Spatial processing techniques for Envisat and Saral/Altika altimetry data of the São Francisco River, Brazil

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Introduction

- Increasing pressure on water resources make water agencies seek new, more effcient technologies to monitor rivers
- Satellite altimetry (SA) has the advantage of being almost instantly available
- SA applied to continental hydrology still faces many challenges
- With finer resolutions SA becomes a tool for narrower rivers (less than 100 m in some cases)
- SARAL/Altika is a welcomed improved continuation of the Envisat mission

Introduction

- The São Francisco is the largest watershed entirely comprised in Brazil
- By crossing 5 states it is called the river of national integration
- It is navigable for a 1000 km stretch
- The focus of (polemic) attention with the transposition of its course
- SARAL offers an opportunity to convince water agencies of Brazil to create a network of VHS's for operational purposes

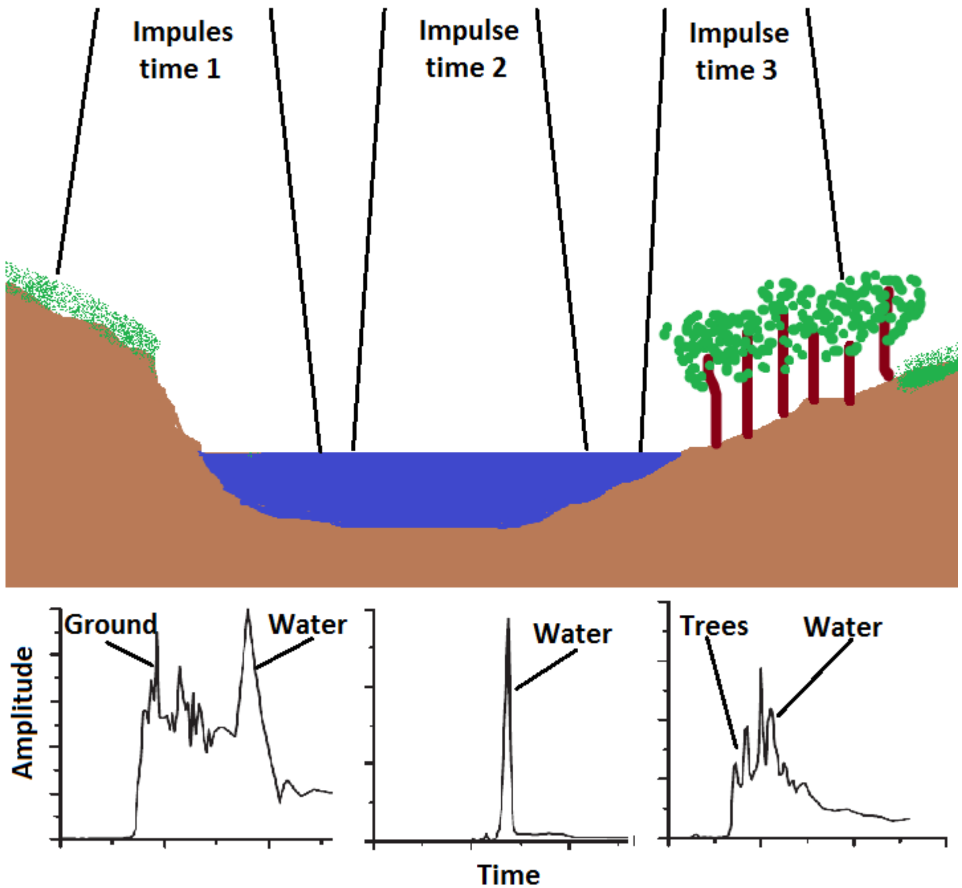

Bacia do
São Francisco
PALMAS
TO
26 9'98

Objective

- Implement spatial processing techniques for extracting water levels on medium size rivers (< 1 km)
- Create application tools to systematically and efficently make measurements on VHS
- Compare results with *in situ* measurements from the São Francisco River, Brazil
- Compare Envisat and SARAL/Altika

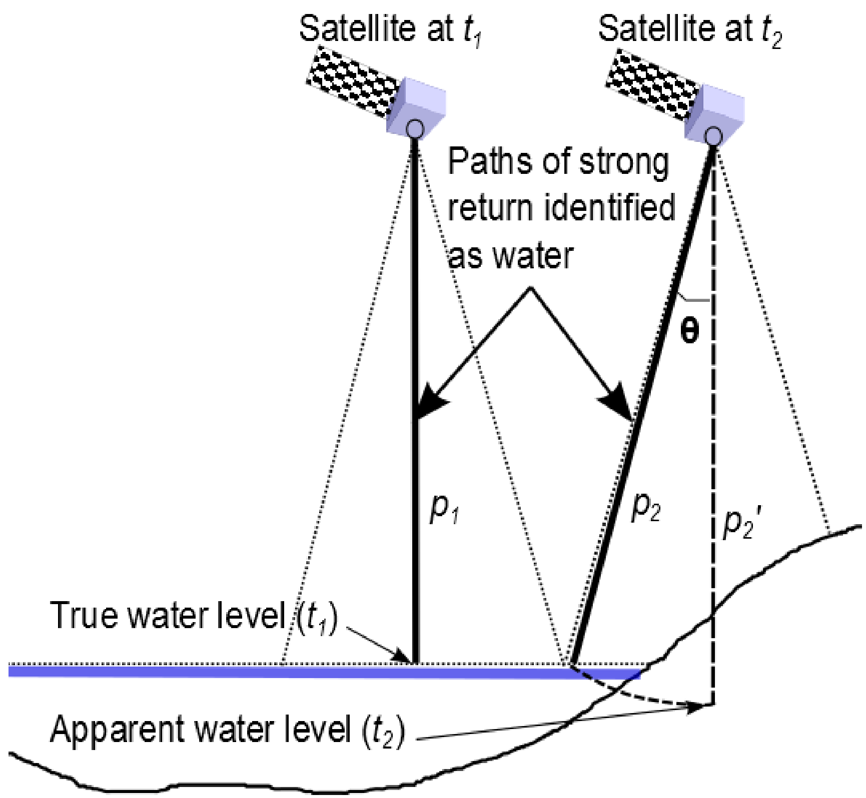
Problem of hydrological altymetry

- First strong return is not always from nadir and retracker must select a «probable» target

