Comparison of One-Dimensional Pseudo-Lagrangian and Three-Dimensional Fully Lagrangian Trajectories when Forecasting Hail Size

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BACKGROUND

- CAM-HAILCAST uses one-dimensional updraft profiles retrieved from CAM grid columns as input to its hail model.
- An updraft multiplier is applied to mimic the embryo's path across the updraft ("pseudo-Lagrangian", or quasi-1D; Adams-Selin and Ziegler 2016).

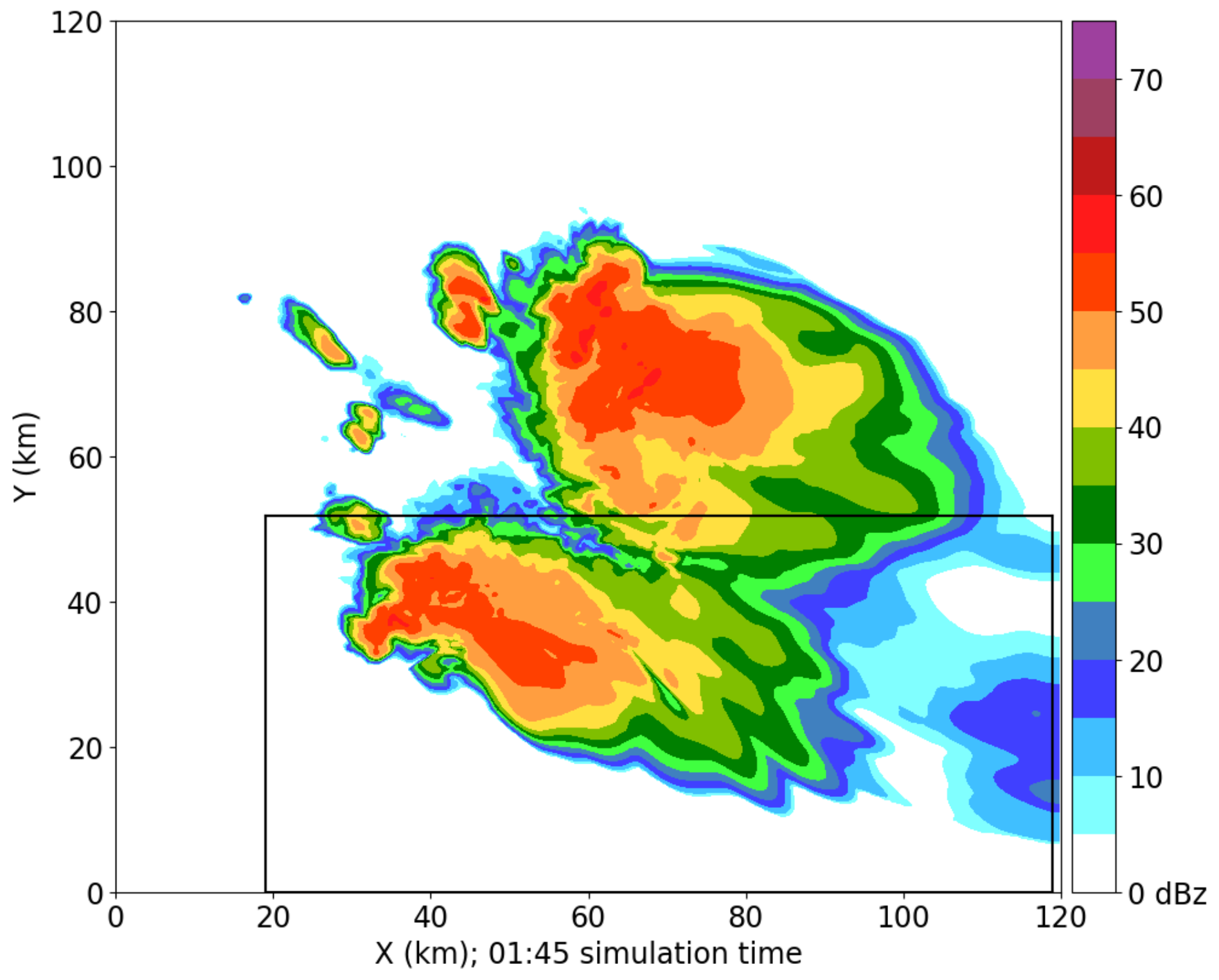
$$W_{hail}(z,\tau) = \left(0.6\sin\frac{\pi\tau}{2000}+0.6\right)W(z)$$

PURPOSE

How important are incorporating three-dimensional characteristics of hailstone trajectories when considering hail growth?

