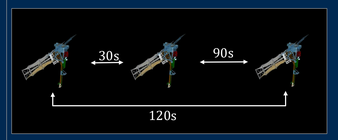
Observing the Relationship Between Changes in Reflectivity and Vertical Velocity in Convection

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Introduction

- With the upcoming INCUS (INvestigation of Convective UpdraftS) project set to be observing tropical convection with three radar satellites (diagram to right), there is a need to understand convective updrafts and the relationship between mass flux and reflectivity changes as well as the challenges with collecting and analyzing these data using ground-based methods.



- TIME SLICE CO 2024 was an opportunistic field campaign designed to test INCUS methods, refine data collection techniques, as well as develop a "playbook" that could be shared with other institutions to replicate the methods and findings. All data shown in this project was collected during TIME SLICE CO.
- This project is an extension of findings from Dolan et al. (2023) that observed coherent changes in reflectivity over INCUS-like timescales (< 120s). This extension is based on theory from Stephens et al. (2020) and Grant et al. (2022) and supplementary equations from Giangrande et al. (2013)

Background

CSU-CHIVO; C-band radar - Scanning strategy consisted of three vertical scans per scanning period. One in a central target volume, then one to the left and one to the right of that central volume. When guided autonomously, the target was decided by a tracking algorithm, otherwise targets were selected manually. Range-altitude plots are from CHIVO.

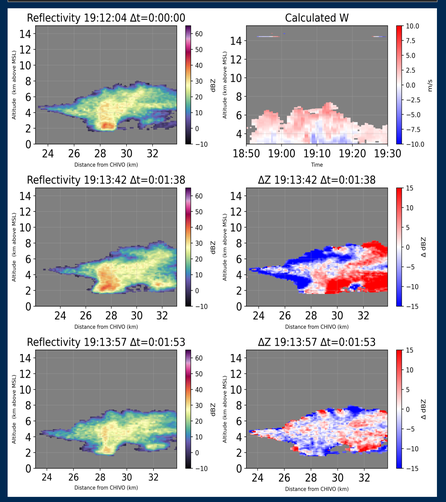
Snow Level Radar (SLR) - Vertically pointing radar, used to collect vertical velocity data and identify overpass times. Time-altitude plots are from SLR.

Hypothesis:

- **Reflectivity changes (ΔZ) and vertical velocity (w) exhibit a positive relationship in convection above 5km AGL with the most significant ΔZ and w being near/at the tropopause.**

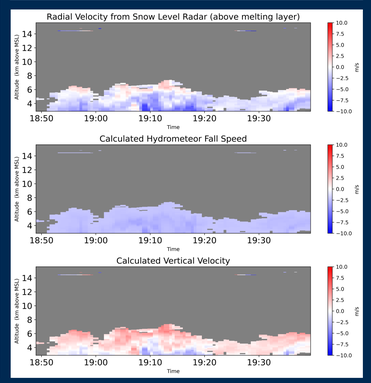
Methods

Fig. 1 (below). Reflectivity at different times (left)with ΔZ plots (plotted middle and bottom right). Top right is estimated w from SLR (bottom figure on Fig. 2). Middle plots represent along-radial advection correction. This method works best to show a 2-D representation of ΔZ. The bottom plots represent between-radial advection correction. This is only effective when differencing individual columns because the distance between radials changes.



Methodology consisted of time differencing CHIVO scans and comparing them to SLR vertical velocities. Some additional modifications were required to account for advection.

Fig. 2 (below) w estimated above melting layer using reflectivity-hydrometeor fall speed equation for graupel from Giangrande et al. (2013)



★ Advection correction is necessary when determining reflectivity changes due to vertical motion, especially in midlatitudes ★

Case 1: April 26th, 2024

Note: All analysis was done both at 100m resolution and at a coarser resolution to simulate INCUS data. Only 100m resolution plots are shown, but results between resolutions were similar.

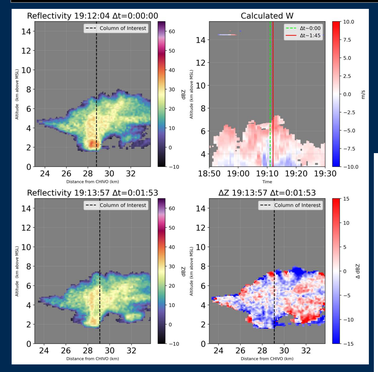
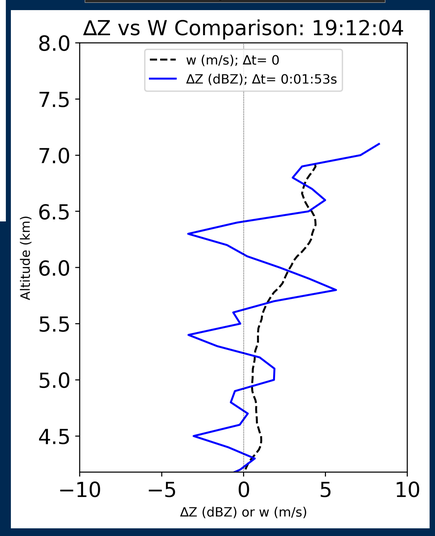


Fig. 3 (above) ΔZ and w with columns of interest marked.

