Book of presentations

Politecnico di Milano

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Contents

Keywords

Politecnico di Milano – Mechanical Engineering Department

Floating offshore wind turbines; Permeable Double Skin Façades; Long-span bridge aerodynamics; Train aerodynamics; Cable aerodynamics; Wind farm control; Cycling aerodynamics.

Università degli Studi di Genova

Urban wind flow and comfort analysis; Wind-induced fatigue of slender structures; Thunderstorm outflows: wind field and wind loading; Structural monitoring; Wind actions on moored ships.

Technical University of Civil Engineering Bucharest

Wind loads on lattice towers; Wind-induced damage.

Università degli Studi di Firenze

VIV-Galloping interference for slender BB in SF and TF; VIV on bridge decks; Permeable buildings envelopes; Buffeting response of long span bridges.

University of Bologna – DICAM

Validation of LES as a design tool; Synthetic inflow condition generation; Porous bluff bodies aerodynamics; Buffeting analysis ; Calculation of Equivalent Static Wind Loads; Bluff Body Aerodynamics (CFD).

KU Leuven

Synoptic winds modeling; Non-synoptic winds modeling; Pollutant dispersion; Indoor & outdoor ventilation; Building aerodynamics; Vehicle aerodynamics; Sport aerodynamics; Wind Energy.

Politecnico di Torino

Bluff-body aerodynamics; Multiphase flows; Windblown sand action; Design and performance assessment of sand mitigation measures.

University of Stavanger, Reykjavik University, University of Bergen, The Norwegian Public Roads Administration

Full-scale monitoring of suspension bridges; Bridge decks aerodynamics; Wind conditions in complex terrains; Remote sensing of wind.

Università di Pisa – Dipartimento di Ingegneria Civile e Industriale

Experimental and numerical study of separated flows; Transverse grooves to delay flow separation ; BARC: accuracy of LES through stochastic sensitivity analysis; BARC: effect of upstream-corner roundings ; Uncertainty quantification and stochastic sensitivity analysis; Wavelet and Hilbert time-frequency analysis; Wind turbines: modeling and simulations; Micro-mixers and micro-reactors (exp/num); Hemodynamics: in-vivo exp, in-vitro exp, simulations and UQ; Cavitation and Internal Injector Flows.

Università di Modena e Reggio Emilia

Direct Numerical Simulation of separating and reattaching flows; Turbulence physics and modelling in separating and reattaching flows; Wind-induced natural ventilation in buildings.

École Centrale de Lyon

Atmospheric heavy gas dispersion; Impact of atmospheric ship emissions on urban areas; Flow and dispersion in urban canopy ; Atmospheric dispersion models; A Complex Network Perspective for dispersion in the urban canopy; LES for atmospheric dispersion; Analytical dispersion models.

Zhejiang University

Cable aeroelastic behavior; Ice accretion effects on the cable aerodynamic stability; Probabilistic assessment of the damping required to cable avoid vibrations; Field observations of wind-induced cable vibrations; Wind profile identification; Combined wind-seismic response of wind turbines; Aerodynamics of cooling towers.

Cranfield University

Wind effects on ground vehicles; Wind effects on buildings; Wind effects on helidecks; Sport and bluff-body aerodynamics; Motorsport aerodynamics.

RWDI

On-site monitoring; Pedestrian Level Wind; Double Skin Façade; AFAS Stadium Collapse.

University of Birmingham

Pedestrian Safety & Urban Winds; Urban Wind Energy; Crop Lodging; Train Aerodynamics; Extreme transient winds; Vehicle aerodynamics & platooning.

Sapienza University of Rome

Nonlinear parametric modeling of suspension bridges for aeroelastic analysis; Flutter and post-flutter control in suspension bridges; Control of vortex-induced parametric instabilities in suspension bridges.

Research group info

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Floating offshore wind turbines

Core activities

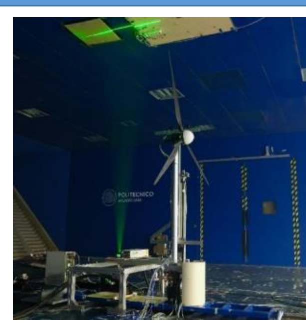
- Large wind turbine scale model with realistic control capabilities
- Hybrid hardware-in-the-loop scale model experiments for the assessment of global dynamics and validation of new wind turbine control strategies
- Experimental investigation of unsteady aerodynamic loads in imposed motion tests
- Experimental investigation of the wind turbine wake (hot wire / PIV)
- Design of new control strategies
- Design of large (1:50) and very-large scale models (1:10)

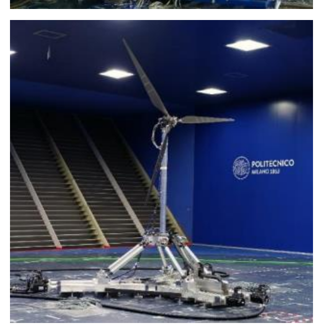
Ongoing projects

- The blue growth farm (EU H2020 grant agreement number 774426)
- Corewind (EU H2020 grant agreement number 815083)

Collaborations

- Delft Center for Systems and Control – TUDelft





Permeable Double Skin Façade

PURPOSE

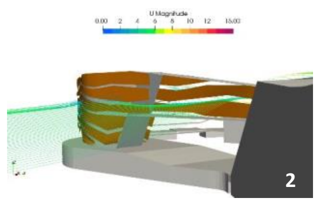
Development of a *combined experimental numerical methodology* allowing a validated and quantitative approach to the *wind loads assessment* on the *Permeable Double Skin Façade*, a building cladding system made by an external porous screen in addition to a inner glazed façade.

METHODOLOGY

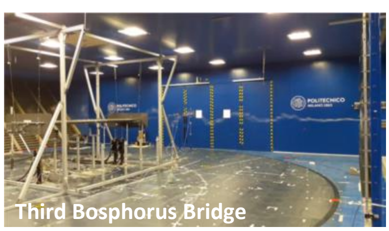
1. Aerodynamic characterization of the porous skin by means of small-scale wind tunnel tests will provide the input parameter for the CFD model

2. Computational Fluid Dynamic approach: the Darcy-Forchheimer model being implemented is used to properly reproduce the aerodynamic behaviour of the porous screen

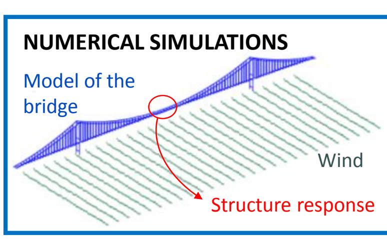
3. Validation of the CFD model through large scale wind tunnel tests, able to catch the building behaviour in the ABL

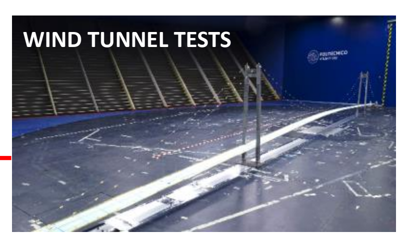


Long-span bridge aerodynamics



- Static response
- Motion-induced forces
- Buffeting response
- VIV





VALIDATION

From sectional deck models to full aeroelastic ones

Train aerodynamics

Research topics:

Crosswind stability

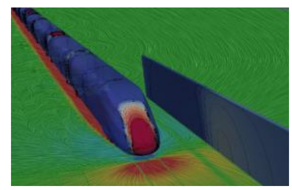
Slipstream

Train-tunnel interaction

Research methodology:

Wind tunnel tests

Full-scale tests

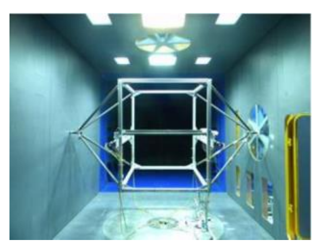


CFD simulations

Cable aerodynamics

Numerical and experimental studies on Aeolian vibrations, subspan oscillations and Ice galloping

Vortex induced vibrations



Subspan oscillations

Ice galloping

Smart Wireless Monitoring System

Wind farm control

Problem identification

Clustering of wind turbines → Wake interaction → Wind speed reduction → Power reduction

Wake interaction → Increased turbulence intensity → Power reduction

Objective of the research activity

Development of numerical methods reliably modelling wind turbines wake dynamics as a tool for optimized solutions of wind farm control. Validation vs wind tunnel experiments (CL-Windcon).

Investigated control strategies

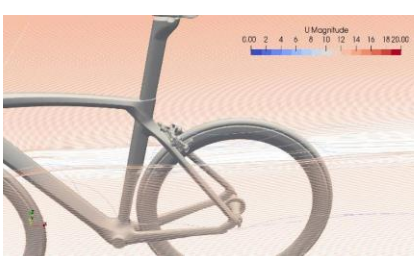
- Wake redirectioning;
- Dynamic wake mixing

Computational framework

- FLORIS;
- WFsim;
- SOWFA

Cycling aerodynamics

- Position of the athlete / body
- Aerodynamic properties of equipment
- Design and styling of the garments and accessories
- Aerodynamic attributes of the garment surface
- Drafting



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Permeable Double Skin Façades

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[2] Z. Zeng, G. Reid, *A criterion for non-Darcy flow in porous media*, Transport in porous media, 2006.

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[2] G. Diana, S. Stoyan, TG 3.1 members, *IABSE Task Group 3.1 Benchmark Results. Part 1: Numerical Analysis of a Two-Degree-of-Freedom Bridge Deck Section Based on Analytical Aerodynamics,* Structural Engineering International (TSEI).

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Train aerodynamics

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Cycling aerodynamics

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[2] S. Giappino, S. Omarini, P. Schito, S. Somaschini, M. Belloli, M. Tenni, *Cyclist aerodynamics: a comparison between wind tunnel tests and CFD simulations for helmet design*, INVENTO, 2018.

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Urban wind flow and comfort analysis

The topic "Urban wind flow and comfort analyses" has been tackled during a double PhD project (2012 – 2017) between UniGe and TU/e [1]. The effects induced by the presence of urban features, local-scale forcing effects and inflow conditions on the atmospheric boundary layer (ABL) development have been investigated by on-site measurements, wind-tunnel tests and CFD simulations.
The aim is to provide the scientific community and all port stakeholders involved in the research project with an operational wind forecast model, whose novelty consists of nesting models from the global scale to the local scale [2].
This approach has already been already applied on some test cases (i.e. the port of Livorno), and future analyses can be targeted to investigate the pedestrian wind comfort associated to strong winds, the prediction of pollution dispersion under different atmospheric stratifications as well as the energetic production of small-size wind turbines inside compact urban districts.

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[1] A. Ricci, *Wind flow modeling in urban areas through experimental and numerical techniques*, PhD thesis, Double PhD UniGe - TUe.

[2] A. Ricci, M. Burlando, M. P. Repetto, B.Blocken, *Simulation of urban boundary and canopy layer flows in port areas induced by different marine boundary layer inflow conditions*, Science of the Total Environment 670, 876-892.

Wind-induced fatigue of slender structures

Wind-induced fatigue is a critical issue in design of many slender structures, such as wind turbines, cranes, poles and towers. Despite this reality, suitable engineering and standards procedures are fragmentary and almost lacking.

Working in this field, a general procedure for determining the wind-induced fatigue damage of slender structures has been formulated by the research group of University of Genoa. Initially, a complete method was proposed to evaluate, in closed form, the cycle and damage histogram induced by alongwind turbulence effect during the whole structural life [1]. Later, a new and refined closed form solution of the alongwind-induced fatigue has been proposed [2], aimed at evaluating the alongwind-induced fatigue damage and the fatigue life of steel structures or steel structural elements, suitable for engineering calculations and code provisions.

A PhD thesis, now in progress (2016-2020), is dealing with this model. It proposes more advance in generalizing the closed form solution, taking into account different materials fatigue resistances and simultaneous alongwind and crosswind structural responses due to turbulence and vortex shedding, discussing the main analytical features and the simplifying hypotheses adopted. The set of input parameters are discussed and simple expressions coherent with standard format are defined for both alongwind and crosswind analysis. Some case studies are discussed to validate the proposed generalized procedure.

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[1] M.P. Repetto and G. Solari, *Bimodal alongwind fatigue of structures*, in Journal of Structural Engineering, 132(6), 899–908, 2006.

[2] M.P. Repetto and G. Solari, *Closed-Form Prediction of the Alongwind-Induced Fatigue of Structures*, in Journal of Structural Engineering, ASCE, 138, 1149-1160, 2012.

THUNDERR Project

Because of their transient nature and short duration, the thunderstorms generate actions on structures which strongly differ from the ones associated to synoptic winds and clear codification is not yet present to support designers [1].
THUNDERR is the acronym of THUNDERstorm that expresses the innovative Roar of this research [2]. The project, funded by the European Research Council, aims to detect thunderstorms, create a database of meteorological records and scenarios, conduct unprecedented laboratory tests and numerical simulations, formulate a thunderstorm model appropriate for both atmospheric sciences and structural design, change the format of wind actions, engineering practice and the codification system, make building safer and more sustainable, bring about a profound impact on society and its economy.
The main topics of this research are the following:

- OBJECTIVE 1 – THUNDERSTORM: Detection, Analisys and Representation;
- OBJECTIVE 2 – STRUCTURES: Structural Analysis and Impact on Construction;
- OBJECTIVE 3 – DISSEMINATION;

Seven PhD students belonging to the group are currently working to Thesis devoted to this subject, concerning several aspects associated to that.
Under the impulse of the assignment of this grant, the University of Genova opened a doctoral curriculum in *Wind Science and Engineering*.

References

1. G. Solari, *Emerging issues and new frameworks for wind loading on structures in mixed climates*, Wind and Structures., Vol 19, No. 3, 295-320, 2014.

2. G. Solari, M. Burlando, M.P. Repetto, *THUNDERR: an ERC Project for the "detection, simulation, modelling and loading of thunderstorm outflows to design wind-safer and cost-efficient structures"*, International Workshop on Wind-Related Disasters and Mitigation, Tohoku University, Sendai, Japan, 2018.

Structural monitoring

In order to validate and calibrate the calculation models devoted to the estimation of the structural dynamic response to synoptic and non-synoptic winds, the Wind Engineering group of the University of Genova is currently carrying out several full-scale measurements over slender structures, like poles and wind turbines [1]. Three monitoring campaigns are ongoing and one more will be launched in the next months. The experimentation takes place in the Harbors of Genoa and La Spezia.

