The Multiple Vortex Structure of a Tornado

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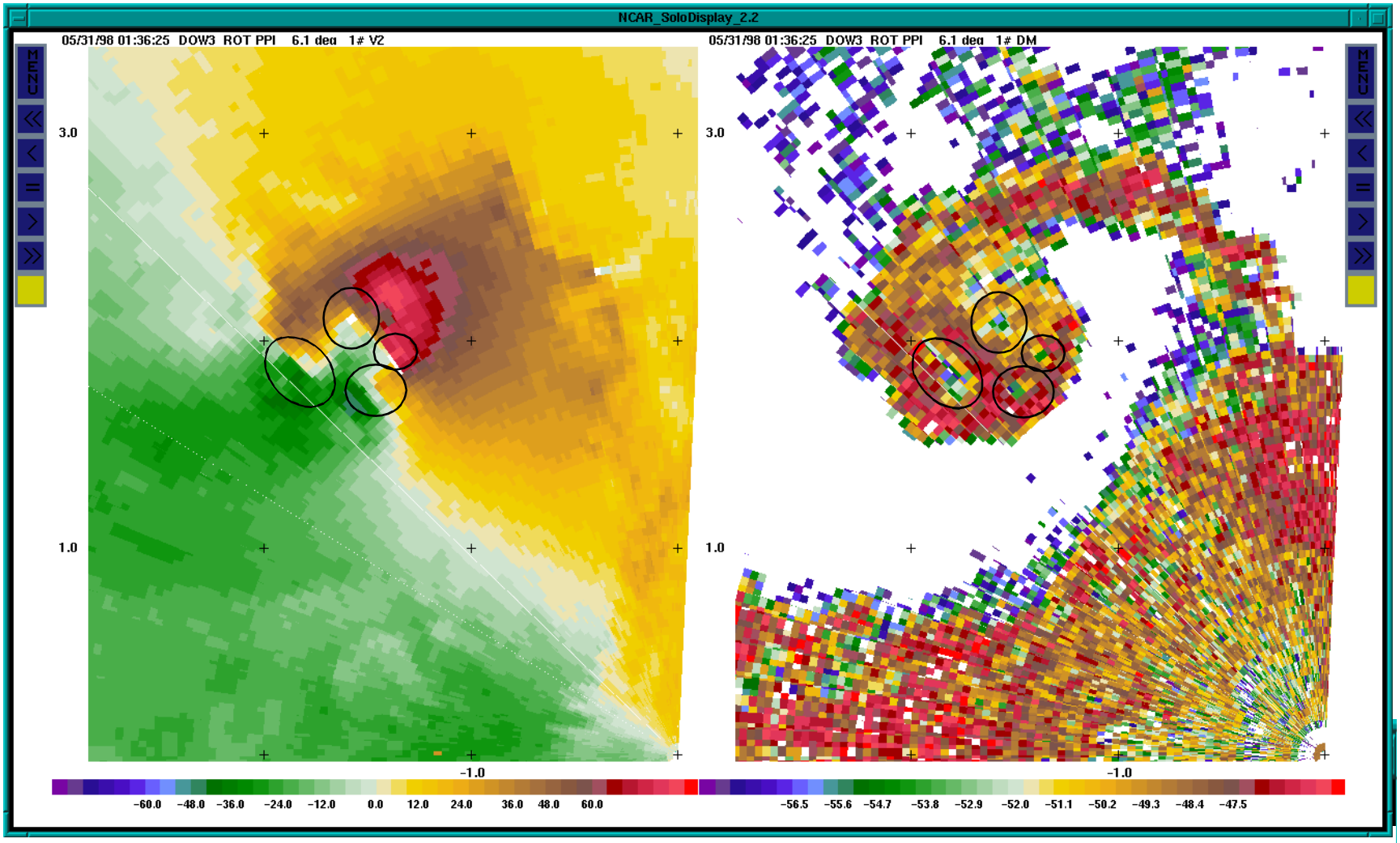
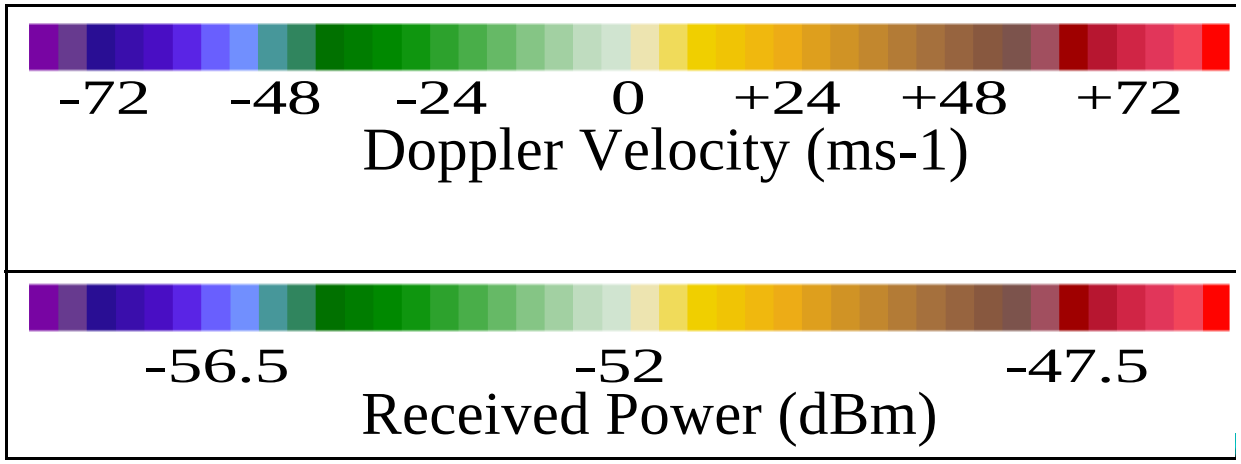
What to do when you fail to get dual-Doppler and don’t have a high resolution 3-mm radar

DOW radars: 250 kW, 0.93° bw, 12.5 m sampling, 133 ns (20 m) pulse, 30°-60°s^{-1} scanning, 5000 Hz (+stagger) PRF



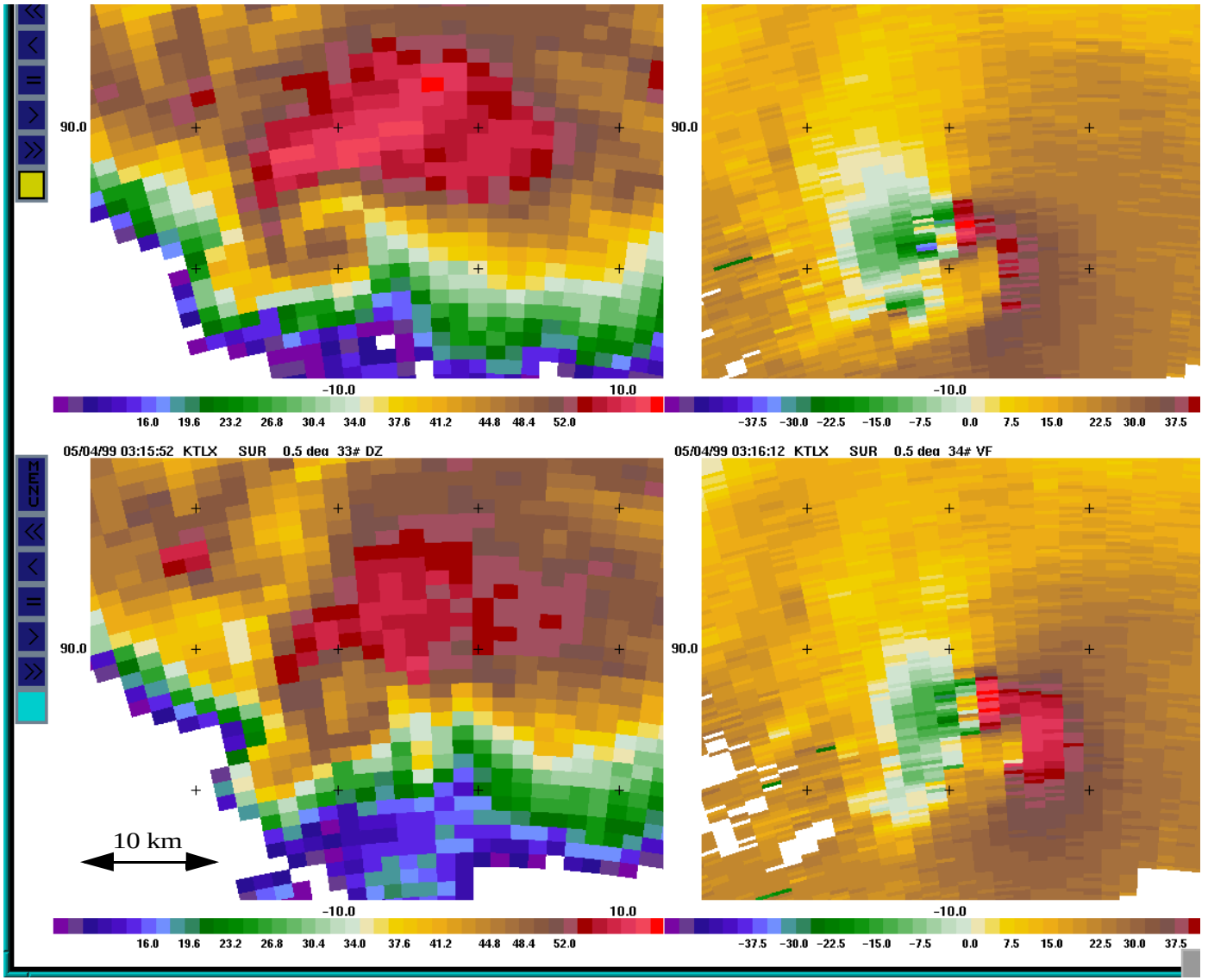
1st Crude Radar Observations of Multiple Vortices

