Radar Meteorology
Introduction and Basic Theory

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भारत मौसम विज्ञान विभाग
INDIA METEOROLOGICAL DEPARTMENT

Credits for content included in this Training Material

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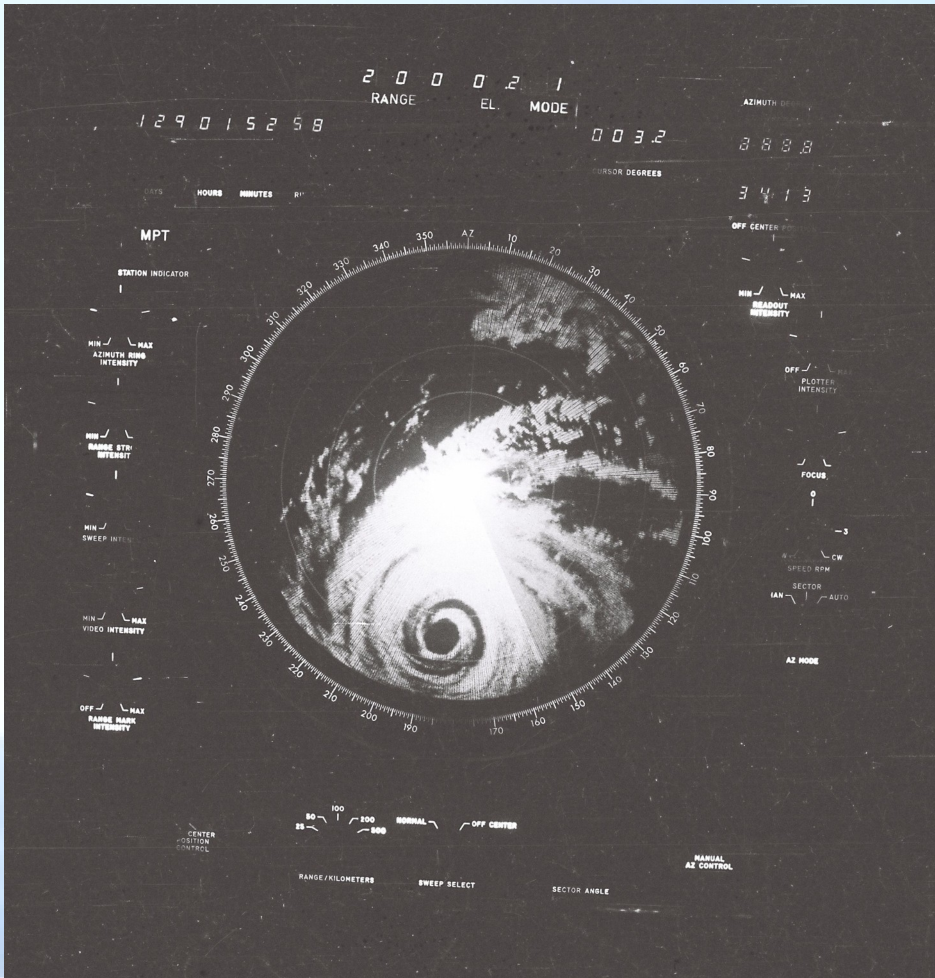
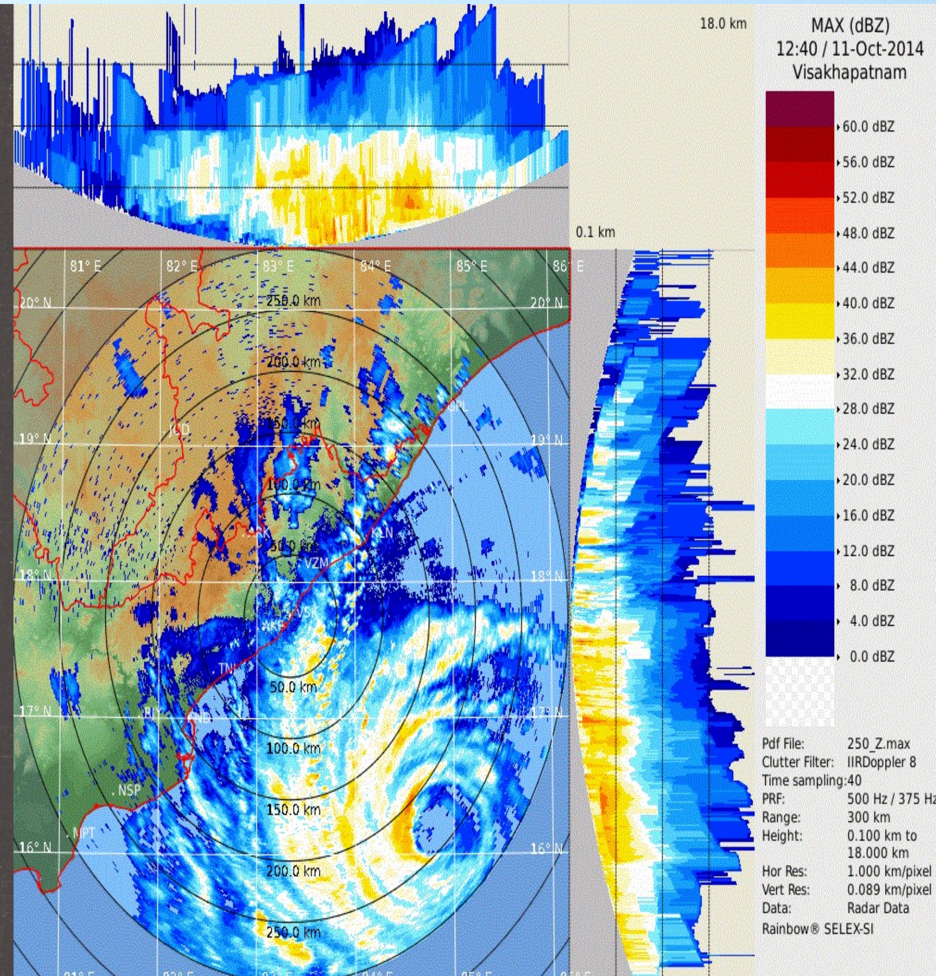
All former and current operational duty staff of DWR Visakhapatnam, DWR Chennai, DWR Machilipatnam, DWR Kolkata for generating the images

Evolution of Radar

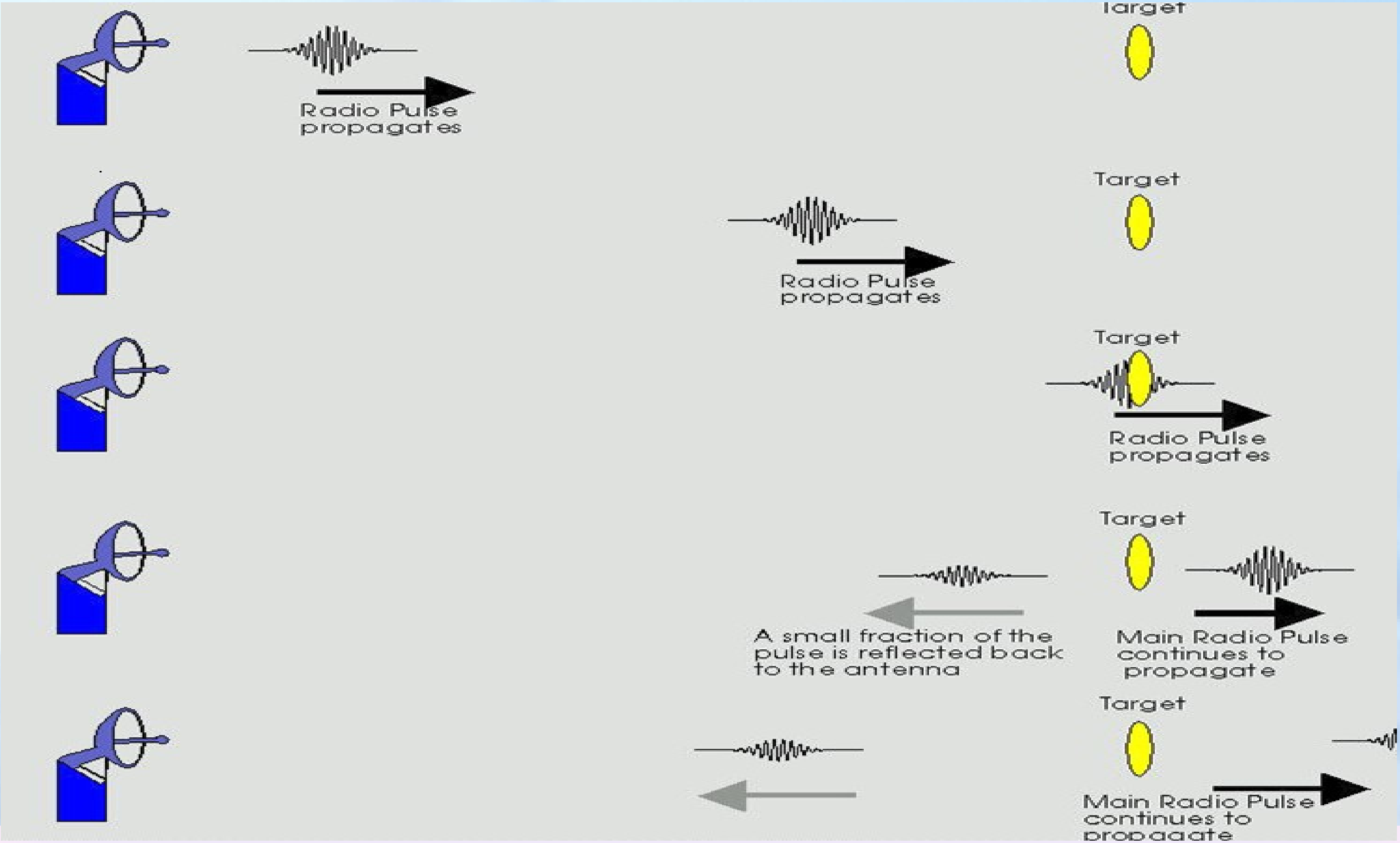




Radar Room

Radar Equipment : Radome & Antenna

How RADAR Works?



Lets find the range

Range Determination

Pulsing allows a radar system to display the target *range*. By measuring the elapsed time between the broadcast of a pulse and subsequent detection of returned energy from a target, the radar system determines the distance between radar antenna and target.

$$r = (c * t) / 2$$

where, r - distance (range) in km,

c - speed of light in km/s,

t - elapsed time since the end of the transmission of the pulse (sec)

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

Power Transmission

Light Bulb = 40 W
Peak powers
S Band Radar = 750000W(klystron)
C band Radar = 2500000W(klystron)
X band Radar = 400 W (SSPA)
Received power after hitting the target / minimum detectable signal is

= 0.000000000000005011 W
= 5×10^{-15} W
= 10 log (5×10^{-15} / 1 mW) dbm
= -113 dbm

Why do we need db?

10 dBm	10 mW			
9 dBm		8 mW		
8 dBm				6.4 mW
7 dBm			5 mW	
6 dBm		4 mW		
5 dBm				3.2 mW
4 dBm			2.5 mW	
3 dBm		2 mW		
2 dBm				1.6 mW
1 dBm			1.25 mW	
0 dBm	1 mW			

The Radar Equation

THE RADAR EQUATION FOR WEATHER TARGETS

$$Z = \frac{1024\ln(2)}{c\pi^3}\left(\frac{\lambda^2}{P_t\tau G^2\Theta\Phi}\right)\left(\frac{\overline{P}_r r^2}{|K|^2}\right)$$

constants

Radar characteristics

Target characteristics

What is actually Reflectivity?

The quantity $\dfrac{\sum_j D_j^6}{V_c}$ is of utmost importance in radar meteorology

It is designated with the symbol Z, and is called the

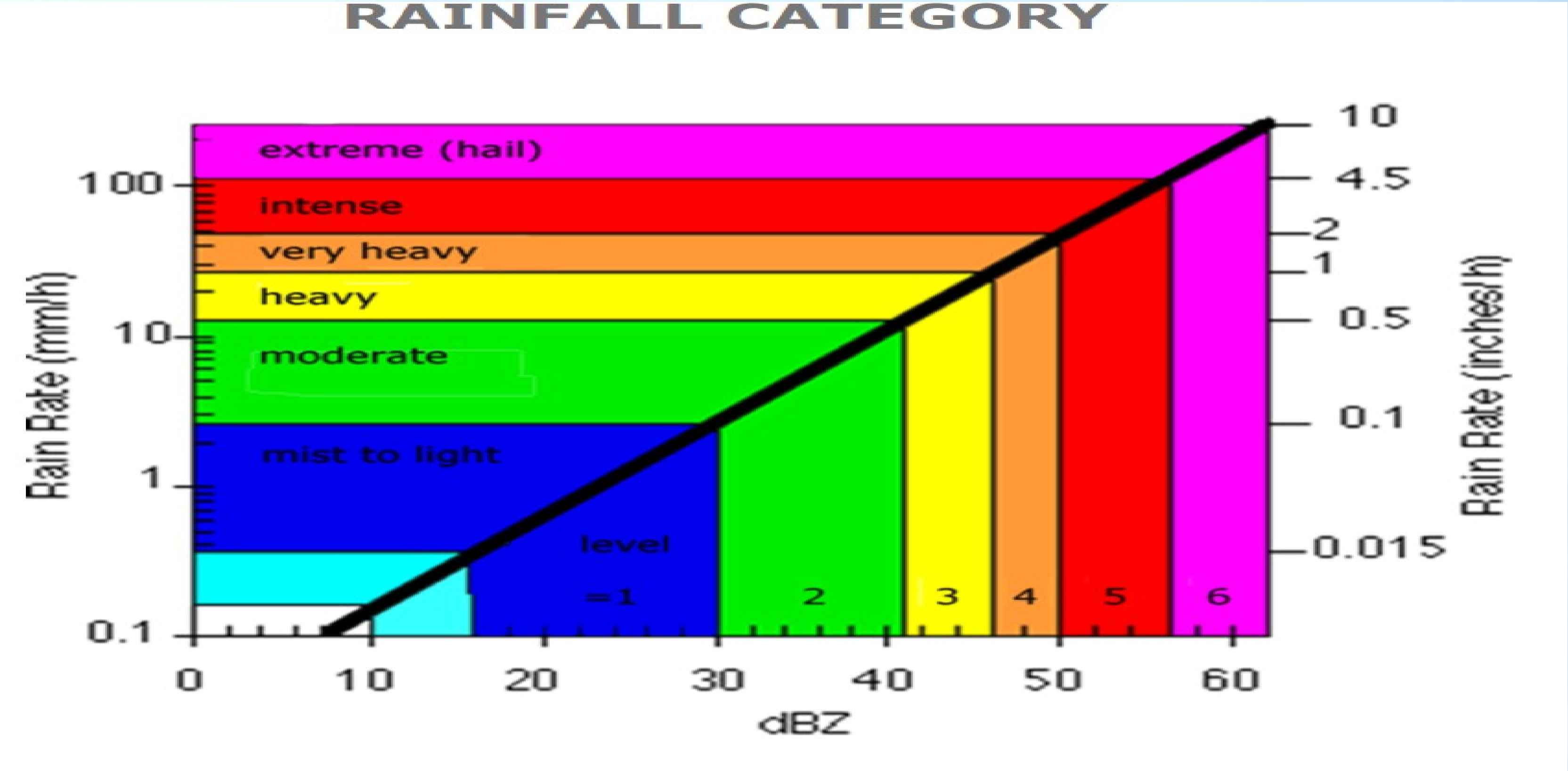
radar reflectivity factor

In logarithmic units:

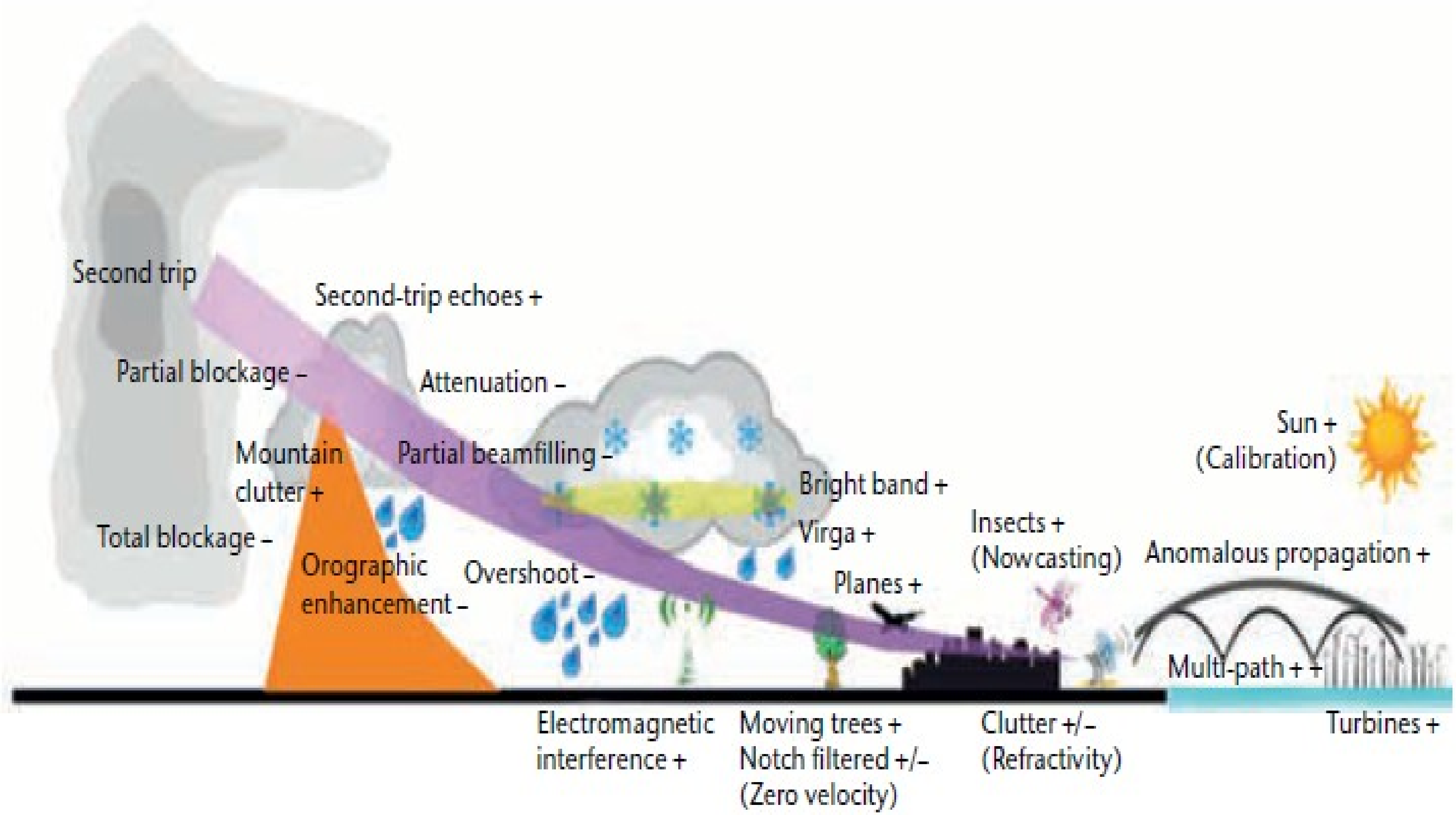
$$dBZ = 10\log\left(\frac{Z}{1\,mm^6/m^3}\right)$$

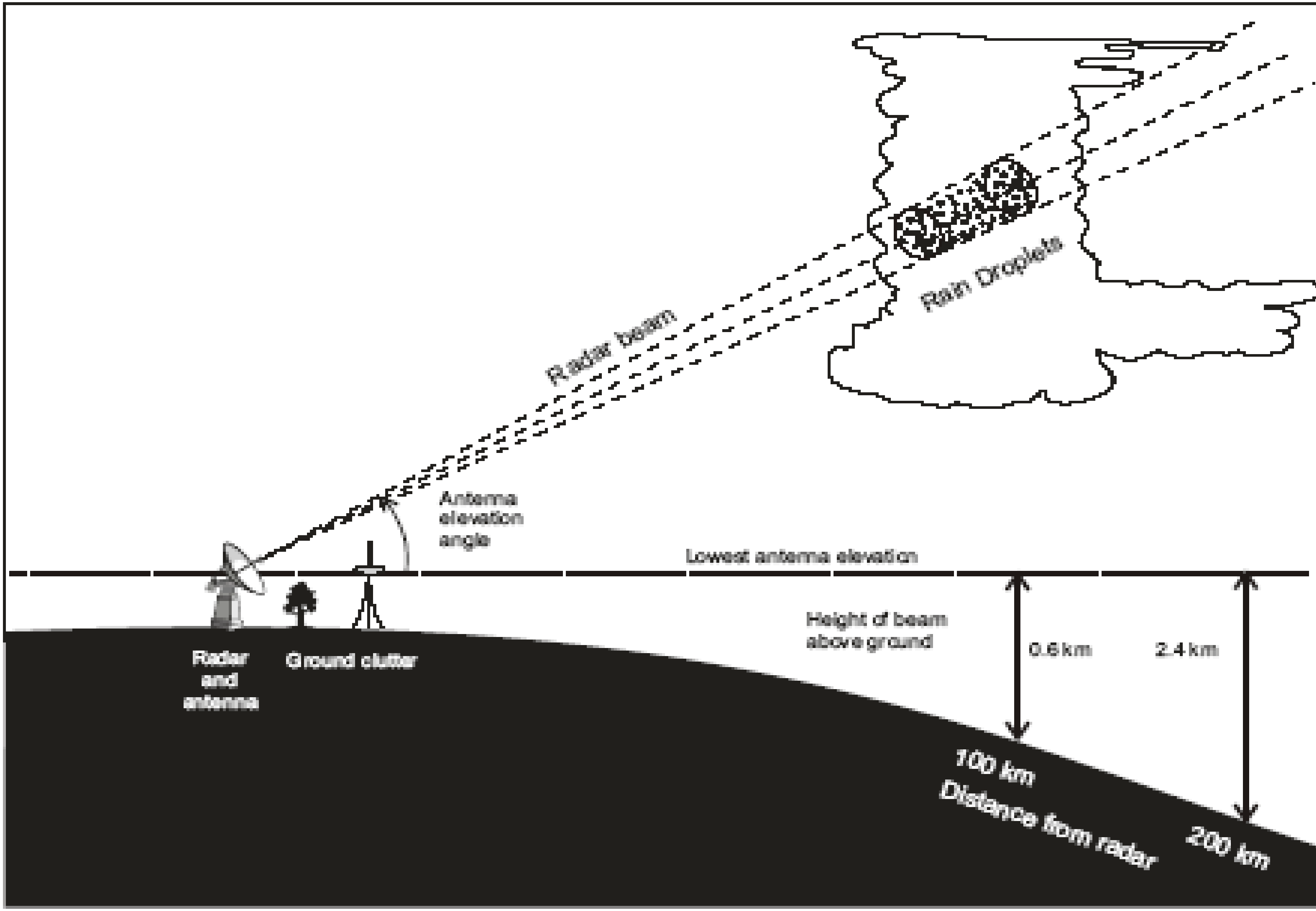
Decibels

40 dbZ is equal to 10 times 30dbZ



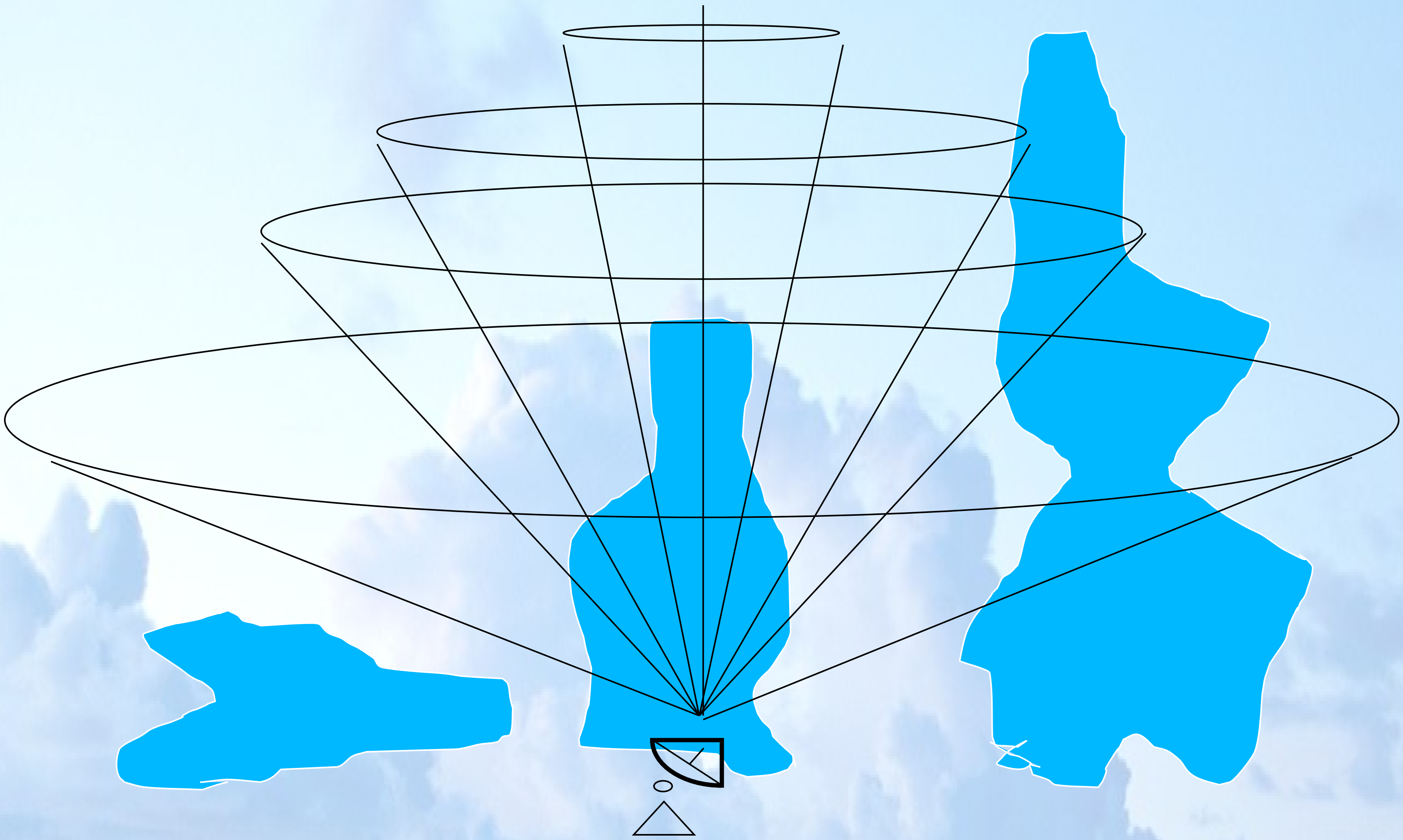
Factors affecting Radar Propogation





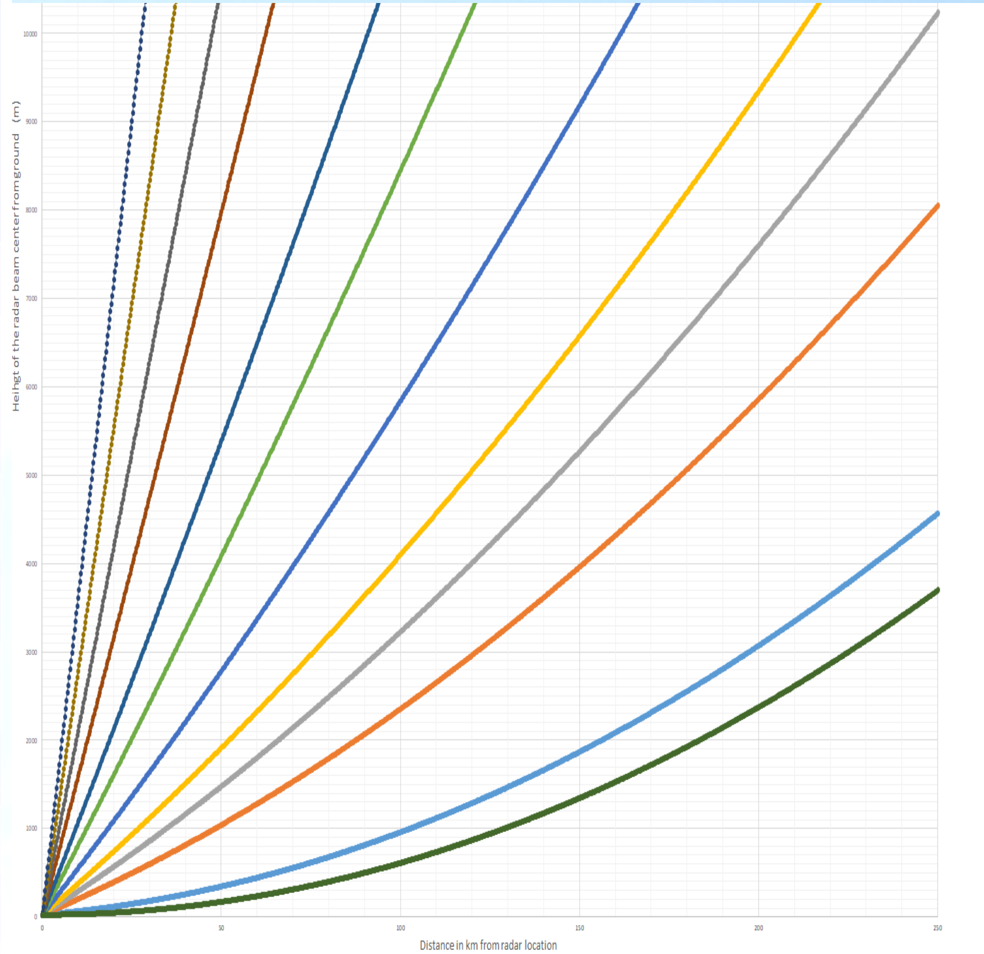
Radar scans this entire volume by raising and lowering the beam as the antenna rotates.

The Radar Volume Scan

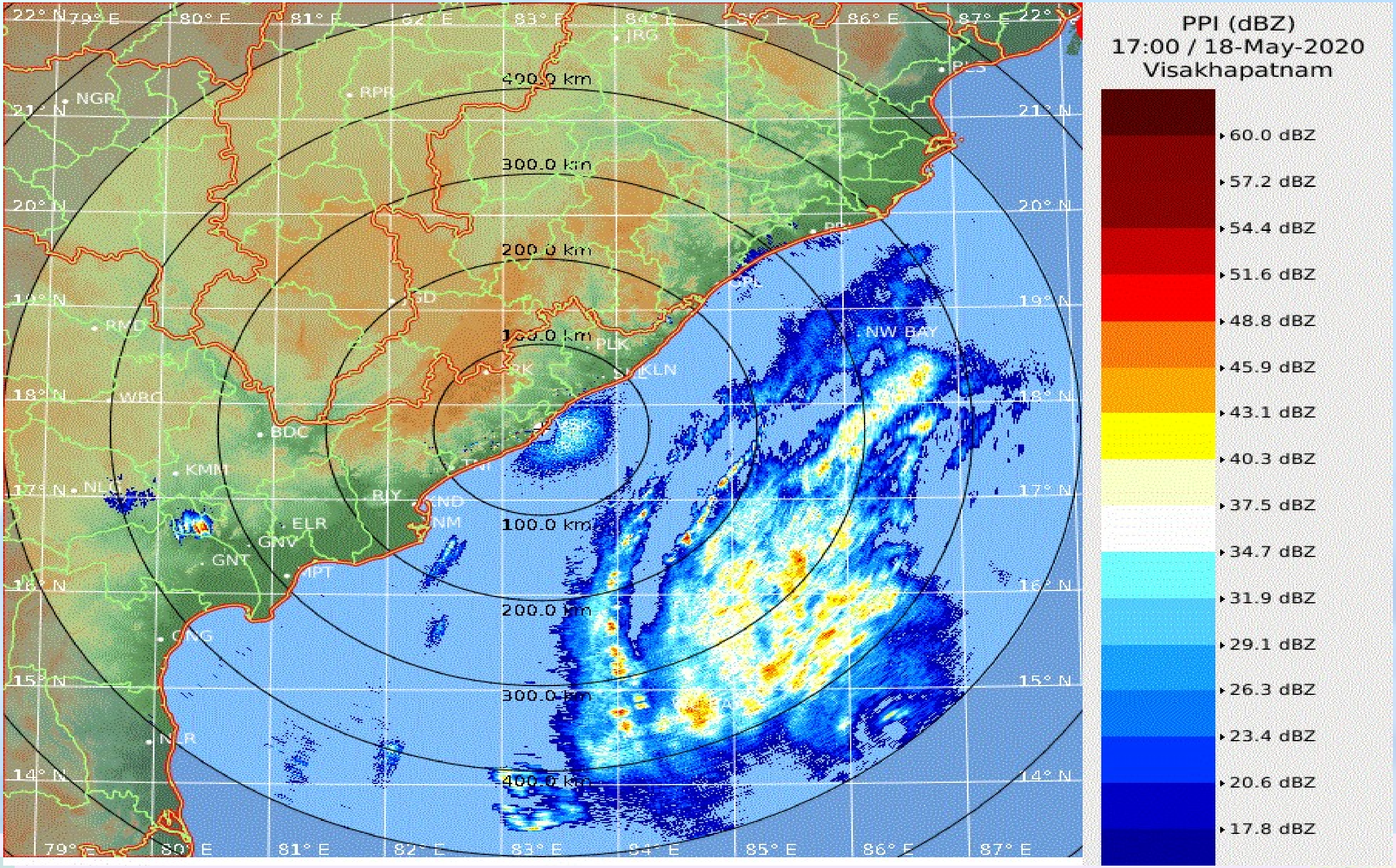


What Height am I looking at?

