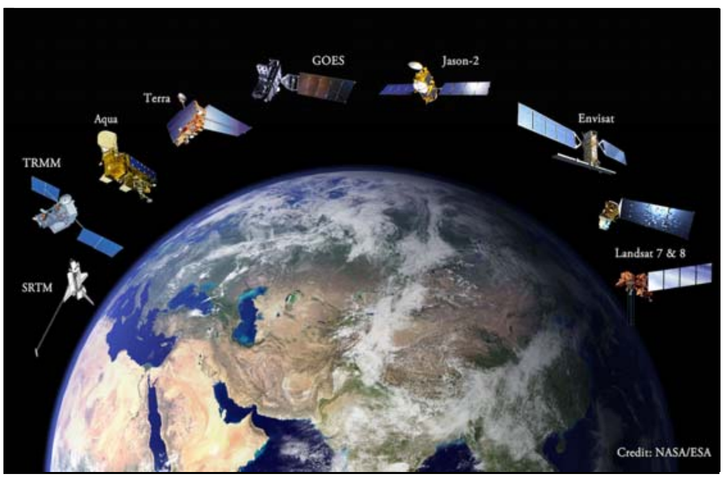
Satellites hold secrets to understanding remote rivers

Published On: December 11, 2014 20:02 UTC-5

If you opened your front door and found water lapping at the doorstep, your first thoughts would probably involve boats, not satellites. But considering the recent findings of some innovative researchers from the NASA/USAID SERVIR project, satellites should be front and center in your mind when it comes to floods – and the rivers that feed them. In fact, using satellite data to understand the behavior of rivers in vast tracts of land where there is no ground data has tremendous implications for the millions of people living in the Nile, Niger, Mekong, Indus, Ganges-Brahmaputra-Meghna (GBM), Salween, and Zambezi river basins.

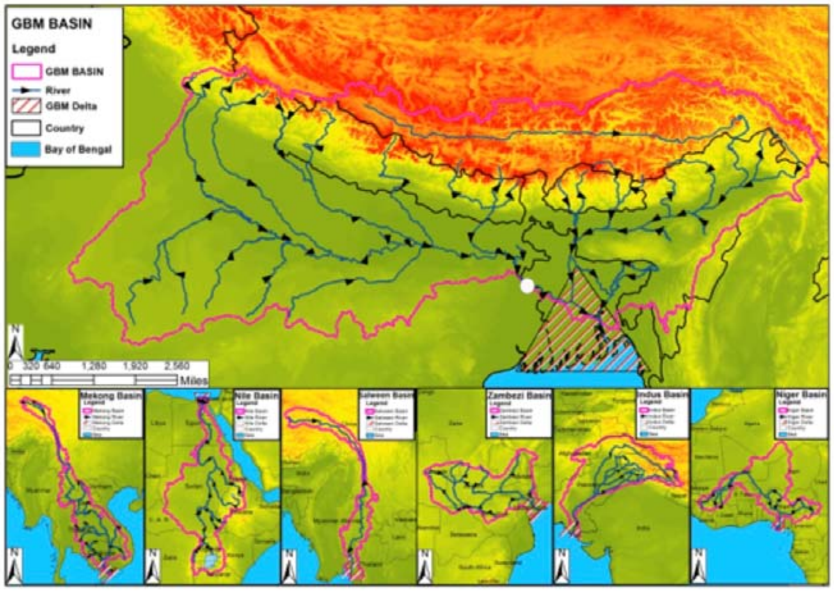
These areas host some of the world's largest population centers, yet people living there are often unaware of how rivers are going to behave upstream until it's too late. That's because regional officials lack the key information they need about rivers and surrounding landscapes to determine how much and how fast river levels will change.



Data from this wide array of satellites can be used to understand rivers.

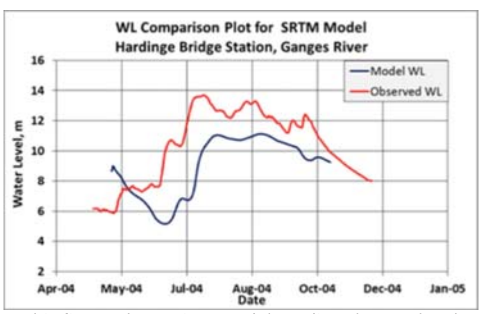
River modeling is used to predict behavior of rivers and serve many important applications – flood forecasting, reservoir operations, irrigation scheduling, and more. These models basically simulate the dynamics of a network of streams and rivers over time and space for changing environmental conditions. But for a model to do this job, the modeler's numerical input must accurately represent the factors that control water flow. For example, the models need to be fed accurate information about the shape and properties of the river channel and surrounding area. It is important to have valid information such as floodplain maps, river bed depth/slope, river width, and shapes of river cross sections for the entire network. Unfortunately, this kind of information is either not measured or not shared among nations that make up the large river basins listed above.

