Predicting Localized Flooding during the 2015 North Alabama Christmas Flood Event Using WRF-Hydro Simulated Streamflow

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1. 22-29 December 2015 North Alabama Flood

- Heavy rainfall over multiple days in excess of 100 mm (4 in.) across much of northern Alabama and over 250 mm (10 in.) in some locations (Figure 1)
- Moderate to major flooding along several rivers in North Alabama, including Flint River and Paint Rock River (Figure 2)

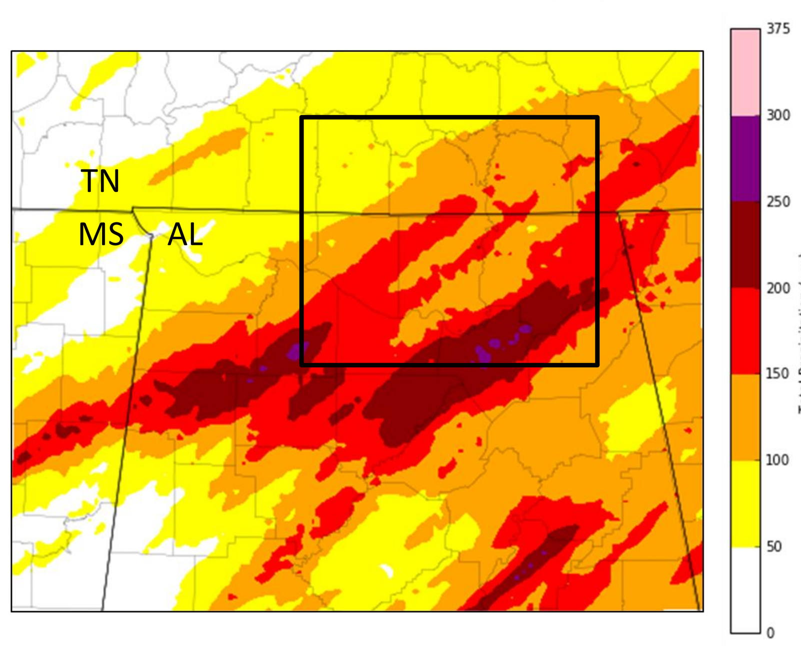

Figure 1. Multi-Radar Multi-Sensor (MRMS) gauge corrected total precipitation (mm) for 72-hour period beginning 1200 UTC 23 December 2015.

