

オープンソースコードによる LESベンチマーク

(株)アライドエンジニアリング
ADVC事業部 北風 慎吾

謝辞

本報告の計算ならびにその他のOpenFOAMを用いた解析のために、日本SGI様のSGI OpenFOAM Cloud環境を使わせていただきました。

この場を借りて、御礼申し上げます。

※SGI OpenFOAM Cloud利用者の皆様には長期に渡って、ノードを占有し、ご迷惑をおかけしました。

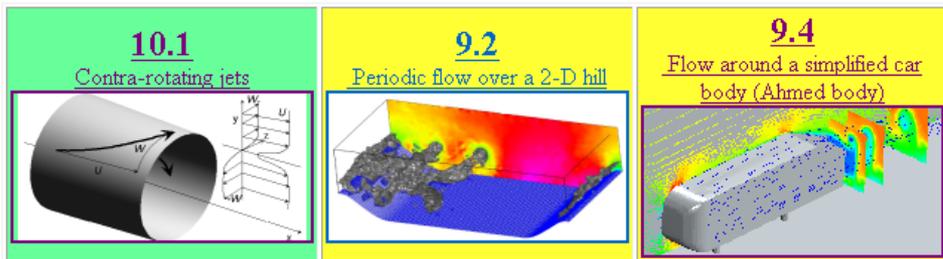
ERCOFTAC(European Research Community of Flow, Turbulence and Combustion)

・・・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 <input type="text"/>	password <input type="password"/>
Special Interest Groups		<input type="button" value="login"/>	
<ul style="list-style-type: none">Large Eddy SimulationTurbulence in Compressible FlowsEnvironmental CFDTransition ModellingDispersed Turbulent Two Phase FlowStably Stratified and Rotating TurbulenceTurbulence ModellingDrag Reduction and Flow ControlVariable Density Turbulent FlowsParticle Image VelocimetryReactive FlowsTransition Mechanisms, Prediction and ControlDesign OptimizationMultipoint Turbulence Structure and ModellingSwirling FlowsBio-Fluid Mechanics and Heat TransferMicrofluidics and Micro Heat TransferAeroacousticsSmoothed Particle Hydrodynamics (SPH)Fluid Structure InteractionSynthetic Models in TurbulenceFibre Suspension Flows	<h3>Special Interest Groups (SIG)</h3> <p>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.</p> <p>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, ...</p> <p>ERCOFTAC Special Interest Groups are associated with at least two <u>Pilot Centres</u>, and have an international organising committee.</p> <h4>SIGs are active on the following topics:</h4> <ul style="list-style-type: none">SIG 1: Large Eddy SimulationSIG 4: Turbulence in Compressible FlowsSIG 5: Environmental CFDSIG 10: Transition ModellingSIG 12: Dispersed Turbulent Two Phase FlowSIG 14: Stably Stratified and Rotating TurbulenceSIG 15: Turbulence ModellingSIG 20: Drag Reduction and Flow ControlSIG 24: Variable Density Turbulent FlowsSIG 28: Reactive FlowsSIG 32: Particle Image VelocimetrySIG 33: Transition Mechanisms, Prediction and ControlSIG 34: Design OptimizationSIG 35: Multipoint Turbulence Structure and ModellingSIG 36: Swirling FlowsSIG 37: Bio-Fluid Mechanics and Heat TransferSIG 38: Microfluidics and Micro Heat TransferSIG 39: AeroacousticsSIG 40: Smoothed Particle HydrodynamicsSIG 41: Fluid Structure InteractionSIG 42: Synthetic Models in TurbulenceSIG 43: Fibre Suspension Flows <p>Missing numbers correspond to SIGs no longer believed to be active. All requests for</p>	Latest Forum Posts <ul style="list-style-type: none"> 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	

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

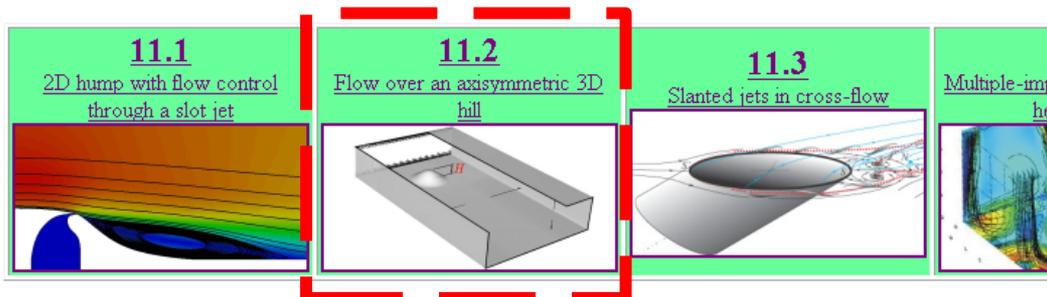


Test case 11.2

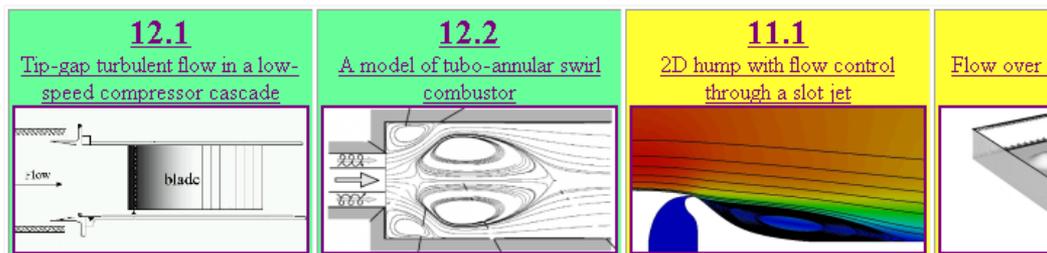
Flow over an axisymmetric three-dimensional hill

