Satellite Based Monitoring of Recent Sept-Oct, 2019 Floods, Bihar

Bihar witnessed heavy rainfall during last week of September, 2019 causing major flooding problem and damage to life and property in many parts of the state. Rivers like Ganga, Gandak Sone and Punpun were reported to have risen above the danger mark.

The present study is carried out with an objective to assess the cumulative flood inundation extent, flood persistence and damage to transport network caused during the recent Sept. and Oct., 2019 floods in Bihar. Flood situation assessment is made using the Sentinel-1 microwave data in conjunction with satellite based precipitation estimates from Integrated Multi-satellitE Retrievals for GPM (IMERG) and river gauge data from Central Water Commission (CWC).

Inundation Extent:

About twelve temporal Sentinel-1 A & B datasets, acquired during recent floods (22, 27, 30 Sept and 02, 03, 05, 06, 07 & 09 Oct. 2019) in Bihar state were used to map the inundation extent (Table-1) of recent floods in Bihar State. The Sentinel-1 synthetic aperture radar (SAR) constellation carries two C-band instruments (1A and 1B) operating at a center frequency of 5.4 GHz, sharing the same orbital plane. In this study, dual polarized (VV and VH) of 5×20 m resolution (10-m pixel spacing) Level-1 Ground Range Detected (GRD) Sentinel-1 SAR datasets acquired in Interferometric Wide Swath (IW) mode were used. The IW mode combines a large swath (250 km) with a moderate geometric resolution (5 m by 20 m), and images in three sub-swaths using the Terrain Observation with Progressive Scans SAR (TOPSAR). Sentinel-1 datasets were downloaded from ESA's Sentinel Scientific Data Hub (SciHub; https://scihub.copernicus.eu).

Table 1. Characteristics and acquisition dates of the used S-1 satellite datasets.

Date	Satellite/Sensors	Mode	Pass	Polarization	Incidence Angle (^{0})	Pixel Spacing	Wavelength	Product Type
22-09-19	Sentinel-1A	IW	Asc	VV, VH	30.7-46.0	10 × 10 m	5.6cm	Level-1 GRD
27-09-19	Sentinel-1A	IW	Asc	VV, VH	30.7-46.0	10 × 10 m	5.6cm	Level-1 GRD
30-09-19	Sentinel-1A	IW	Des	VV, VH	30.7-46.0	10 × 10 m	5.6cm	Level-1 GRD
02-10-19	Sentinel-1A	IW	Asc	VV, VH	30.7-46.0	10 × 10 m	5.6cm	Level-1 GRD
03-10-19	Sentinel-1B	IW	Asc	VV, VH	30.7-46.0	10 × 10 m	5.6cm	Level-1 GRD
04-10-19	Sentinel-1A	IW	Asc	VV, VH	30.7-46.0	10 × 10 m	5.6cm	Level-1 GRD
05-10-19	Sentinel-1A	IW	Des	VV, VH	30.7-46.0	10 × 10 m	5.6cm	Level-1 GRD
06-10-19	Sentinel-1B	IW	Des	VV, VH	30.7-46.0	10 × 10 m	5.6cm	Level-1 GRD
09-10-19	Sentinel-1A	IW	Asc	VV, VH	30.7-46.0	10 × 10 m	5.6cm	Level-1 GRD
IW=Interferometric wide swath; Level-1 GRD= Level-1 (Ground Range Detected)								

The twelve temporal images of Sentinel-1A&B SAR acquired for this study were automatically preprocessed (Fig-1a) using the Sentinel Application Platform (SNAP) 5.0 software. First, S1 images were allocated orbit files, then S1A images were radiometrically calibrated to sigma naught ($\sigma 0$) backscatter coefficients. The spatial refined Lee filter with a window size of 5 × 5 were used to reduce the noise in the SAR data. The output images were orthorectified using the Range Doppler Terrain Correction algorithm with SRTM DEM and spatial resolution of 1sec. Further, the backscattering coefficient (in dB) was acquired from the orthorectified radar backscatter band by the equation $10 \times \log_{10} (\sigma^{\circ})$.

Fig-1a Flowchart for pre-processing of Sentinel-1 Synthetic Aperture Radar (SAR) images.

