Trans-boundary hydro-ecological and spatio-temporal characterization of large water reservoirs

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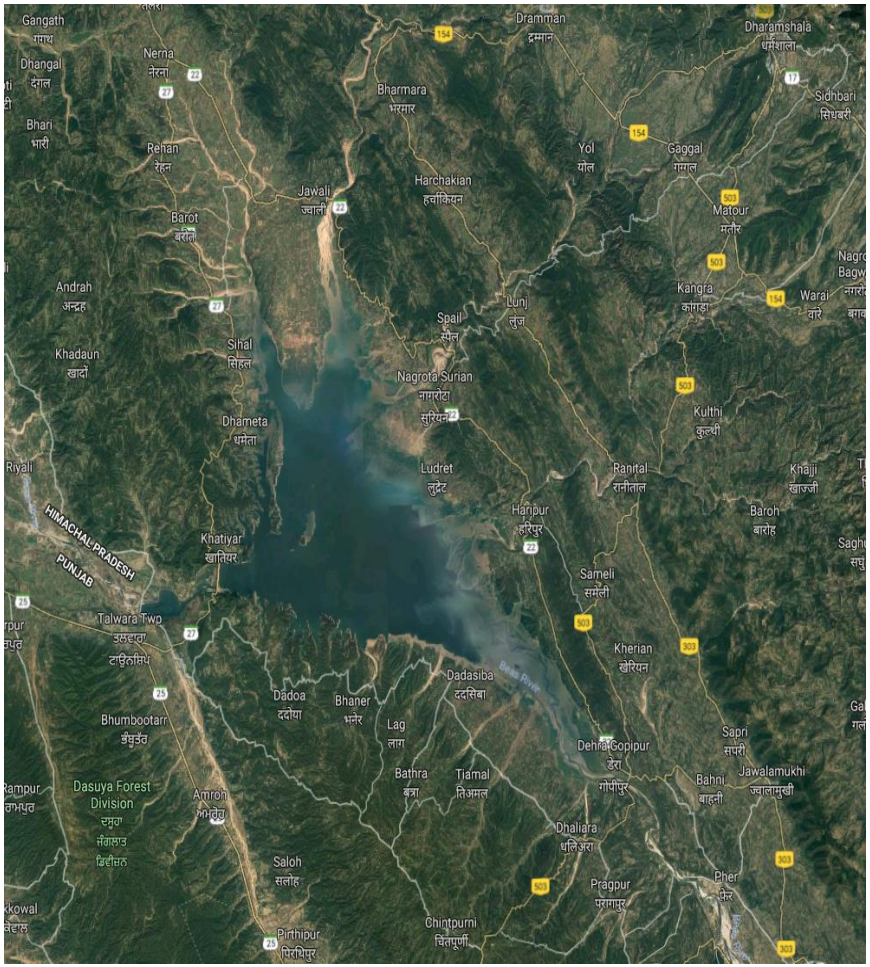
Background

Background

- Can we understand water storage dynamic via Space Technology usage?
- How DEMs can be used for physical characterization of reservoirs?
- How can we estimate the water surfaces and associated volumes through RS/GIS approach?
- Is there any change in spatio-temporal water storage dynamics in selected reservoirs?
- Ground data can represent specific point but will Space Technology improve our understanding for larger areas?

Background



Sources
Google Maps

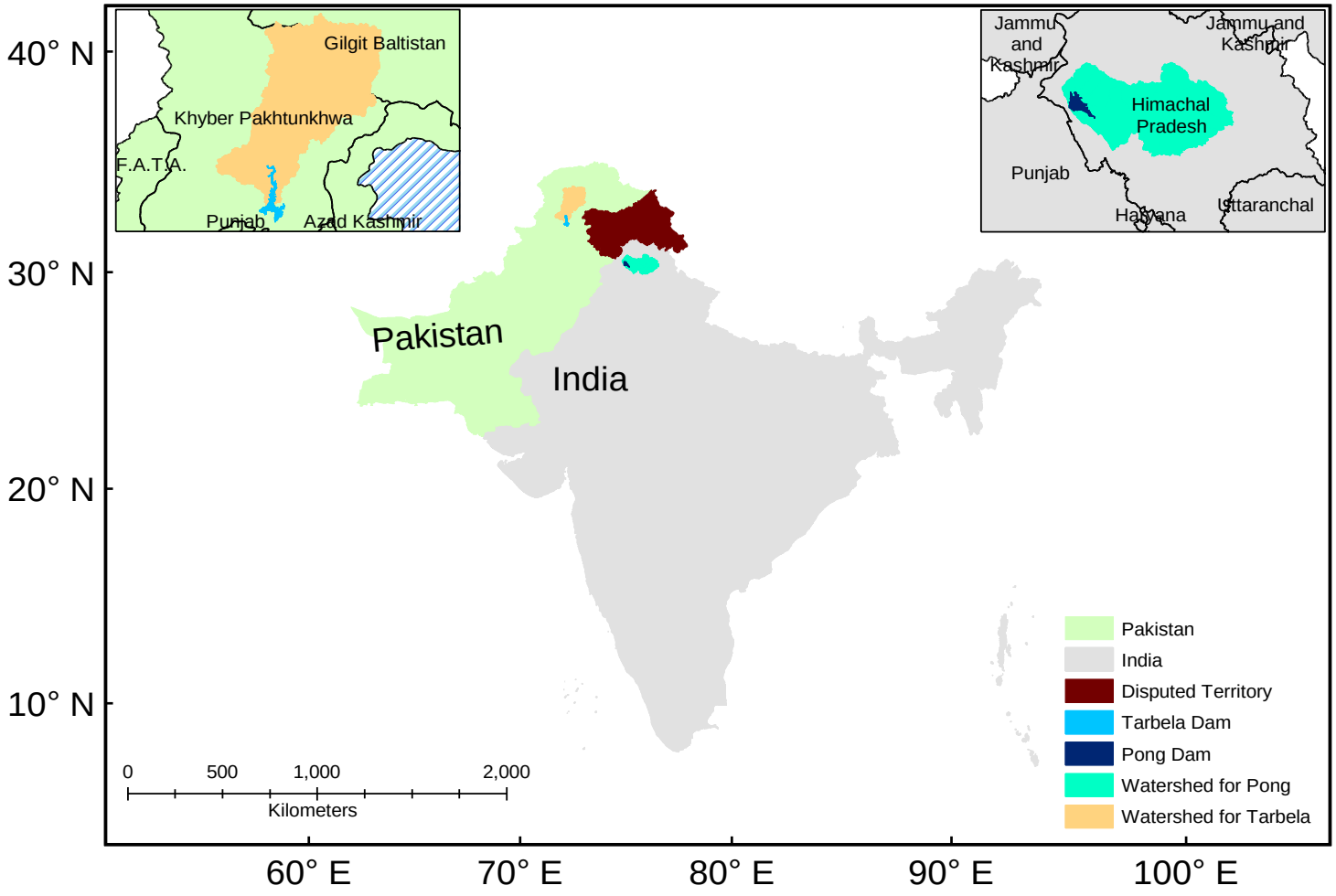
Background

S. No.	Element	Tarbela Dam	Pong Dam
1	Country	Khyber Pakhtunkhwa, Pakistan	Himachal Pradesh, India
2	Construction Year	1968 – 1976	1975
3	Type of Dam	Earth and rock filled Dam	Earth core gravel shell
4	Catchment Area	169600 km^2	12560 km^2
5	Reservoir Area	259 km^2	260 km^2
6	Max reservoir depth	137.00 m	97.84 m
7	Gross storage capacity	11.60/7.99 MAF	6.95 MAF
8	Live storage capacity	9.30/6.85 MAF	5.91 MAF
9	Max reservoir level	472.44 m	433.12 m
10	Normal reservoir level		423.67 m
11	Dead storage level	420.01 m	384.05 m
12	Project Usage	Hydroelectric, Irrigation and Flood Control	Hydroelectric, Flood Control and Irrigation

