Conservation of Vertical Angular Momentum during Tornadogenesis

E. Williams Parson Laboratory, MIT, Cambridge, MA

S. Goodman, D. Buechler, L. Carey, C. Schultz, R. Blakeslee, University of Huntsville, Huntsville, AL

D. Smalley and M. Veillette, MIT Lincoln Laboratory, Lexington, MA

D. Burgess, National Severe Storms Laboratory, Norman, Oklahoma

AMS Conference on Radar Meteorology
Breckenridge, CO
September 16-20, 2013

Outline

- Outstanding questions on tornadogenesis
- Conservation of angular momentum
- History of this study
- Case studies:
  - Sanford, FL tornado Feb. 23, 1998
  - Salt Lake City, UT tornado August 11, 1999
  - Moore-to-Choctaw, OK tornado May 8, 2003
  - Moore, OK tornado May 20, 2013
- Conclusions

Outstanding questions in tornadogenesis

- The angular momentum of most tornadoes is primarily vertical
- What pre-tornadic reservoir of angular momentum is drawn upon to form the tornado?
  - (1) Boundary layer horizontal angular momentum?
  - (2) Vertical angular momentum in the mesocyclone?
- What is the observational evidence for tilting of vorticity?
- Why are there so many mesocylcones without a subsequent tornado?

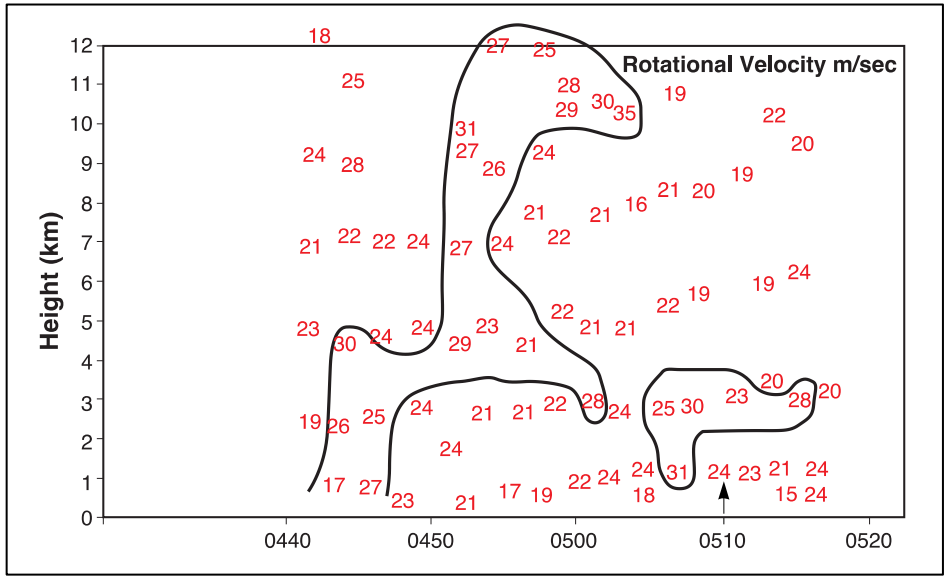
History of this Study

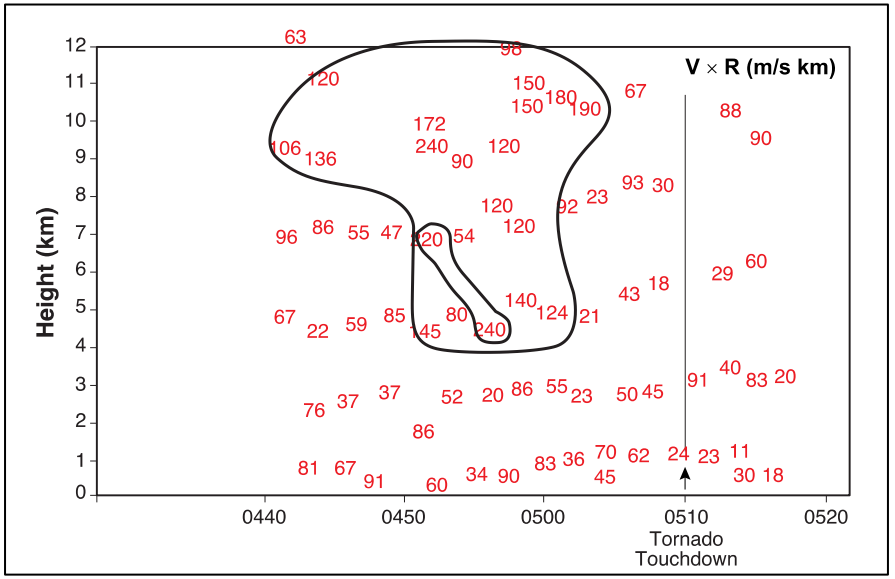
- February 1998: Investigation of F3 tornadoes in central Florida during the LISDAD project
  - Initial idea to examine angular momentum variable: VR
- August 1999: Inquiry into physical origin of Salt Lake City tornado in light of earlier Florida experience
- Summer 2000: Examination of F1 and F2 tornadoes in Colorado explored earlier by Roberts and Wilson (1995)
- September 2013: Application of these ideas to Moore F5 tornado on May 20, 2013

