eNWT - Academic example

DNS of flow over multiscale obstacles

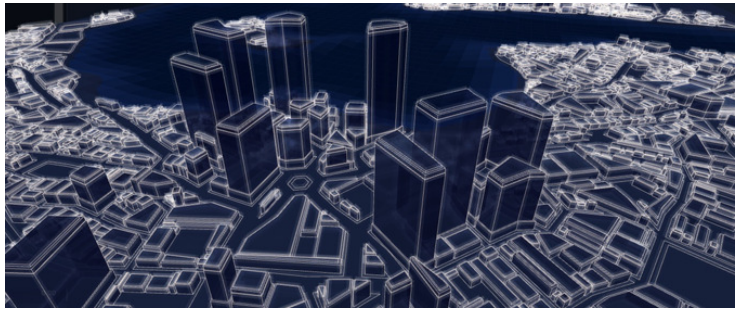
September 20, 2016

A*STAR IHPC

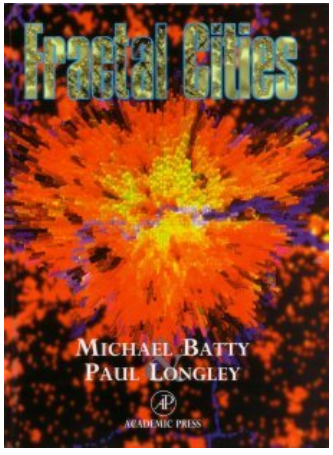
Flow over multi-scale obstacles*

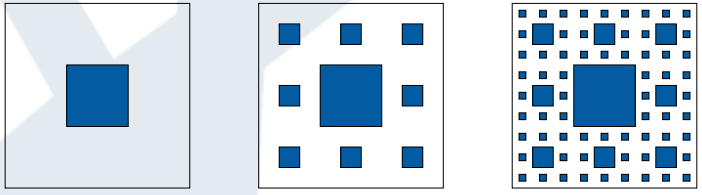
Collaboration with Dr. Wernher Brevis, University of Sheffield

- Complex porous systems, i.e. urban and vegetated areas are well represented using fractals
- Quantification of the role of fractal geometry on flow properties
- Sierpinski carpet patterns → as idealised cities



Source: Introversion games





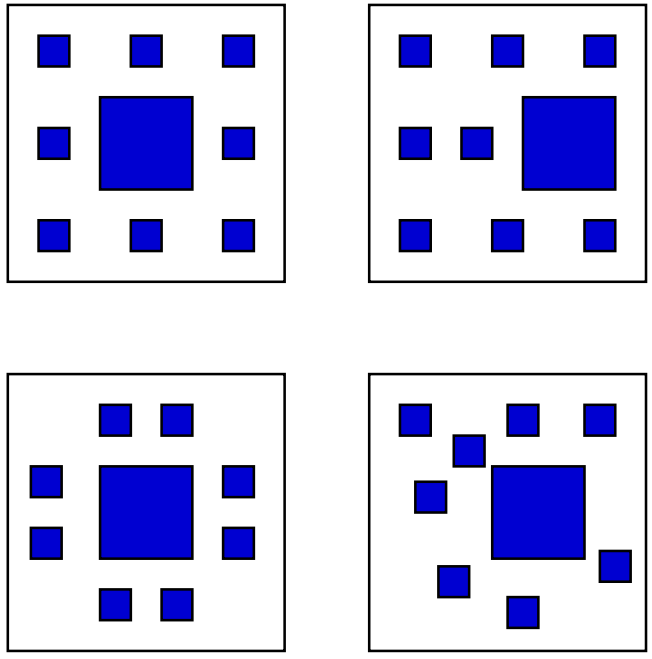
*Wise, D.J. and Brevis, W., *Experimental and numerical assessment of turbulent flow through arrays of multi-scale, surface-mounted cubes*, Inaugural UK Fluids Conference, London, UK. (2016)

A*STAR IHPC

Flow over multi-scale obstacles

Collaboration with Dr. Wernher Brevis, University of Sheffield

- We can keep the same frontal area, plan area, porosity, etc.
- Vary fractal parameters such as lacunarity, succolarity, tortuosity instead†
- How does the appearance of coherent structures → link to these parameters
- Can we find a roughness relationship in fractal space

