Analysis of compound flooding in the Tapi River Basin

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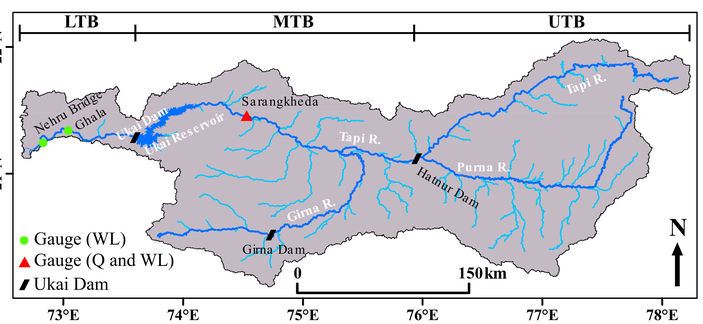
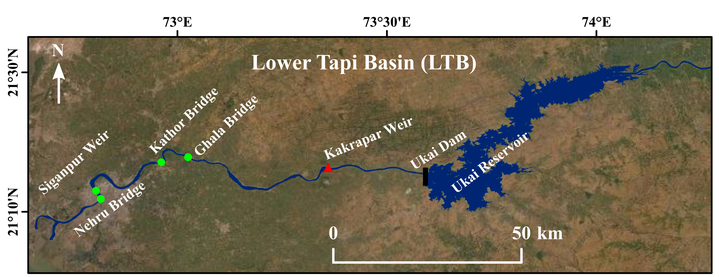
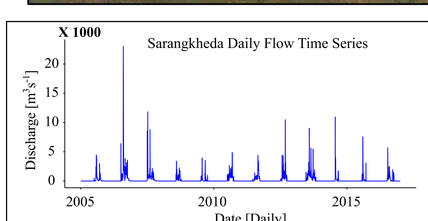
Summary

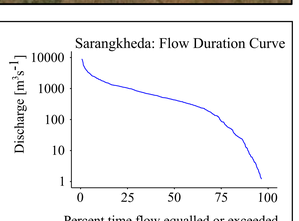
We coupled a hydrologic model Variable Infiltration Capacity (VIC) with the Hydrologic Engineering Center River Analysis System (HEC-RAS-2D) to model the compound impact of flood drivers in the Tapi River basin, India. Our modelling framework consists of two distinct phases; firstly, we calibrate and validate the VIC simulated daily stream flow of the Tapi River using the data observed at the Sarangkheda gauge (upstream of Ukai Reservoir). Consequently, to simulate the high and low flow events, a separate HEC-RAS 2D model is forced with flood hydrograph (Ukai dam release) and stage hydrograph (Tidal level at Hazira) as upstream and downstream boundary conditions, respectively. Initially, we determine sensitive parameters that significantly affect model simulations. To do this, we applied the Fourier Amplitude Sensitivity Test (FAST) a variance-based Global Sensitivity Analysis (GSA) method. Thereafter, we optimise the most sensitive model input parameters obtained from the sensitivity analysis. To do so, we applied shuffled - complex evolution University of Arizona (SCE-UA), a global optimization approach and determine the optimal parameters set values. Further, in calibrating the HEC-RAS-2D model the Tapi River was segmented into five reaches depending on gauges located along the river (Kakrapar Weir, Ghala, Kathor Bridge, Singanpur Weir, and Nehru Bridge). Thereafter, the channel roughness values are adjusted at all segments simultaneously by altered continually to follow the relation between observed and simulated flows and water levels.

Study area



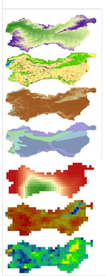






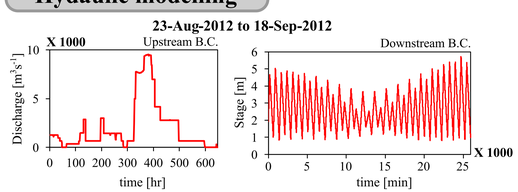
Input dataset

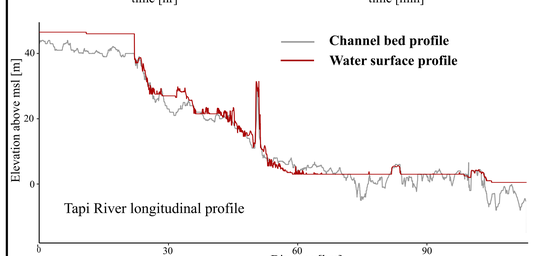
Hydrological modelling



Inputs	Source
Elevation	https://srtm.csi.cgiar.org/srtmdata/
LULC	https://daac.ornl.gov/VEGETATION/guides/Decadal_LULC_India.html
Slope	https://srtm.csi.cgiar.org/srtmdata/
Soil	https://www.fao.org/soils-portal/data-hub/soil-maps-and-databases/harmonized-world-soil-database-v12/en/
Precipitation	https://www.imdpune.gov.in/Clim_Pred_LRF_New/Grided_Data_Download.html
Leaf Area Index	https://neo.gsfc.nasa.gov/view.php?datasetId=MOD15A2_M_LAI
Albedo	https://neo.gsfc.nasa.gov/view.php?datasetId=MCD43C3_M_BSA

