

## 3D hill flow, Test Case 26

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<http://cfd.me.umist.ac.uk/flomania/>

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**ICSTM:** RANS, low-Re RSM,  $128 \times 96 \times 96$  mesh

**FOI:** RANS, EARSM,  $121 \times 71 \times 81$  mesh

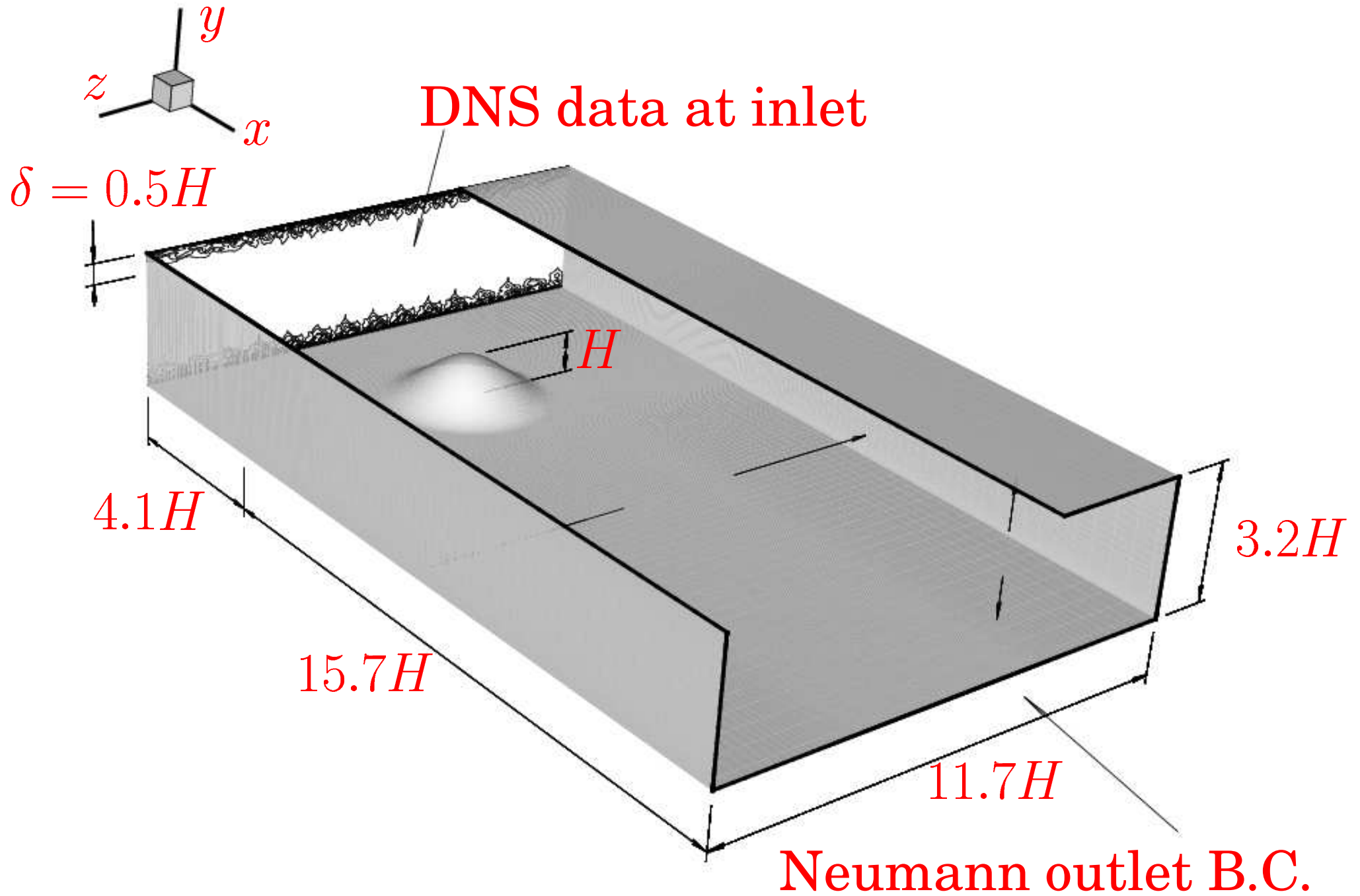
**UMIST:** RANS, Wilcox  $k - \omega$ ,  $128 \times 160 \times 96$  mesh

**SPTU:** RANS, 1-eq. Spalart-Allmaras,  $115 \times 65 \times 67$  mesh

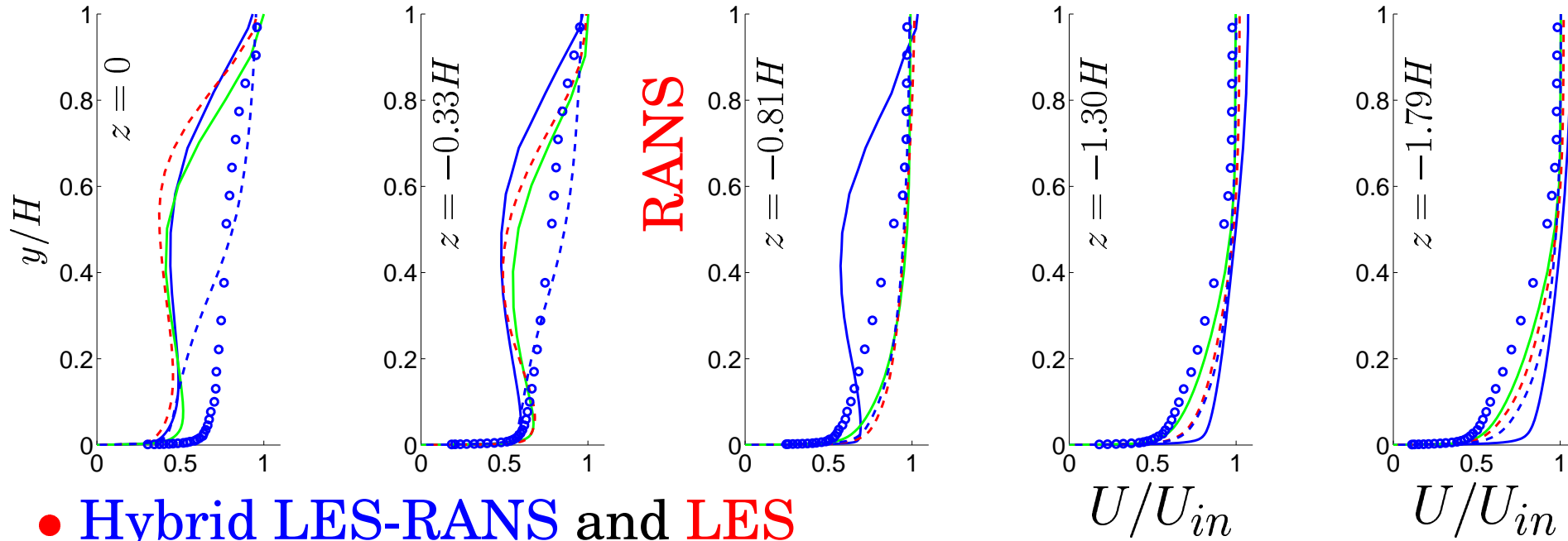
**EDF:** LES, 800 000 cells (unstructured)

