# Adjusted Equivalent Static Wind Loads for non-Gaussian Linear Static Analysis

Nicolas Blaise, Vincent Denoël

University of Liège (Belgium)

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# Context

Le Nouveau Vélodrome Marseille

Stade de Lille Métropole

→ Equivalent Static Wind Loads ?

`<complex structure, load combination, codification, simplicity>`

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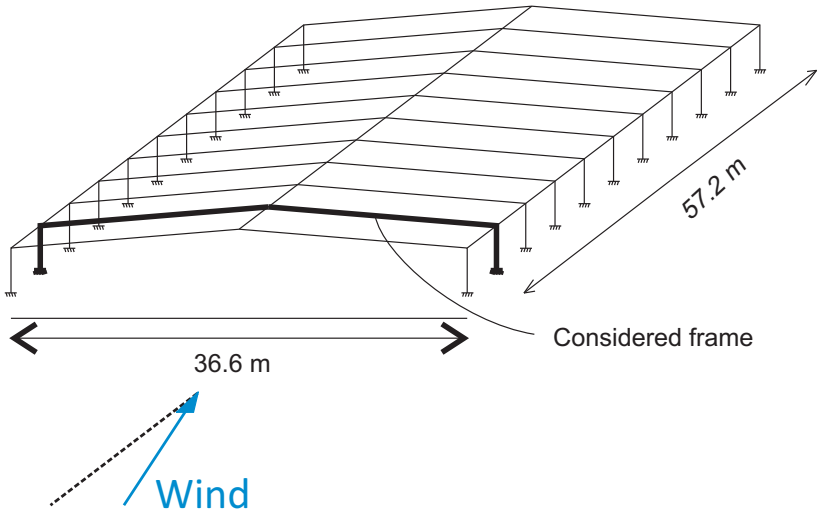
# Academic Example




- ▷ Well-known wind pressure field [Main 2006]
- ▷ Limitations of existing ESWLs
- ▷ Linear & static structural behaviour `<simple enough>`


Non Gaussian pressure field !

