River flow routing using Hydrosheds for North America

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Abstract

HydroSHEDS is a global high resolution geography data of river network and might be useful for stimulation of global streamflow. Here we use HydroSHEDS for linkage between runoff results of land surface model and streamflow routing model (RAPID) for a case study in North America. To establish the framework, ArcGIS is highly required for preprocessing and postprocessing data.

1. Introduction

The National Water Model was launched currently in August 2016. Effectively implementing information of weather forecast to prediction of streamflow and flood to higher resolution and national wide, it transfers “synoptic weather map” to hydrology (Fig. 1).

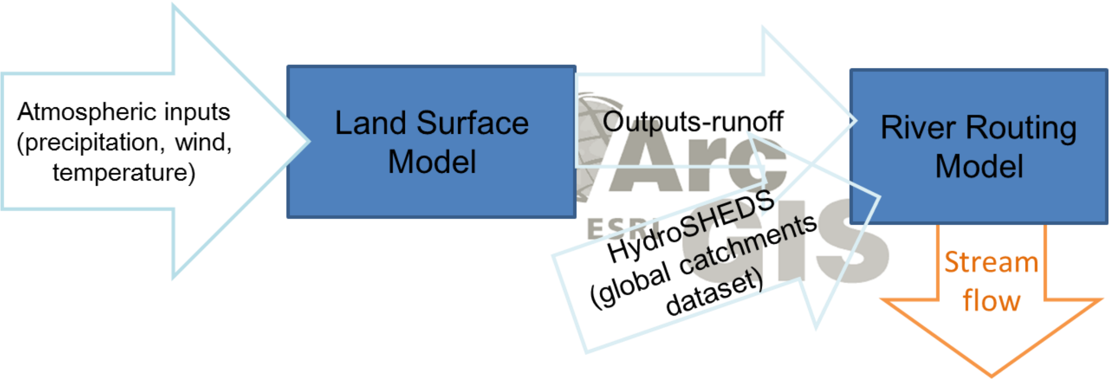

Figure 1. General Framework

2015 Texas-Oklahoma flood during May23-26, which caused serious damage and 58 total deaths, is from storm system that brought heavy precipitation for nearly a week. Here we chose this event for our first study case.

2. Data

2.1 HydroSHEDS

HydroSHEDS (Hydrological data and maps based on SHuttle Elevation Derivatives at multiple Scales) **[Lehner et al, 2006]**is a product developed by program of World Wildlife Fund (WWF) and could be downloaded (http://hydrosheds.cr.usgs.gov/dataavail.php) (Fig. 2). HydroSHEDS is based on high-resolution elevation data obtained from NASA's Shuttle Radar Topography Mission (SRTM). Here we use the “River Network” and “flow direction” on the spatial resolution of 15sec for North America, which contains most part of Canada and United States. The “River Network” is in the vector format of shape-file with information of number of up cells and river ID. The “flow direction” is gridded, raster data which shows the flow direction of each single cell with its eight neighbor cells. There are 467819 streamlines in our study case.

