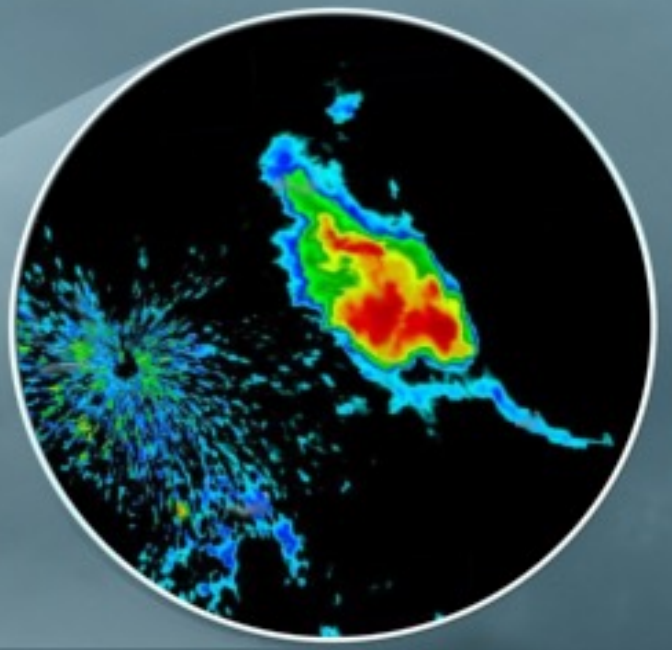
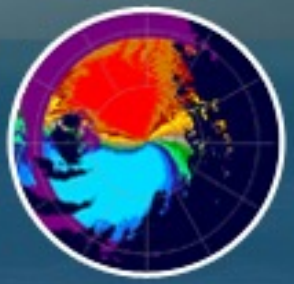
雷达





主要内容

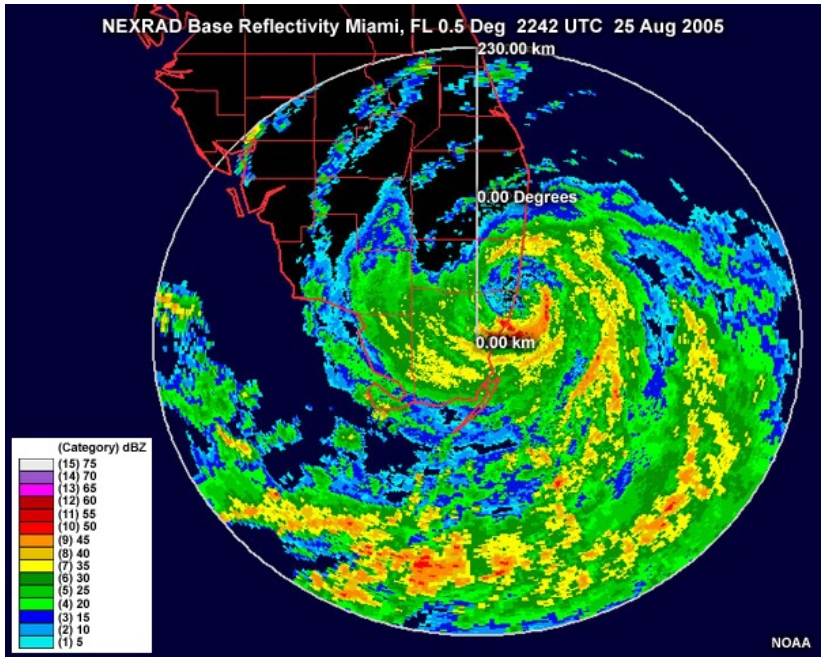
- 雷达基础
- 雷达局限性
- 风场特征识别
- 晴空模式雷达观测特征识别
- 降水模式雷达观测特征识别

Radar

Radio detection and ranging

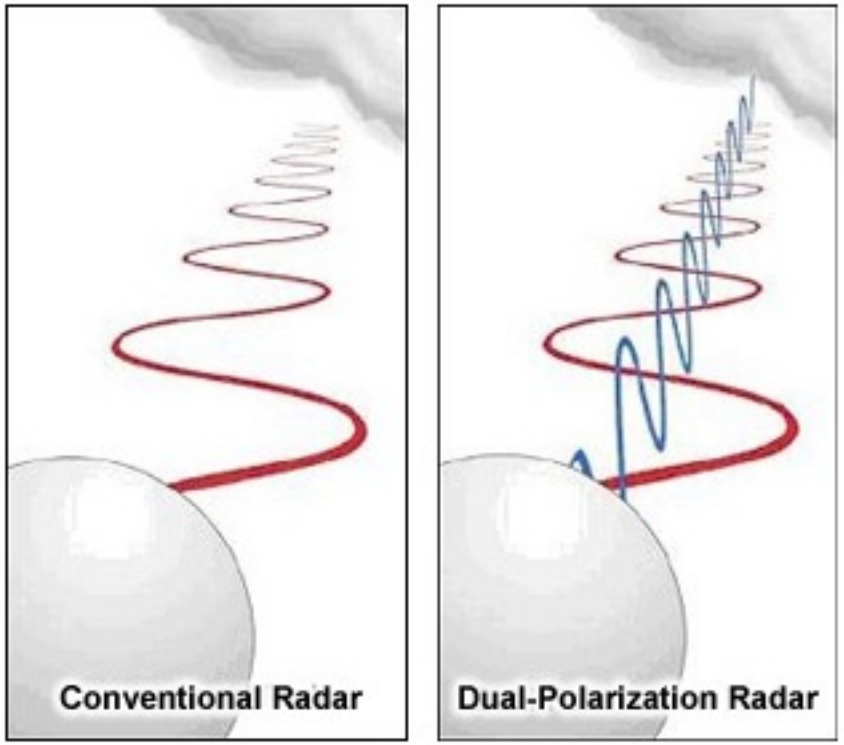
历史

- 始用于二战
- 战后开始用于天气监测
- 已成为天气监测和分析的主要工具之一



雷达种类

脉冲雷达



NOAA

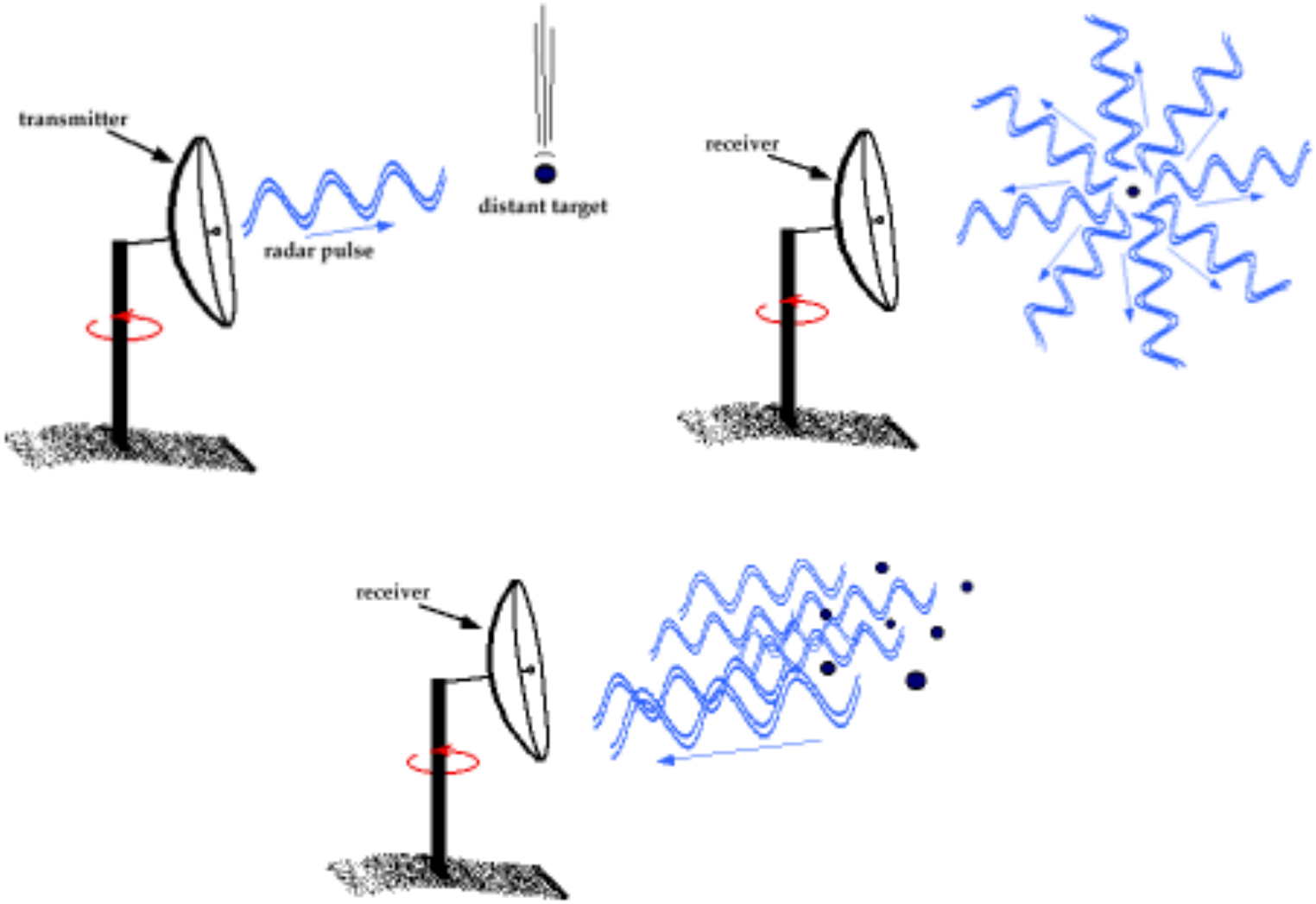
美国： 2011-2013

脉冲雷达观测原理

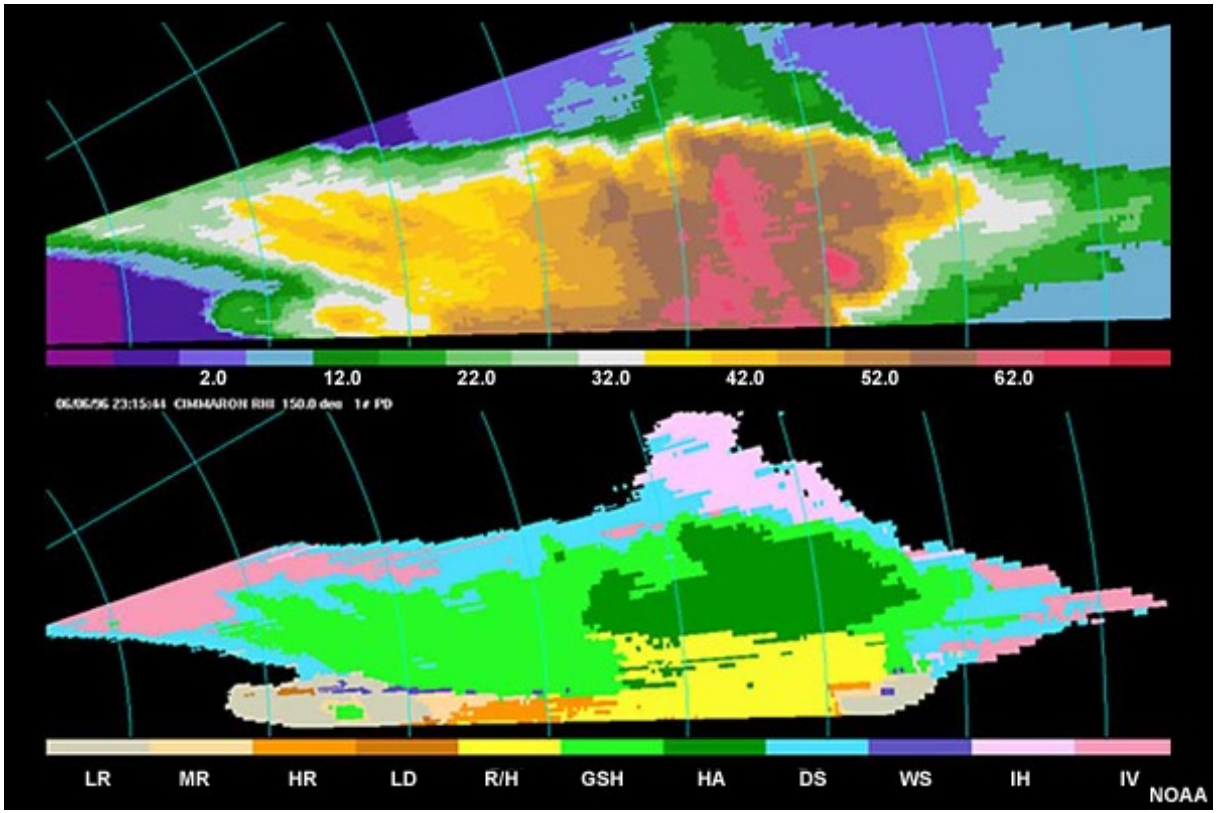
2.0.0

Radar reflectivity: a measure of a radar target's efficiency in intercepting and returning the radar's energy and depends on the physical parameters of the target—its **size, shape, orientation, composition**,

雷达脉冲观测

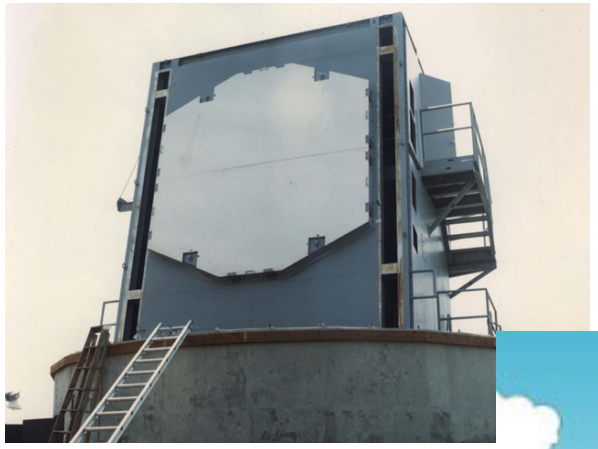

transmitter
radar pulse
distant target
receiver
receiver

雷达种类:双偏振雷达



- Identify non-weather targets more easily
- Differentiate rain, snow, and melting snow
- Detect when hail is present in a thunderstorm
- Detect debris lofted by strong tornadoes

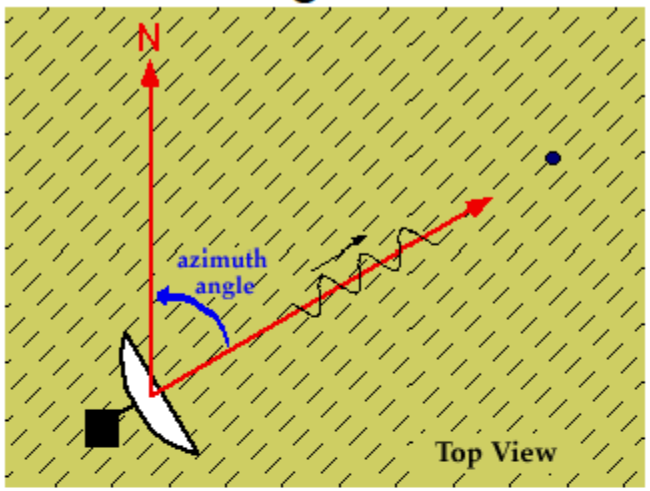
雷达种类

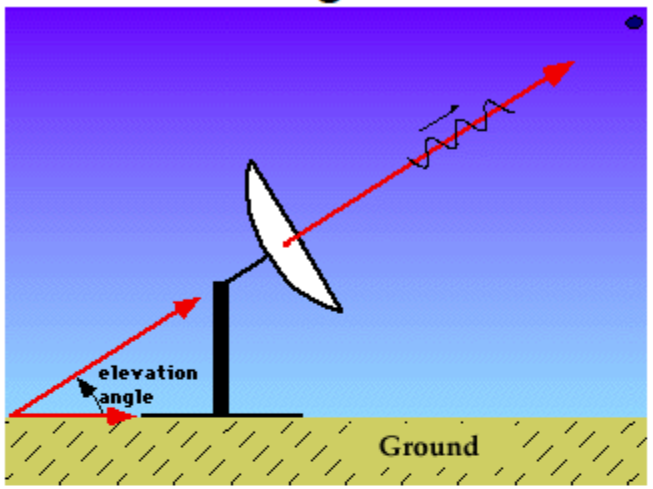


相控阵雷达

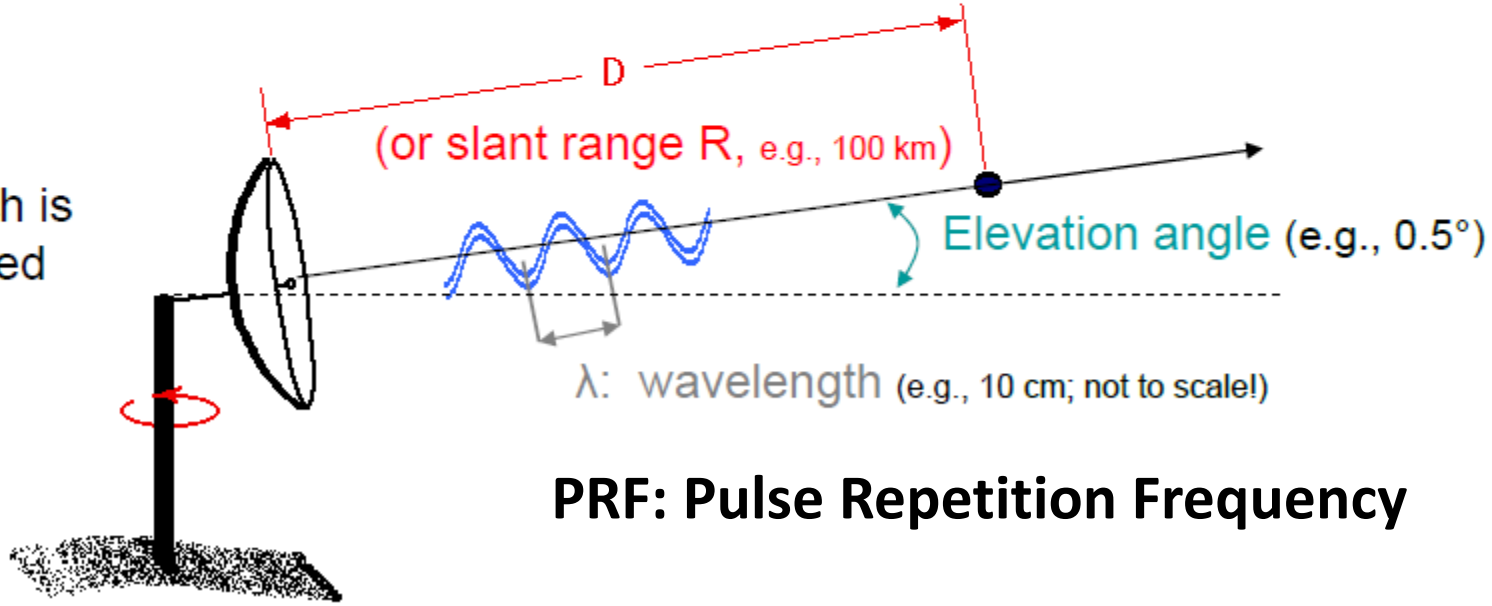
- Use arrays of many small antennas
- Much faster and in any specific area
- Scan multiple areas simultaneously

雷达基本参数





Distance, which is sometimes called **"slant range"**



PRF: Pulse Repetition Frequency

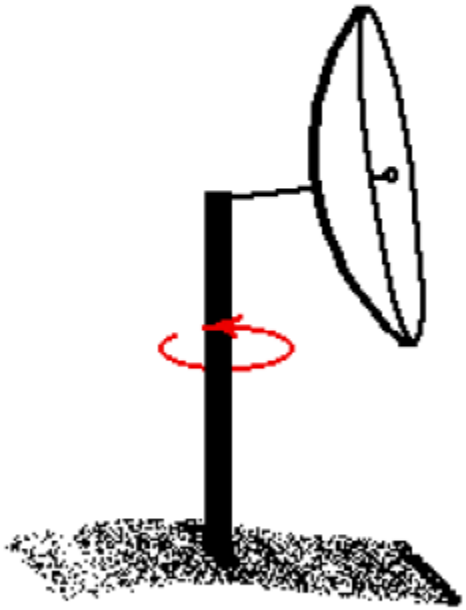
Figures Adapted from: University of Illinois WW2010 http://ww2010.atmos.uiuc.edu/(Gh)/guides/rs/rad/basics/sgnl.rxml

波长

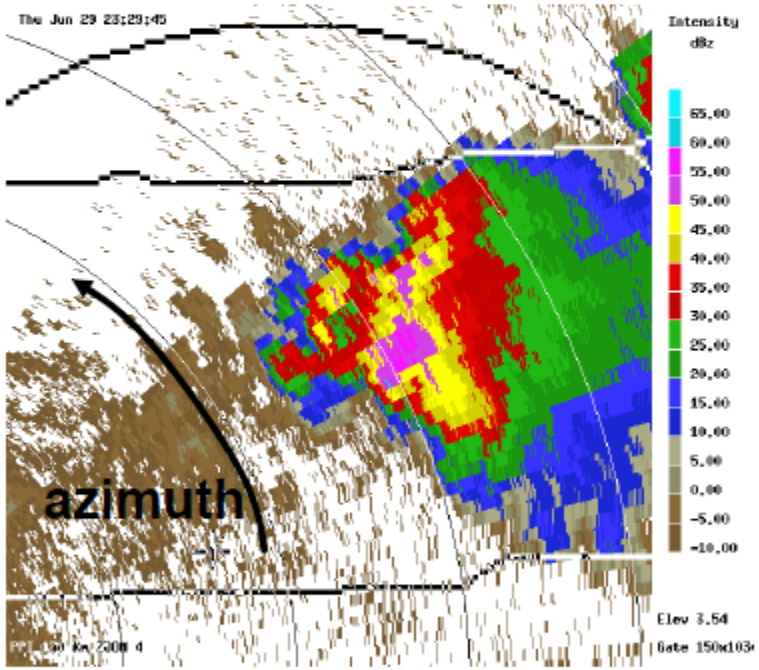
- Frequency 3 MHz-300 GHz
- Microwave: Wave length 1 mm-10 m
  - L-band 23 cm
  - S-band 10 cm
  - C-band 5 cm
  - X-band 3 cm
  - K-band 1.5 cm

雷达扫描模式： PPI

Plan Position Indicator (PPI)



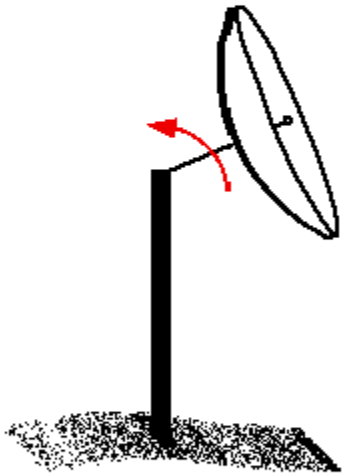
PPI sector of radar reflectivity at 3.54° elevation angle



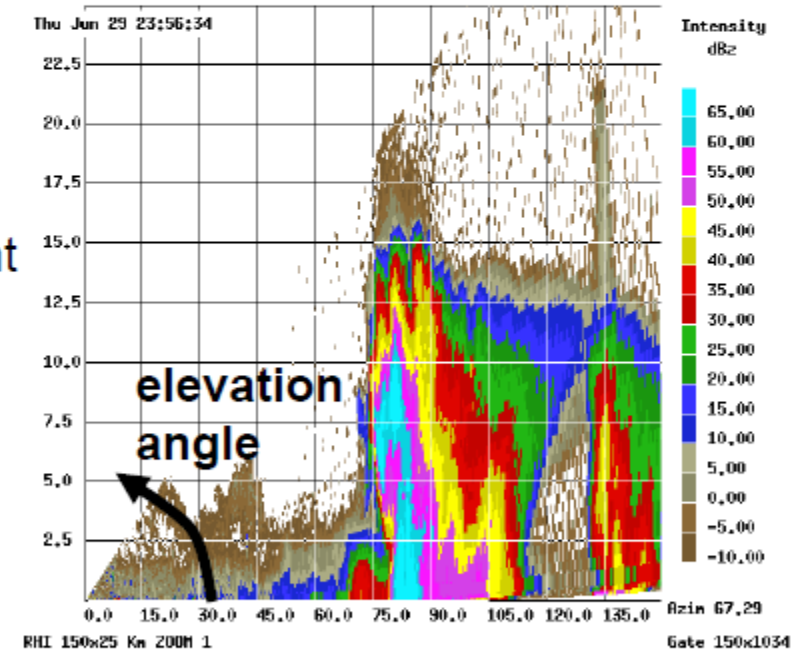
CSU-CHILL S-band radar
Supercell: 29 June 2000

雷达扫描模式： RHI

Range Height Indicator (RHI)



RHI of radar reflectivity
at 67.29° azimuth angle



雷达观测量：反射率

Send 1 megawatt （10^6 w）
Received 1 nanowatt （10^{-9} w）

雷达观测量：反射率

The received power $P_r = \frac{c_2 z}{r^2}$

c_2 **Radar constant, ~1/λ²**

z **Radar reflectivity factor**

- A quantity determined by the drop-size distribution of precipitation.

r **distance from the target to the radar**

雷达观测量：反射率

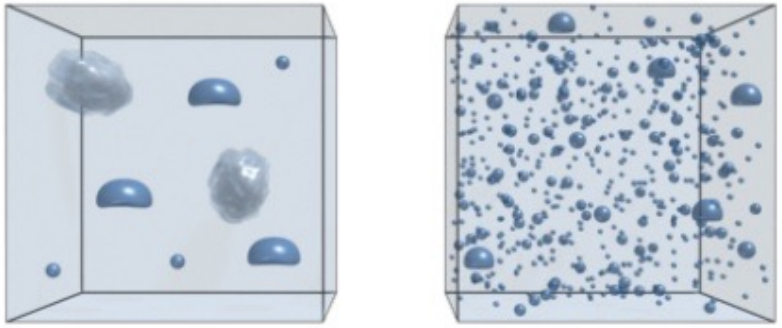
Reflectivity factor $Z = \int_0^{\infty} N(D) D^6 dD.$

N: drop-size distribution

$$Z = \sum_{i=1}^{n} D_i^6$$

Sample Volumes with Equivalent Reflectivity Values

mm^6m^{-3}



Nonprecipitating cloud: 10^{-5}-10^{1}

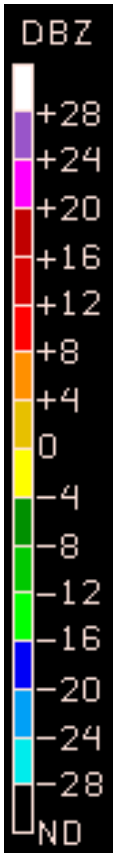
Hail: 10^{7}

雷达观测量：反射率

- **Logarithmic *z* dBZ**
  - **Decibels relative to *z* of 1 mm^6 m^{-3}**

$$Z = 10 \log_{10}\left(\frac{z}{1\ \mathrm{mm}^6/\mathrm{m}^3}\right)$$

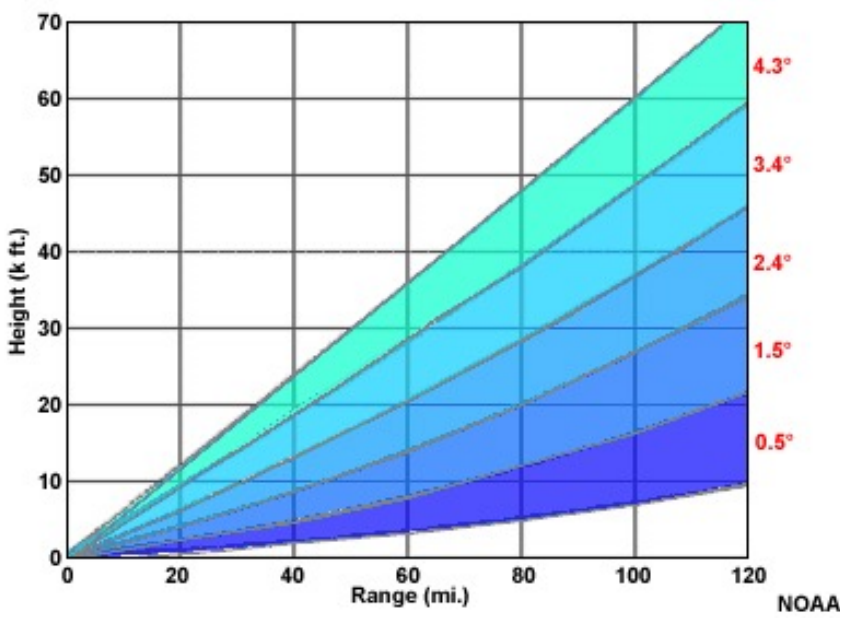
Clear air mode



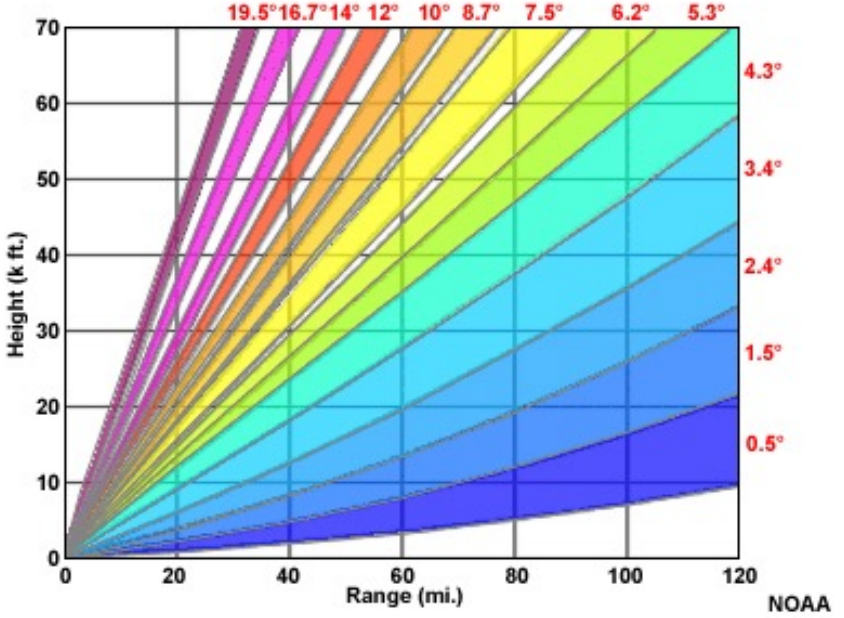
precipitation mode

雷达扫描模式

Clear-air scan mode

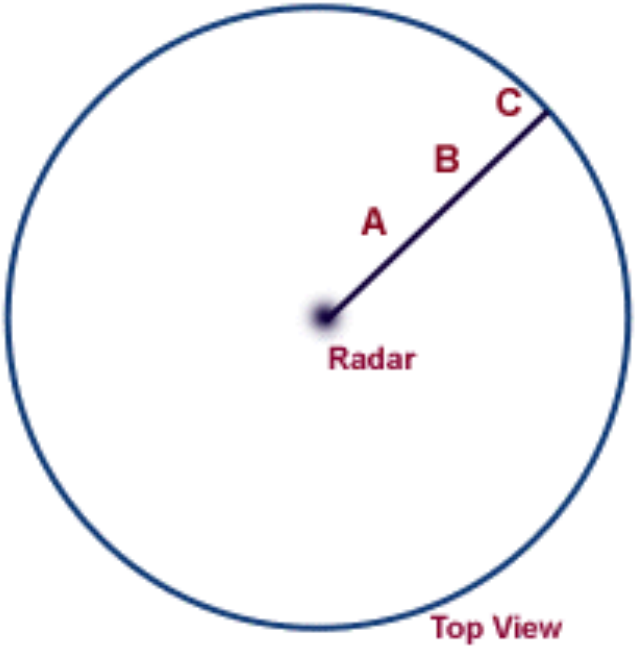


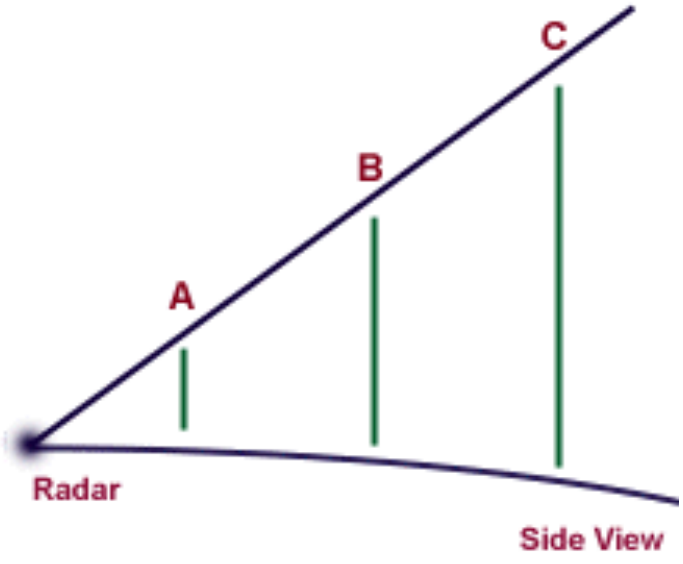
Precipitation scan mode



雷达观测量：反射率

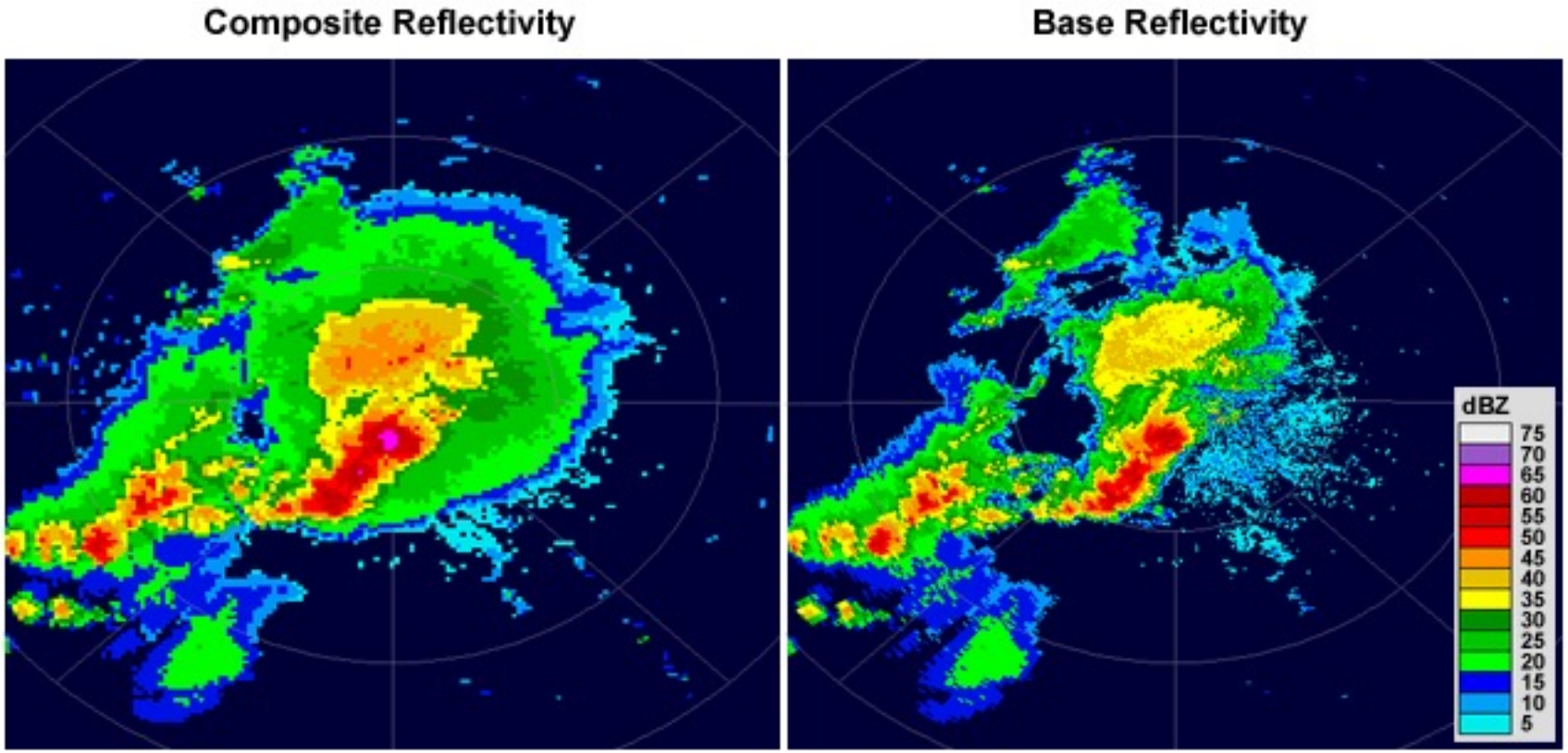
Base reflectivity



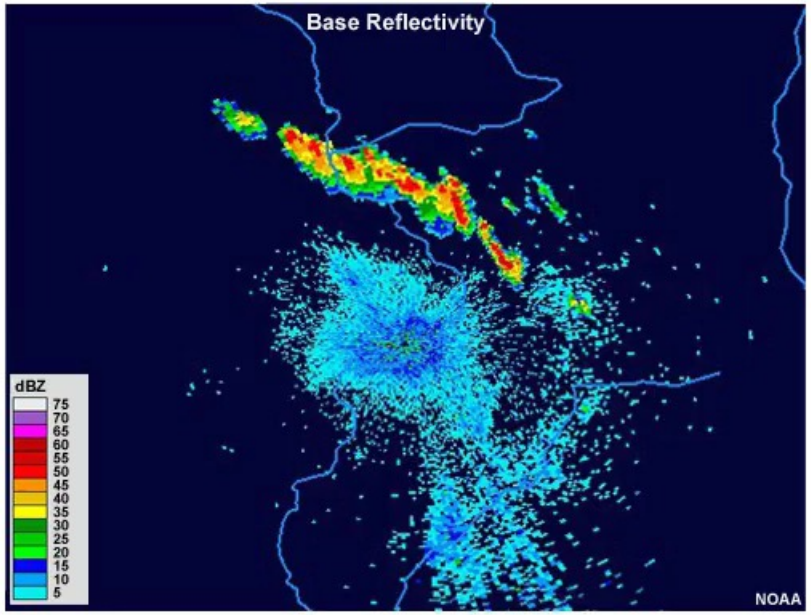


Composite reflectivity: maximum reflectivity in a column

雷达观测量：反射率


Composite Reflectivity
Base Reflectivity
dBZ
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
NOAA

雷达观测量：反射率



<20dBZ Stratiform
>40dBZ Convective
>60dBZ Hail

- **Low dBZ values (blue and green colors) indicate light precipitation**
- **Higher values in the yellow, orange, and red colors mean heavier precipitation.**
- **Motion: looping of continuous imageries**

雷达观测量: 径向速度

Doppler Effect

As the source of the sound waves moves toward the observer, each wave takes slightly less time to reach the observer than the previous one, producing a higher frequency sound.

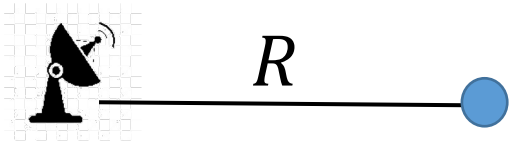
When the source passes, each wave is emitted from farther away, resulting in a lower frequency sound.