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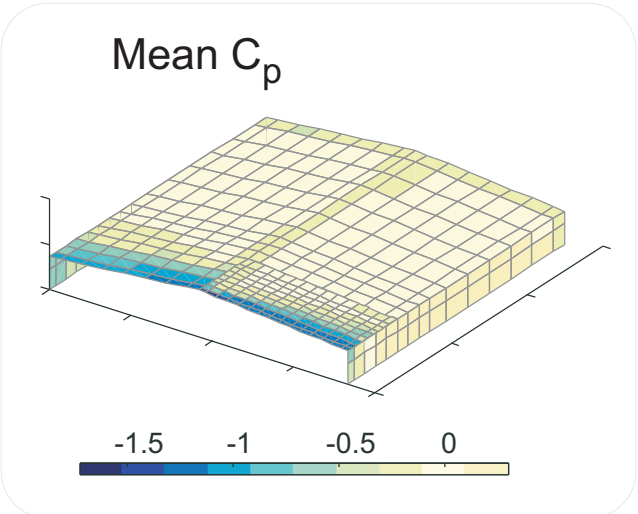
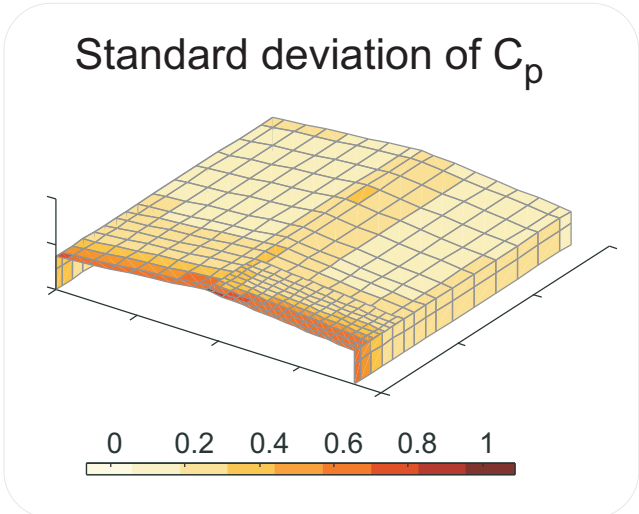
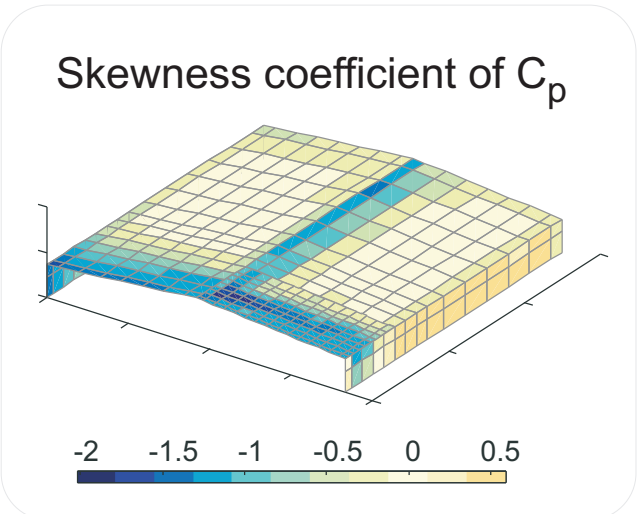
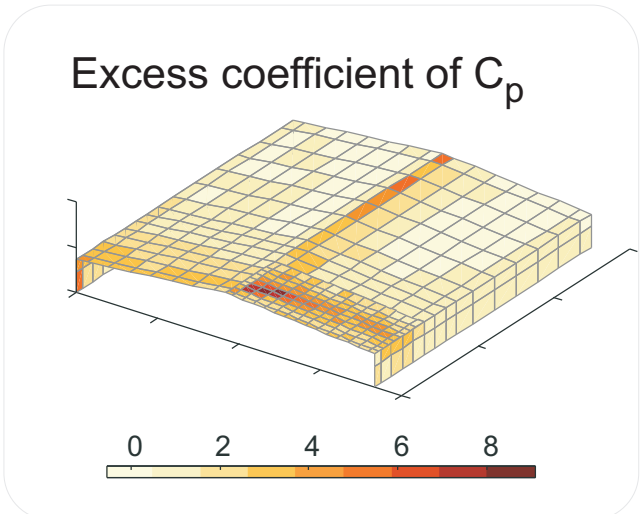
# Academic Example: Pressure Field