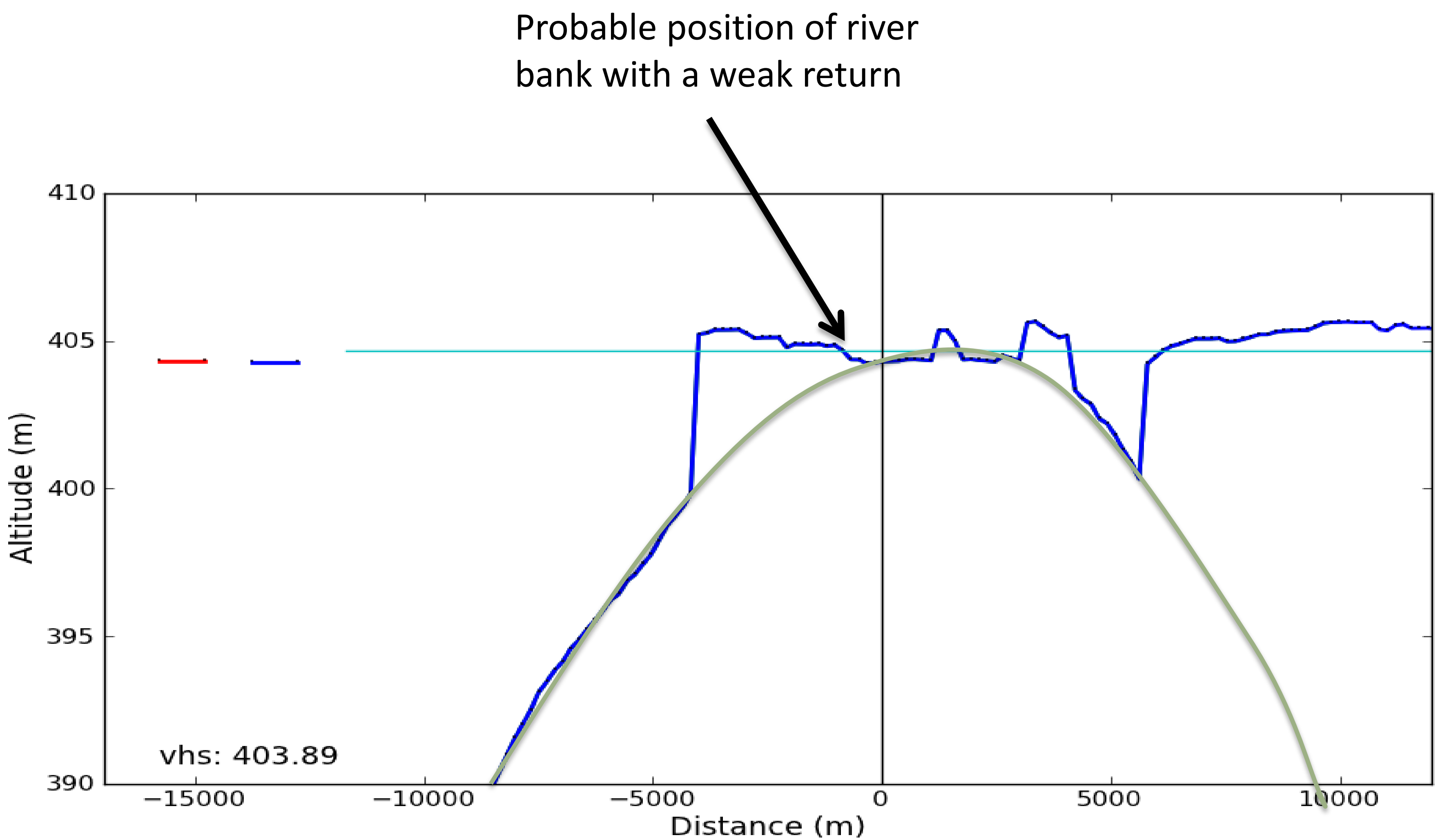


Problem of hydrological altimetry

- Strongest return signal is often taken as water but might be off-nadir (hooking)



SARAL/Altika data



Postulate

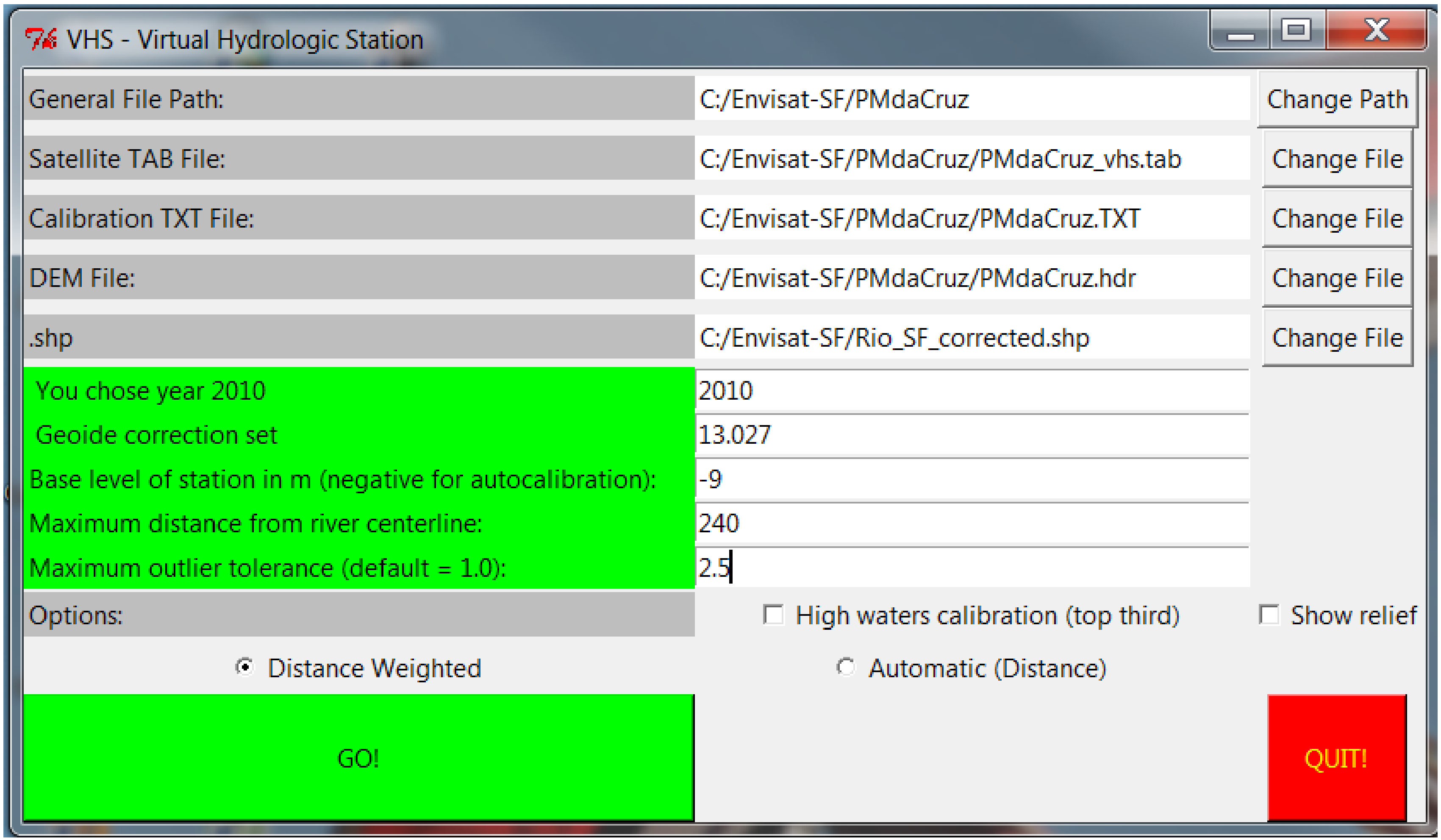
- Visually, all these problems are easily recognizable
- They can be assimilated to a Pattern Recognition problem
- Especially if some prior information is known about the target (river)

VHSTOOLS: utility programs for processing virtual hydrological station data

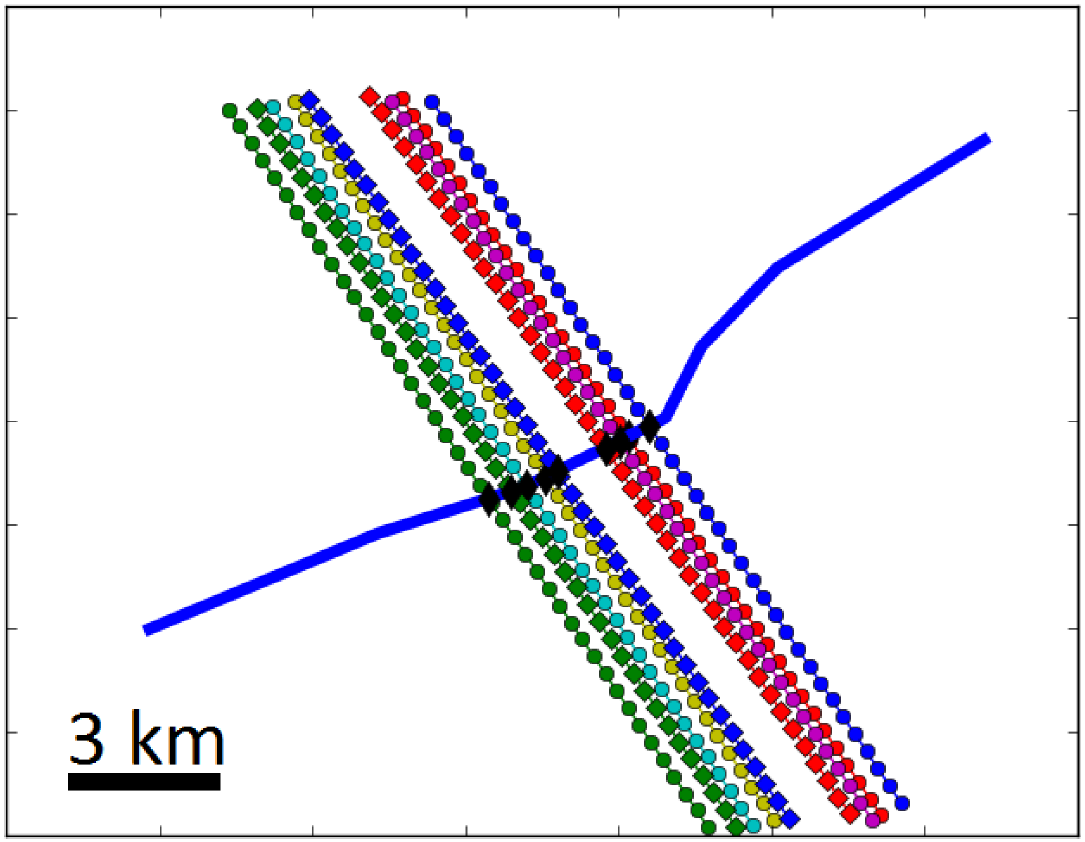
Implemented in Python 2.7 VHSTOOLS perform the following tasks:

1. Extract time series satellite altimetry data (Envisat, Jason2, SARAL-Altika) from multiple NETCDF files (one per track per date) to create VHS's
2. Apply corrections to transform range data into altitude
3. Offer capacity to extract *in situ* data from the Brazilian water agency (ANA) that correspond to dates of the VHS
4. Transform (shift) coordinates of points relative to river centerline and plot points and track overlaying the true river centerline
5. Offer two solutions to process sequences of points to produce water level data (altitude)
6. Plot virtual station data with or without DEM data as background
7. Plot time series superimposing virtual station and in situ data

VHSTOOLS (GUI)



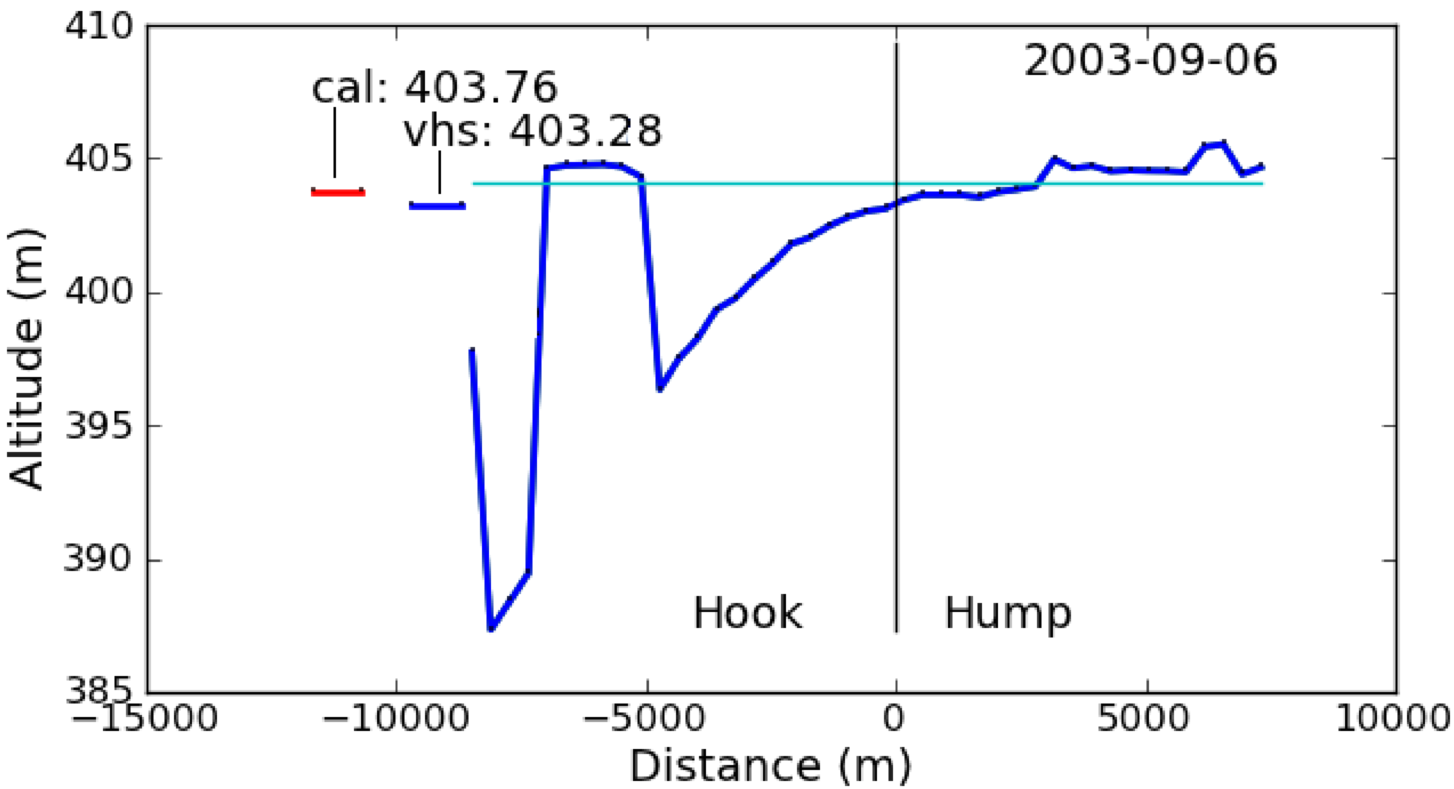
VHSTOOLS Outputs: plot of satellite track over river (true) centerline



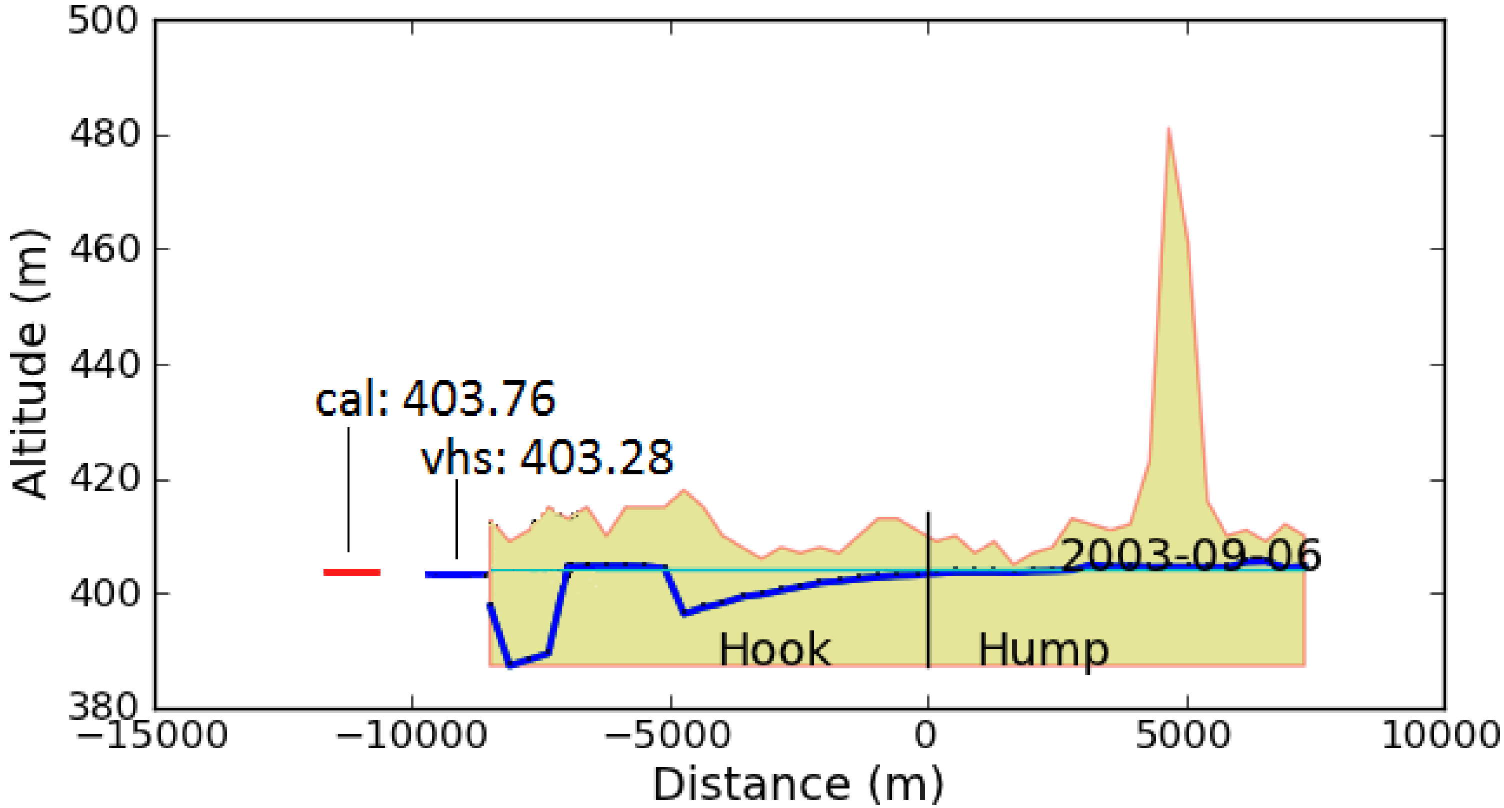
Two solutions to process sequences of points to produce water level data

1. PATTERN RECOGNITION: classification of the shapes is performed using terms a1 and a2 of the second order polynomial function: $x' = a0 + a1y + a2y^2$. The ratio between a1 and a2 is also used.
2. DISTANCE FROM RIVER CENTERLINE: computes the natural average of all points contained within a certain distance of the river centerline.