**Chalmers:** Hybrid LES-RANS, with forcing,  $130 \times 160 \times 82$  mesh

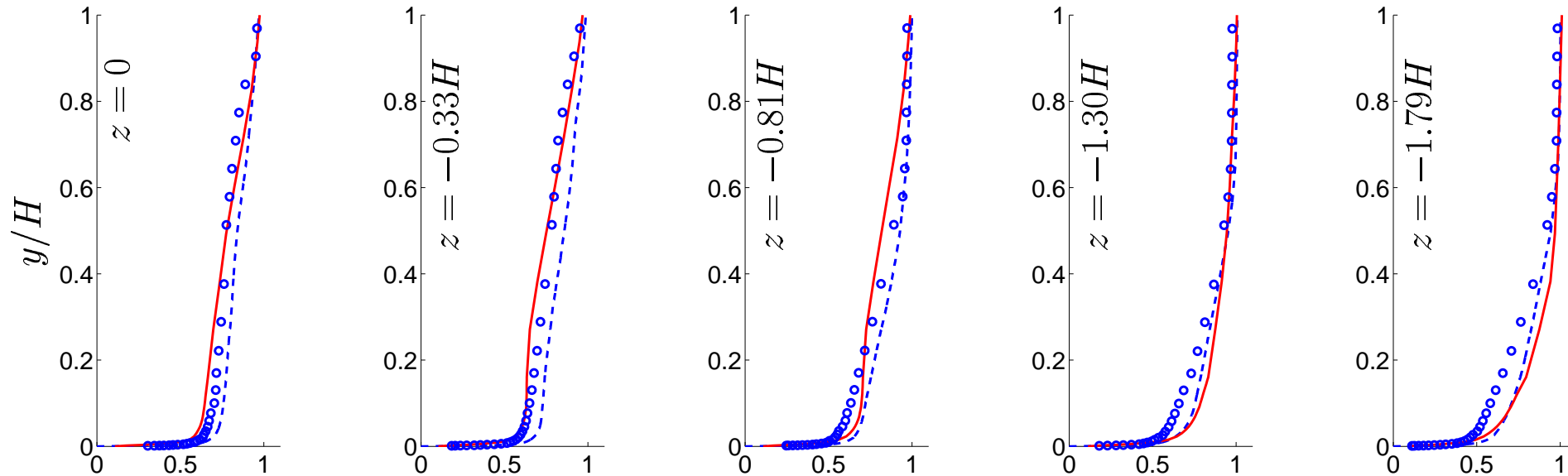
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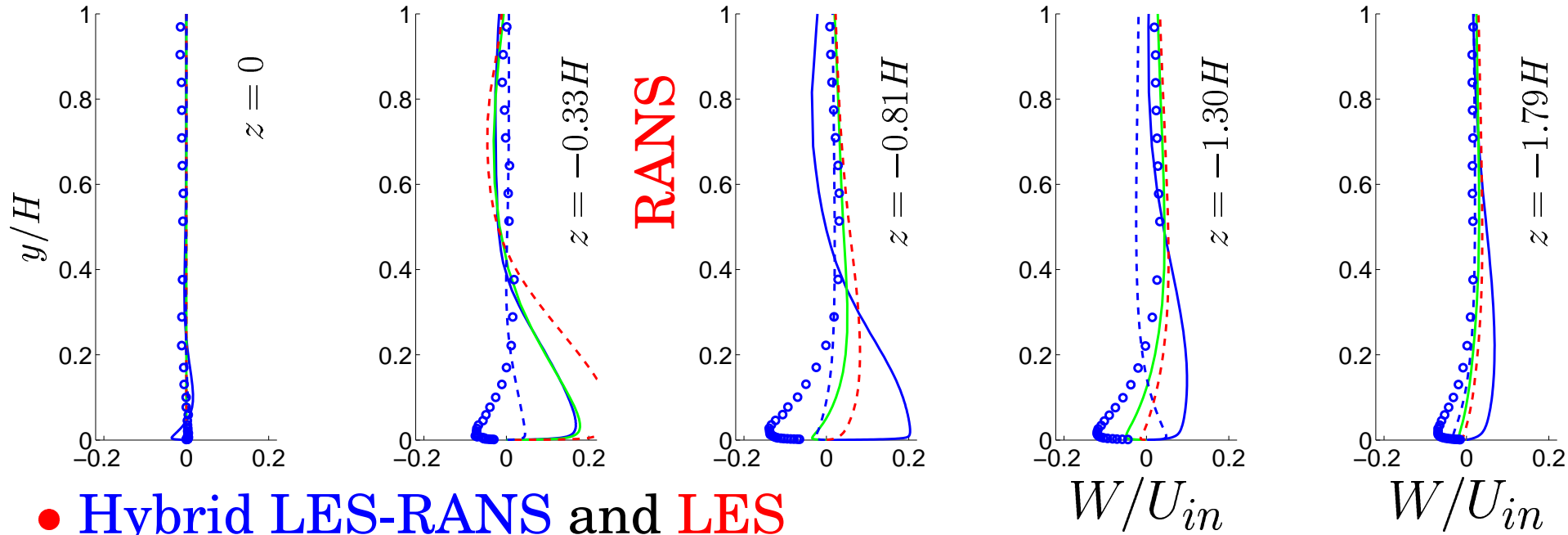
— EARSM; —  $k - \omega$ ; — 1-eq. SA; - - Low-Re RSM



