Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

MIS22-05 Room:106 Time:May 27 10:00-10:15

A phenomenological model for convective cell size in a fluid layer with internal heat generation at low Rayleigh numbers

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The convective behavior of a fluid layer with internal heat generation at low Rayleigh number ($6 \leq$ RaI/RaIc ≤ 12) was experimentally investigated. The horizontal fluid layer of 0.5 wt% KCl water solution was internally heated by Joule heating using the electric current. We quantitatively measured 2-D temperature and velocity fields by seeding the micro-encapsulated thermo-chromic liquid crystals in the fluid layer. We experimentally obtained the fluid dynamic scaling on non-dimensional temperature and the maximum downwelling velocity as a function of the Rayleigh number, and also refined the experimental data obtained by the previous studies. The scaling relations were combined with a phenomenological model based on the stability of the top thermal boundary layer. This phenomenological model consistently explained the increase in convective wavelength with increasing the Rayleigh number.

Keywords: internal heat generation, natural convection, cell size, visualization, experiment, fluid mechanics