ASME 2013 MAY 22–24, 2013 • LAS VEGAS, NEVADA
VERIFICATION AND VALIDATION SYMPOSIUM

An Overview of the First Workshop on Verification and Validation of CFD for Offshore Flows

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1. Objectives of the Workshop

- Assess the numerical accuracy of CFD predictions for unsteady flows typical of Offshore applications (Code and Solution Verification)

- Assess the quality of the mathematical models used in CFD for unsteady flows typical of Offshore applications
(Validation based on the ASME V&V 20 Procedure)

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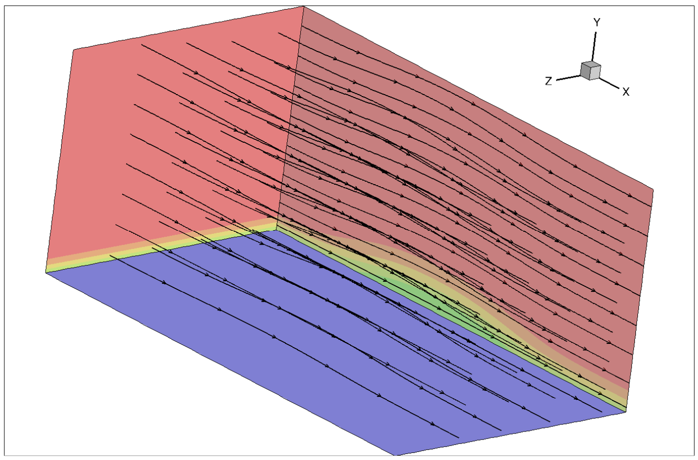
2. Test cases

- 3D Manufactured Solution for URANS solvers based on eddy-viscosity models
(Code Verification)
- Flow around a smooth fixed cylinder
(Solution Verification and Validation)
- Flow around a 3D straked-riser
(Validation)

2. Test cases

- 3D Manufactured Solution for URANS solvers based on eddy-viscosity models



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2. Test cases

- 3D Manufactured Solution for URANS solvers based on eddy-viscosity models

  - Demonstrate that the discretization error tends to zero when the cell size and time step go to zero

  - Assess the asymptotic order of grid and time-step convergence of the flow solver

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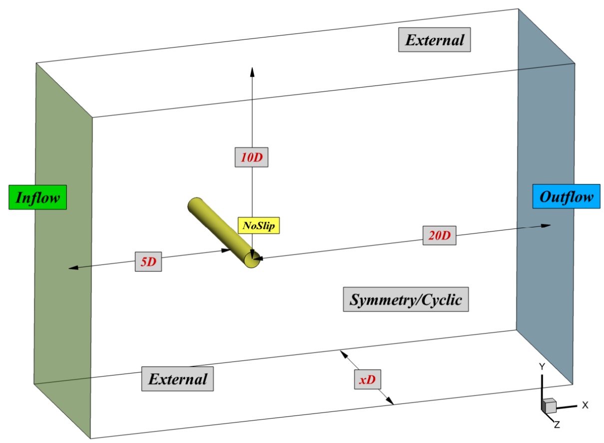
2. Test cases

- Flow around a smooth fixed cylinder



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2. Test cases

- Flow around a smooth fixed cylinder

  - Check the consistency of solutions obtained with the same mathematical model and different flow solvers by comparison of different numerical solutions with their respective uncertainties

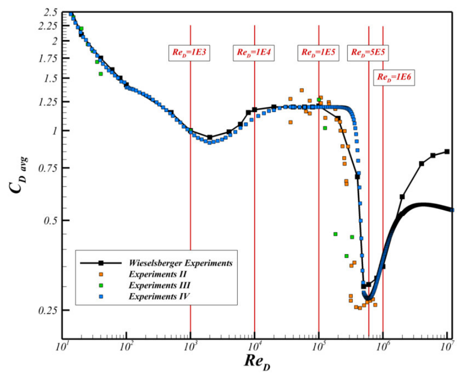
  - Reynolds number ranges from 10^3 to 10^6

