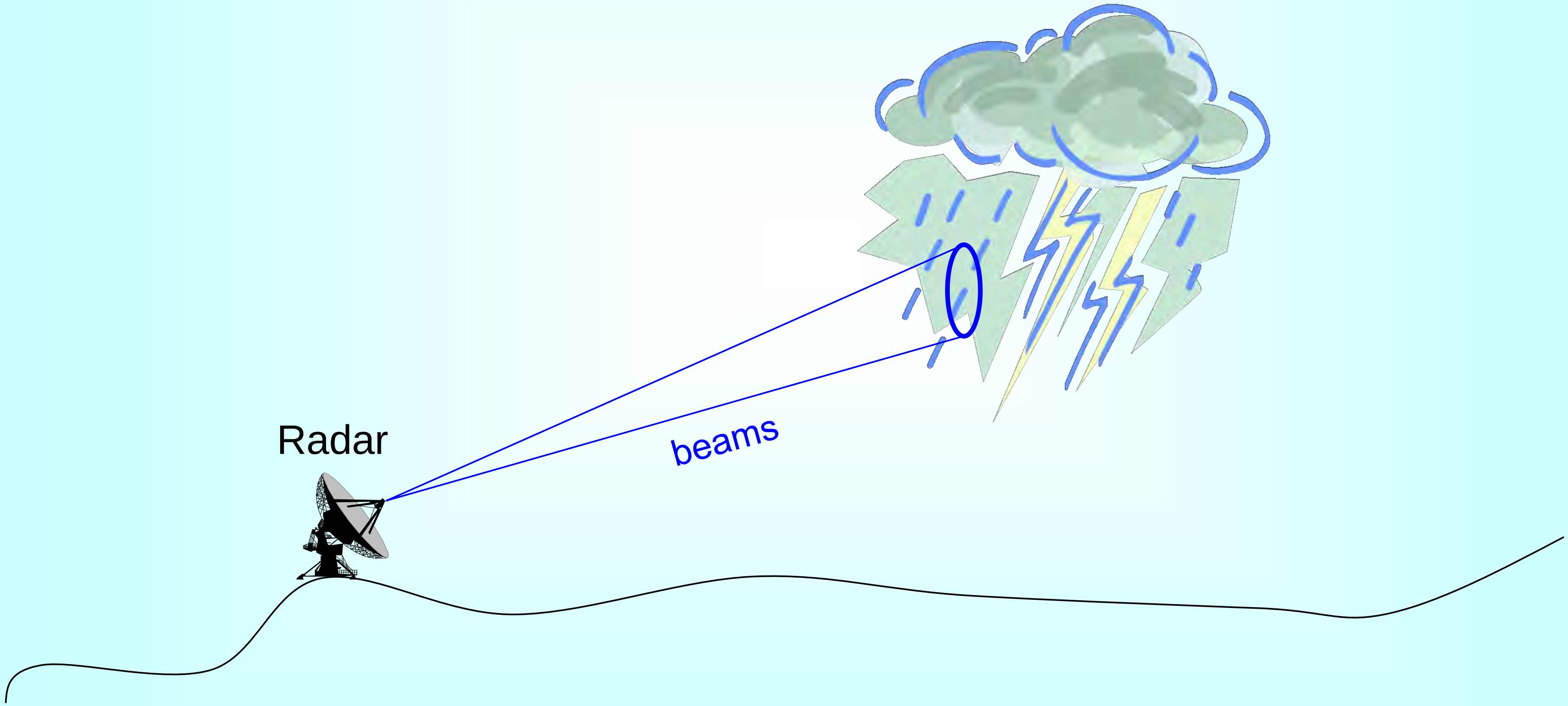
X band Radar Observation of precipitation