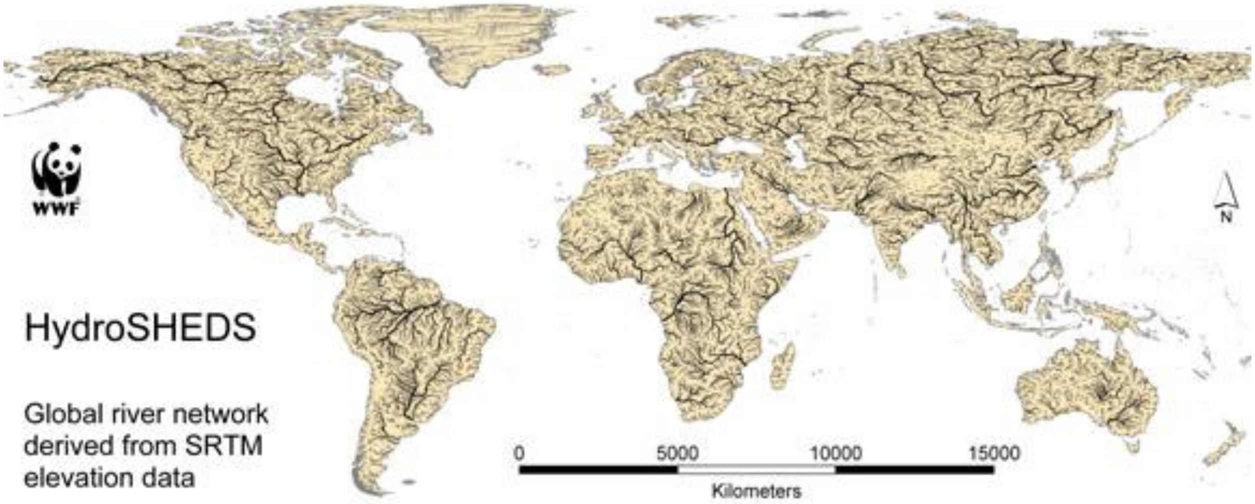

Figure 2. Global river network from HydeoSHEDS, not all the rivers are shown. Image from http://hydrosheds.cr.usgs.gov/

2.2 Runoff from GLDAS

NASA's Global Land Data Assimilation System (GLDAS) **[Rodell, M., et al, 2004]** provides series of fundamental land surface fluxes and water storage components. It was published by NASA Goddard Earth Sciences Data and Information Services Center. Using same atmospheric forcing data from observation-based datasets (radiation, temperature, precipitation etc.) to drive offline land surface model, it provides the outputs of water and energy fluxes and state for recent decades. Here we use the surface runoff and subsurface runoff from Noah model with resolution of 3-hourly and 0.25-degree longitude and latitude (Fig. 3). The data format is gridded in NetCDF file.

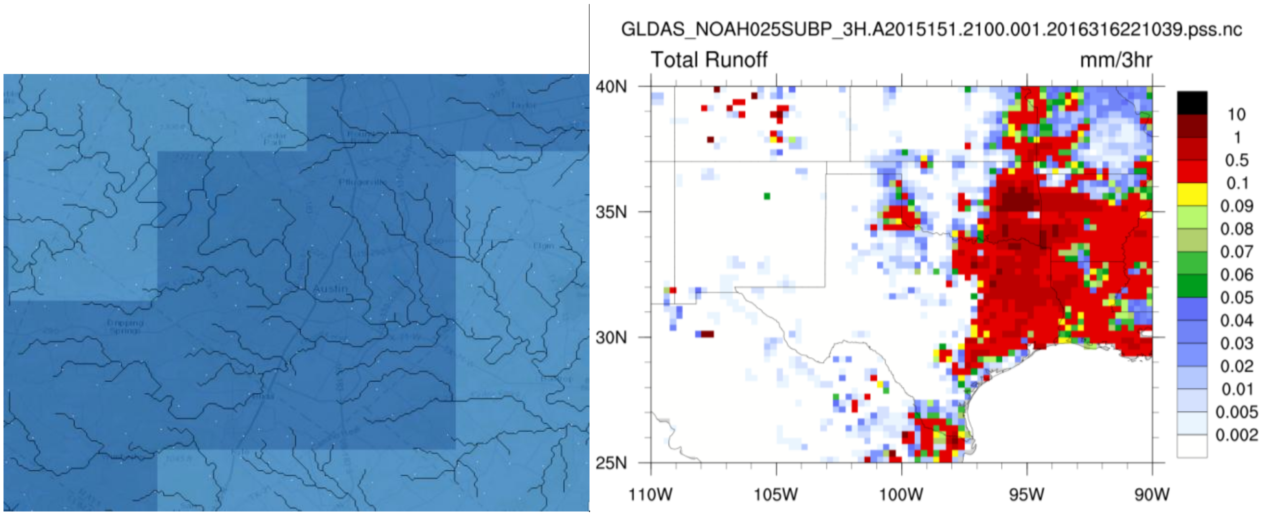

Figure 3. (left) The resolution of GLDAS runoff with river network of HydroSHEDS. The little white dot is the centroid point of each catchment. (right) The total runoff from GLDAS at 01:00 CDT on 31 May of 2015.

2. Method

For preprocessing the data of river network for RAPID. We use ArcHydro Toolbox in ArcGIS to build the river connectivity with each other. The most important reprocessing function is ”Generate from node to node”, which connect the river network by morphology. Simply finding the newly assigned node from previous steps, then I use “Find Next Downstream lines” to link the original HydroID to another HydroID, which is its downstream (Fig. 4).

