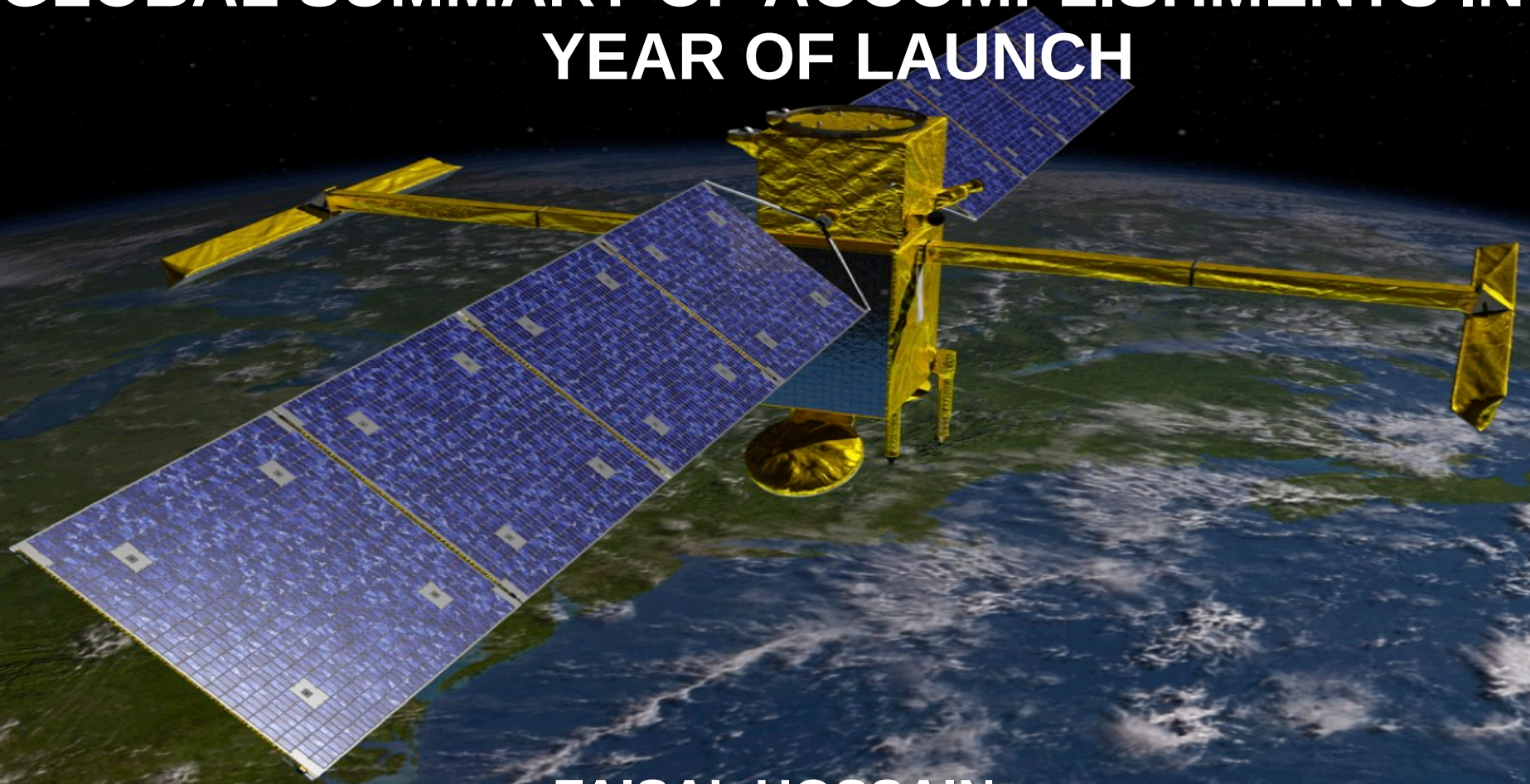
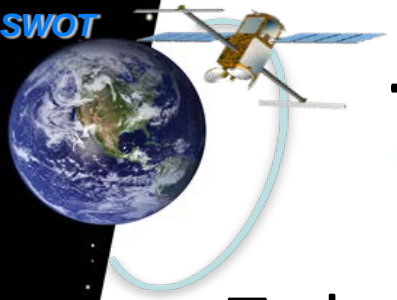
ANTICIPATED HIGH IMPACT SWOT APPLICATIONS: A GLOBAL SUMMARY OF ACCOMPLISHMENTS IN THE YEAR OF LAUNCH



FAISAL HOSSAIN
(On behalf of SWOT Application Leads)

Supported by NASA Applied Science Program (Bradley Doorn), CNES-French Investment Program



THE REAL MISSION OF SWOT APPLICATION ACTIVITIES

To build awareness and literacy of the SWOT Mission on:

- ***Why, What and How SWOT will measure***
- ***Expected SWOT data, its format/structure and availability***
- ***Expected ancillary services and functions for data handling***
- ***User-centric application potential & relevance to current missions/resources***

For a growing and global audience of potential users so that real-world and honestly-brokered societal applications based on SWOT data and SWOT science are accelerated around the world

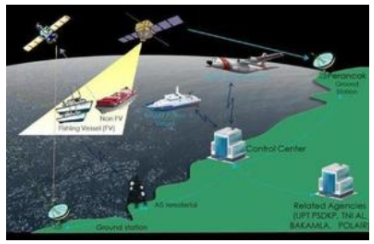
OUR ULTIMATE VISION (After 2024)

- Establish a **self-sustaining mechanism for generation of SWOT success stories** that show SWOT value for issues of societal relevance
- Create **news headlines and press releases** on successful application of SWOT data serving critical needs at local, regional and global scales.

SWOT REVOLUTIONALIZES SUSTAINABLE FISHERIES

Smart satellite technology for inclusive & sustainable fishing practices in Indonesia

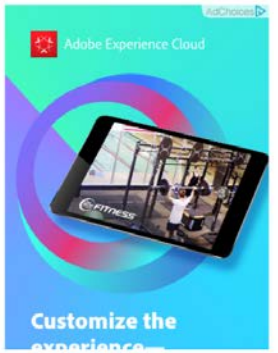
Published 26 January 2017
From: UK Space Agency



Credit: Inmarsat

Economic Policy

SWOT IMPROVES LIVELIHOODS IN COASTAL FORESTS



FIRST, SOME BEAN COUNTING (2016-2021)

- **SEVEN** Application Workshops, **TWO** Virtual Hackathon Delivered
- **SWOT EARLY ADOPTER PROGRAM** (EAP) launched in 2018
- **TWENTY-TWO** agencies signed up as SWOT Early Adopters
- **NINE** wide-audience dissemination articles on SWOT (BAMS, ASCE, EOS, AWRA, SERVIR)
- **FOURTEEN** peer-reviewed research published by SWOT Early Adopter lead authors since 2018 [*8 of them directly related to SWOT Early Adopter Projects*]
- **DEMONSTRATION** of value of SAWG for SWOT Science Team at *no additional cost*

Examples of value added by SWOT Applications:

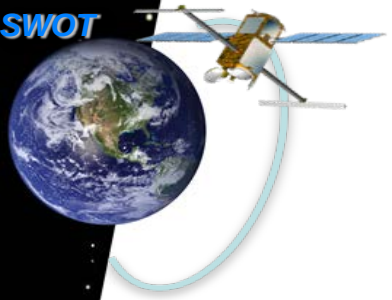
1. **More than 100** Lakes gauged/to-be-monitored in **FIVE** countries via SWOT Early Adopter Program – USA/Texas, Pakistan, Nepal, India, Bangladesh (**Many** under SWOT 1-Day Orbit);

2. **Acoustic Doppler Current Profiler Data** shared by SWOT Early Adopter for SWOT Discharge Algorithm Working Group.

BUT WHO IS BEAN COUNTING?

WHAT ARE THE REAL STORIES THAT WILL BE TOLD TO THE BROADER SCIENTIFIC COMMUNITY AND GENERAL PUBLIC ON ANTICIPATED GLOBAL IMPACT OF SWOT MISSION THROUGH APPLICATIONS?

