The Influence of Microphysical Processes in Extreme Rain Events Found in Complex Terrain

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Introduction

- Extreme rainfall near complex terrain has major societal impacts yet is difficult to predict. A better understanding of heavy rainfall ingredients, including microphysical processes, and their modification by mountainous terrain is needed.
- The mountainous island of Taiwan frequently experiences heavy rainfall, including from the quasi-stationary Mei-Yu front, tropical cyclones, and southwesterly monsoonal flow impinging on the terrain
- This study will analyze the 1-3 June 2017 Mei-Yu heavy rain event. In some mountainous areas, 3-day rainfall totals exceeded 1500 mm (Fig. 1) with over 600 mm falling in 12 h over Taipei basin leading to major flooding.

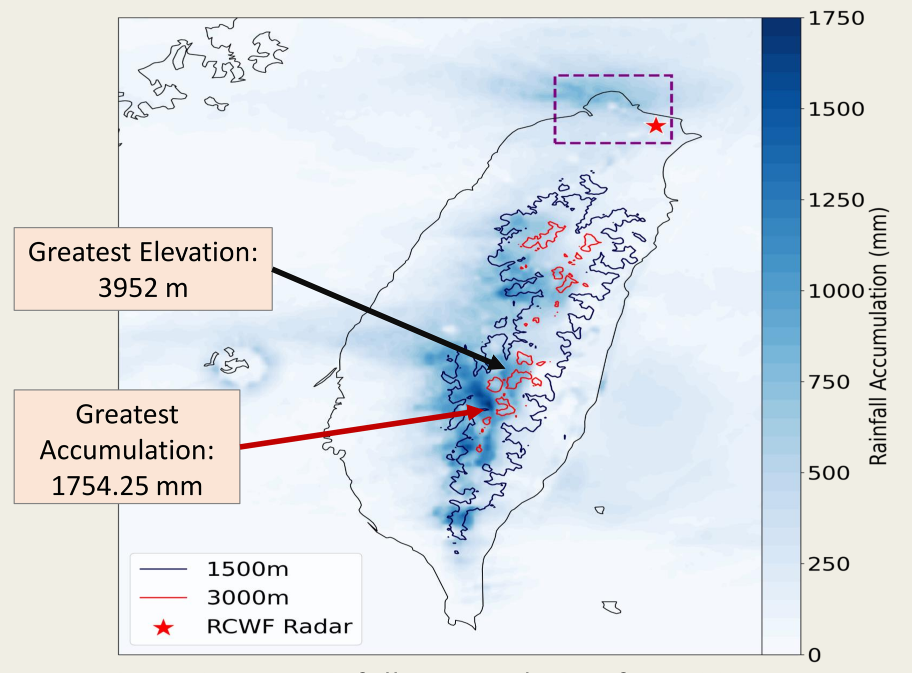


Fig. 1: 3-Day Rainfall Accumulation from 00Z 1 June 2017 to 00Z 4 June 2017 in filled contours. Elevation is shown with unfilled contours. Region of focus is highlighted with dashed line

