Enhanced Fujita Scale

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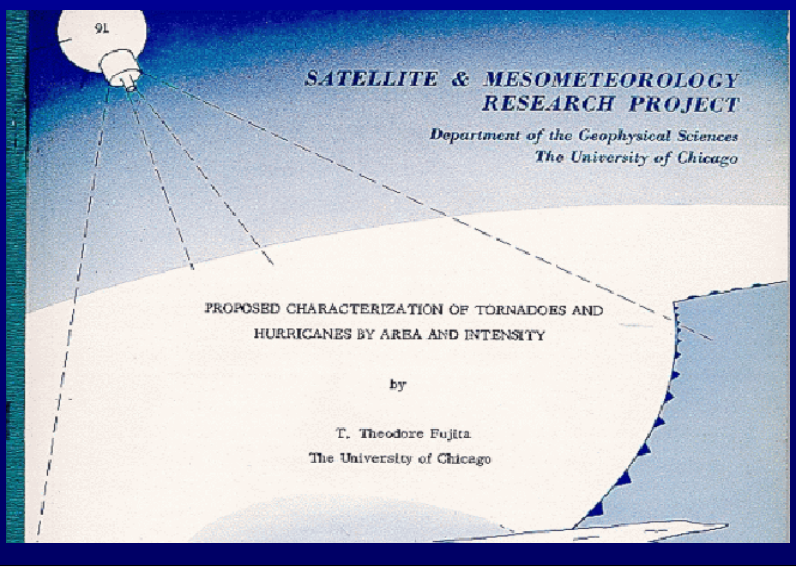
Jim Keysor
Warning Coordination Meteorologist
National Weather Service Gaylord

Outline

- The Fujita Scale
- Why was the new scale created?
- Development of Enhanced Fujita (EF) Scale
- How to use the EF Scale in damage assessment
- Practice assessments
- EF Scale Tools

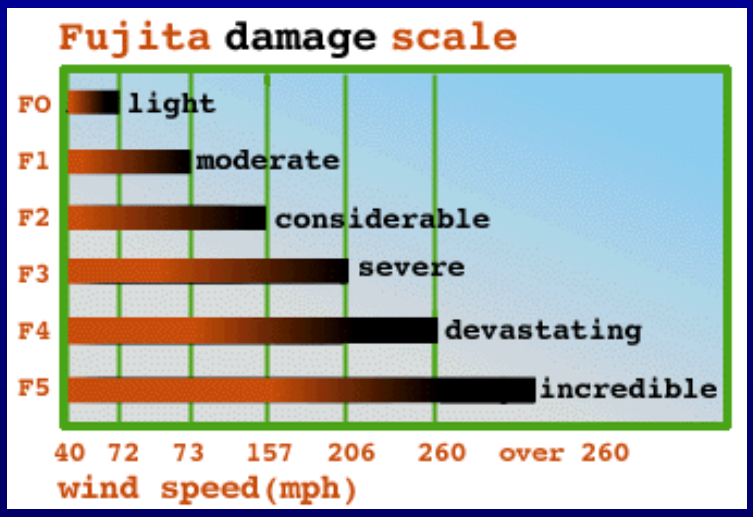
Theodore T. Fujita

Fujita develops the F-scale and it is first seen in this landmark paper



This paper, "Proposed Characterization of Tornadoes and Hurricanes by area and Intensity" by TT Fujita in 1971 is where he first proposes the F-scale. The paper relies heavily on surveys done from the Palm Sunday Tornado Outbreak in 1965 as well as the Lubbock Tornado in 1970. The scale was proposed as a quick means for someone to identify the strength of as tornado based on damage. The proposed upper limit for tornado winds was around 320 mph, which still seems plausible today. The scale was also proposed before much of the engineering research pioneered by Texas Tech University began.

The Original Fujita Scale



F0 and F1

F0…40-72 MPH

F1…73-112 MPH

F2 and F3

F2…113-157 MPH

F3…153-206 MPH

F4 and F5

F4…207-260 MPH

F5…261-318 MPH

Fujita revised his scale in 1990 and attempted to account for variability in construction types

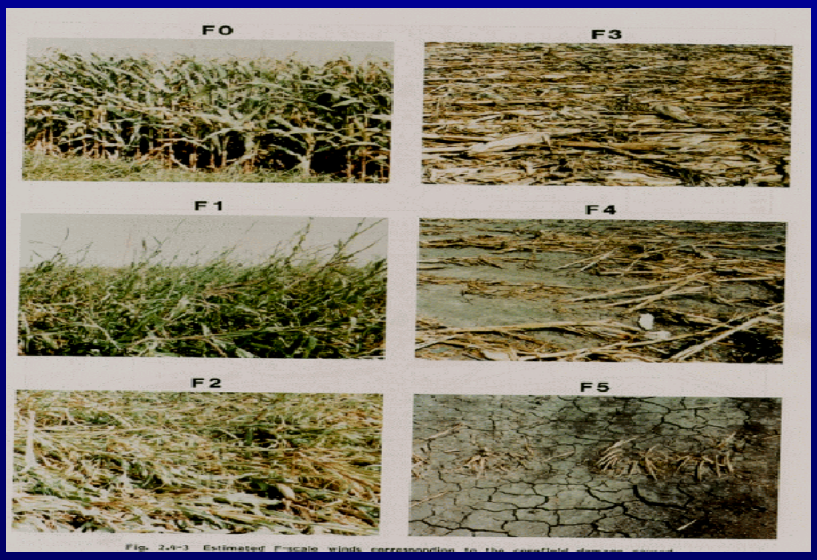
F-SCALE WIND FROM STRUCTURE TYPE AND DAMAGE

STRUCTURE TYPES	DAMAGE CATEGORIES						
	NO DAMAGE	MINOR DAMAGE	ROOFING BLOWN OFF	ENTIRE ROOF GONE	SOME WALLS STANDING	FLATTEN TO THE GROUND	BLOWN OFF FOUNDAT.
MOBILE HOME	F0	F0	F0	F1	F1	F1	F2+
WEAK FRAME HOME	F0	F0	F1	F1	F2	F2	F3+
STRONG FRAME HOME	F0	F0	F1	F2	F3	F4	F5+
BRICK BUILDING	F0	F1	F2	F3	F4	F5+	F5++
CONCRETE BUILDING	F1	F2	F3	F4	F5+	F5++	F5++

MINIMUM WINDSPEEDS: F0(40 MPH), F1 (73), F2 (113), F4(207), F5 (261)

This diagram devised by Fujita in 1990, indicates the subjectivity in describing storm damage. The structure type combined with the amount of damage should be used in accessing the f-scale. Thus, a mobile building or outbuilding can be completely blown away by an F-2 wind, while a reinforced concrete structure may not blow completely off its foundation, unless the winds are greater than F-5, hence the F-5+++. Another factor in building failure is the amount of debris available to produce missiles. The missiles then striking a building can lead to premature failure than just straight winds alone.

Also in 1990 (after the Plainfield tornado), Fujita attempted to correlate corn damage to the F Scale



Limitations of Fujita Scale

- Few damage indicators
  - This was a big problem in rural areas
- Did not account for construction quality in a detailed fashion
- No definitive correlation between damage and wind speed
- Overestimation of wind speeds at higher categories
- Difficult to apply consistently

Recent inconsistencies applying the F-scale

"Since 1999, no tornado has been given a F5 rating. This could be that the damage in Oklahoma City has set an unmatched standard for F5 damage, or that the application of more stringent assessment of structures has led to lower damage ratings.

McCarthy, Schaefer and Edwards, 2006: What Are We Doing with (or to) the F-Scale?, 23rd Conf on Severe Local Storms, St. Louis, MO, 5.6.

You may or may not realize that we may have inadvertently created inconsistencies in rating tornadoes as we've learned more about how structures behave in high winds. After the LaPlata, MD tornado assessment, we have noticed that no F5 tornadoes have been documented. This is the first time in recorded history that no F5's have been recorded for such a long time. You could argue that perhaps no F5 damage has been documented, despite that we've had plenty of destructive tornadoes. This would be especially true after witnessing the benchmark in tornadic violence after the May 3, 1999 OKC tornadoes. But after LaPlata, I can equally argue that we've been more stringent in assigning F4 and F5 ratings to structures. The LaPlata assessment may have been the cause for this climatological break.

Now we're introducing a whole new scale and a method for rating damage. The EF-Scale developers have painstakingly built in a method to avoid a climatological break in tornado ratings. If the training proceeds as planned, then there should not be a serious break in climatology. All this depends on the proper execution of the EF-Scale training that is outlined in this orientation session.

Have there been no F5's in the past several years?

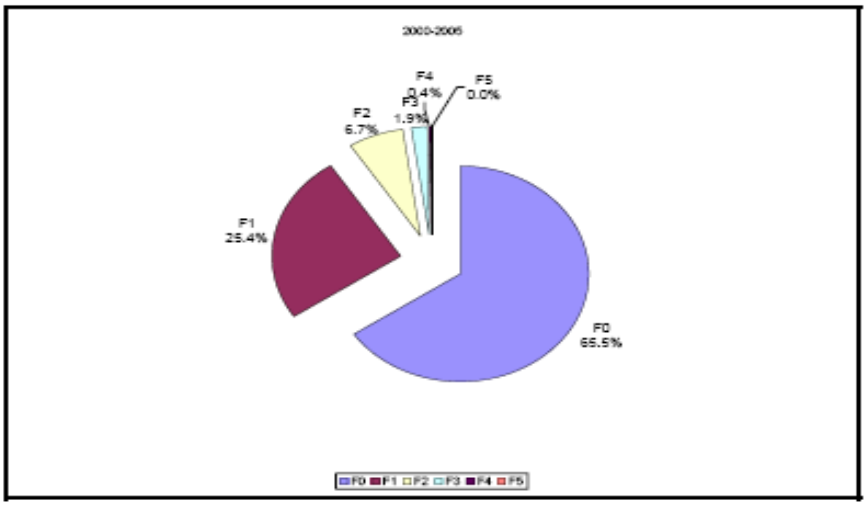


Figure 5b: F-Scale damage 2000-2005.

Why the need for the EF-Scale

- Need more damage indicators
- Recalibrate winds associated with F-scale ratings
- Better correlate wind and rating
- Account for construction variability
- Flexibility, Extensibility, Expandability

The framed house is one of only a few F-scale damage indicators.

