Radar Meteorology
Introduction and Basic Theory

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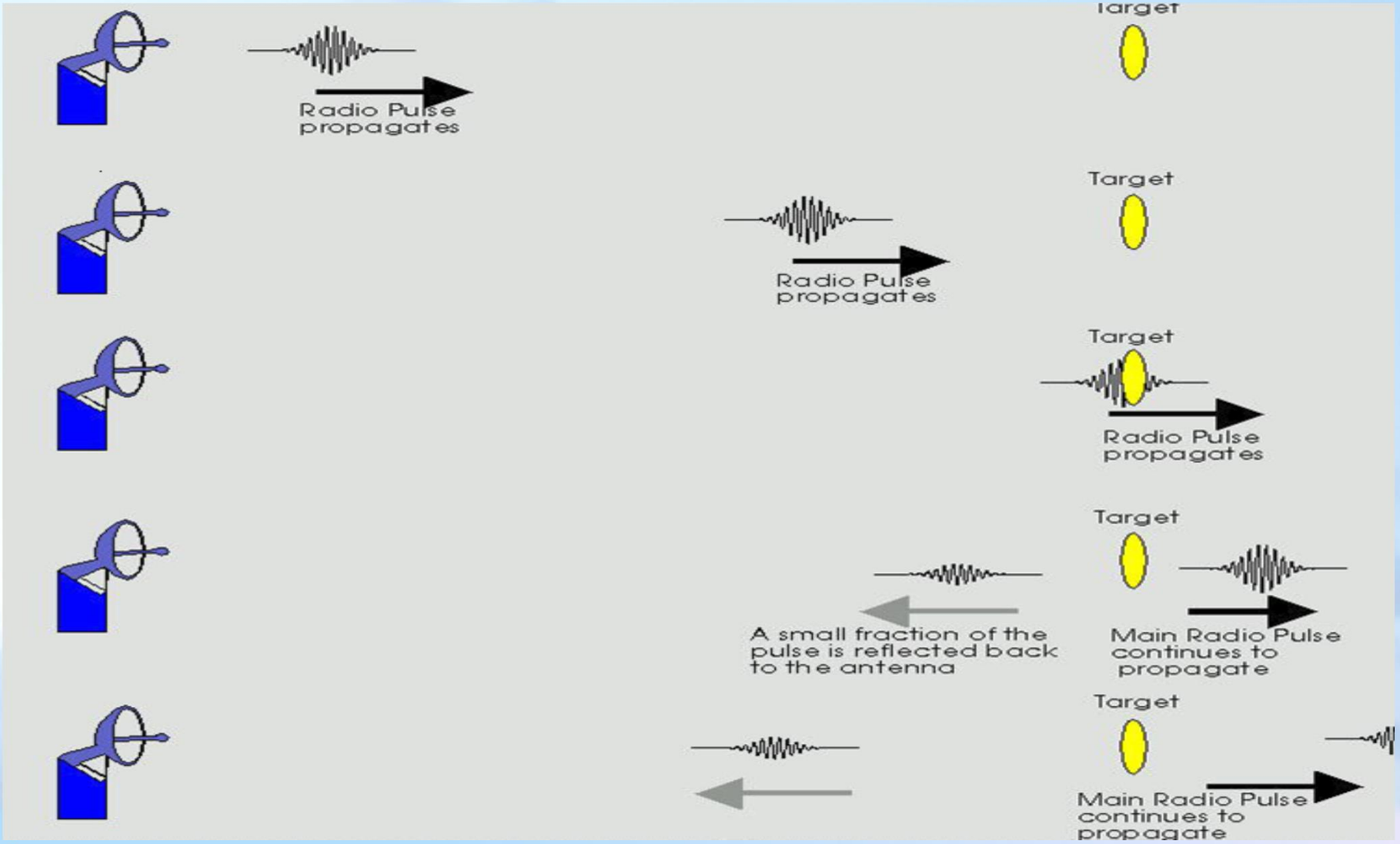
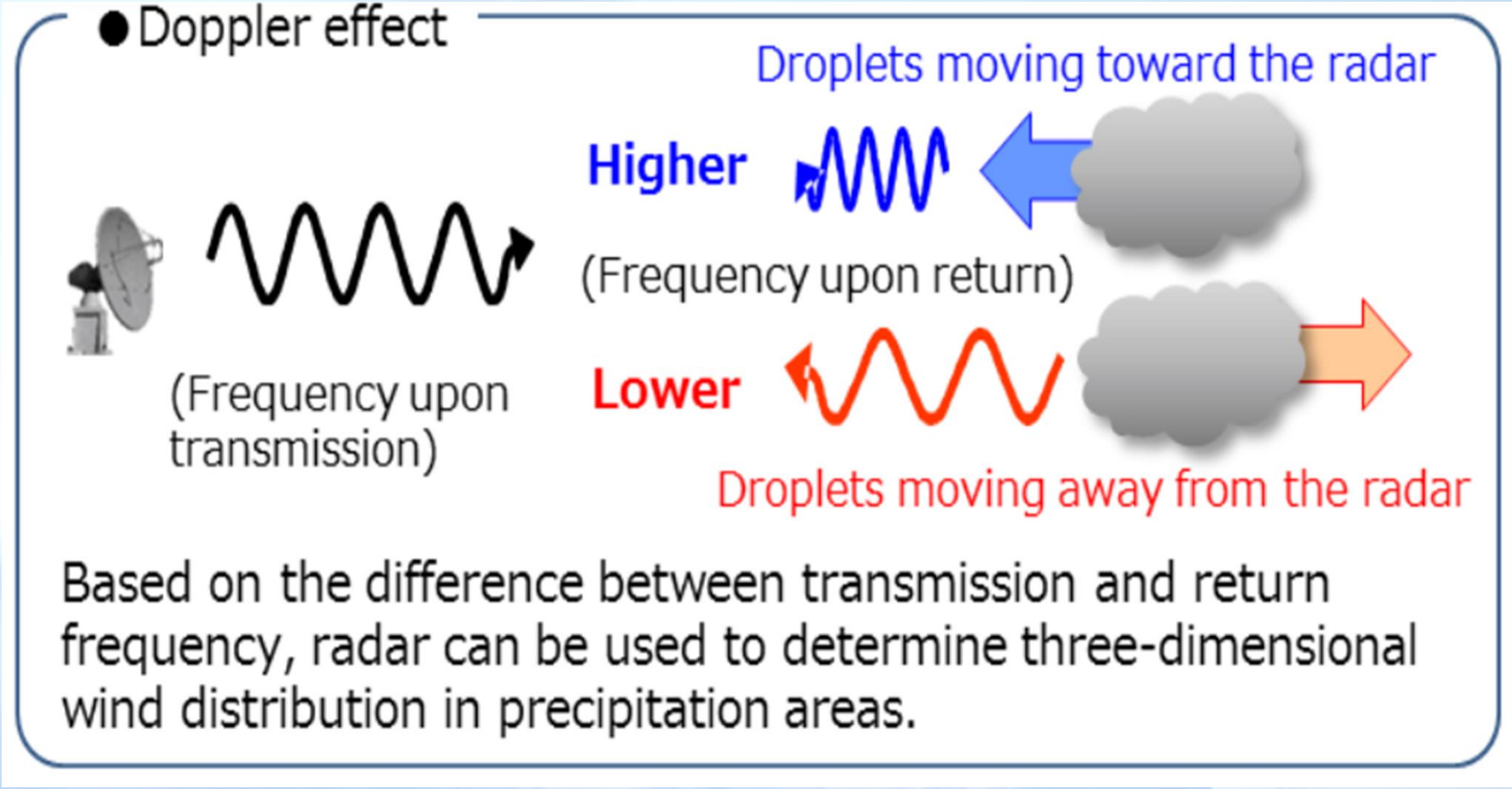
INDIA METEOROLOGICAL DEPARTMENT

How RADAR Works?



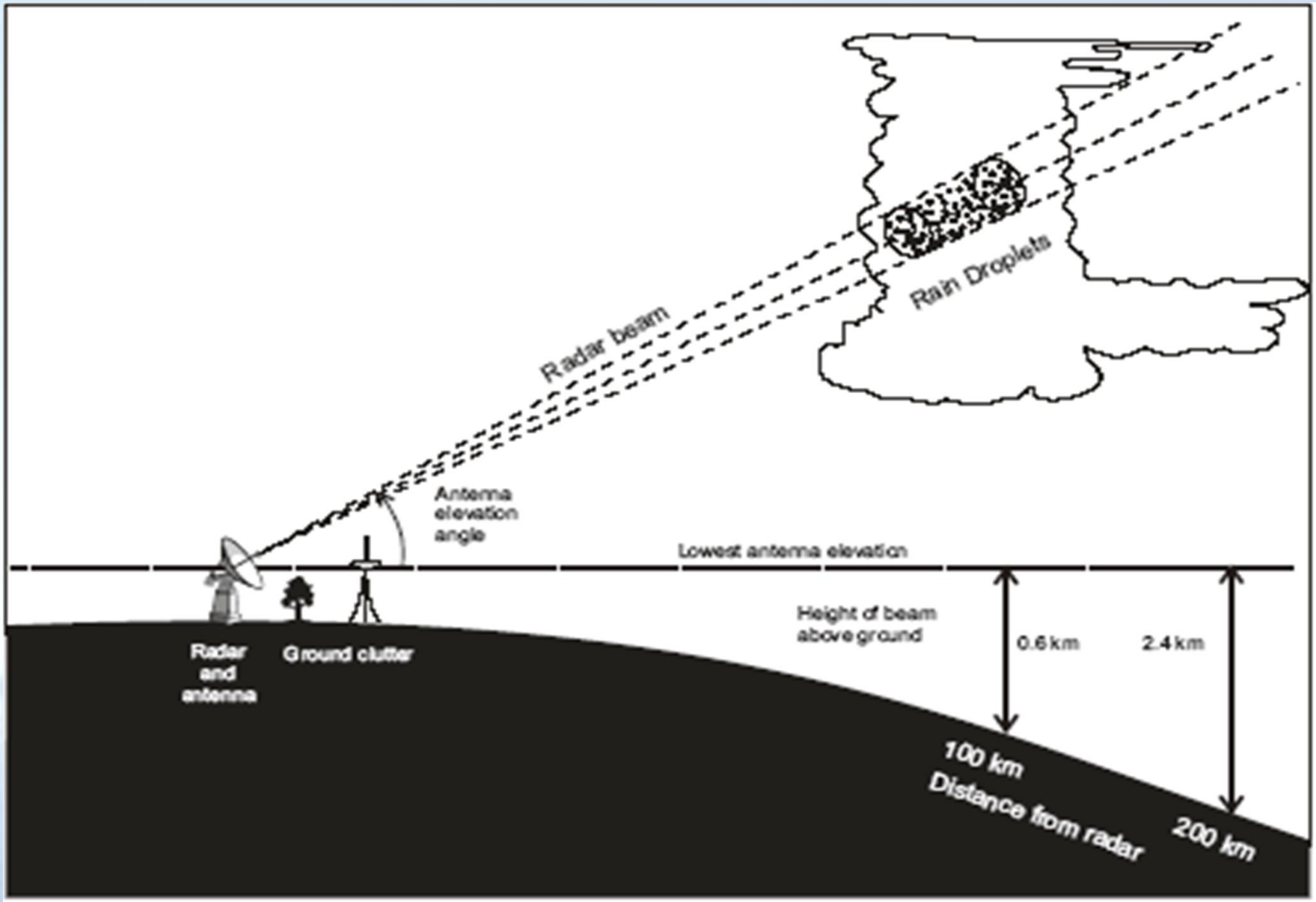
Doppler radar principle



Radar – Frequency bands

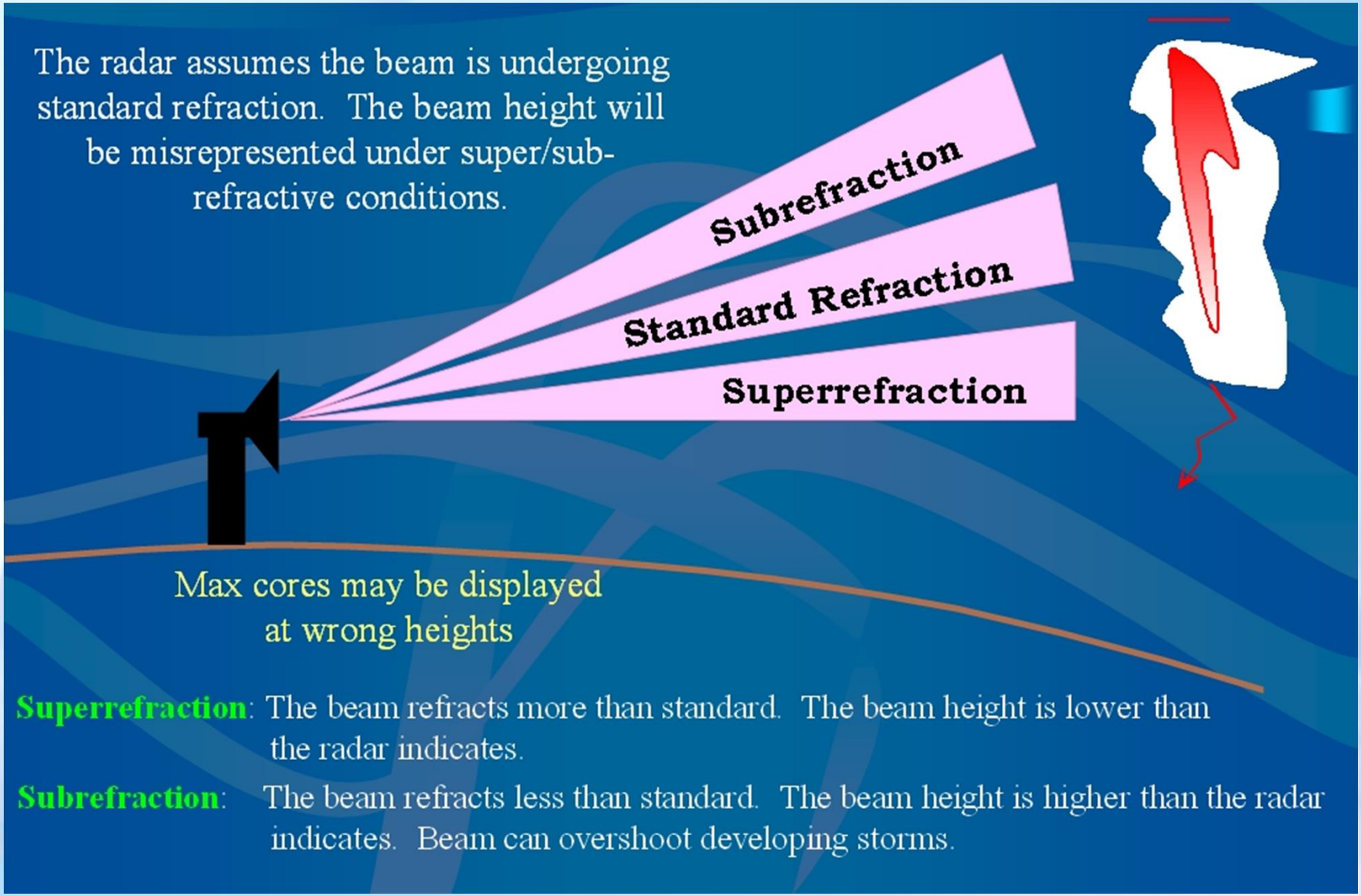
Band Designation	Frequency	Wavelength
S	2-4 GHz	15-8 cm
C	4-8 GHz	8-4 cm
X	8-12 GHz	4-2.5 cm

	Large Wavelength:	Small Wavelength:
☺	Range; V Measurement	Sensitive; Compact
☹	Dimensions, Costs	Attenuation

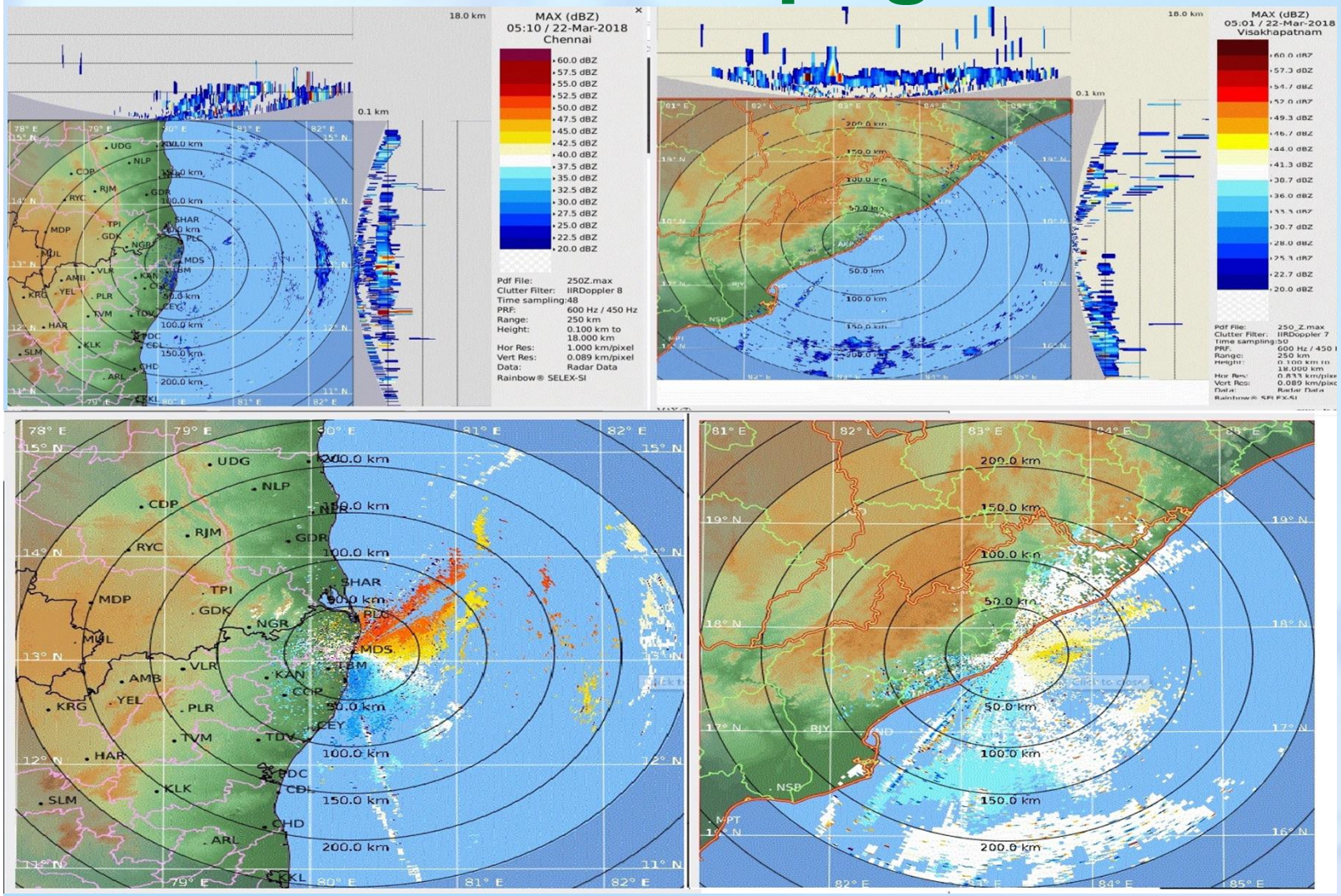


Radar scans this entire volume by raising and lowering the beam as the antenna rotates.