The pre-processed Sentinel-1 images were then used for flood delineation (Fig-1b). The radar return from terrestrial water bodies act as specular reflectors and appear dark in SAR images. Using thresholding technique intensities within the threshold ranges were classified as water, whereas pixels with intensities above the threshold were classified as non-flooded. The inundation layer obtained is further masked using a pre-flood mask consisting water bodies, river channel and waterlogged areas extracted from the land use/land cover layer (Source: NRSC/ISRO) for removal of pre-flood water bodies. Finally, the inundation layer obtained is further refined using GIS tools.

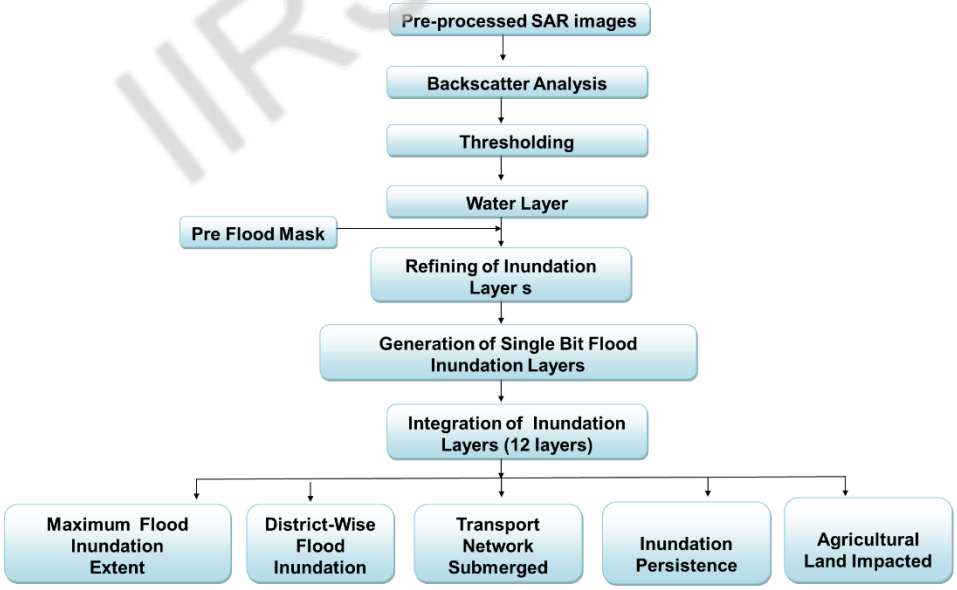


Fig-1b Methodology for inundation mapping and damage assessment

The individual flood layers generated from the satellite data analysis of Sept 22 to Oct 09, 2019 were integrated to obtain the maximum spatial extent of inundation, flood persistence,

agricultural land affected and integrated with administrative boundaries and transport network to compute inundation statistics.

Satellite Based Observations:

- The analysis shows that about 5.91 lakh hectares of total geographical area of state was under submergence during Sept 22 to 09 Oct, 2019 (Fig-2).
- About 35 district were observed to be impacted by flooding.
- In terms of area under submergence 11 district had more than 25000 ha area submerged, 07 districts between 25000-10000 ha, 08 districts between 10000-5000 ha and 09 districts less than 5000 ha (Fig-3).
- Patna district followed by Bhagalpur district were the worst affected districts having 61803 and 58307 ha respectively under submergence.
- Out of the total inundated land about 4.80 Lha agricultural land was submerged.
- Due to flooding about 1,115km of road transport network and about 28km of railway track was impacted (Fig-4).
- In terms of transport network submerged Patna district with more than 165km of road network under submergence whereas Samastipur district with 11km railway track submerged were the worst affected districts.
- Districts like Patna, Bhagalpur, Begusarai, Munger, Khagaria, Lakhaisarai, Samastipur, Vaishali, Saran, Nalanda and Sheikpura adjoining Ganga River and in parts of Darbhanga, Madhepura, Madhubani and Purnia districts were observed to be inundated for about two weeks (Fig-5 & Fig-6).
- Data from IMERG data shows heavy rainfall over parts of western Uttar Pradesh (Ganga and Ghagra basins) during 23-25 Sept. 2019 whereas during 25-29 Sept. 2019 over parts of Bihar state especially over Kosi, Gandak and Sone basins(Fig-7).
- Gauge data from CWC indicates that most of the gauge sites located along River Ganga crossed danger levels and even recorded maximum gauge height of the flood season between 23 Sept and 03 Oct, 2019 (Fig-8).
- Along River Ganga, Gauge site at Gandhi Ghat at Patna was observed to be flowing 1.19m above from the danger level (DL) on 24-Sept-19 and Hathidah gauge site downstream of Gandhi Ghat 0.99m above DL on 25-Oct-2019.