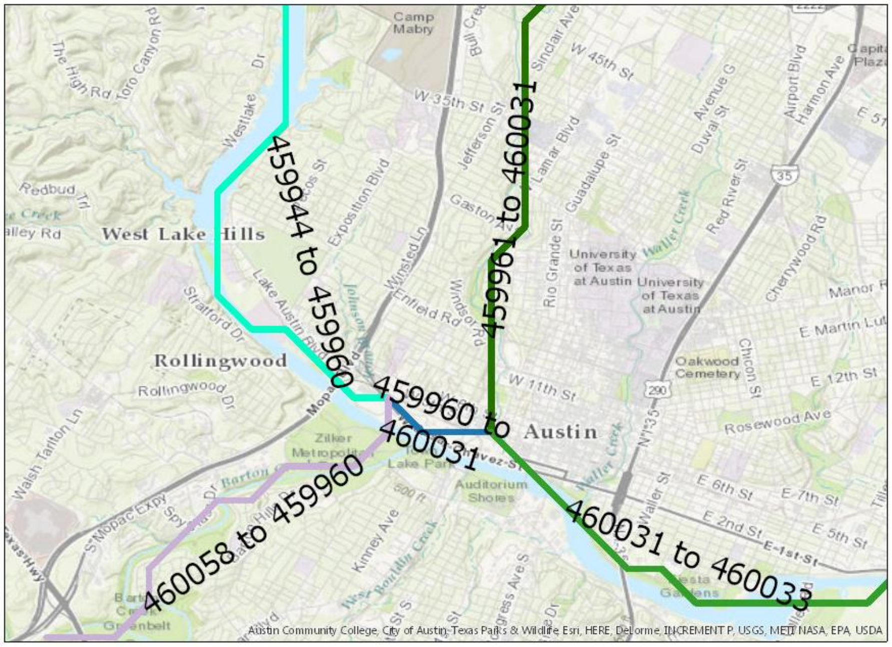

Figure 4. The connectivity of river network in Austin. The number show HydroID of each stream line and its downstream.

For establishment linkage of river and its contributed runoff, we need to know the drainage basin of each single HydroID. Here I use the geoprocessing in ArcGIS called “Watershed” to define watershed (catchment) for each stream line. Since the average area of 467819 catchments is 28.13 km^2 , which is much larger than the a grid cell of runoff data (about 600 km^2), we use the centroid point of the catchment to find its contributed location of runoff data. A geoprocessing called “Extract Value to Point” in ArcGIS is used to find the centroid point (Fig. 5). Then we can overlay the centroid point with raster data to find their connectivity. Finally, we use python code to transfer the runoff (lat, lon, time) to volume runoff (HydroID, time) for input of river routing model.