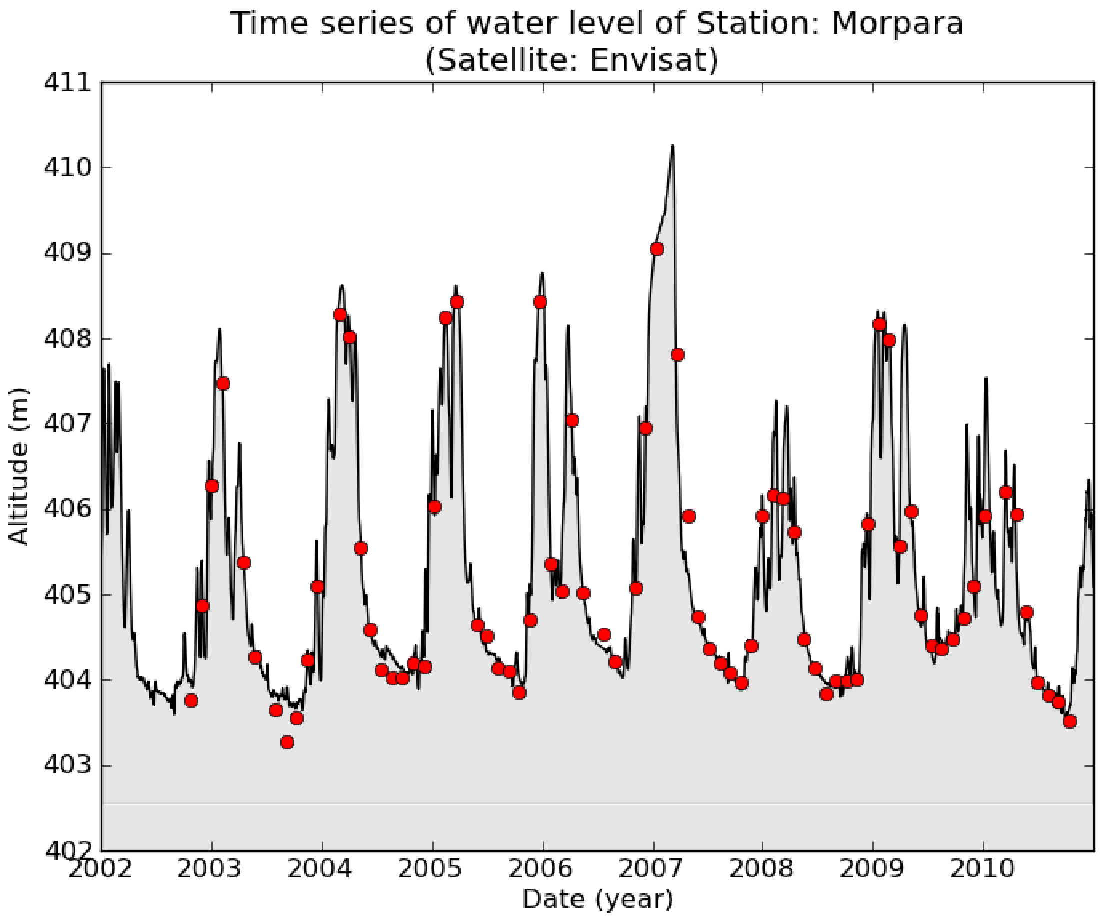
VHSTOOLS Outputs: point sequence with river centerline and classification of pattern



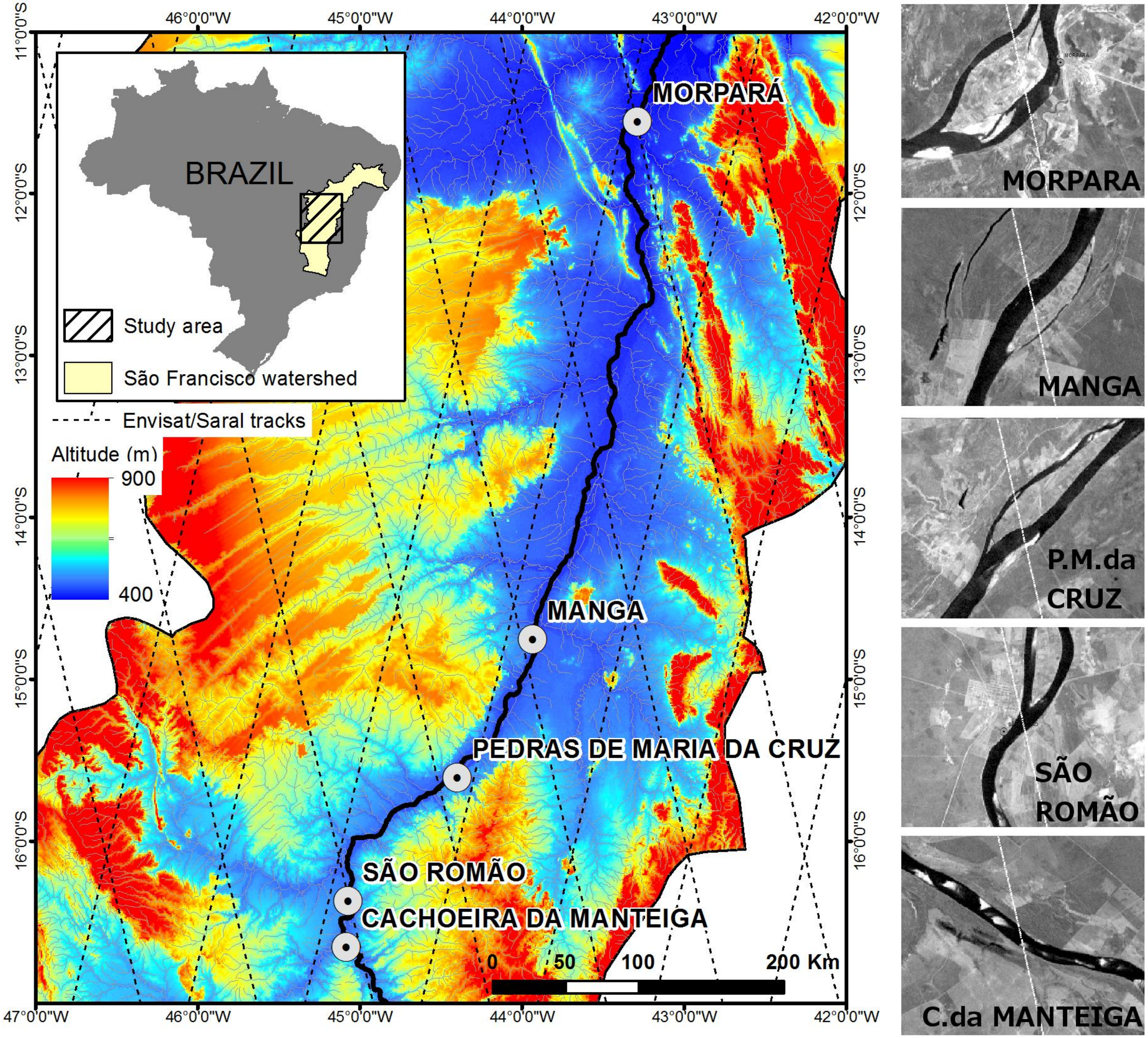
VHSTOOLS Outputs: point sequence with DEM in background



VHSTOOLS Outputs: Time series of VHS's



River stretch of the São Francisco River



River stretch of the São Francisco River

Station name (*in situ*)	Minimum. altitude (m)	Maximum altitude (m)	Amplitude (m)
Cachoeira da Manteiga	467.58	476.36	8.78
São Romão	461.42	469.30	7.88
Pedra Maria da Cruz	449.84	458.15	8.31
Manga	439.03	446.02	6.99
Morpará	403.55	410.26	6.71

