

NASA Science Mission Directorate Earth Science Division Applied Sciences Program



Towards Operational Water Resources Management in South Asia
Exploiting Satellite Geodetic and Remote Sensing Technologies
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Jason Brent Roberts, Franklin Robertson

NASA Water Resources PI Meeting
April 26-28, 2016



PROJECT TITLE: OPERATIONAL WATER RESOURCES MANAGEMENT IN SOUTH ASIA

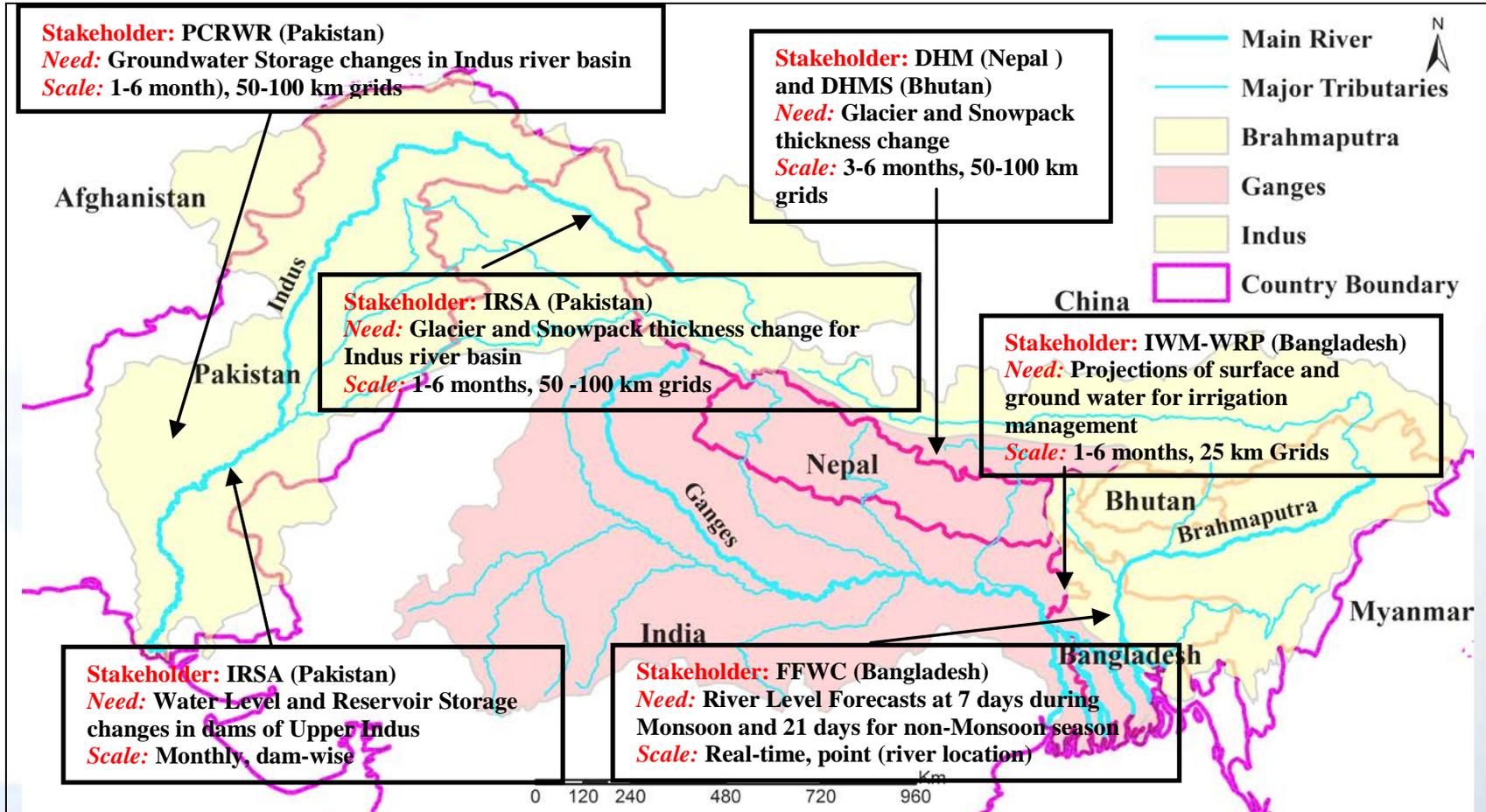
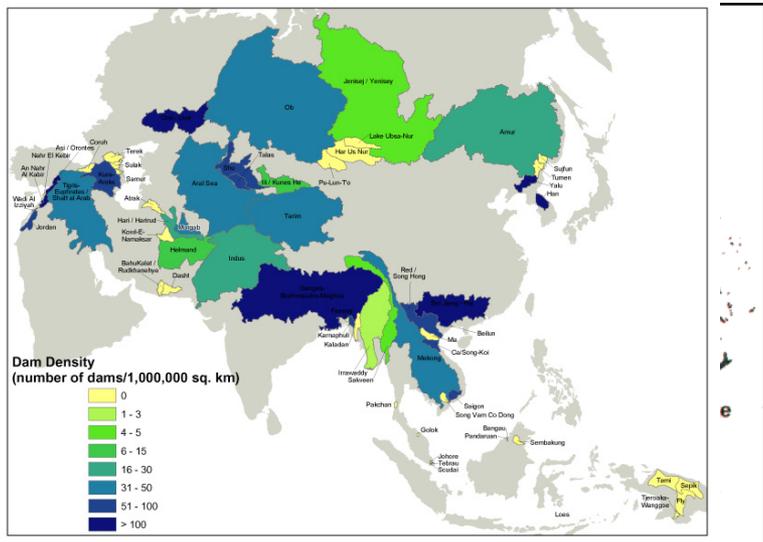


