Correlating the transport of precipitable water vapor with rainfall in a complex orographic environment before, during and after a typhoon: case study of Typhoon Morakot

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Introduction

August 7, 2009, Typhoon Morakot struck Taiwan producing 1,504 mm of rain in a 24-hour period, breaking Taiwan's 50 year record. In 96 hours rainfall accumulated to 2874 mm ranking second in the world's largest rainfall event. The flooding and landslides associated with Typhoon Morakot claimed more than 700 lives and caused an estimated $3.3 billion in damages. It is believed this rain event was sparked by the vertical lofting, due to orographic lift of unusually high precipitable water vapor (PWV) over the Central Mountain Region (CMR). This study is an comparative analysis the evolution of (PWV) and rainfall as Typhoon Morakot propagates over the CMR.

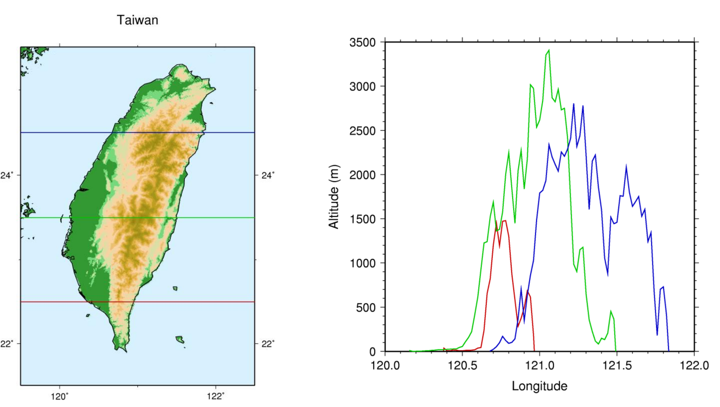

Figure 1. Color coded cross sections correspond of the xy graph on the right with altitude as a function of longitude

Methods

In situ PWV and rainfall observations were collected from the dense network of the Taiwanese Central Weather Bureau's 82 ground-based GPS stations and 450 rain gauges. The temporal resolution of the GPS stations is every 30 mins while rain gauge is for every hour and at a 0.02 degree spatial resolution. The observational data was compared with that of the Advanced Weather Research Forecast (WRF-ARW) model with temporal resolution of every 3 hours at a 4km spatial resolution. The analysis took place from August 6, 2009 0000 UTC through August 10, 2009 0000UTC.

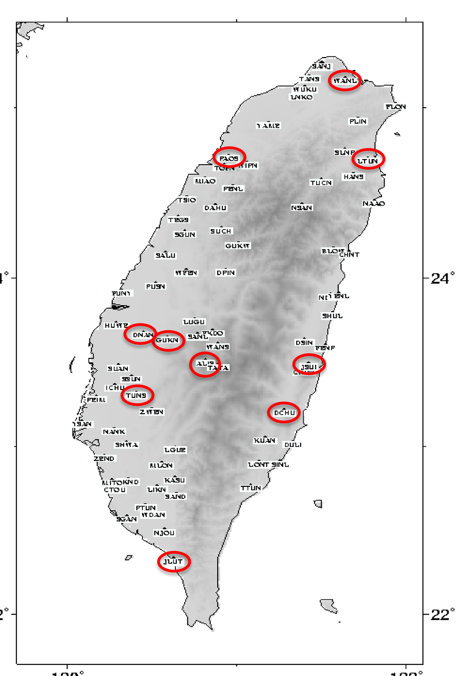

Figure 2. Is a shaded topographical map of Taiwan with four character abbreviations of the ground-base GPS station and location. Circles around the stations show the locations of stations selected to conduct a time series comparison of observed and modeled PWV and rainfall.

Results

- Before Typhoon Morakot above normal PWV was Maximum at PUSN 15.4 (mm) and Minimum at TATA 1.2 (mm)**(fig. 3a)**

- As Typhoon Morakot made landfall above normal PWV was Maximum at NJOU 33.1 (mm) and Minimum at TANS 16.4 (mm)**(fig. 3b)**

- When Typhoon Morakot began to dissipate over China Taiwan still experienced above normal PWV**(fig. 3c)** Maximum at ICHU 17.0 (mm) and Minimum at SINL 4.3 (mm)

