TORNADOES ARE JUST THE LARGEST ATOMIZERS ON EARTH

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Abstract-- This paper brings forth new research on just how tornadoes form and what is their source of energy. Over 1,800 tornadoes were investigated as to how, why, when and where they form, what is their source of energy and why they dissipate. Data was collected as to the relationship of the overhead jet stream's height and velocity compared to the thunderstorms and tornadoes developing below. A definite relationship was noticed. The data showed how a tornado will only form in a thunderstorm which is developing under a jet stream with velocity ≥ 57.4 knots, the TORNADO THRESHOLD. Research shows that a tornado forms under these conditions because of the streamline flow of the jet stream passing over any mesocyclone/vortex created by the thunderstorm has the air entrained per the Bernoulli Effect and Entrainment, just like an atomizer. Anywhere in the world that has thunderstorms can have a tornado, if there is a high velocity overhead jet stream to energize the mesocyclone within the thunderstorm. Information also obtained was, the higher the velocity of the overhead jet stream corresponded to a stronger tornado and the higher the height of the jet stream also corresponded to a stronger tornado, due to the larger RELATIVE AREA OF INTERFACE, the diameter of the vortex at its intersection with the high velocity overhead jet stream. The tornado will dissipate any time the thunderstorm with its imbedded tornado moves out from under or otherwise loses contact with the high velocity overhead jet stream.

Index Terms—Atomizers and tornadoes function alike, Bernoulli Effect of Entrainment causes tornadogenesis, Fujita rating of a tornado is governed by the height and velocity of the overhead jet stream, tornadoes are not caused by just a thunderstorm.

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1 INTRODUCTION

THIS research sheds a whole new light on how tornadoes form, tornadogenesis, and how we can better predict which supercell thunderstorms will produce tornadoes. As an engineer I could never accept the statements that a tornado was just a function of a thunderstorm, because we never see any Equal and Opposite Force to the air going up in the tornado per Newton's Third Law of Motion [1]. Also in over 50 years of research Meteorologists have never found just what makes a tornado form, as it appears they were trying to solve a physics problem with meteorology. Finding no research being done in this area, this research sought to find and answer to tornaodgenesis through physics. The only article found that even remotely suggests that a tornado could form out of the high velocity jet stream passing over a vortex within a thunderstorm was written by a Geophysicist, Dr. Kevin Kilty [2]. In 2010 he wrote an unpublished article, "How the rotation becomes concentrated into a tornado vortex".

Dr. Kevin Kilty reviewed several papers on what he felt to be the most logical tornadogenesis possibilities. He reviewed Kuo's model, The Maxworthy hypothesis, Starr's view, the secondary circulation hypothesis, by Bluestein and Eagleman's model. The most noteworthy was his summarizing of Eagleman's paper, which shows the mature thunderstorm with both the thunderstorm mesocyclone and its embedded tornado curving downstream in the anvil. In fact Eagleman suggests the anvil in this case is like a wingtip vortex. However, research shows that you do not have both the mesocyclone and the tornado at the same time other than when the mesocyclone is being turned into a tornado by the high velocity overhead jet stream from the top down.

In this article Dr. Kilty states, "The tornado is a secondary circulation of air in a complex flow environment of some thunderstorms. Although others have proposed this before him, I'll call it Bluestein's hypothesis because of his strong belief that the mechanism of tornado generation will be discovered by identifying differences between thunderstorms that produce tornadoes and those that do not." In other words what is different about those 20% to 25% of thunderstorms that develop tornadoes and the 75% to

80% that do not? Dr. Kilty goes on to state, "Long-lived inflow to thunderstorm concentrates planetary vorticity. Problems with this hypothesis are apparent immediately. For instance, why are there anticyclonic tornadoes? How does one manage to concentrate the vorticity for 3 to 4 hours? All of the mass in the convergent flow for 3 to 4 hours has to form a long vortex tube of perhaps 300-5000 feet diameter. Where do we stuff this? One possibility is, of course, to send this convergence out the thunderstorm top and down the jet stream." NOTE: While not written in technical terms, this is exactly what research proves!

2 PAST RESEARCH REFERRED TO AND REVIEWED

Many meteorologists suggested I review past research on thunderstorm and tornado dynamics. However, in virtually every case the research papers dealt with thunderstorm dynamics and never came to any conclusion as to how tornadoes form. They always end their papers, stating "but more research is needed." These are the only papers that have any application to tornadogenesis.

2.1 Eagleman, Joe R. and Wen C. Lin, 1977 [3]. Severe Thunderstorm Internal Structure from Dual-Doppler Radar Measurements.

The following is a synopsis of Eagleman's model by Dr. Kilty in his paper, Tornado Project-How the rotation becomes concentrated into a tornado vortex. "Eagleman's model has several appealing aspects. It provides a nearby, ready source of vorticity for the tornado; it provides a mechanism to concentrate circulation as the tornado vortex is drawn downward in the anvil and stretched, and provides a place to dump the core flow and vorticity. It ties the tornado to the jet stream directly; although, the jet stream may be linked to the generation of a tornado only indirectly through the convergence a jet-streak produces." "Unfortunately Eagleman's estimates of wind speeds and central pressure deficit are so badly out of agreement with observation that people may have dismissed the theory for this reason alone."

My analysis: Eagleman's model shows the mature thunderstorm with both the thunderstorm, mesocyclone and its embedded tornado curving downstream in the anvil. However, research shows that you would not have the mesocyclone and the tornado at the same time, as the mesocyclone vortex is what starts the tornado in the first place from the top down. This is what has confused meteorologists in the past. As the first thing the entrainment does while creating the tornado is to devoir the mesocyclone. And since the mesocyclone could already be touching the ground it would appear that the tornado was starting from the ground up, as the only way we see a tornado is by the debris it has picked up. And as air is invisible we cannot see what is happening between the clouds and ground. Eagleman goes on to suggest that the anvil in this case is like a wingtip vortex. It is a wingtip vortex, as the top of the tornado is rotating like a flying disc, so it would have wingtip vortexes created as the high velocity jet stream passes over and around the top of the vortex. The only problem with Eagleman's model was that he didn't go high enough to reach up to the high velocity overhead jet stream. Research shows that we need to be looking at jet stream heights between 8,500 - 14,500 meters.

2.2 Shi-Kuo, Liu, FU Zun-Tao, LIU Shi-Da, XU Huan-Bin, XIN Guo-Jun, LIANG Fu-Ming, [4] Theory on the Funnel Structure of Tornado.

This paper investigates, quoting from the Abstract, "From the governing equations satisfying the balance among pressure gradient force, inertial centrifugal force and viscous force, the three-dimensional velocities of tornado are obtained, and then its funnel structure is shown theoretically. Here it is shown that the funnel structure consists of vortex flow and jet flow, where vortex flow is resulted from inertial centrifugal force and jet flow from strong convection by the horizontal convergence. At the same time, it is shown that the tornado is formed under very unstable atmospheric stratification." In the second paragraph of the INTRODUCTION "It is shown that the three-dimensional velocities of a tornado consist of vortex flow and jet flow, and this implies that the three-dimensional velocities of tornado take a funnel shape."

My comments: The emphasis of this paper was on the funnel structure of the tornado, not the evolution of how the tornado forms. However, this paper confirms what is found in my research. That is, that a tornado takes the shape of a funnel concentrating its energy on the ground while fanning out at its intersection with the jet stream at its top where it is energized by the high velocity overhead jet stream.

2.3 Johannes M. L. Dahl 2006 [5] Supercells-their Dynamics and Prediction

I agree with all the research stated in this paper up to 6.2.1 Tornado-genesis. However, in the third paragraph of this section they state, "The main issue in current tornado research is why tornadoes do not always develop despite the presence of a deep surfaced-based mesocyclone. The question is thus: What inhibits the concentration of angular momentum in some cases, while in others it is promoted?"

My analysis: Research in this paper shows, it is not what inhibits the concentration of angular momentum, but rather what contributes to the angular momentum, as it takes more than a mesocyclone to make a tornado. Therefore, the rest of this paper has nothing to do with tornadogenesis.

2.4 R. Jeffrey Trapp and Robertn Davies-Jones 1997 [6] Tornadogenesis with and without a Dynamic Pipe Effect

Quoting from the abstract for the dynamic pipe effect, "A dynamic pipe effect (DPE) has been used previously to explain the descent from aloft of tornadic vortex signatures (TVSs), and presumably embryonic tornadoes, prior to the near-ground spin up of the tornado. But for many tornadoes the TVS appears to form simultaneously over a depth spanning the lowest few kilometers. A numerical model is used to determine the conditions under which a tornado is or is not preceded by a DPE." In other words, (Mode I) for a tornado starting from the top down and (Mode II) for a tornado starting from the ground up.

My analysis: While meteorologists recognized the possibility of a tornado starting from the top down (Mode I), they have done virtually no research to explain how it could or could not be possible. As at this time virtually all research has been done to prove that a tornado starts from the ground up (Mode II). Therefore, if the tornado were to be formed in some way by (Mode I) then most all past research has nothing to do with how tornadoes form.

And in fact, reading from the original paper on the Dynamic Pipe Effect, as stated in the electronic version of the 2nd Edition of the American Meteorological Society's Glossary of Meteorology Terms [7], "Initially, there is a strong mesocyclone aloft within the convective storm. The incipient tornado vortex that forms within the mesocyclone is assumed to be in cyclostrophic balance, such that the elevated rotating column of air behaves like a dynamic pipe." The point being, that meteorologists, at that time, thought or at least realized that a tornado could in some way be formed out of the mesocyclone but did not follow through with any or very little research.

Also, as meteorologists have said that there was no way a tornado could be formed out of the high velocity overhead jet stream and that entrainment was not possible, they have completely ruled out that possibility without doing any research. But research in this paper confirms how tornadogenesis takes place by entrainment by the high velocity overhead jet stream turning the mesocyclone developed within the thunderstorm into a tornado, by the laws of physics and not meteorology. This paper will also give a simple analytical and mathematical solution for (Mode I) and tornadogenesis.

3 RESEARCH

3.1 The Tri-State Tornado of 18 March 1925

Researching the Tri-State Tornado of 18 March 1925 shows that the real source of energy was overlooked. Some assumptions were made about the formation of the Tri-State Tornado, which misled researchers as to what really happened that day. No one ever explained what were The Equal and Opposite Forces to the air drawn up into the atmosphere by the tornado in order to have compliance with Newton's Third Law of Motion.

