Assessment of surface inundation and changes in water turbidity associated with Cyclone Yaas

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Cyclone induced flash floods influence many low-lying areas in the coastal regions and change the hydrology of the wetlands. Rise in sea levels, extreme groundwater withdrawal rates, land surface deformation, land use and land cover have further intensified the impact and extent of inundation following land falling tropical cyclones. Rivers get swollen due to incessant rain under the influence of cyclone and turbidity of these inland water bodies changes due to inflow of nutrient loaded water from surrounding landmass. Remote sensing techniques are an effective source of information to understand various hydrological aspects related with the cyclone induced flooding and so can be effectively used to map inundated areas with sufficient temporal and spatial resolution. Various Hydrological aspects including surface inundation, rainfall, and water quality were analysed during recent cyclonic events. Surface inundation was estimated using synthetic aperture radar Sentinel-1 and Advanced Microwave Scanning Radiometer AMSR-2 dataset. Optical dataset of Sentinel-2 was analysed to understand the changes in the turbidity of the nearby rivers and lakes.

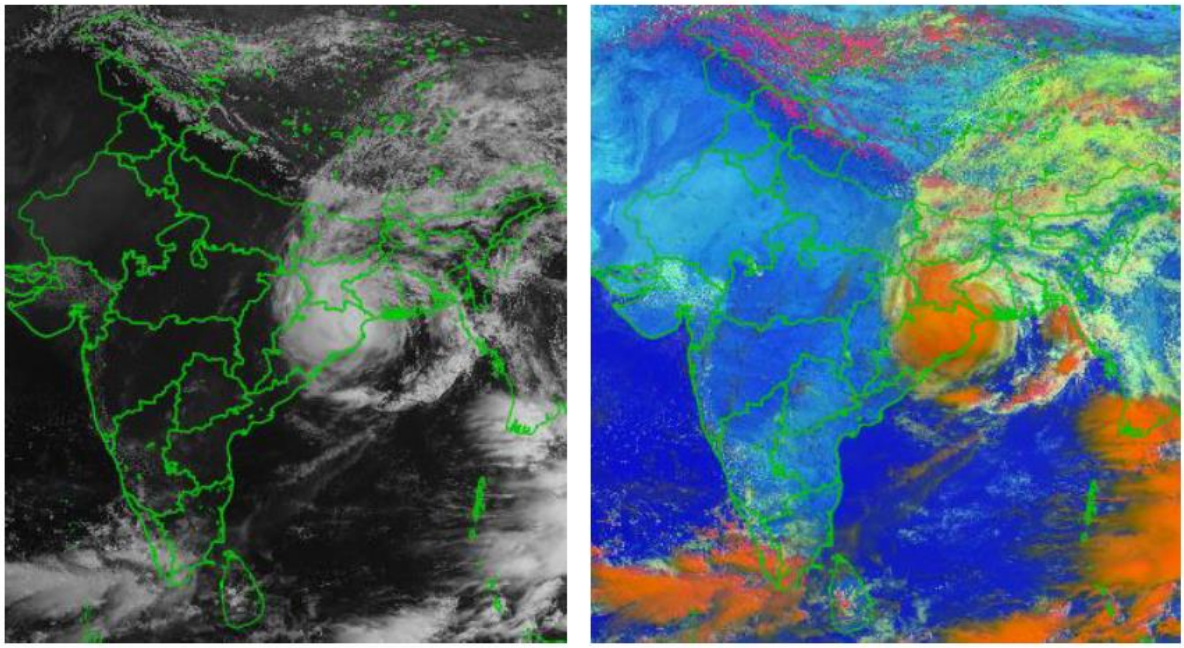

Fig 1: INSAT-3D Visible with Cloud Microphysics during landfall of Cyclone Yaas on 26 May 2021

Recently two major cyclones hit the country within a time span of fortnight. Cyclone Yaas that originates in Bay of Bengal has left behind a trail of disturbance in the East coast of India after Cyclone Tauktea that created havoc on the west Coast of India. Similarity between these two

natural calamities were preceded by relatively high sea surface temperature that leads to link cyclogenesis to climate change related activities. Although the Tautktae cyclone spent several days in the Arabian Sea where it could draw more heat and moisture, on the other hand cyclone Yaas has formed in the North Bay of Bangal and shortly landfall to the East coast of India. Severe Cyclonic Storm Yaas made landfall south of Balasore in the Odisha state on 26 May 2021 and brought a high amount of rainfall that affected the many parts of Odisha, West Bengal and Bihar. Effect of the cyclone was observed all the way up to Jharkhand, Bihar and Eastern parts of Uttar Pradesh (figure 1). Patna and its adjoining districts in Bihar also saw flooding due to heavy rains that continued to batter the region on 26-27 May 2021. Accumulated rainfall showed a high amount (> 300 mm) of precipitation received at the landfall location in Odisha during the period of 23 May 2021 to 28 May 2021.

