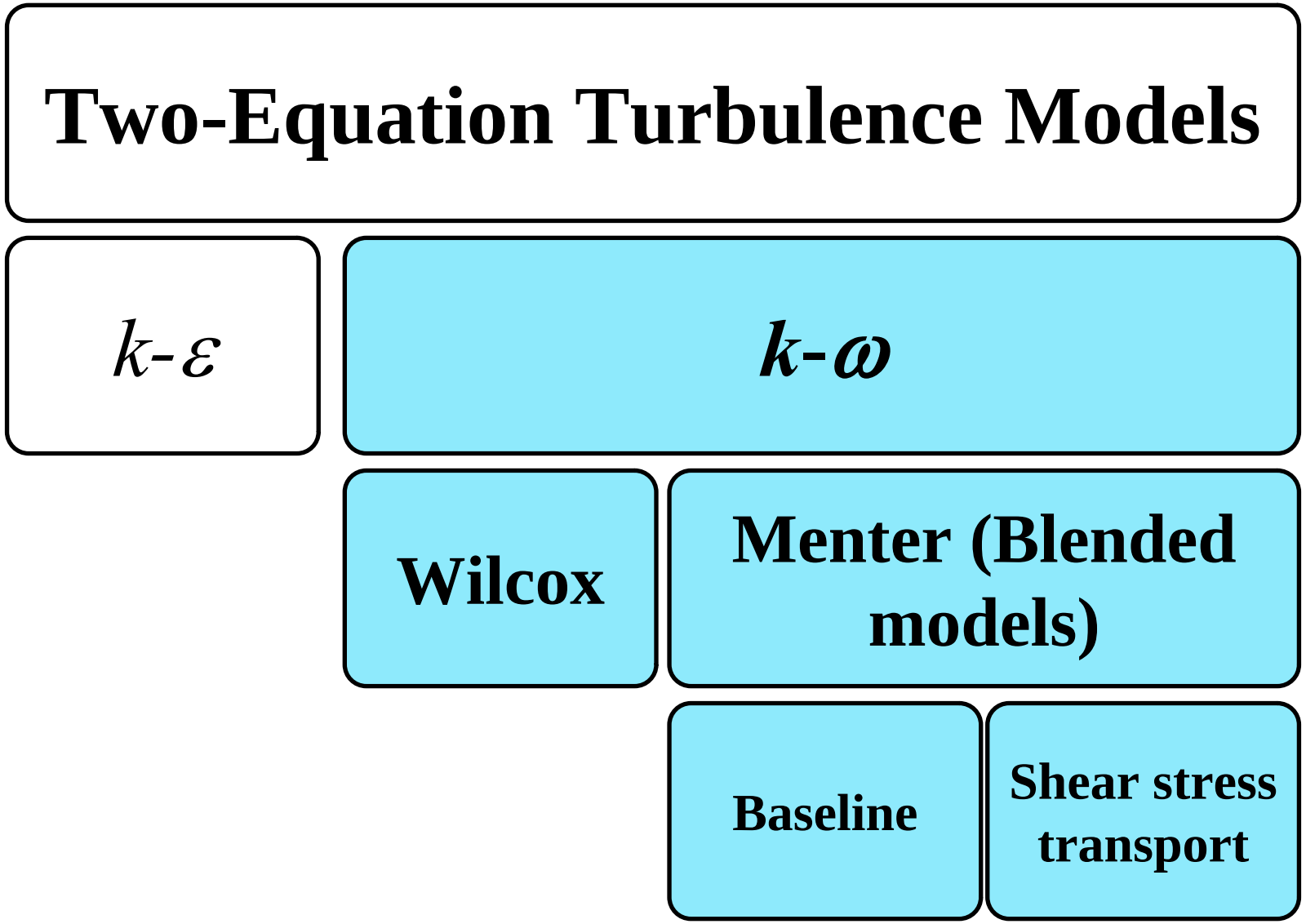
> "*?9"* !

