River and Lake Level data from Radar Altimetry in Support of the Tiger Initiative

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ABSTRACT

A web-based pilot demonstration makes Envisat-derived radar altimetry measurements of the inland surface water level freely available in near-real time, globally, therefore supporting the TIGER Initiative to supply EO data to Africa for water resource management. Envisat's Radar Altimeter-2 data are processed in near real time by a sophisticated algorithm developed by De Montfort University (DMU) in Leicester, UK, under ESA contract. Until now reliable information has been difficult to access because of the high cost in equipment, manpower and communications, and because it still is problematical to obtain hydrological data from many countries, despite efforts from international organizations, agencies and forums. The near-real-time processing system identifies that part of each surface echo originating from inland water, enabling measurement of much smaller targets, with an increased accuracy, than has previously been possible. With the recent improvement of the data processing in real-time of the precise orbit determination system aboard the satellite, DORIS, the system can be pushed further to deliver water levels in less than six hours, in order to better satisfy the actual needs of users.

INTRODUCTION

Supported by the European Space Agency's Earth Observation Data User Element, the River and Lake project is aimed at developing, demonstrating and assessing an information service based on inland water altimetry, globally and both in near real time and for analysing decadal time series. The data retrieved over Africa is supporting ESA's TIGER initiative. Following the 2002 Johannesburg World Summit on Sustainable Development, the European Space Agency has launched the TIGER Initiative - focusing on the use of space technology for water resource management in Africa and providing concrete actions to match the Resolutions. The objective of the River and Lake research and development project is to build and validate a system that retrieves inland water heights from ENVISAT, globally, in Near Real Time, i.e, without time for a posteriori verification, for a substantial set of lakes and rivers, which is the main challenge of the development [1,2]. Data are also provided from the historical archive amassed by ERS2. The ultimate goal is drastically to increase the number of measured inland water bodies, by improving the data processing, meanwhile demonstrating the accuracy and robustness of the approach through a demonstration pilot. When it is confirmed as mature and when the users are satisfied with the data products, this processing should be sustained as an operational service, relying on data from an operational space-borne mission. An important aspect for this demonstration is the involvement of users in the local verification of the accuracy of the river stage derived from the radar altimetry data. Furthermore, the quality of an operational service relies on timeliness, frequency of repetition and location, in other terms, usefulness, for which feedback shall also be gathered from users.

VIRTUAL LIMNOGRAPHS

Satellite altimetry measures the altitude of the river or lake surface, firing 1800 Hz pulses every second averaged on-board by groups of one hundred. Each averaged 18Hz waveform corresponds to 350 m of progression along the orbit. This means that a great number of radar echoes bounce off the water surface, which in turn can be changed into virtual limnograph readings of the stage [1]. Data over inland water are selected using a mask, which is set conservatively so that only those targets known to give reliable height estimates are included. The echoes are then analysed and those with simple shapes known to be associated with inland water are retained. These echoes are then ‘retracked’ using one of a set of algorithms configured for each echo shape, which determines which part of the returned echo corresponds to the ‘mean surface’ directly below the altimeter. The range to surface is then adjusted to use this value, and the data are combined with Geoid model EGM96 [4] to calculate a height above mean sea level [5]. Two important questions are 1) How many virtual limnographs can satellite altimetry generate? And 2) Can these virtual limnographs supplement the existing but decreasing worldwide limnograph network? Taking Central Africa as an example we see that there are approximately 30 EnviSat river and lake crossings that can potentially be processed into virtual limnographs (Figure 1).

However, not all readings go through quality threshold tests all year round, due to environmental variations, from season to season, perturbing the radar echoes. As an indication, the accuracy of the best readings are nearing the accuracy of ocean measurements, around 5 cm and degrade depending on the water body dimension and environment. When the measurement is too convolved with returns from surfaces other than the targeted river, then the data are not supplied in near real time, as it will require a more sophisticate processing which can be done off-line to accurately retrieve the water component within the echoes and convert it to river stage. It is worth noting that the primary limitation is now not the retracking but the atmospheric corrections error, particularly the wet tropospheric correction.

