P11.6

Scales of Motion in Tornadoes
What Radars Cannot See
What Scale Circulation is a Tornado

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1. What Radars Cannot See in Tornadoes

Several papers have reported observations of certain characteristics of tornadoes, including low reflectivity eyes, rings of high reflectivity surrounding these eyes and core flow velocity structure. Several radar systems have collected observations in tornadoes or plan to in the future.

However, the complex and quasi-concentric structure of tornadoes, which contain velocity and reflectivity structures exhibiting multiple scales, can alias these observations, resulting in misleading conclusions unless this aliasing is carefully considered.

In this paper, we report preliminary progress on comparing simulated observations of several radar systems in several actual tornadoes to high resolution 'ground truth' Doppler and reflectivity fields. This is an extension of the work of Wood and Brown, who simulated WSR-88D sampling of idealized vortices. The presentation of figures with little commentary herein is not complete and is meant to accompany presentations at the Conference.

Comparisons in two tornadoes that occurred on 12 May 2004, the Spencer tornado of 1998, and the Kellerville tornado of 1995 are made.

Comparisons among high resolution data obtained by DOW radars from extremely close range to tornadoes to lower resolution simulated data from DOWs, SMART, ELDORA, CASA, and 88D systems is presented (SPY-1 results can be inferred from the CASA simulations). In many cases, aliasing of the lower resolution data from some or all the simulated radars results in images of radar eyes and Doppler velocity couplets that are more representative of circulation scales outside the true tornado.

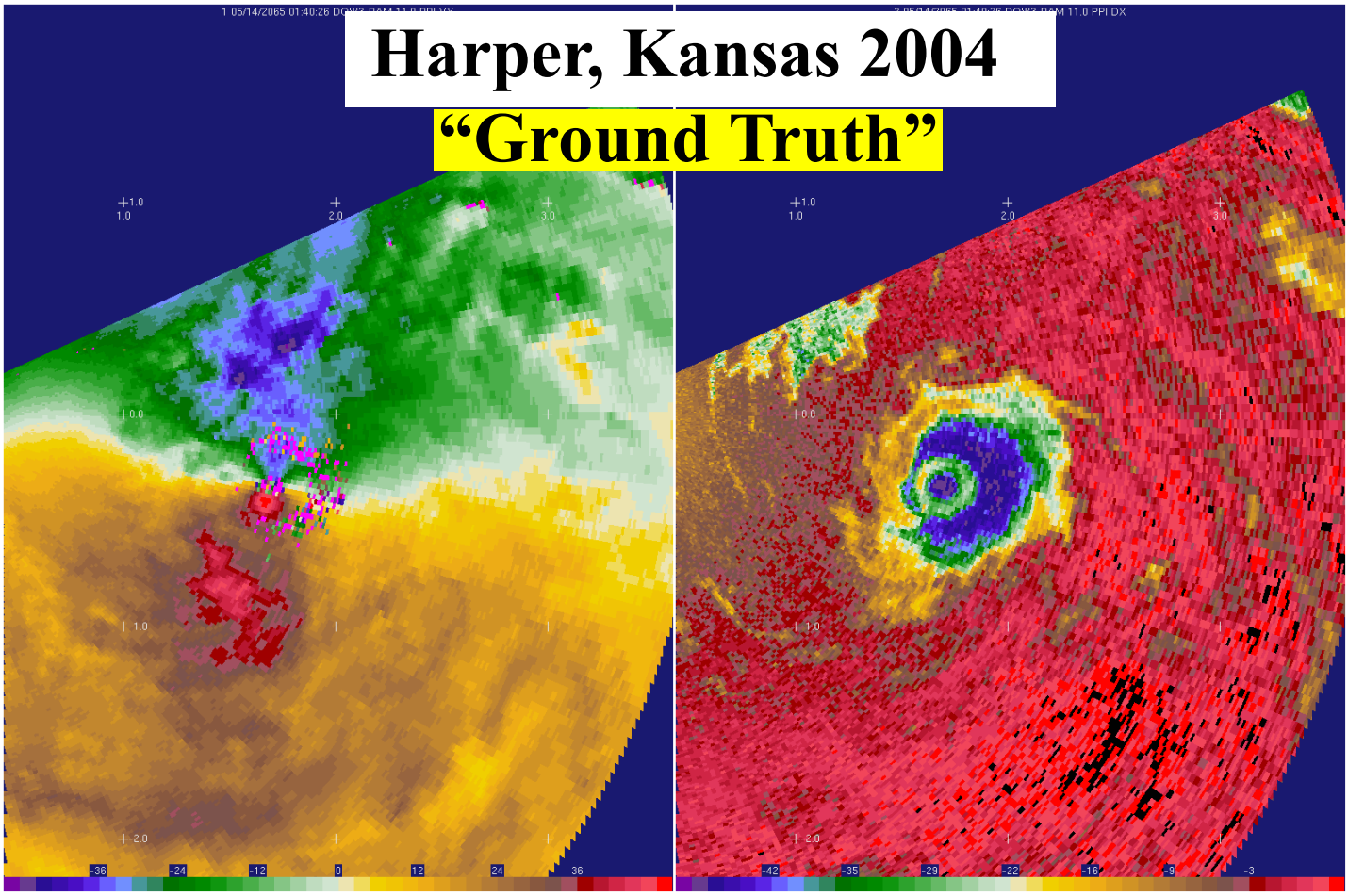
In all simulations, sampling has been rigged to break beams at the center of the tornado circulation, therefore resulting in a best case scenario. In order to simplify these preliminary comparisons, no oversampling has been simulated, even though DOWs nearly always oversample by a factor of 3x and 88D's may begin oversampling soon. All simulated radars have been placed at 10 km to the original "ground truth" radar location, typically about 12 km range to the tornado, except for the 88D. Note that the mean recurrence interval for a tornado passage within 10 km of a stationary system like an individual CASA or SPY-1 radar is many many years. The radar simulations have been conducted in only two dimensions; three dimensional simulations would smear the simulated fields in all but perfectly vertically stacked and non-tapered tornado circulations. Finally, the simulations have neglected any radar horizon effects and may represent altitudes which distant radars cannot sample.

DOW data obtained at close range is treated as 'ground truth', but of course suffer from aliasing of unobserved scales. This is particularly true of older data such as that in the Kellerville tornado in 1995. Later data were obtained at resolutions as low as 12.5 m, using a 0.93° beam that was oversampled by a typical 3x.

All figures in the following pages are at identical scales for each tornado and have identical V and Z keys. The scales and keys vary among the tornadoes, but not among the simulated radars being compared.

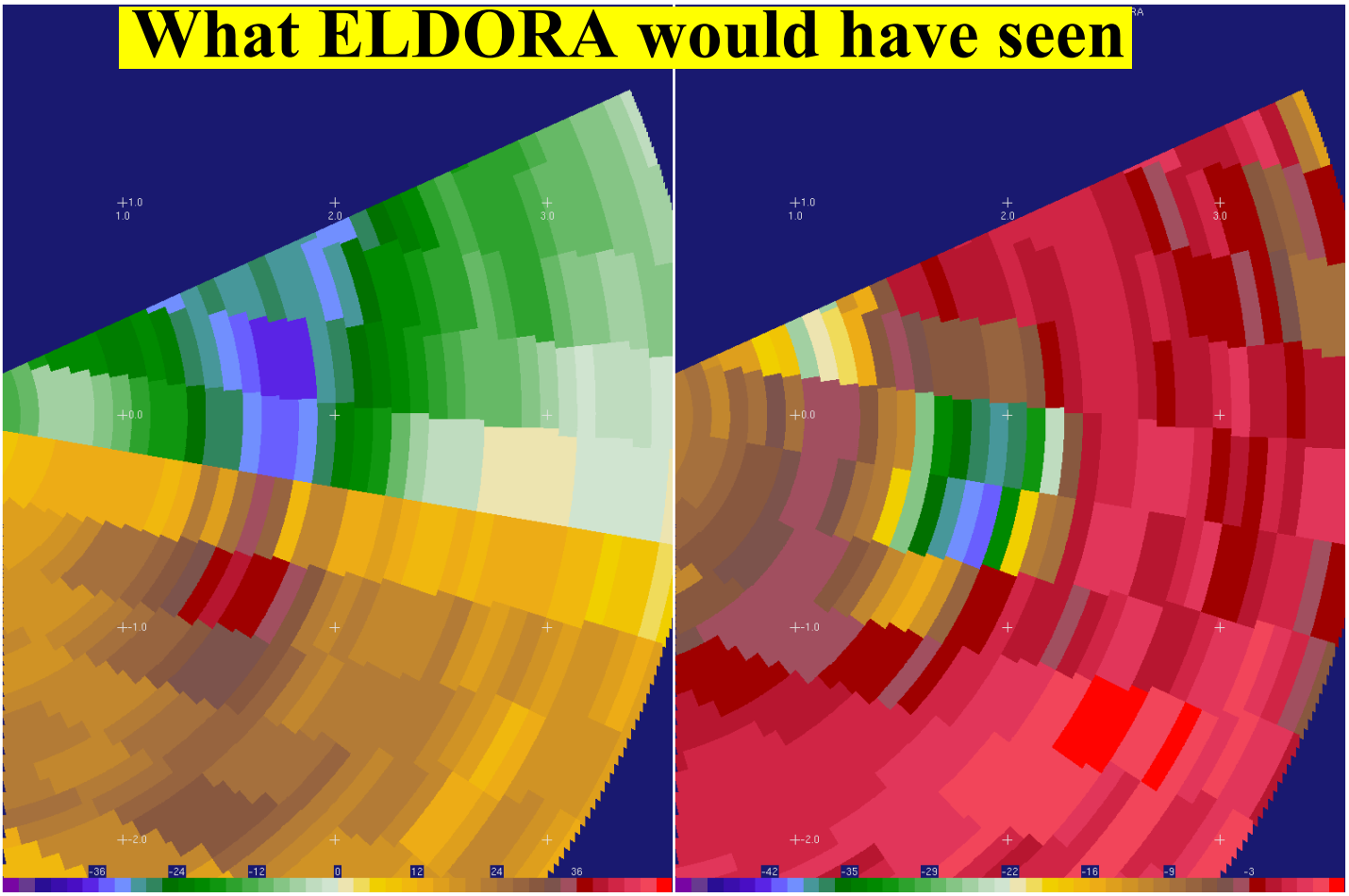
Harper, Kansas 2004

"Ground Truth"