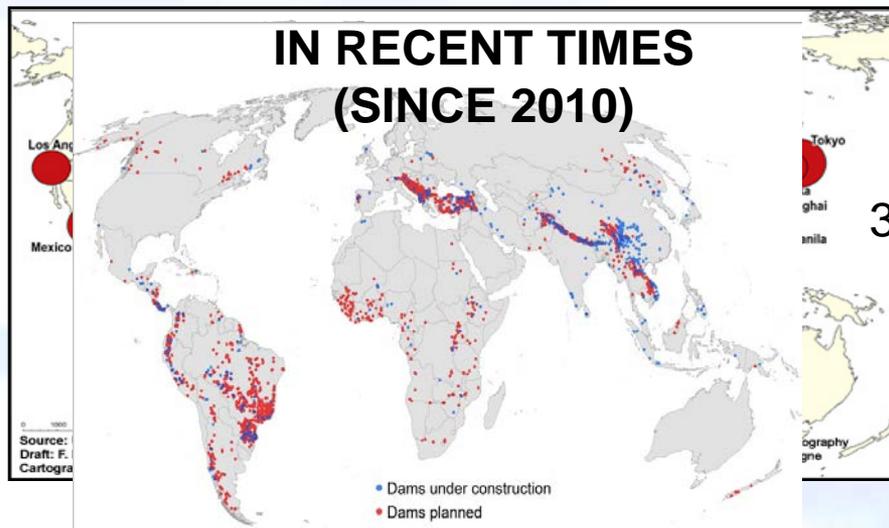
Figure 1. Map showing key water application needs of six end-user water management agencies in the Ganges-Brahmaputra and Indus River basins. FFWC – Flood Forecasting and Warning Center (FFWC-Bangladesh), IWM-WRP (Institute of Water Modeling- Water Resources & Planning-Bangladesh), IRSA (Indus River System Authority – Pakistan), PCRWR (Pakistan Council for Research on Water Resources –Pakistan) and DHM (Department of Hydrometeorology, Nepal), DHMS (Department of Hydromet Services-Bhutan).

STATEMENT OF CHALLENGES / NEED / OPPORTUNITY



What this means for water management in South Asia?

1. Transboundary/Hydropolitics+Development pressures+water demand = **Replumbing of River Basins by Humans**
2. Physical models alone cannot predict the state of water at x,y,z,t given extensive diversion, storage and inter-basin transfer by humans.
3. Assimilation of (space) observations on the state of water needed understand **WHAT IS REALLY HAPPENING** before **MAKING DECISIONS.**

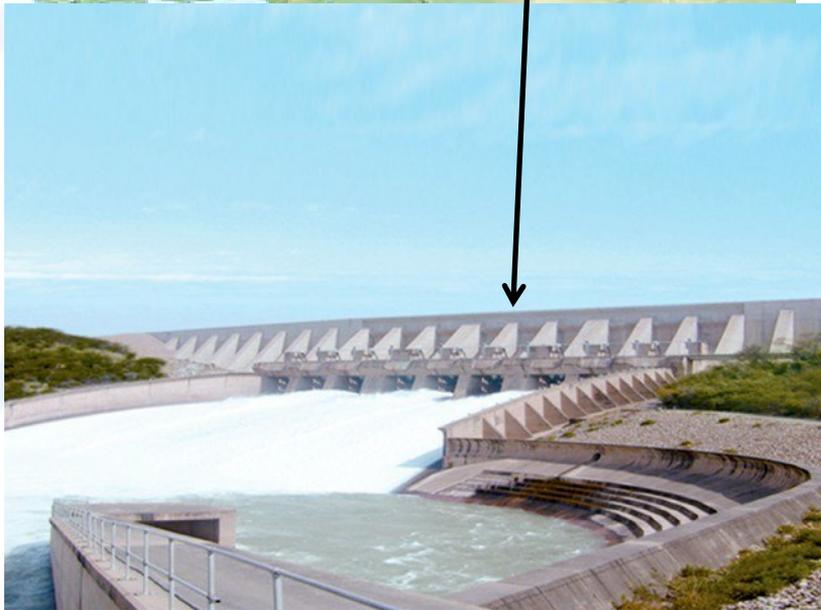


Source: Zarfl et al. 2011

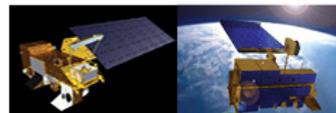
STATEMENT OF CHALLENGES / NEED / OPPORTUNITY



Transboundary flooding or reservoir operation unknown (not shared in real time)



COMPOUND EYE OF SATELLITES FOR OPERATIONAL WATER MANAGEMENT IN THE ANTHROPOCENE OF SURFACE WATER



AQUA and TERRA

Visible and Near Infrared sensing at < 1km and sub-daily scales for routine estimates of land cover and width of large rivers.



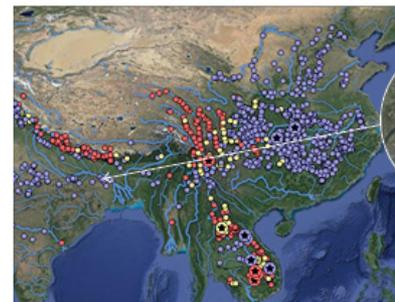
TRMM, GPM and GOES

Microwave and Infrared sensing of precipitation at < 10km and hourly scales for rainfall-runoff transformation, snow and lateral flow estimation in regulated river systems.



Landsat 7 and Landsat 8

Visible and Near Infrared sensing at < 100 meters and monthly scales for estimation of changing river widths of small rivers.



Location of current and planned human regulation of surface water in South and Southeast Asia. Such regulation of surface water by rules set by humans make the use of stand-alone physical models increasingly inadequate without the assistance from the compound eye of water-relevant satellites as shown here.



The Farakka barrage on the Ganges that drastically alters water management complexity between nations (India and Bangladesh) during dry and wet seasons.

Joint use of height and width for more frequent estimate of river regulation
River bathymetry



JASON-2 and Envisat

Microwave nadir altimeter sensing of river levels at weekly timescales for > 300 m wide rivers (JASON-2) and monthly timescales for 150 m wide rivers (AltiKa).