Conservation of angular momentum

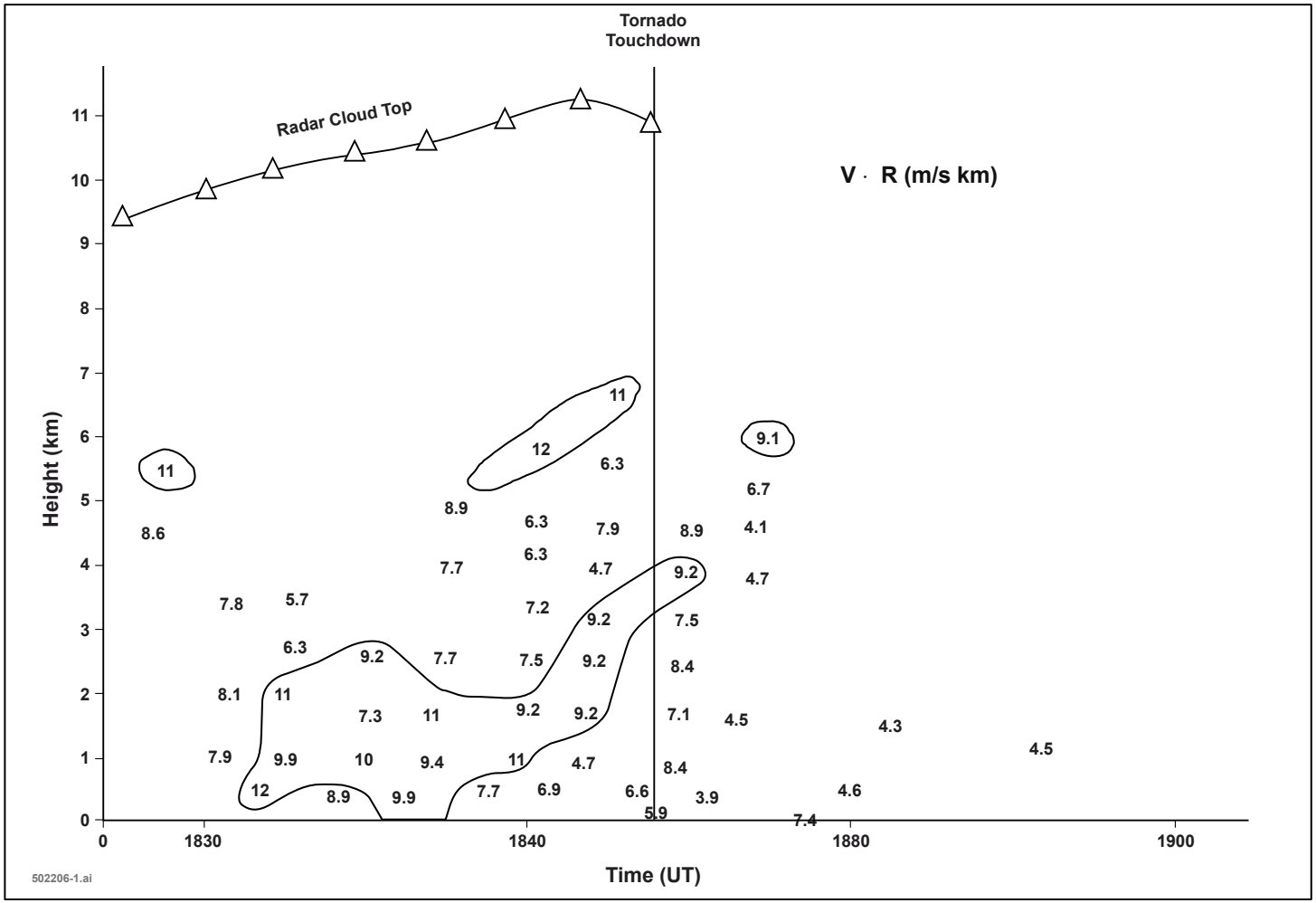
- Circulation theorem (Lord Kelvin, 1969) closed line integral of C= constant
- For circular vortex: 2 pi R V = constant
  (this amounts to conservation of angular momentum)
- Observation from the literature:
- (1) non-supercell tornadoes explained by presence of vertical angular momentum
- (2) the environment of supercell tornadoes contains abundant vertical angular momentum

