Experimental Observation of Oceanic Convection

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OxOceanClimate Seminar

LEGI
LABORATOIRE DES ECOULEMENTS GEOPHYSIQUES ET INDUSTRIELS

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Content

1. Definition of Oceanic convection
2. Presentation of the Coriolis platform
3. Forced convection experiment
4. Free convection experiment
5. Experiment in Oxford

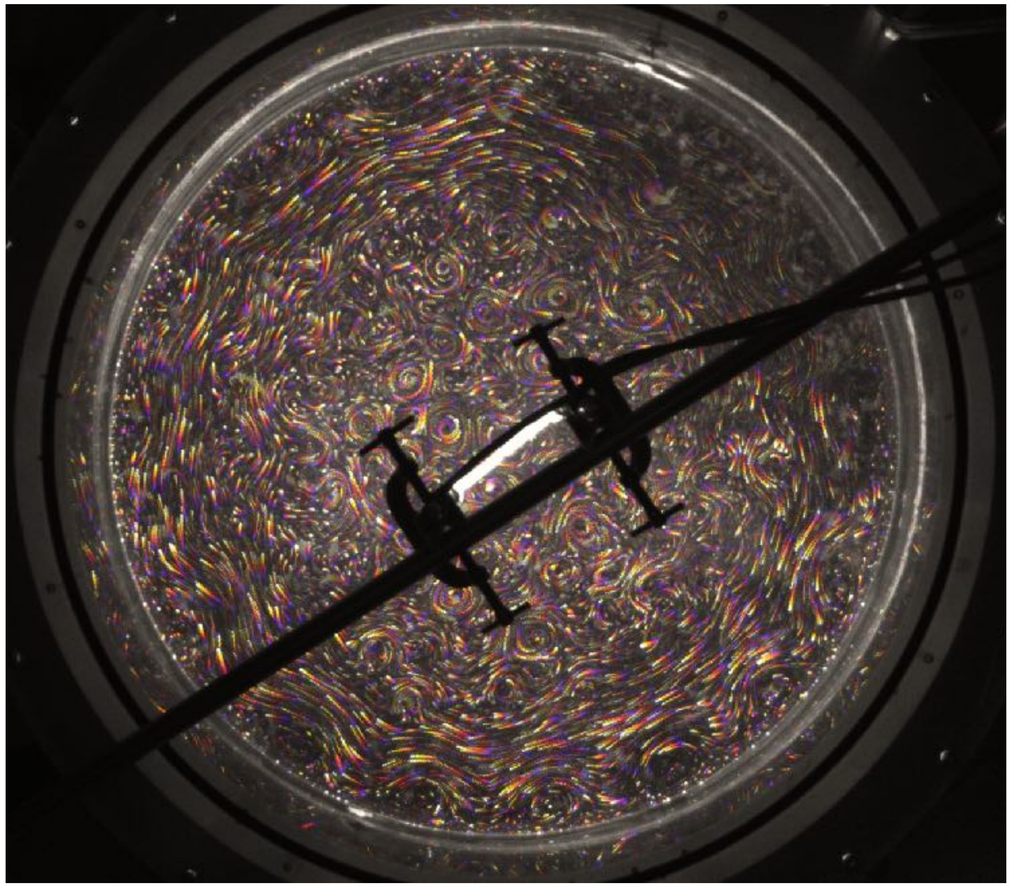
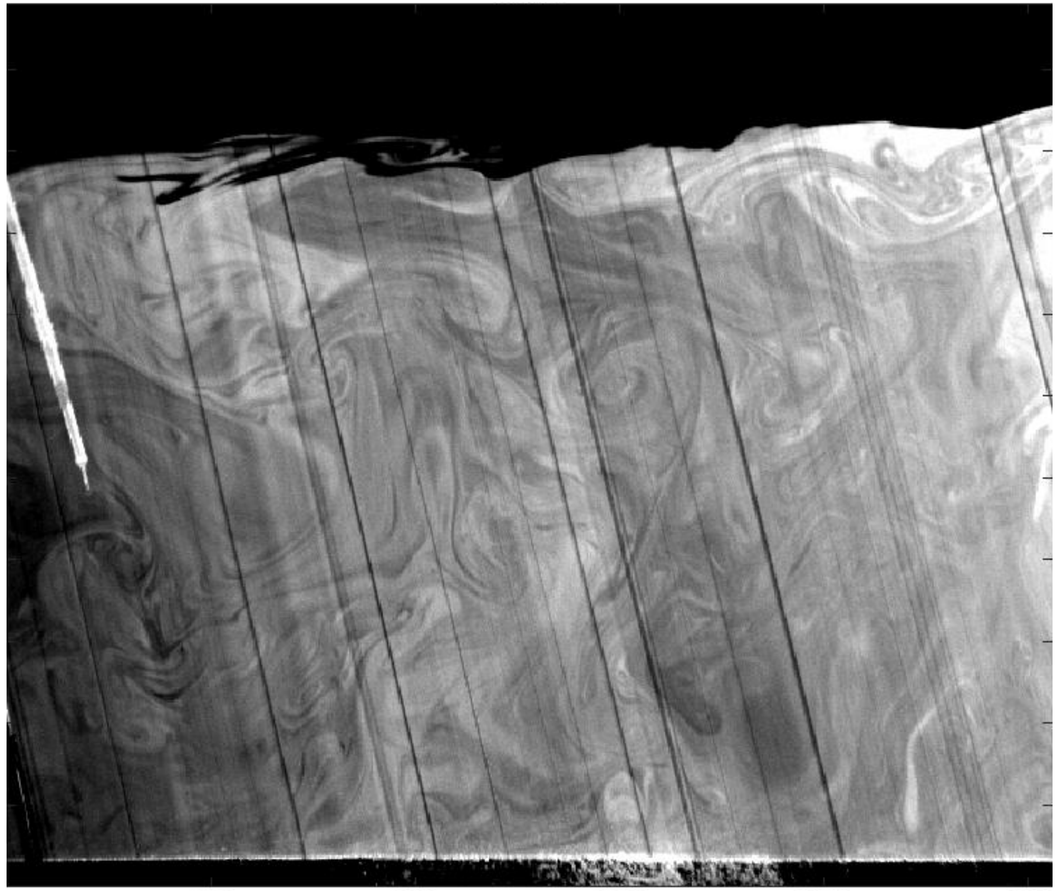


Figure 1 : Horizontal streaks of particules illuminated by LED.
The figure shows the streamline of columnar structure at the center and a baroclinic jet near the edges .

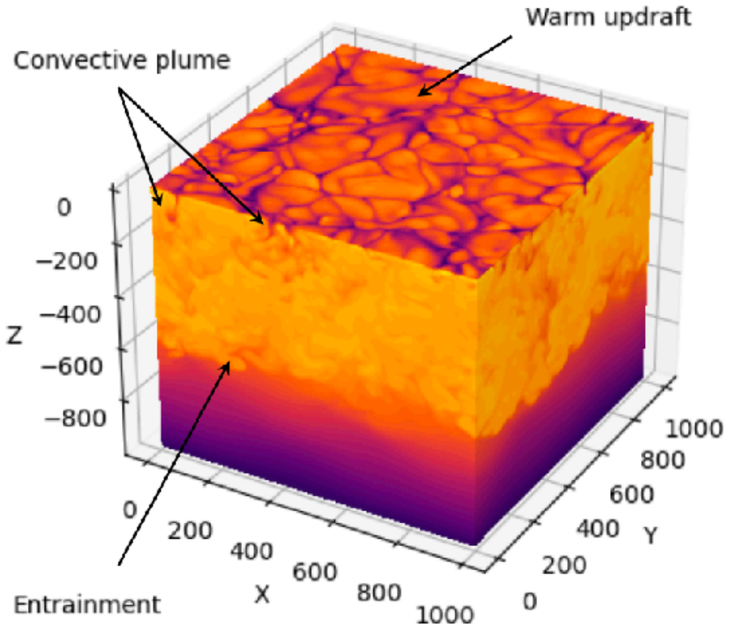
Definition of Convection

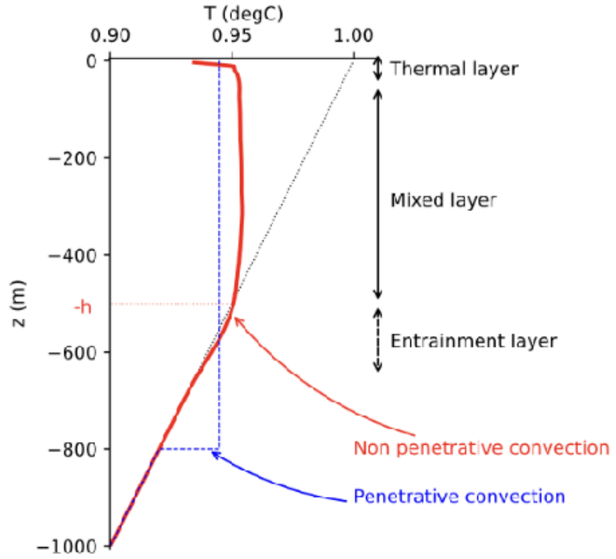
Vertical motion of a fluid parcel caused by:

- **Buoyancy Force** → **Free convection**
- **External Force** → **Forced convection**



Oceanic Convection: Free Convection

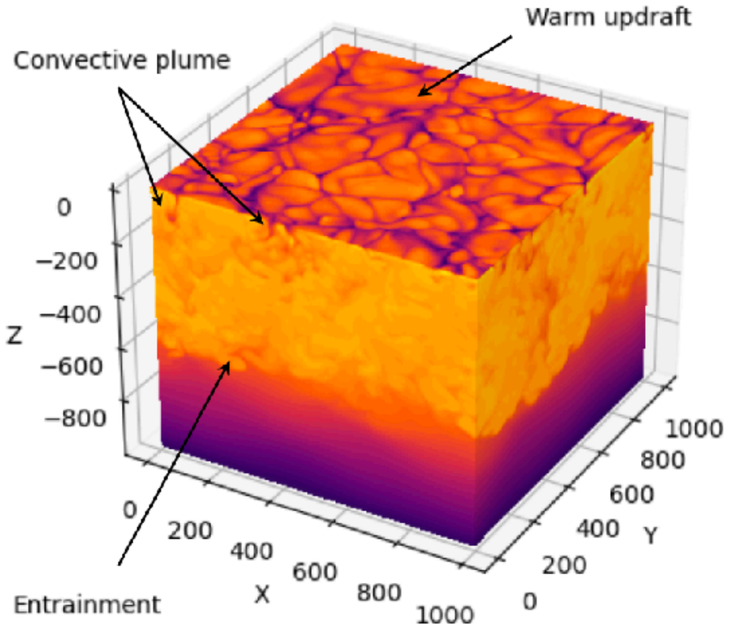


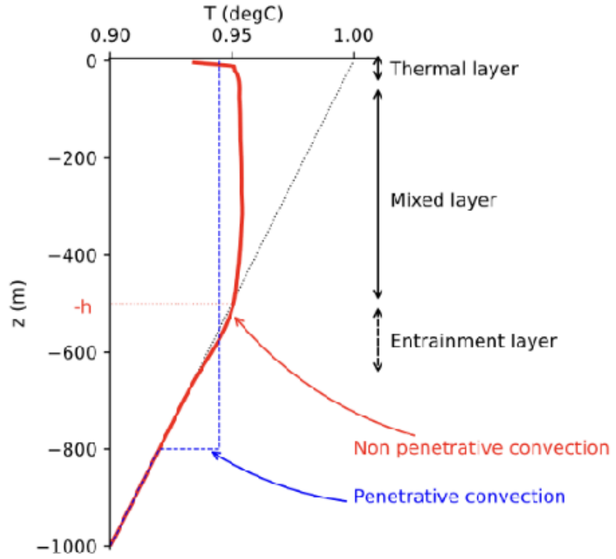


Buoyancy loss at the surface

Free Convection (Heat Flux)

Oceanic Convection: Free Convection





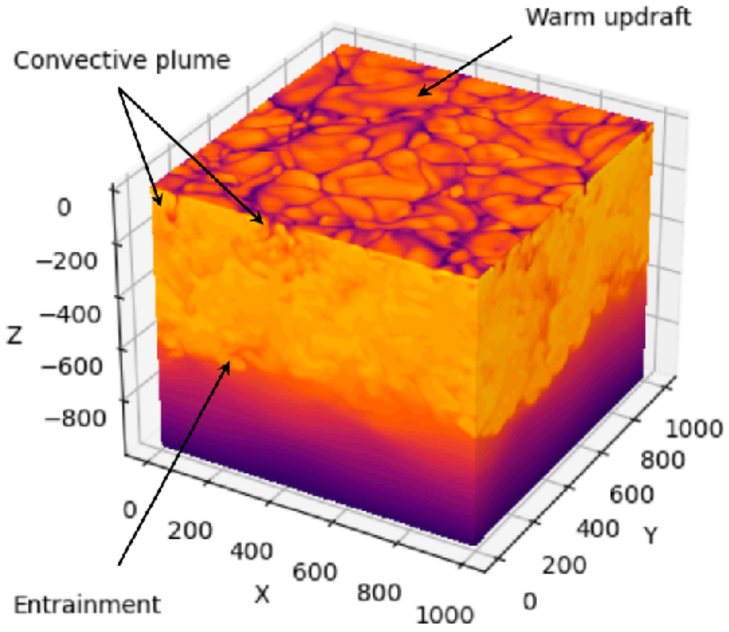
Buoyancy loss at the surface

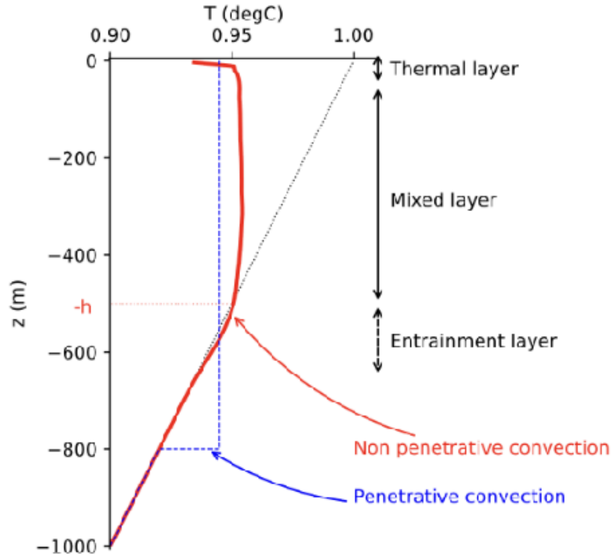
Coherent Structure

- Plume
- Cells

Free Convection (Heat Flux)

Oceanic Convection: Free Convection





Buoyancy loss at the surface

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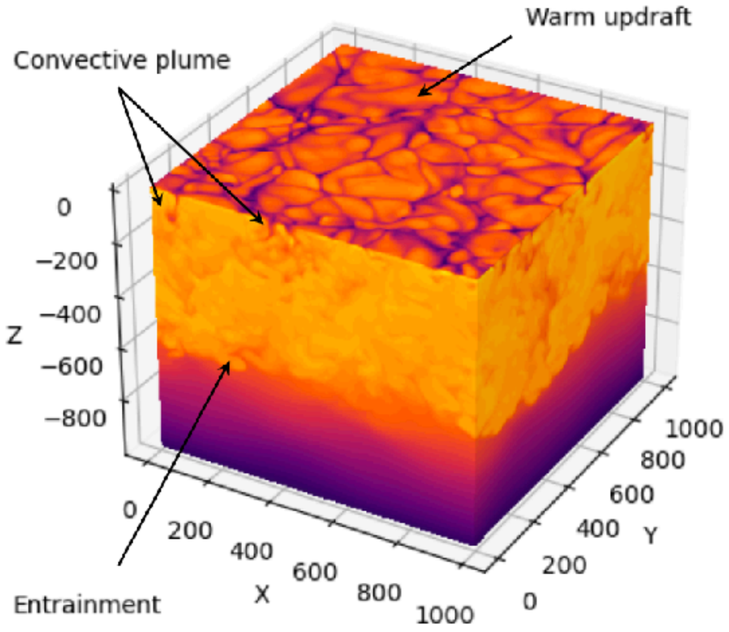
Coherent Structure