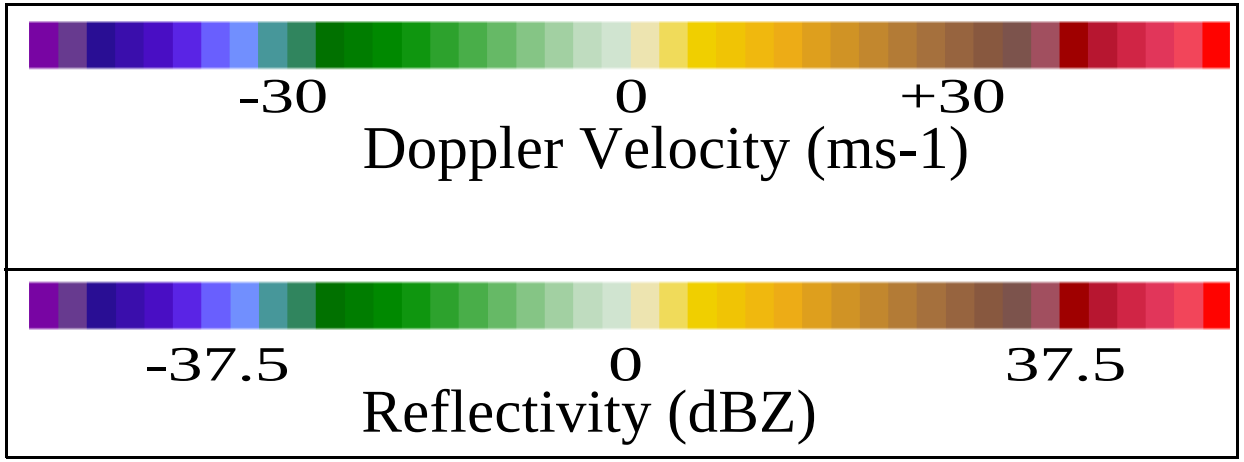
Spencer, South Dakota, 1998



Storm B
3 May 1999
as viewed
by WSR-88D radar

Very Large
Mesocyclone
Travelling Through
Northern Oklahoma





Deployment of DOW and Track of Core Flow Region of Tornado

Very Large Diameter Tornado Passes Just Southeast of Mulhall, Oklahoma

Large Swath of Damaging Winds over 2-3 km Wide

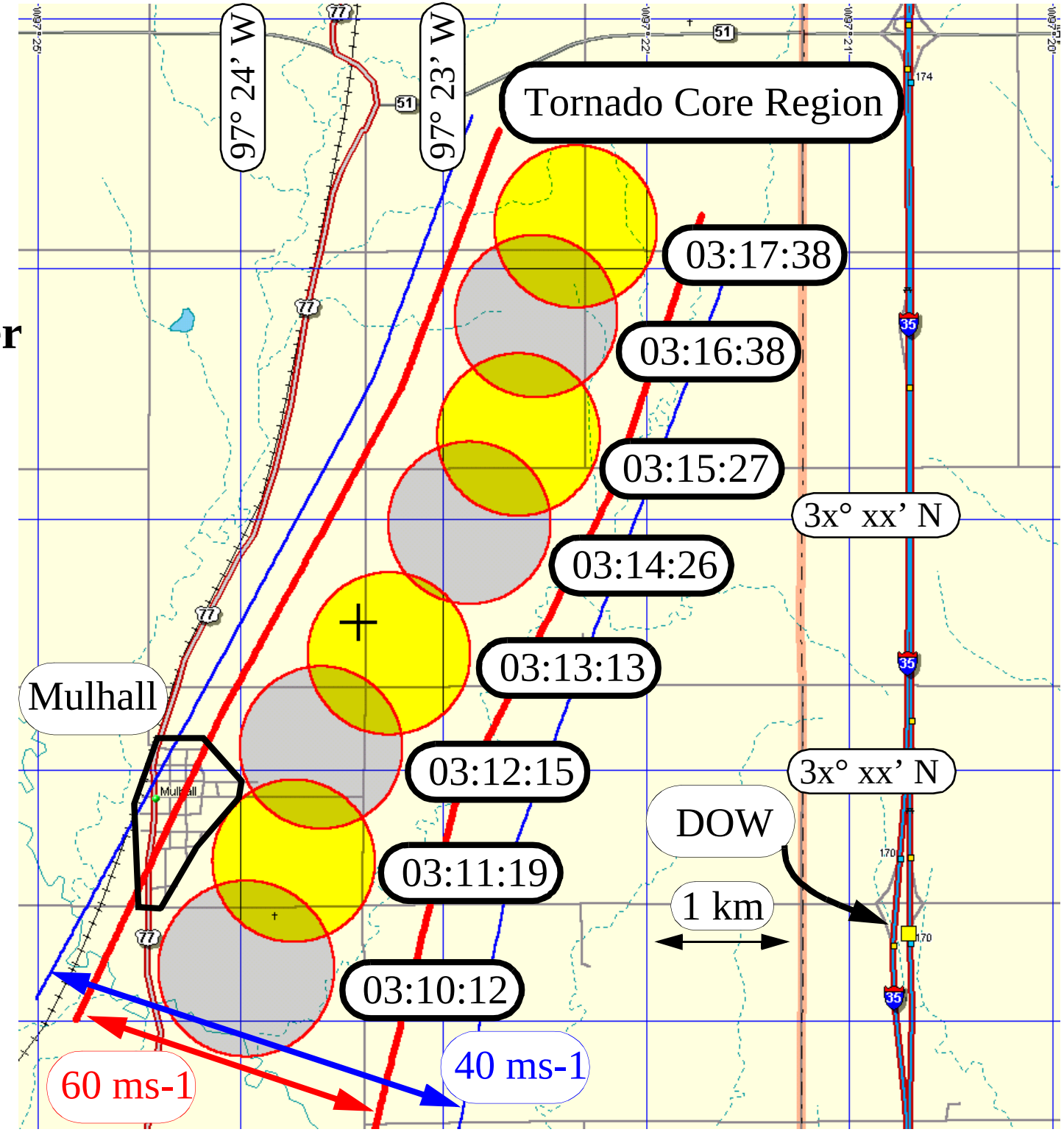


Image from video shot by Herb Stein shows ~1 mile wide (1.6 km) condensation funnel