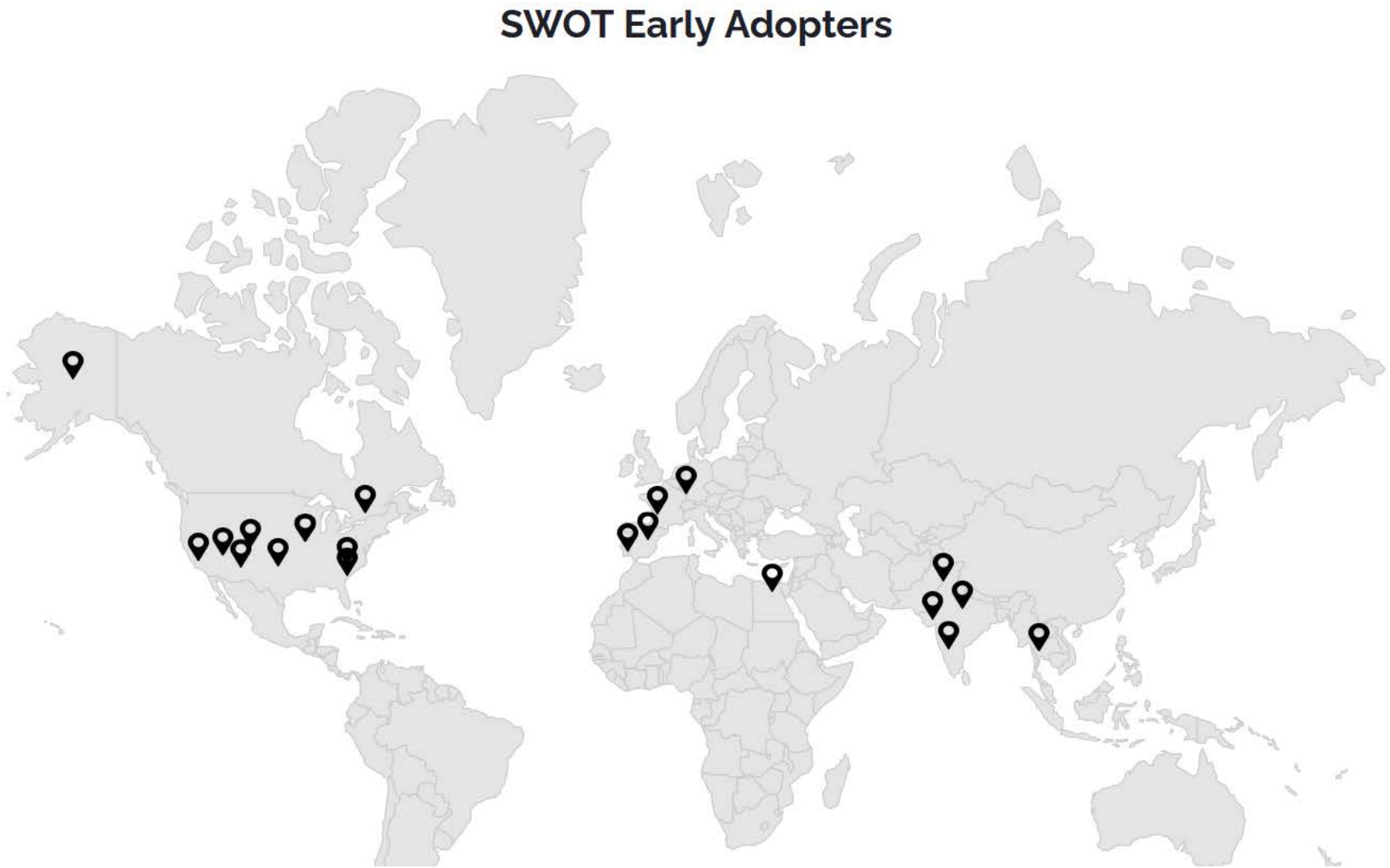
IN OTHER WORDS, ***HOW EXACTLY IS SWOT LIKELY TO IMPROVE THE PRE-SWOT BASELINE AND WHAT IS THE EVIDENCE SO FAR?***



IT IS TIME TO TAKE STOCK OF LIKELY SWOT APPLICATION STORIES AFTER LAUNCH

- We will review select Early Adopter projects that have made most progress in developing user-readiness for the SWOT mission by the end of 2021
- These Early Adopters are most likely to deliver real-world success stories that the broader community and public will understand after 2023
- These Early Adopters are most likely to demonstrate the return in public investment of the SWOT Mission for the greater good to address critical needs at local, regional or global scales.

THE GLOBAL FOOTPRINT OF SWOT APPLICATION ACTIVITIES



Total – **TWENTY-TWO entities interested in getting ready for SWOT**

Visit http://swot.jpl.nasa.gov/applications or http://depts.Washington.edu/saswe/swot

TEXAS WATER DEVELOPMENT BOARD (TWDB)

THE SOCIETAL NEED: Being able to monitor evaporative water loss from all reservoirs of Texas (unmonitored or monitored) by Texas Water Development Board is a critical need that will lead to improved assessments of surface water availability in the state.

THE SPECIFIC PROBLEM: Of the over 7,000+ dams (lakes/reservoirs) in Texas, only 119 are gauged for water level monitoring.

THE SWOT-BASED SOLUTION: SWOT's ability to track water elevation and area/extent will equip TWDB with a monitoring capability that covers all unmonitored water bodies that are greater than 250 m × 250 m. SWOT's storage change data will also help TWDB with a more accurate inventory of water gained through precipitation or depleted through evaporation/water use, leading to improved forecasts of water availability for Texans.

IMPACT OF SWOT APPLICATIONS - TWDB

1. TWDB has built literacy on satellite-based water area classification, cloud computing and set up of CNES SWOT simulator via SWOT Hackathons in 2021.

2. A **multi-sensor SWOT reservoir area estimation tool** has been developed that allows TWDB to estimate with uncertainty the reservoir surface area to quantify evaporative losses using pre-SWOT sensors (Landsat, Sentinel-1, Sentinel-2). This tool can also handle the data structure expected from SWOT for L2 lake products such as *L2_HR_LakeAvg, L2_HR_Raster.*

3. The monitored and recently surveyed reservoirs (such as Lake Buchanan) will serve as validation/verification of the tool

4. This multi sensor tool will help SWOT's calibration/validation of lake products for lakes under SWOT 1-day orbit in Texas.

New technologies

Collison Evaporation Pan
(upper-left, direct measure)

Eddy Covariance
(lower-left, flux)

Buoy Weather Station
(right, aerodynamic method)

Supported by:
TWDB, USBR, USACE, DRI,
TAMU, LCRA, …….

IMPACT OF SWOT APPLICATIONS - TWDB

Experimental Multi-sensor Texas Reservoir Area Estimation for TWDB

An Operational SWOT Early Adopter Program Tool Co-developed by TWDB and University of Washington SASWE Research Group

Calculate Reservoir / Lake area for a time period.

Reservoir:

Enter Reservoir Name

Start Date:

01 / 01 / 2013

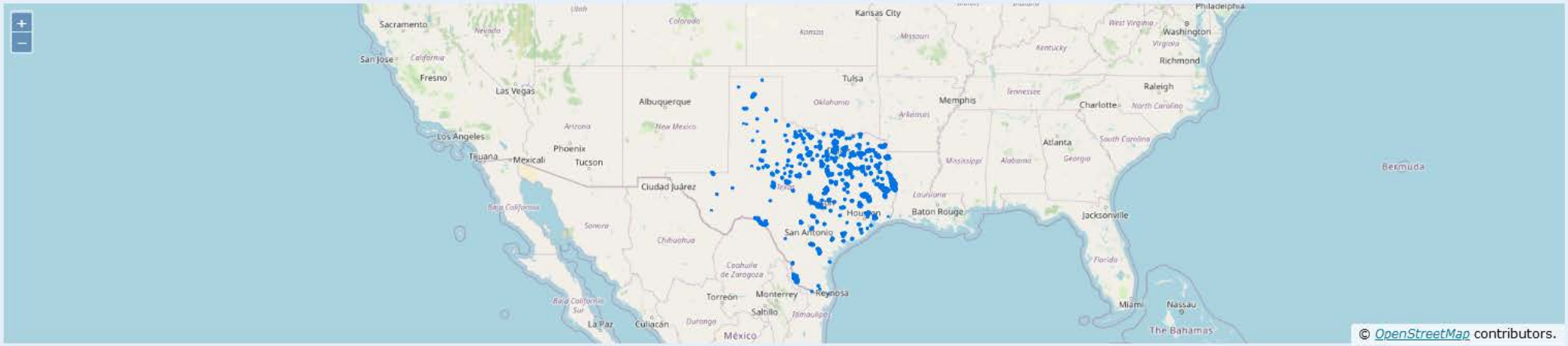
End Date:

01 / 01 / 2021

Cloud Cover:

Percentage: 20

Plot Time Series



Plot time series of any reservoir/lake in Texas by following the below instructions:

1. Enter/Select a reservoir name. You can select it interactively using map as well.
2. Enter a start date for the time series.
3. Enter an end date for the time series.
4. Select an acceptable percentage of cloud cover over the reservoir for time series computation.
5. Click on 'Plot Time Series'.

