Supplement of Nat. Hazards Earth Syst. Sci., 23, 2171–2201, 2023
https://doi.org/10.5194/nhess-23-2171-2023-supplement

Natural Hazards and Earth System Sciences
Open Access
EGU

Supplement of

Review article: A European perspective on wind and storm damage – from the meteorological background to index-based approaches to assess impacts

Daniel Gliksman et al.

Correspondence to: Christian L. E. Franzke (christian.franzke@pusan.ac.kr)

$SSI_{Lamb} = v^3 AD$	Lamb (1991)
$SSI_{Leckebusch} = \sum_{t}^{T} \sum_{k}^{K} \left[max\left(0, \frac{v_{k,t}}{v_{perc,k}}\right)^3 * A_k \right]$	Leckebusch et al. (2008)
$LI_{Pinto} = \sum_{k} \left(\frac{v_k}{v_{98k}}\right)^3 * I_k * P_k * L_k$	Pinto et al. (2012)
$SSI_{Haylock} = \sum_{k} cos\, lat_k [0, v_k - th]^3$	Haylock (2011)

Table S1. Storm severity and loss indices. *A* denotes the area affected by damaging winds, *D* the duration of occurrence of damaging winds, I_k is an an indicator of whether the wind speed exceeds the 98th percentile or not, *k* a location or a grid box index, L_k is an indicator of whether the grid box is over land or sea, lat_k is the latitude at a grid point, *LI* is a loss index, P_k is the population per grid point, *SSI* is the storm severity index, *th* is a wind speed threshold, *t* is a time index, *v* denotes the maximum daily wind speed, and v_{perc} a local percentile of daily maximum wind speed.

Table S2: List of area specific wind speed thresholds and their potential impacts and consequences. Wind gusts values correspond to 3 s averages.

Affected Area/Scale of impact	Threshold [m / s]	Consequences	Reference
Forest (refers to 10 m)			
Local (specific locations)	22-25 (gust)	Limited area of damage. Might not be visible from outside the forest.	Derived from (Gardiner et al., 2010) (Gardiner et al., 2013) (Gardiner et al., 2016) Gardiner (2021) (Mitchell, 2013) (Quine and Malcolm, 2007) (Quine, Gardiner, Moore, 2021) (Usbeck et al., 2010) (Valta et al., 2019)*
Stands/Forest	25-32 (gust)	Individual stands up to the forest level are affected. Damage level is meaningful for the affected forest and for short-term forest planning.	*
County to Department	32-40 (gust)	Affects are important at the scale of whole forests and departmental jurisdictions and have impacts on long term planning.	*

Regional to National	40-45 (gust)	The damage is so severe, that it disrupts forest management and planning and severely affects timber prices at a regional or national level.	*
National/Supernational	>45 (gust)	The storm intensity is so high that damage can occur across several countries and the forest industry and wood supply are affected for a large part of Europe.	*
Urban (refers to 10 m)			
Local	21.5 ± 3.5 (gust)	** Loose light objects lifted from the ground. Scaffolding may be overturned. Slight damage to marquees and tents may occur. Tiles in exposed areas may come loose. No damage to loadbearingstructures.	(Feuerstein et al., 2011)
local	29.0 ± 4.0 (gust)	** Light objects and garden furniture can be knocked over or fly through the air.. Wooden fences may be toppled. Minor damage to roofs (tiles and sheets may come loose and be blown down). Minor damage to light outbuildings. No structural damage.	(Feuerstein et al., 2011)
	37.0 ± 4.0 (gust)	** Heavier objects are lifted from the ground and can become dangerous projectiles.	(Feuerstein et al., 2011)

		Caravans and trailers can be overthrown. Noticeable damage to tiled roofs and unstable flat roofs. Minor to moderate damage to light outbuildings. Initial damage to components of solid buildings possible.	
	41.0 ± 4.5 (gust)	** Numerous caravans and trailers are overthrown. Tiled roofs and unstable flat roofs are heavily damaged. Moderate damage to light outbuildings. Isolated damage to structural elements of perament buildings.	(Feuerstein et al., 2011)
Transport (refers to 10 m)			
Air - local	13 (mean wind speed)	For crosswinds need to change runways	(Pejovic et al., 2009)
Railways and road - local	>17 (gust)	Disrutptions, e.g. roads blocked due to windthrow	(Vajda et al., 2014)
Shipping - Local	>18 (mean wind speed)	Risk of sliding containers and flooding of open cargo holds. Maximum wind speed for crane operations	(Club et al., 2011) (Leviäkangas et al., 2011)
Road	>20 (mean wind speed)	Increasing number of wind-related accidents due to rollover and sideslips	(Snaebjornsson et al., 2007)
Air/Road/Rail - Larger Area	>25 (gust)	Delays or cancellations towards	(Vajda et al., 2014)

