Codification and load combination factors

Appropriate generalisation of (environmental) time variant loads and their combination

Jochen Köhler and John Dalsgaard Sørensen

Motivation

- Partial factor formats are highly simplified/generalized.

$$\sum F_{\mathrm{d}} = \sum_i \gamma_{\mathrm{G},i} G_{\mathrm{k},i} + \gamma_{\mathrm{Q},1} Q_{\mathrm{k},1} + \sum_{j>1} \gamma_{\mathrm{Q},j} \psi_{0,j} Q_{\mathrm{k},j} + \left(\gamma_{\mathrm{P}} P_{\mathrm{k}}\right) \tag{8.12}$$

or

$$\sum F_{\mathrm{d}} = \begin{cases} \sum_i \gamma_{\mathrm{G},i} G_{\mathrm{k},i} + \gamma_{\mathrm{Q},1} \psi_{0,1} Q_{\mathrm{k},1} + \sum_{j>1} \gamma_{\mathrm{Q},j} \psi_{0,j} Q_{\mathrm{k},j} + \left(\gamma_{\mathrm{P}} P_{\mathrm{k}}\right) \\ \sum_i \xi_i \gamma_{\mathrm{G},i} G_{\mathrm{k},i} + \gamma_{\mathrm{Q},1} Q_{\mathrm{k},1} + \sum_{j>1} \gamma_{\mathrm{Q},j} \psi_{0,j} Q_{\mathrm{k},j} + \left(\gamma_{\mathrm{P}} P_{\mathrm{k}}\right) \end{cases} \tag{8.13}$$

or

$$\sum F_{\mathrm{d}} = \begin{cases} \sum_i \gamma_{\mathrm{G},i} G_{\mathrm{k},i} + \left(\gamma_{\mathrm{P}} P_{\mathrm{k}}\right) \\ \sum_i \xi_i \gamma_{\mathrm{G},i} G_{\mathrm{k},i} + \gamma_{\mathrm{Q},1} Q_{\mathrm{k},1} + \sum_{j>1} \gamma_{\mathrm{Q},j} \psi_{0,j} Q_{\mathrm{k},j} + \left(\gamma_{\mathrm{P}} P_{\mathrm{k}}\right) \end{cases} \tag{8.14}$$