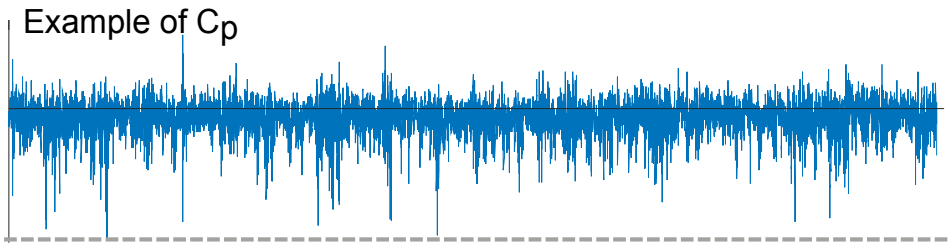


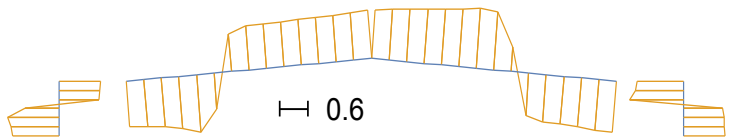



# Academic Example: Response in Frame #2

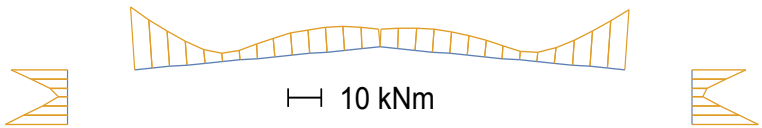



$$\mathbf{r}(t) = \mathbf{A}\mathbf{p}(t)$$

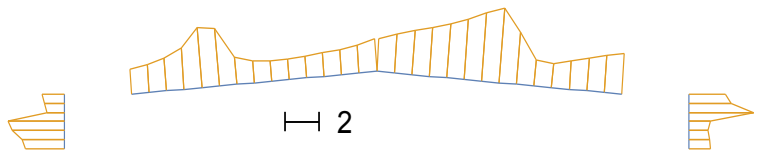

Mean Bending Moment




Skewness of Bending Moment

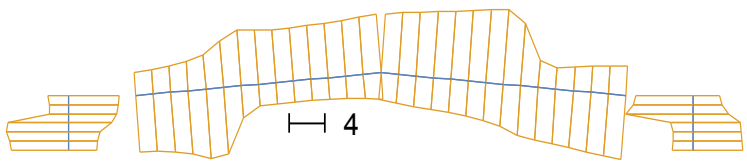



Standard Deviation of Bending Moment

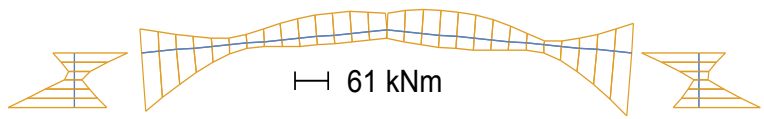



Excess of Bending Moment

$$E = \mu + g\sigma$$




Peak Factor (Nonsymmetric)




Extreme/Design value
Envelope

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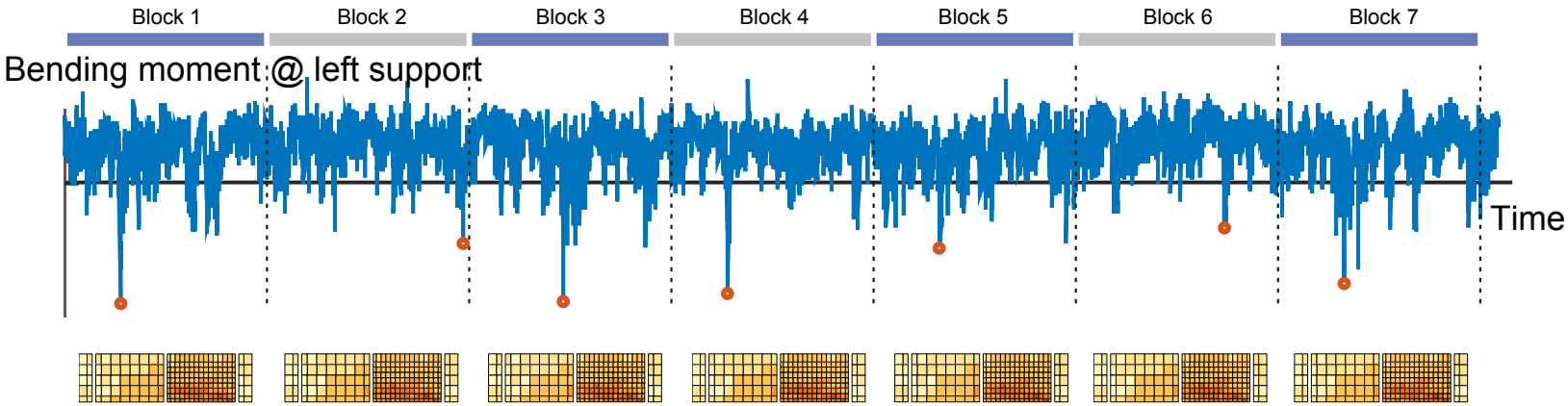
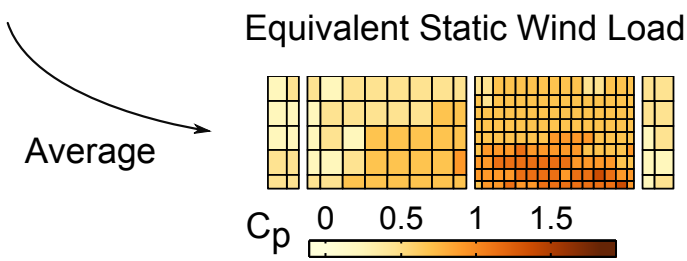
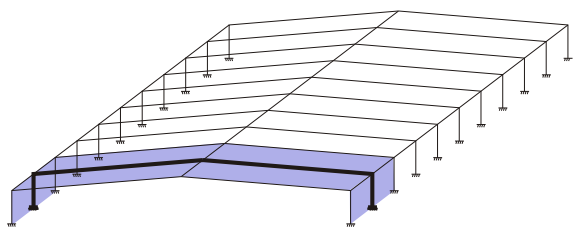
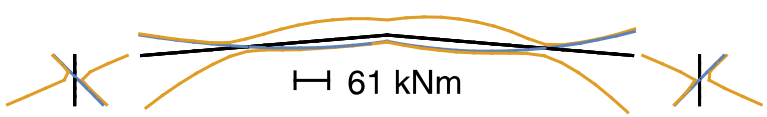
# Equivalent Static Wind Load