Structure of Vortical Separations

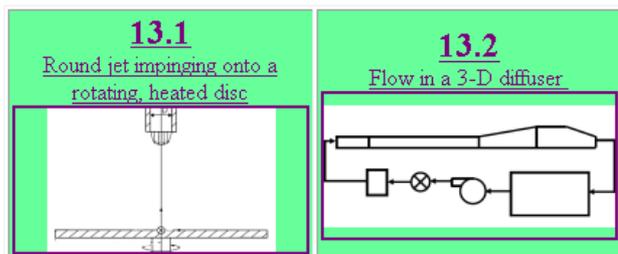
11th workshop at Chalmers University of Technology (7-8 April 2005)



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



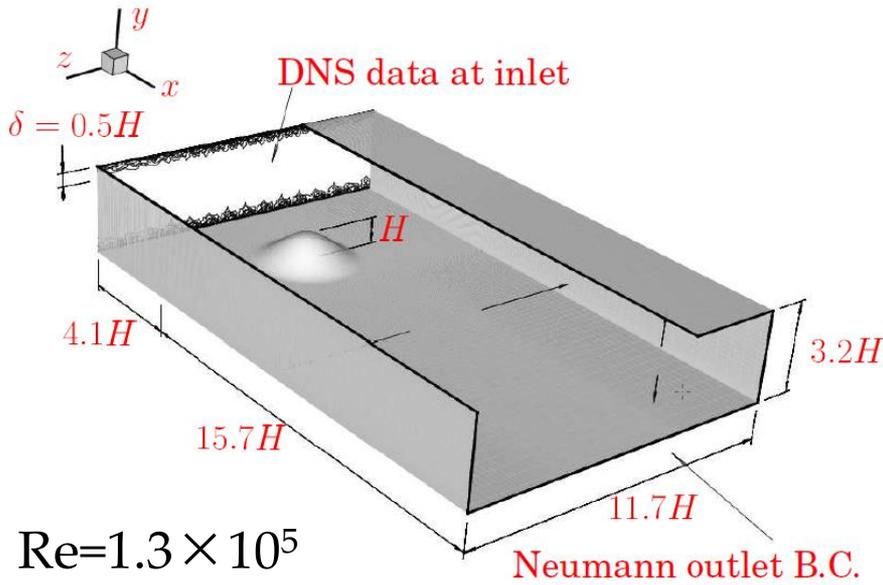
13th workshop at Graz University of Technology (25-26 September 2000)



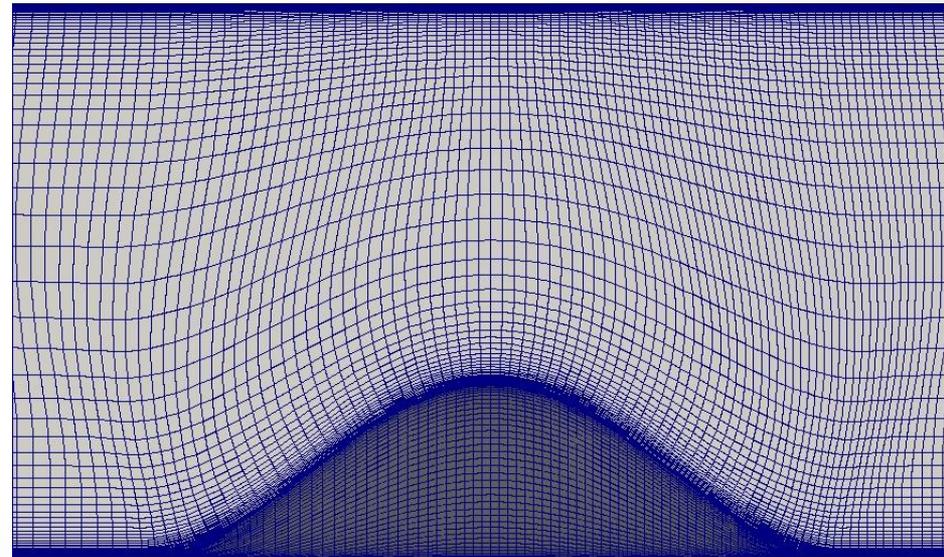
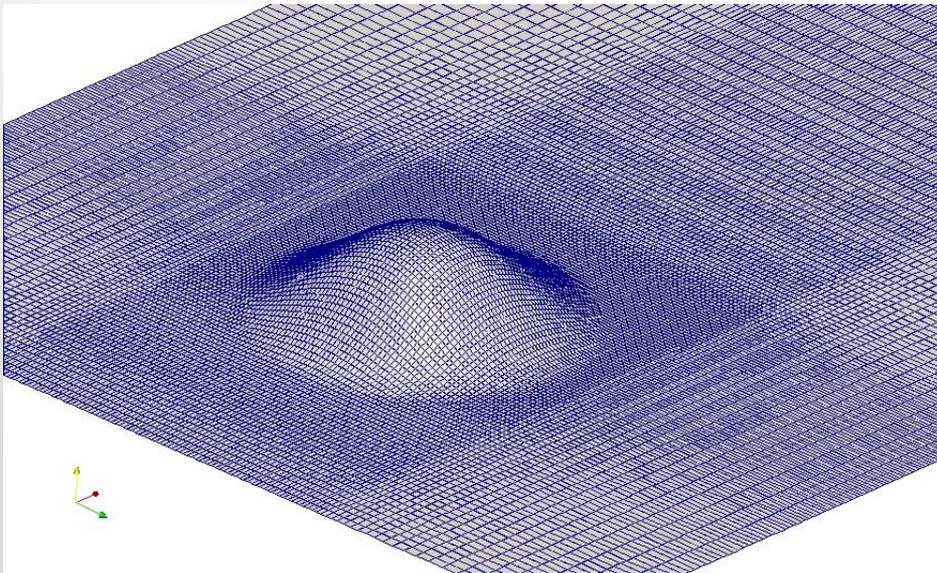
メッシュ、境界条件