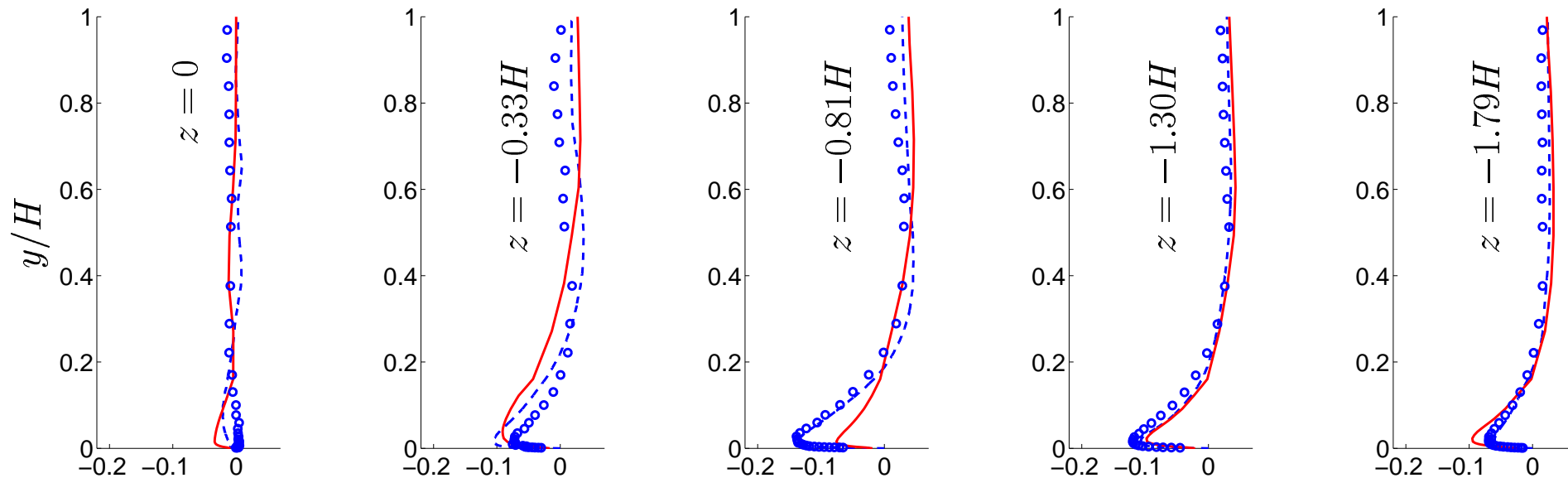
● Hybrid LES-RANS and LES



— EARSM; —  $k - \omega$ ; — 1-eq. SA; - - - Low-Re RSM

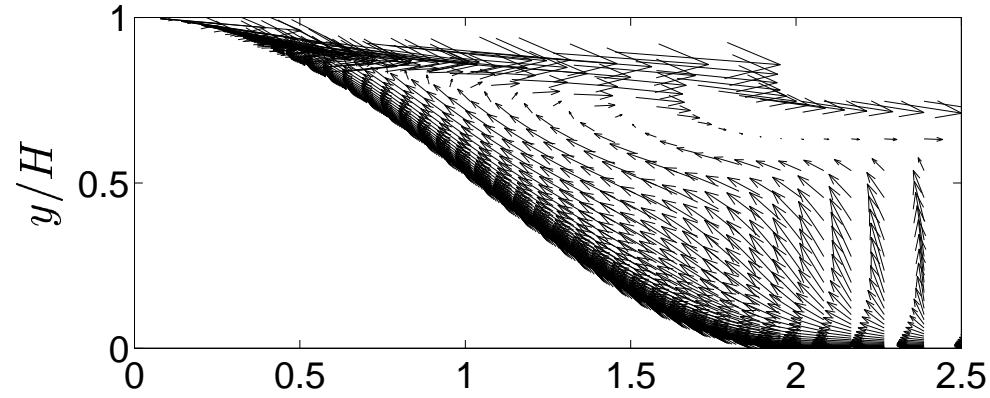


● Hybrid LES-RANS and LES

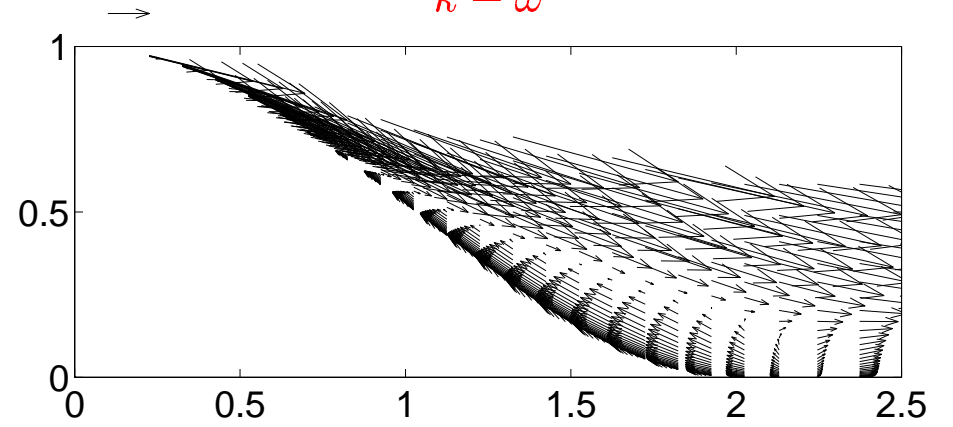


$0.2U_{in}$

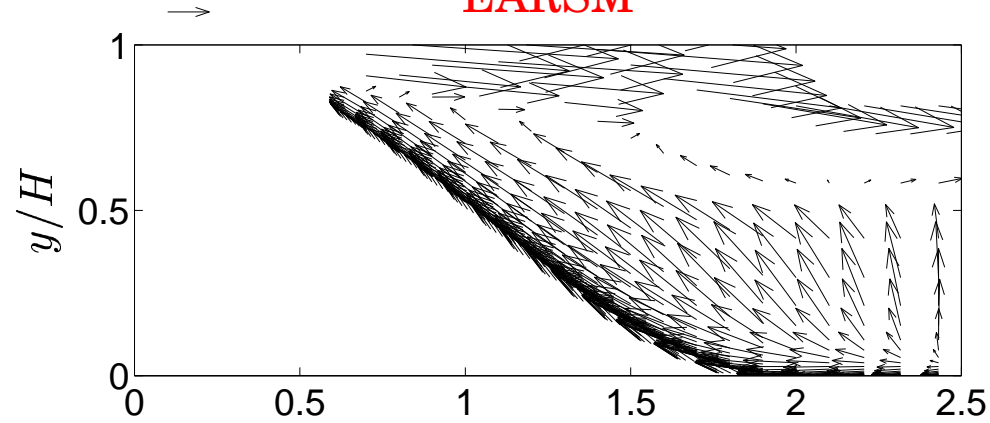
**Low-RE RSM**



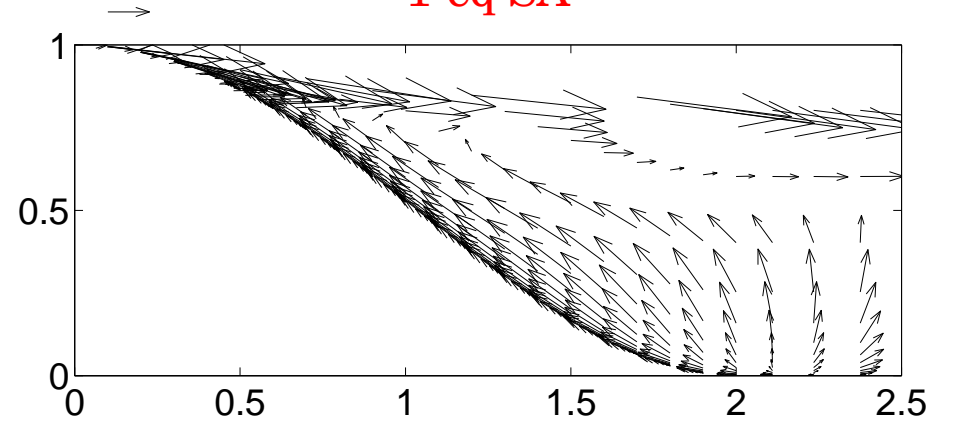
