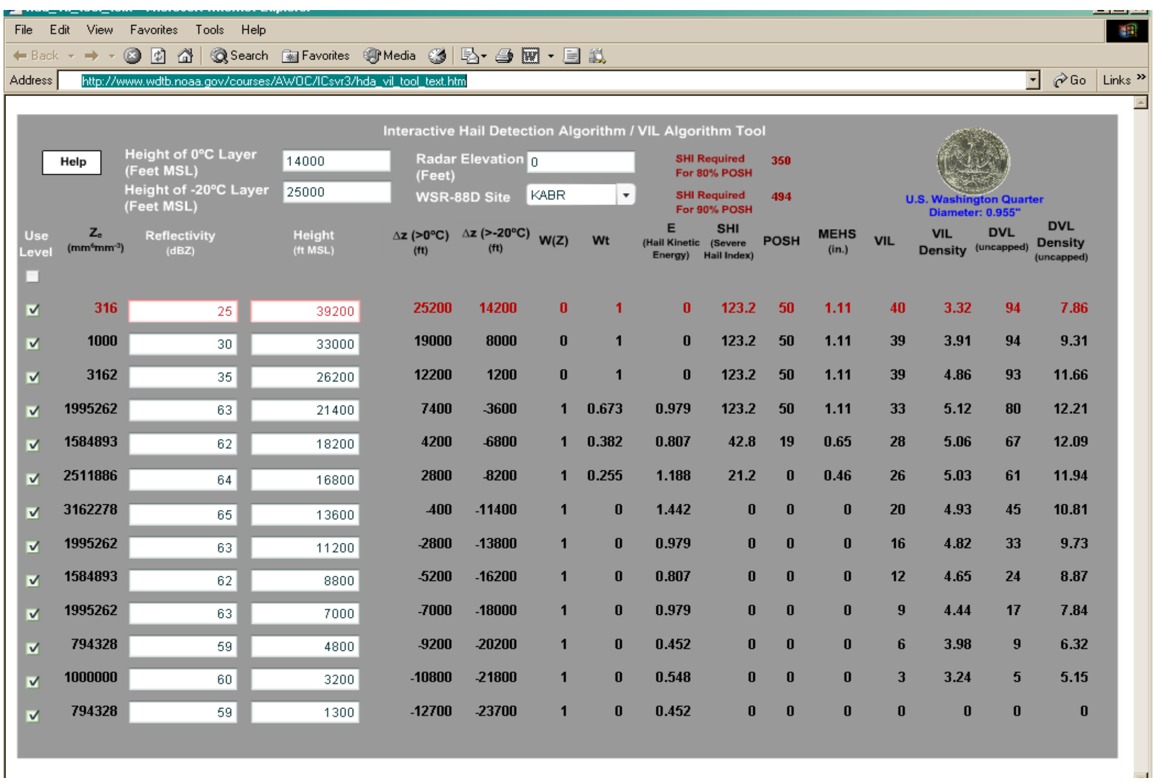
AWOC Severe Track IC 3

HAIL ALGORITHM JOB SHEET

Objective: To understand how VIL, VIL density, high res VIL, and the Hail Detection Algorithm (HDA) arrive at their output. You will understand what may cause some of these algorithms to fail in a hail warning decision process.

Introduction:

- Click HERE or enter this web address into any web browser: http://www.wdtb.noaa.gov/courses/awoc/ICSvr3/hda_vil_tool.html
- You should see something like the image below:



Use Level	Z_e (mm⁶mm⁻³)	Reflectivity (dBZ)	Height (ft MSL)	Δz (>0ºC) (ft)	Δz (>-20ºC) (ft)	W(Z)	Wt	E (Hail Kinetic Energy)	SHI (Severe Hail Index)	POSH	MEHS (in.)	VIL	VIL Density	DVL (uncapped)	DVL Density (uncapped)
☑	316	25	39200	25200	14200	0	1	0	123.2	50	1.11	40	3.32	94	7.86
☑	1000	30	33000	19000	8000	0	1	0	123.2	50	1.11	39	3.91	94	9.31
☑	3162	35	26200	12200	1200	0	1	0	123.2	50	1.11	39	4.86	93	11.66
☑	1995262	63	21400	7400	-3600	1	0.673	0.979	123.2	50	1.11	33	5.12	80	12.21
☑	1584893	62	18200	4200	-6800	1	0.382	0.807	42.8	19	0.65	28	5.06	67	12.09
☑	2511886	64	16800	2800	-8200	1	0.255	1.188	21.2	0	0.46	26	5.03	61	11.94
☑	3162278	65	13600	-400	-11400	1	0	1.442	0	0	0	20	4.93	45	10.81
☑	1995262	63	11200	-2800	-13800	1	0	0.979	0	0	0	16	4.82	33	9.73
☑	1584893	62	8800	-5200	-16200	1	0	0.807	0	0	0	12	4.65	24	8.87
☑	1995262	63	7000	-7000	-18000	1	0	0.979	0	0	0	9	4.44	17	7.84
☑	794328	59	4800	-9200	-20200	1	0	0.452	0	0	0	6	3.98	9	6.32
☑	1000000	60	3200	-10800	-21800	1	0	0.548	0	0	0	3	3.24	5	5.15
☑	794328	59	1300	-12700	-23700	1	0	0.452	0	0	0	0	0	0	0

- The top left white input boxes are the input heights (in feet) of the -20^{o}C and 0^{o}C heights input into the RPG, typically from a recent thermodynamic sounding.

- The top right white boxes are for the radar elevation (above mean sea level) and the 4 letter identifier of the radar you are using. Clicking on the radar ID automatically loads the radar elevation in the top box.
- The red row of numbers are the final values for each parameter as these are vertically integrated quantities.

Z_e (mm^6mm^{-3})	Reflectivity (dBZ)	Height (ft MSL)	Δz (>0°C) (ft)	Δz (>-20°C) (ft)	W(Z)	Wt	E (Hail Kinetic Energy)	SHI (Severe Hail Index)	POSH	MEHS (in.)	VIL	VIL Density	DVL (uncapped)	DVL Density (uncapped)

- The column headers in black (shown above) can be clicked in your browser window to provide information about each variable.
- The 2 columns of input boxes (shown on the right) are where you input the height above MSL and reflectivity values of the maximum reflectivity in the hail core.

