Funded by
NASA Applied Sciences
(NNH11ZDA001N)

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 new real-time Global Flood Monitoring System (GFMS) has been developed by coupling a community Land Surface Model, i.e. the Variable Infiltration Capacity (VIC) model (U. of Washington) with a newly developed Dominant River Tracing-based runoff-Routing (DRTR) model (Wu et al., 2011, 2012a,b, 2013). The new GFMS driven by Tropical Rainfall Measuring Mission (TRMM) Multi-satellite Precipitation Analysis (TMPA) rainfall products is operating routinely and producing flood detection and intensity results at (http://flood.umd.edu/) and TRMM website http://trmm.gsfc.nasa.gov (Fig. 1).

Global to Regional Flood Detection by GFMS

Example: Detection of Flooding over North Korea

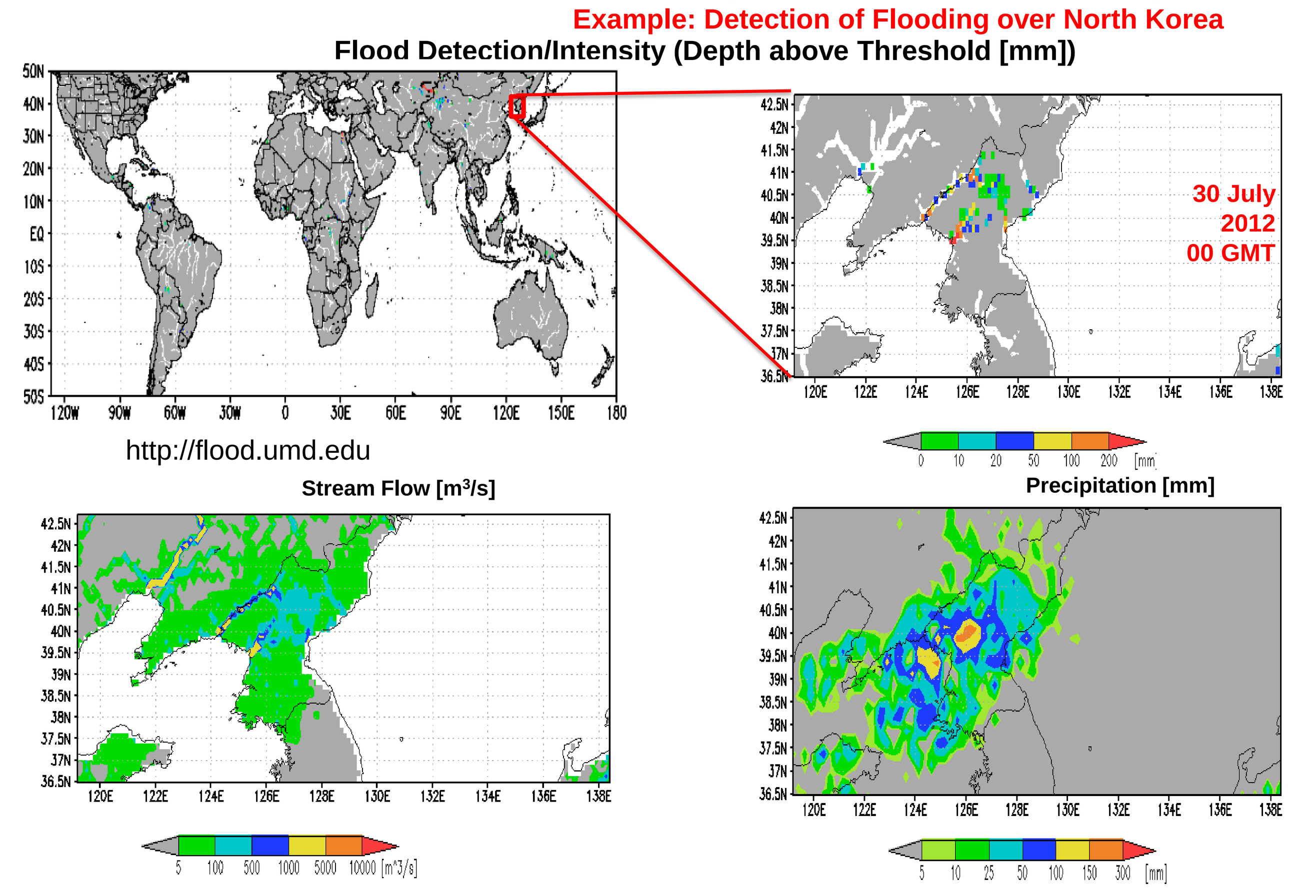


Fig. 1 example of flood detection from GFMS

