The Relationship between Vertical Velocity and the Vertical Distribution of Hydrometeors in Deep Convective Cells

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Introduction

- Dynamical and microphysical processes within deep convection are known to be related, but our understanding of the interaction between these processes is limited by a lack of merged observations.
- Key areas of uncertainties include the coupling of transport of hydrometeors by turbulent drafts to phase changes and associated latent heat release.

Goal

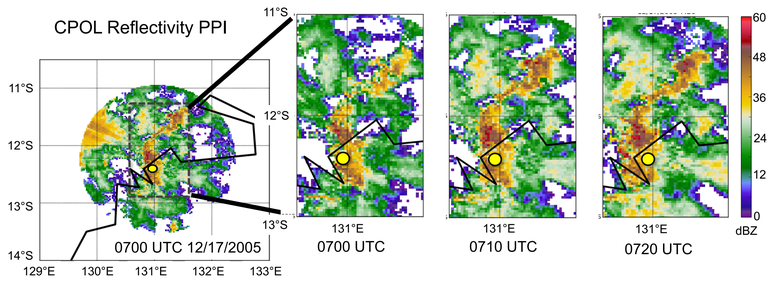
As a step toward addressing this uncertainty, we aim to use principles of kinetic theory to explain the relationship between vertical velocity fluctuations with vertical distribution of hydrometeors.

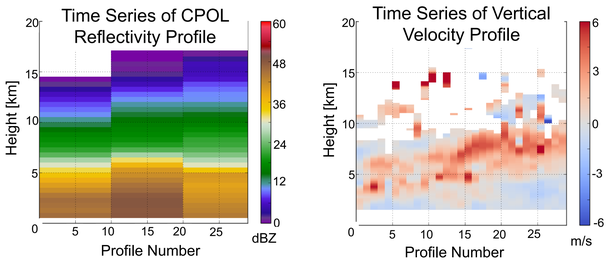
Data

- Darwin, Australia: 2005-06 and 2006-07 wet seasons.
- CPOL (Dual-polarimetric, scanning C-band radar)
  - Time resolution: 10 minutes
- Dual-frequency in-cloud vertical velocity retrieval (Williams et al., 2012)
  - Time resolution: 1 minute

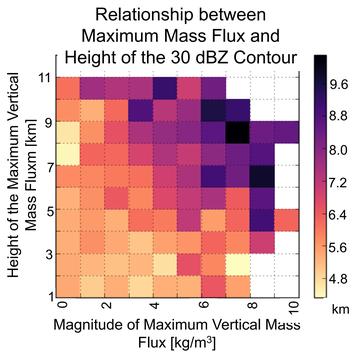
Methodology

- Convective cores over profilers identified using CPOL.
- Reflectivity and hydrometeor profiles derived from CPOL PPIs.
- CPOL and profiler data synchronized to 1 minute resolution.
- Analysis restricted to updraft events (≥ 1 km deep upward motion persisting for 5 consecutive minutes).
- Event vertical velocity mean and variance calculated.

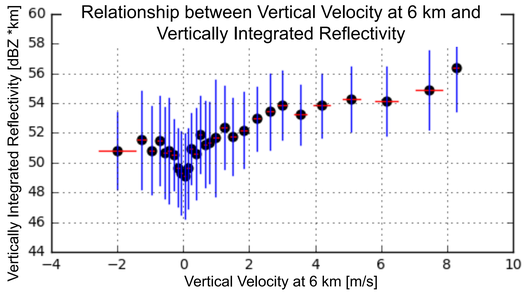




Vertical Velocity – Reflectivity Relationship



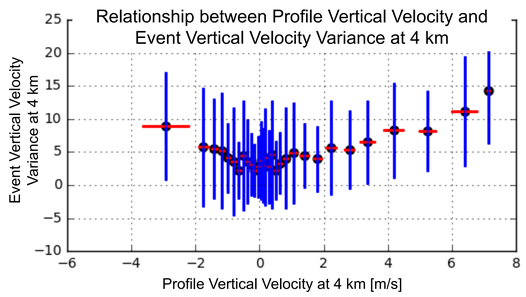
30-dBZ top heights increase with the magnitude and height of the maximum mass flux.



$$\text{Vertically Integrated Reflectivity} = 10\log\left[\sum\left(\frac{\text{dBZ}_2 - \text{dBZ}_1}{2}\right)(0.5)\right]$$

Vertically integrated reflectivity increases as the intensity of the vertical motion increases.