<http://www.tfd.chalmers.se/~lada/3dhill/>

Lars Davidson, Flomania Final Review, 2004から抜粋



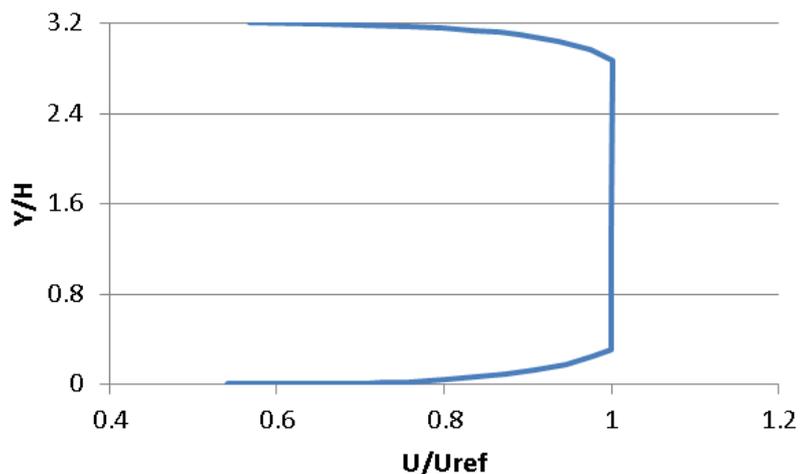
セル数	164万
代表長さH[m]	0.078
代表速度Uref[m/s]	27.5
動粘度[m ² /s]	1.65e-5
入口条件	放物型
乱流モデル	Smagorinsky
delta	vanDriest



メッシュ、境界条件

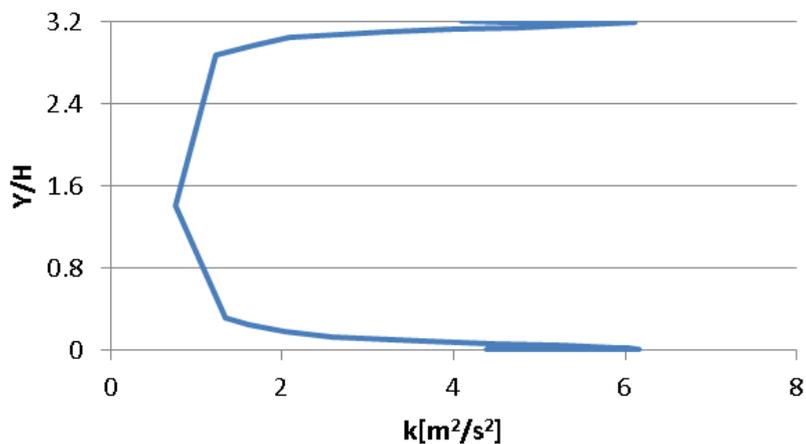
<http://www.tfd.chalmers.se/~lada/3dhill/>

inlet velocity profile

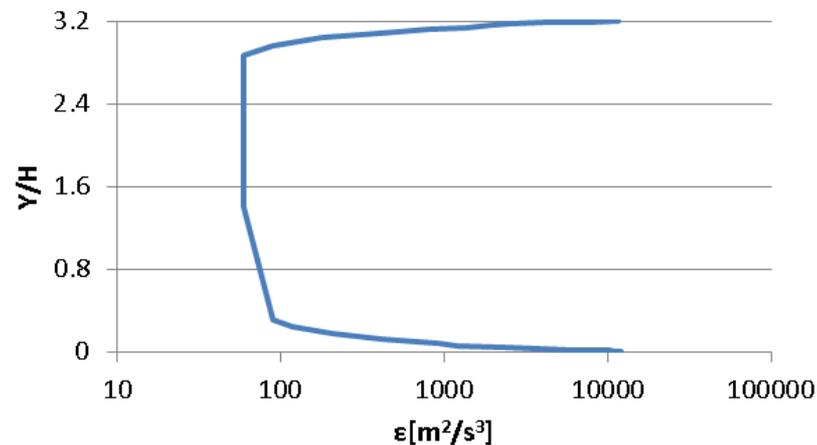


セル数	164万
代表長さH[m]	0.078
代表速度Uref[m/s]	27.5
動粘度[m ² /s]	1.65e-5
入口条件	放物型
乱流モデル	Smagorinsky
delta	vanDriest