SRTM and SWOT

Microwave sensing of land and water surface at < 100m (weekly for SWOT) for routine estimate of river slopes, reservoir storage change, and floodplain.

PROJECT OBJECTIVES



To reach ARL>7 for operational water management in South Asia for the following:

- 1) Monthly-to-seasonal GRACE-based monitoring and projection of ground water storage anomalies (**Pakistan**) ARL 8-9
- 2) Satellite (GPM/TRMM) Precipitation and Model-based seasonal forecasting of water availability (**All nations**) ARL 5-6
- 3) Satellite-based Mountain water budget monitoring (**Nepal/Bhutan**) ARL 3
- 4) Multi-Satellite Altimetry based monthly-to-3 monthly monitoring and projection of reservoir storage changes (**Bangladesh and Pakistan**) ARL 3-4
- 5) Satellite Altimetry-based long-range (> 14 days) river level forecasting during non-Monsoon periods (**Bangladesh**) ARL 5-6

CURRENT PARTNERS AND USER COMMUNITY



- ✓ **Indus River System Authority** – IRSA; national mandate to ensure equitable distribution among provincial stakeholders.
- ✓ **Pakistan Council for Research on Water Resources** – PCRWR; national mandate to do ‘research’ on water resources for policy and planning guidance.
- ✓ **Pakistan Agricultural Research Council** (PARC)-national mandate for crop management.
- ✓ Nepal **Department of Hydrology and Meteorology**
- ✓ Bhutan **Department of Hydrometeorology**
- ✓ Bangladesh **Institute of Water Modeling** (IWM) and **Flood Forecasting and Warning Center** (FFWC)

All agencies are Federal Govt-funded;

Strong potential for opening new positions and hardware infrastructure from permanent budget lines = Higher chance for durable application of products/tools without external funding.



We focused on stakeholder's DNA of inductive learning, to reduce time taken to reach ARL 9 for a new earth-observation application

GRACE Satellite Application for Groundwater Management

STAKEHOLDER AGENCY- PCRWR (PAKISTAN)



Federal research agency mandated to advise Pakistan on policy decisions for sustainable management of water resources in the country.



Headquarters Islamabad



Bahawalpur



Bahawalpur

Regional Centers/Office (5)

**Water Management
Research & Demonstration
Farms (5)**

**GIS and Geo-Hydrological
Laboratory**

Lysimeter Stations (4)

Tile Drainage Facilities

**Desertification Control &
Demonstration Stations (5)**

**Water Quality Laboratories
(24)**

**Commercialization and
Innovation Cell**

**Library, Documentation &
Information Center**



Sindh



WRRC, Quetta

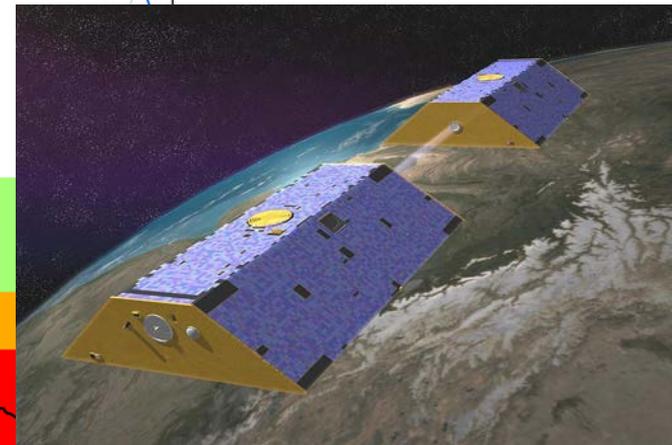
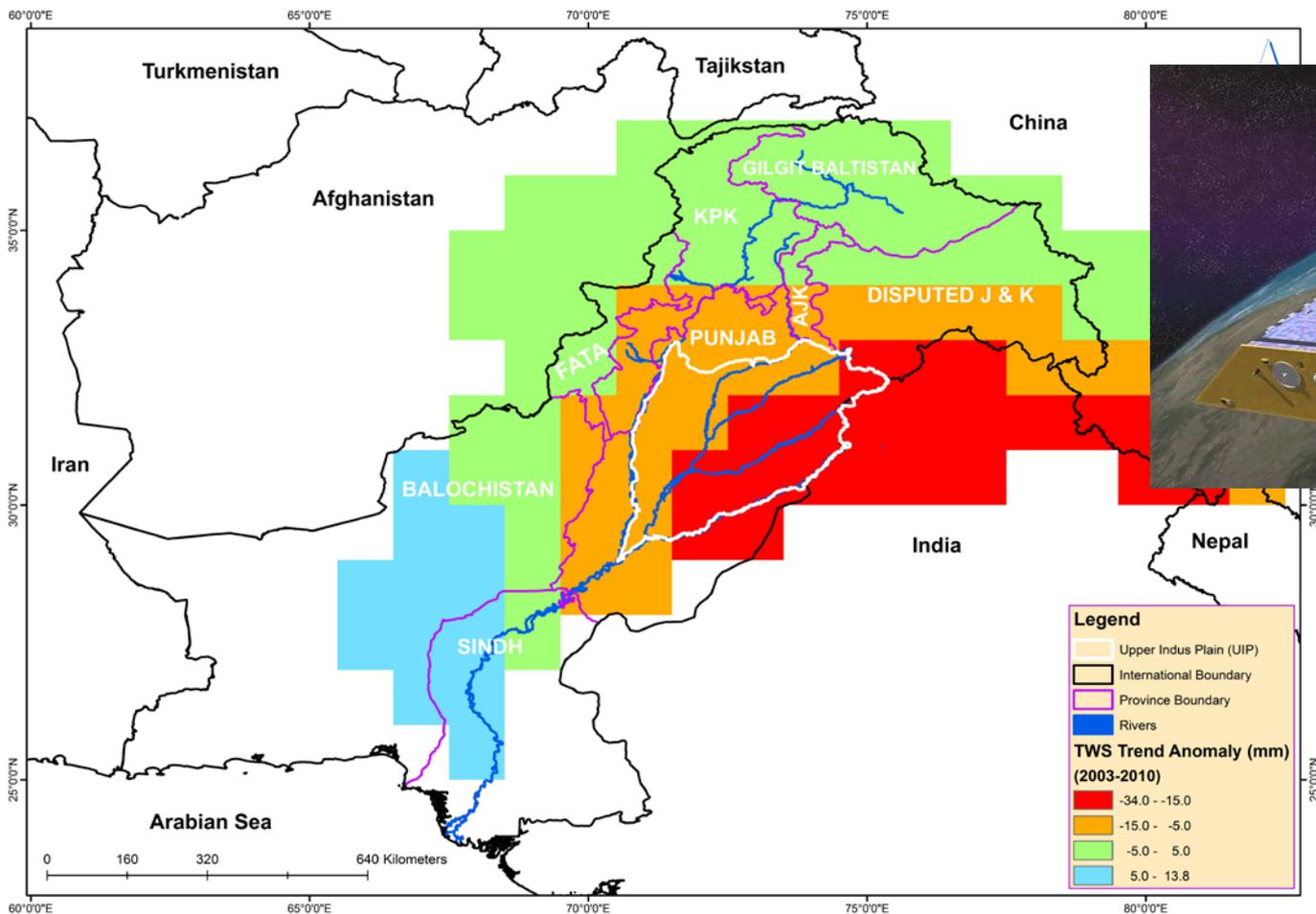


