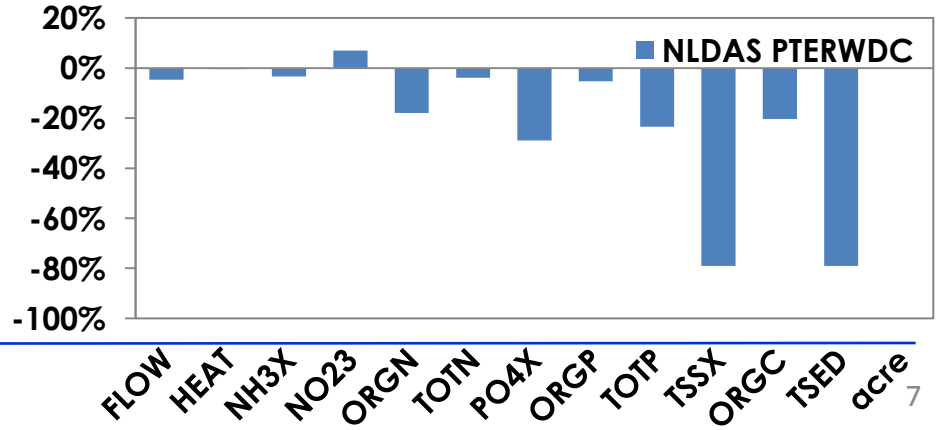

NLDAS TE
7%
6%
5%
4%
3%
2%
1%
0%
-1%
FLOW
HEAT
NH3X
NO23
ORGN
TOTN
PO4X
ORGP
TOTP
TSSX
ORGC
TSED
acre


NLDAS P
20%
0%
-20%
-40%
-60%
-80%
-100%
FLOW
HEAT
NH3X
NO23
ORGN
TOTN
PO4X
ORGP
TOTP
TSSX
ORGC
TSED
acre

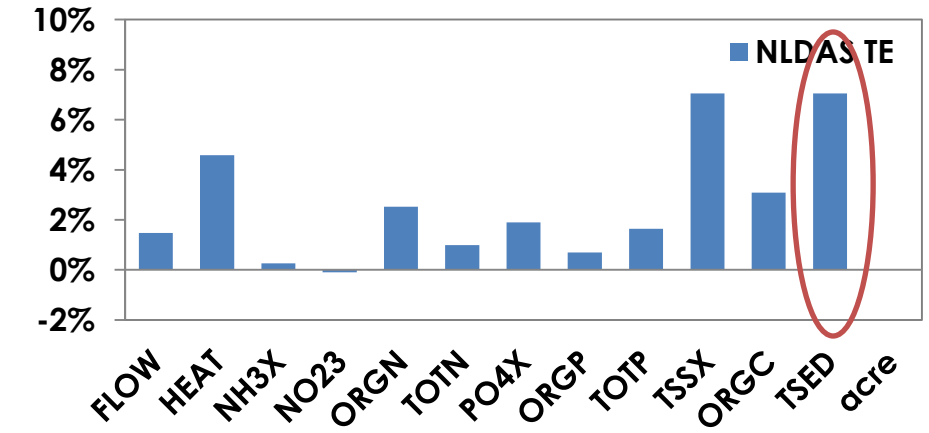

NLDAS PTE
20%
0%
-20%
-40%
-60%
-80%
-100%
FLOW
HEAT
NH3X
NO23
ORGN
TOTN
PO4X
ORGP
TOTP
TSSX
ORGC
TSED
acre

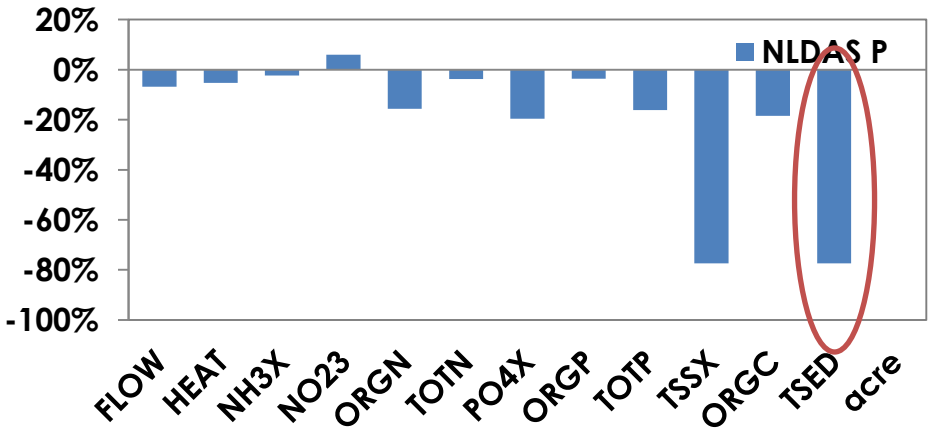

NLDAS PTERW
20%
0%
-20%
-40%
-60%
-80%
-100%
FLOW
HEAT
NH3X
NO23
ORGN
TOTN
PO4X
ORGP
TOTP
TSSX
ORGC
TSED
acre


NLDAS PTERWD
20%
0%
-20%
-40%
-60%
-80%
-100%
FLOW
HEAT
NH3X
NO23
ORGN
TOTN
PO4X
ORGP
TOTP
TSSX
ORGC
TSED
acre


NLDAS PTERWDC
20%
0%
-20%
-40%
-60%
-80%
-100%
FLOW
HEAT
NH3X
NO23
ORGN
TOTN
PO4X
ORGP
TOTP
TSSX
ORGC
TSED
acre

Edge of Field Loads


NLDAS TE
10%
8%
6%
4%
2%
0%
-2%
FLOW
HEAT
NH3X
NO23
ORGN
TOTN
PO4X
ORGP
TOTP
TSSX
ORGC
TSED
acre


NLDAS P
20%
0%
-20%
-40%
-60%
-80%
-100%
FLOW
HEAT
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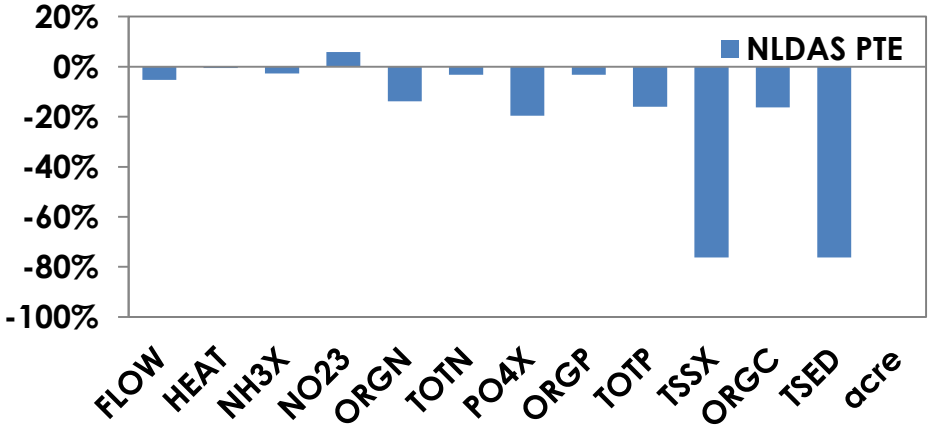
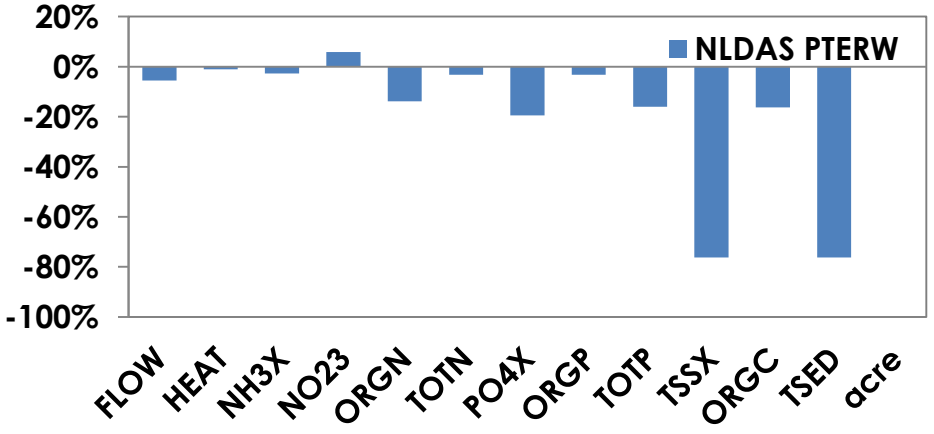
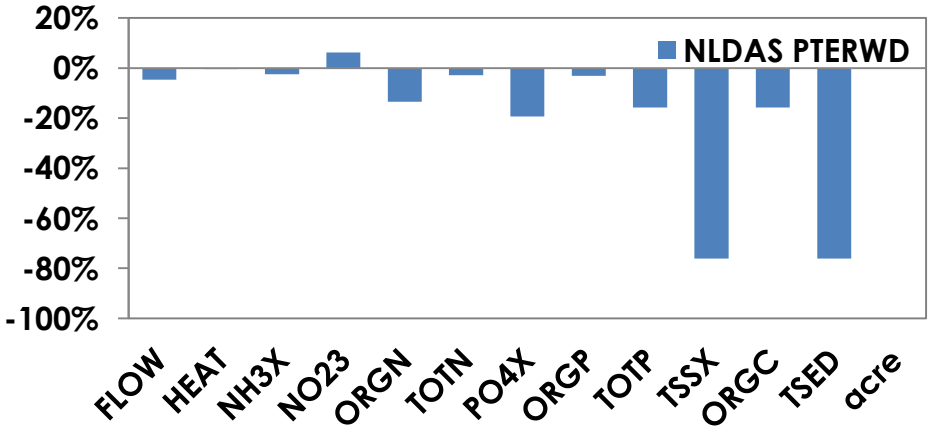
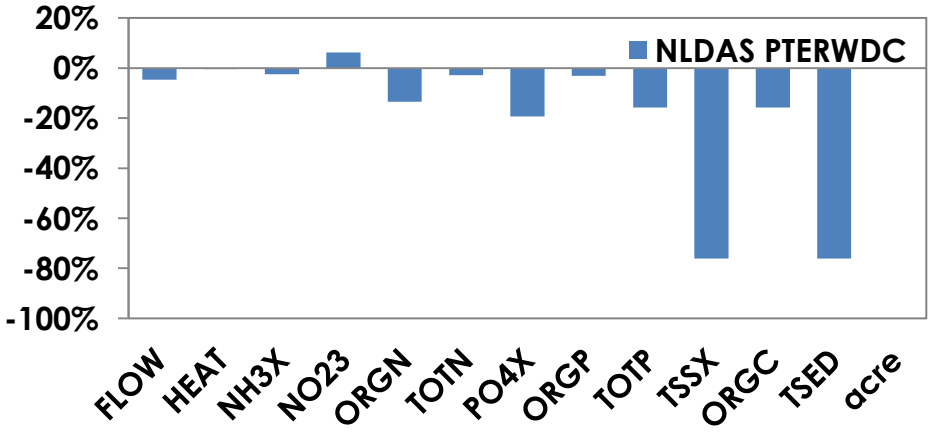
NO23
ORGN
TOTN
PO4X
ORGP
TOTP
TSSX
ORGC
TSED
acre


