Can vertical profiles, or vertical gradients, of radar reflectivity and Doppler velocity yield quantitative insights about process-based changes in microphysical properties?

Observationally-informed Lagrangian modeling to evaluate process-based effects on radar profiles

Measurements collected by the P3 and ER-2 aircrafts in the southern, mixed-phase region of a departing low-pressure system are used to constrain Lagrangian model simulations of precipitation evolution by deposition, aggregation, and riming processes within a semi-idealized cloud profile.

Control run simulation: vertical evolution of ice-phase particles within a semi-idealized winter storm cloud

Addressing the construction of a particle size distribution (PSD) necessary for initialization: Absent measurements from the primary 2D-S and with shattered particle concerns from Hawkeye 2D-S data, a PSD is generated by fitting a Gamma distribution to flight-level HVPS measurements at D ~ 0.5 mm.

Vertical profile of Doppler velocity within an idealized winter storm cloud

Doppler velocity (V_d) abrupt increases at ~4.9 km height coincident with the apparent onset of riming and liquid precipitation.

HIWRAP radar reflectivity (top) and Doppler velocity (bottom) of IMPACTS 04 February 2022 storm. A radar bright band partitions between ice-phase and liquid precipitation. Doppler velocity abruptly increases at ~5 km height coincident with the apparent onset of riming (PHIPS imagery, right).

Do vertical Doppler radar profiles have characteristic responses to process-based effects on radar profiles?

Aggregation and riming are adjusted independently to evaluate process-based sensitivities.

Reducing aggregation or riming by 0.5x yields similar Z_{Ku}.

Difficult to distinguish process effects in Z_{Ku}.

Distinct change in V_d gradient with riming.

Potential for process-based discrimination from V_d.

Particle density is uniquely sensitive to evolution by either aggregation or riming. The PSD, and therefore, Z_{Ku} and V_d, are modulated by particle density.

How does the process-based particle evolution relate to vertical gradients in Doppler radar?

If vertical profiles of Z_{Ku} and V_d are measured, the relationship between coincident relative gradients in Z_{Ku} and V_d may provide a framework for estimating particle density.

Limitations to the current study and considerations for future work:

- Single event considered; analysis may include additional IMPACTS events.
- Density relationships derived from model; estimation of density from obs.
- Some uncertainties remain for the initial PSD characteristics, including m-D and A-D relationships; do additional data sources (i.e., Hawkeye 2D-S LISPER) provide a means of constraint in the upper boundary conditions?

Summary

1. Unique microphysical effects of aggregation and riming are difficult to distinguish in radar reflectivity (single-frequency) but appear distinct in Doppler velocity.

2. Particle-based simulations suggest that coincident relative gradients in reflectivity and Doppler velocity may inform estimates of bulk particle density.

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IMPACTS Data

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