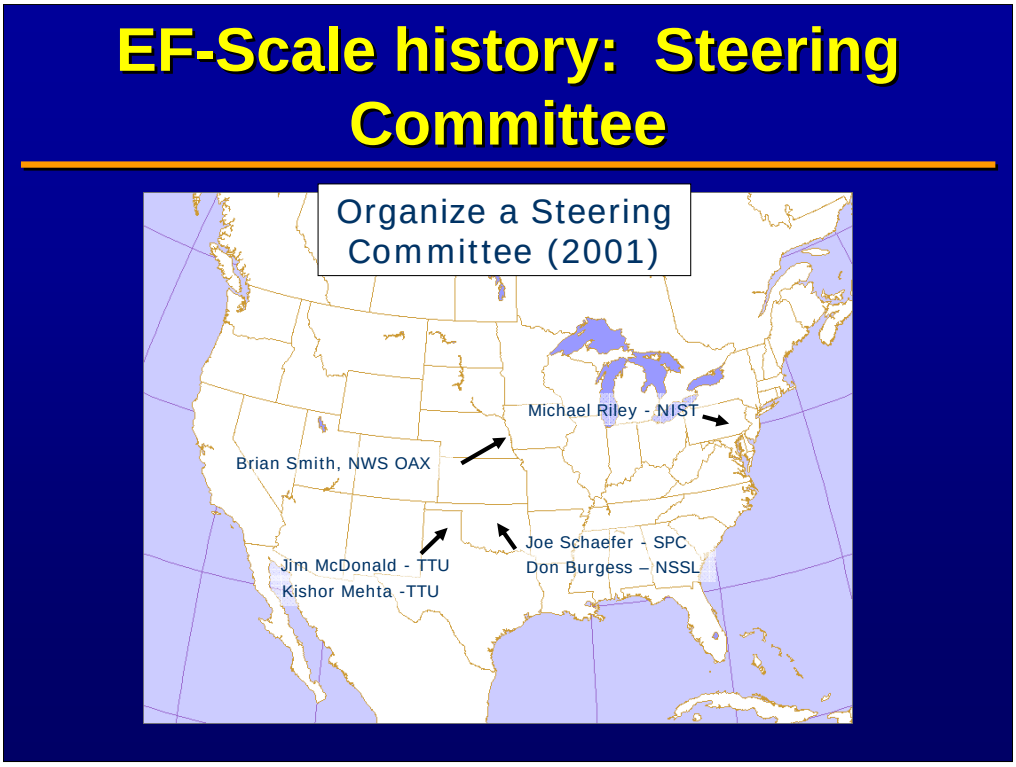
Evidence indicates a well constructed house can be blown away by winds much less than 260 mph (Phan and Simiu,2003).

The NWS has been using the F-scale in the mid-late 1970s. The original F-scale only contained an example of documented structures and their a description of expected damage for each rating from F0 to F5. Thus, one of the goals was to provide more damage indicators along with a series of pictures as examples.

Several studies also indicate that lower wind speeds could do F3 to F5 damage than was documented in the F-scale. We needed to better correlate the degree of damage and the wind speed which includes the variability in construction quality. Fujita realized in his memoirs “Mystery of Severe Storms” that it was necessary to include building descriptors in assessing tornado damage and acount for construction accountability.

While not changing the wind estimates, he did create a “modified” scale using a ‘little f’ for the type of building damaged in order to calculate ‘big F’ by the degree of that damage.

The EF-Scale to be implemented in the NWS is an extension of this idea but to many more types of structures. Finally, we need a scale that can be changed so it has to have flexibility, extensibility, and expandability.



The Texas Tech University (TTU) Wind Science and Engineering (WISE) Research Center personnel recognized that a change to the rating system was needed. They created an original steering committee that you see listed up here to generate a process to build a new rating system, namely the EF-Scale. These people all have experience in engineering and the F-Scale. Two of them worked with Fujita closely during parts of their careers, one has extensive research with storm damage and Doppler radar, another has extensive experience in developing and working with the current tornado database and one has vast knowledge of engineering and statistics. There were a lot of issues to discuss and the steering committee decided that a forum (workshop) be organized and experts in various aspects of tornadoes be invited to this forum.

The steering committee had these objectives

- Identify additional Damage Indicators (DI)s
- Correlate damage to wind speed
  - Degrees of Damage (DOD) for each DI
- Preserve the historical database
- Seek input from users
- Maximize usability

The forum participants met for a day and a half and set a plan in motion that would create the EF-Scale.

The NWS personnel wanted many more damage descriptions and photographs.

All the participants wanted to redefine F-Scale wind speed ranges having a sliding scale to account for structural variablity.

They wanted to preserve and continue the historical database.

They wanted input from the field. This will allow to keep the EF-Scale updated constantly.

Maximize its usability by having a PDA or available software so that the WCM or surveyor has the reference right at their fingertips.

They agreed upon the lexicon “D to redefine degree of Damage” (DOD) to identify what wind speed range would be required to produce describable damage for various DIs. The forum wanted to make sure that there was continuity from all tornadoes rated with the F-scale to those to be rated with the EF-Scale. Both scales would need to be correlated with each other. The surveyors decided that the names of the F-Scale and the EF-Scale categories should be similar, i.e. F1 becomes EF1, F2 becomes EF2, etc. Finally, good contacts with the user community are always a good idea as the development proceeded. See McDonald and Mehta, 2001 for more details.

EF-Scale Damage Indicators (DIs)

- 28 DIs were identified by the Steering Committee
- DIs and DODs can be added or modified

Framed house

Single wide mobile home

Small Retail Building

The original steering committee, especially Dr. McDonald and Mehta of TTU, identified 28 Damage Indicators (DIs) based on their experience with tornado damage. The framed house is one DI, a mobile home, and small retail buildings constitute other DIs. Knowing that continued development of the EF-Scale is likely, more DIs can be added once the research on them have been done. Or perhaps some Degrees of Damage (DODs) can be also be changed.

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For each DI, the steering committee decided that the DOD should range from the initiation of damage all the way up to devastation of the structure.

28 Damage Indicators

Table 3.
Damage Indicators for EF Scale

DI No.	Damage indicator (DI)
1	Small Barns or Farm Outbuildings (SBO)
2	One- or Two-Family Residences (FR12)
3	Manufactured Home – Single Wide (MHSW)
4	Manufactured Home – Double Wide (MHDW)
5	Apartments, Condos, Townhouses [3 stories or less] (ACT)
6	Motel (M)
7	Masonry Apartment or Motel Building (MAM)
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24	Transmission Line Towers (TLT)
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26	Free-Standing Light Poles, Luminary Poles, Flag Poles (FSP)
27	Trees: Hardwood (TH)
28	Trees: Softwood (TS)

Barns

Residences

Commercial/retail structures

Auto buildings

Schools

Large Commercial bldgs

Towers

Trees and poles

Here are the 28 DIs. They represent a wide variety of structures. You could break them down into broad categories such as residences, commercial/retail structures, schools, professional buildings (including institutional buildings like universities and hospitals), metal buildings and canopies, and towers or poles. Note that they've included a vegetation category, however we've only begun to study the relationship between wind speeds and crop damage. No flying objects or crop damage have been included as a DI. The categorization of the DIs is not related to the strength of a building, hopefully the pictures can aid you in determining building strength. This list of DIs is subject to modification as we improve the EF-Scale.

Degrees of Damage (DOD's)

- Each DI has several degrees of damage
- DOD's range from no damage to total destruction
- DOD's are arranged in order of increasing damage
- They are a function of wind speed

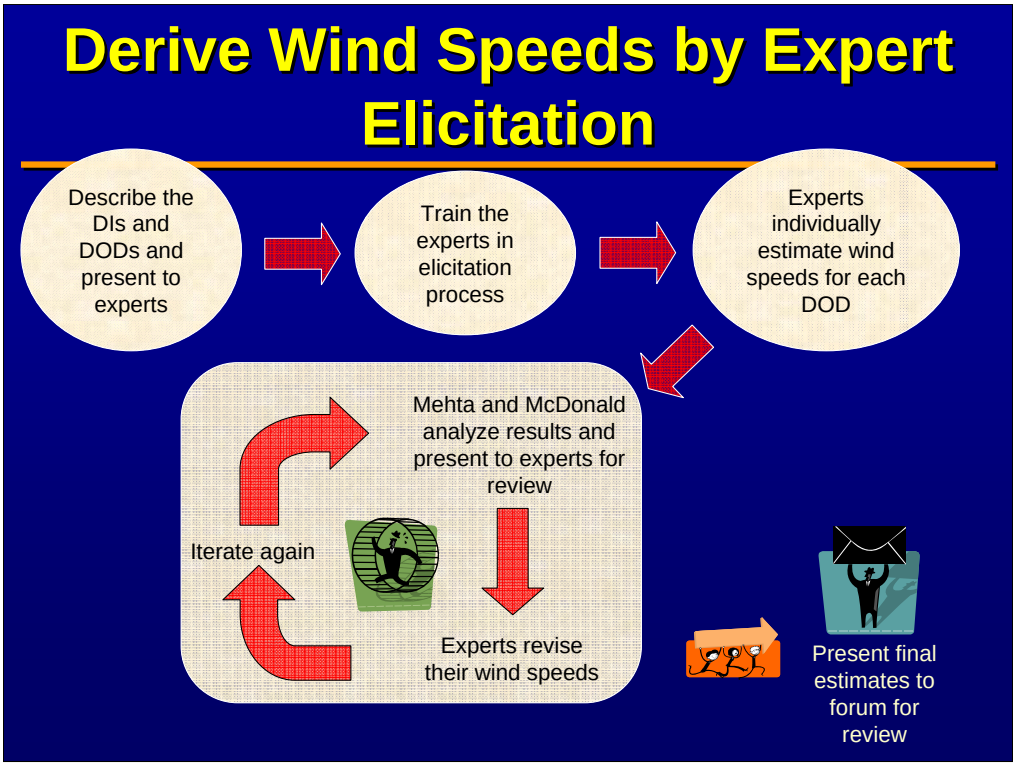
How the winds were derived for each DOD

- Possible Candidates
  - Structural analysis to determine resistance and theoretical failure modes
  - Simulation of tornado winds to produce structural damage
  - Expert Elicitation
- Chosen method?
  - Expert Elicitation

As it turns out, there are a host of methods to derive a wind speed estimate. The Steering committee could've done a detailed structural analysis to determine resistance and failure pressures. A large wind tunnel or perhaps a computer simulation to derive threshold wind speed to cause structural failure. Or a method called expert elicitation could be done where experts are chosen to make the estimates. Expert Elicitation is a method created by the Senior Seismic Hazard Assessment Committee (SSHAC, 1997) to estimate risk potential in seismic zones.

The first two methods required more funding than was available to the Steering Committee. Instead, they chose a more economical method of expert elicitation. Texas Tech chose six experts in damage surveying to estimate the wind speeds. The developers did have some idea of typical wind speeds through many years of experiments within the wind tunnel laboratory at Texas Tech.

As time and resources permit, researchers may pursue one of the more rigorous methods of estimating wind speed. It is also likely that better remote sensing of wind speeds in tornadoes may give us a better relation between 10 m, 3 second winds and building damage.



Here is what the TTU did. First, they created detailed descriptions of each DI and DOD and then presented them to the experts.

They trained the experts on how to elicit their estimates. The DODs were given to the experts along with pictures where possible.

The experts made the estimates, of expected, upper and lower bound winds.

Then Drs Mehta and McDonald took the average and standard deviations of the expected, upper and lower bound winds and presented them back to the experts as part of round #1. The DODs were arranged in order of increasing wind speed.

Round #2 involved the experts refining the wording of the DODs, and the expected, upper and lower bound winds and handing their elicitations back to Drs. Mehta and McDonald. The process was repeated until fewer changes were made. In this case, three rounds were all that were needed.

Finally there is a peer review process where the original forum members commented on the results.

