A Hydrodynamics and Remote Sensing-based Framework for Establishing Virtual Streamflow Measurement Stations in Scantily-gauged River Reaches

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Background

- Real-time discharge estimation at different locations of a river reach has always been a challenging task.

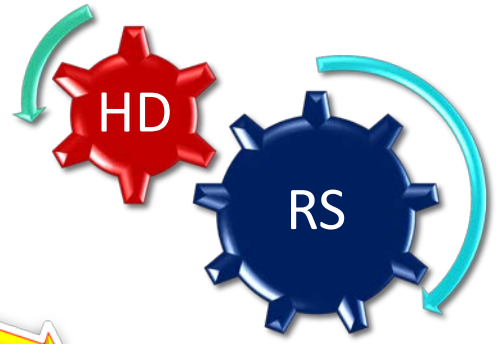
Challenges

- Lack of human resources
- Costly maintenance
- Remoteness of gauging stations
- Theft of sensors

- Decline in number of gauging stations
- Water conflicts between the states
- Inequitable water distribution among stakeholders

Cost - effective alternative tool

Hydrodynamic Models (HD)

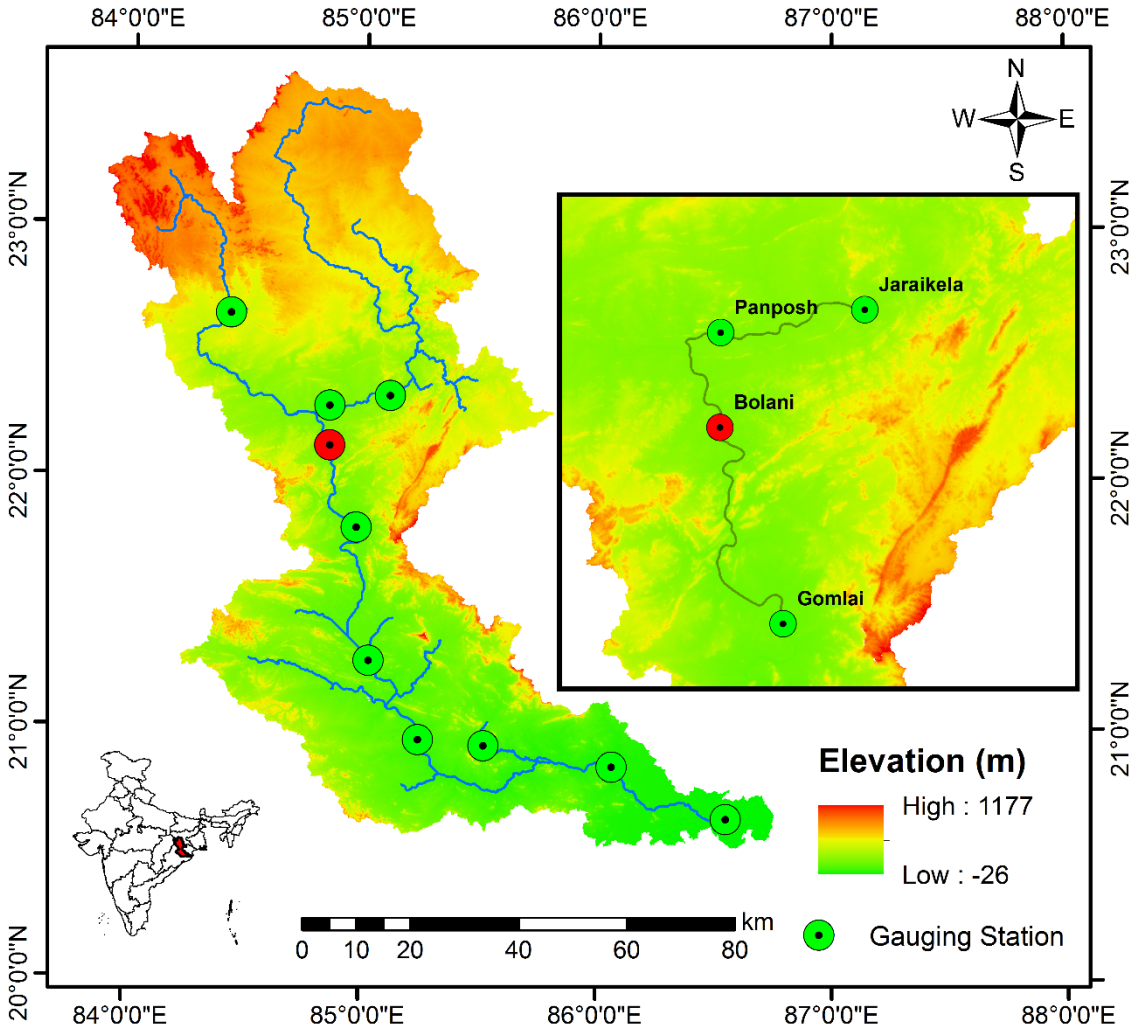


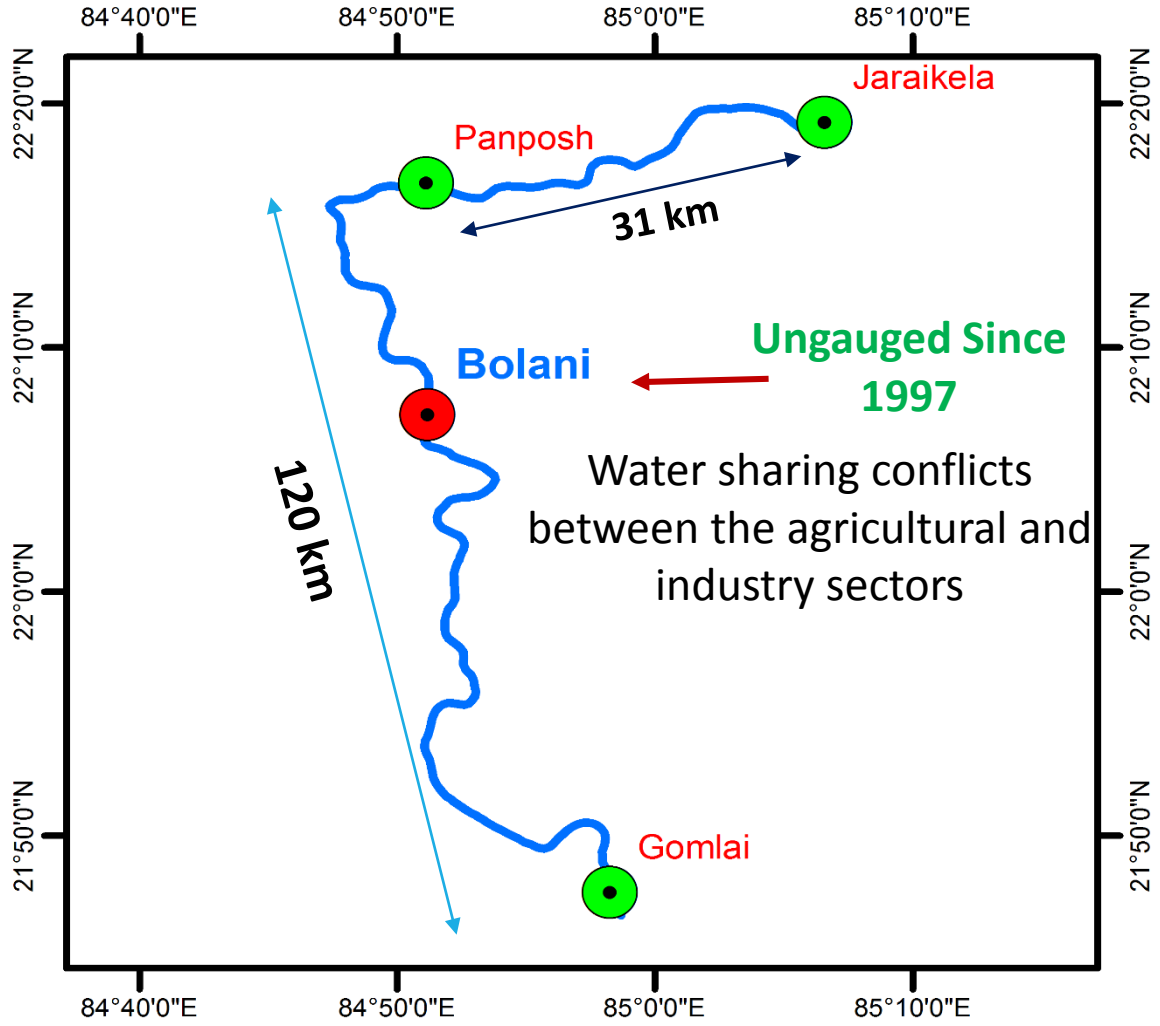
Remote Sensing (RS)