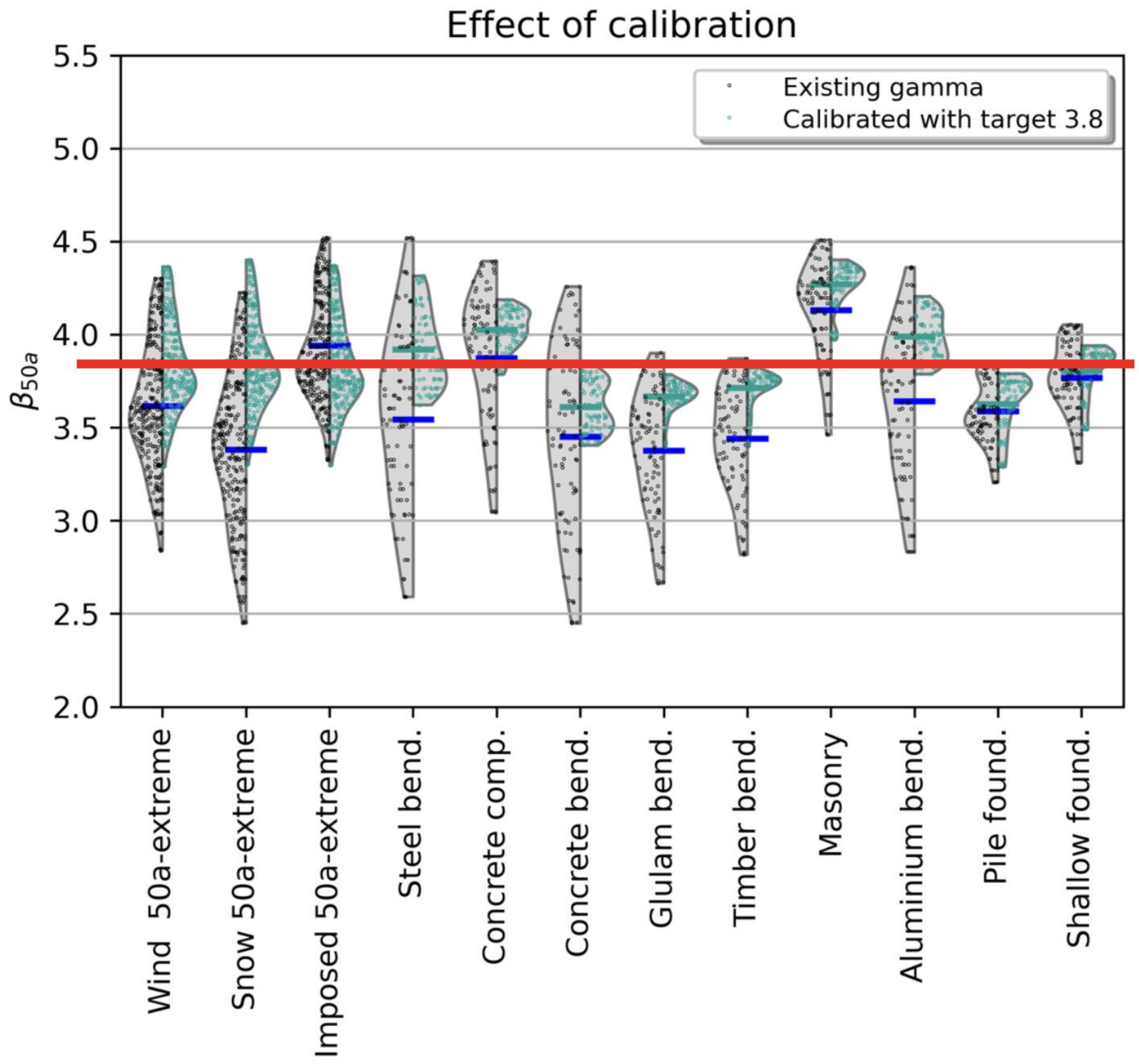
Motivation

- The revision of the Eurocodes is an opportunity to revisit code calibration.

$\gamma_G =$ 1.35

$\gamma_Q =$ 1.5

$\gamma_G =$	1.19
$\gamma_{Q,wind} =$	1.94
$\gamma_{Q,snow} =$	2.35
$\gamma_{Q,imp} =$	1.60



Motivation

- The tentative calibration results are based on rather genric representation of variable loads.

Table 3: Load Variables

Variable	Distribution	Mean Value	C.o.V.	char.value	fractile
Load Effect MU Frames	lognormal	1.000	0.100	1.000	not used
Self weight steel	normal	1.000	0.025	1.000	not used
Self weight concrete	normal	1.000	0.050	0.980	not used
Self weight glulam	normal	1.000	0.100	0.950	not used
Self weight timber	normal	1.000	0.100	0.950	not used
Self weight masonry	normal	1.000	0.070	1.000	0.500
Self weight aluminum	normal	1.000	0.040	1.000	0.500
Self weight soil	normal	1.000	0.050	1.000	0.500
Permanent load small V	normal	1.000	0.100	1.000	0.500
Permanent load large V	normal	1.000	0.200	1.329	0.950
Wind MU	lognormal	0.970	0.260	-	-
Wind 50a-extreme	gumbel	1.000	0.140	1.084	0.980
Snow MU	lognormal	0.810	0.260	-	-
Snow 50a-extreme	gumbel	1.000	0.200	0.821	0.980
Imposed MU	lognormal	1.000	0.100	-	-
Imposed 50a-extreme	gumbel	1.000	0.260	1.350	0.990