Core flow region was about 1.3 km diameter at surface

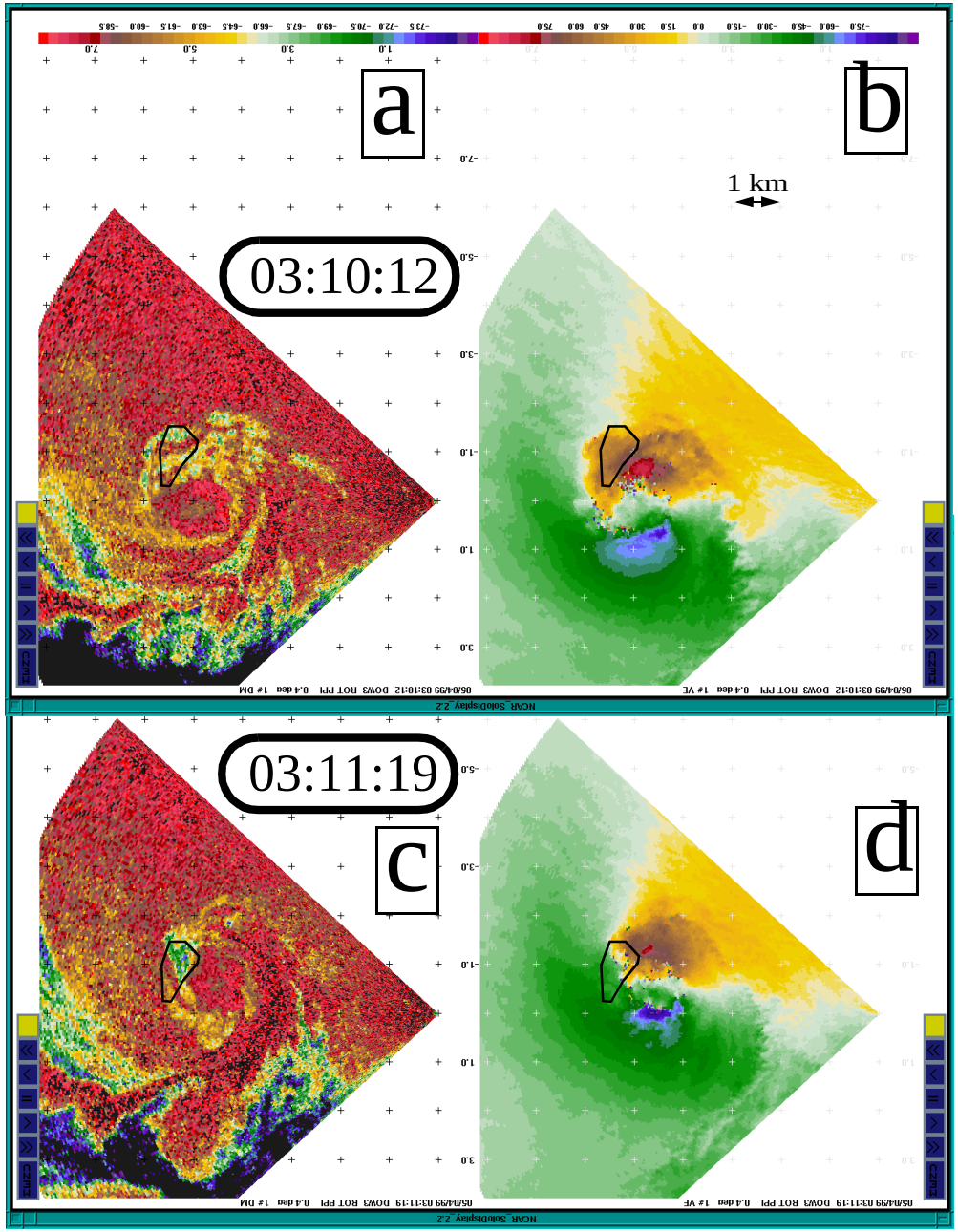
Large scale images of tornado during 1st and 2nd volume scans.

Large and intense core flow region passes just southeast of town outline.

Hook echo has wrapped around tornado.

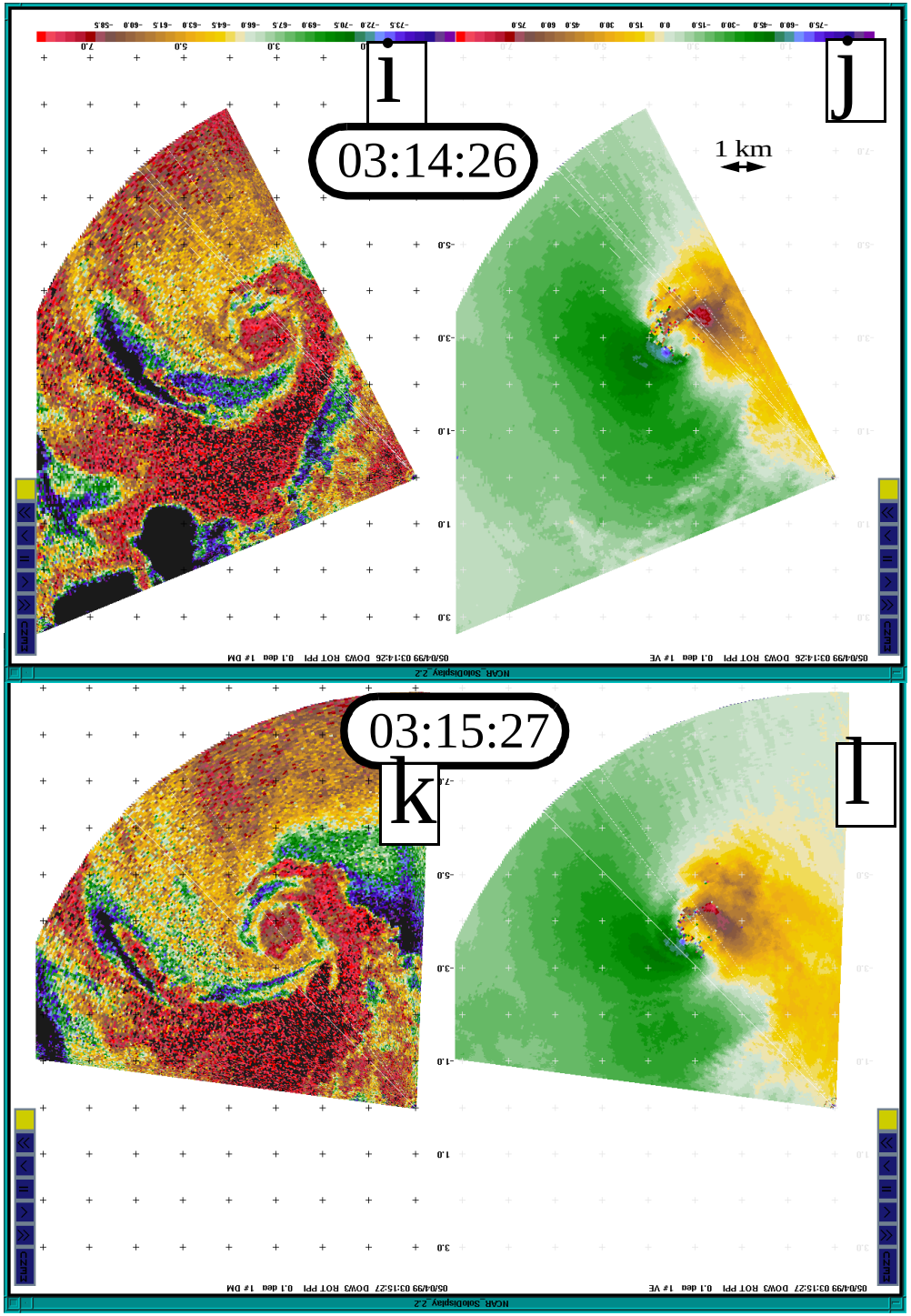
Typical tornado couplet
- **multiple windfield maxima**
- **solid body core flow**
- **1/sqrt(r) decay outside**