2. The model framework of the new generation GFMS

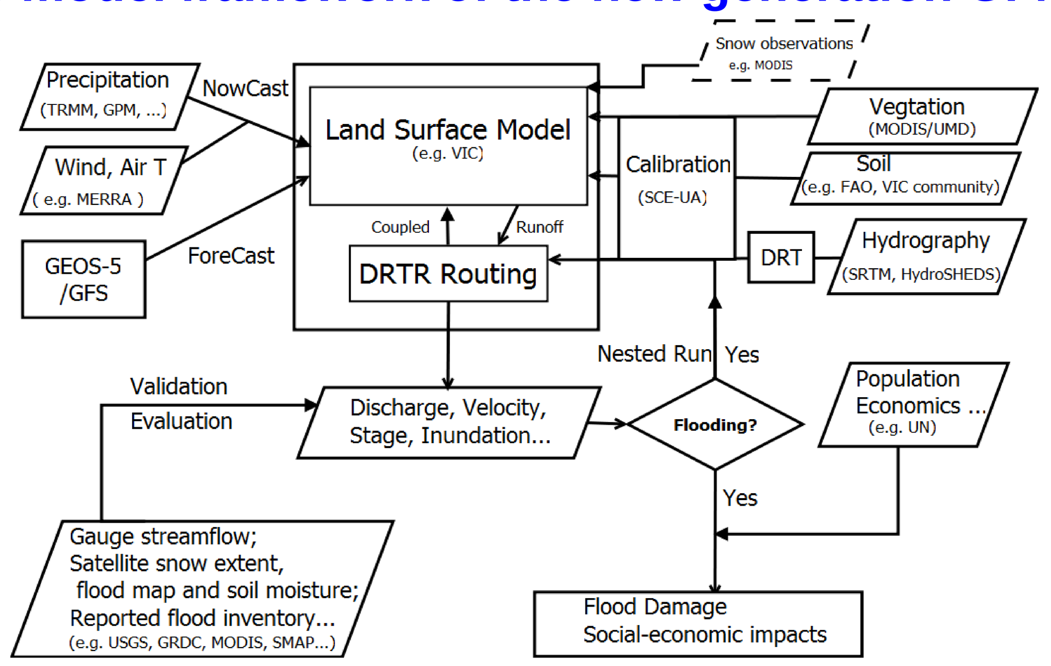


Fig. 2 Schematic of the next generation of GFMS

The overall system (Fig. 2) uses a two-level approach where the global, relatively coarse resolution products (~ 12 km) are available to serve as background (e.g., identifying emerging flood hazards) and provide routine information across the globe. A global high-resolution flood products (~ 1 km) has also been developed. Global 12 km runs of the flood model using NWP precipitation will be done routinely out to seven to ten days, with high resolution model runs being done for ~ 5 additional (forecast, not ongoing) floods. A nested approach will provide high-resolution products for all potential flood areas for use in pinpointing the hazard locations and evolution, using the NWP forecasts.

