Next Generation of a Real-time Global Flood Monitoring System Using Satellite-based Precipitation and a Land Surface Model

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1. Introduction

A real-time Global Flood Monitoring System (GFMS) using Tropical Rainfall Measuring Mission (TRMM) Multi-satellite Precipitation Analysis (TMPA) rainfall products and a hydrologic model (Wang et al., 2011) is operating routinely and producing flood detection and intensity results (http://oas.gsfc.nasa.gov/globalflood/). This current system is discussed elsewhere in this session and was evaluated recently regarding the performance in flood detection against available flood event archives (Wu et al, 2012). The evaluation showed positive performance of the current system. Flood detection probabilities improve with larger, longer floods and false alarms are more frequent in basins with large dams. For floods with durations > 3 days and in areas without large dams, the current system gets POD of 0.74 and FAR of 0.63.

Global to Regional Flood Detection by current GFMS

Example: Detection of Flooding over North Korea

Flood Detection/Intensity (Depth above Threshold [mm])

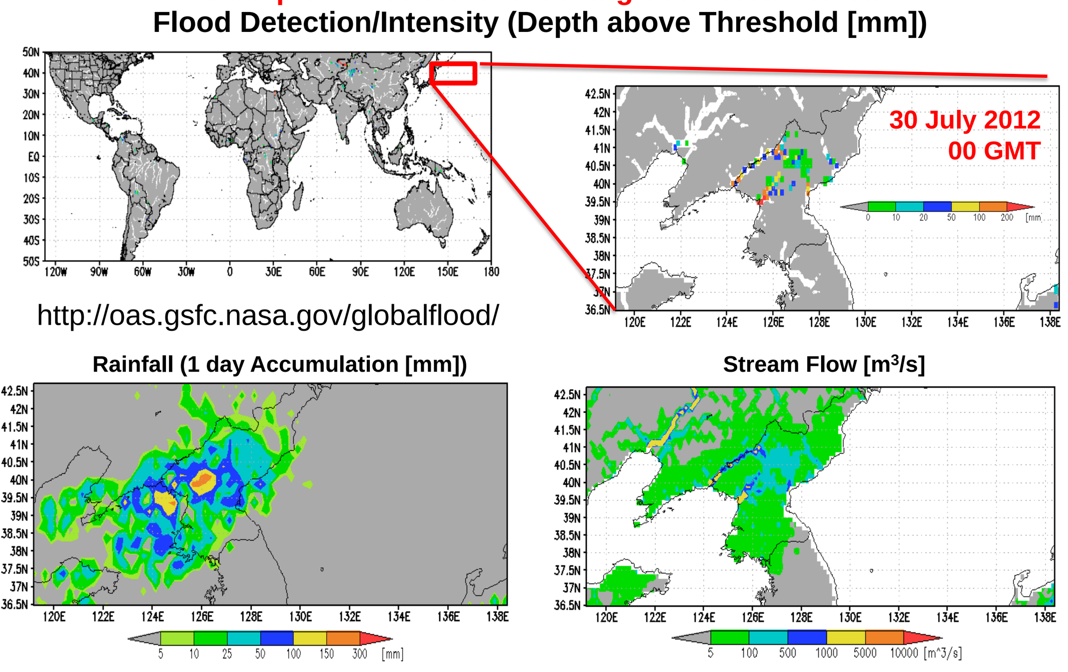


Fig. 1 example of flood detection from current GFMS

This evaluation also provided a pathway forward for improvement through the use of the hydrologic model component of the GFMS by coupling a more physically-based land surface model, the Variable Infiltration Capacity (VIC) Model (U. of Washington), with a newly developed routing model. The VIC model also includes a snowmelt and soil frost process, which will also benefit the GFMS in forecasting spring streamflow and snowmelt related floods.