The structures are equipped with anemometers, accelerometers and strain gauges, enabling the simultaneous record of wind loading and structural response.

The research is supported also by experimental data coming from wind tunnel tests.

A PhD thesis is dealing with this topic. Focusing with attention on the effects induced by synoptic winds, the research uses the experimental data to validate the current response models for poles and towers [2] and to extend these models to rotating-masses structures like wind turbines.

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[2] G. Solari, L.C. Pagnini, *Gust buffeting and aeroelastic behaviour of poles and monotubular towers*, Journal of Fluids and Structures, 13, 877-905, 1999.

Wind actions on moored ships

Due to the increasing of the modern naval units dimensions, the wind actions on ships are becoming really important but, at the same time, difficult to quantify.

The wind actions depend on the structure dimensions as well as on the climatology of the area and the degree of exposure. They may greatly vary from port to port, and within the same area from a quay to another one, or even from location to location along the same quay. Moreover, the wind force affects the design and the management of mooring systems. Accidents frequently occur due to the breakage of mooring clamps, which can lead to risk situations as well as to significant damage and economic loss.

A PhD Thesis (supported by CETENA S.p.A and funded by Regione Liguria) has been assigned regarding this topic, the aim of which is the evaluation of the wind loading conditions that affect large ships and the mooring systems at berth (i.e. [1]), by employing combinate use of experimental data and full-scale measurements.

References

[1] S. Torre, B. Burlando, M.P. Repetto, D. Ruscelli, *Aerodynamic coefficients on moored ships*, Proceedings of the 15th International Conference of Wind Engineering, Beijing, 2019.

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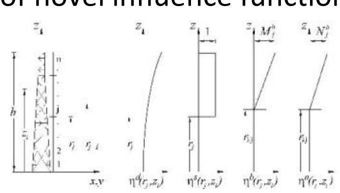
Wind loads on lattice towers

Investigation of the alongwind load effects on free-standing lattice towers by application of the 3D-Gust Effect Factor technique and introduction of novel influence functions specific to such structures.



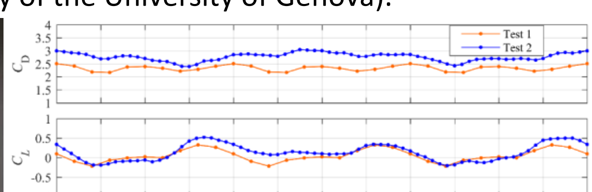
$$\eta^{d}(r_j, z_i) = \frac{\psi_1(r_j)\psi_1(z_i)}{m_1(2\pi n_1)^2}$$

$$\eta^{s}(r_j, z_i) = H(z_i - r_j)$$

$$\eta^{b}(r_j, z_i) = \frac{M_j^h}{(h - r_{\lambda j})}(z_i - r_{\lambda j})H(z_i - r_{\lambda j})$$

$$\eta^{n}(r_j, z_i) = \frac{N_j^h}{(h - r_{\lambda j})}(z_i - r_{\lambda j})H(z_i - r_{\lambda j})$$

Wind tunnel testing of lattice towers to investigate the influence of ancillaries on the aerodynamic coefficients (tests were carried out at the wind tunnel laboratory of the University of Genova).

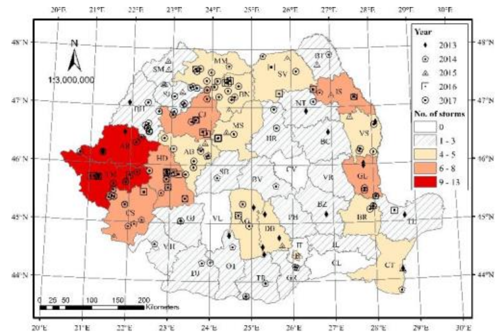


Test 1 – model with no ancillaries
Test 2 – model with linear ancillaries

Wind-induced damage

Investigation of damage caused by strong wind events in Romania in order to identify best possible locations for installation of instrumentation to measure thunderstorms for future research.

Events were identified by means of mass-media reports. The figure (right) shows areas where most thunderstorms occured during the investigated time period (between 2013 and 2017). Figures below are examples of damage caused by identified events.






References

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[3] I. Calotescu*, Overview of Recent Wwind-induced Damage in Romania Based on Mass-media Reports*. International Workshop on Wind-Related Disasters and Mitigation (WRDM), Tohoku University, Sendai, Japan, March 11-14 2018.

[4] I. Calotescu, *Damage from recent thunderstorms in Romania*, Lecture Notes in Civil Engineering, 27, pp. 143-156, 2019.

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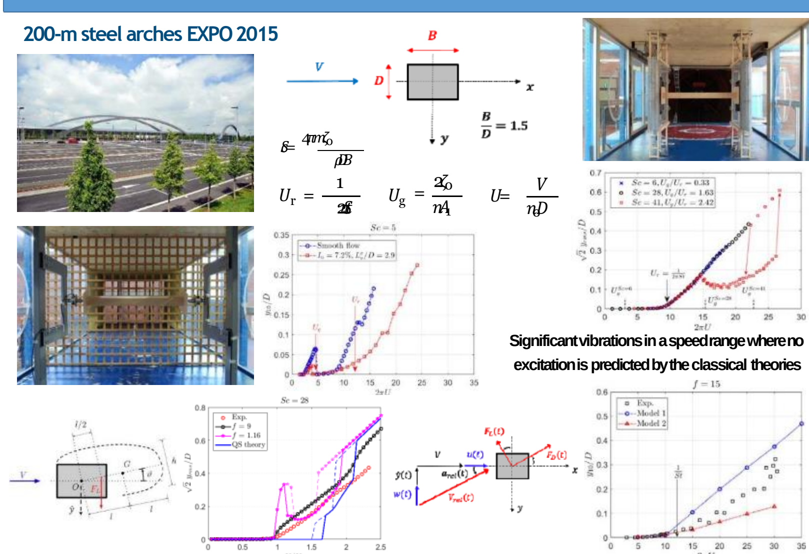
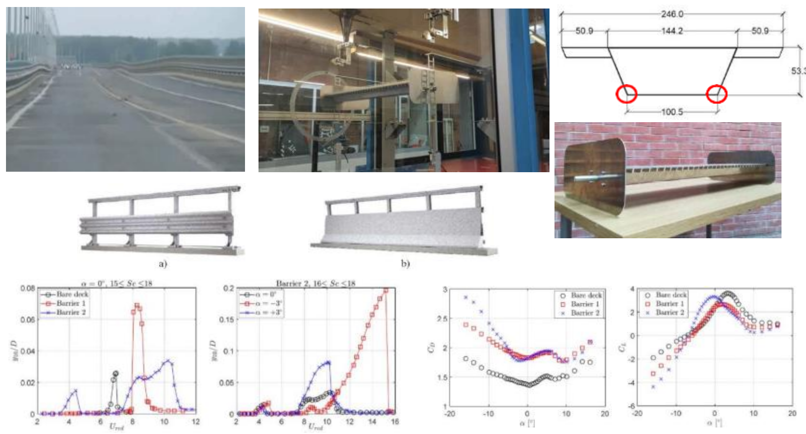
VIV-Galloping Interference

200-m steel arches EXPO 2015



VIV of Bridge Decks

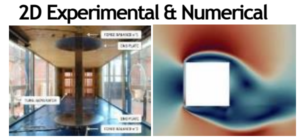


- Effects of cross-section details (section geometry, lateral barriers or screens) and flow angle of attack on bridge decks response to VIV .
- Simplified modeling for evaluation of bridge decks peak response amplitude.

Permeable Building Envelopes

Permeable Building Envelope (PBE)

2D Experimental & Numerical



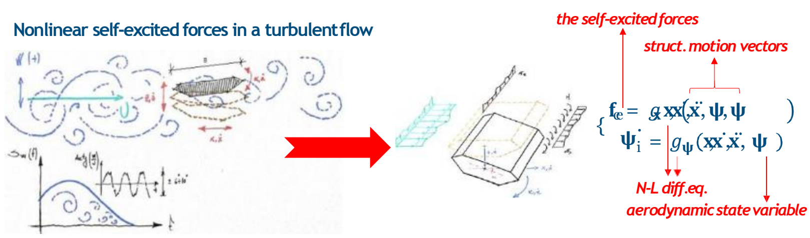
3D Experimental

- Aerodynamic Effects on the overall system "building + PBE"
- Wind loads on screen attached at a small distance
- Porous screens / Airtight Screens with specific openings
- Multi-scale problem

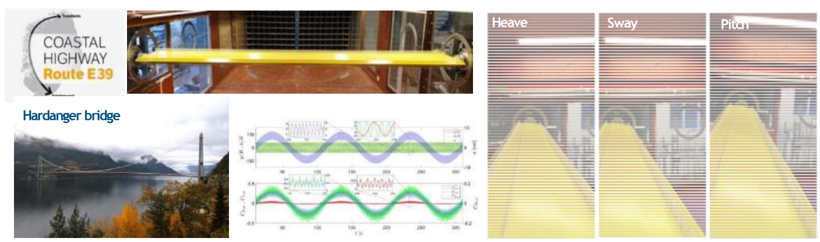
After a PhD thesis concluded in 2017, an Research Competition Award, a PhD student (from December 2019) is working on this topic

Buffeting response of Long-span

Nonlinear self-excited forces in a turbulent flow



Nonlinear self-exited forces evaluation in a turbulent flow using a nonlinear state-space model framework



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VIV-Galloping Interference

4A.M. Marra, C. Mannini, G. Bartoli. *Modeling of vortex-induced vibrations of an elongated rectangular cylinder through wake-oscillator models*. Proceedings of 7th European and African Conference on Wind Engineering, Liège, Belgium, **2017**.
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VIV on bridge decks

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Permeable building envelopes

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9N. Barni, O. Øiseth, C. Mannini. *A new time-variant formulation of self-excited forces in a turbulent flow*, BBAAX, Birmingham, **2020**. *(submitted)*

Buff. resp. of L-S bridges

Research group info

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Keywords:	1. Validation of LES as a design tool 2. Synthetic inflow condition generation 3. Porous bluff bodies aerodynamics 4. Buffeting analysis 5. Calculation of Equivalent Static Wind Loads 6. Bluff Body Aerodynamics (CFD)
Members:	Stefano de Miranda, Luca Patruno, Mao Xu, Jin Xing

Validation of LES as a design tool

Overview

The use of CFD techniques for the calculation of wind loads on structures is becoming increasingly popular. Despite the good results already presented in the literature, it is important to keep investigating how traditional methods compare to CFD evaluations.

Open problems

The accuracy of CFD simulations is not only related to the particular case but it is also related to the considered quantity (e.g. mean pressure, spectra, peaks). Each application would thus require a separate validation. Summarizing, first and second order pressure statistics are only the tip of the iceberg.

Research group contribution

Comparison between wind tunnel and LES taking into account:

- pressure statistics
- design envelopes in terms of internal actions in the structural elements

on a low-rise building [1] and a high-rise building [2].

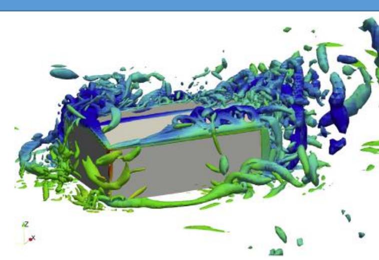

Fig. 1: Example of flow field around a low-rise building calculated with LES.

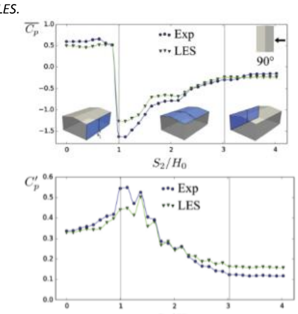

Fig. 2: Comparison between wind tunnel and LES statistics of the pressure field.

Synthetic inflow condition generation

Overview
A prerequisite to obtain accurate CFD simulations for wind loading is to generate appropriate inflows.

Open problems
Numerous methods have been proposed in the literature in order to generate inflow conditions for LES. Precursor simulations are not optimal (it is unlikely that they will be the accepted solution in the long run). Synthetic turbulence generation methods often need *a posteriori* calibration in order to obtain good results and lead to pressure fluctuations at the inflow patch.

Research group contribution
The authors first tackled the generation of synthetic turbulence proposing a new generation method called PRFG^3 which is div-free, respects Taylor assumption and allows to control 3 turbulence intensity as well as 9 length scales [3]. You can download it at https://site.unibo.it/cwe-lamc/en/downloads.
We also developed an inflow correction method, VBIC, which allows to avoid the insurgence of pressure fluctuations [4] (soon available on our website).

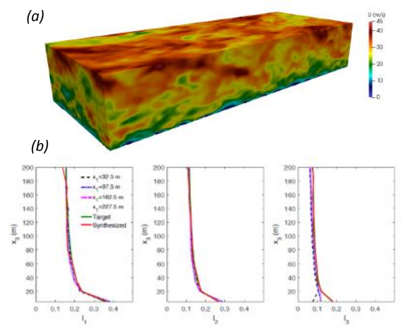

Fig. 3: Example of ABL flow generated with PRFG^3*: (a) instantaneous velocity magnitude and (b) turbulence intensity profiles.*

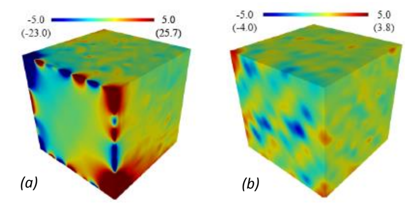

Fig. 4: Pressure fluctuations at the inflow patch: (a) no corrections, (b) VBIC corrections. Notice that extreme values are reported in parenthesis.

Porous bluff bodies aerodynamics

Overview
In applications it is sometimes found that building surfaces are made out of porous screens. Currently, the aerodynamic behaviour of porous bluff body has been almost ignored in the literature.

Open problems
Firstly we need to increase our understanding of the main phenomena which govern the aerodynamic behaviour of porous bluff bodies (e.g. recurrent flow patterns, main parameters and mechanisms affecting the flow, scaling rules). Then, based on such knowledge, we need to investigate how CFD analysis can be used to study them. The “brutal force” simulation usually leads to impossibly high computational costs.

Research group contribution
Currently making research on a parallelepiped characterized by porous facades. Comparing wind tunnel tests and LES. Investigating in detail the mechanisms responsible for the pressure jump through porous screens.

Fig. 5: Parallelepiped characterized by porous facades (collaboration with Tamkang University).