Distance From radar	Height of Centre Beam at lowest Elevation (0.2 Deg) in km(170MSLP)
50 km	0.5km
100km	1.10km
150km	2.01km
200km	3.22km
250km	4.71km
300km	6.51km
350km	8.6km
400km	11km
450km	13.65km
500km	16.61km



Super Cyclone AMPHAN



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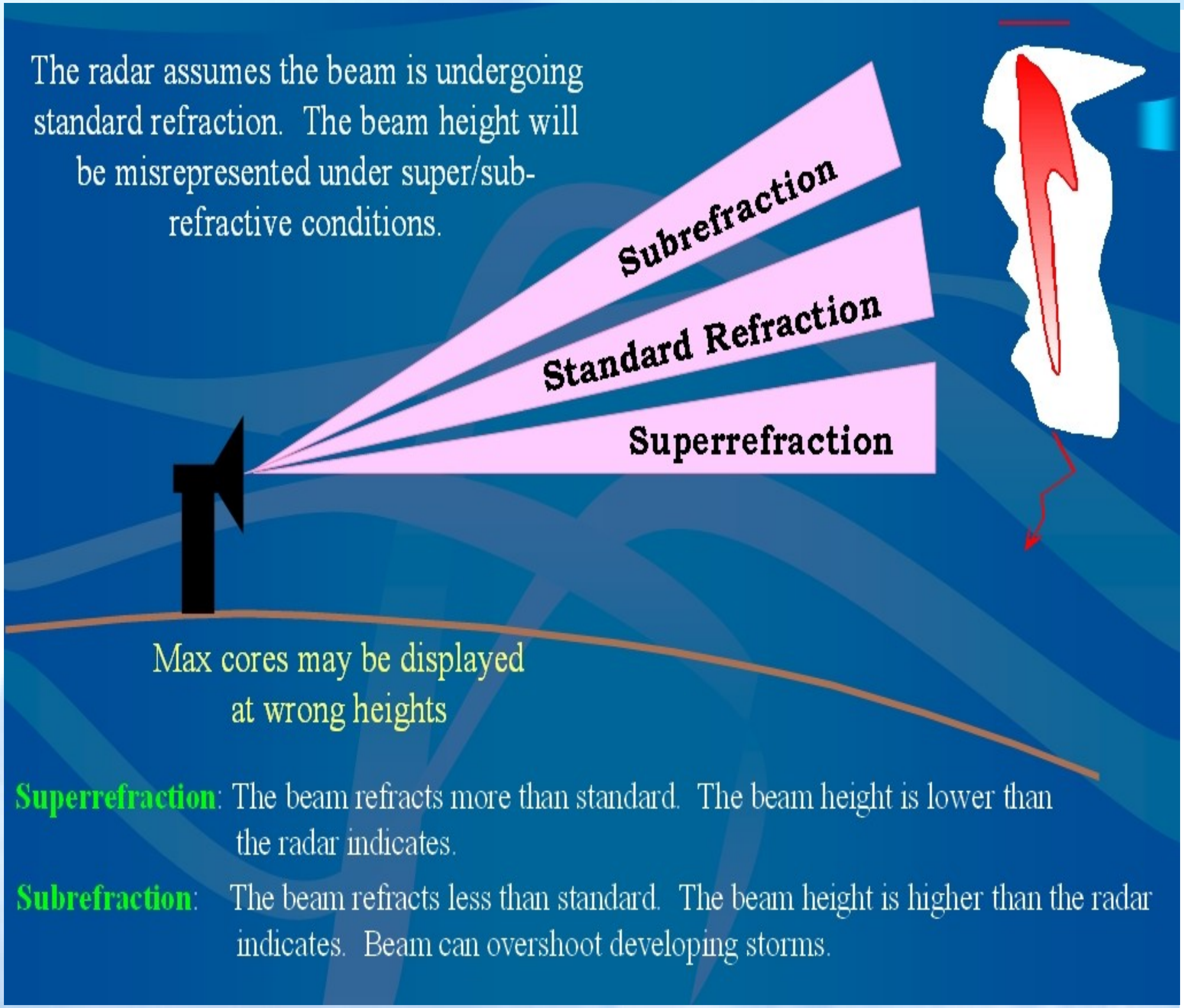
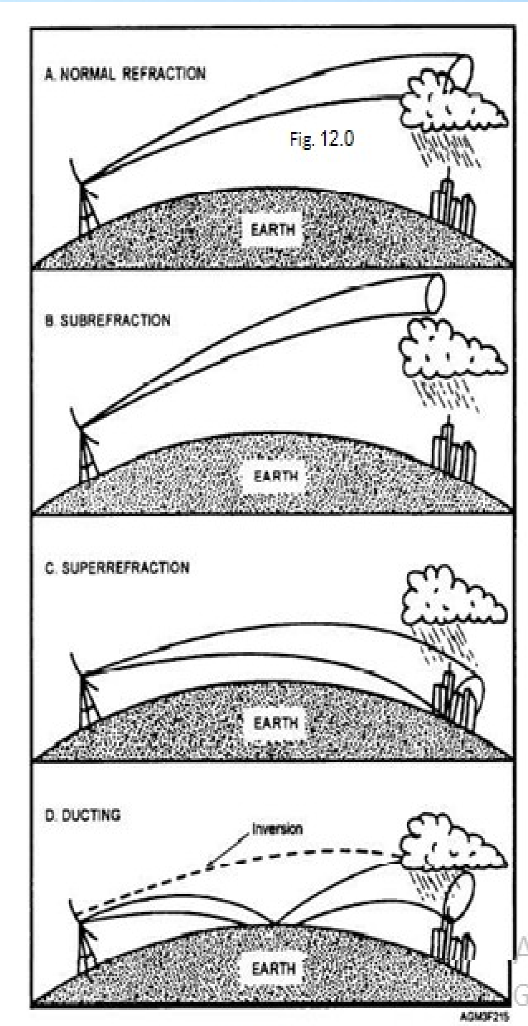
Sub and Super Refraction





Different types of clutter

Clutter can be classified into 3 groups

(i) Ground clutter (land clutter(Buildings/wind turbine and sea clutter – Lower elevations)

(ii) Air borne clutter (Biological targets (insects/bird)/Air-planes/ Aerosols/Particulate matter)

(iii) Interference clutter (sun/Transmitting Antenna).

"An analysis of Anomalous propagation parameters and its effect on the intensity of clutter in weather radars", R.Bibraj, B.Arul Malar kannan, K. Ramachandra Rao and K.C.Saikrishnan, Mausam ,71,1(January 2020), 11-20

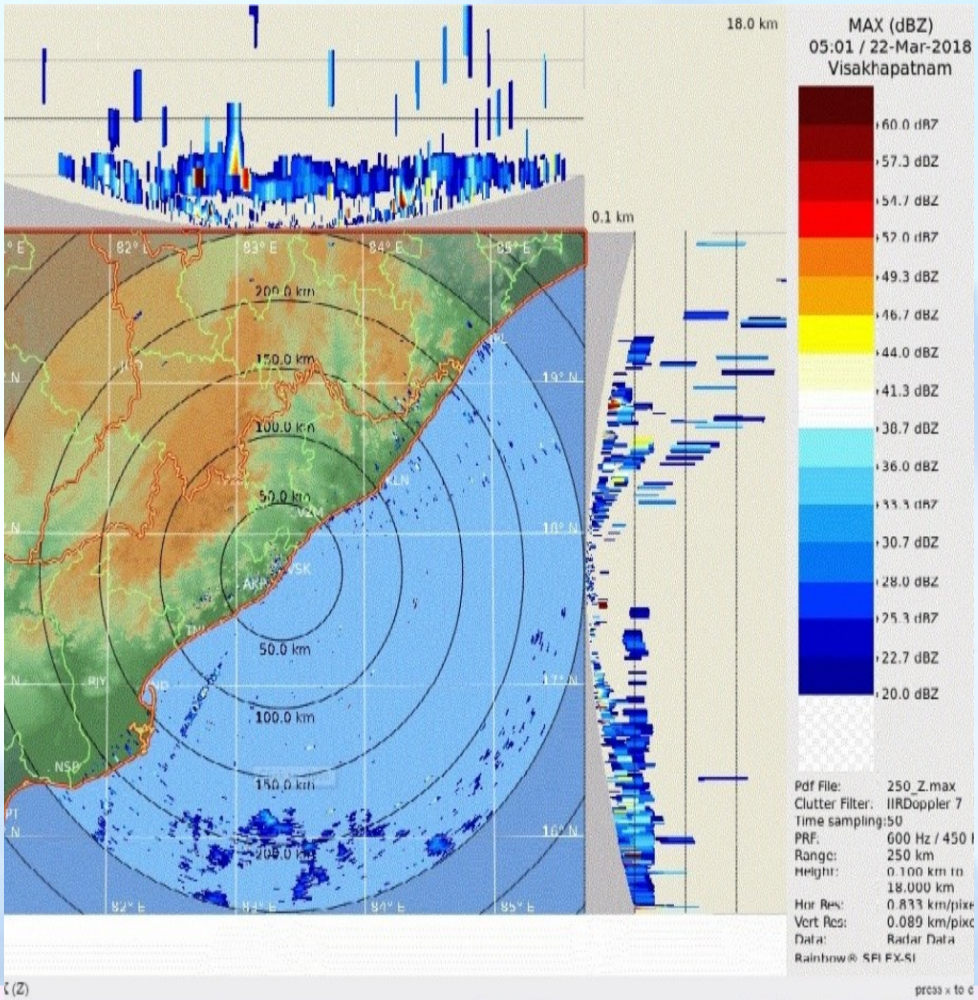
Clutter Echoes

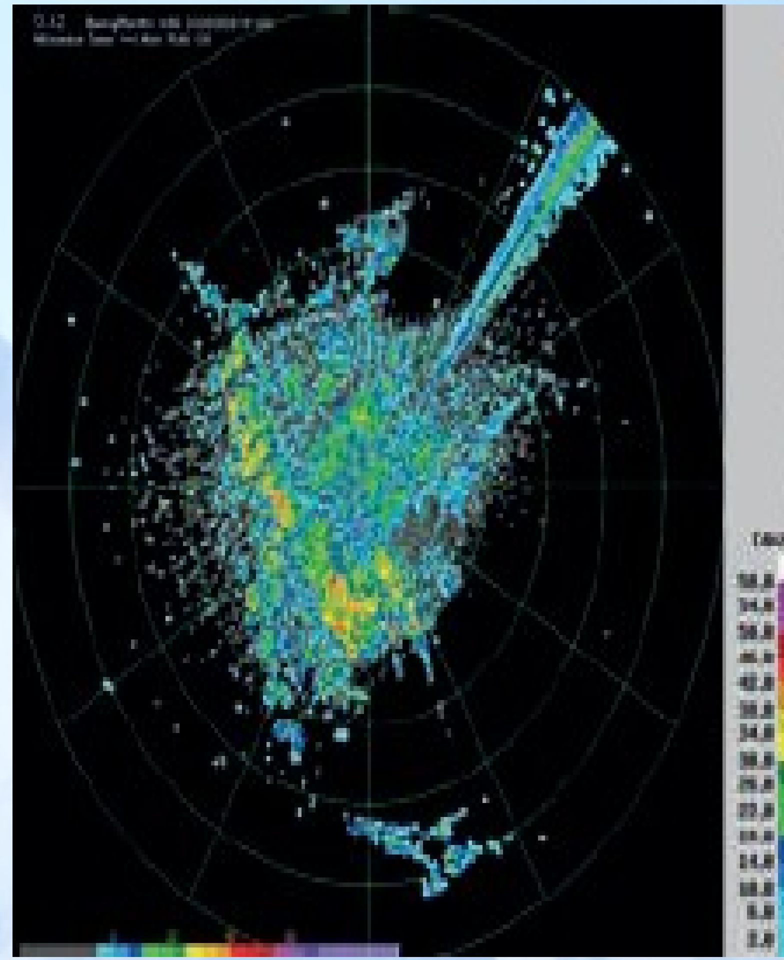
- **Multi Radar Radars**

Velocity

Standard Echoes

Dual Polarization



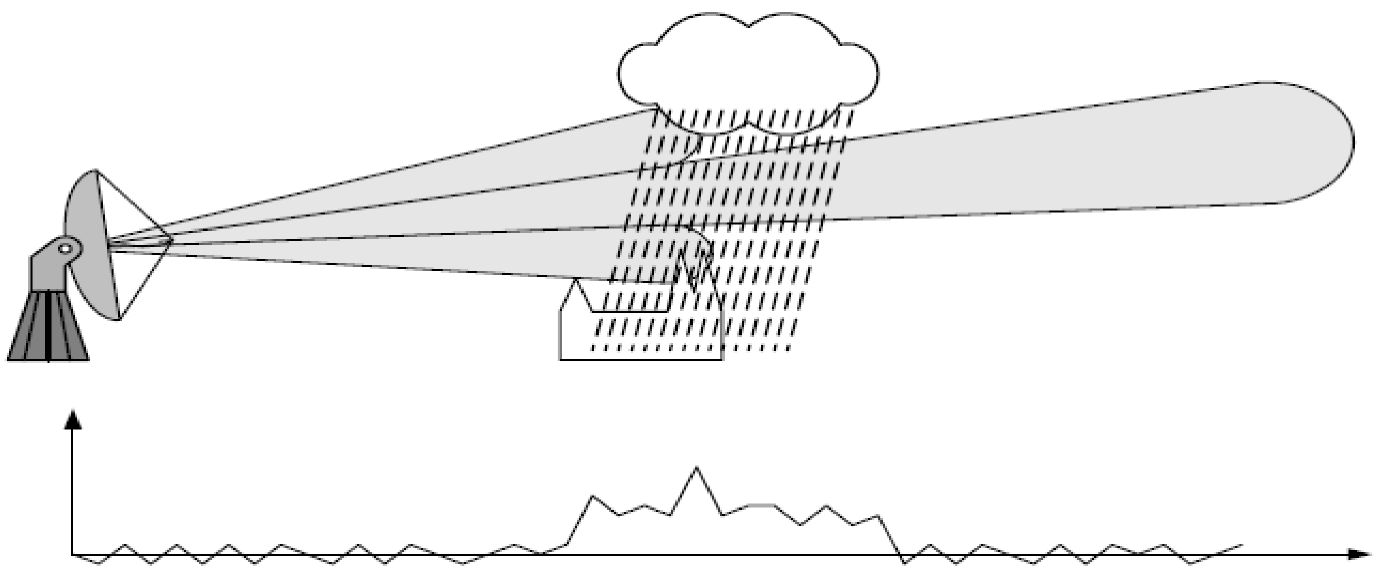


Side Lobes in the beam

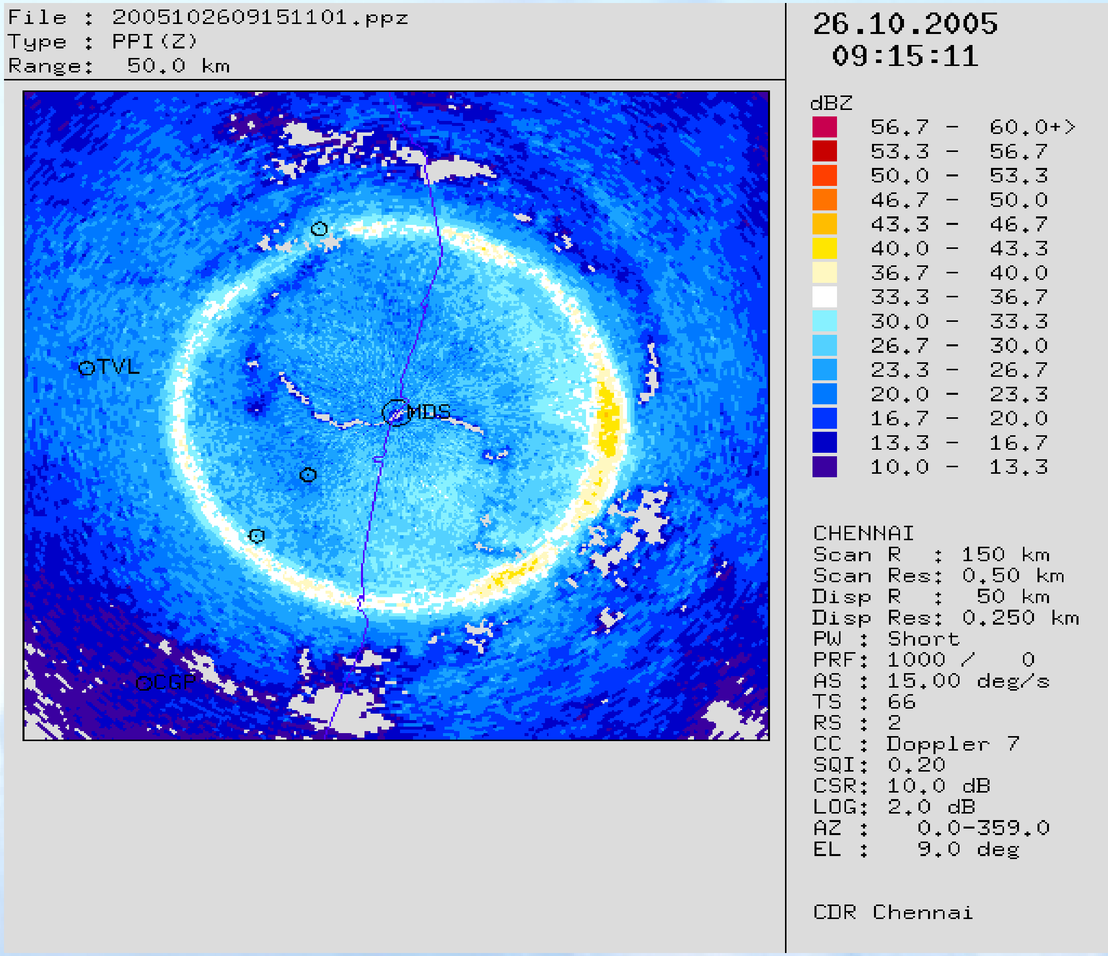
Side Lobes

All the energy not contained in the "main lobe" tends to travel in some preferred directions forming the so called "side lobes". Side lobes are presently an unavoidable and detrimental part of any weather radar system.

The main effects of the side lobes are in producing multiple displays of the same target. Side lobes increase the ground clutter.



Bright band



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

Attenuation

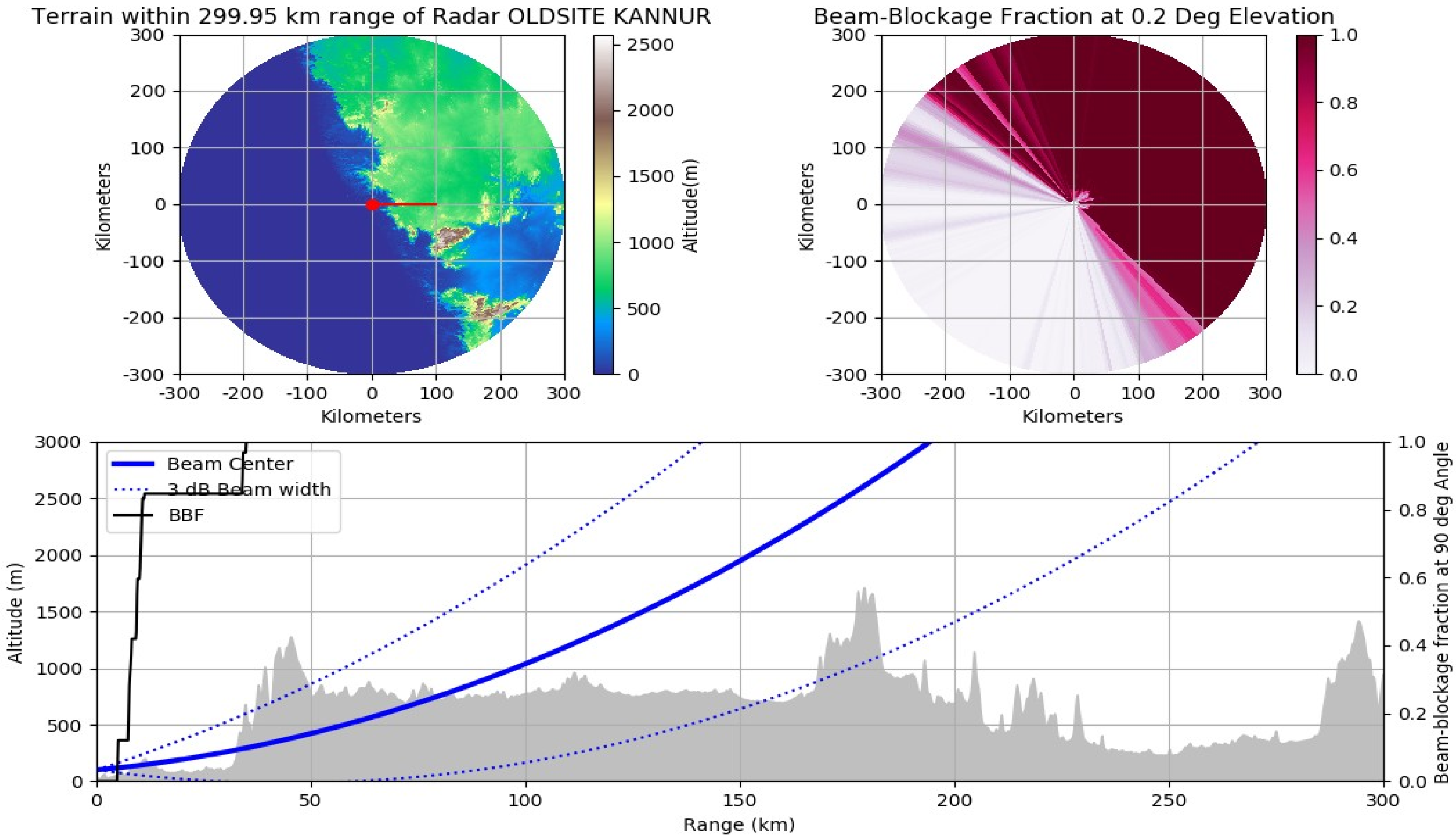
Attenuation	S- Band	C -Band	X- band
Clear Air(500km) Two way	4.5 db	5 db	6 db
Two way attenuation Rainfall(100mm/hr) (10 km)	0.6db	9.6 db	62 db

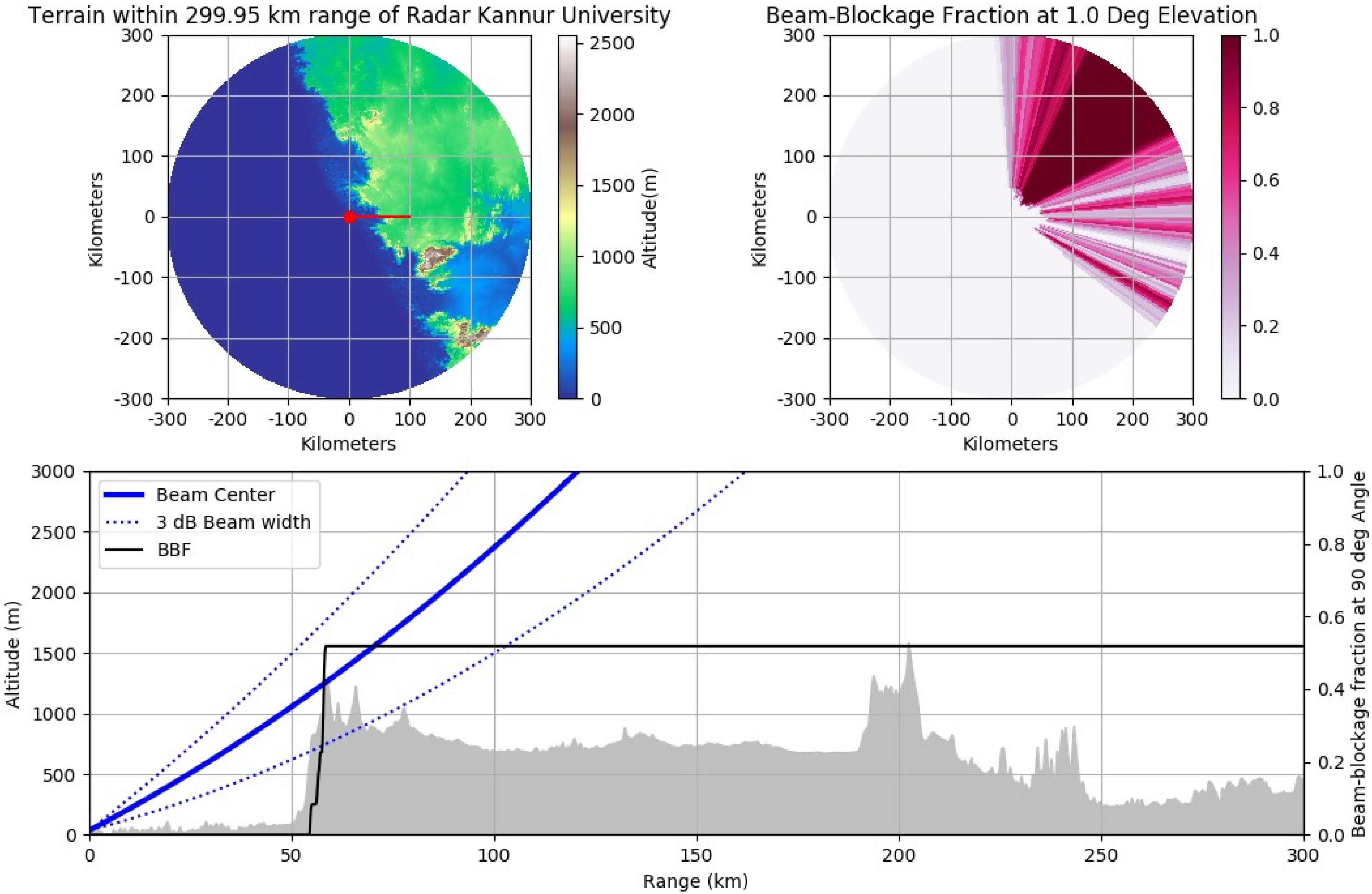
Wavelength (cm)	*Relation (dB km^{-1})*
10	$0.000\,343\,R^{0.97}$
5	$0.00\,18\,R^{1.05}$
3.2	$0.01\,R^{1.21}$

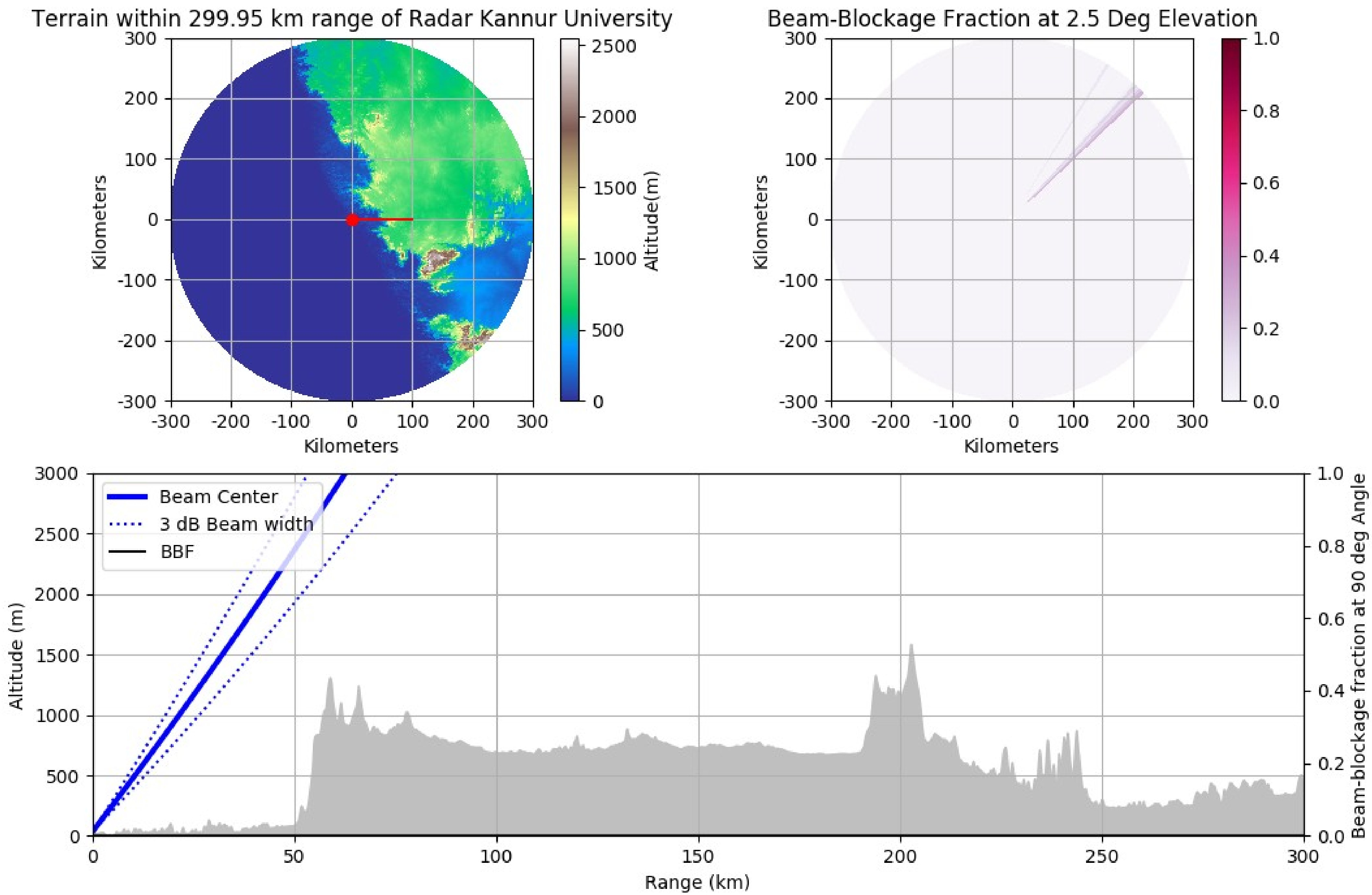
Note: After Burrows and Attwood (1949).
One-way specific attenuations at 18 °C.
R is in units of mm hr^{-1}.

Attenuation correction using Dual Polarization Techniques

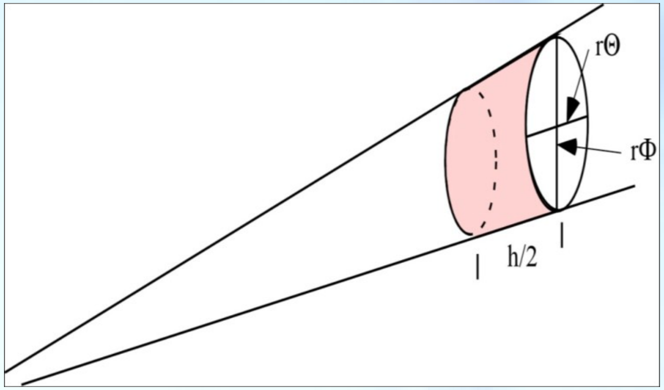
Beam Blockage

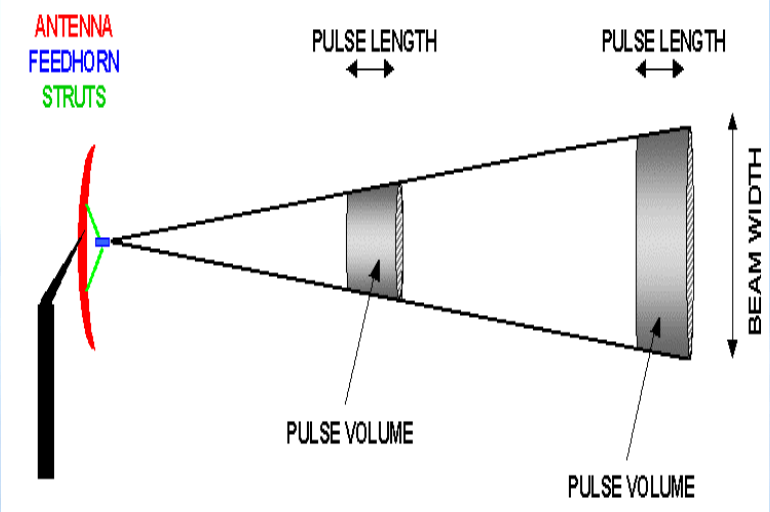


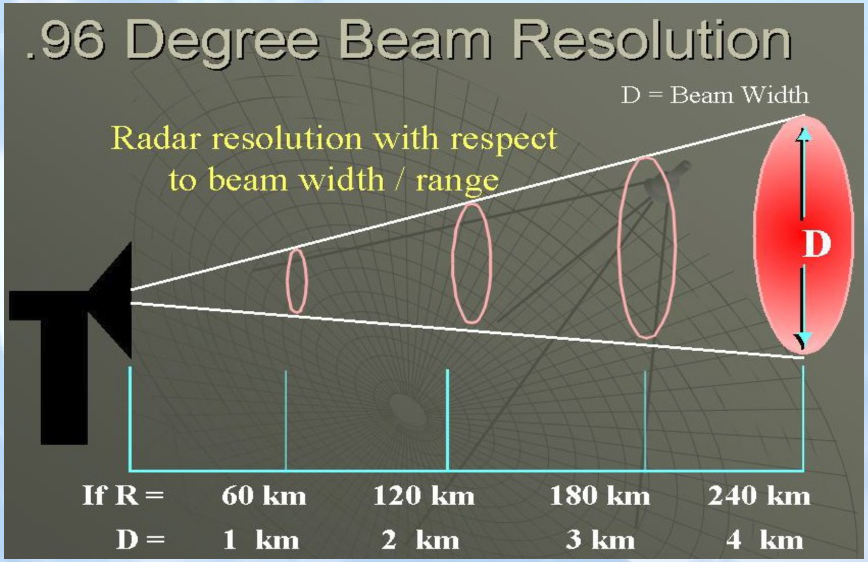

Terrain within 299.95 km range of Radar Kannur University
Altitude(m)
Kilometers
Beam-Blockage Fraction at 1.0 Deg Elevation
Beam Center
3 dB Beam width
BBF
Altitude (m)
Range (km)
Beam-blockage fraction at 90 deg Angle


Terrain within 299.95 km range of Radar Kannur University
Kilometers
Altitude(m)
Beam-Blockage Fraction at 2.5 Deg Elevation
Kilometers
Beam Center
3 dB Beam width
BBF
Altitude (m)
Range (km)
Beam-blockage fraction at 90 deg Angle

Radar Resolution







Bin Resolution and Beam Width

Range res

Pulse width

Peak Power

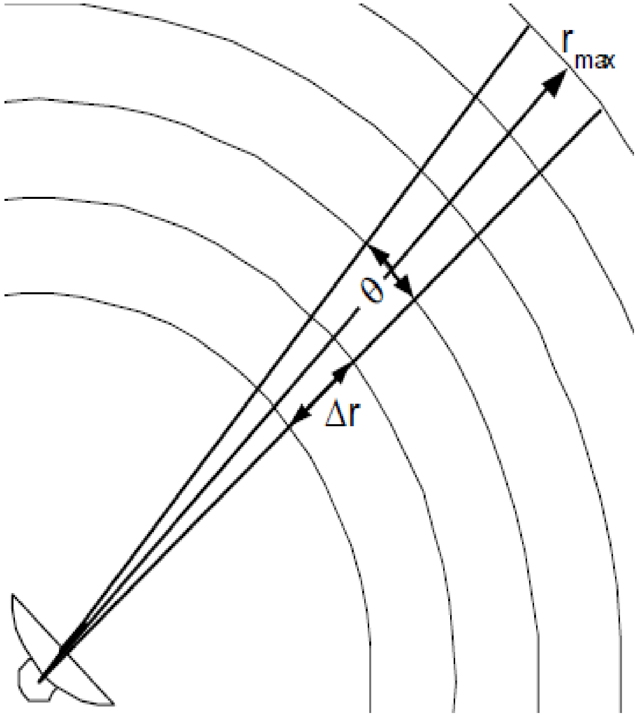
Azimuth Resolution

ϴ[°]: 3dB Antenna Beam Width

Radial (Range) Resolution

$\Delta r = c \cdot \Delta t/2$

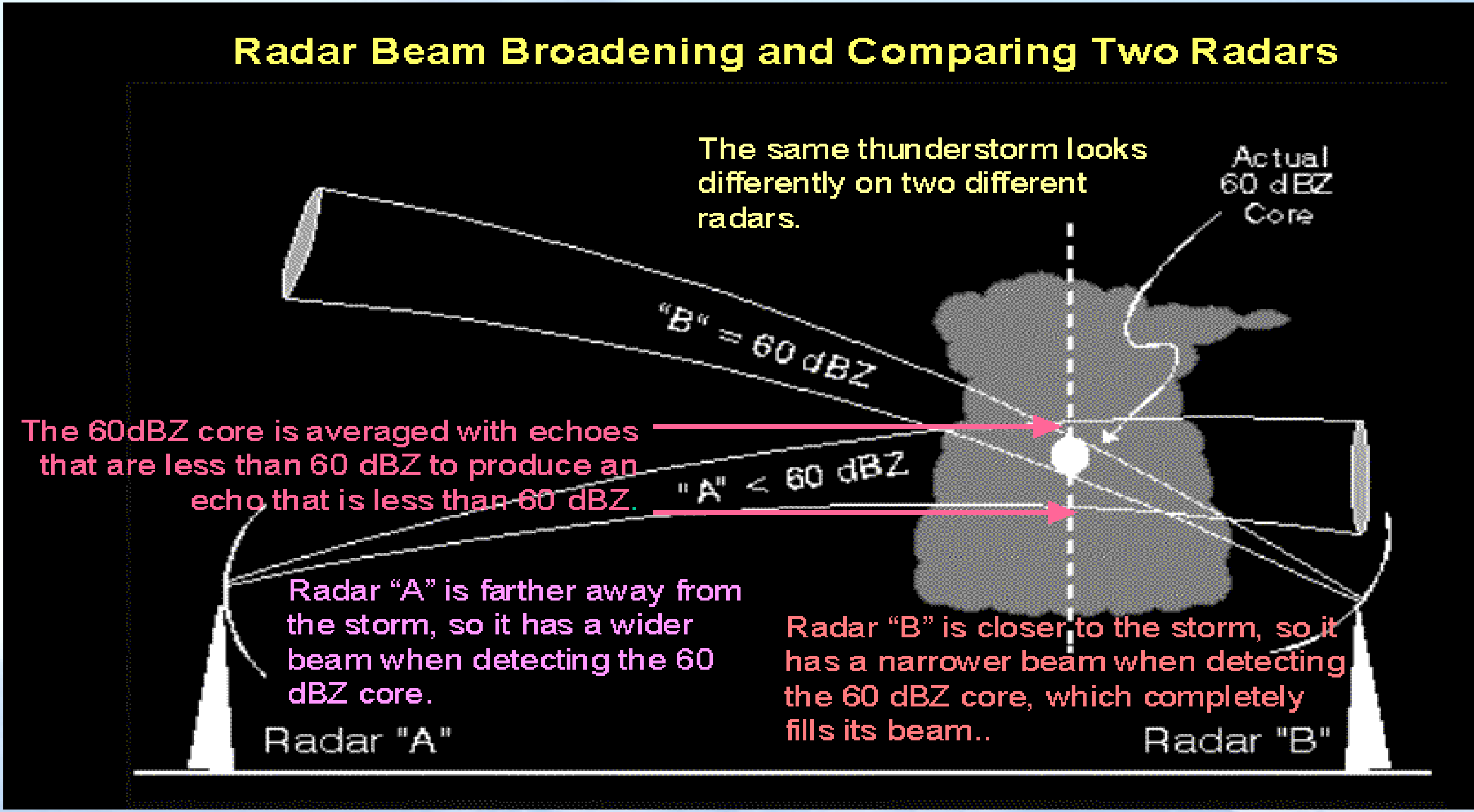
(With: Δt = Pulse Length)



Beam Width = 70λ / D

	S- Band	C-Band	X-Band
1 Deg	23 ft/7m	11ft/ 3.5m	7 ft/2.1m

Beam Broadening



Pulse Repetition frequency

Pulse

The rate at which pulses are transmitted is called **Pulse Repetition Frequency** (PRF). PRF is usually expressed in terms of number of pulses per second.