Early the morning of 18 March 1925 at 8 AM there was a low pressure area situated over northwest Arkansas, see Fig. 1A. That low pressure area had vectors circling counter clockwise on the north side, but vectors showing air flowing into the low pressure area from the south, showing a typical low pressure area.

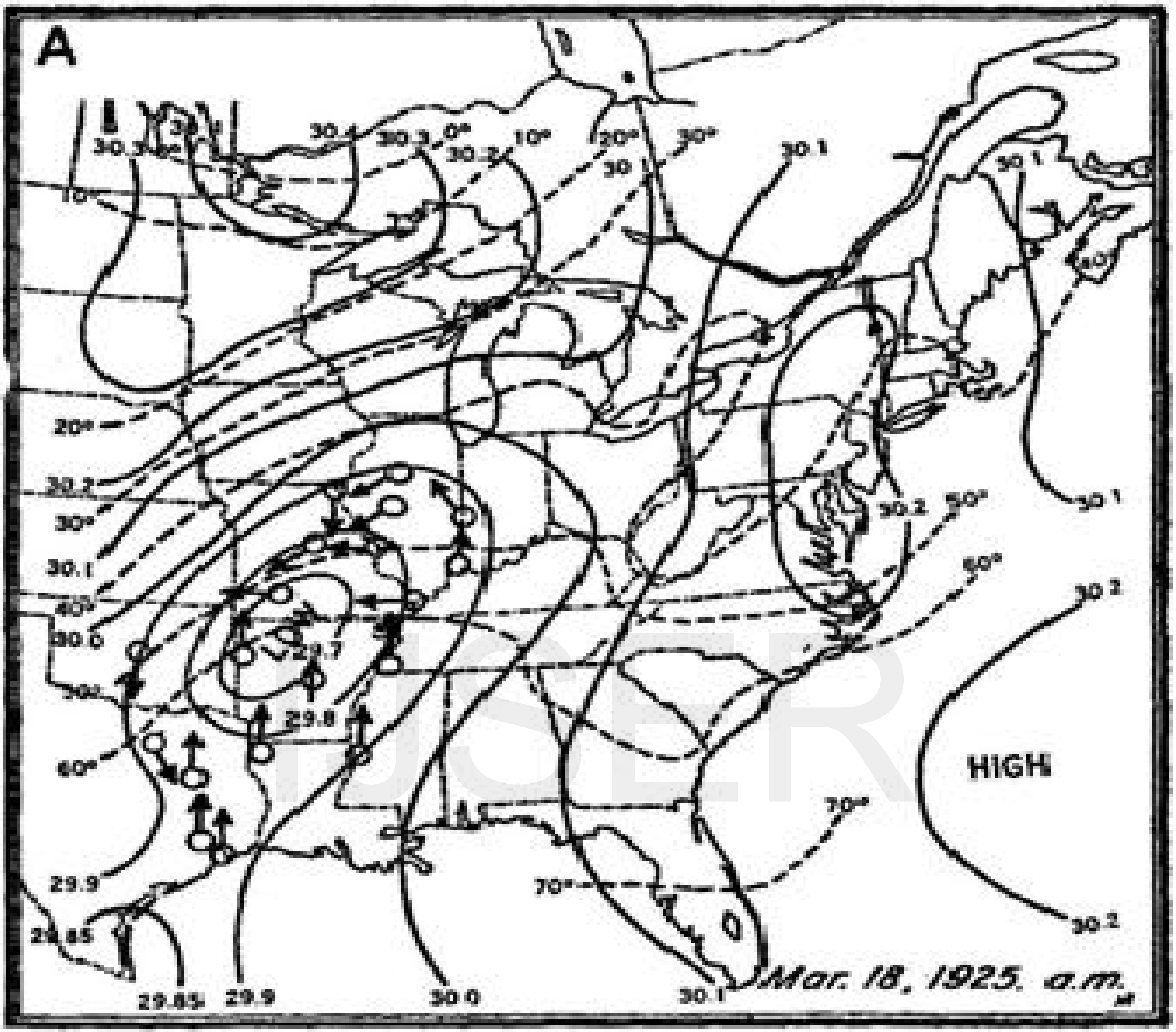

Fig. 1A. This pressure map was taken at 8 am before the Tri-State Tornado started. Note that this was typical low pressure area with inflow from the south and only about a 0.7% pressure drop.

Reviewing an article written by Alfred J. Henry [8] in the April 1925 issue of the MONTHLY WEATHER REVIEW an original map, see Fig. 2A, was presented to have been a map of the low pressure area that formed the Tri-State Tornado of 18 March 1925. However, if you look closely at that map, it shows vectors where the air is completely encircling the low pressure area, which should have made someone question that statement. But, if this low pressure area was caused by a cyclonic tornado drawing the air up into the jet stream, then we would see the vectors completely encircling in a counter clockwise direction and drawing the air up by the tornado.

See Fig. 2A, included in the original report published by Alfred J. Henry in the MONTHLY WEATHER REVIEW of April 1925.

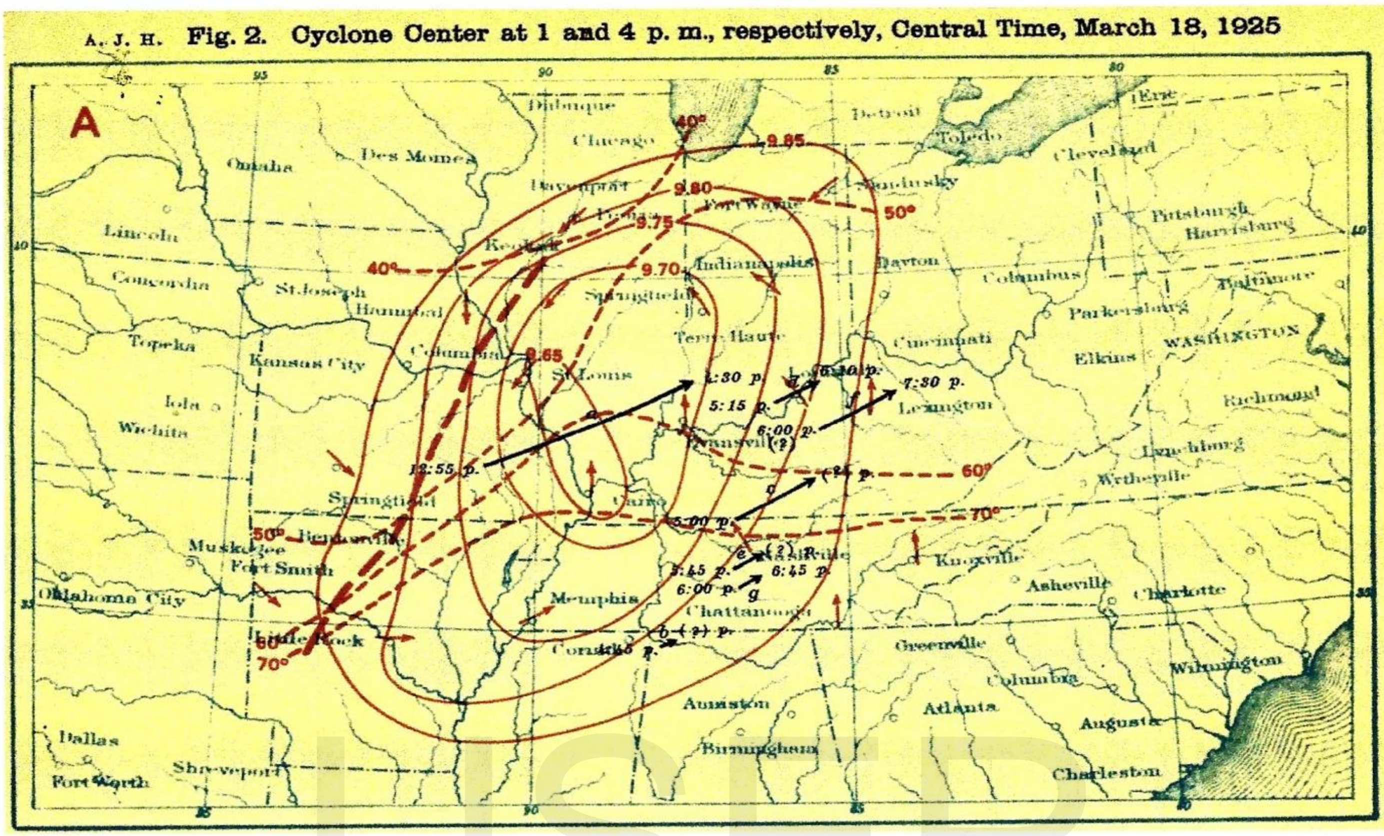

Fig. 2A. This map of the Tri-State Tornado shows the tornado's path, long black arrow, along with other tornadoes that occurred on 18 March 1925. Solid red lines are pressure gradients in units of Earth-surface gravitational acceleration. Red arrows show surface wind directions encircling then low pressure area. Note, the time listed as 1 pm does not agree with the final statement in the article written by Clarence J. Root [9] in the March issue of the MONTHLY WEATHER REVIEW, CLIMATOLOGICALDATA, Vol. XXX 12a, that "the tornado occurred exactly the same time of the passage of the center of the low." It is more likely that this map was taken about 2:30 pm when the tornado struck Murphysboro, Illinois.

This map was not a map showing a typical low pressure area that caused the tornado, but was a map showing how the tornado created this low pressure area by drawing the air up into the stratosphere. The pressure appears to be in units of Earth-surface gravitational acceleration. Comparing the pressure differences of 9.85 to 9.65 we see a very large pressure drop of ≈ 2.0% covering an area about 600 miles in diameter, but still about 50 miles from the center of the tornado.

According to all meteorologists, a tornado is just a result of the thunderstorm. But the pressure data from the Tri-State Tornado of 18 March 1925 Fig, 2A shows that the air was drawn from a very large area, with nothing flowing downward for an area approximately 600 miles in diameter and the only explanation for that is that the air was being drawn up into the stratosphere by the tornado. The Action is the air being entrained by the jet stream, per Daniel Bernoulli [10], The Bernoulli Effect and Entrainment and the Equal and Opposite Reaction is the tornado we see on the ground.