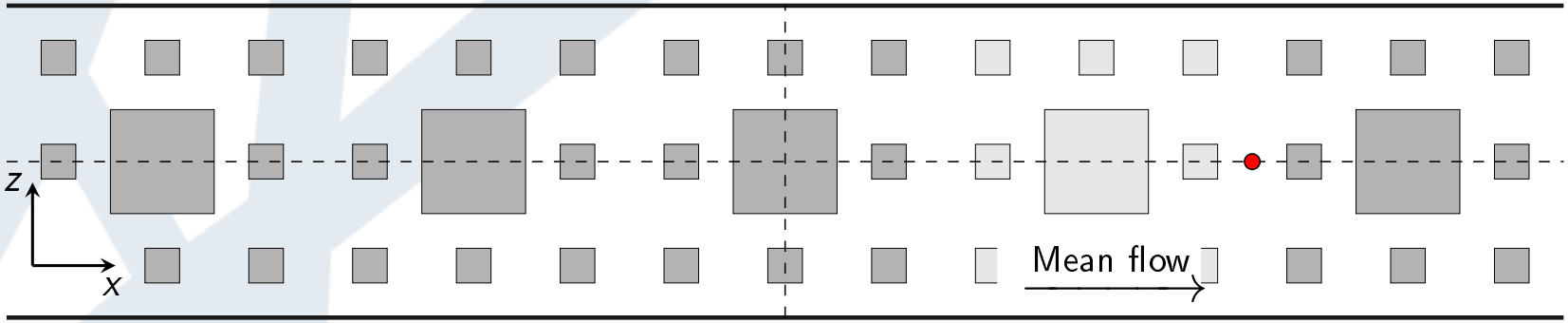


† Lacunarity → spatial heterogeneity, Succolarity→connectivity between porous channels
Tortuosity→'twistedness' of porous channels

A*STAR IHPC

Experimental set-up

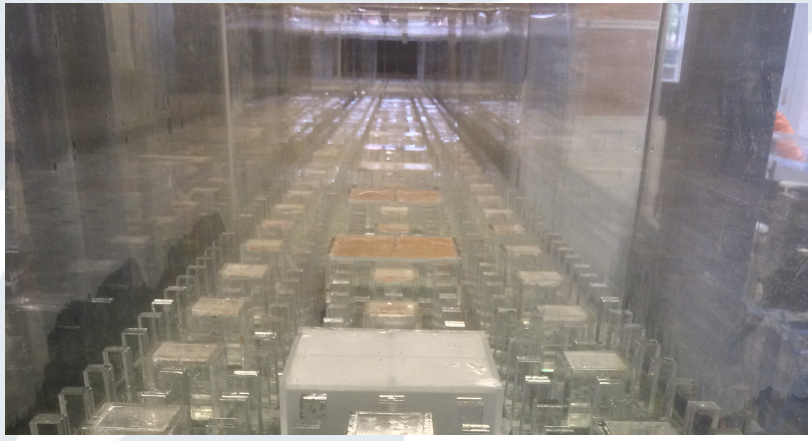
- Performed in Dept. Civil and Struct. Eng., University of Sheffield
- 18m open-channel water flume, 0.486m wide, h^*=0.3m, $Re_b = U_b^* h^* / \nu^*$=30,000
- Periodic obstacle arrays fabricated from laser-cut perspex

