Understanding Surface Water Flow and Storage Changes using Satellites: Emerging Opportunities for Bangladesh

Faisal Hossain
Department of Civil and Environmental Engineering
Tennessee Technological University
&
Douglas Alsdorf
School of Earth Sciences
Ohio State University

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OUTLINE

1. **Problem Statement: Surface Water Monitoring Issues and Challenges for Bangladesh and South Asian Nations.**
2. **Potential Solution: Surface Water Ocean Topography (SWOT) mission.**

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Overview of Surface Water-related Hazards

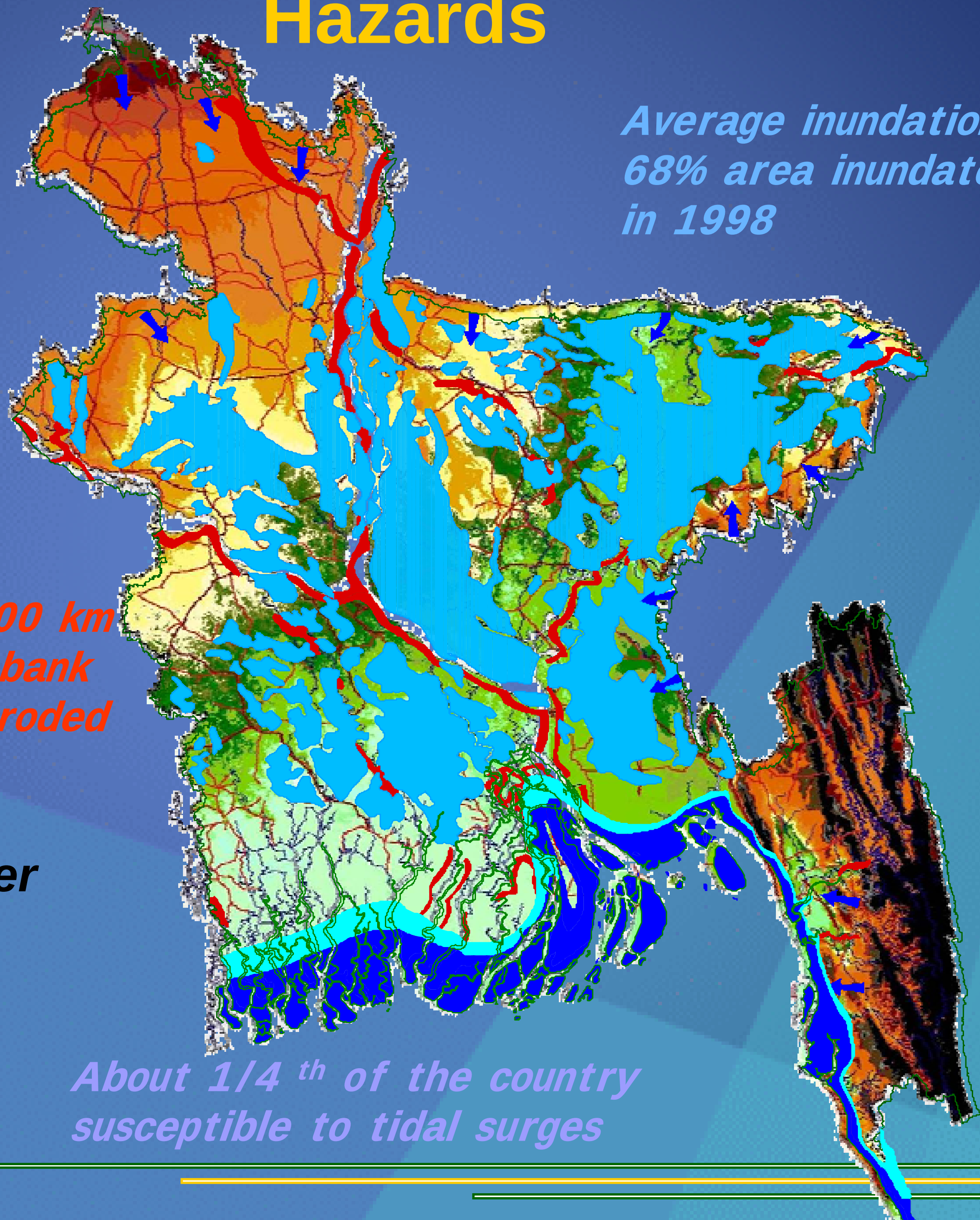
The geographical location and average land levels of Bangladesh are conducive to