  - Selected flow quantities include maximum, average, rms and amplitude of C_L, C_D, S

2. Test cases

- Flow around a smooth fixed cylinder

  - Compare numerical predictions with experimental data including their respective uncertainties



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2. Test cases

- Flow around a straked riser

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2. Test cases

- Flow around a straked riser
  - Compare numerical predictions with experimental data including their respective uncertainties (ASME V&V20 Validation procedure)
  - Selected flow quantities include maximum, average, rms and amplitude of C_L, C_D, S
  - Experimental data not available a priori

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3. Participants

Organization	Flow Solver	Mathematical Model	Test Case
Instituto Superior Técnico (IST) Maritime Research Institute Netherlands (MARIN)	ReFRESCO	URANS	Manufactured Solution
École Polytechnique de Montreal (EPM)	CADYF	URANS	Manufactured Solution
SBM Offshore	STARCCM	URANS	Cylinder
West Virginia University (WVU)	DREAM	Navier-Stokes	Cylinder
West Virginia University (WVU)	FLUENT	Navier-Stokes	Cylinder
Shangai Jiaotong University (SJTU)	FLUENT	URANS	Cylinder
University of São Paulo (USP)/MARIN	ReFRESCO	URANS	Cylinder
MMI Engineering	VIV-Sim	URANS	Cylinder
Abengoa Research SL (AR)	XFlow	Lattice-Boltzmann	Straked Riser
MARIN	ReFRESCO	URANS	Straked Riser
Hamburg University of Technology (TUHH)	FreSCo+	URANS	Straked Riser
University of Michigan	OpenFoam	URANS	Cylinder
Krylov Shipbuilding Research Institute	ANSYS CFX	URANS	Cylinder

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4. Overview of results

- Only two groups addressed the Code Verification exercise
- Several modifications or alternative formulations to the proposed MS were adopted by both groups
- Results addressed Code Verification of unsteady flow solvers with different orders of grid and time convergence and the effects of turbulence models on the asymptotic order of grid convergence

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4. Overview of results

- Error estimation based on a least squares solution of

$$\phi_i = \phi_o + \alpha_x \left(\frac{h_i}{h_1}\right)^{p_x} + \alpha_t \left(\frac{\tau_i}{\tau_1}\right)^{p_t}$$

for monotonic convergence and

$$\phi_i = \phi_o + \alpha_{1x} \left(\frac{h_i}{h_1}\right) + \alpha_{1t} \left(\frac{\tau_i}{\tau_1}\right) + \alpha_{2x} \left(\frac{h_i}{h_1}\right)^2 + \alpha_{2t} \left(\frac{\tau_i}{\tau_1}\right)^2$$

for non-monotonic convergence

- Numerical uncertainty obtained from the estimated error and a safety factor (“G.C.I. Type”)

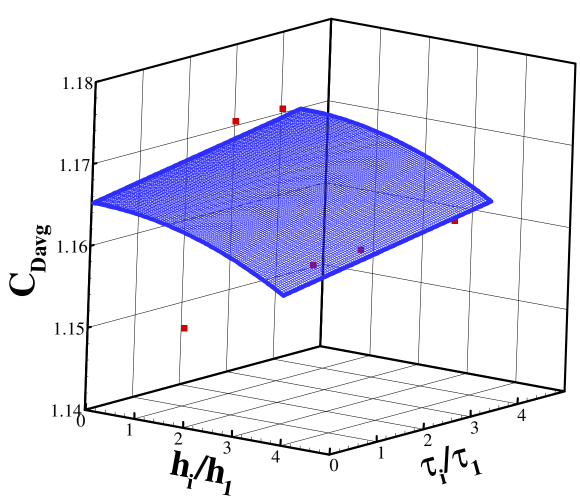
4. Overview of results

- Flow around a smooth cylinder

Reynolds Number	Turbulence Model	Number of Submissions
1×10^3	k-ω SST	2
1×10^3	None	2
1×10^4	k-ω SST	2
1×10^5	k-ω SST	4
1×10^5	None	2
1×10^5	k-ε	1
1×10^5	Spalart & Allmaras	1
5×10^5	k-ω SST	4
5×10^5	None	2
5×10^5	k-ε	1
5×10^5	Spalart & Allmaras	1
1×10^6	k-ε	1