Reflectivity (dBZ)	Height (ft MSL)
25	39200
30	33000
35	26200

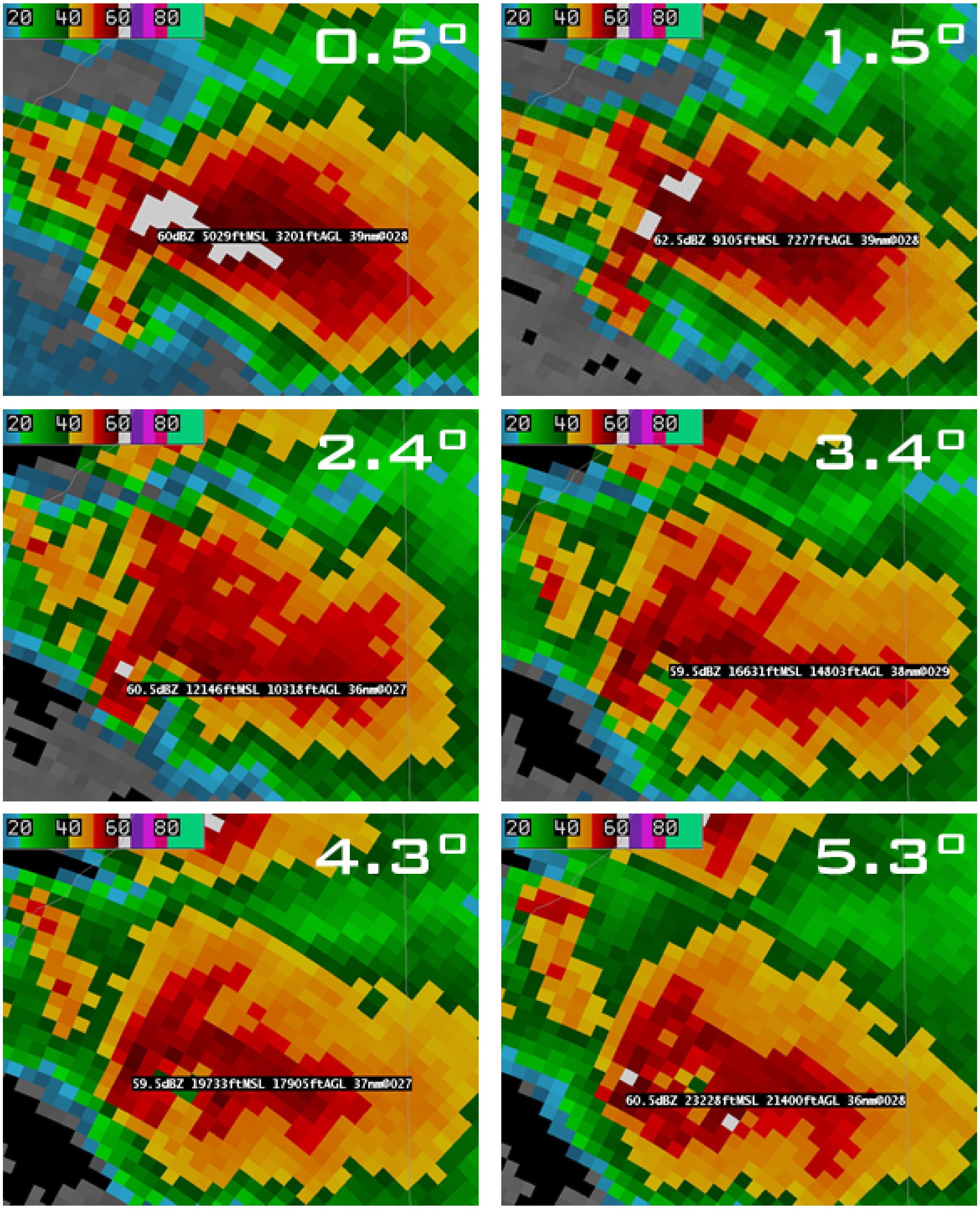
- Use the check boxes on the far left to include (or not include) elevation angles (see image below). For example, a severe storm 80 nm from the radar may only be sampled by the **lowest 6 tilts**, and entering the data would require the checking of the **lowest 7 boxes** (because of algorithm extrapolation as mentioned next), and then entering the reflectivity values and heights.

