Thermodynamic and Kinematic Observations within Severe Convective Storm Updrafts

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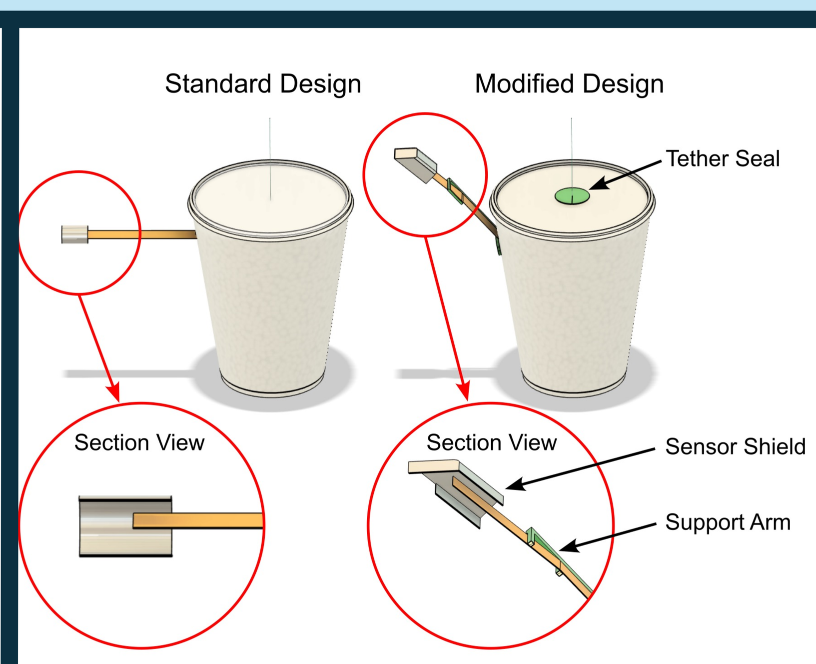
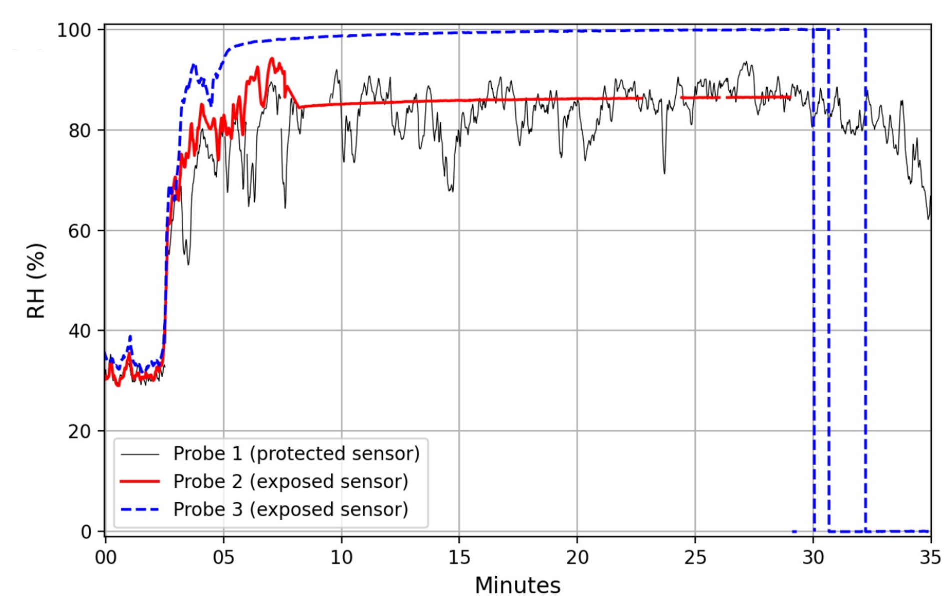
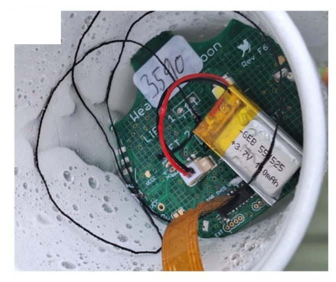
SUMMARY: During the NSF-funded In-situ Collaborative Experiment for the Collection of Hail in the Plains (ICECHIP) in summer 2025, balloon-borne probes, Windsonds from Sparv Embedded, were released into the inflow regions of supercells to obtain observations within the storms' updrafts. This allows for exploration of how updraft thermodynamic and kinematic profiles vary between storms and within the lifetime of a storm.

