Direct Numerical Simulations of Saltfingers

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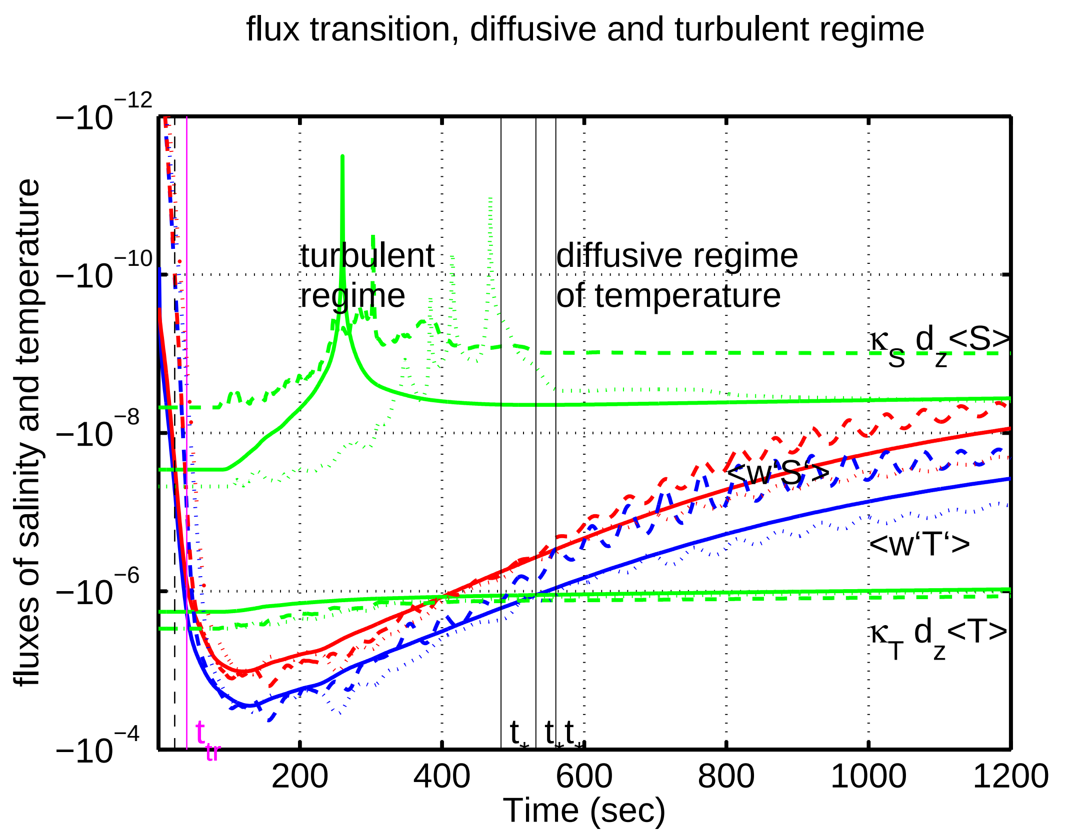
1 Introduction

The ocean is mostly stratified with light water overlying dense water, but double-diffusive processes can erode this statically stable stratification. Double-diffusion is a concequence of the two dynamically active scalars temperature (T) and salinity (S) having molecular diffusivities that differ by two oders of magnitude.
There are two main types of double-diffusive processes in the ocean:

1. **Saltfingering**: warm and saline water overlies cold and fresh water. The vertical salinity gradient tends to destabilize and the temperature gradient stabilizes the water column (e.g. Tyrrhenian Sea, Caribbean Sea)
2. **Semiconvection**: cold and fresh water overlies warm and saline water. The vertical salinity gradient stabilizes and the temperature gradient tends to destabilize the water column (e.g. in the Arctic, underneath melting sea ice).

Double-diffusive processes are simulated with the non–hydrostatic finite-volume code of the Massachusetts Institute of Technology general circulation model (MITgcm) (1). Several **D**irect **N**umerical **S**imulations of 2.5D and a 3D problem provide estimates of turbulent fluxes of heat and salinity. In 3D we used 50^3 gridpoints and Lewis Number $\tau = 0.1$, while the 2.5D simulations were carried out with $512 \times 8 \times 512$ gridpoints and $\tau = 0.01$, $\tau = 0.1$ respectively.

