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From TOPEX/Poseidon to Jason-2/OSTM in the Amazon basin

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Abstract

A major interest of radar altimetry over rivers is to monitor water resources and associated risk in basins where there is little or no conventional in situ data. The objective of the present study is to calibrate altimetry data in a place where conventional data are available, and use the results to estimate the potential error committed in the estimation of water levels in an ungauged or poorly gauged basin. The virtual stations extracted with Jason-2 in this study concern a very broad sample of river channel width and complexity. Minimum channel width has been estimated at 400 m. Unlike TOPEX/Poseidon (T/P), Jason-2 seems to have the capability to distinguish the river bed from its floodplain. The quality of the results obtained with Jason-2 is incomparably better than that obtained with T/P. Despite the fact that no absolute calibration has been assessed for river in this study, the bias calculated converge around 0, 35 m, which could be then the error estimated on the water stage derived from Jason-2 ranges, when no other validation is available. ICE3 algorithm seems to be performing as well as ICE1, and further research is needed to design retracking algorithm specifically for continental water.

Keywords: Altimeter calibration; Jason-2; Amazon basin; Hydrology

1. Introduction

The family of TOPEX/Poseidon (T/P) satellites (Fu et al., 1991) extends over 20 years of altimetry history, since T/P was launched August 10, 1992 from Kourou in French Guiana. It is only in 1996 that the retracking of T/P archive by the Science Working Team on the T/P project, achieves 2–3 cm error in estimating the ocean surface. This accuracy has been reached because of reduced radial orbit errors (Bertiger et al., 1994), reaching the sub-centimetric accuracy for the Jason-2 mission (Bertiger et al., 2010). It is also about that time that are emerging the first applications of altimetry for inland waters (Morris and Gill, 1994; Birkett, 1995a,b, 1998; Ponchaut and Cazenave, 1998). It is only 10 years later that are published early works on multi altimeter mission for inland waters (Berry et al., 2005; Frappart et al., 2006). Jason-1 that was highly anticipated as a following of T/P, was for inland waters a "gap" in data since very few data of Jason-1 are useful for monitoring inland waters. It was not until 2008 and the launch of Jason-2 to continue the Poseidon family on inland water bodies.

In the studies of the ocean, it is possible to combine data from different missions as long as the relative biases are estimated. This is due to the spatial and temporal continuity of the ocean environment. The case of rivers and lakes is different. Most lakes of small area will no longer be

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monitored if the trace of the orbit changes during a mission or between two different missions. In the case of rivers, there exists a spatial continuity but limited to the hydrographic network. The water level in the river system results from the combination of hydrodynamic factors (slope, flow velocity, roughness of the bed), morphological factors (shape of the section that is variable throughout the hydrological cycle), the contribution of the tributaries and the various exchanges with the watershed and the floodplain (direct rainfall, evaporation, diffuse runoff, groundwater contribution and subtraction). It is easily understandable that this combination of factors is highly and non linearly variable in space and time. In addition, the use of satellite altimetry for monitoring river stage allowed defining the notion of virtual station (Frappart et al., 2006; Leon et al., 2006; Roux et al., 2008). A virtual station is constituted by the measurement points from the ground track portion located at the intersection with the river. This concept was designed partly to be close to terrestrial water level monitoring networks that consist of fixed stations. The interest and value of a water level measurement station is linked to its lifespan in a specific place. This persistence allows following changes in the hydrological regime in the long term and predicting extreme events. Monitoring and forecasting is of course even more significant in the context of climate change. It is why the concept of lineage of the missions is an important concept for hydrology, as at a family of satellite corresponds a common orbit, which ensures continuity in the river or lake monitoring. It is the first objective of this study to compare the results obtained by T/P and by Jason-2 in estimating the water stage at virtual stations.

In hydrology, the need for temporal continuity of the missions is accompanied by a need for a spatial distribution as dense as possible. This is one of the great advantages of altimetry over conventional hydrological measurement networks to be globally distributed in a dense network constituted by the different satellite ground tracks. For example, the study of Frappart et al. (2005) calculated the storage of the inundation plain of the Rio Negro sub-basin. This sub-basin of about 700 000 km^2 counts 25 in situ stations and T/P altimetric virtual stations added 88 monitoring points of the water stage. Using multi-mission sources allows densifying the monitoring network of virtual stations. In this respect the relatively loose mesh of the Jason-2 orbit is complementary to that of Envisat, much denser. The reverse is true for the temporal resolution. The revisit period greater than one month prevents a number of hydrological applications to be contemplated with Envisat data. In this respect, Jason-2 is better suited for some applications needing frequent observations. However for using multi-mission data, it is necessary to determine possible bias between sensors. If there are a number of studies on absolute bias of Jason-1 and 2 in the oceanic domain (Dettmering and Bosch, 2010; Bonnefond et al., 2010; Haines et al., 2010; Mertikas et al., 2010, 2011; Arnault et al., 2011; Watson et al., 2011; Washburn et al., 2011, among others), a few studies of calibration over lakes (Birkett and Beckley, 2010; Cheng et al., 2010; Cretaux et al., 2009, 2011), there is currently no estimate of absolute bias for Jason-2 on rivers. This is the second objective of this paper to determine if absolute calibration for Jason-2 is possible over river.

The advantage of using data processed by tracker designed specifically for inland waters has been repeatedly shown (Frappart et al., 2006; Birkett and Beckley, 2010). Cited studies established that the algorithm ICE1 was more robust than the other retracking algorithms (OCEAN, SEAICE and ICE2) for both Envisat and Jason-2 over inland waters. When estimating the water height, ICE1 do not always give the less noisy result but it gives nearly the better result in most cases. In addition comparing with other retracking algorithm, ICE1 has the lowest rate of data loss. As soon as 2004, considerable effort has been made by the CASH project (Contribution of Satellite Altimetry to Hydrology, funded by the *Réseau Terre & Espace*,[1] on behalf of the French Ministry of Research) for processing the whole T/P archive for the nominal orbit, with the trackers used for the Envisat mission (namely ICE1, ICE2 and SeaIce). During the PISTACH project, Mercier et al. (2007) have developed for CNES a tracker specific for inland waters called ICE3, that has been applied to the Jason-2 data. No studies comparing the two trackers ICE3 and ICE1 have been published and this is the third objective of the present study.

2. Data and methods

Data used in this study were from two radar altimeter satellite mission, T/P and Jason-2/OSTM. Were also used data from GPS acquisition campaigns and in situ limnimetric data.

T/P satellite was launched on August 10th, 1992 by NASA, U.S. space agency and CNES, the French space agency. It is given a sea level overall accuracy over one month better than 2 cm. In September 2002, T/P was moved to a new orbit, now used by Jason-1, liberating the orbit for Jason-2 after a tandem phase. The tandem formation was maintained (both ground track within 1 km of each other) from the launch of Jason-2 in June 2008 until January 26th, 2009, when Jason-1 was moved from that orbit into the T/P one. This phase has been used for calibrating the entire altimetric system (Quartly, 2010), mainly over ocean. It could not have been used over land surface as very few continental Jason-1 data is available.

The T/P data used in this study encompass then the period 1992–2002 (http://www.aviso.oceanobs.com/en/missions/past-missions/topexposeidon.html). In the scope of the CASH project, the whole archive of T/P data on the nominal orbit has been retracked with the four algorithms used for the Envisat mission, i.e. ocean, ICE1, ICE2, and SEAICE. In this study we used the T/P data of the CASH

[1] In French – means Earth and space network.