

Natural convection with mixed insulating and conducting boundary conditions: low and high Rayleigh regimes

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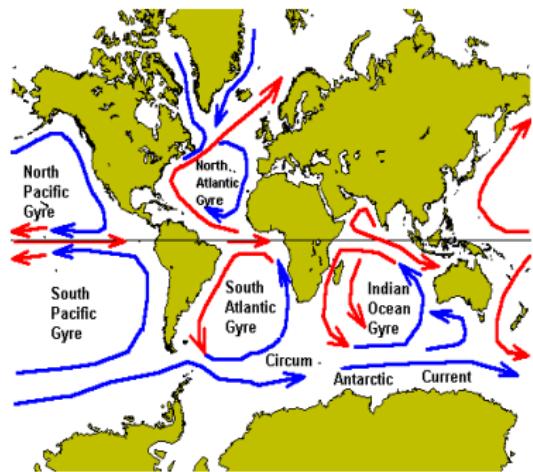
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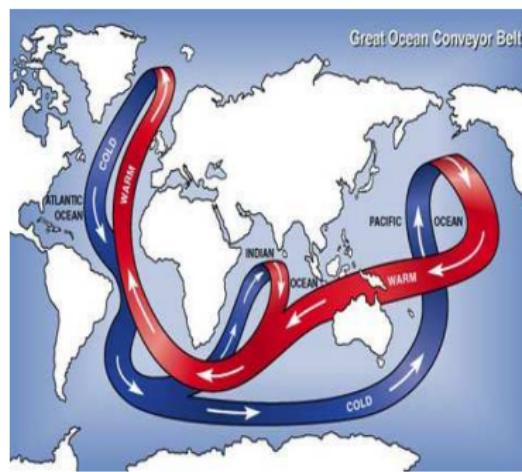
ETC14, september 3, 2013

Ocean Circulation

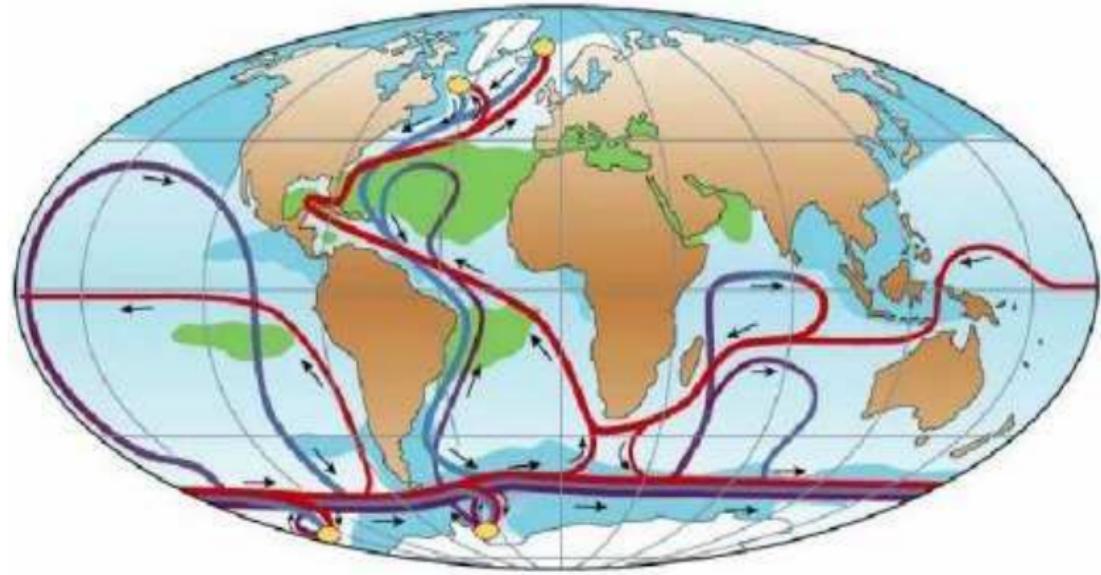
Gyre
“weather”



Overturning
“climat”



