ModelFLOWs

Artificial intelligence, machine learning and data-driven methods to model complex problems

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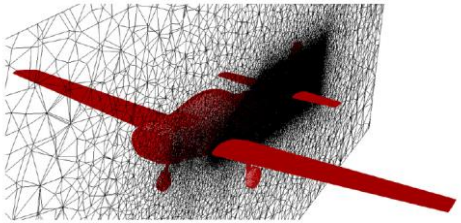
CFD simulations & Data-driven tools: applications

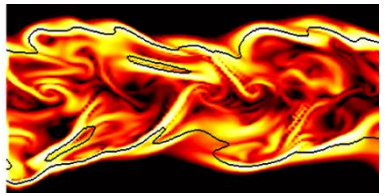
Marine propulsion

Medicine & Non-Newtonian flows

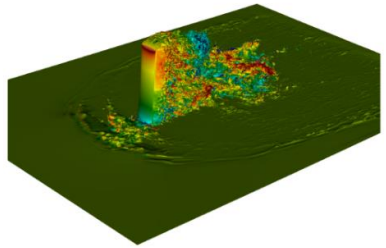
Aerodynamics & Aeroelasticity



Combustion



Urban flows



Wind Energy

Artificial intelligence tools: reduced order models

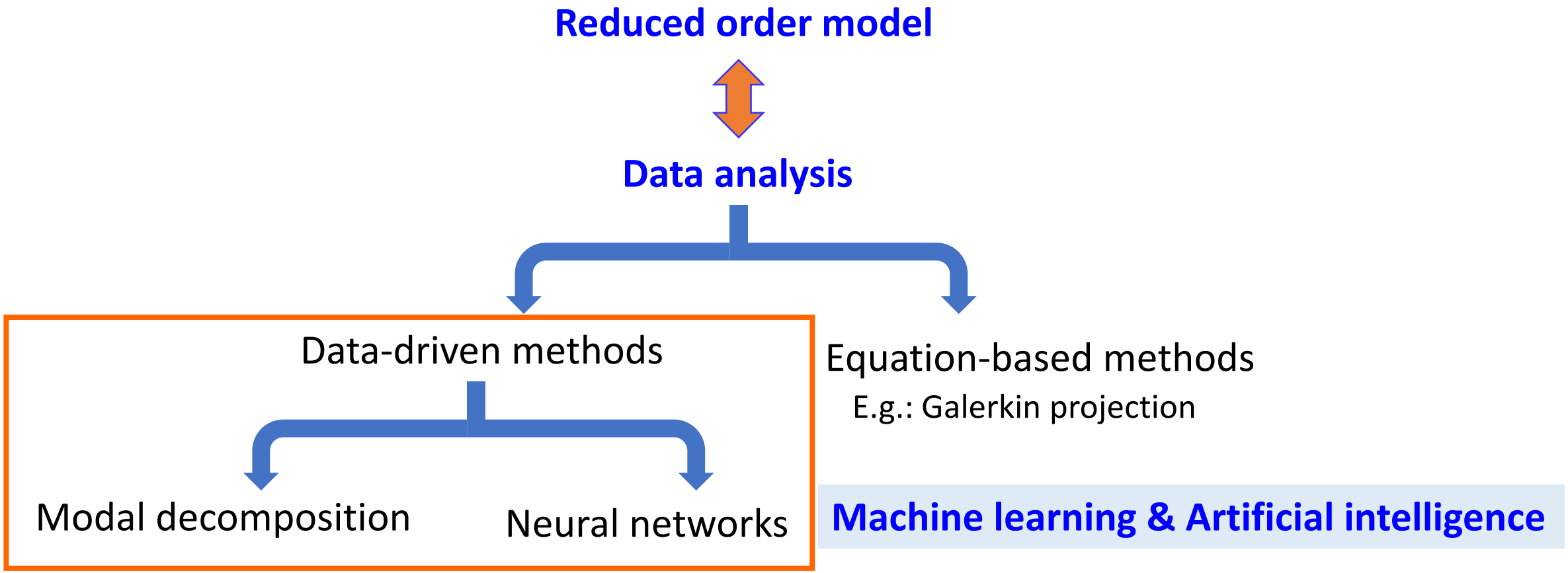
Study and understand **database general behaviour**

Deeper understanding of physics

Reduce computational cost

Control & design optimization

Methods for data analysis



Methods for data analysis

Artificial intelligence tools

Reduced Order Models: hybrid **machine learning** models based on physical principles

Modal decomposition

DMD, POD, PCA, HOSVD, HODMD, etc.

Extract physical patterns

Reduce data dimensionality

+

Neural networks

Recurrent Neural Networks, Convolutional Neural Networks, Autoencoders, Transformers, PINNs, etc.

Data forecasting

Data reconstruction & repairing

etc.

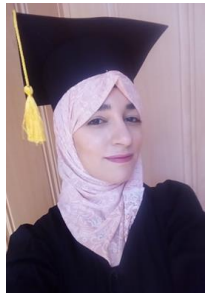
Data assimilation to develop robust architectures

Combine numerical and experimental databases

ModelFLOWs - Research Group

Adrián Corrochano

Rodrigo Abadía-Heredia



Nourel Groun

Eneko Lazpita

Christian Amor

Ashton Ian Hetherington

Andrés Bell

Mahesh Nagargoje

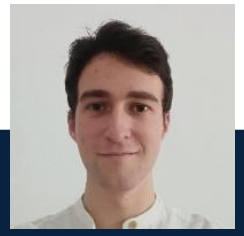
Daniel Serfaty

Juan Sánchez

Eva Muñoz

Sofia Tagliaferro

Egoitz Maiora



Paula Díaz

Funded projects in ModelFLOWs

Fight climate change & advance in personalized medicine

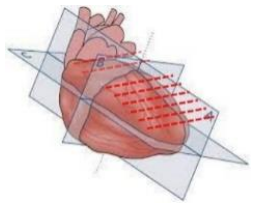
Artificial intelligence tools & CFD simulations

MODELAIR

MODELAIR

MODEL-CO, ENCODING

NEMDAEA



DigitHEART, CardioAging

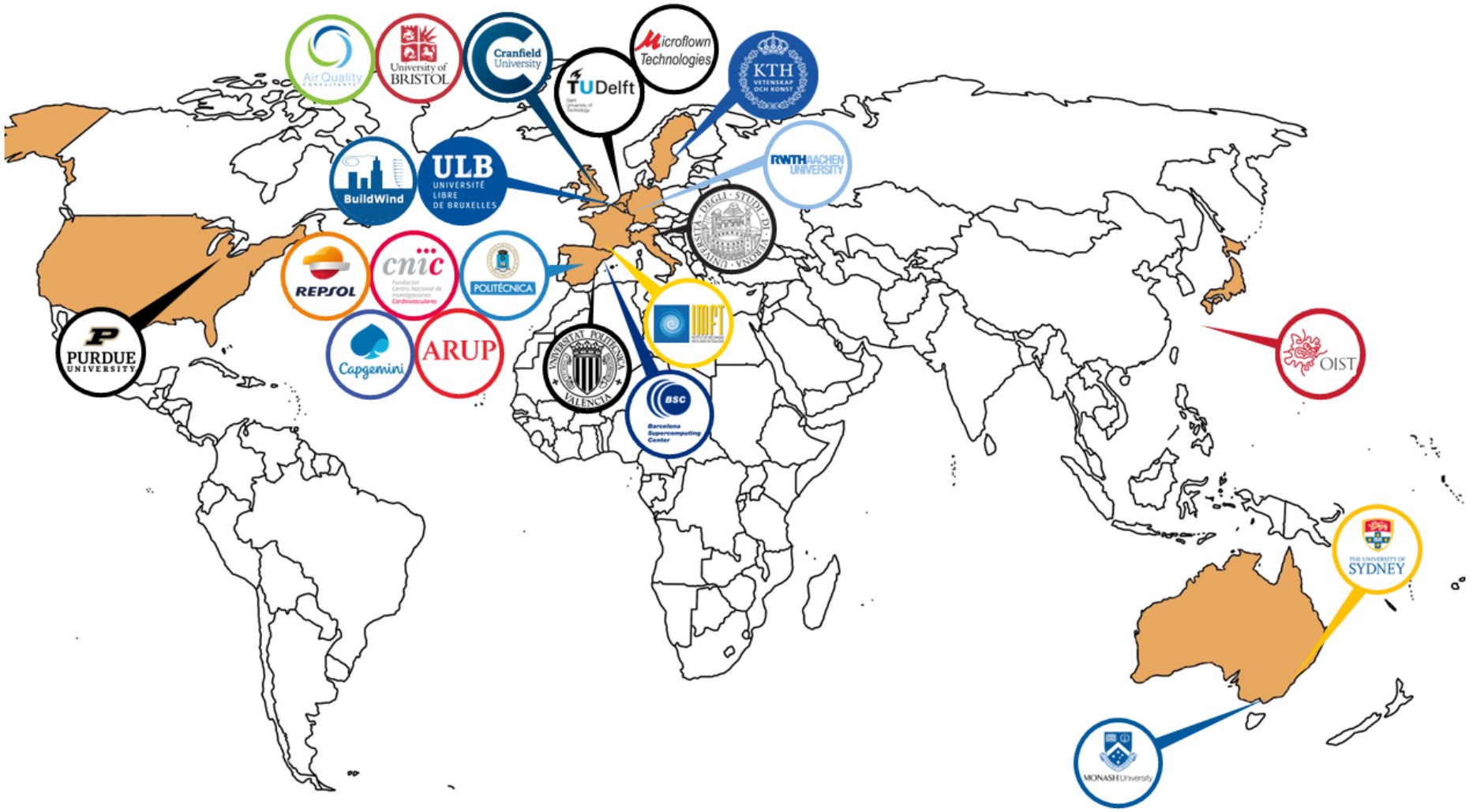
MSCA Marie Skłodowska-Curie Actions DOCTORAL NETWORKS - 2022