Hydaulic modelling

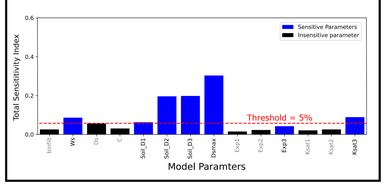




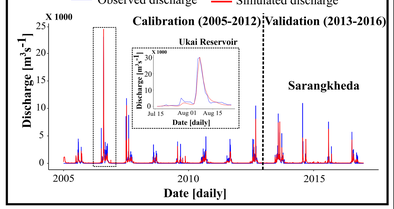
Results

Results: Hydrological Modelling

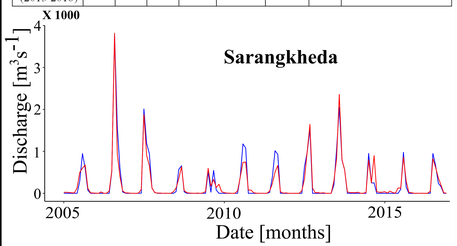
Parameter	Description	Unit	Range	Total Sensitivity Index (S_i)
binf	Variable infiltration curve parameter	-	0.001-0.5	< 5%
Dsmax	Maximum velocity of baseflow	mm/day	1-50	30%
Ds	Fraction of Dsmax, where non-linear baseflow occurs	-	0.001-0.5	5%
Ws	Fraction of maximum soil moisture where non-linear baseflow occurs	-	0.5-1	7%
C	Exponent used in baseflow curve	-	0-5	< 5%
d1	Thickness of layer 1	m	0.1-0.3	5%
d2	Thickness of layer 2	m	0.3-1.5	20%
d3	Thickness of layer 3	m	0.3-1.5	20%
Exp_1	Exponent of Brooks-Corey drainage equation	-	5-30	< 5%
$Ksat_1$	Saturated hydraulic conductivity	mm/day	1-10000	< 5%

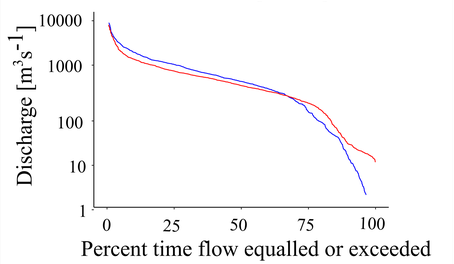


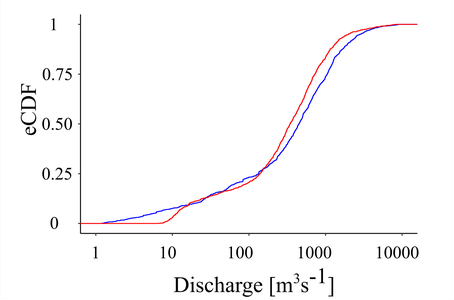
Parameter	Description	Unit	Range	Adopted Value
binf	Variable infiltration curve parameter	-	0.001-0.5	0.07
Dsmax	Maximum velocity of baseflow	mm/day	1-50	1.51
Ds	Fraction of Dsmax, where non-linear baseflow occurs	-	0.001-0.5	0.01
Ws	Fraction of maximum soil moisture where non-linear baseflow occurs	-	0.5-1	0.90
C	Exponent used in baseflow curve	-	0-5	3.93
d2	Thickness of layer 2	m	0.3-1.5	0.94
d3	Thickness of layer 3	m	0.3-1.5	0.67
Exp_2	Exponent of Brooks-Corey drainage equation for layer 2	-	5-30	25.89
$Ksat_3$	Saturated hydraulic conductivity for layer 3	mm/day	1-10000	2784



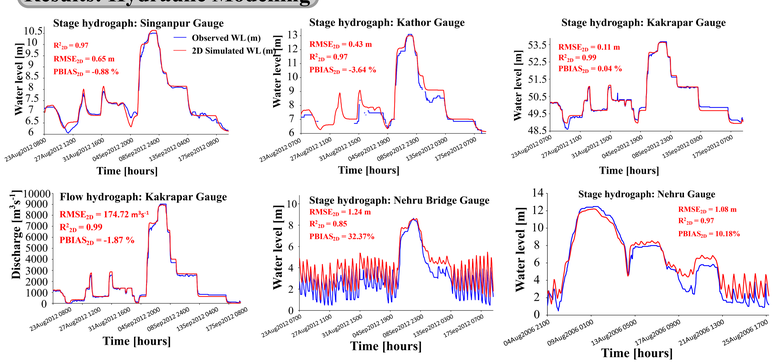
	r	R^2	NSE	KGE	PBIAS (%)	RMSE	RSR	Performance rating (Moriasi et al., 2007)
Calibration (2005-2012)	0.93	0.86	0.86	0.84	-9.40	373.53	0.38	Very Good
Validation (2013-2016)	0.85	0.72	0.71	0.78	9.16	385.02	0.53	Good

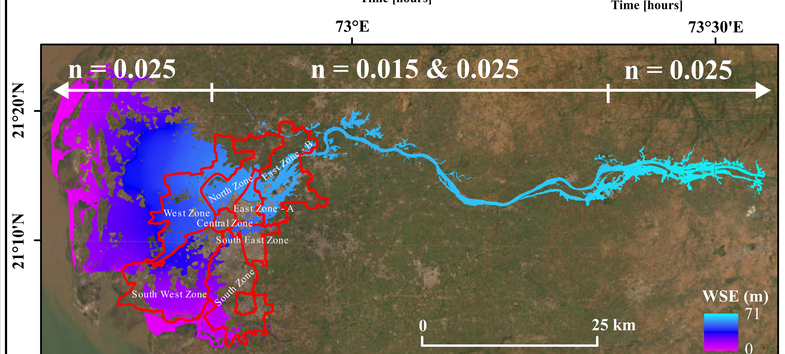






Results: Hydraulic Modelling





Conclusions

The VIC model simulation considerably reproduces the seasonal peaks at the Sarangkheda Gauge.

The HecRAS model efficiently capture the flood plain and hydrological processes both high and low flow conditions