Retrieving geophysical signals from GPS in the La Plata River region

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SIMPOSIO SIRGAS

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Introduction

- Non-tidal loading (NTD) produces a transient elastic response of the earth's crust.
- GNSS time-series positions measure this effect mainly in the vertical position.
- A storm surge is a particular case of a non-tidal transient hydrological load, than occurs when wind drag causes an increase or decrease in the height of a water body with respect to the value predicted by the astronomical tide.
- Large storm surges, with a typical duration of around one day, can change the vertical position of the affected area by up to a few centimeters.

Introduction

- The estimation of positions with high temporal resolution is intrinsically a problem with many degrees of freedom.
- The higher the desired temporal resolution, the greater the number of independent parameters to be estimated from the same data sample.
- Since not exploiting the stability of certain unknowns reduces the reliability of the estimated parameters, strategies have been developed to constrain, these without losing the temporal resolution of the estimated positions.

Proposed Approach

- Precise Point Positioning (PPP): TOmographic Model for precise IOnospheric sounding and GNSS Navigation (TOMION) (Hernández-Pajares et al. 2003)
- We modified the way in which TOMION estimates the receiver coordinates.
- We neglected the effect of the storm surge on the horizontal components of the position
- To describe the variation in the vertical coordinate of the station, we adopted an empirical elastic model which assumes that the earth's crust behaves as an elastic, homogeneous, and isotropic body, characterized by Young's modulus *E* and Poisson's ratio

Proposed Approach

- Let *e* (east), *n* (north) and *u* (up) be the axes of the local coordinate system

$$u(t) = \frac{1-\nu^2}{\pi E} P(t)$$

P(t) is the Newtonian potential created at the station location by the water height distribution of the storm surge *w(n, e, t)*