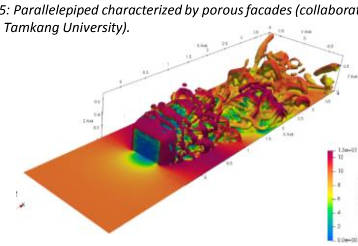

Fig. 6: LES of the porous parallelepiped in smooth flow conditions.

Buffeting analysis

Overview

From the theoretical point of view, linear buffeting analyses are well established but, in practice, still present critical aspects.

Open problems

The calculation of the structural response involves cumbersome data exchange between the designer and wind engineers. Additionally, using only structural modes to build Reduced Order Models (ROM) can sometimes lead to inaccurate results when static and quasi-static contributions are dominant and do not "project well" on the considered modes.

Research group contribution

We developed the concept of Proper Skin Modes (PSMs) which allow to build ROMs for buffeting analyses in an inexpensive and convenient way [5,6]. PSMs can be seen as a modal approach to influence coefficients or, alternatively, to a simplified approach to calculate POD. The use of PSMs greatly simplifies the calculation of the buffeting response form the operational point of view.

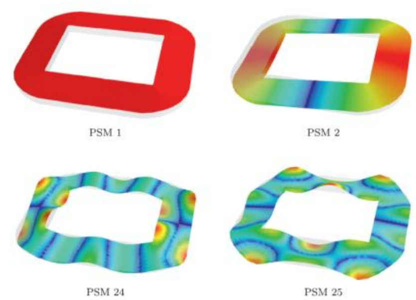

Fig. 7: Overview of the PSM calculated for the suspended roof of the Juventus Stadium.

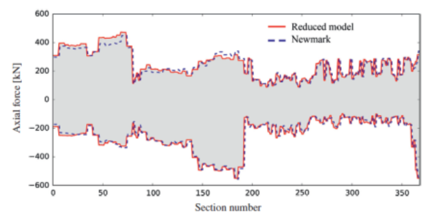

Fig. 8: Comparison between our ROM and complete model in terms of design envelop of axial forces in the structural members.

Calculation of Equivalent Static Wind Loads

Overview

Usually structural engineers require to provide Equivalent Static Wind Loads (ESWLs). The automatic identification of ESWLs is thus a problem of remarkable practical importance.

Open problems

We would like to have an efficient univocal procedure (which does not depend on the structure typology) which does not rely on engineering judgment (we always need it but it should not be an essential ingredient in the methodology!).

Research group contribution

We developed a new methodology for the extraction of ESWLs able to easily account for static, quasi-static and resonant contributions. The procedure allows to select an arbitrary number of ESWLs which, once enveloped, reconstruct the design values. The procedure can be modified in order to avoid underestimations and take into account the contemporaneity between effects [7]. It has been also shown that the procedure can be seen as a simple neural network [8].

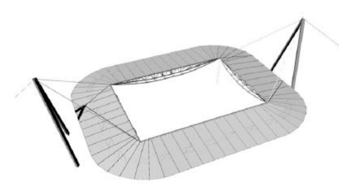

Fig. 9: Overview of the suspended roof of the Juventus Stadium.

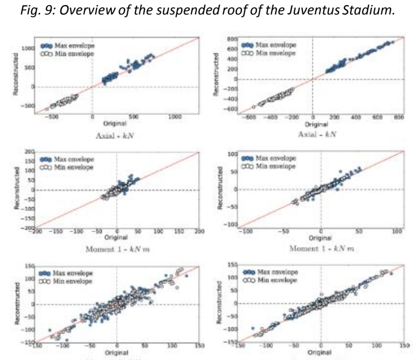

Fig. 10: Scatter plot of extremes from dynamic analyses and ESWLs: left column are 3 ESWLs and right column are 6 ESWLs.

Bluff Body Aerodynamics (CFD)

Overview

Bluff Body Aerodynamics is a classical topic in Wind Engineering. Many advanced and detailed analyses have ben performed but the topic complexity is still high and a unifying work would be need. We do not even know if this is actually possible…

Open problems

In recent years CFD allowed to study the flow around bluff bodies with unprecedented level of detail. This produced (and it is still producing) a great number of publications describing such flows in detail (e.g. BARC). How do we use such knowledge to build simplified models? How do we use in practice such knowledge to build better CFD models?

Research group contribution

We performed many analyses involving bluff bodies in static and dynamic conditions using RANS as well as LES and comparing the obtained results with experimental datasets. Particular attention has been paid to the rectangle 1:5 at non-null attack angle [9] and with turbulent inflow conditions [10].

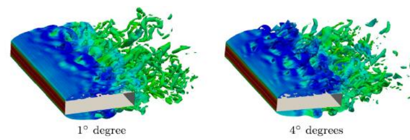

Fig. 9: Rectangle 1:5 at non-null angle of attack.

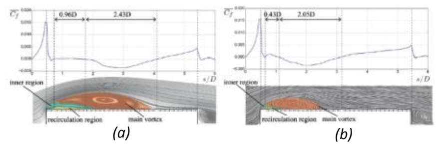

Fig. 10: Flow around a 5:1 rectangle with two different turbulence intensities: (a) I=2.9% and (b) I=13.6% .

Fig. 11: Example of flow field in the proximity of a twin-box deck with large gap.

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6) Equivalent Static Wind Loads: recent developments and analysis of a suspended roof. L. Patruno, M. Ricci, S. de Miranda, F. Ubertini. Engineering Structures, 148, 1–10, 2017.
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9) Numerical simulation of a 5:1 rectangular cylinder at non-null angle of attack. L. Patruno, M. Ricci, S. de Miranda, F. Ubertini. *Journal of Wind Engineering and Industrial Aerodynamics*, 151, 146–157, 2016.
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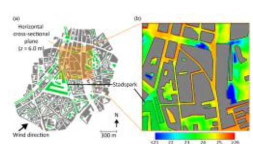
Members (#31):	*Group chairman*: B. Blocken; *Assistant professors & PostDoc*: T. van Hooff, M. Hamid, A. Ricci, S. Gillmeier, R. Rezaeiha, Y. Du; *PhD students*: K. Kosutova, R. Vasaturo, S. Iousef, F. Geng, O. Palusci, F. Malizia, N. Antoniou, J.H. Thysen, A. Moediartianto, A. Giacomo, T. Van Druenen, X. Zheng, R. Vervoort, C. Alanis Ruiz, G. Fernandes, L. Xia, Y.H.Juan, M. Sudirman, P. Qin, A. Krishnan, M. Lei, J. Žužul, S. Sahebzadeh

Synoptic winds modeling

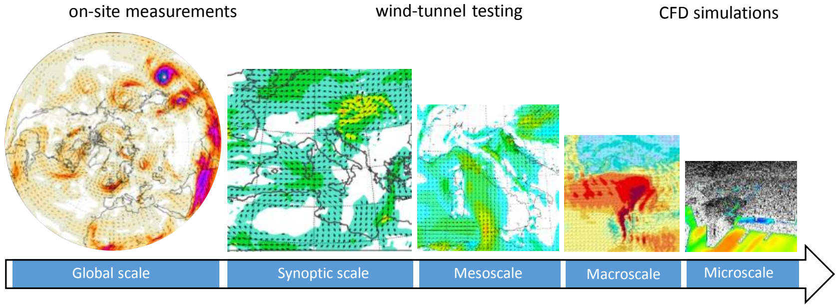
On-site measurements, wind-tunnel testing and Computational Fluid Dynamics (CFD) are used to model "synoptic winds" for various wind engineering applications (e.g. pedestrian wind and thermal comfort) [1-2]

on-site measurements

wind-tunnel testing



CFD simulations



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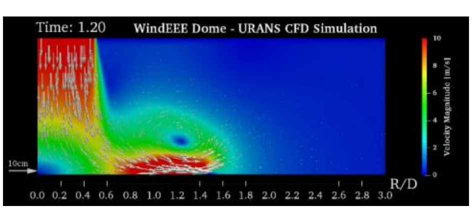
Non-synoptic winds modeling

Extreme winds, as downbursts, are reproduced by CFD simulations using the impinging jet approach [1]

Numerical results are validated with experimental data of downburst winds simulated in the WindEEE Dome Research Institute of the Western Ontario University (London, Canada) [2]

A cross-validation of experimental and numerical results will be carried out using on-site measurements detected by a scanner LiDAR



Picture credit to Žužul et al. (2019)


Picture credit to Romanić et al., 2019

References

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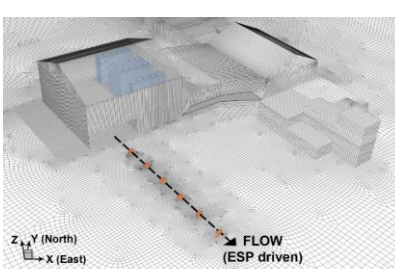
Pollutant dispersion

Generation of a validated modeling procedure for assessment of local PM mitigation strategies in the built environment and characterization of potential PM concentration reductions [1]

On-site measurements, 3D steady RANS simulations [1], large-eddy simulations (LES) and the transport-based recurrence CFD (rCFD) [2] are used



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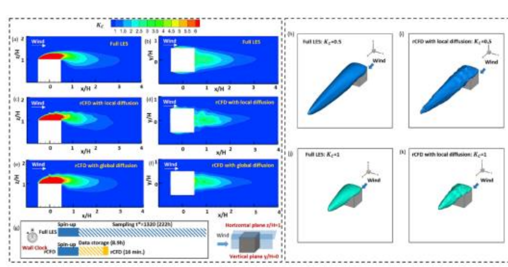

Picture credit to Du et al. (2020)

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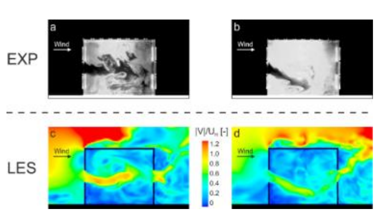
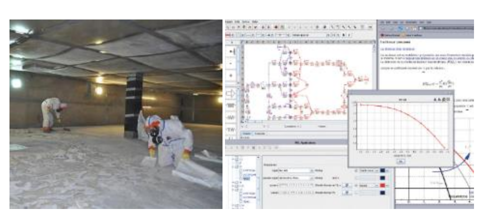
Indoor/outdoor ventilation

Increase knowledge on building ventilation flows and associated heat and mass-transfer processes with the aim to reduce energy use and increase the indoor environmental quality [1]

To investigate and quantify the effect of meteorological conditions on the performance of mechanical ventilation systems in asbestos removal worksites by predicting the internal-external pressure differences as a function of wind [2]



Picture credit to van Hooff et al. (2017)


Picture credit to Krishnan et al. (2019)

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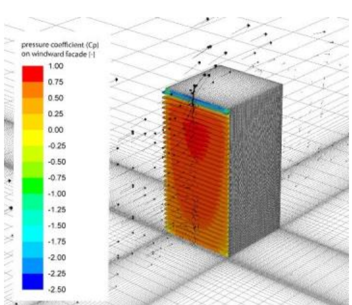
Building aerodynamics

Pressure coefficients and wind loads on low and high-rise buildings are analyzed under different atmospheric conditions through experimental (wind tunnel testing) and numerical (CFD simulations) techniques in order to optimize their aerodynamic performance [1-2]



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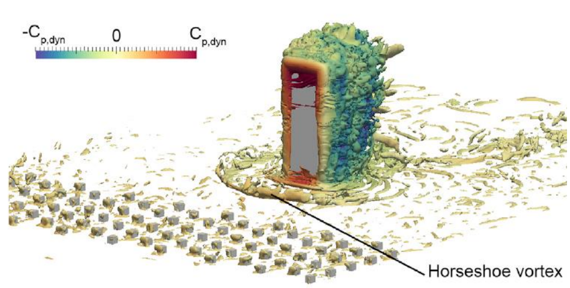

Picture credit to Ricci et al. (2018)

References

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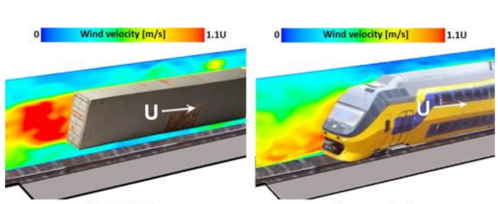
Vehicle aerodynamics

Train can cause pedestrian wind discomfort or danger at the platforms as trains will be allowed to pass small railway stations at high speeds up to 140 km/h. These effects can be evaluated using LES simulations in order to improve the pedestrian comfort [1].

Vehicle-induced turbulence can largely affect the pollutant dispersion in urban areas under low-wind speed and cannot be neglected. The pollutant dispersion, affected by static and dynamic vehicles, in urban areas can be very different.



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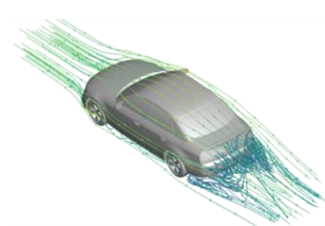

Picture credit to P. Qin

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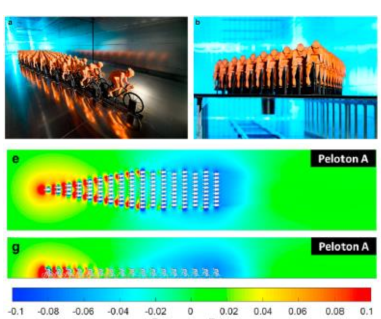
Sport aerodynamics

Wind-tunnel testing and CFD simulations can be of great help in improving the aerodynamic performance of able-bodied athletes as well as para athletes [1-2].

Inside a tightly packed peloton with multiple rows of riders providing shelter, larger drag reductions can be expected [1].



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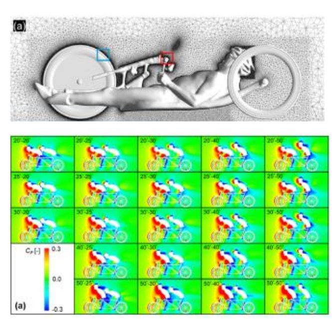

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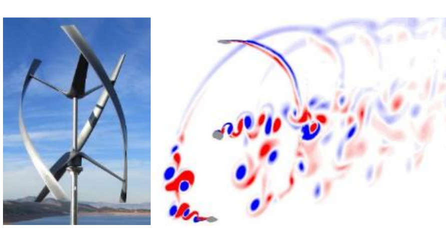
Wind energy

To improve the aerodynamic performance of vertical axis wind turbines using active and passive flow control devices [1-2].