▷ Conditional Sampling technique [Holmes 1988]

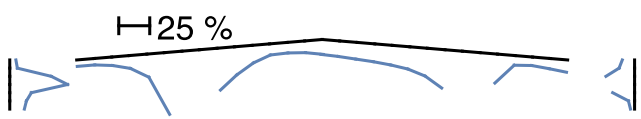





Bending moments under ESWL




Envelope overshooting

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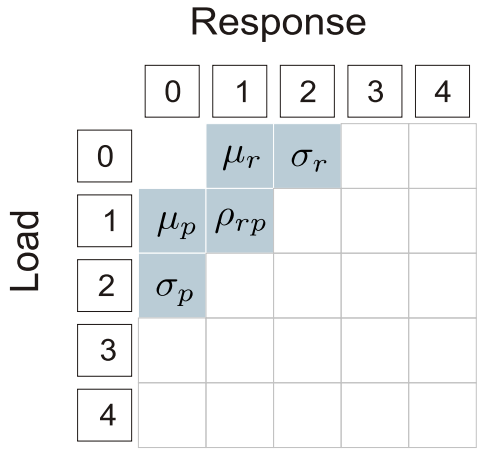
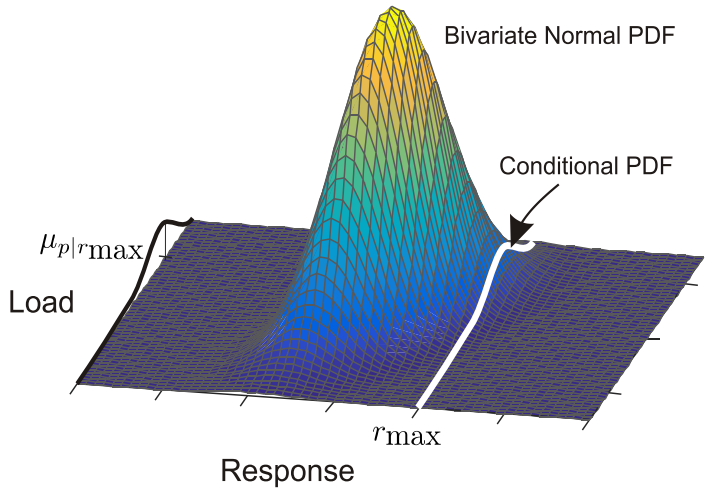
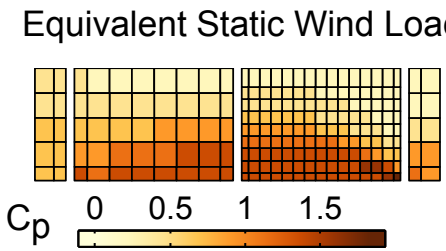
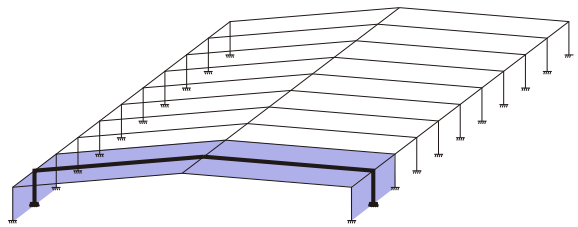
# Equivalent Static Wind Load

