

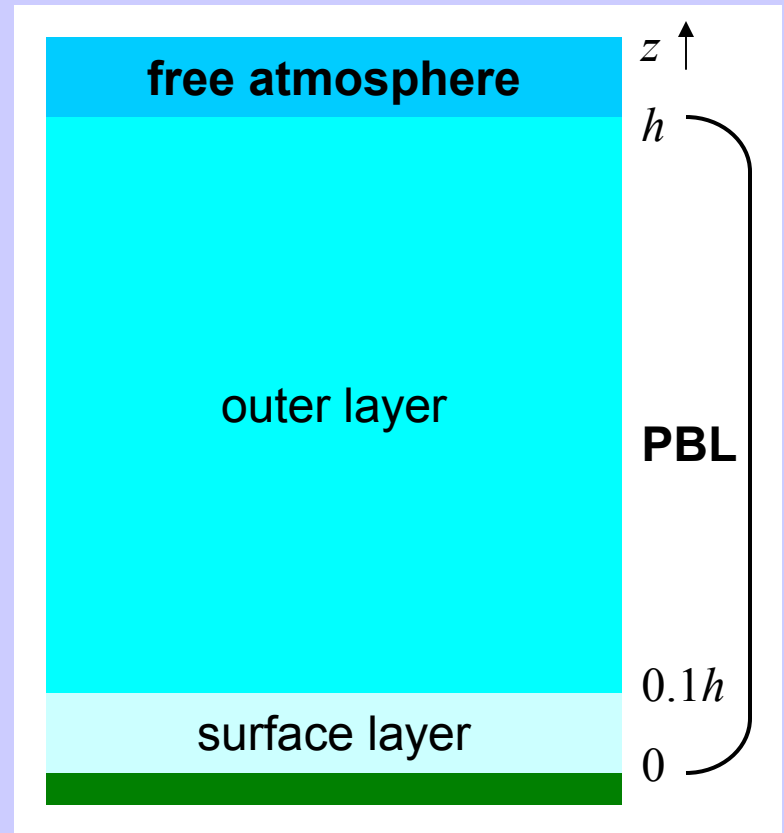
The Non-Local Scheme in CAM3

Michael A. Brunke

introduction

$$\frac{\partial C}{\partial t} = \dots + \frac{\partial}{\partial z} (\overline{w'C'}) + \dots$$

$$\overline{w'C'} = -K_c \left(\frac{\partial C}{\partial z} - \gamma_c \right)$$