The next map, see Fig. 2B, shows the pressure and wind direction listed at 4 PM CST and is centered on the Tri-State Tornado which was still on the ground in Indiana. It should be noted that the center of the low pressure moved along with the tornado's path into Indiana and now we have an even greater pressure drop down to 9.55 or a total pressure drop of about 3%, but still approximately 50 miles from the tornado's center.

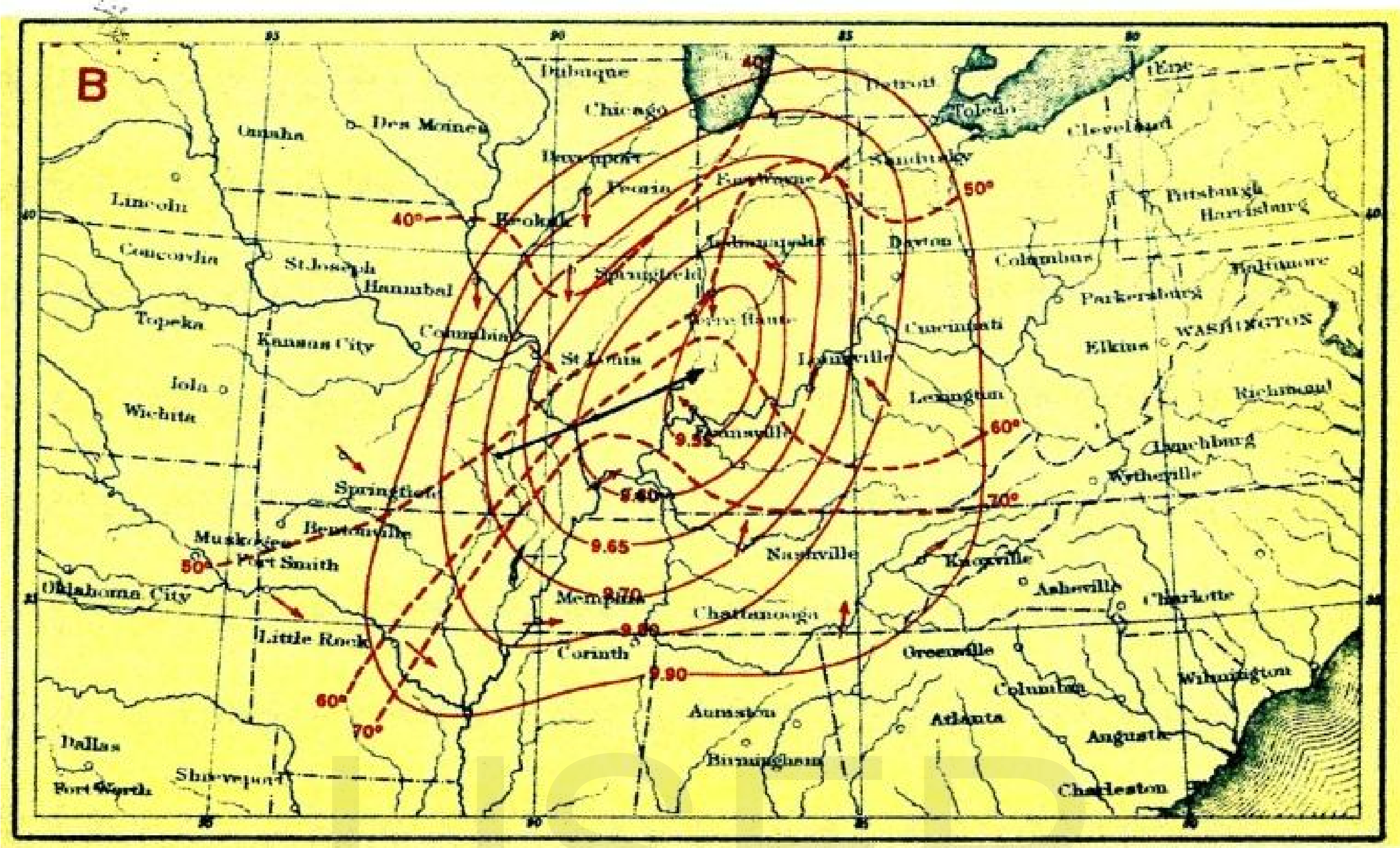

Fig. 2B. This map of the Tri-State Tornado shows its location at 4 pm with the low pressure centered on the tornado in Indiana. Note that the inner pressure gradient has now dropped to 9.55. This would give a pressure drop of about 3.5% but still about 50 miles from the center of the tornado.

A fourth pressure map taken at 8 PM CST, see Fig. 1B, once again shows a normal low pressure area on the Indiana, Ohio, boarder after the tornado had dissipated.

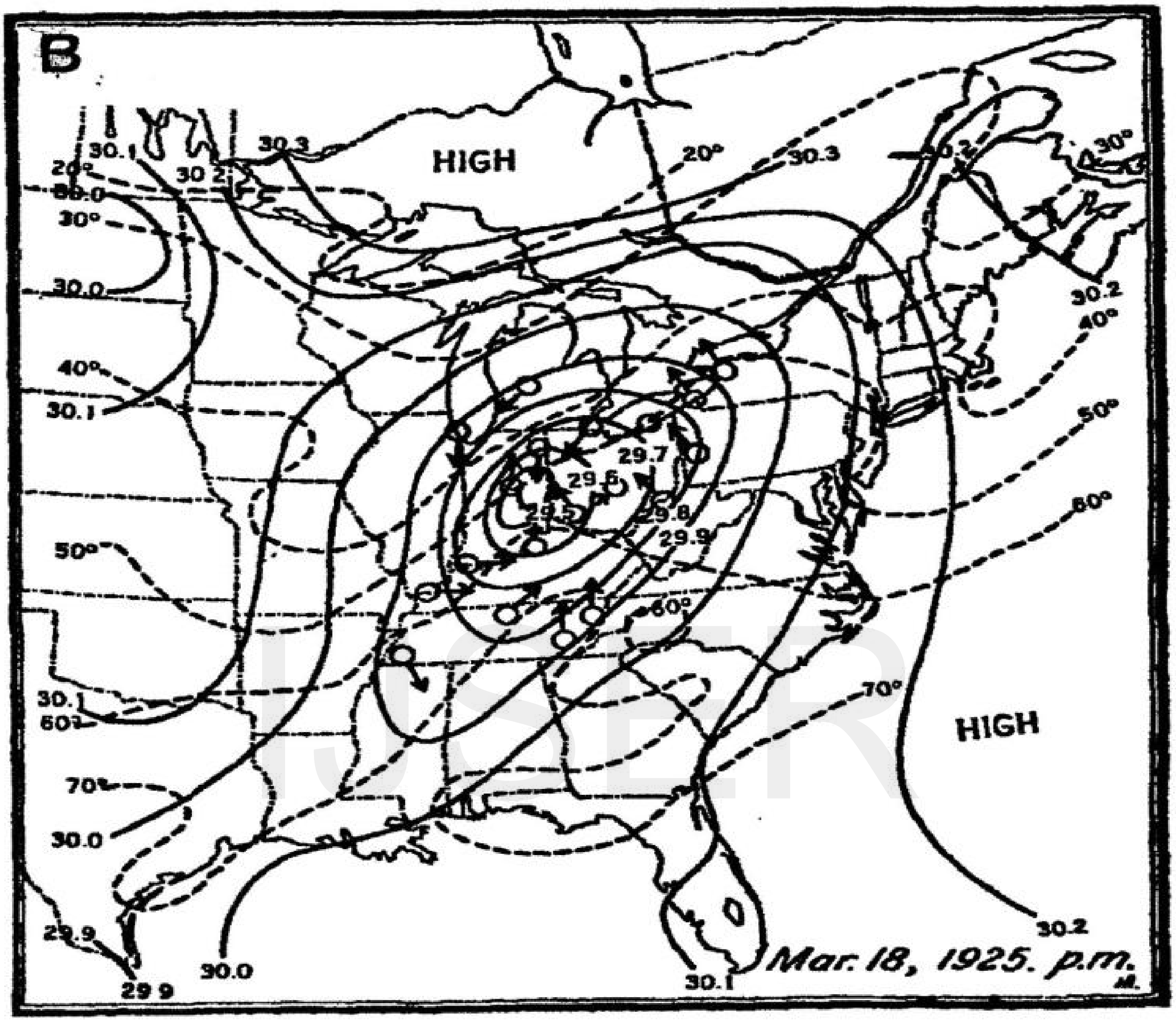

Fig. 1B. This pressure map was taken at 8 pm after the Tri-State Tornado had dissipated. Once again we see a normal low pressure area with inflow from the south.

3.2 The Washington, Illinois tornado of 17 November 2013

While researching the Washington, Illinois tornado of 17 November 2013 a moisture convergence map made by Unisys Weather was found, it was taken about 50 minutes after the tornado started. See Fig. 3.

