Banded convection in Colorado snowstorms: insights obtained from X-band radar observations and numerical simulations

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INTRODUCTION

- Several snowstorms in northern Colorado in spring 2013 exhibited complex banded structures that determined the spatial distribution and intensity of snowfall
- During some of these storms, the CSU-CHILL radar was operating at X-band (3 cm) and observed the detailed structures of these bands
- This research integrates these radar observations with numerical simulations of several events to understand the key dynamical and microphysical processes responsible for the banding and snowfall production

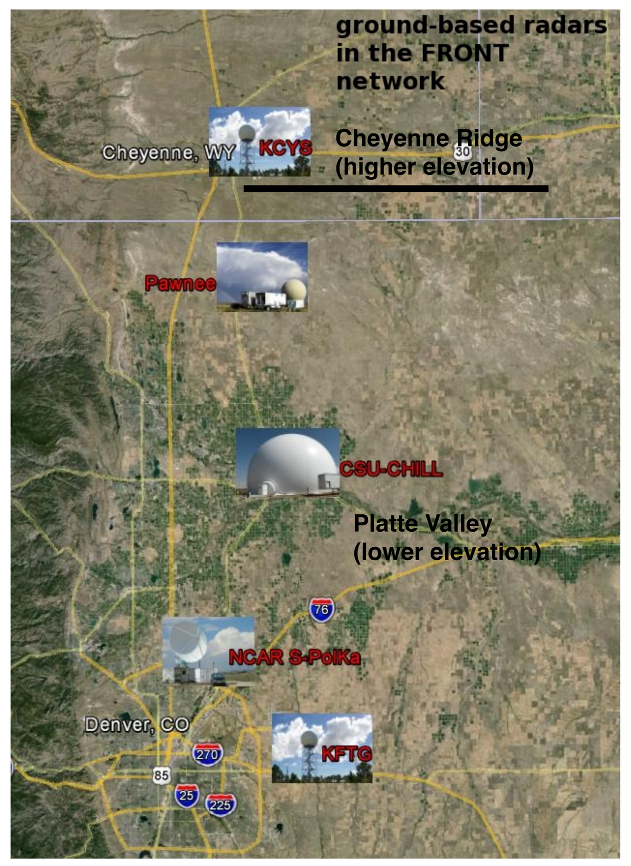
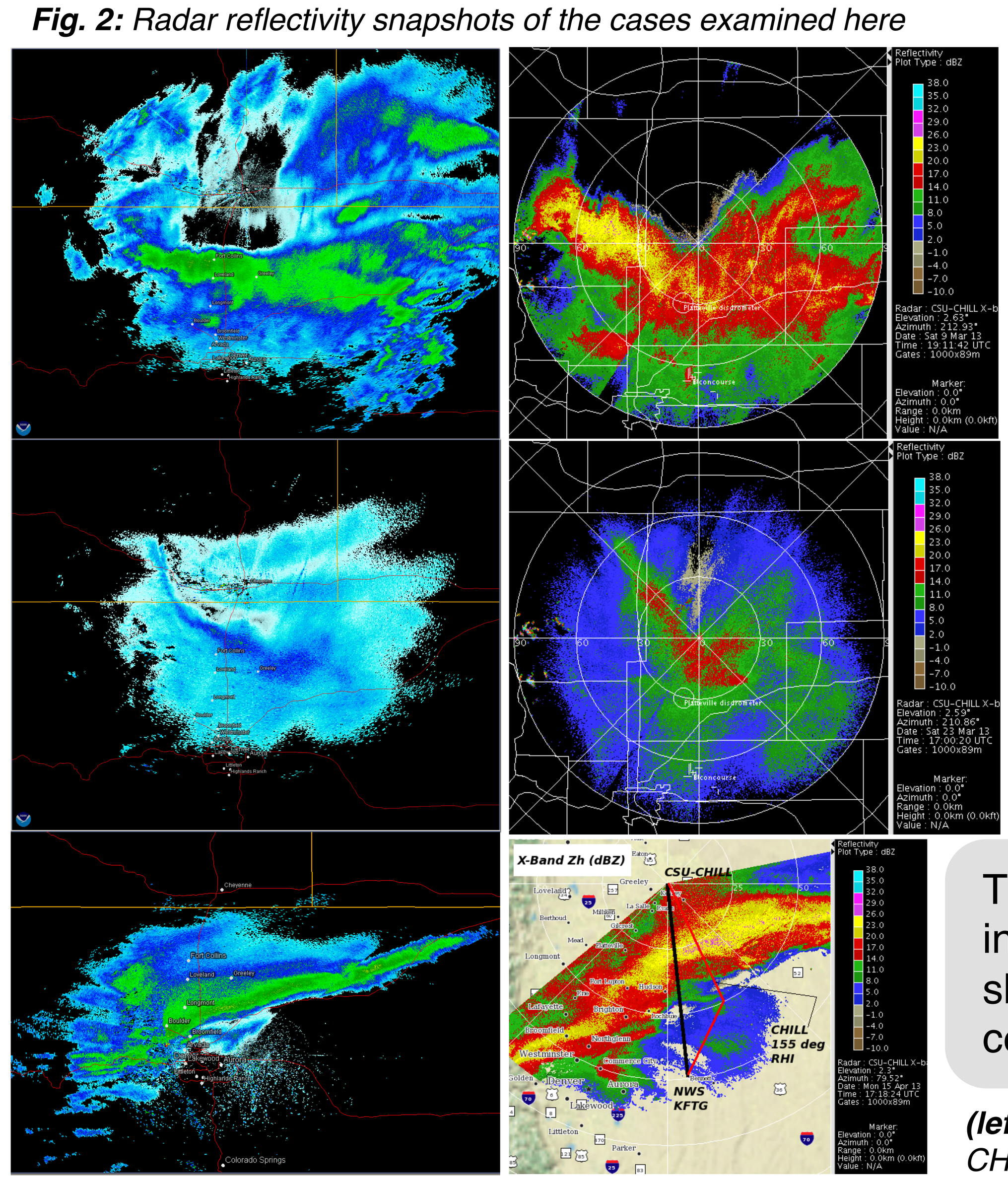