Objective

To develop and evaluate an integrated remote sensing-hydrodynamic (RS-HD) model framework for river discharge estimation at any scantily gauged river reach.

Study Area

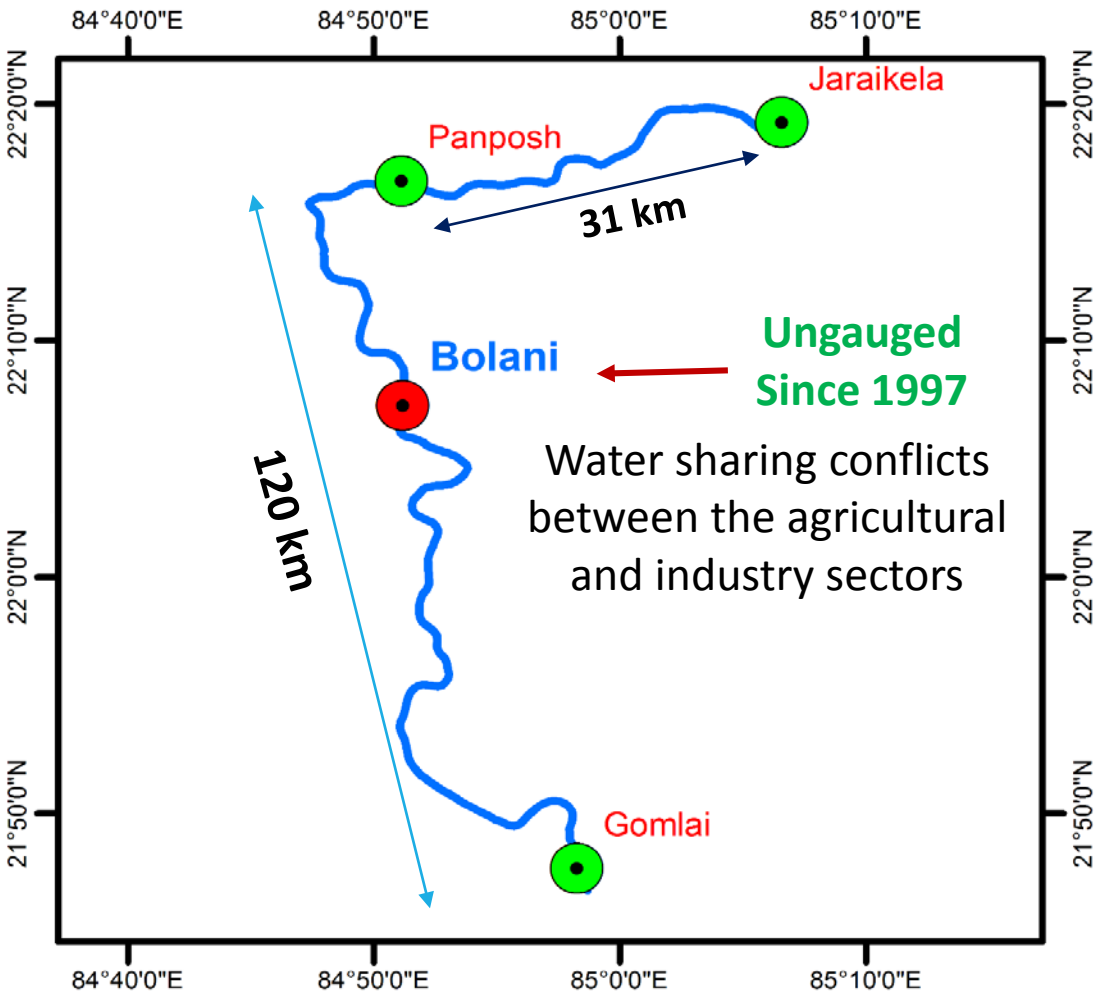




- Geographical area = 39,269 km^2
- Average annual rainfall = 1238 mm

Brahmani River in Eastern India

Problem Statement



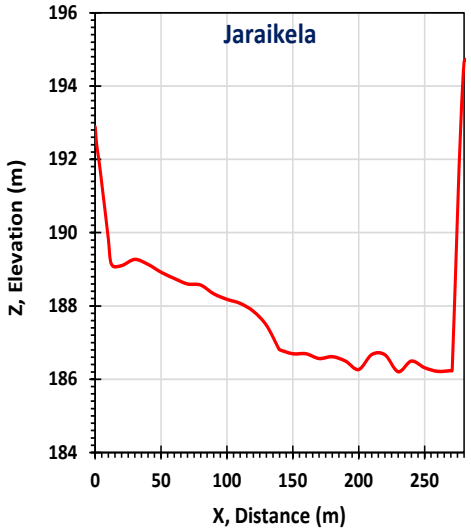
1. The reach shown alongside is the main channel of the Bramhani river from which water is extracted for industrial and agricultural activities.
2. Although there are four gauging stations available along the reach, the Bolani station (marked “red” in the Fig.) is defunct since 1997.
3. This ungauged section of the river reach, covering nearly 120 km from Panposh to Gomlai, gives rise to water sharing conflicts among the stakeholders.
4. Hence, there is an urgent need of establishing an RS-based Virtual Monitoring Session (VMS) to measure the discharge at this defunct station (Bolani) which is an attempt to resolve the water management issues among the stakeholders.

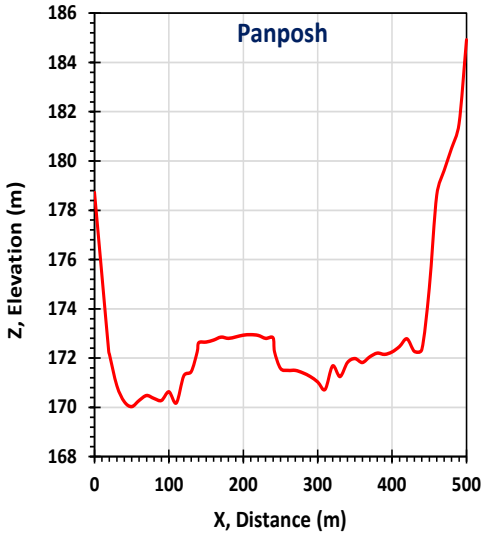
Data Used

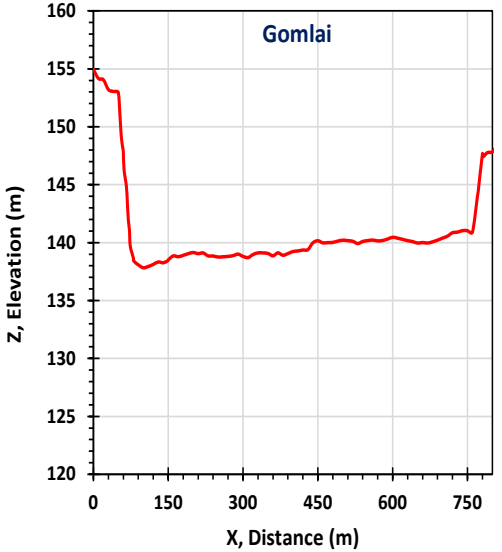
Hourly stage-discharge data procured from CWC: 2007 – 2016.