Sources
WAPDA, Pakistan
Central Water Commission, India

Data and Method

Data and Method



Data and Method

Landsat constellation time series data

- Earlier Satellite image used for Extent Mapping only
- 1998-1999 (6 Satellite images)
- 2016-2017 (6 Satellite images)
- Bands of Green, Red, NIR and Two SWIR
- Monsoon (Pre Kharif), Post Monsoon (Post Kharif) and Post Western Disturbances (Post Rabi)

Data and Method

Digital Elevation Models (DEMs)

- **Shuttle Radar Topography Mission (**SRTM, 2003) – 90m
- **Advanced Space borne Thermal Emission and Reflection Radiometer** (ASTER, 2009) – 30m
- **Advanced Land Observing Satellite** "DAICHI" (ALOS) PRISM (Panchromatic Remote-sensing Instrument for Stereo Mapping), 2014 – 30m

Data and Method

In situ Water levels and Volumes

- Tarbela Dam Water levels (meters amsl)
- Pong Dam Water Levels (meters amsl) and Volume (Million Acre Feet)

Data and Method

GDEMs Comparison based on Topographic Analysis

- SRTM
- ASTER
- ALOS

SWAT Model based Watershed analysis

- DEMs Processing for input
- SWAT mode installation
- SWAT configuration
- Watershed Delineation

Water Surface and Volume Estimation

- Landsat Satellite Data Downloading and Processing
- Water Index and Thresholding
- Dams Water Level based Volumetric Analysis
- Grid based volumetric Analysis

