

Framework of operational flash flood forecast system: NCM CREST

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Course timeline

15:30 - 17:30 GMT+3

3 Sessions (30-40 mins each), 2 breaks (5-10 mins each).

Outline:

1. Overview of the system developments.
2. Function of each components.
3. System workflow.
4. Comparison to existing regional/global modeling systems.
5. Flood warning showcases.
6. Ongoing improvements.
7. CREST tutorial and sample projects.

NCM flash flood forecast system

Meteorology



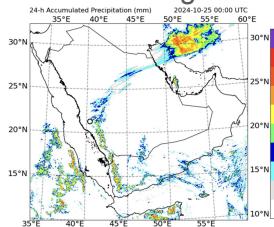
Hydrology



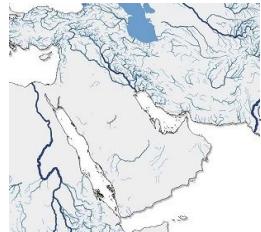
Hydraulics



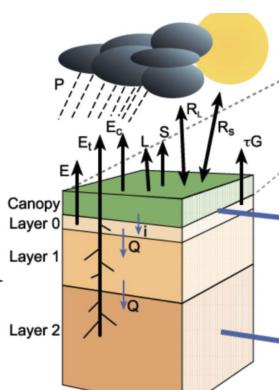
Forcing



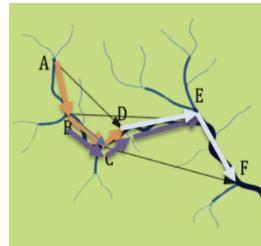
Hydro fabric



Land Surface

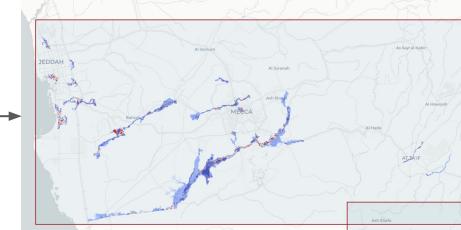


Routing

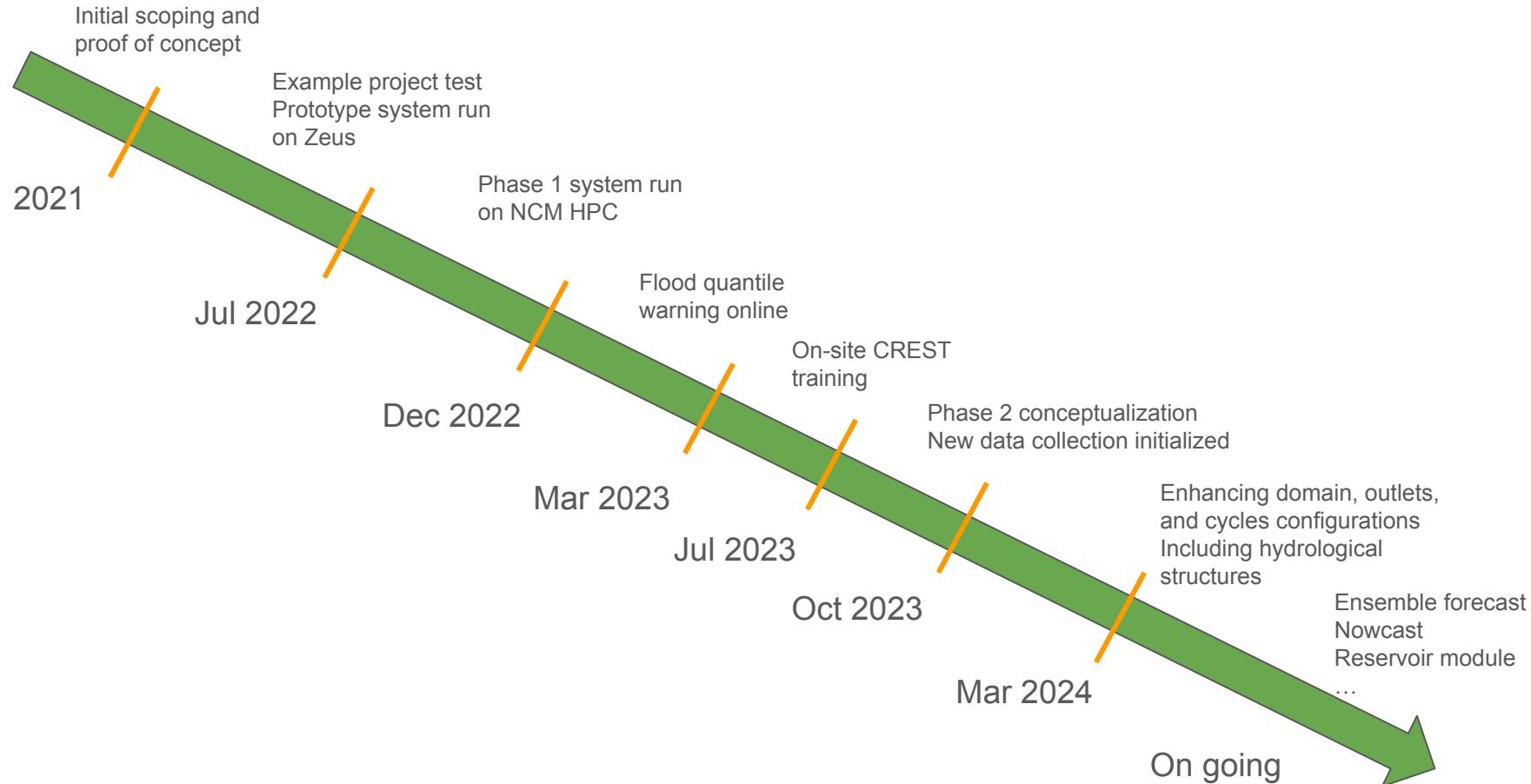