$k - \omega$



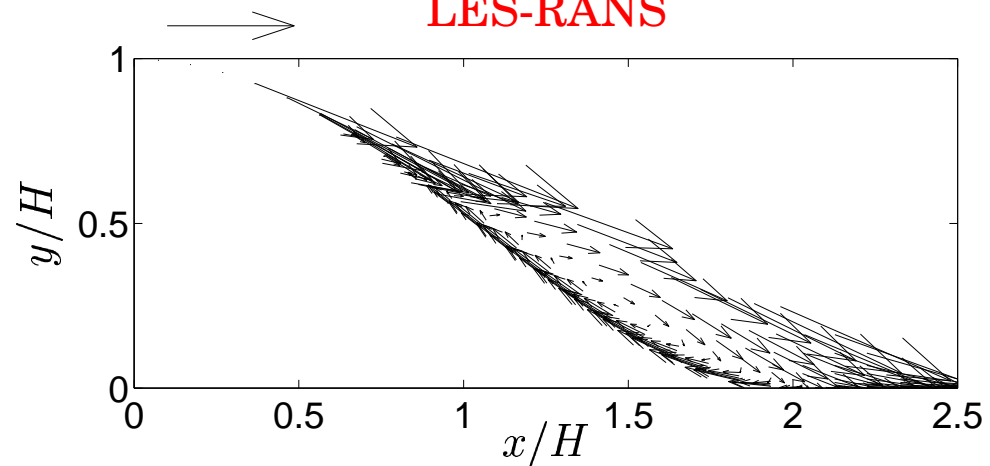
**EARSM**



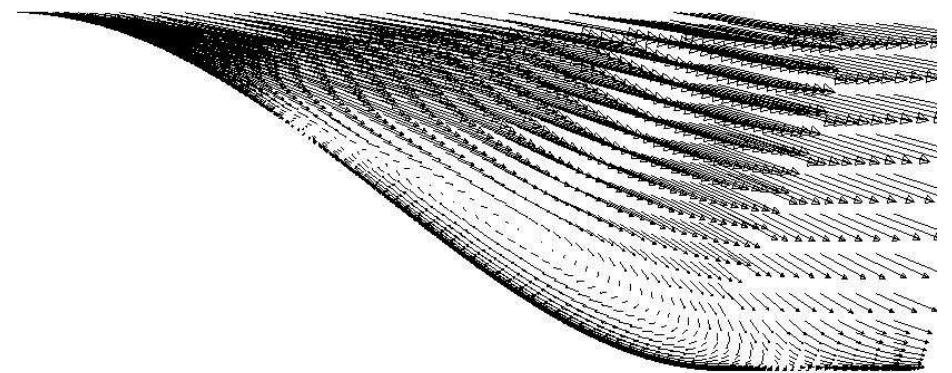
**1-eq SA**



**LES-RANS**

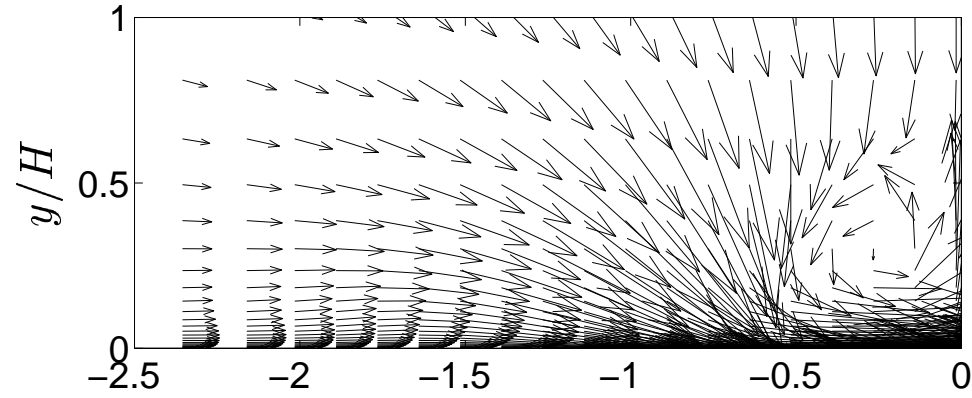


**LES**

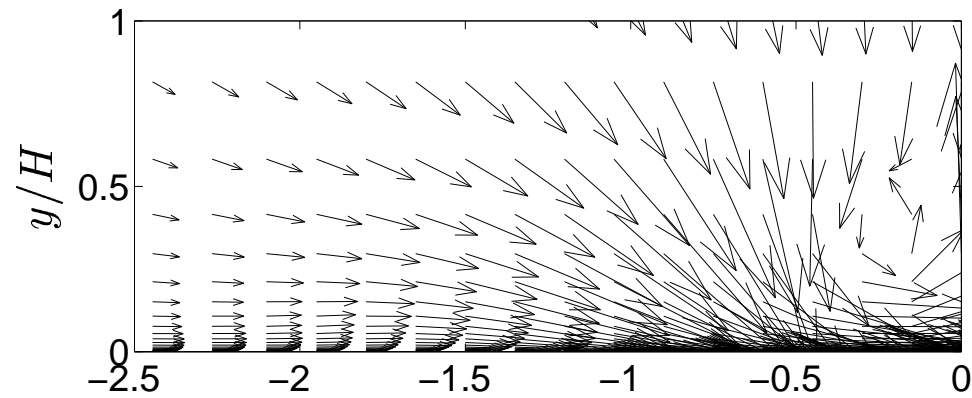




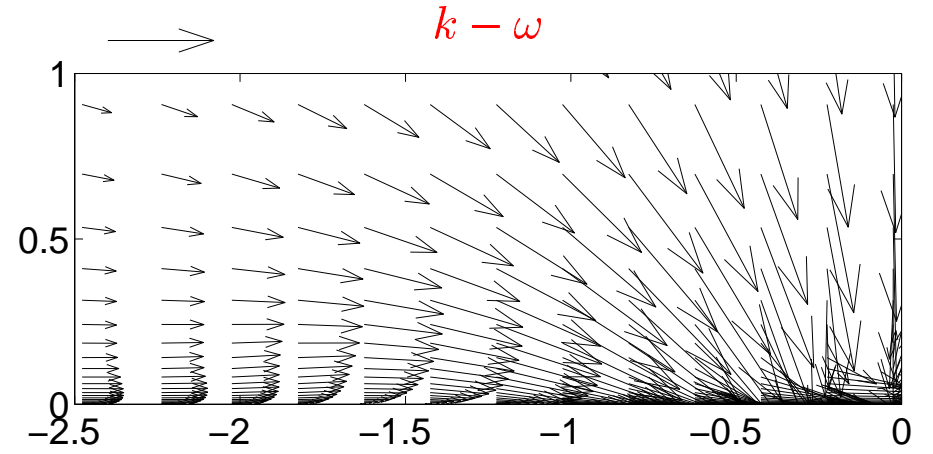
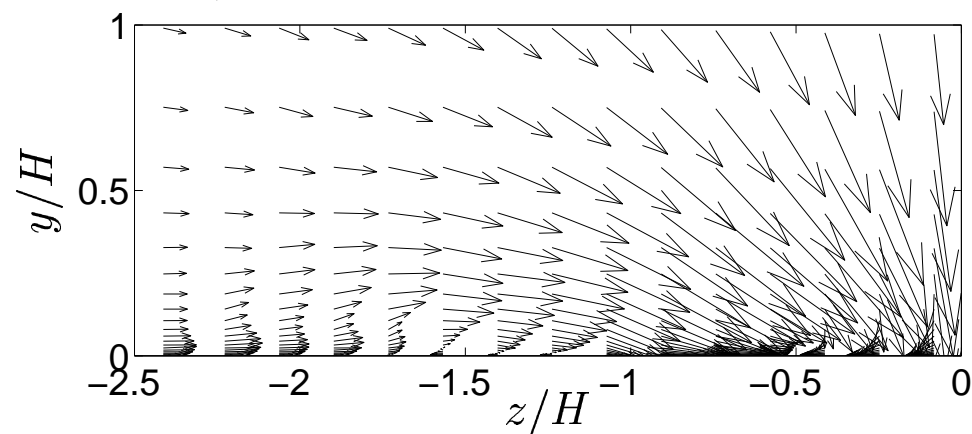
$0.1U_{in}$  Low-RE RSM  $x/H = 2$