Selected streamflow gauging stations	Jaraikela, Panposh, Gomlai
Hydrodynamic Model	MIKE-11 HD
River cross section	SRTM DEM, Surveyed cross sections at gauging sites

MODIS	Spatial Resolution	Temporal Resolution
MOD09GQ	250 m	1 day
	Band Information	
Band 1	RED	620 – 670 nm
Band 2	NIR	841 – 876 nm







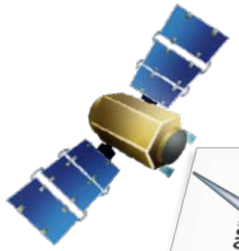
Remote Sensing Data

Terra MODIS (MOD09GQ)

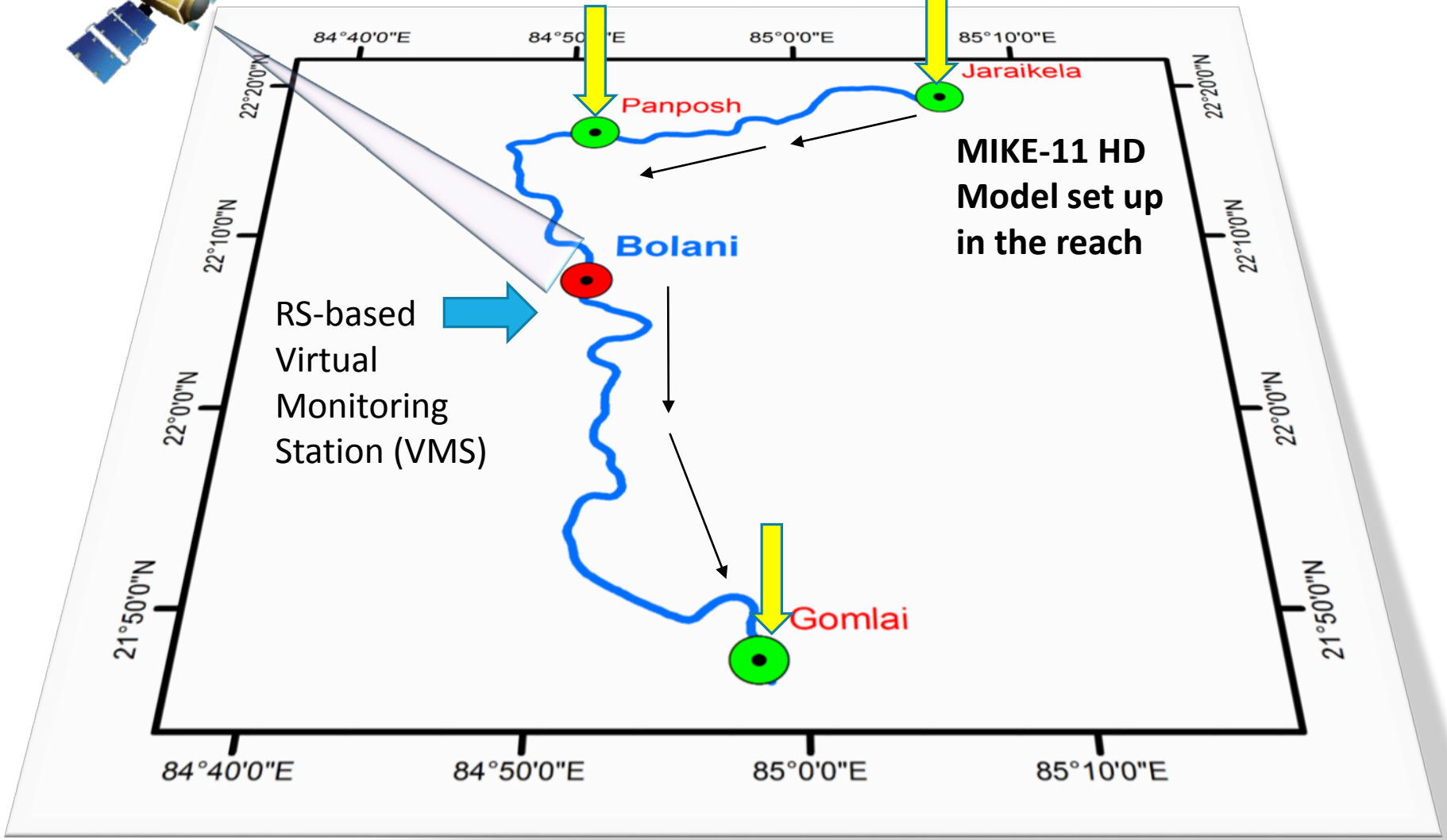
Satellite passage time 9:30 to 11:00 AM (IST)
Study period: 2009-16

<https://reverb.echo.nasa.gov/reverb/> (EOSDIS NASA)

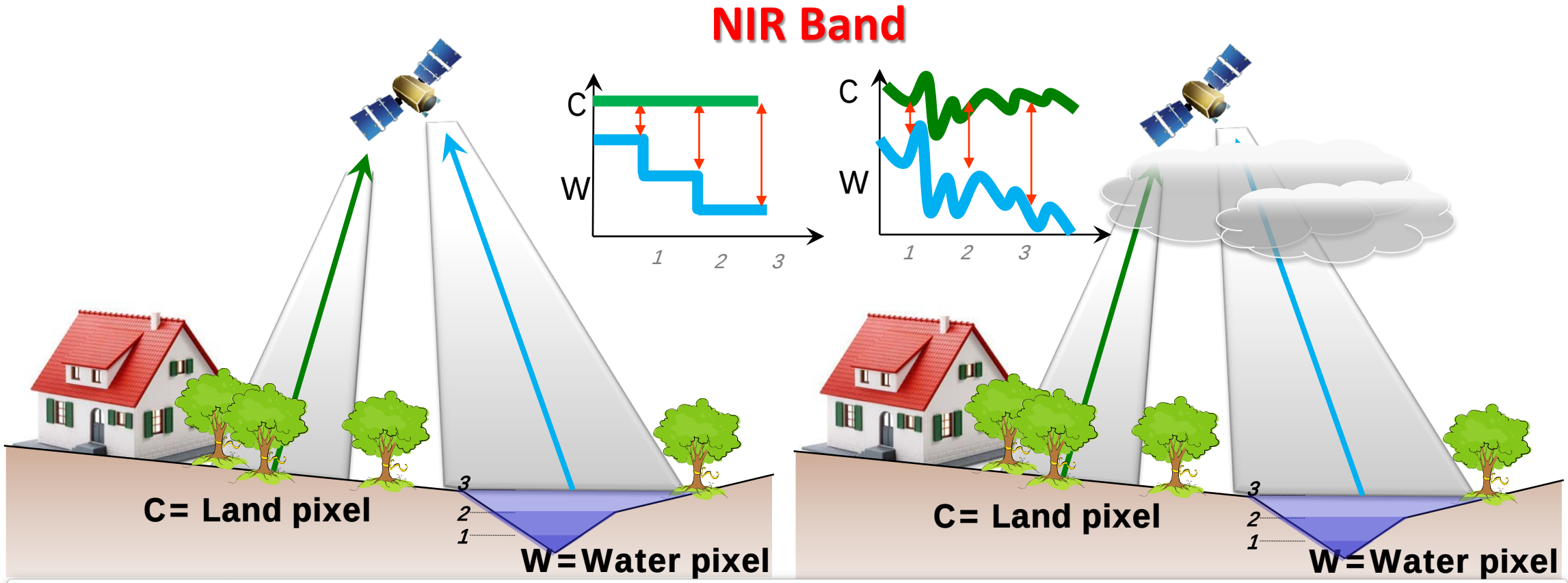
Schematic Representation of RS-HD Framework



