CEN/TC250/SC1
Eurocode 1 - Actions on structures

SC1.T6 Interdependence of climatic actions (wind, snow, thermal and atmospheric icing) and glass structure

Modelling of climatic action for Code implementation

Francesco Ricciardelli

75th JCSS Meeting
Dublin, December 8-9, 2021

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Dipartimento di Ingegneria

WHO

Svend Ole HANSEN (Svend Ole Hansen ApS, DK)
Filippo LANDI (University of Pisa, IT)
Jana MARKOVA (Czech Technical University, CZ)
Harold McINNES (Meteorolosisk Institutt, NO)
Francesco RICCIARDELLI (University of Campania, IT)
Nick MALAKATAS
Jens BRUNNER

WHAT

- Reduction in number of National Choices (NDPs)
- Enhanced ease of use
- Variability and interdependence of climatic actions: Probabilistic basis and load combination factors
- Structural glass structures: Snow loads, wind actions and thermal actions

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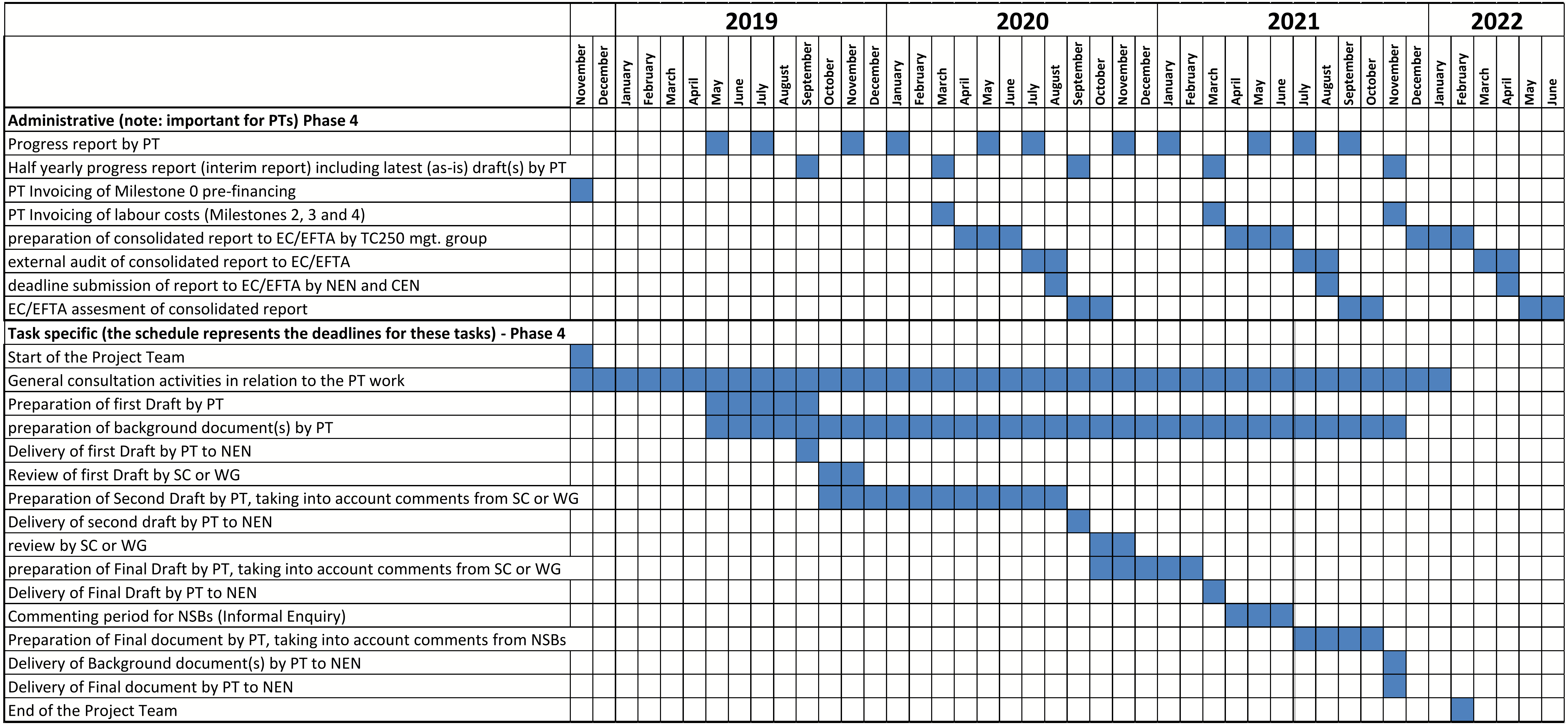

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RECIPIENTS: Code writers

(*Semi-probabilistic people*)

Project directors

(*Reliability-based people*)

SCOPE: Summarize physical aspects of climatic actions and their probabilistic modelling

Point out issues in the calibration of γ and ψ factors for climatic actions

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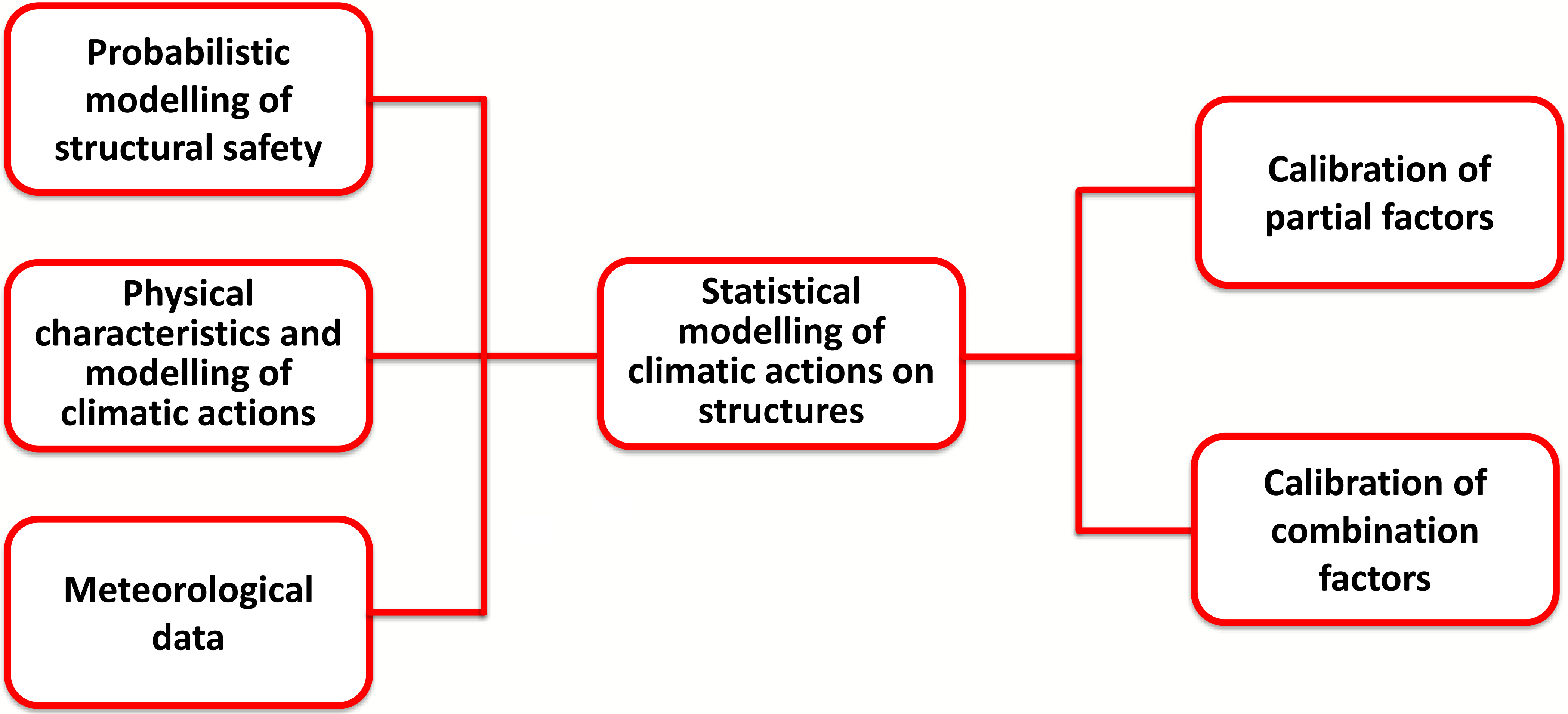
Probabilistic basis for determination of partial safety factors and load combination factors

BACKGROUND DOCUMENT

30 November 2021



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BACKGROUND DOCUMENT

- Brief history
- EN1990 implementation
- Calibration

11 pages

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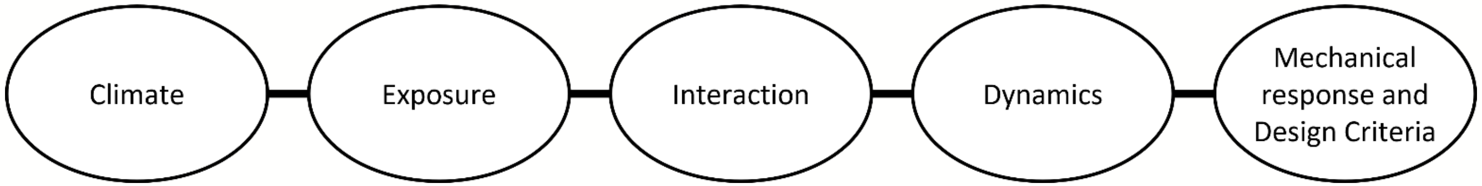
40 pages