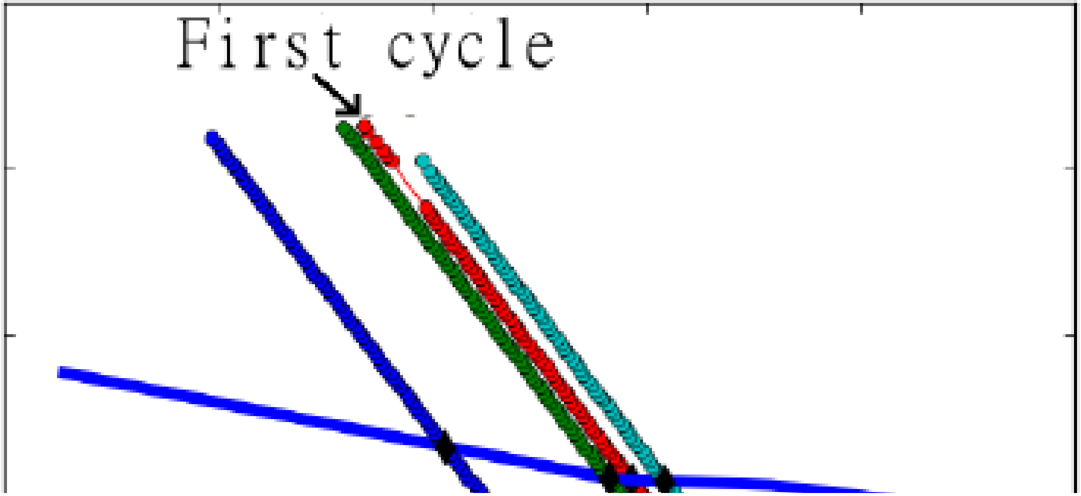
Satellite Altimetry Data

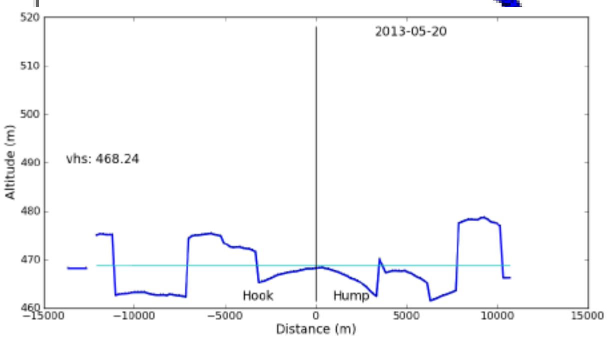
Envisat		Saral/Altika	
Parameter	Use	Saral/Parameter	Use
alt_cog_ellip	Altitude of the satellite relative to the elipsoid at 1 Hz.	alt_40hz	Altitude of the satellite relative to the elipsoid.
hz18_diff_1hz_alt	Altitude difference values to interpolate at 18 Hz.	time_40hz	Date in microseconds since 2000.
dsr_time_days	Date in number of days since 2000.	lat_40hz	Latitude of satellite point.
dsr_time_microseconds	Seconds and microseconds.	lon_40hz	Longitude of satellite point.
lat	Latitude of satellite point at 1 Hz.	ice1_range_40hz	Ice1 range retracker product.
hz18_diff_1hz_lat	Latitude difference values to interpolate at 18 Hz.	ice1_qual_flag_40hz	Quality flag for ice1.
lon	Longitude of satellite point at 1 Hz.	ice2_range_40hz	Ice2 range retracker product.
hz18_diff_1hz_lon	Longitude difference values to interpolate at 18 Hz.	ice2_qual_flag_40hz	Quality flag for ice2.
hz18_ku_ice1	Ice1 range retracker product.	iono_corr_gim	Ionosphere correction at 1 Hz (to be interpolated at 40 Hz).
hz18_ku_ice2	Ice2 range retracker product.	mod_dry_tropo_corr	Pressure variation correction at 1 Hz (to be inter. at 40 Hz).
ku_ice1_retrk_qua_flags	Quality flag for ice1.	model_wet_tropo_corr	Humidity variation correction at 1 Hz (to be inter. at 40 Hz).
ku_ice2_retrk_qua_flags	Quality flag for ice2.	pole_tide	Polar tide correction at 1 Hz (to be inter. at 40 Hz).
ion_corr_doris_ku	Ionosphere correction at 1 Hz (to be interpolated at 18 Hz).	solid_earth_tide	Crustal vertical motion correction at 1 Hz (to be inter. at 40 Hz).
mod_dry_tropo_corr	Pressure variation correction at 1 Hz (to be inter. at 18 Hz).		
mod_wet_tropo_corr	Humidity variation correction at 1 Hz (to be inter. at 18 Hz).		
geocen_pole_tide_ht	Polar tide correction at 1 Hz (to be inter. at 18 Hz).		
solid_earth_tide_ht	Crustal vertical motion correction at 1 Hz (to be inter. at 18 Hz).		

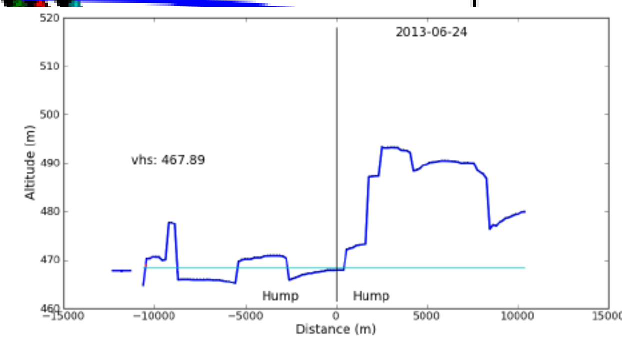
Results (Envisat)

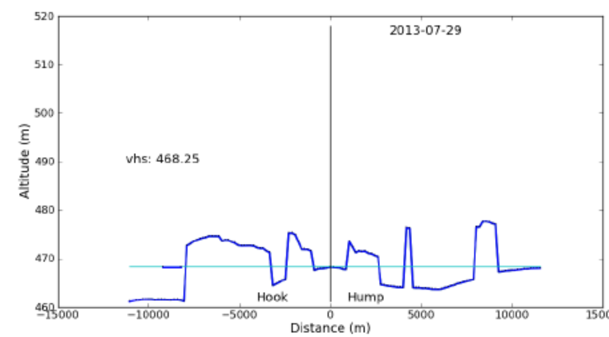
VHS name	RHS number (ANA)	VHS - RHS dist. (m)	River width (m)	River xsing angle	Base altitude of RHS	Pattern recog. RMS error	Distance based RMS error
C_da_Manteiga	42210000	-23605	640	58	466.030	0.729	0.736
Sao_Romao	43200000	515	610	60	459.530	1.044	1.043
PM_da_Cruz	44290002	-13849	475	71	449.000	1.231	0.789
Manga	44500000	-19707	690	65	438.590	0.267	0.303
Morpara	46360000	-531	690	72	401.253	0.188	0.210