The reciprocal of PRF, 1/PRF, is referred to as **Pulse Repetition Time** (PRT).

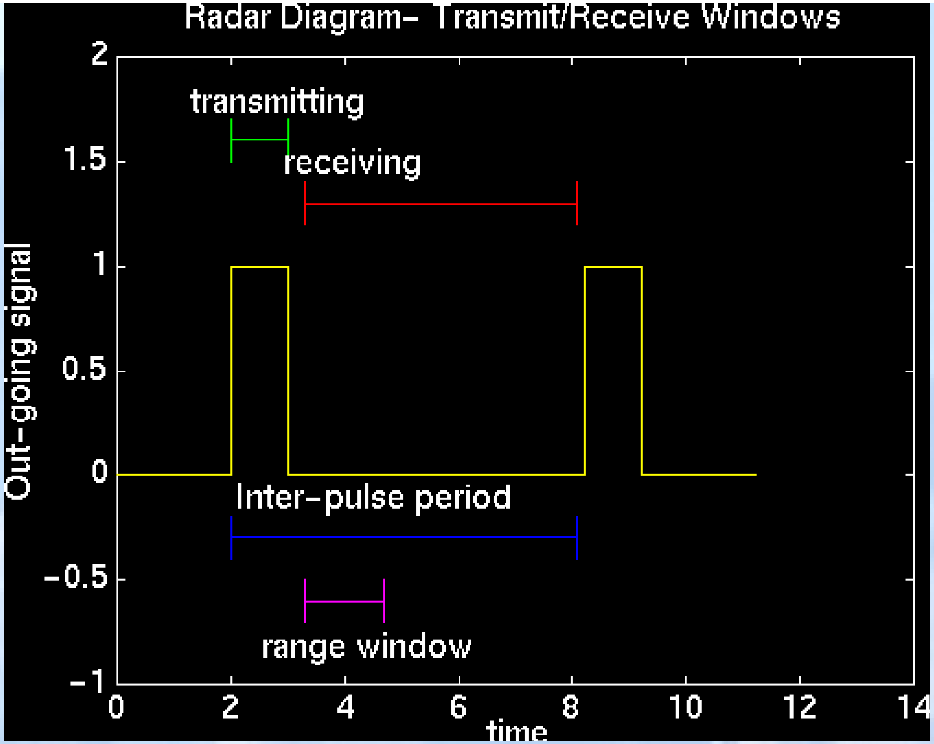
Lets say,
Pulse has to travel 500 km
(to and fro 1000km)
Speed is 3 x 10 ^{8} m/sec

Time taken: distance/speed

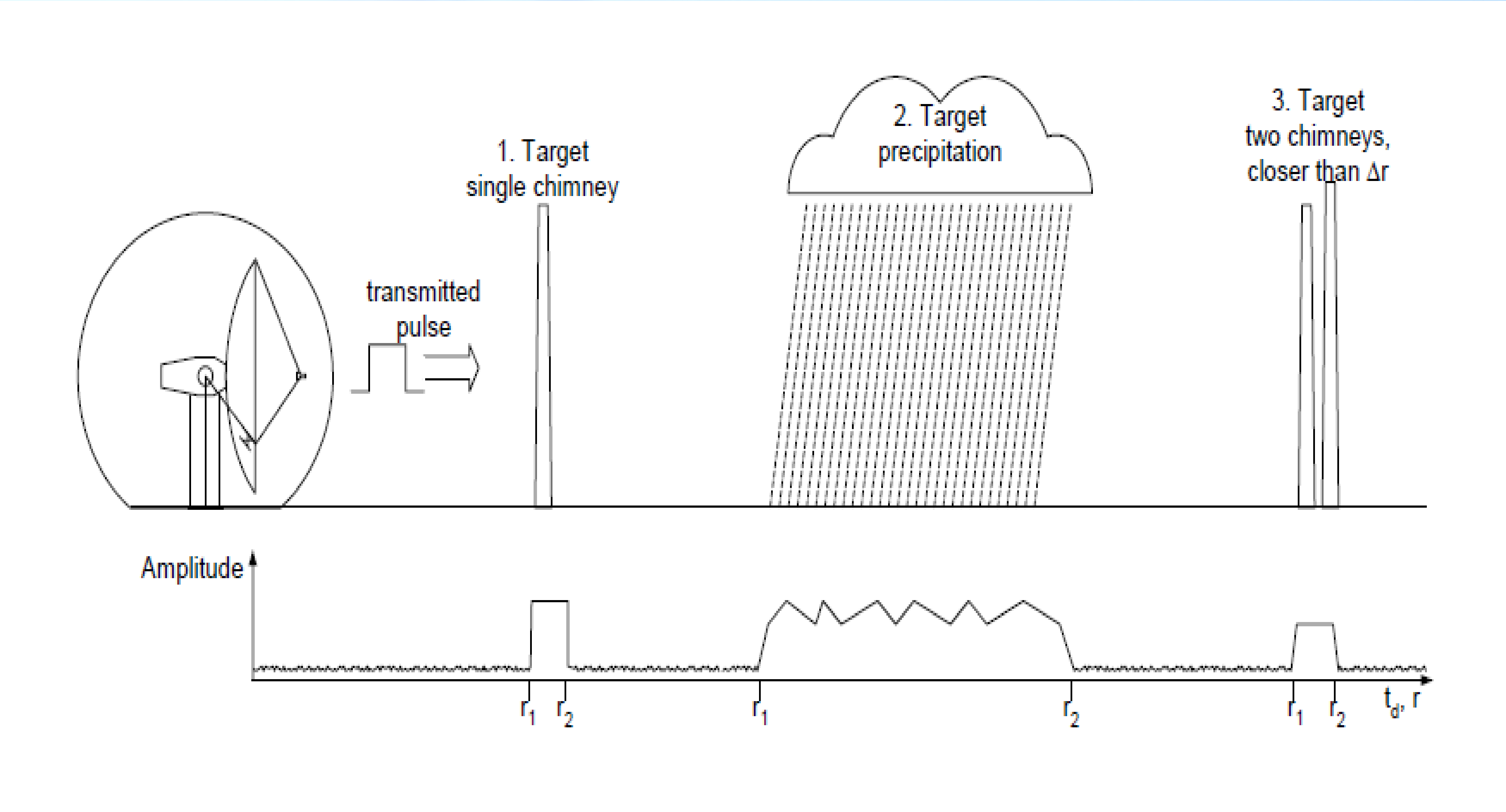
PRT = 3 milli seconds

PRF = 1/ PRT

PRF = 300 pulses /sec (Hz)



How Radar detects the signal

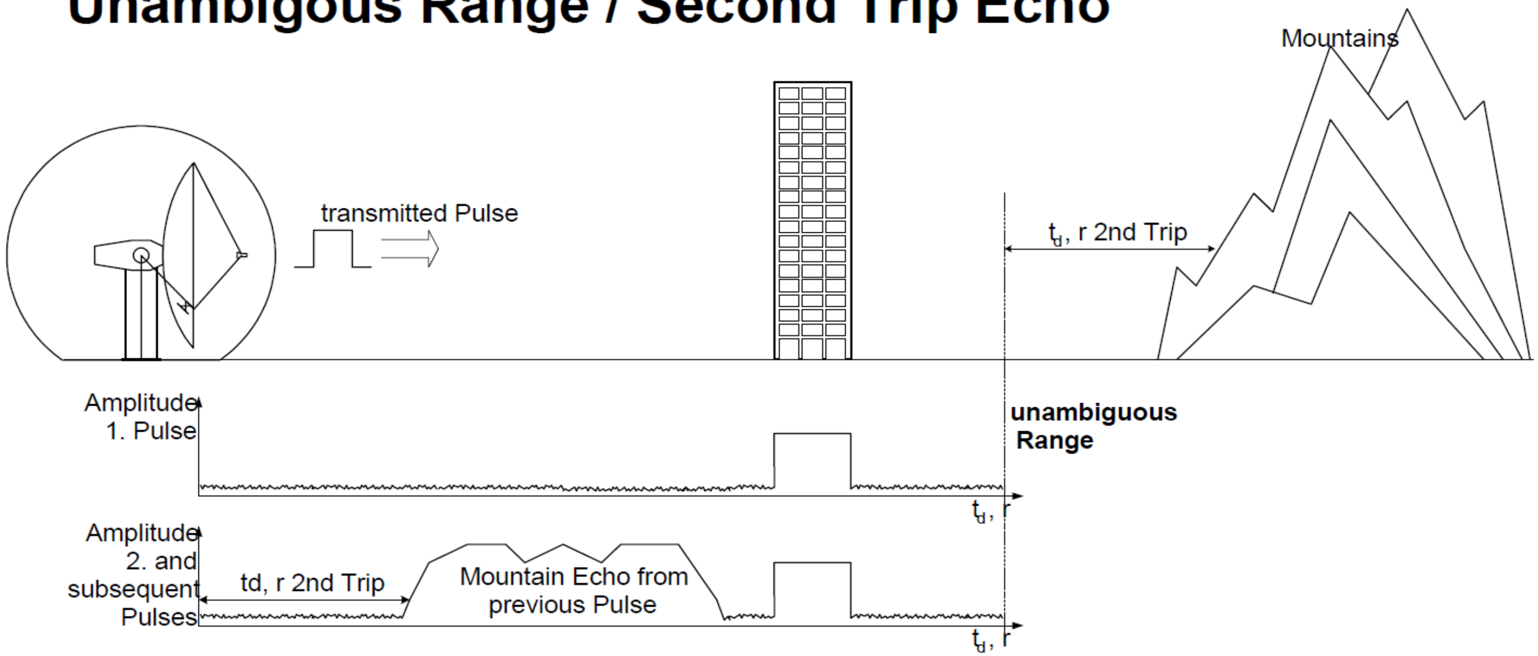


Range Folding

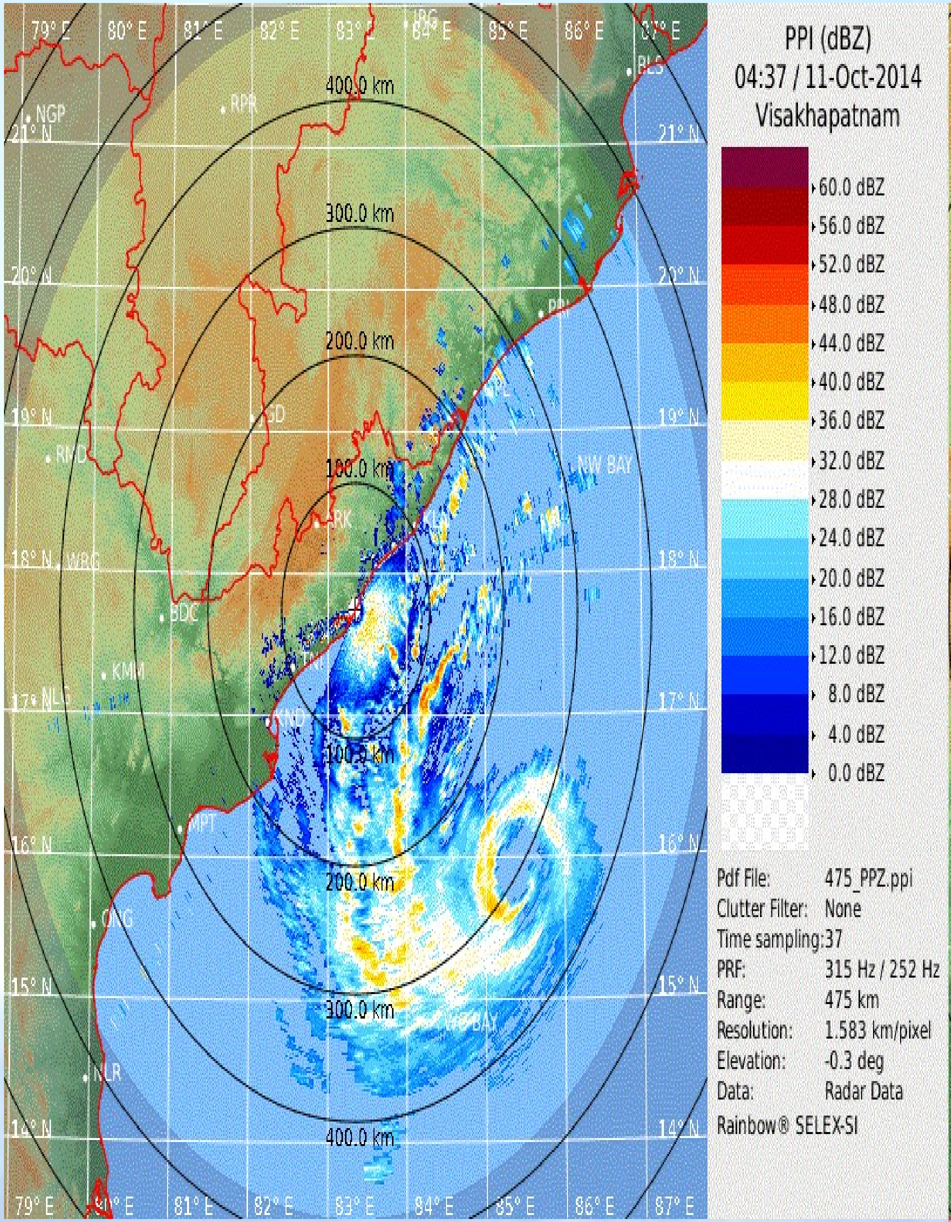
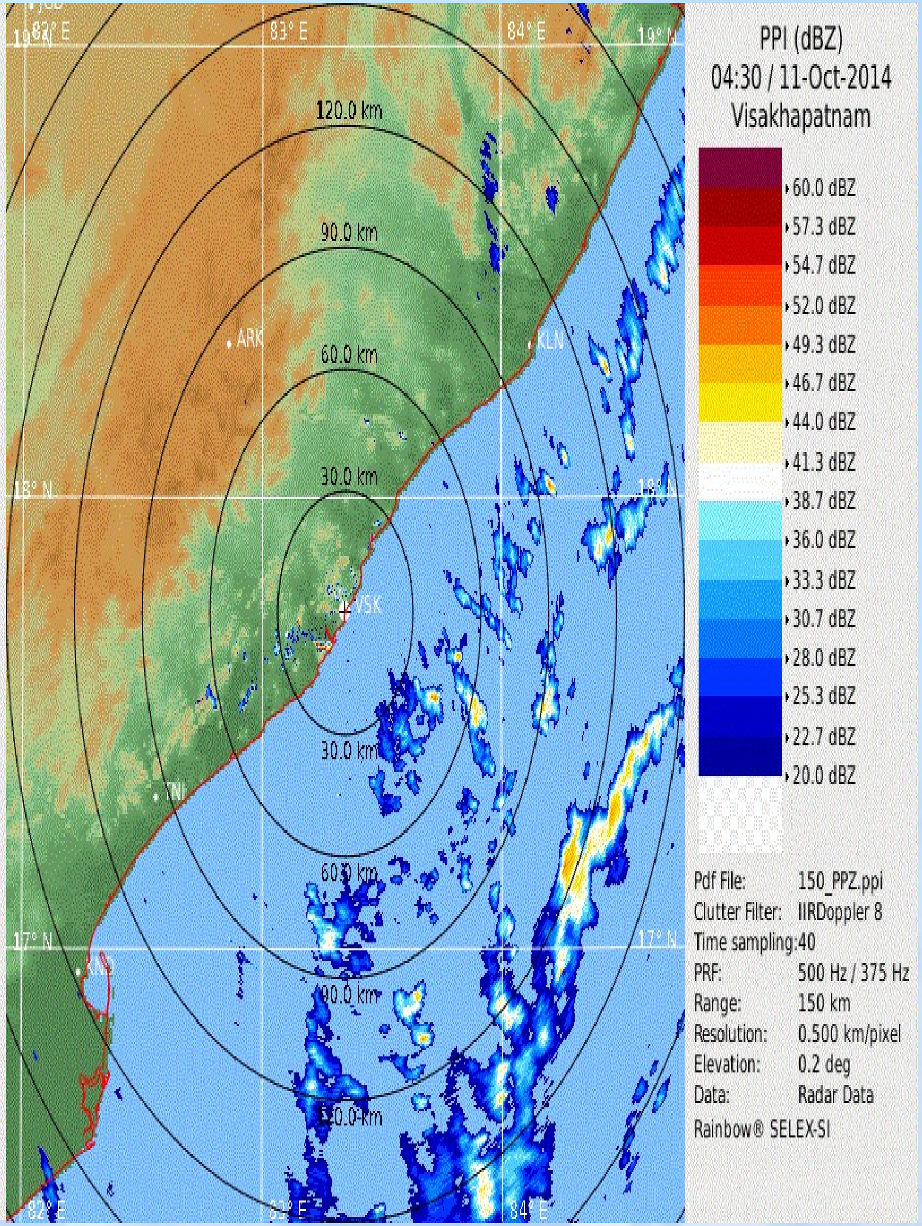
FOR LONGER RANGE – LOW PRF, HIGH PRT

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

Unambigous Range / Second Trip Echo

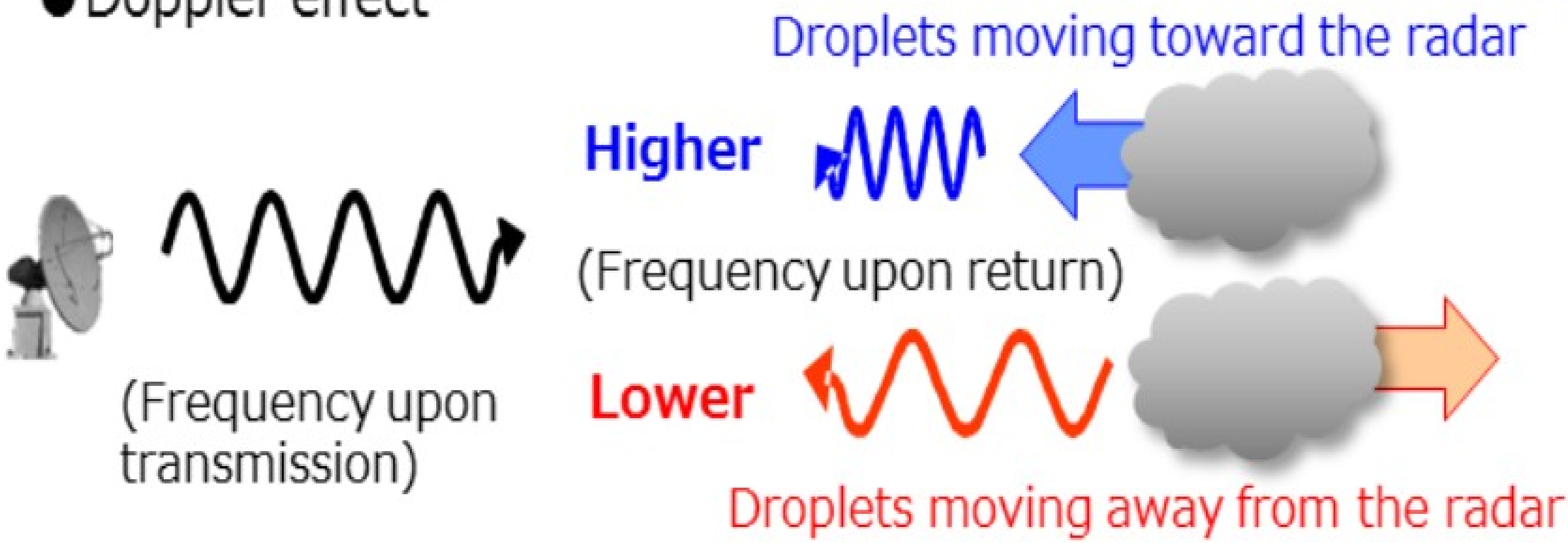


Change PRF: second trip echo will shift position


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
100.0 km
200.0 km
300.0 km
400.0 km
NW BAY
79° E
80° E
81° E
82° E
83° E
84° E
85° E
86° E
87° E
21° N
20° N
19° N
18° N
17° N
16° N
15° N
14° N

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
Rainbow® SELEX-SI
30.0 km
60.0 km
90.0 km
120.0 km
ARK
KLN
VSK
83° E
84° E
19° N
18° N
17° N

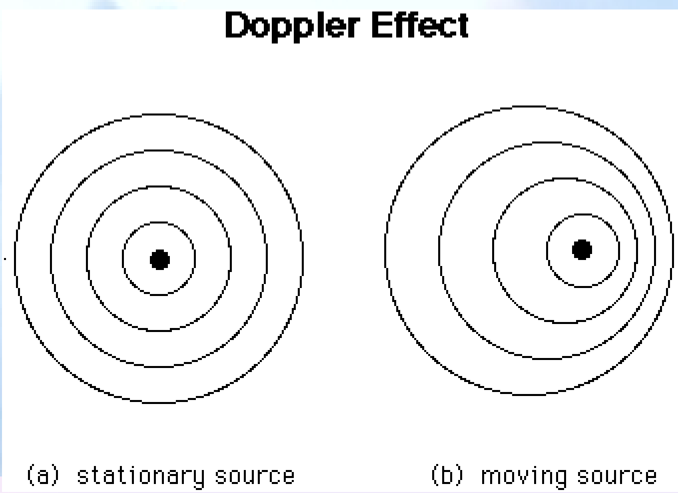
Doppler radar principle

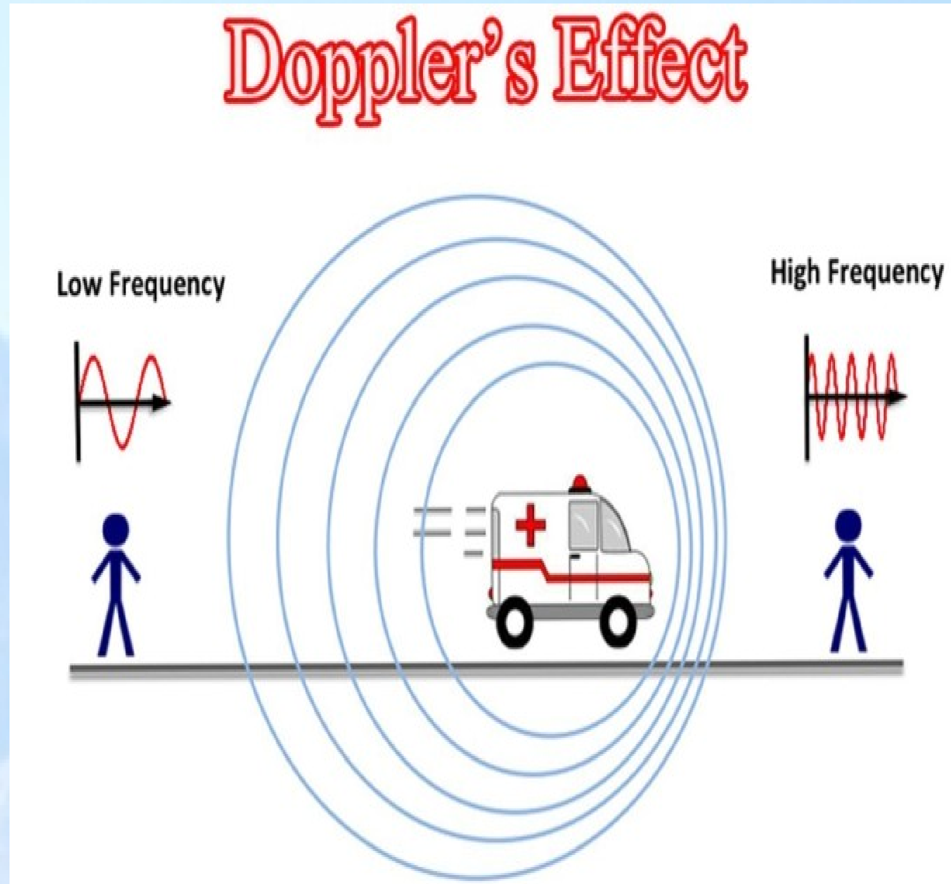
● Doppler effect



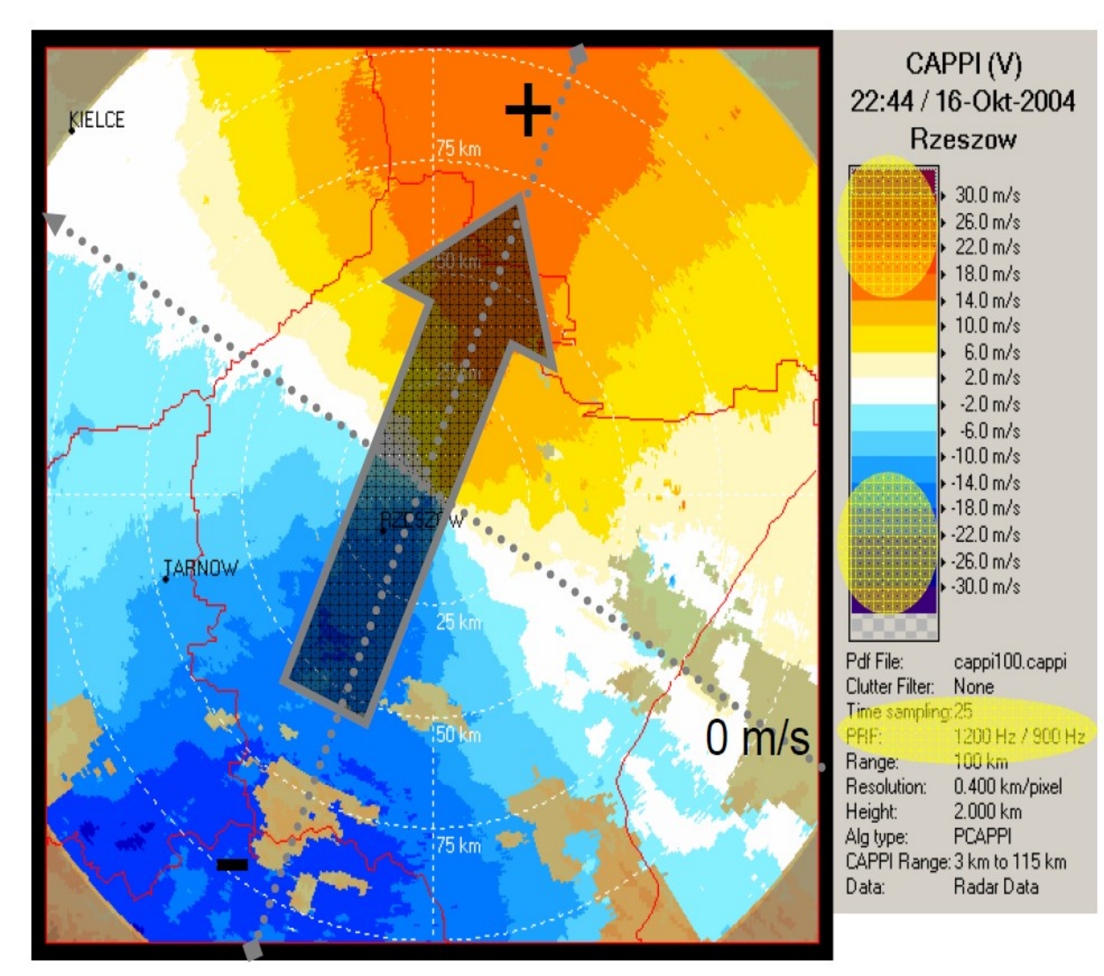
Based on the difference between transmission and return frequency, radar can be used to determine three-dimensional wind distribution in precipitation areas.

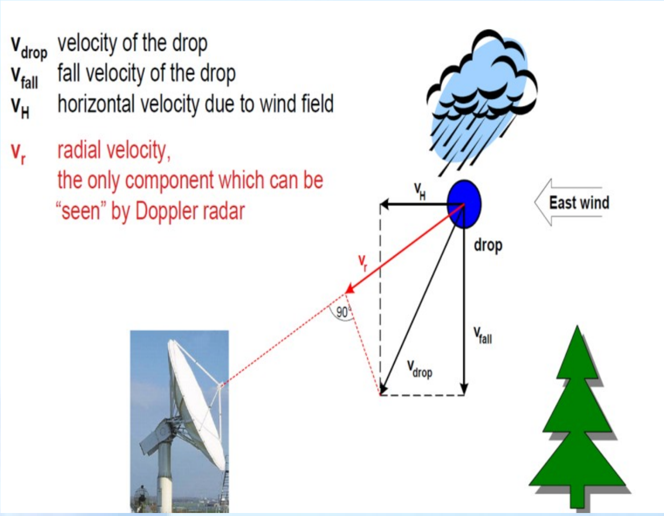
Doppler radar principle

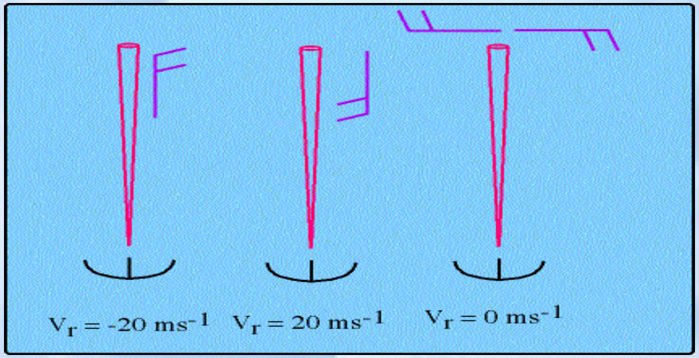


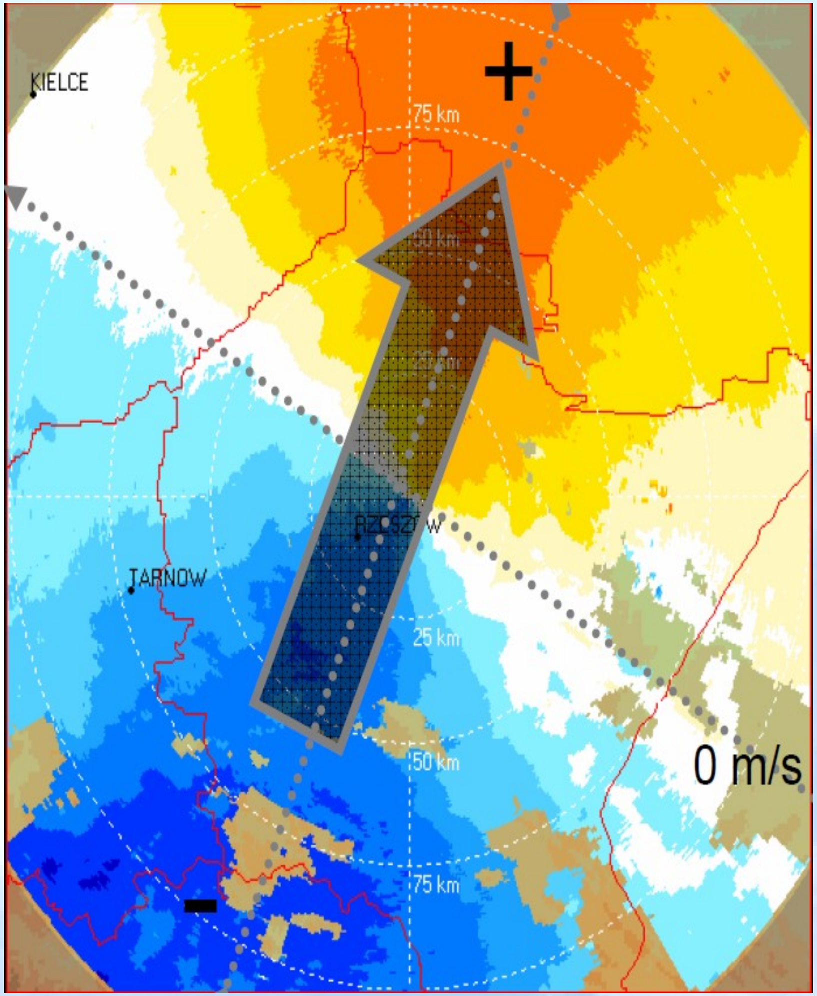


PPI(V)

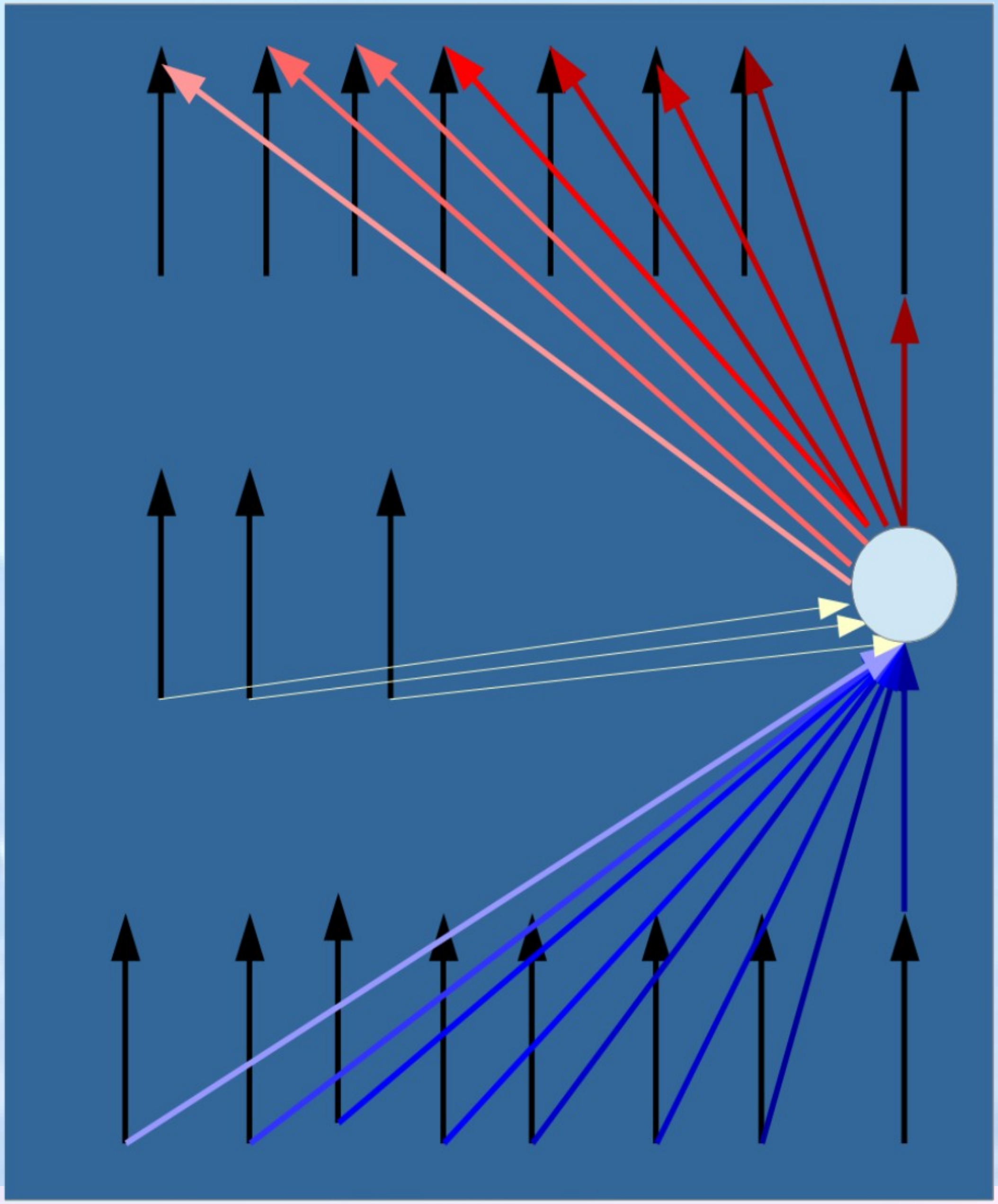

CAPPI (V)
22:44 / 16-Okt-2004
Rzeszow
30.0 m/s
26.0 m/s
22.0 m/s
18.0 m/s
14.0 m/s
10.0 m/s
6.0 m/s
2.0 m/s
-2.0 m/s
-6.0 m/s
-10.0 m/s
-14.0 m/s
-18.0 m/s
-22.0 m/s
-26.0 m/s
-30.0 m/s
Pdf File: cappi100.cappi
Clutter Filter: None
Time sampling: 25
PRF: 1200 Hz / 900 Hz
Range: 100 km
Resolution: 0.400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

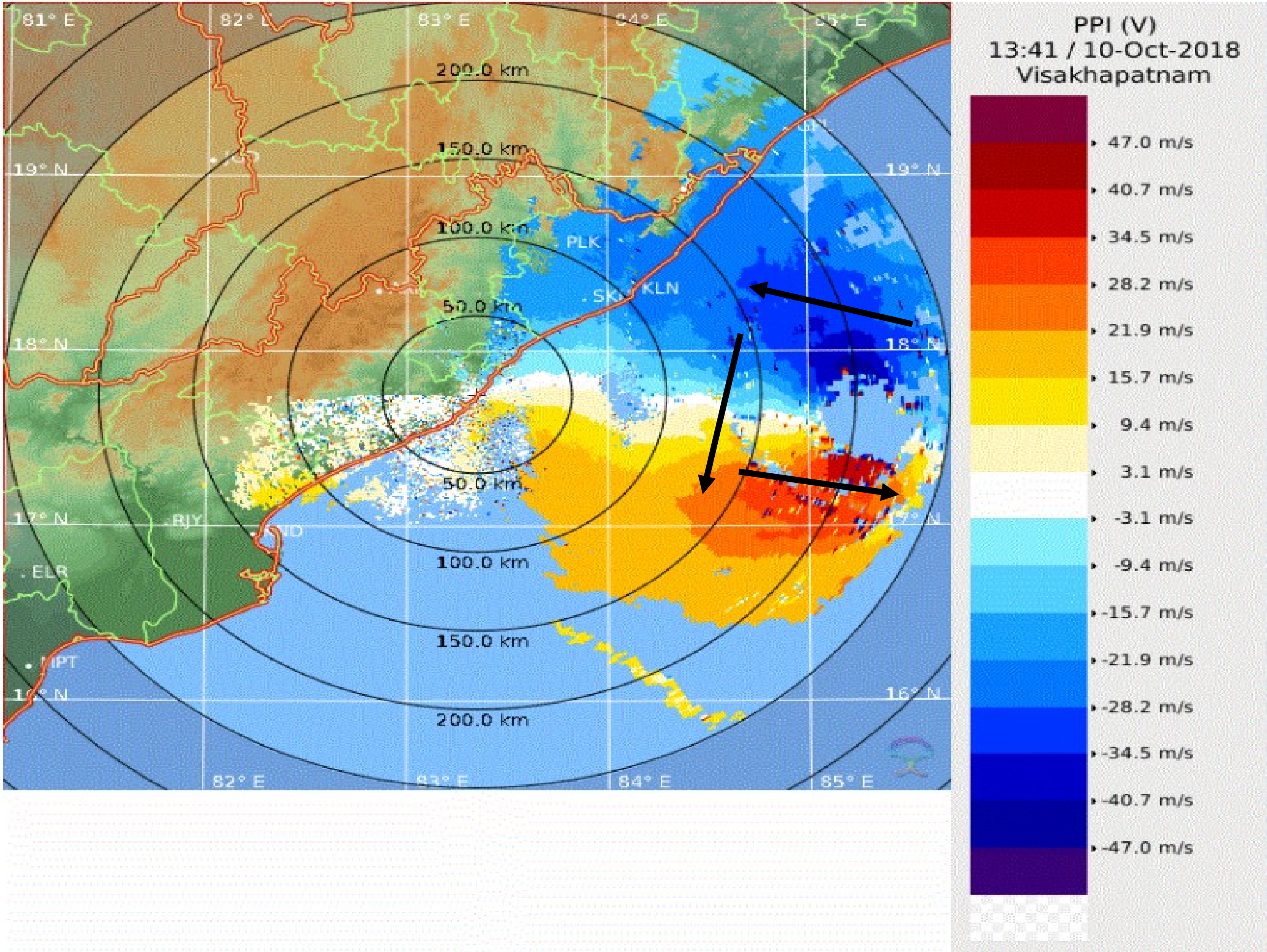

V_{drop} velocity of the drop
V_{fall} fall velocity of the drop
V_H horizontal velocity due to wind field
V_r radial velocity,
the only component which can be
"seen" by Doppler radar
V_H
East wind
drop
V_r
90°
V_{fall}
V_{drop}

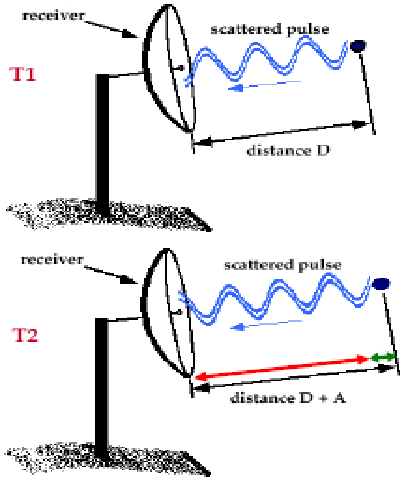

$V_r = -20\ ms^{-1}$
$V_r = 20\ ms^{-1}$
$V_r = 0\ ms^{-1}$



KIELCE
75 km
+
TARNOW
RZESZOW
25 km
50 km
75 km
0 m/s
-




PPI (V)
13:41 / 10-Oct-2018
Visakhapatnam
47.0 m/s
40.7 m/s
34.5 m/s
28.2 m/s
21.9 m/s
15.7 m/s
9.4 m/s
3.1 m/s
-3.1 m/s
-9.4 m/s
-15.7 m/s
-21.9 m/s
-28.2 m/s
-34.5 m/s
-40.7 m/s
-47.0 m/s
200.0 km
150.0 km
100.0 km
50.0 km
81° E
82° E
83° E
84° E
85° E
19° N
18° N
17° N
16° N
PLK
KLN
RJY
ELR



Pulse at time T1 is sent towards a target.