4. Overview of results

- Flow around a smooth cylinder



SST *k-ω*, $Re_D=10^5$
Submission includes
6 calculations using

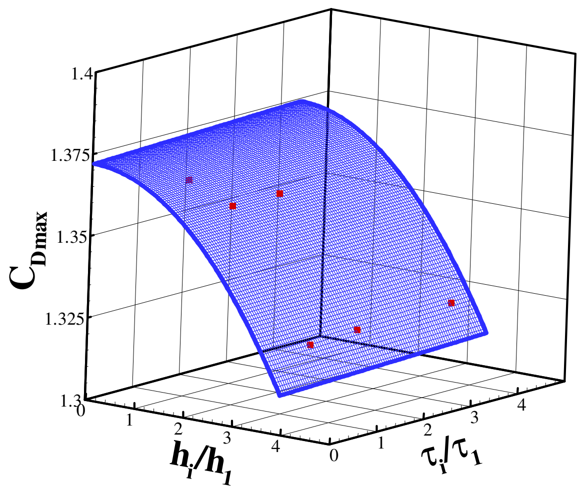
$$\left[\left(\frac{h_i}{h_1}\right)=1,\left(\frac{\tau_i}{\tau_1}\right)=1\right]_1 \quad \left[\left(\frac{h_i}{h_1}\right)=1.9,\left(\frac{\tau_i}{\tau_1}\right)=1\right]_2$$

$$\left[\left(\frac{h_i}{h_1}\right)=1.9,\left(\frac{\tau_i}{\tau_1}\right)=2\right]_3 \quad \left[\left(\frac{h_i}{h_1}\right)=3.6,\left(\frac{\tau_i}{\tau_1}\right)=1\right]_4$$

$$\left[\left(\frac{h_i}{h_1}\right)=3.6,\left(\frac{\tau_i}{\tau_1}\right)=2\right]_5 \quad \left[\left(\frac{h_i}{h_1}\right)=3.6,\left(\frac{\tau_i}{\tau_1}\right)=4\right]_6$$

4. Overview of results

- Flow around a smooth cylinder



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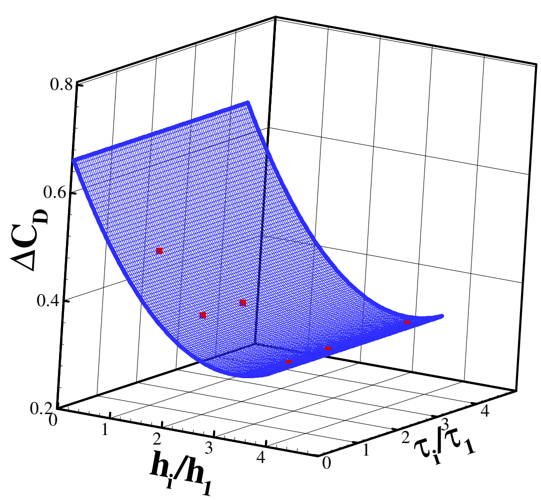
4. Overview of results