To provide fundamental knowledge on aerodynamics, power performance and wake interactions of an array of VAWTs placed in close proximity.

To explore possibilities for layout optimization and wind farm design for roof-mounted VAWT farms.



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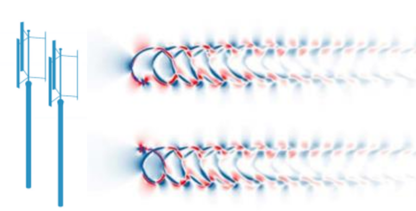

Picture credit to S. Sahebzadeh

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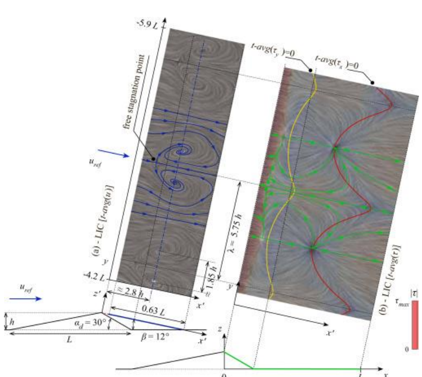
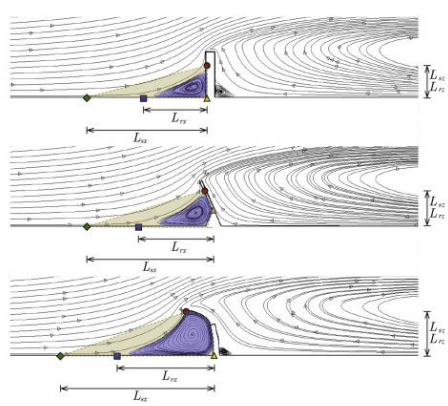
Keywords:	• Bluff-body aerodynamics • Multiphase flows • Windblown sand action • Design and performance assessment of sand mitigation measures
Members:	Luca Bruno, Nicolas Coste, Marko Horvat, Sami Khris, Andrea Lo Giudice, Roberto Nuca, Luigi Preziosi, Lorenzo Raffaele

Bluff-body aerodynamics

Computational studies aimed at investigating bluff body aerodynamics problems characterized by separation, reversed flow and reattachment. Recent studies comprehend sand transverse dune aerodynamics [1] and the aerodynamic behavior of Sand Mitigation Measure [2].



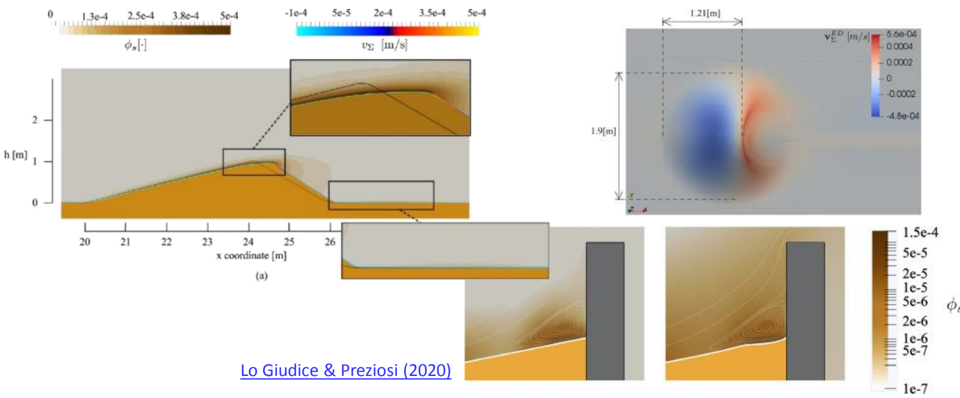
Bruno & Fransos (2015)



Bruno et al. (2018)

Multiphase flows

Development and validation of a multiphase first order model to couple wind flow aerodynamics, windblown sand erosion, transport, sedimentation and resulting morphodynamic evolution of the sand bed [3,4]. Recent studies comprehend the simulation of motion of a 2D transverse dune, the morphodynamics evolution of a sand pile, and sand erosion around non-erodible obstacles [4].

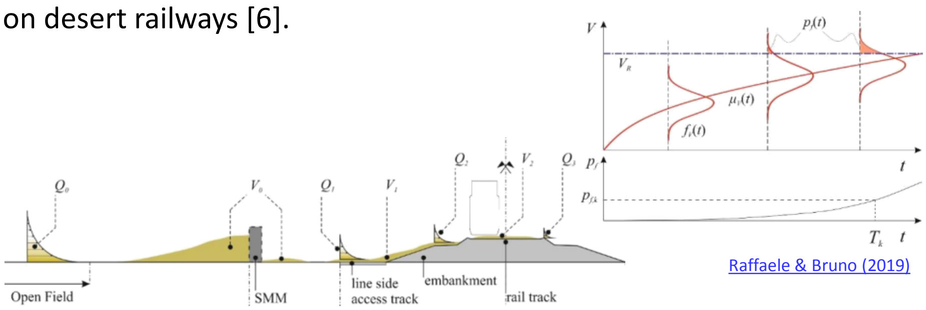


Lo Giudice & Preziosi (2020)

Windblown sand action

Windblown sand is modelled as an environmental action that results from the interaction between wind and sand, in analogy to snowdrift. As an environmental action, windblown sand is intrinsically affected by inborn uncertainties, so that its probabilistic modelling is mandatory.

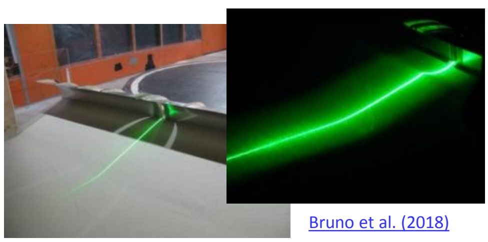
Recent studies include the probabilistic modelling of sand grain features such as particle threshold velocity and sedimentation velocity [5], and the probabilistic modelling of windblown sand action on desert railways [6].



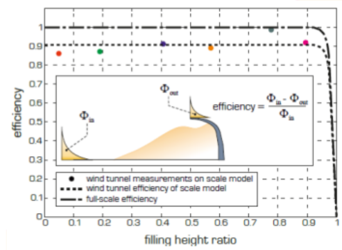
Raffaele & Bruno (2019)

Design and Performance assessment of SMM

To reduce windblown sand effects, a number of so-called windblown Sand Mitigation Measures (SMM) have been proposed in the last decade, mostly inspired by a trial-and-error empirical approach. SMM generally aim at avoiding sand sedimentation on the protected infrastructure. However, the systematic and comprehensive guidelines for the design, analysis, and performance assessment of SMM are still missing in both literature and standards. Recent studies comprehend the wind tunnel performance assessment [7] and the aerodynamic shape optimization [8] of a patented SMM.



Bruno et al. (2018)



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Research group info

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Keywords:	• Full-scale monitoring of suspension bridges • Bridge decks aerodynamics • Wind conditions in complex terrains • Remote sensing of wind
Members:	Jasna Bogunović Jakobsen (1), Jónas Snæbjörnsson (1,2), Etienne Cheynet (3), Ibuki Kusano (1), Nicolò Daniotti (1), Bernardo Morais da Costa (1,4), Jungao Wang (4,1)

Full-scale monitoring of suspension bridges

The Lysefjord Bridge is a full-scale outdoor laboratory. It is instrumented with a Wind and Structural health monitoring system since 2013: Nine 3D sonic anemometers, Four couples of tri-axial accelerometers and one real-time kinematic GNSS system. Since 2018, a cable-stayed bridge, named Bybrua, has been instrumented by UiS to study the wind-induced cable vibrations.

- Automated operational Modal Analysis based on ambient vibrations data from the bridge
- Cable vibrations [1]
- Estimating structural damping of wind-sensitive structures
- Validating the buffeting theory for long-span bridges [2]
- Modelling traffic-induced vibrations
- Utilizing GNSS sensors to monitor wind-induced vibrations (ongoing)

Bridge deck aerodynamics

Atmospheric measurements, Lidar technology and wind-induced surface pressures are utilized to study the deck-flow interaction and improve the wind load modelling.

- Assessing the uncertainties involved in the atmospheric turbulence measurements [3]
- Deck-induced flow distortion [3]
- Sectional buffeting load mechanism based on atmospheric measurements and wind-induced surface pressures (ongoing)
- Flow downstream of a suspension bridge deck [4]
- Span-wise coherence of the aerodynamic forces
- Aerodynamic admittance functions (ongoing)
- Bridge deck aerodynamic and shape optimization
- Wind effects on a bridge deck for non-zero yaw angles (ongoing)

Wind conditions in complex terrain

Mean wind characteristics and the structure of turbulence have been studied using data from sonic anemometers mounted on suspension bridge and met-masts both on- and offshore.

- Assessment of the wind conditions in Norwegian fjords [5]
- Coupled wind and wave-induced response of a 3-km floating suspension bridge
- One-point spectrum and vertical coherence in marine atmospheric boundary layer (FINO1) [6]
- Combined full-scale and numerical study of the Influence of the local topography of the flow conditions recorded on a suspension Bridge (ongoing)

Remote sensing of wind

Doppler wind Lidar technology is utilized for wind engineering application, e.g. atmospheric turbulence characterisation and wind load modelling.

- COTUR: Studying turbulence and horizontal coherence of offshore atmospheric turbulence using three long-range pulsed scanning wind Lidars, one lidar wind profiler and one passive microwave radiometer (ongoing)
- Assessing the capabilities of synchronized long-range pulsed scanning wind Lidars in measuring the 1 and 2-point statistics of atmospheric turbulence in complex terrain [7]
- Measuring lateral coherence of along-wind and across-wind turbulence components using short-range dual-Doppler lidars instruments [8]

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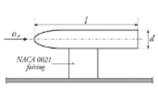
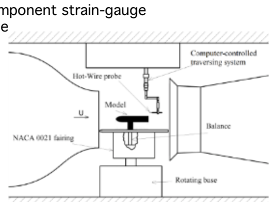
Keywords:	• Experimental and numerical study of separated flows • Transverse grooves to delay flow separation • BARC: accuracy of LES through stochastic sensitivity analysis • BARC: effect of upstream-corner roundings • Uncertainty quantification and stochastic sensitivity analysis • Wavelet and Hilbert time-frequency analysis • Wind turbines: modeling and simulations - - - - - - - other research topics @FluidDynamicsLab UniPI - - - - - - - • Micro-mixers and micro-reactors (exp/num) • Hemodynamics: in-vivo exp, in-vitro exp, simulations and UQ • Cavitation and Internal Injector Flows
Members:	Alessandro Mariotti, Benedetto Rocchio, Alessandro Anderlini, Elena Pasqualetto

Experimental and numerical study of separated flows

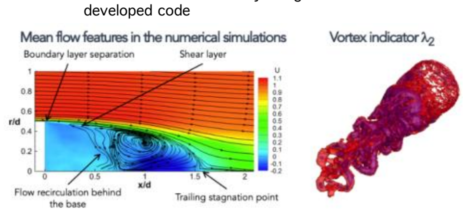
Synergic use of wind tunnel tests and high-fidelity simulations: **axisymmetric blunt-based body**

Subsonic wind tunnel @ UniPI
(closed circuit, open test section):
- differential pressures
- hot-wire velocity measurements
- six-component strain-gauge balance

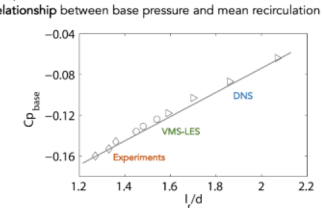




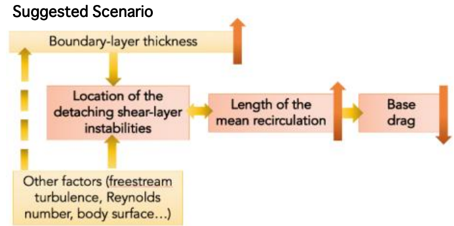
High-fidelity simulations: VMS-LES simulations carried out by using an in-house developed code



Experimental, VMS-LES and DNS data all show the **same linear relationship** between base pressure and mean recirculation length



Suggested Scenario



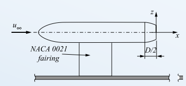
Transverse grooves to delay flow separation

Classical boat tailing: strategy to reduce the drag of bluff bodies **consisting in a gradual reduction** in the cross-section upstream of the base

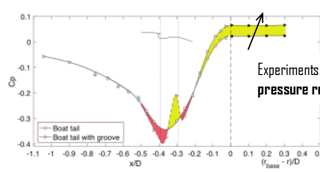
The pressure recovery increases by increasing β, **but** the boat tail is **effective** as long as the **flow remains flow remains almost attached up to attached up to the base**

Subsonic wind tunnel @ UniPI (closed circuit, open test section):

- differential pressures
- hot-wire velocity measurements



Variational MultiScale Large Eddy Simulations carried out by using an in-house developed code

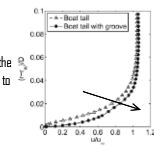


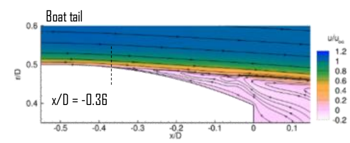
Experiments: **increase in the pressure recovery**

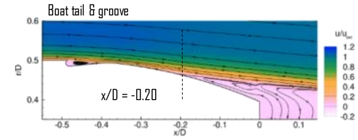
New idea: Transverse groove in the boat tail to delay separation and increase its effectiveness *(Mariotti et al. JFM 2017)*

When the groove is introduced, a **small steady recirculation** forms within the groove

Relaxation of no-slip condition on the streamlines bounding the groove. The boundary layer downstream of the groove has more momentum near the wall and this leads to a **delay of flow separation**





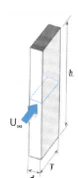


BARC: accuracy of LES through stochastic sensitivity analysis

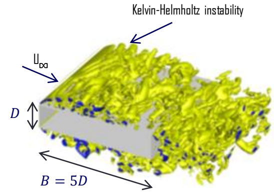
From the real geometry to the rectangular cylinder…

Tall buildings, towers and bridges can be modelled by a rectangular cylinder, which despite the simple geometry contains most of the difficulties found in realistic bluff bodies.