Sanford (Florida) tornado (F3) February 23, 1998

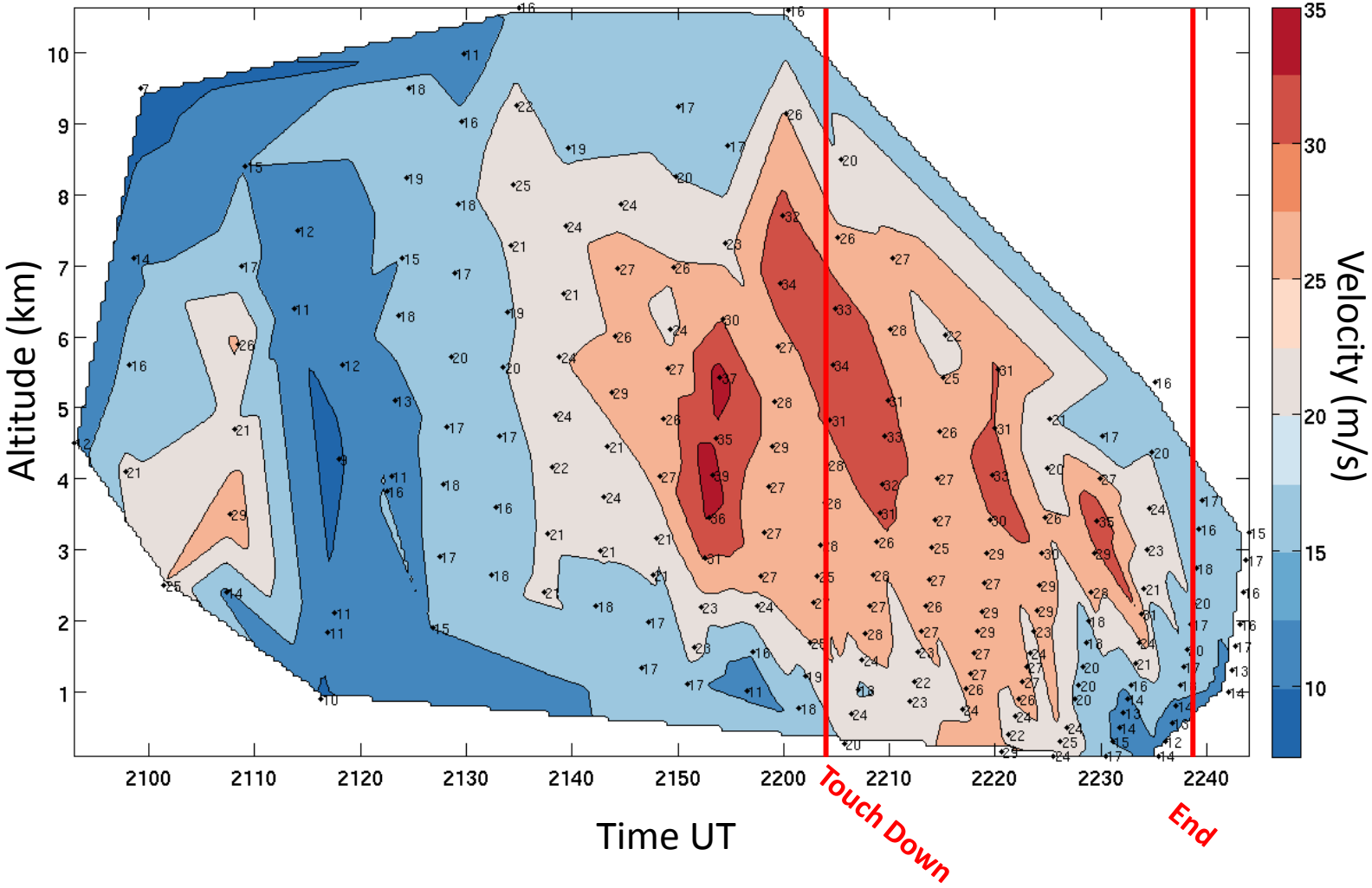