2. The model framework of the next generation GFMS

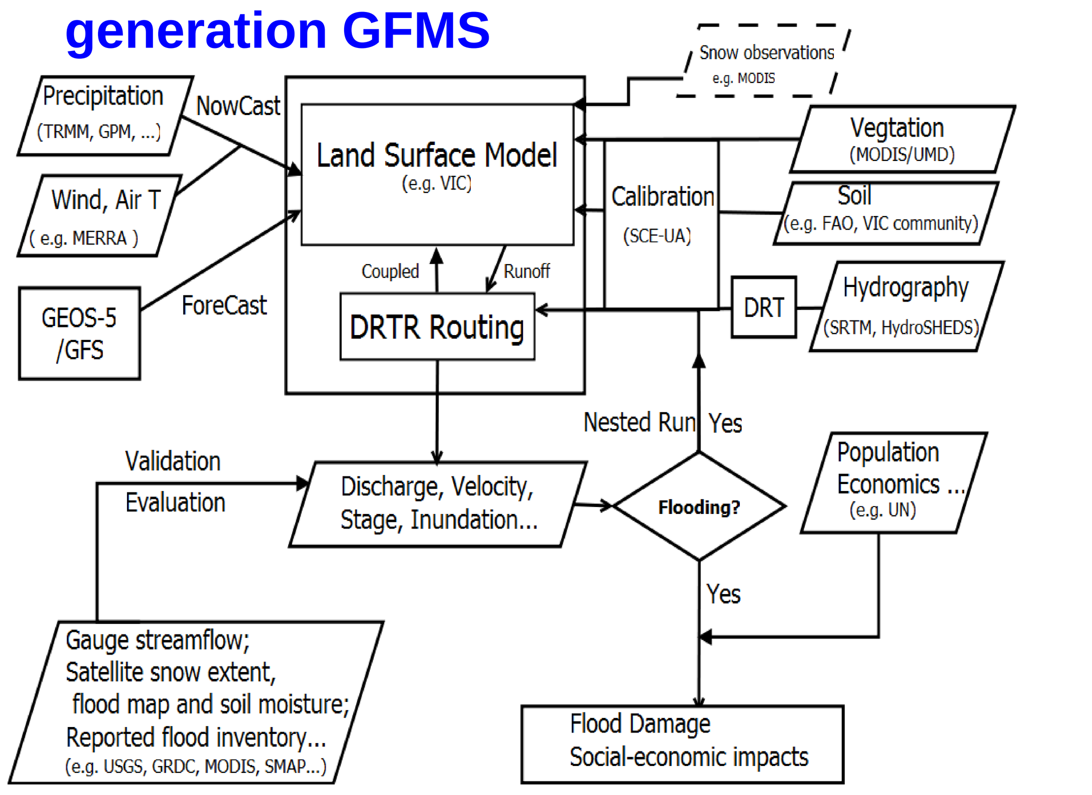


Fig. 2 Schematic of the next generation of GFMS

The overall system (Fig. 2) will use a two-level approach where the global, relatively coarse resolution products (~ 10 km) will be available to serve as background (e.g., identifying emerging flood hazards) and provide routine information across the globe. For those areas identified as having floods from the global 10 km-resolution run, we will provide high-resolution flood products (~ 1 km). This nested approach will provide high-resolution products for all identified flood areas for use in pinpointing the hazard locations and evolution. A similar approach will be done using the NWP forecasts, i.e., global 10 km runs of the flood model using NWP precipitation will be done routinely out to five days, with high resolution model runs being done for ~ 5 additional (forecast, not ongoing) floods.

Dominant River Tracing-based Routing (DRTR) Runoff (VIC)

