Evaluation of a Hail Size Discrimination Algorithm for the Polarimetric WSR-88D

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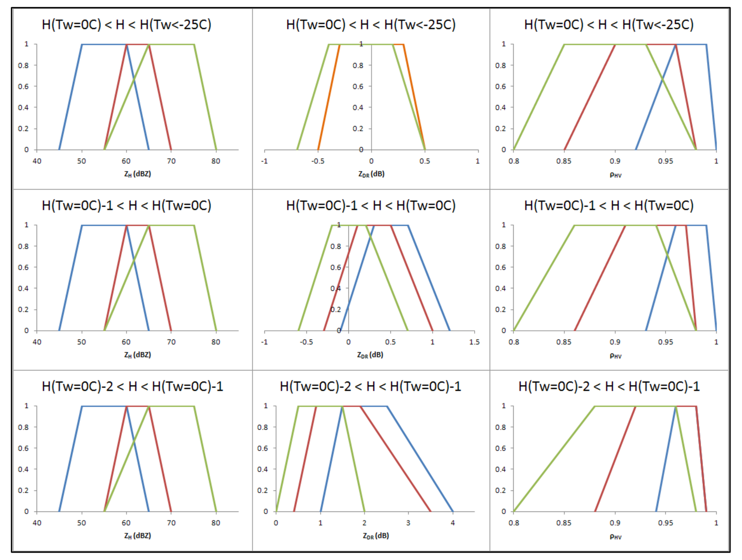
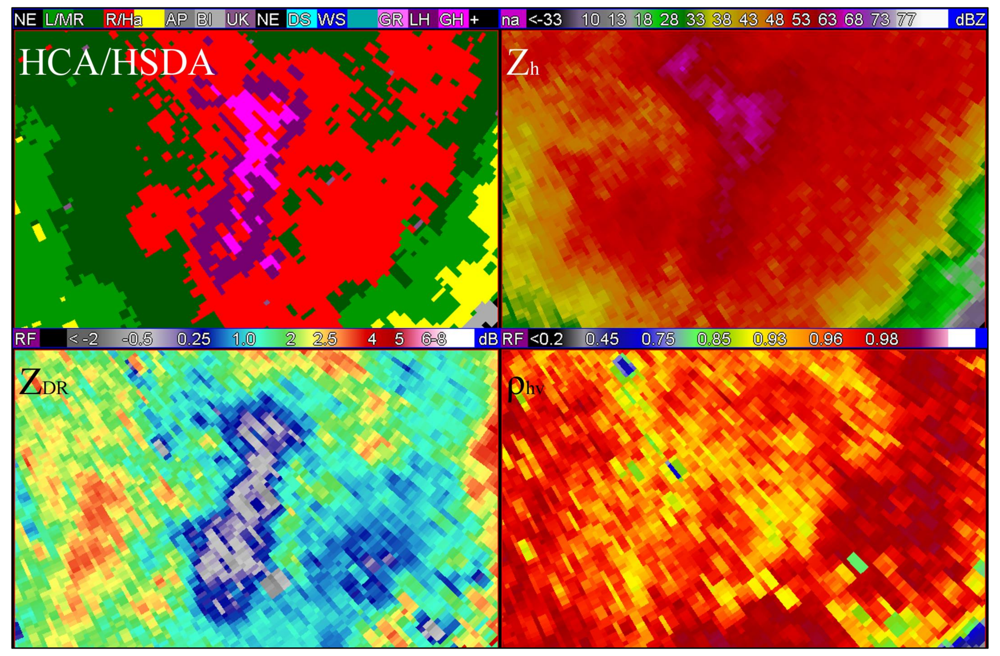
Hail Size Discrimination Algorithm