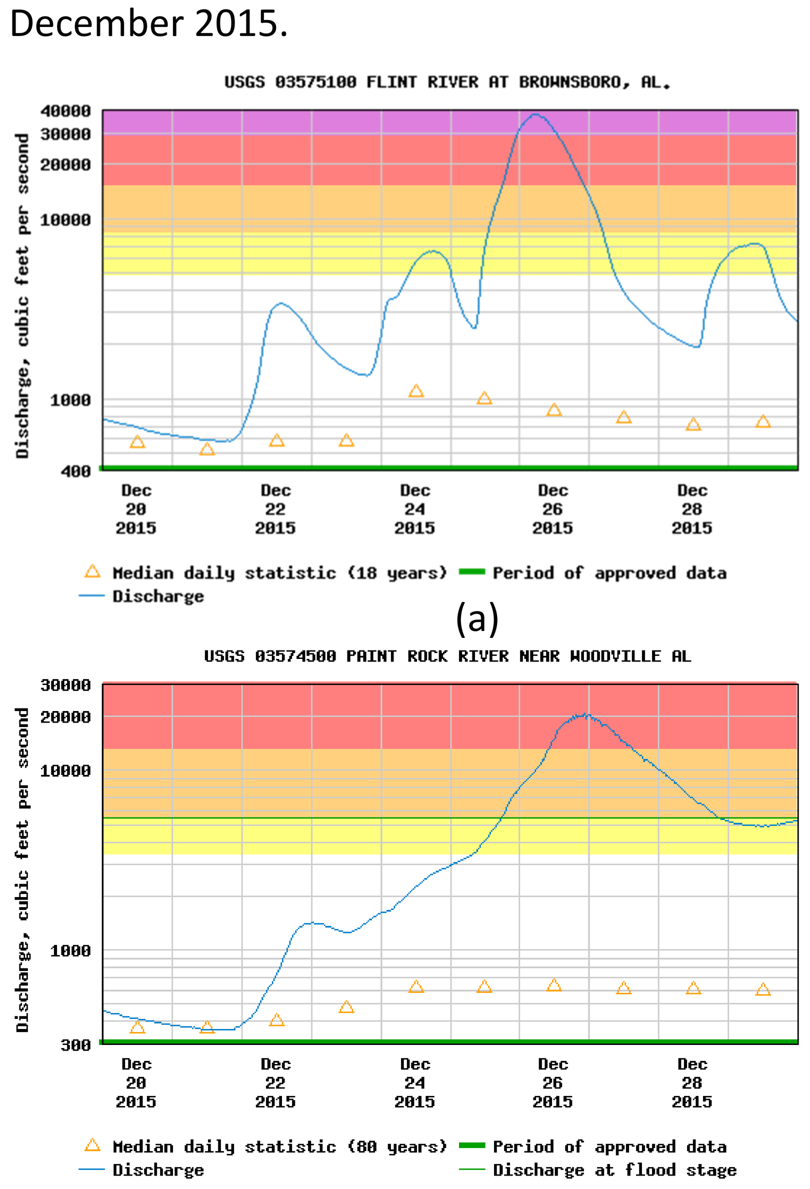

Figure 2. 20-29 December 2015 observed streamflow for the (a) Flint River and (b) Paint Rock River. National Weather Service flood categories (action, flood, moderate, major) are indicated by the colored shading (yellow, orange, red, and purple, respectively). Gauge locations are shown in Fig. 3. Hydrographs generated by http://nwis.waterdata.usgs.gov/.

Acknowledgements

We would like to acknowledge Kris White and Michelle Amin (NOAA NWS Huntsville) for providing forecaster insight of the 2015 December North Alabama Flood.

2. WRF-Hydro Configuration

- Uncoupled Weather Research and Forecasting model hydrological extension package (WRF-Hydro) version 3.0 (Gochis et al. 2013) (Figure 3)
- Resolution:
  - 100-m terrain and channel routing grid
  - 1-km Noah Land Surface Model with multi-parameterization options (Noah-MP; Niu et al. 2011)
- North American Land Data Assimilation System Phase 2 (NLDAS-2; Xia et al. 2012) forcing regridded to 1-km resolution
- 30-month spin-up period
- Manual calibration
- WRF-Hydro channel network shown in Figure 4