多普勒效应

多普勒速度观测原理

当雷达与目标物之间存在相对运动时， 回波信号的频率与发射信号频率不相等，这个频率差值称为**多普勒频移** f_{d}。

发射频率 f_0　　目标物移速 v　　波长 λ



圆频率波长 $\omega = 2\pi f = 2\pi \dfrac{\mathrm{c}}{\lambda}$

$$t_{\mathrm{r}} = \frac{2R}{\mathrm{c}}$$

发射时信号　$s(t) = \mathrm{A}\cos(\omega_0 t + \theta)$

接收时信号　$s_{\mathrm{r}}(t) = \mathrm{K}\, s(t - t_{\mathrm{r}})$

$$= \mathrm{K}\,\mathrm{A}\cos[\omega_0 （t - t_{\mathrm{r}}） + \theta]$$

在t时刻接收的$s_{\mathrm{r}}(t)$上的某点是在$t - t_{\mathrm{r}}$时刻发射的。其与发射信号的相位差为 $\varphi(t) = -\omega_0 t_{\mathrm{r}}$

多普勒速度观测原理

假定$t=0$时雷达距离目标物的距离为R_0，目标物朝雷达移动，则t接收时刻目标物到雷达的距离为：

$$R(t)=R_0-v_{\mathrm{r}}t \qquad t_{\mathrm{r}}=\frac{2R(t)}{\mathrm{c}}=\frac{2}{\mathrm{c}}(R_0-v_{\mathrm{r}}t)$$

相位差 $\varphi(t)=-\omega_0 t_{\mathrm{r}}=-\omega_0\frac{2}{\mathrm{c}}(R_0-v_{\mathrm{r}}t)$

$$=-2\pi\frac{\mathrm{c}}{\lambda}\frac{2}{\mathrm{c}}(R_0-v_{\mathrm{r}}t)$$

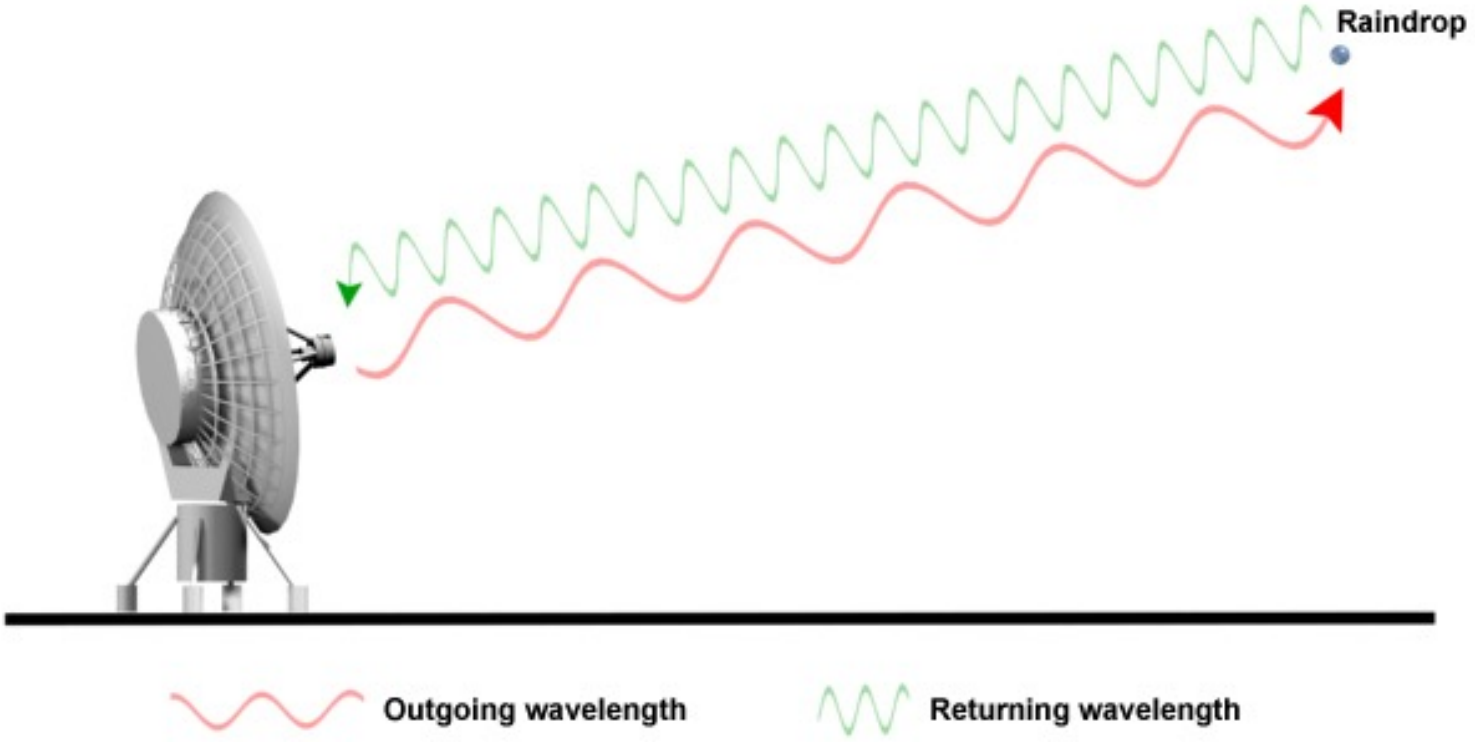
$$=-2\pi\frac{2}{\lambda}(R_0-v_{\mathrm{r}}t)$$

频率差 (假定v_{r}为常数)

$$f_{\mathrm{d}}=\frac{1}{2\pi}\frac{d\varphi}{dt}=\frac{2v_{\mathrm{r}}}{\lambda}\Rightarrow v_{\mathrm{r}}=\frac{f_{\mathrm{d}}\lambda}{2}$$

雷达观测量: 径向速度

Vr: The magnitude and direction of the shift，giving information about the motion of the target objects either toward or away from the radar. This measurement is called the "radial velocity."



Doppler or Radial Velocity (V_r)

V: target velocity
α: angle between target motion and radar pointing directions

$$V_r = V\cos(\alpha)$$

Note: A Doppler radar only detects the radial component of the velocity.

- i.e., towards or away

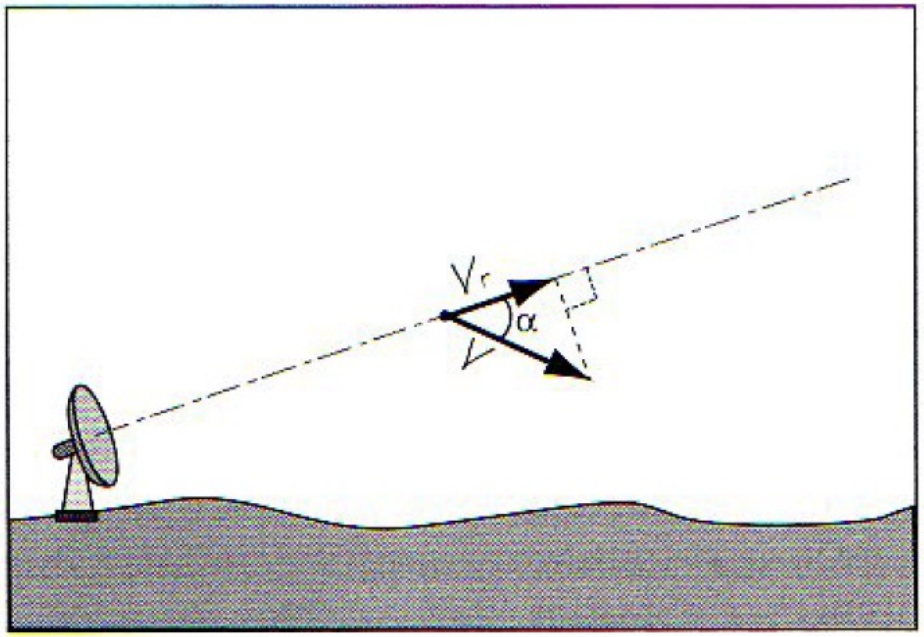
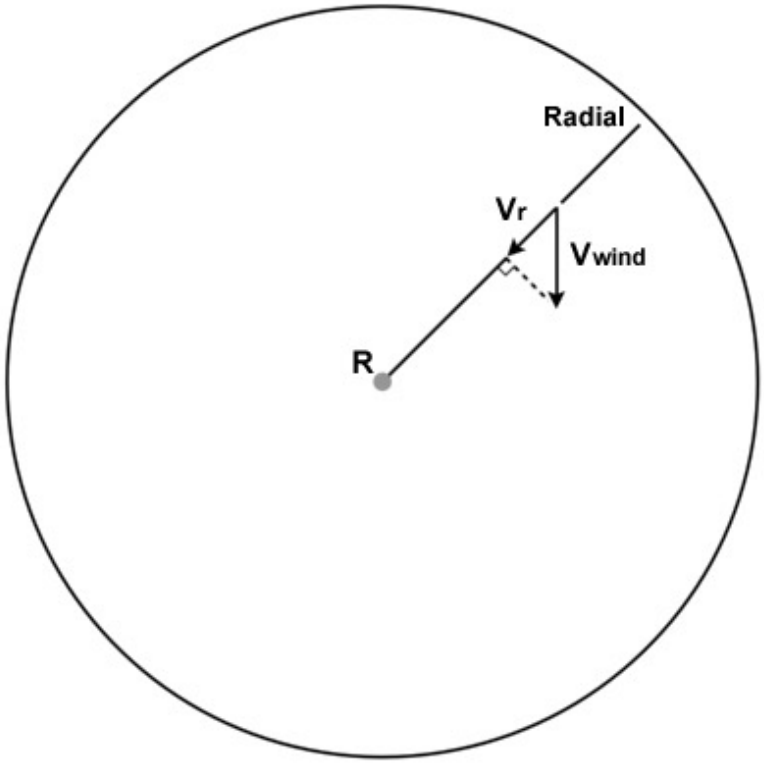


Figure 6.2 Geometric relationship of a target located on the center of the antenna beam axis moving with velocity V at an angle α relative to the pointing direction. The radar detects the radial component of velocity V_r.

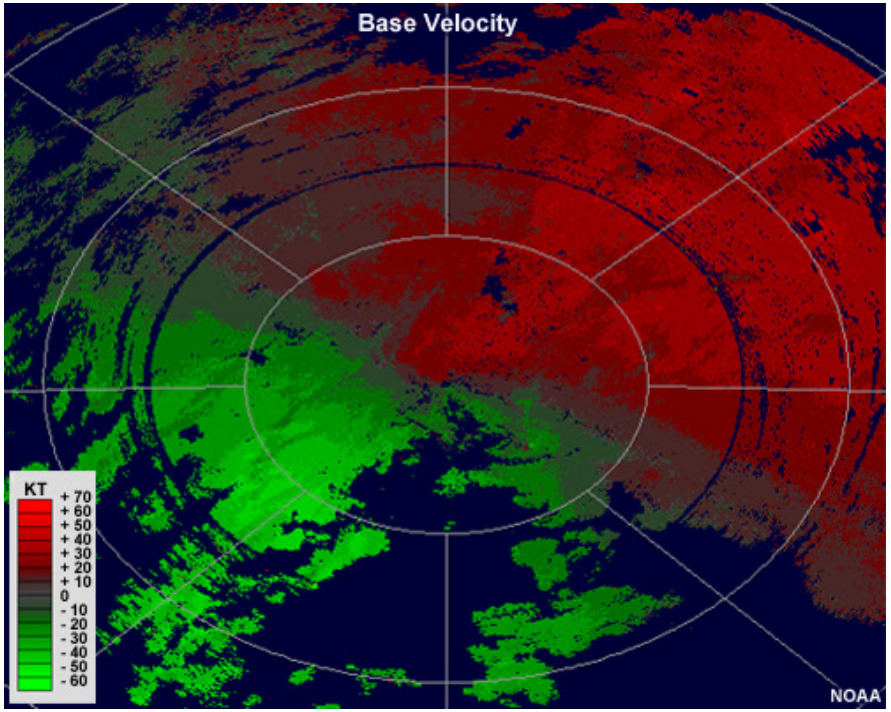
Rinehart (2004)

雷达观测量: 径向速度

The actual speed and direction of the wind will only be observed at points where the radar beam aligns perfectly parallel to a target's direction of travel.



雷达观测量: 径向速度

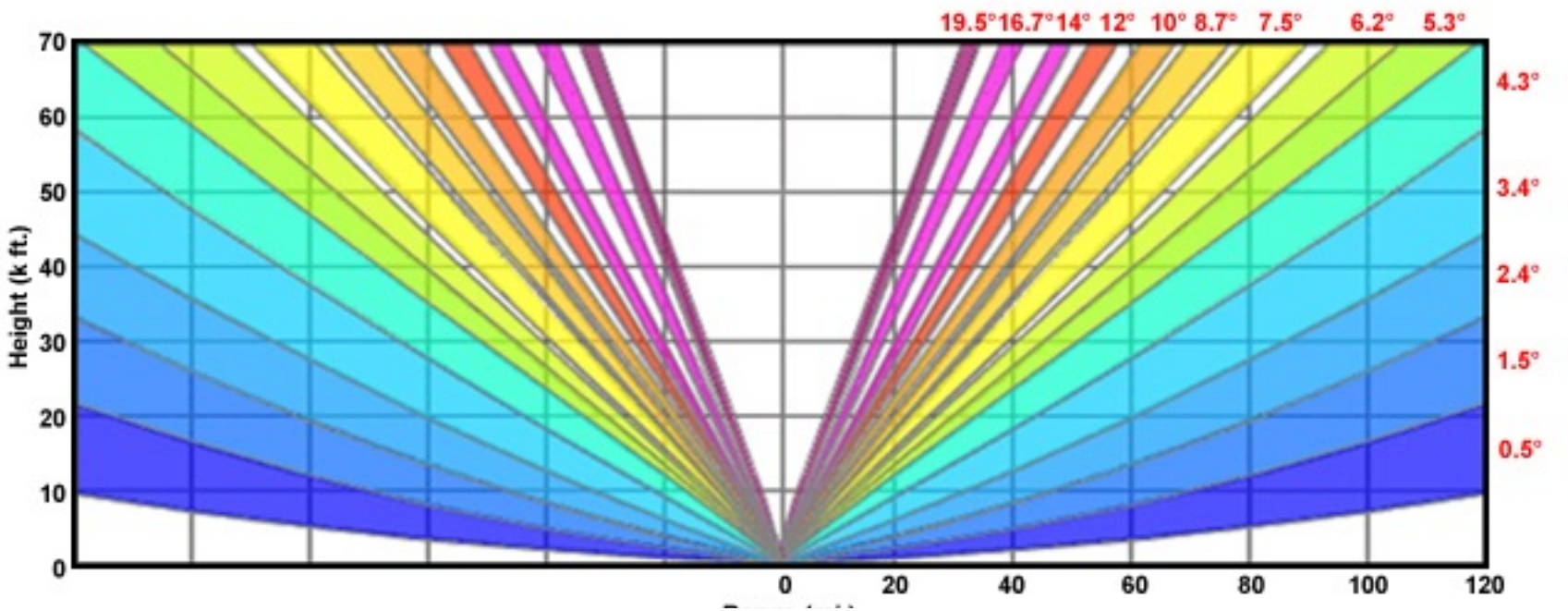


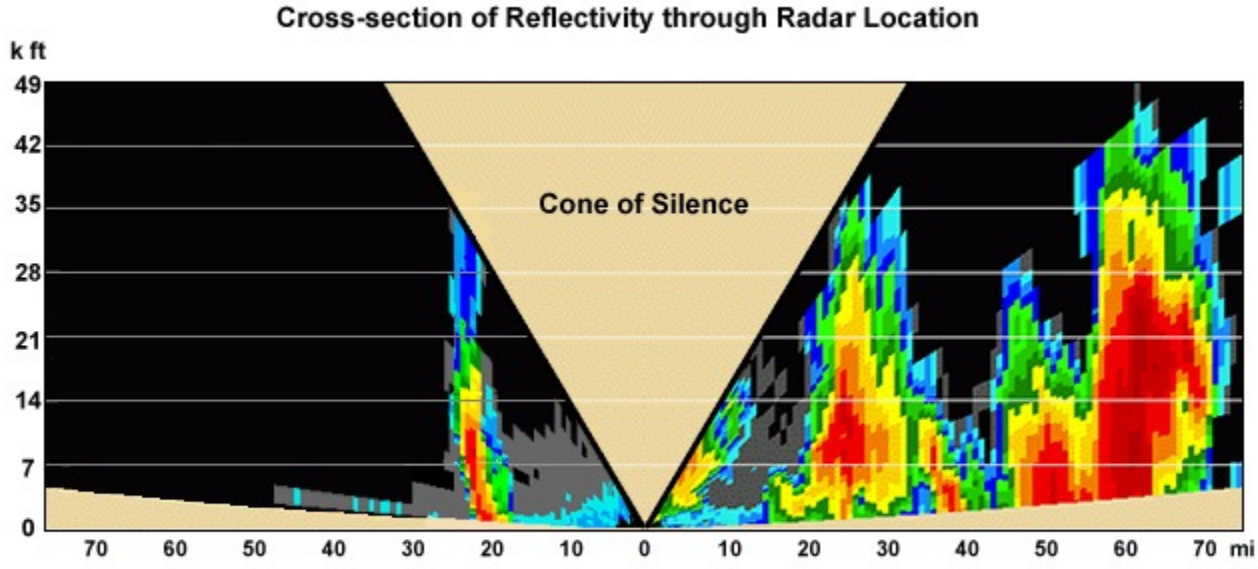
Warm colors (reds) : Motions away from the radar
Cool colors (greens): Motions toward the radar.
Gray colors : Stationary or moving perpendicular to the radar beam

主要内容

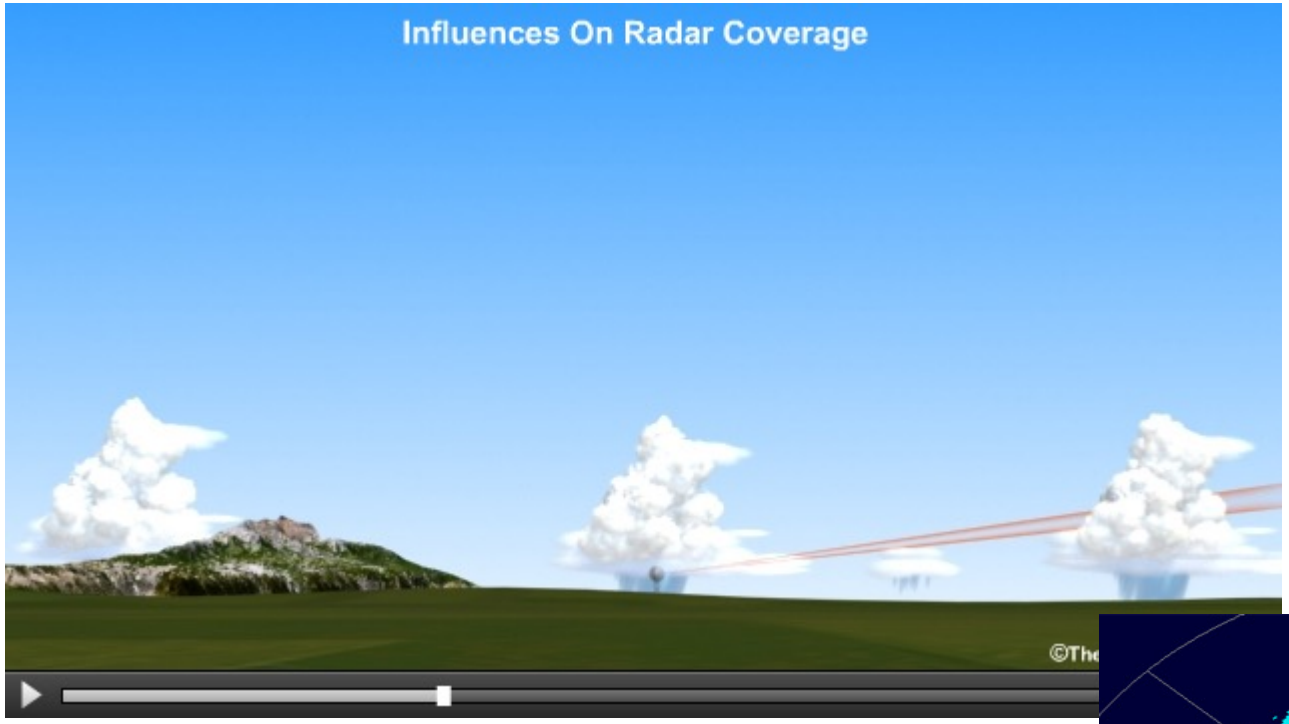
- 雷达基础
- 雷达局限性
- 风场特征识别
- 晴空模式雷达观测特征识别
- 降水模式雷达观测特征识别

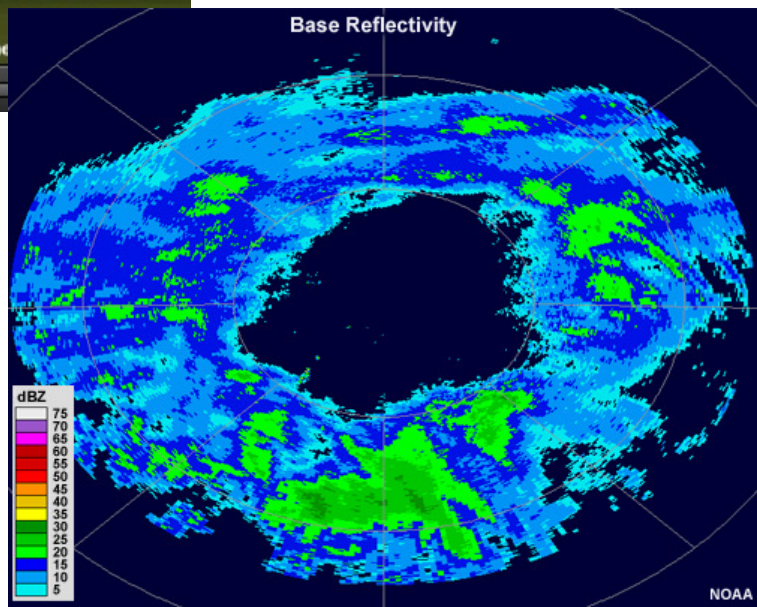
盲区


19.5° 16.7° 14° 12° 10° 8.7° 7.5° 6.2° 5.3°
4.3°
3.4°
2.4°
1.5°
0.5°
Height (k ft.)
70
60
50
40
30
20
10
0
0
20
40
60
80
100
120


Cross-section of Reflectivity through Radar Location
k ft
49
42
35
28
21
14
7
0
Cone of Silence
70
60
50
40
30
20
10
0
10
20
30
40
50
60
70 mi

盲区

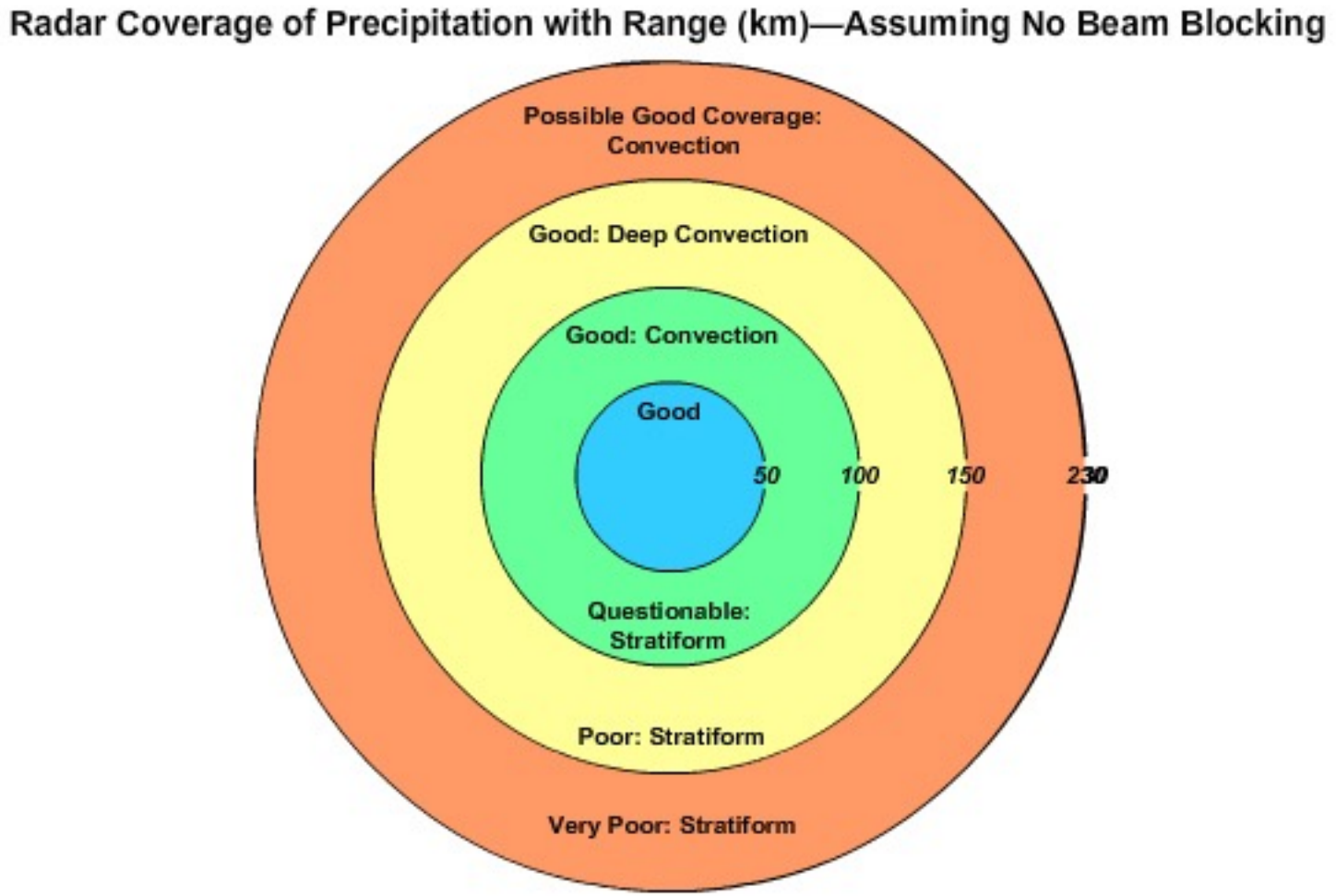

Influences On Radar Coverage


Base Reflectivity
dBZ
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
NOAA

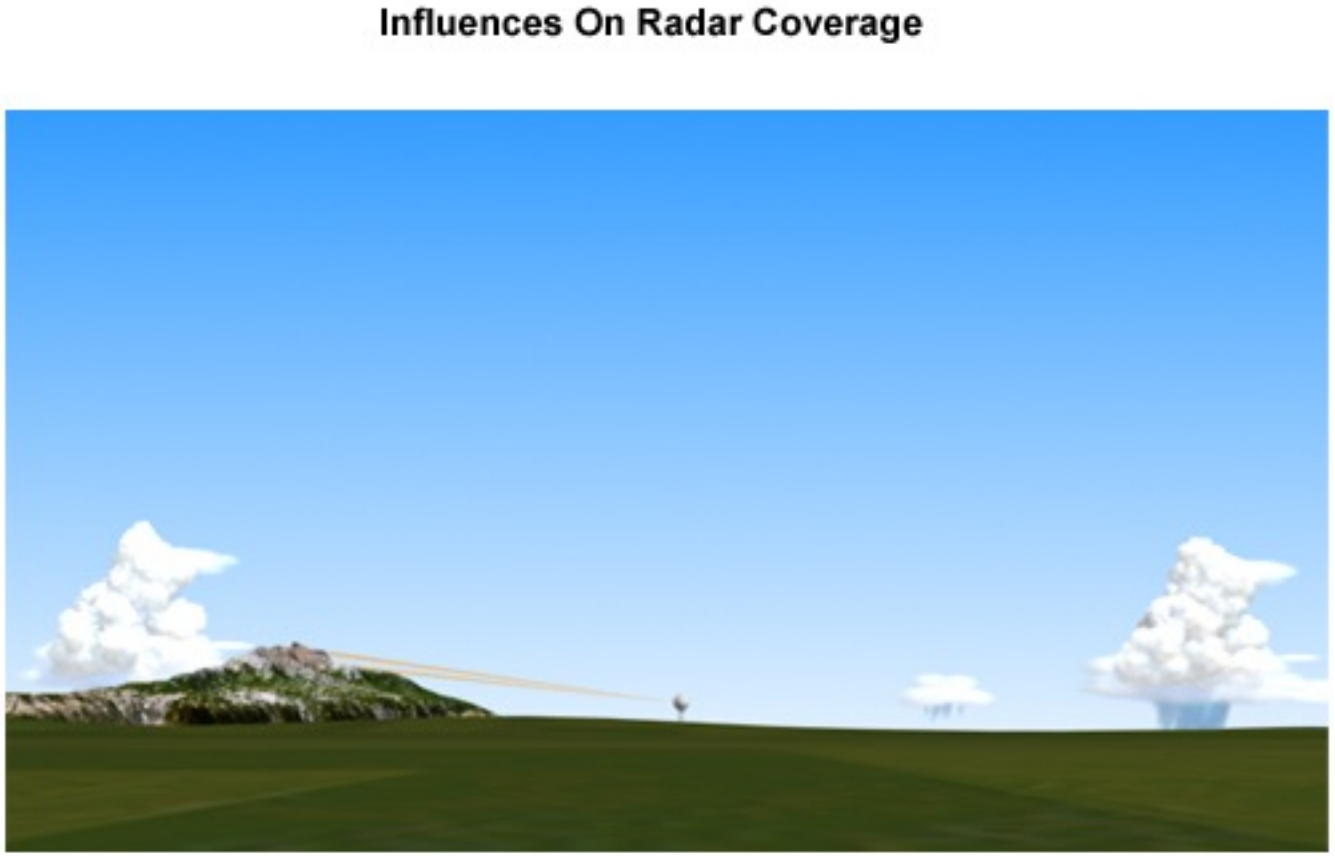
盲区

Most of the time, fog goes undetected by radar because of its very low altitude and the small droplet sizes

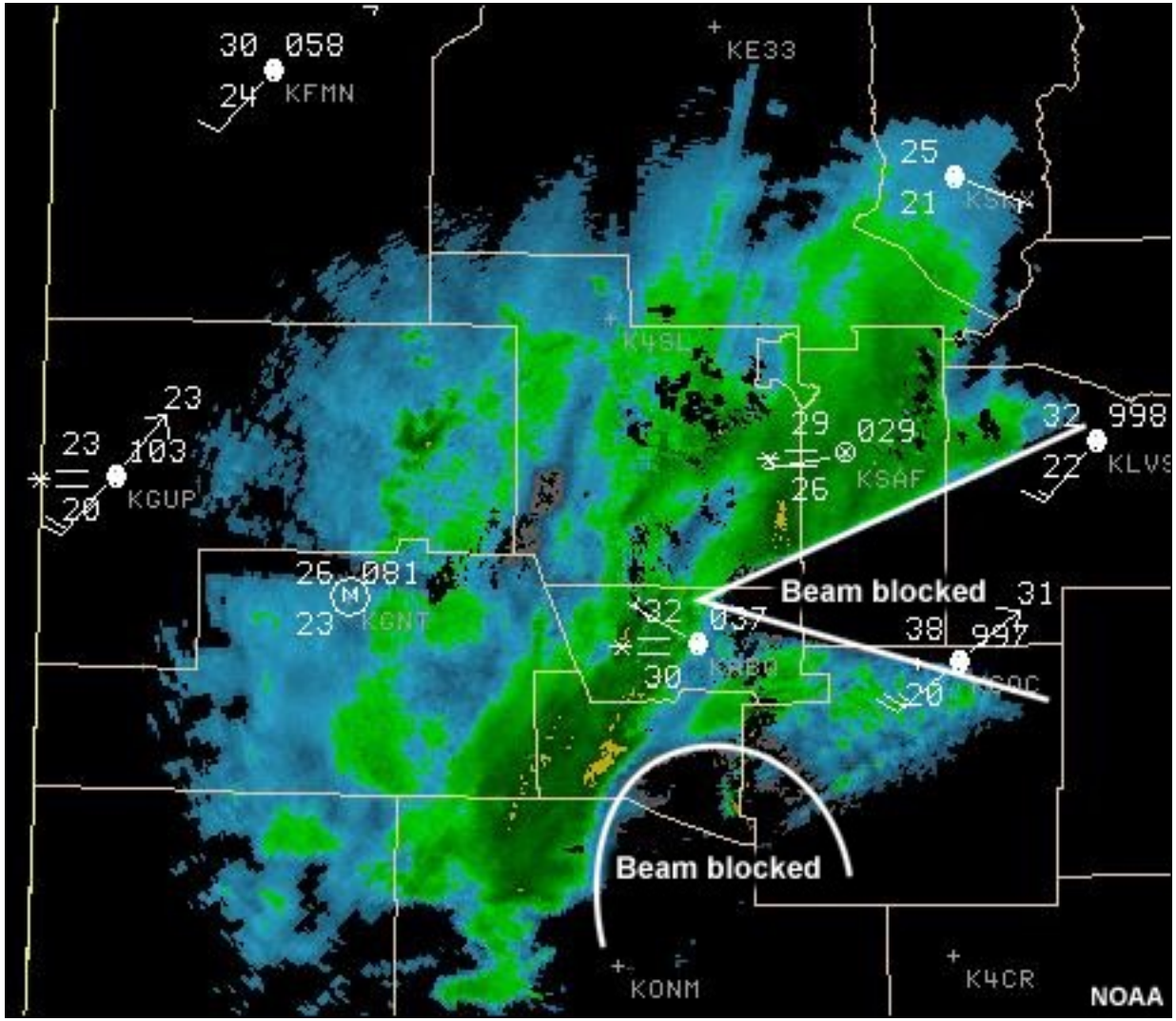
雷达覆盖度


Radar Coverage of Precipitation with Range (km)—Assuming No Beam Blocking
Possible Good Coverage:
Convection
Good: Deep Convection
Good: Convection
Good
50
100
150
230
Questionable:
Stratiform
Poor: Stratiform
Very Poor: Stratiform

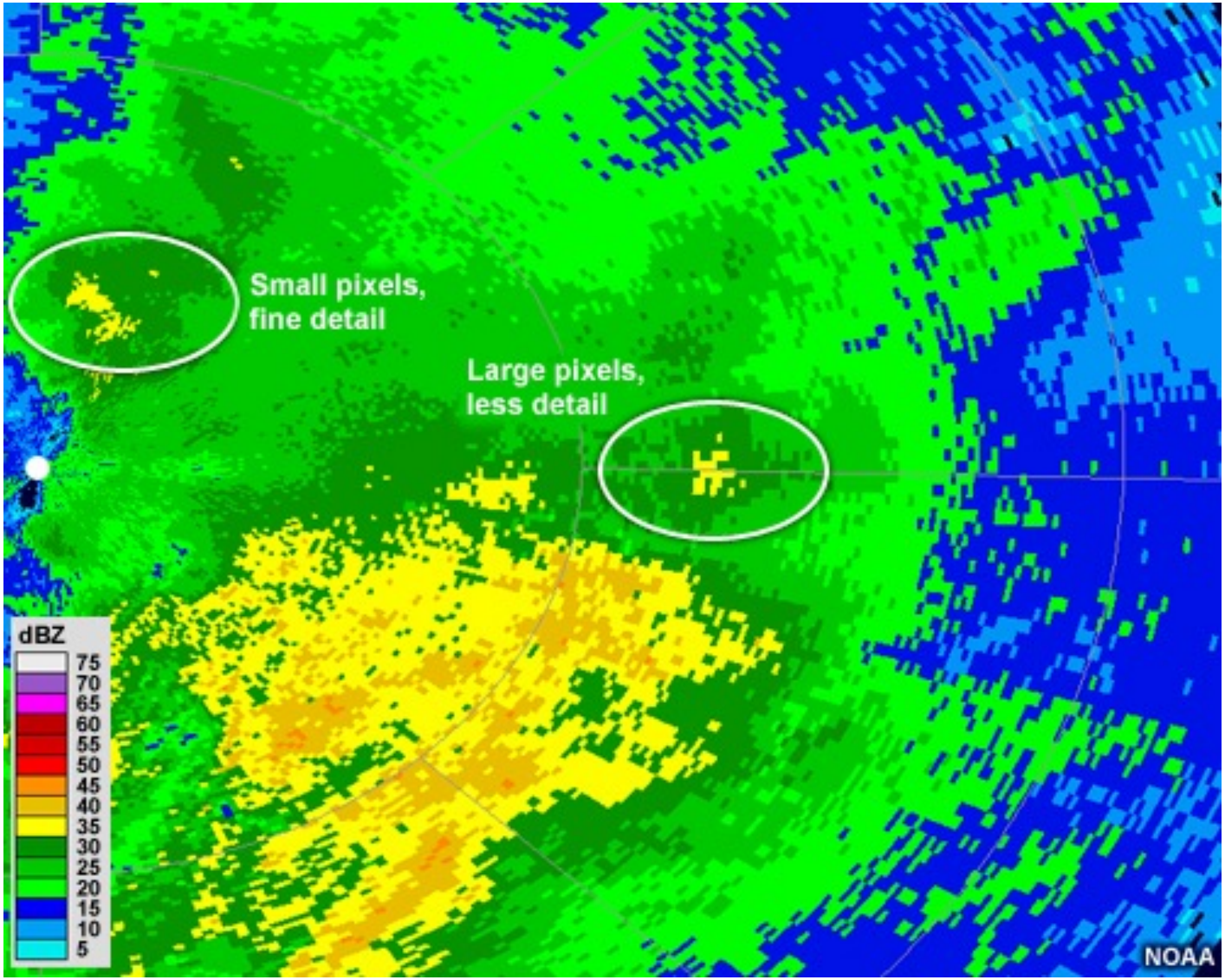
Beam blocking



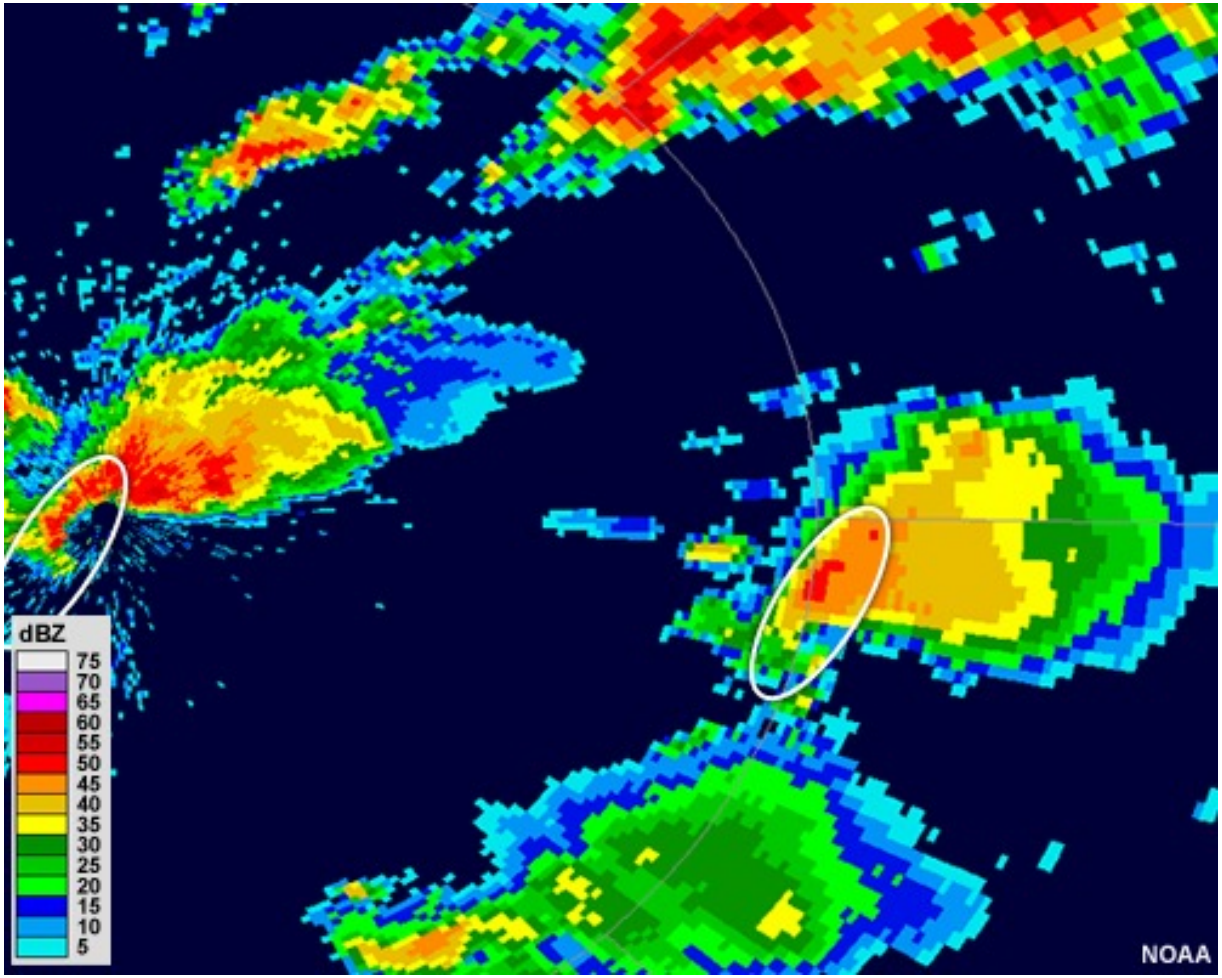
Beam blocking



Resolution


Small pixels,
fine detail
Large pixels,
less detail
dBZ
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
NOAA

Resolution



Small but important features may not be observable as they will be averaged over an area that is larger than they are

距离模糊

Range is defined by $R = ct/2$

t: The time between signal sending and receiving

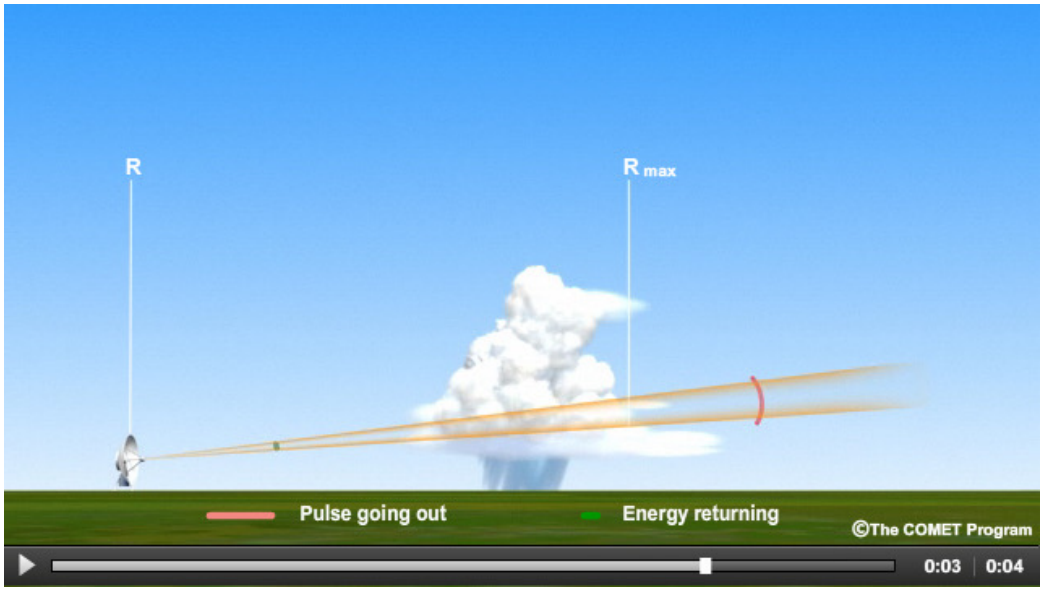
Ambiguous: If the second pulse is sent before the first pulse returns, t is regarded as the time between the sending of one pulse and returning of a previous one.