GitHub Code

Texas Water Development Board – Surface Water

Surface Water and Ocean Topography Mission

SWOT Applications Landing Page

SWOT Early Adopter Success Stories

UW SASWE Research Group

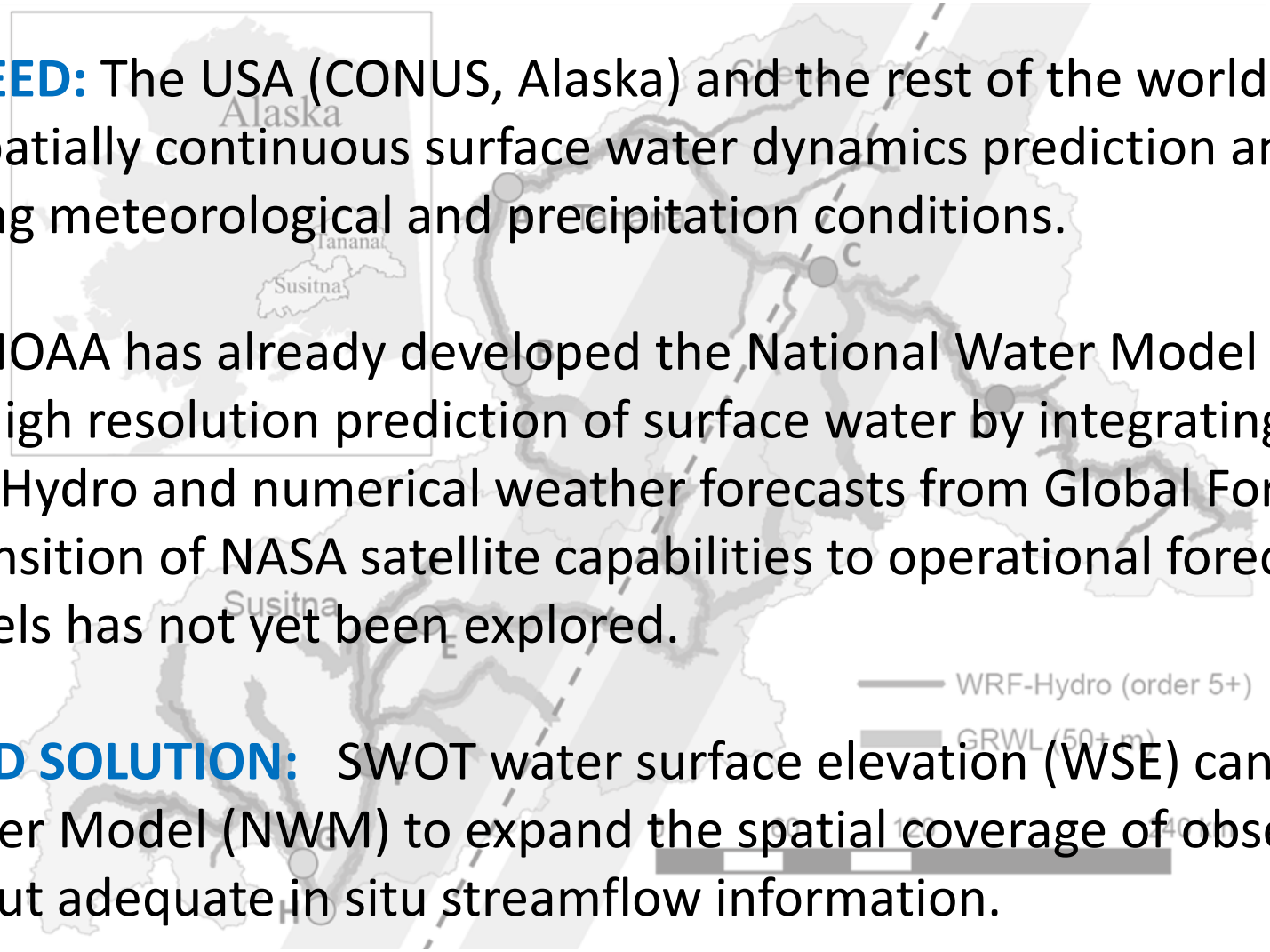
Visit http://depts.Washington.edu/saswe/TexasLakes

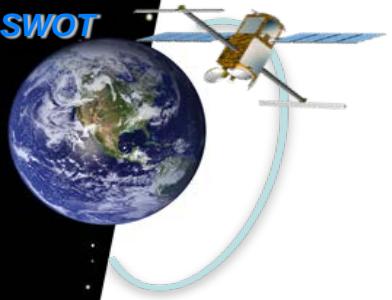
NASA SPoRT

THE SOCIETAL NEED: The USA (CONUS, Alaska) and the rest of the world require high resolution and spatially continuous surface water dynamics prediction and forecasting based on changing meteorological and precipitation conditions.

THE PROBLEM: NOAA has already developed the National Water Model for spatially continuous and high resolution prediction of surface water by integrating advanced routing schemes in WRF-Hydro and numerical weather forecasts from Global Forecasting System. However, the transition of NASA satellite capabilities to operational forecasters and operational models has not yet been explored.

THE SWOT-BASED SOLUTION: SWOT water surface elevation (WSE) can be assimilated into the National Water Model (NWM) to expand the spatial coverage of observations to regions of the USA without adequate in situ streamflow information.