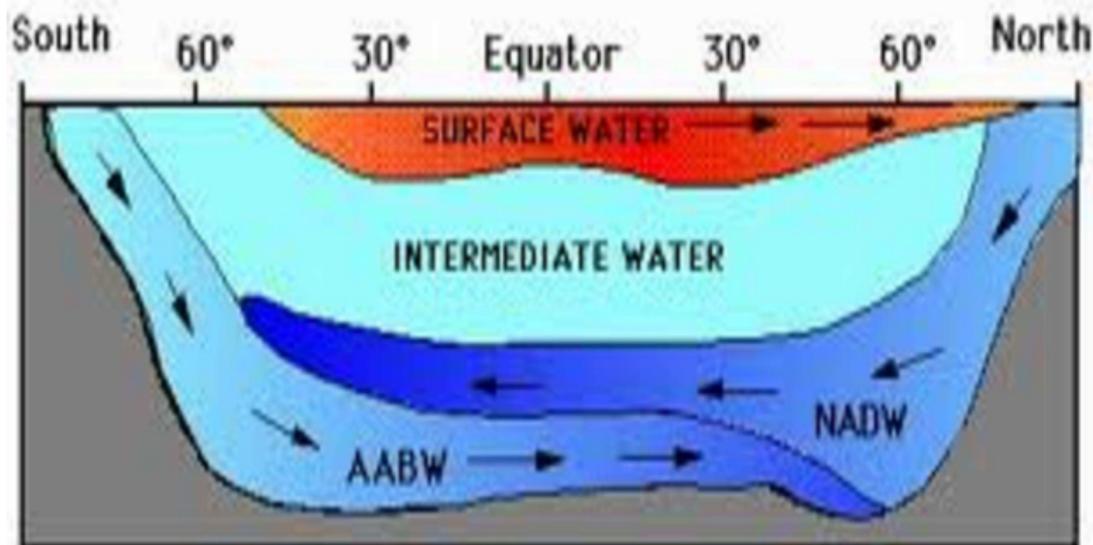
Ocean Deep Convection Sites



- Surface
- Deep
- Bottom
- Salinity > 36 ‰
- Salinity < 34 ‰
- Deep Water Formation

(Rahmstorf, Nature 2002)

Atlantic Ocean Thermohaline Circulation



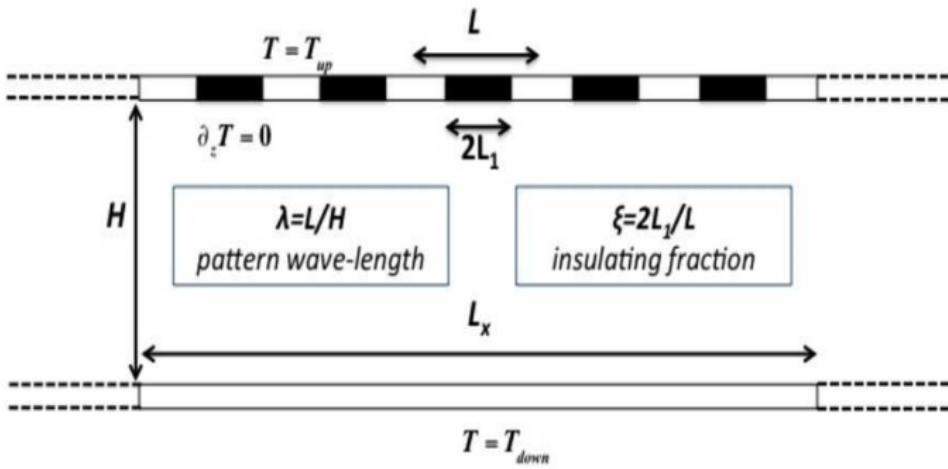
Labrador Sea



Antarctic Sea



Inhomogeneous R-B Geometry



Boussinesq Eq.

$$\partial_i u_i = 0$$

$$\partial_t u_i + u_k \partial_k u_i = -\partial_i P + \nu \Delta u_i - \alpha T g \delta_{i,z}$$

$$\partial_t T + u_i \partial_i T = \kappa \Delta T,$$

Boundary Cond.