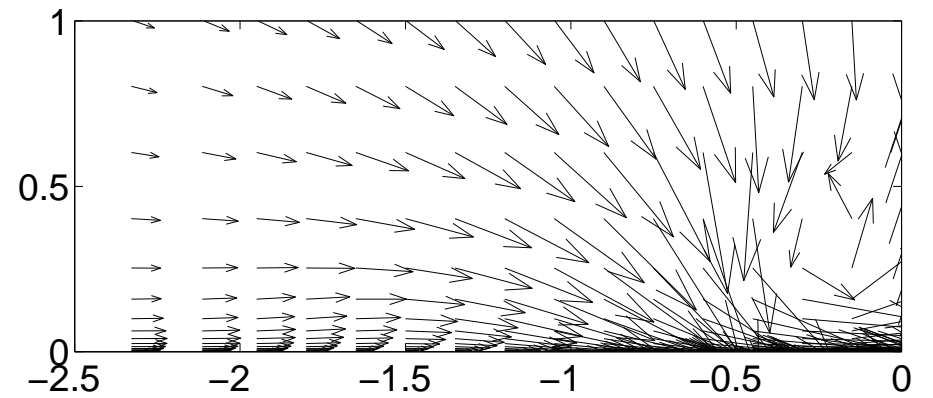
**EARSM**



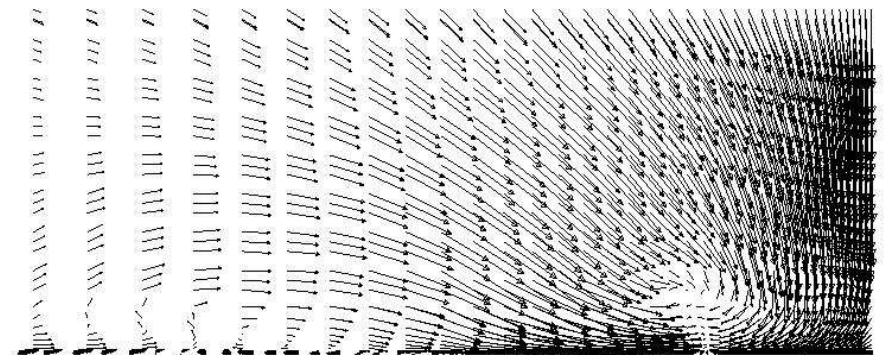
**LES-RANS**



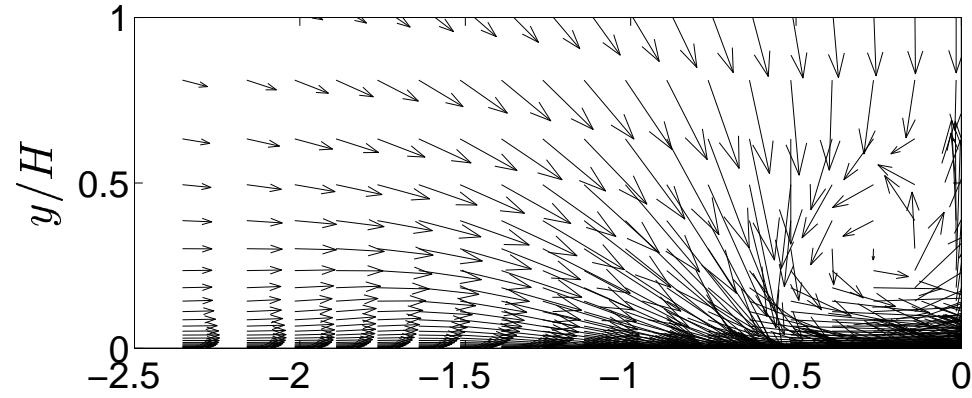
**1-eq SA**



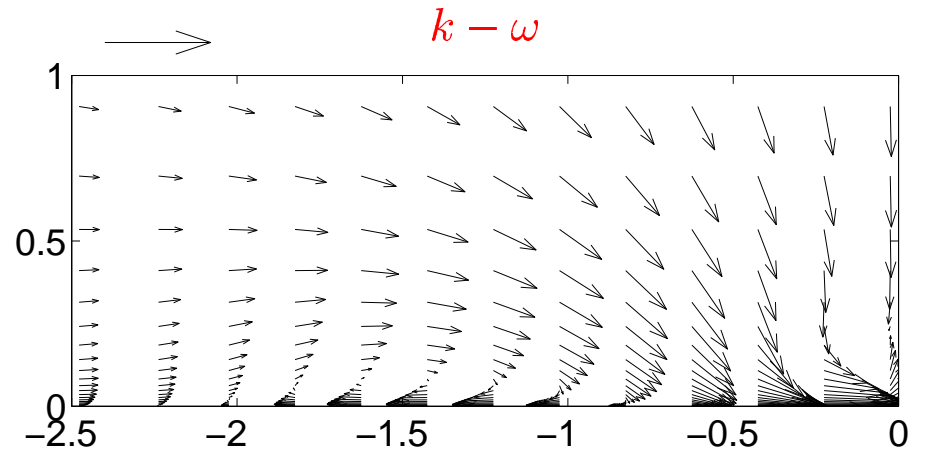
**LES**



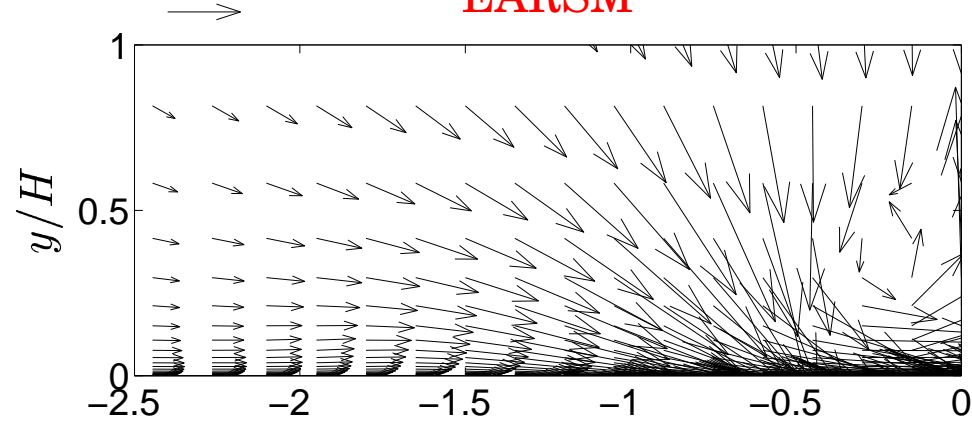
$0.1U_{in}$  Low-RE RSM  $x/H = 3$



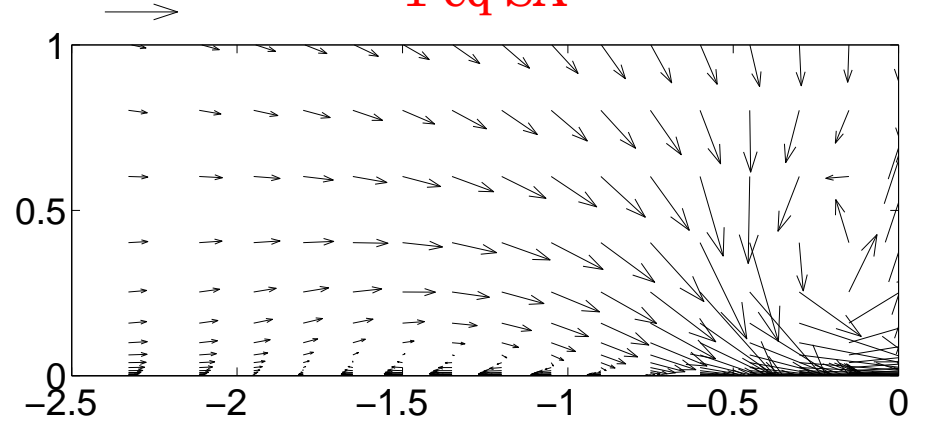
**EARSM**



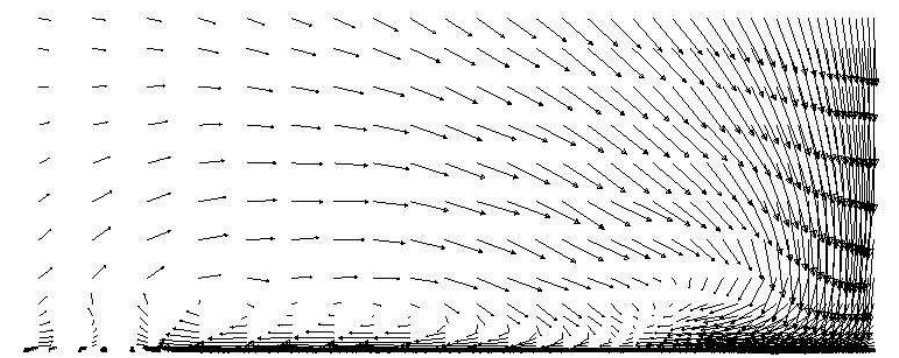
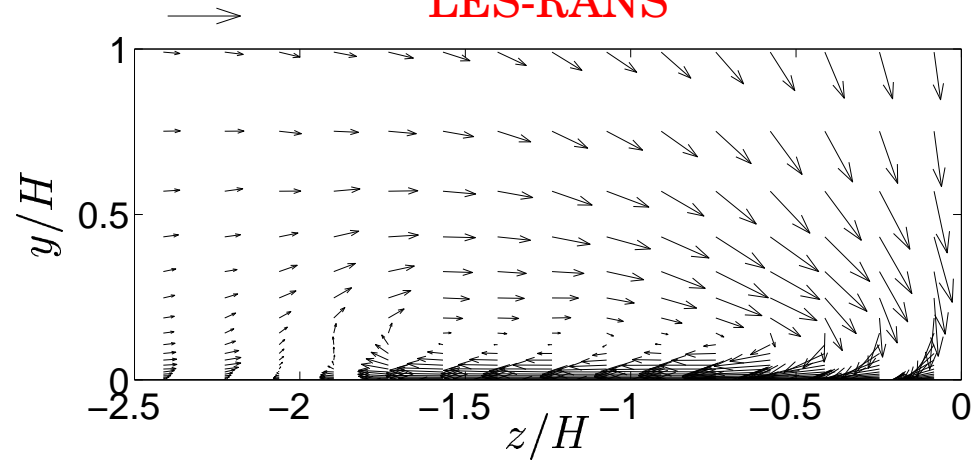
**1-eq SA**