NLDAS PTE
20%
0%
-20%
-40%
-60%
-80%
-100%
FLOW
HEAT
NH3X
NO23
ORGN
TOTN
PO4X
ORGP
TOTP
TSSX
ORGC
TSED
acre

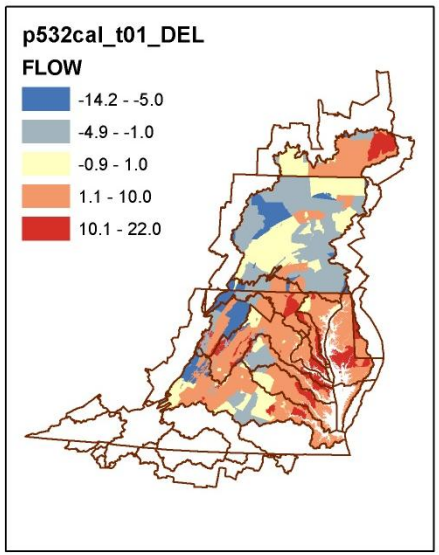

NLDAS PTERW
20%
0%
-20%
-40%
-60%
-80%
-100%
FLOW
HEAT
NH3X
NO23
ORGN
TOTN
PO4X
ORGP
TOTP
TSSX
ORGC
TSED
acre

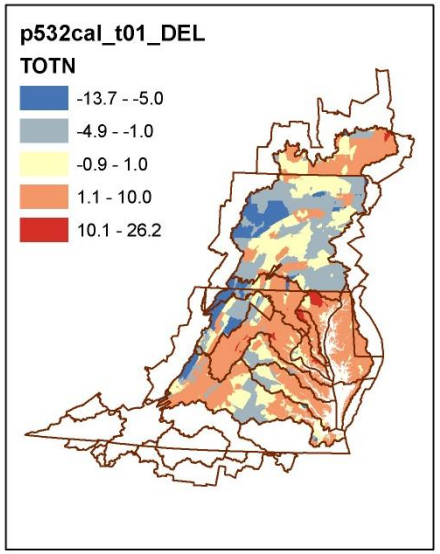

NLDAS PTERWD
20%
0%
-20%
-40%
-60%
-80%
-100%
FLOW
HEAT
NH3X
NO23
ORGN
TOTN
PO4X
ORGP
TOTP
TSSX
ORGC
TSED
acre

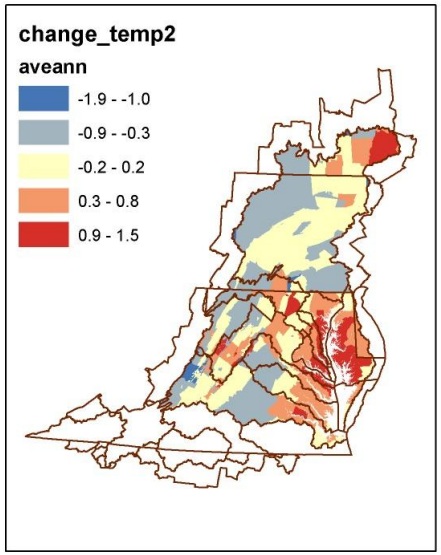

NLDAS PTERWDC
20%
0%
-20%
-40%
-60%
-80%
-100%
FLOW
HEAT
NH3X
NO23
ORGN
TOTN
PO4X
ORGP
TOTP
TSSX
ORGC
TSED
acre

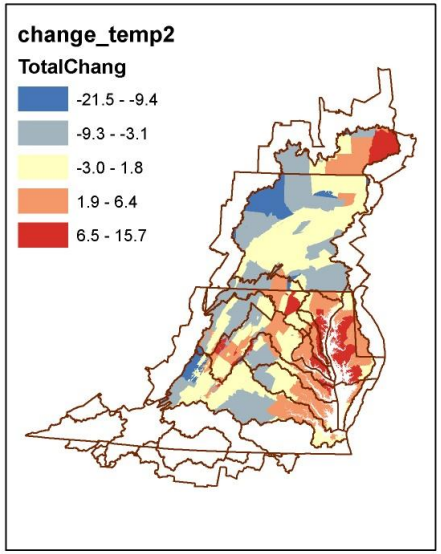
f (NLDAS-TE – P532)
f (NLDAS2 – XYZ)

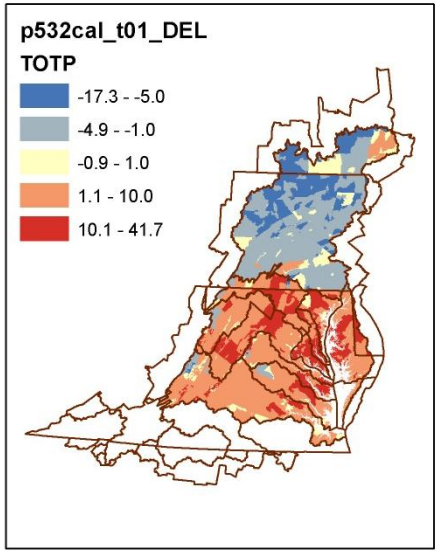
Temp (XYZ – NLDAS2)

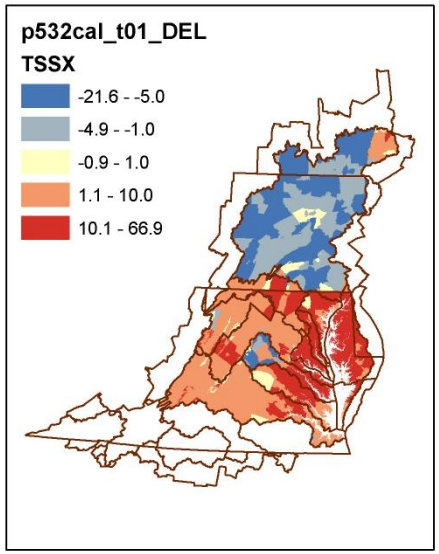


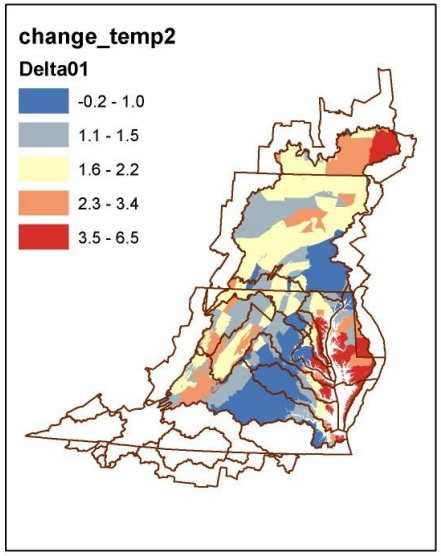


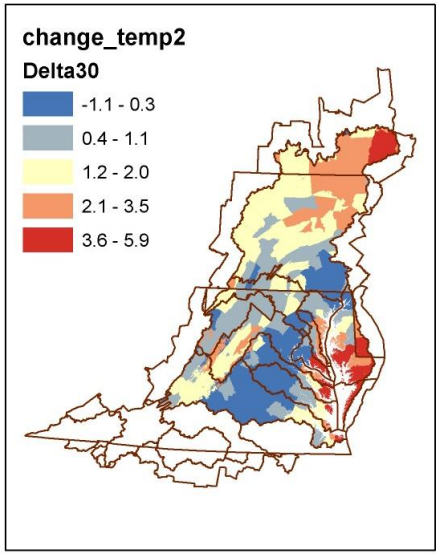






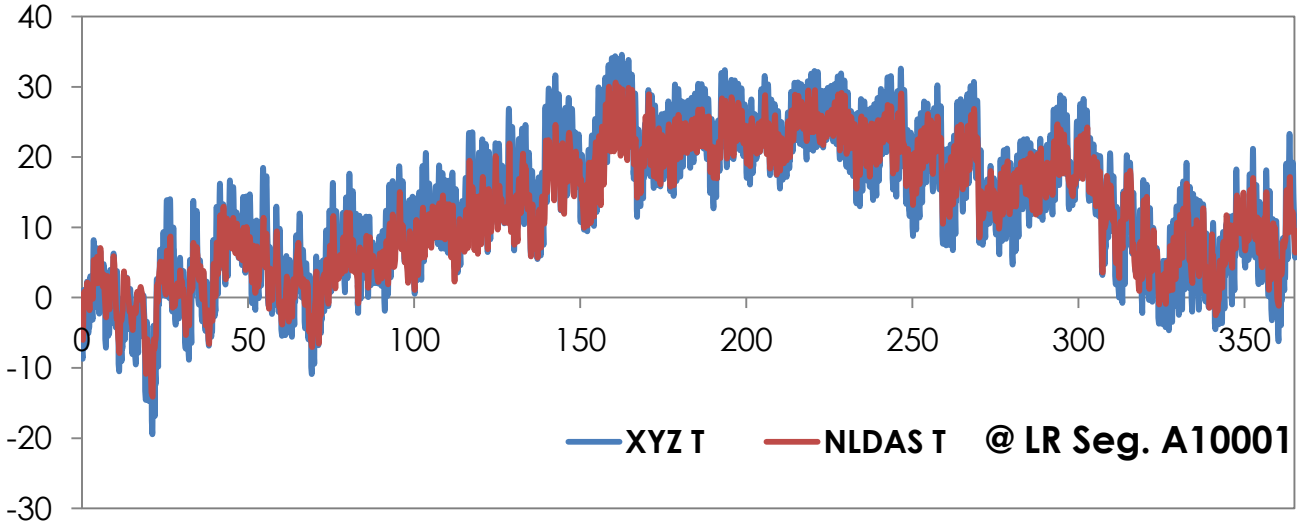


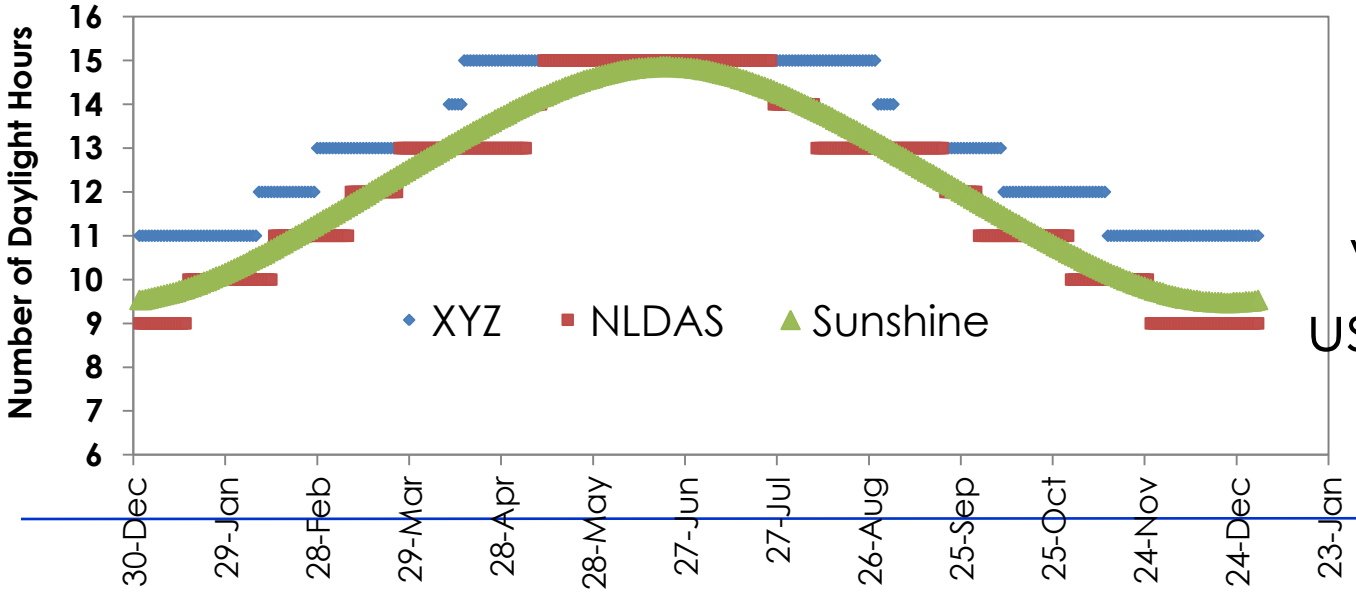




Hamon Method
Daily PET *f* (Daily T, Daylight Hours)