WRRC, Peshawar

- No centralized groundwater data base system at federal level.
- PCRWR started a national program to evaluate groundwater resources and formulate future management strategies using geophysical tools.
- One decade to investigate just Punjab Province.
- Very laborious, time-consuming and costly.
- Some areas are inaccessible due to security issues.

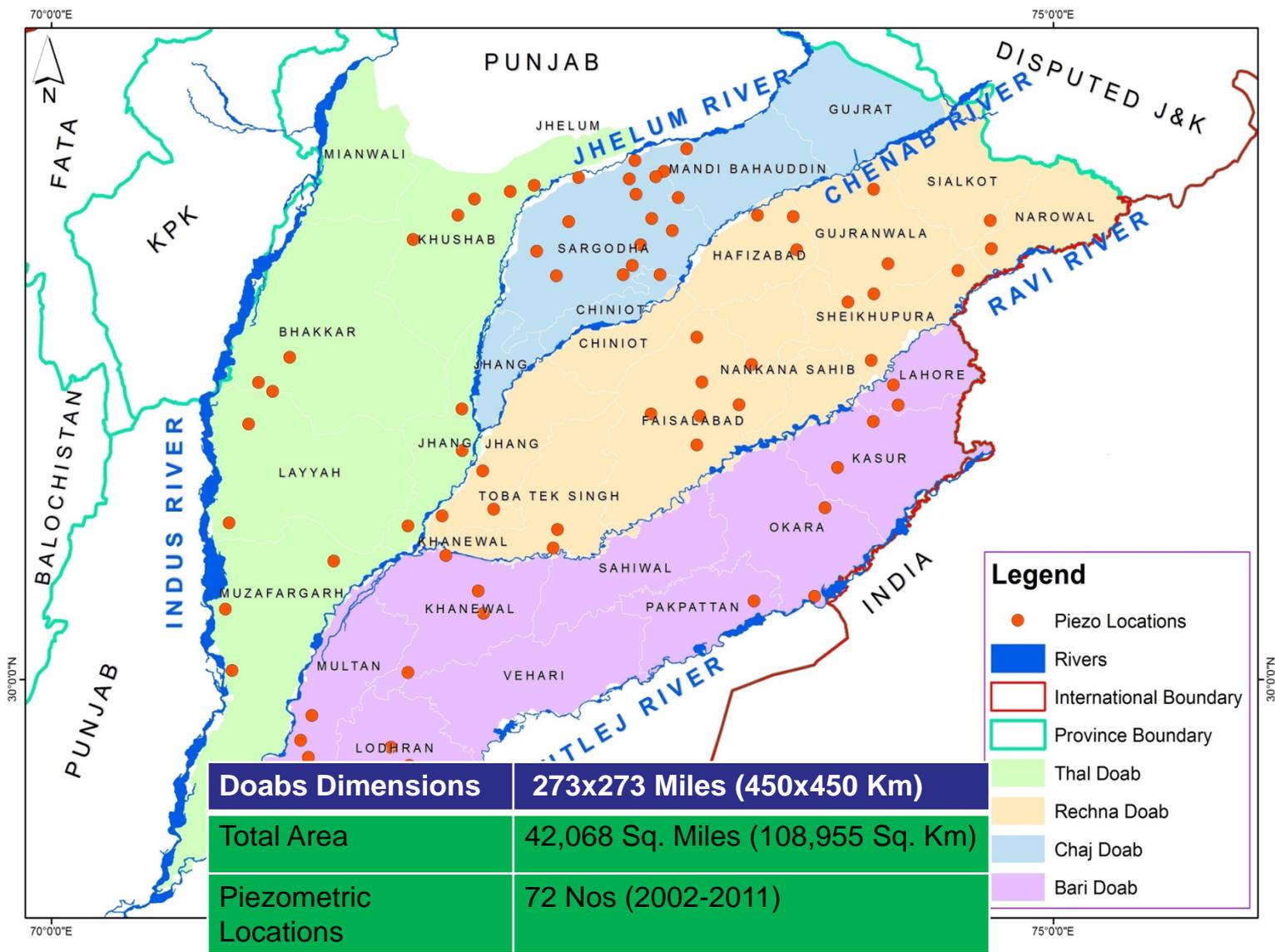


GRACE SATELLITE BASED GROUND WATER MONITORING (OPERATIONAL BY PCRWR)



