

ELECTROMAGNETIC FIELDS RECORDED IN MESOCYCLONES

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Abstract

Initial findings taken from ongoing field research, seeking to better understand the relationships between electrical charge, magnetic fields, and the evolution of vortices, are presented. Despite inherent difficulties in collecting real-time data associated with vortices, measurements of magnetic fields close to and within dust devils, mesocyclones, and a hurricane were successively recorded using magnetometers.

Speculations about possible mechanisms accounting for the variability in the electromagnetic fields observed are offered, although without quantitative proof. Of particular interest for additional research are: i) measurements showing an increase in the magnetic field of the mesocyclones' torus compared to the decreasing magnetic fields found in the center; ii) a sharp drop in magnetic field readings upon entering the eye of Hurricane Wilma; and iii) a consistent change in the direction of rotation of large dust devils as they moved across fields with significantly different pH soil values.

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1. Introduction

After observing what appeared to be magnetic field lines in the debris fields of tornadoes and non-rotating spoke-like projections that appeared to be the influence of magnetic field lines in 4-second NASA satellite images of Hurricane Guillermo 2 August 1997 from GOES-9, (<http://rsd.gsfc.nasa.gov/rsd/movies/preview.html>), experimental investigation into the variability of surface electromagnetic fields of mesocyclones was initiated. Current literature of electromagnetic theory and tornadoes includes research measuring how severe storms become electrified and how variations in type and flash rates of lightning relate to the type of storm and its evolution as conducted during STEPS (Severe Thunderstorm Electrification and Precipitation Study) project (STEPS 2004). Previous magnetic field research involving tornadoes (Brook 1967) showed that large currents of electricity (up to 225 Amperes) were generated during the tornadoes' lifetimes. Brook (1967) also mentioned one instance where a tornado was detected at a distance of 150 km by using a magnetometer, but that more observations were needed to confirm that such large charges actually occur with tornadoes. Vonnegut (1960) speculated that tornadoes were powered by the parent thunderstorms that caused rotation similar to an electric motor. If this is true, then there will be a stronger magnetic field within the rotation. However, because of the difficulty in obtaining inner-vortex data, there is a lack of magnetic field research with regards to tornado generation.

Our magnetic field recordings of Hurricane Wilma coupled with our observations of dust devils led us to speculate on the role of electromagnetic fields during mesocyclones and how tornadoes may develop. The purpose of this paper is to share with the scientific community our recordings of magnetic fields associated with vortices of various spatial scales and future plans for additional research. Although considerable more research is needed, we *speculate* about the potential of utilizing magnetic field measurement as an additional means to current methods for anticipating tornadogenesis.

2. Data Collection and Initial Results

a. Dust devils

The magnetic fields of dust devils were recorded in the San Joaquin Valley of California in 2003. The San Joaquin Valley consists of thousands of square miles of flat terrain, punctuated by farm fields. Research was conducted in farm fields that were sectioned into blocks of one square mile, with each square mile being connected by straight dirt

roads. The freshly tilled soil in each block had previously yielded cotton, onions, or wheat.

A single-axis geomagnetometer was used to record the magnetic fields. The smallest and most sensitive unit was purchased online from Less EMF, Inc. Measuring 3 x 4 x 7 inches and operating on 9V batteries with an AC power adapter included for extended bench-top use, the magnetometer is totally portable. An axial probe (High Sensitivity Hall Generator) with coiled cable was included and provided a nearly flat response from DC to 10+ Hz, an easily readable 3.5 digit bipolar display, and four ranges: 0-2, 20, 200, and 2,000 milligauss, with a 5% error guarantee.

The magnetometer was mounted on a standardized crate, also known as an "apple box," and fitted with a pinhole camera above to record the digital display. The gauss probe was mounted stationary at an upward position of a 45-degree angle and was set up on the ground facing due north. The magnetometer was then calibrated to account for the Earth's ambient magnetic field, approximately 500 milligauss. When a dust devil was observed, the magnetometer was placed on the ground in the path of the dust devil to record its magnetic field.

Sixteen large dust devils were observed in two large fields and captured on video. We speculate that dust devils electrify themselves through the rotation of dust particles that collide to create an electrical charge, and the moving charge then creates a dipole moment to make a magnetic field. For theories regarding self-excitation leading to vortex generation, see Davies-Jones and Golden (1975), Wilkins (1964), and Vonnegut (1960).

Of particular interest was the change in the direction of the dust devils' rotation as they moved from the field of origin into an adjacent field. The pH levels of the soil in each field was tested. In the tilled field where wheat had previously grown, the soil tested at pH 7 (neutral). In the tilled field to its south, cotton had recently been harvested, and the pH reading was 9. All sixteen large dust devils rotated in a clockwise direction in the field with soil pH levels of 7; however, once the dust devils crossed into the adjacent field, they changed direction, spinning counter-clockwise. We speculate that this consistent change in rotation may be due, in part, to the alkaline material present in the second field, causing the particles to charge positive as opposed to the negative charge induced by the pH 7 balance soils. These initial findings will be subject to further research to be conducted in the San Joaquin Valley this spring (2008).