- Flow around a smooth cylinder



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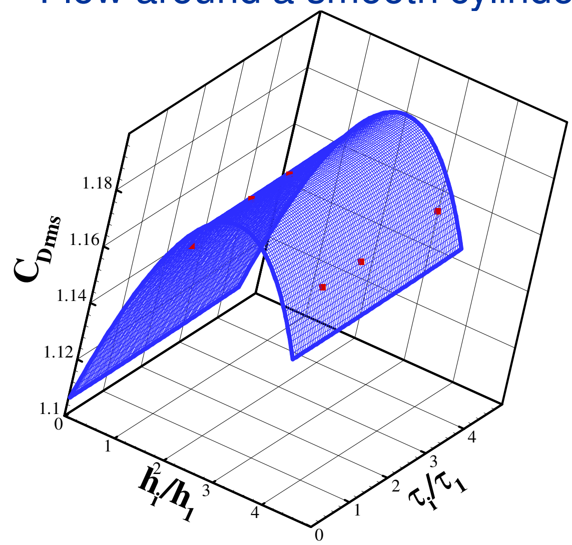
4. Overview of results

- Flow around a smooth cylinder



SST *k*-ω, $Re_D=10^5$
Submission includes
6 calculations using

$$\left[\left(\frac{h_i}{h_1}\right)=1,\left(\frac{\tau_i}{\tau_1}\right)=1\right]_1 \quad \left[\left(\frac{h_i}{h_1}\right)=1.9,\left(\frac{\tau_i}{\tau_1}\right)=1\right]_2$$

$$\left[\left(\frac{h_i}{h_1}\right)=1.9,\left(\frac{\tau_i}{\tau_1}\right)=2\right]_3 \quad \left[\left(\frac{h_i}{h_1}\right)=3.6,\left(\frac{\tau_i}{\tau_1}\right)=1\right]_4$$

$$\left[\left(\frac{h_i}{h_1}\right)=3.6,\left(\frac{\tau_i}{\tau_1}\right)=2\right]_5 \quad \left[\left(\frac{h_i}{h_1}\right)=3.6,\left(\frac{\tau_i}{\tau_1}\right)=4\right]_6$$

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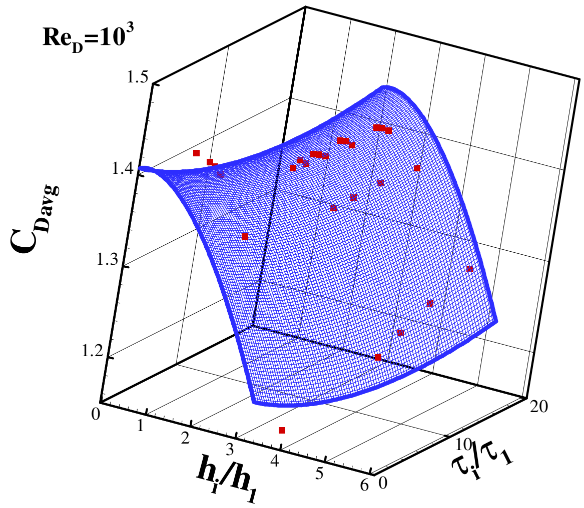
4. Overview of results

- Flow around a smooth cylinder



SST *k*-ω

$Re_D=10^3$
$Re_D=10^4$
$Re_D=10^5$
$Re_D=5\times10^5$

All results are from the same code

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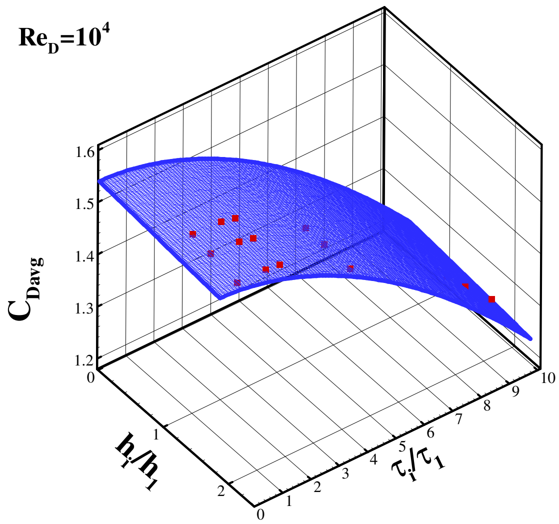
4. Overview of results

