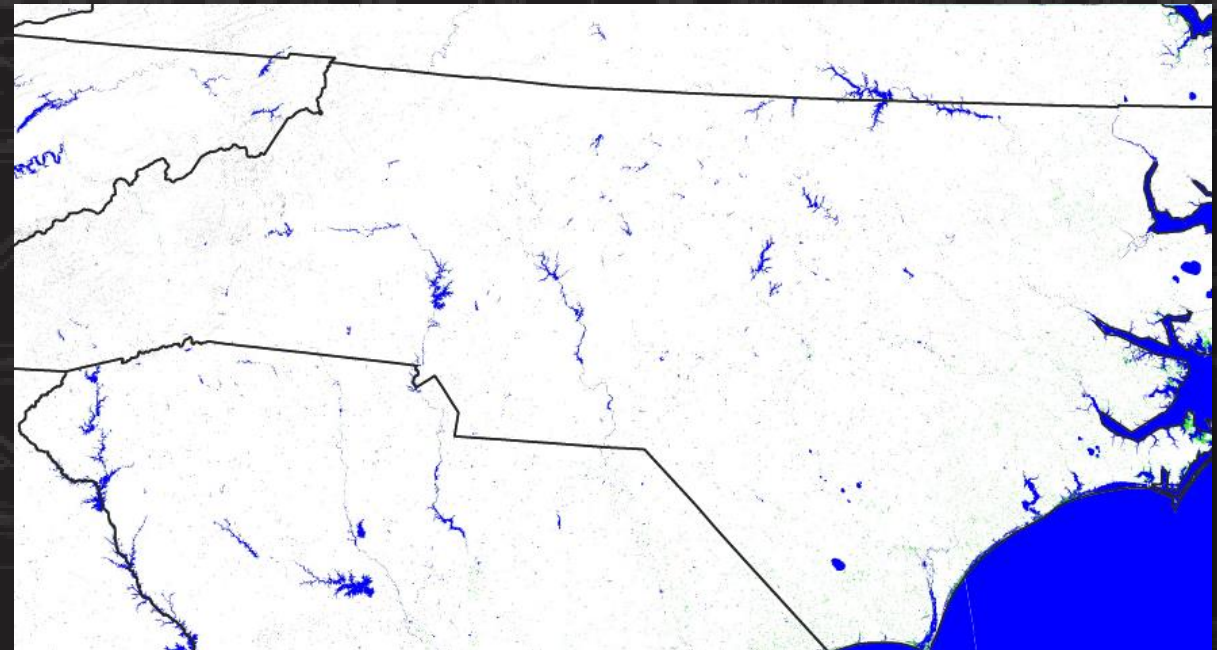


THE IMPACT OF VARYING INPUT DATA ON THE FLOOD INUNDATION MAPPING CASE STUDY: 2022 PAKISTAN & 2024 NORTH CAROLINA, USA FLOODS

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Coastal and Hydraulics Laboratory

Fifth OPERA Workshop
September 11th, 2025



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PROJECT BACKGROUND

- **Objective:** Improve flood inundation estimations through the evaluation of various input data sources and resolutions against OPERA products
- **Two Focuses:** Evaluate accuracy of different combinations of input data source and quantify variation and influence of input data resolution
- **Events of Interest:** Pakistan floods and Hurricane Helene in North Carolina
 - Pakistan – 2022
 - North Carolina – 2024



EVENTS OF INTEREST

PAKISTAN

- Monsoon rains combined with high flows from glacial melt to cause catastrophic flooding in Southern Pakistan causing an estimated \$30 billion in damages and over 1,400 deaths



[Source: Devastating Floods in Pakistan](#)

NORTH CAROLINA

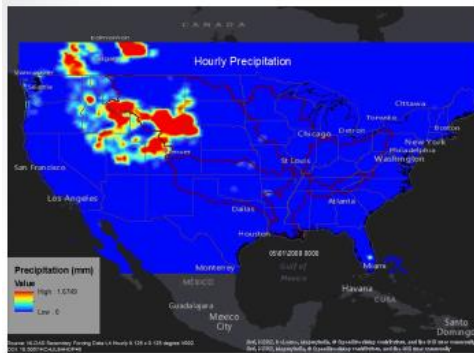
- Hurricane Helene hit North Carolina on Sep. 27, 2024 and caused an estimated \$59 billion in damages across the state
- Asheville and surrounding Buncombe county (our study site) was among the hardest hit counties in the state



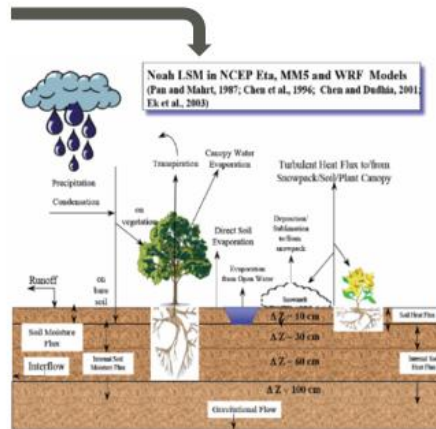
[Source: National Oceanic and Atmospheric Administration](#)

