Radar-detected Mesocyclone Tilt in Tornadic and Nontornadic Supercells

Michelle M. Serino, Christopher J. Nowotarski
Texas A&M University

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 smaller the horizontal distance between the low- and mid-level mesocyclones (i.e., mesocyclone tilt), there exists a greater likelihood for stretching of near-surface vorticity and thus a tornado.
6) We also hypothesize that this tilt is affected by the LCL and LL ambient wind profile, including vertical wind shear, through their effects on outflow properties.

Data & Methods

1) We studied a tornadic (EF2) supercell from June 6, 2009.
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 the storm using the Mesocyclone Detection Algorithm.
5) The distances between the LL and ML mesocyclones (the tilt) were calculated and corrected for radar scan lag.
6) The Rapid Update Cycle (RUC) Analysis was used to improve dealiasing of the velocity data and to create soundings of the inflow environment.[8]

Results

Hypothesis 1 – Case Study

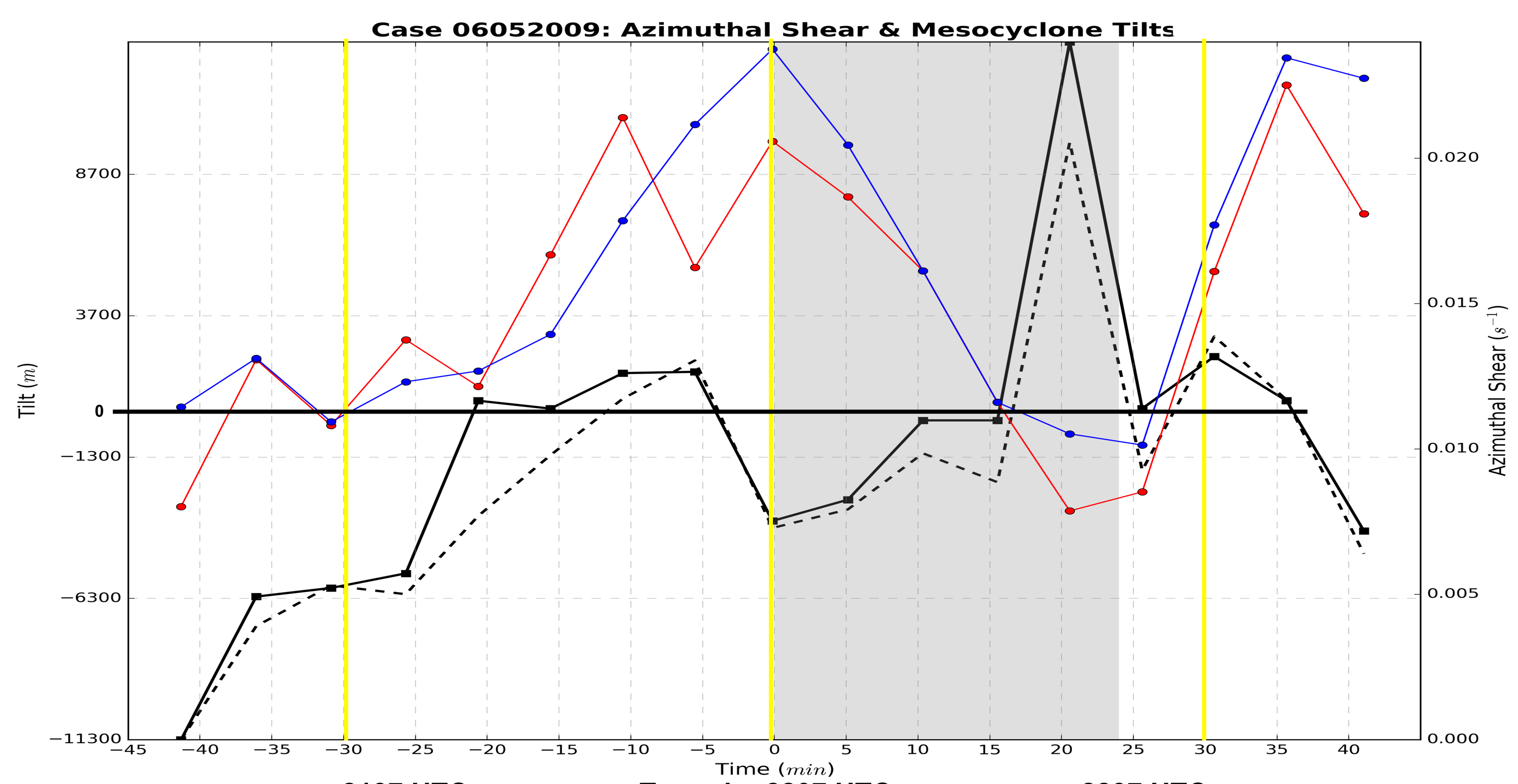


Figure 1. LL (red) and ML (blue) maximum azimuthal shear and observed mesocyclone tilt (solid black) and corrected mesocyclone tilt (dashed black) during the lifetime of the June 5, 2009 tornadic supercell in Wyoming.

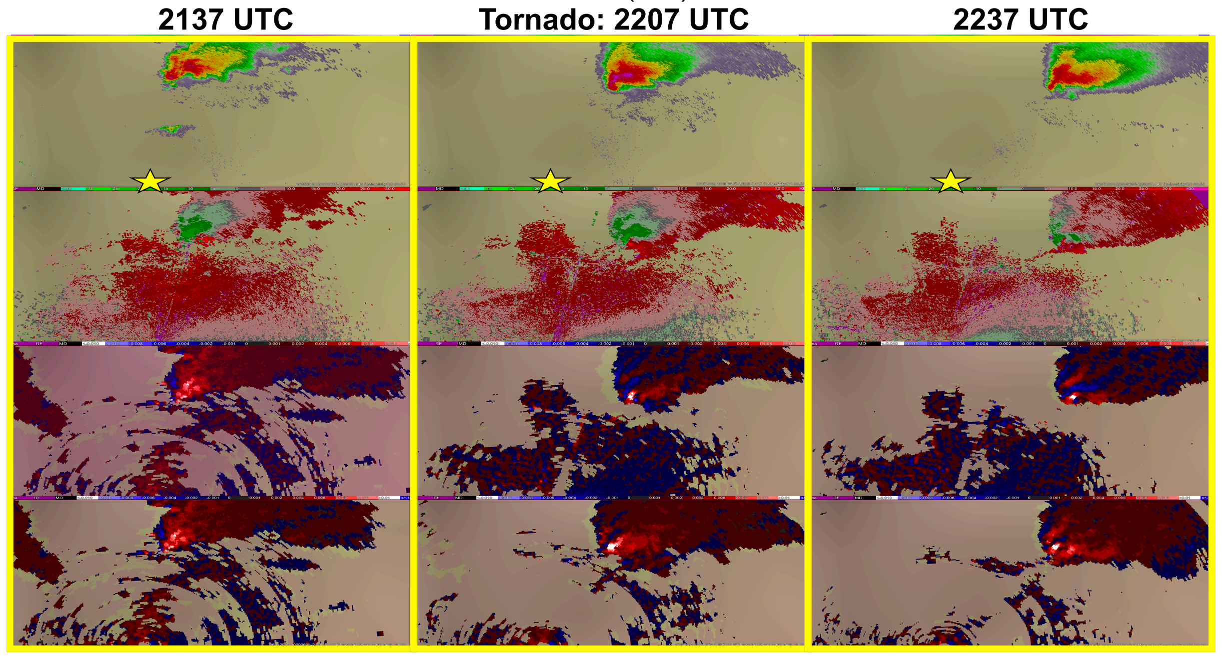
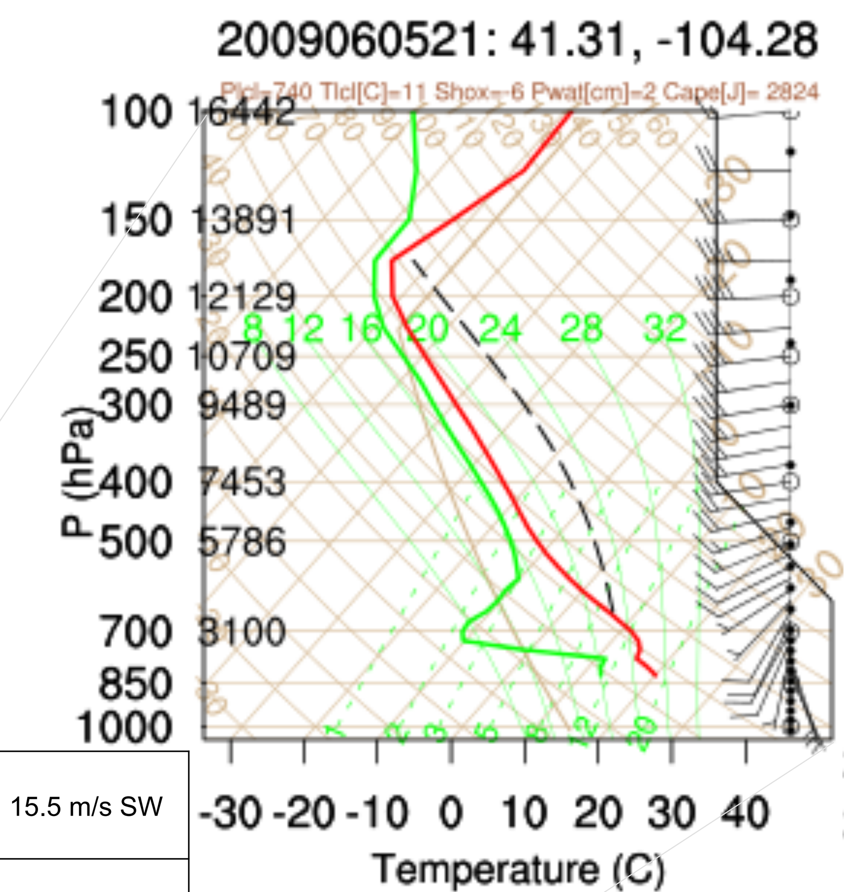