MIKE-11 HD Model
(calibration and validation)



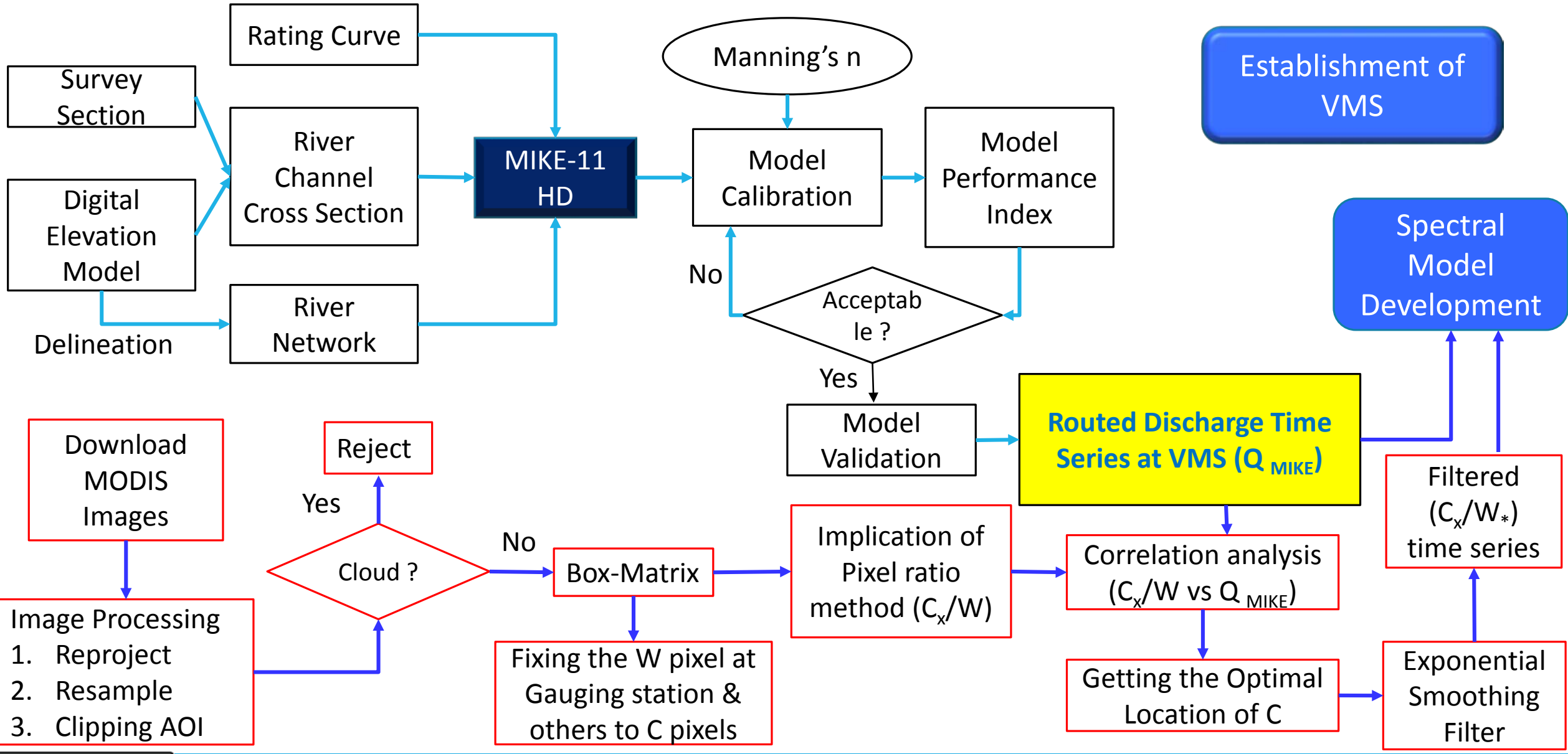
Concept of RS-based Discharge Estimation



C/W increases with the presence of water and, hence, of discharge

(Brakenridge et al., 2007; Tarpanelli et al., 2012; Tarpanelli et al., 2013a)