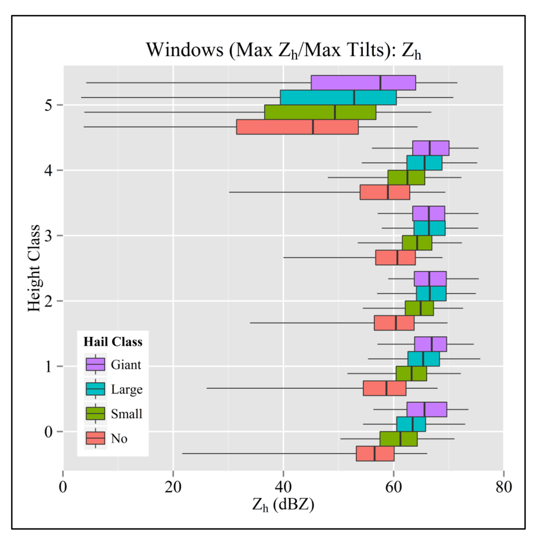


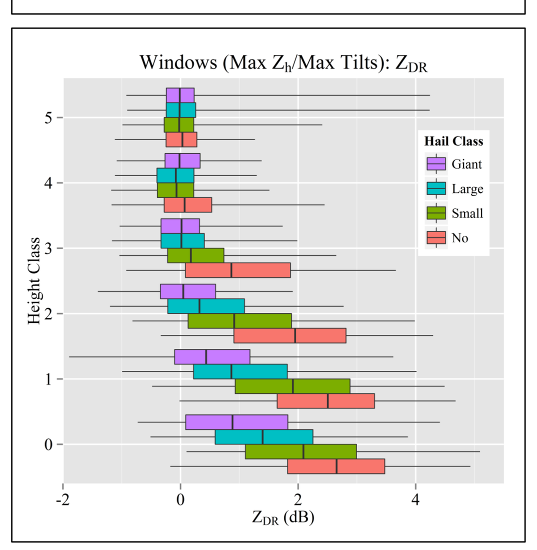


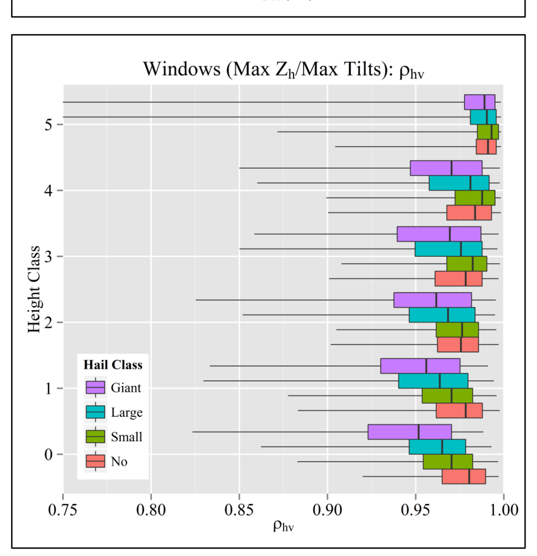
- Fuzzy logic scheme running on Hydrometeor Classification Algorithm (HCA) designations of 'Rain/Hail'
- Uses Z_h, Z_{DR}, ρ_{hv} and 6 different height layers relative to T_w = 0°C and -25°C to estimate hail size
- 3 hail size classes
  - Small (D < 25 mm)
  - Large (25 mm ≤ D < 51 mm)
  - Giant (D ≥ 51 mm)
- Tended to overestimate hail size and produce too large of areas for giant hail

Described in Ryzhkov et al. (2013, *JAMC*) *Polarimetric characteristics of melting hail. Part II: Practical implications*

