NUMERICAL SIMULATION OF PENETRATIVE CONVECTION: A PARAMETRIC STUDY

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Abstract. In continuation of our earlier studies (Singh, Roxburgh & Chan 1997a,b; hereafter SRC97a,b) we perform some further tests to study the general behaviour of penetrative convection and its scaling with rms vertical velocity by varying a number of input parameters like the aspect ratio and the positioning of the interface between the unstable-lower stable layer.

1. Introduction

In a recent study (SRC97a,b), we performed three-dimensional simulations of convection in a three-layer configuration with a view to study the penetration of flows into the lower stable layer and to examine the scaling relationship between the penetration distance (Δ_d) and the vertical velocity given earlier by Schmitt et al. (1984) and Zahn (1991) which may be stated as $\Delta_d \propto V_{zo}^{3/2}$, where V_{zo} is the vertical velocity at the bottom of the middle convective layer. The total domain of computation consists of $\sim$ 7.5 pressure scale heights with the middle unstable region having 5.4 p.s.h. The lower stable layer extends to a height of 0.4 from the bottom and contains 1.2 p.s.h. The aspect ratio of the numerical box is 1.5. Four different models corresponding to four values of the input flux F_b were computed and the following equation was evaluated to examine the relationship described earlier by taking pair of cases

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TABLE 1. Relationship between penetration distance and rms vertical velocity

Model No.	Aspect Ratio	$(F_b(1), F_b(2))$	LHS Eqn.(1)	RHS Eqn.(1)
1	1.5	(0.1875,0.125)	1.18	1.24
2	1.5	(0.1875,0.0625)	1.72	1.78
3	1.5	(0.1875,0.03125)	2.46	2.66
4	1.5	(0.125,0.0625)	1.46	1.43
5	1.5	(0.125,0.03125)	2.08	2.14
6	1.5	(0.0625,0.03125)	1.43	1.49
7	1.5	(0.125,0.0625)	1.40	1.41
8	2.0	(0.125,0.0625)	1.26	1.41
9	3.0	(0.125,0.0625)	1.44	1.54

corresponding to two flux values:

$$\frac{\Delta_d(F_b(1))}{\Delta_d(F_b(2))} = \frac{V_{zo}^{3/2}(F_b(1))}{V_{zo}^{3/2}(F_b(2))}. \tag{1}$$

We obtained six values for the left and the right hand sides of above equation from our four cases. The results are given in Table 1 (Models 1-6). It may be seen that $\Delta_d \propto V_{zo}^{3/2}$.

We do some further tests by shifting the location of the interface between the unstable and the lower stable region from a height of 0.4 from the bottom to a height of 0.5. This provided a larger (2 p.s.h.) lower stable layer at the bottom. Two cases were studied with two different values of the input flux F_b. The ratios of the penetration distances in the two cases were equated with the right hand side of eq.(1). The result for Model 7 confirms the scaling relationship between the penetration distance and the vertical velocity.

The aspect ratio of the box was changed from 1.5 to 2.0 and also by a factor of two from 1.5 to 3.0. Two models (with different F_b values) were computed for each of these aspact ratios. As may be seen from Table 1 (Models 8-9), the scaling relationship implied by eq.(1) has deteriorated slightly and could be attributed to the fact that the number of grid points in the two horizontal directions (35×35) were not changed for the larger aspact ratios. The calculations with improved horizontal resolution for larger aspect ratios are currently under way.

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