Flood

Erosion

Storm Surge

Drought



Average inundation 22%
68% area inundated in 1998

Water scarcity in 7 months a year

Over 3000 km of river bank will be eroded by 2025

About 1/4 th of the country susceptible to tidal surges

Source: Institute of Water Modeling, Bangladesh

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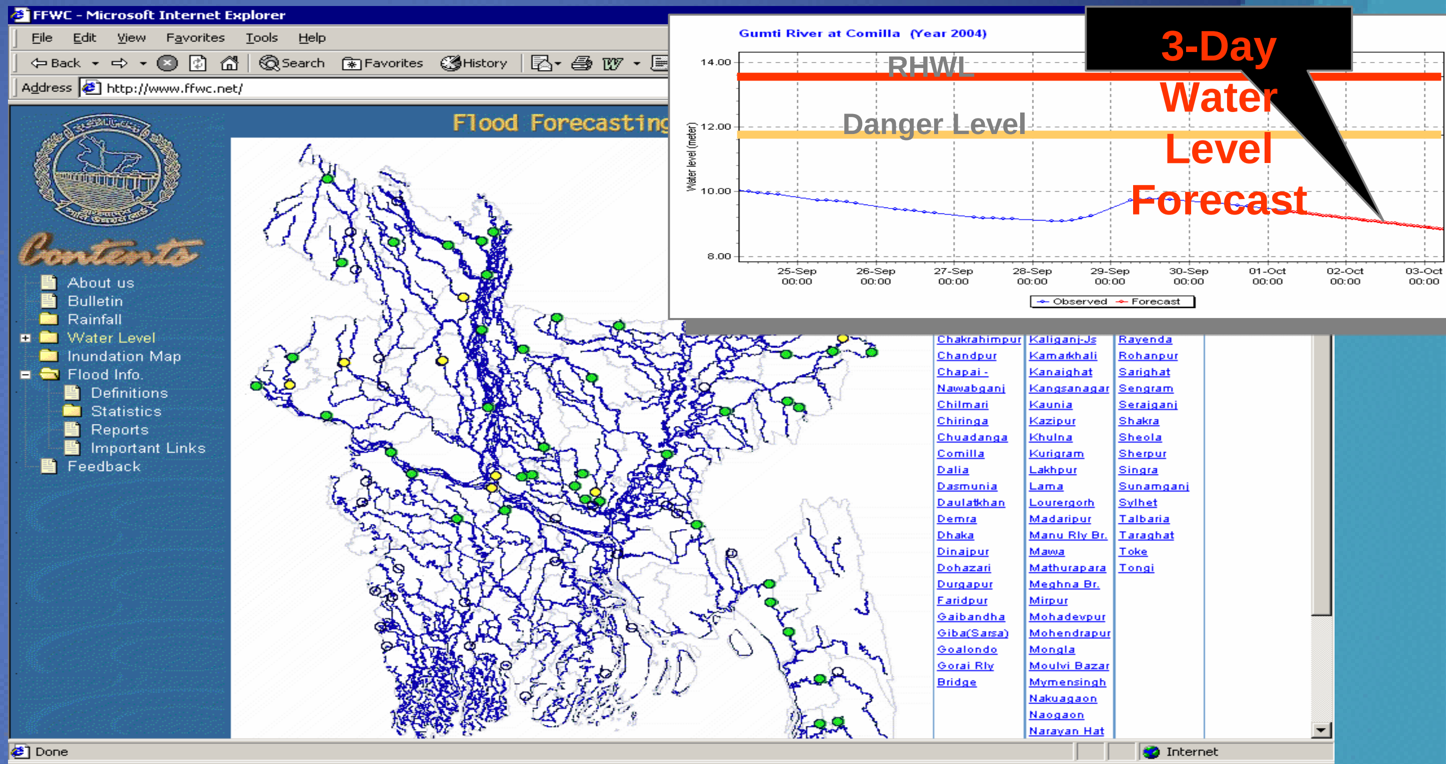
Routine Surface Water Monitoring Needs of Bangladesh

- ✓Flood Forecasting during Monsoon Season.
- ✓About 30 river stations.
- ✓Forecasts for public - 3 days.
- ✓10 day to seasonal forecast under prototype.



Source: *Flood Forecasting and Warning Center; www.ffwc.gov.bd*

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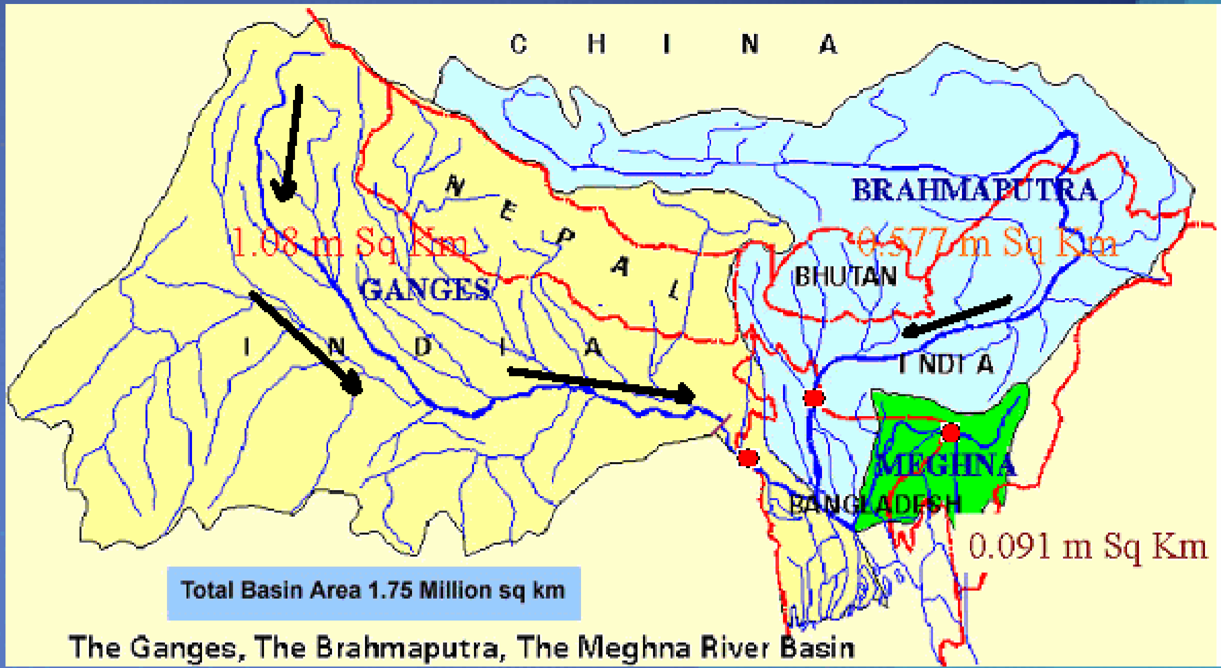
Challenges of Flood Forecasting

- Bangladesh comprises only 7% of Ganges Brahmaputra-Meghna Basin area.
- Lack of upstream (transboundary) rainfall and stream flow *in real-time* limits forecasting range to ~ 3days.
- High costs and maintenance issues for In-situ networks.
- Globally declining trend on in-situ networks.