Another pulse at time T2 is sent towards the same target.

→ Distance to target has changed, resulting in a phase shift $\Delta\Phi$.

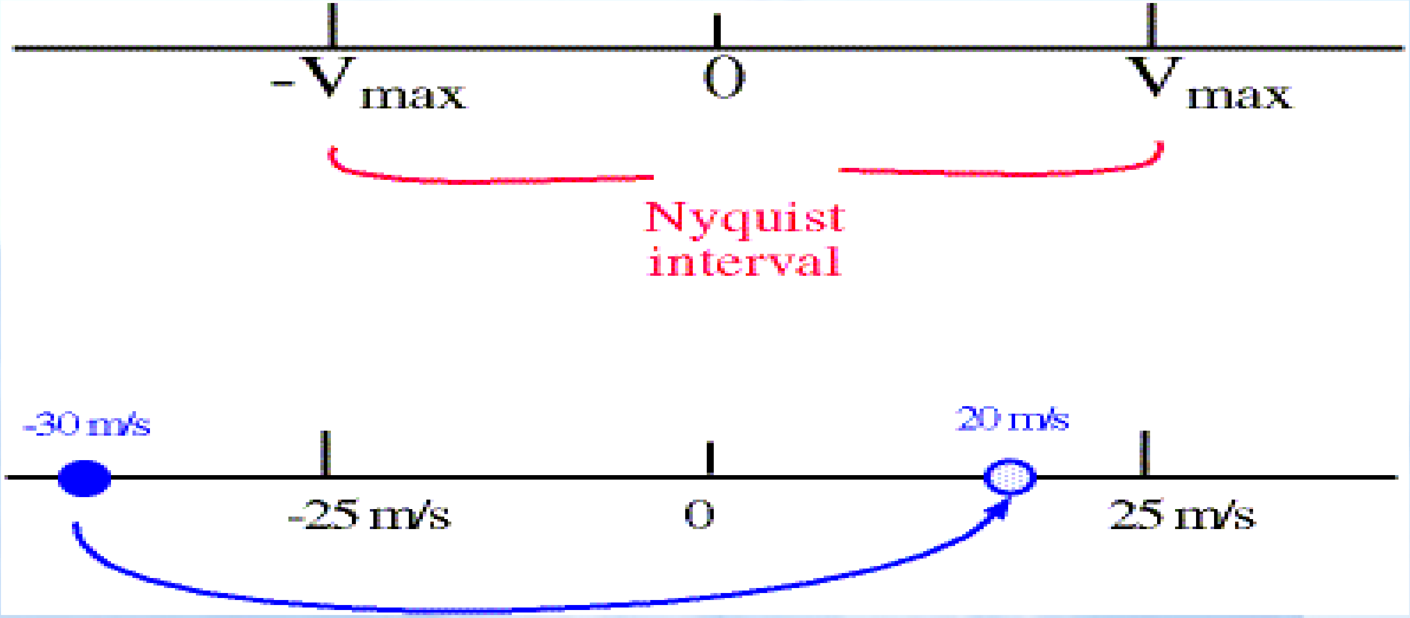
Radial Velocity

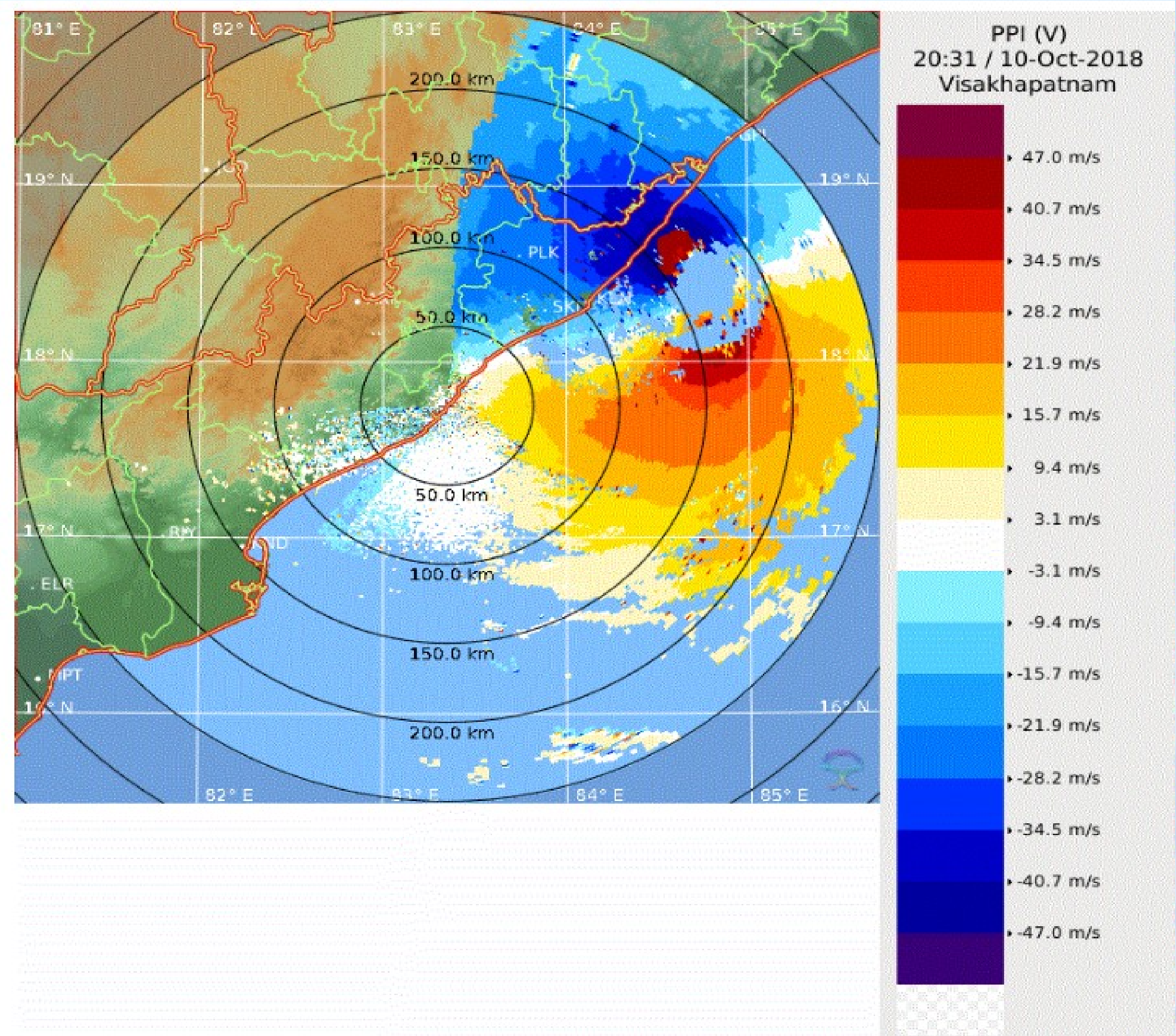
From the phase shift $\Delta\phi$ between two pulses (pulse repetition time Δt) the radial velocity v_r can be derived:

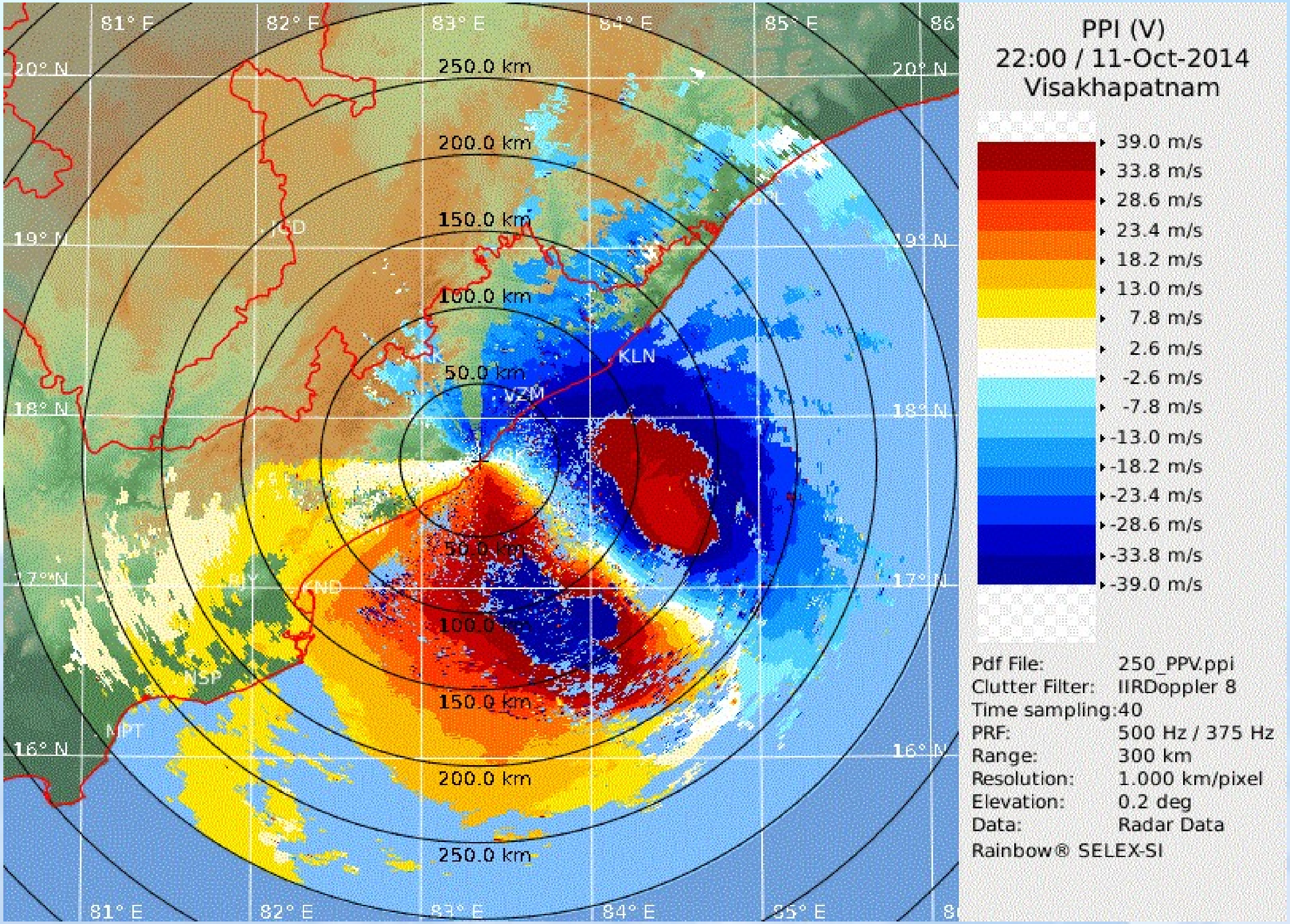
$$v_r = \frac{\Delta r}{\Delta t} = \frac{\lambda}{4\pi}\frac{\Delta\phi}{\Delta t}$$

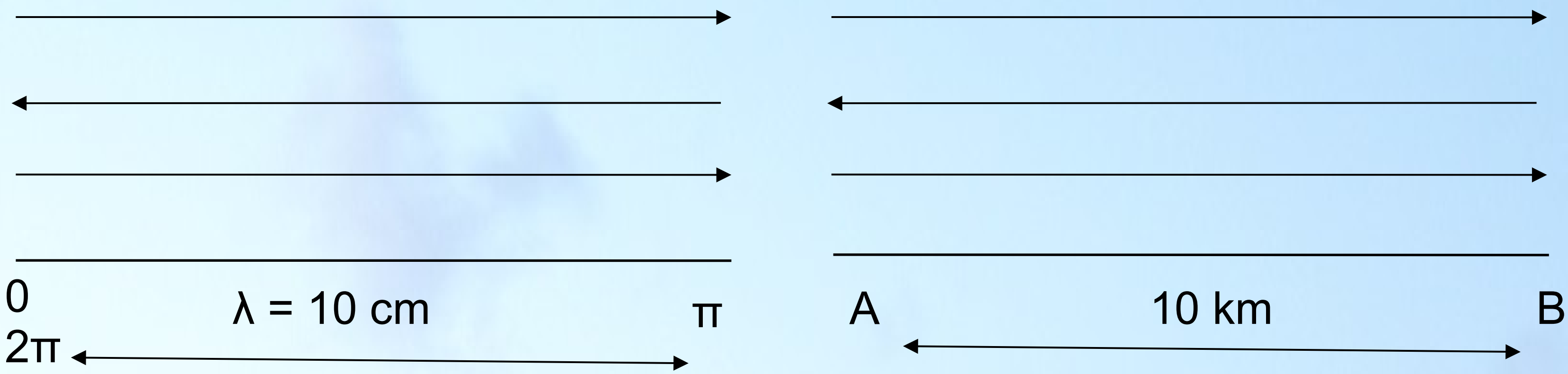
Velocity Folding

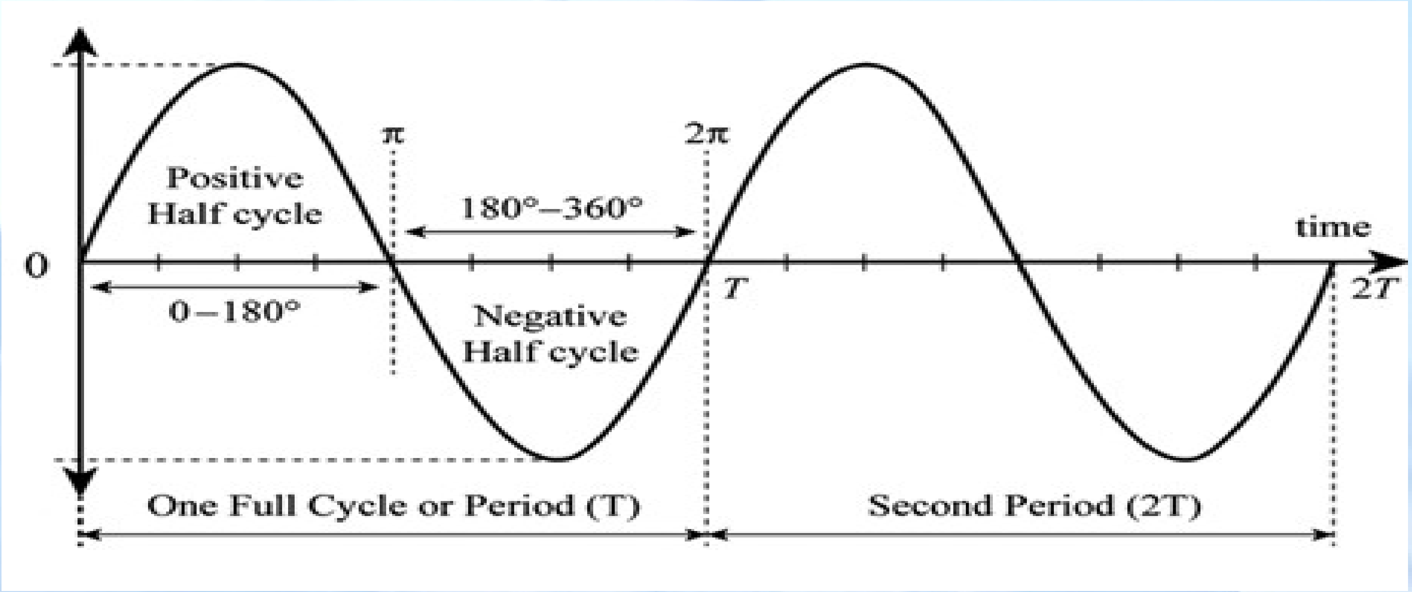
- If a particle's radial velocity is outside the range of the interval, then the radial velocity will be **aliased, or folded**. This is called **velocity folding/aliasing.**
- Example: if max velocity is -25 m/s and the particle's radial velocity is -30 m/s, then it will fold over and the radar will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




PPI (V)
20:31 / 10-Oct-2018
Visakhapatnam
47.0 m/s
40.7 m/s
34.5 m/s
28.2 m/s
21.9 m/s
15.7 m/s
9.4 m/s
3.1 m/s
-3.1 m/s
-9.4 m/s
-15.7 m/s
-21.9 m/s
-28.2 m/s
-34.5 m/s
-40.7 m/s
-47.0 m/s
50.0 km
100.0 km
150.0 km
200.0 km
81° E
82° E
83° E
84° E
85° E
19° N
18° N
17° N
16° N
PLK
ELR
MPT

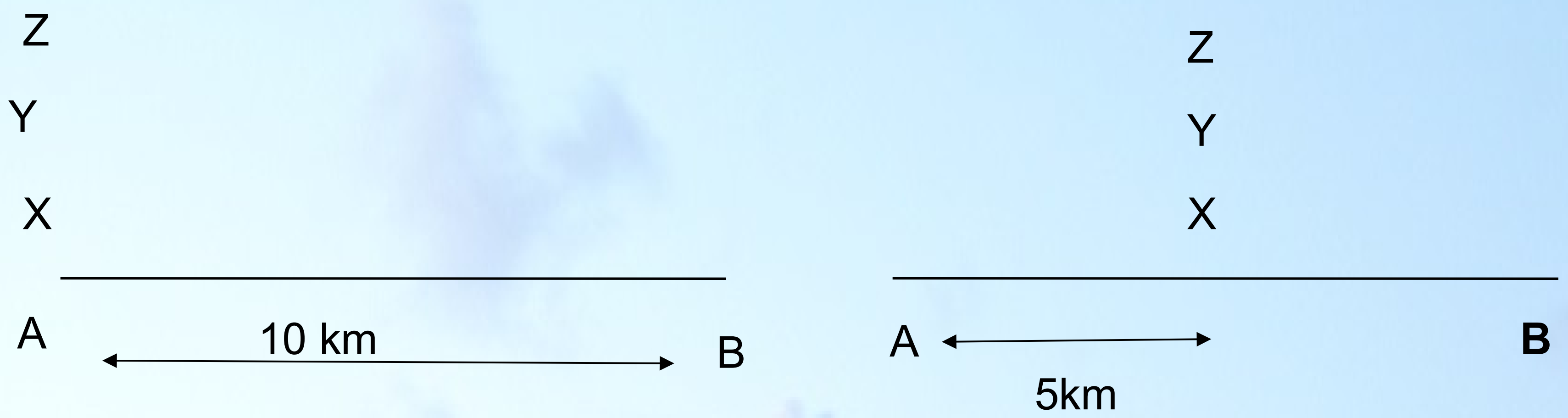

PPI (V)
22:00 / 11-Oct-2014
Visakhapatnam
39.0 m/s
33.8 m/s
28.6 m/s
23.4 m/s
18.2 m/s
13.0 m/s
7.8 m/s
2.6 m/s
-2.6 m/s
-7.8 m/s
-13.0 m/s
-18.2 m/s
-23.4 m/s
-28.6 m/s
-33.8 m/s
-39.0 m/s
Pdf File: 250_PPV.ppi
Clutter Filter: IIRDoppler 8
Time sampling:40
PRF: 500 Hz / 375 Hz
Range: 300 km
Resolution: 1.000 km/pixel
Elevation: 0.2 deg
Data: Radar Data
Rainbow® SELEX-SI
250.0 km
200.0 km
150.0 km
100.0 km
50.0 km
81° E
82° E
83° E
84° E
85° E
20° N
19° N
18° N
17° N
16° N
KLN
VZM


0
2π
λ = 10 cm
π
A
10 km
B

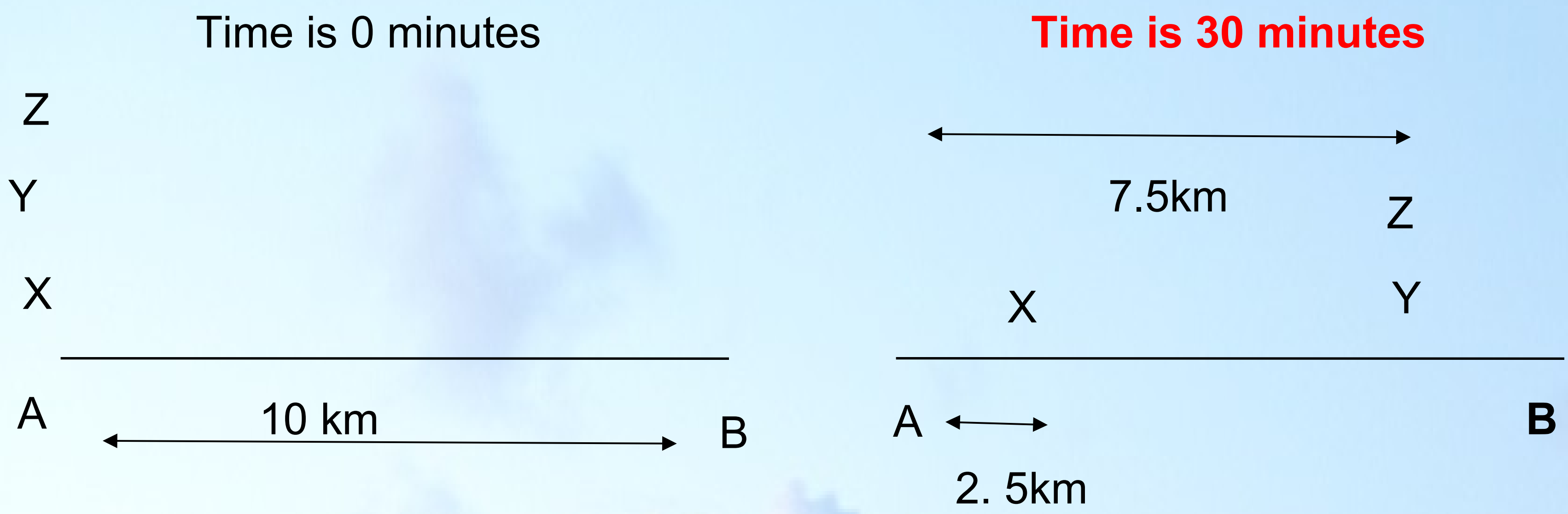

π
2π
Positive
Half cycle
180°–360°
time
0
T
2T
0–180°
Negative
Half cycle
One Full Cycle or Period (T)
Second Period (2T)

Time is 0 minutes

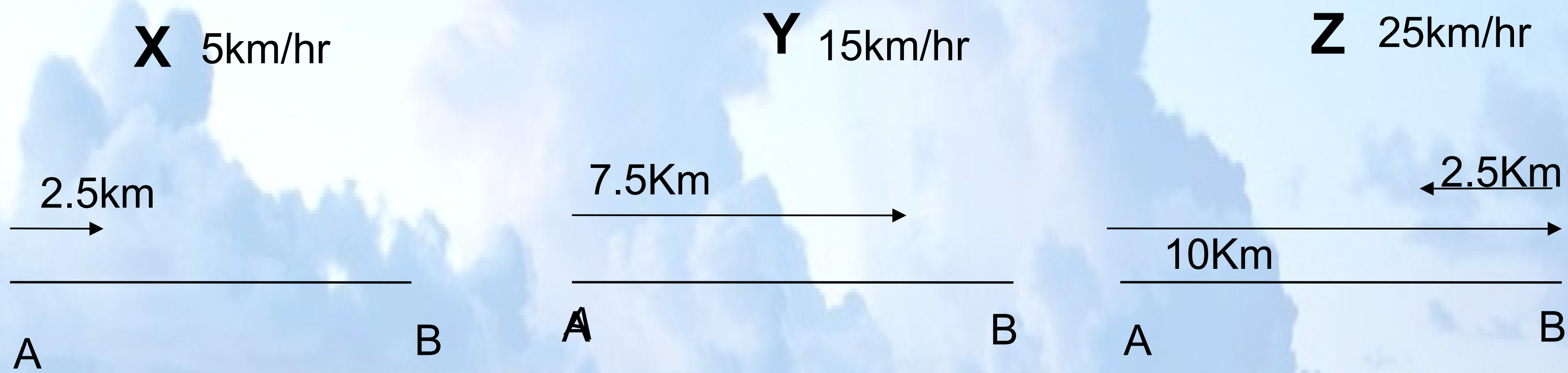
Time is 60 minutes



SPEED OF X Y Z IS 5 Km/hr ?????
UNAMBIGUOS MAX SPEED IS ONLY 10KM/HR



SPEED OF Y Z IS 15 Km/hr ?????
UNAMBIGUOS max SPEED is 10km/0.5 hr = 20 km/hr



Time is 0 minutes

Z

Y

X

A

10 km

B

Time is 15 minutes

Z

Y

X

A

B

SPEED OF X Y Z are not ambiguos
UNAMBIGOUS max SPEED is 10km/0.25 hr =40 km/hr

X 5km/hr

1.25km

A B

Y 15km/hr

3.75Km

A B

Z 25km/hr

6.25Km

A B

DOPPLER DILEMMA

For Higher Velocity – High PRF, Low PRT
For Longer Range – Low PRF, High PRT

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

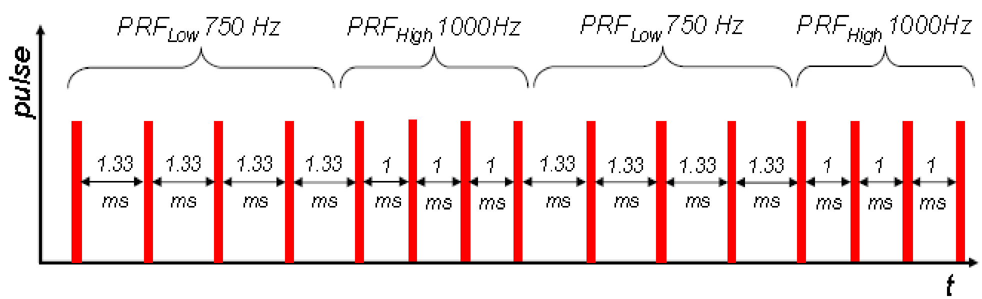
Maximum unambiguous Doppler velocity, v_{max}, is

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

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

Techniques to manage velocity Folding

Dual-PRF (Staggering)



Single-PRF

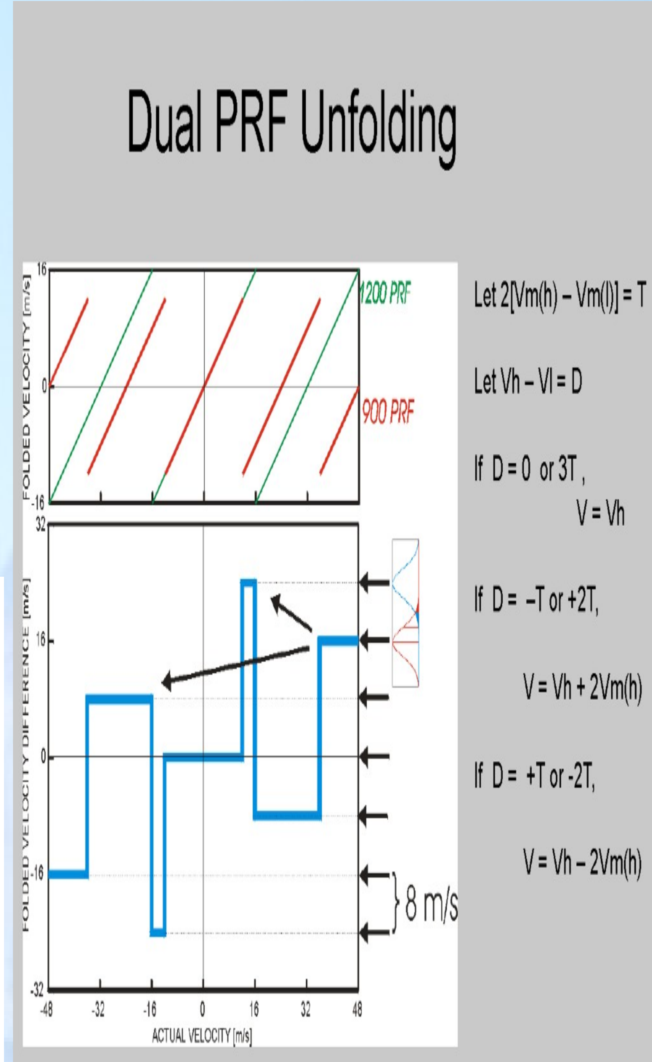
$$v_u = \frac{\lambda}{4 \cdot \Delta t} = \frac{\lambda}{4} PRF$$

Dual-PRF

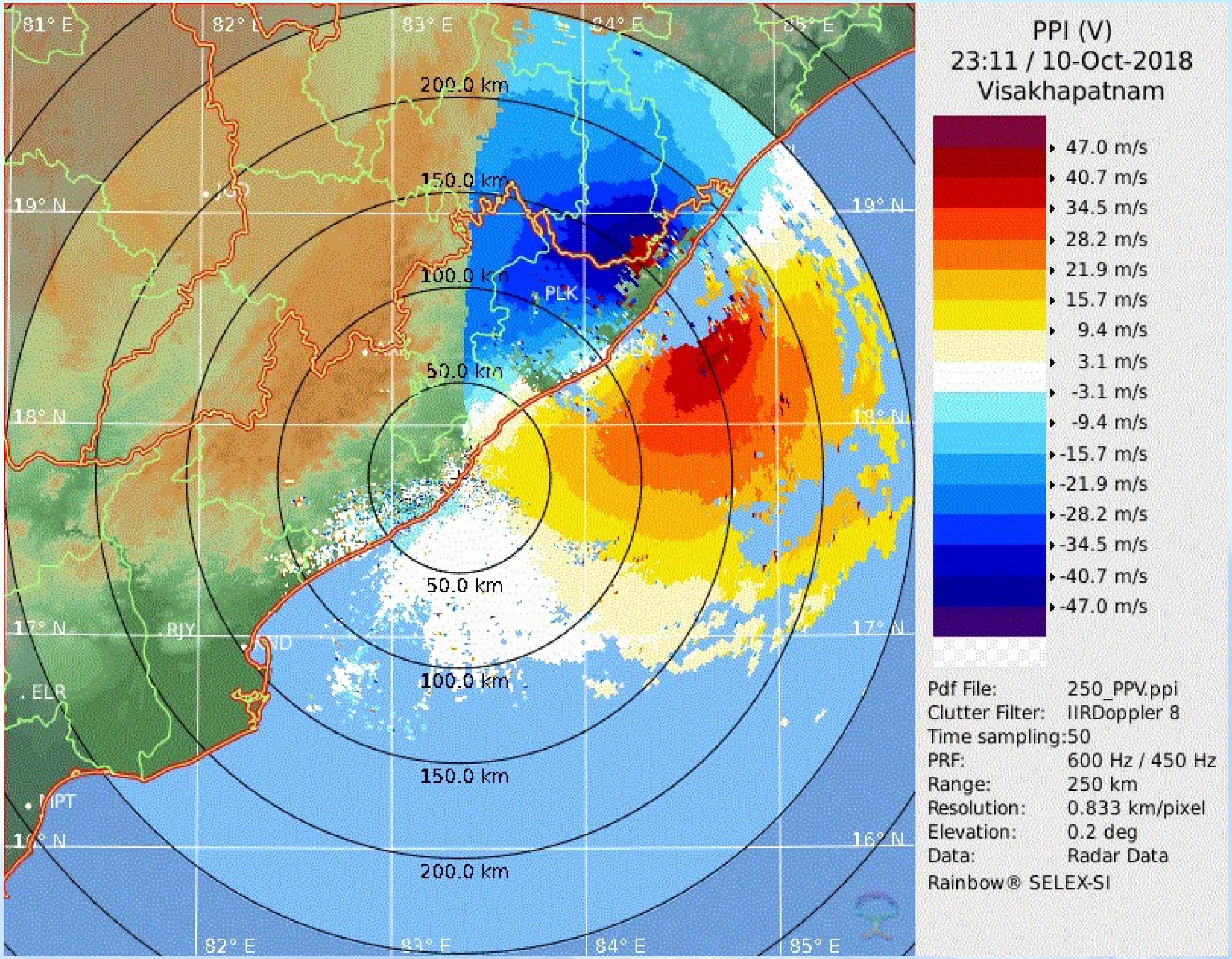
$$v_u = \frac{\lambda}{4} PRF_{High} \cdot \frac{PRF_{Low}}{(PRF_{High} - PRF_{Low})}$$