GOBIERNO DE ESPAÑA MINISTERIO DE CIENCIA E INNOVACIÓN

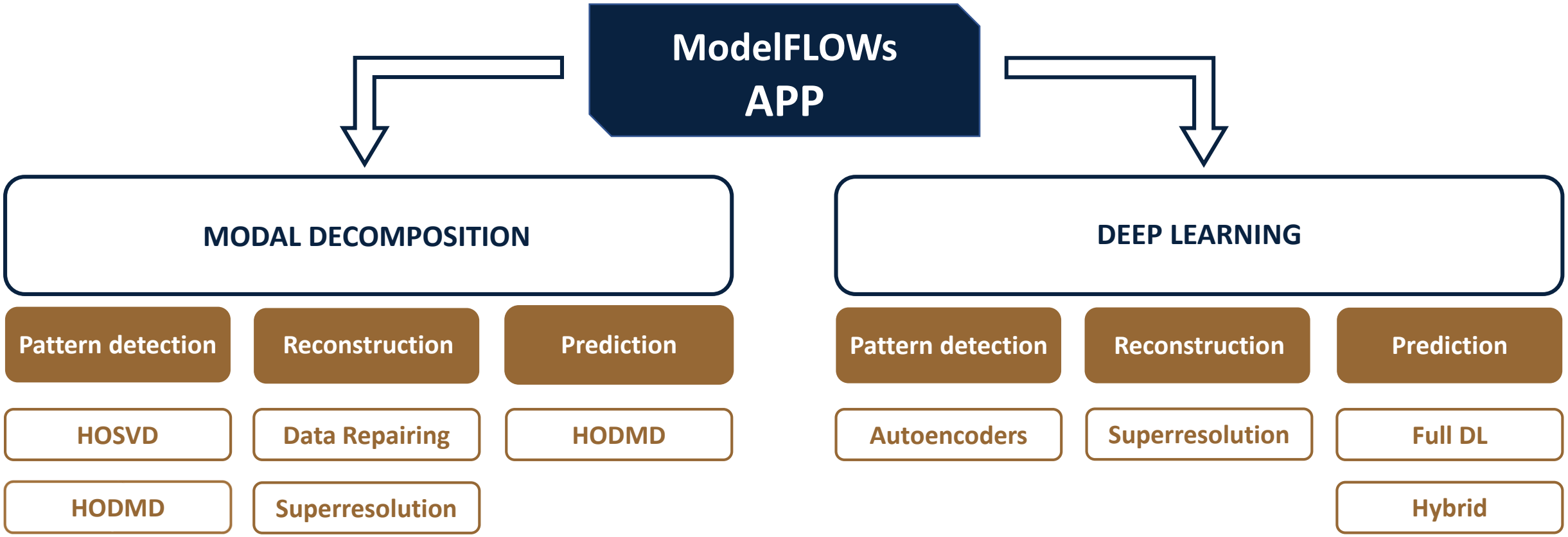
Comunidad de Madrid

POLITÉCNICA

ModelFLOWs national & international collaborations



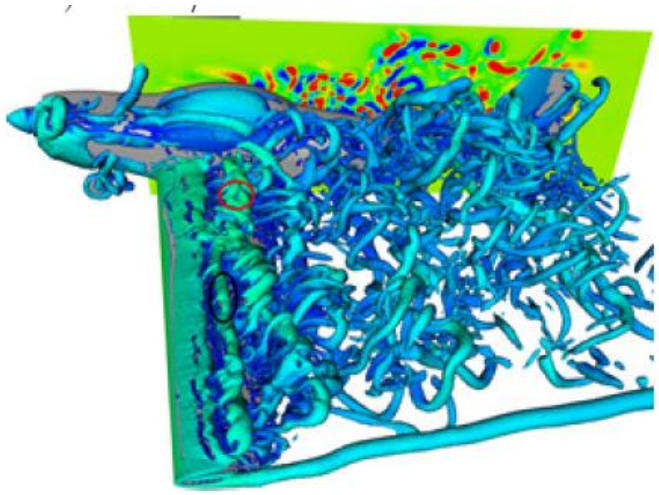
Open Source Software



https://modelflows.github.io/modelflowsapp/

Open Source Software

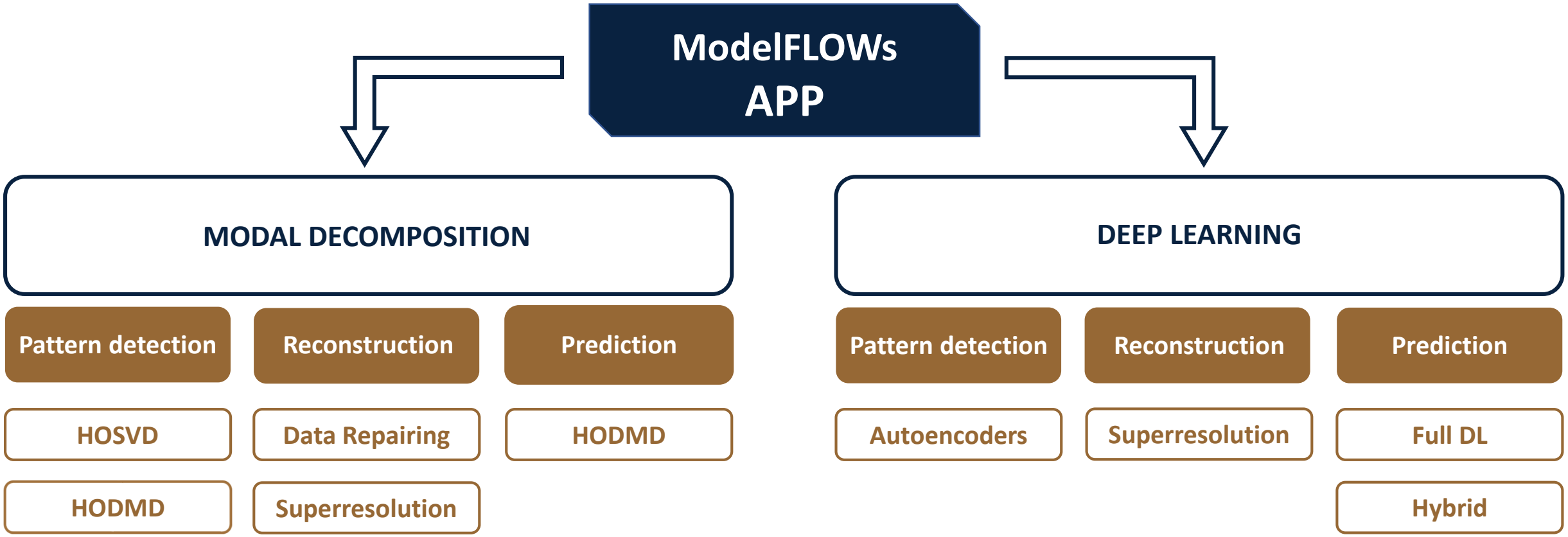
ModelFLOWs APP



Big databases

CPU & GPU

Open Source Software



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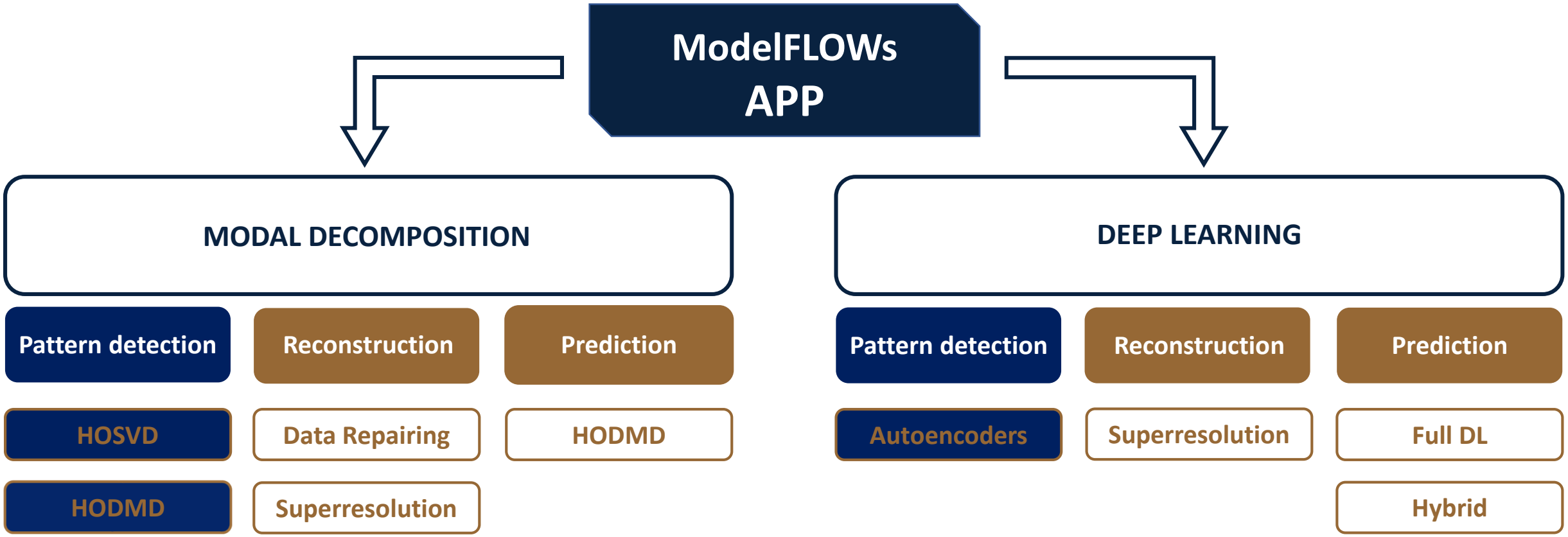

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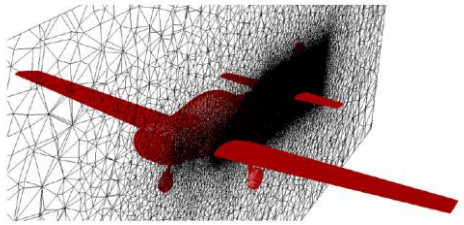
ModelFLOWs App – Patterns detection

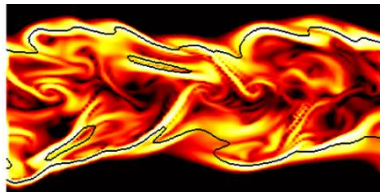
Marine propulsion

Medicine

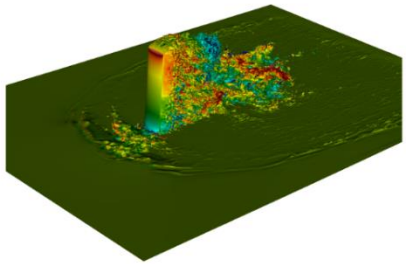
Aerodynamics



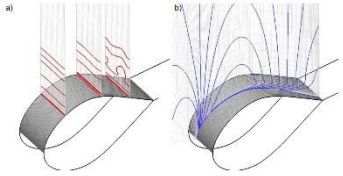
Combustion

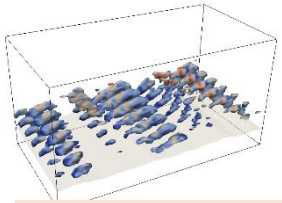


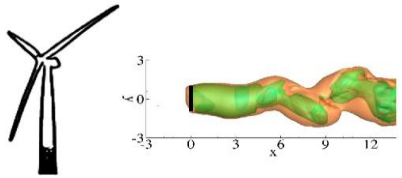
Urban flows



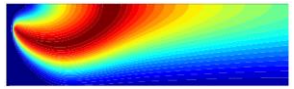
Turbulence, Heat transfer, Flight test, Wind energy







Reactive flows



Le Clainche, Rosti & Brandt (J. Fluid Mech. 2022)
Le Clainche, Izbassarov, Rosti, Brandt & Tammisola (J. Fluid Mech. 2020)