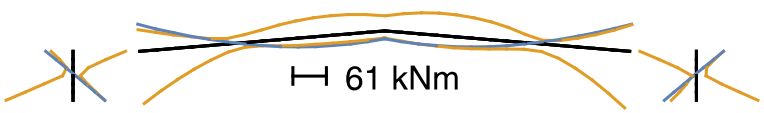
▷ Load-Response Correlation (LRC) [Kasperski 1992]



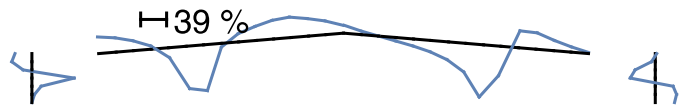






Bending moments under ESWL

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# Equivalent Static Wind Load

▷ Non-Gaussian Load-Response Correlation: **a bi-cubic model**

| Load \ Response | 0 | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| 0 | | $\mu_r$ | $\sigma_r$ | $\gamma_{3,r}$ | $\gamma_{4,r}$ |
| 1 | $\mu_p$ | $\rho_{rp}$ | | | |
| 2 | $\sigma_p$ | | | | |
| 3 | $\gamma_{3,p}$ | | | | |
| 4 | $\gamma_{4,p}$ | | | | |

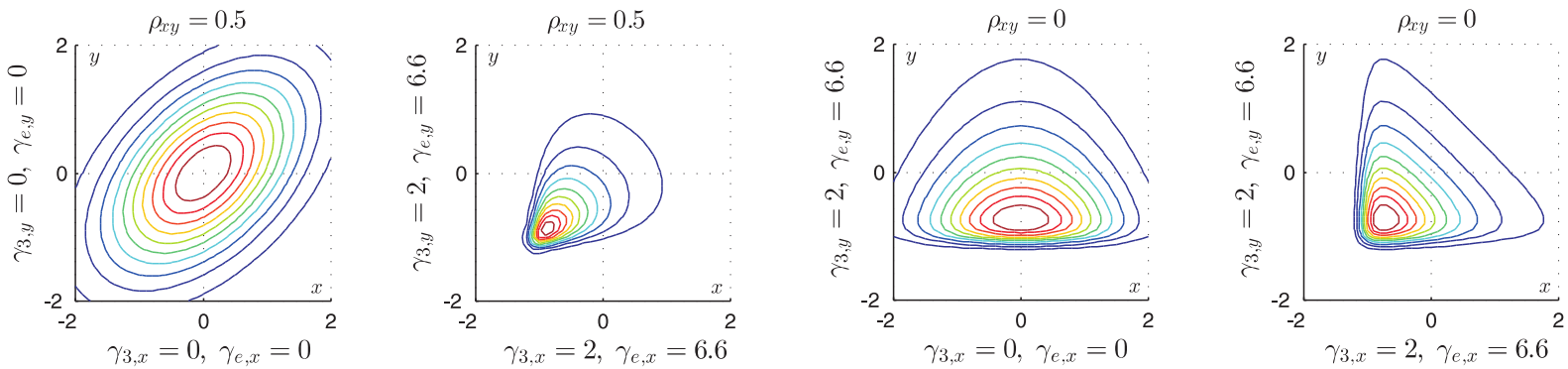
$u_r,\, u_p$ : Two correlated normal R.V.