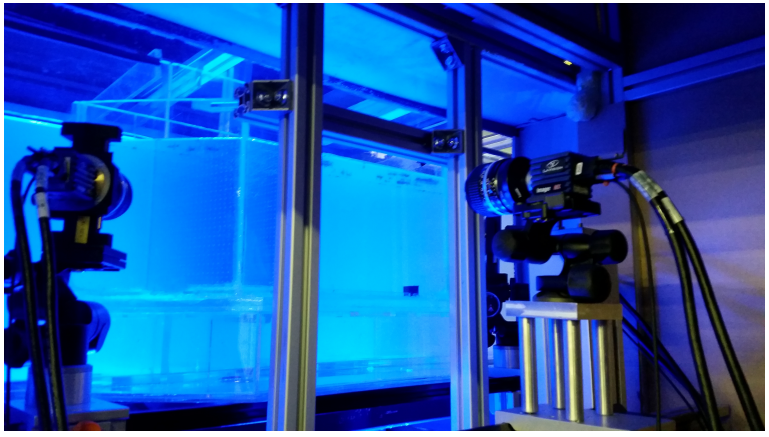


IHPC
A*STAR

Experimental set-up

- Tomographic PIV measurements
  - 100Hz, double-frame, Δt^*=210s $\rightarrow$ Δt=122h^*/U_b^*
- Point measurements, Acoustic Doppler Velocimeter (ADV)

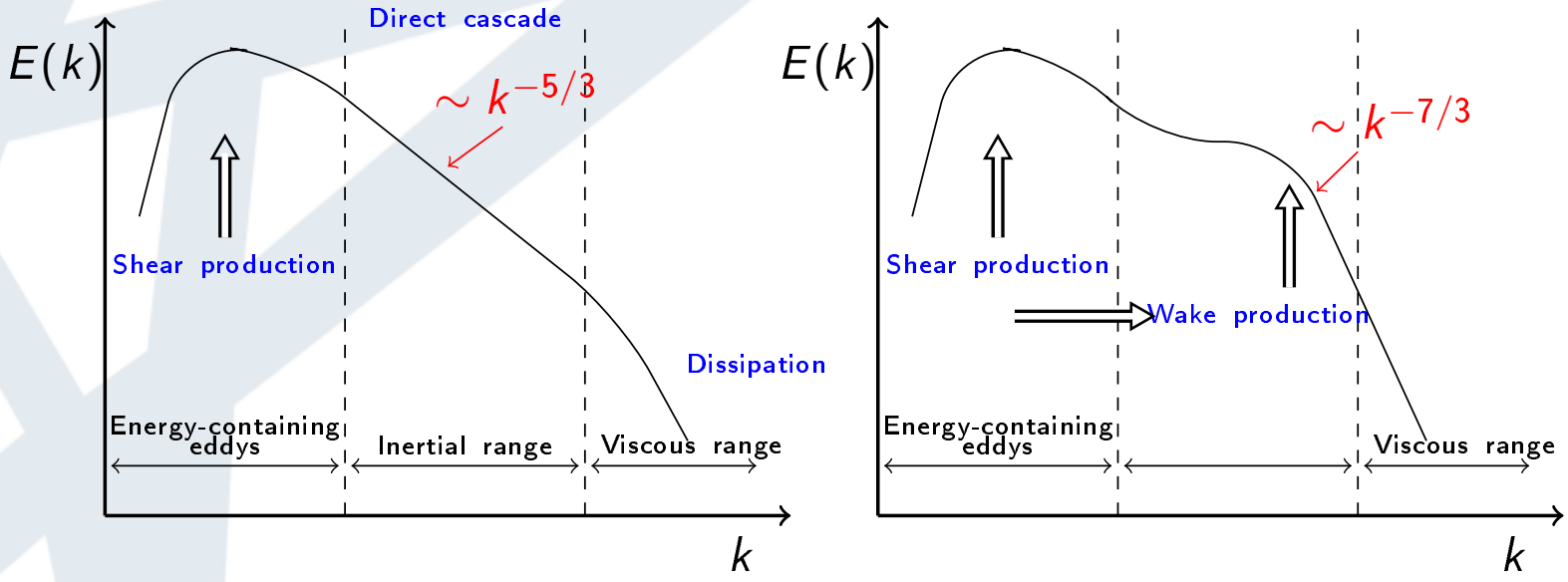




A*STAR IHPC

Numerics

- Open-source DNS code *Incompact3d* [‡] - solves the incompressible Navier Stokes equations on a Cartesian mesh
- Sixth-order compact finite difference, Poisson equation solved in spectral space
- Obstacles implemented with immersed boundary method
- Periodic domain, number of grid points from 74M-590M

