SPATIAL OBSERVATION ERROR COVARIANCE OF GPS ZENITH TOTAL DELAYS

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Abstract

Ground based GPS Zenith Total Delay (ZTD) observations are known to suffer from spatial error covariances. Unless explicitly taken into account in the data assimilation, these error covariances are expected to degrade the quality of the obtained analysis, as unrealistically large weight is given to this specific data source.

A method for estimating the spatial ZTD observation error covariance is developed at the Finnish Meteorological Institute. The method makes use of the innovation (observation minus model background) covariances of ZTD at ground based receiver stations, surface pressure at synoptic stations and Integrated Water Vapour at radiosonde stations. A four-parameter exponential covariance model for ZTD observation error covariance is introduced.

Innovation sequences computed with the High Resolution Limited Area Model (HIRLAM) are used as statistical material for the estimation. Seasonal and yearly mean models are provided for implementation into variational data assimilation systems.

1 Introduction

Tropospheric delays in the microwave propagation can be estimated for networks of ground based GPS (Global Positioning System) receivers (Bevis et al., 1992) to provide information on atmospheric humidity. Due to the extensive preprocessing chain required for production of Zenith Total Delay (ZTD) observations, the statistical properties of the observation errors are complex. However, the optimality of data assimilation requires accurate specification of the observation error characteristics. This poster describes and demonstrates a method for estimation of spatial ZTD observation error covariance. The method is described in more detail in Eresmaa and Järvinen (2005).

2 Estimation method

The estimation is based on the observation method (Hollingsworth and Lönnberg, 1986) intended for background error covariance estimation. In case of correlated observation errors the observation method gives an estimate of the innovation covariance. Some additional information is needed for separation between the contributions from the observation and background errors. Here, the additional information is obtained in the form of surface pressure (p_S) and Integrated Water Vapour (IWV) observations, as observed by synoptic stations and radiosondes, respectively.

ZTD is a linear function of p_S and IWV. With certain assumptions on the decorrelation of conventional observation errors, the ZTD observation error covariance (OBS-

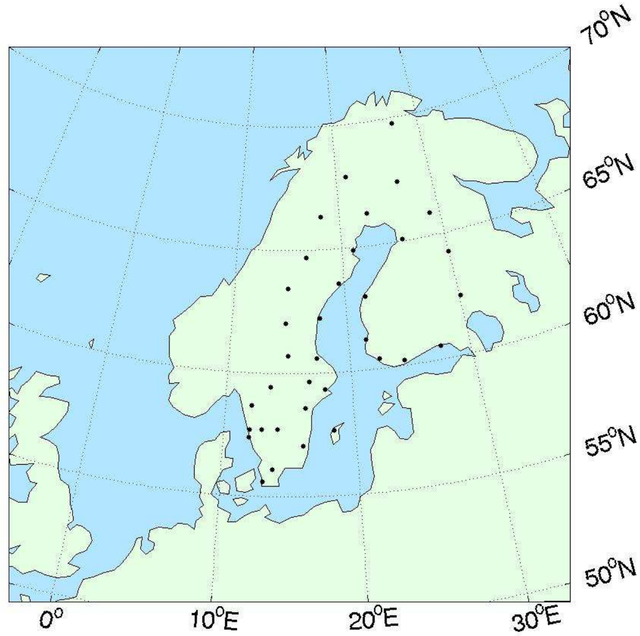

Figure 1: The ground-based GPS receiver station network.

term) can be expressed as

$$\underbrace{cov(\varepsilon^o_{ZTD,i},\varepsilon^o_{ZTD,j})}_{OBS-term} = \underbrace{cov(d_{ZTD,i},d_{ZTD,j})}_{INN-term} - \left(\underbrace{a^2 cov(d_{p_s,i},d_{p_s,j})}_{ZHD-term} + \underbrace{b^2 cov(d_{IWV,i},d_{IWV,j})}_{ZWD-term}\right).$$

The ZTD observation error covariance is thus a linear combination of the innovation covariances of ZTD, p_S and IWV (INN-term, ZHD-term and ZWD-term). Proportionality factors a and b depend on the geographical location and vertical profiles of temperature and humidity. Isotropy and homogeneity are assumed for all the covariances.