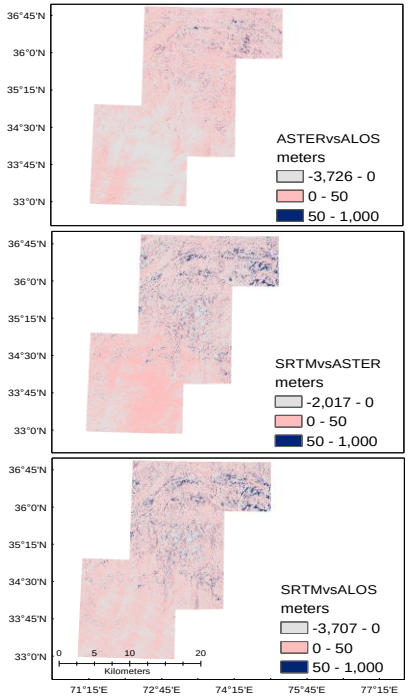
Spatio-Temporal Analysis

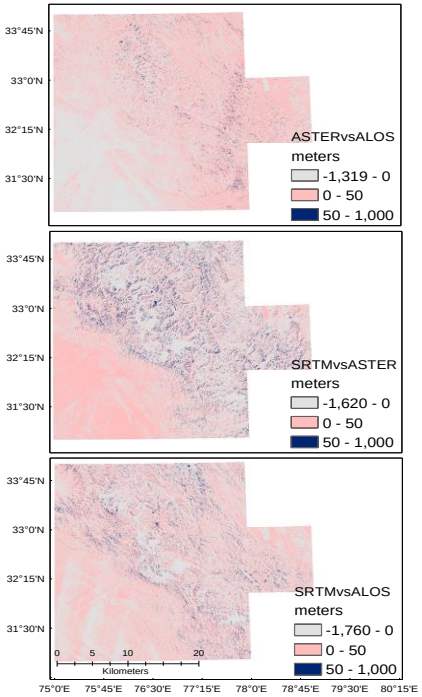
- 1998-1999
- 2016-2017
- Seasonal

Topographic Analysis

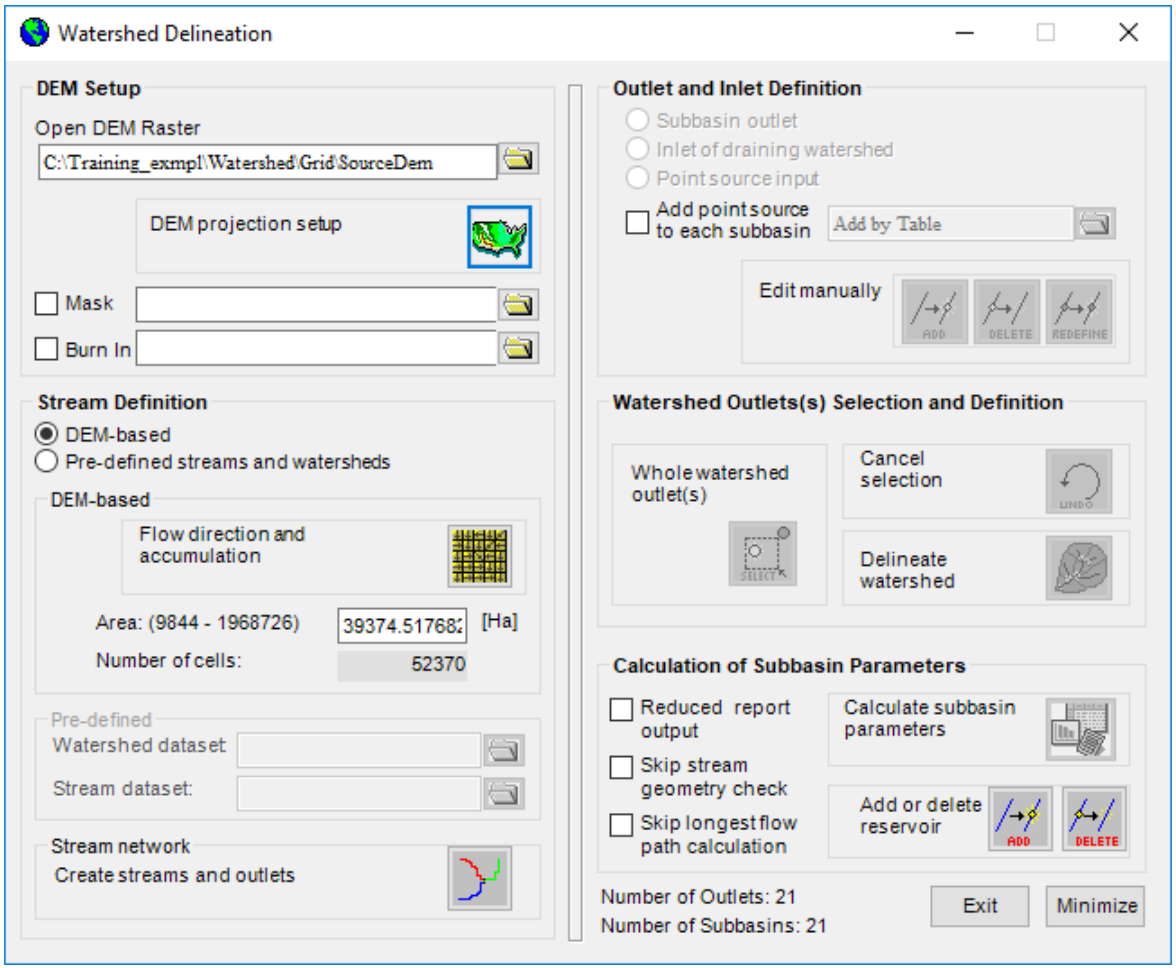
Topographic Analysis

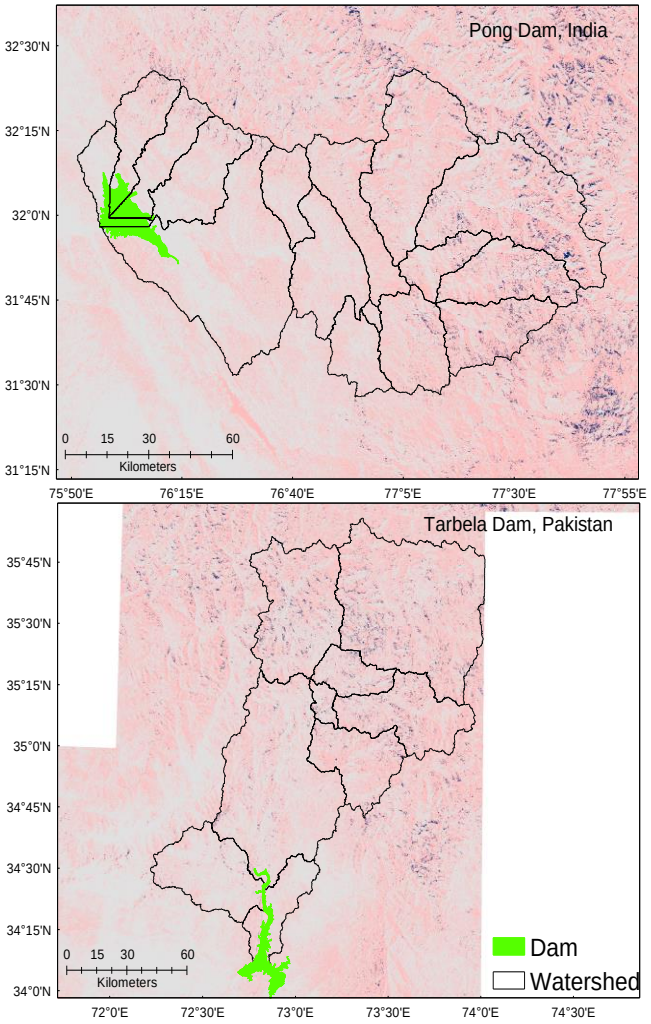
Difference in Elevations	Tarbela			Pong		
	ASTER vs ALOS	SRTM vs ASTER	SRTM vs ALOS	ASTER vs ALOS	SRTM vs ASTER	SRTM vs ALOS
Mean	-1.48	0.29	1.48	0.99	49.98	48.42
Minimum	-6.27	-4.69	-2.14	-3.36	0.21	-1.10
Maximum	2.67	17.40	17.27	5.85	95.29	95.30
S.D.	2.36	6.06	5.35	2.96	34.04	34.03





Topographic Analysis





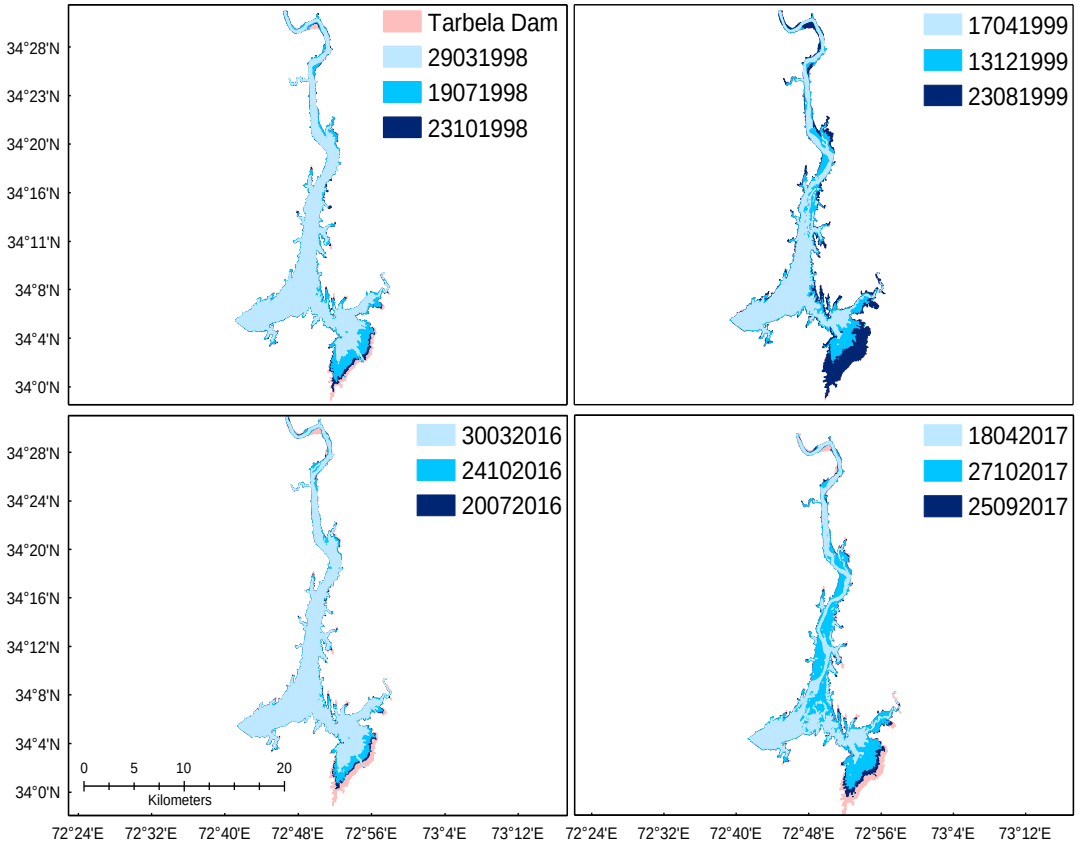
Topographic Analysis

Watershed Characteristics	Units	Tarbela			Pong		
		ASTER	ALOS	SRTM	ASTER	ALOS	SRTM
Total Basin Area	Sq Km	16268.90	16250.80	16172.00	12711.90	12604.50	12601.20
Sub-basins	Numbers	9.00	9.00	9.00	15.00	18.00	18.00
Minimun Sub-Basin Area	Sq Km	200.00	198.00	200.00	0.34	0.32	0.45
Maxuimum Sub-Basin Area	Sq Km	4281.90	4275.00	4196.00	4142.00	2378.60	2401.50