EXPERIMENT DESIGN

- CM1 was used to simulate the Kingfisher, OK hail-producing supercell with 250-m horizontal and vertical grid-spacing with Morrison microphysics. The 29 May 2012 0000 UTC KOUN sounding with moistened lower levels was used for initialization. The simulation was run for 1.75 h until the supercell reached maturity (below).



- Both quasi-1D and 3D hail trajectories were initialized every 250 m, at heights from 3.75 to 11.5 km, and at initial sizes of 7 and 10 mm.
- Updraft duration in the quasi-1D trajectories was capped at 2000 s as in ASZ16.. Steady state conditions were permitted for 3600 s in 3D trajectories.

REFERENCES

Adams-Selin, R.D. and C.L. Ziegler, 2016: Forecasting hail using a one-dimensional hail growth model within WRF. *Mon. Wea. Rev.*, **144**, 4919–4939.

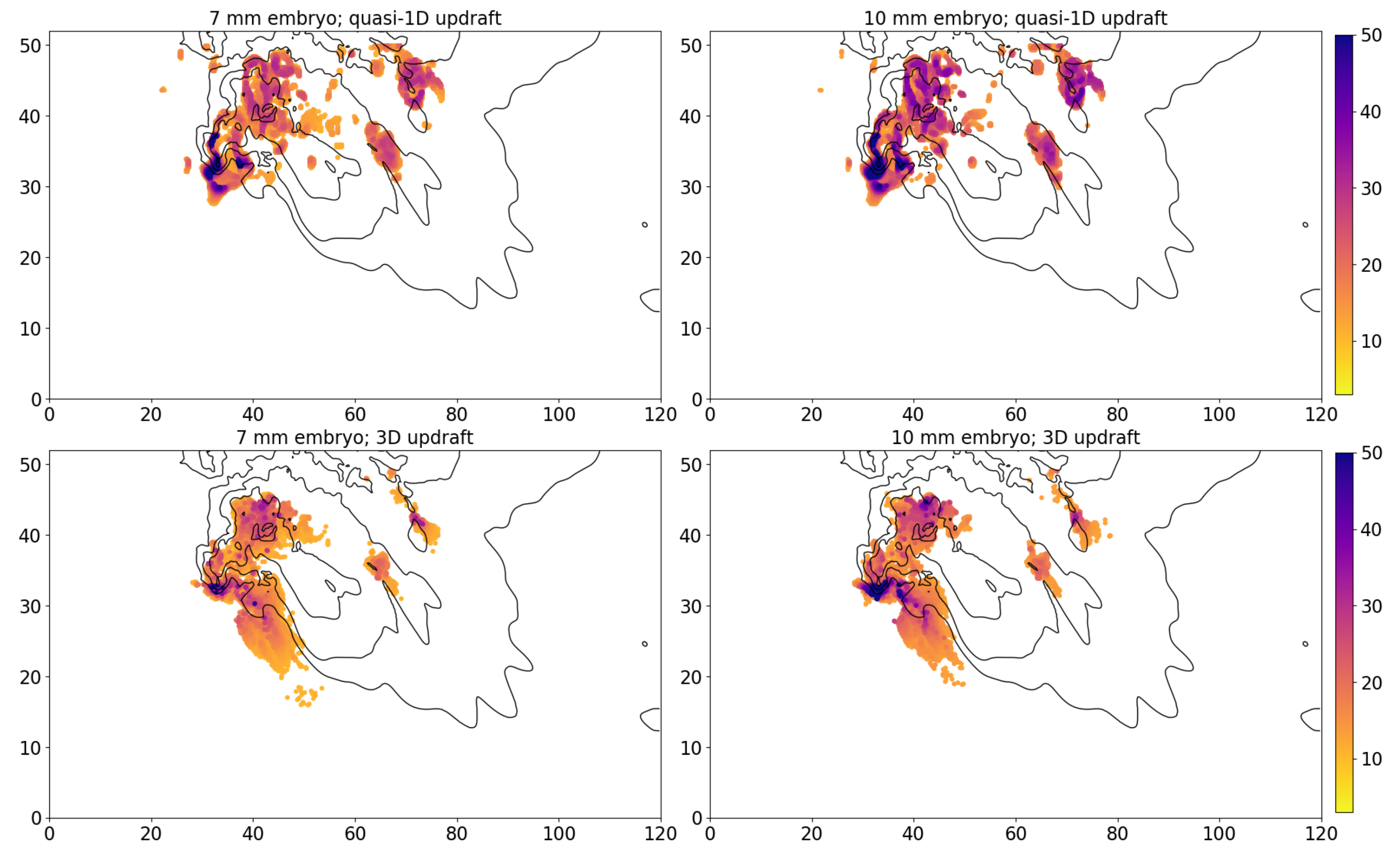


Fig. 1: Final hail diameter (mm) at location it reached the surface. Lowest-level model reflectivity shown in black (20, 40, 50 dBZ).

