The Global Flood Monitoring System (GFMS)

Using Satellite (and NWP Model) Rainfall and a Hydrological Model

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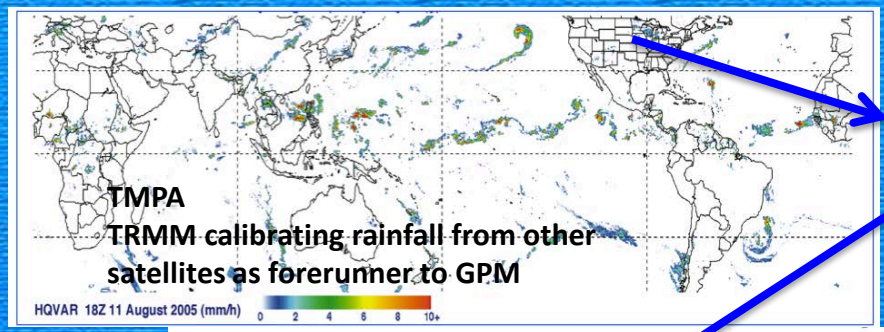
Goal: Develop, test and operate a system to provide national and international organizations (gov't and NGO) useful analysis and forecast information about ongoing and potential floods.

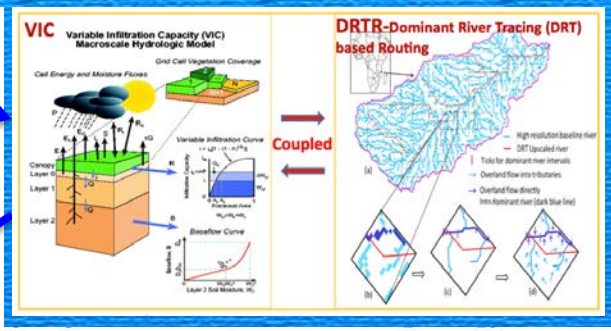
http://flood.umd.edu

Global Flood Monitoring System (GFMS)

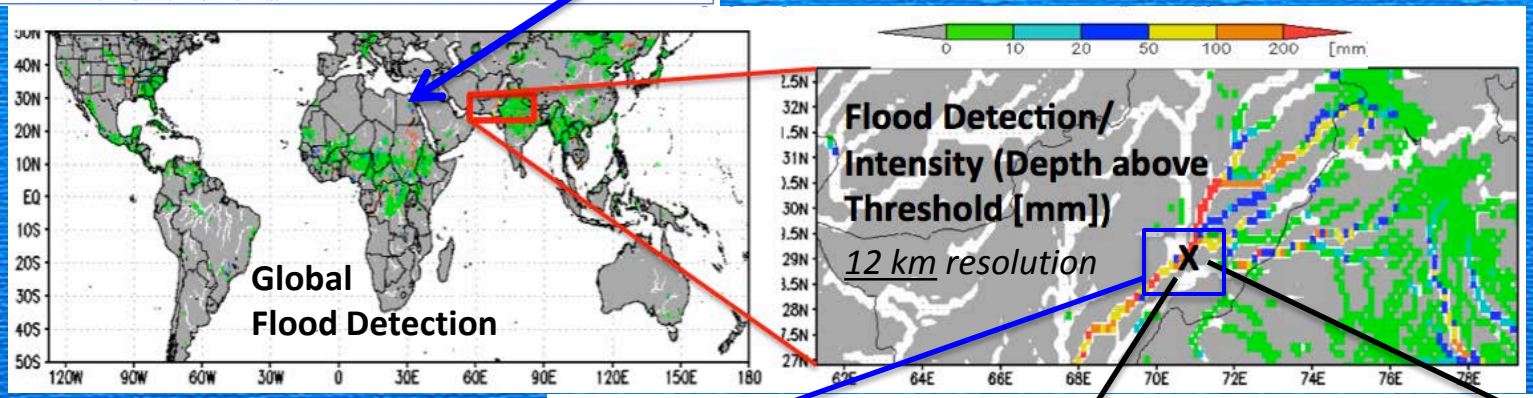
http://flood.umd.edu

Global Real-time Flood Calculations Using Satellite Rainfall and Hydrological Models

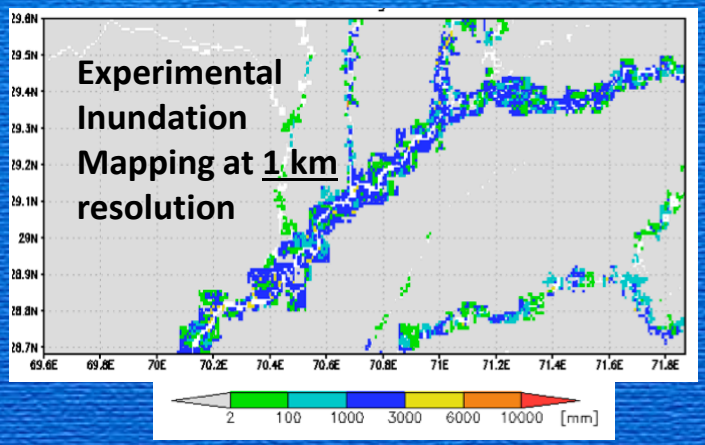


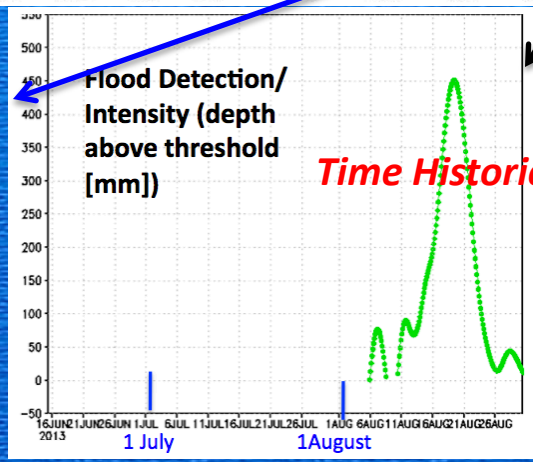


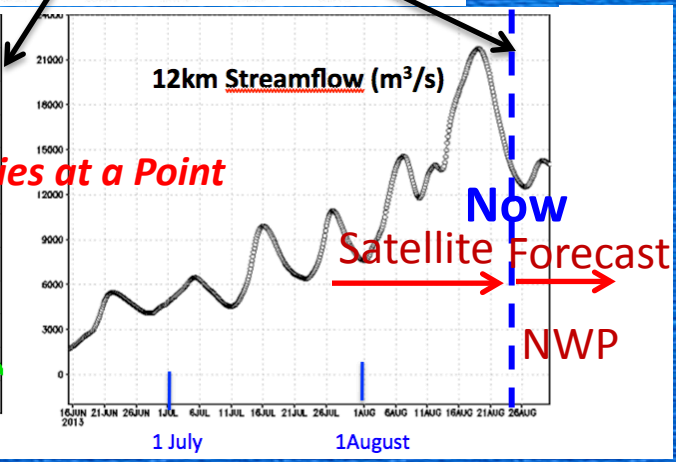
TRMM/GPM rainfall into land surface and routing models for water depth and stream flow calculations compared to flood thresholds--every three hours



Indus River basin Aug. 20, 2013

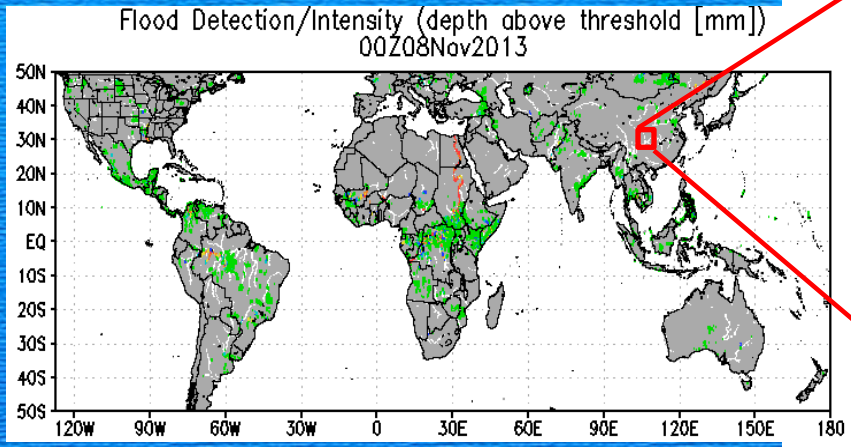


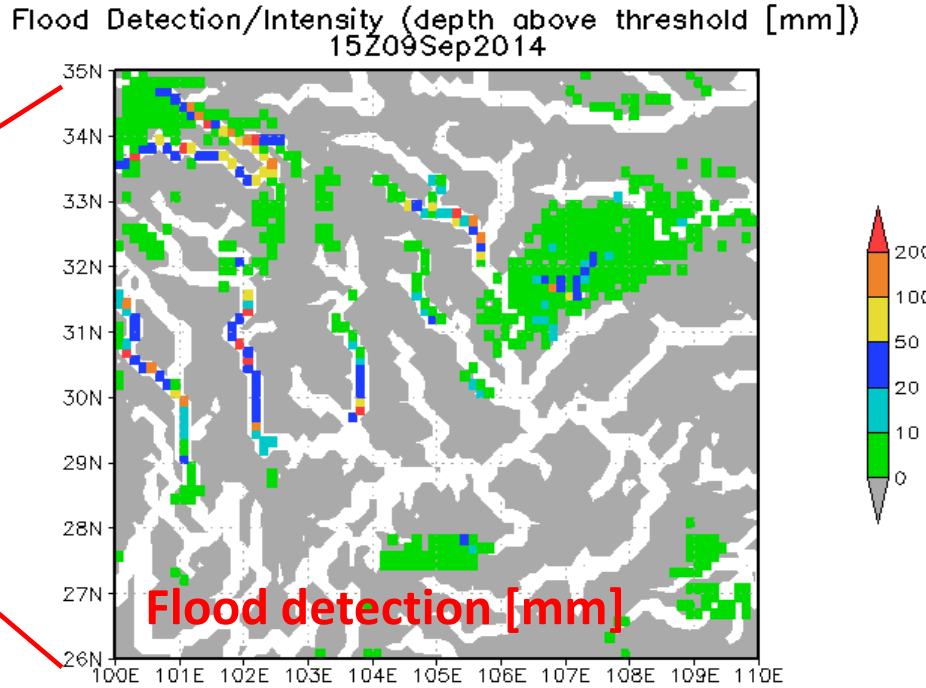


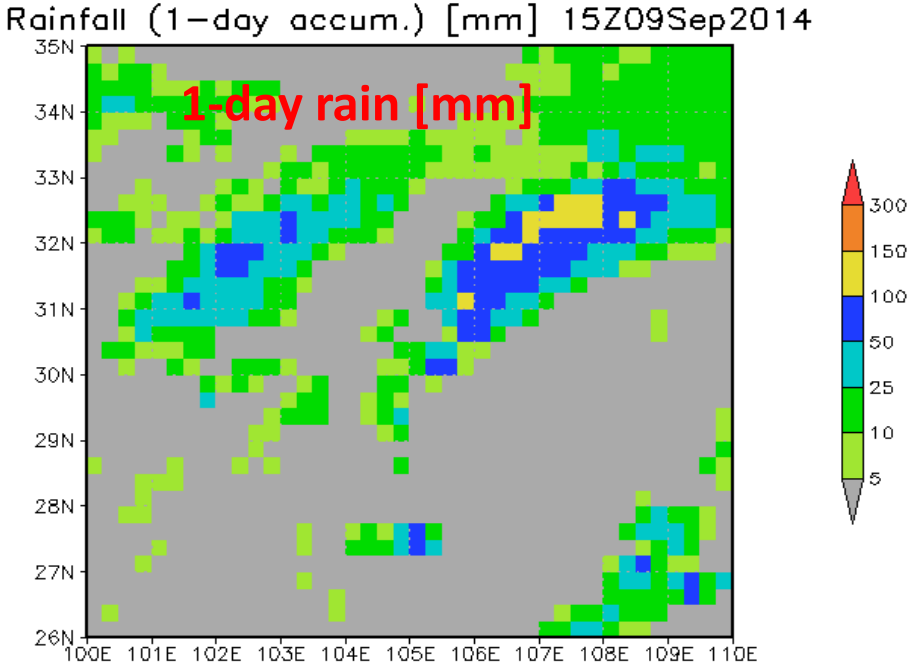


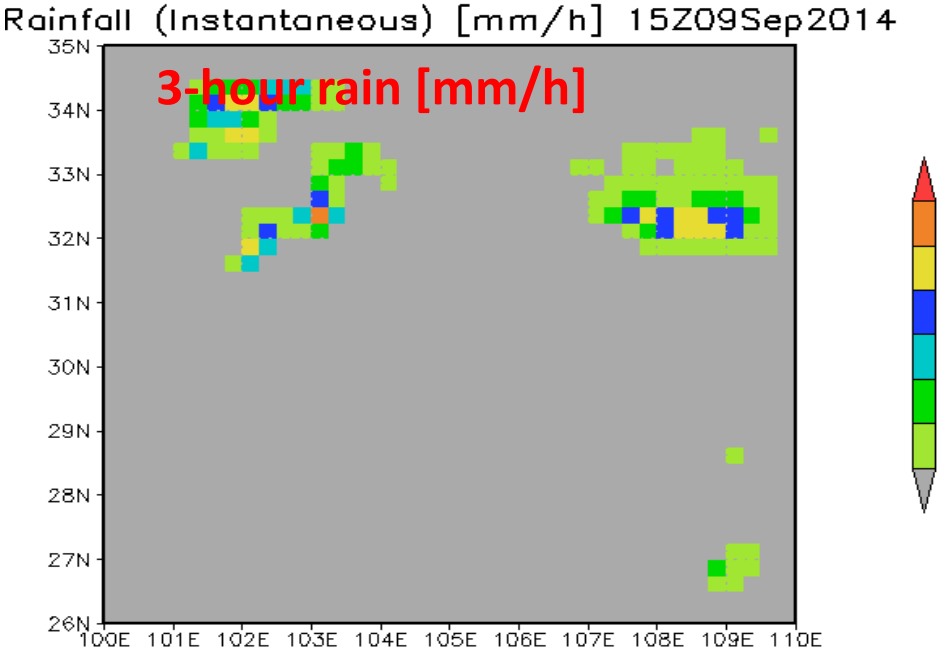
Wu et al., 2011, 2012, 2014 WRR; Wu et al., 2012 JHM;