Sub and Super Refraction



Refraction anomalies – Anomalous Propagation Echoes



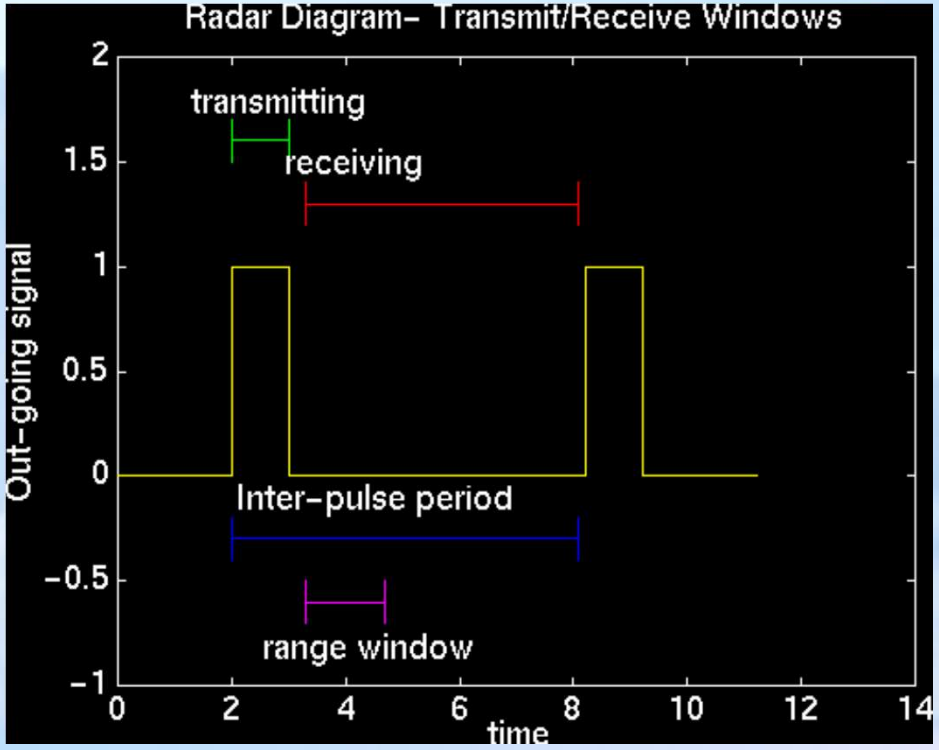
- **Multi Radars**
- **velocity**

Pulse Repetition frequency

- The rate at which pulses are transmitted by the Radar per sec is called Pulse Repetition Frequency (PRF).

- Time interval (t) between two pulses is known as pulse length or pulse repetition time (PRT)

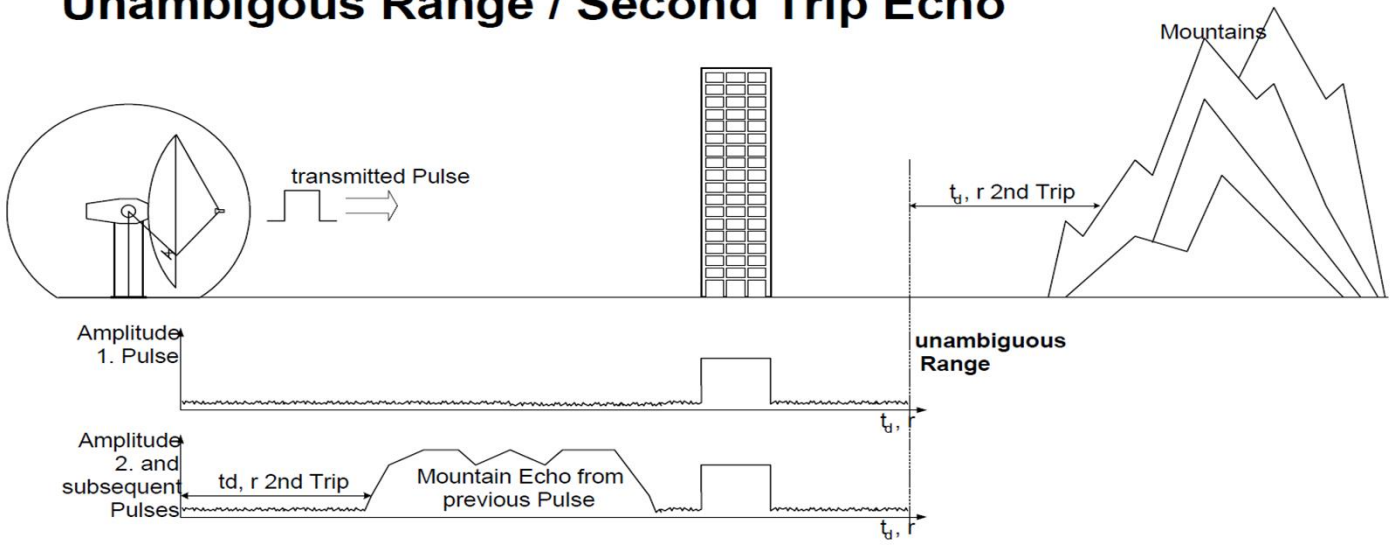
- PRT(t) = 1/ PRF



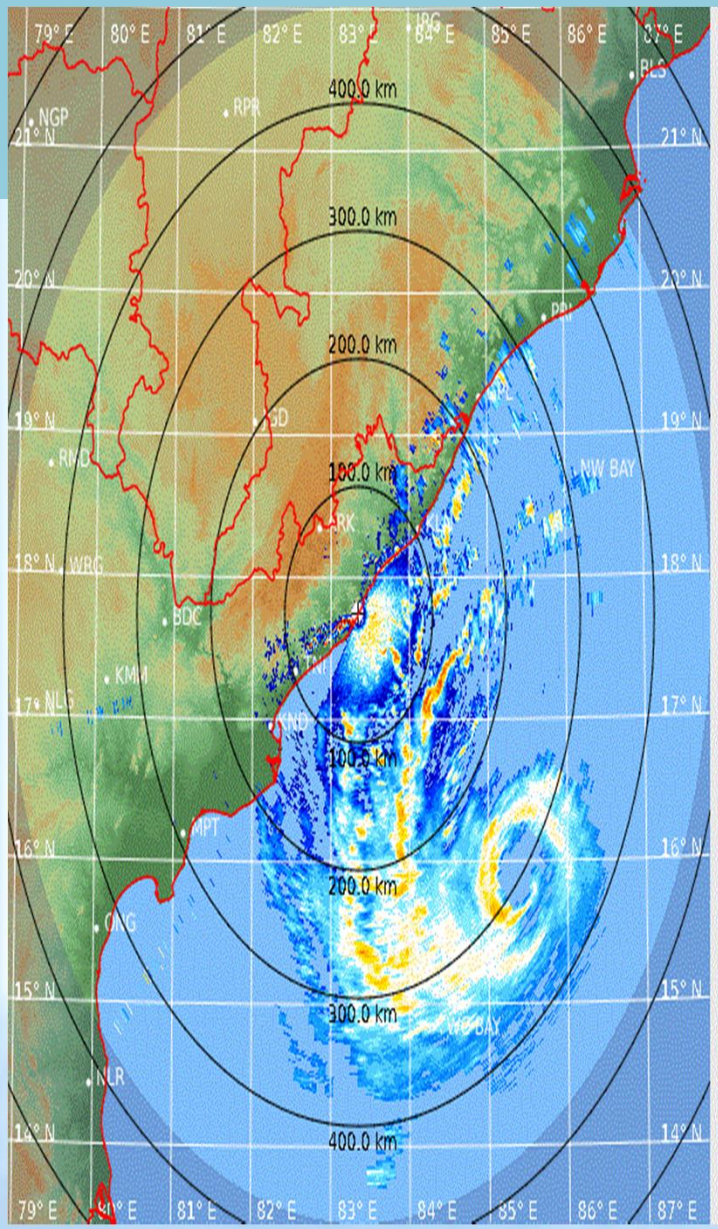
Range Folding

$$Unambiguous\ Range = \frac{c \times (PRT)}{2} = \frac{c}{2 \times (PRF)}$$

Unambigous Range / Second Trip Echo



Change PRF: second trip echo will shift position

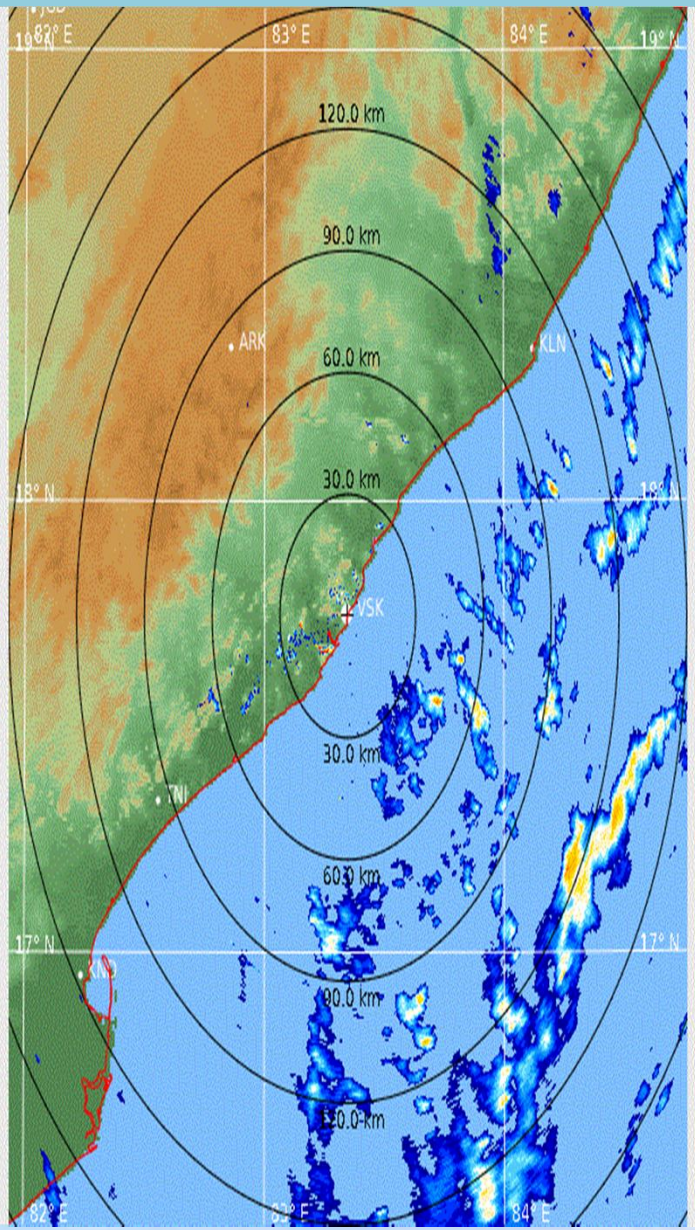


PPI (dBZ)
04:37 / 11-Oct-2014
Visakhapatnam

60.0 dBZ
56.0 dBZ
52.0 dBZ
48.0 dBZ
44.0 dBZ
40.0 dBZ
36.0 dBZ
32.0 dBZ
28.0 dBZ
24.0 dBZ
20.0 dBZ
16.0 dBZ
12.0 dBZ
8.0 dBZ
4.0 dBZ
0.0 dBZ

Pdf File:	475_PPZ.ppi
Clutter Filter:	None
Time sampling:	37
PRF:	315 Hz / 252 Hz
Range:	475 km
Resolution:	1.583 km/pixel
Elevation:	-0.3 deg
Data:	Radar Data

Rainbow® SELEX-SI



PPI (dBZ)
04:30 / 11-Oct-2014
Visakhapatnam

60.0 dBZ
57.3 dBZ
54.7 dBZ
52.0 dBZ
49.3 dBZ
46.7 dBZ
44.0 dBZ
41.3 dBZ
38.7 dBZ
36.0 dBZ
33.3 dBZ
30.7 dBZ
28.0 dBZ
25.3 dBZ
22.7 dBZ
20.0 dBZ

Pdf File:	150_PPZ.ppi
Clutter Filter:	IIRDoppler 8
Time sampling:	40
PRF:	500 Hz / 375 Hz
Range:	150 km
Resolution:	0.500 km/pixel
Elevation:	0.2 deg
Data:	Radar Data

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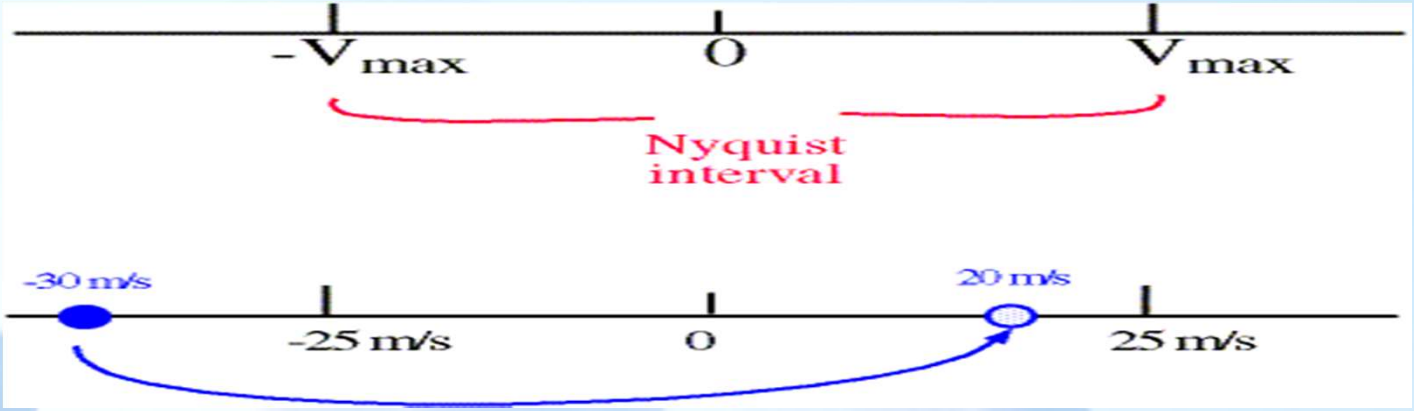
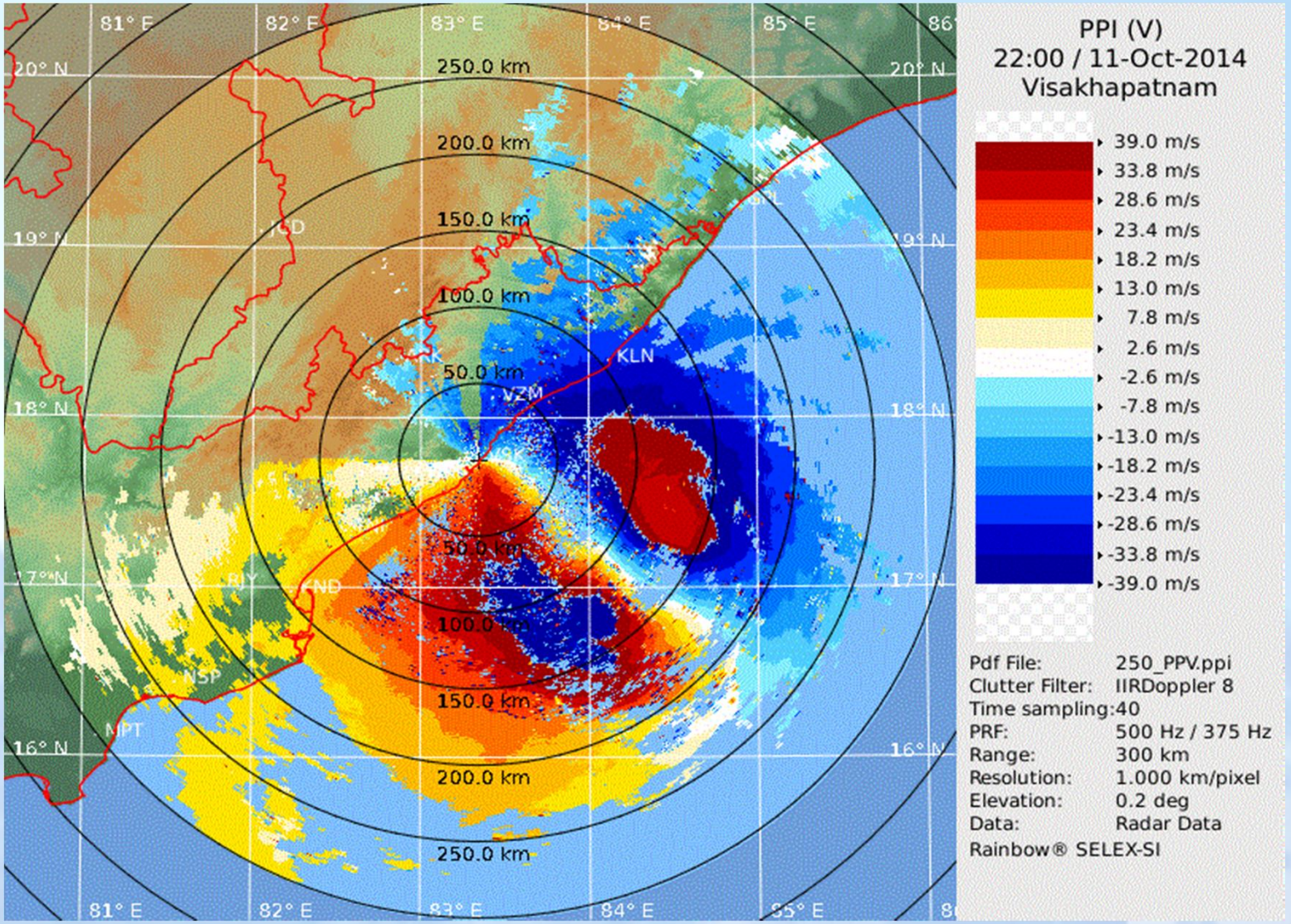
Velocity Folding

- If a particle's radial velocity is outside the range of the palette interval, then the radial velocity will be **aliased, or folded**. This is called **velocity folding/aliasing.**
- Example: if palette velocity range is -25 m/s and the particle's radial velocity is -30 m/s, then it will fold over and the radar will interpret it as +20 m/s -->>



Maximum unambiguous Doppler velocity, v_{max}, is

$$V_{max} = \frac{PRF \cdot \lambda}{4}$$



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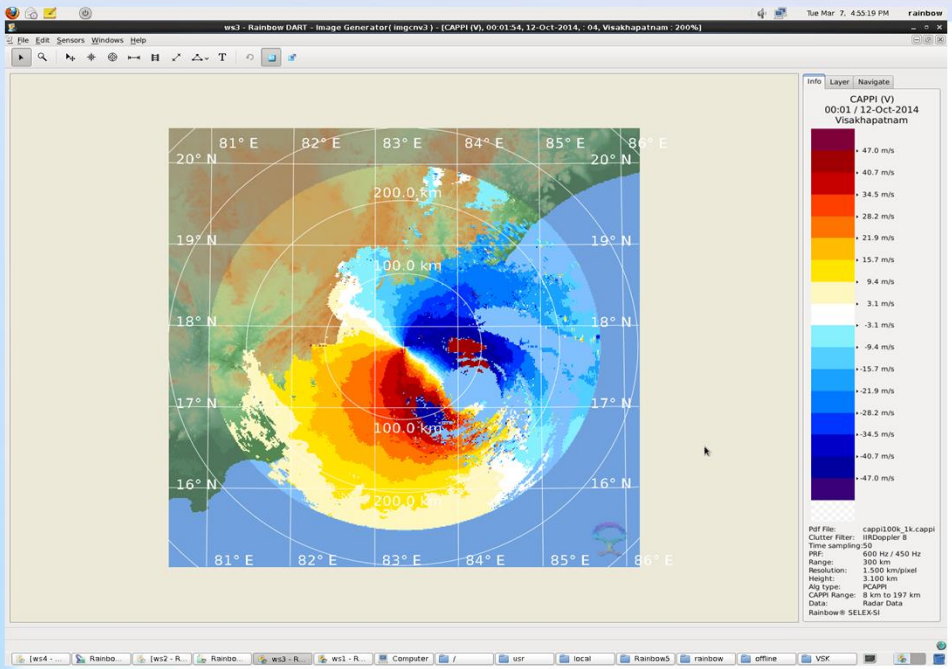

