River Watch Version 2

Experimental Satellite River Discharge and Runoff Measurements

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We use the AMSR-E (soon, GCOM-W) and the TRMM ~37 GHz passive microwave channels to measure river discharge at selected river gauging sites (*Figure 1*). Global hydrological modeling is also accomplished, in order to calibrate the remote sensing to discharge units, in m^3/sec [1-10]. A calibration is provided for each river gauging site: this is a static "rating curve" that is used to convert remote sensing signal to discharge values. The technique is closely analogous to that used for surface gauging stations, where rating curves are used to convert stage measurements to discharge.

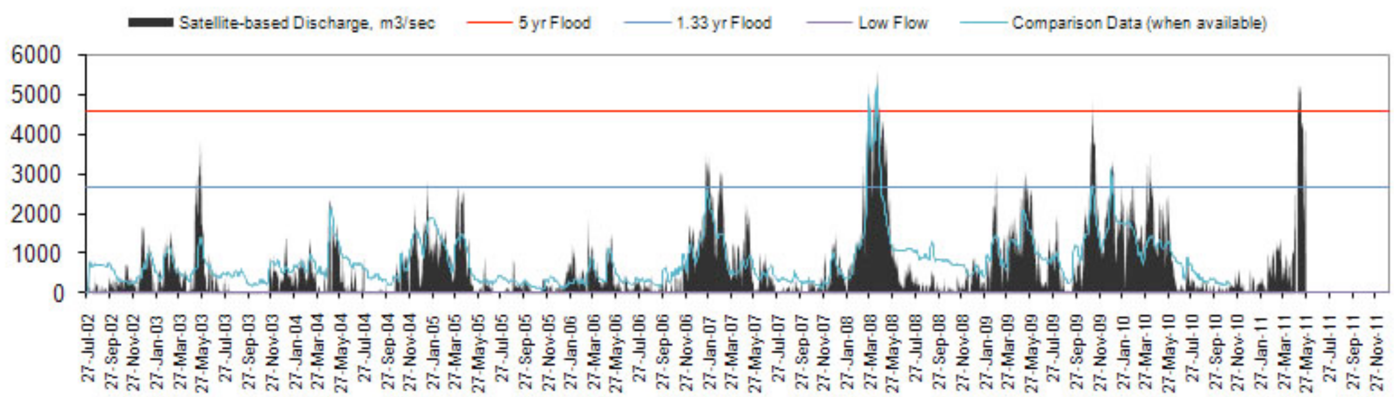
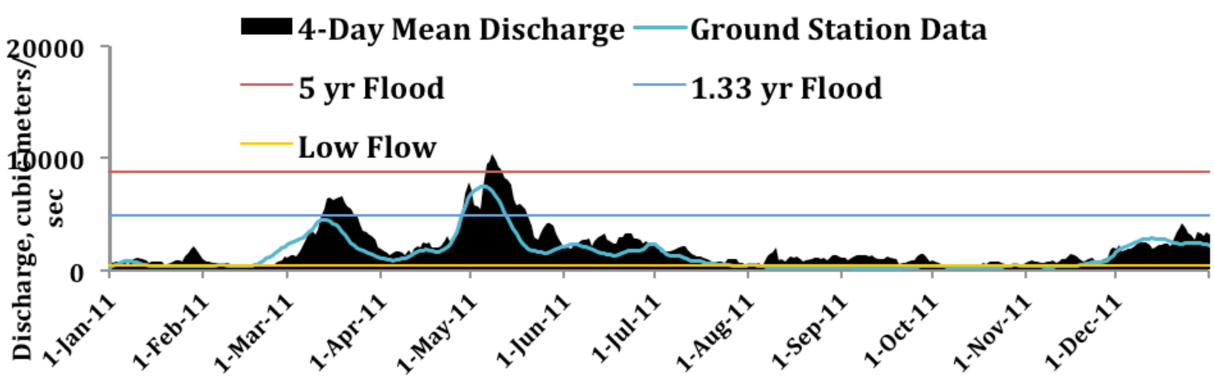
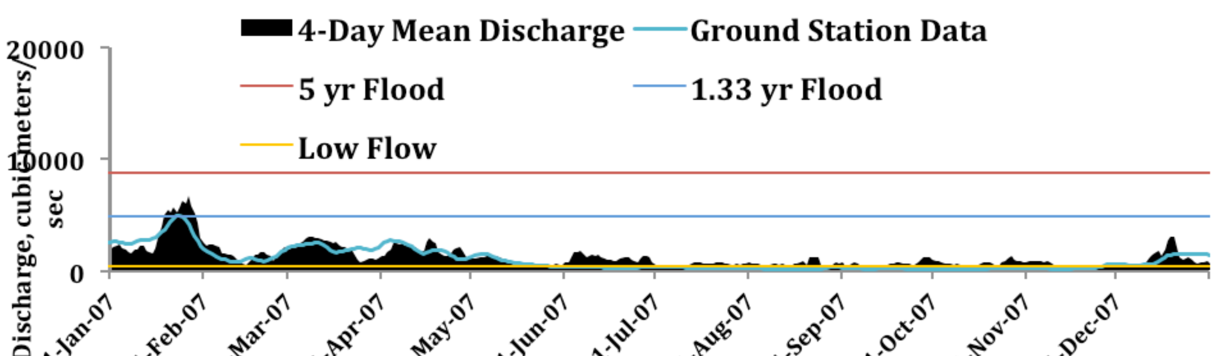