$$P(t) = -\rho g \int_S \frac{w(n,e,t)}{\sqrt{e^2+n^2}} de\,dn$$

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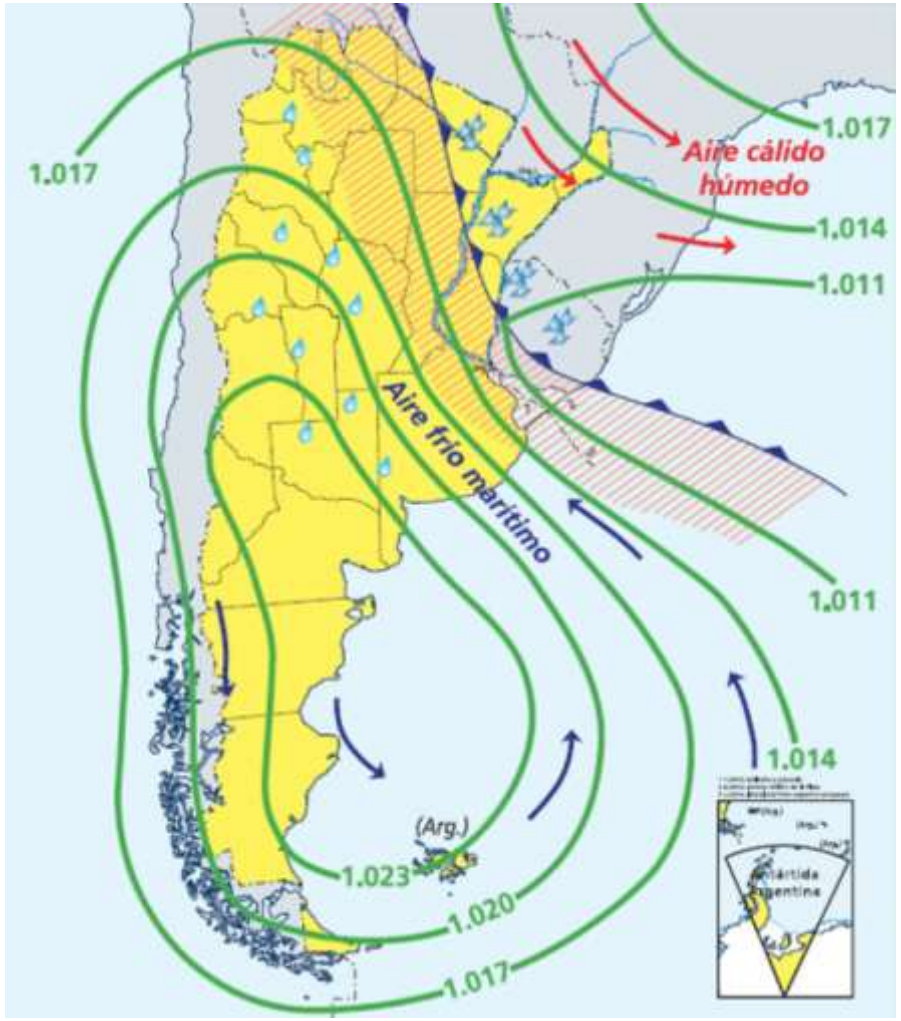
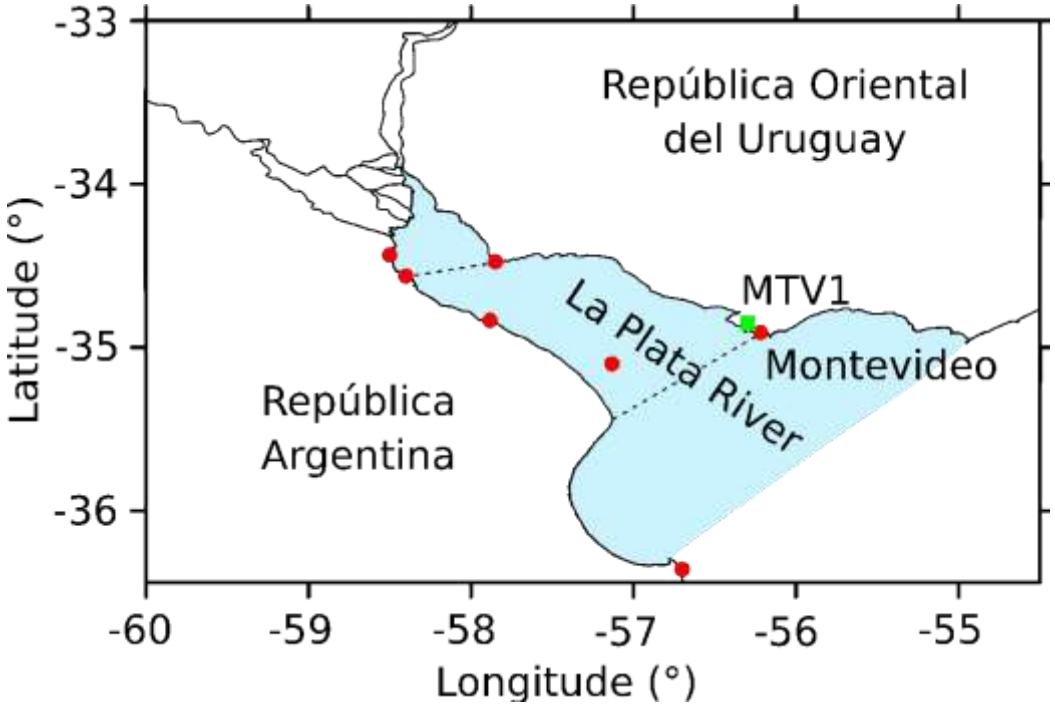
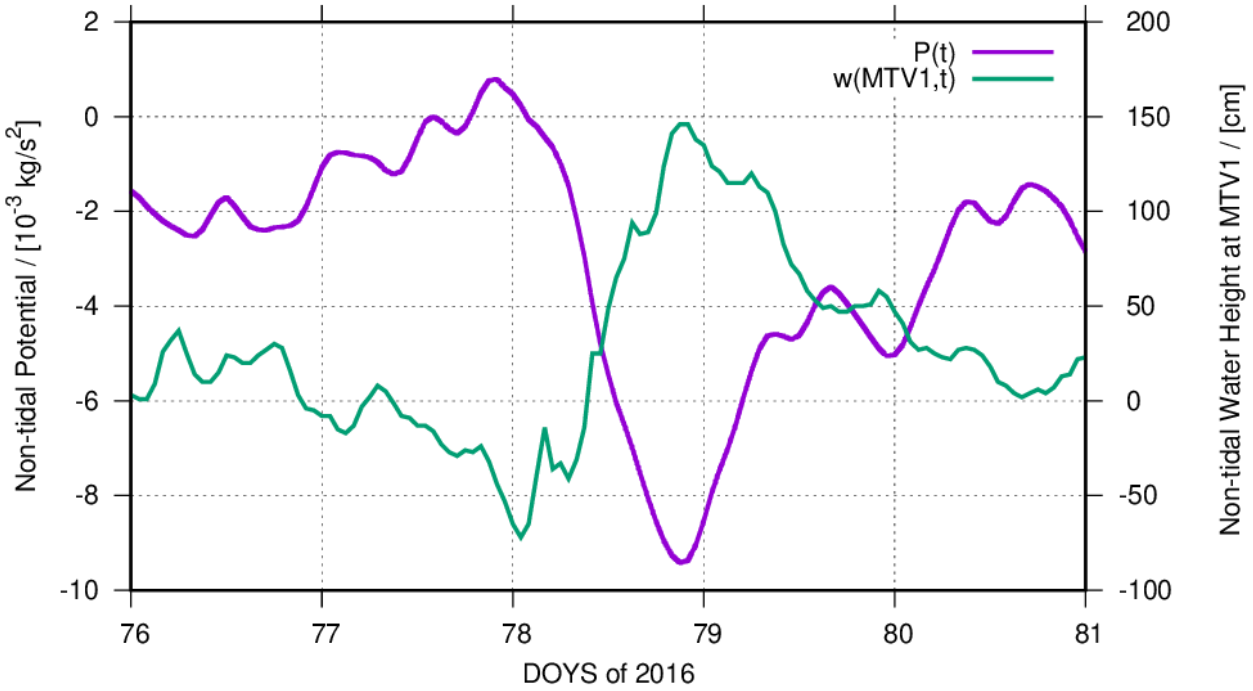
Data and processing strategies