There is relatively small difference in the temperature data



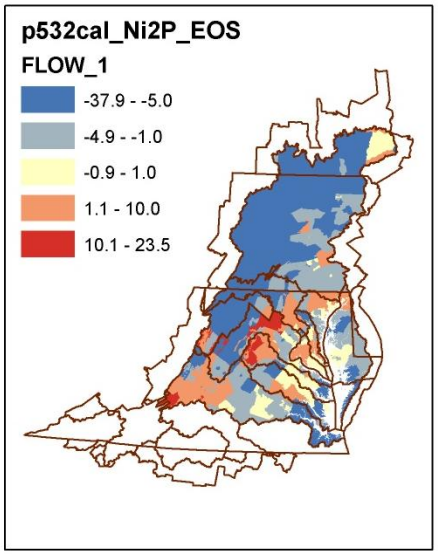


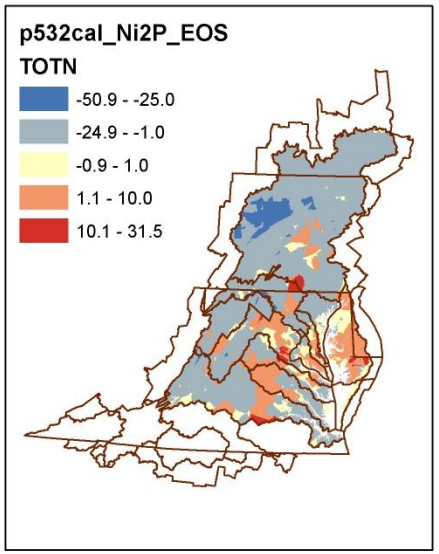
Now: Number of daylight hours were determined using NLDAS2 Solar radiation data

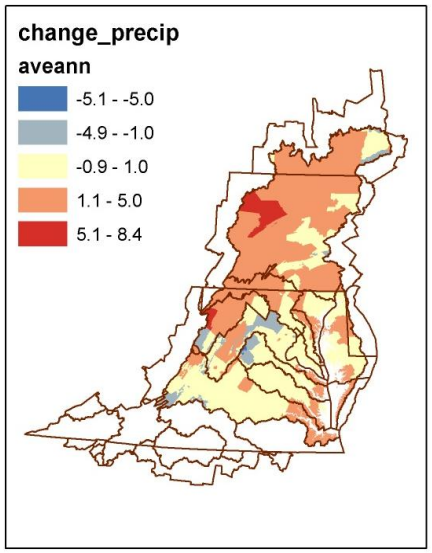
f (NLDAS-P – P532)
f (NLDAS2 – XYZ)

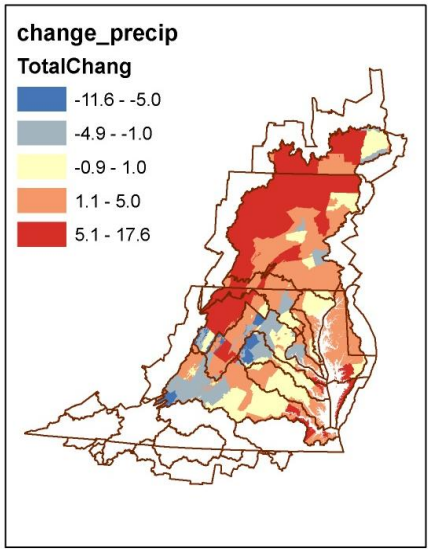
⟺

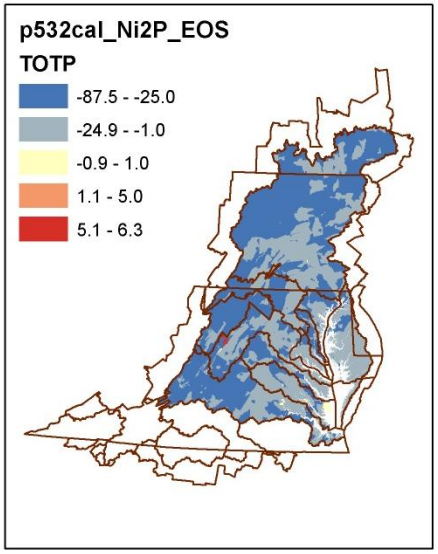
Precip (XYZ – NLDAS2)