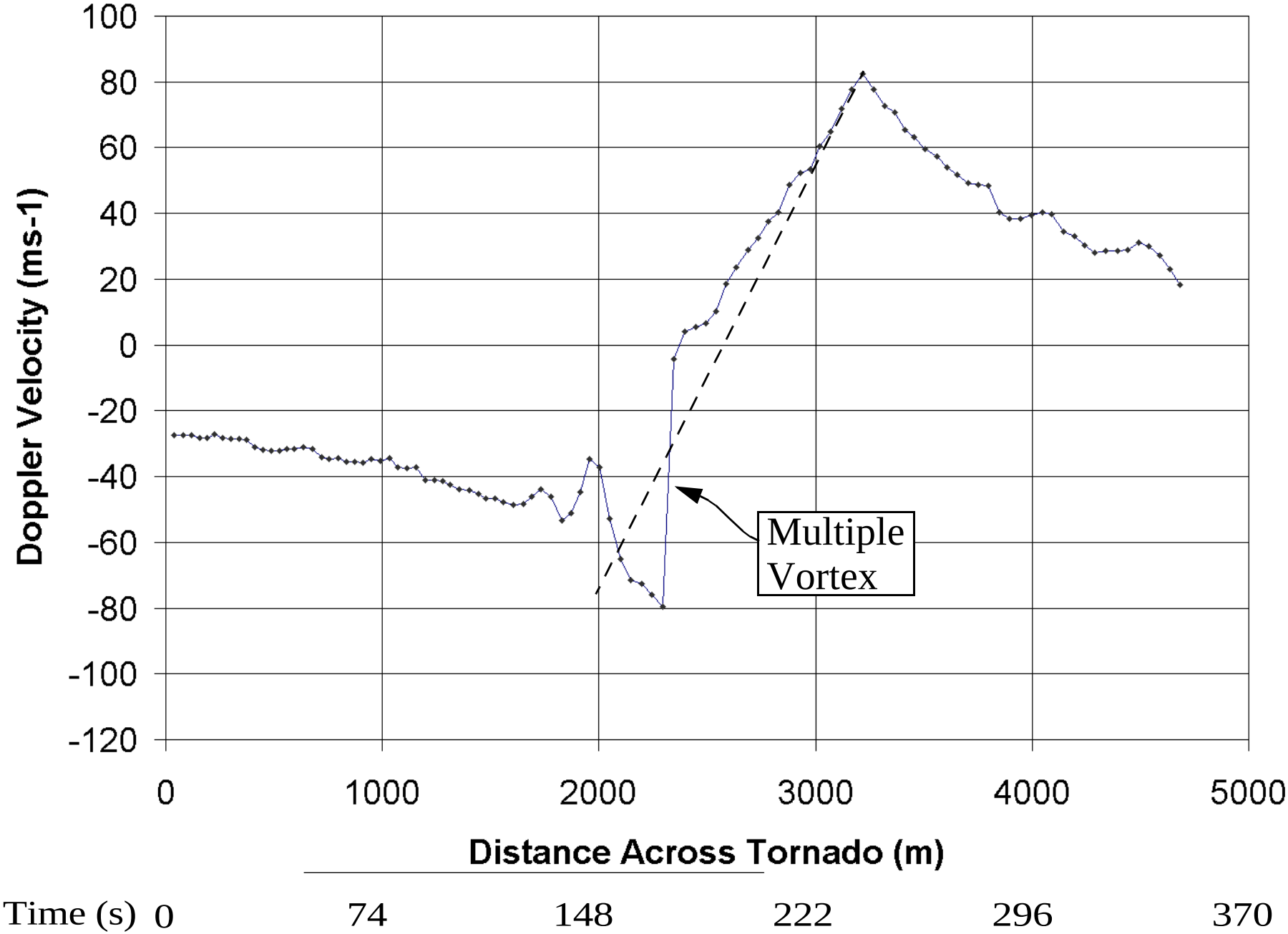
Atypical filled eye



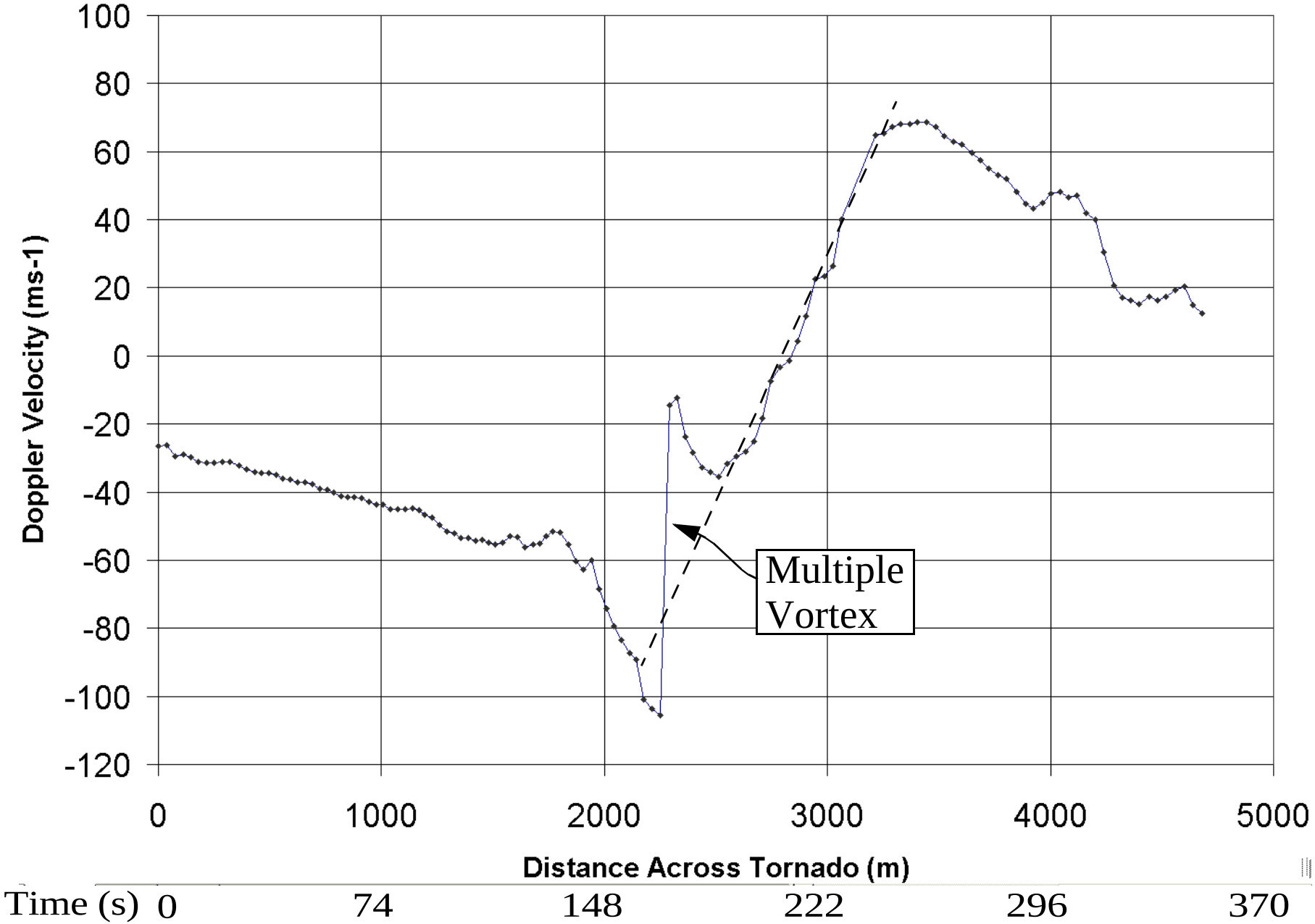
Large scale images of tornado during 5th and 6th volume scans.

Hook feature is more clearly identifiable.



