Instructions to:

TOM: Teaching flow over Mountains - *Worksheet at the radar site*

!!!!! PLEASE MAKE SURE THAT YOUR NOTES ARE LEGIBLE!!!!

Fill out one worksheet per group.

EXERCISE 1

Please sign in (provide all students' names, ATOC course, beginning and end time at the radar) on a new worksheet.

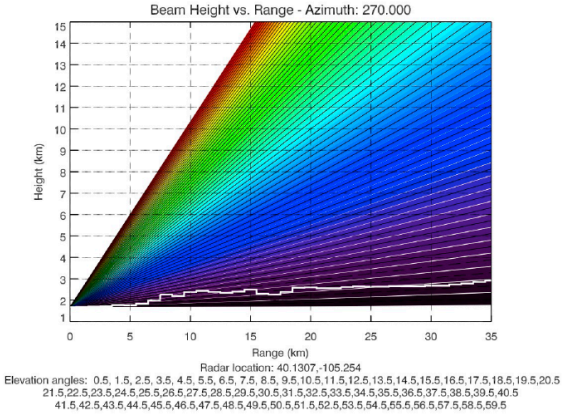
EXERCISE 2

There are three scan configurations:

1. LowresTALL:

Purpose: 3dim, high-resolution scans when snow reaches the Front Range

- made up of 10 scans per volume (360deg azimuth)
- Update every 75 s
- Scanned continuously from bottom to top
- **100 m pulse length – maximum range (100 m x 300 pulses = 30 km)**

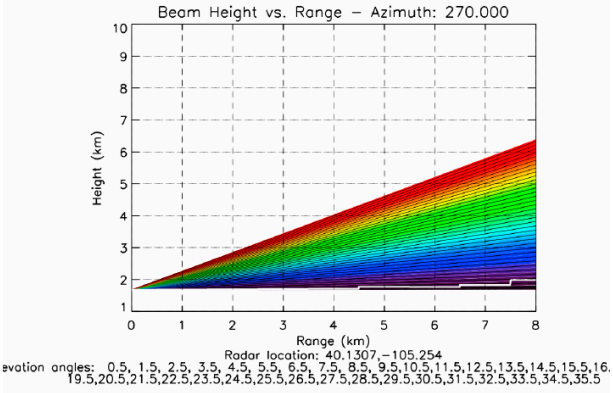


1: 0.5 to 5.5deg	(0.5, 1.5, 2.5, 3.5, 4.5, 5.5)
2: 6.5 to 11.5deg	(6.5, 7.5, 8.5, 9.5, 10.5, 11.5)
3: 12.5 to 17.5deg	(12.5, 13.5, 14.5, 15.5, 16.5, 17.5)
4: 18.5 to 23.5deg	(18.5, 19.5, 20.5, 21.5, 22.5, 23.5)
5: 24.5 to 29.5deg	(24.5, 25.5, 26.5, 27.5, 28.5, 29.5)
6: 30.5 to 35.5deg	(30.5, 31.5, 32.5, 33.5, 34.5, 35.5)
7: 36.5 to 41.5deg	(36.5, 37.5, 38.5, 39.5, 40.5, 41.5)
8: 42.5 to 47.5deg	(42.5, 43.5, 44.5, 45.5, 46.5, 47.5)
9: 48.5 to 53.5deg	(48.5, 49.5, 50.5, 51.5, 52.5, 53.5)
10: 54.5 to 59.5deg	(54.5, 55.5, 56.5, 57.5, 58.5, 59.5)

2. HighresLOW:

Purpose: super high-resolution scans close to the surface when snow reaches the Front Range; **ECHO TOP IS < 44KM MSL AT 8 KM DISTANCE (mount of the canyon)**

- **Shortest (25 m) pulse length**
- Max range 7.5 km (25 m x 300 pulses = 7.5 km)
- 6 sets of PPIs continuously from bottom to the top
- Update 45 s

