

EXPERIMENTAL BOUNDARY LAYER TURBULENCE

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INTERFACES IN THE CLIMATE SYSTEM

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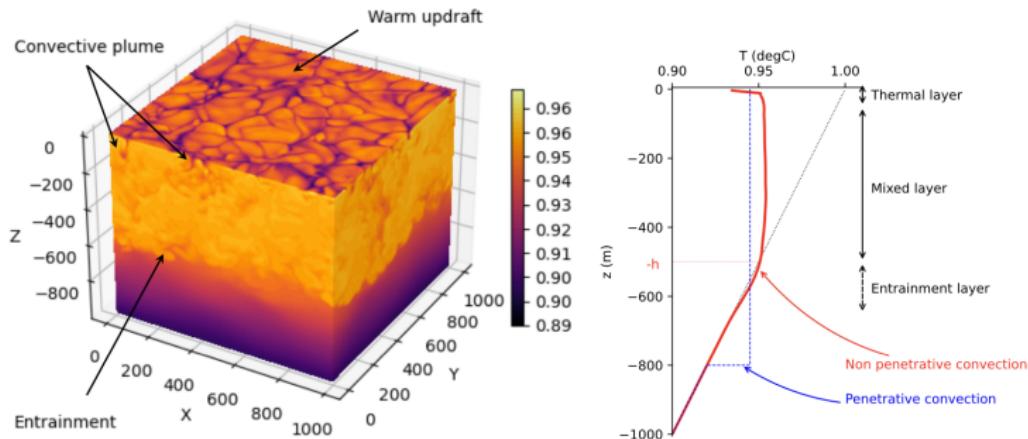
- Experiences on the Coriolis platform
- Thermal Stratification

