Ercoftac SIG15 testcase V&V 進捗報告

（株）アライドエンジニアリング
ADVC事業部　　北風　慎吾

Motivation

元々はOpenFOAMの自習用に取組み始めたのがきっかけ

第１回OpenFOAM 勉強会 for beginner　　2010/6/27@東京大学

本勉強会への期待ならびにOpenFOAMに期待すること

＊サンプルモデルの共有／公開
(swenden Chalmers univ 、Prof. Jasak etc)

＊validation & verification

＊ ベンチマーク、解析コンテスト

＊C＋＋ & Cプログラミング勉強会？

＊詳細マニュアルの整備(特に物性値関係)

ERCOFTAC(European Research Community of Flow, Turbulence and Combustion)
・・・テーマごとにグループ分けされていて、研究活動が行われている(燃焼・混相・粒子法etc)
その中の乱流モデリングのグループ(SIG15)が過去に開催したworkshopにおいて実施されたベンチマークのデータベースがある

Special Interest Groups

username
password
login

Special Interest Groups

- Large Eddy Simulation
- Turbulence in Compressible Flows
- Environmental CFD
- Transition Modelling
- Dispersed Turbulent Two Phase Flow
- Stably Stratified and Rotating Turbulence
- Turbulence Modelling
- Drag Reduction and Flow Control
- Variable Density Turbulent Flows
- Particle Image Velocimetry
- Reactive Flows
- Transition Mechanisms, Prediction and Control
- Design Optimization
- Multipoint Turbulence Structure and Modelling
- Swirling Flows
- Bio-Fluid Mechanics and Heat Transfer
- Microfluidics and Micro Heat Transfer
- Aeroacoustics
- Smoothed Particle Hydrodynamics (SPH)
- Fluid Structure Interaction
- Synthetic Models in Turbulence
- Fibre Suspension Flows

Special Interest Groups (SIG)

ERCOFTAC Special Interest Groups form the second pillar of the Association. SIG are composed of ERCOFTAC members working together on a well defined specific topic on Flow, Turbulence and Combustion.

Activities of Special Interest Groups are organising Workshops, Comparison of Codes, Exchange of Research Results, Creation of Experimental and/or Numerical Data Bases, Organisation of Courses, ...

ERCOFTAC Special Interest Groups are associated with at least two Pilot Centres, and have an international organising committee.

SIGs are active on the following topics:

SIG 1: Large Eddy Simulation
SIG 4: Turbulence in Compressible Flows
SIG 5: Environmental CFD
SIG 10: Transition Modelling
SIG 12: Dispersed Turbulent Two Phase Flow
SIG 14: Stably Stratified and Rotating Turbulence
SIG 15: Turbulence Modelling
SIG 20: Drag Reduction and Flow Control
SIG 24: Variable Density Turbulent Flows
SIG 28: Reactive Flows
SIG 32: Particle Image Velocimetry
SIG 33: Transition Mechanisms, Prediction and Control
SIG 34: Design Optimization
SIG 35: Multipoint Turbulence Structure and Modelling
SIG 36: Swirling Flows
SIG 37: Bio-Fluid Mechanics and Heat Transfer
SIG 38: Microfluidics and Micro Heat Transfer
SIG 39: Aeroacoustics
SIG 40: Smoothed Particle Hydrodynamics
SIG 41: Fluid Structure Interaction
SIG 42: Synthetic Models in Turbulence
SIG 43: Fibre Suspension Flows

Missing numbers correspond to SIGs no longer believed to be active. All requests for

Latest Forum Posts

ERCOFTAC's new web-site is now launched. SIG and PC...8 October 2010

Welcome to ERCOFTAC discussions. Please post here...8 October 2010

Welcome to ERCOFTAC discussions. Please post here...8 October 2010

Discussion group for Fibre Suspension Flows...17 December 2009

Discussion group for Reactive Flows...17 December 2009

Discussion group for Drag Reduction and Flow Control...17 December 2009

Welcome to ERCOFTAC discussions. Please post here...16 December 2009

Welcome to ERCOFTAC discussions. Please post here to...4 December 2009

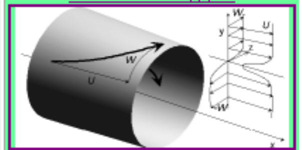
...3 December 2009

Discuss ERCOFTAC web-site issues...1 October 2009

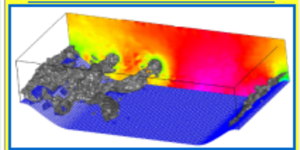
Ercoftac SIG15 test case

10th workshop at University of Poitiers (10-11 October 2002)

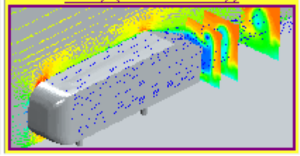
10.1
Contra-rotating jets



9.2
Periodic flow over a 2-D hill



9.4
Flow around a simplified car body (Ahmed body)

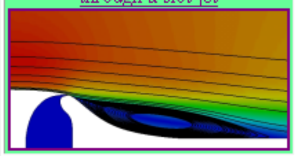


6.2
Fully Developed Flow and Heat

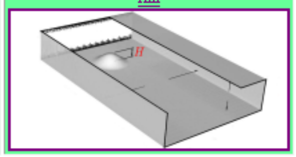
5.3

11th workshop at Chalmers University of Technology (7-8 April 2005)

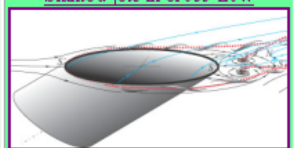
11.1
2D hump with flow control through a slot jet



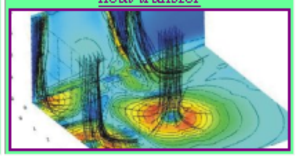
11.2
Flow over an axisymmetric 3D hill



11.3
Slanted jets in cross-flow

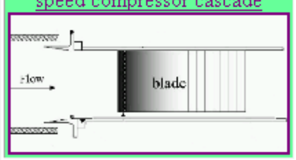


11.4
Multiple-impinging jets: flow and heat transfer

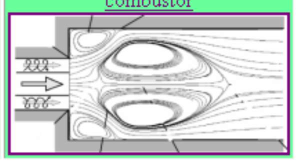


12th workshop at Technical University of Berlin (12-13 October 2006)

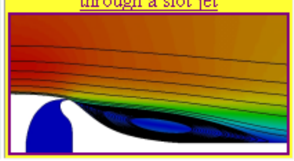
12.1
Tip-gap turbulent flow in a low-speed compressor cascade



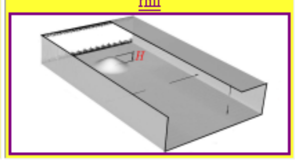
12.2
A model of tubo-annular swirl combustor



11.1
2D hump with flow control through a slot jet

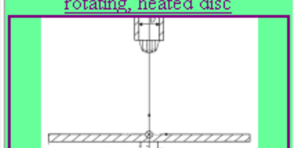


11.2
Flow over an axisymmetric 3D hill

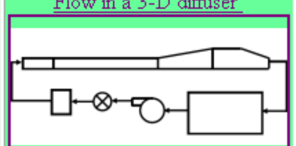


13th workshop at Graz University of Technology (25-26 September 2008)