Flood quantile

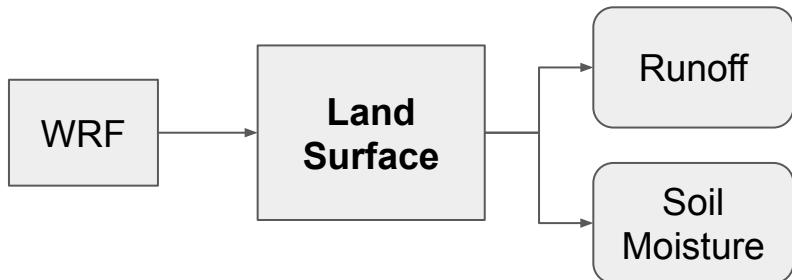
Flood inundation



NCM flash flood forecast system development timeline

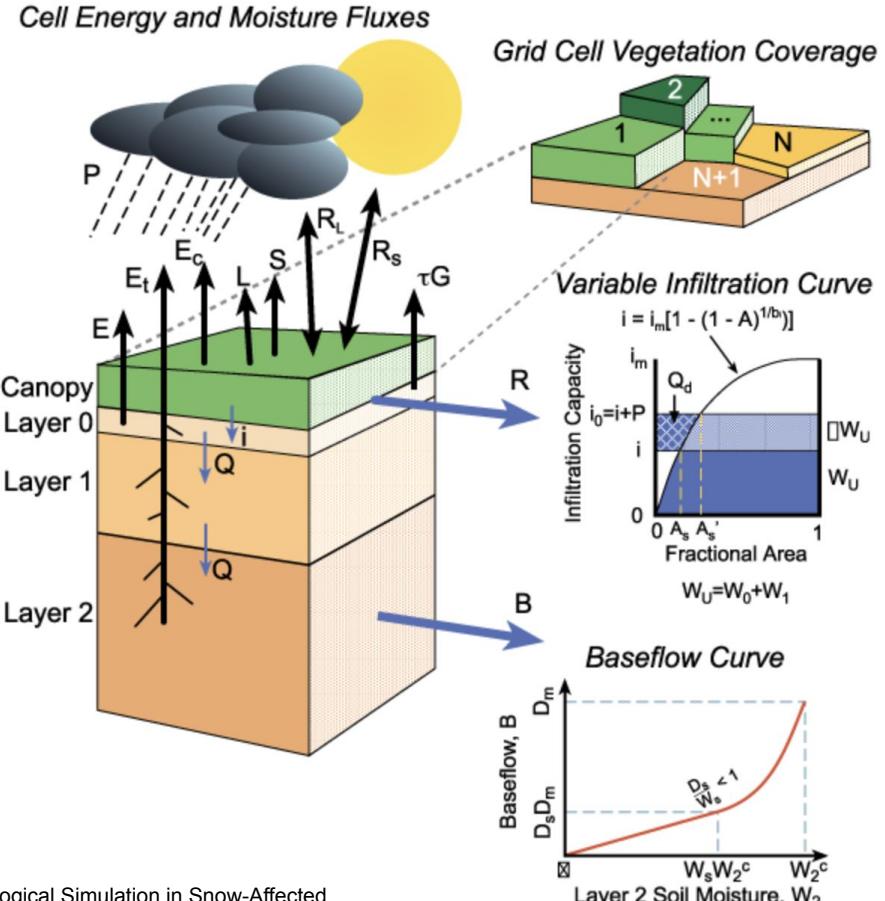


Components: Land Surface Model

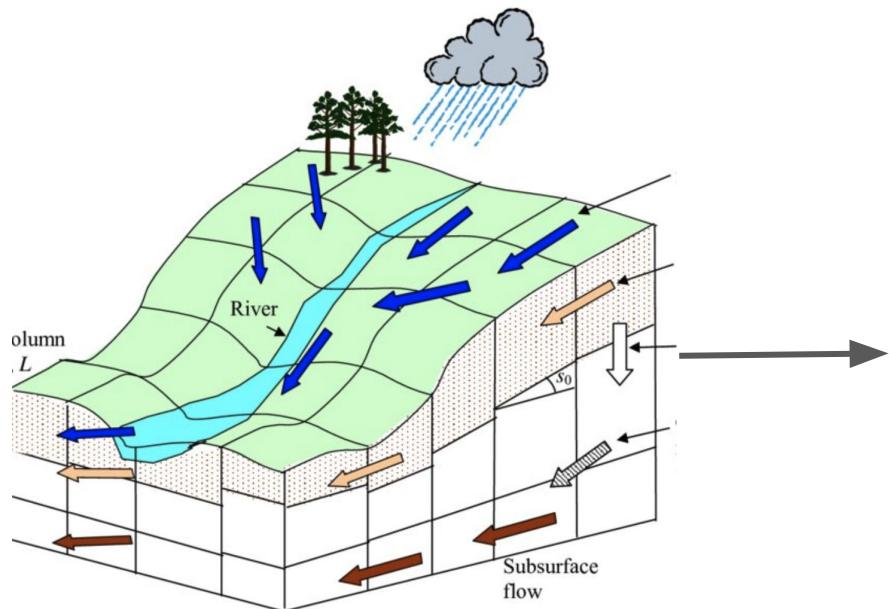
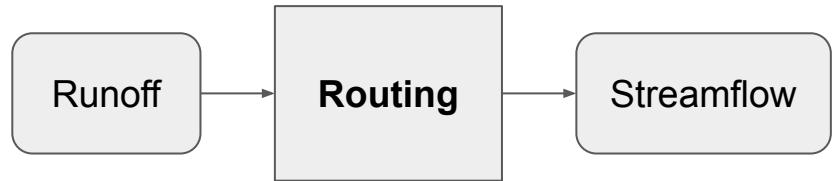


Water balance:

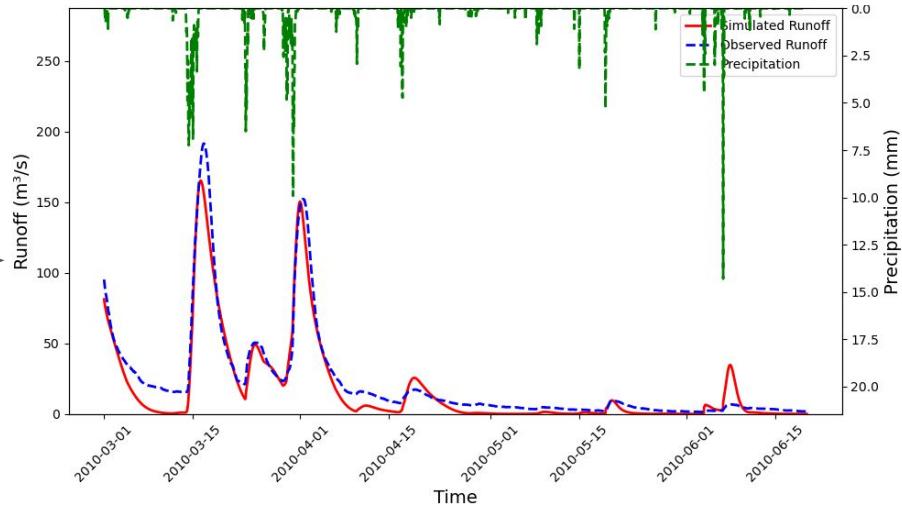
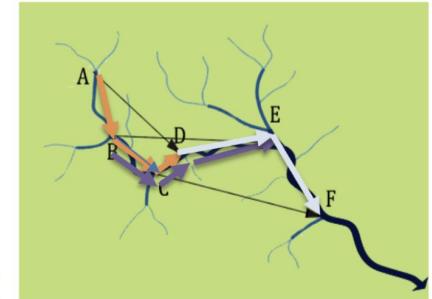
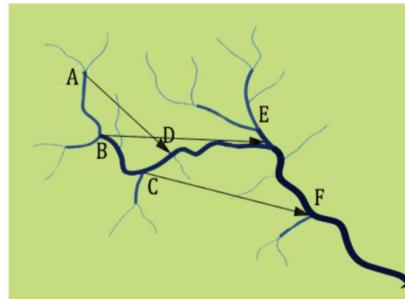
Precipitation (P) -
Evapotranspiration (ET) - Runoff
(R) = Change in Soil Moisture (ΔS)



Components: Routing Model



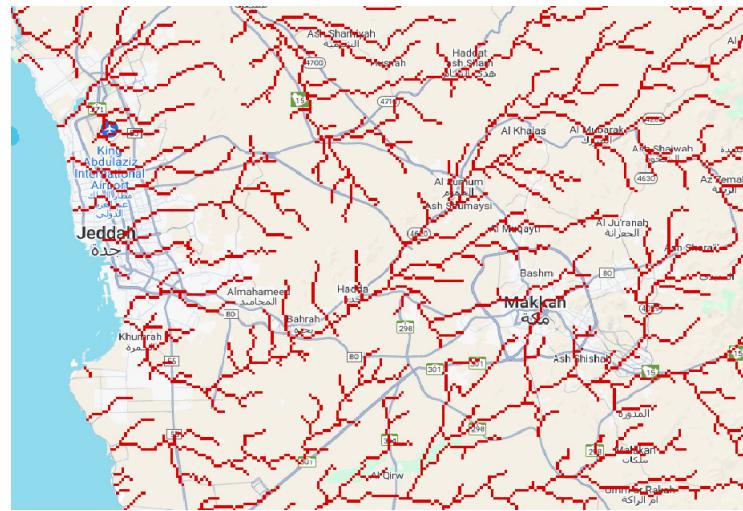
Shen, Xinyi, Yang Hong, Ke Zhang, and Zengchao Hao. 2017. "Refining a Distributed Linear Reservoir Routing Method to Improve Performance of the CREST Model." *Journal of Hydrologic Engineering* 22 (3): 04016061.



