A new model of tropospheric directional gradients in global positioning system and its application to investigate extreme weather events

Salim Masoumi, Simon McClusky, Achraf Koulali, Paul Tregoning
Research School of Earth Sciences, Australian National University, Canberra, Australia
Contact: salim.masoumi@anu.edu.au

Introduction

The delay in GPS L-band frequency signals caused by the presence of atmospheric vapor water molecules has been used for monitoring temporal and spatial changes of the troposphere using permanent ground-based GPS stations. Some research has been dedicated to investigating the relationship between water vapor accumulation and precipitation systems (e.g. Champollion et al., 2004). In a recent study by Labbouz et al. (2015), it was shown that precipitable water vapor (PWV) could potentially be used as a short-term indicator of heavy precipitation. Although such studies are still in early stages, and despite the unknown complications of weather systems, there still seems to be demand for further work on horizontal movements of the moisture and the link with formation of extreme precipitation events.

Tropospheric is usually considered azimuthally symmetric in mapping functions used in GPS modeling. To compensate for this assumption, horizontal gradients are generally estimated together with other parameters. However, the gradient model currently in use by most analysts is a simple NS/EW planar model. While such a planar model is sufficient in most cases, there are specific cases where a plane is not truly representative of the troposphere.

We have developed and implemented a new directional model of gradients in which the gradients are estimated at different directions around the site with a piecewise function between the nodes. The new model has the capability to detect isolated rapid spatial changes in specific azimuth angles. Simulations are performed to validate this capability of the model and to evaluate the effect of the new model on other parameters.

A real case study of the 9 September 2002 extreme precipitation in Southern France is used as an example of how the directional gradients can provide information about the local variability of the troposphere around a GPS site, and how they might potentially be used for investigating specific extreme weather events.

Tropospheric modelling in GPS and the proposed directional gradient model

The azimuthally symmetric part of the tropospheric delay (Davis et al., 1985):

\[ \lambda_{\text{ trop}}(r) = \lambda_{\text{ lat}}(r) + \lambda_{\text{ long}}(r) \]

The azimuthal gradient of the tropospheric delay modelled as conventional North-South and East-West gradients (Chen and Herring, 1991):

\[ \lambda_{\text{ dir}}(r) = \lambda_{\text{ lat}}(r) \cos(\theta) + \lambda_{\text{ long}}(r) \sin(\theta) \frac{\cos(\theta)}{\sin(\theta)} + 0.003 \]

The new proposed model of gradients:

\[ \lambda_{\text{ dir}}(r) = \hat{\nu} \lambda_{\text{ lat}}(r) \cos(\theta) + \hat{\nu} \lambda_{\text{ long}}(r) \sin(\theta) \frac{\cos(\theta)}{\sin(\theta)} \]

Correlations of the simulated planar scenario

- Looking at the correlations between the estimated parameters can give us a clue why the directional model is still unable to fully recover the gradients while position components are also estimated. The new gradient parameters are highly correlated with heights and with each other. These correlations are significantly reduced when applied to height and elevation observations, which results in more accurate estimates.

Real case study of Southern France September 2002

- The proposed gradient model of directions has the capability to isolate rapid spatial changes of the tropospheric delay/water vapor in specific directions around a GPS site.
- This capability may be used for deriving valuable information about the local atmosphere around a GPS site, in particular for extreme weather events.
- While the directional gradient model parameters are highly correlated with height, these correlations are largely broken when the positions are fixed, leading to more realistic estimates of gradients.
- This new model will lead to improved tropospheric slant delays for weather model assimilation purposes.

References