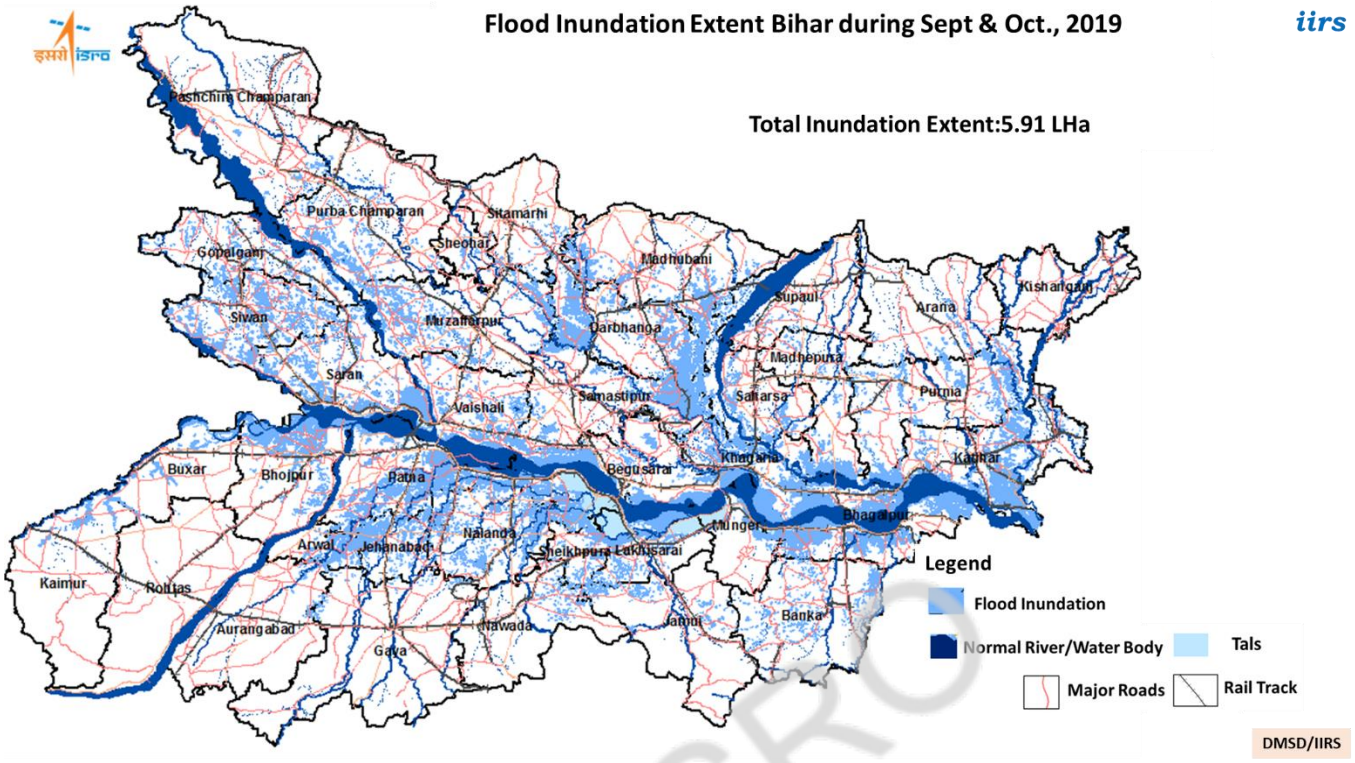


Figure-2 map showing cumulative flood inundation extent in Bihar during Sept-Oct.2019 floods

