Raindrop Size Distribution Characteristics of Summer and Winter Season Rainfall Over North Taiwan

Balaji Kumar Seela
Taiwan International Graduate Program (TIGP) Earth System Science (ESS) Program
Research Center for Environmental Changes (RCEC), Academia Sinica, Taiwan
Institute of Atmospheric Science, National Central University, Jhongli City, Taiwan

Seela, B. K., Janapati, J., ***Lin, P.-L.,Wang, P. K.,*** & Lee, M.-T. (2018). Raindrop size distribution characteristics of summer and winter season rainfall over north Taiwan. Journal of Geophysical Research: Atmospheres, 123. https://doi.org/10.1029/2018JD028307.

Data and methodology:

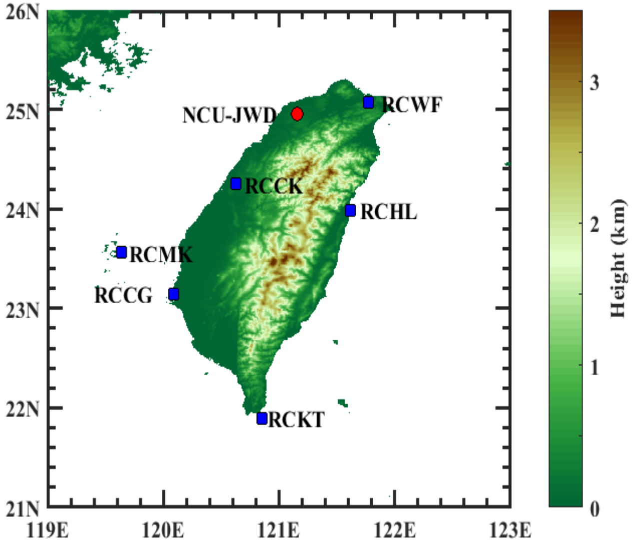


Fig. Geographical location of Taiwan. The red colored circle represents the location of national central university disdrometer (NCU-JWD), and the locations of radar sites are represented with blue color squares.

Joss-Waldvogel Disdrometer (JWD)

JWD @ NCU, Taiwan

(24° 58' N, 121° 10' E)

Data :

Summer (16 June -31 August) : (2002-2016, excl. 2003,2008,2009)

Winter (December-February) : (2002-2016, excl. 2003)

- RSD from Joss-Waldvogel disdrometer (JWD)
- JWD collocated AWS rainfall
- Z – mosaic from 6 radar from CWB
- Convective Available Potential Energy from ERA-Interim
- Storm and bright band heights from TRMM 2A23 product
- Cloud effective radii from MODIS

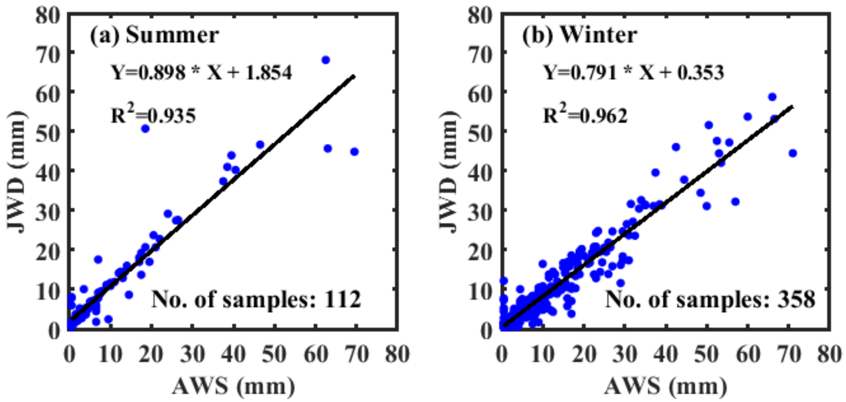


Fig. Scatter plot between daily accumulated rainfall of Joss–Waldvogel Disdrometer (JWD) and the collocated tipping bucket rain gauge of the automatic weather station (AWS)..

Data and methodology:

The rain drop concentration N(D) (m^{-3} mm^{-1}) at an instant of time from the JWD are obtained from the following equation,

$$N(D_i) = \sum_{j=1}^{20} \frac{n_{ij}}{A \Delta t v_j \Delta D_i}$$

where

n_{ij} is the number of drops reckoned in the size bin i and velocity bin j,
A (m^2) and Δt are the sampling area and time,
D_i (mm) is the drop diameter for the size bin i and
ΔD_i is the corresponding diameter interval (mm),
V_j (m/s) is the fall speed for the velocity bin j.