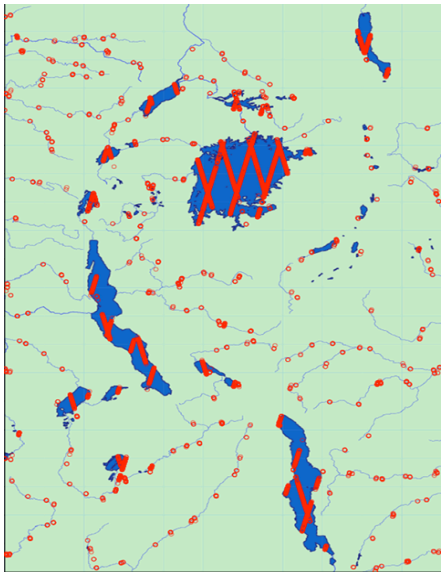

Figure 1: River and lake crossings in Central Africa of the Radar altimeter supplying measurements than can be turned into river or lake stage.

VALIDATION OVER AMAZONIA / GAUGE STATION

To assess the current accuracy of altimeter derived height time series, a validation exercise has been undertaken in the Amazon Basin, using the measurements from the available river gauge network. A typical example of the comparison of River and Lake Output product using ENVISAT measurements is shown here (Figure 2). The comparison from November 2002 to August 2005 yields a correlation coefficient of 0.987 and rms of 36 cm. The rms value is not to be taken as the error of the river level measured by radar altimetry as it includes a difference due to the distance between the satellite river crossing and the location of the river gauge. The very high correlation coefficient shows that the altimeter is retrieving the annual cycle with high fidelity.

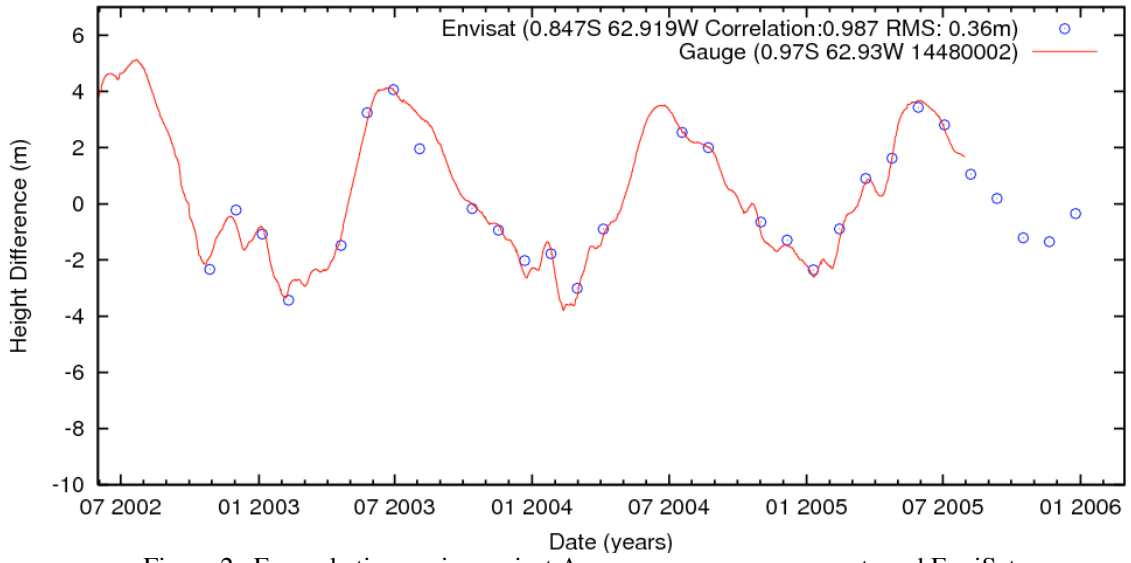

Figure 2: Example time series against Amazon gauge measurements and EnviSat

THE NEAR REAL TIME PILOT DEMONSTRATION

In order to demonstrate and qualify the usefulness of this novel data flow, a pilot experiment was set up to supply river and lake stage data in near real time. The main steps to be performed are summarized in the following:

1) Radar Altimeter waveforms and geophysical corrections are fetched directly from the Envisat ground segment; the level 1B data [3] which contain the waveforms are available within 1-2 days of measurement, and fusing these data with the IGDR product [3], which provides accurate orbit data and the series of atmospheric corrections required to compute the range from the satellite to the surface enables generation of the height measurements.
2) An ad hoc USO correction is computed and applied
3) The near real time River&Lake processor is run as soon as the data is received and corrected
4) The "River&Lake for Hydrology" (RLH) output product is stored on the web site

The longest lag is the availability of the DORIS orbit (3~4 days), but this could improve to a few hours as the DORIS Navigator orbit is fully processed in real time, at the cost of a lower accuracy in the orbit solution. A comparison between the near real-time and off-line SGDR product-derived river level shows very good agreement to the centimeter level. This means that the loss of accuracy for the near real time product derived river and lake heights is within a few cm, compared to the final precision product (Figure 3).