The Alan G. Davenport Wind Loading Chain



Climatic Action Loading Chain

Climatic Action	Climatic Variable	Exposure Factor(s)	Interaction Factor(s)	Dynamic Factor
Snow Load	q_{sk}	c_e	$c_t \cdot \mu_i$	1
Wind Action	q_b	c_e c_s	c_p	c_d
Thermal Action	T_s	T_0 T_{out}	T_{in} T_{out}	1
Atmospheric Icing	$i_{b,o} \cdot c_{dir} \cdot c_{season}$	c_h	$c_{object} \cdot c_{orient}$	1

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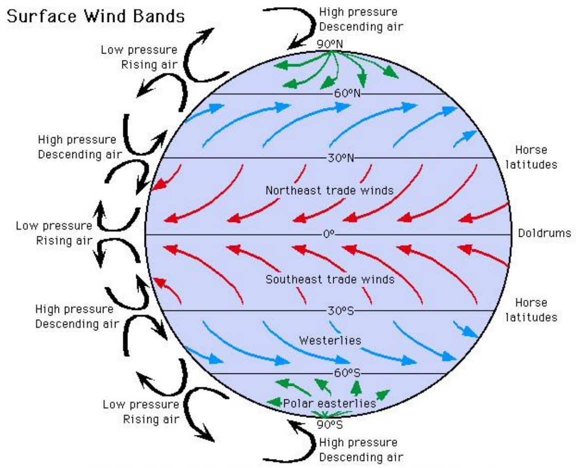

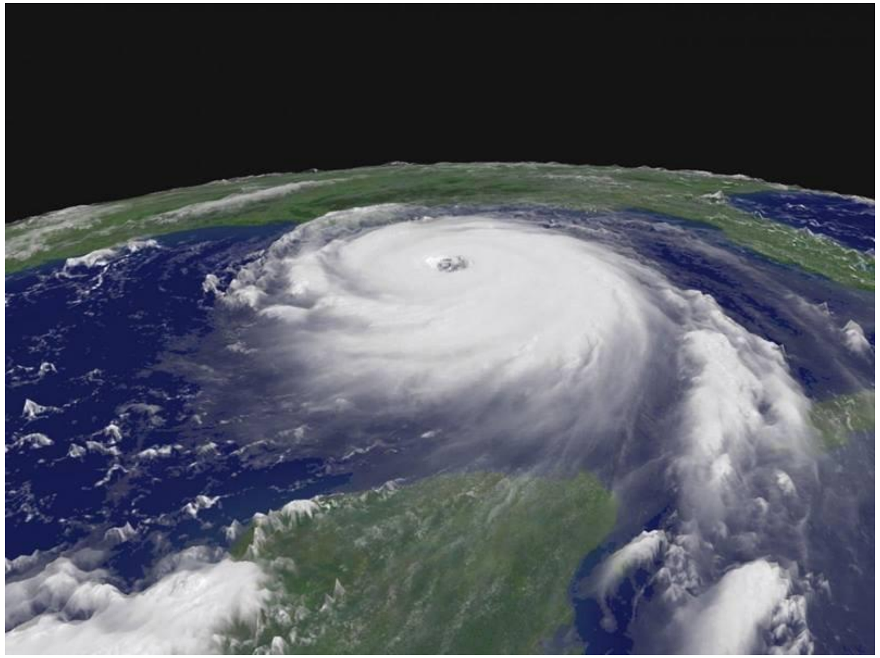

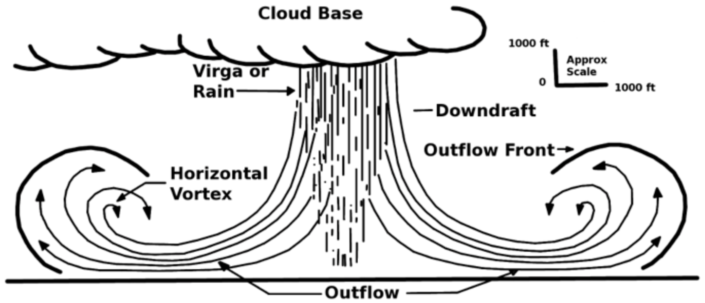

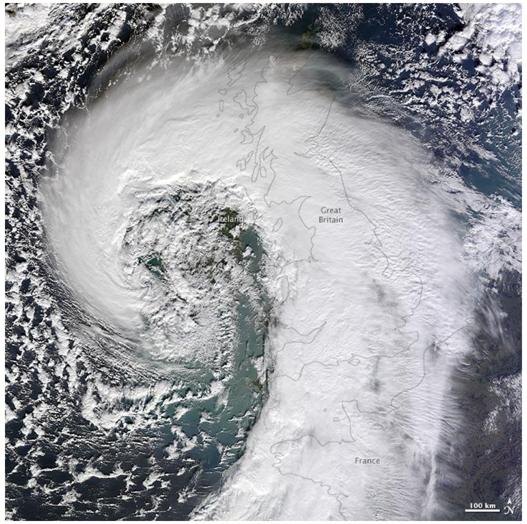

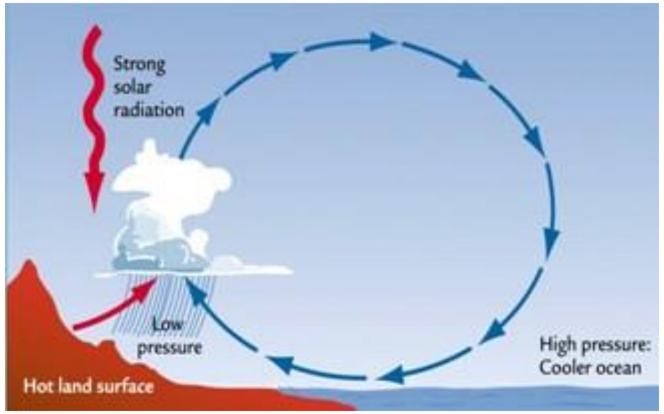

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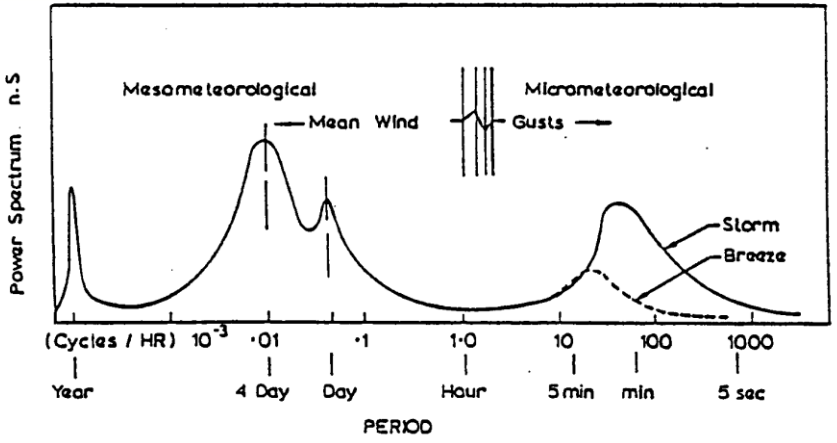