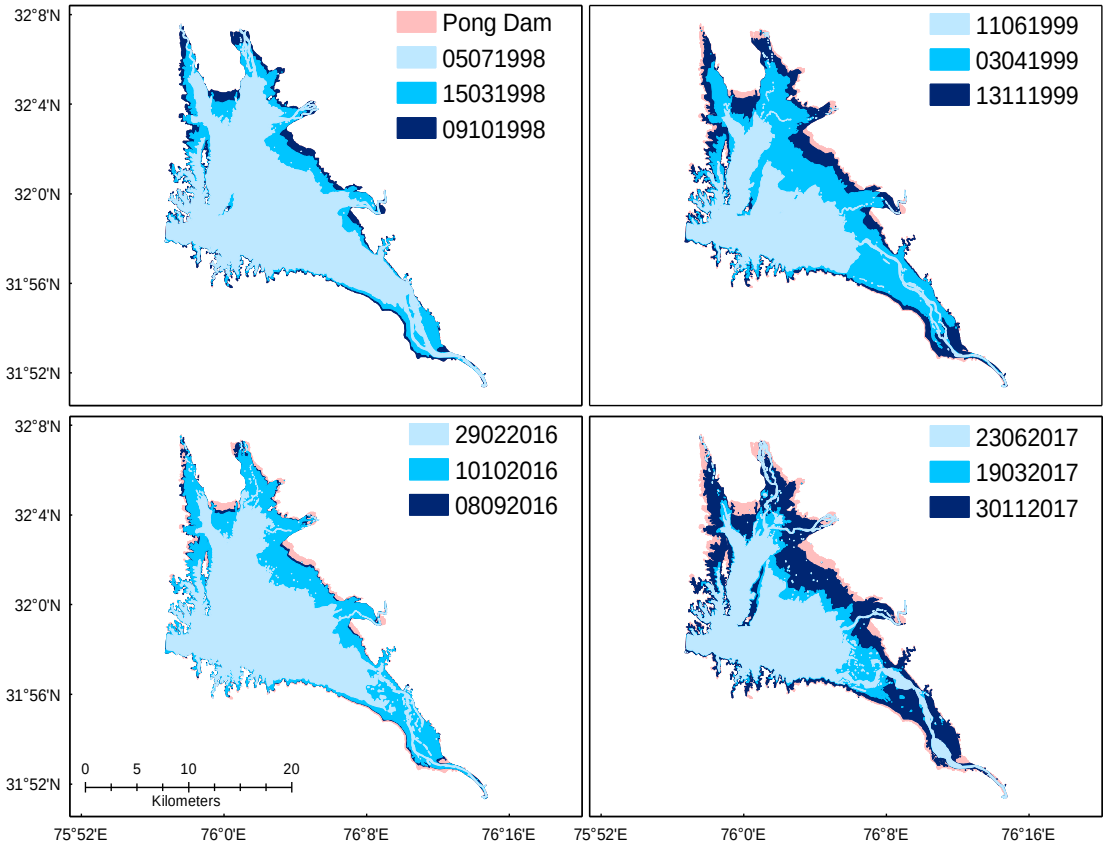
Sub Basin Characteristics	Units	Tarbela			Pong		
		SRTM	ASTER	ALOS	SRTM	ASTER	ALOS
Slope	Percent	56.07	62.96	69.04	43.91	51.41	49.42
Length	Km	39.87	44.38	45.36	28.39	37.40	29.91
Depth	meters	2.42	2.43	2.42	1.57	1.87	1.57
Avg Elevation	meters	2566.00	2573.00	2576.00	1756.93	2122.84	1776.90
Avg Elevation Minimum	meters	361.00	425.00	349.00	393.00	333.00	373.00
Avg Elevation Maximum	meters	5769.00	5915.00	5918.00	6214.00	6582.00	6585.00

