# Radar-detected Mesocyclone Tilt in Tornadic and Nontornadic Supercells


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## Background & Motivation

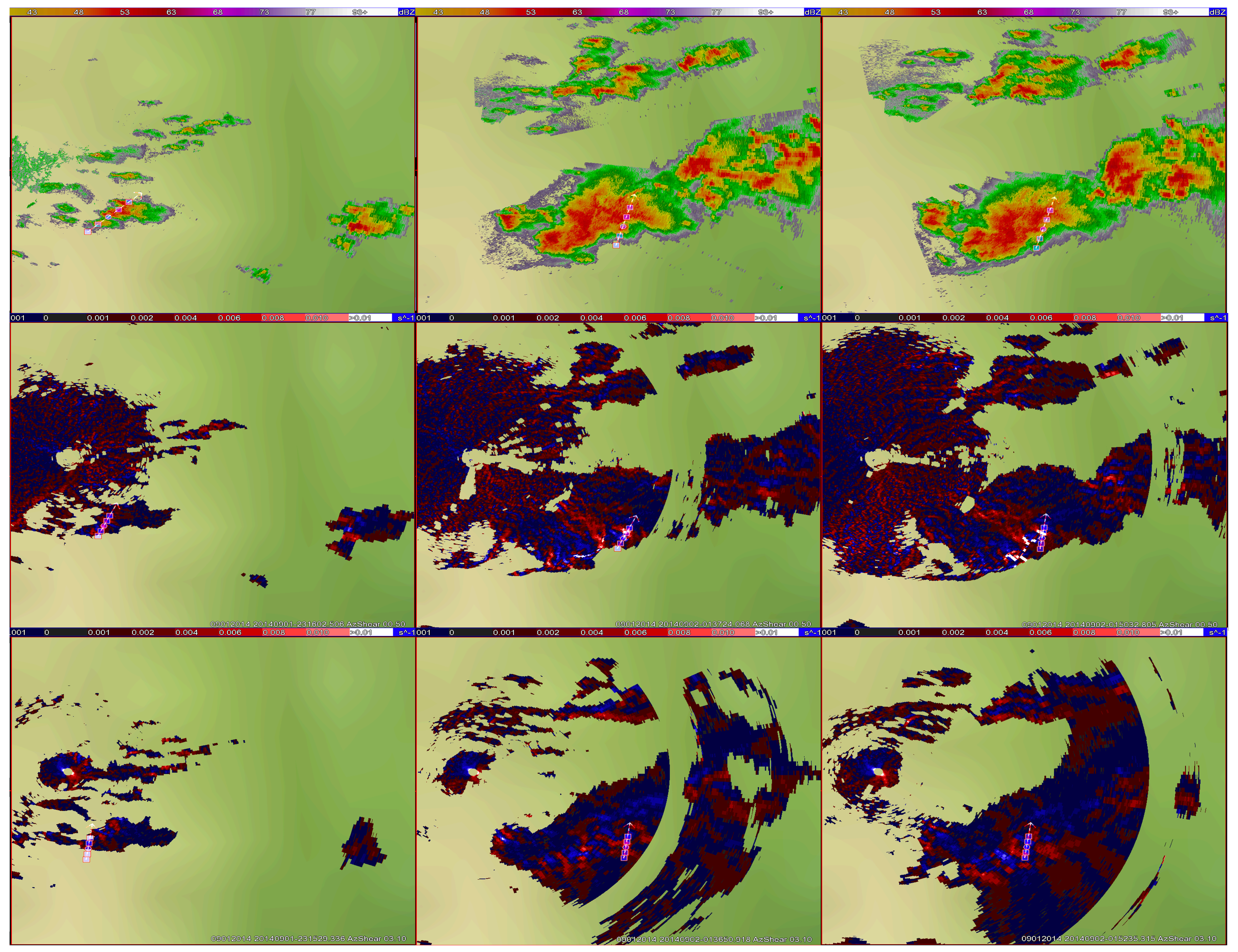
1) Supercells are the storms most likely to produce strong and violent tornadoes (≥ EF2), but only ~30% of supercells do produce tornadoes.[1]
2) It is not fully understood what causes some supercells to produce tornadoes while others do not.
3) Low-level (LL) shear & lifting condensation level (LCL) height are two of the best discriminators between tornadic and nontornadic supercells.[2] The underlying dynamical reasoning for this relationship remains poorly understood.
4) While others have studied the role of vertical wind shear on the strength of dynamic lifting by the midlevel (ML) mesocyclone and LCL height on cold pool buoyancy, there have been limited studies regarding the effects of these parameters on the relative positioning of the LL circulation and the overlying ML mesocyclone.[2]
5) Our hypothesis is that the more upright a supercell's mesocyclone, the greater the likelihood of a tornado. We suppose this tilt is influenced by the LL shear and LCL height.
6) This is a preliminary investigation of a limited number of cases studying the mesocyclone tilt in tornadic and nontornadic supercells.

