Stratified Turbulence and Mixing: Experiments in an Inclined Duct

UNIVERSITY OF CAMBRIDGE

Adrien Lefauve & Paul Linden

DAMTP, University of Cambridge, UK

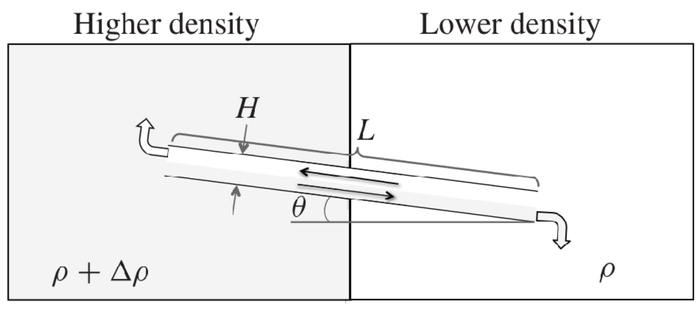
MUST

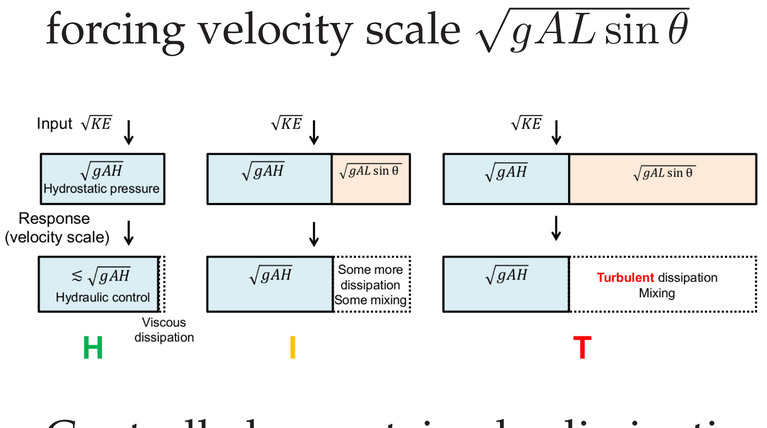
Motivations

- Stratified turbulence and mixing in environmental/geophysical context
- Achieve relevant parameter regime in the lab, inaccessible to simulation
- Dynamics and mixing poorly understood despite a century of efforts
- High-resolution experimental data needed for dynamical system description of turbulence

Laboratory Stratified Shear Flow

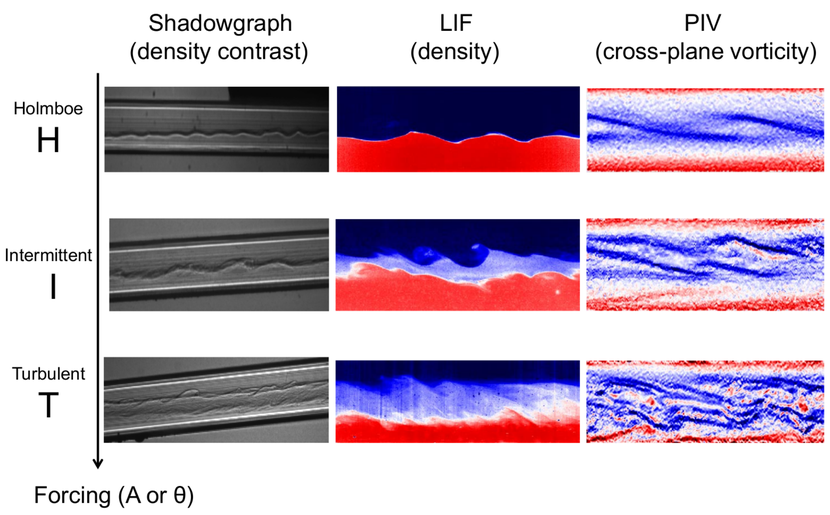
- Buoyancy-driven exchange flow (Atwood number $A = \Delta\rho/\rho$)
- Additional forcing by inclination θ
- Flow sustained for several minutes with constant forcing



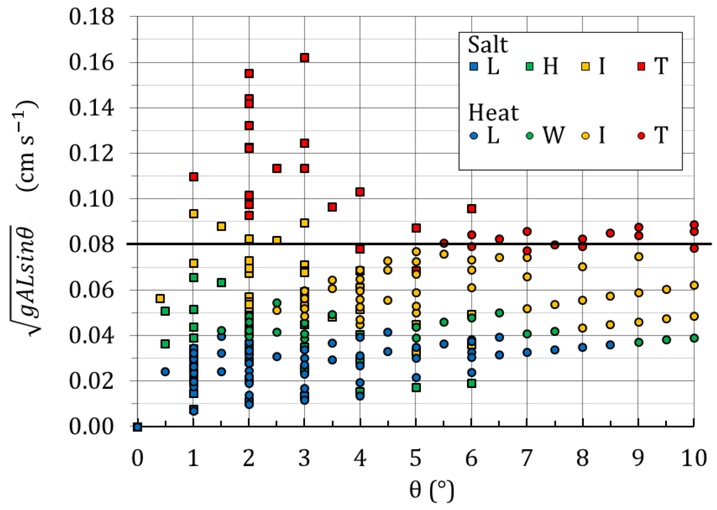


Flow States and Transition to Tubulence

- Flow states depend on forcing (A, θ)