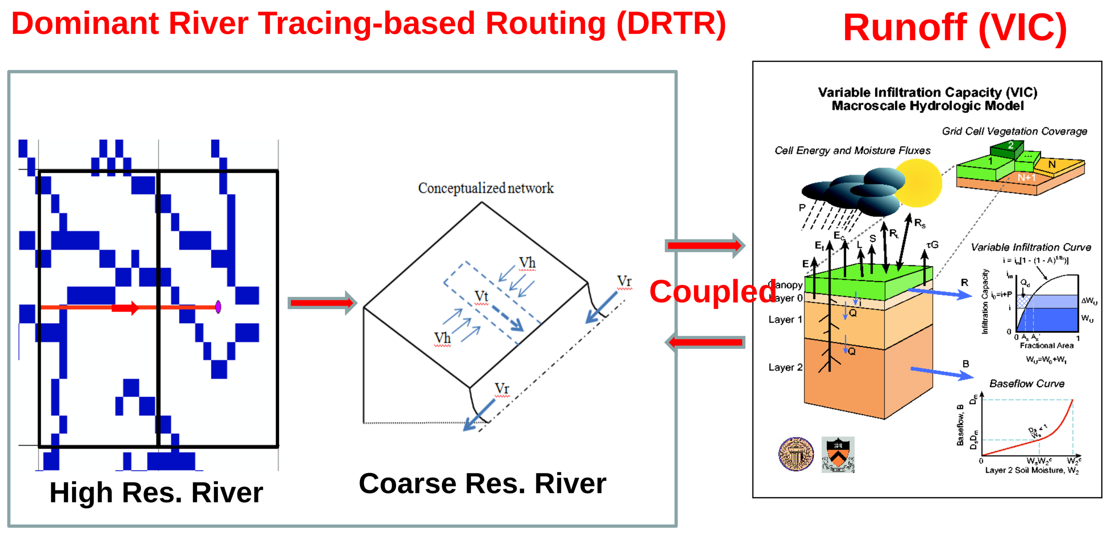


Fig. 3 coupled VIC/DRTR model as the core of the next generation GFMS

The VIC model was adapted from its original individual grid cell based running mode to a mode that is suitable for real-time runoff prediction. A new Dominant River Tracing-based Routing (DRTR) model was developed with innovative features, i.e., the model is physically based, spatial-temporal scale adaptive, suitable for real-time operation, and addresses sub-grid routing, with accurate parameterization from fine-resolution input data. The DRTR model was coupled with the VIC model to form the hydrologic modelling core of the new GFMS. The user community needs high-resolution (~ 1 km) information for many applications of the flood information and the river routing module is the key to obtaining that information.

3. Model set-up

We performed a TRMM era retrospective simulation from 1998 to 2012, using the TMPA V7 research data (with monthly gauge data) to drive the coupled VIC/DRTR model for quasi-globe (50ºN-50ºS), at 3-hourly temporal resolution and 1/8th degree spatial resolution. The quarter-degree resolution global soil and vegetation parameters (provided by Justin Sheffield, University of Princeton) were simply downscaled to 1/8th degree. The hydrographic parameters (e.g. Flow direction, Drainage area, Flow length, Channel width, Channel slope, overland slope, Flow fraction, River order) for DRTR runoff-routing scheme were derived by the hierarchical Dominant River Tracing algorithm (DRT) (Wu et al., 2011, 2012, *Water Resour. Res.*) applied to HydroSHEDS global 1km baseline hydrographic data. Other forcing data (i.e. air temperature and wind) were used from the reanalysis data by NASA Modern-Era Retrospective analysis for Research and Applications (MERRA). The TMPA V7 real-time rainfall data are used for our operational simulation at every three hour intervals.