Degrees of Damage for 1 or 2 family residence (FR12)

DOD	Damage Description	EXP	LB	UB
1	Threshold of visible damage	63	53	80
2	Loss of roof covering material (<20%), gutters and/or awning; loss of vinyl or metal siding	79	63	97
3	Broken glass in doors and windows	96	79	114
4	Uplift of roof deck and loss of significant roof covering material (>20%); collapse of chimney; garage doors collapse inward or outward; failure of porch or carport	97	81	116
5	Entire house shifts off foundation	121	103	141
6	Large sections of roof structure removed; most walls remain standing	122	104	142
7	exterior walls collapsed	132	113	153
8	Most walls collapsed except small interior rooms.	152	127	178
9	All walls collapsed	170	142	198
10	Destruction of engineered and/or well constructed residence; slab swept clean	200	162	220

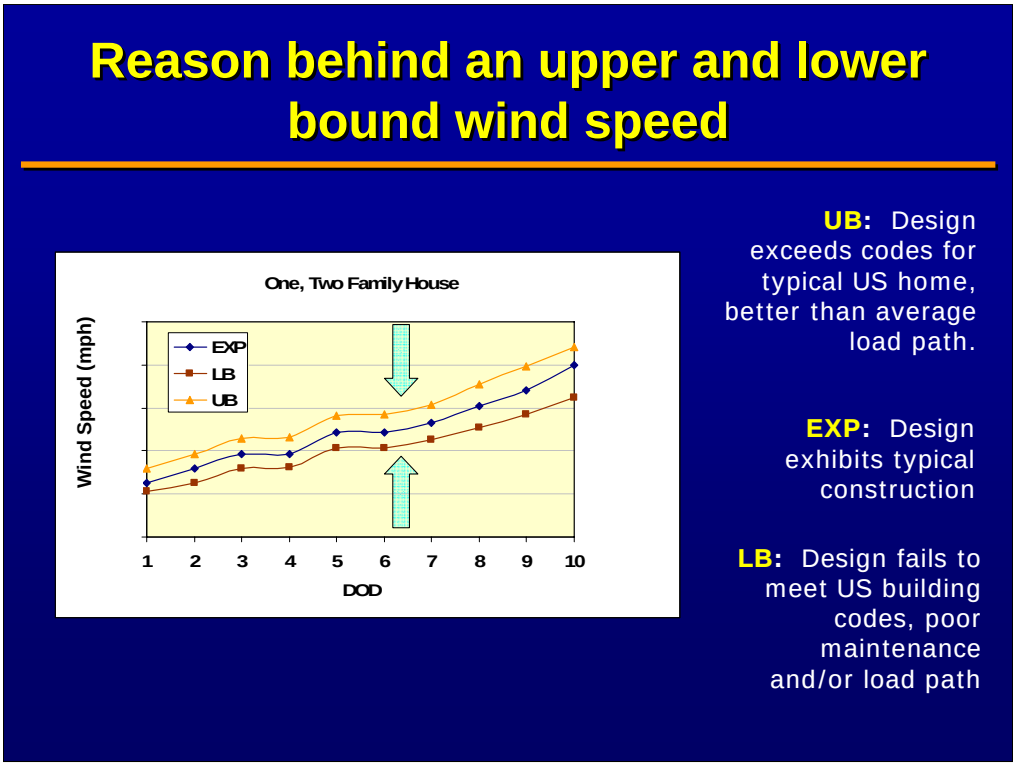
Here's an example of the results. Again for 1-2 family residences, you can see that generally increasing DODs result in increasing winds.

But take note when you go from DOD3 to DOD4 (light colored boxes) the wind speeds don't increase that much. In DOD3, the threshold of breaking glass prompted the expert group to come up with an expected wind speed of 96 mph. DOD4 (uplift of roof deck, collapse of chimney, failure of porch) is a different type of damage but the experts estimated the wind speeds similarly to DOD3. But DOD5 prompted the experts to significantly increase the wind speeds.

Note that DOD5 and DOD6 (darker colored boxes) are also very similar in wind speeds. Does that mean if you have large sections of roof removed, but most walls remaining standing and the house still on the foundation that you have a DOD6? It is conceivable to get that kind of damage and you wonder how you could achieve a rating. Again, you may not see the progression of damage consistent with smaller DODs be evident.

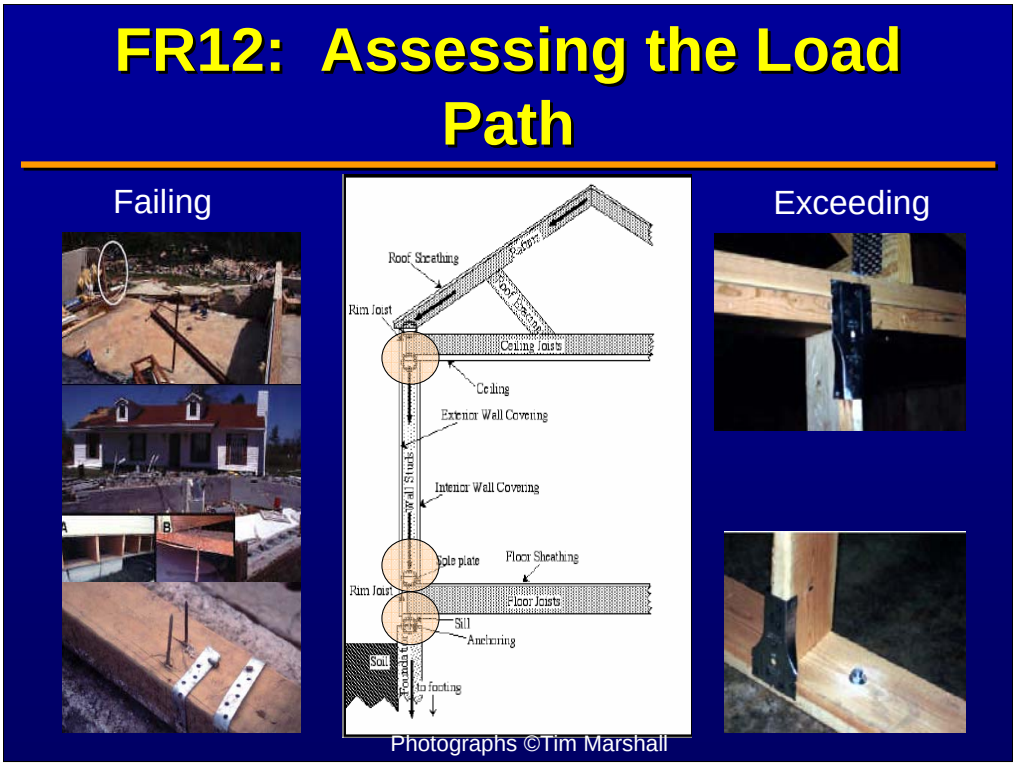
This is an example from 1-2 family residences.

Each Damage Indicator (DI) has 3-12 levels to assess the Degree of Damage

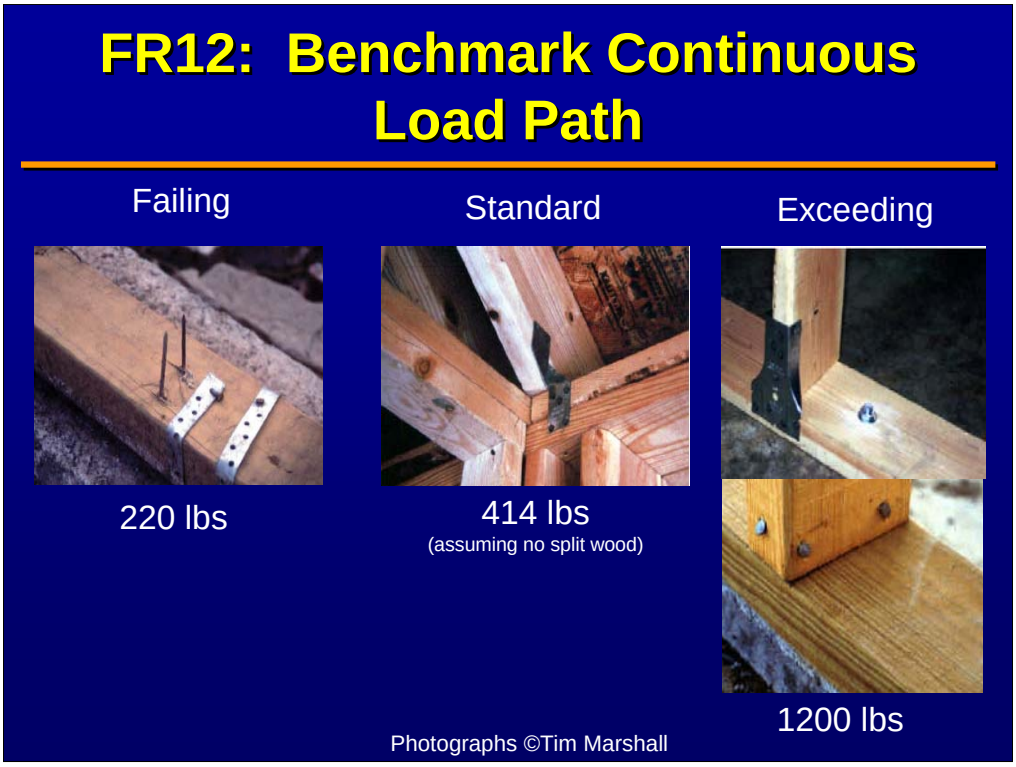


If the house you're inspecting fails to meet building codes (e.g., load path with just straight nailing, no clips, frame nailed to foundation), then you may only need a lower bound (LB) wind to do the damage for any particular DOD. Contrarily, a well engineered house (e.g., load path reinforced with clips, framing properly bolted to foundation), like what you may find near some hurricane prone coastlines, may require an upper bound (UB) wind speed to match the DOD you see. All these considerations eventually filter down to what rating you may give a structure. You may also find that the more you know about structures and how the damage occurred, the more easily you'll be able to rate a structure. The fastest way to build up expertise besides experience is by talking with the experts and your peers to share ideas on how the structures in your area match with those in other areas. More on this later.

This is an example from 1-2 family residences.
(e.g., steel frame, reinforced concrete, strong load path)



Lesson 2 describes construction habits found in one type of DI, the one- and two-family house that help determine a wind speed estimate for a particular DOD. While I describe one type of DI, remember that there are 28 DIs, each with their own peculiarities in construction variability that affect a wind speed estimate. I cannot possibly go into detail about each DI like I have done with this DI unless I capture the student's attention for a much longer course. Instead, I encourage that all of you participate in the collaborative forum so that we may interface with the subject matter experts and to each other.

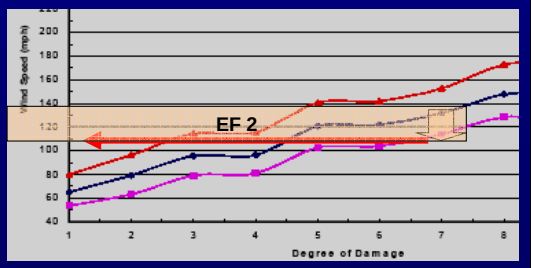


Here is an interesting test that was done by Marshall (1983) that shows the difference in strength between straight nailing, toe nailing and properly attaching clips between the Sill Plate and exterior wall stud. Tim found that a pull of 414 lbs was enough to separate a properly toe nailed stud, but if it was straight nailed, he only needed 220lbs (plus or minus 60lb) to accomplish the same task , a properly attached clip could withstand up to 1200 lbs before failing.