+@ 6#8(9"* !14 '#/$19&#1) 40("9"* !9//-11#) ! 4*)9/1
9!'1&#9$!93/-19))(&9"#A
>#!"#&B$13/#!'#'1C$k-\omega$D14 '#/$1,9?#13##!1"#$"#'12 &1
$*!($ *'9/E1)! *'9/19!'1$9@6" ",1@9?#13 (!'9&-1/9-#&$1
!1$4 ",19!'1& (=,1$(&29)#$A
;0#)*2-*!=1& (=,!#$$1*!1$k-\omega$14 '#/$1*$1#9$*#&1",9!1",9"1*!1
$k-\varepsilon$14 '#/$A
+,#&#1*$19!1*!)&#9$*!=1*!"#&#$"1*!1",#1&#$#9&),1&#/9"#'1" 1
$#'*4#!"1"&9!$0 &"1(!'#&1/ !=1@9?#$A


Two-Equation Turbulence Models
k-ε
k-ω
Wilcox
Menter (Blended models)
Baseline
Shear stress transport

F ?#&!*!=1#8(9"* !$

$$\frac{\partial u}{\partial t}=\frac{\partial U}{\partial t}+\frac{\partial \tau}{\partial y}=\frac{\partial U}{\partial t}+\frac{\partial}{\partial y}\left\{(\nu+\nu_t)\frac{\partial u}{\partial y}\right\}$$

k-ε1 4 '#/

$$\nu_t = C_\mu f_\mu \frac{k^2}{\tilde{\varepsilon}}$$

k-ω1 4 '#/

$$\nu_t = \frac{k}{\omega}$$

F ?#&!*!=1#8(9"* !$1 21$k$-$\omega$14 '#/1

$$\frac{\partial k}{\partial t} = \underbrace{\frac{\partial}{\partial y}\left\{\left(\nu + \nu_t \sigma_{k\omega}\right)\frac{\partial k}{\partial y}\right\}}_{\text{Diffusion}} + \underbrace{\nu_t\left(\frac{\partial u}{\partial y}\right)^2}_{\text{Production}} - \underbrace{\beta^* \omega k}_{\text{Dissipation}}$$

$$\frac{\partial \omega}{\partial t} = \frac{\partial}{\partial y}\left\{\left(\nu + \nu_t \sigma_{\omega}\right)\frac{\partial \omega}{\partial y}\right\} + \gamma \frac{\nu + \nu_t}{\nu_t}\left(\frac{\partial u}{\partial y}\right)^2 - \beta\omega^2$$

$$+ 2\left(1 - F_1\right)\sigma_{\omega 2}\frac{1}{\omega}\frac{\partial k}{\partial y}\frac{\partial \omega}{\partial y}$$

$$k = \frac{\left(\overline{u'^2} + \overline{v'^2} + \overline{w'^2}\right)}{2}$$

H (!'9&-1) !'*"* !$

G &1$4 ",13#' $\omega_0 = 6\nu/(\beta_1 \Delta y_1)^2$

G &1& (=,13#' $\omega_0 = u_f^2 S_R / \nu$

$$S_R = (50/k_s^+)^2 \quad \text{for} \quad k_s^+ \le 25$$

$$S_R = 100/k_s^+ \quad \text{for} \quad k_s^+ > 25$$

"12&##6$"&#94I $$\frac{\partial u}{\partial y} = \frac{\partial k}{\partial y} = \frac{\partial \omega}{\partial y} = 0$$

