



ISTITUTO ITALIANO
DELLA SALDATURA
Il Gruppo

30-31 Maggio 2019

Porto Antico di Genova
Centro Congressi

Giornate
Nazionali di
Saldatura

GNS 10



Il ruolo del vento nell'ingegneria delle costruzioni

Giovanni Solari

*Dipartimento di Ingegneria Civile, Chimica e Ambientale
Scuola Politecnica, Università degli Studi di Genova*



European Research Council
Established by the European Commission



Wind Engineering and Structural
Dynamics Research Group



Danni e perdite di vite umane causate dal vento



United Nations Organization



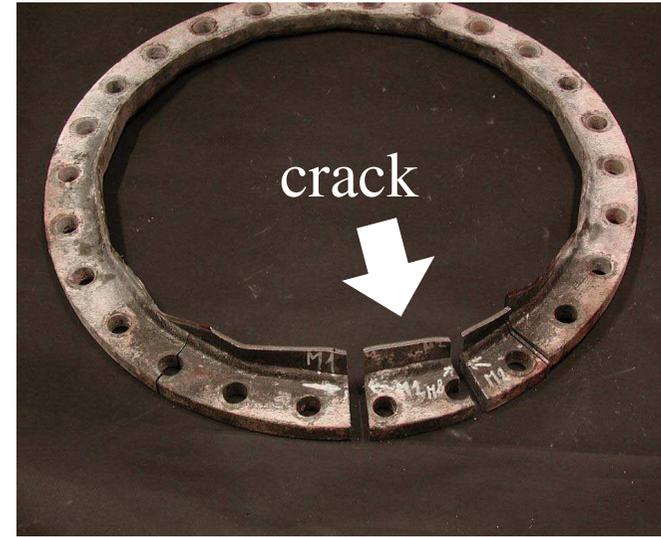
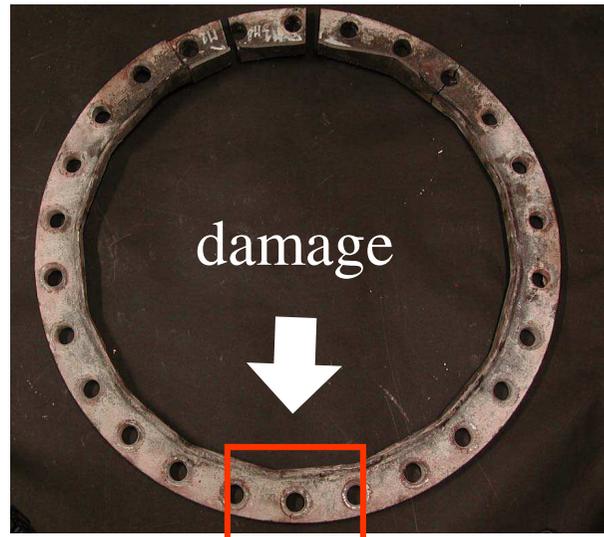
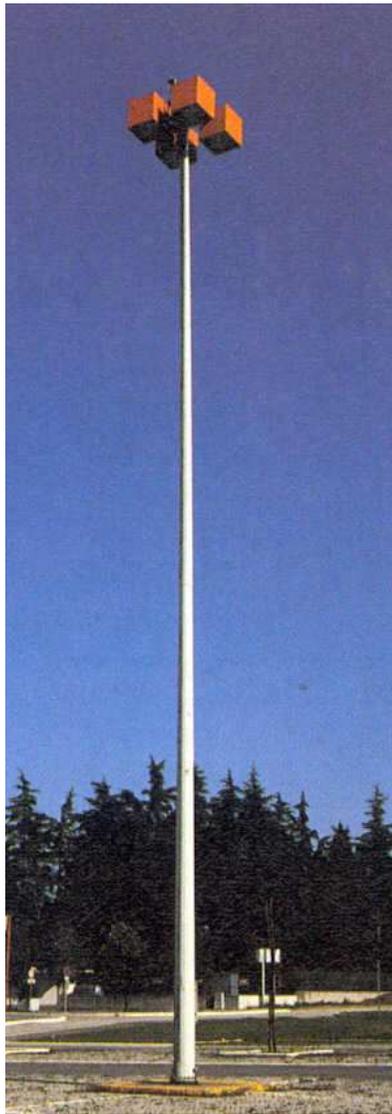
International Association
for Wind Engineering



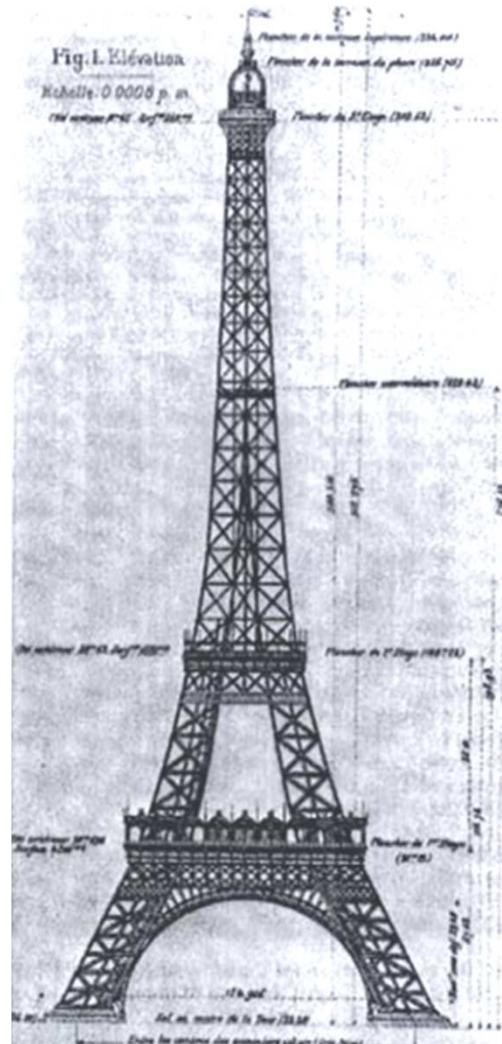
International Strategy for
Disaster Reduction



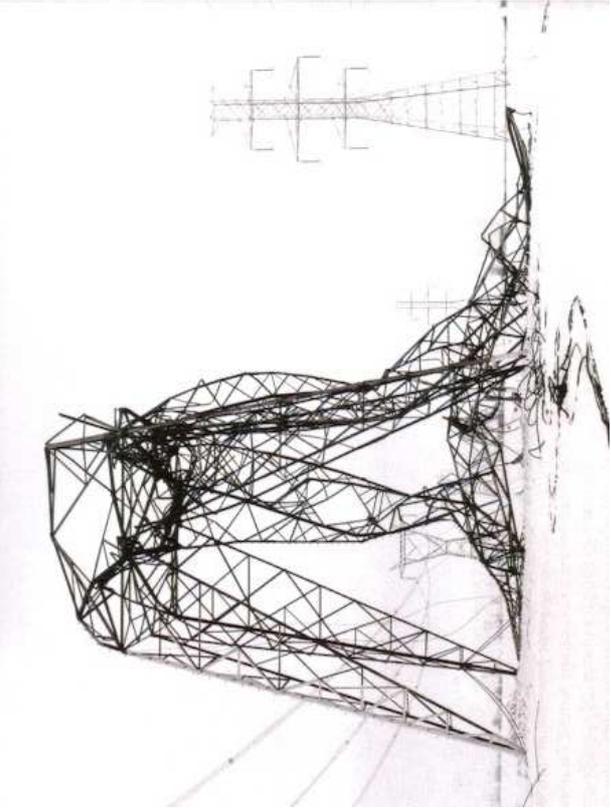
Ginevra, Svizzera (16-19 giugno 2009)

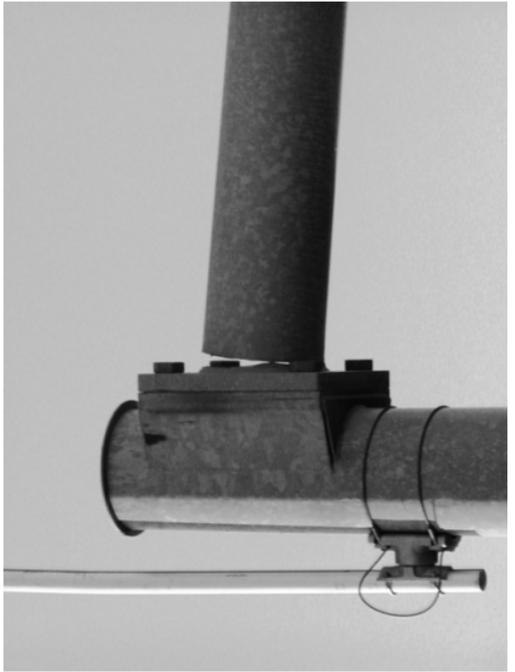


Repetto & Solari. *Engineering Structures* (2010)



Gustave Eiffel (1832-1923) e la Torre Eiffel (1889)







Repetto & Solari. *Engineering Structures* (2010)

Velocità del vento e pressione cinetica

1

v



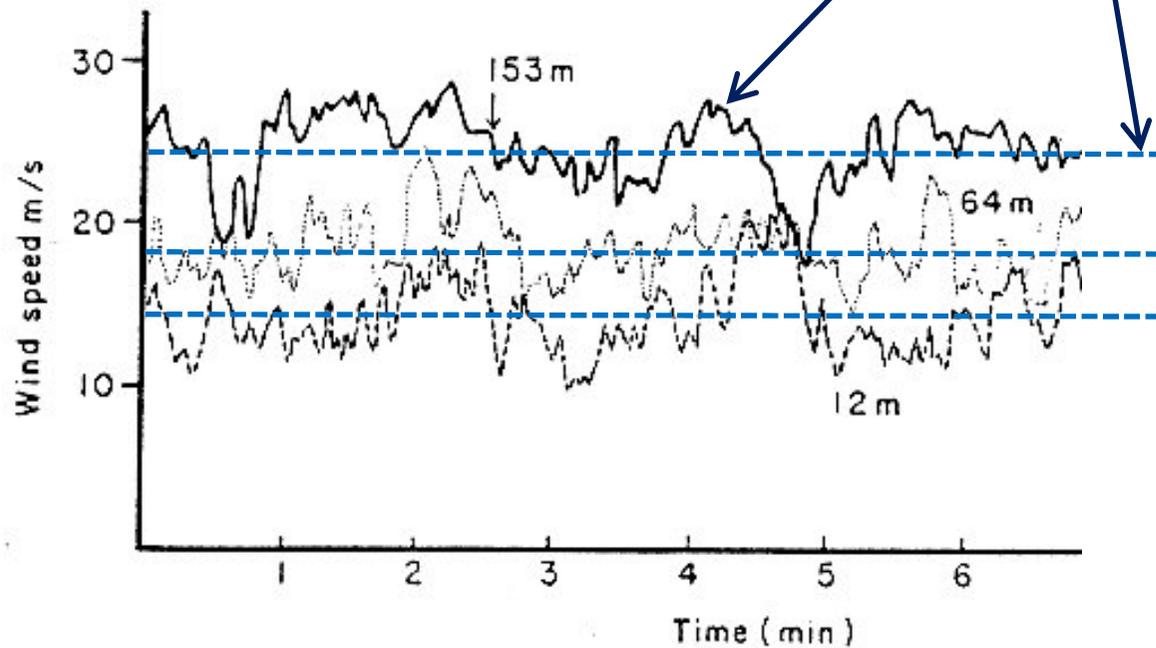
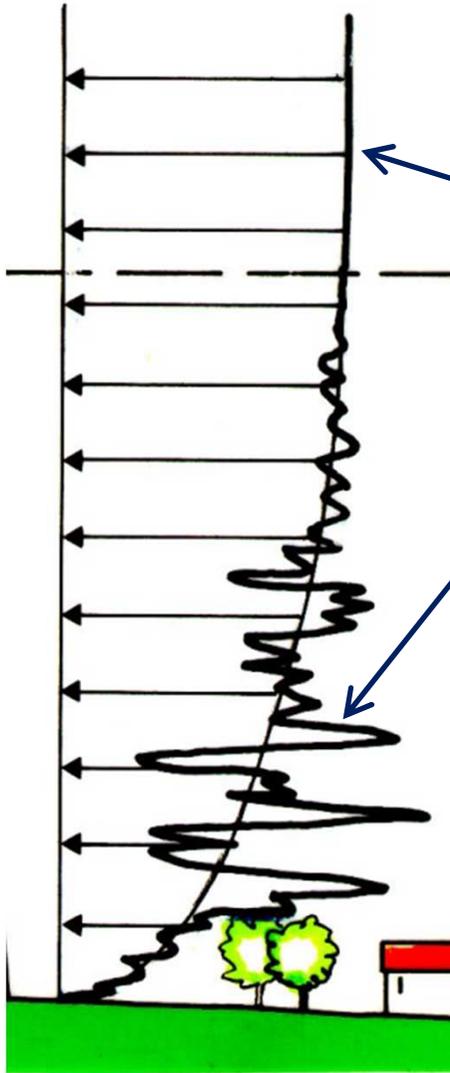
wind
velocity

Velocità del vento

$$u(z, t) = \bar{u}(z) + u'(z, t)$$

\bar{u} = velocità media del vento

u' = fluttuazione turbolenta



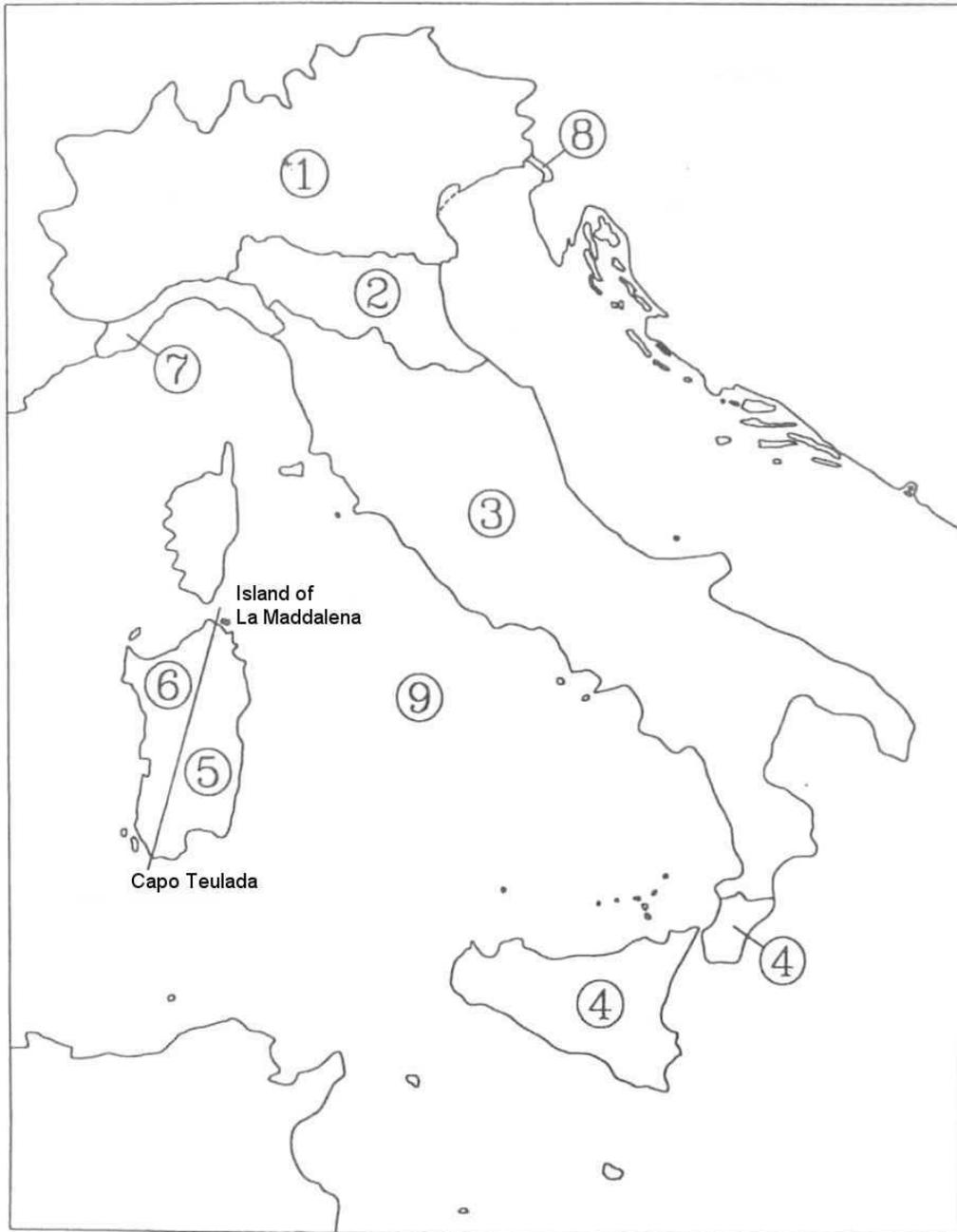
Velocità media del vento

$$\bar{u}(z) = u_{\text{ref}} \cdot c_r(z) \cdot c_t(z)$$

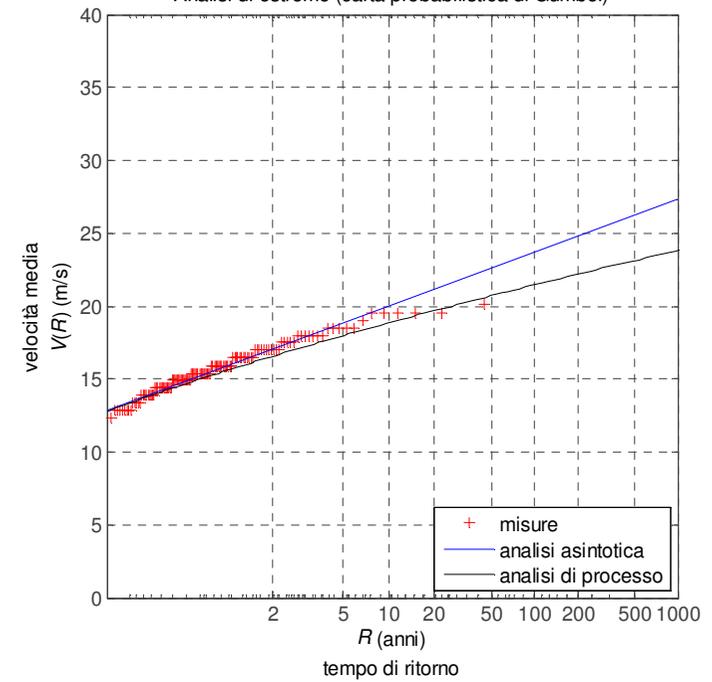
u_{ref} = velocità di riferimento esprime la ventosità a scala territoriale

c_r = tiene conto della scabrezza locale

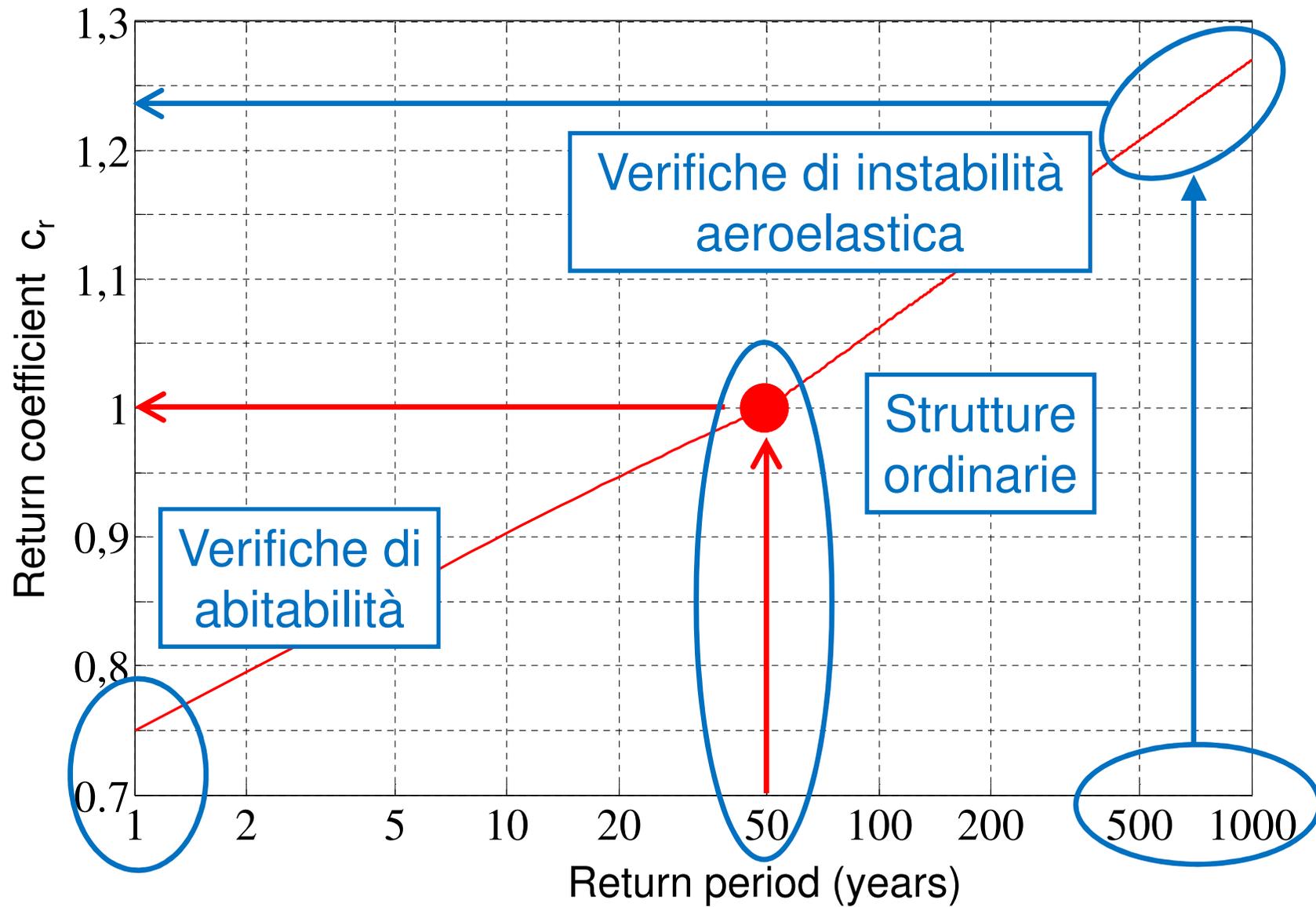
c_t = tiene conto della topografia locale



Analisi di estremo (carta probabilistica di Gumbel)

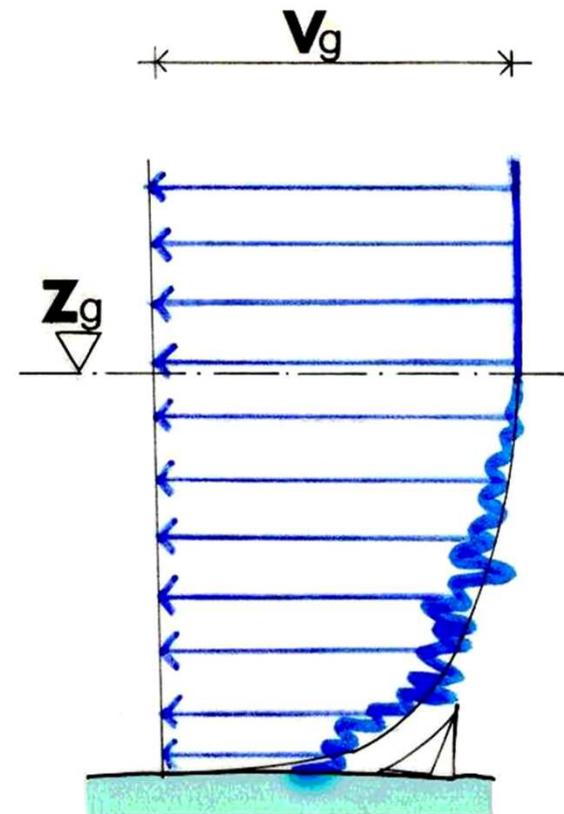
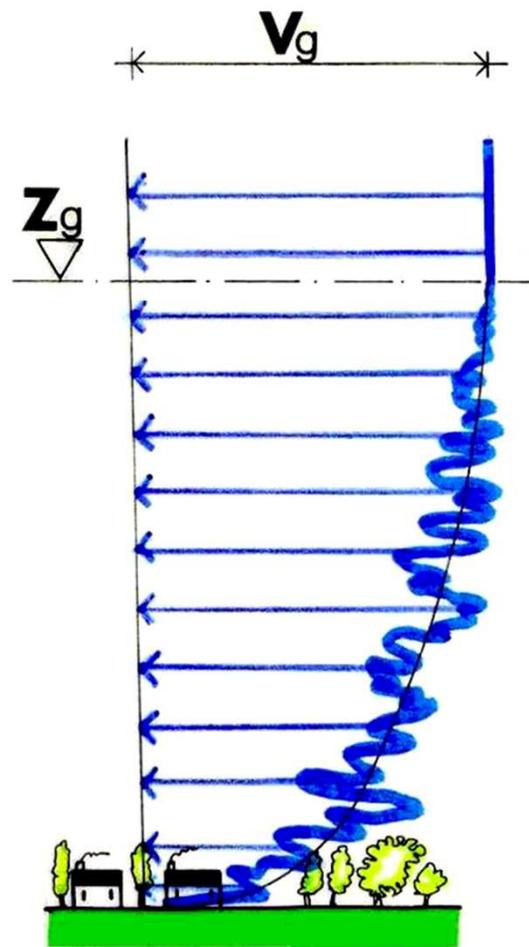
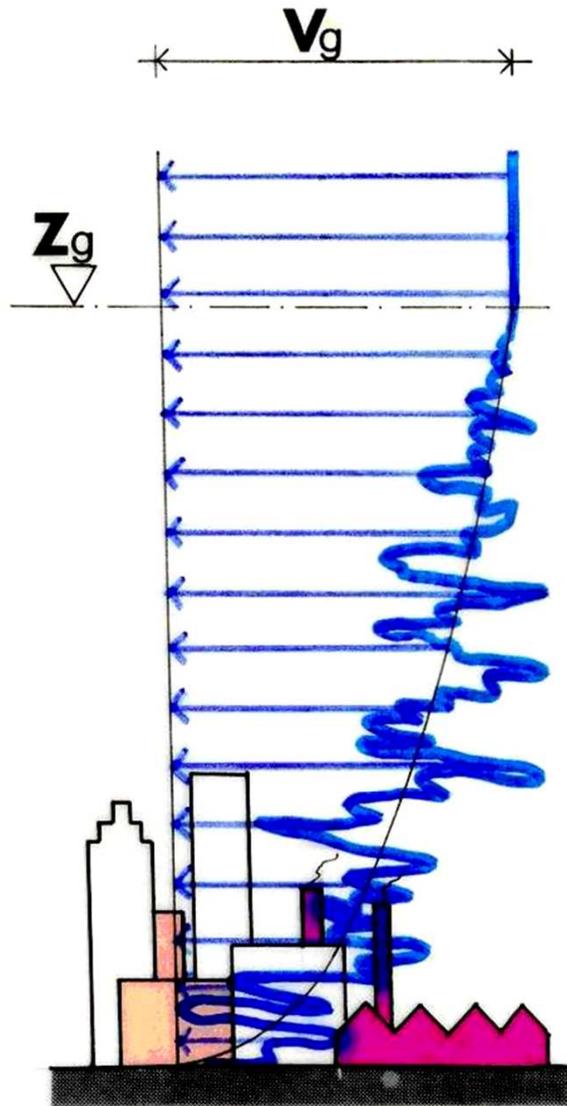


