Experimental Boundary layer Turbulence

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Interfaces in the Climate System
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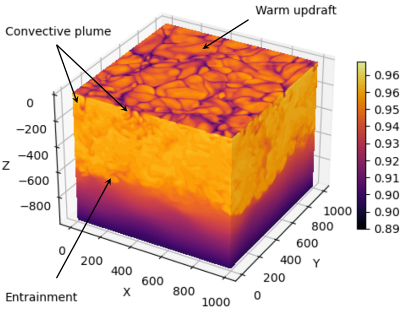
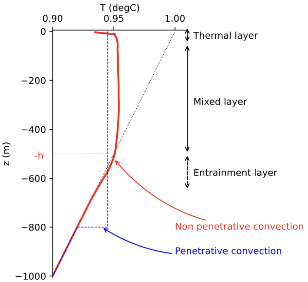
LABORATOIRE DES ECOULEMENTS GEOPHYSIQUES ET INDUSTRIELS

Observation of convection

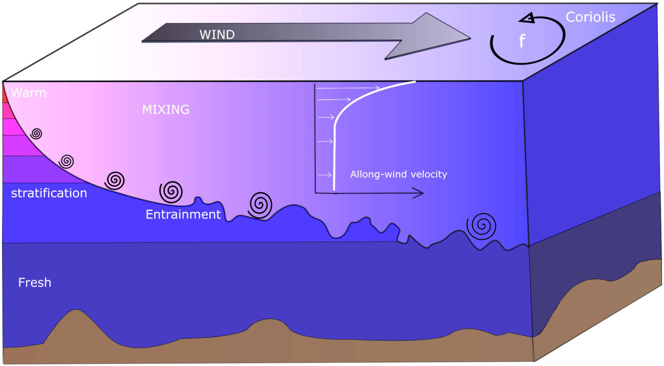




Oceanic convection

- **Organisation of convection**
  1. Coherent convective structures
- **Convective Turbulence**
- **Different convection regimes**
  1. **Forced/Free** Convection
  2. Convection in **rotation**

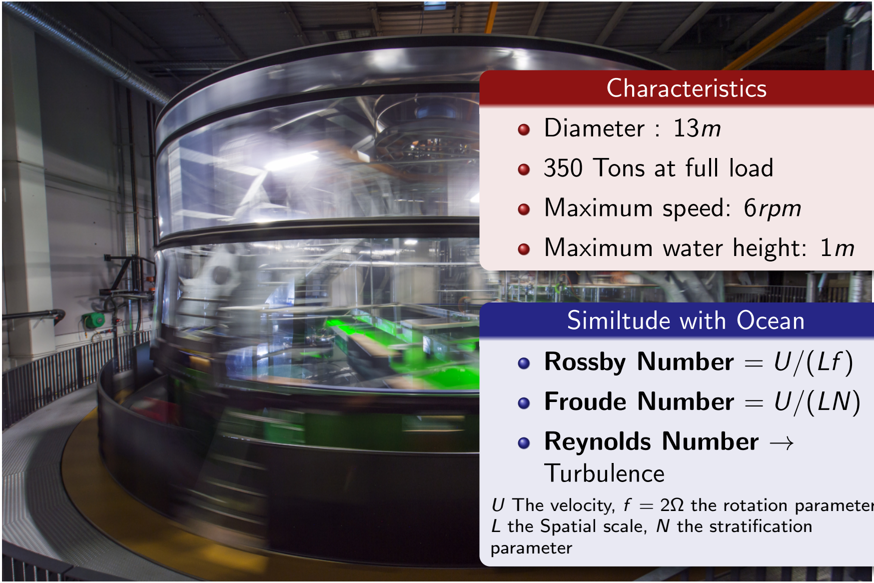
Forced Convection



Processes influencing convection

1. **Rotation** - Ekman/ Inertial waves
2. **Wind forcing** - Energy input
3. **Stratification** - Potential energy modification

Coriolis Plateform



Characteristics

- Diameter : $13m$
- 350 Tons at full load
- Maximum speed: $6rpm$
- Maximum water height: $1m$

Similtude with Ocean

- **Rossby Number** $= U/(Lf)$
- **Froude Number** $= U/(LN)$
- **Reynolds Number** $\rightarrow$ Turbulence

U The velocity, $f = 2\Omega$ the rotation parameter, L the Spatial scale, N the stratification parameter

