

# Wind loads due to turbulence and structural vibrations

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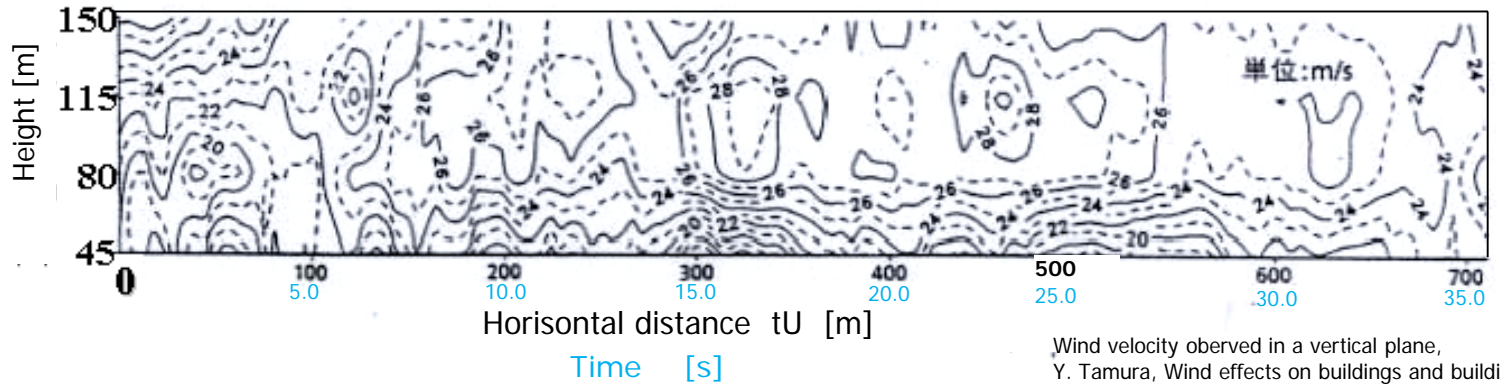
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# Overview

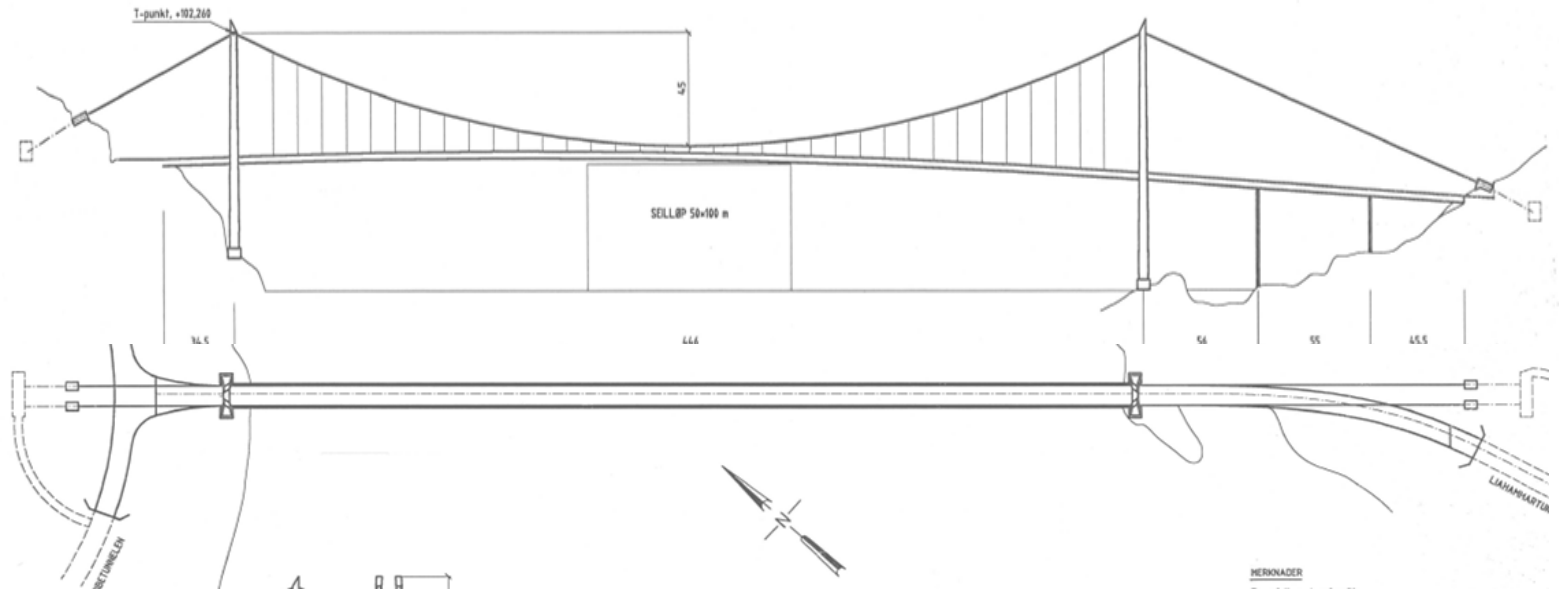
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- Introduction to basic turbulence characteristics: wind field variation in time and space
- Coherence effects on the wind turbine loads (basic analysis)
- NORCOWE work on turbulence characteristics and the associated load on wind turbines (WT)
- Field measurements of turbulence and structural vibrations and the related analysis (E. Cheynet)