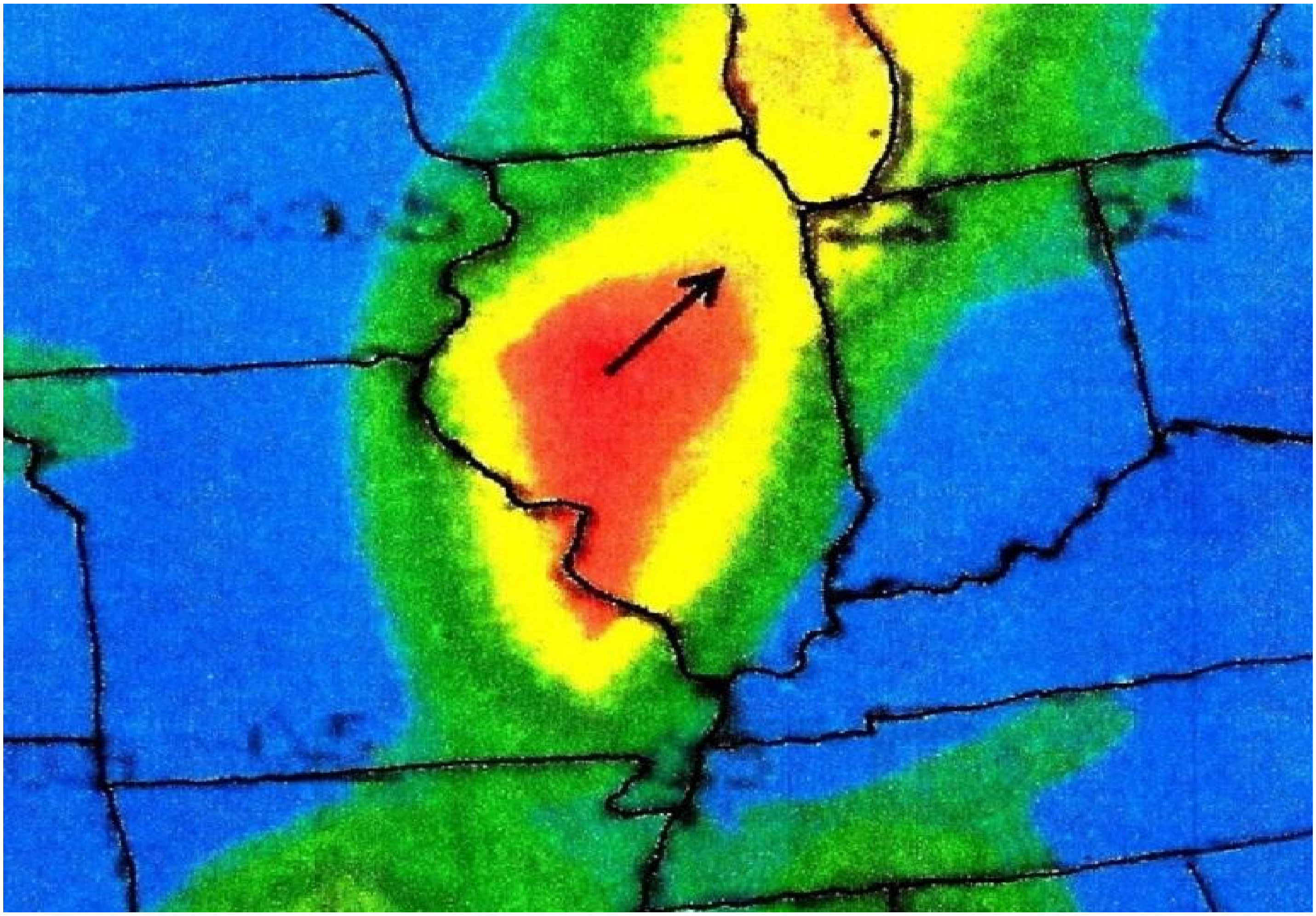

Fig. 3. This is contour plot of the convergence of the surface winds weighted by the moisture in the atmosphere represented by the surface specific humidity taken about 50 minutes after the Washington, Illinois tornado of 17 November 2013 started. The tornado track is shown with a black arrow. Positive areas are highlighted in red colors. It has been stated in the past that this convergence often represents areas where the forced convergence spawns thunderstorms and can create a tornado. By what method does forced convergence take place? Research shows that this convergence is caused by the Bernoulli Effect of Entrainment by the jet stream entraining the air, thus strengthening the mesocyclone which in turn causes the convergence and creates the tornado.

A statement was made that this moisture convergence often represents areas where winds are converging and thus forcing upward motion. But is this really what happens? Did the moisture convergence cause the tornado or did not the mesocyclone and tornado draw the moisture up by Entrainment? Researching the perception map, see Fig. 4, also made by Unisys Weather showing the rainfall for the time including the time of the Washington, Illinois tornado and by comparing the location of the rain at the time of the tornado, the only way we could see this pattern of rainfall was if the tornado was drawing the moisture up and depositing it on the left side of a cyclonic turning tornado. Note that the only rainfall for this 24-hour period was at the time of the tornado.

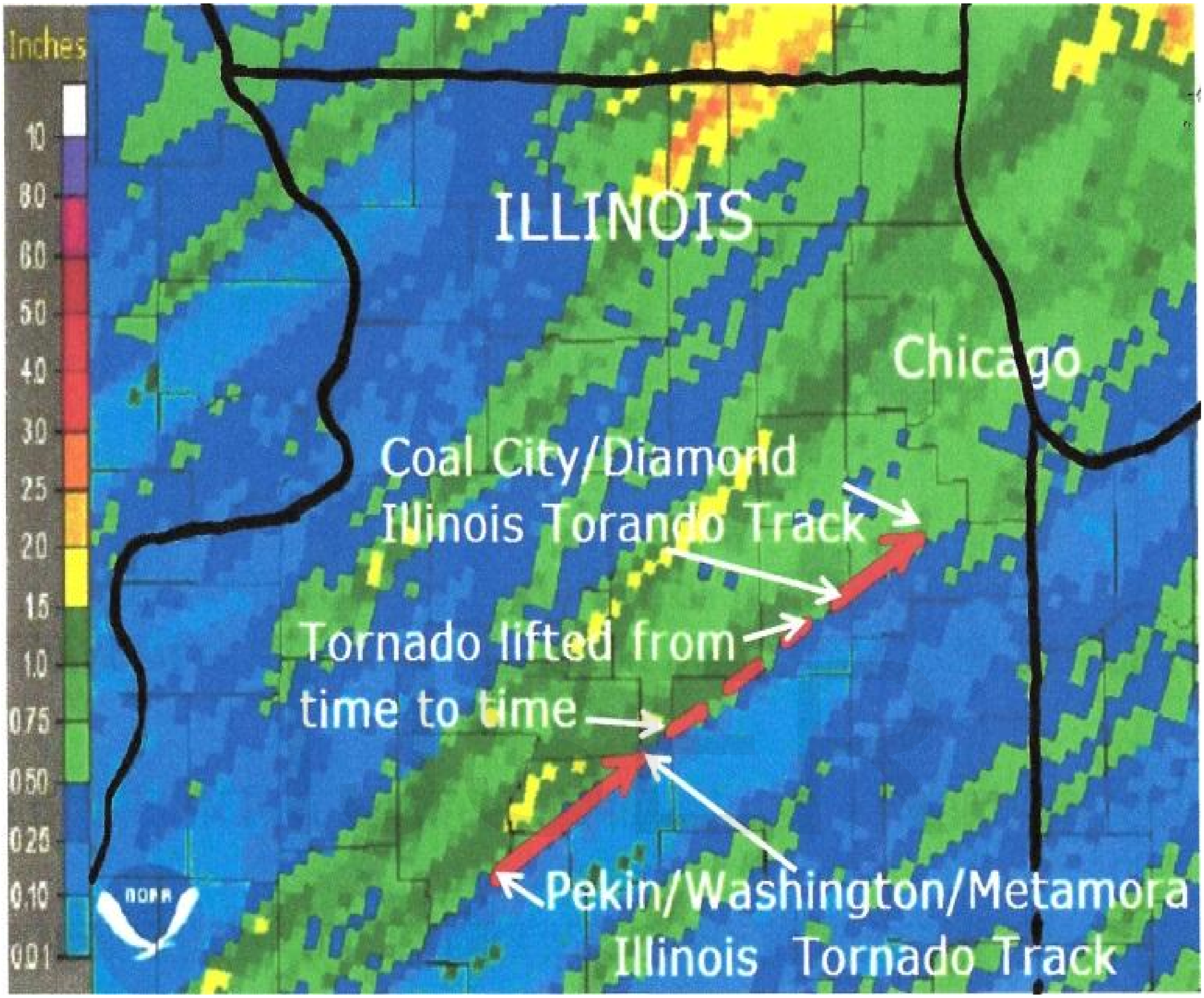

Fig. 4. This is perception map made during the Washington, Illinois tornado of 17 November 2013, tornado track shown in red. Note, the heaviest rain was to the left side of the cyclonic turning tornado, which is what we would expect with the moisture pulled up by the tornado and falling out under the hook echo on the left side of the forward moving tornado.

4 Data

From January, 2008 through May, 2008 data was collected on every tornado outbreak in the United States by comparing their location to the high velocity overhead jet stream. The data for the times, locations and Fujita ratings of those tornadoes were obtained from NOAA'S Storm Prediction Reports [11]. The data for the heights and velocities of the overhead jet streams at the times of those tornadoes were obtained from University of Wyoming, College of Engineering Department of Atmospheric Sciences [12]. See attachment: Table 1, Tornadoes Researched from 7 January 2005 to 15 May 2005.

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TABLE 1

Tornadoes Researched from 7 January to 15 May 2005

Date	State or Country	Jet stream velocity	Tornadoes & EF ratings	
7 - 8 January 2008	AR, IL, MO & WI	90 to 112 Knots	Many EF0's to EF 3's	70 total
8 January 2008	AR, MO, MS & TN	80 to 90 Knots	1 EF2, 2 EF 1's	16 total
10 January 2008	WA	90 Knots	1	1 total
10 January 2008	AL, MS, KY & TN	70 to 126 Knots	4 EF 3,s	36 total
29 January 2008	IL, IN, KY	90 to 110 Knots	4 EF 1's	4 total
5 - 6 February 2008	AR, AL, TN, KY, TN & TX	70 to 110 Knots	EF 1,s to EF 4's	81 total
12 February 2008	FL, LA & MS	70 Knots	Many Non rated	22 total
16 February 2008	AL & LA	70 Knots	Many Non rated	11 total
17 February 2008	AL, FL, GA & NC	70 to 90+ Knots	1 EF2 & 1 EF3	49 total
25 February 2008	AL & GA	90+ Knots	1 EF & 1 EF3	2 total
3 March 2008	AL, AR, LA, MS & TX	70 to 110+ Knots	Many Non Rated	21 total
4 March 2008	AL, GA, KY, NC, SC, VA and TN	70 to 90+ Knots	Many Non rated 1 EF2	7 total
14 March 2008	Atlanta, GA	110 Knots	1 EF2	1 total
15 March 2008	AL, GA & SC	90 to 110 Knots	7 EF0's, 11 EF1's, 8EF 2's and 3 EF3's	51 total
4 April 2008	Portugal	90 Knots	1	1 total
11 April 2008	AL, LA, MS, KY & TN	70 to 90 Knots	Many EF0's to 1 EF3's	27 total
23 April 2008	KA, NE, OK & TX	70+ Knots	10 EF0's, 1 EF2	16 total
28 April 2008	FL, NC & VA	70 to 110 Knots	8 EF0's, 2 EF1's, 1 EF3	26 total
10 May 2008	AR, GA, KA, MO, OK & SC	70 to 110 Knots	EF0's, EF1's & EF3's	43 total
15 May 2008	AL, LA, MS & TX	70 Knots	Non rated 2 EF1's	9 total
				494 Total

This is a list of the tornadoes tracked from 8 January 2008 to 15 May 2008. Also included is one tornado that happened in Portugal, to see if the same parameters fit; they did. These tornadoes and the associated overhead jet stream velocities show how the high velocity overhead jet stream is a condition for a tornado's development. With the research done up to this time It appeared that we had to have at least a 70 knot jet stream to form a tornado on the ground. However, while doing a more refined research, the minimum velocity was actually shown to be about 58 knots.

