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A hybrid POD approach for parametrised turbulent flow problems

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Motivation

- Optimization of energy production of wind farm deployment.
  - Relative positioning and loading of wind-turbine array.

- Adapting to an increasingly demanding environment.
  - Multiple querries.
  - Real-time simulation.

- Nested ROM:
  - POD-Galerkin reduced model for the efficient assessment of wind-turbine flow, given environmental characteristics.
  - Compression of wind data as input of methodology (output of external ROM).
  - Model Reduction of flow around a wind-turbine.

Hybrid POD-Galerkin method

Methodology

System of equations:

$$\boldsymbol{u}^* \cdot (\nabla \cdot (\boldsymbol{u} \otimes \boldsymbol{u}) - \nabla \cdot (\nu_{\text{eff}} \nabla^{\boldsymbol{s}} \boldsymbol{u}) + \nabla p) = \boldsymbol{\mathcal{R}}_{\boldsymbol{u}}$$

$$p^* \nabla \cdot \boldsymbol{u} = \mathcal{R}_p$$

Assumption of separability

$$\boldsymbol{u}^R = \sum_{i=1}^{i=N_u} \alpha^i(\mu)\boldsymbol{\phi}^i(\boldsymbol{x})$$

$$p^R = \sum_{i=1}^{i=N_p} \beta^i(\mu)\chi^i(\boldsymbol{x})$$

$$\nu_{\text{eff}}^R = \sum_{i=1}^{i=N_t} \gamma^i(\mu)\xi^i(\boldsymbol{x})$$

Eddy viscosity

POD:

- Reduced basis
- Parametric dependence matrix

Online:

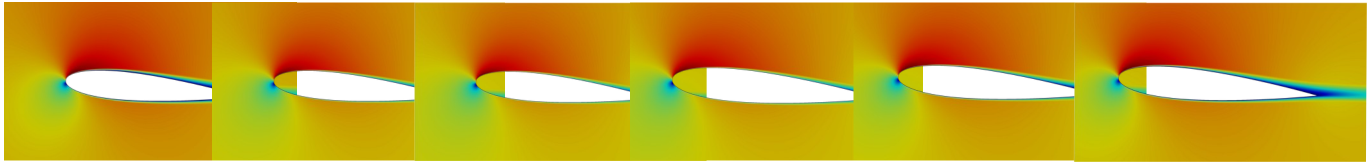
- Interpolation of parametric coefficients