21 day forecast is IDEAL for South Asian nations according to Asian Disaster Preparedness Center.

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Global Synopsis on Surface Water

Around the world, we have a poor understanding of both surface water flows in rivers and the changes in waters stored in lakes, wetlands, and reservoirs. The problems are not unique to Bangladesh, but are certainly felt more intensely.

SCIENCE AND TECHNOLOGY
TO SUPPORT
FRESH WATER AVAILABILITY
IN THE
UNITED STATES

Report of the

NATIONAL SCIENCE AND TECHNOLOGY COUNCIL
COMMITTEE ON ENVIRONMENT AND NATURAL RESOURCES

Subcommittee on Water Availability and Quality

November 2004

"Does the United States have enough water? We do not know."

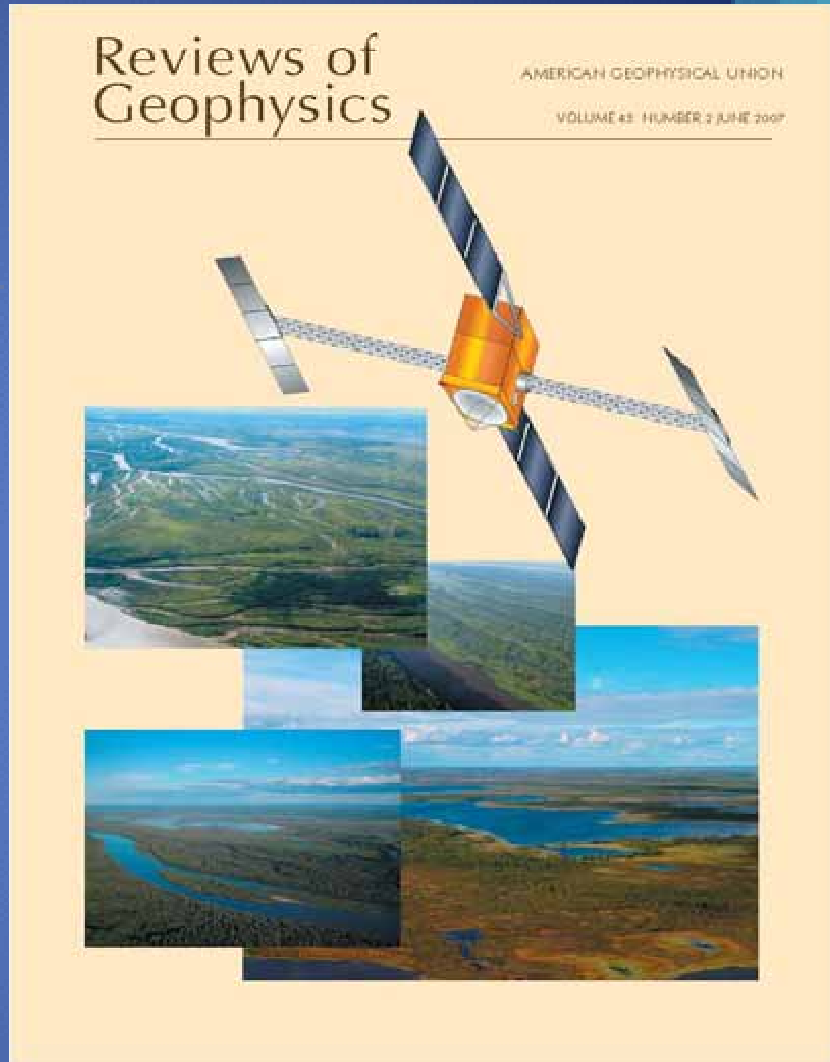
"What should we do? Use modern science and technology to determine how much water is currently available …"

Office of Science & Technology Policy, 2004

www.ostp.gov/NSTC/html/swaqreport_2-1-05.pdf

Potential Solution: Using Satellites

- ✓Surface Water Ocean Topography (SWOT) Mission. Launch Date: 2015.
- ✓Will measure elevation on the basis of near-nadir radar interferometry.
- ✓Stream flow for world's rivers every 10 days, or more often.
- ✓Potential of SWOT for transboundary surface water monitoring in International River Basins (IRBs).



Source: Aaron Wolf, Oregon State University

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TABLE ES.2 Launch, orbit, and instrument specifications for the recommended NASA missions. Shade colors denote mission cost categories as estimated by the NRC ESAS committee. Pink, green, and blue shadings represent large ($600 million to $900), medium ($300 million to $600 million), and small (<$300 million) missions, respectively. Missions are listed in order of ascending cost within each launch timeframe. Detailed descriptions of the missions are given in Part II, and Part III provides the foundation for selection.