2 Experience on Coriolis

- Boundary layer
- Comparison with KP experiment

3 Experimental results

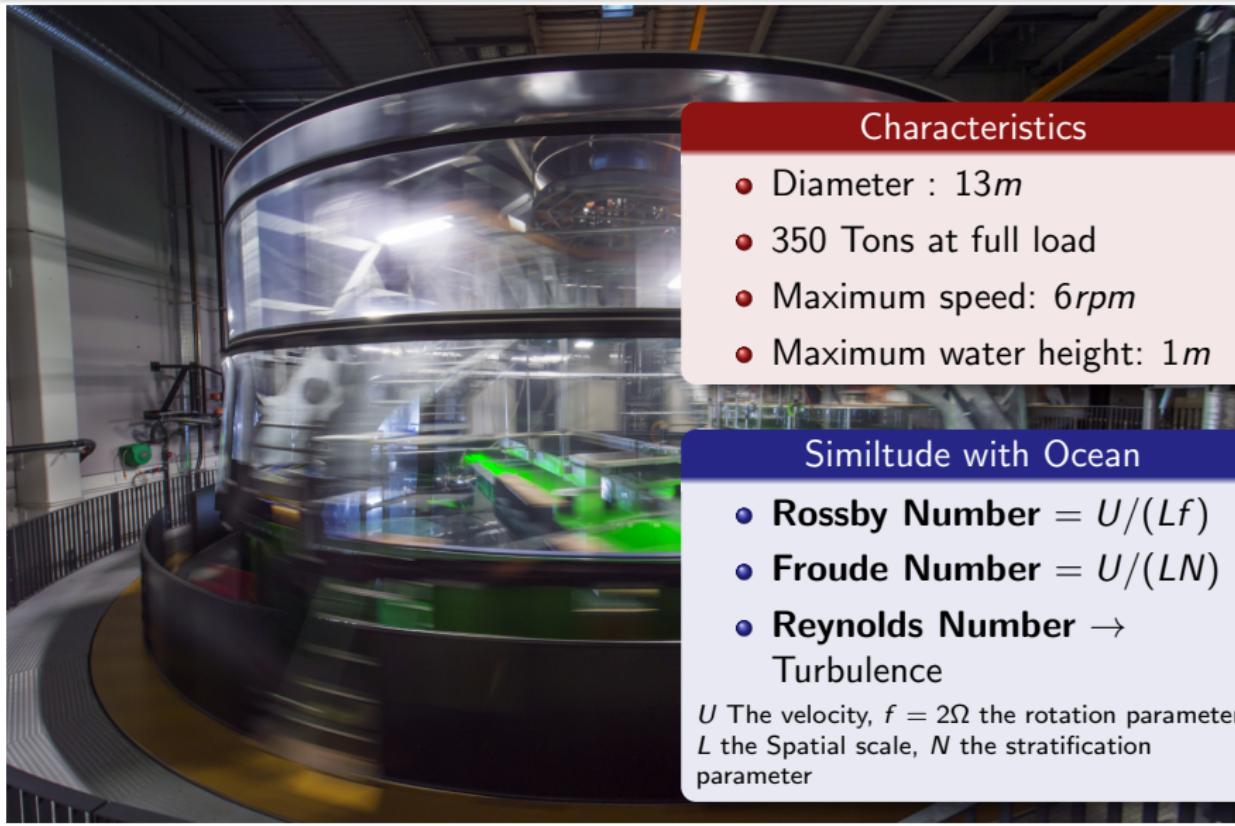
Observation of convection



Oceanic convection

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

Coriolis Plateform



Characteristics

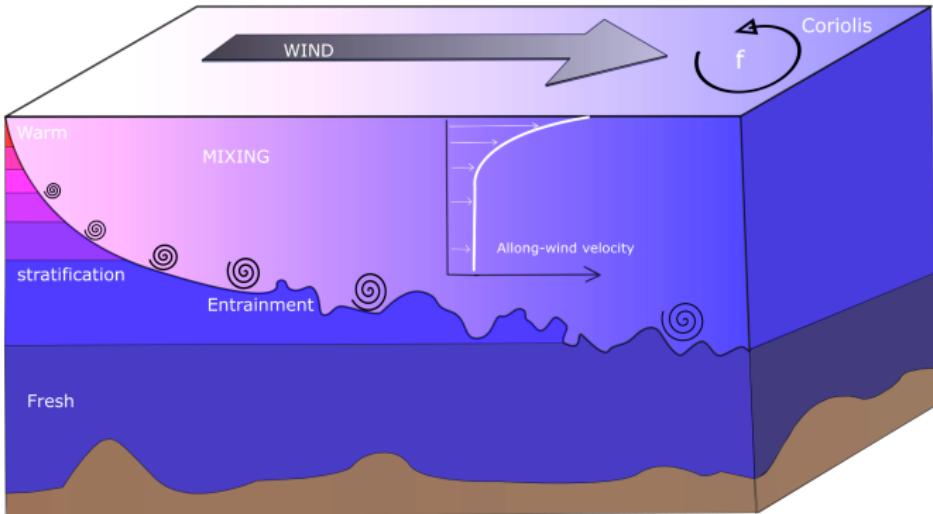
- Diameter : 13m
- 350 Tons at full load
- Maximum speed: 6rpm
- Maximum water height: 1m