4. Model evaluation: streamflow

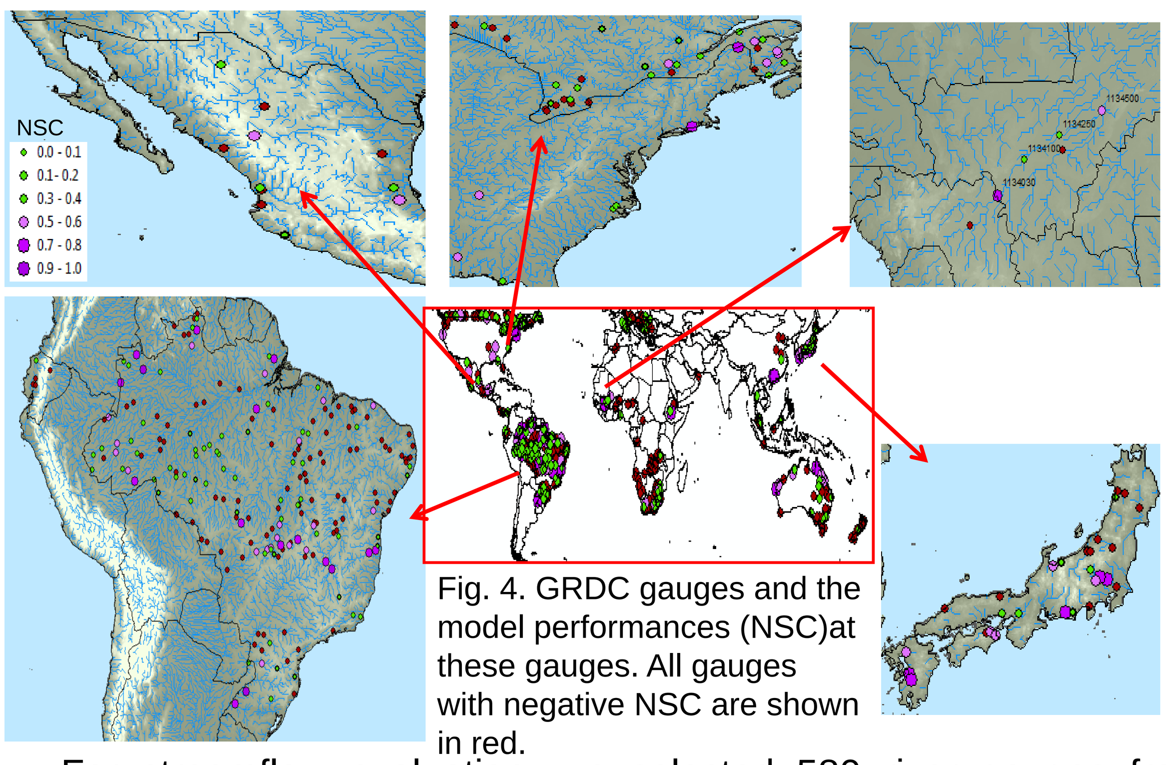


Fig. 4. GRDC gauges and the model performances (NSC)at these gauges. All gauges with negative NSC are shown in red.

For streamflow evaluation, we selected 580 river gauges from Global Runoff Data Centre (GRDC) database with the selection criteria: (1) Gauge data are available from 1999; (2) Gauge can be well located in DRT upscaled river network, which serves the geo-mask for all model simulations; (3) Gauge upstream drainage area>200 km². There are 220 gauges (in green and purple) out of 580 (in red) with monthly NSC >0 with a mean of 0.32; 76 gauges (in purple) with NSC>0.4 with mean of 0.57. There are 123 gauges (not shown) with daily NSC >0 with a mean of 0.17.