Velocità di riferimento di progetto

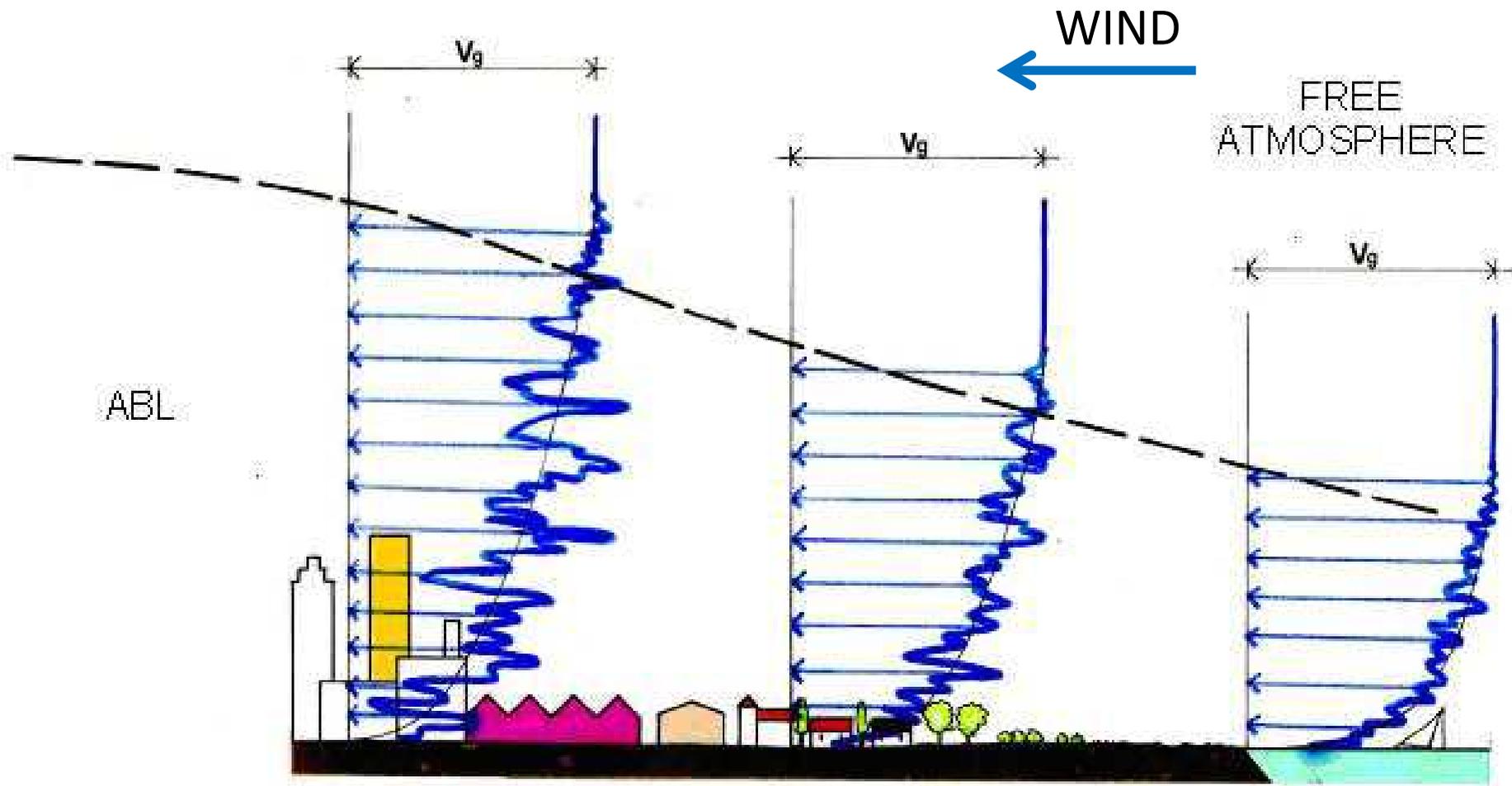


Velocità di progetto in funzione del periodo di ritorno

Terreno omogeneo

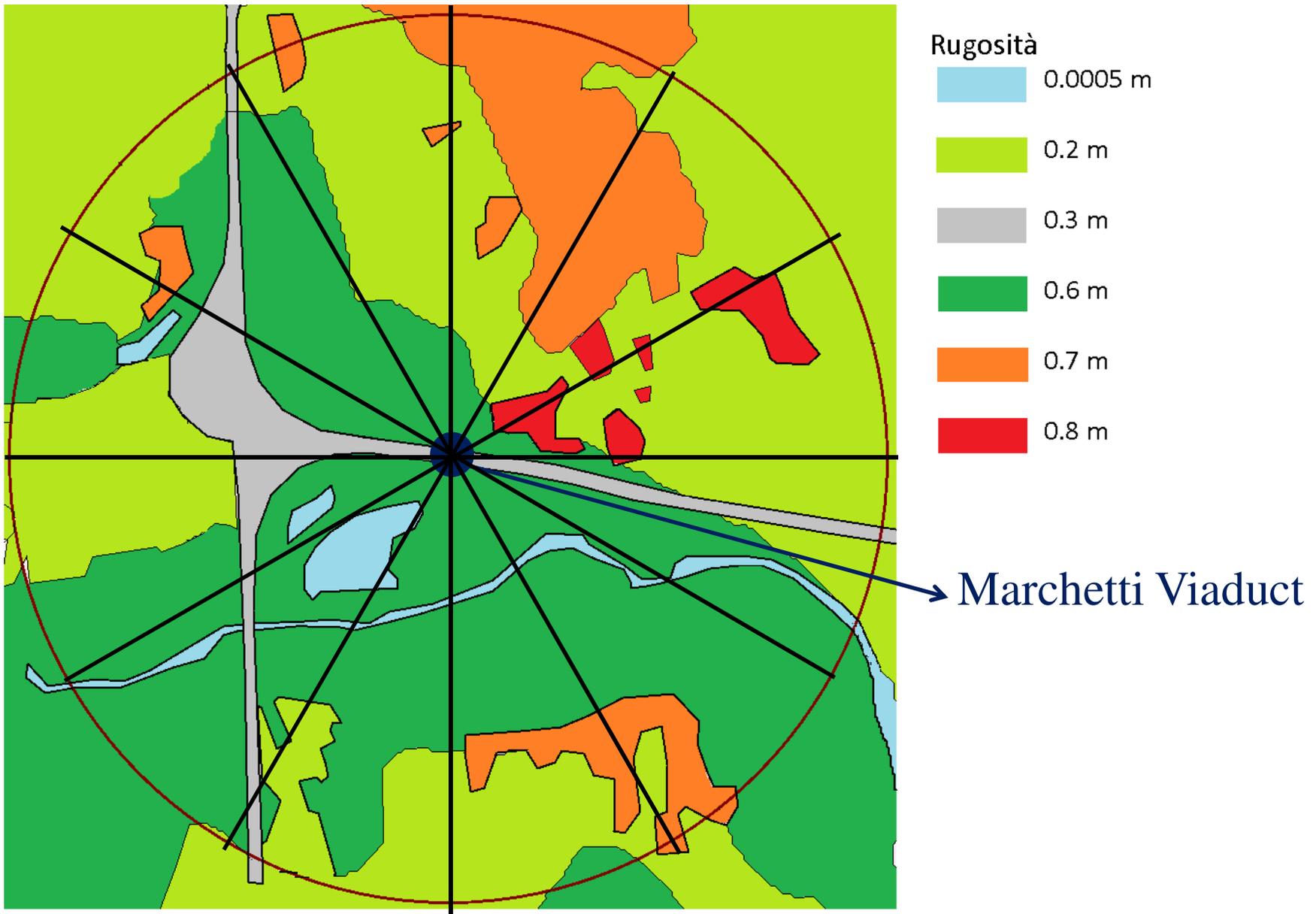


Profili di transizione

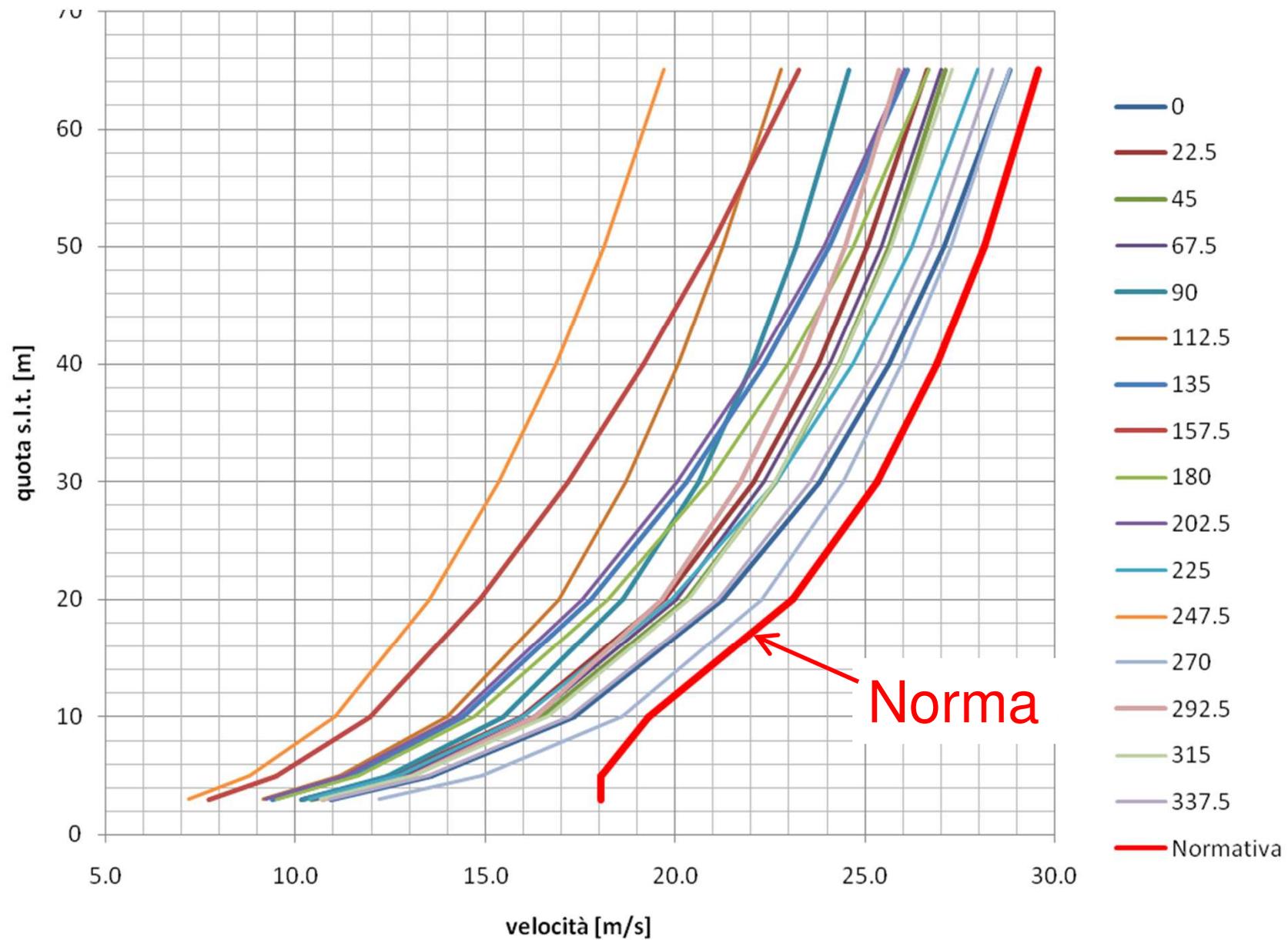




Viadotto Marchetti, Ivrea

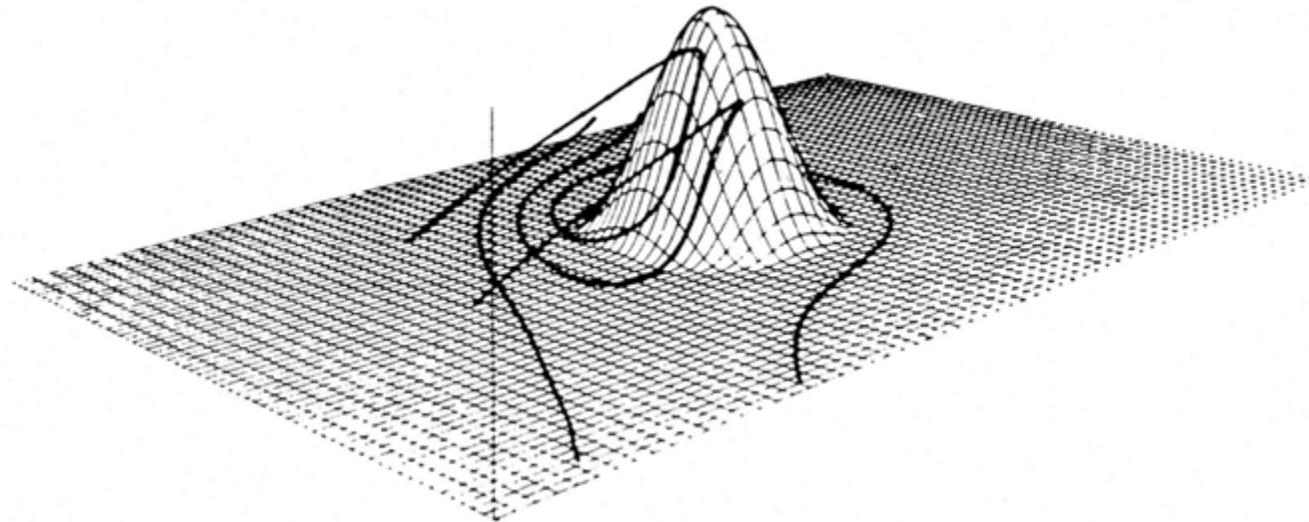
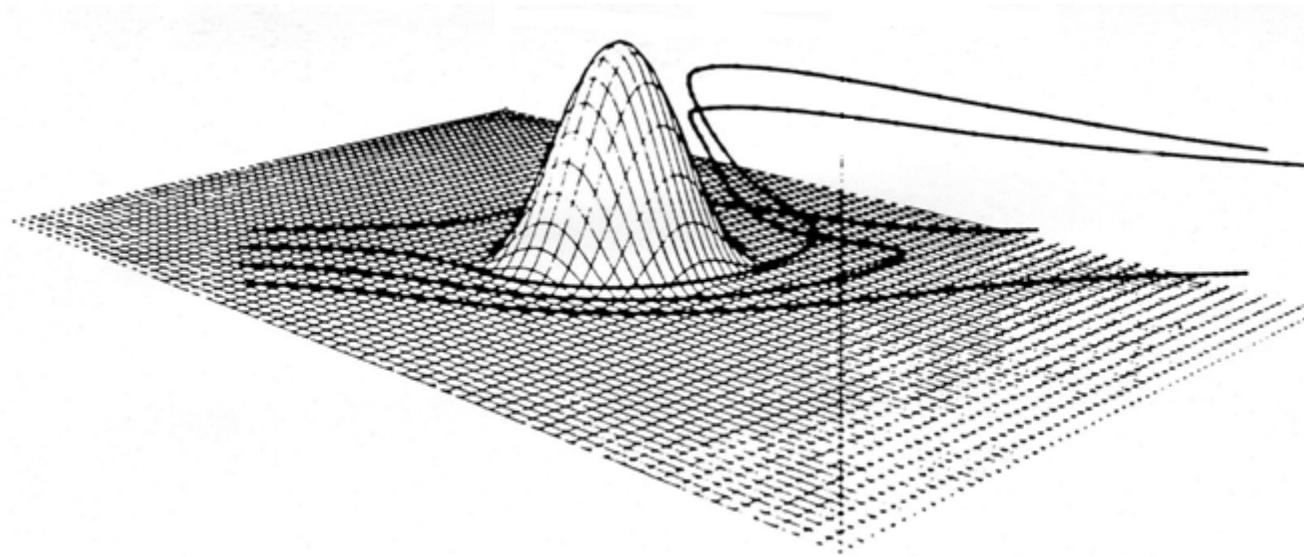


Viadotto Marchetti – Mappa di rugosità – Raggio 1 km

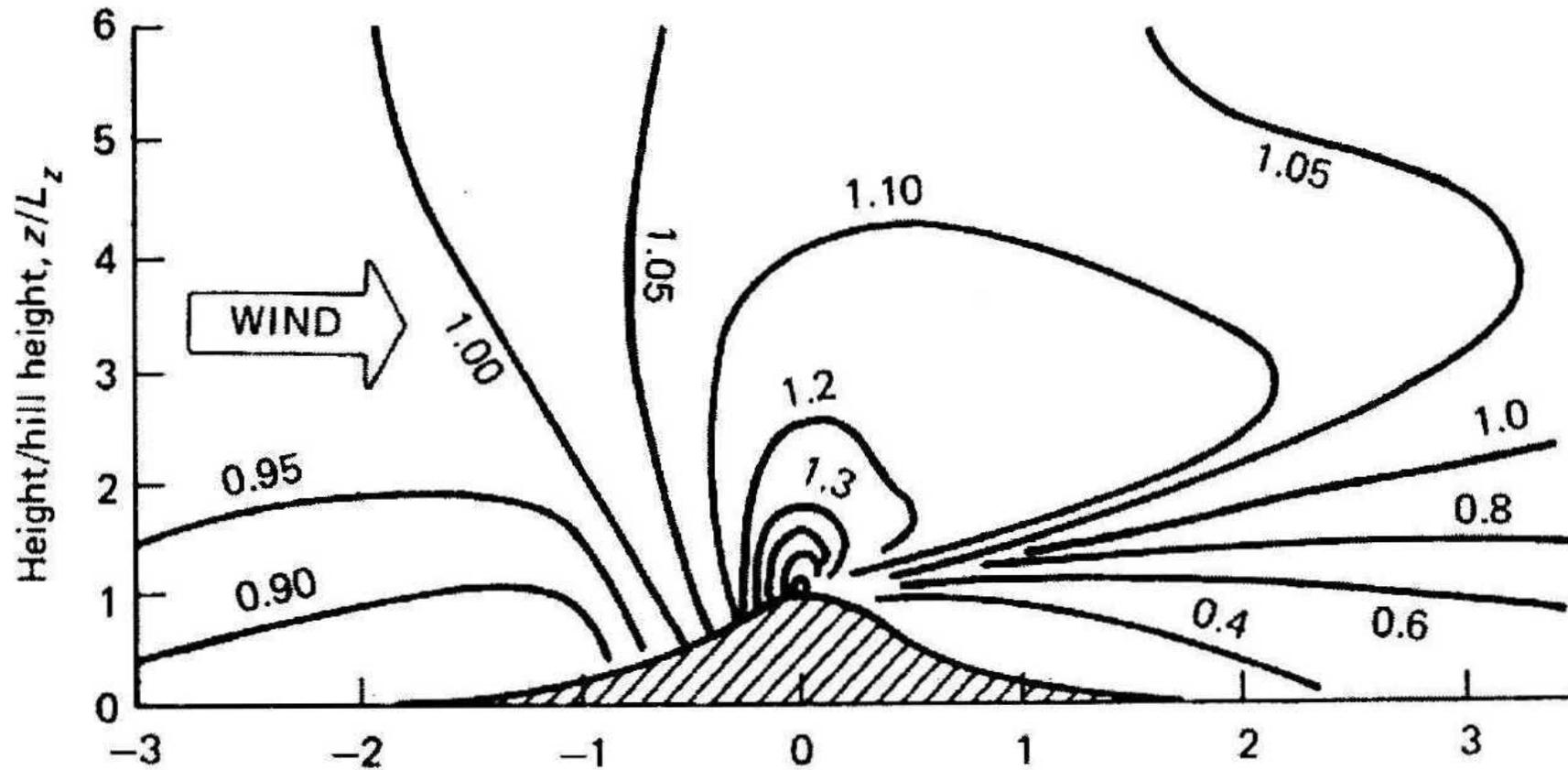


Viadotto Marchetti – Profili della velocità media di progetto

Effetti topografici



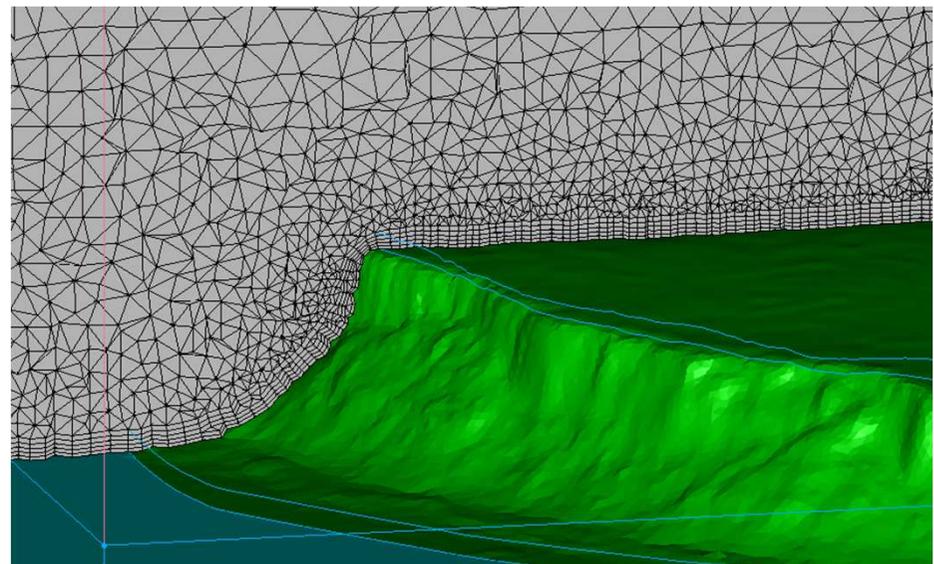
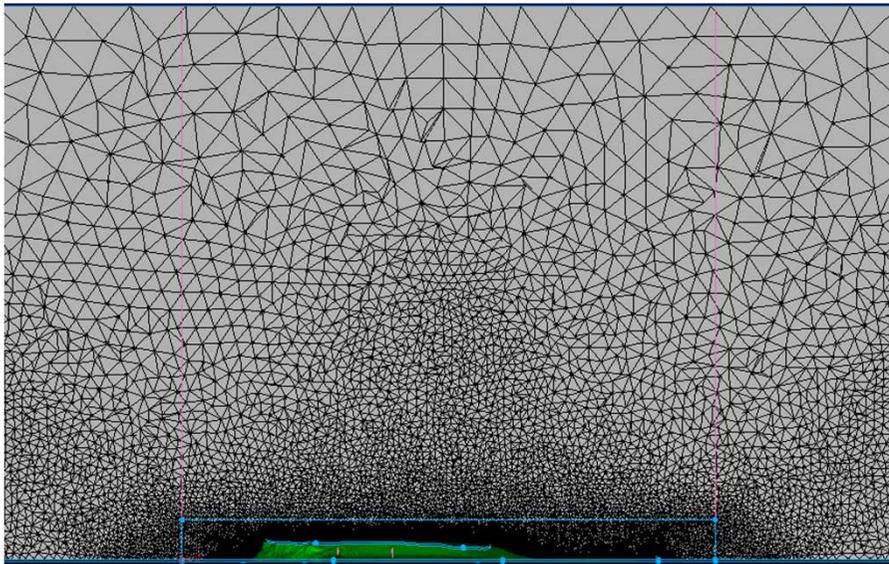
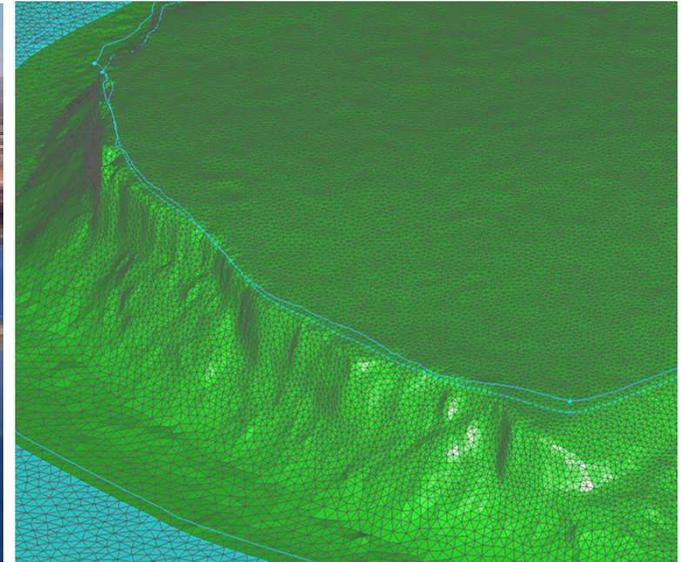
Effetti topografici



Linee di contorno – rapporto tra la velocità media del vento sulla topografia e lontano da essa

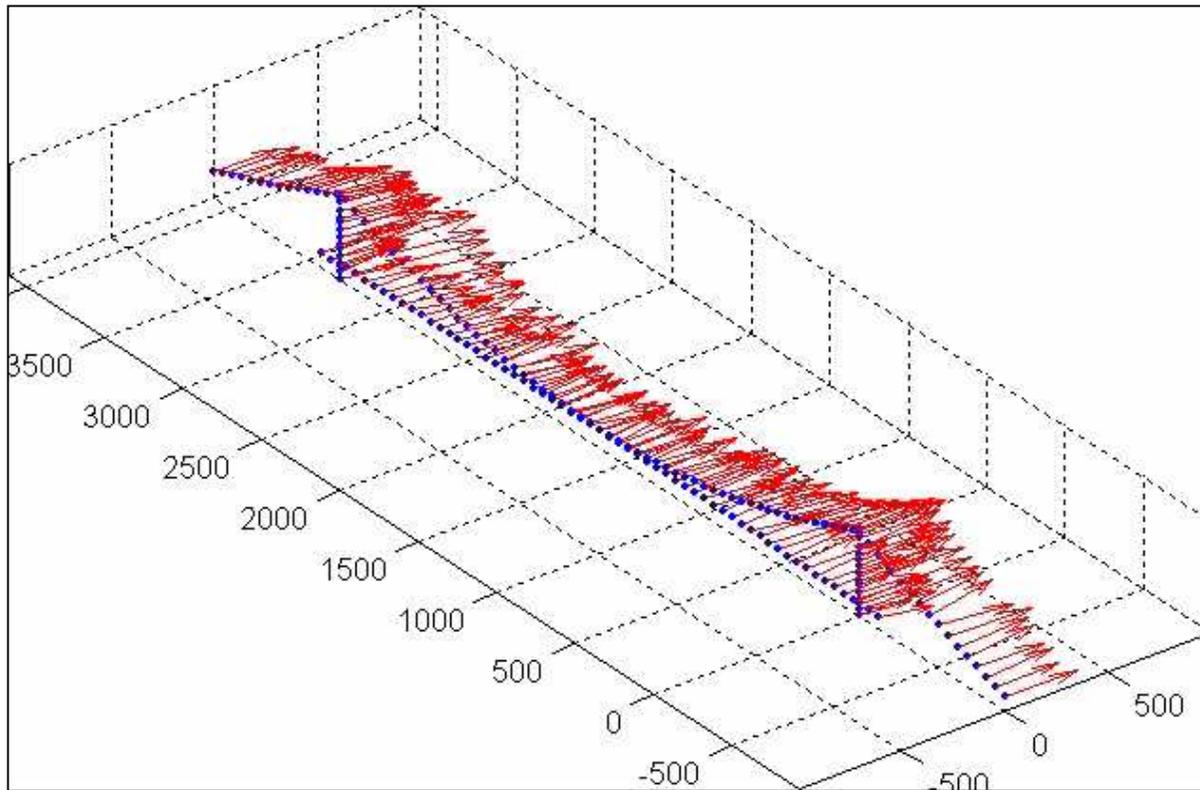


Ponte sullo Stretto di Messina – Modello topografico in galleria



Simulazione CFD dell'Isola di Bolund, Danimarca

Turbolenza atmosferica



Ponte sullo stretto di Messina – Simulazione Monte Carlo del vento

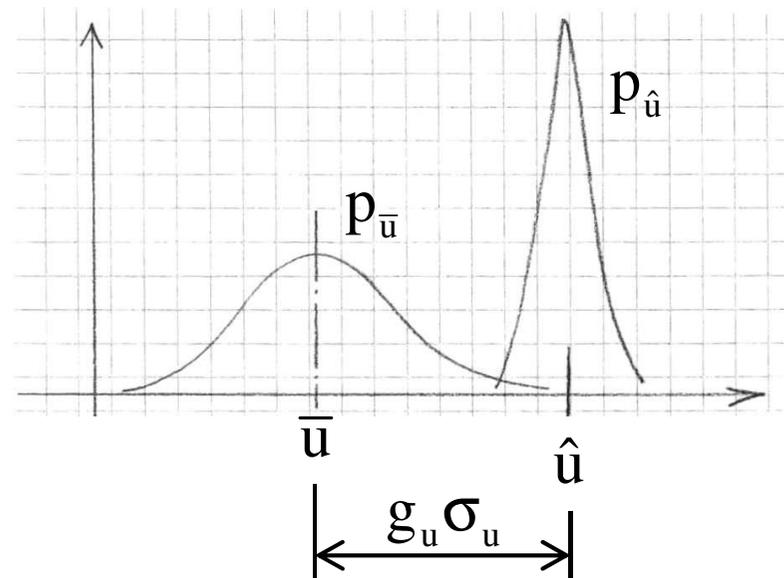
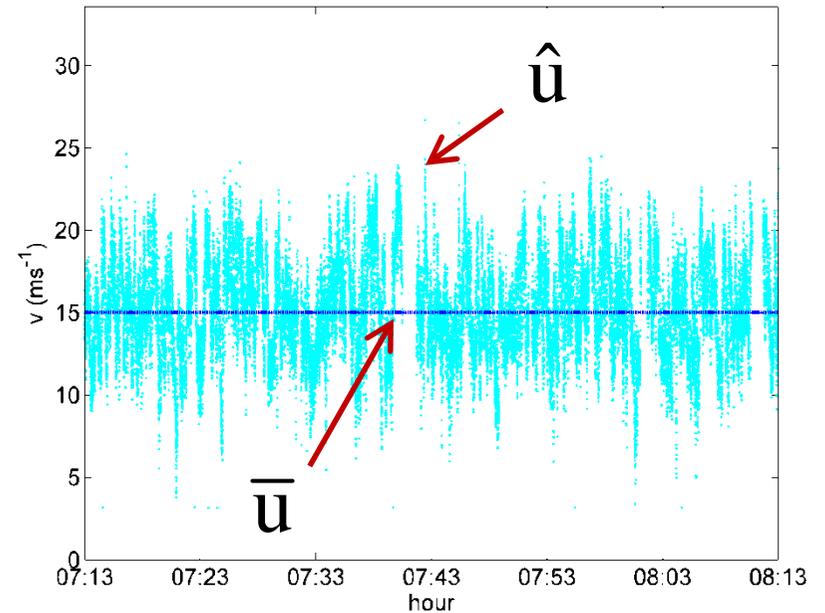
Turbolenza atmosferica