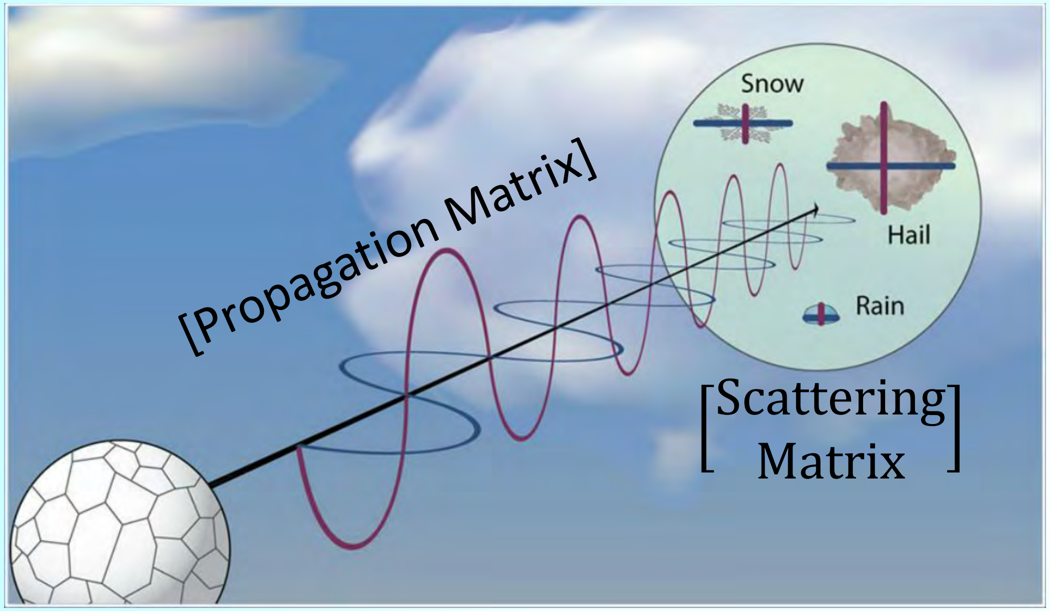
V. Chandrasekar and Daniel Feldman

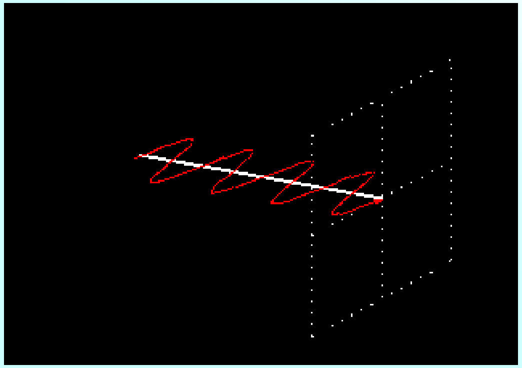
Radar measuring rainfall concept

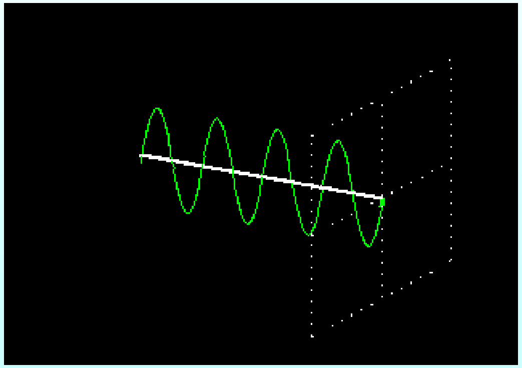


Polarimetric Radar-based Precipitation Estimation

Dual-polarization radar measurements (Bringi and Chandrasekar, 2001)







Reflectivity:

$$Z_h = \frac{\lambda^4}{\pi^5 |K_w|^2} \int \sigma_h(D) N(D) dD$$

$$Z_v = \frac{\lambda^4}{\pi^5 |K_w|^2} \int \sigma_v(D) N(D) dD$$

Differential reflectivity:

$$Z_{dr}(dB) = 10 \log_{10} \frac{Z_h}{Z_v}$$

λ: radar wavelength

$\sigma_{h,v}$: radar cross section at H/V polarization

$|K_w|^2 = |(\varepsilon_r - 1)/(\varepsilon_r + 2)|^2$: dielectric factor of water (ε_r is the complex relative dielectric constant of water)