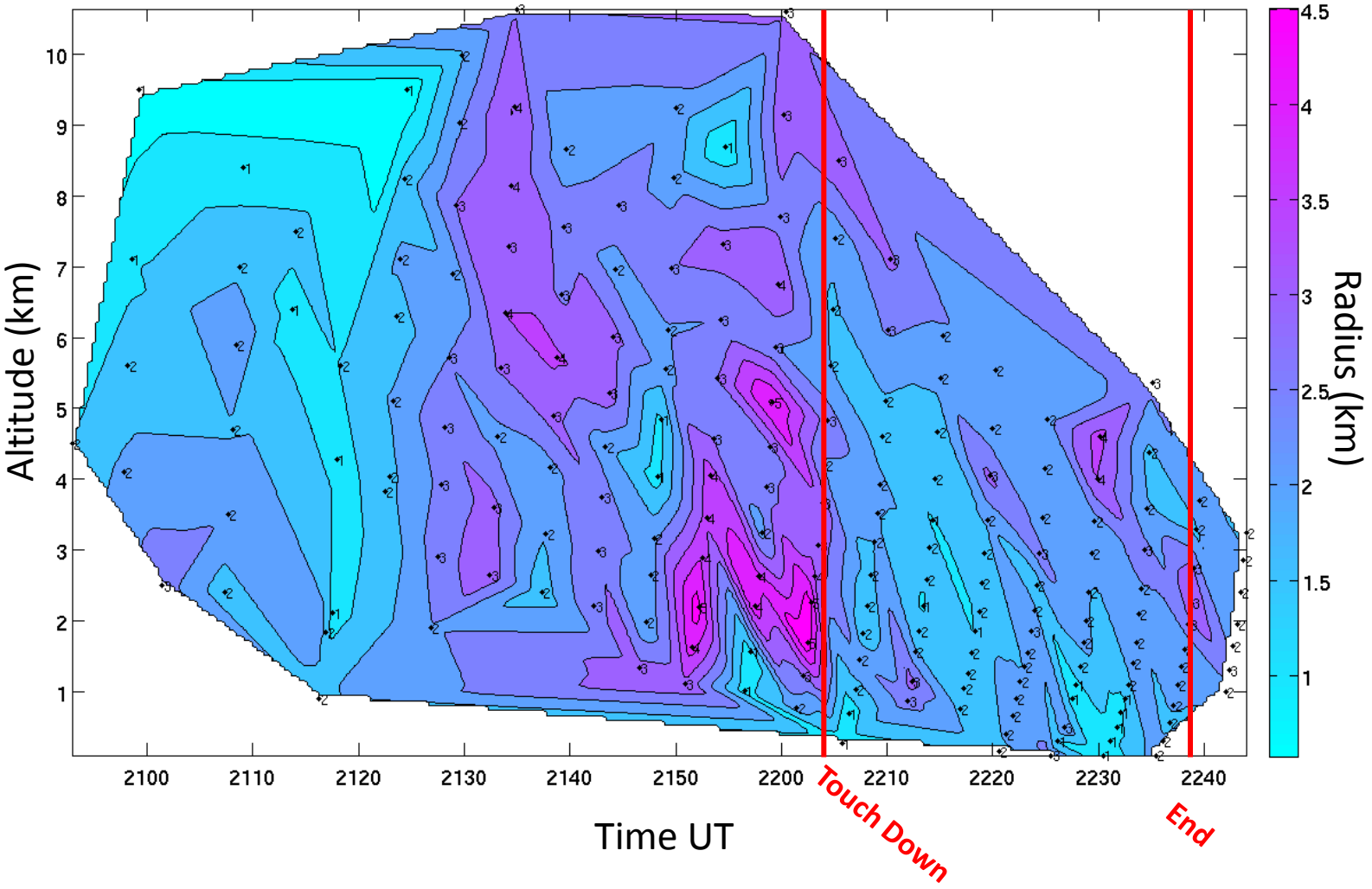
Salt Lake City tornado (F2)
August 11, 1999