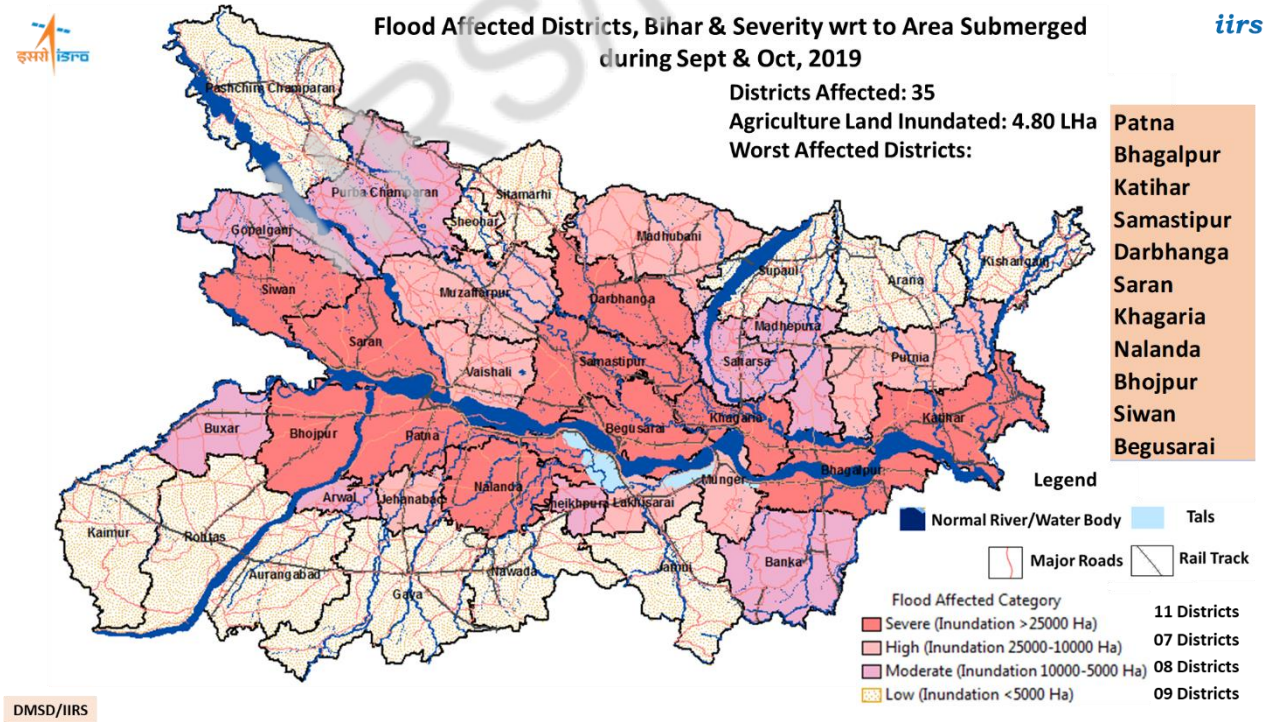


Figure-3 Map showing flood affected districts and their severity wrt to area submerged during Sept-Oct., 2019 floods