Challanges

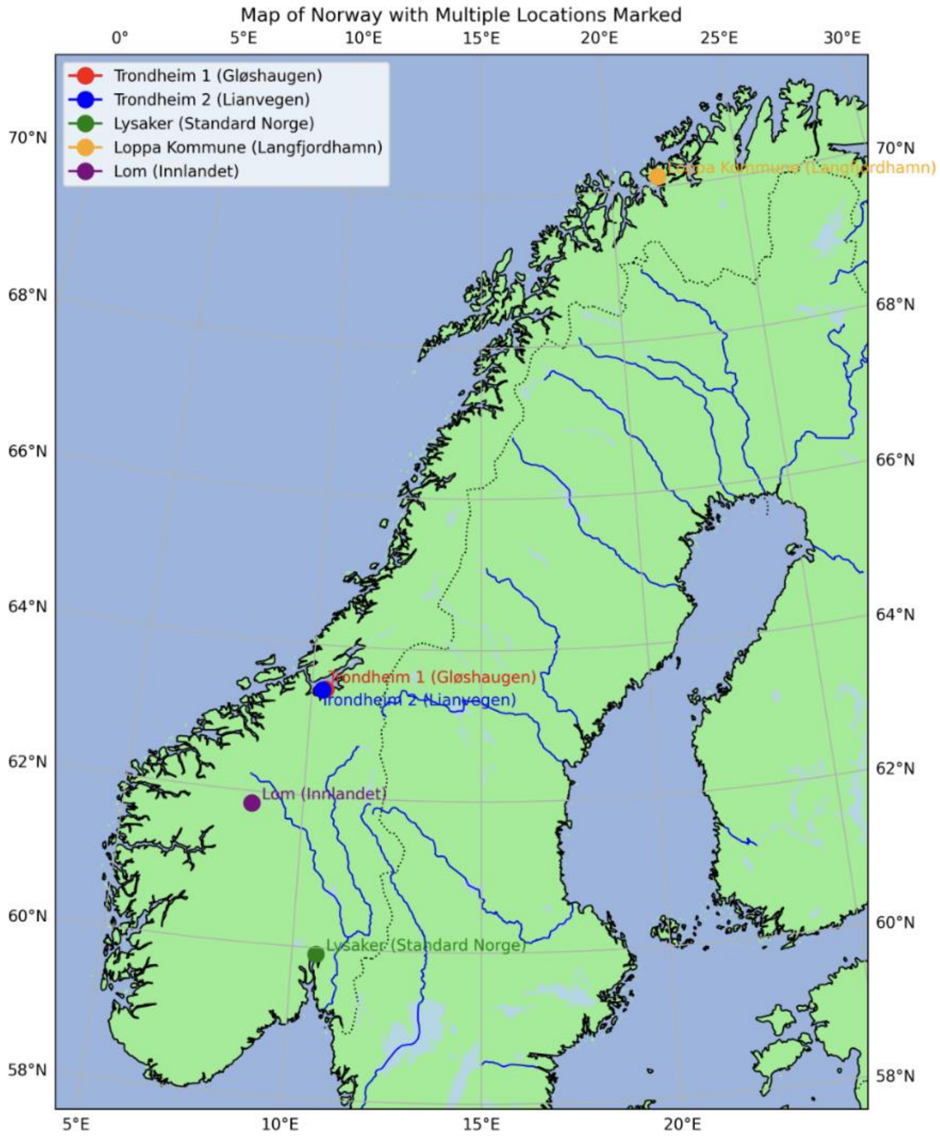
- Environmental loads like wind and snow are represented as 98% fractile of the corresponding yearly extreme value distribution.
- Evidence from data is not very consistent.
- Spatial variability of magnitudes is considered by “zones”.
- Spatial variability of coefficient of variation is ignored.
- The effects of climate change are ignored.

Example: Wind, Norway

- Assessment of weather station data.
- Assuming stationarity.
- Variability of CoV of v_{max}^2 0.24. - 0.31.
- Represent v_{max}^2 with Gumbel seems ok.

Example: Snow, Norway

- Simulated snow (from data on precipitation and temperature).
- Only preliminary assessment of data.
- Variability of CoV of $s_{0,max}$ 0.4 - 0.7.



Example: Snow, Norway

- Simulated snow (from data on precipitation and temperature).
- Only preliminary assessment of data.
- Variability of CoV of $s_{0,max}$ 0.4 - 0.7.
- Large discreipancy to current characteristic values.