When editing the finished video footage of the dust devils, it was discovered that in all 41 recordings there was a glitch in the footage as the tail end of the dust devil passed through the DV camera. We speculate that the magnetic field present with the dust devils interfered

with recording the magnetic information onto the mini DV tape.

Finally the barometric pressure inside and outside the dust devils was also collected using a weather watch containing a barometer. In the successful attempts, barometric pressure drops inside the dust devils of 2-3 millibars were recorded; however, it cannot be discerned whether the pressure drops were due to the dust devils' rotations and electrical charges or due to temperature changes.

b. Hurricane Wilma

On 20 October 2005, we participated with the National Oceanic and Atmospheric Administration's (NOAA) Tampa, FL-based Hurricane Hunters on two missions to record the magnetic fields of Hurricane Wilma aboard a Gulf Stream IV-SP (G-4) and a WP-30 Orion Turboprop (P-3). On the first mission, we used a single-axis calibrated geomagnetometer (identical to the magnetometer we used in the dust devil investigations). The magnetometer was placed on the window using suction cups, and a gauss probe was held on by tie wire and aimed downward at a 50-degree angle (Fig. 1).

On the second mission, the magnetometer was placed on the inside window of a WP-30 Orion turboprop (P-3), again using suction cups. A video camera was used to record each radiosonde drop and then panned over to record the digital display magnetic field reading of the geomagnetometer for reference.

The G-4 mission flew the outer perimeter of the hurricane at an altitude of 34,000-39,000 feet (Fig. 2). The G-4 mission landed 9 hours later at McDill Air Force Base (AFB), and the same calibrated magnetometer was loaded on board the P-3 mission that flew into the eye.

Although the magnetic field readings of the magnetometer changed when the aircraft changed directions, the principal interest of study here was the changes in the magnetic field that occurred when the aircraft was traveling in a straight line. The largest variances were recorded during the P-3 missions into the eye of the storm. As the aircraft maintained a steady and straight line course, a considerably higher magnetic field reading was recorded while in the hurricane's rotating precipitation shield. Once the aircraft entered the clearing of the eye, the readings dropped significantly. Notice that in Fig. 3, while traveling in the same northwesterly direction, a reading of 414 milligauss was recorded with SONDE drop #4 and 77 milligauss was recorded with drop #5. The same general pattern of results occurred from



Fig. 1. The single-axis geomagnetometer attached to the side of the NOAA research aircraft.

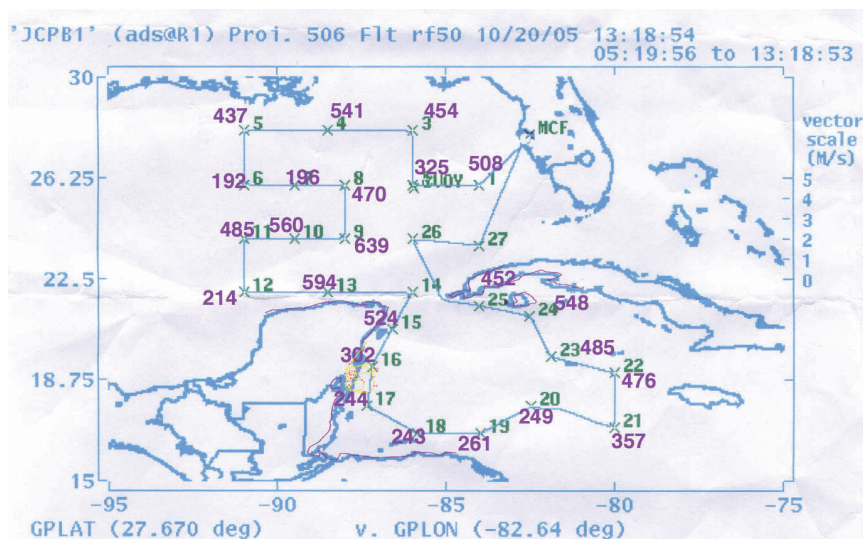


Fig. 2. The sequential magnetic field recordings (highlighted in purple) in conjunction with each NOAA dropsonde deployment (represented in green).

SONDE drop #10, recording a reading of 58 milligauss, and #11, recording a reading of 376 milligauss.

c. Mesocyclones

Magnetic fields associated with nine mesocyclones (Table 1) were recorded over 31 days during May and June of 2006. As in the NOAA investigations of Hurricane Wilma, video cameras were used in conjunction with the magnetometers, enabling us to review the exact times the

Table 1. Dates and locations of mesocyclones recorded.