Joss-Waldvogel Disdrometer (JWD)

Radar Reflectivity (dBZ) $$Z = \int_0^\infty N(D) D^6 dD$$

Rain Rate (mm/h) $$RR = \frac{\pi}{6} \int_0^\infty N(D) D^3 v(D) dD$$

Liquid Water content (kg/m³) $$LWC = \rho_w \frac{\pi}{6} \int_0^\infty N(D) D^3 dD$$

Where N(D) is drop concentration, D drop diameter, v(D) terminal fall velocity, ρ_w is the water density

Data and methodology:

In the present study the gamma parameters (D_m, μ, Λ & N_w) defined by **Ulbrich, (1983)** are used to study the RSD characteristics:

$N(D) = N_o D^{\mu} \exp(-\Lambda D)$

D_m-Mass weighted mean diameter

$$D_m = \frac{M_4}{M_3} \qquad M_n = \int_{D_{min}}^{D_{max}} D^n N(D) dD$$

μ - Shape parameter

$$\mu = \frac{(11G - 8) + \sqrt{G(G+8)}}{2(1-G)} \qquad G = \frac{M_4^3}{M_3^2 \; M_6}$$

Λ- Slope parameter

$$\Lambda = \frac{(\mu + 4) M_3}{M_4}$$

N_w-Normalized intercept parameter

$$N_w = \frac{4^4}{\pi \rho_w} \left(\frac{10^3 W}{D_m^4} \right)$$

Bringi et al., (2003)

W- liquid water content

The normalized intercept parameter N_w, represents N(D) when D approaches to its minimum value.

The shape parameter(μ) describes the breadth of the RSD
concave downward (μ>0), upward (μ<0), or exponential (μ = 0) shape

The slope parameter (Λ) characterizes RSD tail extension along Drop diameter
small (large) Λ indicates an extension of the RSD tail to larger (smaller) D.

Results:

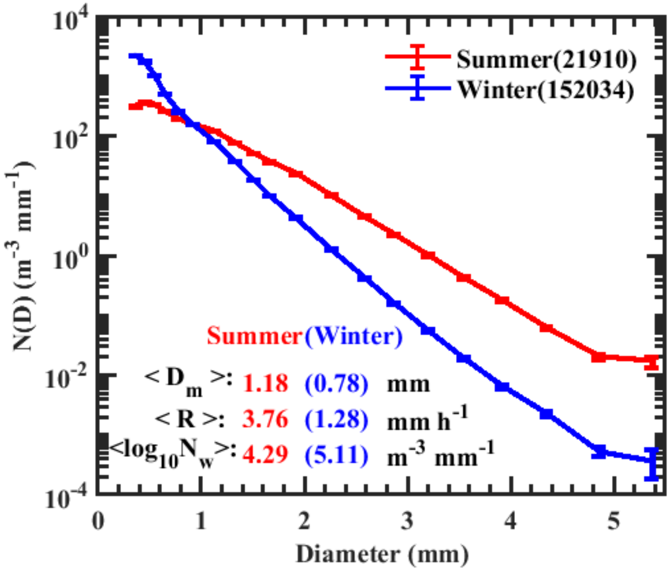


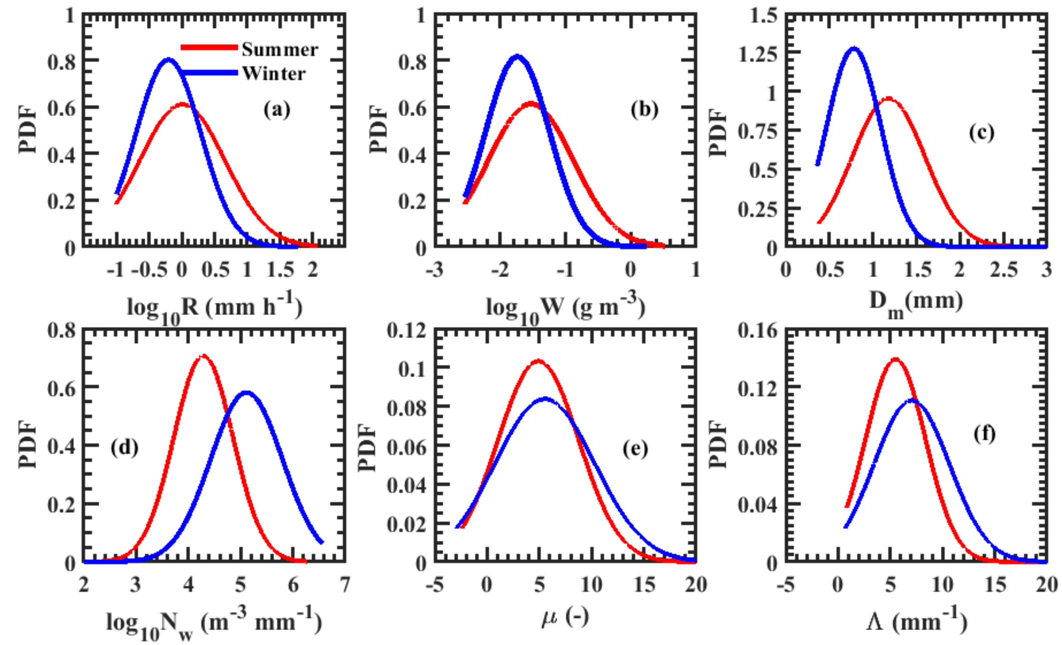
Fig. Variation of mean raindrop concentration, N(D) (m^{-3} mm^{-1}) with drop diameter, D (mm) for summer and winter rainfall.