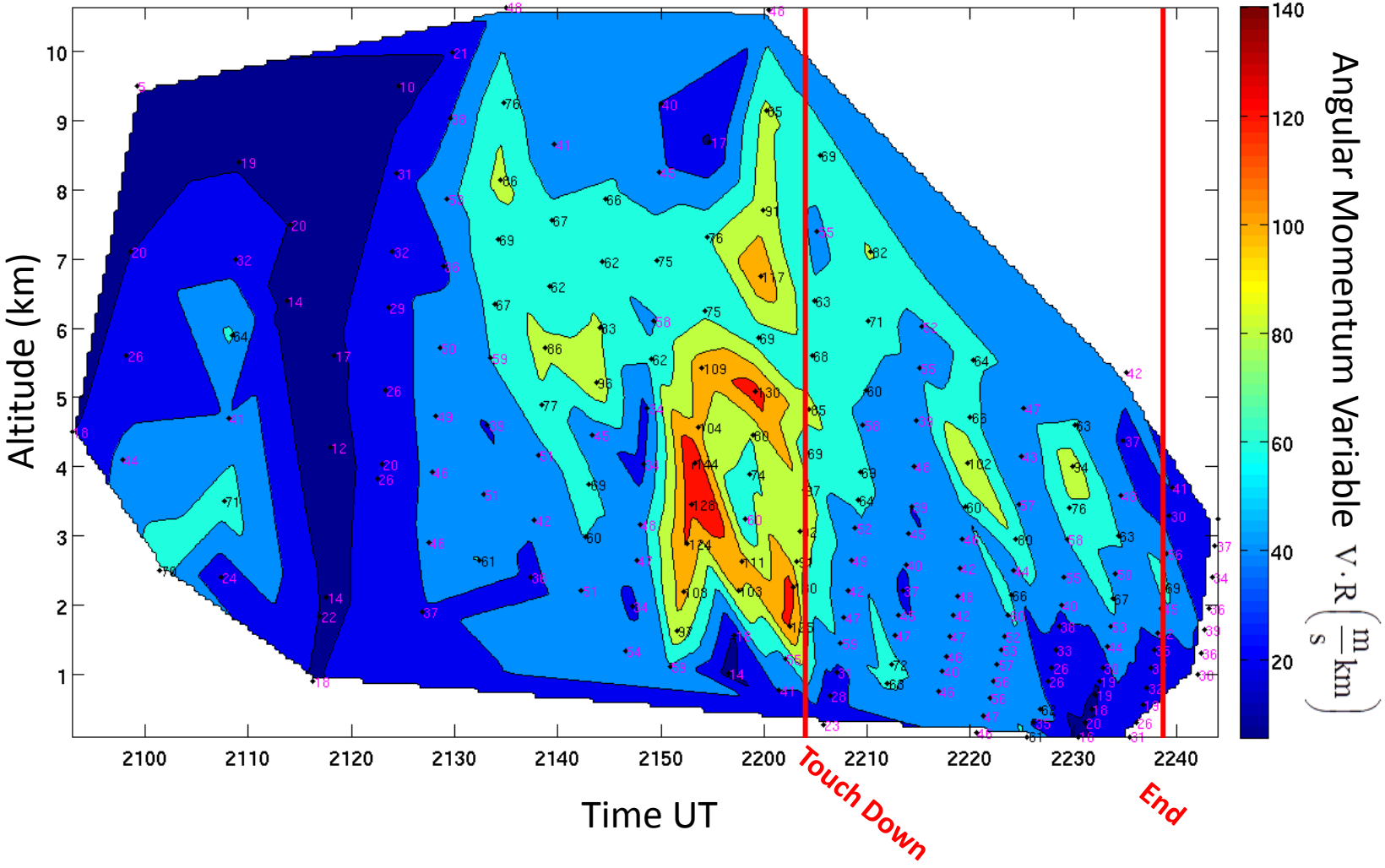
Moore-to-Choctaw tornado (F4)
May 8, 2003