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

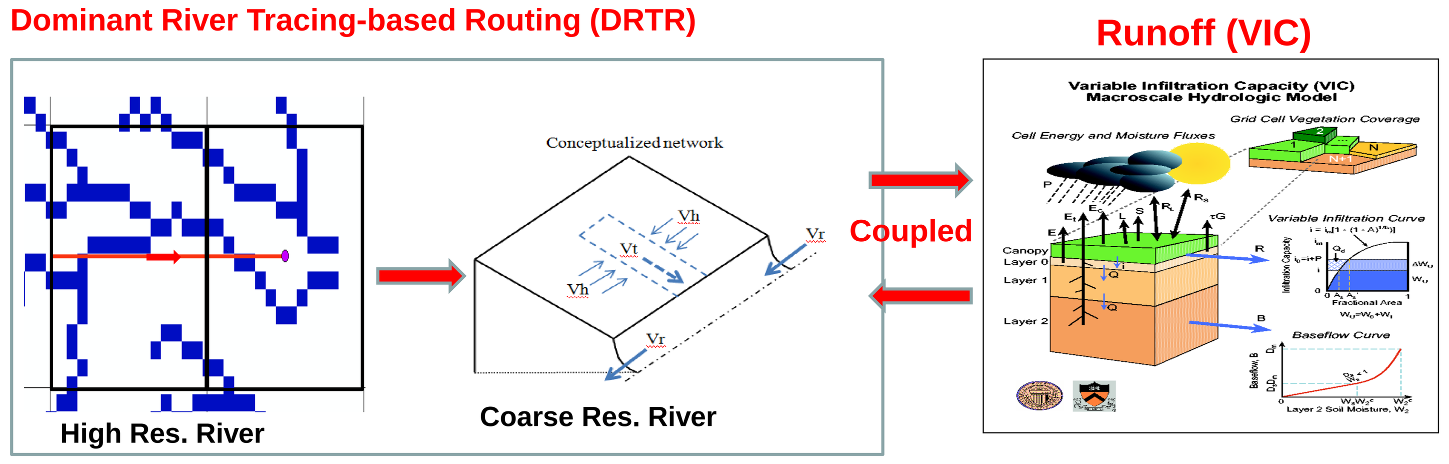


Fig. 3 coupled VIC/DRTR model as the core of the next generation GFMS

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, 2012b, *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

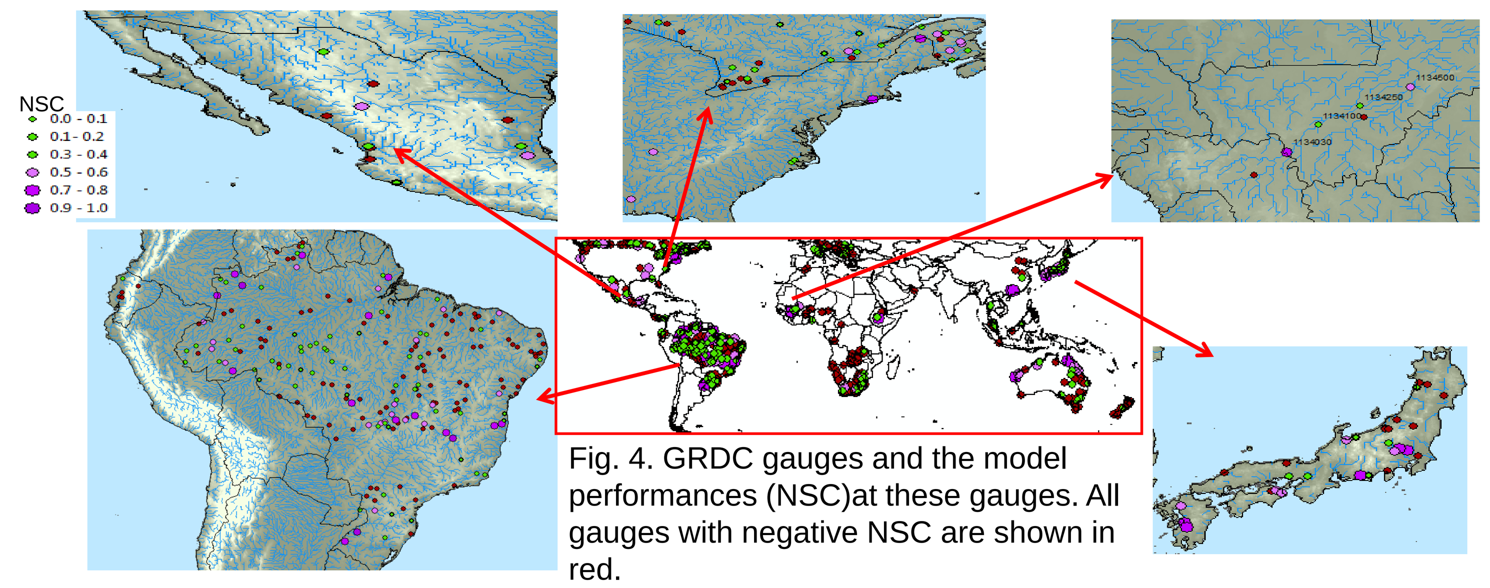


Fig. 4. GRDC gauges and the model performances (NSC)at these gauges. All gauges with negative NSC are shown in red.