Fig. 1: Location of CSU-CHILL and other radars

THE SNOWBAND CASES

Fig. 2: Radar reflectivity snapshots of the cases examined here



(left) *KCYS at 1901 UTC 9 March* ***(right)*** *CHILL at 1911 UTC West-east enhanced band, with "hole" to the north*

These two cases both exhibit a wave-like banding structure

(left) *KCYS at 1702 UTC 23 March* ***(right)*** *CHILL at 1700 UTC SW-NE band, again with "hole" to north*

This event had several narrow, intense snowbands; observations show convective "generating cells" (e.g., Kumjian et al. 2014)

(left) *KFTG at 1704 UTC 15 April* ***(right)*** *CHILL at 1718 UTC. Intense SW-NE band*

Questions to address:

- What was responsible for the wave-like banded structures in the 9 March and 23 March 2013 events?
- What dynamical and microphysical processes were at work in the intense bands on 15 April 2013?

In addition to the radar observations, WRF-ARW numerical simulations were conducted for each of the three events

- Initialized at 0000 UTC 9 March, 23 March, and 15 April, respectively
- 4-km horizontal grid spacing, 51 vertical levels, GFS initial/lateral boundary conditions, Morrison 2-moment microphysics, single domain covering most of western and central US
- 2 nested grids (1.33-km and 444-m grid spacing) were also added over Colorado for the 15 April simulation

RESULTS: 9 AND 23 MARCH CASES

- Model successfully simulates the "band/hole" wave-like structure of the observed snowfall pattern