Example of hydrographs for two relatively natural rivers

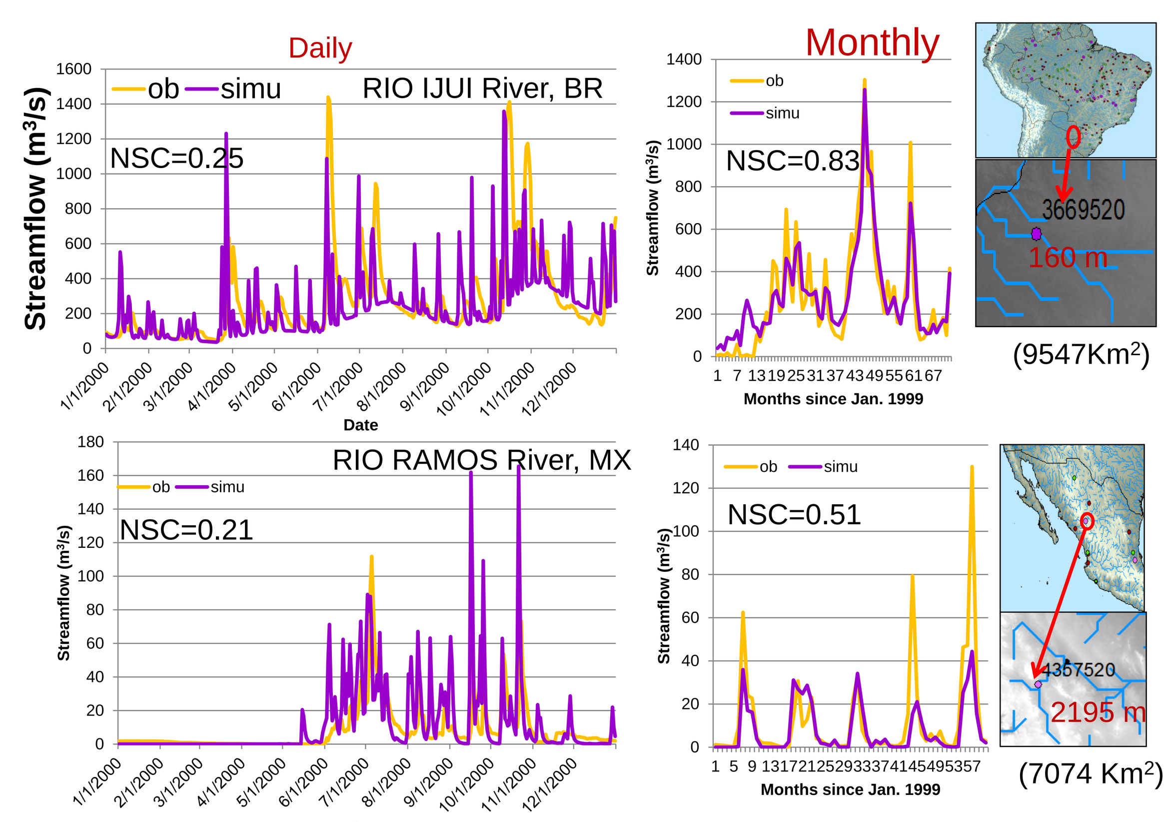
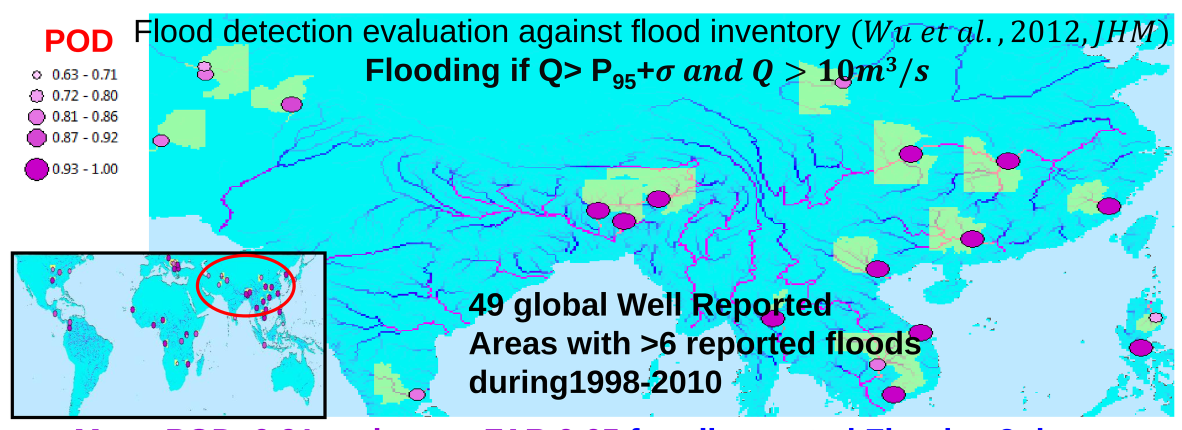


Fig. 5 model streamflow vs. gauge streamflow at two stations

5. Model evaluation: flood event detection

We performed flood event based evaluation of the new generation GFMS in terms of flood event detection based on the TMPA V7 driven retrospective simulation, according to the method by Wu et al., 2012. Each grid cell is determined as flooding at a time step if the streamflow (Q, m³/s) is greater than the flood threshold, i.e. **Q> $P_{95}+\sigma$ and $Q>10$,** where P_{95} and σ are the 95th percentile value and the temporal standard deviation derived from the retrospective simulation time series at the grid cell.