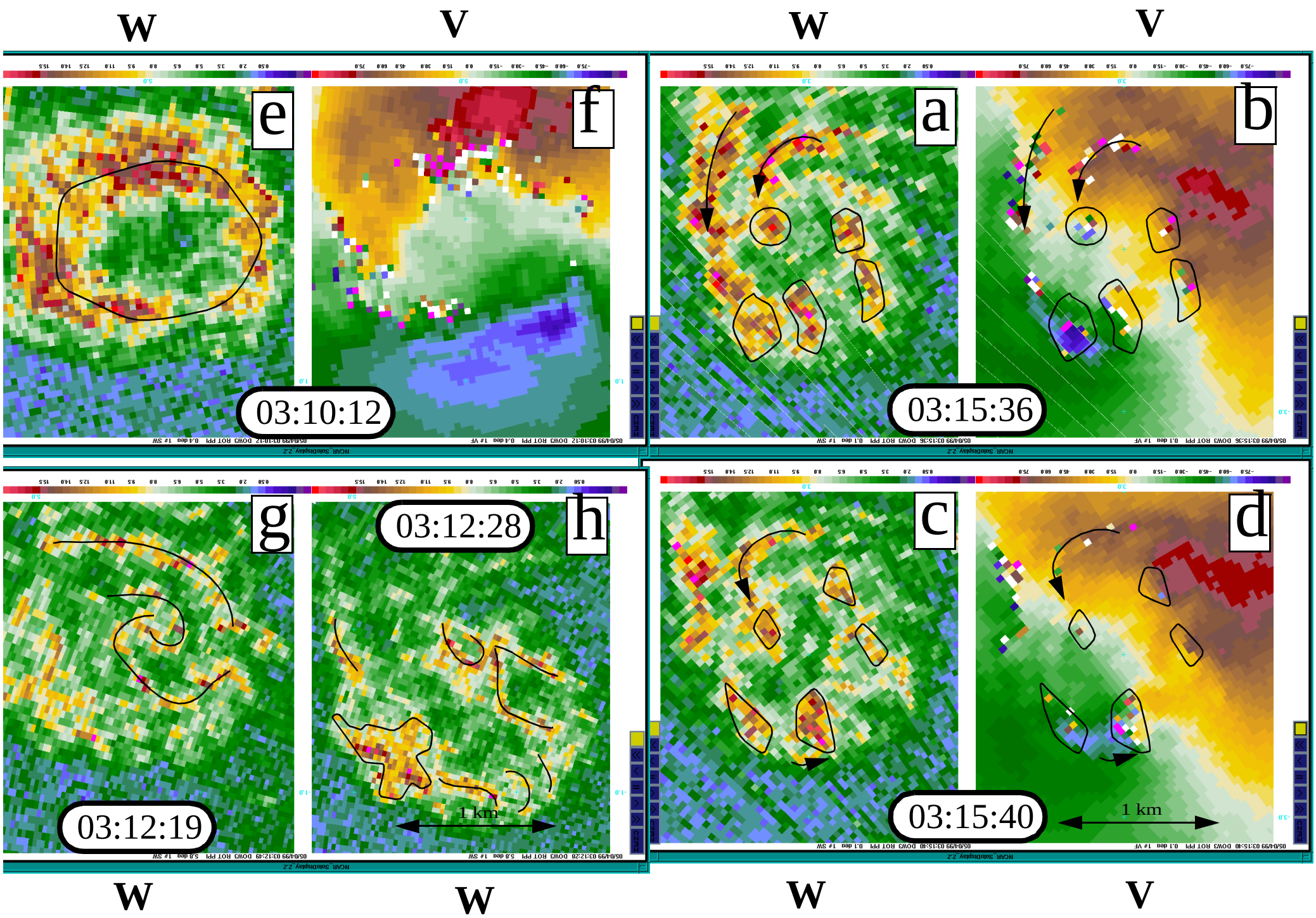


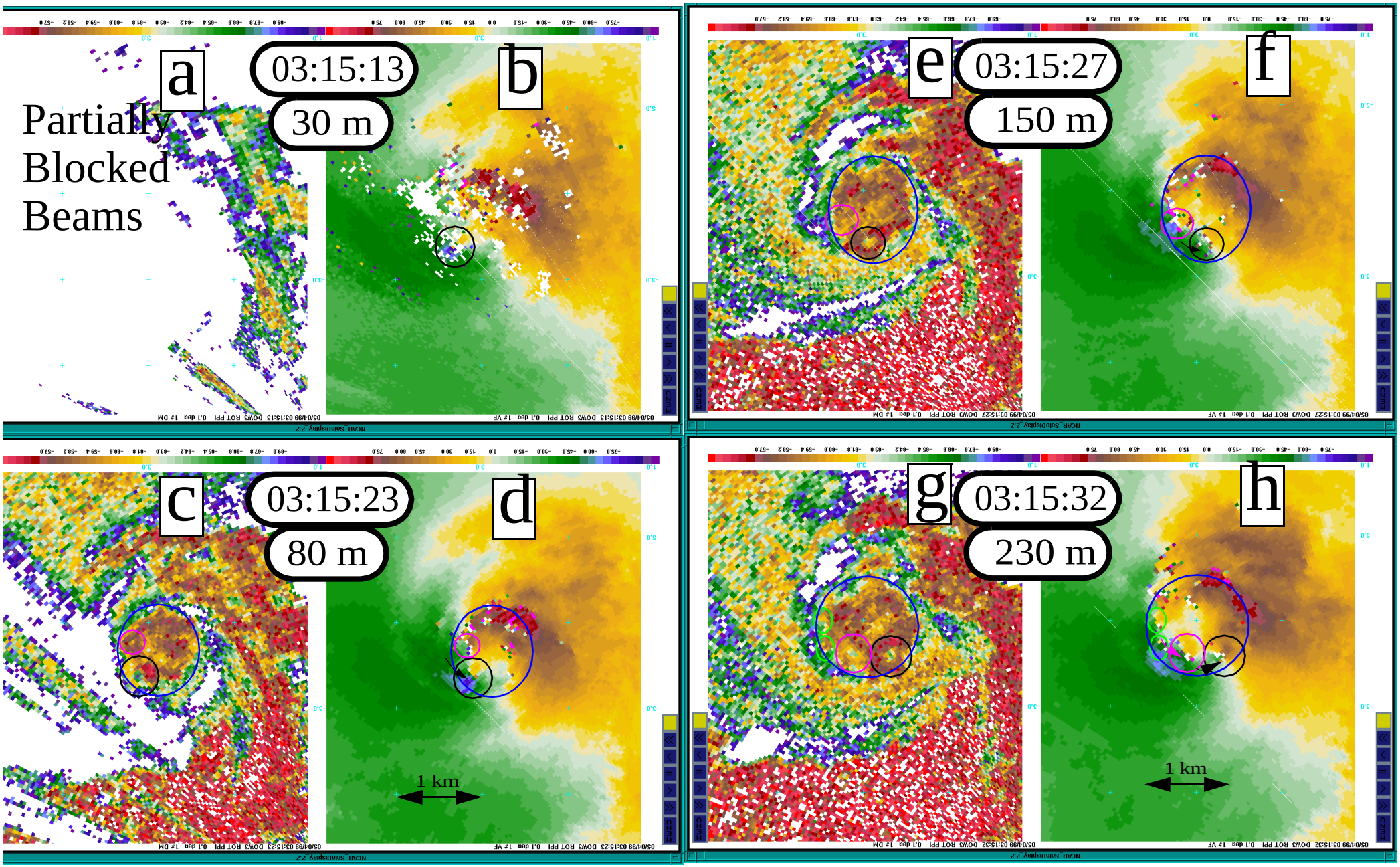
Cross section through velocity field of tornado illustrating perturbation due to one multiple vortex.