$a_r, b_r, \alpha_r, a_p, b_p, \alpha_p, \rho_{rp}$ : 7 parameters

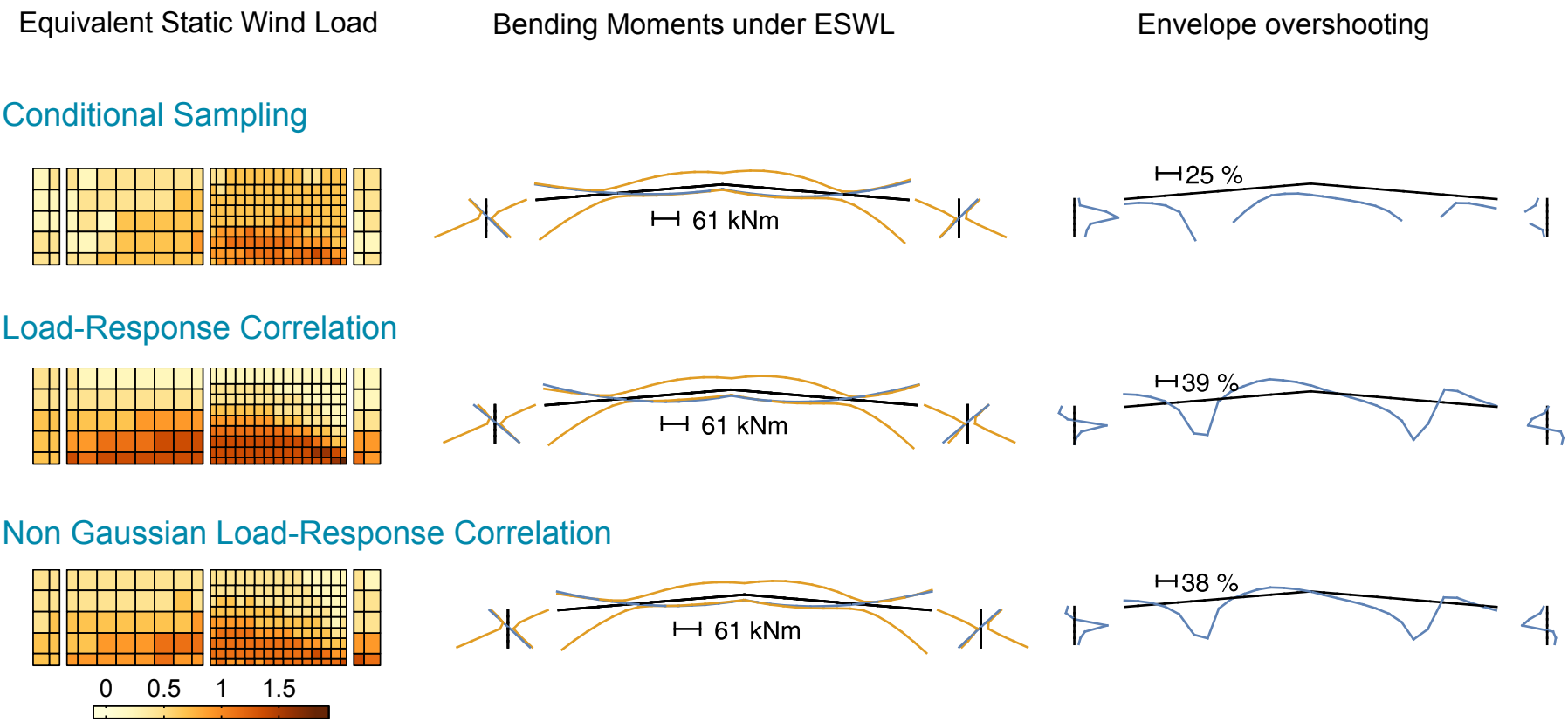
$$r = \frac{\alpha_r}{b_r}\left(\frac{u_r^3}{3} + a_r u_r^2 + (b_r - 1)\, u_r - a_r\right)$$

$$p = \frac{\alpha_p}{b_p}\left(\frac{u_p^3}{3} + a_p u_p^2 + (b_p - 1)\, u_p - a_p\right)$$

Examples of PDFs generated with the bi-cubic model



# Equivalent Static Wind Load: Comparison




- LRC: Severe over-estimation of the envelope
- Non-G. LRC: Slight over-estimation of the envelope

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# Two important properties & Adjustment

1. the *Envelope value condition*
... The ESWL associated with a given response should **return the design value** for that response ...

2. the *Non-overestimation condition*
... The responses under a given ESWL should **not exceed** the target envelope ...