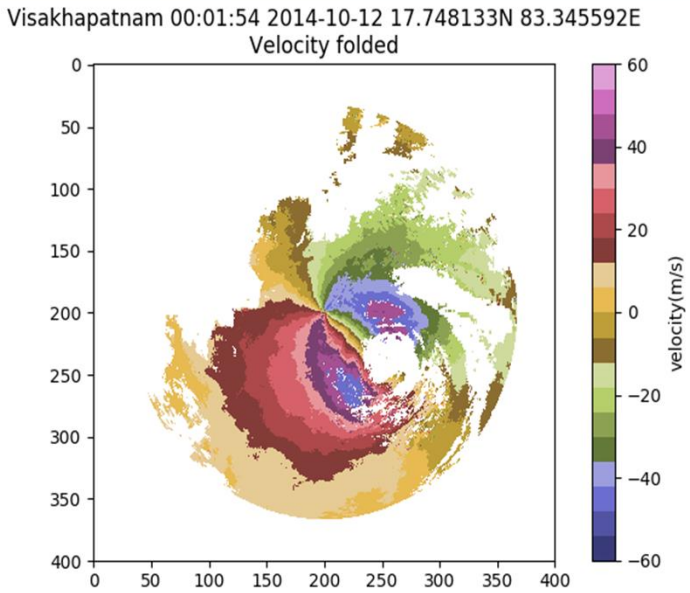

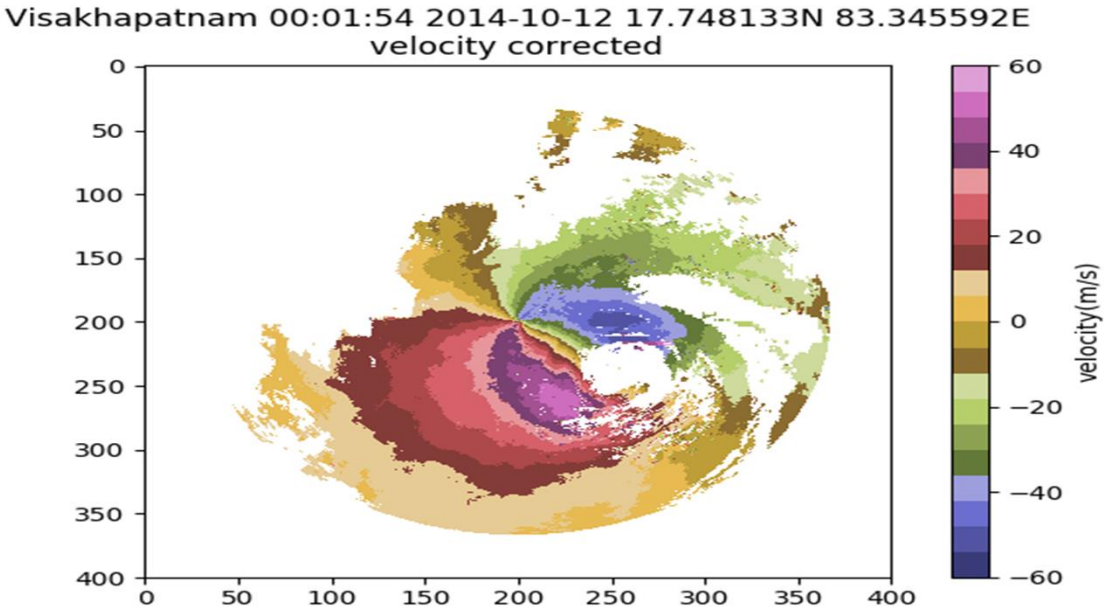

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Doppler Dilemma

$$v_{max} \cdot r_{max} = \frac{c \cdot \lambda}{8} = const.$$

IMD SCAN

IMD C SCAN

Elevation : 2 Elevations 0.2 , 1.0

Products : PPI (dBZ)= 500 KM PRF: 300

IMD B SCAN

Elevation : 10 Elevations 0.2,1.0,2.0,3.0,4.5,6,9,12,16,21

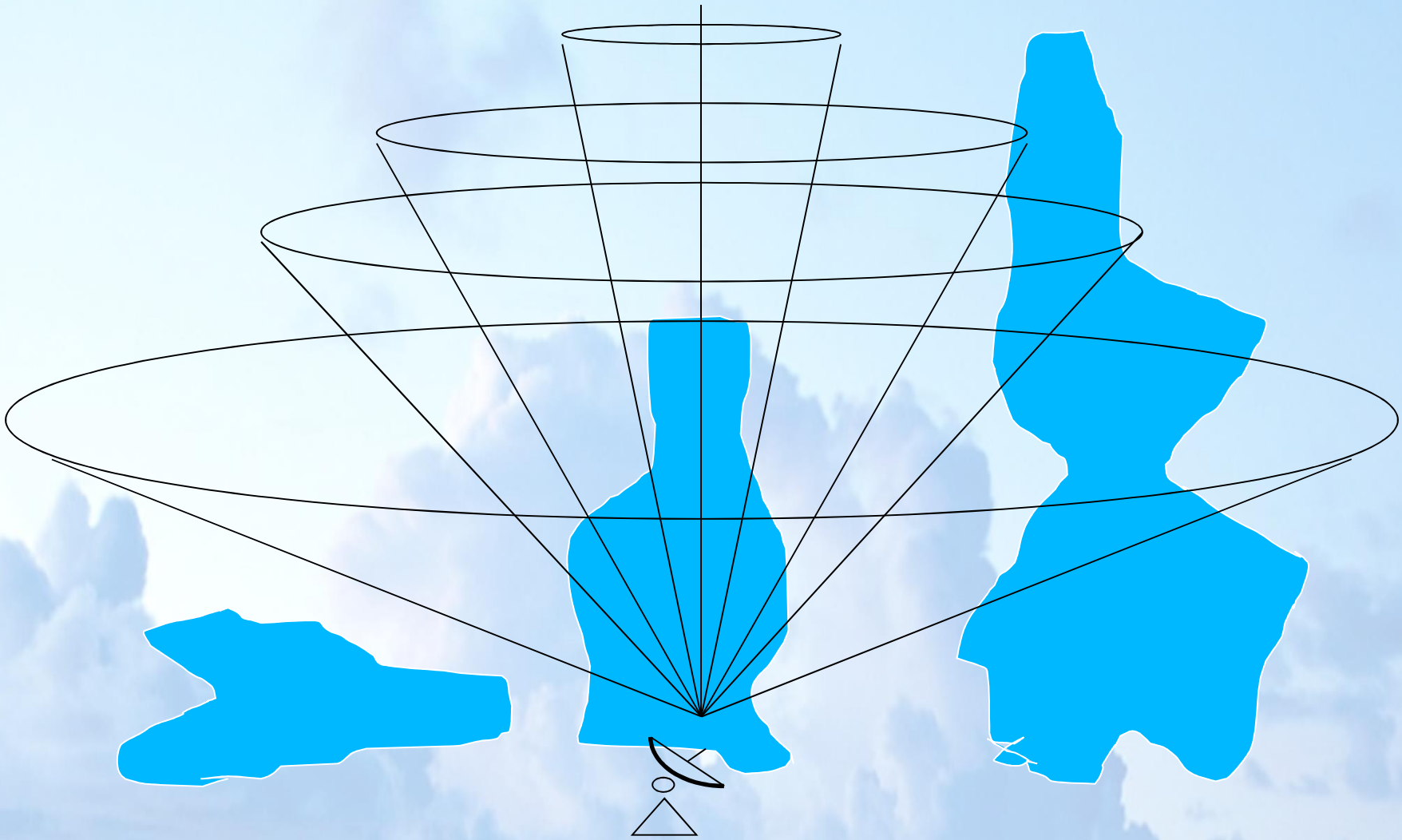
Products : PPI (dBZ)150-PPI(V)250-MAX(Z)250-SRI(100)-PAC(100)-VVP(30)

PRF : 600/450Hz

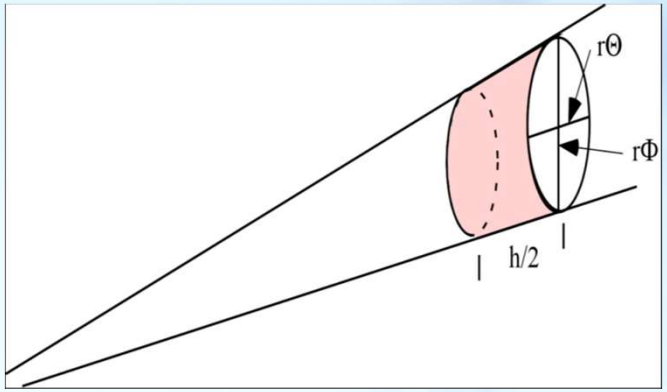
10 minutes for total scan

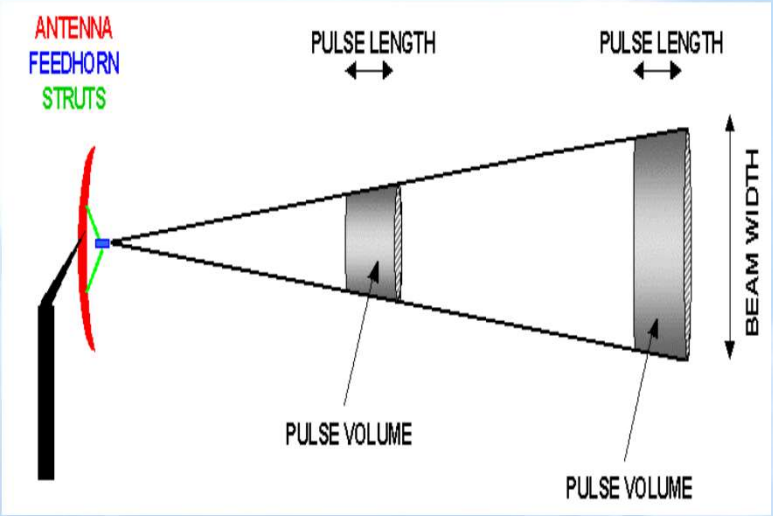
UNDERSTANDING THE DWR PRODUCTS

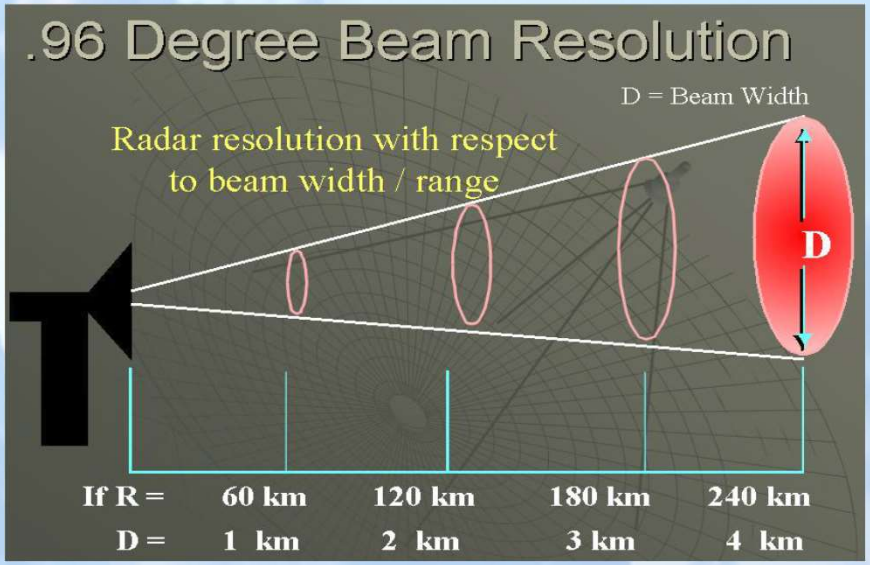
The Radar Volume Scan



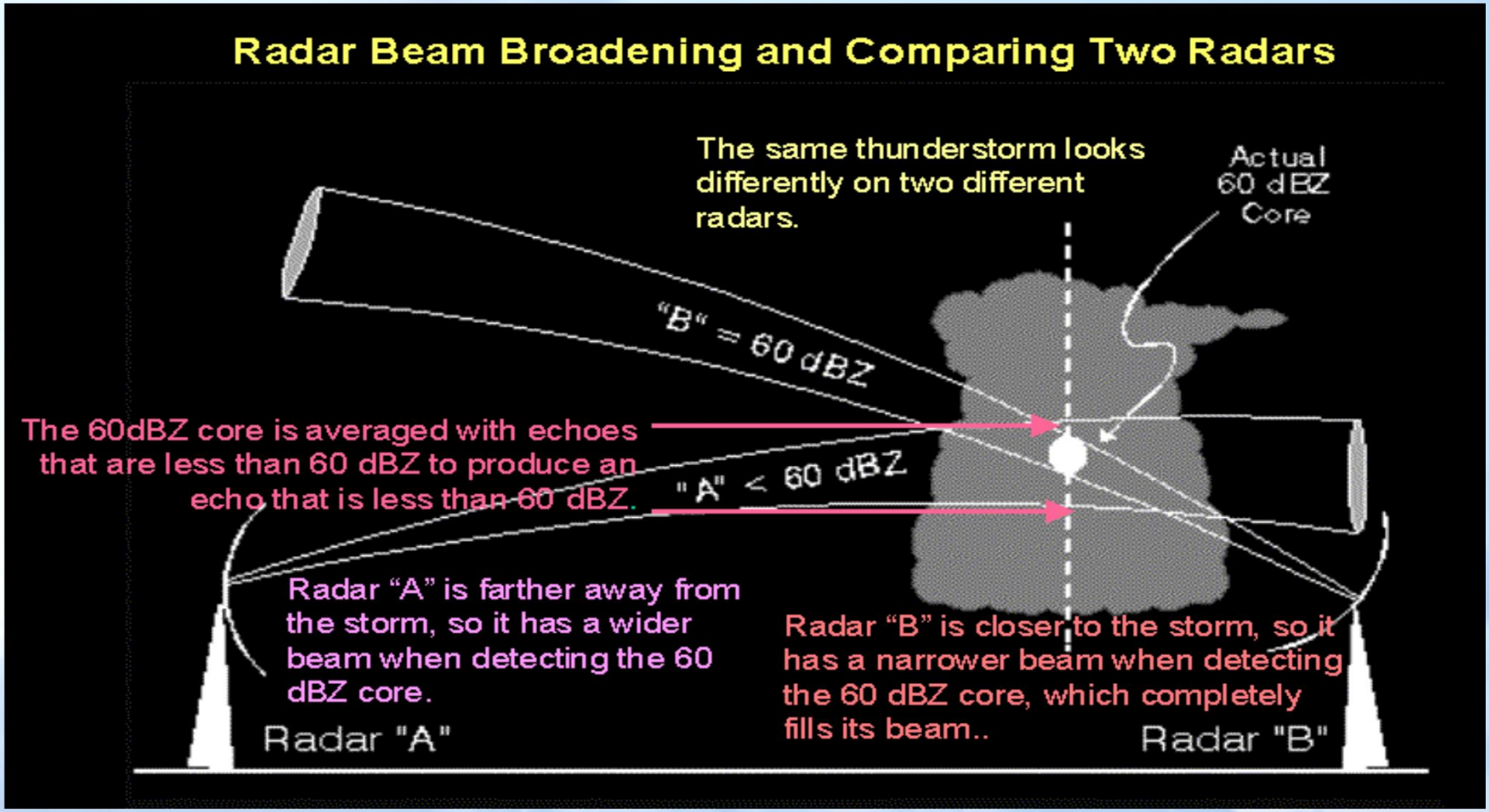
General concepts



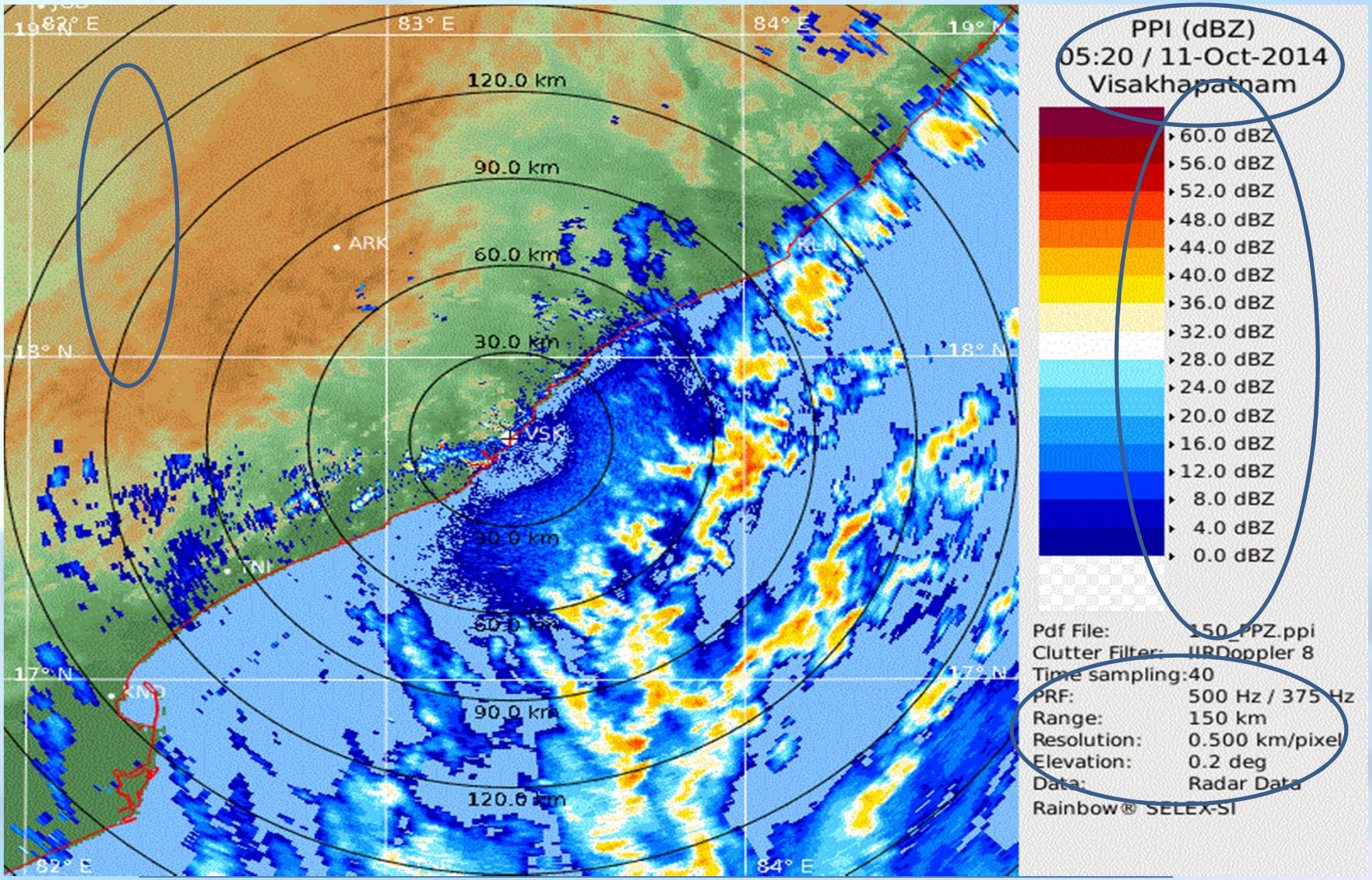




Beam Broadening



PPI(dbZ)