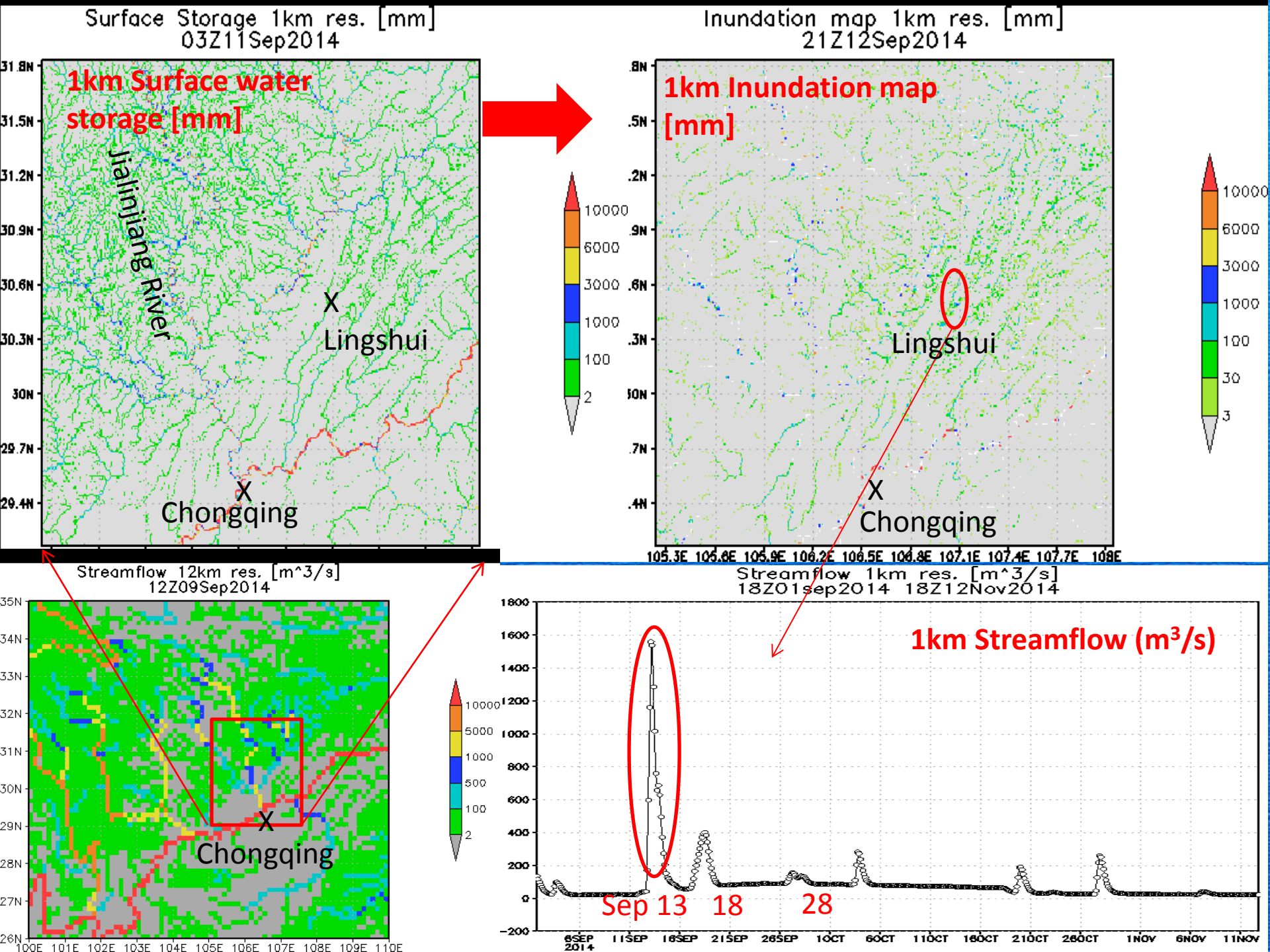
Example of Global to Regional Flood Detection: Recent Flooding caused by Heavy rain in Chongqing, China










Surface Storage 1km res. [mm]
03Z11Sep2014
1km Surface water storage [mm]
Jialinjiang River
Lingshui
Chongqing
Inundation map 1km res. [mm]
21Z12Sep2014
1km Inundation map [mm]
Lingshui
Chongqing
Streamflow 12km res. [m^3/s]
12Z09Sep2014
Chongqing
Streamflow 1km res. [m^3/s]
18Z01sep2014 18Z12Nov2014
1km Streamflow (m³/s)
Sep 13
18
28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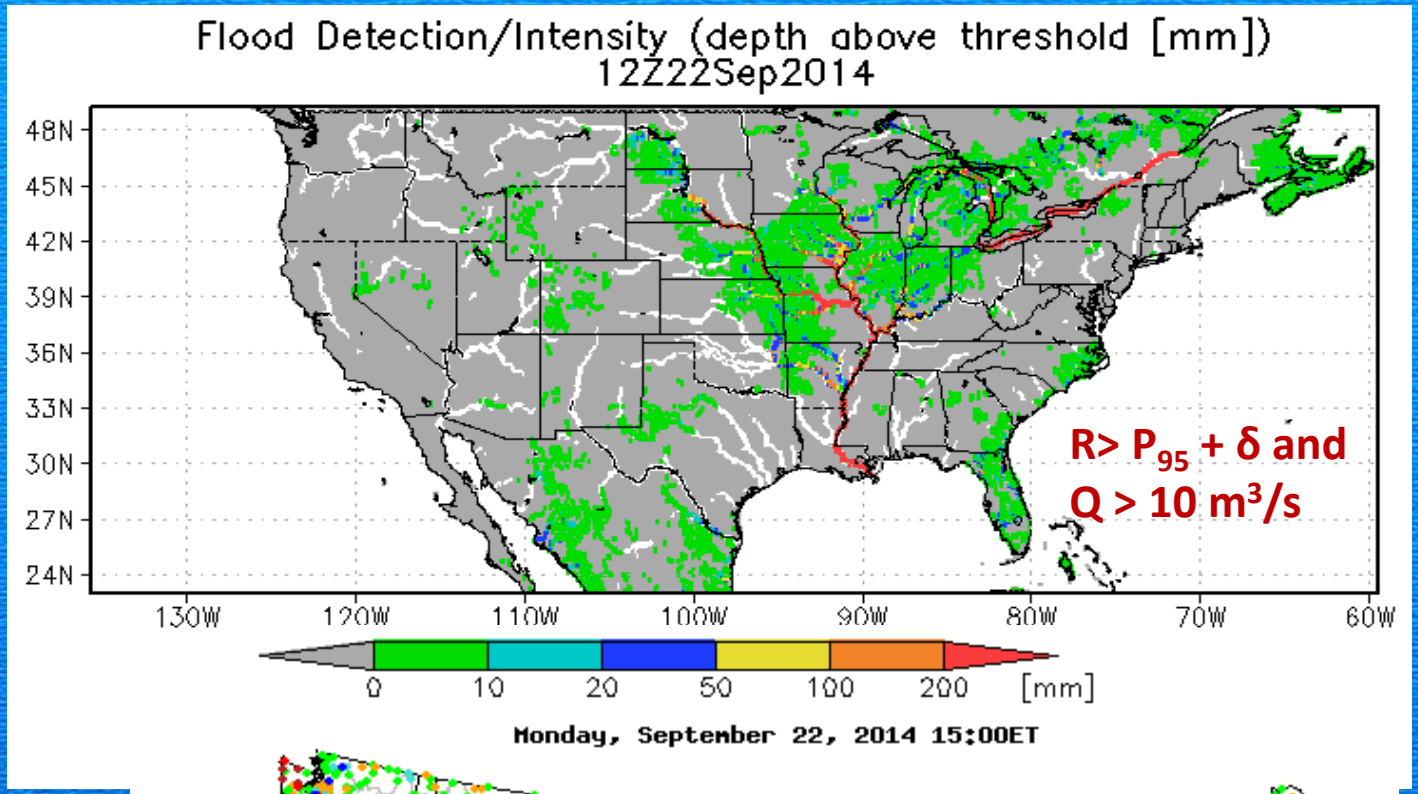
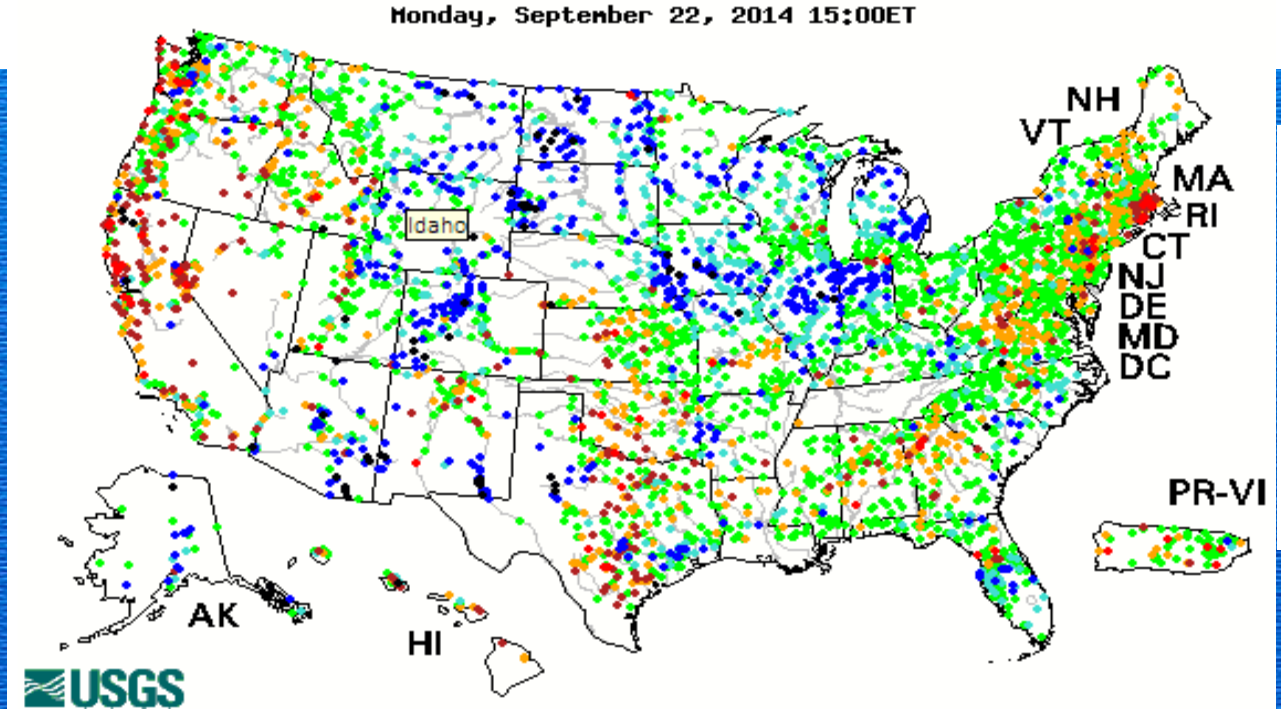
Comparison over U.S. for Today





Explanation

- High
- > 90th percentile
- 76th - 90th percentile
- 25th - 75th percentile
- 10th - 24th percentile
- < 10th percentile
- Low

Global evaluation TMPA real-time (DRIVE-RT) and research (rain gauge adjusted, DRIVE-V7) [15yrs (1998~), 3-hrly, 1/8° res.]

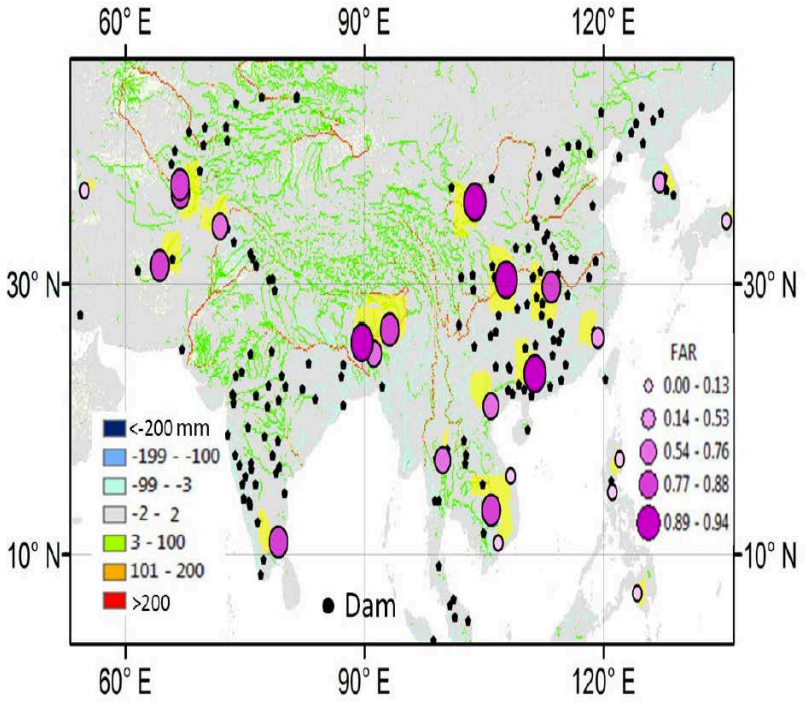
(1) **Flood event** based evaluation using 2,086 archived flood events by Dartmouth Flood Observatory

(2) **Streamflow** based evaluation at 1,121 river gauges by GRDC, across the globe.

