

Applications of GNSS data for hydrological studies in the Amazon basin



Daniel Moreira (1.4), Félix Perosanz (3), Stéphane Calmant (2), Andre Santos (1), Joecila Silva (5), Frédérique Seyler (6), Guillaume Ramillen (3), Otto Rotunno(4), Achiles Monteiro (1), and C.K. Shum (7)

UEA

(1) CPRM/Geological Survey of Brazil, Rio de Janeiro, Brazil. E-mail:daniel.moreira@cprm.gov.br.

- (2) IRD/LEGOS.Toulouse.France.
- (3) CNES/GRGS, Toulouse, France.

(4) COPPE/UFRJ, Federal University of Rio de Janeiro, Rio de Janeiro, Brazil.

(5) UEA- University of the State of Amazonas, Manaus, Brazil,

(6) IRD/LMTG. Toulouse. France.

(7) School of Earth Sciences/The Ohio State University, Colombus, Ohio, USA,

INTRODUCTION

Using of GNSS data in hydrology is being more and more popular. The key applications are the levelling of hydrological gauge stations and characterization of river's longitudinal profiles, these information are required to develop hydrological and hydrodynamic studies and to evaluate the quality of data obtained through space altimetry techniques.

Some factors illustrate the challenge of establishing guality altimetry data from a GNSS receivers to obtain river profiles in Amazon Basin. In this area, the GNSS reference network is sparse, the distance between survey points and reference stations is large and rivers have an extension of several thousands of kilometers. All these factors contribute in limiting the efficiency of classical techniques of GNSS data processing like double difference. In addition the Amazon Basin are strongly affected by charge effects, mainly caused by the hydrological cycle of this basin. These effects can produce a variation of about 10 cm in amplitude of vertical coordinates. In the present work we discuss the capability of kinematic processing strategy to calculate river's longitudinal profiles in the Amazon Basin The profiles are also used to levelling some gauge stations in the Amazon Basin. The seasonal hydrological loading signal of these profiles will be removed by data derived from the series of permanent GNSS stations installed in the Amazon. GRACE data also be used to convert the hydrologic load into crustal displacements to remove hydrological loading effects.

The results of the Amazon rivers profiles will be then compared with profiles obtained by water level variation data using altimetry data from tracks ENVISAT mission.



PATERNSHIP

This work is part of the project "Dinâmica Fluvial" is a partnership between the IRD (Institute of Development Research) and CPRM (Brazilian Geologic Survey) for studies the dynamics of the Amazon Basin, this work is also part of the river section FOAM project. This is the first project ever conducted for the direct validation of altimetry data on rivers. The main objectives of the study is to evaluate and use data from space altimetry to obtain water levels in rivers and floodplains. For processing the GPS data was started a partnership with the GRGS (Research Group on Space Geodesy) and used the GINS software developed by the same laboratory (www.igsac-cnes.cls.fr). This work is also supported by students and professors from UEA and UFRJ. The field campaigns is supported by CPRM/SUREG-MANAUS

GPS DATA PROCESSING STRATEGY

The GPS data processing was made using GINS-PC software. The GINS (Géodésie par Intégration Numérique Simultanée) was originally created in the 70th of the XX century by the group of CNES / GRGS (Centre National d'Études Spatiales / Groupe de Recherche de Géodésie Spatiale) to process space geodesy data. Our data processing strategy was based on PPP (Precise Point Positioning) with GRG (IGS Analysis Center) orbits and clocks products for kinematics solutions to obtain river's profile. For static solutions we used PPP and DD (Double Difference) for levelling gauge stations.

APPLICATIONS OF PPP KINEMATICS FOR HYDROLOGY

The river profiles obtained from GNSS data are compared to profiles measured by water level variation using altimetry data on the tracks of the ENVISAT missions. Also these profiles will be used to leveling gauges stations in Amazon basin

The main goal of comparison the GNSS kinematic solution from the fix point for levelling gauges is a gain of time on the field work. With kinematics PPP solution is possible to level gauge stations in a few minutes while fixed PPP solution requires several hours.



Boat used for GPS data survey

MADEIRA RIVER PROFILE

The river's profiles were processed using data obtained from GPS receivers on boarding boats along the rivers of Amazon Basin such as Madeira river and Amazon/Solimões river. For this purpose, field campaigns were conducted between 2005 and 2010 by ANA (Brazilian National Water Agency), CPRM (Brazilian Geologic Survey), IRD (French Institute of Research by Development), Hybam (Hydrology of Amazon Basin), PROSUL (Remotely Sensed Techniques applied to Hydrologic Monitoring and Climatic Changes in the Amazon Basin Research project by CNPQ/UFRJ) and FOAM (From Ocean to inland waters Altimetry Monitoring) river section project.





