Extraction of total precipitable water and the effect of fine dust on its retrieval in the atmosphere of Mehrabad

Introduction: The distribution of total precipitable water (TPW) across the Earth's atmosphere is crucial for understanding the hydrological cycle, biosphere-atmosphere interactions, energy balance changes, and monitoring climate variations induced by greenhouse gases. Accurate estimation of TPW is essential for flood prediction, rainfall estimation, water resource management, and the development of hydrological models. However, a significant challenge in retrieving TPW from satellite imagery is the presence of fine dust particles (aerosols), which introduce uncertainties in remote sensing measurements. This study aims to retrieve TPW using Moderate Resolution Imaging Spectroradiometer (MODIS) satellite images and investigate the impact of fine dust on its retrieval in the atmosphere of Mehrabad, Tehran.

Material and Methods: The research methodology follows a quantitative-applied approach, utilizing MODIS imagery for Tehran Province, processed through the ENVI software package. The study employs Near Infrared (NIR) retrieval techniques, using MODIS bands 17, 18, 19, and 2, which are particularly sensitive to atmospheric water vapor absorption features. Band 2, with a high signal-to-noise ratio (SNR = 201), was selected as the primary reference for atmospheric window calculations. The spectral transmittance characteristics of water vapor absorption and window bands were analyzed using the LOWTRAN7 atmospheric model to assess aerosol-induced uncertainties.

Results and Discussion: The results indicate that the mean TPW retrieved from MODIS bands 19 to 2 in the upper atmosphere of Mehrabad is 4.69 mm. The findings reveal that the effect of fine dust on water vapor retrieval is highly dependent on surface reflectance intensity. Fine particulate matter attenuates reflected solar radiation within atmospheric windows, reducing the radiance received by the satellite sensor. Additionally, aerosols scatter direct solar radiation towards the sensor, leading to an increase in the input signal. The net effect of aerosols varies based on surface brightness; over bright surfaces, aerosols reduce reflectance, whereas over darker surfaces, they enhance backscatter due to their scattering properties. Sensitivity analysis indicates that under high aerosol optical depths, TPW estimations from MODIS tend to be underestimated by 20–25%, especially in strong absorption bands (e.g., 0.94 µm). One of the major limitations of this retrieval method is the requirement for cloud-free, stable atmospheric conditions to minimize retrieval errors. The study underscores the necessity of incorporating aerosol correction algorithms into TPW retrieval models to improve the accuracy of satellite-based water vapor measurements. The research findings align with previous studies that highlight the significant role of aerosols in modifying atmospheric radiative transfer, affecting both hydrological cycle assessments and climate monitoring.

Conclusion: This study provides a valuable contribution to the field of atmospheric remote sensing by improving the understanding of aerosol interference in TPW retrieval. The results have important implications for climate researchers, meteorologists, and hydrologists involved in weather prediction and water resource planning. Future studies should explore advanced machine learning techniques for aerosol correction and integrate multi-sensor observations, such as GPS-based water vapor retrievals, to enhance TPW estimation accuracy.

Keywords: Total Precipitable Water, MODIS, Aerosols, Fine Dust Mehrabad