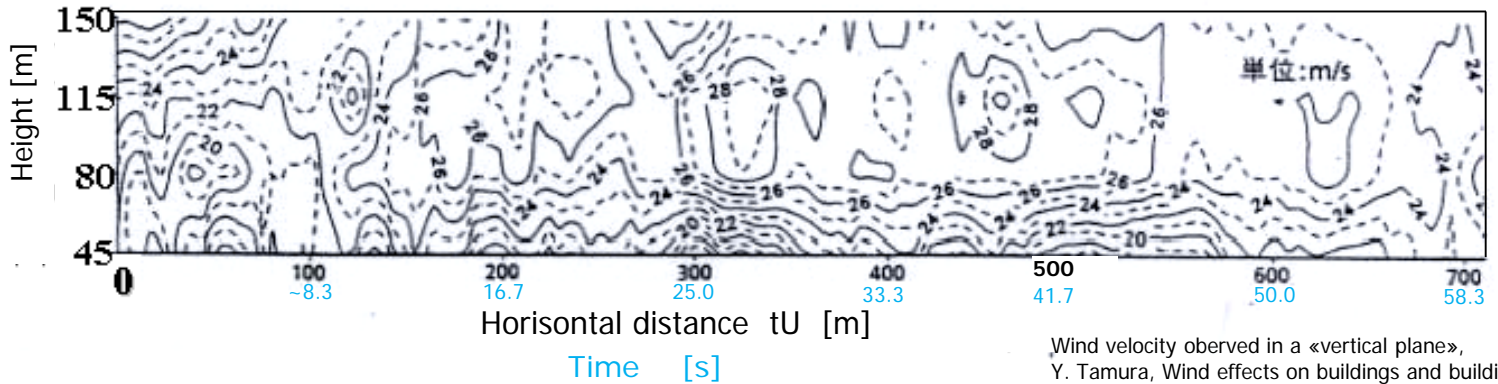
# Wind field variations in time and space



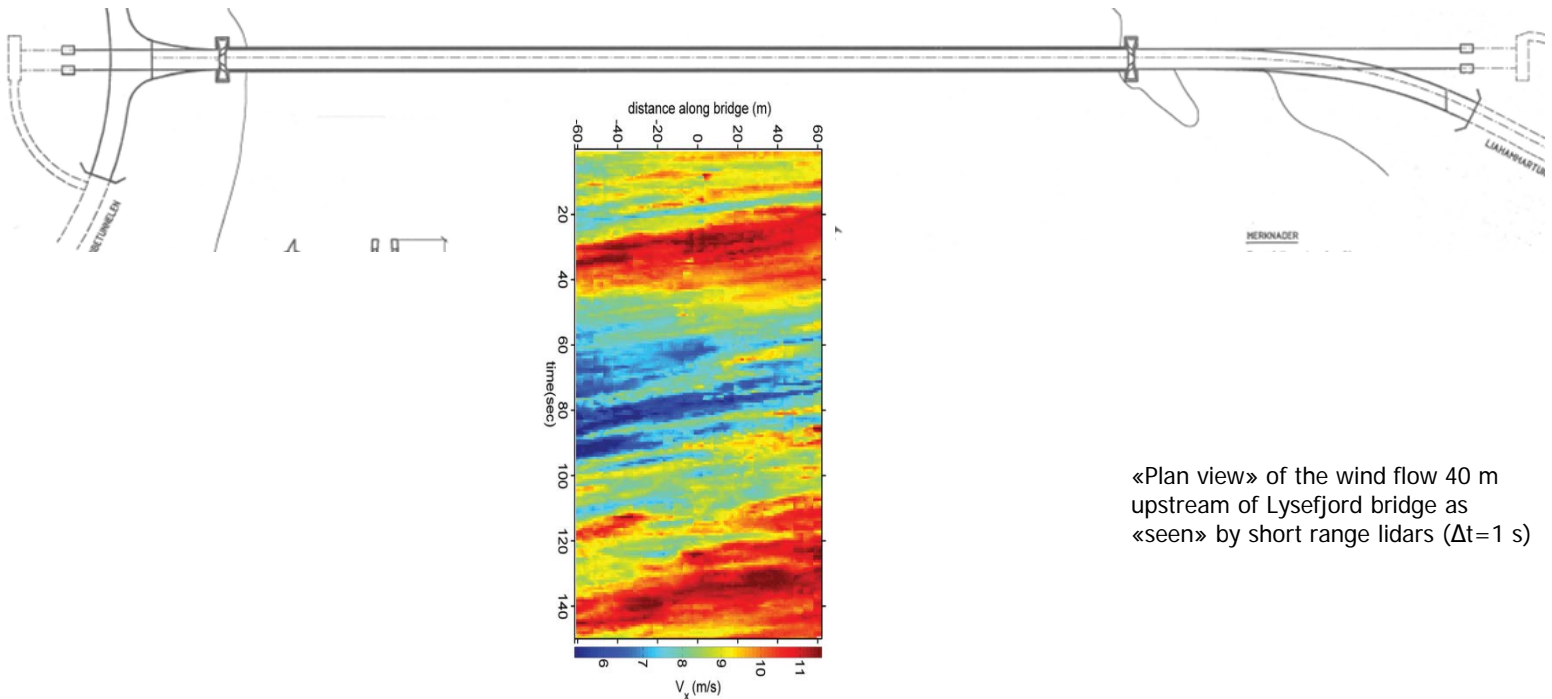
Wind velocity observed in a vertical plane,  
Y. Tamura, Wind effects on buildings and building environment