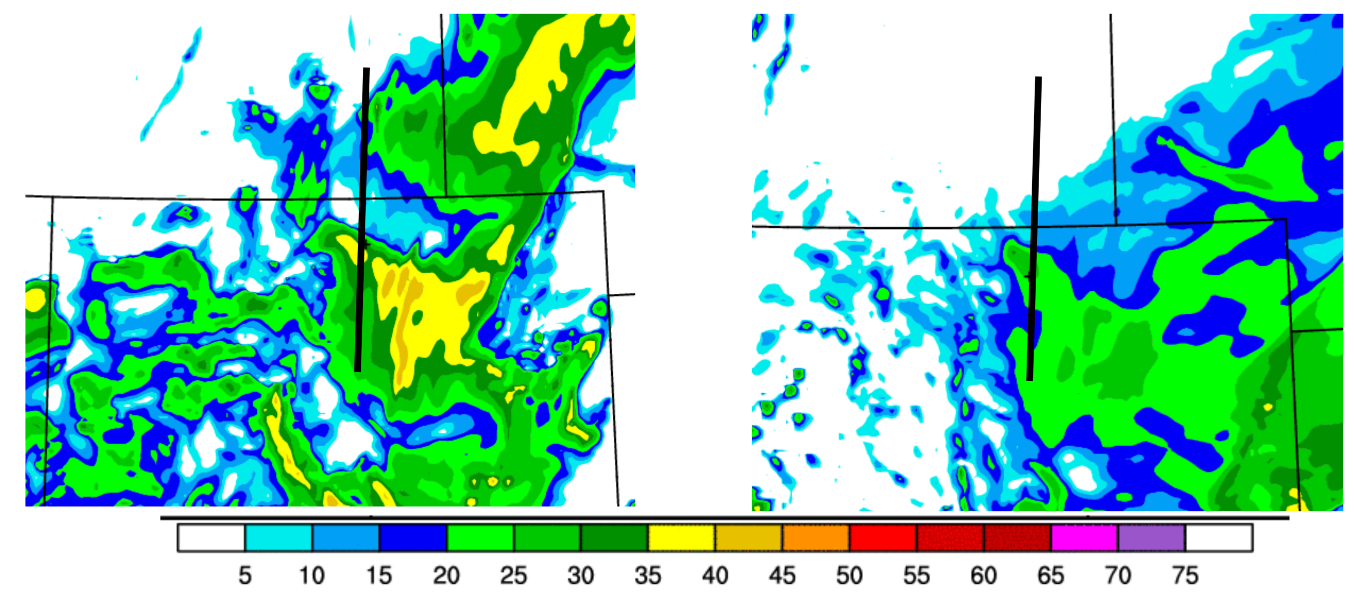


Fig. 3a: *Simulated 10-cm reflectivity at 1 km AGL at 1900 UTC 9 March 2013*

Fig. 3b: *Simulated 10-cm reflectivity at 1 km AGL at 1700 UTC 23 March 2013*

- Low-level northerly flow prevailed in both cases, and vertical sections through the bands reveal a nearly stationary wave with downslope flow over the Cheyenne Ridge, and then upward motion to its south --- this wave persists for several hours