Reviewing the research, there was sufficient data to move ahead and present the hypothesis as a fact, because every tornado investigated happened under a high velocity jet stream. And the stronger tornadoes on the Fujita scale happened under a jet stream of higher velocity and height. A tornado works just like an atomizer. In fact, Tornadoes are Just the Largest Atomizers on Earth.

The Jet Stream has the same effect as the squeeze bulb in a perfume atomizer, by its streamline flow of high velocity air passing over the top of the perpendicular tube which in this case is formed by the mesocyclone/vortex itself. The only difference between an atomizer and a tornado is that instead of a tube in an atomizer we have a confined area held in place by the tornado's outer wall as the fluid motion in a vortex creates a dynamic pressure that is lowest in the core and increases to the outer circumference as one moves away from the core. As the tornado gets larger in diameter at its top, it creates a larger area, RELATIVE AREA OF

INTERFACE, to be influenced by the pressure drop which equates to a stronger tornado on the ground. And just as the tornado gets wider at the top it gets much smaller as it reaches down to the ground concentrating all its energy where it touches down.

For years we have been searching for why only 20% to 25% of supercell thunderstorms have tornadoes. Research shows that those 20% to 25% are made up only when a mesocyclone that has developed within the supercell thunderstorm is energized by the streamline flow of the jet stream above 58 knots by the Bernoulli Effect and Entrainment.

It has long been accepted that a mesocyclone is created by the mixing of the warm and cool air horizontally and then that being turned into a vertical position. Research shows that once this mesocyclone is turned upright, it can be sheared in half by the high velocity overhead jet stream, creating the possibility of two different tornadoes, one turning cyclonic and one anticyclonic. In fact if one thinks about it, how could we ever have an anti-cyclonic tornado unless it started out that way, as any rising column of air would always turn counterclockwise in the northern hemisphere if it were not started by some other force. Over 1,800 tornadoes have been investigated, however due to space limitations only about 500 have been listed in this report. The tornadoes were researched, by checking their location relative to the high velocity overhead jet stream at the time they formed. In every case it shows that there was a direct connection between the high velocity overhead jet stream and the development of a tornado. In some cases individual tornadoes, such as the Joplin, Missouri, tornado 22 May 2011 were investigated and in other cases large tornado out-breaks such as on the 22 May 2010 out-break, where we had 77 tornadoes in the south eastern United States. See Fig. 5 & 6, showing how the tornadoes developed and progressed that day under the high velocity overhead jet stream in more detail. It should be noted, that the highest jet stream velocities at any elevation, is what was plotted. Most of the highest velocities were in the 12,000 meter elevation range that day.

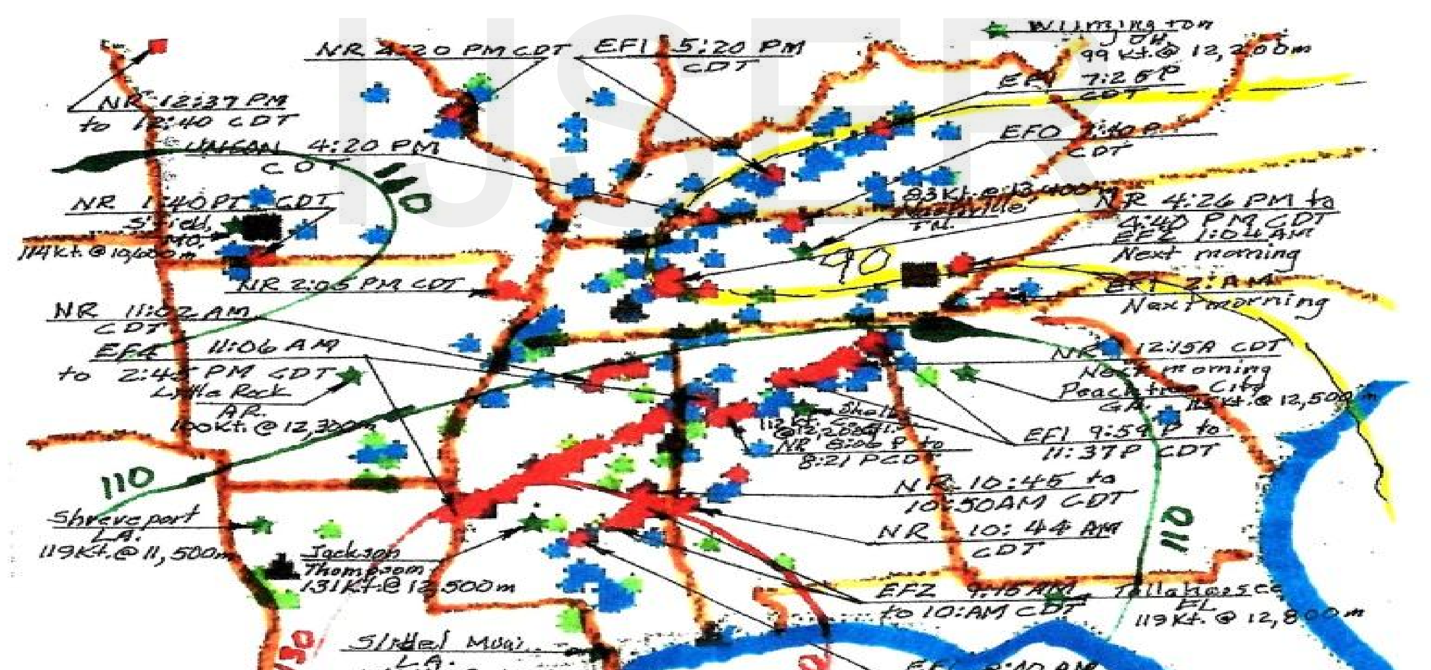

Fig. 5. This map of the southeast United States was made from a NOAA Storm Prediction Center map of 24 April 2010 12Z. The tornadoes are shown in red, the hail storms are shown green and the high winds are shown in blue. The overhead jet stream velocity gradients are shown in yellow for 90 knots, green for 110 knots and red for 130 knots. The weather stations are shown as green stars, with their highest jet stream velocity reading at the noted elevations at the time noted, 12Z. What is most important is to notice the locations of where the tornadoes developed that day as the storms moved under the high velocity overhead jet streams.

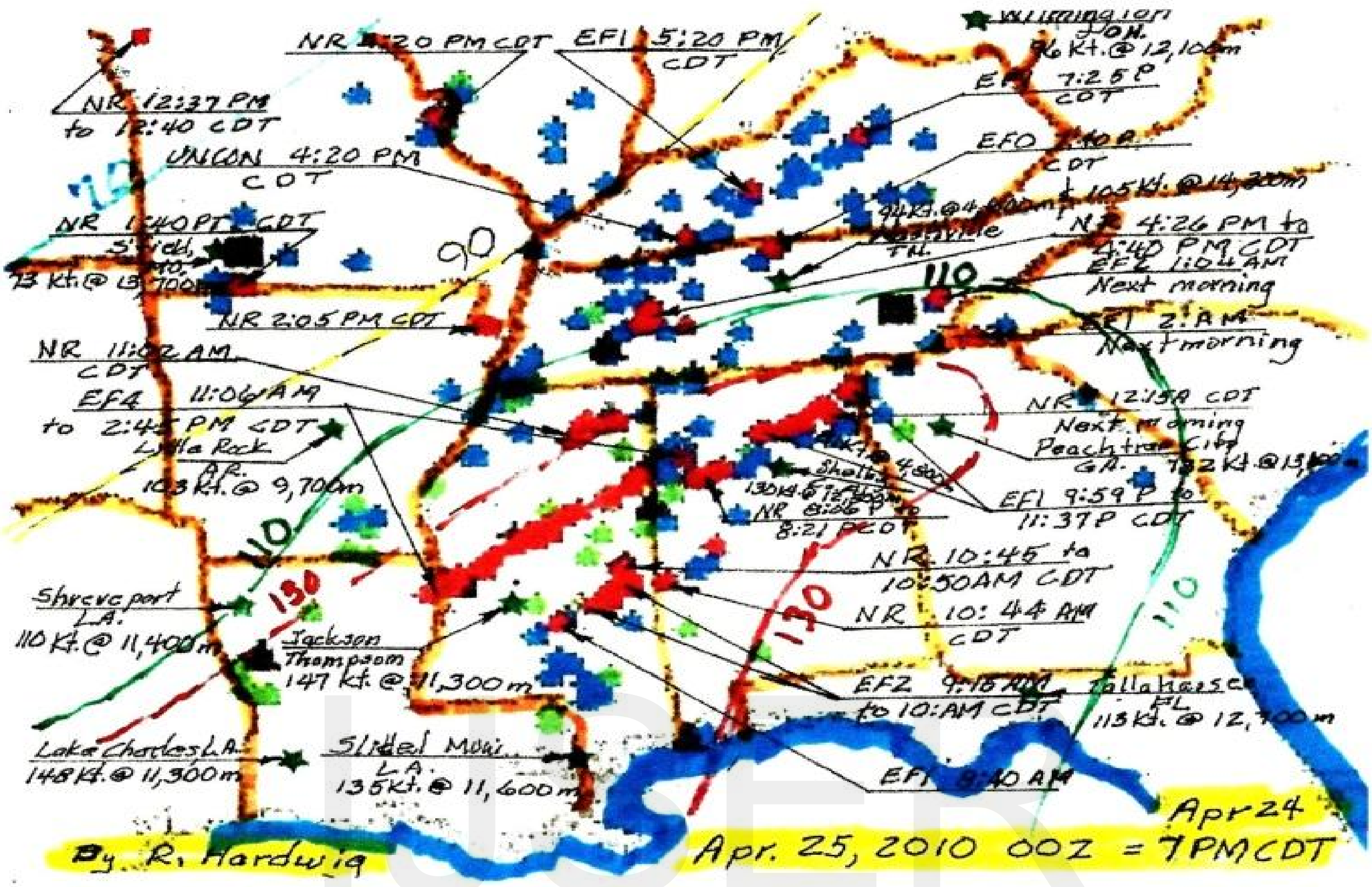

Fig. 6. This map of the southeast United States was made from a NOAA Storm Prediction Center map of 25 April 2010 00Z, 12 hours later than Fig. 5. Once again the locations and times of the tornadoes are shown the same as before. And the hailstorms and high winds are also noted as before. But the one thing that has changed is the locations of the high velocity overhead jet streams. Notice how the jet stream velocities have increased in a northeasterly direction and how the major tornadoes increased also under those jet streams. This correlation is noticed all the time if looked for.