- Turbulent transition in state space (both for $Pr_{\text{salt}} = 700$ and $Pr_{\text{heat}} = 7$)



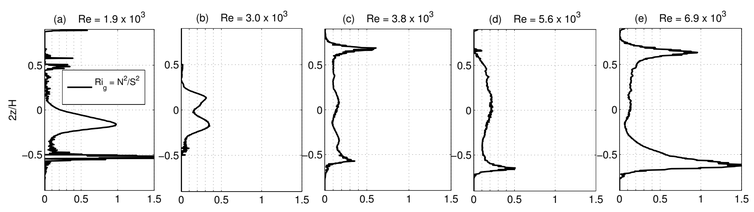
- Hydraulic control: $U \sim \sqrt{gAH}$
- Transition scales with additional forcing velocity scale $\sqrt{gAL\sin\theta}$

- Controlled, sustained dissipation rate and $Re_b = \epsilon/(\nu N^2) \sim 10^2$

Link with Mixing?

- Mean 2D density and velocity

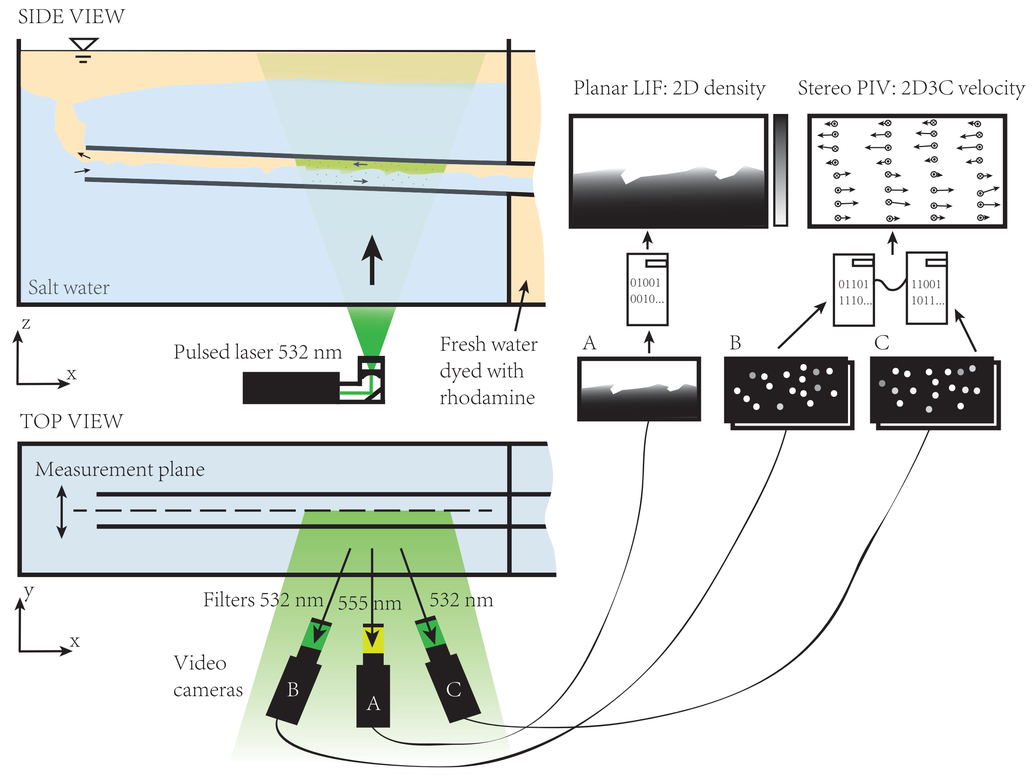
$$\Rightarrow Ri_g = \frac{N^2}{S^2} = \frac{(g/\rho)\partial\overline{\rho}^{x,t}/\partial z}{(\partial\overline{U}^{x,t}/\partial z)^2}$$



- Regions with increasing turbulent mixing exhibits constant $Ri_g \approx 0.1$
- Consistent with Turner's equilibrium Richardson number
- Mixed layer thickness scaling?

In Progress: 3D, Simultaneous LIF/PIV System

- Fast scanning of laser sheet for 3D LIF/PIV
- Next investigations:
  - Holmboe waves
  - Route to turbulence
  - Mixing efficiency
  - Coherent structures
  - Reduced-order models (Koopman)
  - ...



References

- Meyer, C. R. & Linden, P. F. (2014), Stratified shear flow: experiments in an inclined duct, *J. Fluid Mech.*, **753**, 242–253
- Turner, J. S. (1973), *Buoyancy effects in fluids*, Cambridge University Press, §10.2

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