Accounting for construction quality in F vs EF

- F-scale paradigm
- If structure is weaker (stronger) than standard, consider dropping (raising) F-scale

- EF-Scale paradigm
- If structure is weaker (stronger) than standard, lower (raise) wind speed toward the LB (UB) and then see if that lowers (raises) the EF rating.



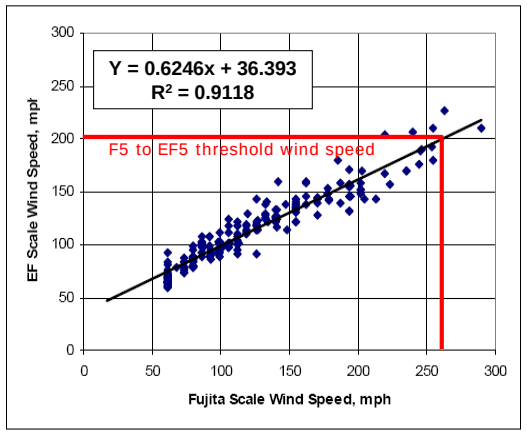
There are differences in assigning a rating when you account for variations in construction quality going from the F-scale to the EF-Scale. For the F-scale, you may consider adjusting the rating as a first step.

In the EF-Scale, check to see if a structure is weaker or stronger than standard, then lower or raise the wind speed toward the LB or UB respectively. Finally, check the impact on the EF rating. In this example, let's say the DOD is 7, then I suspect the structure fails to meet standard practices. I lower the wind speed to the LB. Notice that it doesn't change the EF rating here, both the LB and EXP wind speed correspond to EF2. However, the UB wind speed raises the rating to EF3.

Do not forget to check the exposure to any structure for vulnerabilities for which the wind might have taken advantage, check for collateral damage.

Relating the F-scale with the EF-Scale

- Need of historical continuity
- 2nd set of experts assigned F-scale ratings to the same damage descriptions
- Median F-scale wind speeds compared to that of expected EF-Scale wind speeds



The F-Scale wind speed was converted from the fastest ¼ mi to a 3 sec gust.

Remember that the EF-Scale forum, and we also, want to maintain some type of the integrity and continuity between the old F-Scale and the new EF-Scale. Otherwise, we fear a significant break in the climatology may result. One way to help resolve this is to see how well the EF and F-Scale match up when damage is being assessed by a surveyor.

One way the Steering Committee decided to match the scales was to have a second set of damage survey experts estimate a similar set of pictures as what the EF-Scale expert team saw, but in this case, rate them by the F-scale. The second set of experts consisted of WCMs and other experienced damage survey experts that participated in the Quick Response Teams from 2003 to 2006. Median wind speeds were derived from the F-scale ratings and then compared to the expected wind speed of the EF-Scale.

You may find that the median wind speed in the F-scale represented here is a little different. That is because they were converted from the fastest ¼ mi wind of the F-scale to the 3 second gust frame of reference in the EF-Scale. This analysis serves the function that the old database can be converted to the EF-Scale, or at least the two databases can be reconciled.

Note that the F5 ratings match closely to the EF5 winds, and the same is true for the lower ratings for both scales. Given the good correlation in this curve, there is high confidence that this relation is good. Now we can use the regression equation to establish the wind speed criteria for the EF-Scale ratings.

By the way, this strategy does not eliminate all artifacts that could occur in the climatology by switching to the EF-Scale. There are some differences in the DODs that can result in you deriving a different rating between the two scales. I don't expect that you would come up with a difference greater than one rating. But it is possible in some cases. We don't know about how these differences will impact the climatology.

F-Scale Converted to EF-Scale

F Scale	Wind Speed	EF-Scale	Wind Speed
F0	45-78	EF0	65-85
F1	79-117	EF1	86-109
F2	118-161	EF2	110-137
F3	162-209	EF3	138-167
F4	210-261	EF4	168-199
F5	262-317	EF5	200-234

Wind speeds in mph, 3-second gust

McDonald and Mehta took the regression and applied it to convert the F-scale rating wind speed ranges to the EF-Scale. In this way, there should be continuity in the way we rate the damage. Again, note that the F-scale wind speed ranges you see here are converted from the fastest ¼ mile to a 3 second gust. As a result they are a bit higher than what you may see elsewhere. The 3 second gust is thought to represent how the wind damages structures a little better than the fastest ¼ mile wind speed.

EF Scale Improvements

- Additional Damage Indicators
- Degrees of Damage
- Improved correlation between damage and wind speed
- Less subjective
- More accurate wind speeds

Significant improvement for damage assessment in rural areas

Table 3

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Towers

Trees and poles

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EF-Scale limitations

- Change in scale may introduce artifacts into the historical record
- Complicated
- Wind speeds subject to change for each rating
- Debate continues about wind speed assignments

The EF-Scale isn't perfect. There still could be artifacts introduced into rating structures that could yield difficult to measure changes in tornado intensity climatology. The EF-Scale requires a steep learning curve beyond the capabilities of these modules. You'll need to gain experience in using it given a host of resources (we'll let you know what these are), and by communicating with experts and your peers. Wind speeds are subject to change which may invoke a challenge in public education when these changes occur. As opposed to the F-scale, there is no elegant wind speed vs rating function that helps bridge the gap between the Beaufort and Mach scales. Finally, there is still debate going on with regards to wind speed assignments.

An example of a typical Damage Indicator

- One and Two Family Residences (FR12)

One-and Two-Family Residences (FR12)

- Typical Construction:
  - Asphalt shingles, tile, slate or metal roof covering
  - Flat, gable, hip, mansard or mono-sloped roof or combination thereof
  - Plywood/OSB or wood plank roof deck
  - Prefabricated wood trusses or wood joists and rafter construction
  - Brick veneer, wood panels, stucco, EIFS, vinyl or metal siding
  - Wood or metal stud walls, concrete blocks or insulating concrete panels
  - Attached single or double garage

One-and Two-Family Residences (FR12)

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7	Top floor exterior walls collapsed	132	113	153
8	Most interior walls of top story collapsed	148	128	173
9	Most walls collapsed in bottom floor, except small interior rooms	152	127	178
10	Total destruction of entire building	170	142	198

One-and Two-Family Residences (FR12)

FR12: DOD4: Uplift of roof deck and loss of roof covering (>20%); garage door collapses outward

One-and Two-Family Residences (FR12)

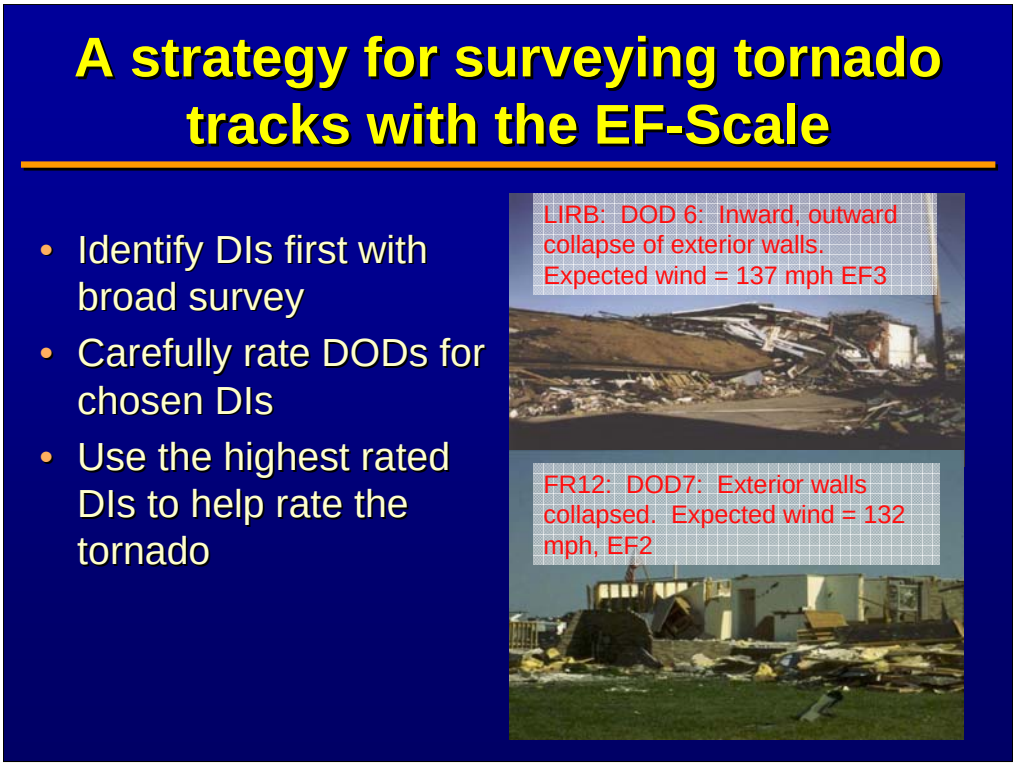
FR12: DOD6: Large sections of roof removed; most walls remain standing

One-and Two-Family Residences (FR12)

FR12: DOD7: Top floor (First floor in this case) exterior walls collapsed

One-and Two-Family Residences (FR12)

FR12: DOD10: Total destruction of entire building



Now that you're familiar with rating a DI, let's talk about a tornado event survey strategy that we'll start off with in this lesson and should be successful in the field. You may recall that there is a 100 page guide to damage assessment online. We put its URL here. While it focuses on using the F-Scale, most of its content is entirely relevant to the EF-Scale.

Transitioning to the EF-Scale means some changes in methodology in rating damage to a structure and rating the tornado. As you survey a tornado, you identify DIs, especially those that have the potential to have the highest rating. Here are two examples of DIs, a large isolated retail building (LIRB) and a one- two-family house (FR12). Preferably you would have aerial surveys done where you can this more effectively.

Then for the chosen DIs, you carefully rate the DOD for each one. If you are to do a detailed damage survey then you would want to do this for each DI. Here is an example of a LIRB with a DOD=6. This corresponds to an EF3 given an expected wind of 137 mph. The FR12 pictured damaged here is given a DOD=7 and an expected wind of 132 mph or EF2.

How you use the highest rated DIs to rate the tornado is a subject that I'll answer coming up next.