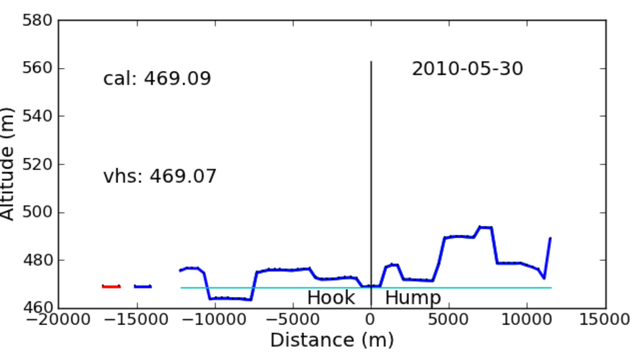
Cacheira da Manteiga

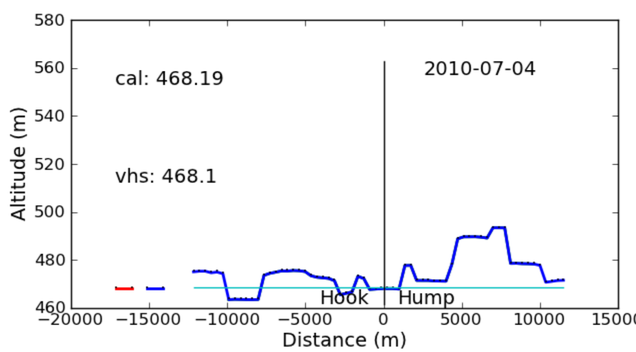


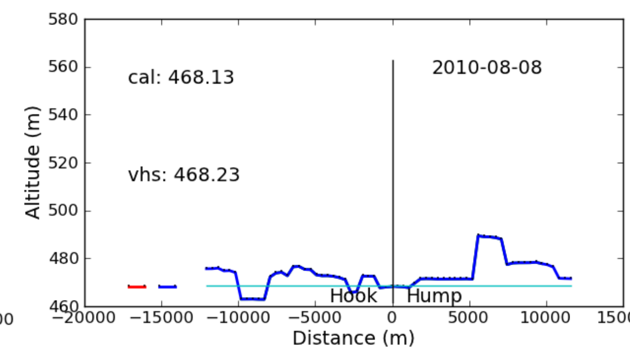


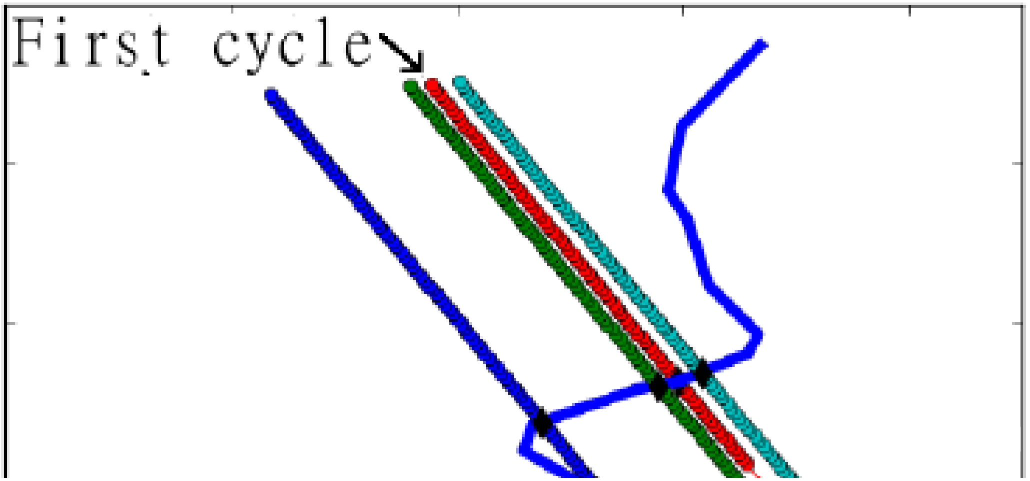




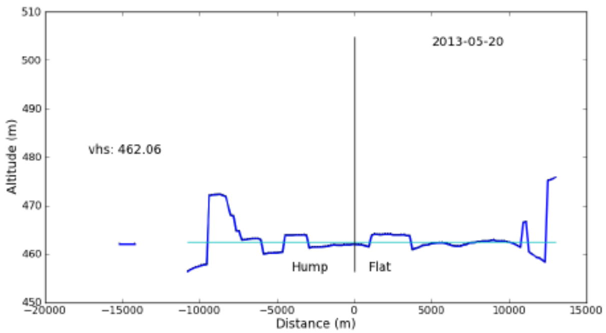


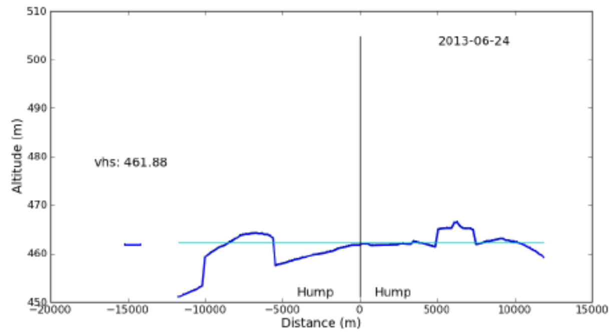


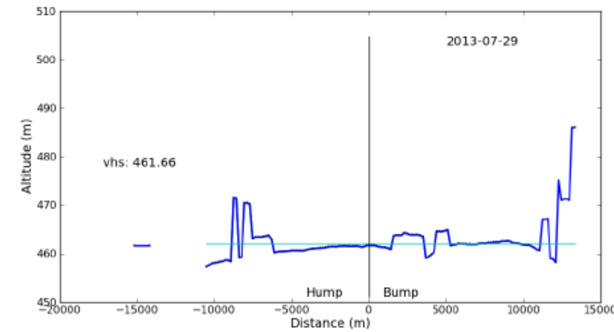


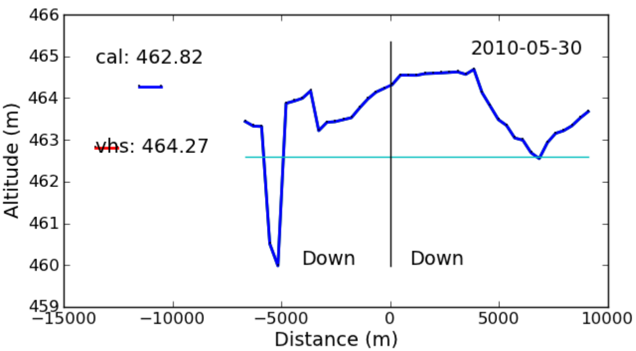

First cycle

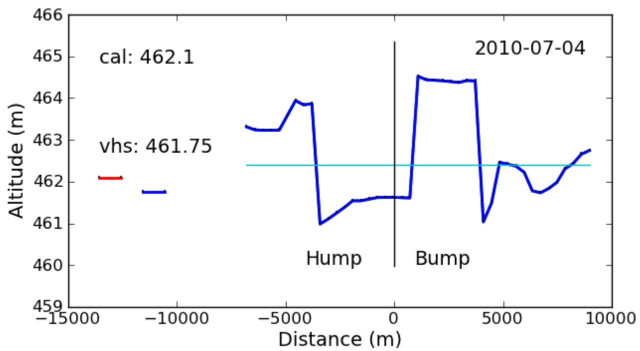
São Romão

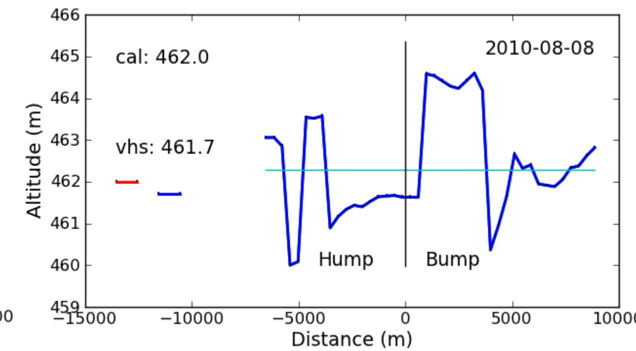

2013-05-20
vhs: 462.06
Hump
Flat
Altitude (m)
Distance (m)


2013-06-24
vhs: 461.88
Hump
Hump
Altitude (m)
Distance (m)

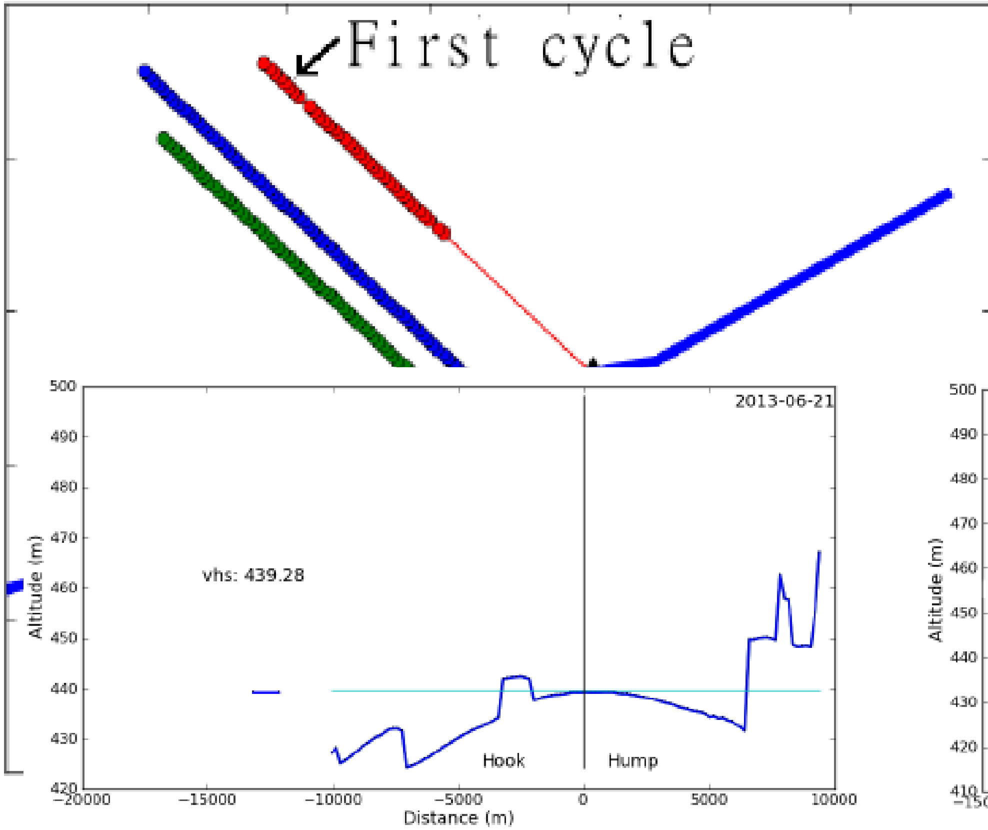

2013-07-29
vhs: 461.66
Hump
Bump
Altitude (m)
Distance (m)