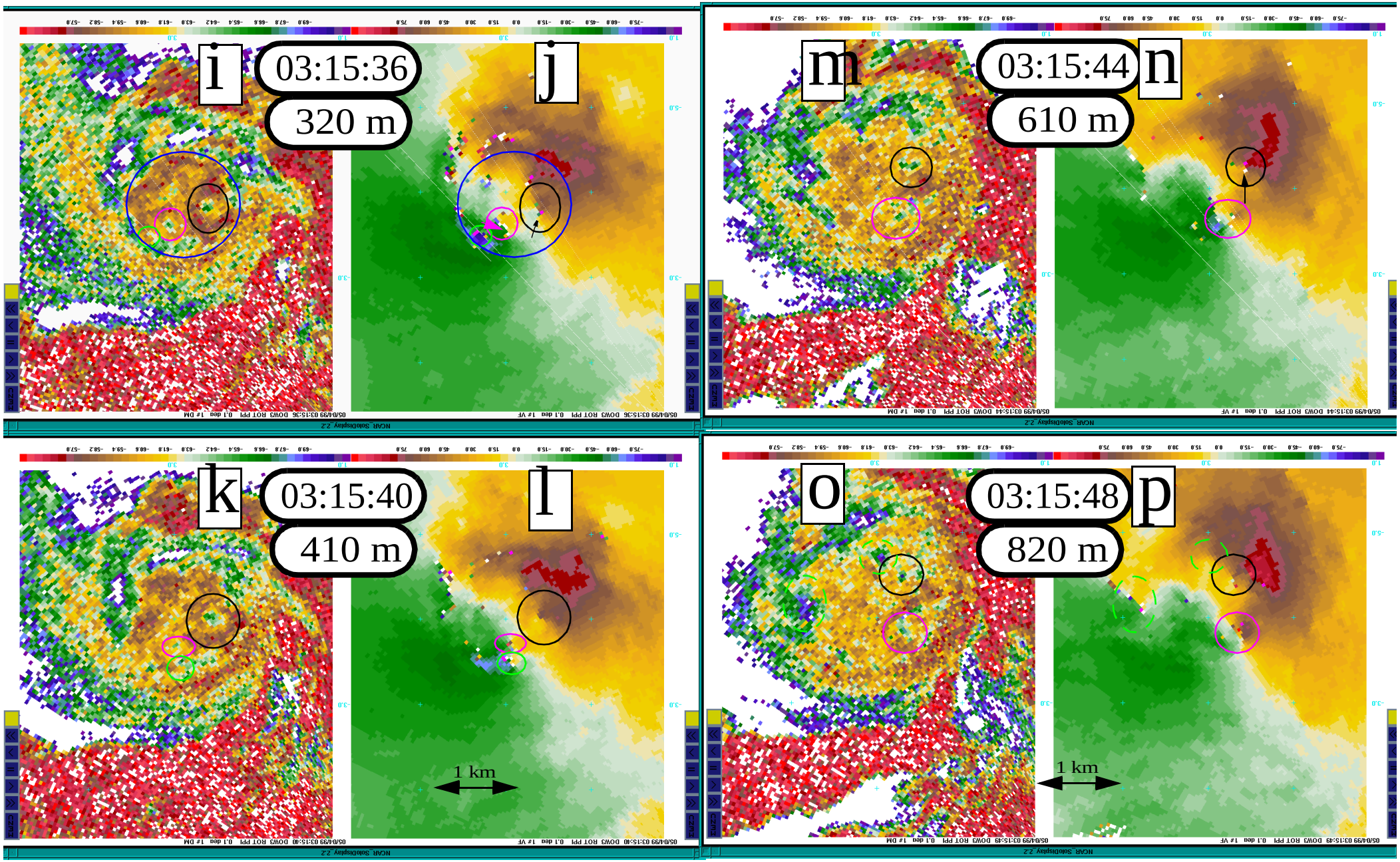


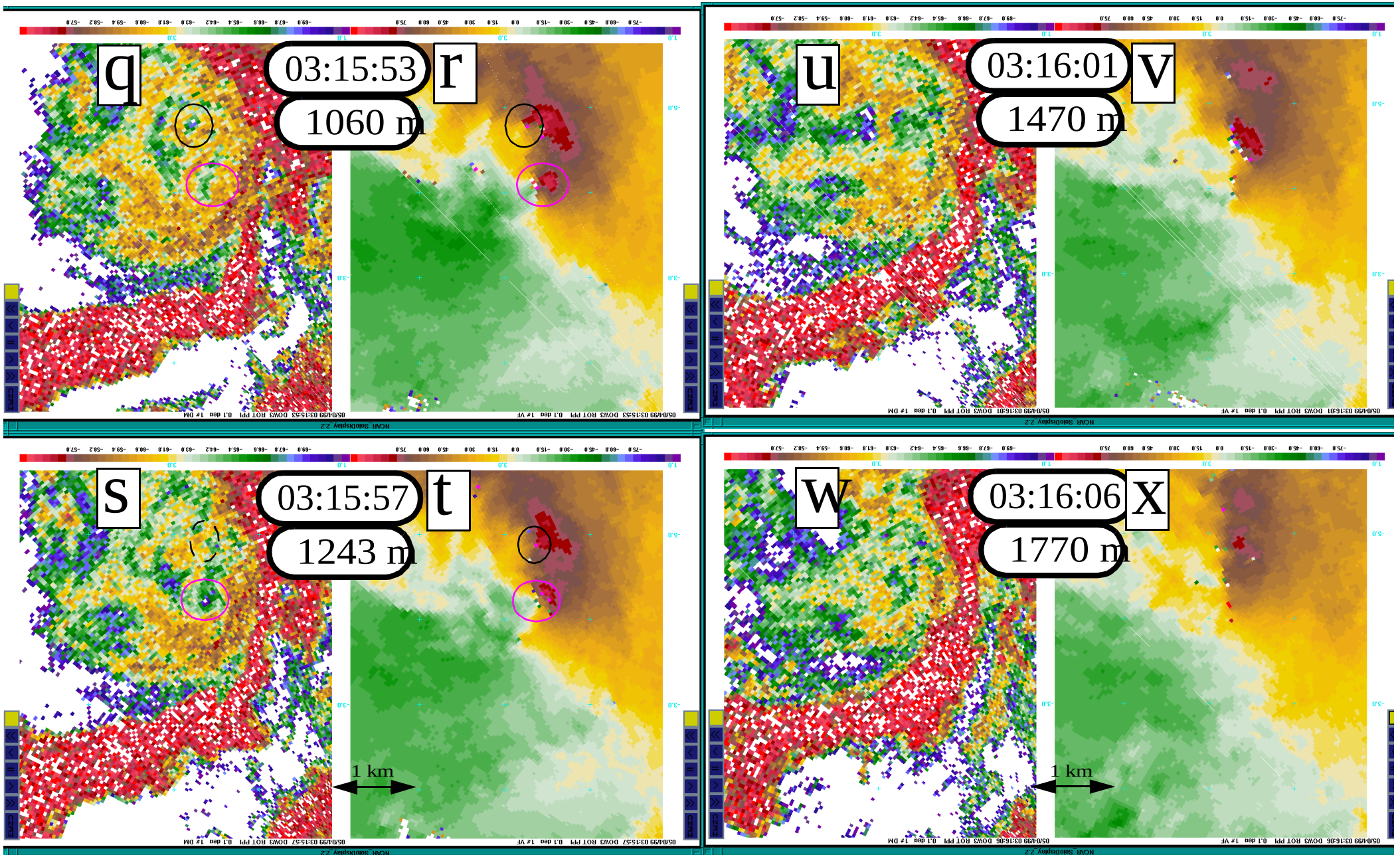
Cross section through velocity field of tornado illustrating perturbation due to another multiple vortex.

Spectral width data showing regions of high width associated with vortices

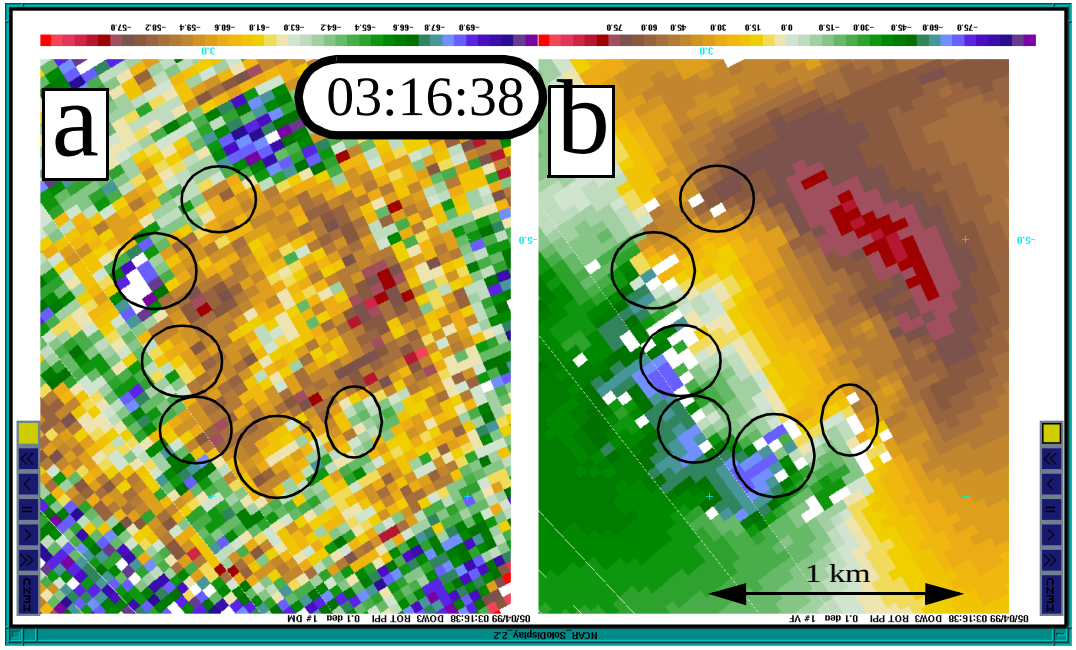



a
b
03:15:13
30 m
Partially
Blocked
Beams
c
d
03:15:23
80 m
1 km
e
f
03:15:27
150 m
g
h
03:15:32
230 m
1 km


i
03:15:36
320 m
j
m
03:15:44
610 m
n
k
03:15:40
410 m
l
1 km
o
03:15:48
820 m
p
1 km


q
03:15:53
1060 m
r
u
03:16:01
1470 m
v
s
03:15:57
1243 m
t
1 km
w
03:16:06
1770 m
x
1 km

