

A National-Scale Experimental Flood Forecasting System Leveraging Supercomputing

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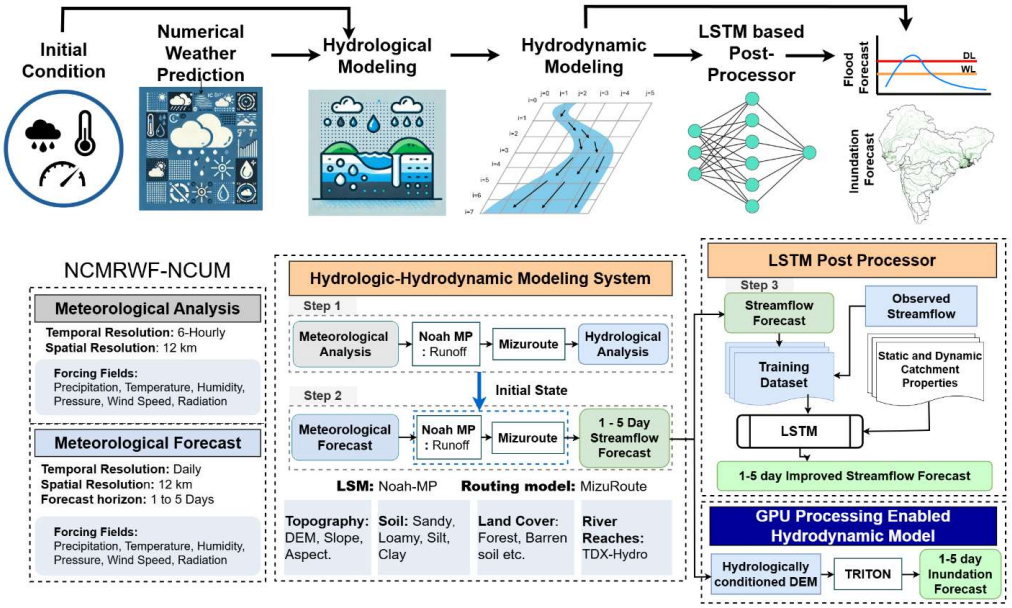
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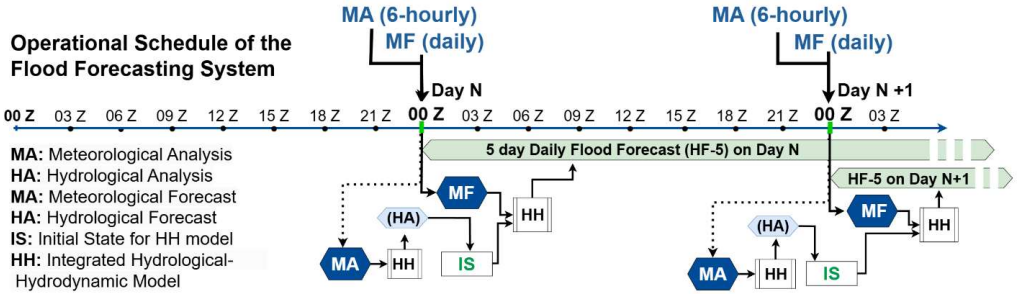
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Date: 24 September 2026

The operational setup of the experimental integrated Physics-AI medium-range (1-5 day) streamflow forecasting system