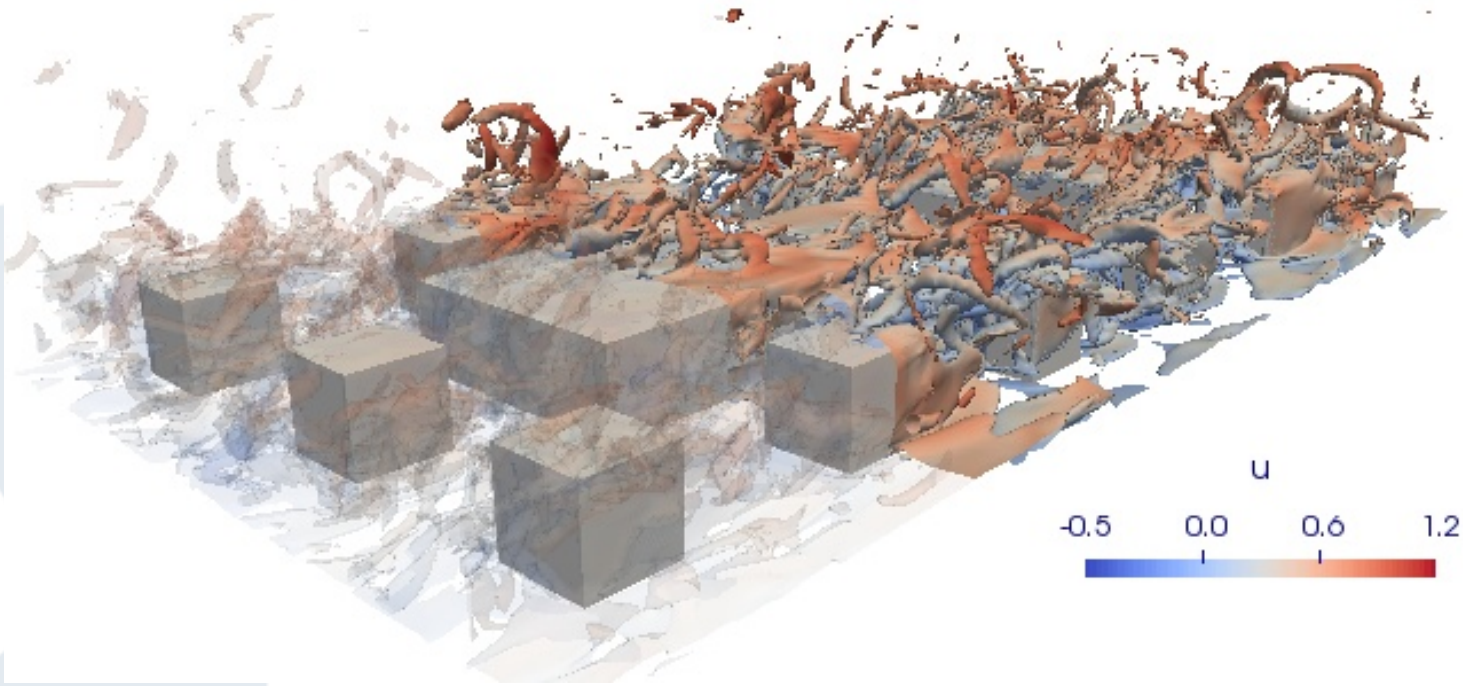


[‡] Laizet, S. and Li N., *Incompact3d: a powerful tool to tackle turbulence problems with up to $\mathcal{O}(10^5)$ computational cores*, Int. J. Comp. Fluid Dyn., 28, (2011)

