Seasonal effects on Laser, GPS and Absolute Gravimetry vertical positioning at the OCA-CERGA geodetic station, Grasse (FRANCE)

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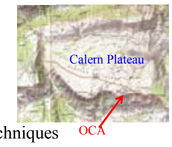
Introduction

Grasse observatory

- Grasse fundamental geodetic station
- Several techniques operating continuously and offering long time series
- Located in the Southern Western Alps on an ~ 1270 m high karstic plateau

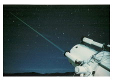


Objectives

- Monitoring the vertical displacements of the Grasse fundamental geodetic observatory
- Comparing the time series of 3 independent geodetic techniques
  - Satellite Laser Ranging (SLR)
  - GPS
  - Absolute Gravimetry (A.G.)
- Comparing the observations with geodynamical models of the different loading effects to better understand the annual signal
- 6-year time series spanning 1998-2003

Data

5 years of SLR time series



- LAGEOS-1 and -2 satellite monthly combined solution
- ITRF2000, GRIM5-S1 gravity field, IERS96 standards, no loading effect
- Mean 1-σ standard deviation of the vertical component: 3 mm

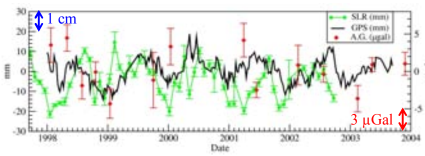
6 years of GPS time series

- Weekly CODE (Centre for Orbit Determination in Europe) position solutions expressed in ITRF2000 with CATREF software (*Altamimi et al. 2002*)
- IERS96 standards, correction for ocean tides (*Scherneck model, 1991*), no atmospheric loading correction
- Standard deviation on the vertical component : 4 mm

14 A.G. campaigns

- FG5 accuracy 1-2 µGal
- Corrections for earth tides, ocean loading, polar motion, and local atmosphere effects (- 0.3 µGal / hPa due to loading and to mass attraction)

Results



- Both SLR and GPS time series of the vertical component show a **significant annual signal**
- Non linear least squares algorithm to search for periodical signal :
  - Amplitude : 5.5 mm (GPS) – 6.1 mm (SLR)
  - Phase : maximum near July
- A.G. time series shows a more complex signal
  - Annual term: 1.7 µGal (8.5 mm)
  - Second principal term: 204-day period, 2.6 µGal (13 mm)
- BUT lack of data could mask an annual signal
- No secular gravity variation higher than ~ 0.7 µGal/yr at the 2-σ level
- If we take a -0.2 µGal/mm gradient to convert gravity variations into vertical deformation, A.G. signal amplitude larger than GPS and SLR signal
- Discrepancy should be due to contribution to gravity measurements of local ground water mass variations in the karst

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Discussion

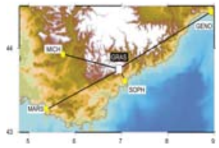
Impact of Newtonian effect

- A.G. measurement = deformation + Newtonian effect
- Initially, conversion of the A.G. measurements in vertical displacements with a ratio of – 0.2 µGal/mm But gradient time variable, for instance because of the water mass redistribution on the Earth surface
- Conversion of gravity into vertical displacement when loading effects is dangerous

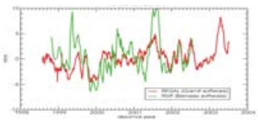
➔ NO conversion in this study

- The A.G. variations (up to 8.8 µGal) would be explained by a cylindrical ground water table located at 800 m deep with either:
  - 5 m level variation for a 1 km radius cylinder and 10% porosity
  - 5 m level variation for a 5 km radius cylinder and 5% porosity
  - 2.5 m level variation for a 5 km radius cylinder and 10% porosity
- But not enough information on the ground water table (deep, size…) located under the observatory to conclude (underground structures with permeable and impermeable layers not well known in this area)

Impact of GPS data processing

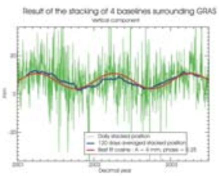


- Influence of the GPS time series computation strategy, and in particular the ZTD (Zenithal Tropospheric Delay) estimation
- Example: Comparison between 2 data processing strategies
  - RGP (French permanent GPS network)
  - REGAL (Regional permanent network in the Western Alps)
- Baseline between Marseille and Grasse (137 km)
- Estimation of annual term magnitude
  - REGAL: 1.5 mm
  - RGP: 2.5 mm
  - Shift in phase: 2.5 months



➔ Influence of the strategy can be of the order of 1 mm in estimating the annual signal amplitude

Local or regional effect ?

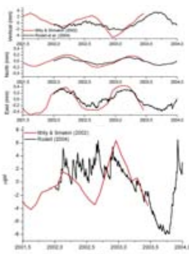


- Analysis of baselines between Grasse and surrounding permanent GPS sites from REGAL network
- If local effect: consistent signal for all the baselines
- If regional effect: random signal on the short baselines (noise)
- We stacked the time series of 4 baselines from REGAL solutions
- Stacked series clearly shows an annual signal with magnitude of 4 mm It corresponds to an annual signal of ~ 1 mm at Grasse (< 2 mm)

➔ 5-6 mm observed annual signal = 1 mm local + 4-5 mm regional

➔ The main part of the observed signal = regional loading effects

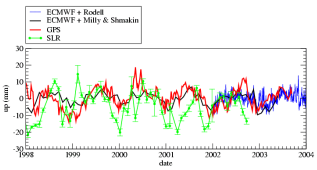
Loading models

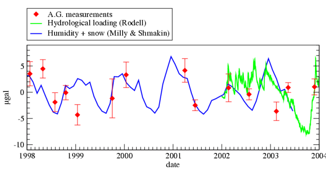


- Atmospheric loading model in vertical displacement from the ECMWF data
- Tidal oceanic loading in displacement and in gravity from the FES99 model
- Hydrological models in displacement and in gravity from (*Milly & Shmakin, 2002)* and (*Rodell et al., 2004)*: seasonal cycle difference of ~ 10-20%)

Observation and model comparison

- Atmospheric loading : 1-2.5 mm
- Ocean loading (tidal and non tidal effects) : 1 mm
- Hydrological loading : 2-3 mm
- Correlation between GPS and (atmosphere + hydrology) = 0.32





Conclusion and prospects

- Amplitude of the signal at magnitude close to the accuracy of each individual technique
- Main part of the annual signal explained (regional loading)
- A.G. = absolute, not dependent on any reference system = very good instrument to constraint the long term stability of the observatory
- Necessity of continuous gravity measurements on the Calern OCA observatory to monitor the variation and extract the local signal linked to the karst
- Comparison with local hydrological measurements (water catchment at Bramafan spring)
- Comparison with other SLR time series (shorter time sampling, new ILRS AWG results) in different sites where independent geodetic technique time series are available