RAPID MODEL

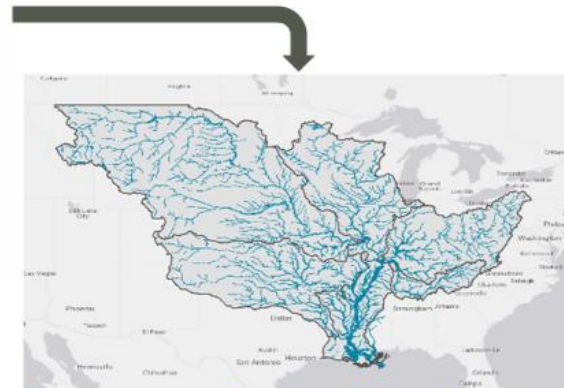
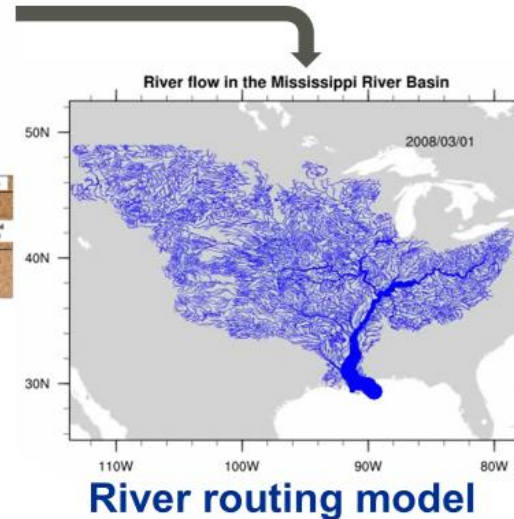
- Routing Application for Parallel computation of Discharge (RAPID) is a stream network routing model based on the Muskingum Method
 - RAPID routes flows and volumes for all reaches in a river network



Atmospheric model
or dataset



Land surface
models

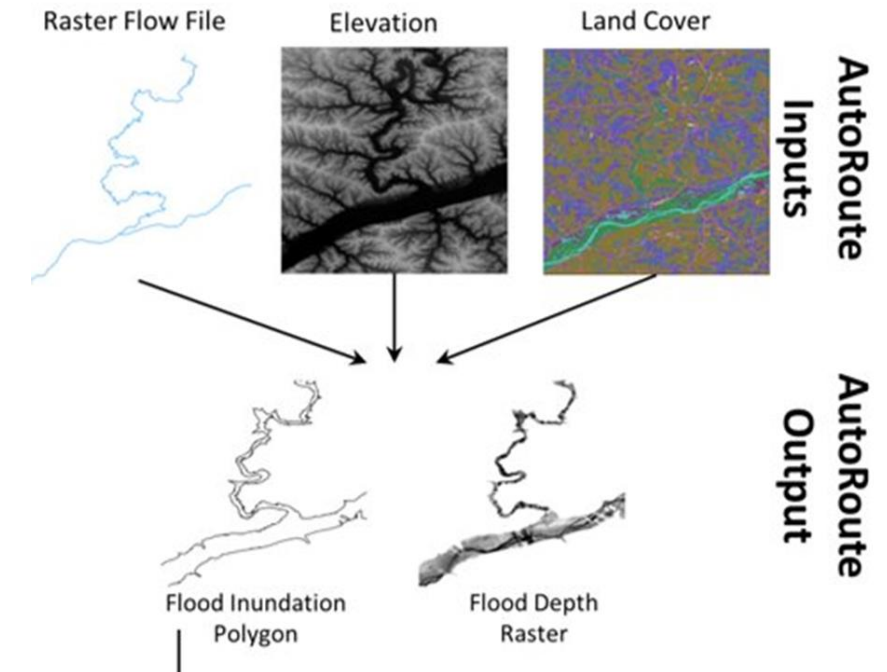


Hyper resolution flood extent

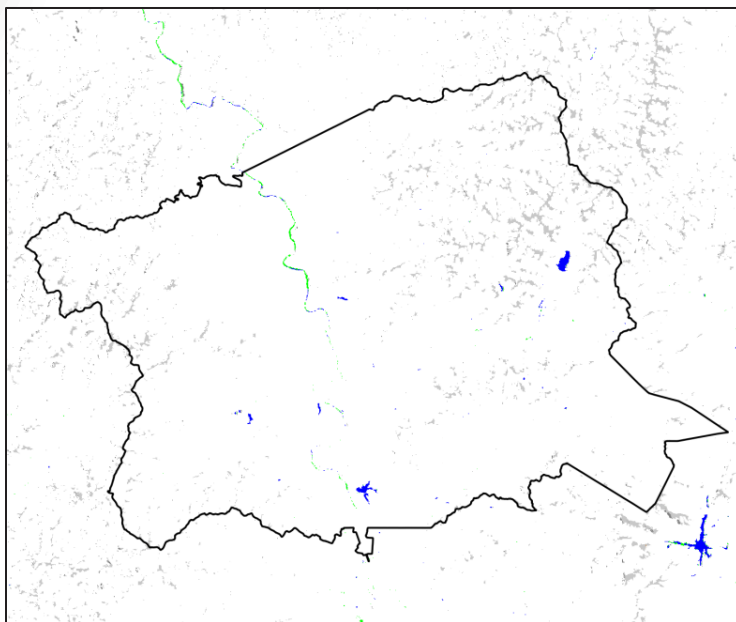
- **Inputs:** Atmospheric data and land surface data
- **Outputs:** Flow file with flow and volumes for stream network

