An Attempt to Distinguish Dynamical and Microphysical Contributions to the Radiative Properties of Cirrus Clouds at the ARM SGP site

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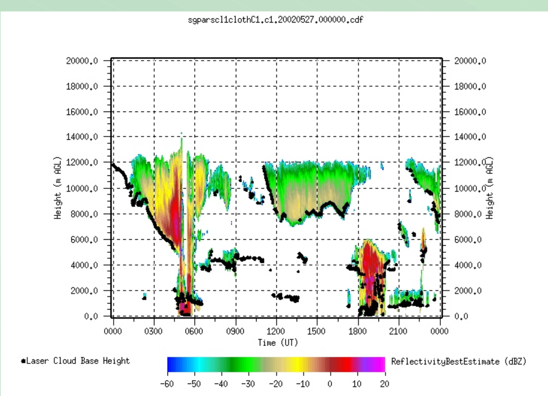
Motivation

- The problem of unraveling the dynamics and microphysics when investigating the internal structure of cirrus clouds has been of interest to the research community for a number of years.
- We present an attempt to distinguish and characterize dynamical and microphysical contributions to the radiative properties of cirrus clouds.

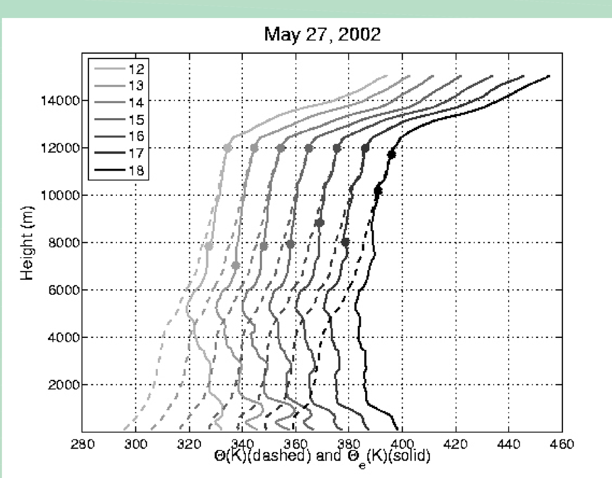
Data



January 26-27, 1997
January 16, 2001
February 13-14, 2001
May 27, 2002

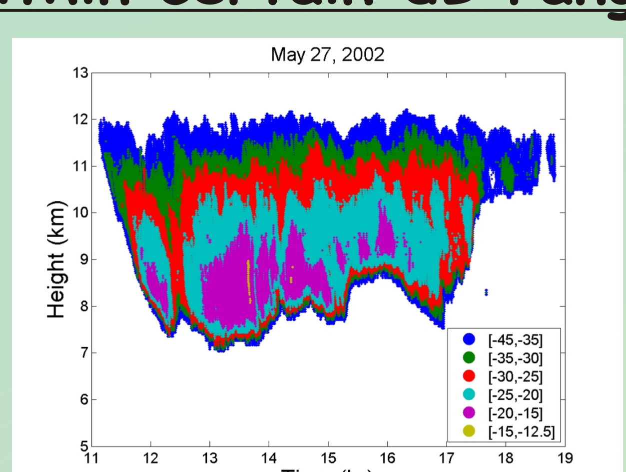
We analyze backscattering cross section data as measured with 35 GHz millimeter wave cloud radar (MMCR)

Assess the thermodynamical stratification



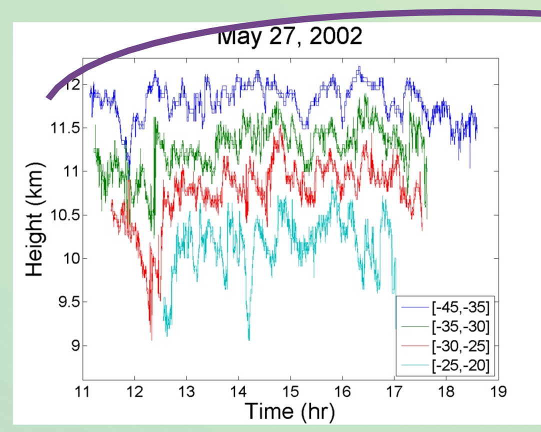
Use Integrate_Column_5min_Mace.cdf data stream from the ARM archive (Mace et al. 2006).

Restrict radiative properties within certain dB range



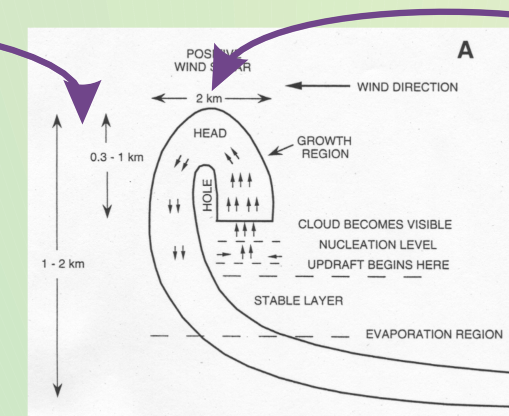
=> Eliminate one of the three unknowns among the interwoven radiative, dynamical, and microphysical properties.