5-14-06	Medina, TX
5-22-06	Jackson, CO
5-23-06	O'Neil, NE
5-23-06	Norfolk, NE
5-27-06	Bismarck, ND
5-28-06	Langdon, ND
5-30-06	Shindler, OK
5-31-06	Boise City, OK
6-06-06	Clarksville, TX

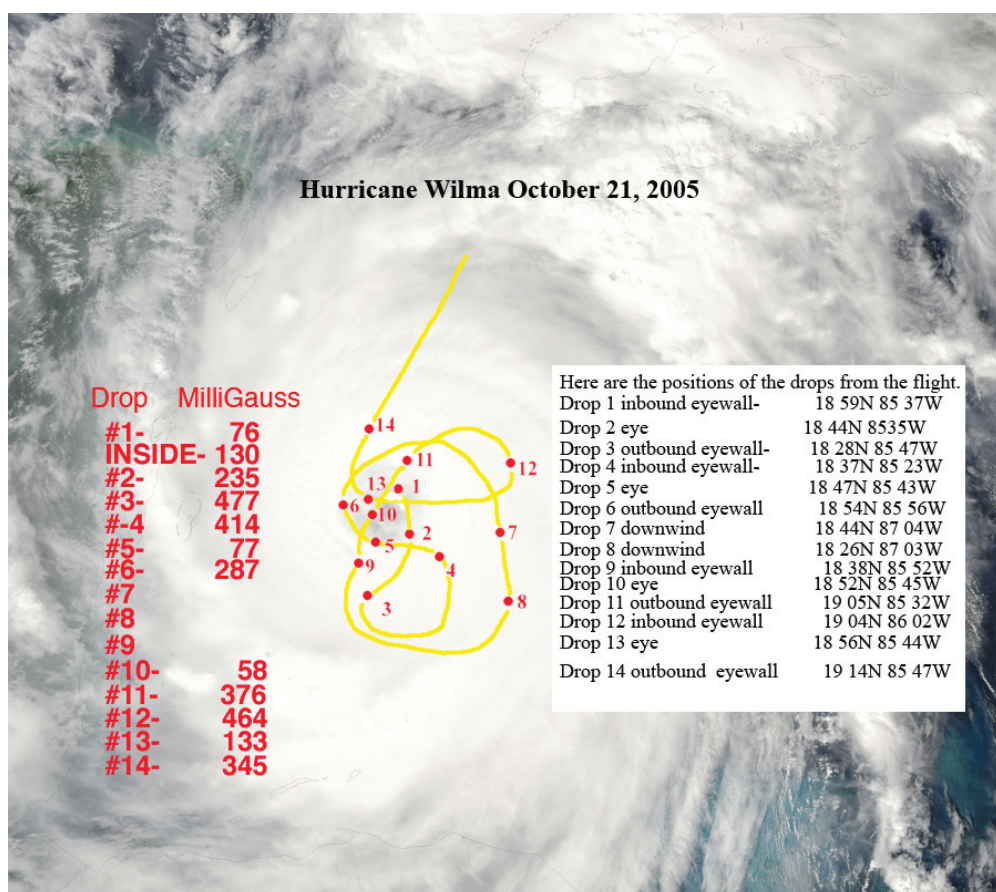


Fig. 3. The P3 magnetic field readings in conjunction with the NOAA dropsonde deployment.

recordings took place in relation to the mesocyclones. Due to the necessary expediency involved in storm chasing, it was not always possible to recalibrate the Honeywell HMR 3000 3-axis magnetometers before deploying at a given test site. In those cases, a close approximation of the magnetic field for a specific location was achieved by assuming that the Earth's surface ambient magnetic field was 500 milligauss. Also, for the two consecutive days immediately following the storms, each recording site was revisited. There, additional readings were obtained under clear skies, establishing a base line on which to further interpret the mesocyclones' magnetic field measurements.

Different methods were attempted for gathering recordings of the storms' magnetic fields, including equipping 3-axis geomagnetometers and data loggers into rockets for launching into the storms and portable pods for recording readings as the storms were intercepted using a motorcycle and car.

The first chase (14 May 2006—Medina, TX) was in conjunction with Dr. David Arnold, formerly of Ball State University. Upon consulting with Dr. Arnold, stationary pods (Fig. 4) were placed in front of the anticipated path of the approaching mesocyclones. This strategy allowed the magnetic field readings to be obtained before, during, and

after the mesocyclones' passage. The stationary pods method provided the best overall results.

3. Storm Chase Results

Presented in this section are examples of electromagnetic signatures recorded during the storm chases. Since Microsoft Excel cannot accommodate more than 67,000 rows of data, the magnetic field recordings were edited to one reading per second and then down to one reading per minute in order to produce the final results shared here. The electromagnetic signatures obtained are indicative of instrument calibration, lightning strikes, cloud cover, and mesocyclones passing nearby or overhead. The readings were recorded on 14 May 2006 near O'Neil, NE (Table 2) and on 31 May 2006 near Boise City, OK (Table 3).



Fig. 4. Shows one of the stationary pods used in the mesocyclone data collection. Each pod housed a Honeywell HMR 3000 three axis magnetometer and an Acumen Instruments RS 232 Data Logger. Aluminum handles were inserted so there would be no influence with the magnetic field. The pod consists of three round 10-inch ABS water valve encasements filled with 50 lbs. of quick dry concrete.

a) O'Neil storm chase

The O'Neil storm readings were taken approximately 5 miles apart (Fig. 5). Recordings of the magnetic field over time at each of the three pods (1-3) are shown in Fig. 6 (a-c).