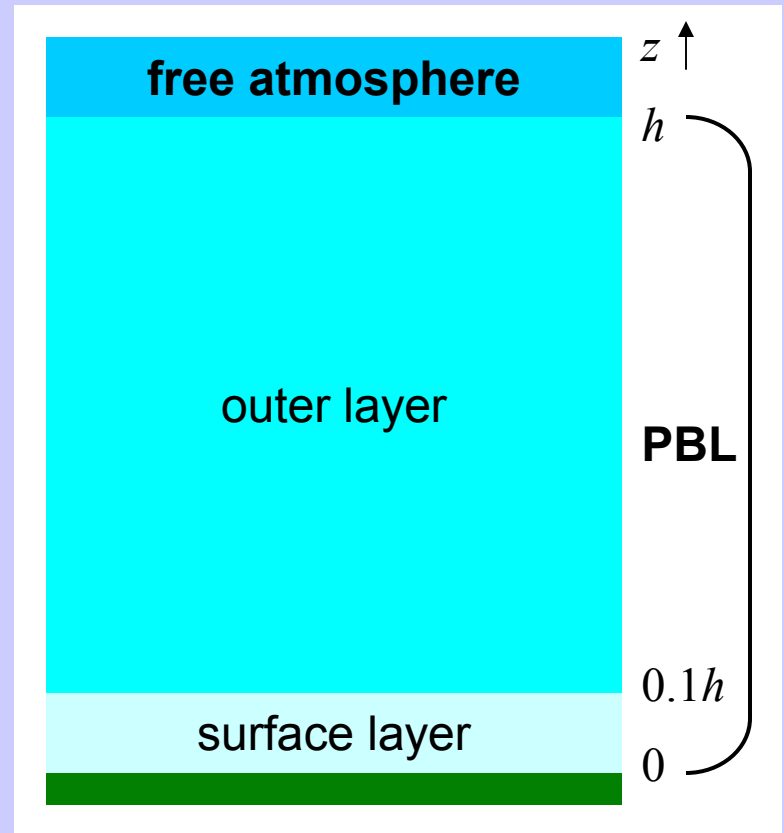


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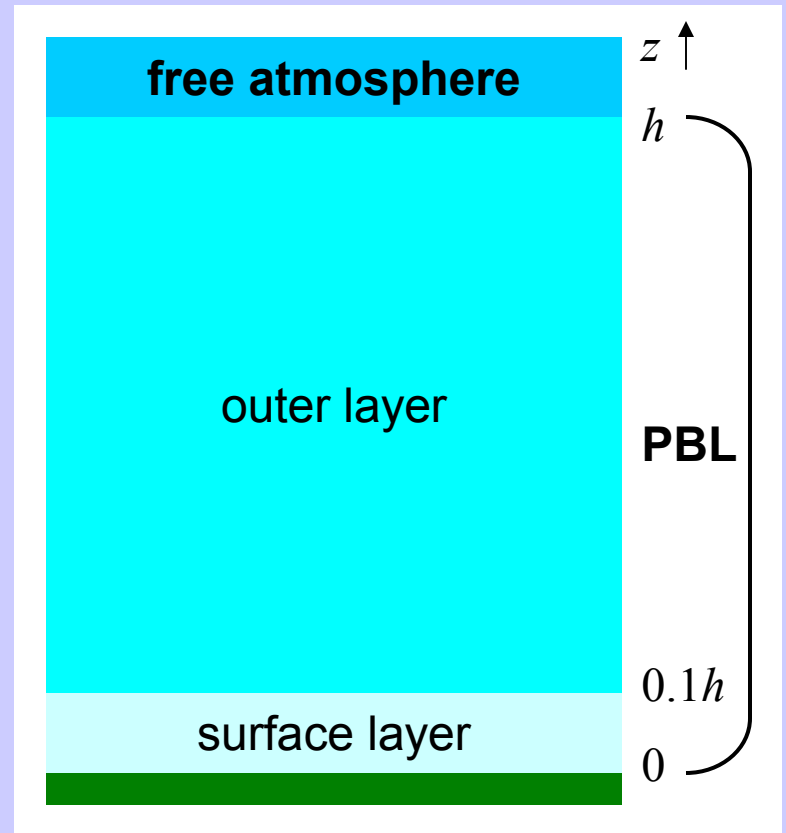
$$K_c \text{ in PBL} = \max(K_{\text{PBL}}, K_{\text{free}})$$



introduction

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input and output

input parameters

potential temperature
temperature
specific humidity
height above surface
pressure
wind speed
surface wind stress
surface SH flux
surface constituent flux

output parameters

kinematic sfc. const. flux
eddy diffusivities
countergradient terms
convective temp. excess
convective hum. excess
surface friction velocity
Obukhov length
PBL height

free atmosphere K_c

(Holtslag and Boville 1993)

$$K_c = \ell_c^2 \left| \frac{\partial \mathbf{V}}{\partial z} \right| F_c(Ri)$$

$$F_c(Ri) = (1 - 18Ri)^{1/2}$$

$$F_c(Ri) = \frac{1}{1 + 10Ri + 80Ri^2}$$

$Ri < 0$

$Ri > 0$

$$Ri = \frac{g}{\theta_v} \frac{\partial \theta_v / \partial z}{|\partial \mathbf{V} / \partial z|^2}$$