Decadal Survey Mission	Mission Description	Orbit	Instruments	Rough Cost Estimate
Timeframe 2010 – 2013, Missions listed by cost				
CLARREO (NASA portion)	Solar radiation: spectrally resolved forcing and response of the climate system	LEO, Precessing	Absolute, spectrally-resolved interferometer	$200 M
SMAP	Soil moisture and freeze/thaw for weather and water cycle processes	LEO, SSO	L-band radar L-band radiometer	$300 M
ICESat-II	Ice sheet height changes for climate change diagnosis	LEO, Non-SSO	Laser altimeter	$300 M
DESDynI	Surface and ice sheet deformation for understanding natural hazards and climate; vegetation structure for ecosystem health	LEO, SSO	L-band InSAR Laser altimeter	$700 M
Timeframe: 2013 – 2016, Missions listed by cost				
HyspIRI	Land surface composition for agriculture and mineral characterization; vegetation types for ecosystem health	LEO, SSO	Hyperspectral spectrometer	$300 M
ASCENDS	Day/night, all-latitude, all-season CO_2 column integrals for climate emissions	LEO, SSO	Multifrequency laser	$400 M
SWOT	Ocean, lake, and river water levels for ocean and inland water dynamics	LEO, SSO	Ka-band wide swath radar C-band radar	$450 M
GEO-CAPE	Atmospheric gas columns for air quality forecasts; ocean color for coastal ecosystem health and climate emissions	GEO	High and low spatial resolution hyperspectral imagers	$550 M
ACE	Aerosol and cloud profiles for climate and water cycle; ocean color for open ocean biogeochemistry	LEO, SSO	Backscatter lidar Multiangle polarimeter Doppler radar	$800 M
Timeframe: 2016 -2020, Missions listed by cost				
LIST	Land surface topography for landslide hazards and water runoff	LEO, SSO	Laser altimeter	$300 M
PATH	High frequency, all-weather temperature and humidity soundings for weather forecasting and SST[a]	GEO	MW array spectrometer	$450 M
GRACE-II	High temporal resolution gravity fields for tracking large-scale water movement	LEO, SSO	Microwave or laser ranging system	$450 M
SCLP	Snow accumulation for fresh water availability	LEO, SSO	Ku and X-band radars K and Ka-band radiometers	$500 M
GACM	Ozone and related gases for intercontinental air quality and stratospheric ozone layer prediction	LEO, SSO	UV spectrometer IR spectrometer Microwave limb sounder	$600 M
3D-Winds (Demo)	Tropospheric winds for weather forecasting and pollution transport	LEO, SSO	Doppler lidar	$650 M

[a] Cloud-independent, high temporal resolution, lower accuracy SST to complement, not replace, global operational high accuracy SST measurement.

NRC Decadal Survey

Released: 15 Jan 07

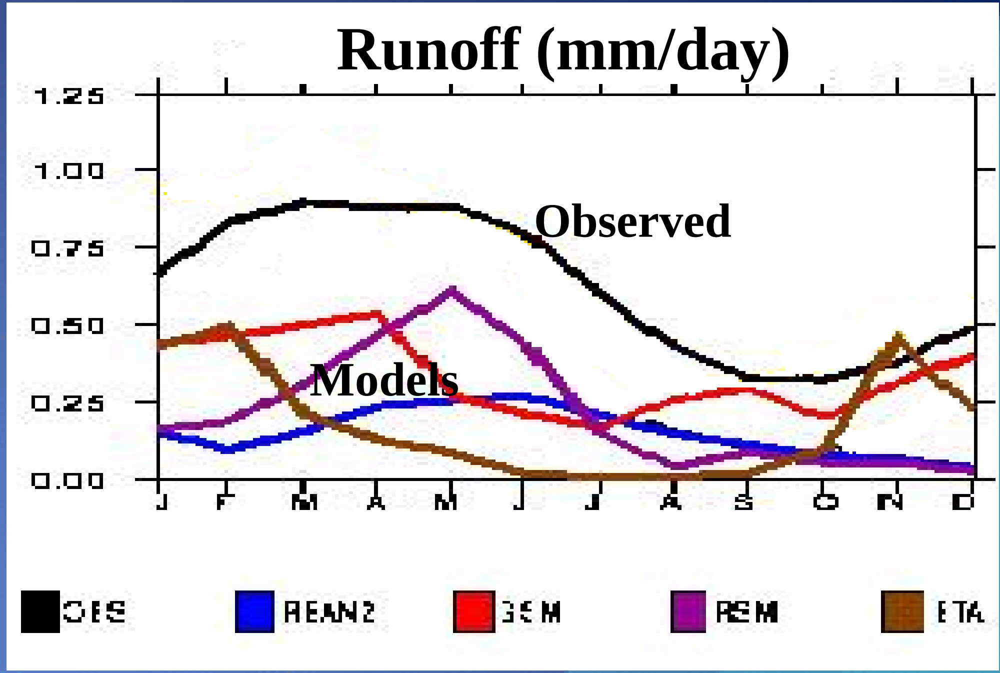
- 100+ submitted mission ideas
  - SWOT is WATER HM
- 115 people involved
  - committee members and referees
- 17 missions selected
  - 14 are exclusively NASA
- 1 of 7 Missions selected by Congress and signed into law (Dec. 26, 2007) by the President to share initial funding of $40M in 2008