Velocità di picco

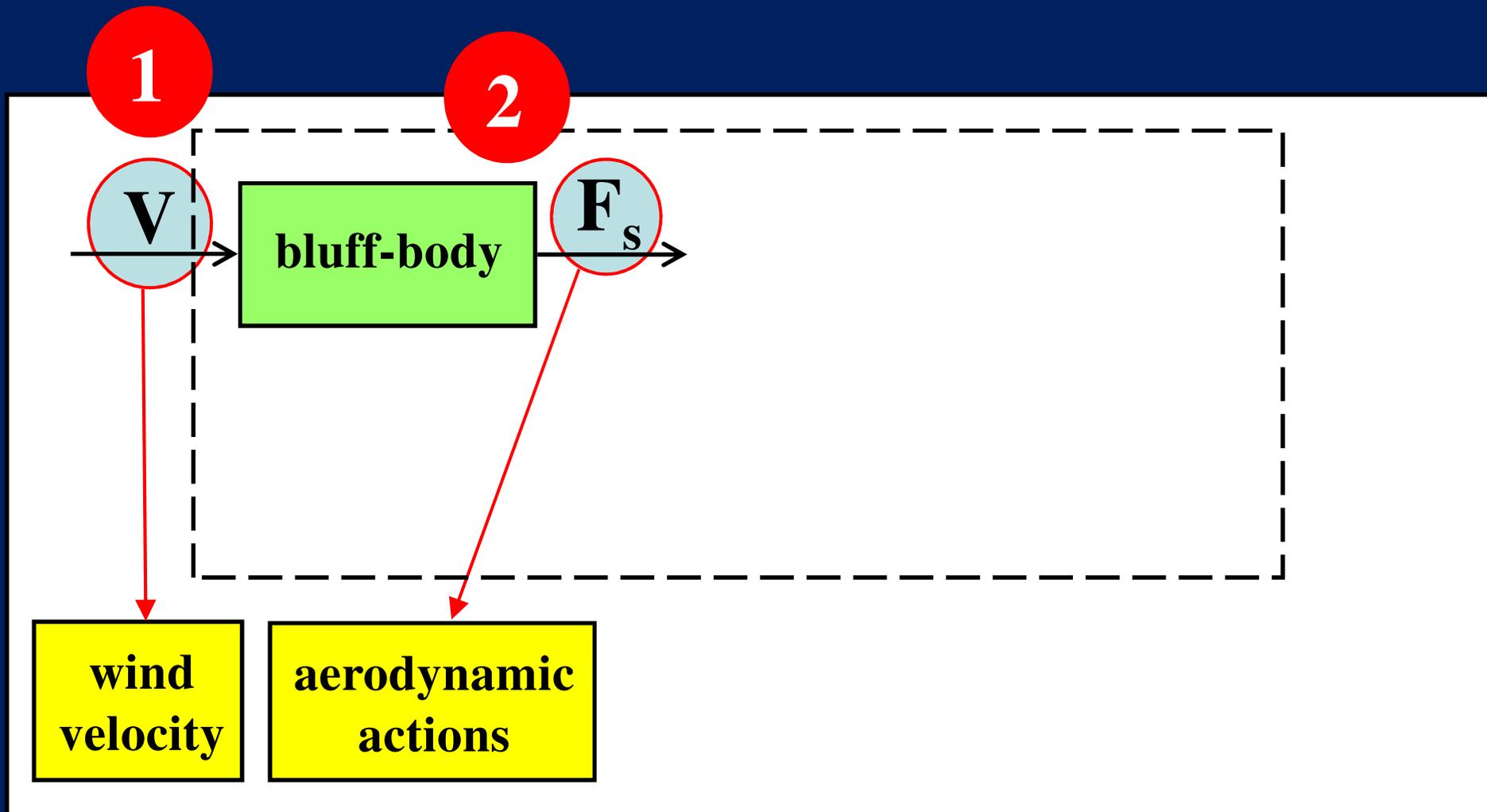
$$\hat{u} = \bar{u} \cdot G_u$$

Coefficiente di raffica

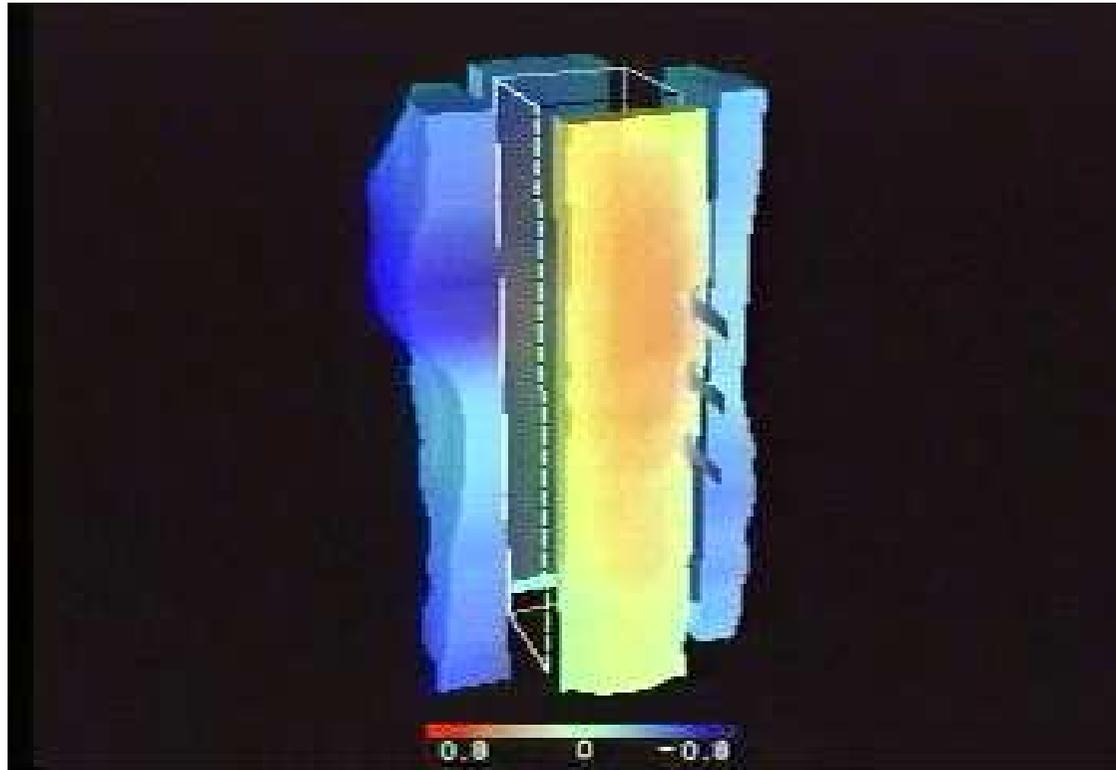
$$G_u = 1 + g_u \frac{\sigma_u}{\bar{u}} \approx 1,5$$



Azioni aerodinamiche del vento

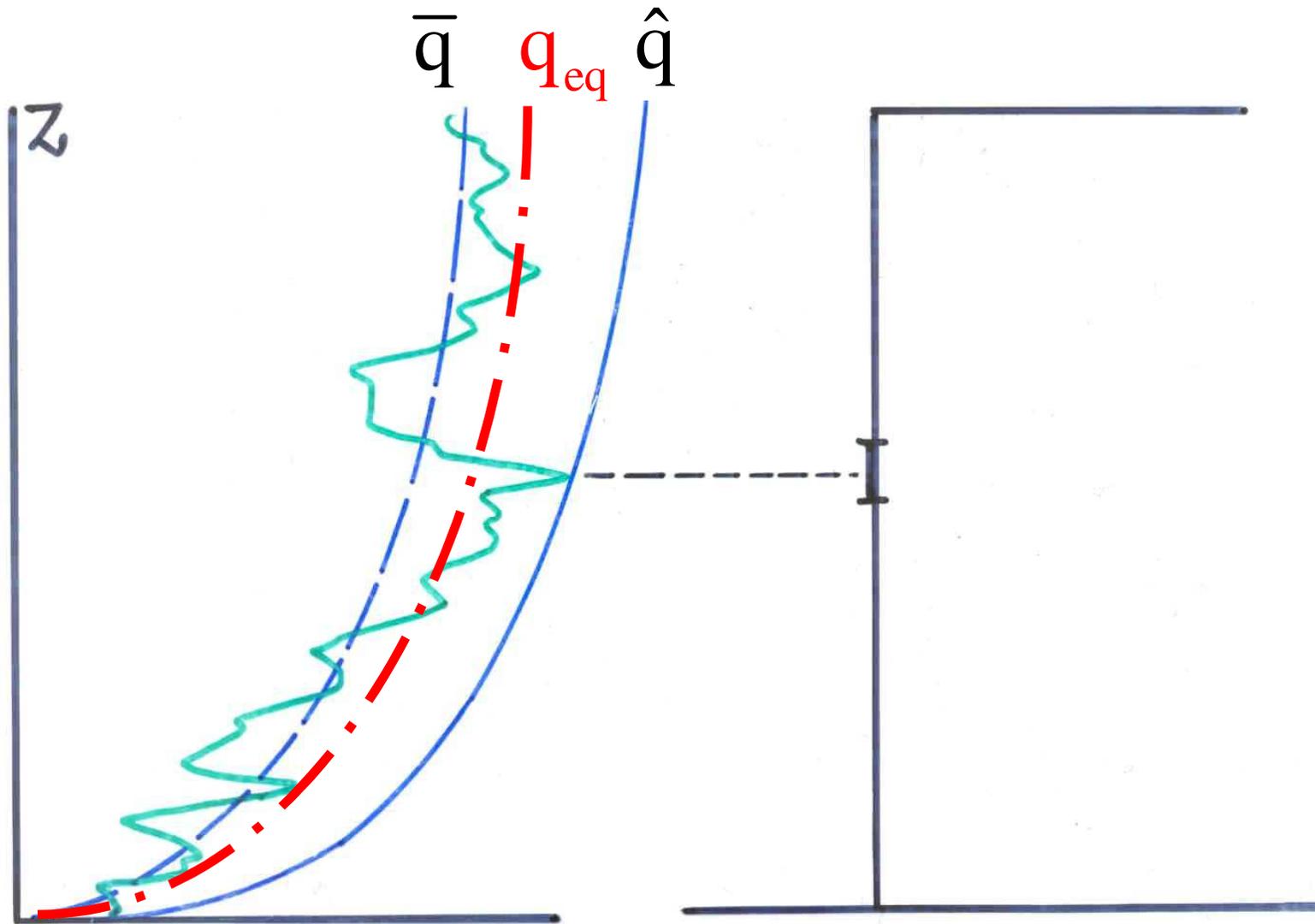


Azioni aerodinamiche del vento



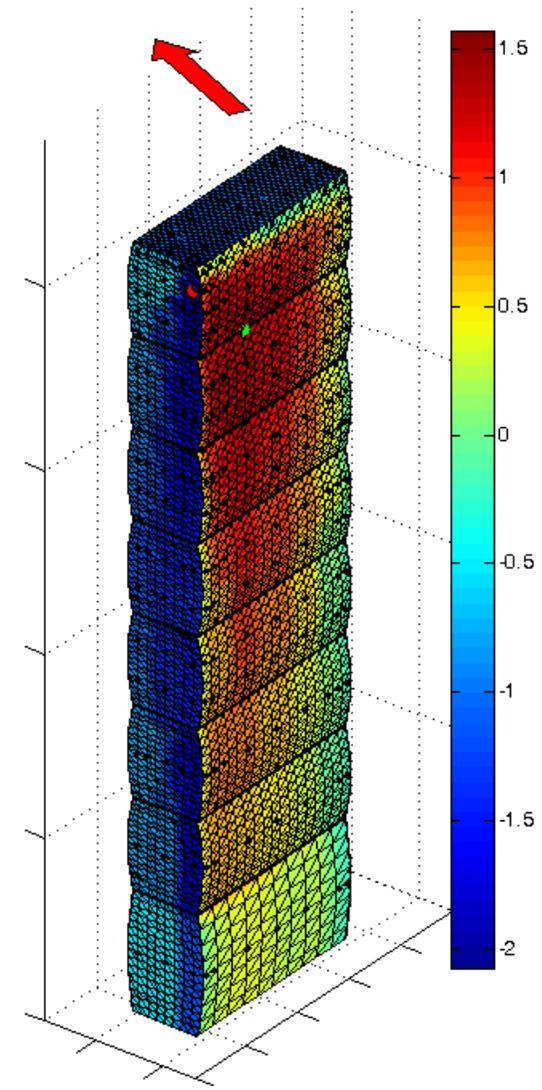
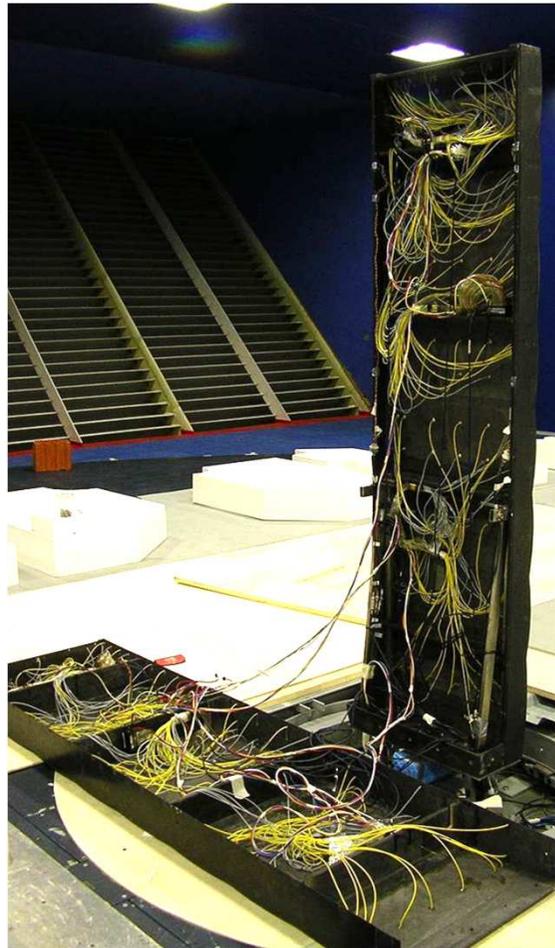
Courtesy Shimizu and Tokyo Politechnic University

Azioni aerodinamiche del vento



Prove in galleria del vento

Misure con prese di pressione



Torre di Isozaki, Quartiere storico della fiera di Milano

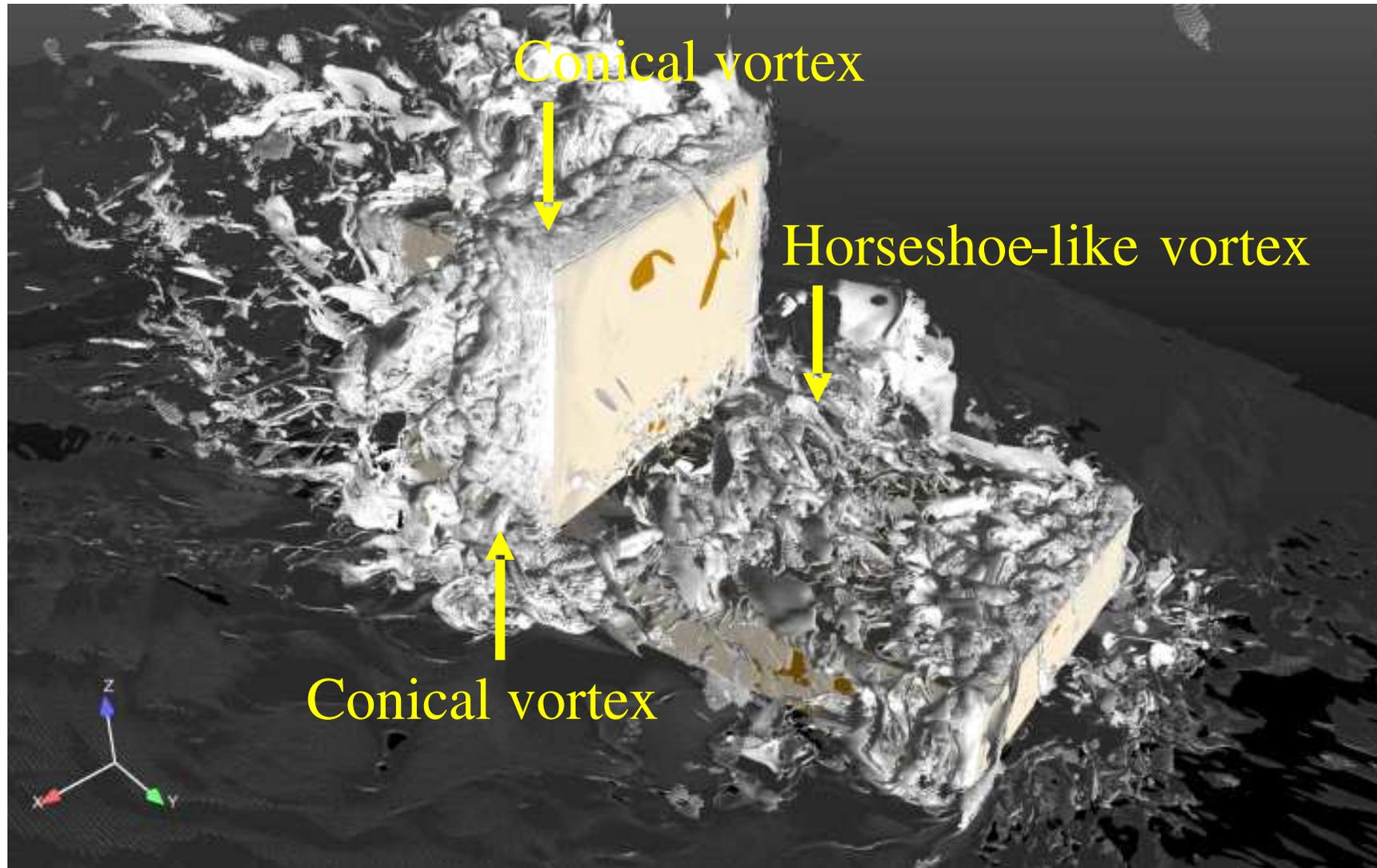
Prove in galleria del vento

Misure con bilancia dinamometrica alla base



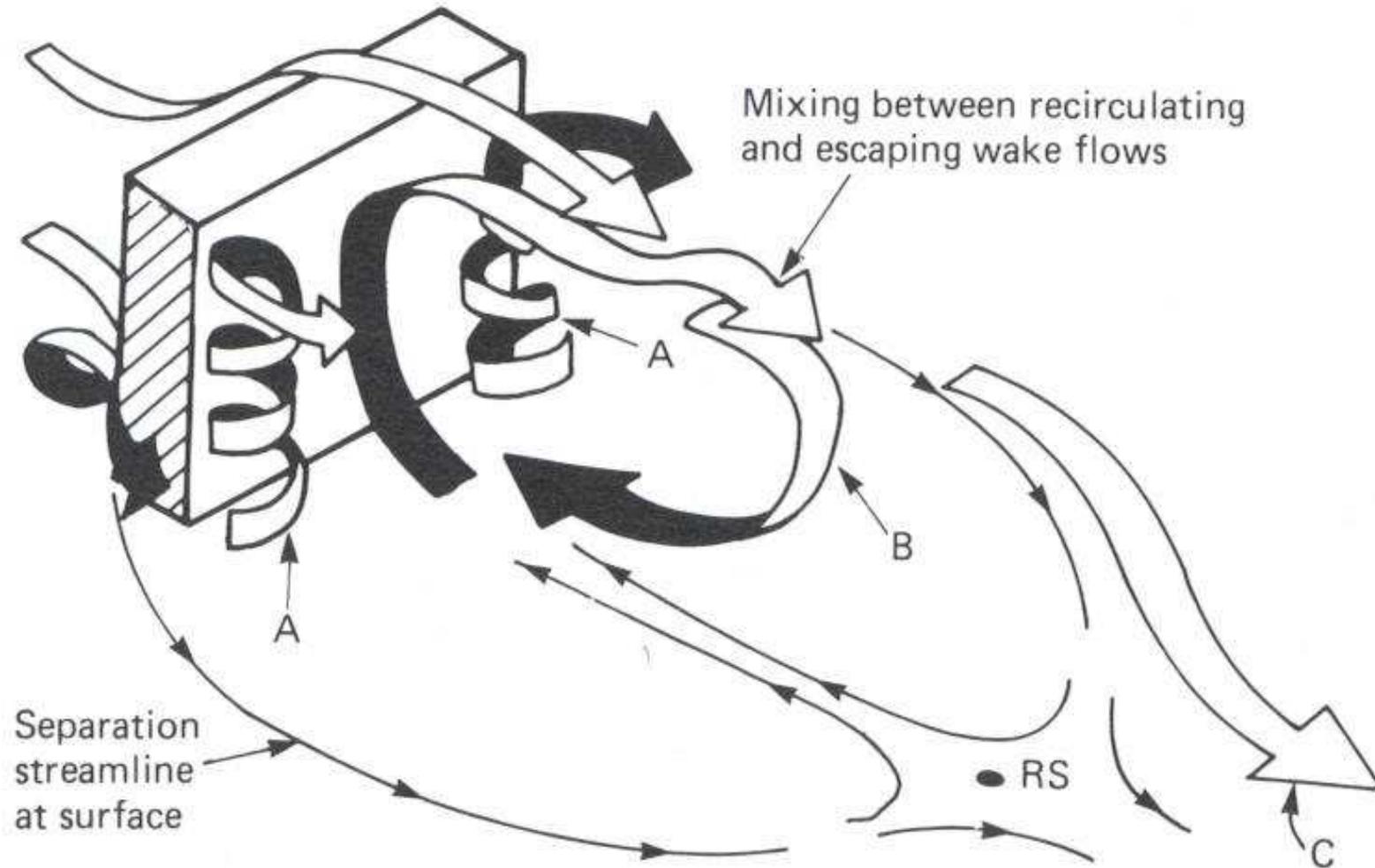
Torre di Hadid, Quartiere storico della fiera di Milano

Simulazioni CFD

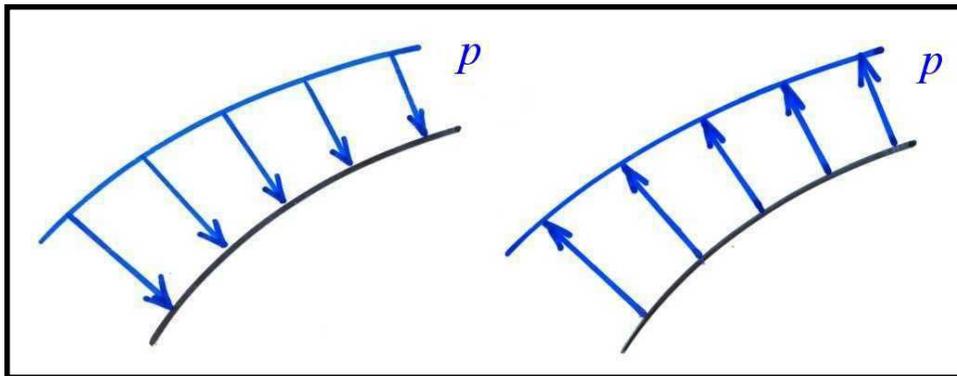
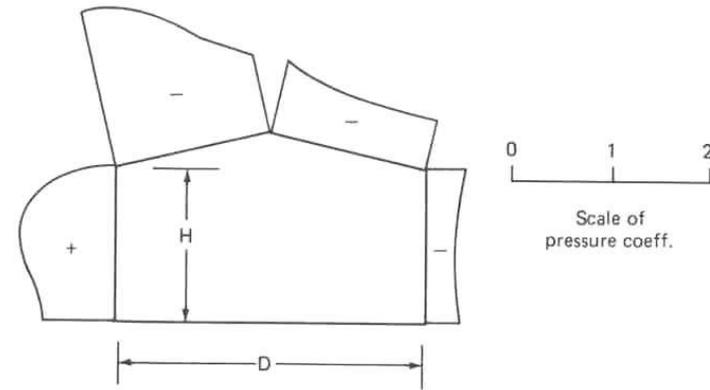
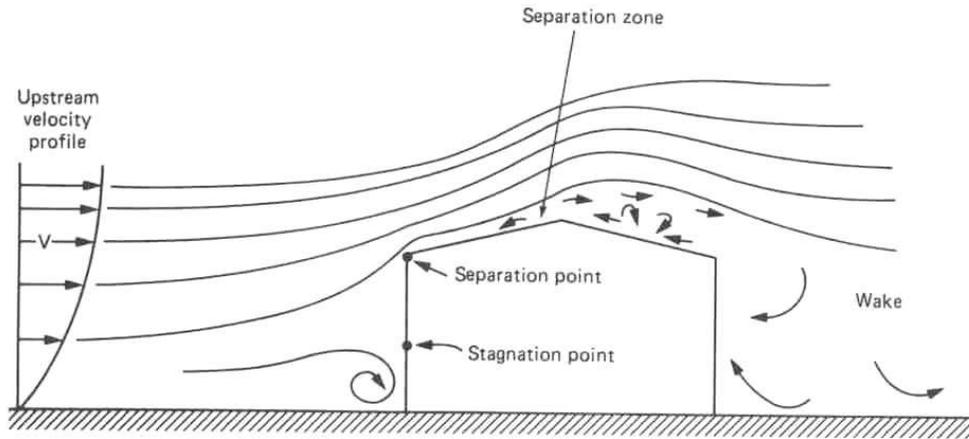


LES vorticity contours, Phuc et al. (2014)