- Flow around a smooth cylinder



SST *k-ω*

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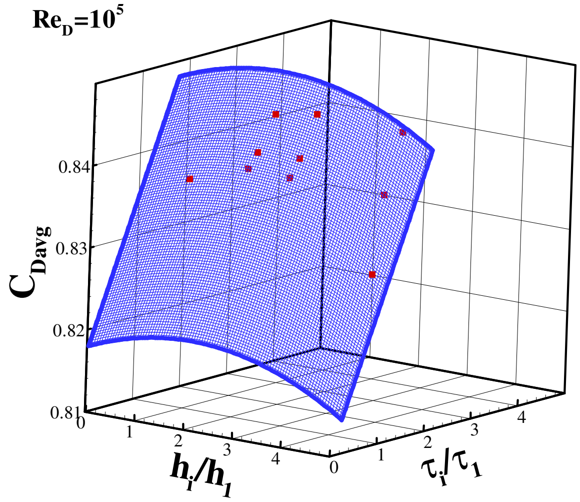

SST *k-ω*

$Re_D=10^3$
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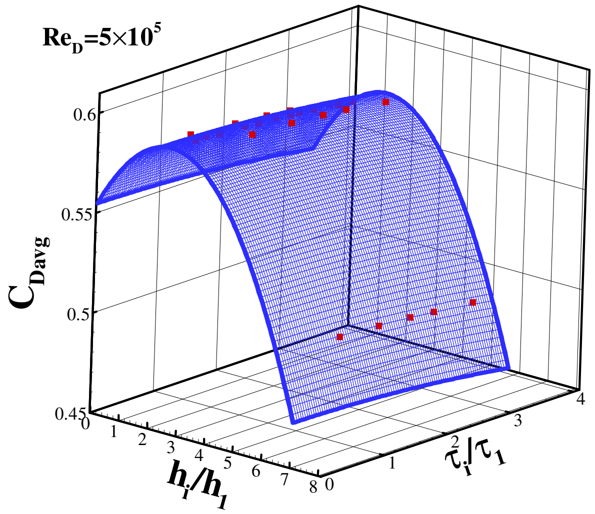
4. Overview of results

- Flow around a smooth cylinder



SST *k-ω*

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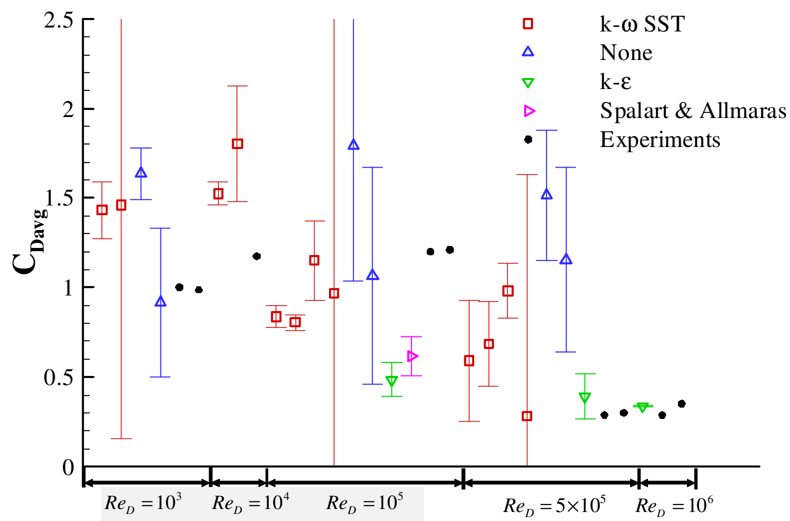
- Flow around a smooth cylinder