D: particle equivalent diameter

$N(D)$: number of drops per unit volume with size from D to $D + dD$

Polarimetric Radar-based Precipitation Estimation

Dual-polarization radar measurements

Specific differential propagation phase:

$$K_{dp} = \frac{180}{\pi}\lambda \mathrm{Re}\int [f_h(D) - f_v(D)]N(D)dD$$

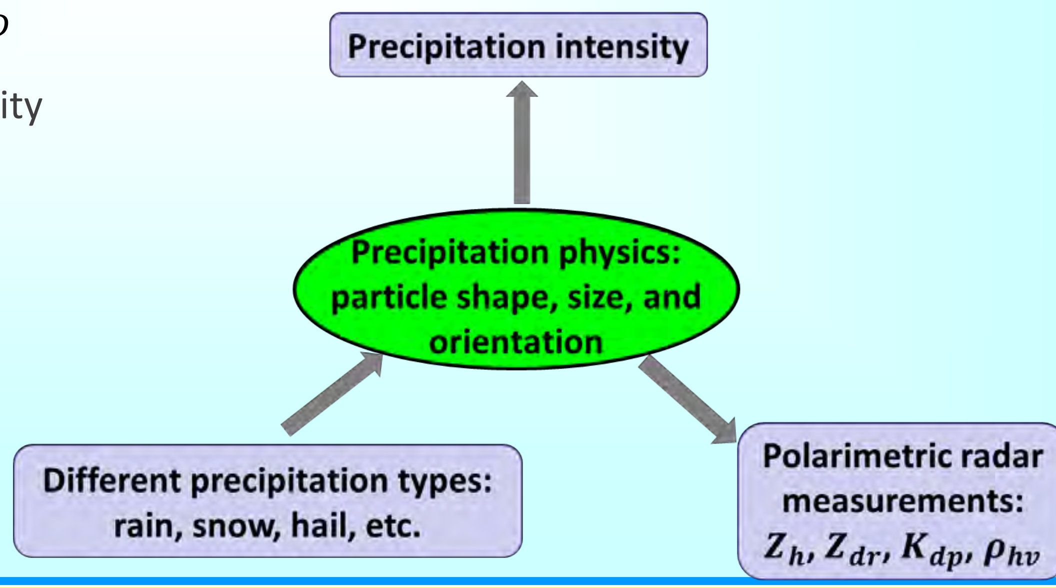
$f_{h,v}$: complex forward scattering amplitudes at H/V polarization

Rainfall rate:

$$R = 0.6\pi \times 10^{-3}\int v(D)D^3N(D)dD$$

$$v(D) = 9.65 - 10.3e^{-0.6D}$$

$v(D)$: raindrop terminal velocity



(Bringi and Chandrasekar, 2001)

Polarimetric Radar-based Precipitation Estimation

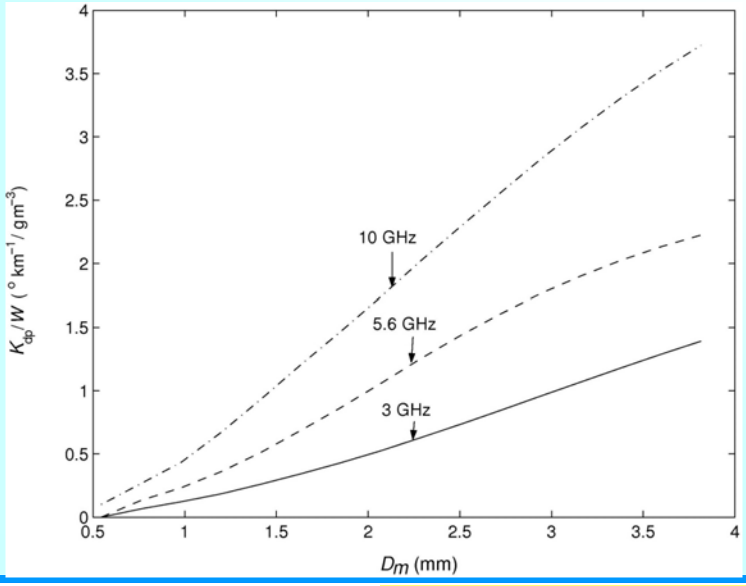
X-band radar rainfall algorithm (Bringi and Chandrasekar, 2001)