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C
5

F
2

determination of h

$h = z$ where $Ri = Ri_{cr} = 0.3$
(Vogelezang and Holtslag 1996)

$$Ri = \frac{\frac{g}{\theta_{v_s}} [\theta_v(z) - \theta_{v_s}] [z - z_1]}{[u(z) - u_1]^2 + [v(z) - v_1]^2 + \beta u_*^2}$$

$$\theta_{v_s} = \theta_{v_1} + b \frac{(\overline{w' \theta'_v})_s}{w_m}$$

sensitivity of h formulation

		L26	L52	L104	20 m
Clear	Median (m)	-73	14	38	79
	IQR (m)	290	161	128	137
	r	0.48	0.80	0.81	0.79
Cloudy	Median (m)	-153	-18	12	47
	IQR (m)	792	396	326	370
	r	0.06	0.78	0.79	0.76

Zeng et al., 2004: Marine atmospheric boundary layer height over the Eastern Pacific: data analysis and model evaluation. *J. Climate*, **17**, 4159-4170.

determination of h

$$h = z \text{ where } Ri = Ri_{cr} = 0.3$$

$$Ri = \frac{\frac{g}{\theta_{v_s}} [\theta_v(z) - \theta_{v_s}] [z - z_1]}{[u(z) - u_1]^2 + [v(z) - v_1]^2 + \beta u_*^2}$$

$$\theta_{v_s} = \theta_{v_1} + b \frac{(\overline{w' \theta'_v})_s}{w_m}$$

C	F
3	0
8	2

determination of K_c

$$K_m = k\omega_m z \left(1 - \frac{z}{h}\right)^2$$

$$K_{(q,H)} = k\omega_t z \left(1 - \frac{z}{h}\right)^2$$

determination of K_c

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$$K_{(q,H)} = k\omega_t z \left(1 - \frac{z}{h}\right)^2$$

turbulent velocity scales

$$w_m = \frac{u_*}{\phi_m} \quad \Rightarrow \quad \phi_m = \left(1 - 15 \frac{z}{L}\right)^{-1/3} \quad \phi_m = 1 + 5 \frac{z}{L} \quad \phi_m = 5 + \frac{z}{L}$$

$$w_t = \frac{u_*}{\phi_h} \quad \Rightarrow \quad \phi_h = \left(1 - 15 \frac{z}{L}\right)^{-1/2} \quad \phi_h = 1 + 5 \frac{z}{L} \quad \phi_h = 5 + \frac{z}{L}$$



$$z/L < 0$$

$$0 \leq z/L \leq 1$$

$$z/L > 1$$

turbulent velocity scales

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$z/L < 0$	$0 \leq z/L \leq 1$	$z/L > 1$

$$w_t = \frac{w_m}{Pr} \quad \Rightarrow \quad Pr = \frac{\phi_h(0.1h/L)}{\phi_m(0.1h/L)} + ak \frac{0.1h}{h} \frac{w_*}{w_m}$$

turbulent velocity scales

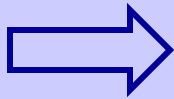
$w_m = \frac{u_*}{\phi_m}$	→	$\phi_m = \left(1 - 15 \frac{z}{L}\right)^{-1/3}$	$\phi_m = 1 + 5 \frac{z}{L}$	$\phi_m = 5 + \frac{z}{L}$
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↓

$w_t = \frac{w_m}{Pr}$	→	$Pr = \frac{\phi_h(0.1h/L)}{\phi_m(0.1h/L)} + ak \frac{0.1h}{h} \frac{w_*}{w_m}$	C	F
			8	0
			16	2

turbulent velocity scales

$$w_m = \frac{u_*}{\phi_m}$$

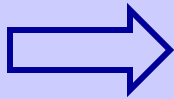


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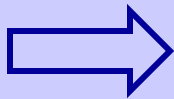
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$$w_t = \frac{w_m}{Pr}$$



$$Pr = \frac{\phi_h(0.1h/L)}{\phi_m(0.1h/L)} + ak \frac{0.1h}{h} \frac{w_*}{w_m}$$



$z/L < 0$

$0 \leq z/L \leq 1$

$z/L > 1$

C

F

8

6

16

8

countergradient term

$$\gamma_c = a \frac{w_* (\overline{w' C'})_s}{w_m^2 h}$$

$$w_* = \left(\frac{g}{\theta_{vs}} (\overline{w' \theta'_v})_s h \right)^{1/3}$$

countergradient term

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$$w_* = \left(\frac{g}{\theta_{vs}} (\overline{w' \theta'_v})_s h \right)^{1/3}$$