For each of the three pods, the first vertical line seen in the time series represents the magnetometers' calibration; the other sharp vertical spikes recorded by pods 2 and 3 signal individual lightning strikes that occurred nearby. The series of rapid rises and falls in the magnetic field readings, seen at the beginning and end of the time series, are associated with the departure of the tail end of a first storm and its mesocyclone and the approach of a second storm. The prominent "leveling out" of the magnetic readings to a constant value (flat horizontal line) is largely indicative of the Earth's ambient magnetic field. The location of the pods and the timing of their placement relative to the storms' paths in the O'Neil chase were less than ideal for capturing a detailed signature of the storms' mesocyclones.

b) Boise City storm chase

Three stationary pods (Fig. 7) were deployed during the Boise City, OK chase. Unimpressive results were obtained from pod 1 (Fig. 8a) and pod 3 (not shown). Pod 1 calibrated itself within the first ten seconds of deployment and very briefly recorded the magnetic field at the very tail end of a storm moving southward. As skies cleared, the plot points seen in Fig. 8a leveled out to around 132 milligauss. The jump in values seen at the end of the time series occurred as the magnetometer was retrieved and loaded into the chase vehicle.

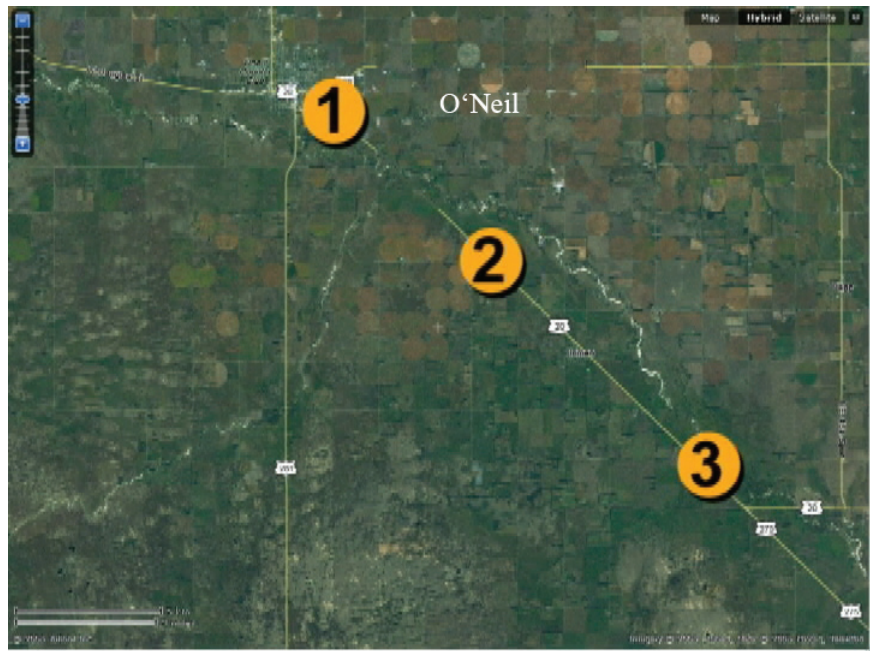
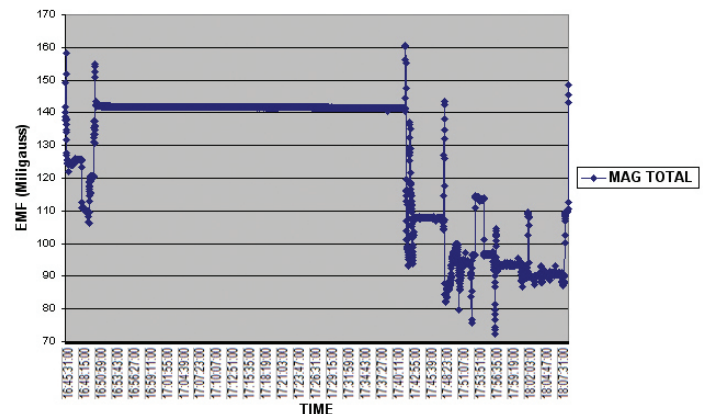


Fig. 5. Pod drop locations around O'Neil, NE.

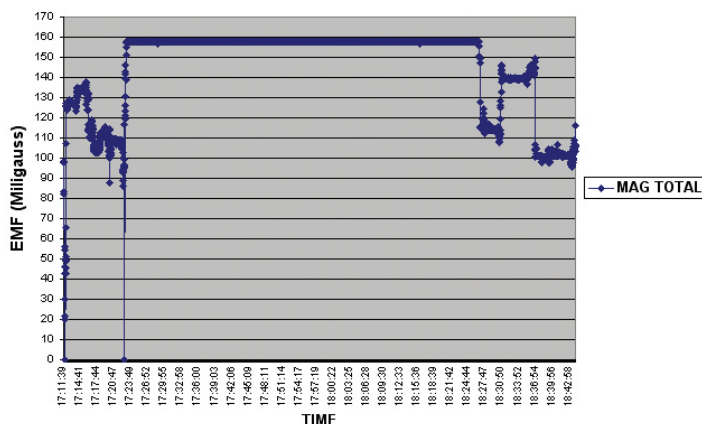
6(a)