Wu, et al., WRR , 2014 [available on flood.umd.edu];
Featured by "Research Spotlight" in Eos, Vol. 95 (30), 29 July 2014)

Flood detection verification against the Dartmouth Flood Observatory (DFO) flood database over the 38 Well Reported Areas (WRAs) for floods with duration more than 3 days.

Metrics	POD	FAR	CSI
Metrics averaged over all the 38 WRAs			
DRIVE-V7RT	0.90	0.73	0.25
DRIVE-V7	0.93	0.65	0.34
Metrics averaged over the 20 WRAs with ≥ 5 dam			
DRIVE-V7RT	0.93	0.80	0.19
DRIVE-V7	0.94	0.73	0.26
Metrics averaged over the 18 WRAs with <5 dam			
DRIVE-V7RT	0.87	0.66	0.32
DRIVE-V7	0.92	0.56	0.43

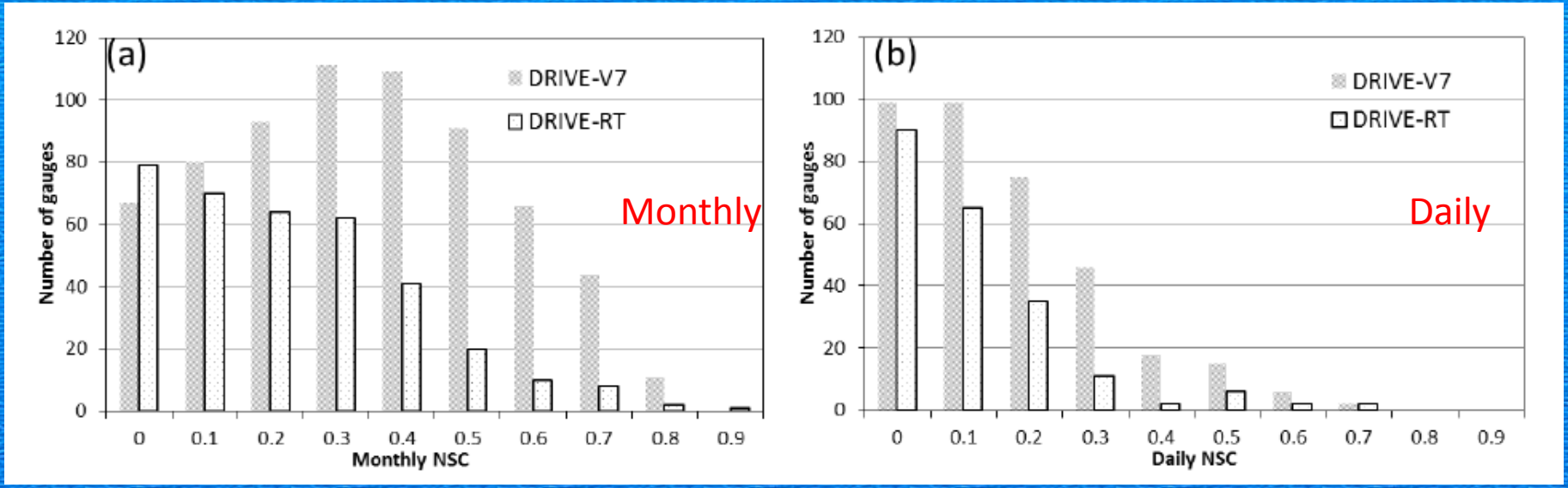


Better flood detection statistics with "research" (instead of RT) rain, with fewer dams (drop in FAR) and for longer, larger floods

Bottom line--For 3-day floods in basins with few dams using RT rainfall:
POD ~ 0.9 FAR ~ 0.7

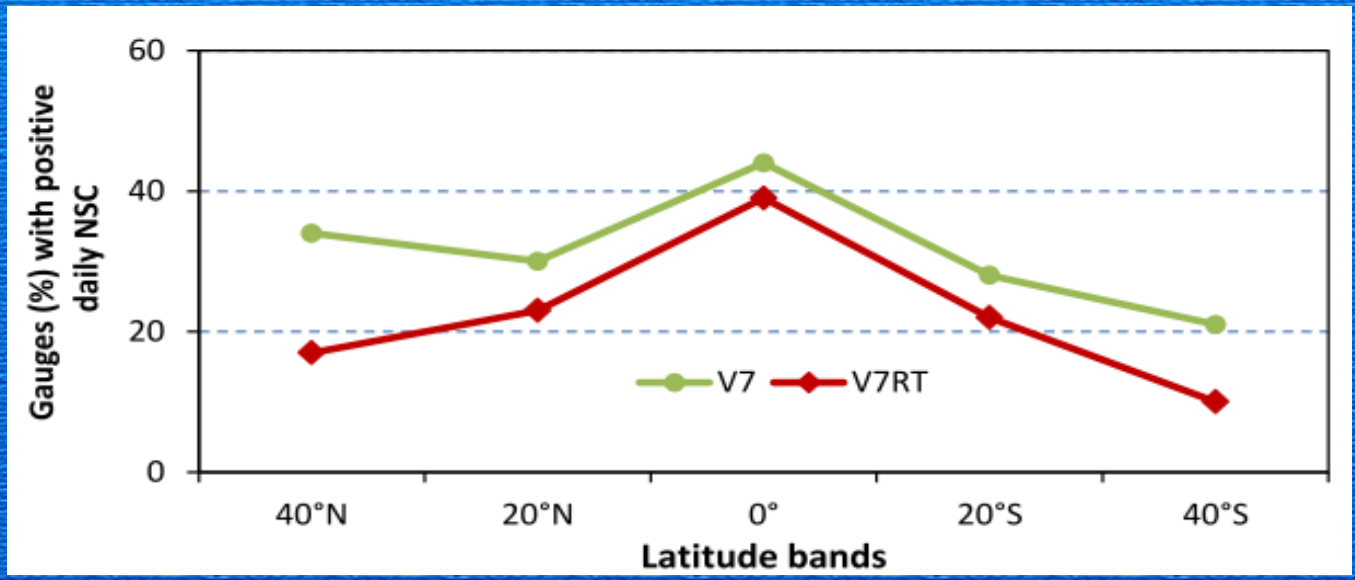
Wu et al., 2012 JHM, 2014 WRR

Distribution of the number of gauges with positive monthly and daily NSC metrics for DRIVE-V7 and DRIVE-RT simulation for 2001-2011, respectively



Daily: 32% of gauges with positive values with mean of 0.22

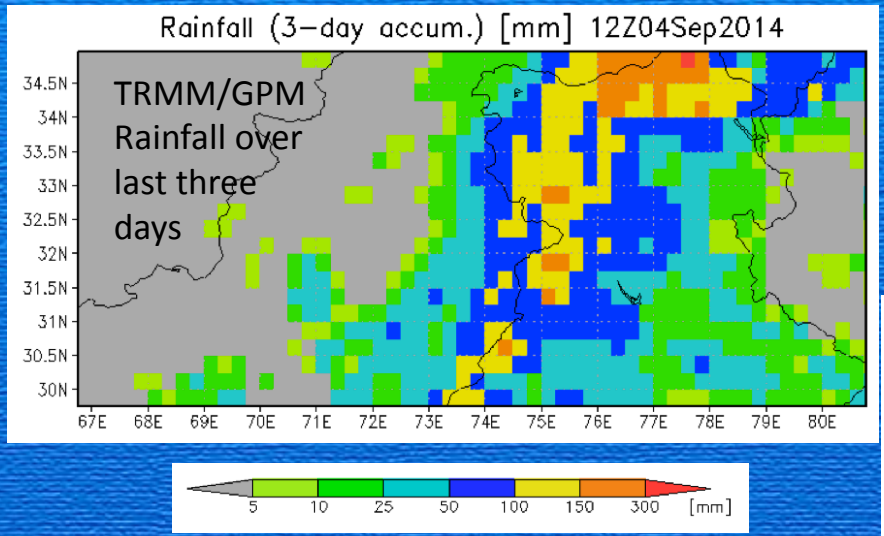
Monthly: 60% of gauges with positive values with mean of 0.39

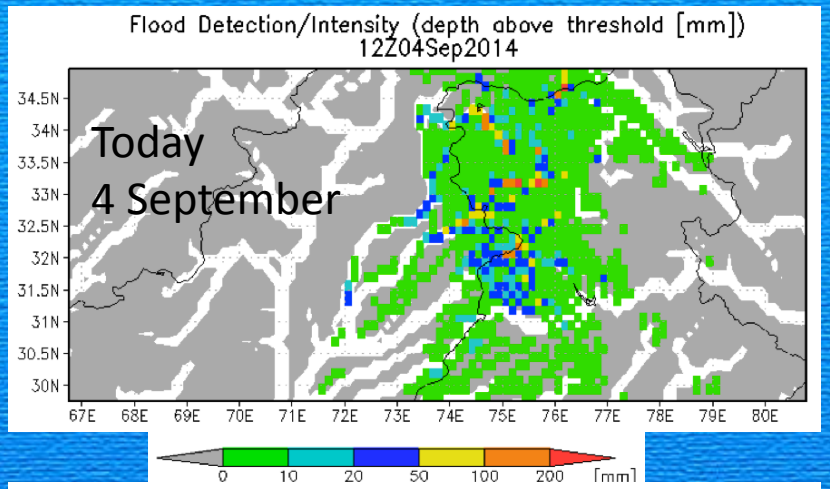


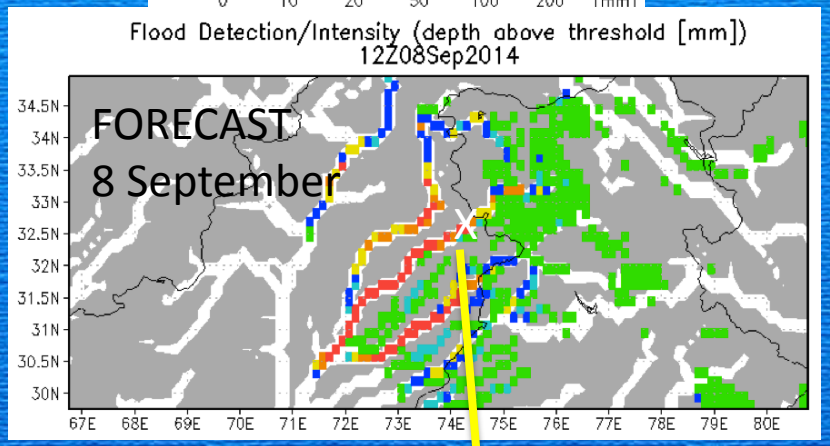
First View: Floods in Kashmir India—4 September 2014

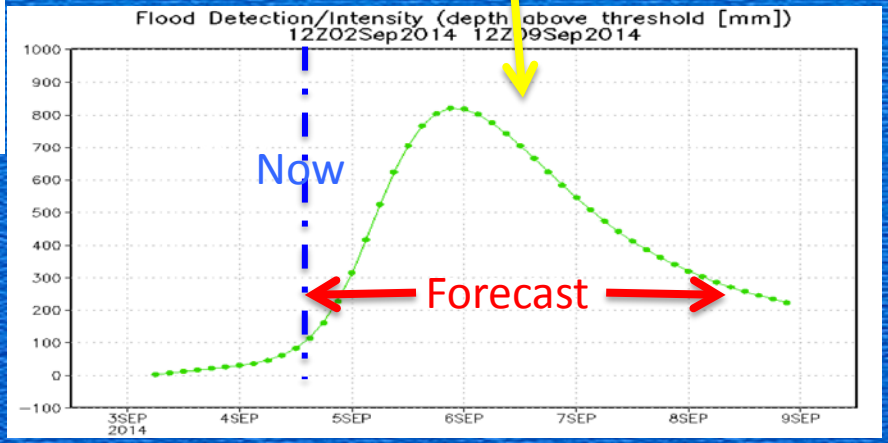
Back on Sep. 4 we used GFMS to report on conditions in India and forecasts for movement of flood waters into Pakistan.

Heavy rains in Kashmir, India (> 300 mm—see map below) have produced floods in that region in multiple locations as can be seen in today's estimation of flood locations and intensities from the GFMS based on hydrological forecasting and satellite rainfall (right). Hydrologic forecast indicates flood moving across border into Pakistan with peak flood values at indicated location in a few days (lower right).