AUTOROUTE MODEL

- **AutoRoute** is a hydrologic model which utilizes Manning's equation to estimate flooding over large areas.
 - AutoRoute is used to provide timely first order streamflow estimations and flood extents
 - Completing this evaluation will help inform improvements to deliverables
- **Inputs:** Digital Elevation Models (DEMs), land cover (LC), and streamflow
- **Outputs:** Velocity, Depth, Top-Width, and flood extents
- **AutoRoute Limitations:** Coastal areas, backwater regions, and engineered rivers



OPERA DYNAMIC SURFACE WATER EXTENT PRODUCT



Hurricane Helene- North Carolina

Data Collection:

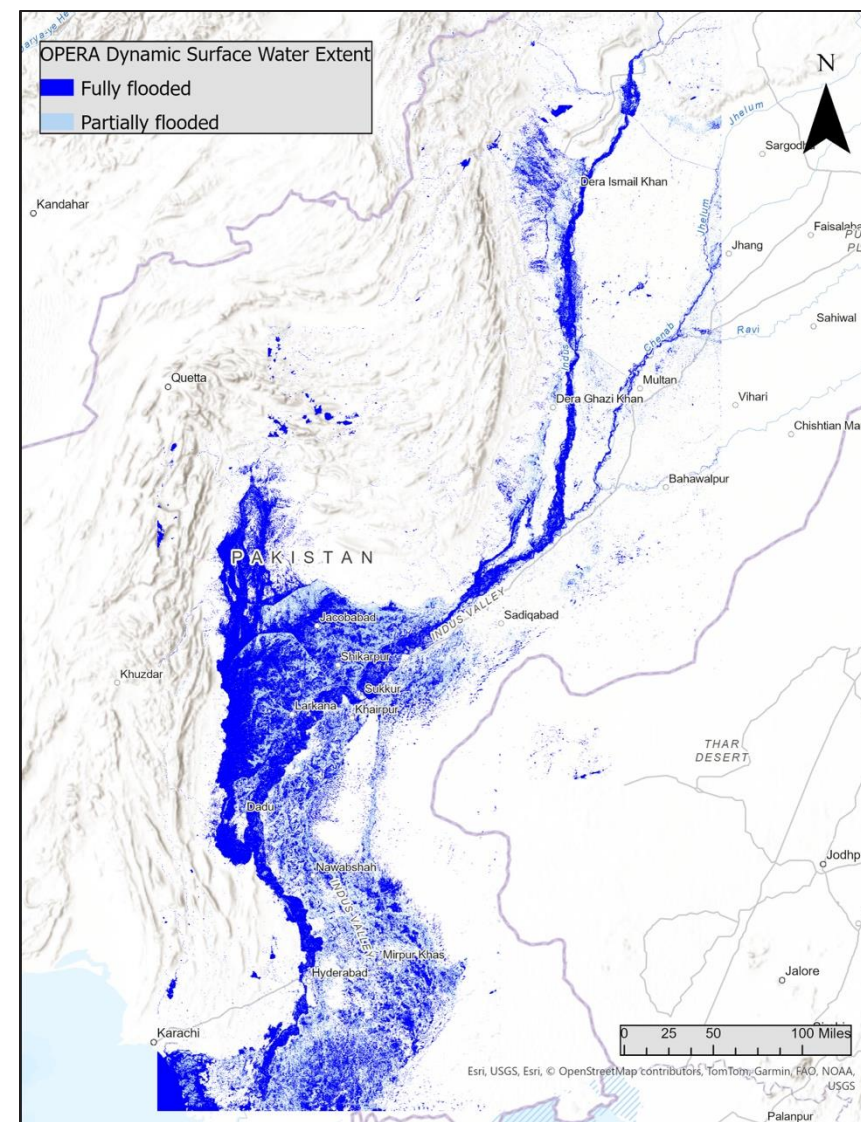
Sep. 26 to Oct. 8, 2024

Classification:

White- Non-inundated

Blue- Inundated

Green- Inundated vegetation



2022 Pakistan Floods

Data Collection:

Aug. 18 to Sept.
17, 2022

Classification:

Dark blue- open
water, high
confidence that the
pixel is fully
inundated

Light blue- partial
water, high
confidence that the
50% to 100% of the
pixel is inundated.