; /("* !10&)#'(&#

F ?#&!*!=1#8(9"* !$1@#&#1#J0&#$$#'1*!1'*4#!$* !/#$$12 &41($*!=I

U_cKU_L1K12&##6$"&#9 4 1?#/)*"-19 4 0/*"('#

χ K1Mπ/TK9!=(/9&12&#8(#!)-

ρ K1 4 9$$1'#!$*"-

ν K1N*!# 4 9"*)1?*$) $*"-

y_h K1'*$"9!)#12& 41",#13 "" 41" 12&##6$"&#9 4 1C9J*$1 21$- 4 4#"&-D

+,#1'*4#!$* !/#$$1= ?#&!*!=1#8(9"* !$1&#8(*&#'1 !/-1@9?#1.#-! /'$1

!(4 3#&E1*RE*E19!'1&#)*0&)9/1 21;"& (,9/1!(4 3#&E1*S*A1

$$RE = \frac{U_0^2}{\nu\chi}, \quad S = \frac{U_0}{\chi y_h}$$

O(4#&*)9/1 4#", '

- &9!N6O*) /$!1"-0#1*40/*)*"12*!*"#1'*22#&#!)#1$),#4#A

- +,#1=&*'1$09)*!=1@9$1?9&*#'1#J0 !#!"*9//-12 &13#""#&19))(&9)-A

- 1%!1$09)#1PLL19!'1*!1"*4#1QMLL1$"#0$10#&1@9?#1)-)/#1@#&#1($#'A

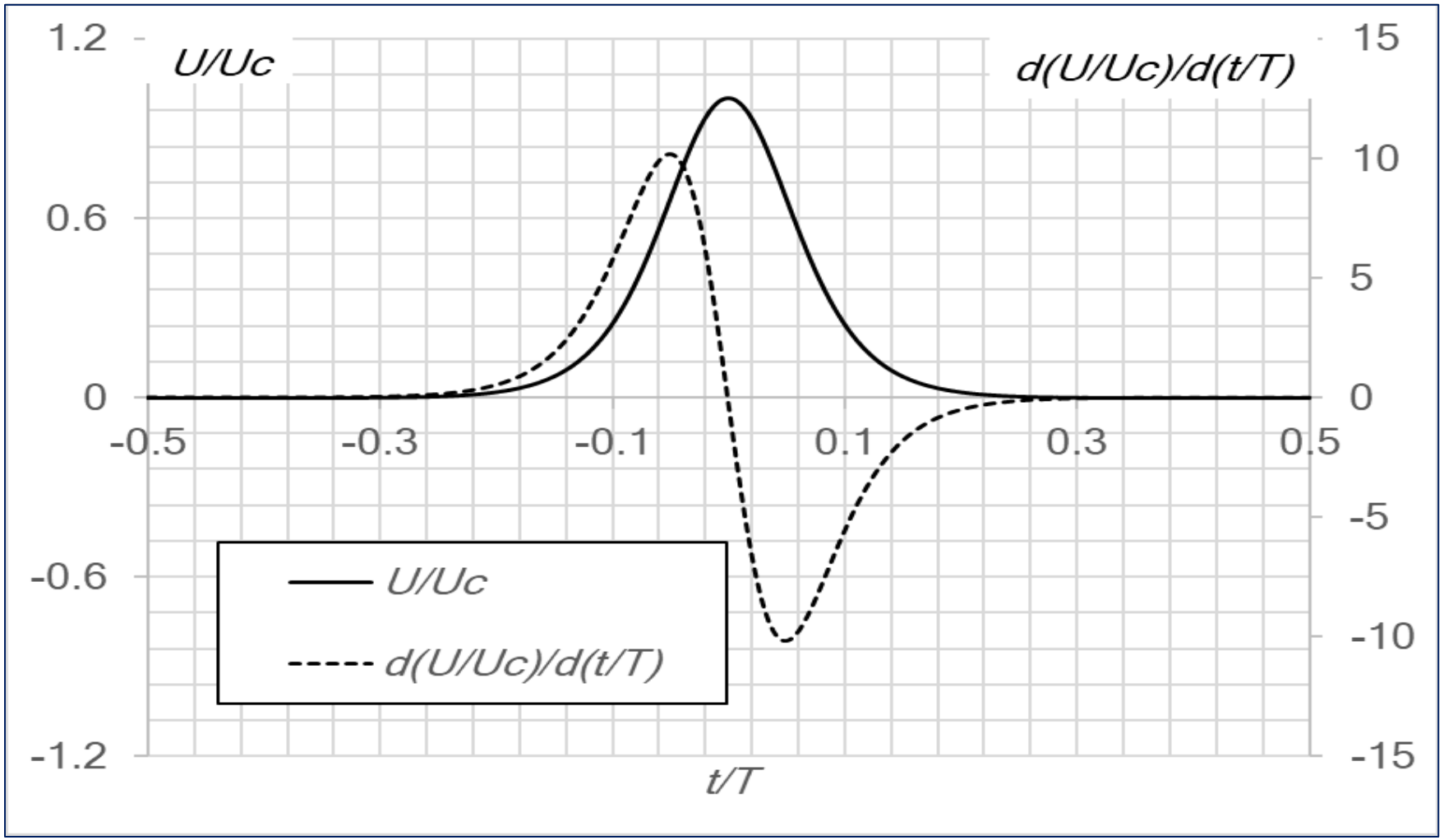
- +,#1) !?#&=#!)#1@9$139$#'10&*49&*/-1 !1?#/)*"-E1*k*19!'1*ω*19!'1
",#!1 !1491J*4(413 "" 41$,#9&1$"&#$$A