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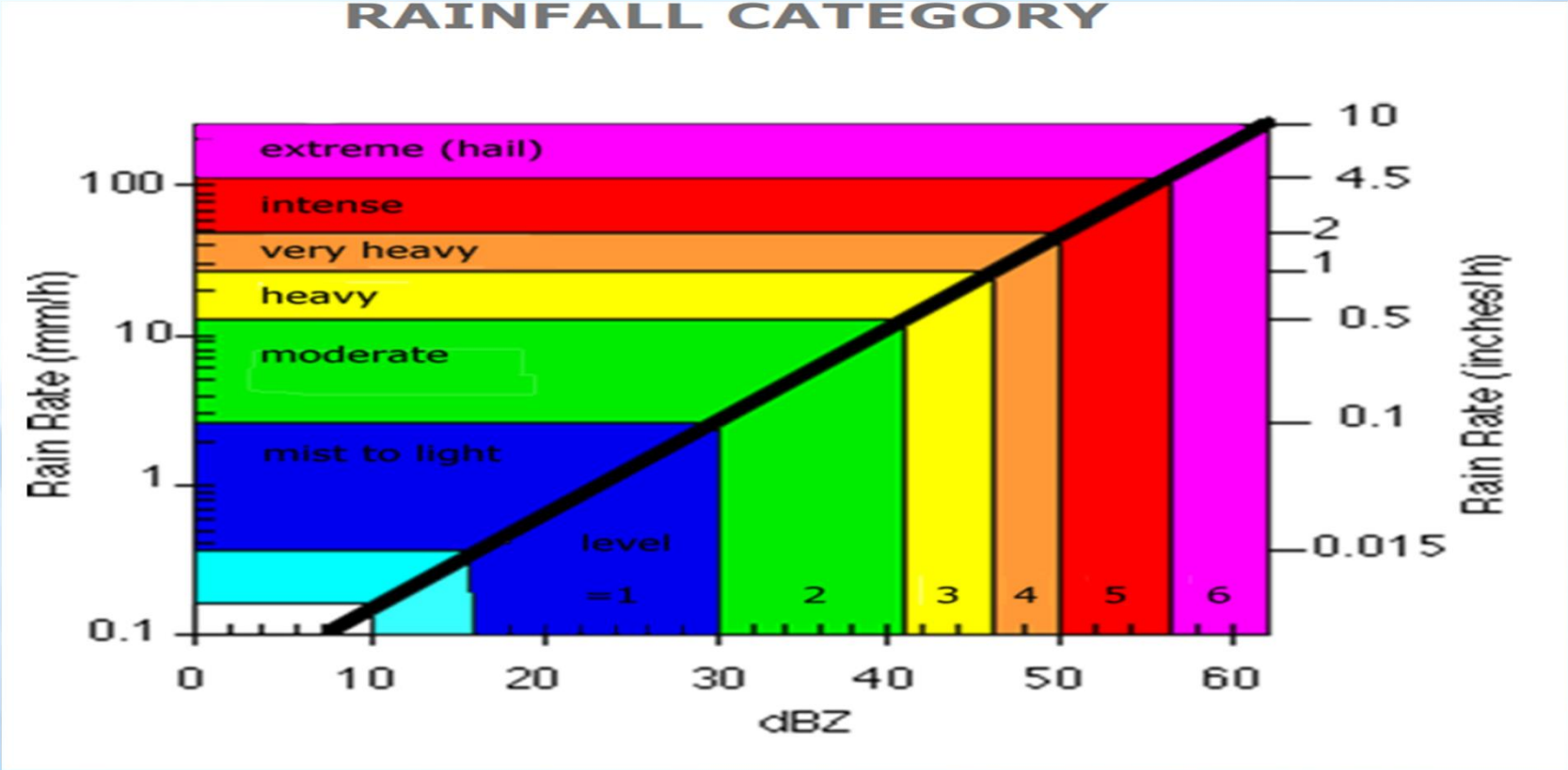
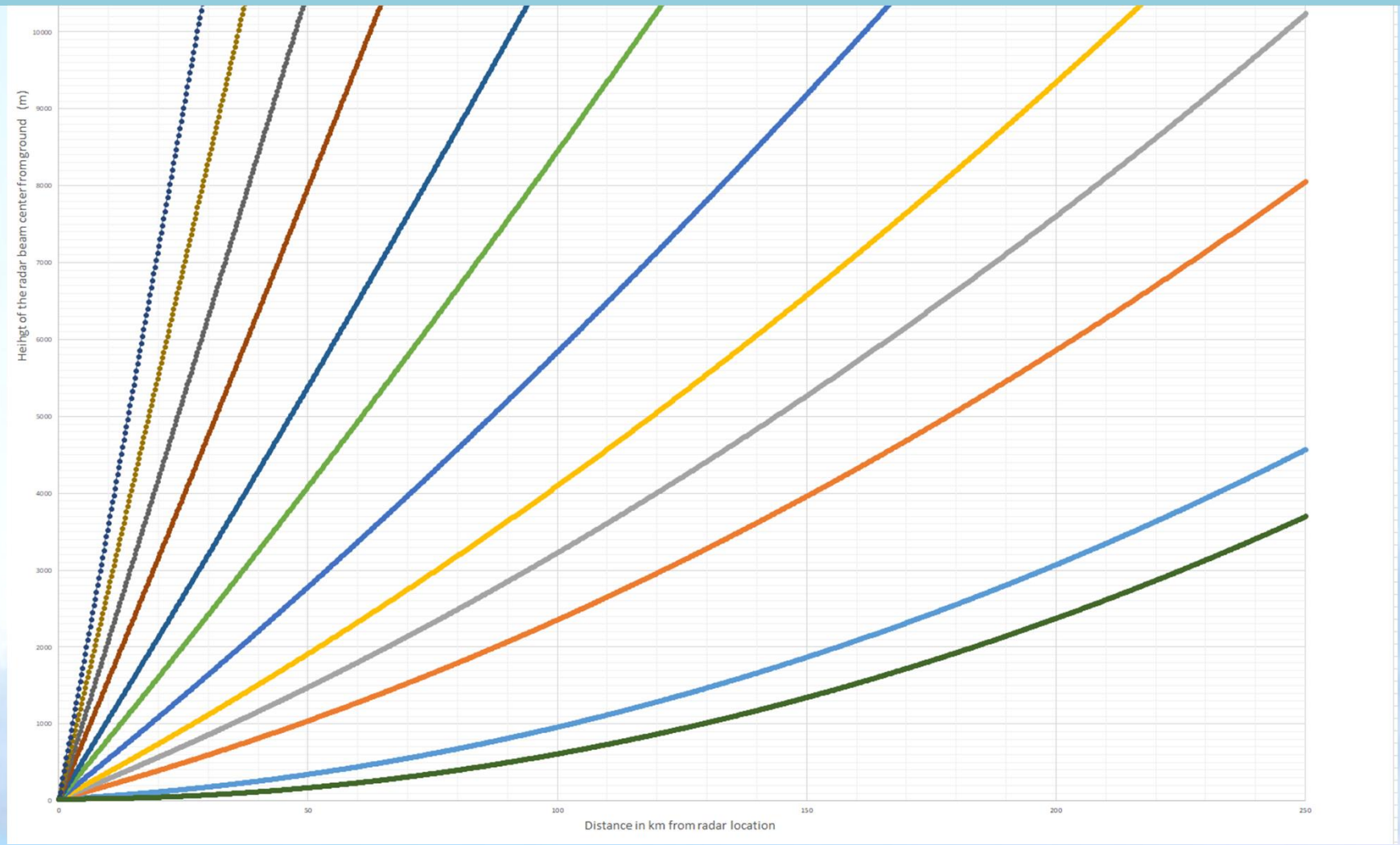
Decibels

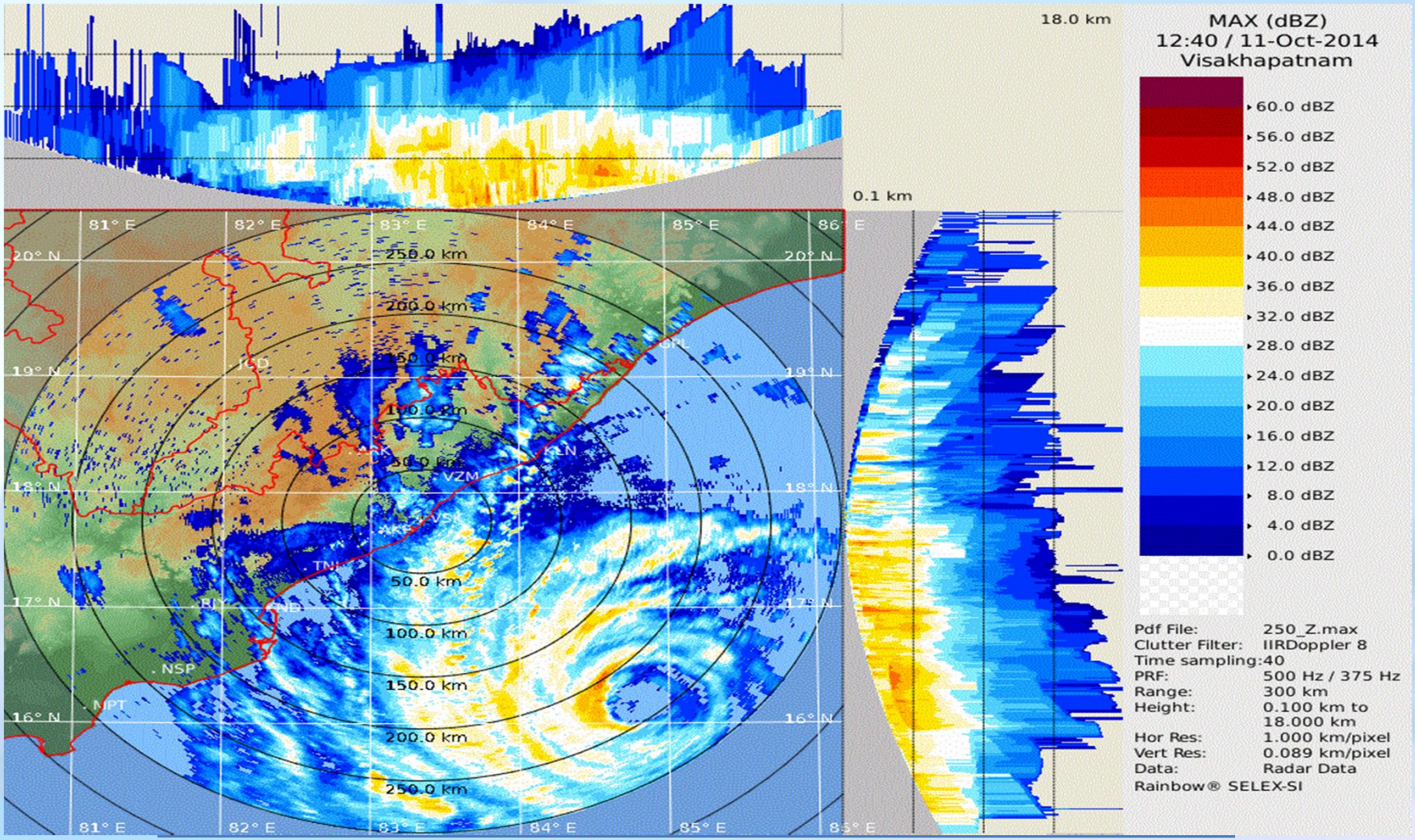
40 dbZ is equal to 10 times 30dbZ



Distance of cloud from ground



Max(Z)



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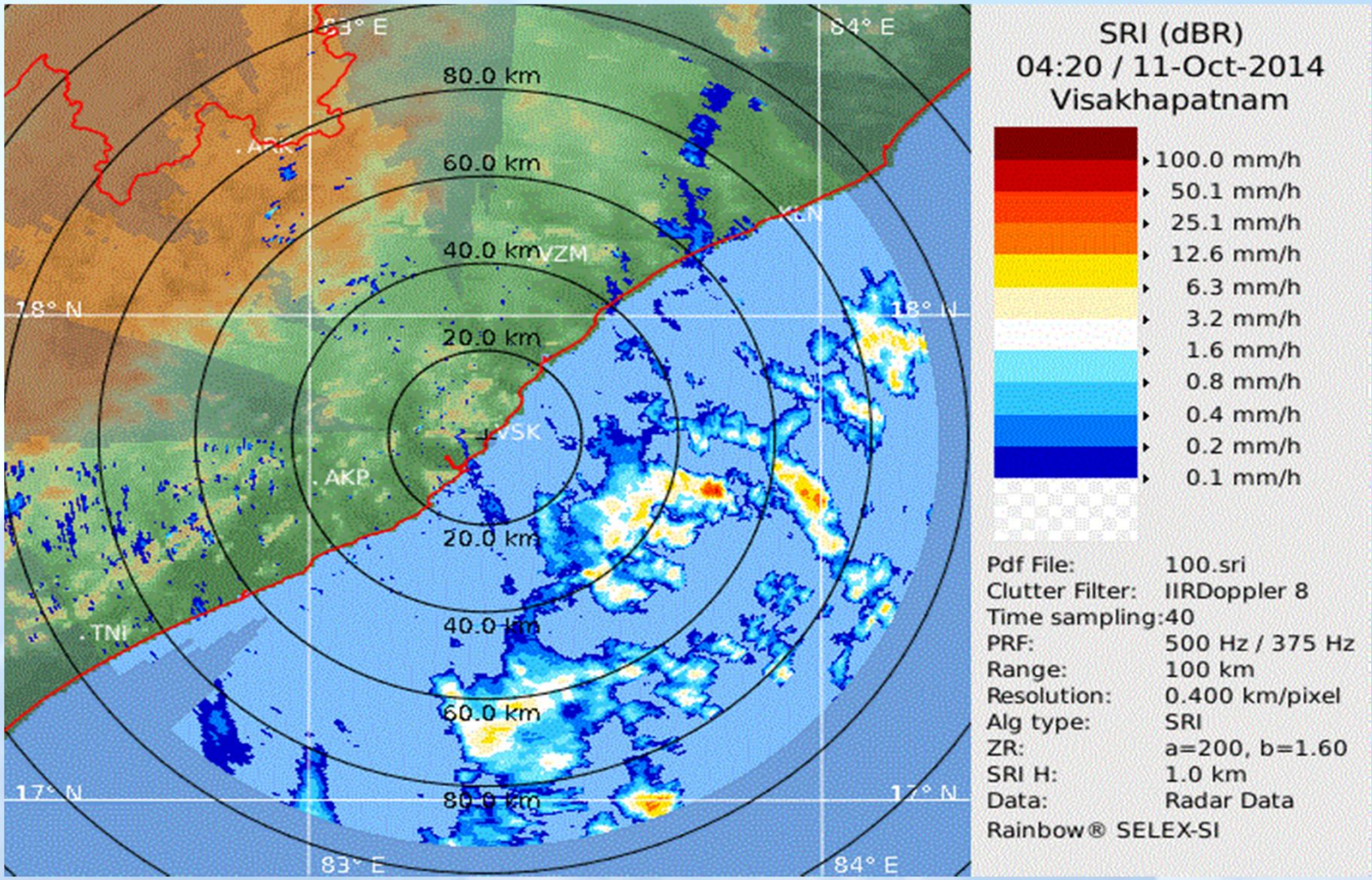
Surface rainfall Intensity

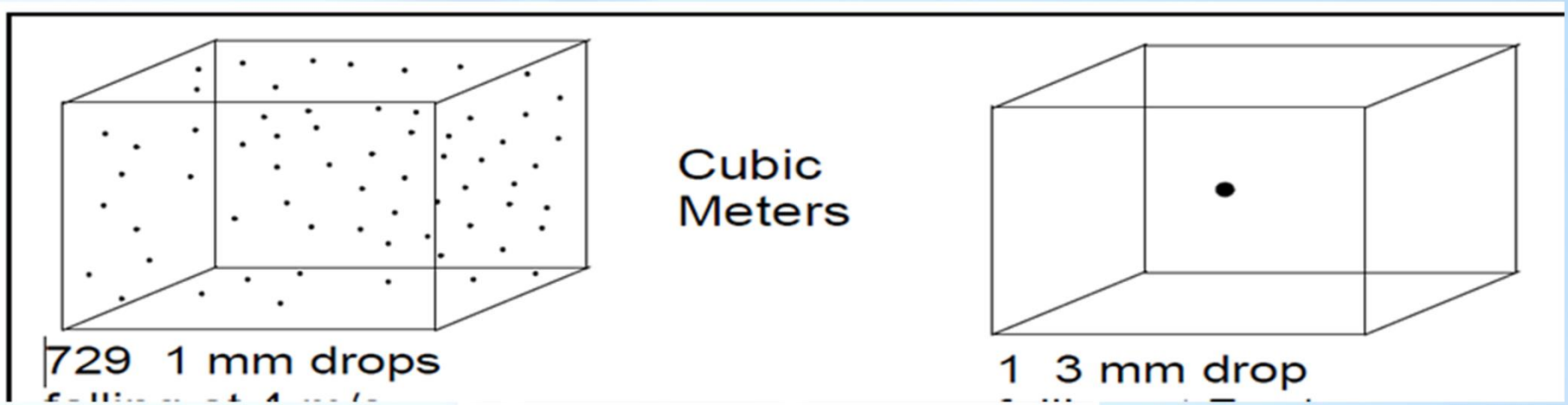


Surface Rainfall Intensity (SRI)

It is pictorial presentation of the rainfall intensity around a radar station based on the reflectivity of clouds.

The **rain rate** is calculated using Marshall-Palmer equation $Z=AR^b$ were **R** is the rainfall intensity and **A** and **b** are constants. The value of A & b varies from season to season and place to place.

Surface Rainfall Intensity



$$Z = \int N(D) D^6 dD$$

$(729 \text{ drops/m}^3)(1 \text{ mm})^6$

$729 \text{ mm}^6/\text{m}^3$

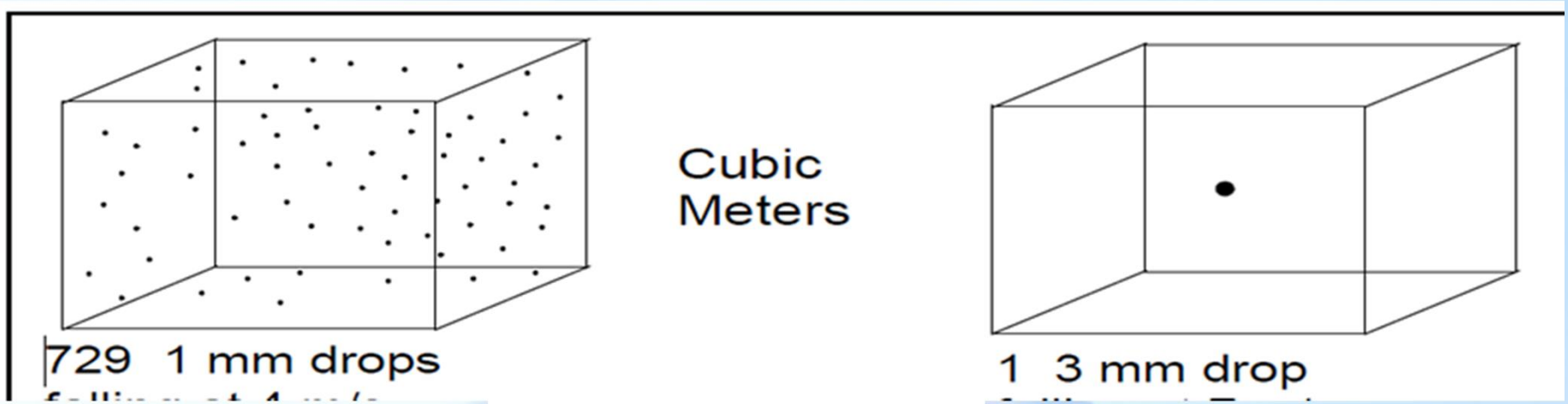
29 dBZ.