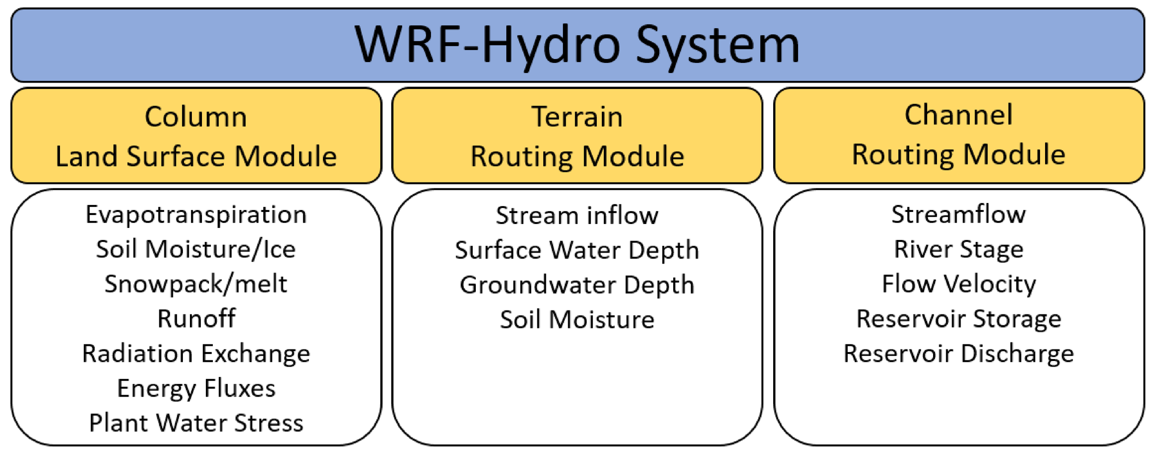

Figure 3. WRF-Hydro modules and output variables (Gochis et al. 2013).

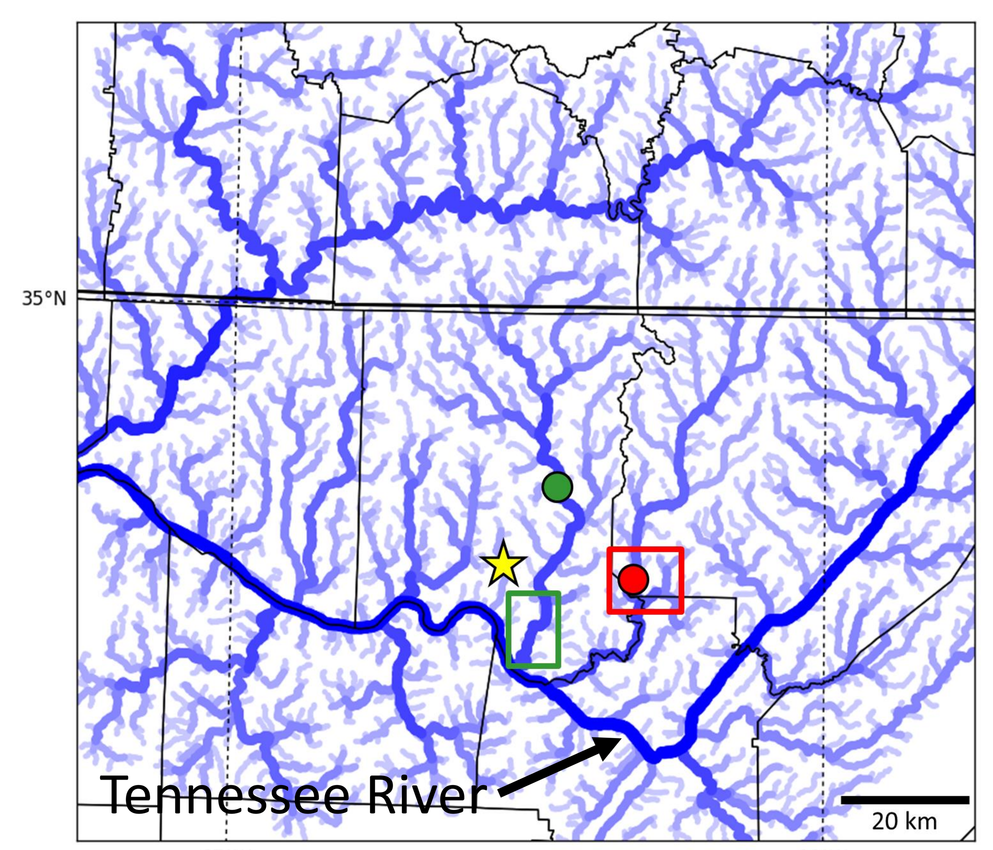

Figure 4. WRF-Hydro channel network for North Alabama. Color scale depicts stream order. Flint River (green point) and Paint Rock River (red point) stream gauge sites are indicated. Domain extent is shown by the black box in Figure 1, and Huntsville, Alabama, is indicated by the yellow star.