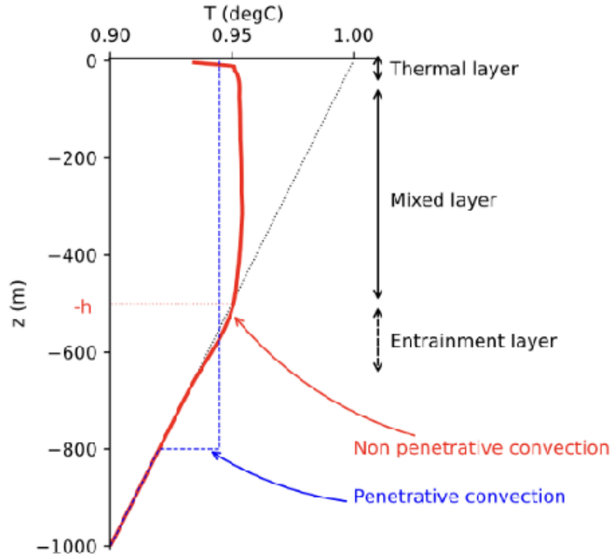
↓

Convective Turbulence

Free Convection (Heat Flux)

Oceanic Convection: Free Convection





Free Convection (Heat Flux)

Buoyancy loss at the surface

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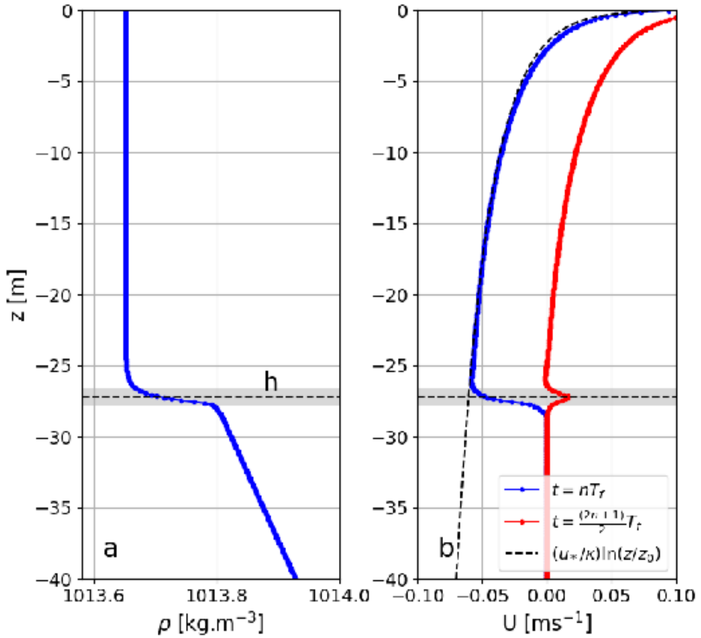
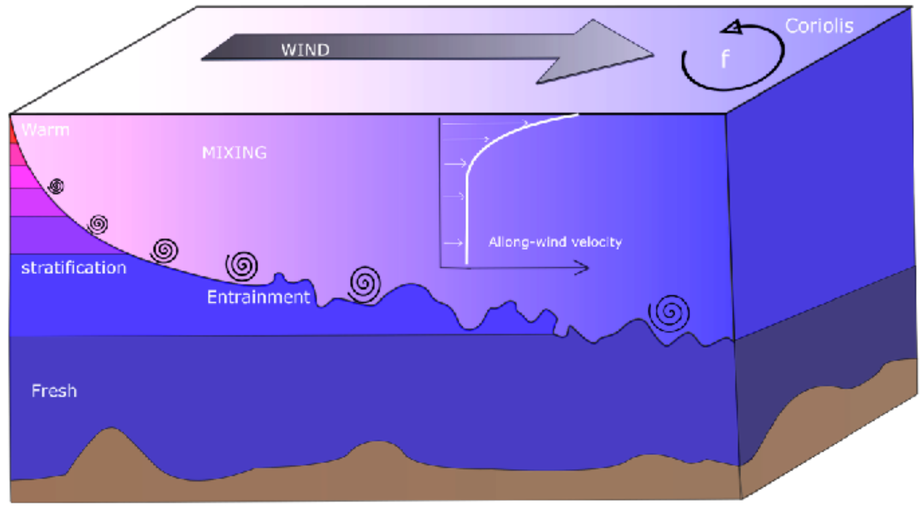
Erosion of the Stratification

Oceanic Convection: Forced Convection

Shear stress at the surface



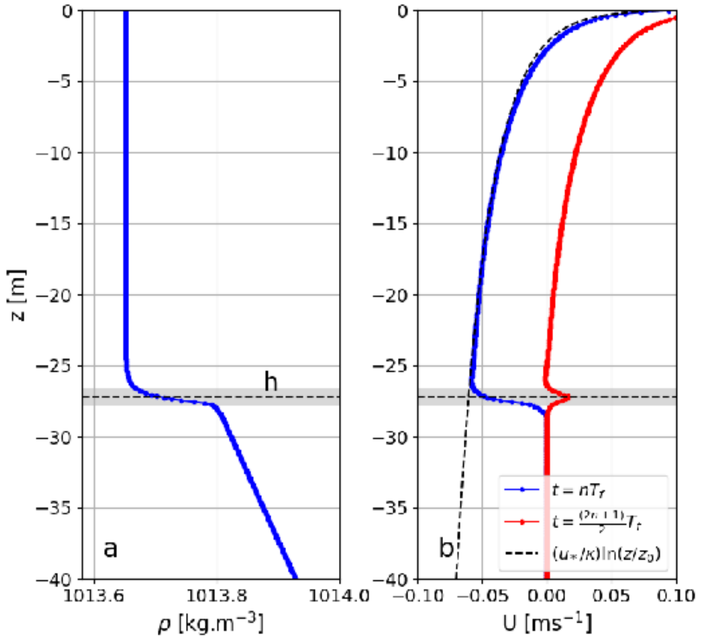


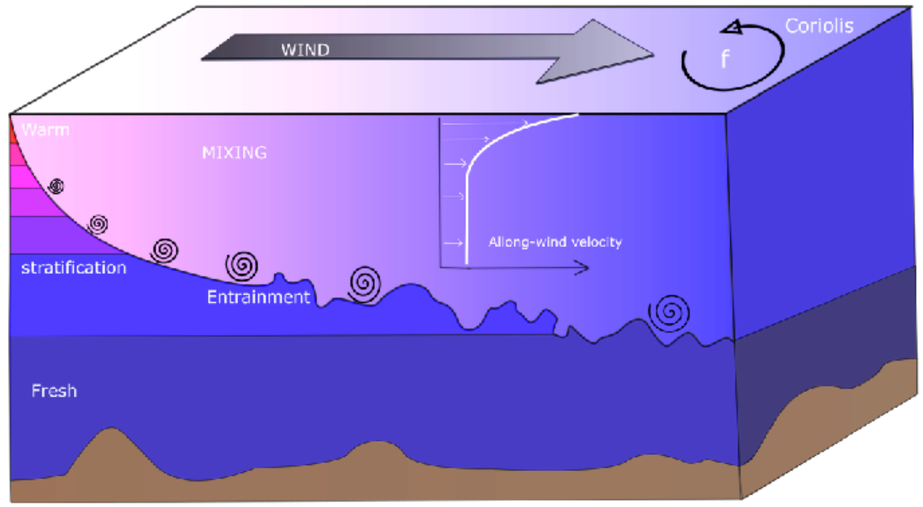
Forced Convection (Momentum Flux)

Oceanic Convection: Forced Convection

Shear stress at the surface

Log layer / Ekman Layer





Forced Convection (Momentum Flux)