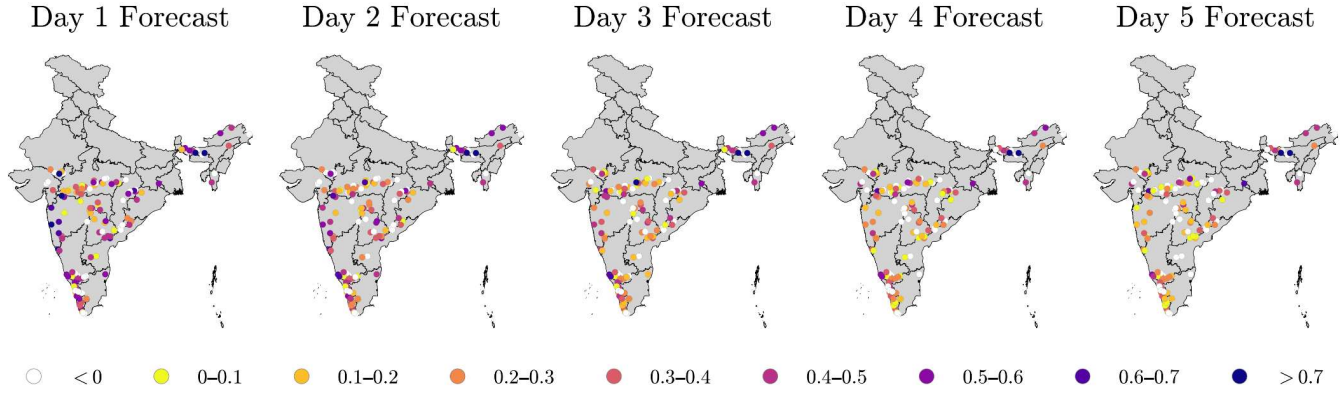


- Methodology of an integrated Physics-AI streamflow forecasting system.
- The system integrates Numerical Weather Prediction (NWP), Physics-based Hydrologic-hydrodynamic modeling, and AI.
- The individual components are integrated together.

- **NWP:** NCMRWF daily forecast from 1-5 days lead times
- **Hydrological Model:** Noah-MP for land surface hydrology within the NASA LIS Framework
- **Routing Model:** MizuRoute (vector-based), TRITON (2D SWE)

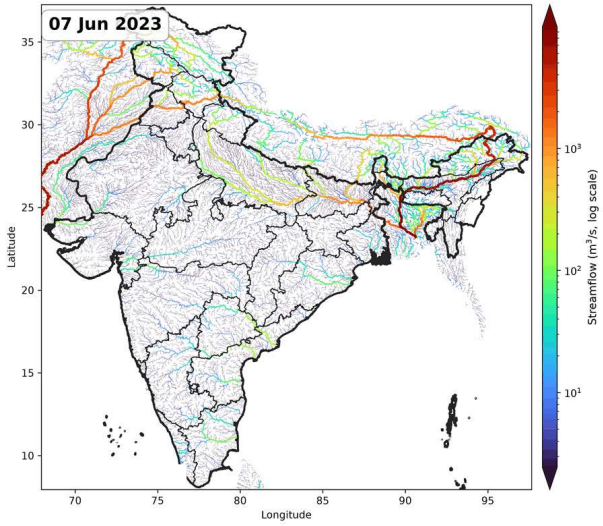
National scale validation of the of the flood forecasting system