Sometimes up to wavenumber ~10



Main Observed Properties of Multiple Vortices

Size ~200-300 m

Motion 0.5 - 1.0 x background flow

Peak velocities in vortices ~1.5 x background flow

Located near edge of core flow region, near updraft/downdraft boundary

Strongest velocity perturbations near ground

Size increases with altitude

1/2 of shear across <= 50 m (limit of observability)

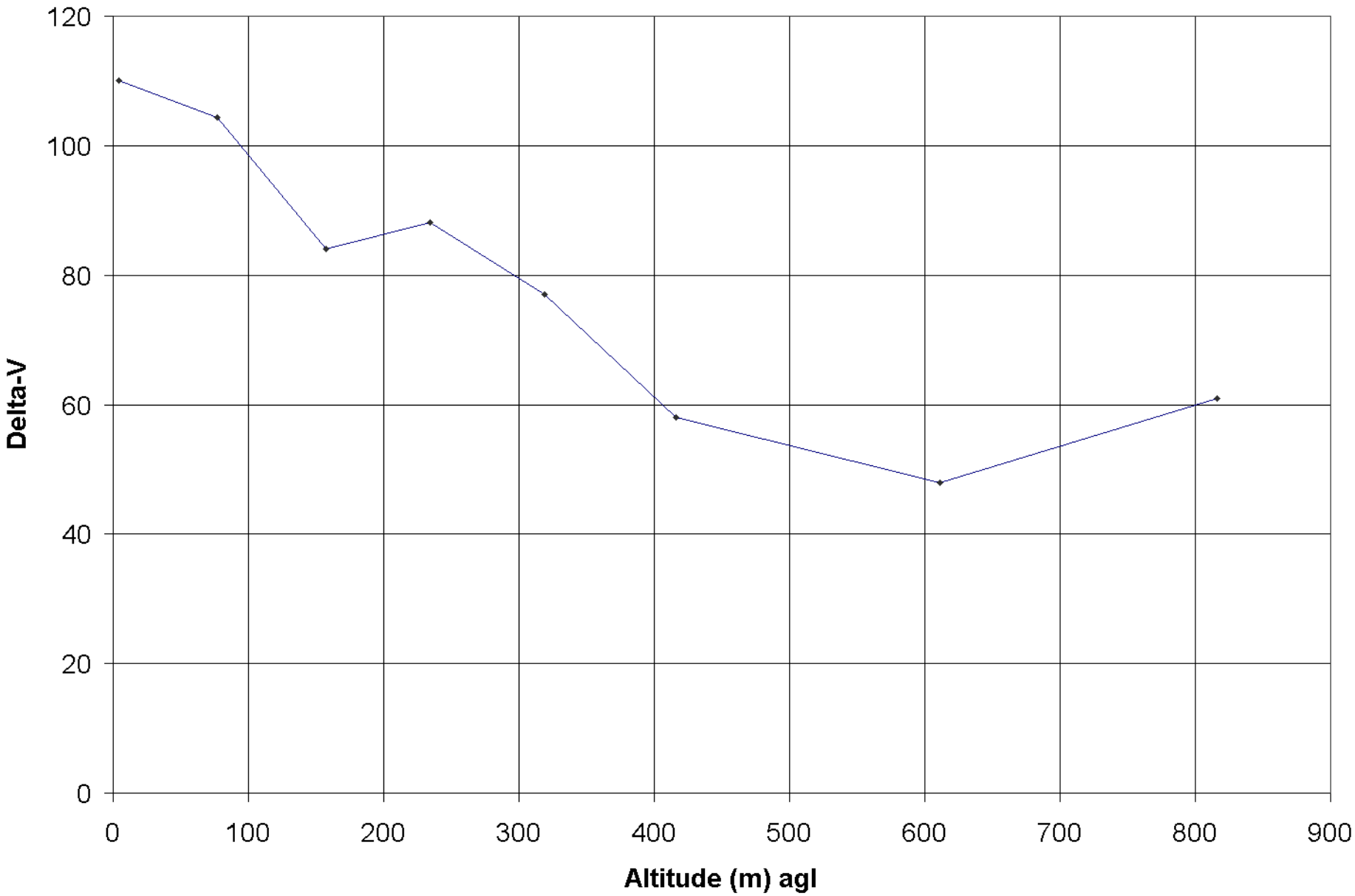
