Towards an International Fujita-Scale (IF-Scale)

ESSLs Current Tornado and Storm Damage Rating Practice

1) ESSL uses the DI/DoD-approach (Damage Indicator/Degree of Damage) - as used for the EF-Scale

Why?

Because this approach minimizes the subjectivity in the process and leads to comparable results for different damage indicators. Here is our table currently in use for buildings:

	Fujita damage class	f0	f1	f2	f3	f4	f5
	loss ratio (%)	0.1	1	10	50	90	100
	degree of damage → / ↓ damage indicator	light roof damage	significant roof damage	roof gone	walls partly collapsed	largely blown down	blown away
A	weakest outbuilding	F0+	F0+	F1-	F1-	F1+	F2-
B	outbuilding	F0+	F1-	F1+	F2-	F2+	F3-
C	strong outbuilding/ weak framehouse	F0+	F1+	F2-	F3-	F3+	F4-
D	weak brick structure/ strong framehouse	F1-	F1+	F2+	F3+	F4-	F5
E	strong brick structure	F1-	F2-	F3-	F4-	F5	F5
F	concrete building	F1-	F2+	F3+	F4+	F5	F5

Table 1: DI-/DoD-decision matrix for buildings

A … like a doghouse or unanchored light outbuildings
B … like huts and barns, anchored light outbuildings
C … like the typical US-midwest framehouses, if weakly anchored/connected to the foundation
D … like the typical US-midwest framehouses, if well anchored and connected. I Europe typically single-row brick strucktures (mainly 2-dimensional single-row brick walls – like garden walls – fall into B or C). This category best corresponds to the original Fujita-scale.
E … the typical central European masonry house
F … steel-reinforced concrete buildings. Some historic fort-like buildings (castles) and some Mediterranean-style buildings in wind-prone-areas (like in Dalmatia) also fall into this category with their extremely thick stone-walls (if well-built and kept renovated).

… and for plants:

	Fujita damage class	f0	f1	f2	f3	f4	f5
	loss ratio (%)	0.1	1	10	50	90	100
	damage prevalence → / ↓ damage indicator	extremely isolated	isolated	significant	frequent	prevalent	total
G	branches - leafy	< F0	F0+	F1-	F1+	F2-	F3-
H	- bare	F0-	F1-	F1+	F2-	F2-	F3-
I	tree stands - diseased/ unstable	< F0	F0-	F0+	F0+	F1-	F1-
J	- strong	F0+	F1-	F1+	F1+	F2-	F2-
K	edge trees, hedges, underwood	F1-	F1+	F2-	F2+	F3-	F3-

Table 2: DI-/DoD-decision matrix for vegetation

2) ESSL doesn't use the current EF-scale. Why?

We like the DI-/DoD-approach, as said before, but many EF damage indicators are of little use outside the US. In addition, research during the past years increasingly showed (e.g. by measured radar wind velocities very close to the ground) that the original wind speed estimates of the Fujita scale do occur in nature. ESSL participates in the EF-Scale redesign process currently ongoing in the USA, but as long as the EF-scale is of little use in Europe and as long as the EF wind-speed estimates are not better routed in science, ESSL will stay with the original values, also for reasons of database homogeneity.

3) ESSL prefers center-values for windspeeds in the different F-Scale classes together with error bars. Why?

Because different errors can reduce the precision and the accuracy of our estimates. In addition, the resolution is limited to (half) scale classes. Our practice shows that for up to F3 (or at least F2) half scale classes can often be distinguished, while for F4 and F5 not. Strict wind-speed class boundaries suggest an unrealistic precision.

4) ESSLs approach for error bars is the following:

- The precision error can only be estimated subjectively: We estimate that with 90% confidence we are within 1 F-scale off at high ratings, and a half F-scale at low ratings.
- The accuracy error (how many m/s is F3 damage?) can only be estimated by taking a typical difference between the F and EF-scale estimates.
- Adding these errors
  Err = sqrt(Err_precision^2 + Err_acc^2)
  yields a fairly consistent 30% relative error for the entire scale
- We estimate that a tornado estimated to have maximum winds of 100 m/s with 90% probability actually had maximum winds somewhere in the range between 70 and 130 m/s.

5) Based on was said before, here is the "practical scale" currently in use at ESSL:

F-Class	m/s	m/s error	km/h	km/h error	mph	mph error
F0-	25	±7	90	±27	56	±17
F0	**27**	**±8**	**97**	**±29**	**60**	**±18**
F0+	30	±9	108	±32	67	±20
F1-	37	±11	133	±40	83	±25
F1	**41**	**±12**	**148**	**±44**	**92**	**±28**
F1+	45	±14	162	±49	101	±30
F2-	55	±16	198	±59	123	±37
F2	**60**	**±18**	**216**	**±65**	**134**	**±40**
F2+	65	±20	234	±70	145	±44
F3-	75	±22	270	±81	168	±50
F3	**80**	**±24**	**288**	**±86**	**179**	**±54**
F3+	90	±27	324	±97	201	±60
F4	**105**	**±32**	**378**	**±113**	**235**	**±70**
F5	**130**	**±39**	**468**	**±140**	**291**	**±87**

Table 3: Best estimates and 30 % relative error for the practical F-Scale

6) Why this "practical scale"?

Because it:

- allows for uncertainty in the estimate
  (like the Feuerstein et al. paper, or Doswell)
- does not use wind speed ranges that can be confused with error bars
- does not imply a lot more accuracy than can reasonably be achieved with damage assessments (which the T or TORRO scale does)
- corresponds to the 'good old' Fujita-scale, with refinements where they can reasonably be made (following Holzer et al. and in line with discussions after the Feuerstein et al. paper)

- its resolution is slightly greater than its precision. Where accuracy is lowest, resolution is too.
- its half-scale classes roughly correspond to the T-Scale (TORRO-Scale) used in some European countries, enabling a conversion.

6) How can we approach an International F-Scale (IF-Scale)?

We think that both, generic (like the ones above) and regional damage indicators (based on regional building codes or typical structures, like the ones in the current EF-Scale) need to be included in a future IF-Scale.

Additional damage indicators in the future could include for example:

- Cars
- Engineered structures (HV power poles, concrete barriers, noise protection walls)
- Non-engineered buildings (typically older ones traditionally built), masonry stone building (typical in Mediterranean countries), fort-type stone and brick structures (historical buildings with very thick walls), strong log construction building (typical in nordic countries)
- Different strengths of roof connections
- Roof types and roof cover types (especially interesting if only the roof is damaged)
- Manufactured homes and wall to foundation connection types
- Concrete steel-reinforced or not
- Different tree types

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