Atmosphere and Ocean Research Institute
The University of Tokyo

資料4－1

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Development and Implementation of Japanese Enhanced Fujita Scale

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1. Introduction

Comparison of tornadoes between Japan and US

	US	Japan	US/Japan
Annual frequency	1253[*1]	21[*3]	60
Annual frequency per 10^4km	1.32	0.54[*3]	2.4
Annual fatalities	70[*2]	0.6[*3]	120

*1:NOAA (1991-2010)
*2:NWS(1986-2015) http://www.nws.noaa.gov/om/hazstats.shtml
*3: Niino et al. (1997) (1961-1993)

Tornadoes are not significant weather disaster in Japan!
(cf. Annual fatalities due to wind and flood damage are 76.
http://www.fdma.go.jp/html/hakusho/h26/h26/pdf/part1_section5.pdf)

In 2006, two tornadoes caused 12 fatalities.

Nobeoka tornado on 17 SEP 2006 (F2)

(Mashiko et al., 2009,MWR)

(Photo: Wind Engineering Research Center, Tokyo Polytechnic University)

3 fatalities, 143 injuries

79 housese completely destroyed

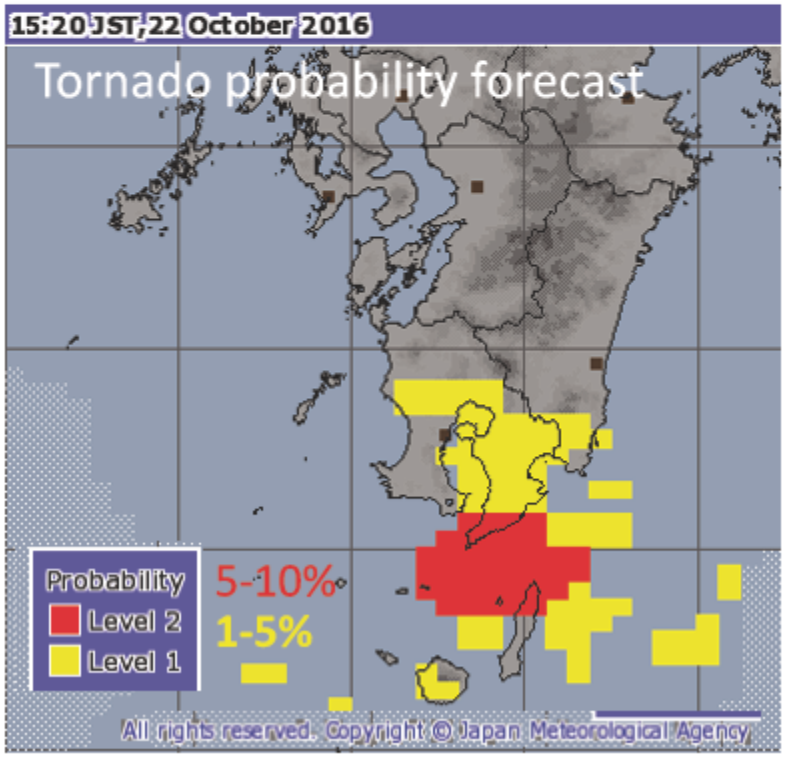
348 houses severely damaged

Saroma tornado on 7 NOV 2006 (F3)

9 fatalities, 33 injuries

JMA* enhanced their operations related to tornadoes:

- Modification of 20 conventional radars to Doppler radars (completed by 2012)
- Tornado advisories (starting from 26 March 2008)
- One hour forecast of tornado probability for 10 km mesh (starting from May 2010)
- Enhancement of damage survey of hazardous winds to determine the cause and strength of the winds