Normative sulle azioni del vento



Strutture tridimensionali

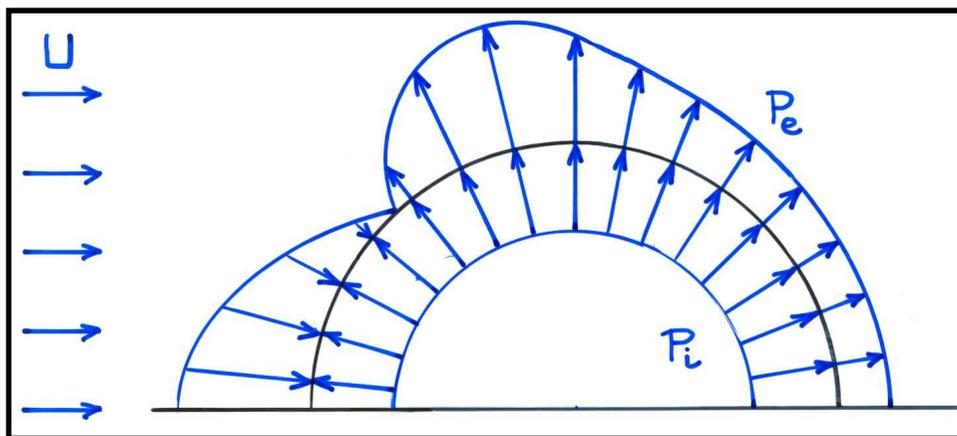


$$p_e(z) = q_p(\bar{z}_e) \cdot c_{pe}$$

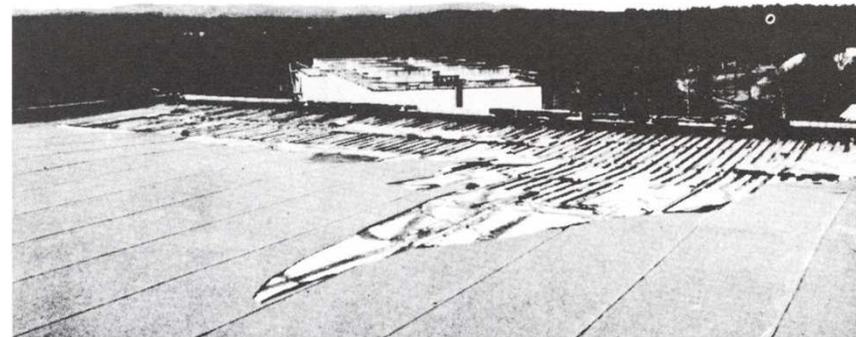
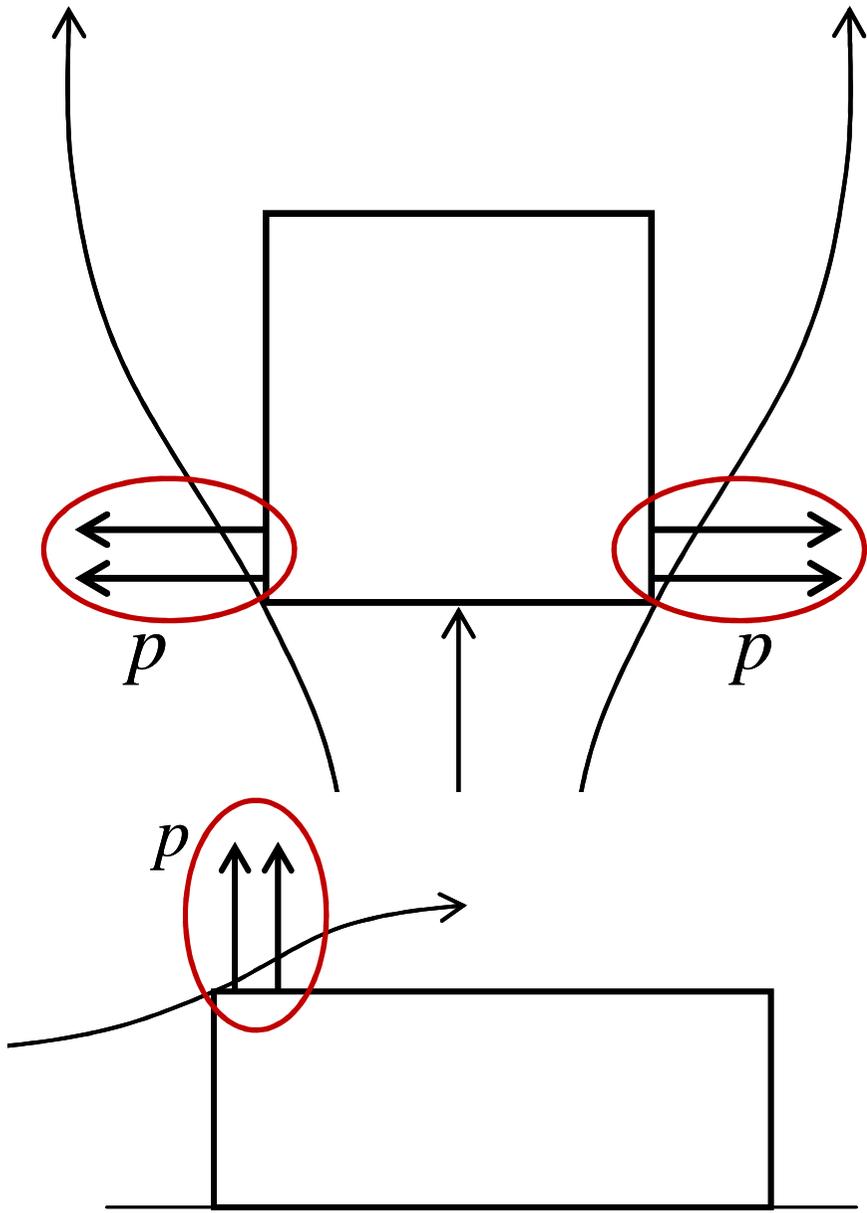
$$p_i(z) = q_p(\bar{z}_i) \cdot c_{pi}$$

p_e = external pressure

p_i = internal pressure



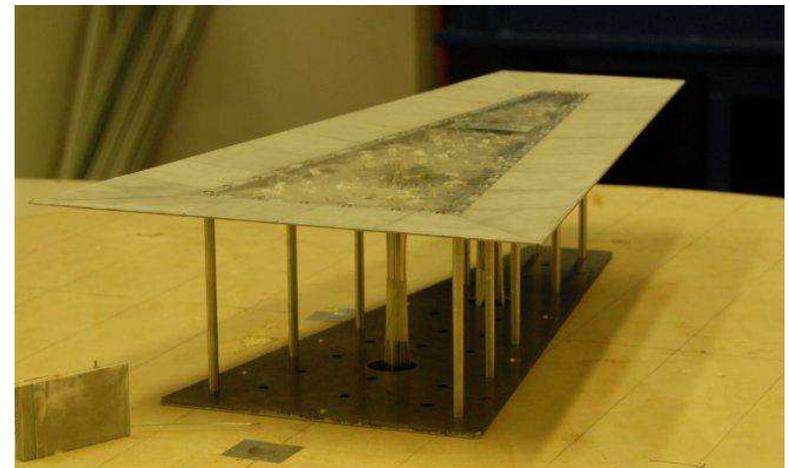
Distribuzione di pressione e coefficienti di pressione



Azioni locali del vento

Prove in galleria del vento

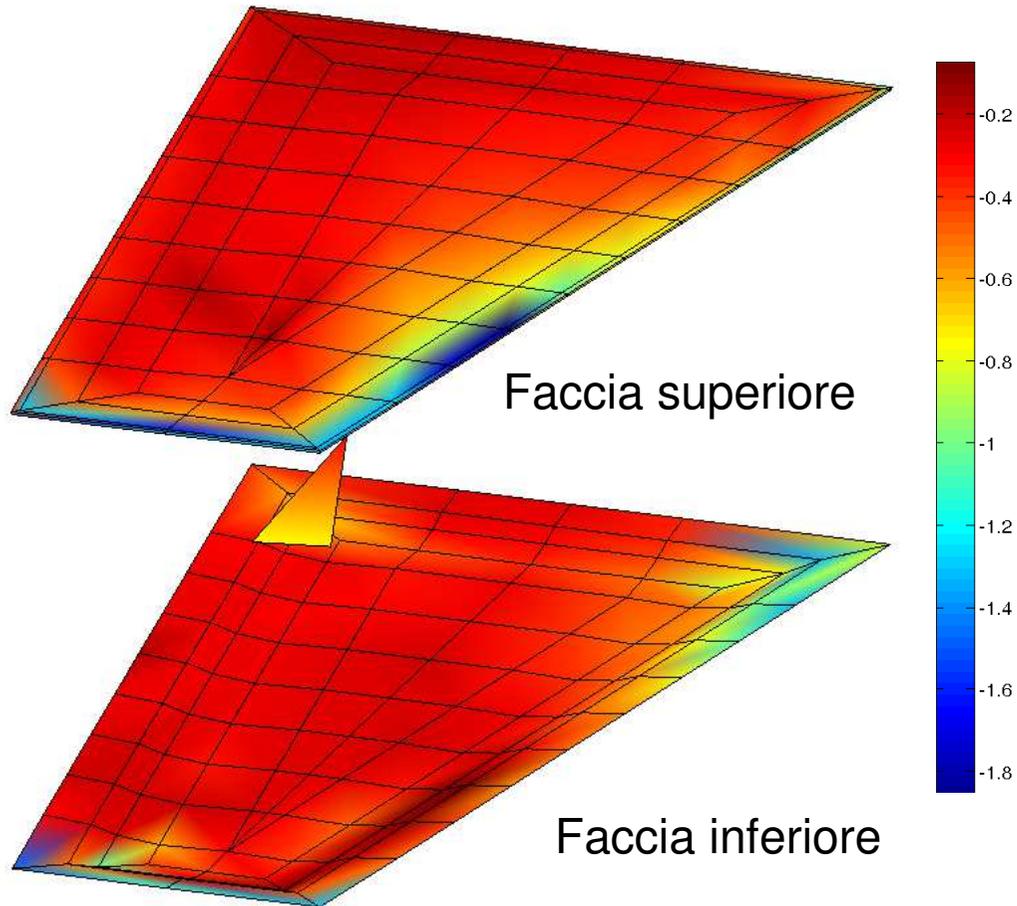
Misure con prese di pressione



Copertura a «vela» Quartiere Portello Milano

Prove in galleria del vento

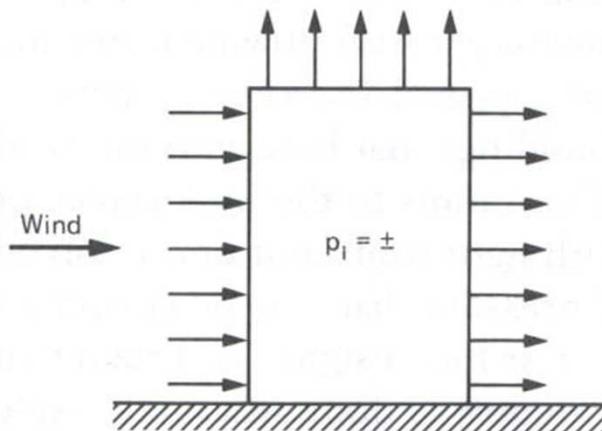
Misure con prese di pressione



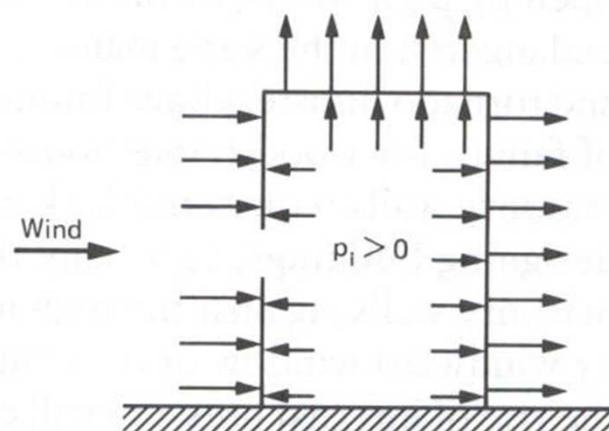
Copertura a «vela» Quartiere Portello Milano

Pressione interna

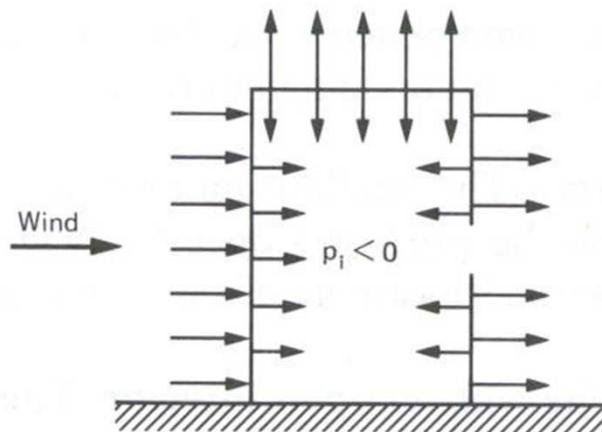
Condizioni di regime



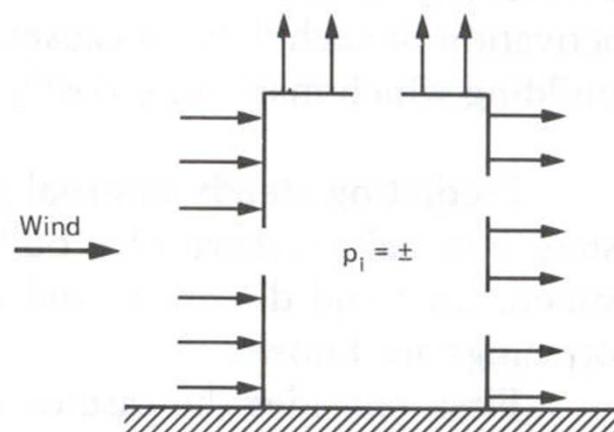
Edificio stagno



Apertura sopravvento



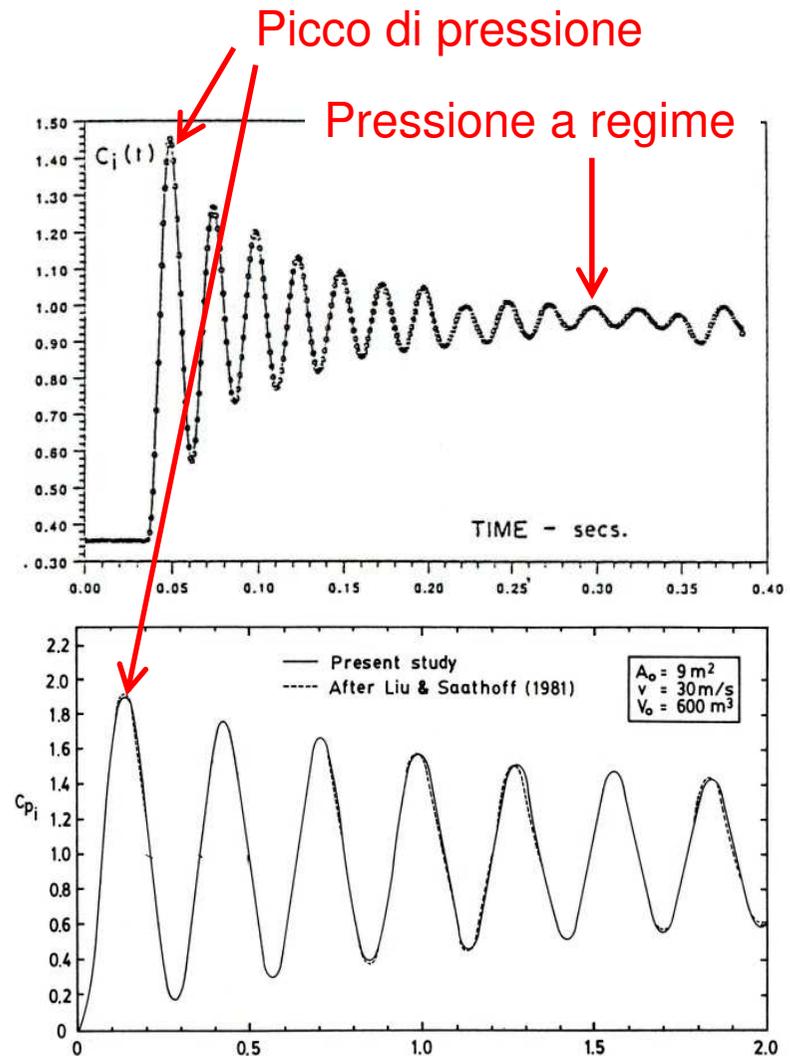
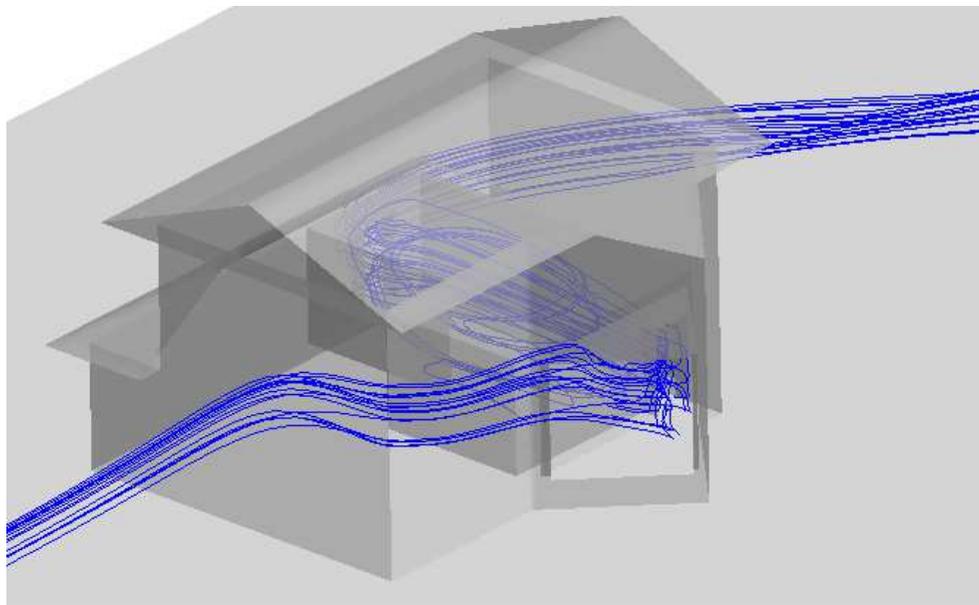
Apertura sottovento

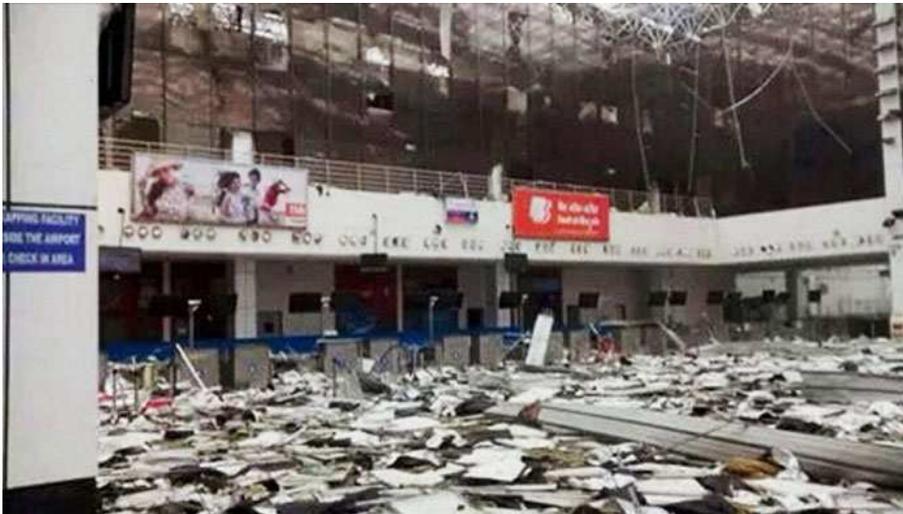


Aperture distribuite

Pressione interna

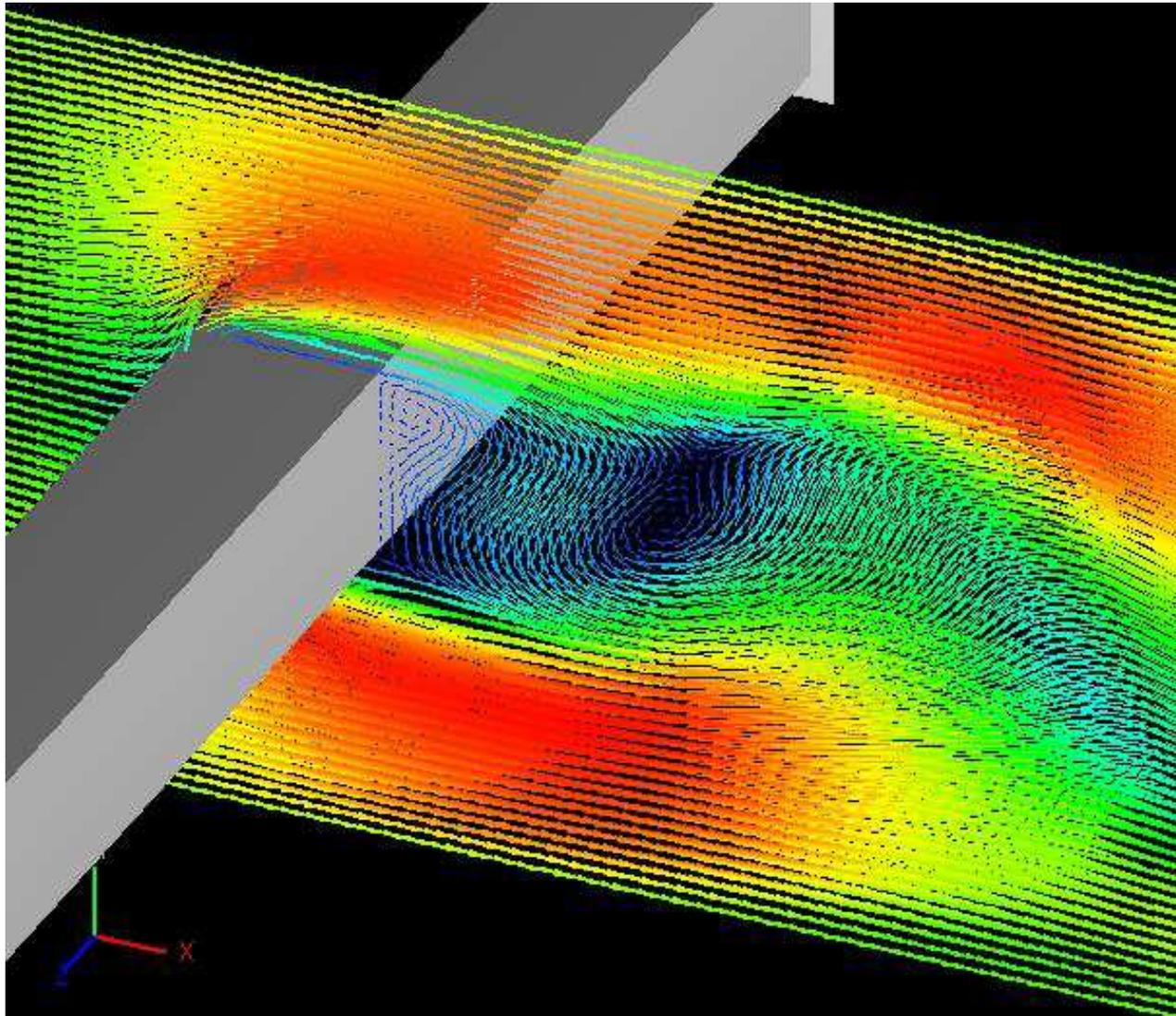
Condizioni transitorie



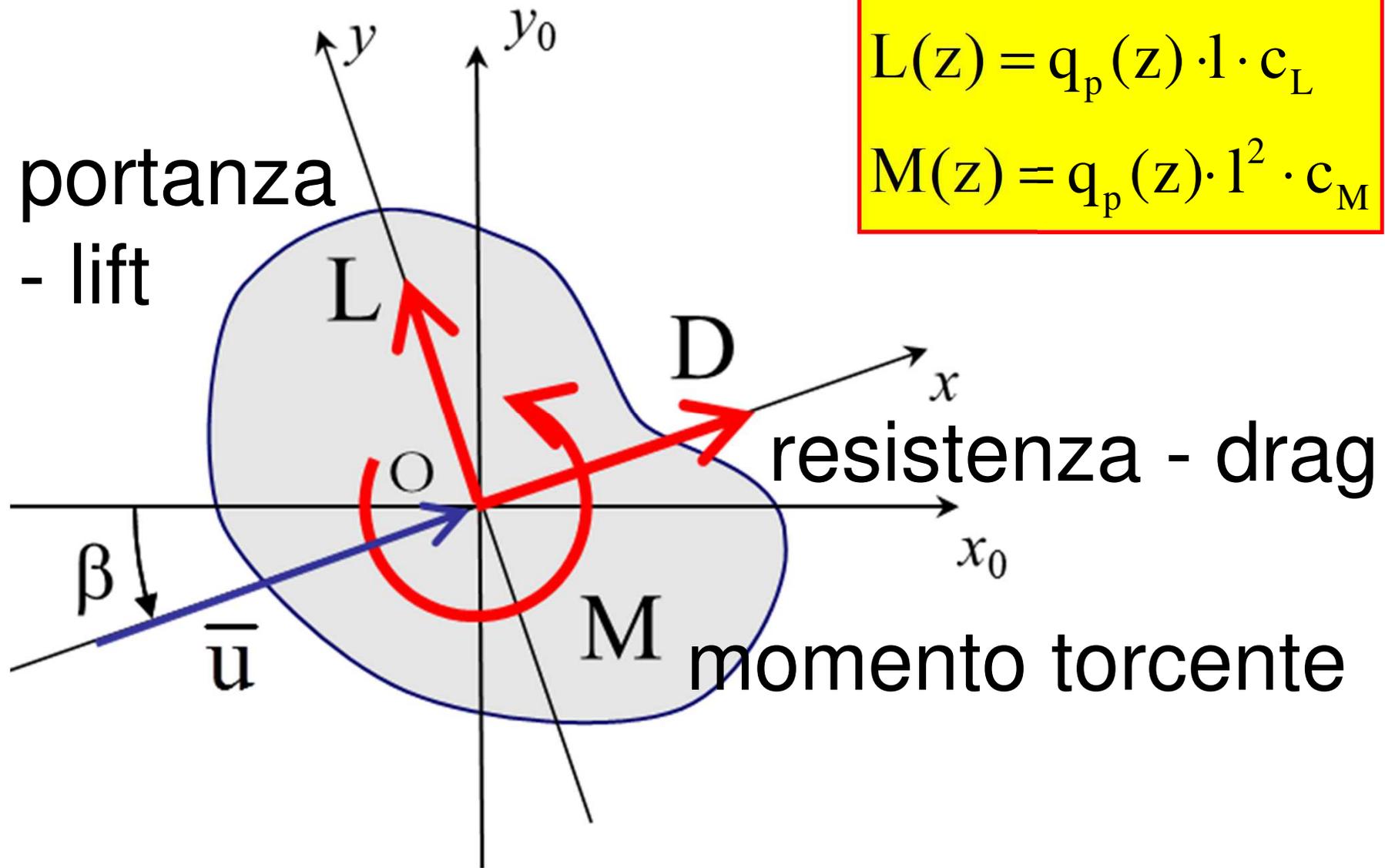


Courtesy Prof. Yukio Tamura

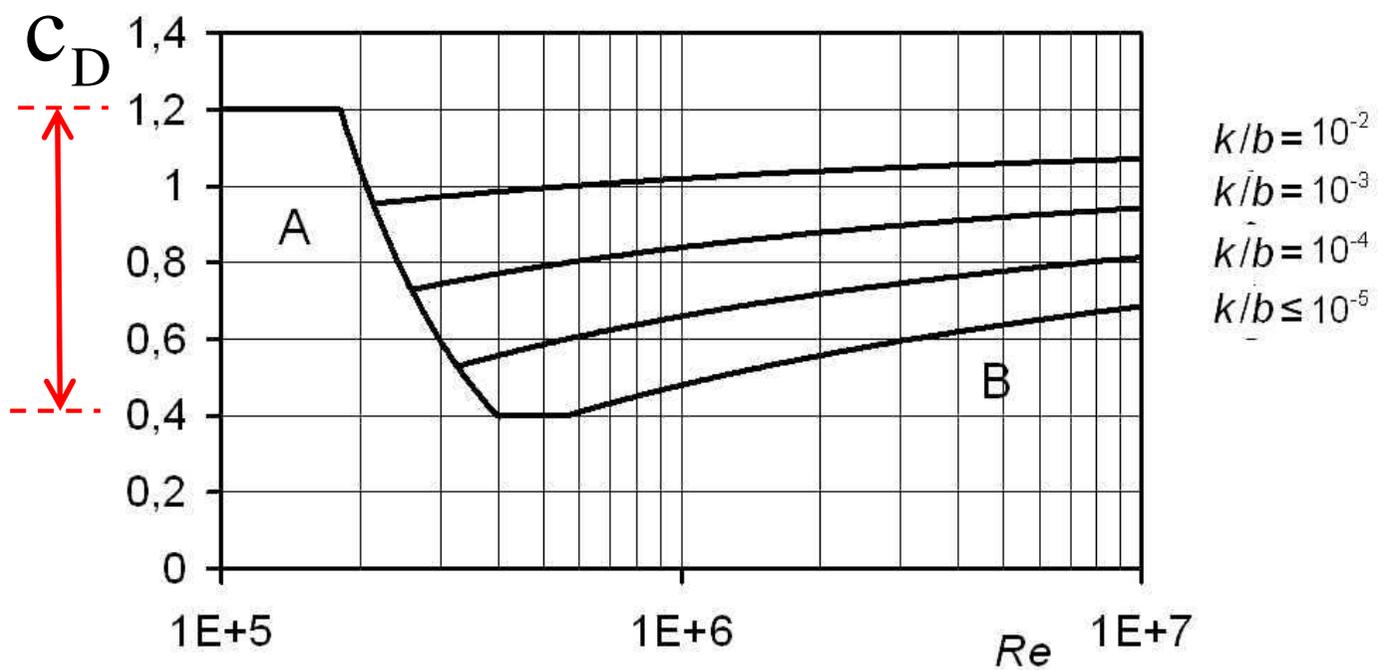
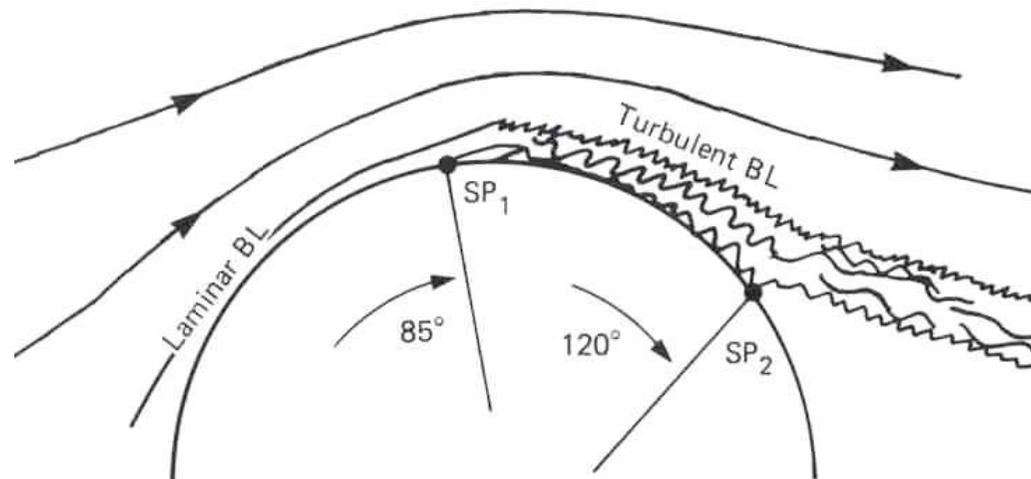
Normative sulle azioni del vento