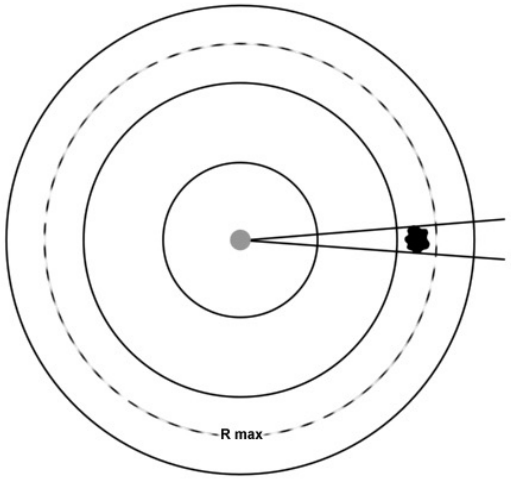
The time between pulse is $\mathrm{T} = \frac{1}{\mathrm{PRF}}$

The maximum unambiguous range is $R_{max} = \frac{cT}{2} = \frac{c}{2\mathrm{PRF}}$

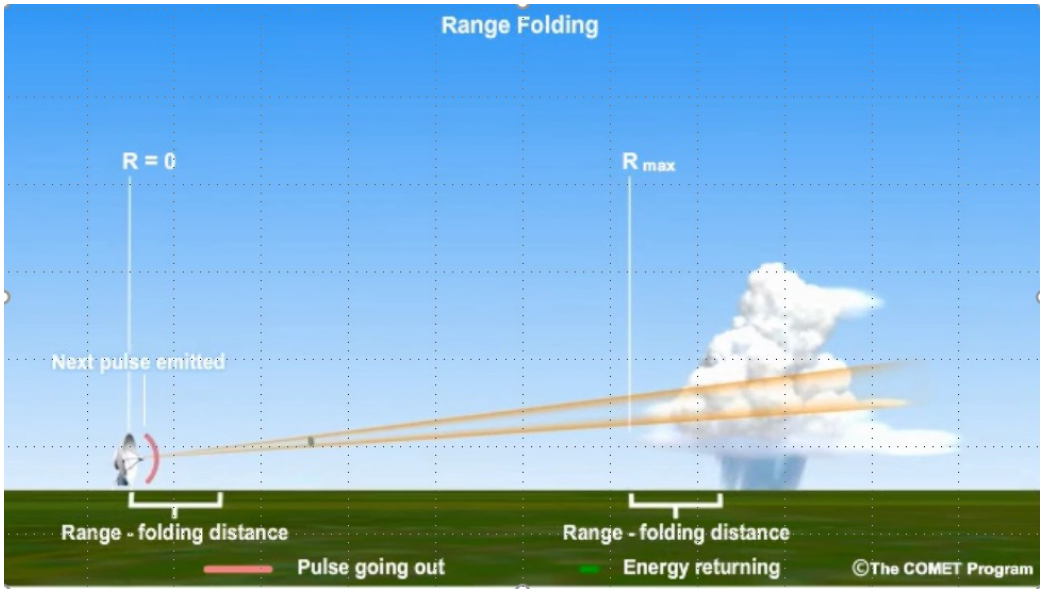
The aliased range will be $R - R_{max}$

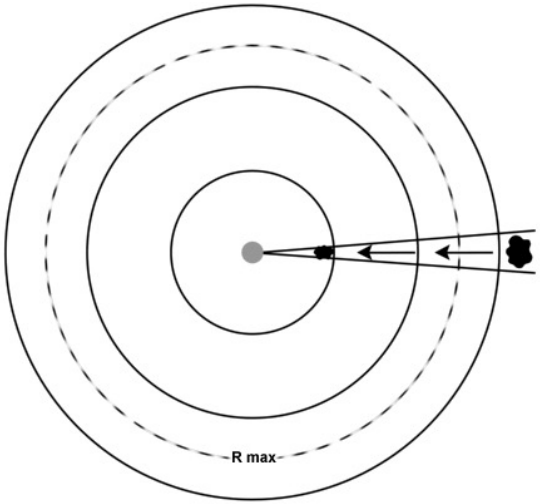
距离模糊



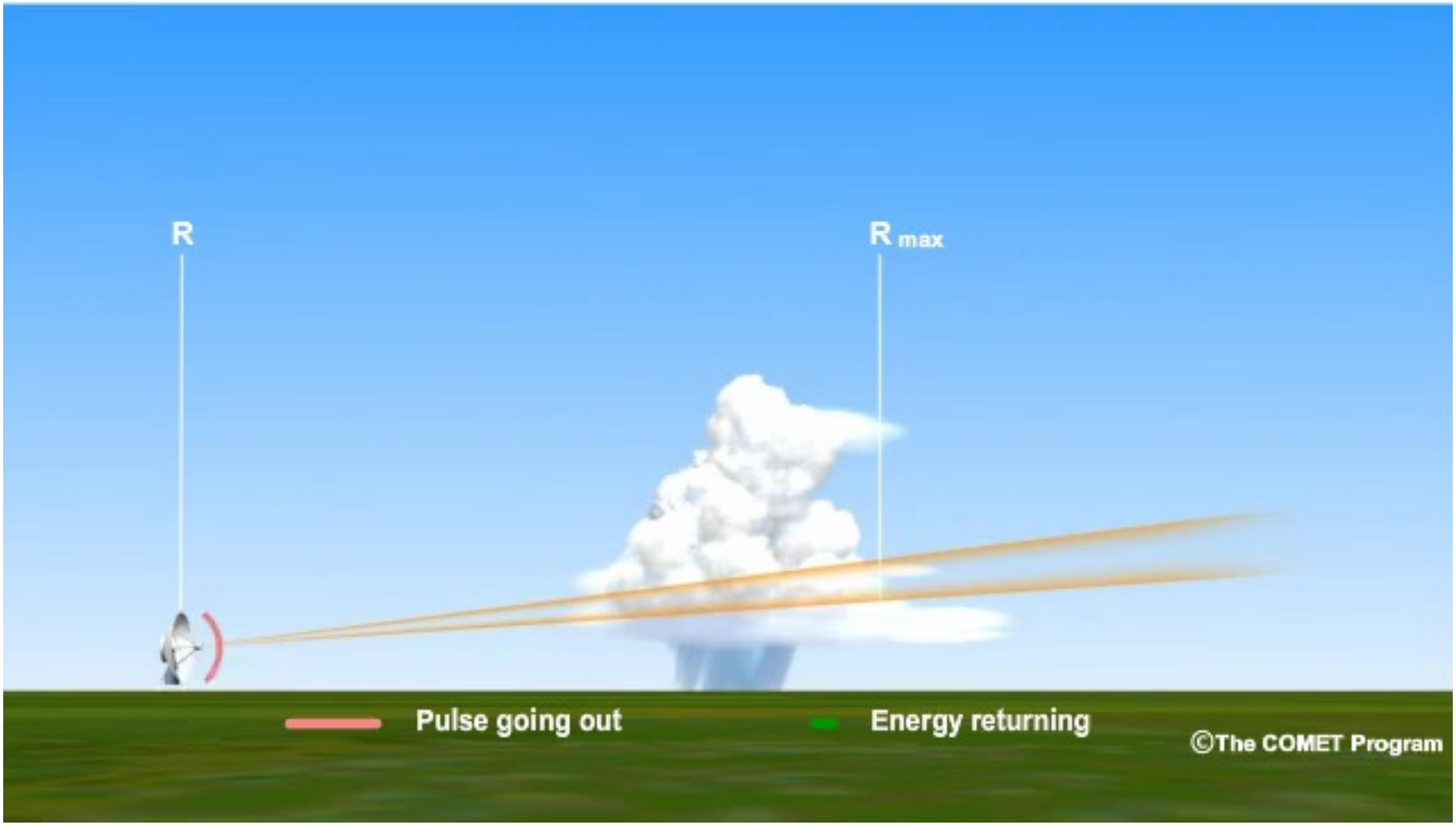


©The COMET Program





距离模糊



速度模糊

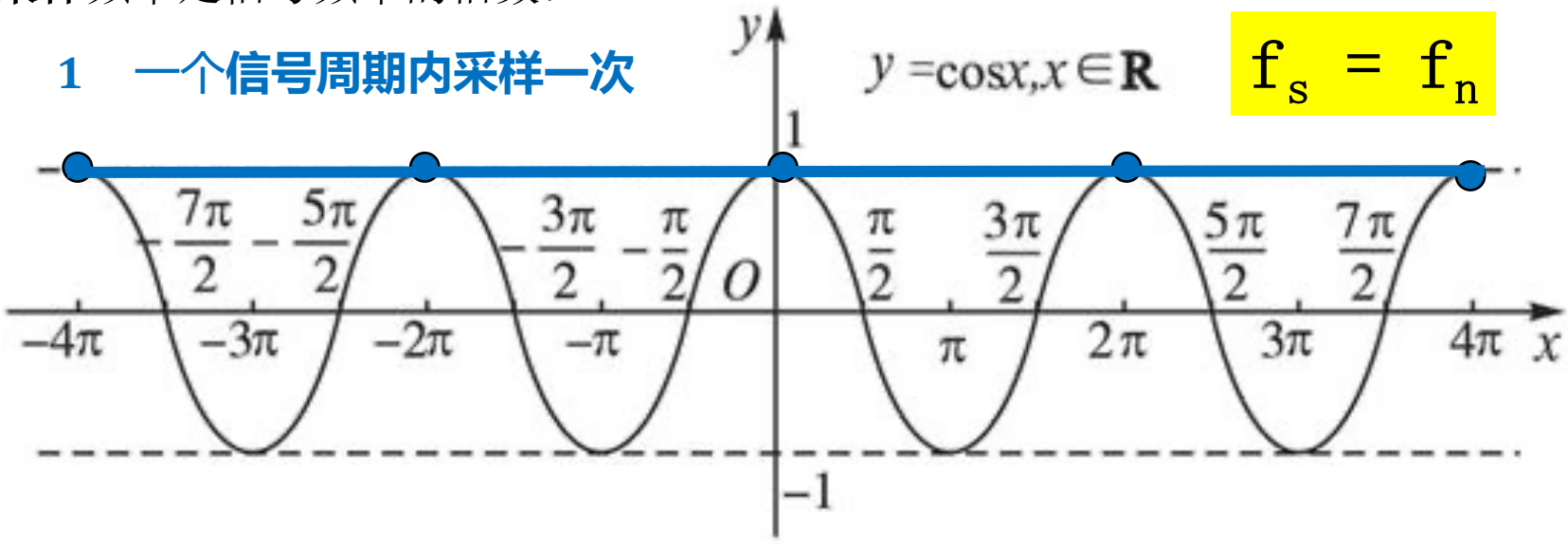
多普勒速度　$V_r=f_d \cdot \lambda/2$　　f_d为多普勒频移

脉冲雷达存在采样频率PRF （Pulse Repetition Frequency)

Nyquist采样定理（Nyquist 1928 ；科捷利尼科夫 1933；香农定理，1948）：重建信号的采样频率至少应为信号频率的2倍。

采样频率是信号频率的倍数：

1　一个信号周期内采样一次



$f_s = f_n$

速度模糊

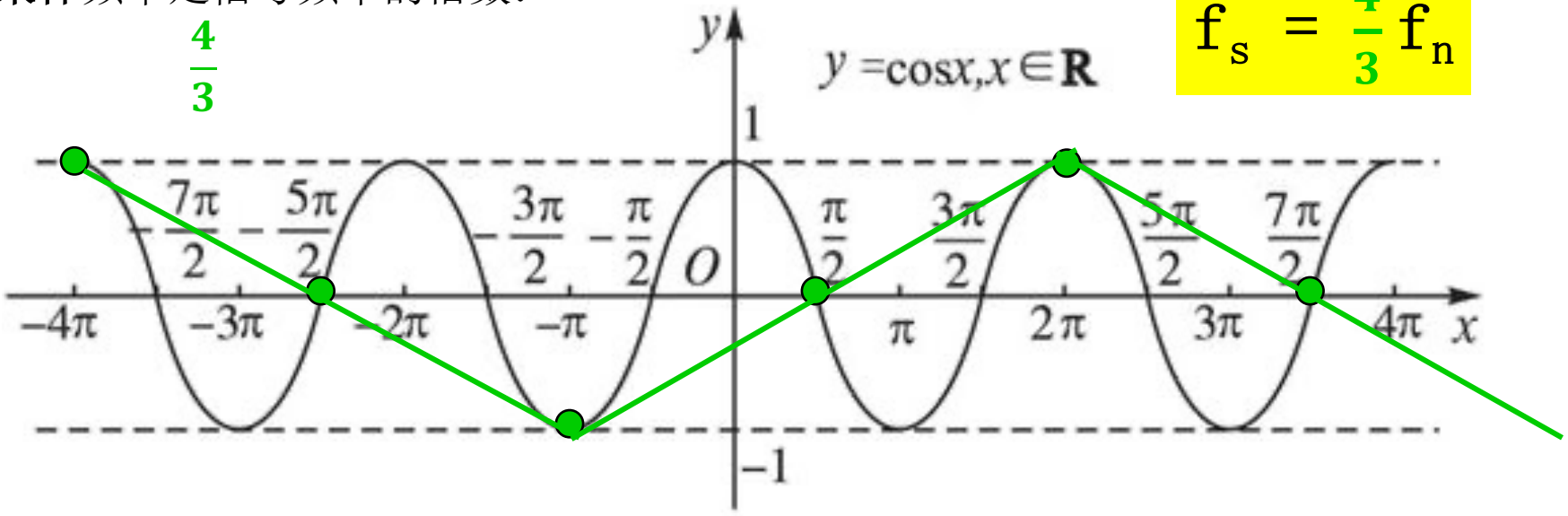
多普勒速度　$V_r=f_d \cdot \lambda/2$　　f_d为多普勒频移

脉冲雷达存在采样频率PRF （Pulse Repetition Frequency)

Nyquist采样定理（Nyquist 1928 ；科捷利尼科夫 1933；香农定理，1948）：重建信号的采样频率至少应为信号频率的2倍。

采样频率是信号频率的倍数：$\frac{4}{3}$

$$f_s = \frac{4}{3} f_n$$



速度模糊

多普勒速度　$V_r=f_d \cdot \lambda/2$　　f_d为多普勒频移

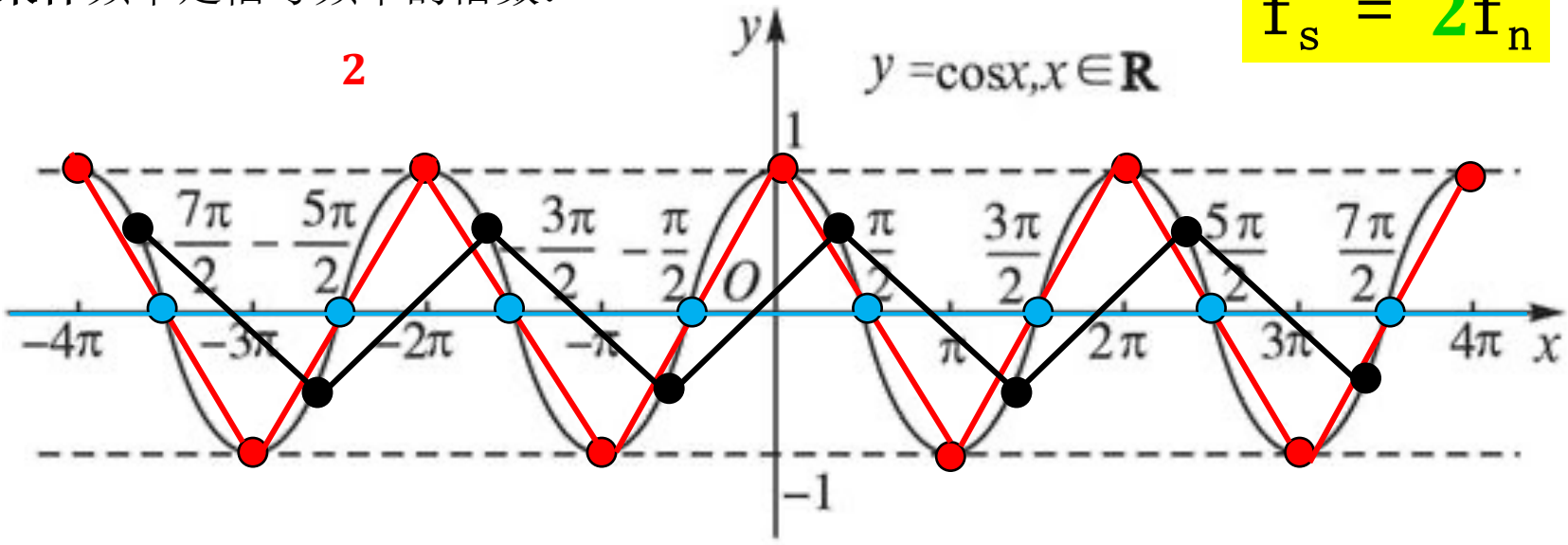
脉冲雷达存在采样频率PRF （Pulse Repetition Frequency)

Nyquist采样定理（Nyquist 1928 ；科捷利尼科夫 1933；香农定理，1948）：重建信号的采样频率至少应为信号频率的2倍。

采样频率是信号频率的倍数：

$f_s = 2f_n$

2



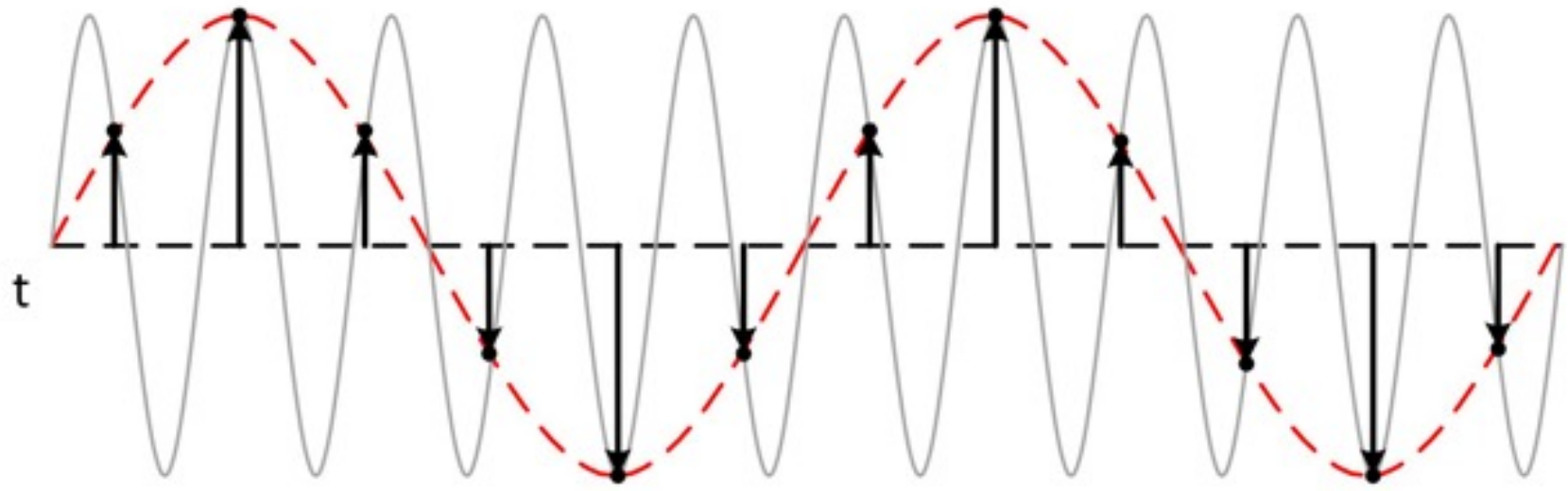
$f_s > 2f_n$ ⟶ $f_{d\ max}=0.5\ PRF$　　波幅失真

速度模糊

$$f_{d\ max}=0.5\ PRF$$

如果采样频率低于信号频率的2倍，采样数据中就会出现虚假的低频成分.

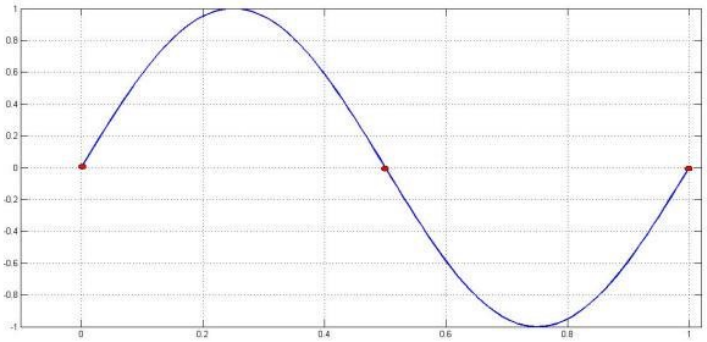
800kHz的正弦波1MS/s（10^6 Hz)的采样，得到了200 kHz的正弦波



速度模糊

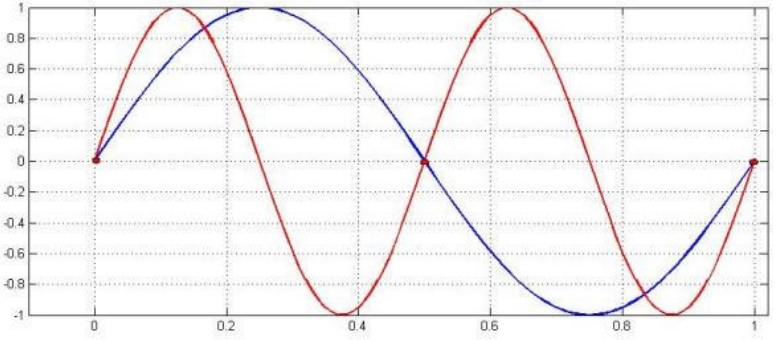
几种相差nf_d的目标多普勒频移会被当做相同的多普勒频移，即速度模糊。

Sin $(2\ \pi/t)$



Sin $(2\ \pi/t)$

Sin $(4\ \pi/t)$



多普勒频移f_d的上限

令 $\mathrm{PRF} = \mathrm{N}f \quad \mathrm{N} > 2 \qquad f = \dfrac{\mathrm{PRF}}{\mathrm{N}}$

f为原信号频率，f'为返回信号频率，要保证都能重建f，f'，PRF要大于二者的2倍。

$$\mathrm{PRF} > 2f \quad \mathrm{PRF} > 2f' \Rightarrow f < \frac{\mathrm{PRF}}{2} \quad f' < \frac{\mathrm{PRF}}{2}$$

设频移 $f_d = \dfrac{\mathrm{PRF}}{\mathrm{n}}$

$$f' = f + f_d = \frac{\mathrm{PRF}}{\mathrm{N}} + \frac{\mathrm{PRF}}{\mathrm{n}} = \frac{\mathrm{n}+\mathrm{N}}{\mathrm{Nn}}\mathrm{PRF}$$

$$\mathrm{PRF} = \frac{\mathrm{Nn}}{\mathrm{n}+\mathrm{N}} f'$$

由$\mathrm{PRF} > 2f'$ $\Rightarrow$ $\dfrac{\mathrm{Nn}}{\mathrm{n}+\mathrm{N}} f' > 2f'$

多普勒频移f_d的上限

$$\Rightarrow \frac{Nn}{n+N} > 2 \quad \Rightarrow \quad Nn > 2N + 2n$$

$$(N-2)n > 2N$$

由于$N > 2$ $\Rightarrow n > \frac{2N}{N-2} = \frac{2}{1-\frac{2}{N}} > 2$

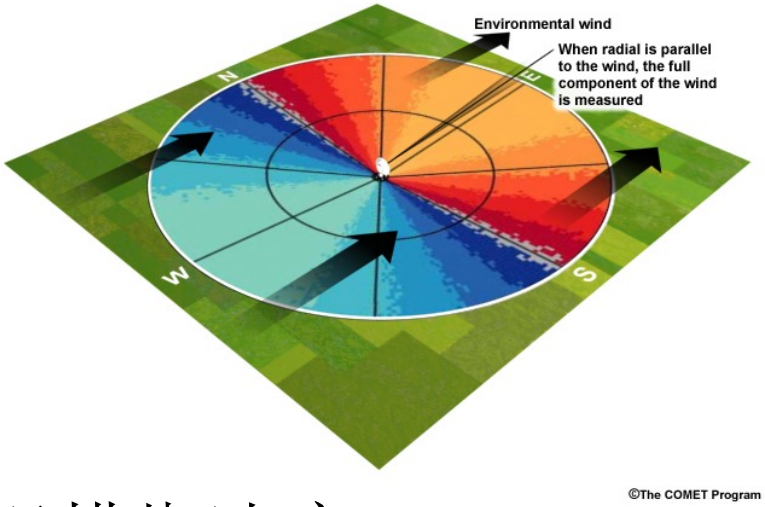
因此，频移f_d的上限为$\frac{PRF}{2}$ $f_{d\ max}=0.5\ PRF$ $V_r=f_d \cdot \lambda/2$

$V_{max}=f_{d\ max} \cdot \lambda/2 = 0.5\ PRF \cdot \lambda/2 = PRF \cdot \lambda/4$

$R_{max}= c/(2\ PRF)$

$V_{max} \cdot R_{max}= c\ \lambda\ /\ 8$ (Doppler Dilemma)

速度模糊



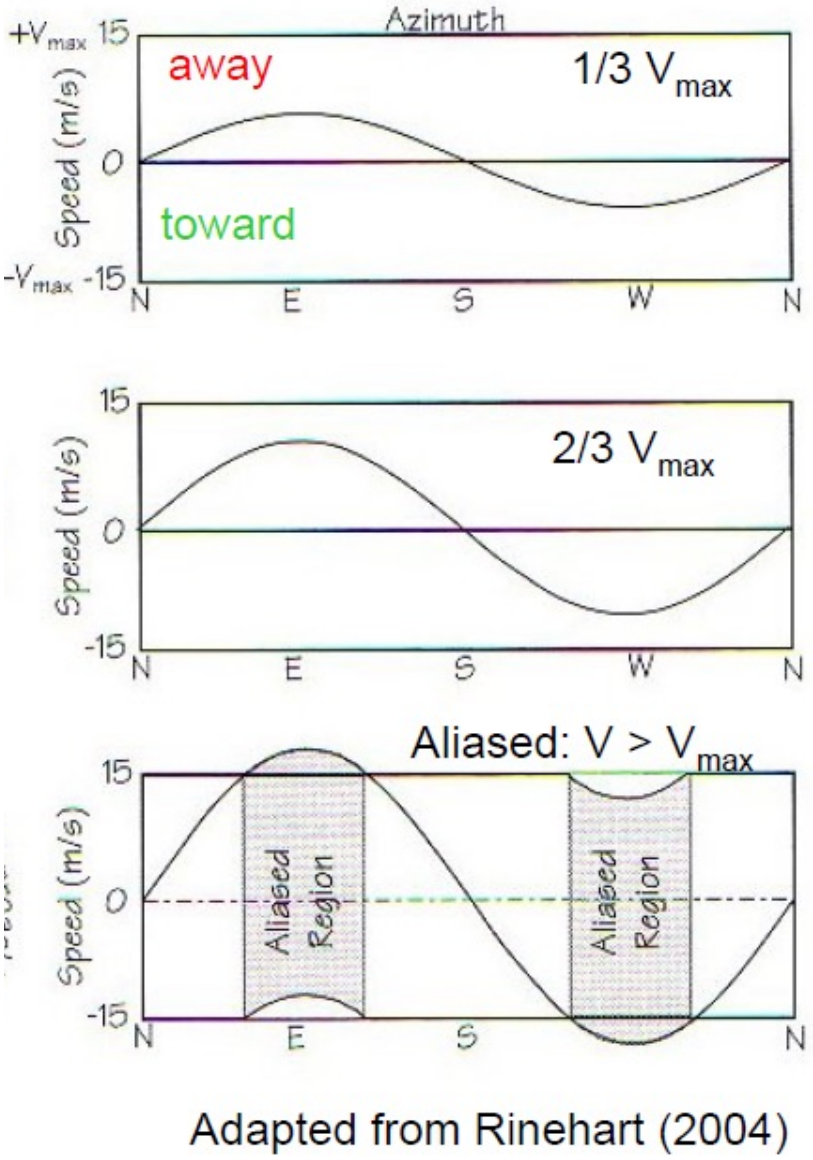
退模糊速度

Dealiased speed:

$V=V_{max}+V_{max}+Aliased\_V$

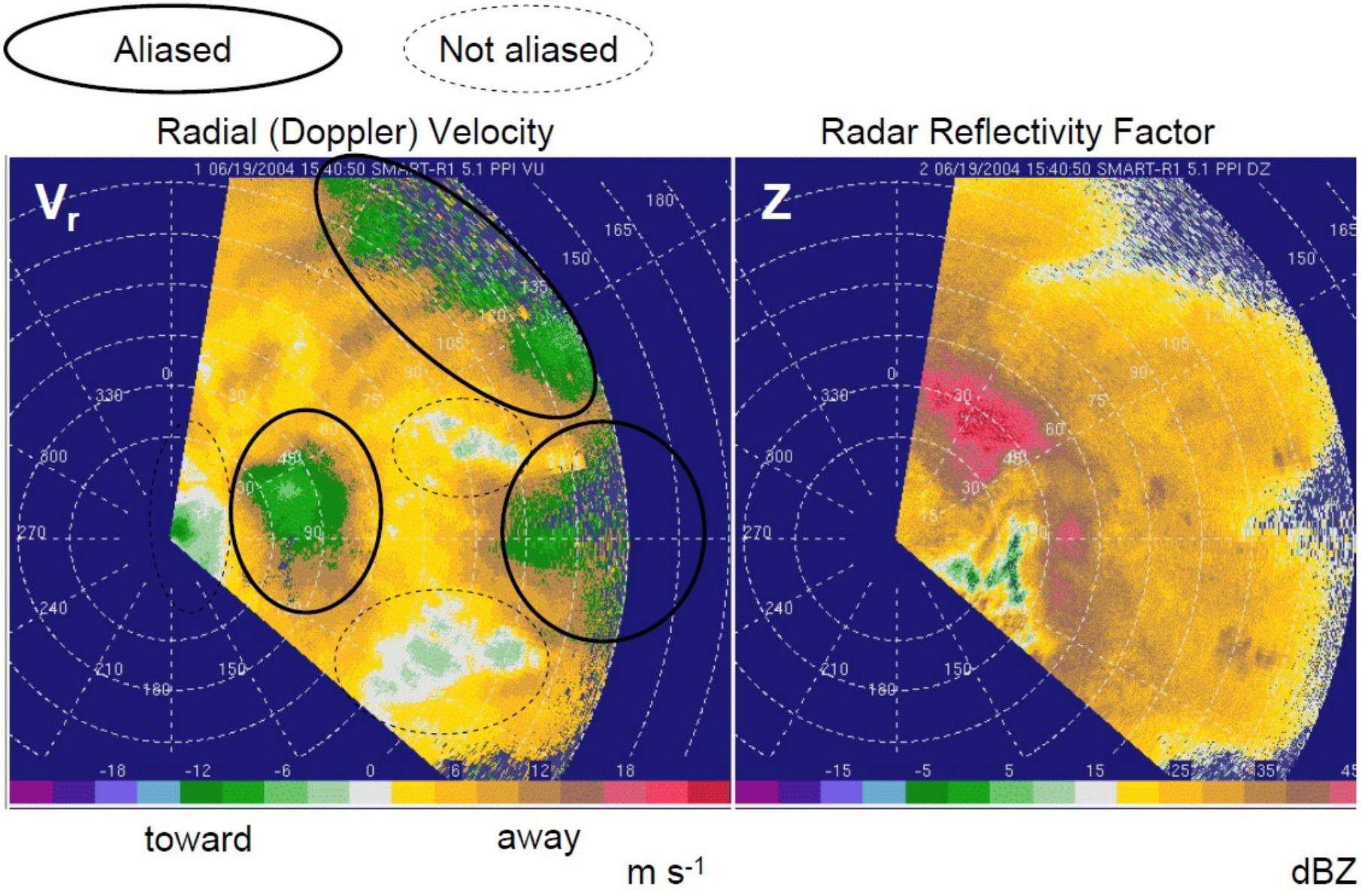
$=2*V_{max}+Aliased\_V$

V_{max} 为模糊速度出现值域的最大非模糊速度



Adapted from Rinehart (2004)

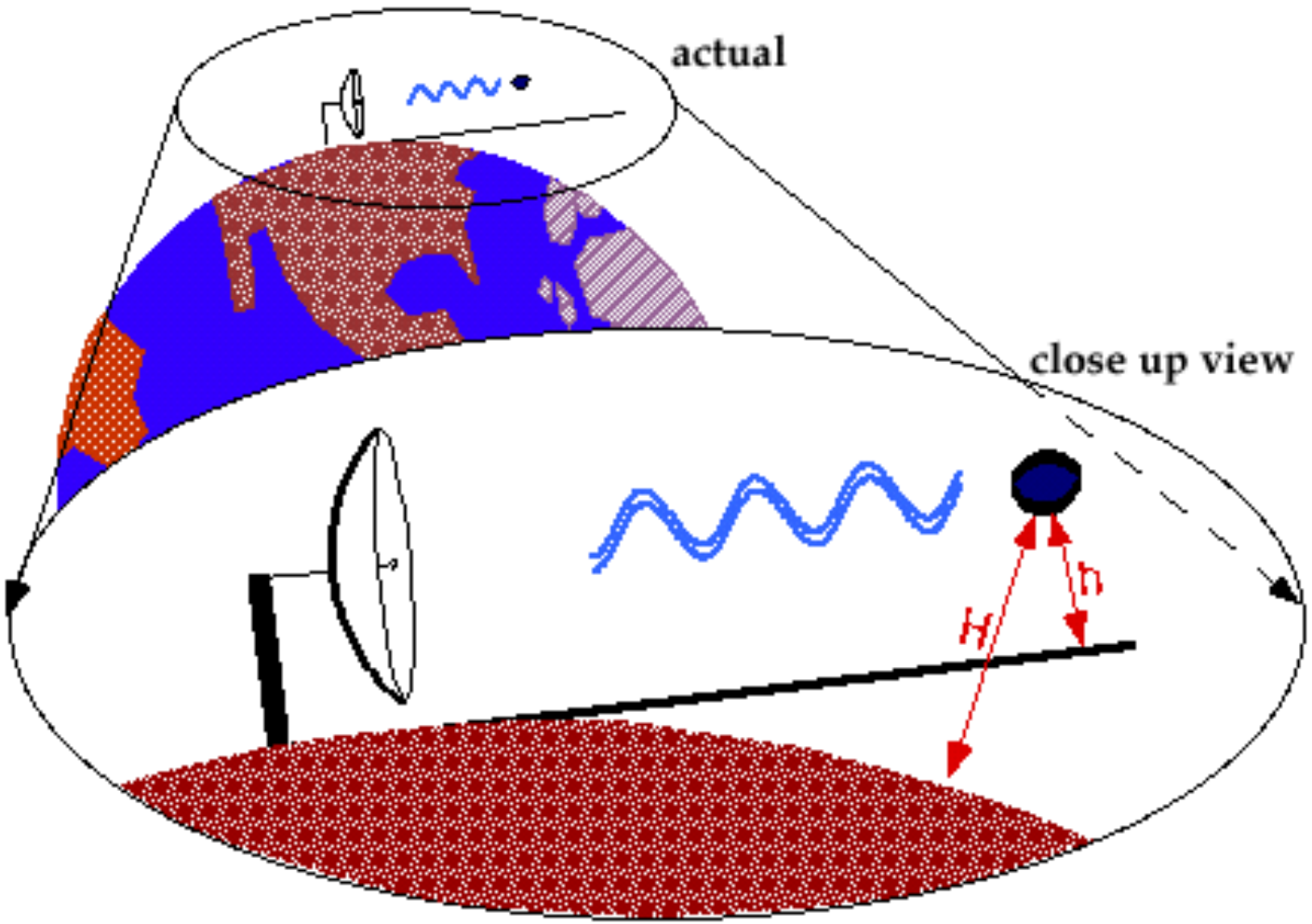
速度模糊


Aliased
Not aliased
Radial (Doppler) Velocity
Radar Reflectivity Factor
1 06/19/2004 15:40:50 SMART-R1 5.1 PPI VU
2 06/19/2004 15:40:50 SMART-R1 5.1 PPI DZ
Vr
Z
-18 -12 -6 0 6 12 18
-15 -5 5 15 25 35 45
toward
away
m s-1
dBZ

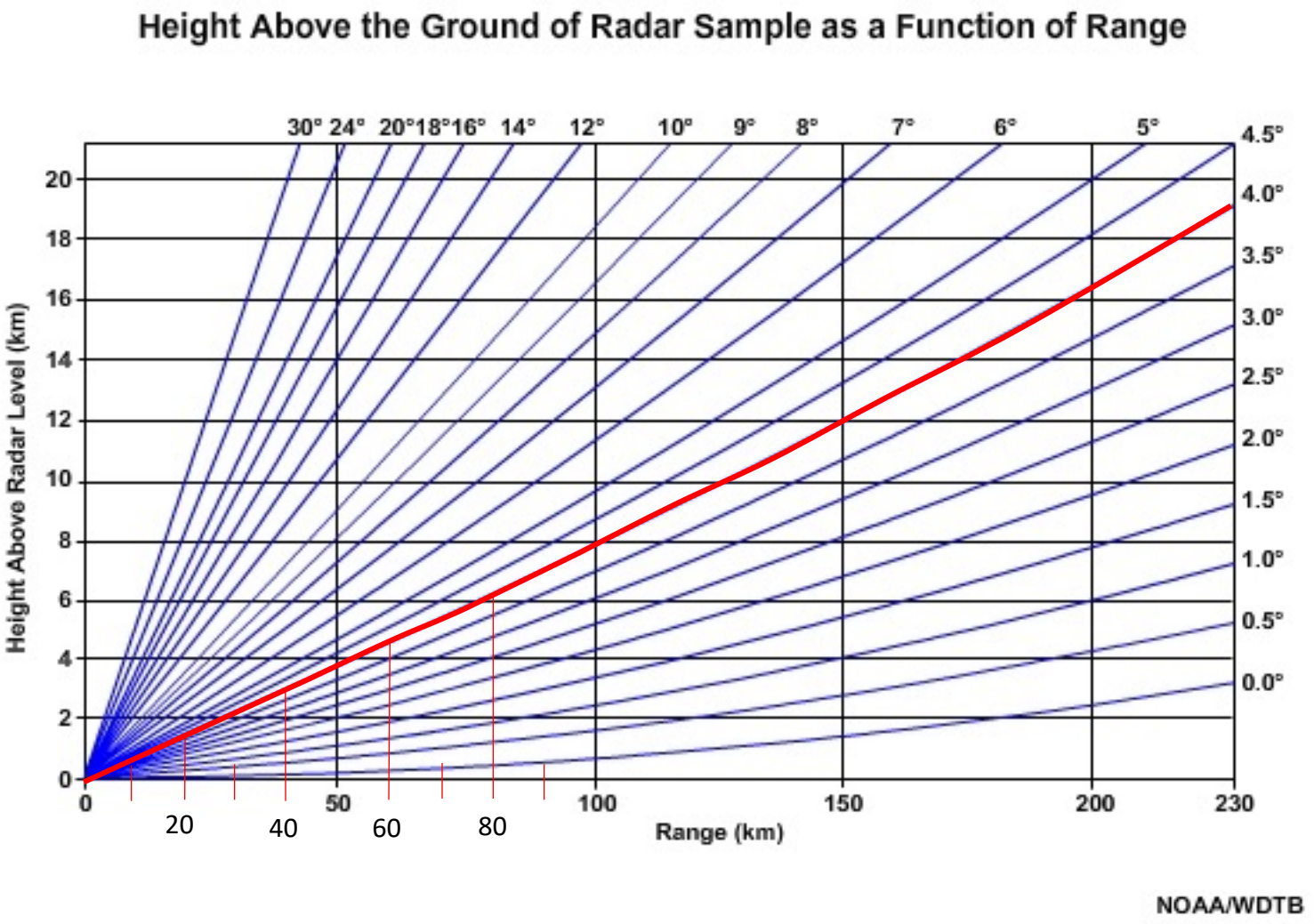
Radar Assumptions

1. The beam travels at the original inclination angle.
2. The targets absorb very little of the radar's electromagnetic energy.
3. Target particles are small, homogeneous precipitation spheres with diameters much smaller than the radar's wavelength.
4. All targets are either liquid or frozen, but not a mixture.
5. Targets are uniformly distributed throughout the sample volume.