13.1
Round jet impinging onto a rotating, heated disc

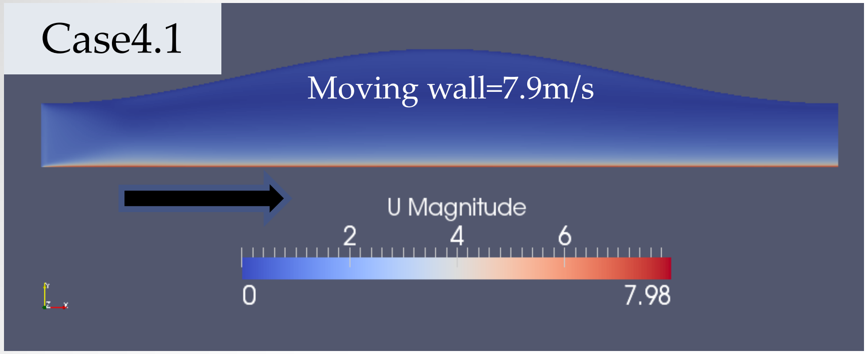


13.2
Flow in a 3-D diffuser

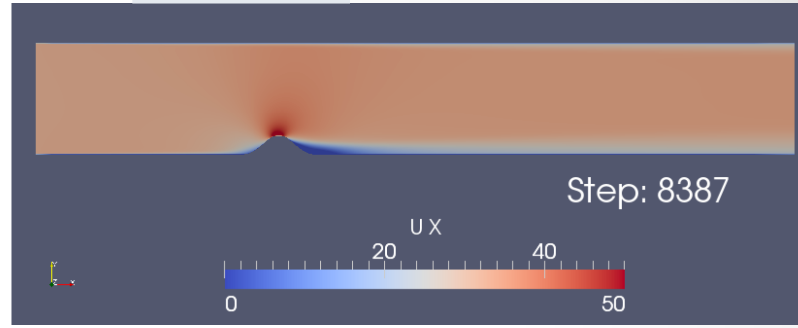


Validation Examples

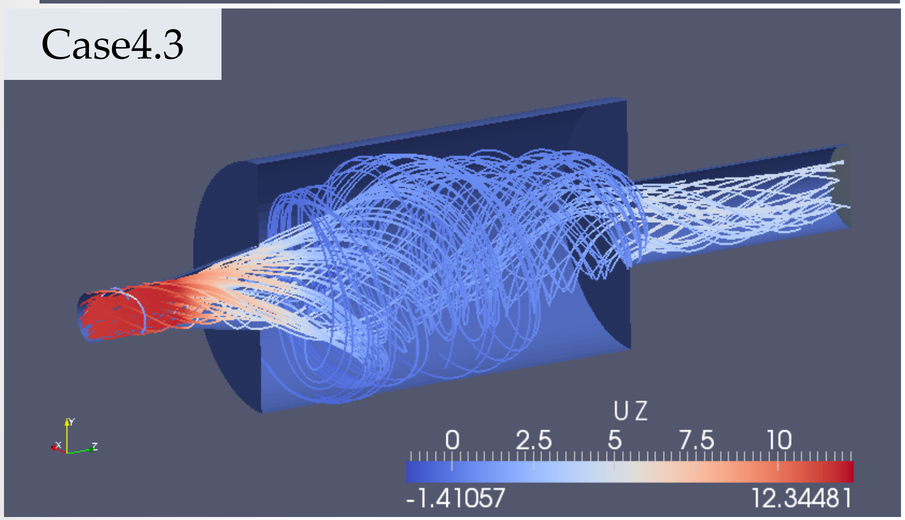
Case4.1

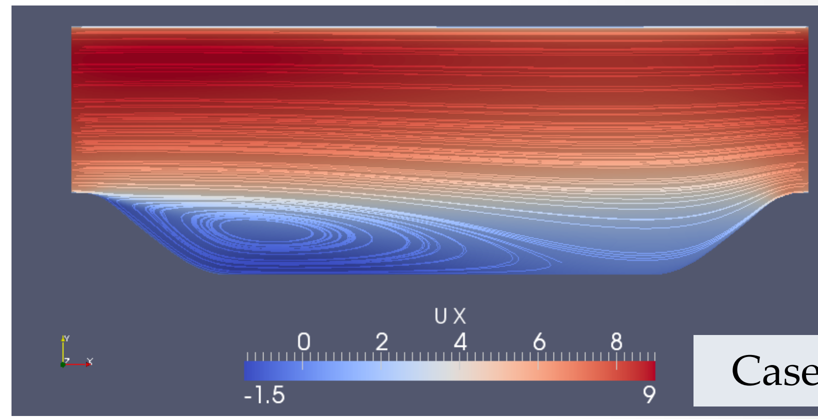


Case4.2

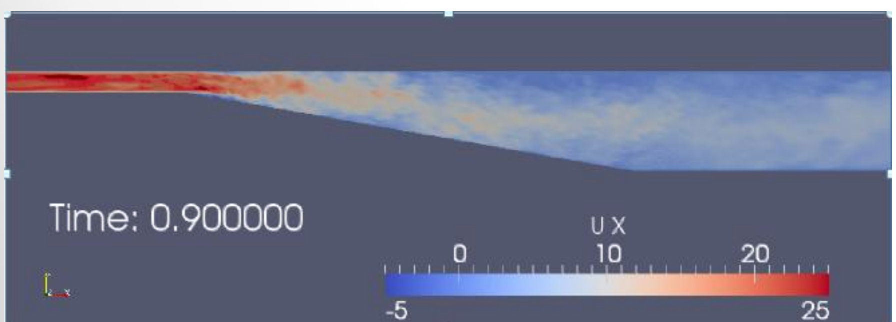


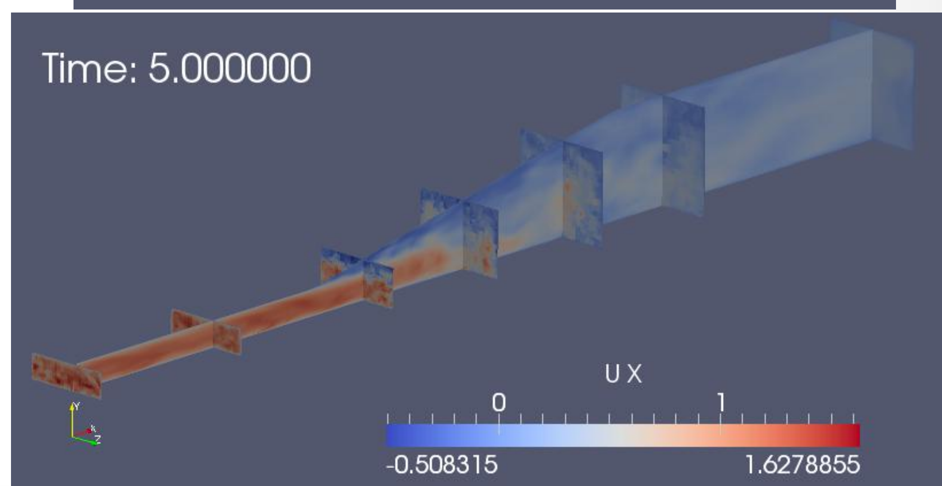
Case4.3





Case9.2

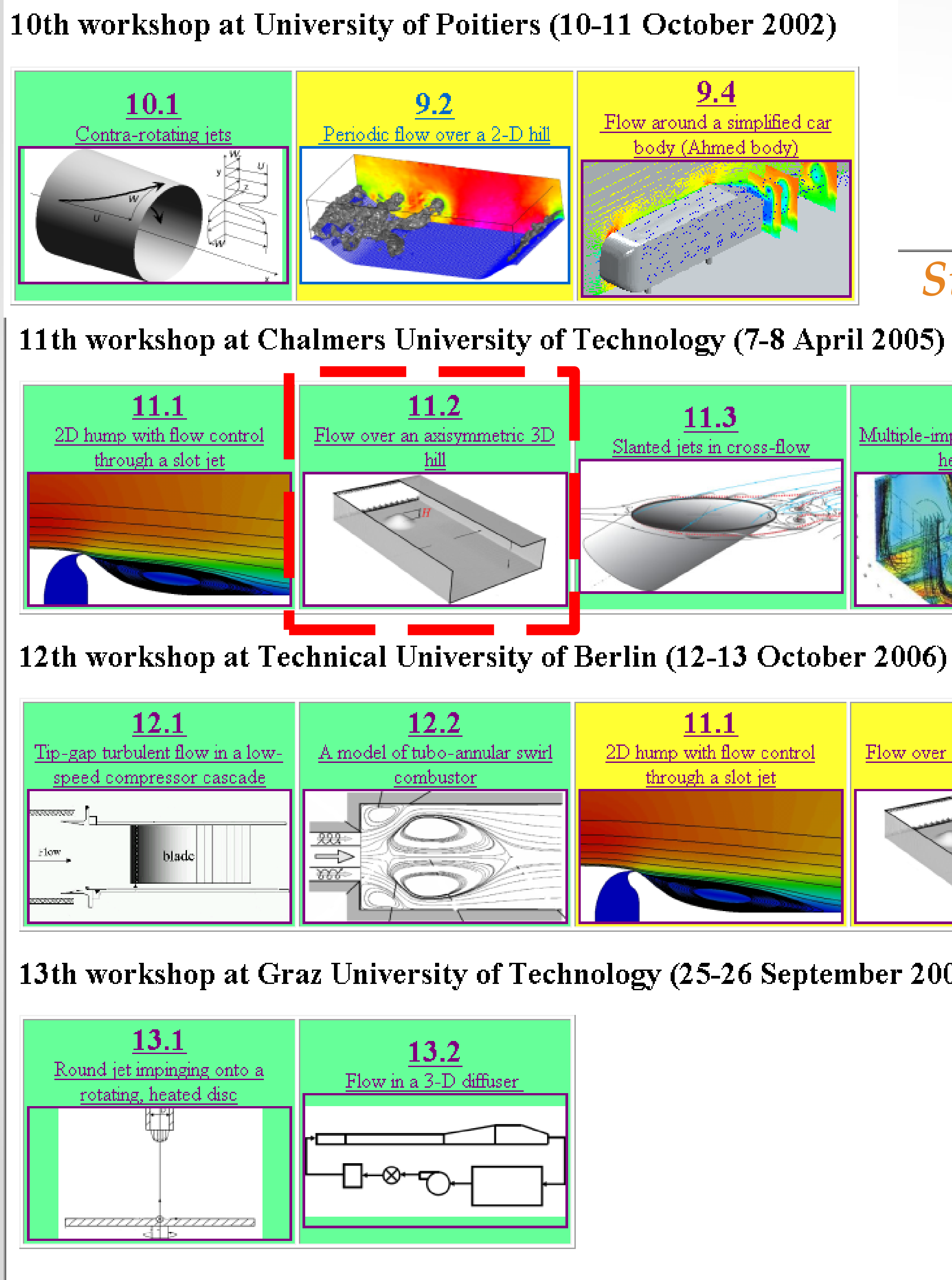




Case8.2

Case13.2

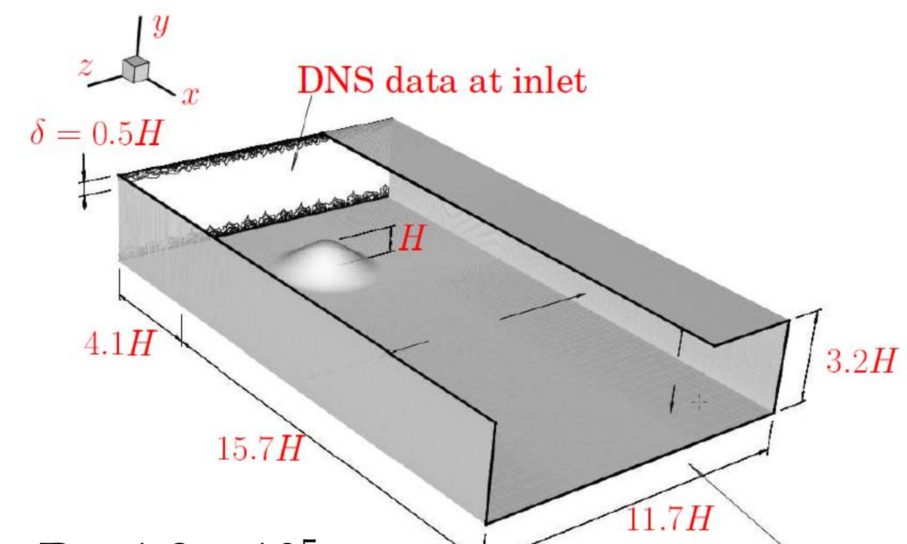
Test case 11.2
Flow over an axisymmetric three-dimensional hill