2010-05-30
cal: 462.82
vhs: 464.27
Down
Down
Altitude (m)
Distance (m)

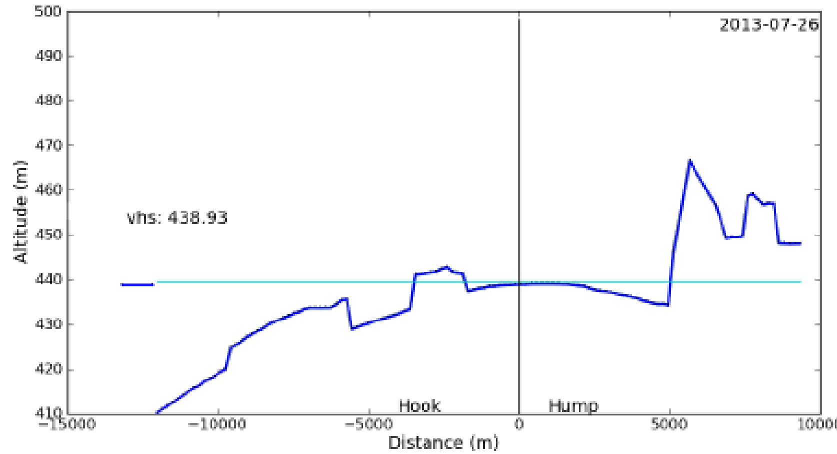

2010-07-04
cal: 462.1
vhs: 461.75
Hump
Bump
Altitude (m)
Distance (m)


2010-08-08
cal: 462.0
vhs: 461.7
Hump
Bump
Altitude (m)
Distance (m)

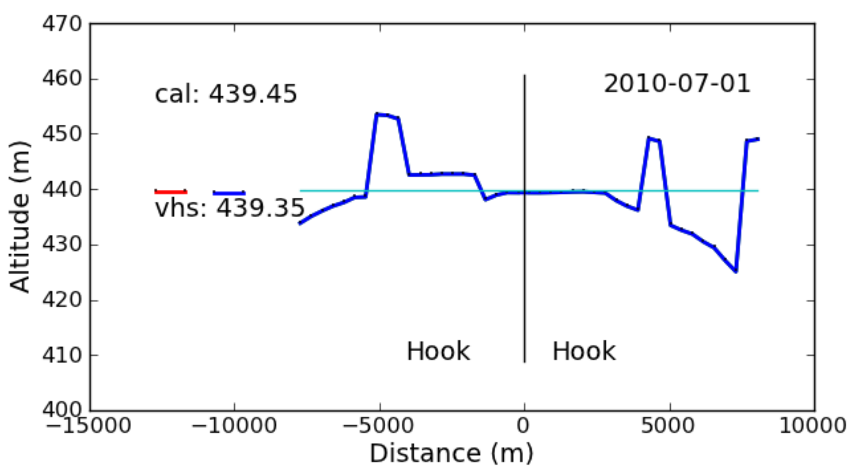
Manga



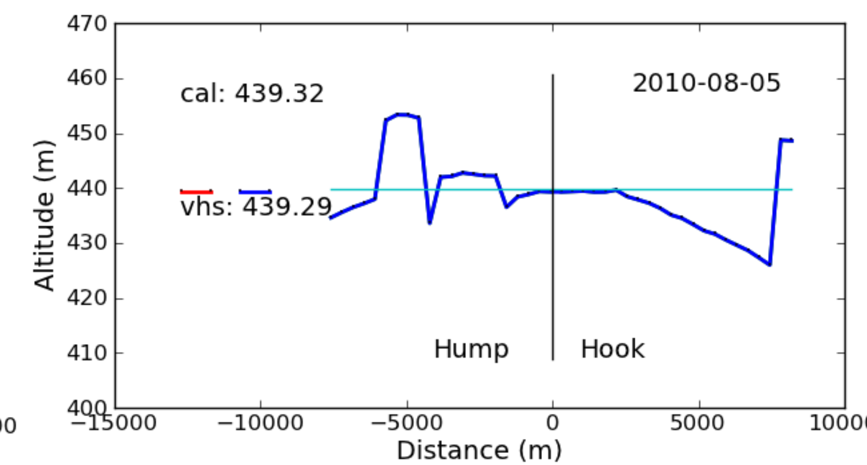
First cycle
2013-06-21
vhs: 439.28
Hook
Hump
Altitude (m)
Distance (m)



2013-07-26
vhs: 438.93
Hook
Hump
Altitude (m)
Distance (m)

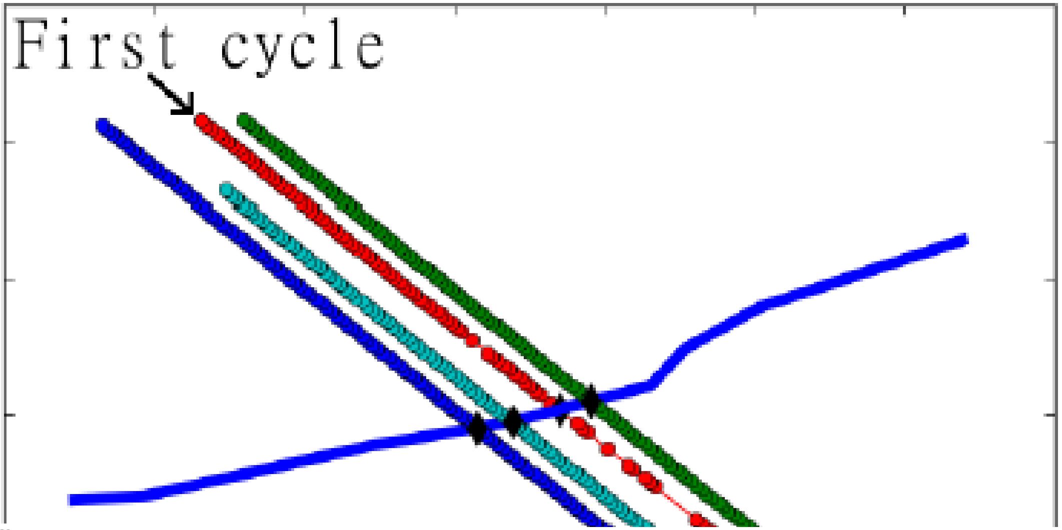


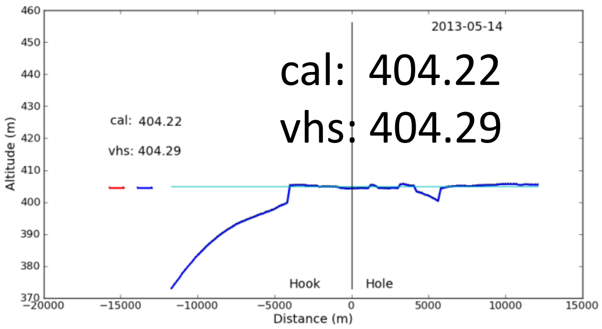
2010-07-01
cal: 439.45
vhs: 439.35
Hook
Hook
Altitude (m)
Distance (m)

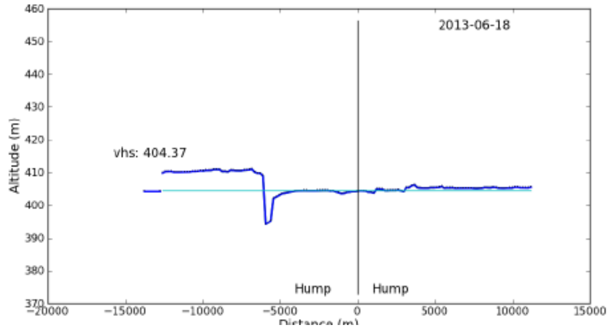


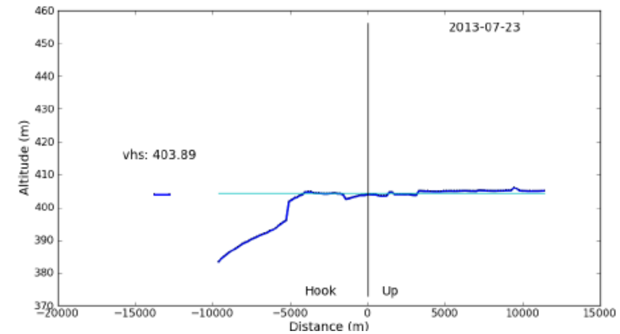
2010-08-05
cal: 439.32
vhs: 439.29
Hump
Hook
Altitude (m)
Distance (m)