Credit:Cyril Fresillon/LEGI/CNRS Photothèque

Kato and Phillips experiments

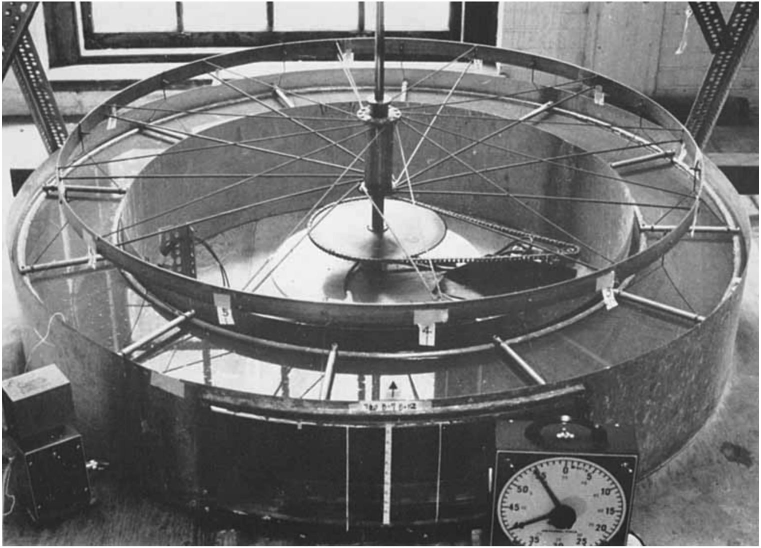


FIGURE 1. The experimental apparatus.

Figure: Kato, H., Phillips, O.M., 1969. On the penetration of a turbulent layer into stratified fluid. Journal of Fluid Mechanics 37, 643–655.

Kato and Phillips experiments

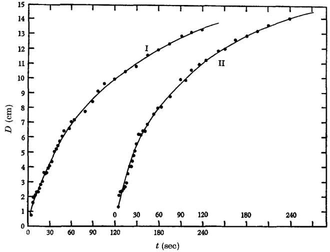


FIGURE 5. Typical variations in depth D of the mixed layer with time. Curve I: $d\rho/dz = 0{\cdot}00192$, $\tau_0 = 0{\cdot}995$ c.g.s. Curve II: $d\rho/dz = 0{\cdot}00384$, $\tau_0 = 2{\cdot}12$ c.g.s. Curve II is shifted to right by 120 seconds.

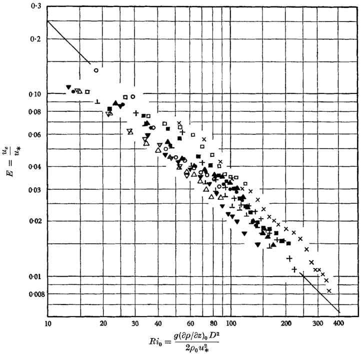


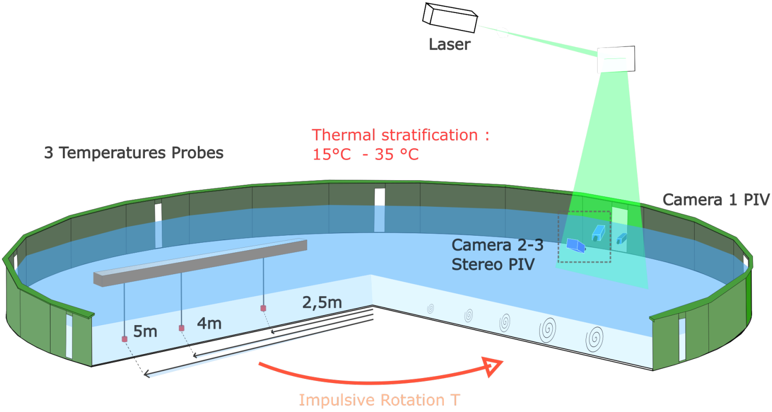
FIGURE 6. The entrainment coefficient E as a function of the overall Richardson number.

1. Deepening of the mixed layer
2. Entrainement law

Results used in numerical modelling

Figure: Kato, H., Phillips, O.M., 1969. On the penetration of a turbulent layer into stratified fluid. Journal of Fluid Mechanics 37, 643–655.

Presentation of the Experiences - Forced Convection



Forced convection experiments

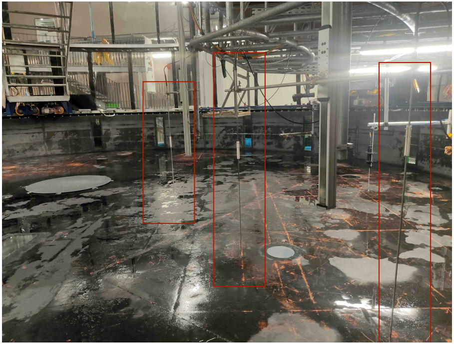
Reproduce the *Kato-Phillips*

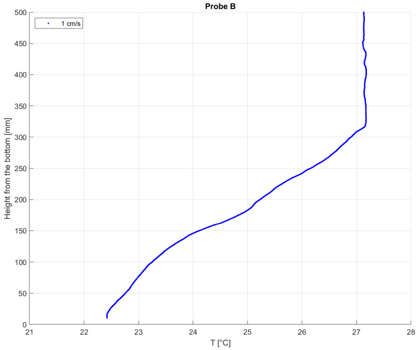
- *Kantha, Phillips et Azad [1977] / Deardoff et Willis [1981]*