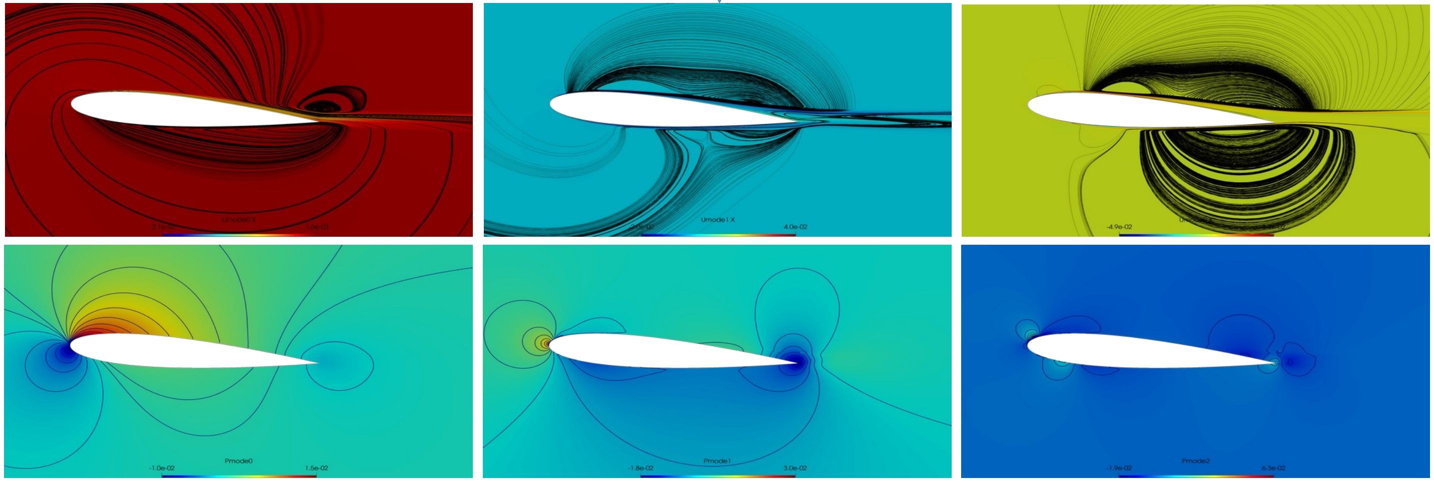
Flow around a NACA 0015 airfoil

Offline phase

Sampling

- Angle of attack: 10^o
- Reynolds number range: $[32\cdot10^3, 32\cdot10^4]$





Velocity modes

Pressure modes

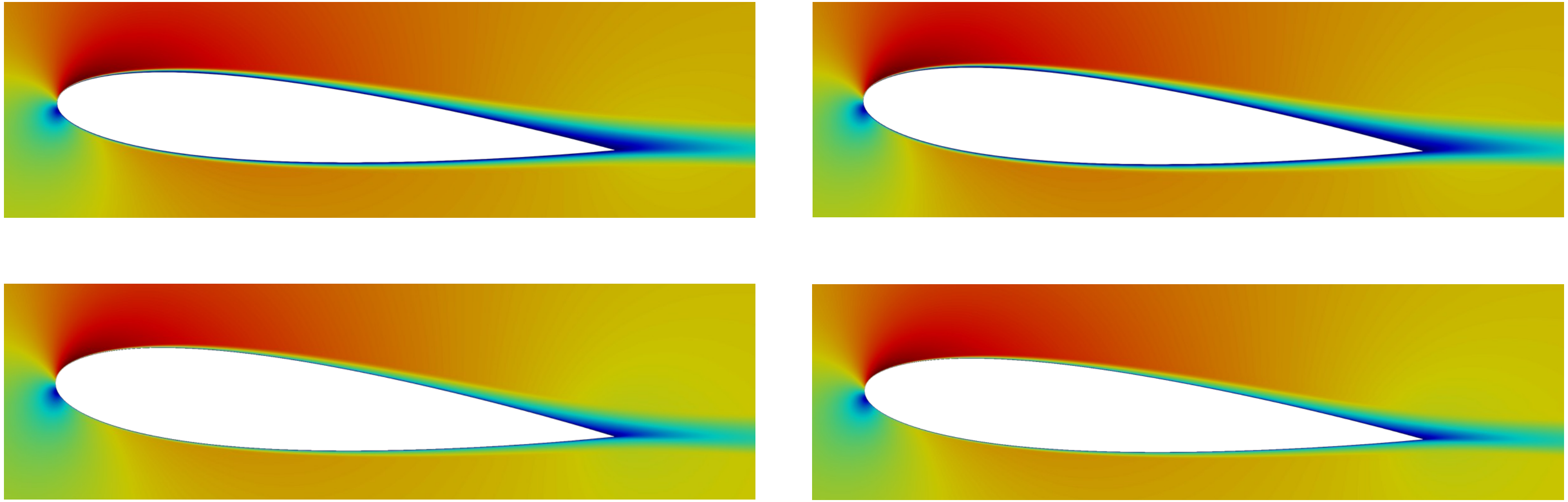
Flow around a NACA 0015 airfoil

Online phase

FOM | **ROM**

$Re = 48 \cdot 10^3$

$Re = 272 \cdot 10^3$



Speed-up of 10^4

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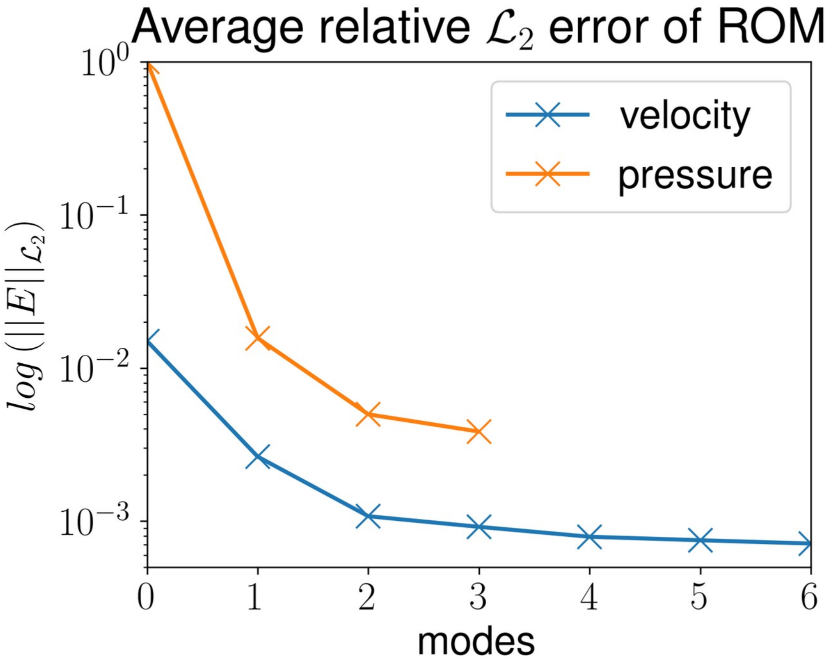
Summary

- A POD-Galerkin approach was developed based on OpenFOAM's FVM solvers.
- Focus on high Reynolds numbers.
- Online phase:
  - Pressure Poisson Equation.
  - Eddy viscosity parametric dependence is computed using POD-i.

- Next steps:
  - Geometric parametrisation.
  - Further increase of Reynolds number.
  - Transient problems.



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