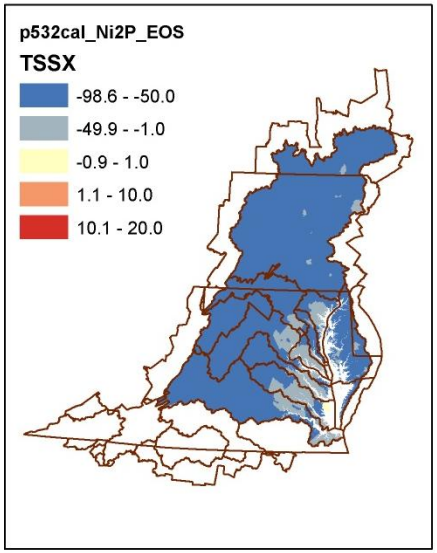


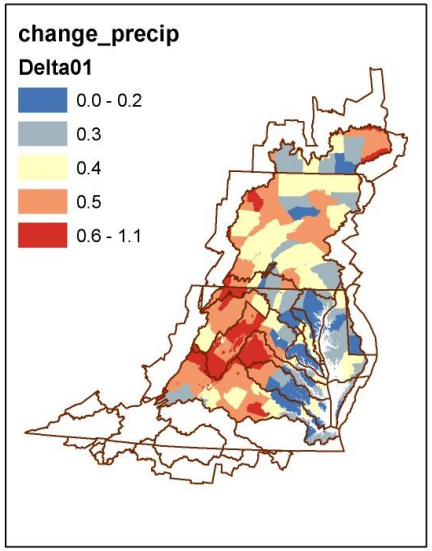


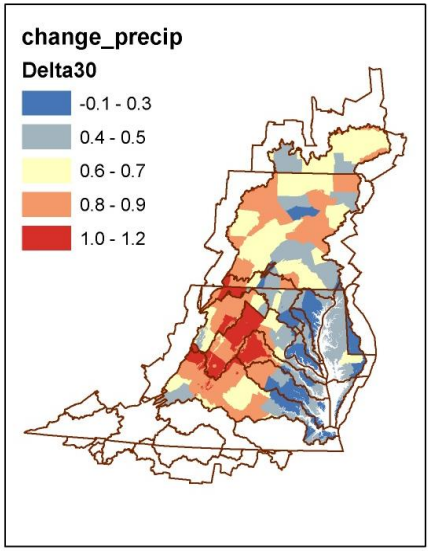


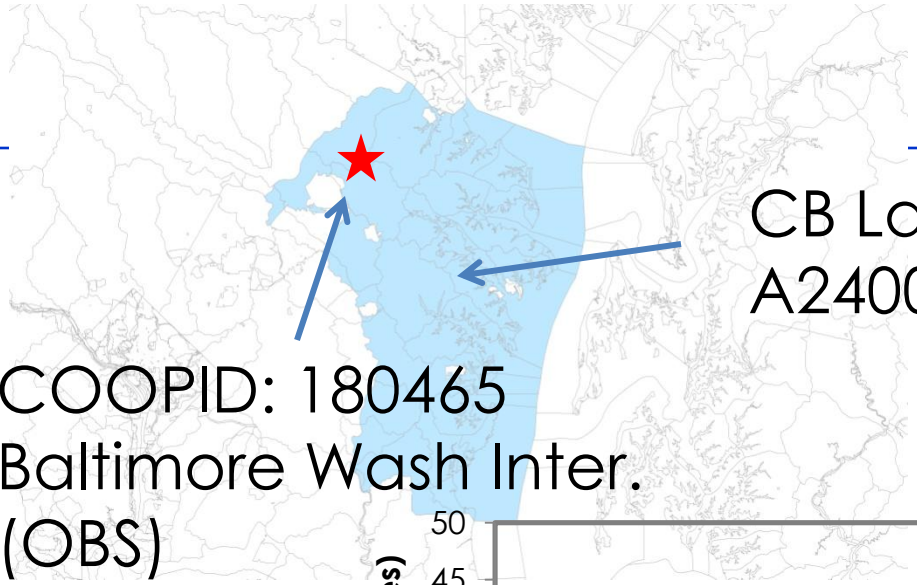






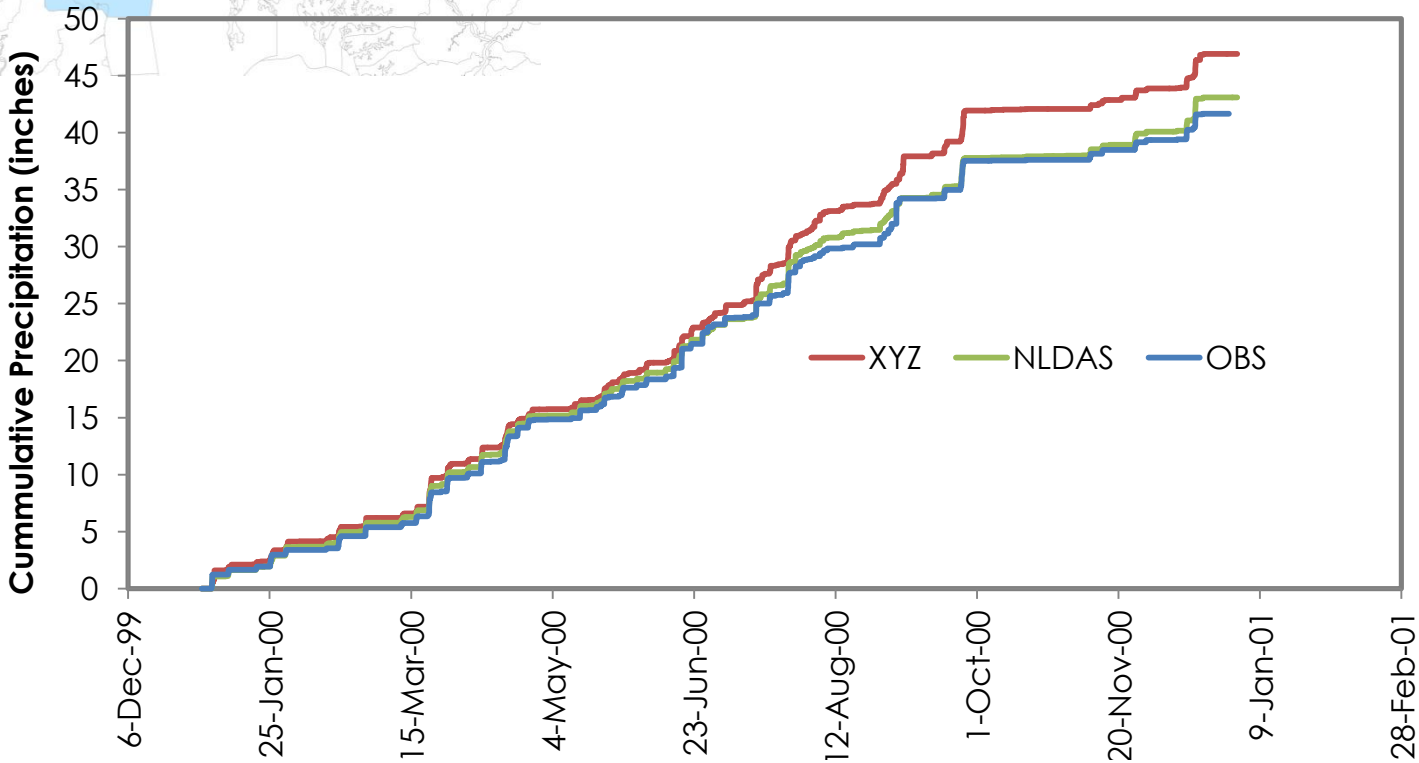


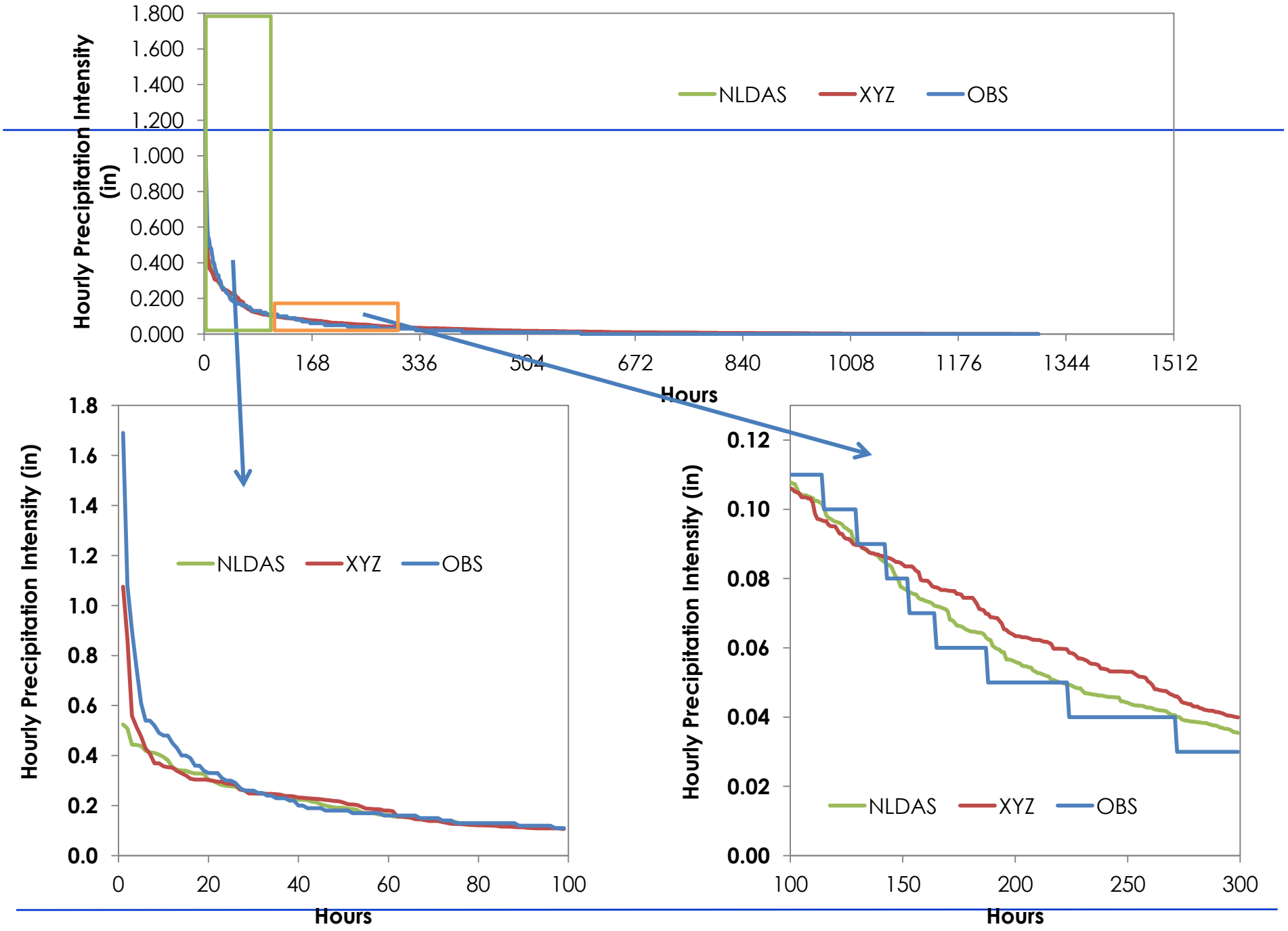




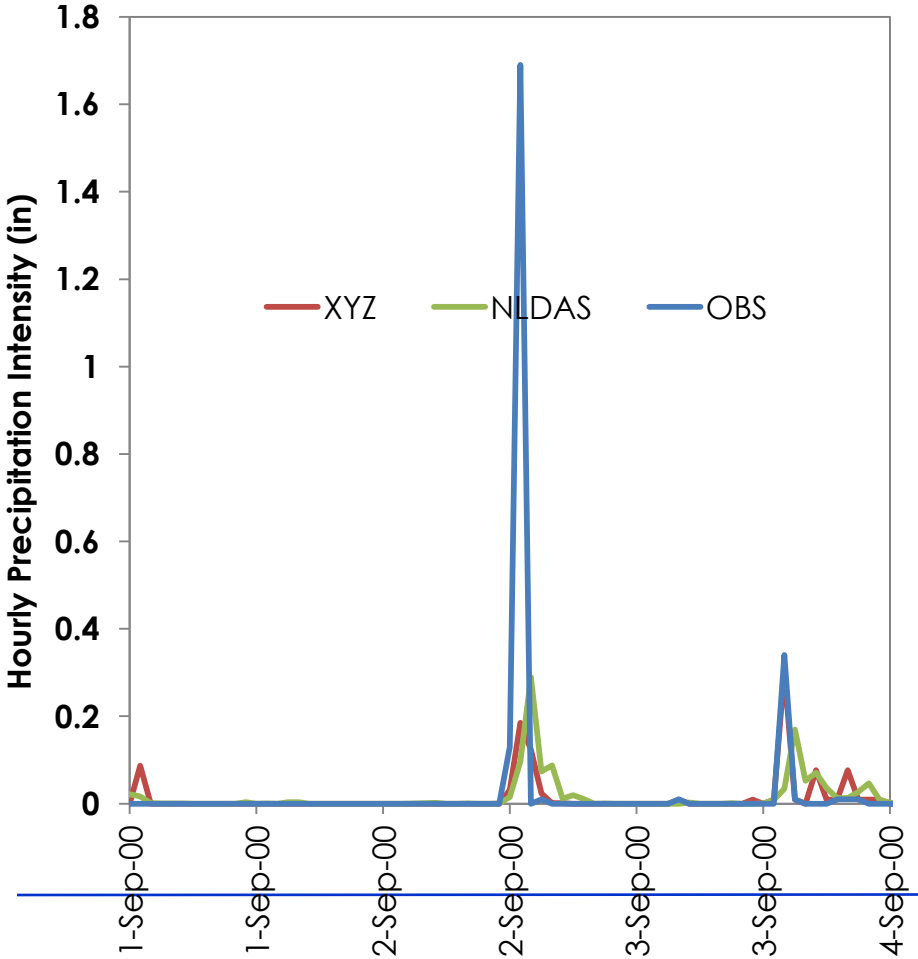
CB Land Segment
A24003 (XYZ, NLDAS)

COOPID: 180465
Baltimore Wash Inter.
(OBS)

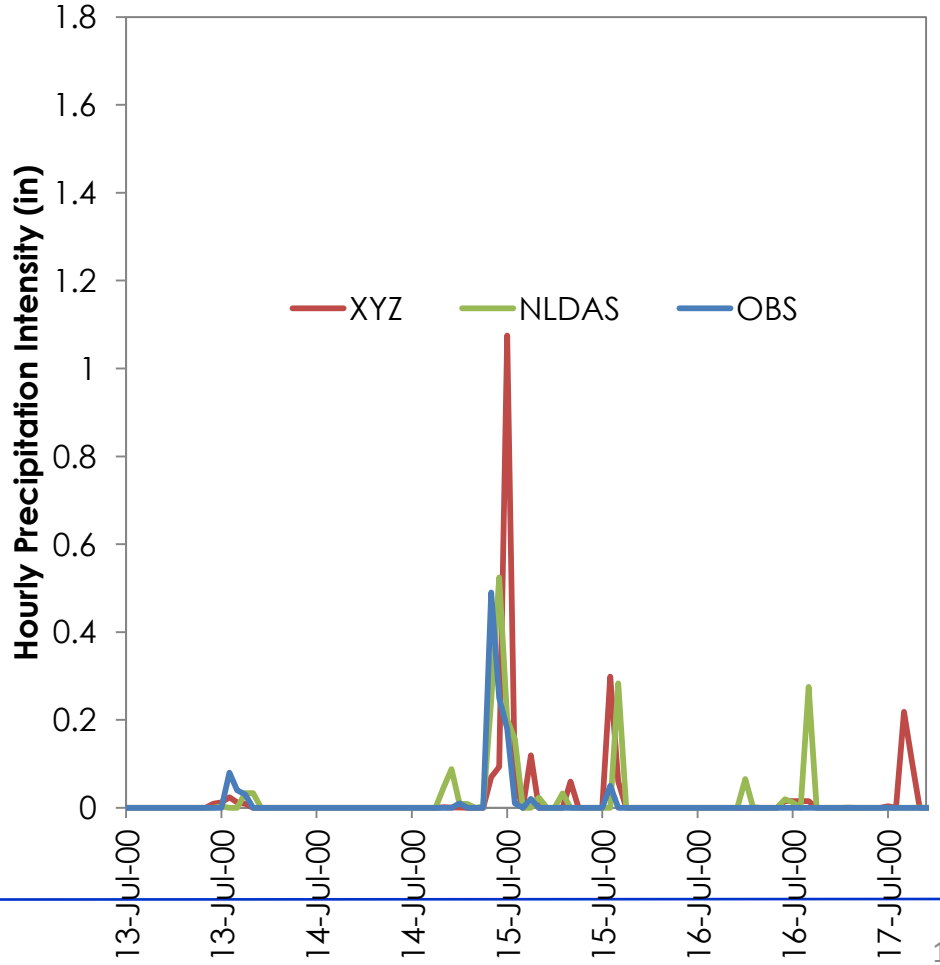



Hourly Precipitation Intensity (in)
1.800
1.600
1.400
1.200
1.000
0.800
0.600
0.400
0.200
0.000
NLDAS
XYZ
OBS
0
168
336
504
672
840
1008
1176
1344
1512
Hours
Hourly Precipitation Intensity (in)
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
NLDAS
XYZ
OBS
0
20
40
60
80
100
Hours
Hourly Precipitation Intensity (in)
0.12
0.10
0.08
0.06
0.04
0.02
0.00
NLDAS
XYZ
OBS
100
150
200
250
300
Hours

GAUGE STATION HAS THE ANNUAL MAX ON SEPT 02 2000



XYZ-METHOD HAS THE ANNUAL MAX ON JUL 05 2000



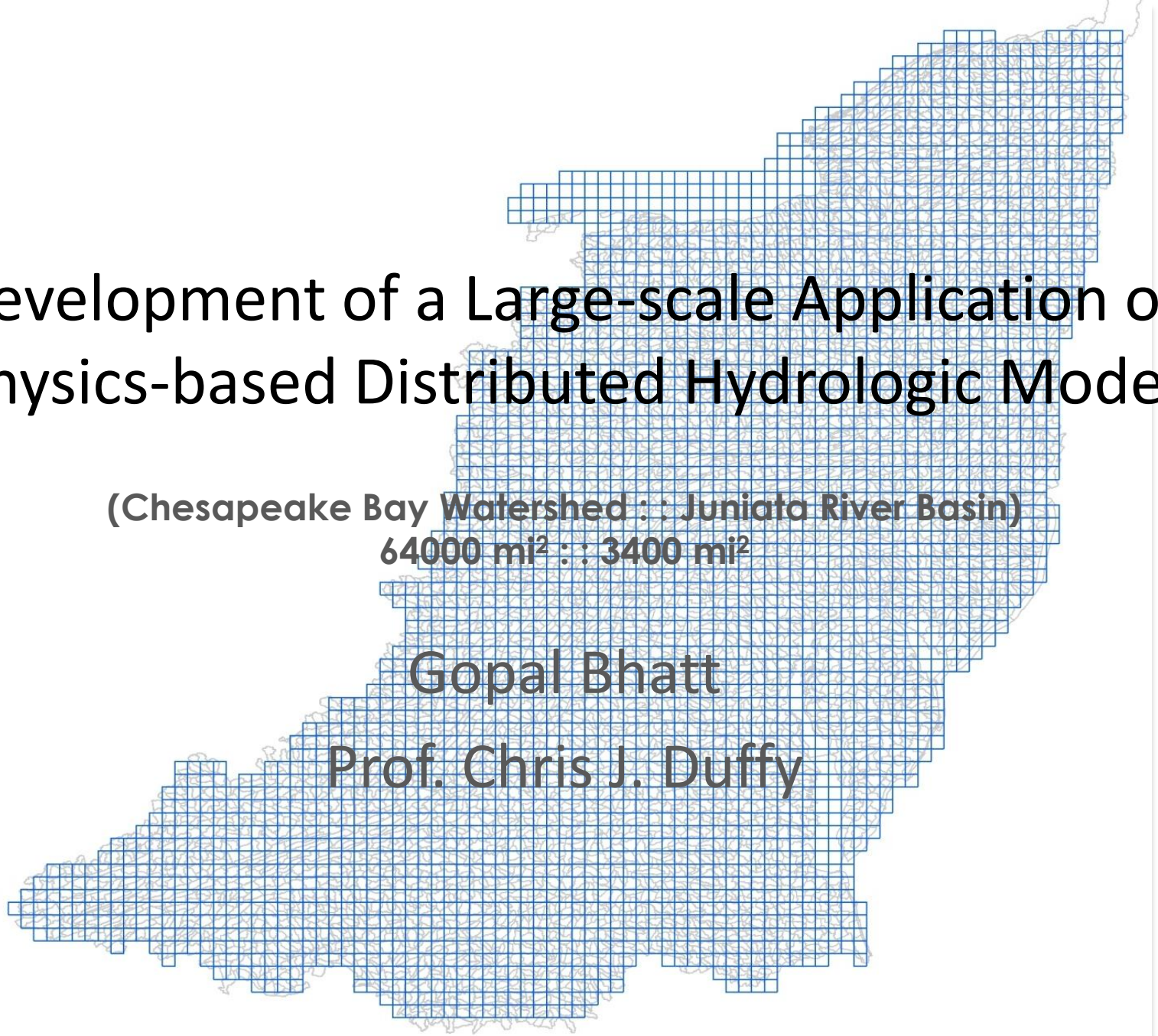
- Extended Period of Continuous forcing data (1979 – current)