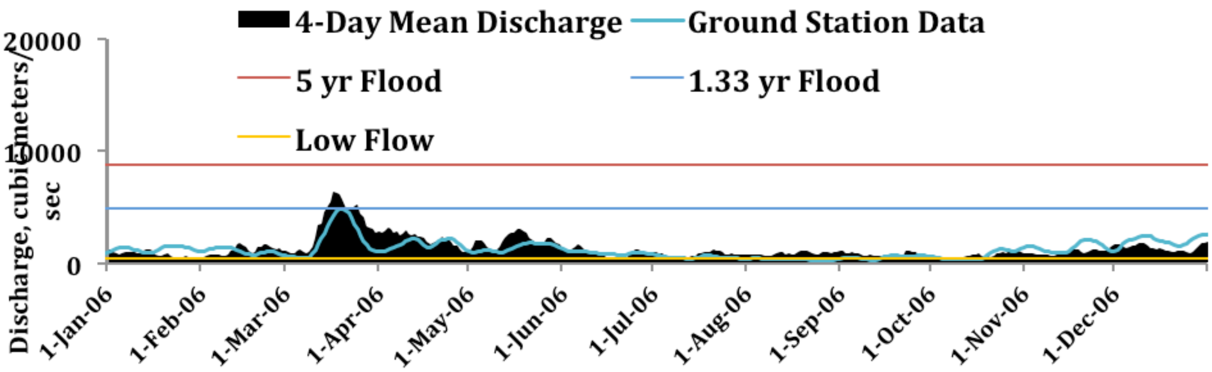
Figure 1. Daily-updated, 4-day forward running mean river discharge measurements via satellite (black curve) and as compared to (blue curve, ending late 2010) co-located surface gauging station data (White River, Arkansas; also as 4-day running means,). These results use the AMSR-E 36.5 GHz channel. This and other measurement sites are presently being monitored using the TRMM 37 GHz channel at (http://floodobservatory.colorado.edu/CriticalAreas/DischargeAccess.html). The satellite-based discharge time series shown in black is obtained without any supporting ground station information.