$\rightarrow$ 2-step adjustment

$$\tilde{p}^{(e)} = \beta \circ \left( \alpha p^{(e)} \right)$$

$\alpha$: load scaling coefficient
$\beta$: local adjustment coefficient

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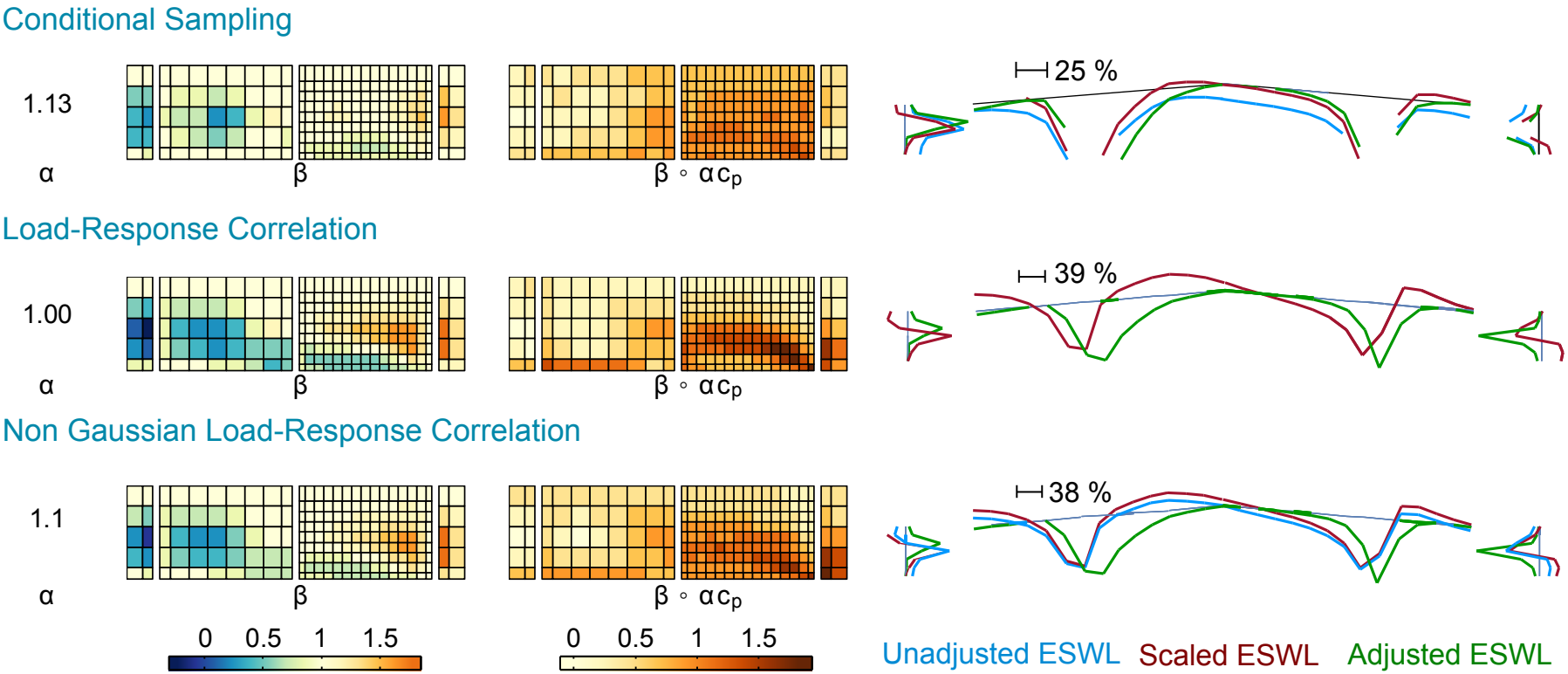
# Illustration of Adjustment




- $\alpha = 1$ for the LRC method
- $\beta$ is obtained with a constrained optimization algorithm (as close as 1 as possible)