$$R(K_{dp}) = aK_{dp}^{b}$$

$$W = \frac{\pi}{6} \times 10^{-3} \rho \int_{D_{\min}}^{D_{\max}} D^3 N(D) dD$$

$$D_{\mathrm{m}} = \frac{\int_{D_{\min}}^{D_{\max}} D^4 N(D) dD}{\int_{D_{\min}}^{D_{\max}} D^3 N(D) dD}$$

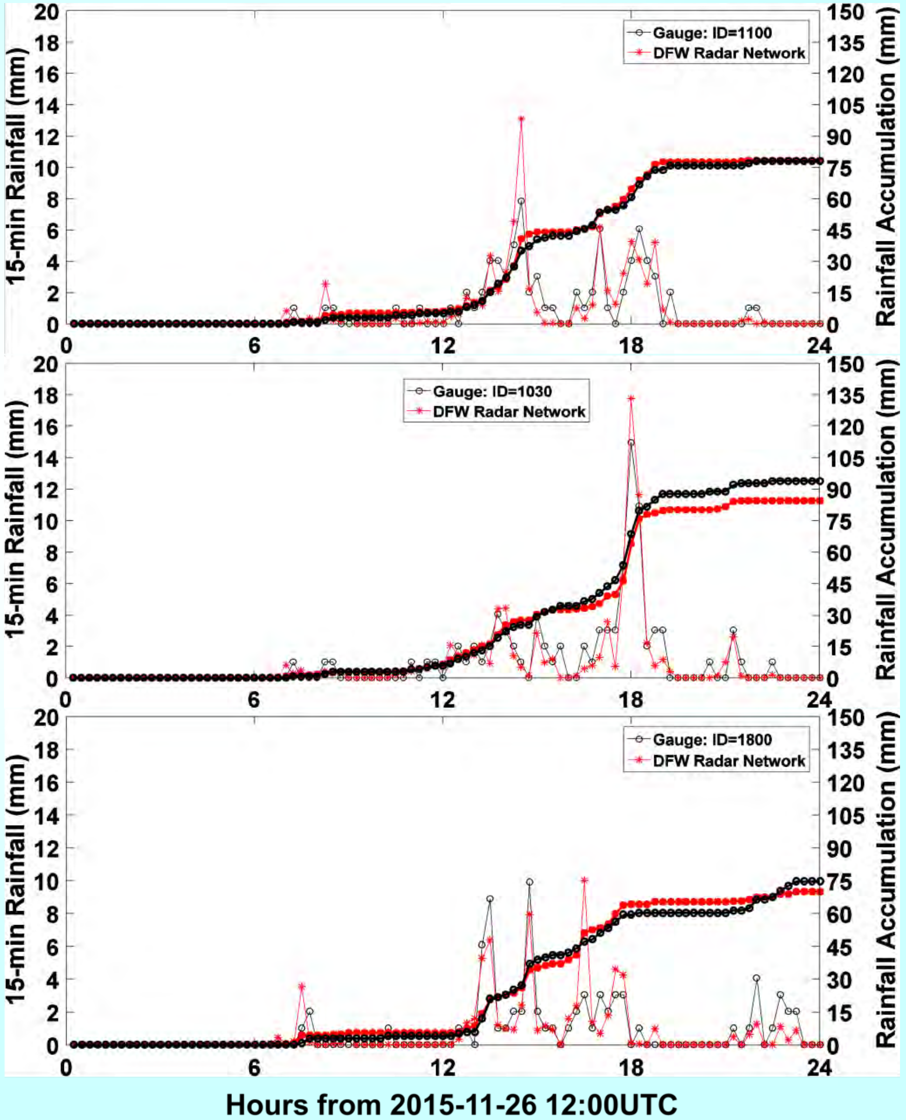
In applications, K_{dp} is estimated as $\widehat{K}_{dp} = \frac{\Phi_{dp}(r_2) - \Phi_{dp}(r_1)}{2(r_2 - r_1)}$, where differential phase Φ_{dp} is obtained from radar measured differential phase ψ_{dp}.