The solution: Recruit a 'team' of Earth observation satellites. The researchers cited here decisively demonstrated the effectiveness of synergistically using satellite data in three unique wavelengths -- microwave, visible, and infrared -- for predicting a river's behavior when ground data is unavailable.

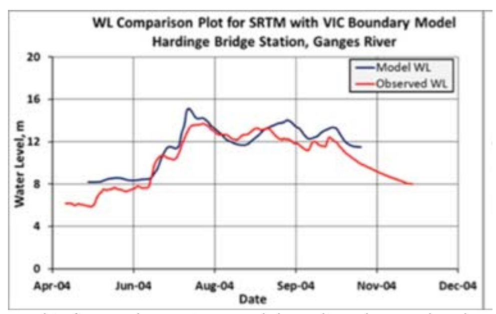


Upper row: The Ganges Brahmaputra Meghna (GBM) river basins and the Ganges-Brahmaputra (GB) delta. The white circle denotes the location of the Ganges River as it enters the delta where the effectiveness of using satellite data over the entire basin was assessed. Bottom row: The many river deltas (shown as a triangle in each region) located in large remote river basins that lack information for modeling rivers and water management.

"We found that it's possible to reduce uncertainty by 300% in river level simulations by using satellites from various missions as a team to overcome the lack of ground data," says Faisal Hossain of the University of Washington, the principal investigator of this SERVIR-sponsored study. "By using satellite precipitation data (microwave and infrared), radar altimeter data (microwave), and visible data together, we were able to 'see' many of the river flow controlling factors that a single 'eye in the sky' simply could not have shown us. For example, by joint use of radar altimetry and Landsat data, we inferred the cross section of rivers, a practical feat not yet reported in literature for river modeling."



This figure shows river model predicted water level in Ganges River without use of satellites.



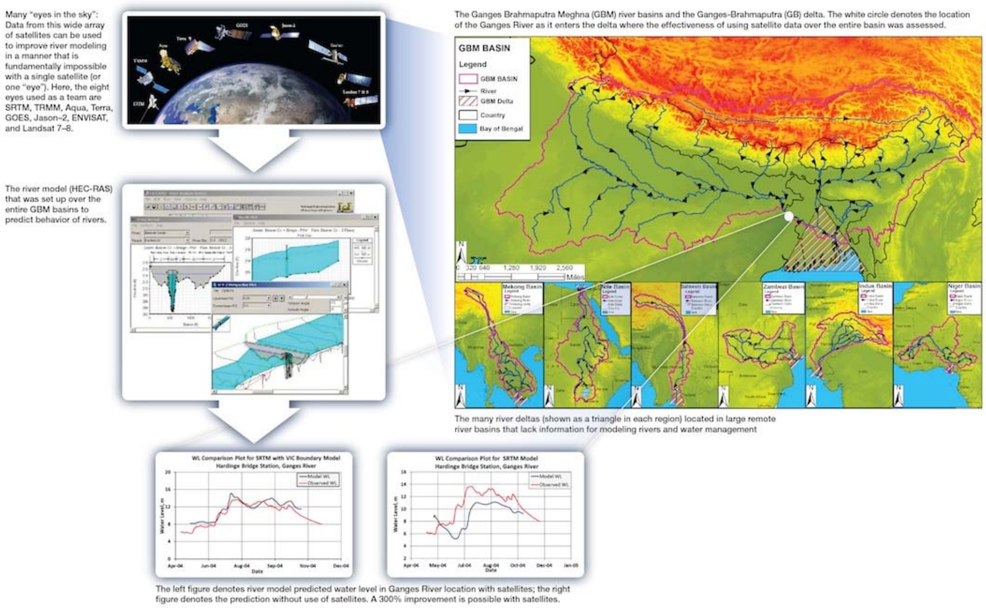
This figure shows river model predicted water level in Ganges River location with satellites. A 300% improvement is possible with satellites.