- 1+,#1) !?#&=#!)#1/*4*"1@9$1$#"1" 1 1×10^{-6}

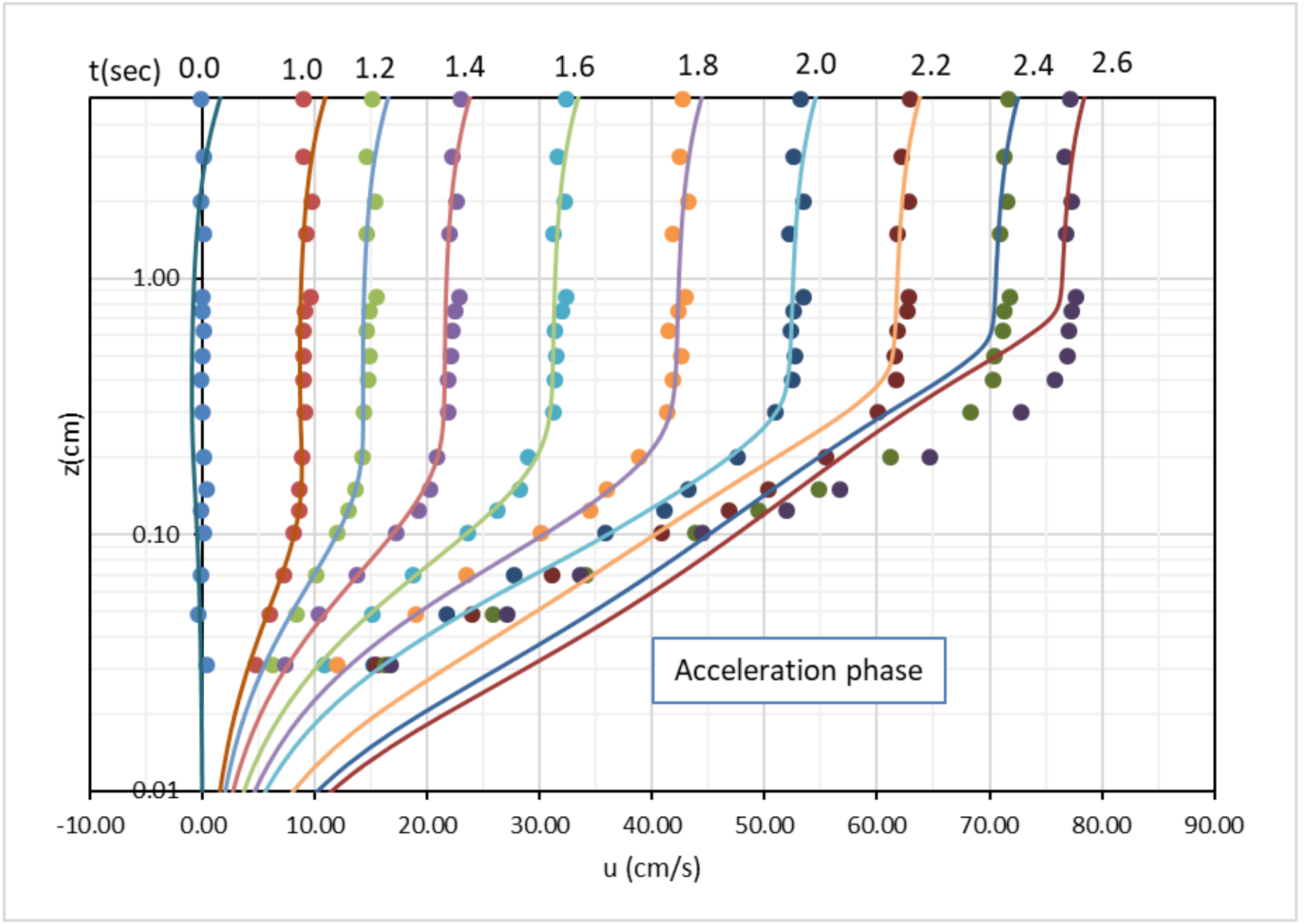
7 JO#&* 4#!"9/1R9"9

; /*"9&-1@9?#1HA<A1 9$#1M6M1C+9!9N91#"19/AE1MLPPD