Water Surface Extraction

Water Surface Extraction

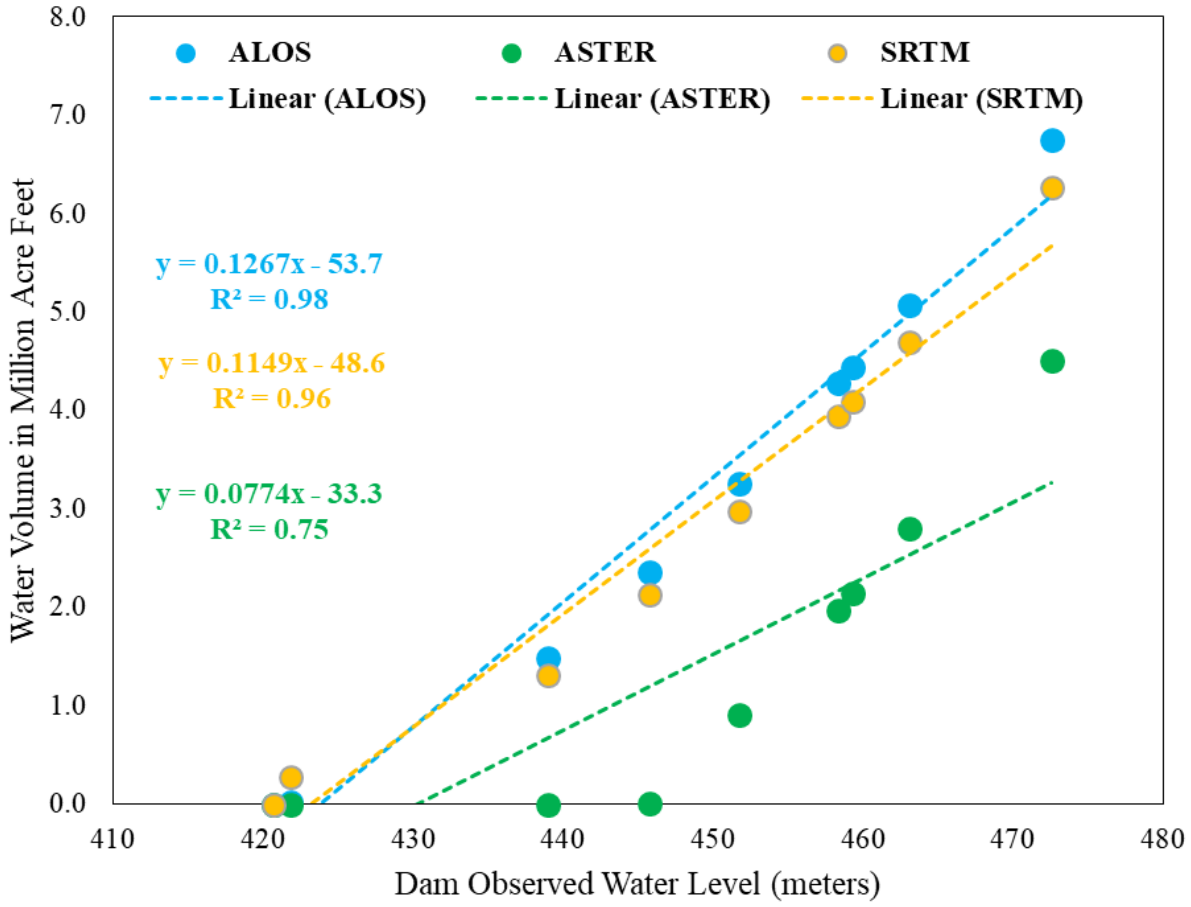


Water Surface Extraction



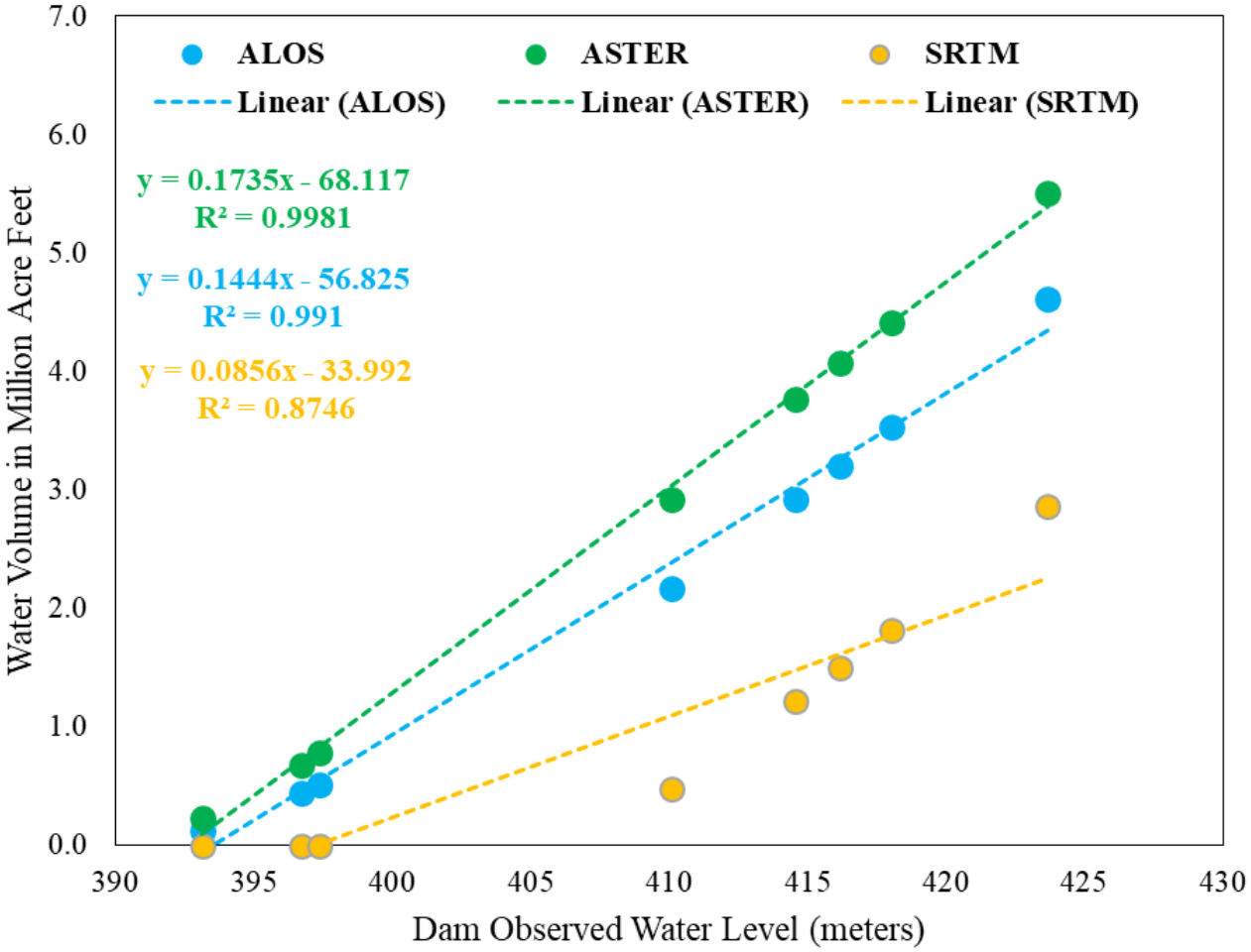
Water Volume Analytics

Reservoirs Water volume analytics



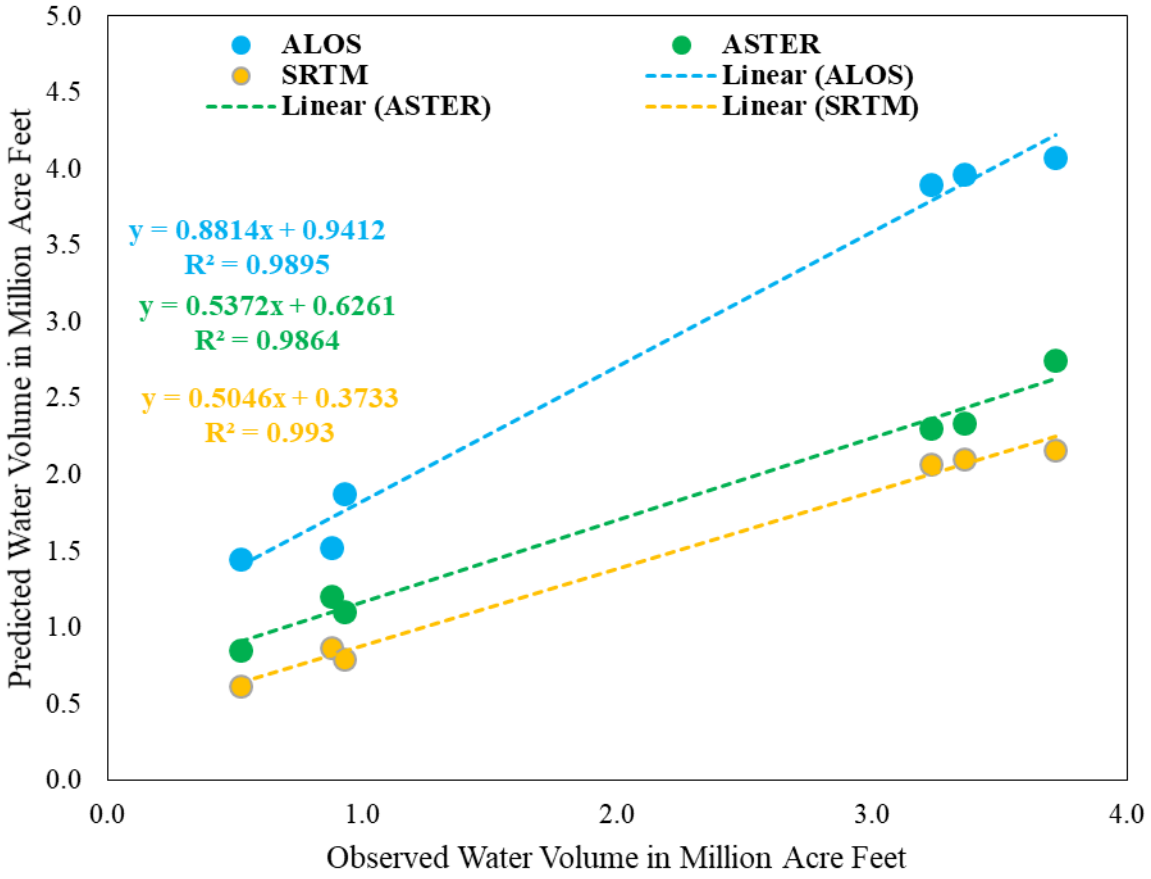
Tarbela Dam

Reservoirs Water volume analytics