INPUT PRODUCT SOURCES – PAKISTAN

Kaitlyn Engel



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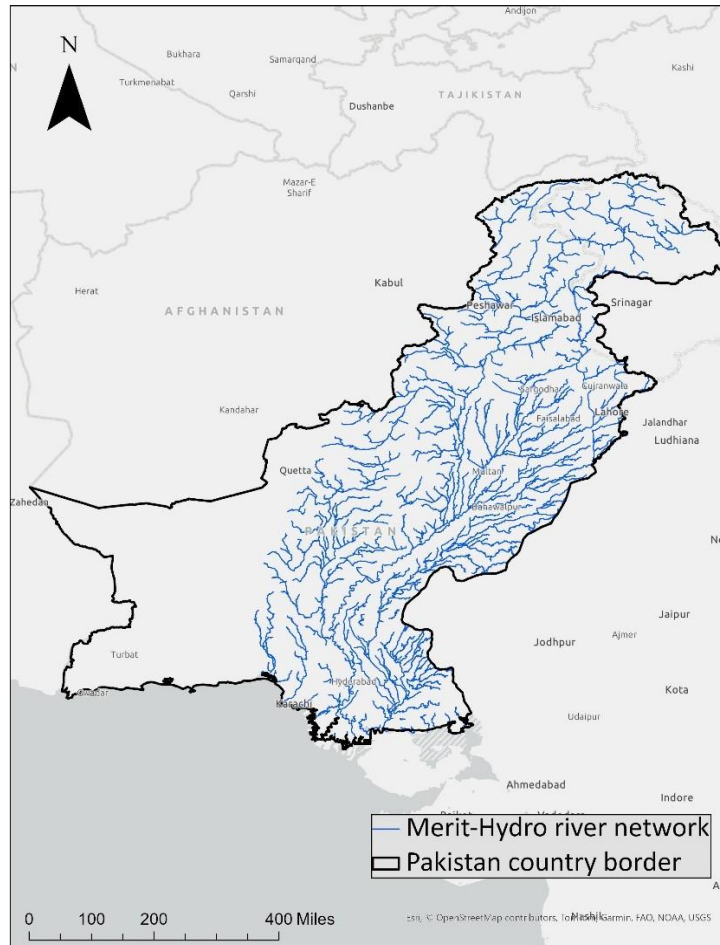
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PAKISTAN - METHODS

- 12 different AutoRoute runs using different input data combinations



Basin Area: 663,678 km²

Runoff Data	Stream Network	DEM
GHI-noahmp (USAF)	MERIT	FABDEM (U. of Bristol) -30 m
GHI-noahmp (USAF)	MERIT	MERIT (Yamazaki)- 90 m
GHI-noahmp (USAF)	MERIT	TDX NR v2 (NGA)- 12 m
ERA5 (ECMWF)	MERIT	FABDEM (U. of Bristol)-30 m
ERA5 (ECMWF)	MERIT	MERIT (Yamazaki) -90 m
ERA5(ECMWF)	MERIT	TDX NR v2 (NGA) 12 m
GHI-noahmp (USAF)	TDX Hydro v1 (NGA)	FABDEM (U. of Bristol) -30 m
GHI-noahmp (USAF)	TDX Hydro v 1 (NGA)	MERIT(Yamazaki) -90 m
GHI-noahmp (USAF)	TDX Hydro v 1 (NGA)	TDX NR v2 (NGA) 12 m
ERA5 (ECMWF)	TDX Hydro v 1 (NGA)	FABDEM (U. of Bristol) -30 m
ERA5 (ECMWF)	TDX Hydro v 1 (NGA)	MERIT(Yamazaki)-90 m
ERA5 (ECMWF)	TDX Hydro v 1 (NGA)	TDX NR v2 (NGA) 12 m

STATISTICAL ANALYSIS

- Results from each AutoRoute run evaluated against the **OPERA Dynamic Surface Water Extent Product** using:
 - **Overall Accuracy:** matching predicted wet and dry cells to observed inundated and dry cells
 - **F-score:** Removes skew of size if dry cells dominate the study area
- Capture all metrics of accuracy

$$\text{Overall Prediction Accuracy} = \frac{N_{\text{both wet}} + N_{\text{both dry}}}{\text{Total Pixels}}$$