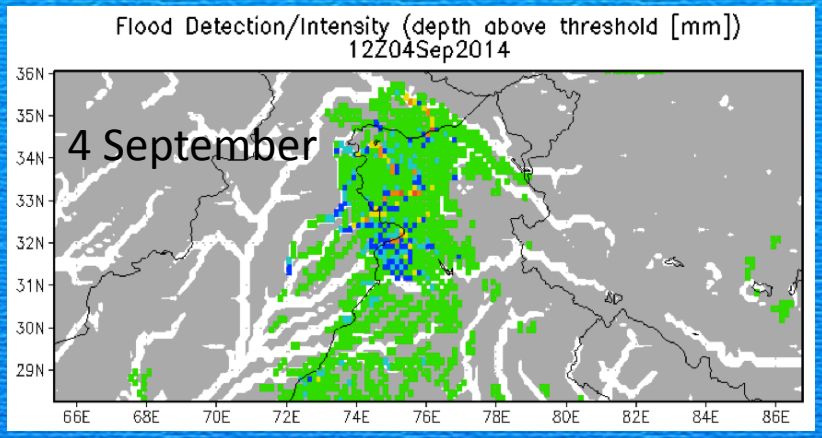


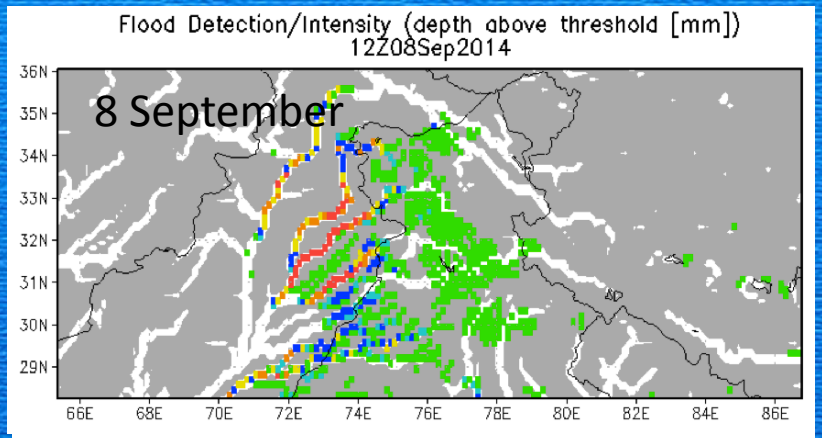


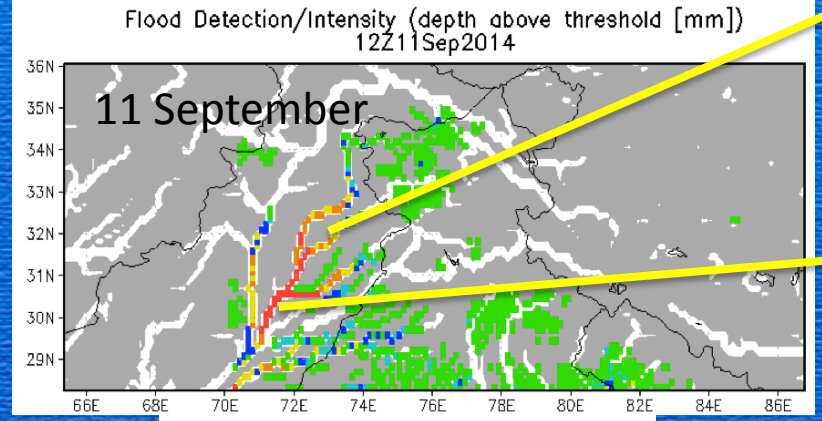


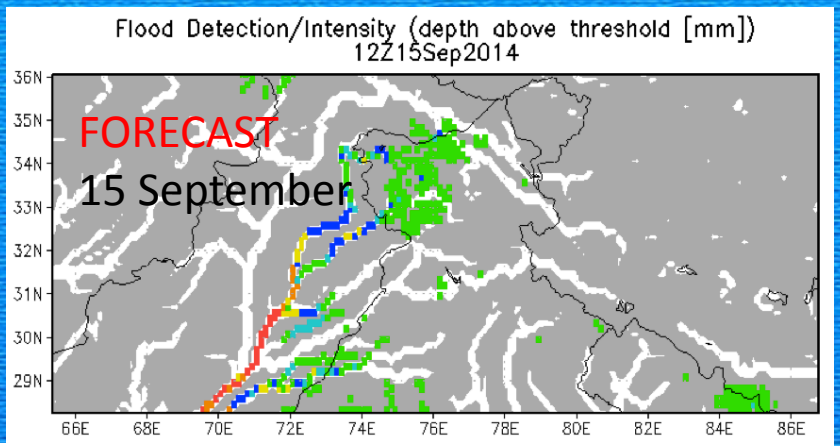
Time History and Forecast (4-15 Sep. 2014)

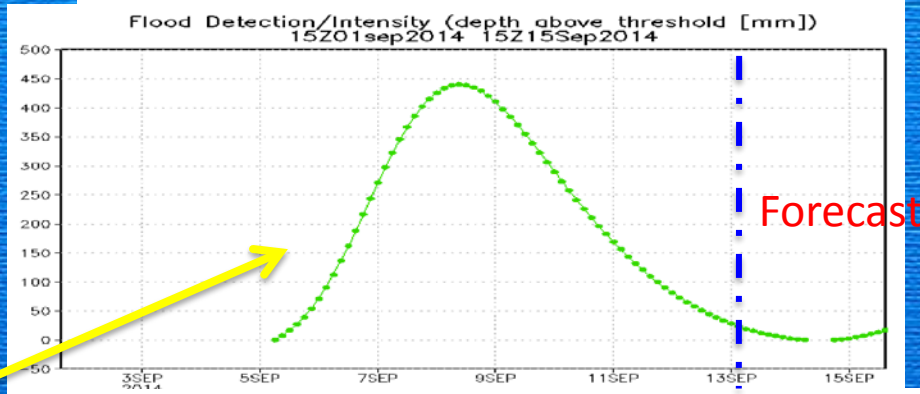
Floods begin in Kashmir, India (2-4 Sep.) and move downstream further into Pakistan by today (11 Sep.) with forecast further movement southward 15 Sep. and beyond.

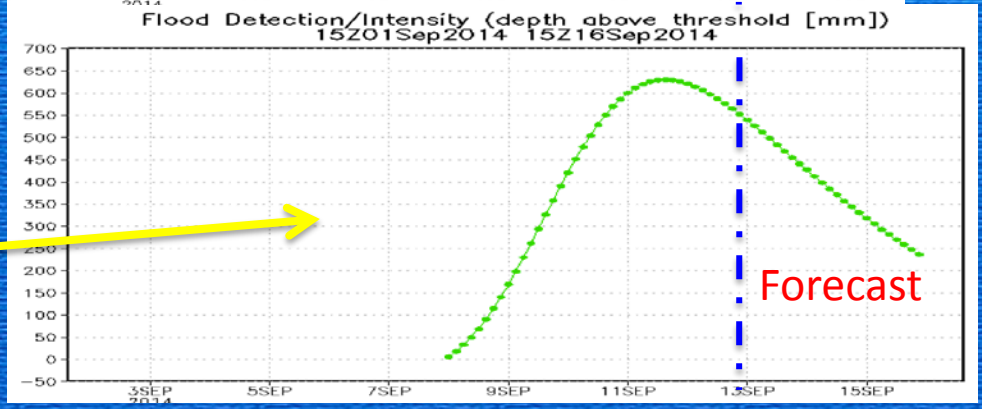




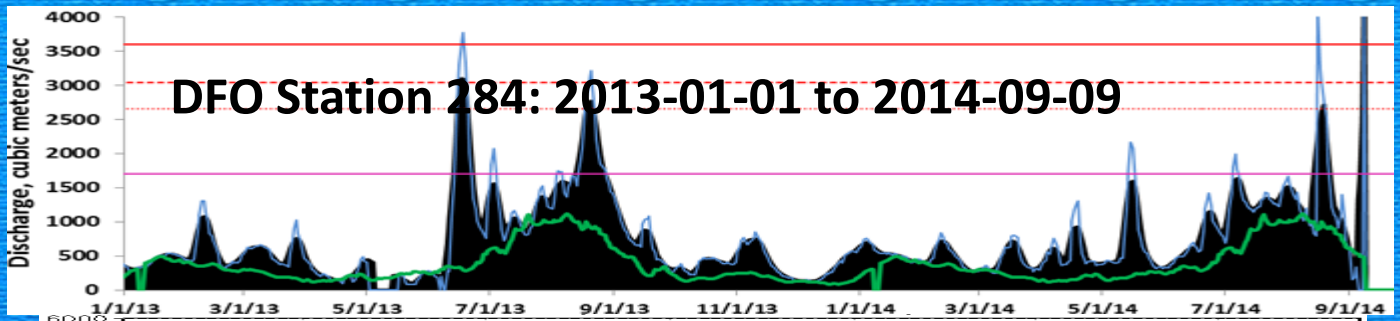




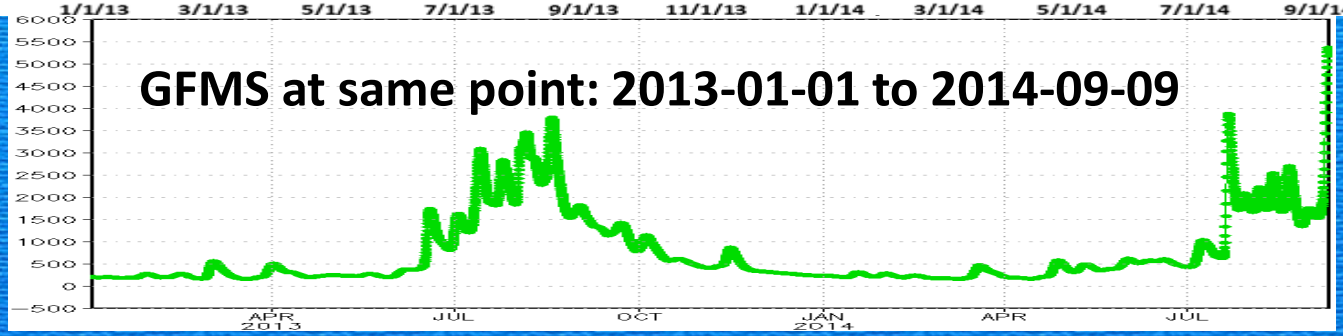




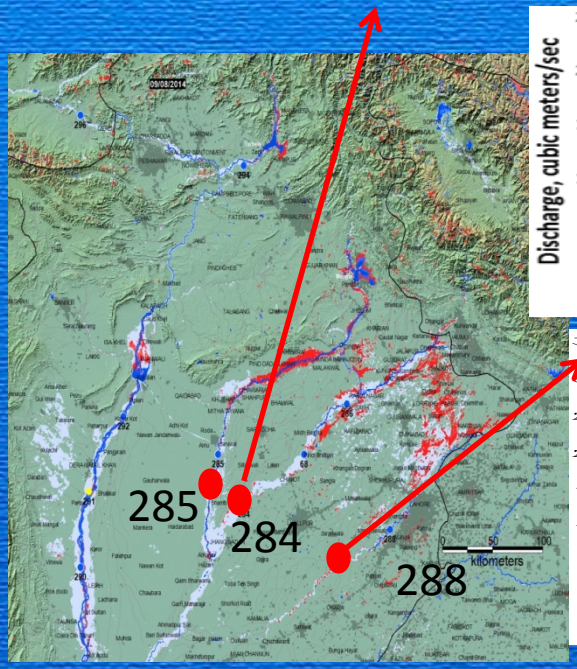
Comparison of Two Remote Sensing-based Streamflow Estimates

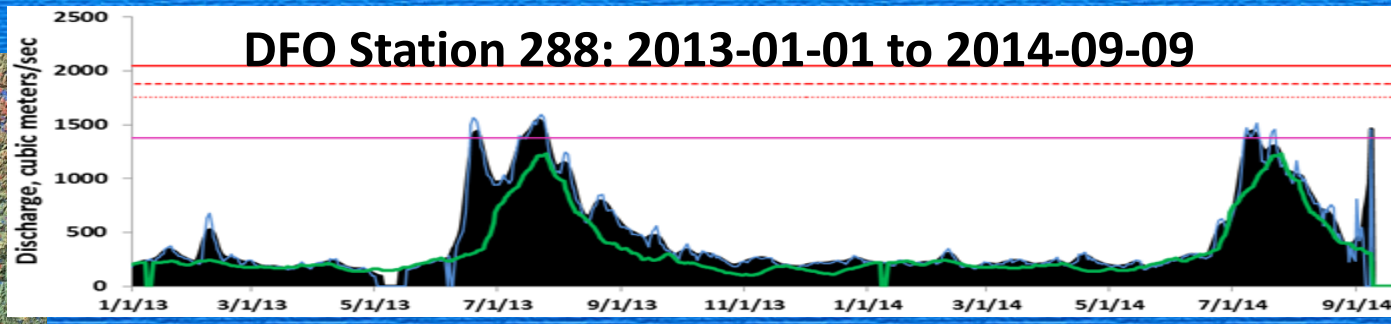


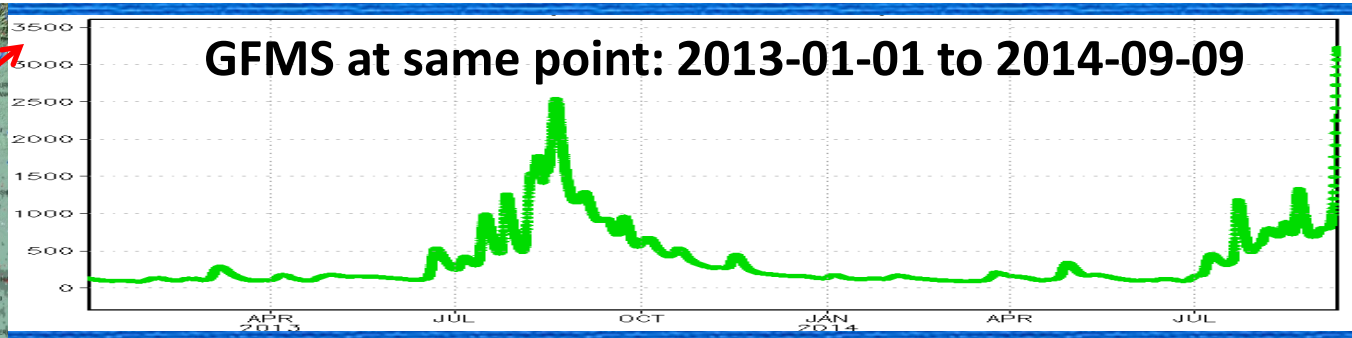
Based on Riverwatch (U. of CO) Surface Microwave