Méndez, Le Clainche, Moreno, Vega (Arosp. Sci. Tech. 2021)
Le Clainche, Zhan & Ferrer (Phys. Fluids 2019)
Wu et al. (Chin. J. Aero., 2019)
Méndez, Le Clainche, Vega, Moreno, Taylor (AIAA 2019)
Le Clainche, Mao & Vega (Wind Energ. 2018)
Le Clainche, Moreno, Taylor, Vega (J. Aircraft 2018)
Le Clainche, Pérez & Vega (Fluid Dyn. Res. 2018)
Le Clainche, Sastre, Vega & Velázquez (AIAA 2017)

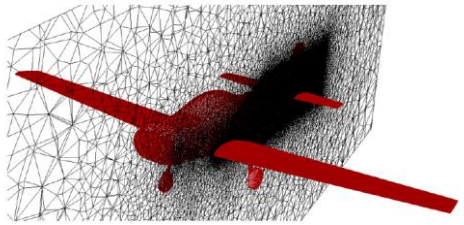
Corrochano, D'Alessio, Parente, Le Clainche (arxiv, 2022)
Corrochano, Freitas, Parente, Le Clainche (ISUDEF, 2022)

ModelFLOWs App – Patterns detection

Marine propulsion

Medicine

Aerodynamics



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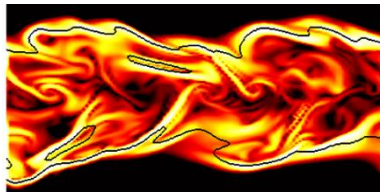
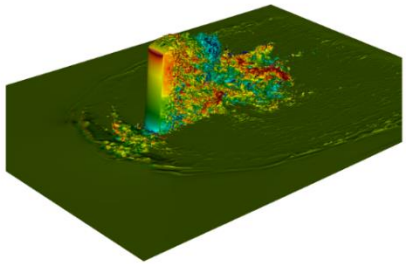
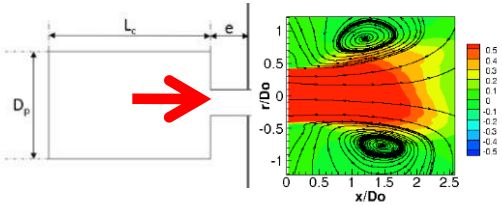
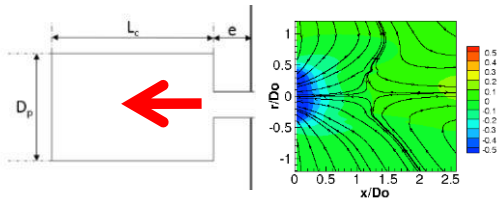


Urban flows



Synthetic jets

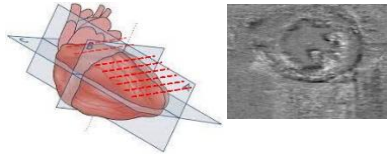




Muñoz & Le Clainche (Phys. Fluids, 2022)
Le Clainche (Energies 2019)
Palomo, Pérez & Le Clainche (RIENG 2019)
Le Clainche, Vega & Soria (Exp. Therm. Fluid Sci. 2017)

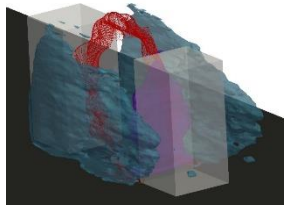
Multi-phase flows
Non-newtonian flows
etc.

