Turbulent wake prediction using deep convolutional neural networks

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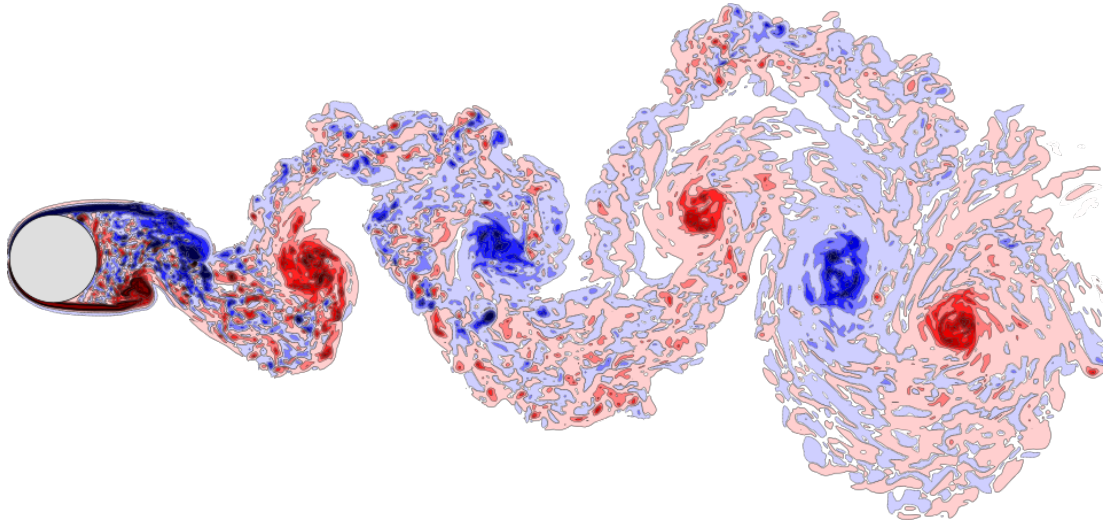

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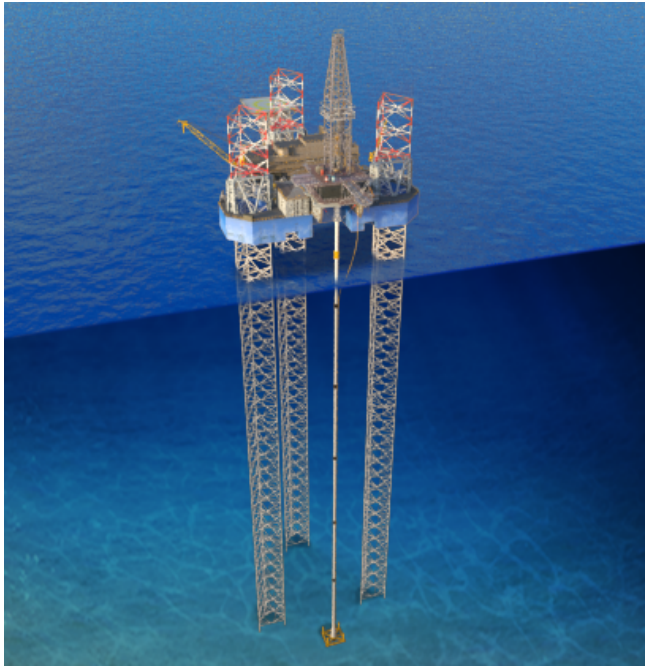
Simulating flow past long flexible structures is computationally expensive



◦ Marine riser

[https://oilstates.com]

◦ Tall pilar

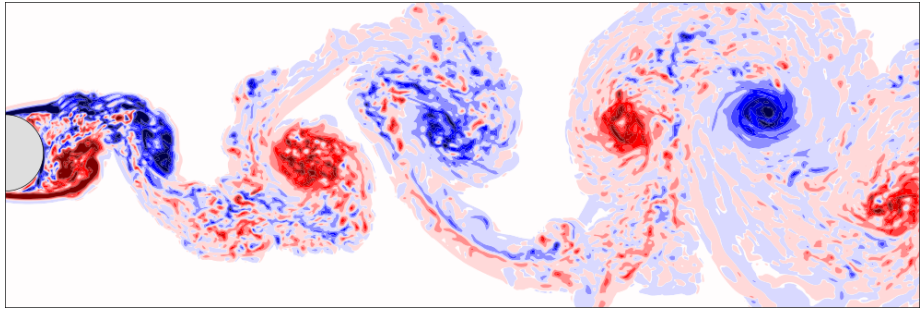
[http://www.ewea.org]

◦ Aircraft wing

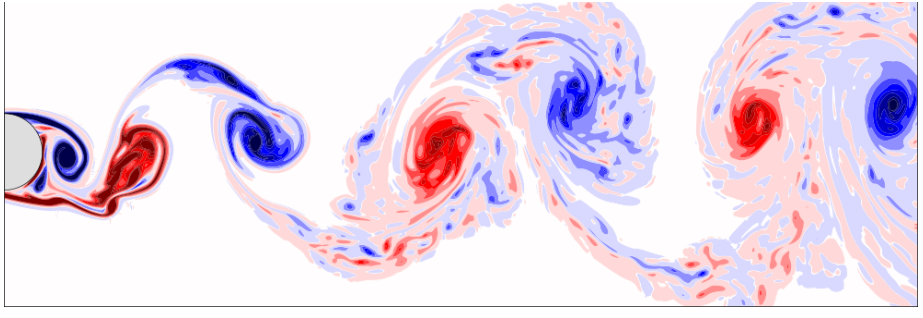
[https://en.wikipedia.org/wiki/Aspect_ratio_(aeronautics)]