inlet turbulent kinematic energy profile

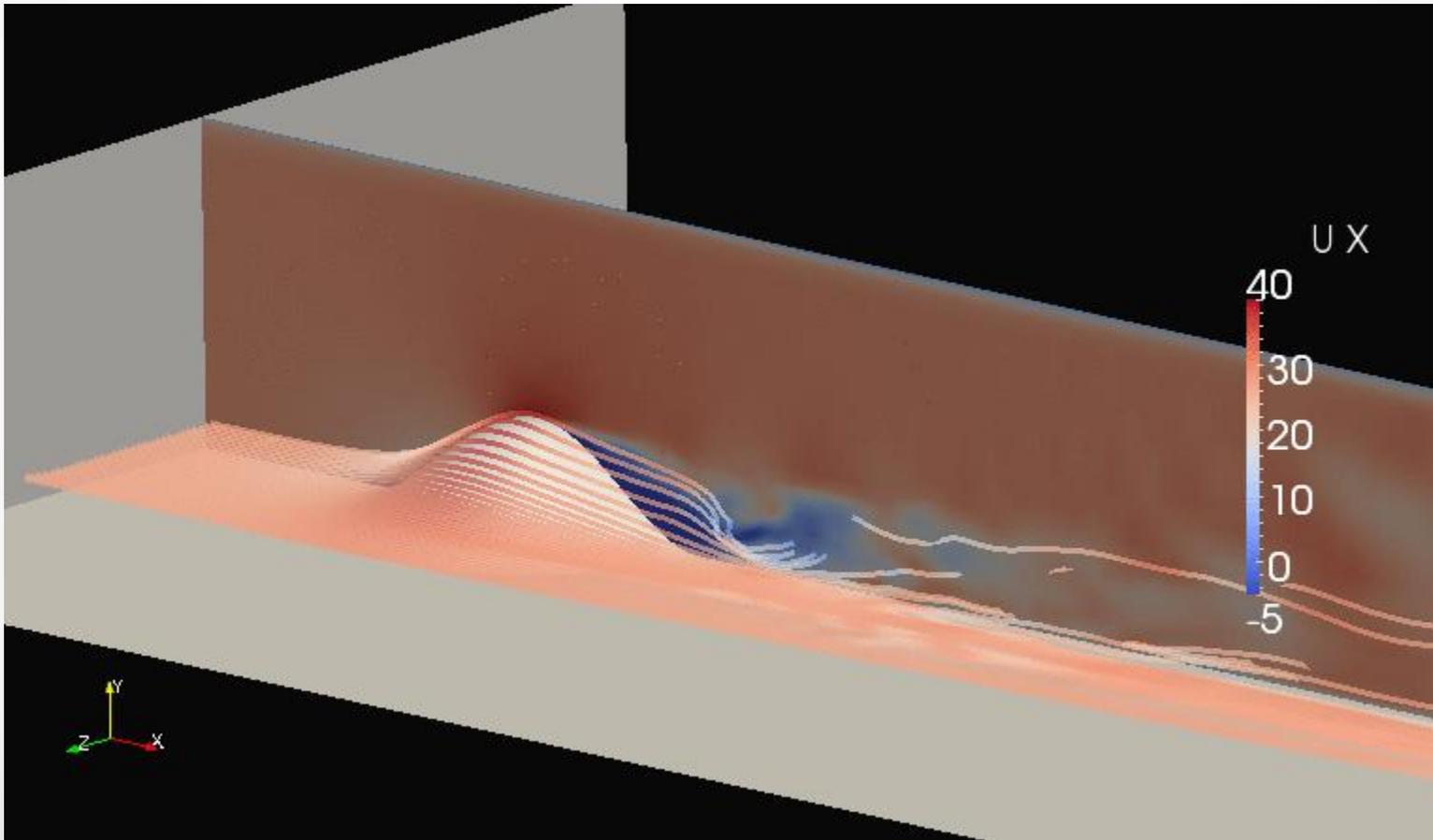


inlet turbulent energy dissipation profile

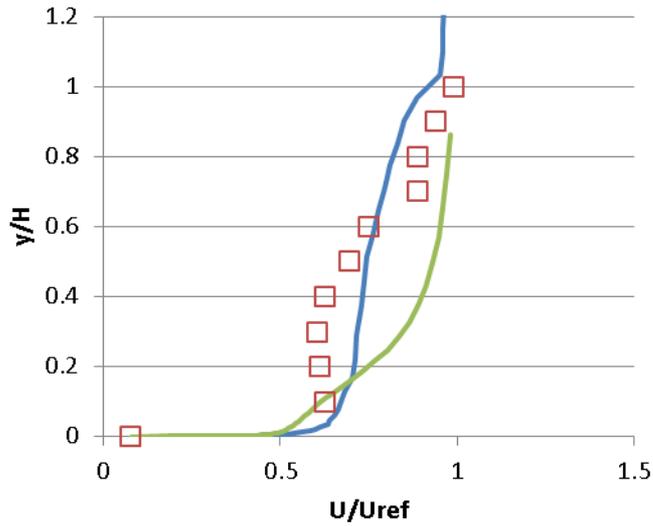


フローパターン

- ・ 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0.6秒+0.6秒(時間平均)
- 比較対象として、定常RANS(LienLeschzinerLowRe)の収束解を比較