The strongest tornado, an EF4, started at 11:06 AM CDT at the Louisiana, Mississippi border and moved northeasterly under the 130 knot jet stream until 2:45 PM CDT. As we only get jet stream velocities two times a day 00Z and 12Z it is necessary to interpolate where the jet stream would be in between. But by looking at the maps and comparing the times of the tornadoes with the overhead jet stream velocities, one can see how the stronger tornadoes formed under the higher velocity jet tornadoes forming underneath, just as was noted in the 22 May 2010 example above.

One thing we have missed is that the jet stream is not always at its highest velocity at the 300mb/32,000 foot range. While we take weather balloon soundings normally up to about 34,000 meters, we only plot the jet stream at the 300mb–10,000 meter range; however, any

streams as they moved in a northeasterly direction. Also, it should be noted that the nonrated tornadoes formed outside the high velocity overhead jet streams.

The 25 - 28 April 2011 out-break was also investigated in detail, where we had a total of 392 tornadoes in the south eastern United States again, including the EF 4 tornado that hit Tuscaloosa, Alabama. In every case there was a high velocity jet stream overhead with

high velocity jet stream between about 8,500 meters and 14,500 meters can cause a tornado.

Data was again collected on the tornado outbreaks of 25 – 28 April 2011 and of 21 – 25 May 2011. It was during this research that it became apparent what was happening and why we were not making the correlation between the high overhead jet stream and the tornadoes that form underneath. While in all past research most of the tornadoes seemed to fit the pattern of forming under the jet stream maps which were compiled at 300mb or about 32,000 feet; however, the new tornadoes researched didn't seem to fit this pattern, as no high velocity jet stream was noted at that elevation. However, the answer was found by checking the jet stream velocities at any elevation where a tornado had formed, by looking at the raw data available from the University of Wyoming, College of Engineering Department of Atmospheric Sciences. The first tornado investigated was the Joplin, Missouri tornado of 22 May 2011. This tornado didn't seem to fit until looking at the jet stream velocities at other heights than just 300mb or 32,000 ft. What was found was that while the jet stream velocity wasn't that high that day at the 300mb range, only about 30 knots the overhead jet stream velocity at the Springfield, Missouri National Weather Station about 50 east of Joplin, Missouri was ≈77 knots at 43,000 ft. Therefore it became apparent that the jet stream's height had as much to do with tornadogenesis as the jet stream's velocity.

To better show how the jet stream's velocity and jet stream's height influence the development of a tornado a TORNADOGENESIS JET STREAM VELOCITY-HEIGHT INTERACTION plot was made. The plot included; 10 EF1, 10 EF2, 10 EF3, 10 EF4 and 10 EF5 tornadoes and to have a base line, 10 supercell thunderstorms where we had large HAIL STORMS but no tornadoes were also plotted, see Fig. 7.

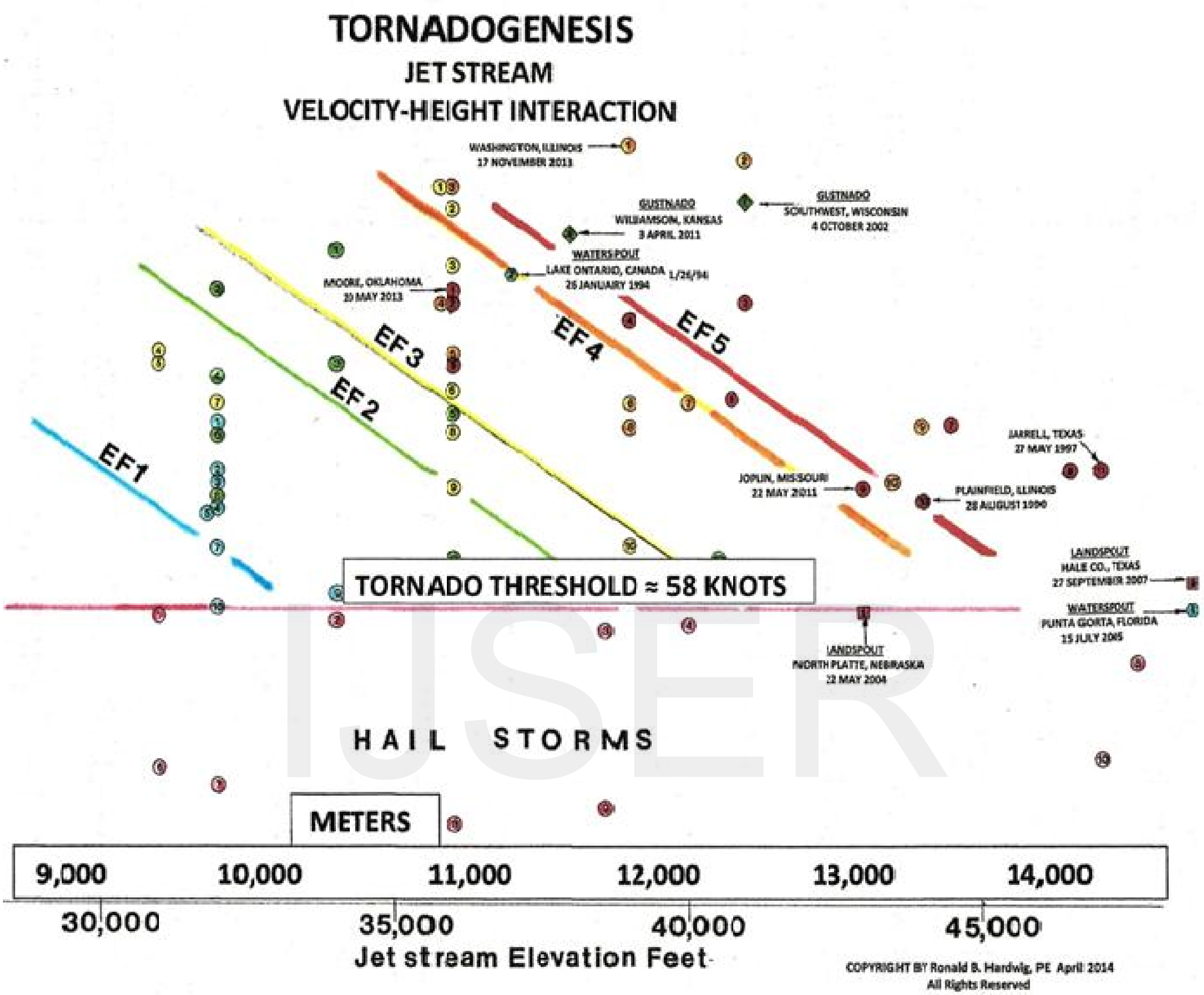

Fig. 7. This plot was made to show how the velocity and height of the overhead jet stream determine the strength of a tornado. However, as where to plot any one tornado is purely objective and tornadoes don't come in even numbers some scattering of the plots will be seen. But it is quite obvious that there is a definite correlation to the strength of a tornado and the height and velocity of the overhead jet stream. One very important thing found with this plot was the fact that no tornadoes formed and touch down if the high velocity overhead jet stream was less than about 58 knots. It was always felt by the researcher that finding out why there was this TORNADO THRESHOLD was the key to solving tornadogenesis. And it was, as about a year and a half later the answer was found.

The plot involved plotting the jet stream's overhead velocity where each tornado had formed, relative to the height of the jet stream at the same time. Some tornadoes plotted were well-known ones and some had been requested, as the gentlemen didn't think there was any high velocity overhead jet stream that could cause a tornado. Once again however, they were not looking for a high velocity jet stream other than at the 300mb or 32,000 ft. range. It should be noted that Fujita/EF Scale ratings used were those that were determined by tornado researchers looking at the damage on the ground after each tornado. And as the determination where to rate a tornado is up to the individual and it's very subjective it can easily vary. Also some of the tornadoes plotted were rated under the old Fujita scale. However, a definite pattern can be observed between

International Journal of Scientific & Engineering Research, Volume 7, Issue 10, October-2016
ISSN 2229-5518

the different Fujita ratings given to each tornado class and the velocity and height of the overhead jet stream at the time of their occurrence. Some tornadoes requested to research, were the Plainfield, Illinois tornado on 28 August, 1990 requested by Dr. Robert Rauber, Chairman of the Meteorological Department at the University of Illinois and the Jarrell, Texas tornado of 27 May 1997 requested by Dr. David Dempsey, Chairman of the Meteorological Department at San Francisco State University. Dr. Dempsey also asked me to look at Landspouts, Waterspouts and Gustonadoes. See Table 2, the Tornadogenesis Data Sheet, for a list of those Tornadoes, Waterspouts, Landspouts, Gustnadoes and HAIL STORMS plotted. It should be further noted that many meteorologists, besides Dr. Rauber and Dr. Dempsey, have made statements, to the fact without fully researching it, that some tornadoes have formed and touched down under jet stream velocities of less than about 58 knots. However upon investigation, no tornadoes have been found that did not meet the criteria when you check the high velocity overhead jet stream anywhere between 8,500 and 14,500 meters. As in the past they apparently only looked at the jet stream velocities at the 300mb or 10,000 meter range.