Oceanic Convection: Forced Convection

Shear stress at the surface

↓

Log layer / Ekman Layer

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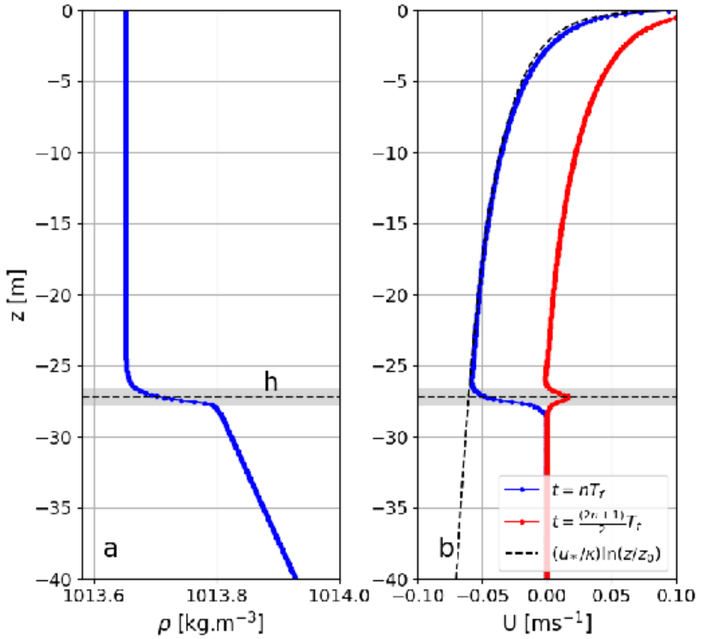
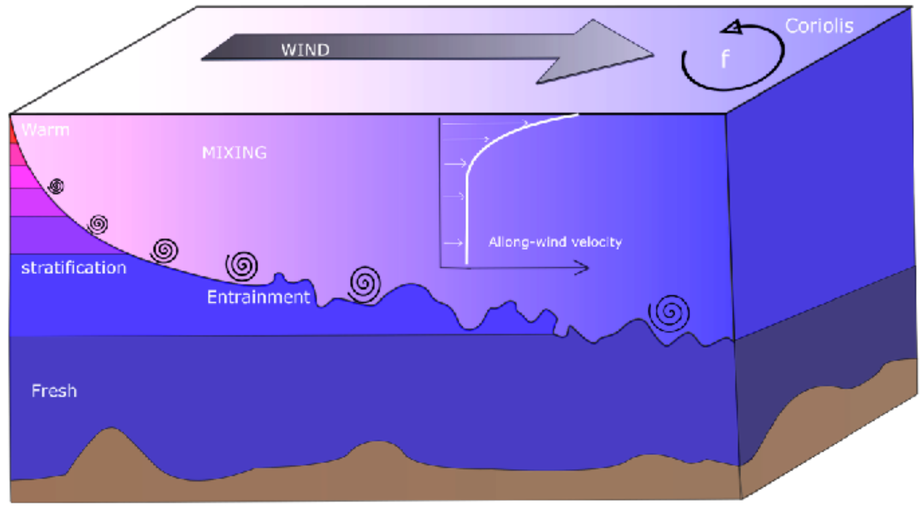
Entrainement turbulence





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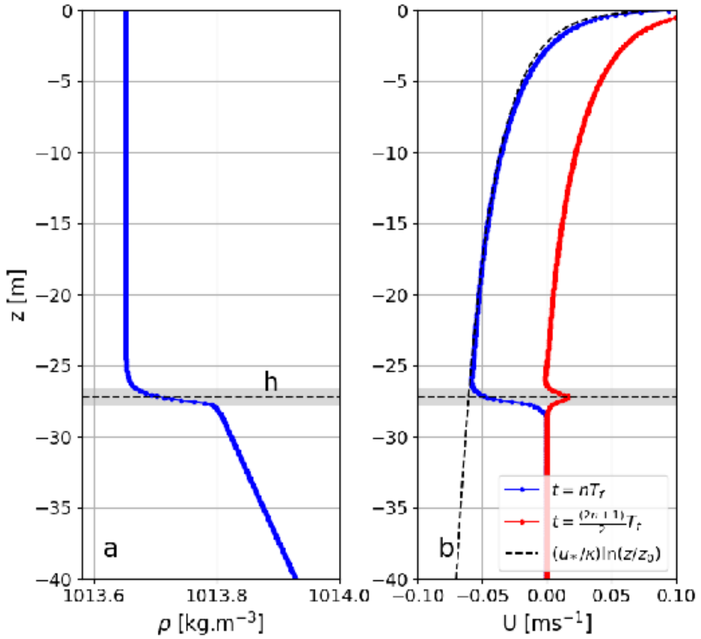
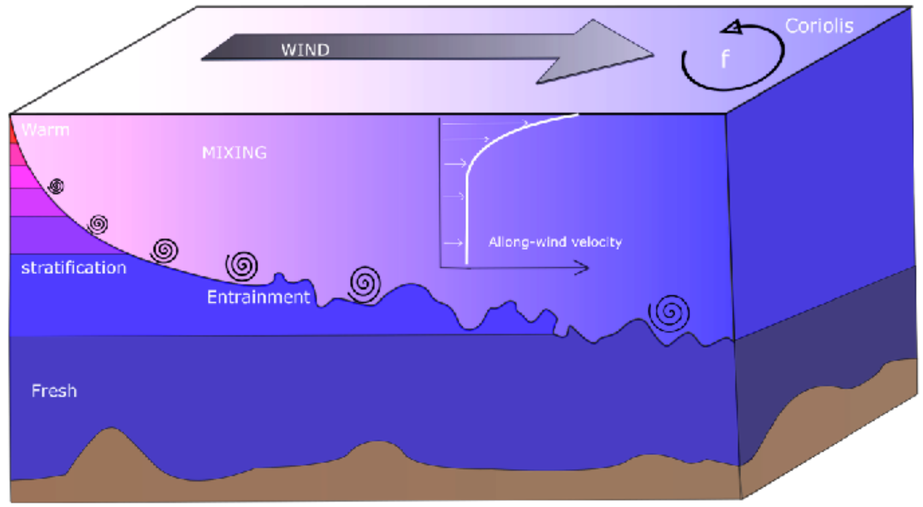
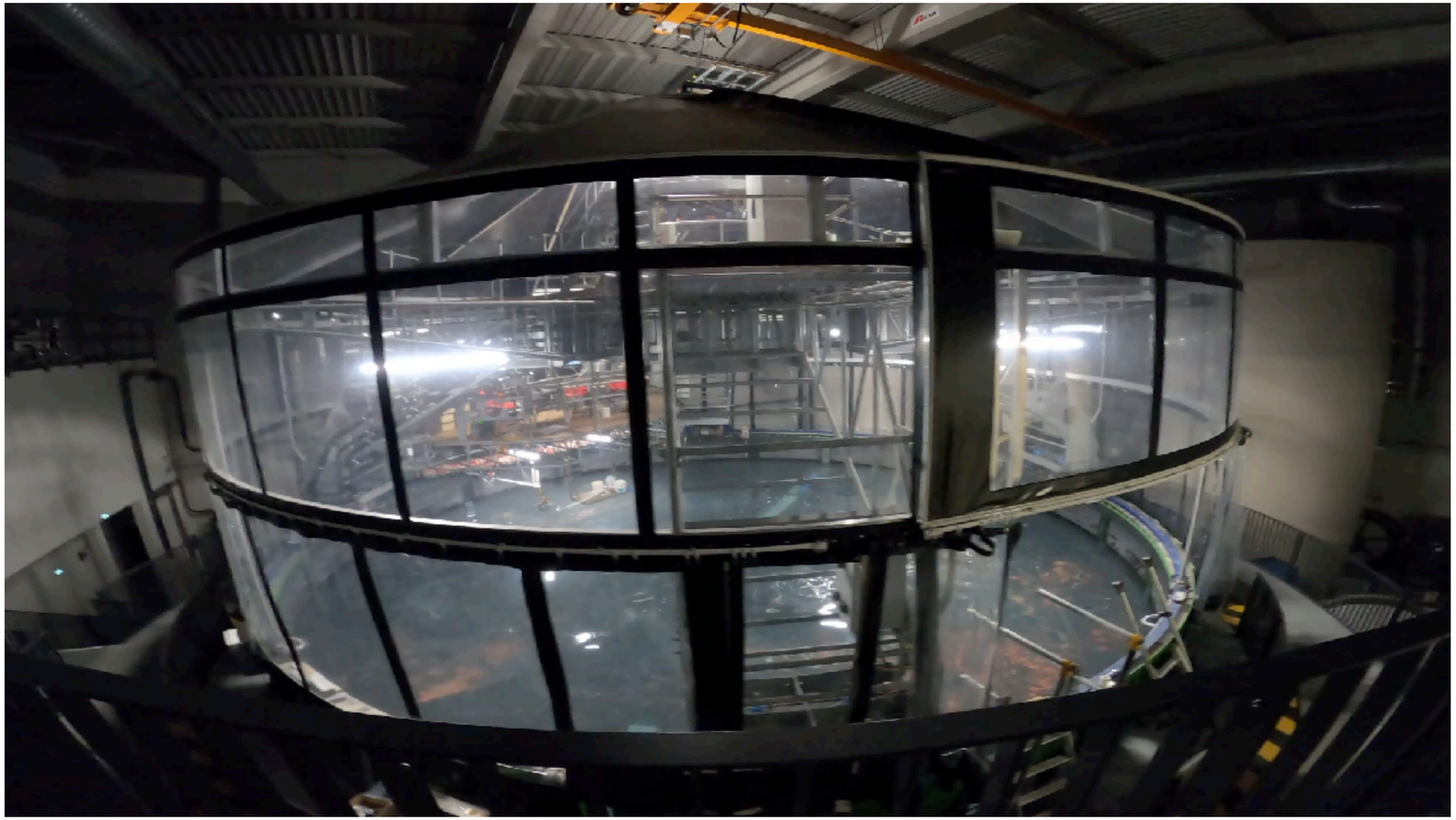