Similitude with Ocean

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

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

Forced Convection



Processes influencing convection

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

Kato and Phillips experiments

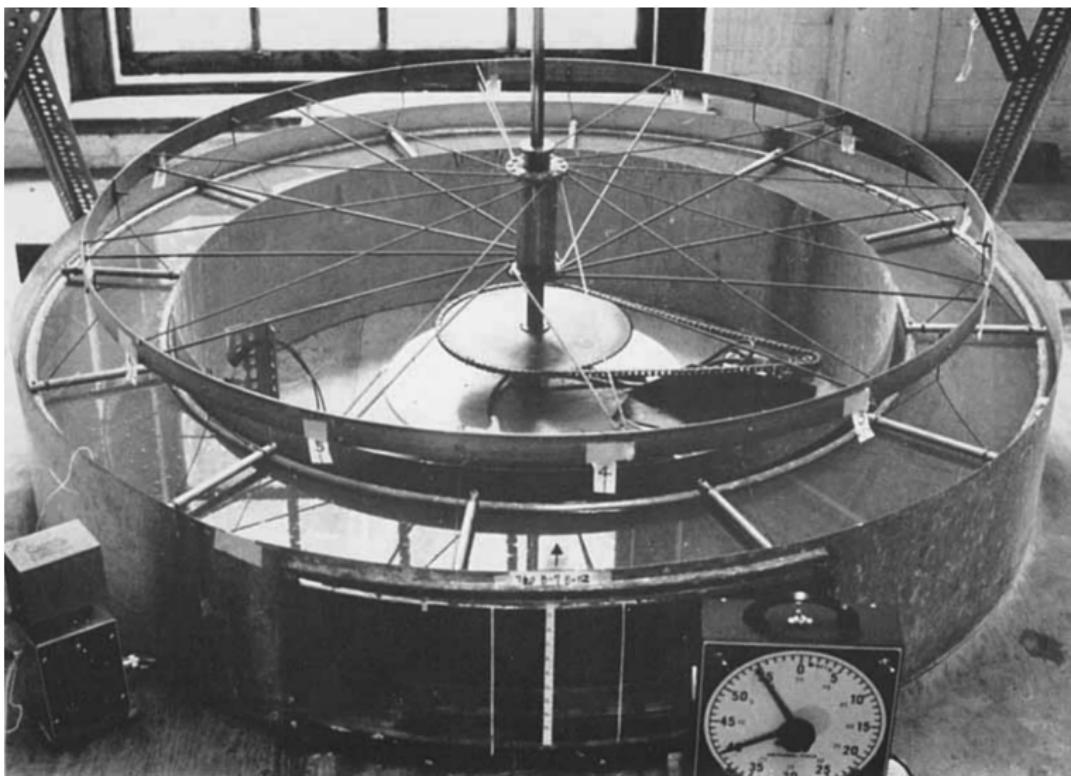


FIGURE 1. The experimental apparatus.

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

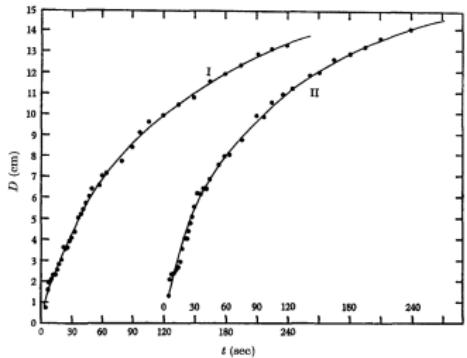


FIGURE 5. Typical variations in depth D of the mixed layer with time. Curve I: $d\rho/dz = 0.00192$, $\tau_e = 0.995$ c.g.s. Curve II: $d\rho/dz = 0.00384$, $\tau_e = 2.12$ c.g.s. Curve II is shifted to right by 120 seconds.

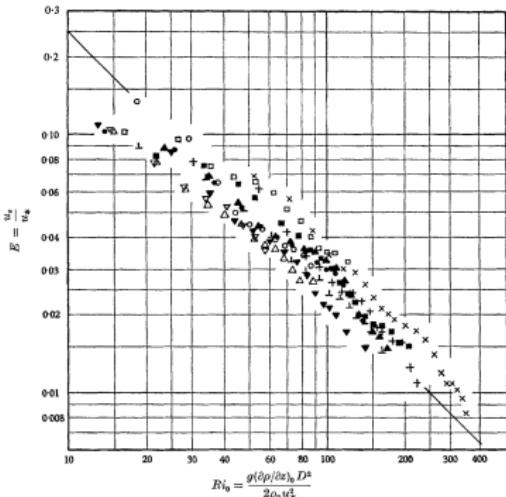


FIGURE 6. The entrainment coefficient E as a function of the overall Richardson number.

