An exercise of combining tide gauge and GPS results to derive trends in the sea level

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I. INTRODUCTION

Trends in global sea level over the last century have been estimated based on tide gauge records. But the issue of correcting the tide gauge records for the vertical land motions upon which the gauges are settled has only been partially solved. At best, the analysis performed so far have included corrections for one of the many processes that can affect the land stability, namely the post glacial rebound (PGR). An alternative approach is to measure (rather than to model) the rates of vertical land motion at the tide gauges by means of space geodesy. However, this has proven not as straightforward as supposed 15 years ago.

This poster shows how we address some of the current challenges to determine the rates of vertical land motion with an accuracy better than 1 mm/yr with GPS. In particular, we show the recent improvements that we have recently achieved in the implementation of a more stable and accurate reference frame. Next, we use the GPS vertical trends to correct the tide gauge records, and thus to obtain a GPS-corrected set of sea level trends. Finally we discuss to what extent our appro[redacted]oves the estimates of the absolute sea level rise.

II. DATA AND METHODS

Mean sea level data from PSMSL RLR tide gauge databank
http://www.pol.ac.uk/psmsl/

Weekly solutions of GPS station coordinates from ULR/AC

→ Software used:
GAMIT 10.2 (King and Bock 2005) for processing GPS measurements
CATREF (Altamimi 2005) for combining GPS solutions

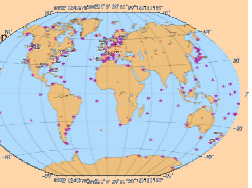
→ New GPS processing strategy implemented in January 2006
Backwards reprocessing with new models from 2005.7 up to 2001.4
Old strategy solutions available up to 1997.0 (Wöppelmann et al. 2003)

→ Important changes w.r.t. previous strategy includes:
Absolute antenna phase centre corrections for satellites and receivers (IGSMAIL-5272, Gendt 2005)
Troposphere VMF or GMF mapping function (Boehm et al. 2005)
Ocean loading corrections from Scherneck CSR4.0 model
Atmospheric pressure loading corrections (Tregoning and van Dam 2005)
Network extension to 92 IGb00 RF stations (IGSSTATION-352, Ferland 2005)

Analysis of GPS solutions

→ Time series combination of station coordinates solutions (Altamimi et

→ Iterative procedure to identi and reject outliers, as well as t handle discontinuities in the tim series using a break-wise approach



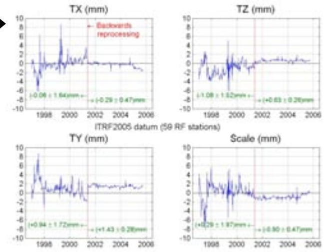
Map of the 222 GPS stations processed at ULR analysis centre, among which 160 are less than 10 km from a Tide Gauge, and 92 are 'IGb00' stations that are recommended for the reference frame implementation (red circles inside the stars)

The labels correspond to stations used in section IV

III. IMPLEMENTATION OF THE REFERENCE FRAME

How stable and accurate is the reference frame with the new GPS processing strategy?

The weekly RF realisation improves from sub-c to better than 0.5 m

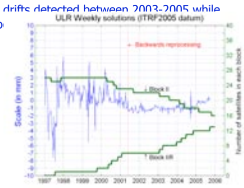


Transformation parameters between each weekly solution and the combined one expressed in ITRF2005

Tracking small drifts in RF scale

→ Ge et al. (2005) showed a scale drift in GPS solutions while BlockIIR satellites increased between 2000 and 2001

→ Implementation of absolute antenna phase centre corrections for both satellites and receivers: no drifts detected between 2003-2005 while Blo



The number and the geometry of the RF stations used in the alignment of ITRF2005 may explain the small drift in scale in 2005...

IV. SYNERGY OF TIDE GAUGE & GPS RESULTS

A careful inspection of both the tide gauge records (TG) and the co-located GPS time series is conducted to derive absolute sea level trends

→ Relative sea level trends from TG records are derived from the PSMSL RLR data set (1135 TG sites, http://www.pol.ac.uk/psmsl/datainfo/rlr.trends)
Selection of GPS co-located TG records according to Douglas (2001) criteria: (i) more than 60 yr of data, (ii) more than 85% valid data.

→ Only GPS records greater than 2.5 years are considered so as to minimise the influence of the seasonal residuals on the estimated linear velocity (Blewitt and Lavalee 2002)

Assumptions: (a) current observed vertical land motions are valid for the last century, (b) the vertical motion observed at the GPS station applies to the TG.

Discussion

The variability of the estimated sea level trends is remarkably reduced after the GPS correction. The RMS of the GPS-corrected trends is 1.2 mm/yr whereas the RMS of the TG records is 2 mm/yr.

The RMS of the sea level trends corrected for GPS is comparable to those obtained after correction for the PGR (RMS = 1.5 mm/yr). However, if we have a closer look into each region, it appears that GPS-corrected trends are more homogeneous than PGR-corrected ones. This would argue in favour of incorporating additional sets of GPS@TG stations in future global sea level studies and thus making it possible to include previously discarded regions.

Compared to previous PGR-corrected published estimates (Douglas 2001 and references herein) our results show a greater variability in the sea level trends obtained between regions. This could be taken as a measure of the error of the estimate and further efforts have to be undertaken to understand the origin of those differences.

