An improved model for snowfall measurement using lidar and radar

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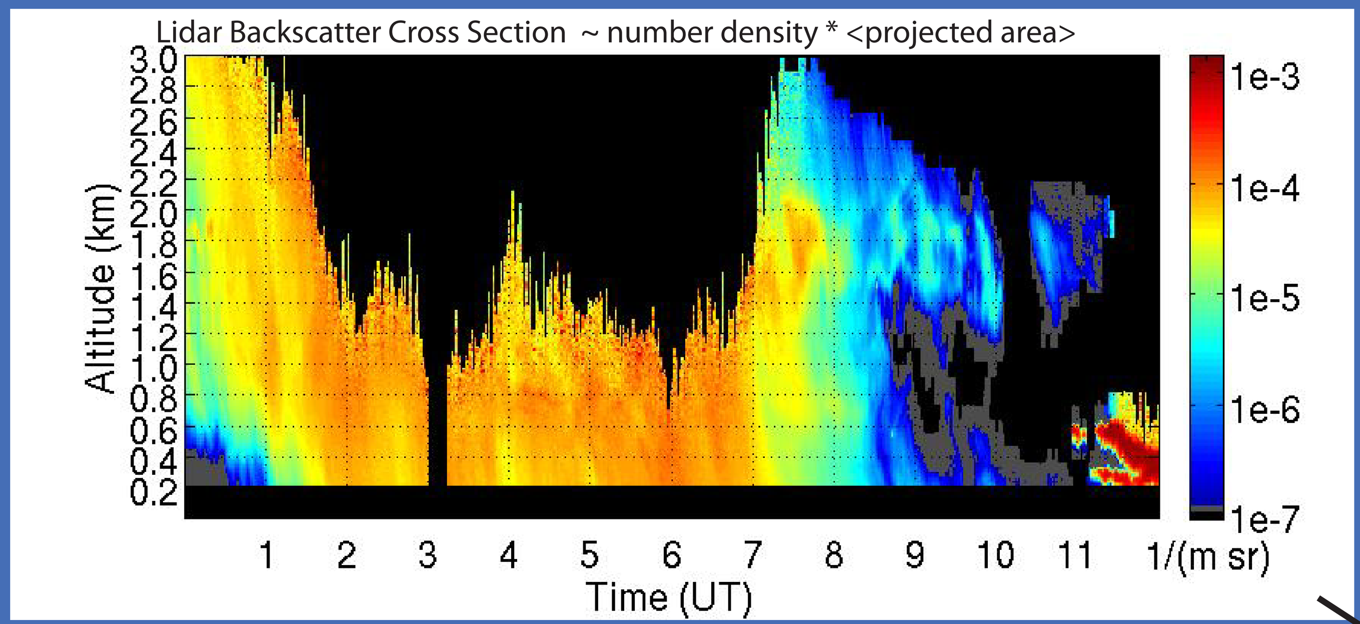
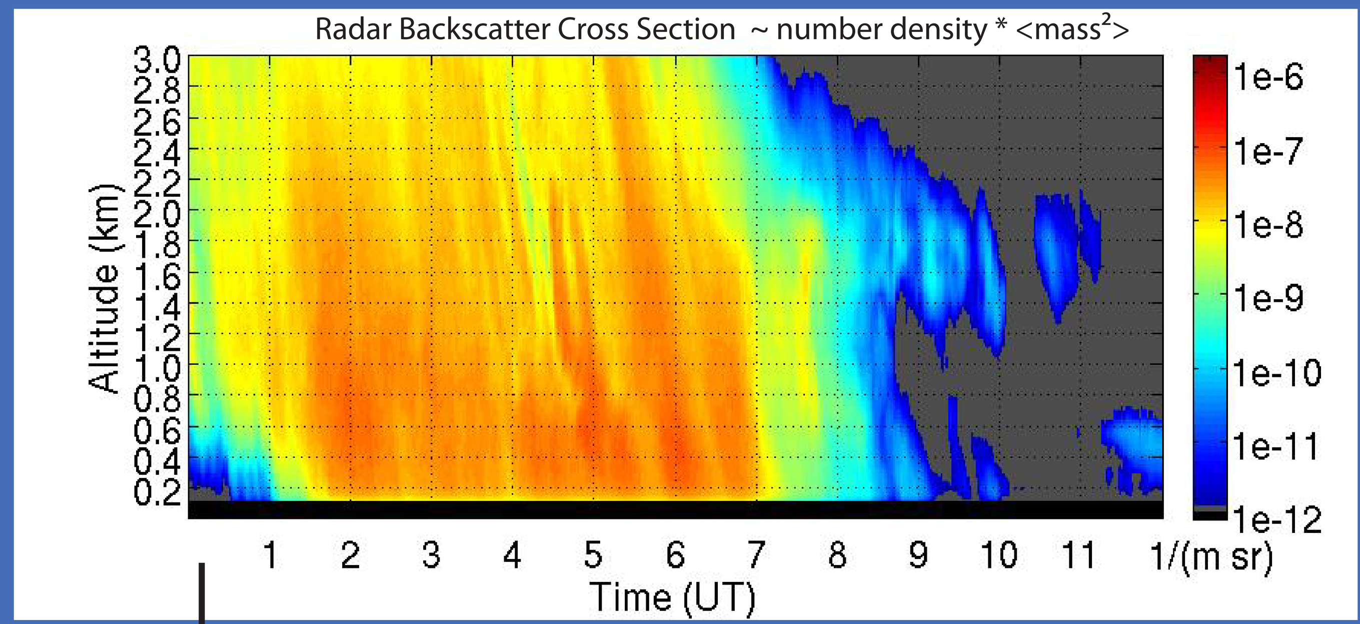
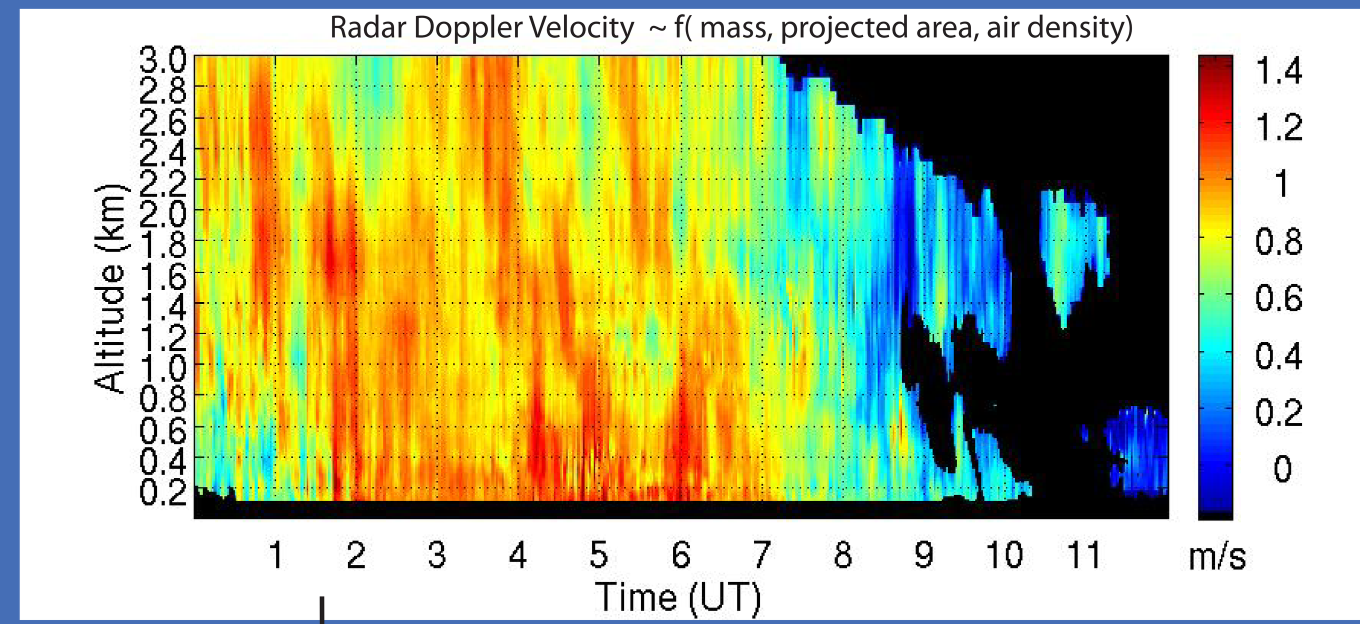