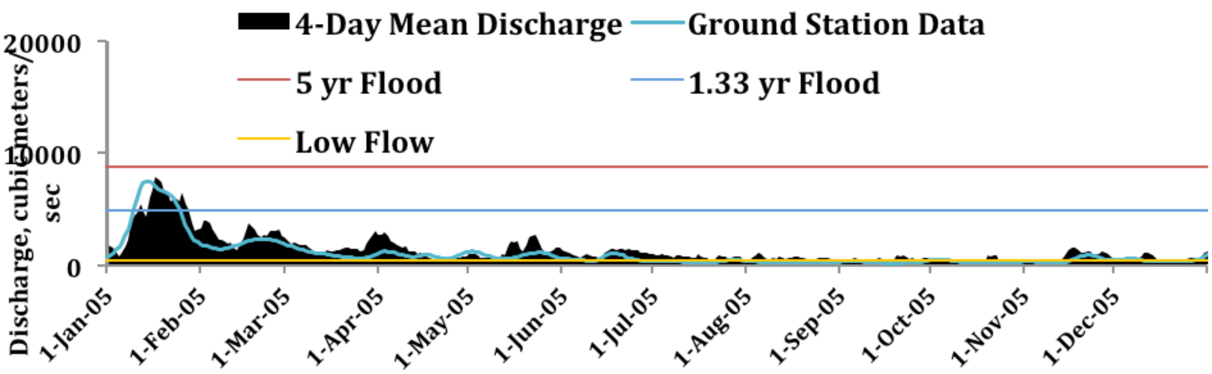
Figure 2 provides a more detailed comparison of the satellite discharge results to independent ground station data. The plot is shown at expanded time scales in order to illustrate the daily time-step resolution of the measurements and in parallel with the stage-based information. In general, these and other U.S. sites show the good agreement with "ground truth" measured discharge. Measurement accuracy statistics are currently being developed. There are, clearly, various errors: 1) in some cases, heavy cloud cover can cause interference, 2) there are intermittent sensor noise values, and 3) certain forms of agricultural irrigation produce surface water and affect the signal. However, because no ground-based information was used, satellite-based discharge values with at least this level of discharge value accuracy can now be obtained for a globally-distributed array of river measurement sites. Additional sensor data input can help reduce error sources, and any ground-based information can also be incorporated into site rating curves to improve their accuracy.

Figure 2 (following 6 plots, below). Comparison of measured discharge using the TRMM 37 GHz signal (in black) over the satellite gauging site to a local ground gauging station (blue line). Daily-updated four-day running mean discharge data are shown in increments of one year, for 2011, 2007, 2006, 2005, and 2002. Bottom plot shows entire time series. Site 91, Wabash River, U.S.; latitude 37.16 to 39.25 N; longitude 89.02 to 86.93 W; contributing area 76133 km^2.






4-Day Mean Discharge
Ground Station Data
5 yr Flood
1.33 yr Flood
Low Flow
Discharge, cubic meters/ sec
20000
10000
0
1-Jan-06
1-Feb-06
1-Mar-06
1-Apr-06
1-May-06
1-Jun-06
1-Jul-06
1-Aug-06
1-Sep-06
1-Oct-06
1-Nov-06
1-Dec-06


4-Day Mean Discharge
Ground Station Data
5 yr Flood
1.33 yr Flood
Low Flow
Discharge, cubic meters/ sec
20000
10000
0
1-Jan-05
1-Feb-05
1-Mar-05
1-Apr-05
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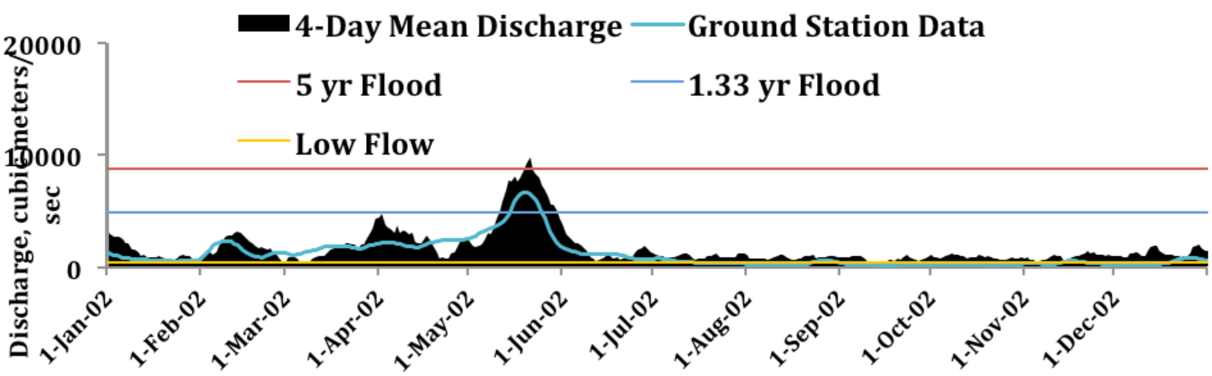
1-Nov-05
1-Dec-05