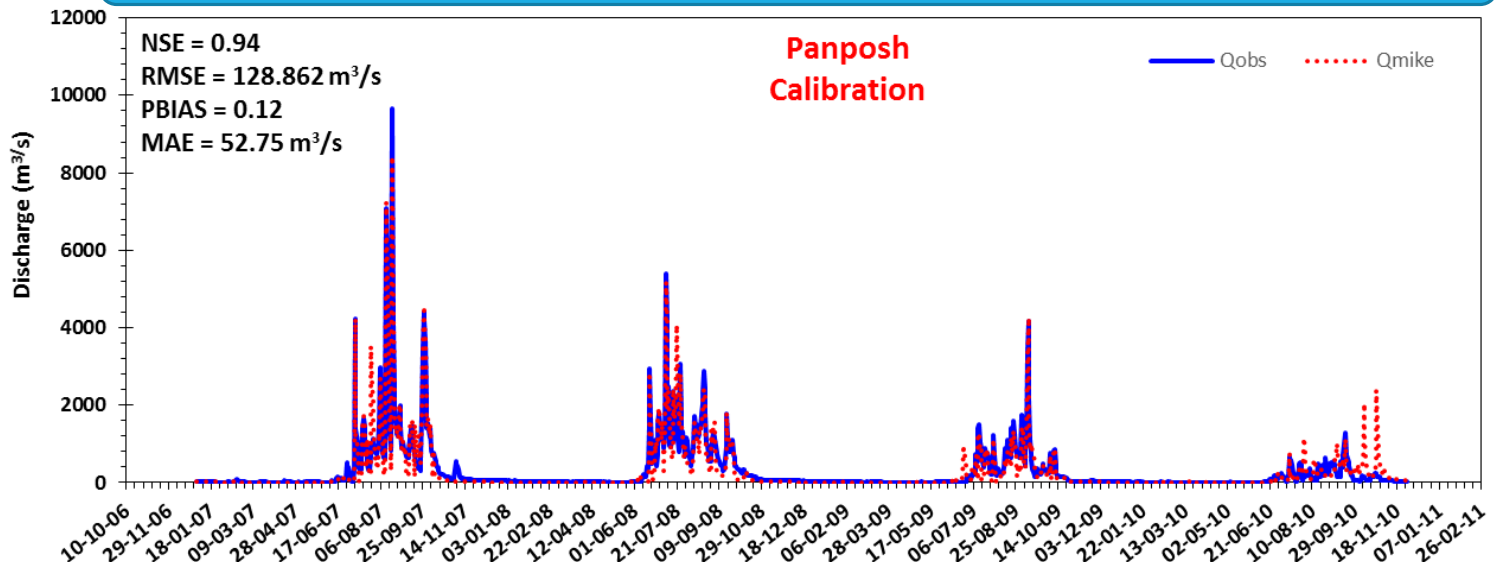
MIKE-11 HD-RS Setup Framework

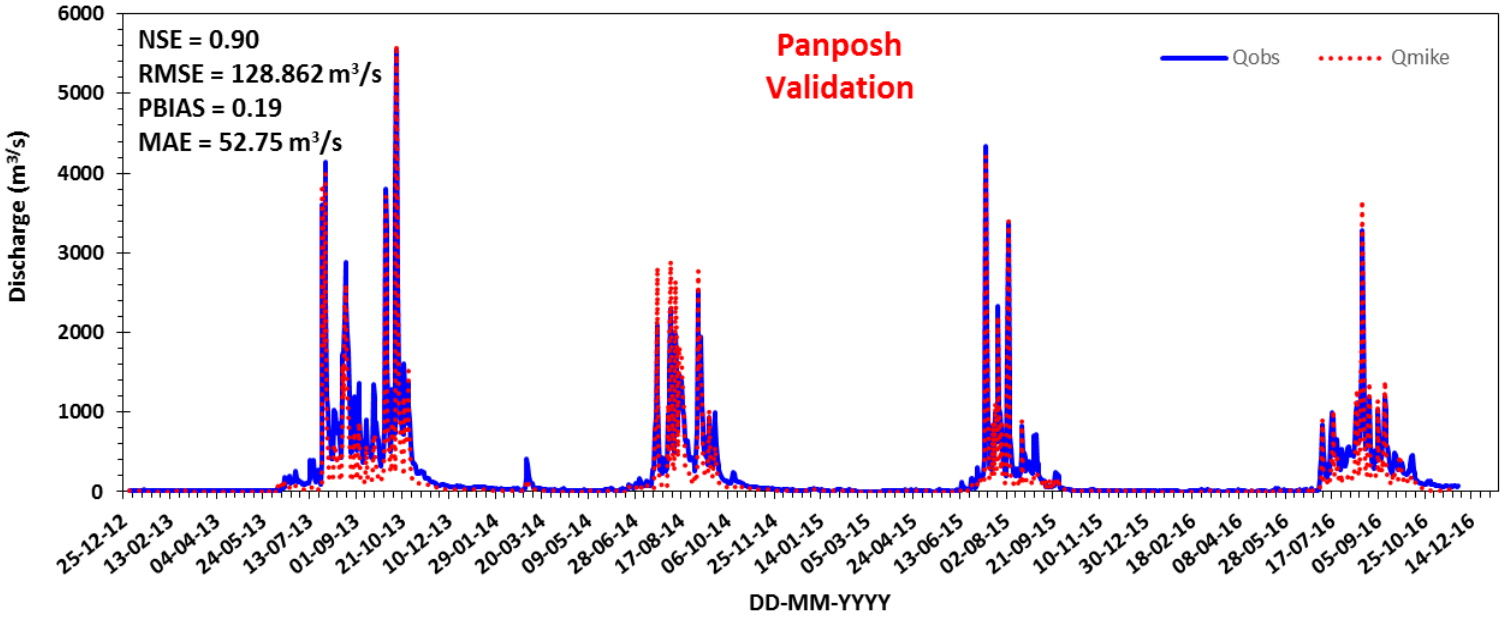


Setting up of MIKE-11 HD model

Reach reach	Chainage (km)	Calibrated Manning's n
Jaraikela - Panposh	0 to 31	0.02
Panposh - Bolani	31 to 65	0.025
Bolani - Gomlai	65 to 114	0.03

- SRTM DEM-based river cross sections (CS) were extracted at an interval of 1 km with a total of 114 CS, which were used as input to the MIKE-11 HD model.
- The MIKE-11 HD model was calibrated and validated at Panposh gauging station which is located at 31 km downstream to the inflow boundary.