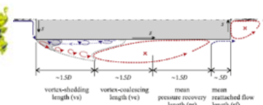
The flow is complex: flow separation at the upstream corners, unsteady reattachment on the cylinder side, vortex shedding from the downstream corners.



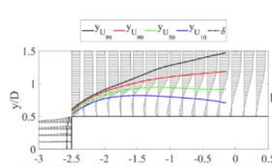
Kelvin-Helmholtz instability



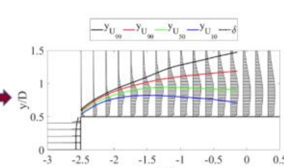
Instantaneous flow



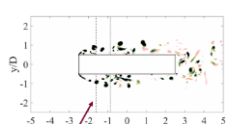
Accuracy and reliability of LES through stochastic sensitivity analysis
(gPC and partial sensitivity)



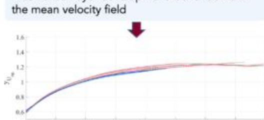
Mean shear-layer development identified from the mean velocity field



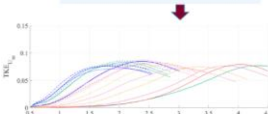
TKE evaluated along the shear-layer



The **peak** of the **TKE** along the shear-layer is located slightly **downstream** of the **shear-layer roll-up**

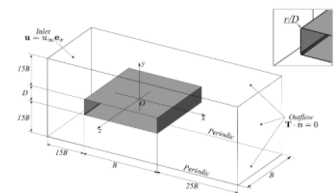


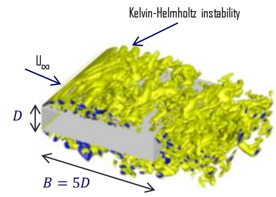
Results for **sharp corners** with different grid resolutions and amounts of SGS dissipation



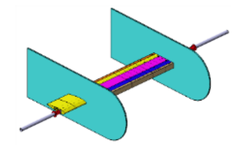
Resolved **TKE grows faster** for those simulations characterized by **more upstream roll-up** of the shear-layer

BARC: effect of upstream-corner roundings





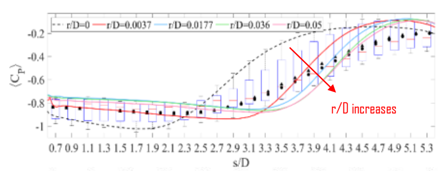
Work in progress: we are currently carrying out wind tunnel tests @ UniPI



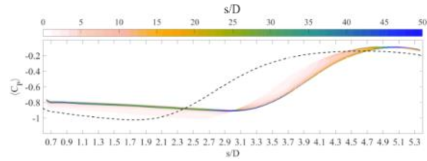
The **rounding of the upstream corners** has a **strong impact** on the length of the mean recirculation region and, thus, on the pressure distribution over the cylinder side

Increasing the curvature radius the length of the mean recirculation region increases

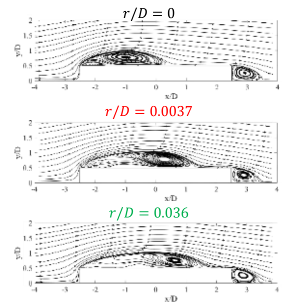
Deterministic results: mean pressure coefficient



PDF of the mean pressure coefficient from the stochastic sensitivity analysis

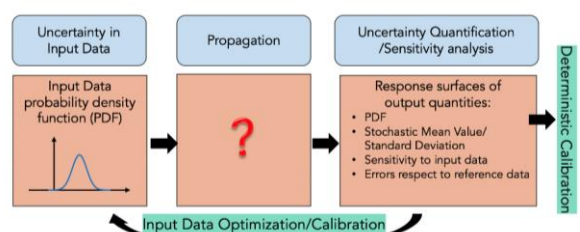


Time-averaged flow



Uncertainty quantification and stochastic sensitivity analysis

The idea is to consider some of the modeling and simulation parameters as **uncertain random variables**, described by a given PDF, and to **propagate** these uncertainties through the computational model to **quantify statistically the variability** of the results.

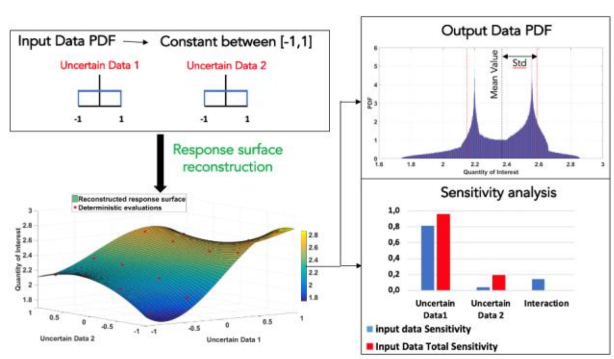


The **key-point** of the methodology is the reconstruction of a **high-quality approximated response surface** of the output quantity of interest quantity of interest in the input parameter space **by using a limited number of deterministic deterministic simulations/experiments simulations/experiments** (surrogate models). (surrogate models).

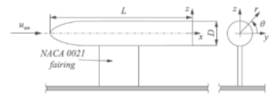
Main techniques:

- generalized Polynomial Chaos
- Stochastic collocation method

Application @ UniPI: BARC flow, Transverse Transverse contoured grooves, wind turbines, hemodynamics, …



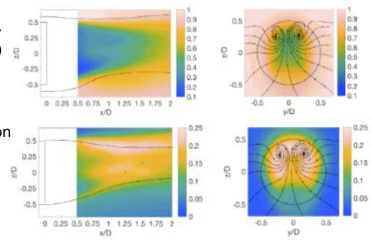
Wavelet and Hilbert time-frequency analysis

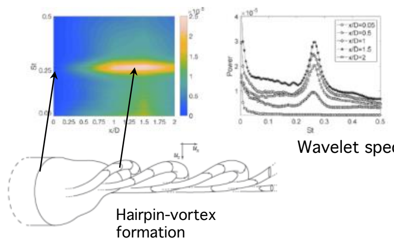


Wind tunnel tests @ UniPI on **axisymmetric blunt-based models**

mean x-velocity fields (hot-wire)

standard deviation of x-velocity

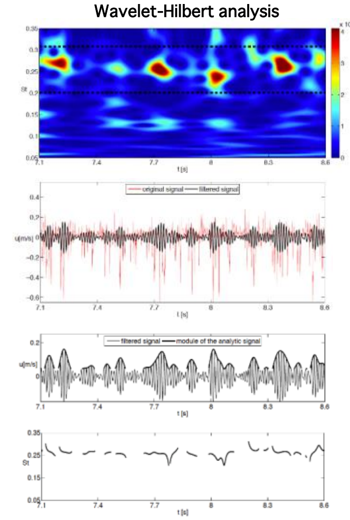




Wavelet spectra

Hairpin-vortex formation

Wavelet-Hilbert analysis

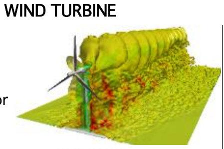


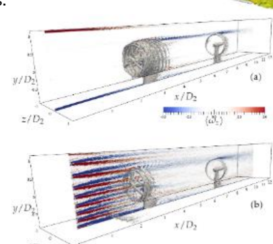
x-velocity signal measured outside the wake edges in the upper side at x/d=2

Wind turbines: modeling and simulations

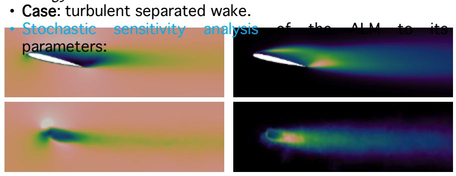
HORIZONTAL AXIS WIND TURBINE

- AIM1: numerical simulation of wind turbines.
- Study of the wake evolution.
- Study of their performances for different turbulent inlet conditions.



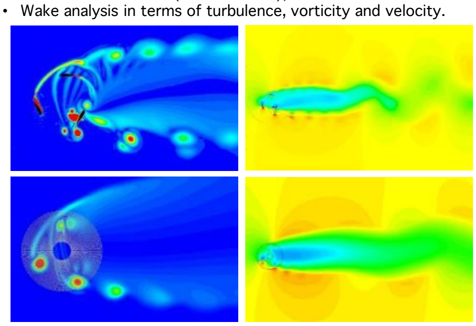


- AIM2: Actuator Line Model. Influence of its parameters on the wake evolution in terms of *velocity field* and *Turbulent Kinetic Energy.*
- **Case**: turbulent separated wake.
- Stochastic sensitivity analysis of the ALM to its parameters:



VERTICAL AXIS WIND/TIDAL TURBINE

- AIM1: development of actuator models (ALM and RACM) for a commercial software (**ANSYS** Fluent);
- Wake analysis in terms of turbulence, vorticity and velocity.



- AIM2: consistent study of the Dynamic stall, a fundamental phenomenon which influences the aerodynamic of VATs;
- Simple "in-house" model for the so-called deep stall condition.

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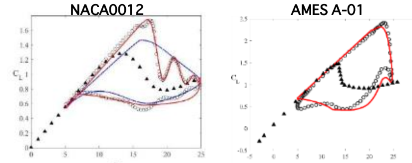
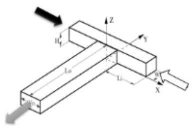
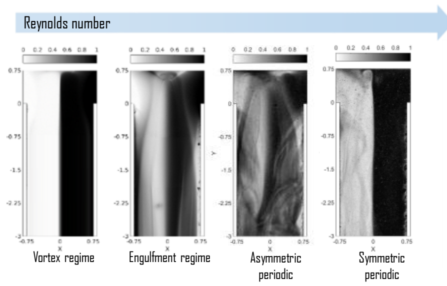
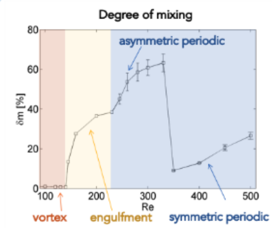


Micro-mixers and micro-reactors (exp/num)

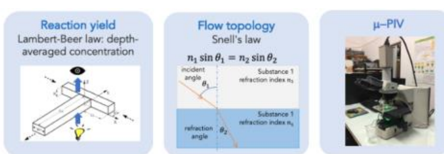


Challenge: **efficient mixing in laminar flows (low Reynolds)** is a fundamental step towards an **efficient reaction**



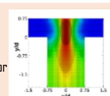


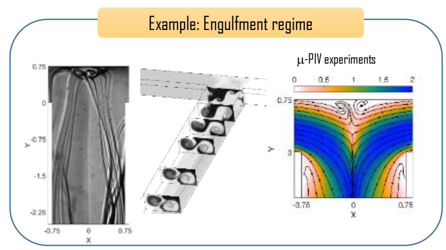
Experimental and numerical set-ups



Numerical simulations:

- Navier-Stokes equations
- transport + reaction equation for

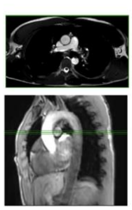


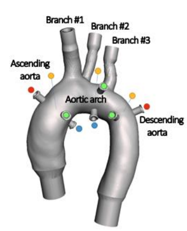


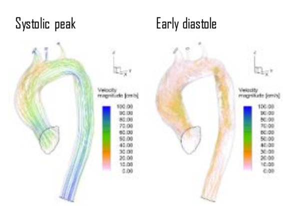
Hemodynamics: *in-vivo* exp, *in-vitro* exp, simulations and UQ

Set-up and validation of a platform which efficiently **integrates simulation models** with ***in-vivo* data**

Predict the hemodynamics in **patient-specific** healthy/pathological cases

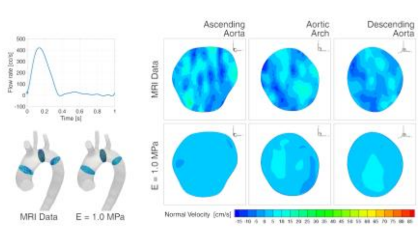






Flow streamlines

Comparison between ***in-vivo* MRI** data and **numerical results**



Circulatory mock loop for *in-vitro* experiments

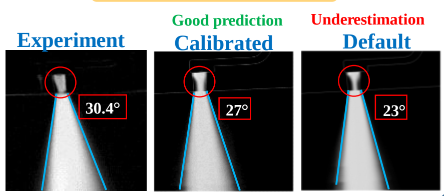
Cavitation and internal injector flows

Vehicles emissions strongly depend on the quality of the combustion, but……

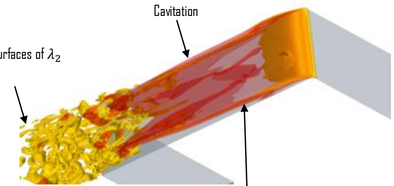
The combustion is, in turn, affected by the spray behaviour exiting the injector, and thus by the characteristics of the **internal injector flow**.

Calibration of modeling parameters through stochastic approach against experimental data

Example: Realistic 3-phase injector flow

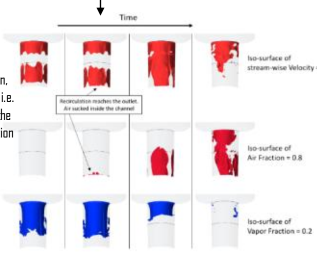


The flow is characterized by geometrical complexity, **high-pressures** (up to 100/1000 bar), flow separation and **turbulence** interacting with **cavitation** in channels of very small size (~100 μm)



Analysis of both liquid-into liquid (2-phase flow) and liquid-into-air (3-phase flow) injections

In 3-phase flow condition, hydraulic flip may occur, i.e. a backflow of air inside the channel replacing cavitation



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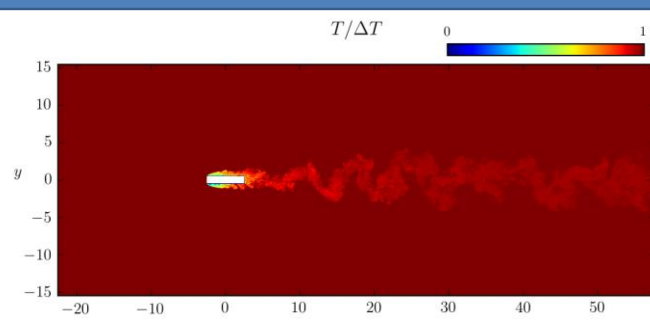
Keywords:	• Direct Numerical Simulation of separating and reattaching flows • Turbulence physics and modelling in separating and reattaching flows • Wind-induced natural ventilation in buildings
Members:	Diego Angeli, Enrico Stalio, Adriano Leonforte, Roberto Corsini, Andrea Fregni, Pietro Cingi, Elisabetta Salerno, Federica Romoli

Direct Numerical Simulation



Experience in developing and setting numerical tools for the Direct Numerical Simulation of bluff bodies with sharp and smooth edges.