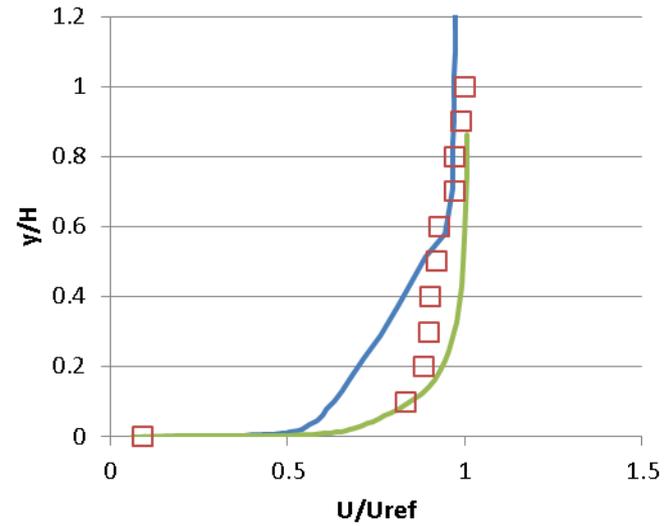


実験との比較



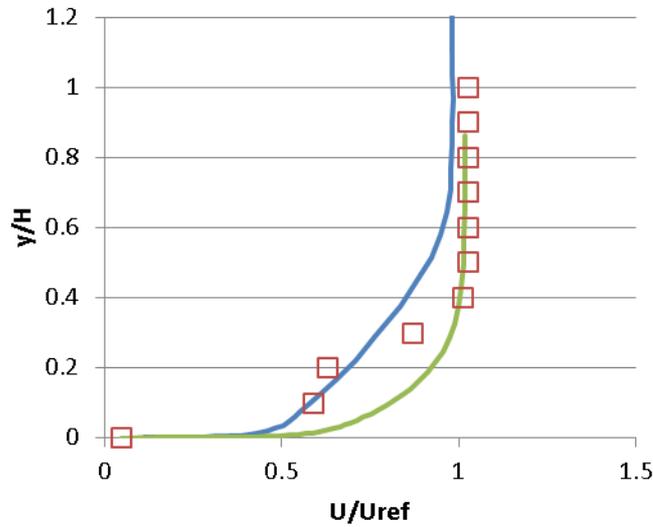
$x/H=3.63$
 $Z/H=0$

— exp
□ Smag
— LienLeschziner



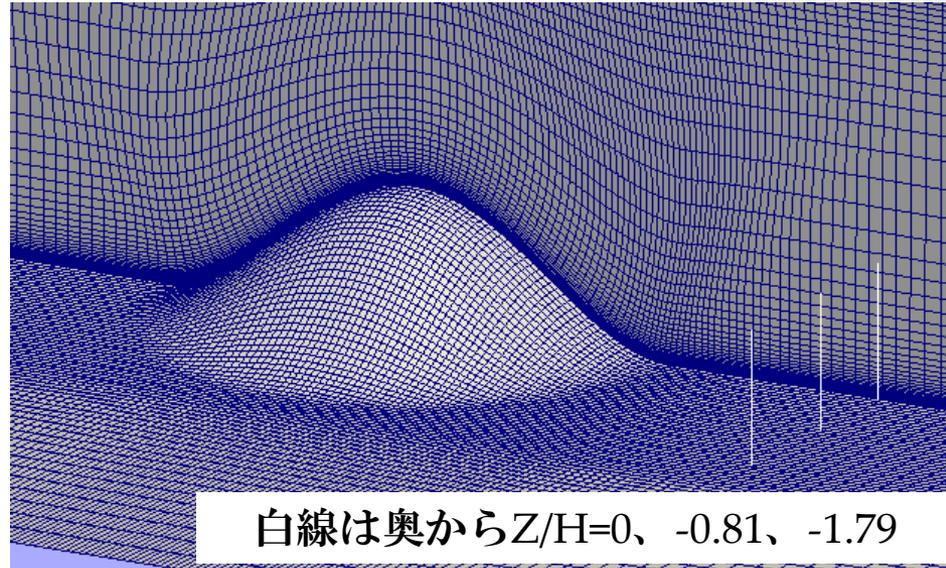
$x/H=3.63$
 $Z/H=-0.81$

— exp
□ Smag
— LienLeschziner



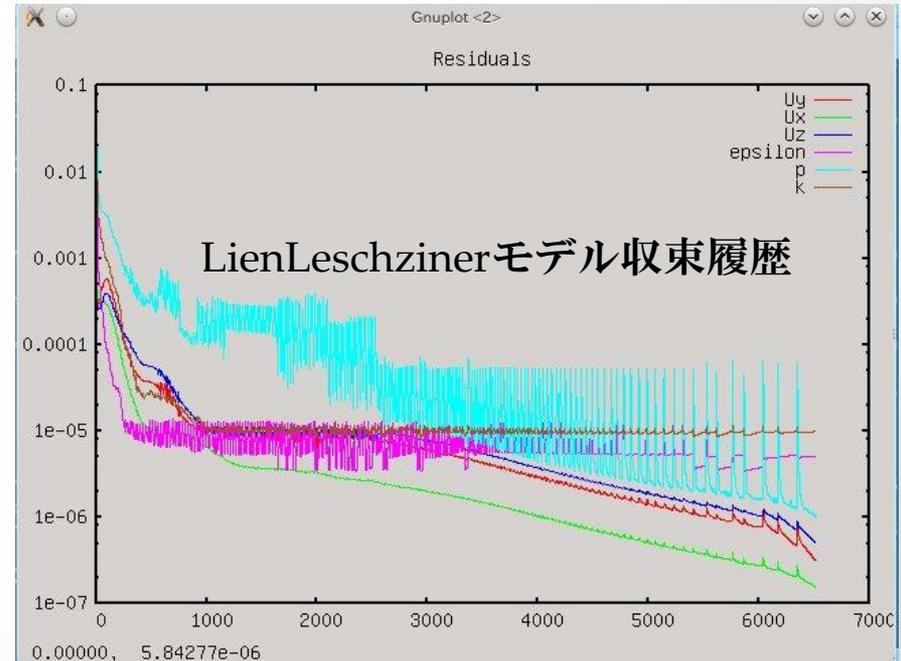
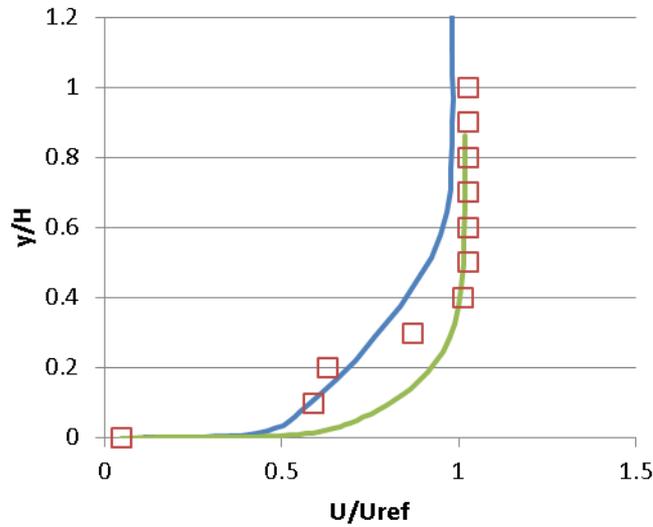
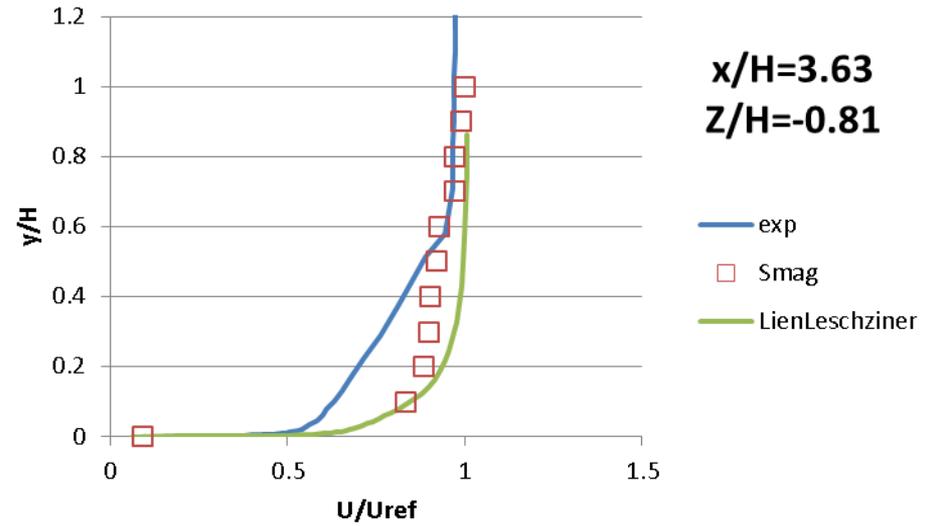
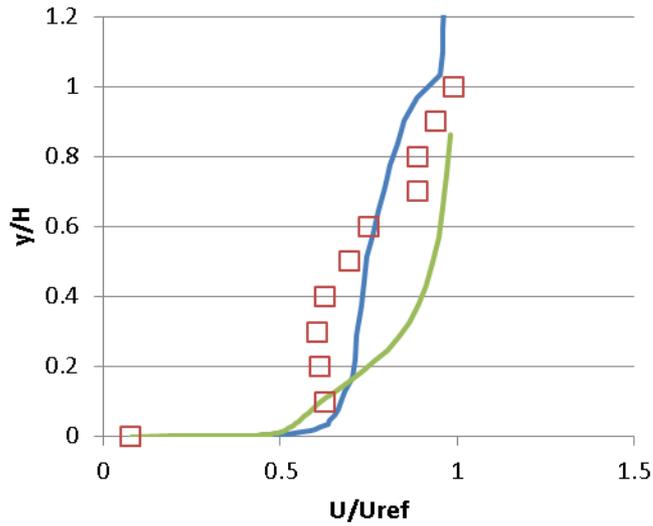
$x/H=3.63$
 $Z/H=-1.79$