- La Plata River estuary is one of the largest estuaries in the world (35000 km^2)
- Its width varies from 220 km at its mouth to 2 km in its interior
- The range of the astronomical tide is 1.4 m at its mouth and 0.4 m in its interior.
- Storm surges can cause the water level to rise above, or fall below, the astronomical tide by about 1 m, with a historical maximum of 3.89 m, which happened in 1989 (D'Onofrio et al. 2008).
- The time period analyzed in this study spans from March 16, 2016, at 0 UT (Day Of Year [DOY] 76) to March 21, 2016, at 24 UT (DOY 81).
- During this period, a strong positive storm surge developed, raising the water level of the river from about 0.4 m below the astronomical tide (at DOY 77.92) to about 2 m above the same reference (at DOY 78.88).



Data and processing strategies





Data and processing strategies

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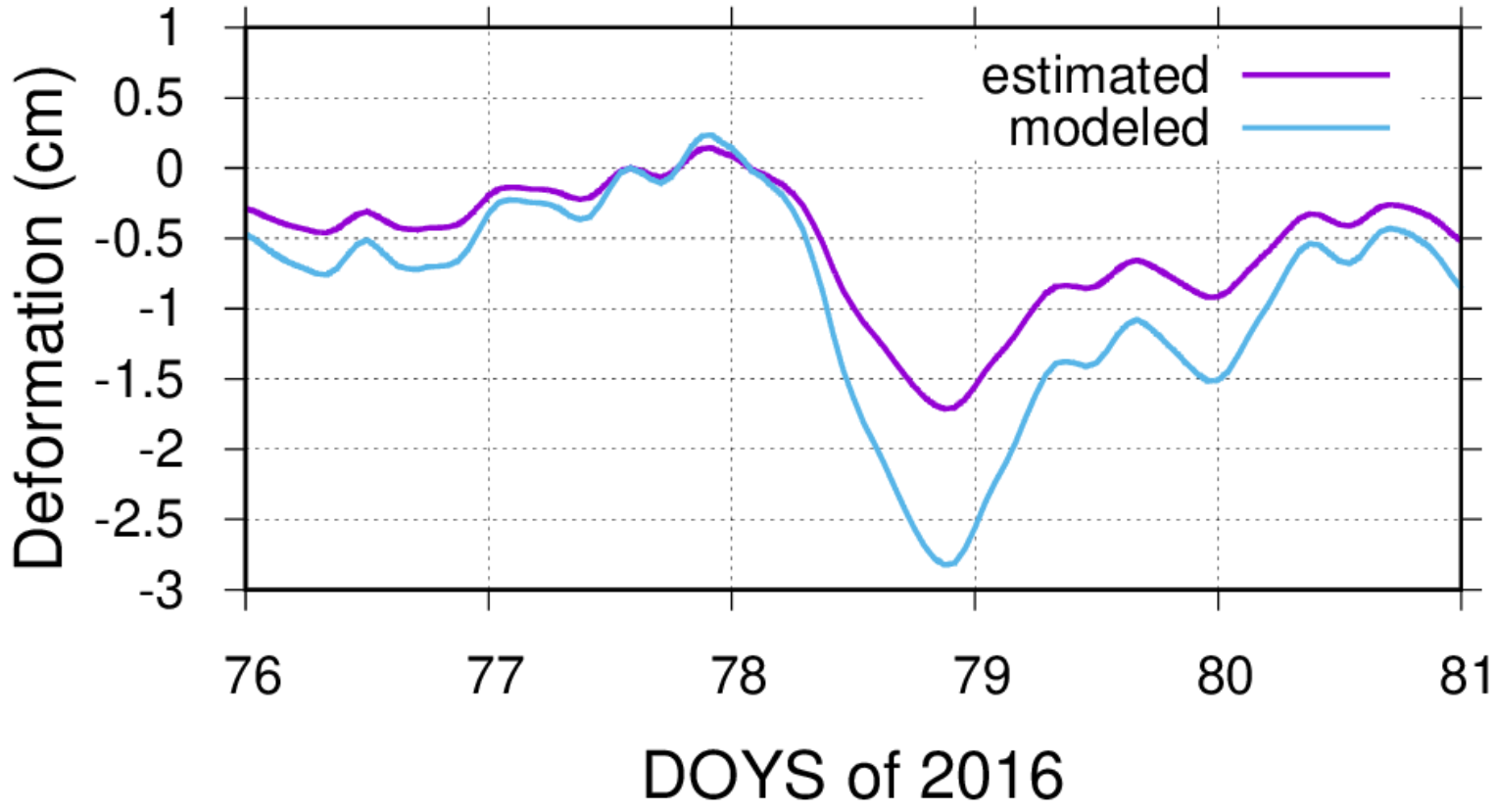
Río de Janeiro, Brasil

- Data
  - GPS observations were obtained from MTV1 (56.1763ºW, 34.9136ºS)
  - A core station of the International GNSS Service's global network.
  - Dual frequency P-code GNSS receiver with a choke ring antenna.
  - Data records are given with a sampling rate of 30 s.
  - The receiver is tied to an external cesium clock.
- Strategy
  - PPP
  - Parameter estimated
    - Zenith Tropospheric Delay
    - Receiver clock
    - One elastic parameter