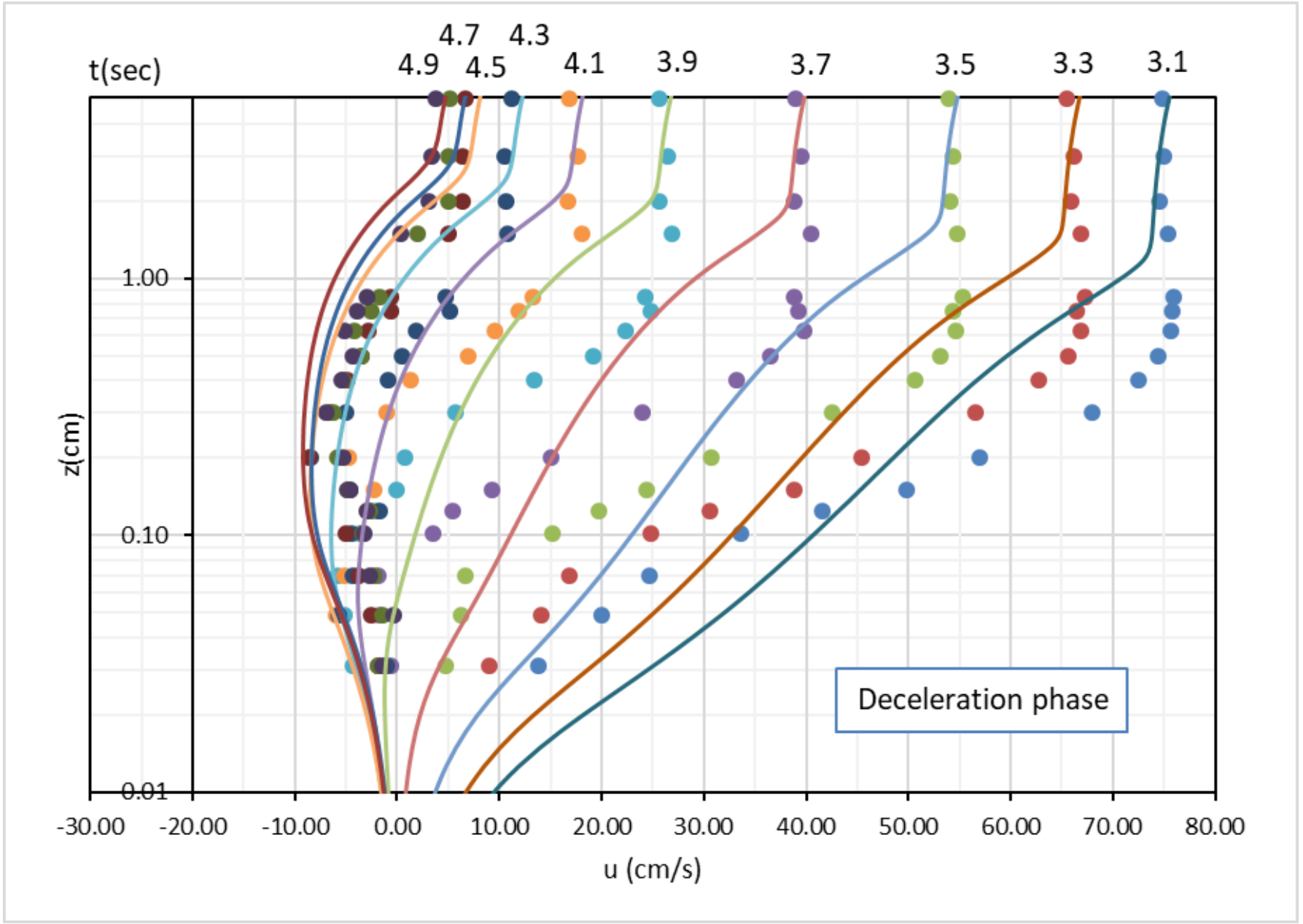
RE K1PASS×PL^{T}E1 *S* K1PTAUQ $U = U_c sech^2(\alpha t)$ $\alpha = \sqrt{\frac{3H}{4h^3}}\sqrt{g(h+H)}$