D (mm) < 1 mm -Small size drops

1 ≤ D (mm) ≤ 3 mm - Mid size drops

D (mm) > 3 mm - Large size drops

Fig. The probability distribution functions (PDF) of (a) rain rate, $log_{10}R$ (mm h^{-1}), (b) liquid water content, $log_{10}LWC$ (g m^{-3}), (c) mass-weighted mean diameter, D_m (mm), (d) normalized intercept parameter, $log_{10}N_w$ (m^{-3} mm^{-1}), (e) shape parameter, μ (-), and (f) slope parameter, Λ (mm^{-1}) for summer and winter rainfall



Results: RSD variation in different rain rate classes:

$$\delta(D, R_{Ck})_{summer} = \frac{[N(D)_{summer}]_{Ck}}{([N(D)_{summer}]_{Ck} + [N(D)_{winter}]_{Ck})} \times 100$$

$$\delta(D, R_{Ck})_{winter} = \frac{[N(D)_{winter}]_{Ck}}{([N(D)_{summer}]_{Ck} + [N(D)_{winter}]_{Ck})} \times 100$$

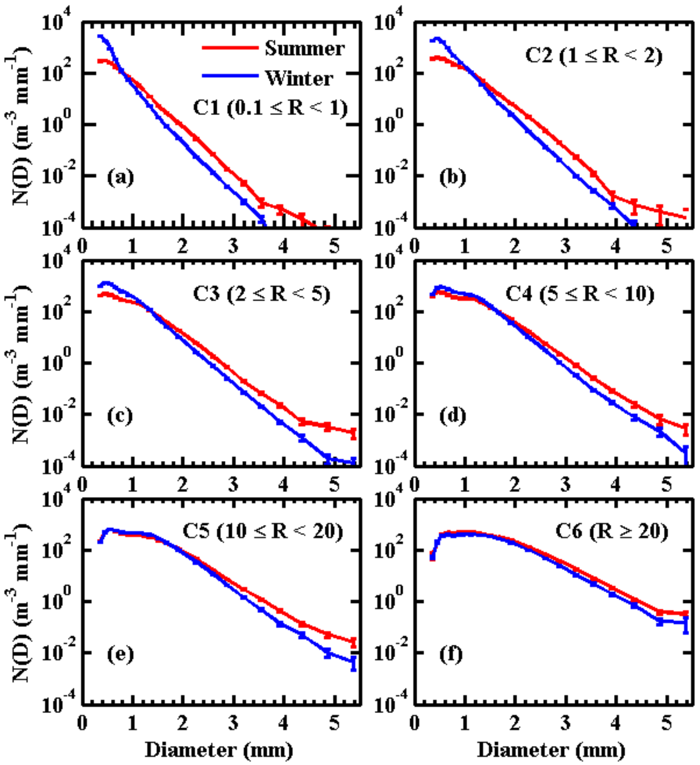


Fig. Average raindrop spectra for winter (blue color) and summer (red color) rainfall in six rain rate (R) classes (C1:0.1-1, C2:1:2, C3:2:5, C4:5-10, C5:10-20, C6: > 20 mm h^{-1}).