Pong Dam

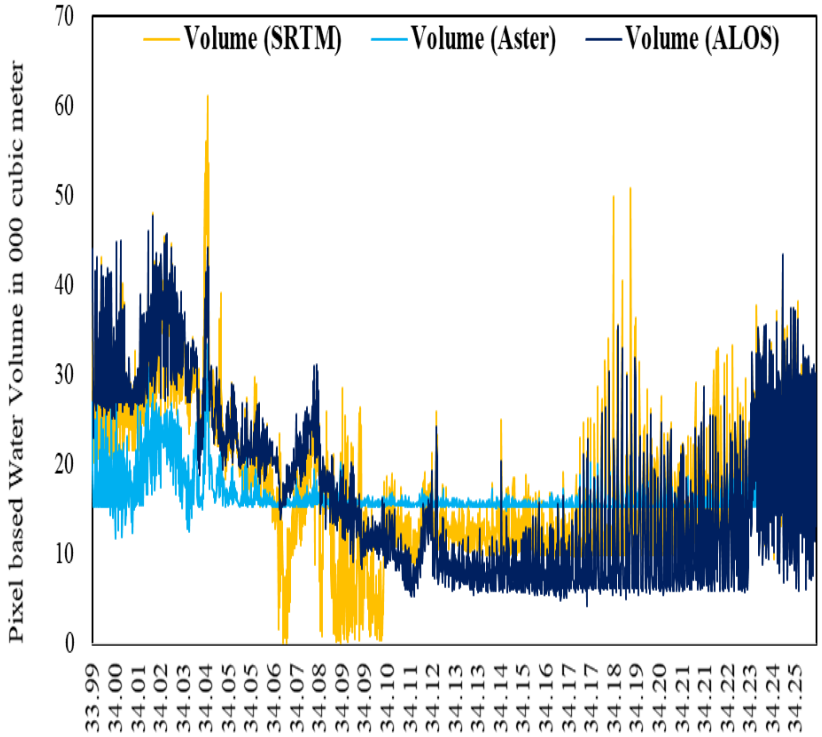
Reservoirs Water volume analytics



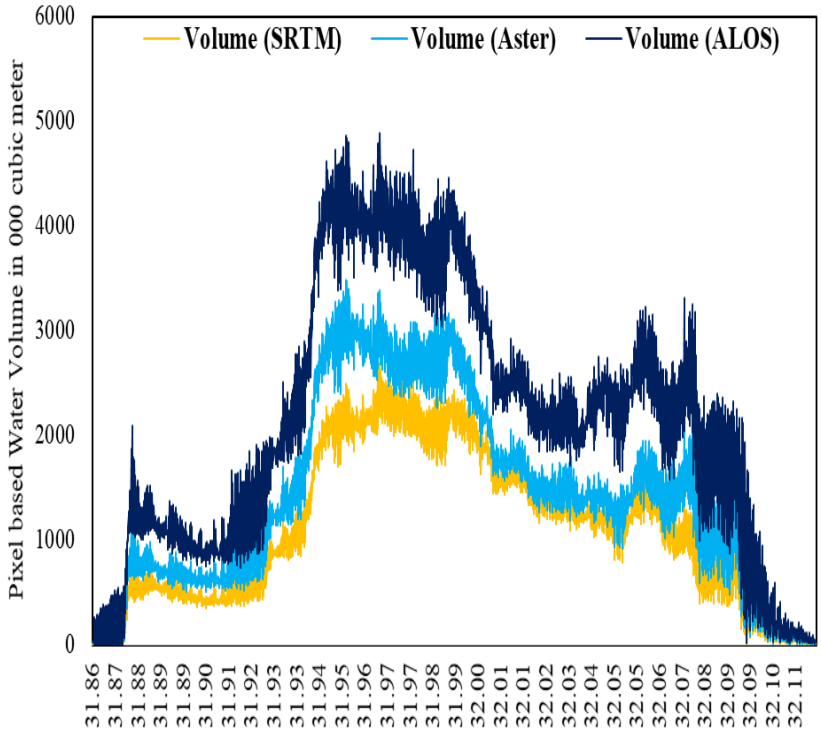
Pong Dam

Reservoirs Water volume analytics

Water Storage Profile along Latitude



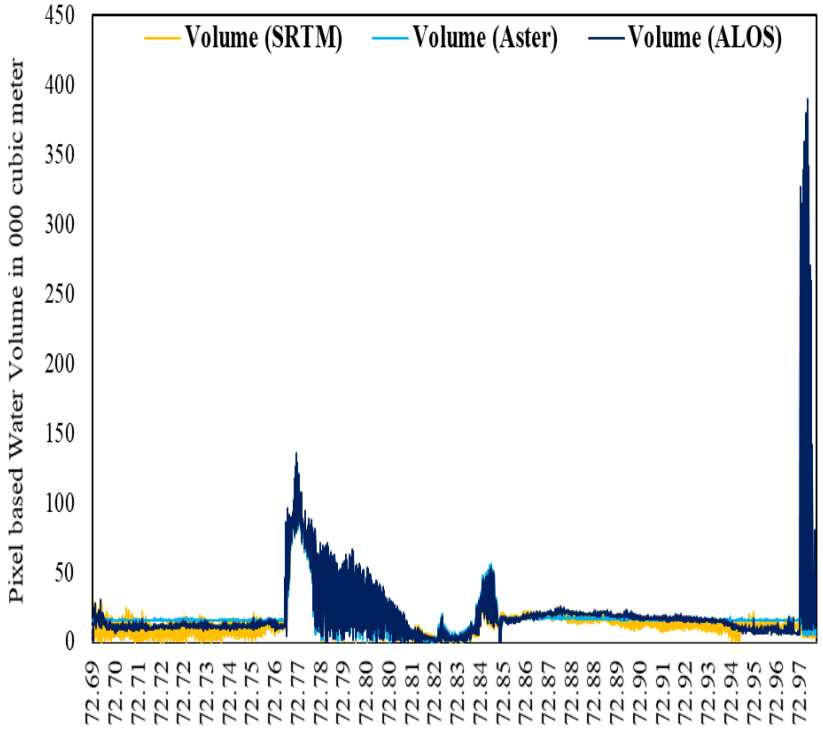
Tarbela Dam



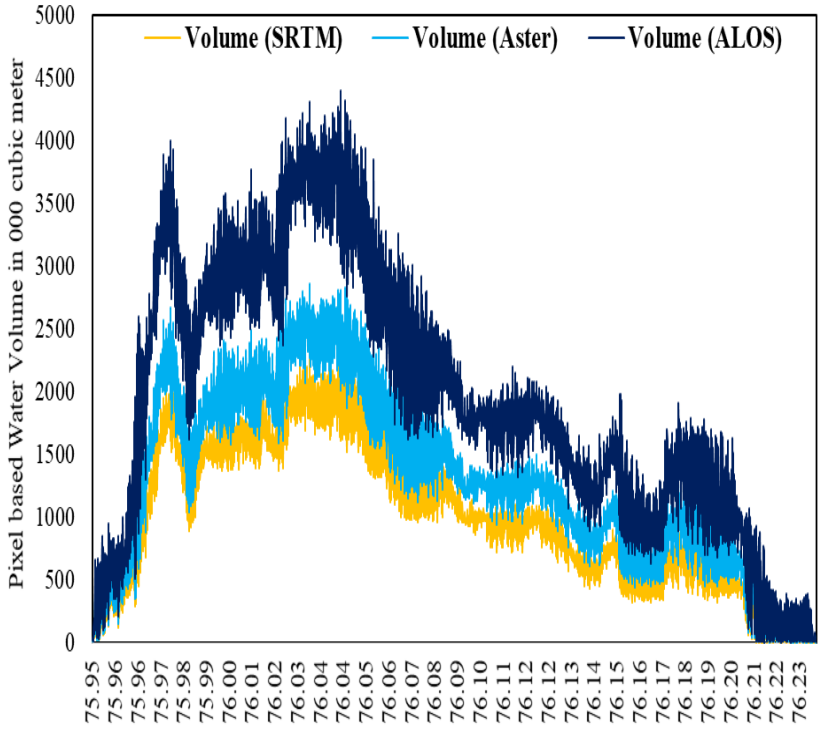
Pong Dam