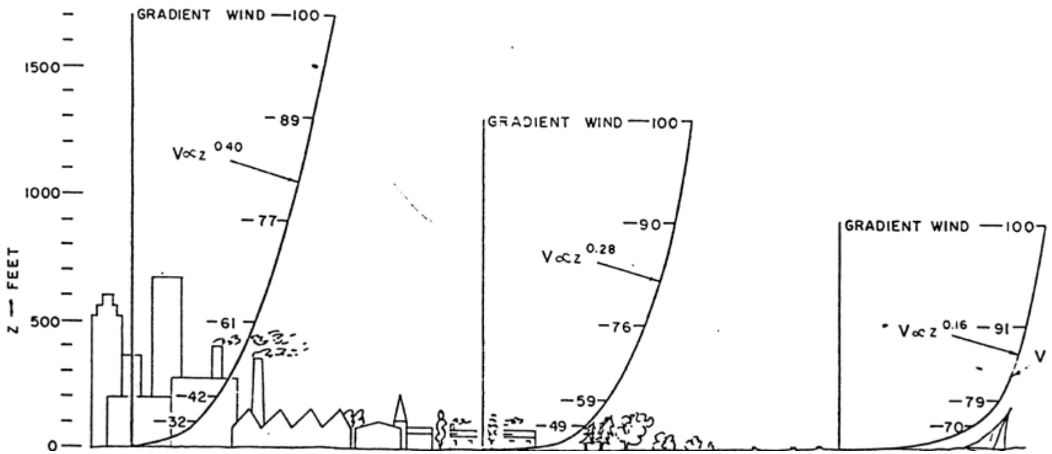

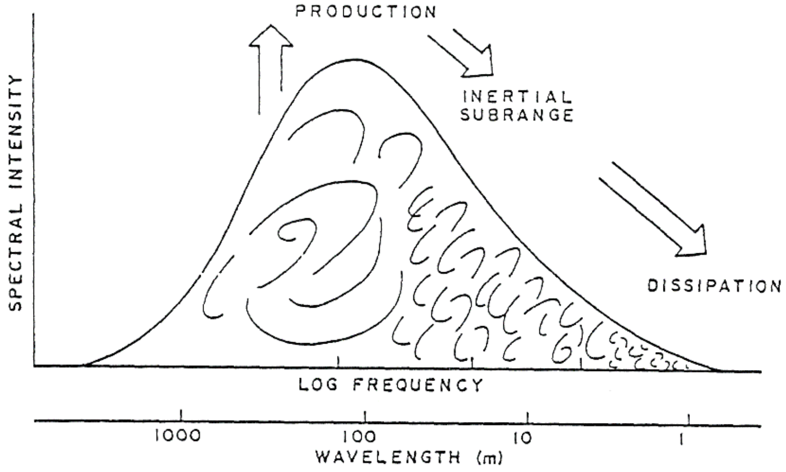

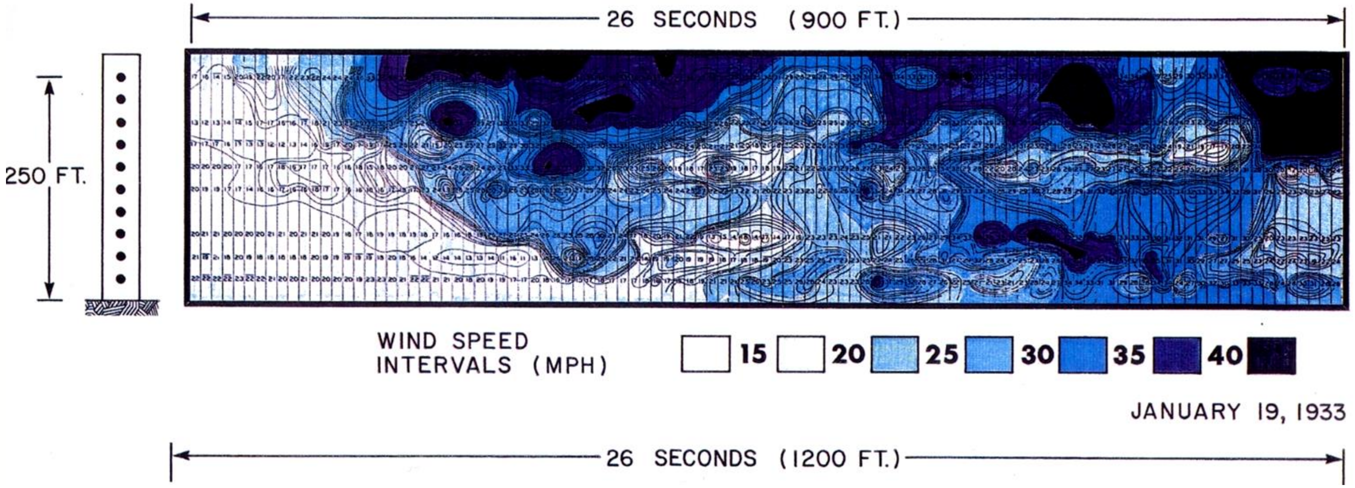

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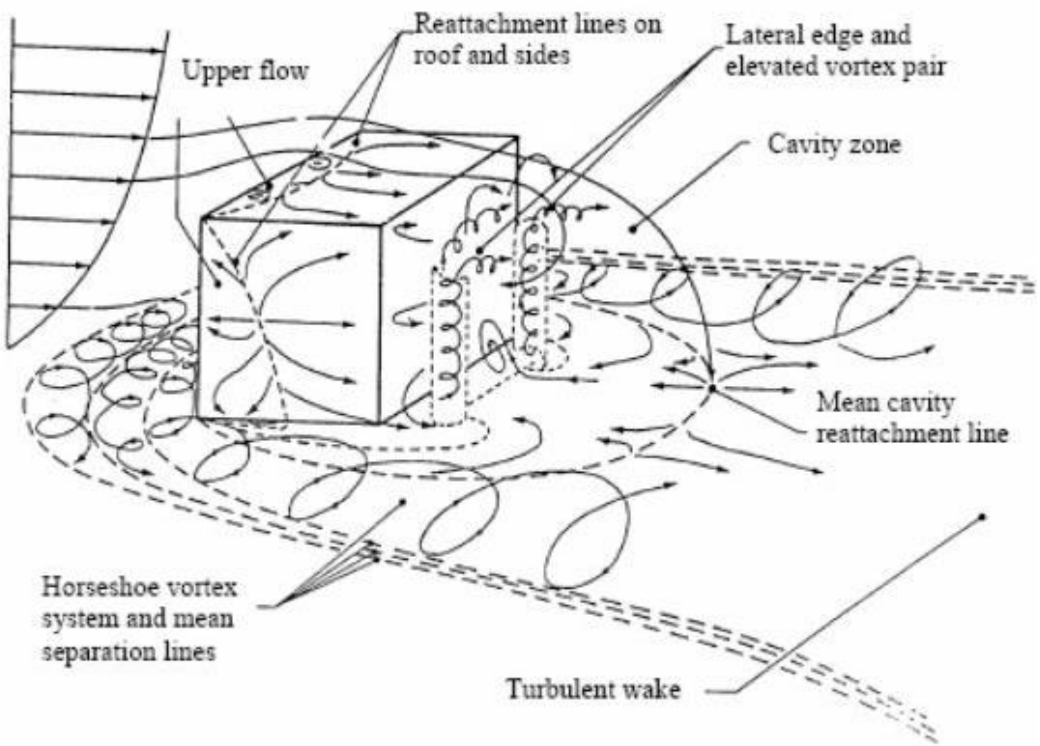

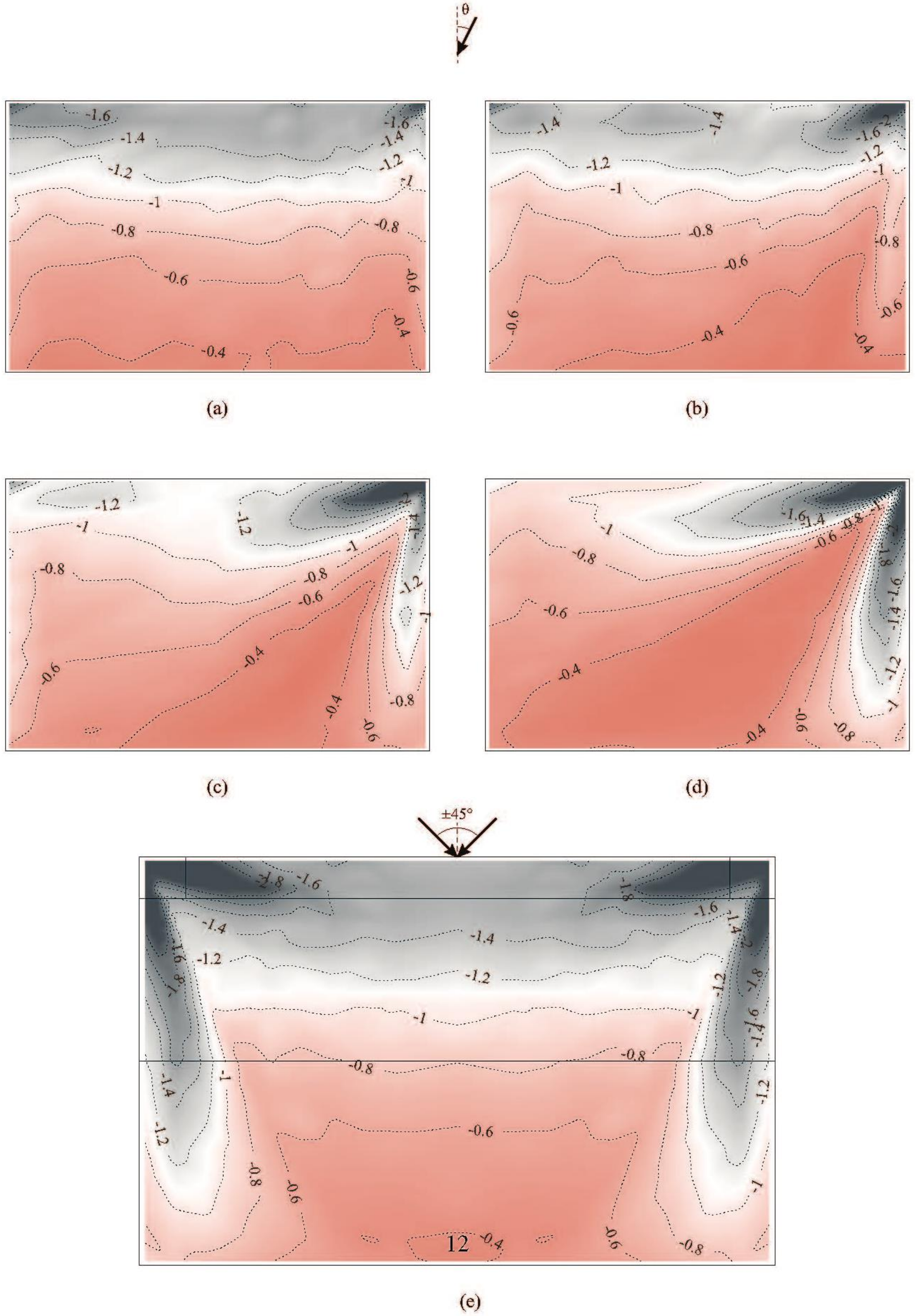

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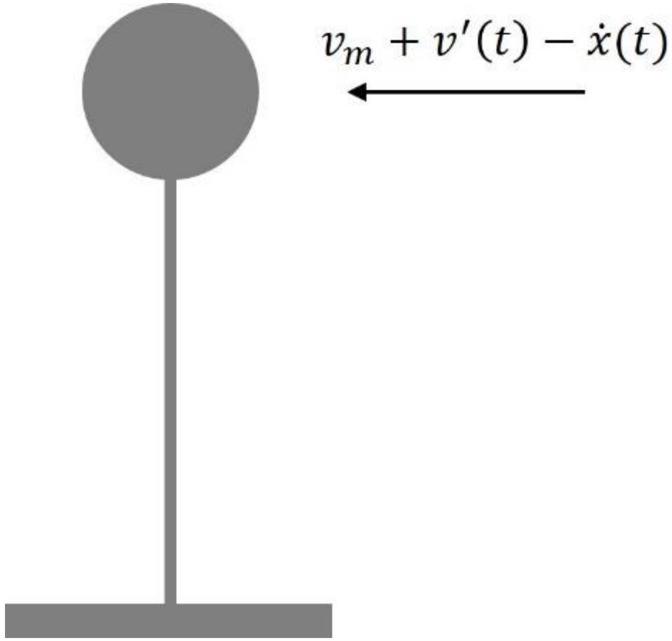