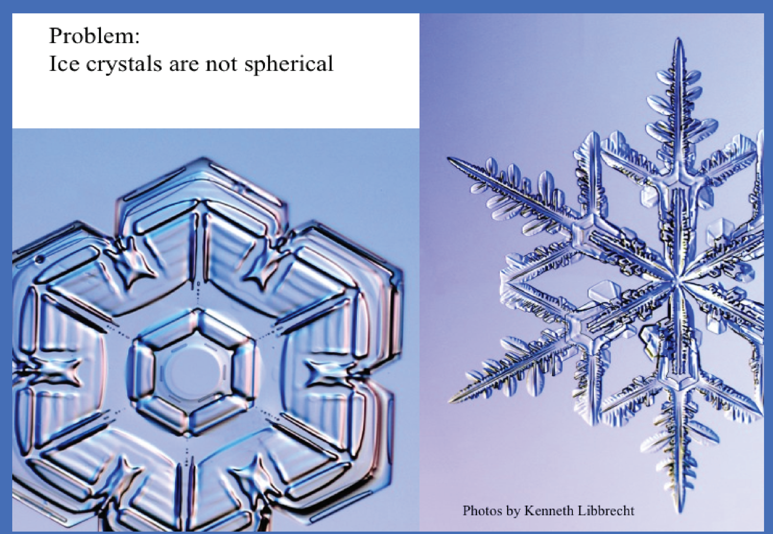
HSRL and MMCR data from a snow storm on 27-Oct-06 is used as input data to illustrate the technique that does not require a pirori assumption of crystal shape



