Science & Technology Facilities Council

LES of a simplified HVAC system used for aero-acoustic predictions

S. Rolfo[1]
C. Moulinec [1] D. R. Emerson [1]

[1]STFC Daresbury Laboratory, Warrington, Cheshire WA4 4AD, United Kingdom
stefano.rolfo@stfc.ac.uk

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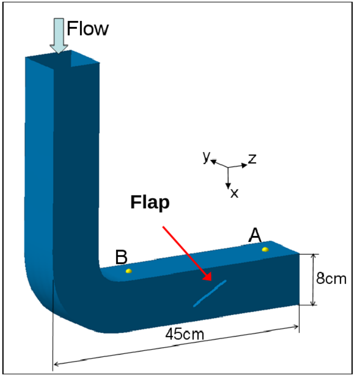
Overview

1. Heat and Ventilation Air Conditioning: HVAC
   - Introduction
   - Flow Features
   - Acoustic
2. Paraview in a Visualization Cluster (Placement of E. Harrison)
3. Conclusions and Future Work

HVAC: Introduction

HVAC

- HVAC stands for Heat and Ventilation Air Conditioning and it is a common system in several engineering application
- This simplified configuration has been proposed by German car industry for validation of numerical methods
- The system is a composed by a duct bend with a flap
- The duct creates a jet in an open space
- Both experimental data for fluid flow (PIV) and aeroacoustic are available



HVAC: Test case definition

Test case definition

- LES with Smagorinsky model
- Standard air at $15^o\ C$
- Inlet based on a fully developed duct flow computed with RANS model (4 eqs $v^2 f$) with DF-SEM for turbulent fluctuations
  - Bulk velocity $U_B = 7.5\ m/s \Rightarrow Re \approx 40000$
  - Low-Re Reynolds stress model also tested but flow is re-laminarize
- Free inlet/outlet BC at the side and at the exit of the plenum
  - BC based on the Bernoulli relation between the face and a point on the same stream-line place at ∞ in case of incoming flow
  - Homogeneous Neumann is applied on the velocity
  - Assuming $\underline{u}_\infty = 0$ the dynamic pressure at the face is:

$$p_f = -\frac{1+K}{2}\rho_f \underline{u}_f \cdot \underline{u}_f$$

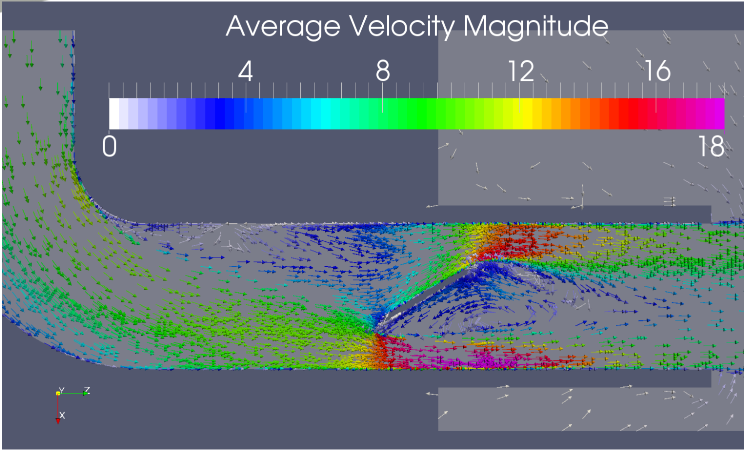
with K being a head loss.

Flow Visualisation

(Loading movie)

Figure 1: Iso-surfaces of Vorticity.