* The data from altimeter was collected before and after the boat passage over the satellite track

GAUGE STATIONS LEVELLING

The method of leveling gauges stations by PPP kinematics has an precision of about 10 cm in relation of fixed solutions

The probable other errors which increase the difference between both solutions are

- · error in measuring of the antenna boat height; · antenna height variation due to the change in mass of the boat (due to changes in fuel and other
- resources). antenna height variation due to boat's speed;
- water slope between the boat position and gauge station:
- · gauge data error:
- hydrological loading variations between the time of boat passage and fixed point levelling.

| GAUGES STATIONS | RIVER | DATE_FIX_POINT | GAUGE_LEVEL_FIX_POINT | DATE_KINEMATICS | GAUGE_LEVEL_KINEMATIC | DIFF_FIX_KINEMATIC |
|-----------------|---------|----------------|-----------------------|-----------------|-----------------------|--------------------|
| | | | METERS | | METERS | METERS |
| PORTO VELHO | MADEIRA | Dec-05 | 54.79527802 | Dec-09 | 54.840709 | -0.04543098 |
| HUMAITÁ | MADEIRA | Jul-11 | 31.52300871 | Dec-09 | 31.627406 | -0.10439728 |
| MANICORÉ | MADEIRA | Jul-11 | 2.501739065 | Dec-09 | 2.626888 | -0.12515293 |
| BORBA | MADEIRA | Jul-11 | -6.572531731 | Dec-09 | -6.615231 | 0.04269926 |
| VISTA ALEGRE | MADEIRA | Jul-11 | -4.424681197 | Dec-09 | -4.544114 | 0.11943280 |
| RUCIRTIRA | MADEIRA | .16411 | .14.77 | Dec.09 | -14 126617 | .0 1433 |

HYDROLOGICAL LOADING AT GAUGE STATIONS

An important issue to realize is that most sites of GPS stations in Brazil have a considerable signal caused by hydrological loading. When a centimeter level accuracy is need, it is necessary to take this into account.









•The PPP capabilities of the CNES/GRGS GINS software is very useful

to process hydrological measurements especially in very remote places

•The main errors of the PPP kinematics method are still in the antenna

height variations due to the movement of the boat, this effect should be

•However, kinematic PPP is a great alternative option in areas like the

GNSS receivers along river margins because of tall trees causing bad

leveling gauge stations can reduce costs and time during measurement

·Validation of satellite altimeter data for hydrology applications has also a great interest in terms of cost reduction compared to conventional

monitoring. For satellite altimetry data validation the use of GNSS data is

satellite visibility. Also the attempting to use the kinematic method for

Amazon basin. In the Amazon basin it can be extremely difficult to install

CONCLUSIONS

better considered in our further analysis

one of the best evaluation method.

such as the Amazon basin

campaigns

Water Level and Hydrological Loading



 The risk of use GPS processing technical of double difference, especially when the objective is to validate remote sensing techniques that have another perceptions of this loading effects. In some cases using a DD solution the station can been had some vertical effects negated or smoothed.

· For that and for this case we concluded that the PPP approach is more appropriated to get the "absolute" vertical displacement of stations in the Amazon basin.



| SAUGES STATIONS | RIVER | DATE_PIX_POINT | GAUGE_LEVEL_FIX_POINT | DATE_KINEMATICS | GAUGE_LEVEL_KINEMATIC | DIFF_FIX_KINEMATICS |
|-----------------|---------|----------------|-----------------------|-----------------|-----------------------|---------------------|
| | | | METERS | | METERS | METERS |
| ORTO VELHO | MADEIRA | Dec-09 | 54.79527802 | Dec-09 | 54.840709 | -0.04543098 |
| IUMAITÁ | MADEIRA | Jul-11 | 31.52300871 | Dec-09 | 31.627406 | -0.10439728 |
| MANICORÉ | MADEIRA | Jul-11 | 2.501735065 | Dec-09 | 2.626888 | -0.12515293 |
| ORBA | MADEIRA | Jul-11 | -6.572531731 | Dec-09 | -6.615231 | 0.042699268 |
| ISTA ALEGRE | MADEIRA | Jul-11 | -4.424681197 | Dec-09 | -4.544114 | 0.119432800 |
| IRUCURITUBA | MADEIRA | Jul-11 | -14.27 | Dec-09 | -14.126617 | -0.14338 |