3. WRF-Hydro Streamflow

- Model hydrographs roughly follow observation trend (Figure 5), especially for Flint River
- Magnitude of simulated streamflow much lower than observed streamflow, which will addressed in future work by using more sophisticated calibration methods

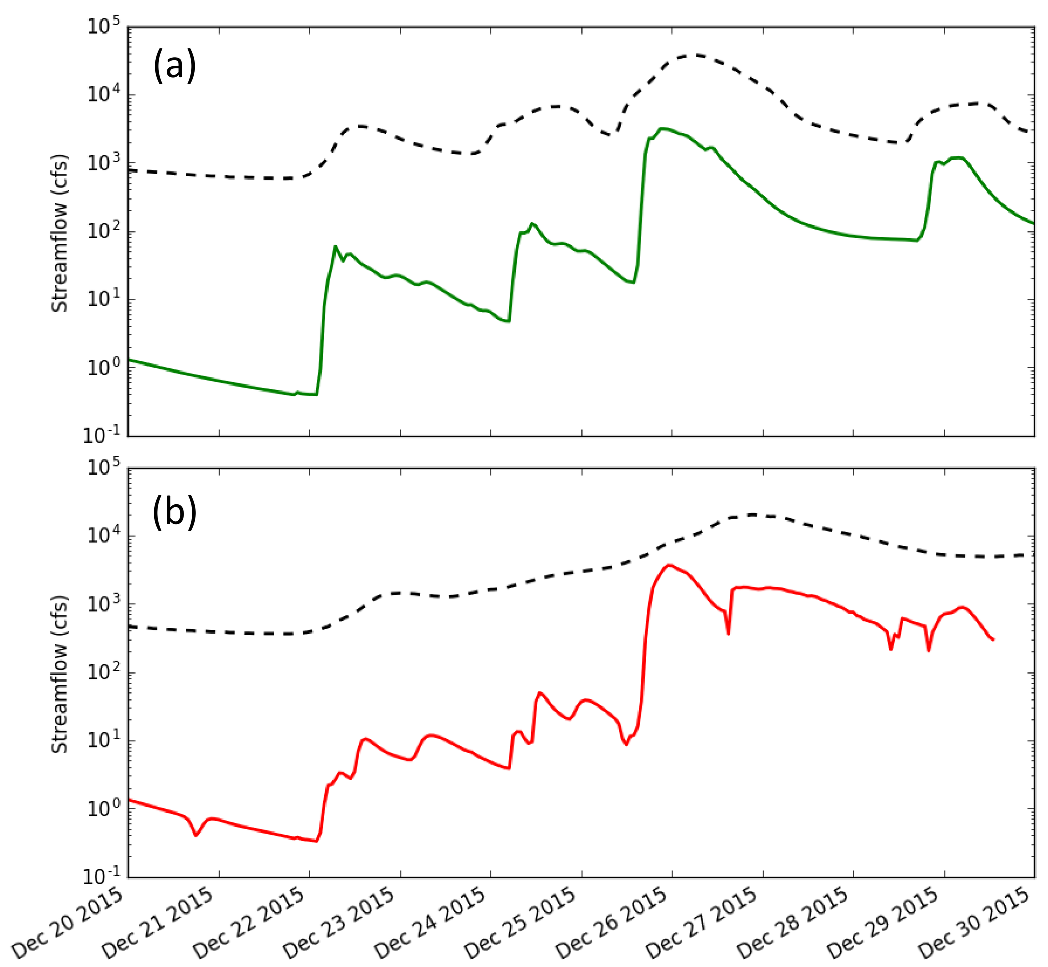

Figure 5. 20-29 December 2015 simulated (solid) and observed (dashed) streamflow for the a) Flint River and b) Paint Rock River. Line colors correspond to station point colors in Figure 4.