Structure of Vortical Separations

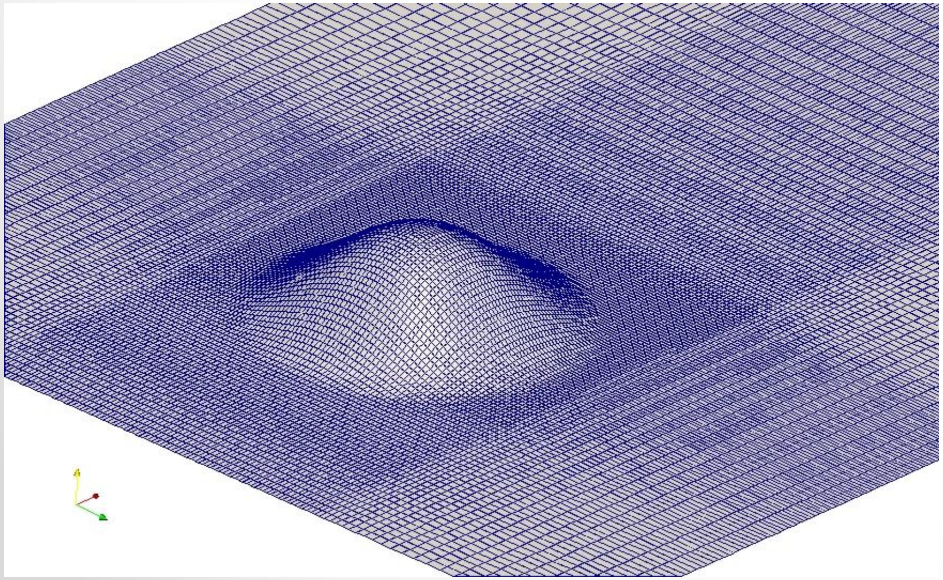
Mesh/BoundaryCondition http://www.tfd.chalmers.se/~lada/3dhill/

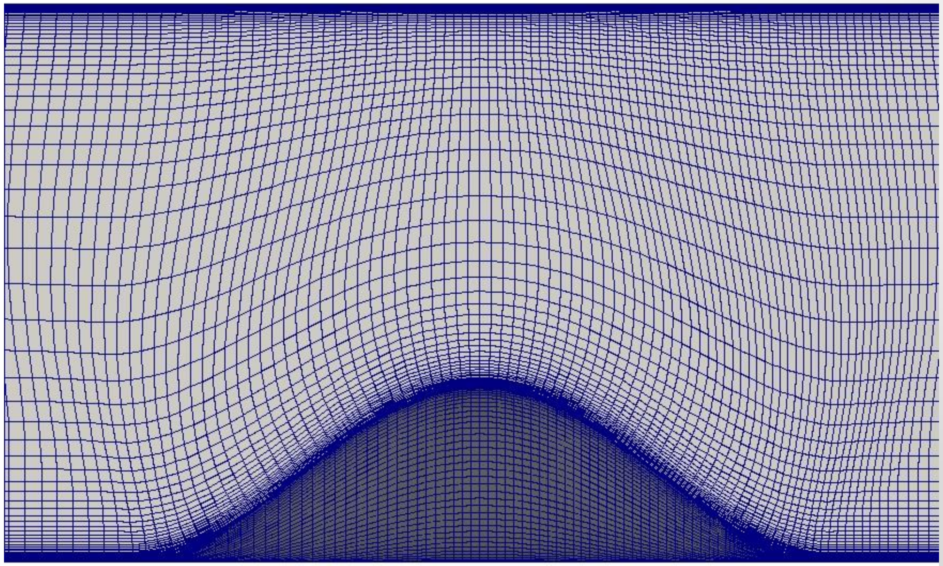
Ref:Lars Davidson, Flomania Final Review,2004



Re=1.3×10^5

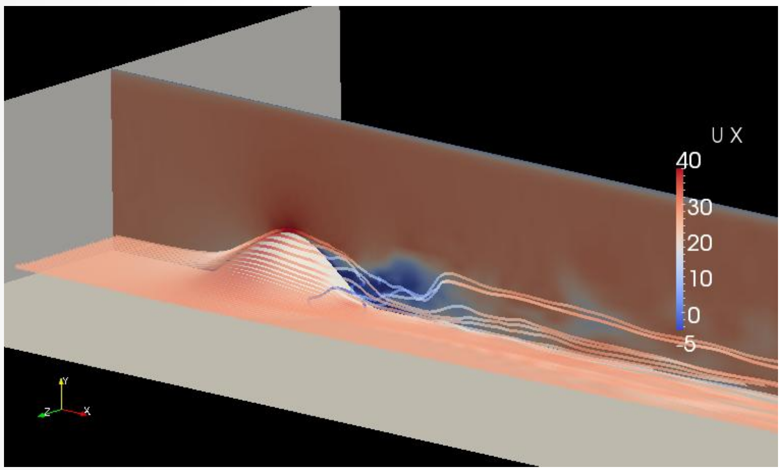
Solver	PisoFoam
Total Cell	1.64 millon
Bump Height	0.078[m]
Free-stream Velocity	27.5[m/s]
Kinetic viscosity	1.65e-5[m^2/s]
LES model	Smagorinsky
delta	vanDriest

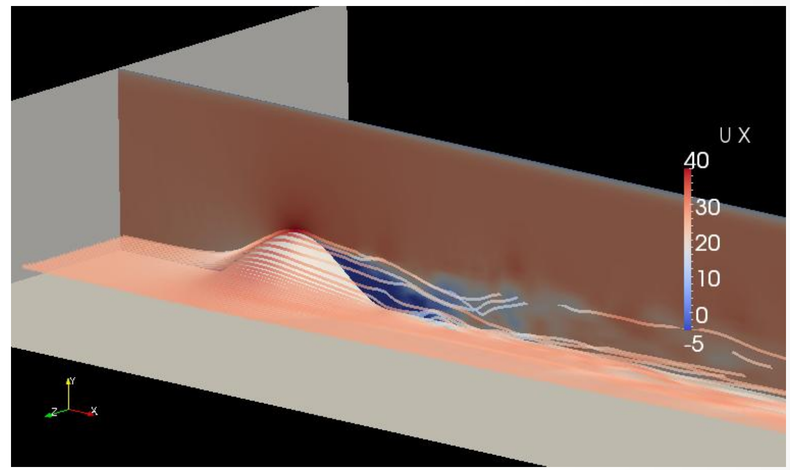


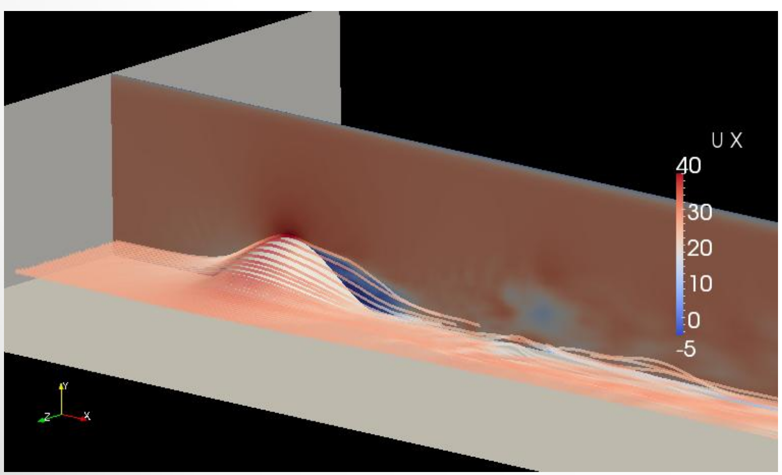


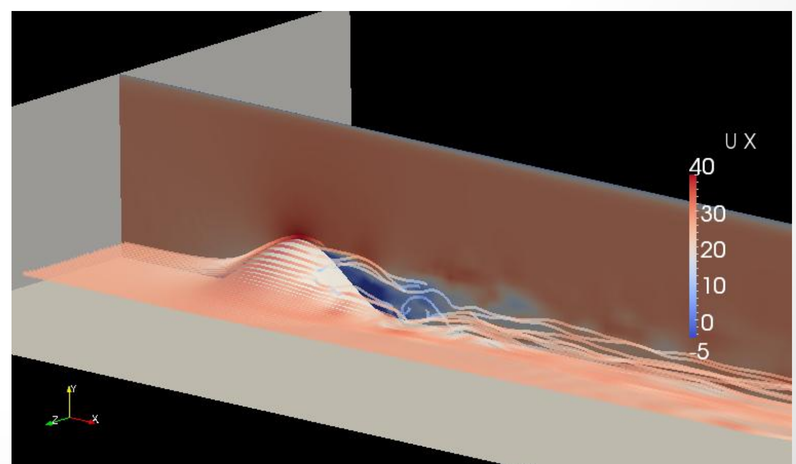
Flow Pattern(Steady Inlet Flow)