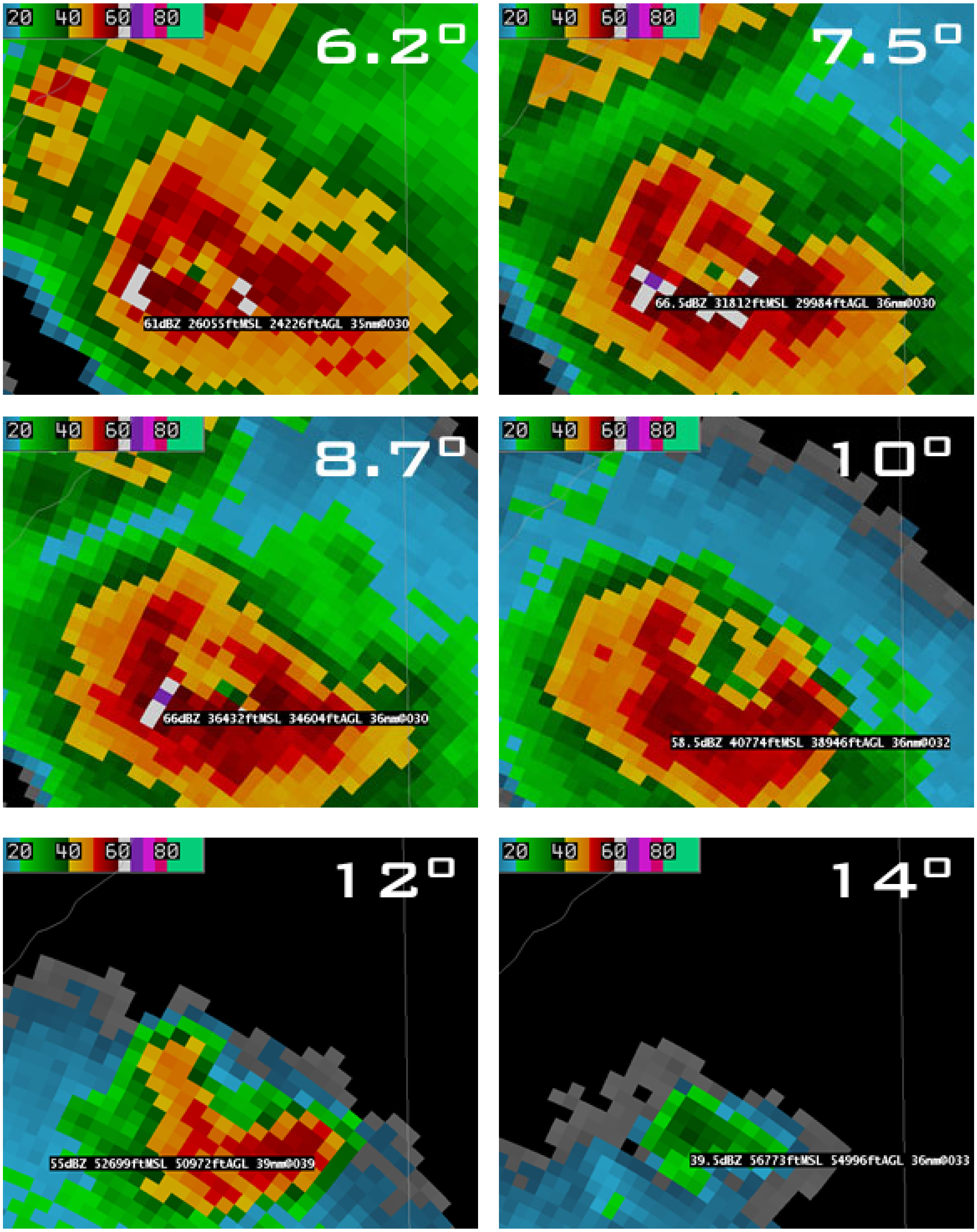
✓	1995262	63	11200
✓	1584893	62	8800
✓	1995262	63	7000
✓	794328	59	4800
✓	1000000	60	3200
✓	794328	59	1300

- **Very Important:** The 1st Row needs to be reserved for the "ground extrapolation" input. The HDA and VIL algorithms extrapolate to the radar elevation MSL the lowest available data, thus you must enter the identical reflectivity values in the lowest 2 rows, and set the height of the first row to match that of the radar elevation.

- The top right region (below) of the window contains the values required of the Severe Hail Index (SHI) to produce POSH’s of 80% and 90%, given the input height of the 0°C level. The image in the upper right corner changes to fit the maximum expected hail size output, up to softball size diameter (3.75 inches)

- Your Task #1: Examine the images on the next two pages, and enter the appropriate reflectivity and height values into the spreadsheet. Be sure to enter the 0.5 degree reflectivity and height data in the 2nd lowest row. The bottom row should have the 0.5 degree reflectivity at the approximate height of the radar elevation, which is automatically given to you when you choose a radar from the list. The 1.5 degree data goes in the 3rd row from the bottom, and so on through the depth of the storm.
- The 0°C and -20°C levels were 15,200 and 23,600 feet, respectively. The radar is KUEX.
- You may notice that the values you are entering would be comparable for “cell-based” products as opposed to “grid-based” products because the cursor readout is displaying the maximum reflectivity values with the cell at each elevation angle. Unless you keep the cursor in the same spot each time you increase elevation angle, you will be recording cell-based VIL. Thus, VIL values are likely higher on your spreadsheet than what you would see with the VIL product in AWIPS. VIL listed in a SCAN attributes table should be close to the values you arrive at because it is computed with the cell technique.