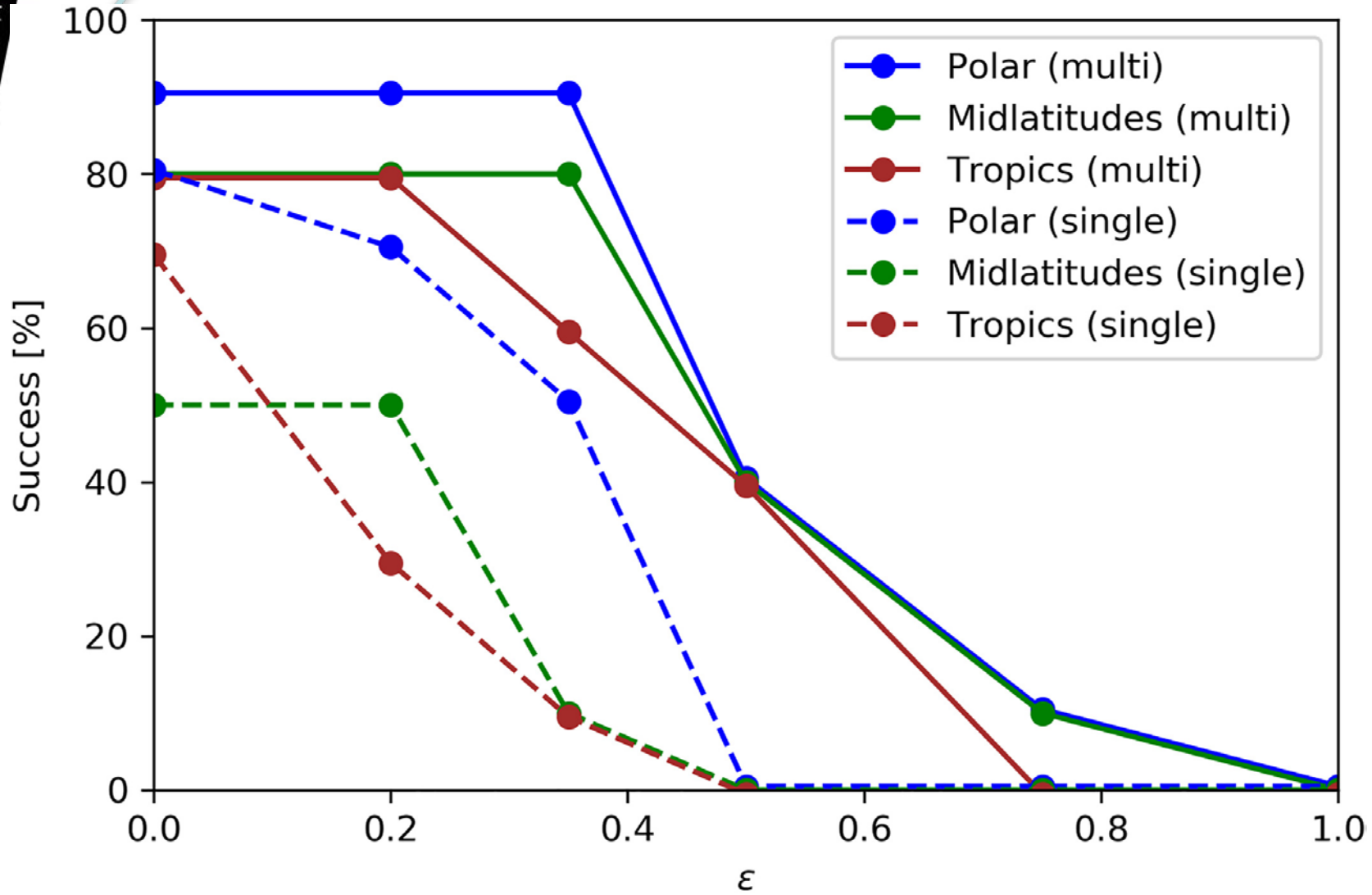


IMPACT OF SWOT APPLICATIONS - NASA SPoRT

1. NASA SPoRT developed a **SWOT CNES Simulator Tutorial** with examples for running CNES Large-scale Hydrology Simulator. SPoRT also provided several codes for processing time series of water surface elevation inputs and enriched the CNES github page for SWOT simulator.

2. NASA SPoRT has demonstrated the robustness of parameter calibration for hydrodynamic-hydrologic models using multi-point water surface data (that will be available from SWOT) when compared to single-point water surface data (that is the current pre-SWOT norm today).

IMPACT OF SWOT APPLICATIONS - NASA SPoRT



Probability of successful single (pre-SWOT) and multi-point (SWOT) parameter selection (%) for each latitude zone as a function of relative measurement random error (ε).

[Based on SWOT Early Adopter Project by Dr. Elmer, formerly with NASA SPoRT]

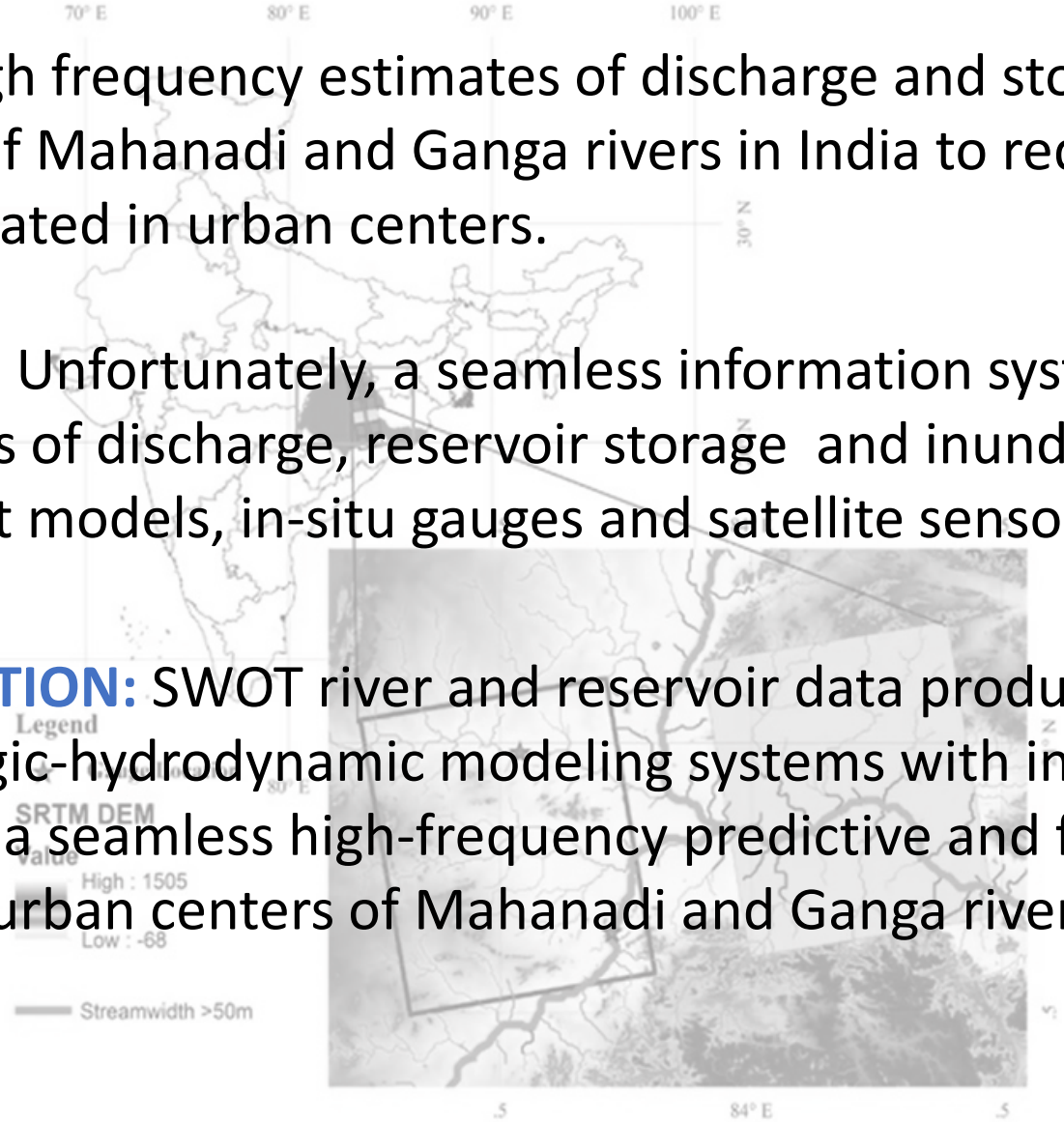
Elmer, N. J., McCreight, J., & Hain, C. (2021). Hydrologic model parameter estimation in ungauged basins using simulated SWOT discharge observations. *Water Resources Research*, 57, e2021WR029655.

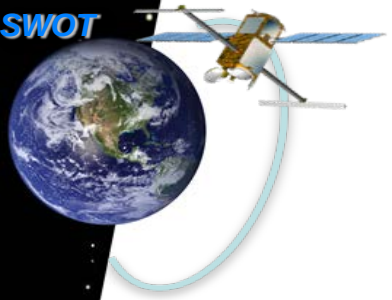
INDIAN INSTITUTE OF TECHNOLOGY - BOMBAY

THE SOCIETAL NEED: High frequency estimates of discharge and storage are needed in river-reservoir systems of Mahanadi and Ganga rivers in India to reduce and adapt to flood risks for stakeholders located in urban centers.

THE SPECIFIC PROBLEM: Unfortunately, a seamless information system that can provide high frequency estimates of discharge, reservoir storage and inundation without gaps is not possible with current models, in-situ gauges and satellite sensors.

THE SWOT-BASED SOLUTION: SWOT river and reservoir data products can be assimilated operationally in hydrologic-hydrodynamic modeling systems with in-situ gauges and other satellite sensors to build a seamless high-frequency predictive and forecasting tool for stakeholder agencies of urban centers of Mahanadi and Ganga river basins.