Figure 2. Plan views of reflectivity (top row), velocity (second row), LL azimuthal shear (third row), and ML azimuthal shear (bottom row) at the three time intervals indicated by the yellow lines in Figure 1. The star marks the position of the WSR-88D, KCYS.

Hypothesis 2 – Case Study

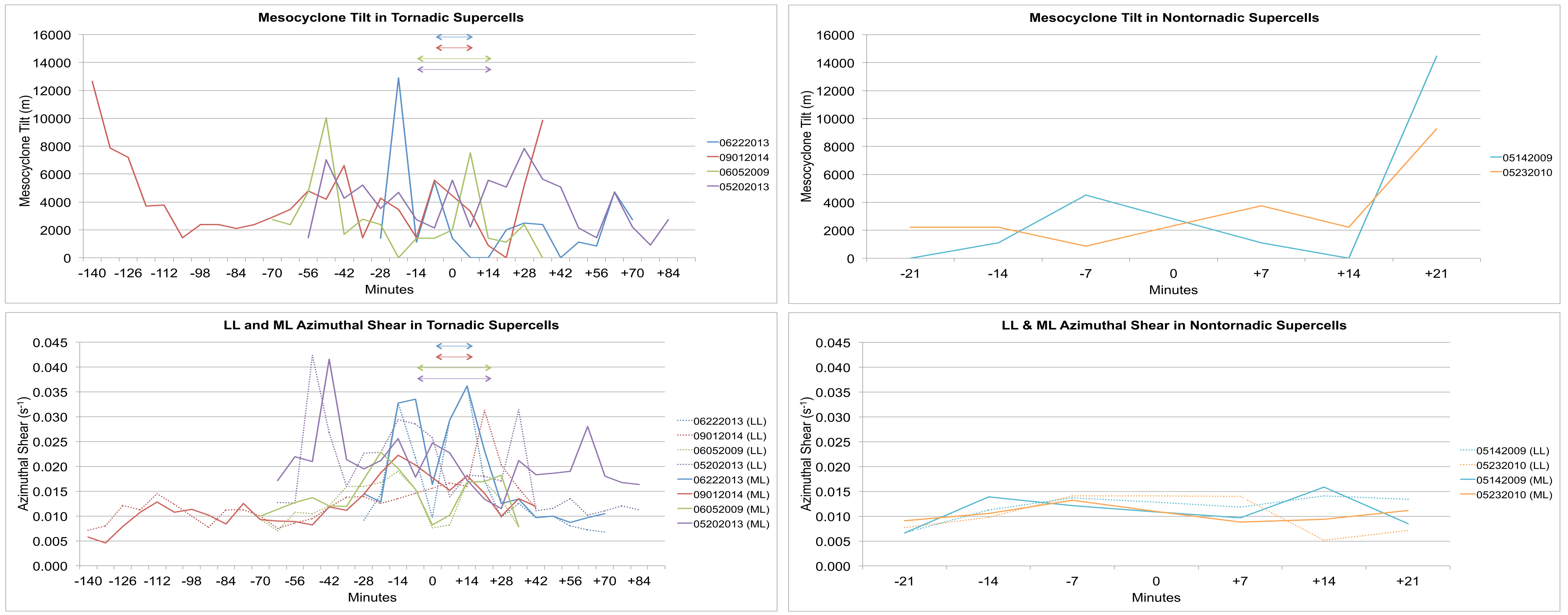


0-6 km Bulk Vertical Wind Shear	15.5 m/s SW
0-1 km Vertical Wind Shear	2.5 m/s SW
LCL Pressure	740 hPa
Relative Humidity	62%
Surface CAPE	2907 J

Figure 3. Sounding (left) of the inflow environment one hour before the middle of the June 5, 2009 tornadic supercell. Several dynamic and thermodynamic parameters are summarized in the table to the left.

Figure 4. Summary of the mesocyclone tilts and LL and ML azimuthal shear throughout the duration of both the 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 case. 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.

Hypothesis 1 – Multiple Cases



Preliminary Conclusions

1) It is unclear if there is a robust relationship between mesocyclone tilt and the likelihood of tornadoes, although the mesocyclone tilt for the tornadic supercells generally decreases before or during the tornadoes.
2) However, the mesocyclone tilt during the tornadoes is not as small as expected.
3) The deep layer environmental shear tends to be larger in the tornadic supercells.
4) Errors in the calculated azimuthal shear may be present due to a supercell's distance from the radar and the resolution of the radar.

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) The RUC Analysis data will be studied to determine how the LL shear and relative humidity in the storm inflow are correlated with mesocyclone tilt.

References & Acknowledgements