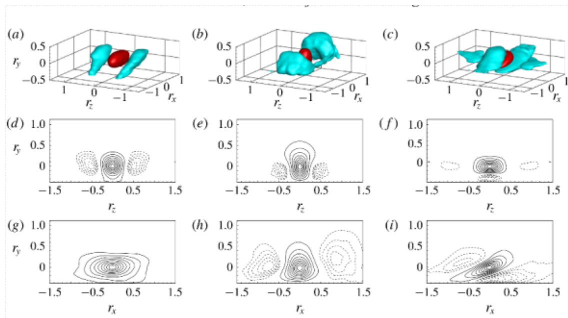
Accurate characterization of

- wind loads;
- heat exchange;
- pollutant dispersion;

Software used:

- OpenFoam (finite volume method)
- NEK5000 (spectral element method)
- Incompact3D (finite differences and immersed boundaries method)

Physics and Modelling

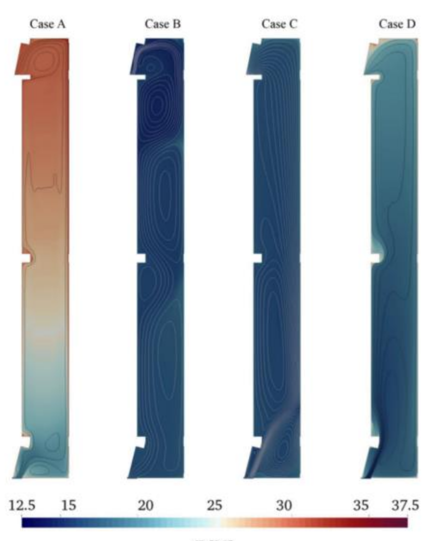


Study of the self-sustaining mechanisms at the basis of the development of velocity, temperature and pressure fluctuations.

Development of a best practice in terms of spatial resolution and turbulence model for the accurate solution of the flow via LES approaches.

Development of alternative turbulence closures both for LES and RANS

Wind-induced natural ventilation



Development of rapid, robust and accurate tools for performance evaluation of naturally ventilated double-skin façade constructions.

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Physics and modelling

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Wind-induced natural ventilation

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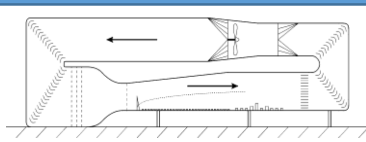
Keywords:	• Atmospheric heavy gas dispersion • Impact of atmospheric ship emissions on urban areas • Flow and dispersion in urban canopy • Atmospheric dispersion models • A Complex Network Perspective for dispersion in the urban canopy • LES for atmospheric dispersion • Analytical dispersion models
Members:	Matteo Bertagni, Sofia Fellini, Jheyson B. Mejia Estrada, Domenico Toscano, Cristina Vidali

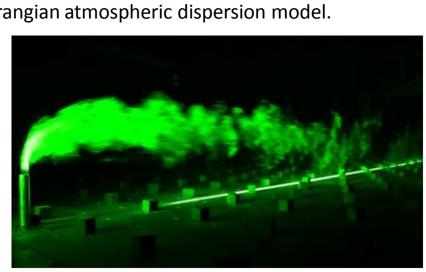
Atmospheric heavy gas dispersion



Atmospheric wind-tunnel of the Laboratoire de Mécanique de Fluide et de Acoustique of the École Centrale de Lyon (France) is a **recirculating** wind-tunnel regulated in temperature (working section: 14m long, 3.7m wide) [1]

In this study [2] we simulate **heavy** and **passive gas** release from an elevated source placed within a turbulent neutral boundary layer, with a mixing of **CO_2, air, ethane**.

We analyse **high order statistics** and **fluctuations** of plume concentration and velocity and to provide experimental evaluation of the **turbulent mass fluxes**. We validate gaussian and lagrangian atmospheric dispersion model.

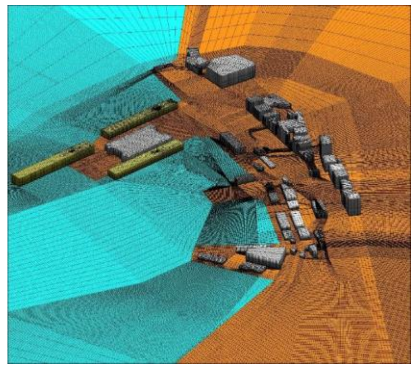


Coupled measurement of velocity and concentration:

- X-Probe **Hot Wire Anemometry**
- **Flame Ionization Detector**

Impact of atmospheric ship emissions on urban areas

Validation of dispersion models and computational fluid dynamics models with wind tunnel measurements [3]



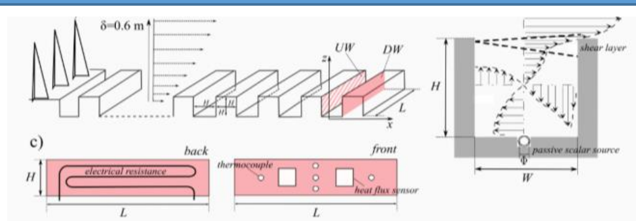
Dipartimento di Ingegneria Chimica, dei Materiali e della Produzione Industriale
Università degli Studi di Napoli Federico II

Laboratorio di Monitoraggio e Modellazione degli Inquinanti in Atmosfera

Laboratoire de Mécanique des Fluies et d'Acoustique

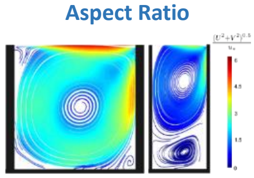
UMR CNRS 5509

Flow and dispersion in urban canopy

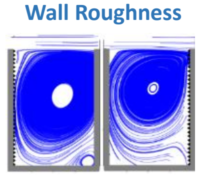


Wind-tunnel experiments to investigate the transport of pollutants in a street canyon [4]. Effects of:

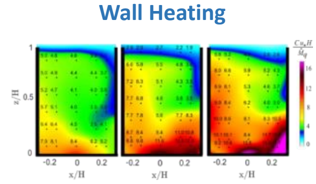
Aspect Ratio



Wall Roughness



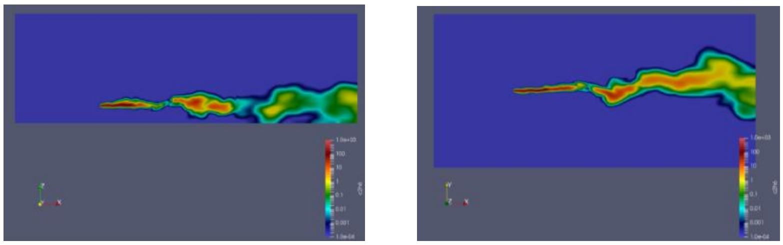
Wall Heating



... Trees (ongoing)

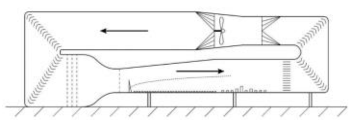
LES for atmospheric dispersion

1. LES simulation of a passive scalar (preliminary results) [5]

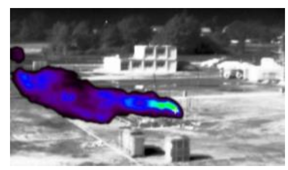


Passive scalar instantaneous field. Vertical plane (left) and horizontal plane (right)

2. Validation of the model thanks to:



Wind tunnel measurements [1]

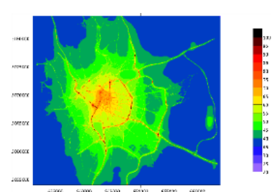


Optical measurements in real scenarios

LMFA TOTAL ÉCOLE CENTRALE LYON

Atmospheric dispersion models

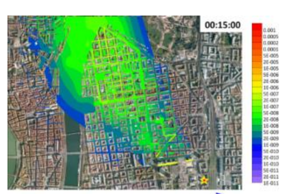
SIRANE
Urban Air Quality Model



SIRANE on Lyon

Urban air quality model, of chronic pollution in urban environment (gaussian plume + urban canopy) [6]

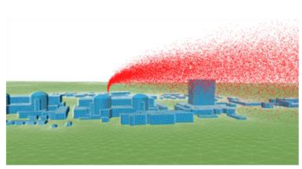
SIRANERISK
Dispersion for NRBC releases in urban area



Logiciel SIRANERISK

Atmospheric pollution model in urban canopy for dangerous substances. Adapted for accident and terrorist risk (puff gaussien + urban canopy)

Safety Atmospheric Lagrangian Model (SLAM)



SLAM software on a nuclear powerplant

Lagrangian particle dispersion model coupled with 3D CFD wind field simulation of pollutant dispersion on industrial sites

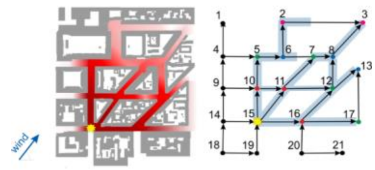
A Complex Network Perspective for dispersion in the urban canopy

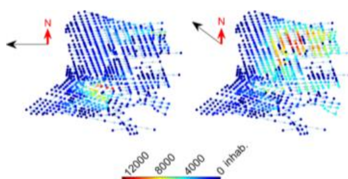
Aim

Models based on **complex network theory** for **rapid prediction** of pollutant dispersion in the urban canopy and for **assessment** of **urban vulnerability** in multiple scenarios.

Methods

Propagation is modelled as a **spreading process on a network**. The vulnerability of a source node is estimated as the extension of its **zone of influence [7].**





Results

Vulnerability maps for different **wind directions** and different **urban topologies.**

What is the the link between **urban vulnerability** and **city plan**?

Analytical dispersion models

Wind turbulence randomly disperses contaminants released into the atmosphere (**Fig.1**), so that, at a fixed location downwind of an emission, the contaminant concentration exhibits a strongly fluctuating dynamics (**Fig.2**). Determining the statistics of these fluctuations is necessary for human-health and environmental risk assessment. Yet, simple relationships are currently limited to the mean value of concentration (Gaussian models), while for higher order statistics demanding numerical simulations are commonly used.

Fig.1

In my research, I provide physically-derived simple relationships for the probability of the peak events (PDF)[8] and their average rate of occurrence (crossing times T)[9].

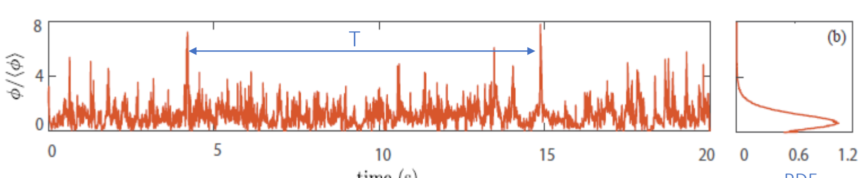


Fig.2

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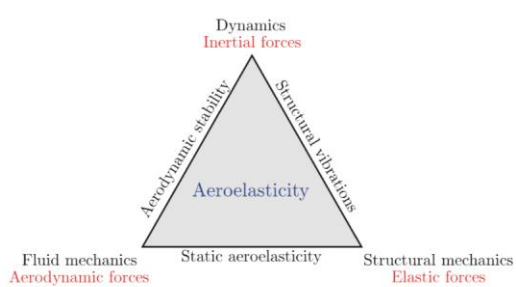
Keywords:	• Cable aeroelastic behavior • Ice accretion effects on the cable aerodynamic stability • Probabilistic assessment of the damping required to cable avoid vibrations • Field observations of wind-induced cable vibrations • Wind profile identification • Combined wind-seismic response of wind turbines • Aerodynamics of cooling towers
Members:	Cooperation with: Francesco Ricciardelli, Alberto Maria Avossa, Christos Georgakis, Holger Koss, Giulia Matteoni, Claudia Roberta Calidonna, Daniel Gullì, Vincenzo Picozzi, Mustafa Vardaroglu, Zhen Sun, XuYong Ying, Cheng XiaoXiang.

Cable aeroelastic behavior

Team: Christos Georgakis, Giulia Matteoni



Equations of motion:

$$\boldsymbol{M}\ddot{\boldsymbol{x}} + \boldsymbol{C}\dot{\boldsymbol{x}} + \boldsymbol{K}\boldsymbol{x} = \boldsymbol{F}_m(U) + \boldsymbol{F}_b(\boldsymbol{U}'(t)) + \boldsymbol{F}_a(\boldsymbol{U}, \dot{\boldsymbol{x}}, \boldsymbol{x}) + \boldsymbol{F}_s(St, Sc)$$

Aeroelastic forces can be considered as an external force depending on some parameters or to be linearized to become a stiffness and damping terms.

$$\boldsymbol{F}_a(\boldsymbol{U}, \dot{\boldsymbol{x}}, \boldsymbol{x}) = \boldsymbol{C}_a(\omega_r)\dot{\boldsymbol{x}} + \boldsymbol{K}_a(\omega_r)\boldsymbol{x}$$

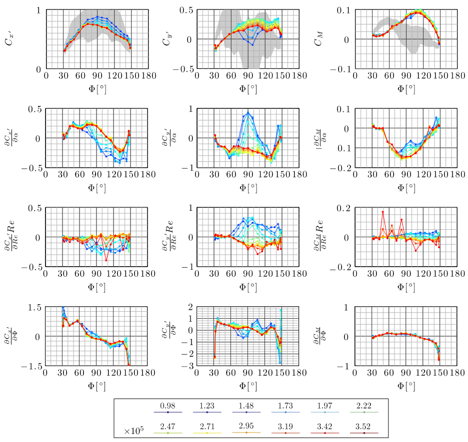
with

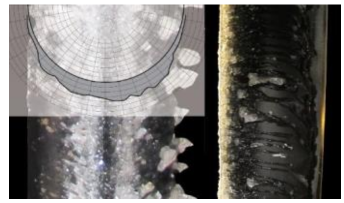
$$\omega_r = \frac{2\pi f_p D}{U}$$

Development of a 3D aeroelastic model.