Mean Flow (Mid Plane)



- Flow separation after the bend
- Impingement of the separated flow on the obstacle
- Recirculation behind the obstacle
  - Two counter-rotating vortices

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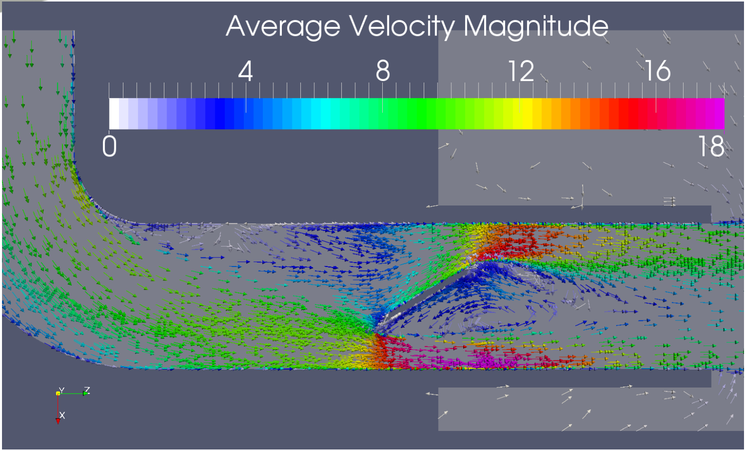

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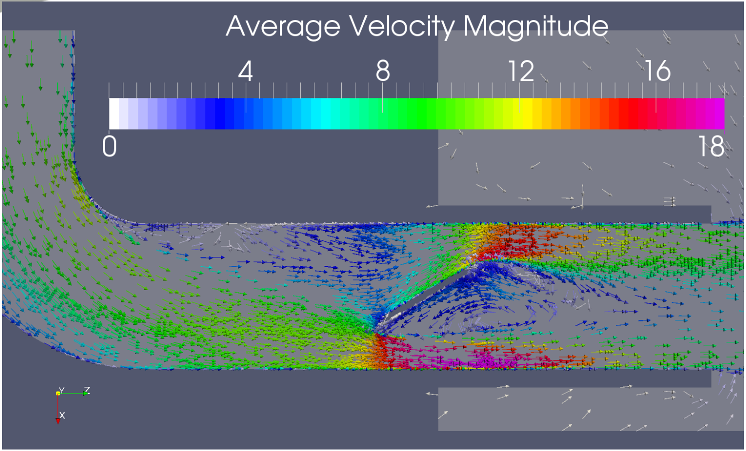

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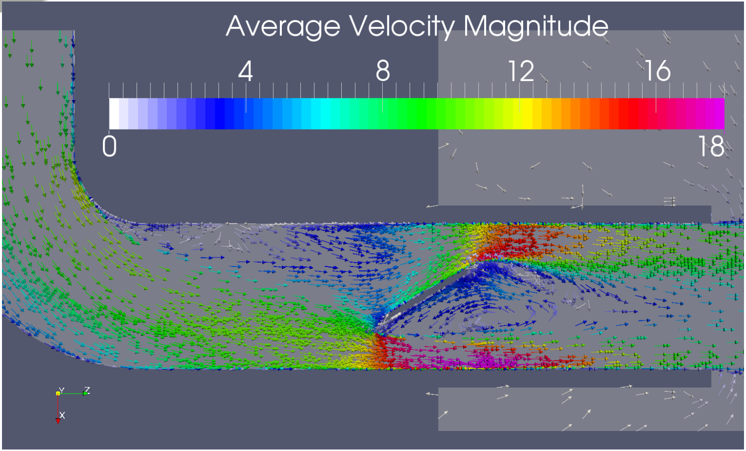