12 May 2004: 0140 UTC. DOW About 2 km 12.5 m gates, oversampled. Inner eye is true tornado.

What ELDORA would have seen

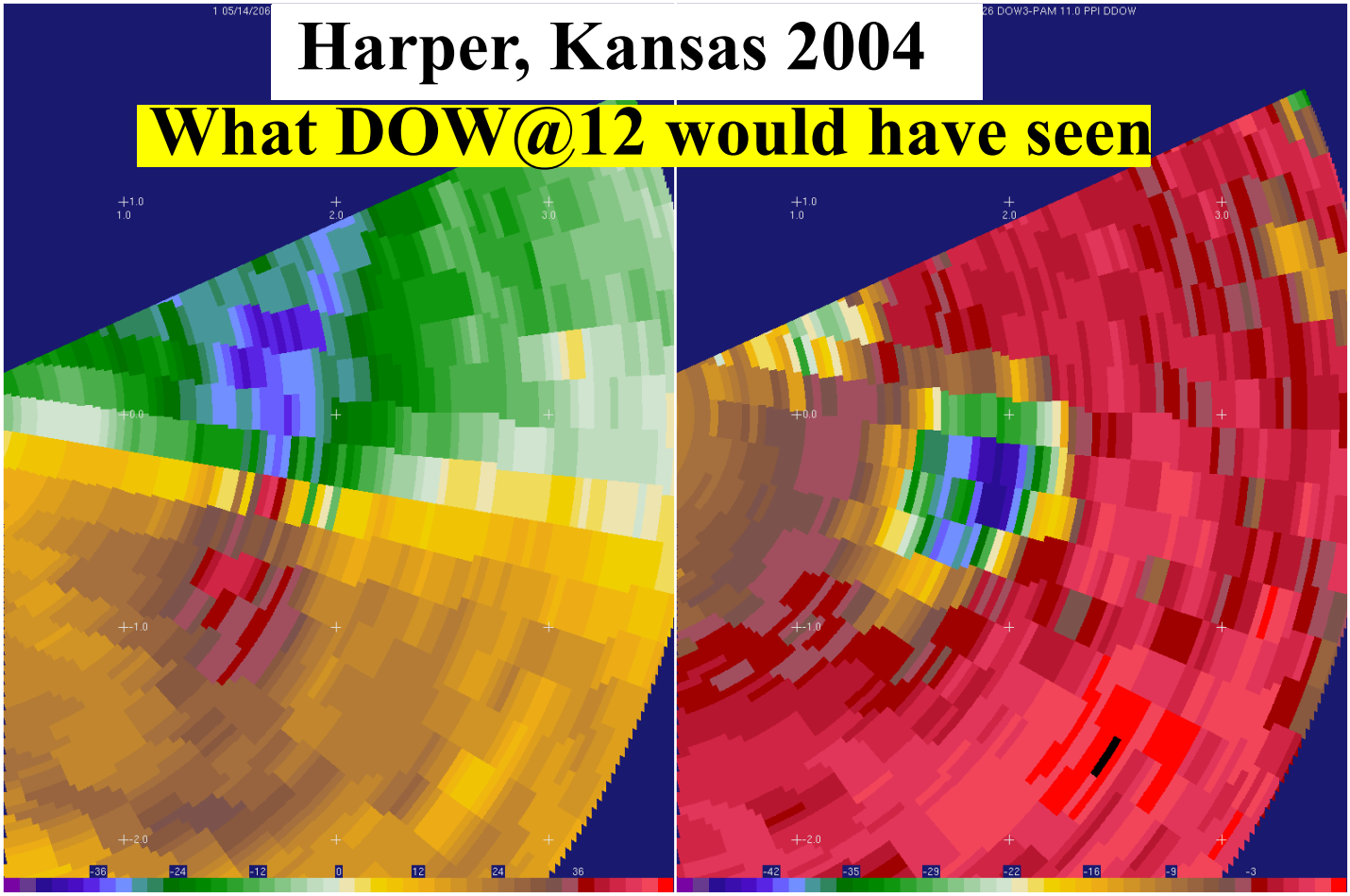


ELDORA simulated @12 km range, 75 m gates. Couplet and eye resolve outer circulation not tornado

12 May 2004 0140 UTC

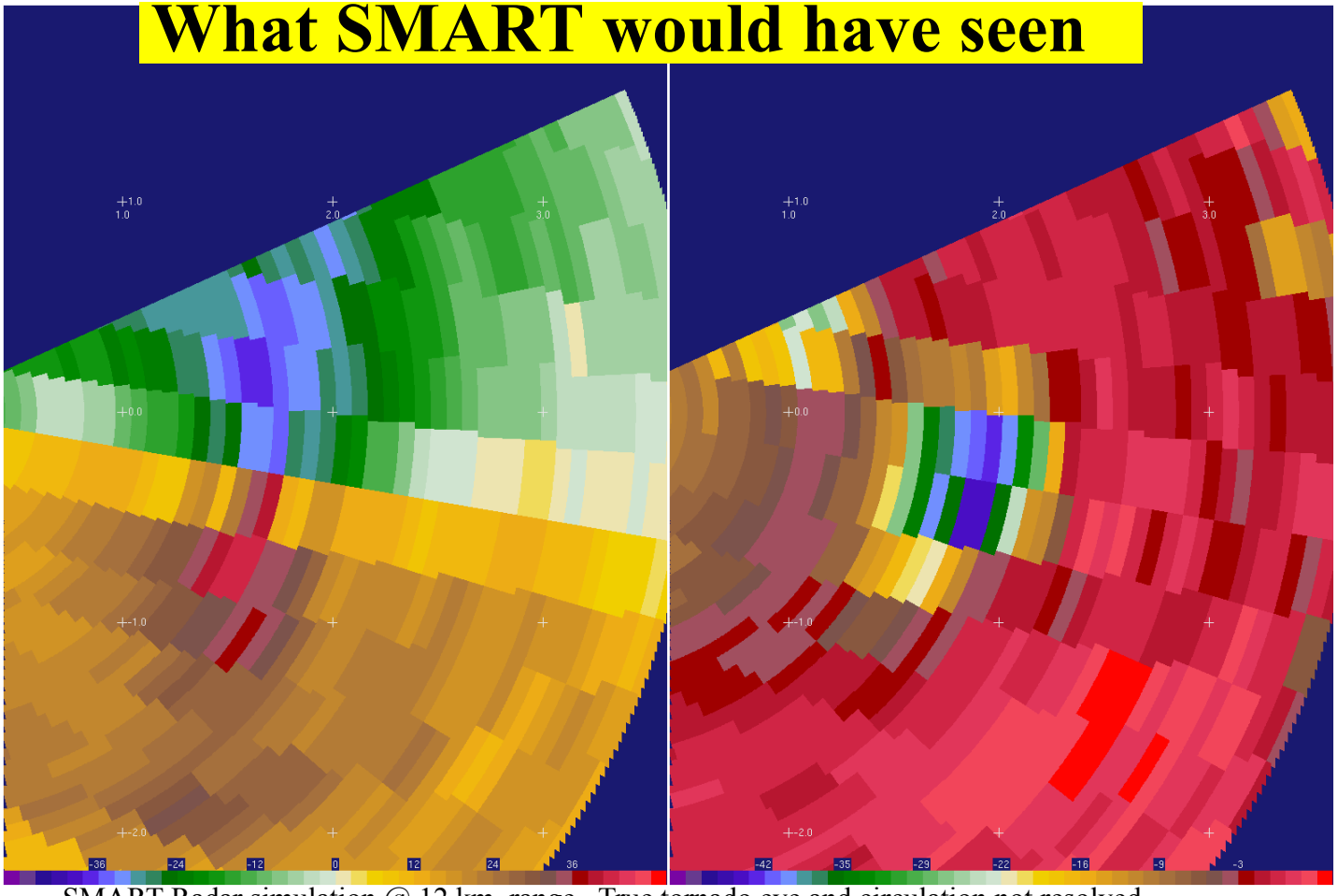
Harper, Kansas 2004

What DOW@12 would have seen



DOWsimulated at 12 km range, no oversampling. Inner Z eye not seen. Hint of inner V circulation

What SMART would have seen

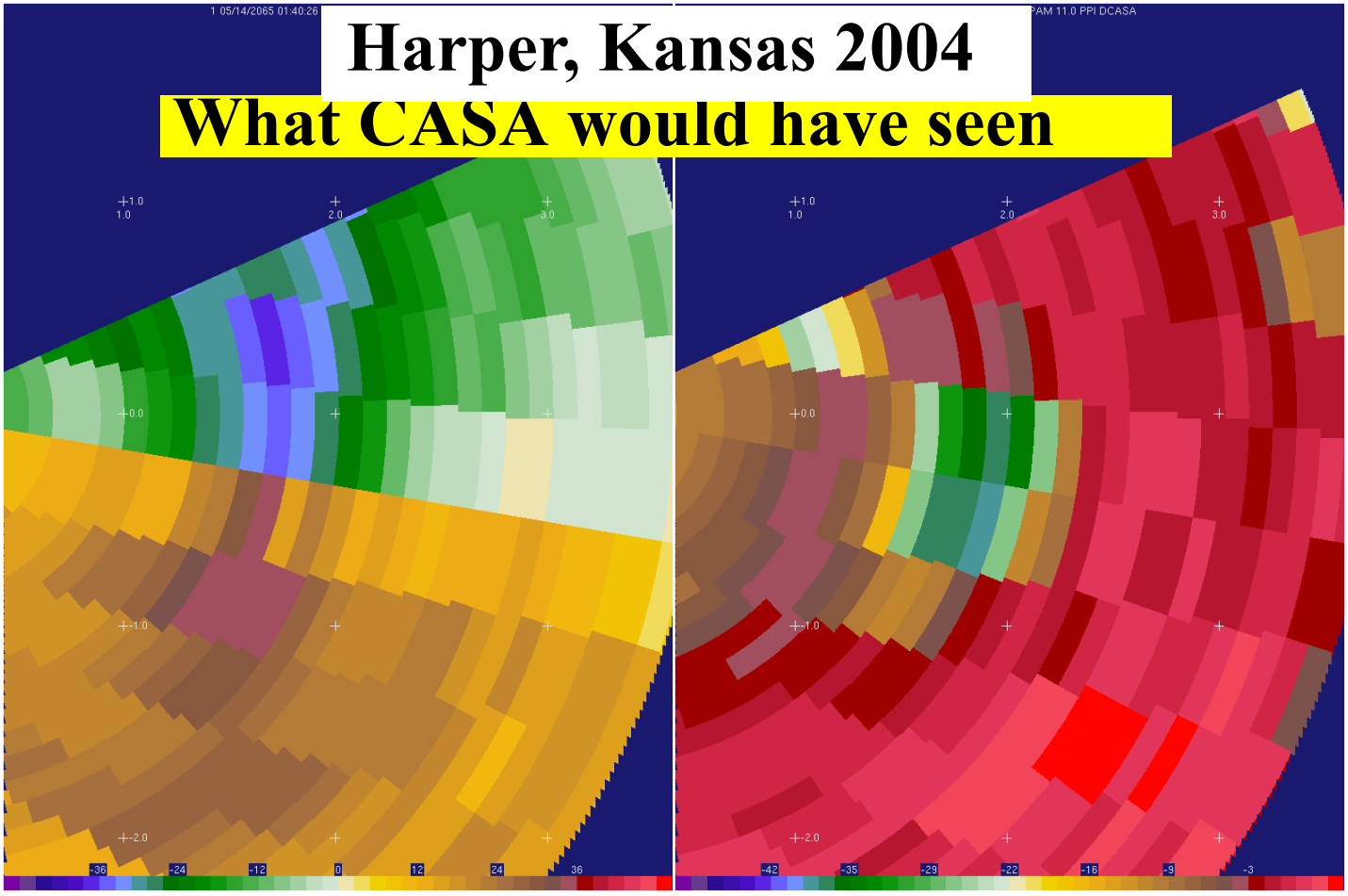


SMART Radar simulation @ 12 km range. True tornado eye and circulation not resolved

