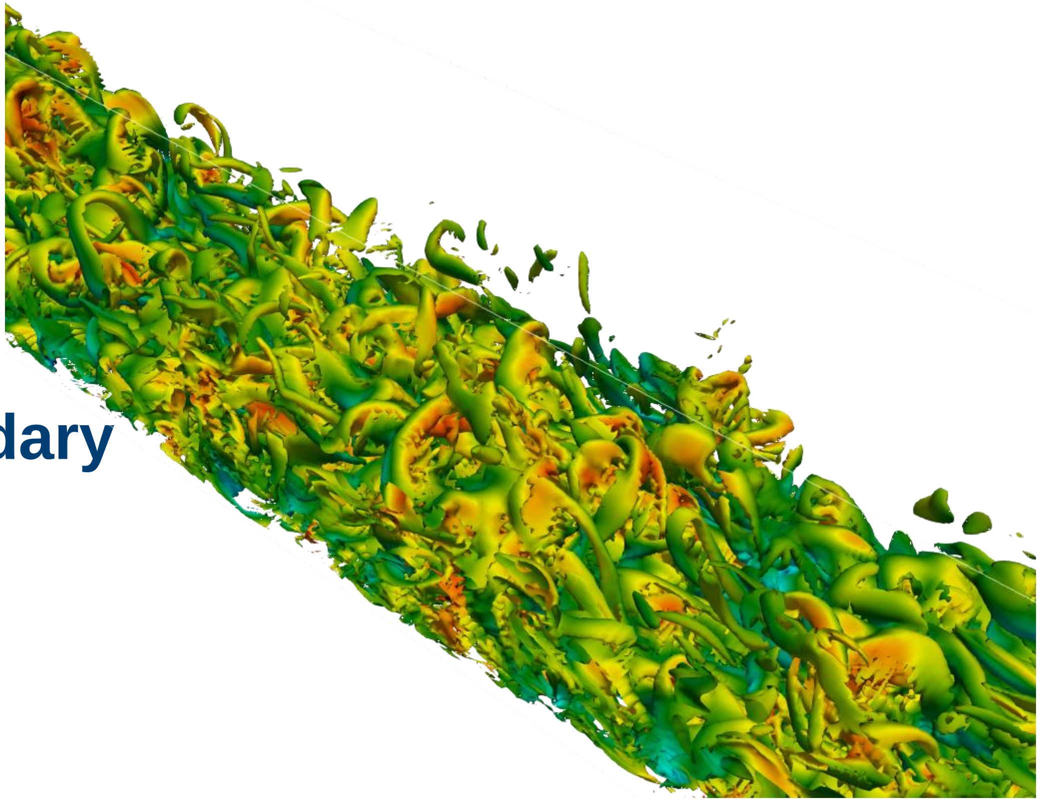
Imperial College London

Bayesian Optimisation of Wall Blowing for Drag Reduction of a Spatially Evolving Turbulent Boundary Layer



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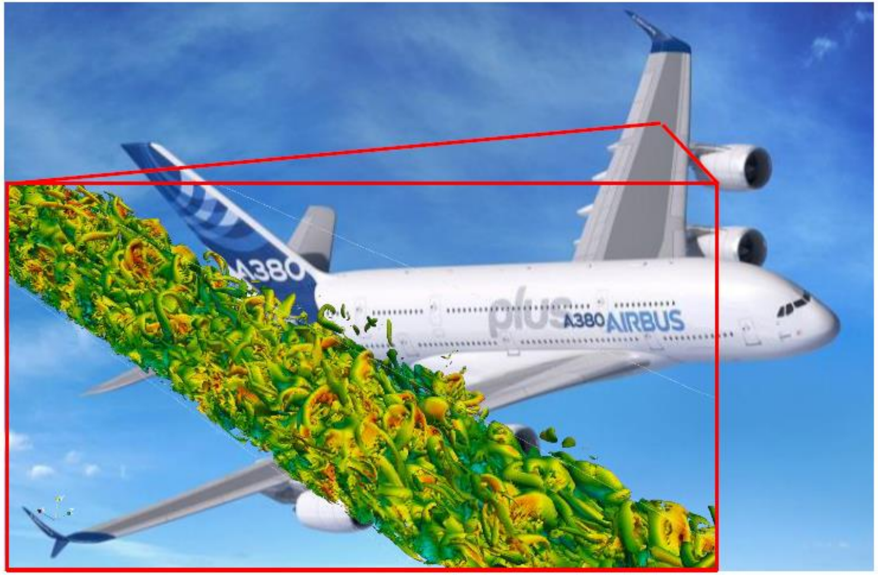
Introduction