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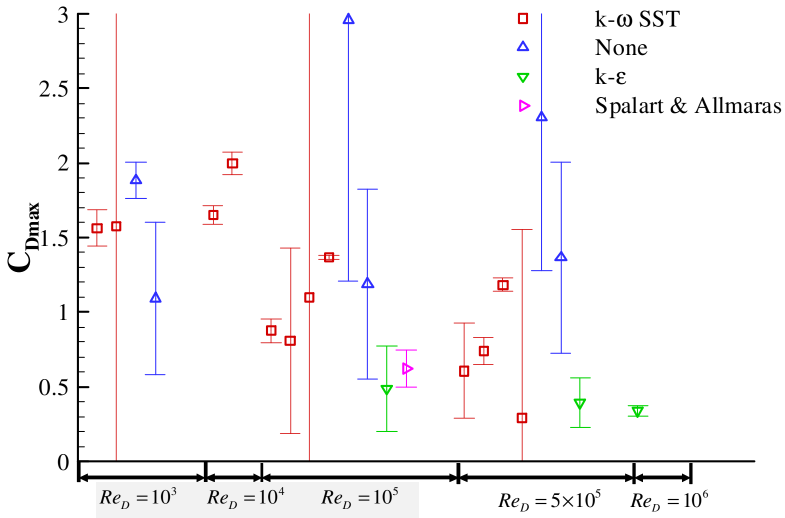
- Flow around a smooth cylinder



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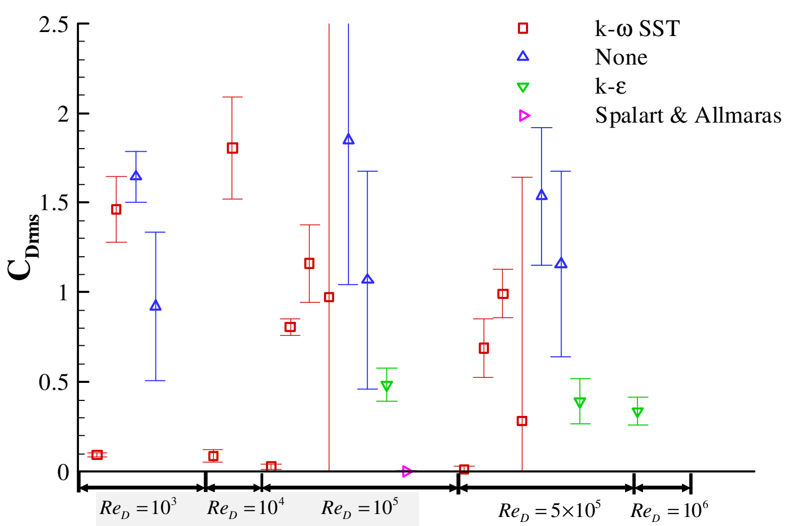

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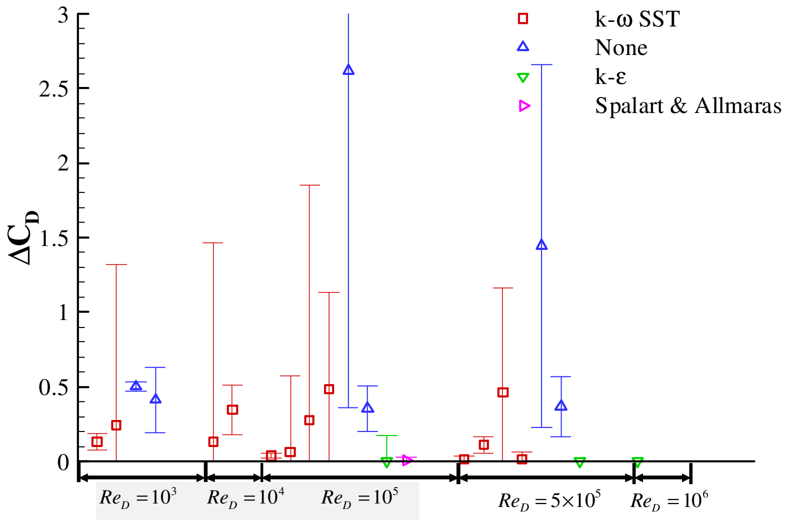