Assumption 1: Angle

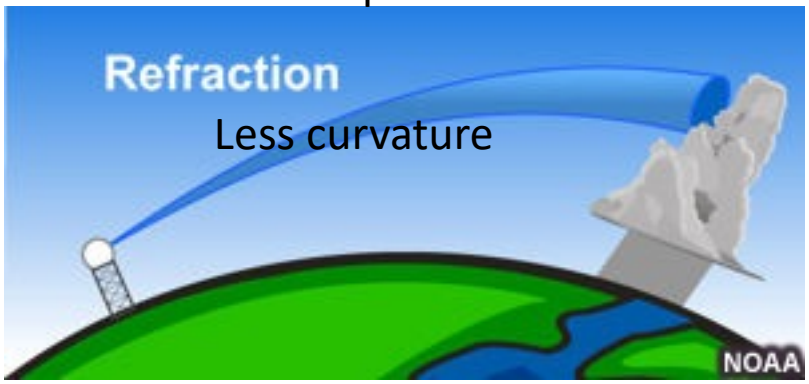


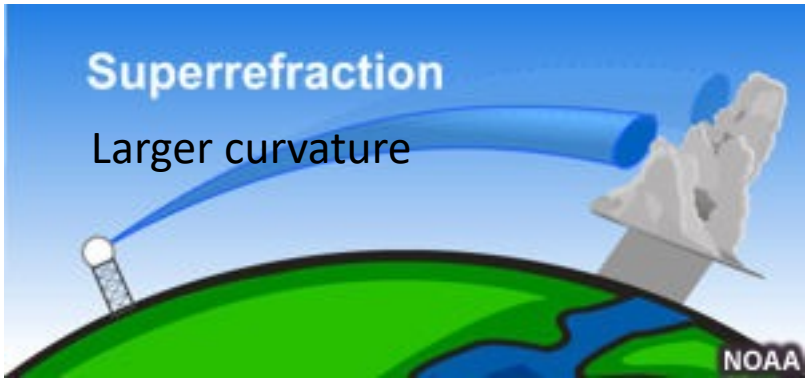
Assumption 1: Angle



Assumption 1: Angle

normal atmospheric conditions





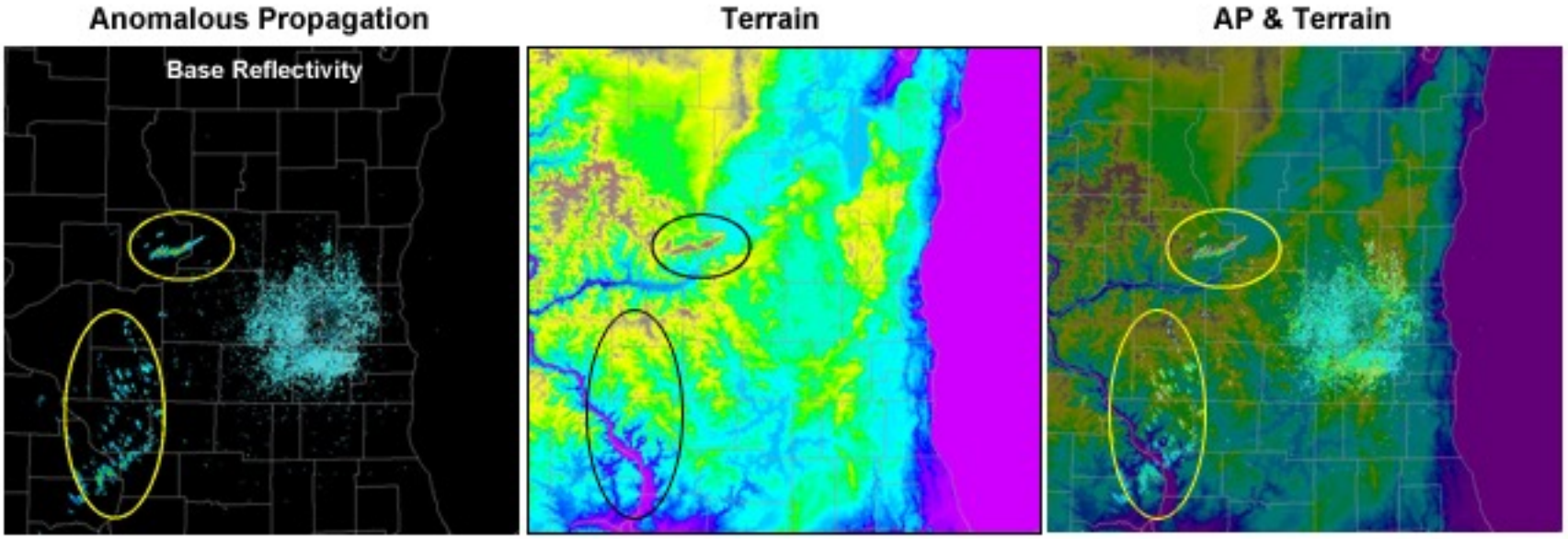
Occurs mainly when: temperature inversion, a sharp decrease in moisture with height

For examples:

- **Nocturnal radiation**
- **Warm, moist air flowing over cooler surfaces, especially water**
- **Downdraft cools area under a thunderstorm**

Assumption 1: Angle

Superrefraction makes the terrain 50 km away seen by radar



Assumption 2: Attenuation

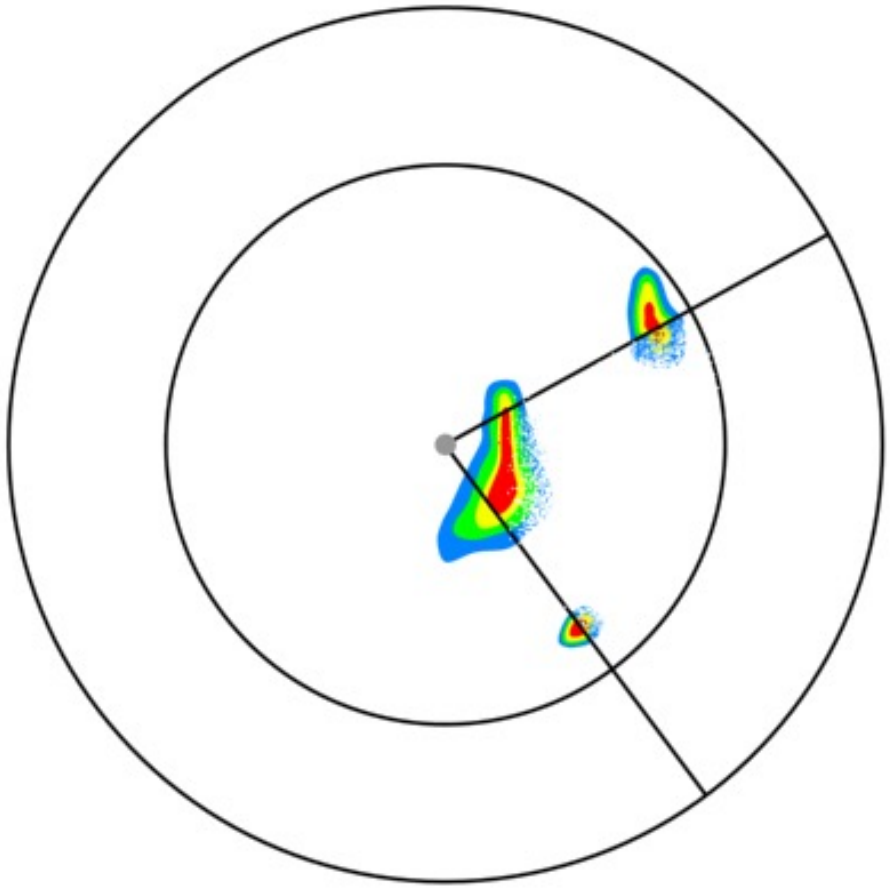
Assumption 2: Attenuation

- Attenuation by air is very small
- Attenuation by ice clouds is also negligible
- Attenuation by water clouds is NOT negligible
  - For a liquid water content of 4 g/m^3, a 3 cm radar may have 10 DB attenuation in one-way path length of 25 km.
- Attenuation by rain is big
  - For a rain of 100 mm/h, a 3 cm radar may have 11.6 DB attenuation in one-way path length of 10 km.

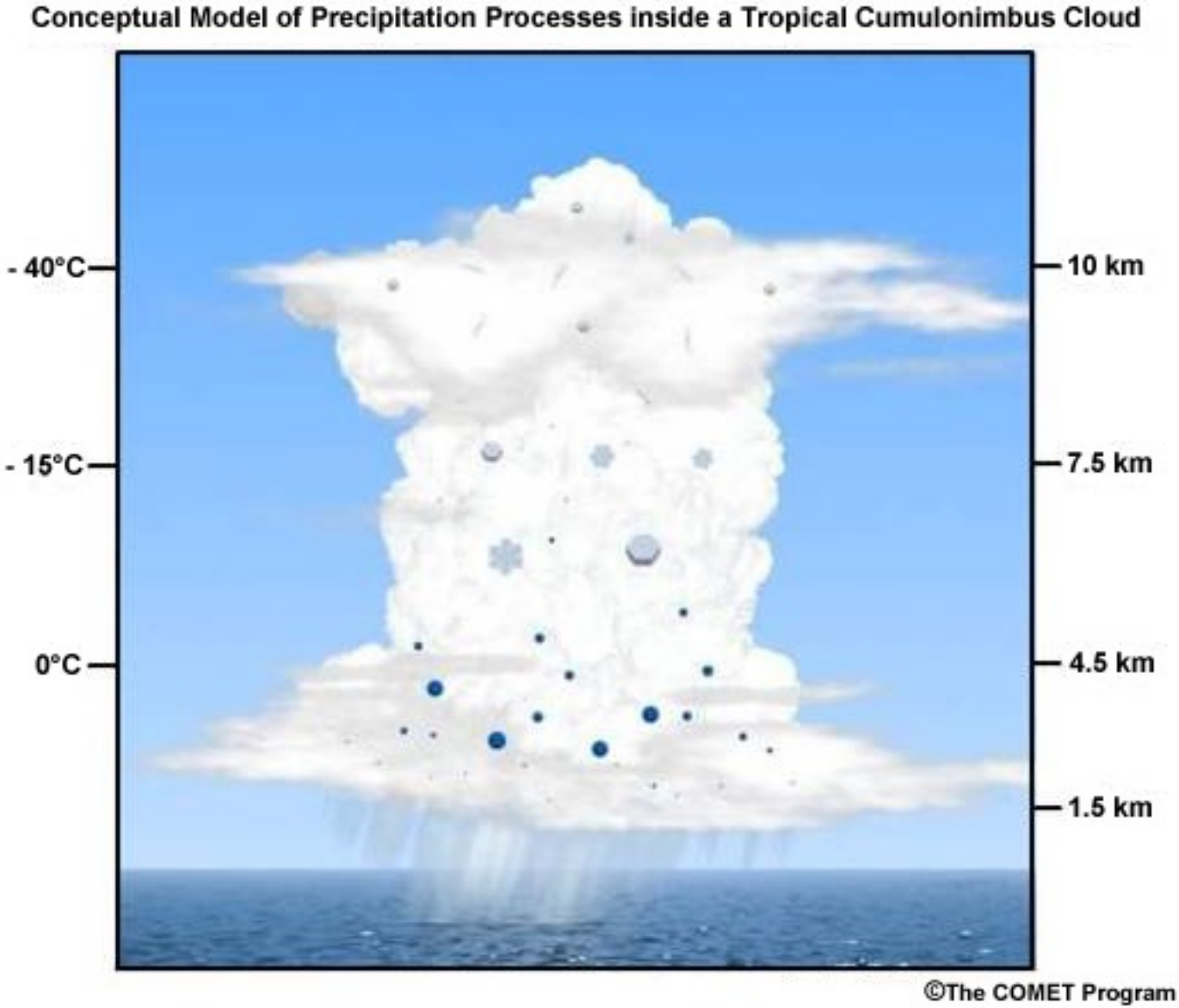
The shorter the wave length, the larger the attenuation will be.

3-cm and 5-cm radars suffer attenuation losses as much as 100 times higher than those experienced by a 10-cm radar.

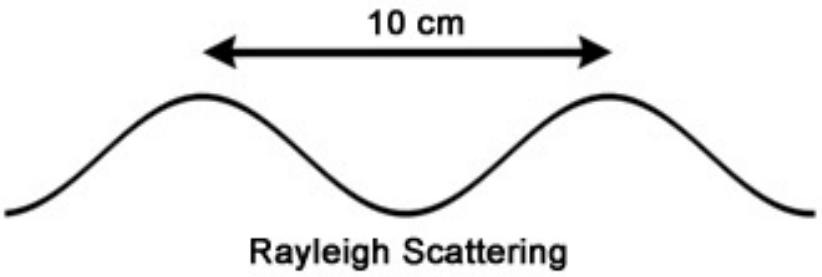
Assumption 2: Attenuation

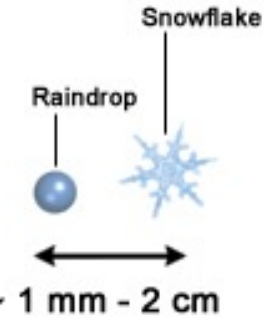


Assumption 3: Homogeneity

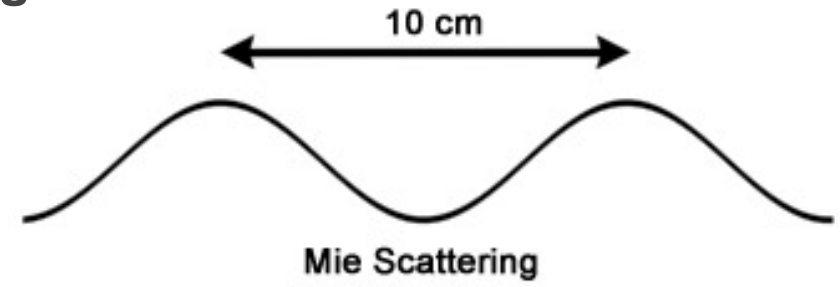


Assumption 3: Homogeneity



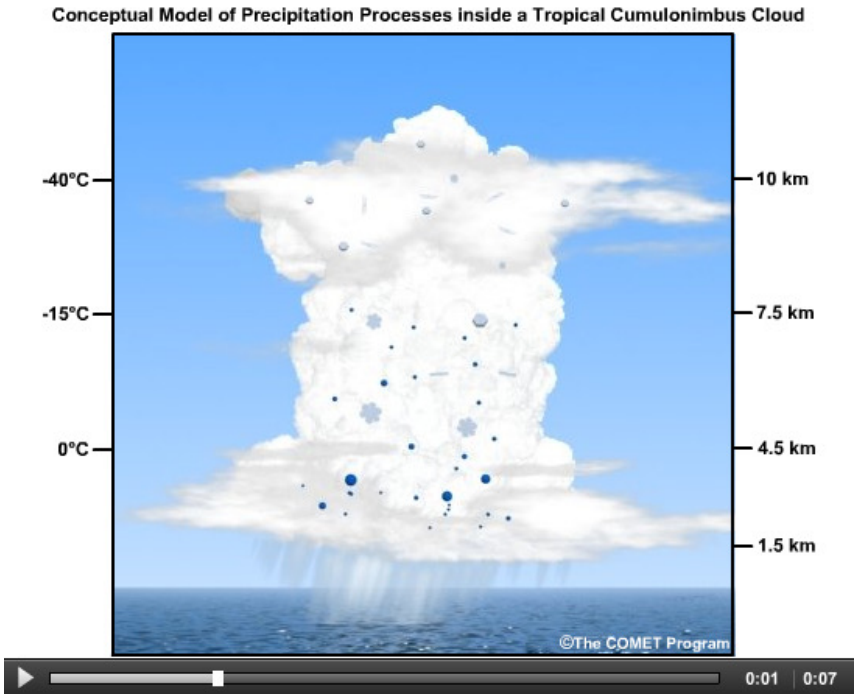


A nearly linear relationship between the size and the amount of scattering



Reflectivity values from large targets should not be taken to be representative of their size.

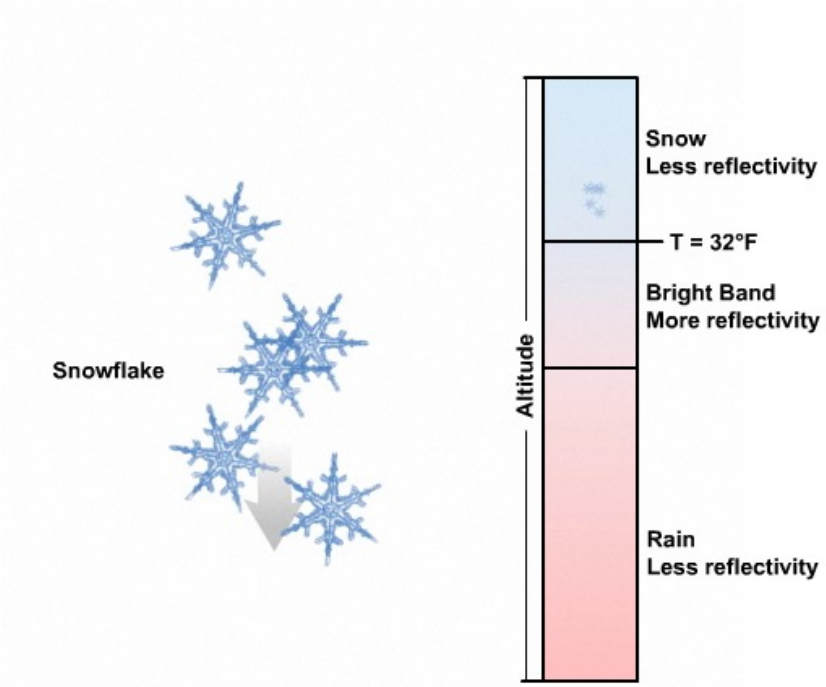
Assumption 4: Phase



Ice does not scatter energy as effectively as water and returns about 7 dBZ weaker echoes than water droplets of the same size.

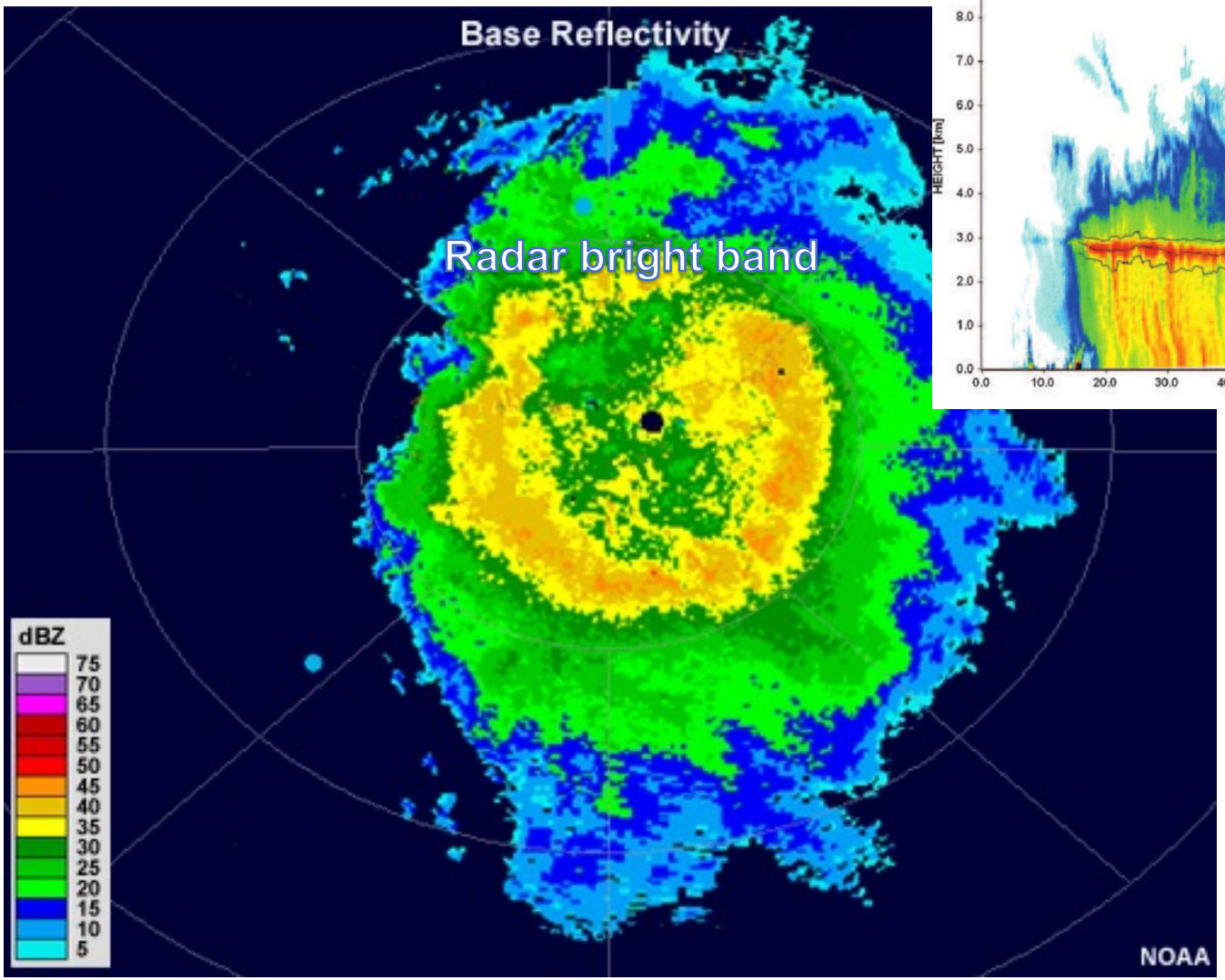
Difficult to determine whether an echo resulted from a region of snow, rain, or mixed precipitation

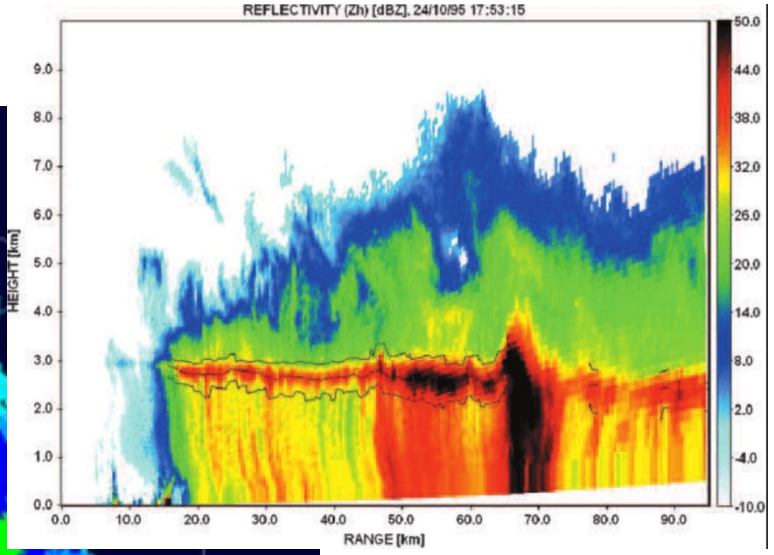
Assumption 4: Phase



Snow flakes melt-aggregate-water coating
- Radar bright band, as much as 15 dBZ
- Melt further- more compact raindrops - fall much faster - reducing the number of targets

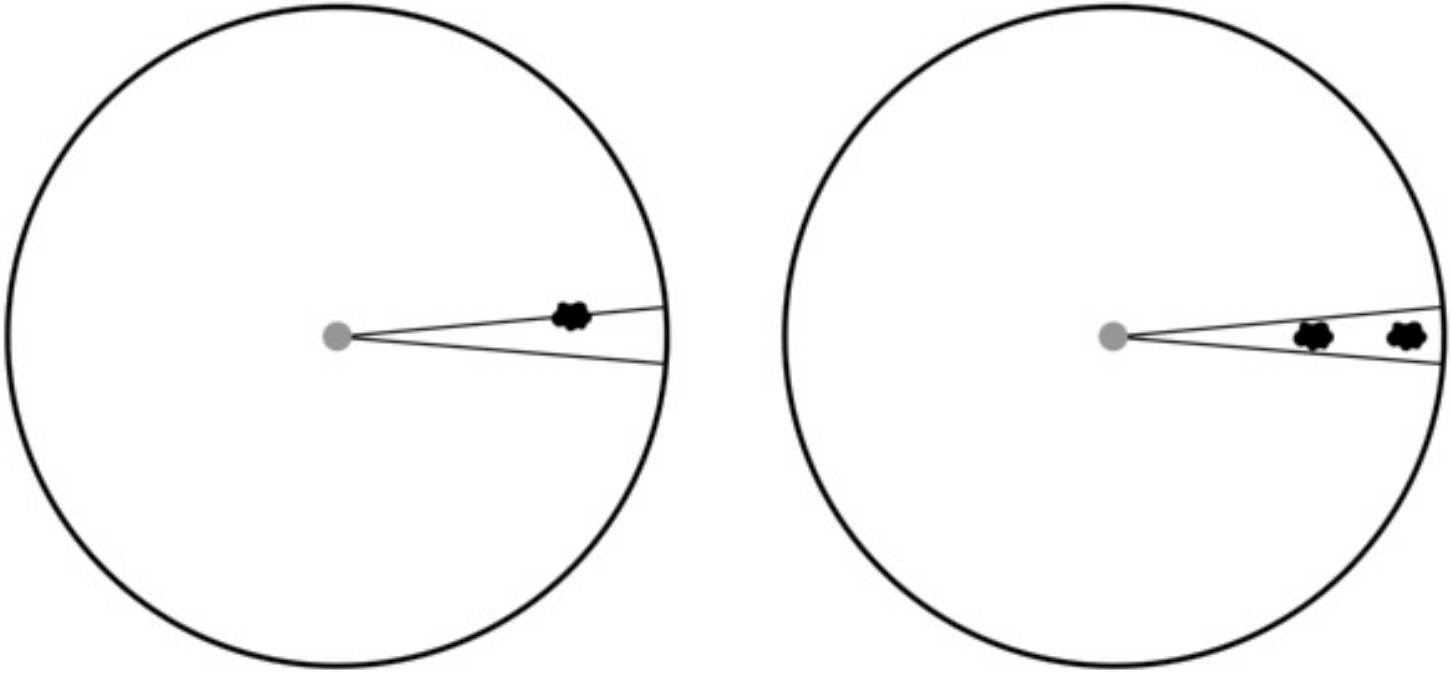
Assumption 4: Phase



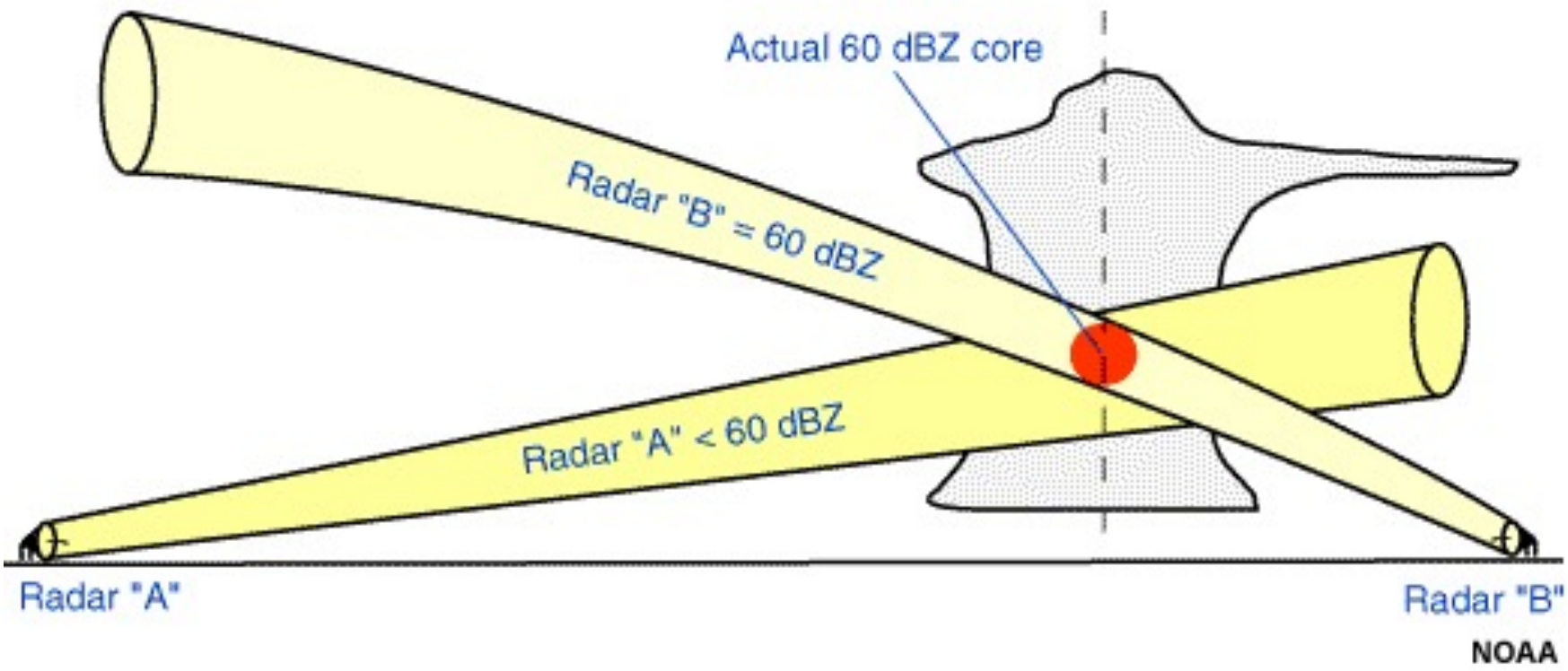


Assumption 5: Uniformity

The scattering is averaged over the entire width of the beam in that location



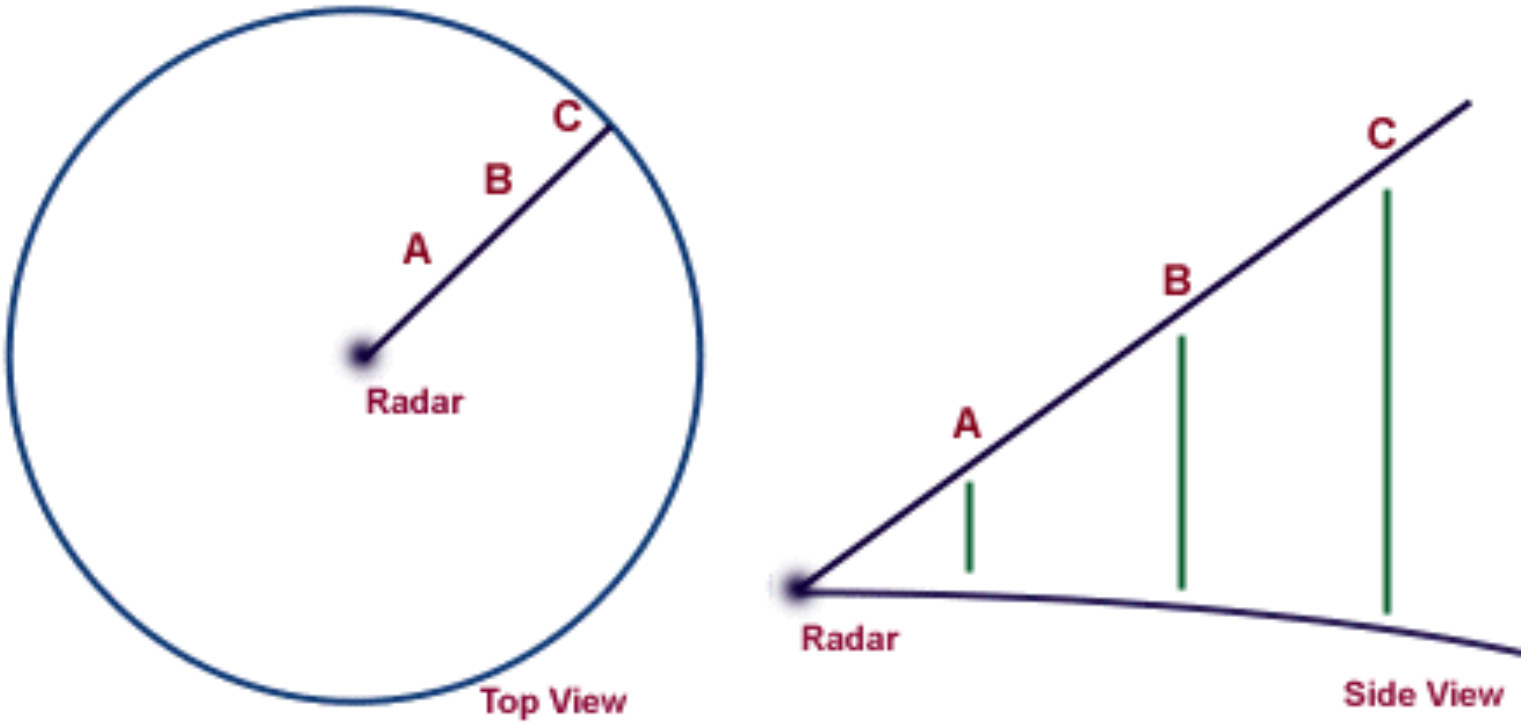
Assumption 5: Uniformity



主要内容

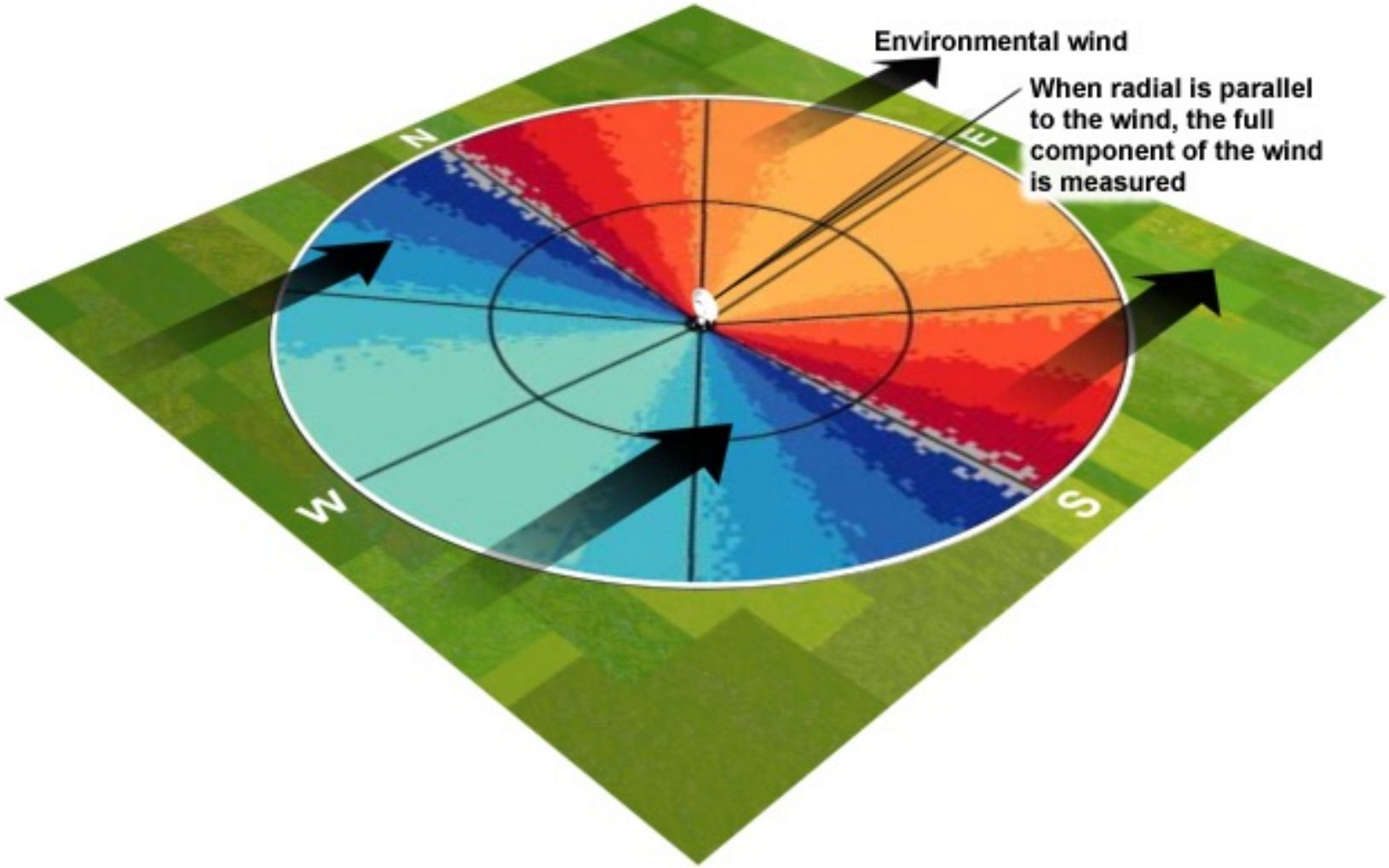
- 雷达基础
- 雷达局限性
- 风场特征识别
- 晴空模式雷达观测特征识别
- 降水模式雷达观测特征识别

风场分布

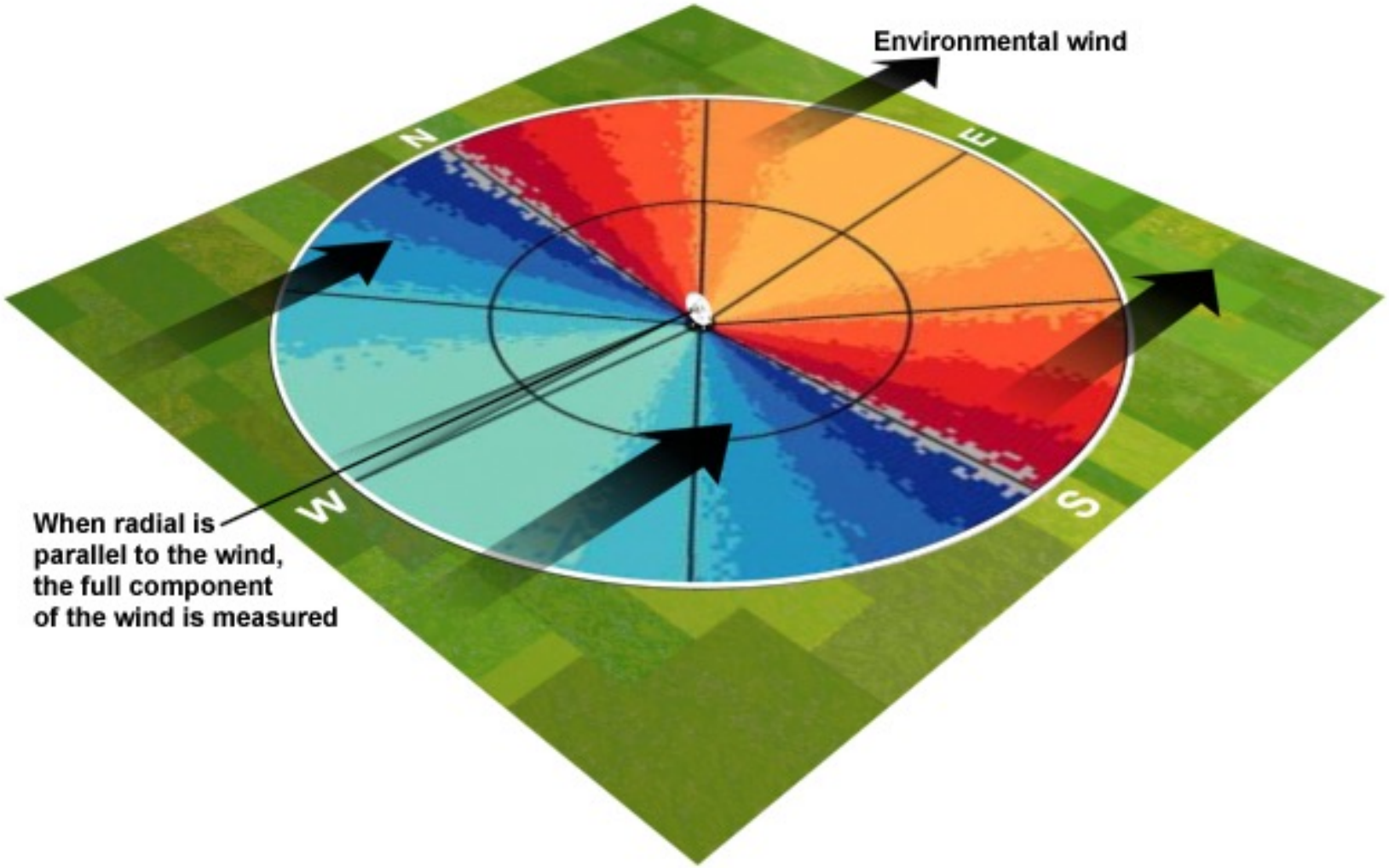


Targets near the radar represent the low-level wind field, and targets farther away represent winds at higher altitudes.