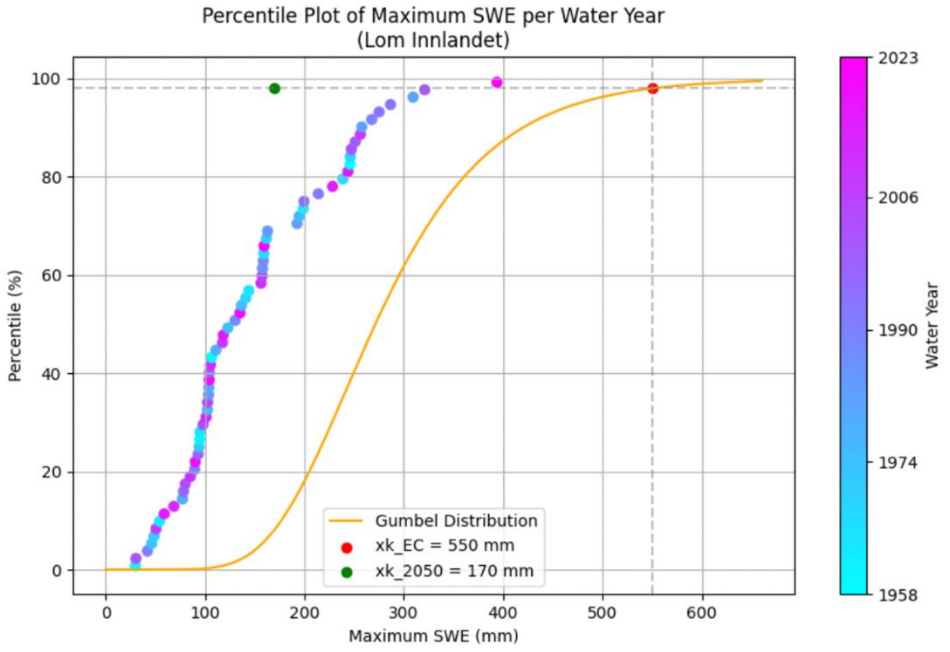
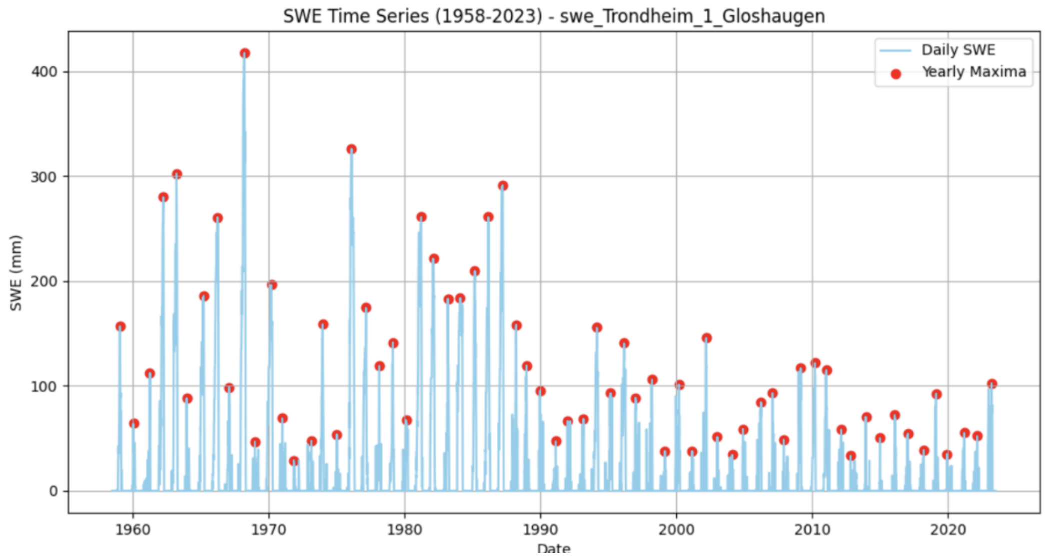


Figure 17: Percentile comparison of SWE for Lom, Innlandet with Eurocodes and Klima2050 study.