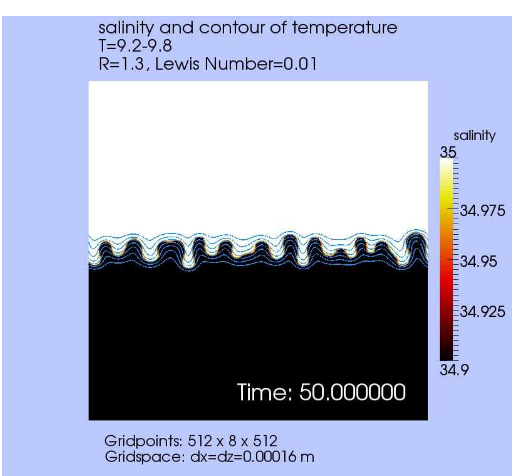
2 A Zoo of Turbulent Fluxes

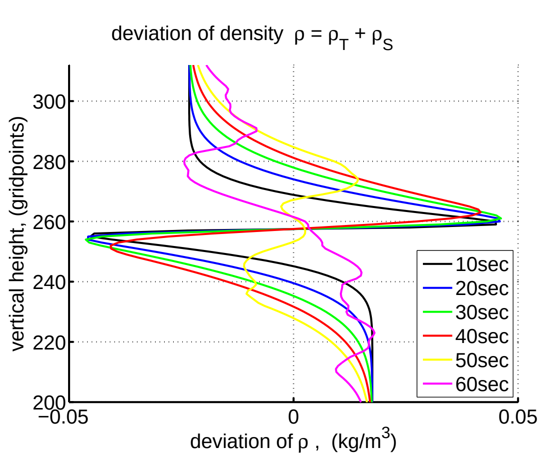


Mean turbulent fluxes of 3D (solid line) and 2.5D (dottet and dashed lines) simulation. The turbulent fluxes depend only weakly on the Lewis Number. Different regimes can be obseverd: a) ***diffusive regime***: at the initial state from $t = 0 - 50$ sec (e.g. Figure 3, left), b) ***turbulent regime***: mixing between layers from $t = 100 - 500$ sec (Figure 4), c) ***diffusive regime***: saltfingers decay by diffusive processes $t > 500$ sec (Figure 5).

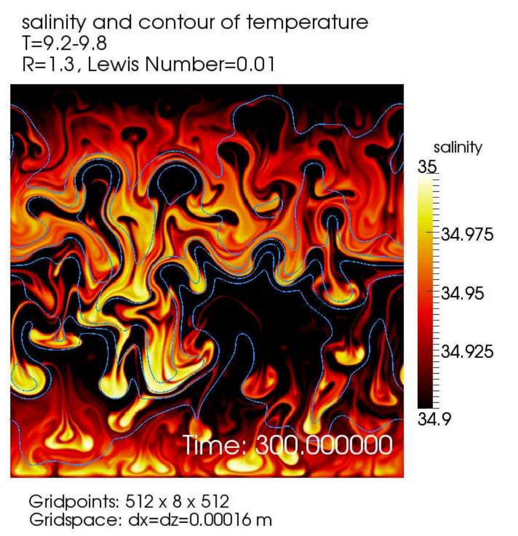
3 Diffusive Regime: Growing Saltfinger Instability

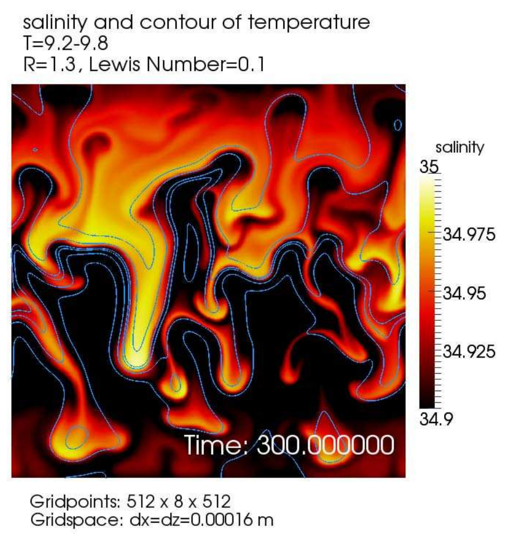
The stability of the water column following linear theory (e.g. (2), (3)) is preserved, but because of the non–linearity of the equations saltfingers develop from local instability at the initially sharp density interface after $t \sim 50$ sec.