**LES-RANS**

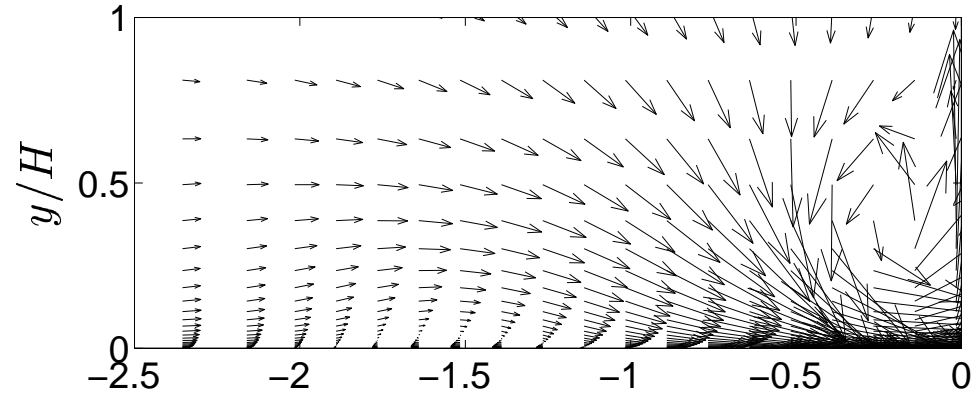


**LES**

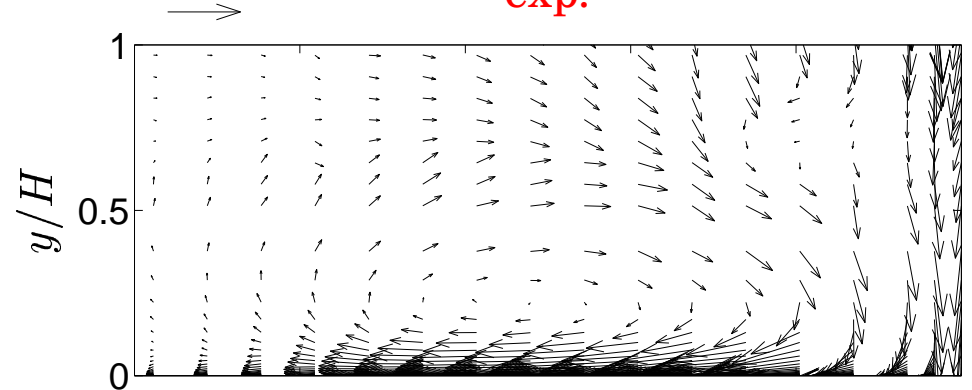




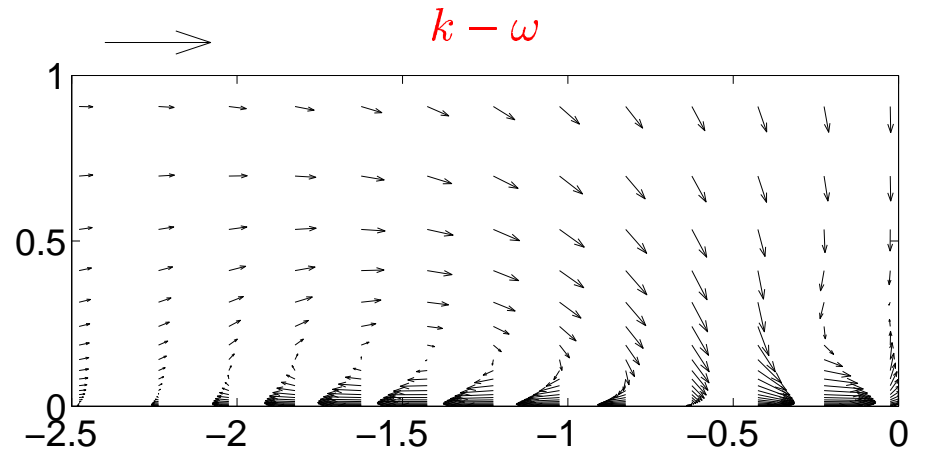
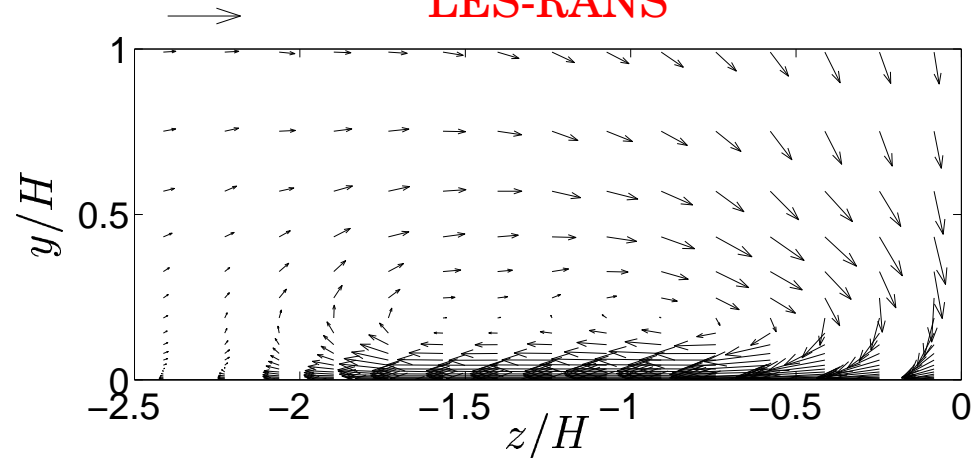
$0.1U_{in}$  **Low-RE RSM, EARSM**  $x/H = 3.69$