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

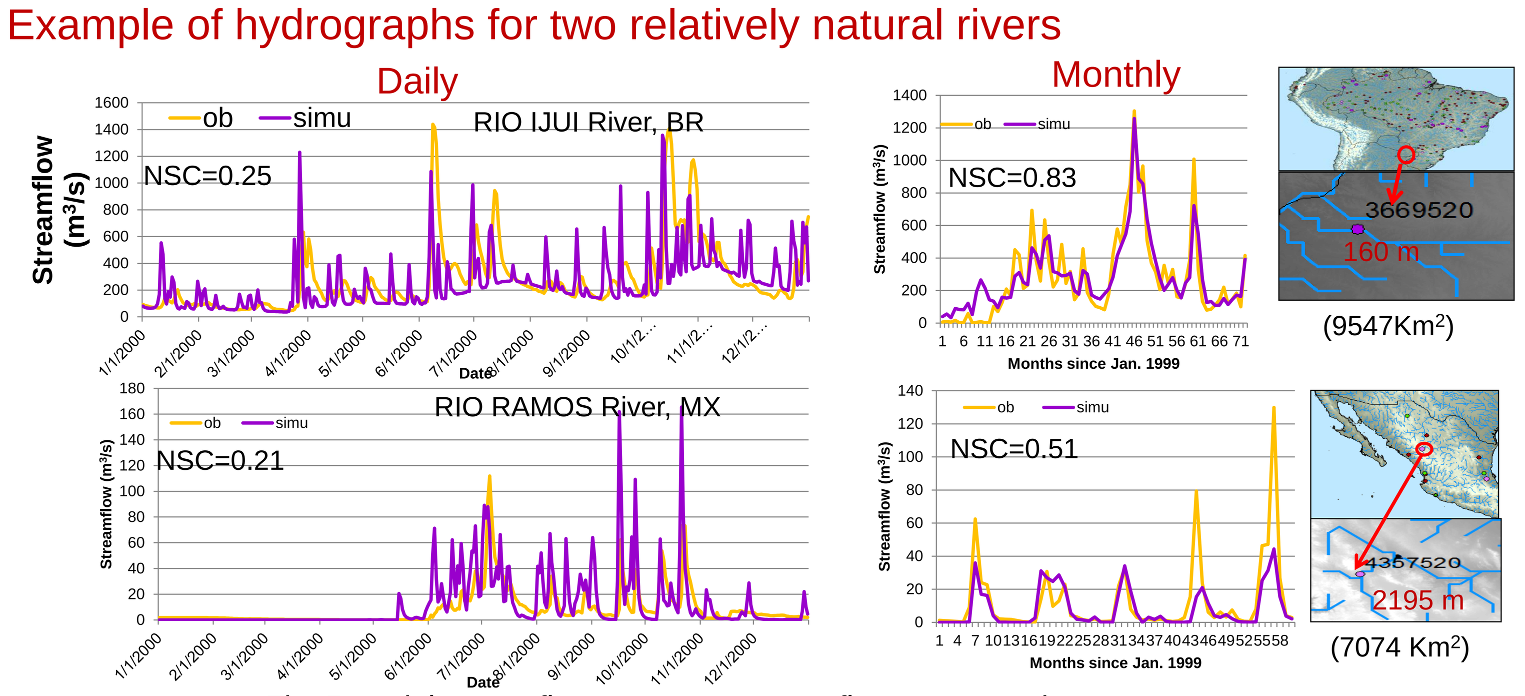


Fig. 5 model streamflow vs. gauge streamflow at two stations

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.

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 one day.