# Wind field variation in time and space



Wind velocity observed in a «vertical plane»,  
Y. Tamura, Wind effects on buildings and building environment



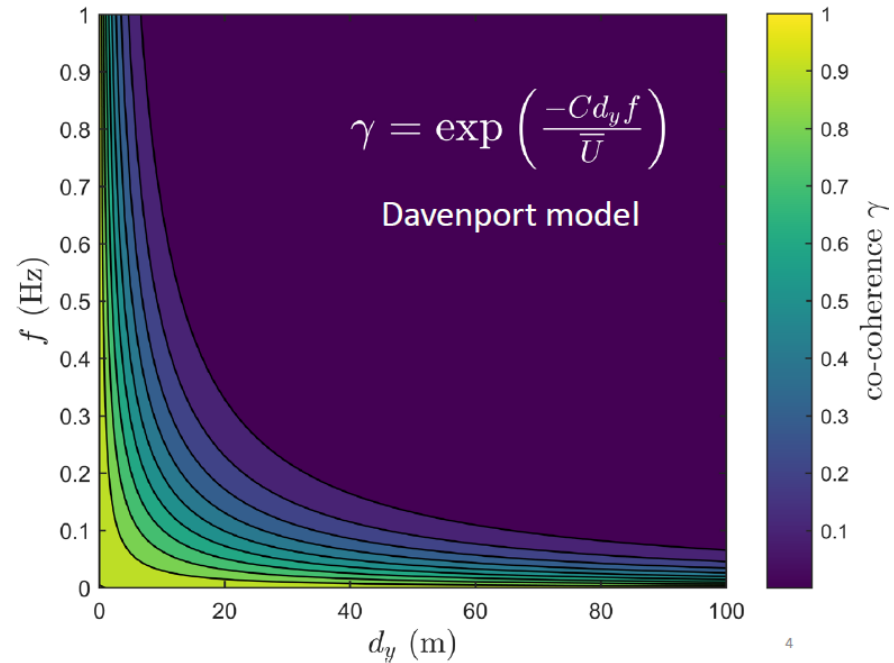
«Plan view» of the wind flow 40 m  
upstream of Lysefjord bridge as  
«seen» by short range lidars ( $\Delta t=1$  s)

# Spatio-temporal characteristics of wind fluctuations (i.e. turbulence)



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- Coordination of turbulence (wind gusts) decreases with increase in distance and frequency.
- Simple analysis of the significance for the wind turbine loads, based on the across-flow cross-correlation coefficient governed by a length scale  $L_u^y$ :