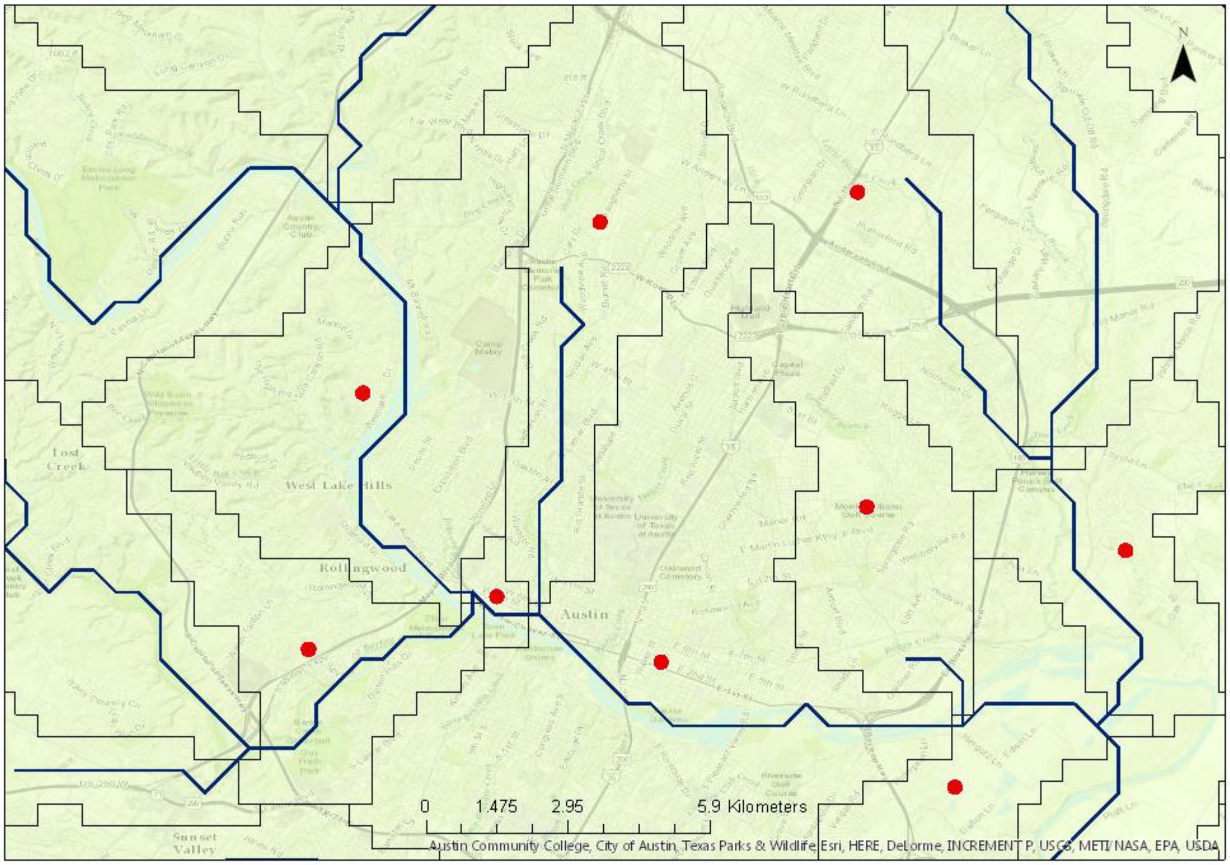

Figure 5. The catchment and centroid point of river network in Austin.

We use RAPID (The Routing Application for Parallel computatIon of Discharge) as the river routing model in this study. With the information of river network and runoff data, RAPID can simulate volume of flow in the river networks. The model is written in Fortran programing and we ran it on super computer on Texas Advanced Computing Center (TACC).

In summary, for preprocessing and post-processing files for RAPID, we mainly use ArcGIS but also NCAR Command Language (NCL), Python, MATLAB, and Excel.

3. Results

In this case study, we simulate the 2015 Texas-Oklahoma flood with a model run from

May15 to May31. The first week is for spin-up and so here we only show results after May22. (There is continuous subsurface runoff in Texas before the flooding event.) Fig. 6 shows that the downstream of major rivers has larger streamflow than upstreams, which shows spatial pattern before the flooding.