Reservoirs Water volume analytics

Water Storage Profile along Longitude



Tarbela Dam

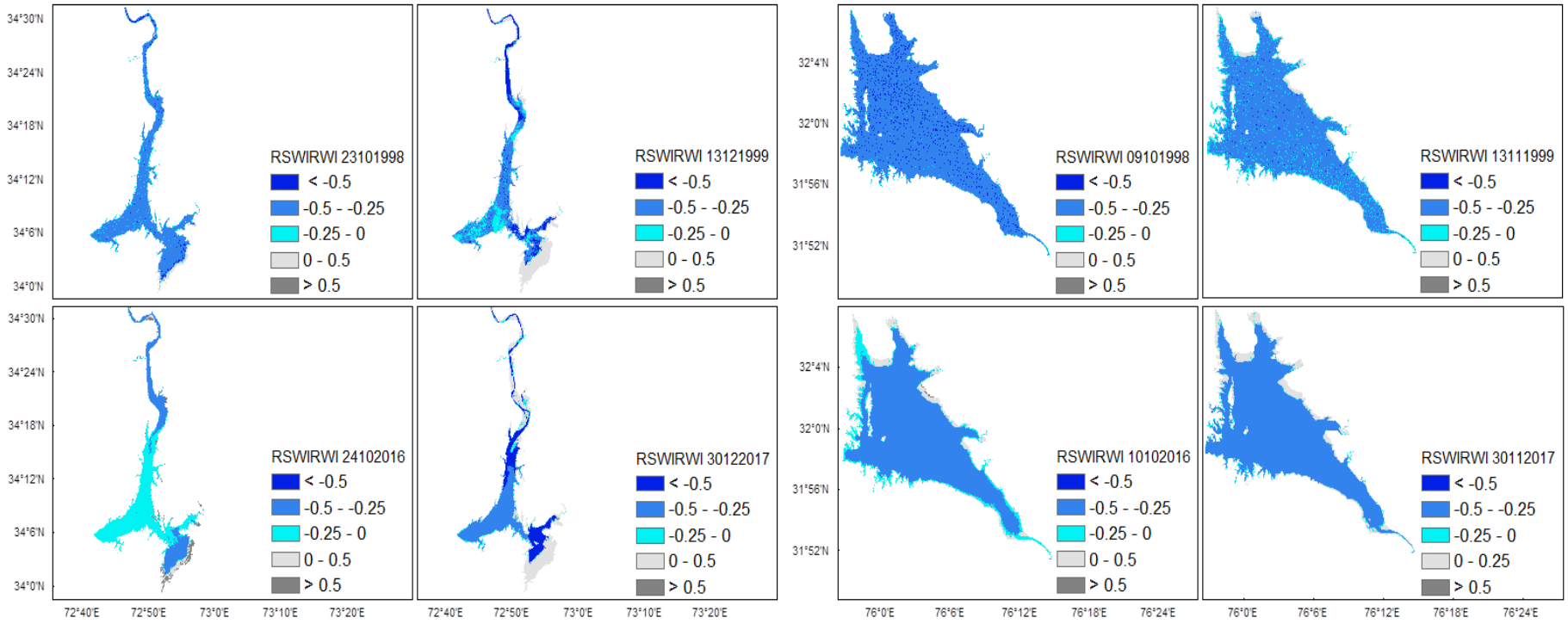


Pong Dam

Spatio-Temporal Analysis

Spatio-Temporal Reservoirs Characteristics

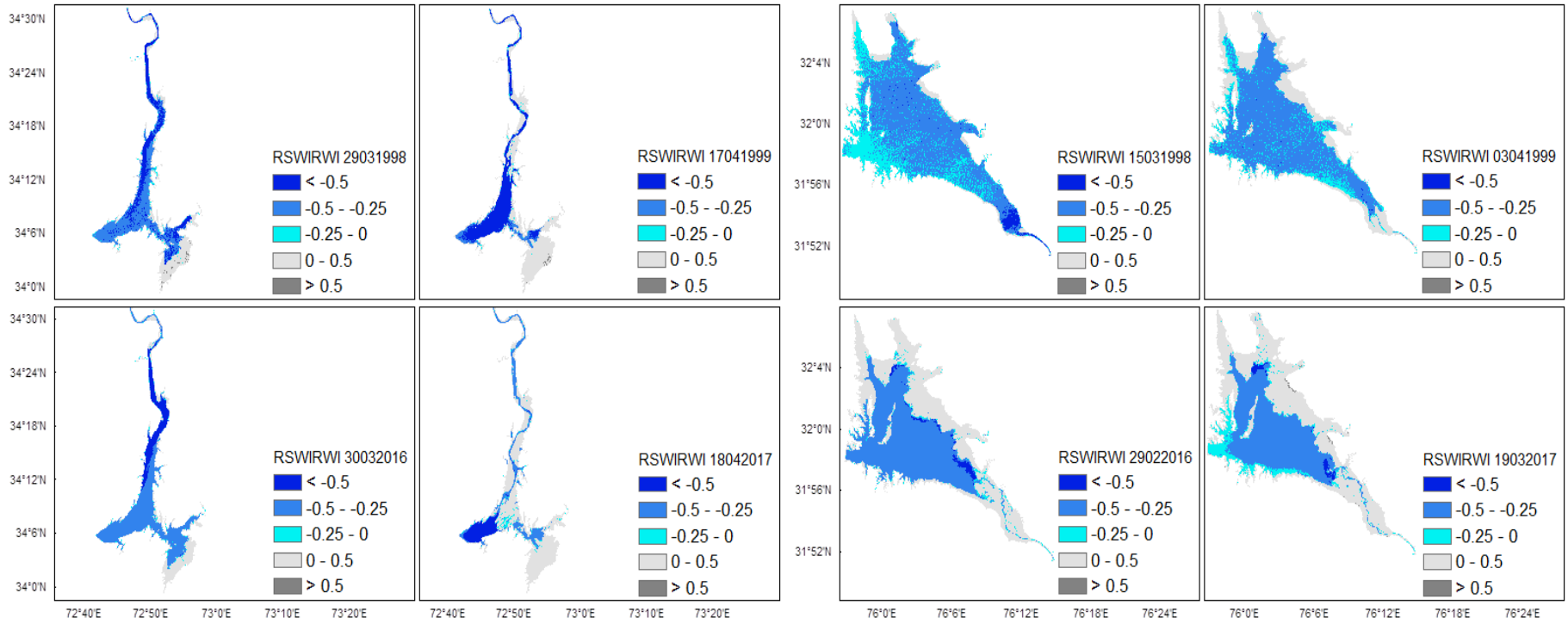
Red Shortwave Infra-Red Water Index



Post Monsoon (Post Kharif)