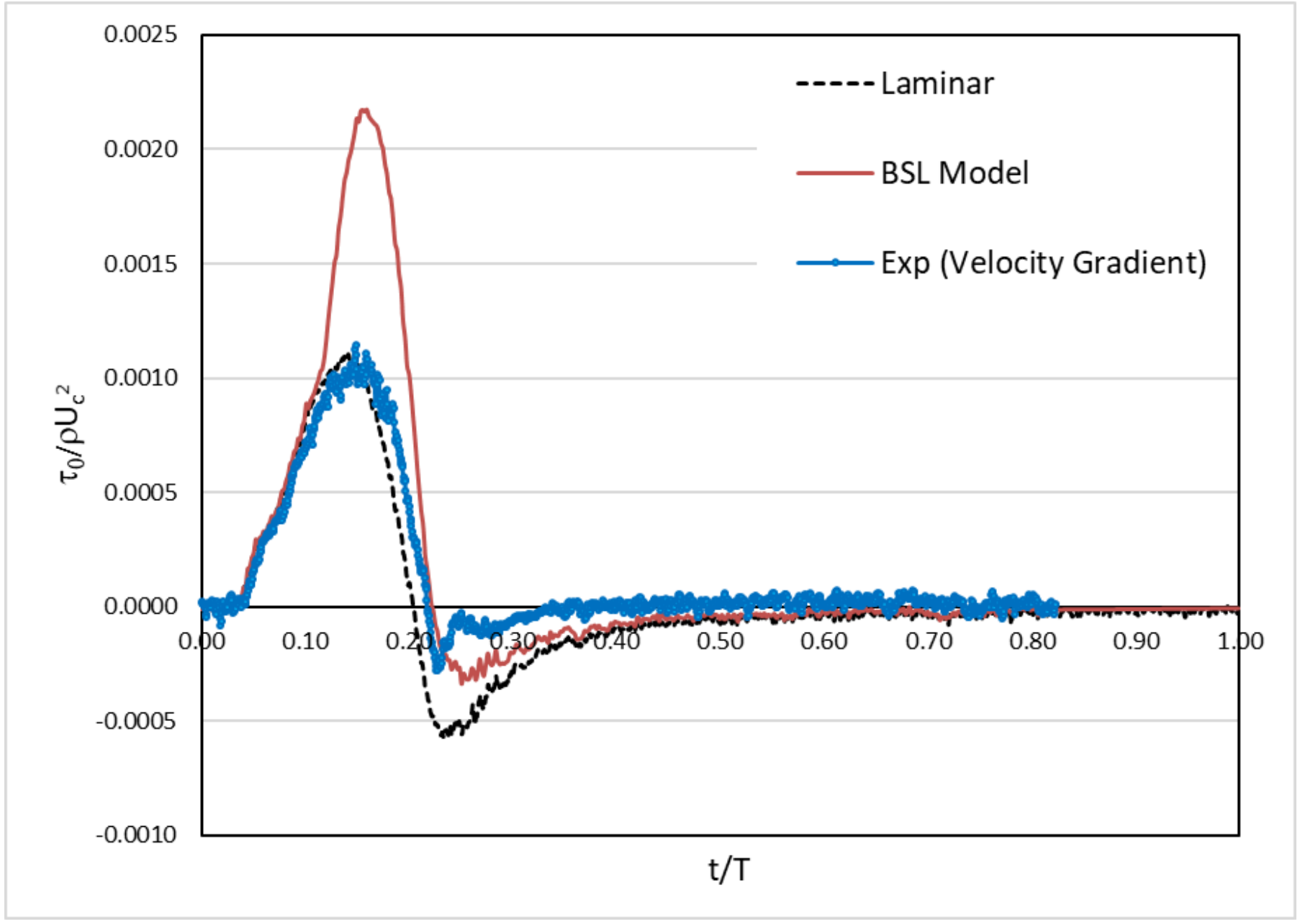
V#/)*"-1W& 2*/#


t(sec) 0.0 1.0 1.2 1.4 1.6 1.8 2.0 2.2 2.4 2.6
1.00
0.10
0.01
z(cm)
-10.00 0.00 10.00 20.00 30.00 40.00 50.00 60.00 70.00 80.00 90.00
u (cm/s)
Acceleration phase

V#/)*"-1W& 2*/#


t(sec)
4.9
4.7
4.5
4.3
4.1
3.9
3.7
3.5
3.3
3.1
z(cm)
1.00
0.10
0.01
-30.00
-20.00
-10.00
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
u (cm/s)
Deceleration phase

H "" 41$,#9&1$"&#$$


0.0025
0.0020
0.0015
0.0010
0.0005
0.0000
-0.0005
-0.0010
$\tau_0/\rho U_c^2$
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
t/T
Laminar
BSL Model
Exp (Velocity Gradient)

!)/($* !$