www.nap.edu/catalog/11820.html

Three of Several Issues Motivating SWOT

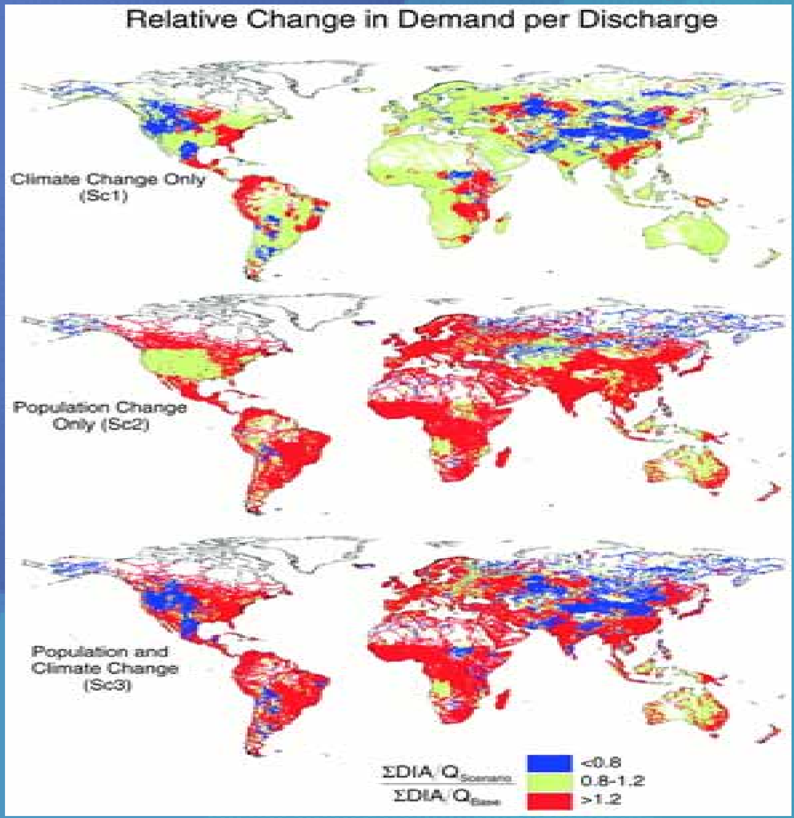
1. Water Cycle and Climate Modeling

- How does the lack of measurements limit our ability to predict the land surface branch of the global hydrologic cycle?
- In locations where gauge data is available, GCM precipitation and subsequent runoff miss streamflow by 100%.
- The question is unanswered for ungauged wetlands, lakes, and reservoirs throughout the world.



2. Population Health and Sustainability

- Ability to globally forecast freshwater availability is critical for population sustainability.
- Water use changes due to population are more dynamic than climate change impacts.
- Predictions also demonstrate the complications to simple runoff predictions that ignore human water usage (e.g., irrigation).

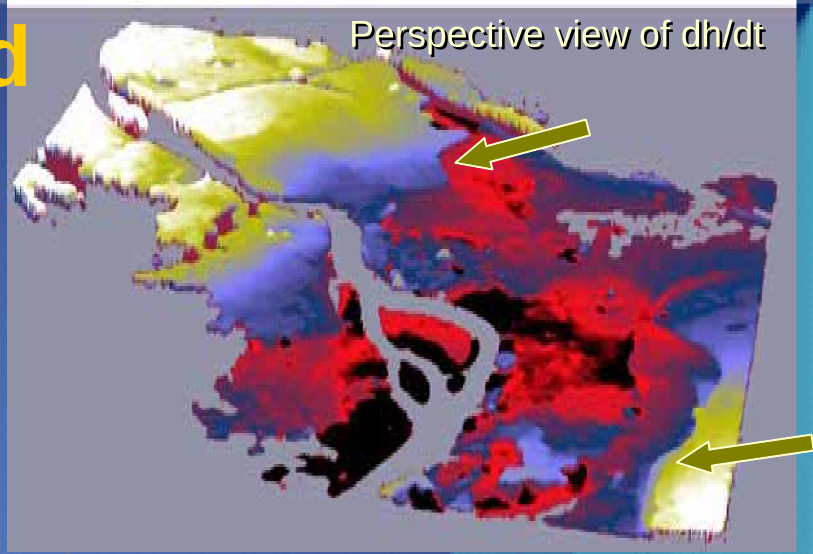


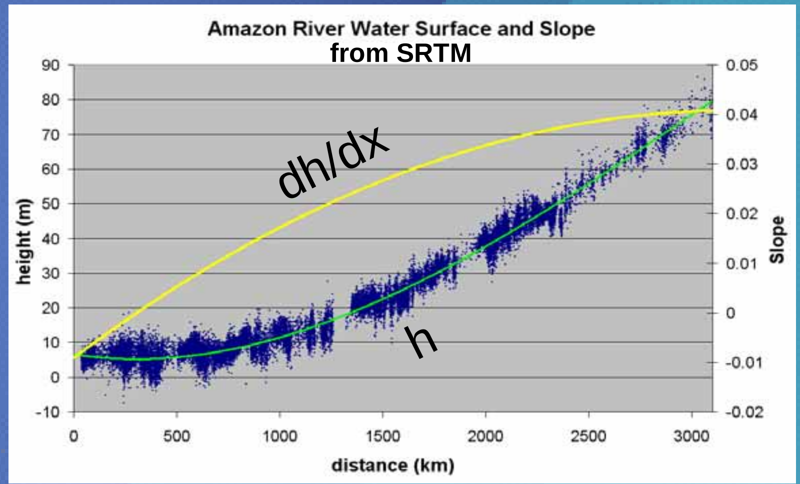
3. Flooding Hazards

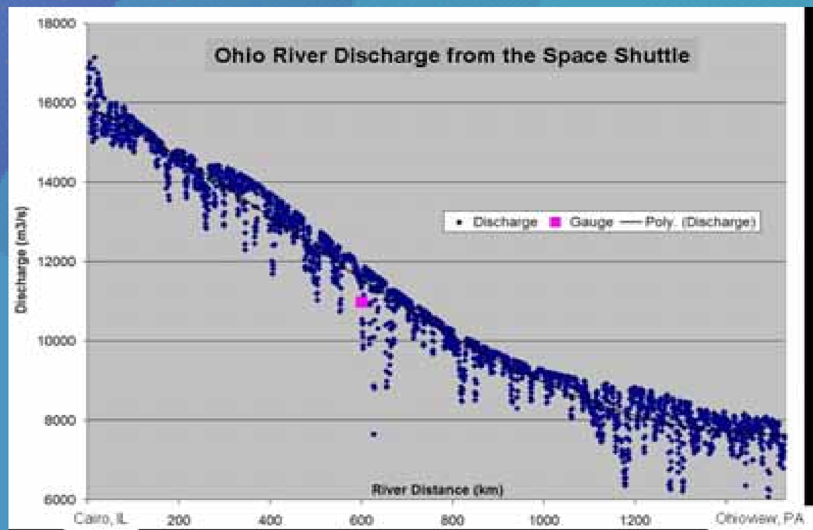
Roads et al., GCIP Water and Energy Budget Synthesis (WEBS), *J. Geophysical Research,* 2003
Vörösmarty, et al., Global water resources: Vulnerability from climate change and population growth, ***Science**, 289,* 284-288, 2000