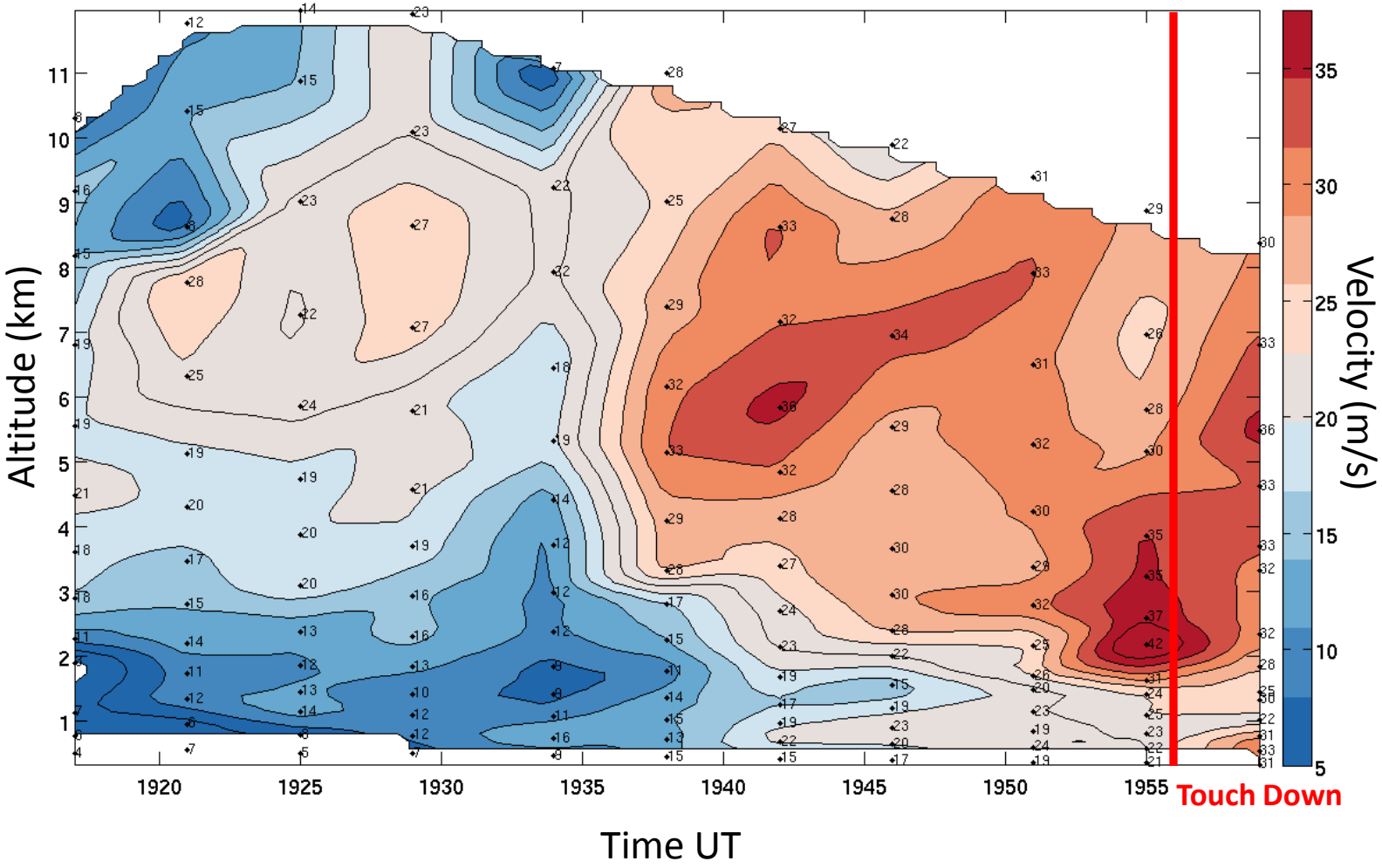
Moore-to-Choctaw tornado (F4)
May 8, 2003



