Forward modelling of ground based GPS Slant Total Delay observations

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1 Introduction

The NWP systems with horizontal resolutions near kilometric scales require high resolution observations. Microwave phase delays observed at geodetic Global Positioning System (GPS) receiver stations provide potential for exploitation in numerical humidity analysis (e.g. Bevis et al., 1992). The phase delay observations can be directly assimilated in the variational assimilation system of High Resolution Limited Area Model (HIRLAM 3D-Var; Gustafsson et al., 2001). Observation modelling by an observation operator is a necessary step in the variational assimilation.

2 Slant Total Delay observation operator

Modelling of a Slant Total Delay (STD) observation is complicated by the following aspects. First, the observation is dependent on refractivity N and thus on several model variables (pressure p, temperature T and specific humidity q). Second, the observed quantity is an integral of refractivity along the signal path. Third, the values of p, T and q need to be interpolated to the slanted signal path and not only to the vertical column at the observation location. However, the signal path is not known in advance. Therefore, signal path determination is an important task of the observation operator. Other tasks are projection of the model variables from the model grid to the signal path, calculation of refractivity as a function of the model variables, and integration of refractivity to produce STD.

The STD observation operator has been implemented in HIRLAM 3D-Var at the Finnish Meteorological Institute (FMI). In this observation operator, the signal path determination algorithm is based on the Line of Sight (LoS) -approximation. Thus, it uses the azimuth and zenith angles corresponding to the geometrical direction in which the broadcasting satellite is as viewed at the receiver. This direction is called here as the Direction of Geometry (DoG). Explicit corrections have been added on top of the simplest LoS -based model in order to account for zenith angle variations along the signal path.

3 Validation of the observation operator

The observation operator is validated by comparing the modelled STD with the observations. The STD observations used here are post-processed at the Technical University of Delft and they originate from 17 receiver stations in the Western Europe. STD is modelled using the operational HIRLAM of FMI with 0.2° horizontal resolution. The significance of each of the explicit corrections has been investigated by constructing five observation operator versions. These are summarized in Table 1.

The systematic part (bias) of the difference between modelled and observed STD is plotted in the upper panel of Fig. 1 as a function of the satellite zenith angle. The shaded region shows the number of observations in each 1° zenith angle bin. At the small zenith angles, i.e. when the satellite is close to the zenith direction, the bias is negative (the modelled STD is smaller than the observed). This is consistent with the biases of Zenith Total Delay (ZTD) observations reported by Gustafsson (2002). The bias at the large zenith angles is strongly sensitive to the forward modelling strategy. The most important single modelling improvement on top of LoS -approach is accounting for the effect of the curvature of the Earth.

Version	**Characteristics**
DOG	Uses Direction of Geometry
ITER	Like DoG, but the NWP model level height gradients included
CURV	Like DoG, but the effect of the curvature of the Earth included
BEND	Like DoG, but the effect of the refractive bending included
ADVV	The effects of model level height gradients, curvature of the Earth and refractive bending included

Table 1: Observation operator versions used for comparison between modelled and observed STD.

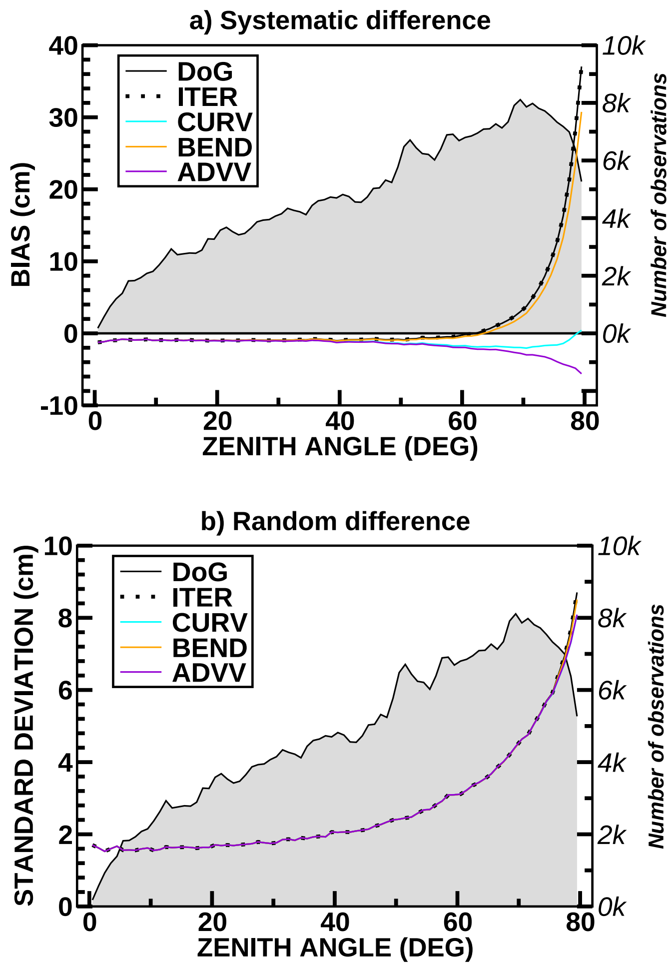

Figure 1: Systematic (upper) and random (lower) parts of the difference between modelled and observed STD as a function of satellite zenith angle.

The lower panel of Fig. 1 shows the random part (standard deviation) of the difference between modelled and observed STD. There is practically no difference between observation operator versions. This suggests that the signal paths as determined by one or the other observation operator version are fairly close to each other and therefore the model state differences along the different paths are negligible. Thus, it is concluded that the accuracy of the signal path determination algorithm seems to be sufficient for STD modelling.

References

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