Sea Level Change using Vertical Land Motion from GNSS: Higher-Order Ionospheric Effects

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1. Introduction

Continuous GPS at tide gauges (CGPS @ TG) is a promising way to link relative tide gauge measurements to a global geocentric reference frame, so that absolute sea level change can be calculated.

Vital considerations when processing the CGPS data include:

- **Consistent processing of the whole time series**
- **Careful investigation of effects that may introduce spurious trends.**

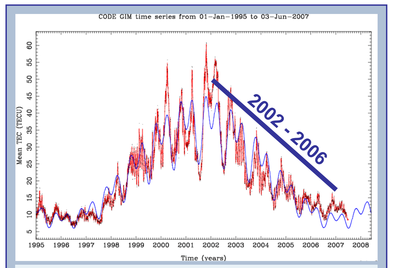

Figure 1: Total Electron Content (TEC) variation over the last solar cycle
Figure from CODE site: http://www.aiub.unibe.ch/ionosphere/

The ionosphere varies on an 11 year cycle with the last peak ~2002 (see Figure 1, left). If the refractive index of the ionosphere is expanded as a series, the majority of the effect on the GPS signals is in the first term and can be eliminated when using dual frequency GPS data. However, effects due to the higher order terms remain.

2. Method

- **One run with a global network of ~ 60 stations (odd days 1995–2006), using consistent GPS reprocessing, estimating satellite orbits and station coordinates.**
- **A second identical run but with the second and third order ionospheric terms modelled (after Fritsche et al. 2005).**

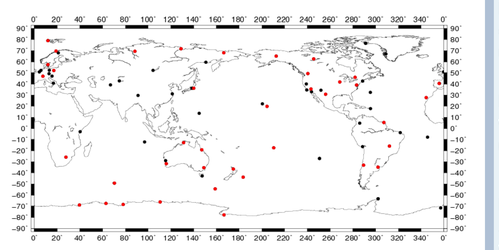

Figure 2: Distribution of CGPS stations used.

Red: 2002-2006 with > 4.5 years data (see also Figure 3)

Black: 1996-2006 Additional stations with > 2.5 years data

The processing strategy used adapted GAMIT GPS software and included:

- **International Geomagnetic Reference Field to calculate ionospheric correction**
- **VMF1 tropospheric mapping functions**
- **Hydrostatic zenith delay from Rinex met files or VMF1 grids**
- **Absolute antenna phase centres**
- **TANYA software to combine into reference frame and compare to ITRF2005**

3. Vertical effects on time series?

Tide gauge calibration is affected by any change in the vertical rate. We investigated the trend of the difference in CGPS vertical position time series due to higher order ionospheric effects.

- **5 years of data from 2002 to 2006 (only stations with at least 4.5 years data).**

This time period covers a large change in ionospheric activity (see Figure 1, left), so any difference in trend should be close to a maximum value.

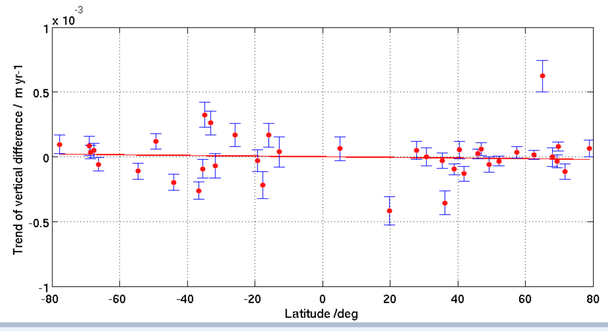

Figure 3: Difference in vertical trend due to modelling 2nd and 3rd order ionospheric effects, by latitude.
Time period 2002 – 2006 (5 years). Only stations with > 4.5 years data shown.

Vertical trends were calculated by linear regression on time series with outliers more than 0.3m from a median of the detrended time series removed.

4. Reference frame effects

Considerable effects on the z translation to ITRF2005 are apparent.

The data are daily sessions (odd days only) from 1996 to 2006.

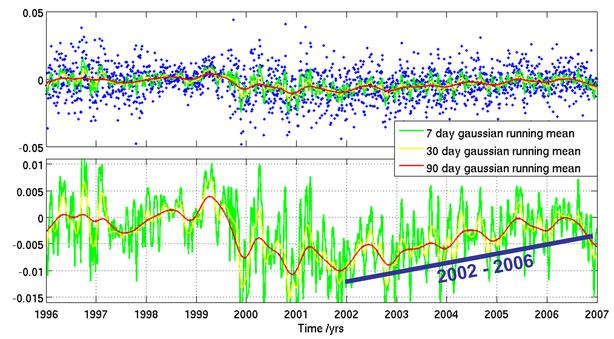

Figure 4: Top: Difference in z-translation to ITRF2005 with/without second and third order ionospheric GPS corrections. Bottom: as top, enlarged.

5. Conclusions

Our analysis suggests that:

- **The effect of the second and third order ionospheric terms on CGPS vertical rates is generally < 0.5mm/yr. Also, as the bulk of CGPS sites at tide gauges have started operating since ~2000, considering the effect during the period 2002-2006 may be useful.**
- **There is up to 10 mm effect on the Z translation between the GPS network reference frame and ITRF2005. This is broadly consistent with a previous unpublished study using simulated data (Palamartchouk, 2007).**
- **The Z translation during 1998 and 1999 may be affected by the degraded tracking from TurboRogue GPS receivers before their replacement in ~ 2000. As they tracked fewer low elevation satellites, there will be less effect from the ionosphere, as the effect is much greater at low elevation angles. A drop in the total number of ambiguities was apparent during this period.**

6. Further Work

- **Increase network size, include stations near long tide gauge records**
- **Assess periodicity of time series**
- **May perform noise analysis to assess proportion of coloured noise in series**

7. Underlying Issues

- **Link between CGPS and tide gauges is assumed**
- **Constant rate of land motion must be assumed if wish to use CGPS time series to correct for the whole of long tide gauge records**

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References

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