NLDAS_FORA0125_H.A20120411.1200.002.grb 1850 KB 4/14/12 7:43:00 PM
NLDAS_FORA0125_H.A20120411.1200.002.grb.xml 20 KB 4/14/12 7:43:00 PM

- Incorporation of recent observations to the model calibration & validation process

- Next Step: Calibrate CBP Model with NLDAS2

Development of a Large-scale Application of Physics-based Distributed Hydrologic Model

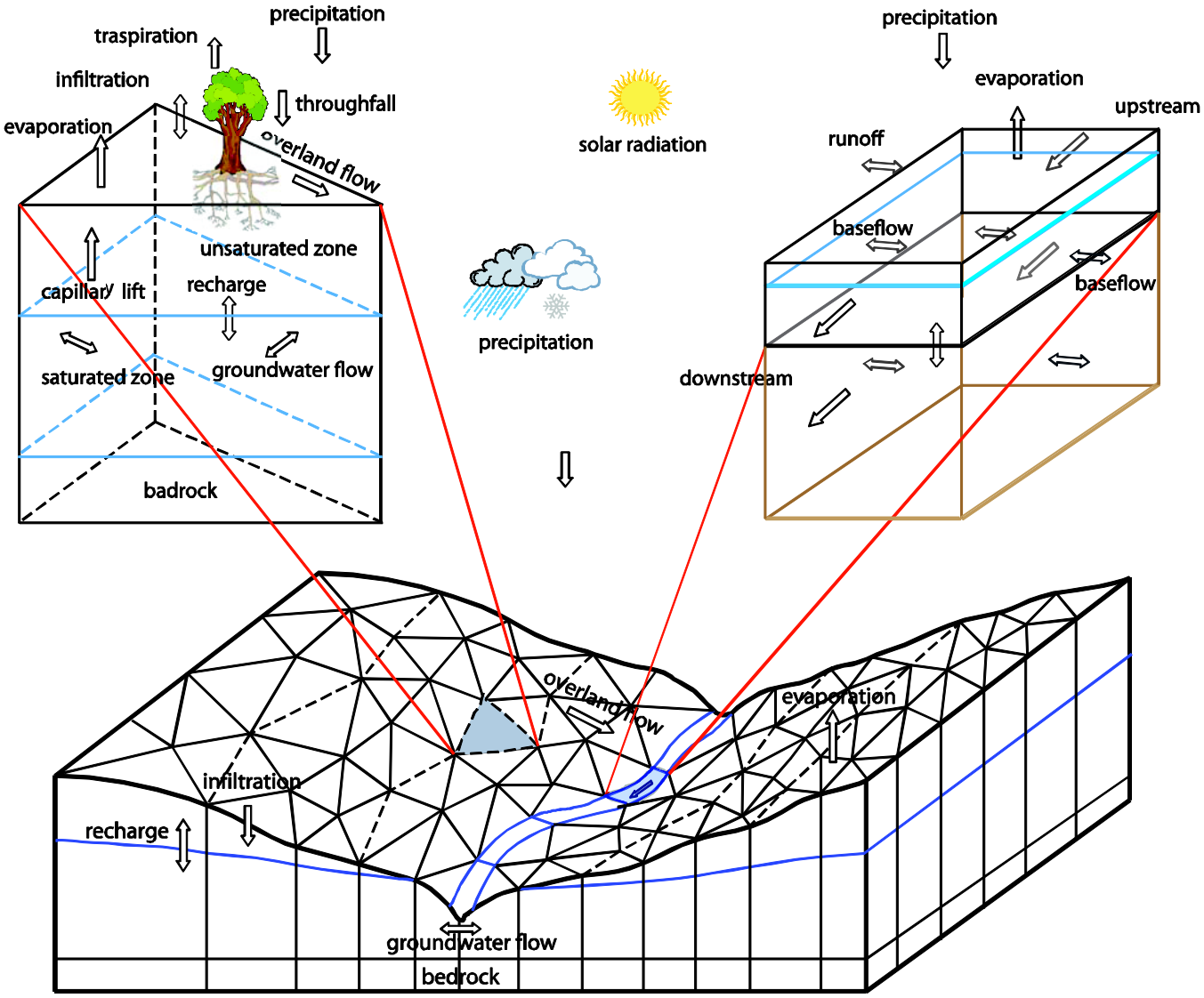


(Chesapeake Bay Watershed : : Juniata River Basin)
64000 mi^2 : : 3400 mi^2

Gopal Bhatt

Prof. Chris J. Duffy

Penn State Integrated Hydrologic Model (PIHM)



Recent Model Improvements

Complete restructuring of the model code to allow easy incorporation of new processes and updates thereafter

Full integration of topographic corrections of the triangular mesh (artifacts resulting from transformation of topographic data from Raster to Vector representation) – done manually earlier! [results in fast model prototype and simulation]

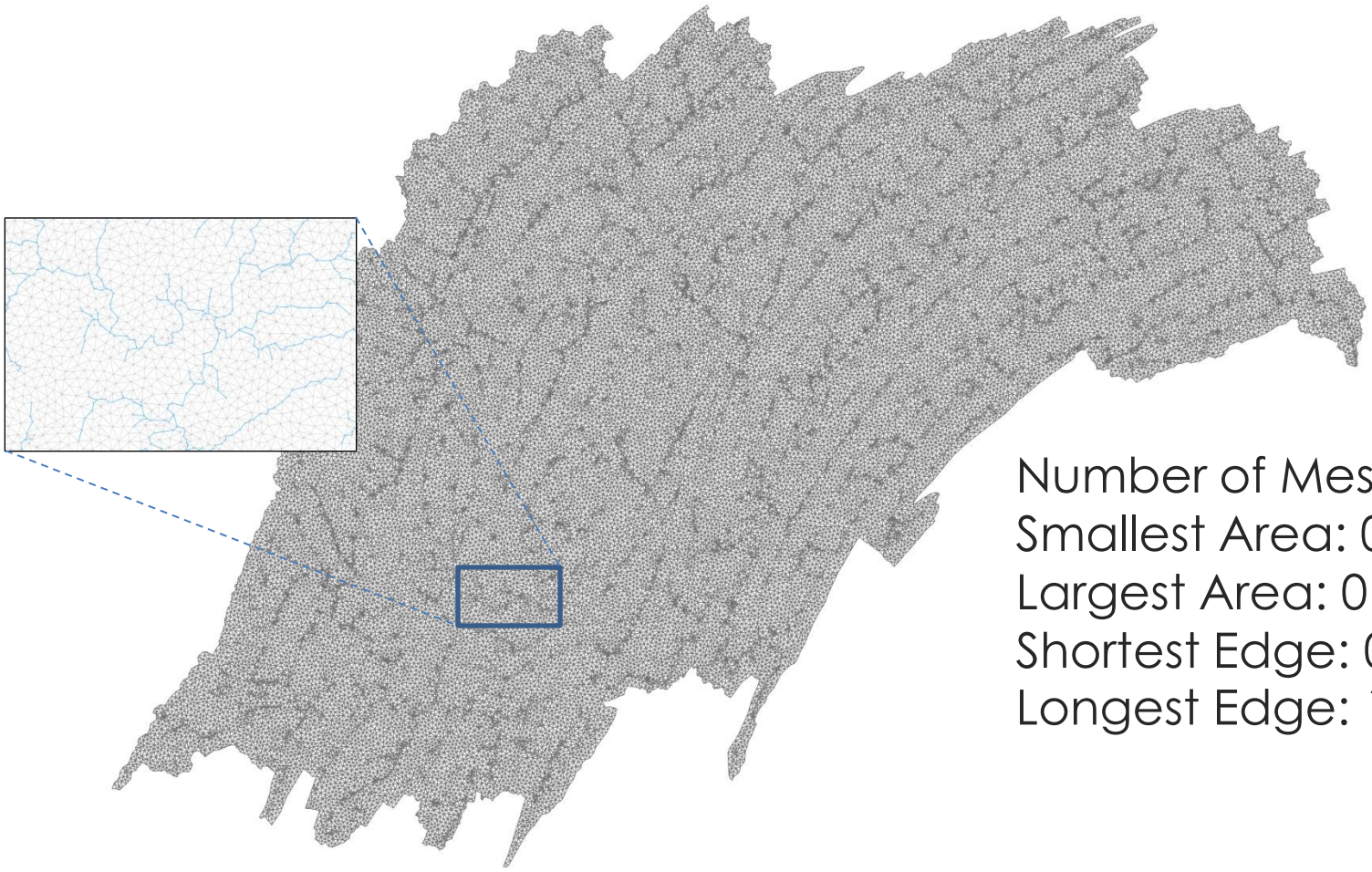
Tools to extract climate data for the region and period of interest from the NLDAS-2 national climate reanalysis product (desktop based tool)

Parallelization for large scale applications: fully synchronized distributed computing of individual sub-watersheds (partitions) and data (stream flow) communication in real-time (at user specified time interval) – code resolves all of the partition and communication information automatically

Complete integration of the ability to access and read NLDAS-2 climate files only necessary for a sub-watershed (better data storage and runtime memory management)

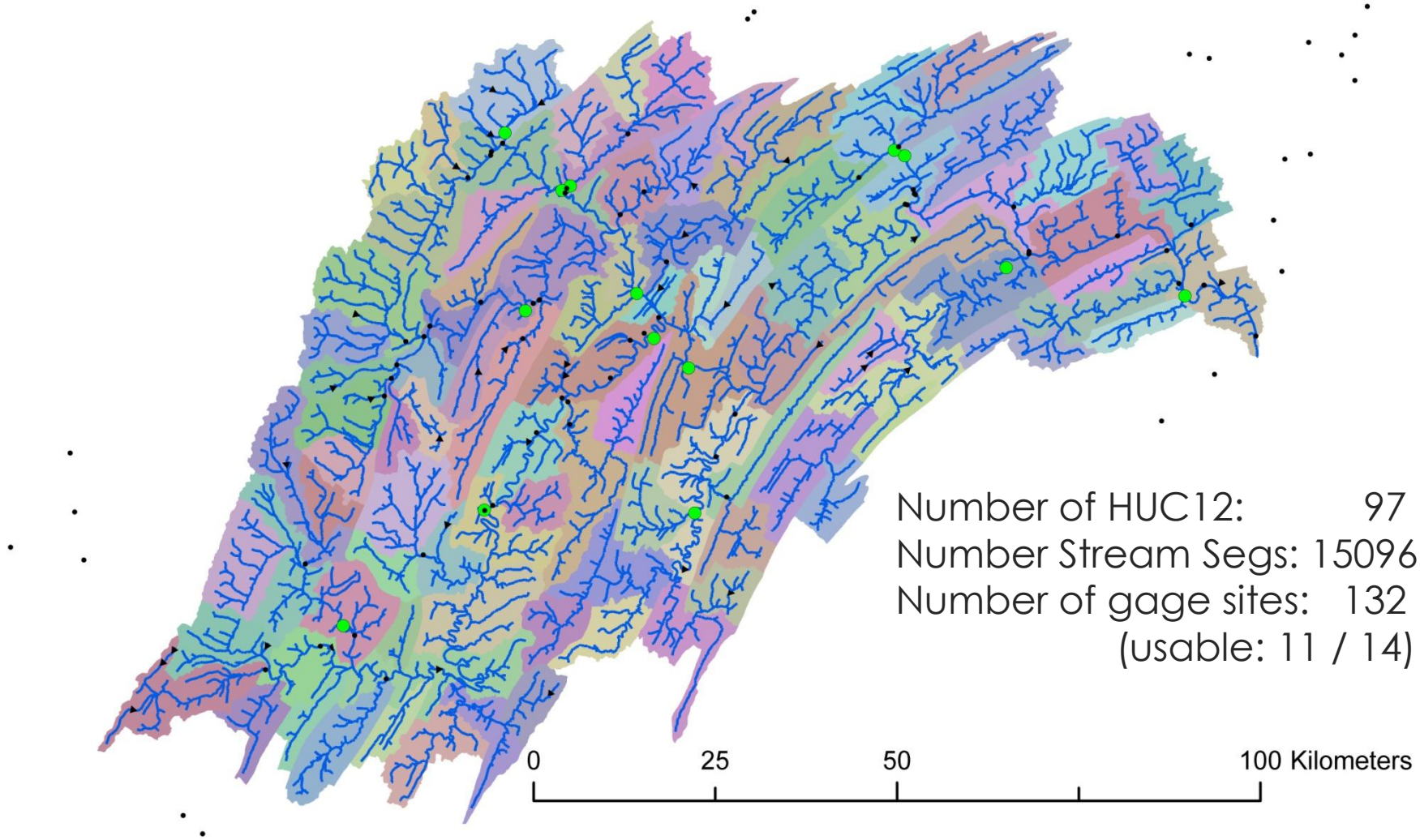
Fully integrated with the CMA-ES based PIHM calibration (Yu et. al., 2012)