4. Inundation Extent/Depth

- Inundation extent/depth derived using USGS rating curves (Figure 6) and Height Above Nearest Drainage (HAND) model (Nobre et al. 2011, Maidment 2017) (Figure 7)
- Inundation depth map for Flint River and Paint Rock River (Figure 8) partially confirmed by observed flood extent (Figure 9)

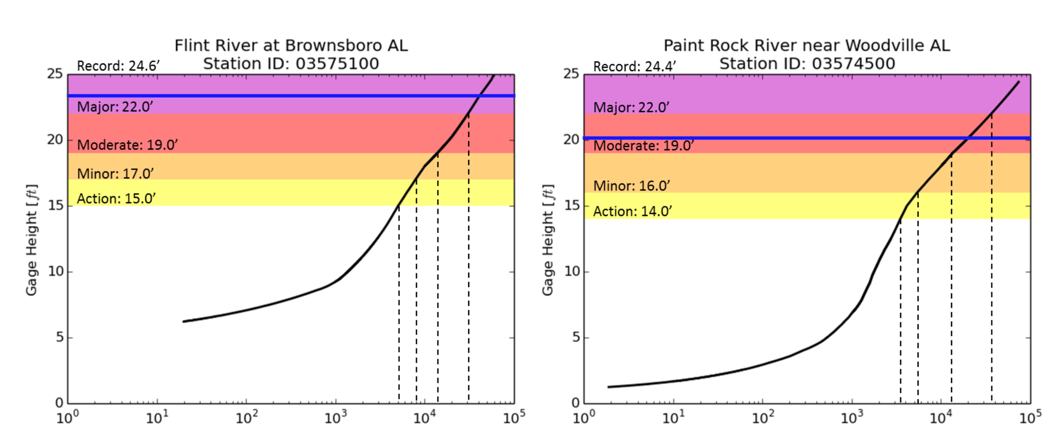

Figure 6. Rating curves for the (left) Flint River and (right) Paint Rock River. Blue line indicates peak of hydrograph. NWS flood categories are indicated as in Figure 2.

(a)

87	88	87	90	96	98
86	85	84	86	94	99
88	84	83	86	91	94
96	87	84	82	83	82
98	95	86	82	81	80
98	97	93	88	83	81

(b)

87	88	87	90	96	98
86	85	84	86	94	99
88	84	83	86	91	94
96	87	84	82	83	82
98	95	86	82	81	80
98	97	93	88	83	81

(c)

2	3	4	7	13	15
1	0	1	3	11	11
5	1	0	4	9	14
13	4	2	0	3	2
15	13	4	1	0	0
16	15	12	7	3	1

(d)

0					
1	2	1			
	1	2			
		0	2		0
			1	2	2
					1

Figure 7. Development and application of HAND model. a) Original DEM (meters) and channel network, b) each cell mapped to the nearest channel cell by flow direction, c) the elevation difference between each cell and its assigned channel cell, i.e., height above nearest drainage (HAND), and d) inundation extent and depth (meters) corresponding to a gauge height 2 meters above flood stage.