IMPACT OF SWOT APPLICATIONS – IIT BOMBAY

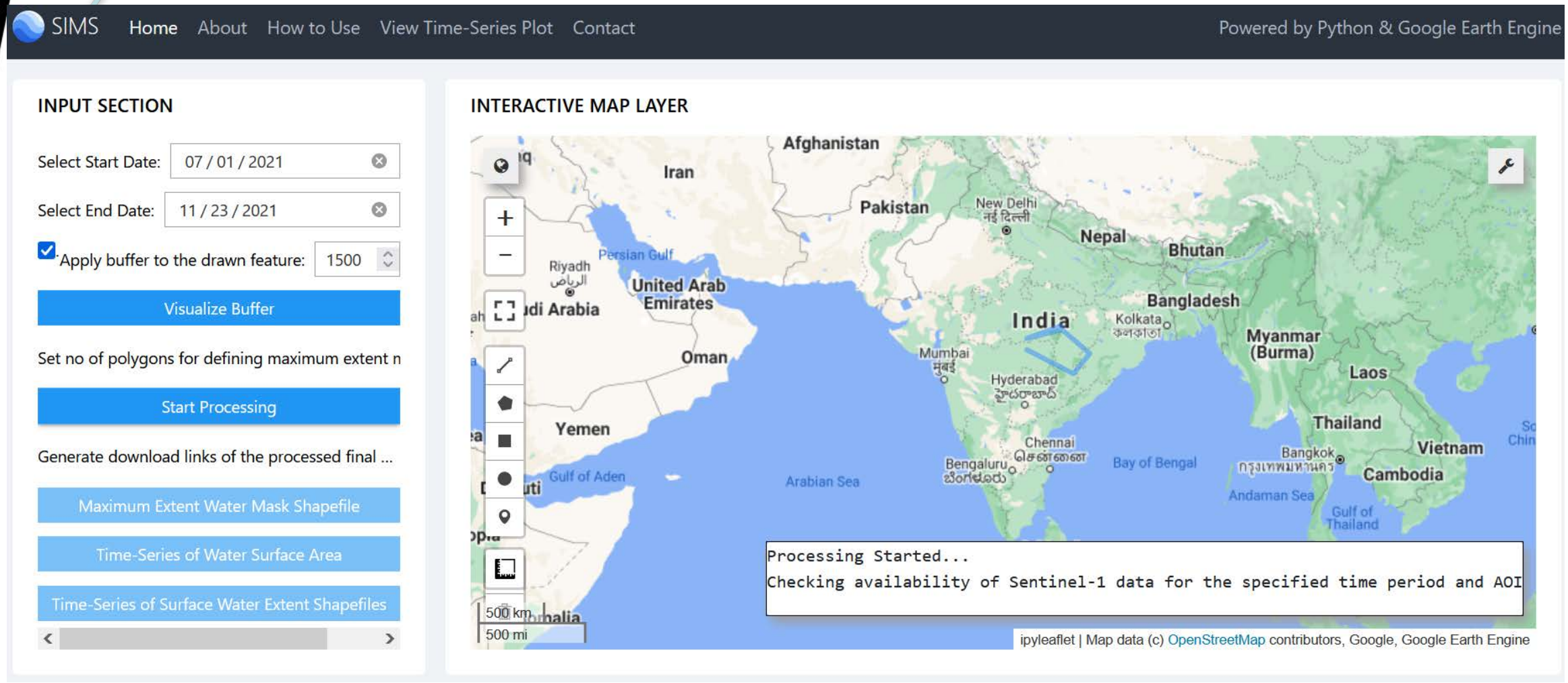
1. IIT Bombay developed, tested and made available an open-source Sentinel-1 based Inland water dynamics Mapping System **(SIMS)** for the SWOT community. **SIMS** can be used to prepare water surface inputs to SWOT simulator for designing and testing of an operational high-frequency data assimilation forecasting tool.

2. IIT Bombay successfully set up CNES SWOT large-scale simulator over Mahanadi river basin to develop data assimilation scheme for operational flood forecasting systems

3. IIT Bombay published three peer-reviewed papers based on Early Adopter Project.

4. IIT Bombay provided SWOT simulated data for USGS (new SWOT Early Adopter); Acted as a helper for other Early Adopters during SWOT Virtual Hackathon in 2021

IMPACT OF SWOT APPLICATIONS – IIT BOMBAY



Sentinel-1 based Inland water dynamics Mapping System (SIMS)

https://sims-toolkit.herokuapp.com/

ASIAN DISASTER PREPAREDNESS CENTER (ADPC)

THE SOCIETAL NEED: Rivers in Southeast Asia, such as the Chindwin River in Myanmar, Tonle Sap River in Cambodia, transboundary Mekong River, are prone to flooding. In such rivers, stakeholders require an accurate prediction, modeling or monitoring of inundation extent during flood events for early flood preparedness or to plan disaster response and relief operations.

THE SPECIFIC PROBLEM: Conventional ground-based monitoring stations are very limited in Southeast Asia, and institutional barriers constrain current capacity to observe and predict flood inundation.

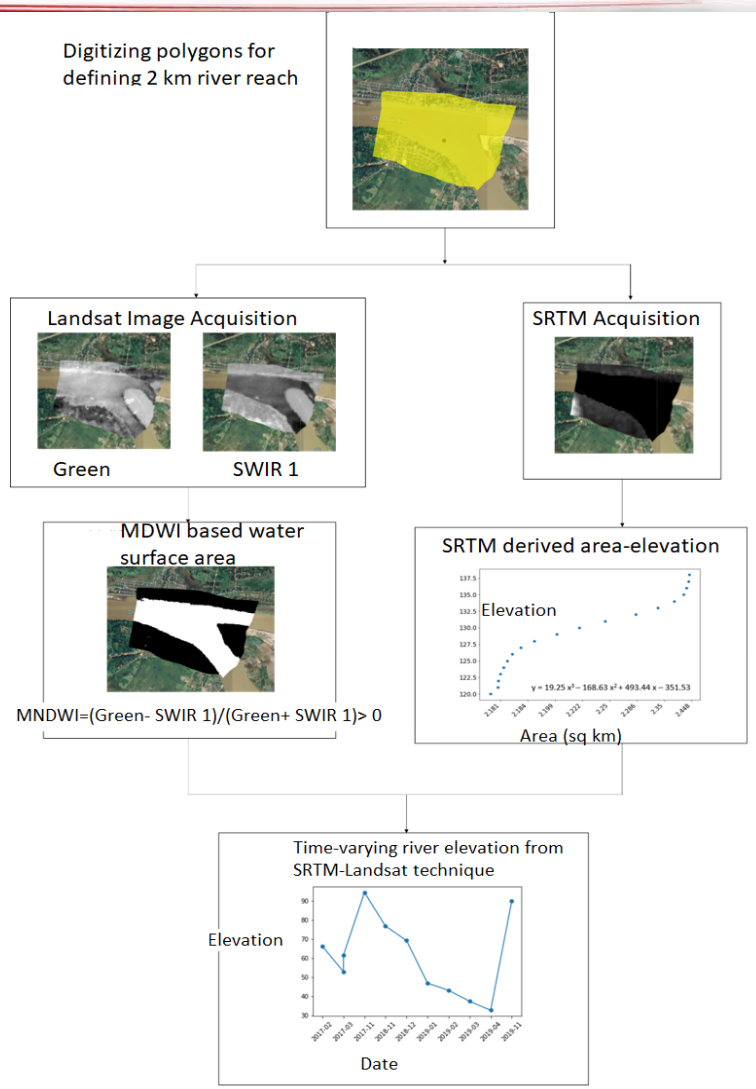
THE SWOT-BASED SOLUTION: SWOT's river width with elevation over a long period of time, combined with baseline river bathymetry derived from optical sensors (Landsat) and SRTM DEM data can provide a formidable source of river hydraulic data required to setup a high resolution flood inundation model.

IMPACT OF SWOT APPLICATIONS - ADPC

1. ADPC published one peer-reviewed publication in *ASCE Journal of Hydrologic Engineering* based on SWOT Early Adopter project - selected as EDITOR'S CHOICE