Mean POD 0.91 and mean FAR 0.65 for all reported Floods >3 days

Mean POD 0.92 and mean FAR 0.85 for all reported Floods >1 days

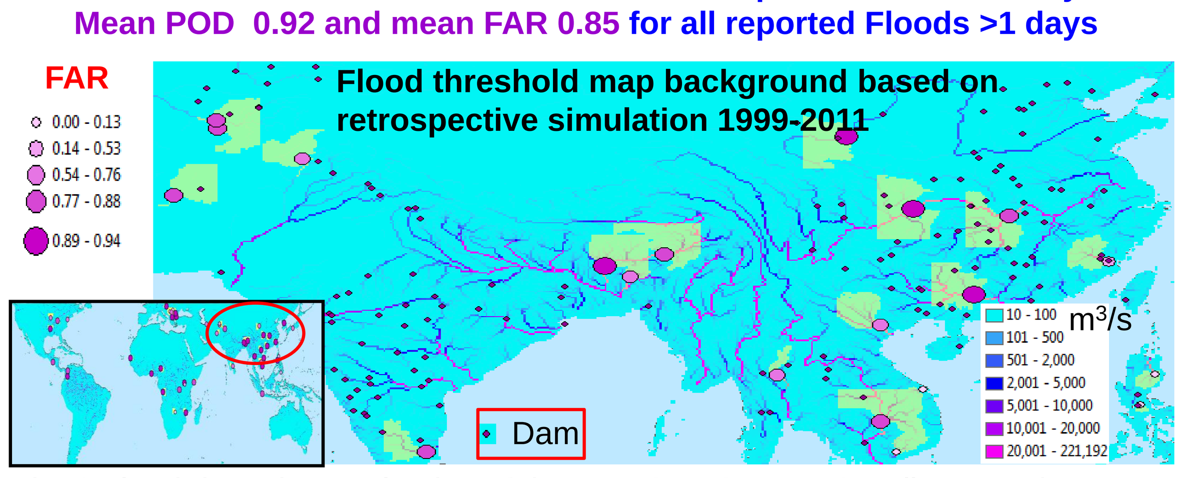


Fig. 6 Flood detection evaluation of the new GFMS over 49 well reported areas

There are 49 well reported areas (yellow shaded in Fig. 6), with each having at least six reported floods during 1998-2010, selected for evaluation. The new system showed a better flood detection performance than the current system with mean POD of 0.91 and FAR of 0.65 for all reported floods greater than three days and mean POD of 0.92 and mean FAR 0f 0.85 for all reported floods greater than 1 day.

