Surface Load Models and Validation by GPS

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1. Ocean Tide Loading

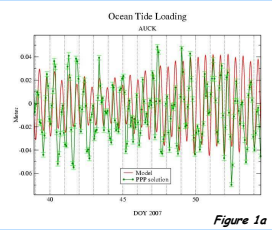

Figure 1a

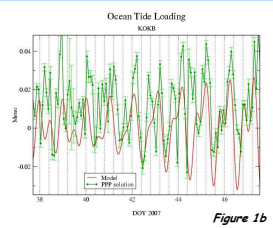

Figure 1b

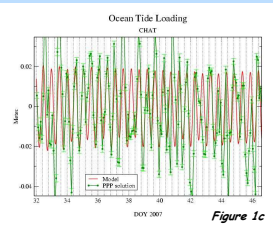

Figure 1c

- **Figure 1a, 1b and 1c** compare OTL vertical displacements from GPS PPP series and FES2004 model at 3 IGS sites : AUCK, KOKB and CHAT
- Daily variability can reach up to 8 cm in AUCK during the considered period (February 2007)
- OTL model were not applied to the GPS processing
- The current strategy to produce GPS PPP solutions for high-frequency (few hours) high-amplitude (several centimetres) signals is not satisfactory. In this particular case, a double-differential approach including integer ambiguity resolution would give better results

2. Oceanic atmospheric (non IB) loading

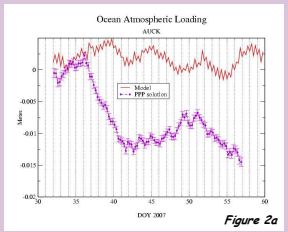

Figure 2a

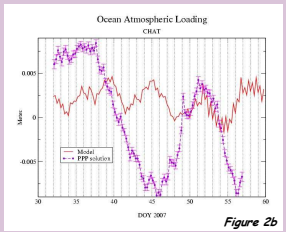

Figure 2b

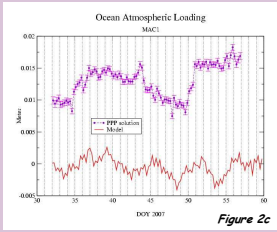

Figure 2c

- Non tidal oceanic models like MOG2D (Carrere and Lyard, 2003) exist today. In some costal areas the derived loading signal reach 1 or 2 centimeter on the vertical displacement. Considering this source of station coordinate changes is under discussion in the framework of the IERS. We wanted in this section to check if any non tidal oceanic loading signal could be detected in GPS PPP series.
- We selected the AUCK, CHAT and MAC1 IGS stations where a significant signal is expected. **Figures 2a, 2b and 2c** compare the non tidal oceanic loading signal derived from the MOG2D model and the GPS PPP series. OTL model have been applied and the expected remaining signal has a lower frequency (few days) and a lower amplitude (few millimeters). The GPS PPP series is supposed to be realistic in this context. However the agreement with the models can not be demonstrated.
- Additional signals like hydrological loading could be significant but were not considered in this study

