Geophysical Research Abstracts
Vol. 21, EGU2019-15953-1, 2019
EGU General Assembly 2019
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Tropospheric delay models based on GNSS and space-borne SAR interferometry at ETH Zurich

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Space-borne microwave techniques, such as the Global Navigation Satellite Systems (GNSS) or Synthetic Aperture Radar Interferometry (InSAR), are subjected to the atmospheric delay. The delays estimated by one technique can be useful for mutual corrections. The GNSS technique is characterized by very high temporal but sparse spatial resolution. In contrast, SAR satellites have overpasses separated by days or weeks. During this time, the tropospheric conditions, especially the water vapor density, may change completely. Unless the atmosphere is accounted for, any tropospheric changes can be misinterpreted as deformation. In this paper, we present various activities at ETH Zurich where we study the benefits of using GNSS-based models in mitigating the troposphere-induced errors in InSAR or combining both techniques together.

In the first step, we compare the GNSS-based difference slant delays (dSTD) with the dSTD estimated with the InSAR Persistent Scatterer Interferometry (PSI) for alpine regions in Switzerland. The GNSS-based models are interpolated to PS locations using the in-house developed software package COMEDIE (Collocation of Meteorological Data for Interpretation and Estimation of Tropospheric Pathdelays). The models are calculated for 32 acquisitions of X-band COSMO-SkyMed satellite in a period between 2008 and 2013. The results show a good agreement between InSAR and GNSS estimates for more than a half of the interferometric images. The correlation coefficient averaged from all the interferograms is 0.64. Investigating the reasons for the poor agreement between InSAR and GNSS estimates shows that the main cause is the low variability of the troposphere, expressed for example in standard deviations of the GNSS-based dSTDs. We also tested including data from a set of low-cost L-1 only GPS stations located within the study area. Unfortunately, adding this information into the models results in an increase of biases for most of the dates, though for some limited areas, the standard deviations between InSAR and GNSS are decreased.

When only a few SAR acquisitions are available, the PSI cannot be efficiently employed to differentiate atmospheric effects and displacement. In these cases, the use of external tropospheric models may be a possibility to mitigate the atmospheric disturbances. In our current study, we introduce GNSS-based atmospheric models into processing of C-band Sentinel-1 data. We conduct tests on two larger areas: almost entire Switzerland (including the mountainous regions) and the Big Island in Hawaii. Preliminary tests for the Kilauea Volcano eruption and M6.9 earthquake that took place in May 2018 show that using the GNSS-based atmospheric phase screens improves the resolution of the displacement field.

In another activity, we combine GNSS and SAR tropospheric estimates to leverage both the high temporal resolution of GNSS measurements and the high spatial density of InSAR. The combined product can serve as an input for data assimilation in numerical weather prediction (NWP) models. We perform the tests for both simulated and real data. The simulation shows how many points and how large an area is necessary to achieve a few-millimeter level of agreement with NWP models. For the real data, the combination model is dominated by the InSAR data.