Ice accretion effects on the cable aerodynamic stability

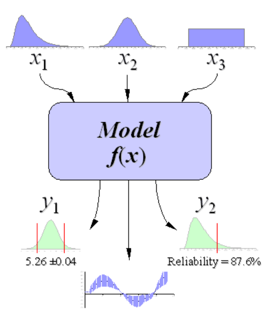
Team: Francesco Ricciardelli, Christos Georgakis, Holger Koss





Probabilistic assessment of the damping required to cable avoid vibrations

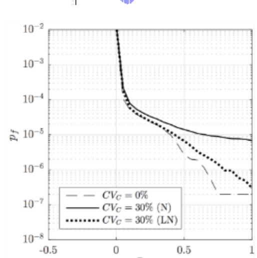
Team: Francesco Ricciardelli



$$\xi_c(\overline{m}, \boxed{f_x}, \boxed{\kappa}, \overline{D_h}, \overline{\rho}, \overline{\nu}, \boxed{\mathbf{C}}(\boxed{U(z_{ref})}, \boxed{\alpha}), \boxed{\alpha_s})$$

$$f_D(\xi_c) = \int_0^{360^\circ}\int_0^{360^\circ}\int_0^{\infty}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}\int_0^{\infty} f_D(\xi_c|\overline{m}, f_x, \kappa, \overline{D_h}, \overline{\rho}, \overline{\nu}, \mathbf{C}(U(z_{ref}), \alpha), \alpha_s)\, \mathrm{d}f_x\, \mathrm{d}\kappa\, \mathrm{d}\mathbf{C}\, \mathrm{d}U(z_{ref})\, \mathrm{d}\alpha\, \mathrm{d}\alpha_s$$

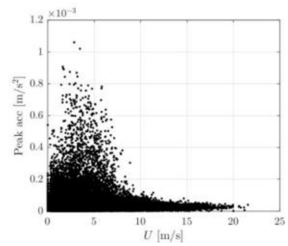
$$p_f = \iint_{C \le D} \boxed{f_C(\xi_s)} \cdot f_D(\xi_c)\mathrm{d}\xi_s\, \mathrm{d}\xi_c$$

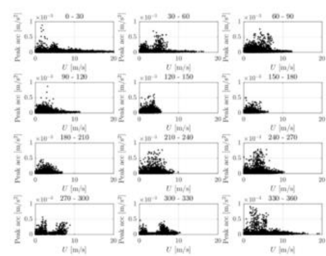


$$f_C(\xi_s) = \begin{cases} N(\bar{\xi}_s, CV_C\bar{\xi}_s) & \textit{Normal distribution} \\ \ln\mathcal{N}(\mu, \sigma) & \textit{Log-normal distribution} \\ \delta(\xi_s - \bar{\xi}_s) & \textit{Deterministic} \end{cases}$$

Field observations of wind-induced cable vibrations

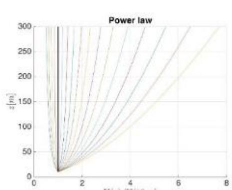
Team: Zhen Sun, XuYong Ying

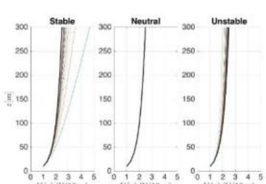


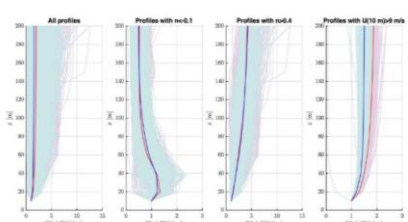


Wind profile identification

Team: Francesco Ricciardelli, Alberto Maria Avossa, Claudia Roberta Calidonna, Daniel Gullì





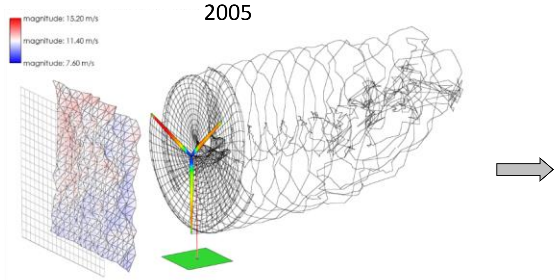


Combined wind-seismic response of wind turbines

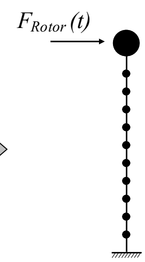
Team: Francesco Ricciardelli, Alberto Maria Avossa, Vincenzo Picozzi, Mustafa Vardaroglu

- The aerodynamic analysis of the rotor, subjected to wind loads, can be carried out in the time-domain through the application of the Blade Element Momentum Theory (FAST).
- The support structure can be modelled within a Structural dedicated FEM computer program (OpenSees).

FAST
Jonkman et al. 2005



OpenSees
Mazzoni et al. 2006



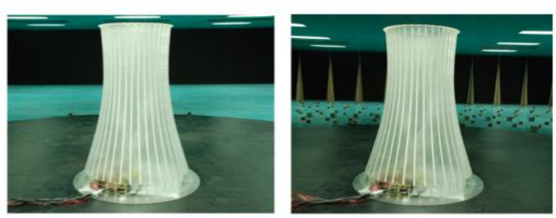
Beam element

Linear elastic behaviour

Time-History Analysis

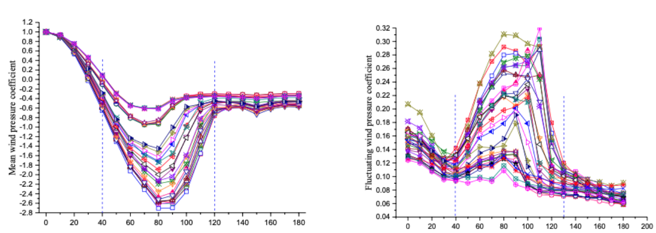
Aerodynamics of cooling towers

Team: Cheng XiaoXiang



(a) (b)

Figure 2. Tower model in two flow fields: (a) uniform flow field and (b) Type B flow field.



(a) Mean wind pressure distribution (b) Fluctuating wind pressure distribution

Fig. 4 Circumferential distributions of the wind pressure coefficient in Type B flow field

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Research group info

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Contact email:	F.Dorigatti@cranfield.ac.uk
Keywords:	• Wind effects on ground vehicles • Wind effects on buildings • Wind effects on helidecks • Sport and bluff-body aerodynamics • Motorsport aerodynamics
Members:	Dr. Francesco Dorigatti, Prof. Kevin Garry, Dr. Simon Prince, Dr. Davide Di Pasquale

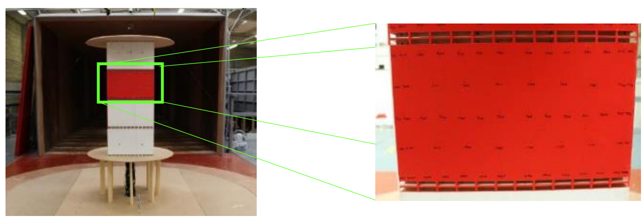
Wind effects on ground vehicles

- **Crosswind effects on trains and road vehicles**
  - Aerodynamic stability of trains: static vs moving model tests [1]
  - Aerodynamic of road vehicles in overtaking maneuvers
  - Aerodynamics of lorries in platoon formation

- **Drag reduction of road vehicles**
  - Shape optimization of cars, light and heavy good vehicles with and without crosswind through wind tunnel tests
- **Aerodynamic stability of high-sided vehicles on bridges**
  - Wind tunnel test of wind barrier for long-span bridges [2] (in conjunction with Polimi)

Wind effects on buildings

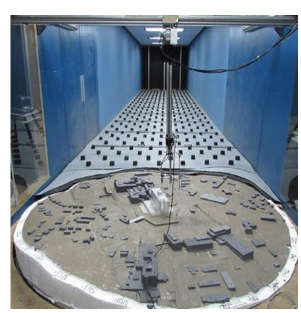
- **Aerodynamic optimization of tall buildings**
  - Mitigation against excessive wind-induced building responses through wind tunnel parametric studies [3] (in conjunction with RWDI)
- **Wind-induced pressures on Double-Skin Façade systems**
  - Experimental analysis of wind-induced pressures on DSFs through large scale sectional model testing [4] (in conjunction with RWDI and University of Genova)



RWDI wind tunnel

Wind effects on helidecks

- **Experimental assessment of wind conditions on helidecks and development of mitigation techniques**
  - Wind assessments and mitigation of helidecks on buildings and in urban areas [5] (in conjunction with RWDI)
  - Wind assessment of helidecks on oil rigs
  - Wind assessment of helidecks on ships

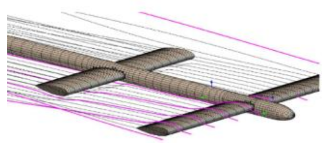


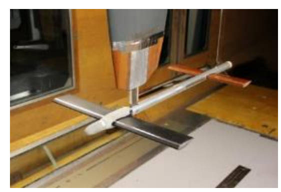
RWDI wind tunnel

Sport and bluff-body aerodynamics

- **Bluff body aerodynamics**
  - Explore the aerodynamic characteristics of flexible kites in relation to wind power generation [6]
  - Aerodynamics of a spinning cylinder [7]

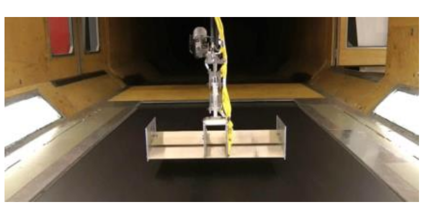
- **Sport Aerodynamics**
  - Analysis of aero-hydrodynamic characteristics of windsurfer foil configurations through wind tunnel tests and CFD





Motorsport aerodynamics

- **Wind tunnel tests and CFD analysis**
  - Wind tunnel performance analysis of race cars [8]
  - Wind tunnel investigation on the flow features in proximity of a race car (pressure rake, HWA, Cobra probe, Stereo-PIV)
  - CFD analysis and benchmarking (RANS, DES)
  - underbody flow optimization [9] (in conjunction with University of Southampton)
  - Aerodynamic optimization of race car wings



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Research group info

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Keywords:	• About RWDI • On-site monitoring • Pedestrian Level Wind • Double Skin Façade • AFAS Stadium Collapse
Members:	Fabio Faseli ,Silvia Giuliarini, Emanuele Mattiello, Edoardo Nicolini, Chiara Pozzuoli.

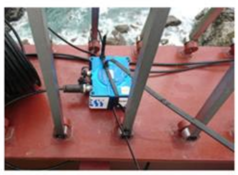
About RWDI

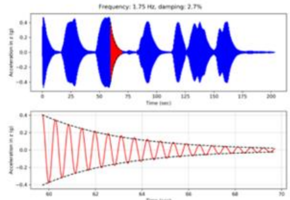
- We define ourselves as specialist consultants, scientists & engineers
- Established in 1972
- Approximately 500+ employees
- World Leader in climate adaptive structures
- Exclusive methods and equipment
- Proven problem solving track record

On-site monitoring

Site measurements

- Ambient vibration measurements
- Forced vibration measurements
- Various pedestrian loading
  - Random crowd walking
  - Group walking
  - Random crowd jogging
  - Group jogging
  - Random jumping



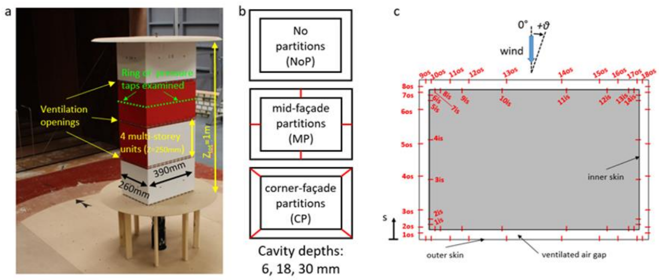


Pedestrian Level Wind

- Desk-based assessment and design review
- CFD/Wind tunnel testing
- Lawson Comfort Criteria
- Wind Mitigation Workshop
- Trees investigation

Key	Comfort Category	Threshold	Description
● (light green)	Sitting	0-4 m/s	Light breezes desired for outdoor restaurants and seating areas where one can read a paper or comfortably sit for long periods
● (blue)	Standing	4-6 m/s	Gentle breezes acceptable for main building entrances, pick-up/drop-off points and bus stops
● (yellow)	Strolling	6-8 m/s	Moderate breezes that would be appropriate for strolling along a city/town street, plaza or park
● (magenta)	Walking	8-10 m/s	Relatively high speeds that can be tolerated if one's objective is to walk, run or cycle without lingering
● (red)	Uncomfortable	>10 m/s	Winds of this magnitude are considered a nuisance for most activities, and wind mitigation is typically recommended

Double Skin Façade



- Scale 1: 50
- Rectangular Section 0.39 x 0.26 **m**
- 466 taps total
- Impermeable IS, glazed OS
- Rectangular openings, 1.5 x 0.4 **m**
- 9 configurations tested

Air cavity depth		Vertical partitions		
Model-scale	Full-scale	No partitions (NoP)	Façade middle (MP)	Façade corners (CP)
6 mm	0.3 m	G6-NoP	G6-MP	G6-CP
18 mm	0.9 m	G18-NoP	G18-MP	G18-CP
30 mm	1.5 m	G30-NoP	G30-MP	G30-CP

AFAS Stadium Collapse

Research group info

Main affiliation:	University of Birmingham
Group website:	https://www.birmingham.ac.uk/research/activity/civil-engineering/wind-engineering-group/index.aspx
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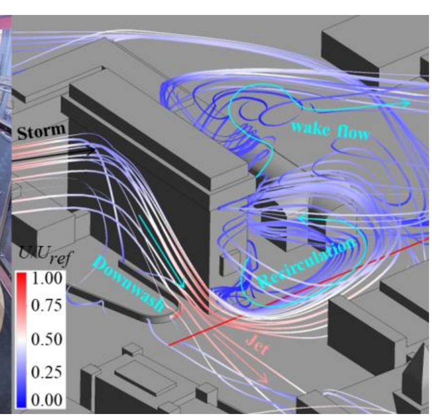
Contact email:	g.vita@bham.ac.uk
Keywords:	• Pedestrian Safety & Urban Winds • Urban Wind Energy • Crop Lodging • Train Aerodynamics • Extreme transient winds • Vehicle aerodynamics & platooning
Members:	Dr Hassan Hemida, Prof Chris Baker, Prof Lambis Baniotopoulos, Prof Mark Sterling, Prof Greg Kopp, Dr David Soper, Dr Mike Jesson, Dr Zhenru Shu

Pedestrian Safety & Urban Winds

CIs: Dr Giulio Vita, Dr Mike Jesson, Dr Hassan Hemida, Prof Chris Baker

The interaction of incoming wind with high-rise buildings can lead to dangerous wind conditions in towns and cities. The Project aims to develop a risk-based framework incorporating wind tunnel modelling, computational fluid dynamics and full-scale tests to improve our understanding of how gusty urban environments affect pedestrians.