	DATE	LAUNCH TIME (UTC)	LAUNCH TIME (LOCAL)	LAUNCH LAT / LON	LOCATION
IOP7	29 MAY 2025	2156	4:46 PM	33.12, -102.26	Lubbock, TX
		2206	5:06 PM	33.10, -102.25	
IOP11	05 JUNE 2025	2228	5:28 PM	33.75, -102.76	Morton, TX
		2347	6:47 PM	33.59, -102.17	
IOP12	06 JUNE 2025	2232	5:32 PM	33.50, -102.96	Levelland, TX
		2333	6:33 PM	33.46, -102.61	
		2348	6:48 PM	33.39, -102.61	
		0027	7:27 PM	33.33, -102.23	
		0047	7:47 PM	33.33, -102.08	
IOP19	17 JUNE 2025	0039	7:39 PM	36.13, -100.05	Higgins, TX
		0119	8:19 PM	35.89, -99.73	
		0132	8:32 PM	35.78, -99.71	
		0157	8:57 PM	35.36, -99.44	
IOP20	20 JUNE 2025	2352	5:52 PM	45.60, -103.55	Bison, SD
		2357	5:59 PM	45.60, -103.55	
		0105	7:16 PM	45.53, -102.46	
IOP21	22 JUNE 2025	2321	6:22 PM	42.09, -99.07	Chambers, NB

A notable feature observed in all updraft thermodynamic profiles is an increase in equivalent potential temperature (θ_e). Theroretically, θ_e is conserved for saturated parcels undergoing pseudo-adiabatic motion. This suggests either (1) the probes are translating across different airmasses within the updraft, or (2) microphysical processes within the storm alter the updraft θ_e, deviating from conservation principles.

