Laboratory simulation of the influence of geothermal heating on the global oceanic circulation

Sheng-Qi Zhou, Xiao-Zheng Zhao

State Key Laboratory of Tropical Oceanography, South China Sea Institute of Oceanology, Chinese Academy of Sciences, Guangzhou 510301, China

The influence of geothermal heating on the global oceanic circulation has been evaluated with laboratory experiments and scaling analysis. Upon a well-developed large scale convective flow, an additional heat flux perturbation $\delta F/F$ is employed. As listed in Table 1 and shown in Figure 1, 2 and 3, the increments of the flow and thermal properties, including eddy diffusivity K_T, flow velocity V and bottom temperature T_b, are independent of the applied heat flux F. Together with the scaling analysis of convective flow at different configurations, where the flow is thermally driven in the relatively low and extremely high turbulent thermal convections or the horizontal convection, the variance of flow properties, $\delta K_T/K_T$ and $\delta V/V$, are found to be close to 0.5% and 0.75% at $\delta F/F = 2\%$. It means that the small heat flux perturbation plays a negligible role to the global convective flow. However, $\delta T_b/\Delta T$ is found to be 1.5% at $\delta F/F = 2\%$, which might have significant effect in the local region. Our results provide a clue to understanding the influence of geothermal heating on the global oceanic circulation. It is that expected the geothermal heating will contribute less than 1% in turbulent mixing and volume flux to the global oceanic circulation, and its influence can be negligible in this sense. But, its contribution to the local environment cannot be ignored. For example, the temperature increases $0.5°C$ with the geothermal heating, which will have significant effect on the physical environments within the benthic boundary layer and abyssal circulation.

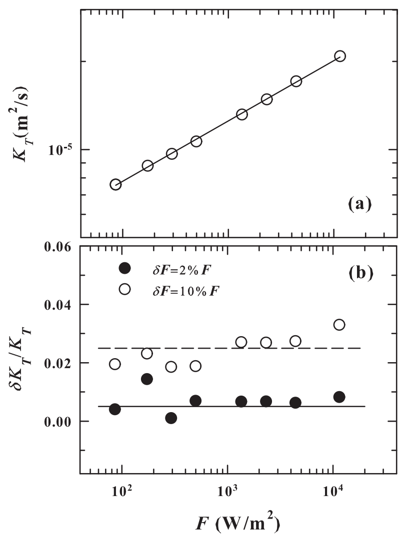

Figure 1: (a) The eddy diffusivity K_T as a function of heat flux F, the solid line is the best power law fit: $K_T \sim F^{0.21}$. (b) The relative eddy diffusivity increment $\delta K_T/K_T$ as a function of heat flux F for $\delta F/F = 2\%$ (solid circles), and 10% (open circles). $\delta K_T/K_T = 0.5\%$ and 2.5% are marked as solid and dash lines.

Reference:

[1] Ahlers, G., S. Grossmann, and D. Lohse (2009), Heat transfer and large scale dynamics in turbulent Rayleigh-Bénard convection, *Rev. Mod. Phys.*, *81*(2), 503–537.

[2] Adcroft, A., J. R. Scott, and J. Marotzke (2001), Impact of geothermal heating on the global ocean circulation, *Geophys. Res. Lett.*, *28*(9), 1735–1738.

[3] Huang, R. X. (1999), Mixing and energetics of the oceanic thermohaline circulation, *J. Phys. Oceanogr.*, *29*(4), 727–746.

[4] Scott, J. R., J. Marotzke, and A. Adcroft (2001), Geothermal heating and its influence on the meridional overturning circulation, *J. Geophys. Res.*, *106*, 31,141–31,154.

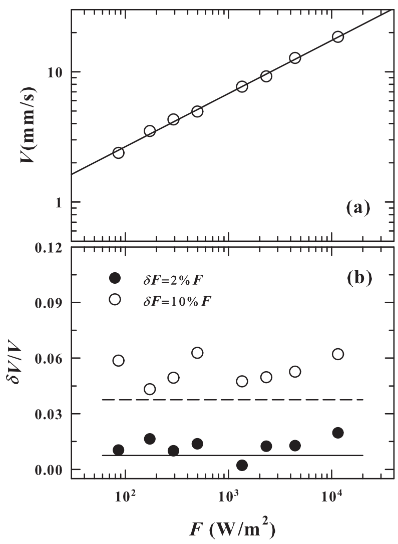

Figure 2: (a) The velocity V as a function of heat flux F, the solid line is the best power law fit: $V \sim F^{0.39}$. (b) The relative velocity increment $\delta V/V$ as a function of heat flux F for $\delta F/F = 2\%$ (solid circles), and 10% (open circles). $\delta V/V = 0.75\%$ and 3.75% are marked as solid and dash lines.

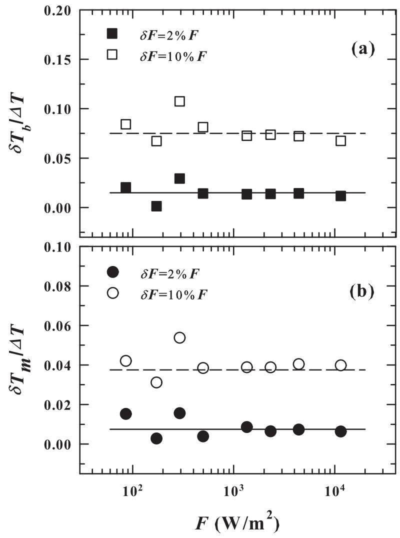

Figure 3: (a) The relative bottom temperature increment $\delta T_b/\Delta T$ as a function of heat flux F for $\delta F/F = 2\%$ (solid squares), and 10% (open squares). $\delta T_b/\Delta T = 1.5\%$ and 7.5% are marked as solid and dash lines. (b) The relative bulk temperature increment $\delta T_m/\Delta T$ as a function of heat flux F for $\delta F/F = 2\%$ (solid circles), and 10% (open circles). $\delta T_m/\Delta T = 0.75\%$ and 3.75% are mark ed as solid and dash lines.

Table 1: The increments of the relative variances $\delta\Delta T_b/\Delta T$, $\delta K_T/K_T$ and $\delta V/V$ for the additional heat flux $\delta F/F = 2\%$ and 10% at three different working conditions under assumption of simple scaling laws: $Nu = ARa^a$ and $Re = BRa^b$. *Case I: the relatively low turbulent thermal convection. Case II: the extremely high turbulent thermal convection. Case III: the horizontal convection.*

	$\delta F/F$	Case I $a = 1/3$ $b = 1/2$	Case II $a = 1/2$ $b = 1/2$	Case III $a = 1/6$ $b = 1/3$
$\delta K_T/K_T$	2%	0.5%	0.67%	0.29%
	10%	2.5%	3.3%	1.4%
$\delta V/V$	2%	0.75%	0.67%	0.86%
	10%	3.75%	3.3%	4.34%
$\delta\Delta T/\Delta T$	2%	1.5%	1.33%	1.7%
	10%	7.5%	6.7%	8.6%