Examining the Relationships Between Dynamics, Microphysics, and Rainfall Intensity in a Mei-Yu Front during PRECIP 2022

Sam Irvine[1], Jen DeHart[2], Tyler Barbero[2], Angelie Nieves-Jiménez[2], and Michael Bell[2]

[1]Georgia Institute of Technology, [2]Colorado State University, Department of Atmospheric Science

Introduction

- Extreme rainfall can quickly lead to dangerous flash floods, yet our understanding of its formation, and hence our forecasting skill are limited.
- During the spring and summer, Taiwan experiences heavy rainfall from the Mei-Yu front = a nearly stationary front that forms where warm, southwesterly air meets cool, dry northeasterly air.
- Prediction of Rainfall Extremes Campaign in the Pacific (PRECIP) sought to understand the kinematic, thermodynamic, and microphysical properties of extreme precipitation in a moisture rich region.
- Past studies have found mixed results on the importance of warm rain and ice phase processes in extreme rainfall (Yang et al., 2011; Zagrodnik et al., 2018).

Hypothesis

Collision-coalescence and accretion processes are important in **high intensity** precipitation while vapor deposition and ice aggregation are important in **low intensity** precipitation.

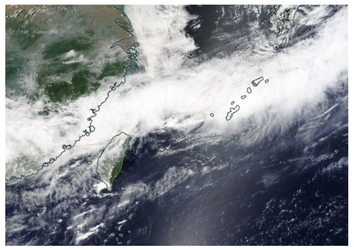


Figure 1. The Mei-Yu front located north of Taiwan on June 6, 2022. Source: NASA Worldview



Figure 2. The SPOL radar in use during the campaign.

Credit: Angelie Nieves-Jiménez

Methods

- Data Period: 06-12 UTC on 6/6/2022
- 3-D gridded kinematic, polarimetric fields created from S-Pol and 5 PRECIP radars using SAMURAI (Bell et al., 2012; Cha and Bell, 2023) and Radx2Grid (DeHart et al., 2024)
- Case Studies: subjectively identified heavy and light rainfall regions based on radar structure, created gridded kinematic cross-sections and selected nearby S-Pol RHIs
- Selected grid points from the 6-hour period at 1.5 km altitude (land and unrealistic data removed), sorted them into low and high rain rate categories, and calculated mean vertical profiles of polarimetric and kinematic variables
- Polarimetric and kinematic variables enable identification of microphysical processes and hydrometeor type

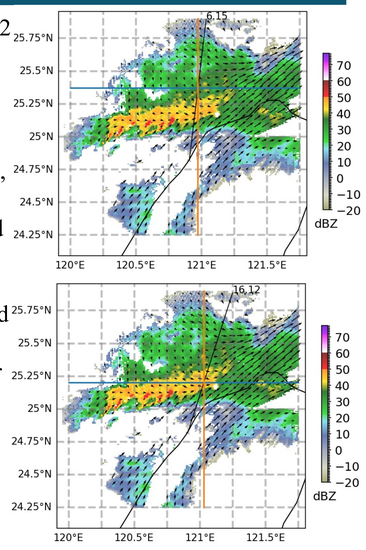


Figure 3. Stratiform (top) and convective (bottom) regions selected for analysis. Black line indicates the RHI scan and the intersection of orange and blue lines indicates the point that corresponds to the arrow in the RHI scans.

Results

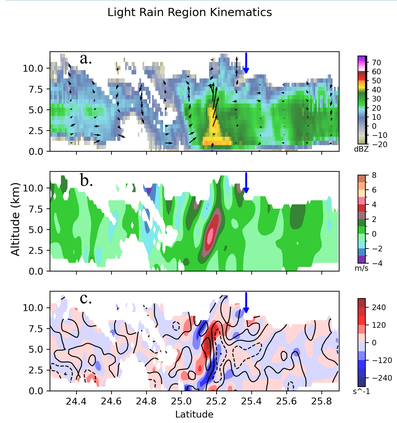


Figure 4. Vertical cross-section (SAMURAI) of the stratiform region with plots of (a) reflectivity and wind direction, (b) vertical velocity, and (c) divergence with vorticity contours where solid lines are positive and dashed lines are negative. Cross-section was taken from the orange line shown in Figure 3.