Unfolding method to extend unambigous velocity:

PRF_{High}	Stagg.	PRF_{Low}	S-Band	C-Band	X-Band
1000 Hz	non	----	27 m/s	13 m/s	9 m/s
1000 Hz	3 : 2	667 Hz	54 m/s	27 m/s	18 m/s
1000 Hz	4 : 3	750 Hz	81 m/s	40 m/s	27 m/s
1000 Hz	5 : 4	800 Hz	108 m/s	54 m/s	36 m/s



Manual unfolding



V max = -47 m/s = 169 km/hr for 600/450Hz

1st Folding Max= 340 km/hr

Cyclone cannot have wind speed to give 2nd folding

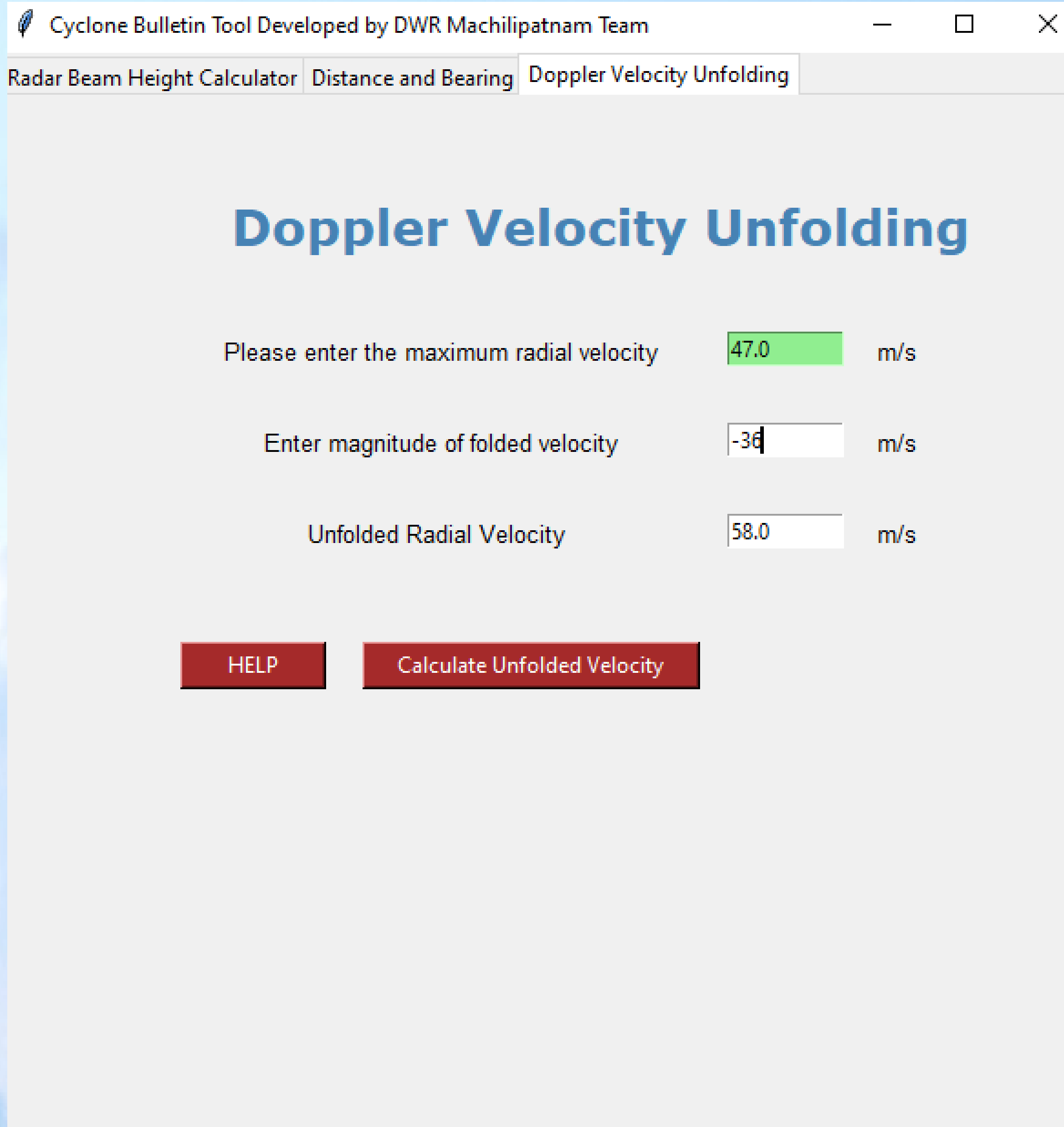
Manually convert the max velocity for Bulletin

Works for 1st Folding only

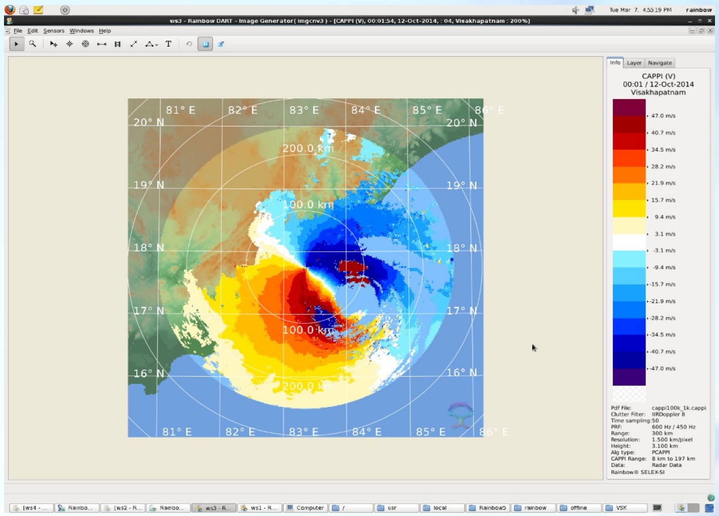
Unfolded velocity

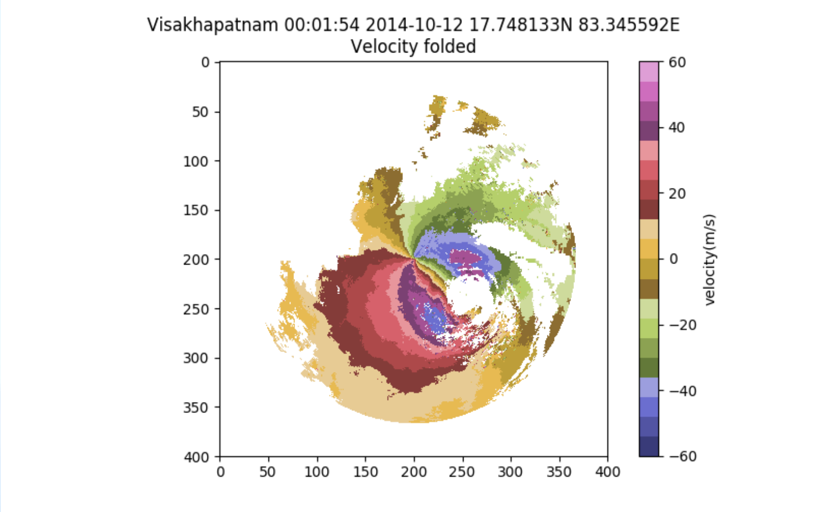
= 2Vmax + folded velocity

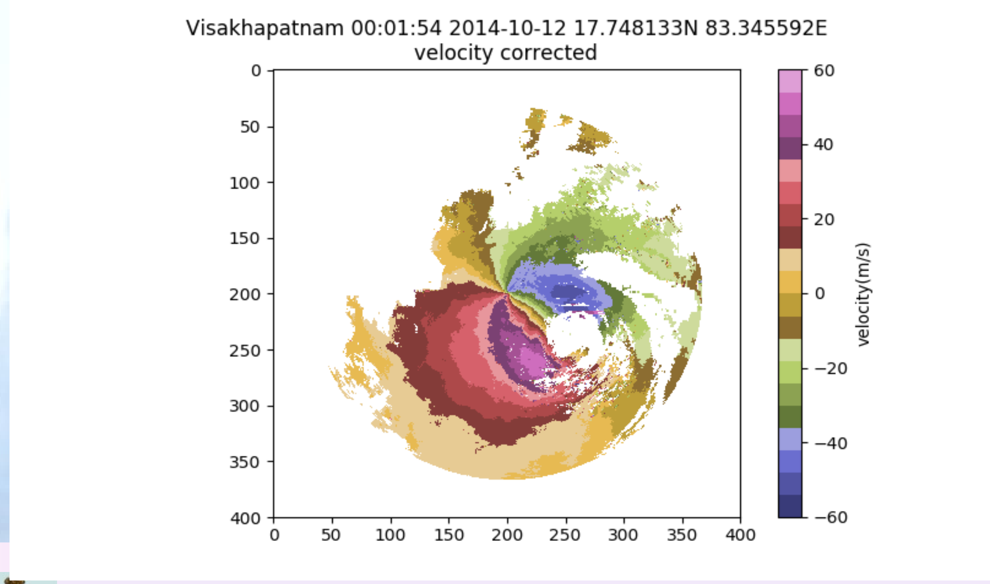
= -2Vmax + folded velocity



Algorithms for de-aliasing







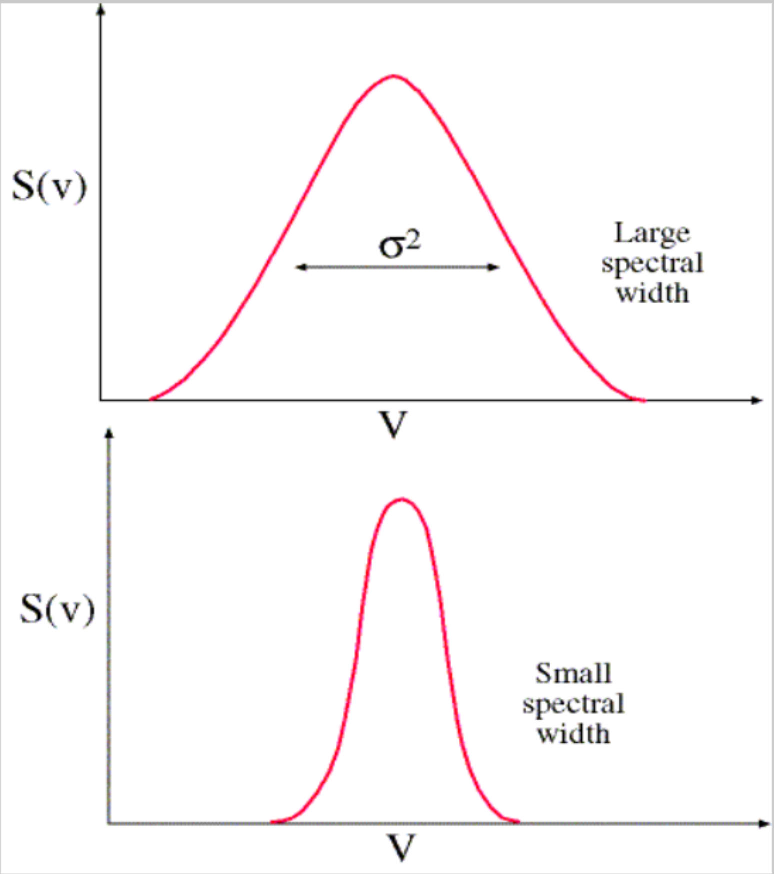
"De-aliasing velocity folding and estimation of surface wind speed in Cyclone using Doppler weather Radar products " , Bibraj R, K Ramachandra Rao , Journal of Polytechnics in Andhra Pradesh, 3(1), 51-55, 2019

Spectrum width

The width of the Doppler power spectrum can tell us more about the scatterers:
The spread of the Doppler power spectrum, referred to as the **spectral width,** is found by computing the variance. The spectral width depends on:
1.the spread, range of terminal fall speeds of the scatterers (more pronounced for rain than for snow)

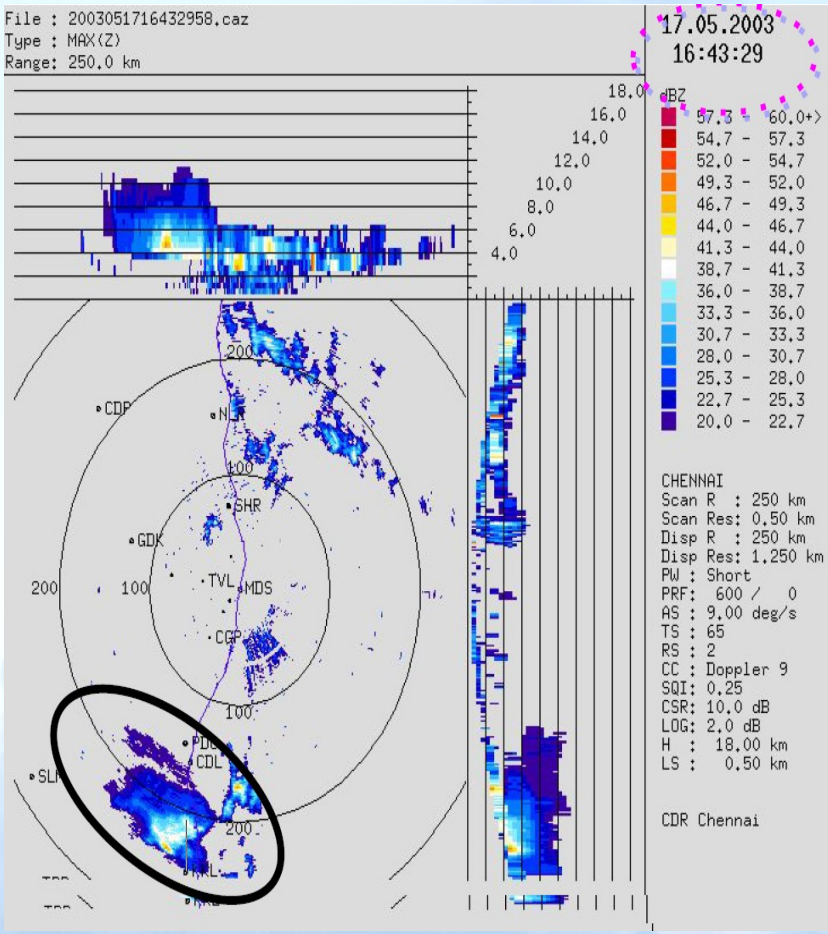
1. spectra for rain
2. spectra for snow

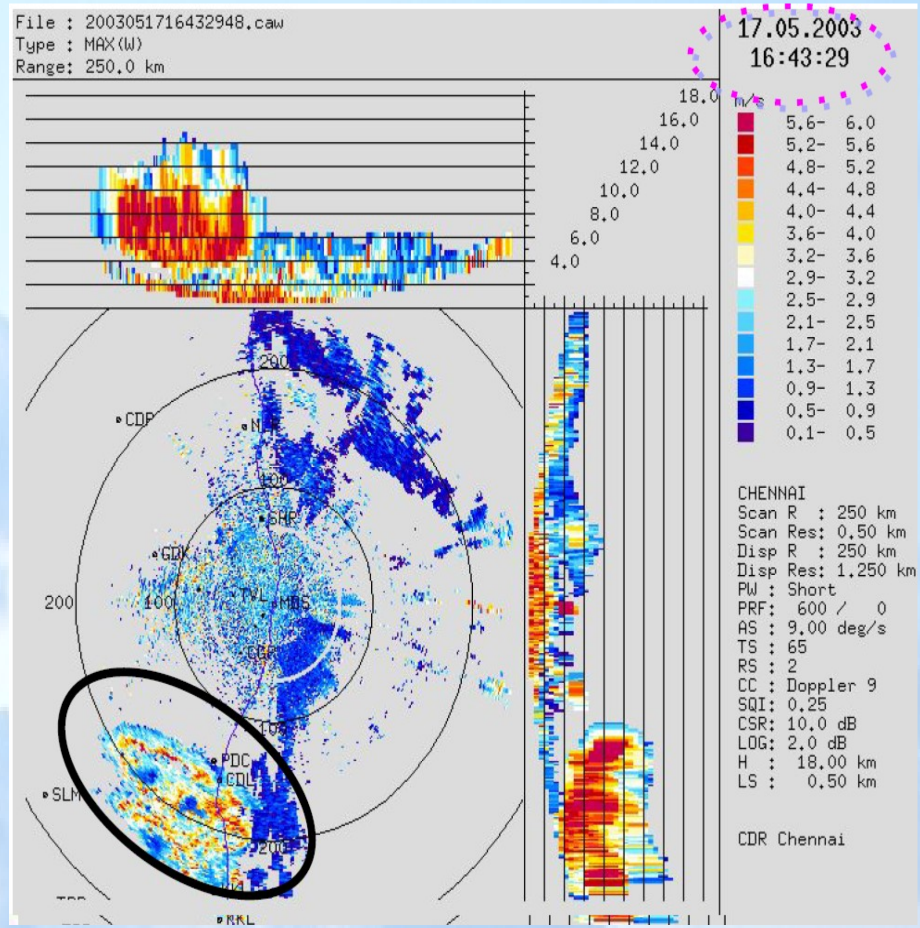
2.turbulence of the air (upper levels in severe convection)
3.vertical wind shear (e.g., along a gust front)
4.antenna motion
Then, the total spectral width is due to the sum of the aforementioned effects



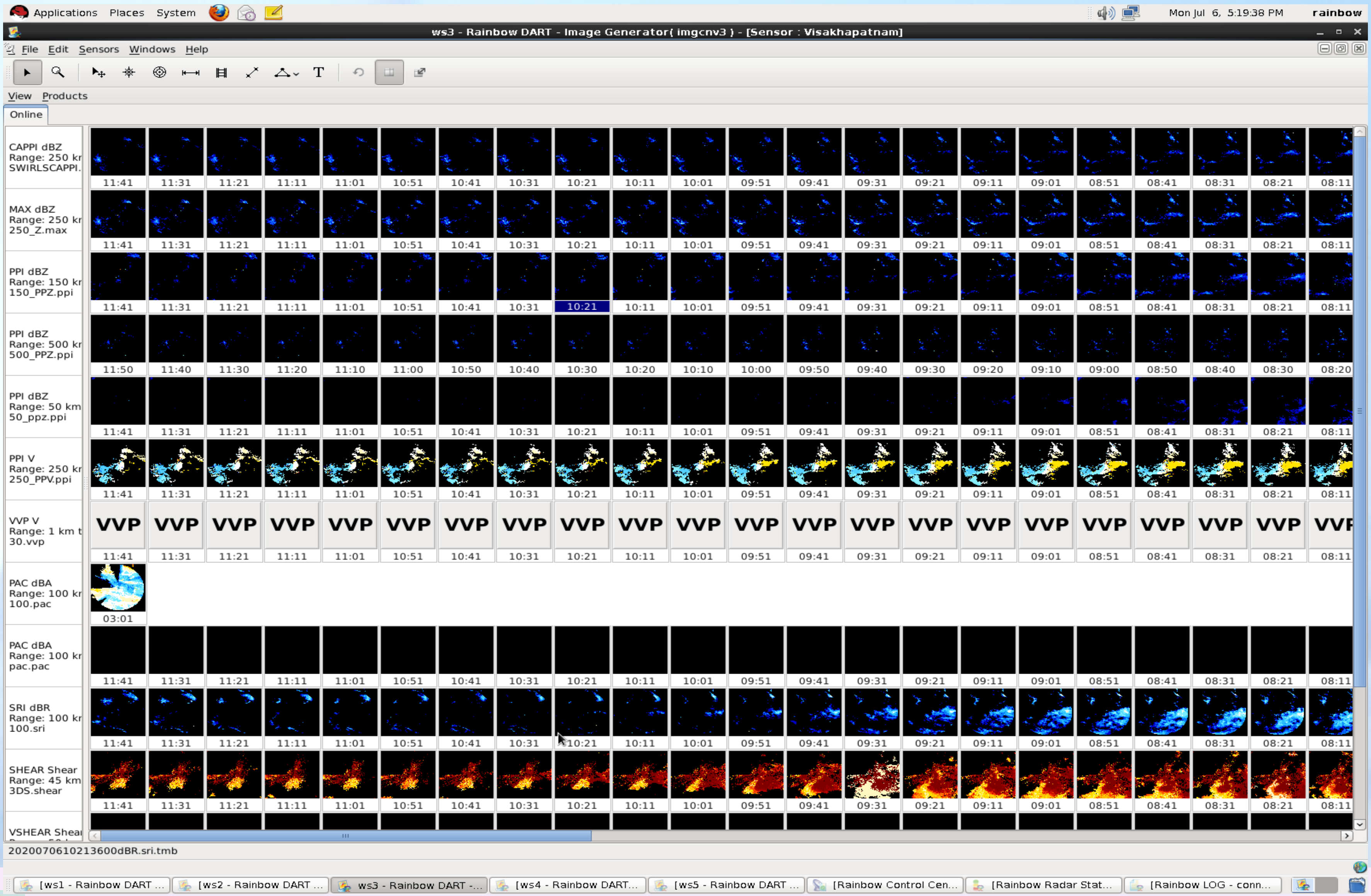
High Spectrum Width

Low Spectrum Width


File : 2003051716432958.caz
Type : MAX(Z)
Range: 250.0 km
17.05.2003
16:43:29
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
CHENNAI
Scan R : 250 km
Scan Res: 0.50 km
Disp R : 250 km
Disp Res: 1.250 km
PW : Short
PRF: 600 / 0
AS : 9.00 deg/s
TS : 65
RS : 2
CC : Doppler 9
SQI: 0.25
CSR: 10.0 dB
LOG: 2.0 dB
H : 18.00 km
LS : 0.50 km
CDR Chennai

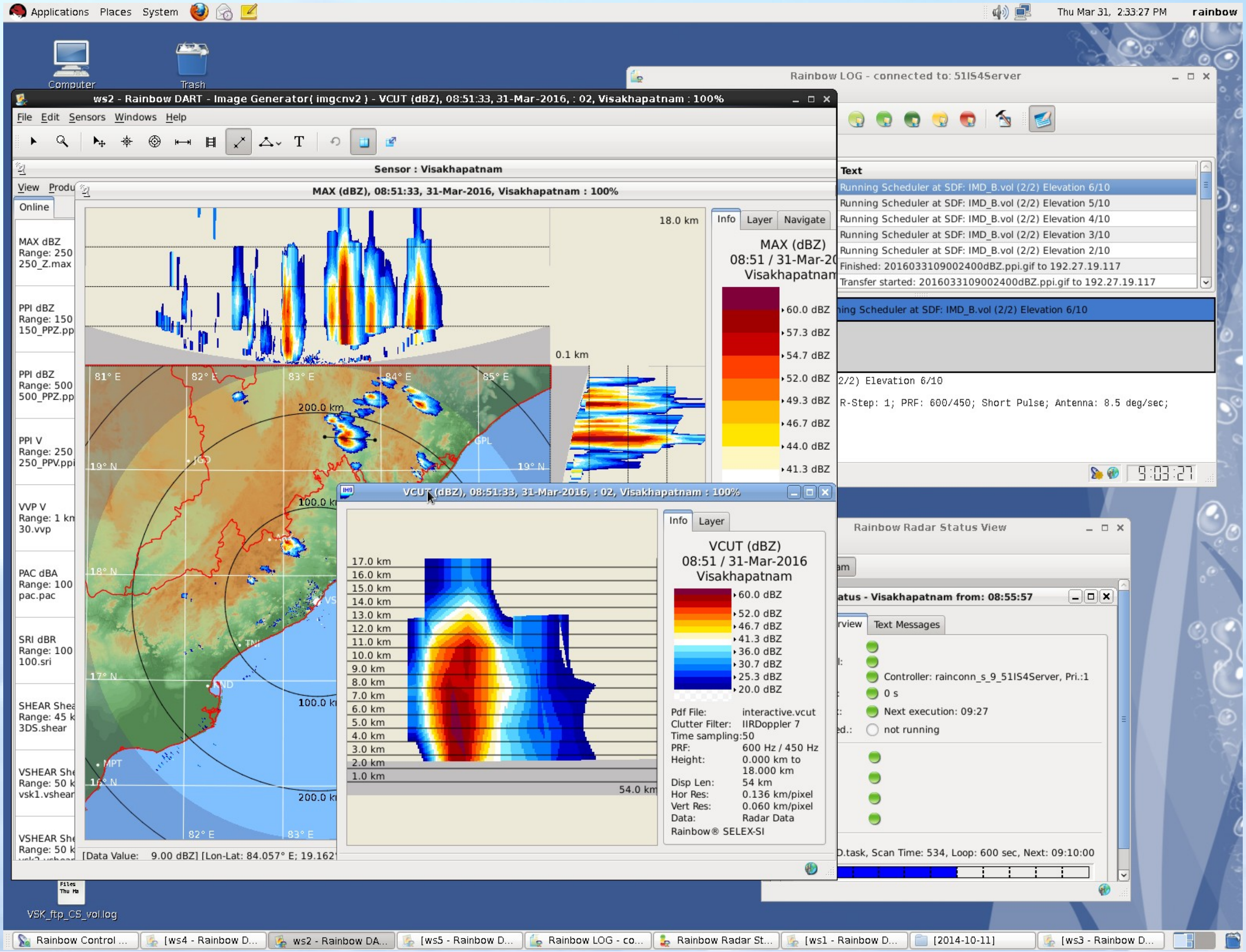

File : 2003051716432948.caw
Type : MAX(W)
Range: 250.0 km
17.05.2003
16:43:29
m/s
5.6- 6.0
5.2- 5.6
4.8- 5.2
4.4- 4.8
4.0- 4.4
3.6- 4.0
3.2- 3.6
2.9- 3.2
2.5- 2.9
2.1- 2.5
1.7- 2.1
1.3- 1.7
0.9- 1.3
0.5- 0.9
0.1- 0.5
CHENNAI
Scan R : 250 km
Scan Res: 0.50 km
Disp R : 250 km
Disp Res: 1.250 km
PW : Short
PRF: 600 / 0
AS : 9.00 deg/s
TS : 65
RS : 2
CC : Doppler 9
SQI: 0.25
CSR: 10.0 dB
LOG: 2.0 dB
H : 18.00 km
LS : 0.50 km
CDR Chennai

Rainbow Software



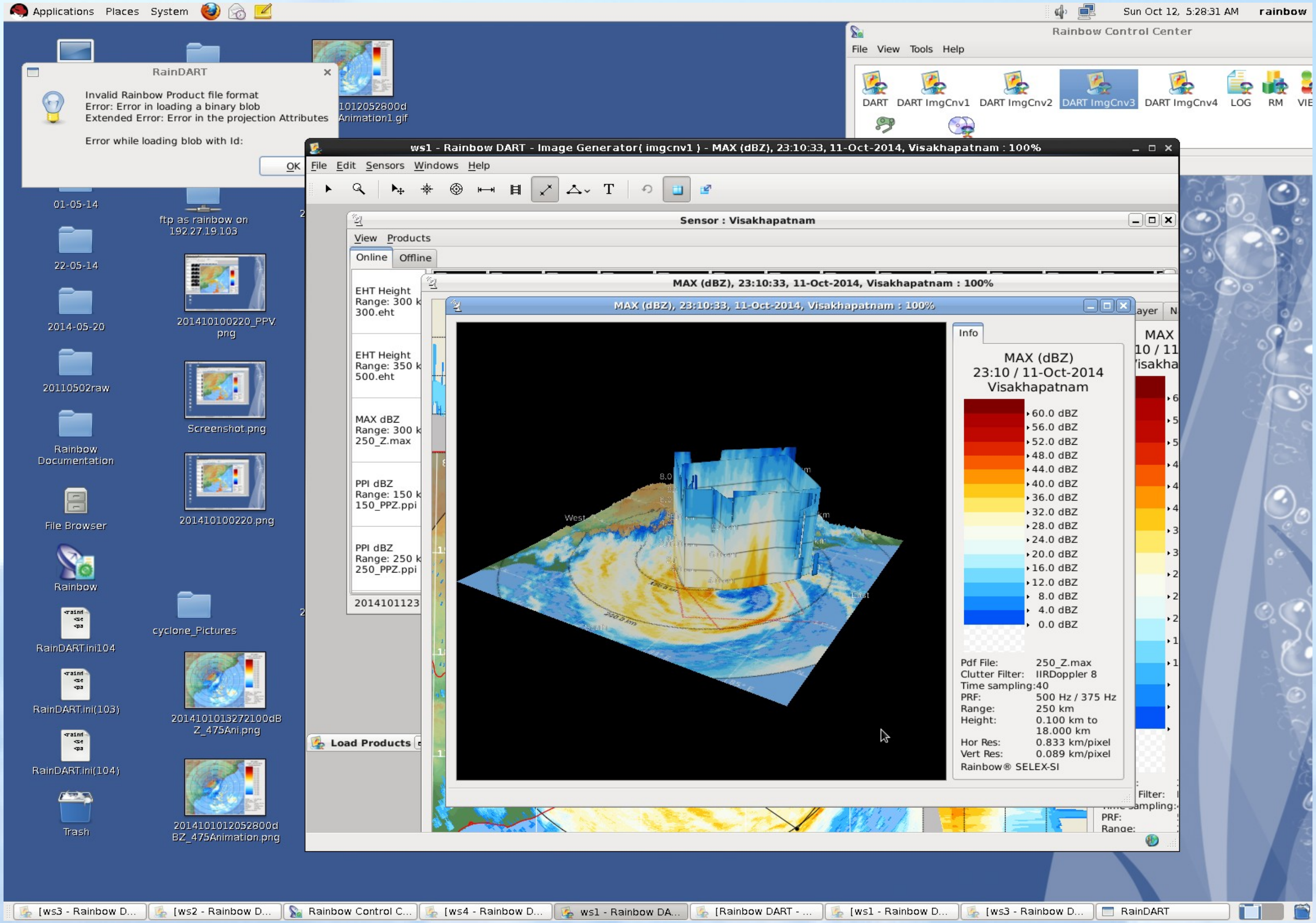
भारत मौसम विज्ञान विभाग

INDIA METEOROLOGICAL DEPARTMENT

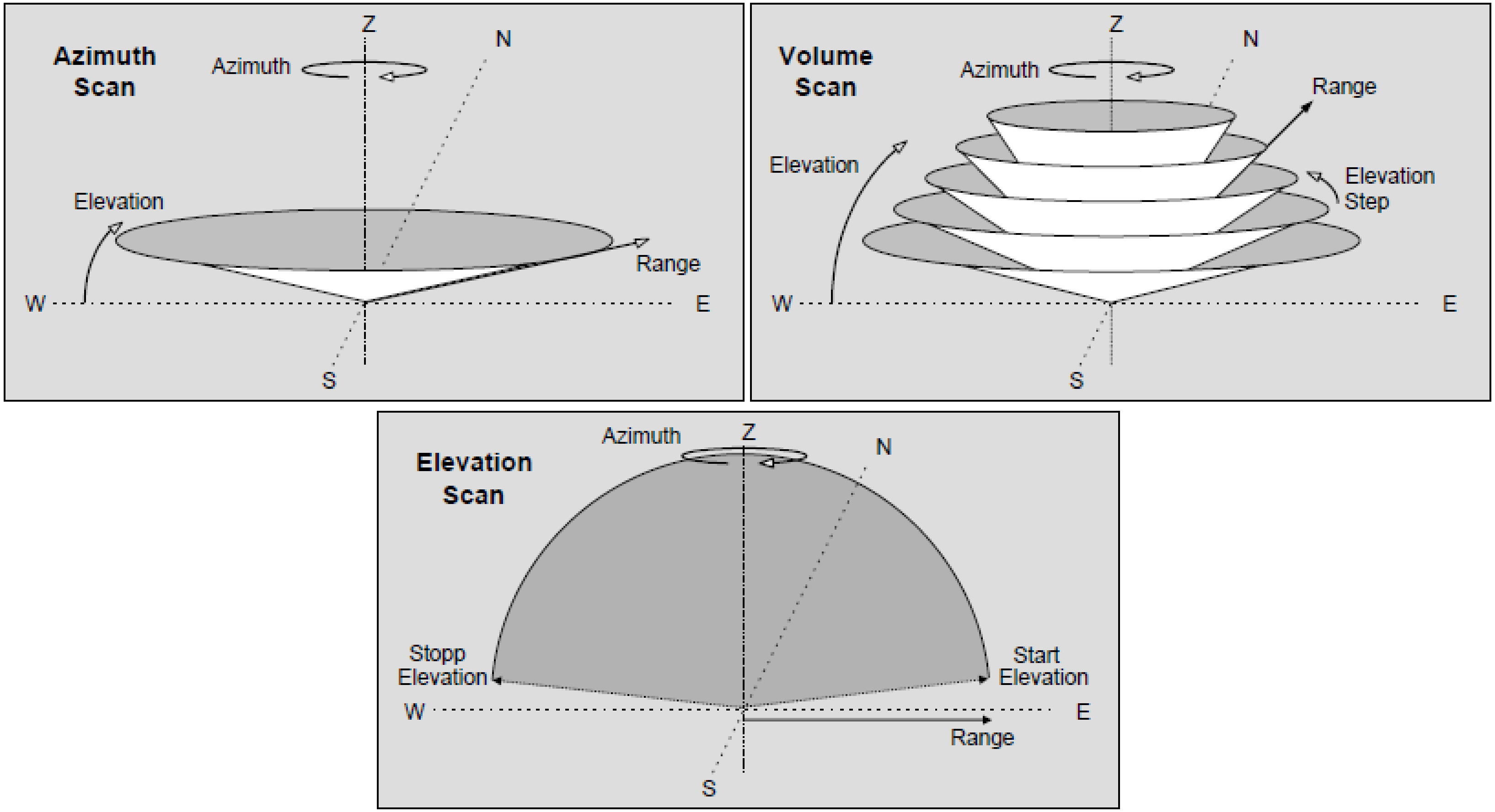


भारत मौसम विज्ञान विभाग

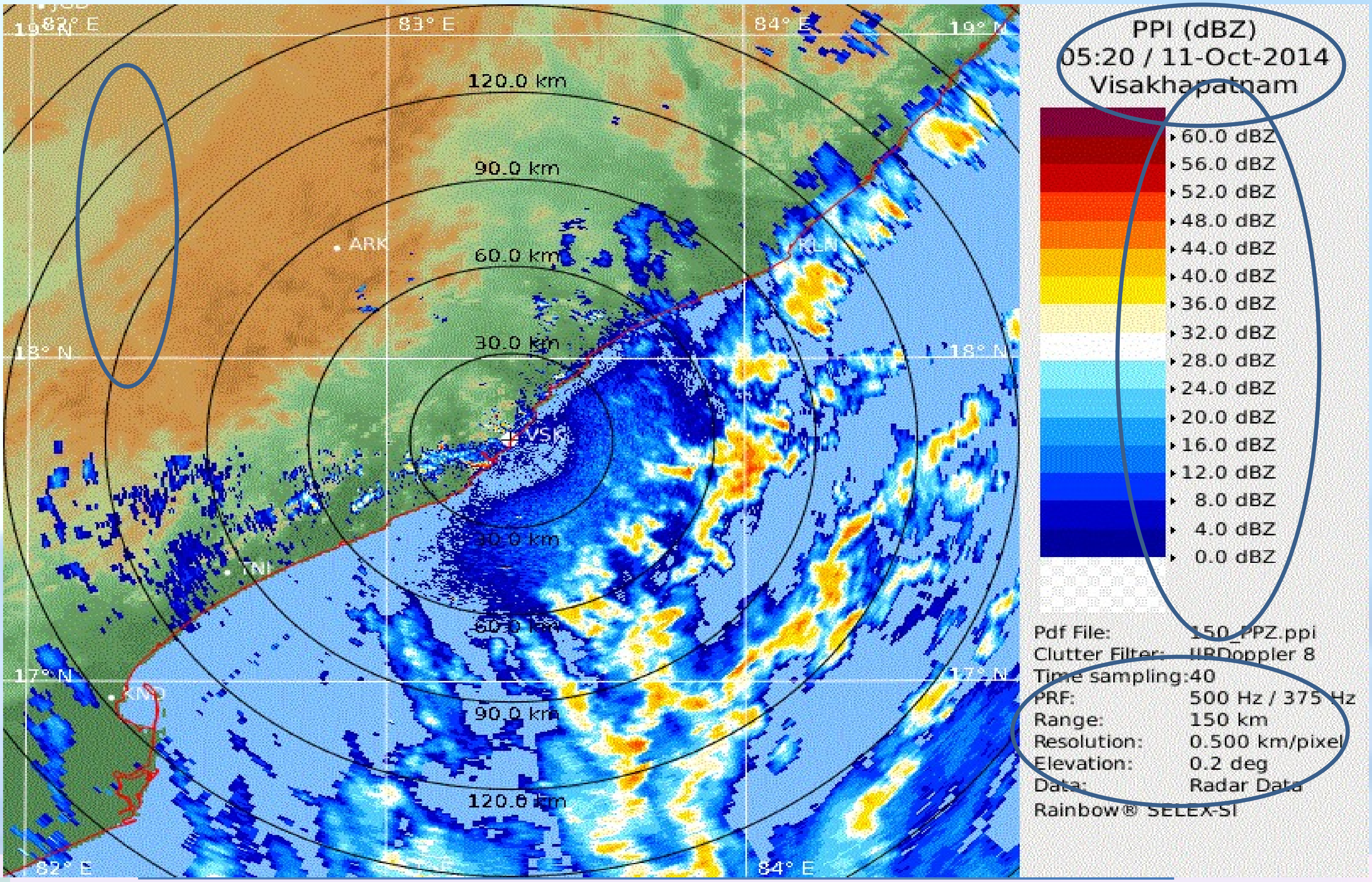
INDIA METEOROLOGICAL DEPARTMENT


Applications Places System
Sun Oct 12, 5:28:31 AM rainbow
RainDART
Invalid Rainbow Product file format
Error: Error in loading a binary blob
Extended Error: Error in the projection Attributes
Error while loading blob with Id:
OK
Rainbow Control Center
File View Tools Help
DART DART ImgCnv1 DART ImgCnv2 DART ImgCnv3 DART ImgCnv4 LOG RM
ws1 - Rainbow DART - Image Generator(imgcnv1) - MAX (dBZ), 23:10:33, 11-Oct-2014, Visakhapatnam : 100%
File Edit Sensors Windows Help
Sensor : Visakhapatnam
View Products
Online Offline
EHT Height Range: 300 k 300.eht
EHT Height Range: 350 k 500.eht
MAX dBZ Range: 300 k 250_Z.max
PPI dBZ Range: 150 k 150_PPZ.ppi
PPI dBZ Range: 250 k 250_PPZ.ppi
Load Products
MAX (dBZ), 23:10:33, 11-Oct-2014, Visakhapatnam : 100%
Info
MAX (dBZ)
23:10 / 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: 250_Z.max
Clutter Filter: IIRDoppler 8
Time sampling: 40
PRF: 500 Hz / 375 Hz
Range: 250 km
Height: 0.100 km to 18.000 km
Hor Res: 0.833 km/pixel
Vert Res: 0.089 km/pixel
Rainbow® SELEX-SI
01-05-14
22-05-14
2014-05-20
20110502raw
Rainbow Documentation
File Browser
Rainbow
RainDART.ini104
RainDART.ini(103)
RainDART.ini(104)
Trash
ftp as rainbow on 192.27.19.103
201410100220_PPV.png
Screenshot.png
201410100220.png
cyclone_Pictures
2014101013272100dBZ_475Ani.png
2014101012052800dBZ_475Animation.png
[ws3 - Rainbow D... [ws2 - Rainbow D... Rainbow Control C... [ws4 - Rainbow D... ws1 - Rainbow DA... [Rainbow DART - ... [ws1 - Rainbow D... [ws3 - Rainbow D... RainDART