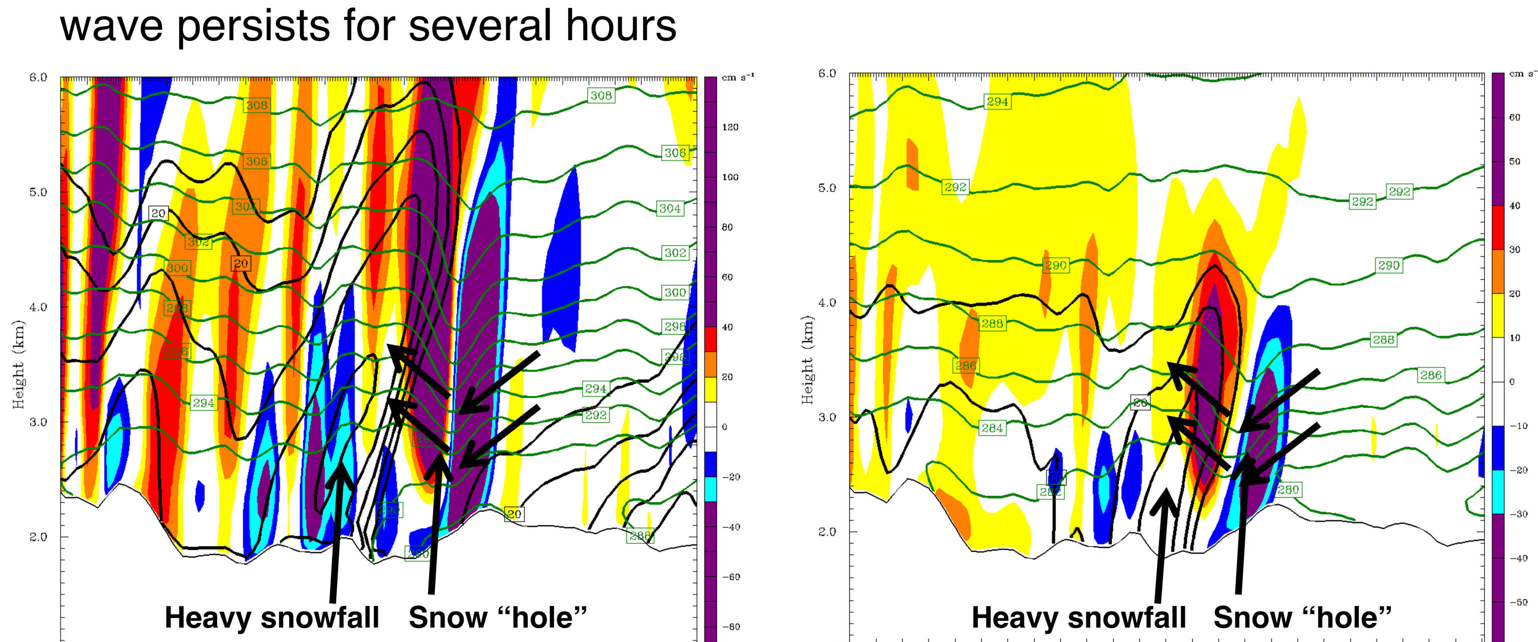


Fig. 4: *Vertical sections showing vertical velocity (colors, cm/s); potential temperature (green contours every 2 K; and simulated reflectivity (black contours every 5 dBZ starting at 15) for (a) 1900 UTC 9 March and (b) 1700 23 March 2013*

- Upstream soundings from the two events are quite similar, with shallow mixed layer topped by a stable layer and then a moist-neutral layer: likely favorable for wave trapping