4-Day Mean Discharge
Ground Station Data
5 yr Flood
1.33 yr Flood
Low Flow
Discharge, cubic meters/ sec
20000
10000
0
1-Jan-02
1-Feb-02
1-Mar-02
1-Apr-02
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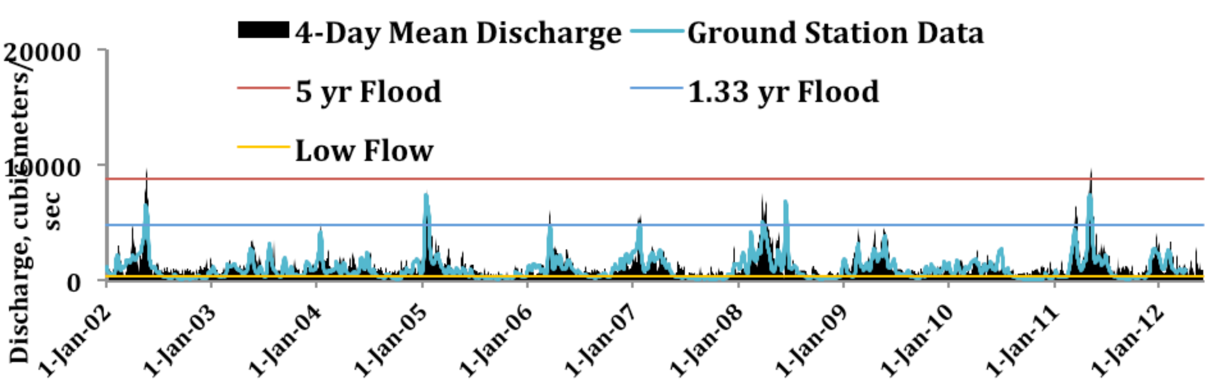
1-Nov-02
1-Dec-02


4-Day Mean Discharge
Ground Station Data
5 yr Flood
1.33 yr Flood
Low Flow
Discharge, cubic meters/ sec
20000
10000
0
1-Jan-02
1-Jan-03
1-Jan-04
1-Jan-05
1-Jan-06
1-Jan-07
1-Jan-08
1-Jan-09
1-Jan-10
1-Jan-11
1-Jan-12

Using these remote sensing data, storm-related discharge hydrographs are being accurately detected and quantified. This allows for computation of runoff water volumes given a defined contributing watershed area. Also, standard flood frequency statistical techniques (based on the Log Pearson III distribution) are applied to the discharge time series to compute the discharges associated with different flood recurrence intervals (exceedance probabilities). These "5 yr" and "1.33 yr", etc. floods provide convenient thresholds for automatically detecting when a river measurement site is experiencing flooding, and as based on customary hydrologic practice. The near real time information may also be used in providing basin hydrological model updates for improved flood prediction[11-15].

As the case for *in situ* gauging stations and their stage/discharge relations, the satellite signal/discharge relation is empirical and may be nearly linear or instead be better approximated by a low order polynomials [3,4] or other curves**.** They will vary with individual measurement site channel and floodplain geomorphology.

The satellite gauging sites currently being measured are mainly single-pixel (within a gridded TRMM 37 GHz brightness temperature global image), ~10 km square river reaches (*Figure 3*). The footprints (ground areas actually sampled) are available online for each satellite gauging site as well.

