Abstract

The atmospheric water vapor is generally expressed in terms of Precipitable water vapor (PWV). It is an important indicator of water vapor climatology and variability in the lower troposphere and related climate processes. PWV values are traditionally calculated using the radiosondes, microwave-radiometers and satellite based instruments. These technologies have limitations in capturing PWV data with good spatial and temporal resolutions in all weather conditions. Therefore, to overcome these short comings, Global Positioning System (GPS) satellite signals are being used to derive PWV values with high spatio-temporal resolution which is available in all-weather conditions. The PWV values are derived using the delay information from GPS signals. When GPS signals travel from a GPS satellite to a receiver on the ground, the signal undergoes delay caused by the ionosphere and the troposphere layers. In troposphere layer, the delay caused by the water vapor is termed as wet delay. PWV values are derived using these zenith wet delay (ZWD) values. In this thesis, a comprehensive literature review is done on the tropospheric delays and different terminologies associated to it.

When converting the ZWD values to PWV, it involves the use of a dimensionless constant called PI. This PI value is found to rely on a water-vapor weighted mean temperature (T_m) value which varies according to different locations and different seasons. It is therefore, both site and time specific. Analysis of the PI value and its effect on the retrieved PWV from the data obtained for tropical, sub-tropical and temperate regions show that although the PI value is time and site specific, the change in the median value of PI for different years is minimal and is dependent only on factors like the latitude coordinates of the particular site and the day-of-

the year. Therefore, using the data obtained from 174 different sites, a latitude-coordinate and day-of-year based PI value model is proposed for the retrieval of PWV. The proposed model has been successfully validated using data from different databases: the IGS GPS NASA database (International Global Navigation Satellite System Service, National Aeronautics and Space Administration), the IGS GPS GGOS database (Geodetic Observing System) and the very-long-baseline interferometry (VLBI) database. Results show a strong agreement between PWV values calculated using the proposed model and that calculated using the temperature dependent models with 99%, 98% and 93% of error within ± 1 mm for IGS GPS NASA, IGS GPS GGOS and VLBI databases, respectively. Moreover, the proposed model allows for the ease of PWV retrieval.

With the rapid deployment of the GPS stations, many researchers are studying the PWV values and its usefulness in prediction of a rainfall event. In literature, there are long term rainfall prediction algorithms that are proposed using the data from tropical and sub-tropical stations. We review these algorithms and apply on the data from tropical region. It was found that the absolute value of PWV plays an important role in long term rainfall prediction, unlike temperate and sub-tropical region. In addition to the long term rain forecasting, a simple algorithm is proposed to perform the nowcasting of a rainfall event in the tropical region. The algorithm applies GPS-derived PWV values and its second derivative for the short-term prediction of rainfall. The proposed algorithm incorporates the seasonal dependency of PWV values for the prediction of a rain event in the coming 5 minutes based on the past 30 minutes of PWV data. This proposed algorithm is based on the statistical study of 4 years of PWV and rainfall data from a station in Singapore and is validated using 2 years of independent data for the same station. The results show that the algorithm can achieve an average true detection rate and a false alarm rate of 87.7 % and 38.6 % respectively. To analyze the applicability of the proposed algorithm, further validations are done using 1 year of data from one independent station from Singapore and 2 years of data from one station from Brazil. It is shown that the proposed algorithm performs well for both the independent stations. For the station from Brazil, the average true detection and false alarm rates are around 84.7 % and

37 % respectively. All these observations are compared to the existing literature and it is concluded that the proposed algorithm is reliable and works well with a good detection rate for tropical region.

It has been pointed out that the occurrence of rainfall is dependent on myriad of atmospheric parameters. Thus, in this thesis, we also systematically analyze various parameters that affect the precipitation in the atmosphere. Different ground based weather features like Temperature, Relative Humidity, Dew Point, Solar Radiation, PWV along with the Seasonal and the Diurnal features are identified and a detailed feature correlation study is presented. It has been shown that all features play a significant role in rainfall classification, whereas only a few parameters; PWV , Solar Radiation, Seasonal and Diurnal features stand out for the rainfall prediction applications. Therefore, an optimum set of features are used in a data-driven machine learning algorithm for rainfall prediction. The train/test results using a four year (2012-2015) database show a true detection rate of 83.0%, false alarm rate of 24.0%, and an overall accuracy of 76.0%. When these results are compared to the existing literature, which shows the true detection and false alarm rates of 87.7% and 38.6% respectively, our proposed implementation shows a significant drop of up to 14.6% in the false alarm rates for rainfall prediction.

In summary, in this thesis, we have studied the GPS signal delays and related processes in detail. We have proposed a simplified PI model that is globally applicable, easy to implement and has good resolution. We have analyzed different rainfall prediction algorithms using data from the tropical region and proposed a rainfall nowcasting algorithm that works with better accuracy for stations from the tropical region. We have implemented a data-driven approach that uses other meteorological parameters to improve the rainfall prediction. We believe that the models and algorithms proposed in this thesis will assist researchers in remote sensing and satellite communication applications.