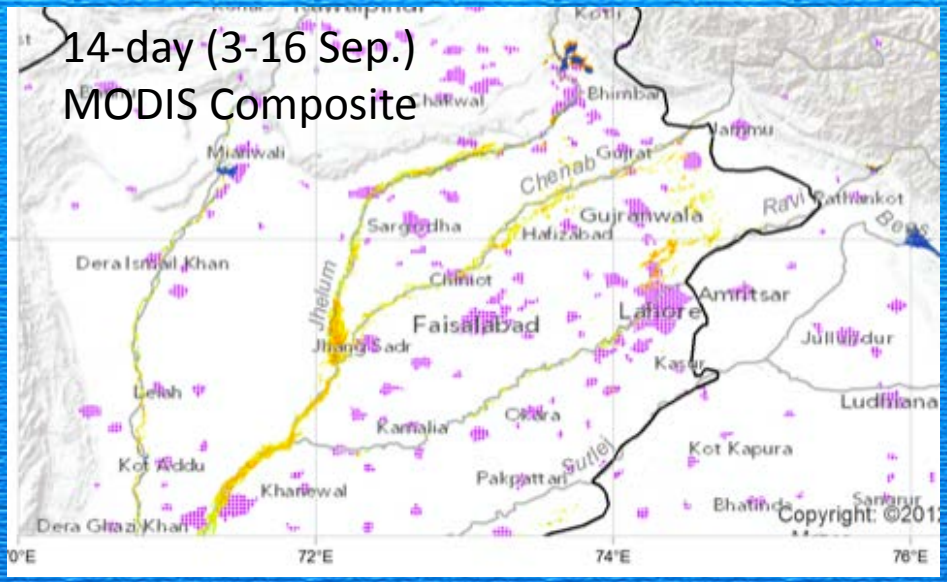


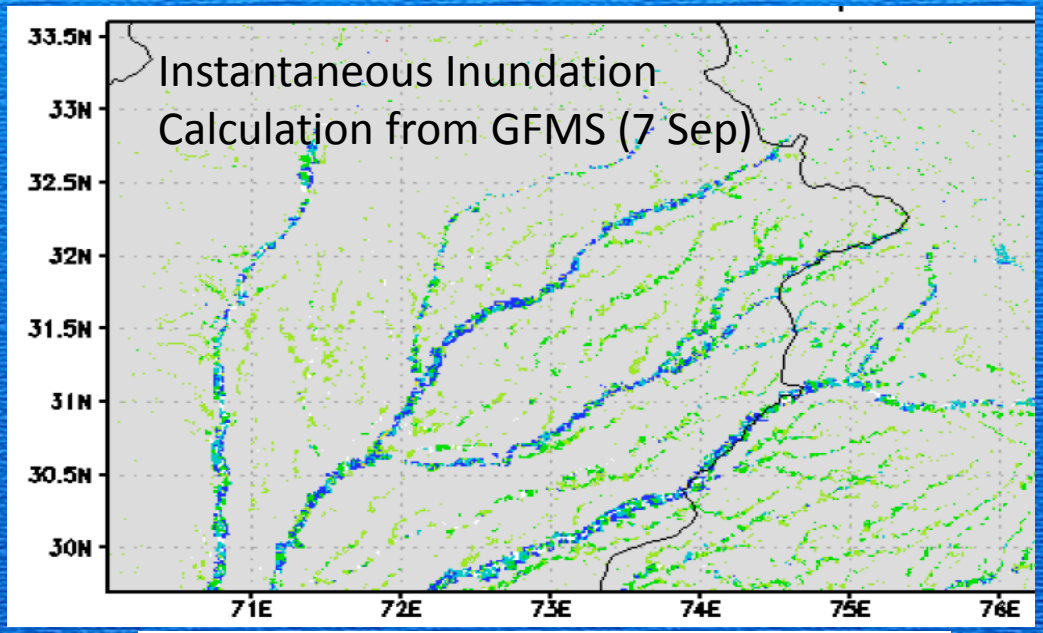
Based on TRMM/GPM Rainfall into Hydrologic Model









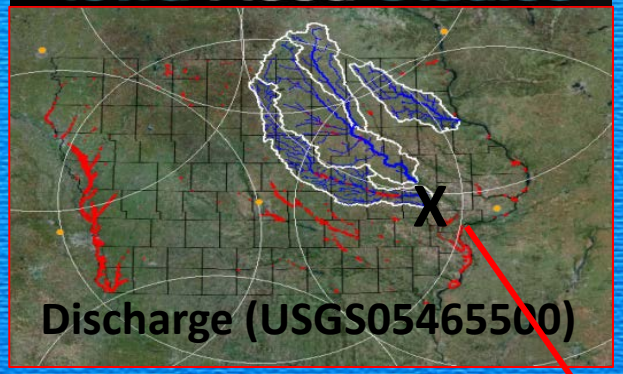


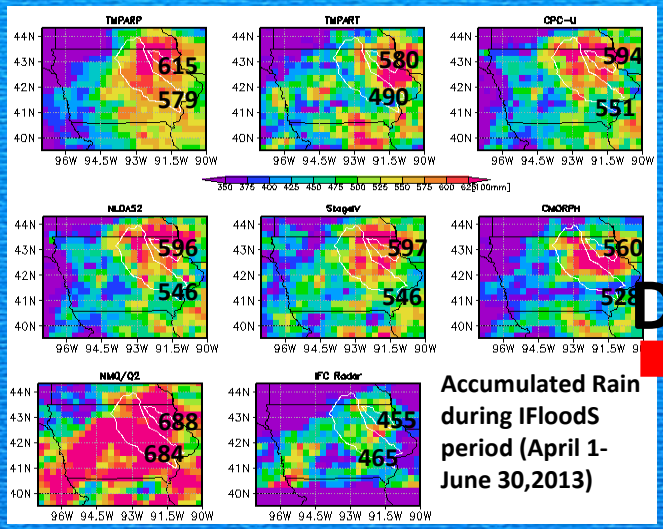
Inundation Estimates from MODIS (GSFC) and GFMS (U. of Maryland)

Experimental inundation calculations from GFMS available every three hours for comparison with automated MODIS estimates (when available). Results in this case show some similarities, but also differences.

Further comparison of various remote-sensing-based flood intensity, streamflow, and inundation estimates as illustrated here are needed to lead to integration of all flood information to maximize information content and timeliness.

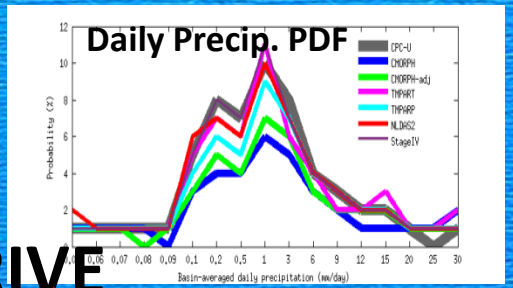
IFloodS
Iowa Flood Studies

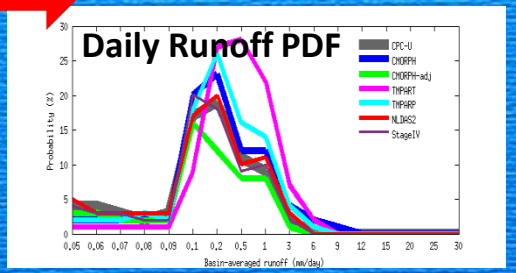




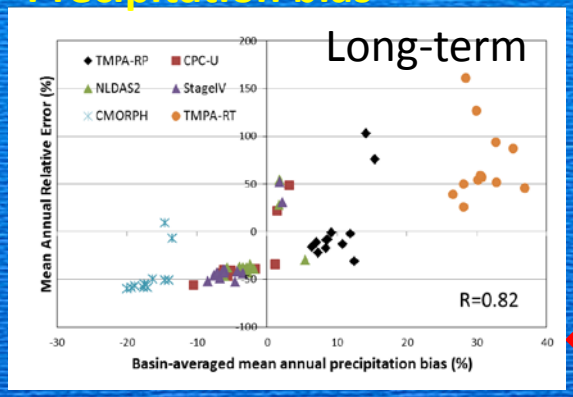
Accumulated Rain during IFloodS period (April 1-June 30,2013)

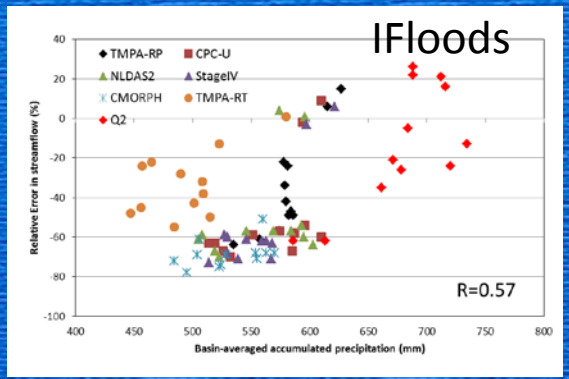
DRIVE

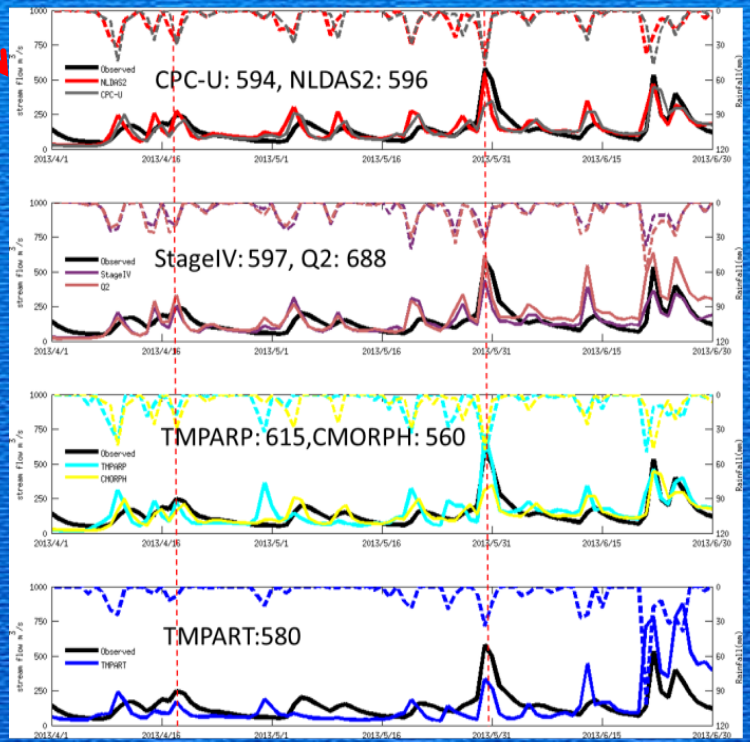




Model performance vs. Precipitation bias







NLDAS2
NSC=0.47
MARE=1%
CPC-U
NSC=0.57
RE=-2%

StageIV
NSC=-0.37
RE=-3%
Q2
NSC=0.1
RE=22%

TMPARP
NSC=0.30
MARE=6%
CMORPH
NSC=-0.24
RE=-51%

TMPART
NSC=-1.22
RE=1%

Recent (Oct.13-Nov 12, 2014) Visitors/Users of GFMS website (http://flood.umd.edu)

Weekly Stats Report: 15 Sep - 21 Sep 2014
Project: Global Flood Monitoring System

	Mon	Tues	Wed	Thur	Fri	Sat	Sun	Total	Avg
Pageloads	104	29	25	17	25	4	5	**209**	30
Unique Visits	50	28	21	16	15	4	5	**139**	20
First Time Visits	27	11	10	9	10	2	3	**72**	10
Returning Visits	23	17	11	7	5	2	2	**67**	10

Summary and Future

1. The Global Flood Monitoring System (GFMS) has been developed for real-time application. Evaluation of system shows promising performance in retrospective runs vs. observed streamflow records and in flood event detection against global flood event statistics. System results are being used internationally.

2. High resolution (1 km) routing and water storage calculations has lead to beginnings of high resolution inundation mapping for comparison with high resolution visible (e.g., MODIS) and SAR imagery of floods.

3. Significant improvement in results expected in near future with improved satellite precip. information, including CMORPH and GPM products (IMERG).

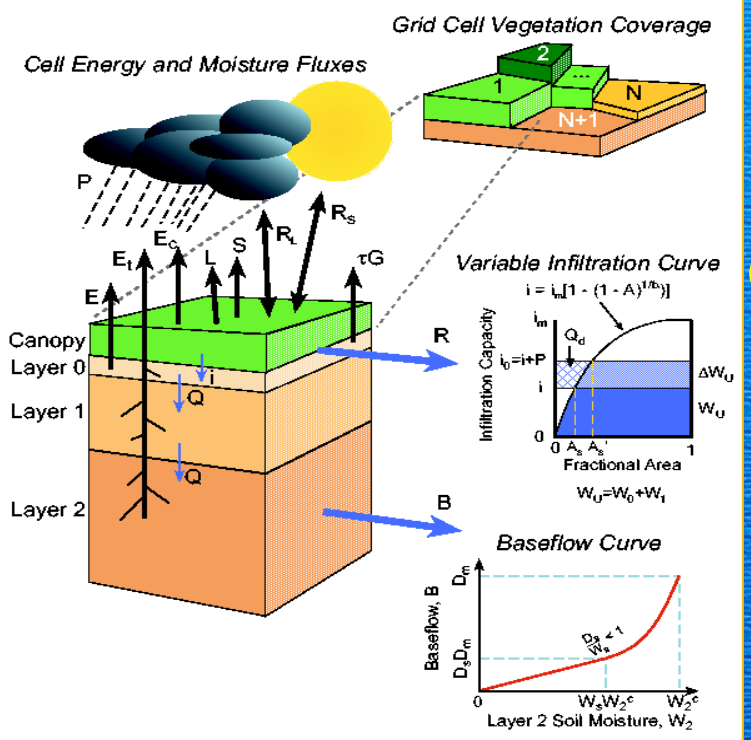
4. For the future we will also be:
   - implementing a "dam module" to try to include the impact of man-made structures on the calculations
   - improving the regional calibration of the hydrology model
   - improving and validating the inundation calculations
   - improving the use of NWP precipitation info to extend the calculations a few days into the future


Thanks!