Historically datasets acquired by optical sensors have been widely used for natural hazard and disaster management. Algorithms based on reflectances in the green and NIR bands can be utilized to map the water surfaces. But these extreme events are usually associated with high cloud cover in which inundation mapping is difficult from optical datasets. Synthetic Aperture Radars like RISAT, Sentinel-1 prove very useful in delineating inundated regions during cyclones and floods. SAR sensors emit electromagnetic pulses in the microwave region and receive the signal returned from the surface, termed as backscatter, in the form of amplitude and phase. The backscatter signal from a surface depends on the sensor parameters (wavelength and polarisation) and other parameters like dielectric constant, the geometry of the target, and surface roughness. Inundation after Cyclone Yaas in the Eastern Coast of India is shown in figure 2. Sentinel-1, C band SAR has been used to map inundation regions at a 10 m resolution. The regional threshold was determined based on the histogram backscatter values to delineate the still water surface and quasi inundated areas. Heavy flooding was observed in the coastal districts of Orissa including Bhadrak, Kendrapara.

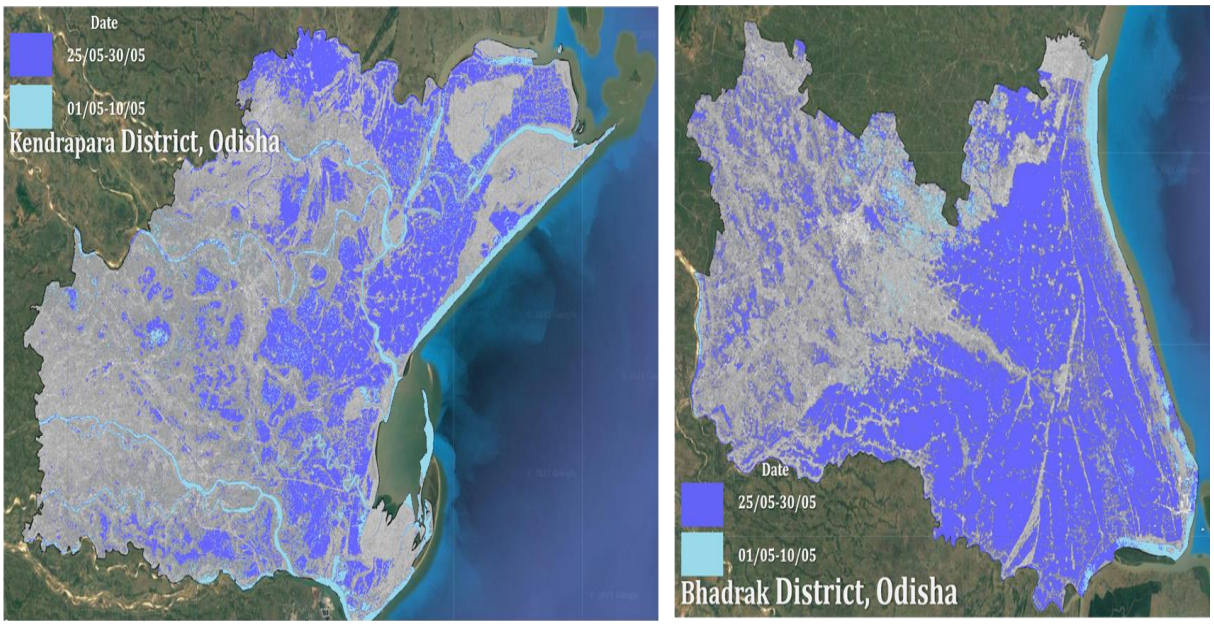

Fig 2: Inundation after Cyclone Yaas in the Kendrapara district, Odisha and Bhadrak district, Odisha using Sentinel-1 C band 10 m spatial resolution dataset