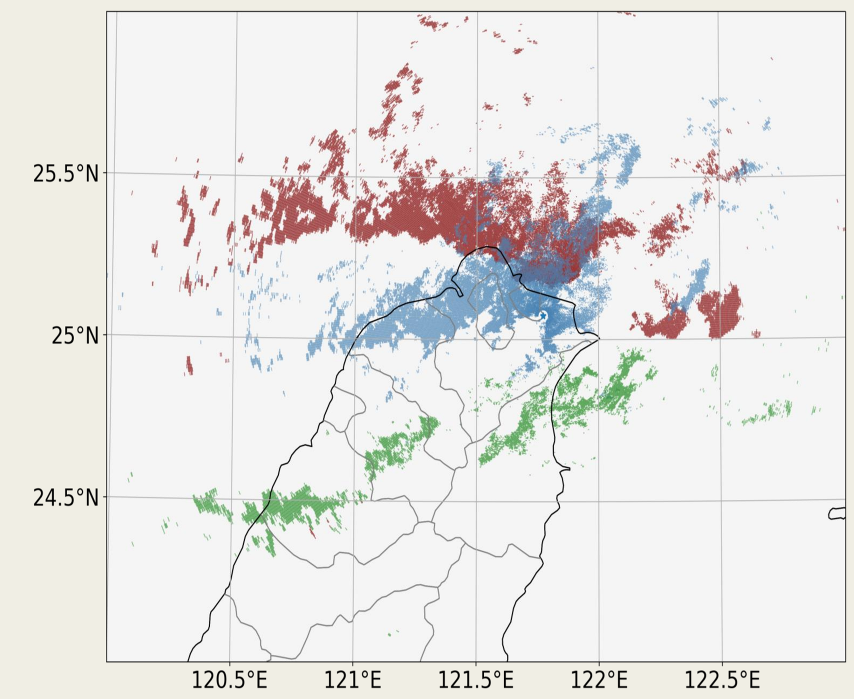
Questions

How does **terrain elevation** affect the **intensity** and **duration** of extreme rainfall events?

Do the **microphysics** associated with rainfall change relative to terrain gradient (**slope**)?

Data

- The following datasets from Taiwan's Central Weather Bureau (CWB) are used for this analysis:
  - S-band Dual-Polarization RCWF Doppler Radar located on the northern coast of Taiwan part of the CWB operational network (121.77°E, 25.07°N, 766m asl). Intense radar echo can be tracked in Fig. 2. Data was processed with the Python ARM Radar Toolkit[1] and Lidar Radar Open Software Environment[2].
  - Hourly Quantitative Precipitation Estimate and Elevation products from the Quantitative Precipitation Estimation and Segregation Using Multiple Sensors (QPESUMS). Spatial Resolution for QPESUMS is 0.0125° x 0.0125°. The accumulations used in Fig. 1 are from QPESUMS.



Red: 00Z 2 June 2017
Blue: 03Z 2 June 2017
Green: 06Z 2 June 2017

Fig. 2: RCWF radar reflectivity > 40 dBZ for three times (color shading)

How does intensity and duration vary with elevation?

- Every QPESUMS grid point during the 3-day event was grouped into 500-m elevation bins. Each hour with nonzero accumulation counted towards noncontiguous duration and the total accumulation was divided by this value to get the average rain rate.
- Fig. 3a shows a higher frequency of medium duration rainfall with varying intensity at low elevations (0-0.5 km). A shift toward longer duration, high intensity rainfall is observed for higher elevations (1.5-2 km; Fig 3b).