May 23, 2006 O'Neil Pod #1



6(b)

May 23, 2006 O'Neil Pod #2



6(c)

May 23, 2006 O'Neil, NE Pod #3

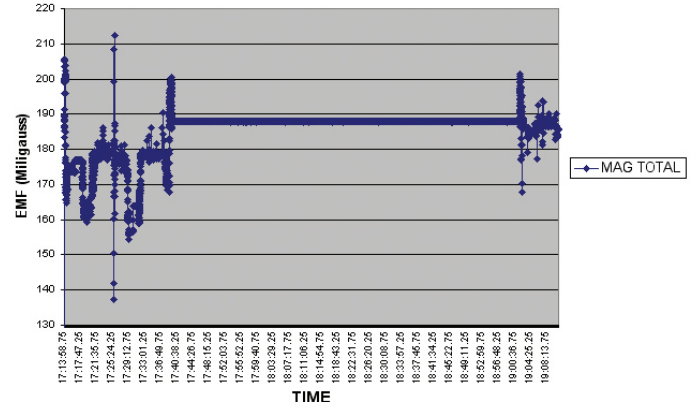


Fig. 6(a-c). Time series of magnetic field readings in milligauss as recorded from Pods 1-3, O'Neil, NE. (Details above in text).

The second magnetometer (pod 2) was deployed along RTE 325 about 15 miles west of Boise City (Fig. 7). The deployment took place prior to the approach of a developing, quasi-stationary supercell with marked rotation in the clouds clearly observed. The very slow movement of this storm made for excellent observation as the mesocyclone eventually passed directly overhead of the stationary pod. A drop in atmospheric pressure of 7 millibars was recorded beneath the center of the mesocyclone.

The resulting recording of the mesocyclone's magnetic field (Fig. 8b) shows considerable detail in contrast to the other recordings previously shared. Note that the pod was positioned at 17:44 (local time) and quickly calibrated to 164 milligauss. As the outer portion of the mesocyclone very slowly approached the magnetometer, an increase in the magnetic field values began at 17:45. At 18:00, 16 minutes later, the reading peaked near 192 milligauss. Once the center of the mesocyclone moved directly over the magnetometer, a minimum of 172.76 milligauss was

recorded at 18:13. As the rear portion of the mesocyclone approached, the magnetic fields began once again to increase, peaking near 200 milligauss at 18:25. When the tail end of the mesocyclone passed over the magnetometer at 18:38, a minimum of 170 milligauss was recorded. Finally, the readings leveled off to an average near 178 milligauss, holding at the same values for three hours until the magnetometer was turned off. The magnetic field readings recorded for two consecutive days (with mostly clear skies) following the storm's departure also held steady with no significant variance observed.

c) Discussion of Boise City mesocyclone results

For illustration purposes (Fig. 9), the actual time series of magnetic field values (from Fig. 8b) have been "stretched out" to enhance the signals recorded from the very slowly moving and developing Boise City mesocyclone. An ideal graphical representation of the magnetic field lines

and its associated mesocyclone are shown above the time series as they might have appeared while passing over the stationary pod. The small scale oscillations seen in the magnetic field values may have been due to variations in the mesocyclone cloud base which ranged from 800-2,000 feet AGL. If true, the mesocyclone may have acted as a Ferro magnet, which means that the magnetic field at the cloud's base should, in theory, be much stronger.

In general the Boise City mesocyclone magnetic field readings, recorded from the ideally placed magnetometer, are consistent with the magnetic field readings recorded with Hurricane Wilma. Moreover, the outer portion of the mesocyclone had the highest magnetic field readings, while the center of the mesocyclone showed a much lower magnetic field reading. These lower magnetic field readings in the center of the mesocyclone corresponded with the lower magnetic field readings recorded in

Date: 23 May 2006			
Place: O'Neil, NE			
	Pod 1	Pod 2	Pod 3
Street:	US-275	US-20	US-275
City:	O'Neil	O'Neil	Inman
State:	NE	NE	NE
Zip:	68763	68763	68742
# on the Map	#24	#25	#26
Time start recording:	16:45:31	17:11:32	17:13:58
Time stop recording:	18:09:00	18:44:05	19:11:00
Video start recording:	Yes	Yes	Yes
Map start recording:	Yes	Yes	Yes
Latitude:	42.45559 N	42.40806 N	42.36110 N
Longitude:	98.63333 W	98.56473 W	98.49550 W
Baron start recording:	Yes	Yes	Yes
Remarks:	Not Raining	Not Raining	Not Raining
Video stop recording:	Yes	Yes	Yes
Map stop recording:	No	No	No
Baron stop recording:	No	No	No
Result:	6-AA battery working Data Recorded	6-AA battery working Data Recorded	6-AA battery working Data Recorded

Table 2. Recordings of Mesocyclone at O'Neil, NE.