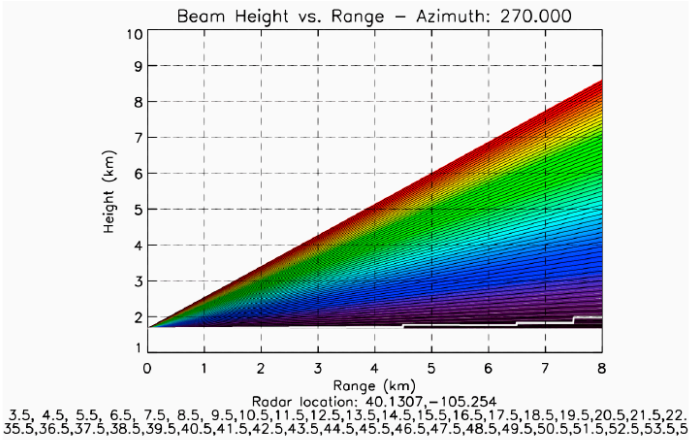


1: 0.5 to 5.5deg	(0.5, 1.5, 2.5, 3.5, 4.5, 5.5)
2: 6.5 to 11.5deg	(6.5, 7.5, 8.5, 9.5, 10.5, 11.5)
3: 12.5 to 17.5deg	(12.5, 13.5, 14.5, 15.5, 16.5, 17.5)
4: 18.5 to 23.5deg	(18.5, 19.5, 20.5, 21.5, 22.5, 23.5)
5: 24.5 to 29.5deg	(24.5, 25.5, 26.5, 27.5, 28.5, 29.5)
6: 30.5 to 35.5deg	(30.5, 31.5, 32.5, 33.5, 34.5, 35.5)

3. HighresTALL:

Purpose: super high-resolution scans close to the surface when snow reaches the Front Range; **ECHO TOP IS > 4KM MSL AT 4 KM DISTANCE (mount of the canyon)**

- **Shortest (25 m) pulse length**
- Max range 7.5 km (25 m x 300 pulses = 7.5 km)
- 10 sets of PPIs continuously from bottom to the top
- Update 75 s

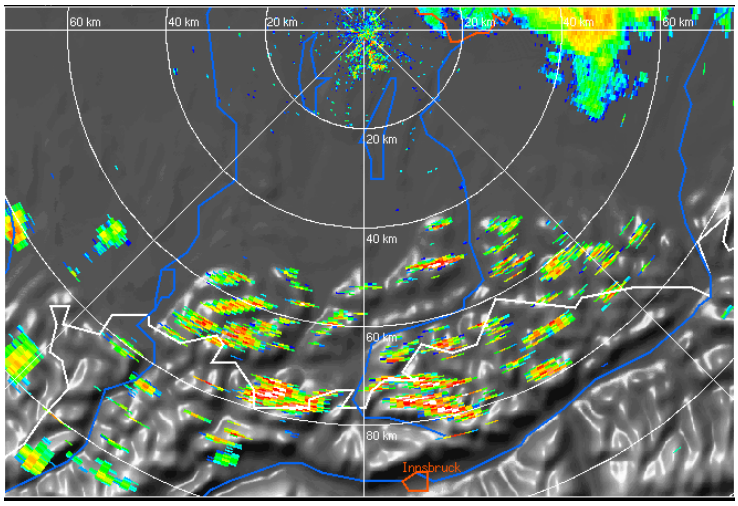


1: 0.5 to 5.5deg	(0.5, 1.5, 2.5, 3.5, 4.5, 5.5)
2: 6.5 to 11.5deg	(6.5, 7.5, 8.5, 9.5, 10.5, 11.5)
3: 12.5 to 17.5deg	(12.5, 13.5, 14.5, 15.5, 16.5, 17.5)
4: 18.5 to 23.5deg	(18.5, 19.5, 20.5, 21.5, 22.5, 23.5)
5: 24.5 to 29.5deg	(24.5, 25.5, 26.5, 27.5, 28.5, 29.5)
6: 30.5 to 35.5deg	(30.5, 31.5, 32.5, 33.5, 34.5, 35.5)
7: 36.5 to 41.5deg	(36.5, 37.5, 38.5, 39.5, 40.5, 41.5)
8: 42.5 to 47.5deg	(42.5, 43.5, 44.5, 45.5, 46.5, 47.5)
9: 48.5 to 53.5deg	(48.5, 49.5, 50.5, 51.5, 52.5, 53.5)
10: 54.5 to 59.5deg	(54.5, 55.5, 56.5, 57.5, 58.5, 59.5)