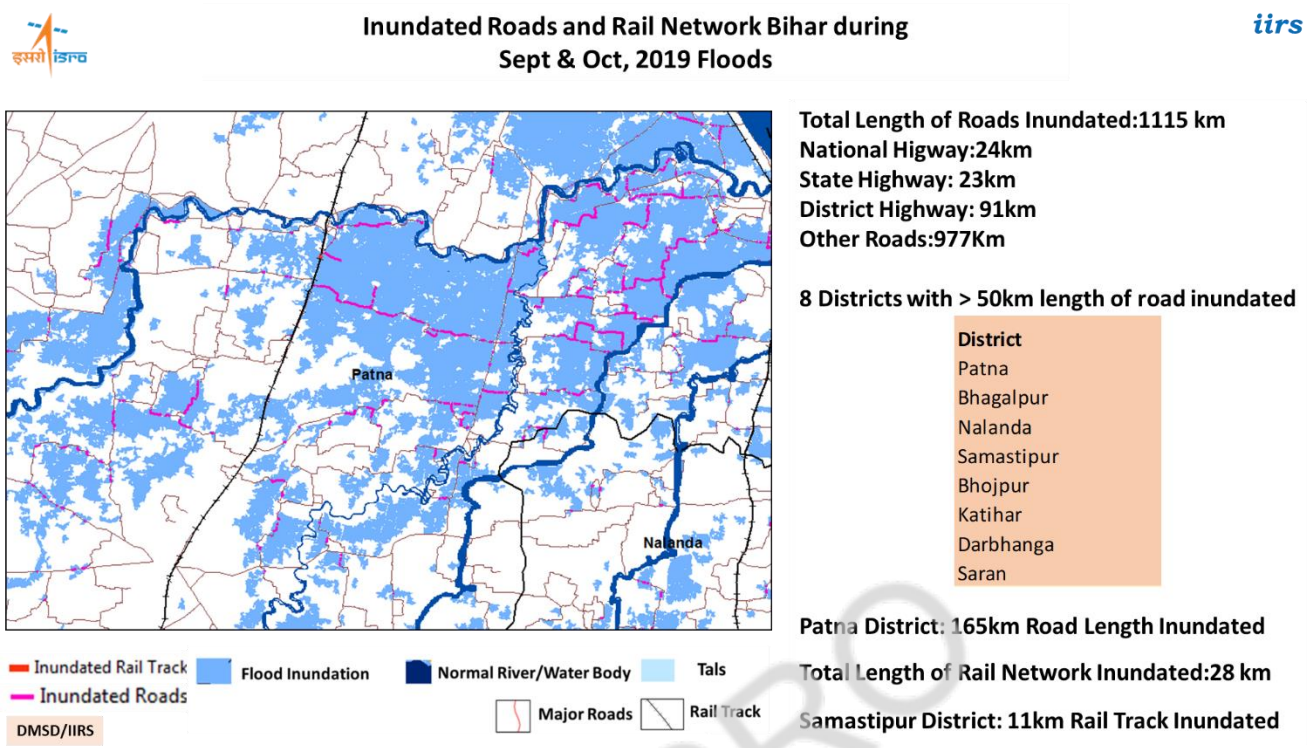
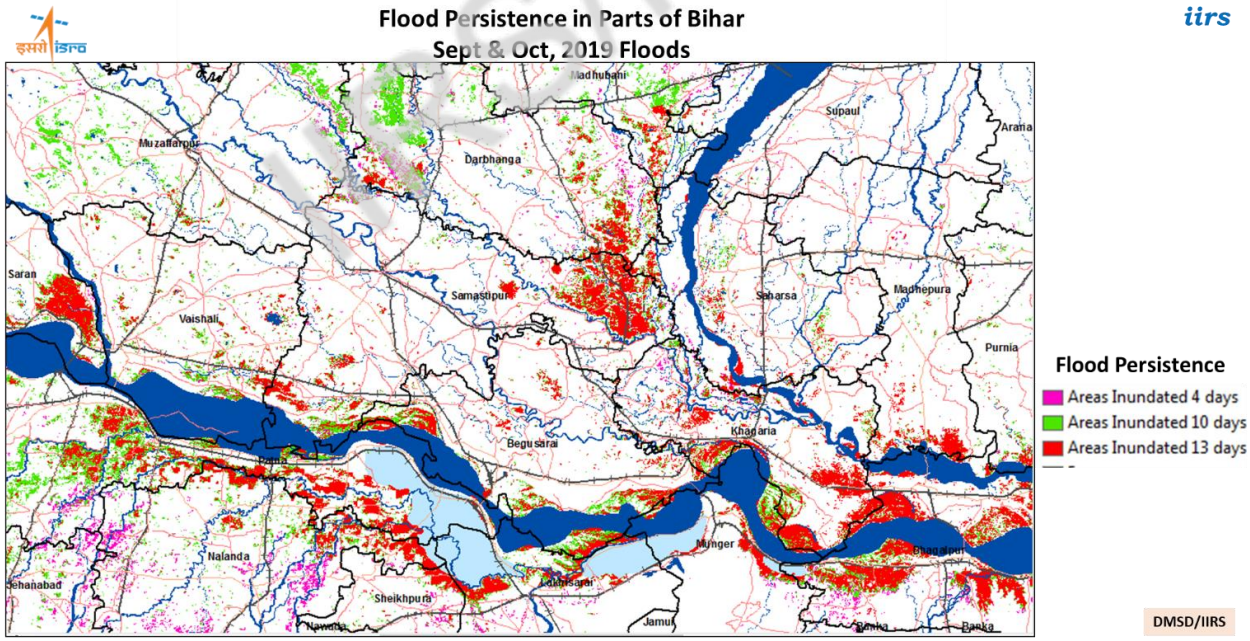