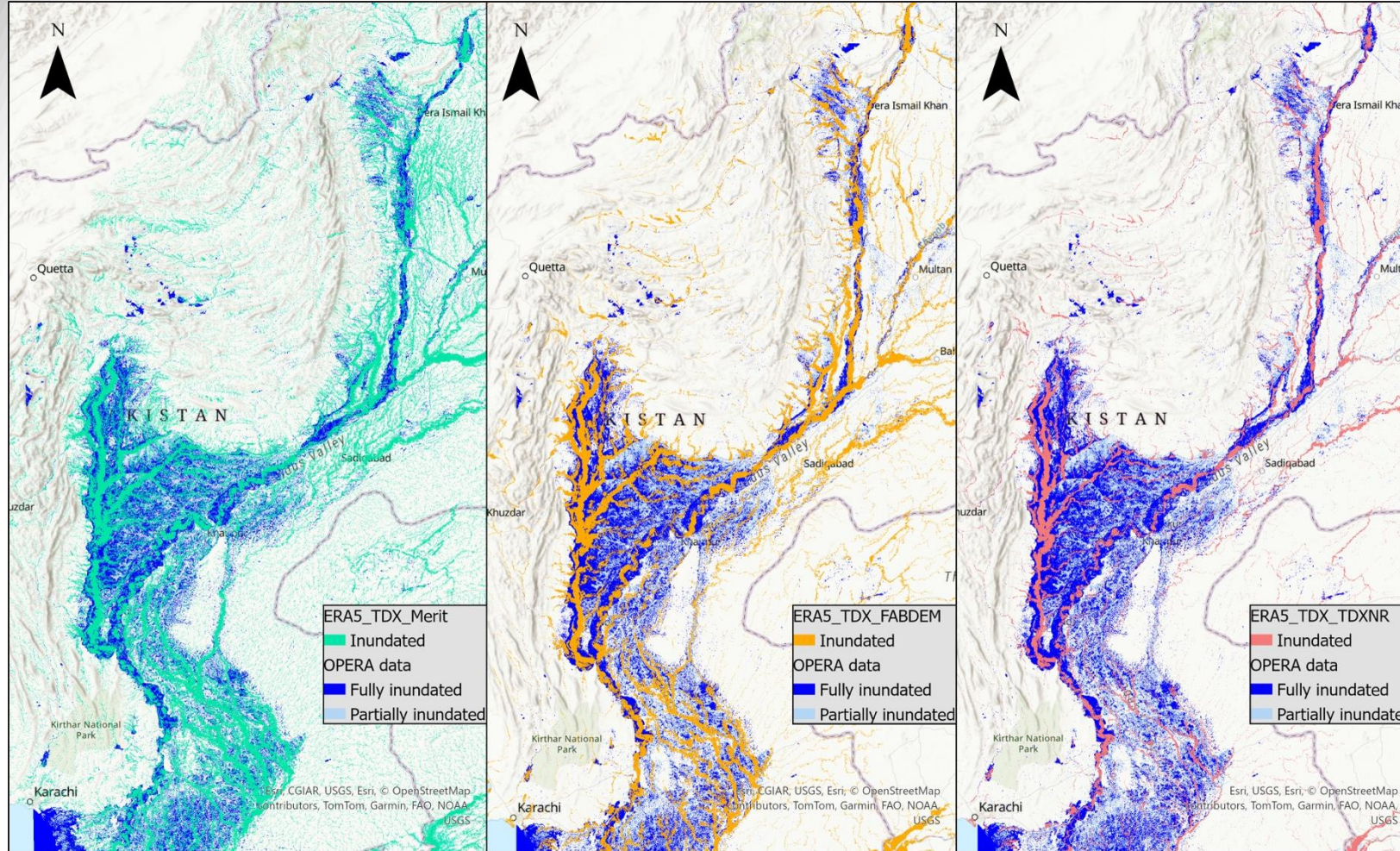
$$F = 100 \times \frac{N_{\text{both wet}}}{N_{\text{predicted wet}} + N_{\text{observed wet}} + N_{\text{both wet}}}$$

Sources:

Horritt MS, Bates PD. 2002. Evaluation of 1D and 2D numerical models for predicting river flood inundation. *Journal of Hydrology* 268: 87–99.

Tayefi, V., Lane, S. N., Hardy, R. J., and D. Yu. 2007. A Comparison of one- and two-dimensional approaches to modeling flood inundation over complex upland floodplains. *Hydrol. Process.* 21, 3190-2303.

PAKISTAN - RESULTS



Data combination	Overall accuracy	F
ERA5_TDX_TDXNR	0.896	20.683
ERA5_Merit_TDXNR	0.894	19.535
ERA5_Merit_FABDEM	0.882	24.881
ERA5_TDX_FABDEM	0.879	25.249
ERA5_TDX_Merit	0.841	22.210
ERA5_MERIT_MERIT	0.849	21.768
GHI_MERIT_MERIT	0.860	20.660
GHI_TDX_MERIT	0.851	21.514

INPUT PRODUCTS RESOLUTION – ASHEVILLE, NC

Josh Smallwood



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DATA SOURCES

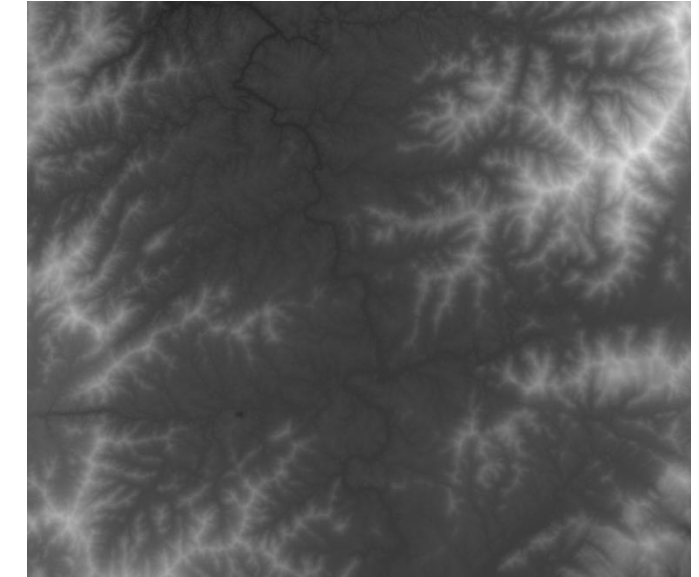
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- Input streamflow data was acquired from GEOGLOWS bias corrected retrospective streamflow
- Observational flood extents were acquired from **OPERA DSWx-S1** (dynamic surface water extent – Sentinel-1)
 - Radar based dataset to overcome cloud cover issue