12 May 2004 0140 UTC

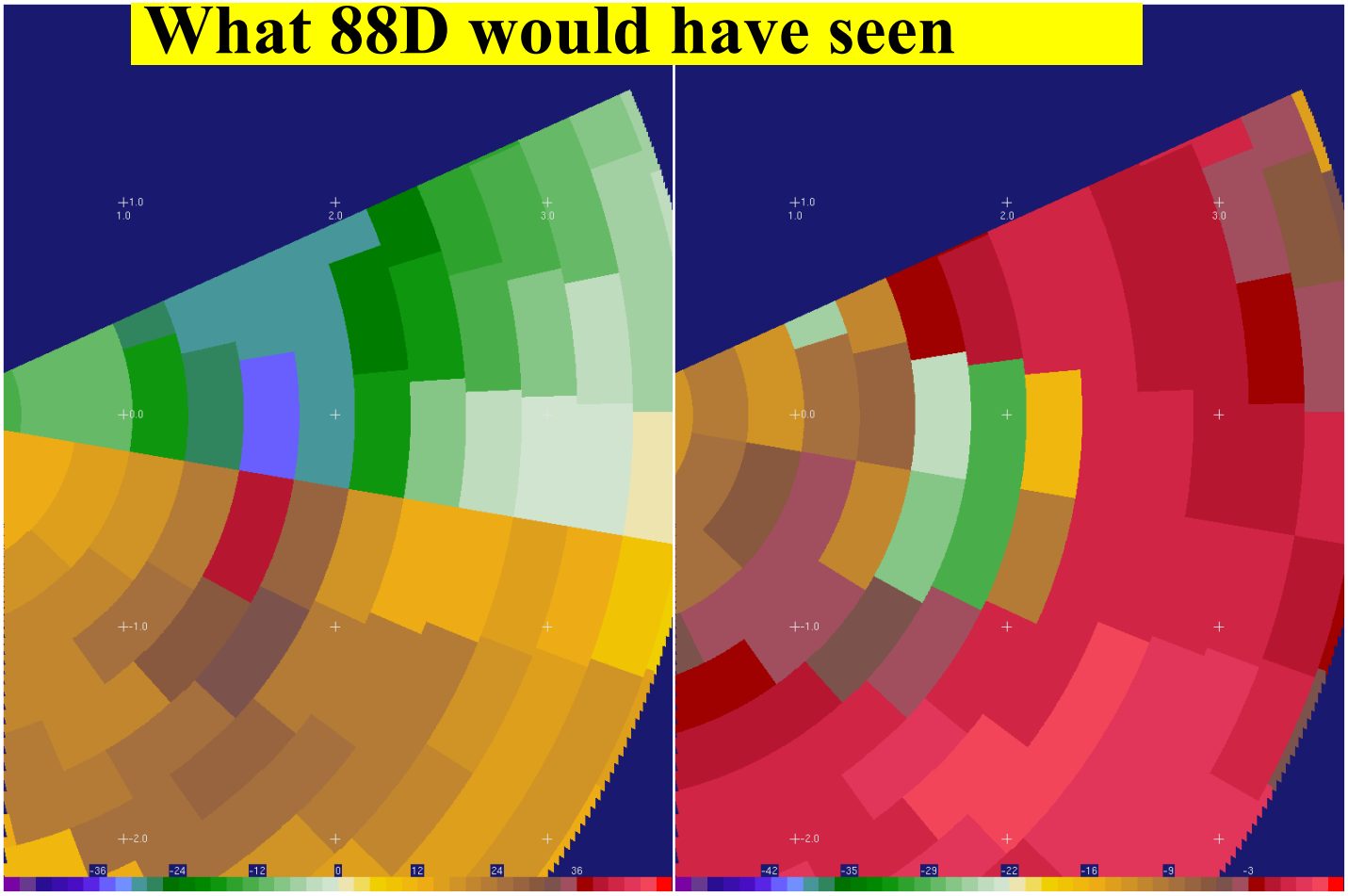
Harper, Kansas 2004

What CASA would have seen



CASA simulated data at 12 km range. True tornado circulation and eye not resolved.

What 88D would have seen

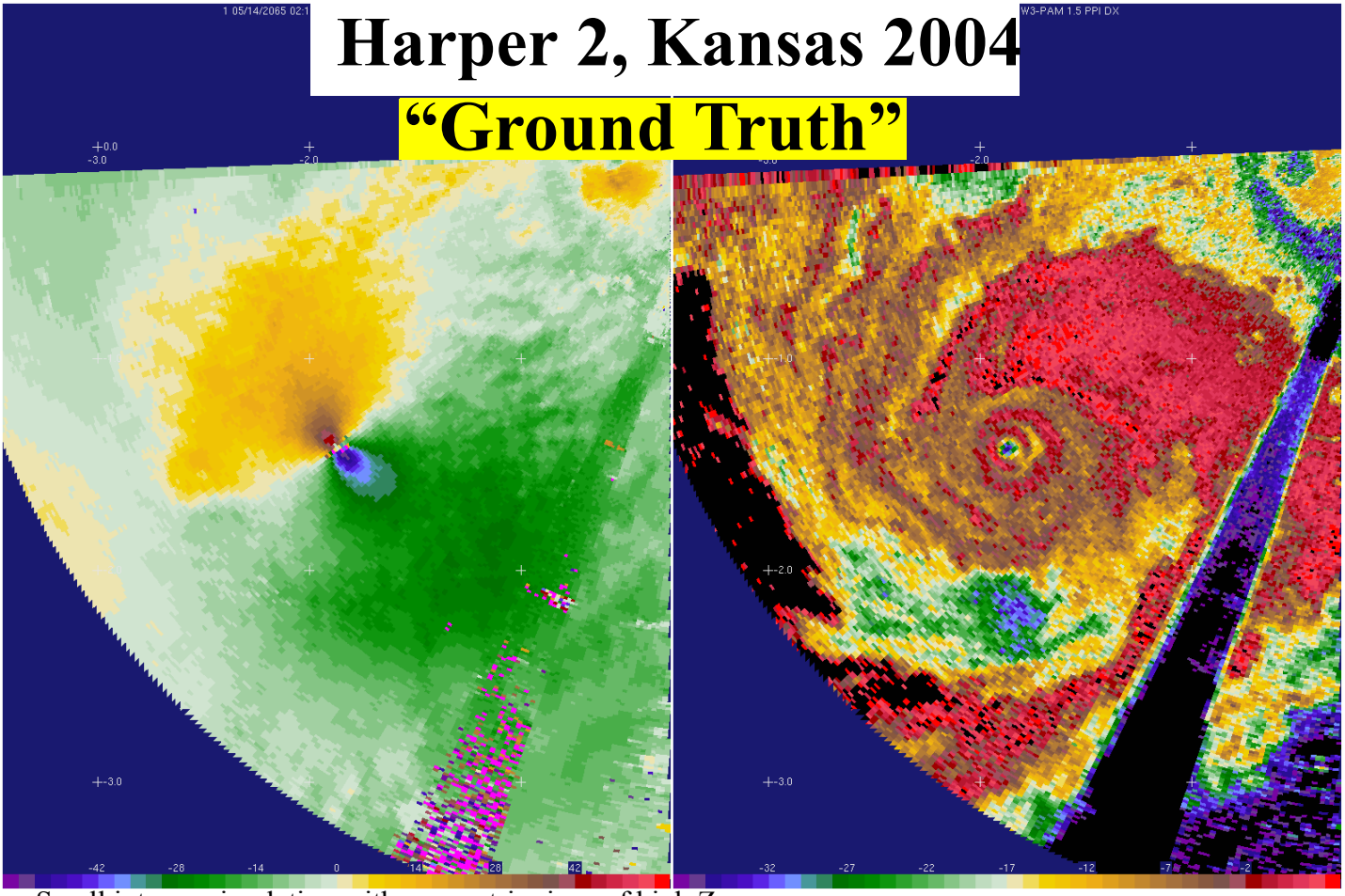


WSR-88D simulated data @ 32km range to tornado. Tornado and surrounding circulations merged.

12 May 2004 0140 UTC

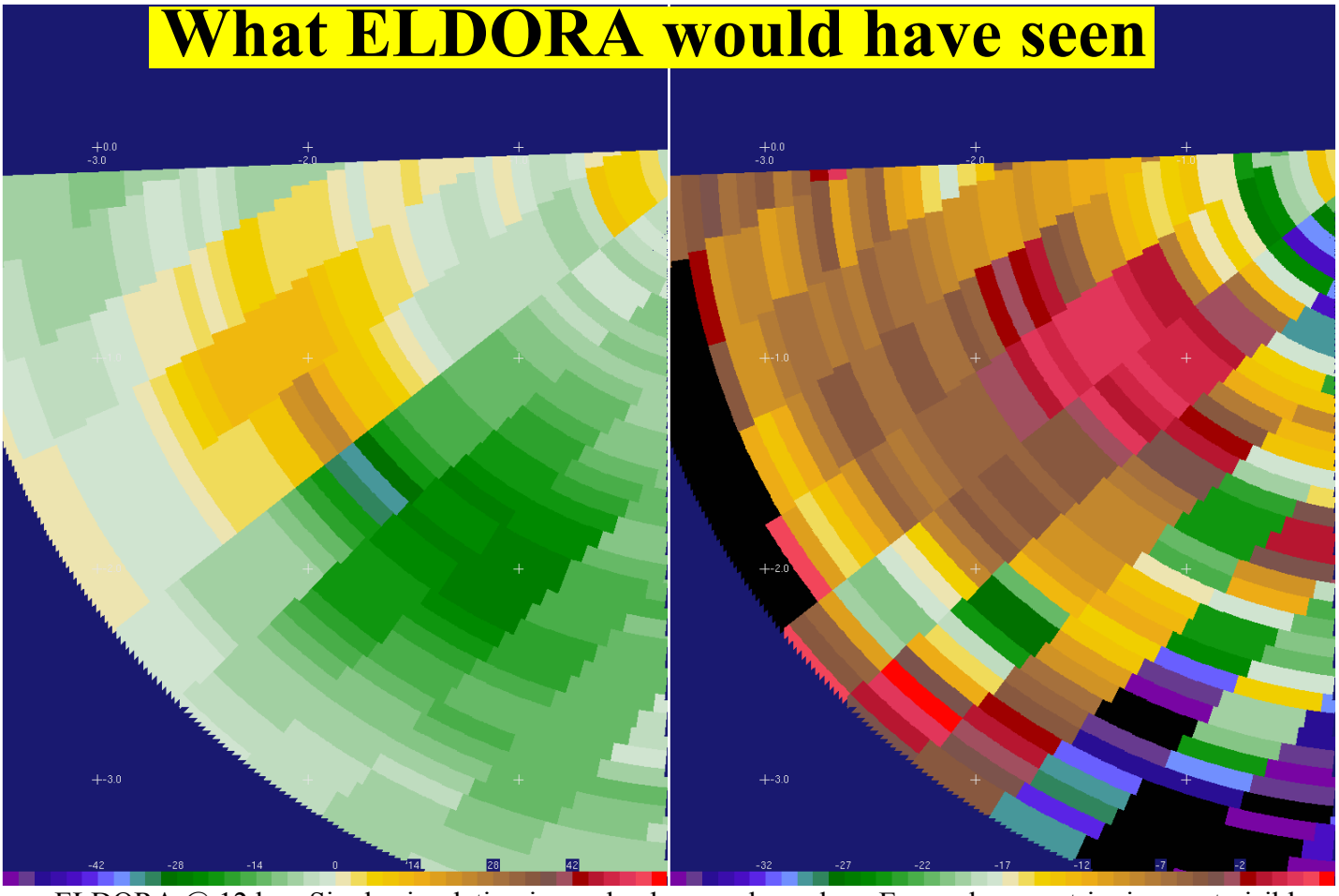
Harper 2, Kansas 2004

"Ground Truth"



Small intense circulation with concentric rings of high Z

What ELDORA would have seen

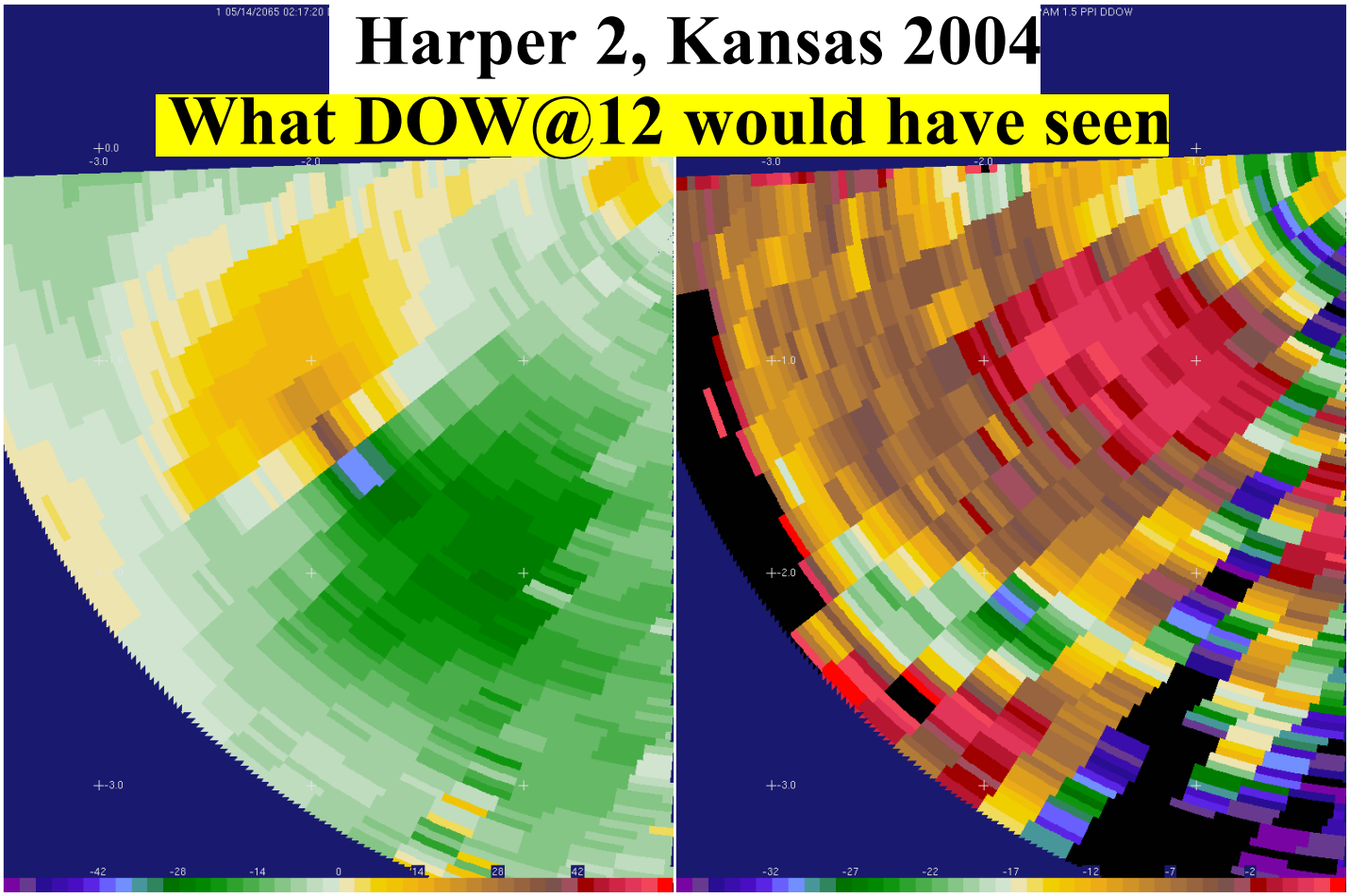


ELDORA @ 12 km Single circulation is resolved as much weaker. Eye and concentric rings not visible