Figure-4 Enlarged view of transport network submerged due to flood inundation in parts of Patna district, Bihar during Sept and Oct. 2019 floods.



Districts (Patna, Bhagalpur, Begusarai, Munger, Khagaria, Lakhaisarai, Samastipur, Vaishali, Saran, Nalanda, Sheikpura) adjoining Ganga River and in parts of Darbhanga, Madhepura, Madhubani and Purnia districts were observed to be inundated for about two weeks

Figure-5 Persistence of flood water especially along Ganga River and in parts of Darbhanga, district, Bihar. (Red colour indicates persistence for about two weeks, green colour for ten days and pink colour for four days)

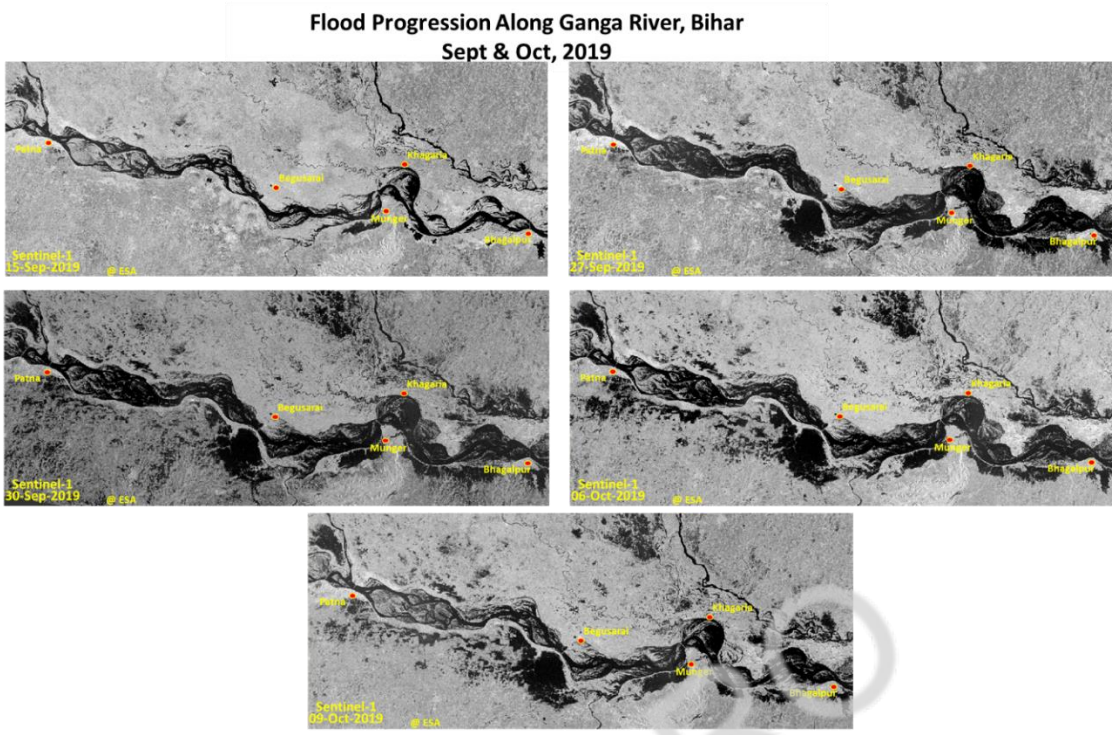


Figure-6 Sentinel-1 images showing flood progression along Ganga River during Sept. 27, 30 & Oct, 06 and 09 2019. First image top left is pre flood image acquired on Sept.15, 2019