A*STAR IHPC

Results

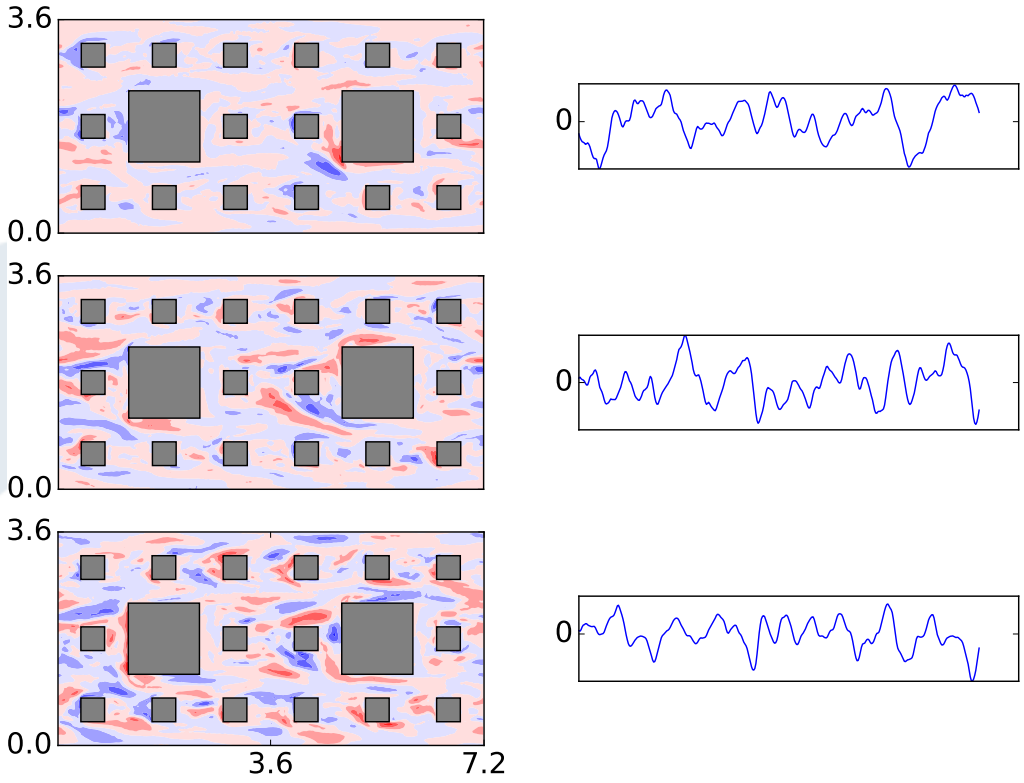
- How do we complement the experiments?
- What are we looking for? From there we decide the appropriate analysis technique.



IHPC
A*STAR

Results
Strong wind events

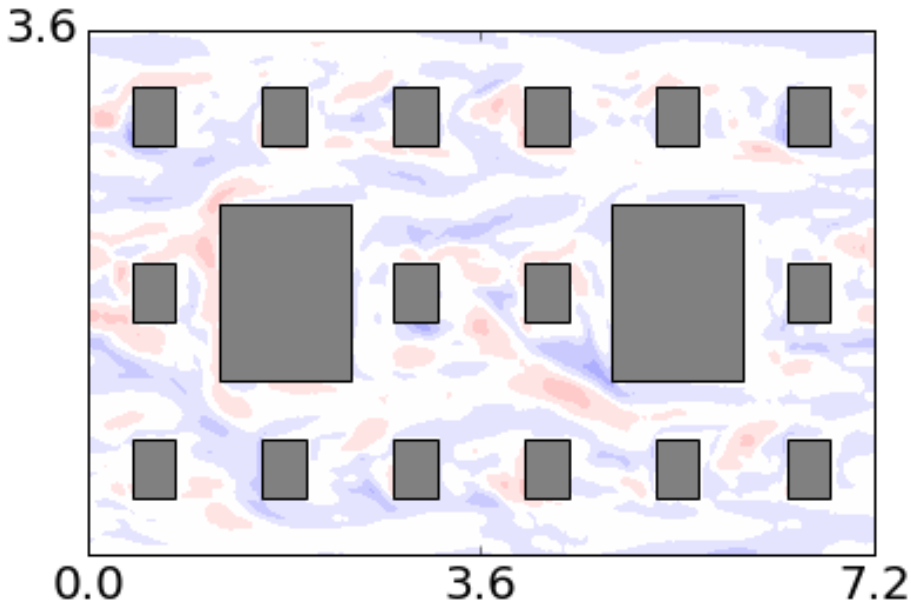
- One option is modal decomposition
- We can look for areas which experience 'gusty' events
- We can find out how frequent they occur, and how strong they are