Forced Convection (Momentum Flux)

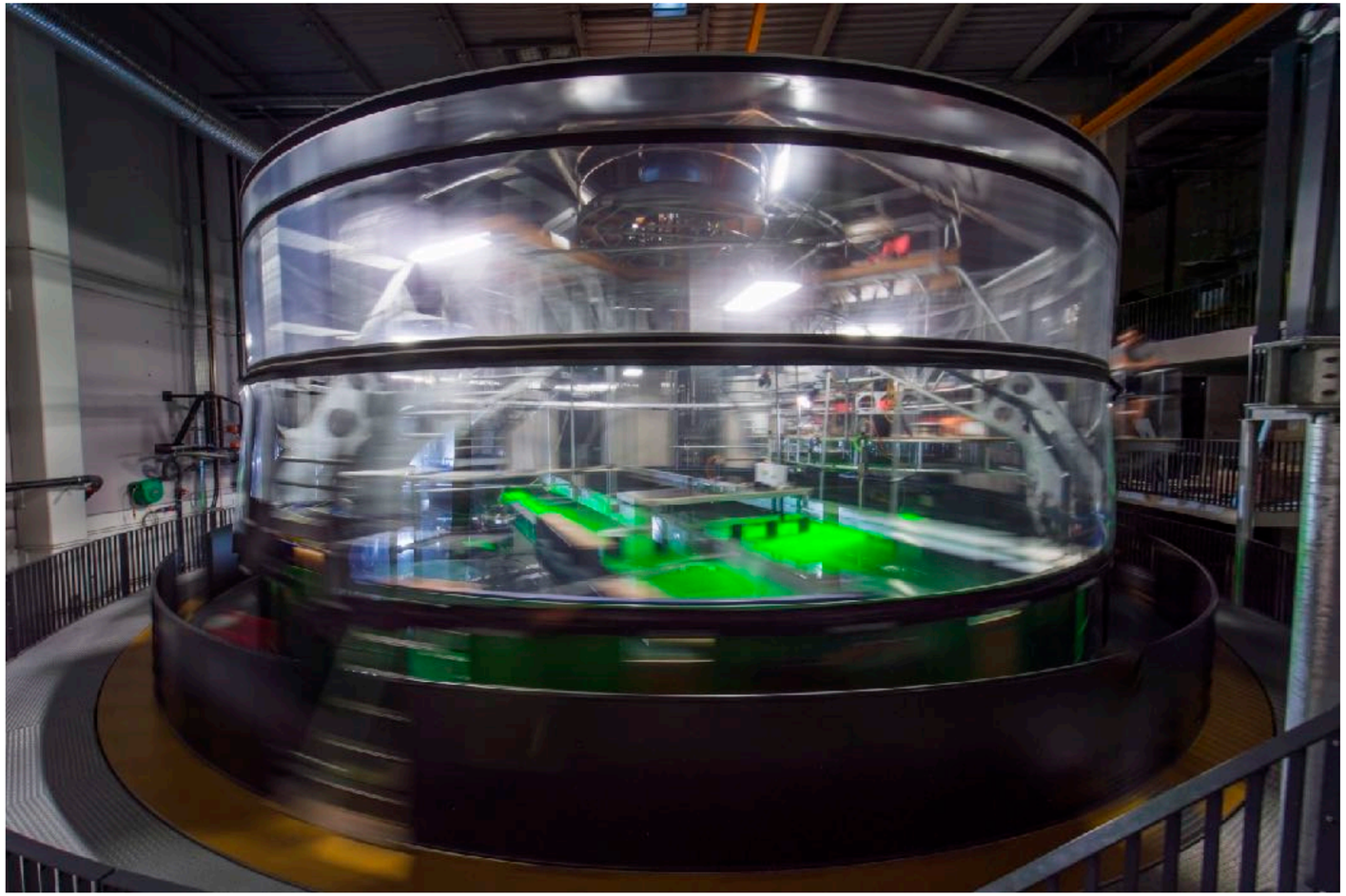
Coriolis Platform



- **Diameter:** 13 m
- **Weight :** 350 Tones at full load
- **Maximum Speed:** 6 rpm
- **Max water height:** 1 m
- **Volume:** 132 m^3

- **Rossby Number** $U/(fL)$
- **Froude Number :** $U/(NL)$
- **Reynold Number:** $UL/(\nu)$
- **Rayleigh Number:** $Ra = \frac{g\alpha\Delta TL^3}{\nu\kappa}$

Coriolis Platform



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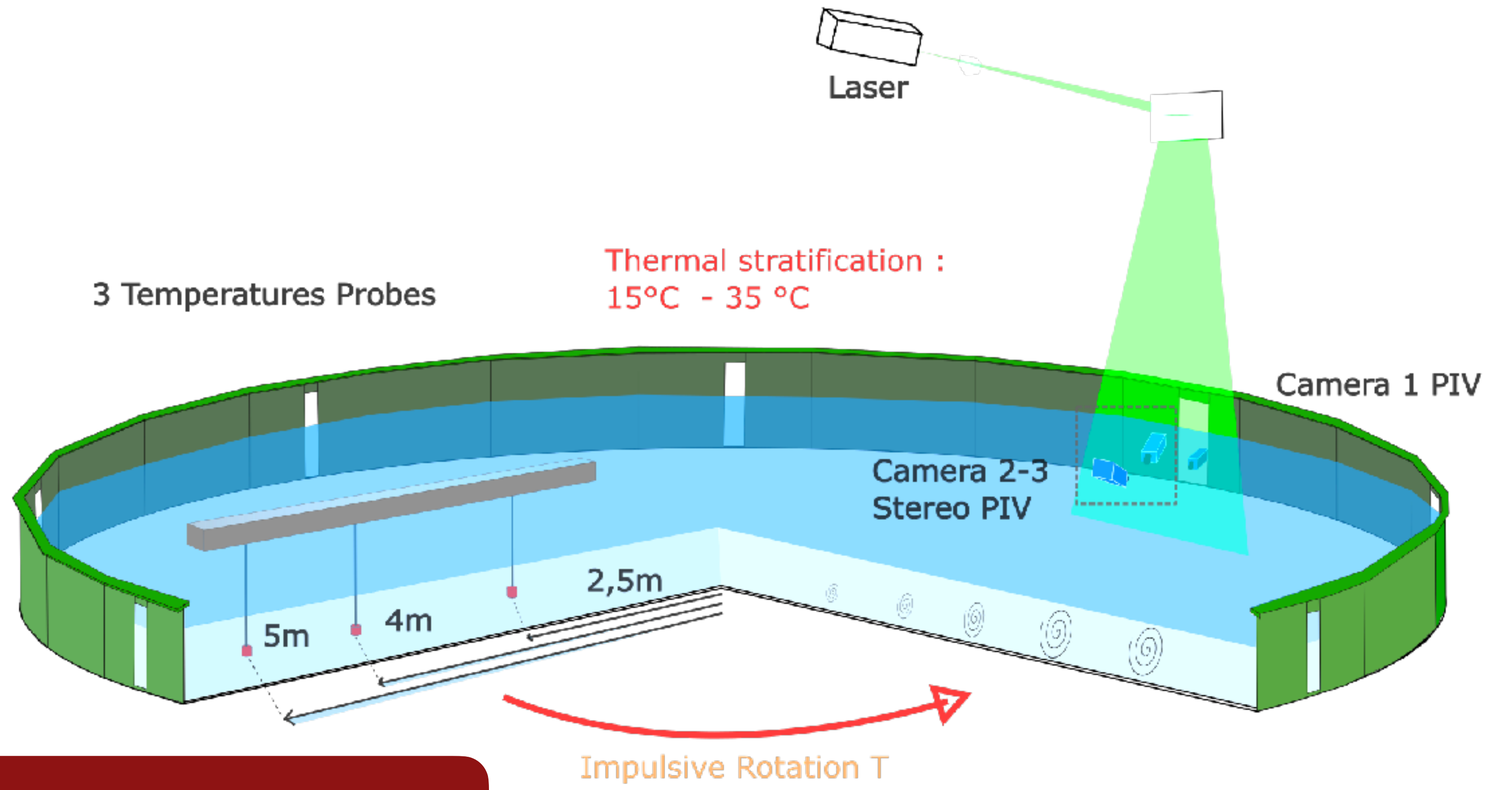
Forced Convection Experiment