Test Bed :: Juniata River :: Domain Decomposition



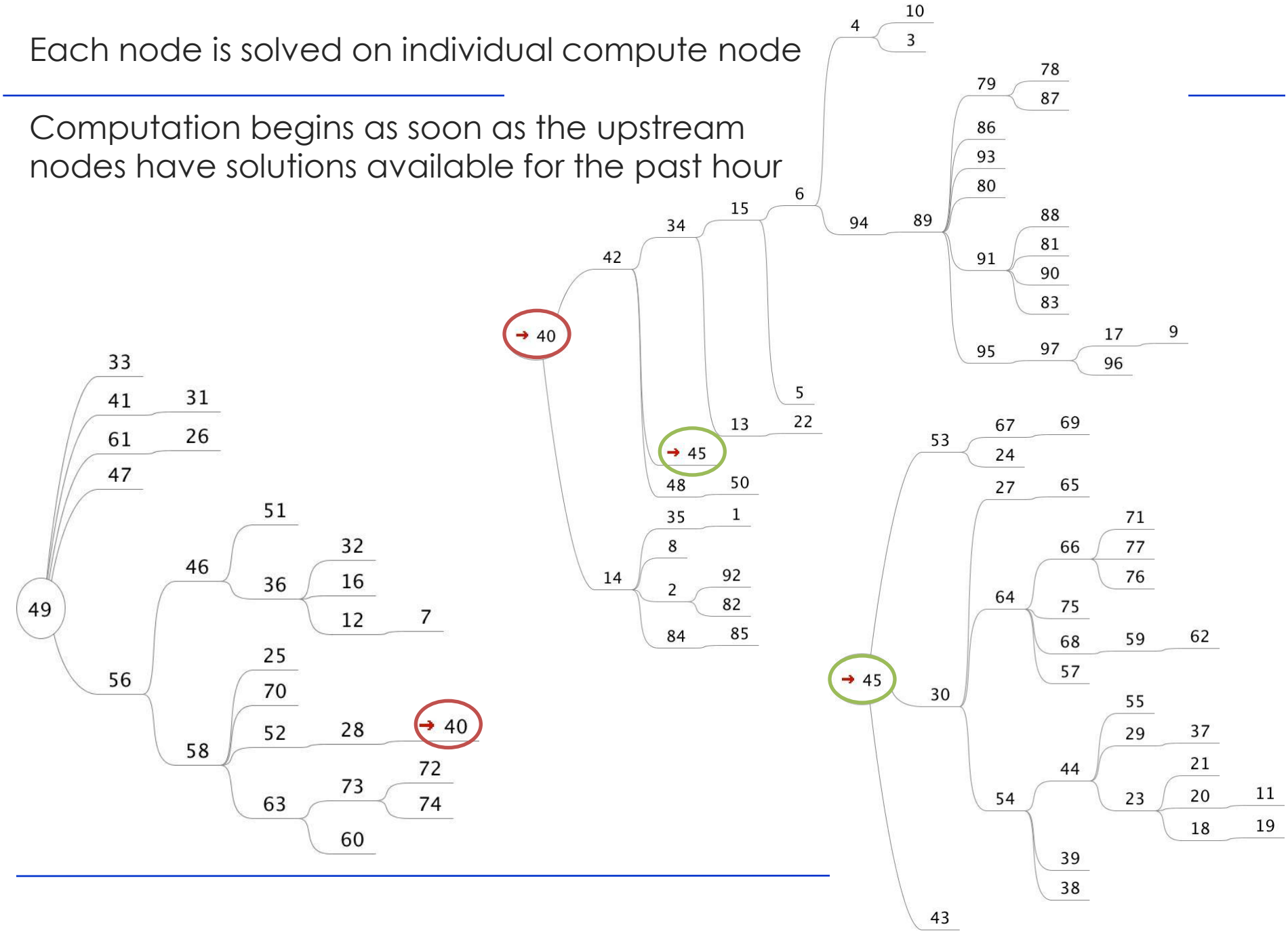
Number of Mesh: 85817
Smallest Area: 0.00096 sq. km
Largest Area: 0.02 sq. km
Shortest Edge: 0.027 km
Longest Edge: 1.360 km

NHD+ HUC-12s are used for Domain Partitioning



Each node is solved on individual compute node

Computation begins as soon as the upstream nodes have solutions available for the past hour



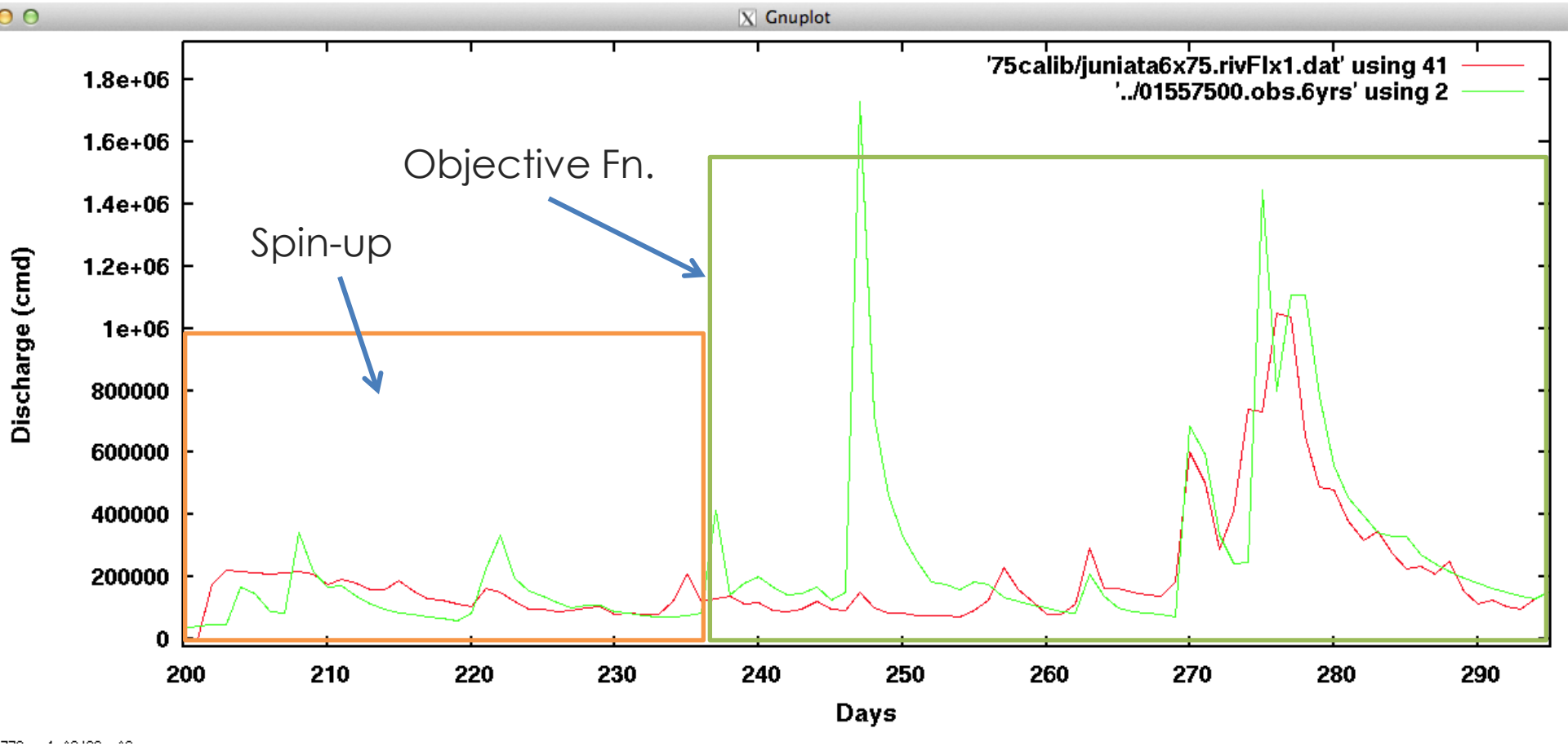
Model Calibration & Validation

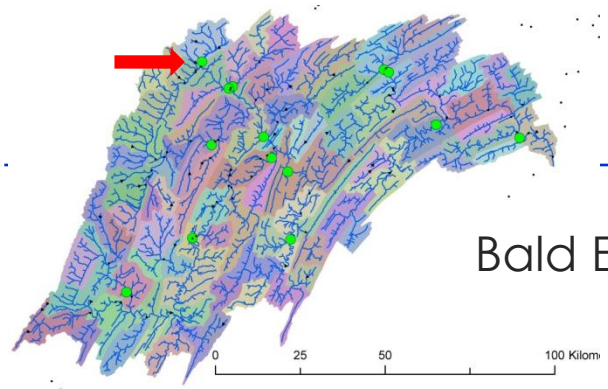
Agency	GaugeID	Gauge_Name	Area_sq_mi	Area_sq_km	START	END
USGS	01557500	Bald Eagle Creek at Tyrone, PA	44	114	10/1/1944	11/22/2011
USGS	01564997	Kishacoquillas Creek at Lumber City, PA	57	149	6/1/1993	5/18/1995
USGS	01558098	Spruce Creek near Spruce Creek, PA	107	277	8/9/2007	1/7/2010
USGS	01565000	Kishacoquillas Creek at Reedsville, PA	164	425	10/1/1939	11/22/2011
USGS	01560000	Dunning Creek at Belden, PA	172	445	10/1/1939	11/22/2011
USGS	01564500	Aughwick Creek near Three Springs, PA	205	531	6/1/1938	11/22/2011
USGS	01566000	Tuscarora Creek near Port Royal, PA	214	554	9/1/1911	11/22/2011
USGS	01558000	Little Juniata River at Spruce Creek, PA	220	570	10/1/1938	11/22/2011
USGS	01556000	Frankstown Br Juniata River at Williamsburg, PA	291	754	10/1/1916	11/22/2011
USGS	01562000	Raystown Branch Juniata River at Saxton, PA	756	1958	10/1/1911	11/22/2011
USGS	01559000	Juniata River at Huntingdon, PA	816	2113	10/1/1941	11/22/2011
USGS	01563200	Rays Br Juniata R bl Rays Dam nr Huntingdon, PA	960	2486	10/1/1946	11/22/2011
USGS	01563500	Juniata River at Mapleton Depot, PA	2030	5258	10/1/1937	11/22/2011
USGS	01567000	Juniata River at Newport, PA	3354	8687	4/1/1899	11/22/2011

Gages in the watershed with observations 1979 onwards
Highlighted are the ones with data between 1979-1984

mpirun -np 12 /home/bgb/mpi/pihm.v24.N19.valg.3.20120124/pihmcalib -f=juniata6 -n=/home/bgb/PIHM/JuniataForcing -**p=75** -C=1 -**start=200** -**calib=235** -**end=295**