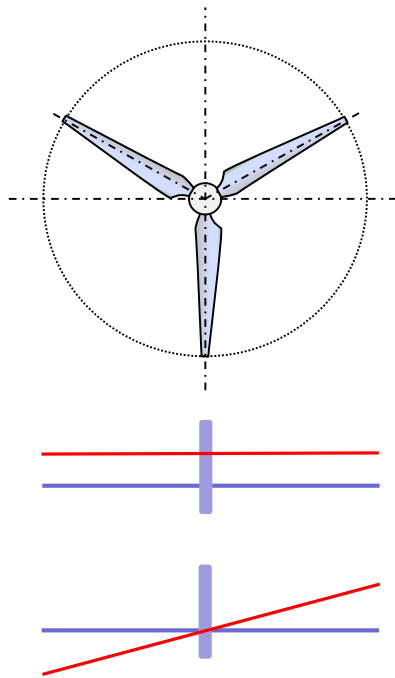
Cheynet, E., 2016

$$\gamma(d_y, f) = \exp\left(-\frac{C \cdot f \cdot d_y}{U}\right)$$

$$\tilde{\gamma}(d_y) = \exp\left(-\frac{d_y}{L_u^y}\right)$$

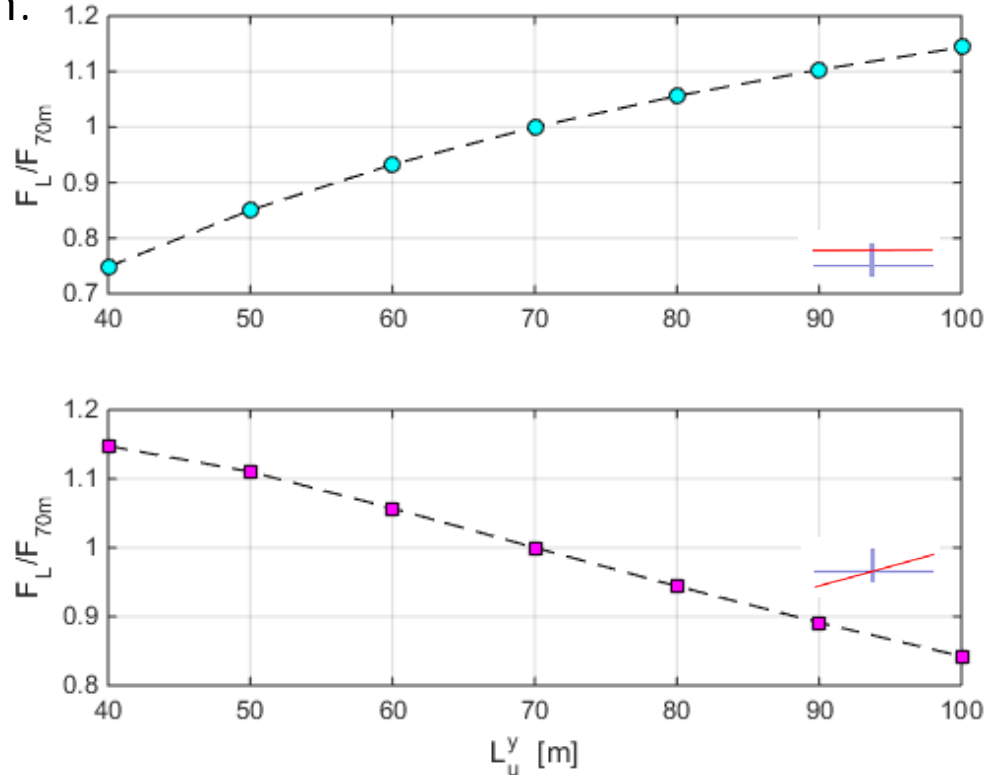
# Significance of turbulence spatio-temporal variability for wind turbine loads

- Influence of  $L_u^y$  on the quasi-steady «modal» force, relative to  $L_u^y = 70$  m,  $D = 150$  m.



Mode shapes / influence lines studied

Simple stationary «cantiliver» model



Load effects due to «symmetric» wind action increase with increase in lateral correlation of turbulence (larger length scales), while load effects related to «asymmetric» wind actions (e.g. yaw response of a floater) increase with a reduction in turbulence correlation (smaller length scales).

# Turbulence frequencies «investigated» in the simple analysis

Load frequencies in Hz for which the presented load sensitivity analysis is most relevant

C [-]	5		10		15	
U [m/s]	10 m/s	20 m/s	10 m/s	20 m/s	10 m/s	20 m/s
$L_u^y$ [m]						
40	0.0500	0.1000	0.0250	0.0500	0.0167	0.0333
50	0.0400	0.0800	0.0200	0.0400	0.0133	0.0267
60	0.0333	0.0667	0.0167	0.0333	0.0111	0.0222
70	0.0286	0.0571	0.0143	0.0286	0.0095	0.0190
80	0.0250	0.0500	0.0125	0.0250	0.0083	0.0167
90	0.0222	0.0444	0.0111	0.0222	0.0074	0.0148
100	0.0200	0.0400	0.0100	0.0200	0.0067	0.0133

$$\tilde{\gamma}(d_y) = \exp\left(-\frac{d_y}{L_u^y}\right)$$

$$\gamma(d_y, f) = \exp\left(-\frac{C \cdot f \cdot d_y}{U}\right)$$

# Turbulence and the related aerodynamic load effects on wind turbines

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## NORCOWE activities:

Field measurements and analysis:

Assessment of offshore turbulence characteristics including atmospheric stability conditions, coherence, wake turbulence...

CMR, UiB, UiS...

Parametric studies of the influence of different stability conditions on turbulence characteristics including different coherences on a wind turbine fatigue...

UiS, UiA, UAA, Statoil...