- $R(K_{dp})$ is immune to radar system calibration, attenuation, and partial beam blockage.
- K_{dp} in rain is proportional to the product of rainwater content and the mass-weighted mean diameter.
- K_{dp} is more sensitive at X-band compared to S-band, and it can be directly applied in light rain circumstance.

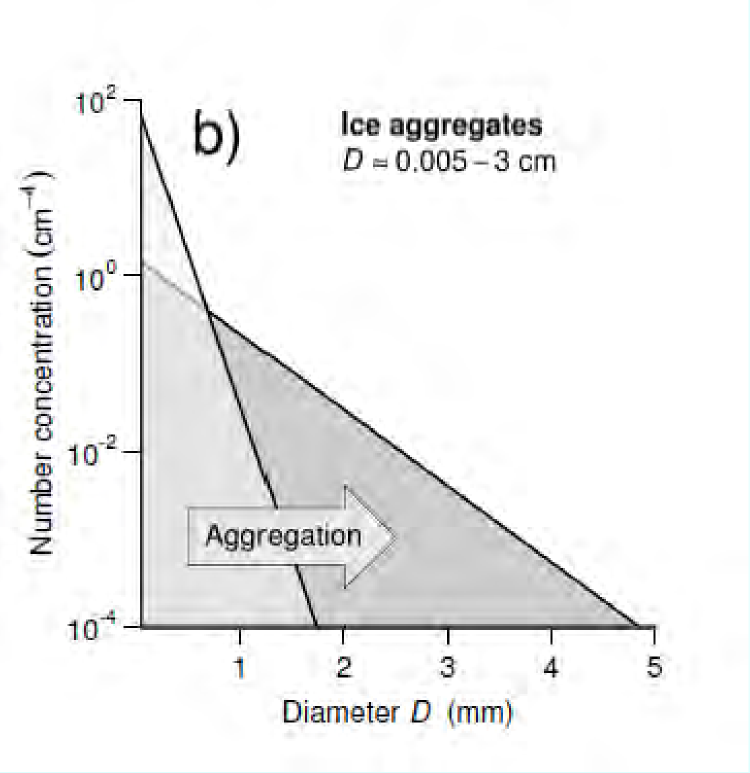
The DFW X band Urban Radar Network