Observed Distributions & HSDA Modifications

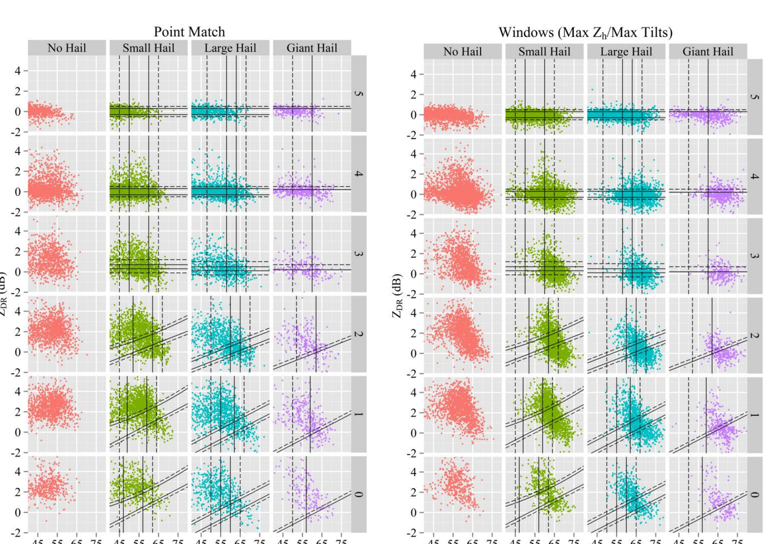






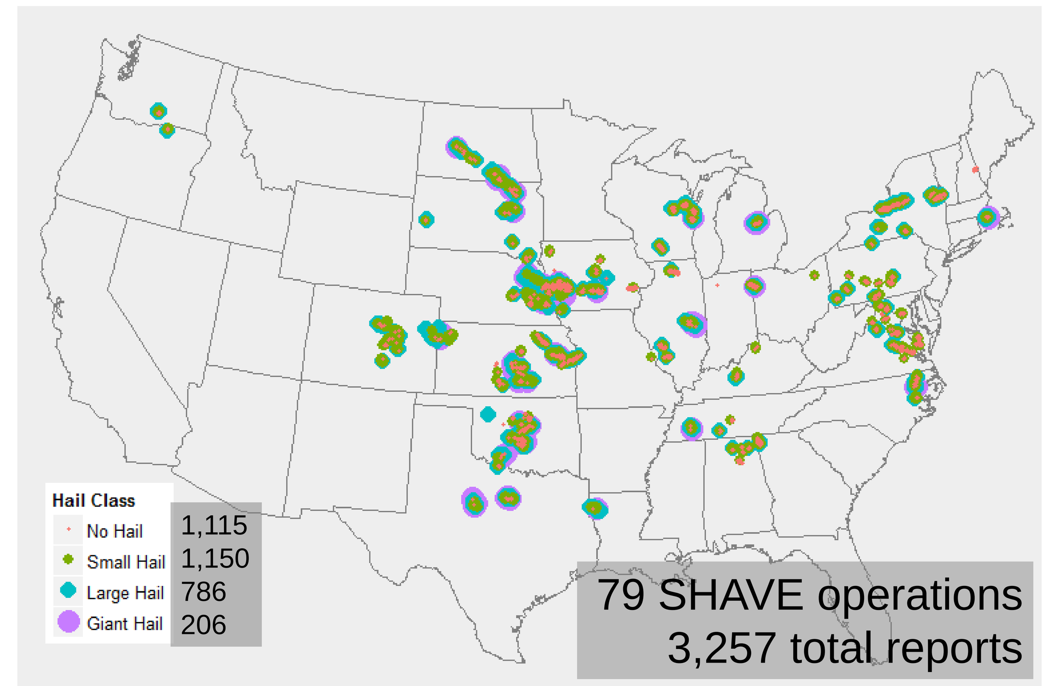
Height Classes:
5: H > H(T_w = -25° C)
4: H(T_w = -25° C) < H < H(T_w = 0° C)
3: H(T_w = 0° C) < H < H(T_w = 0° C) - 1 km
2: H(T_w = 0° C) - 1 km < H < H(T_w = 0° C) - 2 km
1: H(T_w = 0° C) - 2 km < H < H(T_w = 0° C) - 3 km
0: H < H(T_w = 0° C) - 3 km