Medical Imaging



Groun, Villalba, Lara, Valero, Garicano & Le Clainche (Comp. Biol. Med. 2022)
Vega & Le Clainche (Book - Elsevier 2020)
Groun et al. (Com. Biol. Med., 2022)

Urban flows



Lazpita et al. (Phys. Fluids 2022)
A. Martínez-Sánchez et al.
(J. Fluid Mech., submitted)

Pattern detection - New strategies for flow control

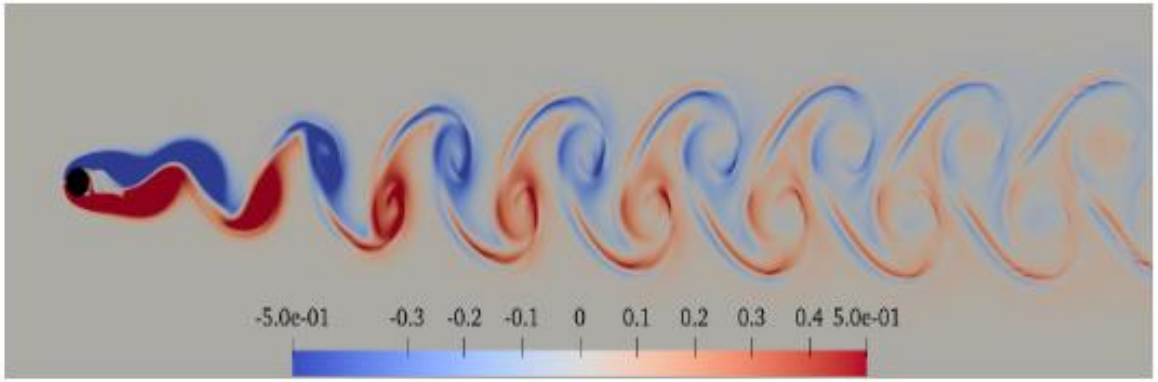
- New algortihm **fully data-driven** to detect **structural sensitivity** → applications in **flow control**

Corrochano & Le Clainche,
Comp. & Maths. with Appl., 2022

- Application to an ElastoViscoPlastic flow past a cylinder 2D

In collaboration with S. Parvar & O. Tammisola

Re = 100
Wi = 1
Bn = 2
n = 0.2
β = 0.9



Pattern detection - New strategies for flow control

- Creation of a new algortihm based on HODMD (fully data-driven) for flow control
- Application to an ElastoViscoPlastic flow past a cylinder 2D

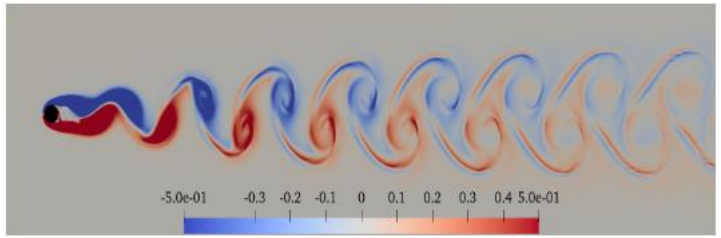


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FOTO DE MODOS DEL CILINDRO DIRECTO Y ADJUNTO???

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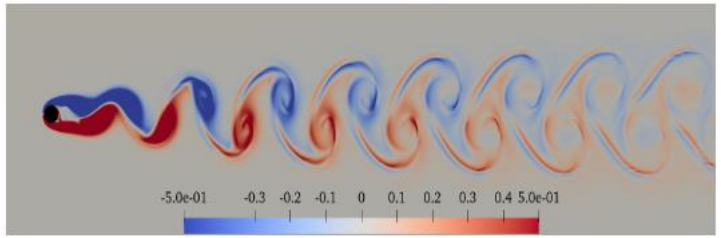

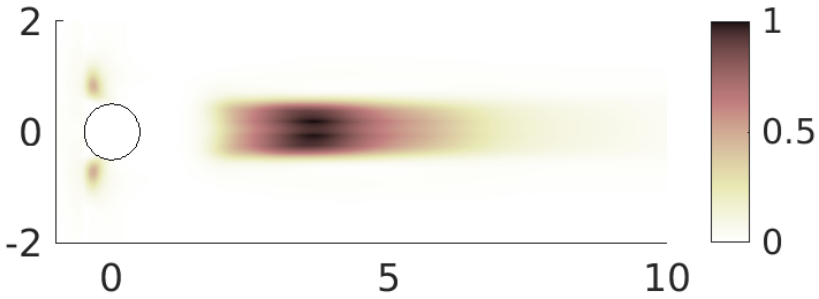

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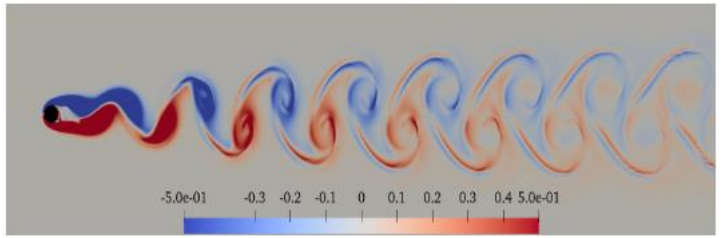

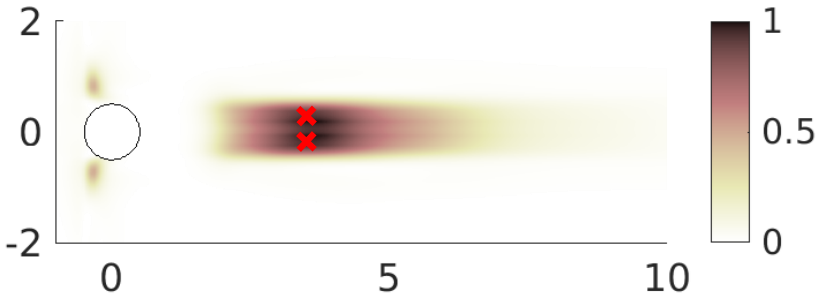

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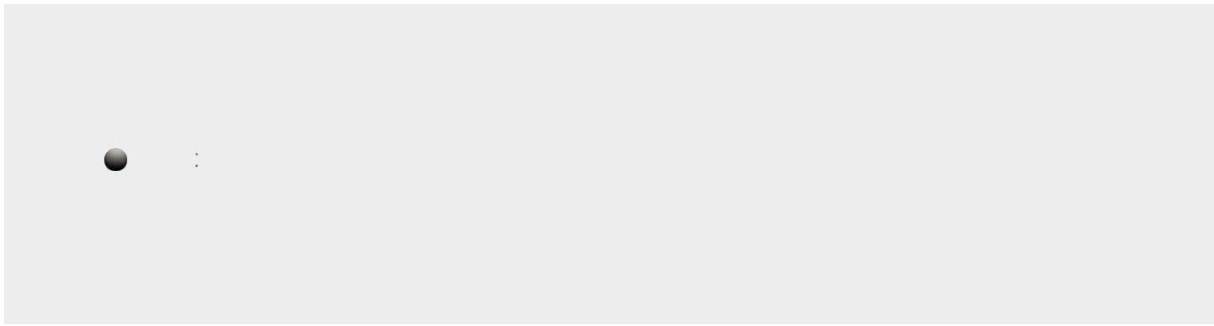

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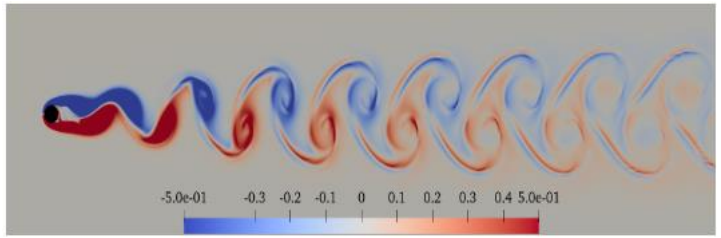