Physics-based System

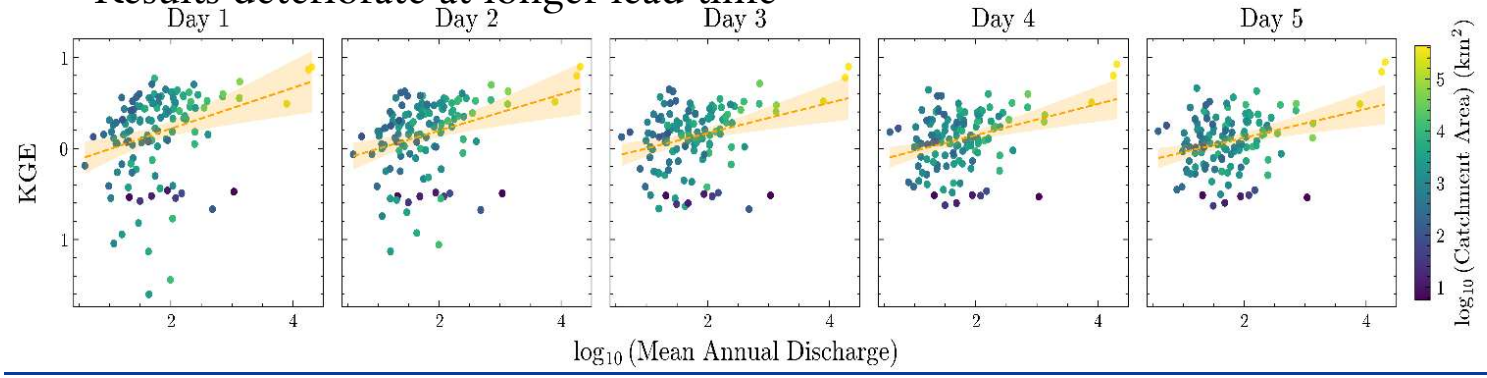


Lead time: 1 day

National Streamflow Forecast



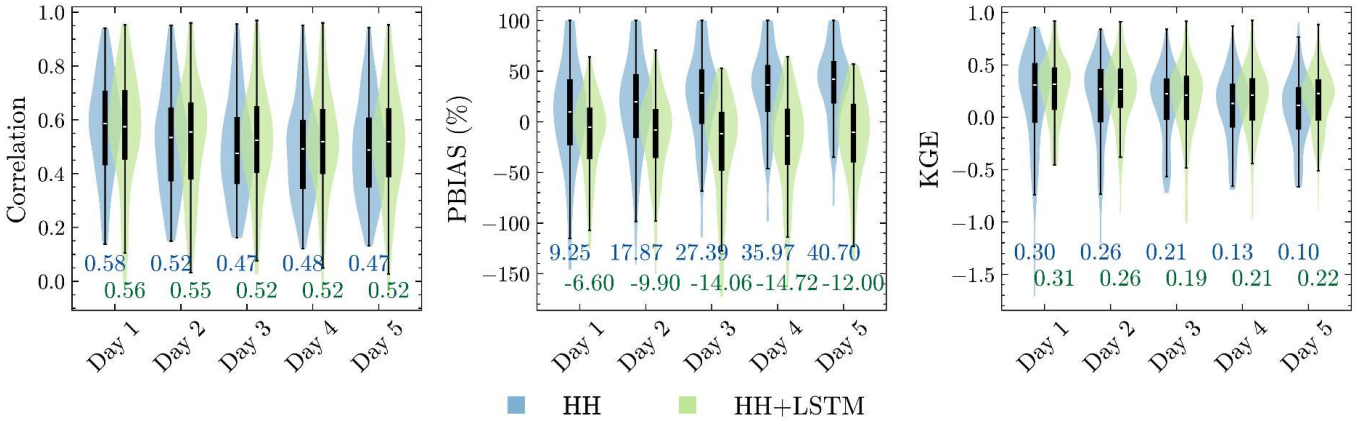
- Out of the total 130 stations considered for validation, about 75% of test locations show a positive KGE, and about 25% show KGE>0.5 on day 1
- Results deteriorate at longer lead time



- KGE is higher for larger basins and basins with higher streamflow

National scale validation of the of the flood forecasting system

Integrated Physics-AI System

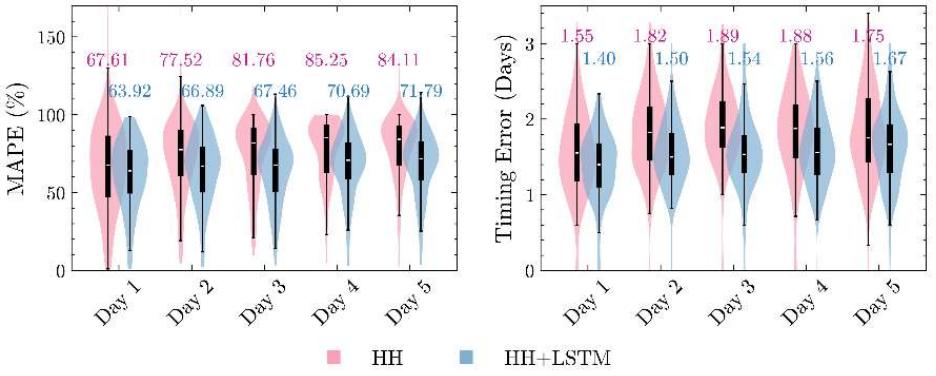


- Improves the KGE, especially at longer lead times, while maintaining a consistent value at shorter lead times.
- The absolute biases are reduced across lead times.