1. Modification of membership functions
2. Membership functions for Z_{DR} as functions of Z_h
3. Adding a tunable ΔZ_{DR} parameter
4. Weighting for each parameter for each height layer
5. If a membership function for any parameter < 0.2, the aggregation value was set to 0 for that hail class
6. If no hail size class aggregation value exceeded 0.6, 'small hail' was assigned
7. If Z_{DR} ≥ 2 dB, 'large hail' and 'giant hail' were disallowed
8. A despeckle method along each radial to downgrade isolated pixels designated 'large hail' or 'giant hail'

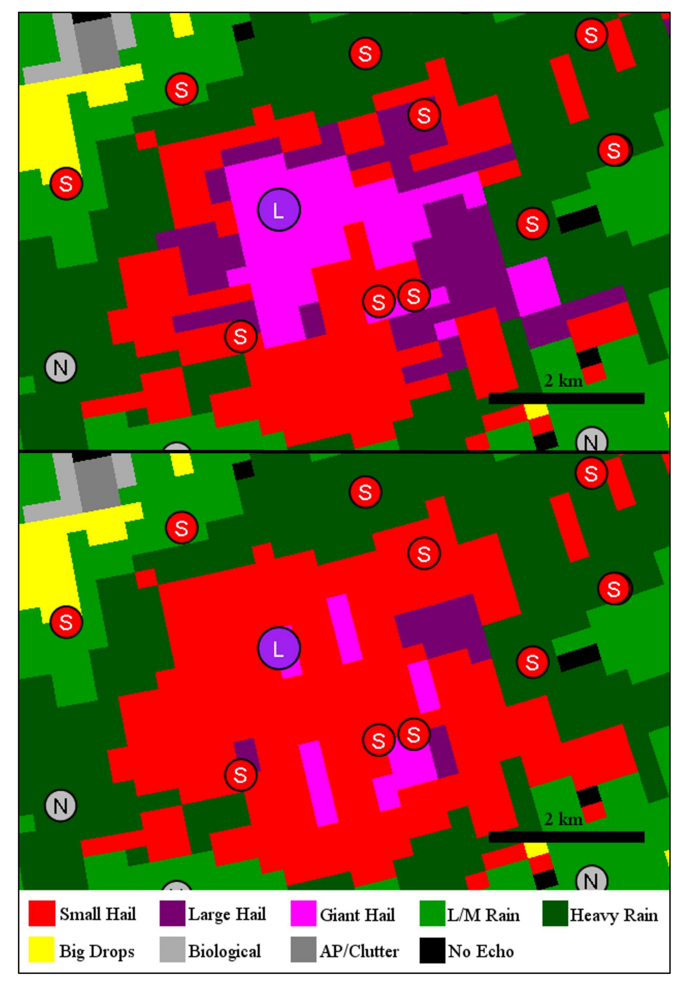


Since hail reports cannot be accurately matched temporally to radar data, multiple methods were used for matching. All methods were based on the maximal reflectivity near the report location. Left, differences between the two of the methods. Lines are new Z_{DR} membership functions.