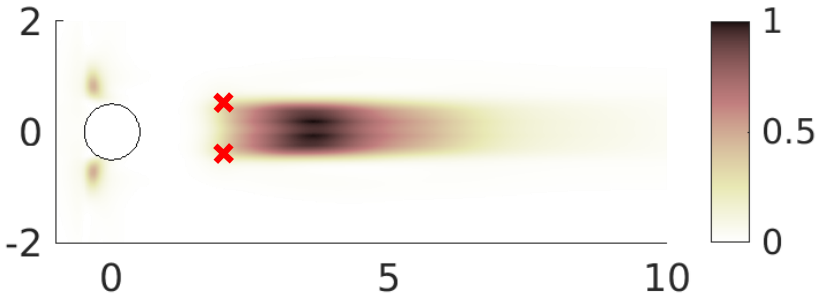

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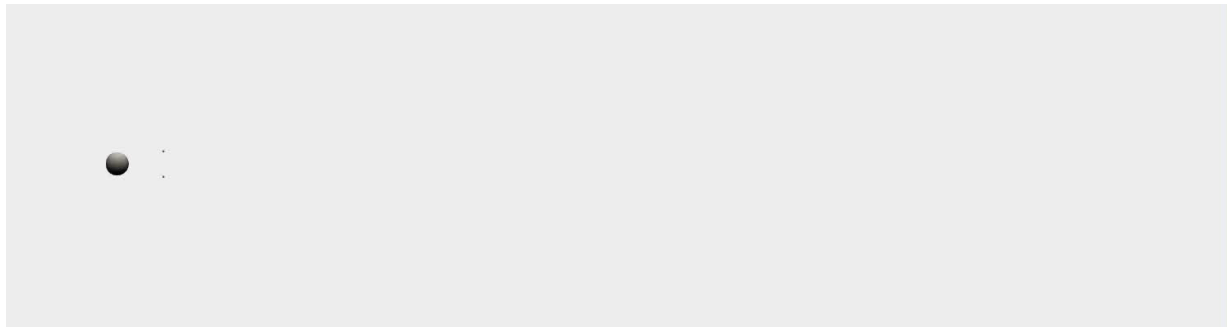
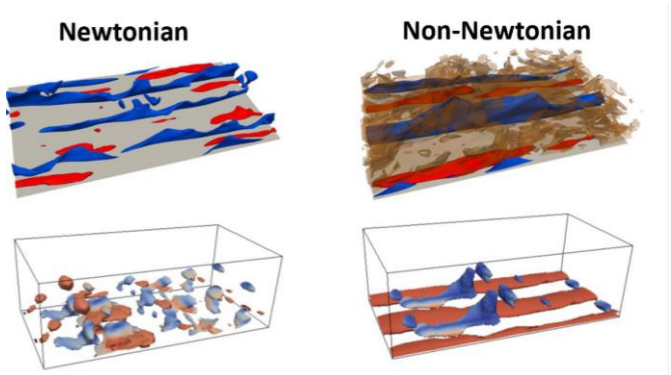


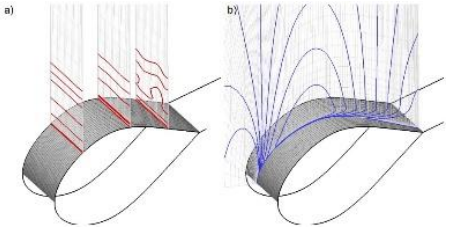
ModelFLOWs App – Patterns detection

More applications

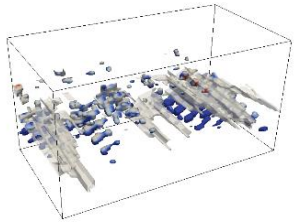
Flow instabilitites in wall bounded turbulence



Global and convective cross-flow instabilitites



Porous wall



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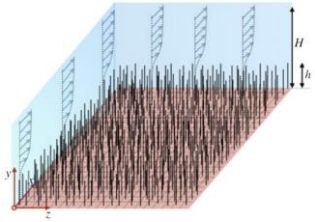
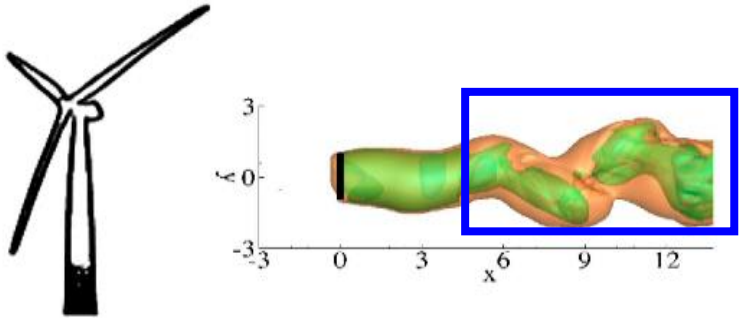
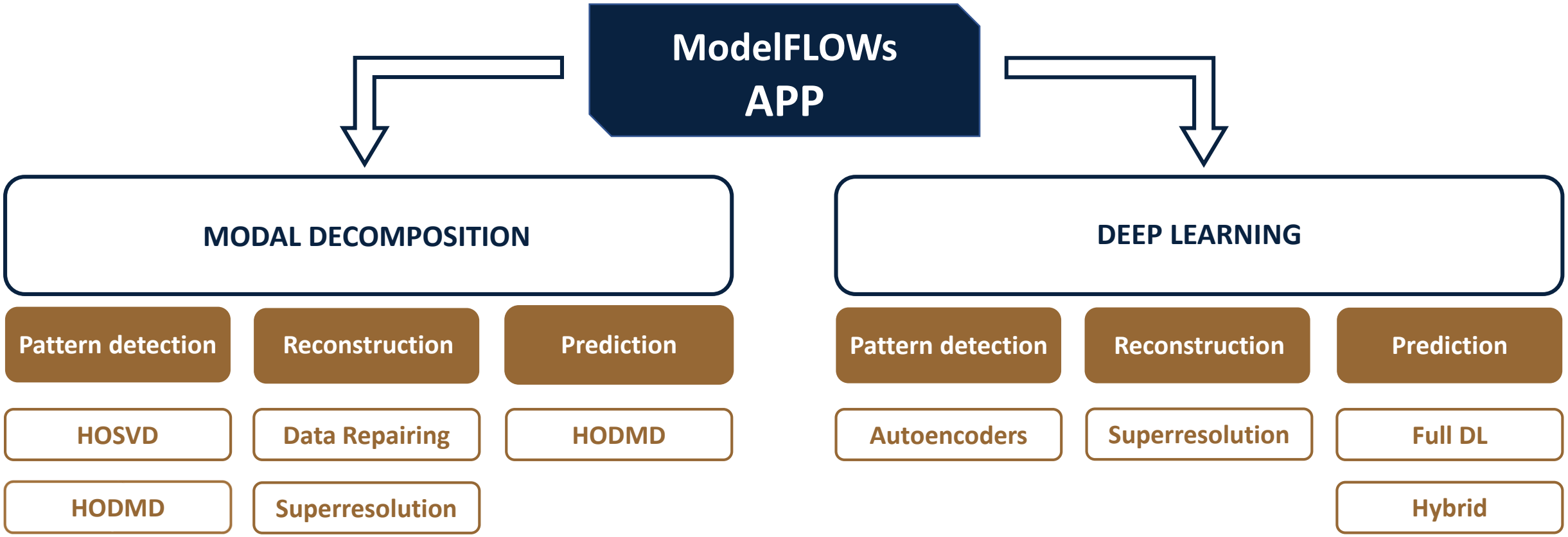


Transition to turbulence in wakes



Open Source Software



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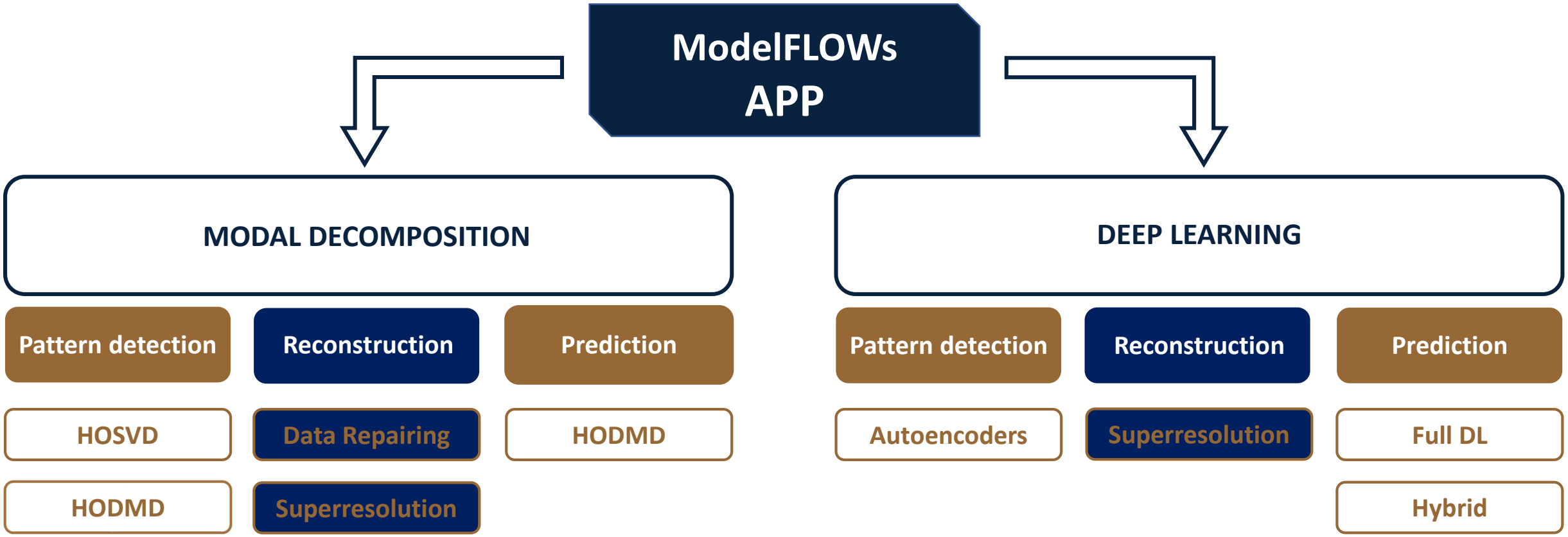
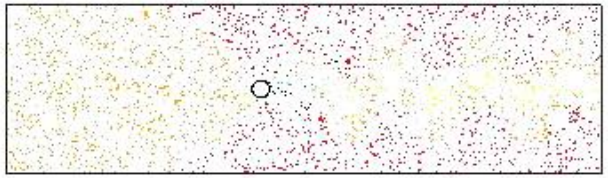