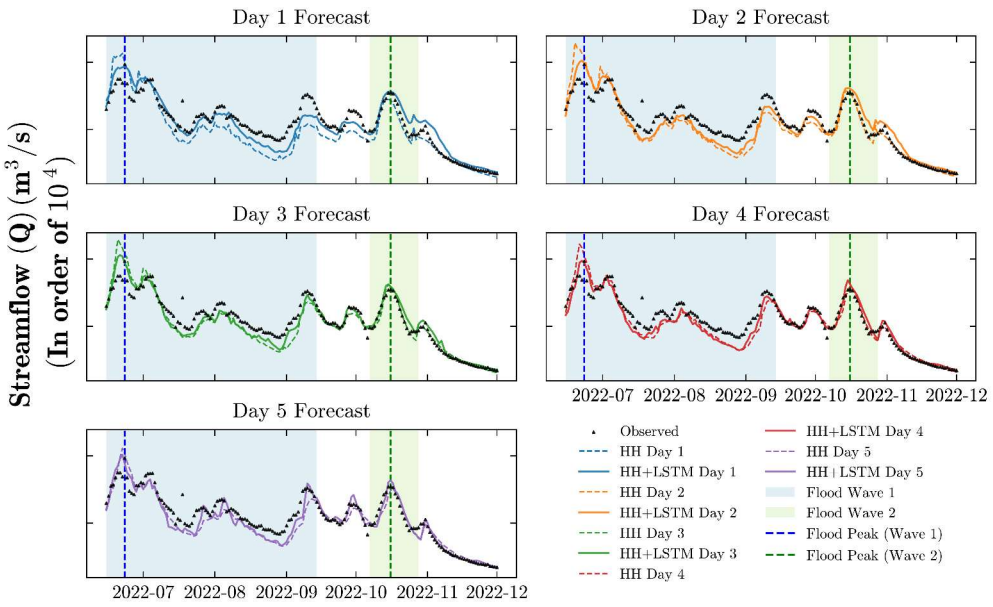
- Consistently maintains or improves POD, CSI, and FBIAS, especially at longer lead times

Metrics	Model	Day 1	Day 2	Day 3	Day 4	Day 5
CSI	HH	**0.67**	**0.64**	**0.56**	0.50	0.35
	HH+LSTM	0.61	0.57	**0.56**	**0.55**	**0.54**
FBIAS	HH	0.90	0.83	0.75	0.50	0.37
	HH+LSTM	0.88	**0.87**	**0.83**	**0.89**	**0.78**
POD	HH	**0.77**	**0.75**	0.66	0.50	0.36
	HH+LSTM	0.69	0.69	**0.69**	**0.70**	**0.67**
FAR	HH	0.13	0.14	0.08	0.00	0.00
	HH+LSTM	0.15	0.16	0.19	0.15	0.14

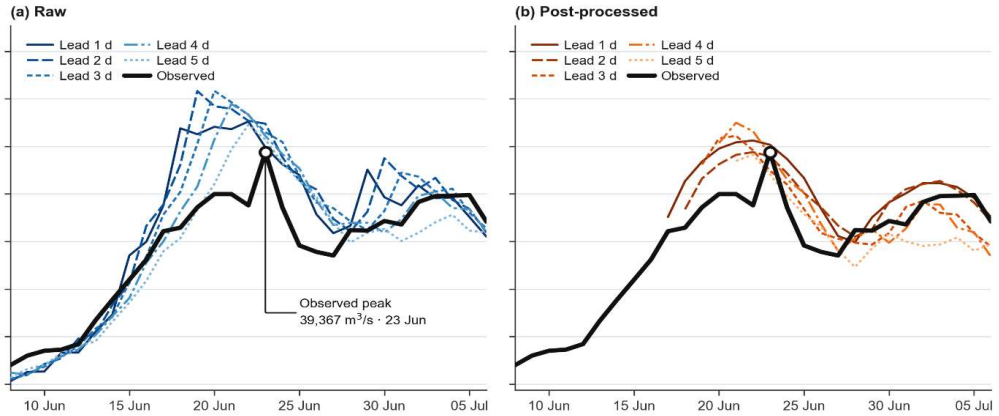
- Integrated system improves the Magnitude and Timing error across the lead times



The integrated physics-AI model consistently provided significant improvements in capturing flood peaks



Station: Pancharatna Bridge
Year: 2022
Observed Peak: 23rd June



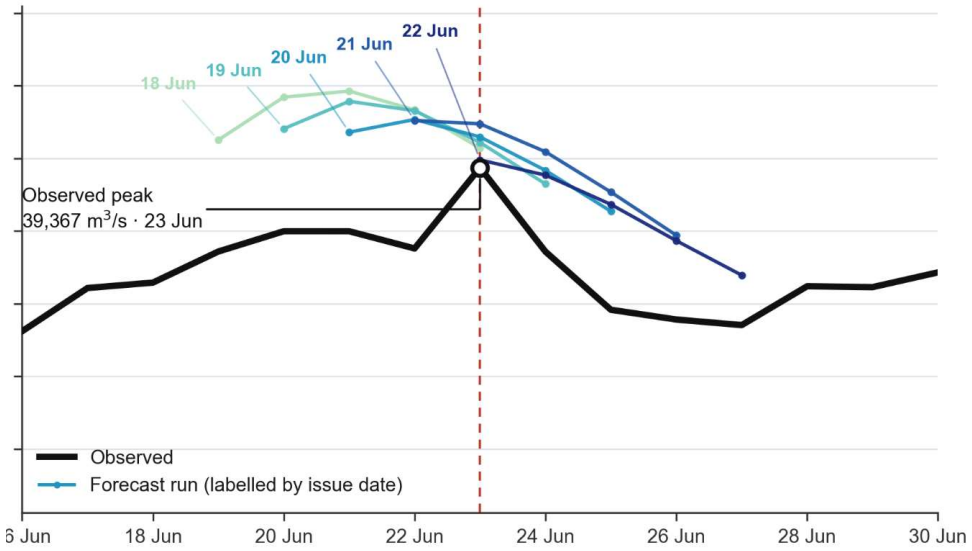
Max Peak magnitude error **16.41%**, Maximum timing error **3 days**