Data and Results

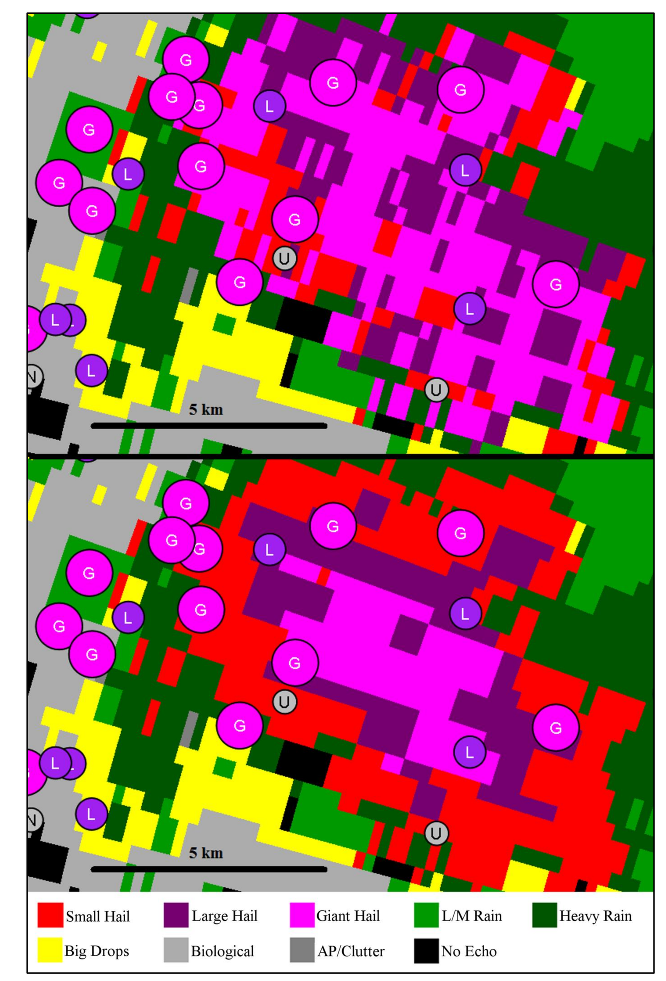


The Severe Hazards Analysis and Verification Experiment (SHAVE) calls members of the public thought to have received hail. The data is collected at high spatial resolution with reports typically spaced ~2 km. While locations and sizes are typically precise, temporal information is very imprecise.



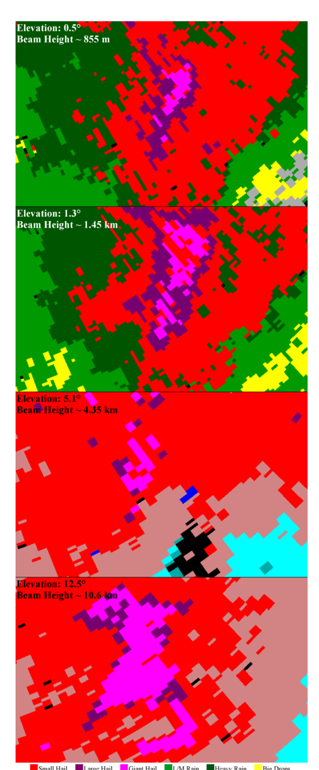
6 April 2012 0011 UTC KHTX

Giant hail false alarm area, a result of very high reflectivity, removed as a result of parameter weighting and Z_{DR} threshold of large and giant hail.



15 May 2013 2328 UTC KFWS

Spatial coherency added to the HSDA designations by restricting aggregation values to a minimum threshold, Z_{DR} threshold for large and giant hail, and by making Z_{DR} membership functions dependent on Z_h