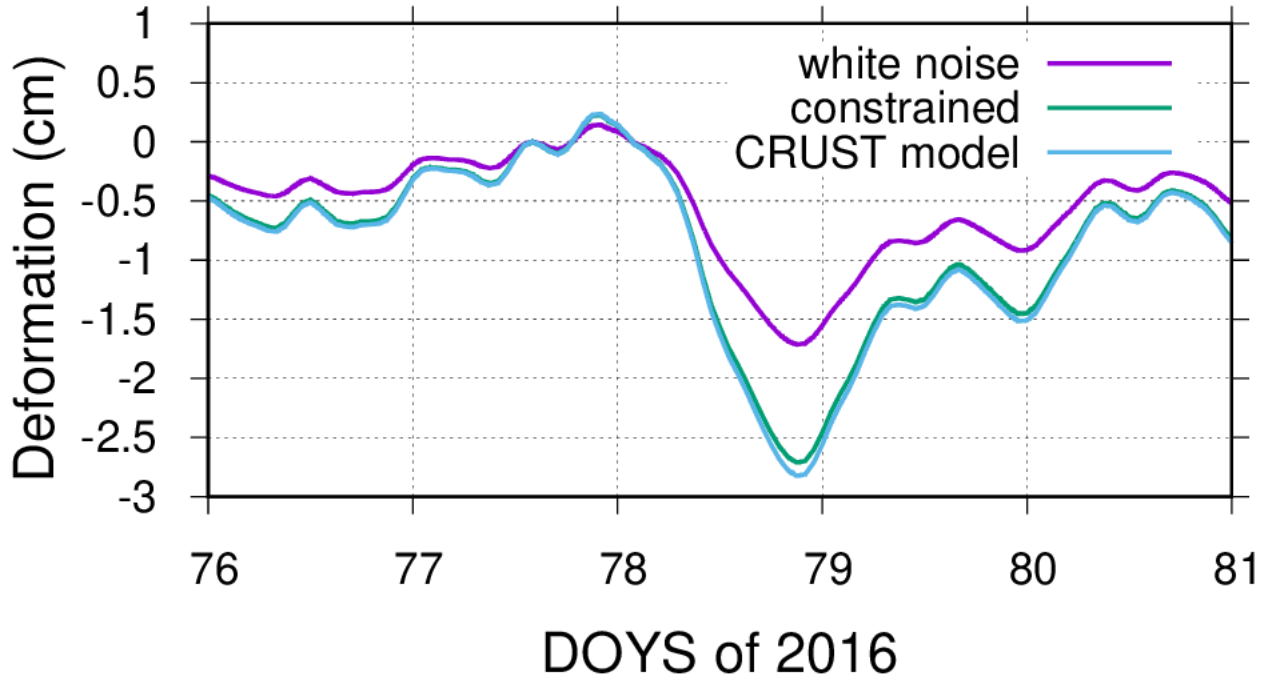
Results :-(


Deformation (cm)
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
estimated
modeled
76
77
78
79
80
81
DOYS of 2016

Processing strategies

- Strategy I
  - Zenith Tropospheric Delay
  - Receiver clock as white noise
  - One elastic parameter

- Strategy II
  - Zenith Tropospheric Delay
  - Receiver clock constrained (external source)
  - One elastic parameter



Conclusions

- We have shown that the elastic response of the earth's crust, resulting from a short-term loading event, can be successfully accounted for using an empirical storm surge model for the La Plata River.
- This model includes the time-dependent Newtonian potential to describe the variable mass load.
- By means of adjusting only one elastic parameter, instead of the vertical deformation for each time epoch, we were able to estimate a sub-daily displacement.
- We captured an empirical elastic parameter, in good agreement with the CRUST 1.0-A model, when the atomic clock model was also considered, recovering a deformation that only differed from the model by 0.1 cm.
- Without constraining the receiver clock variability, however, the difference between the recovered signal and the model was of the order of 1 cm.

Stability and reliability