Max Peak magnitude error **4.7%**, Maximum timing error **1 day**

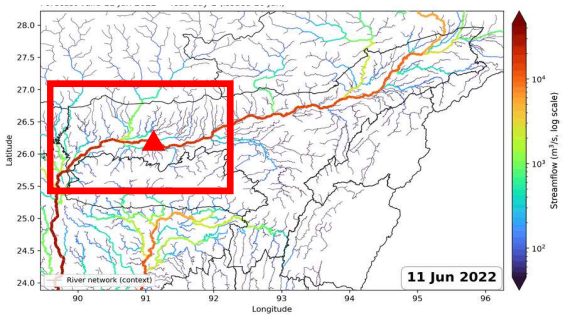
Forecast Horizon		Day 1		Day 2		Day 3		Day 4		Day 5	
Error		PME (%)	PTE (Days)	PME (%)	PTE (Days)	PME (%)	PTE (Days)	PME (%)	PTE (Days)	PME (%)	PTE (Days)
Wave 1	HH	8.25	-1	12.33	-3	16.41	-3	12.94	-2	7.38	**-1**
	HH+LSTM	**-1.96**	**0**	**2.95**	**-1**	**4.66**	-2	**0.28**	**-1**	**2.63**	**-1**
Wave 2	HH	-6.59	**-1**	**1.46**	**-1**	**4.68**	**-1**	**2.74**	**0**	**-2.30**	1
	HH+LSTM	**0.81**	**-1**	4.27	-2	**4.75**	**-1**	8.82	-1	5.69	**0**

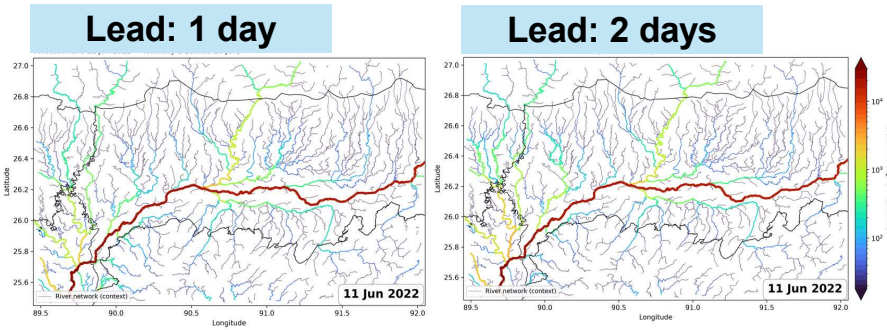
Case study of the Assam floods (Lower Brahmaputra basin), 2022

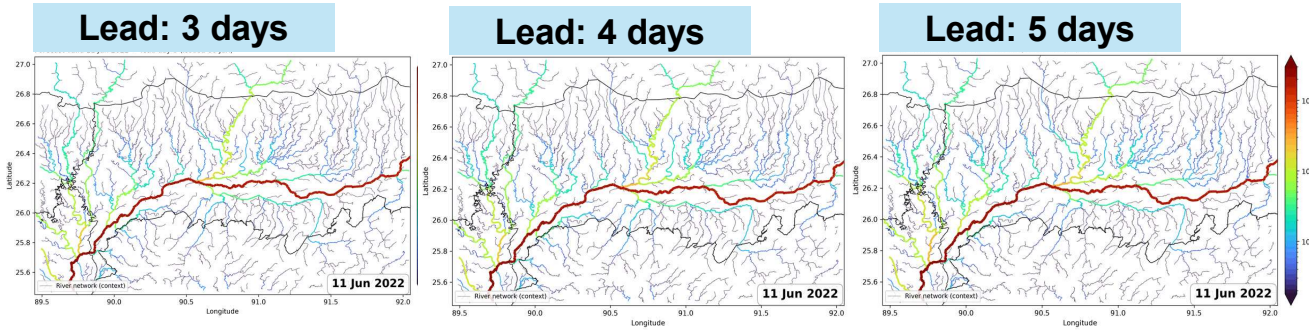
Peak flood on 23rd June at the Pancharatna bridge Station on the Brahmaputra River.