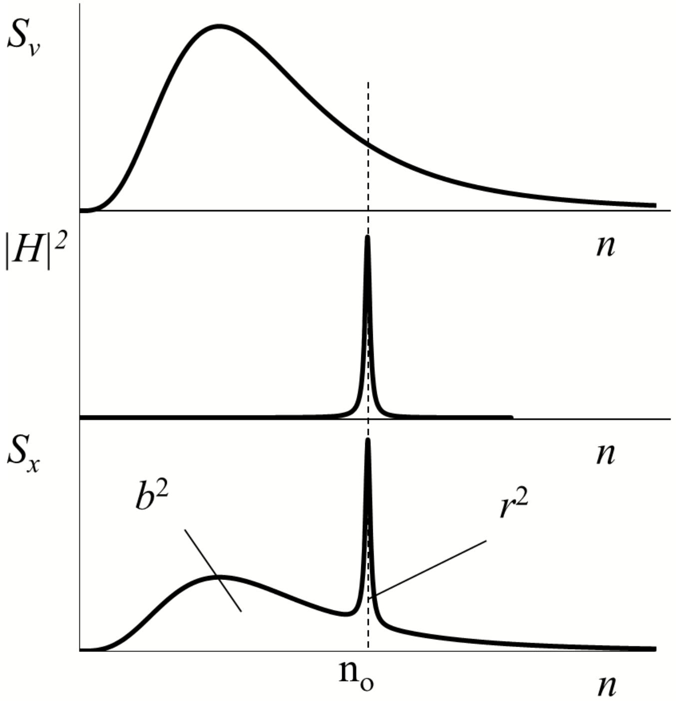

$$p = q_b \cdot c_e \cdot c_p \cdot c_s c_d$$

$$c_e = c_{ABL} \cdot (1 + 7I_u)$$

$$c_s c_d = \frac{G_R}{1 + 7I_u}$$

$$G_R = 1 + k \cdot \sqrt{4I_v^2 + \pi \frac{n_o}{v_m^2} S_v(n_o)}$$

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Probabilistic basis for determination of partial safety factors and load combination factors

BACKGROUND DOCUMENT

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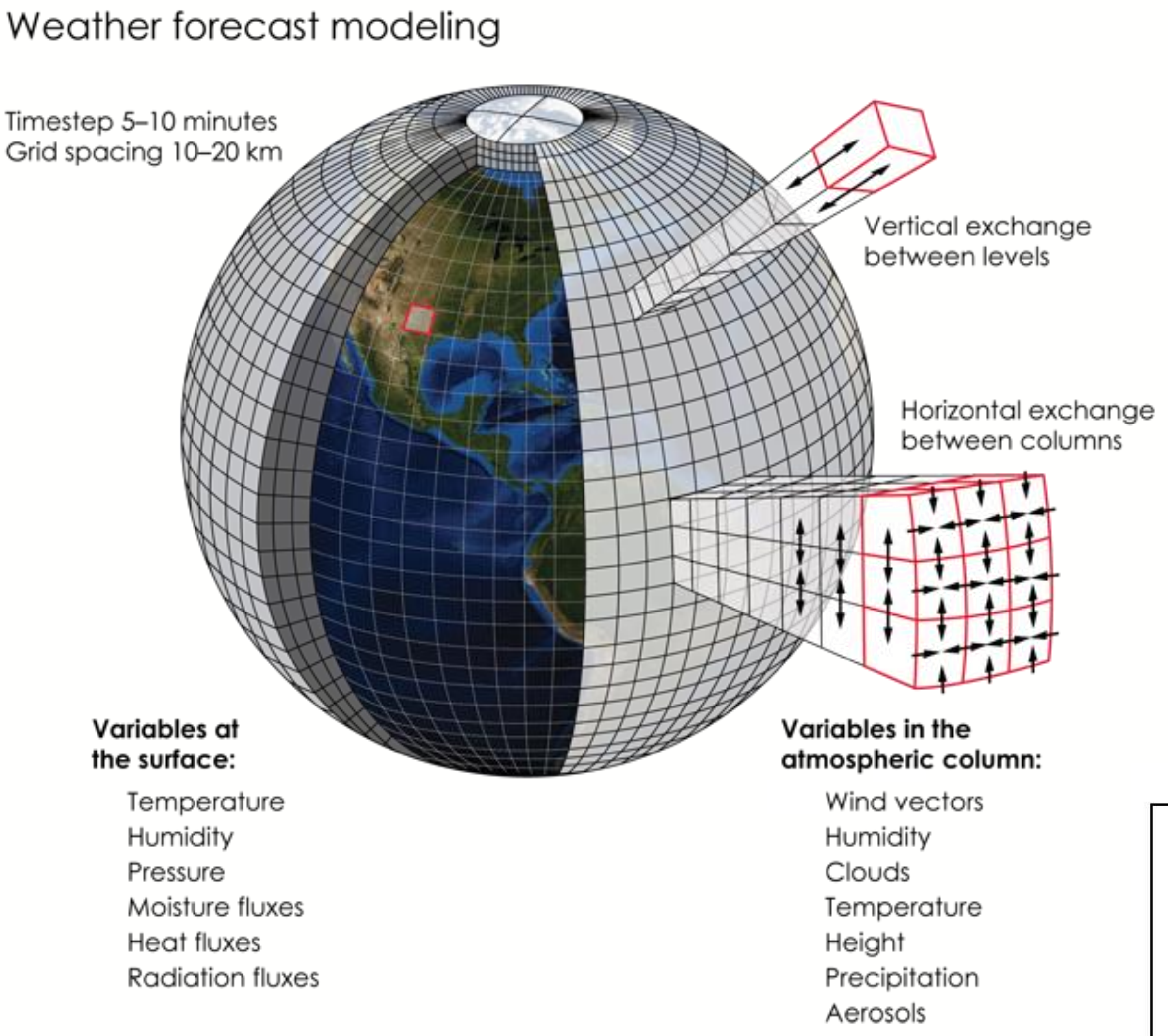
104 pages

Reanalysis and Hindcasting



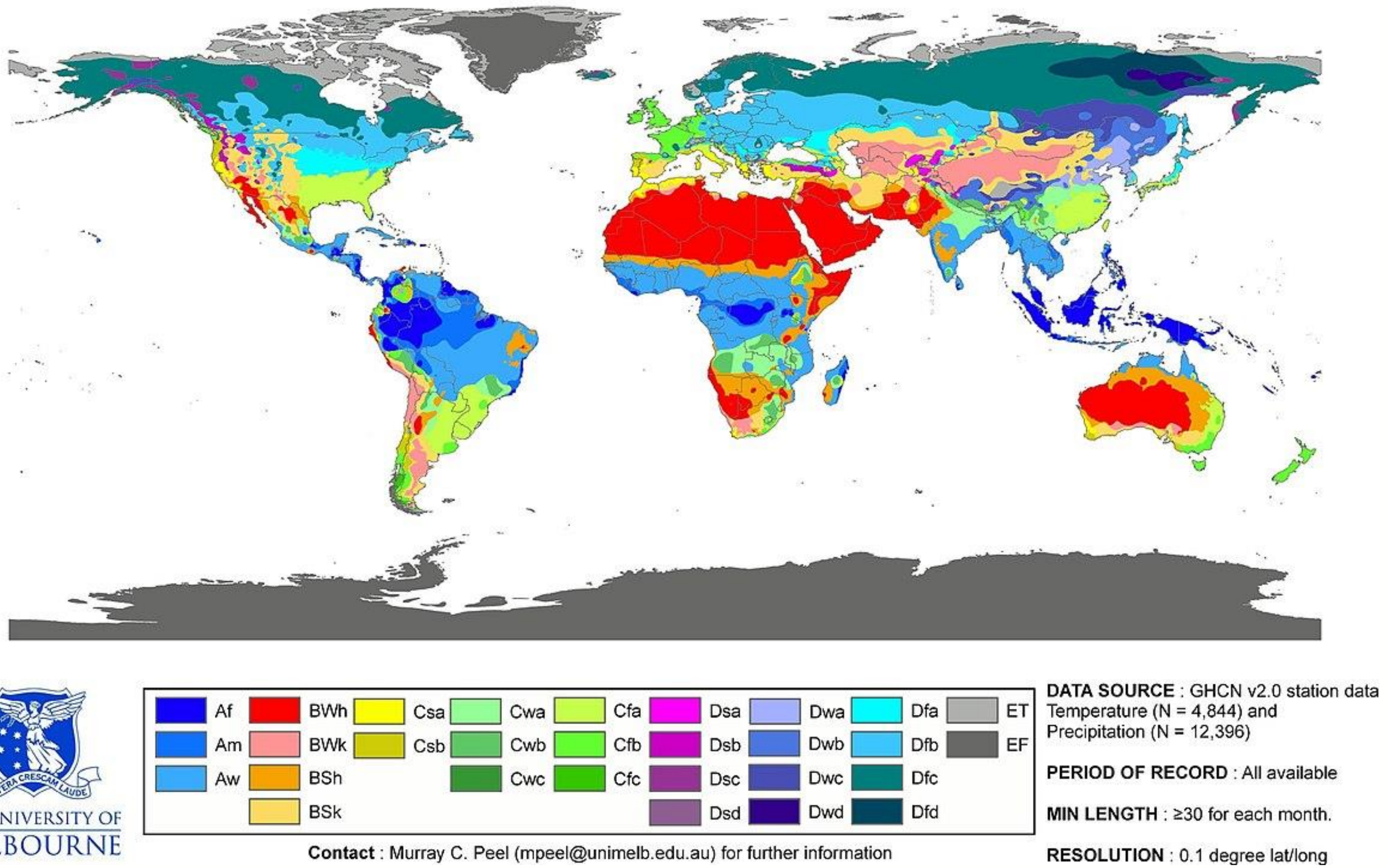
NWP model (basic equations)

- Equation of motion (wind)
- Continuity equation (mass conservation)
- First law of thermodynamics