Bald Eagle Creek at Tyrone, PA; Drainage Area = 114 sq. km





Bald Eagle Creek at Tyrone, PA; Drainage Area = 114 sq. km

Gnuplot

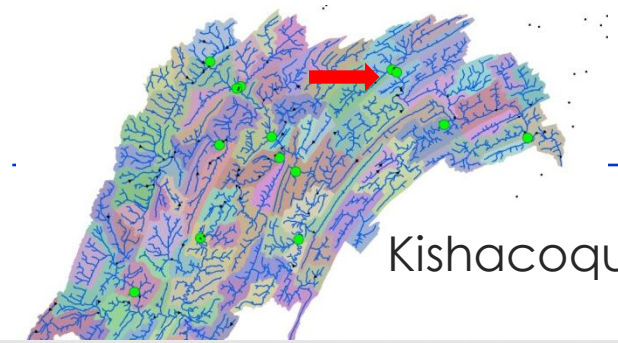
'75/juniata6x75.rivFlx1.dat' using 41
'../01557500.obs.6yrs' using 2

Discharge (cmd)

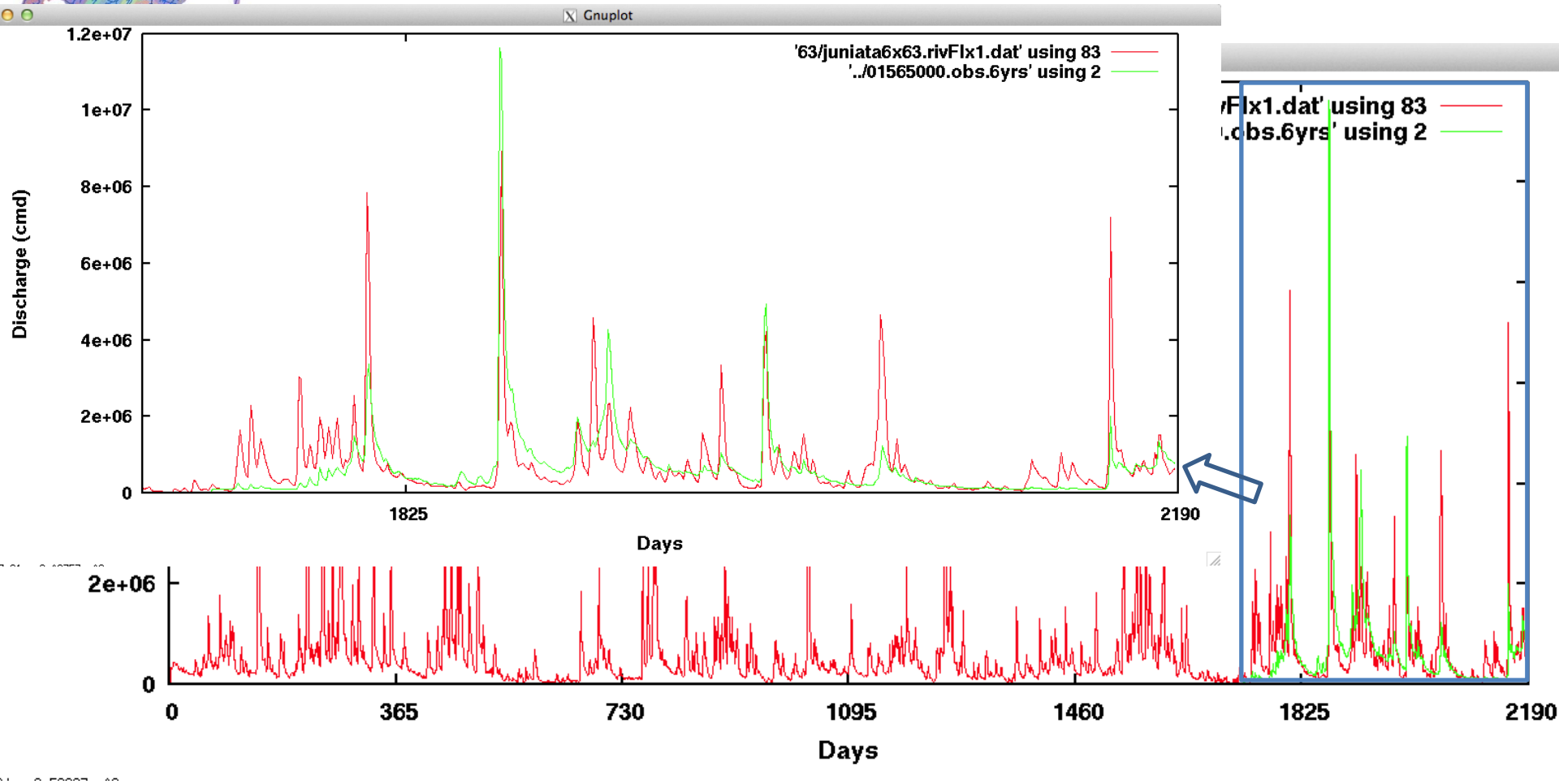
4e+06
3.5e+06
3e+06
2.5e+06
2e+06
1.5e+06
1e+06
500000
0

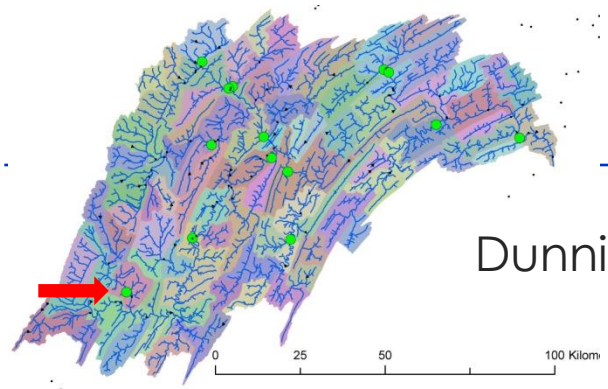
0
365
730
1095
1460
1825
2190

Days



Kishacoquillas Creek at Reedsville, PA; Drainage Area = 425 sq. km





Dunning Creek at Belden, PA; Drainage Area = 445 sq. km

Gnuplot

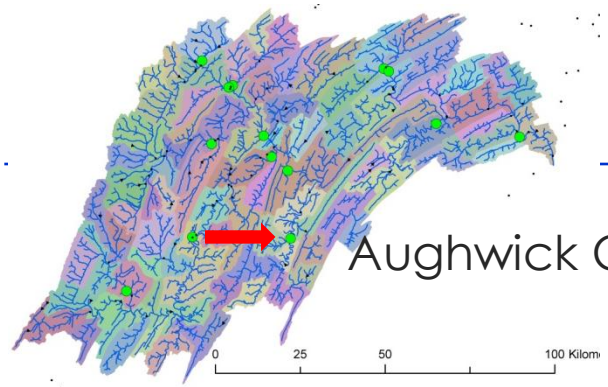
'95/juniata6x95.rivFlx1.dat' using 33
'../01560000.obs.6yrs' using 2

Discharge (cmd)

1.8e+07
1.6e+07
1.4e+07
1.2e+07
1e+07
8e+06
6e+06
4e+06
2e+06
0

0
365
730
1095
1460
1825
2190

Days



Aughwick Creek near Three Springs, PA; Drainage Area = 531sq. km

Gnuplot

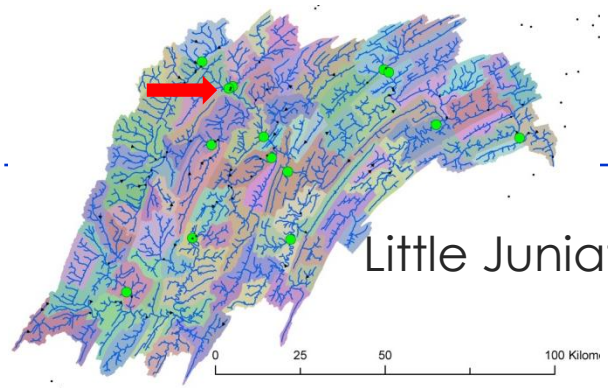
'14/juniata6x14.rivFlx1.dat' using 172
'../01564500.obs.6yrs' using 2

Discharge (cmd)

2.5e+07
2e+07
1.5e+07
1e+07
5e+06
0

0
365
730
1095
1460
1825
2190

Days



Little Juniata River at Spruce Creek, PA; Drainage Area = 570 sq. km

Gnuplot

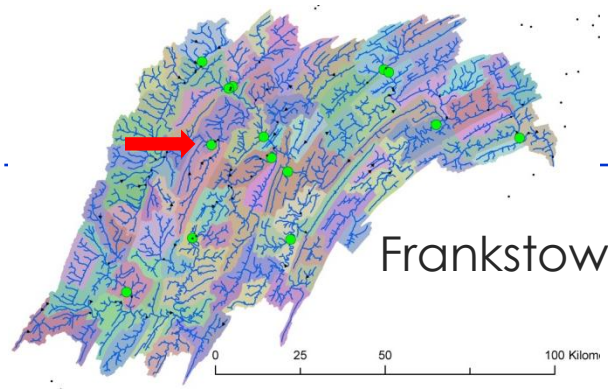
'64/juniata6x64.rivFlx1.dat' using 50
'../01558000.obs.6yrs' using 2

Discharge (cmd)

1.8e+07
1.6e+07
1.4e+07
1.2e+07
1e+07
8e+06
6e+06
4e+06
2e+06
0

0
365
730
1095
1460
1825
2190

Days



Frankstown Br Juniata at Williamsburg; Drainage Area = 754 sq. km

Gnuplot

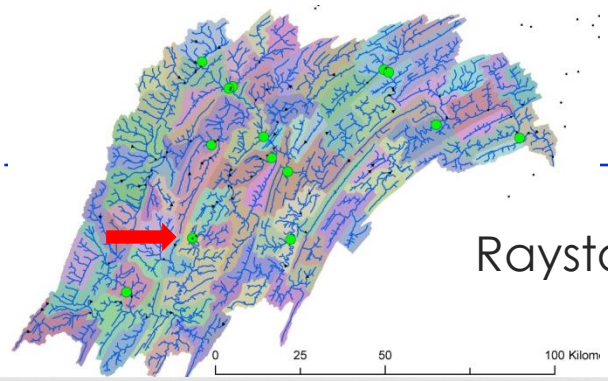
'54/juniata6x54.rivFlx1.dat' using 166
'../01556000.obs.6yrs' using 2

Discharge (cmd)

2e+07
1.8e+07
1.6e+07
1.4e+07
1.2e+07
1e+07
8e+06
6e+06
4e+06
2e+06
0

0
365
730
1095
1460
1825
2190

Days



Raystown Br. Juniata at Saxton; Drainage Area = 1958 sq. km

Gnuplot

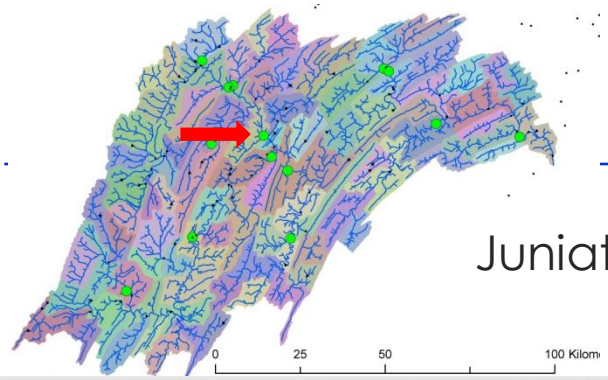
'6/juniata6x6.rivFlx1.dat' using 28
'../01562000.obs.6yrs' using 2

Discharge (cmd)