Spanwise-averaged Navier-Stokes equations: $\langle 3\text{-D} \rangle = 2\text{-D} + \mathcal{S}^R$

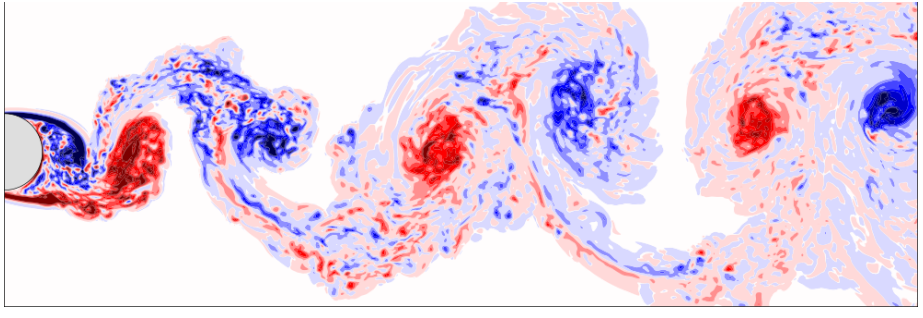
$\langle 3\text{-D} \rangle \ (t_0^*)$



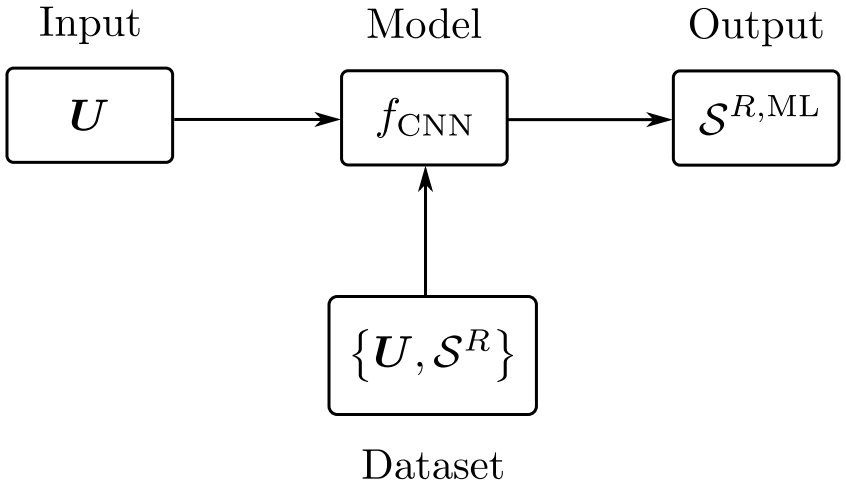
2-D $(\Delta t^* = 2)$



SANS : 2-D $+ \mathcal{S}^R$ $(\Delta t^* = 2)$



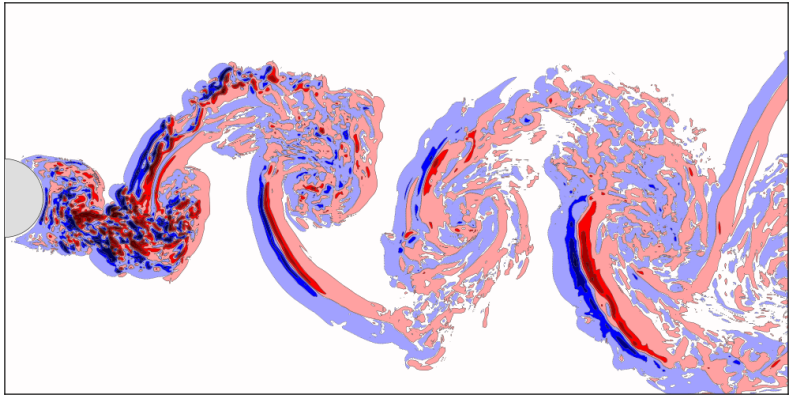
Modelling the SANS stresses through a deep convolutional neural network (CNN)



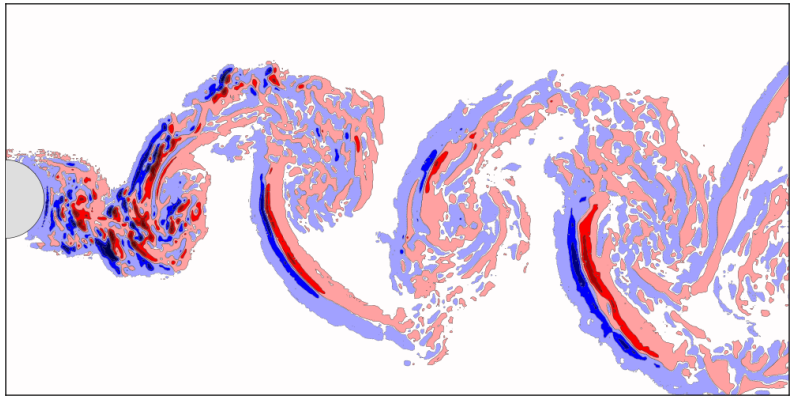
- The CNN can reveal deep correlations for which physics are a-priori unknown.
- Hyper-paremetric analysis on: CNN architecture, loss function, network size, input set, etc...

ML prediction using the best model

$\mathcal{S}_x^R$



$\mathcal{S}_x^{R,\mathrm{ML}}$ (post-processed)



- M3, SSE, 64, 5x5, $\{U, V, P\} \longrightarrow$ CC=89%
- High CC, mid- and large-scale structures correctly captured.

Remarks

- Adding the SANS stresses in a 2-D simulation recovers the spanwise-averaged flow solution.
- EVM cannot provide a physical closure to SANS.
- Modelling the SANS stresses with a CNN yields 89% correlation w.r.t. target data.
- The ML closure presents stability challenges for an a-posteriori set-up.

Download the presentation!

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