TOUCANS : An attempt at synthesising new findings in turbulence + diffusion over the past 10 years

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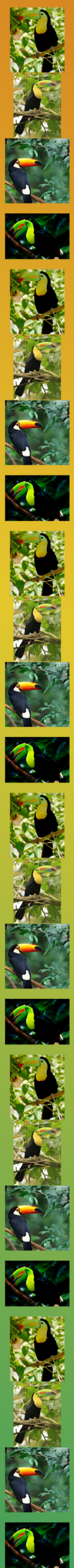


Acronym

TOUCANS:

- T - Third
- O - Order moments (TOMs)
- U - Unified
- C - Condensation
- A - Accounting and
- N - N-dependent
- S - Solver (for turbulence and diffusion)

TOMs

- $\overline{w'^3}, \overline{w'^2\theta'_L}, \overline{w'\theta'^2_L}, \overline{w'q'^2_T}, \overline{w'^2q'_T}$
- incorporation of non-local effects
- inclusion in eTKE scheme framework without additional prognostic equations [1]

eTKE scheme

- full prognostic TKE (Turbulence Kinetic Energy) equation

$$\frac{\partial E}{\partial t} = Adv(E) + \frac{1}{\rho}\frac{\partial}{\partial z}\frac{\rho K_m}{\sqrt{C_K.C_\epsilon}}\frac{\partial E}{\partial z} + K_m\left[\left(\frac{\partial \overline{u}}{\partial z}\right)^2 + \left(\frac{\partial \overline{v}}{\partial z}\right)^2\right] - \frac{g}{\theta}K_h\frac{\partial \overline{\theta}}{\partial z} - C_\epsilon\frac{(E)^{\frac{3}{2}}}{L}$$

$$K_m = LC_K\sqrt{E}\chi_3(Ri) \quad K_h = LC_KC_3\sqrt{E}\phi_3(Ri)$$

$E = \frac{1}{2}(\overline{u'\cdot u'} + \overline{v'\cdot v'} + \overline{w'\cdot w'})$-TKE,
C_K, C_ϵ - closure constants, L - mixing length, Ri - Richardson number
θ - potential temperature, ρ -density, u,v ,w - wind components , z - height

- computation separated in two steps: static($\frac{dE}{dt} = 0$), prognostic
- can emulate multiple turbulent schemes: QNSE [6], CCH02 [2]
- separation of the stability dependencies for momentum($\chi_3(Ri)$) and for heat/moisture ($\phi_3(Ri)$)

Anisotropy of turbulence

- isotropy only in the 'free convective limit'
- with increasing stability grows anisotropy

$\Rightarrow \frac{\partial \chi_3(Ri)}{\partial Ri} \neq 0$, $\frac{\partial \phi_3^I(Ri)}{\partial Ri} \neq 0$

critical Richardson number Ri_{cr} ?

- recent measurements confirm existence of $Ri > Ri_{cr}$
- recent theories [7], [6]: there is no Ri_{cr}

$\Rightarrow \lim_{Ri\to\infty} \chi_3(Ri) = const > 0$

'Filtering condition'

= TKE equation in stationary equilibrium ($\frac{dE}{dt} = 0$) [5]

- expresses conservation of TT(otal)E=TKE+TP(otential)E [7]
- leads to using Ri instead of N^2 (B-V frequency) and S^2 (shear) separately

$\Rightarrow \frac{\partial \phi_3^{II}}{\partial Ri} \neq 0$

Modified CCH02 scheme

- derived from CCH02 [2] with assumptions
- 3 degrees of freedom:
  - C_3 - inverse Prandtl number at neutrality
  - R - parameter characterising the flow's anisotropy
  - $Ri_{fc} = \lim_{Ri\to\infty} Ri_f$ - critical flux-Richardson number

$$\chi_3(Ri) = \underbrace{\frac{f(Ri)}{f(Ri).R + 1 - R}}_{\text{anisotropy}}$$

$$\phi_3(Ri) = \underbrace{\frac{1}{Q}\left(1 - \frac{1-Q}{f(Ri).R + 1 - R}\right)}_{\phi_3^I\text{ : anisotropy}}\underbrace{\frac{1}{1 + \frac{3\lambda_0 Ri}{f(Ri).Q}}}_{\phi_3^{II}\text{ : TPE} \Leftrightarrow \text{TKE conversion}}$$