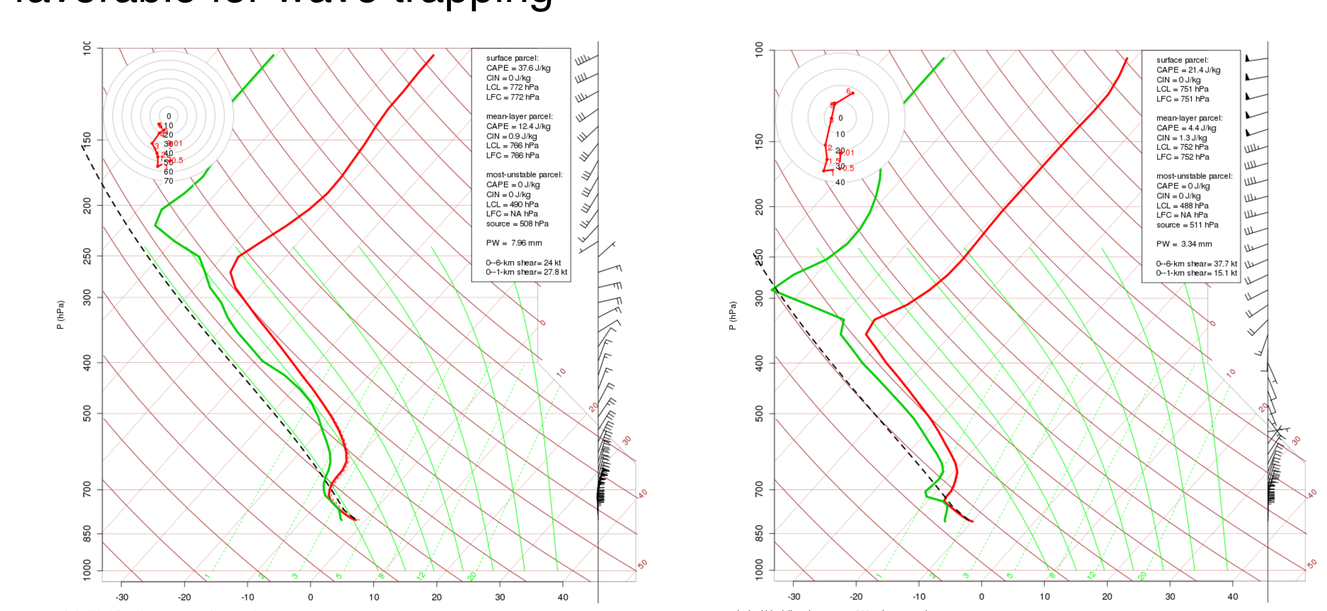


Fig. 5: *Model-simulated soundings at Cheyenne, Wyoming at (a) 1900 9 March and (b) 1700 23 March 2013*