Scan Types

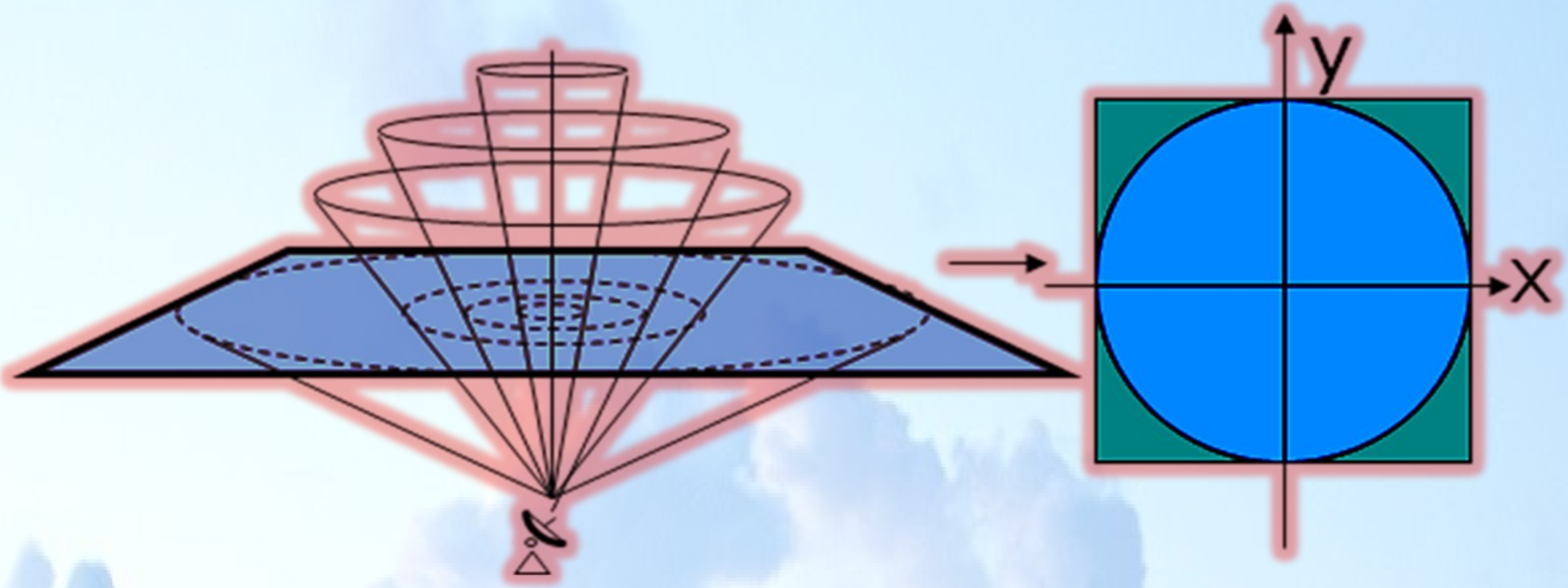

Azimuth
Scan
Z
N
Azimuth
Elevation
Range
W
E
S
Volume
Scan
Z
N
Azimuth
Range
Elevation
Elevation
Step
W
E
S
Elevation
Scan
Azimuth
Z
N
Stopp
Elevation
Start
Elevation
W
E
Range
S

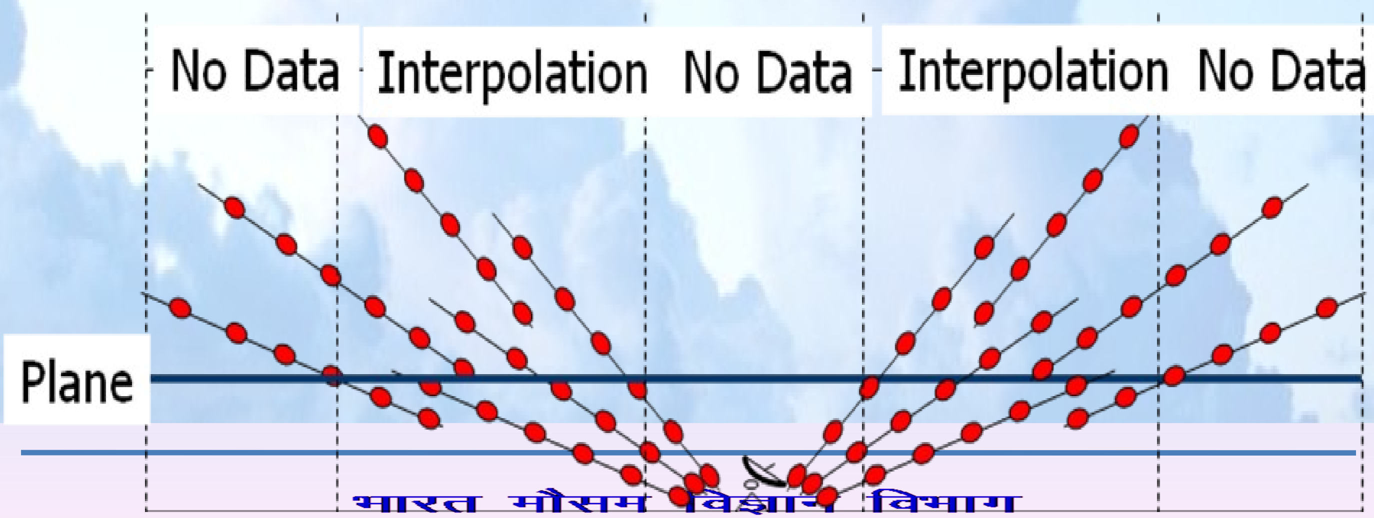
PPI(dbZ)

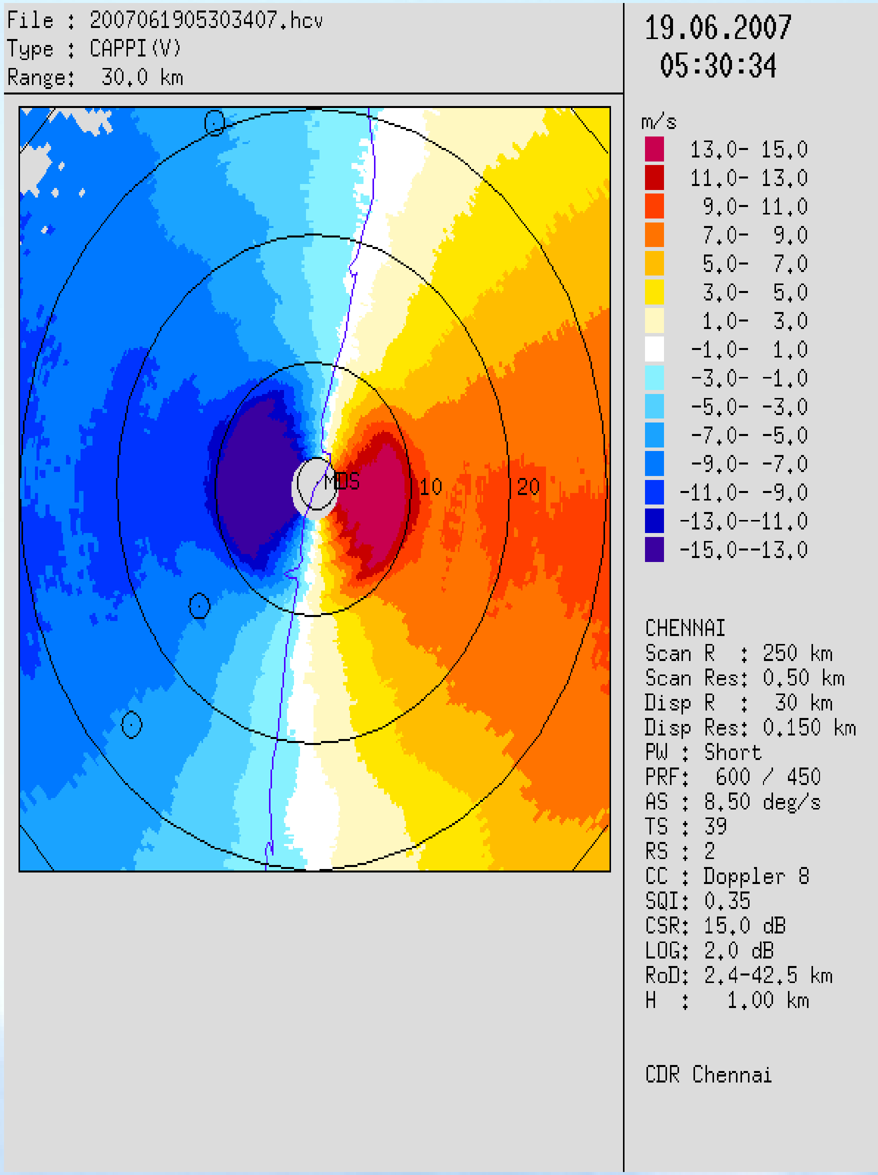


83° E
84° E
19° N
120.0 km
90.0 km
60.0 km
30.0 km
ARK
VSK
18° N
17° N
82° E
84° E
PPI (dBZ)
05:20 / 11-Oct-2014
Visakhapatnam
60.0 dBZ
56.0 dBZ
52.0 dBZ
48.0 dBZ
44.0 dBZ
40.0 dBZ
36.0 dBZ
32.0 dBZ
28.0 dBZ
24.0 dBZ
20.0 dBZ
16.0 dBZ
12.0 dBZ
8.0 dBZ
4.0 dBZ
0.0 dBZ
Pdf File: 150_PPZ.ppi
Clutter Filter: 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
Rainbow® SELEX-SI

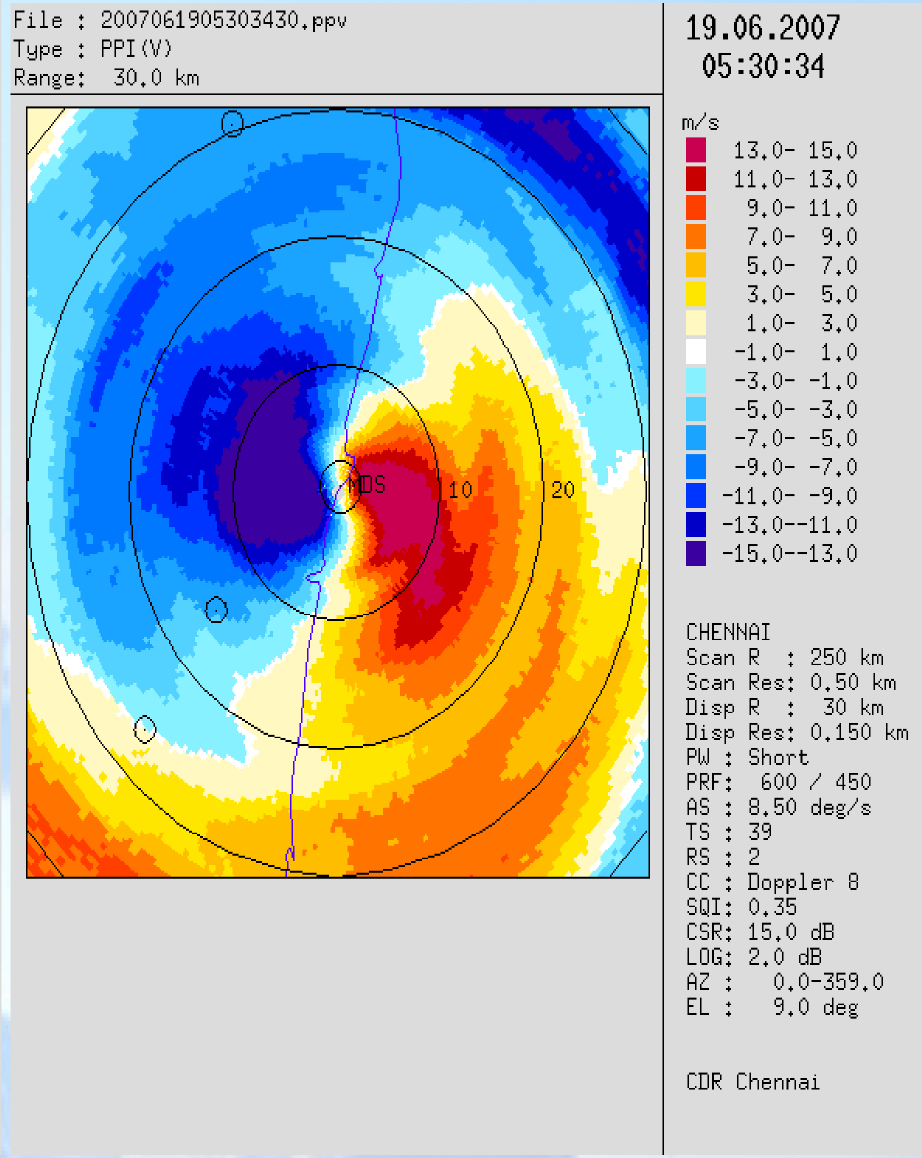
Constant Altitude PPI



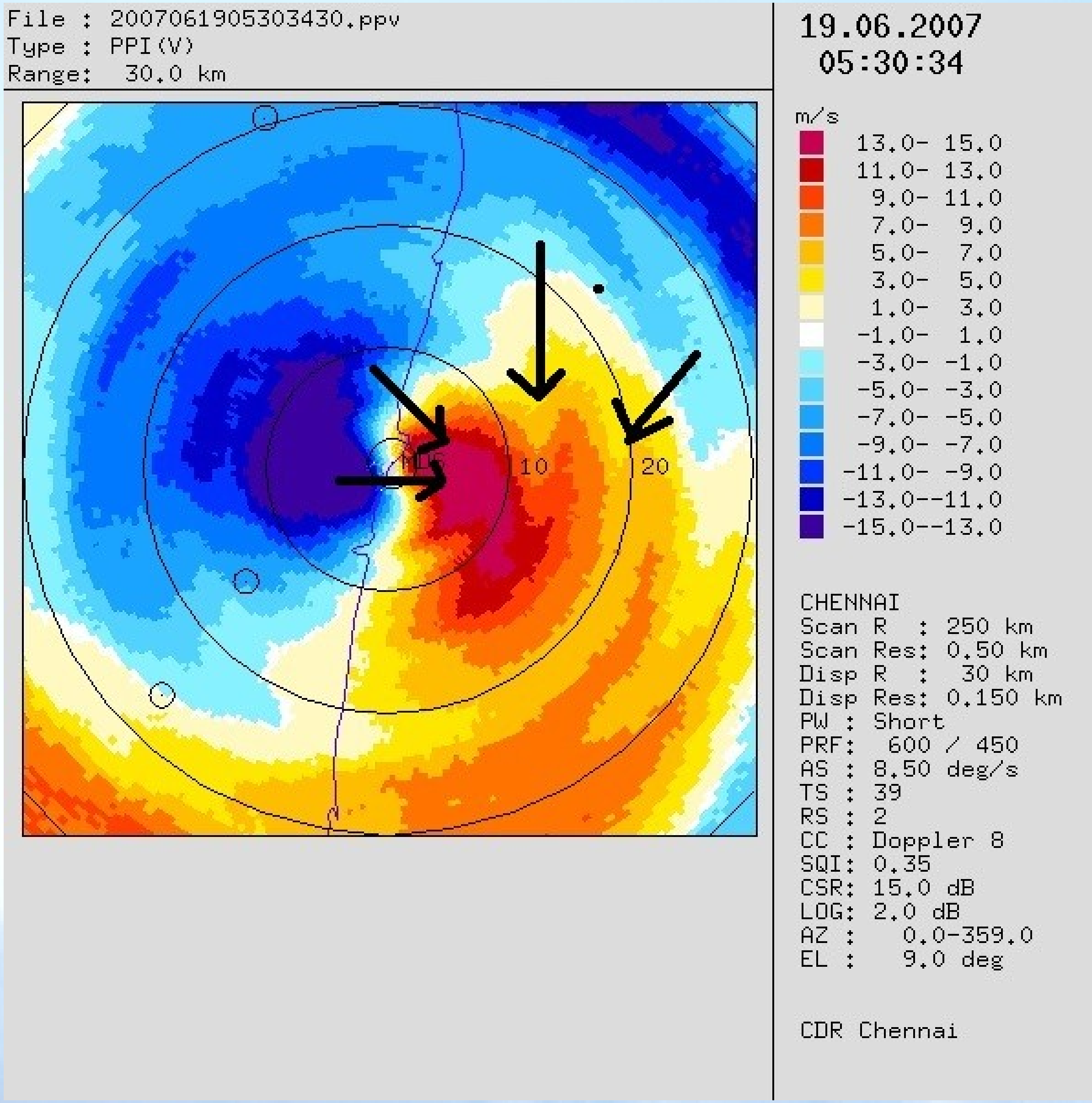


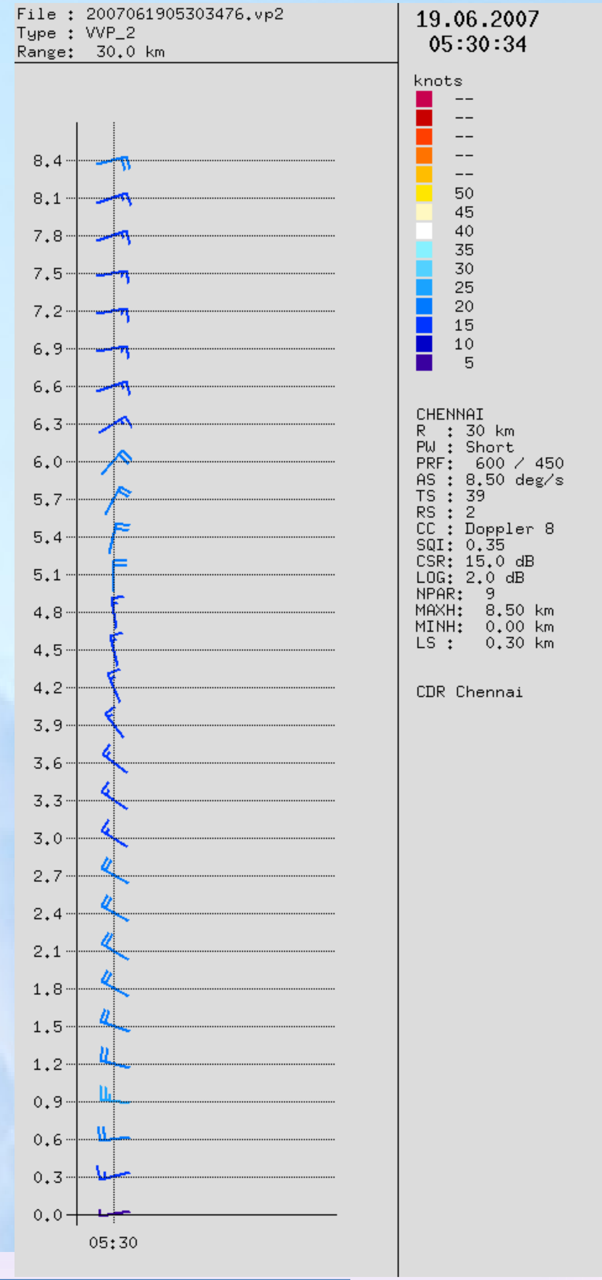

File : 2007061905303407.hcv
Type : CAPPI(V)
Range: 30.0 km
19.06.2007
05:30:34
m/s
13.0- 15.0
11.0- 13.0
9.0- 11.0
7.0- 9.0
5.0- 7.0
3.0- 5.0
1.0- 3.0
-1.0- 1.0
-3.0- -1.0
-5.0- -3.0
-7.0- -5.0
-9.0- -7.0
-11.0- -9.0
-13.0--11.0
-15.0--13.0
MDS
10
20
CHENNAI
Scan R : 250 km
Scan Res: 0.50 km
Disp R : 30 km
Disp Res: 0.150 km
PW : Short
PRF: 600 / 450
AS : 8.50 deg/s
TS : 39
RS : 2
CC : Doppler 8
SQI: 0.35
CSR: 15.0 dB
LOG: 2.0 dB
RoD: 2.4-42.5 km
H : 1.00 km
CDR Chennai

CAPPI

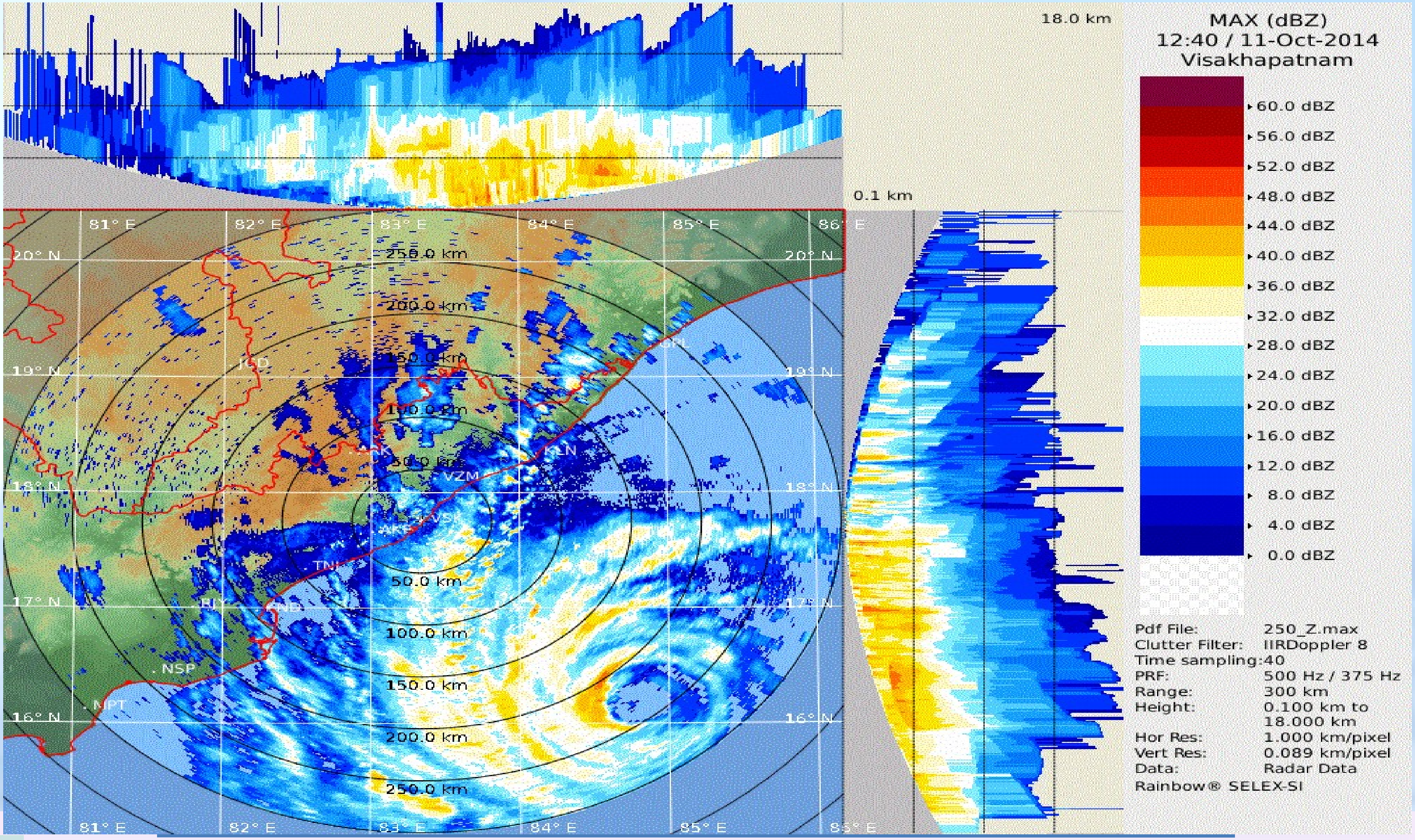

File : 2007061905303430.ppv
Type : PPI(V)
Range: 30.0 km
19.06.2007
05:30:34
m/s
13.0- 15.0
11.0- 13.0
9.0- 11.0
7.0- 9.0
5.0- 7.0
3.0- 5.0
1.0- 3.0
-1.0- 1.0
-3.0- -1.0
-5.0- -3.0
-7.0- -5.0
-9.0- -7.0
-11.0- -9.0
-13.0--11.0
-15.0--13.0
MDS
10
20
CHENNAI
Scan R : 250 km
Scan Res: 0.50 km
Disp R : 30 km
Disp Res: 0.150 km
PW : Short
PRF: 600 / 450
AS : 8.50 deg/s
TS : 39
RS : 2
CC : Doppler 8
SQI: 0.35
CSR: 15.0 dB
LOG: 2.0 dB
AZ : 0.0-359.0
EL : 9.0 deg
CDR Chennai

PPI


File : 2007061905303430.ppv
Type : PPI(V)
Range: 30.0 km
19.06.2007
05:30:34
m/s
13.0- 15.0
11.0- 13.0
9.0- 11.0
7.0- 9.0
5.0- 7.0
3.0- 5.0
1.0- 3.0
-1.0- 1.0
-3.0- -1.0
-5.0- -3.0
-7.0- -5.0
-9.0- -7.0
-11.0- -9.0
-13.0--11.0
-15.0--13.0
10
20
CHENNAI
Scan R : 250 km
Scan Res: 0.50 km
Disp R : 30 km
Disp Res: 0.150 km
PW : Short
PRF: 600 / 450
AS : 8.50 deg/s
TS : 39
RS : 2
CC : Doppler 8
SQI: 0.35
CSR: 15.0 dB
LOG: 2.0 dB
AZ : 0.0-359.0
EL : 9.0 deg
CDR Chennai

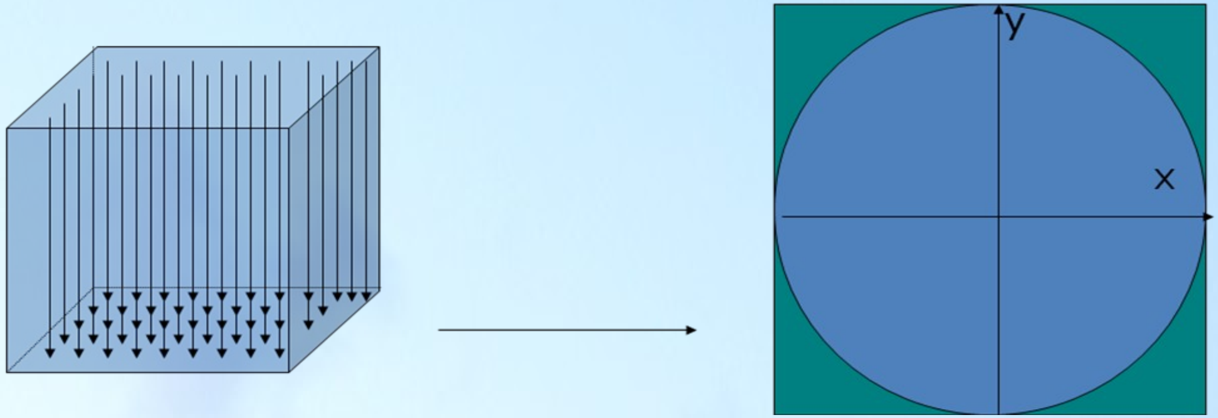

File : 2007061905303476.vp2
Type : VVP_2
Range: 30.0 km
19.06.2007
05:30:34
knots
50
45
40
35
30
25
20
15
10
5
8.4
8.1
7.8
7.5
7.2
6.9
6.6
6.3
6.0
5.7
5.4
5.1
4.8
4.5
4.2
3.9
3.6
3.3
3.0
2.7
2.4
2.1
1.8
1.5
1.2
0.9
0.6
0.3
0.0
05:30
CHENNAI
R : 30 km
PW : Short
PRF: 600 / 450
AS : 8.50 deg/s
TS : 39
RS : 2
CC : Doppler 8
SQI: 0.35
CSR: 15.0 dB
LOG: 2.0 dB
NPAR: 9
MAXH: 8.50 km
MINH: 0.00 km
LS : 0.30 km
CDR Chennai

Max(Z)



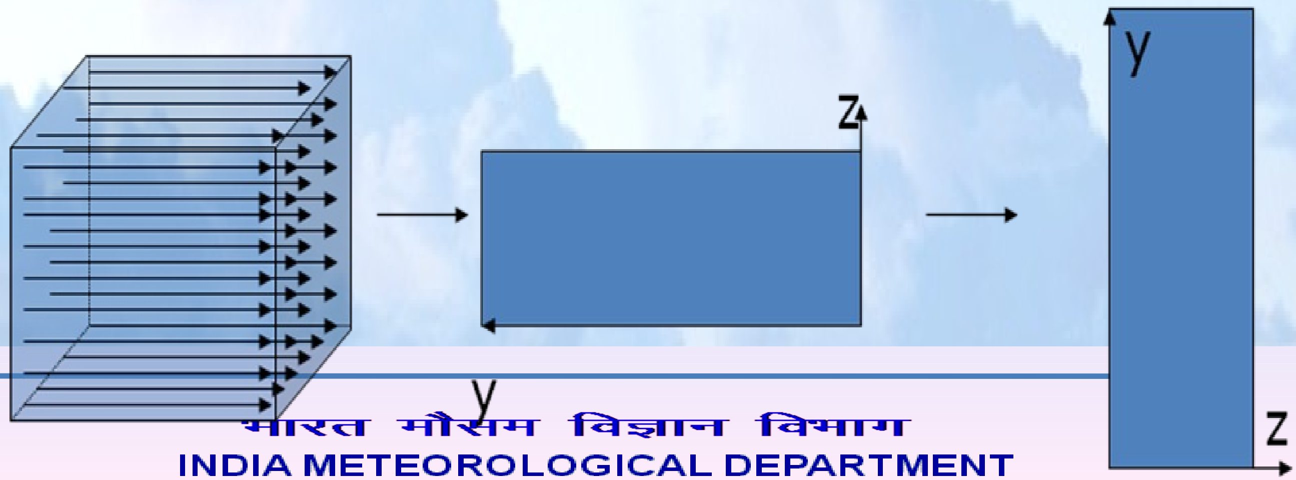
MAX (dBZ)
12:40 / 11-Oct-2014
Visakhapatnam
18.0 km
0.1 km
60.0 dBZ
56.0 dBZ
52.0 dBZ
48.0 dBZ
44.0 dBZ
40.0 dBZ
36.0 dBZ
32.0 dBZ
28.0 dBZ
24.0 dBZ
20.0 dBZ
16.0 dBZ
12.0 dBZ
8.0 dBZ
4.0 dBZ
0.0 dBZ
Pdf File: 250_Z.max
Clutter Filter: IIRDoppler 8
Time sampling:40
PRF: 500 Hz / 375 Hz
Range: 300 km
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
81° E
82° E
83° E
84° E
85° E
86° E
20° N
19° N
18° N
17° N
16° N
250.0 km
200.0 km
150.0 km
100.0 km
50.0 km
VZM
VSK
NSP
NPT