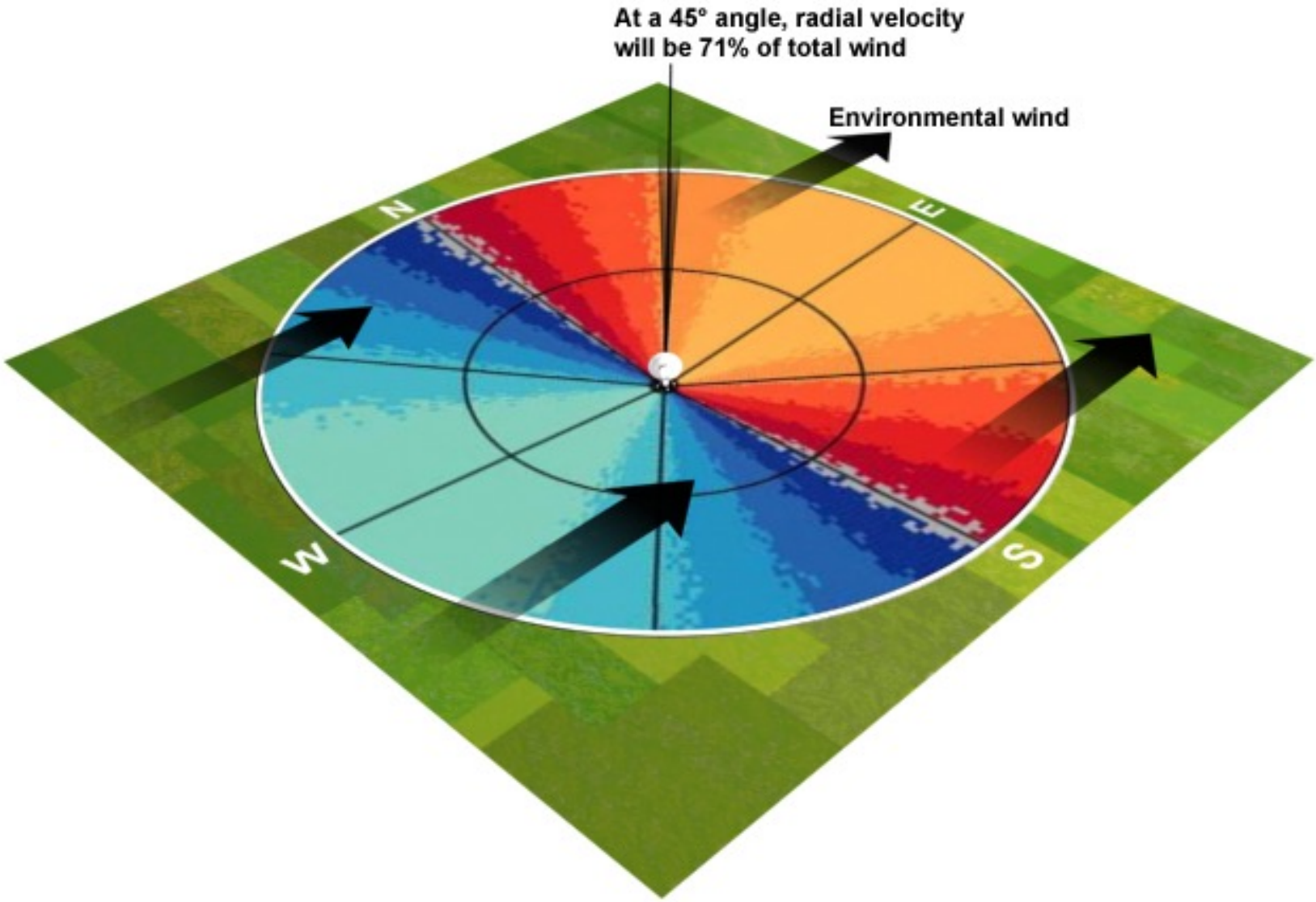
均匀西风



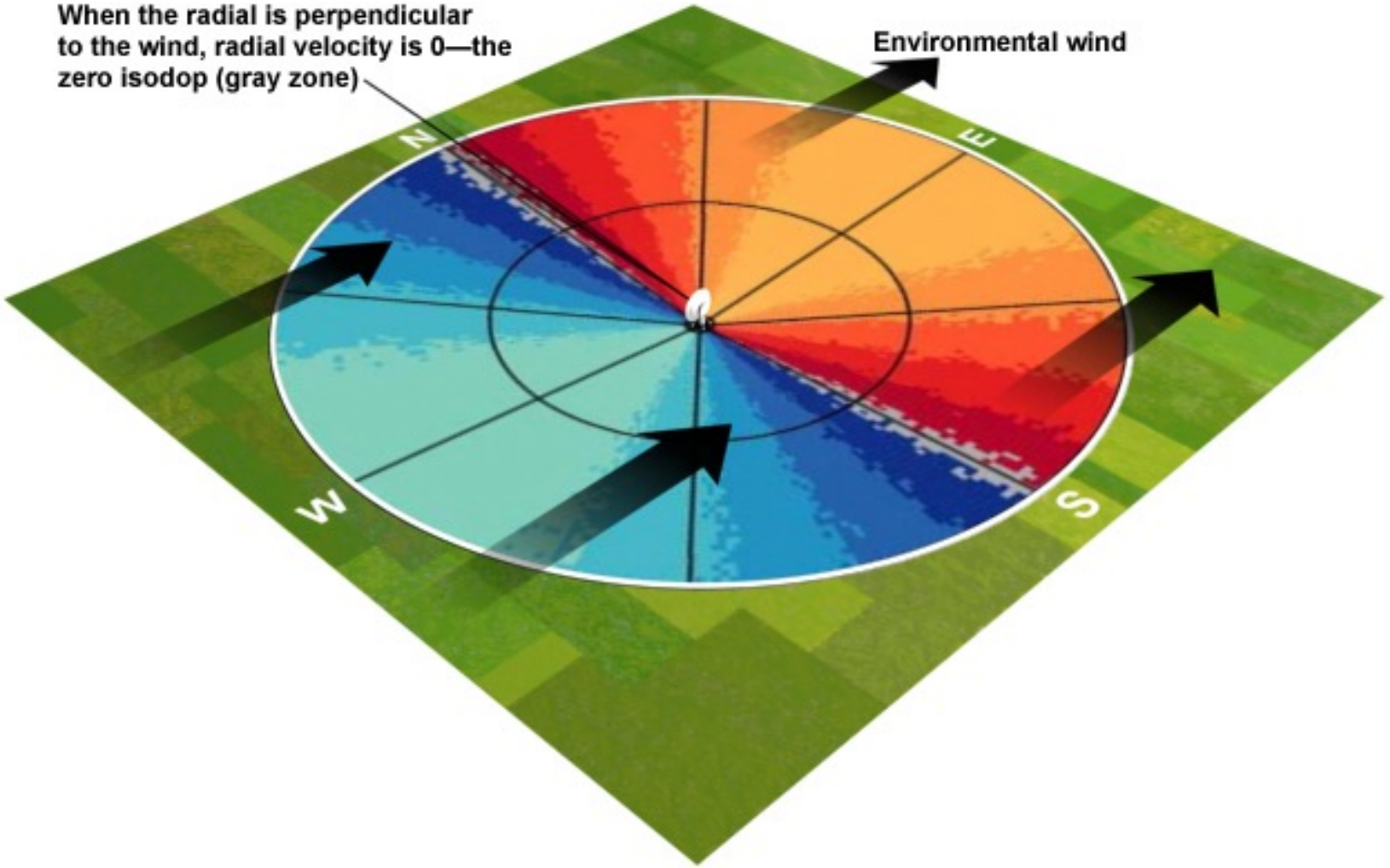
均匀西风



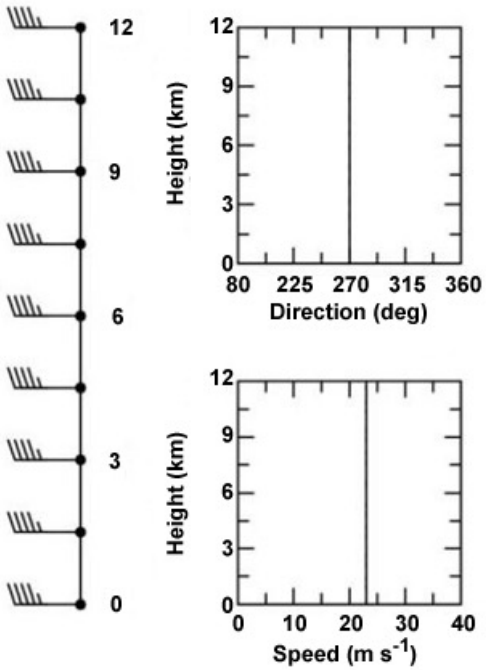
均匀西风

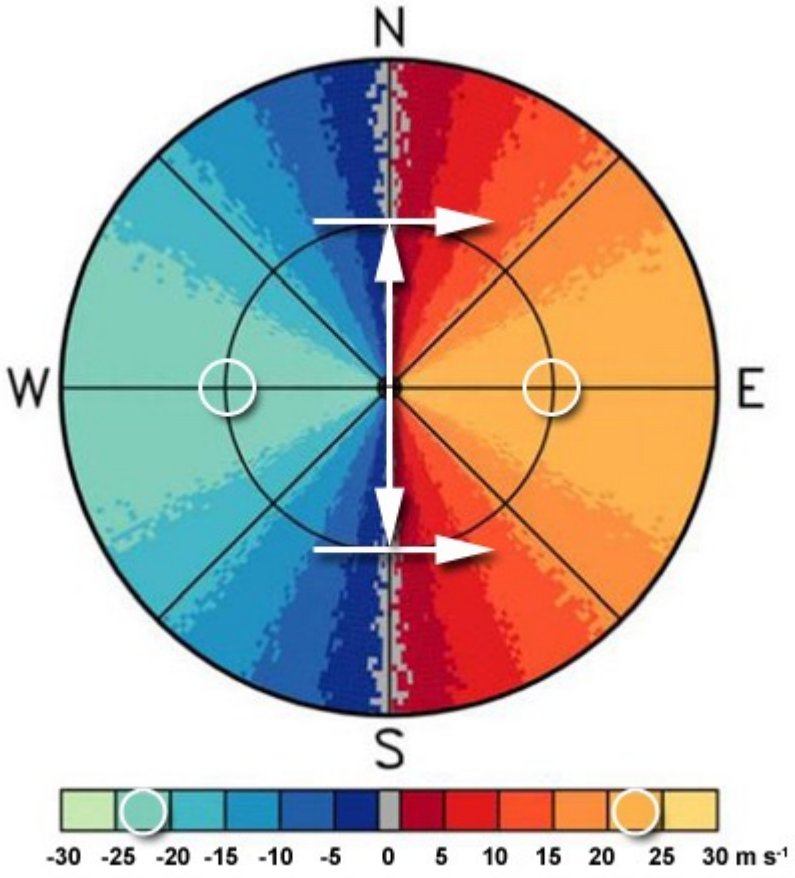


均匀西风



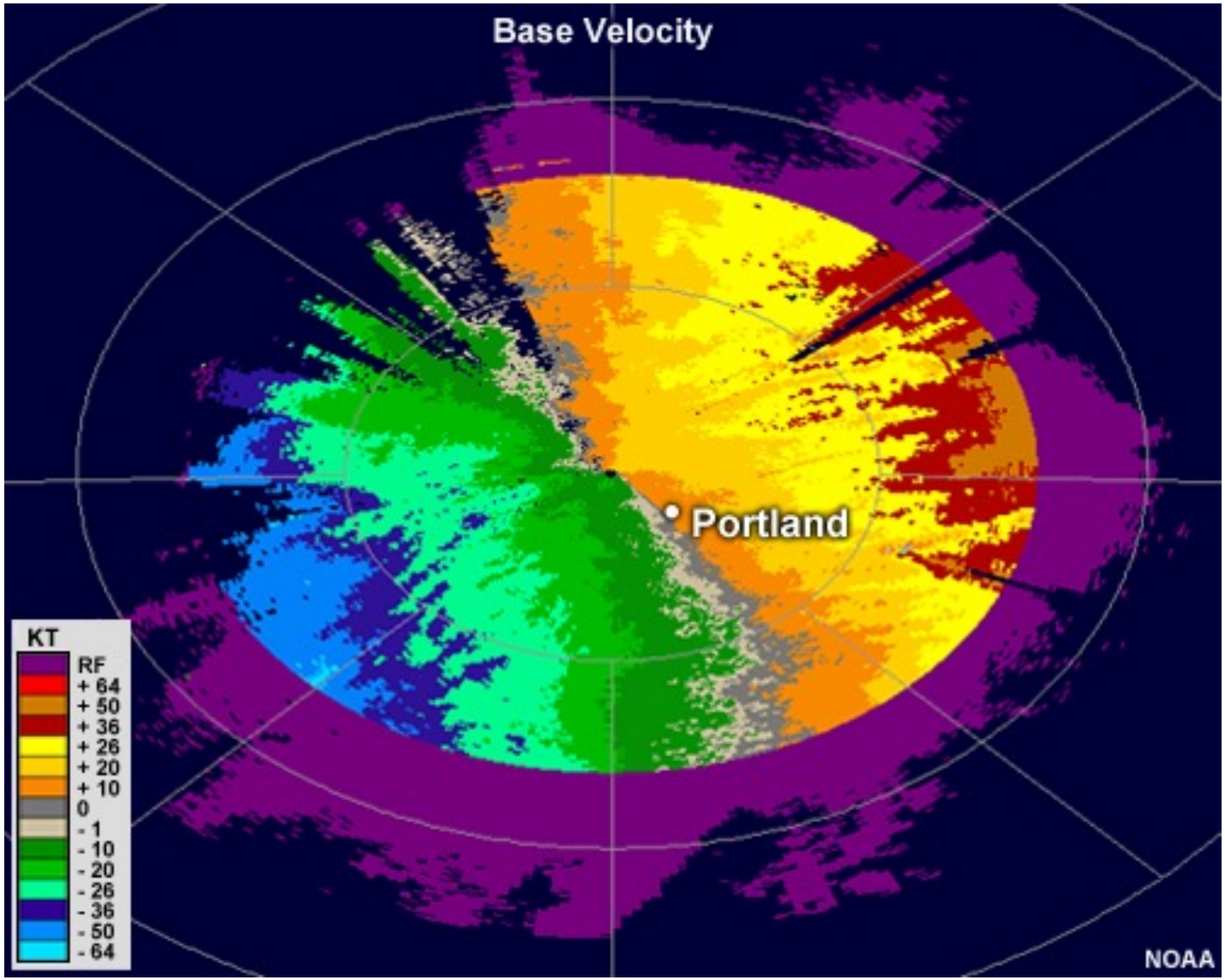
均匀西风


12
9
6
3
0
Height (km)
12
9
6
3
0
80 225 270 315 360
Direction (deg)
Height (km)
12
9
6
3
0
0 10 20 30 40
Speed (m s-1)


N
W
E
S
-30 -25 -20 -15 -10 -5 0 5 10 15 20 25 30 m s-1

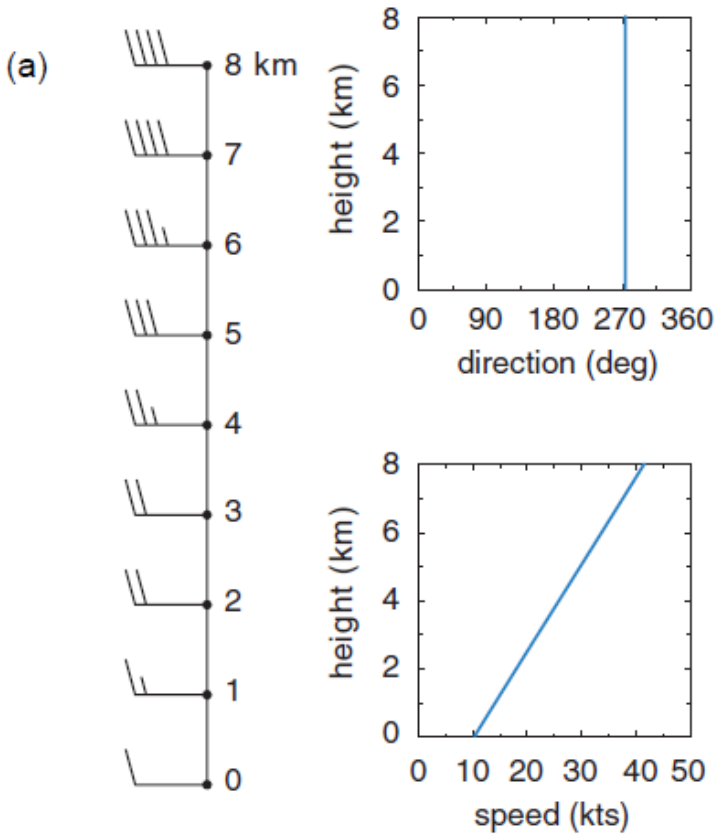
NOAA

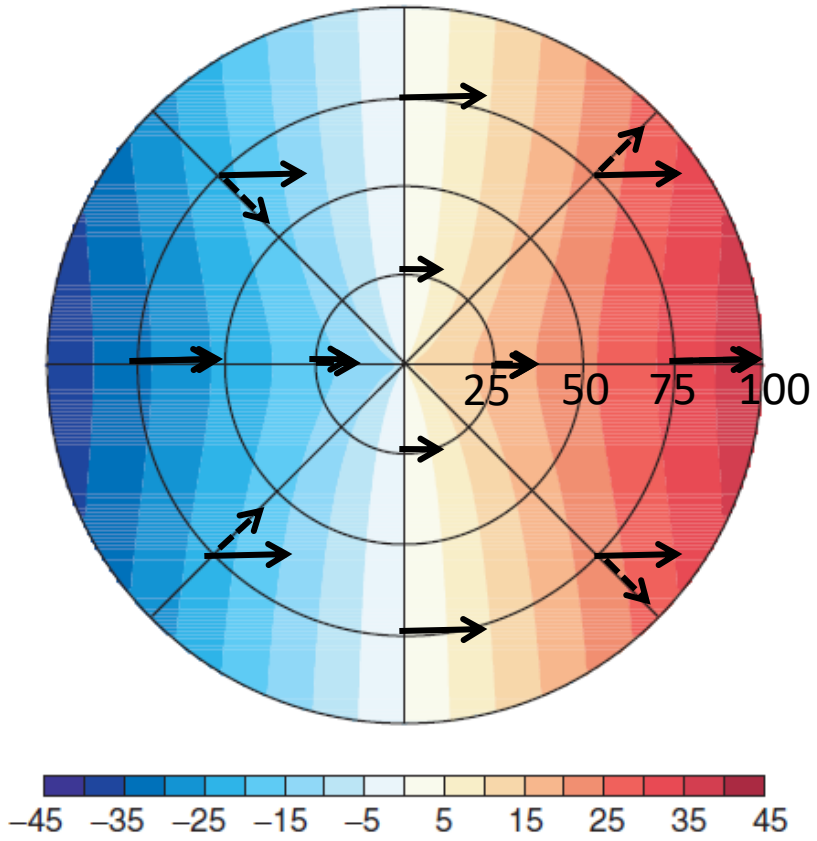
例子

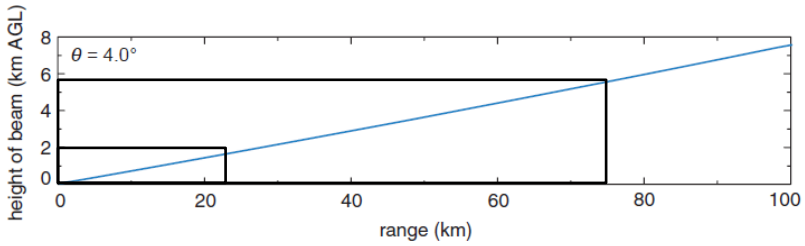

Base Velocity
Portland
KT
RF
+ 64
+ 50
+ 36
+ 26
+ 20
+ 10
0
- 1
- 10
- 20
- 26
- 36
- 50
- 64
NOAA

Westerly wind increasing in magnitude with height

练习： 1.标风矢量， 2. 雷达测到的风 at 20 and 60 km





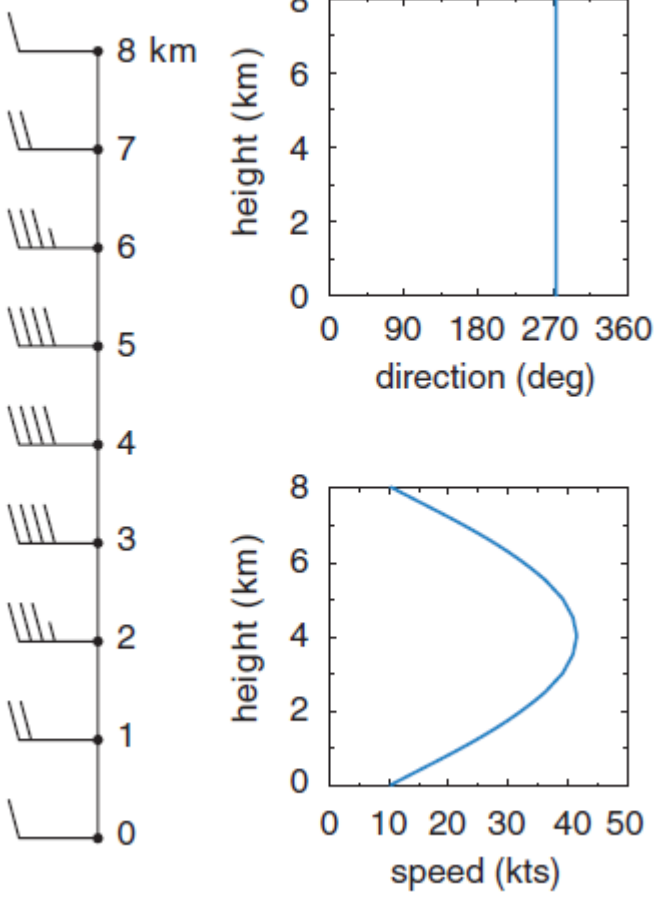


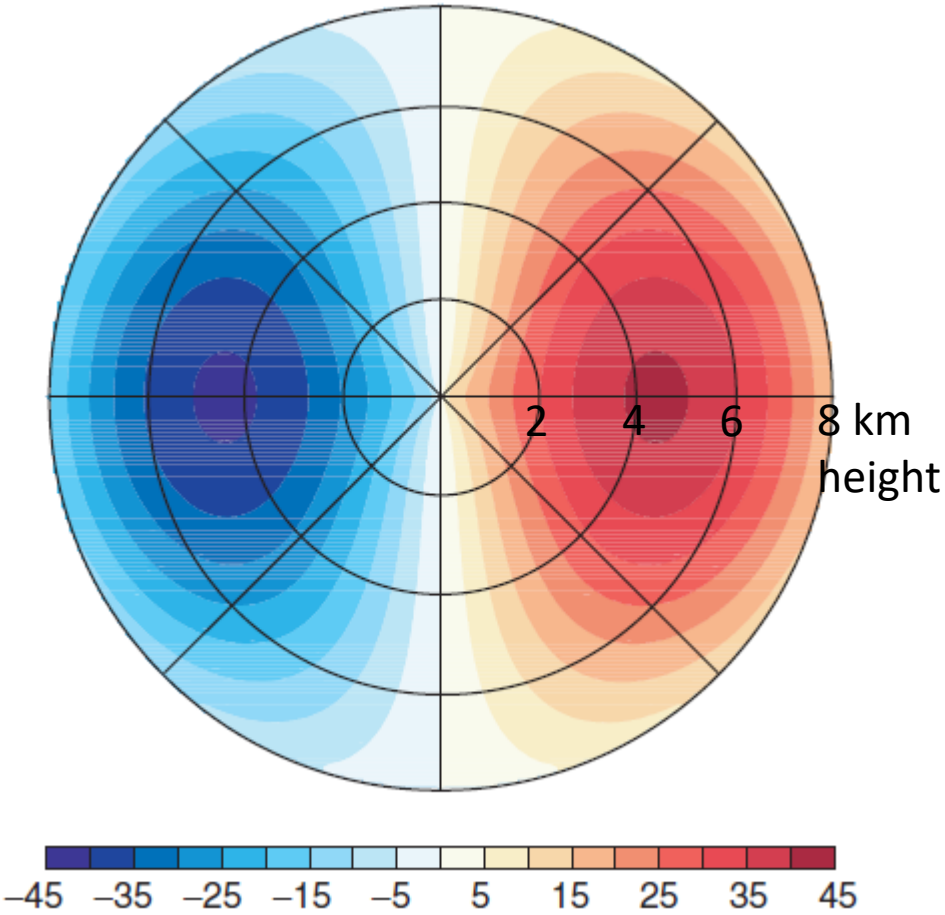
Cool colors
Negative (-)
TOWARD radar
along radial.

Warm colors
Positive (+)
AWAY FROM
radar along radial.