・計算手順として、
同一メッシュのkEpsilonで定常計算⇒初期値として0.6sec+0.6sec(時間平均)
RANS inlet profileをそのまま適用（定常流入風）
Smagorinsky Constant Cs ≒ 0.165(defalut)







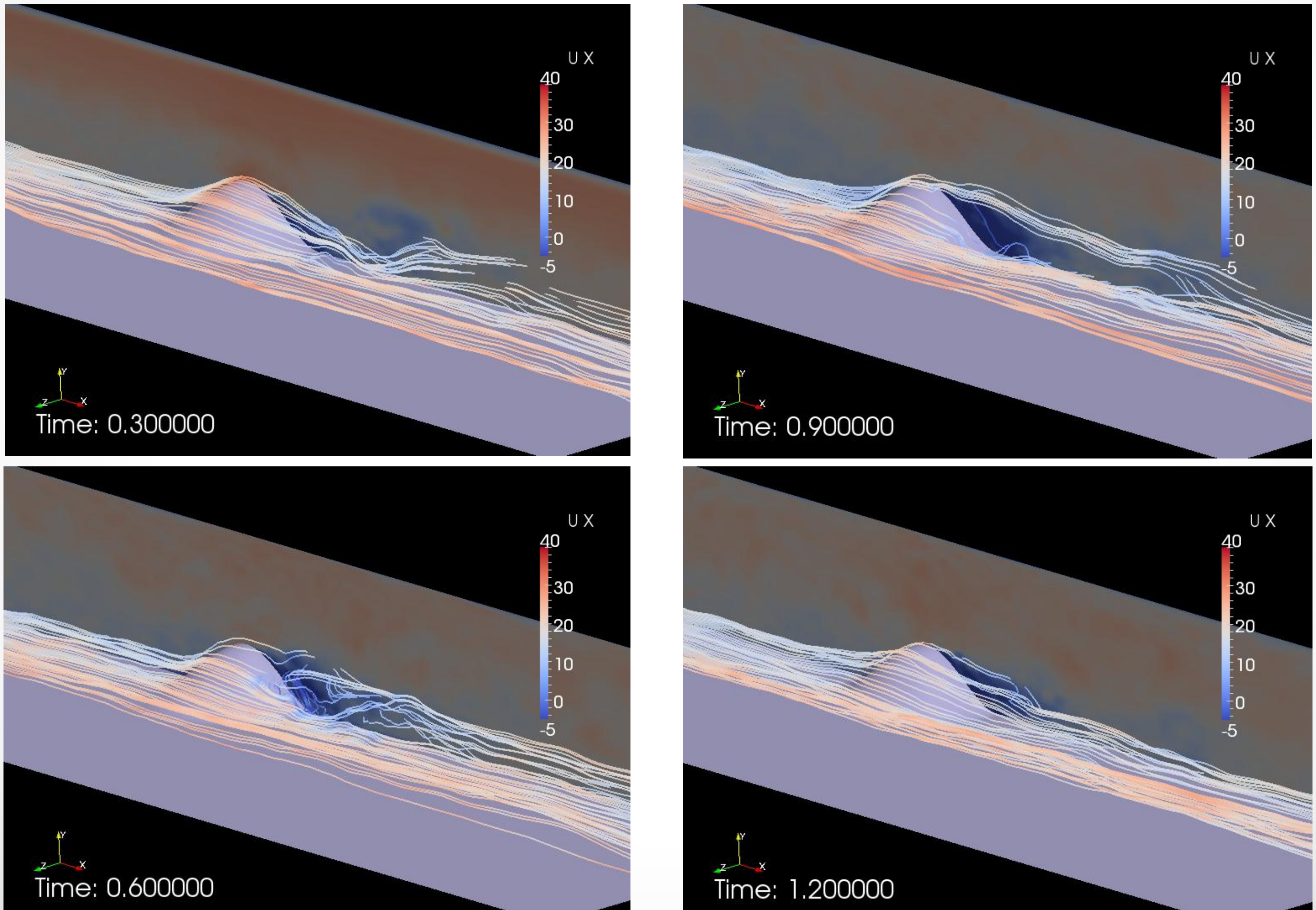


Flow Pattern(With Inlet Driver Region)

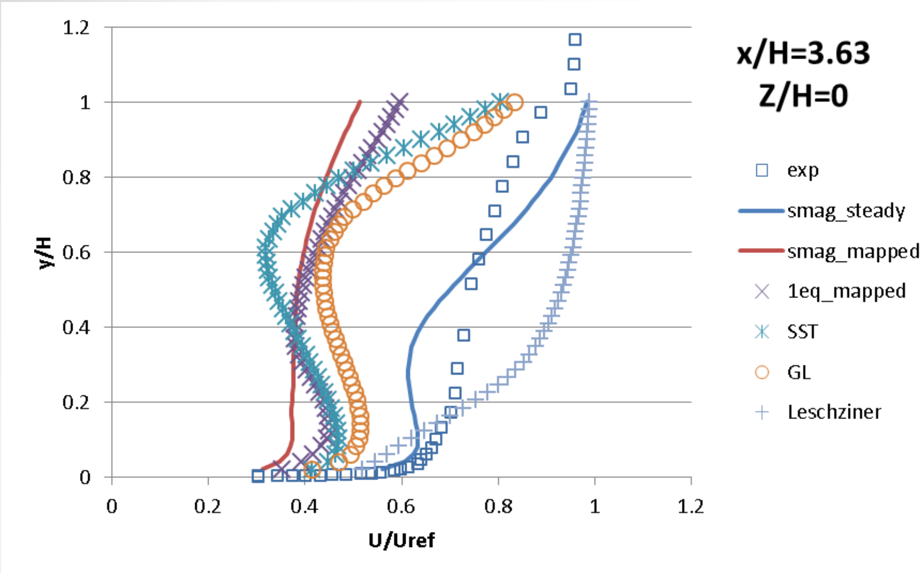
※実験で観察された丘後方の渦形成には流入変動風の影響が大

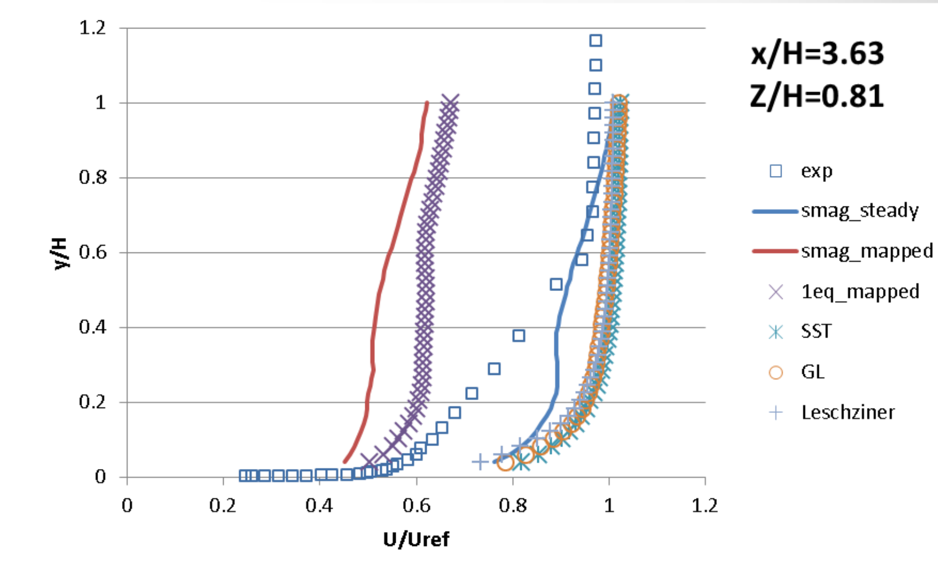
Smagorinsky Constant Cs = 0.1

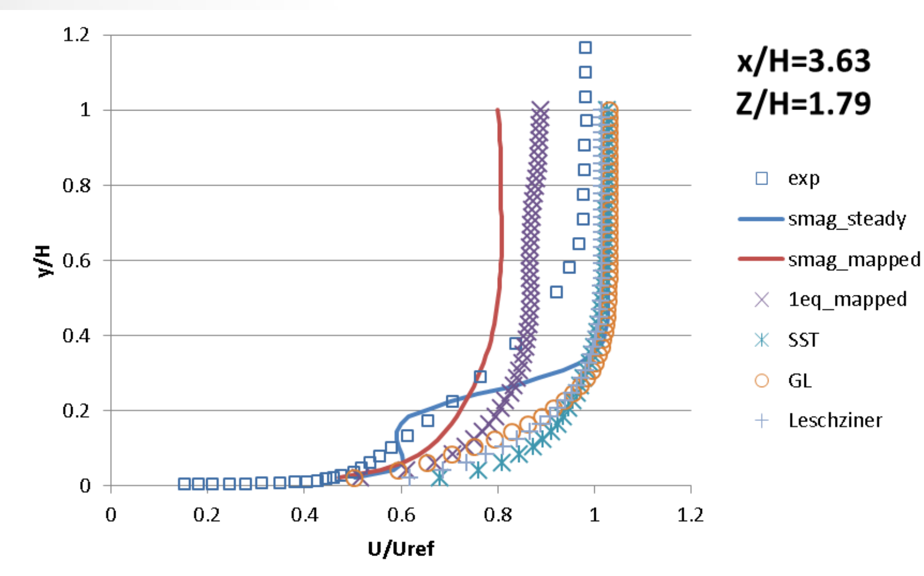
⇒入口部を押し出して、ドライバー部を設置(type mapped)