https://modelflows.github.io/modelflowsapp/

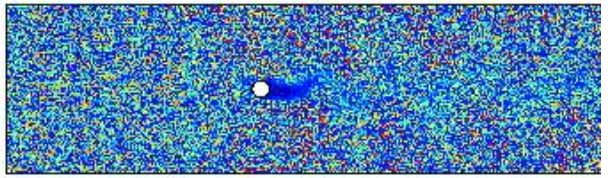
ModelFLOWs App – Reconstruction

Data repairing & enhacement of resolution

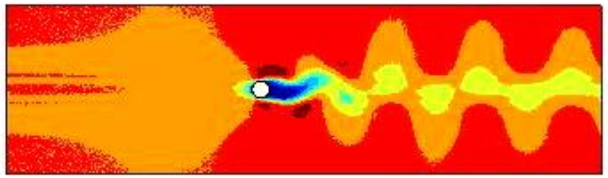
Gappy



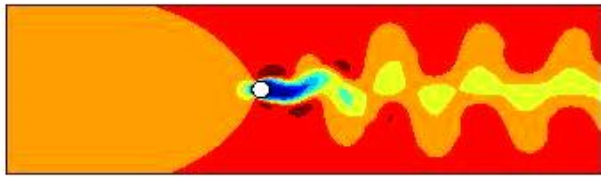
Initial Reconstruction



Reconstruction



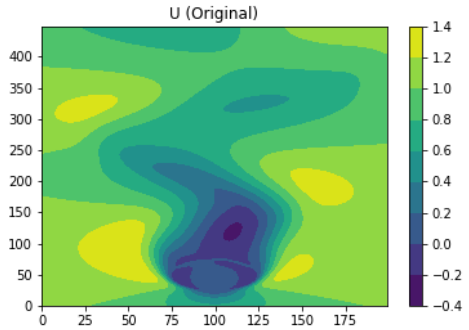
Real



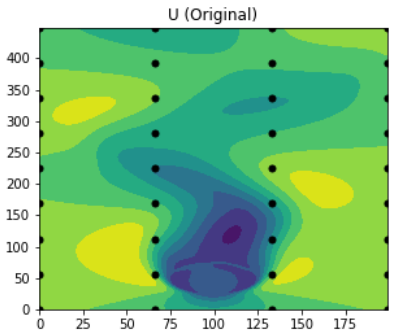
RRMSE: 2%

ModelFLOWs App – Reconstruction

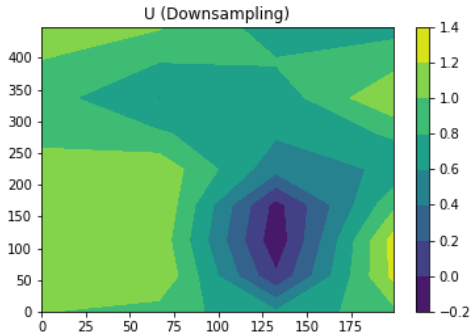
From sensors to 3D fields



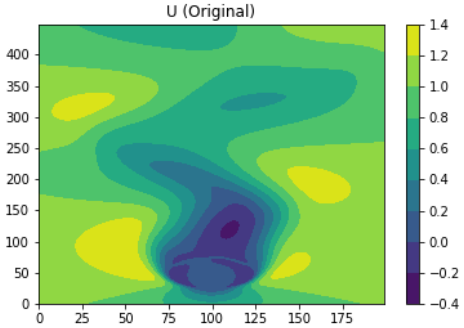
Original



Sensors



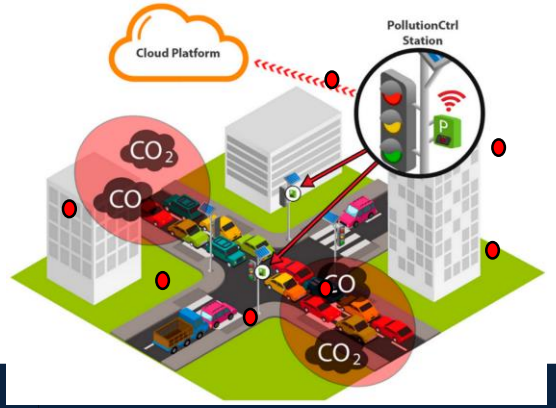
Input database



Reconstruction

ROM