- In the vicinity of a moving surface, the fluid can be full of small eddies that leads to a significant increase of the fluid friction on a surface (Skin-friction)
- Around 50% of the power consumption on aircraft is due to the skin-friction.
- The skin-friction can be reduced by 80% by uniformly injecting flow from the surface with minimal speed ($0.1\%\ U_\infty$), called **wall blowing**
- However, the net-power saving is very small.
- The aim is to optimise the wall blowing to enhance the net-energy saving

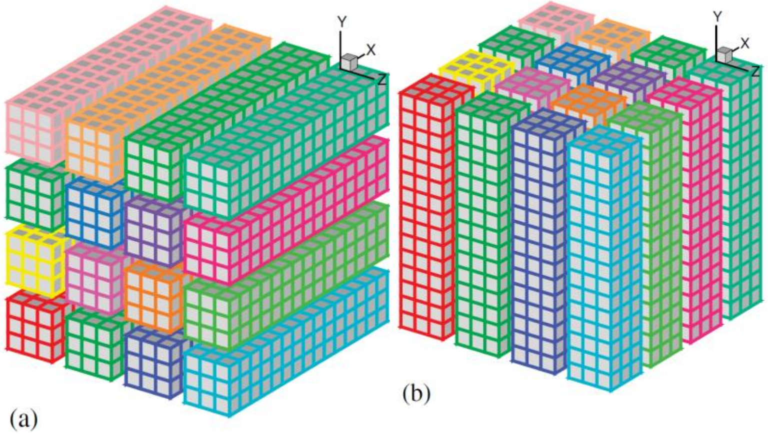
INCOPACT3D

- Fortran code to solve incompressible Naiver-Stokes equations on Cartesian Coordinates:

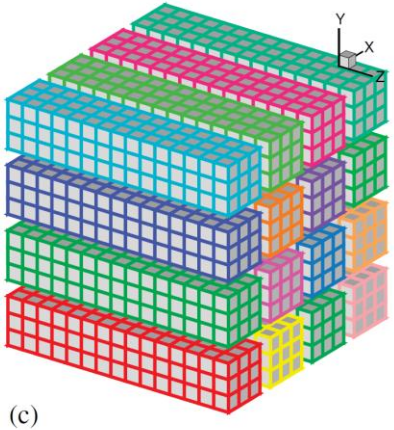
$$\frac{\partial u}{\partial t} + u \cdot \nabla u + \frac{1}{\rho} \nabla p - \nu \nabla^2 u = 0,$$

$$\nabla \cdot u = 0,$$

- Semi-spectral code that utilises FFT with 6th order accuracy compact finite difference
- 2D decomposition of the computational domain is used
- Highly efficient and scalable code up to $O(10^5)$ computational Cores



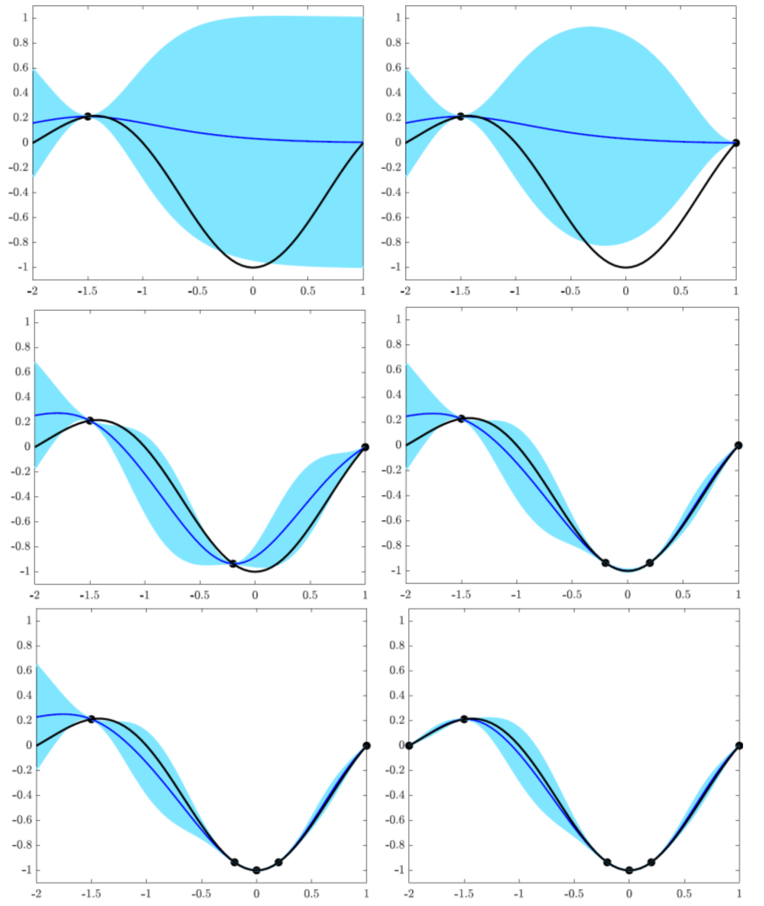
(a) (b)