ACKNOWLEDGMENTS

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RESULTS: 15 APRIL CASE

- Again, the model simulates the observed appearance of the snowbands

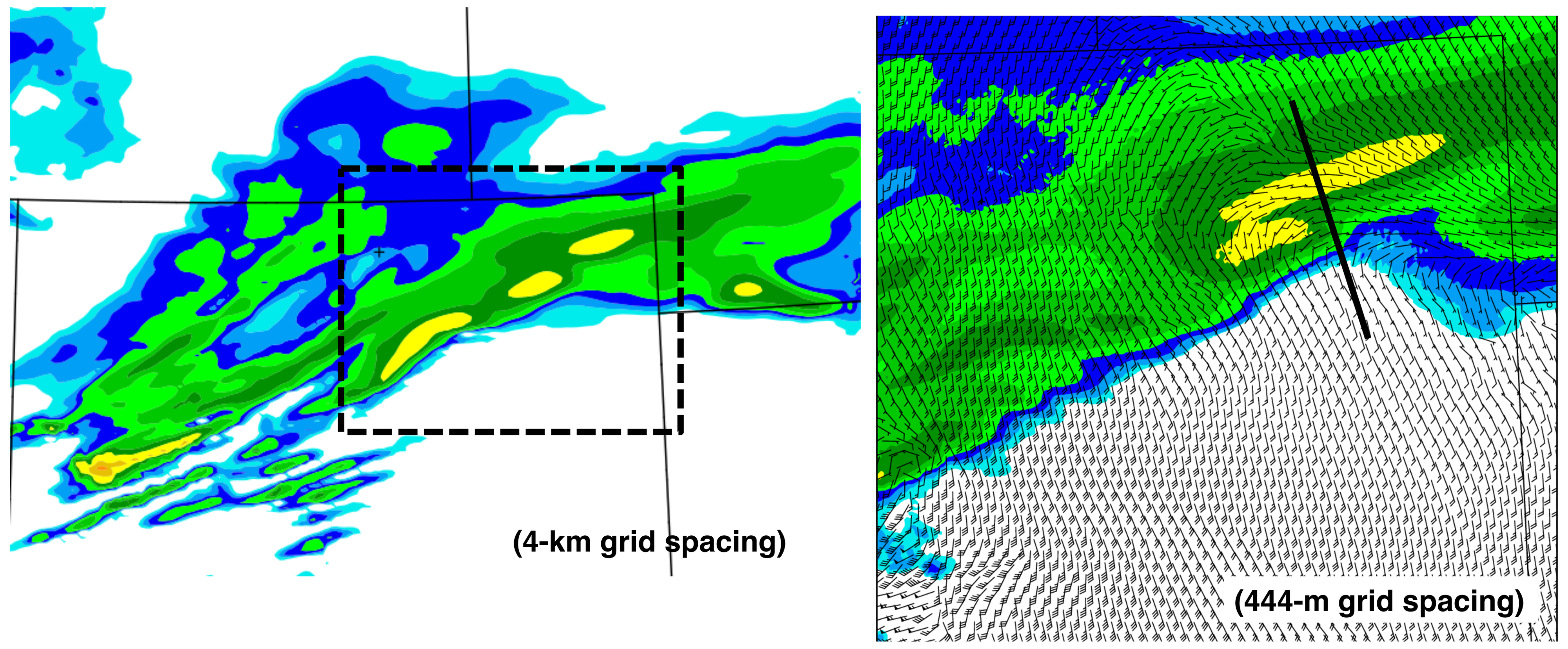

Fig. 6: *Simulated 10-cm reflectivity at 1 km AGL at 1400 UTC 15 April 2013 for (a) a real-time 4-km forecast, and (b) a 444-m nested grid. Panel (b) also shows winds at 1 km AGL.*

- CHILL X-band observations show convergent flow at the leading edge of the band at low levels, with a midlevel "overhang" of high reflectivity associated with a convective generating cell