$(1 \text{ drop/m}^3)(3 \text{ mm})^6$

$729 \text{ mm}^6/\text{m}^3$

29 dBZ.

Surface Rainfall Intensity



$$R = \frac{\pi}{6}\int N(D)D^3 w_t(D)\,dD$$

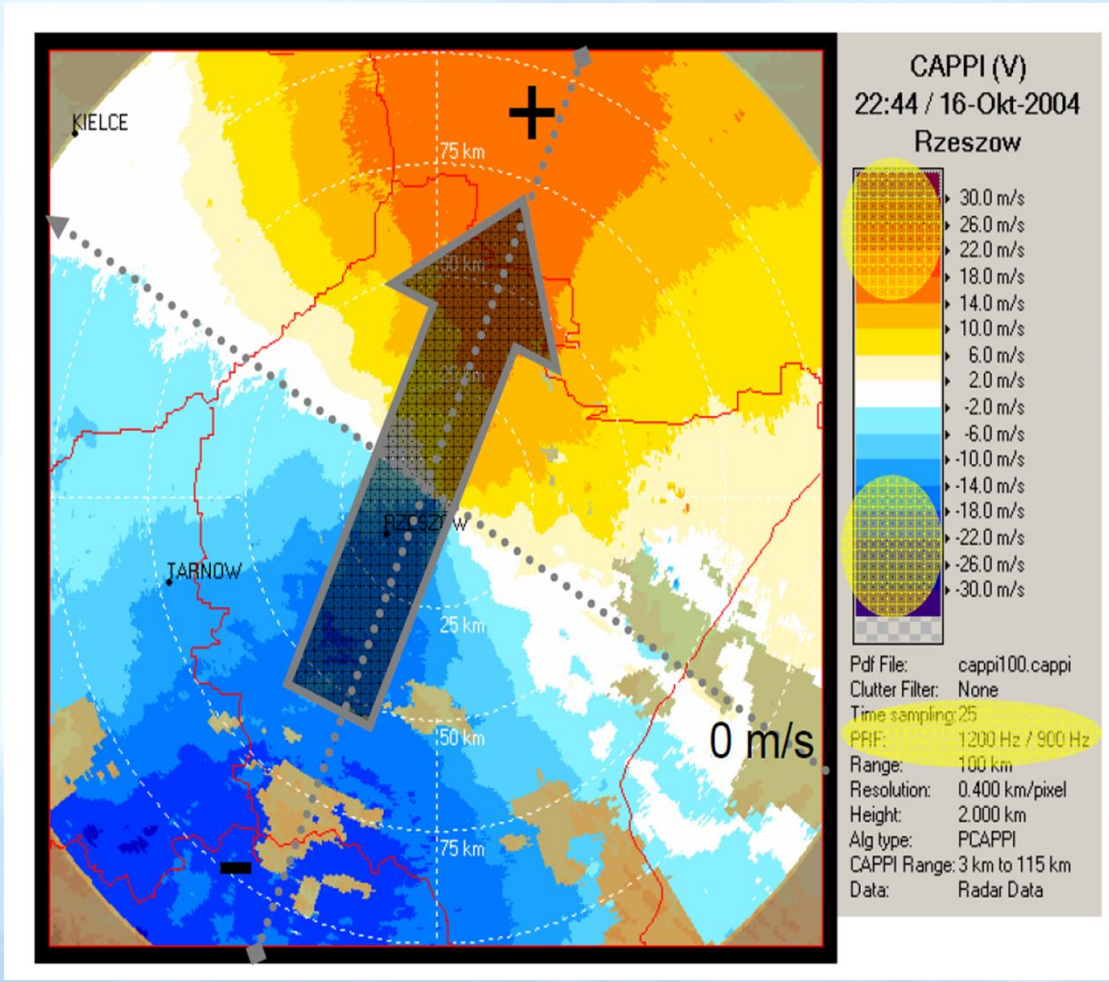
29 dBZ.

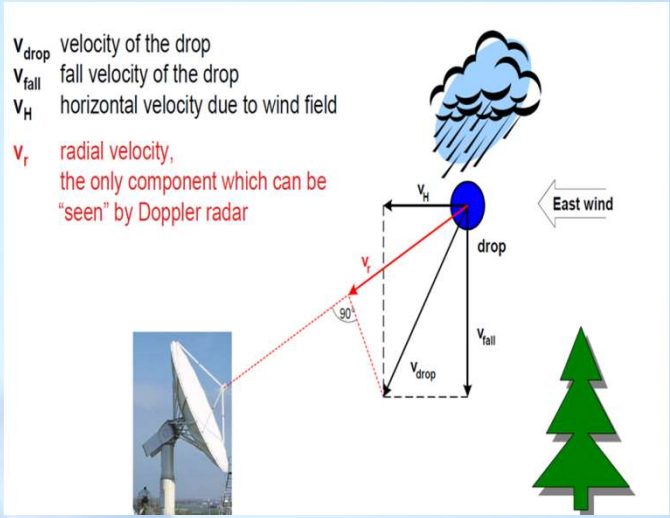
R_1 = 5.55 mm/hr.

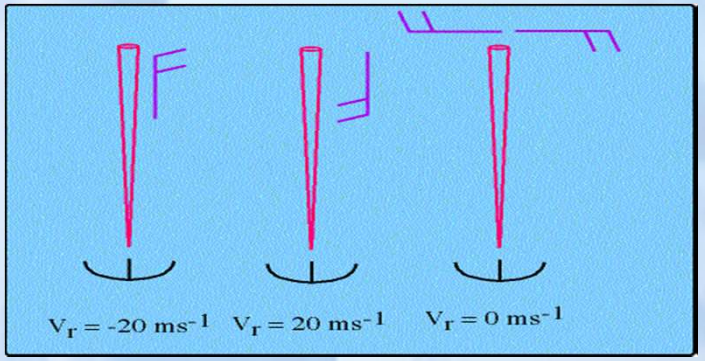
29 dBZ.

R_2 =0.3564 mm/hr

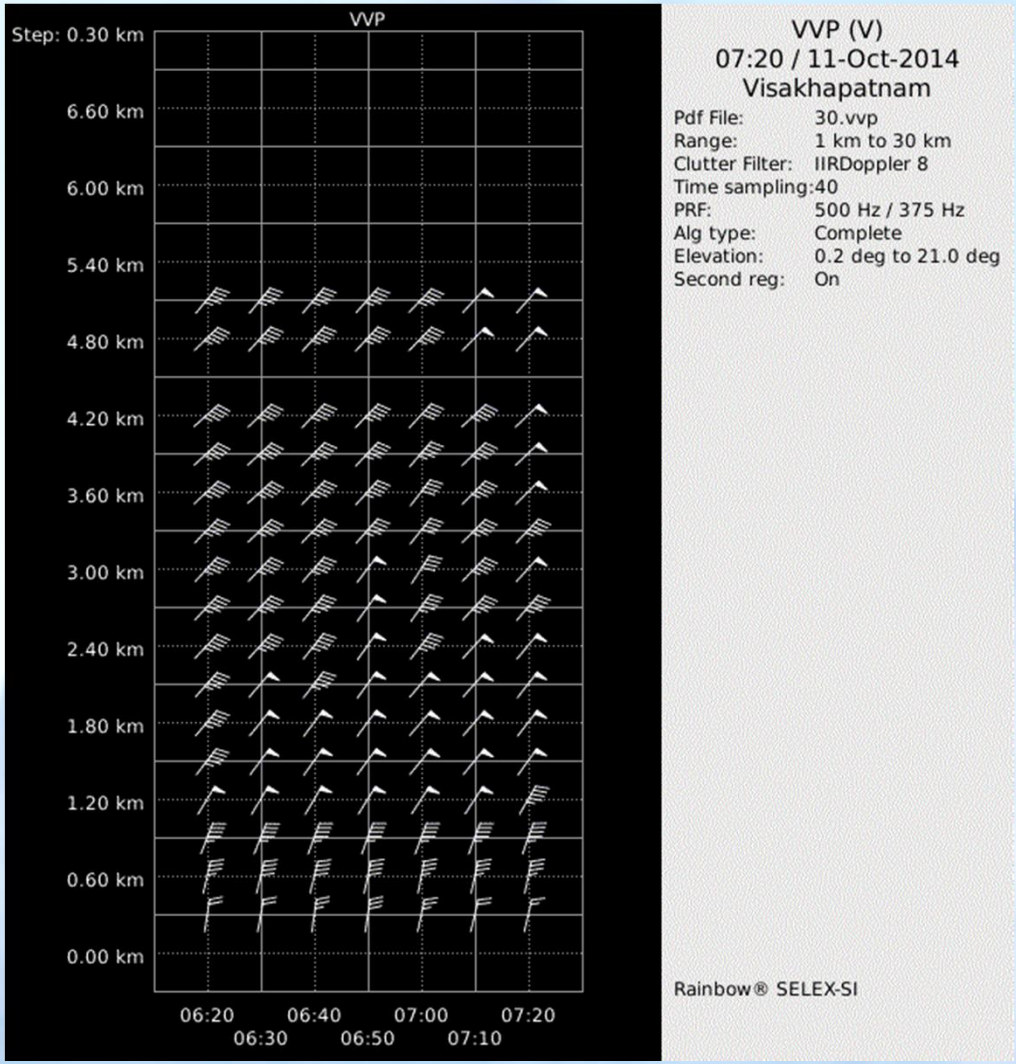
PPI(V)


KIELCE
75 km
50 km
25 km
TARNOW
RZESZOW
0 m/s
CAPPI (V)
22:44 / 16-Okt-2004
Rzeszow
30.0 m/s
26.0 m/s
22.0 m/s
18.0 m/s
14.0 m/s
10.0 m/s
6.0 m/s
2.0 m/s
-2.0 m/s
-6.0 m/s
-10.0 m/s
-14.0 m/s
-18.0 m/s
-22.0 m/s
-26.0 m/s
-30.0 m/s
Pdf File: cappi100.cappi
Clutter Filter: None
Time sampling:25
PRF: 1200 Hz / 900 Hz
Range: 100 km
Resolution: 0.400 km/pixel
Height: 2.000 km
Alg type: PCAPPI
CAPPI Range: 3 km to 115 km
Data: Radar Data


v_{drop} velocity of the drop
v_{fall} fall velocity of the drop
v_H horizontal velocity due to wind field
v_r radial velocity, the only component which can be "seen" by Doppler radar
East wind
drop
90°


$V_r = -20\ ms^{-1}$
$V_r = 20\ ms^{-1}$
$V_r = 0\ ms^{-1}$

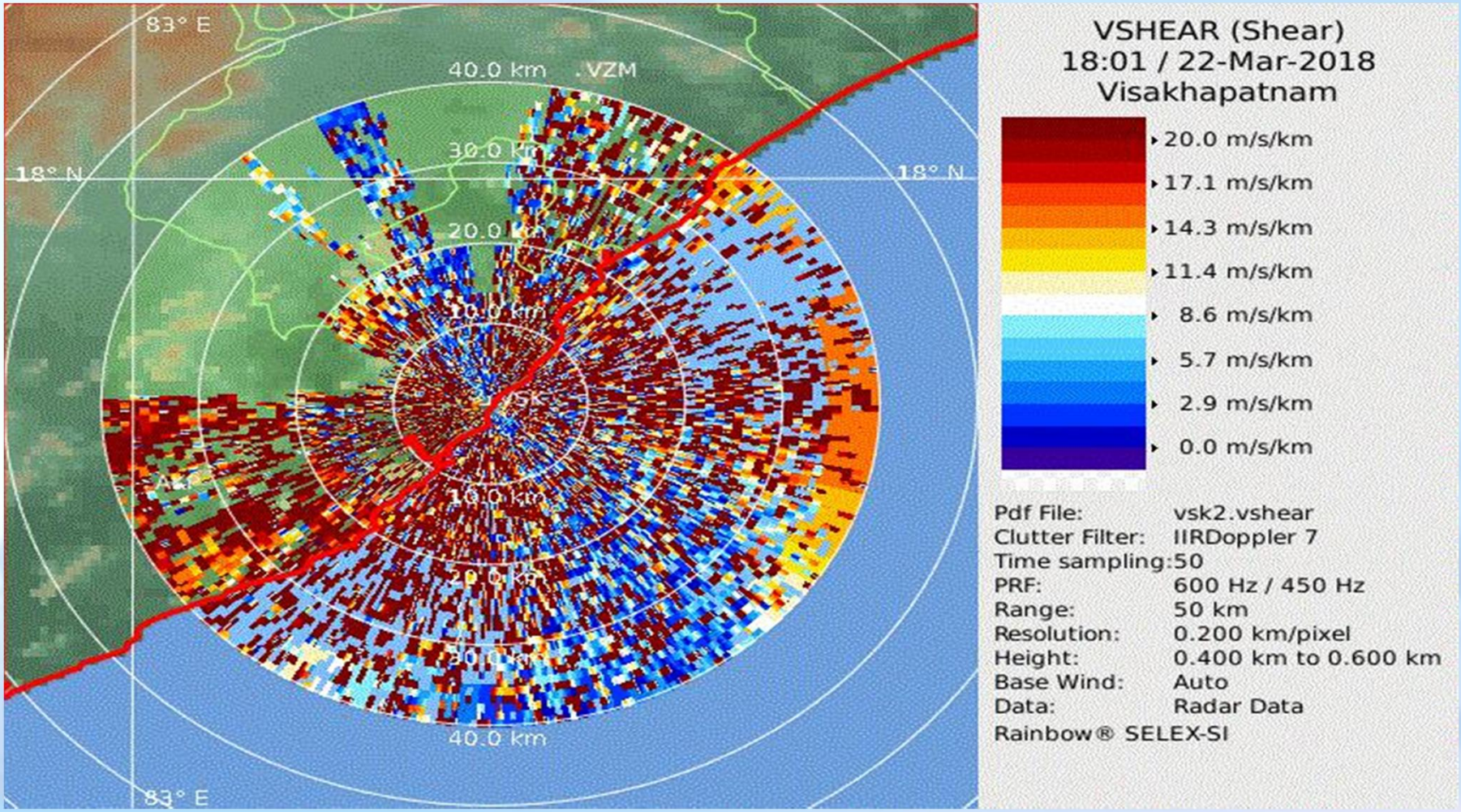
VVP 30 Km



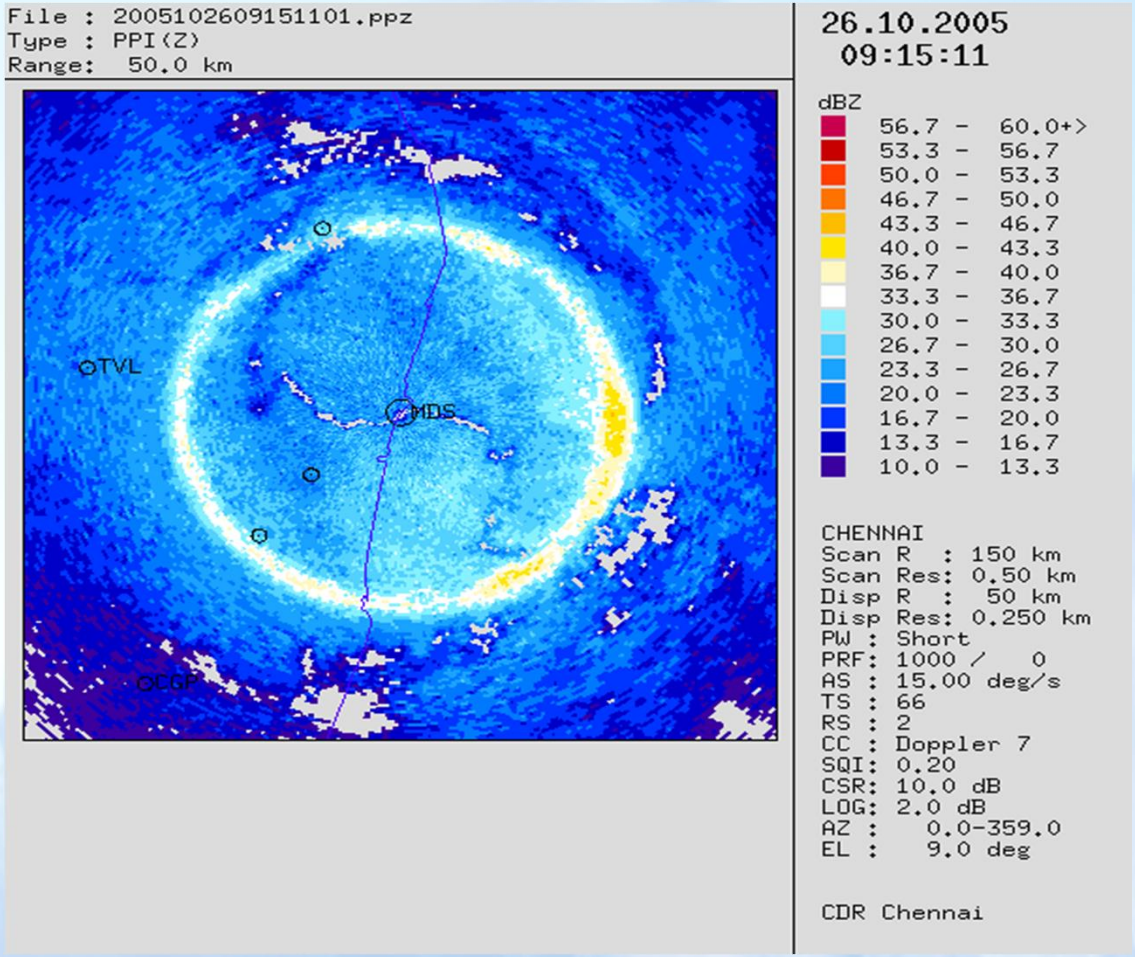
The *wind barb* presentation displays the horizontal wind velocity and direction of a vertical cylinder around the radar site over the time axis.