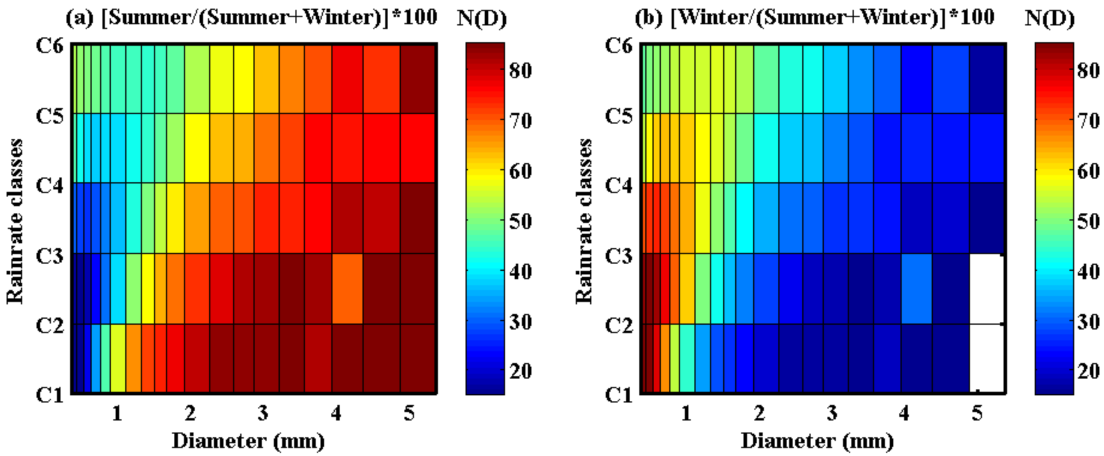


Fig. Percentage parameter, δ(D, R) for (a) summer and (b) winter rainfall.

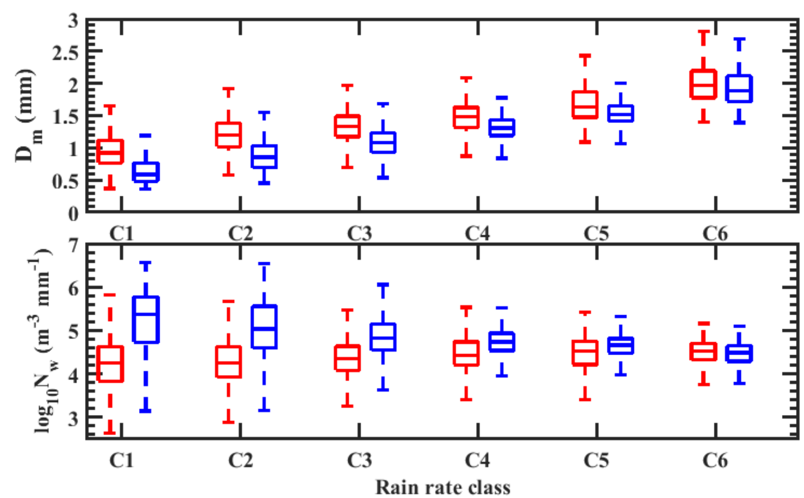


Fig. Variation of mass weighted mean diameter, D_m (mm) and normalized intercept parameter, $\log_{10}N_w$ ($m^{-3}\,mm^{-1}$) in six rain rate classes of summer (red color) and winter (blue color) rainfall. The center line of the box indicates the median, and the bottom and top lines of the box indicate the 25th and 75th percentiles, respectively. The bottom and top of the dashed vertical lines indicate the 5th and 95th percentiles, respectively.

Results: Diurnal variation of RSD:

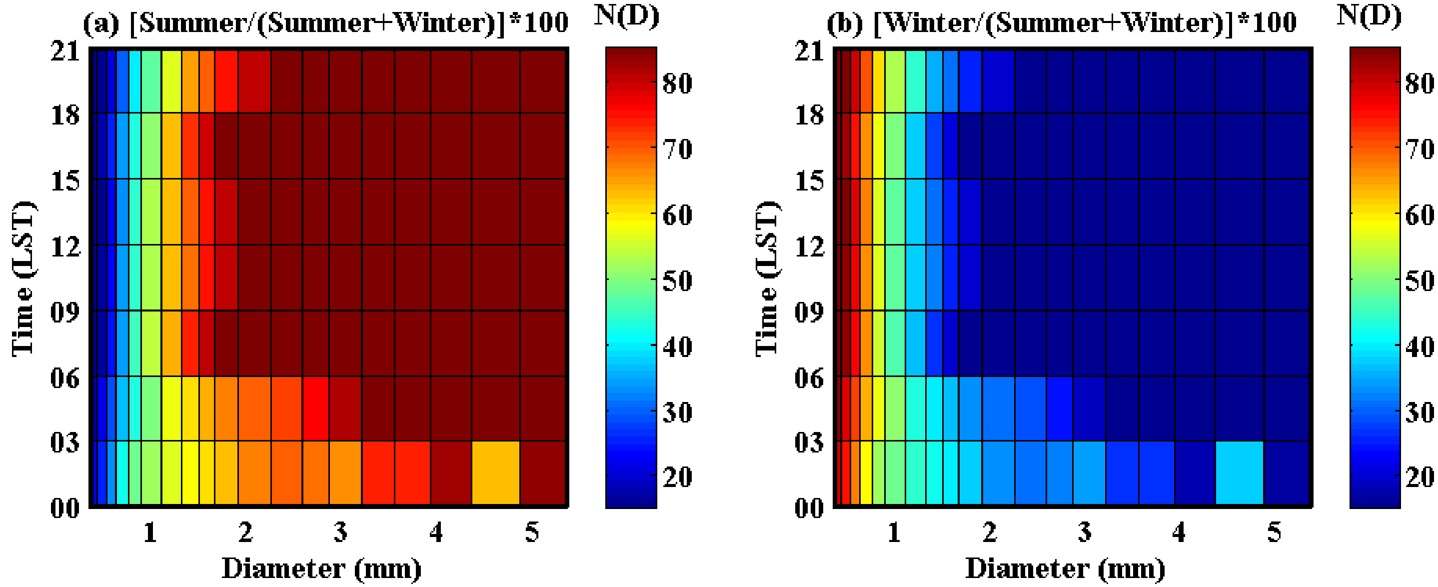


Fig. three hourly percentage parameter, δ(D,T) for (a) summer and (b) winter rainfall.

$$\delta(D, T_h)_{summer} = \frac{[N(D)_{summer}]_h}{([N(D)_{summer}]_h + [N(D)_{winter}]_h)} \times 100$$

$$\delta(D, T_h)_{winter} = \frac{[N(D)_{winter}]_h}{([N(D)_{summer}]_h + [N(D)_{winter}]_h)} \times 100$$

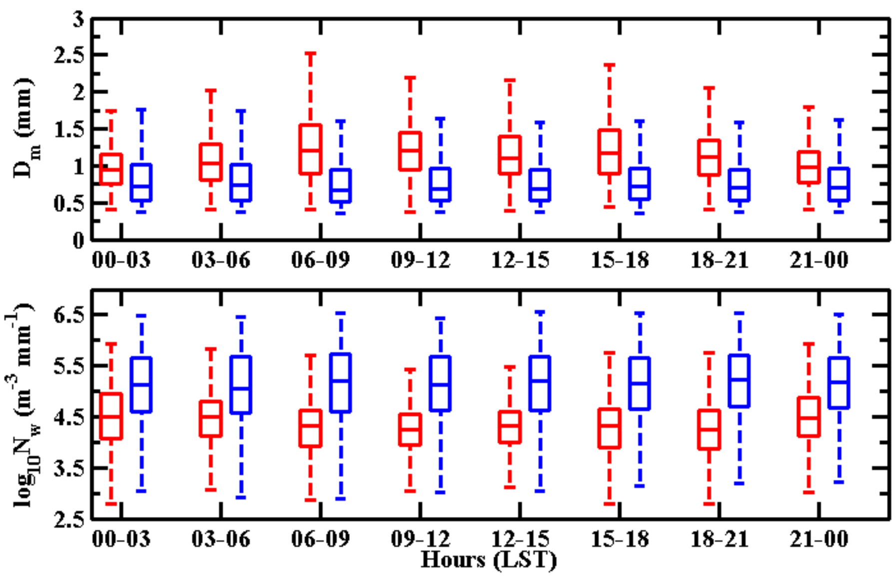


Fig. Three hourly variation of mass weighted mean diameter, D_m (mm) and normalized intercept parameter, $\log_{10}N_w$ (m^{-3} mm^{-1}) in summer (red color) and winter (blue color) rainfall. Three hourly observations represented in above plot are in local time (UTC+8 hr).

Results: Stratiform and convective RSD *Bringi et al*. [2003].

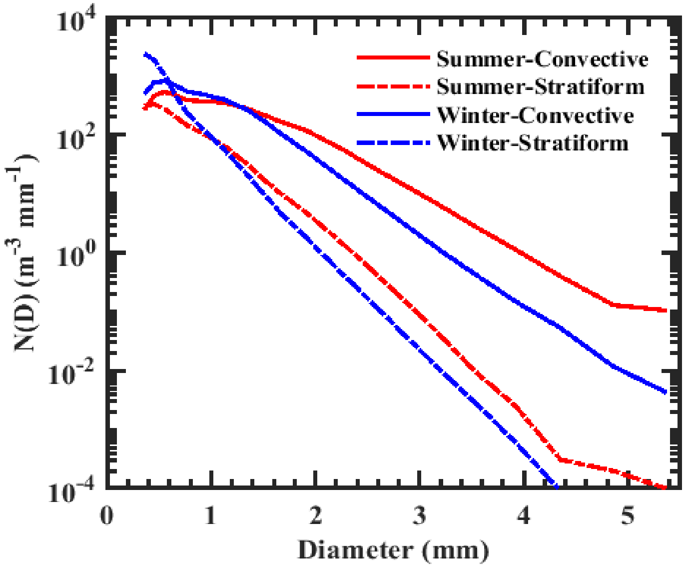


Fig. Mean raindrop concentration in stratiform and convective regimes of summer and winter rainfall.