- Forecast issued on **22nd June (1 day lead) best captured the peak**
- Forecast issued on 20th and 21st June (2-days and 3-days) overestimates the magnitude
- The skill of the forecast issued on **18th and 19th June** are weak







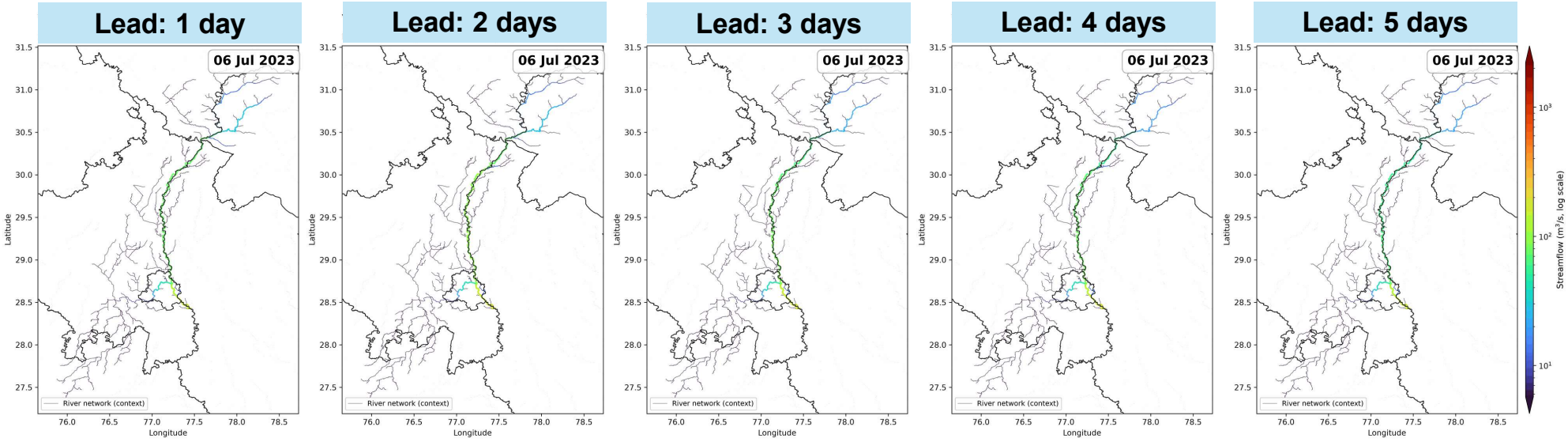
Case study of the Yamuna (Delhi) floods of 2023

Yamuna's water level still above danger mark in Delhi

The water level at the Old Railway Bridge has been hovering around the danger mark after reaching an all-time high of 208.66 metres on July 13.



- On **July 13, 2023,** the Yamuna swelled to 208.66 meters at Delhi's Old Railway Bridge, its highest level ever, breaking a record set during the 1978 flood.