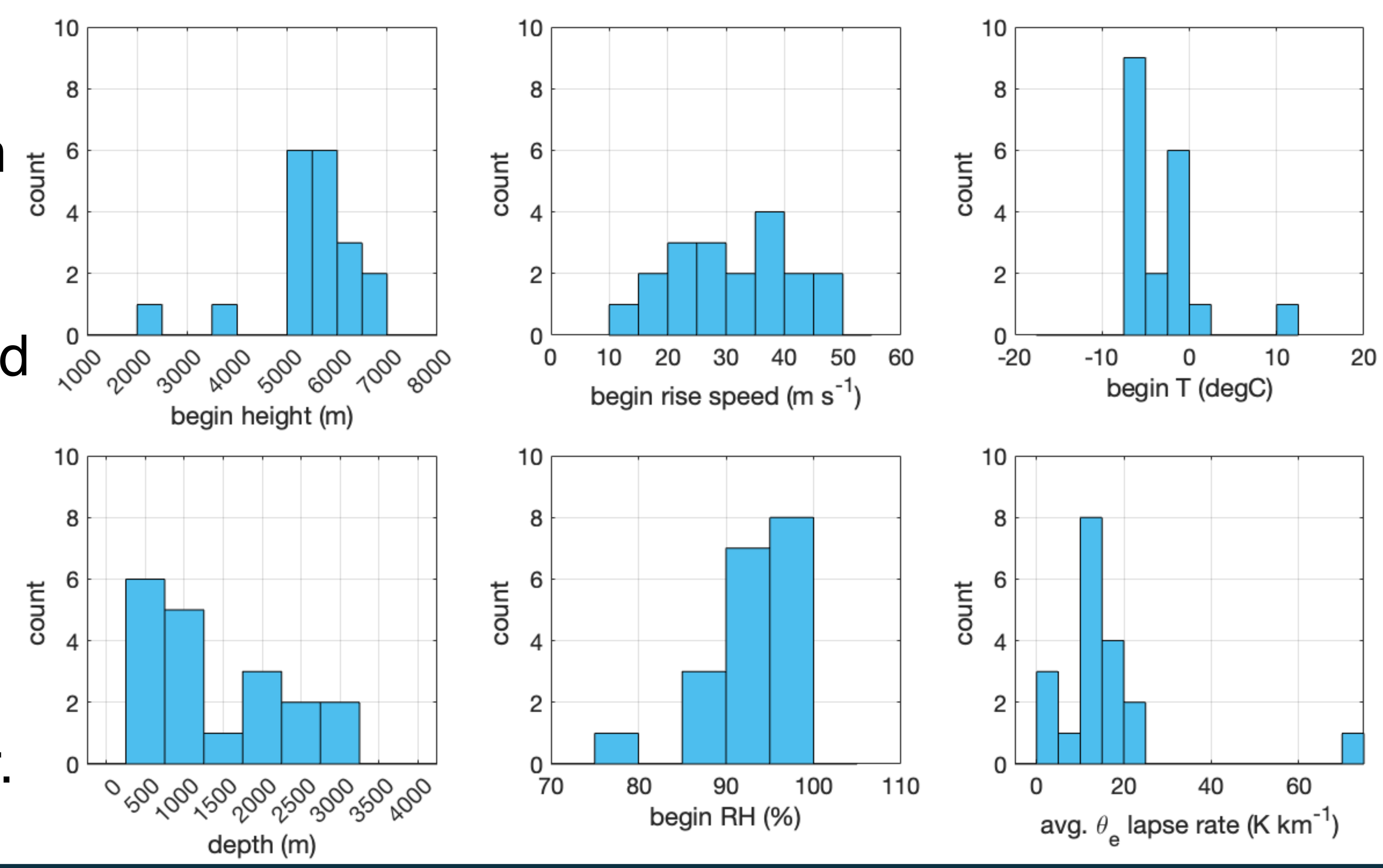




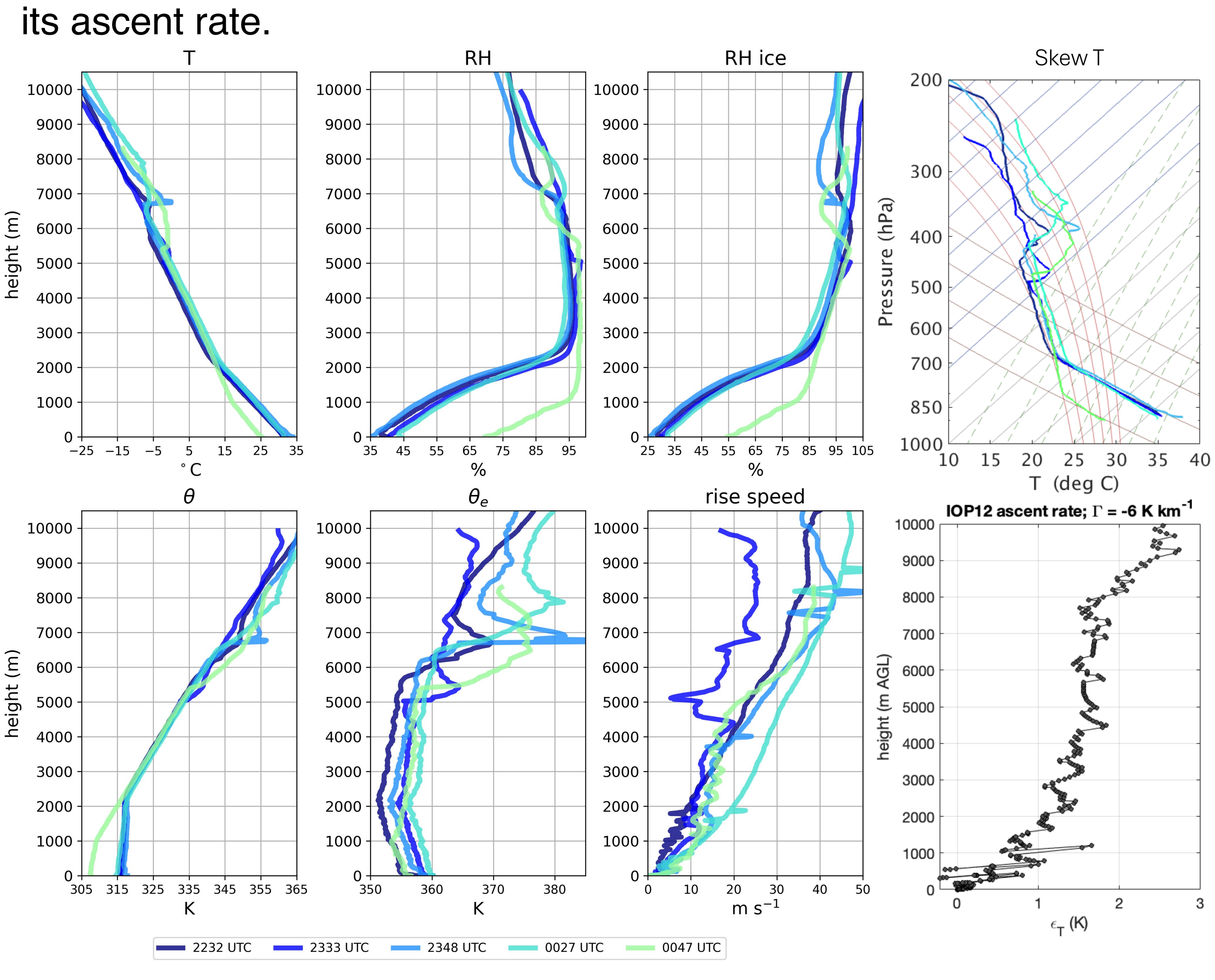


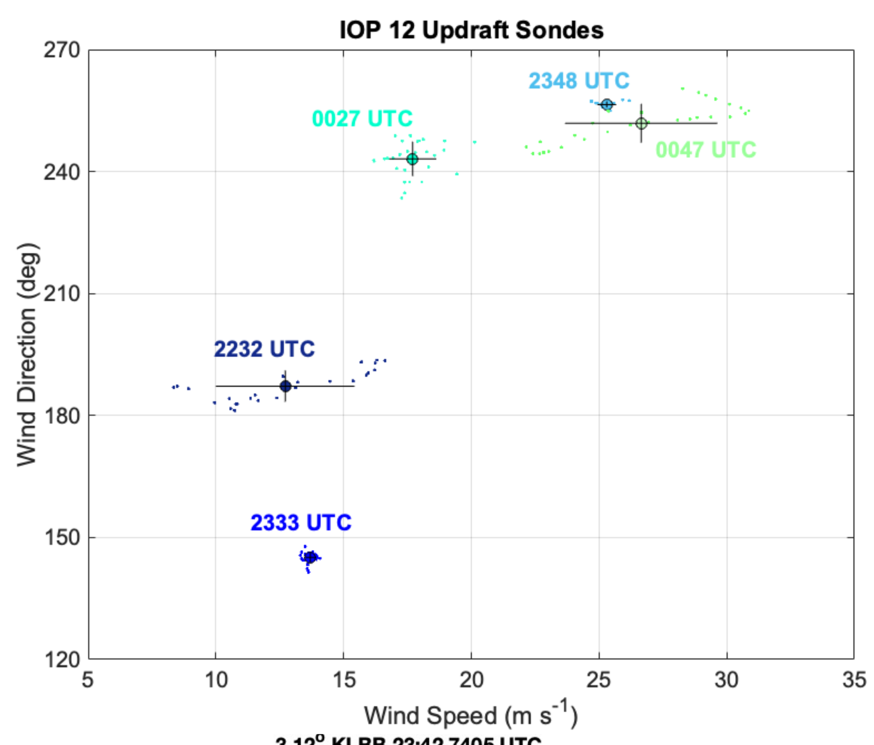
INSTRUMENT MODIFICATIONS: Modifications were made to protect the Windsonds' temperature and relative humidity sensors from precipitation[1]. Common sensor failure modes from water ingress: suppressed relative humidity (RH) variability (probes 2 & 3), software re-initializations and power failure (probe 2), erroneous RH saturation and folding (probe 3).

LAYER OF INCREASING θ_e WITH HEIGHT CHARACTERISTICS: The θ_e increase typically begins between 5000–7000 m in altitude within the storm updraft; therefore, T at the bottom of the layer is often <0 ºC. Layer depths range from 250 – 3000 m, with average θ_e lapse rates within the layer typically between 10–20 K km^{-1}. At the bottom of most layers, RH >90%. These layers are observed within a variety of updraft speeds, with ascent rates ranging from 10–50 m s^{-1} at the bottom of the layer.