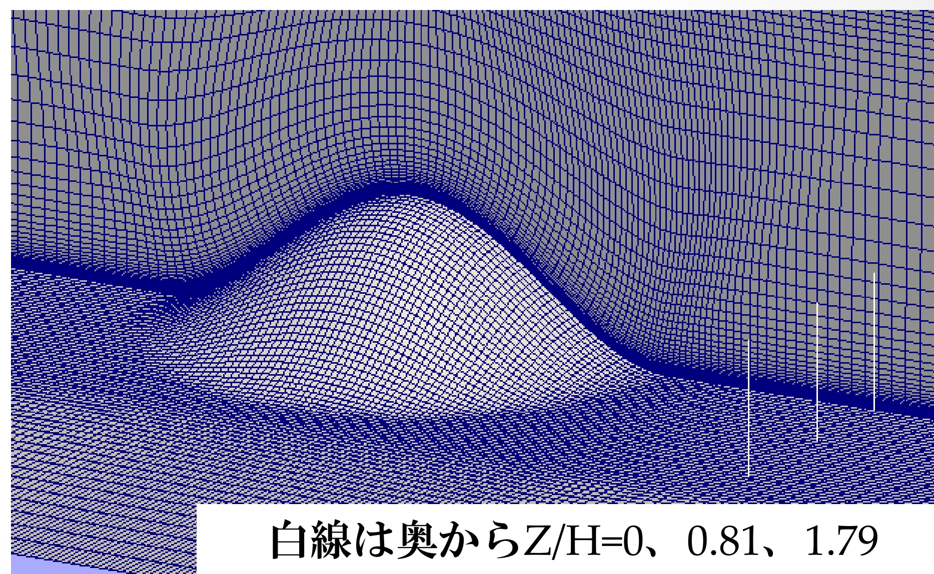


Result : Mean Streamwise Velocity

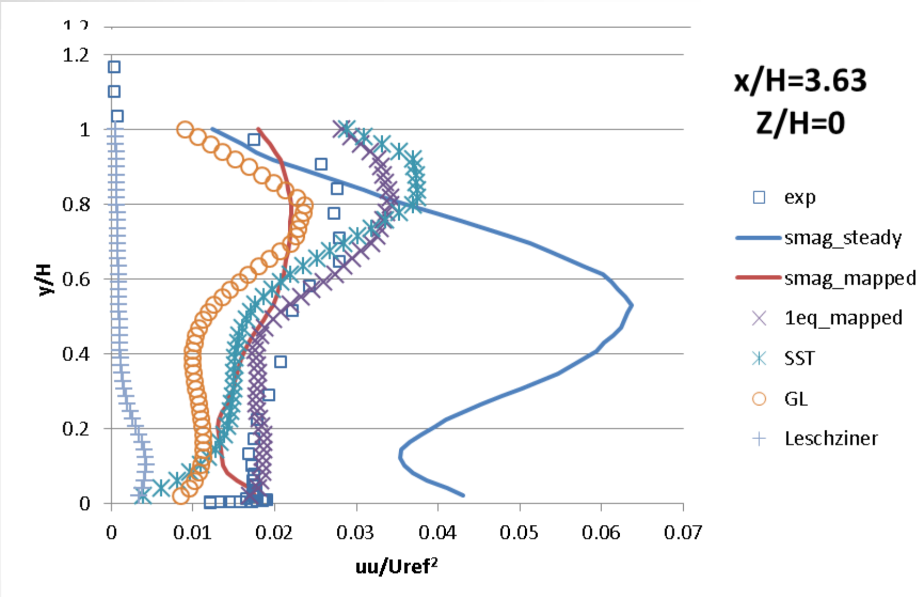


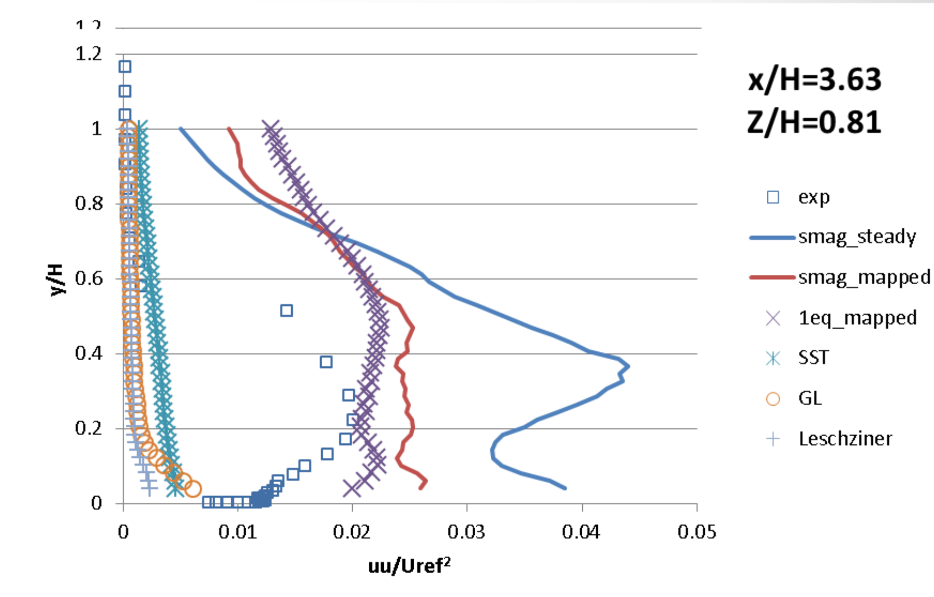


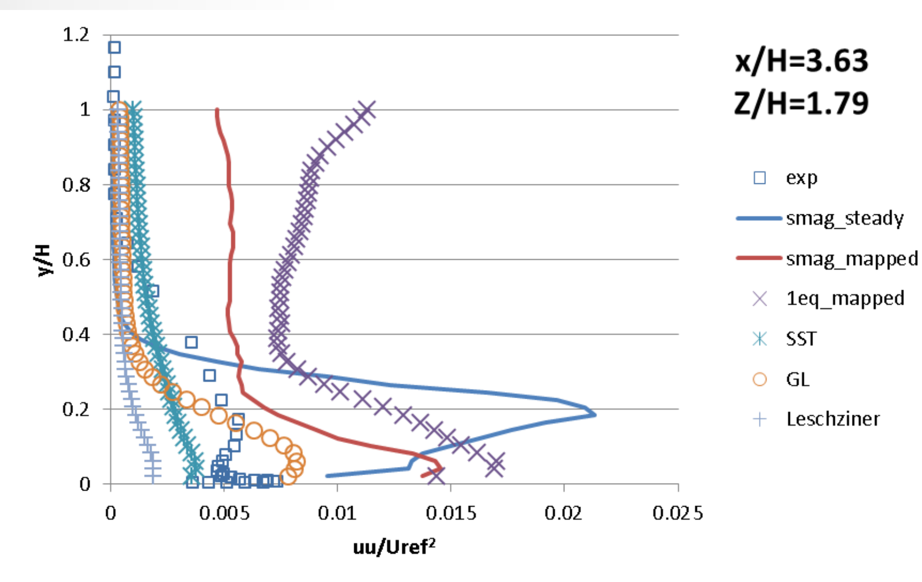


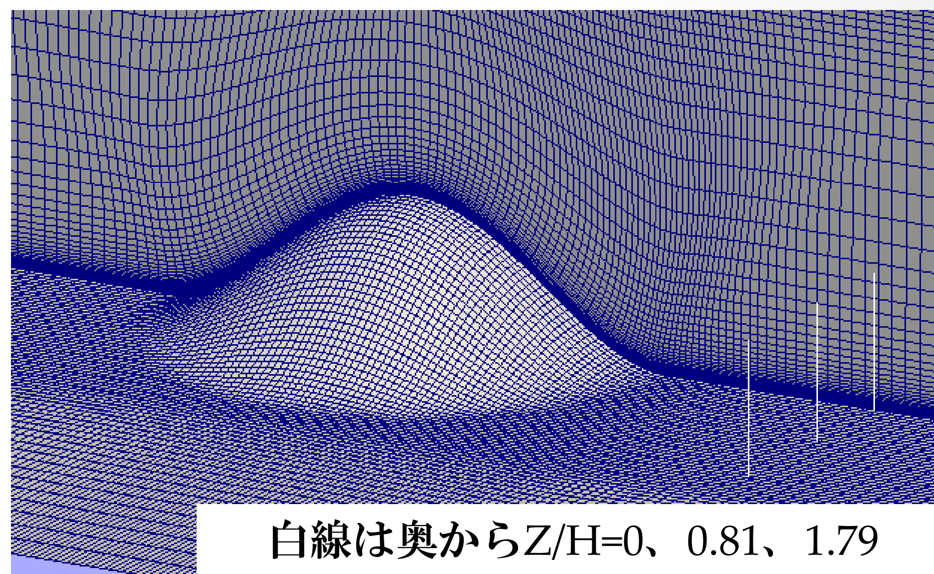


Result : Streamwise Velocity Fluctuation



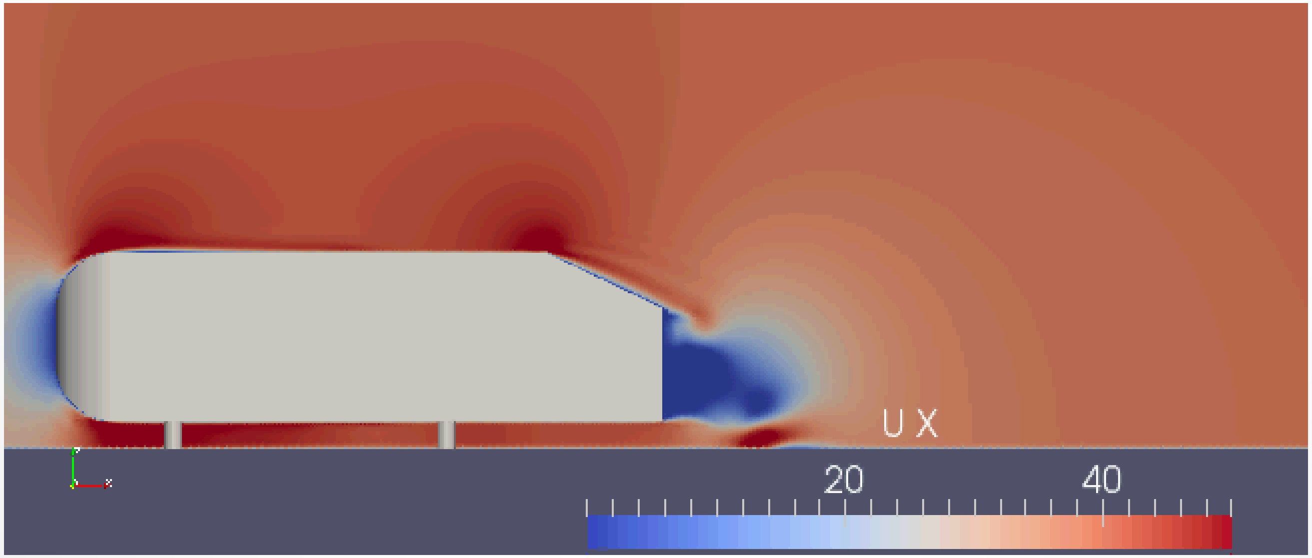






Case9.4 Flow around Ahmed body (Ahmed, 1984)

Solver	PimpleFoam	Reynolds Number	768,000
Unstructured Cell	8.0 mil / 2.5 mil	Time step	Auto Increment courant limit≒2
Ahmed body Height	0.288[m]	Task flow	0.1sec(develop) 0.1sec(average)
Free-stream Velocity	40[m/s]	Time Accuracy	backward
Wind Tunnel Domain	10×2×2[m]	Div Schemes U	LUST (2ndUpwind + linear)
Kinetic viscosity	1.5e-5[m^2/s]		