Passive microwave remote sensing involves the measurements of natural thermal emission from the surface. Brightness temperature measured in different frequencies is used to retrieve the dielectric constant and soil moisture condition. Generally, wet soil that has high soil moisture is associated with high dielectric constant and lower emissivity. Hence High soil moisture reduces the brightness temperature. This principle is used to derive surface inundation during cyclones and floods. Further to improve the temporal period of the analysis radiometry brightness temperature (BT) difference at 36 GHz from Advanced Microwave Scanning Radiometer (AMSR2) at 0.1-degree spatial resolution was utilized for estimating the inundated areas at a much finer temporal resolution. Although microwave radiometers have a coarse resolution, it provides repeat observations of the entire country with 2-day repetivity, which makes it suitable for analysis of regional scale inundation from extreme events. Microwave Polarisation Difference Index (MPDI) based flood inundation map was also generated using BT in H and V polarisations at 36 GHz. This frequency is suitable to assess surface flooding and avoid signals due to wet soil. As shown in figure 3, surface flooding map clearly shows the affected regions of Orissa, Orissa, Bihar and West Bengal.

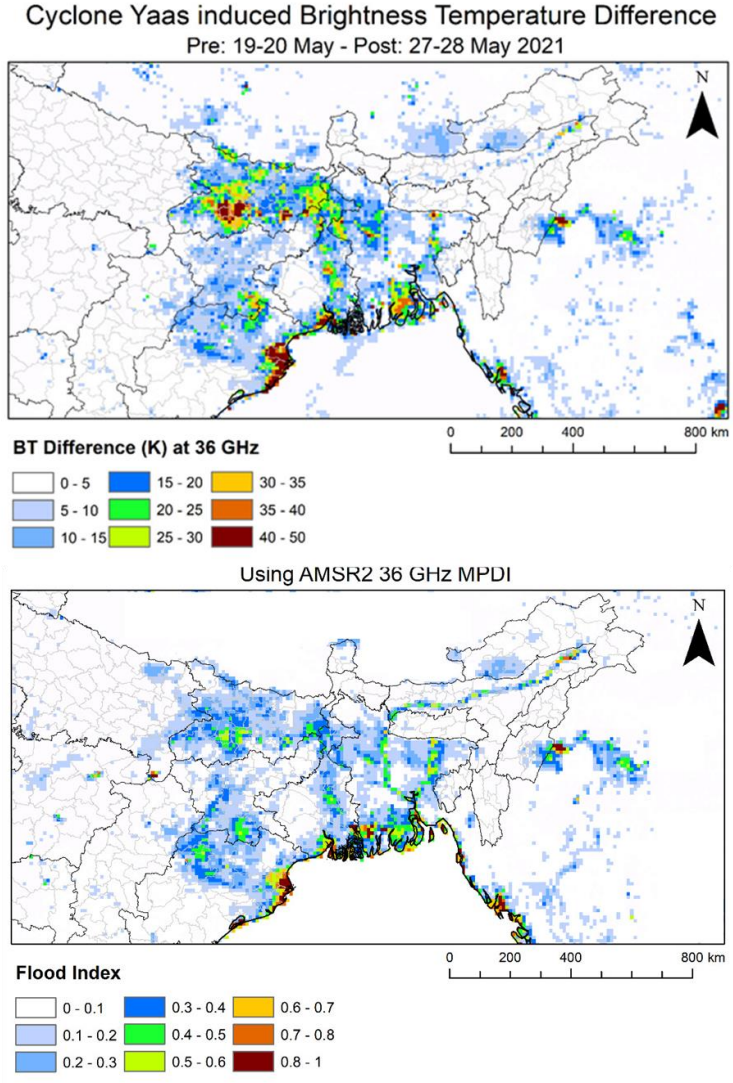

Fig 3: Surface flooding map after Cyclone Yaas using AMSR -2 36 GHz dataset

Extreme events like cyclones, floods, landslides are associated with changes in turbidity and water quality in coastal regions, wetlands, lakes, rivers and reservoirs. Optical satellite datasets were used to understand these changes in turbidity levels pre and post extreme events. Here, we look at the changes in the level of turbidity, an important water quality parameter, through Sentinel-2 optical datasets. Near Digha coast (figure 4) a high amount of river discharge at the ocean mouth was observed in comparison to pre cyclone time. The turbidity of the water was observed to be high due to sediments carried by the river.