Rating a tornado event

- Rate the tornado based on the highest EF-Scale rating for any DI
  - Confirm with another DI
  - Check surrounding non DI's for consistency
- Be careful about too much precision with wind speed estimates

Confirm with another DI

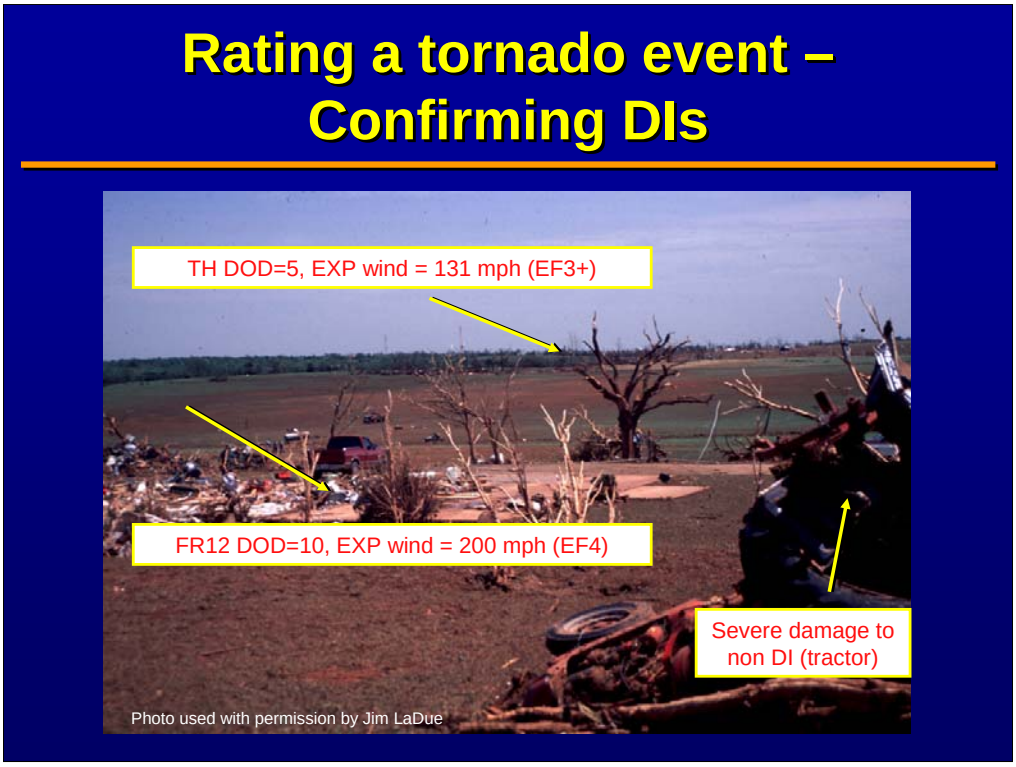
Check surrounding non DI's for consistency

So far we've talked about rating an individual DI. How about rating the entire tornado?

In an effort to be as consistent as we can with the past, we'll rate it the same way we always have, that is by using the highest EF-Scale rating found for any DI within the damage track. However…let's be very careful that the highest rating is a good one. Many times, you'll have multiple confirmations from other DIs like in this field of destroyed homes.

Sometimes you may not be so lucky and the only thing you have would be one form of DI and then surrounding non DIs. In this picture, you only have trees in the background, a grassy field and a vehicle. Only the hardwood trees represent a DI. They're debarked and that represents a DOD=5 or an expected wind of 143 mph corresponding to an EF3. How does the non DI damage in the immediate surroundings correspond to the target DI? Make sure the damage supports your claim. Document this in your report.

Even though you may be estimating specific wind speeds down to the mph in the process of assessing an EF-Scale rating for a specific DI, don't carry over such precision when you make your final rating assessment for the DI or tornado. We're not that good.

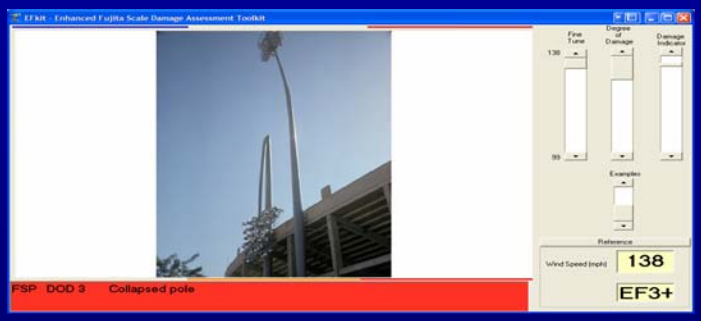


I present two hypothetical examples where the pictures represent the highest potential rating by a DI that you could give a tornado.

In the first example of a house completely blown away take a look at the damage in context with its surroundings. Technically, the DOD of the house (FR12) is maximized at 10 with an expected wind solidly in the EF4 range, and a lower bound wind equating to an EF3. However, does an EF3 fit within the surrounding damage, including the non DIs? There are a few uprooted trees, some snapped perhaps due to collateral damage. But that DI doesn't warrant more than an EF2. There's not much damage to the shrubbery either. I certainly want more confirmation elsewhere of EF3 damage, otherwise, an EF2 for this slider is the maximum for which I feel comfortable….hypothetically speaking.

On the other hand, another house was completely swept away in this picture giving it a DOD=10 and an expected wind speed of 200mph. The trees surrounding the house, including the non DI vegetation appears much more severely damaged. The tractor is a non DI but it's mangled appearance is something I expect to see. This house was rated F5, and should be rated EF5 here. If the damage pictured here represents what I have available to me for rating the entire tornado, I would be more confident rating the tornado an EF5.

Rating a tornado event – exceeding your maximum rating possible?



EF#+, where + means you've maximized the rating of a DI before EF5 was reached.

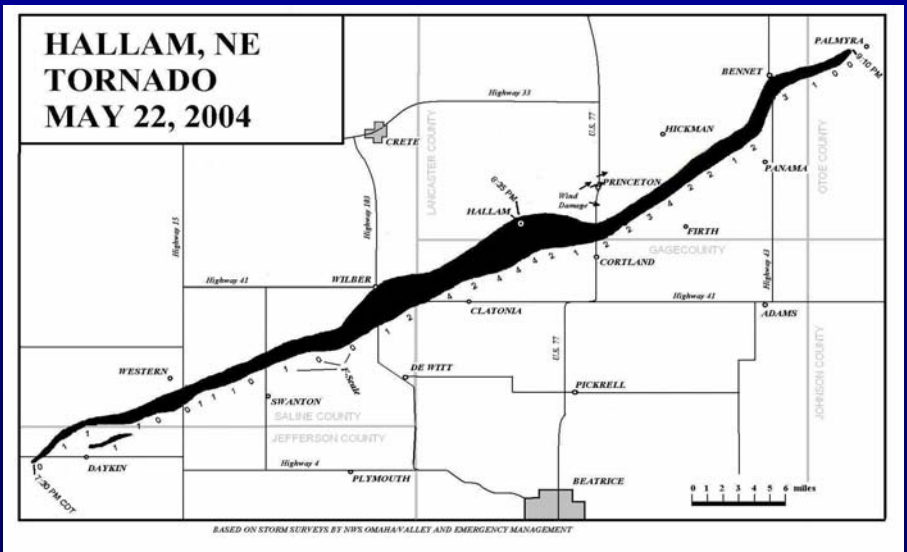
- A tornado can only be rated within the ranges of available DIs
  - This could still present problems in rural areas with mainly tree damage

There are many DIs that get completely destroyed with wind speed estimates well below that of the EF5 threshold.

In such cases, when using EFkit, you will see an EF#+, where + indicates you've maximized the rating of a DI before you reached an EF5 rating. It's our way of telling you that you've reached the maximum possible rating you can achieve with a DI, however the winds might or might not have been stronger. If only you had a DI that could give you a higher rating. Many times, you'll be limited by your DIs.

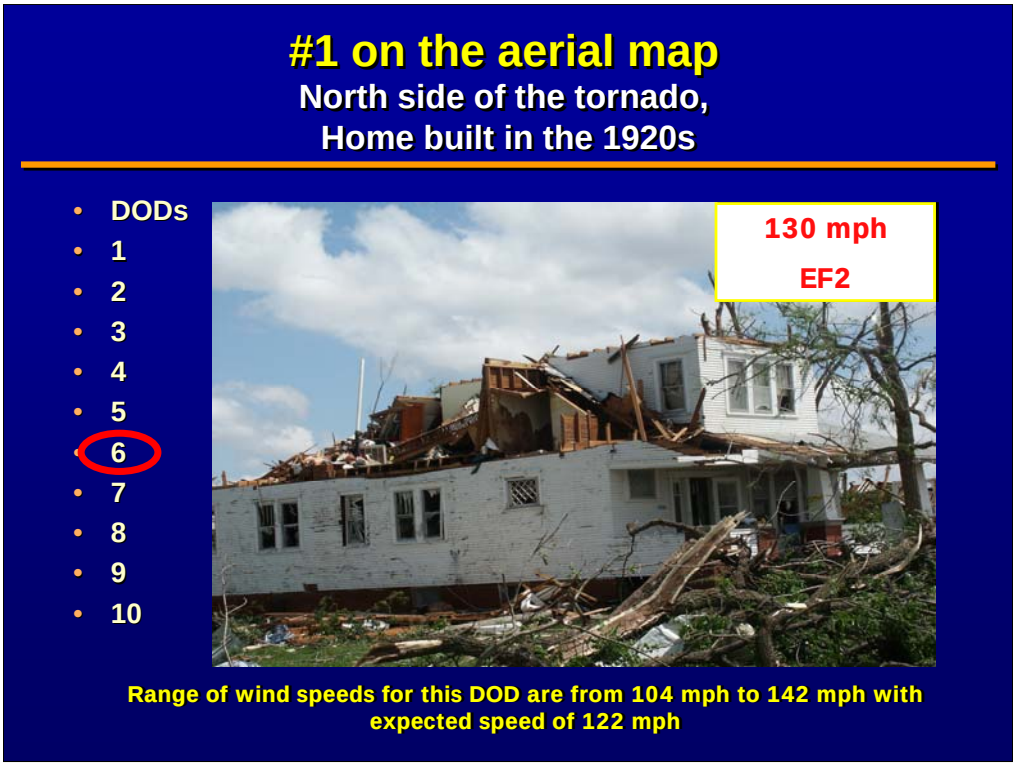
A tornado cannot be rated beyond what the DIs can give you. However, if you believe the tornado to be stronger, then reflect your opinion and why in your report. This kind of information can be useful to researchers, even if you're opinion's based on non DIs. In the future, the EF-Scale may include the same non DIs from which you based your opinion.

Let's go on a storm survey …



This is an aerial photo of Hallam. North is at the top of the picture. This photo was taken by Cornerstone Mapping in Lincoln, NE several days after the tornado. This is only a small section of the tornado path. The tornado path width for another 1.5 miles to the south. An empty coal train was derailed by the tornado and part of it can be seen in the lower left part of the photo. Notice the demolished grain storage bins at the center of the photo.

The numbers correspond to photo locations in the case study. Click on the boxes to go to the locations. This map will be available to you via a flash-based popup window linked from the survey locations you see here.



