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Author: Mr. Endrit Shehaj
ETHZ, Switzerland, endrit.shehaj@geod.baug.ethz.ch

Mr. Luca Miotti
ETHZ, Switzerland, miottil@student.ethz.ch
Prof. Alain Geiger
ETHZ, Switzerland, alain.geiger@geod.baug.ethz.ch
Dr. Stefano D'Aronco
ETHZ, Switzerland, stefano.daronco@geod.baug.ethz.ch
Dr. Jan Dirk Wegner
ETHZ, Switzerland, jan.wegner@geod.baug.ethz.ch
Dr. Gregor Moeller
ETHZ, Switzerland, gmoeller@ethz.ch
Prof. Benedikt Soja
ETHZ, Switzerland, soja@ethz.ch
Prof. Markus Rothacher
Institute of Geodesy and Photogrammetry, Technical University of Zürich (ETH), Switzerland, markus.rothacher@ethz.ch

HIGH-RESOLUTION TROPOSPHERIC REFRACTIVITY FIELDS BY COMBINING MACHINE LEARNING AND COLLOCATION METHODS TO CORRECT EARTH OBSERVATION DATA

Abstract

Signals used for Earth observation, when travelling through the atmosphere, are sensitive to refractivity; especially high spatio-temporal variations of water vapor are difficult to model and correct. Remaining unmodeled tropospheric delays deteriorate the positioning solution and therefore limit the accuracy of sensing and navigation applications. These delays are usually computed with empirical models based on ground meteorological parameters (pressure, temperature and water vapor partial pressure). However, existing models are not accurate enough for high-precision applications such as GNSS, where in consequence the so-called zenith total delay (ZTD) has to be estimated together with other unknown parameters (coordinates etc.).

For decades the Institute of Geodesy and Photogrammetry at ETH Zurich has been studying collocation methods for modeling of tropospheric delays using meteorological parameters, successfully interpolating pointwise or integral atmospheric observations. Meanwhile, machine learning has become a widely used and valuable alternative when big datasets are available for the training process. Indeed, we have already successfully predicted ZTDs based on meteorological parameters with an accuracy of 1-2 cm for locations (GNSS stations) already seen in the training phase. However, difficulties arise to predict delays at new locations.

In this work, we take a step forward in investigating the combination of machine learning algorithms and physical models used in a collocation approach to derive atmospheric delay fields at a very high resolution. Thus, without processing any GNSS data we can predict tropospheric delay fields everywhere in the area of investigation. In this paper, we firstly describe the designed architecture of the neural network, secondly, the combination of least-squares collocation and artificial neural network for high

resolution prediction of tropospheric delays. We benefit from the complementary characteristics of these algorithms. While machine learning is capable of successfully predicting the variation of time series for given points, empirical models based on collocation are well suited for describing spatial variations within the area of investigation. Finally, we report the achieved performance for the entire territory of Switzerland, showing that the synergic combination of these algorithms can overcome the individual drawbacks of each method and provide more accurate delay estimates than either method individually.

Datasets of 11 years, covering the territory of Switzerland, consisting of GNSS ZTDs from 72 permanent AGNES/COGEAR (swisstopo, ETHZ) stations and meteorological data from MeteoSwiss were used for this research.