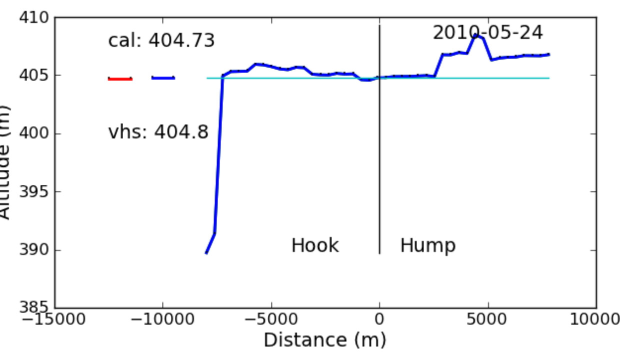
Morpara

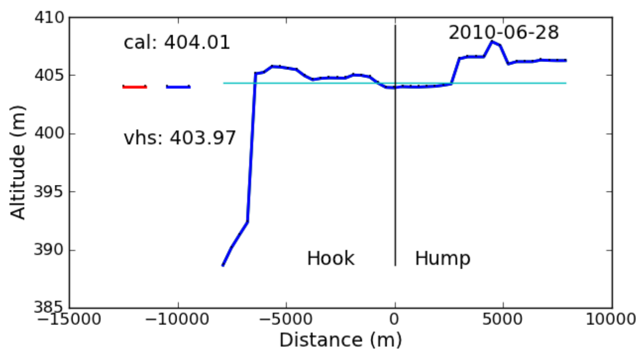

First cycle

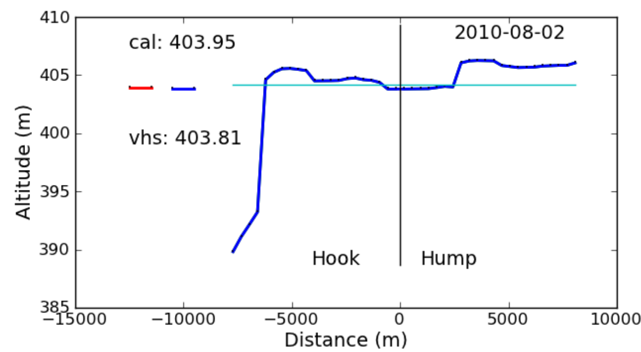

2013-05-14
cal: 404.22
vhs: 404.29
cal: 404.22
vhs: 404.29
Hook
Hole
Altitude (m)
Distance (m)


2013-06-18
vhs: 404.37
Hump
Hump
Altitude (m)

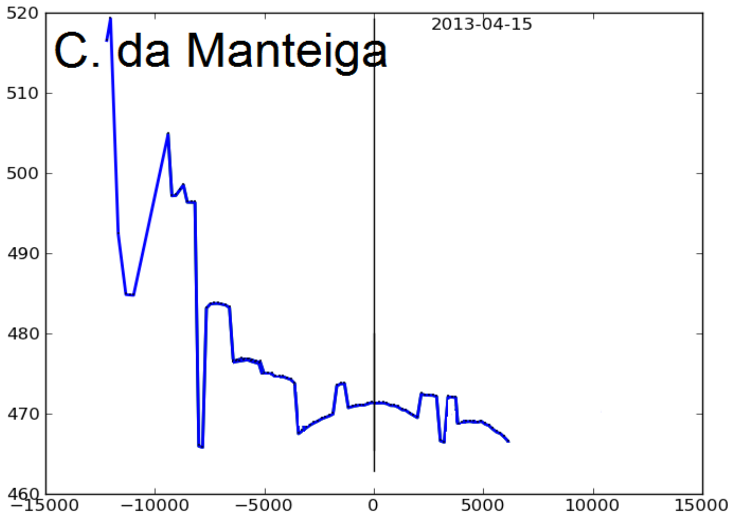

2013-07-23
vhs: 403.89
Hook
Up
Altitude (m)
Distance (m)

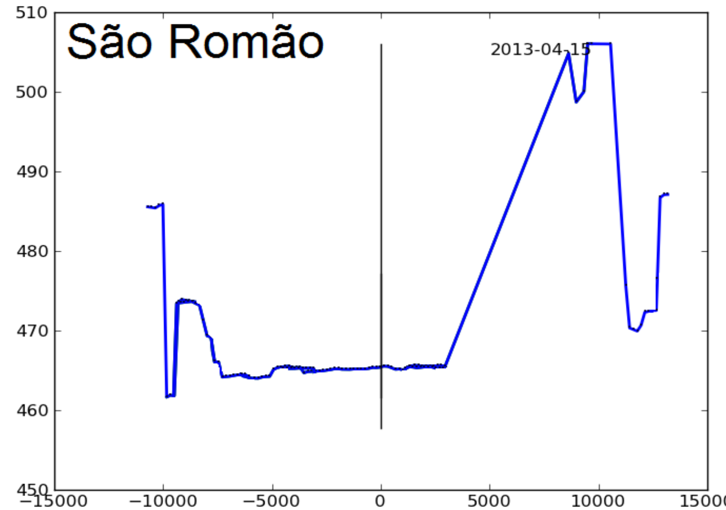

cal: 404.73
2010-05-24
vhs: 404.8
Hook
Hump
Distance (m)

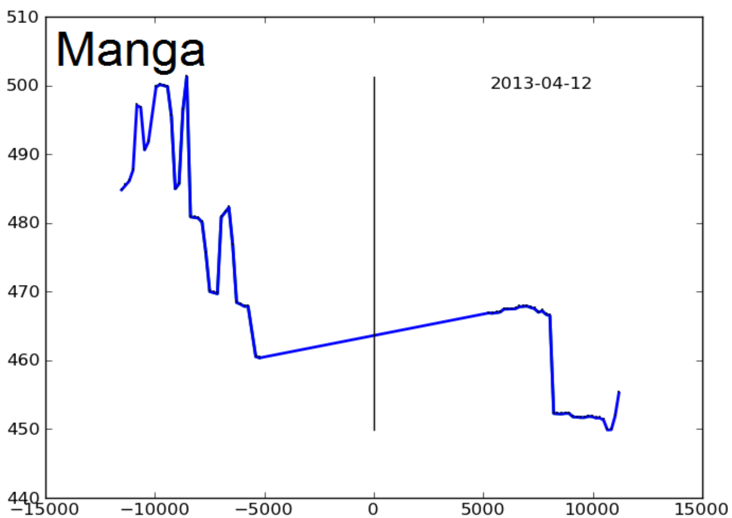

cal: 404.01
2010-06-28
vhs: 403.97
Hook
Hump
Altitude (m)
Distance (m)

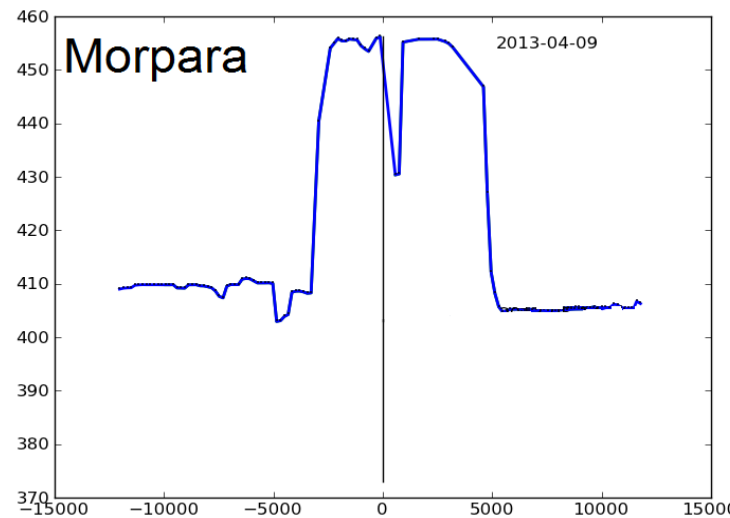

cal: 403.95
2010-08-02
vhs: 403.81
Hook
Hump
Altitude (m)
Distance (m)

Altika's first cycle









Discussion and Conclusion

- The two different processing methods yielded similar results
- Pattern recognition is probably better when location of river centerline is approximate and when width is not precisely known
- There is a relation between RMSE and distance to *in situ* station showing that the hydraulic conditions have changed
- The effect of the environmental context should be taken into account to improve results
- Altika appears to bring increased details but did not reduce « hooking » effects
- The fact that *in situ* measurements are still not available stands to show the advantage of satellite altimetry
- (I think) Results could only really be improved using the wave forms in a contextual approach instead of using retracked data