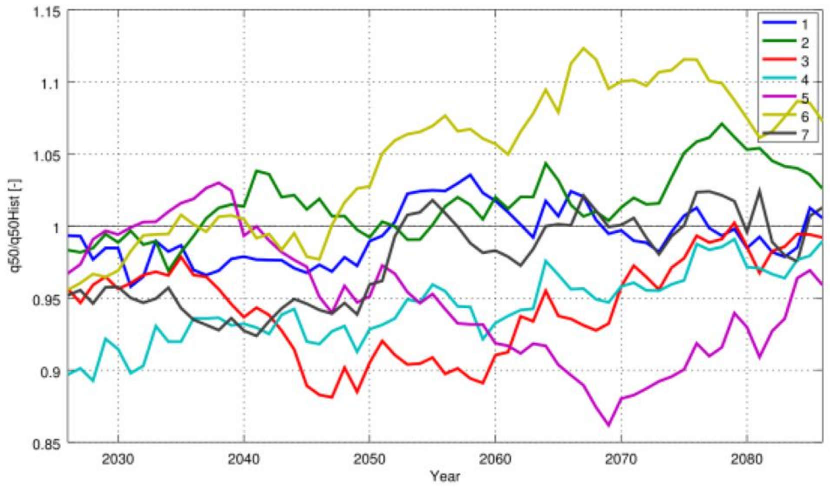
Example: Snow, Norway

- Simulated snow (from data on precipitation and temperature).
- Only preliminary assessment of dat
- Variability of CoV of $s_{0,max}$ 0.4 - 0.7.
- Large discripancy to current characteristic values.
- Rather evident non-stationarity.

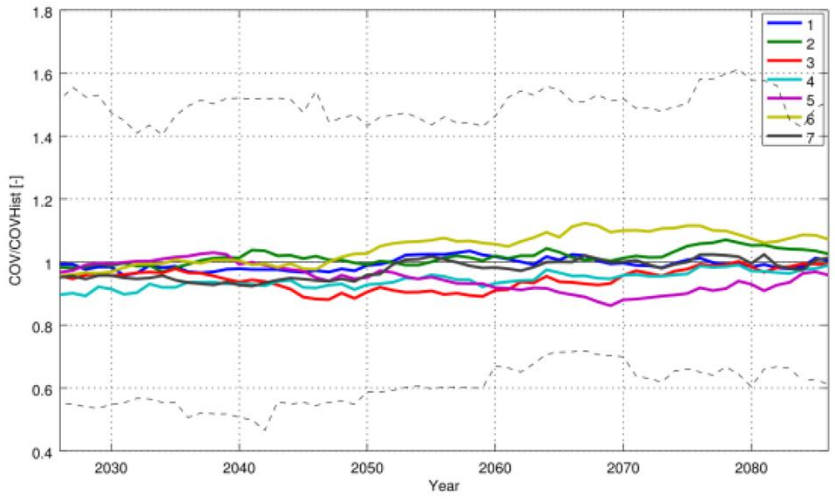


Example: Wind, Denmark

- Simulations based on different climate change scenarios.
- Change in characteristic value +/- 10 %.
- CoV keeps similar.



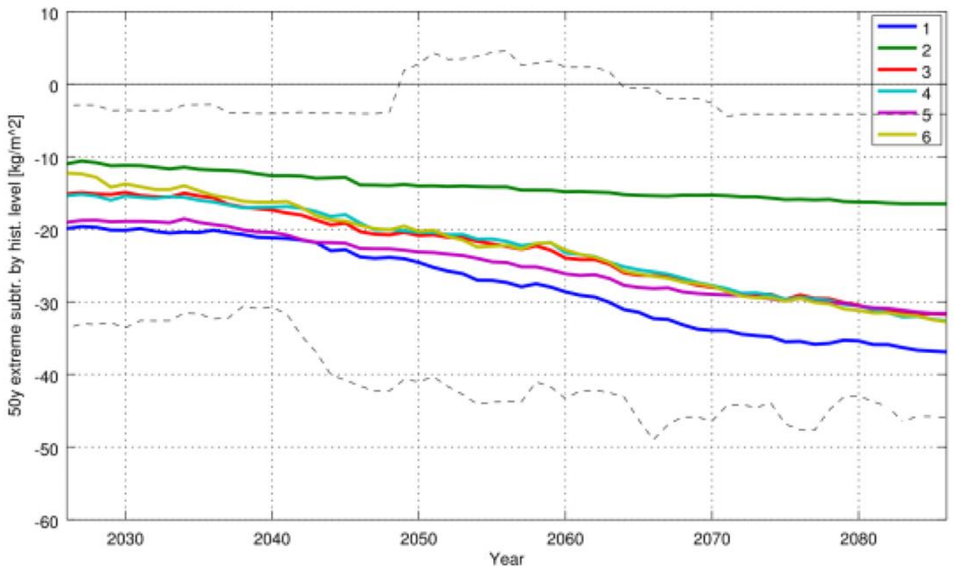
(a) SfcWindmax



(b) sfcWindmax, med ekstremkurver

Example: Snow, Denmark

- Simulations based on different climate change scenarios.
- Decrease in characteristic approximately 30%
- Increase in COV



Approach for calibrating load combination factors.