- **Acceleration of rotation (Spin-Up)**
- **Temperature stratification**
- **Temperature probes**
  - 3 Vertical profilers
- **Vertical laser sheet (30x25)cm**
  - PIV Stereo (2D - 3 components)



Control parameters

Friction : u_* **Rotation :** f **Stratification** $N^2 \equiv (\Delta T)$

Configuration 1 : Seminal Experients

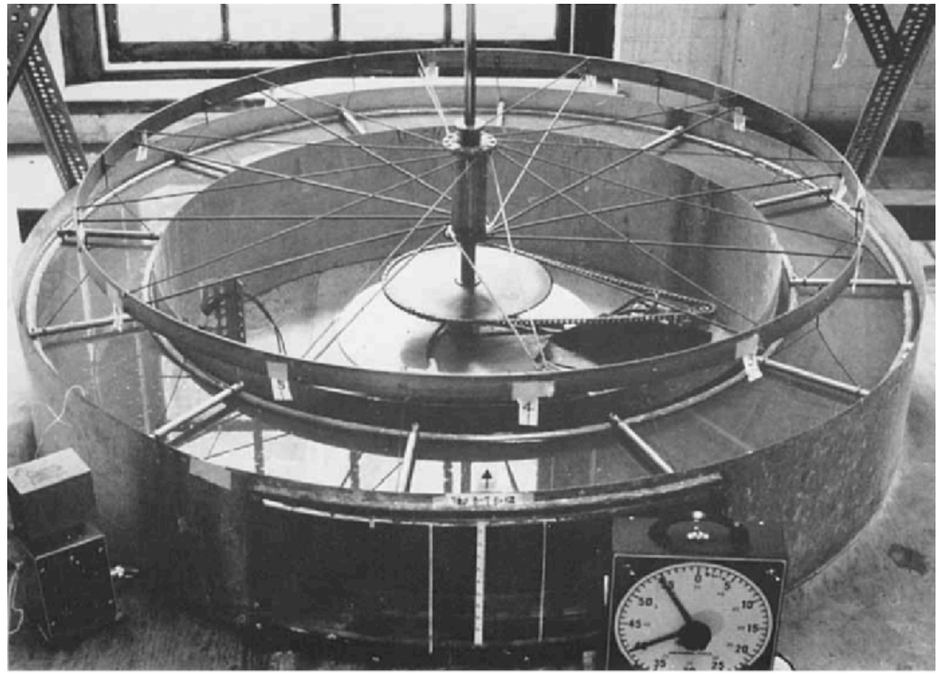


FIGURE 1. The experimental apparatus.

Kato - Philips 1969

Entrainement Law

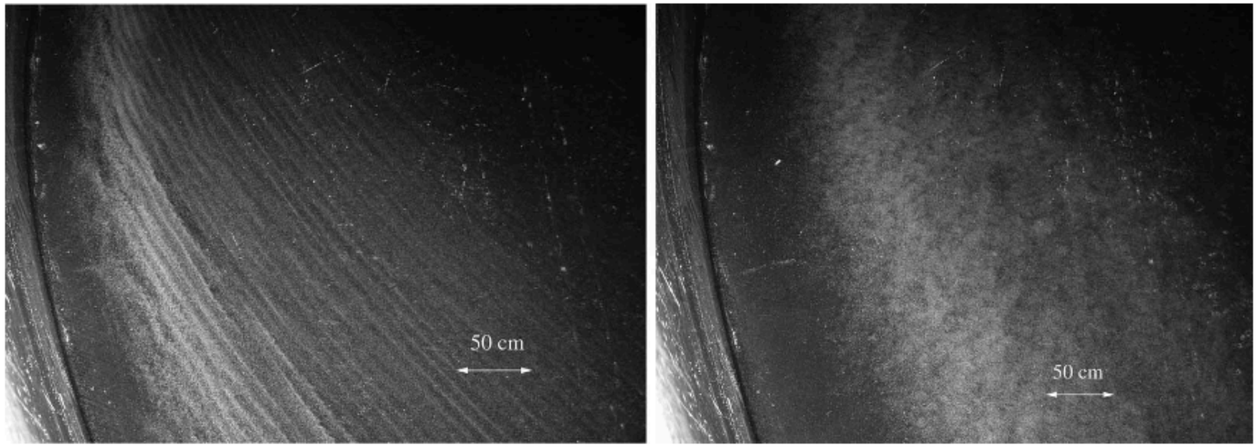
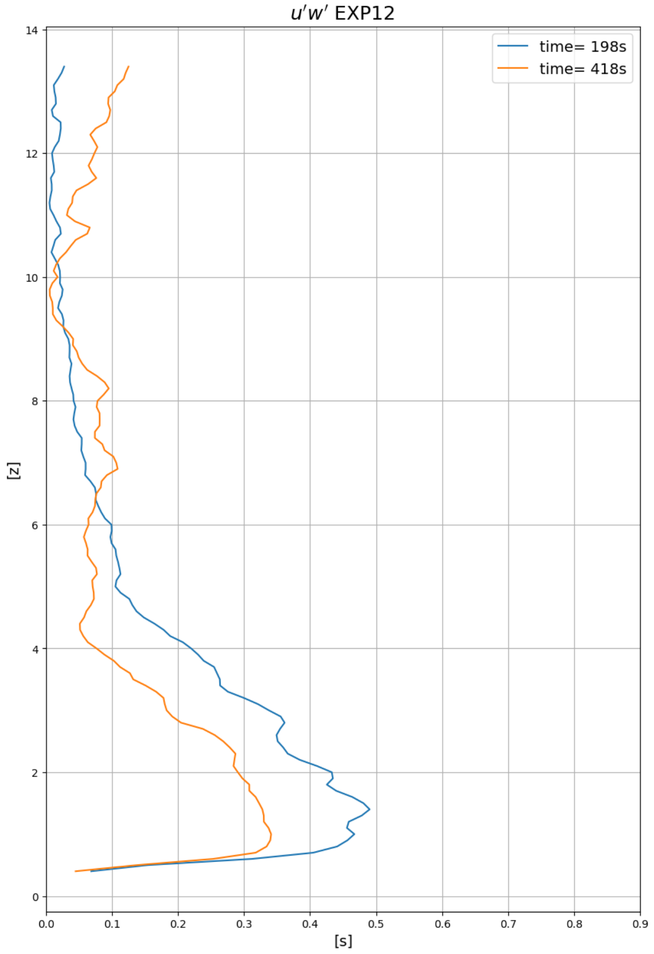


