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How important is the site distribution for a GNSS water vapour tomography using a Compressive Sensing solution?

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Motivation:

An accurate knowledge of the 3D distribution of water vapor in the atmosphere is a key element for weather forecasting and climate research. In addition, a precise determination of water vapor is also required for accurate positioning and deformation monitoring using Global Navigation Satellite Systems (GNSS) and Interferometric Synthetic Aperture Radar (InSAR). Several approaches for 3D tomographic water vapor reconstruction from GNSS-based Slant Wet Delay (SWD) estimates exist. However, the accuracy of the tomographic solution largely depends on the observing geometry related to the orbits and to the GNSS site distribution. Therefore, the performance of different site distributions is tested in this study.

Goal of this work:

In this work, we analyze the performance of different site distributions for reconstructing neutrospheric refractivity from GNSS SWD estimates using a Compressive Sensing (CS) approach. In particular, we focus on the question in how far the horizontal site distributions should differ in different latitudes.

Approach:

For three $100 \times 100\ \mathrm{km}^2$ large test regions at the equator, in mid latitudes, and in high latitudes, a large number of observing geometry settings is defined. These settings result from the combination of i) many samples of the real GNSS orbit geometry with ii) different site numbers, and iii) different distributions of these sites within the study areas. Evaluation metrics that mathematically describe the site distributions are defined (e.g., site density and standard deviation of the site density in longitude and in latitude, number of visible satellites, percentage of ground voxels in which no GNSS site is situated). From this large number of observing geometry settings, 100 settings are arbitrarily selected. For each of the selected tomographic settings, a synthetic SWD dataset is generated based on a synthetic 3D refractivity field. The synthetic datasets do not represent the latitude dependent meteorological conditions of the three study regions. Instead, they serve as means for geometrically analyzing the performance of the different site distributions at different latitudes, independently of the prevailing weather. The topography of the study regions is set to zero in order to concentrate purely on the horizontal site distribution. For each of the synthetic datasets, a Compressive Sensing solution benefitting of the sparsity of the signal as a prior for regularization is computed. The mean and the standard deviation of the difference between the estimated refractivities and the input WRF refractivities are analyzed as a function of latitude and of the site distribution descriptors.