Assess the scale τ



$\Delta t_0 = 10s$

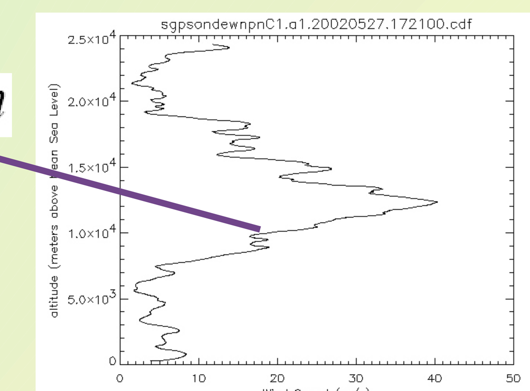
Analysis is done over concatenated time series of $\eta(t)$ at two heights



Schematic diagram of cirrus uncinus cloud (after Heymsfield 1975)

$\tau_s = 1.2km$

$\tau = 6\Delta t_0$



Use sgpsondewnpnC1.a1 data stream from ARM archive

Method of Analysis

It is known that two equations govern the dynamics of a system (Ivanova et al. 2006):

The Fokker-Planck equation (FPE) for the probability density

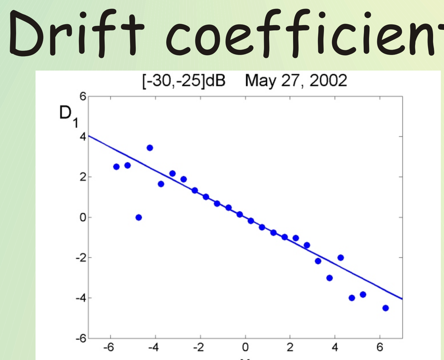
$$\frac{\partial p(x,t)}{\partial t} = \left[-\frac{\partial}{\partial x} D_1(x,t) + \frac{\partial^2}{\partial x^2} D_2(x,t) \right] p(x,t)$$