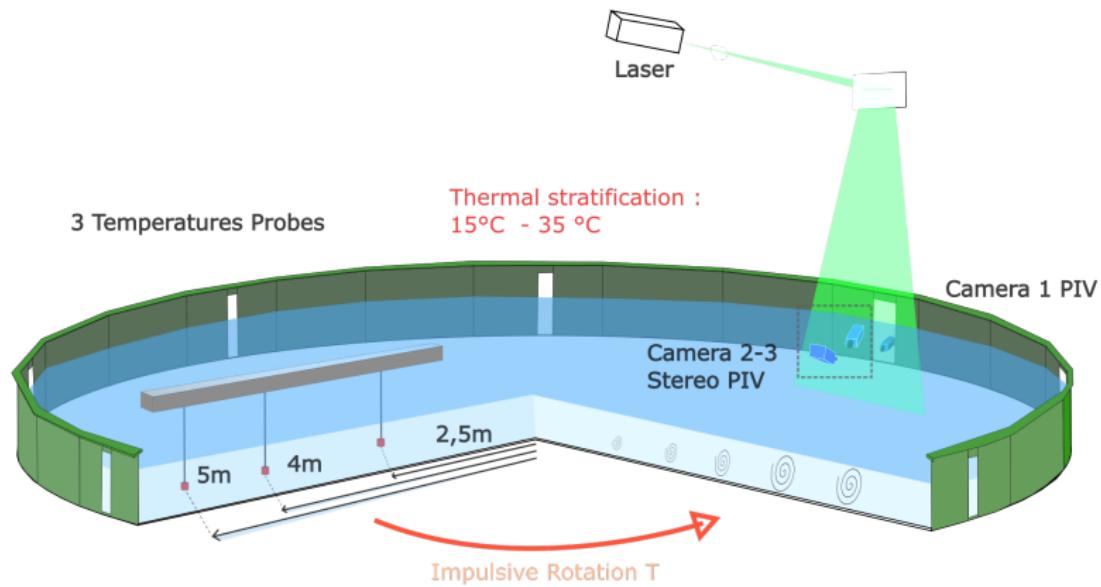
① Deepening of the mixed layer

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*

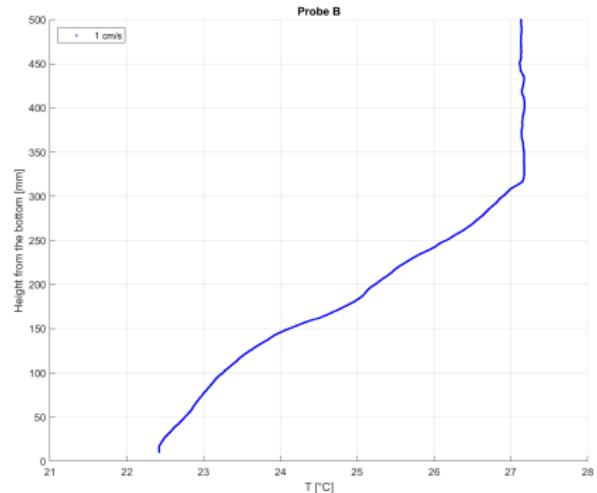
- Kantha, Phillips et Azad [1977] / Deardoff et Willis [1981]

Pictures of the bottom boundary layer

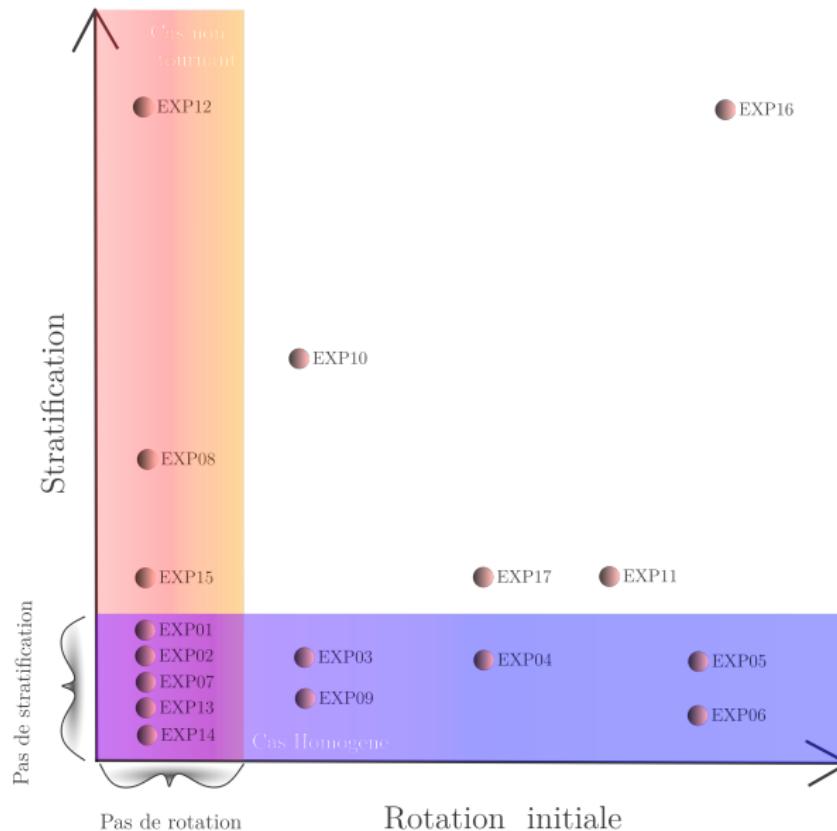


Thermal Stratification

- Thermal Stratification $\Delta T \sim 20^\circ\text{C}/30\text{cm}$ (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

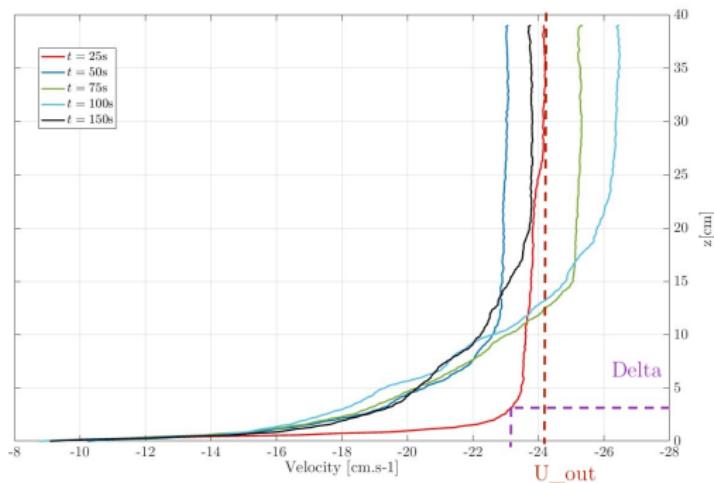


Figure: Definition of the thickness δ from the vertical velocity profile at different times in EXP 04