- **Moisture influx at lower level**
- **Cloud Movement at higher levels**
- **Veering at low to mid and backing from mid to high(instability)**
- **Backing at low levels (stability)**

Vertical Wind shear

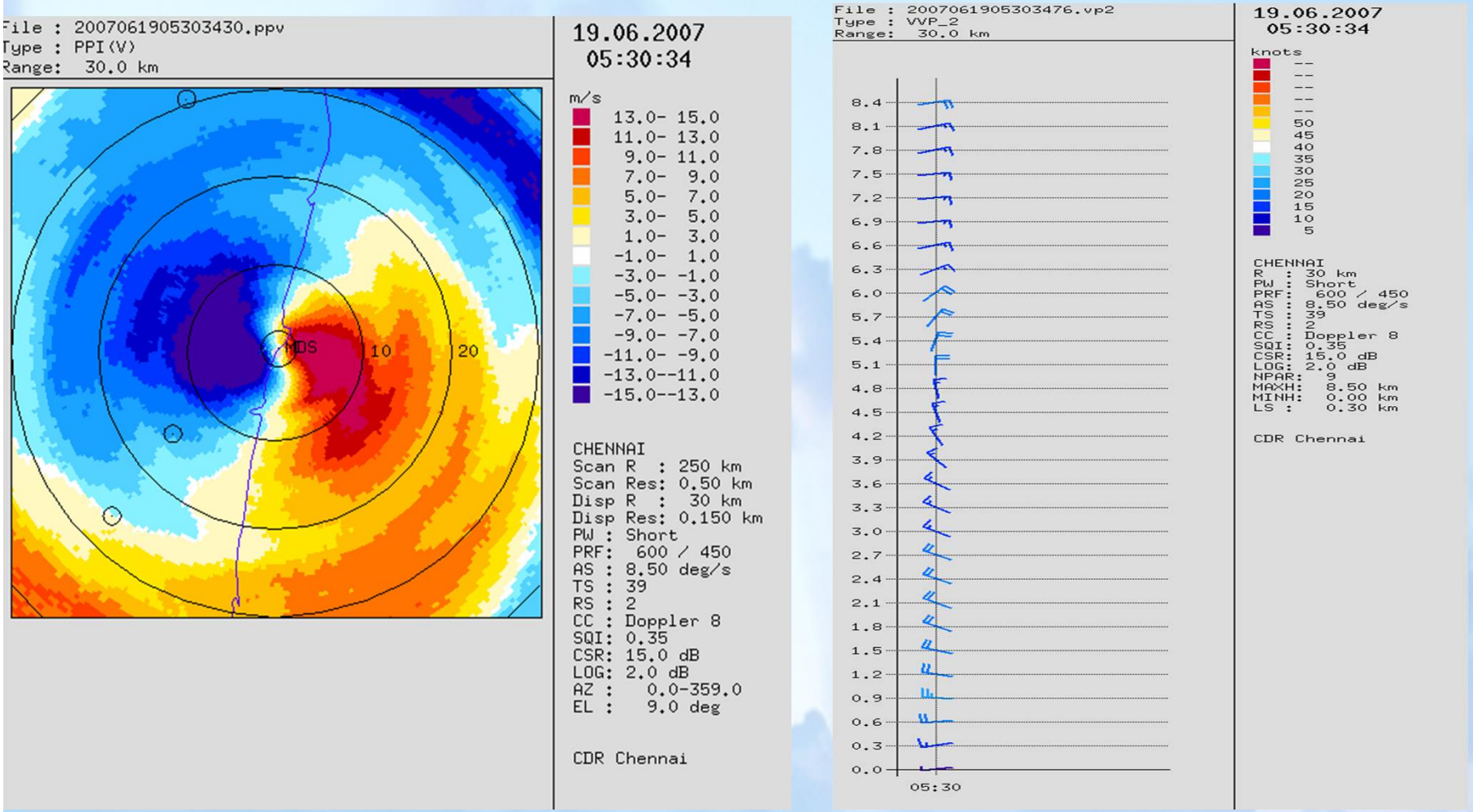


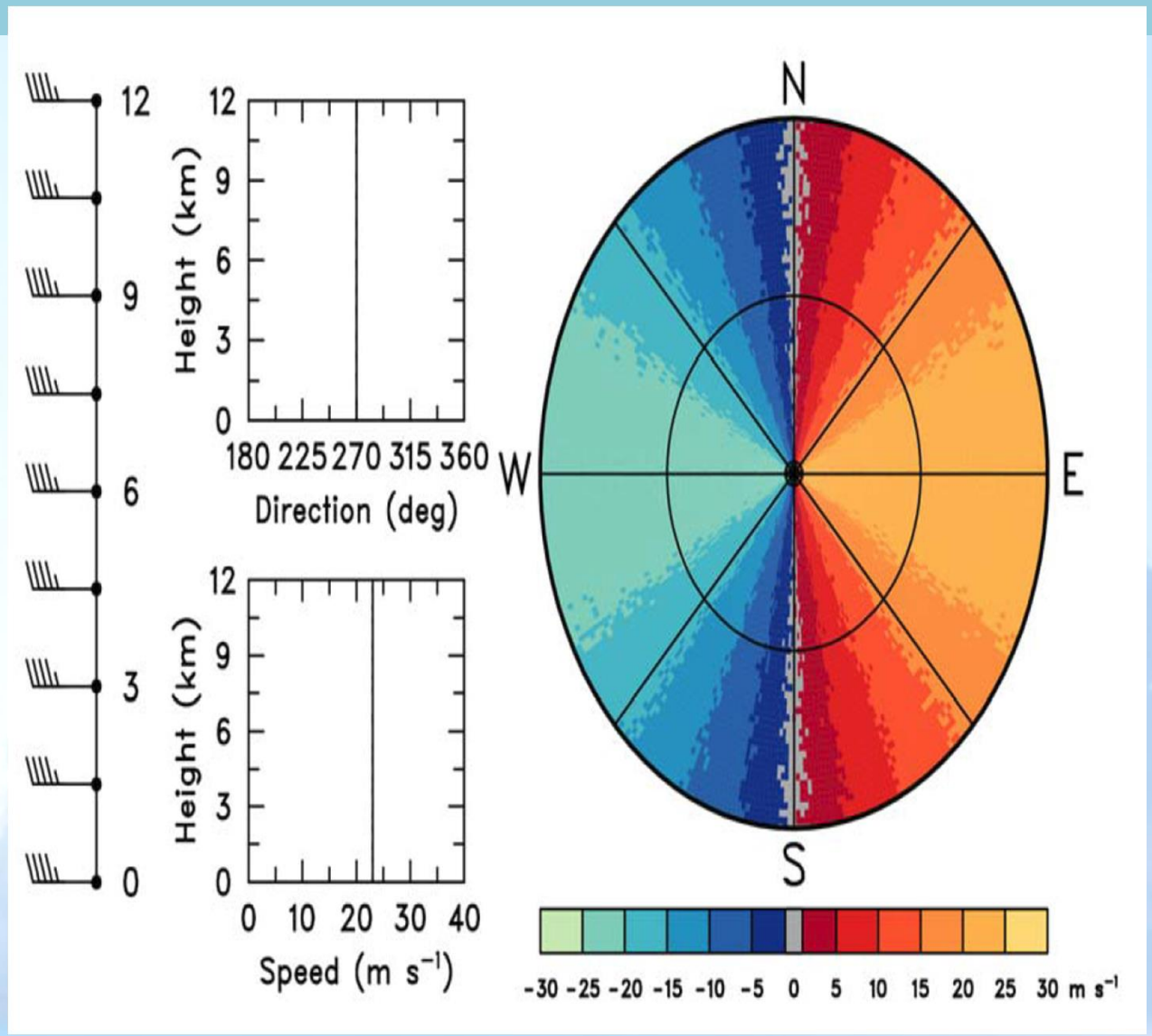
Bright band



- Just below freezing level
- Ice crystals are surrounded in the surface by water droplets during melting
- Gives very high reflectivity