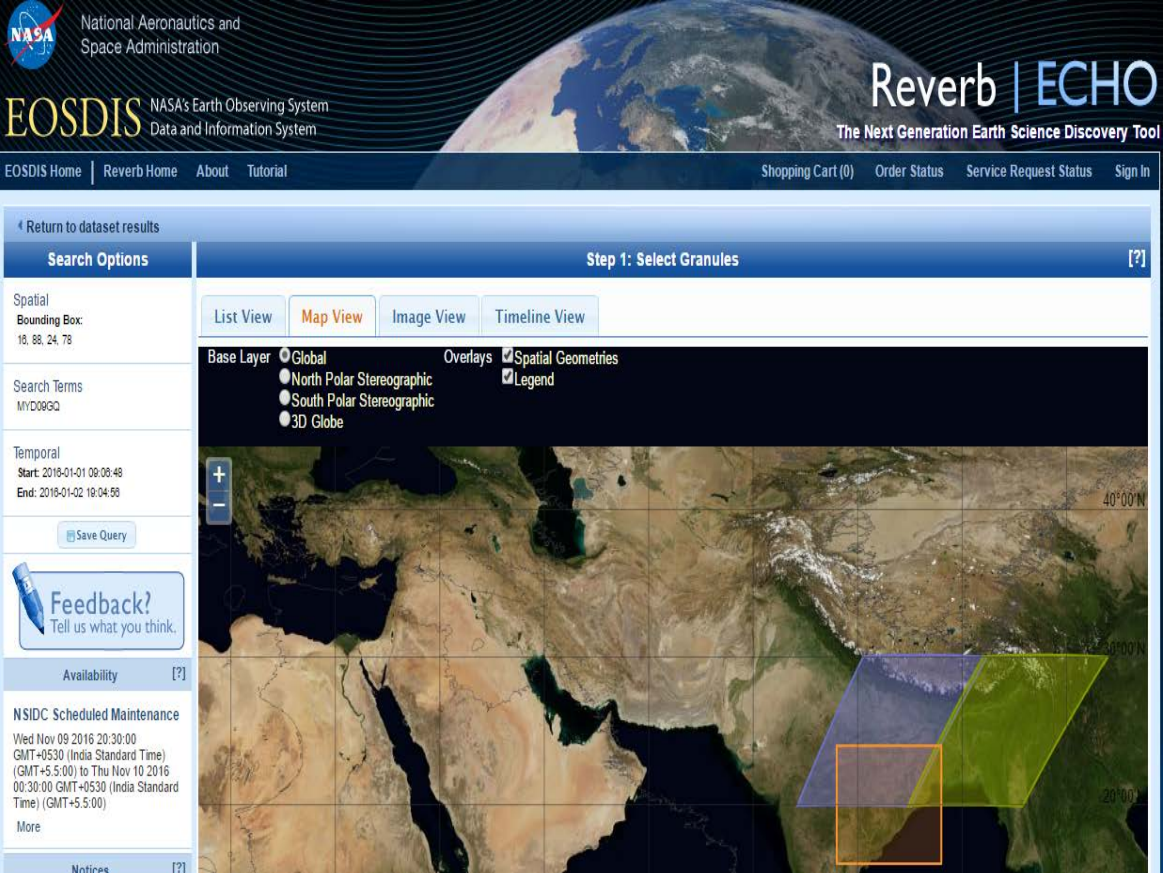
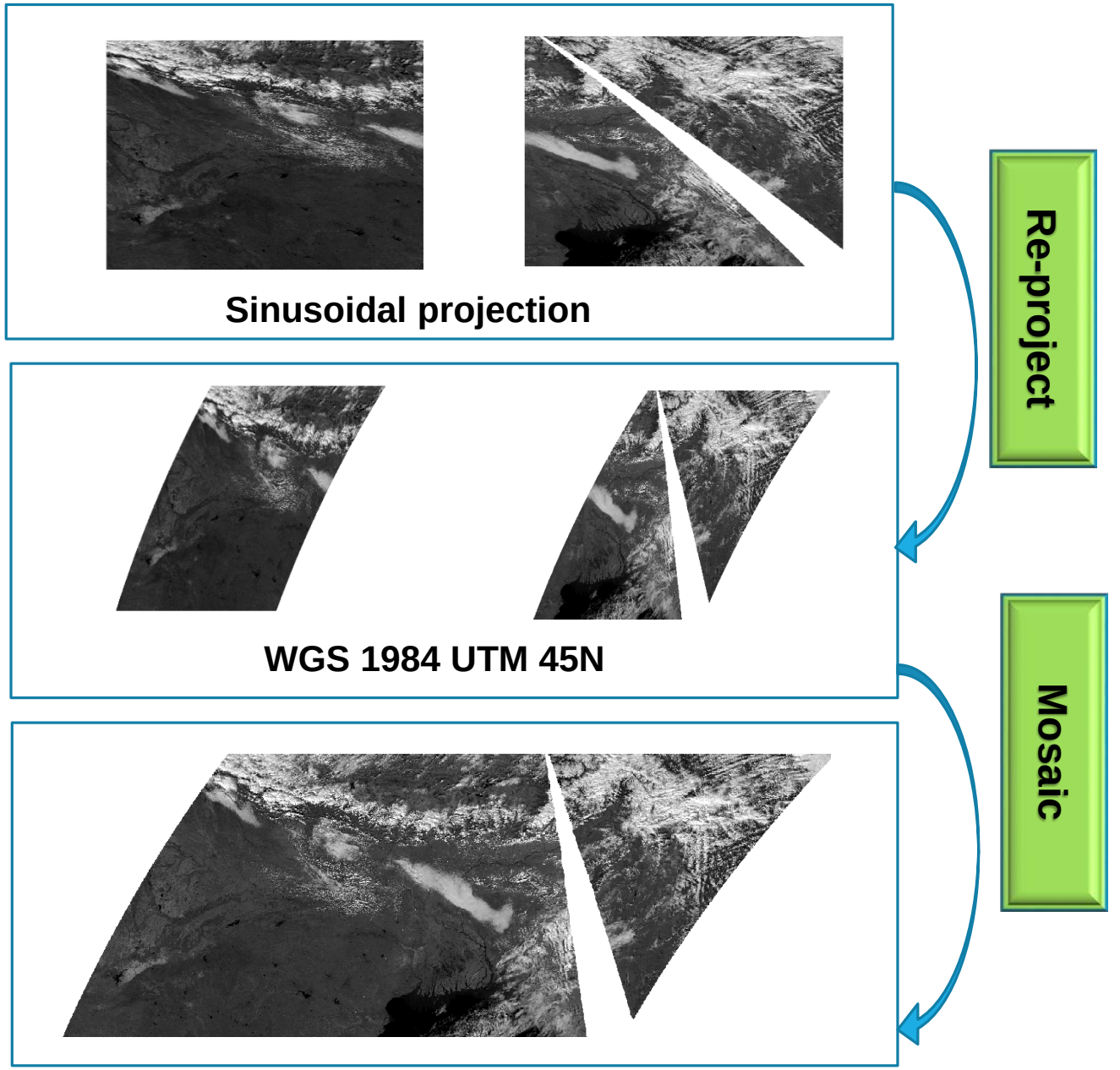
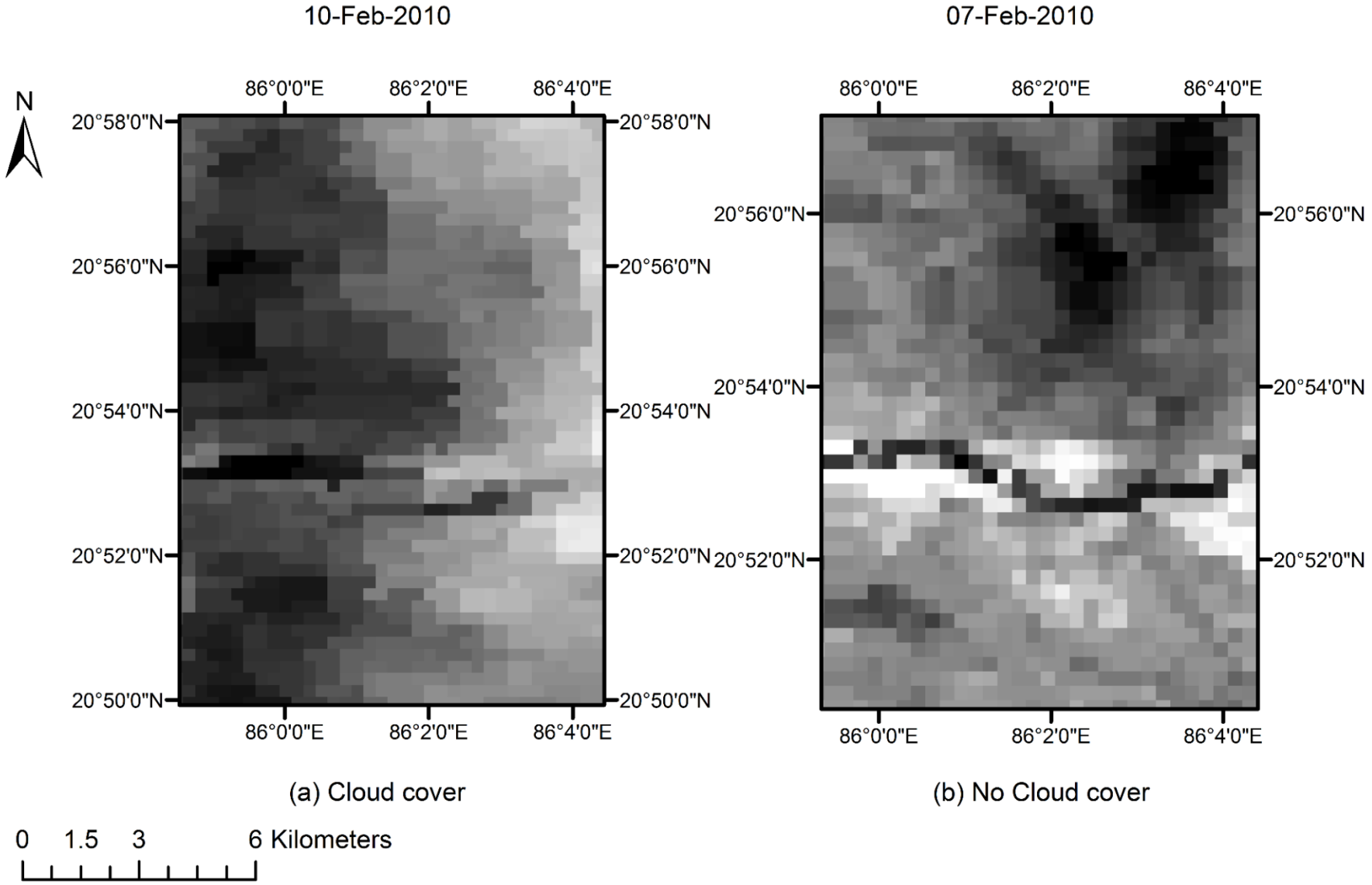