3. Continental atmospheric loading

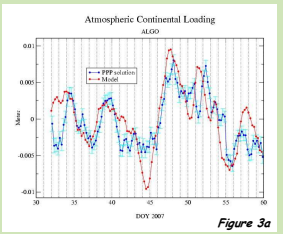

Figure 3a

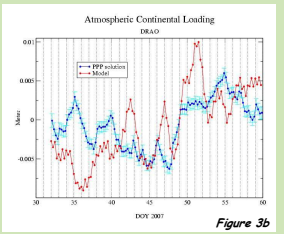

Figure 3b

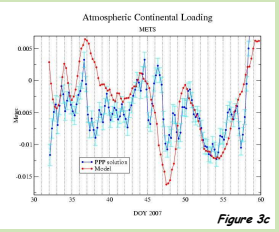

Figure 3c

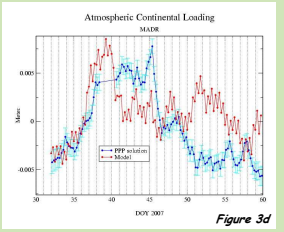

Figure 3d

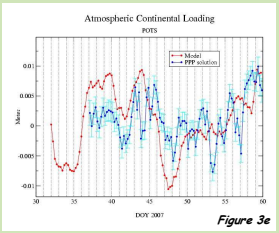

Figure 3e

- World Pressure data are available at a 6 hours time sampling from the ECMWF for example
- **Figures 3a,3b,3c,3d and 3e** compare the GPS PPP series to the modelled vertical displacement
- A global correlation can be seen between the series even if clear discrepancies remain.

Motivation

Load effects are due to surface mass variations and affect directly station positioning. Some of these effects are usually taken into account in station positioning (like ocean tides loading), some others not, depending on the access to load models. For instance meteorological atmospheric pressure variations are still not used generally in reference system computation; load from continental water or snow or oceanic non IB response are in the same way often neglected. However these phenomena can induce absolute centimetre vertical deformation at sub-daily, weekly and seasonal time scales.

CNES/GRGS has implemented the capability to process GPS data in the PPP mode in its GINS software which was already capable to realise classical network adjustment using Double-Difference observable.

The goal of this work was to evaluate the quality of GINS PPP sub-daily solutions by comparing the series of vertical displacements to the ocean and atmosphere load models.

GNSS Precise Point Positioning (PPP)

PPP allows single point positioning at the millimeter level even on isolated GNSS receivers. It represents a powerful alternative to the "classical" network approach which consists in the global estimation of a common set of parameter. In the PPP approach, no baseline is needed and parameters are processed independently. However, GNSS satellite position and clock offsets (ephemeris) must be fixed to precise solutions.

The availability and the quality of precise ephemeris is a key issue for PPP. The International GNSS Service (IGS) plays a major role by providing (Internet) high accuracy "rapid" and "final" products for GPS and GLONASS constellations. The IGS will also provide Galileo products as soon as the constellation will be deployed. Starting January 2007, IGS provides high rates 30 seconds constellation clock corrections which allows sub-daily PPP.

However, the PPP approach needs to pay attention on the following points (J. Kouba 2003) :

- Any cause of station displacement affects the solution (while they cancel in a baseline approach)
- Sensitive to *Reference Frame* and instrumental *Phase Center* conventions (Gendt and R. Schmid, 2004)
- Ambiguity fixing is more challenging even if recent progress have been made (Mercier and Laurichesse, 2008)

GPS PPP with the GINS software

GINS is the CNES/GRGS GPS data processing software currently used for CNES-CLS IGS Analysis Center activities
www.igsac-cnes.cls.fr

- The PPP capability has been recently implemented. The processing strategy characteristics are :
  - Constellation orbit parameters fixed to "final" precise IGS products
  - Constellation clock parameters fixed to IGS precise 30 second products
  - Station coordinates processed independently
  - 5 days arc and normal equation accumulation over a 30 days time span (February 2007)
- Estimated parameters :
  - Coordinates (Lon/Lat/H) every 2 or 6 hours
  - Ambiguities (real)
  - Zenithal Tropospheric Delays every 2 hours
  - Receiver clock corrections (1/epoch)
  - Continuity constraint are applied to tropospheric and coordinate parameters
- PPP GPS series of vertical displacement are compared to 3 different loading phenomena estimated from crustal deformation models
  1. Ocean Tide Loading (OTL) (FES2004 tide model)
  2. Oceanic atmospheric (non IB) loading (MOG2D model)
  3. Continental atmospheric loading (ECMWF data)

Conclusions

- Thanks to IGS precise orbits and 30 second clocks, hourly PPP is now possible
- The GINS CNES/GRGS software has the capability to process long term (few days) millimetre station vertical displacement due to atmospheric loading
- Higher frequency signals recovery seems to be limited to integer ambiguity fixing and needs more investigation
- Additional signals like hydrological loading could be significant but were not considered in this study

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