12 May 2004 0217 UTC

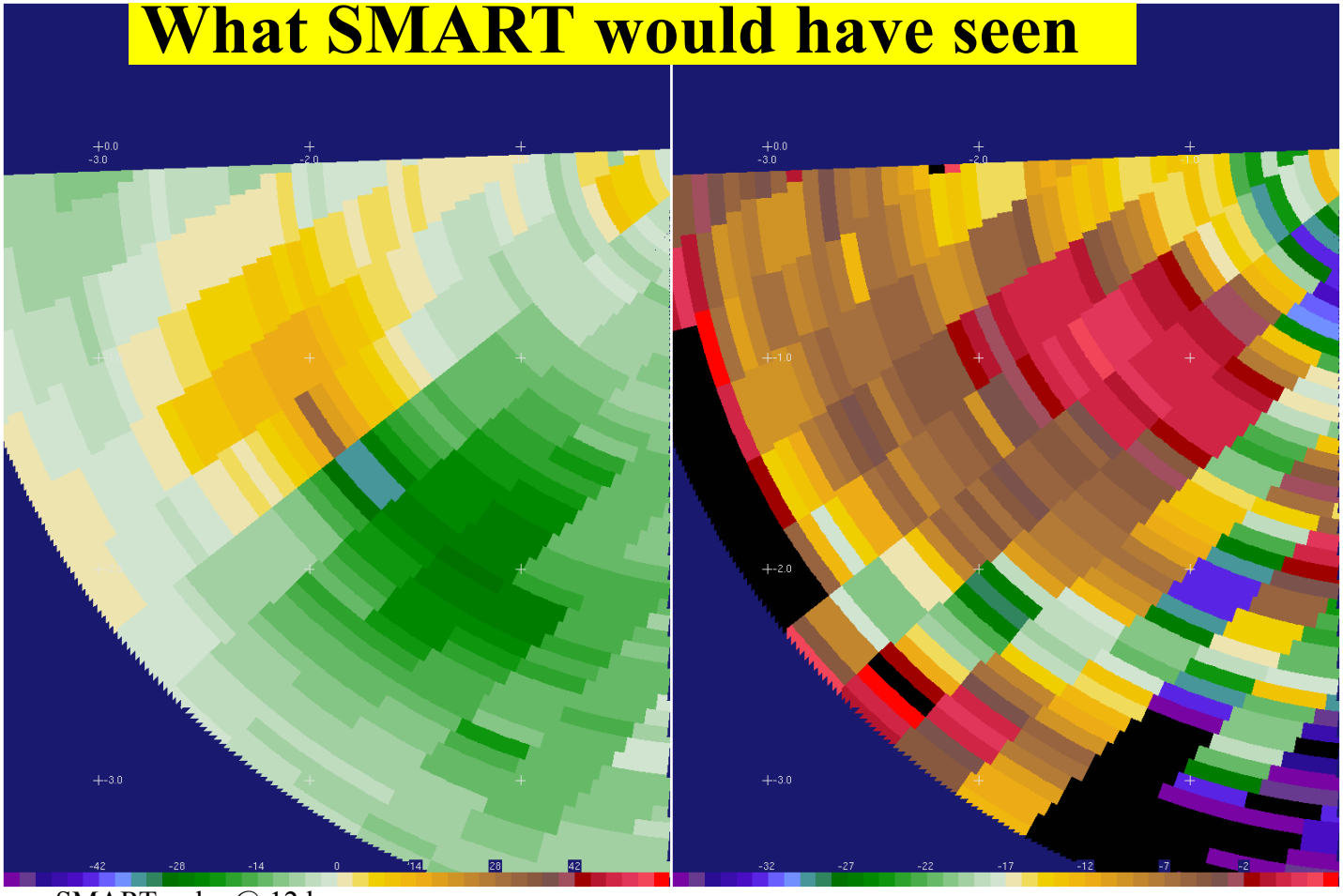
Harper 2, Kansas 2004

What DOW@12 would have seen



DOW @ 12 km range. Tornado circulation not fully resolved. No eye or concentric rings resolved

What SMART would have seen

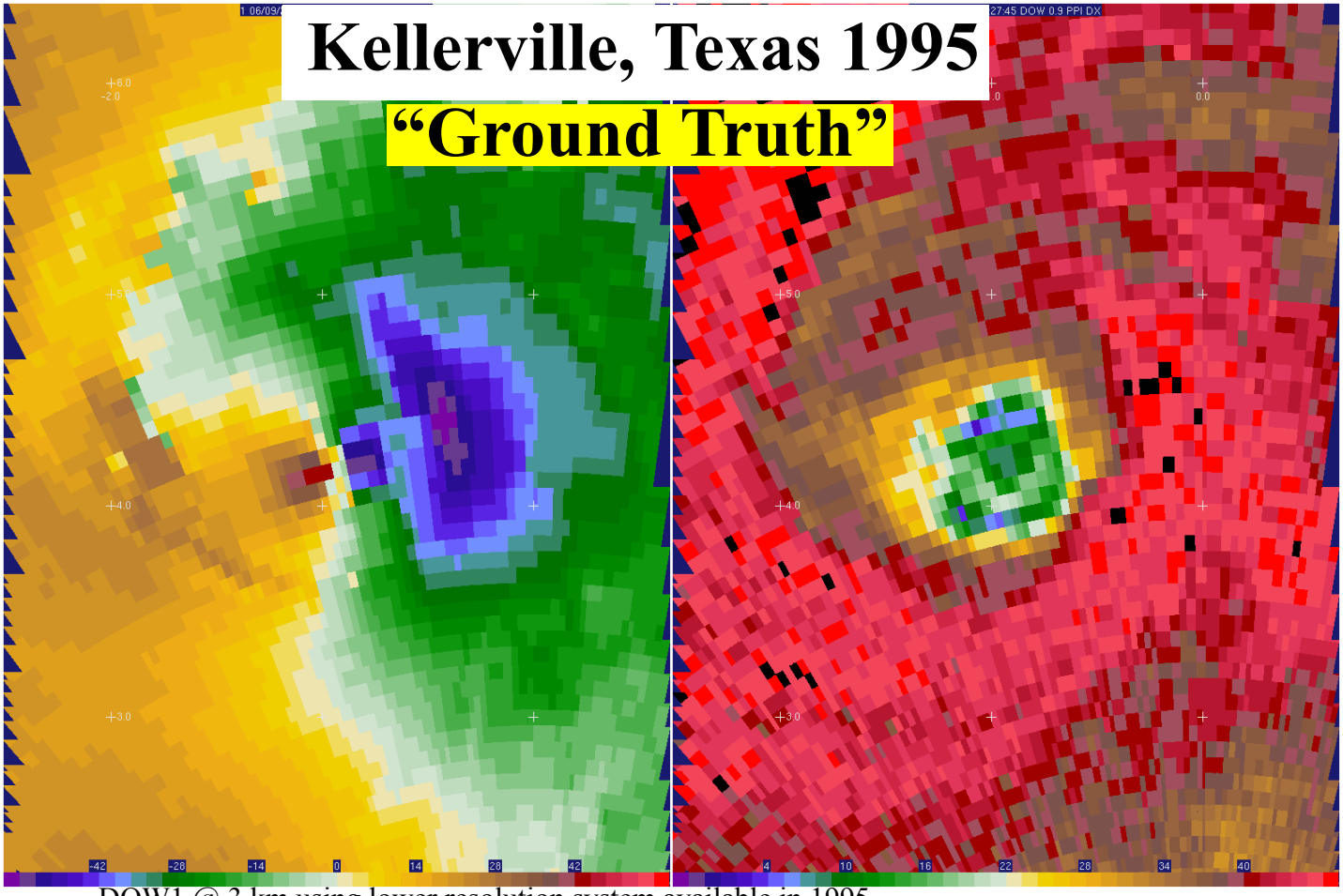


SMART radar @ 12 km range

12 May 2004 0217 UTC

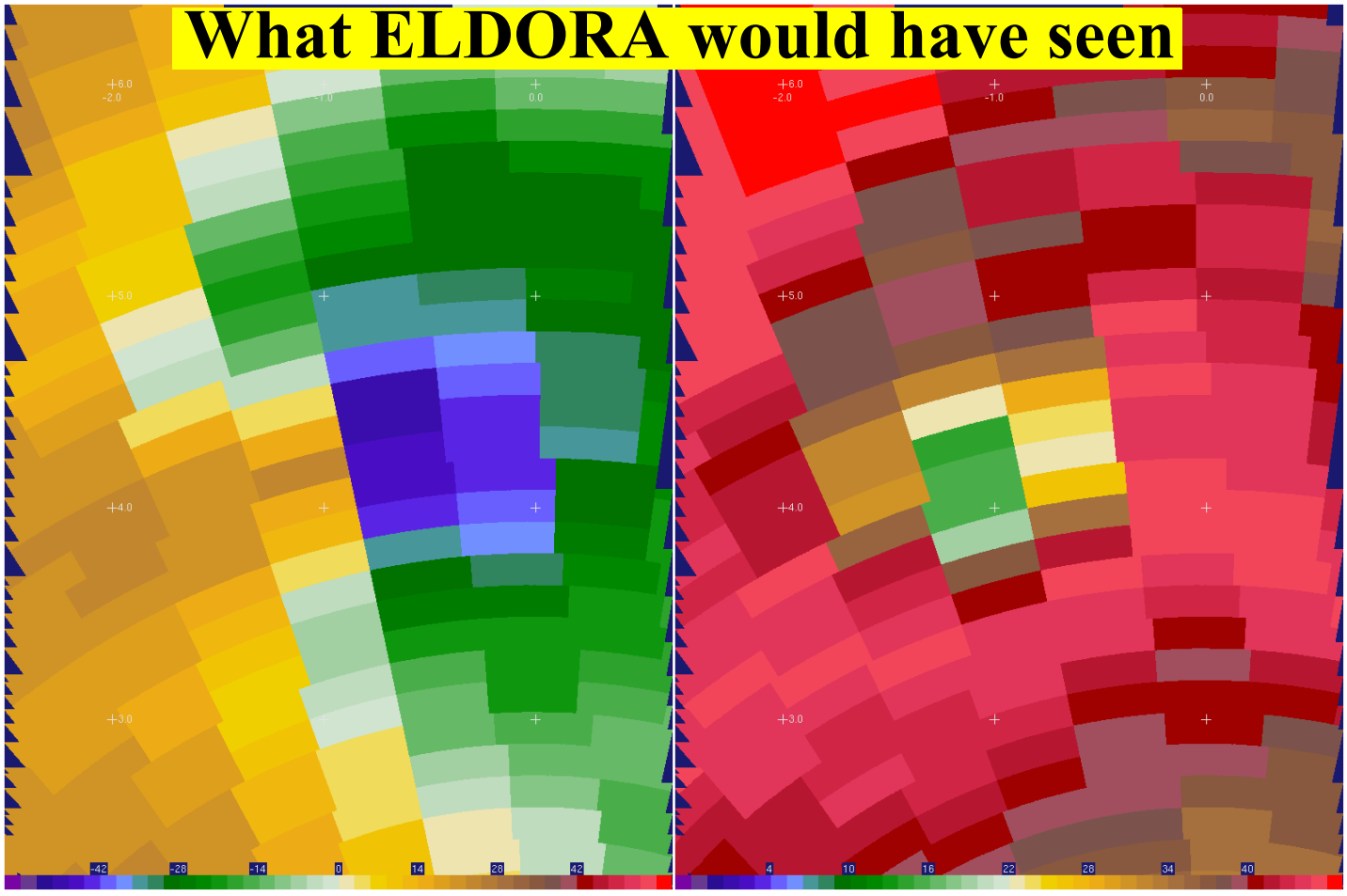
Kellerville, Texas 1995

"Ground Truth"