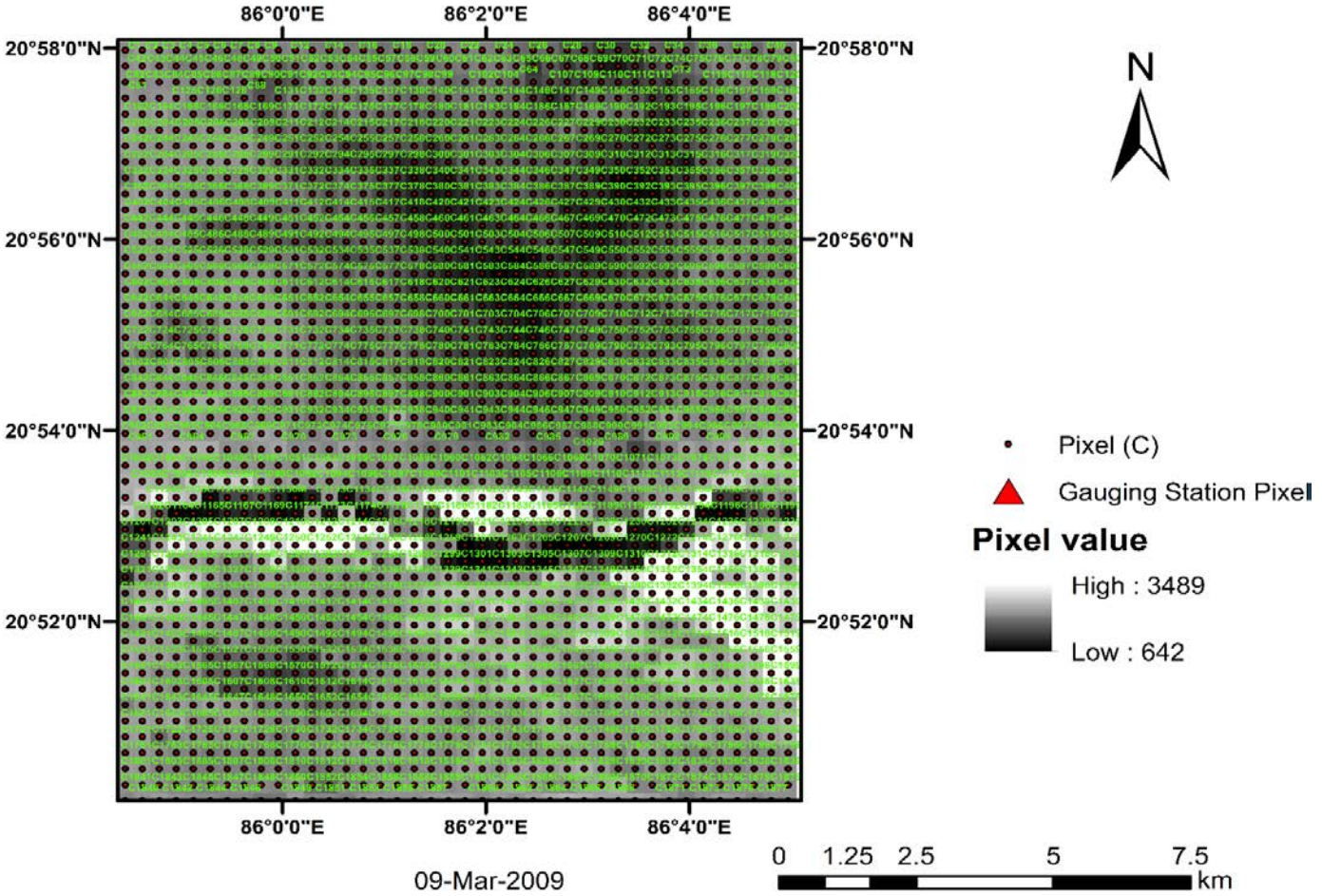
Image processing 2009 – 2016

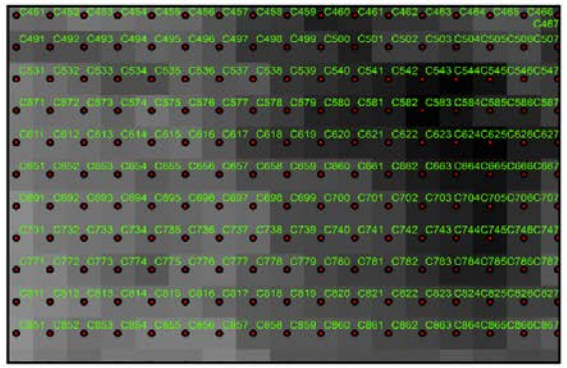


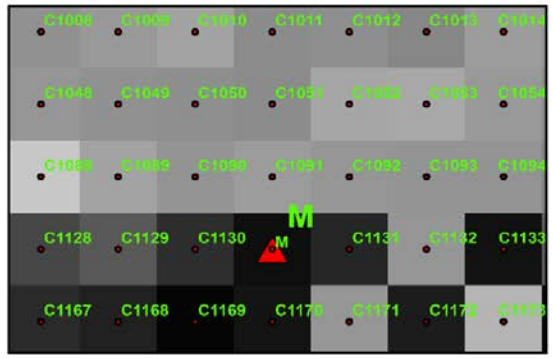
Selection of Cloud-free MODIS Image



Box-Matrix Orientation







Noise reduction filter used for spectral reflectance

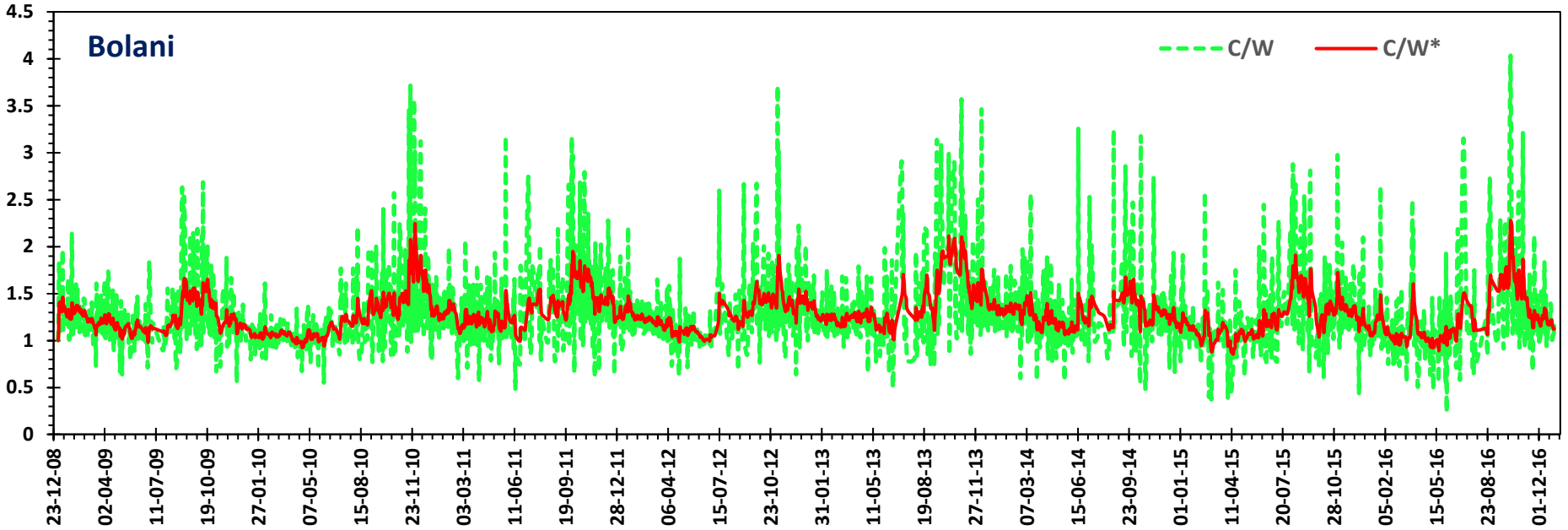
$$\frac{C}{W^*_{t_{n+1}}} = \frac{C}{W^*_{t_n}} + K_{t_{n+1}}\left[\frac{C}{W_{t_{n+1}}} - \frac{C}{W^*_{t_n}}\right]$$