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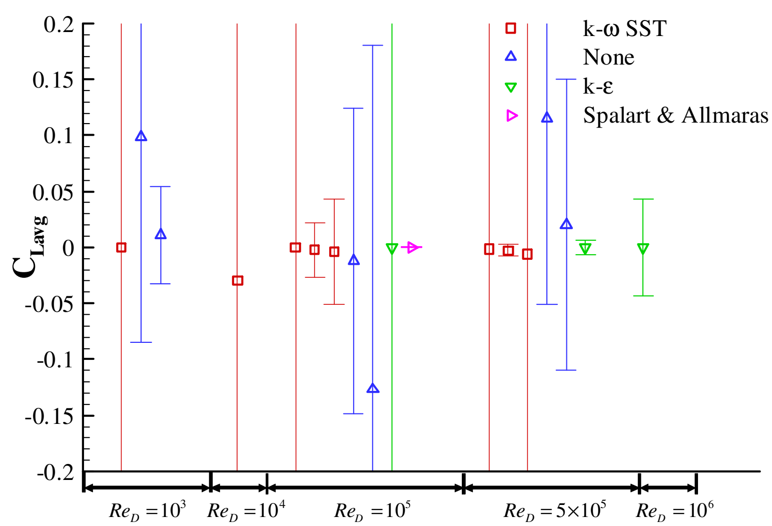

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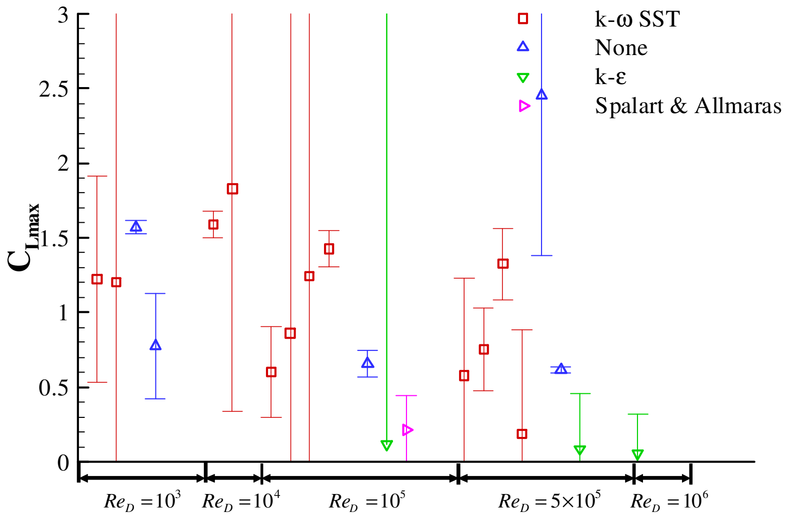

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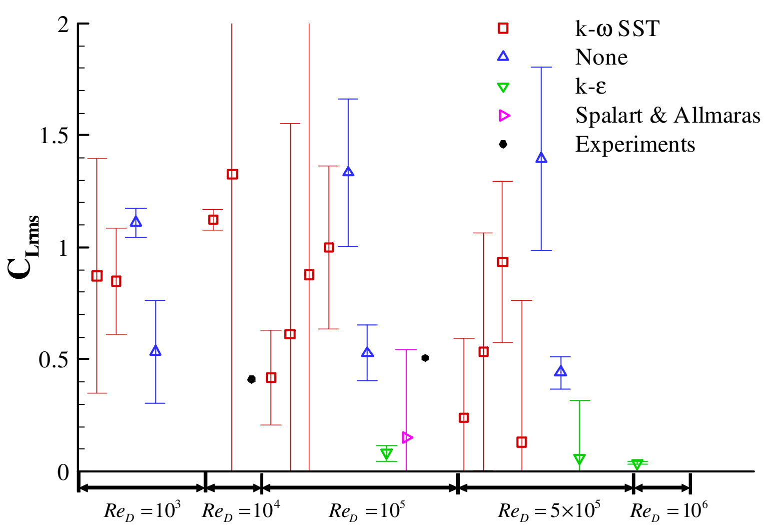