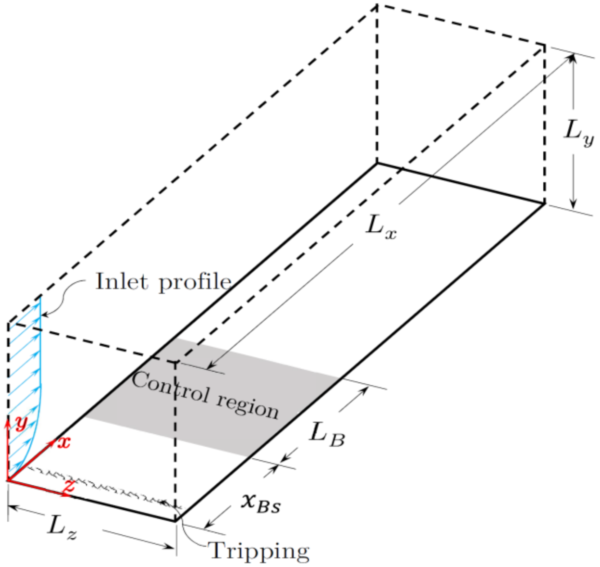
(c)

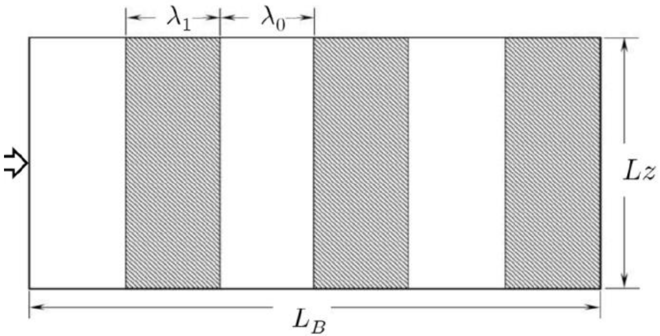
Bayesian Optimisation

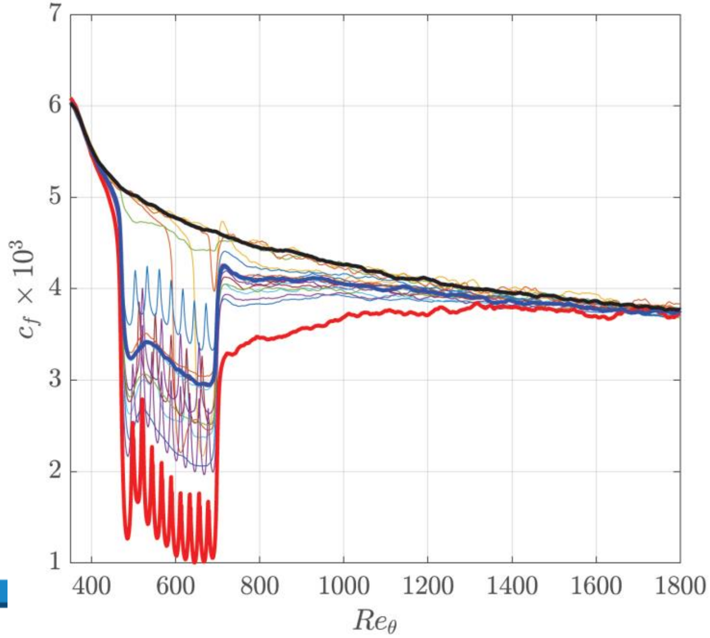
- Very efficient in dealing with non-convex and costly objective functions
- One simulation takes 72 hours on 2048 cores (~150,000 CPU hours)
- The Gaussian process is used to create a probabilistic model of the objective function, then a trade-off between **exploration** and **exploitation** determine the next evaluation point.



Results







- The optimised parameters are λ_1, λ_2 and blowing velocity
- The optimisation converged after 13 evaluations
- The optimum net-energy saving is 5% with maximum local drag reduction of 40%