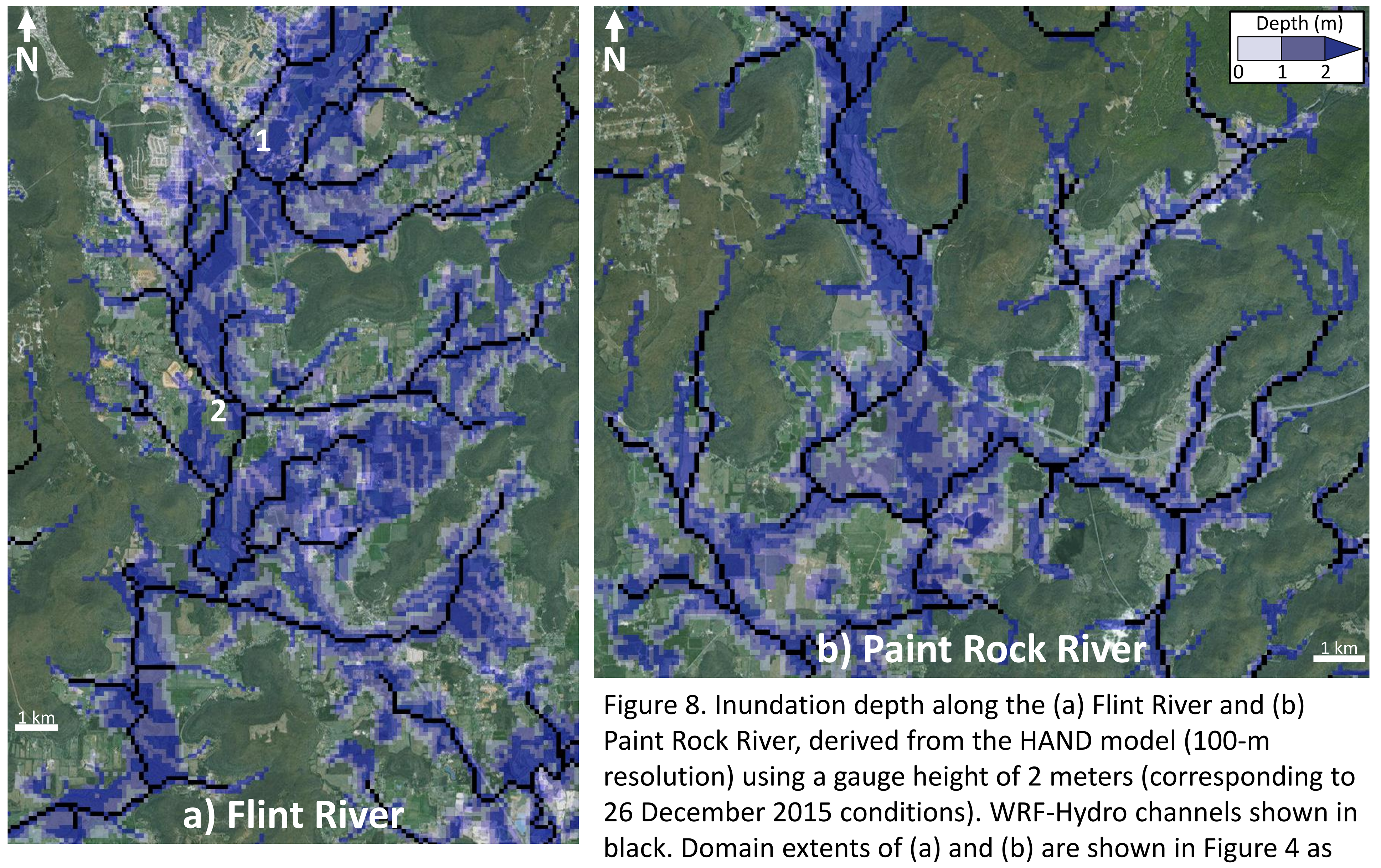

Figure 8. Inundation depth along the (a) Flint River and (b) Paint Rock River, derived from the HAND model (100-m resolution) using a gauge height of 2 meters (corresponding to 26 December 2015 conditions). WRF-Hydro channels shown in black. Domain extents of (a) and (b) are shown in Figure 4 as green and red boxes, respectively.

Figure 9. 26 December 2015 observed flood waters along the Flint River near Owens Cross Roads, Alabama. 1) Hays Nature Preserve (photo by Clay Blankenship) and 2) Old Big Cove Road (photo taken by J3Systems). Figure 8a shows the site of each of these photos.

5. Conclusions

- HAND model provides viable methodology to predict inundation extent from WRF-Hydro streamflow
- Derived inundation products can assist in flood response and emergency management efforts

6. Future Work

- Calibrate model using National Center for Atmospheric Research (NCAR) WRF-Hydro calibration scripts to obtain more accurate streamflow
- Validate inundation extent derived from WRF-Hydro using Visible Infrared Imaging Radiometer Suite (VIIRS) and Synthetic Aperture Radar (SAR) imagery

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