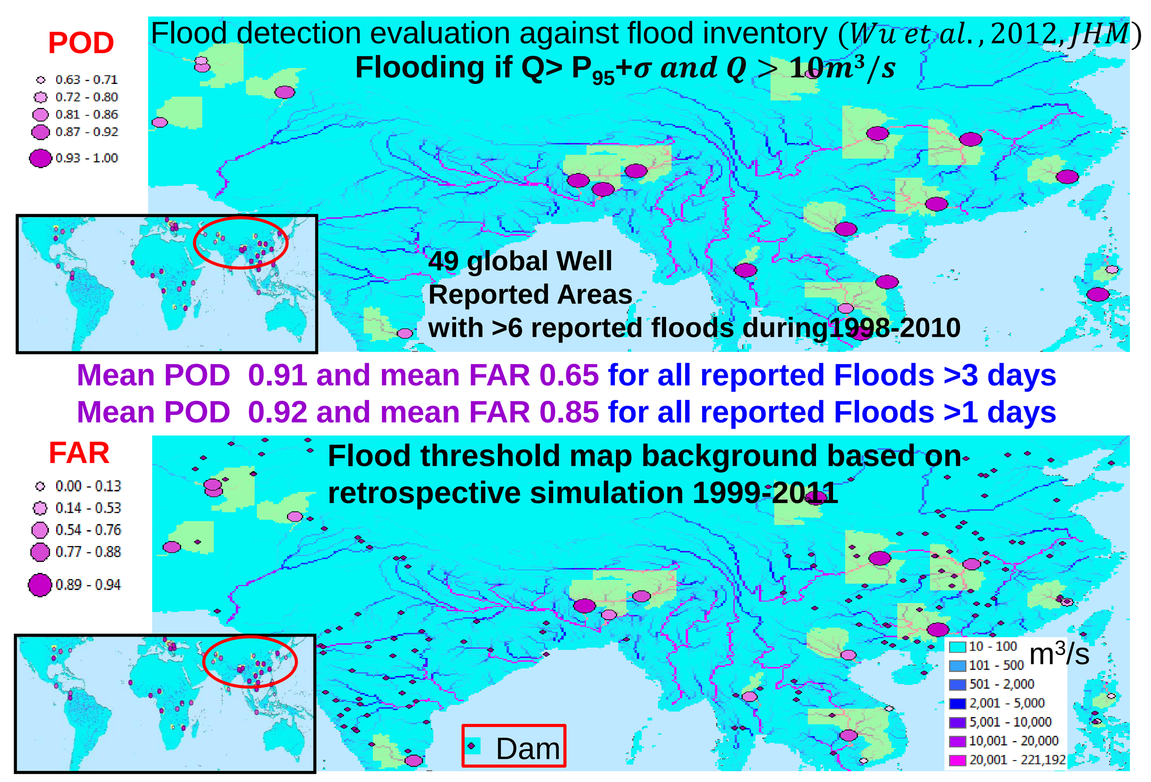
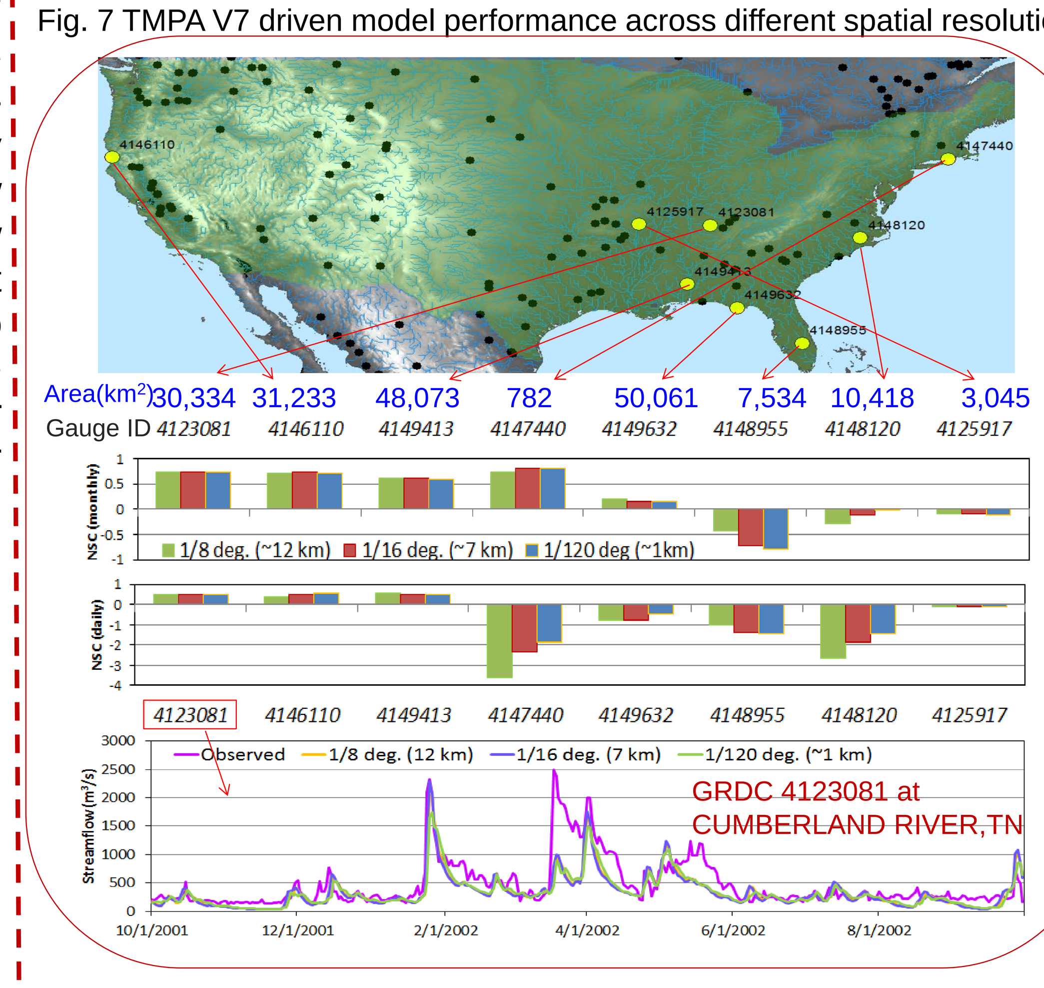