Input to model
Surface observations
Radiosondes
Radar
Satellite data

Output from model
Forecast
Reanalysis
Resolution 0.5 to 30 km

World map of Köppen-Geiger climate classification



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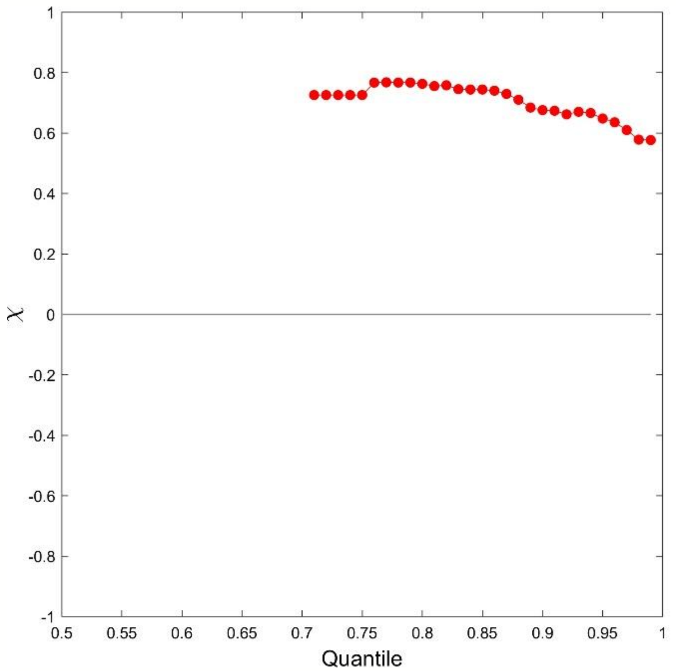
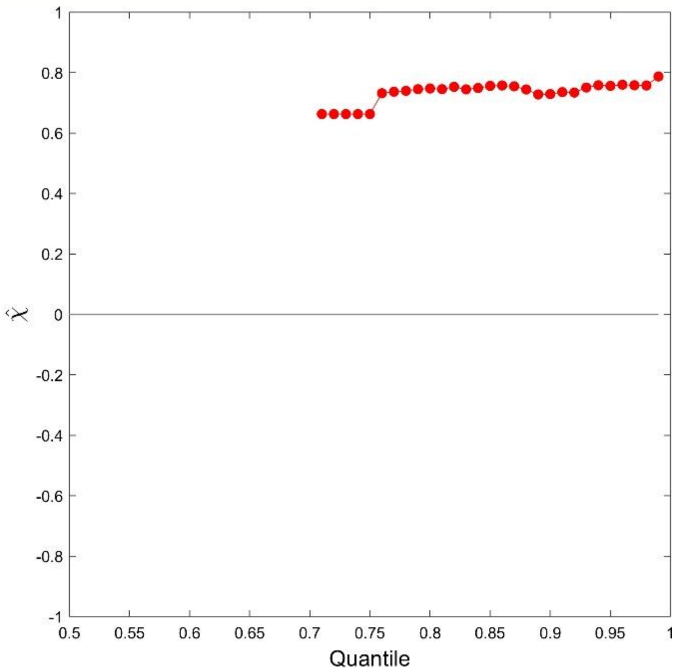
Correlation of climatic variables





$$\chi_p = \lim_{p \to 1} \Pr\{F_x(X) > p | F_y(Y) > p\}$$

$$\chi(p) = 2 - \frac{\log(P(F_x(X) < p, F_y(Y) < p)}{\log(P(F_x(X) > p}$$

$$\bar{\chi}(p) = \frac{2\log(P(F_x(X) > p)}{\log(P(F_x(X) > p, F_y(Y) > p))} - 1$$

- $\chi > 0$ and $\bar{\chi} = 1$ asymptotically dependent variables with the increase of χ representing the increase in the strength of dependence;
- $\chi = 0$ and $\bar{\chi} < 1$ means asymptotic independence and the value of $\bar{\chi}$ determines the strength of dependence within this class;
- $\chi = 0$ and $\bar{\chi} = 0$ asymptotically independent variables;

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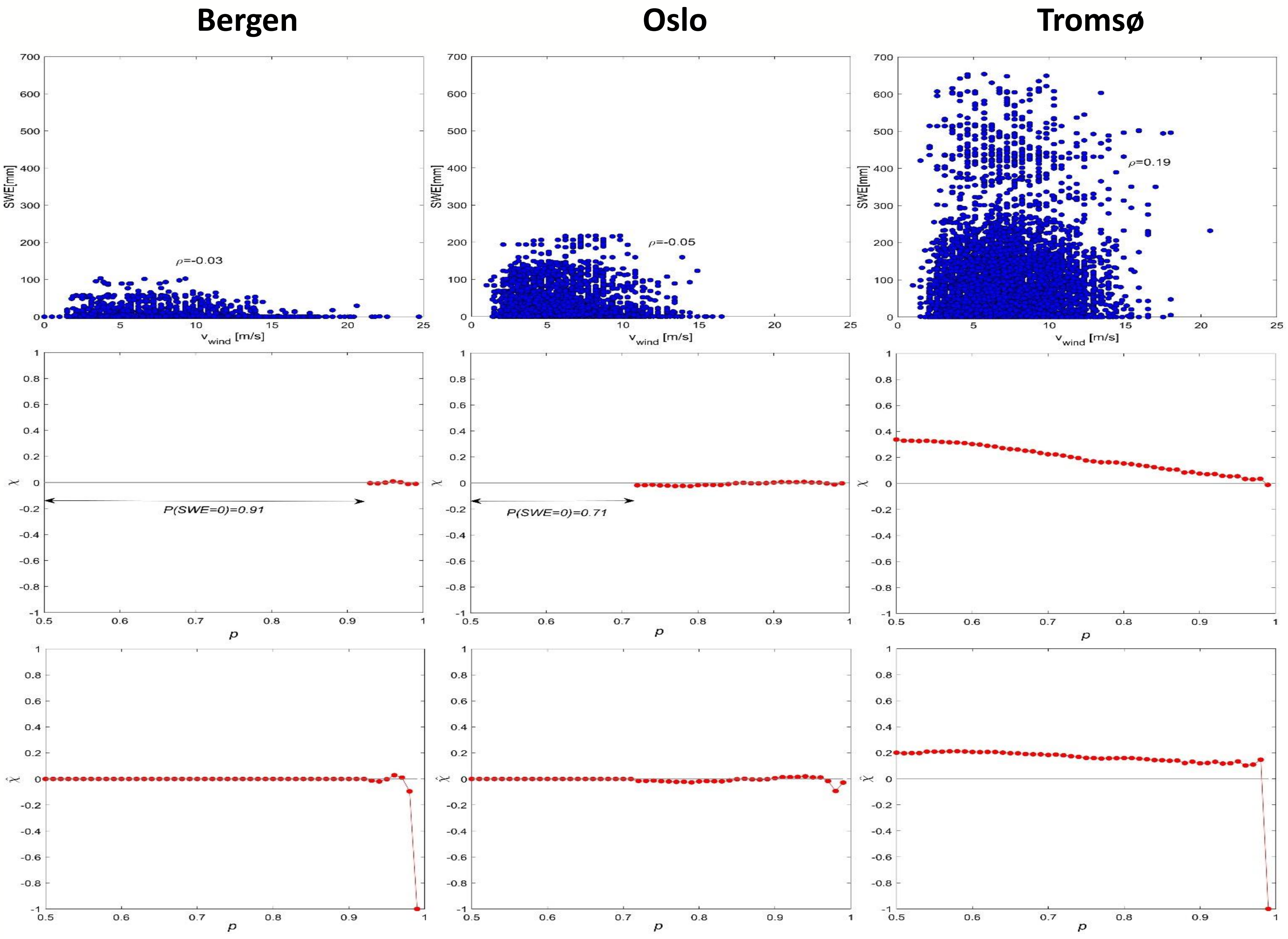
Snow and Wind
NORWAY