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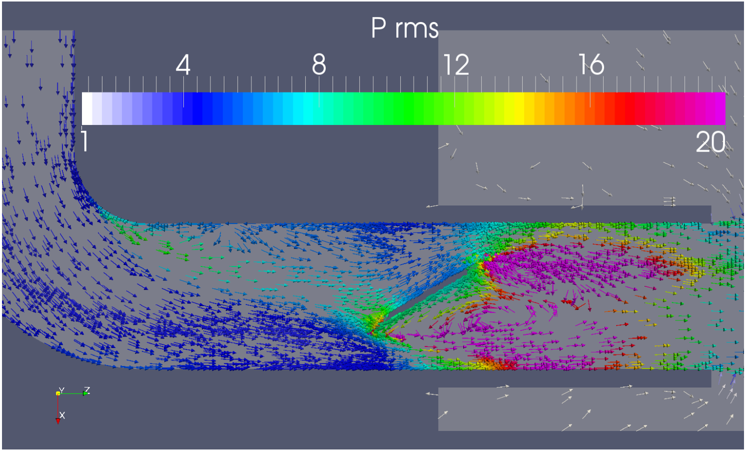
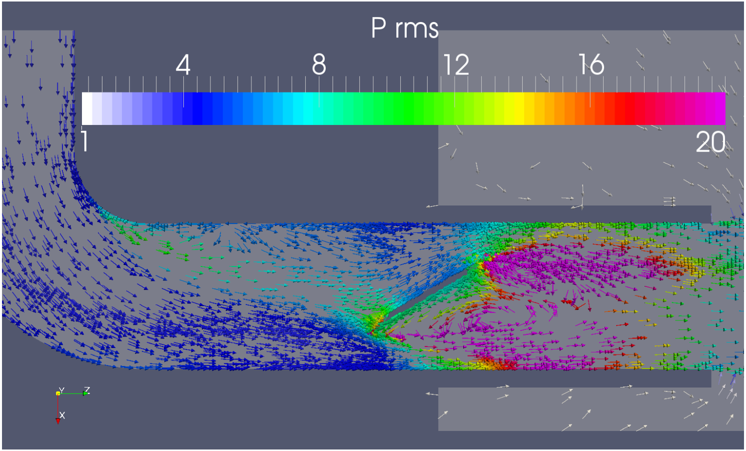
Pressure RMS (Mid Plane)



- Pressure fluctuations are peaking in recirculation areas
- These areas are candidate to be the location of the noise sources

Pressure RMS (Mid Plane)



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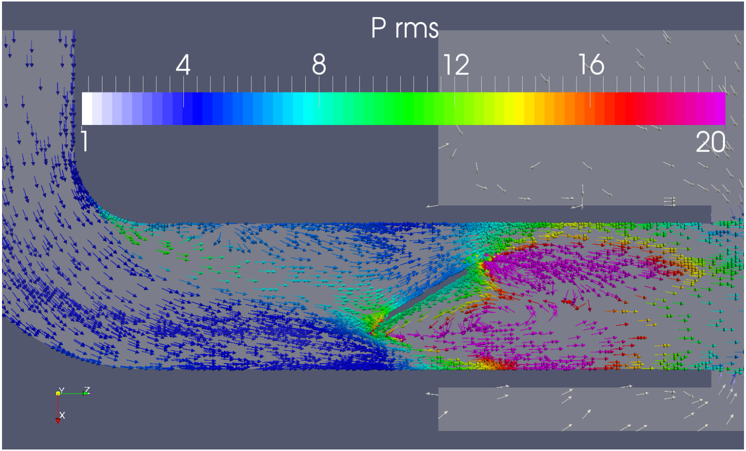

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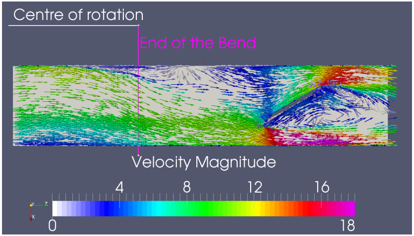
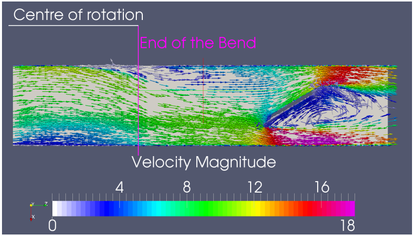
3D effets
XZ plane (obstacle plane)