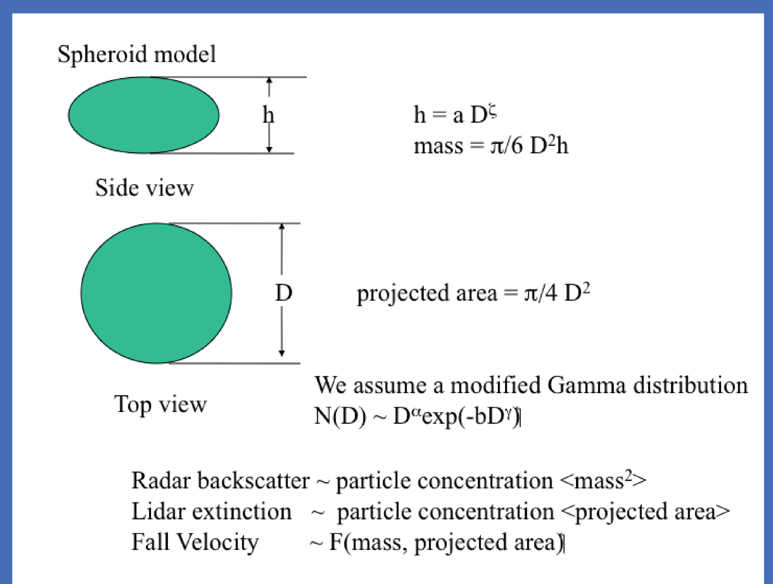




A relationship between D_{eff}' and D_{eff} is needed to compute LWC from the lidar and radar data. In the past, this required an assumed crystal shape.



Snowflakes are modeled as prolate spheroids with the same mass and projected area as the actual snow-flakes. Their aspect ratios are given as a power law of their diameters following Auer and Veal , JAS, Sept 1970, V27 pp 919-926.



The spheroid model is then used to compute the radar reflectivity weighted fall velocity as a function of D_{eff}' and the aspect ratio power law exponent, ξ.

The size distribution and the spheroid model are used to compute the observable quanities:

Integrating over the size distribution N(D) to derive D'_{eff}

$$D'_{eff} = \sqrt[4]{\frac{9<V^2>}{\pi<A>}} = \sqrt[4]{\frac{\int a^2 D^4 D^{2\xi} N(D)dD}{\int D^2 N(D)dD}} = \sqrt[4]{\frac{2\lambda^4 \beta_{radar}}{\pi^3 k^2_{ice} \beta_s}}$$