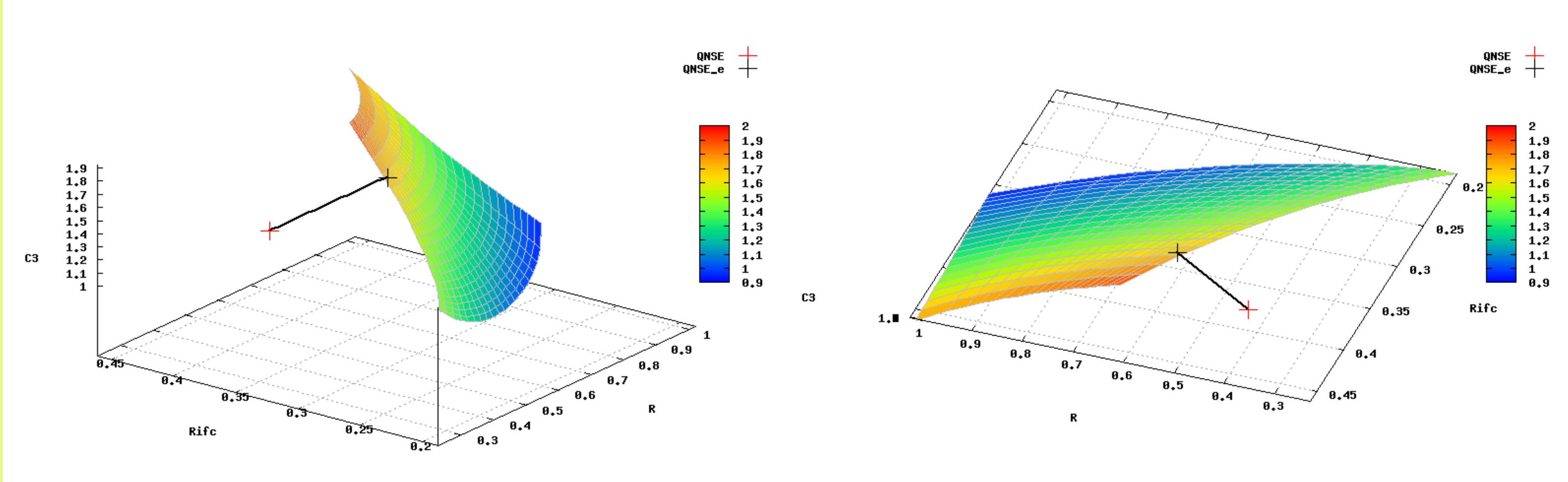
$$Ri_f = \frac{C_3 Ri\phi_3(Ri)}{\chi_3(Ri)}, \qquad f(Ri) = \chi_3(Ri)(1 - Ri_f)$$

$$Q = Q(R, C_3), \quad \lambda_0 = \lambda_0(R, C_3, Ri_{fc})$$

-$\chi_3(Ri)$, $\phi_3(Ri)$ functions are fully separated

QNSE scheme

- QNSE (Quasi-Normal Scale Elimination) [6]
- spectral approach
- $\chi_3(Ri)$, $\phi_3(Ri)$ functions are separated
- valid mainly for stable stratification
- 'extend' for $Ri < 0$ with modified CCH02
- QNSE is outside the modified CCH02 plane of "physical solution" in (R, Ri_{fc}, C_3) -space:



Shallow convection cloudiness - SCC

- 'moist' link between turbulence and diffusion (displaces staggering problem from diffusion to radiative input)
- computed from modified Ri [3] at beginning of physics time-step ⇐ link between N^2 and SCC

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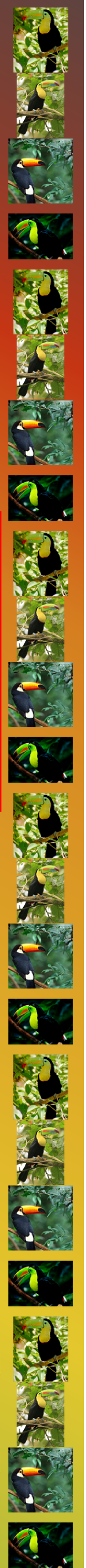

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