Elementi monodimensionali – flusso bidimensionale

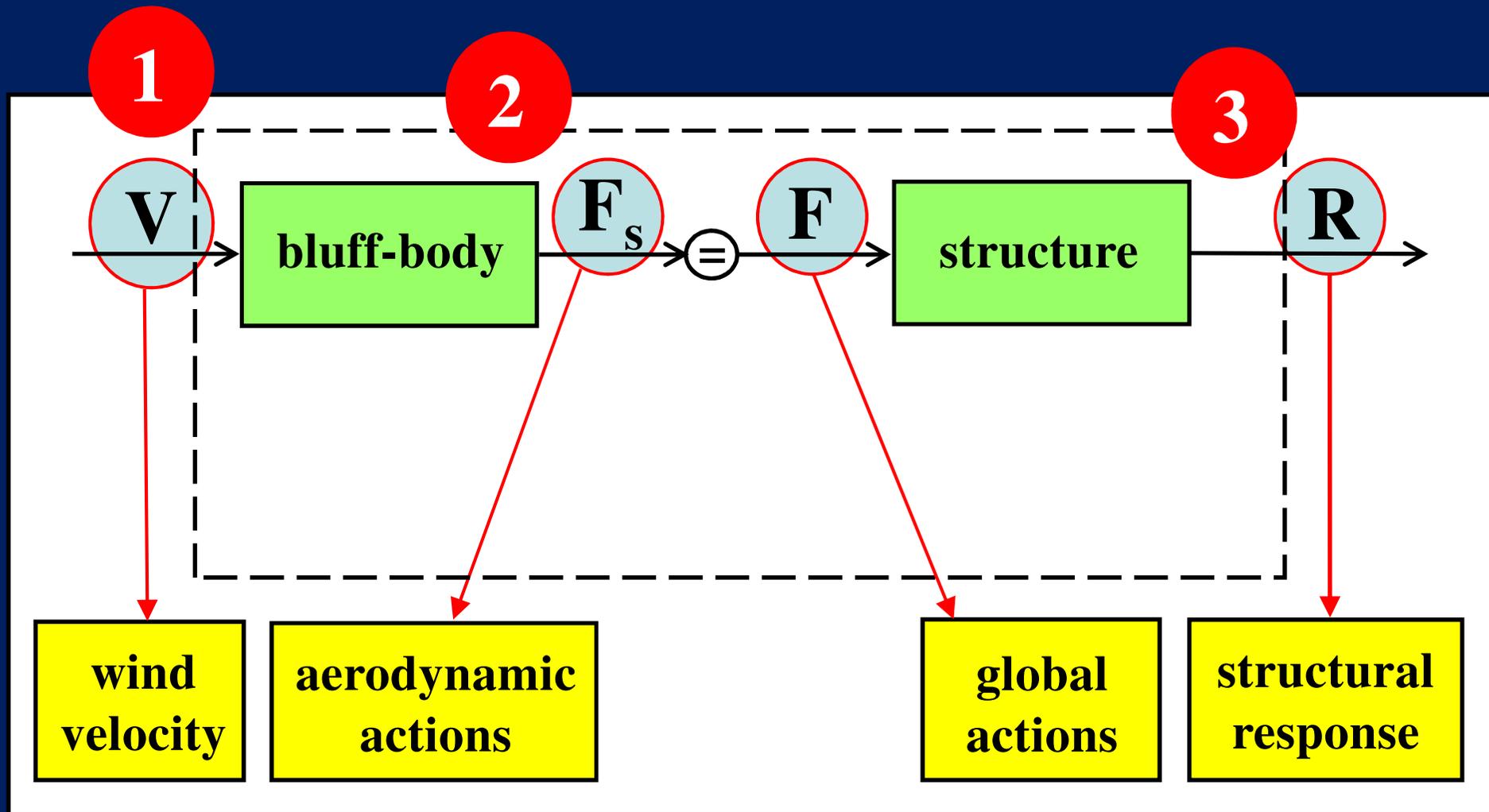


Forze e momento torcente per unità di lunghezza



Elemento con sezione circolare

Risposta dinamica al vento

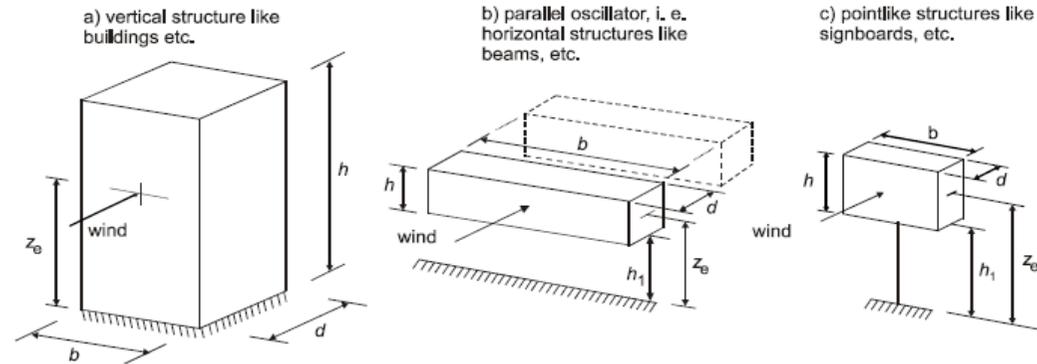
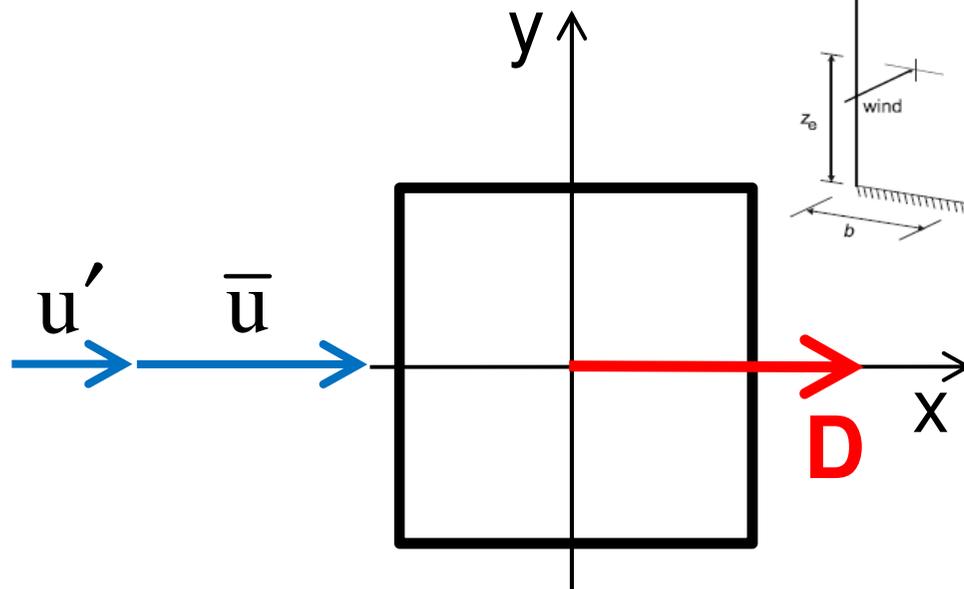




Modello aeroelastico - Akashi-Kaikyo Bridge, 1998 (1990 m)

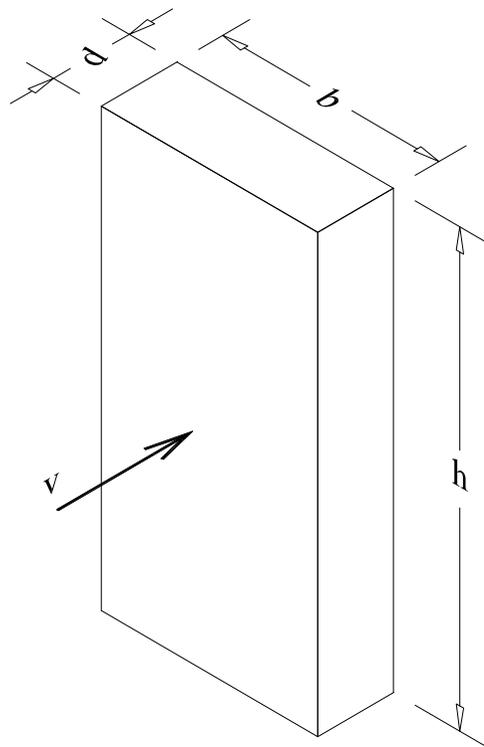
Azioni stiche equivalenti =
Azioni aerodinamiche di picco \times Coefficiente dinamico

Alongwind response

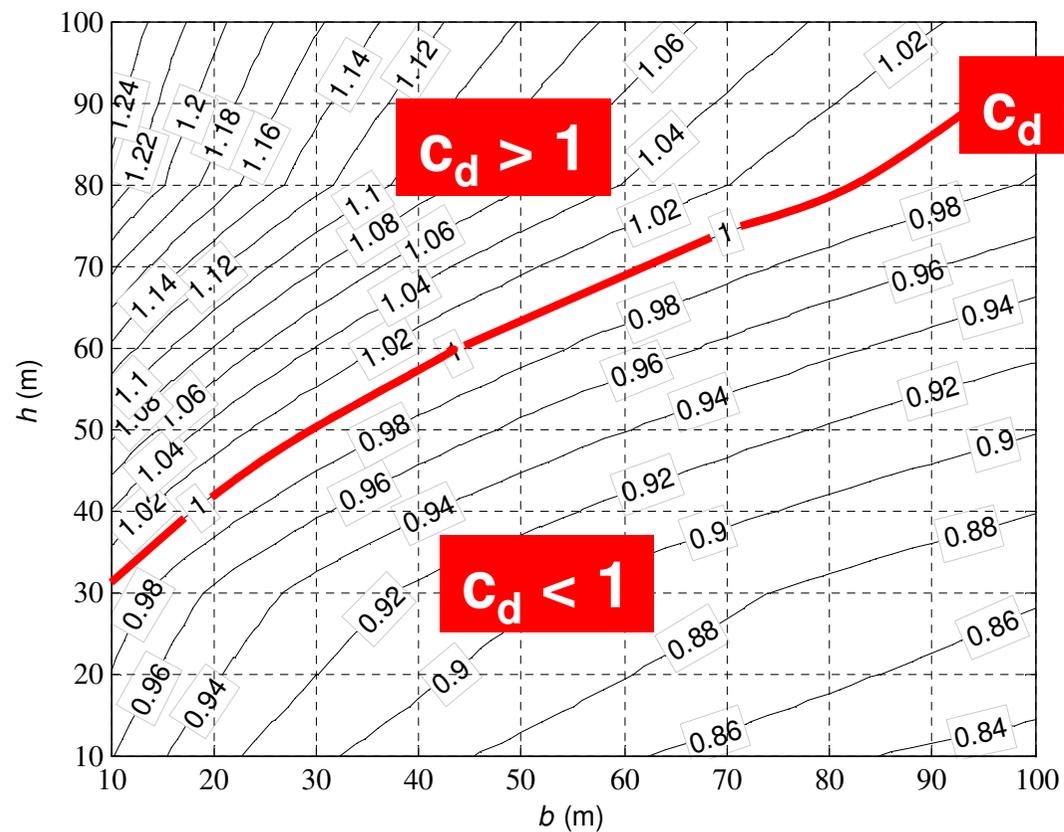


$$c_{dD} = \frac{1 + 2 \cdot g_D \cdot I_v(z_e) \cdot \sqrt{B^2 + R_D^2}}{1 + 7 \cdot I_v(z_e)}$$

Azioni stiche equivalenti =
Azioni aerodinamiche di picco \times Coefficiente dinamico



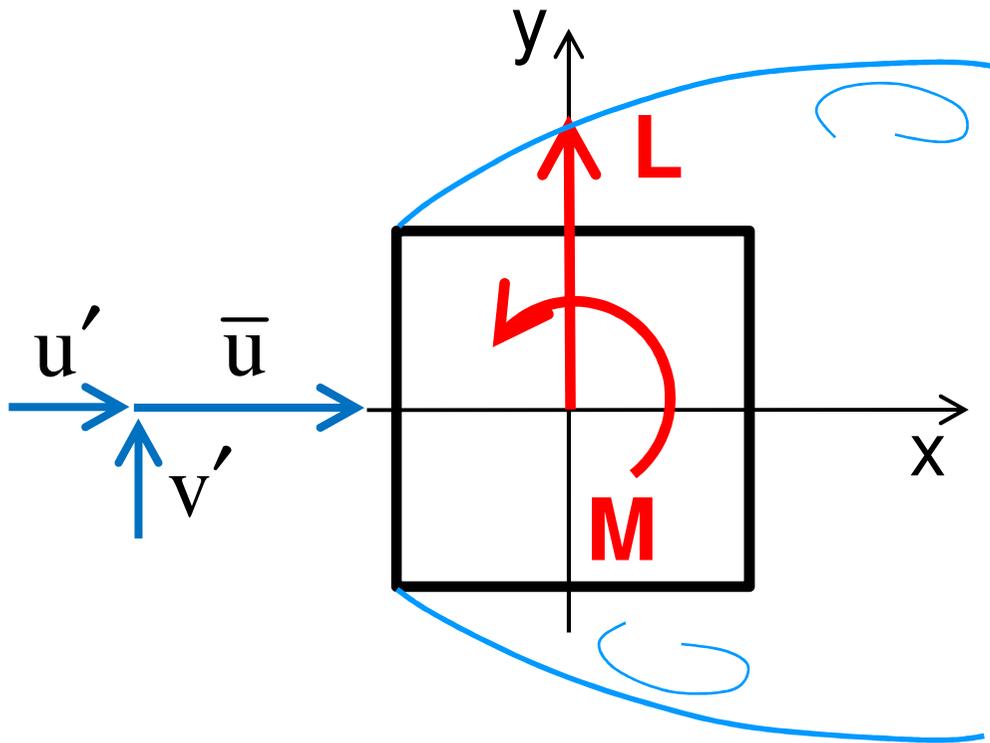
$$0,8 < C_d < 1,2$$



Coefficiente dinamico per edifici metallici

Azioni stiche equivalenti =
Azioni aerodinamiche di picco \times Coefficiente dinamico

Crosswind and torsional response



Azioni stiche equivalenti =
Azioni aerodinamiche di picco \times Coefficiente dinamico

Crosswind response



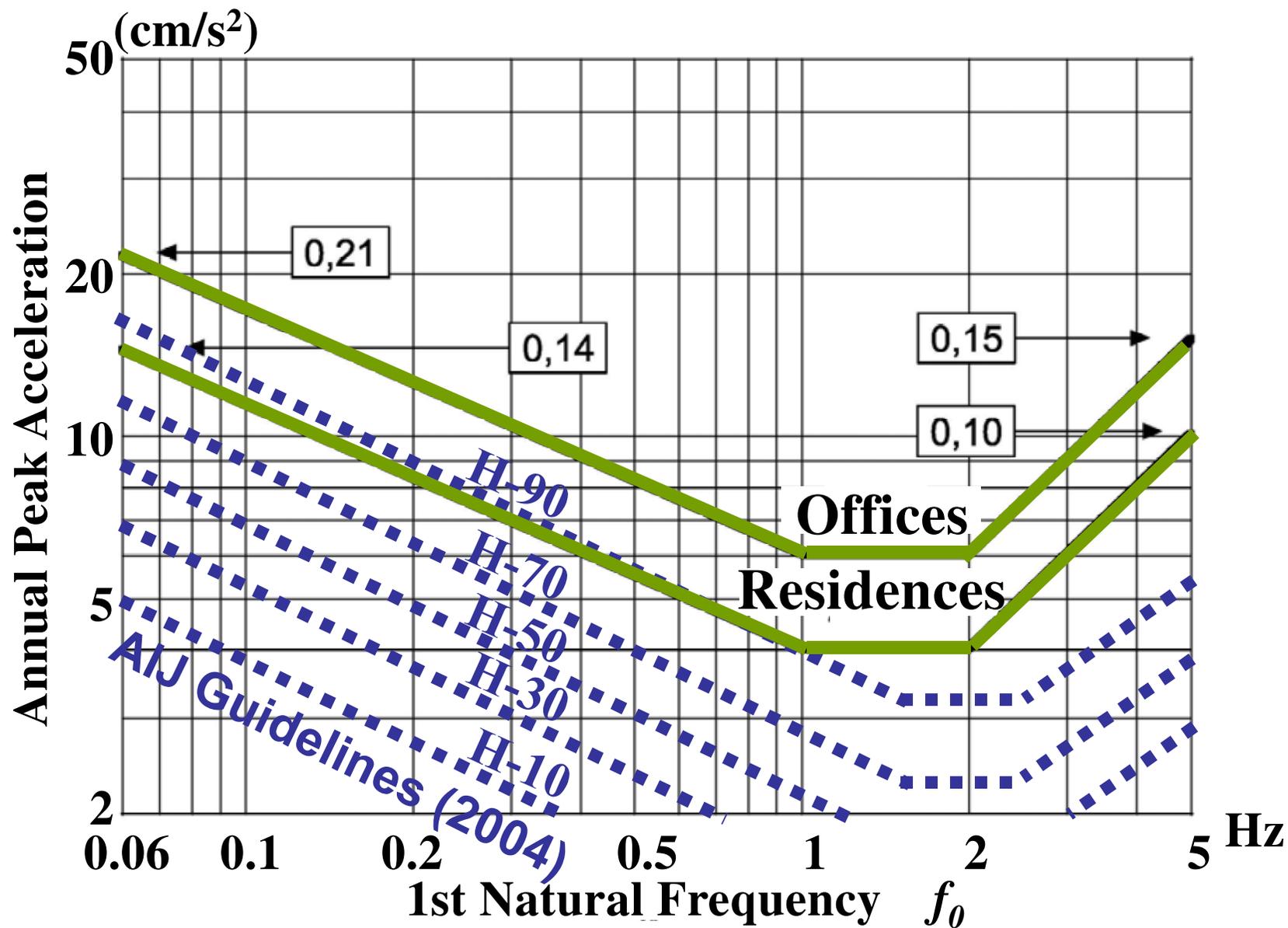
Courtesy Shimizu Corporation

Azioni stiche equivalenti =
Azioni aerodinamiche di picco \times Coefficiente dinamico

Crosswind response



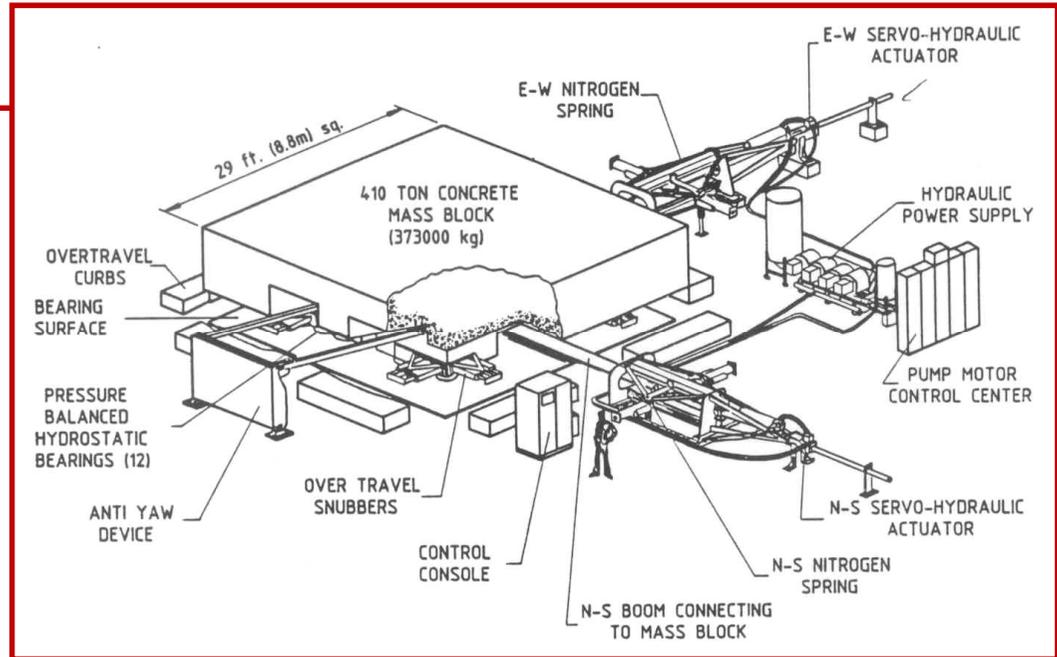
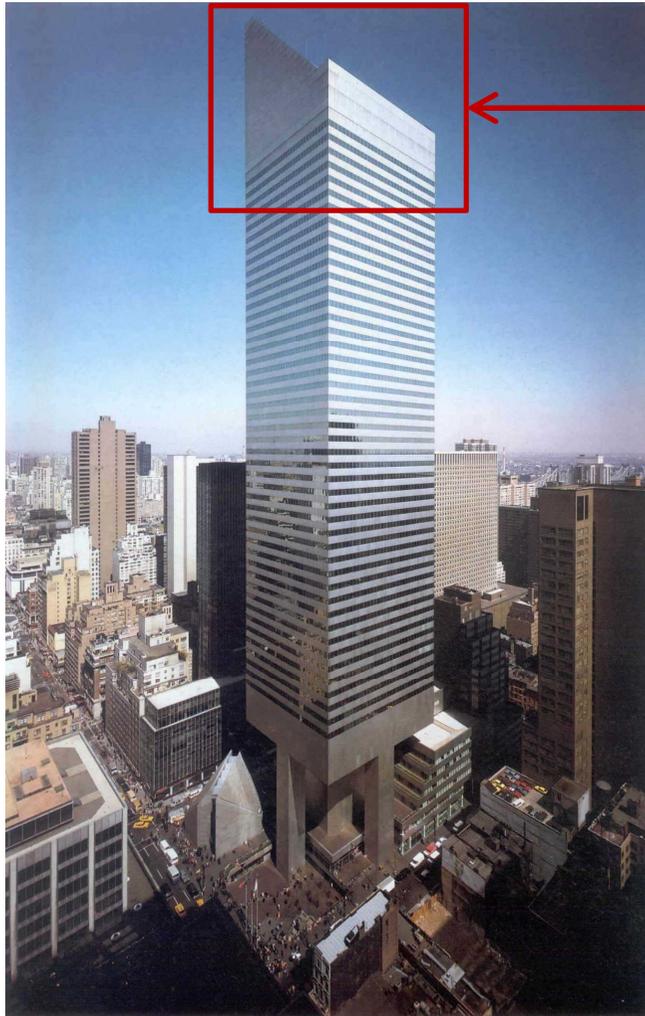
Courtesy Shimizu Corporation



Tollerabilità fisiologica al moto – ISO 10137 (2007)

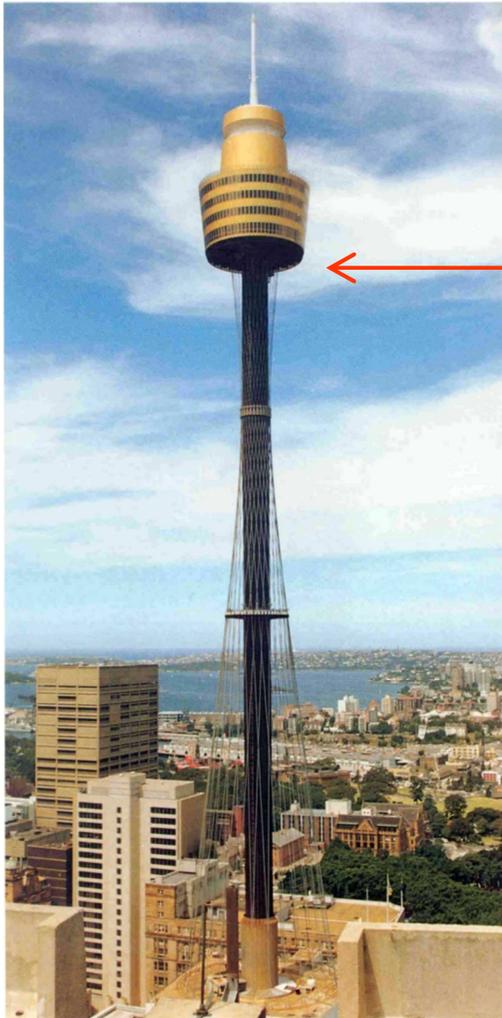
Controllo passivo

Tuned-Mass-Damper (TMD)

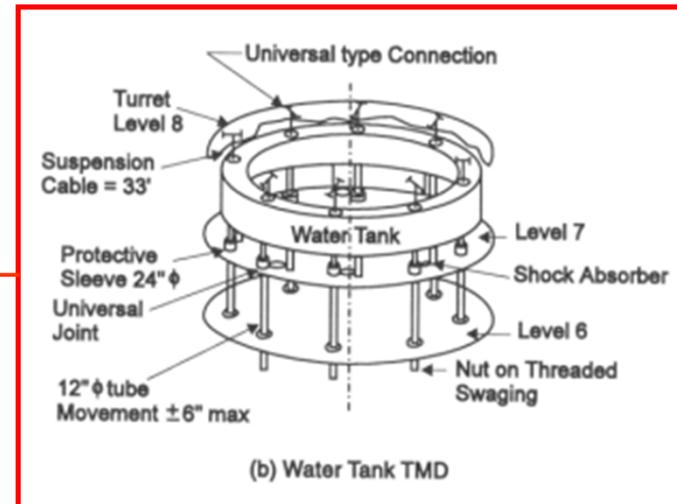


Citicorp Building, New York, 1977

Controllo passivo Tuned-Liquid-Damper (TLD)