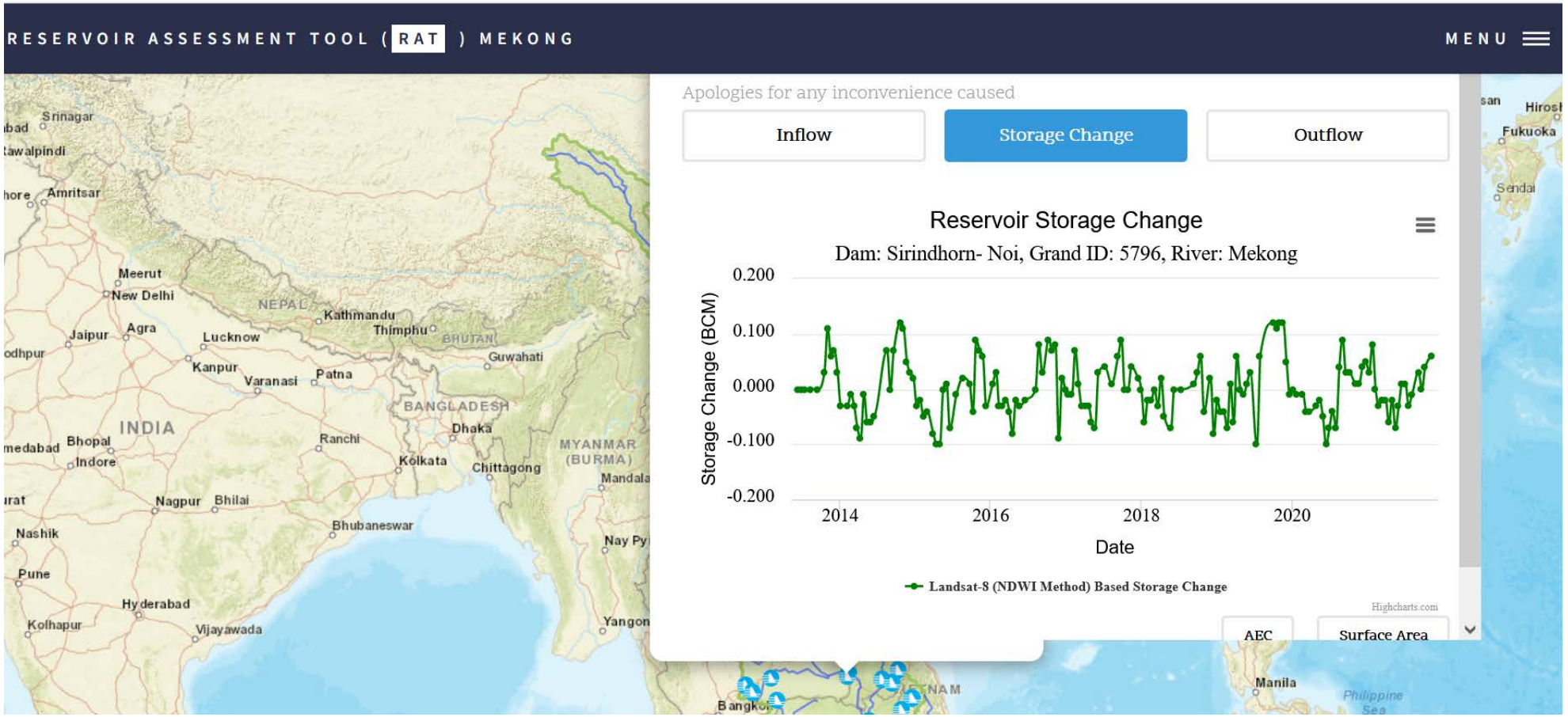
2. ADPC co-developed a method for baseline characterization of river bathymetry and time varying heights using globally available datasets from Shuttle Radar Topography mission (SRTM) elevation data and Landsat visible imagery. This method can use SWOT floodplain DEM product and SWOT river width data.

3. ADPC has prototyped a Reservoir Assessment Tool (**RAT-Mekong**) for the Mekong river basin. The tool will ingest SWOT L2 lake data



Journal of Hydrologic Engineering
Vol. 26, Issue 11 (November 2021)

IMPACT OF SWOT APPLICATIONS - ADPC



Reservoir Assessment Tool for Mekong

at http://58.137.55.230/ or http://depts.Washington.edu/saswe/mekong

CENTRE FOR WATER RESOURCES DEVELOPMENT AND MANAGEMENT (CWRDM)

THE SOCIETAL NEED: The Indian state of Kerala is home to Western Ghats that nourish many lakes of varying shapes and sizes. These need to be monitored of its change in storage to track the impact on vital eco-system services, recreational environment and livelihood needs.

THE PROBLEM: Lakes of Kerala (and the world) today are poorly gauged of their storage change due to scarce in-situ network for lake monitoring and sheer number and widespread nature of lakes.

THE SWOT-BASED SOLUTION: SWOT will provide lake storage data for most lakes around the world as small as 250mX250m. Most of Kerala lakes are under the SWOT 1-day orbit. By installing in-situ gauges at select lakes under a Citizen Science scheme, the power of citizen scientists can be leveraged to gather lake elevation data, which can then be used to validate/calibrate SWOT lake storage estimates for similar environments around the world.

IMPACT OF SWOT APPLICATIONS - CWRDM

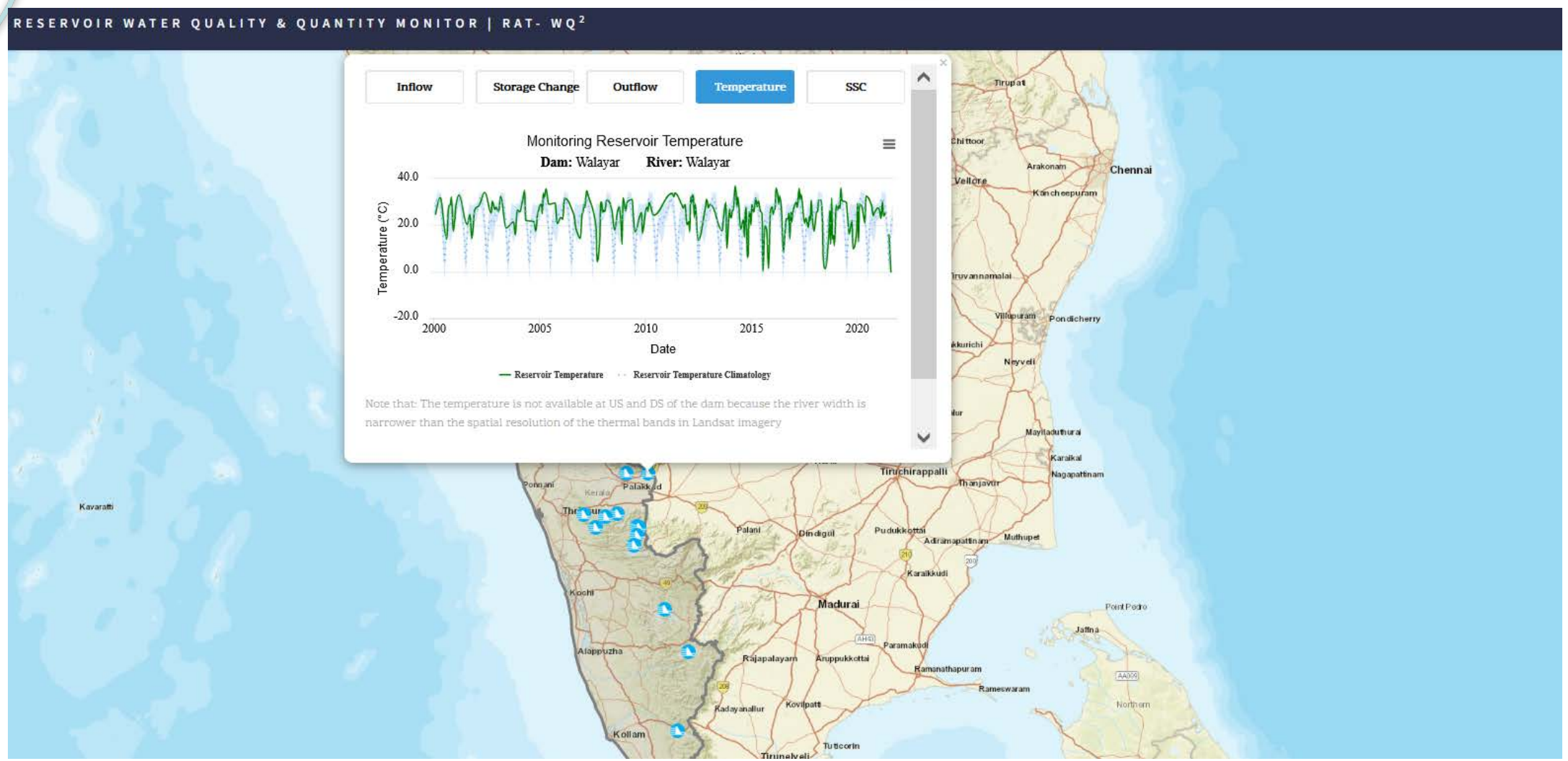
1. CWRDM has installed citizen science gauge over Lake Pookode (under SWOT 1 day orbit) in collaboration with SWOT Early Adopter from IITB (Dr. Indu Jayaluxmi) and NASA Project Lake Observations by Citizen Scientists and Satellites (Dr. Tamlin Pavelsky).

2. Automatic sensors are being installed for validation of citizen science lake height data with plans for expansion to more lakes.