$$T(x, H) = T_{up} \quad x \notin [-L_1 + jL, L_1 + jL], j \in \mathbb{Z}$$

$$\partial_z T(x, H) = 0 \quad x \in [-L_1 + jL, L_1 + jL], j \in \mathbb{Z}$$

$$T(x, 0) = T_{down} \quad \forall x.$$

Non Dim. Parameters

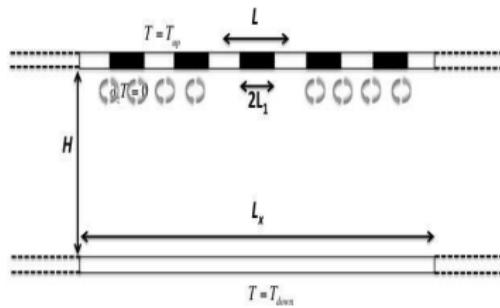
$$Pr = \frac{\nu}{\kappa} = 1. \quad Ra = \frac{g\alpha\Delta TH^3}{\kappa\nu}$$

$$\xi = \frac{1}{2} \quad \lambda = \frac{L}{H}$$

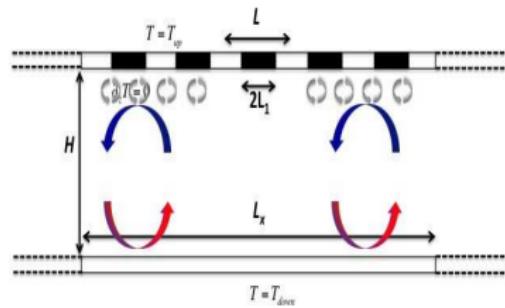
Bulk Critical Rayleigh

inhom. bc. \rightsquigarrow horizontal density gradient \rightsquigarrow fluid motion $\rightsquigarrow Ra_C = 0$