Radial wind Interpretations

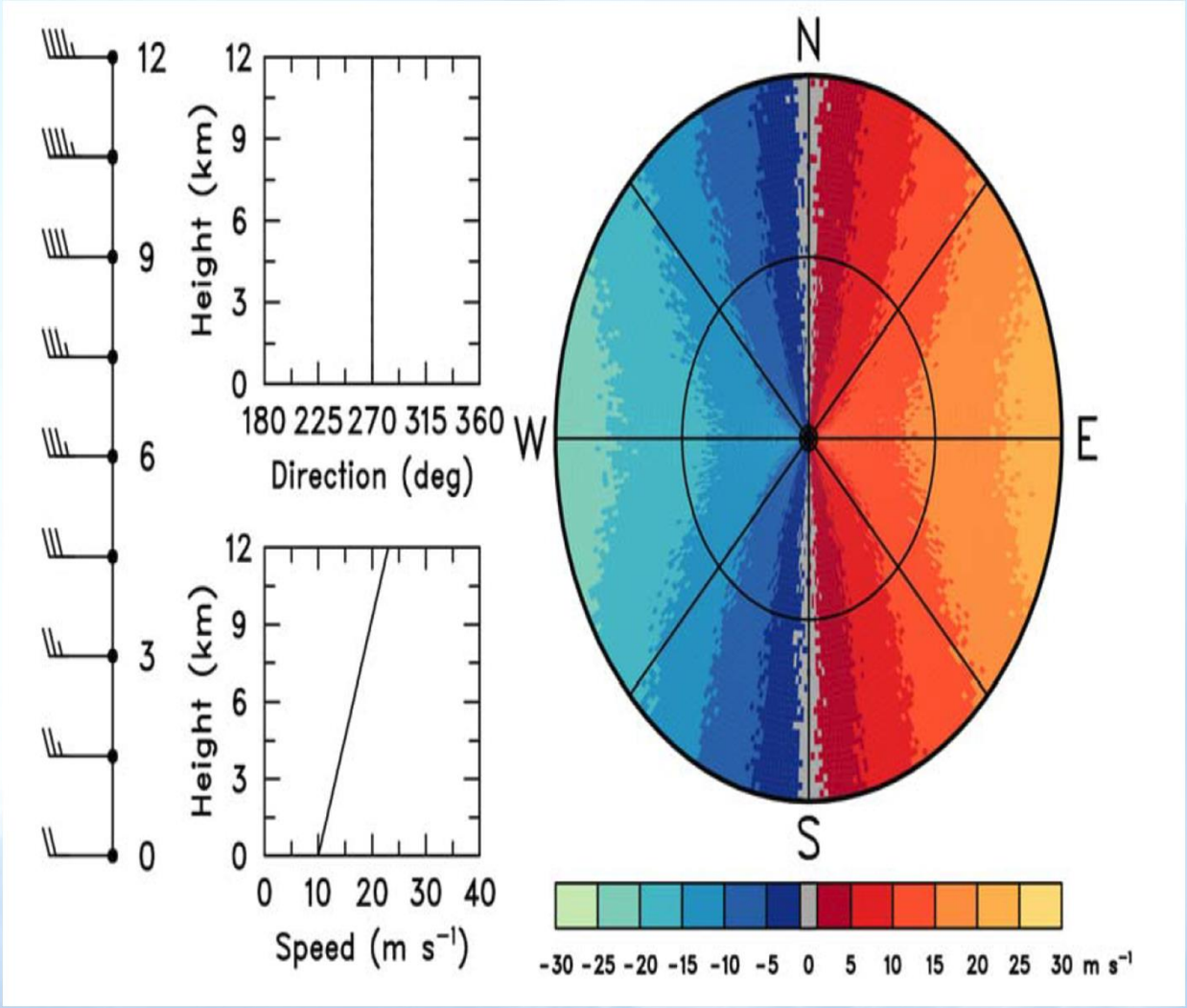




With Height

Wind Speed :Constant

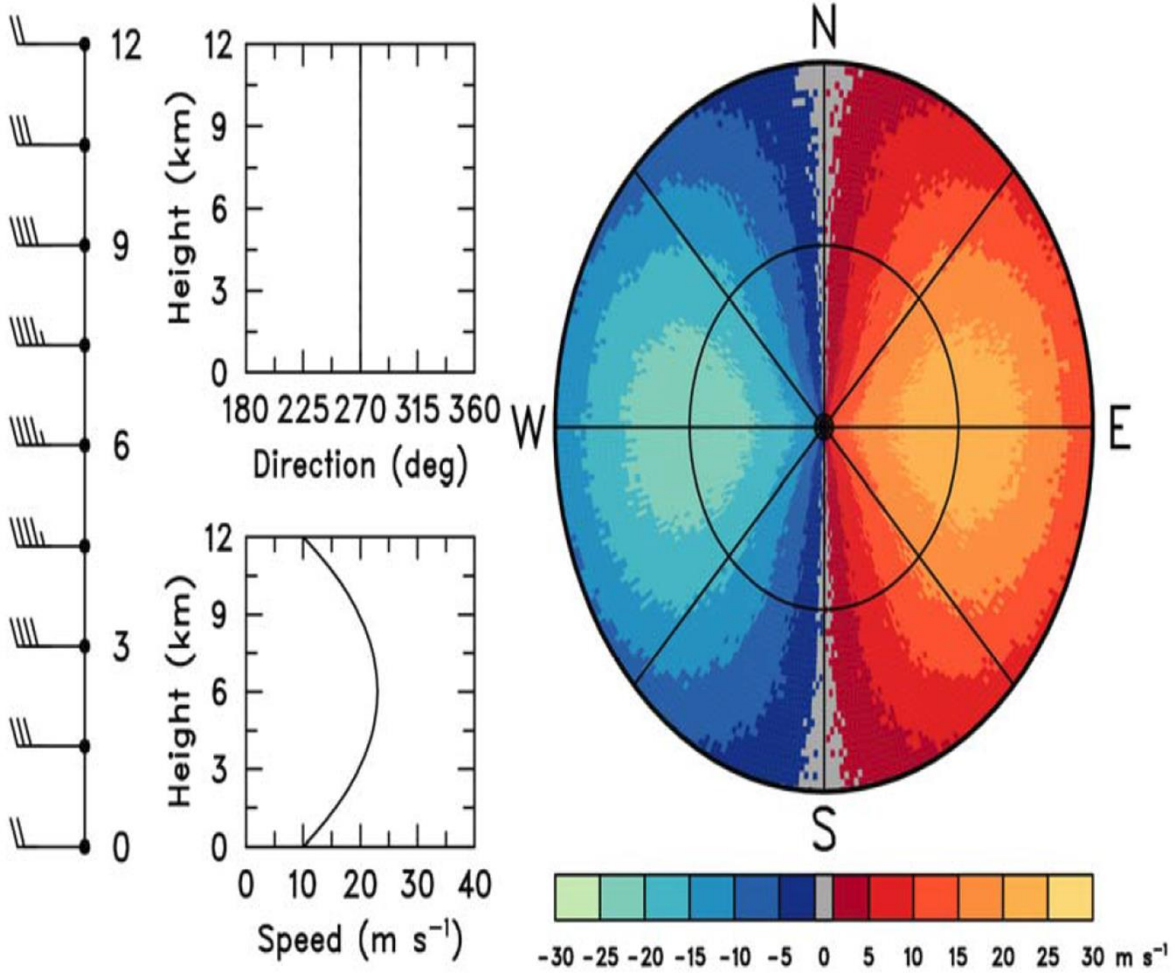
Wind Direction: Constant Westerly



With Height

Wind Speed :Increasing

Wind Direction: Constant Westerly

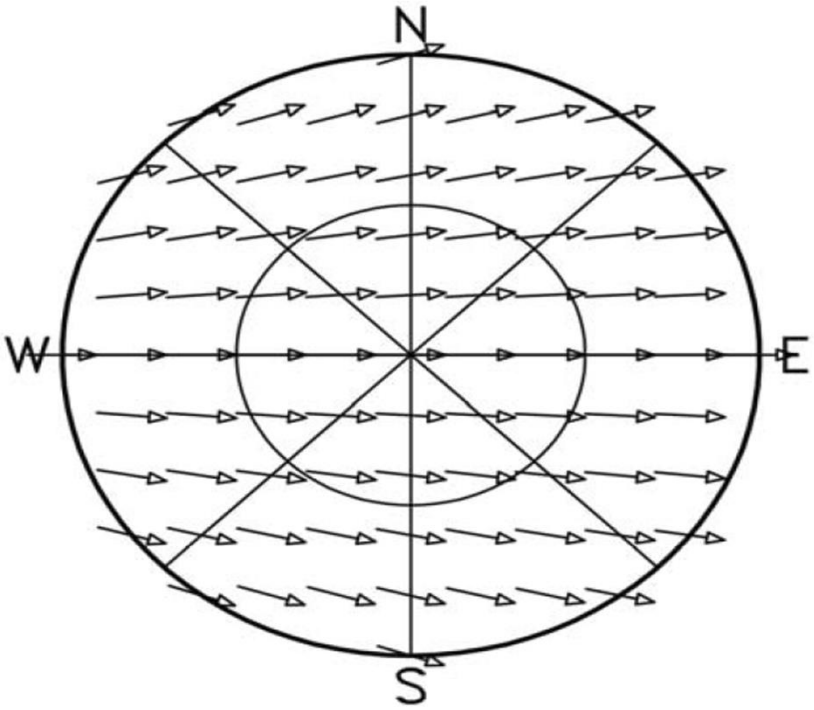


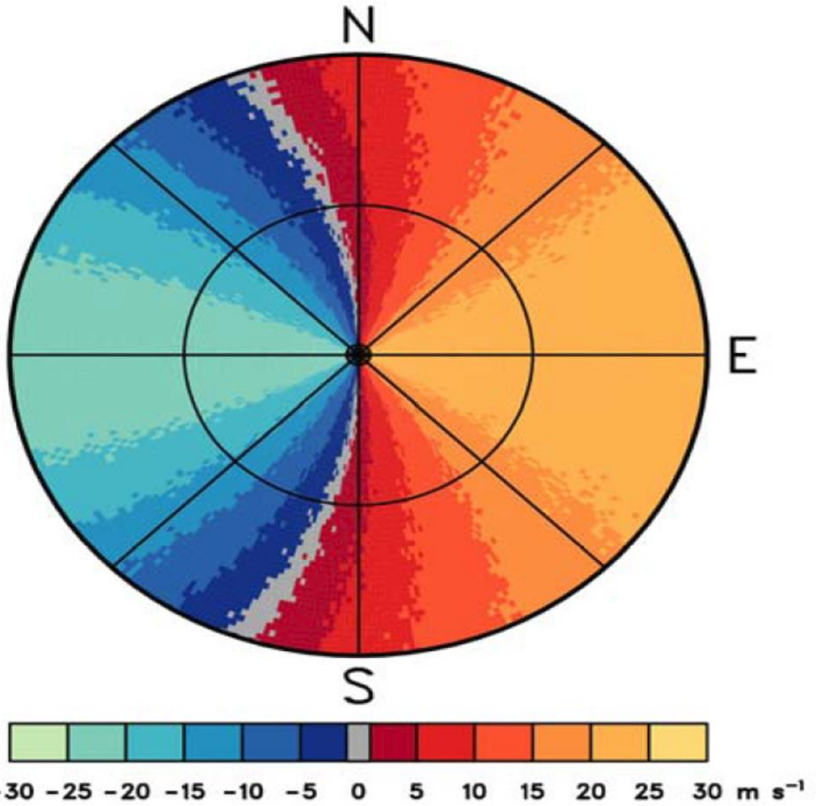
With Height

Wind Speed :Increasing and then Decreasing

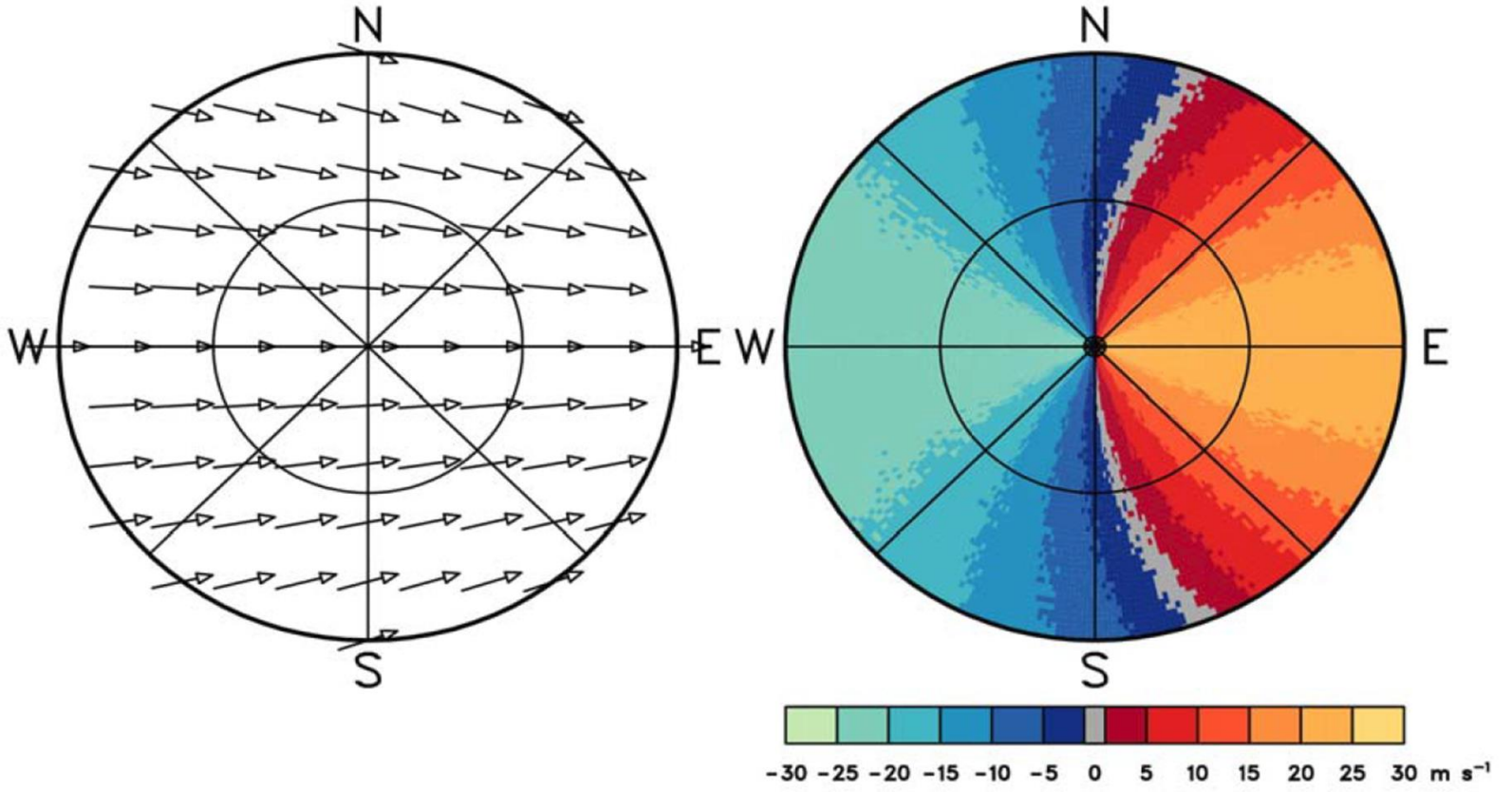
Wind Direction: Constant Westerly

Divergence

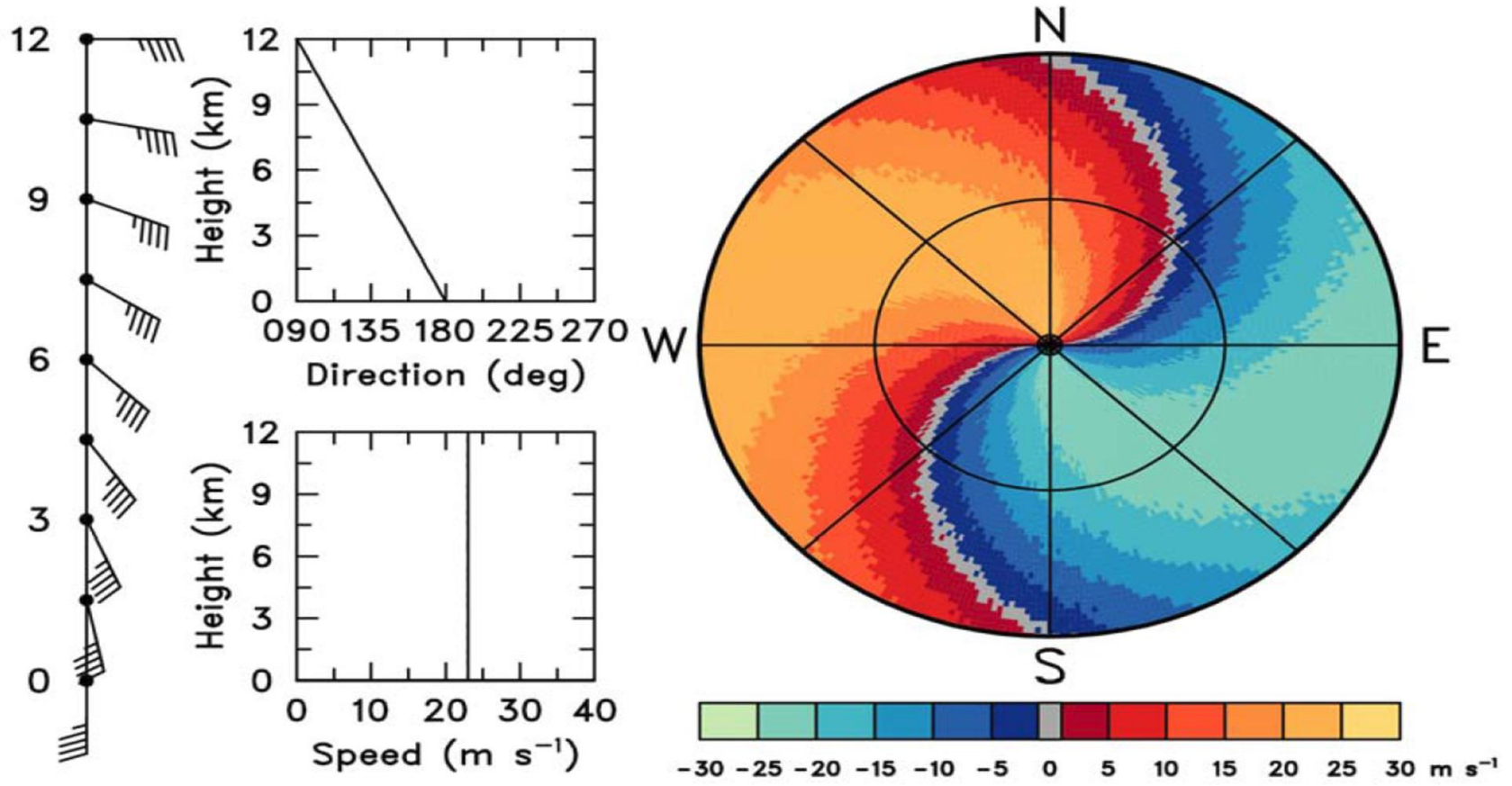




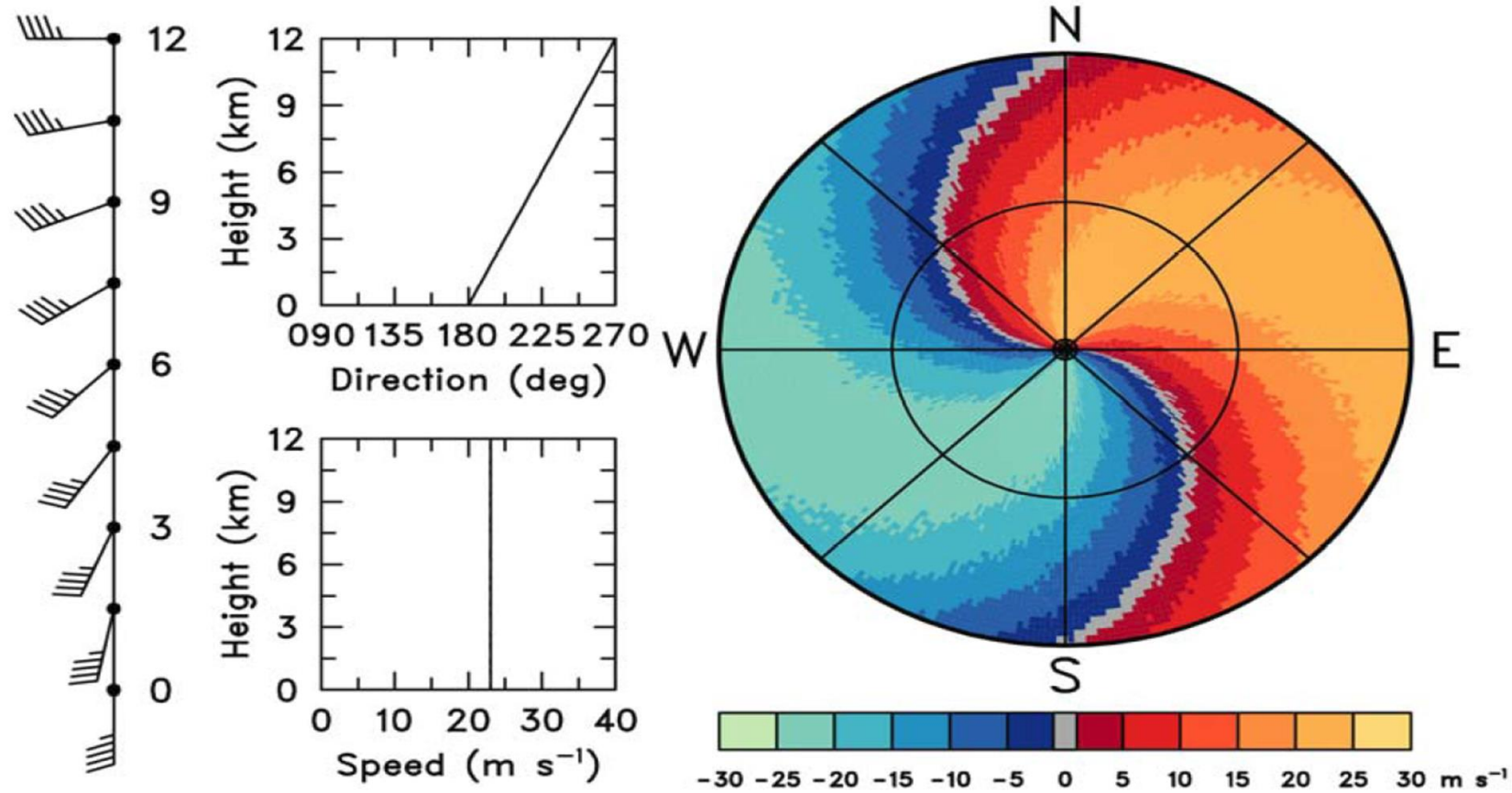
Convergence



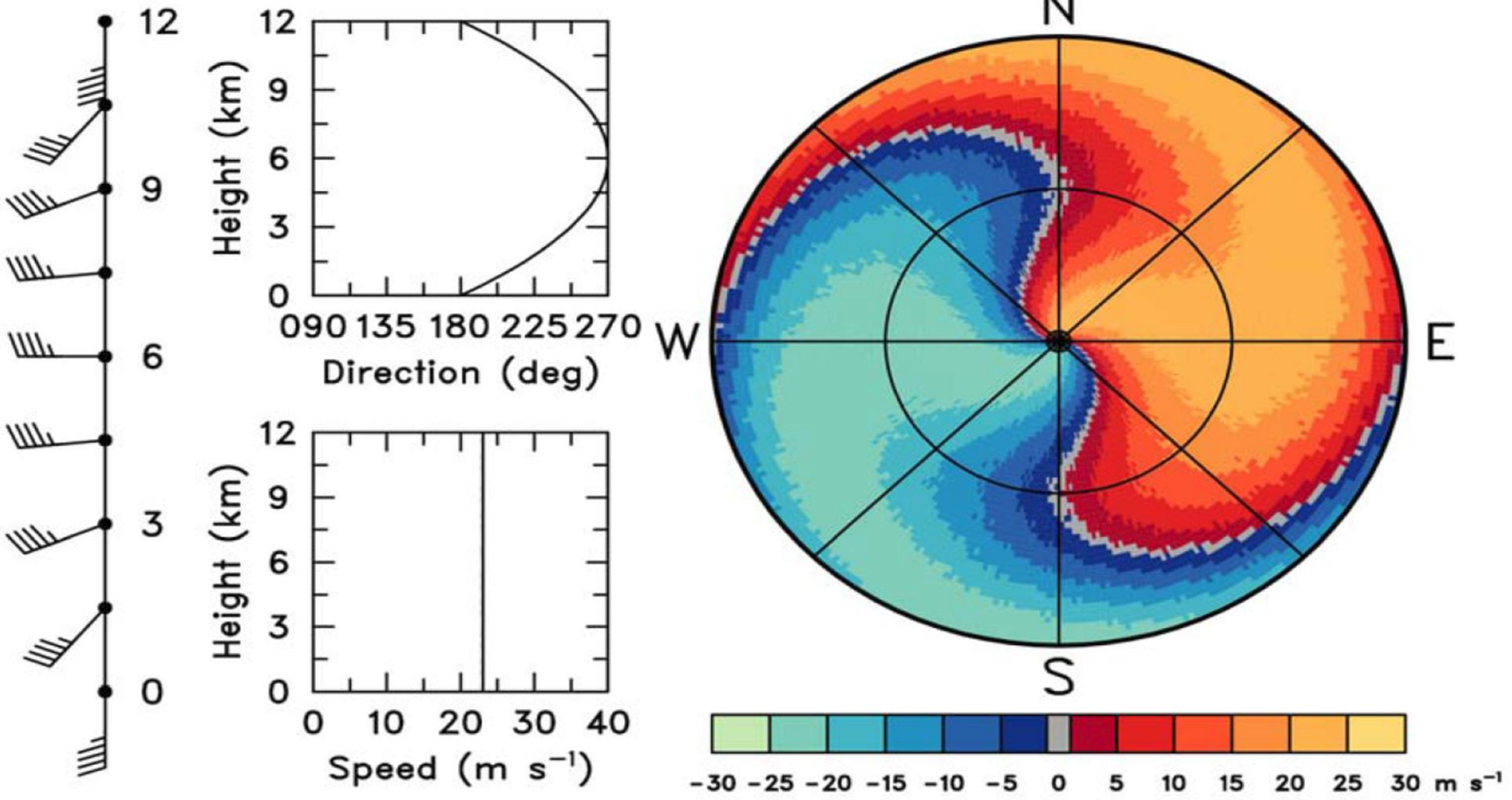
Backing


12
9
6
3
0
Height (km)
090 135 180 225 270
Direction (deg)
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

Veering


12
9
6
3
0
Height (km)
090 135 180 225 270
Direction (deg)
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

Instability



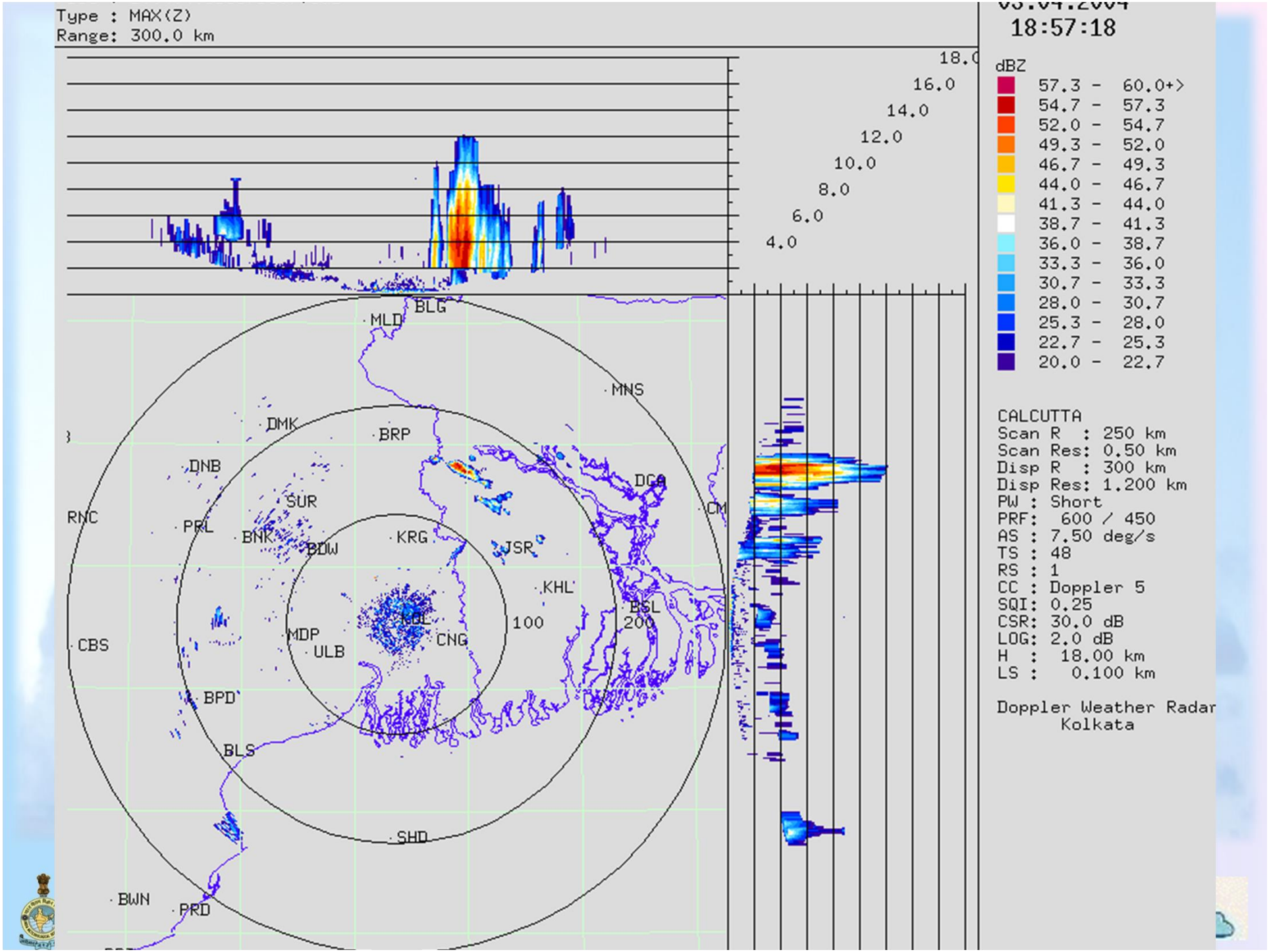
Thunderstorms

- - Single cell thunderstorm
- - Multiple cell thunderstorm
- - Squall line system
- - Super Cell thunderstorm

Dr. D. Pradhan, Scientist-G, Instruments, IMD

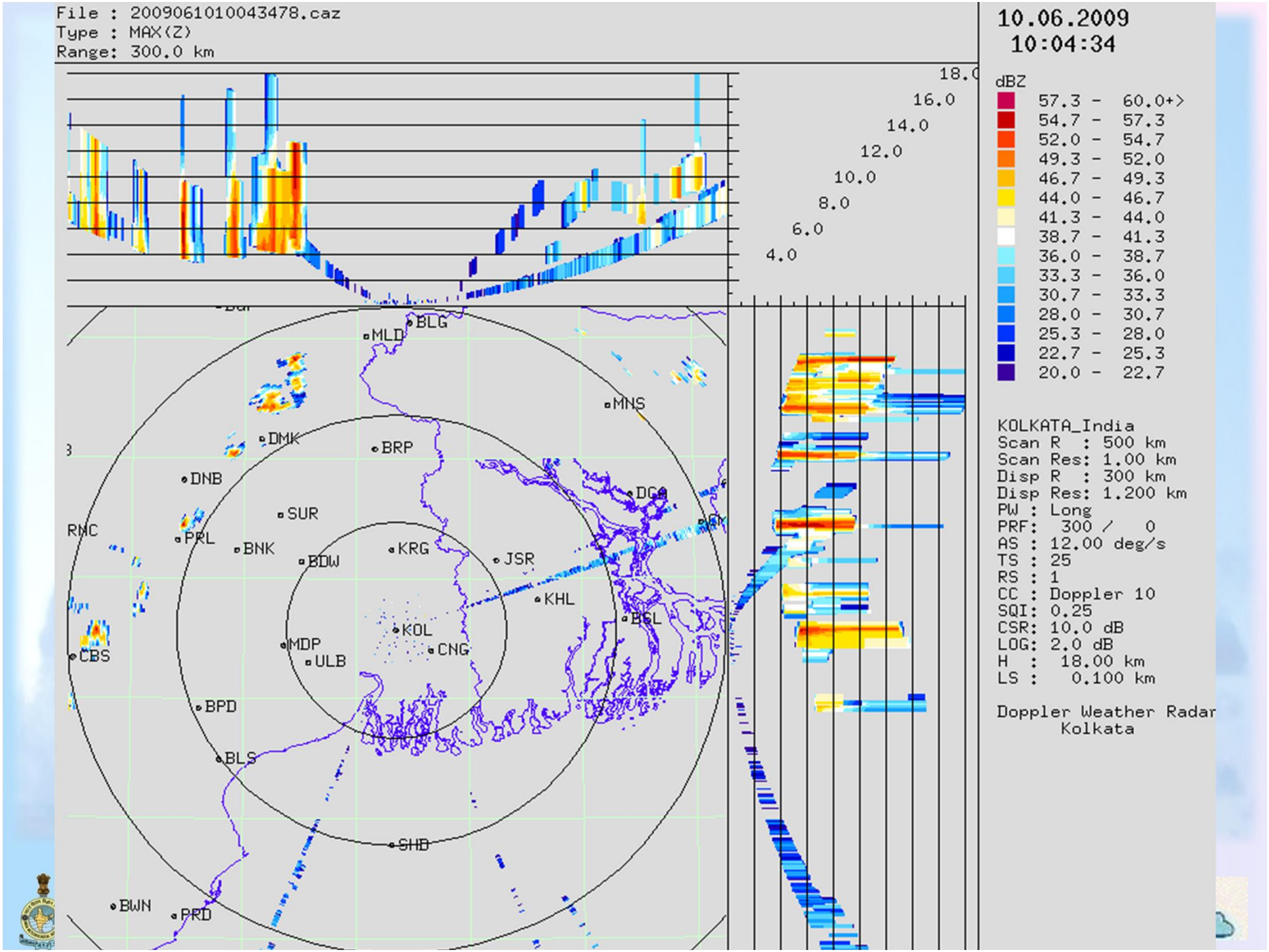
Single cell storms

- A single cloud development moves independently without merging with any other cloud is termed as a single cell storm.
- Such storms normally occur in environments where winds are relatively light and vertical wind shear is small.
- The life of such storms is usually 60-90 mts from development to dissipation.
- Such thunderstorms move with average speed of 40-45 km/h.