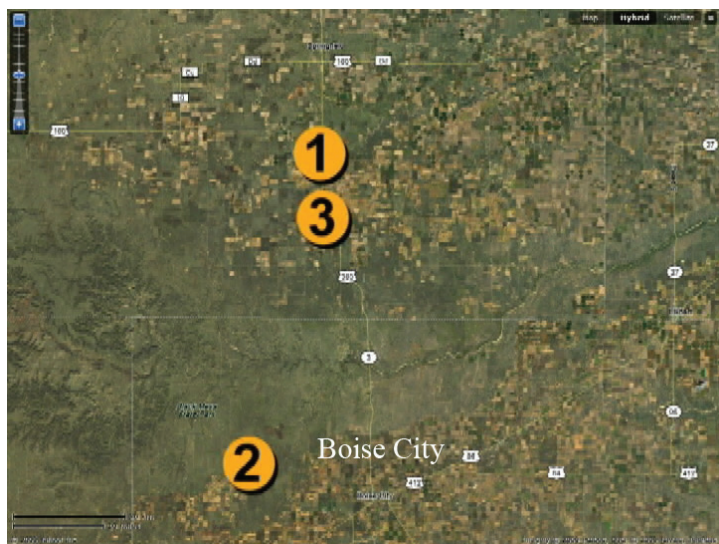


Fig. 7. Pod drop locations around Boise City, OK.

Hurricane Wilma's eye, while the highest magnetic field readings found in Wilma's rotating precipitation shield corresponds to the highest mesocyclone readings observed with the outer portions of the mesocyclone.

Based upon these empirical observations and recordings the question remains how then, could a mesocyclone create a magnetic field? Dr. Marty Simon, Professor Physics Department, UCLA, suggested that perhaps the magnetic field was created by a moving charge. In his opinion, this was not a case of spin-polarization, as the dipole moments would have trouble lining up while moving (M. Simon 2006, personal communication).

4. Conclusions

The inherent difficulty with measuring magnetic fields near and within vortices in real-time has impeded the progression towards a better understanding of the relationships between electrical charge, magnetic fields, and the evolution of vortices. Using magnetometers in real-time, we have obtained magnetic field measurements for vortices of various scales.

Field results from our ongoing research thus far include evidence of anomalously low magnetic field readings near and within the vortices of mesocyclones and the eye of Hurricane Wilma. Relatively high readings were measured

Date: 31 May-2 Jun 2006
Place: Boise City, OK

	Pod 1	Pod 2	Pod 3
Street:	US-287	SR-325	CR-T
City:	Springfield	Boise City	Springfield
State:	CO	OK	CO
Zip:	81073	73933	81073
# on the Map	#48	#49	#50
May 31, 2006			
Time start recording:	17:38:52	17:27:00	16:49:14
Time stop recording:	23:56:00	22:45:00	23:42:36
June 1, 2006			
Time start recording:		11:48:00	
Time stop recording:		14:18:00	
June 2, 2006			
Time start recording:		13:59:00	
Time stop recording:		15:22:00	
Video start recording:			
Map start recording:			
Latitude:	37.30892 N	36.73373 N	37.23582 N
Longitude:	102.61501 W	102.74758 W	96.65726 W
Baron start recording:			
Remarks:	Not Raining	Not Raining	Not Raining
Video stop recording:			
Map stop recording:			
Baron stop recording:			
Result:	6-AA battery working Data Recorded	6-AA battery working Data Recorded (All 3 days)	6-AA battery working Data Recorded

Table 3. Recording of Mesocyclone at Boise City, OK.

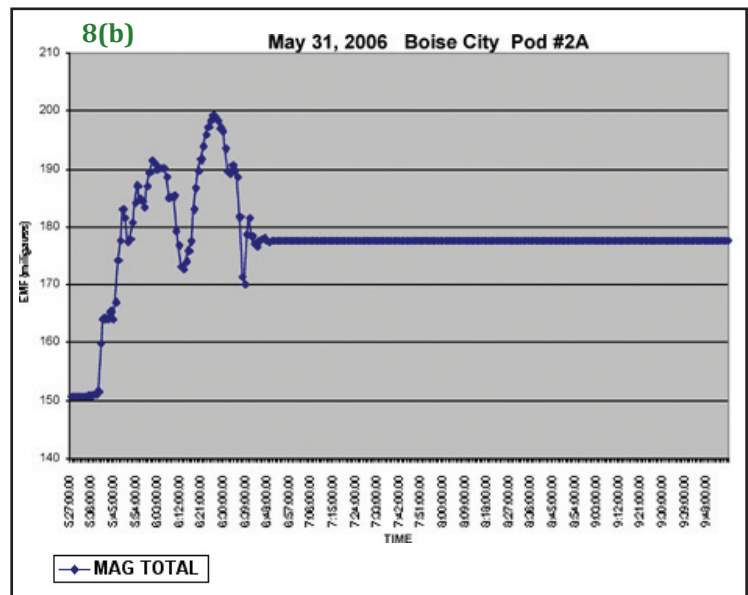
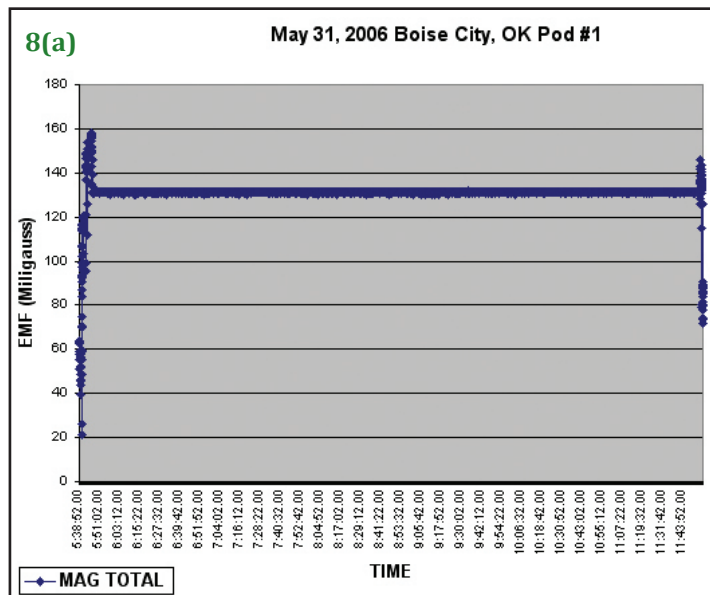