Radar reflectivity weighted fall velocity:

$$<V_f> = \frac{\int V_f\, D^4 D^{2\xi} N(D)dD}{\int D^4 D^{2\xi} N(D)dD}$$

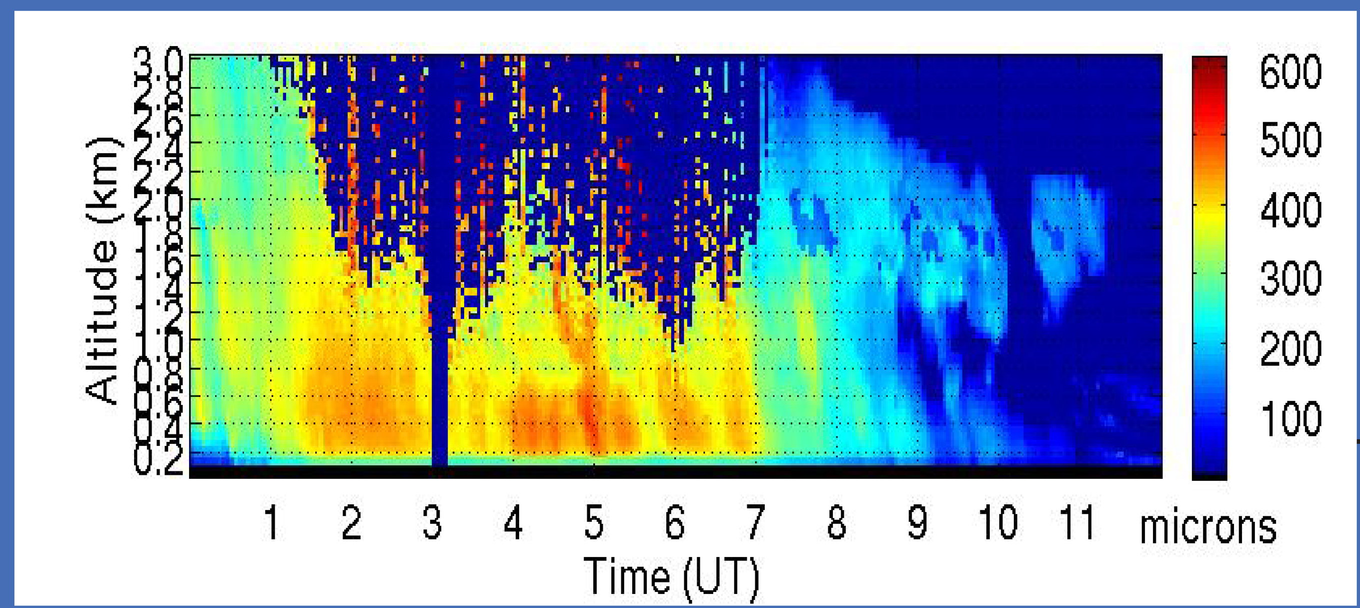
Fall velocity is parameterized in terms of X, the Best # :