Westerly wind with mid-tropospheric wind maximum

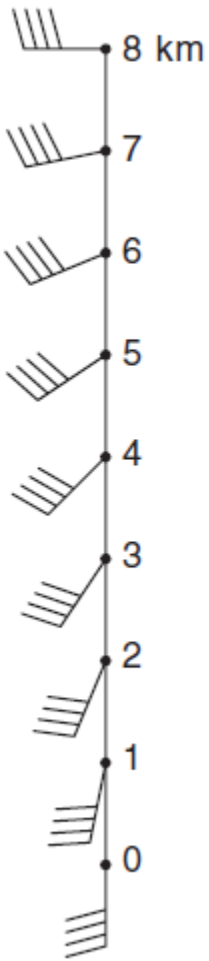
练习： 1.标风矢量， 2. 雷达测到的风

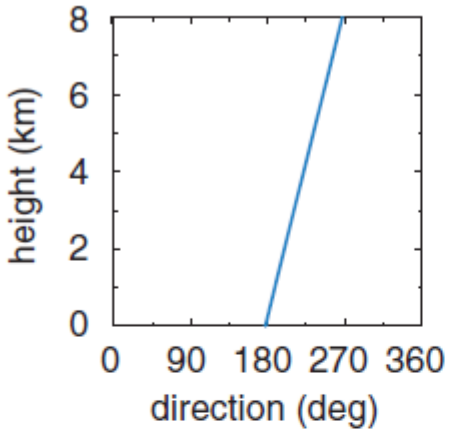


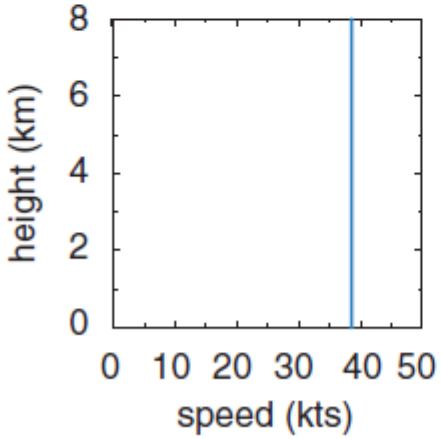


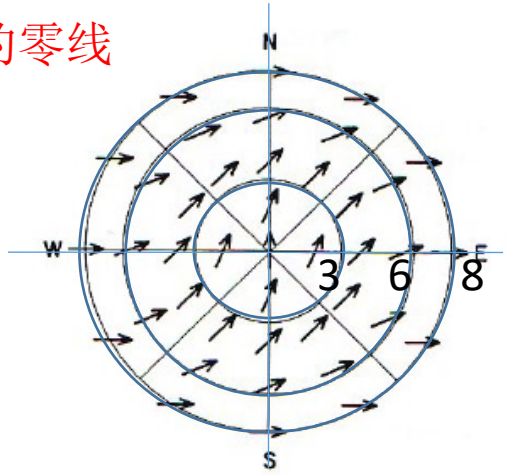
Veering wind with same speed

练习： 1.标风矢量， 2. 画出径向风的零线

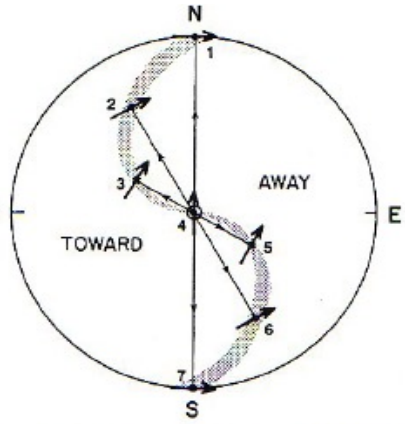




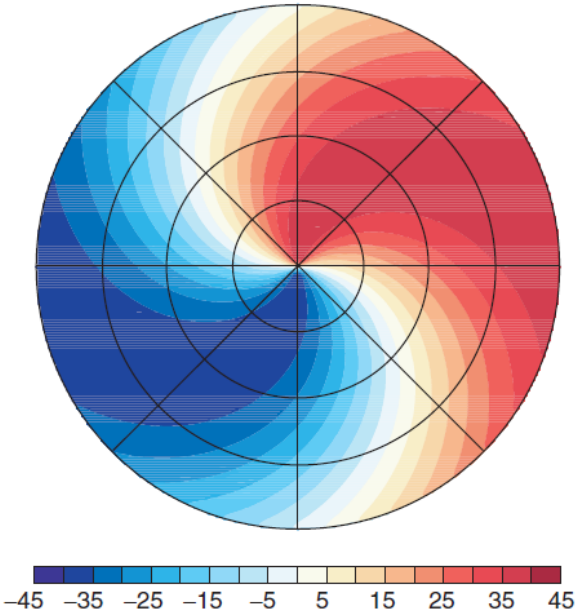




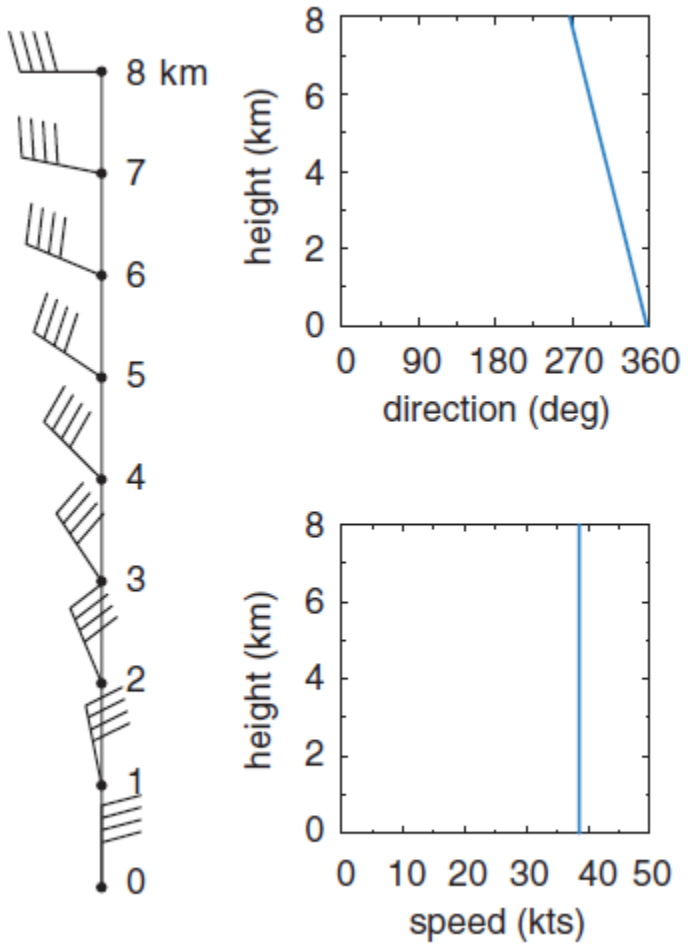
(b) Winds on PPI surface

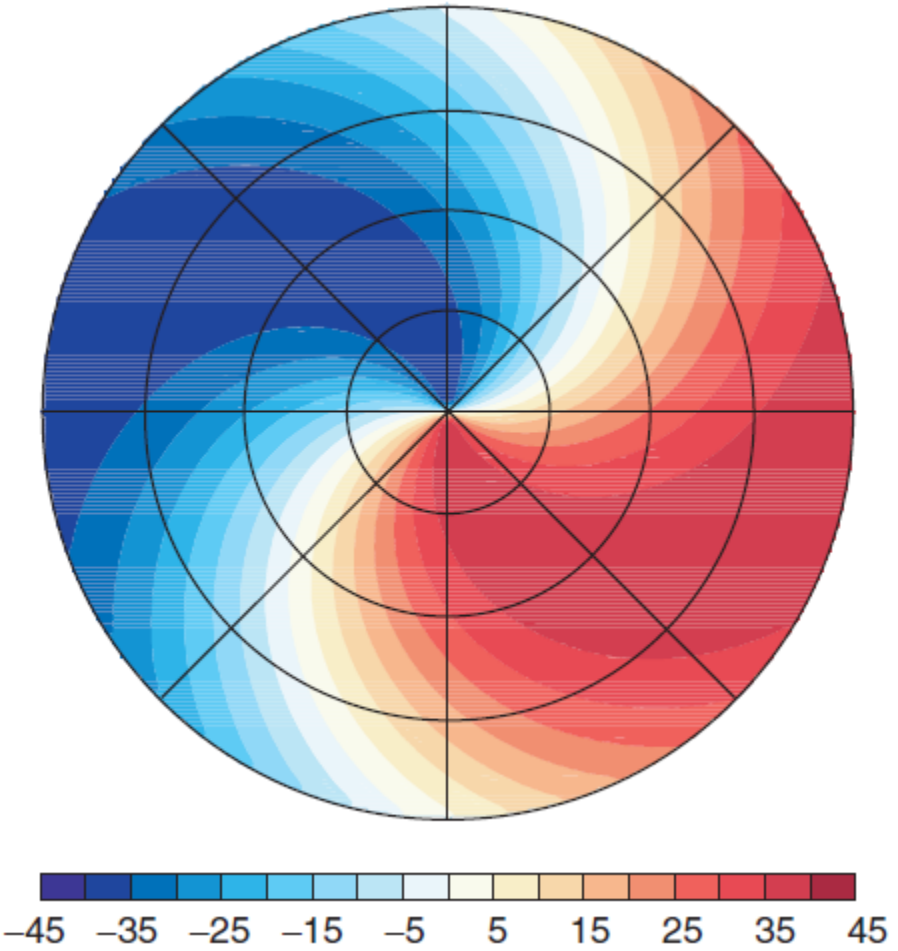


(c) Interpretation of display

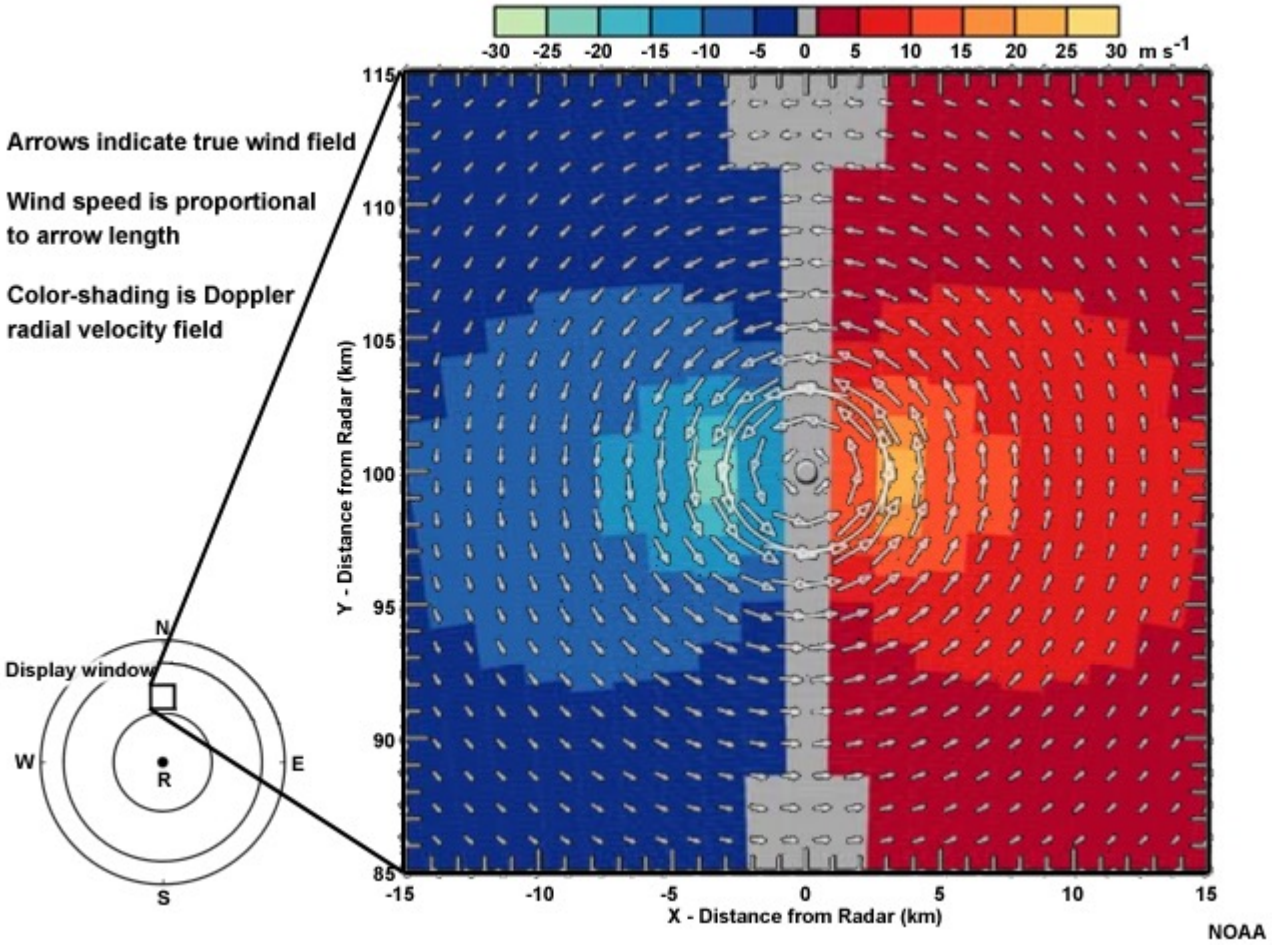


Backing wind with same speed

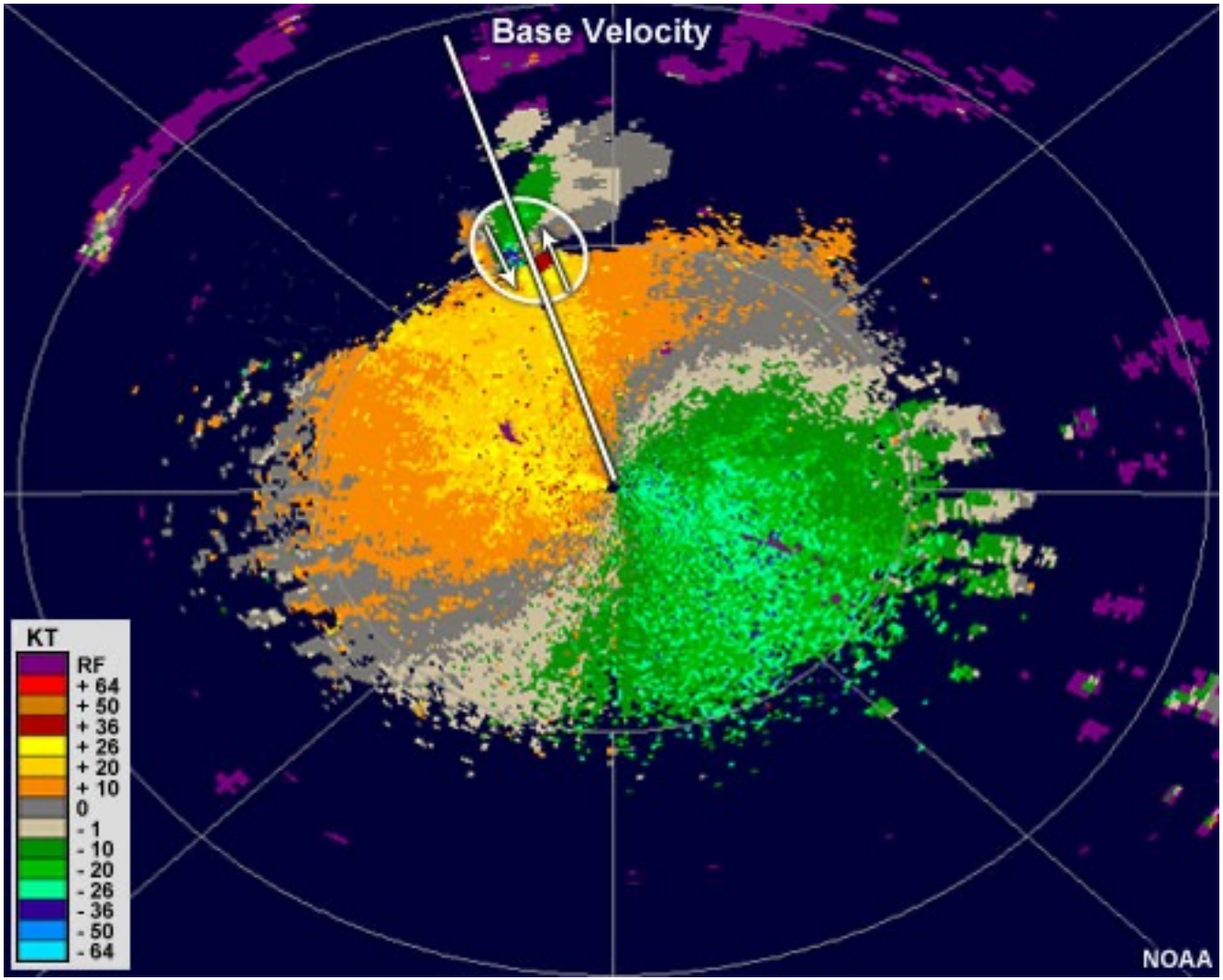




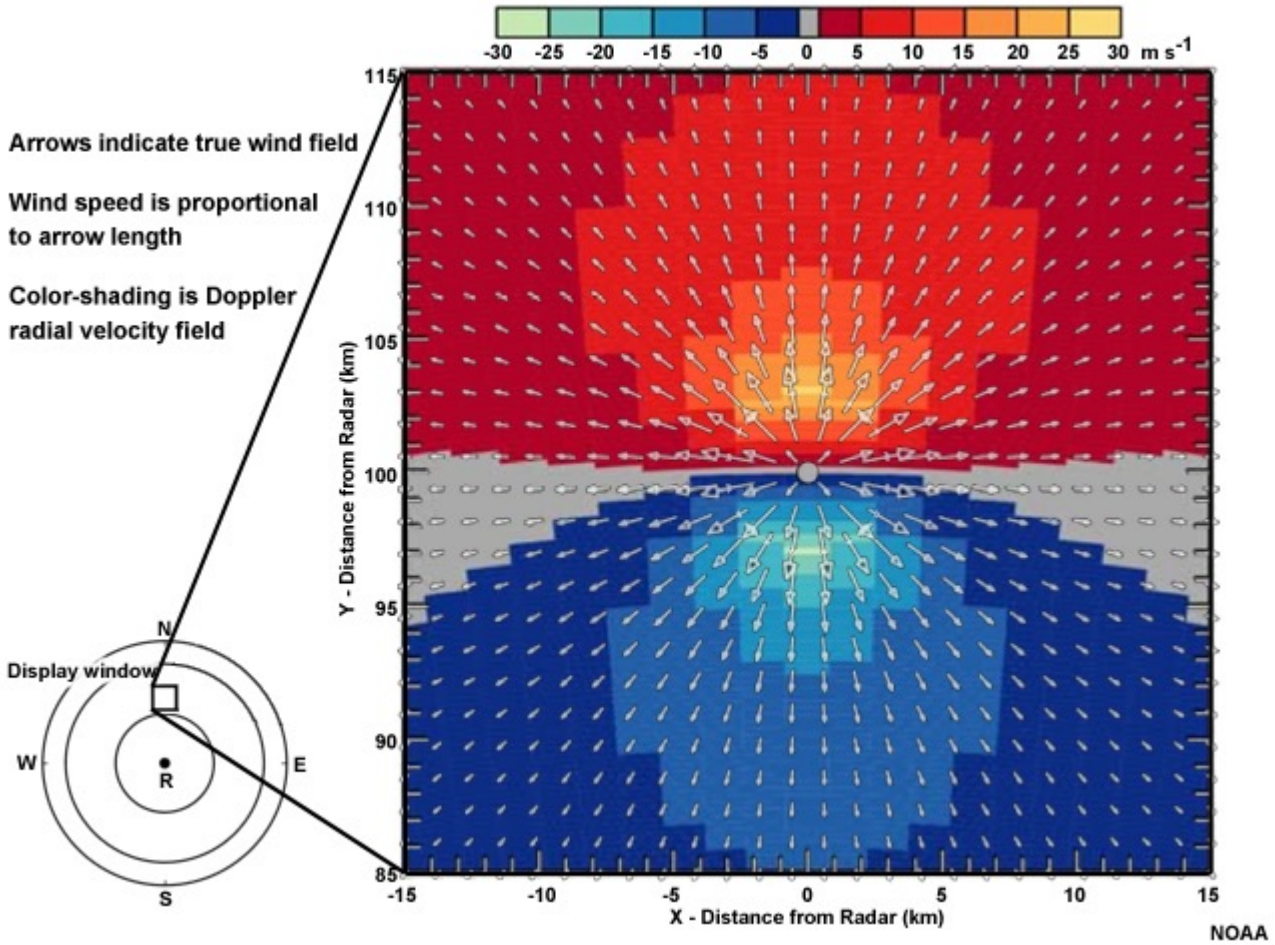
小涡旋


-30 -25 -20 -15 -10 -5 0 5 10 15 20 25 30 m s-1
Arrows indicate true wind field
Wind speed is proportional to arrow length
Color-shading is Doppler radial velocity field
Y - Distance from Radar (km)
115
110
105
100
95
90
85
-15 -10 -5 0 5 10 15
X - Distance from Radar (km)
Display window
N
W
E
S
R
NOAA

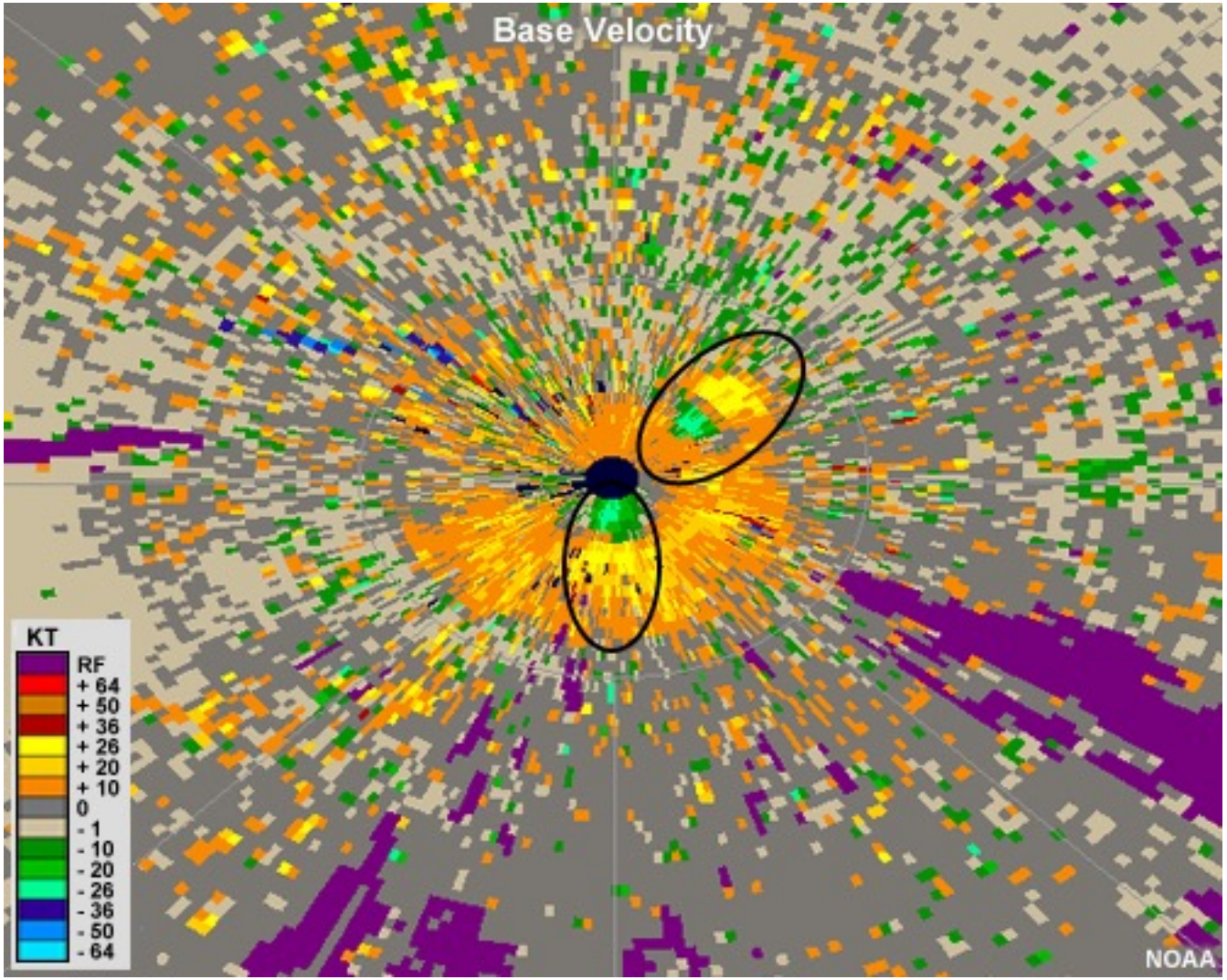
小涡旋



小的辐散


-30 -25 -20 -15 -10 -5 0 5 10 15 20 25 30 m s-1
Arrows indicate true wind field
Wind speed is proportional to arrow length
Color-shading is Doppler radial velocity field
Y - Distance from Radar (km)
X - Distance from Radar (km)
115
110
105
100
95
90
85
-15 -10 -5 0 5 10 15
N
W
E
S
R
Display window
NOAA

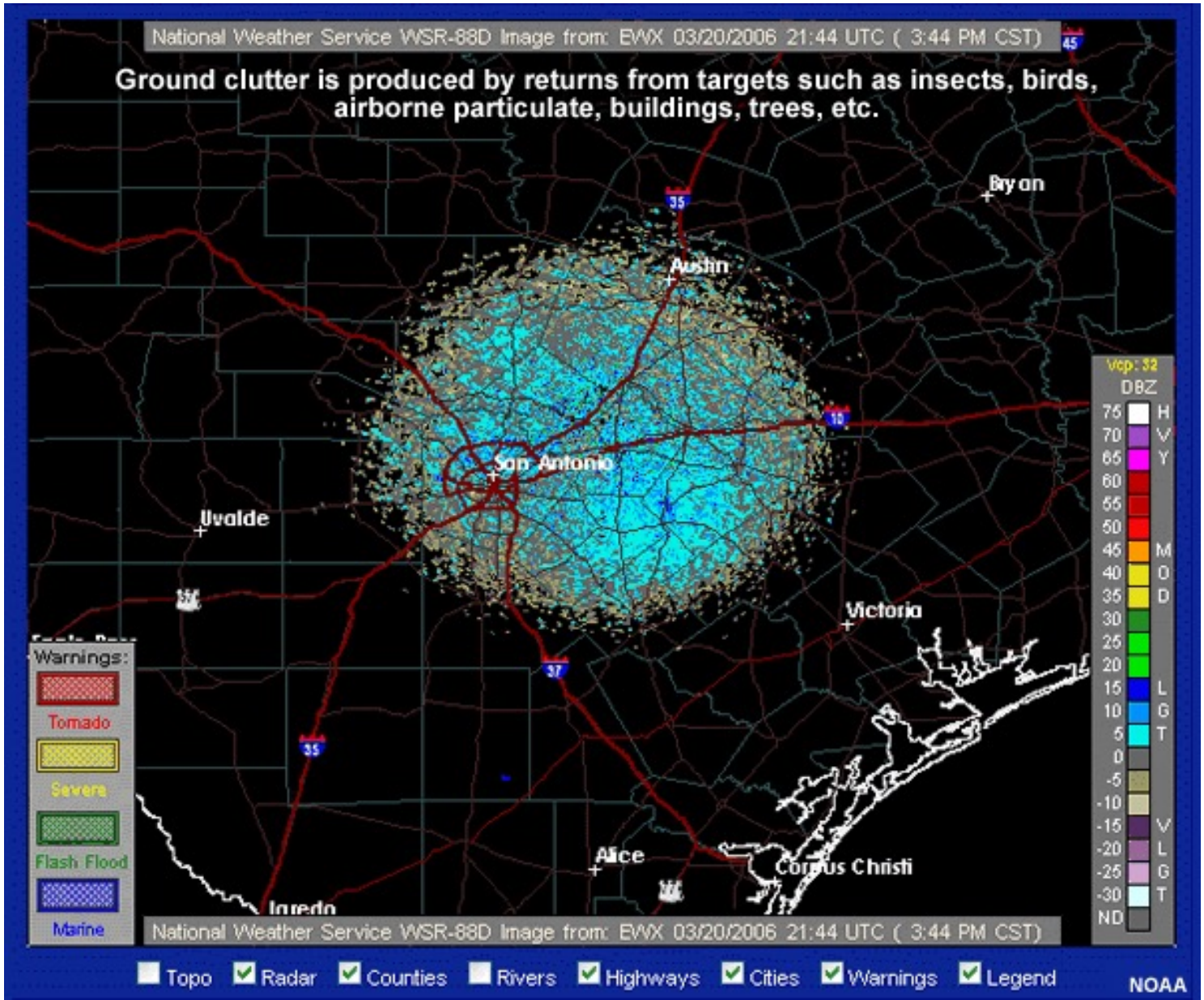
小的辐散



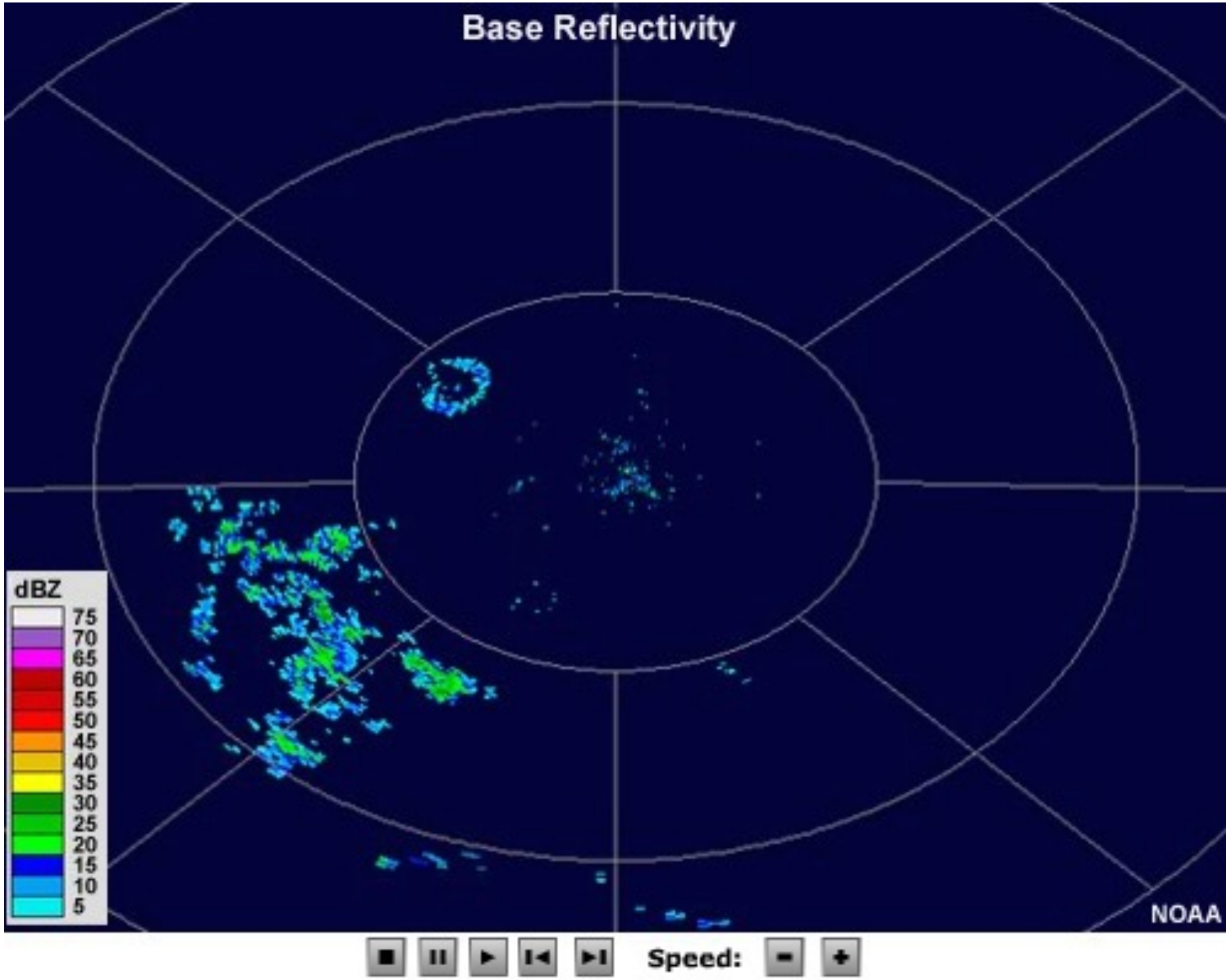
主要内容

- 雷达基础
- 雷达局限性
- 风场特征识别
- 晴空模式雷达观测特征识别
- 降水模式雷达观测特征识别

非气象回波：Ground clutter



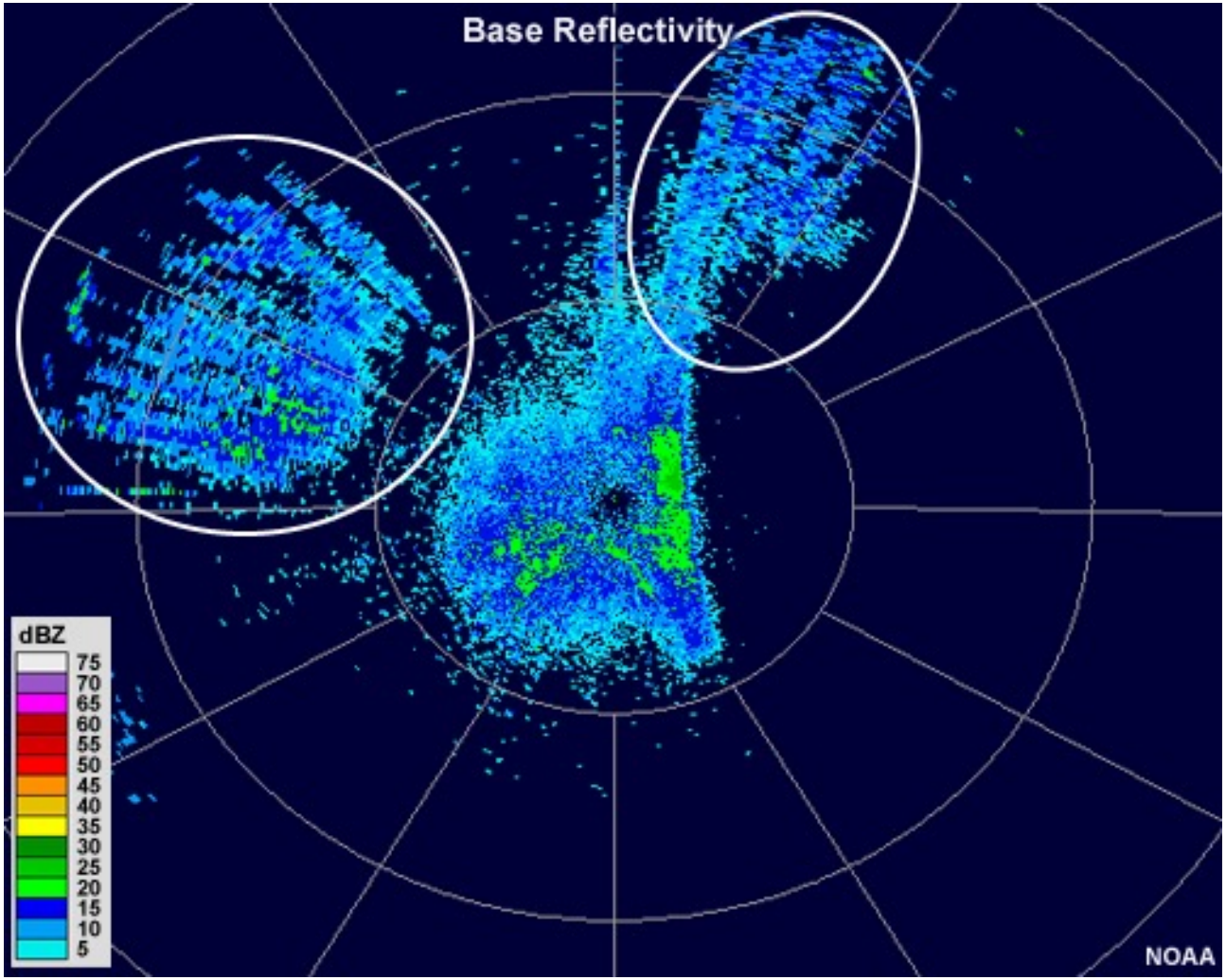
非气象回波：Biological targets



非气象回波：Biological targets

- Reflectivities usually <15 dBZ, for small birds and bats.
- Often a small patch will move against winds
- An expanding ring may signal takeoff en masse.
- Take note of the time of day and season.
  - Mass exit of roosting areas is typical at sunrise (birds) and sunset (bats, insects)
  - Migration is most common in spring and fall.
- Birds typically cause wind speed errors of 10-15 m s^{-1};
- Large insects might generate a bias as high as 6 m s^{-1}.

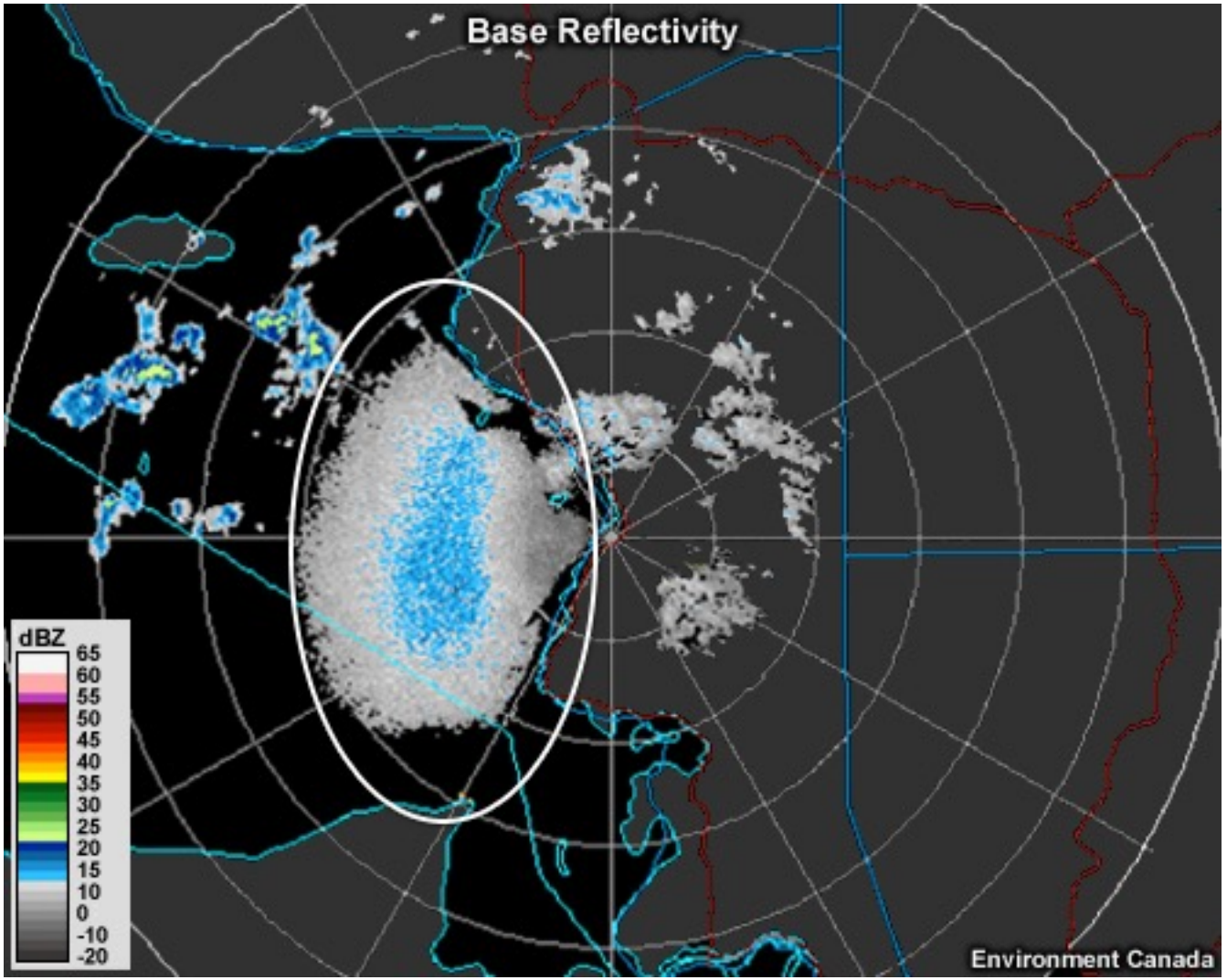
非气象回波：Anomalous Propagation



非气象回波：Anomalous Propagation

- Echoes will not change much. may disappear or reappear, but will do so in mostly the same location.
- The targets' velocities will be at or nearly zero.
- Reflectivity values are often erratic and do not resemble any usual precipitation patterns.
- Echoes may also be relatively weak and extend for great distances in a beamlike shape.
- Look at another nearby radar or satellite data
- Look at the most recent local sounding to see if a sharp inversion is present.
- Look at a map of local topography to see if echoes are collocated with higher terrain.

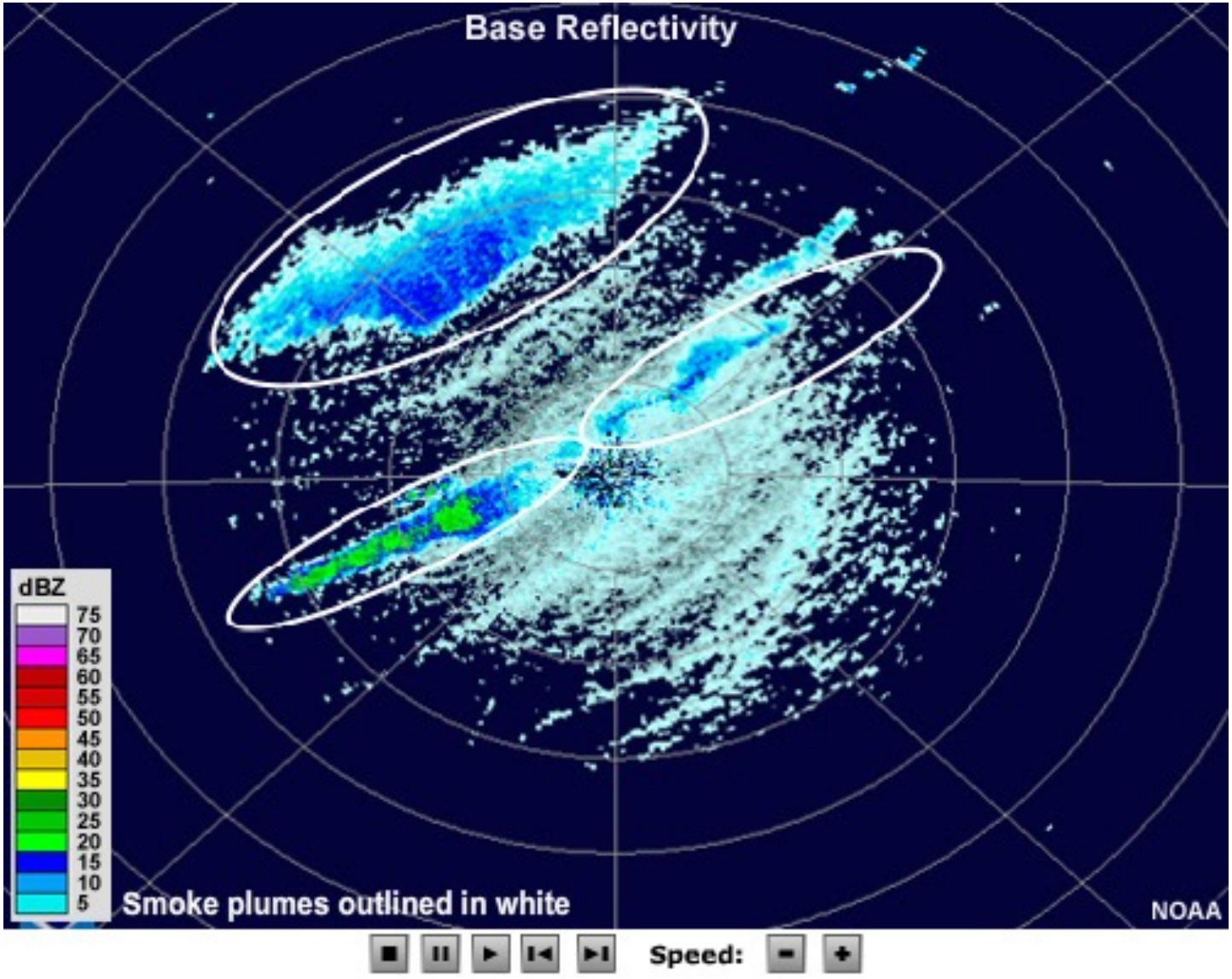
非气象回波： Sea Clutter



非气象回波： Sea Clutter

- Low reflectivity values
- Usually present in only the lowest scans
- A fine, slightly grainy texture
- Echoes generally persist in their location and intensity
- Radial velocity shows prevailing wind direction, as waves and spray move with the wind

非气象回波： Smoke


Base Reflectivity
dBZ
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
Smoke plumes outlined in white
NOAA
Speed:

非气象回波： Smoke

- Low reflectivity (<20 dBZ)
- The echo elongates over time in the direction of the wind
- Radial velocity will indicate the prevailing wind direction and speed, as smoke particles act as tracers
- The echo will persist in the location of the source

气象回波： 非降水回波

- In clear air mode, the radar can also reveal a number of meteorological features produced by **temperature and moisture gradients** that can be precursors to precipitation events.