20 40 60 80
0.5°
60dBZ 5029ftMSL 3201ftAGL 39nm@028
20 40 60 80
1.5°
62.5dBZ 9105ftMSL 7277ftAGL 39nm@028
20 40 60 80
2.4°
60.5dBZ 12146ftMSL 10318ftAGL 36nm@027
20 40 60 80
3.4°
59.5dBZ 16631ftMSL 14803ftAGL 38nm@029
20 40 60 80
4.3°
59.5dBZ 19733ftMSL 17905ftAGL 37nm@027
20 40 60 80
5.3°
60.5dBZ 23228ftMSL 21400ftAGL 36nm@028


20 40 60 80
6.2°
61dBZ 26055ftMSL 24226ftAGL 35nm@030
7.5°
66.5dBZ 31812ftMSL 29984ftAGL 36nm@030
8.7°
66dBZ 36432ftMSL 34604ftAGL 36nm@030
10°
58.5dBZ 40774ftMSL 38946ftAGL 36nm@032
12°
55dBZ 52699ftMSL 50972ftAGL 39nm@039
14°
39.5dBZ 56773ftMSL 54996ftAGL 36nm@033

- Once your values are entered, your spreadsheet should look like the below image:

Interactive Hail Detection Algorithm / VIL Algorithm Tool

Help

Height of 0°C Layer (Feet MSL): 15200

Height of -20°C Layer (Feet MSL): 23600

Radar Elevation (Feet): 2041

WSR-88D Site: KUEX

SHI Required For 80% POSH: 409

SHI Required For 90% POSH: 578

Baseball Diameter: 2.75"

Use Level	Z_e (mm^6mm^{-3})	Reflectivity (dBZ)	Height (ft MSL)	Δz (>0°C) (ft)	Δz (>-20°C) (ft)	W(Z)	Wt	E (Hail Kinetic Energy)	SHI (Severe Hail Index)	POSH	MEHS (in.)	VIL	VIL Density	DVL (uncapped)	DVL Density (uncapped)
☑	10000	40	56800	39559	31159	0	1	0	888.4	100	2.98	87	5.22	186	11.15
☑	316228	55	52700	35459	27059	1	1	0.208	888.4	100	2.98	83	5.38	182	11.79
☑	794328	59	40800	23559	15159	1	1	0.452	837.6	100	2.89	64	5.46	158	13.39
☑	3981072	66	36400	19159	10759	1	1	1.75	725.3	97	2.69	57	5.46	138	13.16
☑	5011872	67	31800	14559	6159	1	1	2.123	485.3	85	2.2	50	5.46	107	11.83
☑	1258925	61	26000	8759	359	1	1	0.665	148.7	51	1.22	40	5.46	76	10.4
☑	1258925	61	23200	5959	-2441	1	0.709	0.665	61.5	25	0.78	35	5.46	67	10.38
☑	1000000	60	19700	2459	-5941	1	0.293	0.548	16.1	0	0.4	29	5.46	56	10.47
☑	1000000	60	16600	-641	-9041	1	0	0.548	0	0	0	24	5.47	48	10.74
☑	1258925	61	12100	-5141	-13541	1	0	0.665	0	0	0	17	5.47	34	11.12
☑	1995262	63	9100	-8141	-16541	1	0	0.979	0	0	0	12	5.48	23	10.66
☑	1000000	60	5029	-12212	-20612	1	0	0.548	0	0	0	5	5.53	9	9.36
☑	1000000	60	2000	-15241	-23641	1	0	0.548	0	0	0	0	0	0	0

Answer the Following 5 Questions Regarding Your Spreadsheet after reading about each parameter:

1. Why is W(z)=0 in the top row (40 dBZ row)?
2. Why is Wt=0 for the bottom 4 rows, less than 1 for the next 3 rows, and equal to 1 for the top 6 rows?
3. Why is VIL increasing with each ascending elevation scan?
4. Why did VIL density decrease from 5.4 to 5.2 at the top 2 rows?
5. Why is DVIL so much higher than VIL?