Table 2

TORNADOGENESIS DATA SHEET
JET STREAM VELOCITY - HEIGHT INTERACTION

	EF1	EF2	EF3	EF4	EF5	HAIL STORMS
1	Dallas, Texas 9 April 2008 88 Kt. @ 32,000 Ft.	Allendale Co., S. Carolina 15 March 2008 99 Kt. @ 32,000 Ft.	Floyd Co., Georgia 15 March 2008 126 Kt. @ 36,000 Ft.	Washington, Illinois 17 November 2013 132 Kt. @ 39,000 Ft.	Moore, Oklahoma 20 May 2013 109 Kt. @ 36,000 Ft.	Lincoln Co., Missouri 28 April 2012 57 Kt. @ 31,000 Ft.
2	Halifax Co., Virginia 28 April 2008 80 Kt. @ 32,000 Ft.	Elbert Co., Georgia 15 March 2008 109 Kt. @ 32,000 Ft.	Thompson, S. Carolina 15 March 2008 122 Kt. @ 36,000 Ft.	Yazoo, Mississippi 25 May 2010 130 Kt. @ 41,000 Ft.	Niles, Ohio 31 May 1985 107 Kt. @ 36,000 Ft.	Marissa, Illinois 28 April 2012 56 Kt. @ 34,000 Ft.
3	Trigg Co., Kentucky 5 May 2008 78 Kt. @ 32,000 Ft.	Shelbyville, Tennessee 11 April 2008 97 Kt. @ 34,000 Ft.	Prosperity, S. Carolina 15 March 2008 113 Kt. @ 36,000 Ft.	Harrisburg, Illinois 29 February 2012 126 Kt. @ 36,000 Ft.	Wayne Co., Indiana 16 April 1998 107 Kt. @ 41,000 Ft.	Clayton, Georgia 13 June 2012 54 Kt. @ 38,600 Ft.
4	Rankin Co., Tennessee 12 February 2008 74 Kt. @ 32,000 Ft.	Elbert Co., Georgia 15 March 2008 95 Kt. @ 32,000 Ft.	Devil's Elbow, Missouri 7 January 2008 99 Kt. @ 31,000 Ft.	Picher, Oklahoma 10 May 2008 117 Kt. @ 36,000 Ft.	El Reno, Oklahoma 31 May 2013 104 Kt. @ 39,000 Ft.	Rockfish, North Carolina 16 May 2010 54 Kt. @ 40,000 Ft.
5	Calhoun Co., Florida 17 February 2008 73 Kt. @ 32,000 Ft.	Atlanta, Georgia 14 March 2008 89 Kt. @ 36,000 Ft.	Monroe Co., Kentucky 5 February 2010 97 Kt. @ 31,000 Ft.	Marquette, Kansas 14 April 2012 99 Kt. @ 36,000 Ft.	Andover, Kansas 26 April 1991 98 Kt. @ 36,000 Ft.	Williston, Florida 13 June 2012 49 Kt. @ 48,000 Ft.
6	McAfee, Kentucky 24 April 2010 70 Kt. @ 28,000 Ft.	Madison Co., Tennessee 5 February 2008 86 Kt. @ 32, 000 Ft.	Giles Co., Tennessee 11 April 2008 93 Kt. @ 36,000 Ft.	Crittenden, Kentucky 2 March 2012 92 Kt. @ 49,750 Ft.	Parkersburg, Iowa 25 May 2008 92 Kt. @ 43,000 Ft.	Dallas, Texas 13 June 2012 32 Kt. @ 31,000 Ft.
7	Bainbridge, New York 19 April 2013 68 Kt. @ 32,000 Ft.	Haywood Co., Tennessee 5 February 2008 82 Kt. @ 28,000 Ft.	Evansville, Indiana 6 November 2005 91 Kt. @ 32,000 Ft.	Green Co., Alabama 27 April 2011 91 Kt. @ 40,000 Ft.	Marion Co., Alabama 27 April 2011 87 Kt. @ 44,500 Ft.	Marion, Iowa 23 July 2010 29 Kt. @ 32,000 Ft.
8	Jacksonville, Texas 25 April 2011 60 Kt. @ 28,000 Ft.	Green Co., N. Carolina 18 February 2008 75 Kt. @ 32,000 Ft.	Trenton, Georgia 27 April 2011 86 Kt. @ 36,000 Ft.	Philadelphia, Mississipp 27 April 2011 87 Kt. @ 39,000 Ft.	Jarrell, Texas 27 April 1997 80 Kt. @ 46,500 Ft.	Hargill, Texas 16 May 2010 23 Kt. @ 36,000 Ft.
9	Christian Co., Kentucky 25 April 2011 60 Kt. @ 34,000 Ft.	Mansfield, Georgia 19 April 2013 66 Kt. @ 36,000 Ft.	Europa, Mississippi 26 April 2011 77 Kt. @ 36,000 Ft.	Henryville, Indiana 2 March 2012 87 Kt. @ 44,000 Ft.	Joplin, Missouri 22 May 2011 77 Kt. @ 43,000 Ft.	Dighton, Kansas 23 July 2011 26 Kt. @ 38,600 Ft.
10	Junction City, Louisiana 26 April 2011 58 Kt. @ 32,000 Ft.	Thayer, Missouri 5 November 2005 66 Kt. @ 40,500 Ft.	Coaling, Alabama 26 April 2011 68 Kt. @ 39,000 Ft.	Moville, Iowa 4 October 2013 78 Kt. @ 43,400 Ft.	Plainfield, Illinois 28 August 1990 75 Kt. @ 44,000 Ft.	Reeves, Louisiana 13 June 2012 33 Kt. @ 47,000 Ft.
11					Jarrell, Texas 27 May 1997 80 kt. @ 47,000 Ft.	

	GUSTANDOES	LANDSPOUTS	WATERSPOUTS
1	Southeast Wisconsin 4 October 2002 123 Kt. @ 41,000 Ft.	North Platte, Nebraska 24 May 2004 57 Kt. @ 43,000 Ft.	Punta Gorta, Florida 15 July 2005 57 Kt @ 100,000 Ft.
2	Williamston, Kansas 3 April 2011 117 Kt. @ 38,000 Ft.	Hale Co., Texas 27 September 2007 59 Kt. @ 49,000 Ft.	Lake Ontario, Canada 26 January 1994 111 Kt. @ 37,000 Ft.

5. Analysis

The TORNADOGENESIS JET STREAM VELOCITY-HEIGHT INTERACTION plot showed a definite connection between the overhead high velocity jet stream's velocity and height. But what was most intriguing was what appeared to be a TORNADO THRESHOLD. Just what did this mean? Why were there no tornadoes below that velocity? This had to be telling me something.

After about 1 1/2 years of research, the answer! Just as one does not suck water up through a straw, the physics is, that one draws water up in a straw by sucking the air out thus reducing the atmospheric pressure in the straw and allowing the atmospheric pressure pushing down on the liquid in the glass to force the liquid into your mouth. The same thing is happening to develop a tornado. As the high velocity jet stream passes over the outer edge of the mesocyclone it is deflected as if it hit the leading edge of a wing of a plane. Thereby, the overhead atmospheric pressure is offset enough to have the atmospheric pressure from below push the air within the confines of the mesocyclone/vortex up, which develops the tornado. And it just so happens at about 58 knots there is sufficient lift created to completely offset the atmospheric pressure from above the vortex, allowing the higher atmospheric pressure from below to flow into the vortex creating the tornado and for the air from below to be ultimately carried away by the high velocity overhead jet stream. As the top of the vortex of the tornado is like a flying disc with a hole in the center the lift can be calculated using the formula for the lift of a plane wing. Lift = C x 0.5 x pV^2x S.

Calculating the required jet stream velocity needed to offset the pressure from above proved to be the answer. See Table 3, Atmospheric Pressure to be Offset

Table 3

ATMOSPHERIC PRESSURE TO BE OFFSET

Height meters	Pressure to be offset hPa)	Density (kg/m3)	Knots required
4,000	616.4	0.8191	63.4
6,000	471.8	0.6507	61.6
8,000	356.0	0.5252	60.0
9,000	307.4	0.4663	59.1
10,000	264.4	0.4127	58.3
11,000	226.3	0.3639	57.4
12,000	193.3	0.3108	57.4
13,000	165.1	0.2655	57.4
14,000	141.0	0.2268	57.4
15,000	120.4	0.1937	57.4
18,000	75.05	0.1207	57.4
20,000	54.75	0.0880	57.4

These were calculated using the lift formula for a plane wing. Lift = C x .5 x pV^2 x S
C=Coefficient of lift p = Fluid Density V = True Airspeed S = Planform Area

Note: The Coefficient of Lift "C" used was where the lift and drag intersect ≈ 1.425

For example at 10,000 meters the pressure that would have to be offset per square meter is
264.363 Hectopascals and the Density at that elevation is 0.4127 Kg/M^3.
∴ Solving for the velocity, the Lift or pressure to be offset 264.4 = 1.425 x 0.5 x 0.4127 x V^2 x 1
V = 29.98 m/s or 58.3 knots

While it takes a little more than a 58 knots velocity to offset the overhead pressure at lower levels, from about 11,000 meters and up, it is a constant and the overhead atmospheric pressure can be offset by a calculated 57.4 knot jet stream of air. I find this to be another method of Entrainment that has never been researched. This substantiated my 58 knot TORNADO THRESHOLD research and confirmed my theory. This proves that tornadoes are formed by the Bernoulli Effect of Entrainment. And while there is always some Entrainment, when the jet stream velocity is less than 58 knots, once it surpasses that velocity it is like opening a valve at the top of the tornado to open up and the air to be forced out the top due to the higher atmospheric pressure from below and the air to be carried away by the jet stream. See Fig. 8, TORNADO DYNAMICS, on how it all fits together.