## Data & Methods

1) We studied 6 cases of tornadic (4) and nontornadic (2) supercells from 2009-2014.
2) The Level-II radar data was quality controlled, dealiased, and converted to a lat-lon grid using the Warning Decision Support System-Integrated Information (WDSS-II).[3,4,6,7]
3) The LL (0-2 km AGL) and ML (3-6 km AGL) layer-maximum azimuthal shear were calculated using WDSS-II.[5] We use this shear as a proxy for both the strength and location of supercell mesocyclones at different heights.
4) We tracked the coordinates of the maximum LL and ML azimuthal shear over the duration of each storm.
5) From the coordinates, the distances between the LL and ML mesocyclones (the tilt) was calculated for each storm using the Vincenty ellipse formula.
6) We used soundings from the Storm Prediction Center's (SPC) archive to collect environmental parameters before each supercell: convective available potential energy (CAPE), LCL, deep layer (0-6 km) shear, and storm-relative, inflow (0-1 km) helicity (SRH).

## Results

**Before** **During** **After**

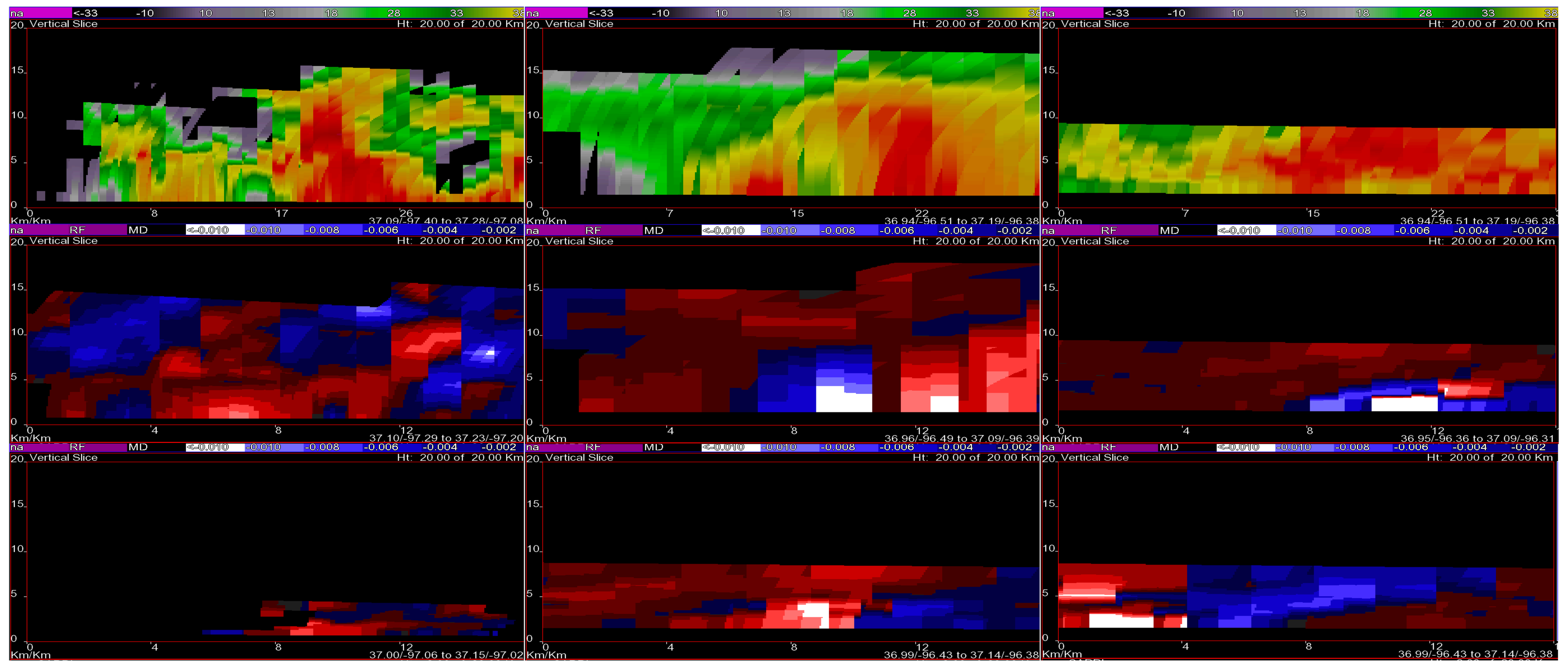


**Example summary of the processed data using the 09012014 case**. The top row shows quality controlled reflectivity, which was used to locate appropriate areas of LL and ML azimuthal shear, shown in the bottom rows, respectively. The columns show snapshots 'before the tornado,' 'during the tornado,' and 'after the tornado,' the duration