SWOT Will Provide These Required Measurements

- **From equations of fluid flow**
  - h, ∂h/∂x, ∂h/∂t, and area
  - globally, on a ~weekly basis
- **Existing/previous Interferometric platforms (e.g. SRTM mission in 2000) are not ideal:**
  - SRTM only operated for 10 days and has poor accuracy (> ± 5 m);
  - repeat-pass InSAR requires double-bounce from flooded vegetation.
- **Existing satellites (altimeters) only provide water surface elevations at points, not mappings (16-day repeat cycle misses 70% of all lakes and 30% of all rivers in the world)**







Potential of SWOT for Surface Water Modeling for Bangladesh?

Given the climate change scenario and increasing difficulty of monitoring transboundary and in-boundary surface water flow for Bangladesh and South Asian Nations, what is the potential of SWOT for providing cost-effective and useful measurements?

Answer sought via SRTM overpasses over Ganges/Brahmaputra rivers; **SRTM - Shuttle Radar Topography Mission**

SRTM is a precursor to SWOT based on satellite interferometry.

SRTM data is insightful on SWOT's potential in the 2015+ era.

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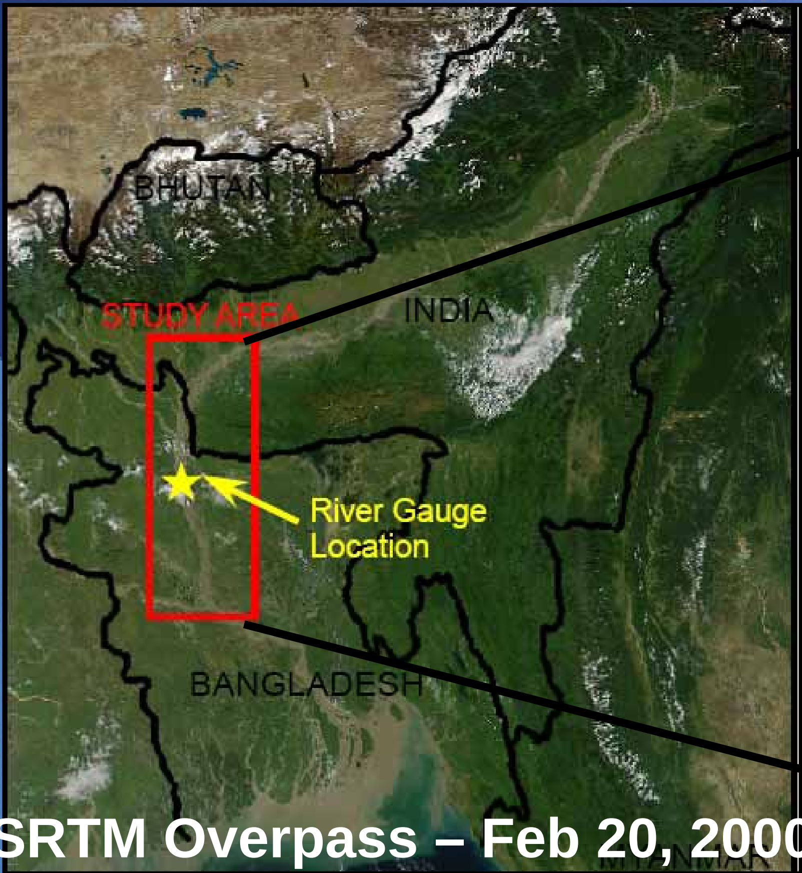
Space-borne Discharge Estimation of Brahmaputra River (a Braided River)

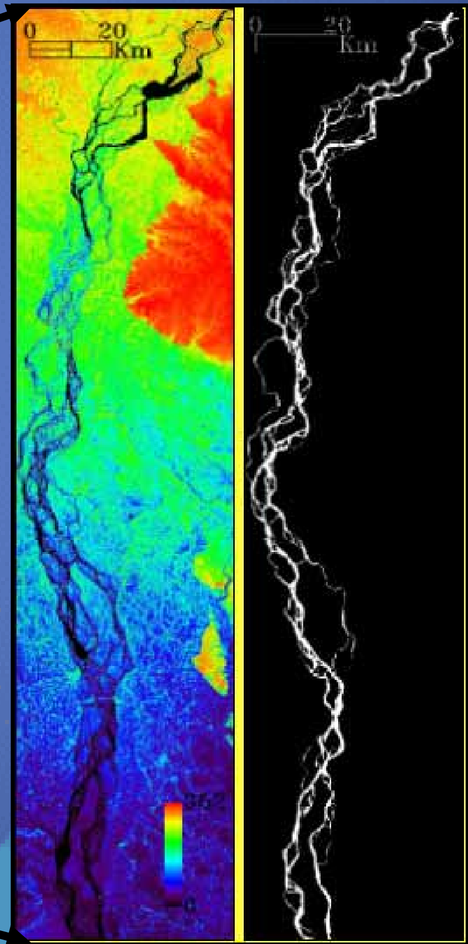
What is the Uncertainty of satellite interferometry (SRTM) -based discharge estimation of braided rivers?