DOW1 @ 3 km using lower resolution system available in 1995

What ELDORA would have seen

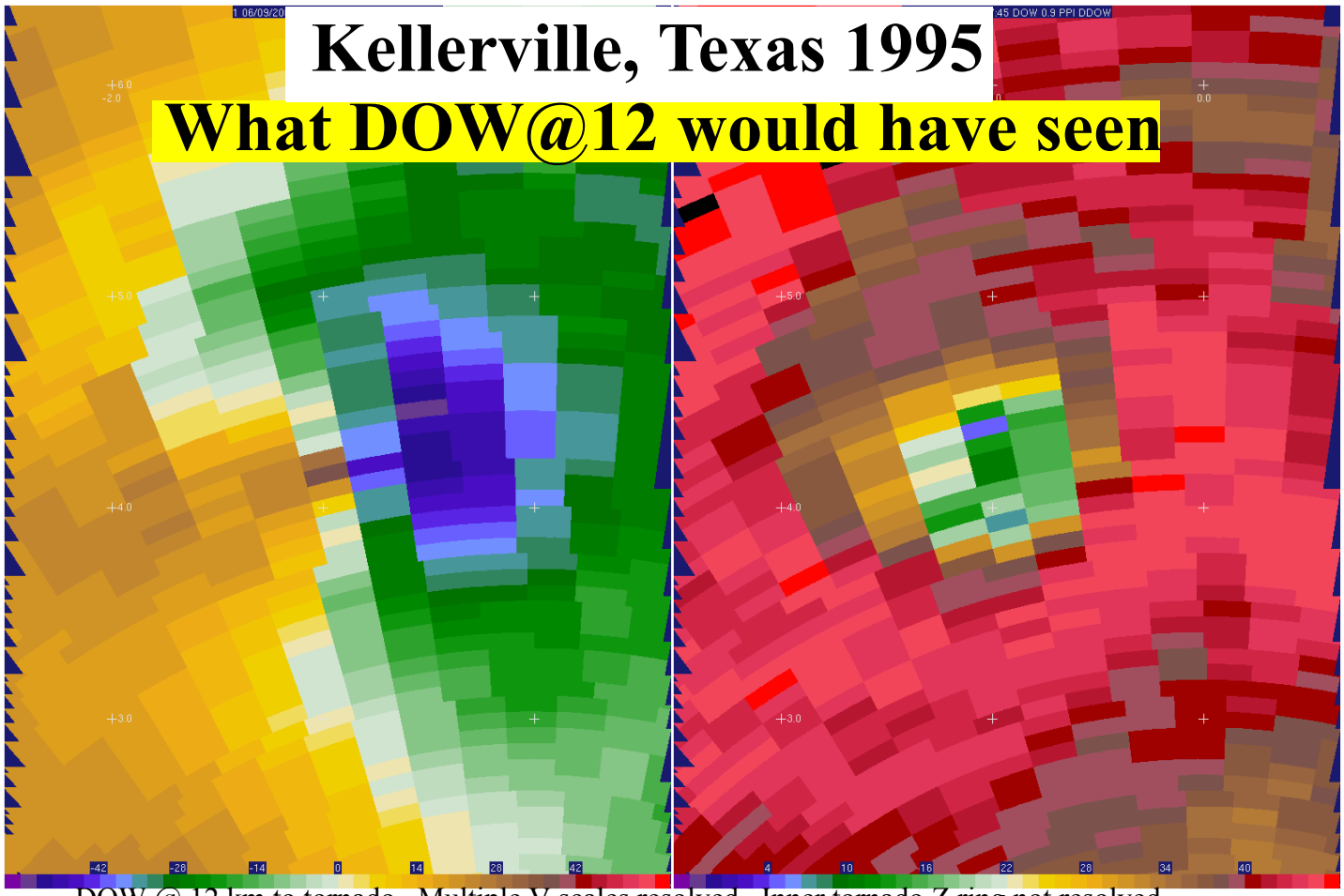


ELDORA simulation @ 12 km to tornado. Multiple V scales and inner eye not resolved

08 June 1995 Kellerville

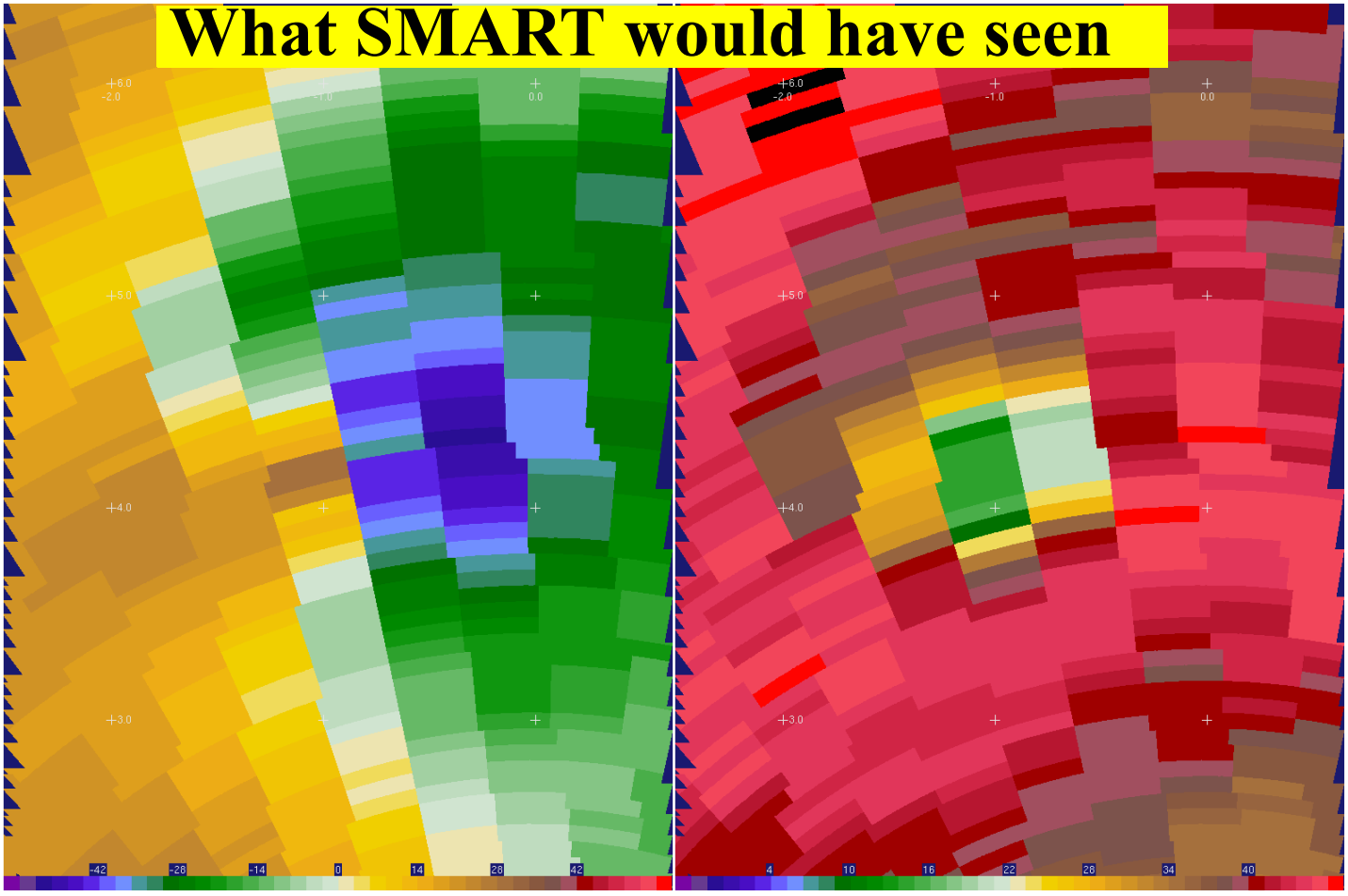
Kellerville, Texas 1995

What DOW@12 would have seen



DOW @ 12 km to tornado. Multiple V scales resolved. Inner tornado Z ring not resolved

What SMART would have seen

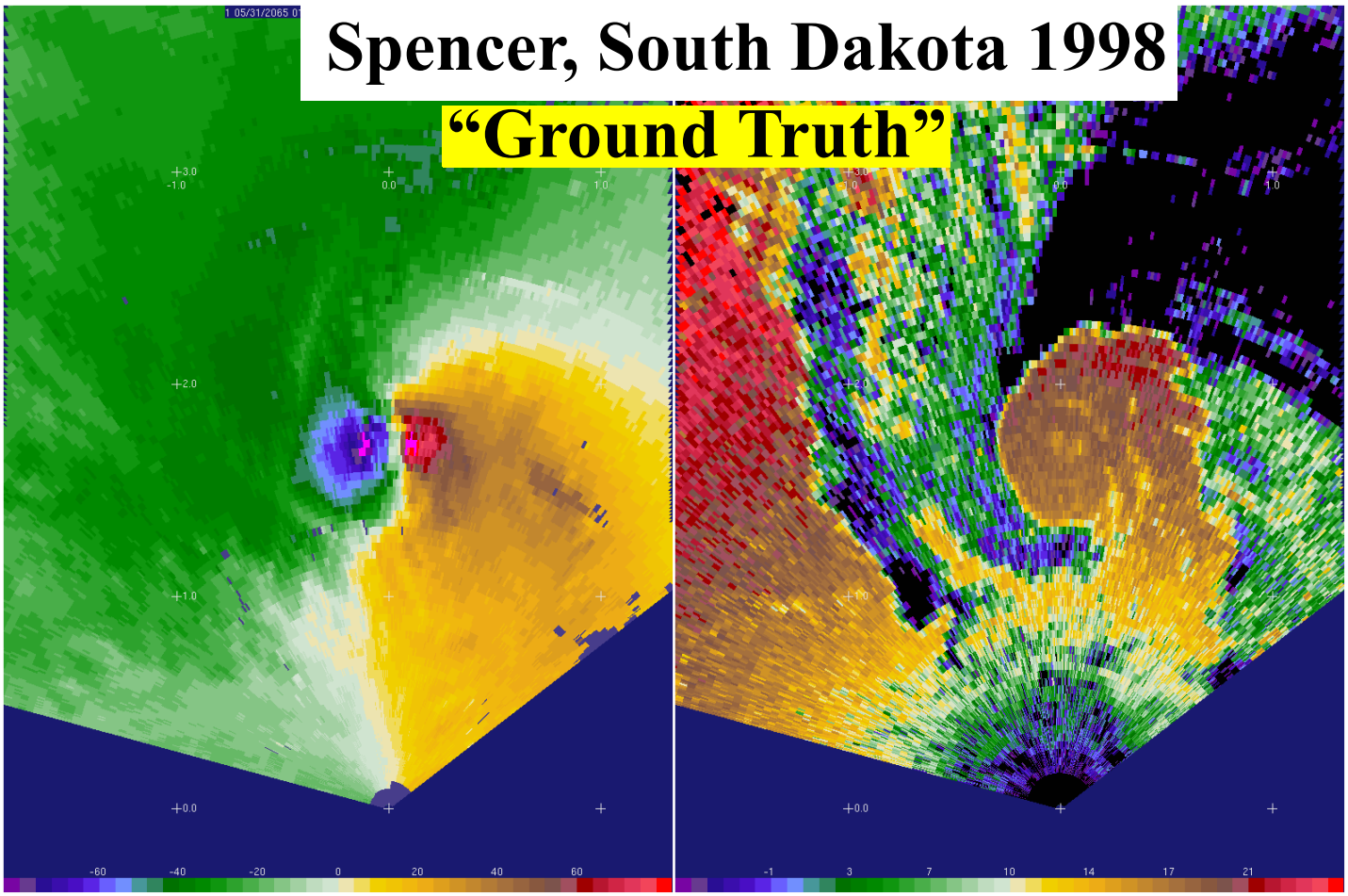


SMART radar @ 12 km. Inner tornado scale not resolved.