Fig. 6 Flood detection evaluation of the new GFMS over 49 well reported areas

6. Model sensitivity to spatial resolutions

Fig. 7 TMPA V7 driven model performance across different spatial resolutions



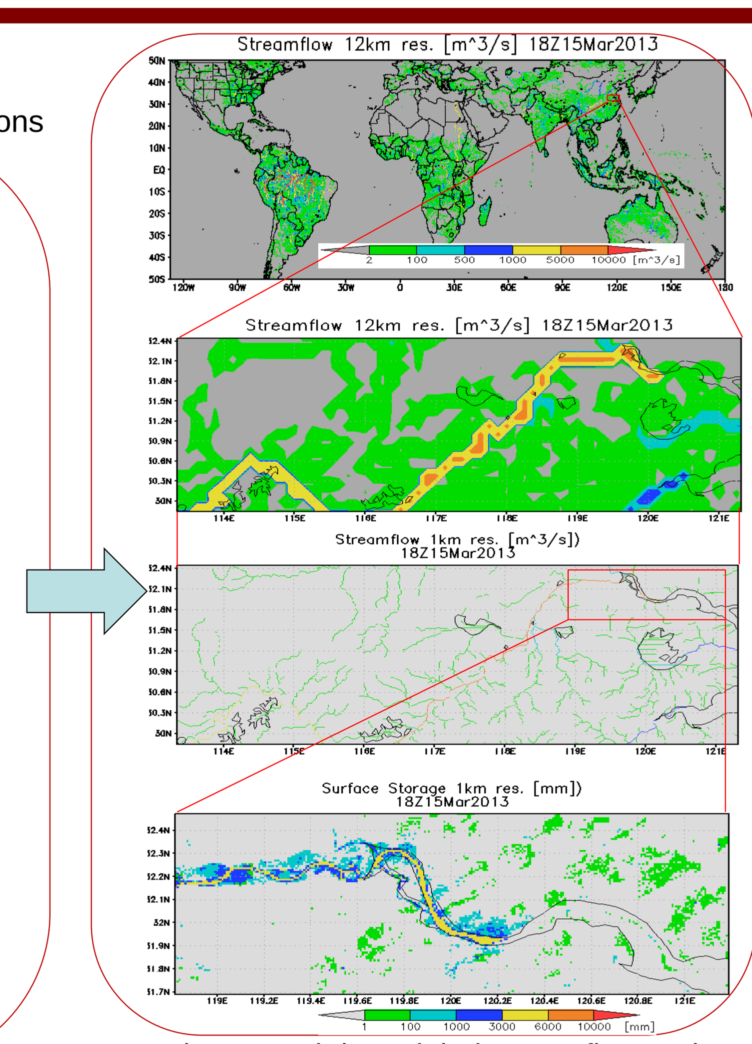
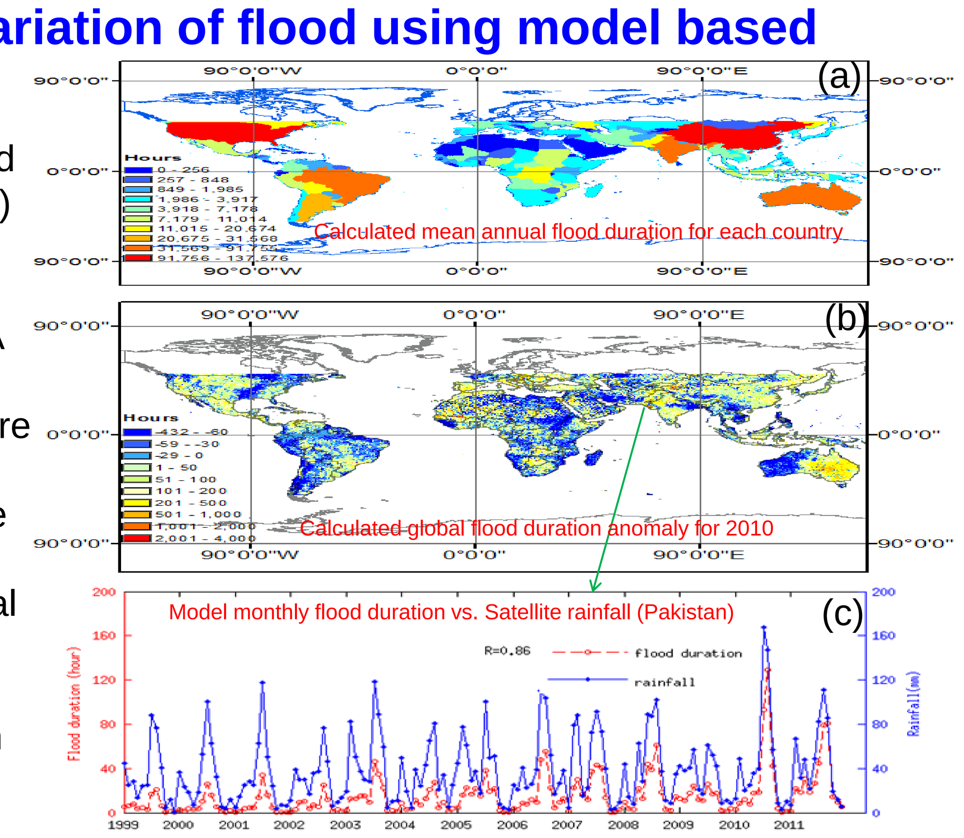


Fig. 8. Real-time global streamflow and inundation calculation across resolutions

The evaluation of the VIC-DRTR model over CONUS showed a consistent model performance across various spatial resolutions from 12km to 1km (Fig.7). **The modelling skill has been applied in the new GFMS generating real-time global streamflow and inundation map at high resolution (i.e. 1km), as shown in Fig.8.**

7. Analysis of spatial-temporal variation of flood using model based Global Flood Archive (GFA)

Fig. 9(a, b) shows the global mean annual flood duration according to our 15-years (1998-2012) retrospective VIC-DRTR run at 3-hour interval and 1/8th deg. Resolution driven by TMPA V7 research data. From the well validated 3D GFA database, we can extract the time series data and statistics at any time intervals and anywhere from a grid point to city, state, country until global scale. Fig.9 (c) shows an example of the monthly flood duration and rainfall over Pakistan, which clearly shows that the seasonal variation of flood duration follows well with the rainfall variation, and the correlation coefficient between the monthly rainfall and flood duration for Pakistan is 0.86.



8. Conclusion

1. 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.

2. 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 good performance of flood event detection with POD of 0.92 and FAR of 0.85 for floods greater than one day.

3. The consistent routing model performance across spatial resolutions showed a promising capacity of the new satellite–precipitation driven GFMS in deriving more useful real-time flood information at high spatial resolutions (e.g. 1km, 90m, 30m) .

4. The new GFMS is currently available from http://flood.umd.edu and TRMM website http://trmm.gsfc.nasa.gov/.

9. References

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