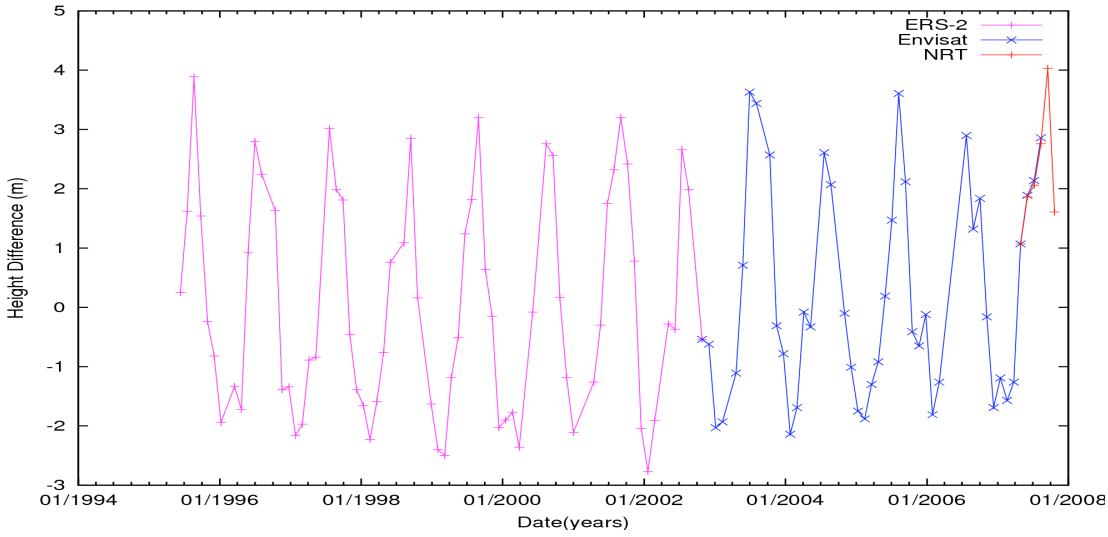

Figure 3: The data processed in near real time (red) show very good agreement to the centimeter level with the SGDR off-line precision product from ENVISAT (blue) and ERS-2 (pink) past data.

THE RIVER AND LAKE MASK OVER AFRICA

In order not to supply erroneous data in near real time, targets in which we have confidence to retrieve good data all year round are identified in the mask used to screen the input to the processing (Figure 4). Red indicates areas where NRT products are currently generated, blue indicates area where products may be generated in the future, after additional research is done to enhance the data processing. As the pilot demonstration continues and water level output products are assessed, the mask will periodically be upgraded to include additional sites. Note that at any time a specific site can be added upon special user request for the purpose of validating the stage measurement produced on this site.