Map of groundwater storage change created independently by stakeholder agency PCRWR

STAKEHOLDER VALIDATION BEFORE ADOPTION & OPERATIONS (ARL 9)





Pakistani Water Resources Management "Looking Up"

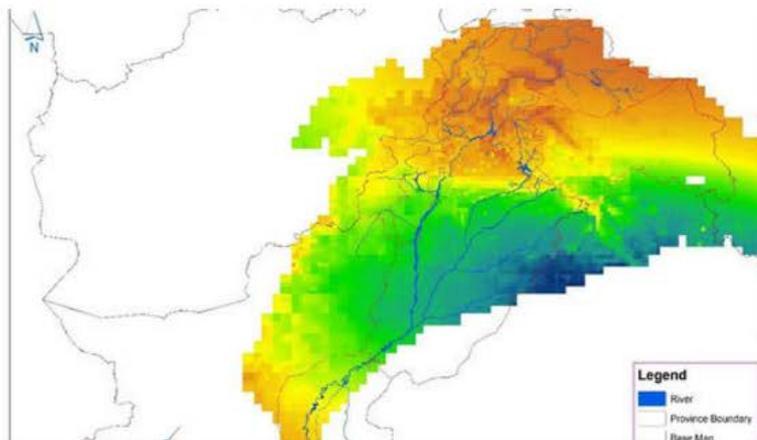
Published: Feb 01 2016

With its economy based largely on agriculture, water is a critical resource for Pakistan. The country's vast farm lands are supported by the largest contiguous irrigation system in the world – the Indus Basin Irrigation System. The system includes the Indus River and its tributaries, as well as a myriad of canals, watercourses, farm channels, and field ditches, and serves about 100 million people in the Indus region. If managed efficiently, there is enough water in the basin to support the livelihoods of those people. Water distribution and management are crucial issues.

Groundwater contributes more than 60% of the region's surface water supplies. To manage the Indus Basin Irrigation System effectively and fairly, water resources managers must monitor how much groundwater there is, where it is, and how it is changing. Where are groundwater storage levels

[NEWS](#) | FEBRUARY 29, 2016

NASA Data Used to Track Groundwater in Pakistan



Exercise now being repeated regularly at PCRWR as GRACE SHC data becomes available

Popular

[Investigating the Mystery of Migrating 'Hot Jupiters'](#)

[Mini NASA Methane Sensor Makes Successful Flight Test](#)

[Site List Narrows For NASA's Next Mars Landing](#)

[Comet Flying by Earth Observed with Radar and Infrared](#)

[Tests on Earth to Help Free Spirit Rover on Mars: Live Webcast, Chat](#)

TRAINING STAKEHOLDERS FOR UPTAKE OF EARTH OBSERVATIONS



FORWARD TRAINING at Stakeholder Agency



FEBRUARY 2015



SEPTEMBER, 2015

BACKWARD LEARNING at UW



NOVEMBER, 2015 (MOU signing for strategic collaboration 2015-2020)



DECEMBER 2013



NEXT TARGET STAKEHOLDERS

March-April, 2016 –Vietnam (National University of Civil Engineering and NAWAPI)
– Water Management in Red River and Lower Mekong

April, 2016 –Nepal (Department of Hydrology and Meteorology) – Snowpack and glacier mass balance monitoring

June-Sept, 2016 – Bhutan, Myanmar, Thailand

Departed UW and UHouston April 8 after receiving training on hydrologic modeling for Mekong and Red Rivers, Satellite Geodesy (Altimetry and GRACE) for groundwater management

Arrived April 14 for a 6 week training on satellite based glacier and snowpack monitoring (water budget estimation) using GRACE, MODIS, altimetry and hydrologic models

South-to-South Cooperation (Bangladesh agencies training agencies from neighboring countries – July 24-28, 2016

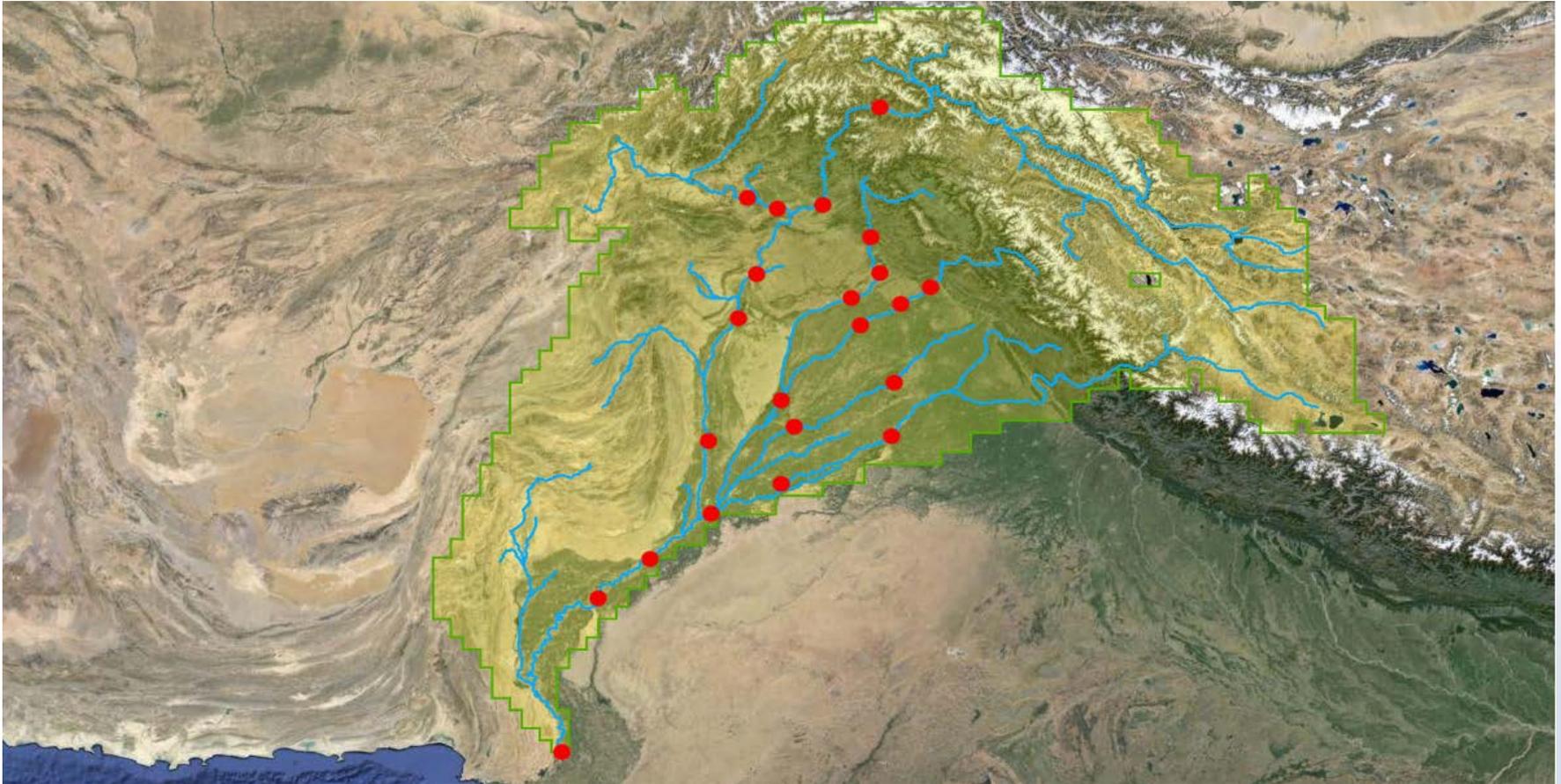
WATER AVAILABILITY (NOWCAST AND FORECAST)