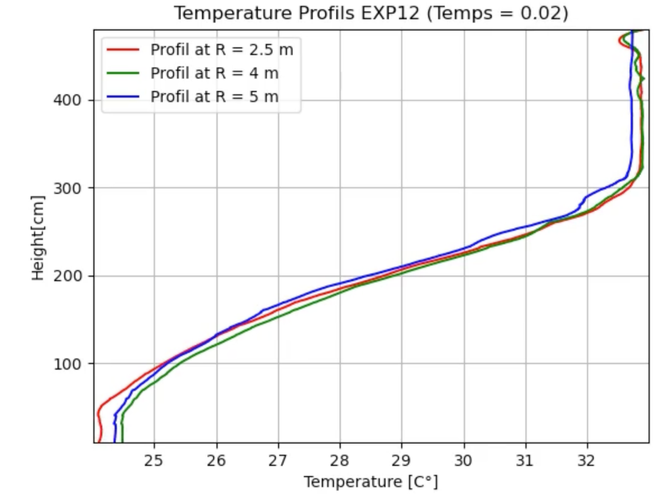
FIG. 3. Snapshots taken during the SD30-60-H66 spin-down case. (Left) Top view of instabilities in the Ekman layer developing during the initiation of the spin-down flow at $t = 2$ s after the flow initiation. (Right) Top view of the fully turbulent Ekman layer at $t = 42$ s after the flow initiation.

Sous et al., 2013

Turbulent Ekman layer

Observation of Forced Convection





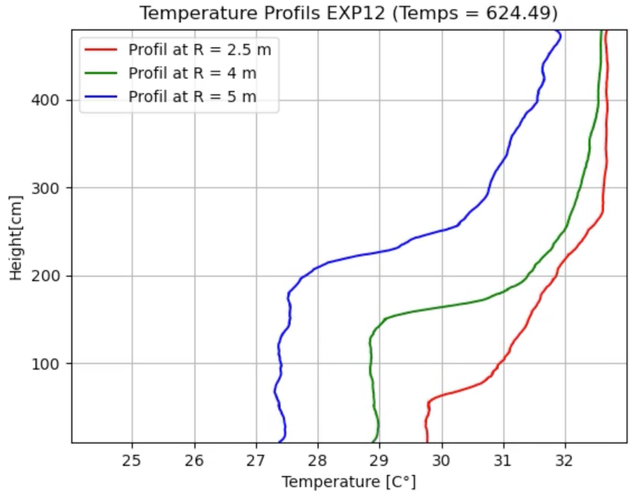


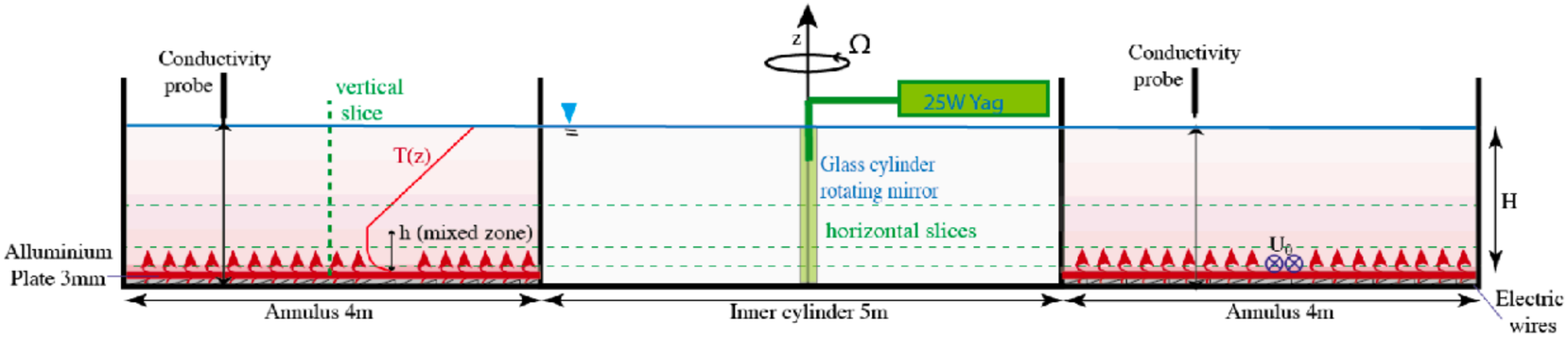
Figure :Evolution of the vertical temperature profile for an experiment without initial rotation

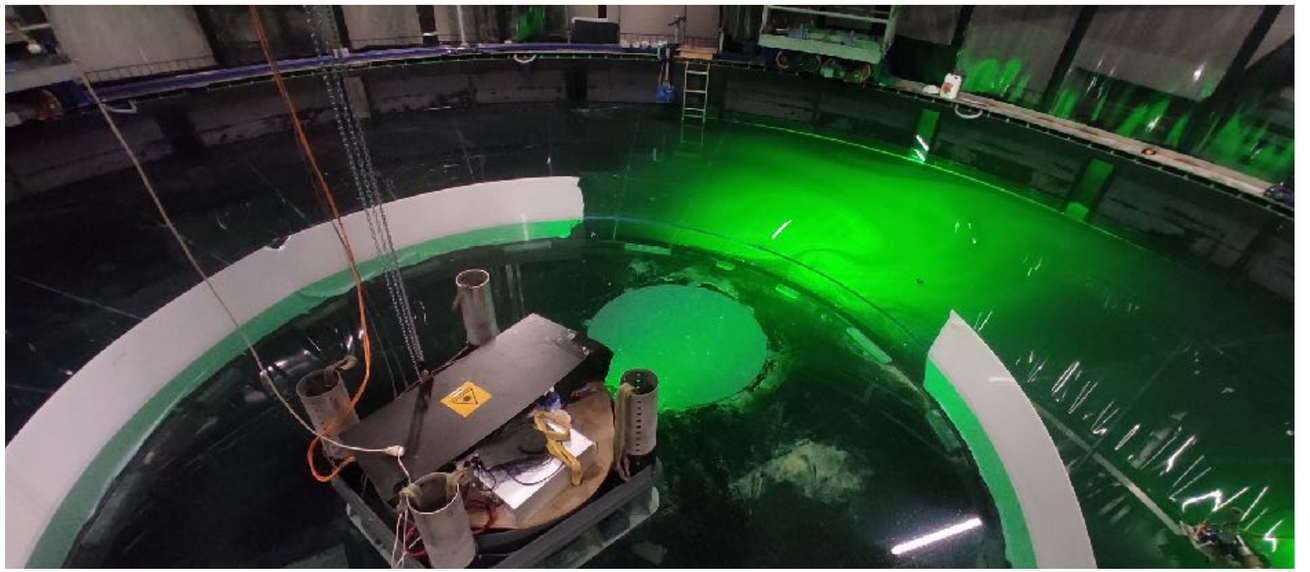
Growth of the mixed layer by momentum turbulent flux

Figure :Evolution of the vertical turbulent flux profile for an experiment without initial rotation

Free / Mixed Convection

- **Heated floor [290-353] kW**
- **Inner cylinder (5m)**
- **Temperature probes**
  - 3 Vertical profilers
  - 2 Fixed probes (z =0; 12cm)
- **Vertical laser sheet (30x25)cm**
  - PIV Stereo
- **Horizontal laser sheet (3x4)m**
  - PIV (z = 10cm)
  - PIV in volume (multi- layer)
- **IR camera (3x4)m**