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

Boundary layer $\delta(t)$

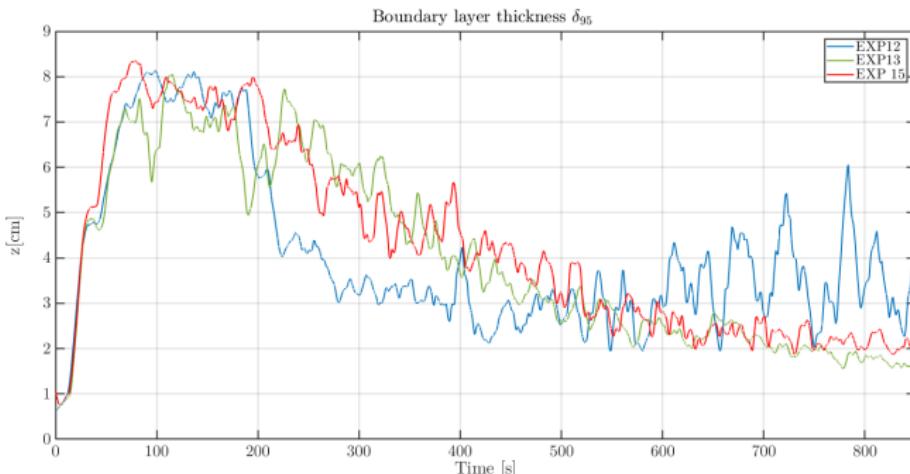
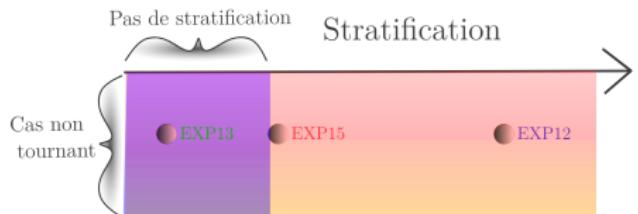


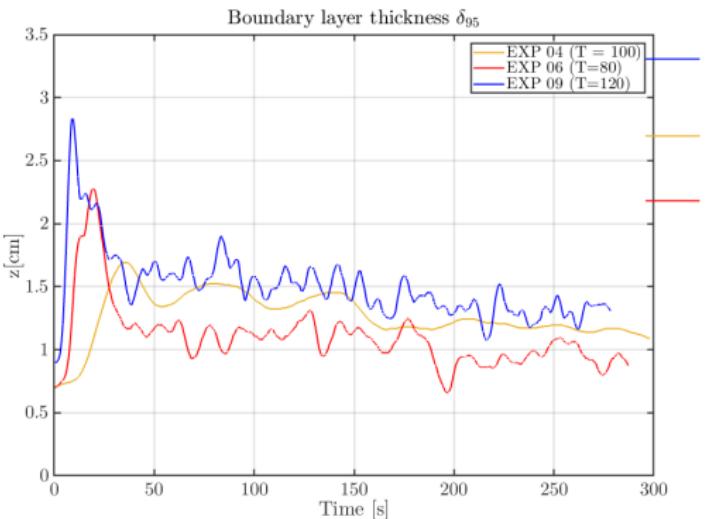
Figure: Spin-up with stratification and without rotation



Different regimes

- Initial Growth
- Decay dependent on stratification

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

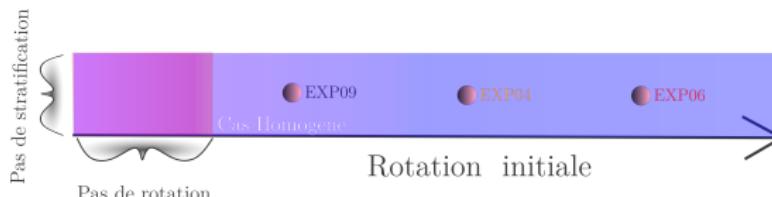


Ekman Layer

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

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

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



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