The team cites the six tenants listed below for using Earth observation data to develop a river model that can accurately simulate river flow dynamics to forecast river levels downstream in the absence of sufficient in-situ gauges and information.

1. Use pre-existing local or regional knowledge about the shape, size, length, and behavior of the rivers as archived in historical books. Combine this information in the river model to get a river model running, albeit with errors.
2. Then, use remotely sensed elevation data to map in detail the river network and the flow direction. Use the detailed river network as a key input to the river model.
3. Next, use satellite data in the visible range (basically camera-ready photographs), for example from Landsat, to correct any misinformation on the river network derived from the satellite-based elevation data in the previous step. For example, rivers can often change course over a decade in low lying deltas. Comparison with day-time pictures of the rivers (from Google Earth, or other high resolution photographs from satellites) can help correct a lot of missing and non-existent river channels and significantly improve river model accuracy.
4. For a more realistic estimate of river bed slope and profile (which is a key input to a river model), use satellite data revealing land elevation along each river. Compute the slope of the land surface along a river reach. Assume that to be parallel to the river bed (bottom) and use it as a proxy for river bed slope in the river model.
5. Next, use satellite data from active microwave platforms (radar altimeters) to directly measure river levels over as many river locations as possible where ground information on water depth at the river cross section (bathymetry) is absent. Combine this altimeter river height information with coincident satellite data in the visible range (camera-ready photographs) that can

inform a user about the river's width. When such height versus width relationships are captured periodically over a year's time as the river swells and shrinks, the river's cross sectional shape -- a key feature of a river model -- can be inferred with reasonable accuracy. Use this satellite-based height-versus-width relationship as a proxy for river cross section shape to refine the 'guessed' shapes in river models where ground information is lacking.

6. When trying to predict the behavior of rivers over a long period of time (greater than a month) in a large basin, use a satellite-precipitation data and a hydrologic model to derive the additional flow that enters the rivers due to rainstorms in the region. This addition will result in significant improvement in accuracy of river level prediction during the flood season.



This image illustrates the method used in this study. Click the image to enlarge.

The team published a scientific paper documenting their findings, but they want the news to reach well beyond the scientific community -- to the stakeholder agencies, partners, and development agencies who need to know about these results for use in the real world of river modeling and water management. The team ultimately wants the information in the hands of stakeholders around the world who need innovative, creative, and yet practicable methods in a resource-limited operational environment for various applications so they can enhance and even save lives in their countries.

"They are usually accustomed to thinking in an environment either where there is 'data' on the ground, or where the lack of such data means they can do no modeling," says Hossain. "This work of ours should help them believe in themselves that sometimes one can overcome a lot of the hurdles if they use satellite data of various kinds synergistically."

Supported by SERVIR, the team of researchers plans to hold training workshops to get this method in the hands of officials responsible for monitoring and forecasting flood conditions. For example, they will hold a workshop in Pakistan in the near future to train representatives from five agencies. The team will help ensure that these agencies have access to data from different kinds of satellite sensors working as a 'team' so that they can extract the data themselves.

Notes:

SERVIR is a joint development initiative of NASA and USAID, working in partnership with leading regional organizations around the globe, to help developing countries use information provided by Earth observing satellites and geospatial technologies for managing climate risks and land use.

Here is the SERVIR product catalogue entry about this method: http://catalogue.servirglobal.net/Product?product_id=32

The study focused on the Ganges-Brahmaputra basins, but the findings are applicable to river level modeling in general in any large ungauged river basin.

Some of the satellites that can serve as sources of data for understanding rivers:

SRTM - Shuttle Radar Topography Mission (http://srtm.usgs.gov/index.php)
TRMM - Tropical Rainfall Measuring Mission (http://trmm.gsfc.nasa.gov/)
Aqua - (http://aqua.nasa.gov/)
Terra - (http://terra.nasa.gov/)
GOES - Geostationary Operational Environmental Satellite (http://www.goes.noaa.gov/)
Jason-2 - (http://www.nasa.gov/mission_pages/ostm/main/#.VInpQRCwWSo)
ENVISAT - (https://earth.esa.int/web/guest/missions/esa-operational-eo-missions/envisat)
Landsat 7-8 – (http://landsat.usgs.gov/ , http://landsat.usgs.gov/)

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