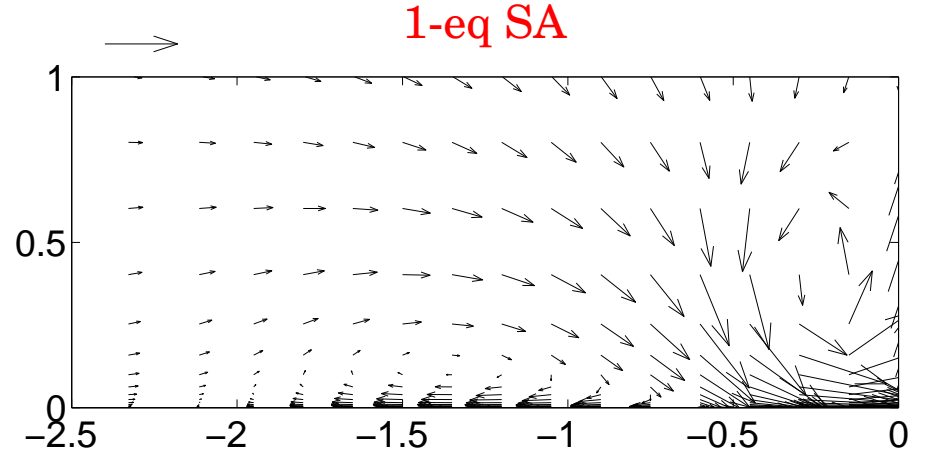
**exp.**



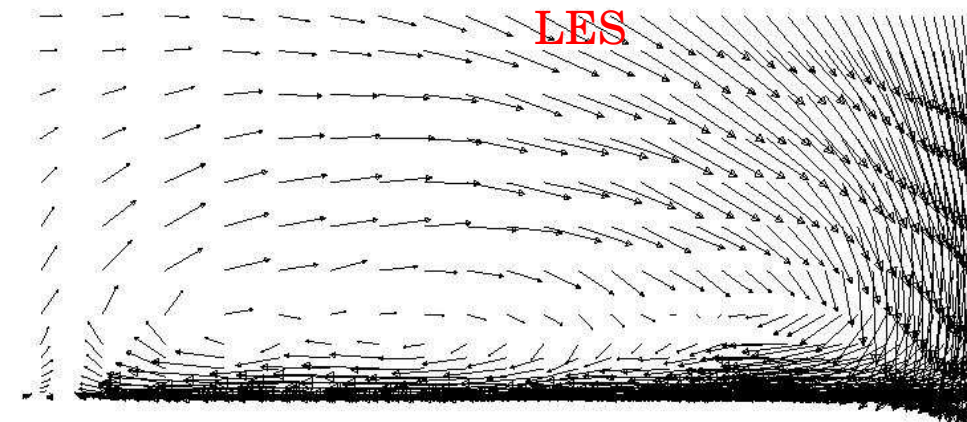
**LES-RANS**



**k-omega**

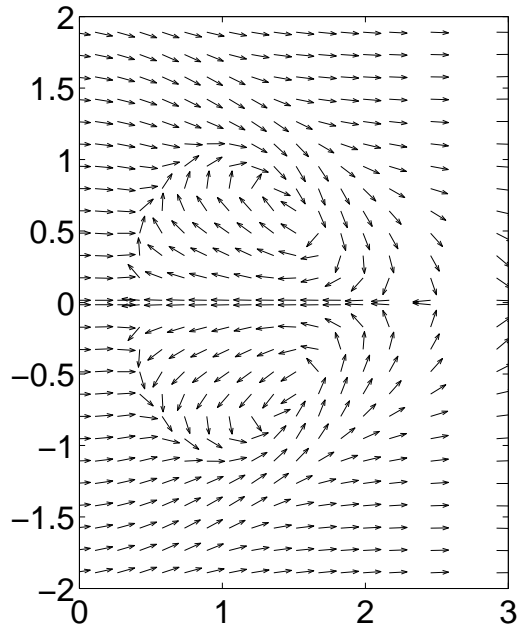


**1-eq SA**

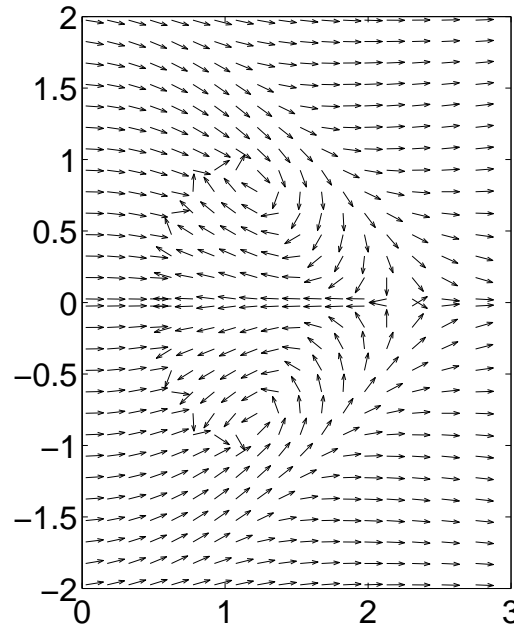


**LES**

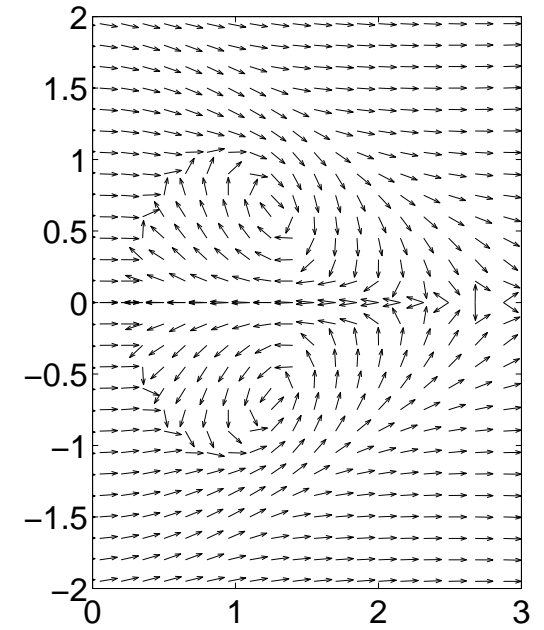
**Low-RE RSM**



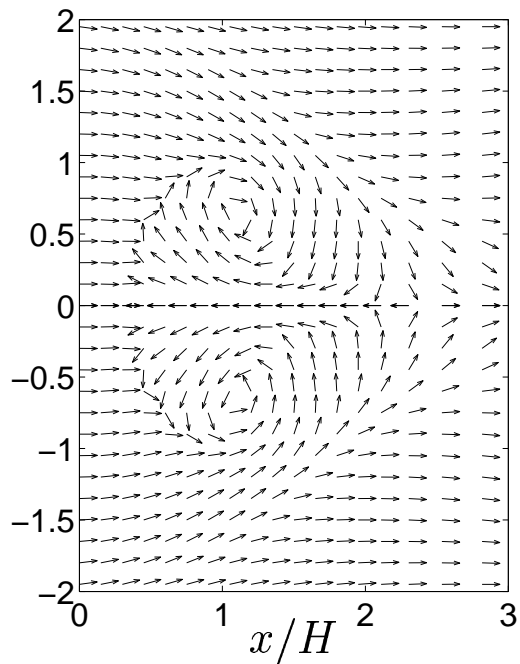
**$k - \omega$**



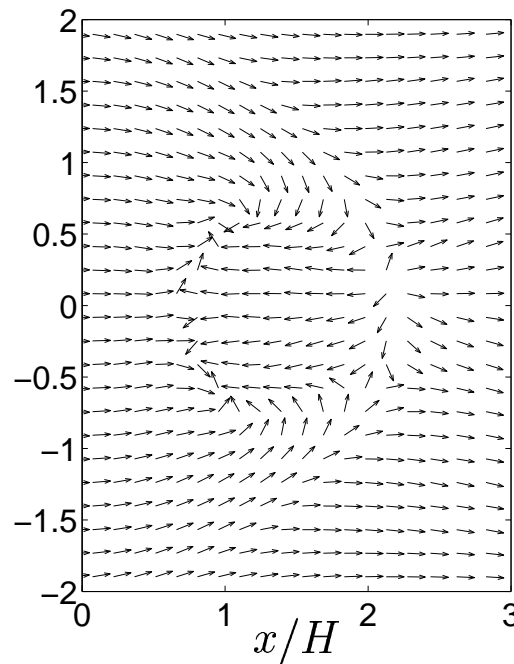
**EARSM**



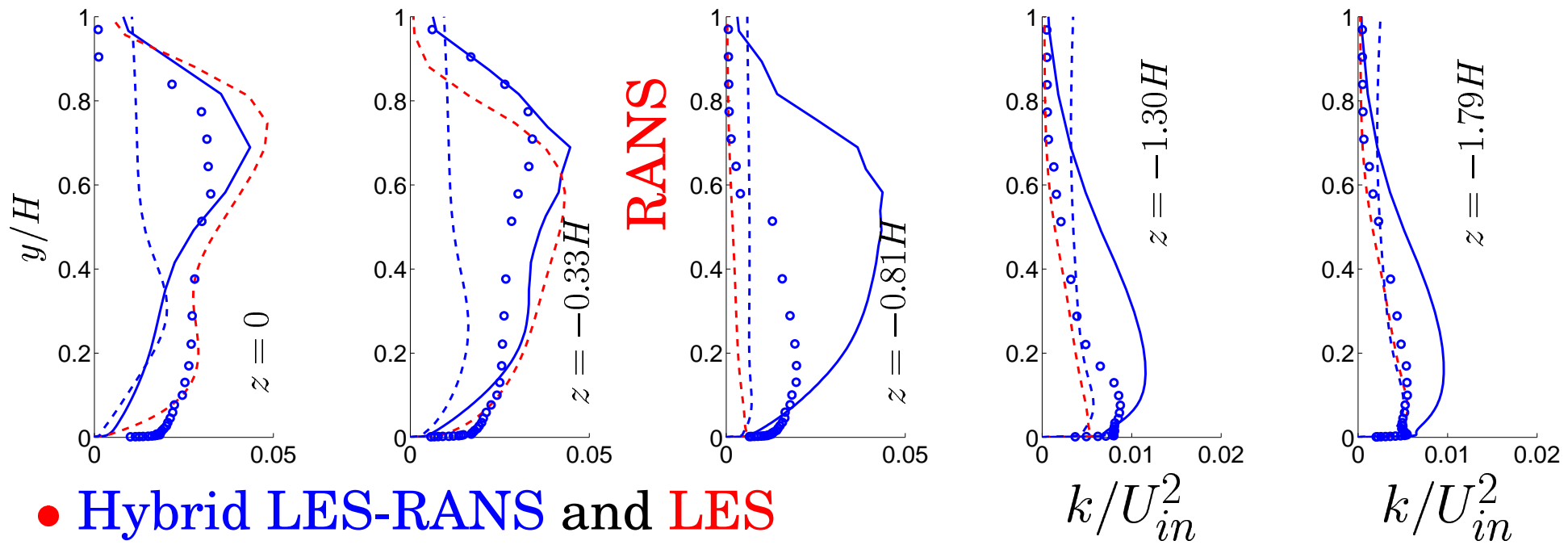
**1-eq SA**



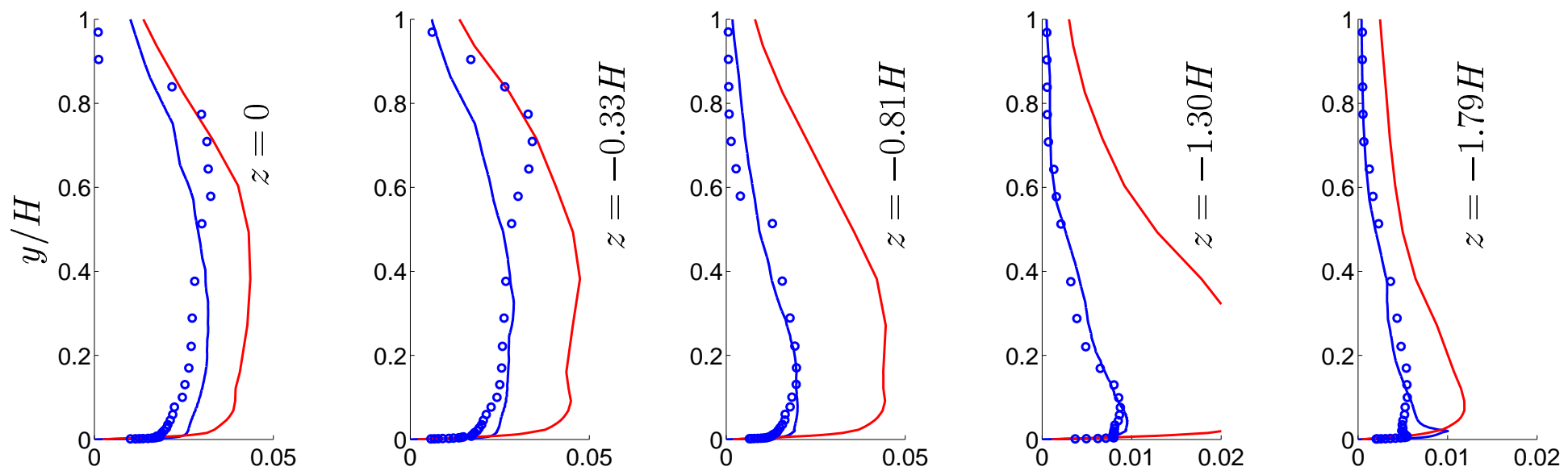
**LES-RANS**



— EARSM;    —  $k$  —  $\omega$ ;    — Low-Re RSM

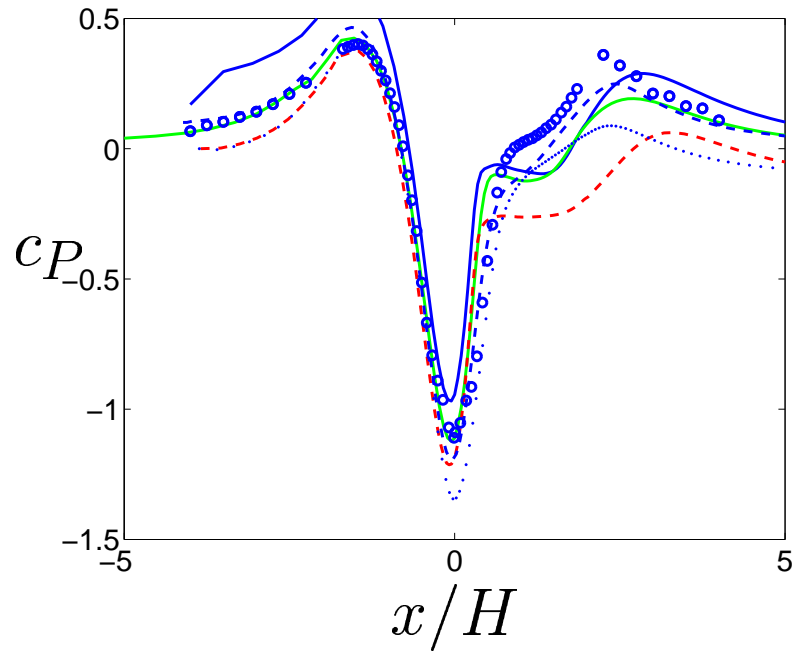


● Hybrid LES-RANS and LES