08 June 1995 Kellerville

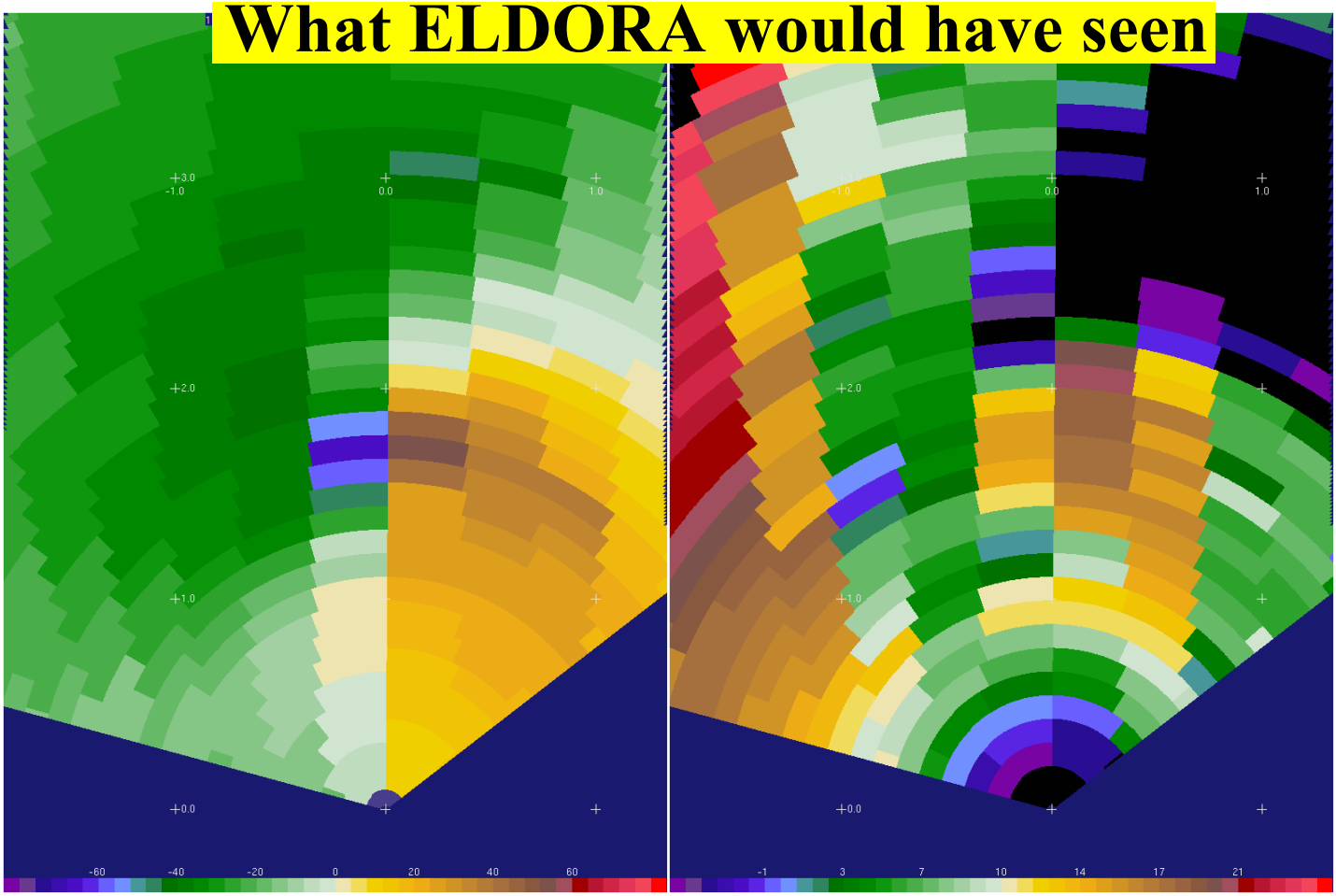
Spencer, South Dakota 1998

"Ground Truth"



Spencer tornado @ 1.7 km range to DOW

What ELDORA would have seen

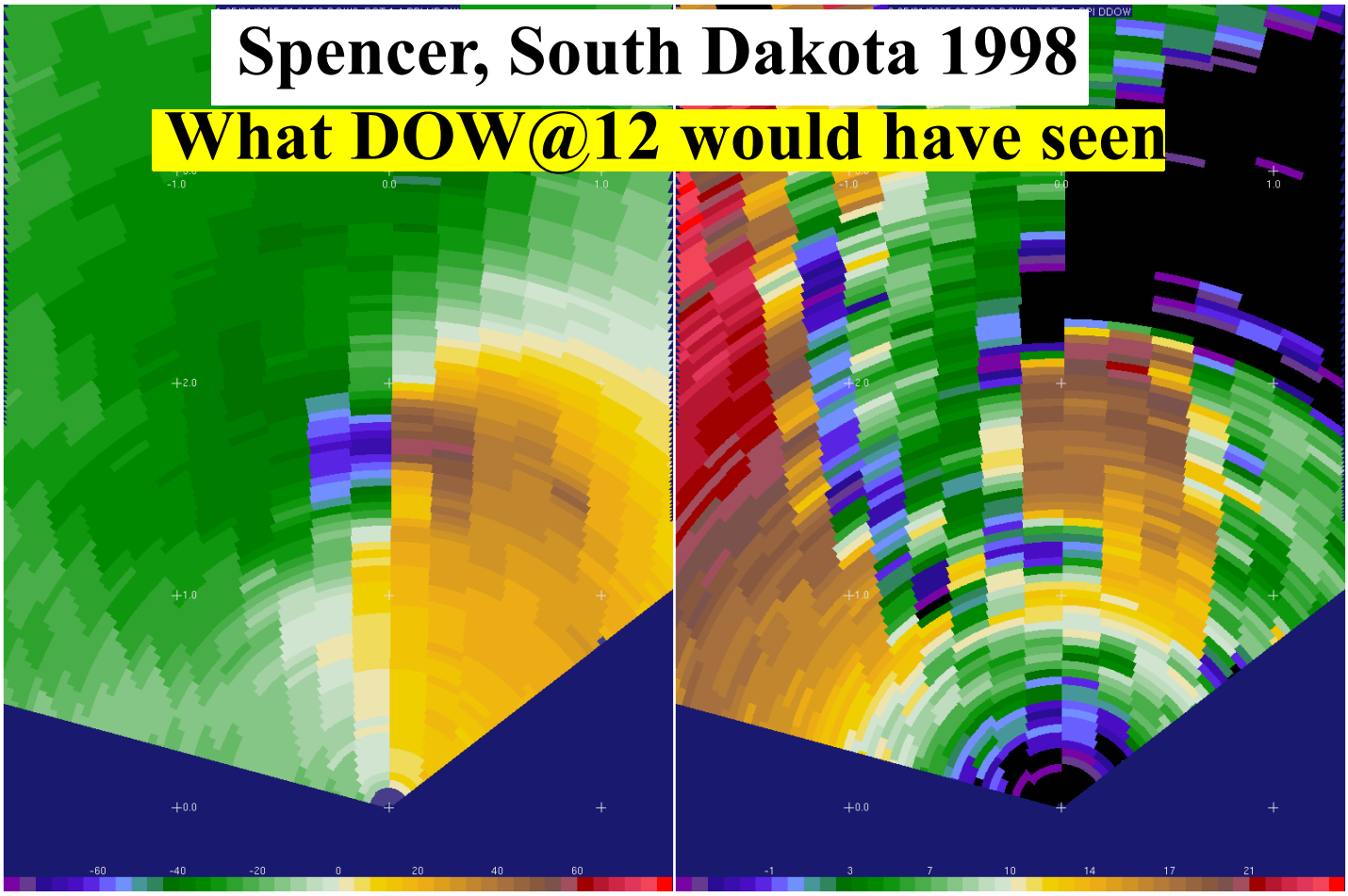


ELDORA simulated @ 12 km

30 May 1998 Spencer

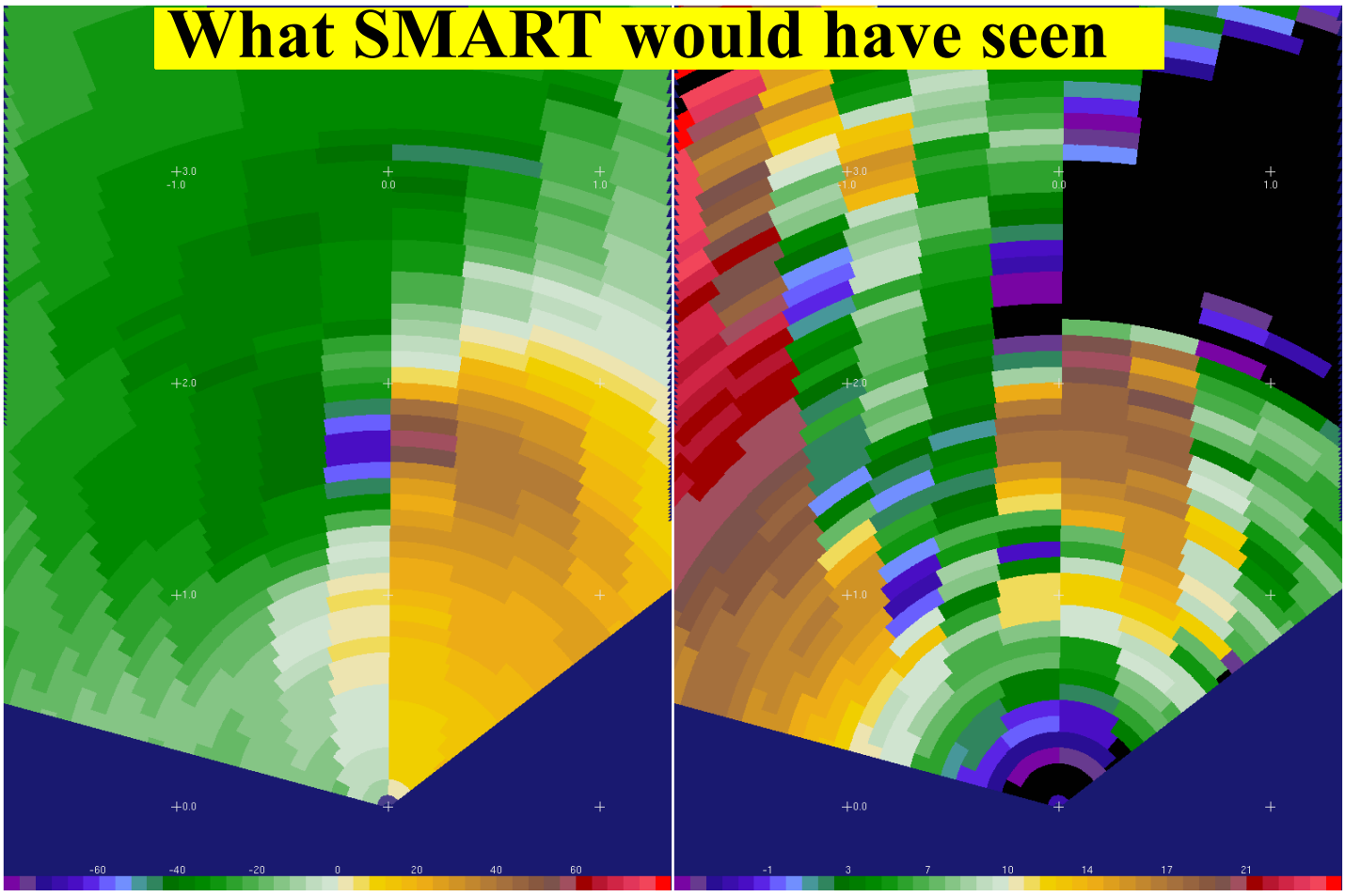
Spencer, South Dakota 1998

What DOW@12 would have seen



DOW simulated @ 12 km

What SMART would have seen



SMART radar simulated @ 12 km

30 May 1998 Spencer

2. Scales of rotation in and near tornadoes

Several large tornadoes and tornadoes with large circulations surrounding them have been observed by the DOWs. In some cases it has been difficult to determine exactly the nature or title of the observed circulations. The situation is complicated when there are tornado-intensity circulations embedded within other tornado-intensity circulations. Whether the complete multi-scale system is a mesocyclone or 'tornado cyclone' with embedded tornado(es) or a large tornado with embedded multiple-vortices is difficult to determine.