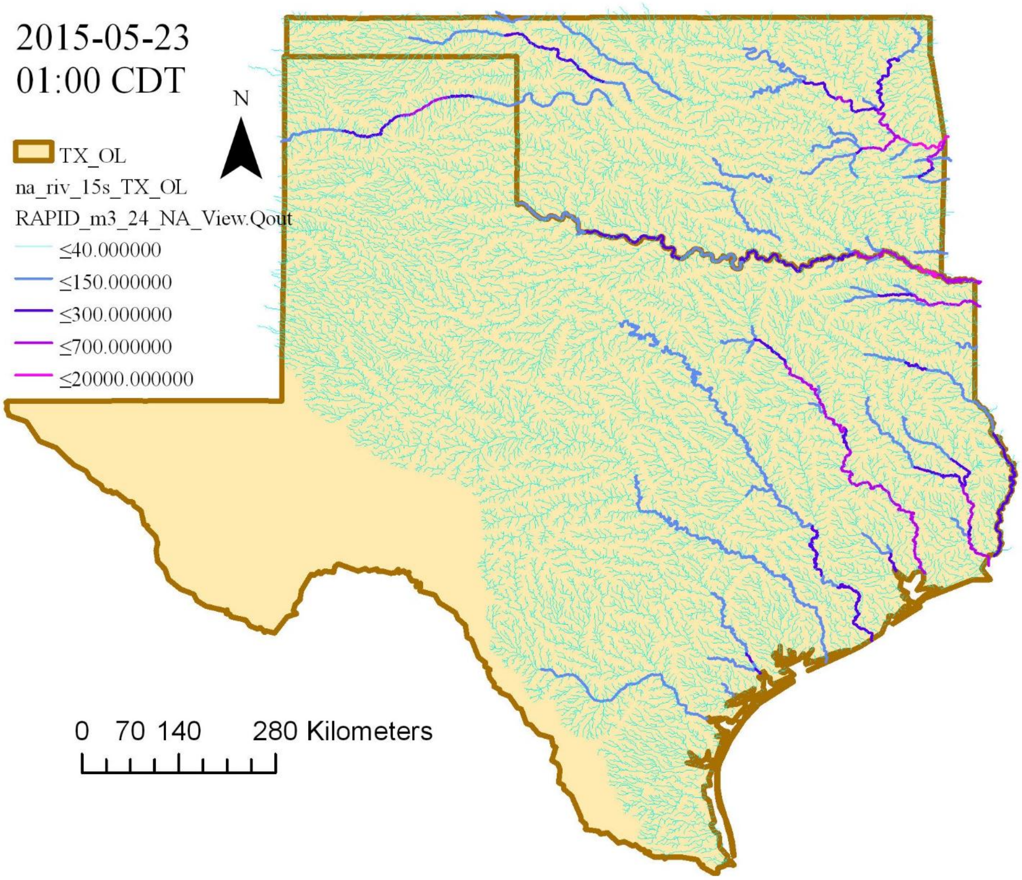

Figure 6. The Streamflow in cubic meter second in Texas and Oklahoma at 01:00 CDT on 23May of 2015. (An animation of RAPID output is in the presentation slide.)