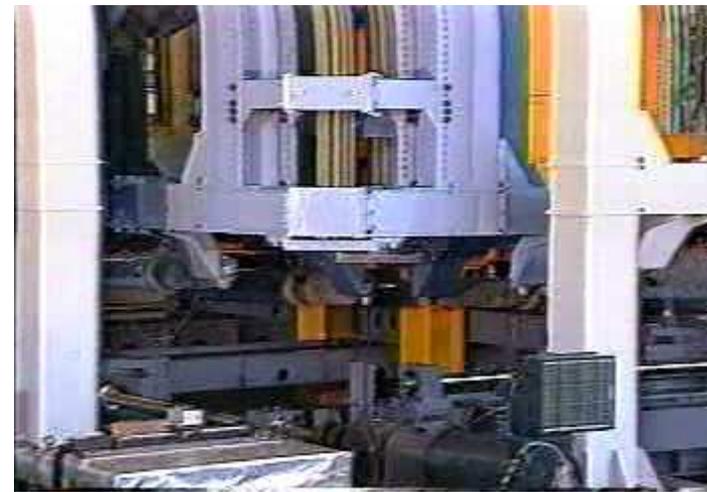


primary damper



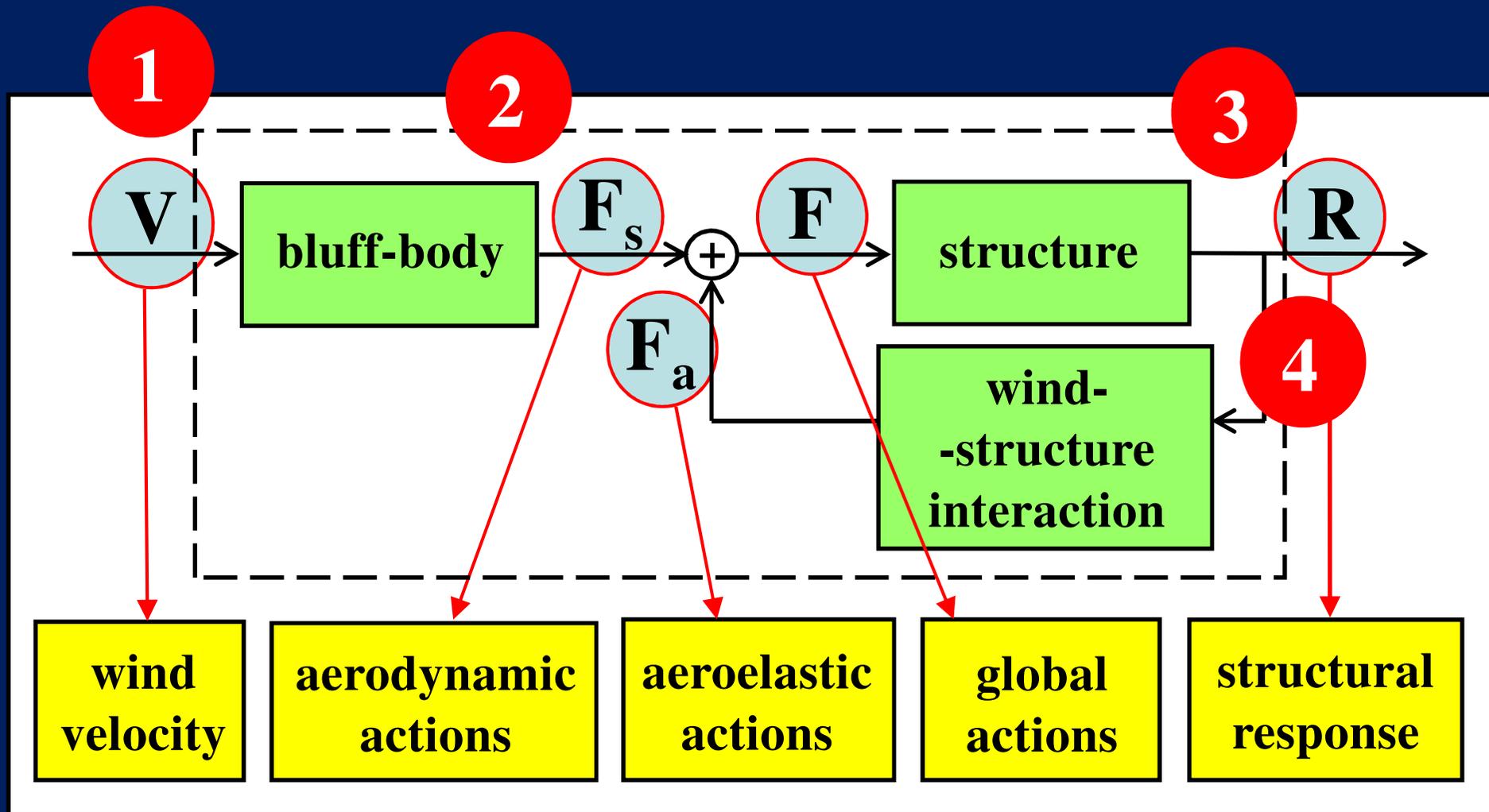
Sydney Center Point Tower, 1981

Controllo attivo Active-Mass-Damper (AMD)



Landmark Tower, Yokohama, Japan, 1993

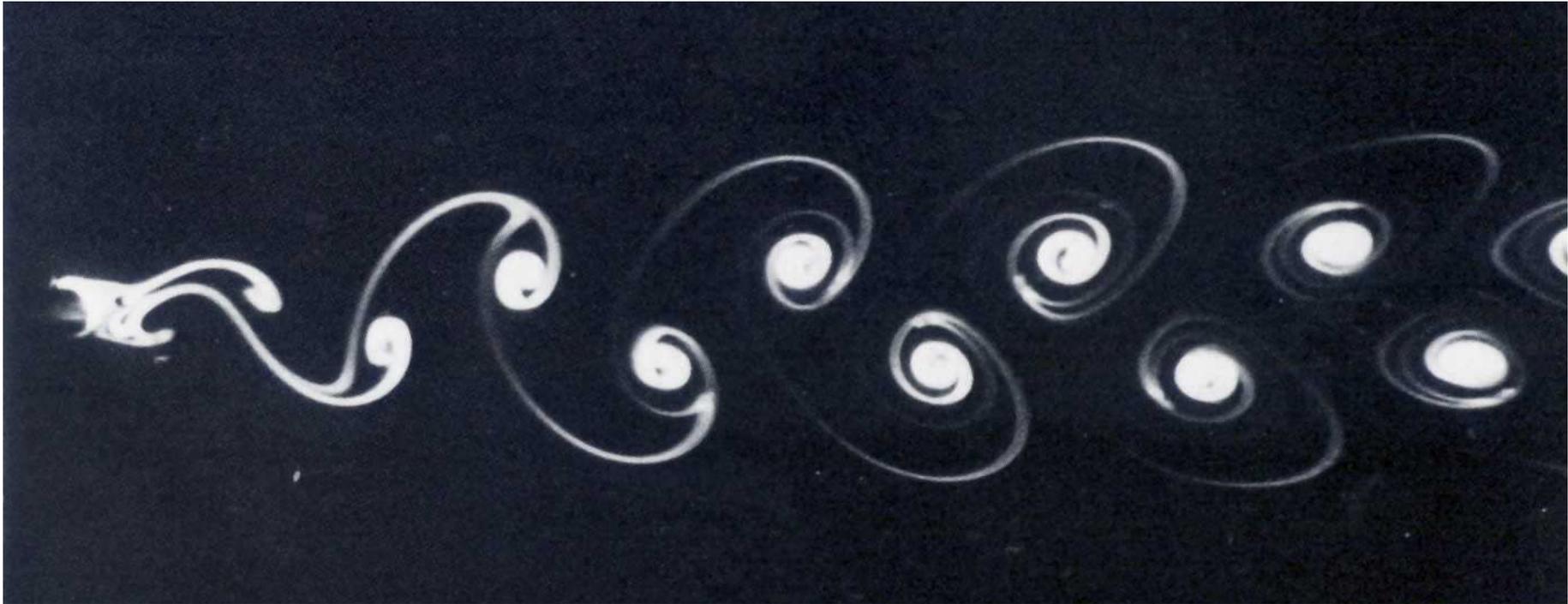
Fenomeni aeroelastici





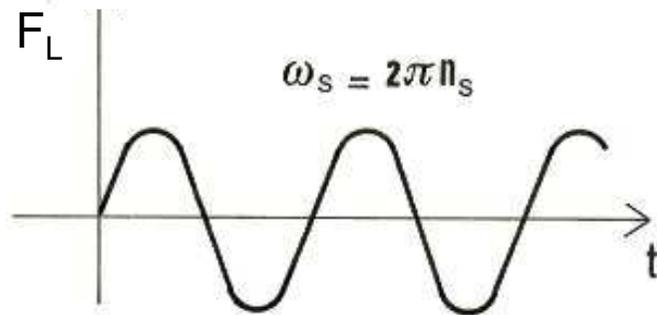
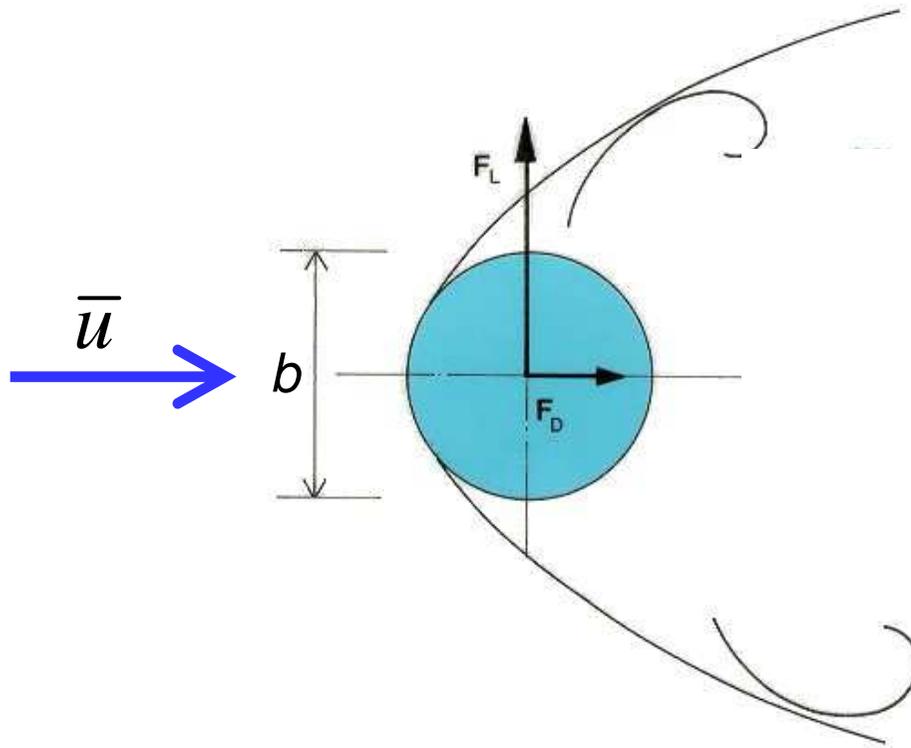
Tacoma Narrows Bridge, 7 november 1940

Vibrazioni indotte dai vortici (VIV)



Von Karman (1911-1912)

Distacco dei vortici da elementi snelli



Frequenza di distacco

$$n_s = \frac{S \bar{u}}{b}$$

S = Numero di Strouhal

Velocità critica

$$\bar{u}_{cr,j} = \frac{n_j b}{S}$$

Distacco dei vortici da elementi snelli



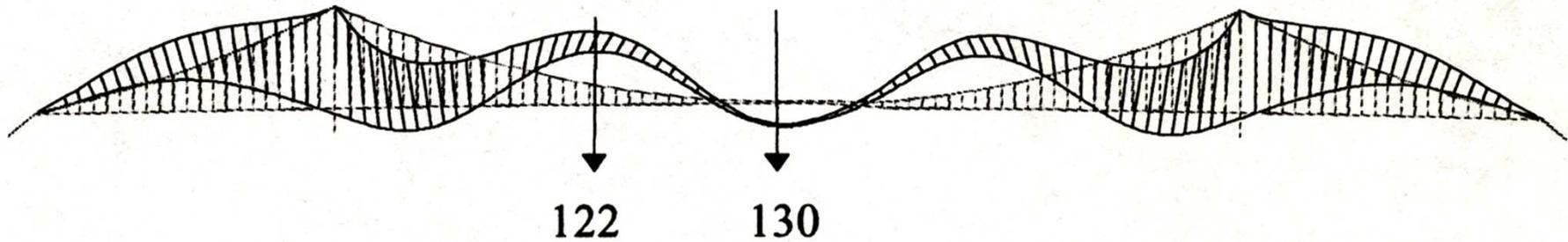
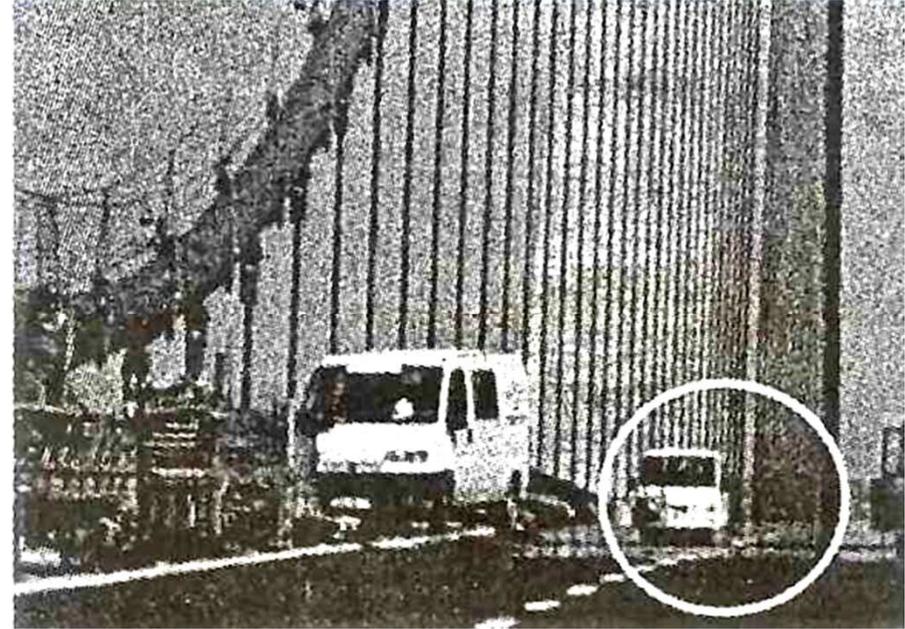
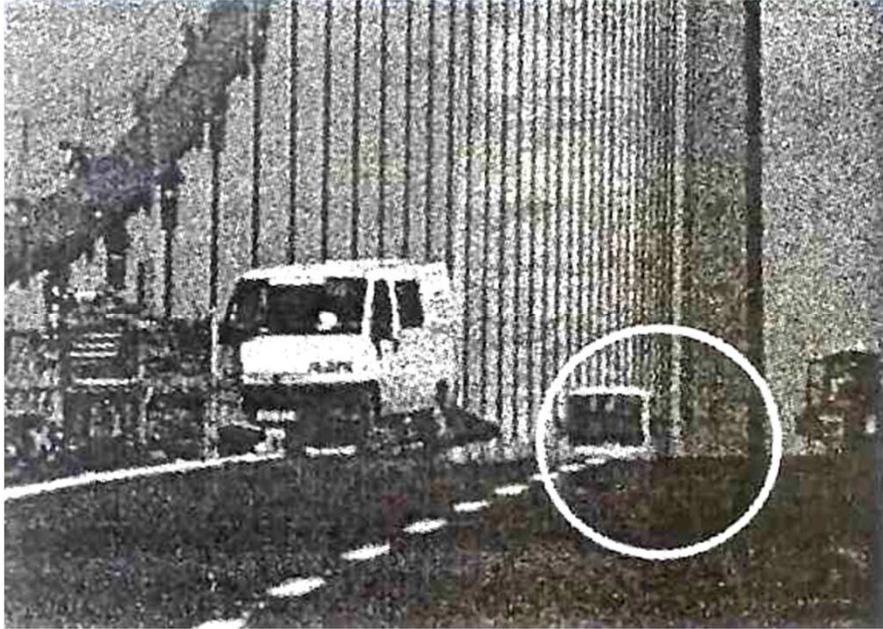
Distacco dei vortici da elementi snelli



Distacco dei vortici da elementi snelli



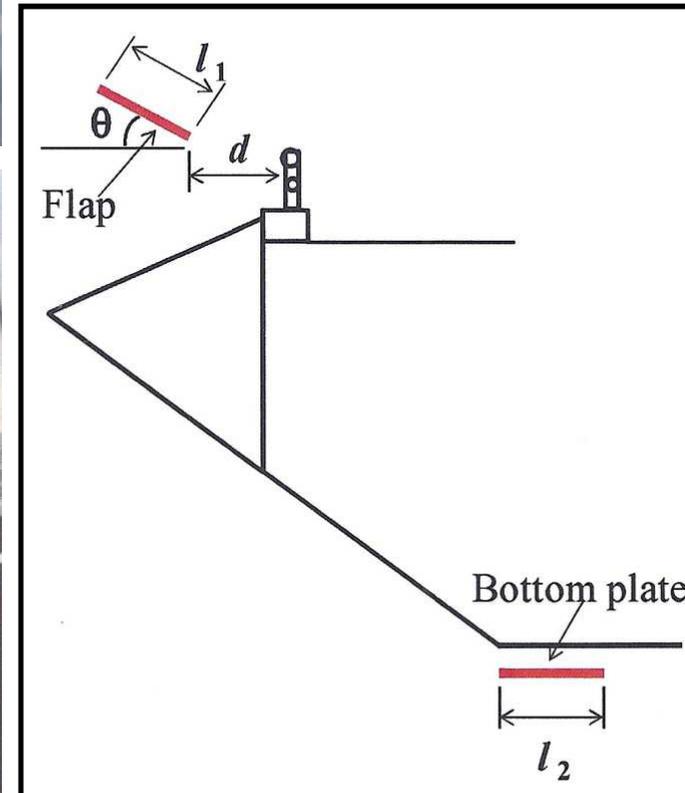
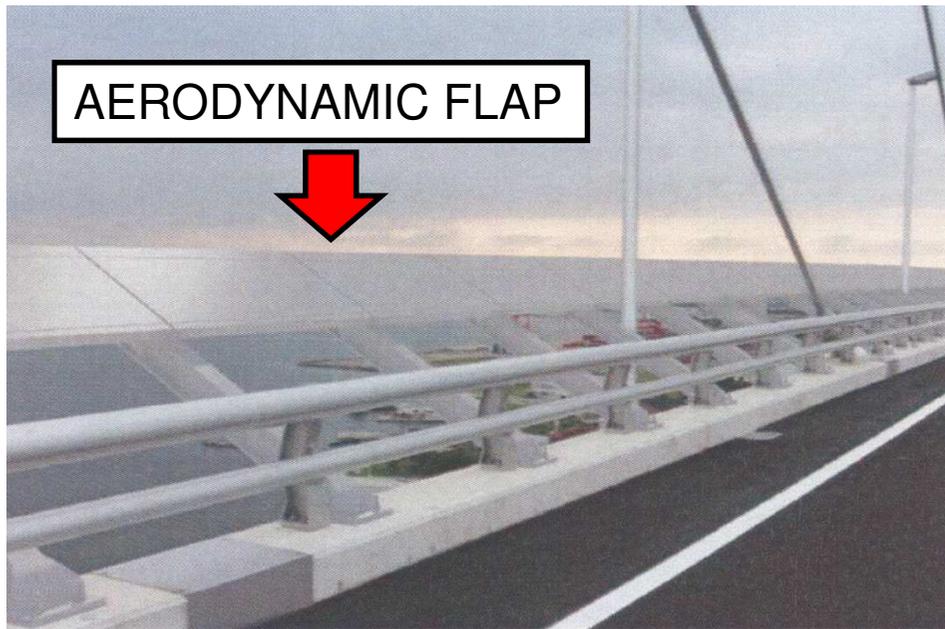
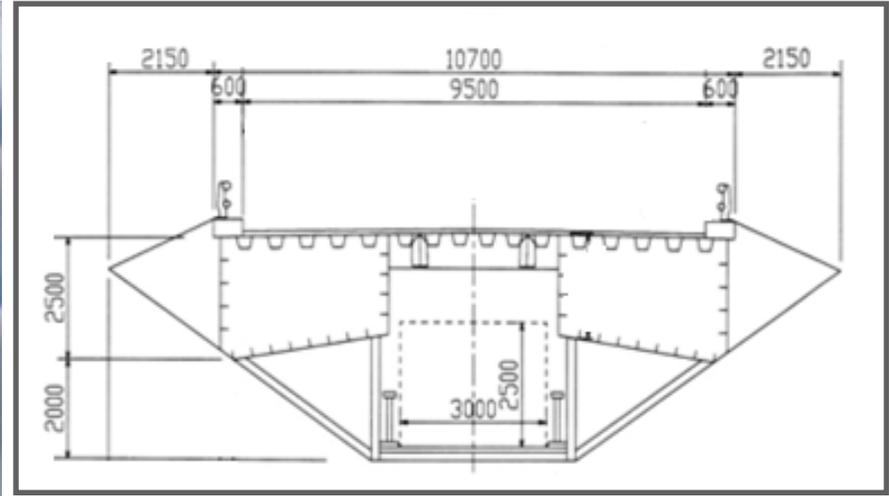
Great Belt East Bridge, Denmark, 1998, $L=1624$ m



Great Belt East Bridge, Denmark, 1998, L=1624 m



Volgograd Bridge, Russia



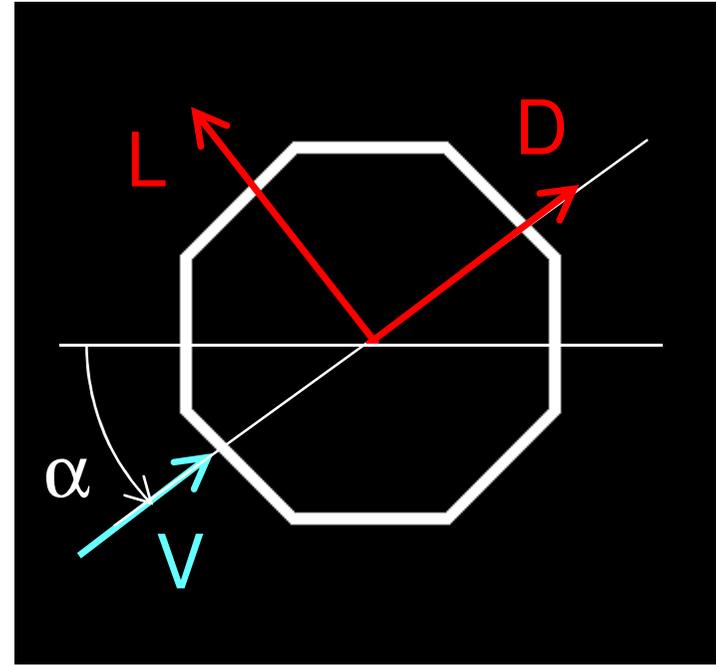
Ponte strallato, Giappone, campata centrale $L = 360$ m

Galoppo

Condizione necessaria

Criterio di Glauert-Den Hartog

$$\left(D + \frac{dL}{d\alpha} \right) < 0$$



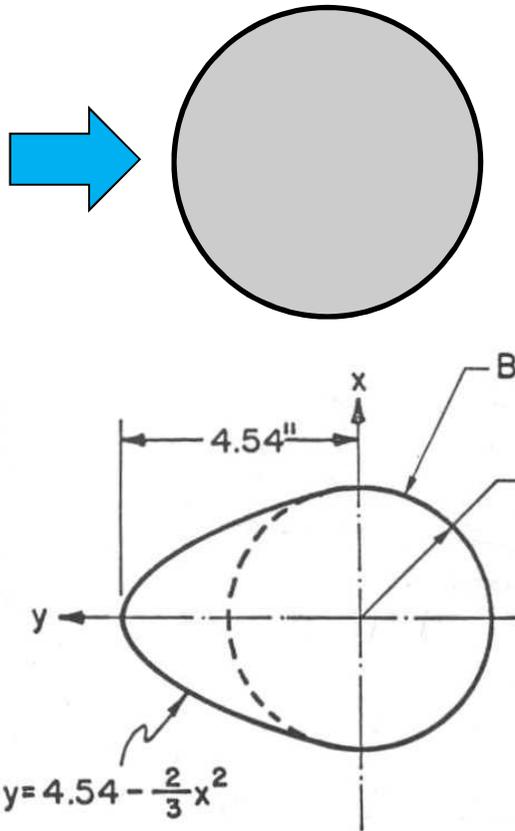
Condizione necessaria e sufficiente

Velocità critica

$$\bar{u}_{cr} = \frac{4m\omega_0\xi_s}{\rho b(c_d + c'_1)}$$

Condizione necessaria

$$c_d + c'_1 < 0$$



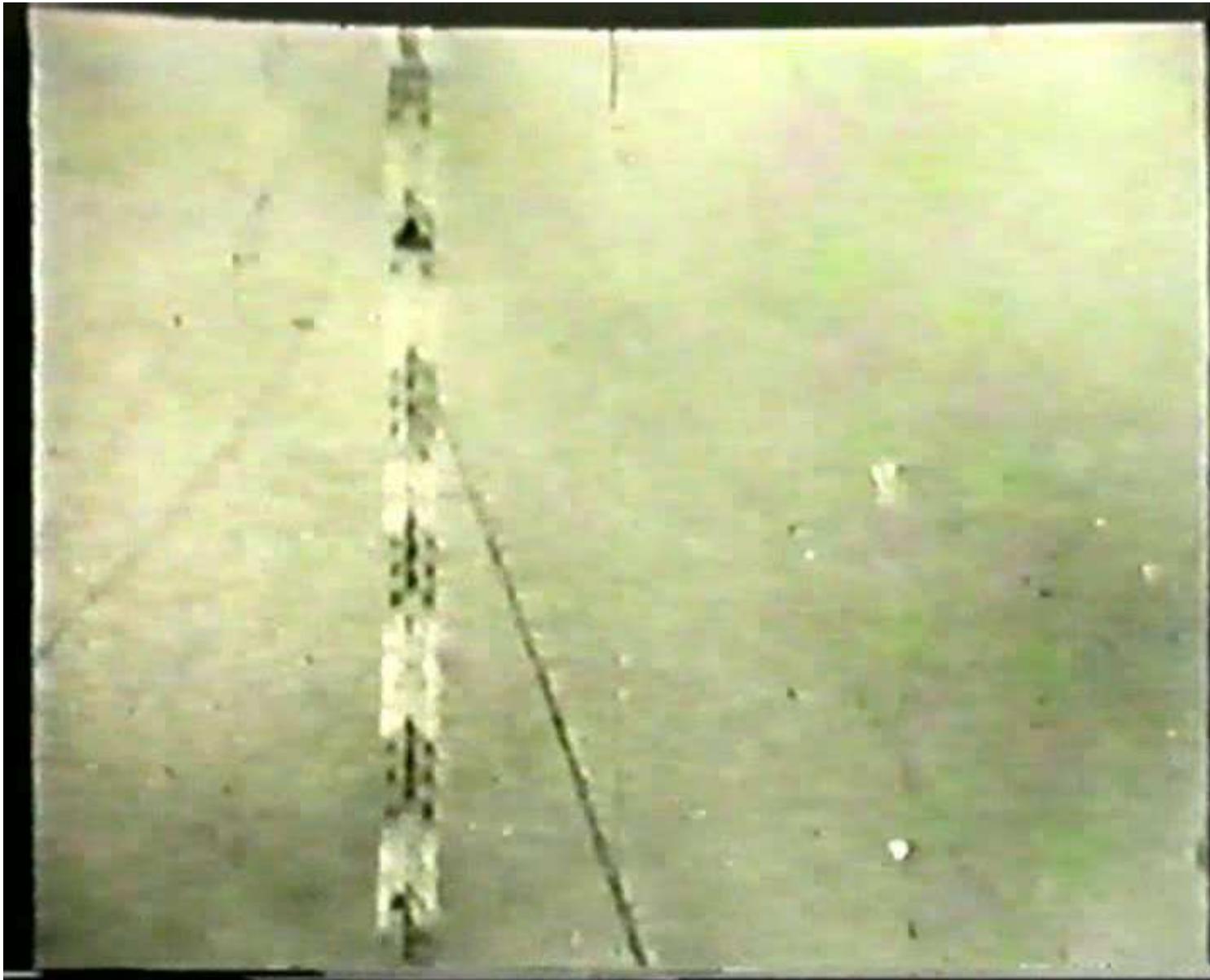
Cavi ghiacciati



Galoppo di conduttori elettrici



Collasso di una torre di una linea di trasmissione



Galoppo dei cavi di una torre strallata



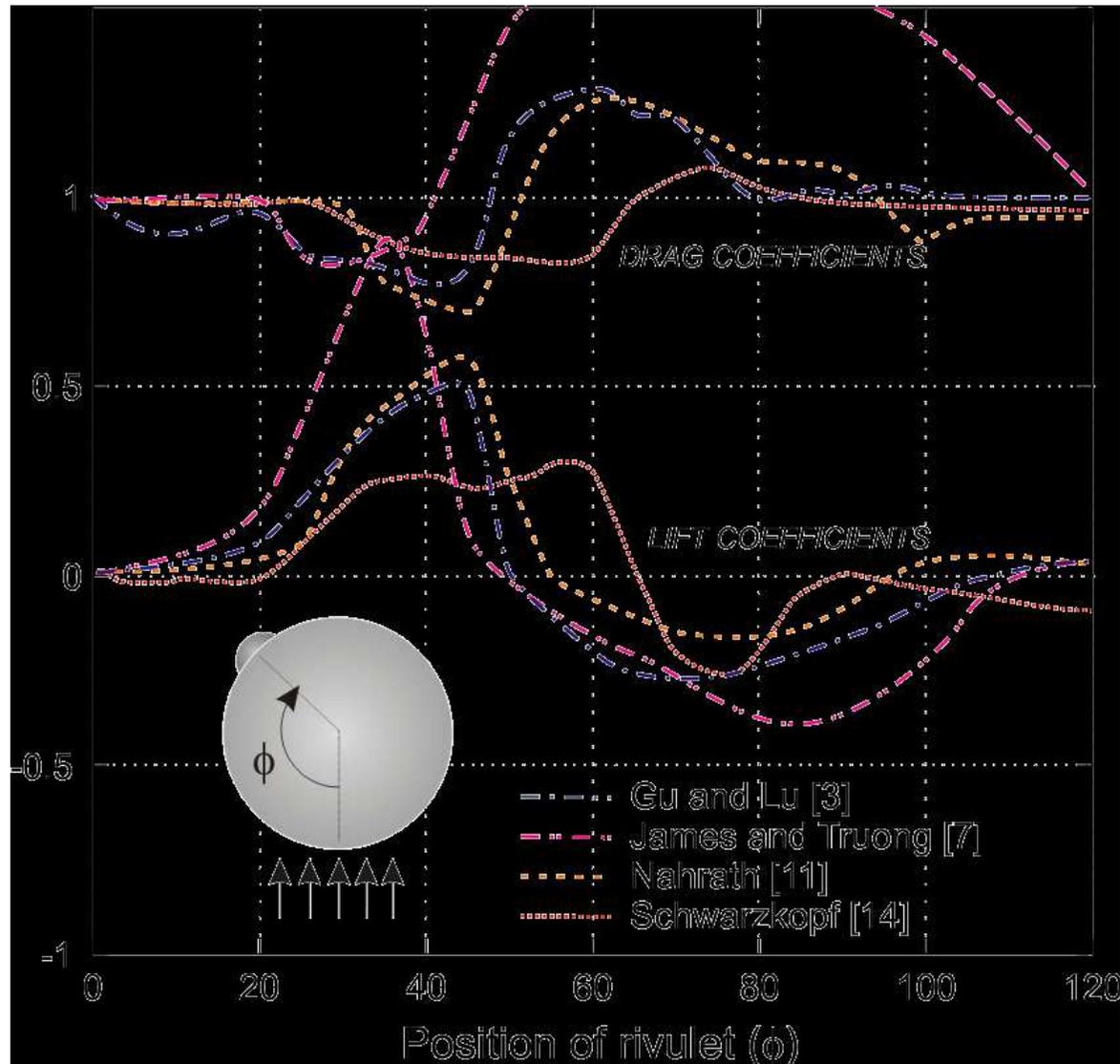
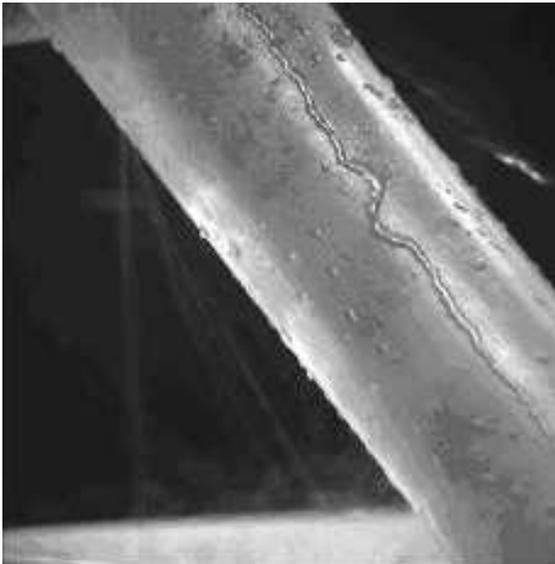
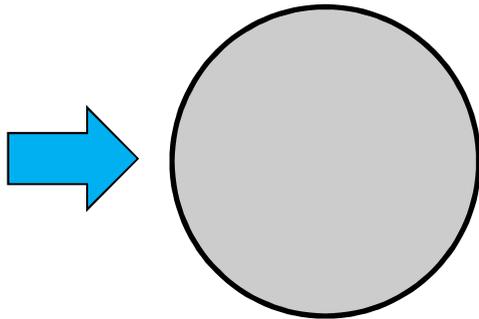
Dong Ting Bridge, China