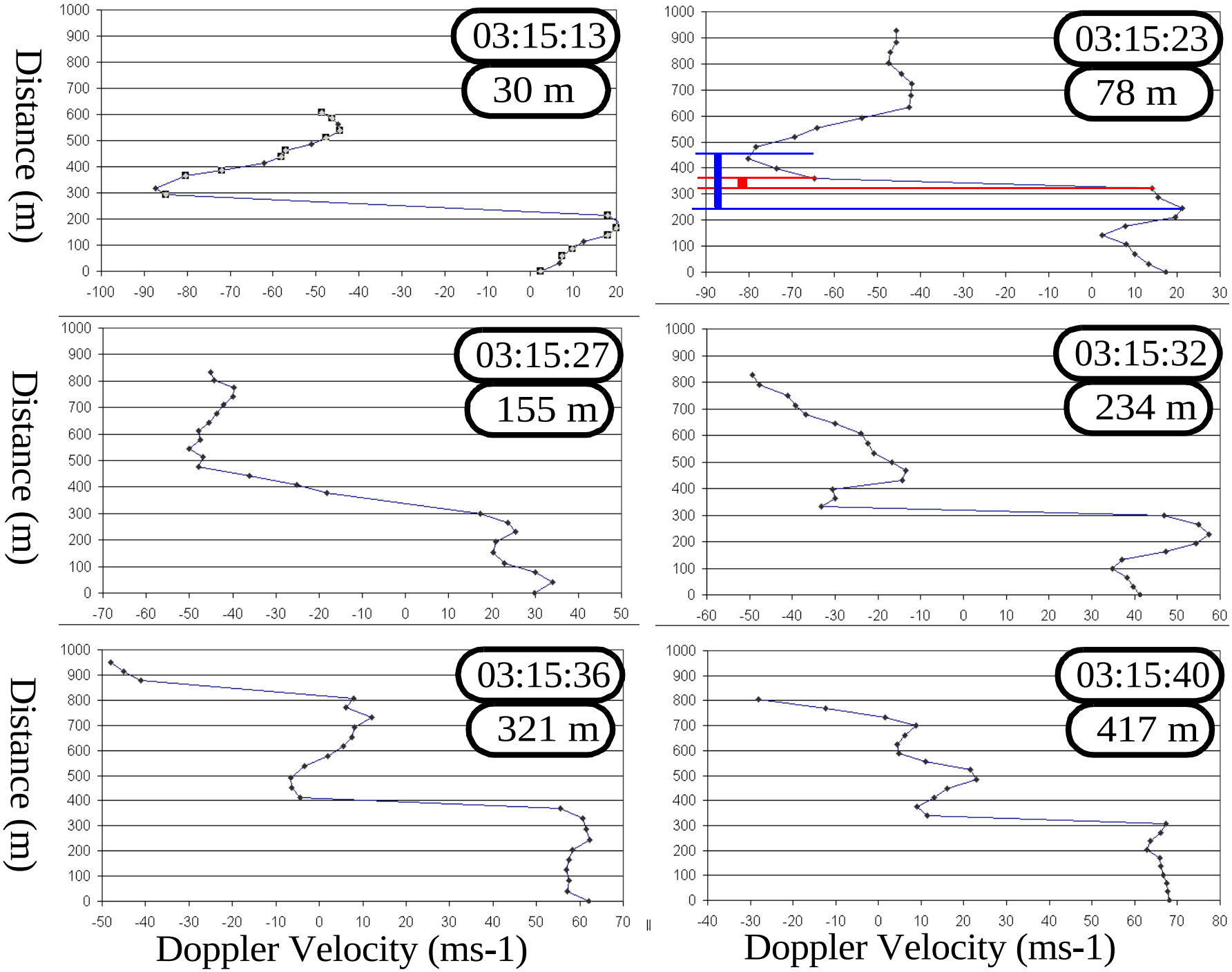
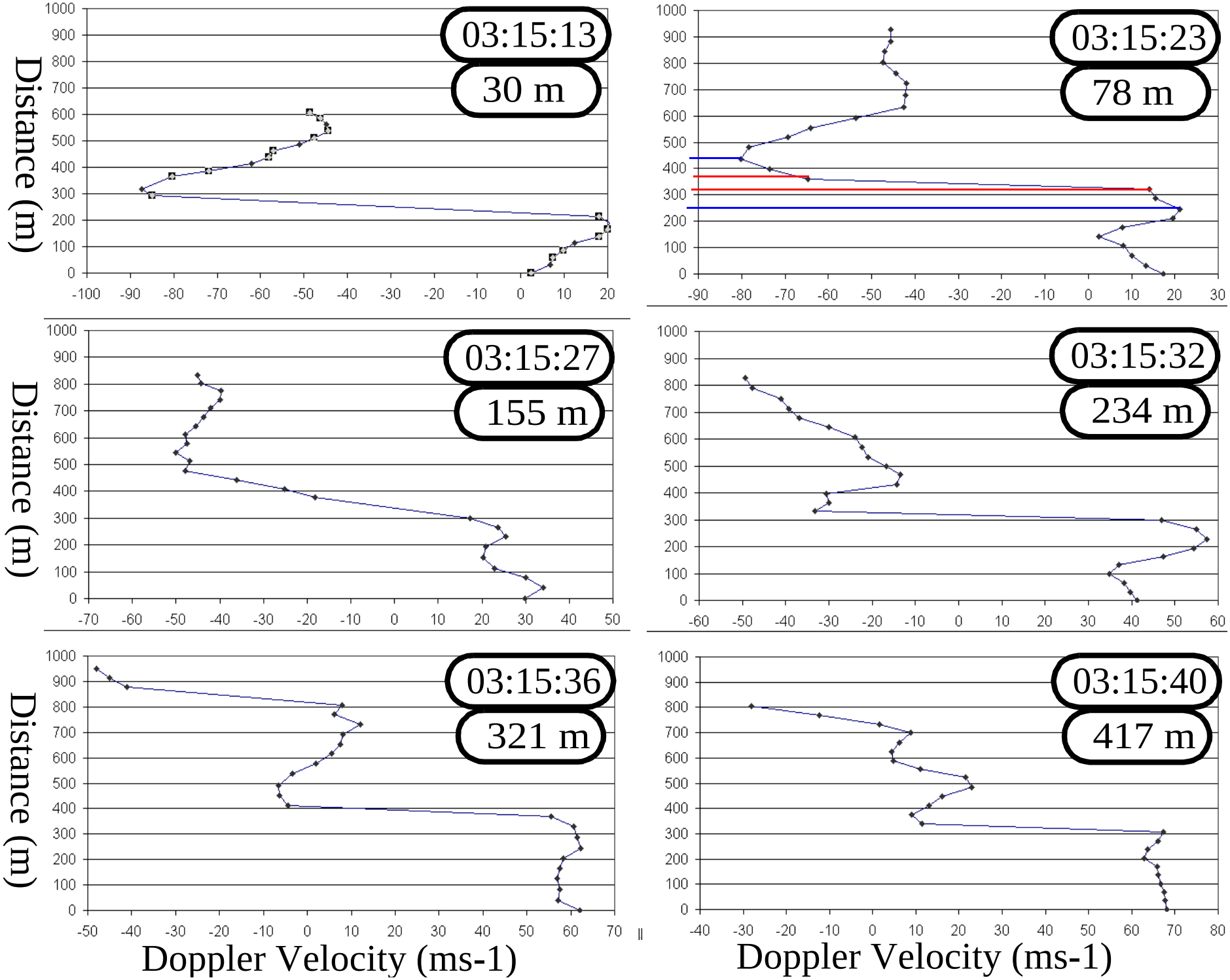
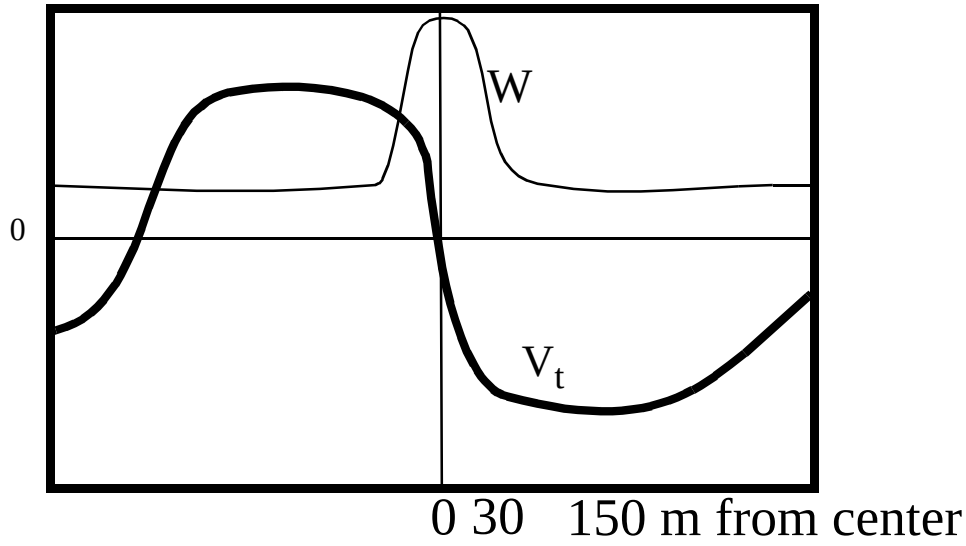
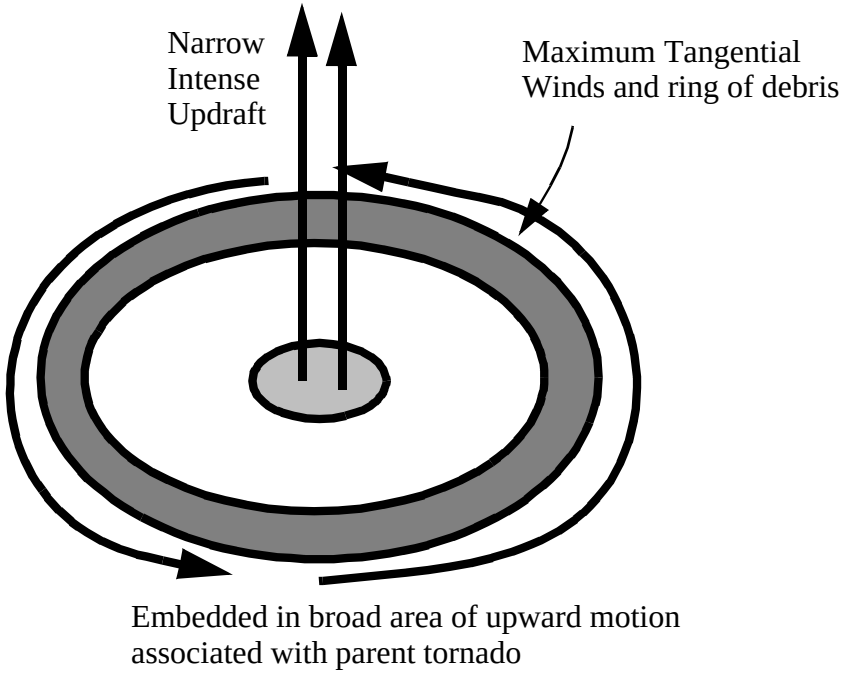

120
100
80
60
40
20
0
Delta-V
0
100
200
300
400
500
600
700
800
900
Altitude (m) agl

Figure 11

Velocity xsections across vortex A 1/2 of shear over 50 m



Xsections across vortex B



Possible Structure of Multiple Vortices