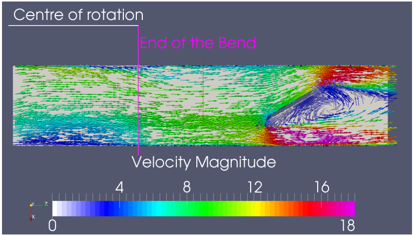
Mid Plane



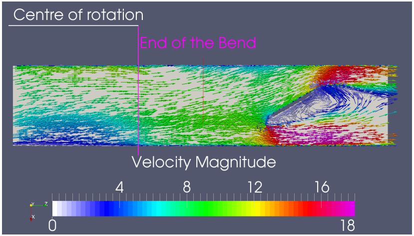
$2y/D_H = 0.5$



$2y/D_H = 0.75$



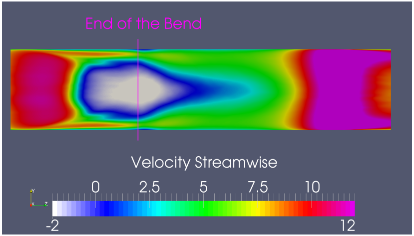
$2y/D_H = 0.85$



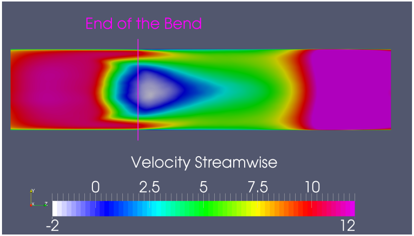
3D effets

YZ plane (View from bending centre)

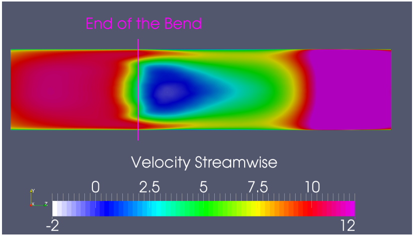
Top wall $x/D_H = 0.01$



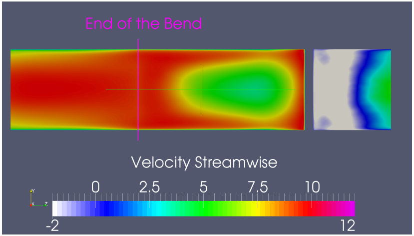
$x/D_H = 0.06$



$x/D_H = 0.125$



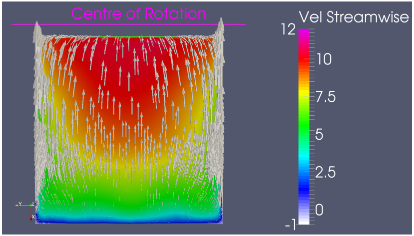
$x/D_H = 0.375$



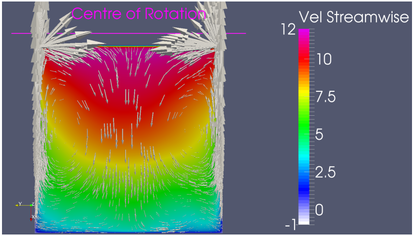
3D effets

XY plane (Streamwise)

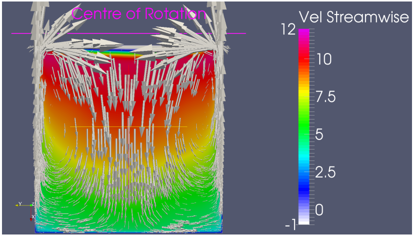
Inlet bend $\theta = -90^o$



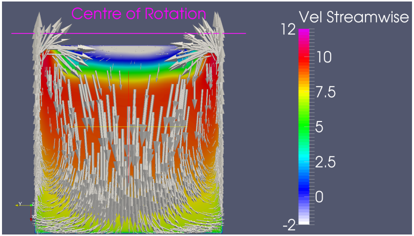
$\theta = -60^o$



$\theta = -30^o$



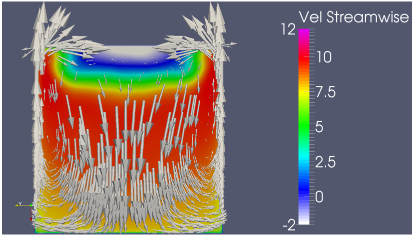
Outlet bend$\theta = 0^o$



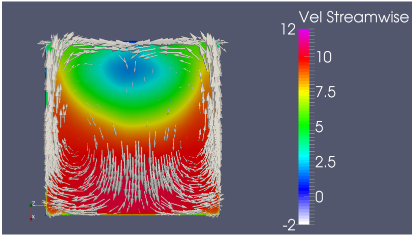
3D effets

XY plane (Streamwise)