Fred Hatman Bridge, U.S.A., 1995

Condizione necessaria

$$c_d + c'_1 < 0$$



Rivolo d'acqua su un cavo inclinato



Ponte di Bretannia, Francia, 1977



Rain-wind-induced vibrations

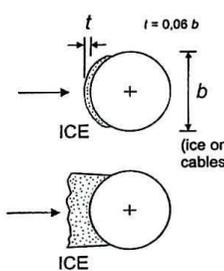
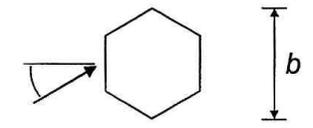
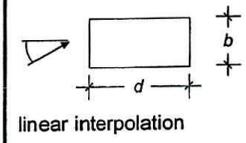
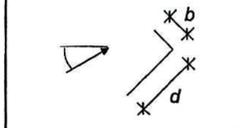
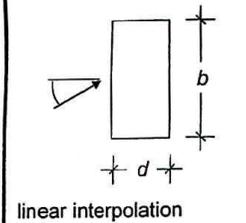
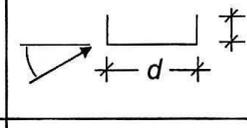


Fasciatura corrugata

Tatara Bridge, Japan, 1999

Coefficiente di galoppo

$$a_G = (c_d + c'_1)$$

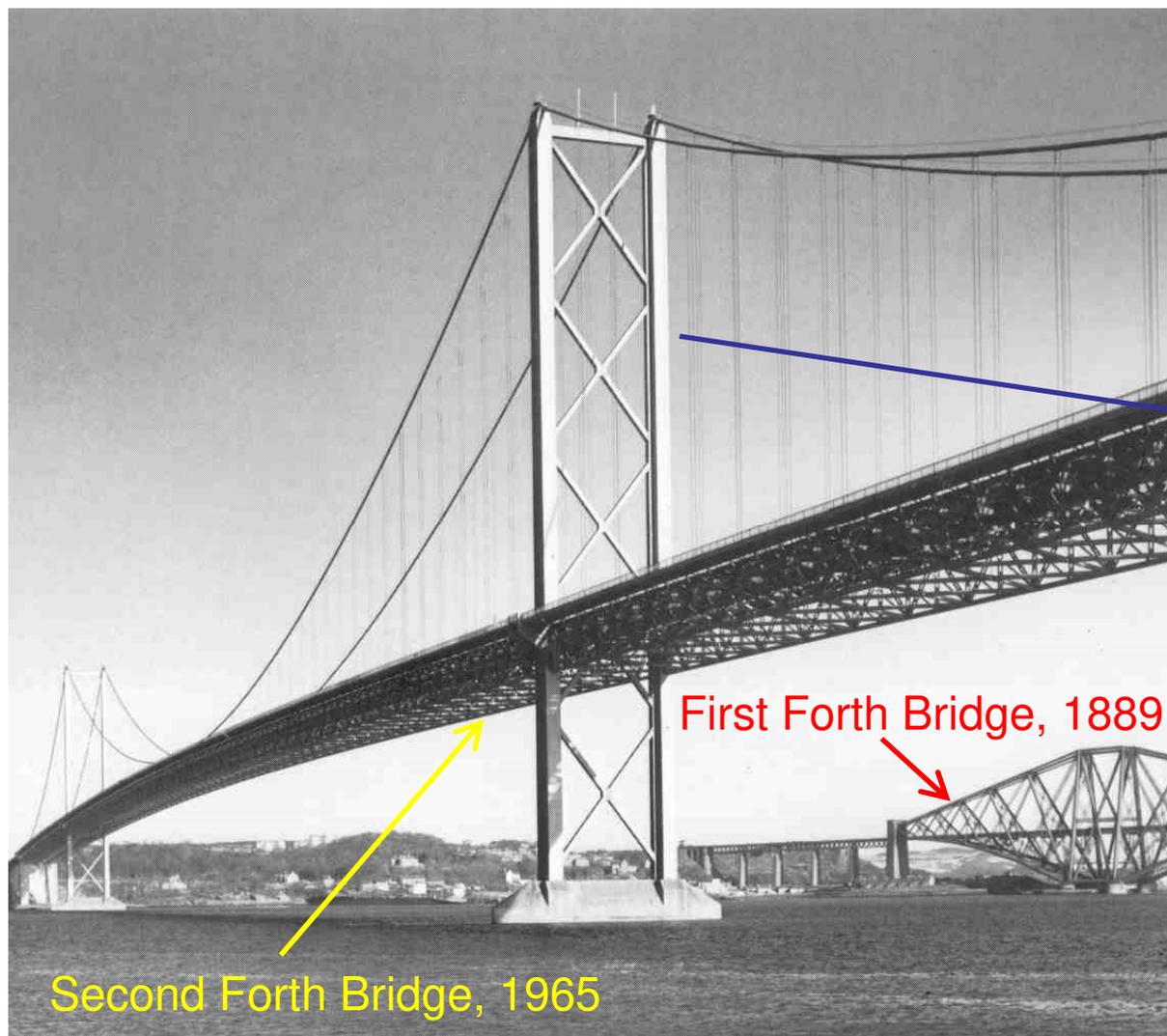
Cross-section	Factor of galloping instability a_G	Cross-section	Factor of galloping instability a_G
	1,0		1,0
	$d/b=2$ 2 $d/b=1,5$ 1,7 $d/b=1$ 1,2		$d/b=2$ 0,7 $d/b=2,7$ 5 $d/b=5$ 7
	$d/b=2/3$ 1 $d/b=1/2$ 0,7 $d/b=1/3$ 0,4		$d/b=3$ 7,5 $d/b=3/4$ 3,2 $d/b=2$ 1

Galoppo trasversale

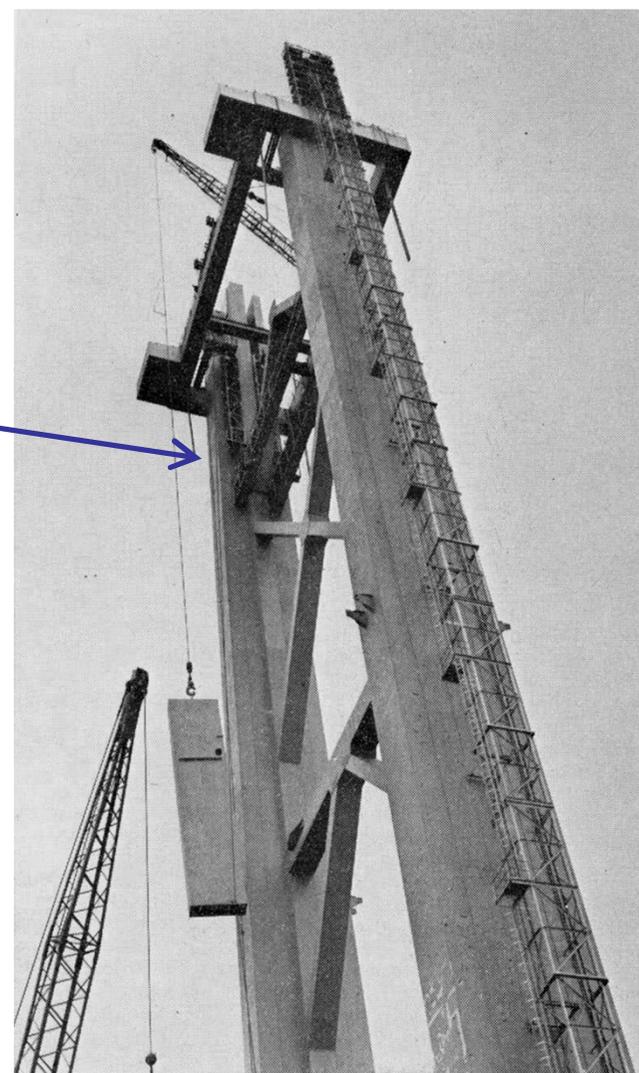


Mersey wave, Liverpool, United Kingdom

Fase di esercizio



Fase di costruzione



Forth Bridges, U.K.

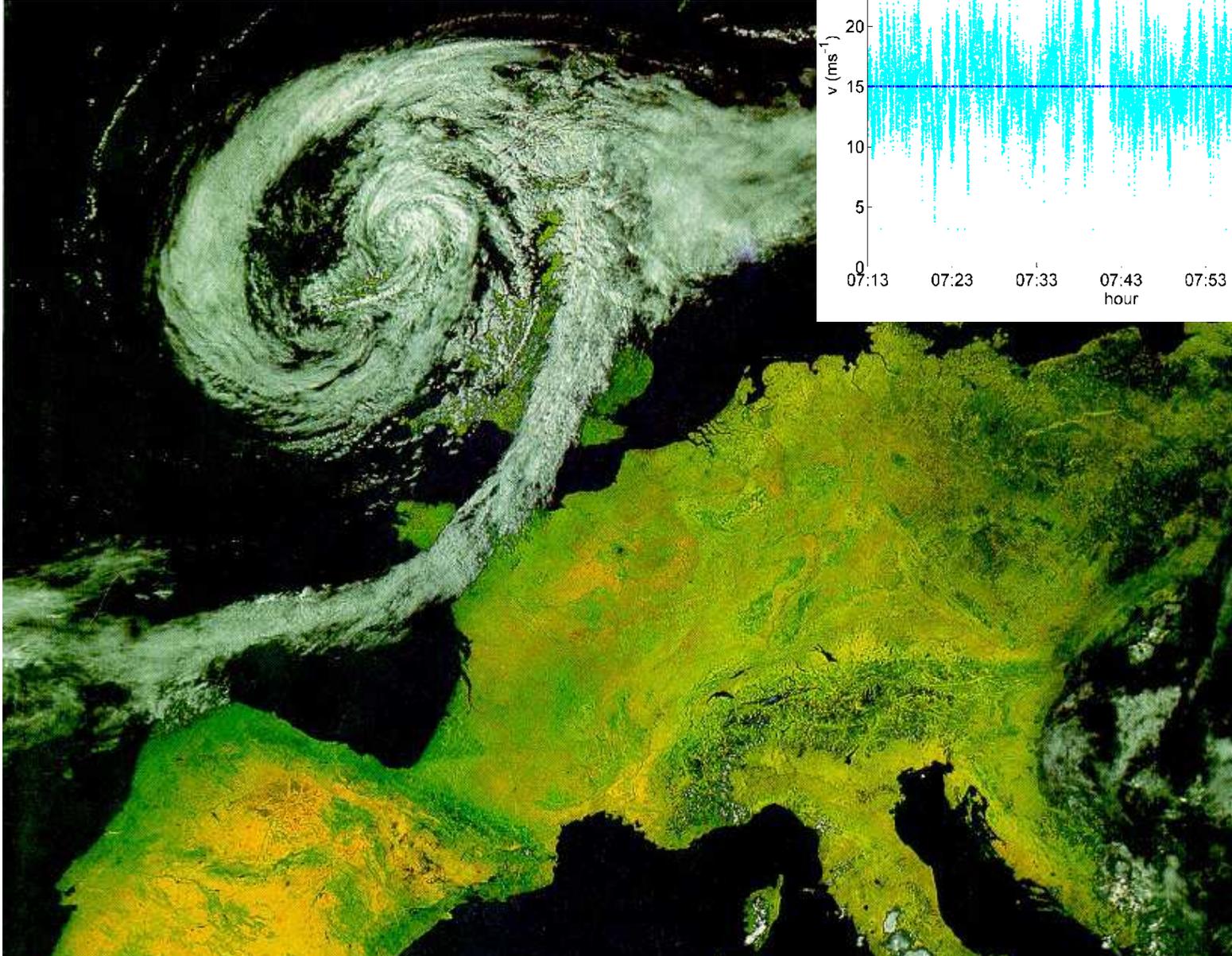


Alconétar Arch - Fase di costruzione

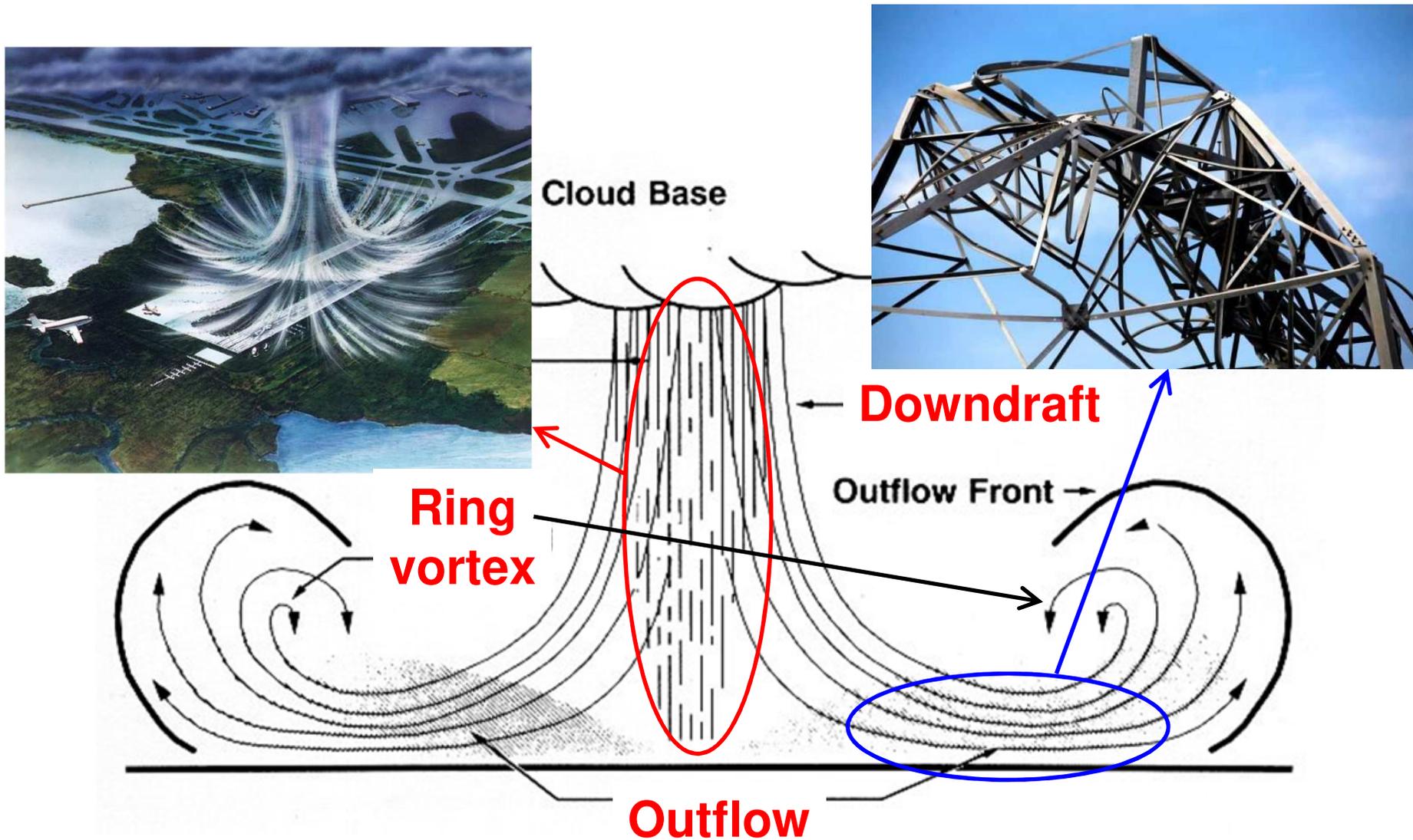


Galoppo torsionale

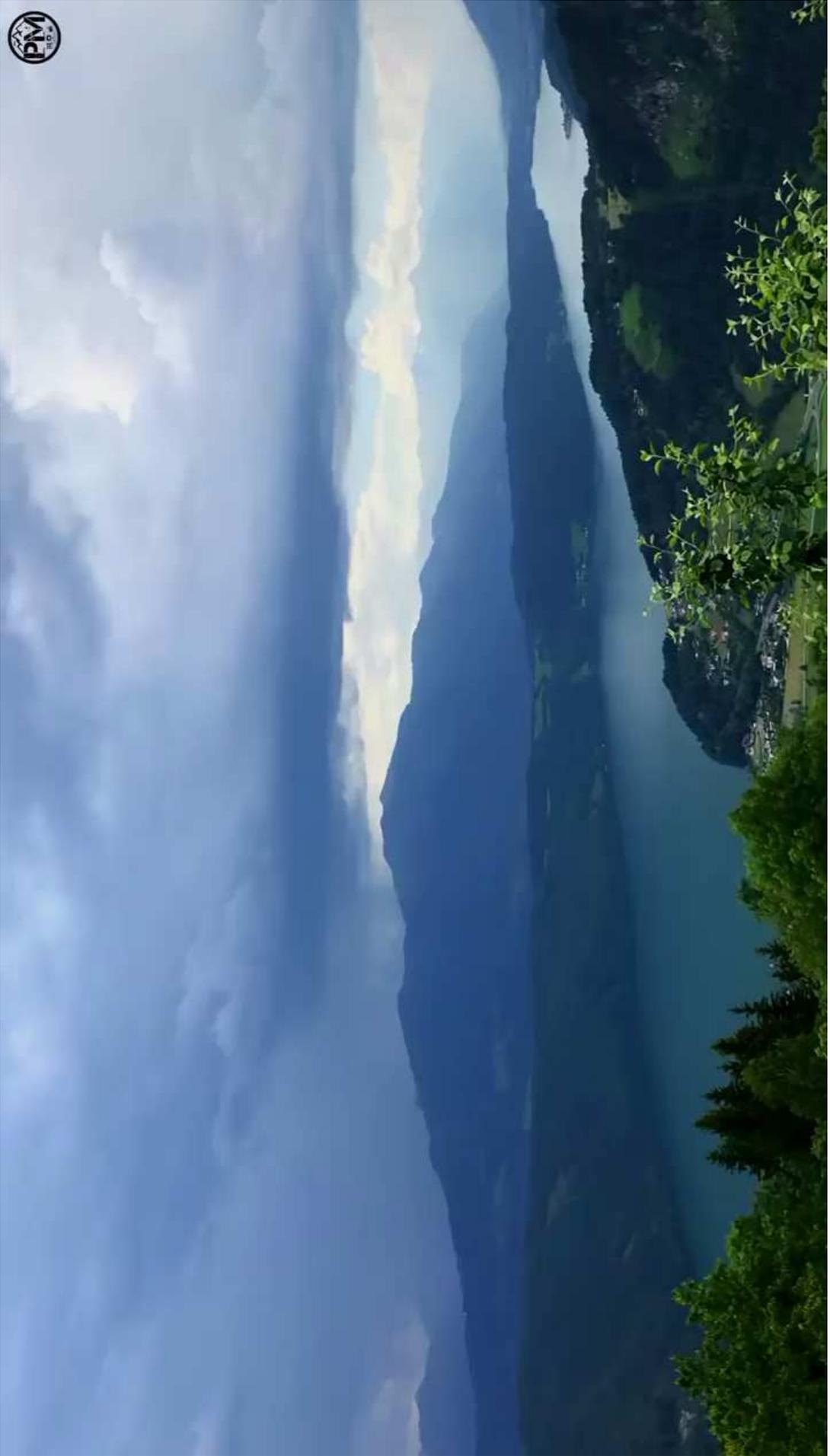
Ciclone extra-tropicale

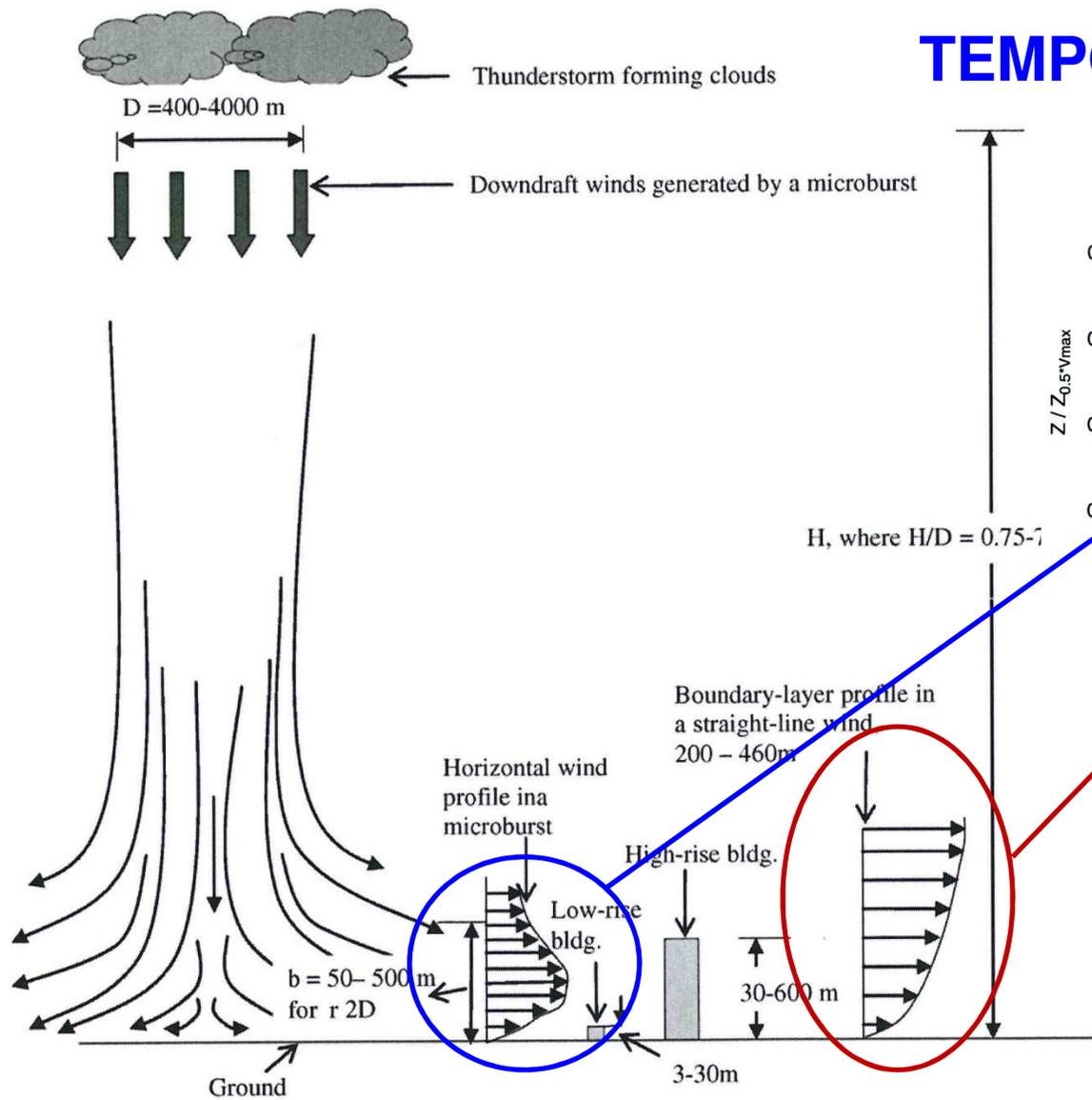


Downburst - Temporale



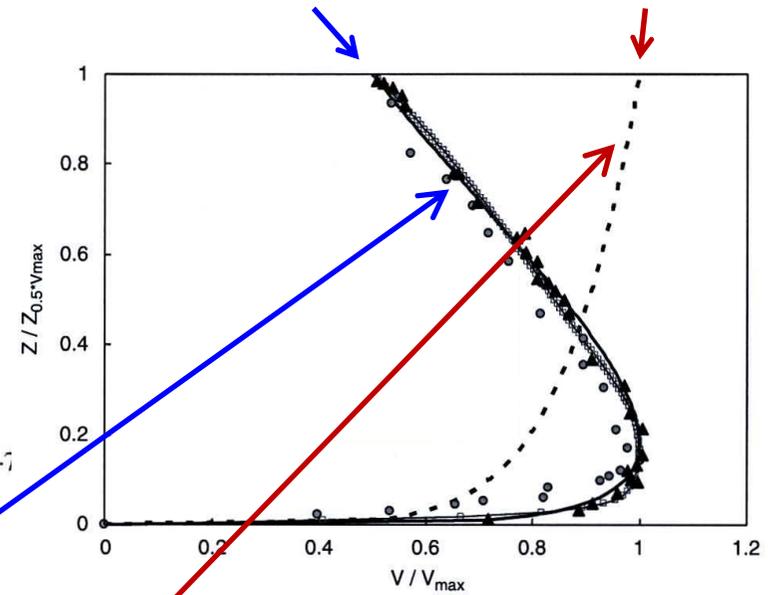
Downburst, Fujita (1981, 1985, 1990)