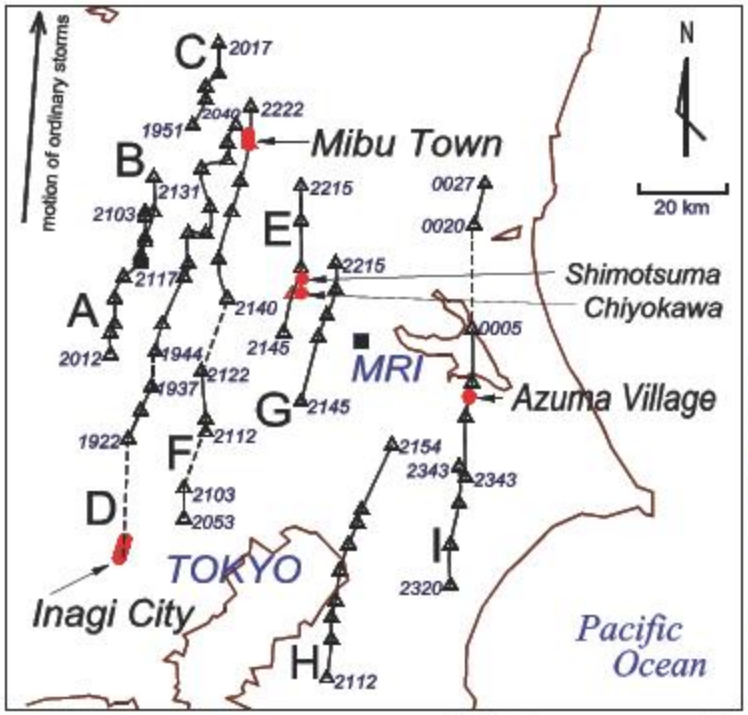


*JMA: Japan Meteorological Agency

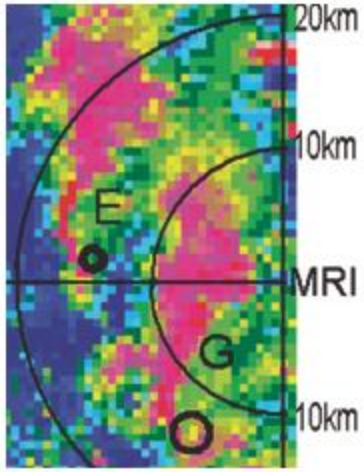
Rating of tornado intensity in Japan

- Before 1990 No systematic rating
- Since 1991 Rating based on F-scale by JMA

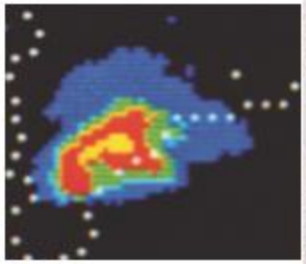
Mibu tornado on 19 SEP 1990 (F2)



Mini-supercell
(Suzuki et al., 2000, MWR)



Mobara tornado on 11 DEC 1990 (F3)



Classic supercell

(Niino et al., 1993, MWR)

- Fujita-scale (Fujita, 1971)
  slightly modified by himself to adapt to Japanese houses (Fujita, 1973)
- Enhanced Fujita-scale (Texas Tech Univ., 2004)
  implemented by NWS in the US (FEB 2007):
  28 Damage Indicators(DIs) & Degree of Damage(DOD)
- Canadian EF-scale (Sills, 2013)
  implemented by Environment Canada(APR 2013):
  31 DIs

Necessity for developing **Japanese EF-scale** which is based on DIs commonly found in Japan, and is easily used for damage surveys by staff of local meteorological observatories.

2. Design for the Japanese Enhanced Fujita(JEF)-scale

Advisory Committee for Rating Intensity of Tornadoes

organized by JMA in JUL 2013

- Chair: Yukio Tamura (Tokyo Polytech Univ.)
- Vice-Chair: Hiroshi Niino (Univ. of Tokyo)
- 7 members: Masaru Ito, Hitomitsu Kikitsu, Junji Maeda, Yasuo Okuda, Hiroyasu Sakata, Yoshinori Shoji, Satoru Suzuki

Guideline for the JEF-Scale in DEC 2015 (in Japanese).
JMA operationally implemented it for rating tornado intensities from 1 APR 2016.

Three steps for designing the JEF-scale:

1) Select DIs and DODs
2) Estimate wind speeds corresponding to DIs and DODs
3) Determine the relation between the wind speeds and JEF-scale class

1) Damage Indicators (DIs): 30

Houses and Buildings

No.	DI
1	Wooden residential houses or stores
2	Industrialized steel-framed houses (prefabricated houses)
3	RC apartment houses
4	Temporary buildings
5	Large eaves
6	Steel framed warehouses
7	Small wooden non-residential buildings
8	Greenhouses, Gardening facilities
9	Wooden livestock sheds

Other structures

No.	DI
10	Small sheds
11	Shipping containers
12	Vending machines
13	Light vehicles
14	Ordinary vehicles
15	Large vehicles
16	Train cars
17	RC utility poles
18	Ground standing billboards
19	Traffic sign boards
20	Carports

No.	DI
21	Hollow concrete block (HCB) walls
22	Wooden, plastic, aluminum or mesh fences
23	Wind or snow breaking fences for traffic roads
24	Net fences
25	Broad-leaved trees
26	Coniferous trees
27	Gravestones
28	Road surface
29	Temporary scaffolds (with wall ties)
30	Gantry cranes

2)Estimated wind speed corresponding to DIs and DODs

DI- 1 Wooden residential houses or stores

1 or 2-story conventional wooden houses (including dwelling houses combined with stores), 2-story wooden multiple dwelling houses