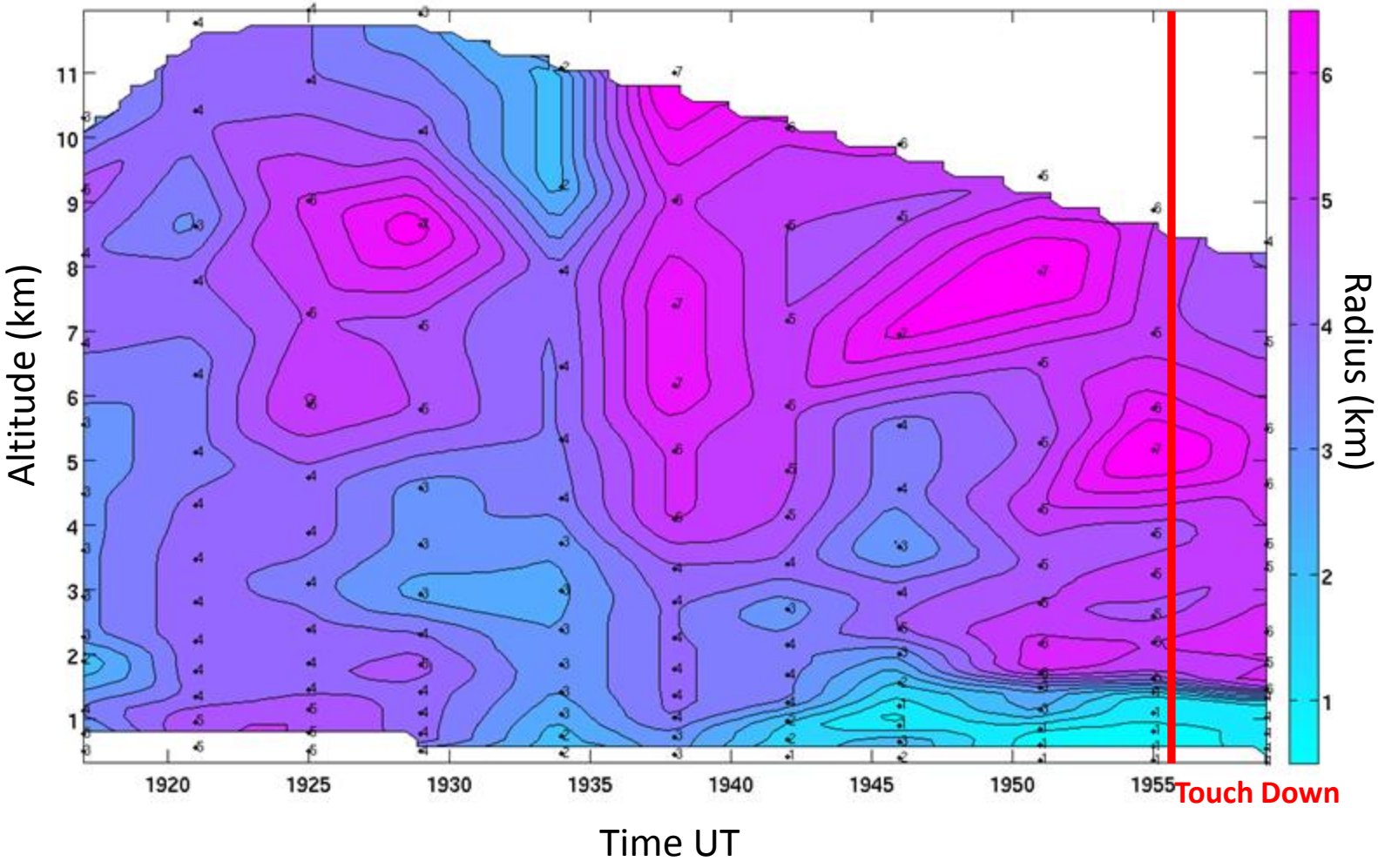
Moore-to-Choctaw tornado (F4)
May 8, 2003