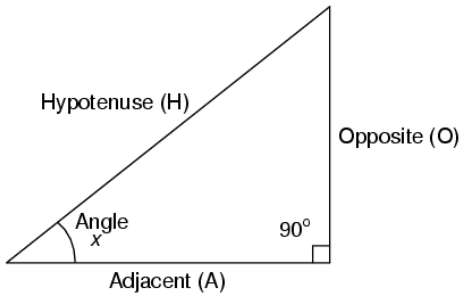
a) Estimate the distance. Convert miles in km: 1 km = 1.6 miles, 1 mile = 0.6 km

b) Mountains are relatively easy to identify.
   a. If the radar beam is fully blocked you would only see reflectivity echoes between the radar and the mountains, i.e., no reflectivity shows up ‘behind’ the mountains.

b. As soon as the radar beam hits the mountains it will return an echo with high reflectivity (see image below) and zero velocity since mountains do not move.



c) In order to answer this questions you need to apply some trigonometry: In the example below the distance is A = 5 km and the height is O = 1. The angle to be calculated is x. Use the trigonometric identities to calculate the elevation angle.



$$\sin x = \frac{O}{H} \qquad \cos x = \frac{A}{H} \qquad \tan x = \frac{O}{A} \qquad \tan x = \frac{\sin x}{\cos x}$$

$$\csc x = \frac{H}{O} \qquad \sec x = \frac{H}{A} \qquad \cot x = \frac{A}{O} \qquad \cot x = \frac{\cos x}{\sin x}$$

EXERCISE 3

Describe the weather at the radar site during your stay: Is it snowing/raining? What is the intensity (light, heavy)? What do you think the temperature is? How much snow is on the ground? Is it windy? How does the weather in Boulder compare to the weather at the radar site (outside of Boulder). How does the amount of snow on the ground differ between Boulder and the radar site? Note when something has changed (e.g., wind, temperature, snow/rain intensity)

For instance:
As we were driving to the radar site it was cold and snowing lightly. The snowflakes were small. There was no wind. The temperature felt to be just above freezing. When we arrived at the radar site (8:00 am MST) there was slightly more snow and it was slightly cooler than it was in Boulder.

8:30 am MST: It started to snow harder and larger, fluffier flakes. Visibility decreased and we could no longer see the mountains.
9:00 am MST: Snowfall decreased. The snow on the ground looks wet.
9:30 am MST: There is not much snow on the ground but the ground is moist from the melting snow. It felt like the temperature is just below freezing and there is still no wind.

EXERCISE 4

Once you are done with Exercises 1-3 complete Exercise 4 every 15 minutes: Check if all elevation angles are correctly scanned based on the scan configuration. Make a note in the table when you checked the scan configuration and add comments - see the example below. If you see that the scans are not done correctly please notify the radar operator and make a note in the table. Write down every activity that might impact the quality of the radar data and relevant for later data analysis. See example below.

Time (MST/UTC)	Scan Strategy	Comments
8:30 am / 0130 UTC	LowresTall, HighresLOW	okay
8:35 am / 0135 UTC		Radar stopped – need to remove snow
8:40 am / 0140 UTC	Start LowresTall followed by HighresLOW	
8:42 am / 0142 UTC		Radar truck leveled

EXERCISE 5

Once you are done with Exercises 1-3 complete Exercise 5 every 15 minutes:

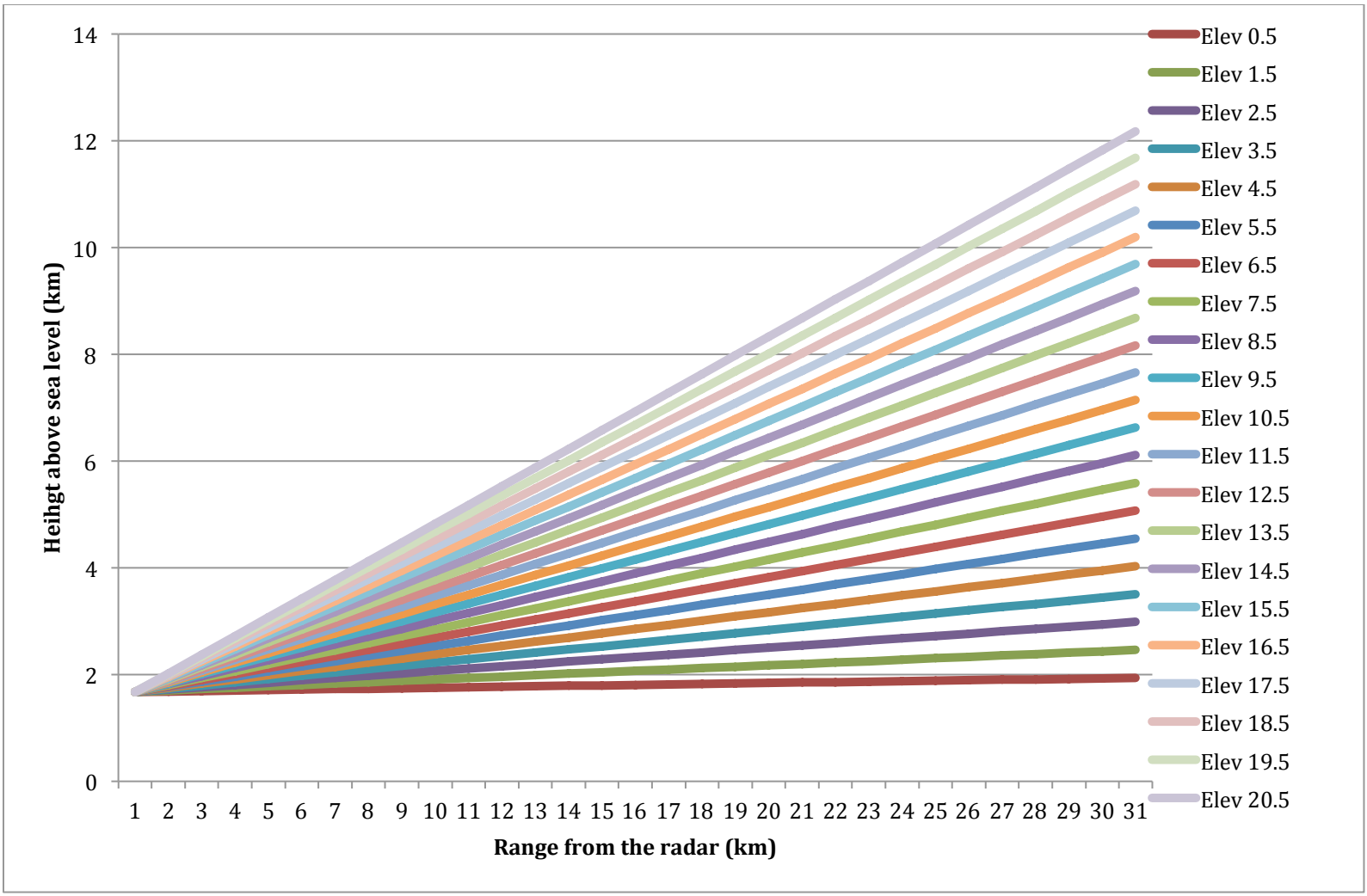
Before you do this exercise practice by observing some radar scans. Choose an elevation angle > 6 degree and determine the following parameter of the storm.