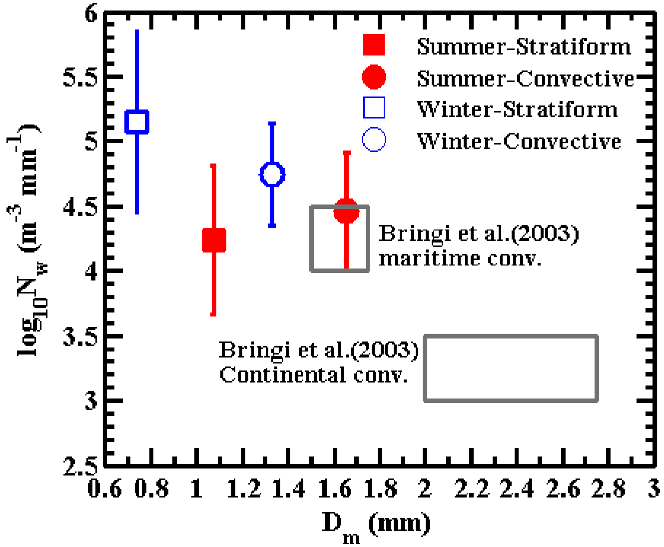


Fig. Variation of normalized intercept parameter, $\log_{10}N_w$ ($m^{-3}\ mm^{-1}$) with mass weighted mean diameter, D_m (mm) in stratiform and convective regimes of summer and winter rainfall.

Z-R and and μ-Λ relations:

Precipitation type	Summer	Winter
Stratiform	$Z = 276.13\ R^{1.41}$	$Z = 127.67\ R^{1.54}$
Convective	$Z = 237.88\ R^{1.41}$	$Z = 142.94\ R^{1.52}$
Total	$Z = 266.42\ R^{1.38}$	$Z = 129.76\ R^{1.55}$

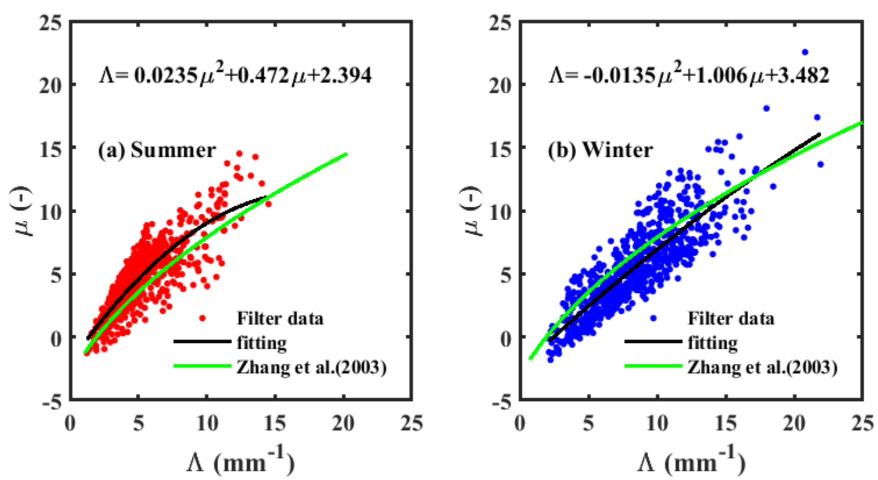


Fig. Scatterplots of μ versus Λ for (a) summer and (b) winter rainfall of north Taiwan.

Discussion:

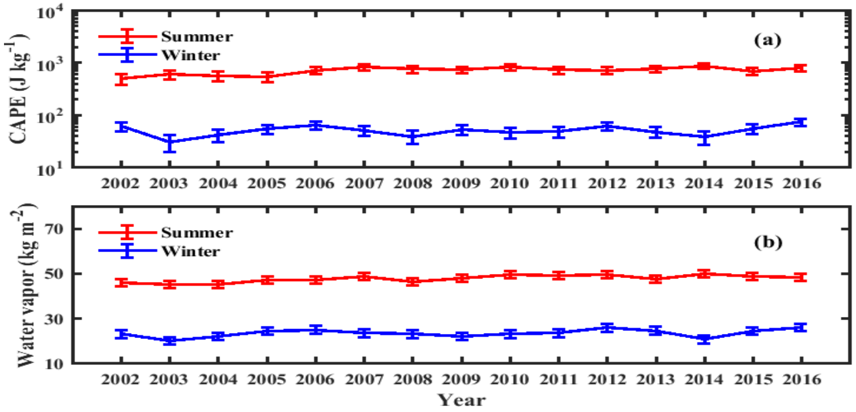


Fig. Annual variations in monthly mean of (a) Convective available potential energy (CAPE, J/kg) and (b) vertical integral water vapor (kg/m^2) obtained from ERA-Interim for summer and winter seasons