Localized SubGrid Scale model

SGS Reynolds Stress $\tau_{ij} = -2C\overline{\Delta}^2|\bar{S}|\,\overline{S_{ij}}\,,\qquad |\bar{S}| = \sqrt{2\overline{S_{ij}}\,\overline{S_{ij}}}$

＊WALE(Wall Adapting Local Eddy-Viscosity) *Nicoud et al 1999*

$$\tau_{ij} = -2(C_w\overline{\Delta})^2 \frac{({S_{ij}}^d{S_{ij}}^d)^{3/2}}{(\overline{S_{ij}}\,\overline{S_{ij}})^{5/2}+({S_{ij}}^d{S_{ij}}^d)^{5/4}}\overline{S_{ij}} \quad {S_{ij}}^d = \frac{1}{2}\left(\overline{g_{ij}}^2 + \overline{g_{ji}}^2\right) - \frac{1}{3}\delta_{ij}\overline{g_{kk}}^2\,, \overline{g_{ij}} = \frac{\partial \overline{u_i}}{\partial x_j}$$

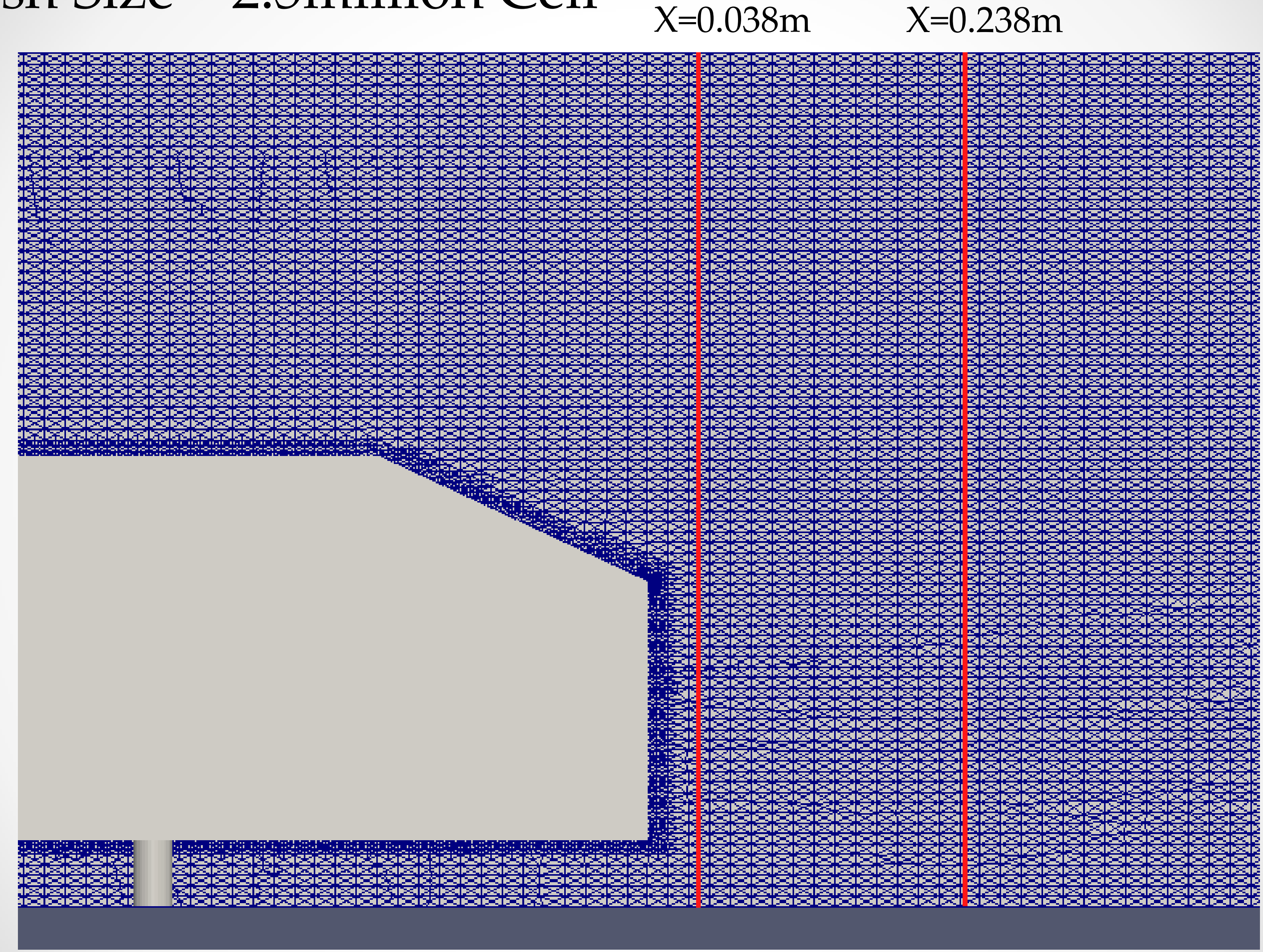
＊CSM(Coherent Structure Smagorinsky model) *Kobayashi 2005*