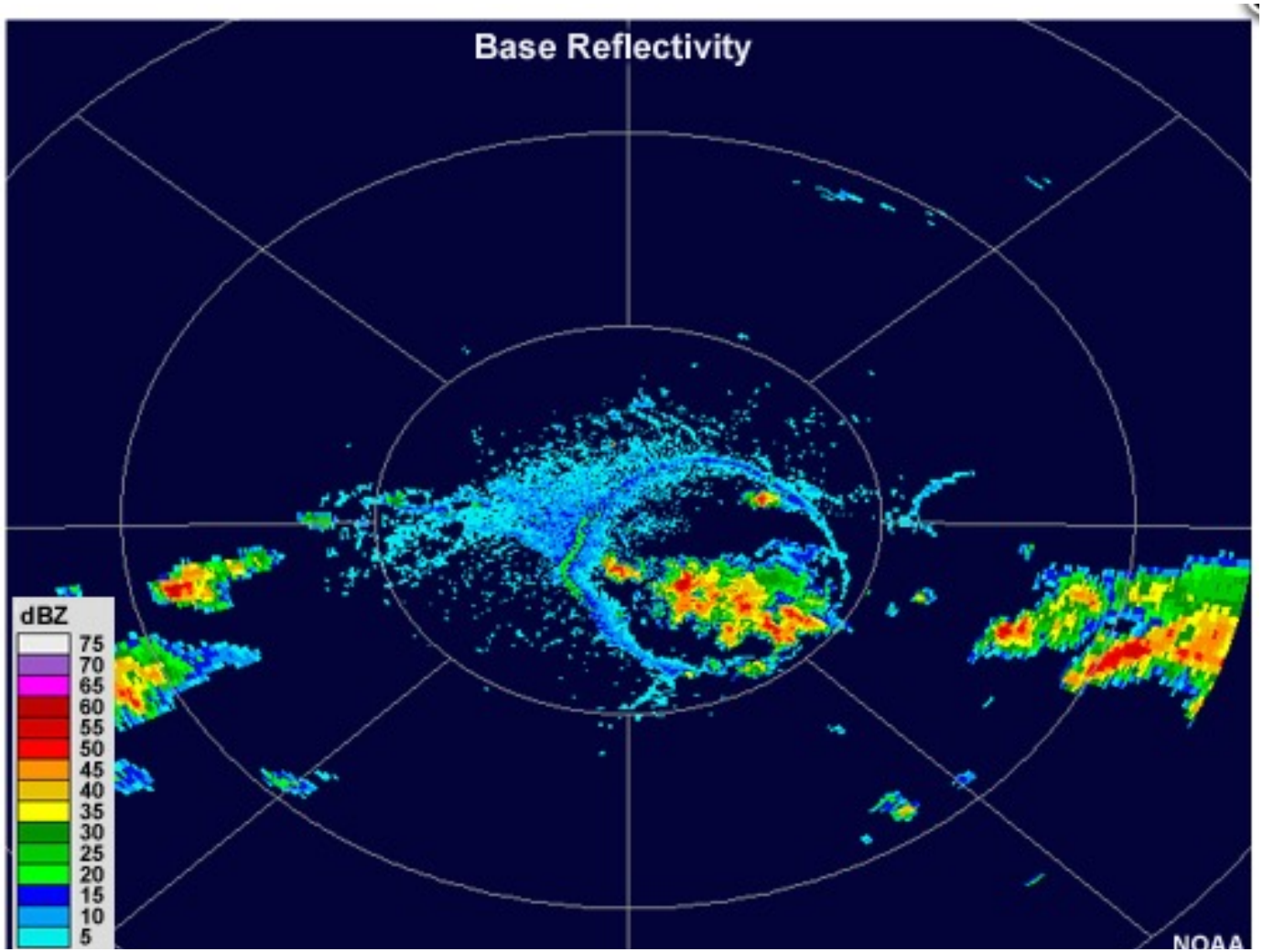
- **insects and other particulate** being concentrated due to convergence and turbulence along the front, and some degree of **beam-bending** due to density gradients along the boundary

- Warm and cold fronts, drylines, outflow from thunderstorm downdrafts, and sea and lake breezes

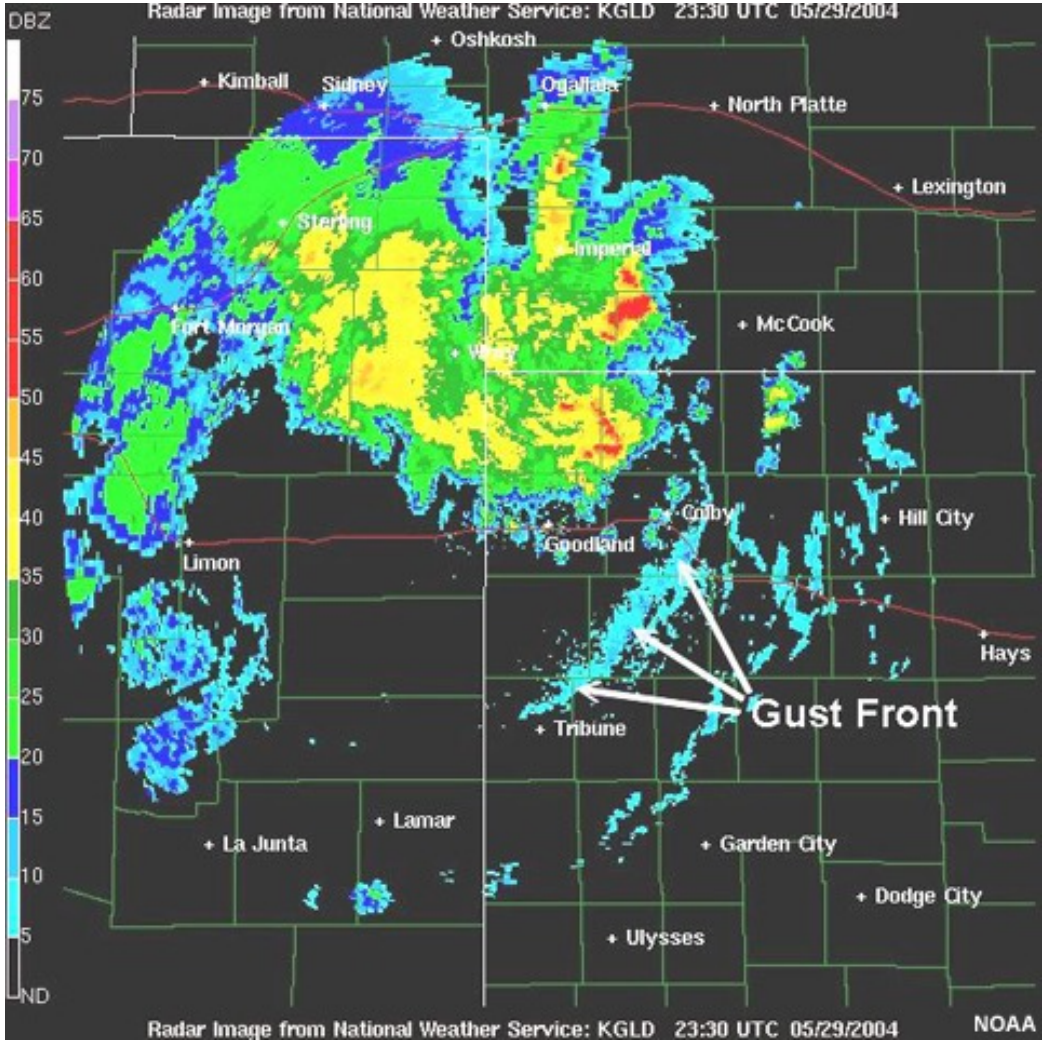
气象回波： 非降水回波

- A very thin line of low reflectivity (<=15 dBZ), which is often called a "fine line."
- An arc-shape to the fine line, which moves away from a recent thunderstorm in the case of outflow boundaries
- A distinct difference in wind direction behind and ahead of the front, if enough scatterers are present on both sides

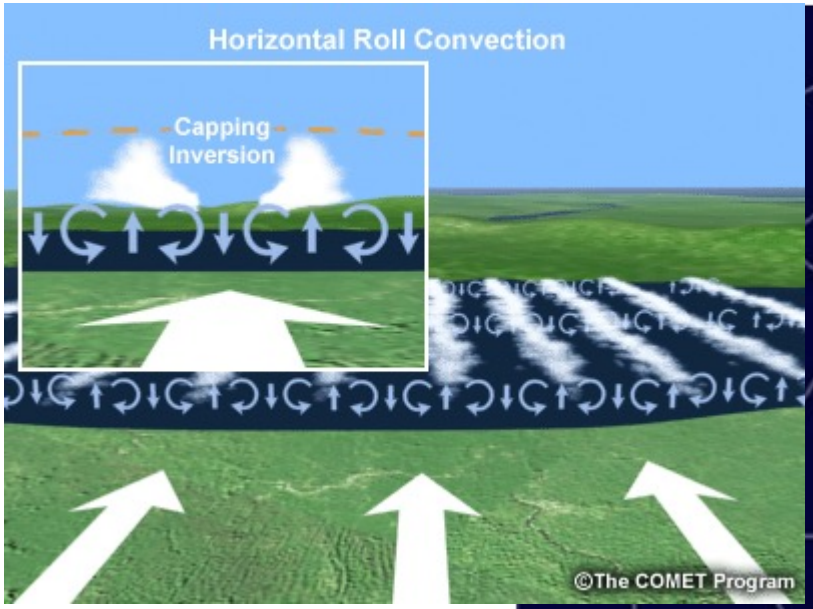
气象回波： Outflow boundary

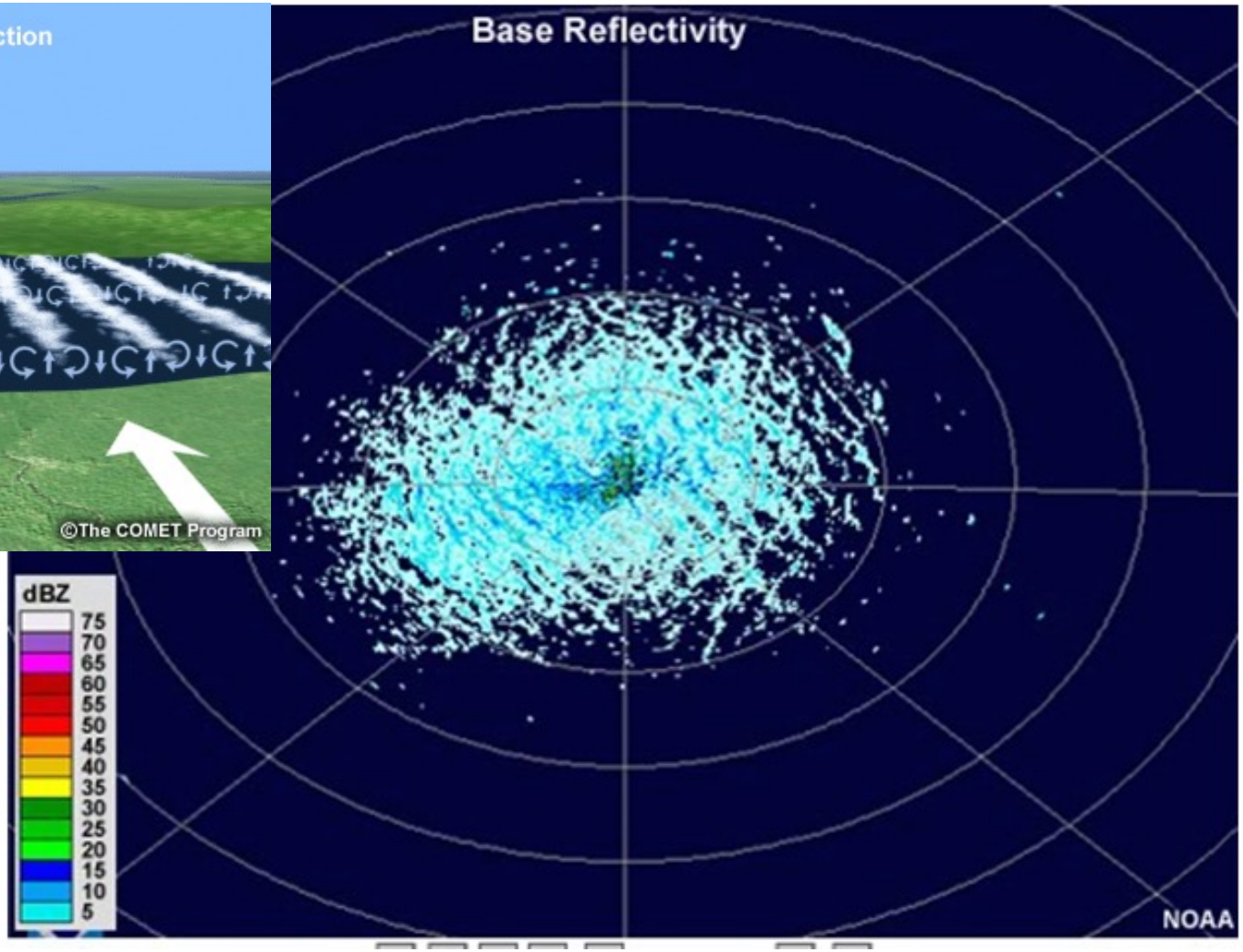


气象回波： Gust front

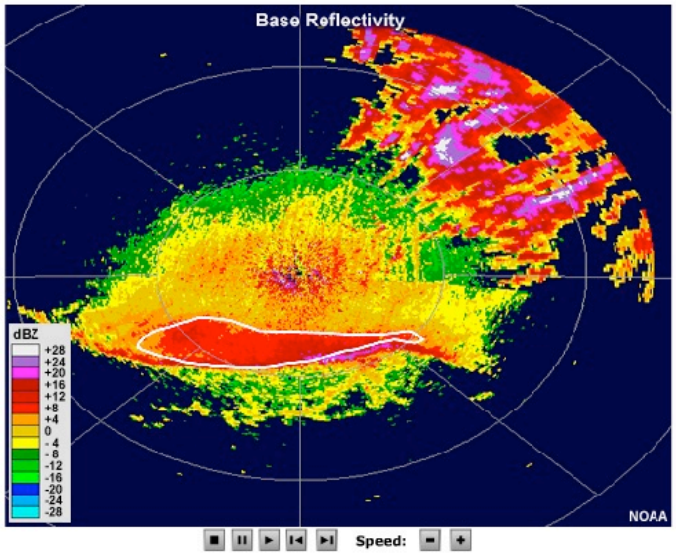


气象回波： Horizontal convective roll





Dust



- Often associated with outflow boundaries and very strong synoptic fronts
- Low values
- Fine line with clutters behind
- Highest near the surface

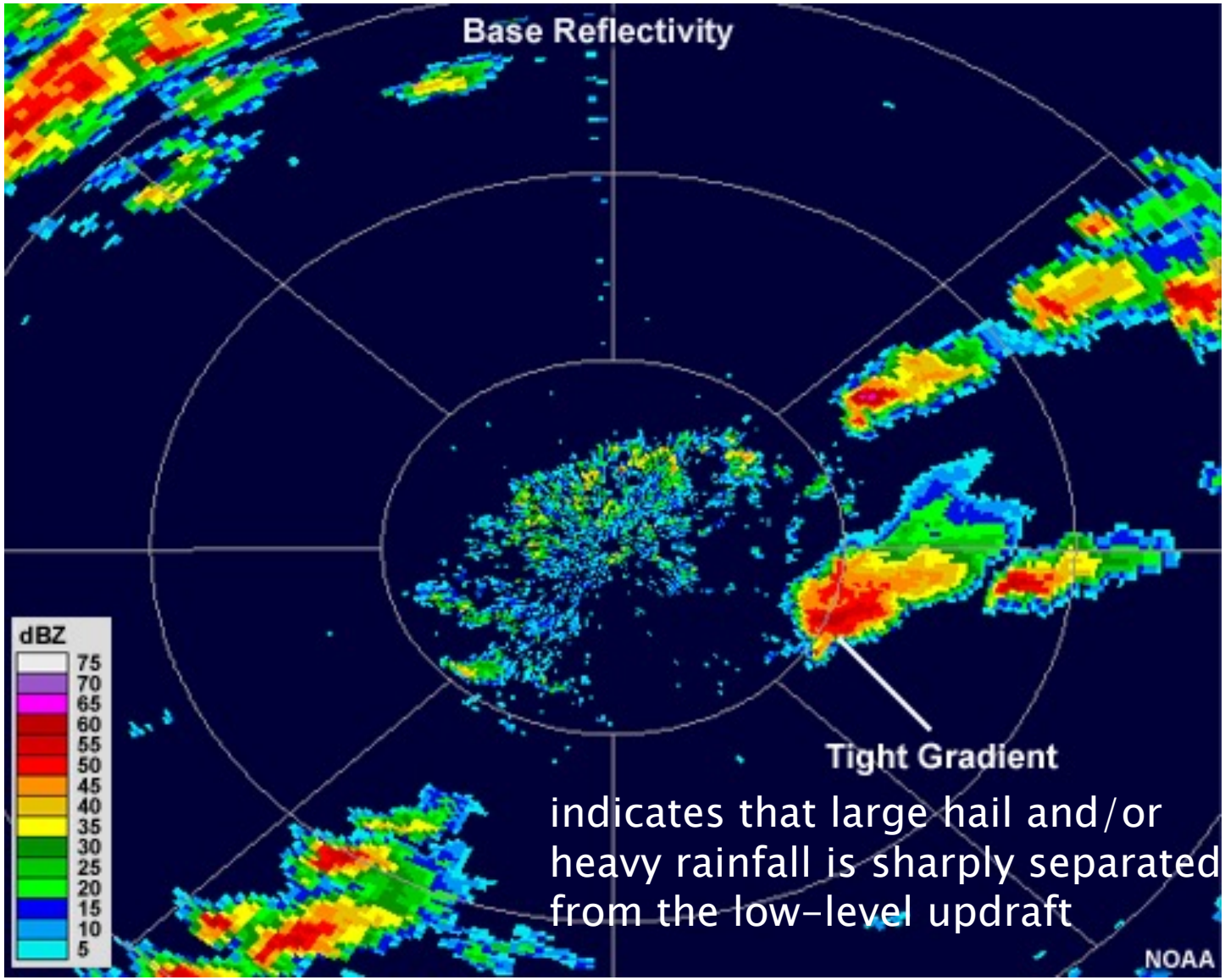
主要内容

- 雷达基础
- 雷达局限性
- 风场特征识别
- 晴空模式雷达观测特征识别
- 降水模式雷达观测特征识别

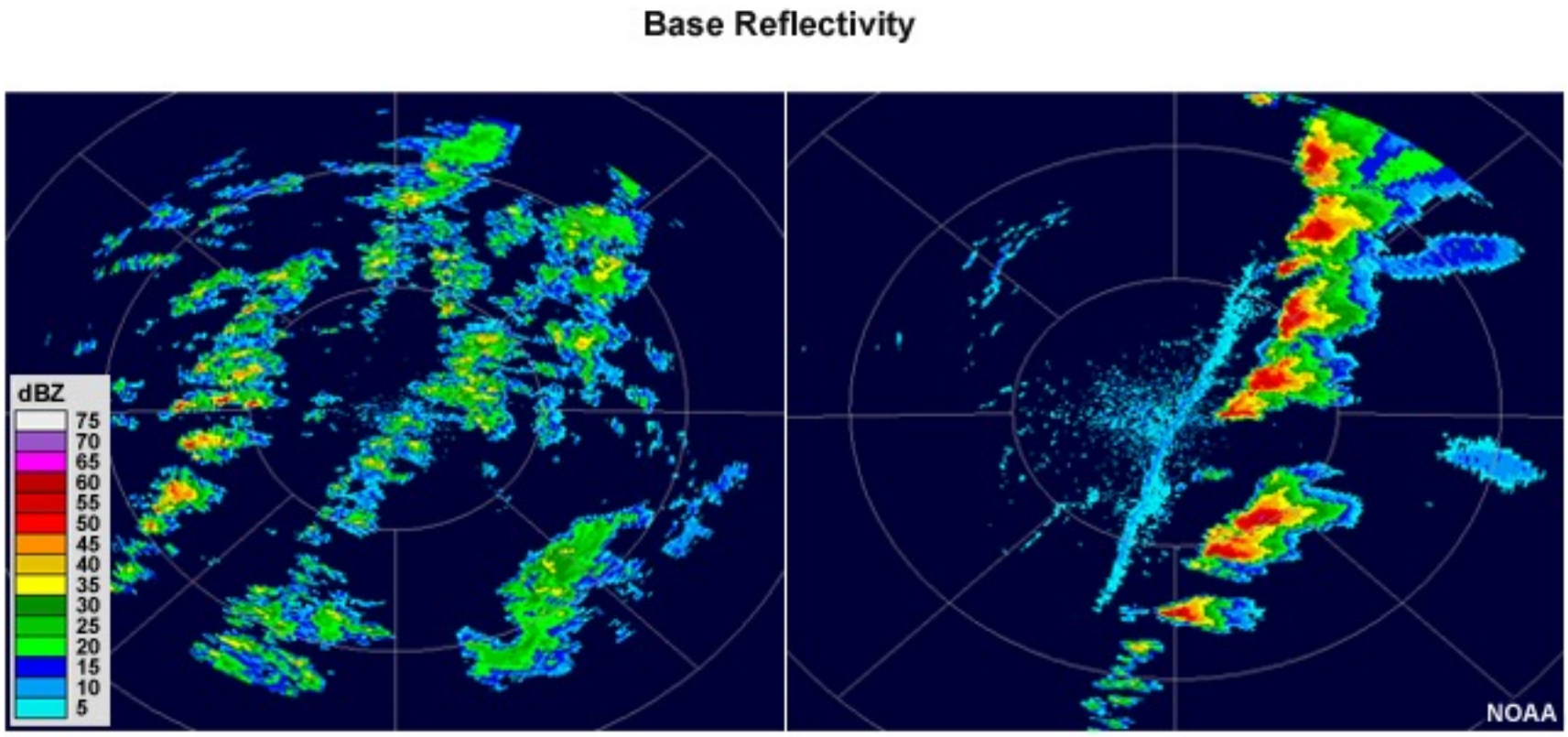
Convection

- **High reflectivity values (>45 dBZ)**
- **Its initially cellular shape**
- **Three categories:**
  - **Ordinary thunderstorms**
  - **Supercell thunderstorms**
  - **Mesoscale convective systems.**

Low-level Reflectivity Gradient



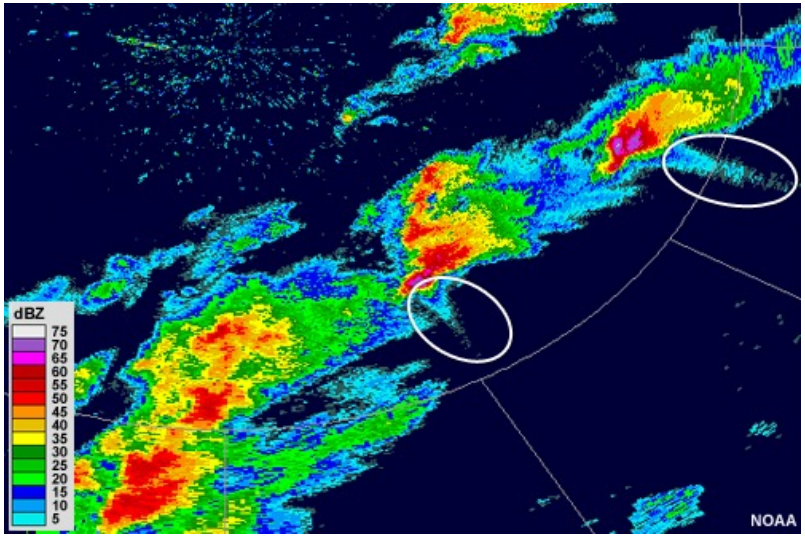
Different intensity of the convection

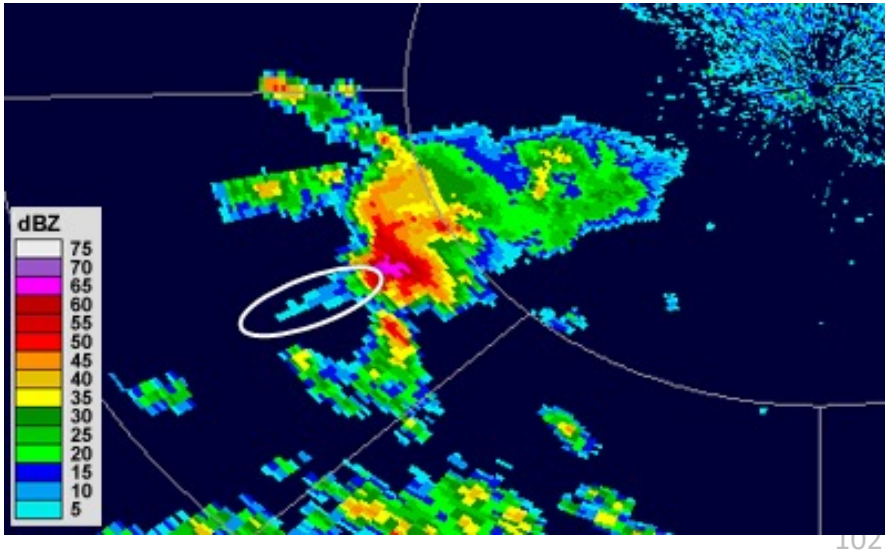


Hail

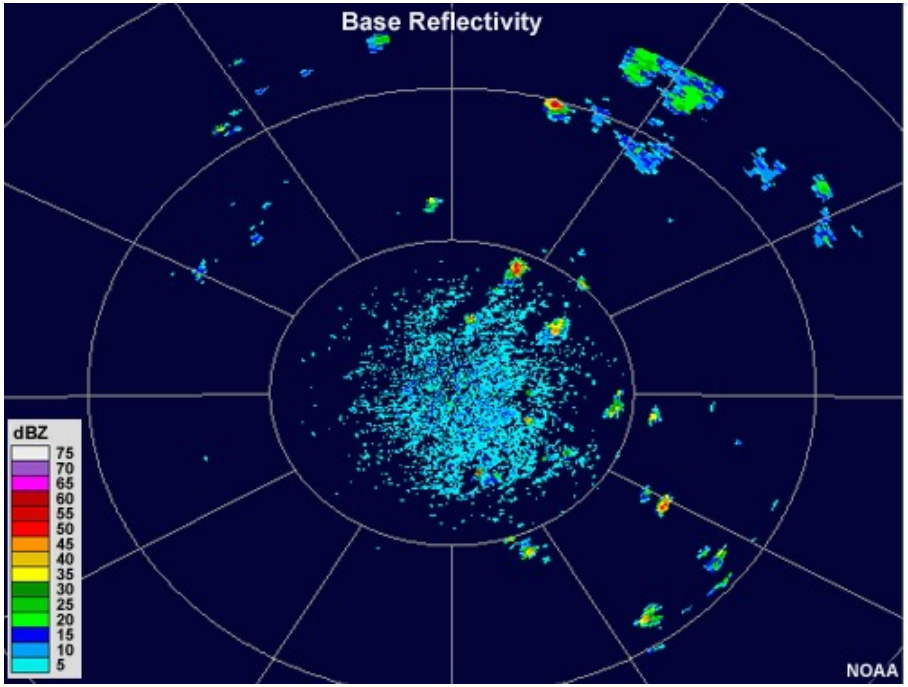
- Above about 60 dBZ
- Three Body Scatter Spike (TBSS)

  A 10-30 km long, low reflectivity (< 20 dBZ), mid-level echo "spike" that extends outward along a radar beam from a high reflectivity core. Certain indicator of large hail.





Ordinary thunderstorms



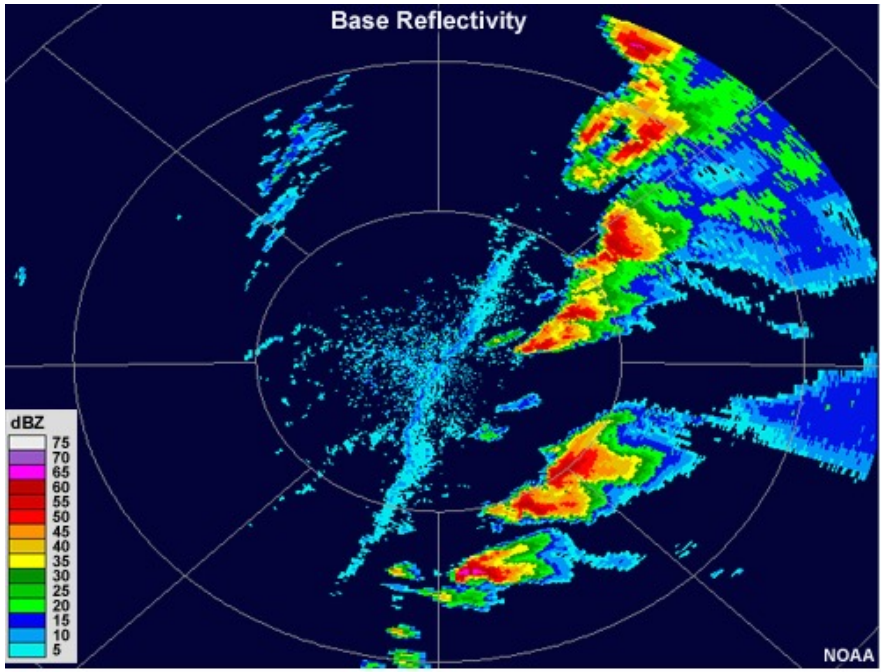
Location

- Maritime tropical airmasses in the warm sector of mid-latitude cyclones
- Back side of low pressure systems
- Edges of high pressure systems
- Along locally high terrain

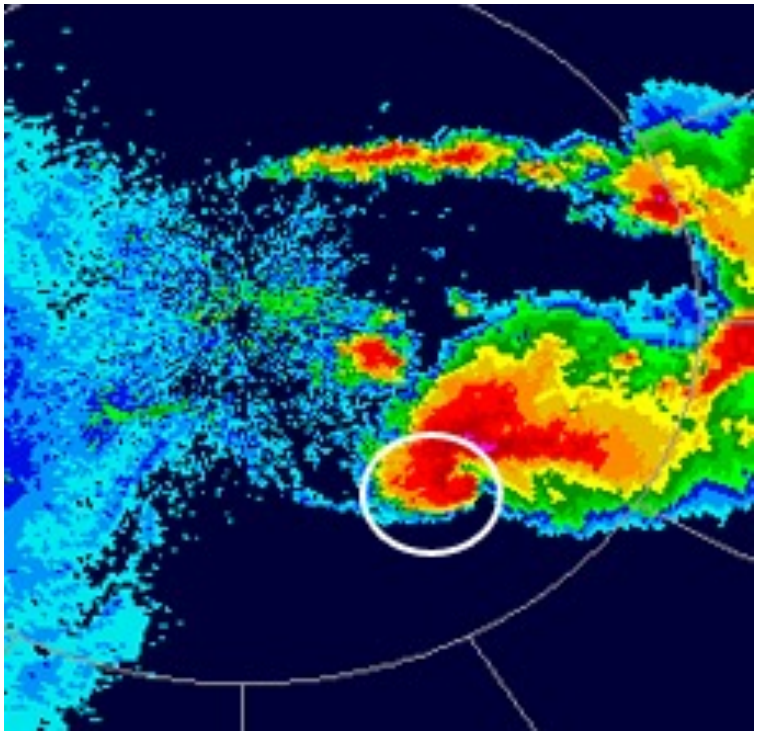
Weather: small hail, gusty winds, weak tornado

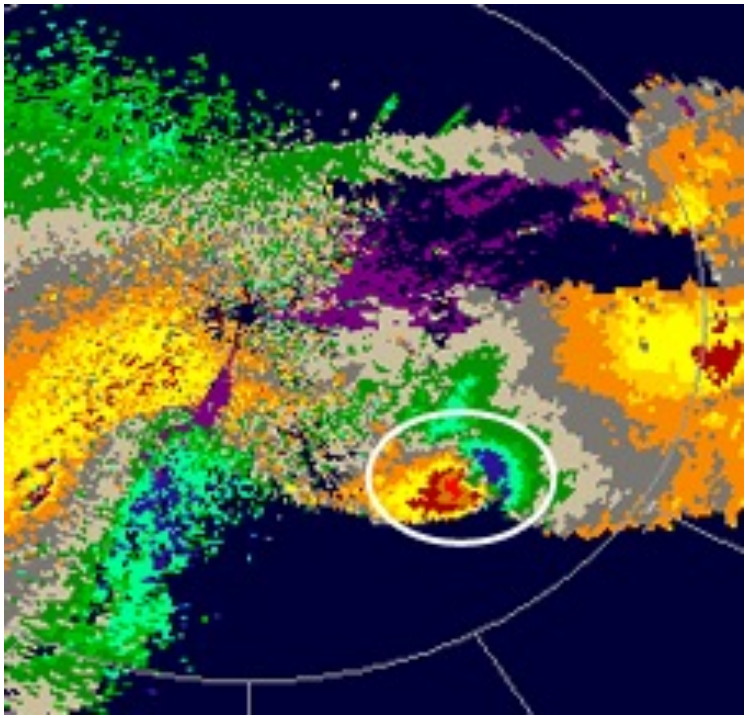
Supercell


Doug Rafik

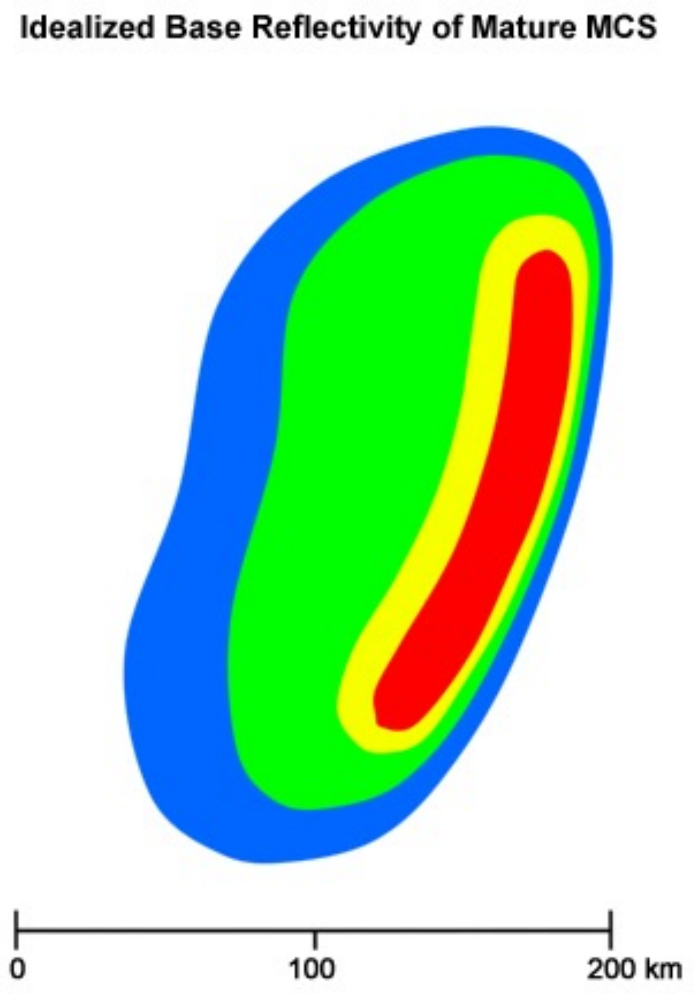

Base Reflectivity
dBZ
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
NOAA

Supercell



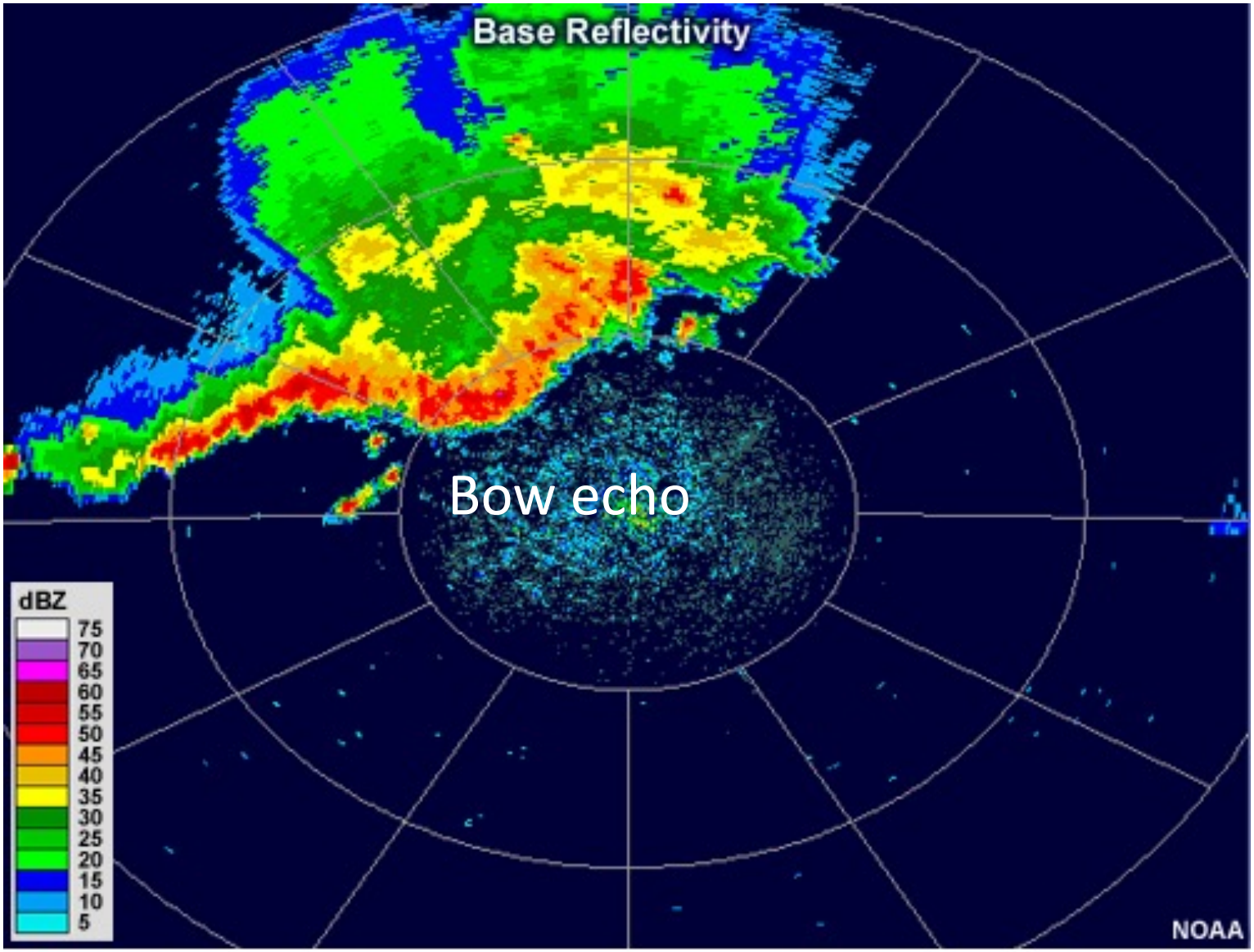


Mesoscale Convective Systems

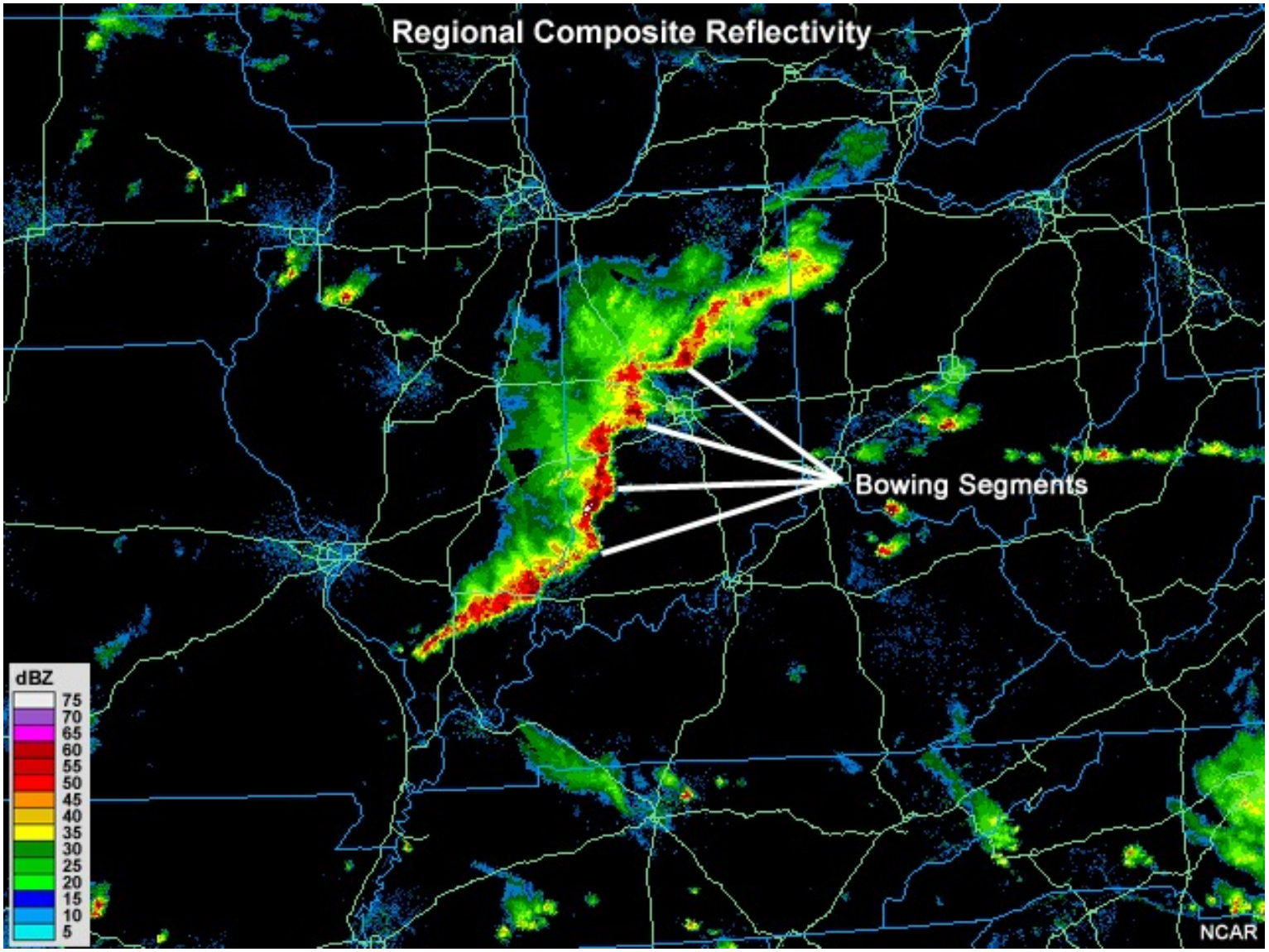


- Warm season mid latitude
- Tropics
- Near warm stationary fronts during night hours in mid-latitude
- Monsoonal circulations, Easterly wave, ITCZ in the tropics

Bow echo


Base Reflectivity
Bow echo
dBZ
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
NOAA