The Answer Key is in Appendix A.

<u>Your Task #2:</u> You should now be familiar enough with the spreadsheet to run your own calculations on whatever data you want. Your first task was an analysis of the Aurora, NE record breaking hail storm, and the radar data was from ~10 minutes before the record breaking hail fell. That storm was ideal for the algorithms in that it was 30-40 nm from KUEX and had nearly uniformly distributed reflectivity throughout a depth of ~50 kft. Your second task is to examine a storm at a greater distance from the radar to see how the algorithms handle it.

- Enter the following data into the spreadsheet:

  Radar: KFWS, 0^{o}C and -20^{o}C input heights are 11,200 and 20,500 feet
  Lowest Tilt: 71 dBZ at 14,000 feet
  Next Tilt: 66 dBZ at 24,500 feet
  Next Tilt: 60 dBZ at 34,000 feet
  Next Tilt: 29 dBZ at 44,500 feet

- Be sure to remember to extrapolate 71 dBZ down to the elevation of the radar (~500 feet) in the lowest row of data.

Answer the following 2 questions after you have finished entering the above data:

1. Why are DVIL values so high (~325!), other than because of the lack of an upper cap at 56 dBZ?
2. Now click the box of the lowest row, wiping it out and thus eliminating the extrapolation from the lowest tilt down to the surface. What happens to the VIL and DVIL values? What happens to the HDA MEHS and POSH?

An Answer Key is in Appendix A.

<u>Your Task #3:</u> Your next set of reflectivity data are an example of an elevated hail core.

- Enter the following data into the spreadsheet:

  Radar: KICT, 0^{o}C and -20^{o}C input heights are 16,300 and 25,500 feet
  Lowest Tilt: 29 dBZ at 6000 feet
  Next Tilt: 37 dBZ at 11,500 feet
  Next Tilt: 43 dBZ at 16,500 feet
  Next Tilt: 54 dBZ at 21,000 feet
  Next Tilt: 59 dBZ at 26,000 feet
  Next Tilt: 61 dBZ at 31,500 feet
  Next Tilt: 58 dBZ at 37,500 feet
  Next Tilt: 47 dBZ at 45,000 feet
  Next Tilt: 36 dBZ at 51,500 feet

Answer the following 2 questions after you have finished entering the above data:

1. Explain the discrepancy between the HDA which has 65% POSH and ping pong size hail indicated, and VIL/VIL density which suggest very little threat of severe hail (VIL=44, VIL density=2.86).

2. Based solely on the algorithm data, what do you think the threat of severe hail is? How about when you take into account the reflectivity profile?

An Answer Key is in Appendix A.

<u>Your Task #4:</u> You just looked at a storm with high reflectivity aloft, now you'll look at a storm with high reflectivity in the lower levels.

- Enter the following data into the spreadsheet:

    Radar: KSOX, 0^{o}C and -20^{o}C input heights are 7,400 and 17,100 feet
    Lowest Tilt: 60 dBZ at 9,000 feet
    Next Tilt: 60 dBZ at 12,000 feet
    Next Tilt: 60 dBZ at 15,500 feet
    Next Tilt: 50 dBZ at 18,500 feet
    Next Tilt: 45 dBZ at 22,000 feet
    Next Tilt: 35 dBZ at 25,000 feet

Answer the following 2 questions after you have finished entering the above data:

1. Explain why VIL is just 28 yet POSH is 97% (and would be rounded up to 100%).
2. The storm in question was located above terrain at ~100 feet above sea level, yet the radar and algorithm extrapolations go down to 3000 feet above sea level. Slide the height of the lowest row down to 0. What happens to the HDA products, VIL, and VIL density? Why are they different?