H/#!'#'1 k- ω X k- ε 4 '#/1 0& 0 $#'1 3-1 >#!"#&CPYYSD1 @9$1 900/*#'1 " 1
; /*"9&-1@9?#1HA<A
V#/)*"-1 0& 2*/#1 $, @$1 = '1 9=&##4#!"1 @*",1",#1 #J0#&*4#!"9/1 '9"91 *!1
!"*9/1 09&"1 21",#1 9))#/#&9"* !1 0,9$#A1 H("1 !#9&1",#1 2&##6$"&#9 4 1)&#$"1
?#/)*"-10 &19=&##4#!"1@9$1 3$#&?#'A1
+,#13 (!'9&-1/9-#&1",*)N!#$$1@9$19/$ 1 ?#&#$"*49"#'13-1",#1 4 '#/A1
W#9N1 3#'1 $,#9&1 $"&#$$1 ?9/(#1 @9$1 ?#&#$"*49"#'1 3-1 91 29)" &1 21
900& J*49"#/-1MA
G(&",#&1$"('-1*$1&#8(*&#'1" 1#J0/ &#1",#1)9093*/*"*#$1 21 ",#&1"@ 6#8(9"* !1
4 '#/$19!'1 4 &#1#J0#&*4#!"9/1'9"91$, (/'13#1("*/*Z#'12 &1",9"10(&0 $#A

Acknowledgments

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Thank you