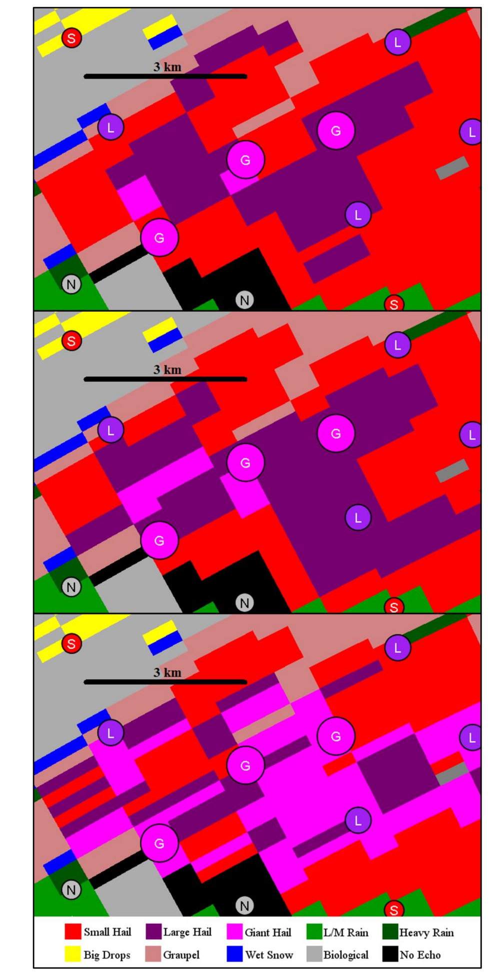


30 June 2014 1854 UTC KDMX
H(T_w = 0° C) = 3.82 km
H(T_w = -25° C) = 8.23 km

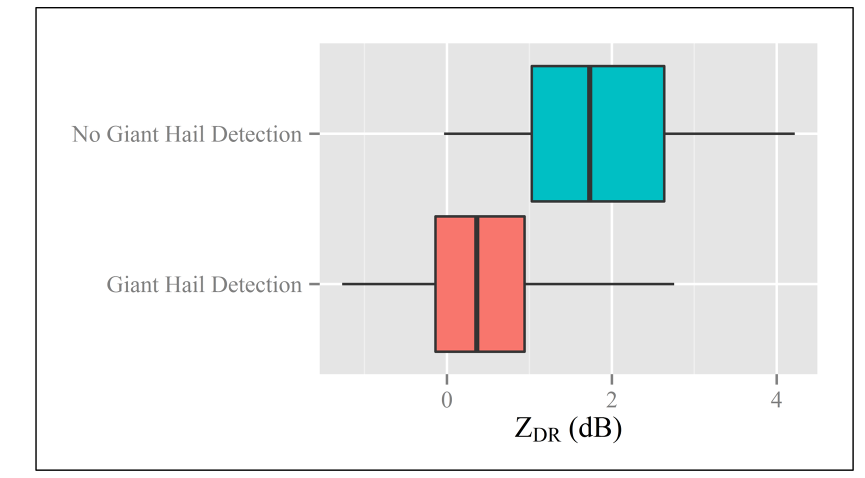
Height Layer	Scoring Method	POD		FAR		CSI	
HSDA Version		New	Orig.	New	Orig.	New	Orig.
$H \geq H(T_w$=-25°C)	Maximum	0.601	0.604	0.414	0.368	0.422	0.447
	Common	0.484	0.484	0.102	0.059	0.459	0.470
	Flex (1 pixel)	0.675	0.705	0.020	0.000	0.666	0.705
	Flex (5 pixels)	0.594	0.624	0.044	0.006	0.578	0.621
$H(T_w$=-25°C) < $H \leq$ $H(T_w$=0°C)	Maximum	0.695	0.760	0.433	0.621	0.454	0.339
	Common	0.557	0.580	0.076	0.113	0.533	0.540
	Flex (1 pixel)	0.752	0.881	0.012	0.001	0.745	0.880
	Flex (5 pixels)	0.657	0.776	0.033	0.017	0.642	0.766
$H(T_w$=0°C) < $H \leq$ $H(T_w$=0°C) - 1km	Maximum	0.768	0.846	0.578	0.789	0.374	0.203
	Common	0.584	0.606	0.131	0.179	0.537	0.536
	Flex (1 pixel)	0.855	0.948	0.015	0.002	0.845	0.946
	Flex (5 pixels)	0.771	0.863	0.041	0.028	0.746	0.842
$H(T_w$=0°C) - 1km < $H \leq$ $H(T_w$=0°C) - 2km	Maximum	0.807	0.891	0.596	0.807	0.369	0.188
	Common	0.584	0.641	0.118	0.264	0.542	0.521
	Flex (1 pixel)	0.898	0.973	0.010	0.006	0.890	0.967
	Flex (5 pixels)	0.823	0.914	0.029	0.031	0.804	0.888
$H(T_w$=0°C) - 2km < $H \leq$ $H(T_w$=0°C) - 3km	Maximum	0.797	0.928	0.484	0.807	0.456	0.190
	Common	0.538	0.709	0.091	0.507	0.511	0.410
	Flex (1 pixel)	0.876	0.982	0.004	0.024	0.873	0.959
	Flex (5 pixels)	0.802	0.948	0.016	0.120	0.792	0.840
$H <$ $H(T_w$=0°C) - 3km	Maximum	0.672	0.949	0.423	0.774	0.450	0.223
	Common	0.429	0.716	0.069	0.500	0.416	0.418
	Flex (1 pixel)	0.771	0.983	0.004	0.042	0.769	0.942
	Flex (5 pixels)	0.708	0.939	0.008	0.149	0.703	0.806

The vertical continuity of detection of hail seems to be good based upon visual inspection and calculated skill scores (see right, 'Skill Scores' box for more detail).