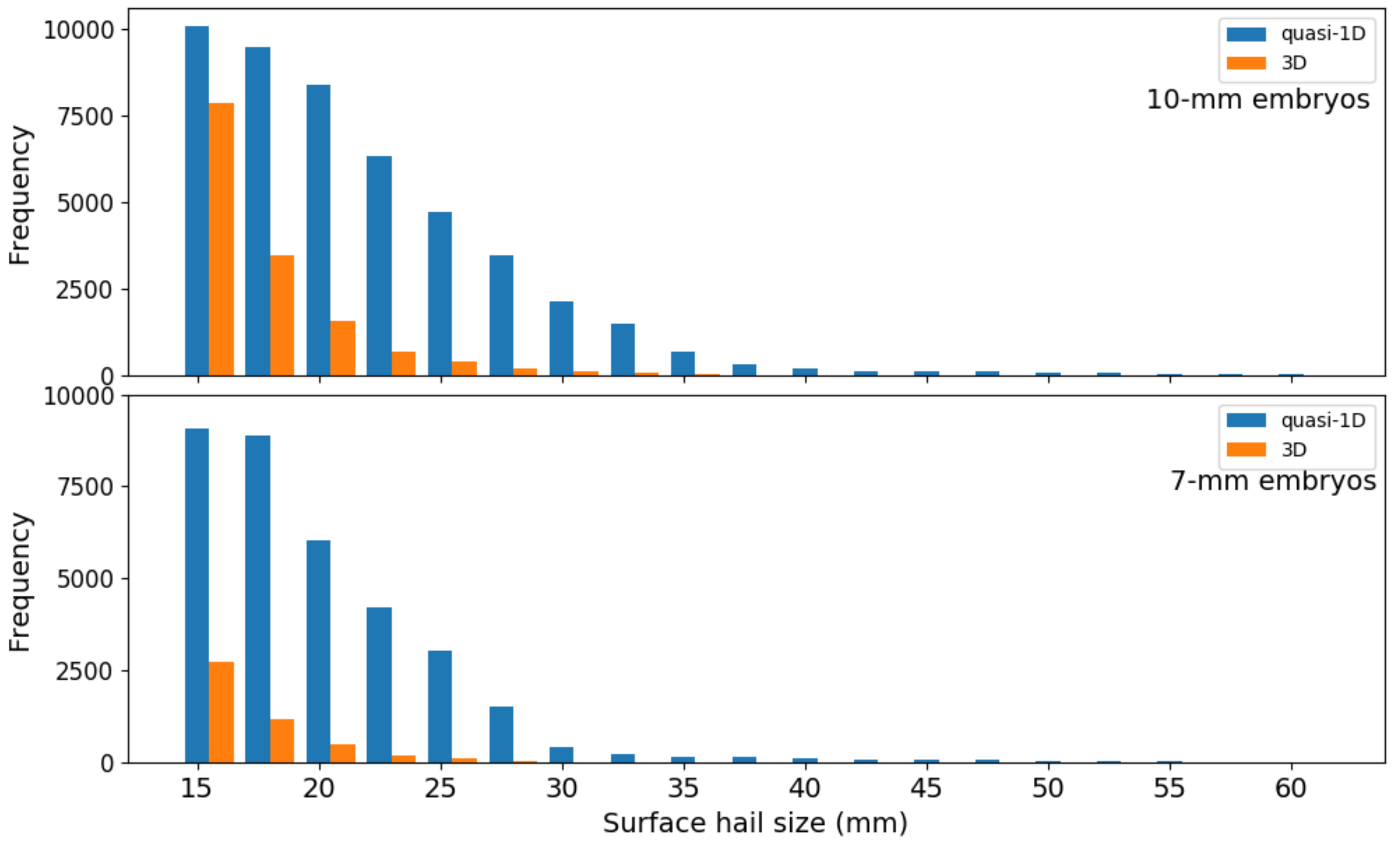


Fig. 2: Hail size distribution produced by quasi-1D (blue) and 3d (orange) trajectories for 10=mm (top) and 7-mm (bottom) initial embryo sizes.