Vertical Velocity Characteristics



Stronger vertical velocities often occur in convective cores with higher vertical velocity variability.

Proposed Application of Kinetic Theory: Brownian Diffusion with Drift

Kinetic Theory

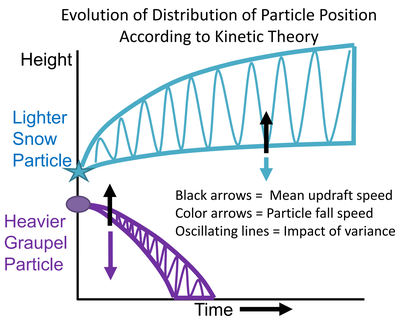
$$\frac{\partial P(x,t)}{\partial t} = -\frac{\partial[v(x)P(x,t)]}{\partial x} + D\frac{\partial^2 P(x,t)}{\partial x^2}$$

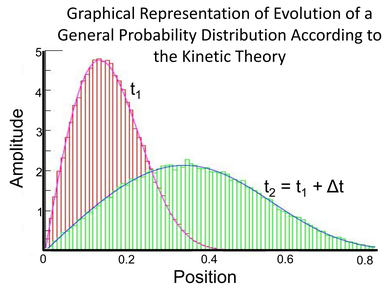
Change in Distribution = Drift (Gravitational Balance) + Diffusion

- Implies reflectivity distribution related to particle size and vertical velocity variance

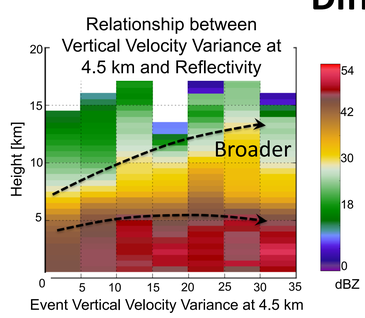
Reflectivity Distribution = Balance between the magnitude of vertical velocity and mass of the particle + Diffusion (caused by vertical velocity variance) results in a broader vertical reflectivity distribution.

$$ETH^2 \propto w'^2 t$$



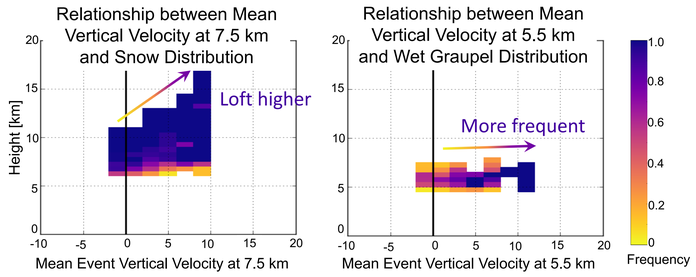


Diffusion



Updraft events with greater vertical variability associated with broader vertical reflectivity distributions

Drift



Greater mean vertical velocities loft small particles (snow) higher and support larger particles (wet graupel)

Conclusions

- Larger vertical velocities are associated with deeper and more intense reflectivity profiles.
- This relationship can be explained through:
  - Diffusion - vertical velocity variability creates broader reflectivity distributions
  - Drift - stronger vertical velocities support heavier particles and loft smaller particles higher
- The reflectivity profile is related to both the magnitude and variance of the vertical velocity in a convective core.

Future Work

- Explore how different particle distributions evolve with time under similar vertical velocity conditions.
- Incorporate these relationships between the vertical velocity variability and microphysical processes into parameterizations.

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