⇒モデル係数Cを速度勾配テンソルの第二不変量Qを用いてモデリング

$$\mathrm{C} = C_2|F_{CS}|^{3/2}F_{\Omega}\,,\qquad F_{\Omega} = 1 - F_{CS}$$

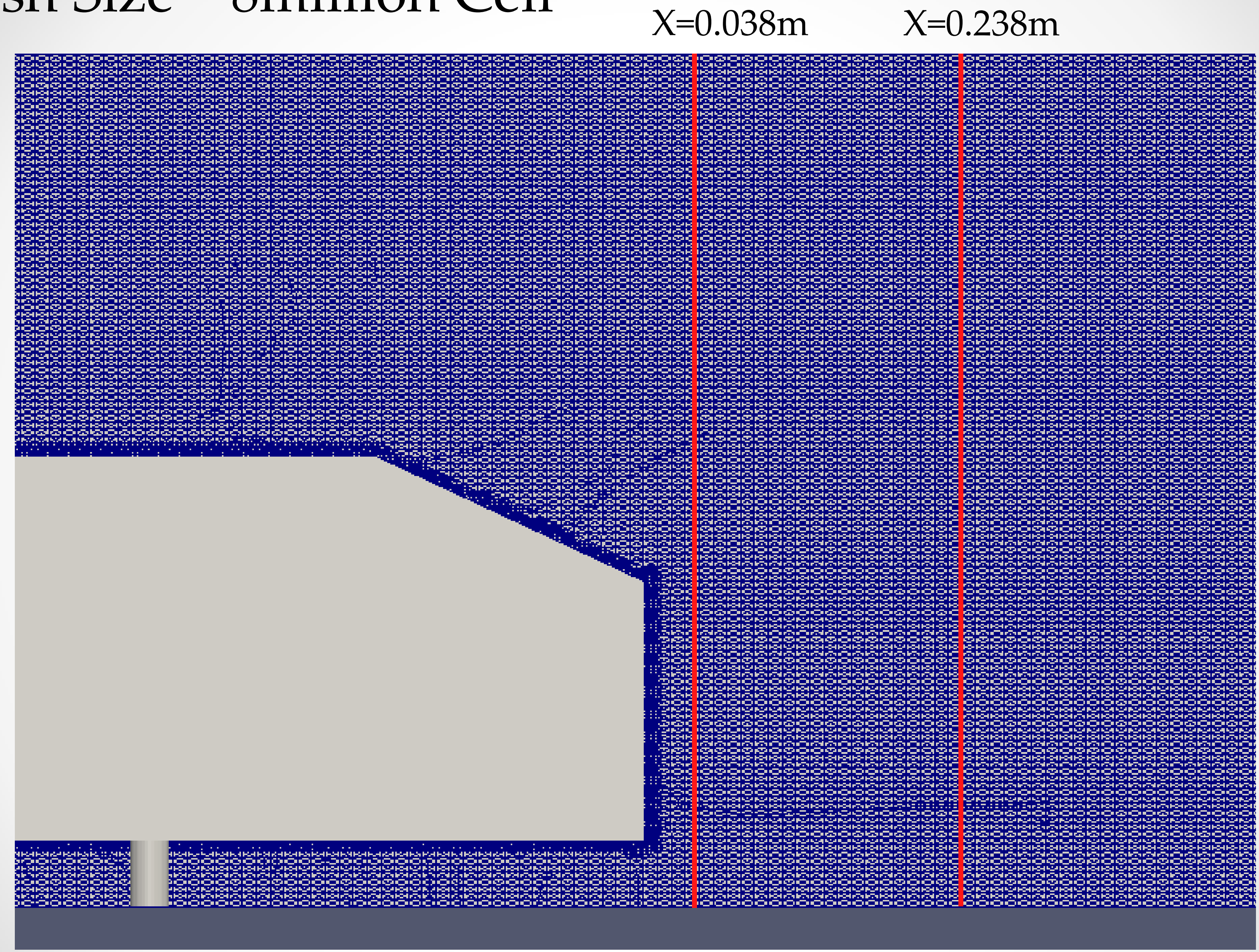
$$F_{CS} = {}^{Q}/_{E} \qquad Q = \frac{1}{2}\left(\overline{W_{ij}}\,\overline{W_{ij}} - \overline{S_{ij}}\,\overline{S_{ij}}\right),\quad \mathrm{E} = \frac{1}{2}\left(\overline{W_{ij}}\,\overline{W_{ij}} + \overline{S_{ij}}\,\overline{S_{ij}}\right)$$