Dominant river tracing-Routing Integrated with VIC Environment (DRIVE) model

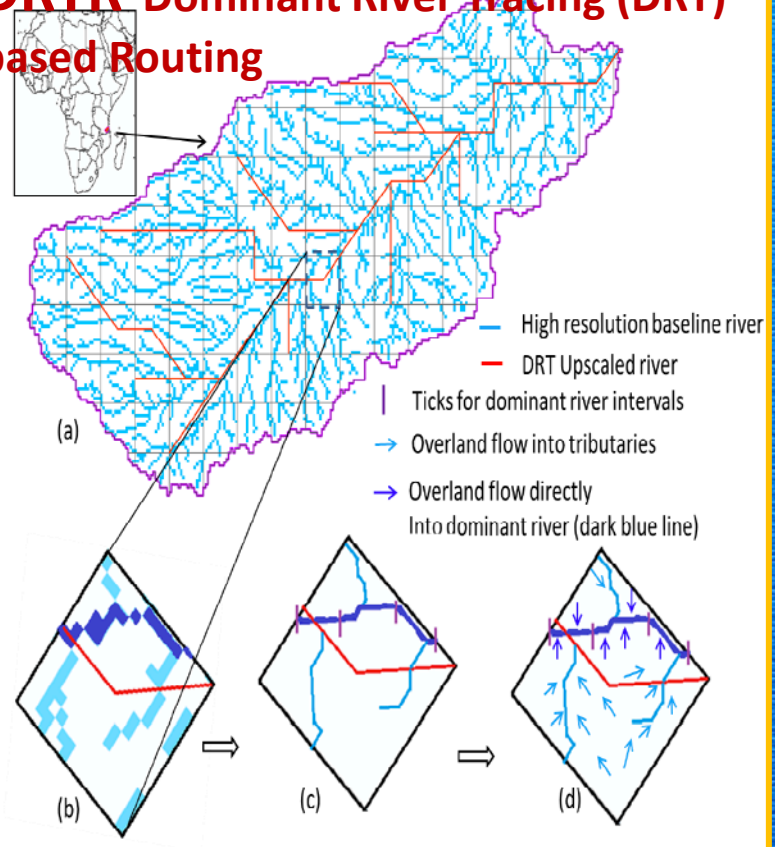
(Wu et al., 2011, 2012, 2014 *Water Resources Research*)

VIC



Coupled

DRTR-Dominant River Tracing (DRT) based Routing



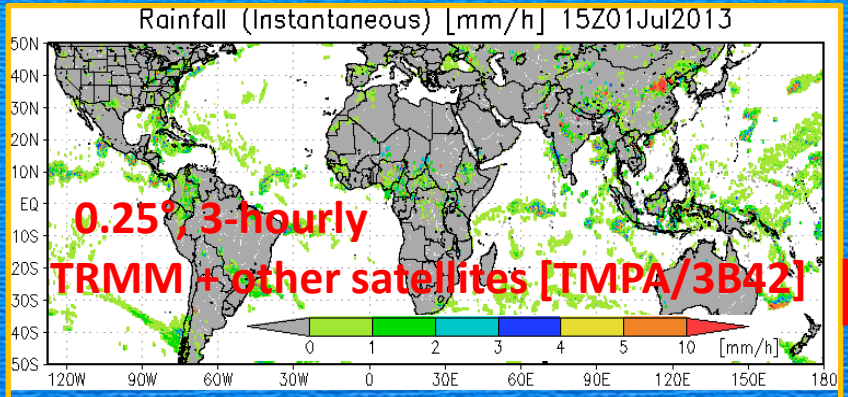
U. of Washington/Princeton U.

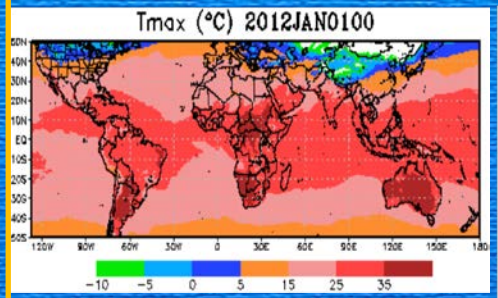
University of Maryland

Global Flood Monitoring System (GFMS) ***is running quasi-globally (50°S-50°N) every three hours at 1/8th degree, and routing is also running at 1km resolution.***

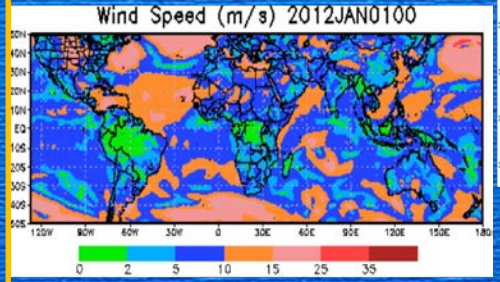
Global Flood Monitoring System (GFMS)/DRIVE model

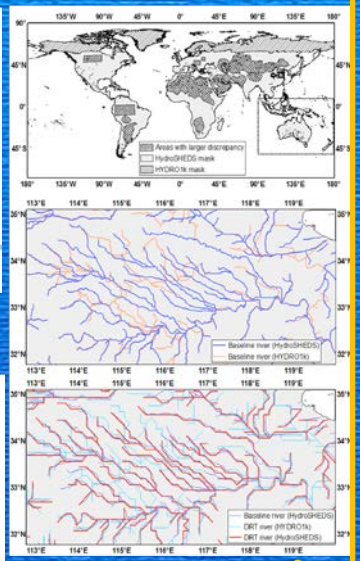
http://flood.umd.edu





MERRA



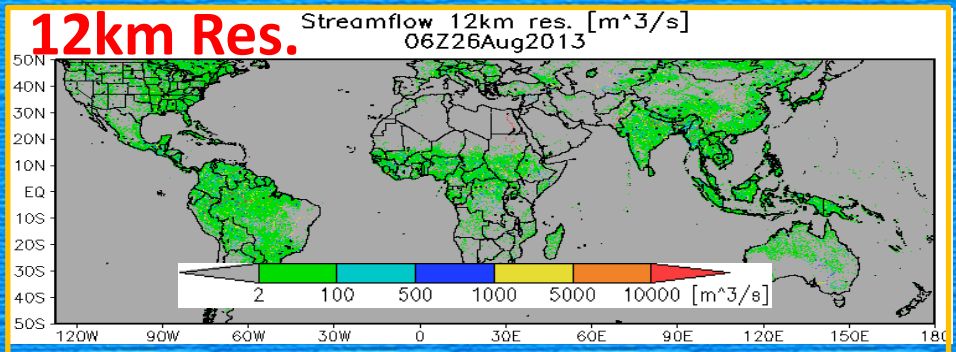


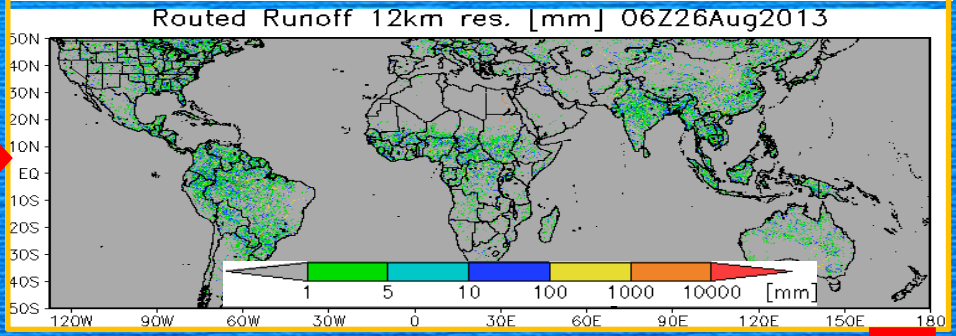
DRT, Wu et al., 2011,2012

Soil, Vegetation, Snowbands (Princeton)

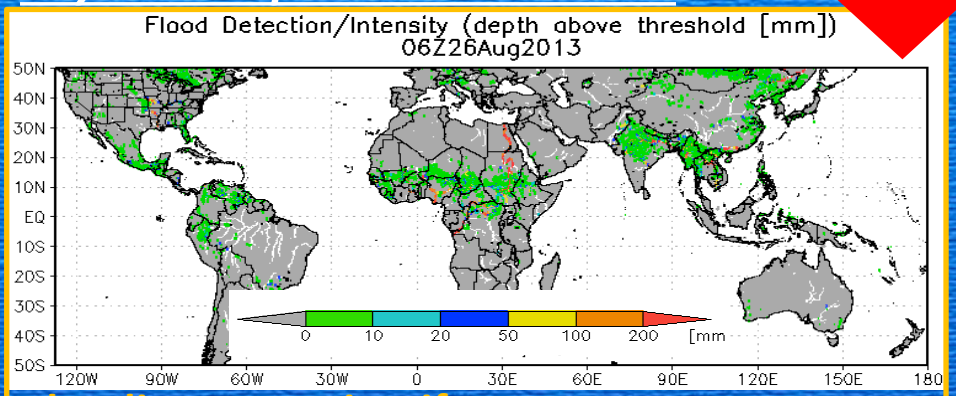
DEM (1km, HydroSHEDS)

12km Res.





15yr Retrospective simulation



Flooding at a point, if:

$$R > P_{95} + \delta \text{ and } Q > 10\ m^3/s$$

R: *routed runoff (mm);*

P_{95}: *95th percentile value of routed runoff;*

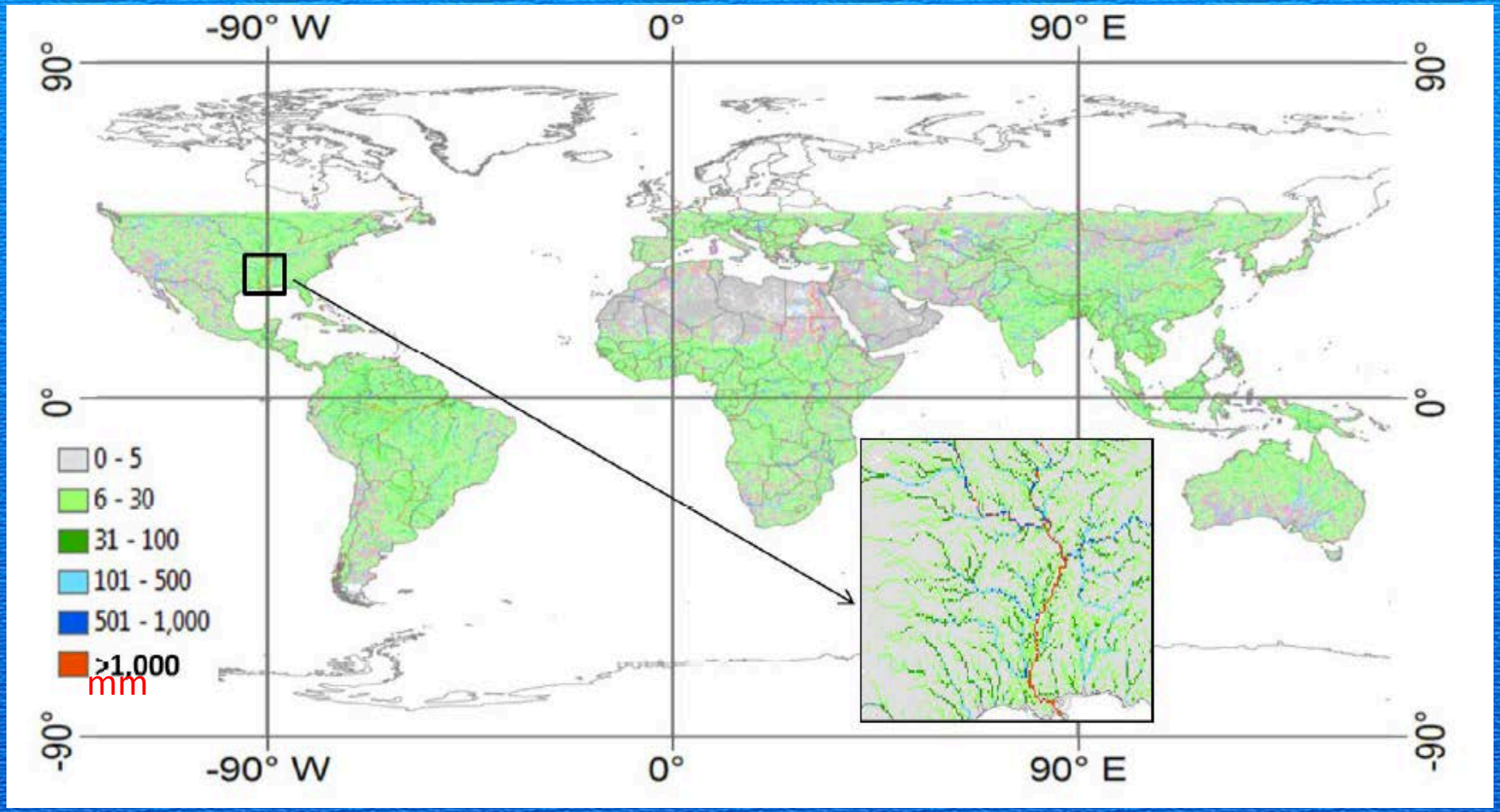
δ: *temporal standard deviation of routed runoff;*

Q: *discharge (m^3/s)*

Flood Threshold Map for Flood Detection/Intensity Parameter

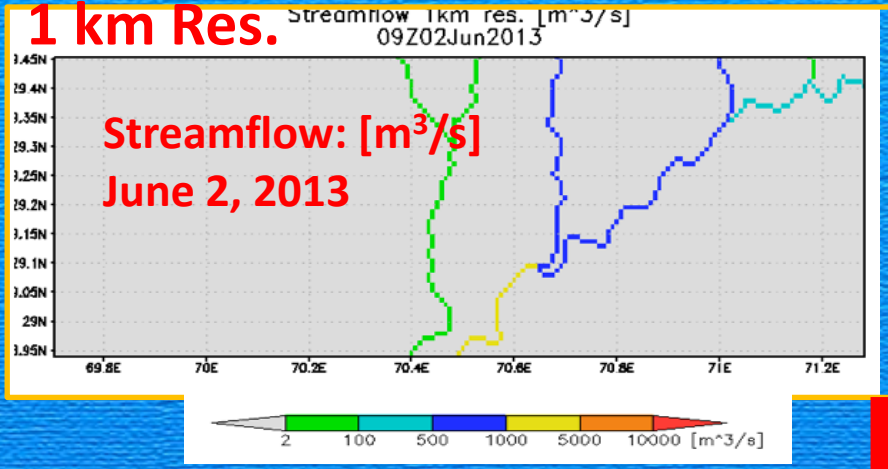
Routed Runoff (RR) > $RR_{95th\ Percentile}$ + δ and Q (streamflow) > 10 m^3/s, where δ is temporal standard deviation of RR.