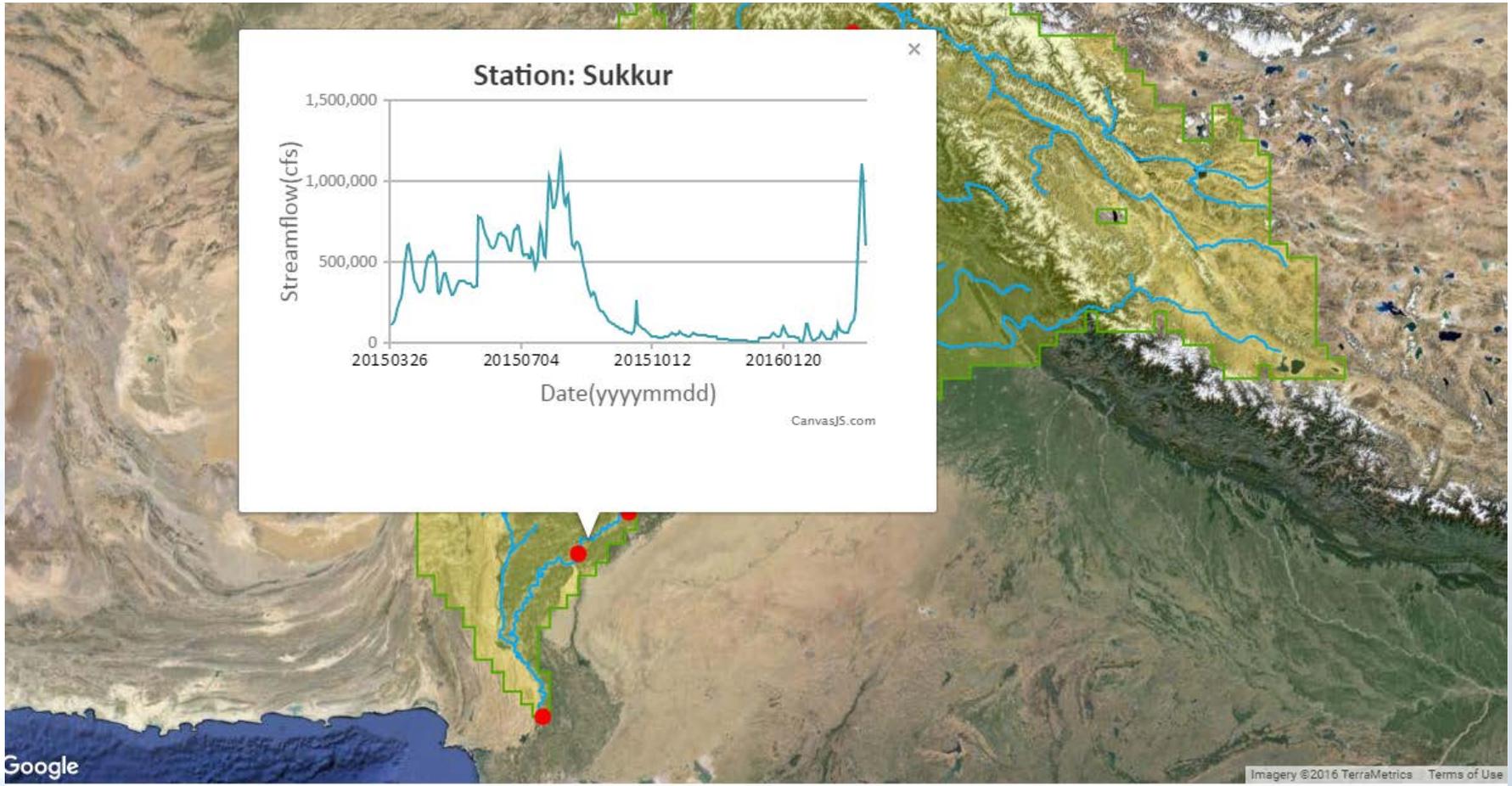
The screenshot shows the website for the South Asian Surface Water Modelling System (SASWE). The browser address bar shows the URL `depts.washington.edu/saswe/`. The page features a large satellite-style map of South Asia with the title "South Asian Surface Water Modelling System" overlaid in white text. Navigation buttons include "Home", "Visualization", "Download", "Publications", "Acknowledgements", "Contact Us", and "Terms of Usage". Below the map, there are two prominent blue buttons: "Learn about Model" and "User Manual". A "Visitors" section displays a grid of flags and visitor counts for various countries: US (104), PK (10), BD (6), TH (3), IN (2), and VN (2). The page also indicates "Pageviews: 485" and includes a "FLAG counter" logo.