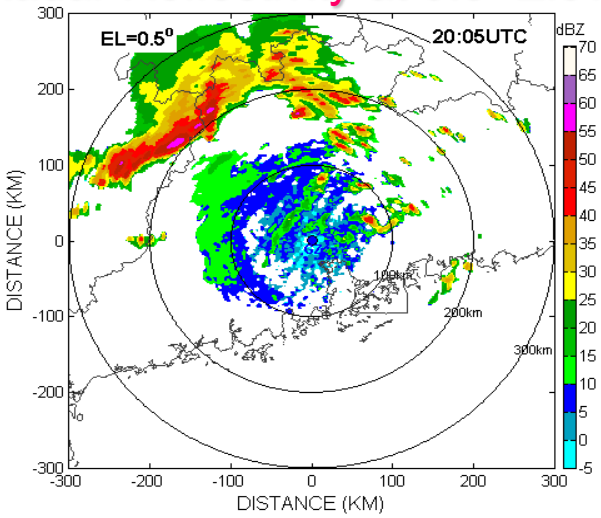
Bowing segements

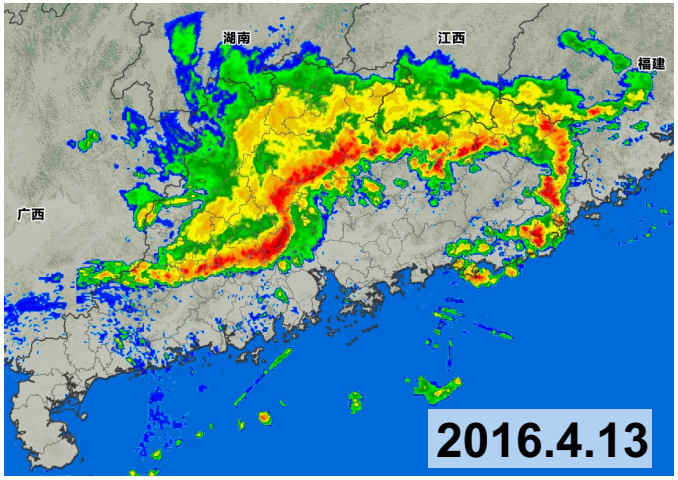


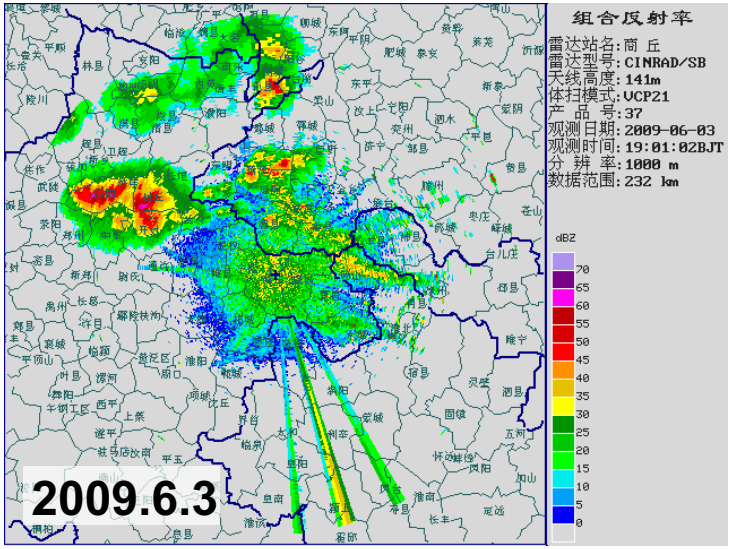
我国的几次飑线过程

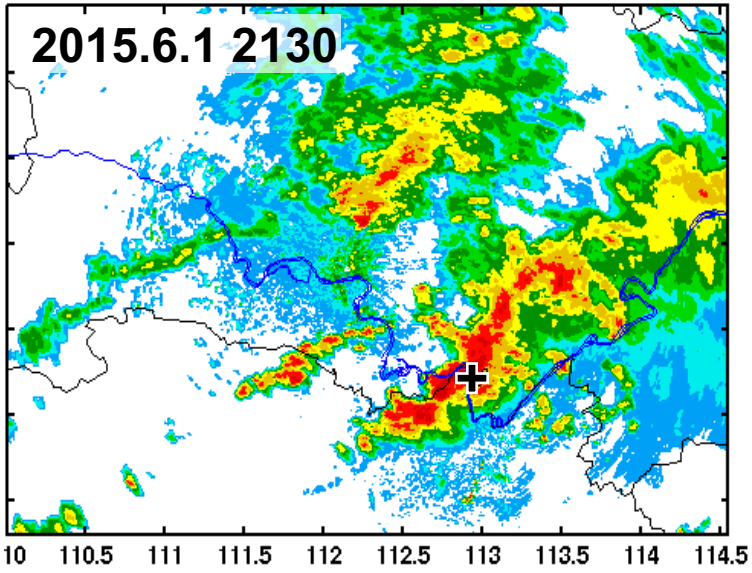
2007年4月23日广东飑线

GZ Radar Reflectivity at 0.5 Elevation

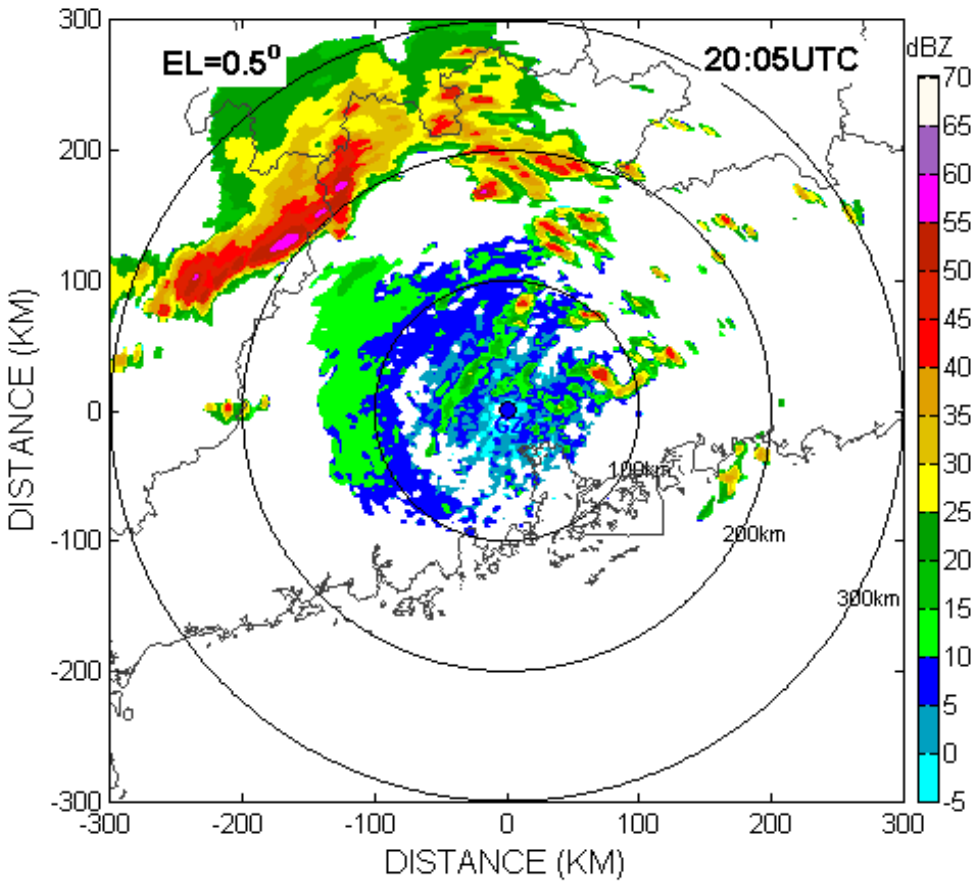








2007年4月23日广东飑线



（Zhao kun 2007）

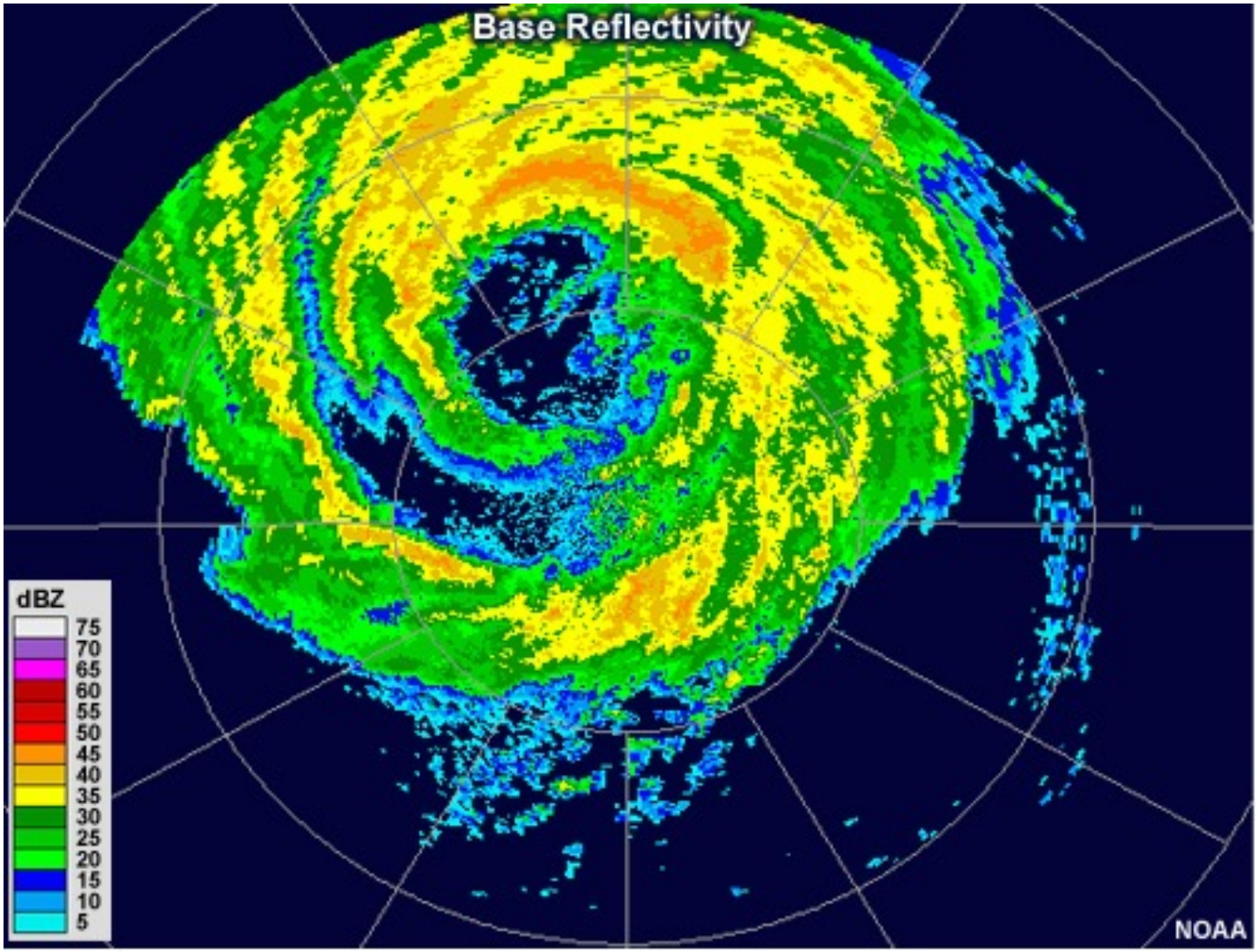
特点: 移速快,45 km / h，
持续时间长，约11 h，
范围广，横跨广东全省.

灾害: 23日至24日，广东遭遇大范围暴雨和雷雨大风天气，全省大部分地区普降强降水。47个市县出现暴雨，局部出现大暴雨，全省最大降雨量186.3毫米。曲江的沙溪镇出现了冰雹。出现了8级至9级的大风，花都大风30米 / 秒（１１级）。

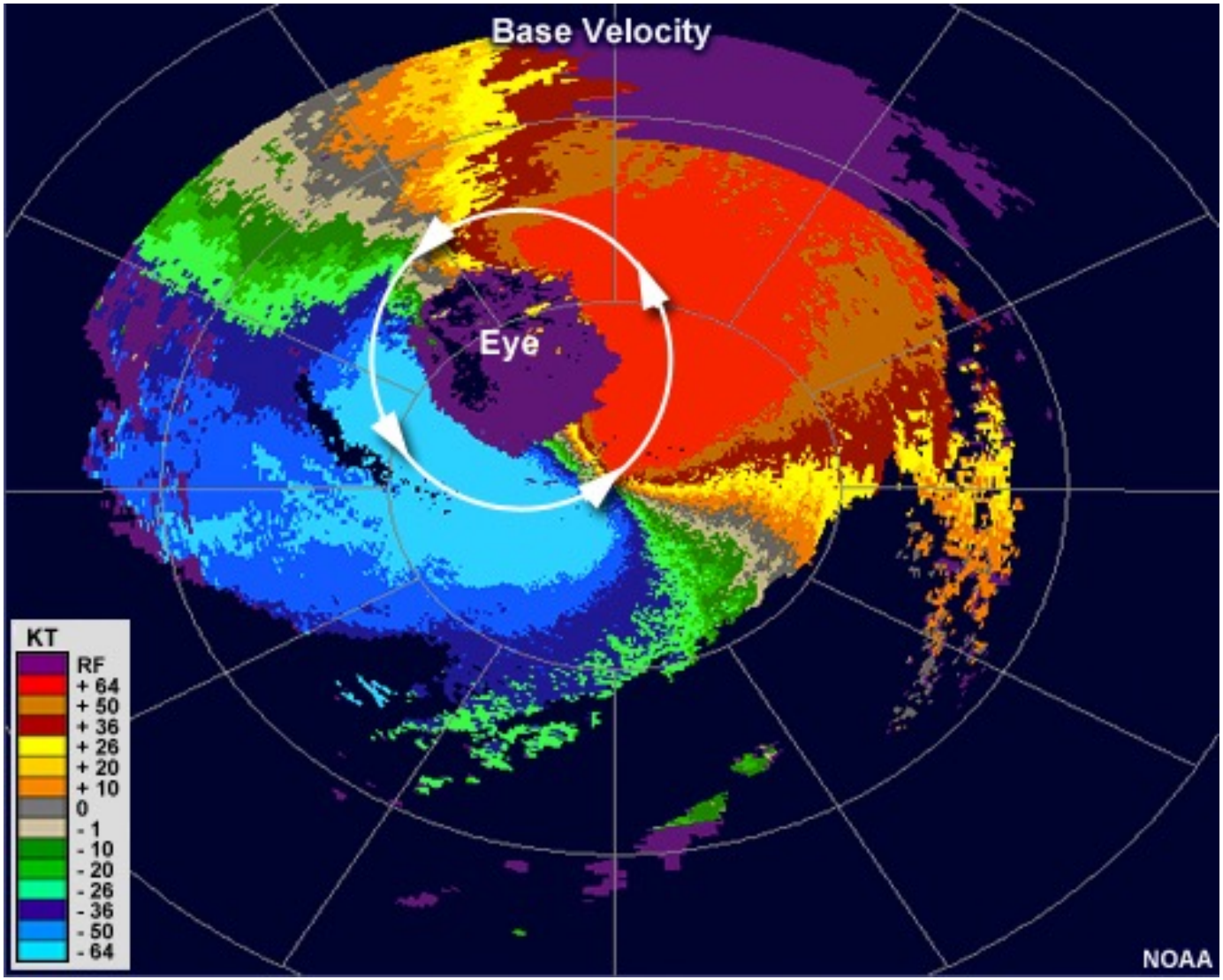
Features

- Long-lived, usually several hours or more
- Often consist of a leading line of strong convection and a trailing region of widespread, moderate precipitation
- May contain bow-shaped segments of intense precipitation within the leading convection
- May also contain damaging straight-line winds, especially at the apex of a bow echo, if it is present

Tropical Cyclone

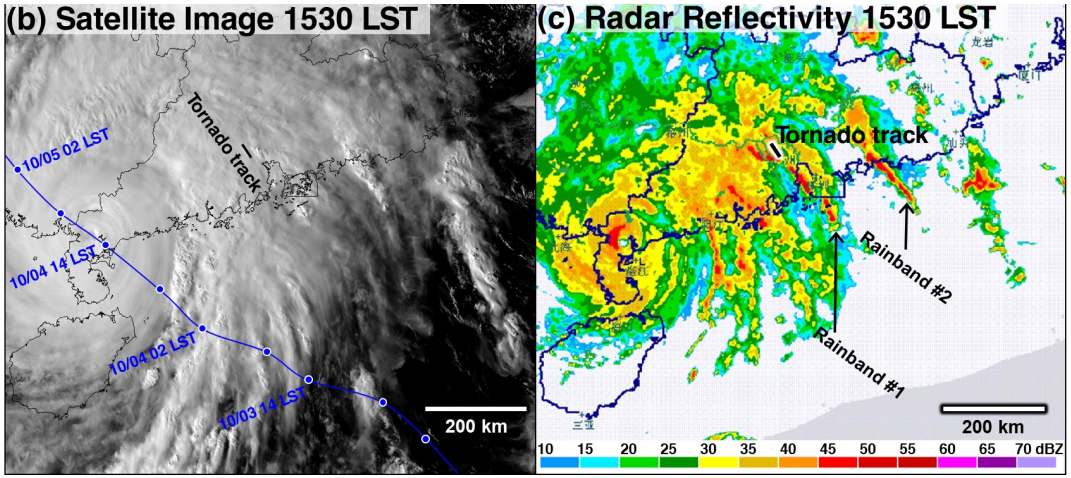


Tropical Cyclone

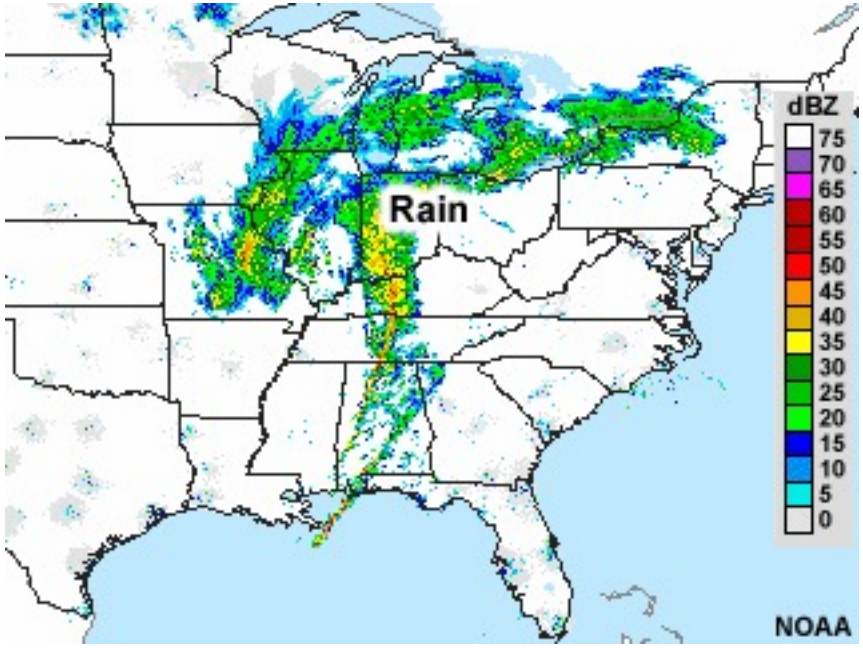


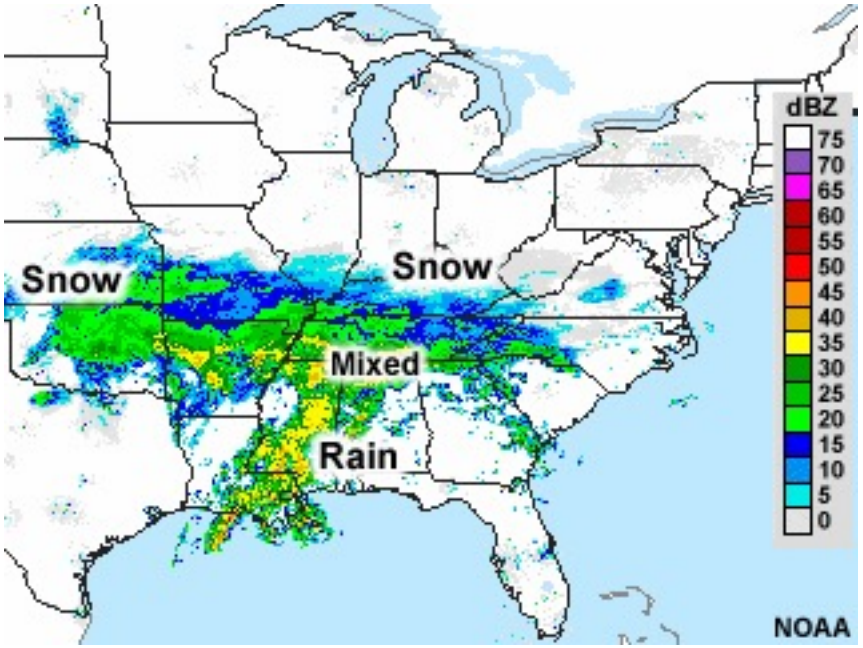
Features

- The **eye**, nearly echo-free
- The **eyewall**, most often seen as a ring of high reflectivity surrounding the eye
- **Spiral rainbands**, which are narrow bands of intense rainfall that extend outward from the center of the storm



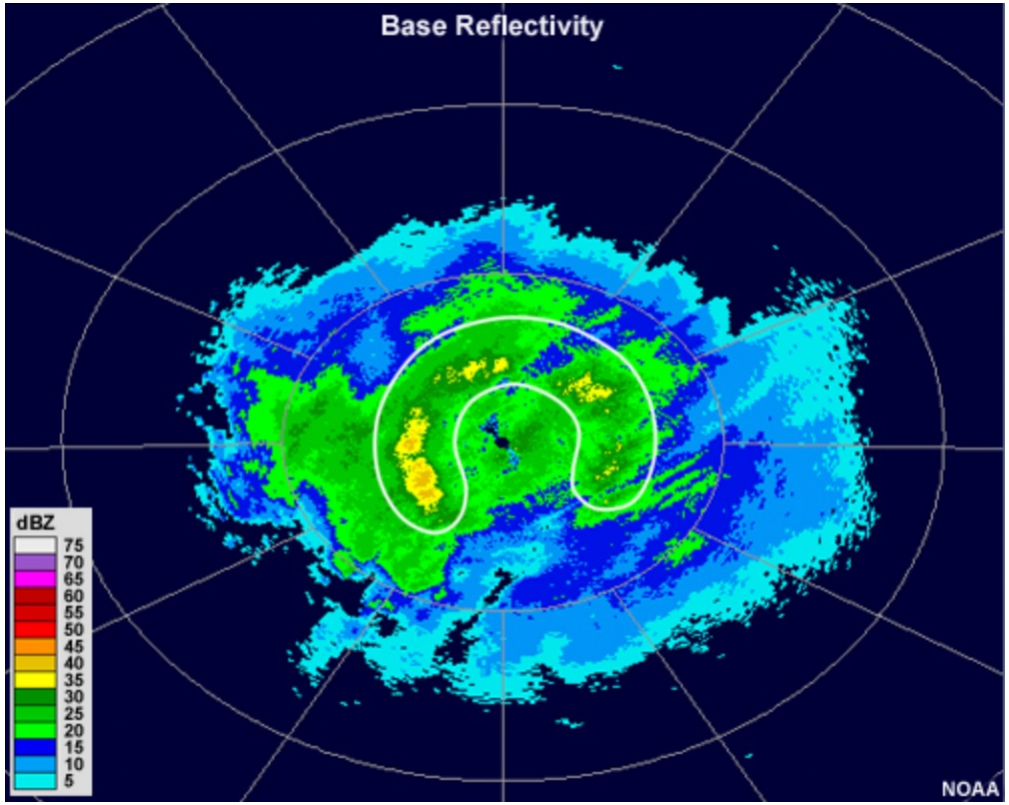
Winter Weather





Ice vs. raindrops

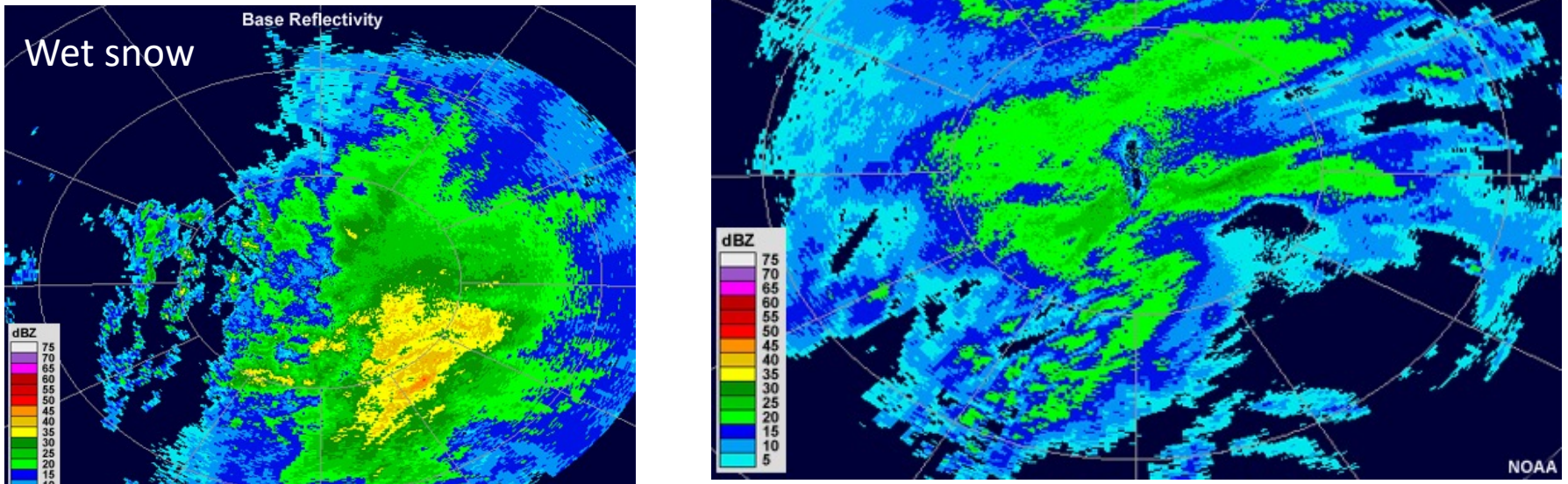
- usually lower reflectivity, but larger size
- Water content may increase the Z



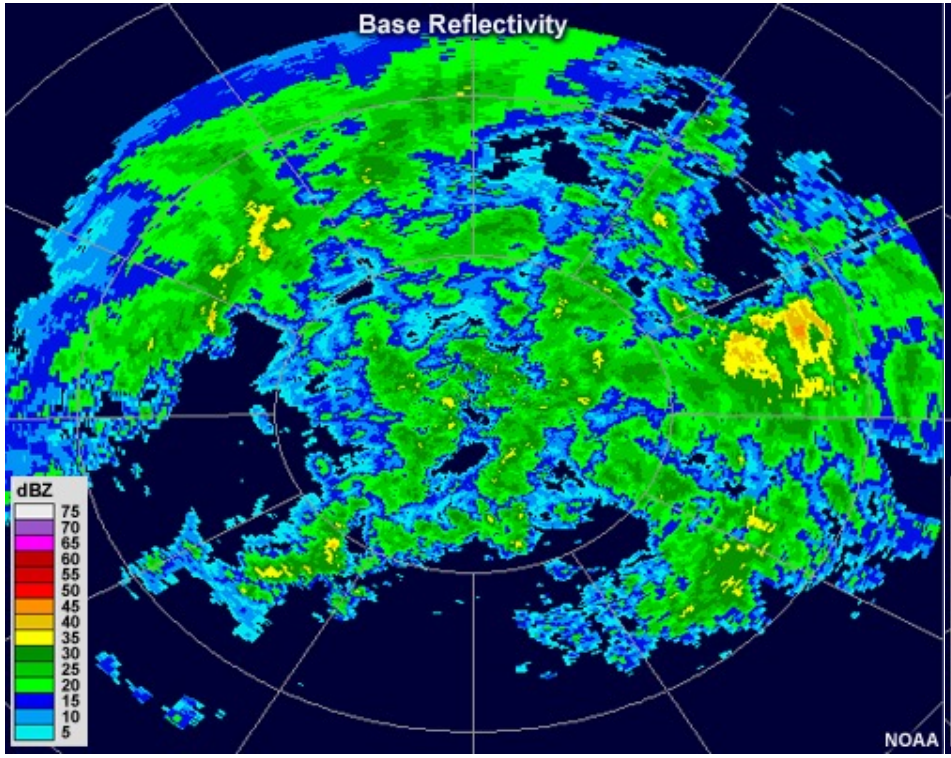
Bright band

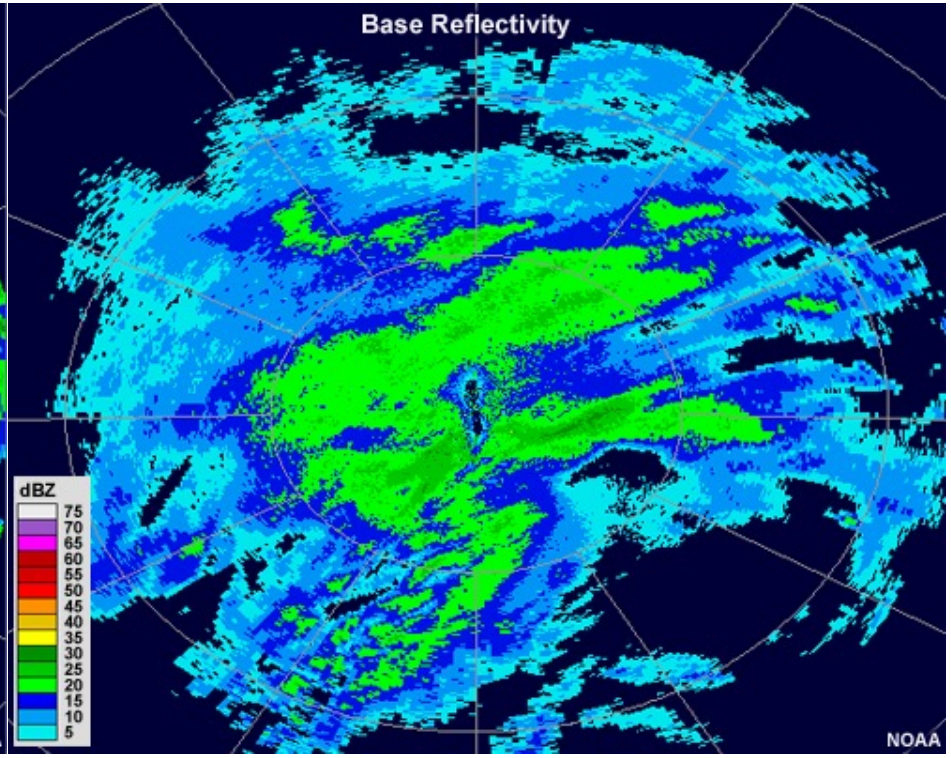
Snow features

- Gradual changes in reflectivity values
- Grainy texture
- Fuzzy echo edges



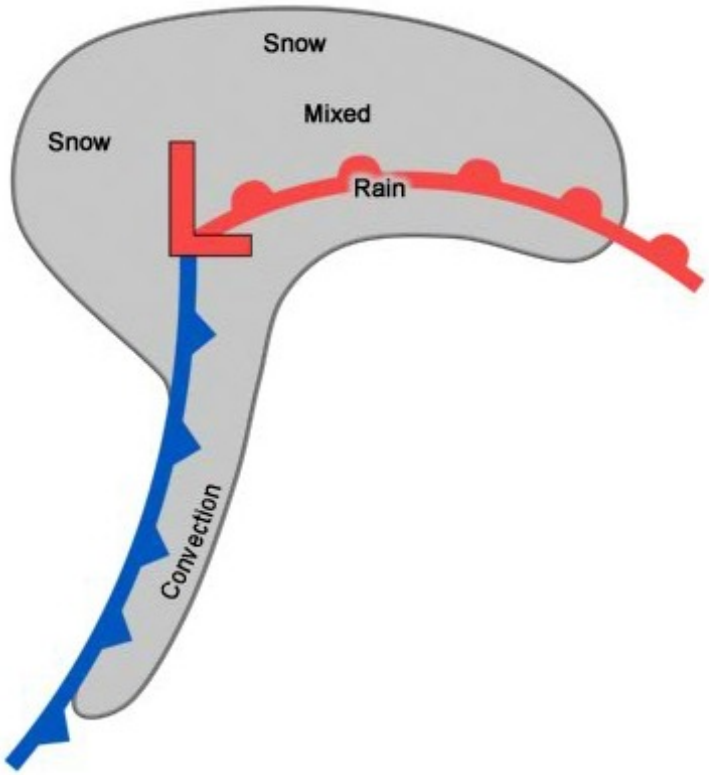
Rain vs. Snow


Base Reflectivity
dBZ
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
NOAA


Base Reflectivity
dBZ
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
NOAA

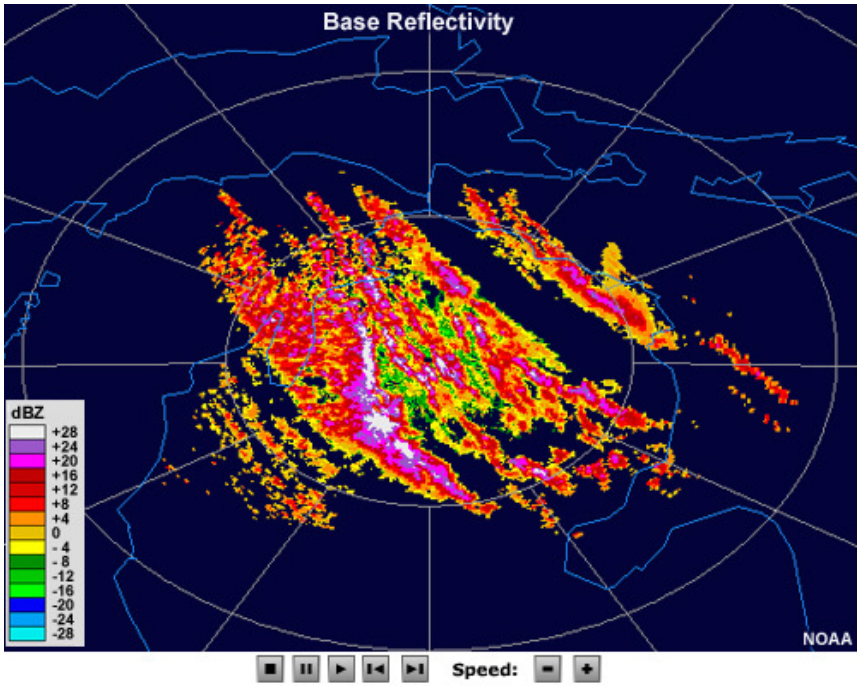
Snow Banding

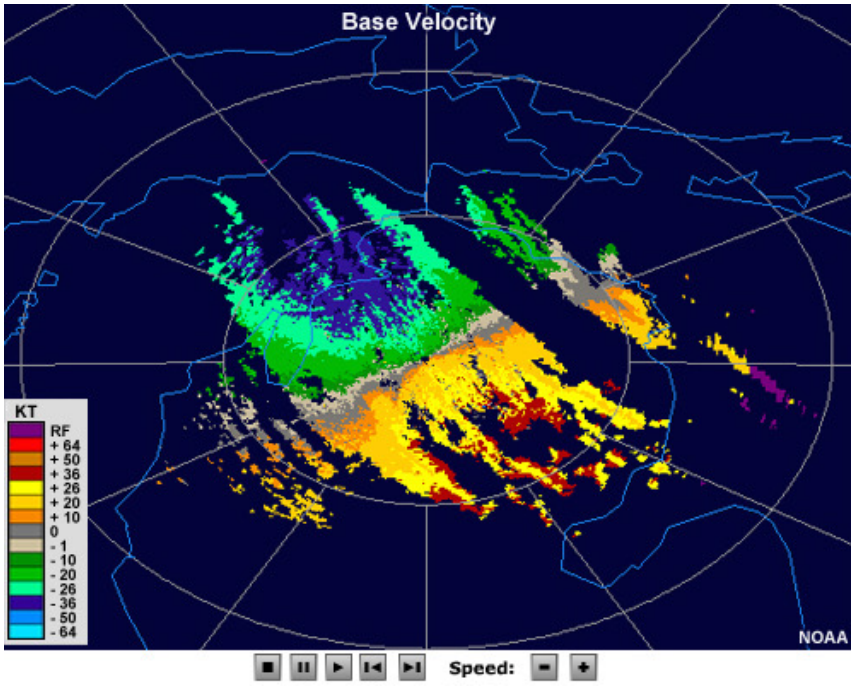
Location of snow



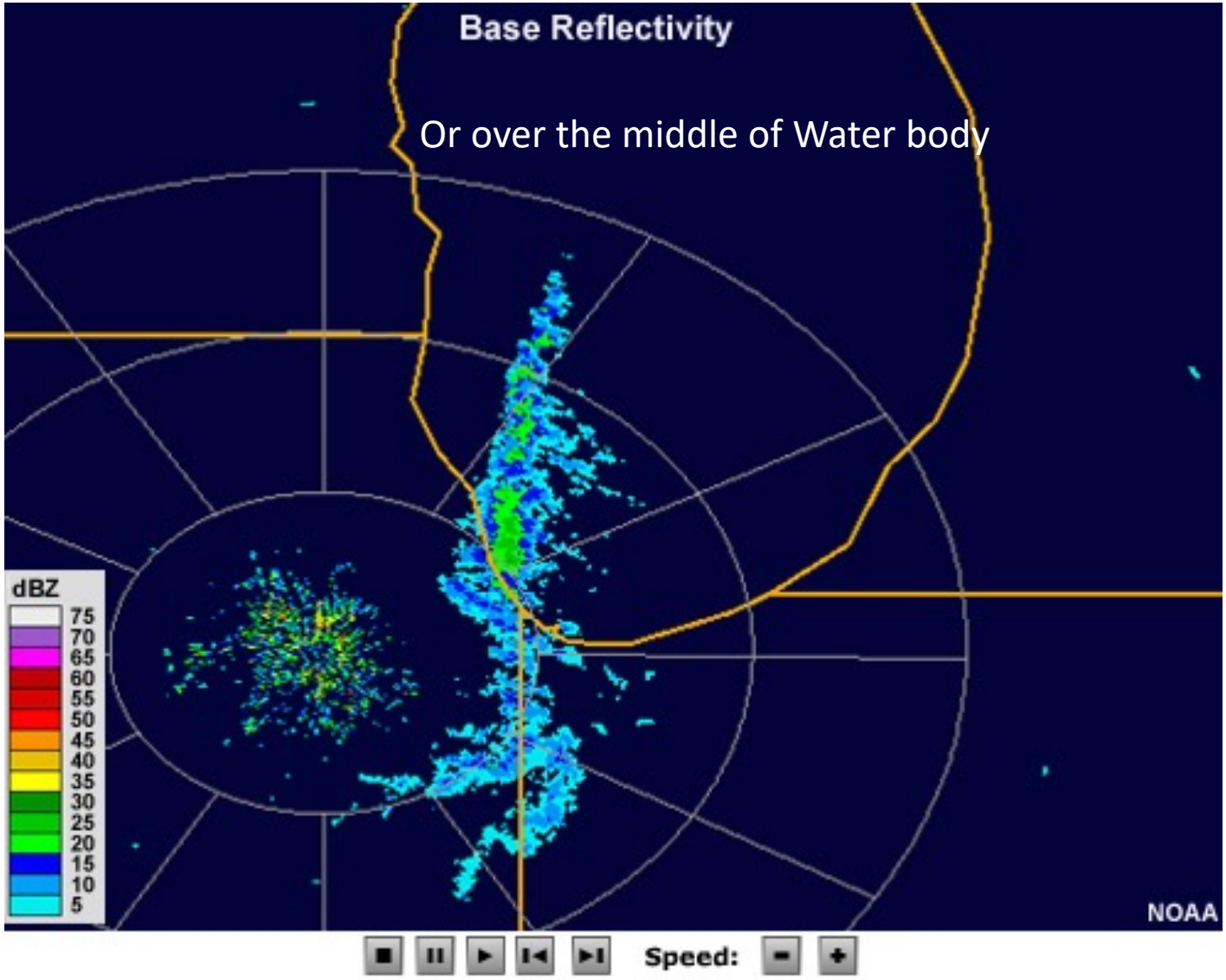
Lake Effect

Over the downwind side of a water body





Lake Effect


Base Reflectivity
Or over the middle of Water body
dBZ
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
NOAA
Speed:

Features

- Very weak gradients in reflectivity value.
- Fuzzy edges instead of a distinct echo edge.
- Grainy, textured appearance.
- Snow may develop into bands of enhanced reflectivity
  - Along the warm front,
  - To the northwest of the low pressure center
  - On the downwind side of lakes and other open water
- Examine your local sounding and low-level temperature data to see what type of precipitation could develop.
- Dual-polarization radar data

Reference

http://www.meted.ucar.edu/radar/basic_wxradar/