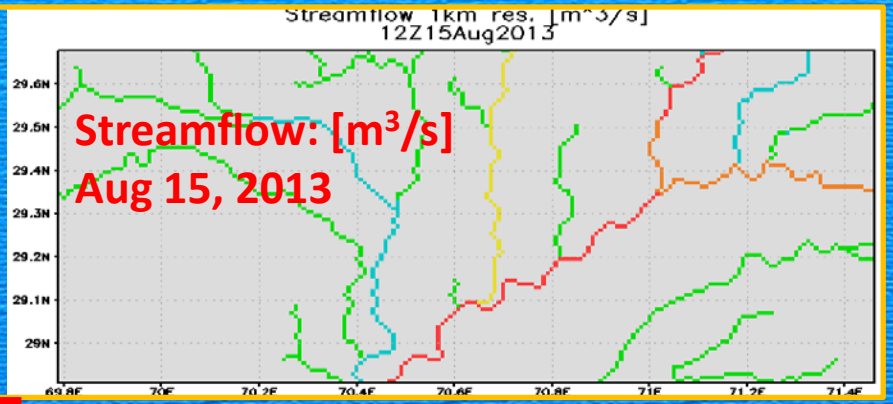
REFERENCE LEVEL at each grid calculated from 15-year global hydrology model run using satellite rainfall data



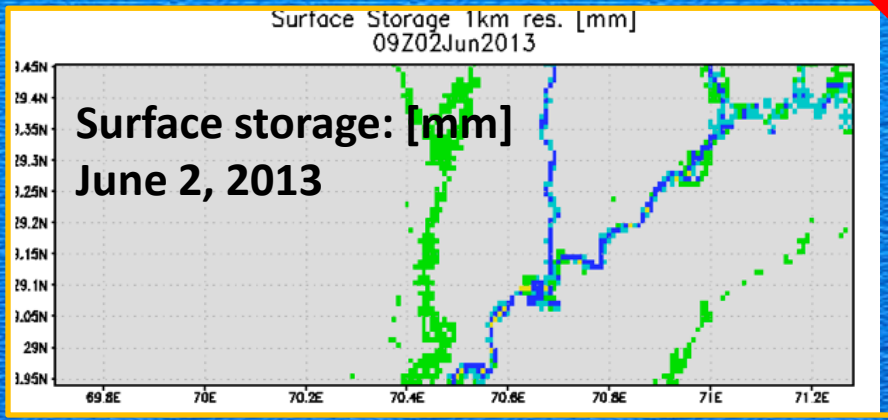
Same Approach is Used for Streamflow

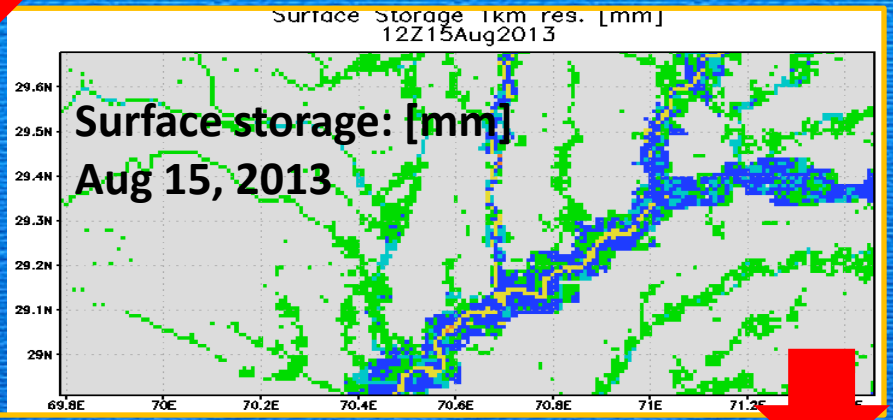
1 km Res.





DRIVE/Inundation module

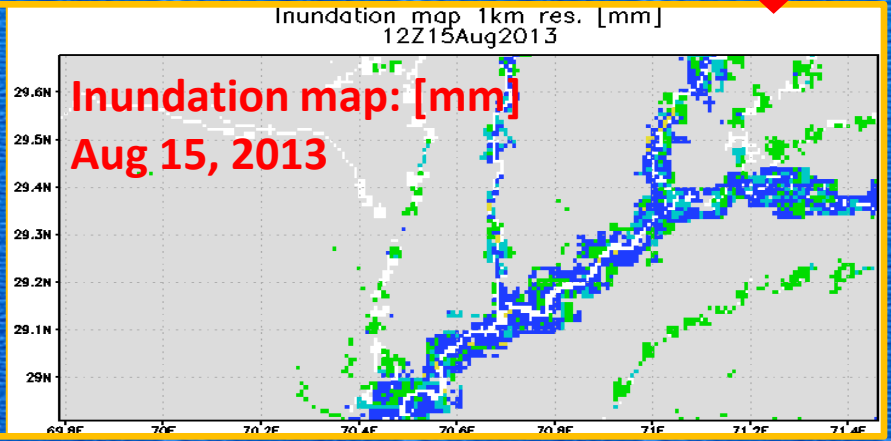




Experimental Inundation Mapping:

(1) Define a referential water coverage based on retrospective model simulation;

(2) Apply a small threshold to consider a certain water capacity of each pixel.



A basic package of flood information that the GFMS delivers every 3 hours to the world (publically accessible: flood.umd.edu):

1. Current flood situation (flood identification and intensity, streamflow, surface water depth, inundation etc.);

2, Satellite-based precipitation: instantaneous, 1-day, 3-day, 7-day (credited to NASA TRMM mission);

3, Spatial and temporal evolution of flood events (animation of each variable);

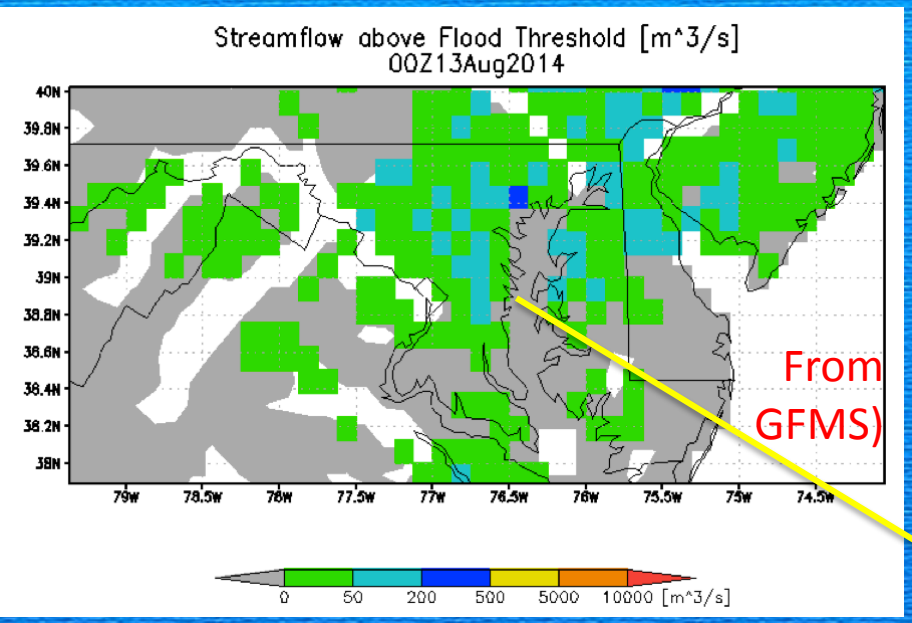
4, Easy to retrieve the time history of quantitative magnitudes of each flood variable for any point over the globe (50°S-50°N);

5, High resolution (up to 1km) flood information, with detailed inundation.

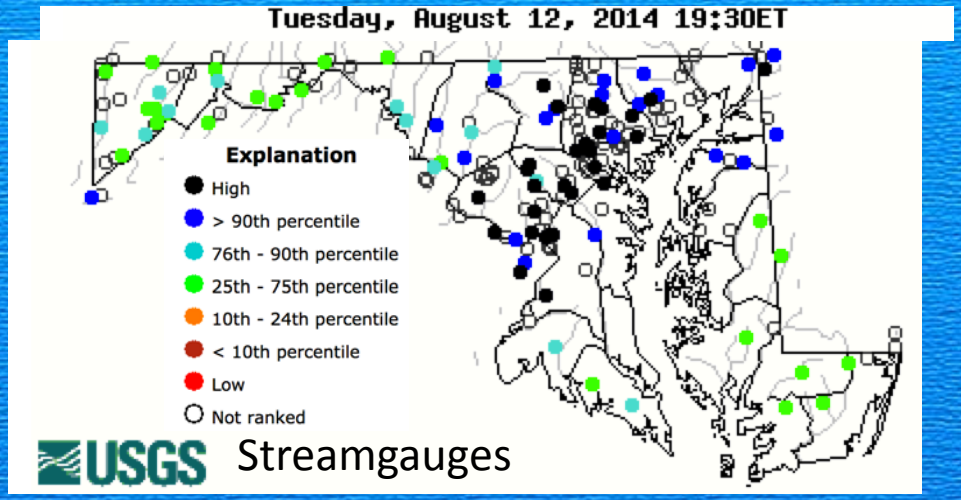
6, Forecast of precipitation (NASA GEOS-5) and floods (DRIVE model) into future four-five days;

Online tour

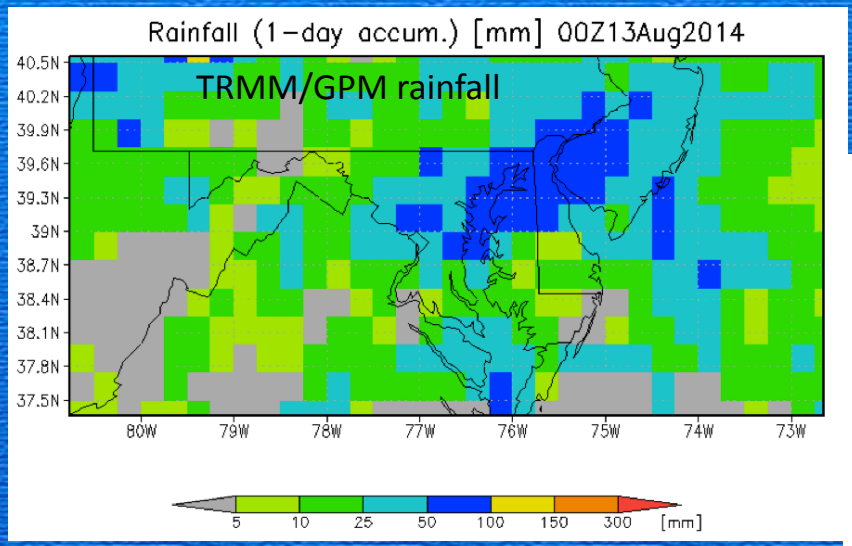
Case 3: Quick Evaluation of GFMS with Heavy Rain Event over Maryland/DC Aug 12, 2014

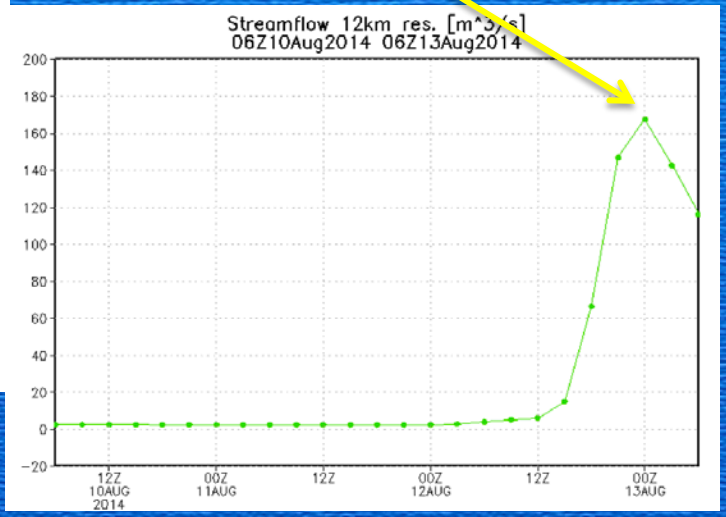


From GFMS)



TMPA rainfall (3-hr snapshot and 25 km resolution) showed peak at ~ 90 mm (nearly 4”), roughly comparable with area means from ground, but lower than 6-8” point measurements. Global system at 12 km resolution picks up location of high streamflows in central Maryland (example time history in Patuxent R.