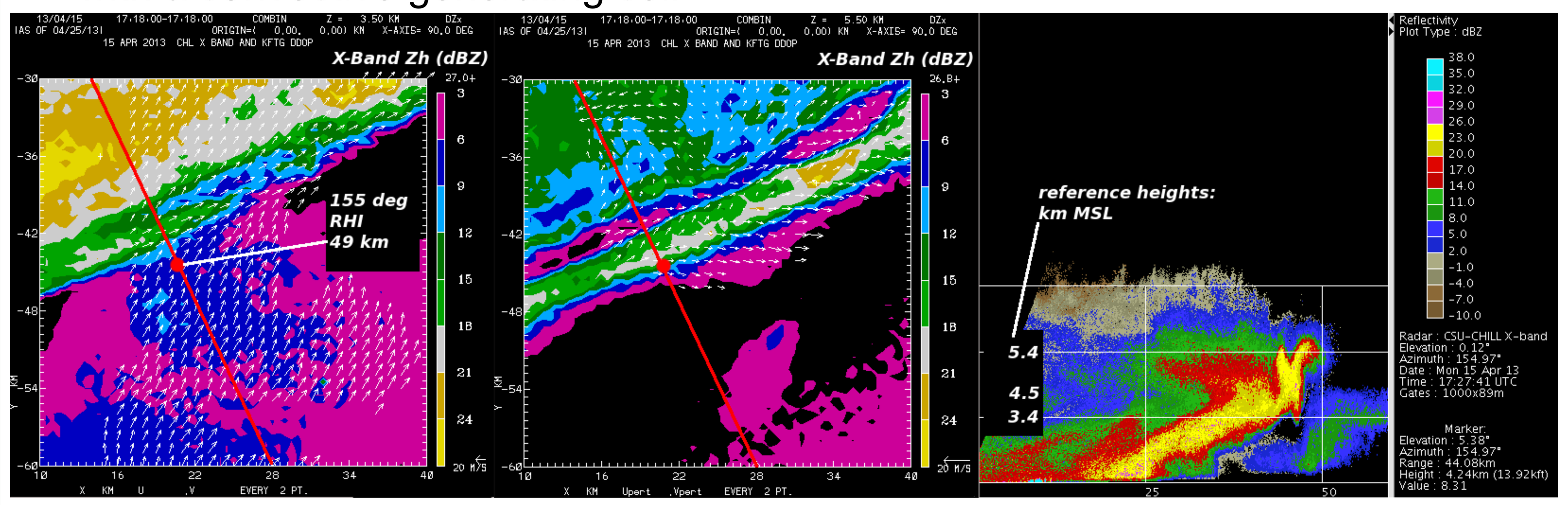

Fig. 7: *CHILL observations and dual-Doppler analysis observations at 1727 UTC 15 April 2013. (a) CAPPI of reflectivity and total winds at 3.5 km MSL. (b) As in (a) except at 5.5 km MSL and showing the perturbation winds. (c) RHI of reflectivity through the band*

- Qualitatively, the 444-m simulation illustrates a very similar structure with updrafts on the order of 0.5 m/s in a region of near-zero $d\theta_e/dz$, similar to the environments observed in other Colorado cases and in the literature—more investigation is needed to understand both the simulated and observed bands

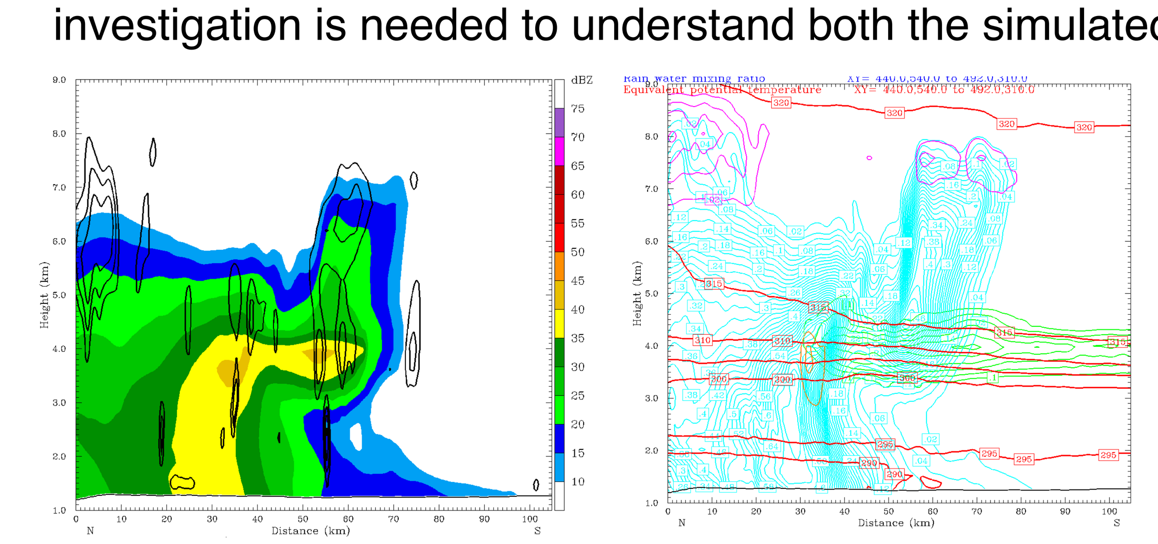

Fig. 8: *(a) Cross-section of simulated reflectivity and vertical velocity (contoured every 10 cm/s starting at 20) (b) Cross-section of microphysical mixing ratios and θ_e (red contours) through the band shown in Fig. 6.*
Cloud water
Snow
Graupel
Cloud ice

SUMMARY

- Observations and simulations illustrate the complex set of processes associated with heavy snowbands in Colorado in 2013
- A standing wave developed south (downstream) of the Cheyenne Ridge in the 9 March and 23 March that caused a "hole-and-band" snowfall structure
- In the 15 April case, a generating cell was observed to overhang the surface snowfall, which was qualitatively simulated in a high-resolution simulation
- More in-depth analysis of both observations and simulations are required to understand the mechanisms associated with these bands