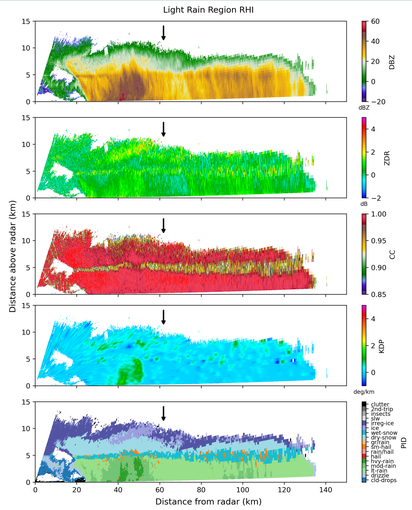


Figure 5. RHI scan (SPOL) of stratiform region featuring reflectivity, differential reflectivity, correlation coefficient, specific differential phase, and particle identification.

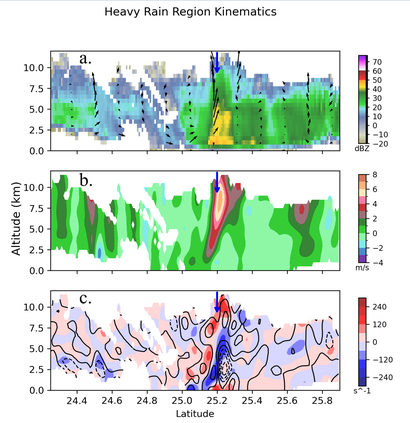


Figure 6 (above). Same as Figure 4 but for the convective region.

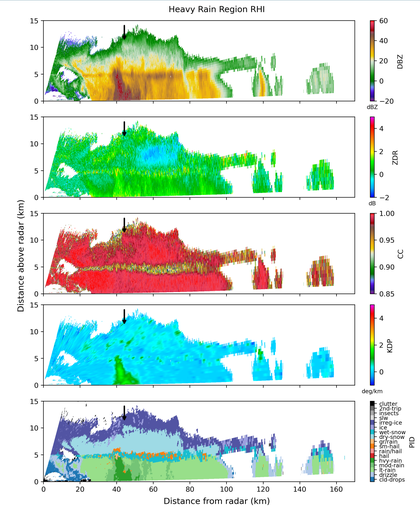


Figure 7 (right). Same as Figure 5 but for the convective region.

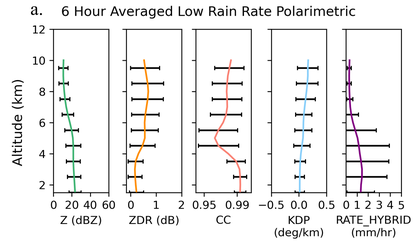


Figure 8. Low rain rate plots include all the points found at 1.5 km altitude during the 6-hour period where RATE_HYBRID was less than 5 mm/hr. (a) Averaged vertical profiles of the polarimetric variables listed, (b) averaged vertical profiles of the kinematic variables listed, and (c) a frequency histogram of the particle identification (NCAR PID) categories.

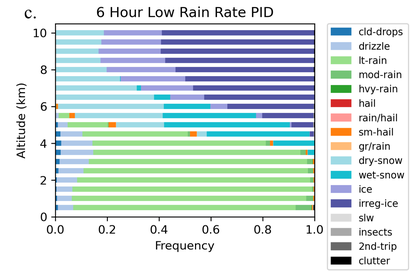


Figure 9. Same as Figure 8, but for high rain rate grid points (i.e., grid points where RATE_HYBRID was 50 mm/hr or higher).

Discussion

Convective Region

- Rain intensifies primarily through collision-coalescence
  - Below 5 km, Z, ZDR, and KDP increase down to the surface
- Strong updrafts around melting layer (ML) produce supercooled water droplets above ML, causing accretion
  - Increase in Z down to the ML
- PID confirms accretion process through presence of hail/graupel categories
  - Ice aggregation may also be a factor (but a minor one)

Stratiform Region

- Less intense rain formed primarily by melting snow that breaks up below ML
  - Z remains constant, ZDR and KDP decrease down to the surface
- Low vertical velocity provides weak support for low-level cloud water production
  - Z increases, ZDR decreases above ML due to ice aggregation and melting

- In this mei-yu front, convection is embedded within stratiform rain, they are not entirely separate

Conclusions

- Precipitation processes are complex, and many can occur at once, but collision-coalescence is critical for heavy rainfall in the mei-yu front.
- Microphysical processes show a relationship with the dynamics, where a slanted updraft and convergence enhances collision-coalescence in convective, and a lack of dynamical support in stratiform allows ice-phase microphysics to control precipitation.
- More regions will need to be evaluated in the future to understand the complexity of these intensity-microphysical relationships.

References

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Acknowledgements

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