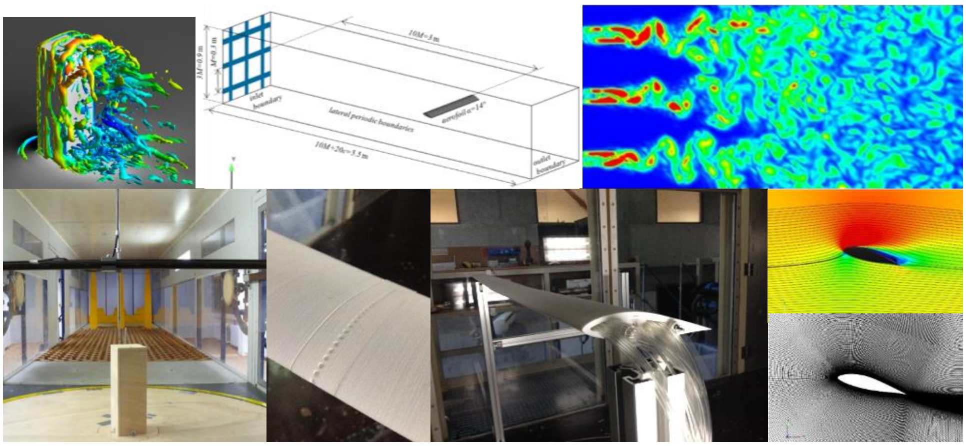




Urban Wind Energy

CIs: Dr Giulio Vita, Dr Hassan Hemida, Prof Lambis Baniotopoulos

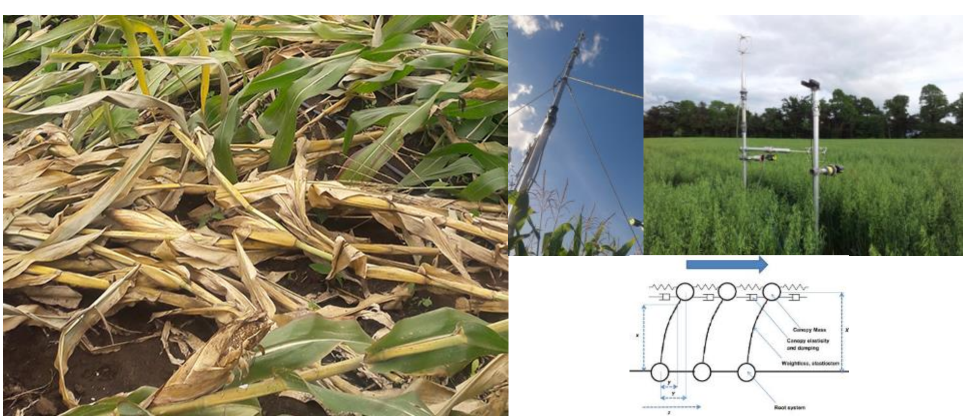
Wind Turbines positioned in the built environment only provide a derisory amount of energy. The effect of a turbulent inflow on aerodynamic performance is normally neglected when designing converters. By providing a suitable atmospheric turbulent inlet in experimental and numerical simulations, this Project aims to shed light on the negligibility of the effects of turbulence and assess the aerodynamic performance of urban wind turbines.



Crop Lodging

CIs: Dr Genora Joseph, Prof Mark Sterling, Prof Chris Baker

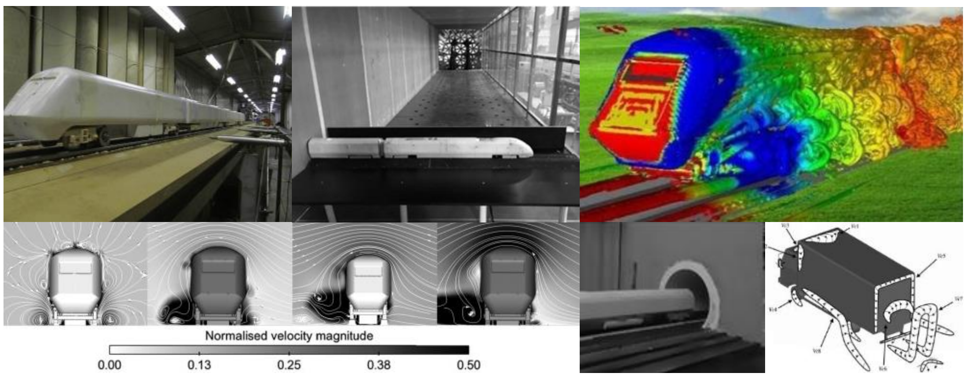
With climate change creating more extreme weather and a growing world population, it is vital that we develop sustainable ways of improving the resilience and productivity of staple crops such as maize and rice. The project adopts a multi-disciplinary approach to problem-solving, involving wind engineers, crop scientists and extension experts in the UK, China and Mexico, helping to address this global challenge to reduce lodging or flattening in maize and rice, which can dramatically reduce crop yields.



Train Aerodynamics

CIs: Dr Hassan Hemida, Dr David Soper, Prof Chris Baker

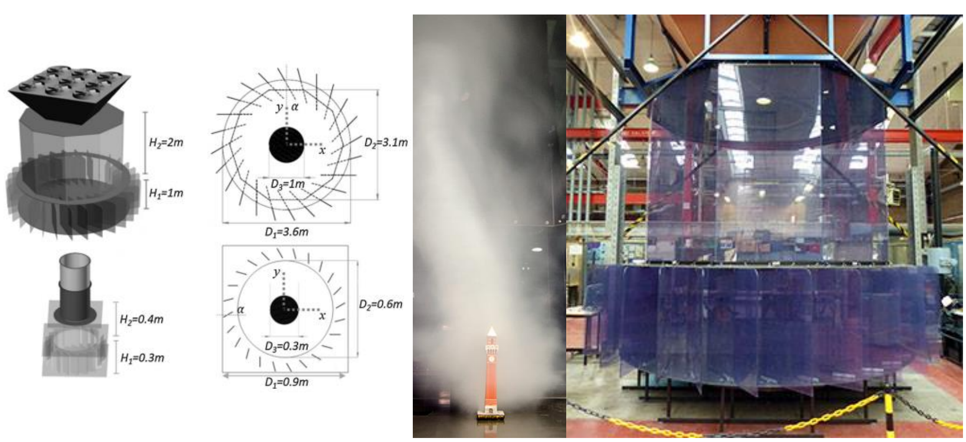
The University of Birmingham is leader in the research on train aerodynamics, with significant results provided to the scientific community over the last 40 years. The TRAINrig facility is one-of-a-kind simulator to test the aerodynamics of trains and vehicles. The group has provided advanced numerical simulations to get insights into the aerodynamic behaviour and advance knowledge to improve the railways industry performance and safety.



Extreme Transient Winds

CIs: Dr Mike Jesson, Prof Chris Baker, Prof Mark Sterling

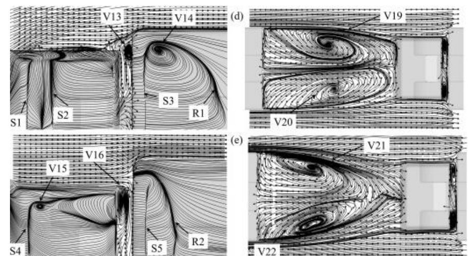
Transient Winds such as Tornadoes and Downbursts are the cause of design load winds in many parts of the world. The difficulties in simulating their flow structure in laboratory, particularly their rapid radial acceleration and associated ring vortices, have complicated measuring wind loads on structures subject to these conditions. The University of Birmingham Transient Wind Simulator is one of few facilities to reproduce such flows.

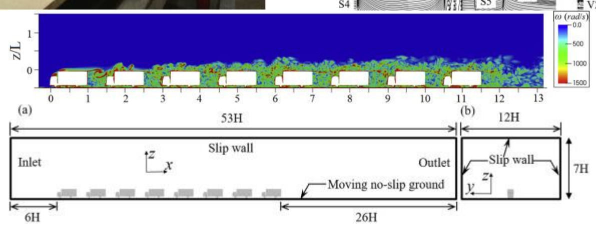


Vehicle aerodynamics & platooning

CIs: Dr Migzhe He, Dr Hassan Hemida, Dr David Soper, Prof Mark Sterling

The concept of autonomous road vehicles has gained a great deal of technical respectability, with expected fuel benefits arising from running vehicles closely in platoons. However, the aerodynamics of such vehicles travelling in close proximity is still not understood. This Project shows the beneficial effect on vehicle drag reduction and assesses the lateral instability risk.





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Keywords:	• Nonlinear parametric modeling of suspension bridges for aeroelastic analysis • Flutter and post-flutter control in suspension bridges • Control of vortex-induced parametric instabilities in suspension bridges
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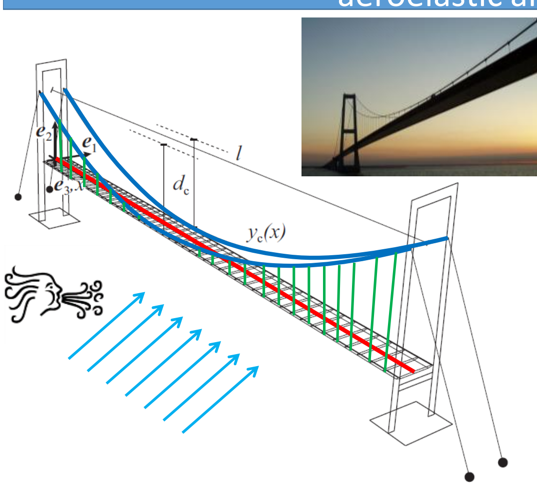
Nonlinear parametric modeling of suspension bridges for aeroelastic analysis



12 kinematic descriptors
(functions of space and time)

$\boldsymbol{u}(x,t)$, $\phi_i(x,t)$ $(i=1,2,3)$
deck dispacements and rotations

$\boldsymbol{v}(x,t)$: cables displacements

Unstretchable hangers

Geometric **nonlinearities**
(elastic constitutive behavior)

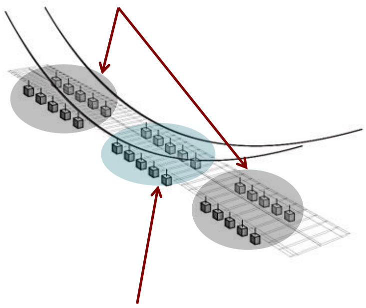
Equations of motions

- Suspension cables (extensible cables)
- Bridge deck (equivalent nonlinear beam)
- Fluid-structure interaction (aerodynamic loads)

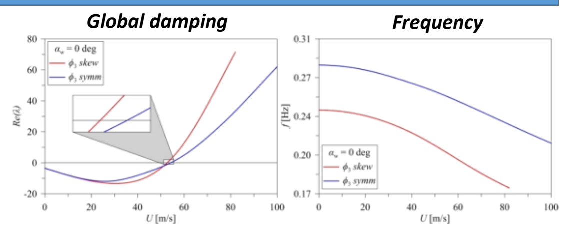
Flutter and post-flutter control in suspension bridges

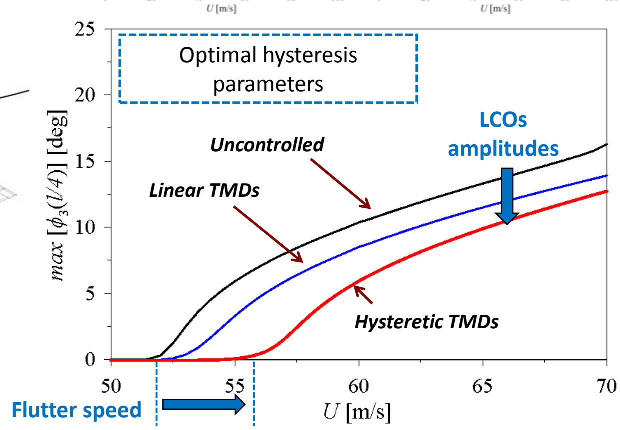
Multi-modal control via arrays of hysteretic TMDs

Clusters of TMDs tuned to the frequency of the skew-symmetric mode



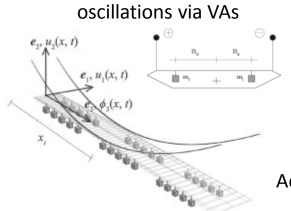
Cluster of TMDs tuned to the frequency of the symmetric mode





Control of VI parametric instabilities in suspension bridges

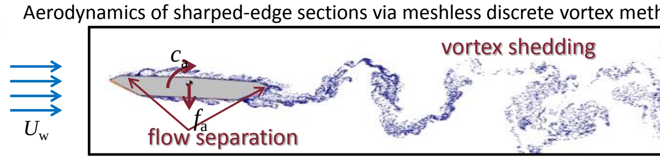
Control of aerodynamic-induced oscillations via VAs



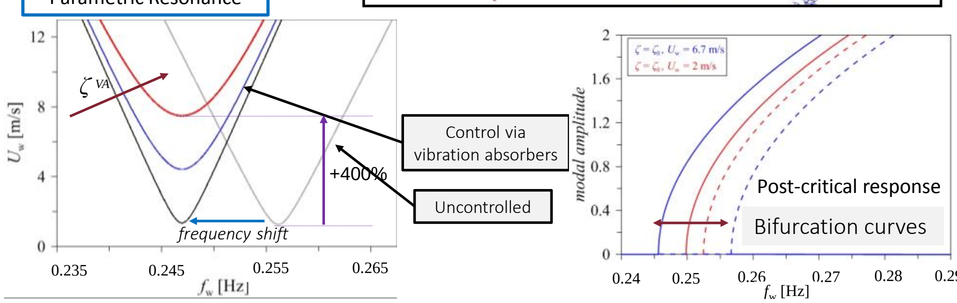
OBJECTIVES

- Investigate the phenomenon of parametric resonance by characterizing the bifurcation scenario
- Describe the stability of the system via perturbation approach (multiple scales method)

Aerodynamics of sharped-edge sections via meshless discrete vortex method



Stability Regions of the Parametric Resonance



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