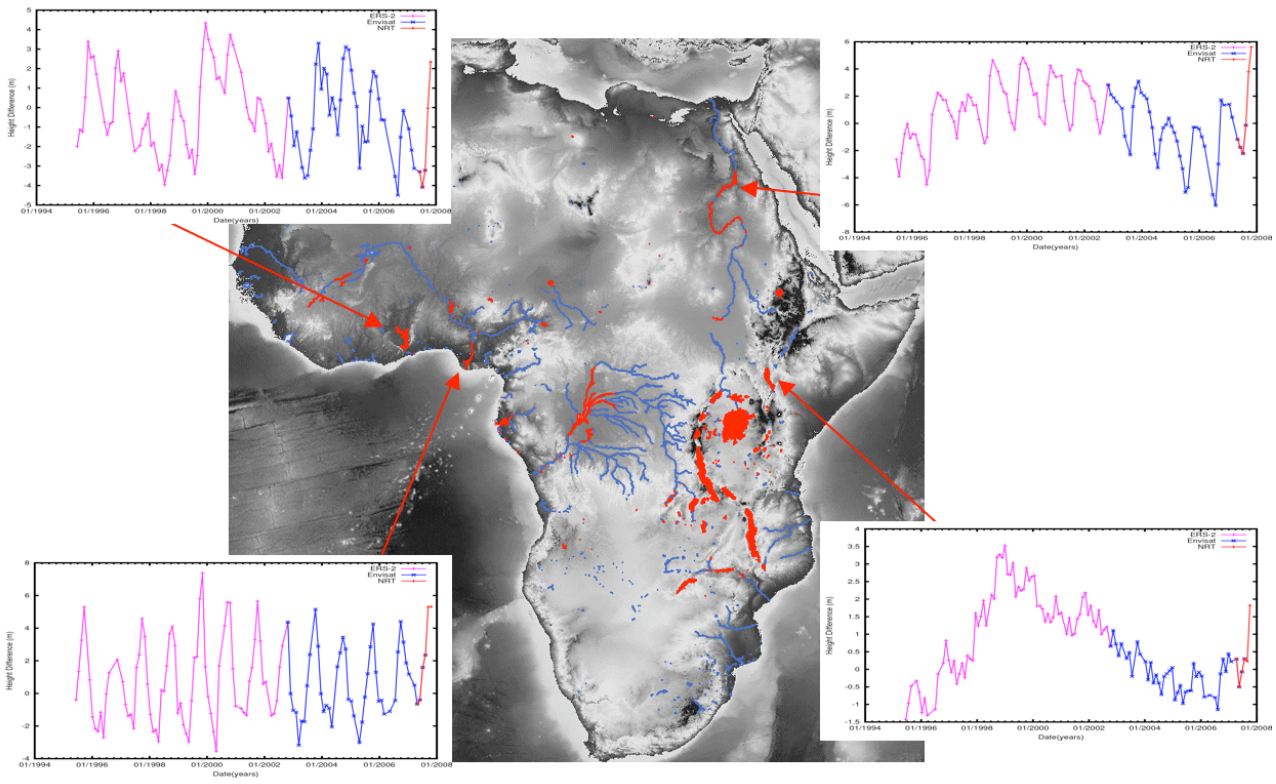

Figure 4: The River and Lake mask over Africa: Red indicates area where NRT products are currently generated, Blue indicates area where products may be generated in the future. Examples of the river and lake level time series since 1995, from ERS-2 (pink) and ENVISAT past data (blue) and Near Real Time data (red), are shown.

DATA ACCESS VIA THE RIVER AND LAKE WEB SITE

The near real time data are made available via the river and lake web site http://earth.esa.int/riverandlake. The web site contains all the user level information and documentation produced since the inception of the Project. It is highly recommended that users make themselves known by signing-up to a distribution list by writing to the email address included in the web site. Some samples of historical data over all continents are shown on plots as well as being provided as the two standard products: RLH for Hydrologists and RLA for altimeter specialists. The user desiring time series on a particular river, lake or catchment basin, is invited to submit the necessary information describing his

requirements and he will be supplied directly, most probably by email as the RLH products are very small [6].

RIVER AND LAKE PROJECT SUPPORTING THE TIGER INITIATIVE

In 2002, ESA launched the TIGER initiative as a CEOS contribution to implement the recommendations of the World Summit on Sustainable Development. The paucity and poor quality of information on water & land resources required for water resource management is considered a key constraint in achieving the WSSD goals. The TIGER goal is to "*assist African countries to overcome problems faced in the collection, analysis and dissemination of water related geo-information by exploiting the advantages of Earth Observation technology"*.

It is clear that EO derived information has major comparative advantages for extensive management of resources such as water in Africa by contributing to overcome the water information gap in Africa, complementing the scarce or deficient in-situ data network infrastructures. It would moreover provide homogeneous overview of large regions, facilitating integration of (neutral) information from local to national to trans-boundary scales, including remote, inaccessible or insecure areas.

The Tiger Initiative shall contribute to enhance institutional, human and technical capacities, in addition to supporting the consolidation of a critical mass of technical centres in Africa with the skills and capabilities to exploit the advantages of EO technology in order to improve water research and knowledge in Africa as well as deriving water-relevant geo-information. The initiative shall also ensure sustainability by developing a strategy for strengthening and sustaining EO-supported water resource management information and decision-support systems in the long term. The Initiative started with a research phase, where Pilot Projects were set-up, evolves in a pre-operational phase with a number of North-South Technology Transfer Projects and should bloom into an operational phase with the set-up of a sustainable African Water Observation system.

CONCLUSION AND OUTLOOK

The "River and Lake" processing system has now matured to a point where river and lake levels can be supplied in near real time, meaning that it produces and disseminates the high quality output products, without human intervention. However, two problems remain to be solved: today, only 25% of the potential data can be supplied accurately in NRT and the data from one single mission are too sparse in space and time to be used directly for assimilation in river basin models. These two problems cannot be resolved without an evolution of the "River and Lake" System. The System will need to be further developed 1) to increase the number of rivers that can be measured from space, processed and delivered automatically without validation and 2) to include the data coming from Jason-1 and Jason-2. Once this is done, the objective is to run another pilot demonstration phase, and support the effort to assimilate the data produced into river catchment models.

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