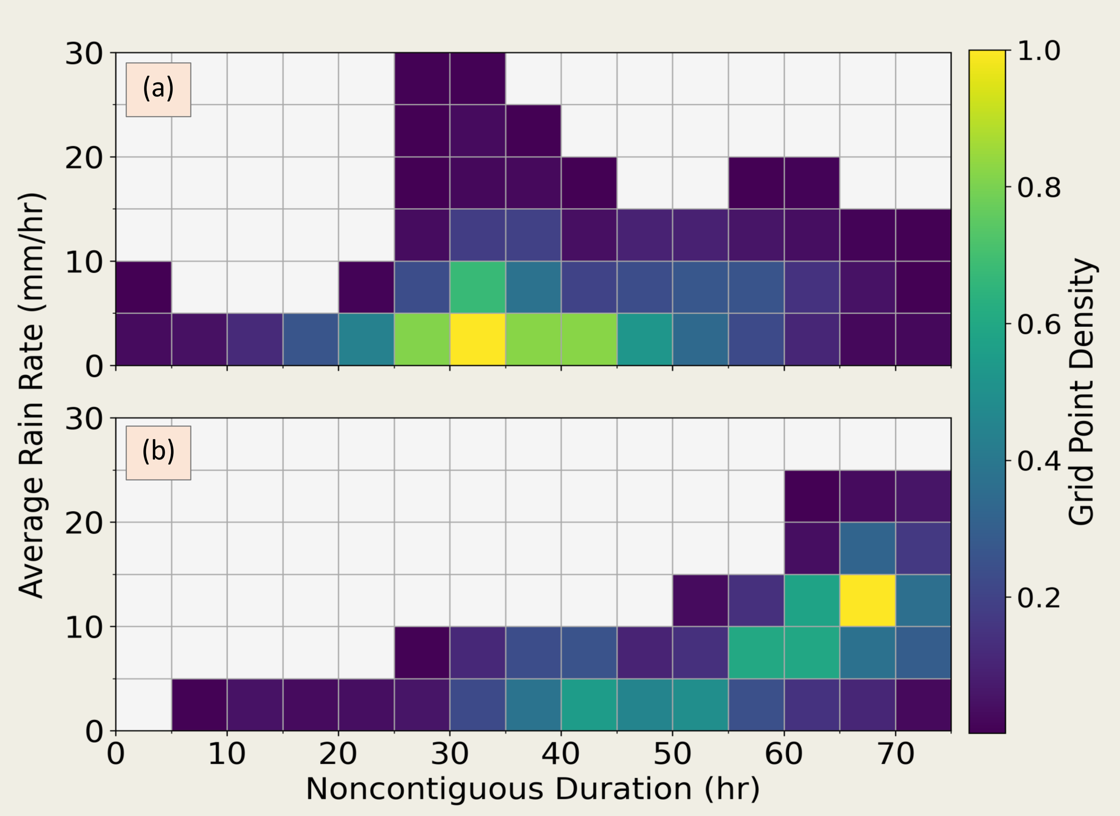


Fig. 3: Normalized Density Heatmap of Noncontiguous Duration and Average Rain Rate for grid points with elevation between (a) ***0 – 500 m*** *(10225 Grid Points) and (b)* ***1500 m – 2000 m*** *(1958 Grid Points)*

How does microphysics change with slope?

- The mountainous northern coast was segmented into "Coastal", "Upslope", "Peak", and "Downslope" regions for the 00-06 UTC 2 June 2017 period when the Mei-Yu moved southward over the mountainous northern coast near the Taipei basin (Fig. 4). During that period, median reflectivity and differential reflectivity are taken and plotted as a joint PDF with respect to time (Fig. 5).
- Median Z/ZDR dropped below the Tropical Reference curve[3] as the Mei-Yu entered each region. Z/ZDR values below the curve indicate smaller and more numerous drops relative to values found in Florida.

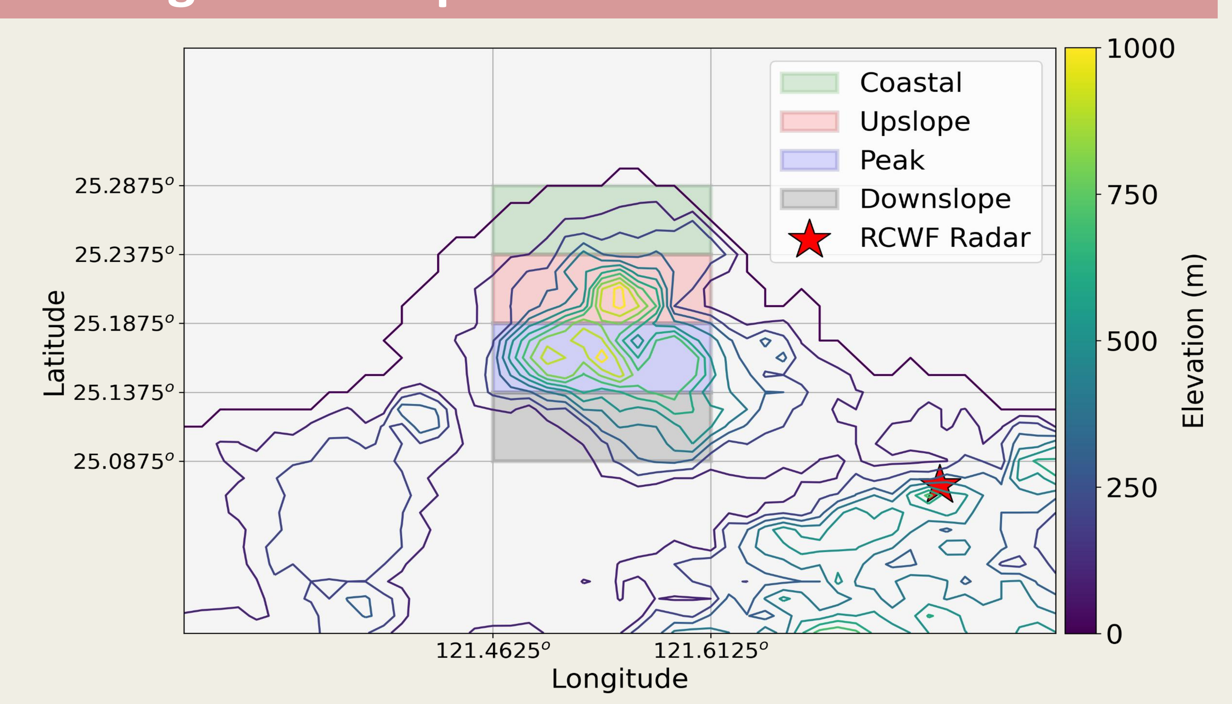


Fig. 4: Northern Coast of Taiwan (box in Fig.1) with Regions of Interest in filled contours and elevation in unfilled contours