The Langevin equation for the increments of the signal

$$\frac{dx}{dt} = D_1(x,t) + R(t)\sqrt{D_2(x,t)}$$

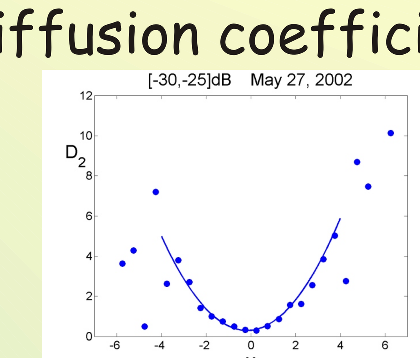
At scale τ ⟶

Drift coefficient



$$D_1(x) = -\gamma x + \gamma_0 \approx -\gamma x$$

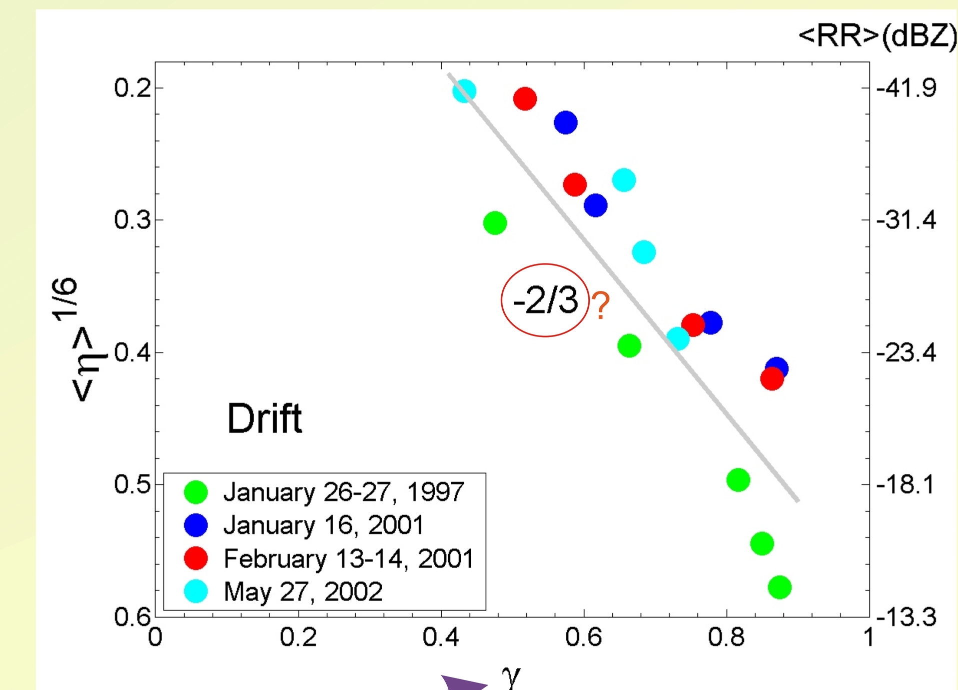
Diffusion coefficient



$$D_2(x) = \beta x^2 + \beta_1 x + \beta_0 \approx \beta x^2$$

Summary

- By considering layers in the cloud having quasi-constant radiative properties, we eliminate one of the three unknowns - the radiative properties.
- Dynamical contributions to the radiative properties, as expressed by γ increase with increasing the layer $\langle\eta\rangle$ (or $\langle RR\rangle$).
- Microphysical contributions to the radiative properties, as expressed by β are approximately constant with increasing the layer $\langle\eta\rangle$ (or $\langle RR\rangle$).

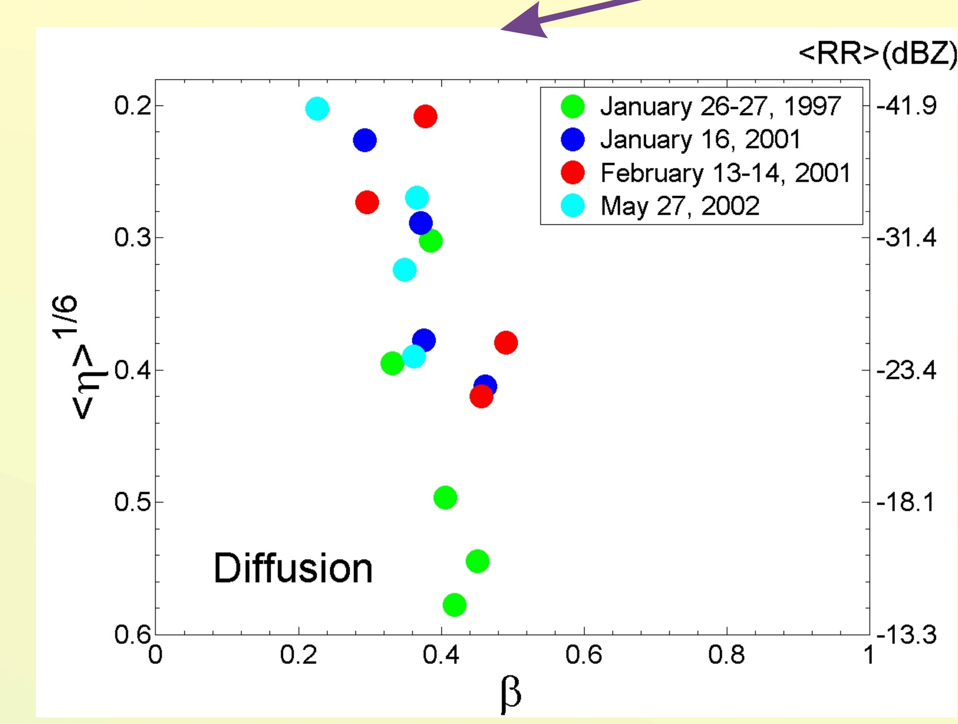


Deterministic

$$\frac{d(\Delta\eta)}{dt} = -\gamma\Delta\eta + R(t)\sqrt{\beta}\Delta\eta$$

$x \equiv \Delta\eta(t)$

Stochastic



Future Work

- To understand the relationship between the drift coefficient γ and Doppler velocity, and between the diffusion coefficient β and particle size distributions. $-\gamma\Delta\eta \sim F = ma$ $\quad -\gamma\Delta\eta \sim \frac{d}{dt}(mv)$
- To study the dynamics and microphysics of the generating cells in cirrus clouds and their coupling with the state of the large-scale atmosphere.
- To study isolated cirrus. This will allow us to use for the analysis both radar and lidar observations from the ARM archive.
- To derive climatology of the drift and diffusion coefficients for the SGP site.

Acknowledgments

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References

Heymsfield, A.J., 1975. Cirrus uncinus generating cells and the evolution of cirriform clouds. Part II: The structure and circulation of the cirrus uncinus generating head, J. Atmos Sci., **4**, 809-819.

Ivanova, K., H.N. Shirer, E.E. Clothiaux, 2006. Internal variability and pattern identification in cirrus cloud structure: Fokker-Plank equation approach, J. Geophys. Res., 111, D0720.

Mace, G. et al., 2006. Cloud radiative forcing at the ARM Program CRF: 1. Technique, validation, and comparison to satellite-derived diagnostic quantities,J. Geophys. Res., 111, D11S90.

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