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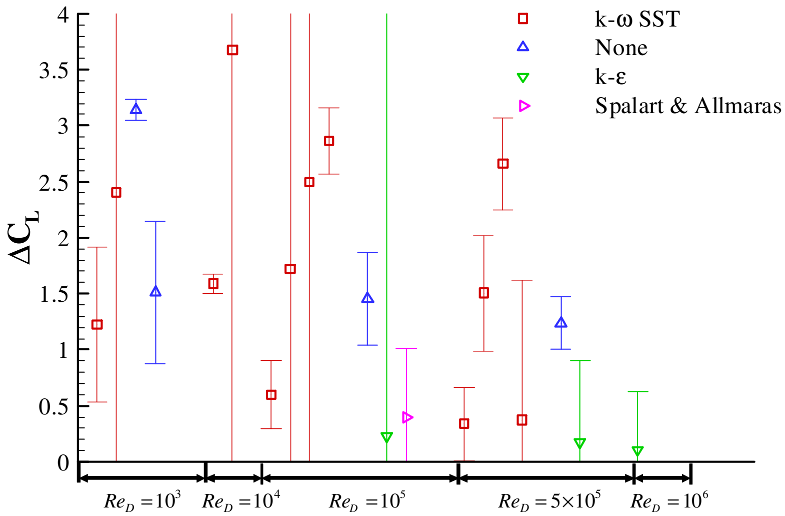

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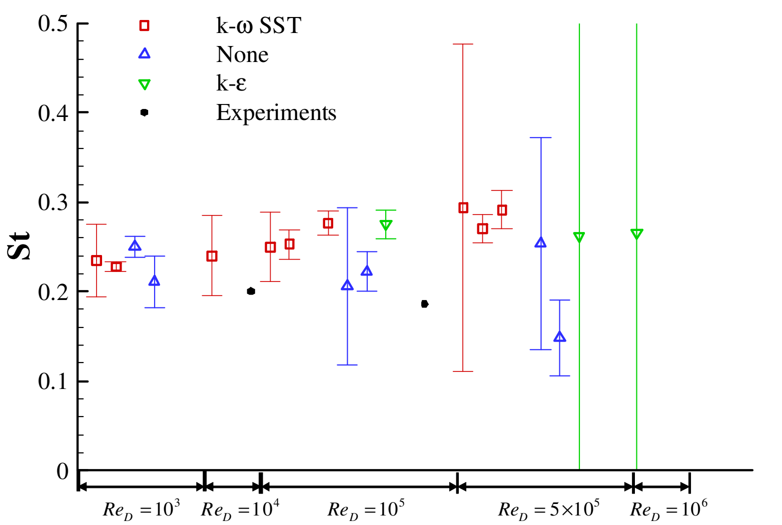

4. Overview of results

- Flow around a straked-riser

Submissions	I	Ia	II	III
C_{Davg}	1.659	1.89	1.242	1.867
C_{Drms}	1.659	1.89	1.242	1.867
C_{Lrms}	0.012	0.015	0.141	0.069
St	---	---	0.154	---

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5. Final Remarks

This first edition of the Workshop on Verification and Validation of CFD for Offshore flows showed the difficulties and advantages in assessing separately numerical (Verification) and modeling (Validation) errors in complex turbulent flows.

All sessions of the Workshop lead to very interesting and fruitful discussions.

Thank you to all the groups that submitted results to the Workshop (including those that have not attended the sessions)

5. Final Remarks

It was a starting point for what we believe to be the most promising way to improve the accuracy of our numerical solutions, understand the limits of our present turbulence models and improve the quality of the mathematical models behind our CFD simulations.

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5. Final Remarks

The second edition will take place in the forthcoming OMAE 2013 Conference to be held in Nantes (France) from 9 to 14 June

The success of these events depends on the submission of data. Therefore, we invite you all to submit data for the next edition of the Workshop even if you are not able to attend the OMAE 2013 Conference!