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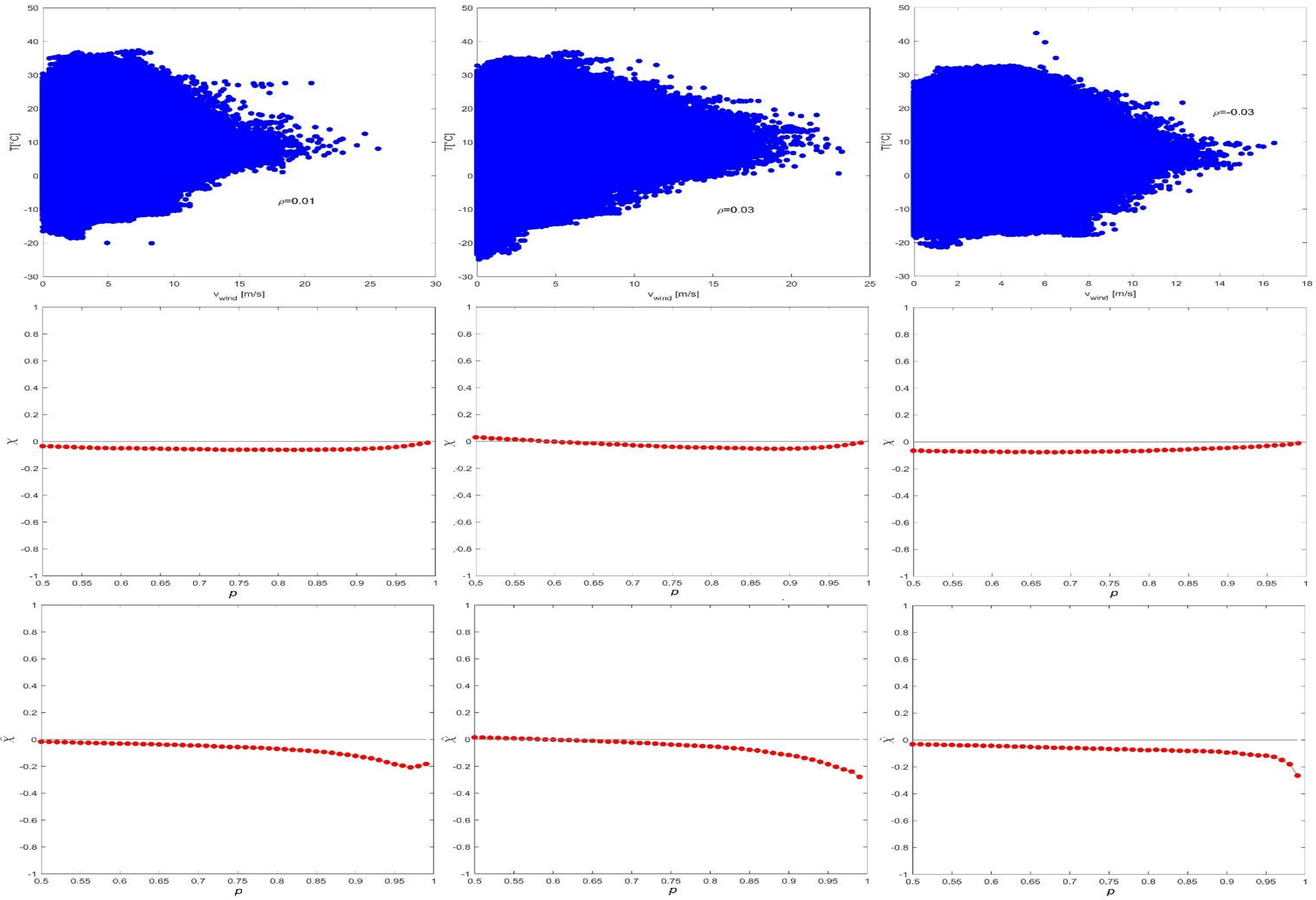
Temperature and Wind
GERMANY

Bremen Munich Braunlage



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Issues with climate changes

- Defining future climate
  - In relation to what “past climate”?
  - To what scale and with what degree of confidence?
- Does climate change impact on structures as it does on the environment?
- If so, how to account for it?

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Table 3.7.5. Estimated return wind speeds for the Rome Ciampino Airport [m/s].

Return Period [years]	Fisher Tippett Type I			Method of Moments	Penultimate Type I Distribution		
	Gumbel	BLUE	Gringorten		Gumbel	BLUE	Gringorten
10	22.28	21.73	21.93	21.84	22.27	21.95	21.68
20	23.95	23.21	23.48	23.35	23.87	23.44	23.09
50	**26.11**	**25.13**	**25.48**	**25.30**	**25.90**	**25.34**	**24.88**
100	27.73	26.57	26.98	26.77	27.40	26.74	26.21
200	29.35	28.00	28.48	28.23	28.87	28.11	27.51
500	31.48	29.89	30.45	30.16	30.79	29.90	29.21
1000	33.08	31.32	31.94	31.62	32.22	31.24	30.48

Table 3.7.5. Estimated return wind speeds for the Rome Ciampino Airport [m/s] (cont'd).

Return Period [years]	GEV Distributions					
	PWM k= 0		PWM k= 1.5211		MLE k=0	MLE k=1.5211
	Gumbel	Gringorten	Gumbel	Gringorten		
10	21.36	22.44	21.62	21.81	20.87	20.40
20	21.85	23.89	22.44	23.29	21.93	21.20
50	**22.26**	**25.71**	**23.27**	**25.20**	**23.20**	**22.08**
100	22.45	27.05	23.75	26.63	24.08	22.65
200	22.59	28.36	24.15	28.06	24.89	23.14
500	22.70	30.05	24.57	29.94	25.89	23.70
1000	22.76	31.30	24.82	31.38	26.58	24.07

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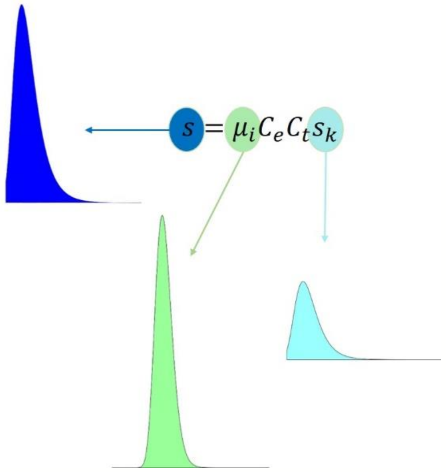

