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

TMPA
TRMM calibrating rainfall from other satellites as forerunner to GPM

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
Comparison over U.S. for Today

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

<table>
<thead>
<tr>
<th>Metrics</th>
<th>POD</th>
<th>FAR</th>
<th>CSI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metrics averaged over all the 38 WRAs</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>DRIVE-V7RT</td>
<td>0.90</td>
<td>0.73</td>
<td>0.25</td>
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<tr>
<td>DRIVE-V7</td>
<td>0.93</td>
<td>0.65</td>
<td>0.34</td>
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<tr>
<td>Metrics averaged over the 20 WRAs with ≥ 5 dams</td>
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<tr>
<td>DRIVE-V7RT</td>
<td>0.93</td>
<td>0.80</td>
<td>0.19</td>
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<tr>
<td>DRIVE-V7</td>
<td>0.94</td>
<td>0.73</td>
<td>0.26</td>
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<tr>
<td>Metrics averaged over the 18 WRAs with &lt; 5 dams</td>
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<tr>
<td>DRIVE-V7RT</td>
<td>0.87</td>
<td>0.66</td>
<td>0.32</td>
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<tr>
<td>DRIVE-V7</td>
<td>0.92</td>
<td>0.56</td>
<td>0.43</td>
</tr>
</tbody>
</table>

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.

- Monthly: 60% of gauges with positive values with mean of 0.39
- Daily: 32% of gauges with positive values with mean of 0.22
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).
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

DFO Station 284: 2013-01-01 to 2014-09-09

Based on Riverwatch (U. of CO) Surface Microwave

Based on TRMM/GPM Rainfall into Hydrologic Model

GFMS at same point: 2013-01-01 to 2014-09-09

DFO Station 288: 2013-01-01 to 2014-09-09

GFMS at same point: 2013-01-01 to 2014-09-09
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.
Model performance vs. Precipitation bias

Long-term

Mean Annual Relative Error (%)

R = 0.82

 Basin-averaged mean annual precipitation bias (%)

Discharge (USGS05465500)

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

Daily Precip. PDF

Daily Runoff PDF

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%
TMPAR
NSC = 1.02
MARE = 8%
CMORPH
NSC = 0.24
RE = 21%
TMPART
NSC = 1.22
RE = 1%

DRIVE

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

<table>
<thead>
<tr>
<th></th>
<th>Mon</th>
<th>Tues</th>
<th>Wed</th>
<th>Thur</th>
<th>Fri</th>
<th>Sat</th>
<th>Sun</th>
<th>Total</th>
<th>Avg</th>
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<td>Pageloads</td>
<td>104</td>
<td>29</td>
<td>25</td>
<td>17</td>
<td>25</td>
<td>4</td>
<td>5</td>
<td>209</td>
<td>30</td>
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<td>28</td>
<td>21</td>
<td>16</td>
<td>15</td>
<td>4</td>
<td>5</td>
<td>139</td>
<td>20</td>
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<tr>
<td>First Time Visits</td>
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<td>11</td>
<td>10</td>
<td>9</td>
<td>10</td>
<td>2</td>
<td>3</td>
<td>72</td>
<td>10</td>
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<tr>
<td>Returning Visits</td>
<td>23</td>
<td>17</td>
<td>11</td>
<td>7</td>
<td>5</td>
<td>2</td>
<td>2</td>
<td>67</td>
<td>10</td>
</tr>
</tbody>
</table>
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!
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

12km Res.

0.25°, 3-hourly
TRMM + other satellites [TMPA/3B42]

15yr Retrospective simulation

Flooding at a point, if:

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

- \( R \): routed runoff (mm)
- \( P_{95} \): 95th percentile value of routed runoff
- \( \delta \): temporal standard deviation of routed runoff
- \( Q \): discharge (m³/s)
Flood Threshold Map for Flood Detection/Intensity Parameter

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

REFERENCE LEVEL at each grid calculated from 15-year global hydrology model run using satellite rainfall data.
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;
Case 3: Quick Evaluation of GFMS with Heavy Rain Event over Maryland/DC Aug 12, 2014

TMPA rainfall (3-hr snapshot and 25 km resolution) showed peak at \( \sim 90 \text{ mm} \) (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
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

Streamflow 1km res. [m$^3$/s]
06Z10Aug2014 06Z13Aug2014

1221 cu feet per sec.

GFMS

NE Branch Anacostia, very near ESSIC/UMD

Streamflow 1km res. [m$^3$/s]
06Z10Aug2014 06Z13Aug2014

2035 cu feet per sec.

GFMS

USGS 01648000 ROCK CREEK AT SHERKILL DRIVE WASHINGTON, DC

~ 3000 cu feet per sec.

USGS

USGS 01649500 NORTHEAST BRANCH ANACOSTIA RIVER AT RIVERDALE, MD

~ 4000 cu feet per sec.

USGS
**Patuxent**

Streamflow 1km res. [m^3/s]
06Z10Aug2014 06Z13Aug2014

5180 cu feet per sec.

GFMS

**Patapsco**

Streamflow 1km res. [m^3/s]
06Z10Aug2014 06Z13Aug2014

4995 cu feet per sec.

GFMS

**Patuxent River Near Bothe, MD**

USGS 01594448

3500 cu feet per sec.

USGS

**Patapsco River at Hollofield, MD**

USGS 01559888

800 cu feet per sec.

USGS

*Big reservoir upstream*