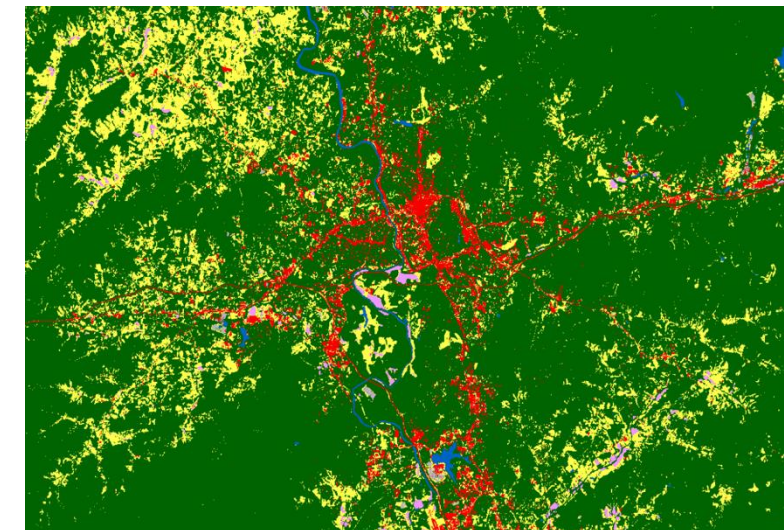
- Input products with varying resolution:

DEM Resolution (m)	Source	LC Resolution (m)	Source
1	North Carolina Spatial Data Download	10	ESA WorldCover
12	TanDEM-X Noise Reduced	30	USGS NLCD
30	FABDEM	1000	AVHRR

TanDEM-X Noise Reduced  ERDC



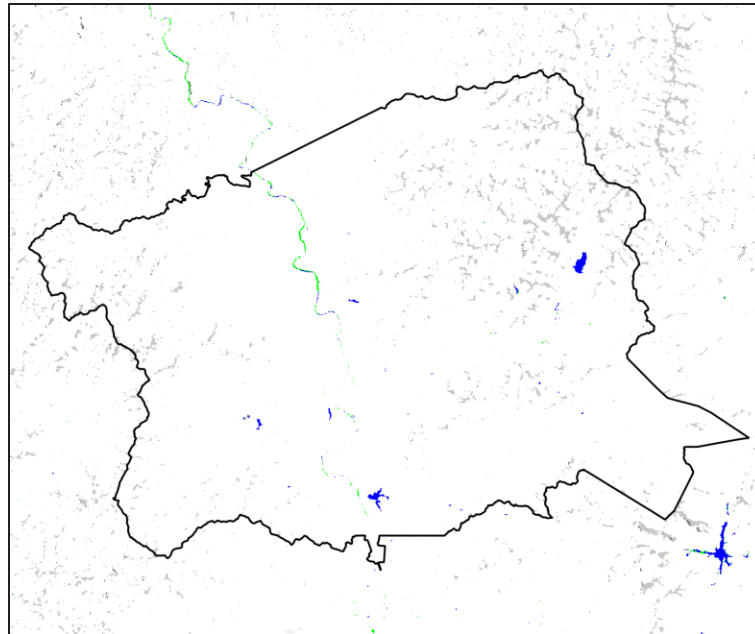
ESA WorldCover:



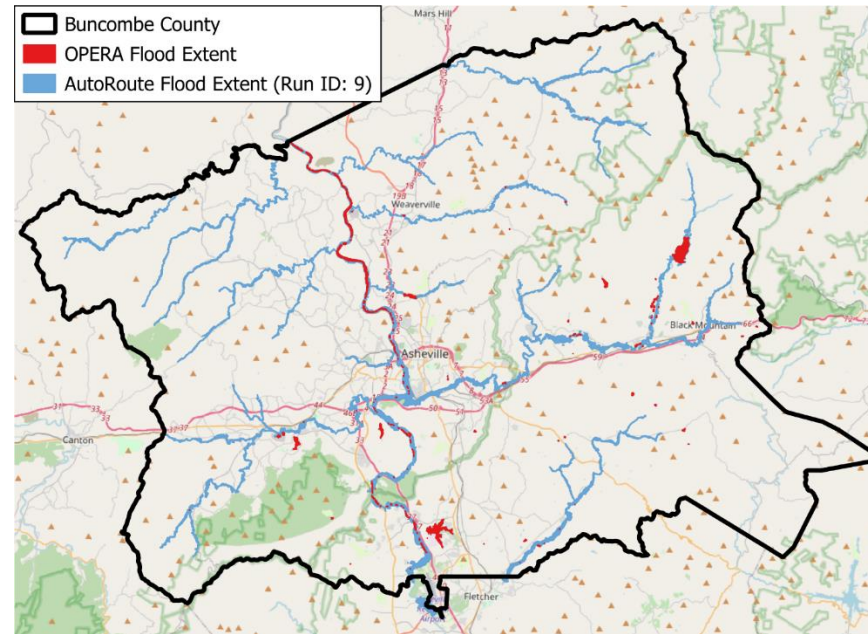
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METHODS