C	F
1	0
17	8

scheme sensitivity

Tested sensitivity to choices for:

▣ Ri_{cr}

▣ β

▣ b

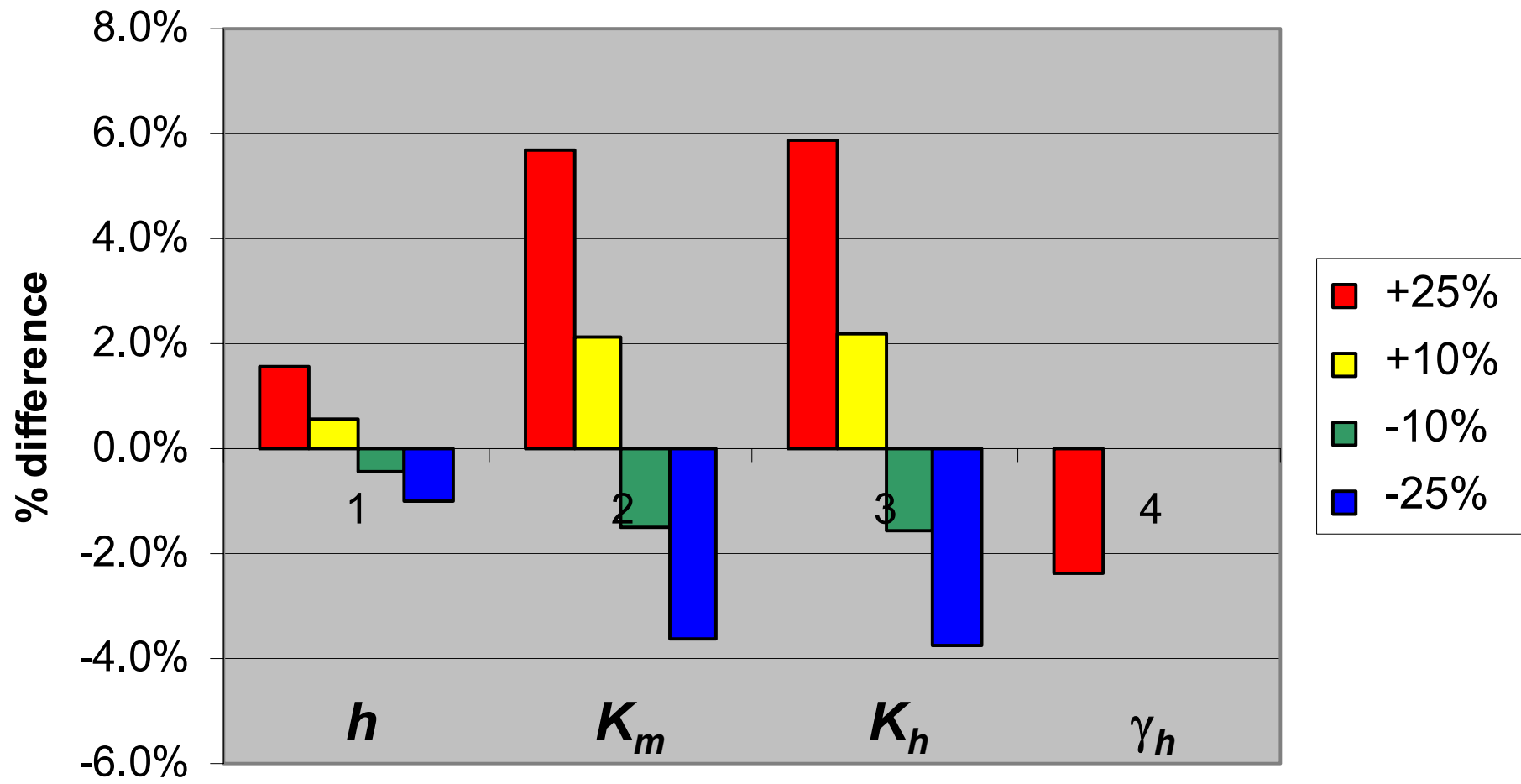
▣ a

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