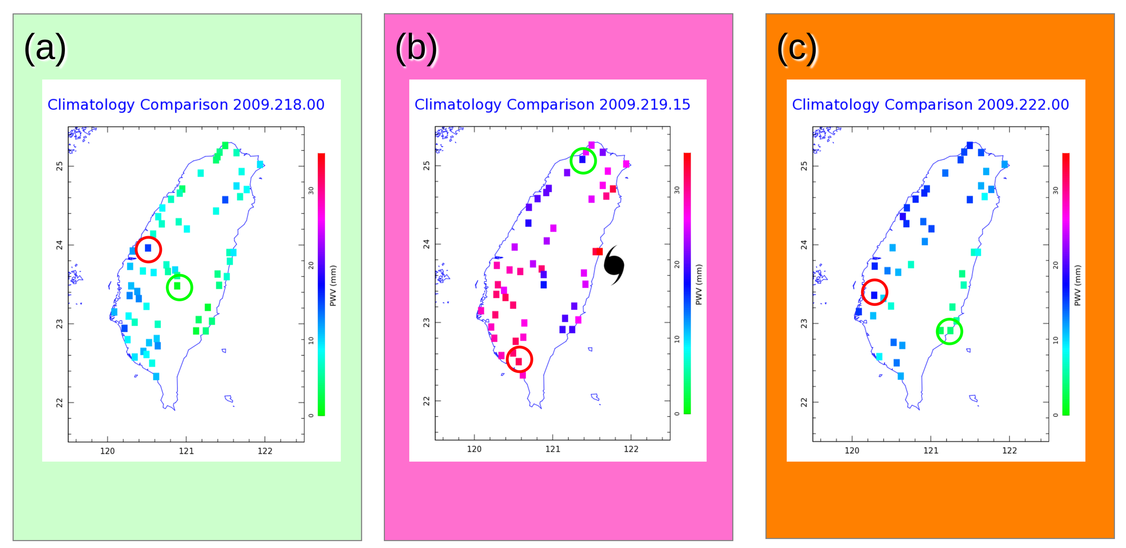

Figure 3. Figures 3 show the difference between the average PWV for August 2008 at each station. It is evident PWV is above normal from August 6, 2009 through August 10, 2009.

Terrain difference in Model for Taiwan

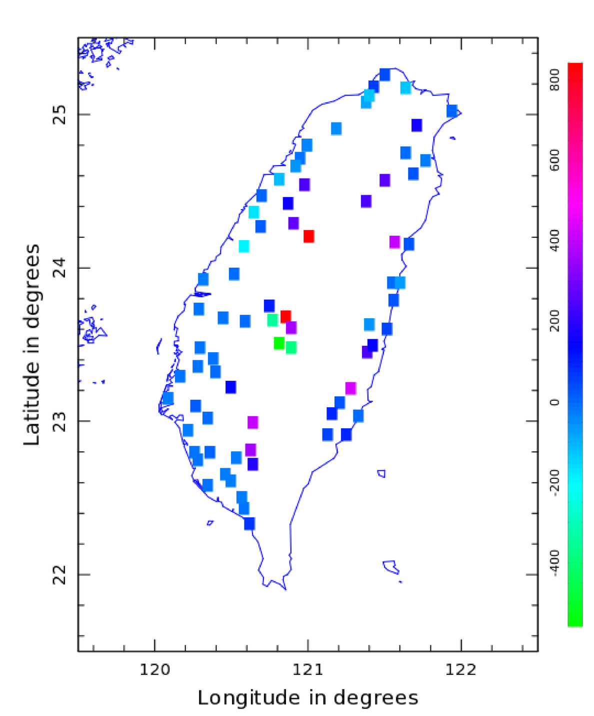

Figure 4. Shows the altitude difference between the observed ground-based GPS station and the WRF-ARW simulated altitude. Underestimates of altitude by the model are shown in green and overestimates are show in red.

How does PWV differ from the west and east coast?