3. CWRDM attended **SWOT Virtual Hackathon 2021** and received training from hacker helpers of University of Washington, IITB and IITD to master the processing of satellite altimeter data over lakes.

4. CWRDM helped prototype and launch a **Reservoir Assessment Tool for Water Quantity and Water Quality (RAT-WQ2)** for Kerala which will operationally assimilate SWOT L2 lake data product.

IMPACT OF SWOT APPLICATIONS - CWRDM



RESERVOIR ASSESSMENT TOOL (RAT) – WATER QUANTIY AND QUALITY (WQ^2) – KERALA

Visit – http://depts.Washington.edu/saswe/kerala

PAKISTAN COUNCIL OF RESEARCH IN WATER RESOURCES (PCRWR)

THE SOCIETAL NEED: In the semi-arid regions of Sindh in Pakistan, wetlands are rapidly appearing and expanding due to water logging and unplanned urbanization. Pakistan also has several transboundary rivers that carry flood waters from across the international border into its reservoirs (such as Mangla reservoir on Jhelum river). These 'artificial' wetlands and reservoirs require constant monitoring to mitigate the negative impacts of artificial wetlands or transboundary flooding.

THE SWOT-BASED SOLUTION: SWOT-based discharge and reservoir estimates of level and storage change for Indus river systems and Mangla reservoir can be used for calibration/validation of forecasting models as well as for assimilation. SWOT lake (high resolution) data can be used to detect and track the suddenly appearing wetlands in Sindh to adapt land use mitigation measures.

لاہور: منگلا ڈیم کے سپل وے سے پانی کا اخراج ہو رہا ہے۔ (فوٹو این این آئی)

IMPACT OF SWOT APPLICATIONS - PCRWR

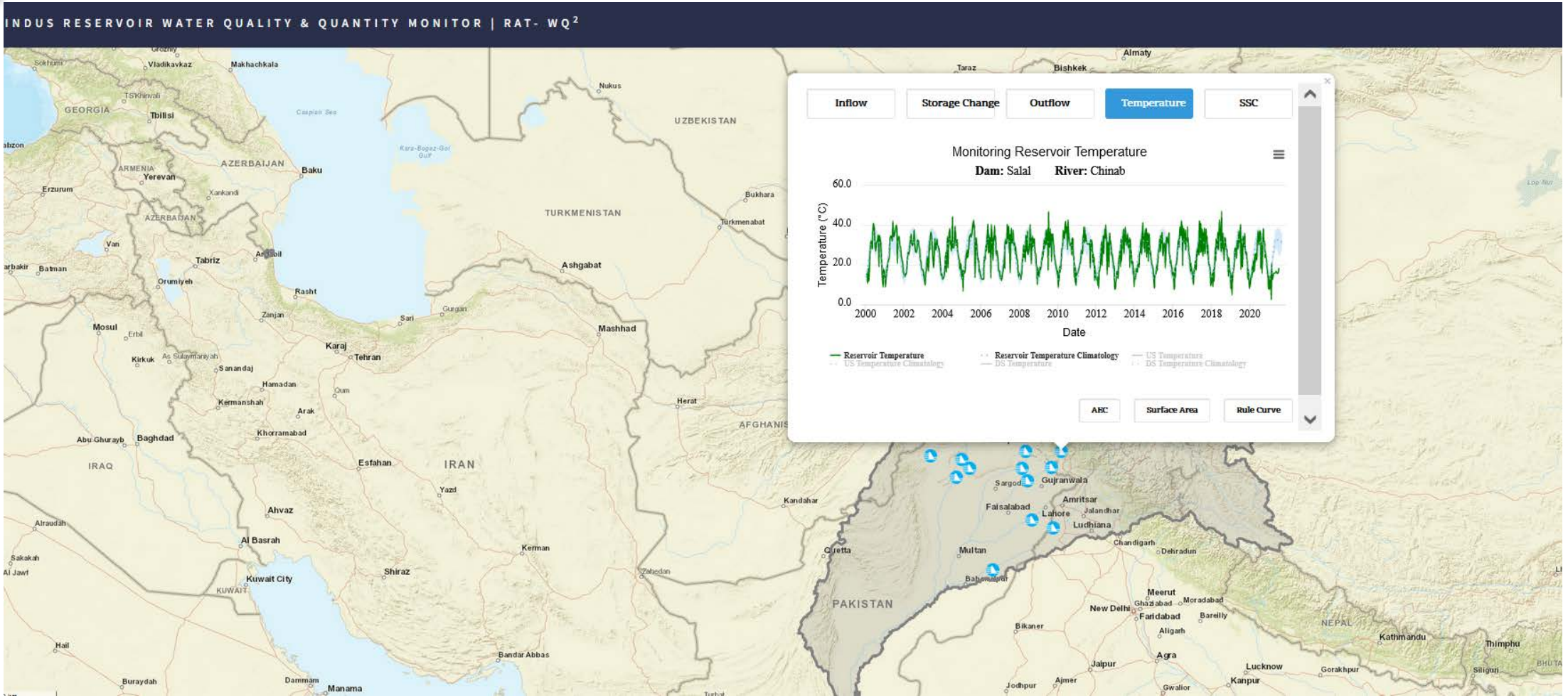
1. PCRWR attended two **Virtual SWOT Hackathons** in 2020 and 2021 and mastered the use of satellite altimeter data and CNES Large-scale Hydrology simulator.

2. PCRWR, in collaboration with University of Washington, has prototyped a Reservoir Assessment Tool for Water Quantity and Water Quality (**RAT-WQ^2**) for Indus river systems. RAT-WQ2 will assimilate SWOT L2 data product on lakes and discharge after 2022.

3. PCRWR contributed high value Acoustic Doppler Current Profiler (ADCP) measurements for two Indus Rivers for potential use by SWOT Discharge Algorithm Working Group of SWOT Science Team.

4. PCRWR contributed to the set up of citizen-based monitoring of two lakes in Pakistan for SWOT Lake Citizen Science led by Dr Tamlin Pavelsky and Dr. Jean-Francois Cretaux.