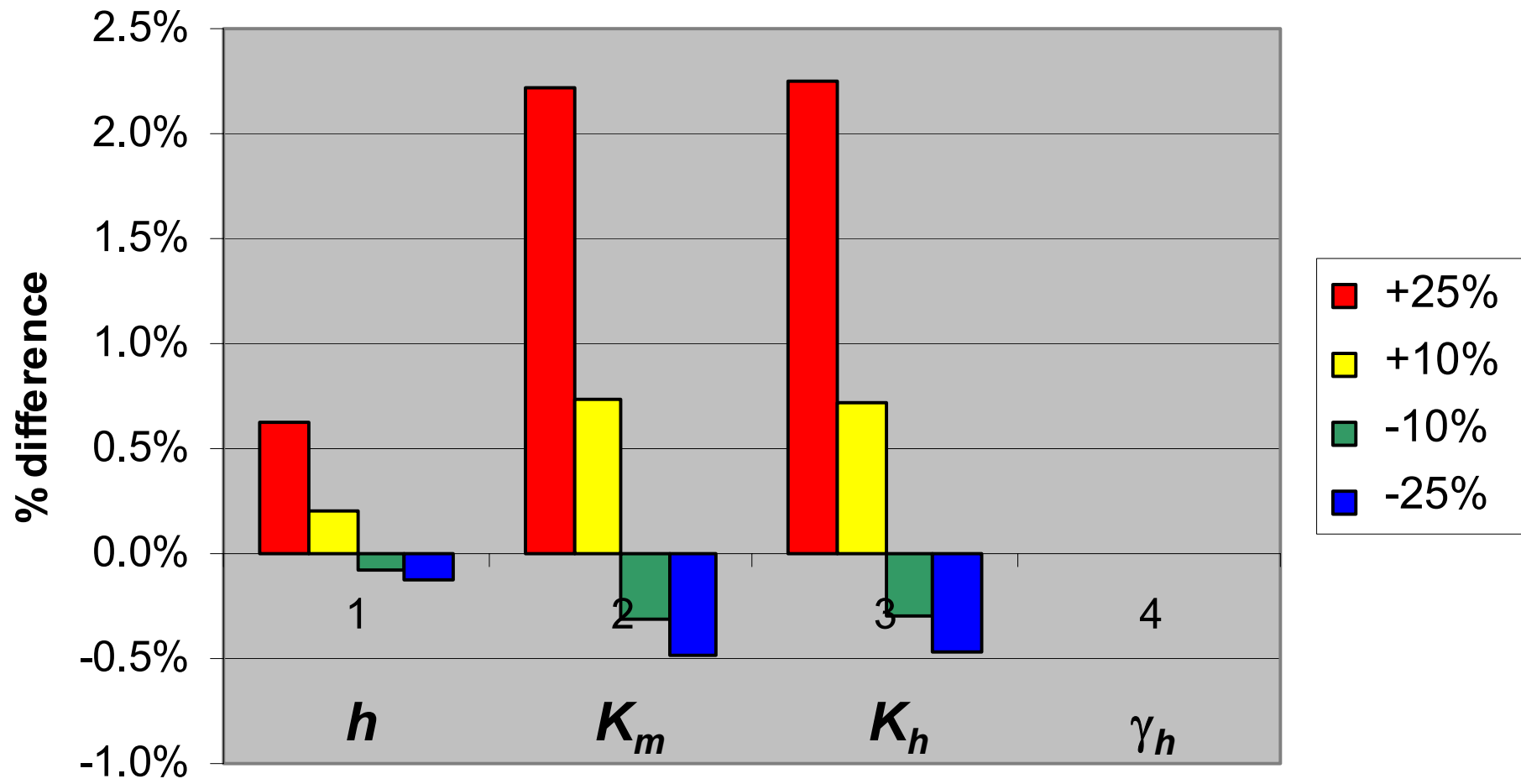
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$$\gamma_c = a \frac{w_* (\overline{w' C'})_s}{w_m^2 h}$$