Case study of the Maharashtra (Konkan) floods of 2021



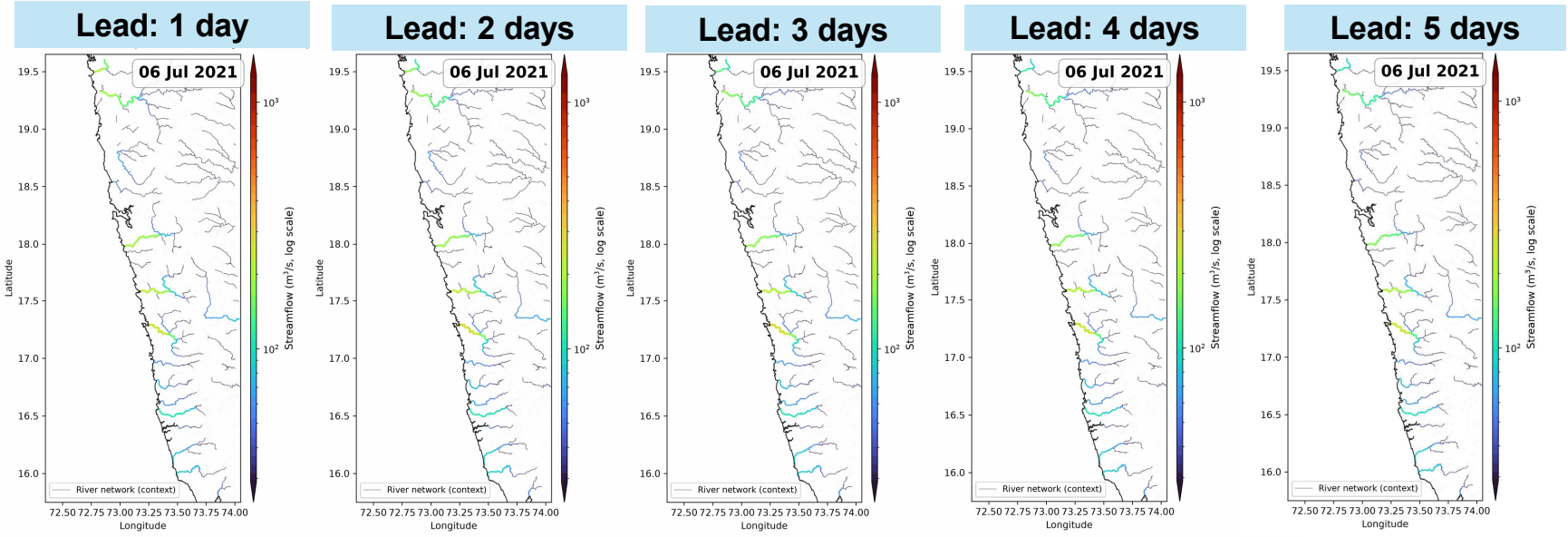
Source: https://theprint.in/india/at-heart-of-maharashtra-floods-a-konkan-river-that-can-drown-the-world-but-theres-more/702838/

- At the end of June 2021, Maharashtra's Konkan region was flooded due to heavy rainfall and dam release.
- High floods on 21st to 24th June.

At heart of Maharashtra floods, a Konkan river that can 'drown the world'. But there's more

Last week, Jagbudi river, along with Vashishti and Kodavali, crossed danger level and submerged large parts of coastal Konkon due to heavy rains and discharge from Koyna dam.

MANASI PHADKE 26 July, 2021 12:14 pm IST

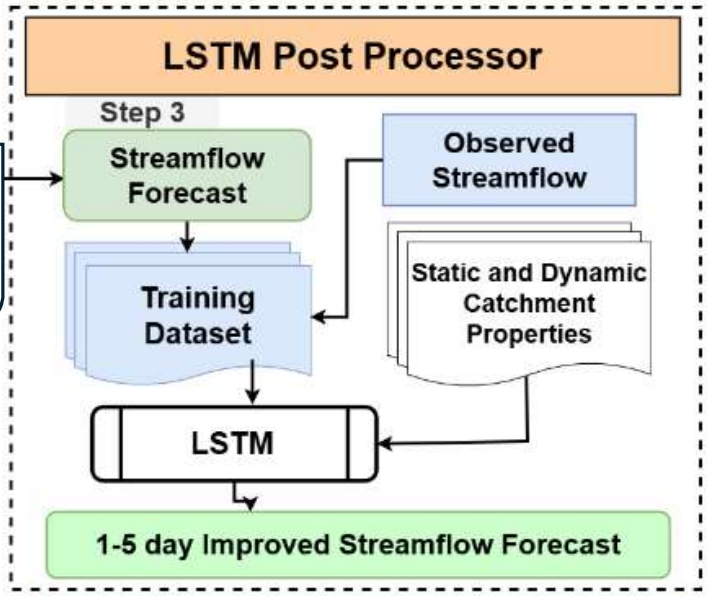


How do we improve the forecast skill?