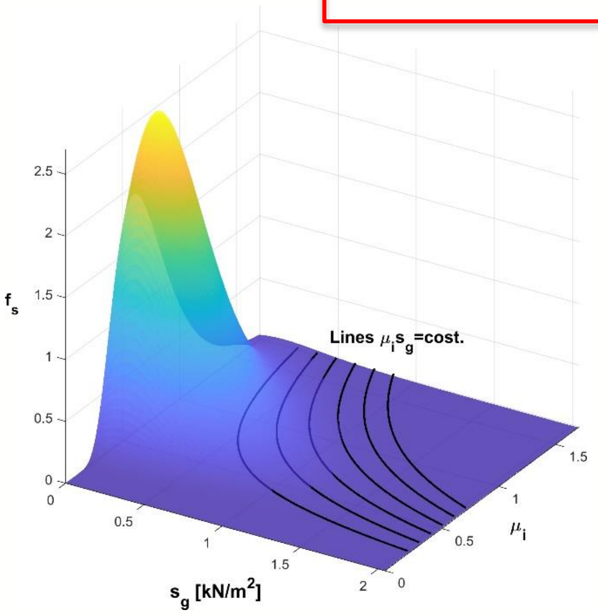

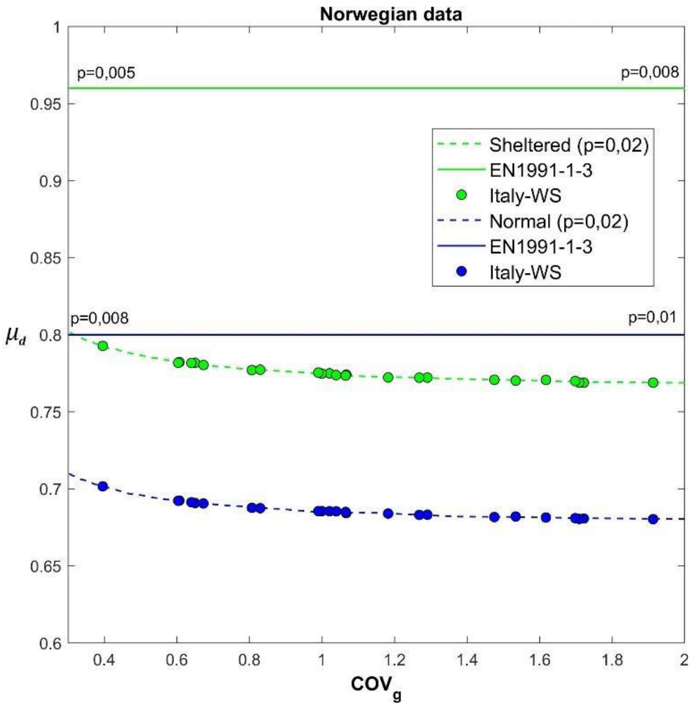

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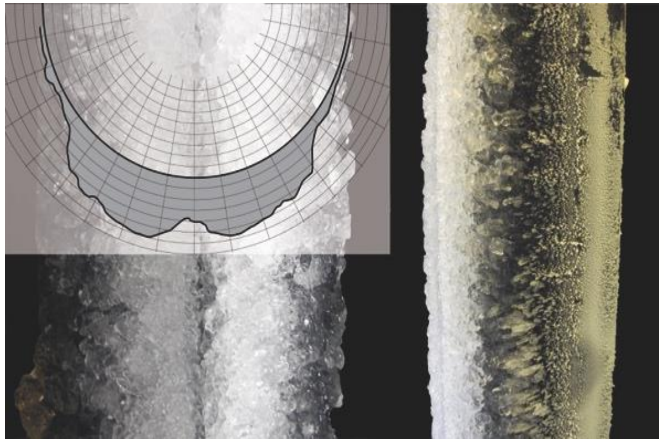
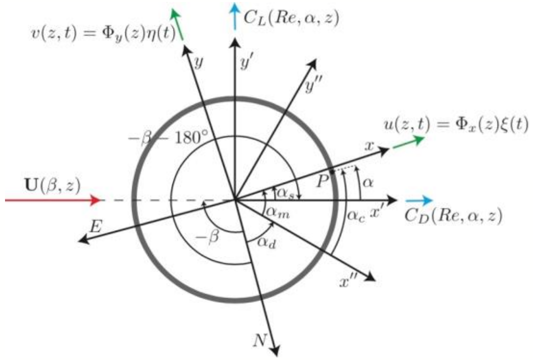
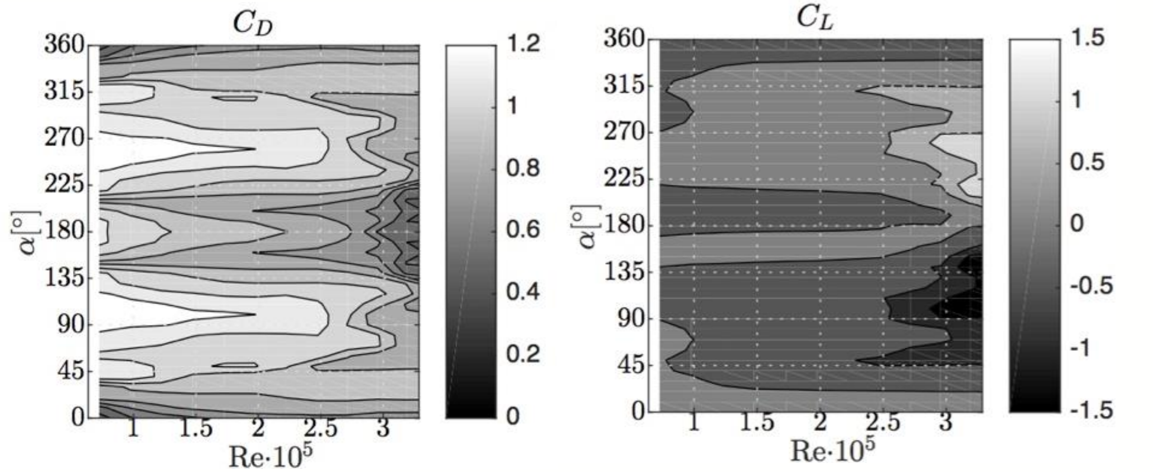
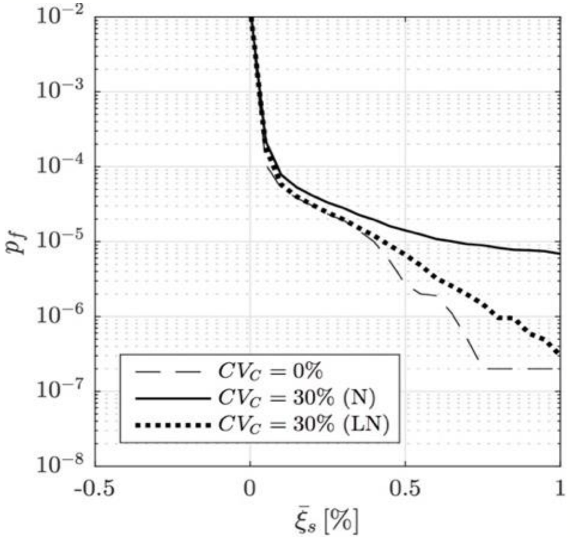
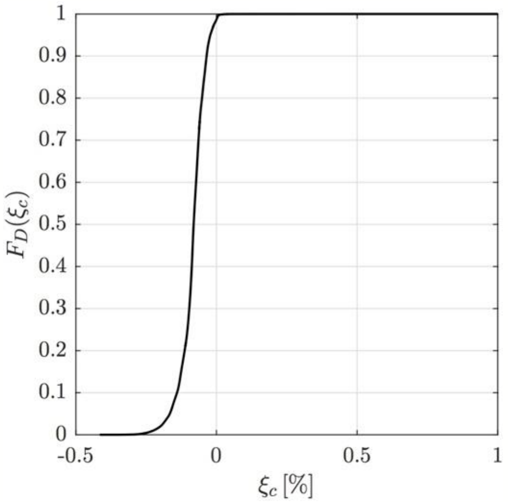






$$f_D(\xi_c) = \int_0^{360°}\int_0^{360°}\int_0^{\infty}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}\int_0^{\infty} f_D(\xi_c|f_x, \kappa, \boldsymbol{C}, U, \alpha\alpha_s)\, df_x d\kappa d\boldsymbol{C} dU(z_{ref}) d\alpha d\alpha_s$$





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Probabilistic basis for determination of partial safety factors and load combination factors

BACKGROUND DOCUMENT

62 pages

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BACKGROUND DOCUMENT

$$w = \theta_w \cdot c_p \cdot c_g^2(z) \cdot c_r^2(z) \cdot c_0^2(z) \cdot q_b$$

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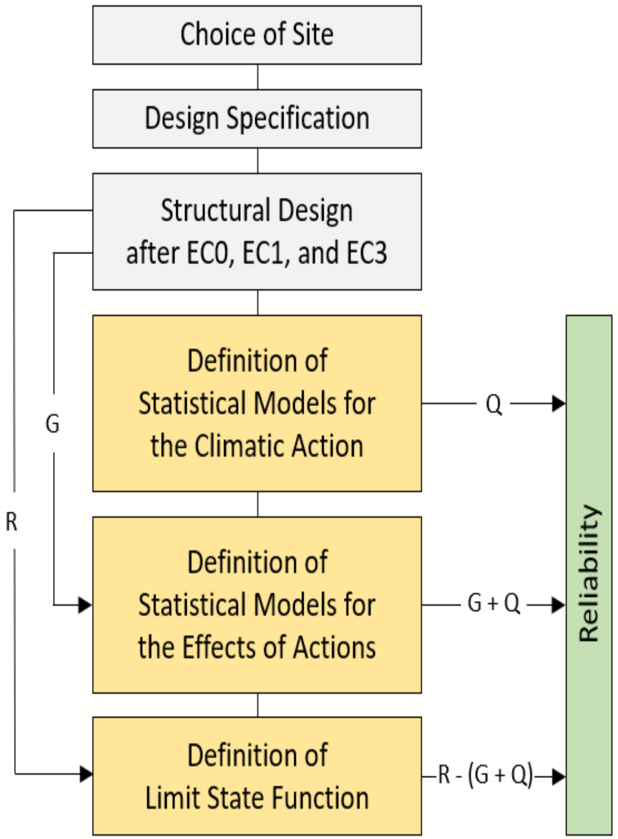