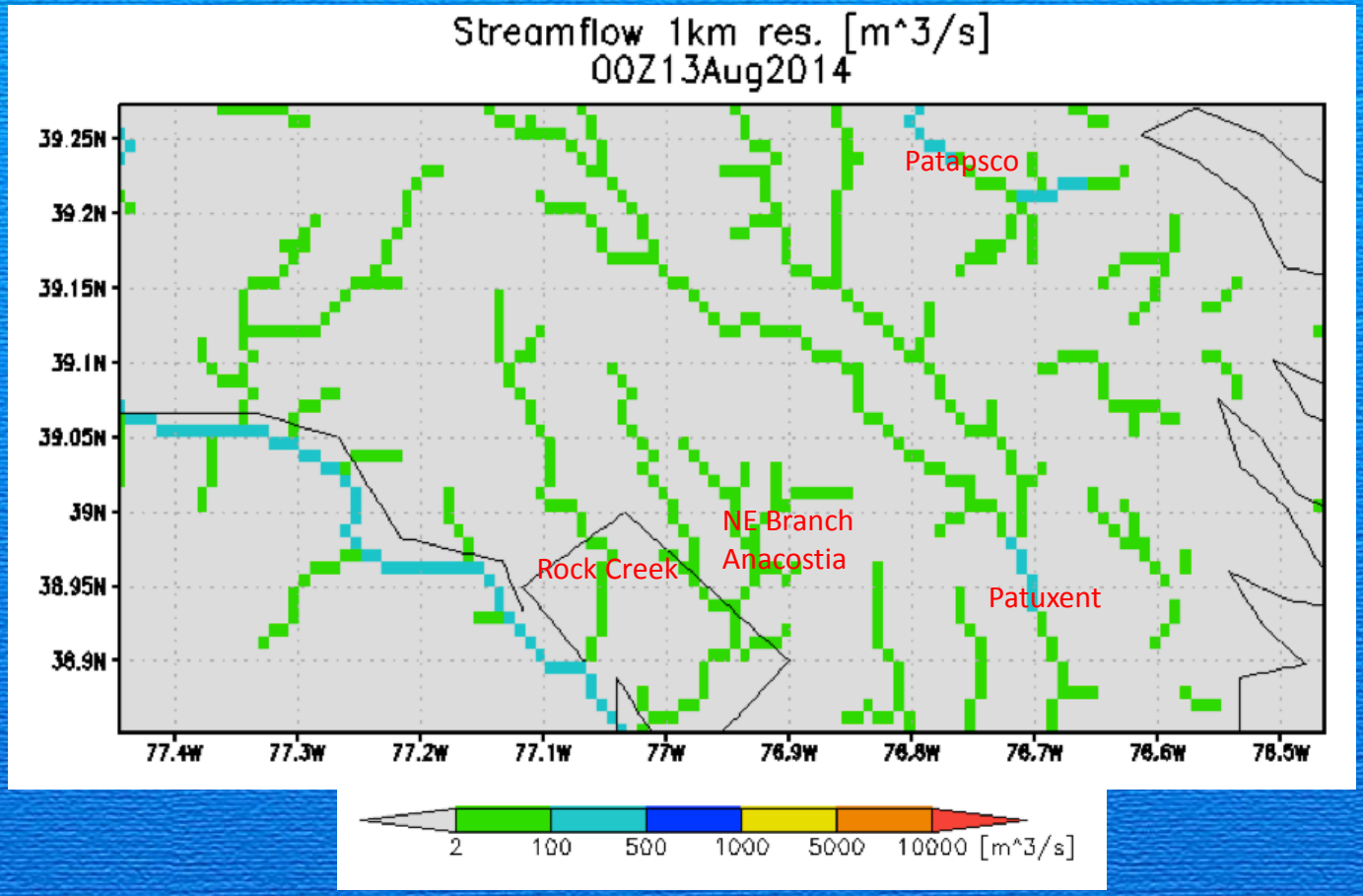




Coarse resolution (12 km) calculations do not discern smaller rivers. GFMS also runs routing at 1km routinely (see next slide)

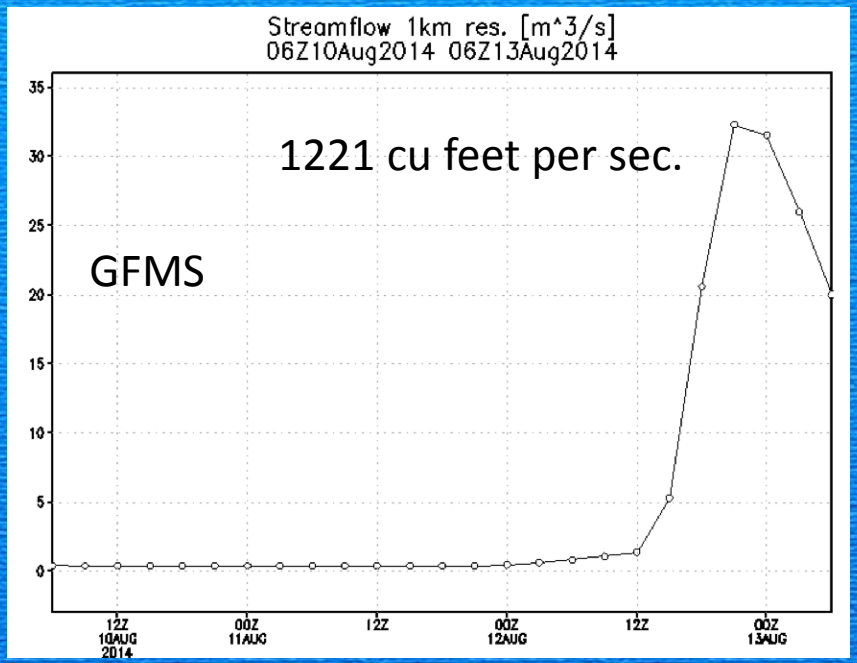
Adler/Wu UMD

1 km Routing (Applied Globally) in GFMS

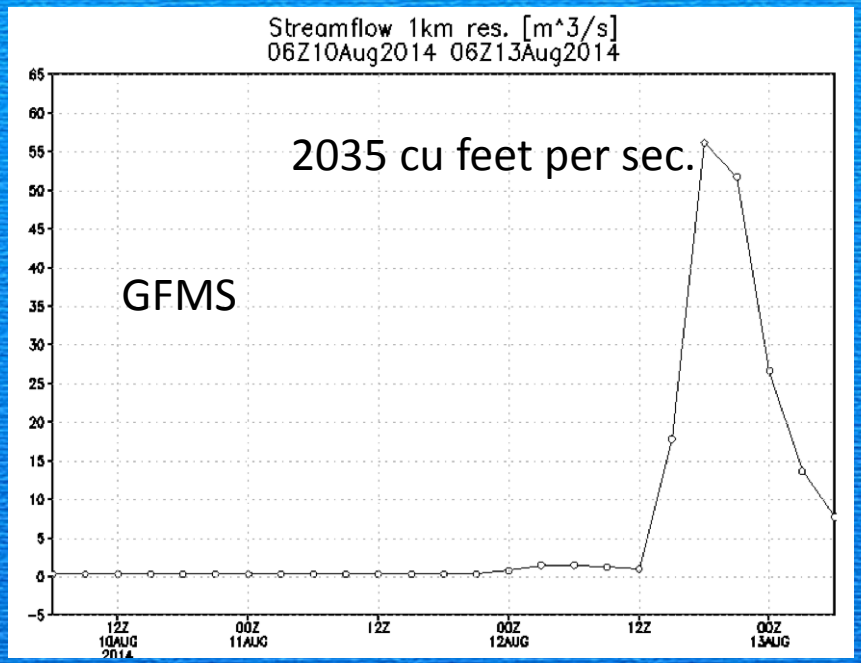


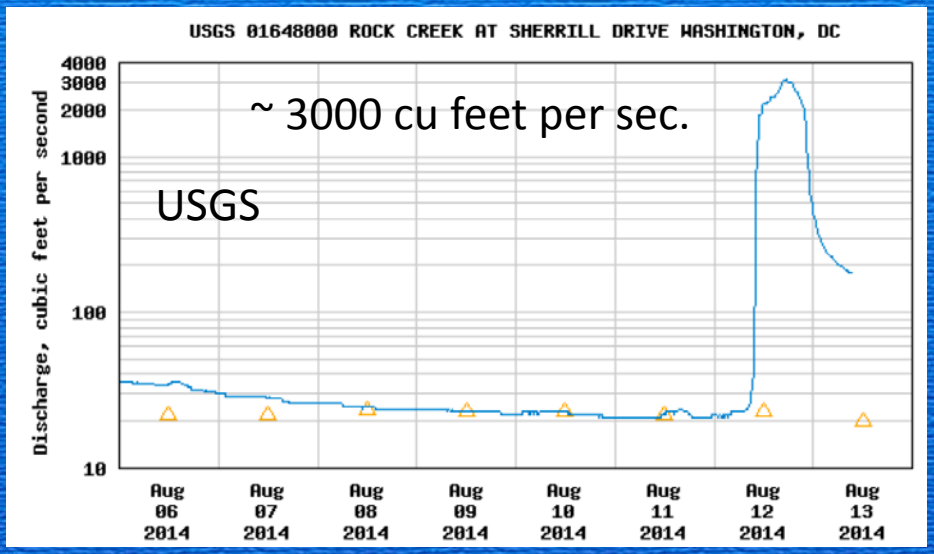
High resolution routing picks out smaller stream/rivers and picks out events. Peak Streamflow comparisons show mixed results (see following slides with near real-time global 1 km calculations compared to in-situ streamgauges) with rough agreement in magnitude, with differences due to incorrect distribution of rain, dams (not in model), or model/routing deficiencies. But, overall good results considering satellite rainfall and global system.

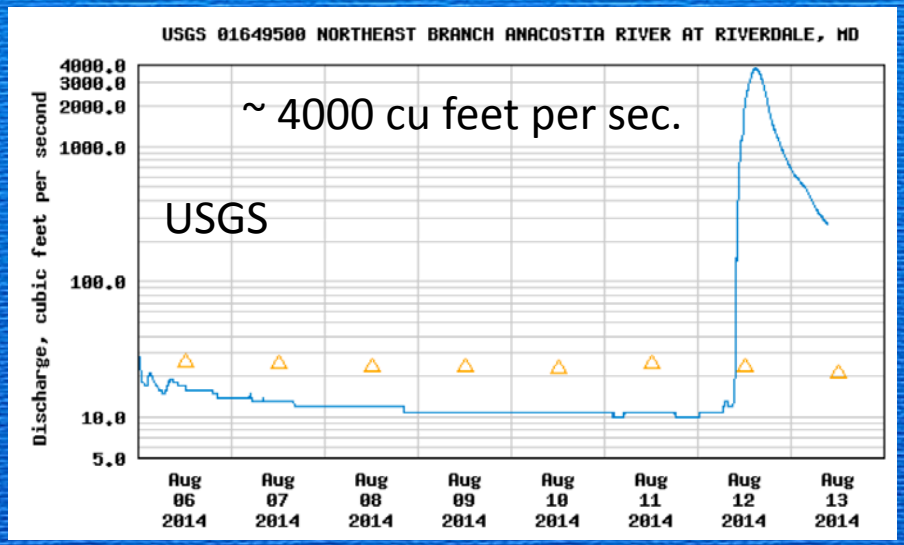
Rock Creek, DC



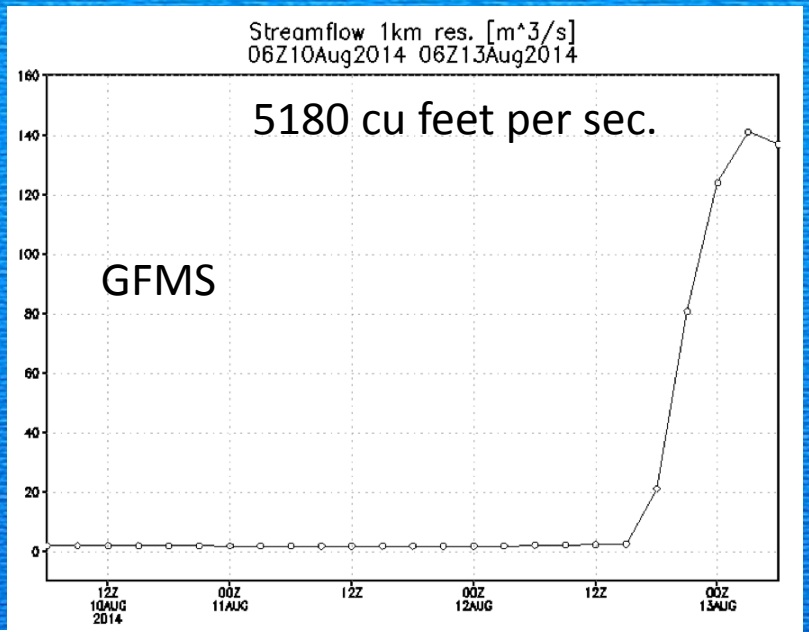
NE Branch Anacostia, very near ESSIC/UMD

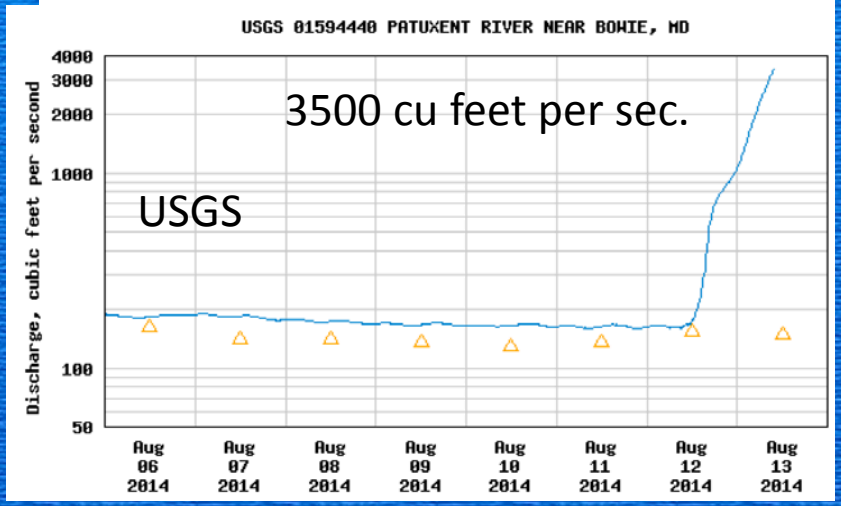






Patuxent





Patapsco