Differential Reflectivity Considerations



27 July 2014 1830 UTC KDTX



Poor Z_{DR} calibration was responsible for most misses for giant hail reports. An analysis revealed that 119 of 204 giant hail reports had no HSDA designations of 'giant hail' within 2 km. The distribution of Z_{DR} for these reports reveal large separation between the 2 groups. The large number of calibration issues encountered dictated the inclusion of the ΔZ_{DR} parameter, which can help adjust for small Z_{DR} calibration deficiencies.

Skill Scores

Height Layer	Scoring Method	POD		FAR		CSI	
HSDA Version		New	Orig.	New	Orig.	New	Orig.
Combined	Maximum	0.782	0.929	0.465	0.792	0.465	0.205
	Common	0.594	0.765	0.136	0.501	0.543	0.432
	Flex (1 pixel)	0.858	0.981	0.010	0.037	0.851	0.945
	Flex (5 pixels)	0.787	0.935	0.037	0.164	0.764	0.790
$H(T_w$=0°C) < $H \leq$ $H(T_w$=0°C) - 1km (65 reports)	Maximum	0.905	0.833	0.698	0.922	0.292	0.077
	Common	0.824	0.813	0.250	0.304	0.646	0.600
	Flex (1 pixel)	0.937	0.969	0.033	0.016	0.908	0.954
	Flex (5 pixels)	0.900	0.897	0.085	0.119	0.831	0.800
$H(T_w$=0°C) - 1km < $H \leq$ $H(T_w$=0°C) - 2km (590 reports)	Maximum	0.859	0.876	0.558	0.816	0.412	0.180
	Common	0.680	0.758	0.203	0.352	0.580	0.537
	Flex (1 pixel)	0.918	0.974	0.015	0.003	0.905	0.971
	Flex (5 pixels)	0.862	0.920	0.060	0.055	0.817	0.873
$H(T_w$=0°C) - 2km < $H \leq$ $H(T_w$=0°C) - 3km (864 reports)	Maximum	0.823	0.949	0.427	0.806	0.510	0.192
	Common	0.619	0.797	0.108	0.567	0.576	0.390
	Flex (1 pixel)	0.885	0.986	0.005	0.040	0.881	0.947
	Flex (5 pixels)	0.799	0.954	0.027	0.204	0.781	0.766
$H <$ $H(T_w$=0°C) - 3km (535 reports)	Maximum	0.661	0.954	0.375	0.727	0.473	0.269
	Common	0.448	0.717	0.060	0.574	0.436	0.364
	Flex (1 pixel)	0.739	0.982	0.008	0.070	0.735	0.914
	Flex (5 pixels)	0.677	0.935	0.016	0.222	0.669	0.735

0.5° Tilt Skill Scores

broken down by altitude and combined

Reports were matched to HSDA designations within a 4 km by 4 km box centered on the report. The matching was accomplished using the maximum designation, most common designation and a flexible method. The flexible methods matched the report's hail size class to the correct HSDA designation as long as there were enough pixels with the search box (default = common). These methods help evaluate reports near gradients and the texture of the designations. The modifications to the HSDA greatly reduced the FAR.

Discussion

Modifications to the original HSDA resulted in more visually coherent HSDA designations along with a large reduction in the FAR with only a slight reduction in overall skill. The POD, and thus overall skill, may be artificially reduced due to poor Z_{DR} calibration. In general, the HSDA should have a POD ~ 0.65 and FAR ~ 0.15 in future evaluations.

Work is ongoing to better relate HSDA designations and polarimetric signatures aloft (altitudes above the melting level) to surface hail fall.

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