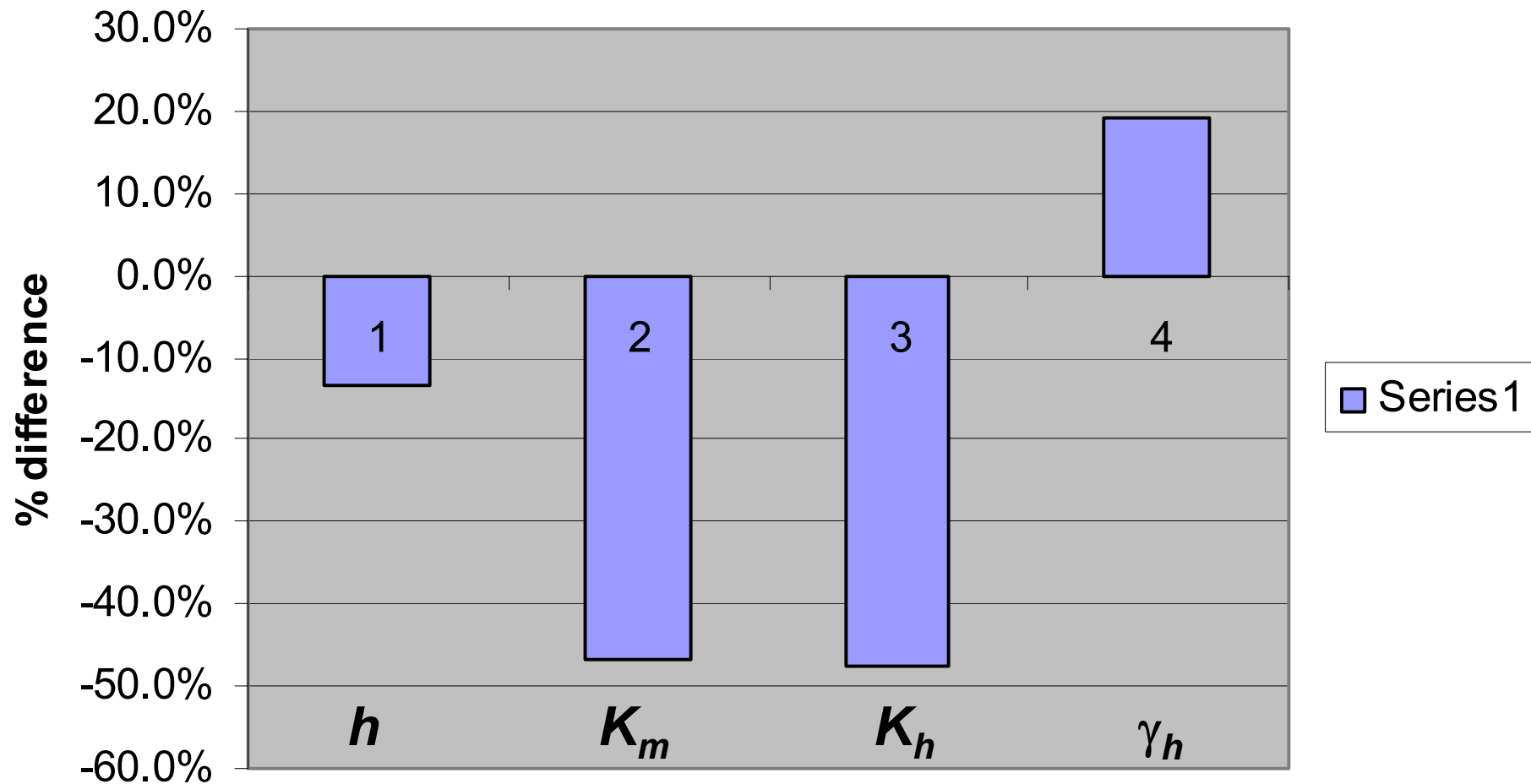
Scheme sensitivity to critical Ri



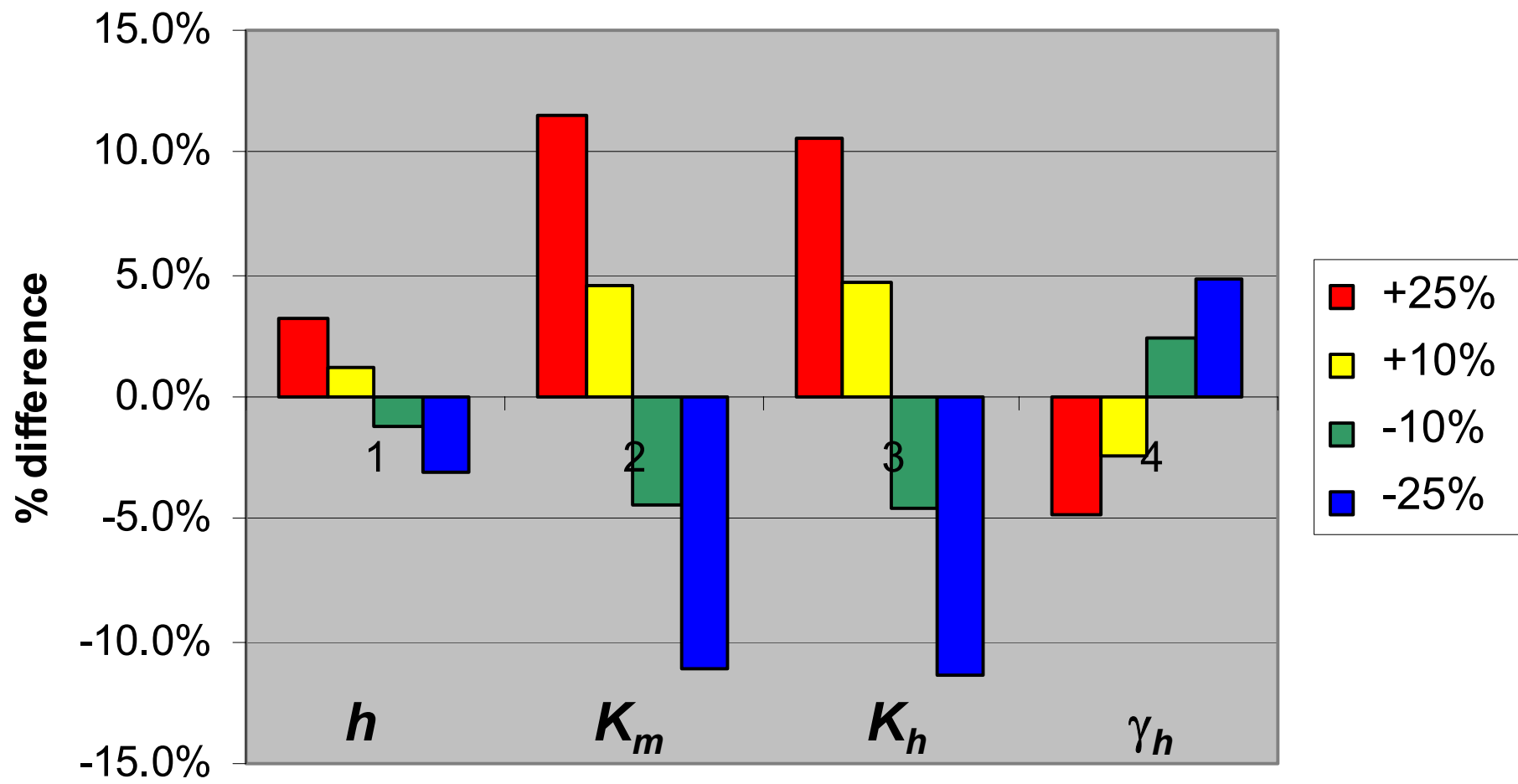
Scheme sensitivity to beta



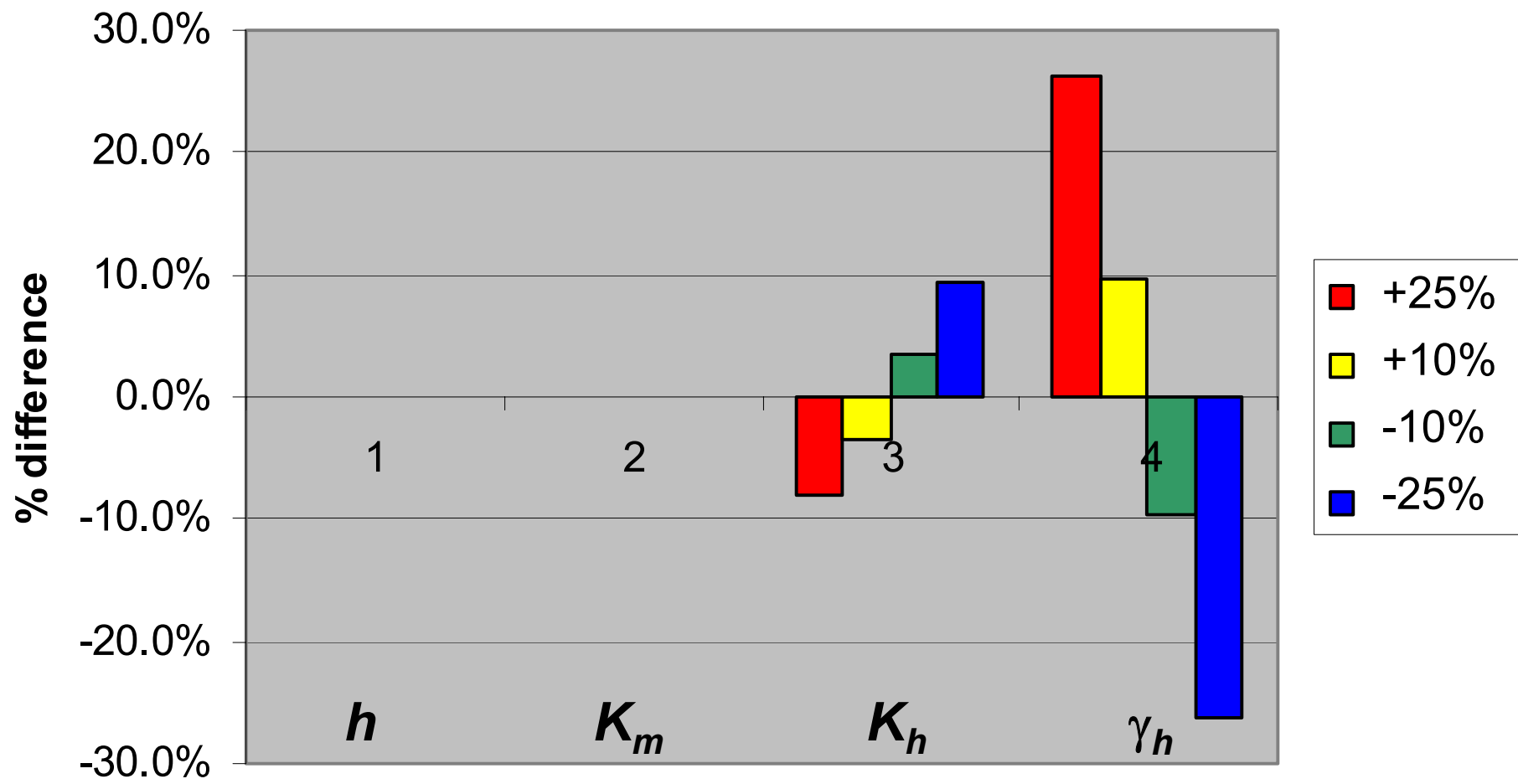
Scheme sensitivity to convective temperature excess



Scheme sensitivity to b



Scheme sensitivity to a



look-up table?

- Not much value added by a LUT.
 - ▣ Simple formulation
 - ▣ Module runs very quickly.
- Pull h 's from a LUT?
 - ▣ Model run to get LUT values could be run at L31.

summary

- CAM3 uses standard non-local turbulence scheme in PBL.
- 17 tunable constants and 8 arbitrary functions.
- Scheme not sensitive to Ri_{cr} and β ; are sensitive to b and a
- Convective temperature excess is needed.
- LUT probably not necessary except maybe to get h .