Spatio-Temporal Reservoirs Characteristics

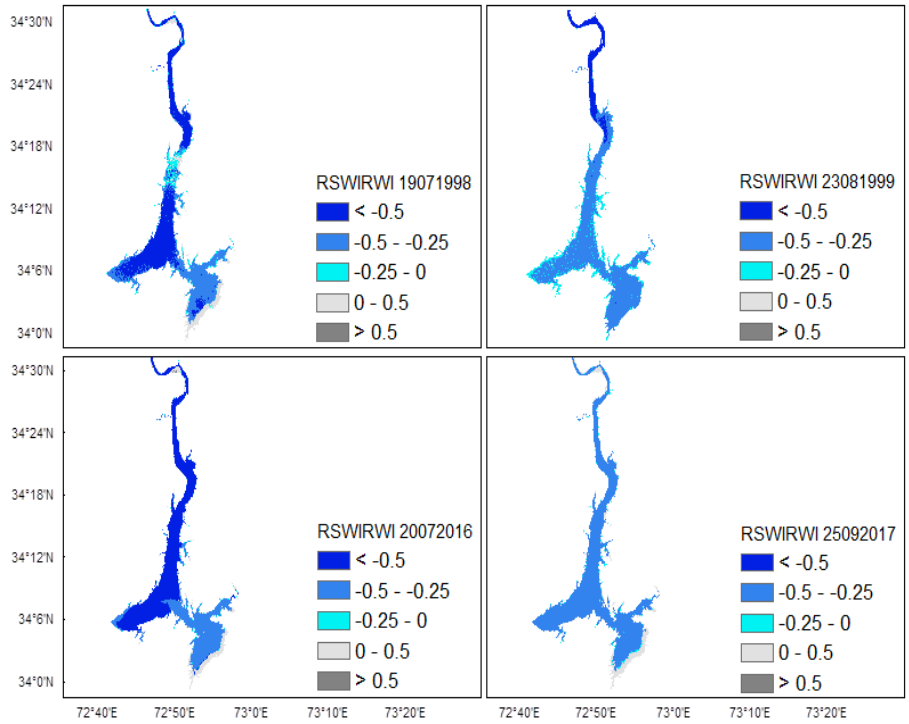
Red Shortwave Infra-Red Water Index

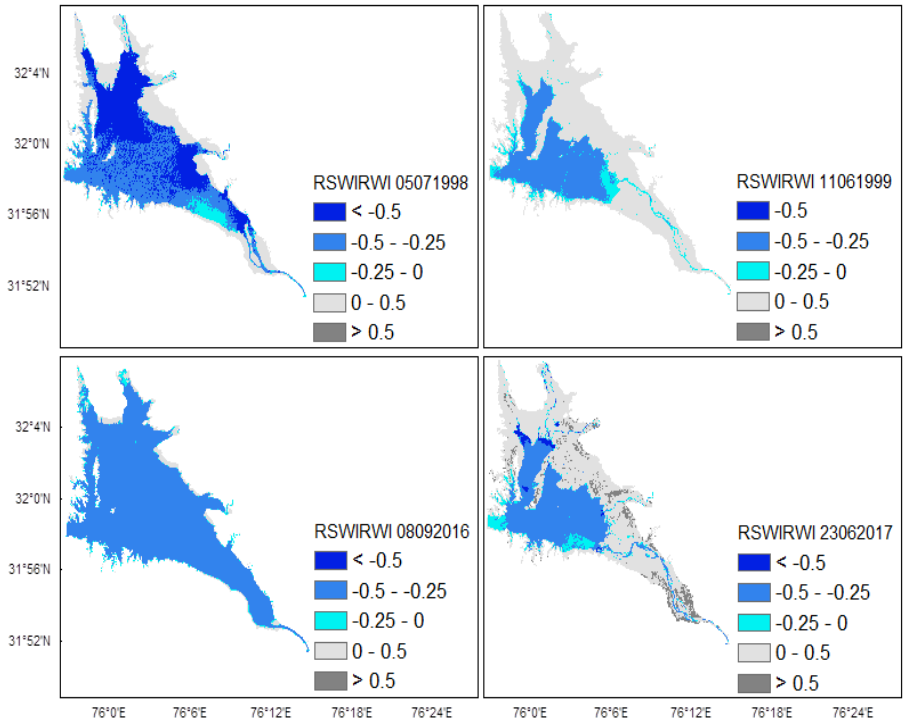


Post Western Disturbances (Post Rabi)

Spatio-Temporal Reservoirs Characteristics

Red Shortwave Infra-Red Water Index





Monsoon (Pre Kharif)

Spatio-Temporal Reservoirs Characteristics

Reservoir Dynamics by Water Surface Area

Year	Monsoon (%)		Post Monsoon (%)		Post Western Disturbances (%)	
	Tarbela	Pong	Tarbela	Pong	Tarbela	Pong
1998	88.9	70.4	92.2	99.7	69.0	89.7
1999	98.2	37.6	71.0	93.5	47.2	74.1
Average	93.6	54.0	81.6	96.6	58.1	81.9
2016	90.2	92.8	86.7	90.0	90.0	55.6
2017	87.9	39.7	81.3	88.5	88.5	51.0
Average	89.1	66.3	84.0	89.3	89.3	53.3
Change	**-4.5**	12.3	2.4	**-7.3**	31.2	**-28.6**

Reservoir Dynamics by Water Volume

Year	Monsoon (%)		Post Monsoon (%)		Post Western Disturbances (%)	
	Tarbela	Pong	Tarbela	Pong	Tarbela	Pong
1998	71.7	60.7	76.8	99.3	44.2	90.0
1999	93.0	31.3	49.0	93.8	40.1	64.1
Average	82.4	46.0	62.9	96.6	42.2	77.1
2016	69.5	92.8	65.2	90.2	47.4	34.7
2017	68.7	32.9	56.6	88.8	44.2	42.7
Average	69.1	62.9	60.9	89.5	45.8	38.7
Change	**-13.3**	16.9	**-2.0**	**-7.1**	3.6	**-38.4**

Conclusion

Conclusion

Key findings are:

- DEMs data from different sources have inherit differences and errors which must be considered for site specific hydro-ecological analysis.
- SWAT model based watershed delineation from DEMs revealed that there are no large differences between two basins but internal sub-basin characteristics varies.
- Landsat Water Indices quite helpful in automatic water surface extraction.
- ALOS and SRTM are better for volumetric estimation based on dam water level for Tarbela Dam while Aster and ALOS are better for Pong Dam.
- Grid based volumetric estimation using DEMs revealed that ALOS overestimated while Aster and SRTM underestimated for Pong. No data are available to evaluate predicted volume in case of Tarbela dam.

Conclusion

- Maximum volume latitudinal/longitudinal DEMs based analysis revealed distinctive water storage profiles for both reservoirs.

- Spatio-temporal evaluation is based on three seasons i.e., Monsoon, Post Monsoon and Post Western Disturbances and change is documented for water surface area and volume for both reservoirs.

  i. Tarbela reach its maximum level during Monsoon season while Pong dam reach during Post Monsoon

  ii. Tarbela command area is facing shortage of irrigation water for Rabi and Kharif cropping season while Pong although not currently directly linked with canal irrigation system is only facing shortage during Rabi season.

- The study demonstrated an effective use of Space Technology through research study on trans-boundary hydro-ecological and spatio-temporal characterization of large water reservoirs