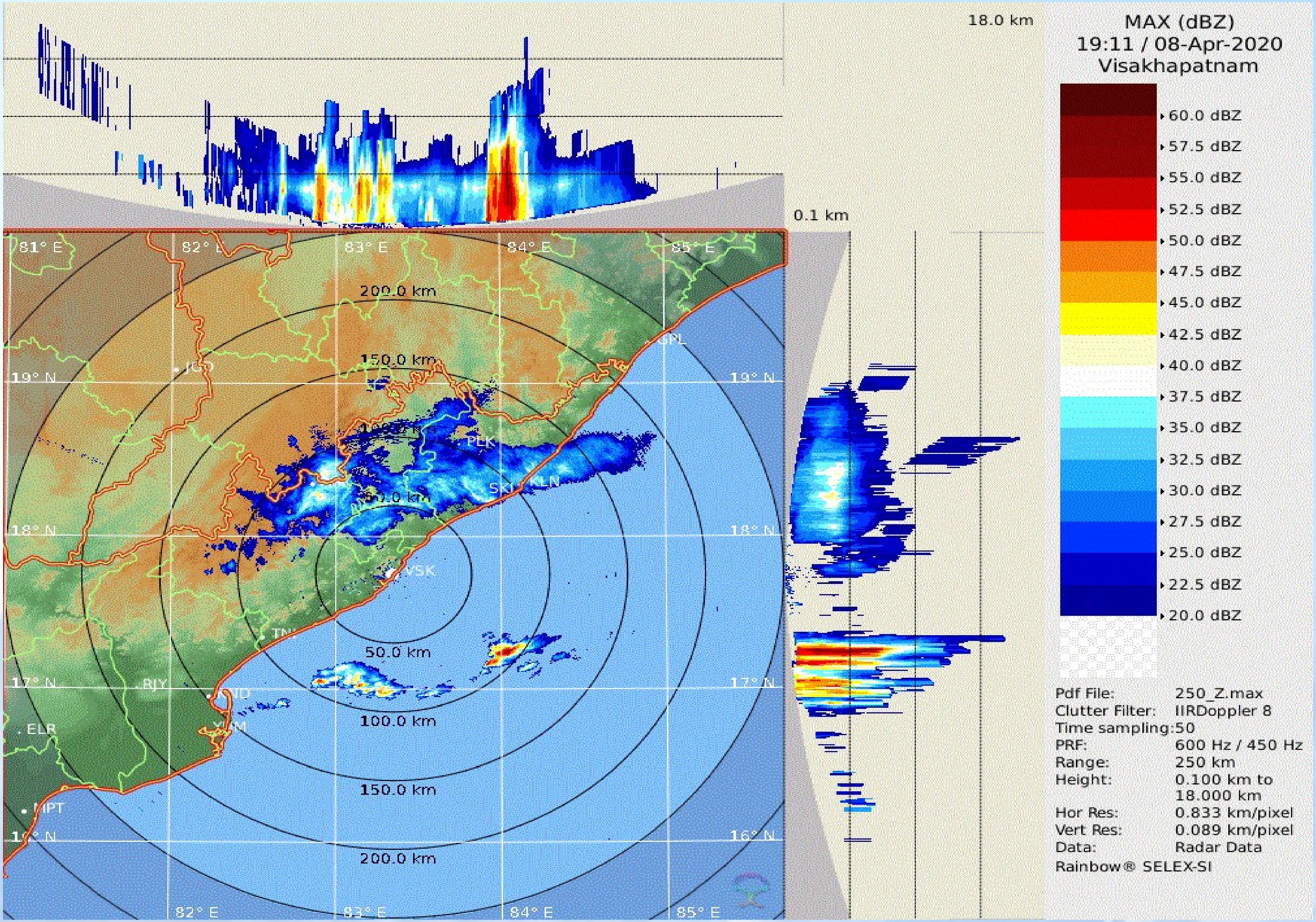
TOP VIEW



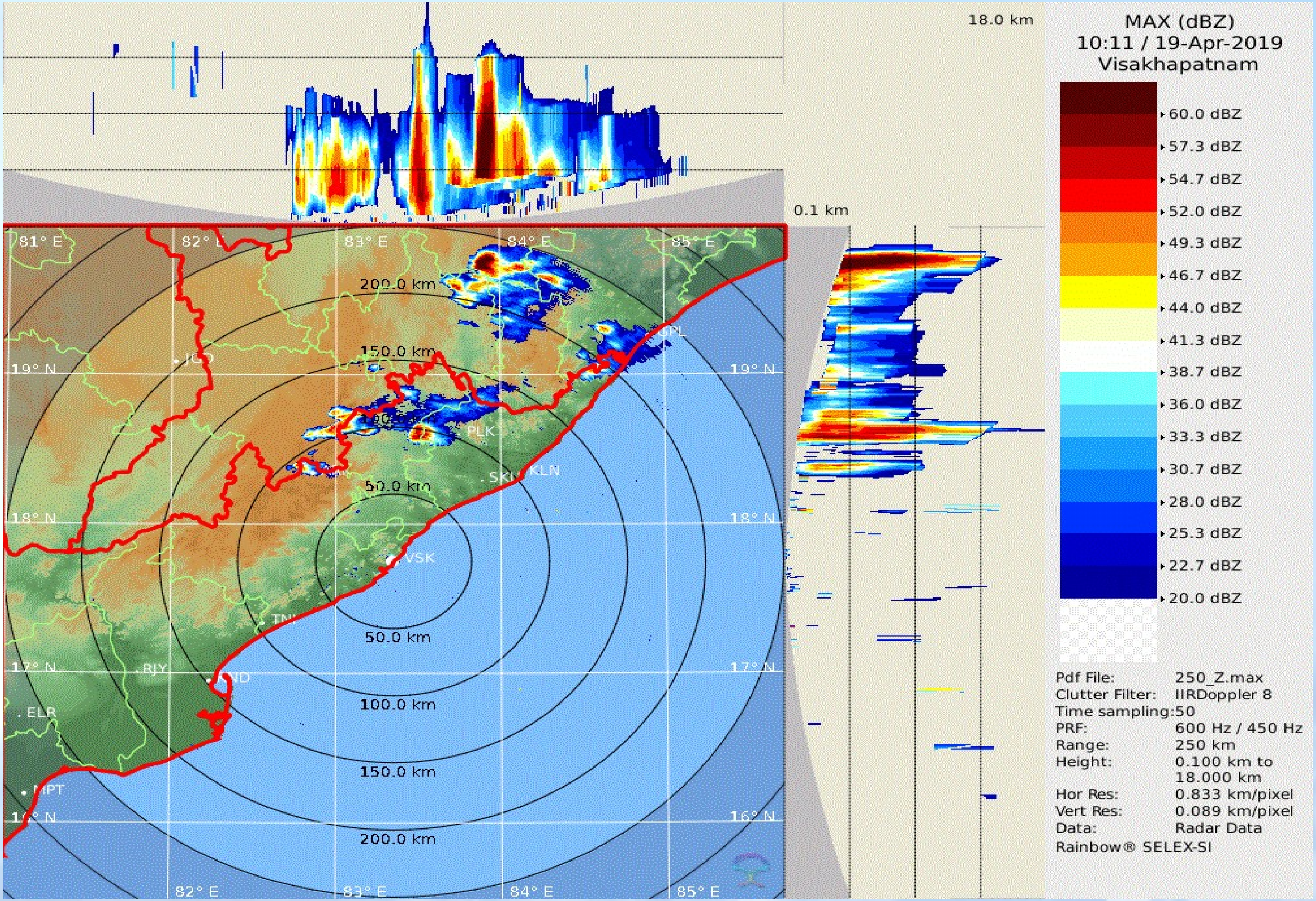
N-S VIEW

E-W VIEW



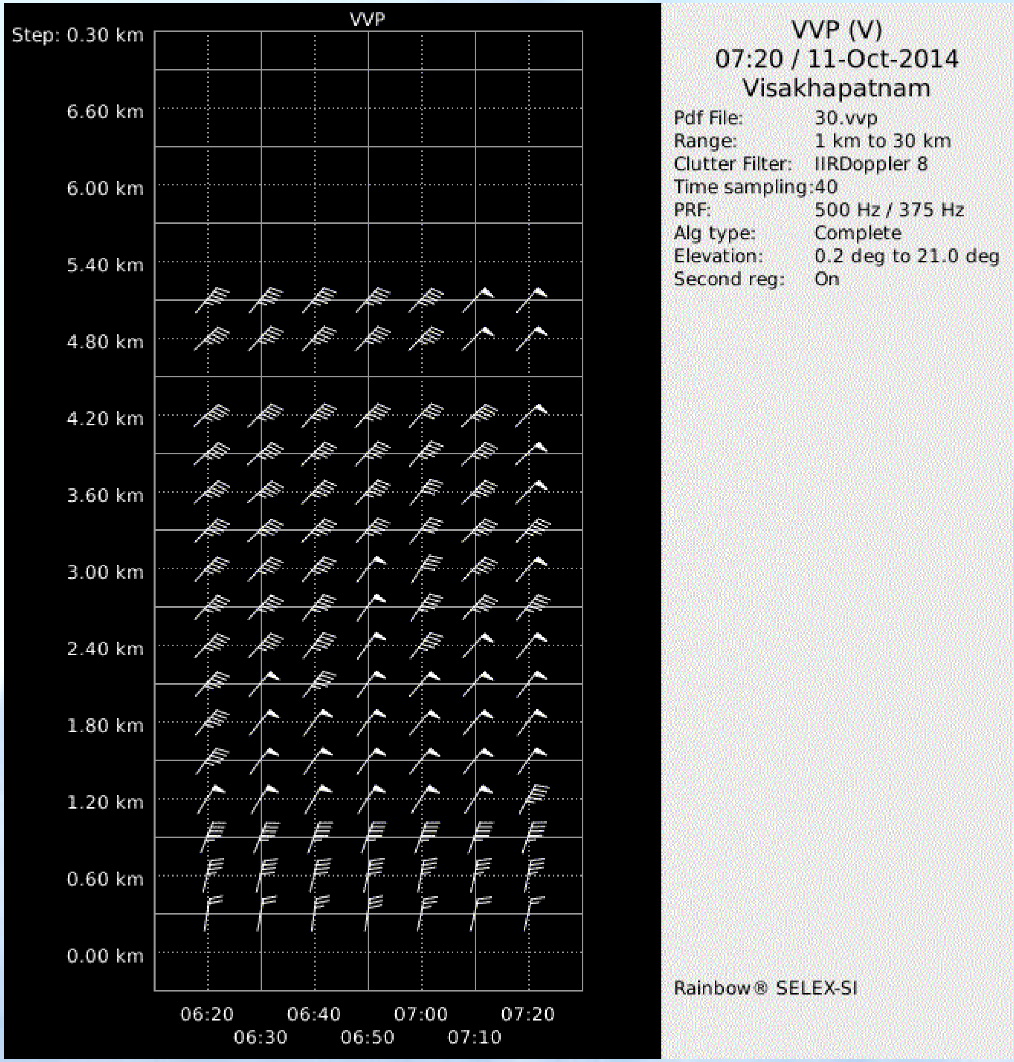


भारत मौसम विज्ञान विभाग
INDIA METEOROLOGICAL DEPARTMENT



भारत मौसम विज्ञान विभाग
INDIA METEOROLOGICAL DEPARTMENT

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)

File : 2011033006275638.vp2
Type : VVP_2
Range: 50.0 km

30.03.2011
06:27:56

knots

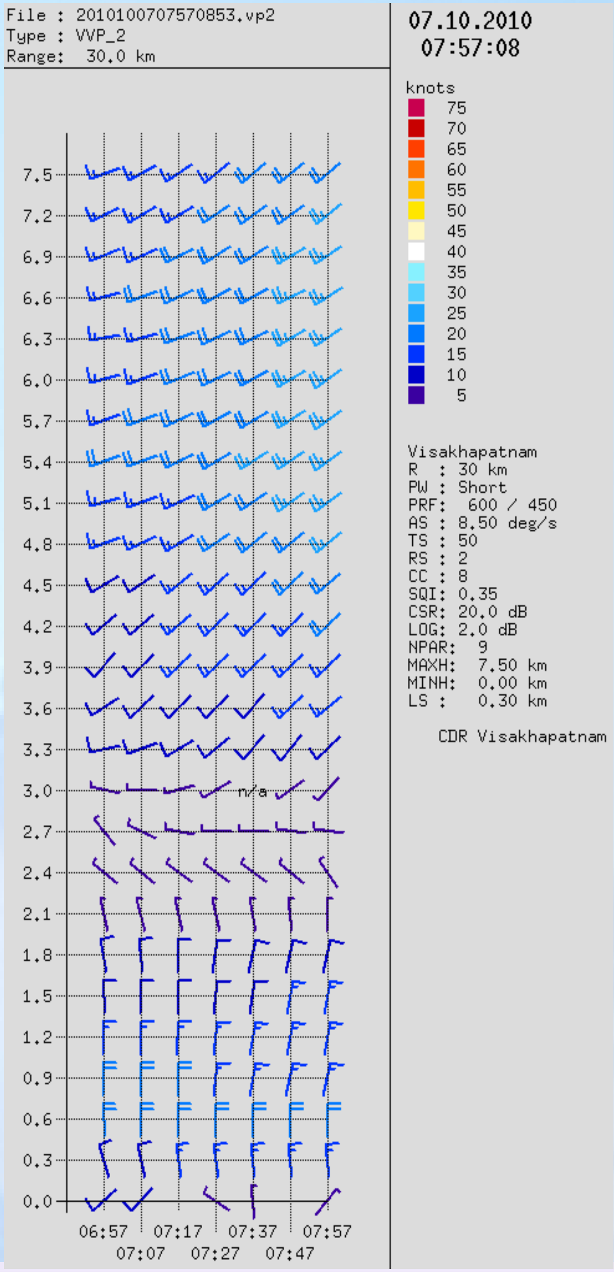
--
--
--
--
--
--
--
40
35
30
25
20
15
10
5

KOLKATA_India
R : 50 km
PW : Short
PRF: 800 / 0
AS : 11.90 deg/s
TS : 64
RS : 2
CC : Doppler 12
SQI: 0.35
CSR: 20.0 dB
LOG: 2.0 dB
MAXH: 7.500 km
MINH: 0.000 km
LS : 0.300 km

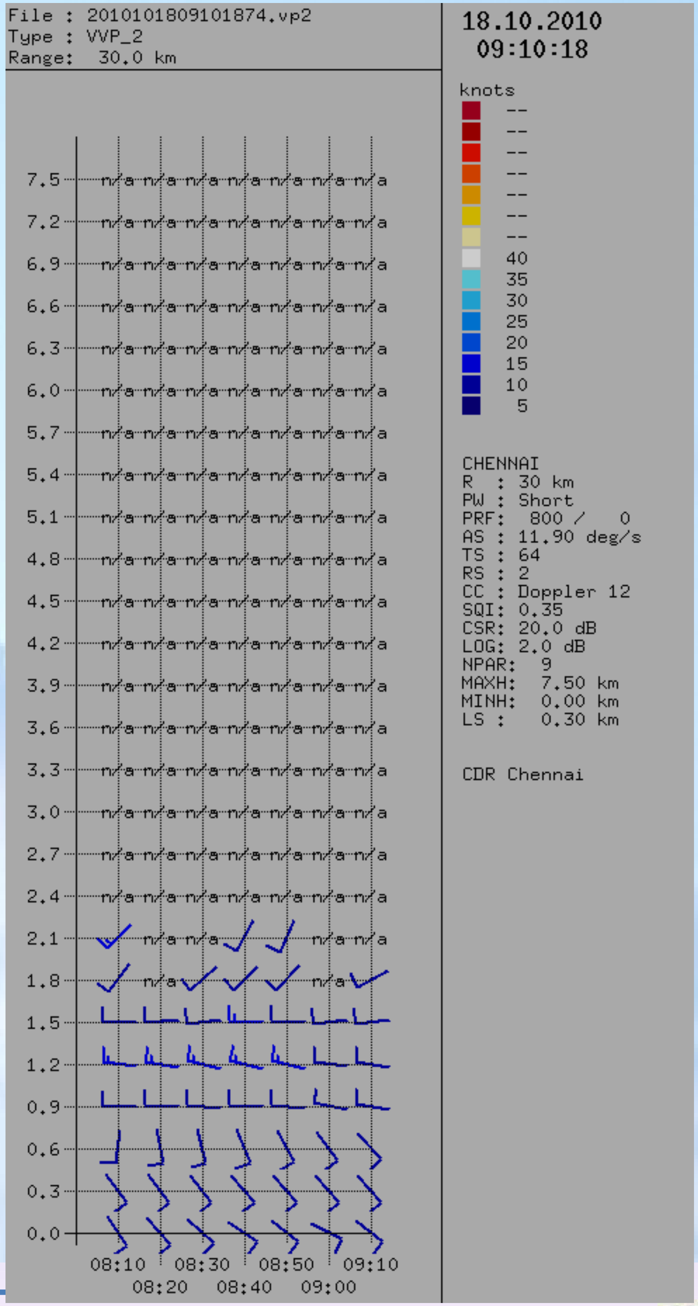
C.D.R. KOLKATA

भारत मौसम विज्ञान विभाग
INDIA METEOROLOGICAL DEPARTMENT

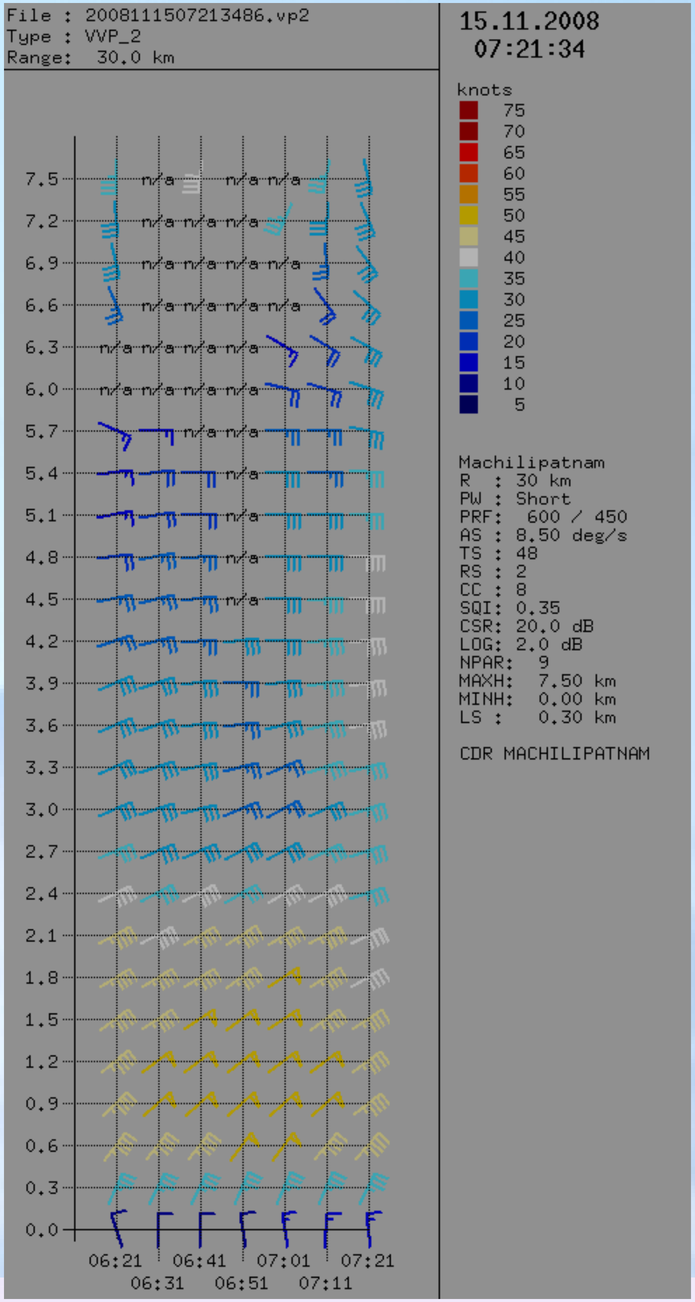
Prediction of Shear Zone



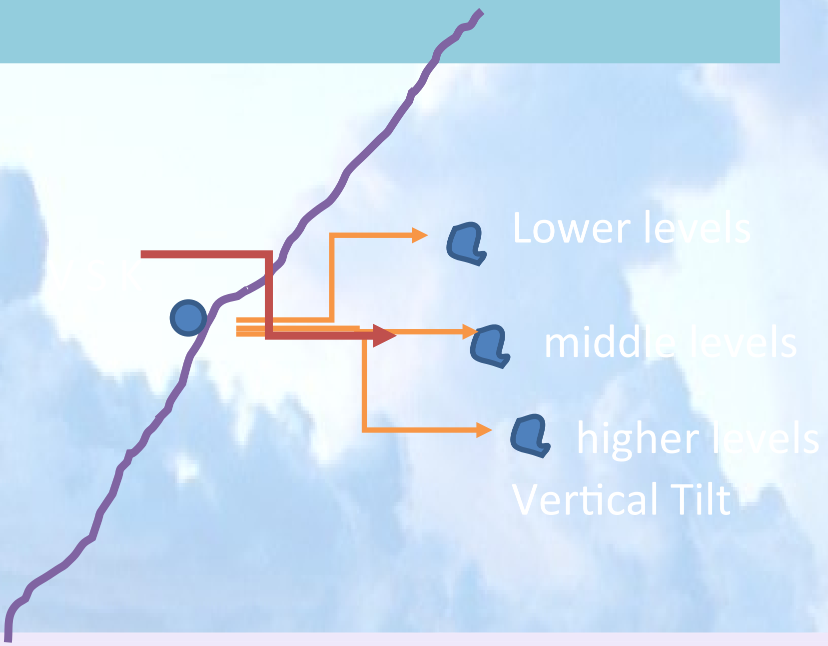
Low level Wind Shear

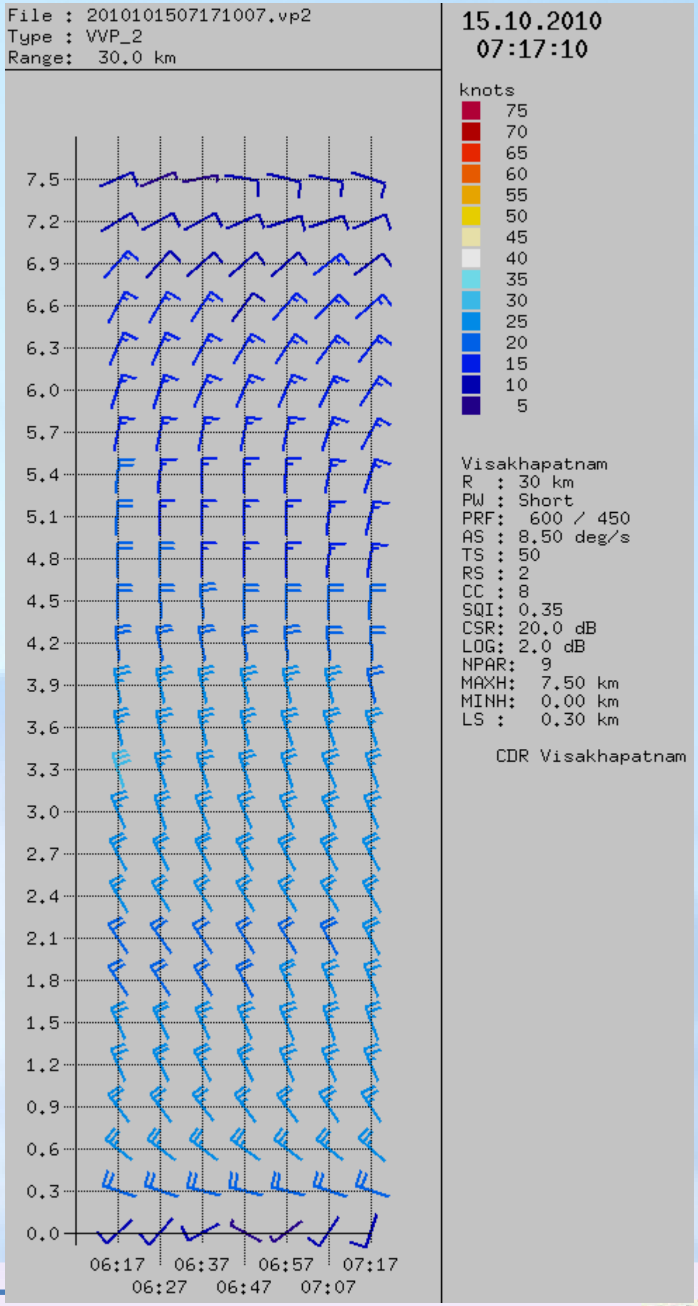


Low level Jet

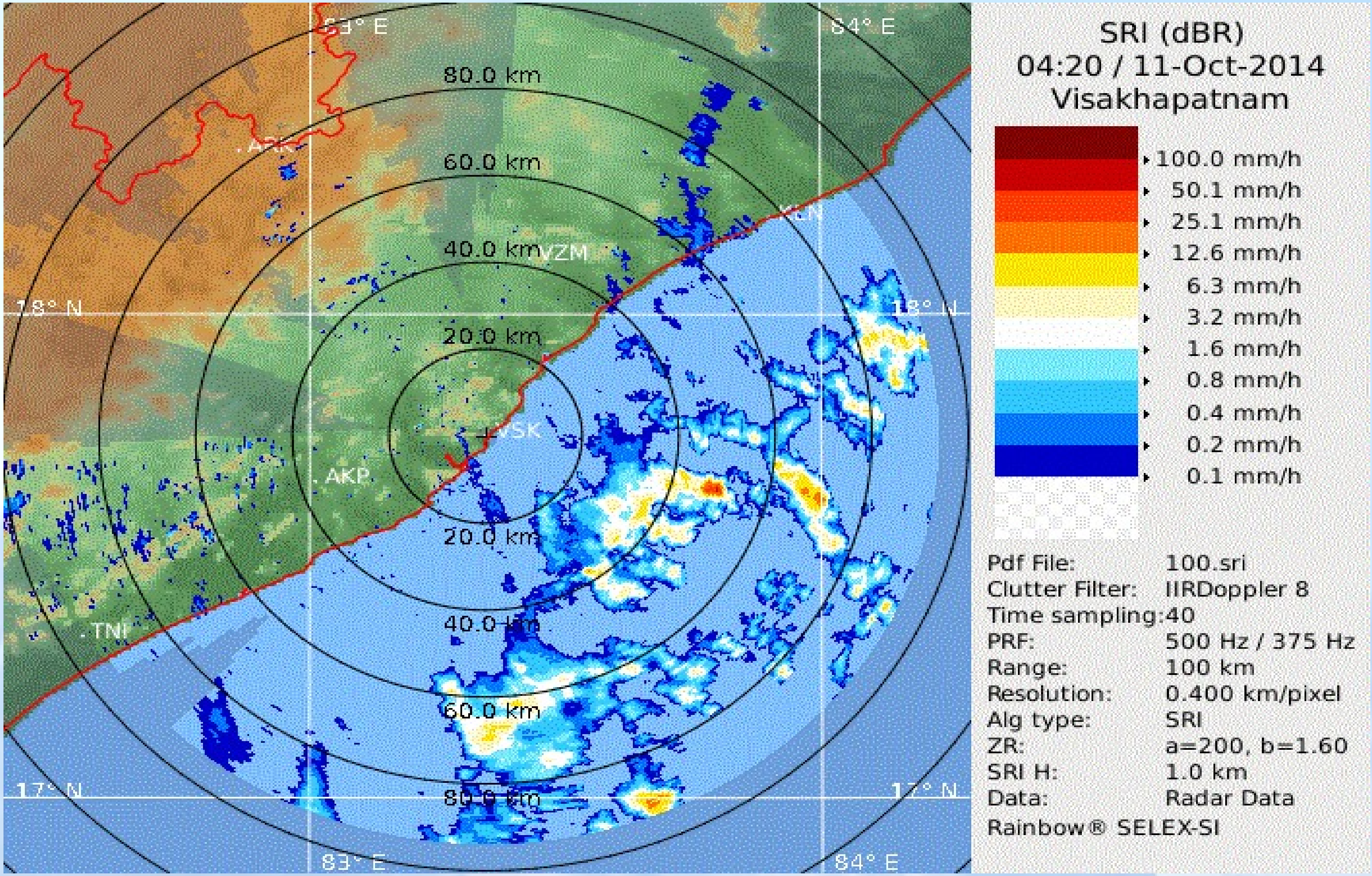


Prediction of Vertical TILT of circulation vortex (Depression)





Surface rainfall Intensity

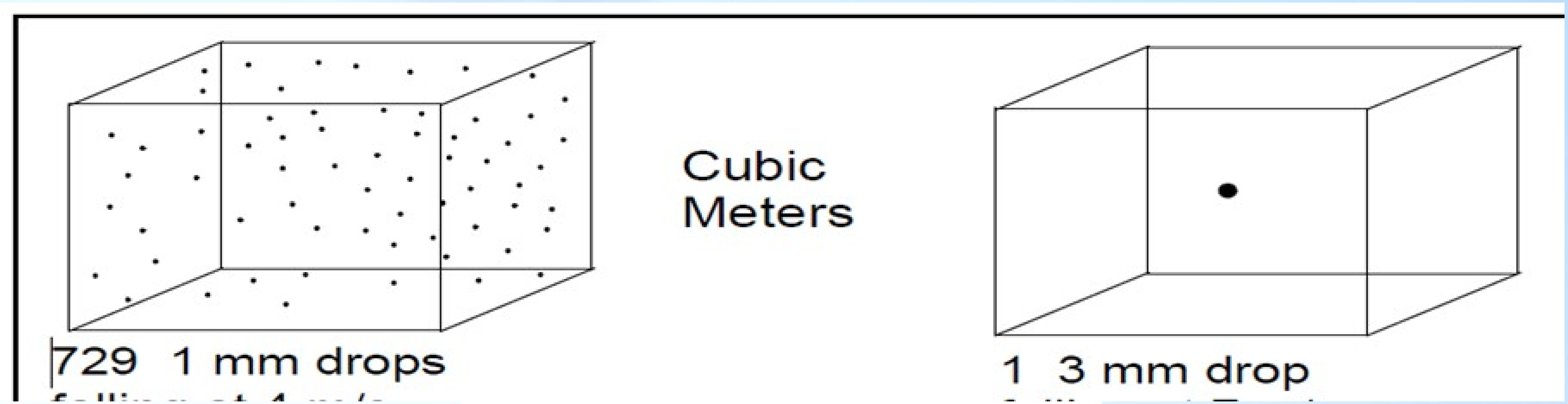


Surface Rainfall Intensity (SRI)

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=ARb 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 drops/m^3)(1 mm)^6

729 mm^6/m^3

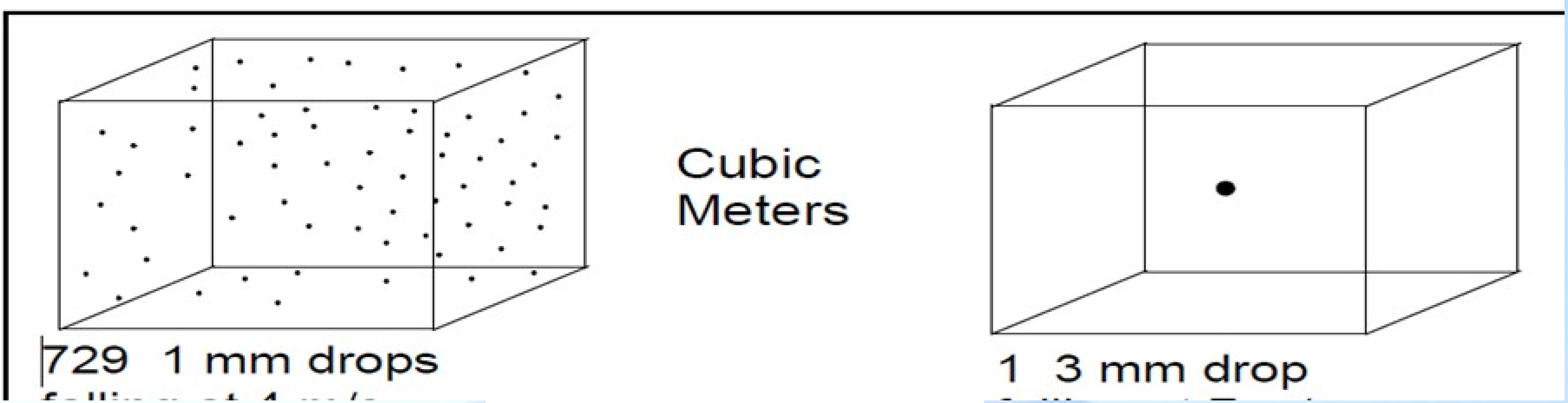
29 dBZ.

(1 drop/m^3)(3 mm)^6

729 mm^6/m^3

29 dBZ.

Surface Rainfall Intensity



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

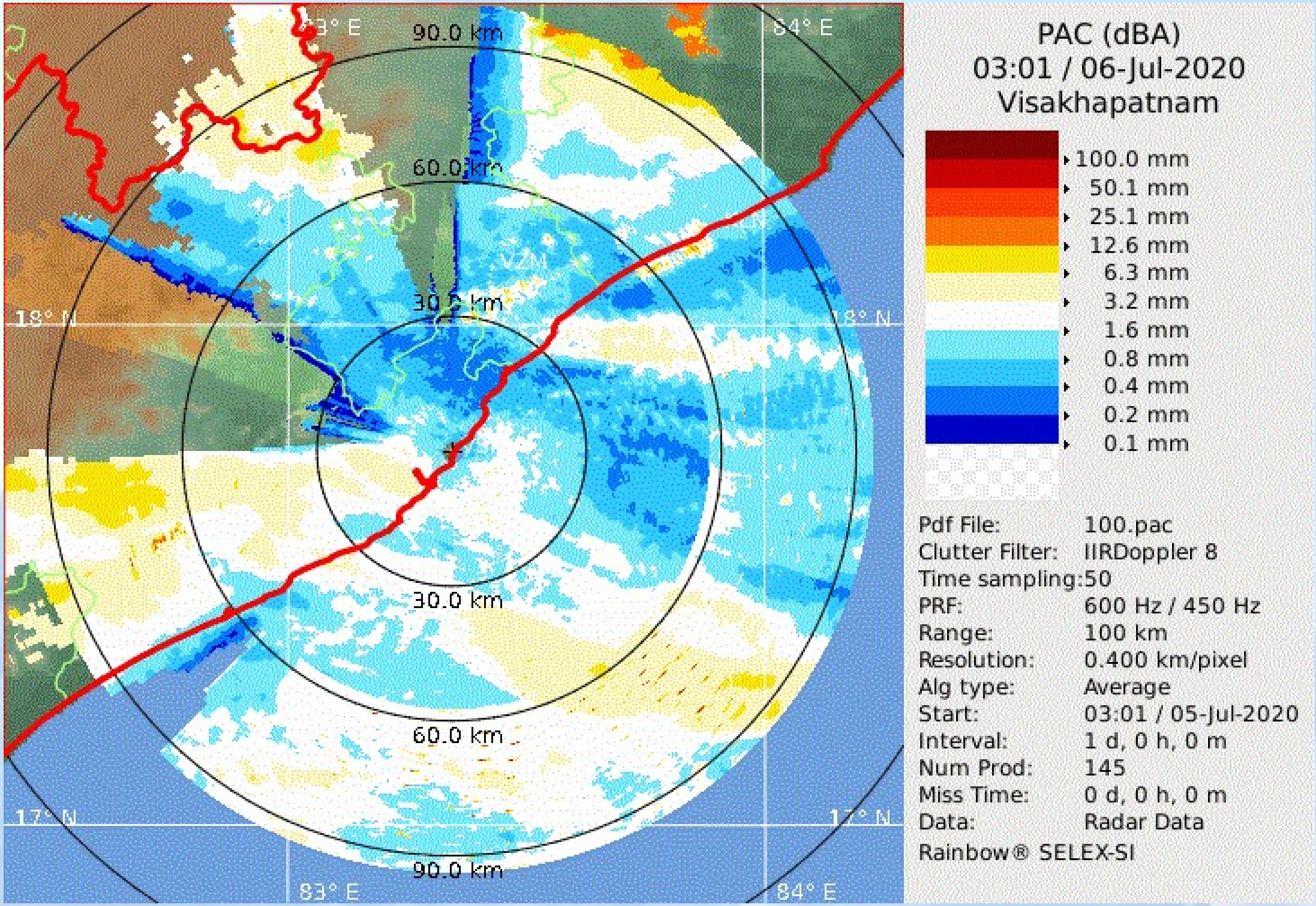
29 dBZ.

R_1 = 5.55 mm/hr.

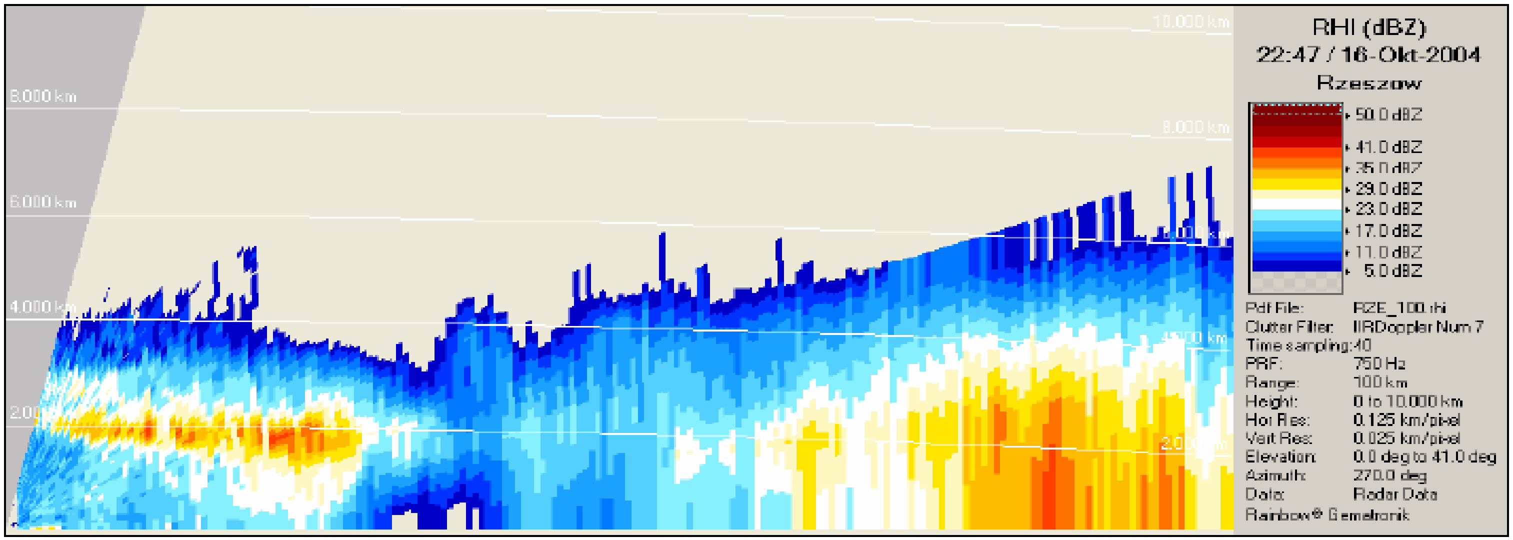
29 dBZ.