SRTM Overpass – Feb 20, 2000

SRTM elevation data

Braided rivers have not been well-studied



Land/Water Mask

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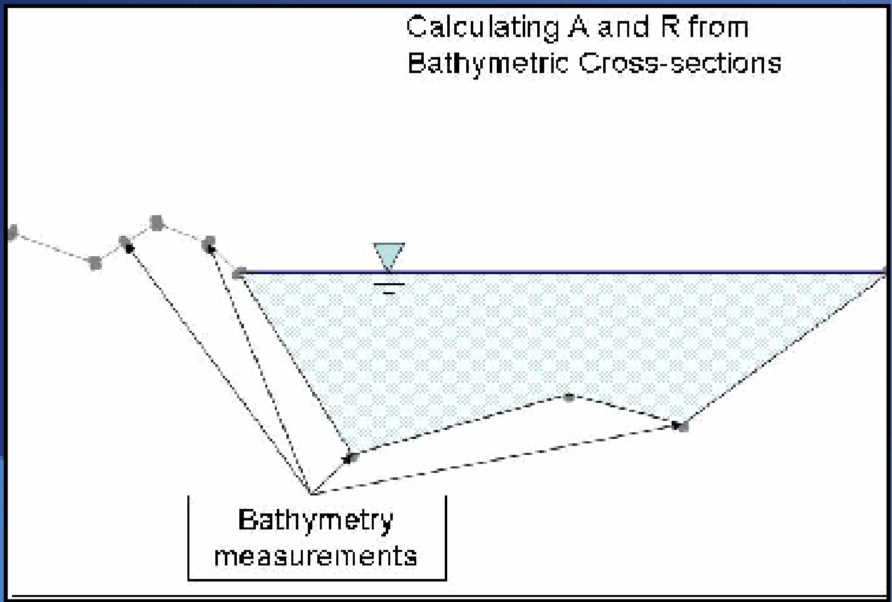
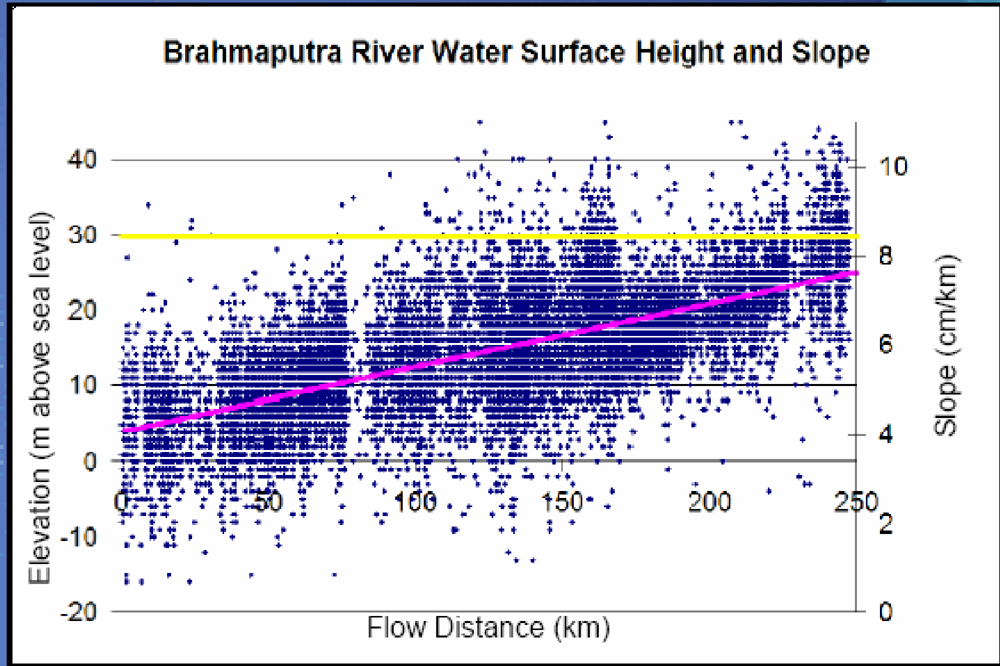
Space-borne Discharge Estimation of Bangladesh Rivers



Bathymetry data of Brahmaputra river cross sections from IWM



Water slope derived from SRTM

Uniform flow conditions: *Water surface slope=Energy gradient: Manning's equation*