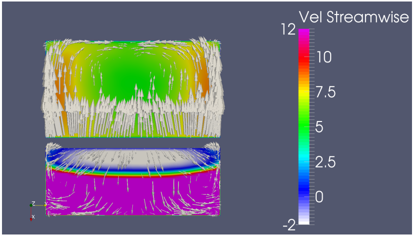
Near outlet bend $z/D_H = 0.125$



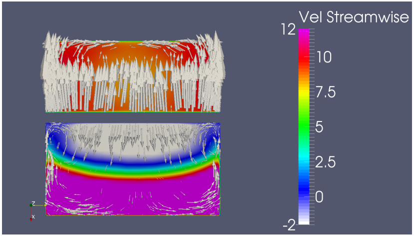
$z/D_H = 1.0$



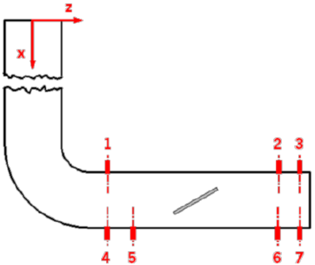
$z/D_H = 1.75$

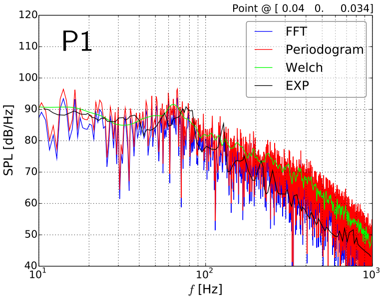


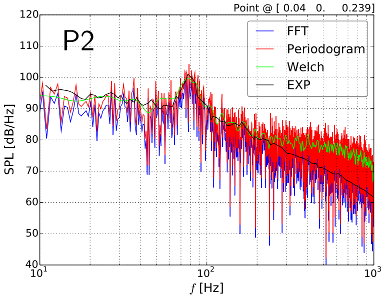
$z/D_H = 2.0$

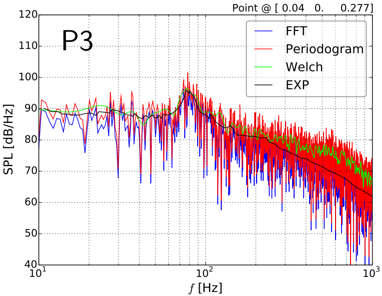


Wall pressure fluctuations









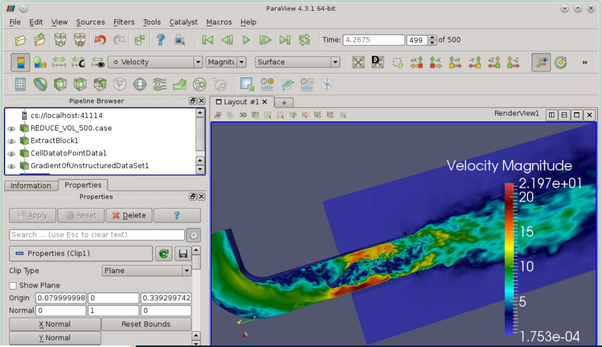
Paraview on a cluster

Why Paraview?

