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Multi-observational Tropospheric Tomography and Its Application in Detecting Water Vapor Variability During Heavy Precipitation Event

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Water vapor plays a key role in various atmospheric processes such as cloud formation, hydrological and energy cycle, atmospheric chemistry and dynamics, and evolution of atmospheric storm systems. Heavy precipitation can cause flash flood and subsequently other natural disasters such as landslide, which is a serious threat to urban regions. Water vapor have a strong influence on the evolution of heavy precipitation events due to the huge latent heat associated with the phase change process of water. Accurate monitoring and observation of the water vapor distribution in the troposphere is thus essential in predicting the severity and lifecycle of heavy rain. Tomography is a very promising technique that is able to characterize spatial structure and temporal variation of the atmospheric water vapor.

In this study, we developed a tomographic method using water vapor data retrieved from multiple techniques which include GPS (Global Positioning System), radiosonde, WVR (Water Vapor Radiometer), NWP (Numerical Weather Prediction), AERONET (AErosol RObotic NETwork) sunphotometer and synoptic stations. With the use of water vapor measurements collected from May to September of 2013 at Hong Kong, we performed massive tests which showed the assimilation of multi-senor data can improve the tomographic solution. Comparisons of SWD (slant wet delay) measurements between GPS and multi-observational tomography showed that the RMS error of their differences is 10.85 mm. Multi-observational tomography achieved an accuracy of 7.13 mm/km when compared with radiosonde wet refractivity observations. The vertical layer tomographic modeling accuracy was also assessed using radiosonde water vapor profiles. An accuracy of 11.44 mm/km at the lowest layer (0 to 0.4 km) and an RMS error of 3.30 mm/km at the uppermost layer (7.5 km to 8.5 km) were yielded.

The solutions of multi-observational tomography are applied to investigate water vapor variations during heavy precipitation events. The wet refractivity field was constructed at a temporal resolution of 30 mins for three heavy precipitation events occurring in Hong Kong during 2010-2014. The variabilities of water vapor at five altitude layers (<1000 m, 1000∼2000 m, 2000∼3000 m, 3000∼5000 m, and >5000 m) were examined. It revealed that water vapor above 3000 m has larger fluctuation than that under 3000 m, though it accounts for only 10∼25% of the total amount of water vapor. The relative humidity fields derived from tomographic results revealed moisture variation, accumulation, saturation and condensation during the heavy rain events. The results positively demonstrated the potential of using water vapor tomographic technique in detecting and monitoring the evolution of heavy rain events.