— exp
□ smag
— LienLeschziner



白線は奥から $Z/H=0$ 、 -0.81 、 -1.79

実験との比較



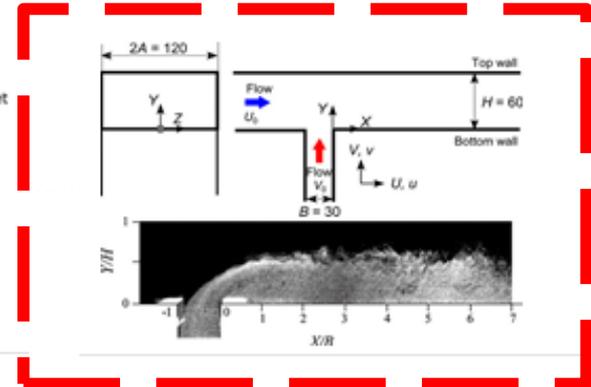
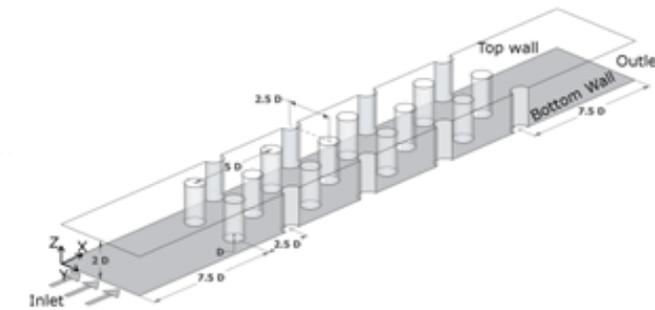
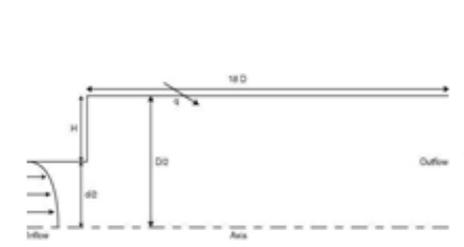


15th ERCOFTAC-SIG15/IAHR Workshop on Refined Turbulence Modelling

" Heat transfer in turbulent flows "

Chatou (Paris), France, 17 - 18 October 2011

Jointly organized by EDF and the Institute PPrime (CNRS/University of Poitiers) and co-sponsored by ERCOFTAC-SIG15 and IAHR



※三重大の廣田先生の研究成果がベンチマーク対象
参考文献：機械学会論文集B編71巻712号(2005-12)

先週まではサイトが存在していましたが、 今週確認すると・・・

Twikiから削除されていきました

Access Denied

Attention

The "WorkshopChatou2011" web does not exist

A [TWikiSite](#) is divided into webs; each one represents one subject, one area of collaboration. You are trying to 'view' in a web that does not exist.

If you came here by clicking on a question mark link

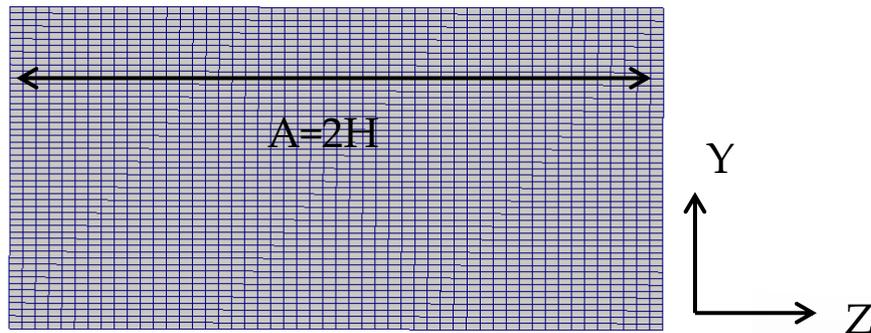
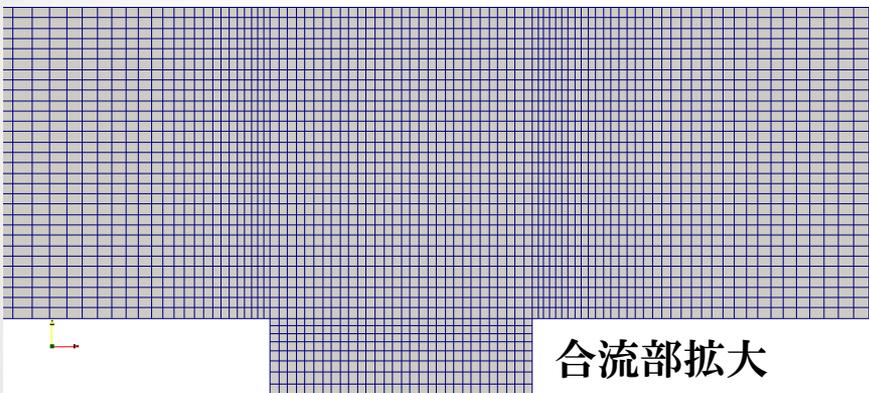
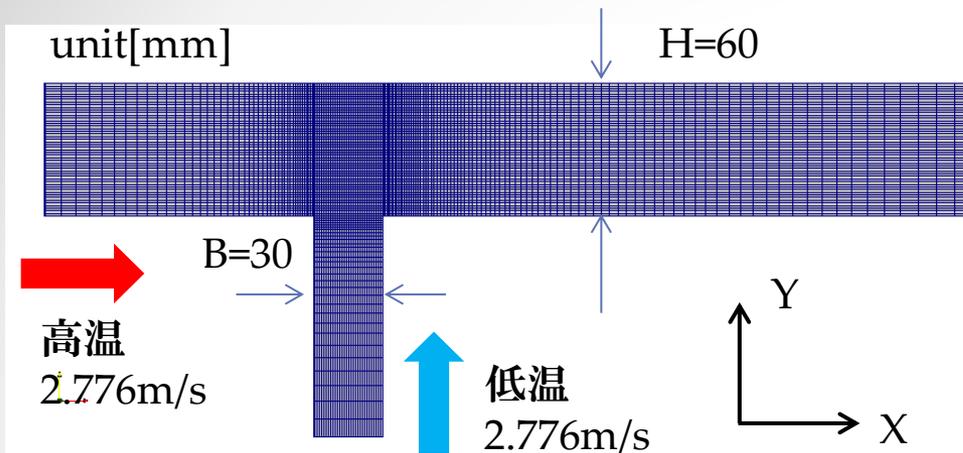
A link to a topic located in another web is written like `Otherweb.TopicName`. Make sure that the name of the web is not spelt wrongly on the previous page; fix the link if necessary.