IMPACT OF SWOT APPLICATIONS - PCRWR

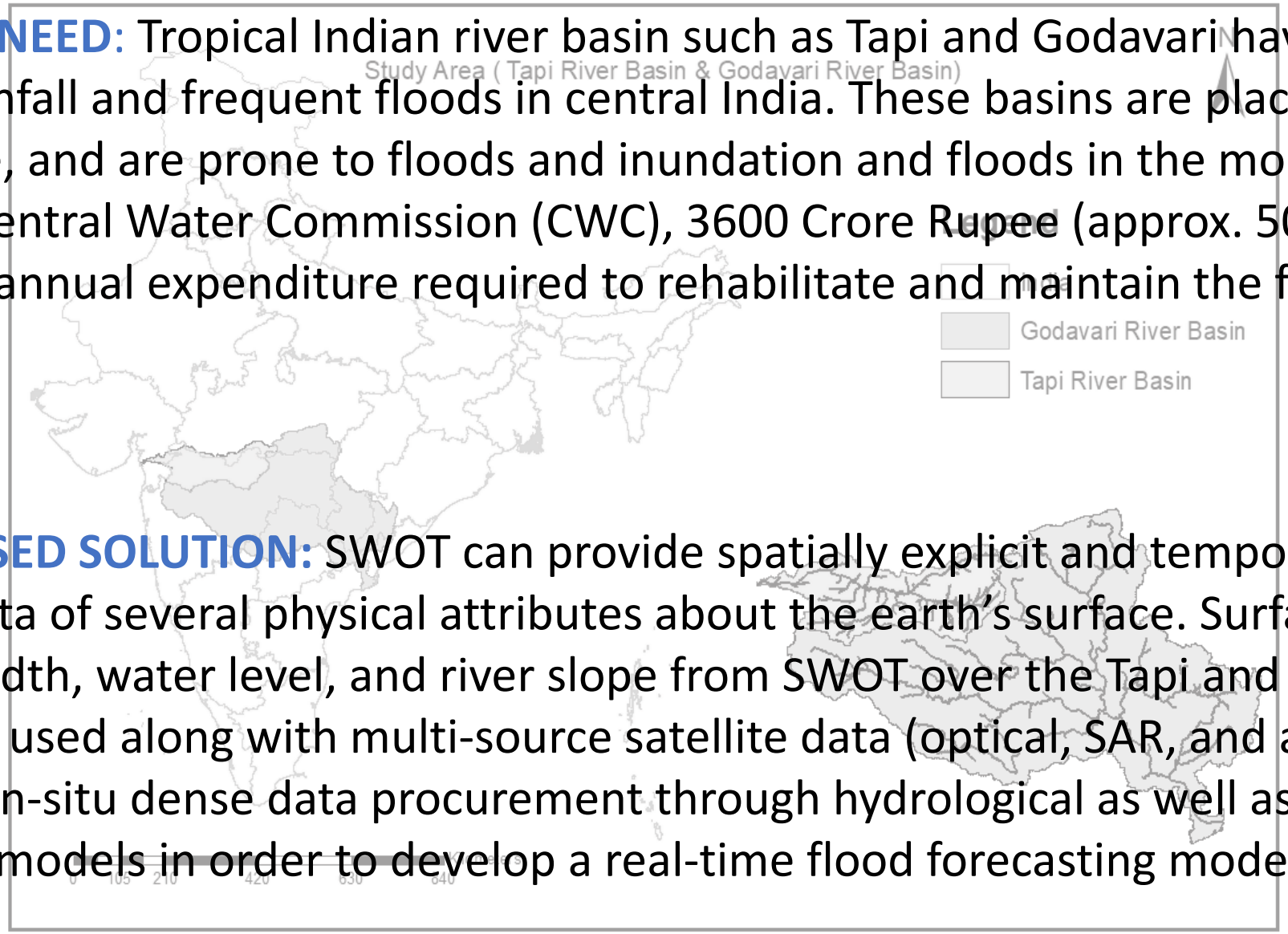


RESERVOIR ASSESSMENT TOOL (RAT) – WATER QUANTIY AND QUALITY (WQ^2) – INDUS

Visit – http://depts.Washington.edu/saswe/Indus

INDIAN INSTITUTE OF TECHNOLOGY - DELHI

THE SOCIETAL NEED: Tropical Indian river basin such as Tapi and Godavari have high intensity of rainfall and frequent floods in central India. These basins are placed in the rainstorm zone, and are prone to floods and inundation and floods in the monsoon season. According to Central Water Commission (CWC), 3600 Crore Rupee (approx. 500 million USD) is India's annual expenditure required to rehabilitate and maintain the floods' damages.



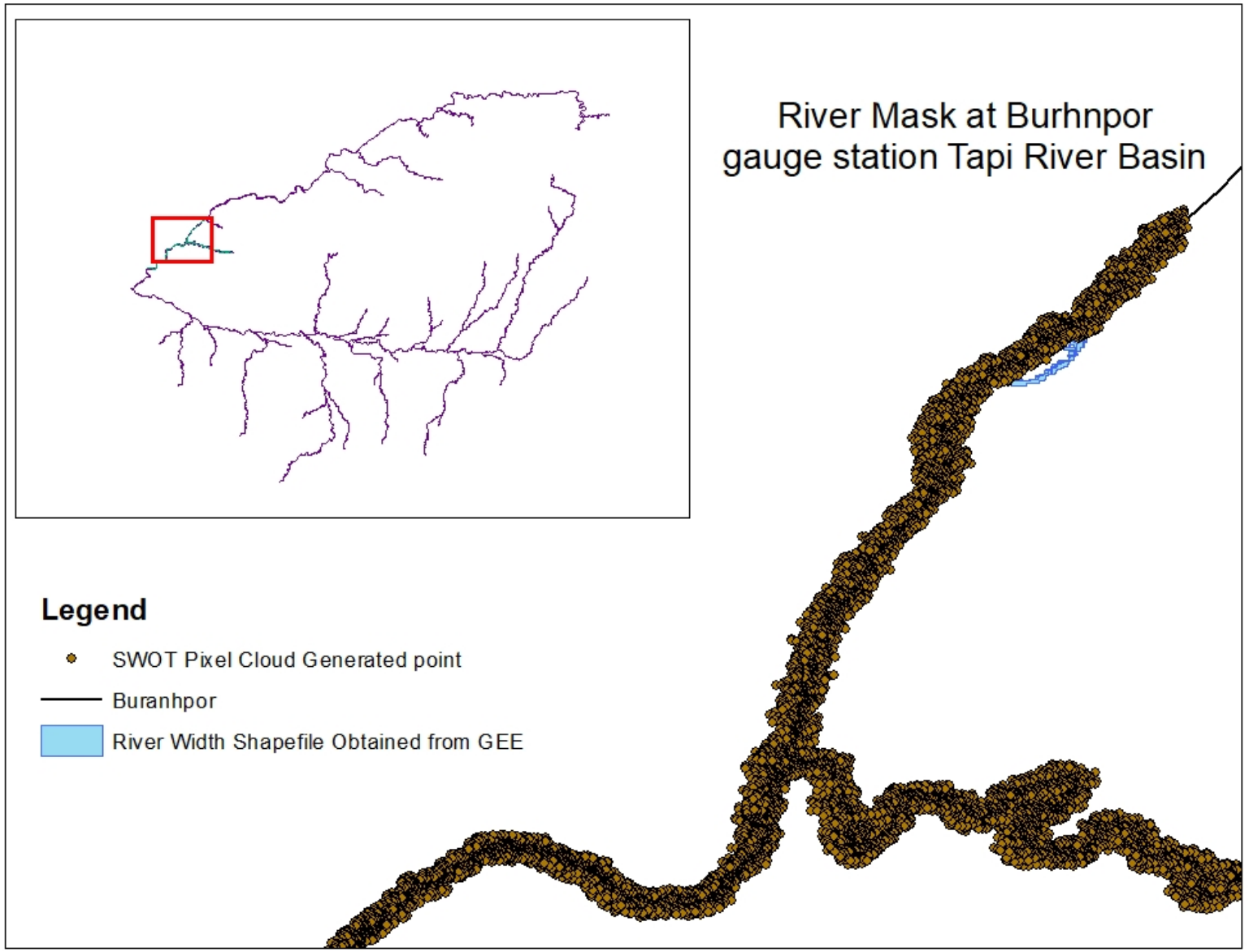
THE SWOT-BASED SOLUTION: SWOT can provide spatially explicit and temporally frequent observation data of several physical attributes about the earth's surface. Surface water extent, river width, water level, and river slope from SWOT over the Tapi and Godavari river reaches can be used along with multi-source satellite data (optical, SAR, and altimeter satellites) and in-situ dense data procurement through hydrological as well as hydrodynamic models in order to develop a real-time flood forecasting model.

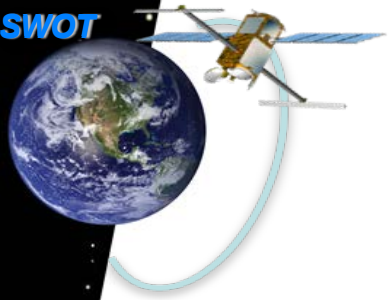
IMPACT OF SWOT APPLICATIONS – IIT DELHI

1. IIT Delhi attended two Virtual SWOT Hackathons and offered assistance for other Early Adopters as trainers.

2. IIT Delhi set up Hydraulic and Hydrologic models from the MIKE suite for the Godavari River basin. CNES Large Scale simulator is being mastered for exploring data assimilation and model calibration exercises.

IMPACT OF SWOT APPLICATIONS – IIT DELHI





LOOKING INTO THE FUTURE

- Since 2016 SWOT Applications program has expanded awareness of SWOT's societal value and generated anticipation for SWOT data among potential users.
- SWOT Applications program pioneered infrastructure for 24/7 community-driven online education/training for building technical literacy on SWOT.
- Many SWOT Early Adopters are doing application-critical science; providing cal/val infrastructure for lake data product, and adding value to Science Team activities at no additional cost.
- SWOT Early Adopter Program continues to grow every year (current total is 22 spanning Americas, Europe, Asia & Africa, private/public and research sectors).

FINAL THOUGHTS: WHO ARE WE REALLY?

Extra-topical (non-SWOT) scientists; Agencies, Private/Public Sectors of Economy; Local/Indigenous communities; Countries; Regional/Global Institutions

- SWOT Applications program is a draw bridge working towards the ‘down’ position.
- Scientists need real-world data and feedback from users for continuous quality improvement;
- Users need tangible solutions based on scientific knowledge and data from scientists.
- It’s a two-way traffic: One needs the other to improve itself continuously.