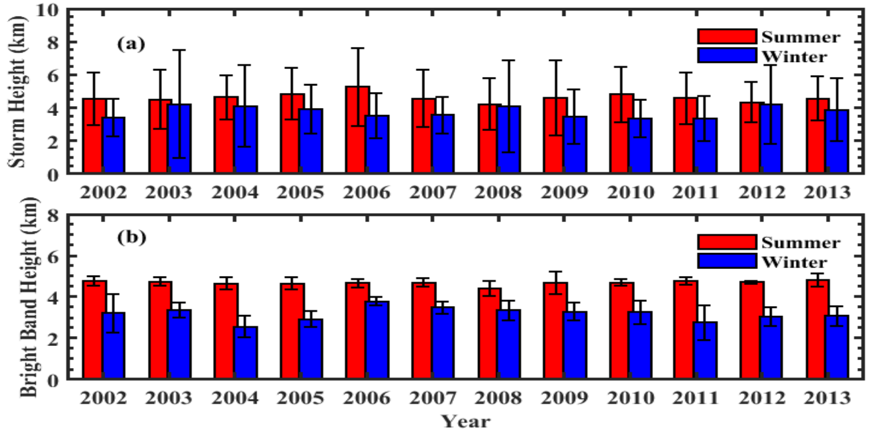


Fig. Annual variation of (a) mean storm top height, and (b) bright band height (BBH) during summer and winter seasons obtained from TRMM PR 2A23 product.

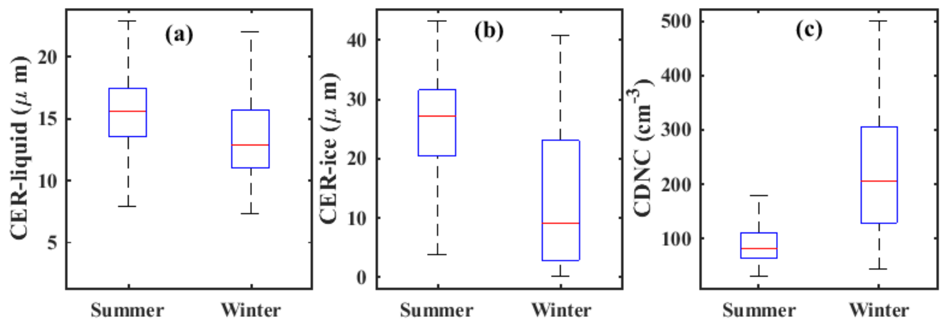


Fig. cloud effective radii (CER, μm) values of (a) liquid, (b) ice particles, and (c) cloud droplet number concentration (CDNC, cm^{-3}) for summer and winter seasons.

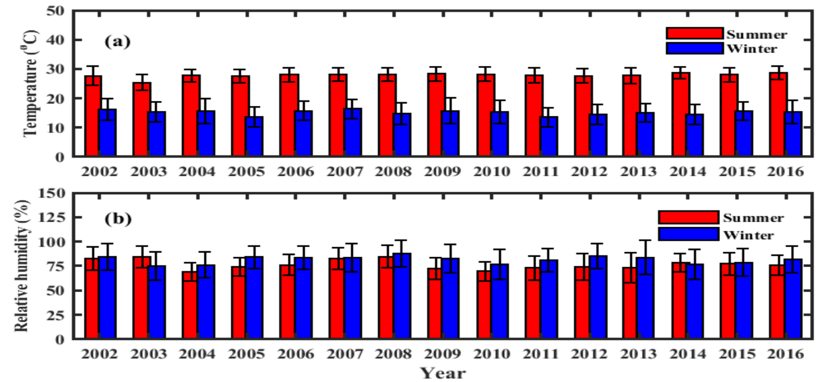


Fig. Annual variations of ground (a) temperature and (b) relative humidity over NCU

Discussion:

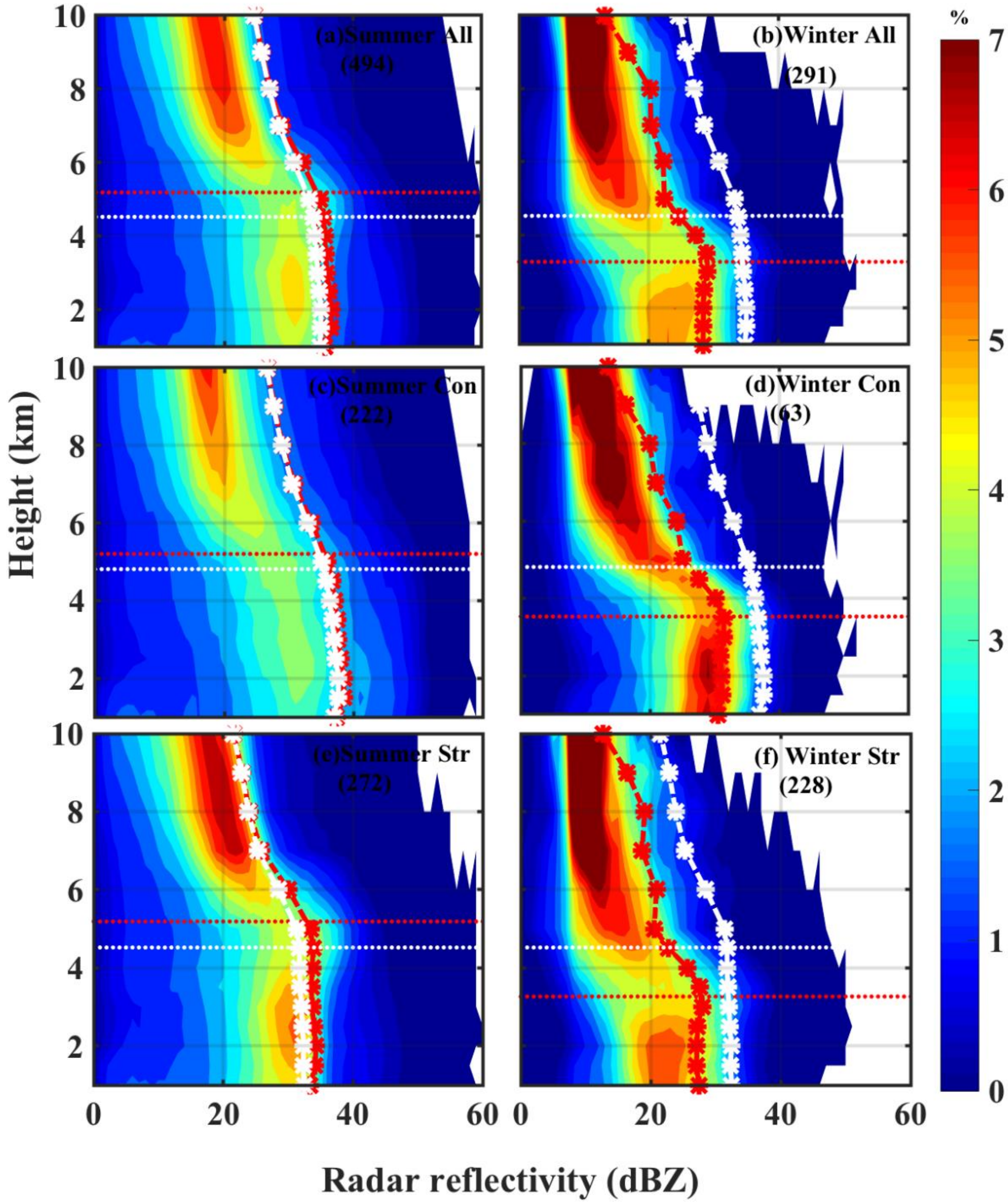


Fig. Contoured frequency-by-altitude diagram of radar reflectivity from six ground-based radars for (a) summer, (b) winter, (c) summer convective, (d) winter convective, (e) summer stratiform, and (f) winter stratiform rainfall

Summary:

- No. of small drops ➔ Winter > Summer
- No. of large drops ➔ Summer > Winter
- PDF distribution of RSD parameters ➔ Summer ≠ Winter
- Mass weighted mean diameter (D_m) ➔ Summer > Winter
- Slope (λ), shape (μ), normalized intercept parameter (N_w) ➔ Palau > Taiwan
- Raindrop concentration ➔ convective > stratiform (in Summer & Winter)
- No. of small drops ➔ Winter > Summer (for both stratiform and convective rainfall)
- Clear variations in Z-R relations between Summer and Winter rainfall.
- Deeply extended clouds in summer (with cold rain process) and shallow clouds in winter (with warm rain process) causing RSD differences at the ground through different microphysical process.


Thanking you