Strategies to mitigate aliasing of loading signals while estimating GPS frame parameters

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Abstract A

Although GNSS techniques are theoretically sensitive to the Earth center of mass, it is often preferable to remove intrinsic origin and scale information since they are known to be affected by systematic errors. This is usually done by estimating the parameters of a linearized similarity transformation which relates the quasi-instantaneous frames to a secular frame such as the International Terrestrial Reference Frame (ITRF). It is well known that non-linear station motions, not-accounted for in the secular ITRF can partially alias into these parameters. We discuss in this paper some procedures that may allow for reducing these aliasing effects in the case of the GNSS techniques, mainly GPS. The options include the use of well distributed sub-networks for the frame transformation estimation, the use of site loading corrections, a modification of the stochastic model by down-weighting heights, or the joint estimation of the low degrees of the deformation field. We confirm that the standard approach consisting of estimating the transformation over the whole network is particularly harmful for the loading signals if the network is not well distributed. Down-weighting the height component, using a uniform sub-network, or estimating the deformation field perform similarly in drastically reducing the aliasing effect amplitude. The application of these methods to reprocessed GPS terrestrial frames permits an assessment of the level of RMS agreement between GPS and our loading model, which is found to be about 1.5 mm in heights and 0.8 mm in the horizontal at the annual frequency. Aliased loading signals are, thus, not the main source of discrepancies between loading displacement models and GPS position time series.

Problem of aliasing B

When GPS position time series are transformed into ITRF frame using the parameters of a similarity, the estimated translations, rotations and scale factor can be biased due to loading effects.

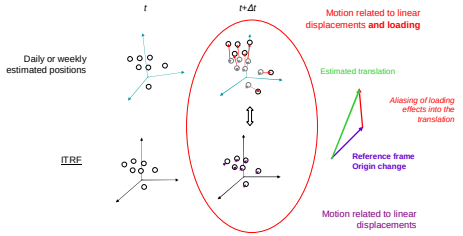
What are the loading effects?

Mass transfers at the Earth's surface (atmosphere, ocean circulation, water) deform the Earth's crust.

To study these effects, we use the following model:

- 6 hour atmospheric loading (NCEP)
- 12 hour ocean non tidal loading (ECCO)
- 1 month hydrological loading (LaD)

What is the problem?



Amplitude of the aliasing effect

The amplitude of the aliasing effect can be higher than 1 mm (annual signal). It is fundamental to mitigate that effect to properly interpret seasonal variations.

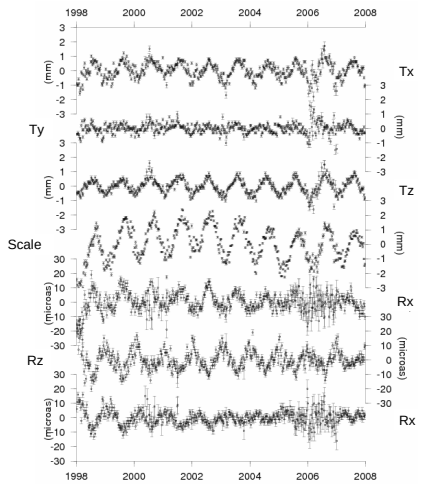


Fig 1. Aliasing effect evaluated with our loading model on the reprocessed GPS network of MIT analysis center. The whole network of stations is used to compute the transformation parameters.

How to mitigate the aliasing effect? C

We tested the following procedures:

- Down-weighting the height component in the adjustment of transformation parameters
- Using a sub-network of well distributed stations to adjust the transformation parameters
- Using loading models to account for station seasonal motions in the adjustment of transformation parameters
- Estimating the low degree of the elastic deformation of the Earth (up to degree 5) with additional transformation parameters (Lavallée et al., 2006)

Application to synthetic data D

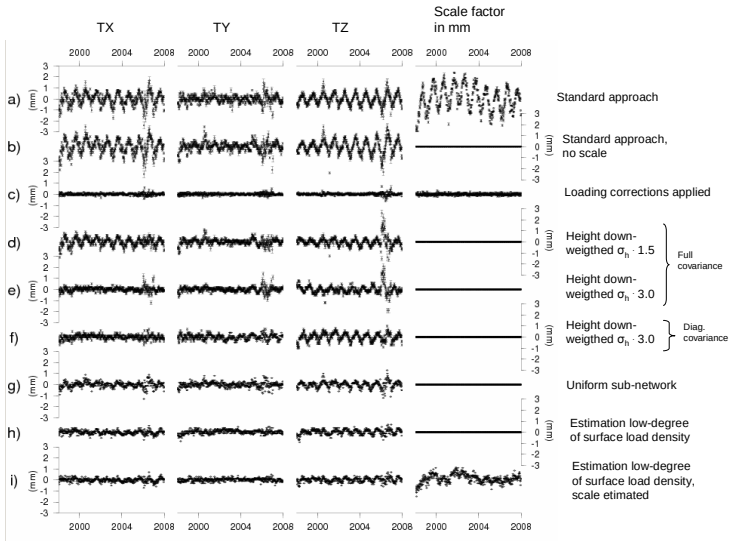


Fig 2. Aliasing effect in the translations (a) to i)) and scale parameter (a), c) and i)) evaluated using synthetic data. In cases b) and d) to h), the scale parameter has not been adjusted.

- The estimation of daily/weekly scale factors is not recommended. If scale factor times series are needed, estimating simultaneously the deformation field significantly mitigates the aliasing effects (see fig 2i)).
- Down-weighting the height component, using a uniform sub-network, correcting with a loading model, or estimating the deformation field perform similarly in drastically reducing the aliasing effect amplitude if scale is not estimated.

Application to real data E

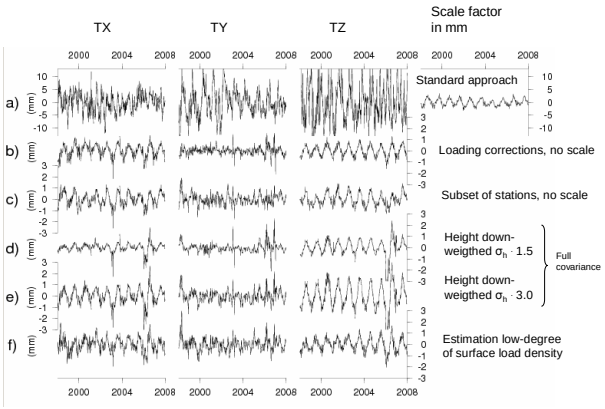


Fig 3. a) MI1 GPS solution translation and scale factor time series estimated with the standard approach.
b-f) Differences between translation estimated with the strandard approach and the approaches tested here. No scale estimated.

- Significantly different transformation parameters are estimated when mitigating the aliasing of loading effects
- If the full or diagonal covariance matrix is used for the weighting, different annual signals may be found in the translation parameters
- Our analysis of entire sets of time series generated with those transformation parameters, indicates that the aliasing of surface mass loading is not the main source of discrepancy between the MI1 GPS time series and our loading model.

References H

Collilieux, X., T. van Dam, J. Ray, D. Coulot, L. Métivier, Z. Altamimi, Strategies to mitigate aliasing of loading signals while estimating GPS frame parameters, J. Geod., to be submitted

Lavallée D., van Dam, T., Blewitt G. and Clarke P., Geocenter motions from GPS: a unified observation model. J. Geophys. Res., 2006