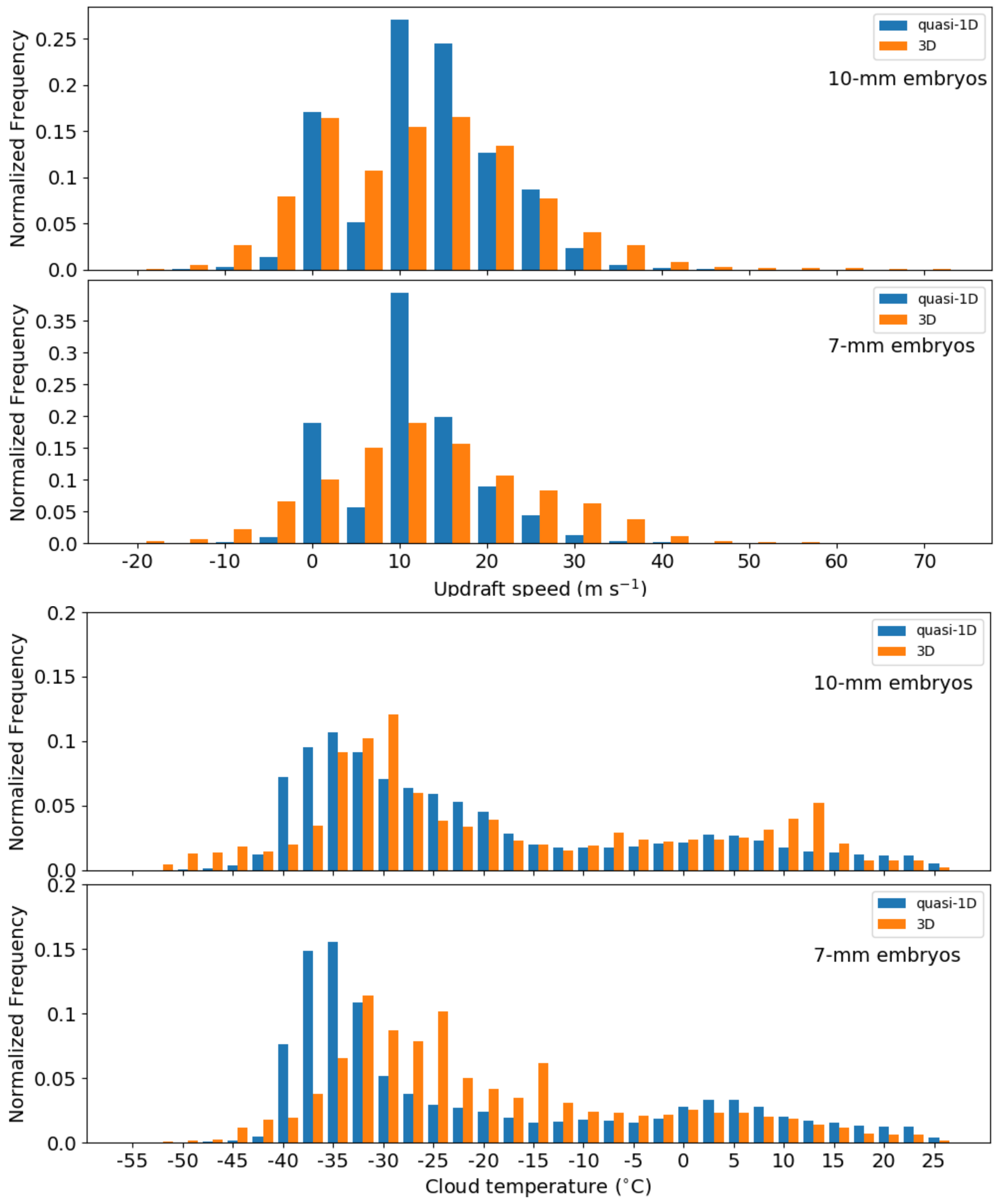


Fig. 3: Histogram of updraft speed (top two panels) and cloud temperature (bottom two panels) for trajectory duration for all hailstones with a final size of 25 mm or larger.