Components: Hydro-fabric

1. Topography: HydroSHED, <https://www.hydrosheds.org/>
2. Land Cover: MODIS-based Land Cover,
<https://lpdaac.usgs.gov/products/mcd12q1v006/>
3. Soil property: <https://www.isric.org/explore/soilgrids>

Components: Hydro-fabric - Stream

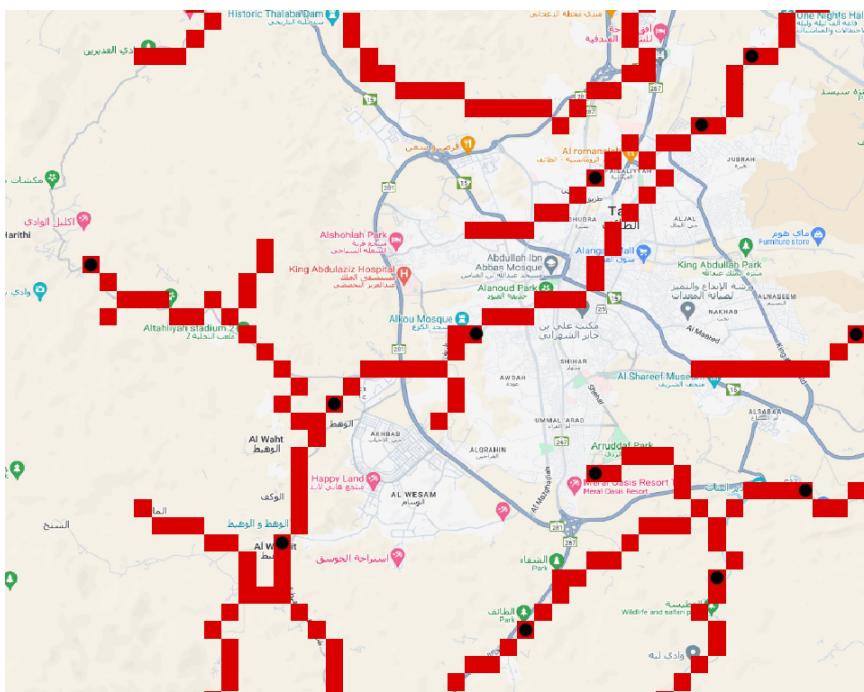


Current Stream: basin area $\geq 24 - 48 \text{ km}^2$

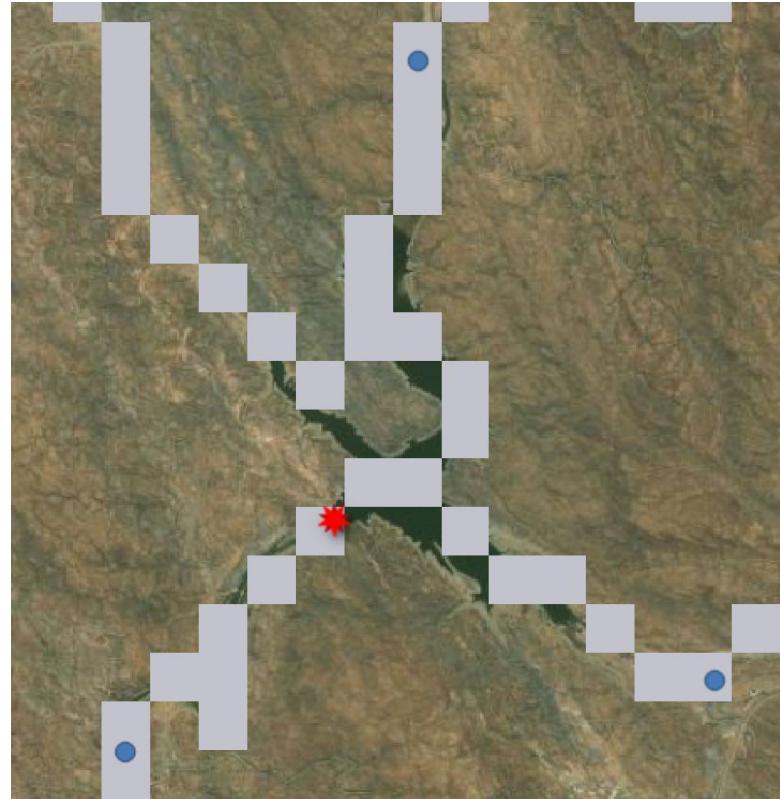
New Stream: basin area >= 12 km²

Components: Hydro-fabric - Outlets