Validation of high-resolution rainfall products

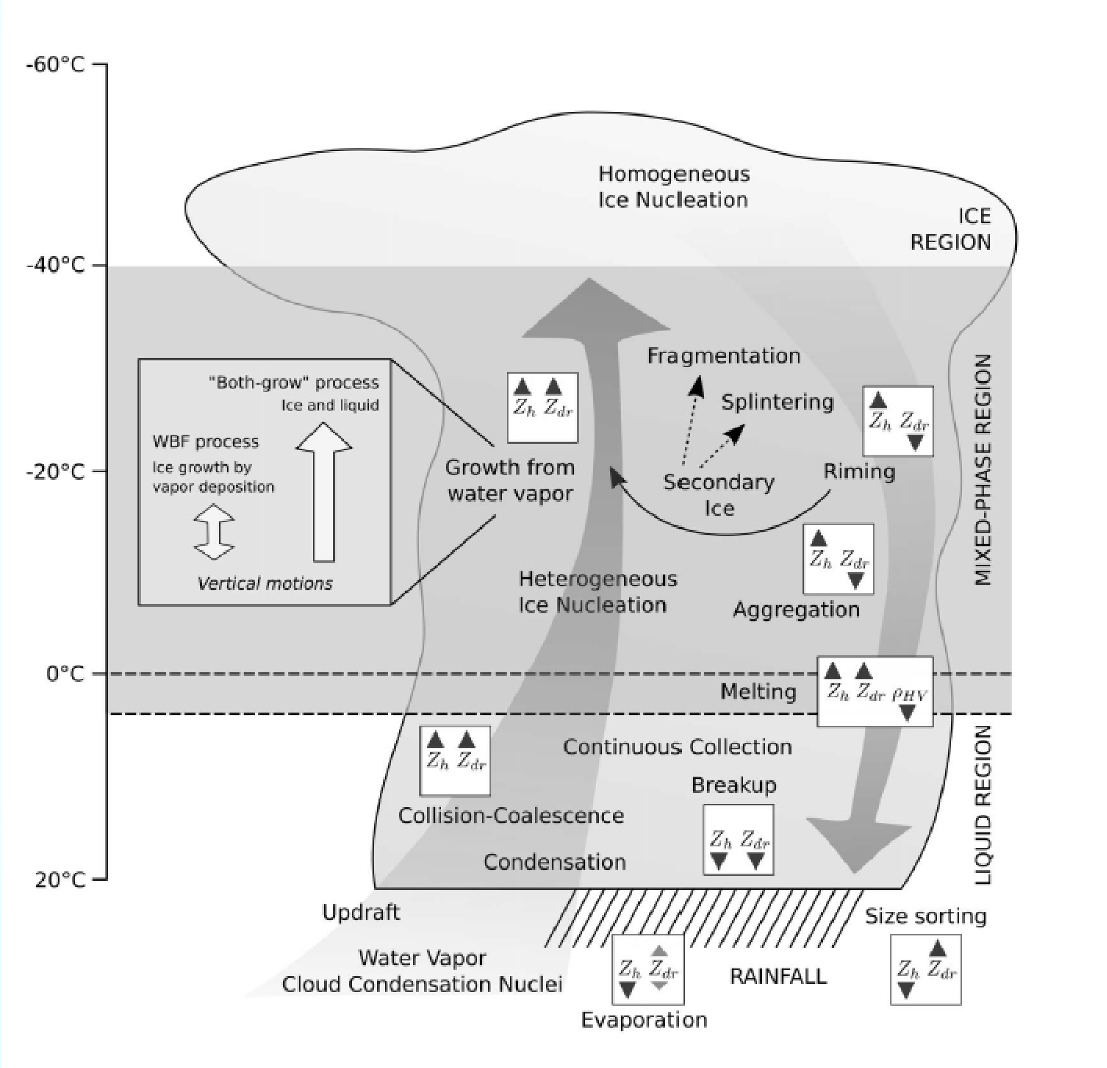


15-min rainfall and rainfall accumulations at sample gauge locations during 2015 Thanksgiving event

Snow processes

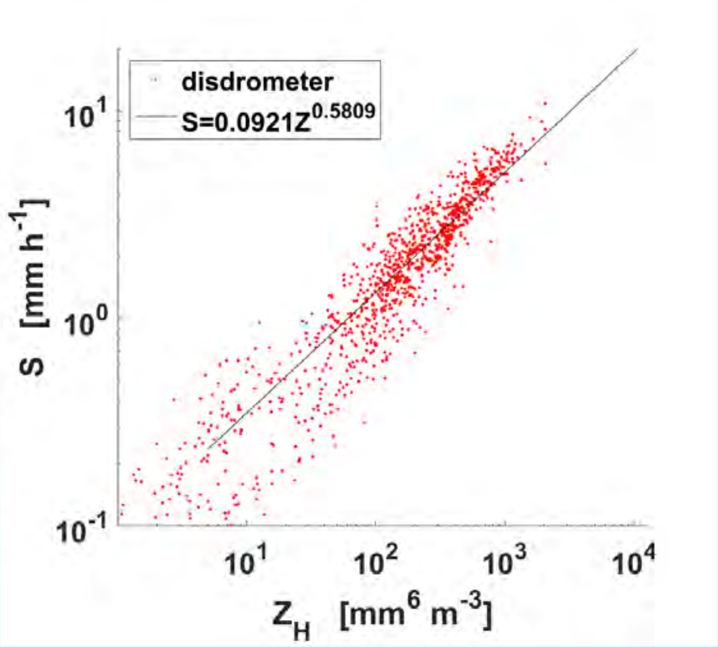


Precipitation processes



Snowfall rate estimation

Scatterplot of Z vs. S derived from disdrometer together with S-Z power-law fitting.