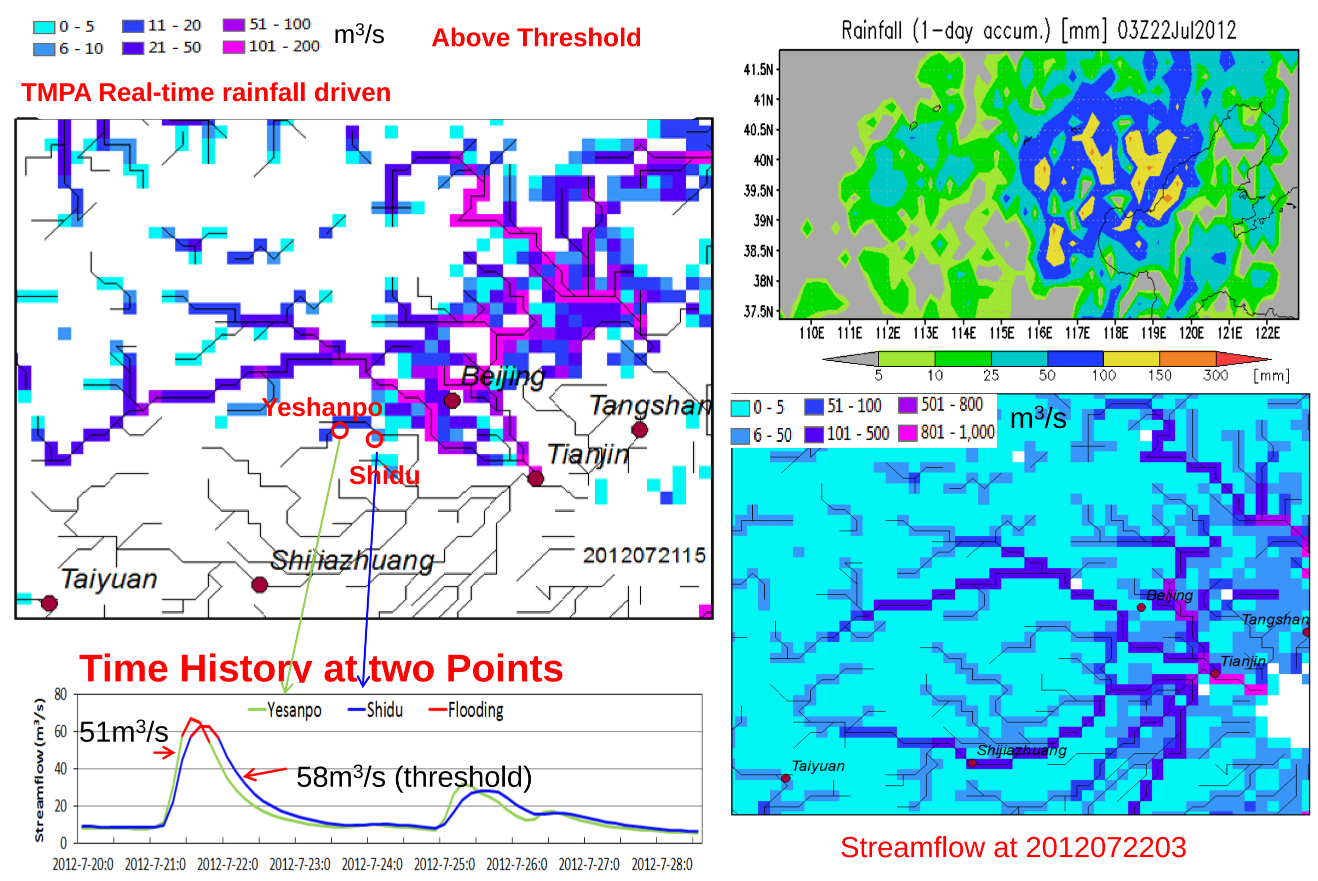


Fig. 7 Simulated Beijing flood in July, 2012 with model driven by TMPA Real-time rainfall

