

TIME TABLE

TIME	Monday	Tuesday	Wednesday	Thursday	Friday
	May 10	May 11	May 12	May 13	May 14
09.00 - 09.45	Registration	Rozza	Magri	Tonicello & Colanera	Tonicello & Colanera
09.45 - 10.30	Cinnella	Rozza	Magri	Tonicello & Colanera	Tonicello & Colanera
11.00 - 11.45	Cinnella	Rozza	Magri	Tonicello & Colanera	Tonicello & Colanera
11.45 - 12.30	Cinnella	Rozza	Magri	Tonicello & Colanera	Tonicello & Colanera
14.00 - 14.45	Cinnella	Yano	Poster Session	Tonicello & Colanera	
14.45 - 15.30	Cinnella	Yano	Poster Session	Tonicello & Colanera	
16.00 - 16.45	Cinnella	Yano	Poster Session	Tonicello & Colanera	
16.45 - 17.30	Cinnella	Yano	Poster Session	Tonicello & Colanera	
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ADMISSION AND ACCOMMODATION

The course is offered in a hybrid format, allowing participants the flexibility to attend either in person or remotely via the Microsoft Teams platform. Admission to on-site attendance is granted on a first-come, first-served basis to comply with the capacity of the lecture room.

Registration fees:

- **Early Bird On-Site Participation: € 650.00 + VAT***

Deadline: March 10, 2027

- **Late On-Site Participation: € 800.00 + VAT***

Deadline: April 28, 2027

- **Live Streaming Online Participation: € 250.00 + VAT***

Deadline: April 28, 2027

On-site participation includes a complimentary bag, five fixed menu buffet lunches, hot beverages, downloadable lecture notes.

Online participation includes downloadable lecture notes.

Application forms should be submitted online through the website: <http://www.cism.it>. A confirmation message will be sent to participants whose applications are accepted.

Upon request, and subject to availability, a limited number of on-site participants can be accommodated at the CISM Guest House for € 35 per person per night. To request accommodation, please contact: foresteria@cism.it

* where applicable; bank charges are not included - Italian VAT is 22%.

CANCELLATION POLICY

Applicants may cancel their registration and receive a full refund by notifying the CISM Secretariat in writing (via email) no later than:

- March 10, 2027, for early bird on-site participation;
- April 10, 2027, for late on-site participation;
- April 28, 2027, for online participation.

No refunds after the deadlines. Cancellation requests received before these deadlines and incorrect payments will be subject to a € 50.00 handling fee.

CISM GRANTS

A limited number of participants from universities and research centers who do not receive support from their institutions can request a waiver of the registration fee and/or free lodging.

Requests must be submitted via the CISM website by **March 10, 2027**. Applicants should select the relevant option in the online application form and provide a curriculum vitae and a letter of recommendation from their department head or supervisor confirming that their institution is unable to provide financial support. Preference will be given to applicants from countries that sponsor CISM.

For further information please contact:

CISM (Seat of the course)
Palazzo del Torso - Piazza Garibaldi 18 - 33100 Udine (Italy)
tel. +39 0432 248511 (6 lines)
e-mail: info@cism.it | www.cism.it



DATA-DRIVEN MODELLING FOR FLUID DYNAMICS

CISM Advanced School
coordinated by

Paola Cinnella
Sorbonne University, CNRS, Paris, France

Gianluigi Rozza
SISSA, Trieste, Italy

Udine May 10 - 14 2027

DATA-DRIVEN MODELLING FOR FLUID DYNAMICS

Turbulent and chaotic flows remain among the most demanding targets for predictive simulation, central to aerodynamics, propulsion, energy systems, geophysical and biomedical applications.

Direct numerical simulation is feasible only for canonical cases, large-eddy simulation remains costly at realistic Reynolds numbers, and industrial practice still relies heavily on RANS models whose accuracy degrades outside calibrated regimes. Meanwhile, growing high-fidelity datasets, modern HPC resources, and machine-learning methods offer new ways to extract structure, identify closures, and build fast surrogates — provided models stay trustworthy, generalizable, and uncertainty-aware.

This course offers an integrated, physics-aware framework bridging classical

CFD and turbulence modelling with data-driven methods, reduced-order modelling (ROM), modal analysis, and sequential data assimilation, turning large datasets into predictive, scalable digital twins.