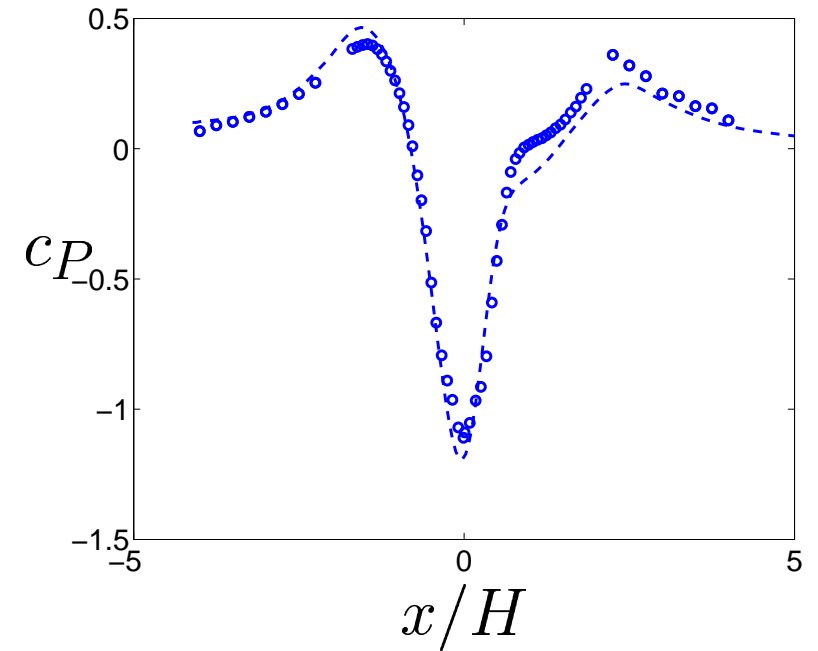


— EARSM;  $\cdot$   $k - \omega$ ; --- Low-Re RSM

**RANS**



**LES-RANS**



**SUMMARY**

- All RANS models give a completely incorrect flow field
- LES and hybrid LES-RANS in good agreement with expts.
- However, it seems that the LES/LES-RANS predictions fail to capture a recirculation region near the crest of the hill.

● Mesh sizes

RANS	0.5 – 1.2 million (half of the domain)
LES	0.8 million
Hybrid LES-RANS	1.7 million

● CPU times

RANS, EARSM	1 – 2 days	1-CPU DEC-Alpha
RANS, RSM	6 hours	4-CPU P4
RANS SA 1-eq	1h40m	2-CPU P3, 1000 MHz
LES	2 weeks	1-CPU, Fujitsu VPP5000
LES-RANS	1 week (10+10 through flows)	1-CPU Opteron 244