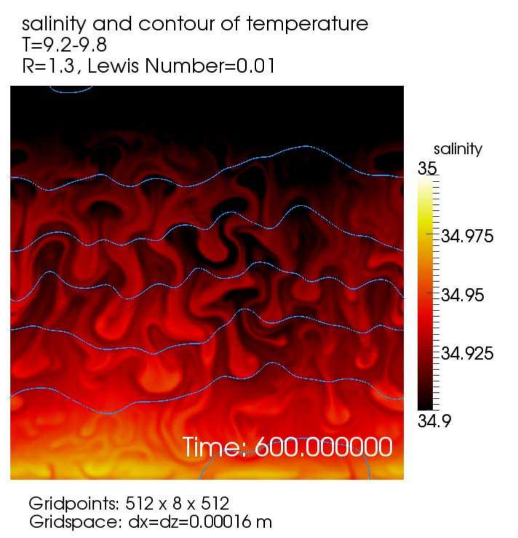


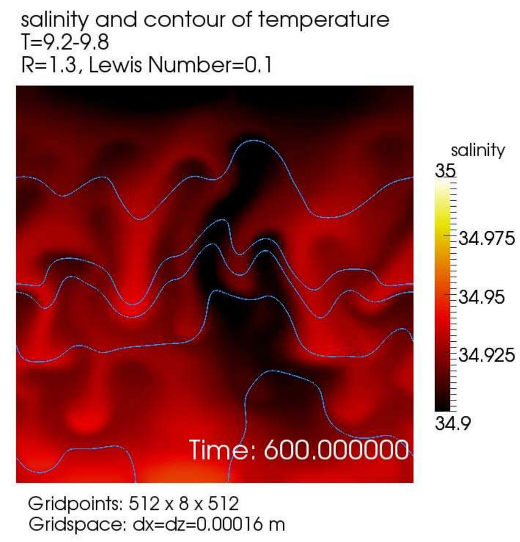
4 Turbulent Regime: Mixing by Saltfingers in 2.5D



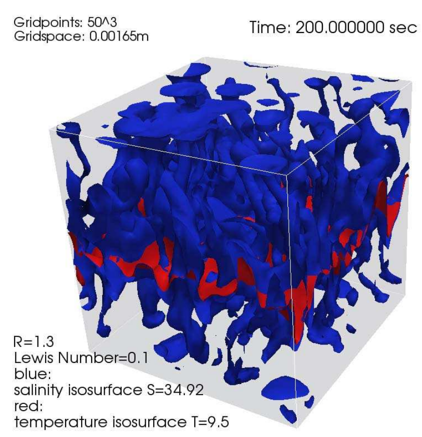


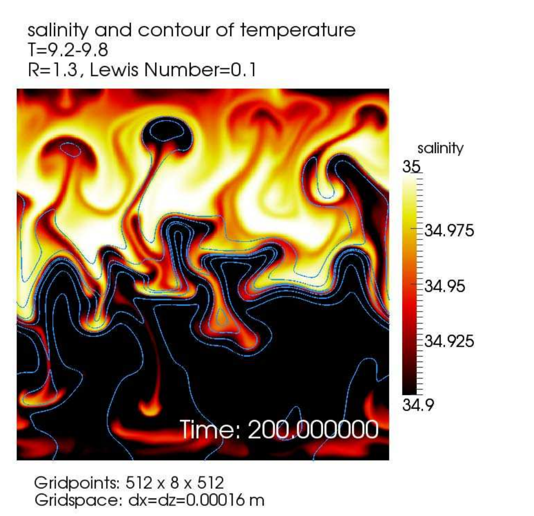
5 Diffusive Regime: Decay of Saltfingers





6 Compare 3D- and 2.5D- Simulation of Saltfingers





7 Observations and Conclusions

The diffusive flux of salinity is smaller than the turbulent flux of temperature by more than $2 - 3$ orders of magnitude. The observed fingerwidth agrees with theory. It is resolved by 10 gridpoints in each simulation except for 3D case, where the resolution is coarse.
Different Lewis Numbers lead to different structures of the saltfingers. The Experiments suggest that 2.5D simulations are sufficient for estimating the effective transport of temperature and salinity. To study the physics of the plumes 3D simulations are neccesary.

References

(1) **M**assachusetts **I**nstitute of **T**echnology **G**eneral **C**irculation **M**odel, http://mitgcm.org

(2) P.G. Baines and A.E. Gill, On thermohaline convection with linear gradients, J- Fluid Mech. vol.37, part 2, pp. 289-306, (1969)

(3) J.R.Gupta, Joginder S. Dihman and Jayant Thakur, Thermohaline Convection of Veronis and Stern Types Revisited, J. Mathematical Analysis and App. vol. 264, pp. 398-507, (2001)

(4) M. Merryfield, Origin of Thermohaline Staircases, J. Phys. Oceanograpy, Vol 30, (1999)

(5) T. Radko, A Mechanism for layer formation in a double–diffusive fluid, J- Fluid Mech. vol. 597, (2003)