- System runs VIC-2L hydrologic model in nowcast mode (above version) – fully automated
- Forecast mode available up to 6 months (in SERVIR HQ version) using NMME forecast forcings
- **ARL=6**
- **Client Stakeholders:** IWM-WRP (getting engaged), PCRWR (engaged), PARC (planned), DHM-Nepal (getting engaged)

STREAMFLOW NOWCAST WITH DIVERSION POST-PROCESSED



STREAMFLOW NOWCAST WITH DIVERSION POST-PROCESSED



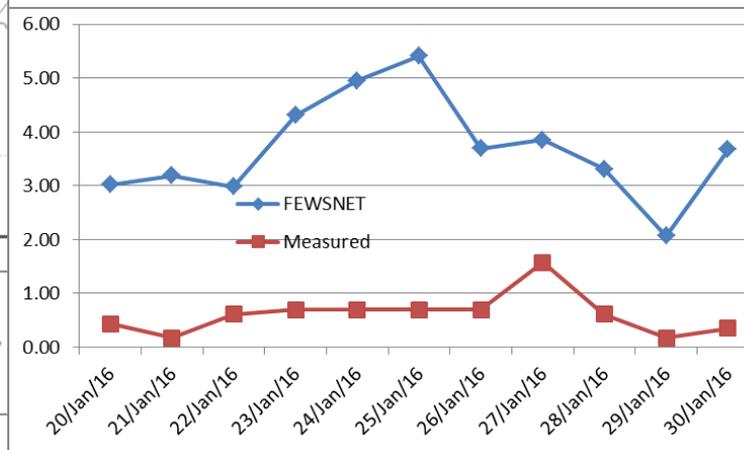
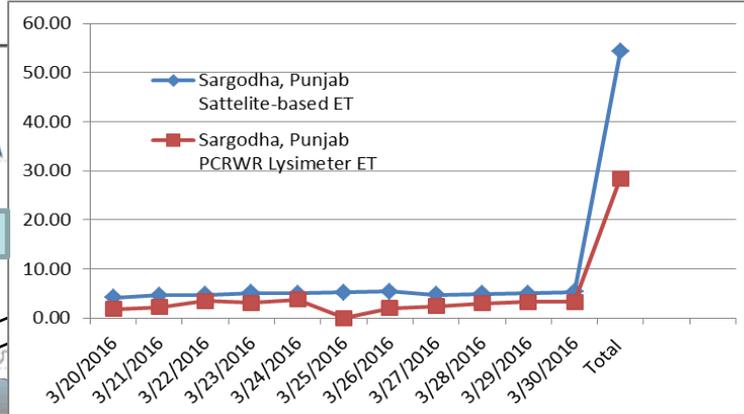
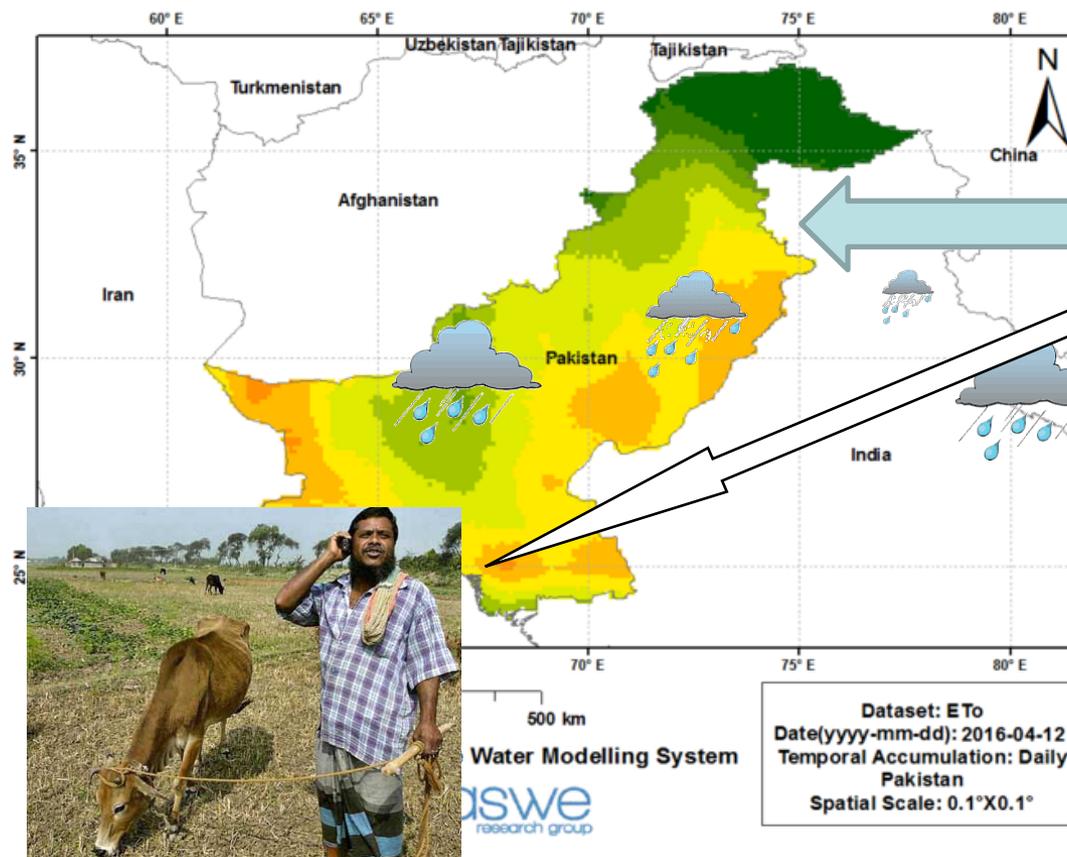
BUILD-IT-YOURSELF WEB INTERFACE TOOLS: Transition Plan for STAKEHOLDER AGENCIES