1. Represent design equations with 1 variable load and calibrate $\gamma_G, \gamma_{Q,snow}, \gamma_{Q,wind}, \gamma_{Q,imposed}$.

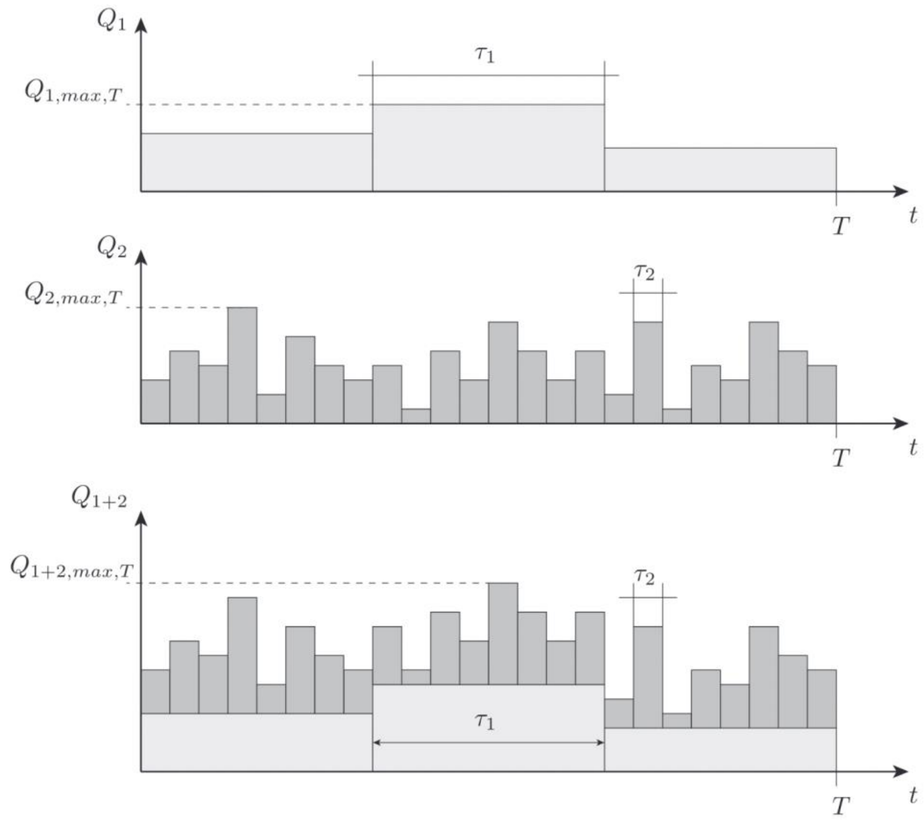
2. Represent design equations with 2 variable loads, keep $\gamma_G, \gamma_{Q,snow}, \gamma_{Q,wind}, \gamma_{Q,imposed}$ fixed and calibrate $\psi_{0,i}$.

- Reliability analysis for step 2 necesitates the solution of the load combination problem.

Load Combination

Load Combination Factors:

- Load combination factors (Ψ_0, Ψ_1, Ψ_2) are essential in determining design values for ultimate and serviceability limit states.
- EN 1990 (Annex C) establishes these factors based on Ferry-Borges-Castanheta's (FBC) simplified load combinations.
- The factors depend on:
  - Coefficients of variation of annual maximum loads.
  - Frequencies of the loads.
  - Duration of the extreme loads.
  - The likelihood of loads occurring simultaneously, which can be modelled using conditional distribution functions.



Load Combination

Impact of Climate Change on Load Combinations:

- Climate change may alter
  - The magnitudes of annual maximum loads.
  - the coefficients of variation for annual maximum loads.
- Other weather phenomena not covered by present codes may become important, e.g. for wind actions.
- Increased frequencies and duration of combined loads in the FBC model are likely due to changing climatic conditions.
- These changes could necessitate adjustments to load combination factors (Ψ_0).
- Load duration factors (Ψ_1 and Ψ_2) could also be affected by altered frequencies of extreme loads.

Load Combination

Data Analysis Challenges:

- No specific analyses on load combinations have been conducted due to:
  - Insufficient data availability.
  - High variability and inhomogeneity in the existing data.

Takeaway:

- Further studies are needed to assess the impact of climate-induced changes on load combination factors and their implications for structural design standards.