PhD Project Policy Brief:

Updating River Basin Models with Radar Altimetry.

(DFC project number 09-043DTU)

Executive summary

While knowledge of the quantity of water flowing in rivers is of vital importance to water managers, up to date hydrological datasets are unavailable in many regions. This can be due to the costly maintenance of gauges, the difficulty in accessing remote areas or because of political unwillingness to share data with riparian countries. Satellite remote sensing data can provide an alternative to traditional monitoring and in this project the potential for using satellite based radar altimetry to monitor rivers and improve model-predicted discharge was investigated for the Zambezi and Brahmaputra Rivers.

Introduction

Hydrological models are simplified representations of the hydrologic cycle and are used to estimate river discharge based on meteorological inputs such as precipitation. They are widely used by water managers for varied applications including reservoir management, flood and drought mitigation and, on longer time-scales, the analysis of the impact of climate change or of planned hydraulic structures. However, discharge predictions from models are highly uncertain. In order to reduce uncertainties and improve predictions for short-term applications, current measurements of river level and discharge are commonly used to update models. In many areas however, access to in situ data is difficult and satellite based measurements can be used instead.

One such type of satellite-based measurement is radar altimetry. Radar altimetry is a technique to measure height and can be used to produce time-series of water level variations for surface water bodies such as rivers, lakes and floodplains.

The objective of the research was the investigation of the potential for the use of radar altimetry over rivers in hydrological applications using two case studies

where only limited in situ data was available: the Zambezi River basin where the operation of reservoirs could be improved with better predictions of future inflows and the Brahmaputra River which is often subject to devastating floods.

In the Zambezi, we found that many rivers with widths between 80 and 400m could be monitored with radar altimetry and that in many cases the measured water levels could be used to estimate flows even with only limited available in situ data. Radar altimetry data was then used to update river models of the Zambezi and Brahmaputra Rivers and good improvements of modeled river discharge were found.

Methodology/Background

Satellite remote sensing has made it possible to monitor the hydrological cycle in innovative ways thanks to many new types of observations and to the global coverage of the datasets. While river discharge is one of the major variables of interest to hydrologists and water managers, there is way to directly measure river discharge from remote sensing. Radar altimetry, which allows for the tracking of river level variations, is the most promising technique in order to be able to obtain river discharge from space.

The datasets obtained from radar altimetry have limitations that can be an obstacle for its use in hydrological applications:

- Quality of altimetry data at a specific location depends on many factors including river width and surroundings.
- Altimetry measures water surface elevations but most applications require river discharge.
- Measurements at each location are only repeated each 10 to 35 days for current satellites while most applications require daily measurements.
- Measurements are available at the intersections of the satellite ground track with the river network and this does not necessarily coincide with the points at which water managers need information.

The project aimed to address these problems by carrying out the following activities:

In the first part of the study, all available radar altimetry data from the ENVISAT satellite mission and the errors associated with the measurements as well as the potential to calculate discharge from altimetry at the time of measurement were analyzed over the Zambezi River basin. This task included analysis of all locations where a useful signal from the altimeter was expected, analysis of other sources of remote sensing data, as well as two months of data collection in Zambia including both obtaining data from the Zambian Department of Water Affairs and field measurements at selected river locations. Using this data, methods to obtain river discharge from altimetry for different data availability scenarios were developed and tested.

The second part of the work consisted in using radar altimetry in order to update model predicted river discharge for the Zambezi and Brahmaputra rivers using data assimilation (see box below). In order to do this, river models were developed for both case studies using remotely sensed data as input and a data assimilation procedure was developed. The performance of the model with and without the use of altimetry was compared to in situ data where available.

Data assimilation
Data assimilation consists in using observations of a system (in this study the altimetry) in order to update a model-predicted state (in this case the volume of water stored in the river) in order to obtain improved estimates of the model state.

Results

Overall, it was found that there is a large potential for radar altimetry to help quantify the amount of available water in the two rivers studied, both to provide instantaneous discharge measurements as well as to improve model results, but that it cannot be used fully independently of traditional in situ measurements. In more detail, the main results can be summarized as follows:

- Radar altimetry level time series were successfully extracted at 31 locations in the Zambezi for rives between 80 and 400 m wide with errors between 0.32 and 0.72 m.
- Discharge at the locations high quality altimetry in the Zambezi was determined with less than 14% error with only limited available ground data.

- Assimilation of radar altimetry to simple routing models provided improved predictions in both case studies.
- There is a need for better understanding and modeling of errors in order to improve model reliability.
- The low temporal resolution of the altimetry dataset can be overcome by using measurements from multiple locations depending on data availability.

Conclusions

In conclusion the study showed radar altimetry is a valuable dataset for hydrologists, in particular in areas where access to traditional data is difficult. While the data is not in a position to replace in situ gauging data, methods that integrate both altimetry data and in situ data with other types of remote sensing data, in particular through modeling efforts, have a great potential of improving our knowledge of freshwater availability.

Implications

Results from both the Zambezi and the Brahmaputra showed that the low temporal resolution of the data could be compensated in part by the use of altimetry data from different locations within the same river system. This highlights the benefits which could be obtained from radar altimeter missions with a denser spatial resolution allowing for more, narrower rivers to be monitored.

It is also expected that studies jointly assimilating assimilation and other types of remotely sensed or in situ data would show promising results and more research in this direction is encouraged.

In both case studies, the simple error model specification used was found to be one of the weak points of the data assimilation approach and further research is suggested in order to improve the quantification of uncertainties.