RRMS error < 2%

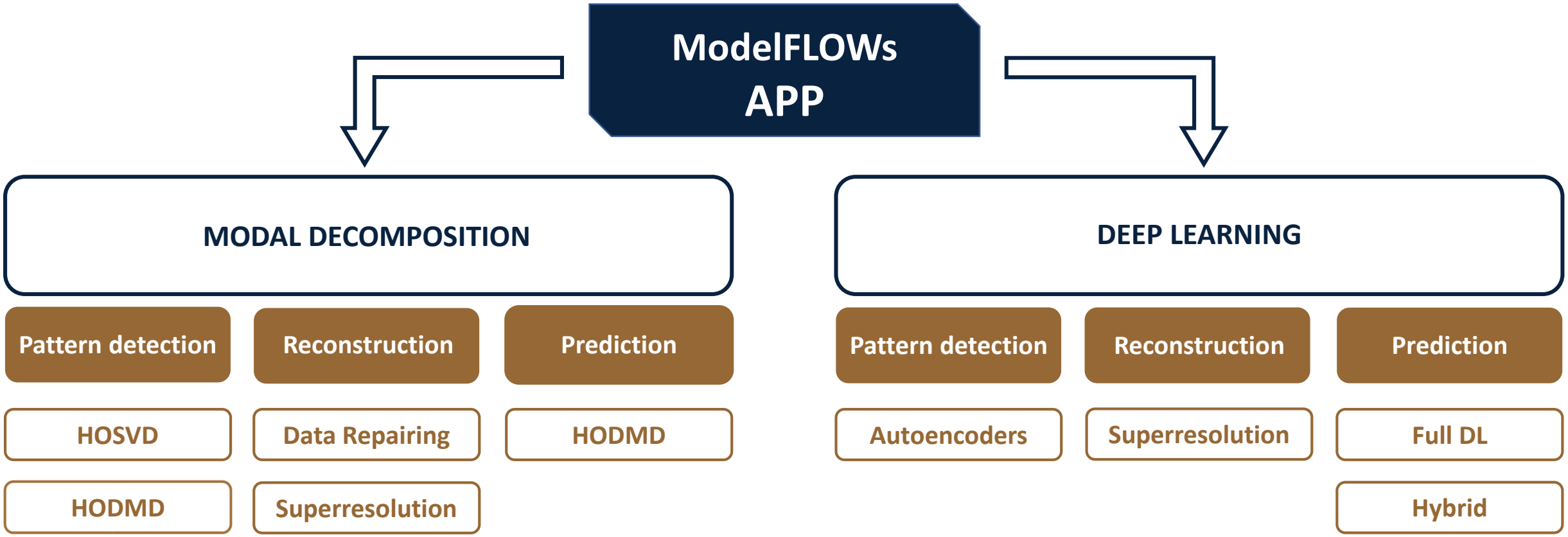


Sensors in cities
3D pollution maps

MODELAIR

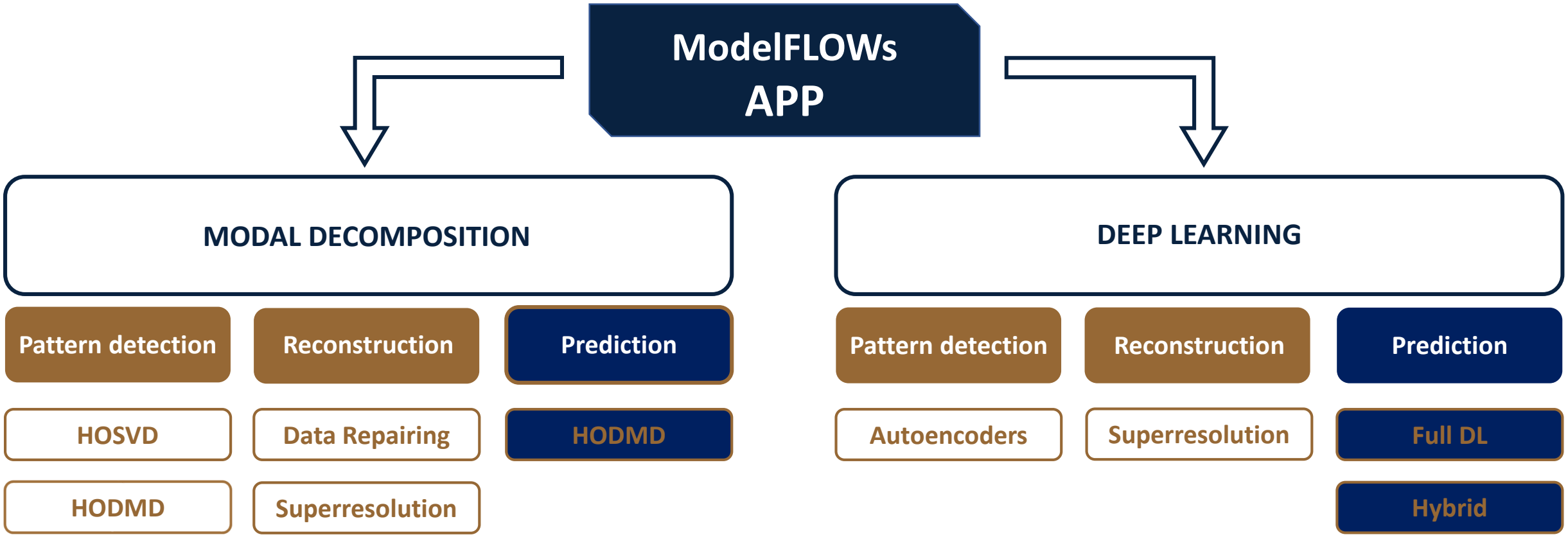
ModelFLOWs

Open Source Software



https://modelflows.github.io/modelflowsapp/

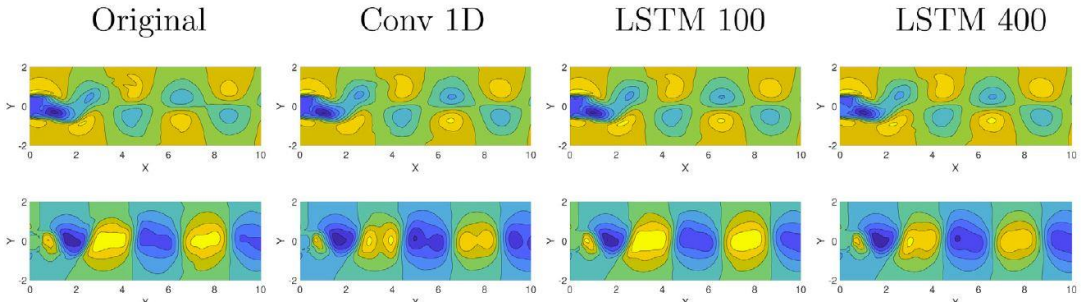
Open Source Software

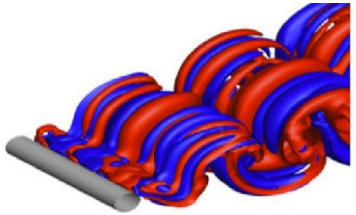


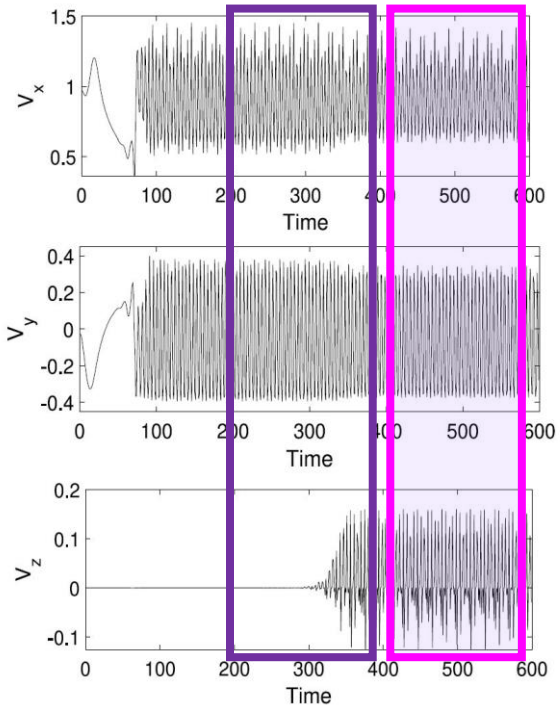
https://modelflows.github.io/modelflowsapp/

ModelFLOWs App – Prediction

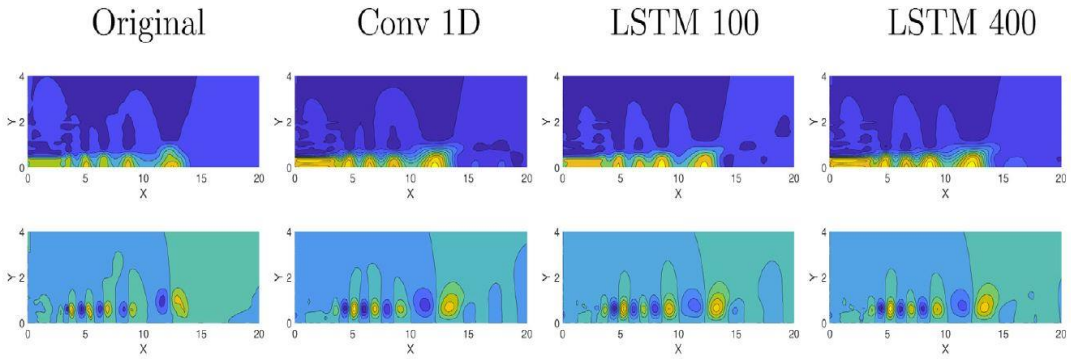
Speed-up numerical simulations

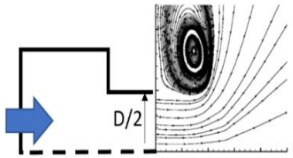


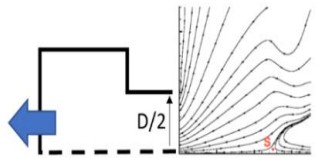




RRMS error ~ 2% & Speed-up >100!!