Participants will learn to: (1) understand where and why RANS/LES/DNS succeed or fail; (2) augment turbulence models with data while enforcing physical constraints and quantifying uncertainty (field inversion, symbolic/sparse regression, Bayesian UQ); (3) build projection-based and data-driven ROMs for many-query CFD applications — design, optimization, control, digital twins — including POD-Galerkin, stability and pressure treatment, hyper-reduction, and geometric parametrization; (4) handle multi-regime and chaotic dynamics through nonlinear

latent representations (autoencoders), data-driven time inference (reservoir computing, recurrent networks), and sequential/Bayesian data assimilation; and (5) apply modal decomposition (POD, SPOD, DMD/Koopman) and cluster-based ROMs to extract coherent structures from turbulent data.

The five-day course combines theory, method development, and hands-on tutorials with opensource tools (EZYRB, PINA, PyTorch, TensorFlow), plus a poster/flash-talk session for participants to present their own research.

Target audience: graduate students, PhD candidates, and researchers in applied mathematics, fluid mechanics, computational physics, and mechanical/aerospace engineering working on RANS/LES/

DNS, turbulence closures, projection-based and data-driven ROMs, modal decomposition, or nonlinear latent modelling of complex/chaotic flows. It also targets senior researchers and industrial practitioners engaged in digital twins, real-time simulation, optimization, and uncertainty quantification who need trustworthy, scalable, physically consistent data-driven tools.

Participants will also have the opportunity to take part in a poster and flash-talk session, where they can present brief contributions highlighting applications, datasets, and open research challenges.

PRELIMINARY SUGGESTED READINGS

Brunton, S. L., Noack, B. R., Koumoutsakos, P., “Machine Learning for Fluid Mechanics,” Annual Review of Fluid Mechanics, 2020.

Davidson, P. A., Turbulence: An Introduction for Scientists and Engineers. Oxford University Press, 2004.

Hesthaven, J., Rozza, G., Stamm, B., Certified Reduced Basis Methods for Parametrized Partial Differential Equations. Springer, 2016.

Holmes, P., Lumley, J. L., Berkooz, G., Turbulence, Coherent Structures, Dynamical Systems and Symmetry. Cambridge University Press, 1996.

Magri, L., Nóvoa, A., Özalp, E., “Prediction of Chaotic Dynamics from Data: An Introduction,” arXiv preprint, <https://arxiv.org/pdf/2604.11624>.

LECTURES

All lectures will be given in English. Lecture notes can be downloaded from the CISM web site. Instructions will be sent to accepted participants.

INVITED LECTURERS

Paola Cinnella - Sorbonne University, CNRS, Paris, France
7 lectures on: RANS/LES/DNS trade-offs; ML-augmented turbulence closures (field inversion, symbolic/sparse regression); generalization and robustness; intro to Bayesian UQ for modelform and data uncertainty.

Luca Magri - Imperial College London, UK & Politecnico di Torino, Italy
4 lectures on: Chaos-aware modelling (Lyapunov time, attractors); nonlinear ROMs via autoencoders; latent dynamics learning (ESN/RNN); sequential Bayesian data assimilation; bias-aware strategies.

Gianluigi Rozza - SISSA, Trieste, Italy
4 lectures on: ROM fundamentals, POD-Galerkin, stability/wellposedness to Navier-Stokes, pressure stabilization, closures, geometry parametrization, non-intrusive/autoencoder ROMs.

Niccolò Tonicello & Antonio Colanera - SISSA, Trieste, Italy
12 lectures on: ML for turbulence/LES: surrogate vs embedded SGS models, intrusive/non-intrusive paradigms, PDE-constrained optimization, adjoints, RL/differentiable solvers.
Data-driven modal analysis (SPOD, multiscale POD, DMD/Koopman) and cluster-based ROMs (CNM, ql-ROM) for multi-regime, nonlinear turbulent dynamics.
Hands-on tutorials with EZyRB/PINA: POD/SPOD/DMD workflows, ROM construction, autoencoder-based ROMs, latent-space interpolation and extrapolation assessment.

Masayuki Yano - University of Toronto, Canada
4 lectures on: Certified and adaptive nonlinear ROMs: a-posteriori error estimation, hyperreduction, space-time/component-based methods, goal-oriented reduction, optimization, real-time CFD.