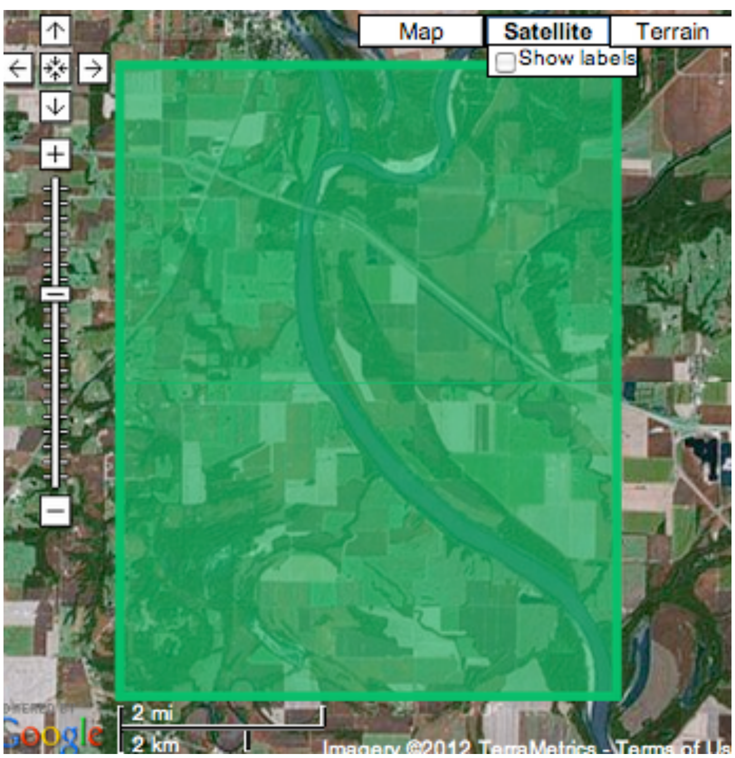


Figure 3. View of the measurement site for the Figure 2 plots (satellite gauging site #91). Microwave emission from this pixel is ratioed to brightness values obtained within a 7 x 7 pixel array centered on this pixel [7,8], thereby removing most daily and seasonal variations due to non-hydrological factors.

Because each reach should exhibit a different satellite signal/discharge relation, we use a global runoff modeling technique to establish the static rating curve (*Figure 4*).

This allows direct and independent construction of the remote sensing signal/discharge relation. The two time series are entirely independent; one is daily modeled discharge, the other is the remote sensing river measurements over the site.

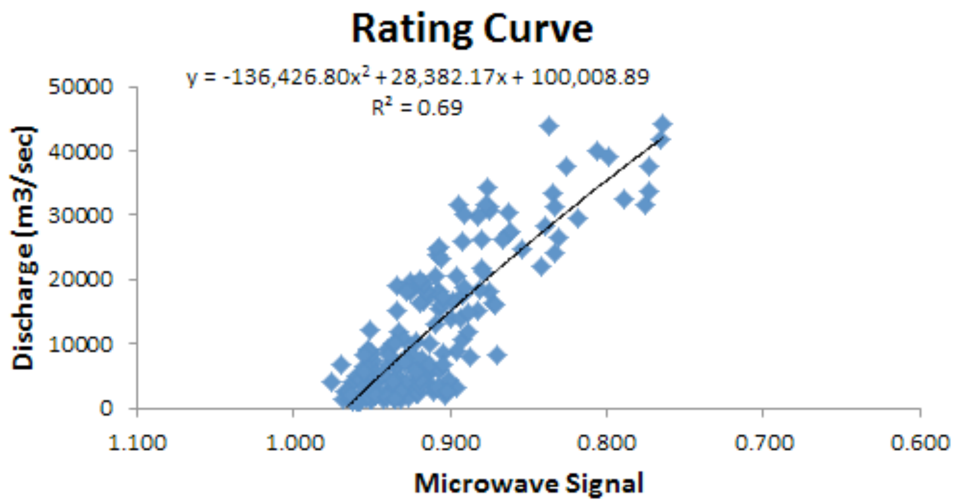


Figure 4. Sample calibration/rating curve (site #1936, Brahmaputra River) comparing the TRMM 37 GHz discharge estimator to WBM hydrology model-estimated discharges. The model was run in one day increments for 2001-2005; the plot compares monthly mean, maximum and minimum values for those years for both signal and modeled discharge. The same technique provided the rating curves for the plots shown in Figure 2.

The degree of correlation of signal to modeled discharge in the rating curves is one indicator of the level of site sensitivity to discharge variation. A strong correlation indicates that both the model and the remote sensing are accurately capturing high, medium, and low discharge values. Some of the scatter in the rating curves is due to the model error, some from remote sensing error. We and other colleagues are currently using the WBM global hydrological model[2,3,16,17] to produce initial rating curves, and as, for example, tested and illustrated here in Figures 2 and 4. It is very likely that the rating curves can be improved by better modeling and by devising more sensitive remote sensing processing strategies. However, the day to day variation and long term time series of discharge is, clearly, already being well-captured by the remote sensing, and even if rating curve error introduces consistent positive or negative bias in the daily results.

This work represents significant progress towards accurate, consistent, timely, and globally-distributed river discharge measurements from satellite sensors. Both existing and planned sensors can be incorporated together, and such observational data can thereby provide independent input into the global hydrological models that are under development. We also hope that multiple other applications, including automated flood detection, will continue to be developed and improved. The >14 yr year period of record already available (commencing with TRMM and supplemented by AMSR-E and now GCOM-W) should also facilitate testing of hypotheses regarding changes in the Earth's hydrological cycle at a variety of time scales.

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(many are available online at: http://floodobservatory.colorado.edu/SupportingPublications.htm)

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