1. On stream.

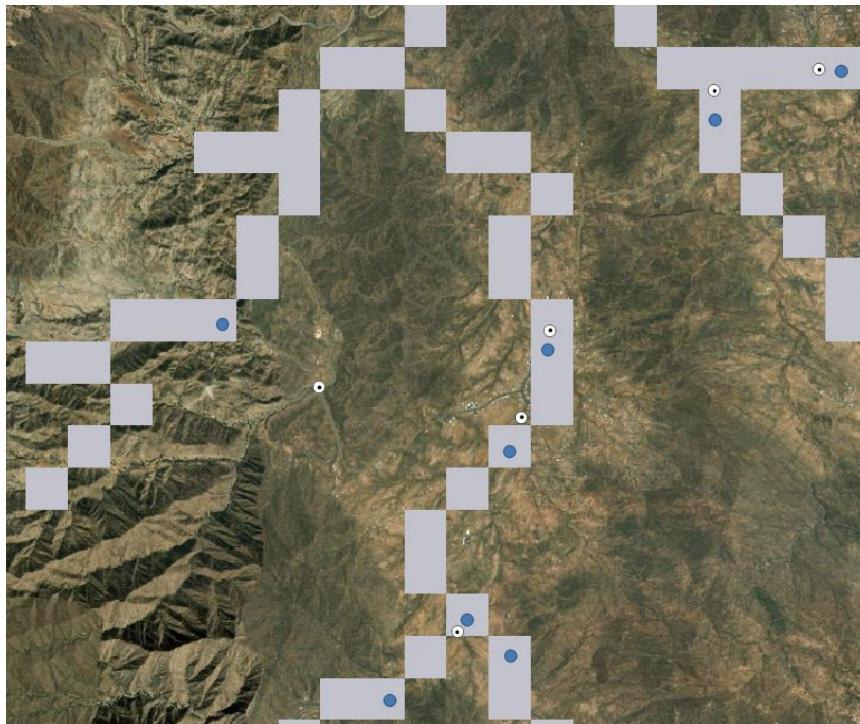


2. Infrastructures.



Components: Hydro-fabric - Outlets

Culvert

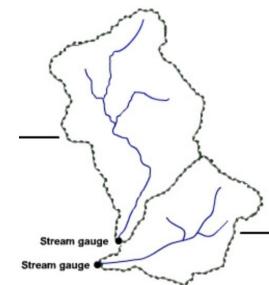


Levee

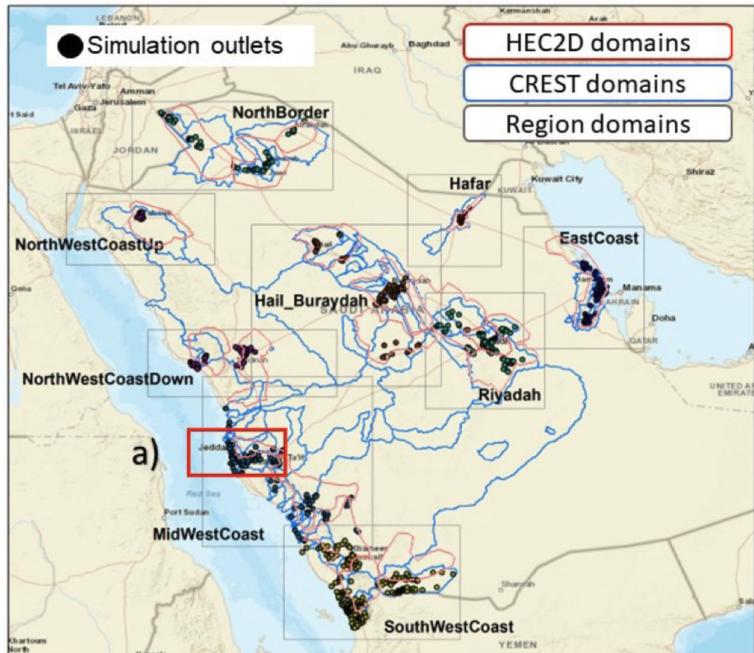


Components: Hydro-fabric - Outlets

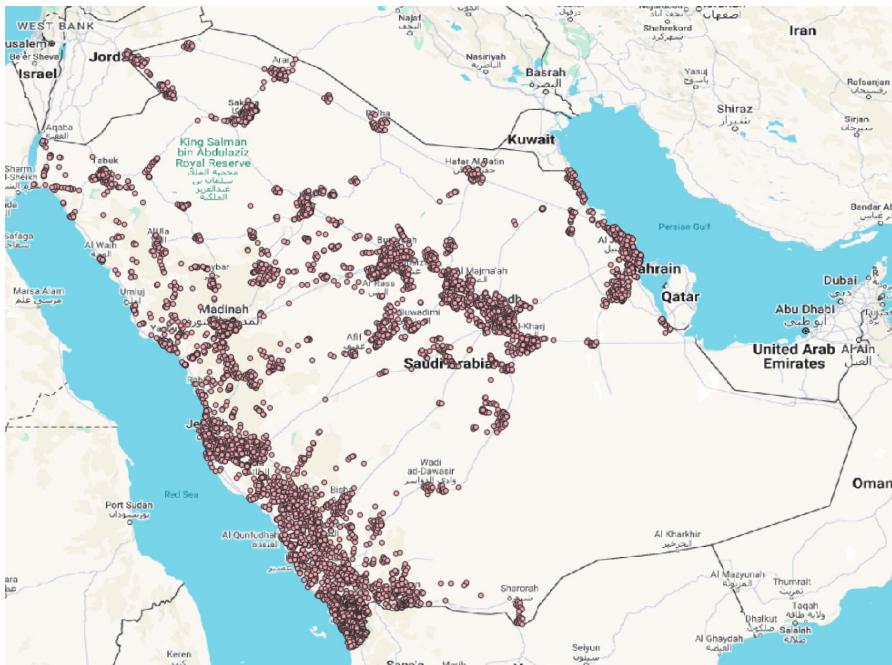
3. Complete basin.



Phase 1: 700+



Phase 2: 6,000+

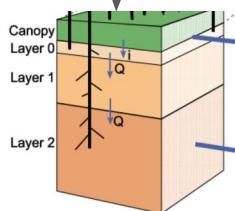
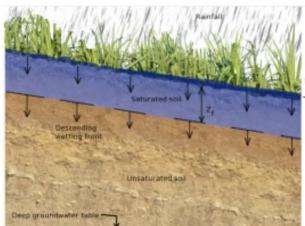
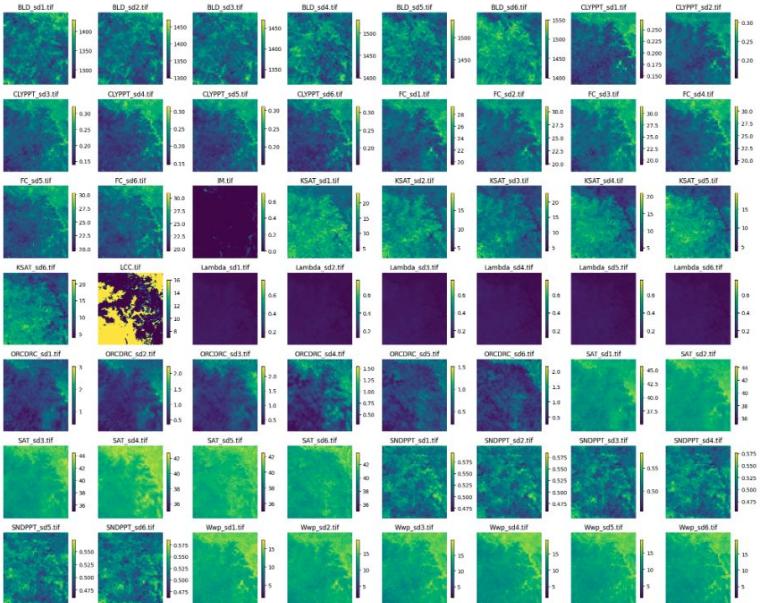