IHPC
A*STAR

Results
Strong wind events

- One option is modal decomposition
- We can look for areas which experience 'gusty' events
- We can find out how frequent they occur, and how strong they are



IHPC
A*STAR

Summary

- Simulations have been performed to complement and validate water-channel experiments at UoS
- DNS necessary in this case due to augmented energy spectra
- Once the simulations are validated, we can obtain results for multiple block arrangements - *no matter how complex the arrangement*

A*STAR IHPC

Summary

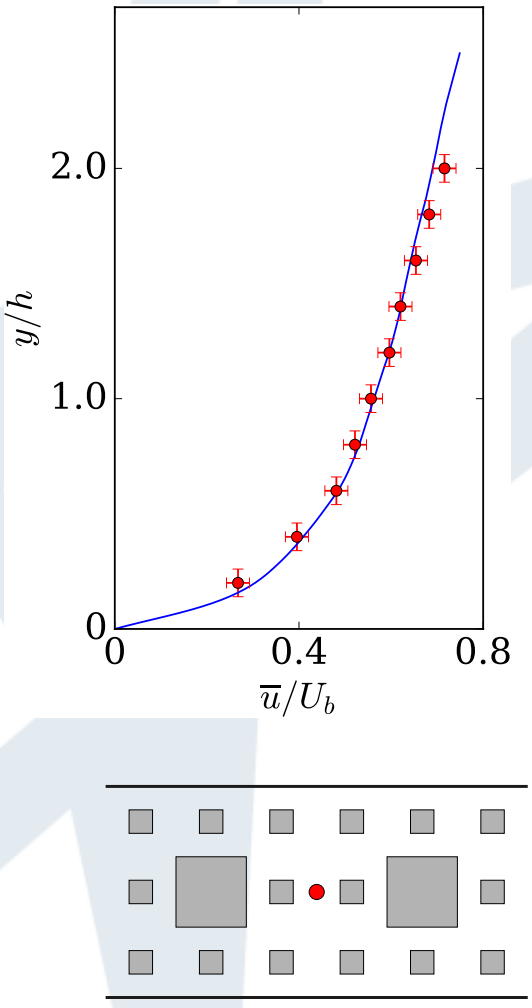
- Simulations have been performed to complement and validate water-channel experiments at UoS
- DNS necessary in this case due to augmented energy spectra
- Once the simulations are validated, we can obtain results for multiple block arrangements - *no matter how complex the arrangement*

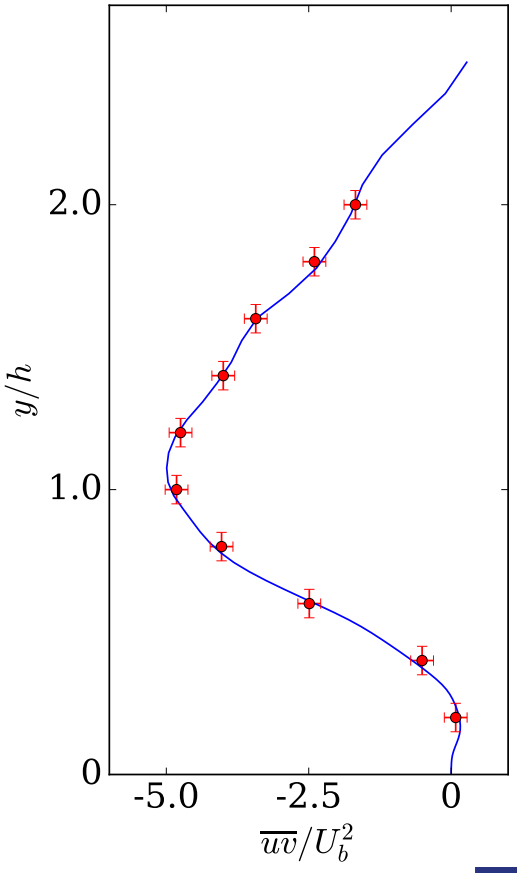
Thank you!

IHPC
A*STAR

Example validation

- Validation of simulations with point profiles - only $\overline{u}$, $\overline{u'v'}$ shown





IHPC
A*STAR