Mesh Size　2.5million Cell

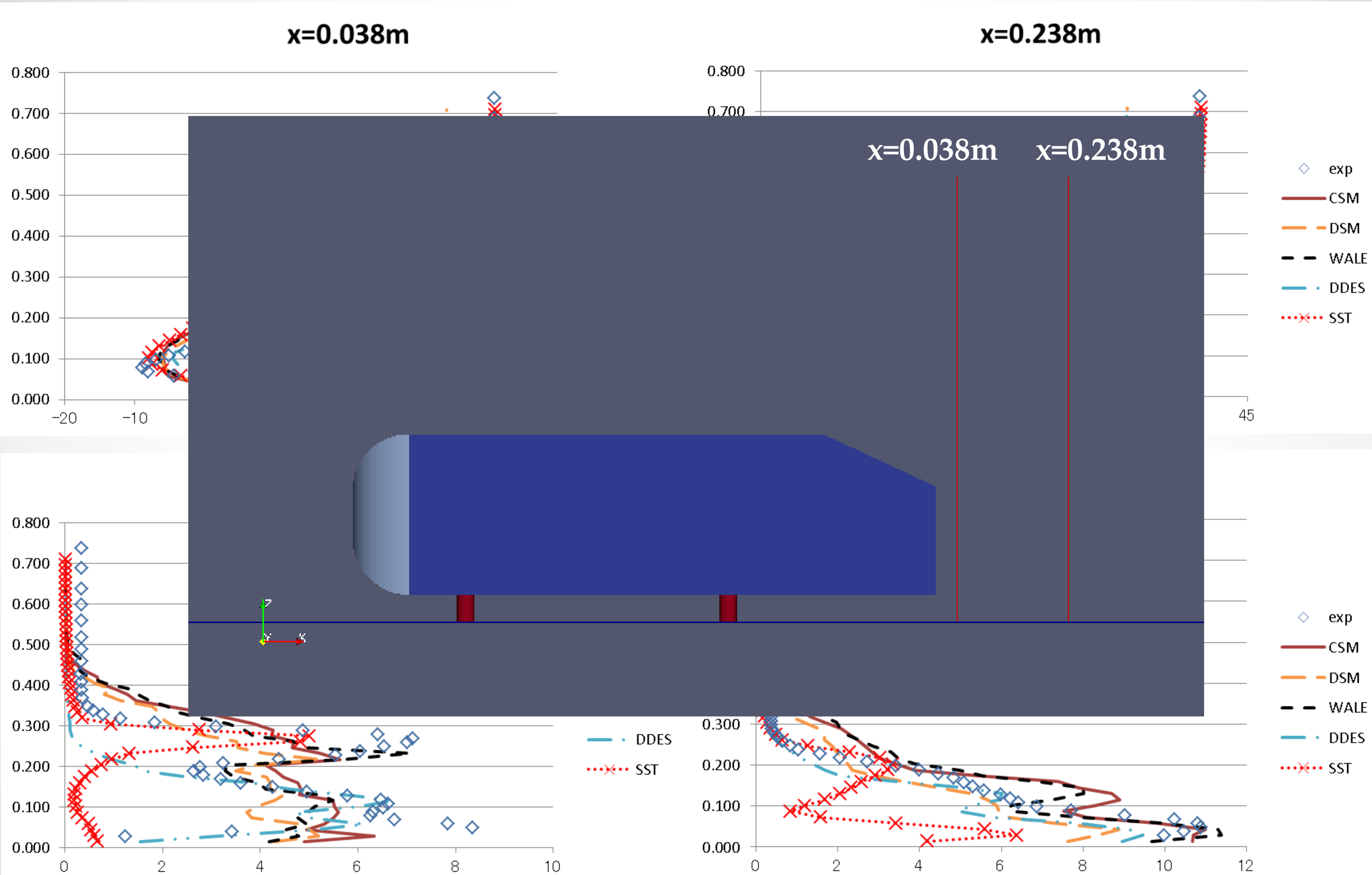


※vtkで抽出した(cuttingPlane)Surfaceメッシュなので、4角形⇒3角形となっている

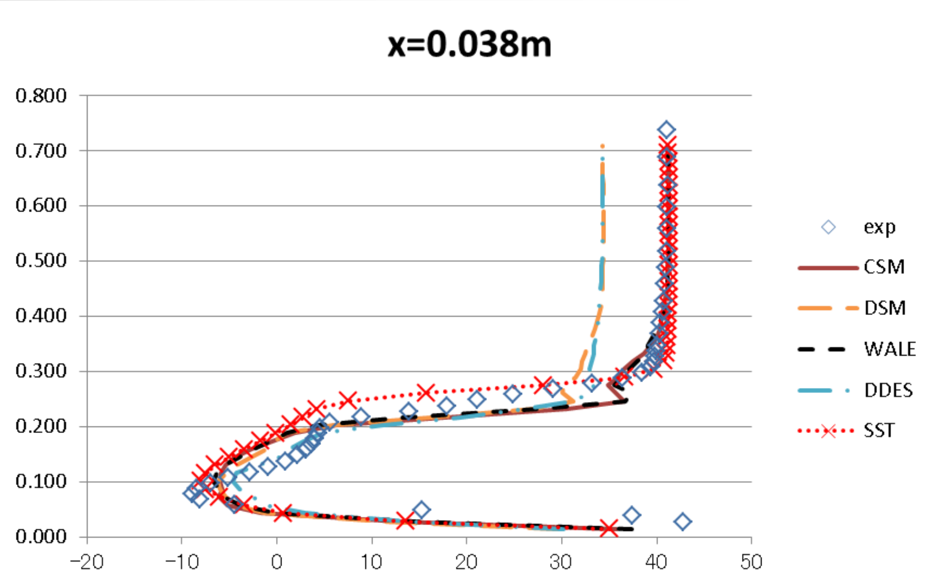
Mesh Size 8million Cell

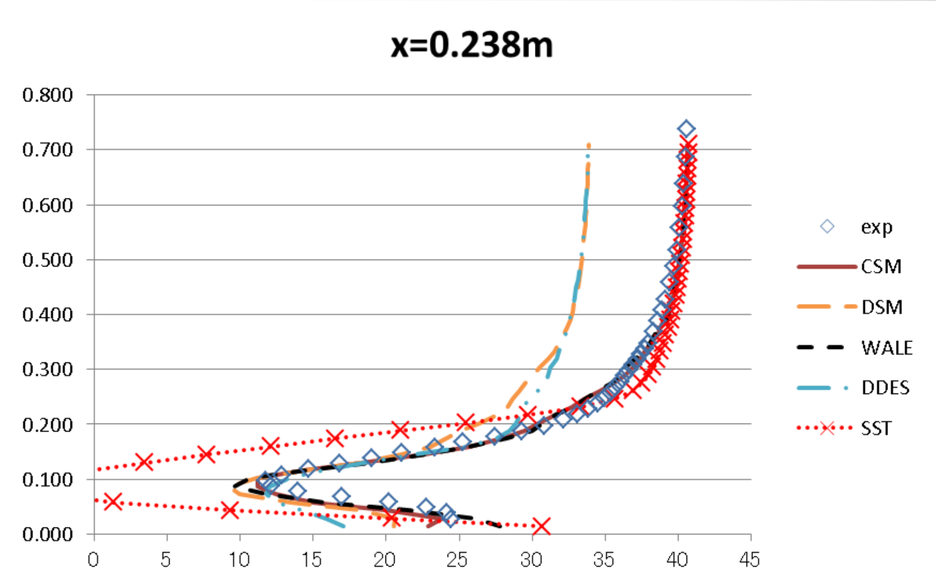


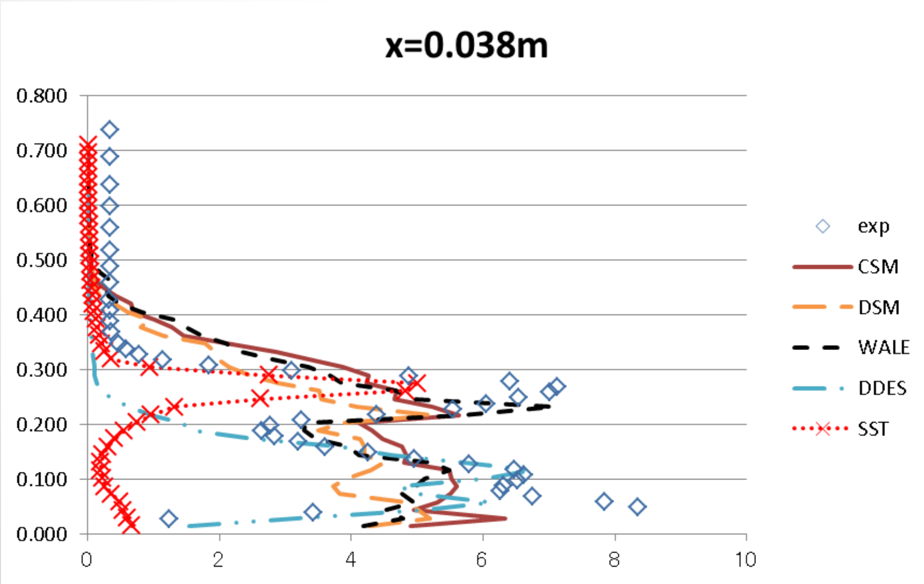
2.5millon Cell (top：Mean Streamwise Velocity、bottom：Velocity Fluctuation)

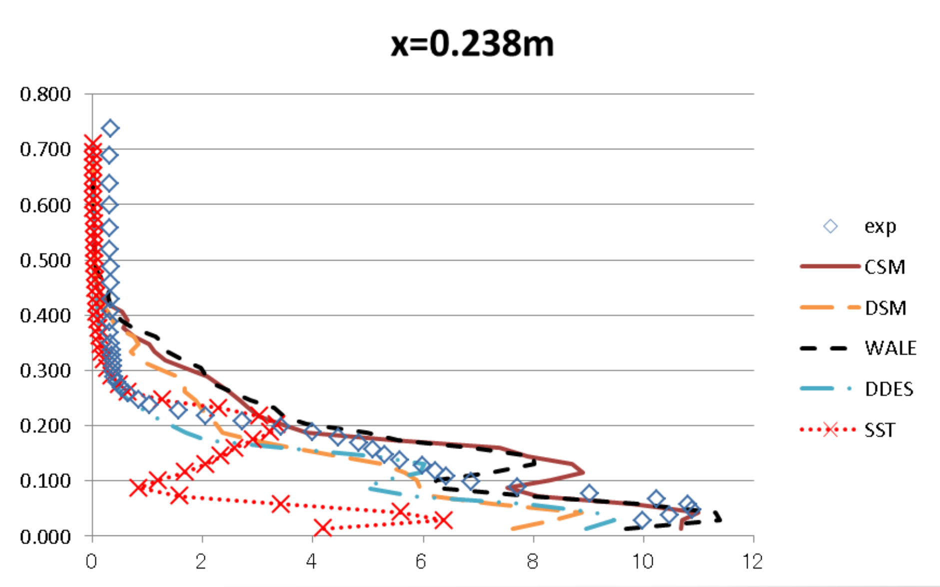


2.5millon Cell　(top：Mean Streamwise Velocity、bottom：Velocity Fluctuation)

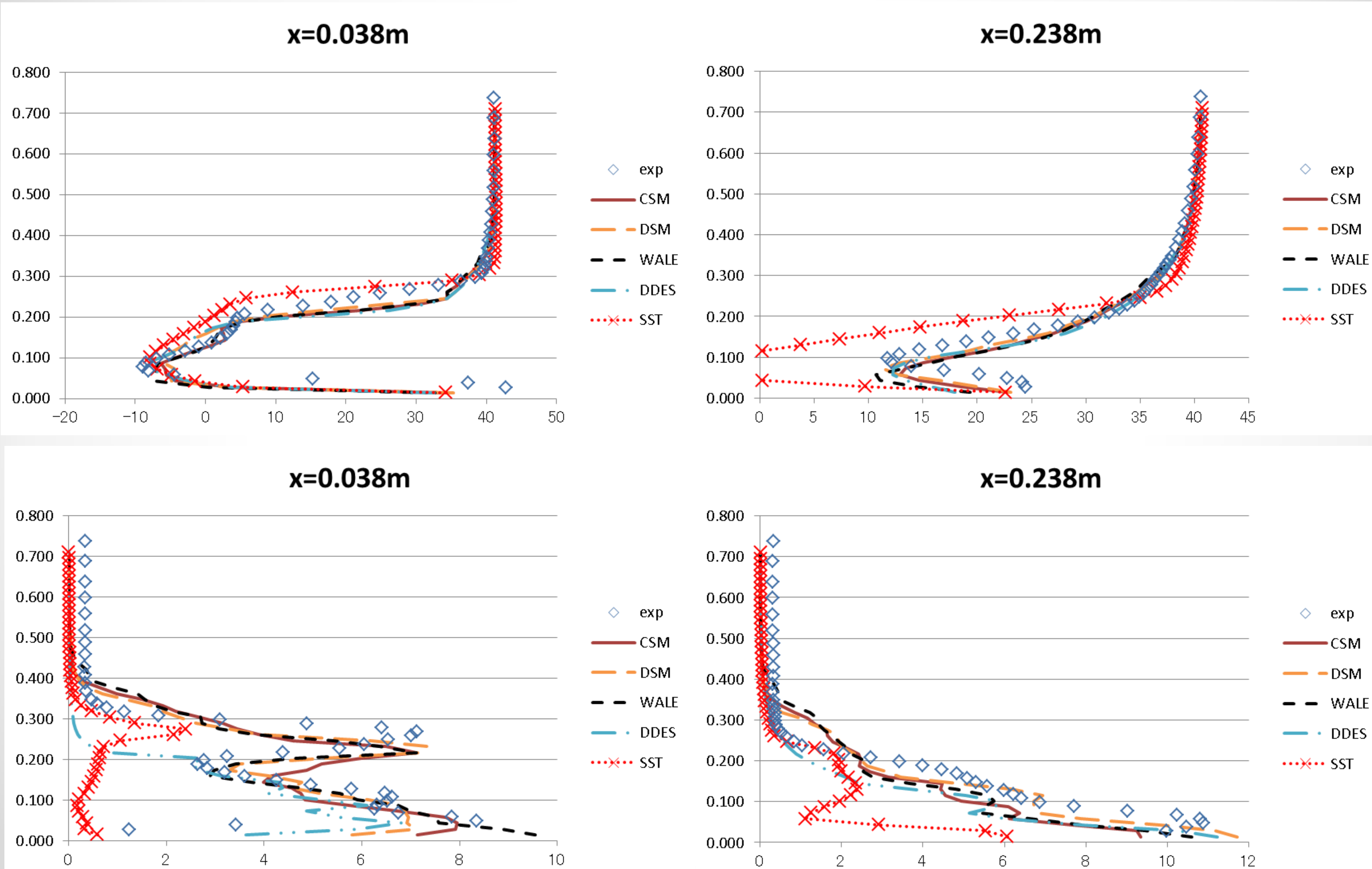








8millon Cell　(top：Mean Streamwise Velocity、bottom：Velocity Fluctuation)



Conclusion

Ercoftac SIG15 test caseを題材にしたデータベース作成作業の進捗状況について報告

・case file作成作業はほぼ完成
⇒ただし、条件設定・メッシュ等は改善要なケース有り

・LESによる定量的な比較結果を紹介、情報の共有

今後
・計算環境が限られているので、自分個人のマシンでは2D,RANSが限界
⇒データベース公開後のfeedbackに期待

Acknowledgment

計算実行にあたって日本SGI株式会社殿の計算機環境を使わせて頂きました。

また、OpenCAE勉強会@関東では本作業を進めるにあたって、有益な議論の機会を頂きました。

この場を借りて、御礼申し上げます。