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Modeling of Tropospheric Delays Using ANFIS

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ISSN 2199-9112 ISSN 2199-9120 (electronic)
SpringerBriefs in Meteorology
ISBN 978-3-319-28435-4 ISBN 978-3-319-28437-8 (eBook)
DOI 10.1007/978-3-319-28437-8

Library of Congress Control Number: 2015958860

Printed on acid-free paper

This Springer imprint is published by SpringerNature
The registered company is Springer International Publishing AG Switzerland

Preface

The Global Navigation Satellite Systems (GNSS) technology was implemented in the field of meteorology in the early 1990s, where scientists successfully developed a technique for determining water vapor in the troposphere by exploiting the signal errors during propagation from satellite to a receiver. One of the main sources of error in the GNSS and its impact, which are crucial in efforts to improve the accuracy of positioning, is the zenith tropospheric delay (ZTD). If ZTD is produced with fine temporal and spatial resolution, the value and variability can be applied to meteorological studies. In other words, ZTD in this case is the main parameter that plays an important role in determining the parameters of water vapor in the atmosphere.

In the advantages of GNSS such as GPS technology for atmospheric research applications, it was found that this method or other methods do not always excel in all circumstances. For example, GPS data is not always available for a full 24-h period, especially for a remote location or a strategic area where the GPS receiver is not installed, while the accessibility and accurate estimation of this parameter is necessary. Hence, we look at a different approach that is cost-effective and robust in retrieving the value of ZTD by applying a soft computing technique such as adaptive neuro-fuzzy inference system (ANFIS) as a new alternative. There are various approaches by other soft computing techniques, such as genetic algorithms (GA), artificial neural network (ANN), fuzzy logic model (FLM), and particle swarm techniques. However, ANFIS was selected as it is emerging as a potential and robust optimization tool in recent years. ANFIS is a method that combines ANNs and a fuzzy inference system. In this technique, a fuzzy clustering algorithm is adopted to enhance the performance of the models, which is able to minimize the number of membership functions and rules for better efficiency of the models.

To investigate the accuracy of the ZTD models developed, a combination of the surface pressure (P), temperature (T), and relative humidity (H) is analyzed to obtain the best estimation of ZTD. The results demonstrate that ANFIS models with three inputs network (P, T, and H) agree very well with the ZTD obtained from GPS. Finally, the three-input network is selected for developing the ZTD predictive models. To perform the ZTD model, five selected stations over Antarctica and three selected stations in regions of Malaysia and Singapore were used to examine the applicability of ANFIS. The ZTD prediction is performed from one to eight-step ahead for Antarctica region and from one to fifteen-step ahead for the equatorial region. The results demonstrate that ANFIS is capable of predicting ZTD with high accuracy.

This book is prepared to help students, lecturers, engineers, geodesists, meteorologists and climatologists, or practitioners to develop new knowledge in applications of the soft computing technique. The example application of soft computing presented here is for estimation and prediction of tropospheric delays. On the other hand, the ZTD parameter obtained from the models or measurements needs to be converted into precipitable water vapor (PWV) to make it more useful for weather forecasting, analysis of atmospheric hazards such as tropical storms, flash floods, landslides, and earthquakes, as well as for climate change studies.

In this book, readers are presented with a detailed theoretical background of ANN and ANFIS in Chap. 2. Chapter 3 describes the modeling of tropospheric delay and mapping functions from GPS observations. Chapter 4 presents the implementation of ANFIS model for estimation of ZTD. In this chapter, the ZTD value from both ANFIS models and GPS measurements for Antarctica and the equatorial regions is compared. The accuracy of each ZTD model for each input used in the training, testing, and validation is comprehensively elucidated, and finally in Chap. 5 the reader is introduced to the prospect of ZTD estimation using ANFIS, which focuses on how to predict the ZTD value using the surface meteorological data as input. With its simple writing style, it is hoped that this book will provide complete knowledge to readers on application of soft computing, in particular, for meteorological applications and processes involved in the method of observation, data processing, analysis, and methods of data interpretation.

In addition to the content of the book, the authors are particularly grateful to agencies such as Scripps Orbit and Permanent Array Center (SOPAC) for archiving GPS data, Crustal Dynamics Data Information System (CDDIS) NASA for archiving the ZPD data, the Australian Antarctic Division (AAD) and the British Antarctic Survey (BAS) for the surface meteorological data, and ANZ and NIWA for the Scott Base data where some data used in the analysis is their contribution. Finally, the author also expresses his gratitude to the publishers for agreeing to publish this book.

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