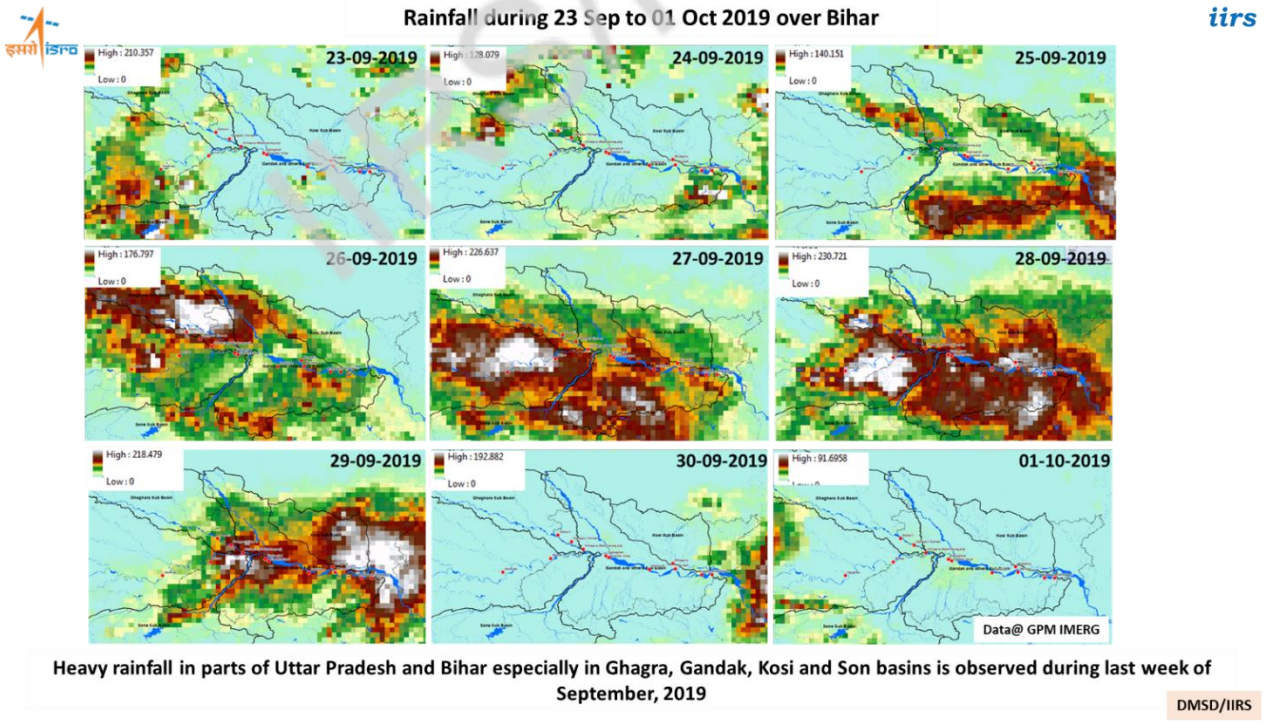


Figure-7 Map showing accumulated rainfall from IMERG (Integrated Multi-satellitE Retrievals for GPM at 0.1 degree resolution) late run data over Bihar and adjoining areas during 23 Sept to 01 Oct., 2019.