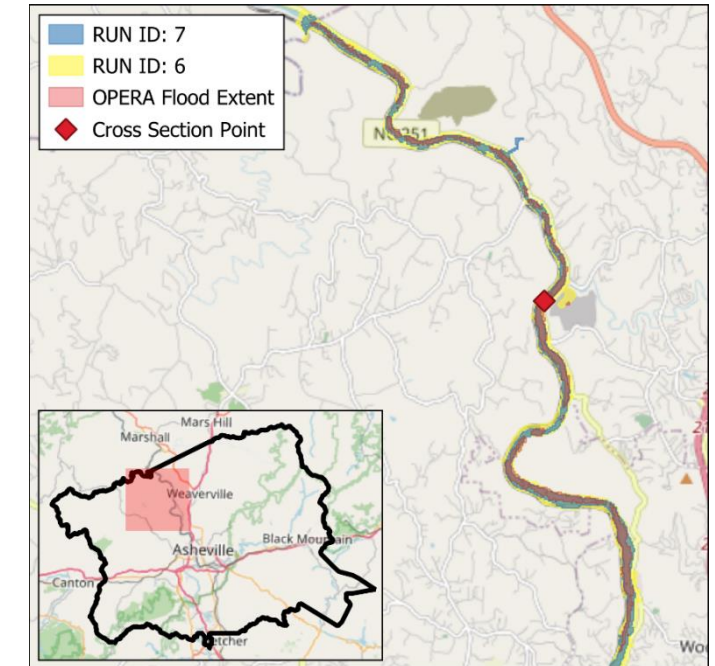
1. AutoRoute simulations produce flood extents for each combination of inputs
2. Convert OPERA DSWx-S1 data from raster to vector
3. Calculate percent overlap between modeled and observed flood extent polygons using Overlap Analysis tool in QGIS



OPERA Raster



OPERA Vector with
AutoRoute comparison



OPERA Vector comparison
with subset of original domain

RESULTS

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- Full extent analysis provides a clear trend – higher resolution DEM and LC provide more accurate results
 - Run ID 1 performed the best, while Run ID 9 performed the worst
- Subset extent analysis provides a less clear trend
 - Run ID 7 performed the best, while Run ID 6 performed the worst
 - A trend in LC remains in the subset, each DEM group received better results with the higher LC resolution

Run ID	DEM Resolution (m)	LC Resolution (m)	Percent Overlap with OPERA Data Full Extent	Percent Overlap with OPERA Data Subset Extent	OPERA Flood Extent Area (km ²)	AutoRoute Flood Extent Area (km ²)
1	1	10	23.68%	52.54%	5.035	11.873
2	1	30	22.39%	49.16%	5.035	12.869
3	1	1000	21.30%	49.10%	5.035	13.470
4	12	10	14.61%	47.02%	5.035	18.451
5	12	30	13.95%	40.43%	5.035	20.858
6	12	1000	12.60%	38.59%	5.035	23.454
7	30	10	7.51%	54.97%	5.035	39.71119983
8	30	30	7.31%	53.88%	5.035	40.94635361
9	30	1000	6.69%	45.75%	5.035	44.88543647

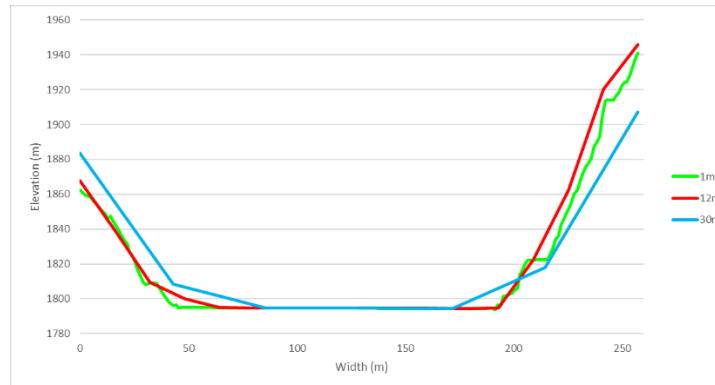
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DISCUSSION

- Full extent analysis low percent overlap can be explained by lack of flooding captured on tributaries
- Subset extent analysis area had less flooding due to steep banks along river segment
 - Likely contributes to a lack of a strong trend among results