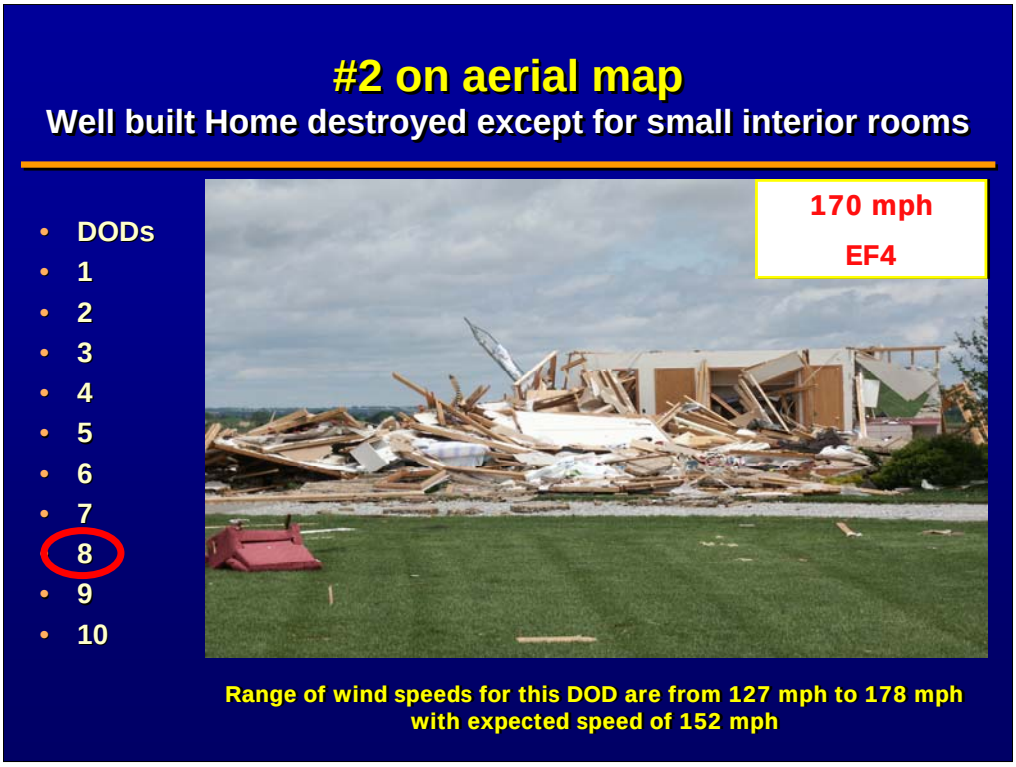
Let us start with an older single family residence .We are looking towards the southeast in this photograph. This structure corresponds to the number 1 in the aerial photo. This structure was on the north side of the cyclonic tornado vortex and the winds passed from left to right across the home.

It was estimated that the home was built in the 1920s or 1930s and was a two story structure. It is of all a wood frame construction.

From the EF-Scale documentation, the appropiate Damage Indicator is One and Two Family Residence (FR12).

The upper floor is missing some exterior walls and the roof of the home is totally gone. A degree of damage of 6 states that “large sections of the roof structure removed, most walls remain standing. The expected wind speed with this DOD is 122 mph with a lower bound wind speed of 104 mph and an upper bound wind speed of 142 mph.

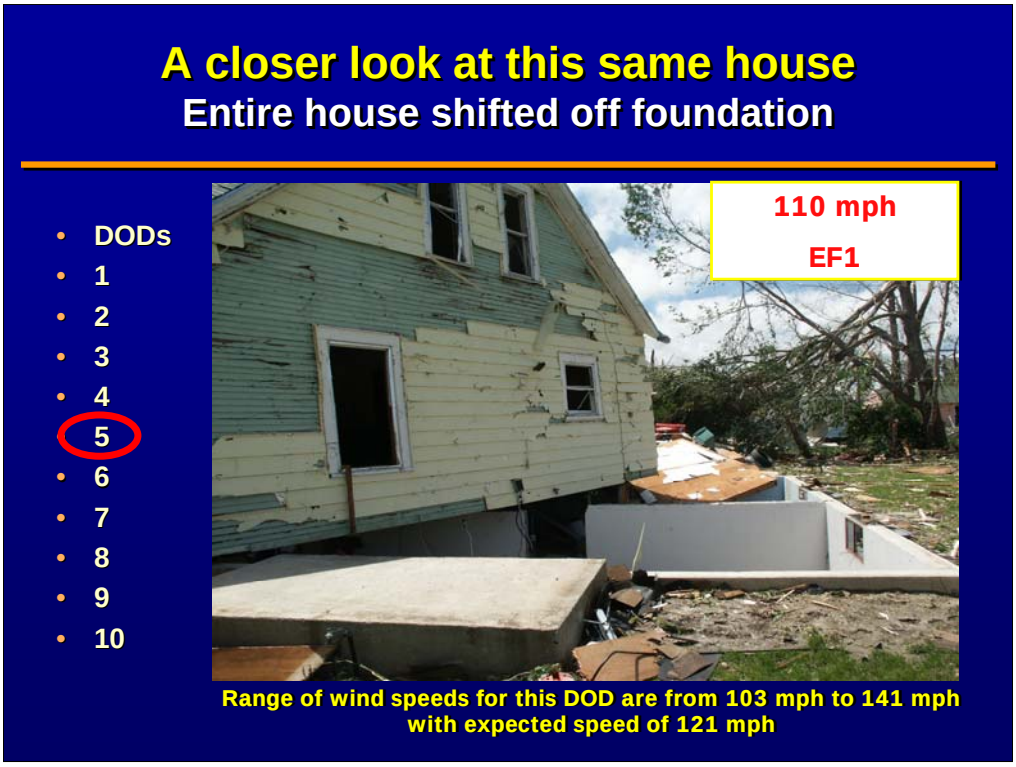
The damage is consistent for a wind speed of 130 mph or EF2.



The closer view of the home shows that a small part of an interior room still stands in the southeast corner. This home was wood frame construction. This destruction corresponds to an DOD 8, where most walls are collapsed on the lower floor, except small interior rooms. The expected wind speed is 152 mph. The Lower bound is 127 mph and the upper bound is 178 mph. We will assume that this is about 162 mph , making this correspond to an EF3.

#3 on aerial map
Minimal structural damage but house is tilting

This home is located at number 5 on the aerial photo. We are looking towards the northeast. The home appears to be intact with minimal damage to the roof and the siding. However, the house looks strange as if it is tilting on the foundation. The next photo reveals what happened.

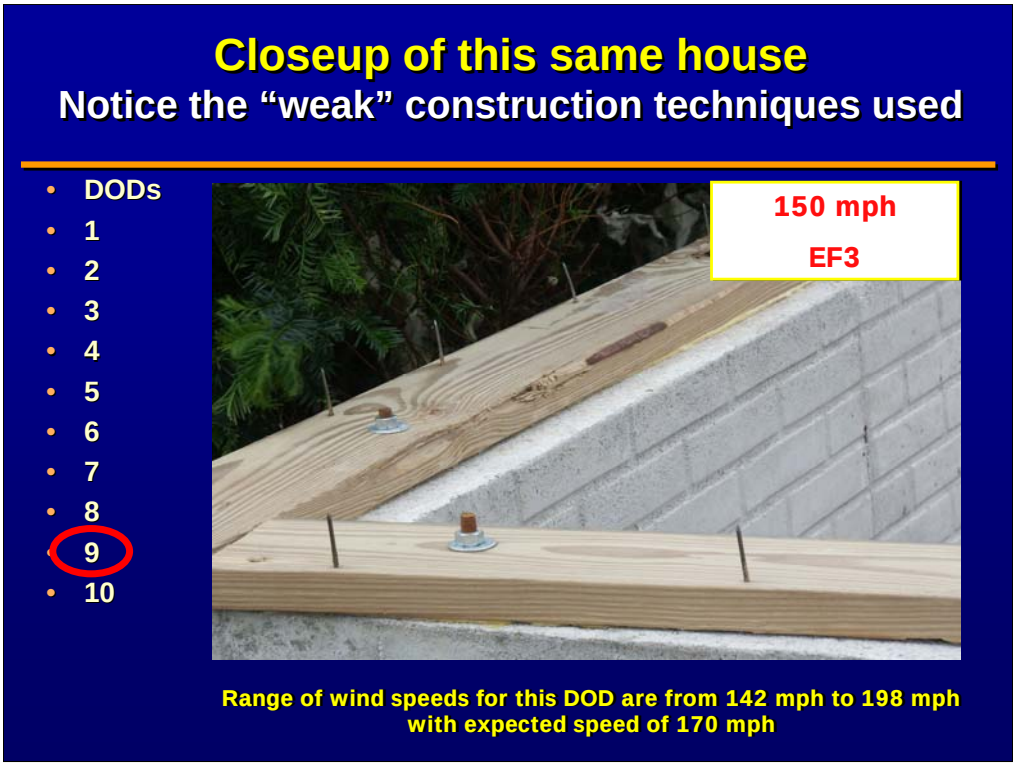


Looking at the north side of the home, the house has shifted off of its foundation. Notice that the home was not anchored down by any rebar or nuts into a bottom plate of the house. Wind engineers affectionately call this a “slider” home. Many homes, especially older ones, in rural areas may not be connected to the foundation.

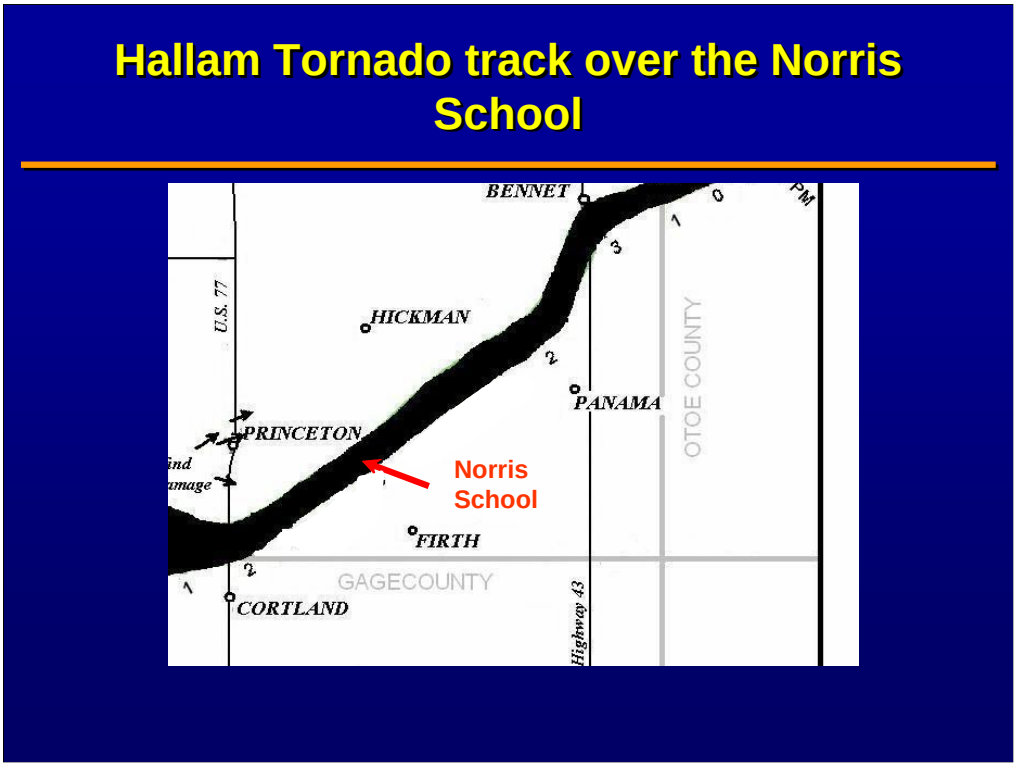
Looking at the DOD table, DOD 5 corresponds to an entire house shifting off of a foundation. The expected wind speed is 121 mph with a lower bound wind speed of 103 mph and an upper bound of 141 mph. Since this home was not anchored well, and shows only siding loss, a wind speed closer to the lower bound would be acceptable. We will choose a 110 mph wind speed that would correspond to a high end EF1.