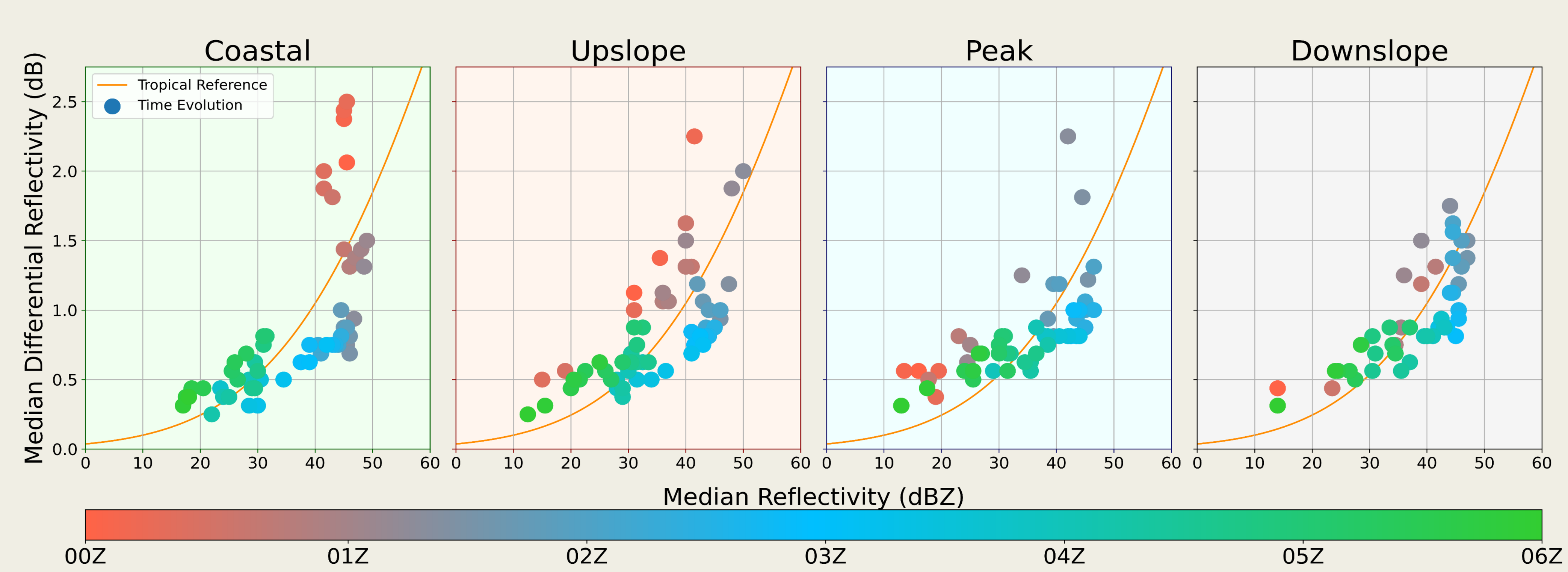


Fig. 5: Time Evolution of mean Z/ZDR for the Regions of Interest. A Tropical Reference curve is added to each.

Discussion and Future Work

- **Higher elevations** experience a greater frequency of **long duration** rain fall. Intensity increases with elevation, although our method will be refined to include intense short-duration contiguous rainfall.
- Each elevation region of interest experiences a similar Z/ZDR time evolution. In the most **intensive periods** where the Mei-Yu is overhead, **Z/ZDR values lie below the tropical reference curve**. With greater amounts of smaller drops, this could be indicative of **enhanced drop break up**.
- Future work will shift toward the southern regions of Taiwan where terrain is steeper than the northern coast and rainfall reached higher durations and intensities. Radar data will also undergo quality control procedures to reduce suspicious data and will later introduce other dual-polarization variables such as KDP.
- This research will also expand to additional cases, including those collected during **PRECIP 2022** in Taiwan to better understand the modification of heavy rain ingredients due to terrain.

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