Additional comments

The joint analysis of TG and GPS records shows that the distance between both instruments is a key factor to comply with assumption (b). Local geodetic monitoring is the most accurate alternative.

Future estimates will surely improve as the GPS time series get longer.

GROUPS	Tide Gauge Span (yr)	Tide Gauge Trend (mm/yr)	GPS/TG Dist. (m)	GPS Span (yr)	GPS Trend (mm/yr)	TG+GPS	PGR	TG-PGR
NORTHERN EUROPE								
STAVANGER	63	**0.3** ± 0.2	16000	5	**-0.4** ± 0.1	**-0.1**	**-0.5**	**0.8**
KOBENHAVN	101	**0.3** ± 0.1	7300	3	**-0.1** ± 0.3	**0.2**	**0.3**	**0.0**
NEDRE GAVLE	90	**-6.1** ± 0.2	11000	6	**5.9** ± 0.1	**-0.2**	**-4.7**	**-1.4**
NORTH SEA								
ABERDEEN I+II	103	**0.6** ± 0.1	2	7	**-0.1** ± 0.1	**0.5**	**-0.8**	**1.5**
ENGLISH CHANNEL								
NEWLYN	87	**1.7** ± 0.1	10	7	**-1.0** ± 0.1	**0.7**	**0.2**	**1.5**
BREST	83	**1.4** ± 0.1	350	7	**-0.9** ± 0.1	**0.5**	**0.2**	**1.2**
ATLANTIC								
LAGOS	61	**1.4** ± 0.2	600	5	**-0.9** ± 0.1	**0.5**	**0.1**	**1.3**
CASCAIS	97	**1.2** ± 0.1	0	7	**-0.8** ± 0.1	**0.4**	**0.0**	**1.2**
MEDITERRANEAN								
MARSEILLE	105	**1.3** ± 0.1	5	7	**0.5** ± 0.1	**1.8**	**-0.1**	**1.3**
GENOVA	78	**1.2** ± 0.1	0	7	**0.5** ± 0.1	**1.7**	**-0.2**	**1.4**
SE NORTH AMERICA								
ANNAPOLIS	70	**3.5** ± 0.2	0	9	**-1.5** ± 0.1	**2.0**	**0.3**	**3.2**
SOLOMON'S ISL.	62	**3.4** ± 0.2	100	8	**-2.6** ± 0.2	**0.7**	**0.2**	**3.2**
CHARLESTON I	82	**3.2** ± 0.2	7400	7	**-1.1** ± 0.3	**2.1**	**0.1**	**3.1**
FERNANDINA	83	**2.0** ± 0.1	5500	8	**-3.4** ± 0.2	**-1.4**	**0.1**	**1.9**
GALVESTON II	94	**6.5** ± 0.2	4200	6	**-5.5** ± 0.3	**1.0**	**0.2**	**6.3**
MIAMI BEACH	45	**2.3** ± 0.3	300	6	**-1.2** ± 0.4	**1.1**	**0.1**	**2.2**
KEY WEST	90	**2.2** ± 0.1	7800	8	**-0.4** ± 0.3	**1.8**	**0.2**	**2.1**
NE NORTH AMERICA								
EASTPORT	63	**2.1** ± 0.2	100	7	**1.6** ± 0.3	**3.6**	**0.2**	**1.9**
NEWPORT	70	**2.5** ± 0.1	1100	6	**-0.4** ± 0.2	**2.1**	**1.1**	**1.4**
HALIFAX	77	**3.3** ± 0.1	3300	3	**-1.9** ± 0.0	**1.4**	**0.7**	**2.6**
SW NORTH AMERICA								
LA JOLLA	72	**2.1** ± 0.2	700	9	**-0.9** ± 0.3	**1.2**	**0.1**	**2.0**
LOS ANGELES	78	**0.9** ± 0.2	2200	4	**-2.2** ± 0.2	**-1.3**	**0.1**	**0.8**
NW NORTH AMERICA								
VICTORIA	86	**1.1** ± 0.2	2	6	**0.2** ± 0.2	**1.3**	**0.2**	**0.9**
NEAH BAY	65	**-1.6** ± 0.2	7900	8	**5.2** ± 0.1	**3.6**	**0.6**	**-2.2**
SEATTLE	104	**2.1** ± 0.1	5900	6	**-0.2** ± 0.1	**1.9**	**0.5**	**1.6**
PACIFIC								
HONOLULU	99	**1.5** ± 0.1	5	7	**0.4** ± 0.2	**1.8**	**-0.2**	**1.6**
NEW ZEALAND								
AUCKLAND II	85	**1.3** ± 0.1	5	4	**1.6** ± 0.4	**2.9**	**-0.3**	**1.6**
LYTTELTON II	48	**2.3** ± 0.2	2	6	**0.7** ± 0.1	**3.0**	**-0.3**	**2.6**

Table 1. Sea level trends obtained from the Tide Gauge (TG) records and formerly corrected for the vertical land motions with the GPS trends (TG+GPS). The sites are grouped into regions according to Douglas (1991, 2001). Sea level trends within a region are expected to be consistent. As a guideline, the table also includes the rates of relative sea level rise due to the Postglacial Rebound (PGR) which uses ICE-5Gv1.2 and VM4 models (Peltier, 2004) and the corresponding corrected sea level trends (TG-PGR)