Post-process the streamflow forecast with ML/statistical-based techniques

Tested with operational forecasts

1-5 days Streamflow Forecast



Forecast skills improve after post-processing with an LSTM-based postprocessor

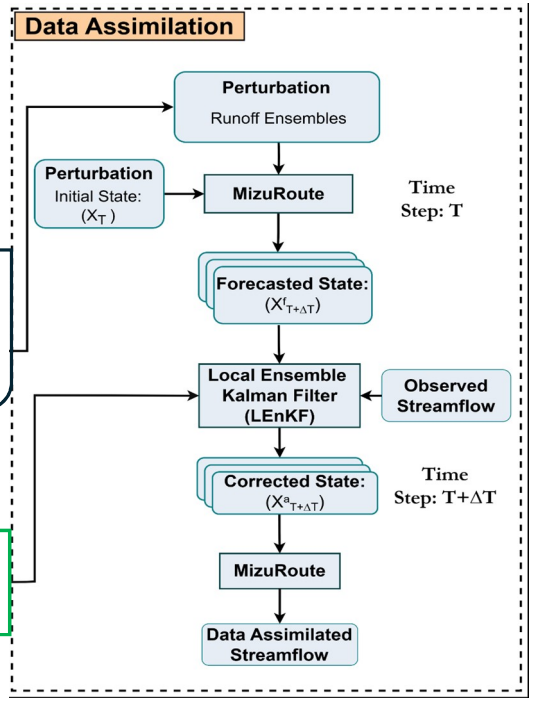
Limitation: Limited to point locations only.

Improve the initial state with Data Assimilation of observed streamflow

Tested on retrospective simulations

Runoff from Hydrological model

Observed Streamflow

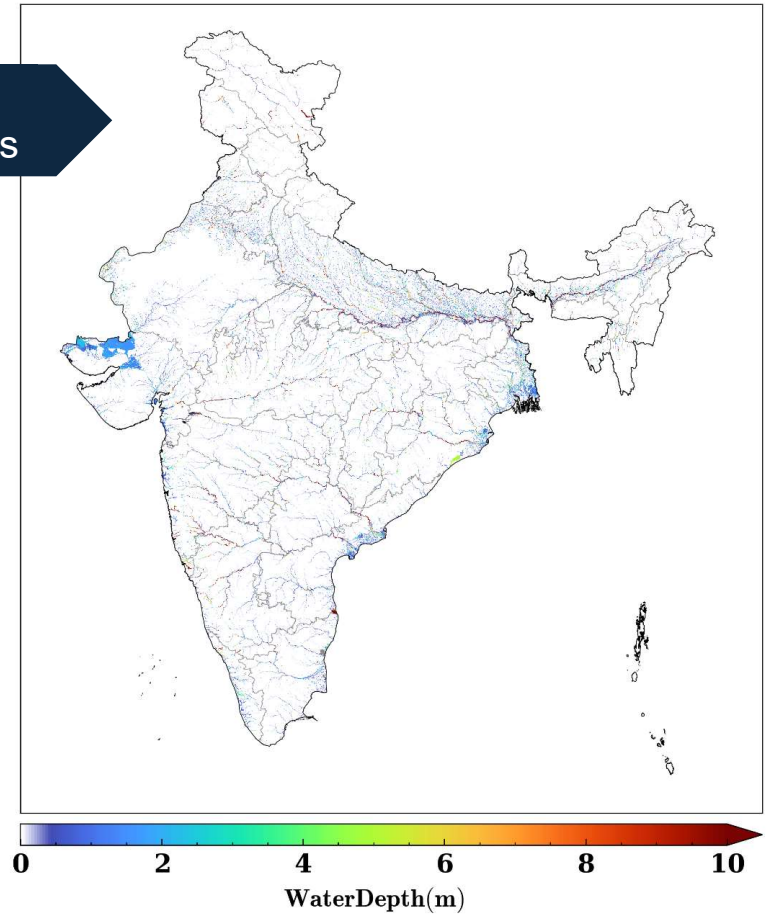


Tests on retrospective simulation shows improvement in model skill.

Limitation: Availability of real-time observed data.

Towards Impact-Based Flood Forecasting: Inundation Simulations with GPU Accelerated TRITON hydrodynamic model

Simulation Date: 23rd June 2022
Northeast India experienced severe floods



- GPU-accelerated hydrodynamic model
- The system is currently running at a spatial resolution of 1km
- **Targeted operational resolution of 30m-90m**
- There might be overestimation due to no representation of protection works. (Work to include them is ongoing)
- **Targeted operational information till the village level** once we get to a finer resolution

"The facts are clear. Early warnings save lives and deliver vast financial benefits."
– UN Secretary-General António Guterres, 2023.

Thank you

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