		windthrow or electricity cuts	
Rail - Large Area	>30 (gust)	Shaking and damage of overhead cables	(Thornes and Davis., 2002)
Air/Rail/Road/ Water	>32 (gust)	Longer power failures lead to delays and cancellation. Damages to traffic control devices and structures can occur. Airports close and ferries stay at the harbors due to reduced visibility and high waves	(Vajda et al., 2014)
Agriculture (refers to 10 m)			
Local	18.5-26.5 m/s (gust, varies across different crops, vegetables, etc.)	Damage to leaves due to windblown dust and rubbing leaves. Yield loss due to lodged fields	(Rouse and Hodges, 2004) (Joseph et al., 2020) (Baker et al., 2014)
Local	9.0-14.5 m/s (gust)	Soil loss to wind erosion, i.e. erosion threshold	Shahabinejad et al. (2019)
Wind Energy (refers to hub-height)			
	2.5-4.5 (mean wind speed)	Start of energy production for wind turbines (cut-in)	(Quaschnig, 2016)
	20-34 (mean wind speed)	Automatic shutdown of wind turbines (cut-out)	(Christakos et al., 2016) (Quaschnig, 2016)
	50-70 (mean	Damage of wind turbines	(Quaschnig, 2016)

	wind speed)		

* All references used in the forest section are the same for each wind speed range.

** Reproduced from Feuerstein et al. (2011)

Table S3. The articles used in the assessment of topographic indices usefulness. “1” and “0” denotes usefulness or not useful, respectively. TPI stands for topographic positioning index.

	Elevation	Slope	Aspect	TOPEX	Curvature	Roughness	Distance to ridge	Distance to river	Inflection	Latitude	TPI	TRI - ruggedness
Albrecht et al., 2012	0			1								
Albrecht et al., 2013	1			1								
Albrecht et al., 2019	0			1								
Batke et al., 2014	0	0	1									
Decker, 2018												
Díaz-Yáñez et al., 2019	1	1								1		
Hanewinkel et al., 2004	0	0	1	0								
Hanewinkel et al., 2014	0	1	1		1							
Jung et al., 2016	0	1	0	1		0						
Kramer et al., 2001	1	1							1			
Krejci et al., 2018	1	0	0		0							
Mayer et al., 2005	1	1										
Mitchell et al., 2001	0	0	0	1								
Morimoto et al., 2019		1		1								
Murshed and Reed, 2016	0	0	0	1								
Pasztor et al., 2015	1	0	0									
Schindler et al., 2012	0	0	0	1	0		0	0				
Schindler et al., 2016	0		0	1	0	1						
Schütz et al., 2006	0	1	1									
Scott and Mitchell, 2005	0	0	0	0								
Suvanto et al., 2016		1	1									
Suvanto et al., 2018		1	1								0	
Takano et al., 2016		0		0								
Taylor et al., 2019		0	0	1								
Torun and Altunel, 2020	1	1							1			0

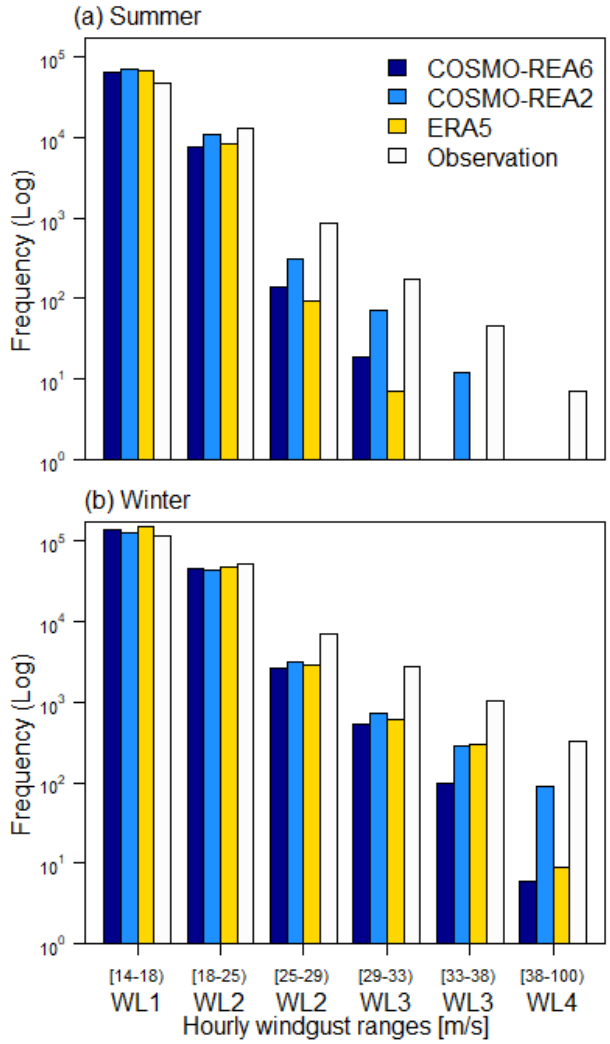

Figure S1: Frequency of threshold exceedance for warning level (WL) 1-4, used at DWD, of hourly wind gusts. The wind speed intervals in m/s corresponding to the different WL are indicated by bracketed numbers under the panels. The Observations (white) come from 145 locations of the DWD-Station network and are compared to the reanalyses ERA5, COSMO-REA6 and COSMO-REA2. Panels show the frequencies for summer months (a) and winter months (b) for the years 2007-2013.