over which the tornadic supercells were analyzed. If a supercell was nontornadic, this interval was instead defined as when the LL azimuthal shear was greater than about 0.006 $s^{-1}$, which is the rough threshold at which the organization in the shear is lost. The lines in each panel indicate where cross sections were taken.

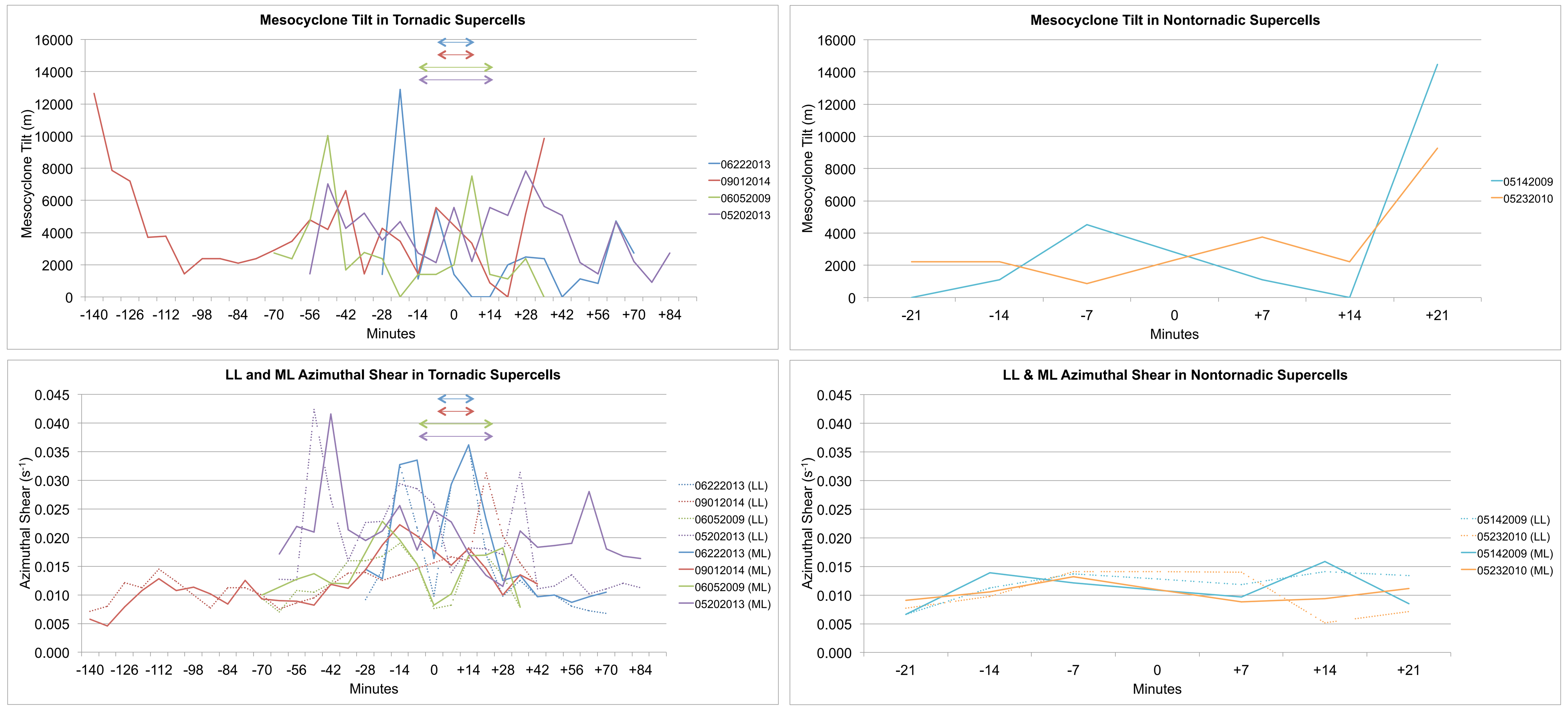
| Date & Location of Supercell | Supercell Type | LL & ML Shear at Midpoint ($s^{-1}$) | Mesocyclone Tilt at Midpoint (m) | Distance from Radar at Midpoint (km) | Max LL & ML Shear ($s^{-1}$) | Max & Min Mesocyclone Tilt (m) | Surface CAPE (J $kg^{-1}$) | LCL (mb) | 0-6 km Shear (kts) | 0-1 km SRH ($m^2 s^{-2}$) |
|---|---|---|---|---|---|---|---|---|---|---|
| 05142009, OK | Nontornadic | 0.01279; 0.01090 | 2819 | 6.5 | 0.01405; 0.01587 | 14454; 0 | 933 | 950 | 19 | 440 |
| 06052009, WY | Tornadic (EF2) | 0.00761; 0.00823 | 2003 | 7.25 | 0.01895; 0.02285 | 10027; 0 | 656 | 820 | 35 | 35 |
| 05232010, KS | Nontornadic | 0.01405; 0.01100 | 2309 | 5.25 | 0.01414; 0.01317 | 9251; 865 | 2193 | 900 | 16 | 134 |
| 05202013, OK | Tornadic (EF5) | 0.02575; 0.02470 | 5567 | 2 | 0.04238; 0.04155 | 7819; 907 | 4946 | 910 | 52 | 131 |
| 06222013, NE | Tornadic (EF1) | 0.00977; 0.01638 | 1388 | 8.5 | 0.03620; 0.03620 | 12908; 0 | 171 | 875 | 38 | 14 |
| 09012014, KS | Tornadic (EF1) | 0.01562; 0.01769 | 4442 | 11 | 0.03129; 0.02225 | 12635; 0 | 1191 | 990 | 13 | 162 |