R_2 =0.3564 mm/hr

PAC

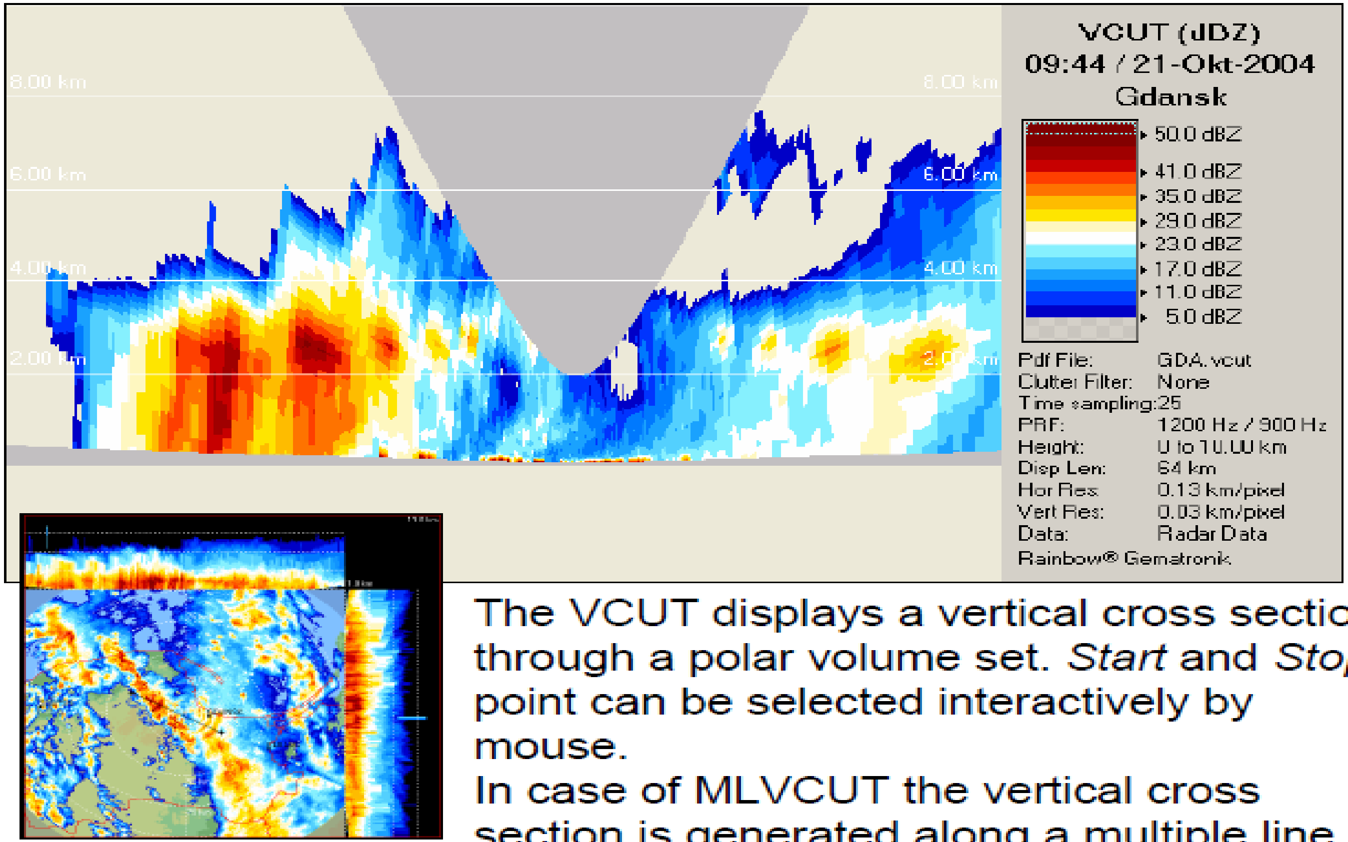

PAC (dBA)
03:01 / 06-Jul-2020
Visakhapatnam
100.0 mm
50.1 mm
25.1 mm
12.6 mm
6.3 mm
3.2 mm
1.6 mm
0.8 mm
0.4 mm
0.2 mm
0.1 mm
Pdf File: 100.pac
Clutter Filter: IIRDoppler 8
Time sampling:50
PRF: 600 Hz / 450 Hz
Range: 100 km
Resolution: 0.400 km/pixel
Alg type: Average
Start: 03:01 / 05-Jul-2020
Interval: 1 d, 0 h, 0 m
Num Prod: 145
Miss Time: 0 d, 0 h, 0 m
Data: Radar Data
Rainbow® SELEX-SI
83° E
84° E
18° N
17° N
30.0 km
60.0 km
90.0 km

Range Height Indicator



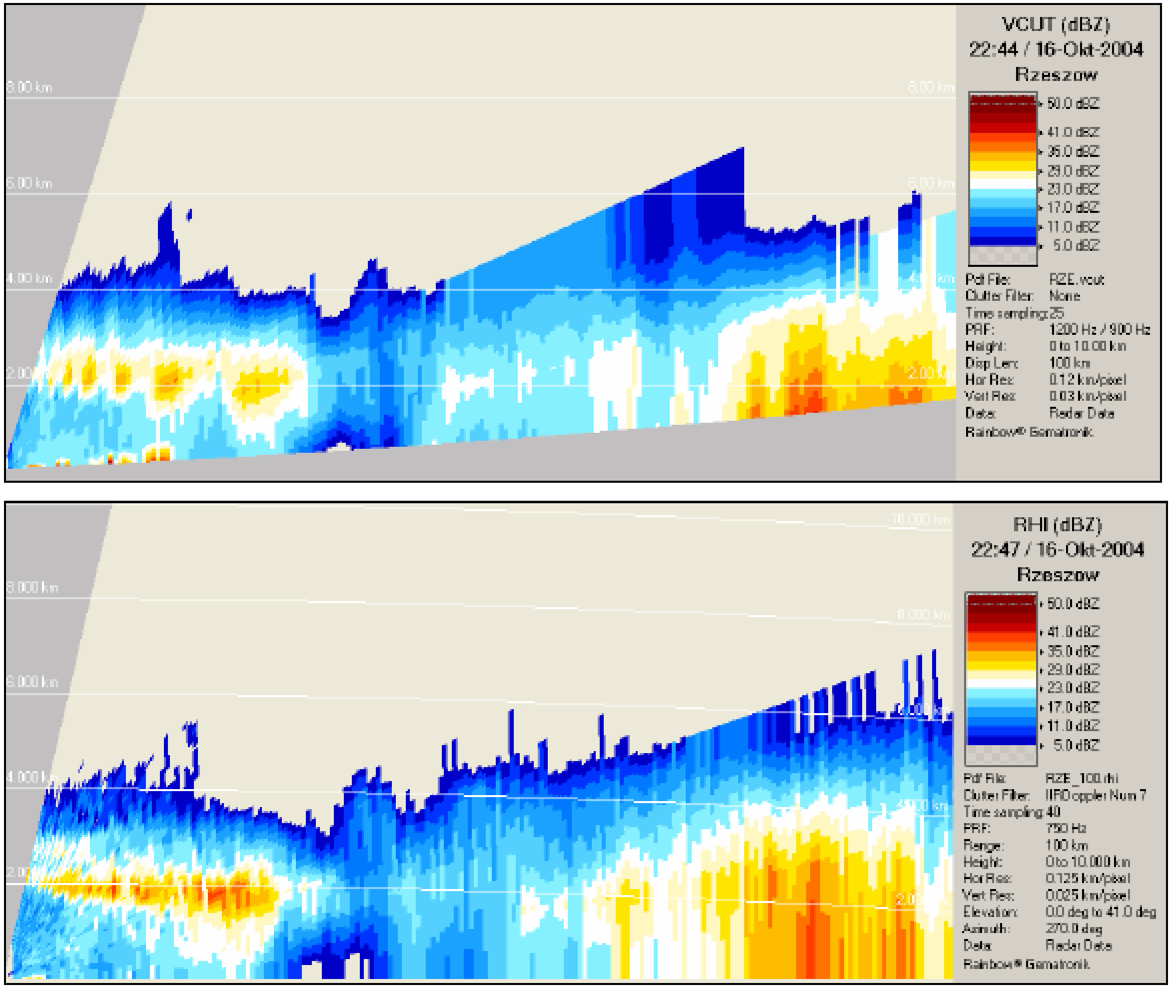
The RHI algorithm takes an elevation scan at a fixed azimuth as input.
A vertical display (range vs. height) is displayed.

Vertical Cut



The VCUT displays a vertical cross section through a polar volume set. *Start* and *Stop* point can be selected interactively by mouse.
In case of MLVCUT the vertical cross section is generated along a multiple line.

VCUT vs RHI



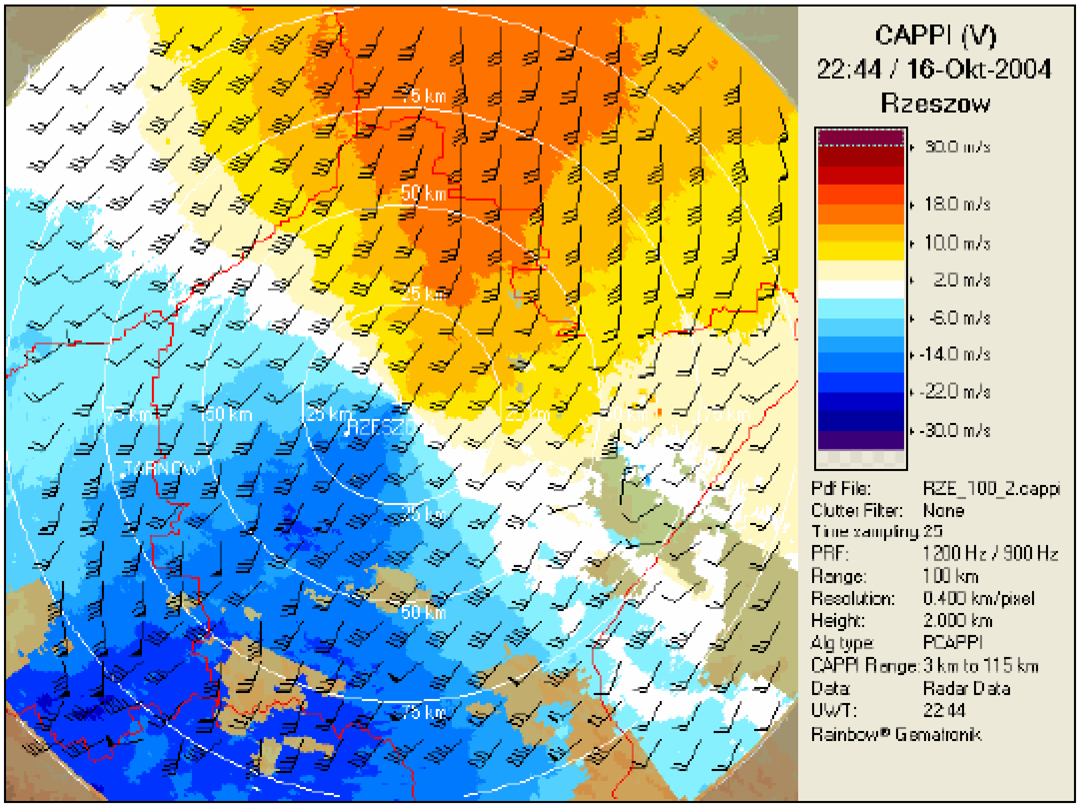
VCUT

versus

RHI

100 km West

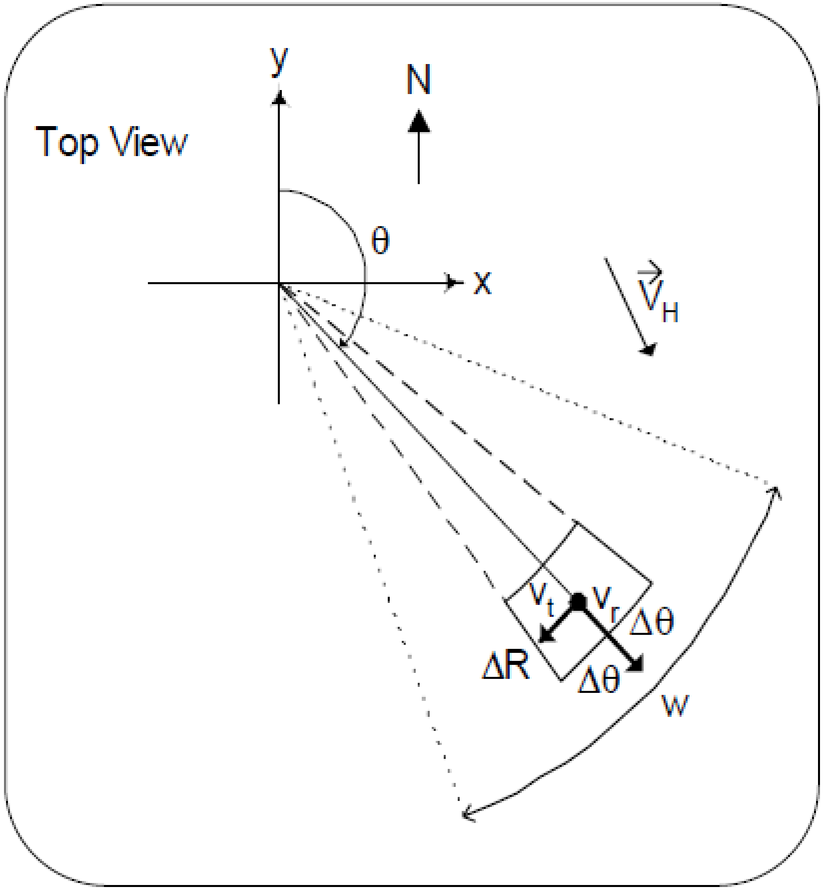
Uniform Wind technique



This product shows horizontal wind vectors in any top projection image as dynamic overlay.

The standard algorithm for uniform wind technique of SMI has been applied.

Uniform Wind technique



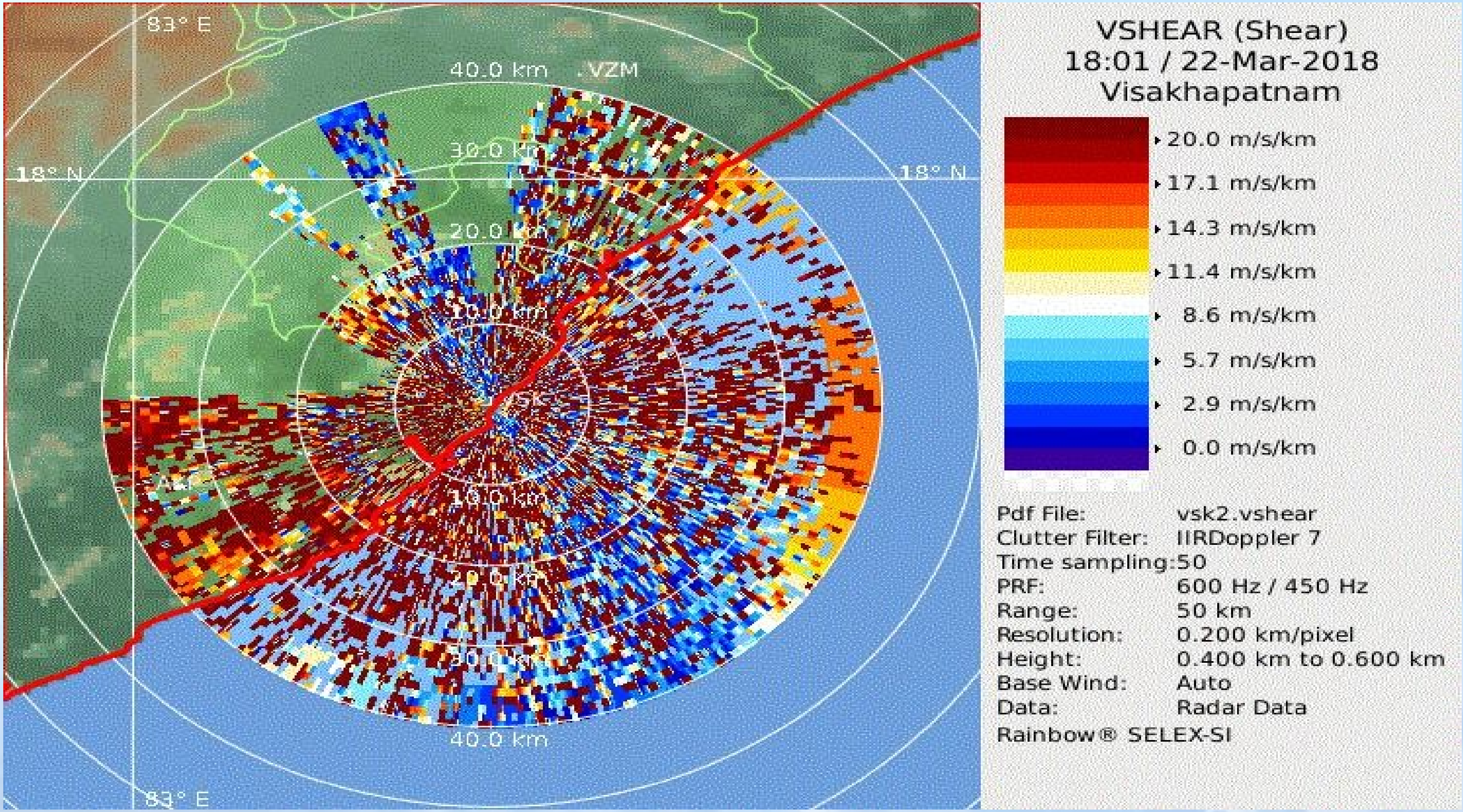
$\boldsymbol{V_H}$ is the horizontal wind vector. At the analysis location, $\boldsymbol{V_H}$ is indicated by its components v_r and v_t.

$$v_r = \text{radial velocity}$$
$$v_t = \partial v_r / \partial \theta_{rad}$$

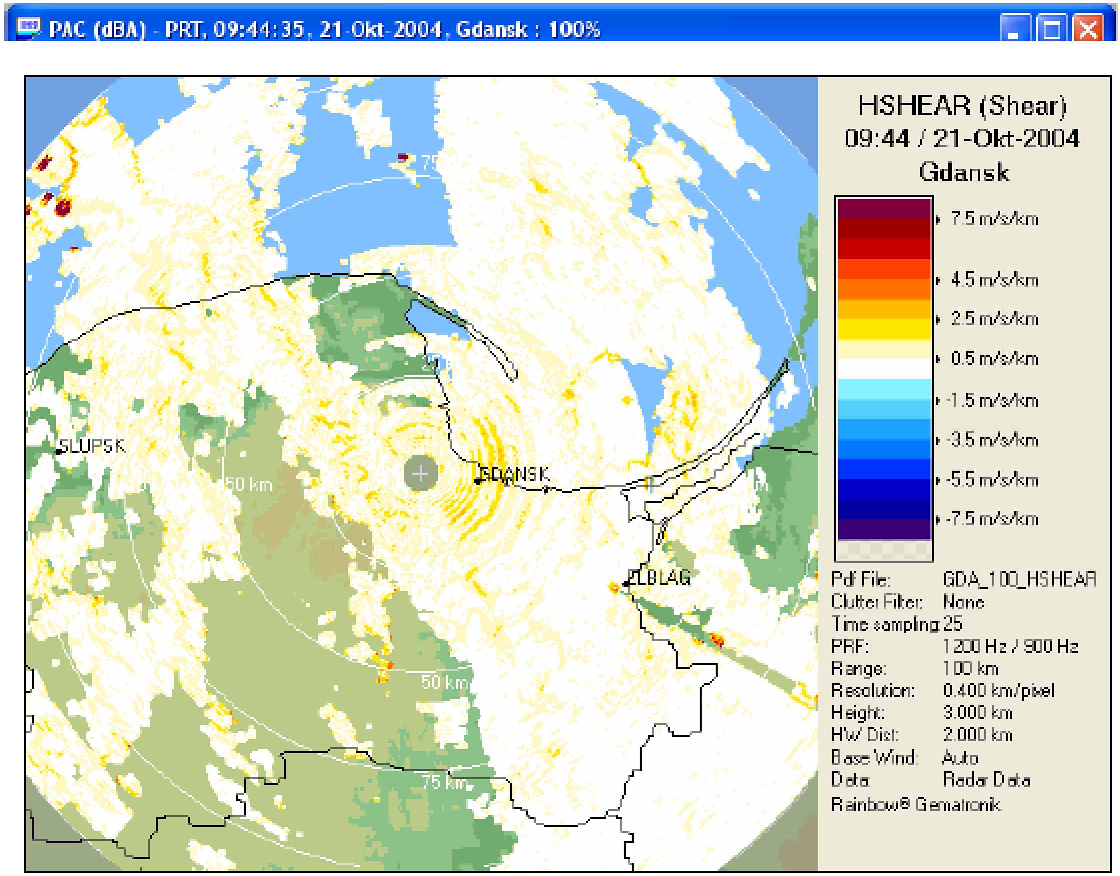
$$u = v_r \cdot \sin(\theta) + v_t \cdot \cos(\theta)$$
$$v = v_r \cdot \cos(\theta) - v_t \cdot \sin(\theta)$$

$$Speed = \sqrt{u^2 + v^2}$$
$$Direction = \arctan(u / v)$$

Vertical Wind shear



Horizontal Shear

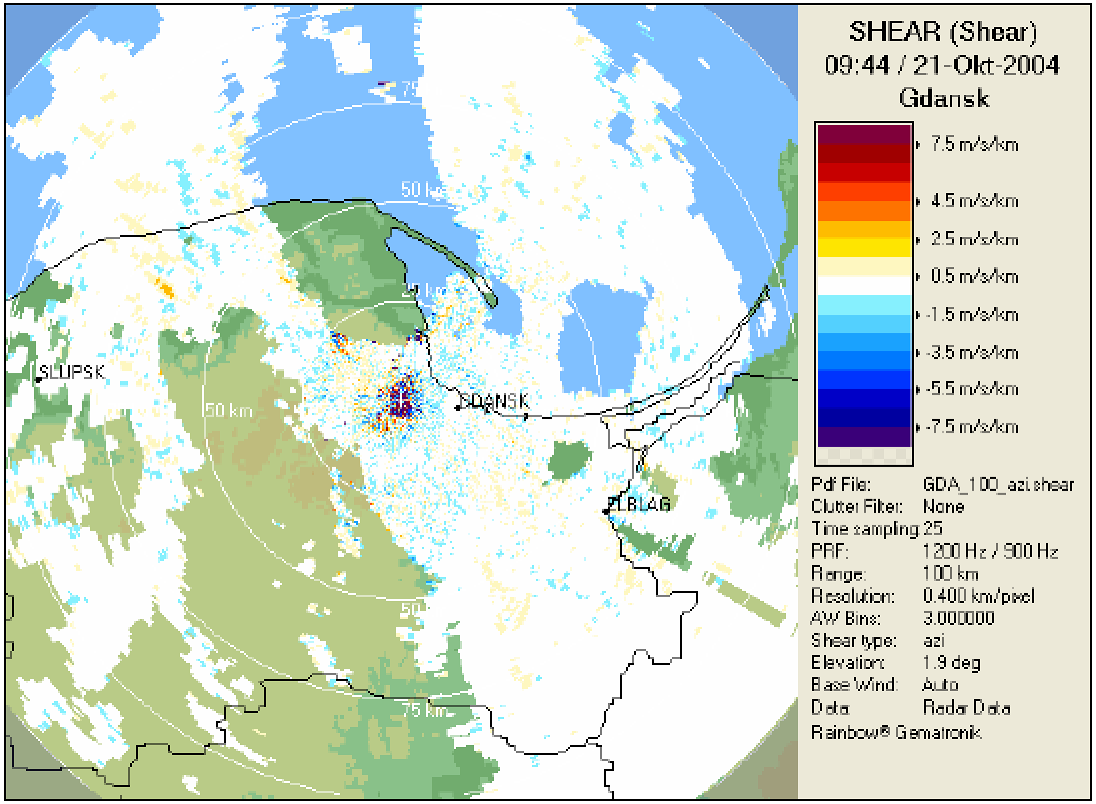


PRT overlay with tool tip information

The PRT product

The change of the wind velocity in north-south direction and in east-west direction in a single layer of constant height above MSL is calculated, and combined to find the value of the horizontal shear.

Azimuth Shear

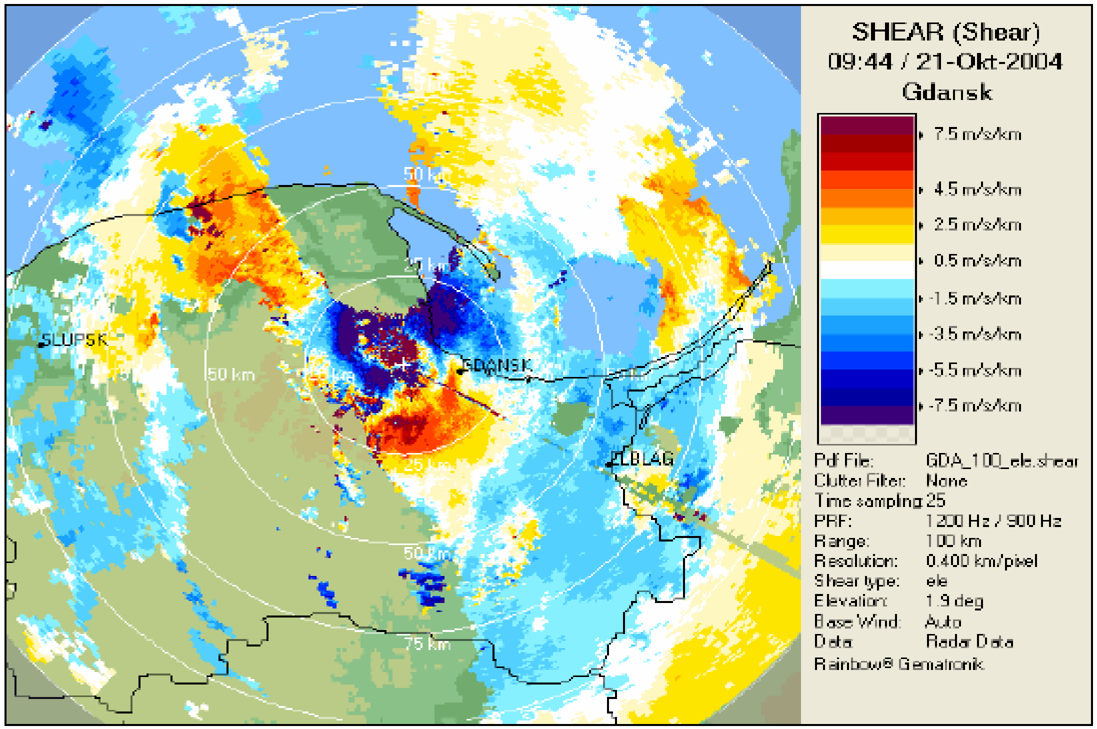


The *azimuth* shear (AZS) evaluates the derivative of the radial wind velocity in azimuth direction.

Positive AZS → *counter clockwise (cyclonic) rotation*.

Negative AZS → *clockwise (anti-cyclonic) rotation*.

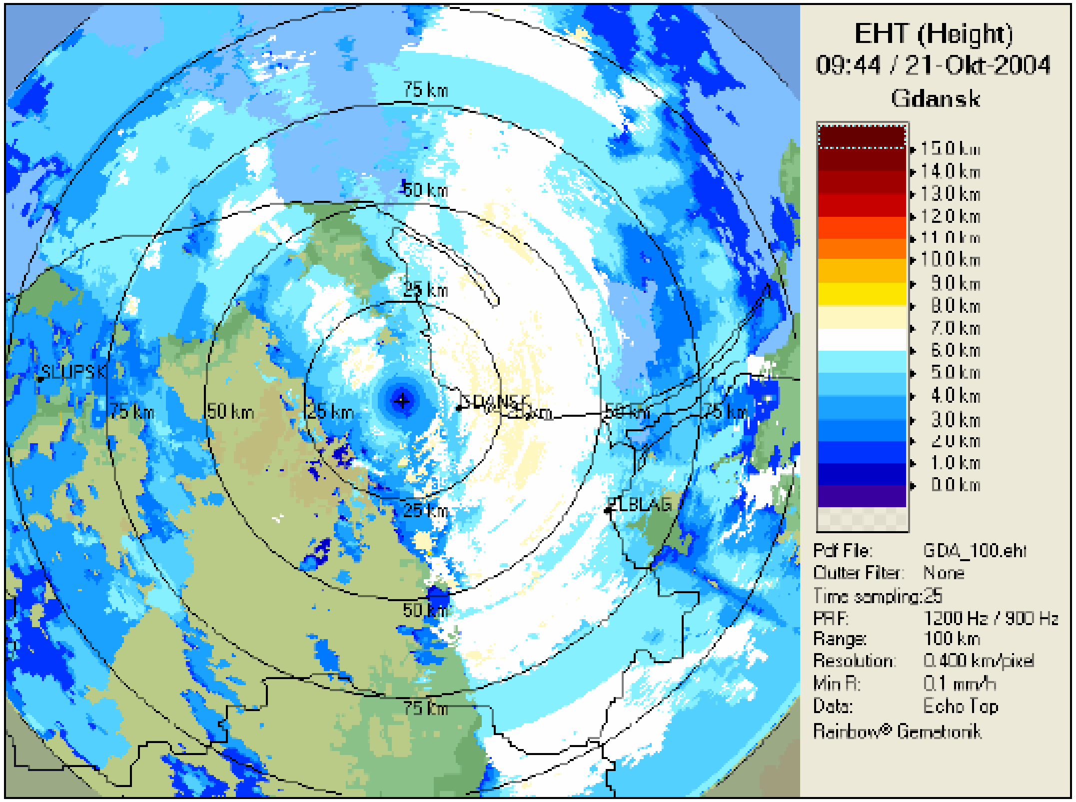
Elevation Shear



The *elevation* shear (ELS) evaluates the derivative of the radial wind velocity in elevation direction. Two planes of constant elevation are taken as input.

The ELS is similar to the vertical shear product VSHEAR.

Echo Top/Base

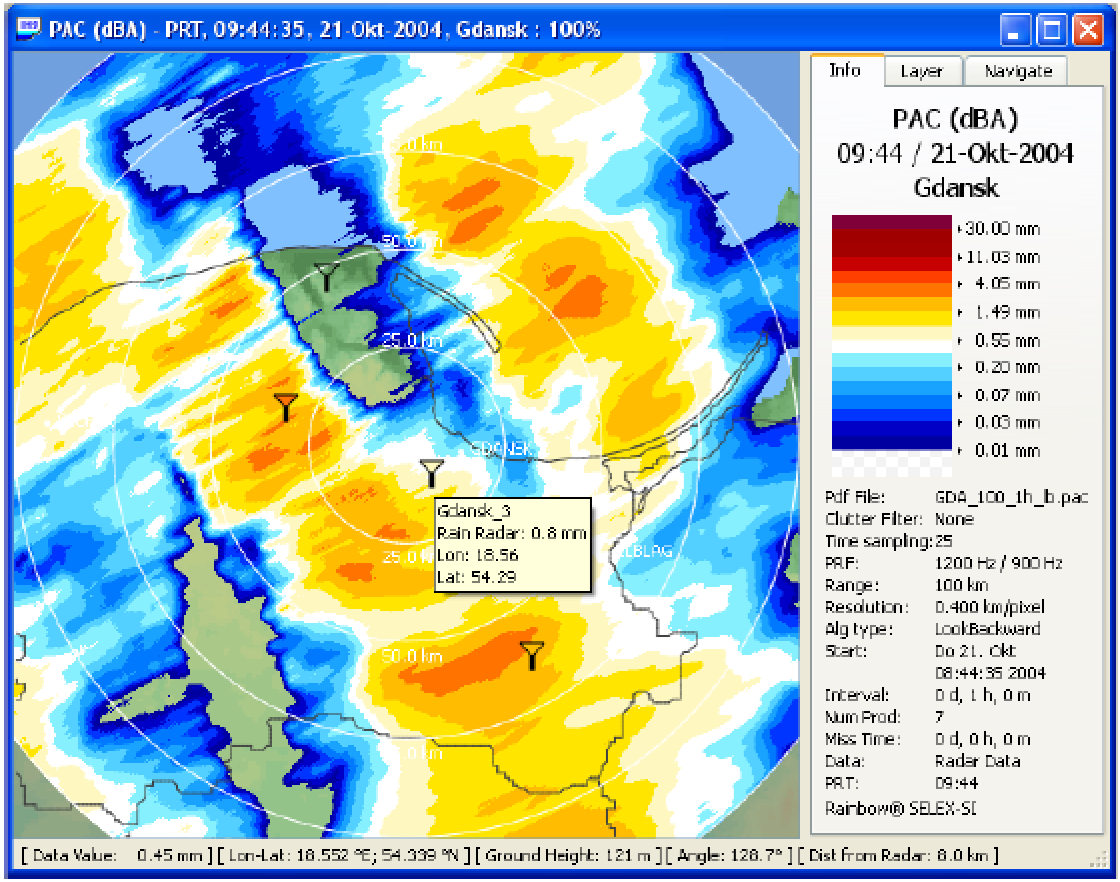


The EHT product shows e.g the uppermost height where the measured value is greater than a user-defined threshold.

Selectable are ...

- Echo Top
- Echo Base
- Height of Z_{max}

Point Rainfall Total

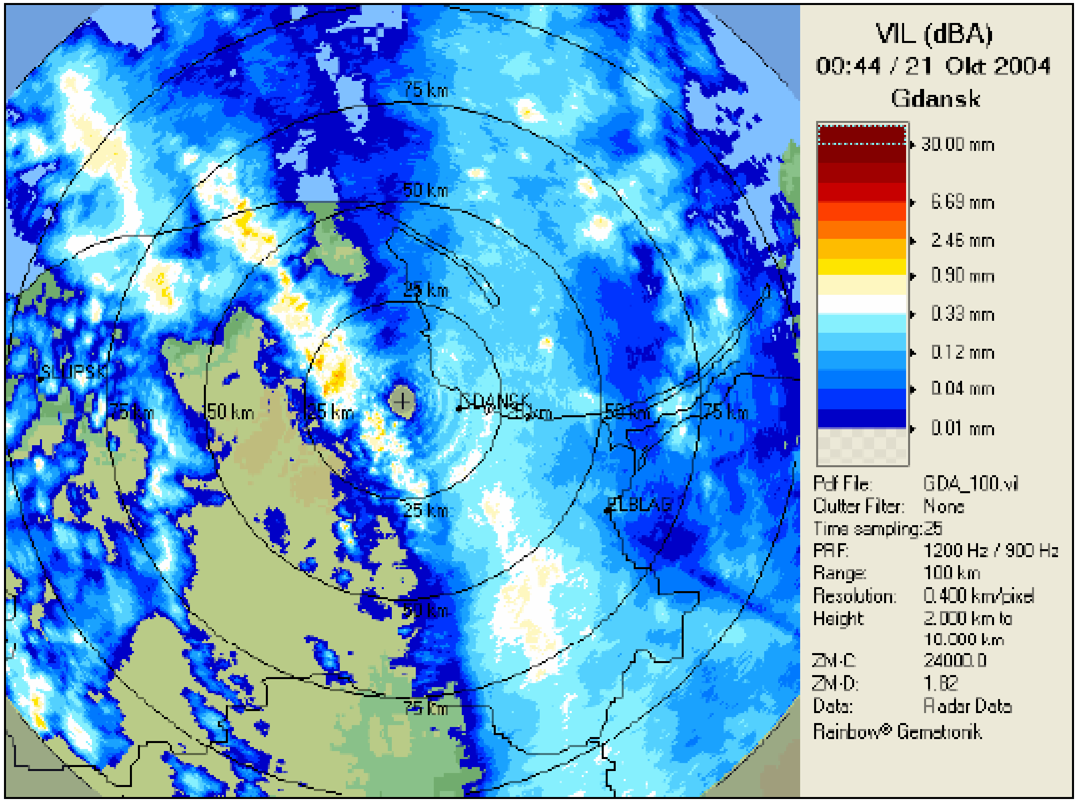


PRT overlay with tool tip information

The PRT product provides information about the rainfall total (accumulated rainfall) at a variety of selectable locations within the radar coverage. The accumulation time interval corresponds to that defined for the input PAC. DART shows colored symbols with

- location name
- radar total
- lon/lat coordinates

Vertical Integrated Liquid



The aim of the VIL product is to give an instantaneous estimate of the water content residing in an user-defined atmospheric layer in order to indicate the rainfall potential of a e.g. severe storm.