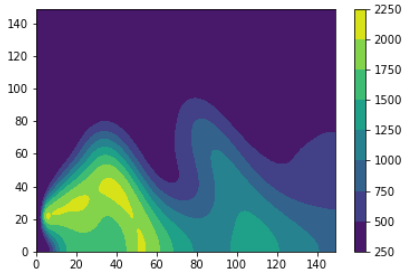


ModelFLOWs App – Prediction

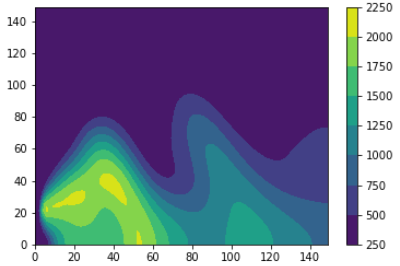
Speed-up numerical simulations

Reactive flows

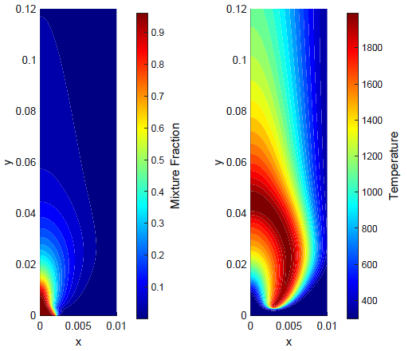
Real



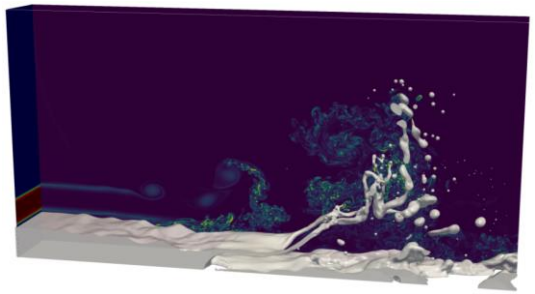
Prediction



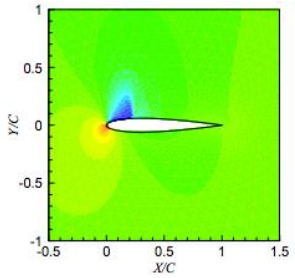
82 Chemical species



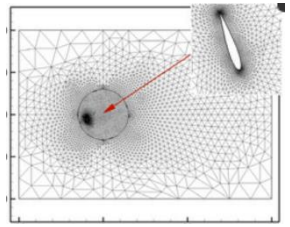
Multiphase flows



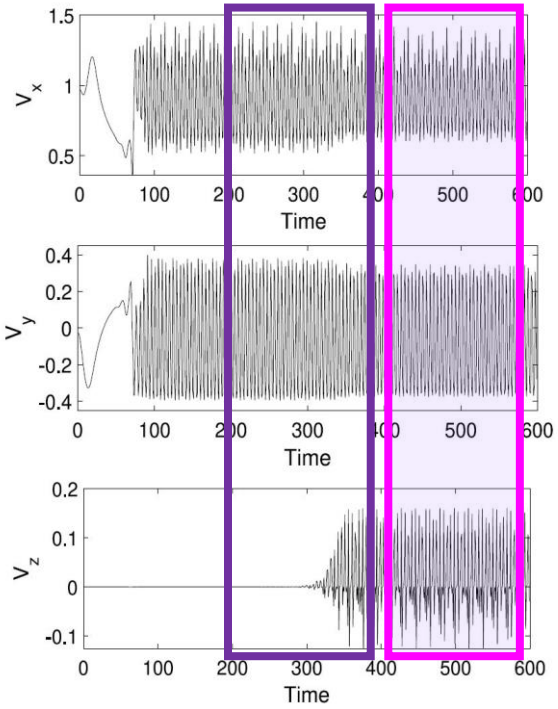
Shock wave with 'buffeting condition'



Wind turbines



Training + validation

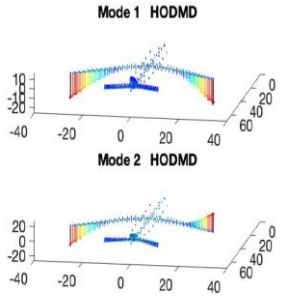


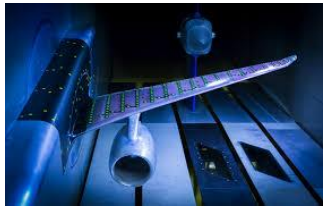
Prediction

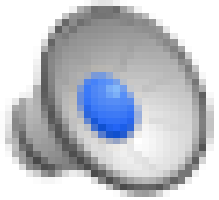
ModelFLOWs App – Prediction

Open-door measurements

Predict flutter in flight test

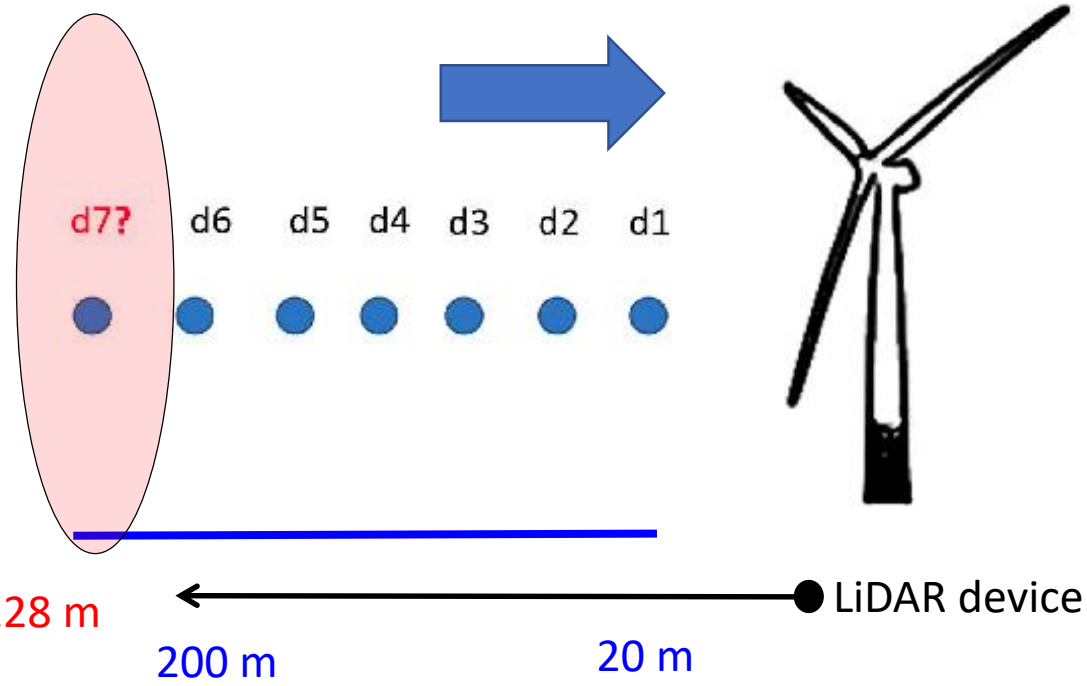






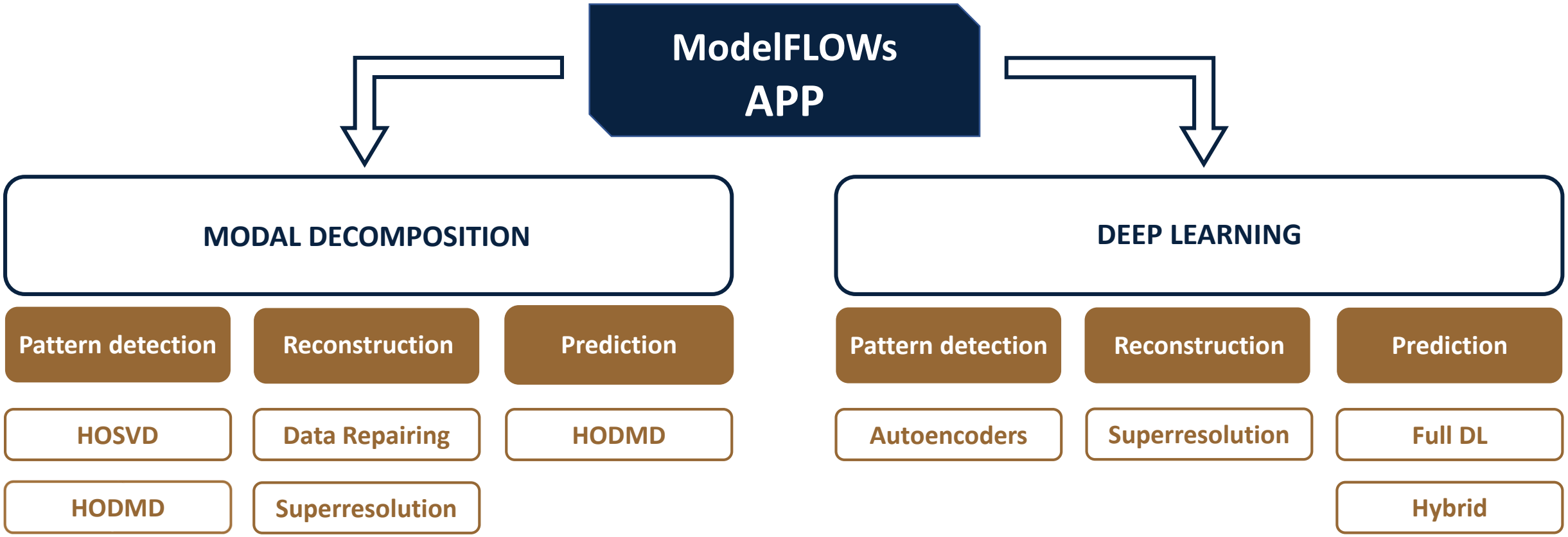
Automatic method (errors smaller than 5%), identify flutter modes in less than **2 minutes**!

Predict wind velocity in LiDAR experiments



RRMS error ~ 2%

Open Source Software



https://modelflows.github.io/modelflowsapp/

Thank you for your attention!

Questions??

soledad.leclainche@upm.es

https://sites.google.com/view/soledadleclainche

https://modelflows.github.io/modelflowsapp/