Type : MAX(Z)
Range: 300.0 km
18:57:18
dBZ
57.3 - 60.0+>
54.7 - 57.3
52.0 - 54.7
49.3 - 52.0
46.7 - 49.3
44.0 - 46.7
41.3 - 44.0
38.7 - 41.3
36.0 - 38.7
33.3 - 36.0
30.7 - 33.3
28.0 - 30.7
25.3 - 28.0
22.7 - 25.3
20.0 - 22.7
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
BLG
MLD
MNS
DMK
BRP
DNB
SUR
DGA
CM
RNC
PRL
BNK
BDW
KRG
JSR
KHL
BSL
100
200
MDP
ULB
CNG
CBS
BPD
BLS
SHD
BWN
PRD
CALCUTTA
Scan R : 250 km
Scan Res: 0.50 km
Disp R : 300 km
Disp Res: 1.200 km
PW : Short
PRF: 600 / 450
AS : 7.50 deg/s
TS : 48
RS : 1
CC : Doppler 5
SQI: 0.25
CSR: 30.0 dB
LOG: 2.0 dB
H : 18.00 km
LS : 0.100 km
Doppler Weather Radar
Kolkata

Multi cell storms

- These storm systems consist of a series of evolving cells which typically form on or near the storm periphery at 10-15 minutes intervals.
- Each cell eventually becomes the dominant cell of the storm complex, building to higher levels as it approaches and finally merges with the main storm complex.
- The life of such storms is usually 2-3 Hrs from development to dissipation.
- Such thunderstorms move with average speed of 40-45 km/h.

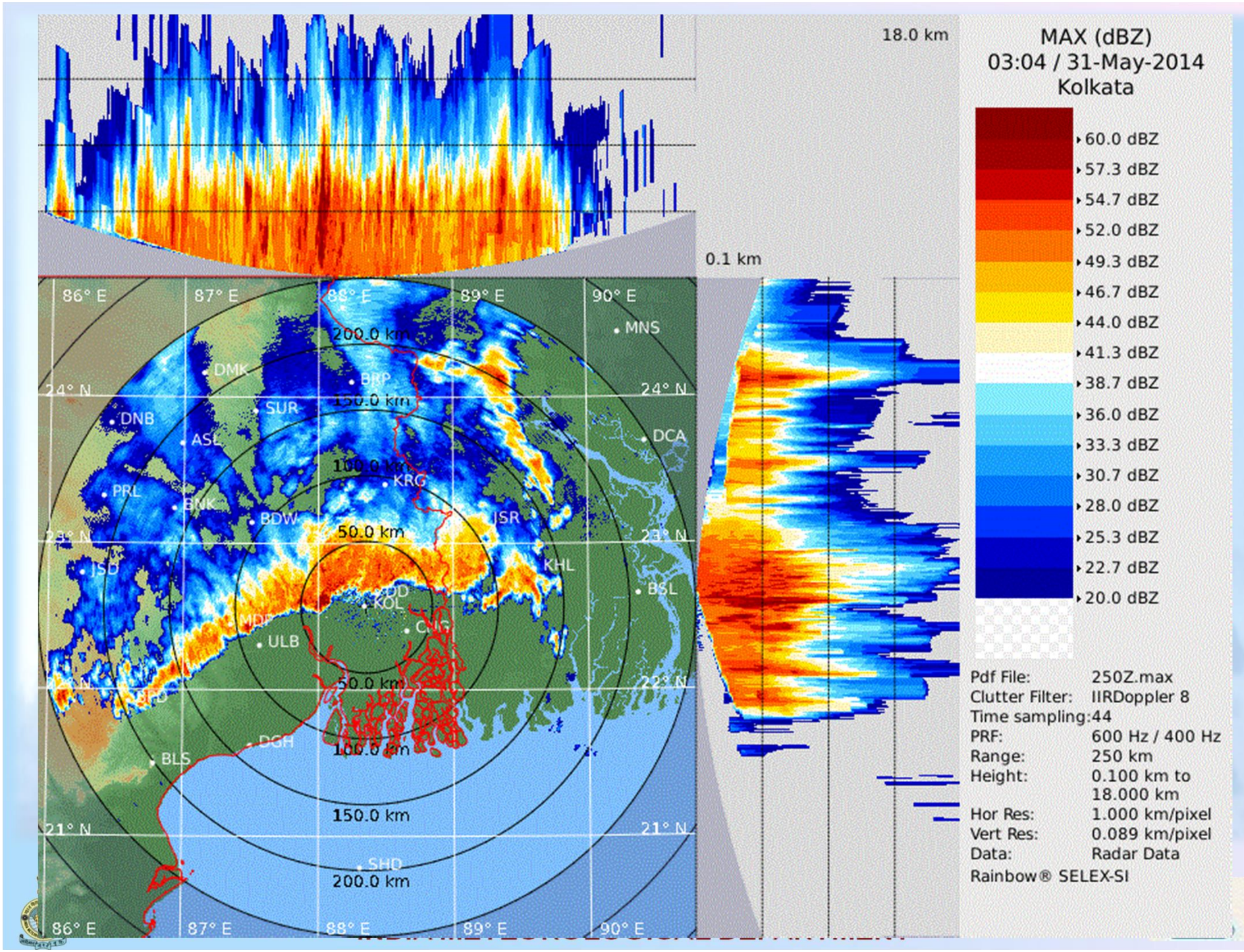

File : 2009061010043478.caz
Type : MAX(Z)
Range: 300.0 km
10.06.2009
10:04:34
dBZ
57.3 - 60.0+>
54.7 - 57.3
52.0 - 54.7
49.3 - 52.0
46.7 - 49.3
44.0 - 46.7
41.3 - 44.0
38.7 - 41.3
36.0 - 38.7
33.3 - 36.0
30.7 - 33.3
28.0 - 30.7
25.3 - 28.0
22.7 - 25.3
20.0 - 22.7
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
KOLKATA_India
Scan R : 500 km
Scan Res: 1.00 km
Disp R : 300 km
Disp Res: 1.200 km
PW : Long
PRF: 300 / 0
AS : 12.00 deg/s
TS : 25
RS : 1
CC : Doppler 10
SQI: 0.25
CSR: 10.0 dB
LOG: 2.0 dB
H : 18.00 km
LS : 0.100 km
Doppler Weather Radar
Kolkata
BLG
MLD
MNS
DMK
BRP
DNB
SUR
RNC
PRL
BNK
BDW
KRG
JSR
KHL
BSL
KOL
MDP
CNG
ULB
CBS
BPD
BLS
SHB
BWN
PRD

Squall Line

- A chain of thunderstorms joined together with length more than 60 km.
- Width to length ratio 1:10.
- Structure is sometimes linear but most of the times as a "BOW Echo".
- More the convex is the structure, more intense is the system.
- The life of such storms is usually 3-6 Hrs from development to dissipation.
- Such thunderstorms move with average speed of 70-100 km/h.

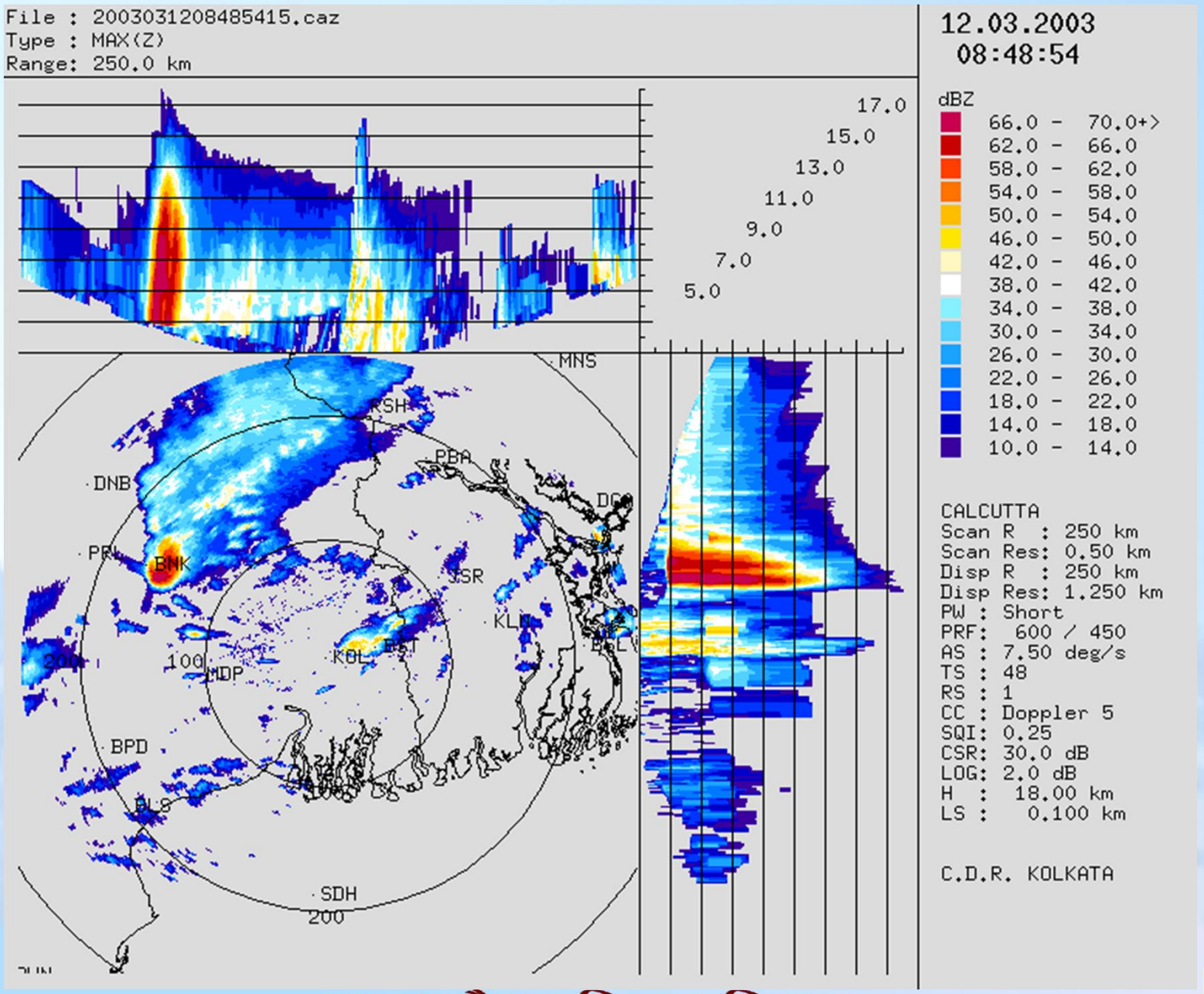
Squall Line (contd.)

- Height of the associated clouds may be of the order of 16-18 km but sometimes it has been found that the top of the clouds reaches to 20 km.
- Strong downdrafts of the order of 100-120 km/h may be originated by such “Squall line” configurations.


18.0 km
0.1 km
MAX (dBZ)
03:04 / 31-May-2014
Kolkata
60.0 dBZ
57.3 dBZ
54.7 dBZ
52.0 dBZ
49.3 dBZ
46.7 dBZ
44.0 dBZ
41.3 dBZ
38.7 dBZ
36.0 dBZ
33.3 dBZ
30.7 dBZ
28.0 dBZ
25.3 dBZ
22.7 dBZ
20.0 dBZ
Pdf File: 250Z.max
Clutter Filter: IIRDoppler 8
Time sampling:44
PRF: 600 Hz / 400 Hz
Range: 250 km
Height: 0.100 km to 18.000 km
Hor Res: 1.000 km/pixel
Vert Res: 0.089 km/pixel
Data: Radar Data
Rainbow® SELEX-SI
86° E
87° E
88° E
89° E
90° E
24° N
23° N
22° N
21° N
200.0 km
150.0 km
100.0 km
50.0 km
MNS
DMK
BRP
SUR
DNB
ASL
DCA
PRL
BNK
BDW
KRG
JSR
JSD
KHL
BSL
KOL
ULB
DGH
BLS
SHD

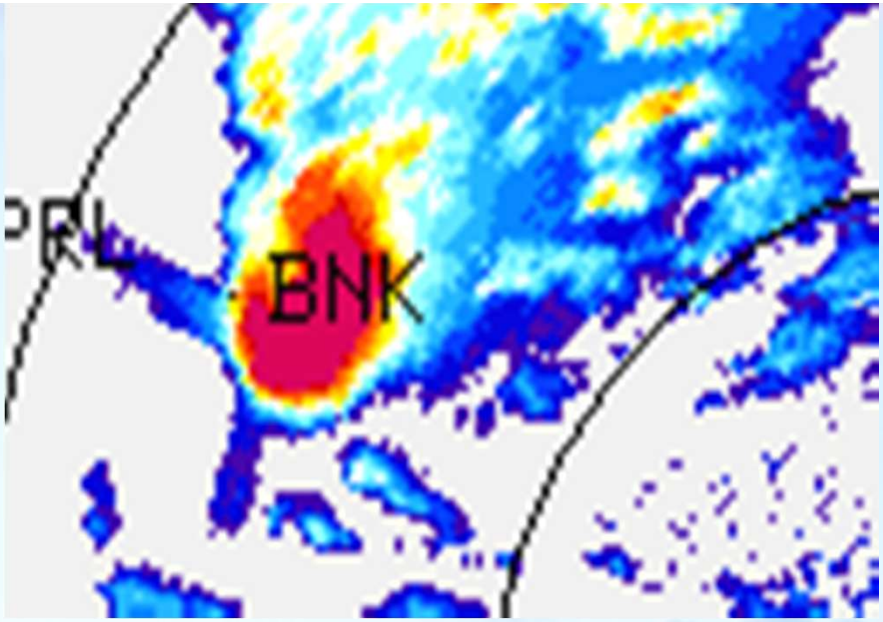
Super Cell Thunderstorm

- Supercell storms are larger, intense and persistent and normally produce more severe weather than other type of thunderstorms.
- A highly organized internal circulation that reaches a nearly steady state enables the super cell to propagate continuously.
- Usually associated with Hailstorms and Tornadoes.
- The life of such storms is usually 6-8 Hrs from development to dissipation and sometimes more.
- Such thunderstorms move with average speed of 70-80 km/h.

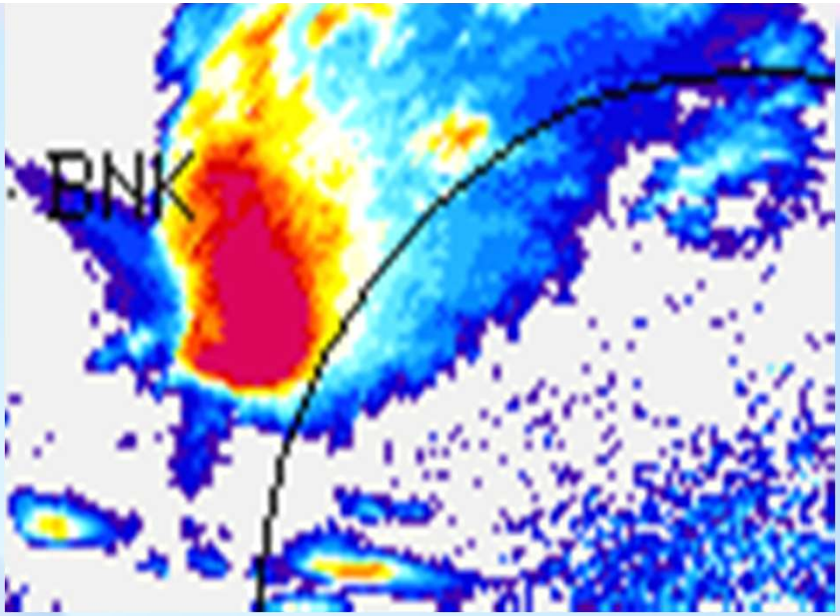


भारत मौसम विज्ञान विभाग

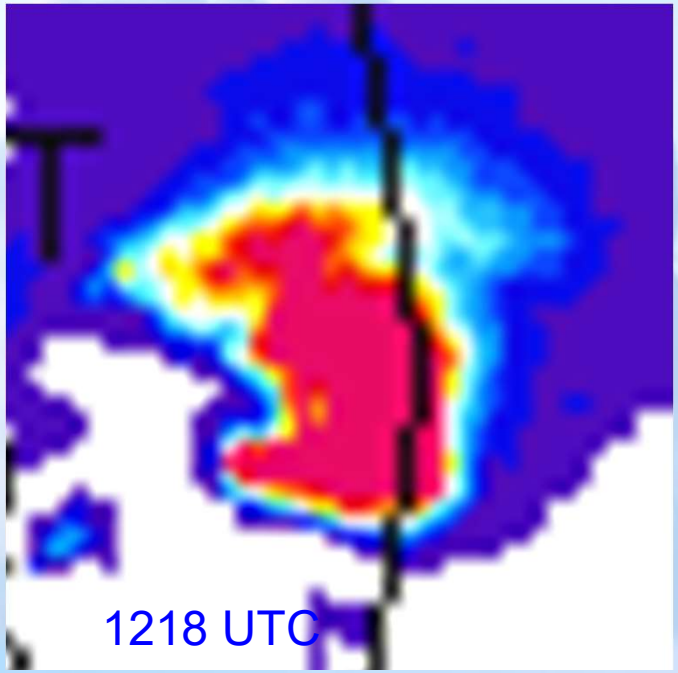
INDIA METEOROLOGICAL DEPARTMENT



0848 UTC



0918 UTC



1218 UTC

Thank you
Any Questions?
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