If you would like to create this web

You can [create a new web](#) if you have permission. Contact remi.manceau@univ-poitiers.fr if you have any questions.

OK

メッシュ、境界条件



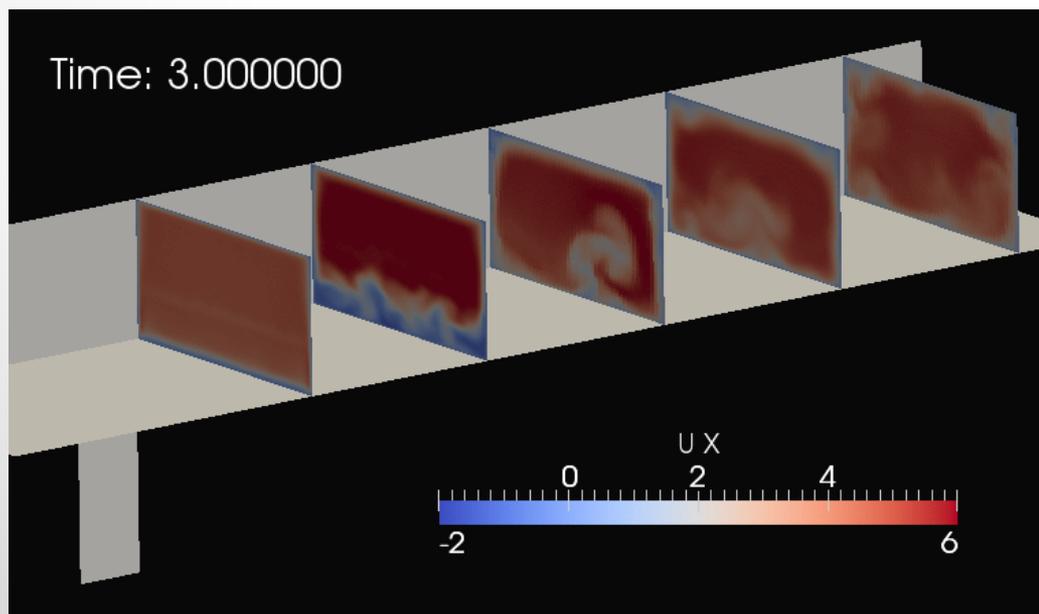
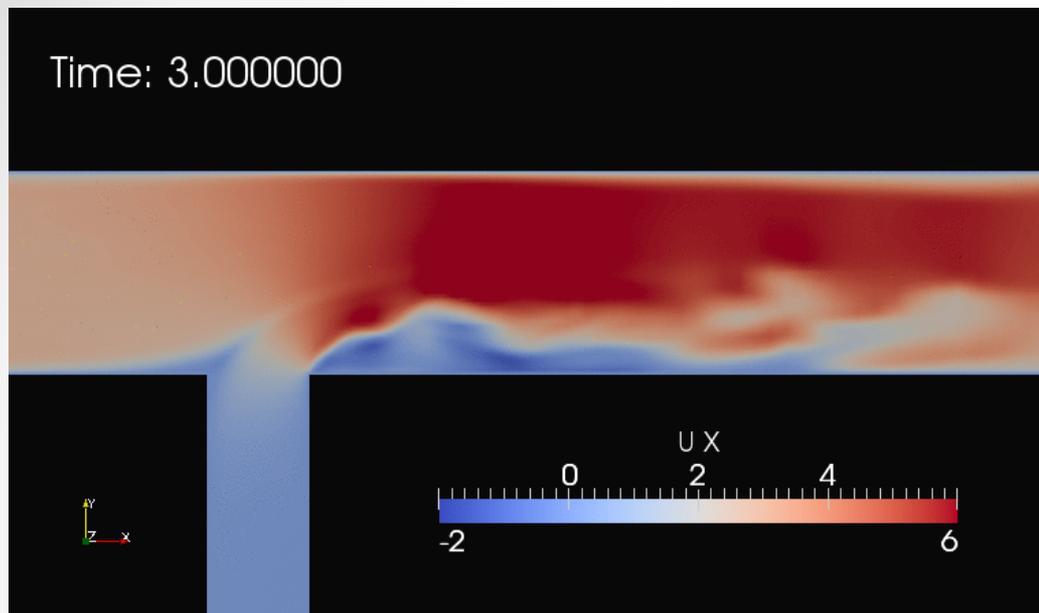
セル数	48万
代表長さH[m]	0.06
代表速度[m/s]	2.776
動粘度[m ² /s]	1.509e-5
入口条件	turbulentInlet
fluctuationScale	高温4% 低温2%
温度条件	等温場
乱流モデル	1)Smagorinsky 2)dynaLagrangian 3)kOmegaSST