[1]Trapp et al. 2005. A reassessment of the percentage of tornadic mesocyclones. Weather and Forecasting. 20, 23-34.

[2]Markowski and Richardson 2009. Tornadogenesis: Our current understanding, forecasting considerations, and questions to guide future research. Atmos. Research. 93, 3-10.

[3]Lakshmanan et al. 2007. The warning decision support system – integrated information. Weather and Forecasting. 22, 596-612.

[4]Lakshmanan et al. 2006. An automated technique to quality control radar reflectivity data. J. Applied Meteorology. 4.

[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.

[8]Potvin, C. K., K. L. Elmore, and S. J. Weiss, 2010: Assessing the impacts of proximity sounding criteria on the climatology of significant tornado environments. *Wea. and Forecasting*, **25**, 921-930.

GLOBE Task Team and others (Hastings, David A., Paula K. Dunbar, Gerald M. Elphingstone, Mark Bootz, Hiroshi Murakami, Hiroshi Maruyama, Hiroshi Masaharu, Peter Holland, John Payne, Nevin A. Bryant, Thomas L. Logan, J.-P. Muller, Gunter Schreier, and John S. MacDonald), eds., 1999. The Global Land One-kilometer Base Elevation (GLOBE) Digital Elevation Model, Version 1.0. National Oceanic and Atmospheric Administration, National Geophysical Data Center, 325 Broadway, Boulder, Colorado 80305-3328, U.S.A. Digital data base on the World Wide Web (URL: http://www.ngdc.noaa.gov/mgg/topo/globe.html) and CD-ROMs.

The authors gratefully acknowledge the National Science Foundation for its support (grant # AGS-1446342). The authors also acknowledge the WDSS-II forum and the NCL forum for advice and assistance with algorithm and language use. In addition, they acknowledge the SPC for providing the Severe Weather Events Archive, Chris Veness for providing the Vincenty formula, Felicia Guarriello for coding assistance.