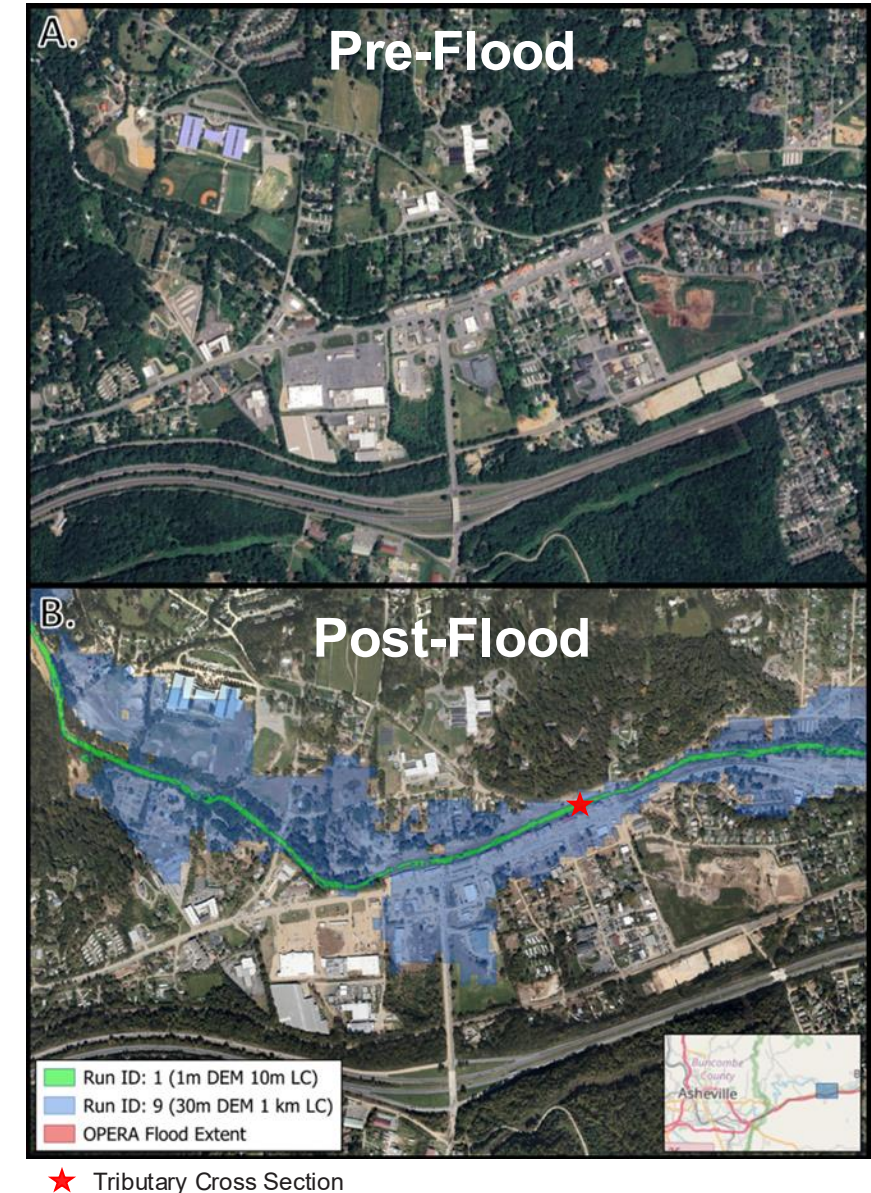
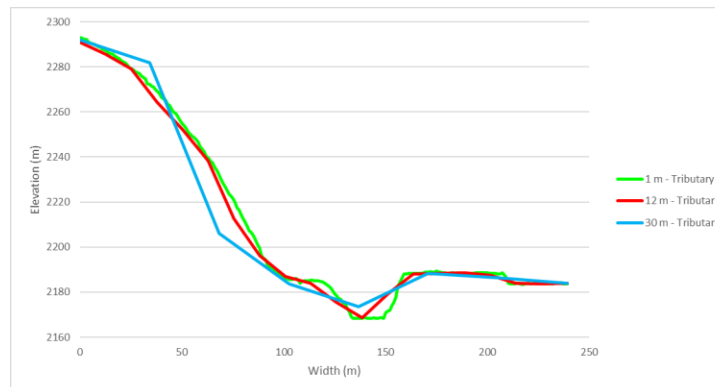
Subset Cross Section:

- Wide main stem river
- Steep banks



Tributary Cross Section:

- Narrower river
- Lowland areas



★ Tributary Cross Section

STATISTICAL ANALYSIS

- Velocity, Depth, and Top-Width outputs were also analyzed using Cliff's δ estimate and Cohen's d estimate to compare variation due to input resolution
 - Depth is least impacted by changes in resolution
 - Velocity and Top-Width moderately impacted
- Dealing with study sites across the globe data availability differs greatly
- This effort helps provide insight into what tradeoffs there are for each combination of resolution that may be available

Run1	Run2	Velocity (V)		Depth (D)		Top-Width (T)	
		Cliff's δ	Bias Corrected Cohen's d	Cliff's δ	Bias Corrected Cohen's d	Cliff's δ	Bias Corrected Cohen's d
1	2	0.091078	0.119668	-0.03669	-0.04517	-0.02145	-0.0266
1	3	0.500989	0.863875	-0.19084	-0.21878	-0.14699	-0.17182
1	4	0.498948	0.858886	-0.07768	-0.09375	-0.3589	-0.38372
1	5	0.506526	0.877506	-0.09459	-0.11326	-0.37597	-0.39928
1	6	0.763997	1.748872	-0.25985	-0.28923	-0.46831	-0.48016
1	7	0.774844	1.802124	0.142332	0.192351	-0.67638	-0.64446
1	8	0.770768	1.781857	0.109296	0.145028	-0.68521	-0.65095
1	9	0.897032	2.640742	-0.06679	-0.08102	-0.74109	-0.69122

Comparison of how each run's results deviated from another run's

CONCLUSION

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Modeling limitations: Run of the river estimated flows, does not capture urban influence or backwater effects does not incorporate monsoon/hurricane specific parameters

Pakistan:

- TDX-NR DEMs performed the best, informing which sources should be utilized in future efforts

North Carolina:

- Input resolution impacts output velocity, depth, and top-width but further investigation is need to quantify impact on flood extent accuracy

Future Work:

- Timely products that capture peak flows and large-scale flooding events will continue to be a challenge
 - Potential next steps: looking at land disturbance products from OPERA, incorporating high water marks, combining multiple data sources

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THANK YOU!

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