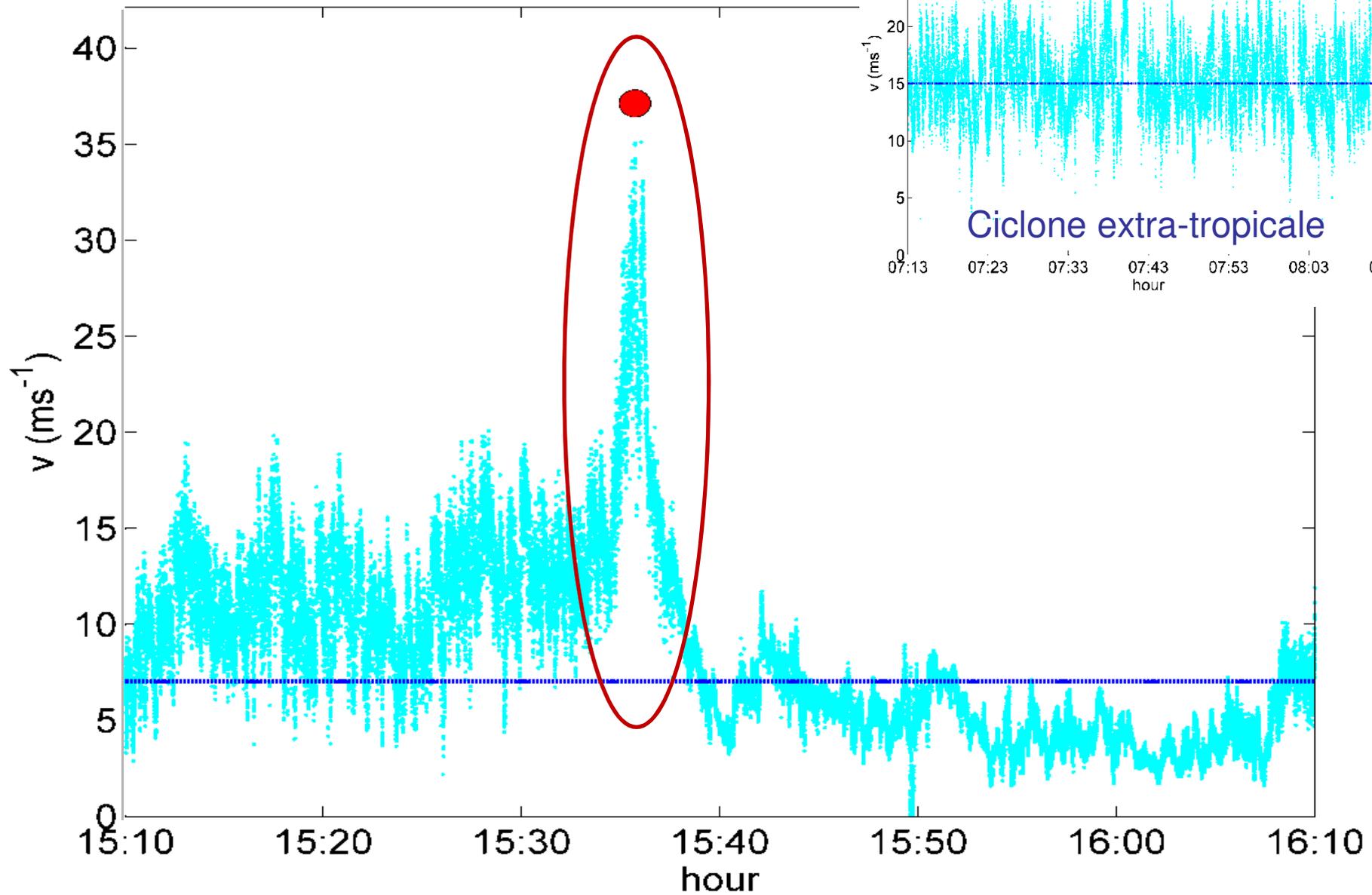


TEMPORALE

CICLONE



Downburst - Temporale





Concerto per Nelson Mandela, Cape Town, Courtesy A. Goliger



Temporale su Genova



Genova, 9-10 ottobre 2014



Genova, 31 agosto 1994



Genova, 31 agosto 1994

Progetti “Vento & Porti” e “Vento, Porti & Mare”

La Cooperazione al cuore del Mediterraneo



MARITTIMO - IIR - MARITIME
TOSCANA - LIGURIA - SARDEGNA - CORSICA

LA PREVISIONE DEL VENTO PER LA GESTIONE E LA SICUREZZA DELLE AREE PORTUALI



VENTO e PORTI

2009-2013

IL MONITORAGGIO E LA PREVISIONE DELLE CONDIZIONI METEO-MARINE PER L'ACCESSO IN SICUREZZA ALLE AREE PORTUALI



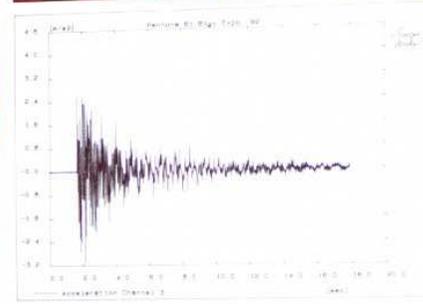
VENTO PORTI e MARE

2013-2015

Genova, 31 agosto 1994



Il signore dei venti e dei temporali
RAI3 TG Leonardo, 24 aprile 2018



Grande Bigo, Columbus Exhibition, Genova (1992)



L'ingegnere del vento - TEDxGenova, 23 febbraio 2019

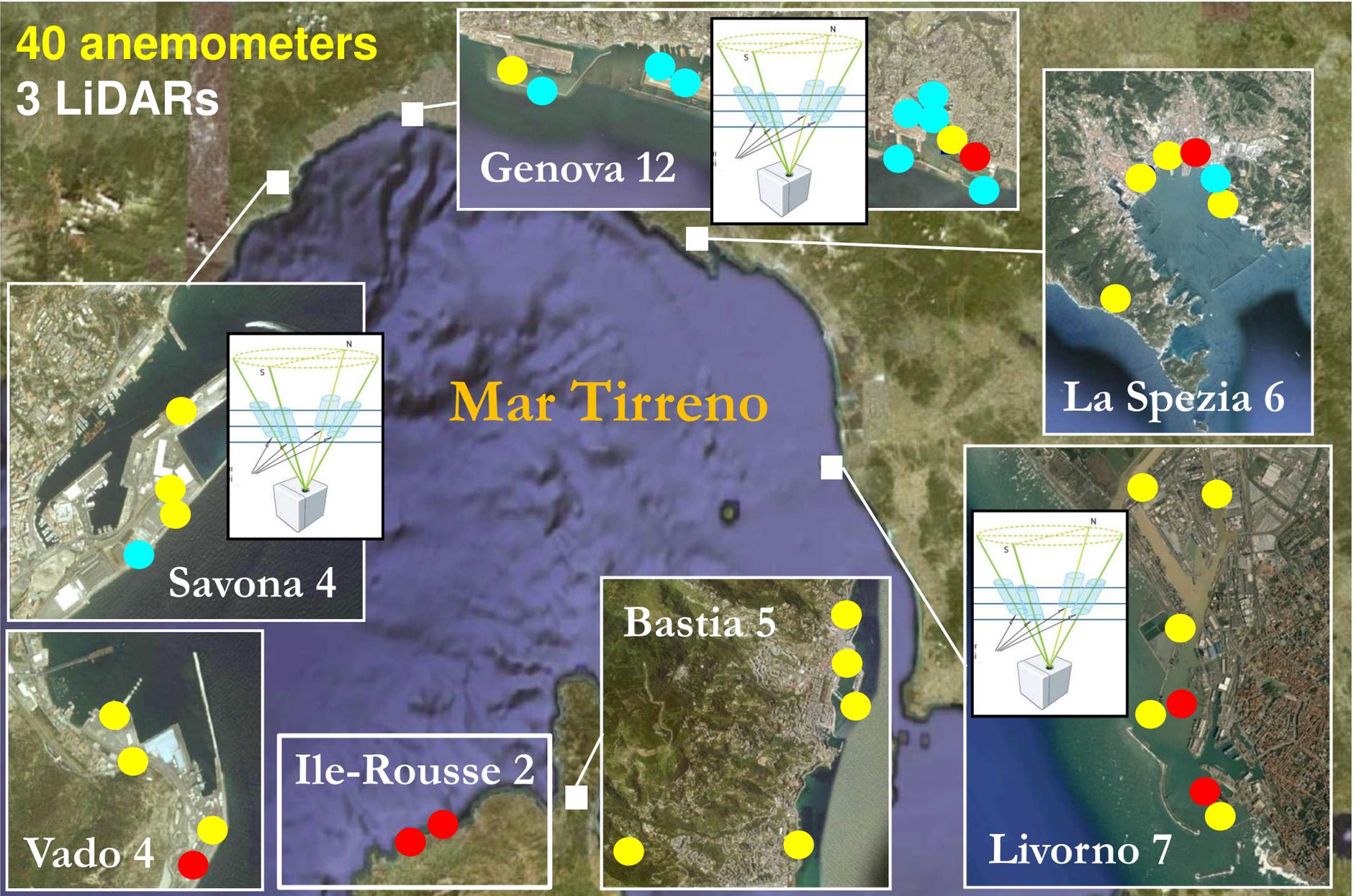
Progetti “Vento & Porti” e “Vento, Porti & Mare”

Biaxial Sonic Anemometer

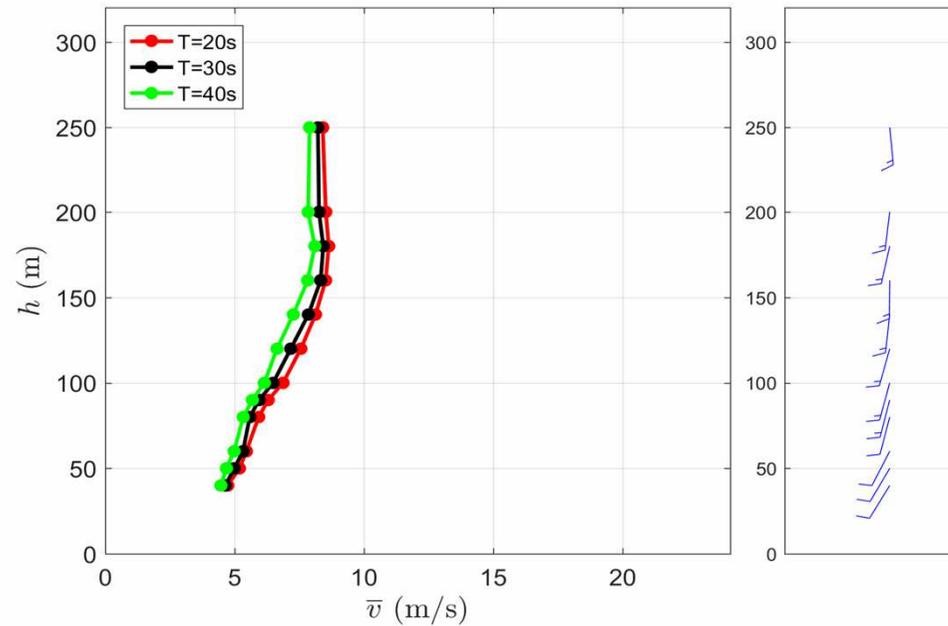
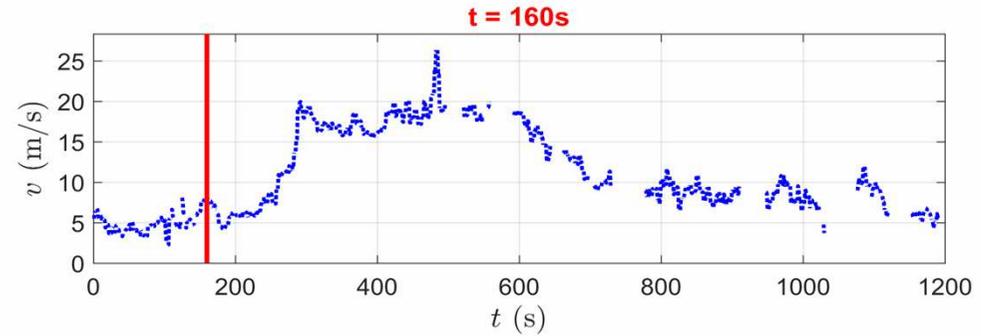
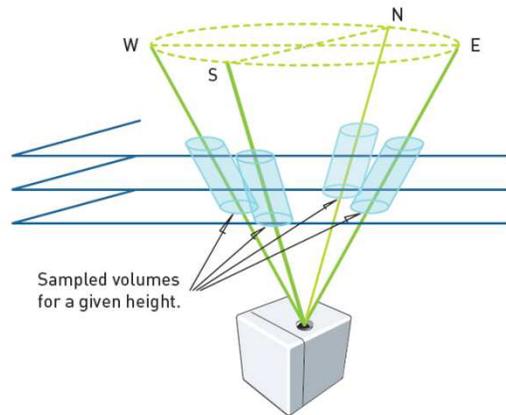


Triaxial Sonic Anem.

Progetti “Vento & Porti” e “Vento, Porti & Mare”



LiDAR Profiler – Velocità media di un temporale



Burlando, M., De Cio, A., Pizzo, M., Solari, G. (2017). APCWE.

PLATINUM

aziende & protagonisti

www.platinum-online.com

The dangers caused by the wind



Thunderstorms are one of the most common causes of natural devastation. How can this be taken into account at construction level?

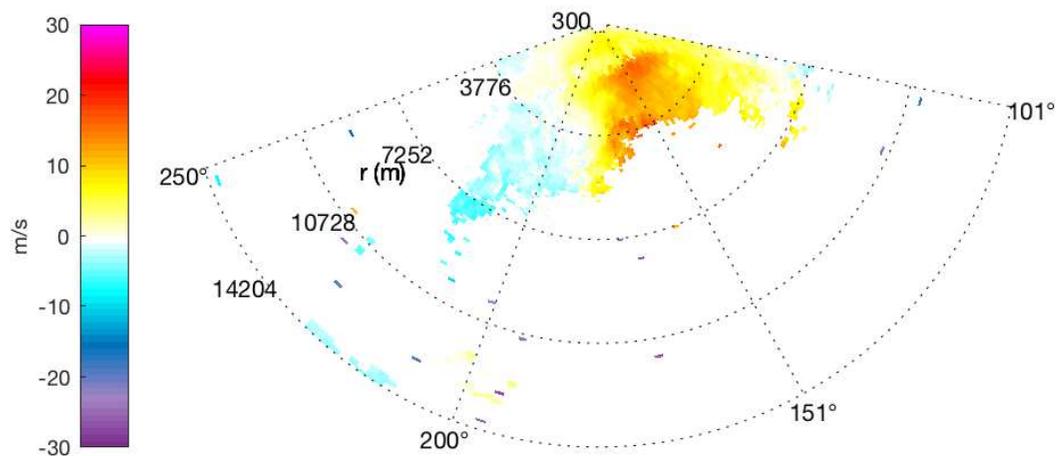
Of all natural disasters, the most common cause of death and destruction is not earthquake (as one might intuitively think), but the wind, especially in those countries affected by tropical cyclones, so much so that the UN has recognised the wind as the strategic element for world safety. Though much is known about cyclones, the other phenomenon associated to wind devastation is less studied, namely, thunderstorms. Launched about a year ago, the Horizon 2020 "Thunder" project is an ERC Advanced Grant that intends to study thunderstorms and their effect on buildings: staff of the Department of Civil, Chemical and Environmental Engineering at the University of

Genova studying historic, coordinated by professor Giovanni Solari, who has been a luminary in this field for many years and already has several projects to his name, which the project was born from. "There never been a high-rise building fall because of the wind - the professor begins - whereas, every day, modern-day constructions collapse such as towers, nesting structures, warehouses, and pedestrian walkways and in 95% of cases this happened during a storm. Starting from here, we would like to return on the safety and economy of constructions, developing new methods of engineering calculation and shifting costs where they are needed. Perhaps the idea is ambitious, but let's see how far we can get." To

begin with, staff from the Dima have bought a very rare instrument - a sensor that measures wind with a precision of 12 kilometers and have installed it in the port of Genova. A group of young postgraduates will have the task, over the next four years, to study the data, while the cooperation with other universities specialised in storms, wind or meteorology (Western University in Canada, the University of Edinburgh and the University of Bath) will also be instrumental to understand if thunderstorms are increasing in number and growing in intensity in the context of climate change. The project website is already online, www.thunder.eu, where the current program can be viewed. ■

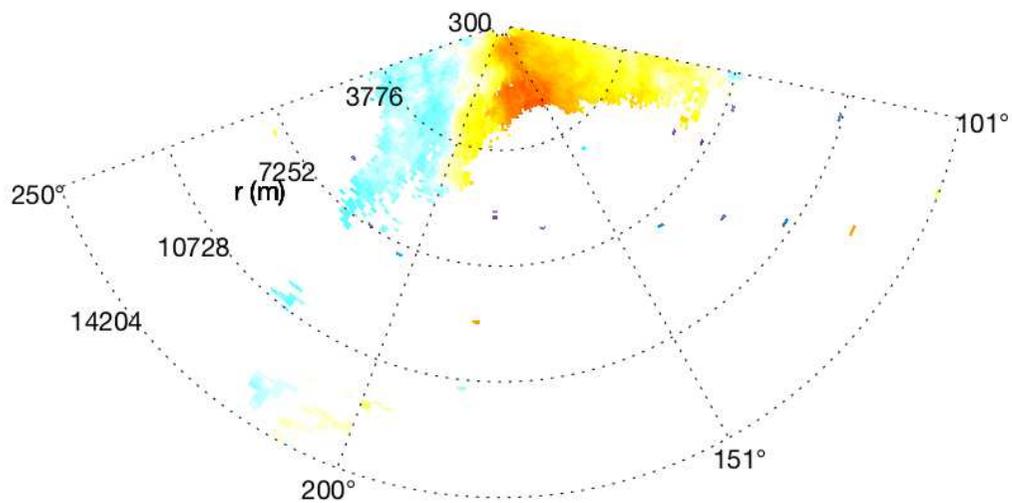


LiDAR Scanner – Porto di Genova Voltri



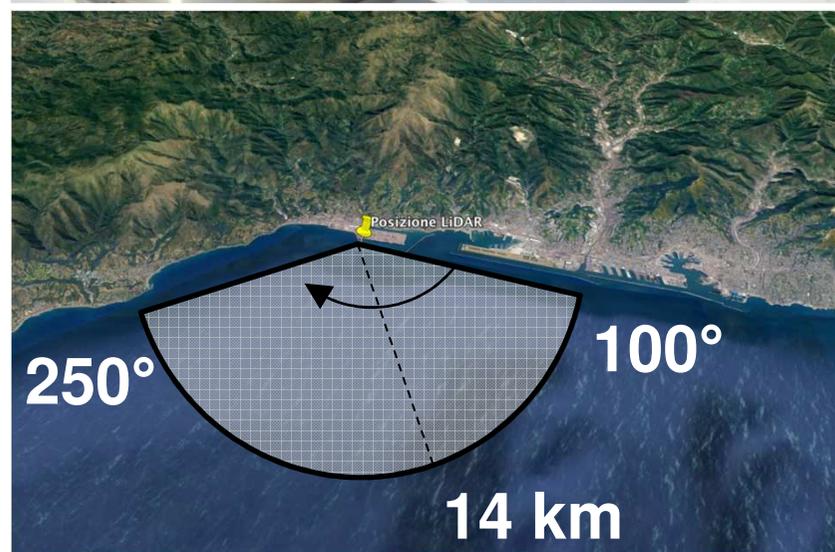
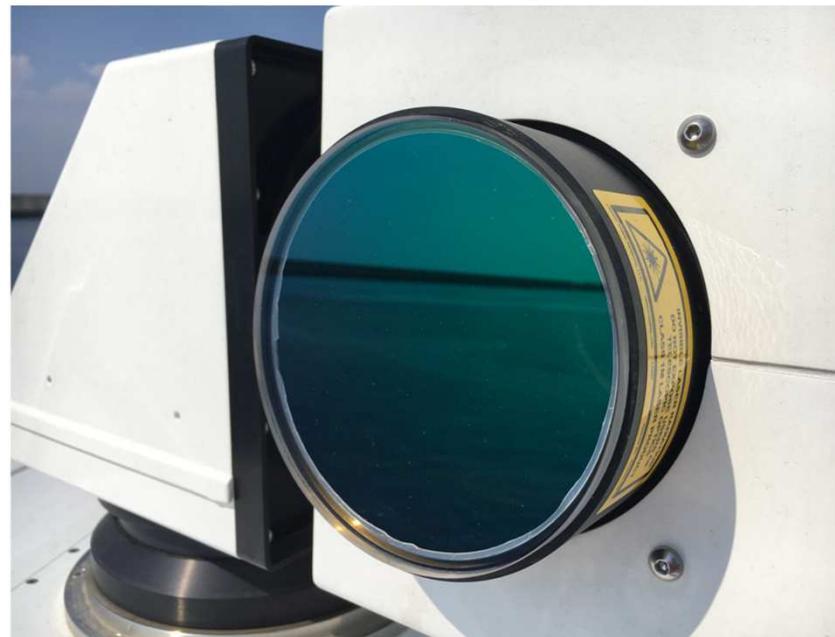
PPI scan

Date: 14-Aug-2018 from 09:18:31 to 09:19:21
Elevation: 2.5°

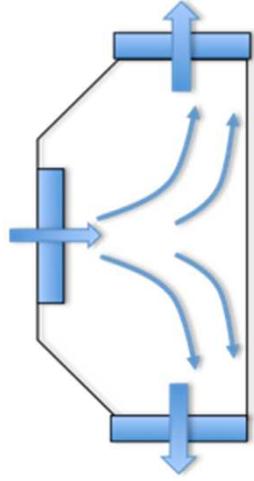


PPI scan

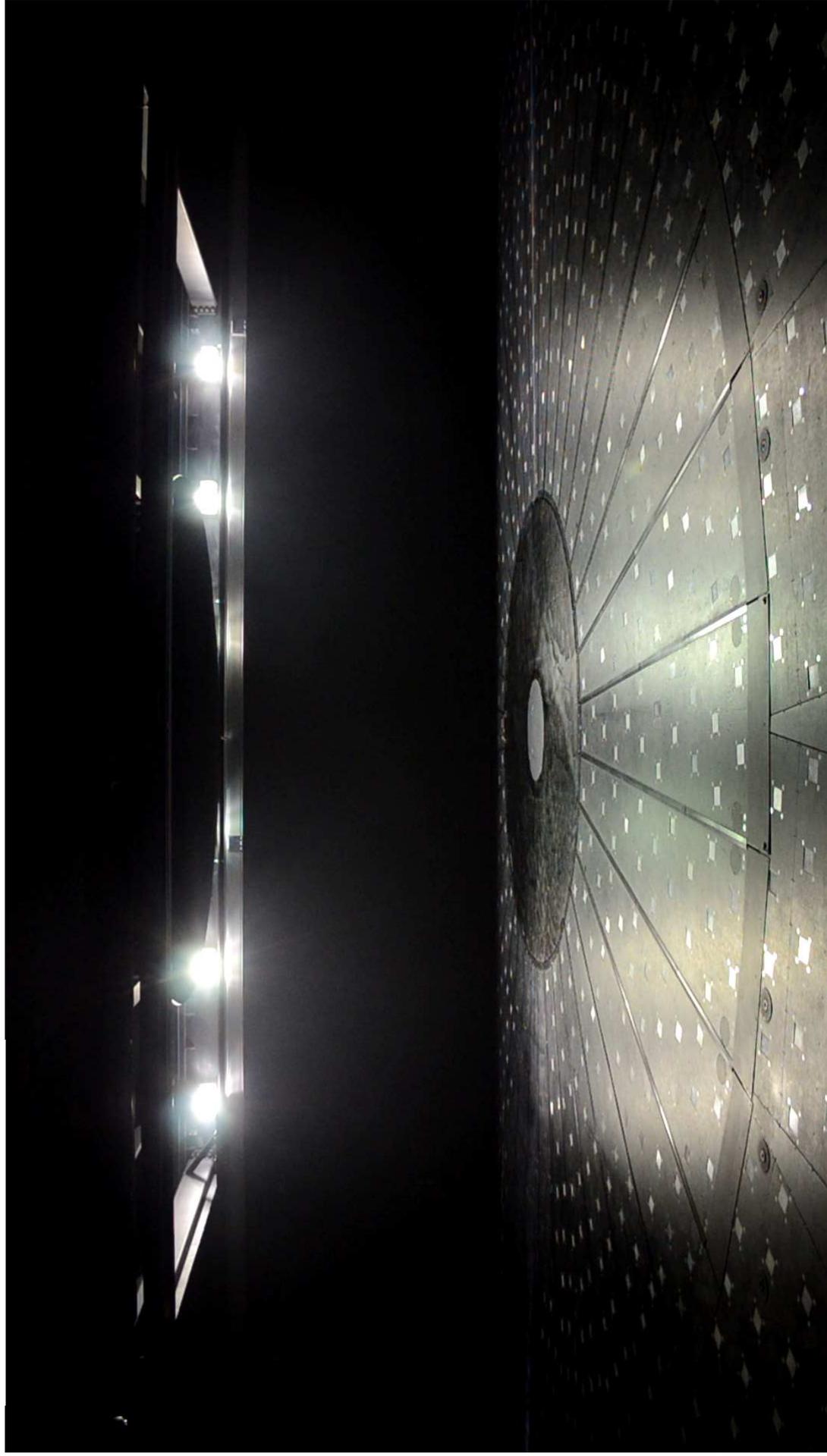
Date: 14-Aug-2018 from 09:21:55 to 09:22:44
Elevation: 2.5°



LiDAR Scanner – Porto di Genova Voltri



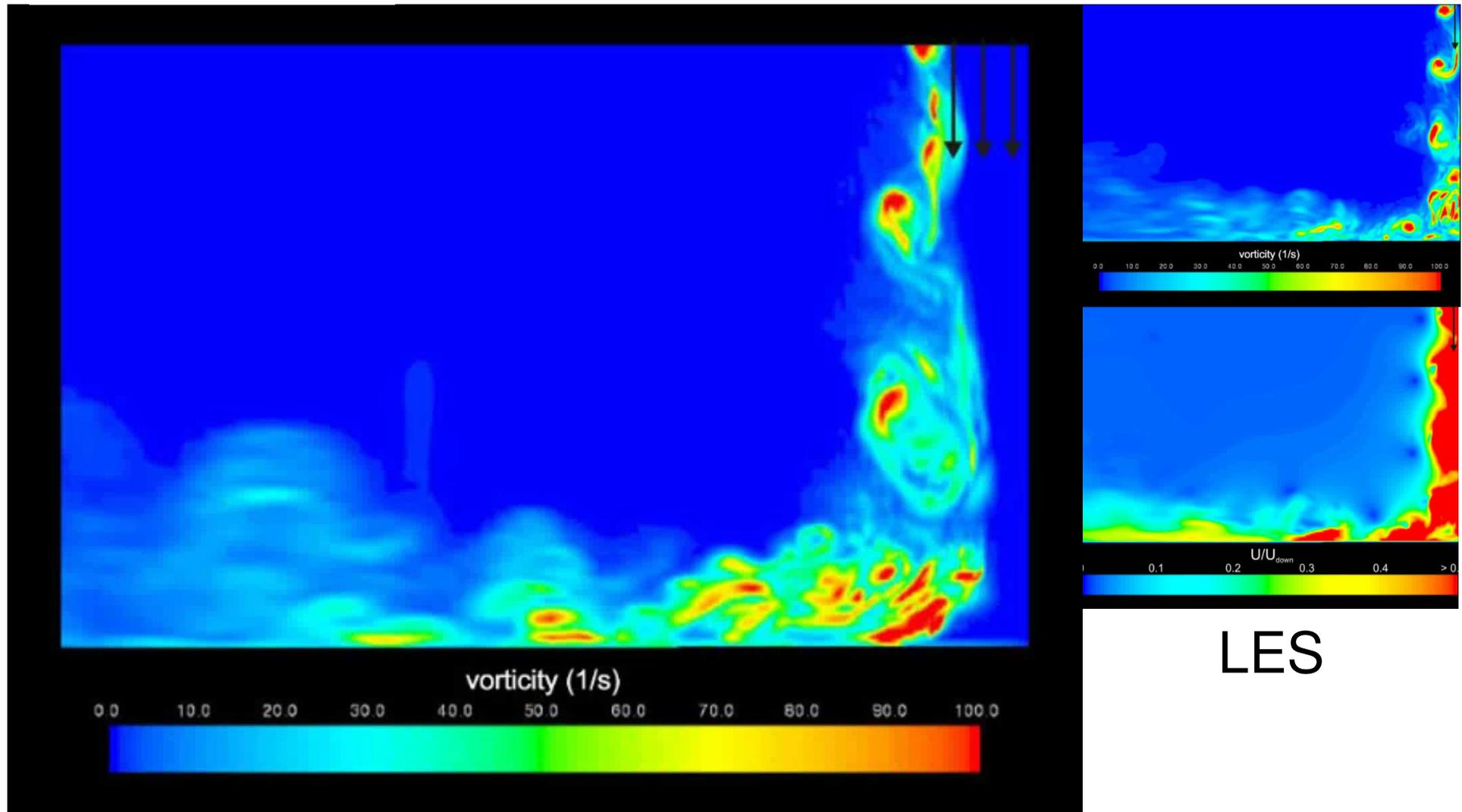
Western
UNIVERSITY • CANADA





TU/e

Technische Universiteit
Eindhoven
University of Technology





RCP 4.5 2021-2050



RCP 4.5 2071-2100