$$Ra < Ra_C^{\text{bulk}}$$

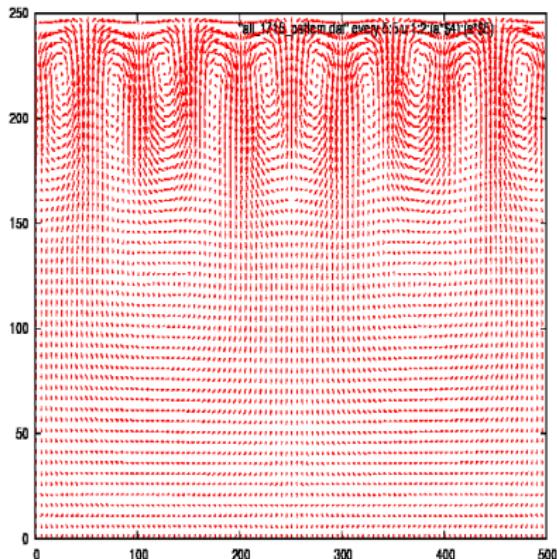


$$Ra > Ra_C^{\text{bulk}}$$

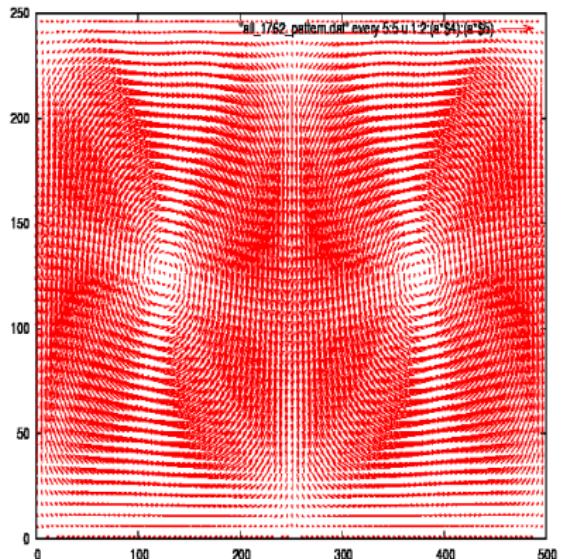


Lattice Boltzmann DNS 2D

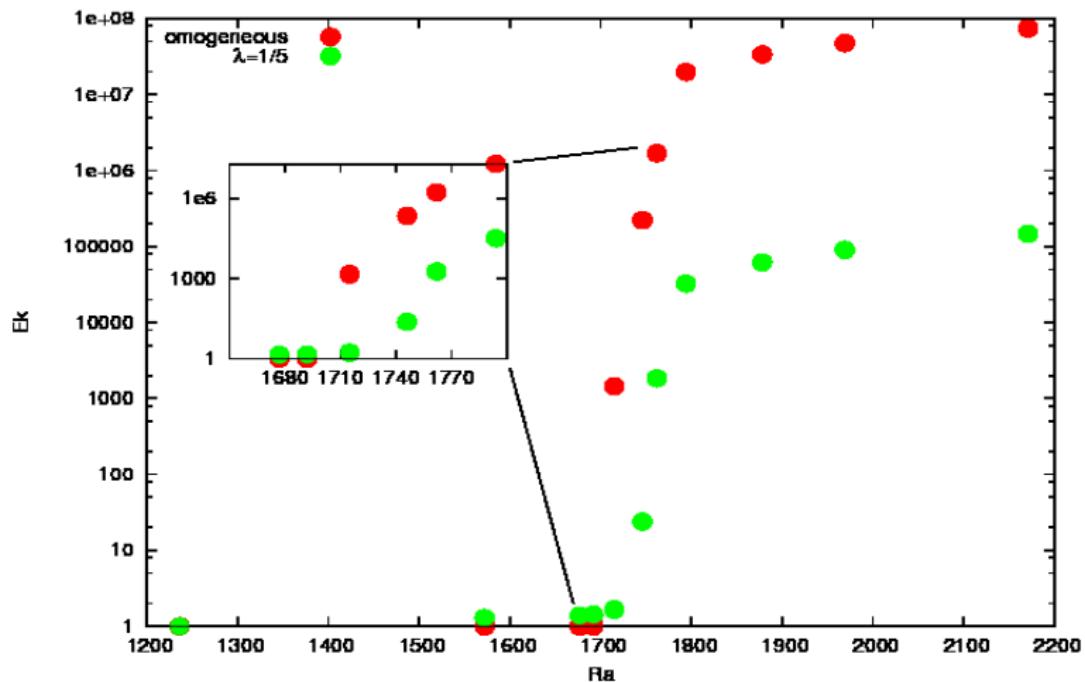
$$Ra = 1715 < Ra_C^{\text{bulk}}$$



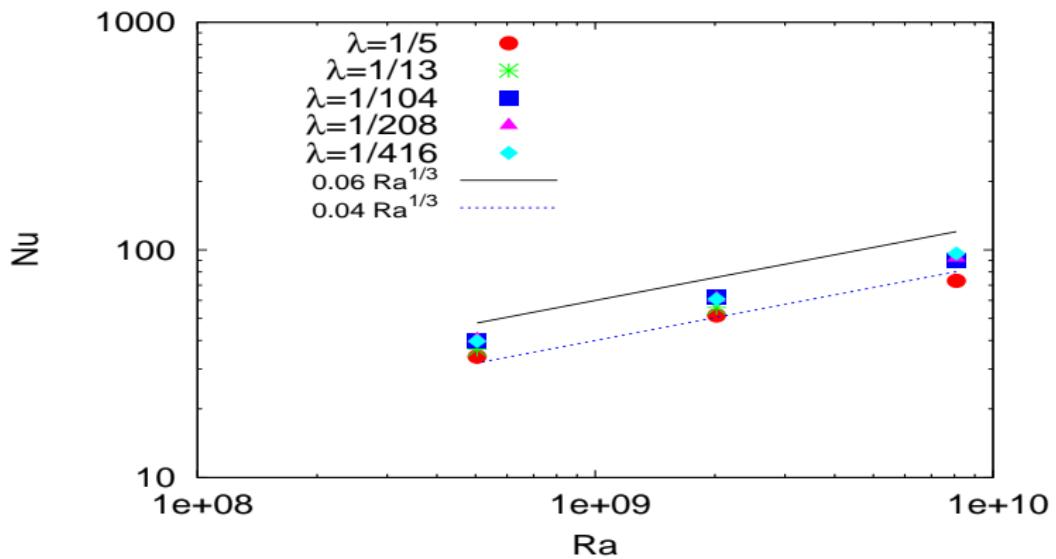
$$Ra = 1762 > Ra_C^{\text{bulk}}$$



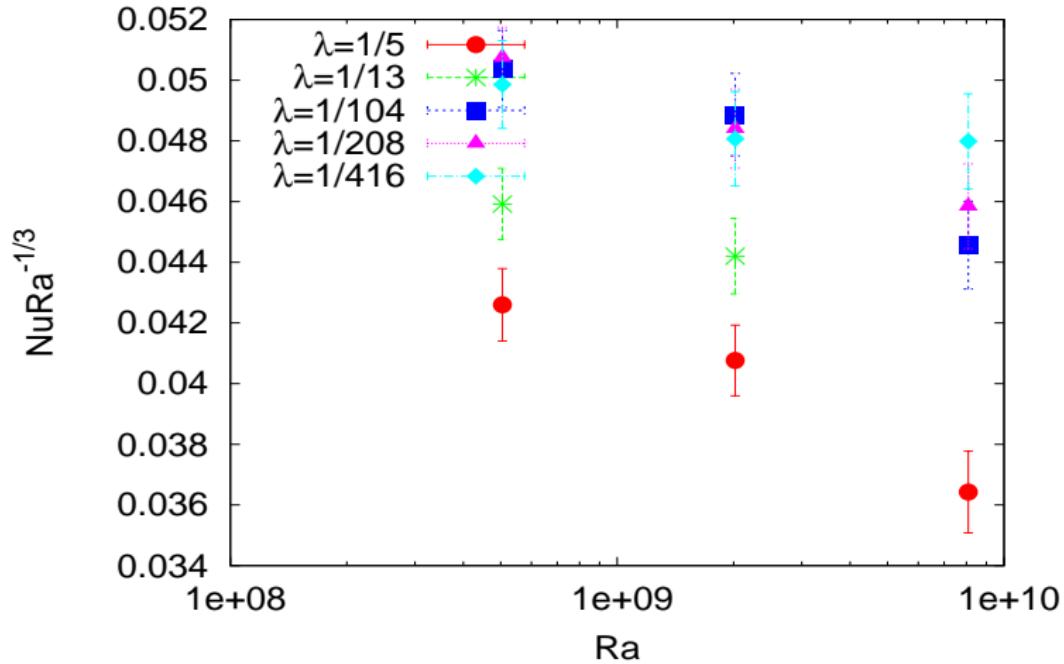
Bulk Critical Rayleigh



Scaling Nu vs. Ra

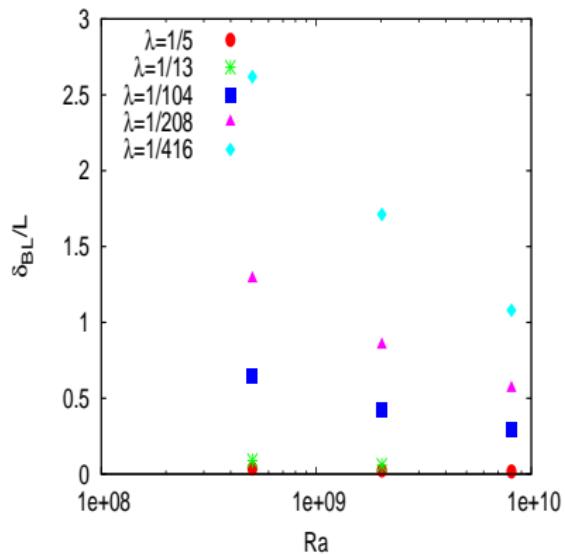
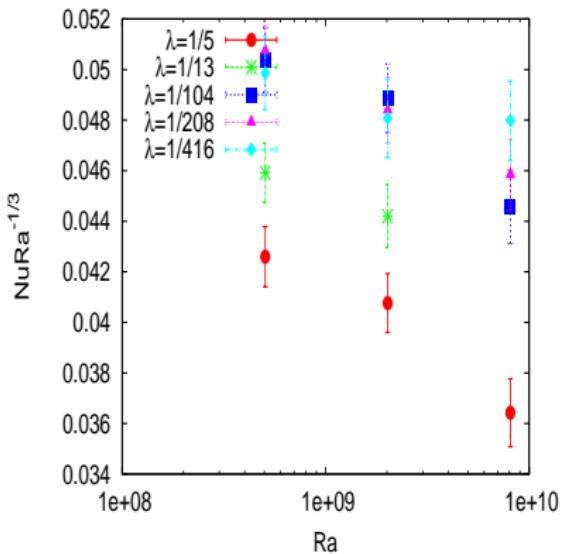


Scaling $\text{Nu} \text{Ra}^{-1/3}$ vs. Ra



heatflux increases with decreasing pattern length-scale.

Scaling $\text{Nu} \text{Ra}^{-1/3}$ vs. Ra



heatflux increases with decreasing pattern length-scale, until it drops below the boundary-layer thickness.

Conclusions

- ▶ For $L \ll H$ there exists a critical bulk Ra number for a transition from localized motion at the inhomogeneous boundary to bulk convective motion.
- ▶ Heatflux increases with decreasing pattern length-scale, until it drops below the boundary-layer thickness.

Open Questions

- ▶ Prandtl number dependence ?
- ▶ What happens at multi-scale inhomogeneities (Ocean) ?