South of Hallam, not labeled on aerial map

This home was located about one mile south of Hallam. This destruction was typical of several homes south of the town. It is not labeled on the map. We are looking northeast in this photograph. Nothing is left from this home and the debris is blown well away from the structure which would lead one to believe that this house may rated EF5.

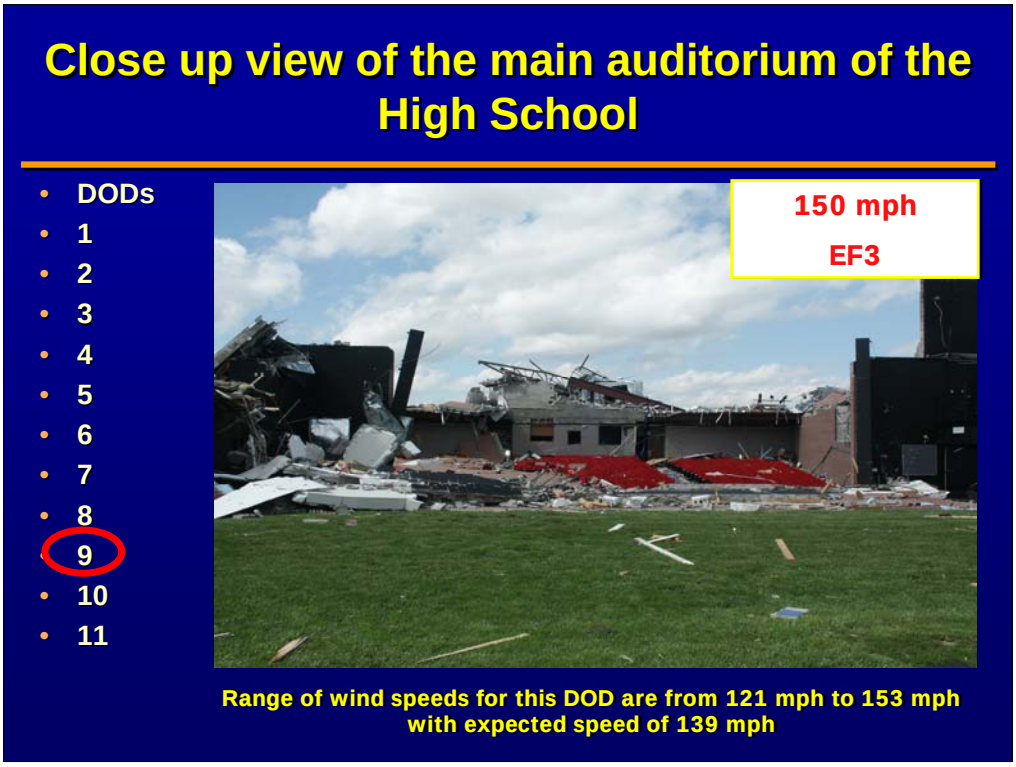


Normally, the studs are nailed into the bottom plate in one of two ways, toe nailed (nailing at an angle from the wall stud to the bottom plate) or Straight-nailed (nailing from the bottom plate into the wall stud). Normally 2 to 4 nails are used per stud. However, the wall studs in this home were attached by only one nail per stud (occasionally there were 2 or 3). Thus, a weaker wind could have created the damage to the home. I opted to use DOD 9 instead of 10 for this which corresponds to most walls collapsed in the bottom floor. The expected wind speed is 170 mph. The Lower bound is 142 mph and the upper bound is 198 mph. We will use a value of around 150 mph wind speed which corresponds to an EF3.

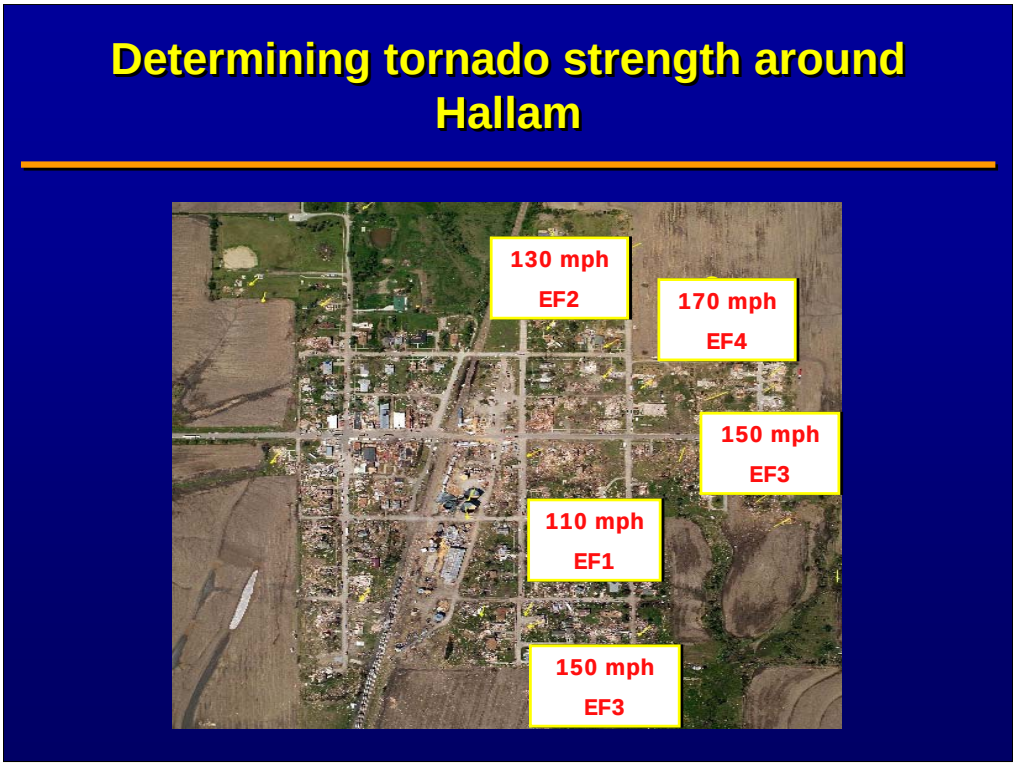


The Norris school sustained significant damage and is located north of the town of Firth. The tornado narrowed significantly here, yet was still strong, demolishing rural homes. School had just finished on Friday the 21st. The tornado occurred on the evening of the 22nd. The following two photos illustrate the damage to this school.

Aerial photo by the Lincoln Journal Star of the Hallam school. Note that severe roof damage occurred to many of the wide-span roofs (auditorium, gymnasium, etc.). The school consists of a junior and senior high school in the foreground as well as an elementary school in the background. Photo courtesy of the Lincoln-Journal Sta.



Here is a close-up of the damage to the main auditorium of the high school. The large-span roof collapsed as well as one of the outer walls. Most of the large-span roofs collapsed in this building as well as some of the roof structure on parts of the elementary school. This damage corresponds to both DOD 7 and 8. We will use 8. The expected wind speed is 125 mph. The lower bound is 108 mph and upper bound is 148 mph. The damage looks to be pretty strong in this case and we will use 140 mph for the wind. This corresponds to EF3. Note that immediately after hitting the school, several homes nearby were totally flattened, which exhibited EF4 damage.



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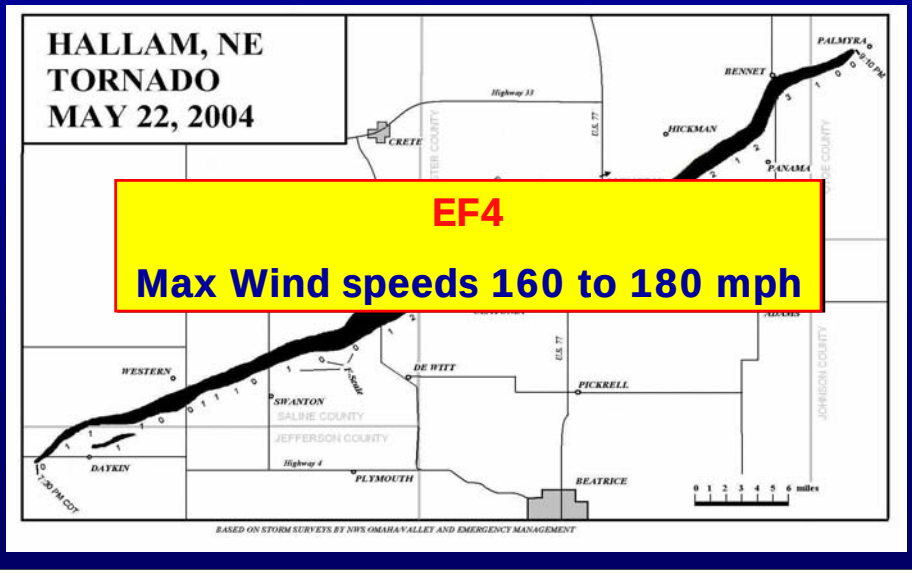
The numbers correspond to photo locations in the case study. Click on the boxes to go to the locations. This map will be available to you via a flash-based popup window linked from the survey locations you see here.

Final EF rating for the Hallam Tornado…



EF4

Max Wind speeds 160 to 180 mph

Summary

- EF-Scale strategy for rating a single DI
  - Start with identifying a DI
  - Then identify a DOD
  - Then adjust the wind depending on the structural integrity of the DI
- EF-Scale strategy for rating a tornado
  - Do a broad survey documenting DIs, note several with the most severe damage
  - For each DI, document the DODs
  - Detailed survey on the most damaged DIs
  - Rate the tornado by applying the highest EF-Scale rating found by a DI…provided that:
    - two confirming DIs of similar rating
    - highest rated DI makes sense given surrounding non DI damage

EF-Scale strategy for rating a single DI

Start with identifying a DI

Then identify a DOD

Then adjust the wind depending on the structural integrity of the DI

Then document the resulting rating

EF-Scale strategy for rating a tornado

Do a broad survey documenting DIs, note several with the most severe damage

For each DI, document the DODs

Detailed survey on the most damaged DIs

Rate the tornado by applying the highest EF-Scale rating found by a DI provided that.