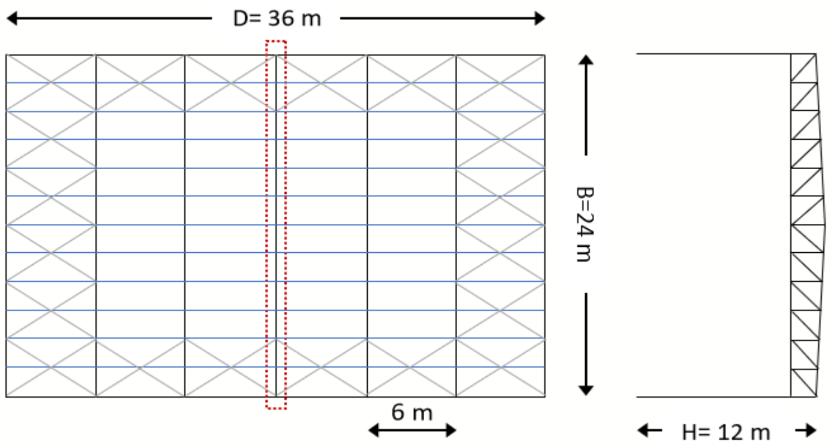

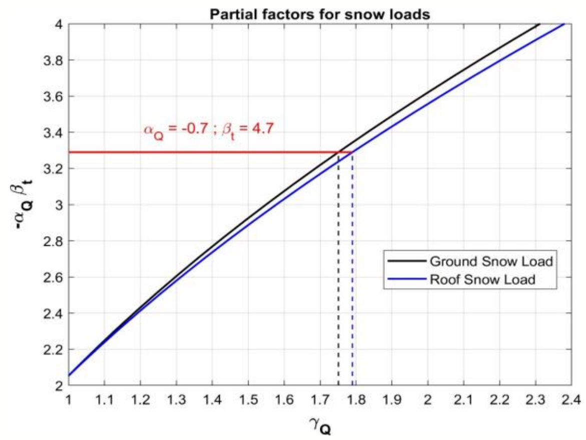

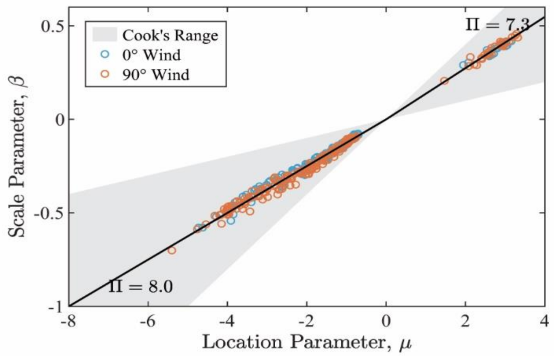

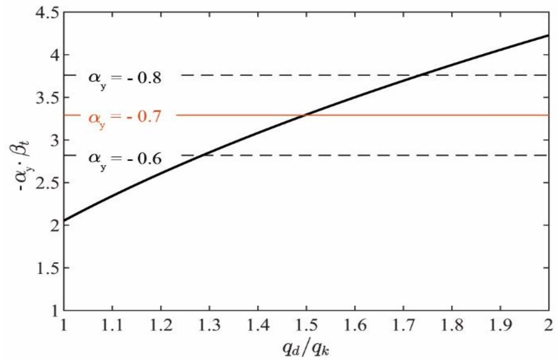

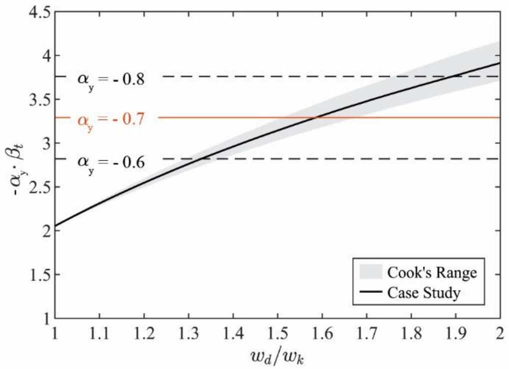

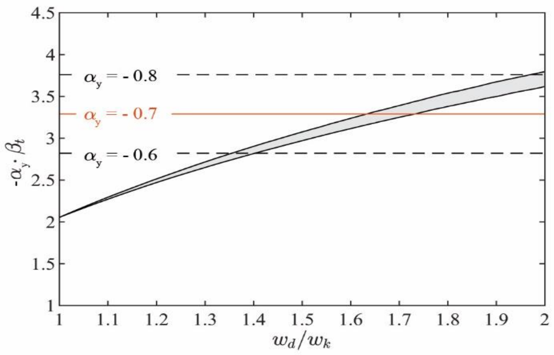

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BACKGROUND DOCUMENT

30 pages

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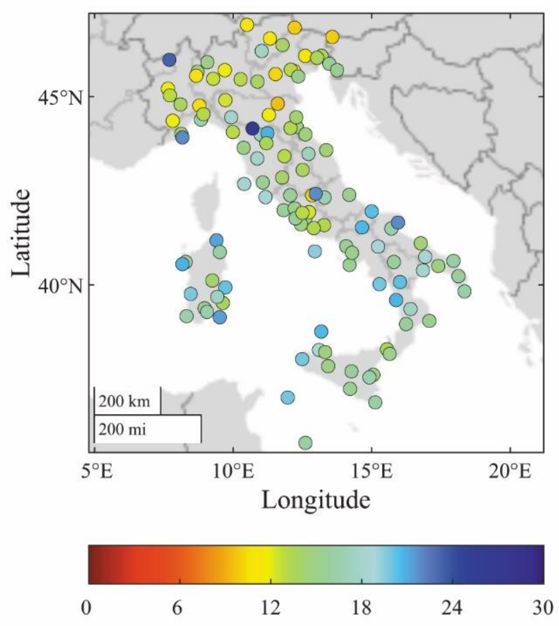
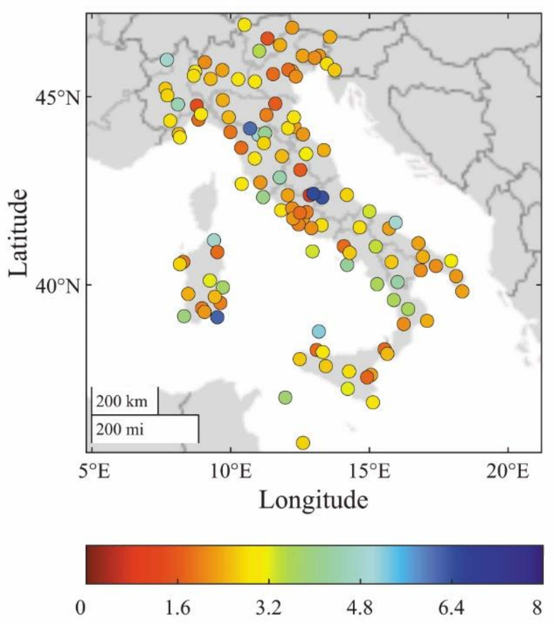
SCALE



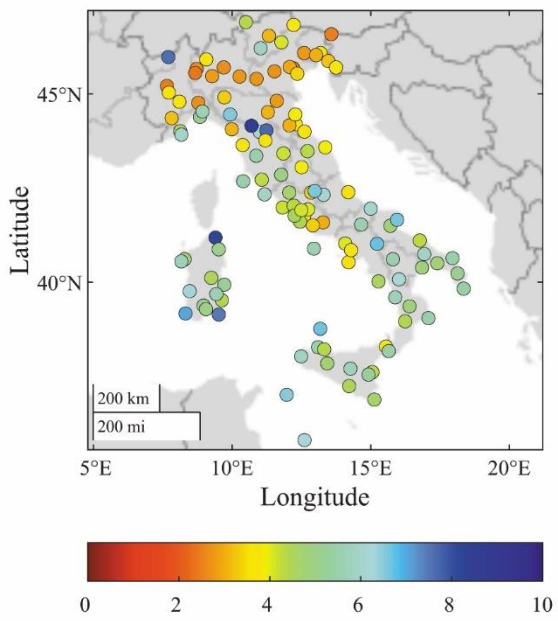
SHAPE



PARENT

EXTREME VALUE

SCALE



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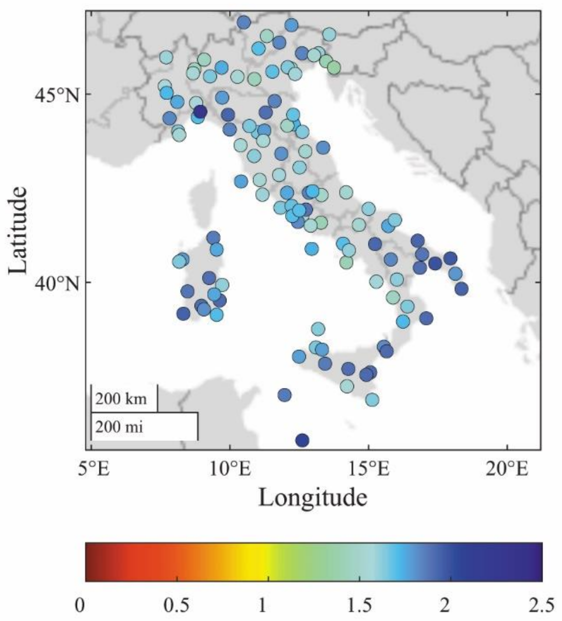

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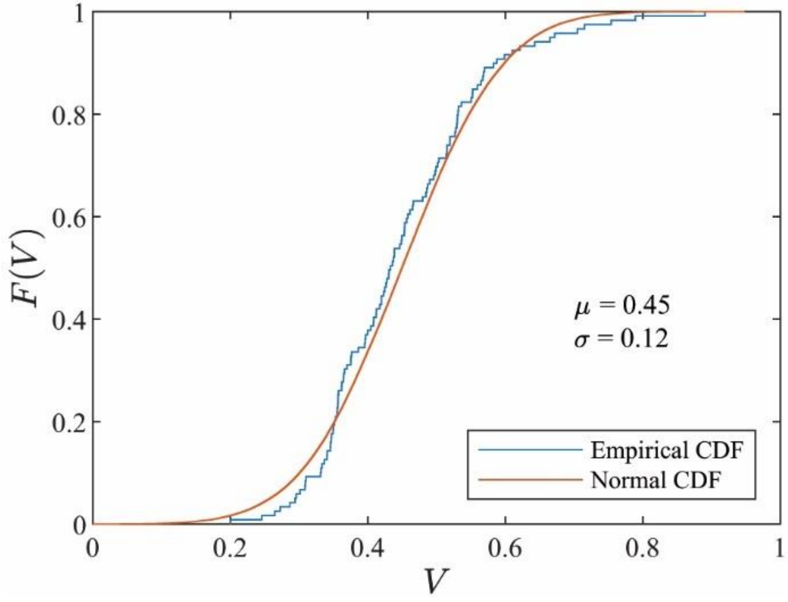
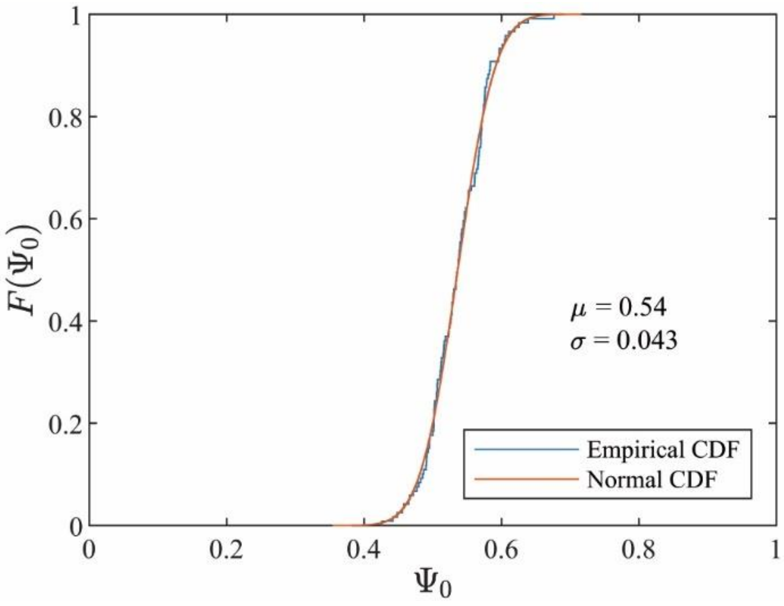
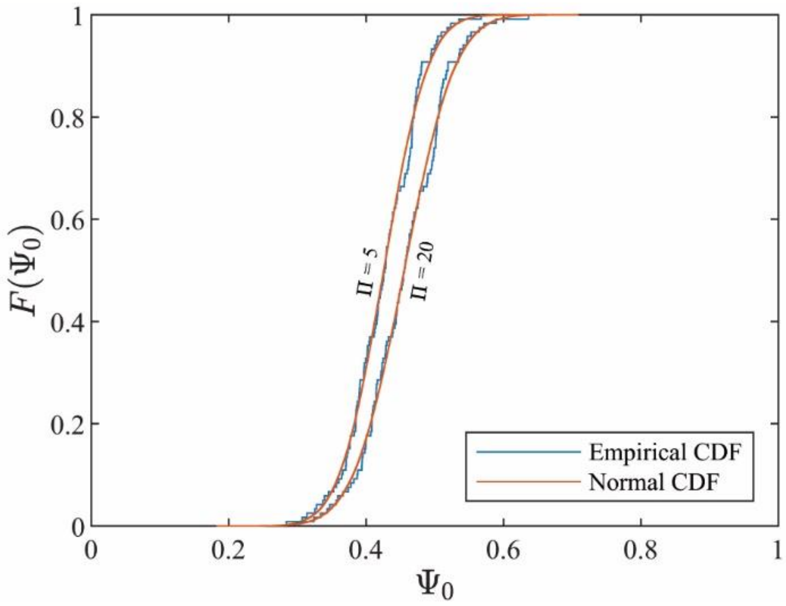




Ψ = 0.54

Ψ = 0.42 ÷ 0.46



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Personal remarks (doubts)

- What degree of complexity in reliability calculations can be justified given the current level of uncertainty we have in the input variables?
- Where must we improve our input data?
- How to manage the discrepancies in Code factors when calibrated at the different levels?
- How broad a class of structures can be when the way the (climatic) action manifests itself rapidly changes from one structure to another?