DOD	Damage Descriptions		Wind Speed (m/s)		
			Rep.	LB	UB
1	Visible minor damage (breakage of glasses)		30	25	35
2	Minor loss (blow-off)/ unevenness of roofing materials	Clay tile roofing	35	25	50
		Metal sheet roofing	40	30	55
3	Major loss (blow-off) of roofing materials	Clay tile roofing	45	30	60
		Metal sheet roofing	50	40	65
4	Destruction/blow-off of eaves or sheathing roof boards		50	40	65
5	Damage (deformation, cracks, etc.) to walls due to deformation of main frames		55	40	65
6	Loss of metal wall cladding		60	45	70
7	Destruction/blow-off of roof frames/components		65	50	75
8	Major destruction/collapse of main structures and frames		75	55	85

DI- 1 Wooden residential houses or stores

1 or 2-story conventional wooden houses (including dwelling houses combined with stores), 2-story wooden multiple dwelling houses

DOD	Damage Description	Wind Speed (m/s)		
		Rep.	LB	UB
1	Visible minor damage (breakage of glasses)	30	25	35

(Photo:
National Institute for Land and Infrastructure Management
Building Research Institute)

DI- 1 Wooden residential houses or stores

1 or 2-story conventional wooden houses (including dwelling houses combined with stores), 2-story wooden multiple dwelling houses

DOD	Damage Description		Wind Speed (m/s)		
			Rep.	LB	UB
2	Minor loss (blow-off)/ unevenness of roofing materials	Clay tile roofing	35	25	50
		Metal sheet roofing	40	30	55

(Photo:
National Institute for Land and Infrastructure Management
Building Research Institute)

DI- 1 Wooden residential houses or stores

1 or 2-story conventional wooden houses (including dwelling houses combined with stores), 2-story wooden multiple dwelling houses

DOD	Damage Description		Wind Speed (m/s)		
			Rep.	LB	UB
3	Major loss (blow-off) of roofing materials	Clay tile roofing	45	30	60
		Metal sheet roofing	50	40	65

(Photo:
National Institute for Land and Infrastructure Management
Building Research Institute)

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DOD	Damage Description	Wind Speed (m/s)		
		Rep.	LB	UB
4	Destruction/blow-off of eaves or sheathing roof boards	50	40	65

(Photo:
National Institute for Land and Infrastructure Management
Building Research Institute)

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DOD	Damage Description	Wind Speed (m/s)		
		Rep.	LB	UB
6	Loss of metal wall cladding	60	45	70

(Photo:
National Institute for Land and Infrastructure Management
Building Research Institute)

DI- 1 Wooden residential houses or stores

1 or 2-story conventional wooden houses (including dwelling houses combined with stores), 2-story wooden multiple dwelling houses

DOD	Damage Description	Wind Speed (m/s)		
		Rep.	LB	UB
7	Destruction/blow-off of roof frames/components	65	50	75

(Photo:
National Institute for Land and Infrastructure Management
Building Research Institute)

DI- 1 Wooden residential houses or stores

1 or 2-story conventional wooden houses (including dwelling houses combined with stores), 2-story wooden multiple dwelling houses

DOD	Damage Description	Wind Speed (m/s)		
		Rep.	LB	UB
8	Major destruction/collapse of main structures and frames	75	55	85

(Photo:
National Institute for Land and Infrastructure Management
Building Research Institute)

3)Relation between wind speeds and JEF-scale classes

- 215 photos of tornado damage during 2007-2013 (with those due to three F3 tornadoes after 1999) were used.