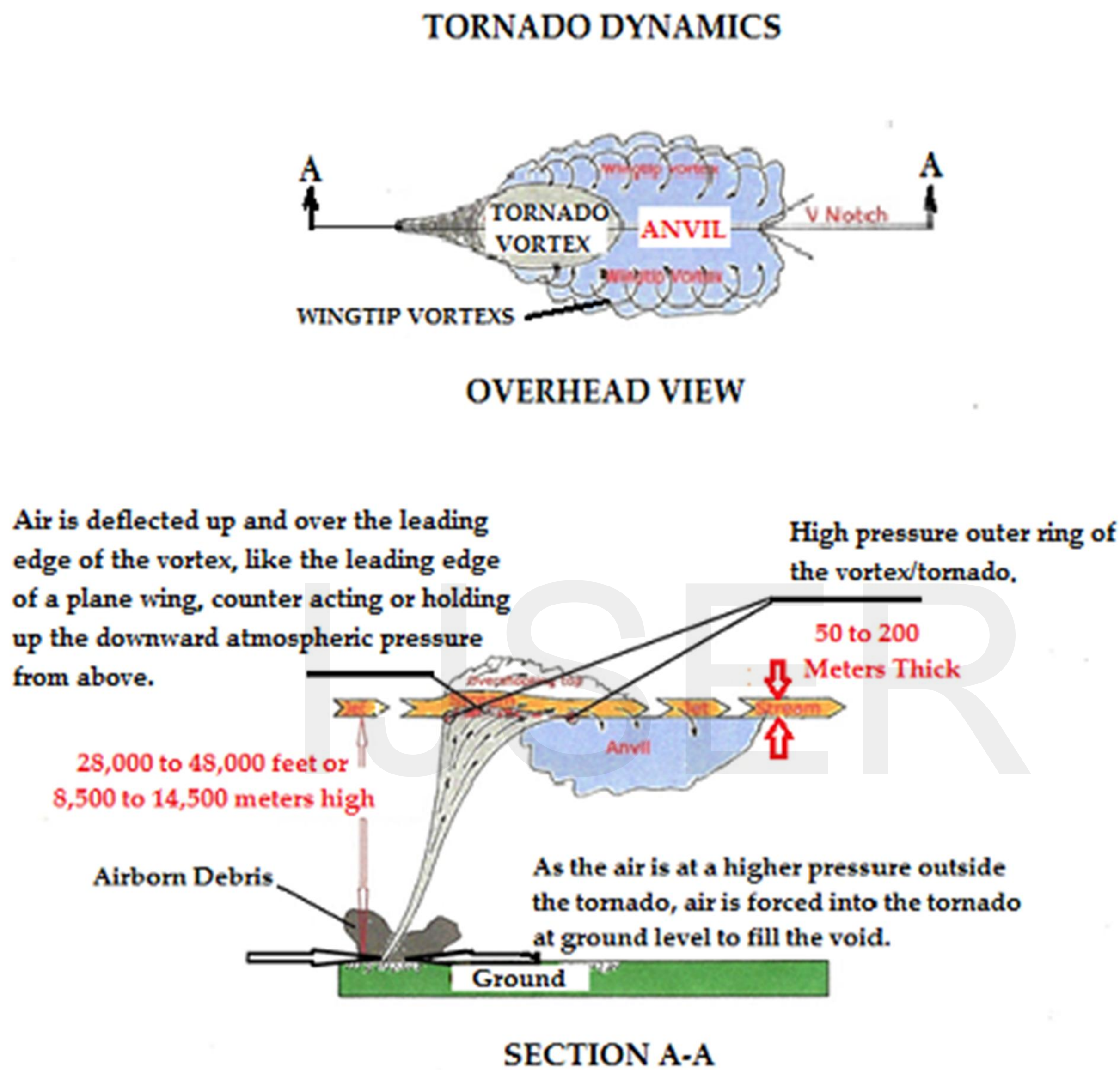

Fig. 8. The Outer high pressure ring of the tornado acts as a barrier taking the shape as the leading edge of a plane wing, thereby deflecting the jet stream up and over the top of the tornado. While the bottom of the wing would appear to be at the lower edge of the jet stream, due to the high pressure of the rotating wall of the tornado all the lift of Entrainment at the top is transferred to the ground which we see as a tornado.

6. The atomizer

Not having found where anyone had actually studied atomizers, they were researched too. An atomizer does not work by actually lifting the liquid but by offsetting the atmospheric pressure above the perpendicular tube sufficiently to allow the atmospheric pressure in the vile below to force the liquid up and out the top. And the lift required to do this can be calculated by using the lift formula for an airfoil just as the lift in a tornado can be calculated. In fact the velocity to lift 5 cm or approximately 2 inches of liquid is not the speed of sound as Dr. Devilbiss said, but about 27 feet per second. This can be confirmed by simply driving down the road with a glass of water, with a straw in it held outside and comparing the lift of the liquid in the straw relative to the speed of the car. This confirms that, Tornadoes are Just the Largest Atomizers on earth.

7. Conclusion

Another item that further attests these findings was mentioned by Dr. Eagleman, that the anvil was like wingtip vortices downstream of the tornado. As the jet stream passes over and around the vortex/tornado, which is circular like a flying disc, it creates wingtip vortices which we see and refer to as an anvil and even has a "V" notch in the center just as the wake of a plane does.

Also while we might not see a tornado, but seeing the overshooting top and anvil, just means we have entrainment and possible rotation aloft hidden in the thunderstorm. This is because even though the jet stream velocity is not 58 knots, any jet stream velocity acting on a mesocyclone can entrain some air, enough to cause rotation, which we refer to as a supercell thunderstorm, but not necessarily sufficient to cause a tornado on the ground. After doing all this research the results show that the jet stream has everything to do with a tornado's formation, tornadogenesis. While it takes a thunderstorm to start the process by the mixing of the warm and cool air or some other upper air disturbance to develop a vortex/mesocyclone, the real energy for the tornado is provided by the jet stream passing over one of the mesocyclones within the thunderstorm and turning it into a tornado by Entrainment.

Meteorologists have said time and again that they were searching to find why only 20% to 25% of the supercell thunderstorms they track develop a tornado. There is an obvious reason for this. That is, because only 20% to 25% of the supercell thunderstorms that form, form under a jet stream of sufficient velocity, at least 58 knots, to energize a mesocyclone within the thunderstorm to create the tornado on the ground. The fact that lighter objects such as pictures and papers are carried aloft in the jet stream, only to fall out hundreds of miles later when the thunderstorm dissipates, further confirms how the jet stream is involved in a tornado's development.

Also the fact that tornadoes have hook echoes further proves that the high velocity overhead jet stream is involved. Just as a spinning baseball deflects as it goes through the air due to the differential pressure on the two sides, the rotation of a tornado is deflected by the action of the high velocity overhead jet stream passing around it. This is why a cyclonic tornado has a hook echo to the left side of its path while an anticyclonic tornado has a hook echo on the right side of its path; they are being deflected by the jet stream passing over and around them.

There has been sufficient data in this research paper to substantiate that the real source of energy for a tornado is the jet stream. By looking at the data there are a few other things that can be derived from this research. As would be expected, and is confirmed by the data, the higher the jet stream velocity overhead where a tornado forms, the stronger the tornado.

Also the higher the jet stream's height allows the tornado to fan out more creating a larger area affected by the jet stream, the Relative Area of Interface. And it would stand to reason that the larger the diameter of the tornado that is affected by the Bernoulli Effect of Air Entrainment at the interface with the jet stream the stronger the tornado will be on the ground. That is what we saw in the Joplin, Missouri tornado of 22 May 2011, the Plainfield, Illinois tornado of 28 August 1990 and the Jarrell, Texas tornado of 27 May 1997.

Also, my research and data show that the crash of Air Asia Flight 8501 on 28 December 2014 was possibly due to the plane flying into an overhead tornado as the conditions were right to have a tornado in that area at that time. And while there is insufficient data to confirm that same thing did not happen to Air France Flight 447 on 1 June 2009, it is quite possible that it happened to that flight also. By the pilot realizing what is happening, in the future these types of accidents should be avoidable.

8. Predictions for the future

This research shows a direct correlation between the overhead jet stream's velocity and height and the development of tornadoes. And there is sufficient data to show that we need to be looking at both the location of the jet stream's height as well as its velocity compared to where thunderstorms are developing when we make tornado advisories. While we might have a very strong supercell thunderstorm, that in itself does not mean we will have a tornado. And conversely just because we don't see a supercell thunderstorm doesn't mean we can't have a tornado as they can develop very quickly, particularly if the high velocity overhead jet stream is much above 58 knots as the Moore, Oklahoma tornado did on 20 May 2013.

The high velocity overhead jet stream means everything in tornadogenesis. It is the one missing element that everyone has overlooked. Using my basic research and expanding on it, we could start better forecasting tornadoes immediately. And not only can we predict where they will form but at what strength on the Fujita scale. And our advanced notice will be much improved, as we will know which supercell thunderstorms are likely to develop tornadoes and which ones will not.

In 10 to 20 years I believe we should be able to find a way to interrupt the development of a tornado. Since the action of the Bernoulli Effect and Entrainment requires that the jet stream be streamline flow, if we were to disturb the streamline flow of air at the interface of the developing mesocyclone/tornado possibly we could short circuit the tornado's development.

Acknowledgements

First I want to dedicate this research to my great grandfather Ernest F. Hardwig, who I never had the chance to know, as he was killed on his 64th birthday by the Tri-State Tornado of 18 March 1925 in Murphysboro, Illinois. His death was the reason for my wanting to better understand just how tornadoes form and even if we might someday stop them from even occurring.

Second I wish to acknowledge the one professor I remember from my college days at Southern Illinois University. Dr. Stoever taught Thermodynamics at Southern Illinois University as a visiting professor. He taught thinking out of the box before it was the thing to do. I once told him how much I appreciated his class, but I was disappointed to think that I would not use his teaching in my field of engineering. His statement stuck with me and really came home when he replied: his job was not to just teach thermodynamics but to teach me how to think.

I would like to thank Dr. David Dempsey with the San Francisco State University for his help instructing me as to where to get data needed for my research and prodding me to make a better case for my theory on tornado-genesis, which is why I came up with my Tornadogenesis Jet Stream Velocity-Height Interaction plot, see Fig. 7. From that time forward I looked at the overhead jet stream velocities, not just on the 300mb maps, but also relying on the raw data available from the University of Wyoming.

Last but certainly not the least I want to thank my wife of 53 years, Nancy "Sue" Hardwig, who puts up with living with an engineer, who sees all things as either black or white, so it is either exactly right or it is wrong and for her editing of this paper.

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