※廣田先生の論文では速度場の測定は25℃等温場で計測しているのので、本解析は**等温LES**として実施

[会場への質問]

OpenFOAMの非等温ブジネスク近似ソルバではデフォルトでLESが使えない。buoyantBoussinesqPimpleFoamでLESを使いたいときは自らリコンパイルが必要？

フローパターン(Smagorinskyモデル)



0~3秒間 流れ場発達
3~5秒間 平均値取得

T字合流管において合流後の
流動パターンとして

- ①壁面噴流
- ②偏向噴流
- ③衝突噴流

の3種類に分類される。

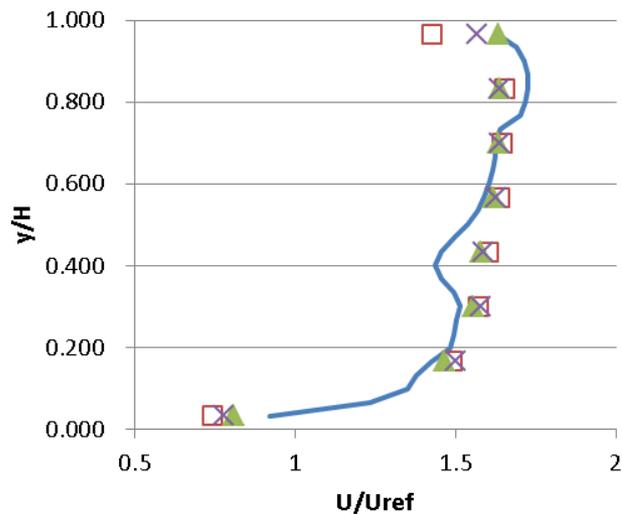
(五十嵐ら、機論B

70-700(2004), p3150-3157)

⇒左図より枝管流は合流箇所
で上部壁面に到達していない
ようなので、偏向~衝突噴流
のマップに対応、

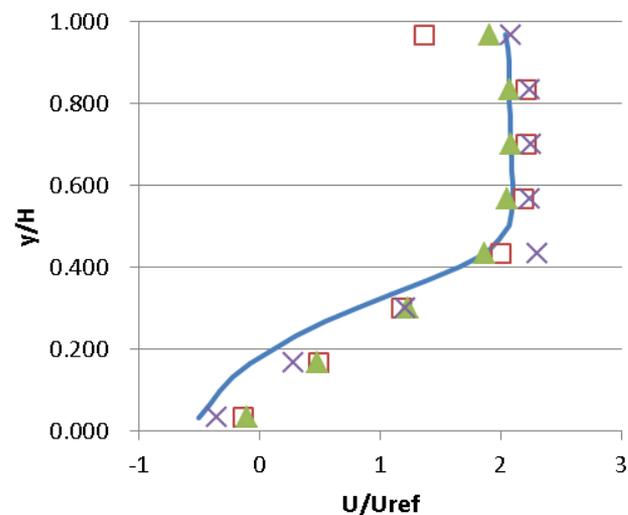
運動量比では主枝比が2なので
壁面噴流になるはずだが・・・

実験との比較



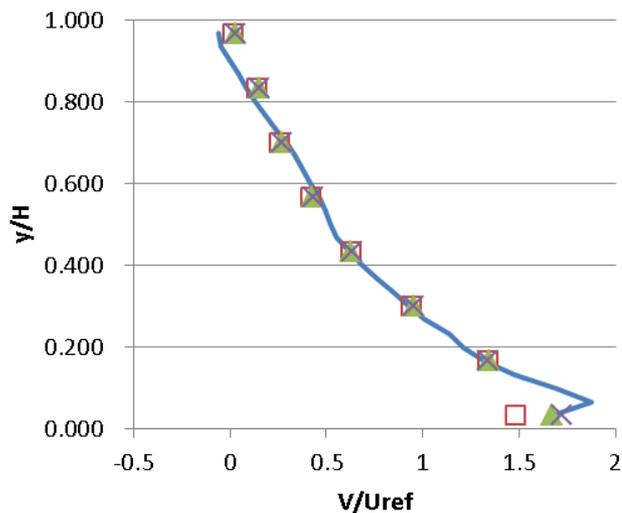
$X/B=0$

- exp
- Smagorinsky
- dynaLagrangian
- kOmegaSST



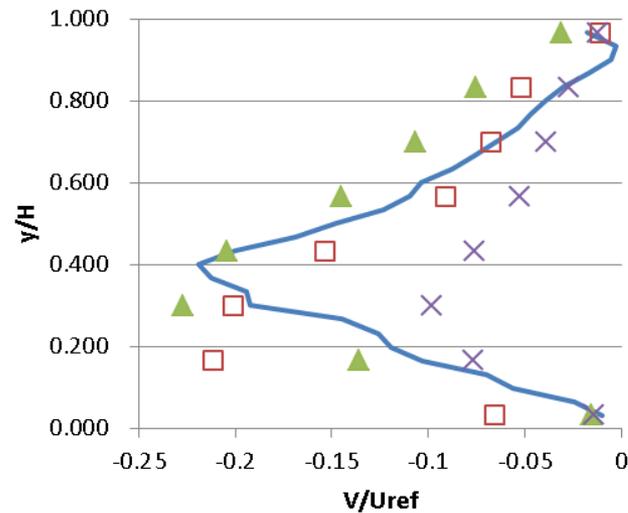
$X/B=3$

- exp
- Smagorinsky
- dynaLagrangian
- kOmegaSST



$X/B=0$

- exp
- Smagorinsky
- dynaLagrangian
- kOmegaSST



$X/B=3$

- exp
- Smagorinsky
- dynaLagrangian
- kOmegaSST

まとめ

- ・OpenFOAMの单相乱流の検証の一環でErcoftac SIG 15 testcaseを対象に3D LESのベンチマークを実施した。
- ・結果の確からしさについては今後検証していく必要があるが、部分的にはLESによる精度改善があることを確認できた。
- ・今後は他のOSSコードを用いて、同様の解析を実施し、比較検証を実施したい。