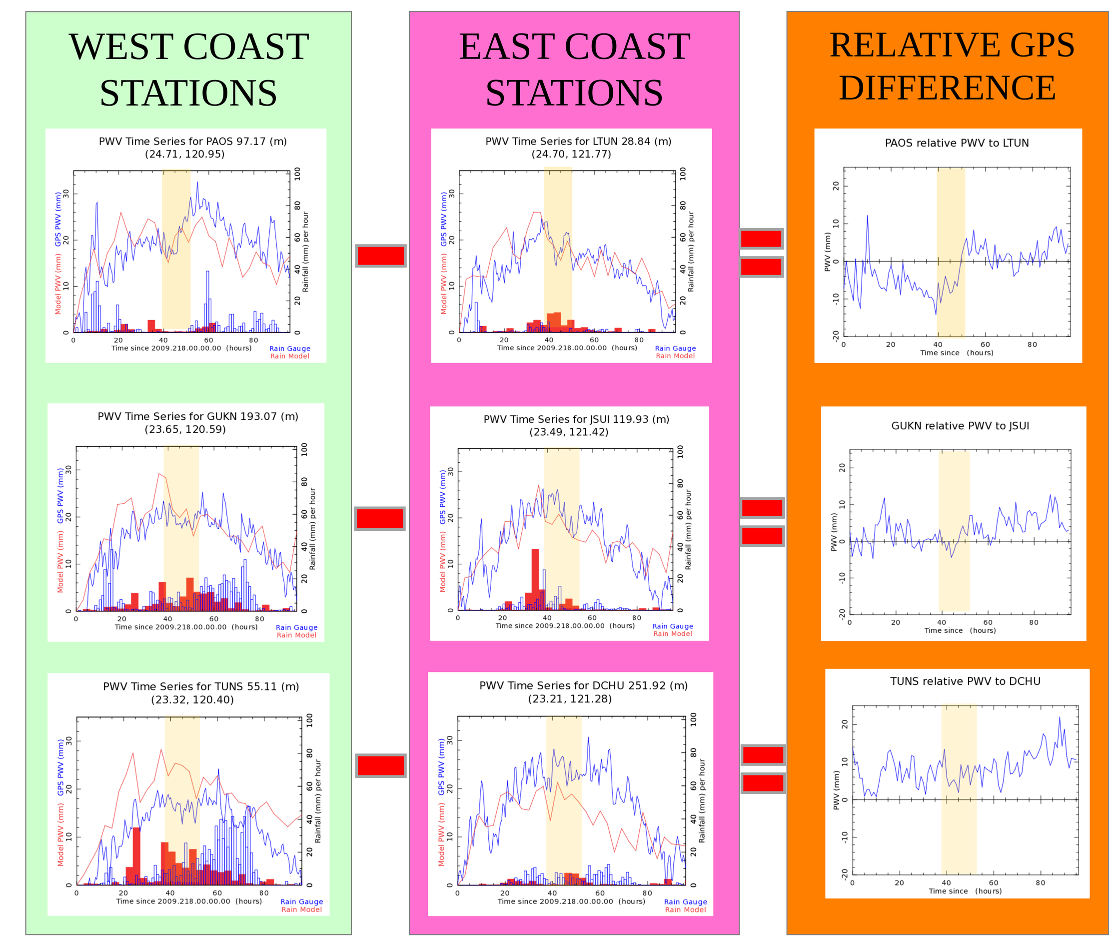

Figure 5. Figure 5 shows selected stations from the west and east coast of Taiwan as time series plots of rainfall and PWV from the WRF-ARW , rain gauges, and ground-based GPS observations. Figures in the orange box show the difference of the west and east coast PWV observed by the ground-based GPS from August 6, 2009 through August 10, 2009.

How is PWV transported around mountainous peaks?

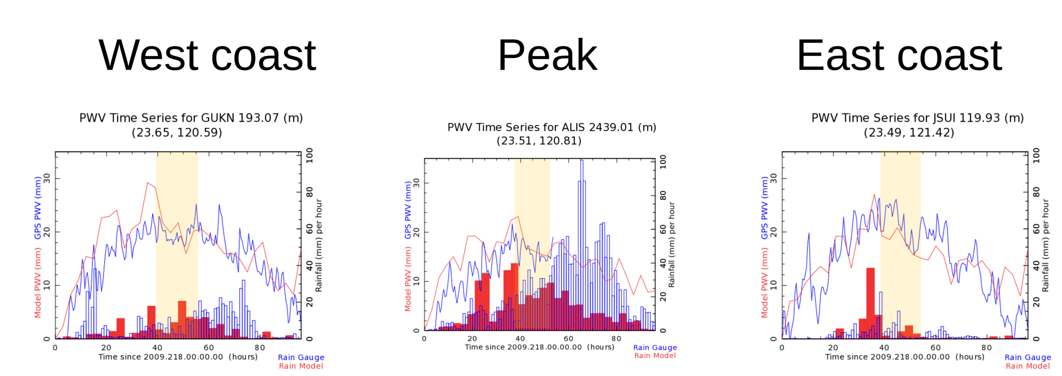

Figure 6. Shows time series comparison of rainfall and PWV simulations of the WRF-ARW and observations from ground-based GPS and rain gauges near the area of Taiwan where the most rainfall occurred

Conclusions

From our results we can conclude the circulation of Typhoon Morakot transported PWV in to localized areas diverted by the CMR. The WRF-ARW captured the evolution of PWV fairly well however did not have a good temporal and spatial resolution of rainfall. From these results we can conclude the WRF-ARW deterministic model run needs more modifications in the precipitation parameterization to produce reliable forecasts for significant weather events such as Typhoon Morakot. A full research on all 32 members of the WRF-ARW could help pin-point which modification would fair well for the island of Taiwan

Figure 7. Aftermath of Typhoon Morakot

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