Appendix A

Task #1 Key:

Answer #1: W(z) is the reflectivity weighting function. Anything below 40 is set at 0, anything above 50 is 1, and in between the weights vary. Because the top row has a reflectivity of exactly 40, no weight is given, and thus W(z)=0.

Answer #2: Wt is the temperature weighting function. Any height value below $0^{o}C$ is set at 0, anything colder than $-20^{o}C$ is 1, and in between $0^{o}C$ and $-20^{o}C$ the weights vary. The bottom 5 rows are all below the $0^{o}C$ height, and thus are given no weight. The next 3 rows lie in between the heights of $0^{o}C$ and $-20^{o}C$, and thus have linearly increasing weights the closer to $-20^{o}C$ they are. The top few rows are all above the height of $-20^{o}C$, and thus a full weight of 1 is given to each.

Answer #3: VIL is an additive algorithm, summed from the surface up. Thus, each successive reflectivity scan (after being plugged into the VIL equation) increasing in height is added to the sum of the previous scans.

Answer #4: VIL density is a function of storm "depth" and VIL values. Adding a row with 40 dBZ adds to the VIL, but the additional depth of 4500 feet to the storm is enough to outweigh the increase in VIL, leading to an overall decrease in VIL density.

Answer #5: Digital VIL is uncapped either on the low or high end (VIL is capped at 18.3 dBZ and 56 dBZ). Thus, with most levels exceeding 56 dBZ, it is not surprising that DVIL far exceeded VIL.

Task #2 Key:

Answer #1: Much like in Task #1 Question 5, DVIL is very large because it is not capped on the upper end at 56 dBZ like the legacy VIL. VIL and DVIL will both be exaggerated because the storm is at a large distance from the radar. This is an extreme case with 71 dBZ, which is then extrapolated 13,500 feet down to the surface, leading to outrageous DVIL values.

Answer #2: VIL and DVIL values both decreased substantially because the first row represented an extrapolation of 13,500 feet down to the elevation of the radar. The HDA products are relatively unaffected by this since the elevation of the radar is below the 0^{o}C level and thus the W(z) weighting function is 0 and contributed very little in the overall integration.

Task #3 Key:
Answer #1: This storm is extremely deep and reflectivity values are above 50 dBZ at only 4 levels. Thus, VIL is low, the storm is very deep so VIL density is also low. The amount of reflectivity greater than 40 dBZ above the -20C level heavily weights the HDA, producing an significant MEHS and POSH. In this case, golfball hail was reported several scans later.

Answer #2: VIL and VIL density both suggest no threat of severe hail at all. HDA hints at the threat with 65% POSH. When you take into account the depth of the storm and the fact that the core is entire aloft, the threat of severe hail is high especially in the next 15 minutes.

Task #4 Key:
Answer #1: VIL is just 28 because with the radar at 3000 feet above sea level, 50 dBZ or greater only extends for a depth of 15,500 feet. You may recall that for the Aurora storm (Task #1), this depth was 50,500 feet. The freezing level is so low and 60 dBZ is above the 0^{o}C level such that a POSH of 97% is achieved.

Answer #2: Extrapolation to the actual elevation of the terrain beneath the storm resulted in an increase in VIL to 32, and VIL density increased to 4.66 (the increase in VIL was greater than the 3000 feet added to depth of storm, thus VIL density increased). The HDA was essentially unaffected by this change (the values in the lowest rows slightly increased but the final values remained the same), because W(z) was 0 at 3000 feet and still 0 at sea level. Had the radar been at a much higher elevation (KGJX at 10,000 feet MSL for example), a significant underestimate could have been possible with a storm that is not “bottom heavy” as in this event. The Lynwood storm produced a prolific amount of pea to marble sized hail, drifting in spots to 3 feet deep in south central Los Angeles.