Representative slices through several tornadoes are shown at the same scale in the following pages. The figures are presented with little commentary or analysis and are intended to accompany a presentation at the conference.

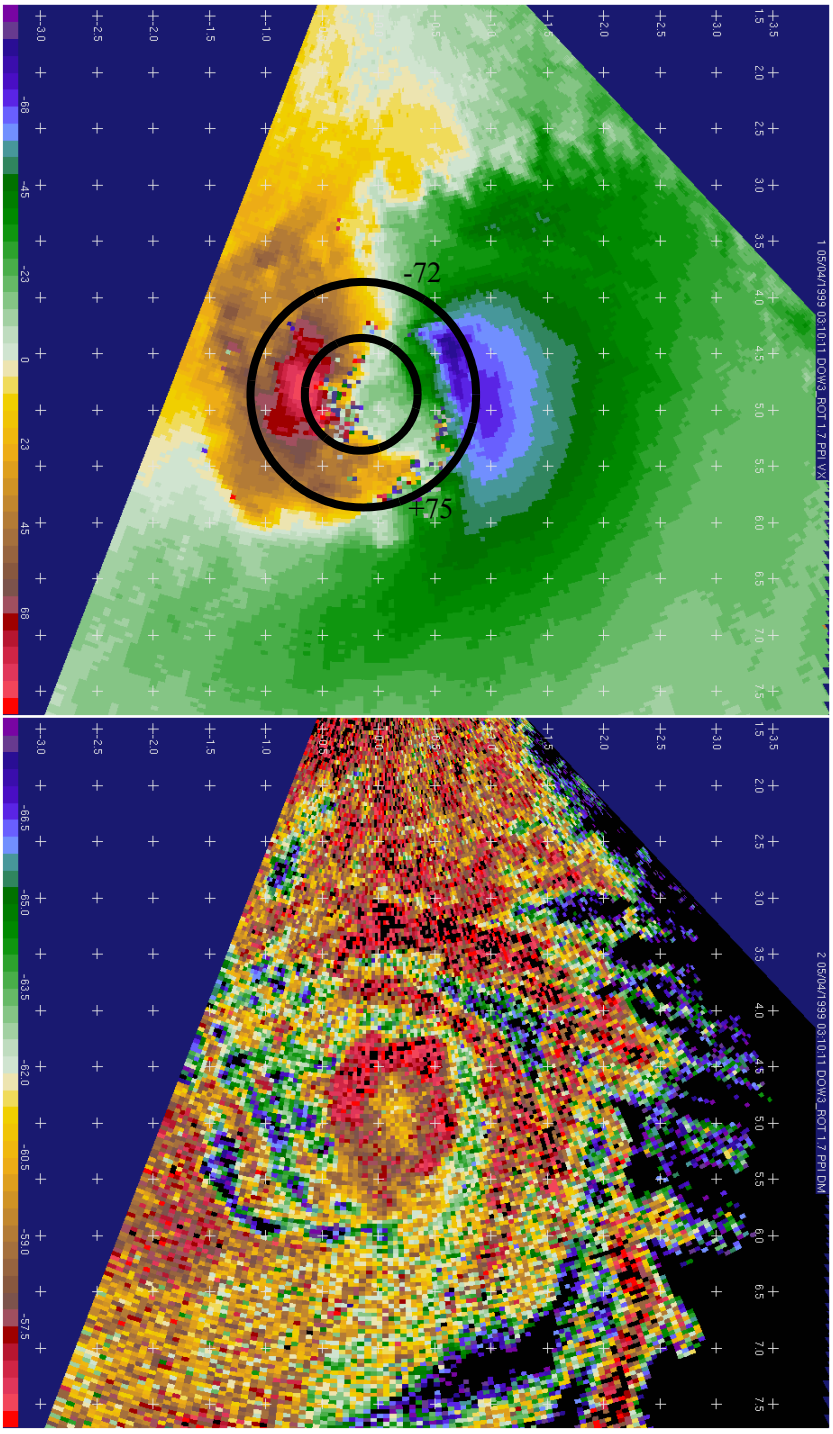
Most figures are at the same scale, but velocity and reflectivity keys have been varied to illustrate details in each tornado. Black concentric circles in each panel have 1km and 2 km diameters to facilitate comparisons among the tornadoes and do not represent core flow diameters of any particular circulation.

Core flow diameters and Delta-V at 1 km radius (2km diameter circle based on Doppler velocity measurements are shown in each slice to facilitate comparisons of the intensity of the 1-2km scale flow (mesocyclone?, tornado-cyclone?, none of the above?) associated with each tornado.