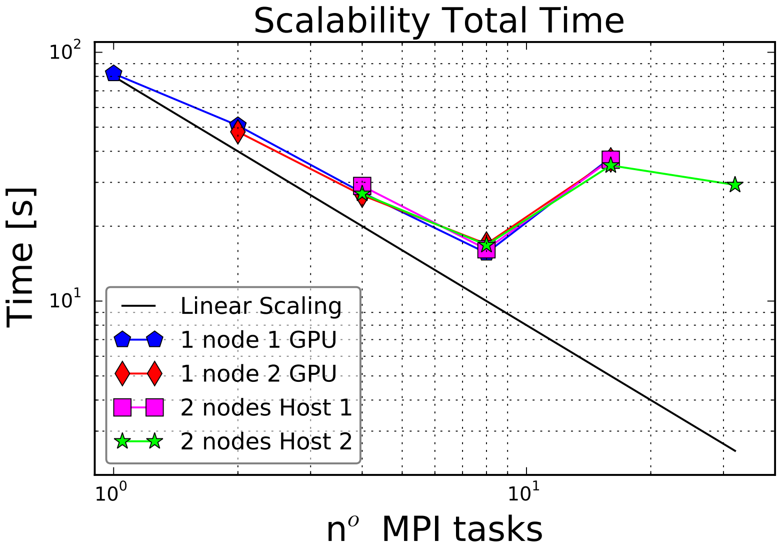
- It is not always possible to use co-processing (i.e. Catalyst)
- Possible to use remote machines with Client/Server mode
- We have a visualization cluster: maybe we can use it:
  - 2 fat nodes with 32 computing nodes and 64GB RAM
  - 2 GPUs attached to each node

The Pipeline

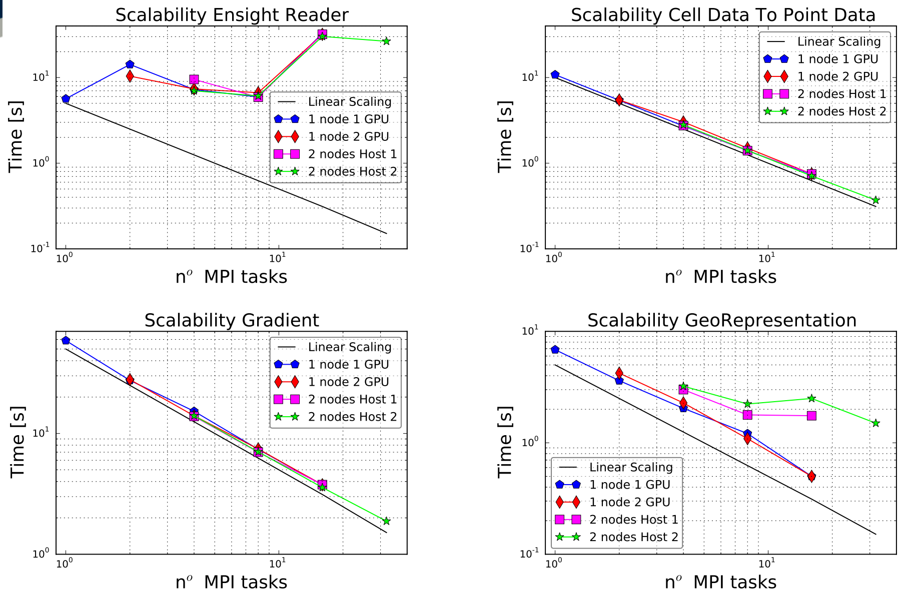
- Load of the data ⇒ **EnsightReader**
- Convert data from cells to nodes ⇒ **CellToPoint**
- Gradient ⇒ **GradUnstructuredMesh**
- Update the layout ⇒ **GeoRepresentation**



Scalability Pipeline in loading a time step



Scalability individual Filters



Conclusions and Future Work

HVAC

- LES of a simplified HVAC has been presented and the available results are in agreement with experimental data available
- Application of Client/Server Paraview mode has been shown and poor scalability of the Ensight reader has been identified

Future work

- Further comparison with experimental value (hydrodynamic)
- Further investigations into aeroacoustic using the Curle's analogy
- More calculations with different SGS models are on going
- Awarding of a 1 year project to implement a FWH aeroacoustic module into *Code_Saturne*