Pictures of the bottom boundary layer

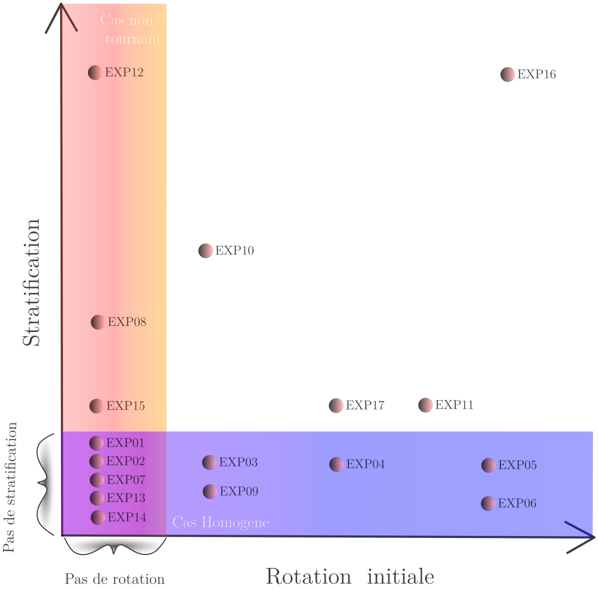
Thermal Stratification

- Thermal Stratification $\Delta T \sim 20^{\circ}C/30cm$ (20-15 last cm mixed)
- Filling time (4h15 / 50cm)
- Destruction of the stratification after 1 night





Experiences



Boundary layer

$U(\delta(t)) = 95\% U_\infty$

U_∞ The velocity of the fluid in the reference frame of the plate far from the wall

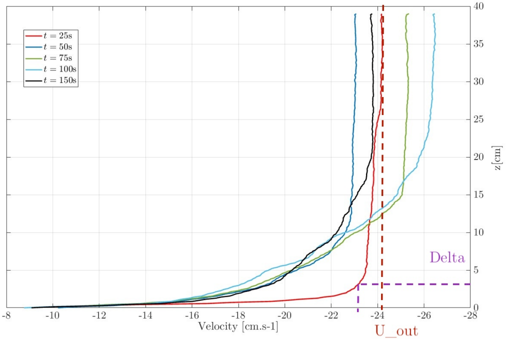


Figure: Definition of the thickness δ from the vertical velocity profile at different times in EXP 04

Vertical profil of the velocity for a Spin-up without initial rotation

Boundary layer $\delta(t)$

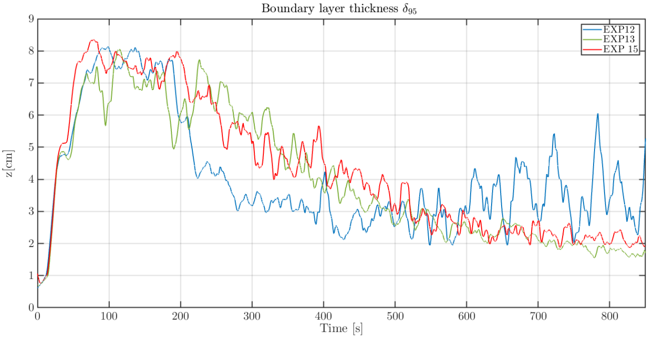
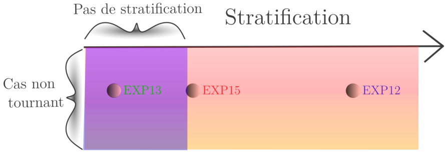


Figure: Spin-up **with** stratification and **without** rotation



Different regimes

- Initial Growth
- Decay dependent on stratification

Boundary layer $\delta(t) = 95\% U_\infty$

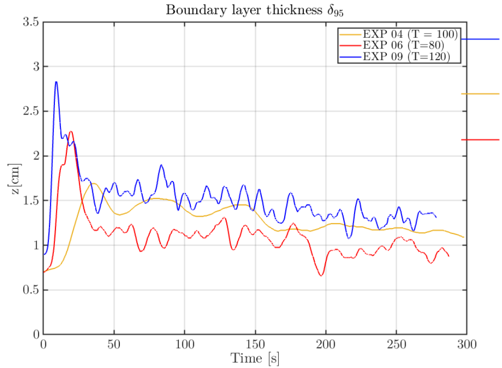
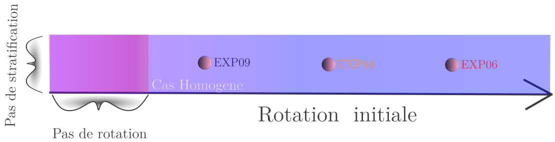


Figure: Spin up **without** stratification and **with** rotation

Ekman Layer

- Limite $\delta_{ek} \sim 0.3 u_*/f$

EXP 09	EXP 04	EXP 06
3.3 cm	2.78cm	2.2cm



Comparison with KP experiment

Similitude

- **Shape:** Cylindrical tanks.
- **Stratification:** KP (Salt) / Coriolis (Temperature).
- **Stress:** Circonferential direction

Differences

- **Aspect Ratio:**
  - KP: 152/28 (with inner cylinder)
  - Coriolis: 6500/50
- **Measurements Available:**
  - KP: Frictional torque and dye-visible mixing zone
  - Coriolis: Velocity and temperature measurements
- **Rotation Effect:**
  - KP: Not considered