As expected, ΔZ and w follow a similar positive trend above 5km. However, large oscillations may be the result of errors in advection correction making this correlation more questionable. Notes: The small peak above the maximum vertical velocity was washed out when looking at coarser data, and the sharp increase at the top is of undetermined origin.

Fig. 4 (below) ΔZ from marked columns (after advection correction) vs w



★ The April 26th case exhibits a weak, but positive, relationship between ΔZ and w ★

Conclusions

- ΔZ and w appear to be correlated above 5km. This relationship breaks down at the top of the cloud in these two cases where other processes appear to be advecting reflectivity into the column in both cases.
  - Possible culprits: advection by environmental wind (Fig. 7), anvil spread, and errors in vertical velocity.
- Coarser resolution (not shown) conserves major features; however, some weaker features can become indiscernible from noise
- For future field campaigns, it would be beneficial for similar analyses to improve the tracking algorithm, to use a multi-Doppler radar array, and to devise a more robust advection correction method.
  - These changes would provide better estimations for advection and would improve sampling of convective cores.

Case 2: June 8th, 2024

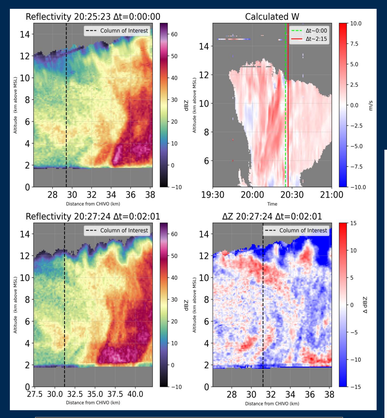


Fig. 5 (above) ΔZ and w with columns of interest marked

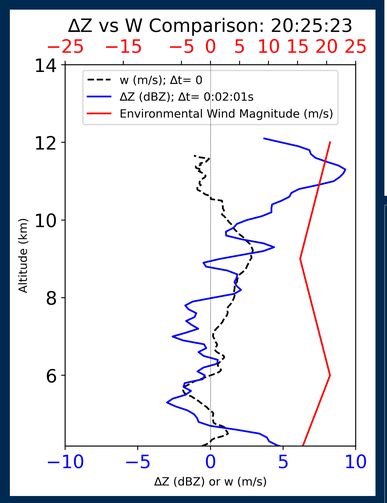
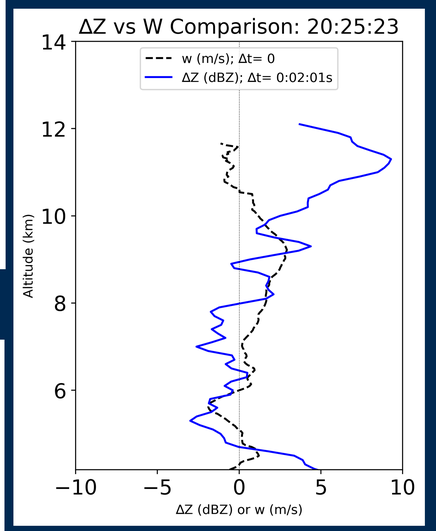


Fig. 7 (above) ΔZ from marked columns vs vertical velocity with observed environmental winds

Fig. 6 (below) ΔZ from marked columns (after advection correction) vs w



As in Case 1, ΔZ and w are correlated above 5km, and they are more closely correlated in Case 2 (Fig. 6) than in Case 1 (Fig. 4). The large spike in reflectivity at the top of the cloud (Fig. 6) is currently not understood. Physically speaking, due to the updraft speed being around 4 m/s, reflectivity from the area of maximum w cannot be advected vertically to 12km with Δt = 2:01. This peak can be attributed to many factors including (but not limited to) environmental winds (Fig. 7), anvil spread, and incorrect hydrometeor assumptions when estimating w (Fig. 2).

★ The June 8th case exhibits a more robust positive relationship between ΔZ and w ★

★ Sharp increases in ΔZ above max w cannot be due to vertical motions; several processes could be causing this ★

Acknowledgements

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