$$V_f = (\eta/(\rho_{air} D))\{(d^2_o/4)[(1+C_1 X^{1/2})^{1/2} - a_o X^{bo}\}$$

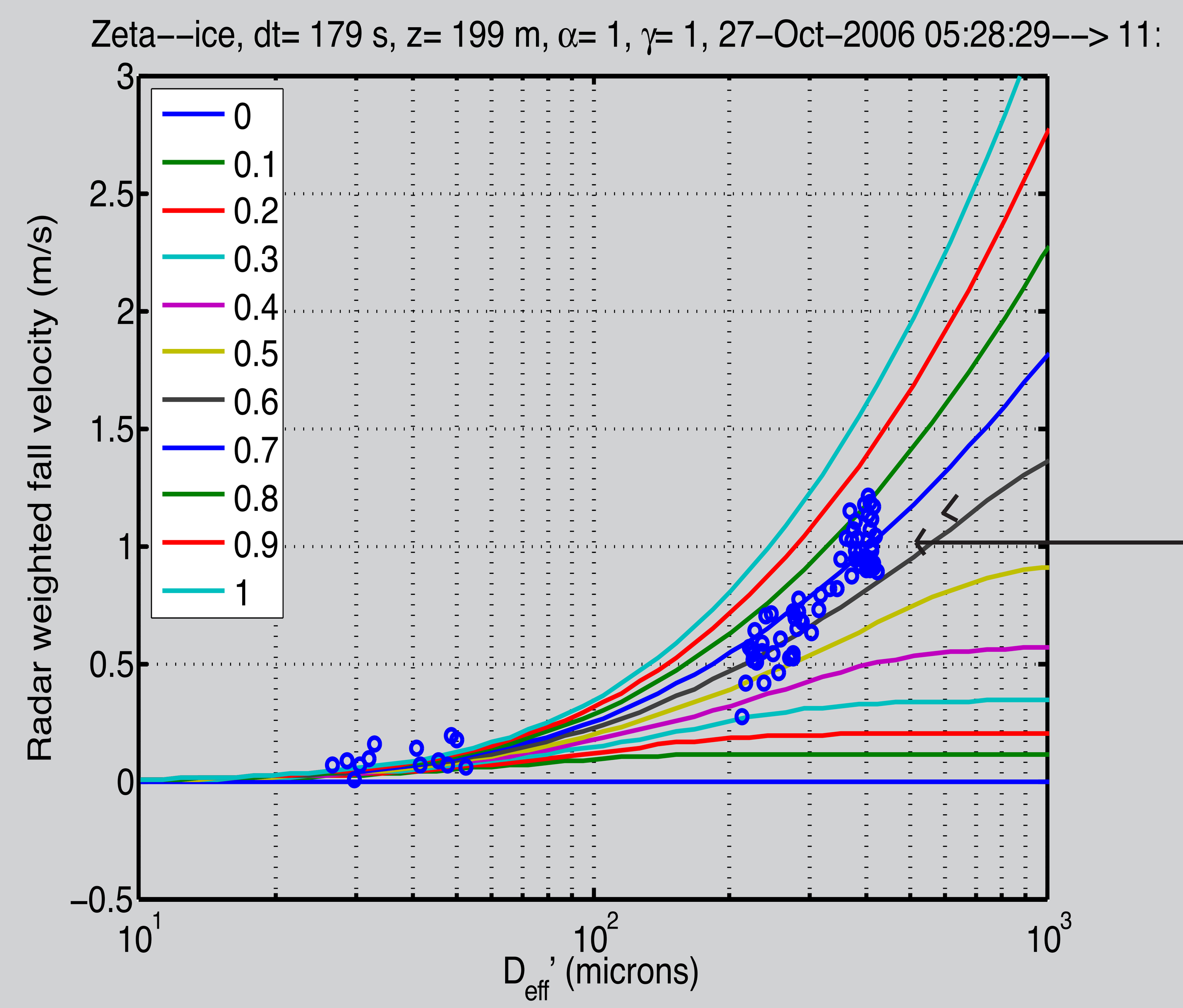
$$X = (2\ \mathrm{mass}\ \rho_{air}\ g\ D^2)/(\mathrm{area}\ \eta^2)$$

$$D_{eff}' = \sqrt[4]{\frac{2\lambda^4}{\pi^3 k^2}} \sqrt[4]{\frac{4\pi * \text{Radar backscatter cross section}}{P(180) * \text{Lidar backscatter cross section}}} \sim \sqrt{\frac{<mass^2>}{<\text{projected area}>}}$$

Lidar and radar backscatter cross sections can be used to compute D_{eff}' (Donovan and Lammeran, J. Geophys. Res. Vo106, 2001, pp



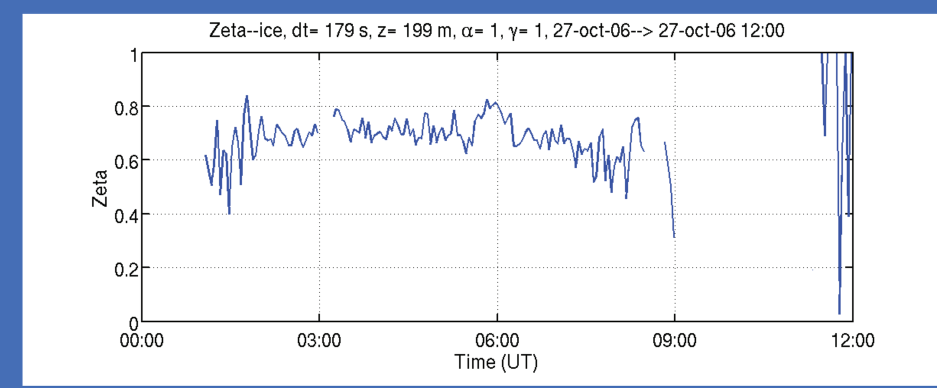
Values of D_{eff}' and fall velocity measued at an altitude of 200 m are shown on a plot derived from the spheroid mode. The position of each point determines a value of ξ for that point.