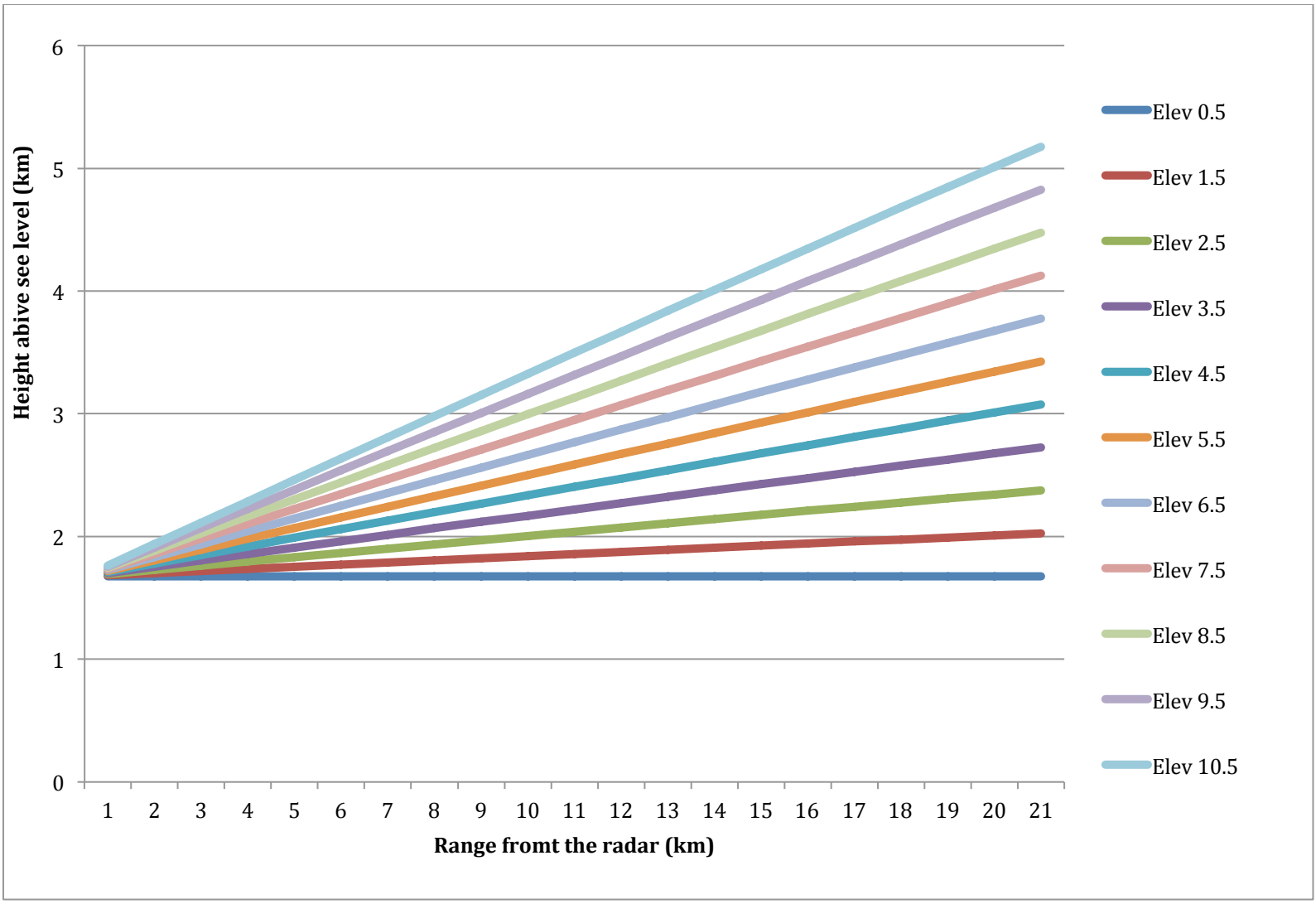
- Range of wind velocity
- Max wind velocity
- Range of reflectivity
- Max value of reflectivity

Time (UTC)	Elevation angle (deg)	Scan Strategy	Range of wind velocity (m/s)	Max wind velocity (m/s) @ range (km)	Mean wind direction	Range of Reflectivity (dBZ)	Max reflectivity (dBZ) @ range (km) / Height MSL (km)
0138	10	HighresLOW	-10 – 10	10@ 8	East	-10 – 20	20 @ 8 / 3.2

Use the images below and determine the height of the radar beam at the location where you observed the maximum reflectivity by using the elevation anglea and range.

For instance, the radar beam has a height of 3.2 km MSL at an elevation angle of 10deg and a range of 8 km.


Heihgt above sea level (km)
0
2
4
6
8
10
12
14
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Range from the radar (km)
Elev 0.5
Elev 1.5
Elev 2.5
Elev 3.5
Elev 4.5
Elev 5.5
Elev 6.5
Elev 7.5
Elev 8.5
Elev 9.5
Elev 10.5
Elev 11.5
Elev 12.5
Elev 13.5
Elev 14.5
Elev 15.5
Elev 16.5
Elev 17.5
Elev 18.5
Elev 19.5
Elev 20.5


Height abive see level (km)
0
1
2
3
4
5
6
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
Range fromt the radar (km)
Elev 0.5
Elev 1.5
Elev 2.5
Elev 3.5
Elev 4.5
Elev 5.5
Elev 6.5
Elev 7.5
Elev 8.5
Elev 9.5
Elev 10.5