Was: 9 Sub-domains

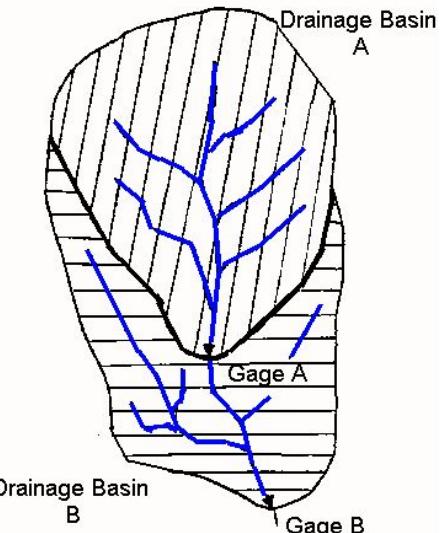
Now: One domain

Components: Parameters

Land Surface: data derived, distributed



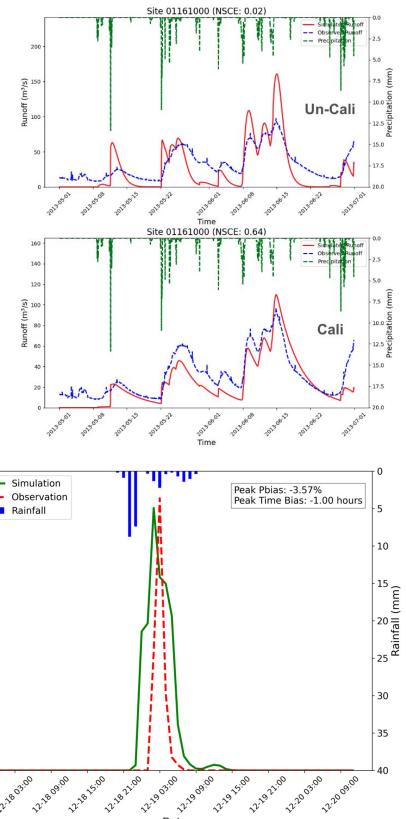
Routing: calibration, uniform



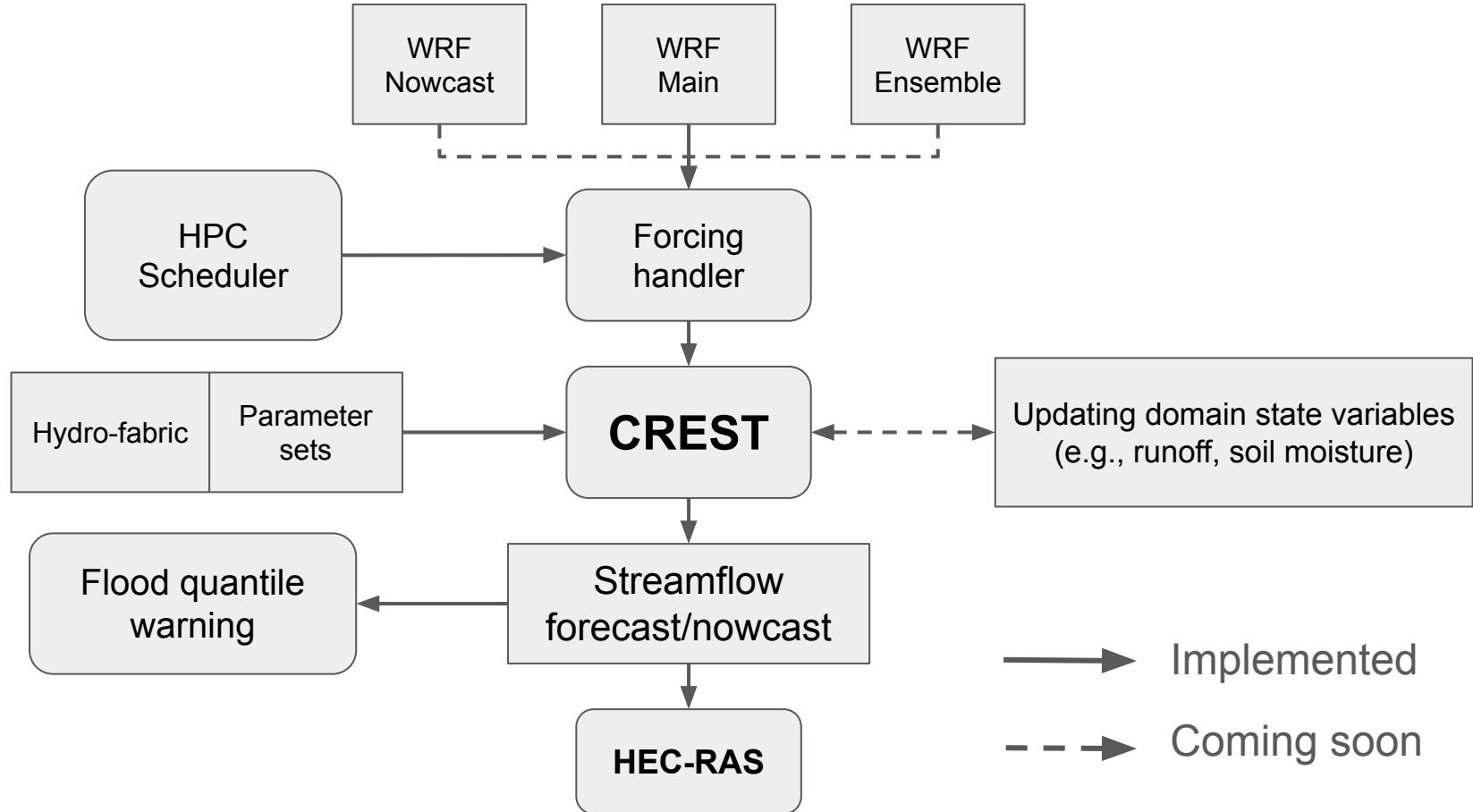
Historical
flood record

Calibration

Parameter



Operational system workflow:



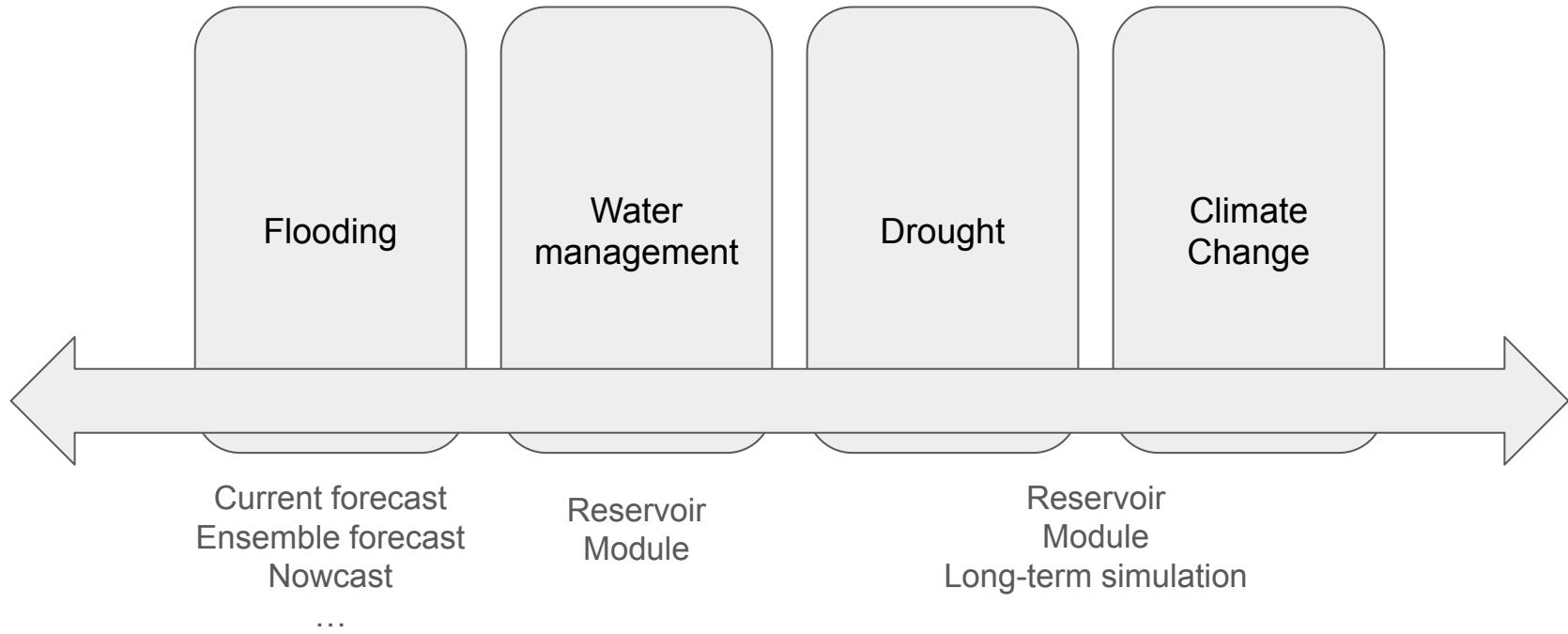
Flash flood forecast operational cycles:

	Cycling	Forecast time	Forcing	Outputs
Main Forecast (Current)	Every 6 hrs	120 hrs	WRF main	Streamflow Flood quantile
Ensemble Forecast	Every 12 hrs	72 hrs	WRF ensemble Total 10 members	Streamflow (Flood quantile)
Nowcast	Every 6 hrs	1-18 hrs	WRF nowcast	Land Surface state Streamflow
Short-Range (Potential)	1-4 x Daily	1-12 hrs	WRF data assimilation	Streamflow (Flood quantile)

Cycles run time and resources:

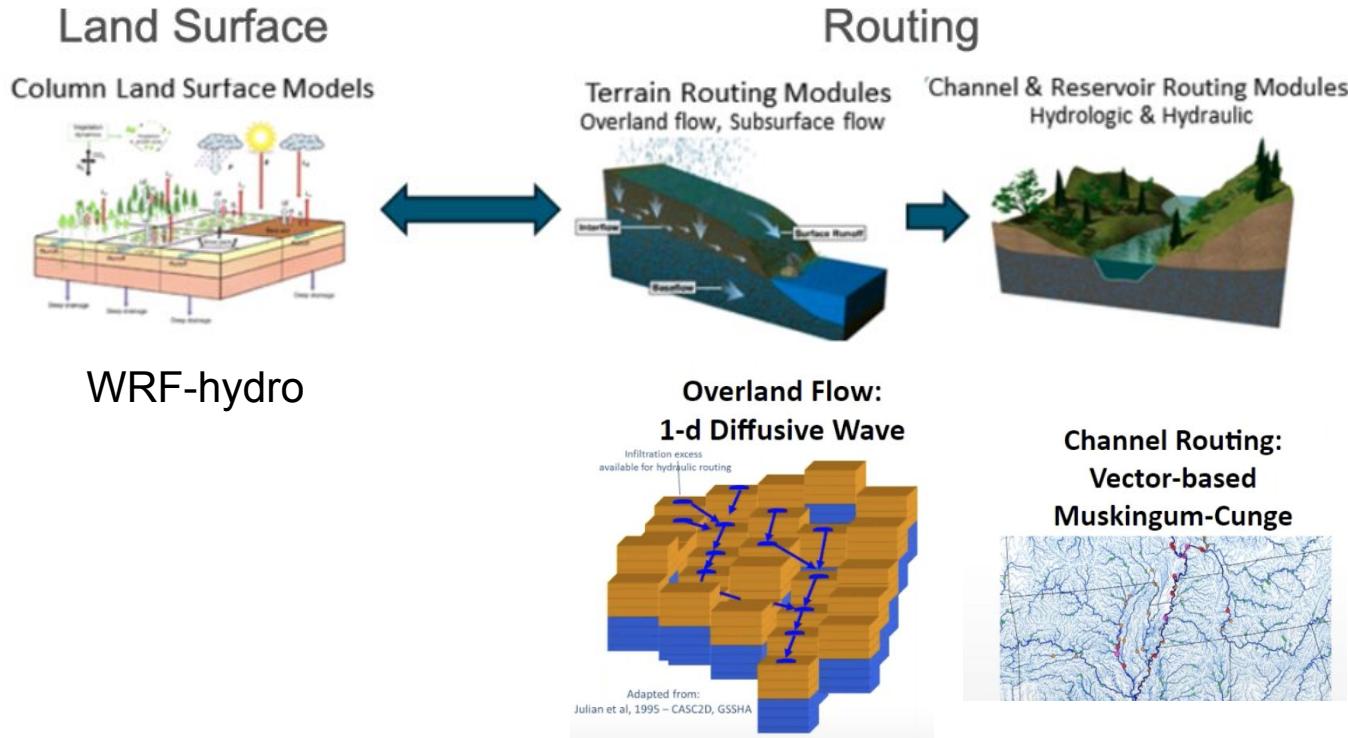
	Cycling	Resources	Run time
Main Forecast	Every 6 hrs	Fat node 96 cpu / 1500g	46 mins (Current) 2 hrs (New)
Ensemble Forecast	Every 12 hrs	matlab node x 5 64 cpu / 256g	3-5 hrs
Nowcast	Every 6 hrs	Fat node 96 cpu / 1500g	1 hr (Estimation)
Short-Range (Potential)	1-4 x Daily	Fat node 96 cpu / 1500g	1 - 2 hrs (Estimation)

Potential stakeholders



Comparison with other systems

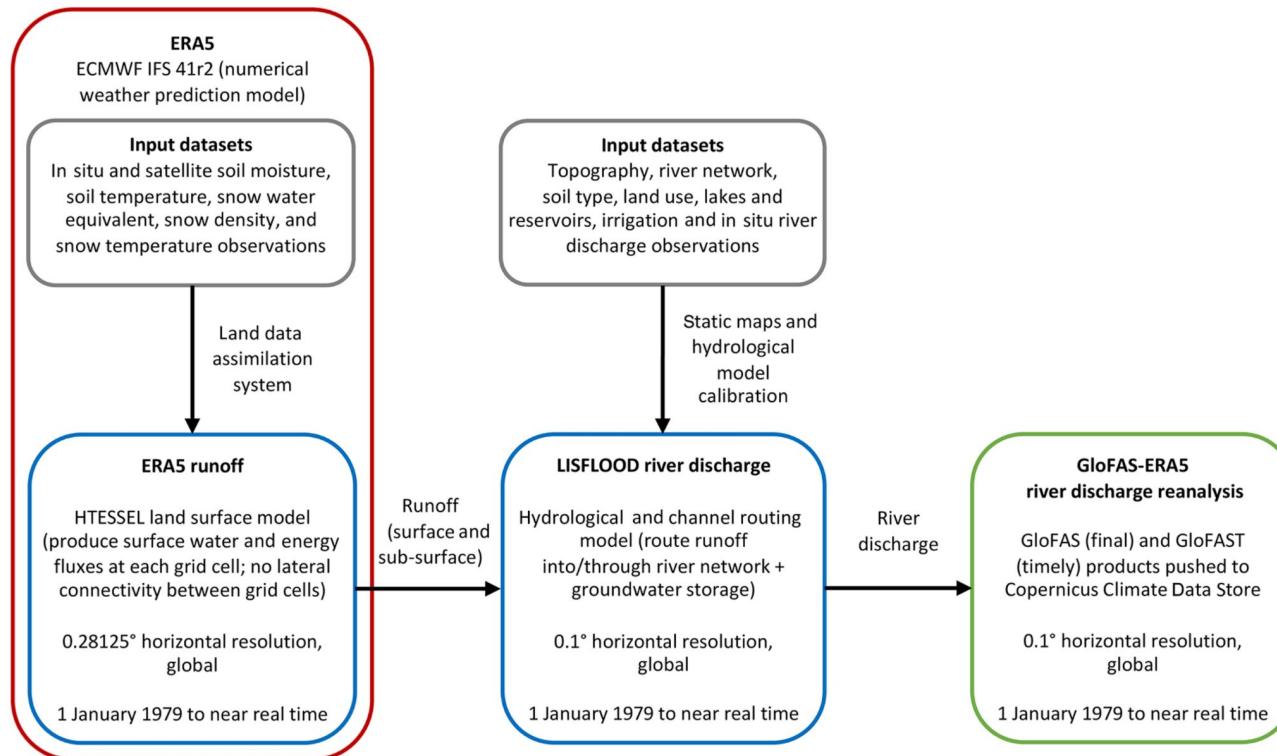
NOAA NWM



Source: <https://water.noaa.gov/about/nwm>

Comparison with other systems

GloFAS



Comparison with other systems

NOAA NWM: Hydro-fabric

Parameters	Data source
Elevation	CONUS: National Elevation Database OCONUS: HydroSHEDS
Channel and waterbody data	CONUS: NHDPlusv2 Medium Resolution OCONUS: Modified Great Lakes Hydrography Dataset (GLHD) and Elevation-Derived Hydrography
Soil type	CONUS: STATSGO Hawaii: SoilGrids Puerto Rico/USVI: gSSURGO
Land cover	CONUS: NLCD 2016 OCONUS: MODIS, Ontario Provincial Land Cover
LAI and greenness fraction	MODIS-based Monthly Climatologies

NOAA NWM: Forcing

Variable	Units	Downscaling	Bias correction
2 m air temperature	K	CONUS: MRF, LRF OCONUS: HI-AnA & SR, PR-AnA & SR	CONUS: SRF, MRF, LRF
2 m specific humidity	kg/kg	CONUS: MRF, LRF OCONUS: HI-AnA & SR, PR-AnA & SR	CONUS: LRF
Surface pressure	hPa	CONUS: MRF, LRF OCONUS: HI-AnA & SR, PR-AnA & SR	CONUS: LRF
Wind speed	m/s		CONUS: MRF, LRF
Incoming shortwave radiation	W/m ²	CONUS: MRF, LRF OCONUS: HI-AnA & SR, PR-AnA & SR	CONUS: SRF, MRF, LRF
Incoming longwave radiation	W/m ²		CONUS: SRF, MRF, LRF
Precipitation rate	mm/s		CONUS: LRF