Fig. 8(a-b). Time series of magnetic field readings in milligauss as recorded from Pods 1 and 2, Boise City, OK. See text (section 3) for details.

along the mesocyclones' outer portions and within Hurricane Wilma's rotating precipitation shield. Also observed were small variations in the magnetic fields of mesocyclones as they passed over the magnetometers. These variations may be associated with changes in the mesocyclones' cloud bases.

Results to date are subject to confirmation given the small sample size of vortices along with the considerable speculations (without quantitative proof) about the mechanism(s) accounting for their evolutions and the role of the magnetic field and electrical charge. However, should additional research support these initial findings there is ample reason to further

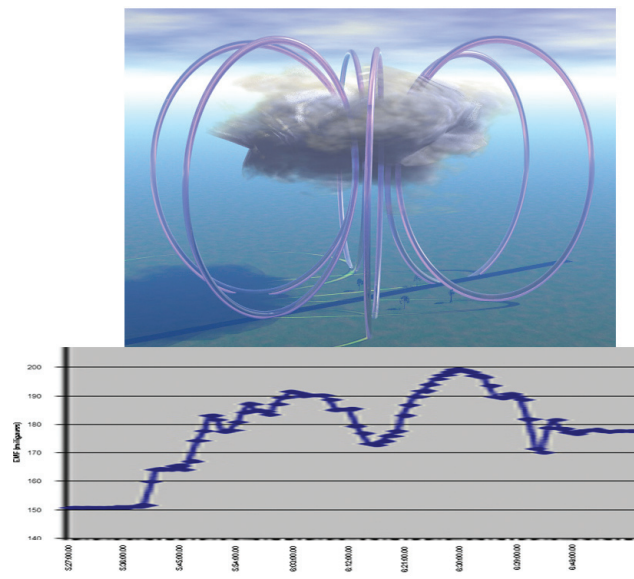


Fig. 9. Actual time series (from Fig. 8b) ("stretched out" to enhance the magnetic signals recorded from the Boise City storm) matched to an ideal representation of the mesocyclone and its associated magnetic field as it moved directly over the stationary magnetometer.

investigate the possibility that as the intensity of the magnetic field increases in a toroidal field, the intensity of the magnetic field within the eye steadily decreases. Should this be true, then perhaps additional insights and/or methodologies for understanding and anticipating tornadogenesis might be found. A conceptual model (H-factor) for these speculations based upon this research is shared (Fig.10). Hopefully, this research will promote additional investigations that will increase the understanding of the role of magnetic fields and electrical charges as they relate to the evolution of vortices.