$$Q = \frac{A\,R^{2/3}\left(\frac{dh}{dt}\right)^{1/2}}{n}$$

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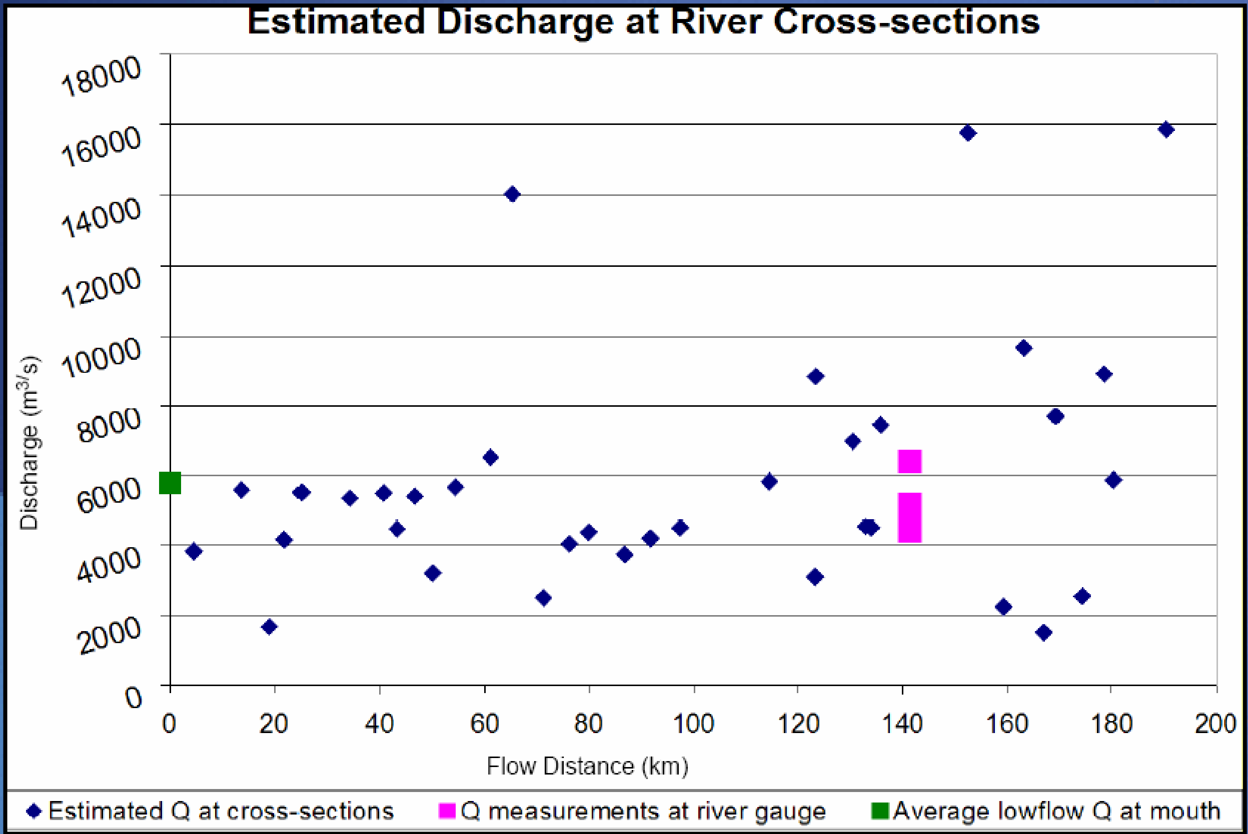
Discharge Estimation of Bangladesh Rivers



Low flow (dry season) discharge can be estimated by satellite interferometry within the natural low-flow variability

Hamski et al (2008) – ASLO – American Society of Limnology and Oceanography Conference March 2-7, Orlando, Florida.

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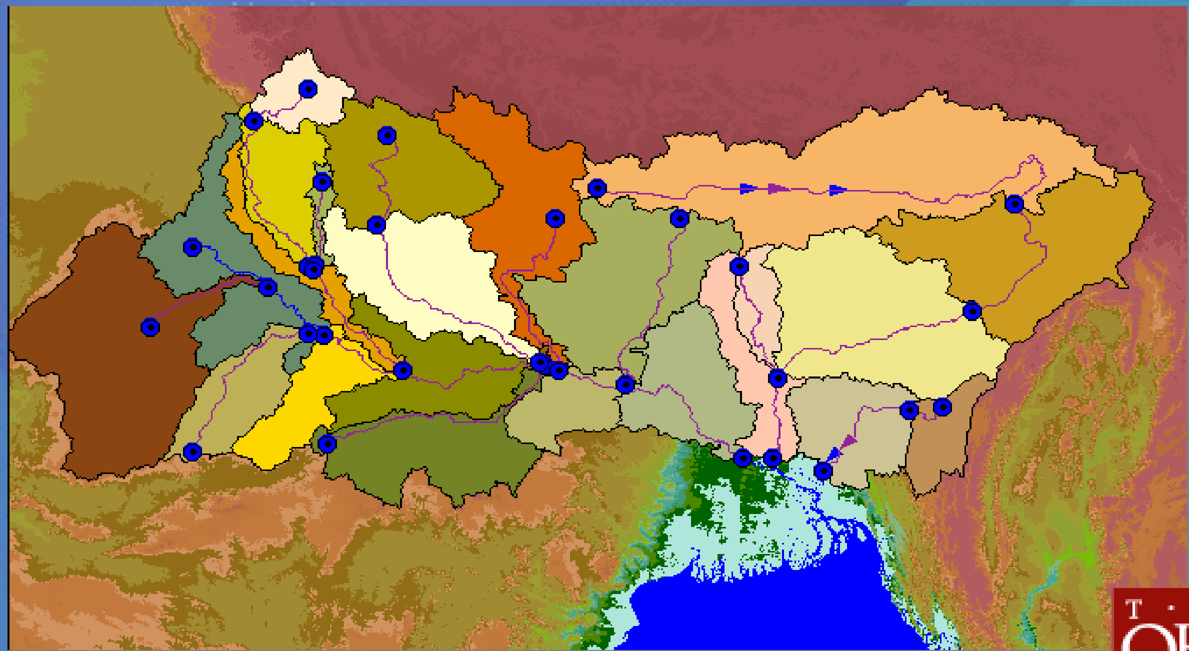
The Future Work Requirements to promote SWOT for Climate Change & Food Security Planning of South Asia

- Assess value of SWOT for high (& transboundary) flow (Monsoon) season for flood forecasting (extending range beyond 3 days through hydrologic modeling-assimilation framework).
- Assess accuracy requirements of SWOT for water resources forecasting & planning of Bangladesh.
- Assess SWOT for Coastal inundation, storm surge and sea level monitoring



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The need for a better under-standing of Bangladesh surface water is clear.

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Thank You!

Photos: Getty Images

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