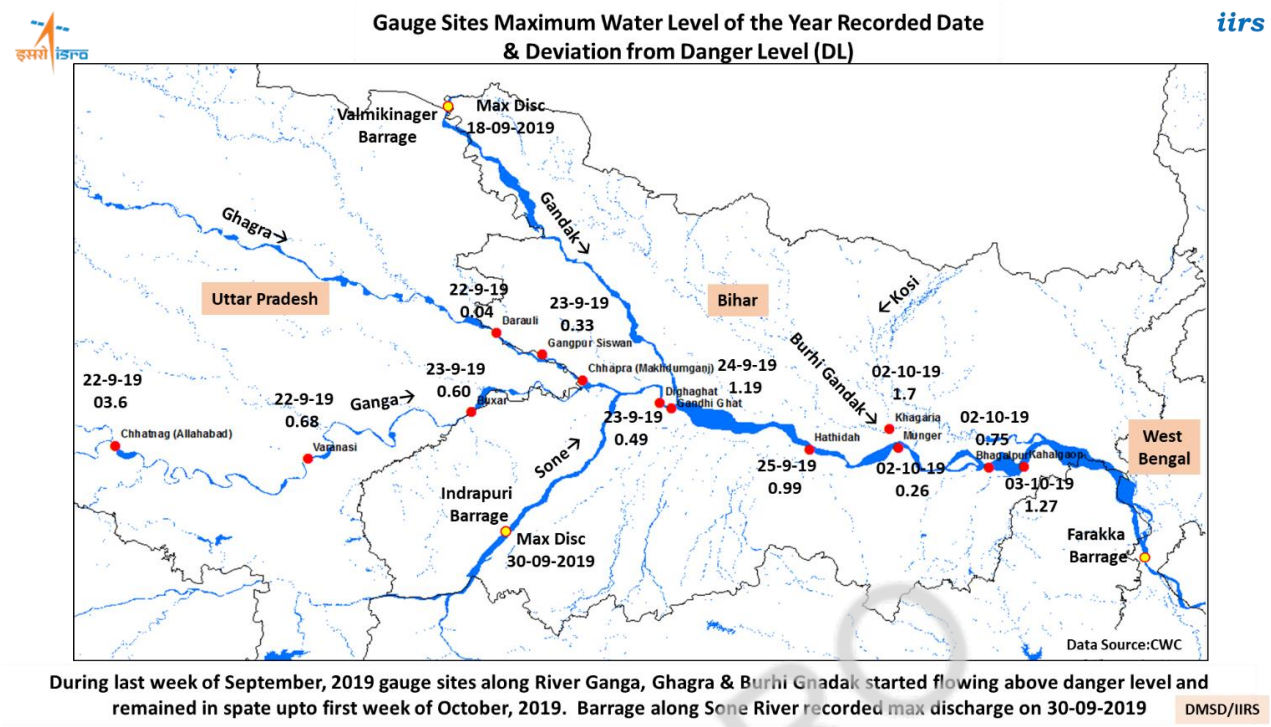


Figure-8 Gauge sites along Ganga crossing danger level and recording maximum gauge height during 23 Sept to 03 Oct., 2019.

Discussion:

The present analysis of recent floods in Bihar during Sept. and Oct. 2019 was carried out using satellite based rainfall observations from IMERG data, CWC recorded gauge data and Sentinel-1 SAR data. The study shows that due to heavy rains in Uttar Pradesh during second last week of September and Bihar during last week of September, especially within Ganga basin, has led to overflowing of the River Ganga. This is reflected in the form of increase in water level above danger level recorded in most of the gauge sites located along the river. Ganga River is observed to remain in spate for several days from the gauge data of seven sites recorded by CWC. Satellite based analysis of flood inundation also supports the rainfall and gauge water level records by showing the districts adjoining Ganga River (Patna, Bhagalpur, Begusarai, Munger, Khagaria, Katihar, Samastipur, Saran, Begusarai and Bhojpur) to be the most affected in terms of submerged area, inundation persistence and transport network submerged due to the recent flooding event.

It is also interesting to note from previous CWC gauge data records from 2000 onwards that Bihar used to witness severe flooding event during Aug. and Sept. and by end of Sept and early Oct. flooding event declined. However, the present flooding event in late Sept. and Oct. shows shift in the flooding pattern.

The SAR satellite based information generated under this due to its all-weather capability and multi- temporal data acquisition capability is an important source of flood hazard information. This information can be useful useful to policy makers and also stake holders in planning mitigation measures.

Disclaimer/Limitations:

The flood inundation extent delineated from satellite images is not verified on the ground. The inundation area represents only the area flooded on the date of acquisition and time of satellite pass. Detection of flooded urban areas and partially flooded vegetation using SAR data is a critical issue and can be underestimated. Current approaches for flood mapping using SAR basically aim at detecting for regions of low backscatter due to specular reflection from water surface. However, techniques searching for regions of low backscatter may not be successful when detecting flooding in urban areas, flooded forests and if vegetation emerges from the water surface as these targets may appear bright in SAR images because of the enhancement of the double bounce effect.

Further detailed analysis of the event is under progress.

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