Mulhall

Dc=1600 m

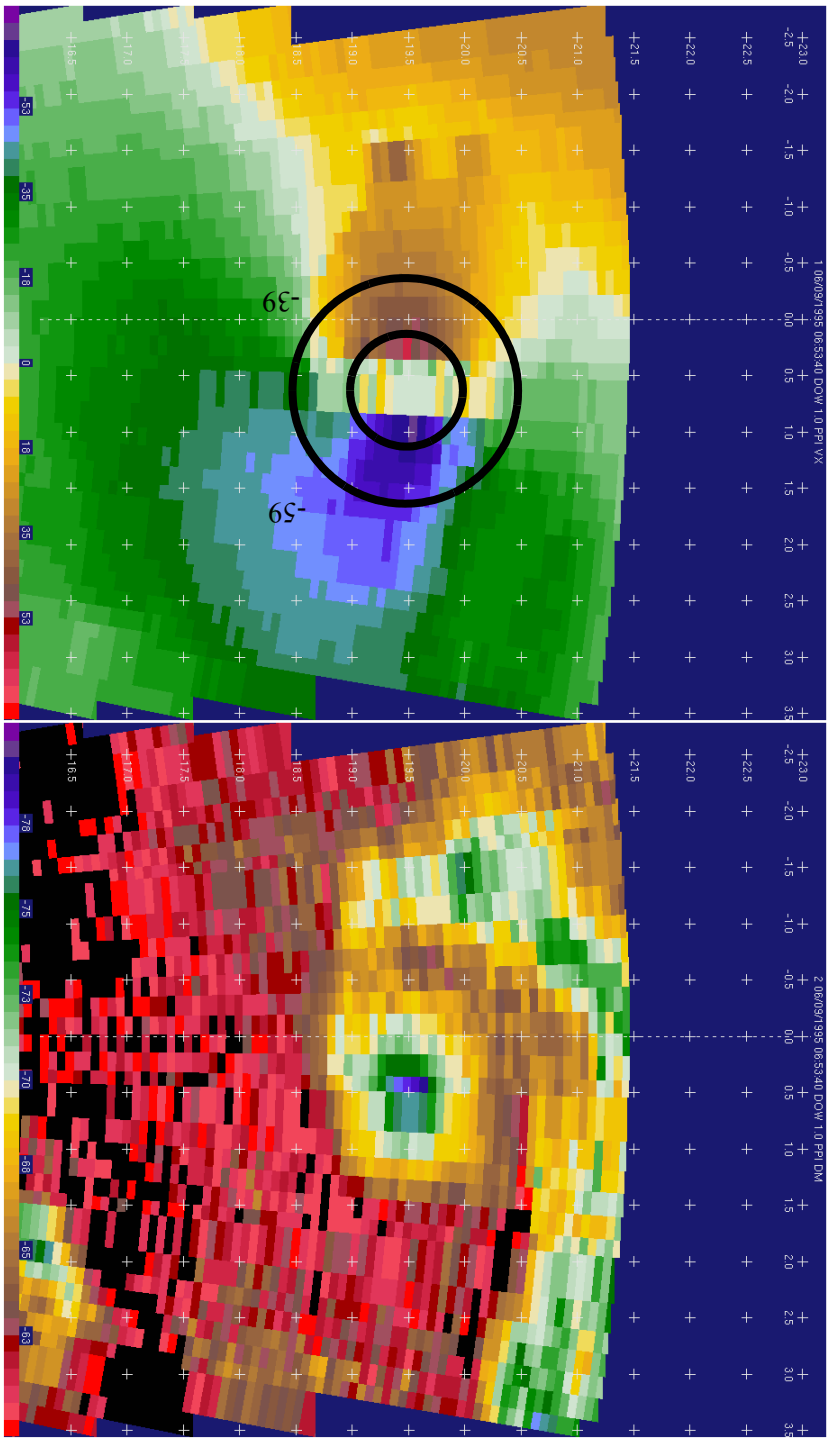
$\Delta V_{2km} \sim 147\ ms^{-1}$



Alison

D_c=800 m

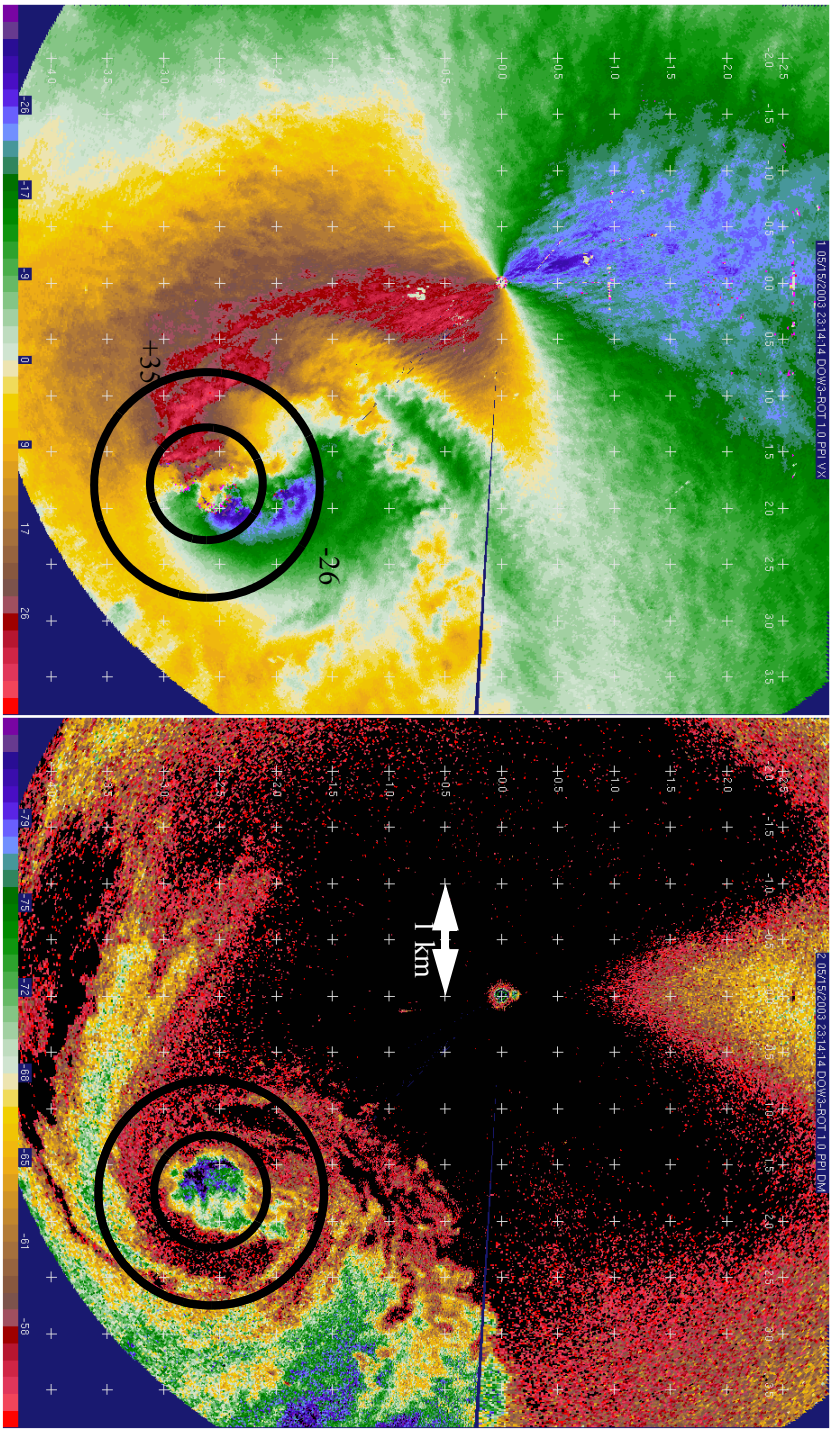
ΔV_{2km}~88 ms^{-1}



Stratford

Dc=800 m

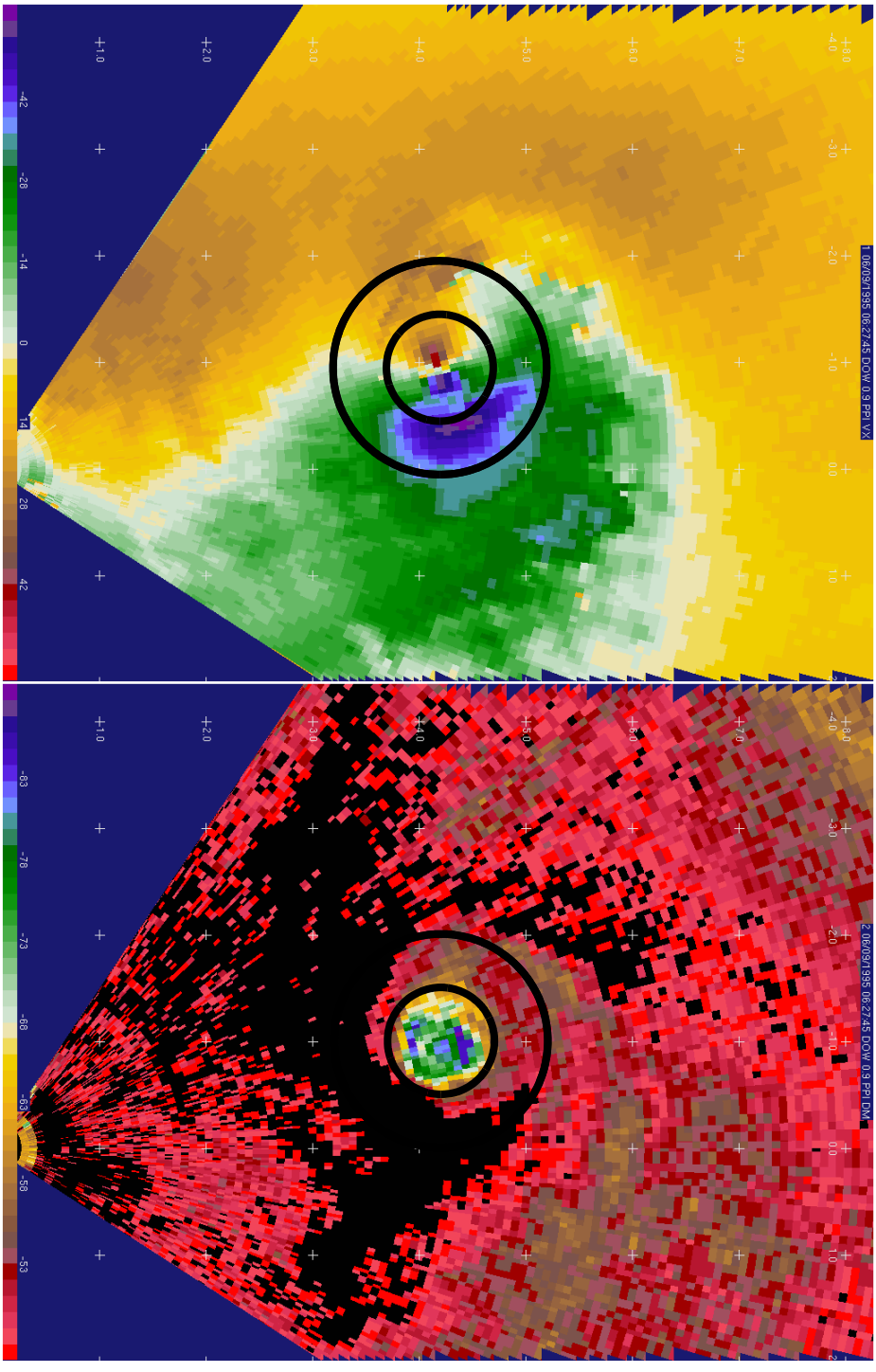
$\Delta V_{2km} \sim 61\ ms^{-1}$



Kellerville

Dc=300/800 m

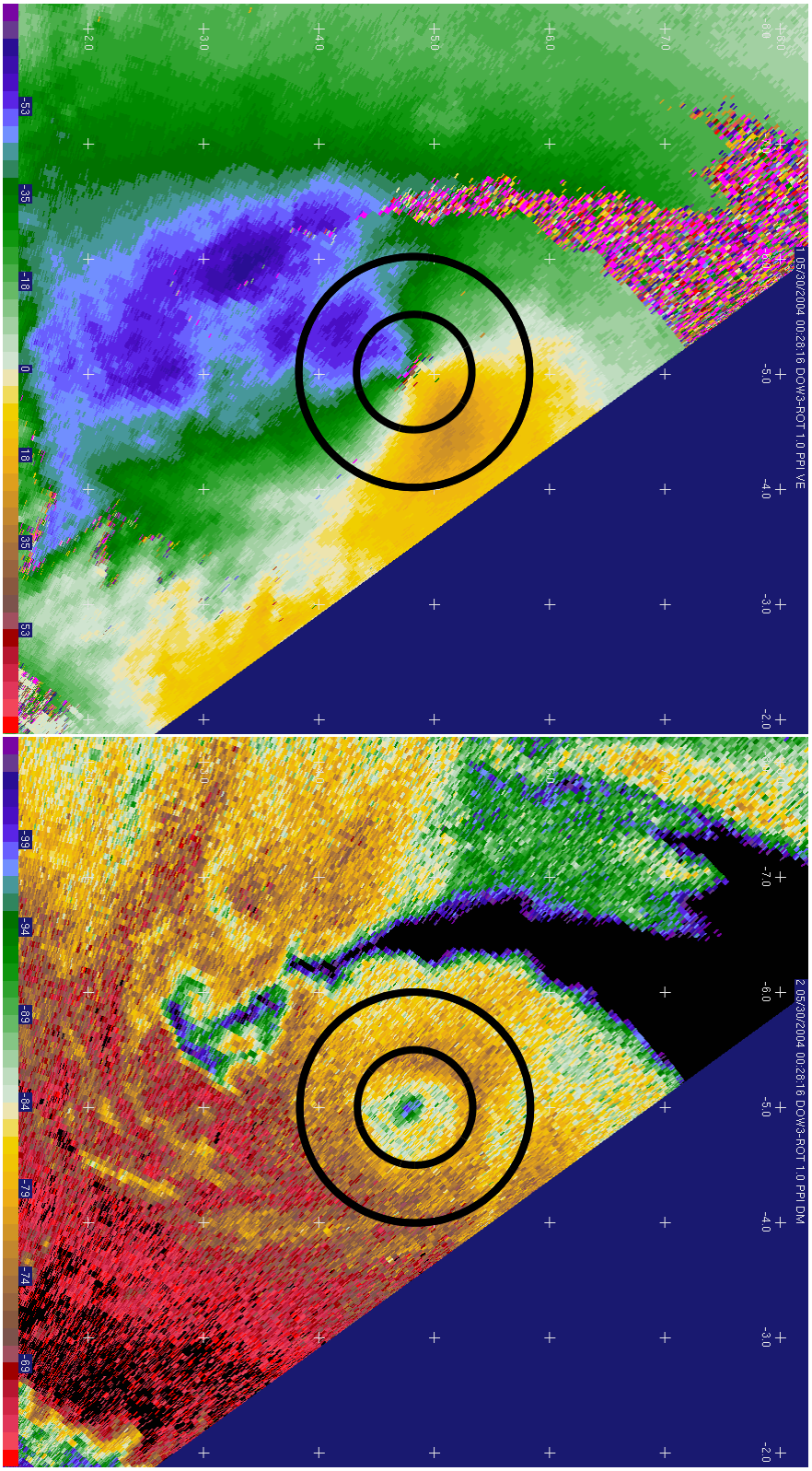
$\Delta V_{2km} \sim 80\ ms^{-1}$



Geary

Dc=300-1000+ m

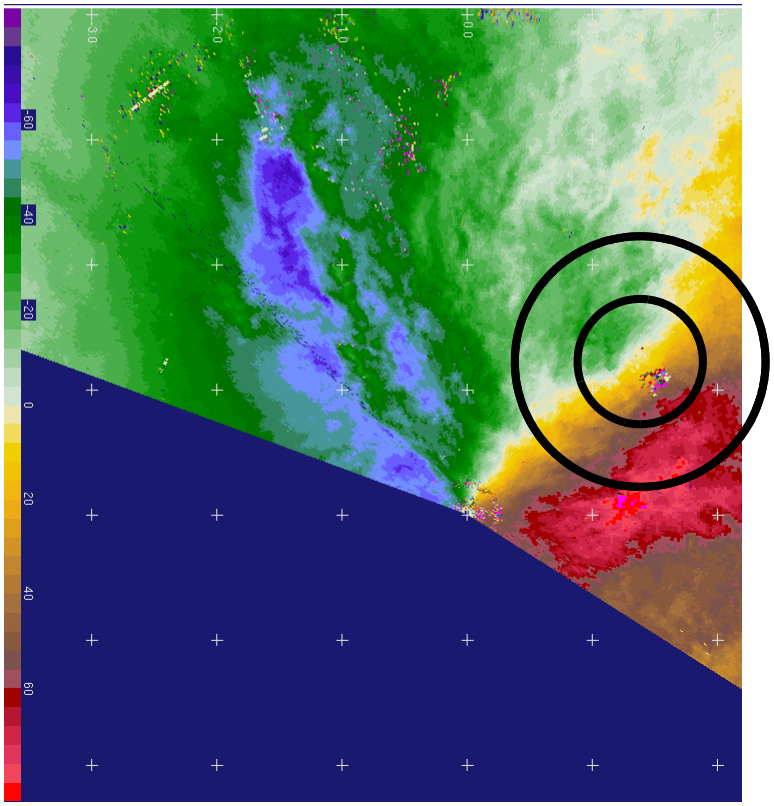
ΔV_{2km}~130+ ms^{-1}



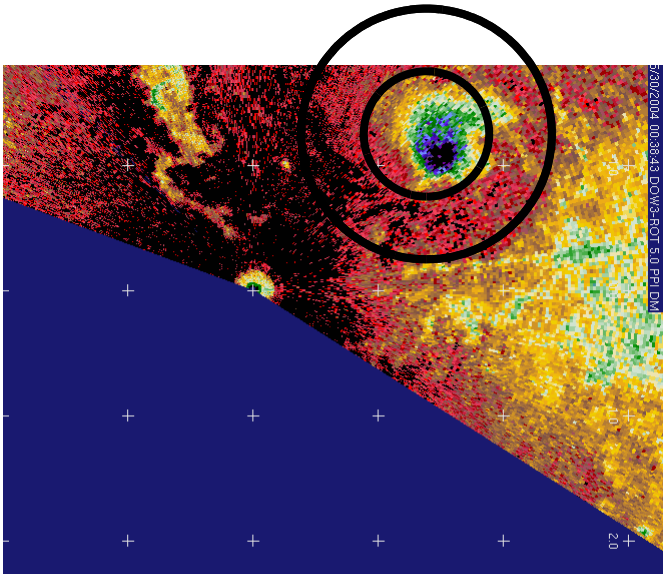
Geary

Dc=300-1000+ m

ΔV_{2km}~130+ ms^{-1}



Tornado with stronger circulation/RFD to south



In Situ Radar Observations of a Mesocyclone