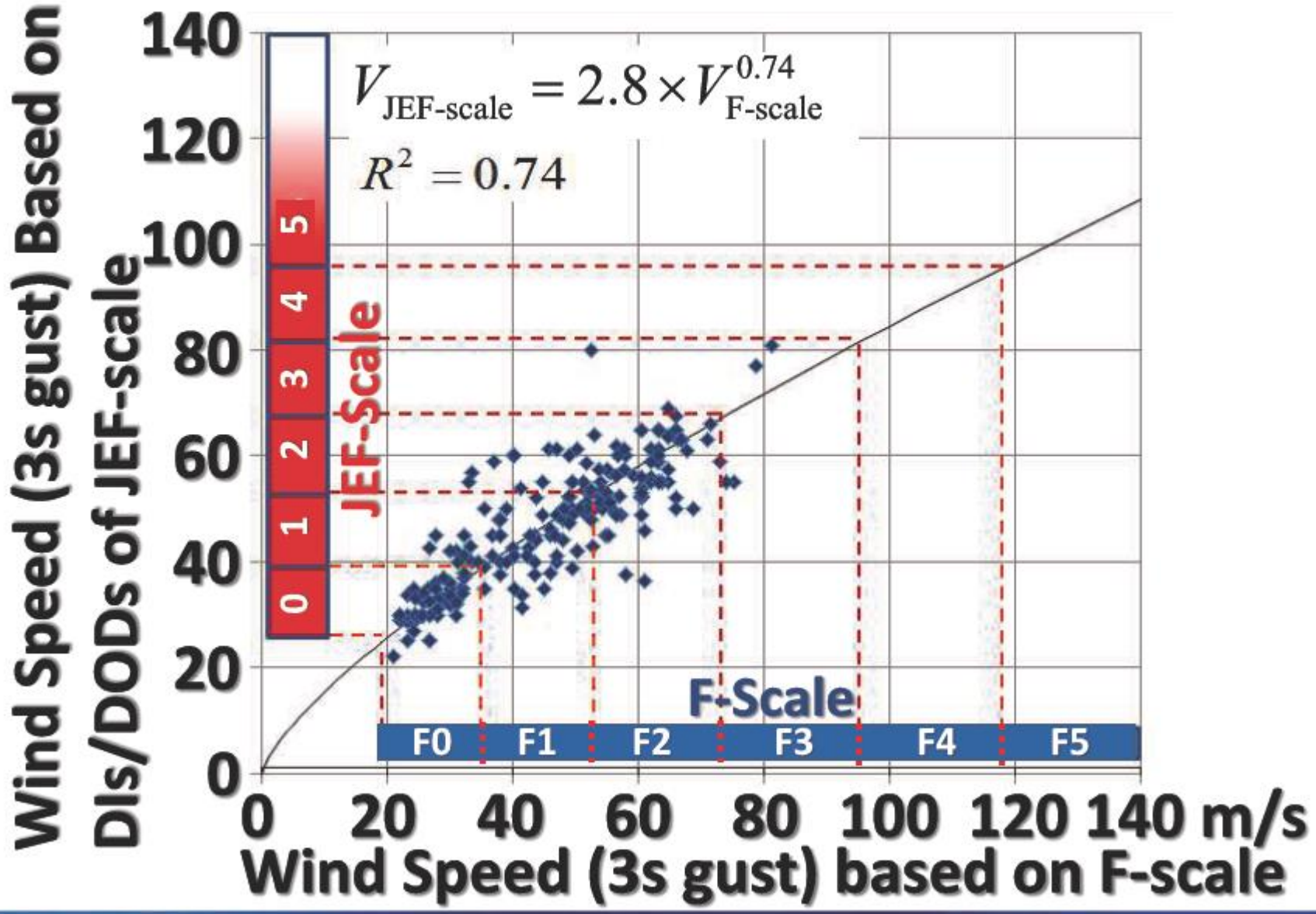
- Wind speed estimation based on F-scale

  5 JMA experts examined each photo, determined the F-scale with subdivisions F*n*+, F*n*, and F*n*-, and the corresponding wind speeds converted to 3-second gusts with Durst's (1960) method were averaged.

- Wind speed estimation based on JEF-scale

  5 wind engineers estimated the wind speeds based on the DIs and DODs and these wind speeds were averaged.

Relation between F-Scale and JEF-Scale



Comparison of F-, EF- and JEF-Scales

F-Scale		EF-scale		JEF -Scale	
F	3s gust (m/s)	EF	3s gust (m/s)	JEF	3s gust (m/s)
F0	19-35	EF0	29-38	JEF0	25-38
F1	35-52	EF1	38-49	JEF1	39-52
F2	52-72	EF2	50-60	JEF2	53-66
F3	72-94	EF3	61-74	JEF3	67-80
F4	94-117	EF4	74-89	JEF4	81-94
F5	117-142	EF5	89-	JEF5	95-

JEFn: $14n$+25 - $14n$+38(m/s)

Linear!(cf. Dotzek, 2008)

First application of JEF-scale: Ohshu City tornado on 20 June 2016 was rated as JEF1(estimated max. wind speed: 45m/s).

So far 14 tornadoes have been rated by JEF-scale (with estimated max. wind speed rounded to multiples of 5m/s) except one categorized to "unknown" due to lack of DIs.

DI 1: Wooden residential houses or stores
DOD 8: Major destruction/collapse of main structures frames (LB 55m/s)
(Chikugo City, 28 September, 2016)

DI 27: Gravestones
DOD 1: Slip or Overturning (LB 45m/s)
(Minami-Boso City, 22 August, 2016)

4. Summary and future subjects

- JEF-scale with 30 DIs was developed in December 2015 and was implemented by JMA in April 2016.
- The tornado database of JMA now records both the estimated max. wind speed and JEF-scale class.
- Advisory Committee for Rating Intensity of Tornadoes plans to review the performance of JEF-scale at least once a year.
- Necessity for accumulation of tornado data for long term: # Only 20 tornadoes per year.
  # Lack of F4 and F5 tornadoes.

*English version of the guideline is under preparation, and will be published online by JMA.


Thank you !
(courtesy of Kazumi Sasaki)
Mobara tornado on 11 DEC 1990