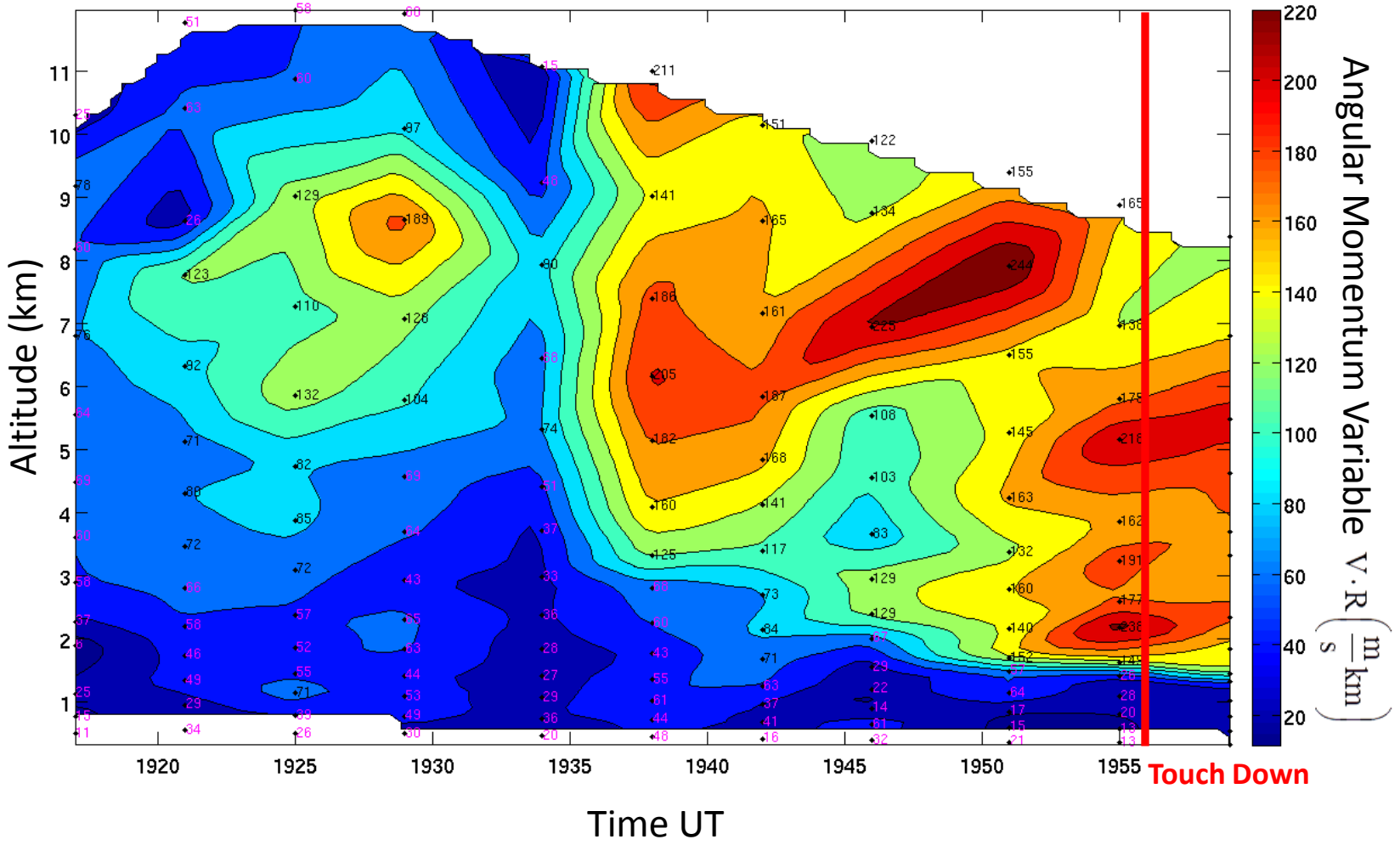
Moore tornado (F5)
May 20, 2013



Moore tornado (F5)
May 20, 2013



Moore tornado (F5)
May 20, 2013



Summary of Tornado Events

Date	Strength	Max V(m/s)	Max R (km)	Max VR (m/s km)	Reference
June 15, 1988 (T1)	F1	14	0.8	13	Roberts and Wilson (1995)
June 15, 1988 (T2)	F2	22	0.8	17	same as above
June 15, 1988 (T3)	F2	15	0.8	6	same as above
Feb. 23, 1998 (Kissimmee, FL)	F3	39	5.3	126	LISDAD case
Feb. 23, 1998 (Sanford, FL)	F3	28	3.5	240	LISDAD case
Feb. 23, 1998 (Volusia, FL)	F2	26	4.5	120	LISDAD case
Apr. 23, 1997	F1			107	LISDAD case
July 11, 1997				45	
Nov. 2, 1997	F3			135	LISDAD case
May 3, 1999	F1	30	2.7	88	D. Burgess, pers. comm.
Aug. 11, 1999	F2	22	1.1	12	M. Isaminger, pers. comm.
May 8, 1999	F4	39	5.0	140	D. Burgess, pers. comm.
May 20, 2013	F5	32	7.0	210	C. Schultz, pers. comm.

Conclusions

1. The presence of a maximum in vertical angular momentum aloft prior to the tornado, and its reduction during the lifetime of the tornado, are together indicators that the reservoir aloft is fundamental to tornadogenesis. The vertical angular momentum in this reservoir is sufficient to account for the angular momentum of the tornado.

2. The collapse of lightning activity prior to tornadogenesis (in earlier studies) is indicative of downward moving air aloft, and consistent with the descent of angular momentum