**Table summarizing the characteristics and environmental parameters for each supercell.**

**Before** **During** **After**



**Cross sections for the 09012014 tornadic supercell**. The top row shows quality controlled reflectivity, the middle row shows LL azimuthal shear, and the bottom row shows ML azimuthal shear. As in the previous figure, the columns show snapshots 'before the tornado,' 'during the tornado,' and 'after the tornado.' The strengthening and subsequent weakening of the storm can be seen in each of the panels. Before the tornado, the mesocyclone tilt is the largest it will be during the supercell's lifetime. During the tornado, the tilt is much smaller. After the tornado, the tilt is virtually zero.




**Summary of the mesocyclone tilts and LL and ML azimuthal shear throughout the duration of both tornadic and nontornadic supercells.** The top row compares the tilts between supercell types, and the bottom row compares maximum values of shear between supercell types, with each color representing a different event. In the left column, the arrows represent the duration of each tornado. In the bottom row, the dashed lines represent the LL shear, and the solid lines represent the ML shear.

## Preliminary Conclusions

1) There is some evidence, in the tornadic supercells, that the mesocyclone tilt decreases leading up to and during a tornado.
2) The tornadic supercells generally have larger values of LL and ML shear during their lifecycles.
3) The deep layer environmental shear tends to be larger in the tornadic supercells.
4) The mesocyclone tilt during the tornadoes is not as small as expected.
5) Errors in the calculated azimuthal shear may be present due to a supercell's distance from the radar and the resolution of the radar.
6) Errors in the environmental data may be present due to radiosonde error and non-representativeness of the supercell inflow region.

## Future Work

1) Our remaining cases will be processed to build a climatology of ~100 supercells. We will automate our methodology.
2) We will determine if there is a statistically significant correlation between mesocyclone tilt and the strength of LL rotation.
3) Higher resolution data from the VORTEX2 project will be analyzed to gain more insight for specific cases.
4) The RUC Analysis data will be studied to determine how the LL shear and relative humidity in the storm inflow affect mesocyclone tilt.

## References & Acknowledgements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[5]Smith and Elmore 2004. The use of radial velocity derivatives to diagnose rotation and divergence. Preprints, 11th Conf. on Aviation, Range, and Aerospace, Hyannis, MA, Amer. Meteor. Soc., P5.6 - CD preprints.

[6]Lakshmanan et al. 2006. A real-time, three dimensional, rapidly updating, heterogeneous radar merger technique for reflectivity, velocity and derived products. Weather and Forecasting. 21, 802-823.

[7]Lakshmanan 2012. Automating the Analysis of Spatial Grids: A Practical Guide to Data Mining Geospatial Images for Human and Environmental Applications. Springer. ISBN: 978-94-007-4074-7.



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