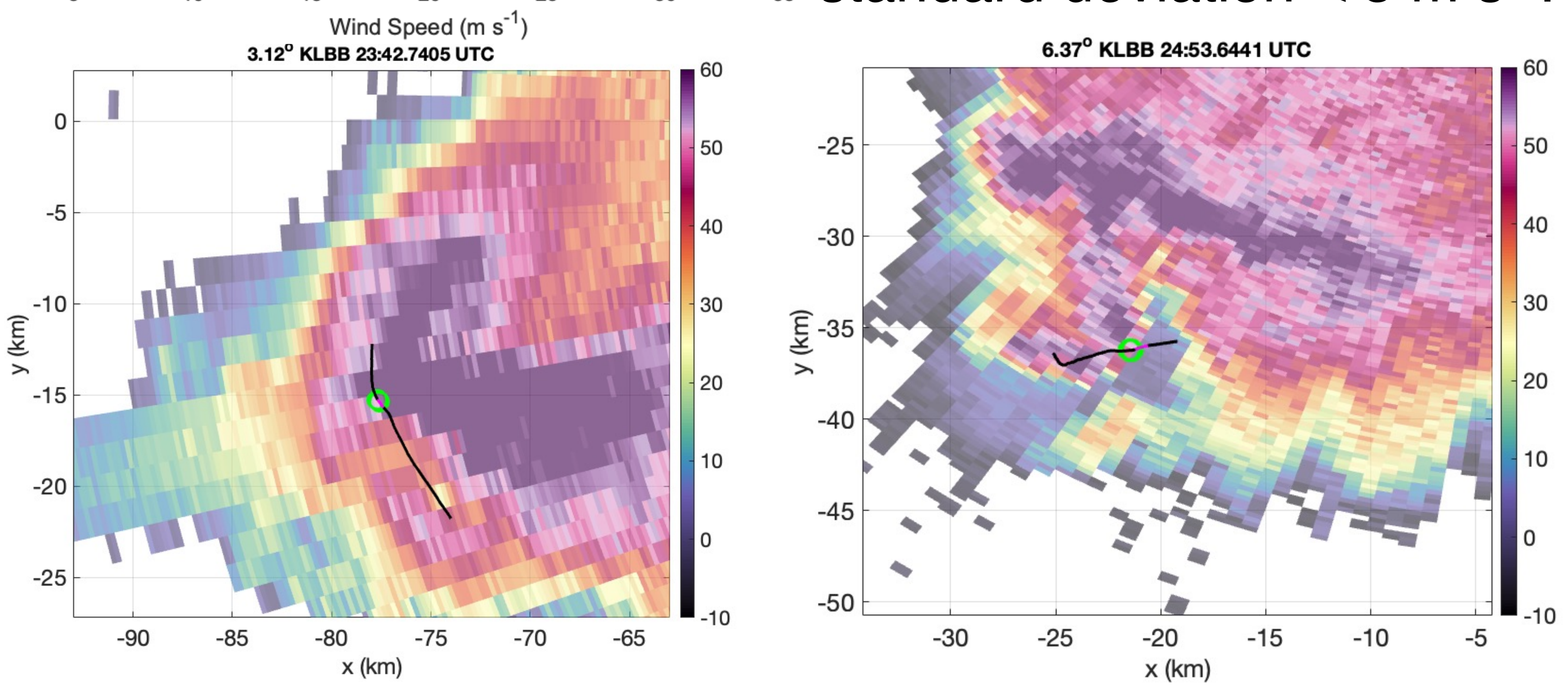


IOP 12 CASE STUDY: Data from ICECHIP IOP12 are shown as an example. Sondes enter cloud at ≤2 km AGL, whereupon T lapse rate changes and RH nears saturation. At between 5–7 km AGL, sondes measure a clear jump in T and θ_e. Rise speed generally increases throughout this layer. In some cases, the peak θ_e value is larger than any recorded in the inflow. The T (and thus θ_e) increases are much larger than can be explained by the instrument's response time given its ascent rate.





Wind direction is notably uniform within the θ_e layer, with a standard deviation typically between 1–10°. The standard deviation of wind speed ranges from near zero – 8 m s^{-1}, though ~75% of cases have a standard deviation < 5 m s^{-1}.



The θ_e increase occurs when the sondes are near the radar-observed BWER. However, the increase occurs in regions of large (>60 dBz) reflectivity values, too, suggesting it is not *simply* the BWER, but rather a region of the updraft with greater positive buoyancy and precipitation-sized hydrometeors.

[1]*Soderholm, J. K. Lombardo, and M. R. Kumjian: Modifying Windsonds to improve in-storm measurements. Atmos. Meas.Tech., in prep.*

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