[HTTP://DEPTS.WASHINGTON.EDU/SASWE](http://depts.washington.edu/saswe)

1. Freely available tools for rapid deployment of complex back end processing through easy to build web interface to facilitate decision making.
2. Can handle automation, ftp (push and pull), visualization, overlay, work with GIS software, markup language etc. – automated per user specifications and request.
3. SIMPLE BUT NOT SIMPLER.
4. 'Build-it-yourself' tutorials so that the GUI can incubate the co-developed solutions for stakeholders in agency environment.
5. PCRWR will be the first test – by passing app development training to their IT specialist and numerous skype trainings – 2017 (target).

AGRICULTURAL IMPACT THROUGH WATER CONSERVATION & YIELD INCREASE

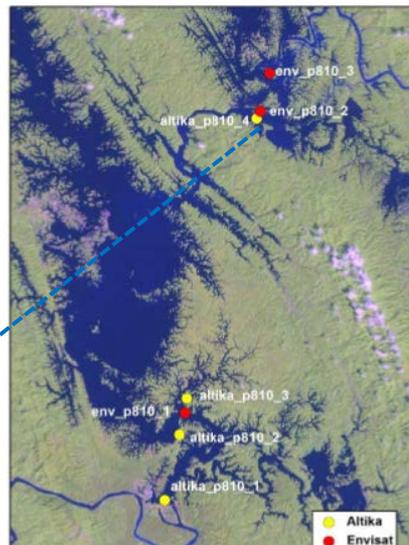


- ❑ ETo is now routinely estimated using GFS and Satellite data (FAO56) at 10 km daily grids.
- ❑ PCRWR is using reference ETo for calculating P-ET (for specific crops) to advise farmers when to water (or not) and for how long.
- ❑ Pilot implementation from April 17, 2016 on 700 farmer followed by full-scale implementation 2017 (housed in 'build-it-yourself' portal in PCRWR)

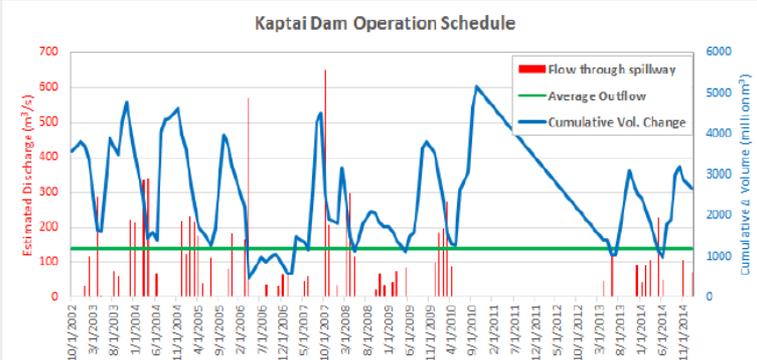
MULTI-MISSION INTERACTION FOR OPERATIONAL RESERVOIR MANAGEMENT



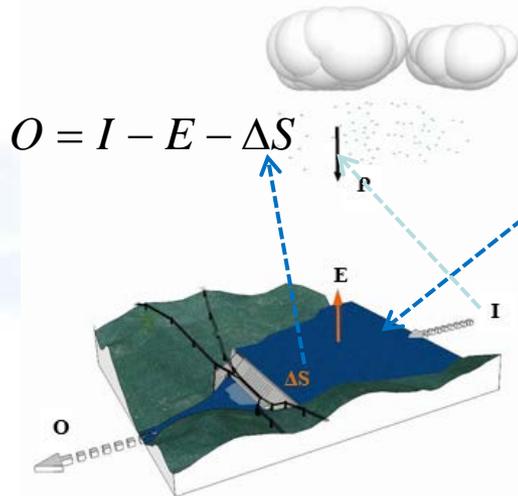
Altimetry+GPM+SRTM+AQUA/
TERRA/LANDSAT+SWOT are
a multi-mission constellation for
outflow estimation for **reservoir
operations management**



Kaptai Dam in Karnaphulli
river



Asian Hydropower and Water
Management Agencies are potential
stakeholder clients



$$O = I - E - \Delta S$$

- **ARL=3-4**; Understanding Satellite-based Monthly-to-Seasonal Reservoir Outflow Estimation as a function of Hydrologic controls, *Water Resources Res.*, doi:10.1002/2015WR017830.
- **Stakeholders for Operational Uptake:** Bangladesh- IWM (WRP), Pakistan (PCRWR, IRSA) – for now (near future – Vietnam)
- **Plan for raising ARL:** Automate the six mission synthesis for elevation-storage volume derivation for a user-selected reservoir and couple it with hydrologic model for GPM-Altimeter based inflow.



- ❑ Study stakeholder agencies very thoroughly and understand their DNA of operations, cultural mindset. Earn their trust to enter their inner circle (true for Asian agencies).**
- ❑ Let the problem define the solution; Do not let the solution define the problem.**
- ❑ Building durable applications requires a balance between 'detail/complexity' and 'need' ('Perfect is the Enemy of Good').**
- ❑ Pursue applications as if everything depends on you and your effort alone.**

ACKNOWLEDGEMENTS



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- SERVIR Program (Dan and Ashutosh for non-stop inspiration)**

- The wonderful stakeholder agencies of South Asia – PCRWR, IWM, PARC/NARC, DHM, DHMS, IRSA and FFWC**

- UW Global Affairs Program and UW Civil Engineering Research**

- The Ivanhoe Foundation**