where $\frac{C}{W_{t_{n+1}}}$ is value of the ratio at time t_{n+1}

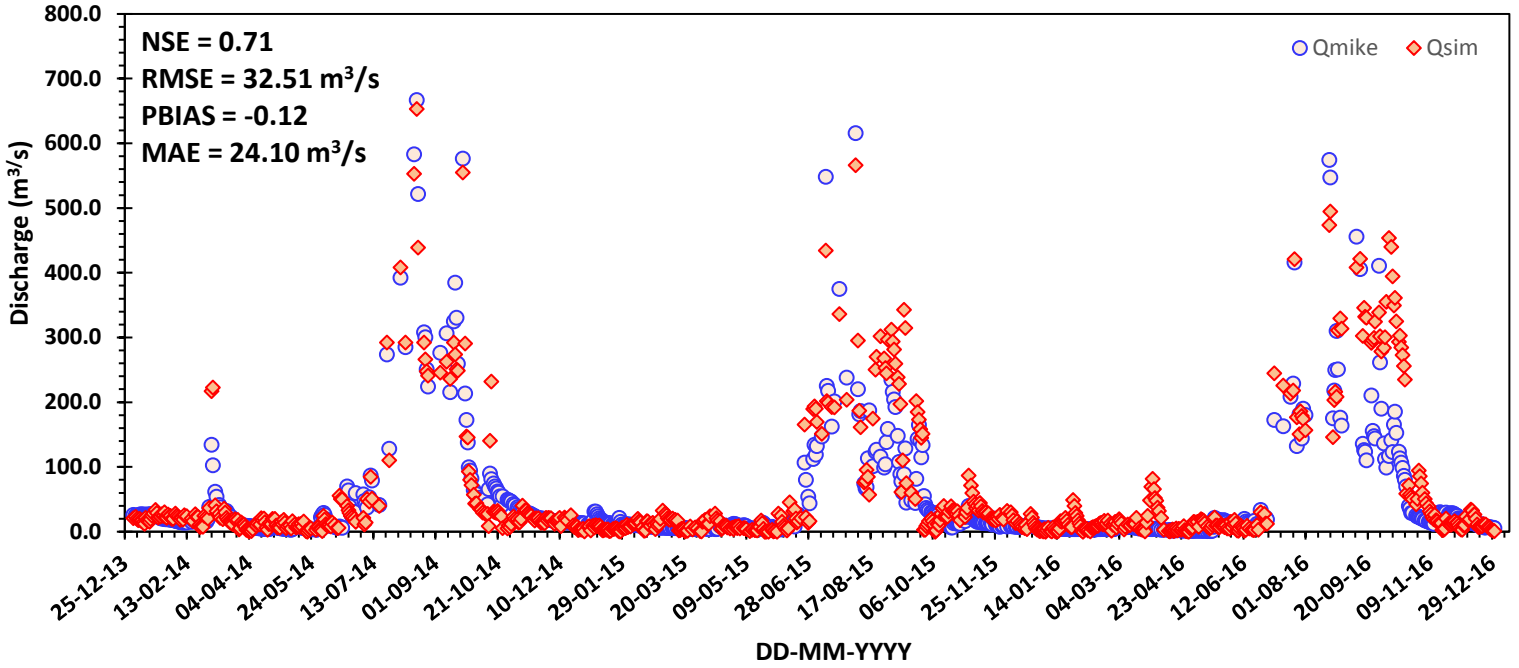
$\frac{C}{W^*_{t_n}}$ is filtered value at previous time, t_n.

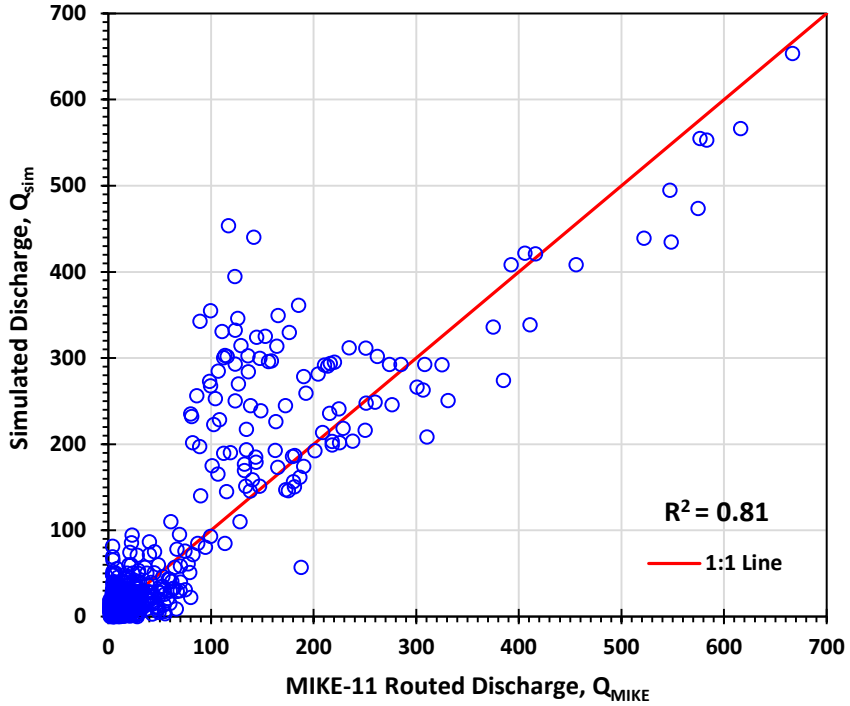
(Albergel et al., 2008)

$$K_{t_{n+1}} = \frac{K_{t_n}}{K_{t_n} + e^{\frac{-(t_{n+1}-t_n)}{T}}}$$ (Range = 0 to 1)



Model Performance and Evaluation of RS-HD VMS (Bolani Gauging Station)





Conclusion

- The MIKE-11 HD model was calibrated (2007-2012) and validated (2013-2016) at Panposh gauging station with NSE values of 0.94 and 0.90, respectively.
- The efficacy of RS-based approach to establish river discharge time series at the VMS (Bolani gauging station) is reasonably validated (NSE = 0.72) with the MIKE-11 HD output (2013-2016).
- The VMS has solved the purpose of real time river discharge monitoring at defunct gauging station at Bolani.
- During monsoon season, the cloud cover is responsible for causing hindrance to estimate river discharge at the VMS with RS-based approach.

Reference

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Brakenridge, G. R., S. V. Nghiem, E. Anderson, and R. Mic (2007). Orbital microwave measurement of river discharge and ice status, Water Resour.Res.,43, W04405.

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Thank you