1e+08
9e+07
8e+07
7e+07
6e+07
5e+07
4e+07
3e+07
2e+07
1e+07
0

0
365
730
1095
1460
1825
2190

Days



Juniata River at Huntingdon, PA; Drainage Area = 2113 sq. km

Gnuplot

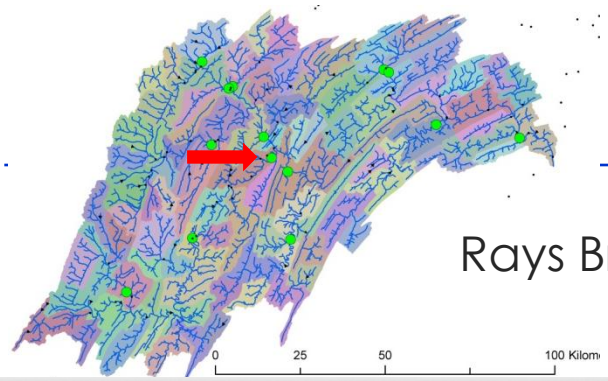
'30/juniata6x30.rivFlx1.dat' using 13
'../01559000.obs.6yrs' using 2

Discharge (cmd)

6e+07
5e+07
4e+07
3e+07
2e+07
1e+07
0

0
365
730
1095
1460
1825
2190

Days



Rays Br Juniata River bl Rays Dam; Drainage Area = 2486 sq. km

Gnuplot

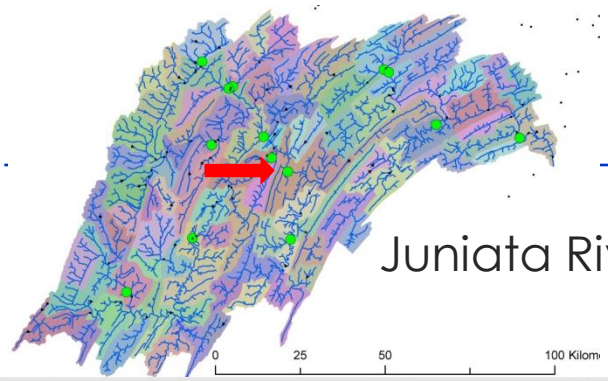
'34/juniata6x34.rivFlx1.dat' using 3
'../01563200.obs.6yrs' using 2

Discharge (cmd)

4e+07
3.5e+07
3e+07
2.5e+07
2e+07
1.5e+07
1e+07
5e+06
0

0
365
730
1095
1460
1825
2190

Days



Juniata River at MapletonDepot, PA; Drainage Area = 5258 sq. km

Gnuplot

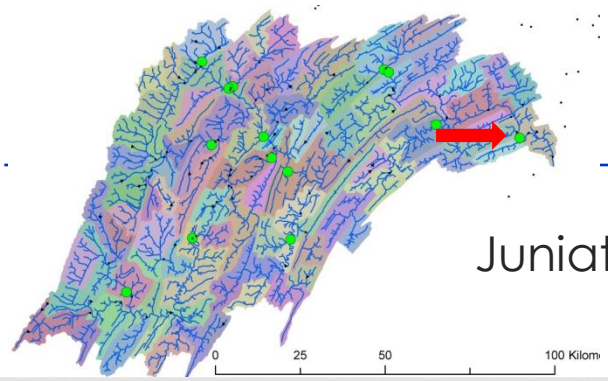
'42/juniata6x42.rivFlx1.dat' using 67
'../01563500.obs.6yrs' using 2

Discharge (cmd)

8e+07
7e+07
6e+07
5e+07
4e+07
3e+07
2e+07
1e+07
0

0
365
730
1095
1460
1825
2190

Days



Juniata River at Newport, PA; Drainage Area = 8687 sq. km

Gnuplot

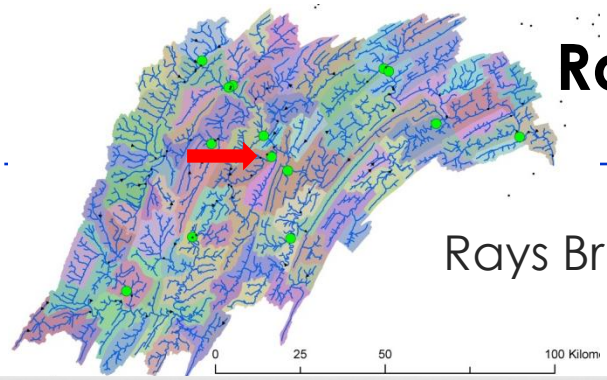
'49/juniata6x49.rivFlx1.dat' using 132
'../01567000.obs.6yrs' using 2

Discharge (cmd)

2.5e+08
2e+08
1.5e+08
1e+08
5e+07
0

0
365
730
1095
1460
1825
2190

Days



Raystown Dam : : Reservoirs

Rays Br Juniata River bl Rays Dam; Drainage Area = 2486 sq. km

Gnuplot

'34/juniata6x34.rivFlx1.dat' using 3
'../01563200.obs.6yrs' using 2

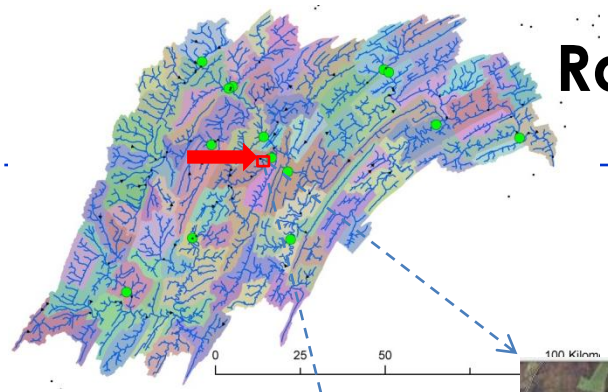
Discharge (cmd)

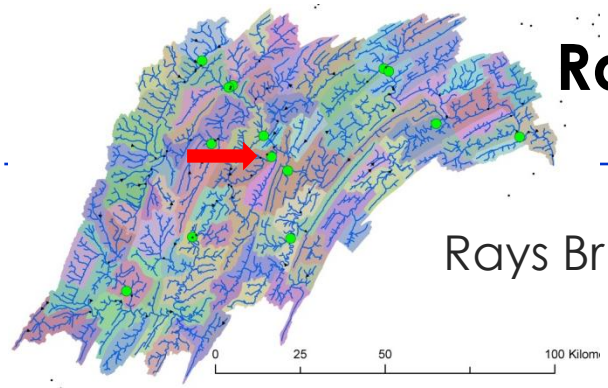
4e+07
3.5e+07
3e+07
2.5e+07
2e+07
1.5e+07
1e+07
5e+06
0

0
365
730
1095
1460
1825
2190

Days

Raystown Dam : : Reservoirs





Raystown Dam : : Reservoirs

Rays Br Juniata River bl Rays Dam; Drainage Area = 2486 sq. km

Gnuplot

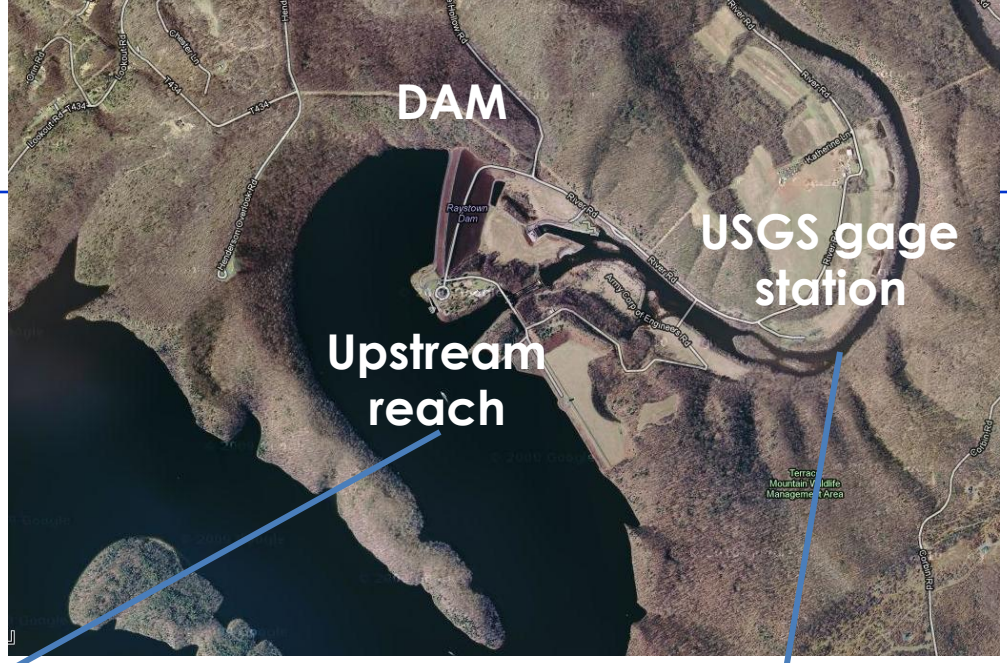
'34/juniata6x34.rivFlx1.dat' using 3
'../01563200.obs.6yrs' using 2
'../Juniata20120408.3.wBC/34/juniata6x34.rivFlx1.dat' using 3

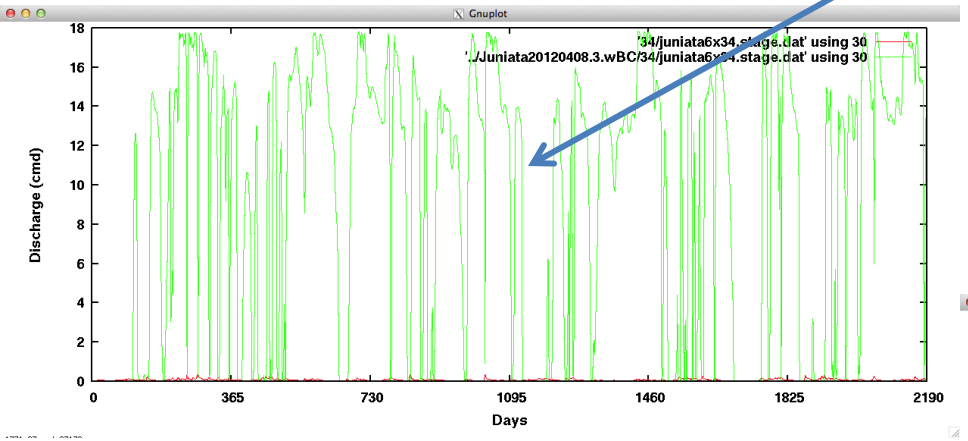
Discharge (cmd)

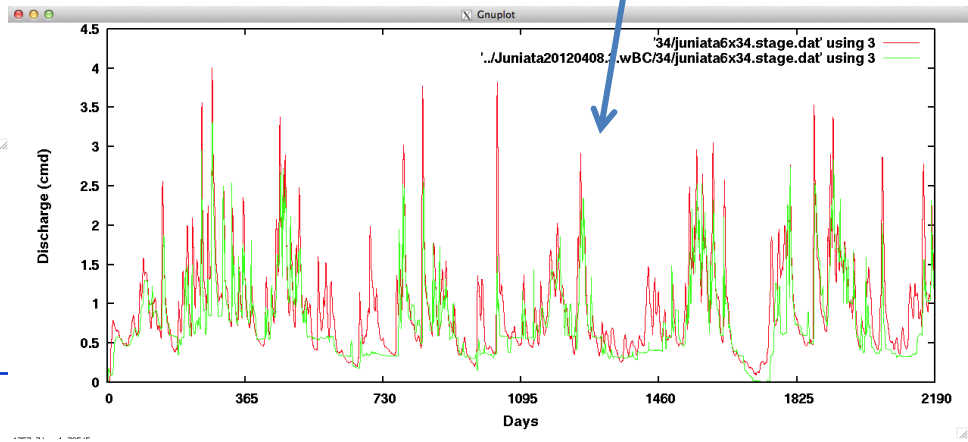
4e+07
3.5e+07
3e+07
2.5e+07
2e+07
1.5e+07
1e+07
5e+06
0

0
365
730
1095
1460
1825
2190

Days


DAM
USGS gage station
Upstream reach


Gnuplot
'34/juniata6x34.stage.dat' using 30
'../Juniata20120408.3.wBC/34/juniata6x34.stage.dat' using 30
Discharge (cmd)
Days
0
2
4
6
8
10
12
14
16
18
0
365
730
1095
1460
1825
2190


Gnuplot
'34/juniata6x34.stage.dat' using 3
'../Juniata20120408.3.wBC/34/juniata6x34.stage.dat' using 3
Discharge (cmd)
Days
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
0
365
730
1095
1460
1825
2190