6. Model sensitivity to spatial resolutions

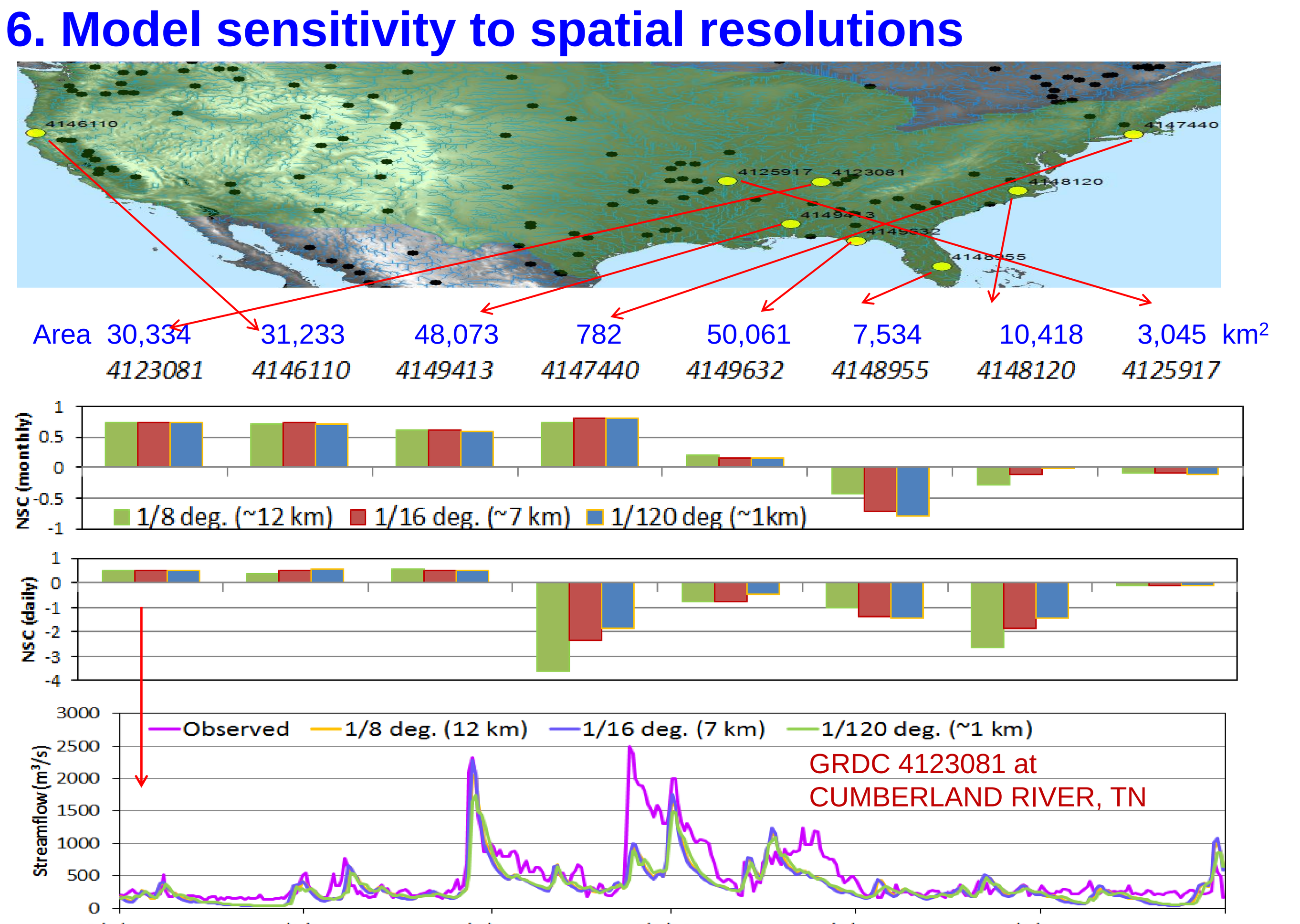


Fig. 8 TMPA V7 driven model performance across different spatial resolutions at eight gauges

8. Conclusion

1. Our current system showed positive performance in terms of flood event detection, available at http://oas.gsfc.nasa.gov/globalflood/.

2. We developed a new physically based routing model (i.e. DRTR) for more accurate flood calculation, which was successfully coupled with a community Land Surface Model (i.e. VIC), forming the core module of the next generation Global Flood Monitoring System (GFMS). The new coupled VIC/DRTR model has a great flexibility in deriving flood information at various spatial-temporal scales and resolutions with generally good *a priori* parameters from the VIC community.

3. So far, our evaluation of the VIC/DRTR model showed very promising performance in reproducing the observed streamflow records according to 580 global DRDC gauges, and a better performance of flood event detection with higher POD while having similar FAR than the current system according to the same available flood archives.

4. The consistent routing model performance across spatial resolutions indicated a promising potential of the new satellite –precipitation driven GFMS in deriving more useful real-time flood information at high spatial resolutions (e.g. 1km) .

5. We are shifting to the new generation GFMS.

9. References

Wang, J., et al., 2011. The coupled routing and excess storage (CREST) distributed hydrological model. *Hydrol. Sci. J.* 56(1), 84–98.

Wu H., R. F. Adler, Y. Hong, Y. Tian, and F. Policelli (2012), Evaluation of Global Flood Detection Using Satellite-Based Rainfall and a Hydrologic Model. J. Hydrometeor, 13, 1268–1284. doi: http://dx.doi.org/10.1175/JHM-D-11-087.1

Wu H., J. S. Kimball, H. Li, M. Huang, L. R. Leung, R. F. Adler (2012), A new global river network database for macroscale hydrologic modeling, Water Resour. Res., 48, W09701, doi:10.1029/2012WR012313.

Wu, H., J. S. Kimball, N. Mantua, and J. Stanford (2011), Automated upscaling of river networks for macroscale hydrological modeling, Water Resour. Res., 47, W03517, doi:10.1029/2009WR008871.