The main limitations of the estimation method are

- covariance structures in scales smaller than about 150 km are not resolved due to the sparseness of the operational radiosonde network,
- in case of biased observations, unrealistically large error covariances in large scales can be obtained; the method is sensitive to the bias reduction approach.

The innovation datasets of ZTD, p_S and IWV are extracted from six hour forecasts of High Resolution Limited Area Model (HIRLAM). The ground based GPS receiver station network used here is shown in Fig. 1.

	R_1 (mm^2)	L_1 (km)	R_2 (mm^2)	L_2 (km)
Spring	90.6	23.0	22.5	214
Summer	175	34.8	28.7	168
Autumn	72.9	45.8	4.92	1730
Winter	29.2	55.5	12.5	870
Yearly mean	61.0	62.3	9.19	476

Table 1: The seasonal and yearly parameters for the ZTD observation error covariance model.

3 ZTD observation error covariance function

Using the innovation datasets of ZTD, p_S and IWV, the mean ZTD observation error covariance is estimated for 100 km separation distance bins. The covariance is modelled by a four -parameter function

$$f(r) = R_1 \left(1 + \frac{r}{L_1}\right) exp\left(-\frac{r}{L_1}\right) + R_2 \left(1 + \frac{r}{L_2}\right) exp(-\frac{r}{L_2}),$$

where r is the separation distance. The model parameters R_1, L_1, R_2 and L_2 are estimated by least squares fitting for each season separately and also for the whole year of data.

4 Conclusions

The resulting covariance function parameters are given in Table 1. The following conclusions are drawn:

- The fitted parameters show large interseasonal differences,
- The small scale covariance follows the annual cycle of water vapour with summer maximum and winter minimum,
- In autumn and winter, the covariance extends to very large scales, which features are absent in spring and summer.

Figure 2 plots the covariance function for the whole year of data. Also the binned covariances and the 95% confidence intervals are shown. It is further concluded, that

- ZTD observation error covariance is evident in scales up to about 1000 km,
- The accuracy of the estimated covariances and fitted parameters is poor in the smallest station separations.

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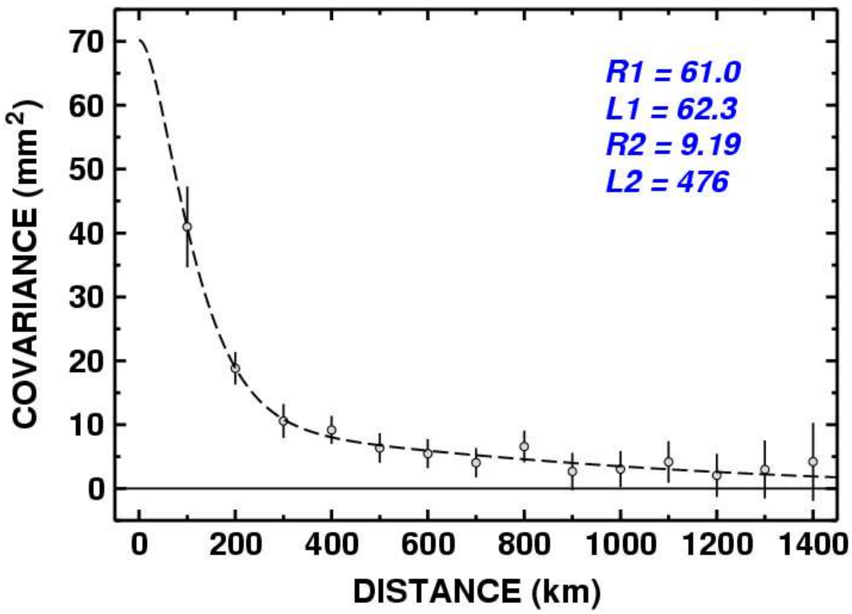

Figure 2: Yearly mean ZTD observation error covariance. Dots and vertical bars indicate the binned observation error covariances and their 95% confidence intervals. Dashed line is the least-squares fitted error covariance model.

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