Authors

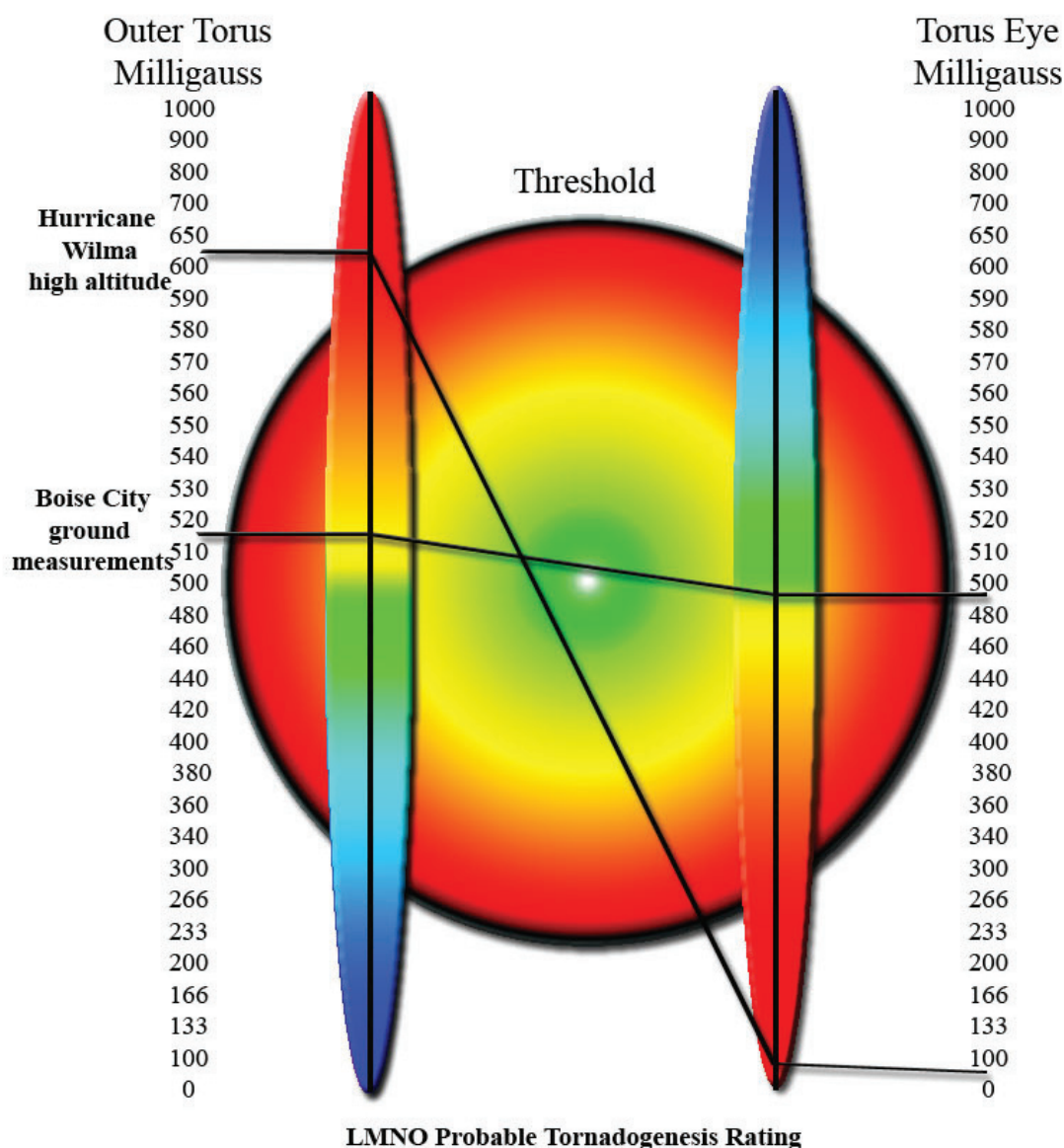
Richard Heene is lead investigator and a co-host of The Science Detectives, a documentary series investigating the mysteries of science. Since 1974, Richard has been working on various gravity propulsion systems using rotating magnetic fields, and has also become a successful inventor, with such inventions as the magnetic-driven bicycle, electricity-less lights for cameras, and a device that extracts the contents from containers in three seconds. After graduating in 1979, Richard began work as a carpenter in Texas, where he experienced firsthand the destructive results of the 1979 Waco F5 tornado. That event prompted him to begin researching tornadoes. Currently a director and producer, Richard has produced Box Time, a children's educational video series. He also hosts his webcast radio show, The Science Detectives, and co-owns (with his wife) My You Me Productions, a video production and post-production facility in Colorado. Richard is currently producing a documentary based on this research.

Robert (Scott) Stevens studied synoptic meteorology at the University of Kansas. A member of the National Weather Association, Scott has worked for 18 years in the field of broadcast TV in Topeka, Kansas; Omaha, Nebraska; Tulsa, Oklahoma; Albany, New York; and Pocatello, Idaho. Scott currently resides in Fort Collins, Colorado, and is also a co-host on The Science Detectives.

Barbara Slusser graduated from Knox College, Galesburg, Illinois, and Oklahoma State University, Stillwater with degrees in Comparative Psychology, Zoology, and Wildlife Biology. As a research associate at Colorado State University, she began editing and producing camera-ready books dealing with statistics and population modeling as well as assisting in producing symposiums and their associated publications. Her interest in tornadoes began at an early age when she and her family experienced firsthand the power of an F5 tornado during the April 1965 Palm Sunday outbreak. Since that time, she has also experienced several other F4 and F5 tornadoes. Barbara currently resides in Fort Collins, Colorado, and owns her own publishing and editing company, as well as being a co-host on The Science Detectives.

H-Factor

(Heene Factor)
Tornadogenesis Detector



L - Equals a low probability as in the H-Factor right angles of 500 Mg.

M- Is for the graphic image that is formed when measuring the magnetic field of a meso.

N- Equals the high magnetic field crossing over to the low magnetic field of the "H" Factor.

O- Demonstrates the full circle strong magnetic field of a tornado.

EXAMPLE;

A no risk is rated at an "L green".

A minor risk is rated at an "L Yellow, or Orange."

A higher risk is an "M Yellow to a Red"

A "N" rating can vary from a Green to a Red depending on how steep the threshold is.

While the outer Torus could have a high magnetic field, the eye of the torus could still be in the 400 to 500 mg range, keeping it within the green to yellow.

Fig. 10. The H-Factor is a "work-in-progress" to find a threshold, if one exists, for tornadogenesis.

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