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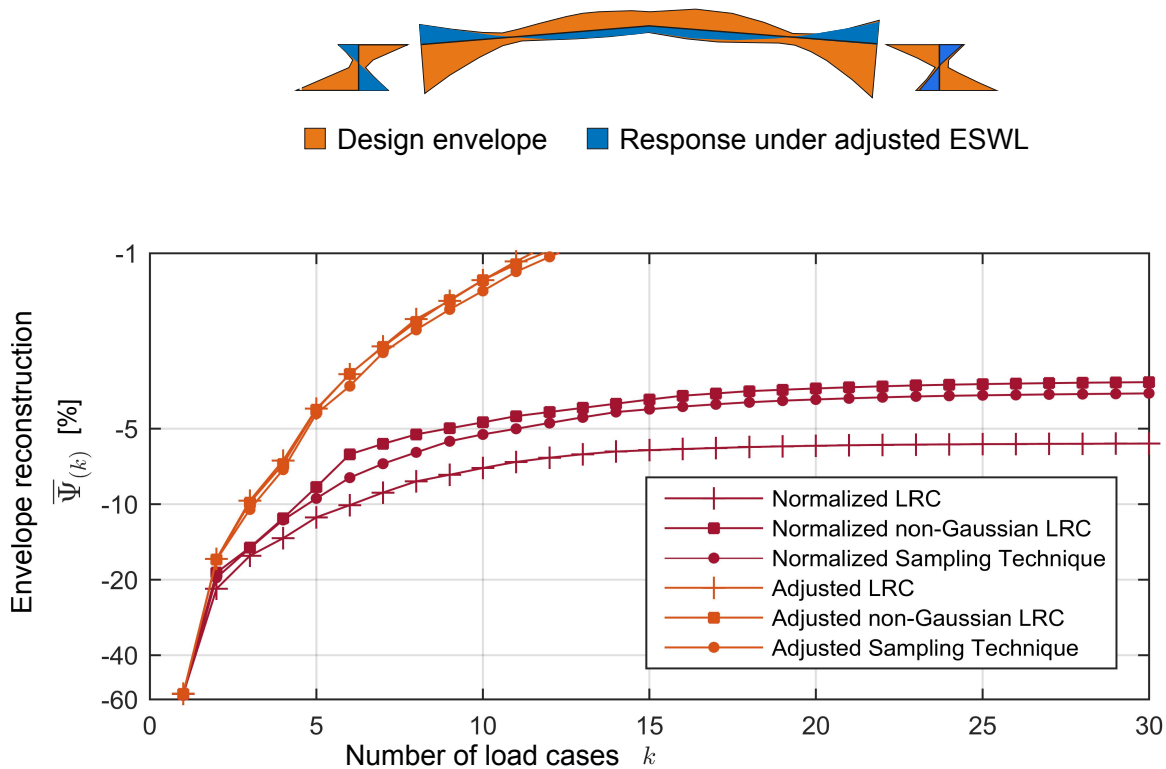
# Envelope Reconstruction




- Adjustment → faster reconstruction
- Conditional Sampling, LRC, nG-LRC perform equally if adjusted

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# Perspectives & Conclusions

**Proposition of a Non Gaussian version of the LRC**

▷ bi-cubic model

▷ regularly extends the LRC for non Gaussian pressure field/responses

**2-Step Adjustment of Equivalent Static Wind Load to meet:**

▷ the Envelope Value Condition

▷ the Non-Overstimation Condition

# Thank you ...

Vincent Denoël, Université de Liège
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www.ssd.ulg.ac.be

Read more about this topic:

- Blaise N., Denoël V. (2013). *Principal static wind loads.* Journal of Wind Engineering and Industrial Aerodynamics 113, 29-39.
- Blaise N., Canor T., Denoël V. (to appear). *Reconstruction of the envelope of non-Gaussian structural responses with principal static wind loads.*
- Kasperski M., (1992). *Extreme wind load distributions for linear and nonlinear design.* Engineering Structures 14, 27-34
- Holmes J.D., (1988). *Distribution of peak wind loads on a low-rise building.* Journal Of Wind Engineering and Industrial Aerodynamics 29, 59-67

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