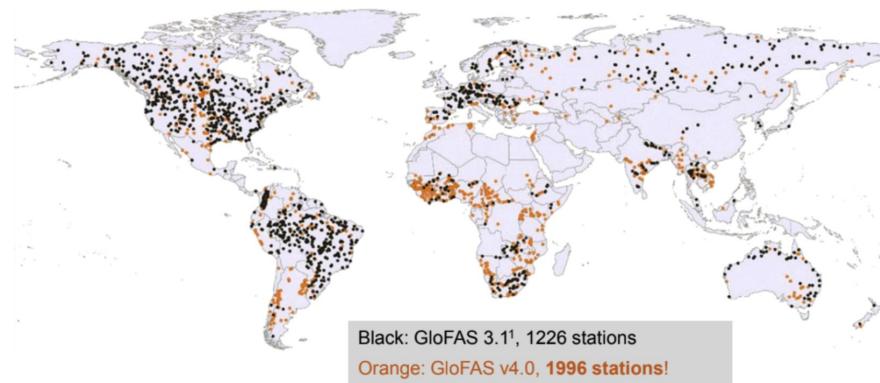
Comparison with other systems

River network and observation

NOAA NWM



GloFAS

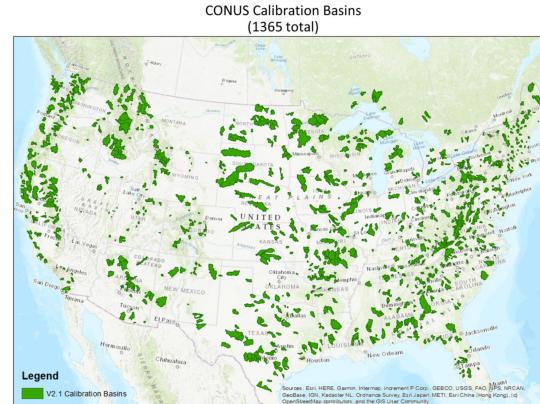


Source: <https://drive.google.com/file/d/1LFTgHGokPAYwAaj0Mzo8JUold9Im1Skw/view>

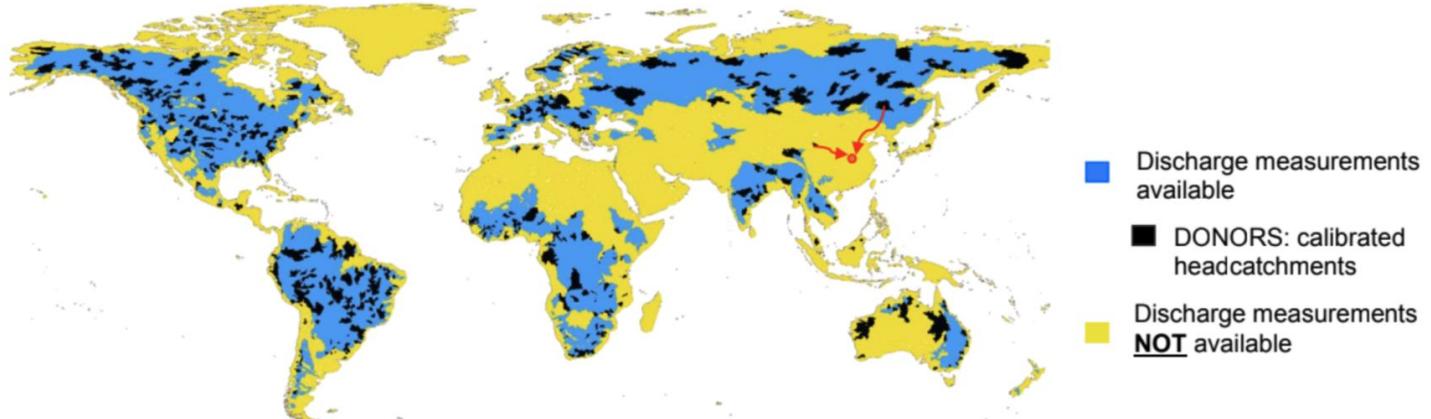
Comparison with other systems

Parameterization

NOAA NWM



GloFAS



Comparison with other systems



Lookback Range 3-28 hrs

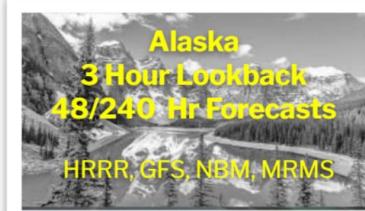
Including open loop
(non-DA) members



18 Hour Forecast

~10 Day Ens Forecast

Including open loop
(non-DA) member

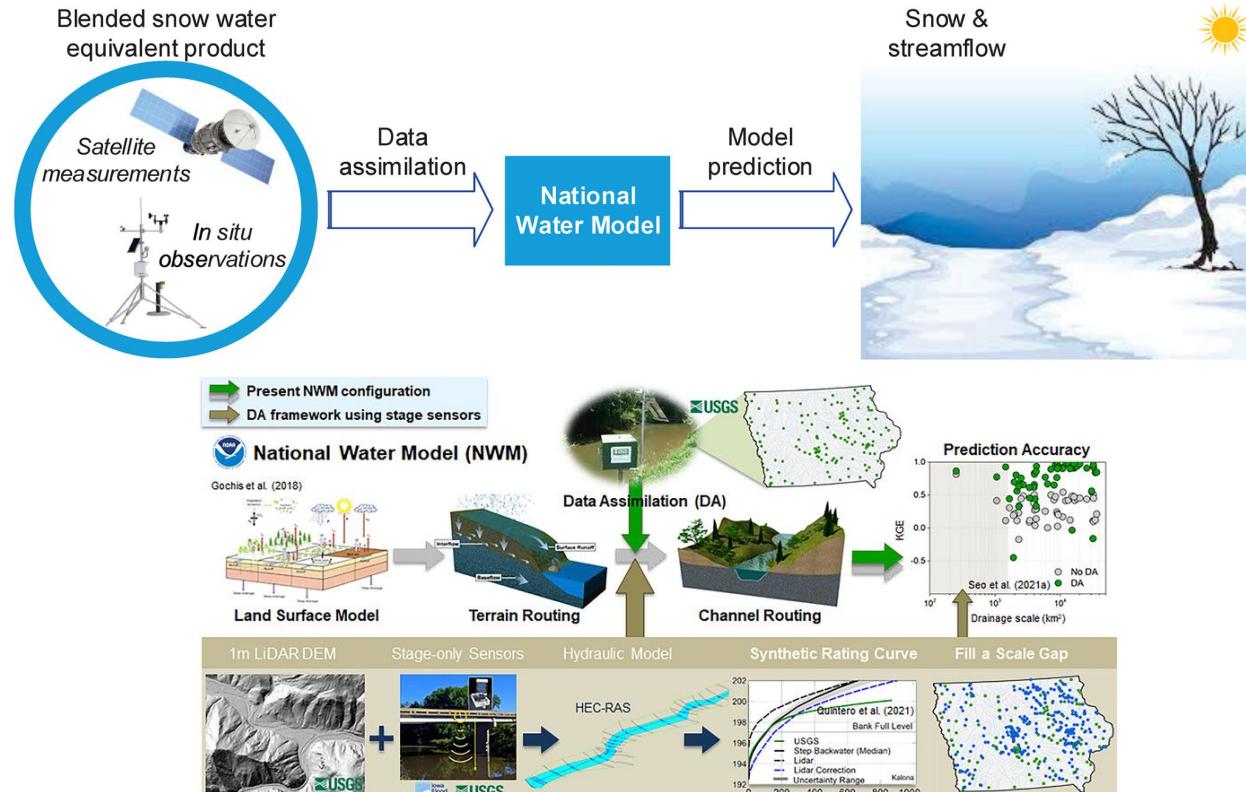


*Coastal Total Water Level

30 Day Ensemble Forecast

Comparison with other systems

Data assimilation



<https://www.sciencedirect.com/science/article/abs/pii/S0048969722036646>

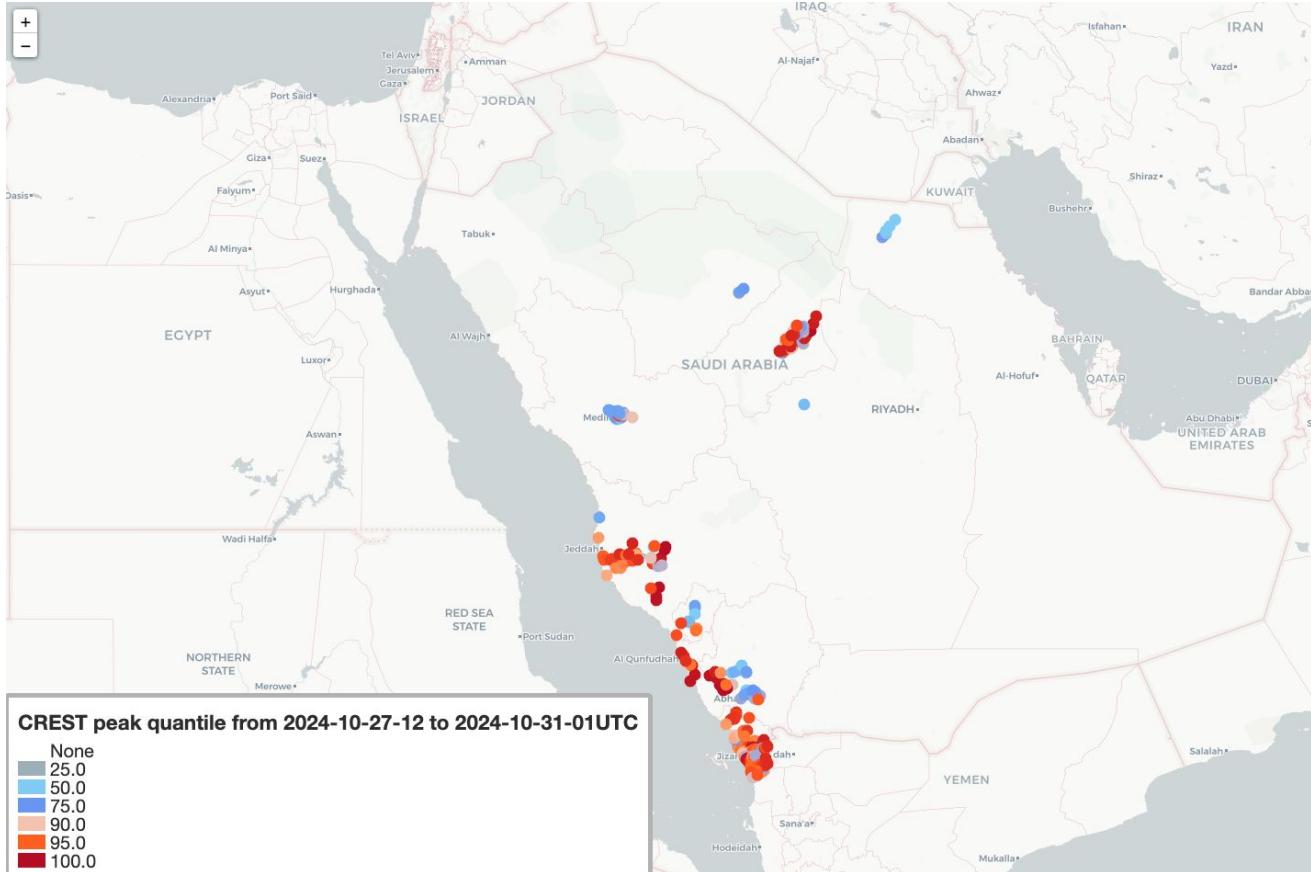
<https://journals.ametsoc.org/view/journals/wefo/37/11/WAF-D-22-0050.1.xml>

Comparison with other systems

Learn from other operational systems:

1. Efficiency, flexibility, and scalability, ensure connection between components.