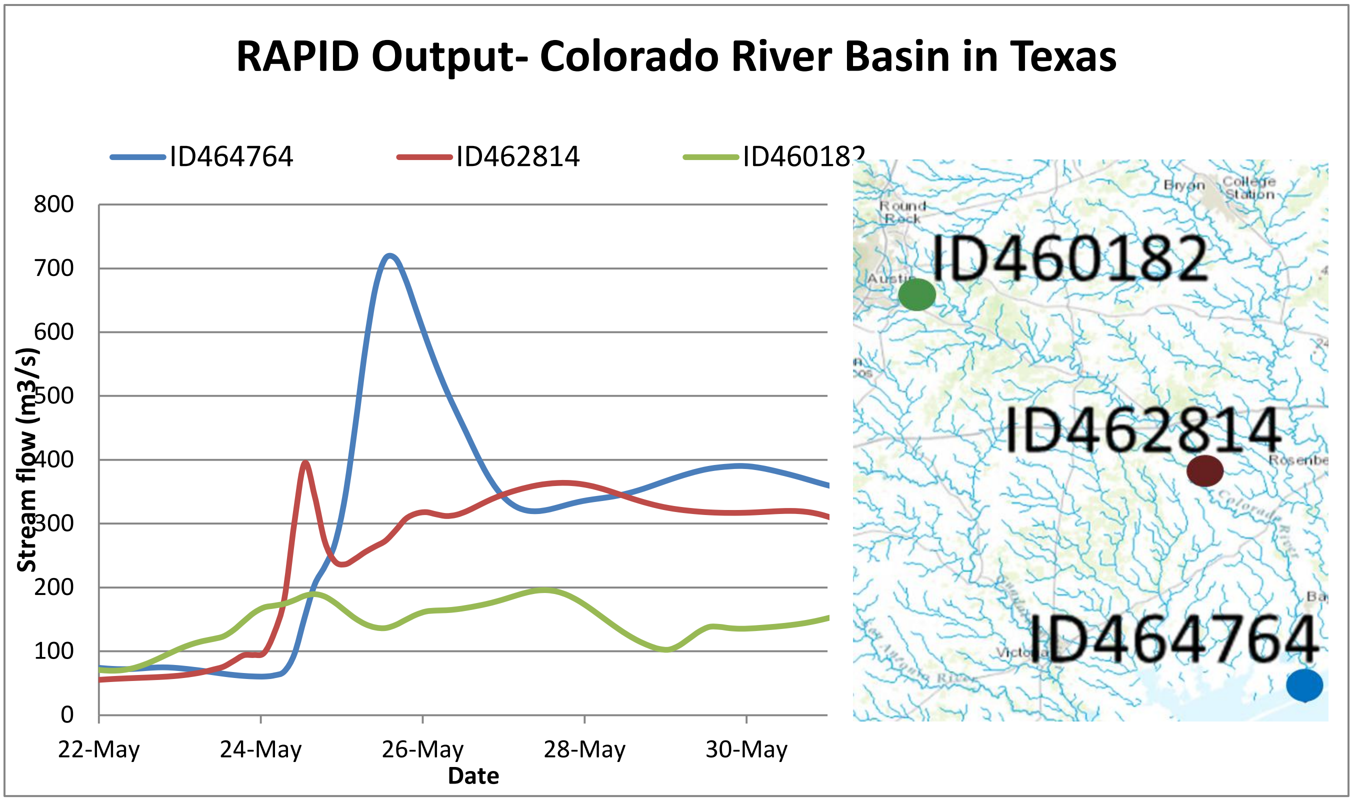

Figure 7. Time series of stream flow in three stream lines in Colorado River basin in Texas.

Shown in time series of Fig.7, the event flow and propagation from 24May to 31May is with overall huge amount of streamflow from Austin to the coastline region.

Although outputs of RAPID successfully reflects the spatial pattern and the temporal variability of runoff data, it could not match the streamflow observed from gage stations (Fig. 8, 9). Because the magnitude of streamflow from observation and model is too different to show in the same axis, here we show the ratio of each streamflow to the maximum stream flow. The maximum streamflow of both stations and models are simultaneous. However, model could not capture several peaks. Therefore, the spatial and temporal resolution of GLDAS might not be suitable for a short time period of flooding event. Here I list some possible reason:

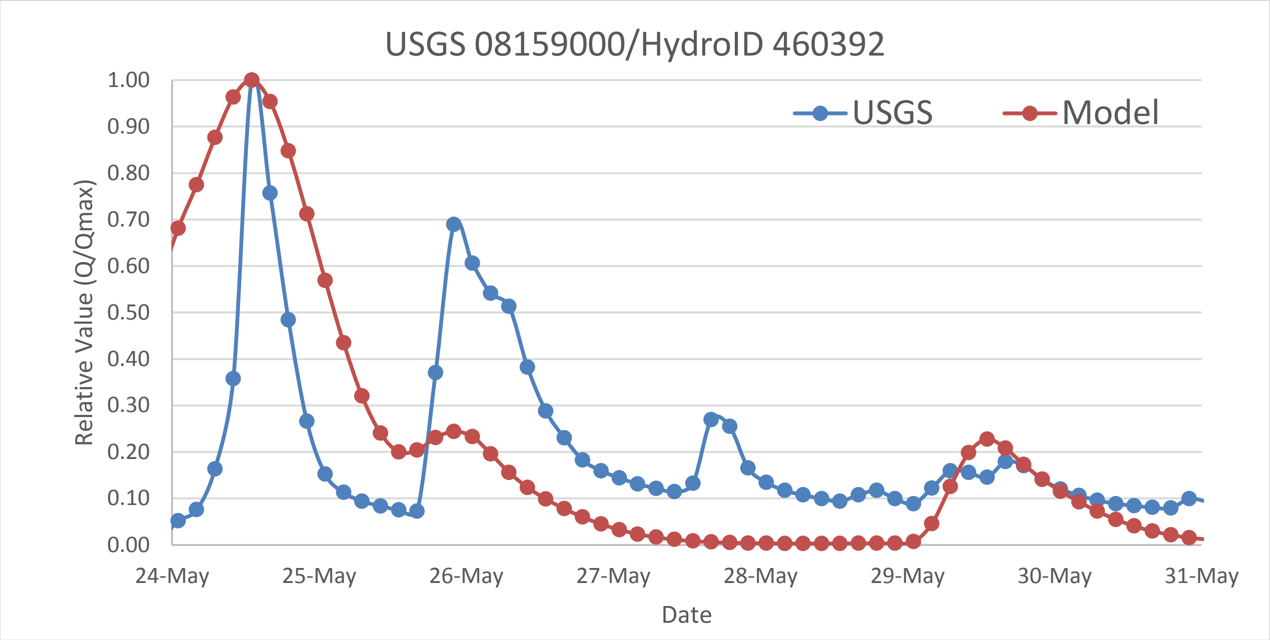

Figure 8. Relative streamflow at Onion Ck at US Hwy 183, Austin, TX

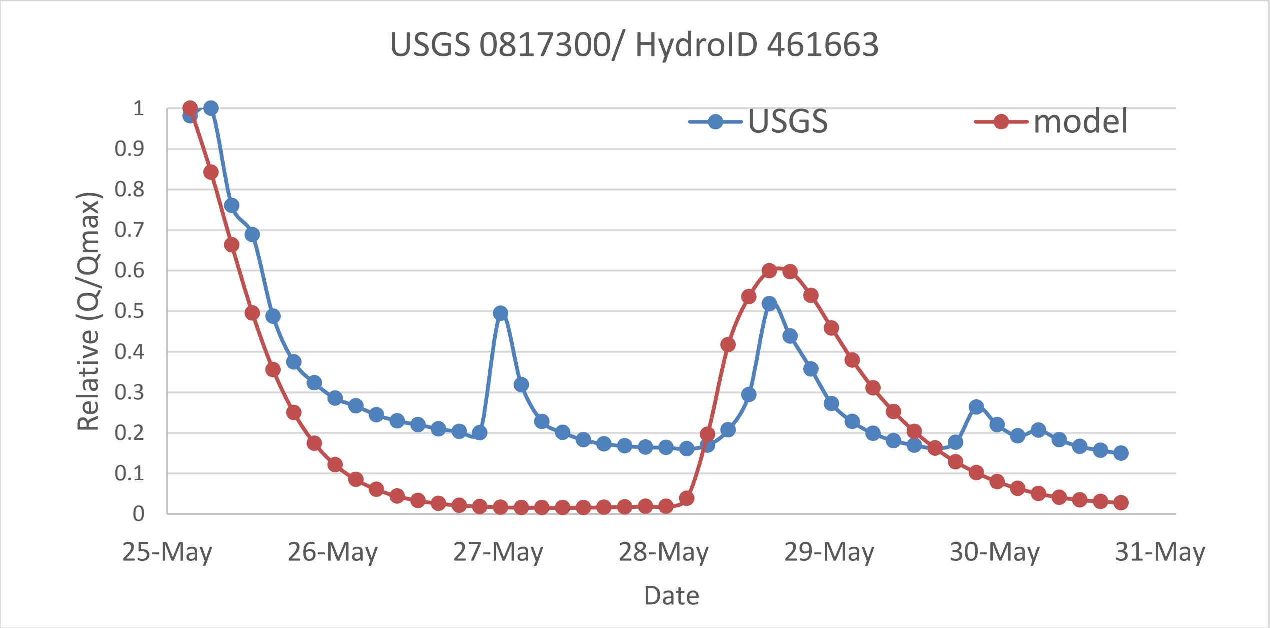

Figure 9 Relative streamflow at Blanco Rv nr Kyle, TX

(1) The GLDAS runoff we use is 0.25 degree lat/lon, which is relatively coarse than the

resolution of river network. As mentioned before, the catchment is smaller than the grid cell of runoff. Therefore, each single river channel (each HydroID) use only one grid cell for the total runoff. And, even several catchments nearby share the same grid cell. But rainfall of short time period is with high spatial heterogeneity and discontinuity, which might only contribute to smaller area.

(2) The GLDAS runoff we use here is 3-hourly, so for the simulation of river routing, same amount of total runoff is used for one 3-hourly period with model time step of half hour. Since, the variability of flooding event could be within 3 hour, using 3-hourly average runoff as the input might be not suitable. As the same reason, 3-hourly output might also be too coarse to be used to interpreted flooding hydrograph.

(3) It usually take several years for river routing model to spin up, which means to get it stable state. At the beginning, there is no water in each river channel, so the runoff of early period is used for "filling up" the channel to its minimum stage height. Especially for the river with stable base flow or the river with very long distance to the mouth at the coastline, it is essential to have a preparing simulation before the analyzed period. On the other hand, for upstream or river in urban area, it might require less time for spin-up.

(4) Other factor that neglected in our simulation such as lake, anthropogenic activity such as dams and water management might impact the streamflow.

4. Conclusion

Our preliminary results show that HydroSHEDs could be used as the information of river network for RAPID. Since the data format of other containments is the same and we already used global runoff, the same framework is able to applied for studies over other regions or even globally. However, it needs much improvement to simulate flooding event. We suggest that the long-term climate simulation of streamflow might be suitable for combination of GLDAS and HydroSHEDs and the results could be implicated for climate change in global hydrologic cycle, such as quantified the contribution of river discharge to global mean sea level.

Acknowledgement

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4. References

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