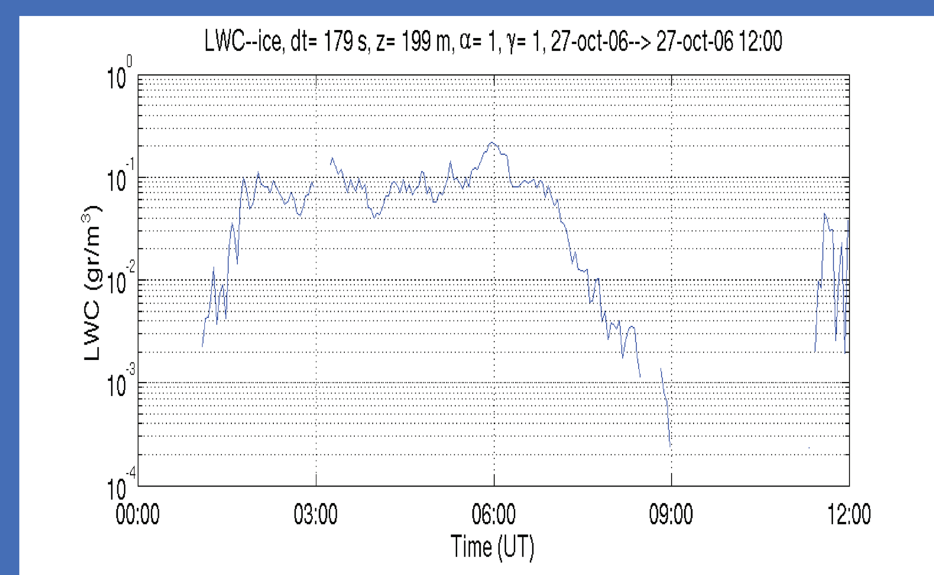
Current limitations:

Single mode size distribution is not correct when a mixture of fog and snow is present.
Doppler velocity is not equal to fall velocity when vertical air motion is present.

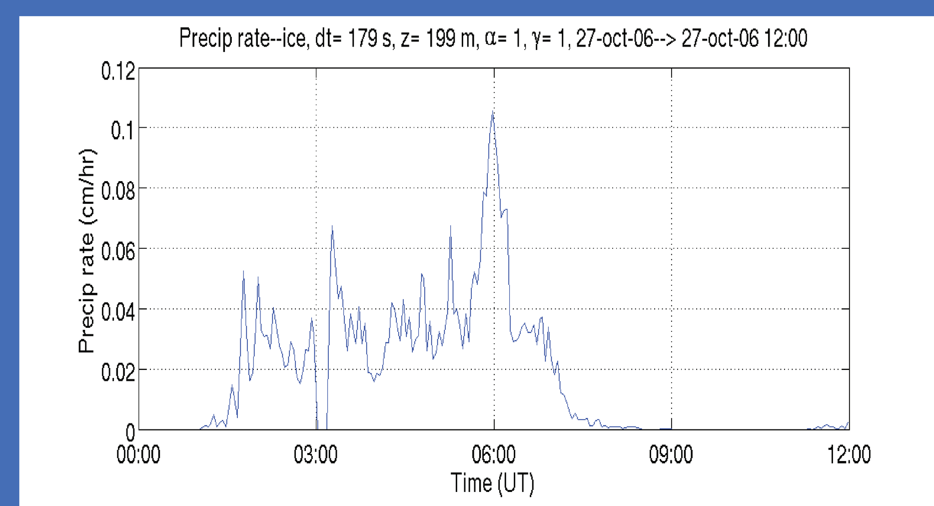
The aspect ratio exponent at z=200 m on 27-Oct-06.



Using values of D_{eff}', the spheroid model, and ξ for each data point we compute D_{eff} and with the lidar scattering cross section this provides LWC .



LWC * radar Doppler velocity = precipitation rate



Integrating precip rate yields total precipitation