

# Simulations of turbulence past realistic, rough surfaces.

archer

XSEDE

Extreme Science and Engineering **Discovery Environment** 







# Southampton

# **ARCHIE**-WeSt

**Academic and Research Computer Hosting Industry and Enterprise** in the West of Scotland





Engineering and Physical Sciences **Research Council** 



# **Engineering significance of surface roughness**

Roughness occurs in nature and industry across multiple scales.



Fig 1: Naturally-occurring multi-scale roughness.

Fig 2: Numerically-generated multi-scale roughness.

• In this work, turbulence is simulated past realistic, rough surfaces.



## Simulation set up & workflow



**1)** Synthesise roughness with specified statistical properties.



**2)** Enforce rough boundaries using an embedded boundary method.





 $\begin{array}{lcl} \displaystyle \frac{\partial u_i}{\partial t} + u_j \frac{\partial u_i}{\partial x_j} & = & \displaystyle -\frac{\partial p}{\partial x_i} + \frac{1}{R_\tau} \frac{\partial^2 u_i}{\partial x_j \partial x_j} \\ & \\ \displaystyle \frac{\partial u_i}{\partial x_i} & = & 0 \end{array}$ 

3) Set up a rough-wall channel flow configuration.

**4)** Simulate turbulence between rough walls by solving the Navier-Stokes equations.

• Fully-resolved simulations of roughness and turbulence are expensive.



# **High-Performance Computing Aspects**

- F90 + MPI
- Finite-volume
- Structured mesh

HIE-WeSt

sting Industry and Enterprise

- Multi-grid
- MPI IO



Fig 3: 3-D Domain Decomposition via MPI

#### Archie-WeSt: Tier 2 HPC

- Established in March 2012.
- ~ 6-core Dual Xeon processors.
- ~ 3500 total cores.
- ~ ~ 38 Teraflops peak performance.

### Archer: Tier 1 HPC

- Established in November 2013.
- ~ 12-core Intel Ivy Bridge processors.
- ~ 120,000 total cores.
- ~ 2.5 Petaflops peak performance.



Fig 4: Strong scaling test performed on Archer.



## Preliminary simulations: Turbulence past rough walls



 Preliminary simulations using modest computational (~ 35 million cells) and small core count (~128 cores).

## On going and future simulations

 In order to simulate turbulence past rough walls at industrially-relevant flow conditions much larger computational mesh (~ 1 billion cells) and resources (~ 4096 cores) will be used.