The reflectivity factor at Ku band can be calculated using the equation:

$$Z_h = \frac{\lambda^4}{\pi^5 |K_w|^2} \int \sigma_h(D) N(D) dD$$

The liquid water equivalent snowfall rate is calculated using the equation:

$$S = 6\pi * 10^{-4} \int \rho_s \, D^3 v(D) \, N(D) dD$$

A power-law equation can be used to obtain a relationship between Z and S

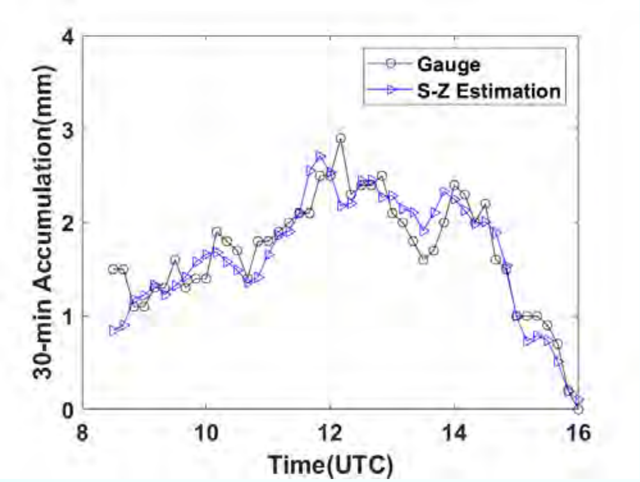
$$S = aZ^b$$

Snowfall estimation

- Density of snow plays a major role in estimating snowfall rate
- There are many size-density relationships not easy to use for the snow rate
- The terminal velocity and diameter measured by disdrometer can be used to indirectly get an idea of the density of snow from which snowfall rate is estimated from particle velocity measurements.

Comparison of snow accumulation

Snowfall estimation using S-Z algorithm from Ku band radar and gauge at YPO site for 30 min accumulation.