There are two confirming DIs of similar rating

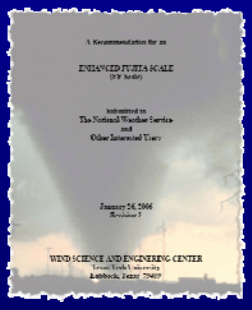
Or the highest rated DI makes sense given surrounding non DI damage

Aerial Storm Surveys are always useful

Vortex marks in Van Wert

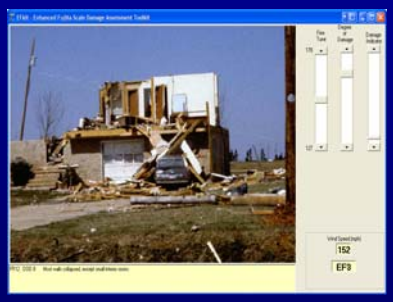
EF-Scale Tools

A Recommendation for the Enhanced Fujita Scale



http://www.spc.noaa.gov/efscale/

The EF Tool Kit



http://wdtb.noaa.gov/courses/ef-scale

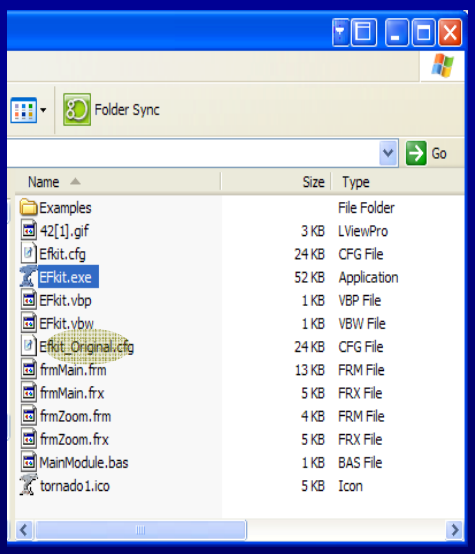
Here are two tools that you'll want to use for the exercises and beyond. First is the document called "A Recommendation for the Enhanced Fujita Scale" of which you can access online. Appendix A shows a list of all the Damage Indicators. Appendix B has a list of all DODs, one table for each DI. You will find it useful as a reference because it shows wind speed graphs for every DOD and DI that includes the expected, lower- and upper-bound wind speed. The second tool is a computer application that you can download and install on your windows PC or laptop. It's designed to be used to get you familiar with the EFkit either in a training environment or out on a survey. Let's go ahead and use the EFkit. Here's how you use it.

EF kit Files

- Download from this site:

  http://wdtb.noaa.gov/courses/ef-scale

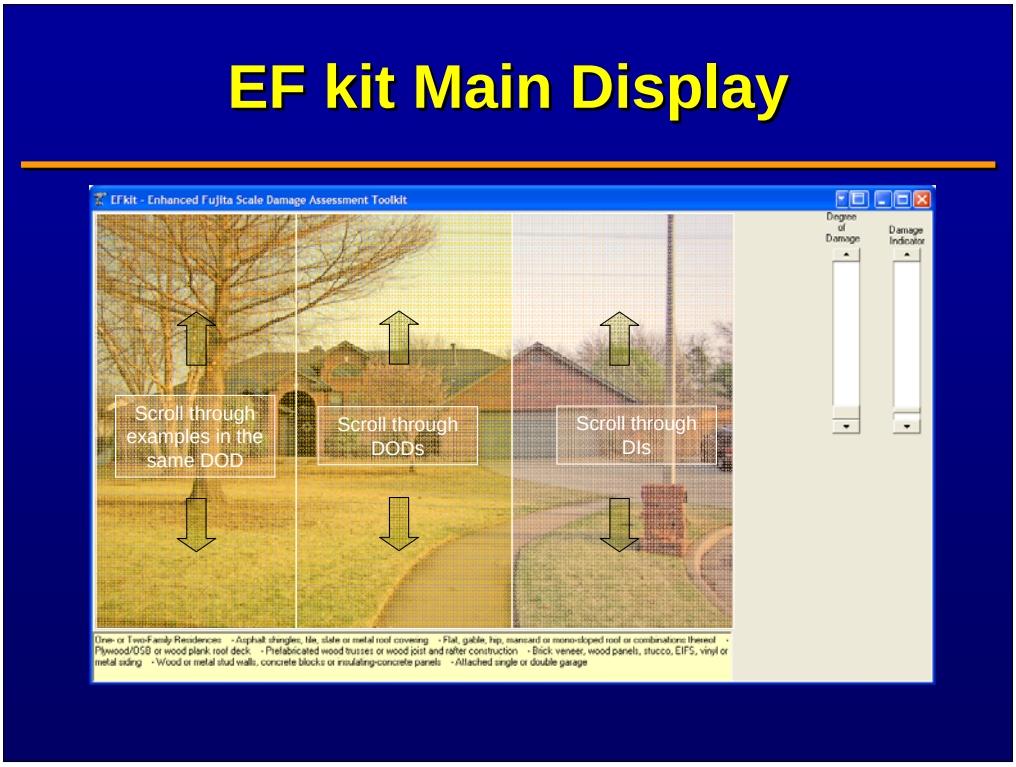
- Make sure you have EFkit folder unzipped
- In the EFkit folder, double click on EFkit.exe



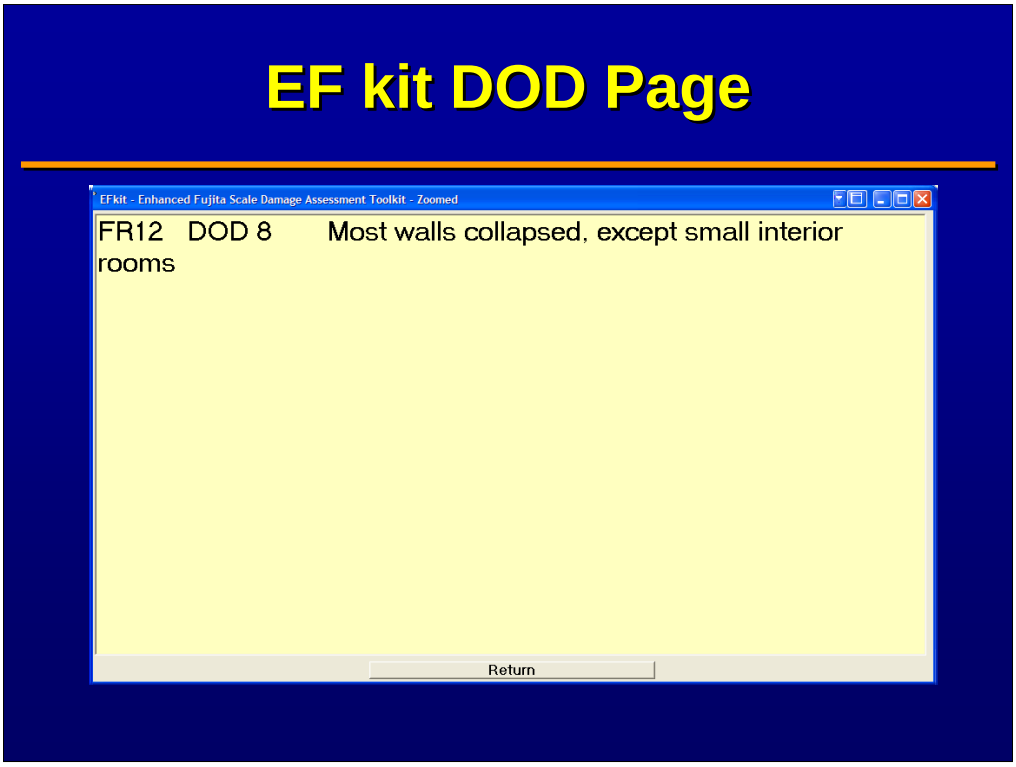
Software developed by Ed Mahoney, WDTB
Image library compiled by Kishor Mehta, TTU

If you haven't downloaded EFkit, go ahead and download it from the site provided in the previous page and here. You'll have to unzip the file if you haven't. Once unzipped, you should see files that look like this. Click on EFkit.exe.

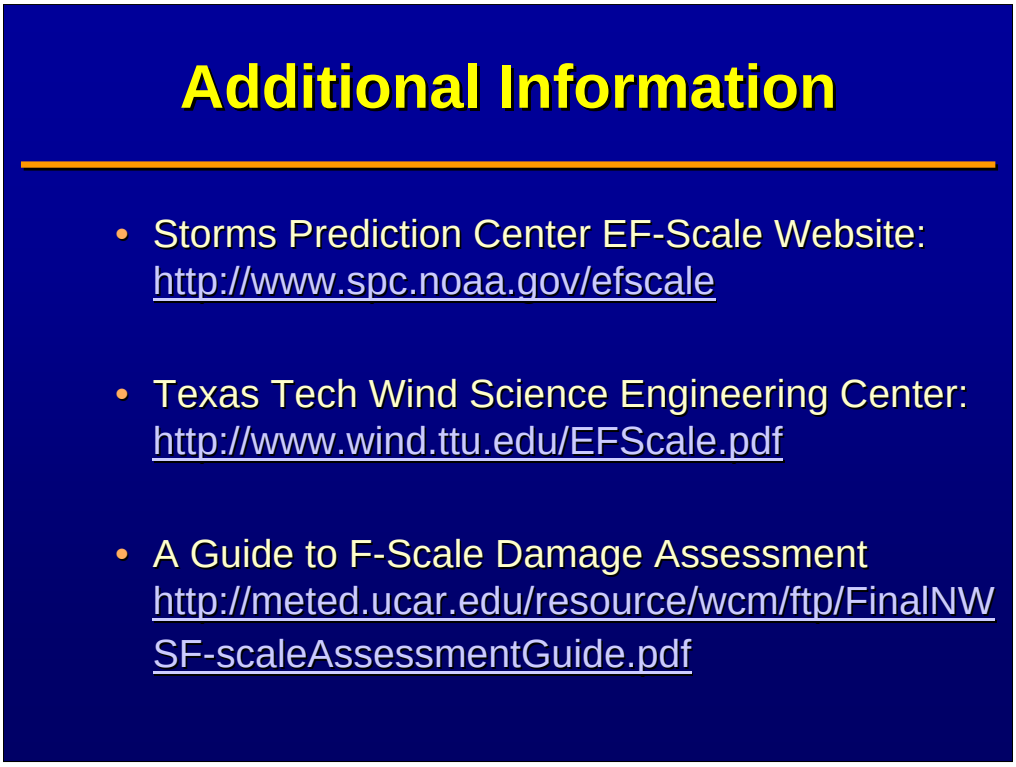
Remember that we will have more updates to the EF-Scale as we document new pictures.



There is the DI display. Just use the scroll bar to move through the DIs. Or you can click on the right third of the main image. To scroll up (down), click on the upper (bottom) right third. All the pictures you see are typical examples undamaged. The DODs can be accessed with the right scroll bar or by clicking in the middle of the main image display. To scroll DODs up (down), click on the upper (bottom) middle third. We'll try to get pictures for all of them. Either way, the descriptions of damage are in text for every DOD. Some DODs may have more than one image available. If so, you can scroll DOD examples up (down), click on the upper (bottom) left third of the main image. When you do scroll beyond the example DI and go into the DODs, the display changes. See the next page.



Going into the DODs adds three displays including the Expected Wind Speed, the EF rating, and then a scroll bar so that you can move between the UB and LB wind speeds. A fourth scroll bar may pop up if the DOD you fall on has more than one picture example. Also, if you click on the text description on the bottom, it'll expand. Click on it again and it will collapse.



Additional information about the Enhanced Fujita Scale is available on the Storms Prediction Center Website and at the Texas Tech University Wind Science and Engineering Center at the addresses listed on this page. The guide to F-scale Damage Assessment is hosted by the WCM resource center at COMET.