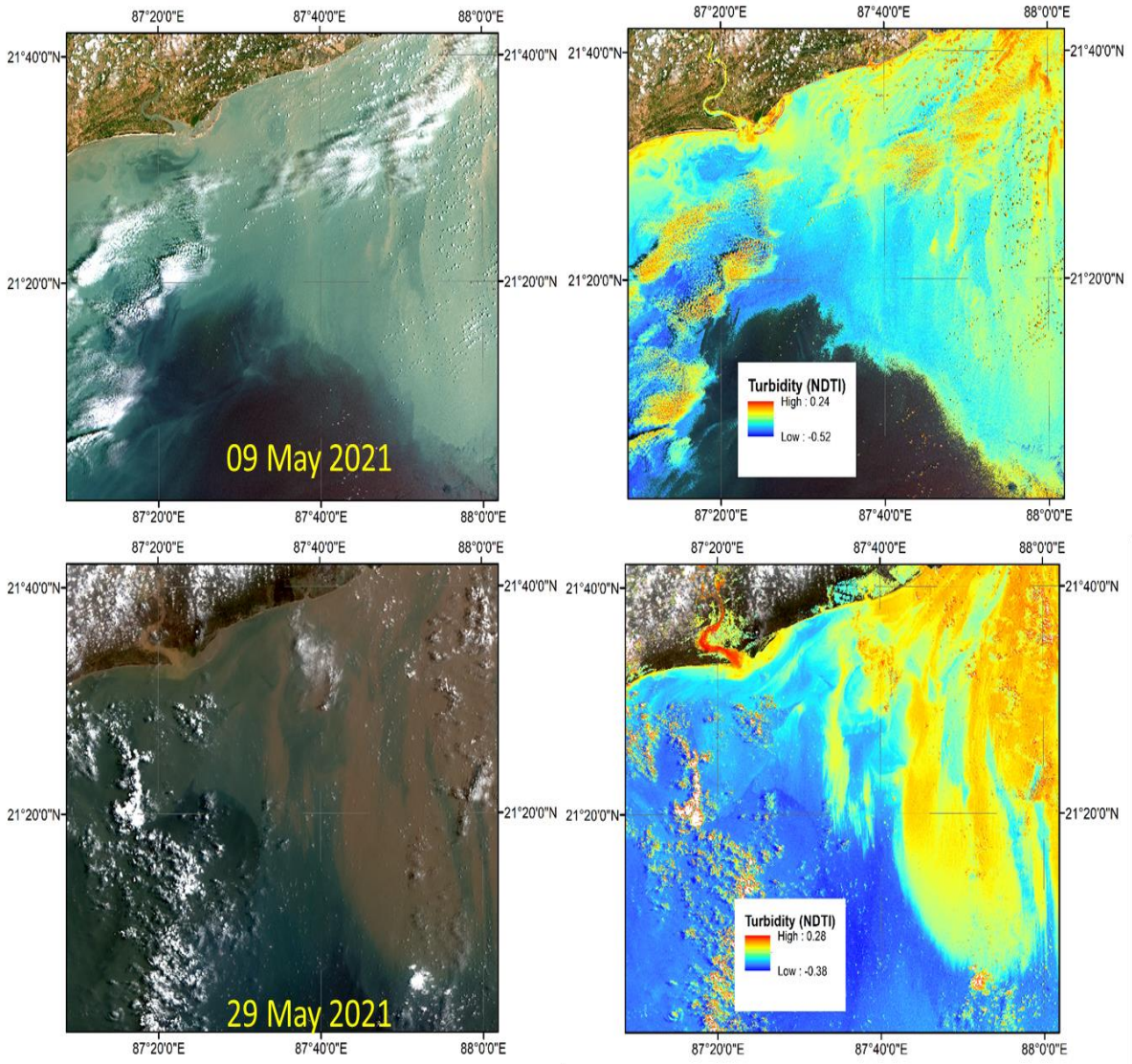

Fig 4: Natural colour composite and derived turbidity variation during pre and post cyclone at the East coast of India using Sentinel-2 multispectral dataset of 10 m spatial resolution

Better understanding of these hydrological aspects can help to outline the susceptibility of different localities to potential floods based on analyses of the impacts from earlier events.