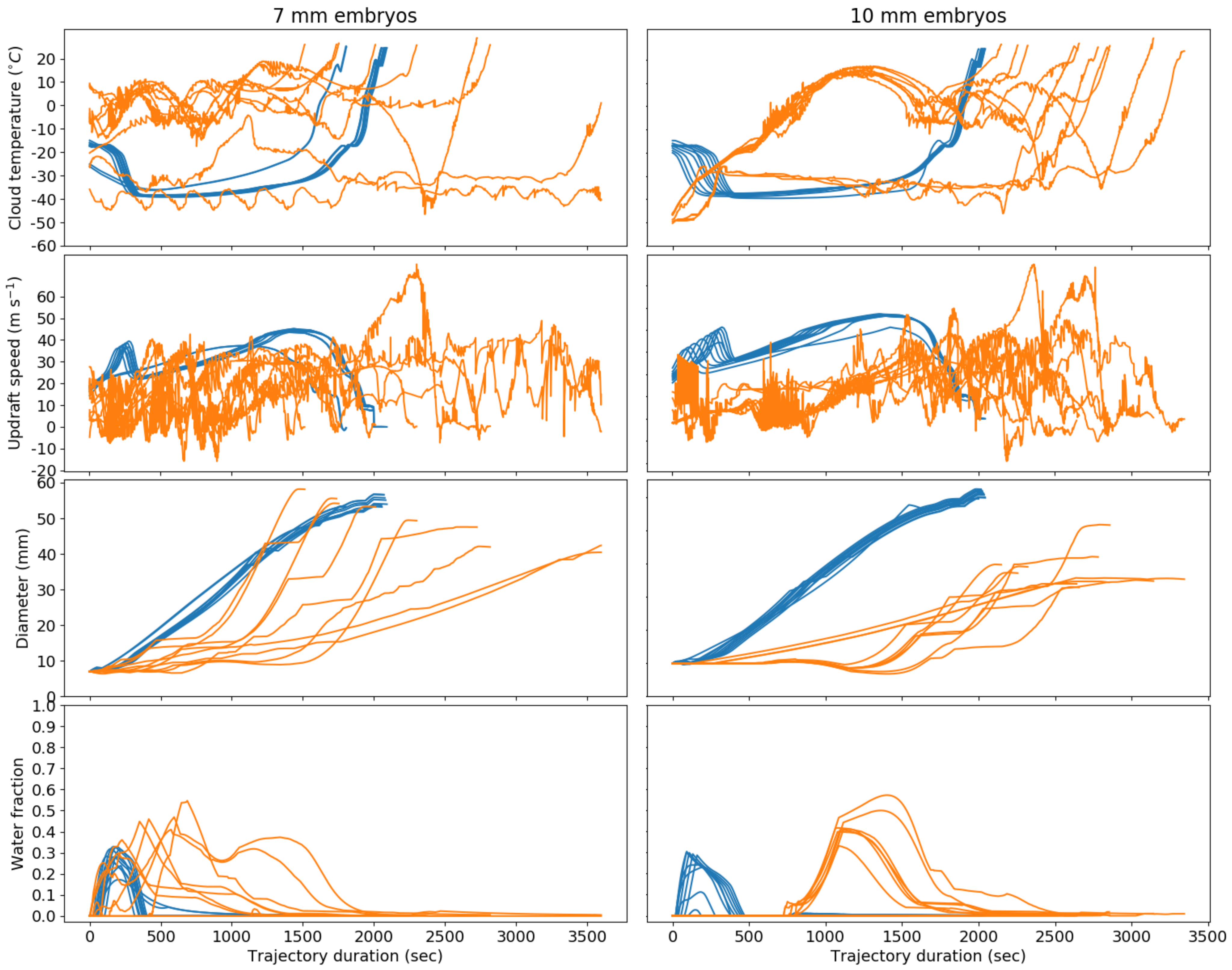


Fig. 4: Timeseries of (first row) cloud temperature, (second row) updraft speed, (third row) diameter, and (fourth row) hailstone water fraction for the trajectories of the 10 largest hailstones produced within each of the quasi-1D (blue) and 3D (orange) methods.

CONCLUSIONS

Despite the pseudo-Lagrangian nature of the quasi-1D trajectories, the 1D hailstones are still spending too much time lofted in the updraft center at colder temperatures. The 3D trajectories spend more of their time at warmer temperatures, circling the updraft below the melting level before being lofted above around 1500 s. Even though the 1D hailstones spend more of their time above the liquid water-rich layer, they grow larger than the 3D hailstones as they spend more of their time in a dry growth regime. **These results suggest our next approach: given many idealized hailstorm simulations across a variety of environments, can machine learning techniques be used to better parameterize 3D trajectories via 1D process?**

ACKNOWLEDGEMENTS

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