2. Better representation > model complication.
3. More configurations = more options.
4. Parameterization.
5. Exploring data assimilation.

Flood quantiles



Current:

Simulation peak
from 160+ historical
flood events.



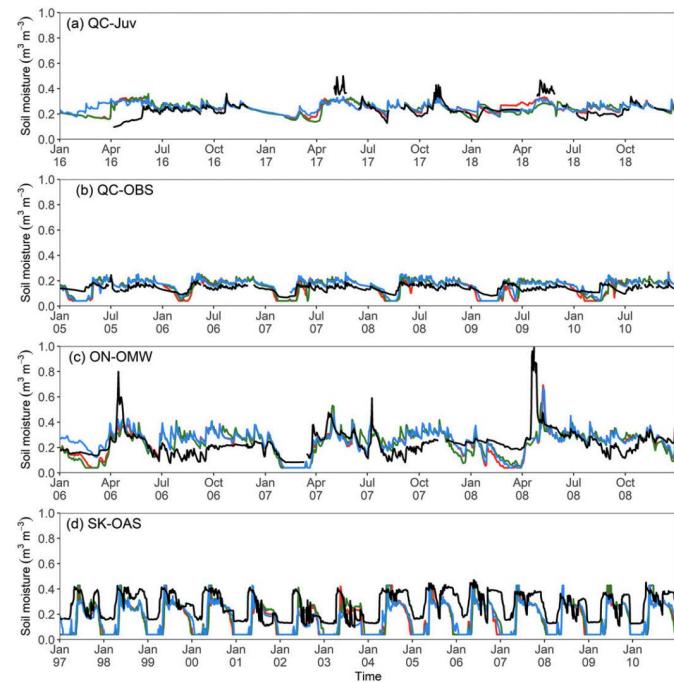
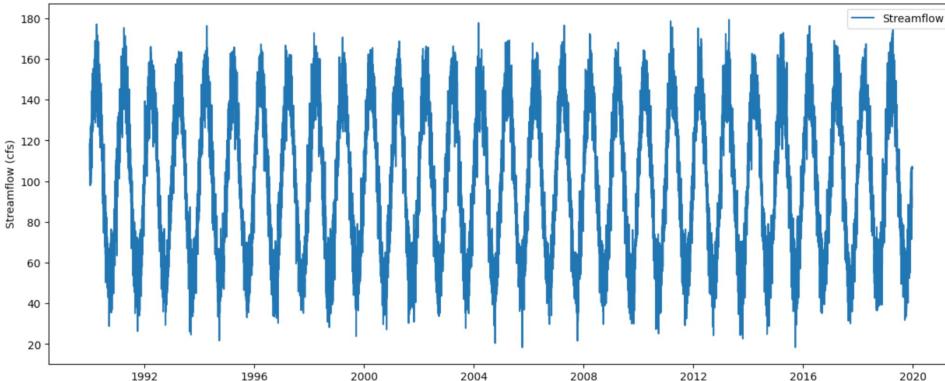
Flood peak quantile
lookup table

Forecast
peak

Forecast
quantile

Improving Flood Quantiles

1. Rerun historical flood events to update lookup table.
2. Incorporating ECMWF Reanalysis v5 (ERA5) for long-term model state.
3. Expert tuning.



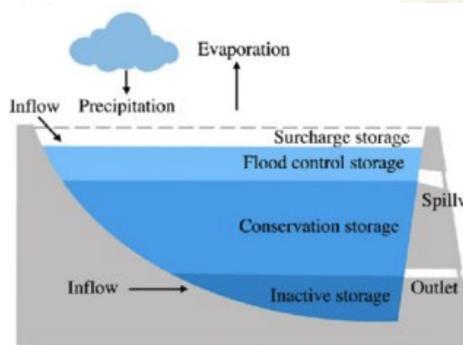
Model Improvements:

1. Developed reservoir modules, digitilizing reservoir/dam modules.

Flood abstraction for downstream sites.

Inflow retrieval for calibration.

Flood/water resource management.



Incoming operation cycles

1. Ensemble prediction: 10 members, 1-2 daily.
2. Nowcast.
3. Radar-WRF, WRFDA. (Potential)

Pass on sample of CREST project

Tutorial for CREST, project configurations, materials:

https://github.com/QingYang6/CREST_tutorial