The Art of Modelling Stars in the 21st Century
Proceedings IAU Symposium No. 252, 2008
L. Deng & K.L. Chan, eds.

© 2008 International Astronomical Union
doi:10.1017/S1743921308022400

Proxies for overshooting above a convection zone

Kwing L. Chan[1] **and Harinder P. Singh**[2]

[1]Department of Mathematics and Center for Space Science Research,
Hong Kong University of Science and Technology, Hong Kong, China
email: maklchan@ust.hk

[2]Department of Physics & Astrophysics, University of Delhi, Delhi, India
email: singh@iucaa.ernet.in

Abstract. Due to the up/down asymmetry caused by stratification, overshooting above differs from overshooting below a convection zone. The flux of kinetic energy, frequently used as a proxy of overshooting below a convection zone, cannot be used for the upward problem.

Keywords. Convection, turbulence, waves, methods: numerical

In many numerical studies, the flux of kinetic energy, F_k, is used as an indicator of the presence of turbulence. The extent of its penetration into the stable layer is taken as the depth of overshooting. Below a convection zone, this is understandable, as F_k tracks the continuation of the down-flow columns into the region below. Above the convection zone, however, this interpretation does not hold. Upward flows disperse and do not form narrow coherent columns. Thus, other proxies for overshooting need to be found. Based on a set of recently computed numerical models, we discuss the difficulties that arise.

Three cases with different input energy fluxes (F) are discussed here. While all other parameters are the same, $F(\text{Case } 3) = 2F(\text{Case } 2) = 4F(\text{Case } 1)$. The domain is a $3 \times 3 \times 1$ rectangular box ($162 \times 162 \times 122$ grids). The depths of the convection zone and the stable zone above are approximately 2.5 and 3.9 pressure scale heights, respectively.

F_k does not turn positive across the unstable/stable boundary

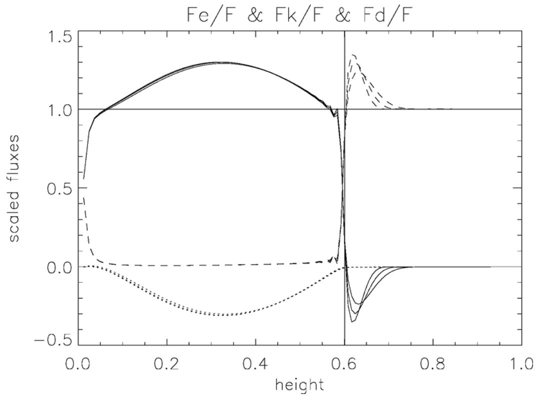

Figure 1. The scaled mean (horizontally and temporally averaged) enthalpy flux (F_e/F), kinetic energy flux (F_k/F), and diffusive flux (F_d/F) are shown by the solid, dotted, and dashed curves, respectively. The value of the total flux F depends on the case. The case with the largest (smallest) F produces maximum (minimum) overshoots in the stable region (height > 0.6).

https://doi.org/10.1017/S1743921308022400 Published online by Cambridge University Press

Different overshooting quantities decay with different spatial scales

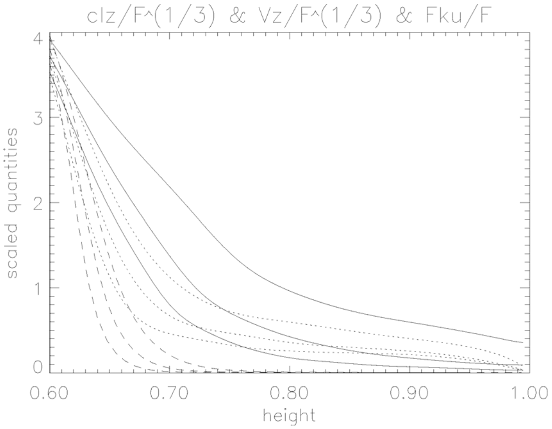

Figure 2. The solid, dotted, and dashed curves show the scaled root-mean-square (rms) vertical vorticity, $(\mathrm{curl}\, V)''_z/F^{1/3}$, the scaled rms vertical velocity, $24.3V''_z/F^{1/3}$, and the scaled upward conditional mean (i.e. average over grid points with positive V_z) kinetic energy flux, $10F_{ku}/F$, respectively. The scalings are to assist visual comparisons only. It is clear that the rates of decay are very different. The case with larger flux generally has slower rates of decay.

Some quantities do decay at similar rates

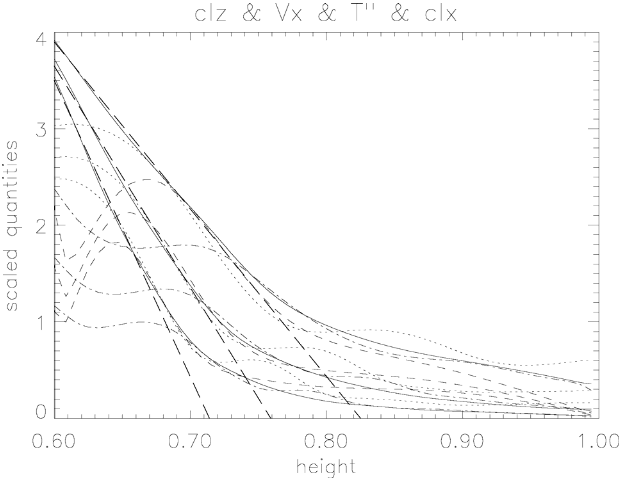

Figure 3. The solid, dotted, dashed, dot-dashed curves show the scaled rms vertical vorticity (same as the previous figure), the scaled rms horizontal velocity, the scaled rms temperature variation, and the scaled rms horizontal vorticity, respectively. The long dashed straight lines show that the initial decay rates of these quantities are similar, over certain portions of the overshoot region. These lines intersect the zero value at distances 0.115, 0.16, and 0.225 from the unstable/stable boundary. The distances scale roughly as $1 : 2^{1/2} : 4^{1/2}$. If they are taken as the 'overshoot distance', the scaling with the flux is $F^{1/2}$.

Acknowledgements

KLC thanks the Hong Kong Research Grants Council for support.

https://doi.org/10.1017/S1743921308022400 Published online by Cambridge University Press