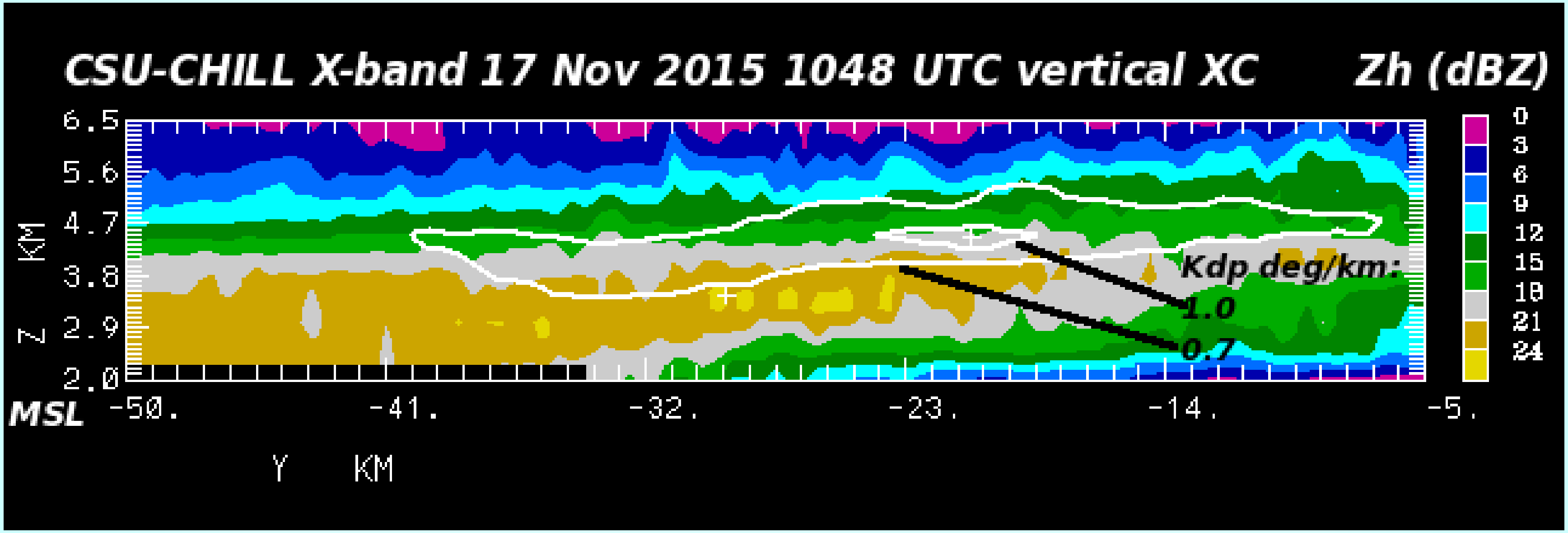


(c)

Statistics:

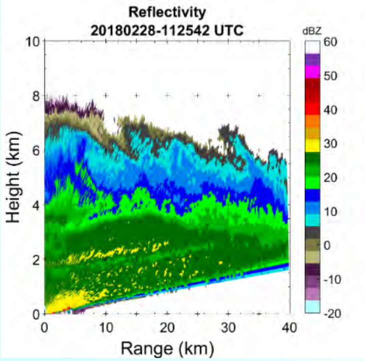
Time scale	Algorithm	MD	NSE (%)	CORR
30-min	S-Z	0.0338	11.86	0.9164

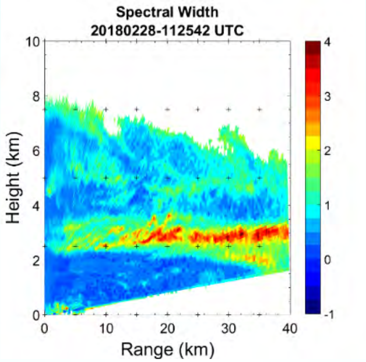
X band observations of vertical cross sections

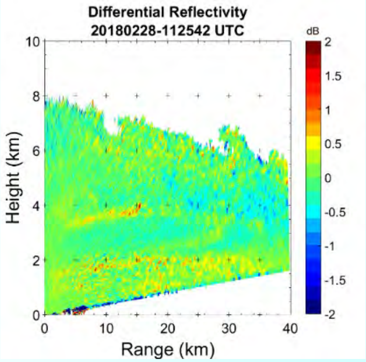


Snow event on 28 Feb 2018

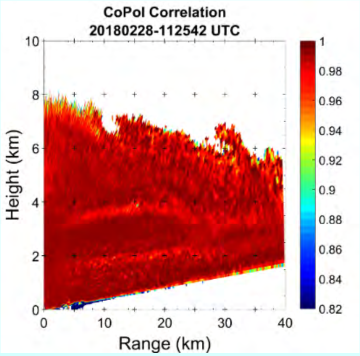
Ku Band data, Azimuth: 51.36°

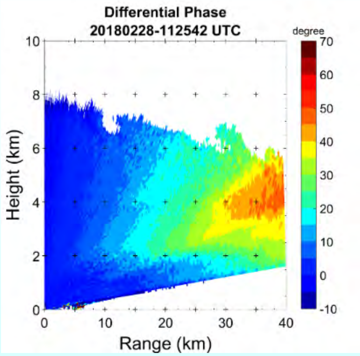






Ka band





Summary

- X band radar deployment to measure rainfall and snowfall.
- Rainfall measurement well established still must be validated locally at a high altitude environment.
- Precipitation processes and snow measurements

Thank You