Observation of Free Convection

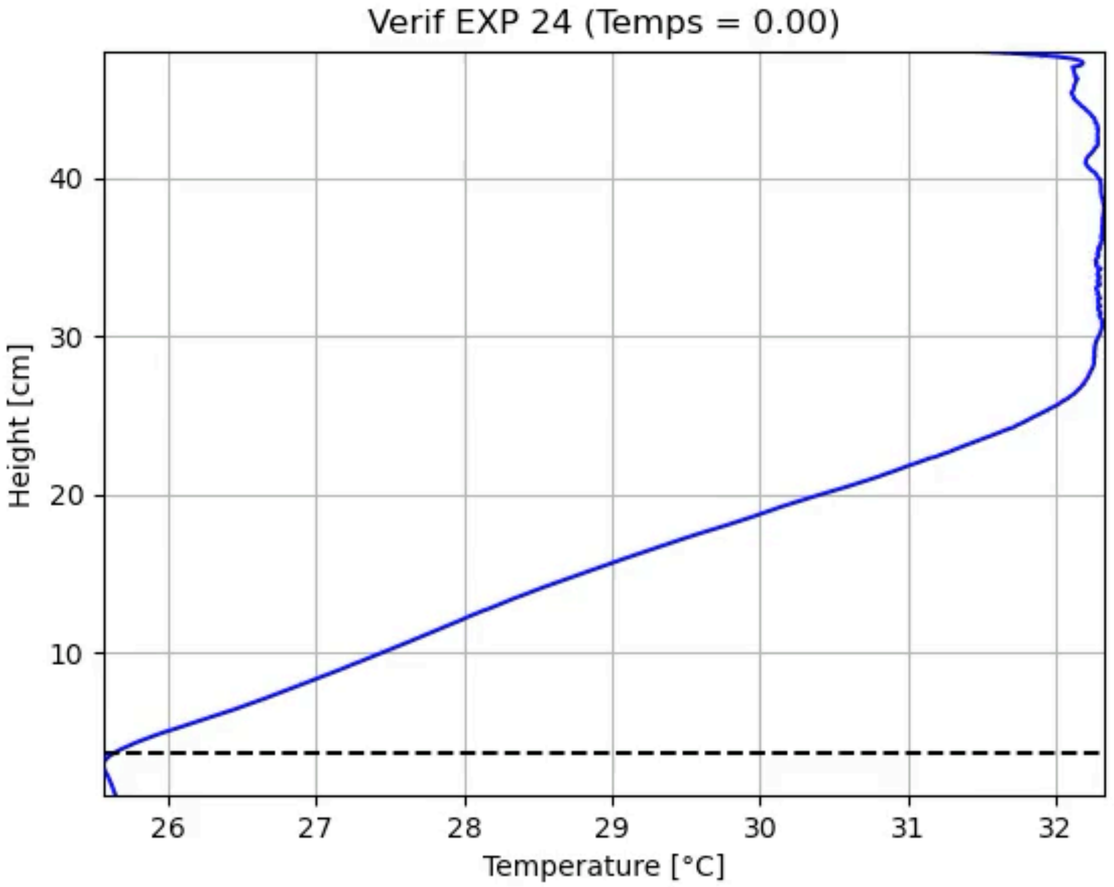
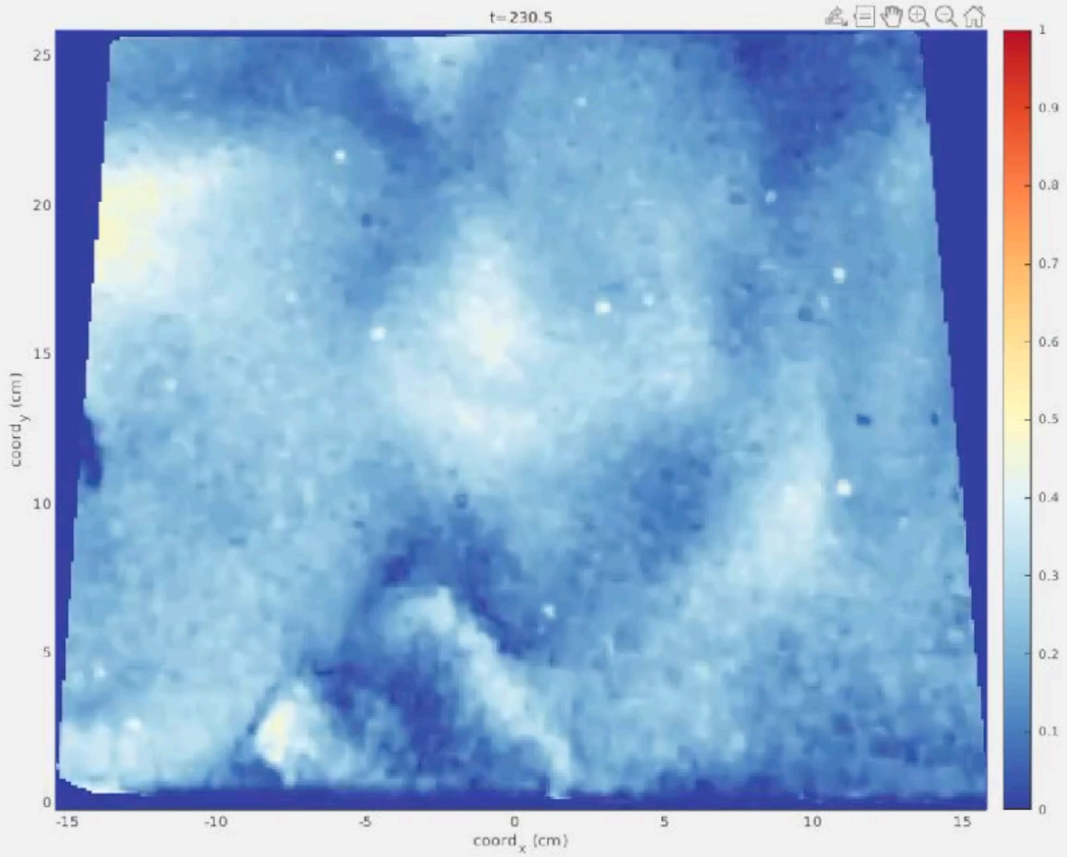


Figure :Evolution of the vertical temperature profile for an experiment without initial rotation

Observation of Free Convection

Figure :Evolution of the norme of the velocity for an experiment without initial rotation



Organisation of convection

Rotation

$f = 0$ $f = 0.1$ $f = 0.3$

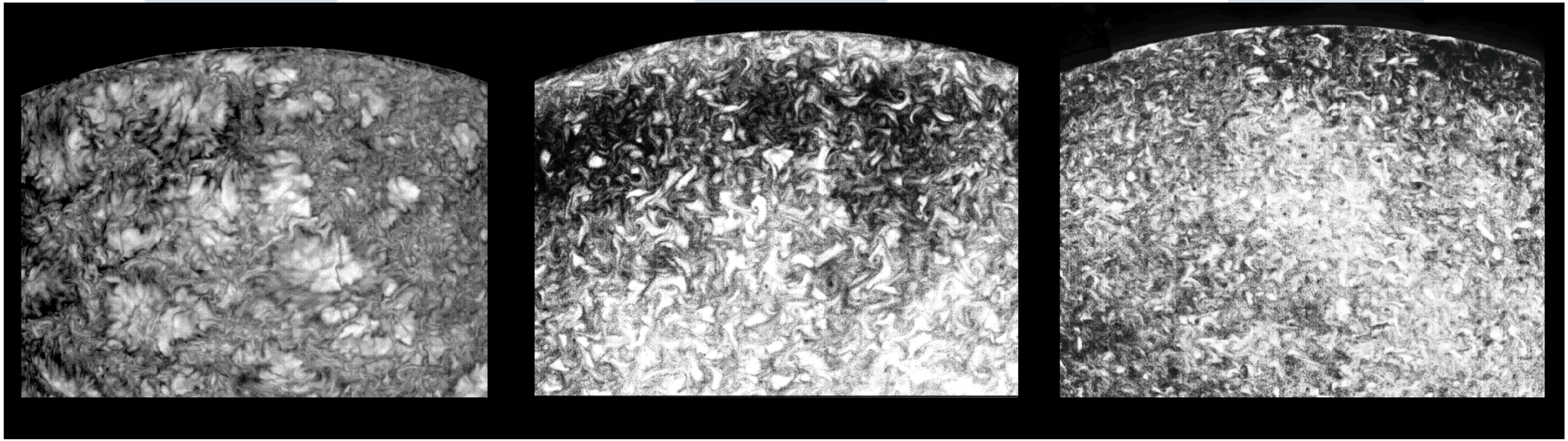


Figure : Surface temperature, top view, captured by infrared camera. The grey levels represent the colour bar of the temperature. White represents the warmest and black the coldest. Video accelerated by a factor of 10

GFD Lab AOPP

Temperature acquisition

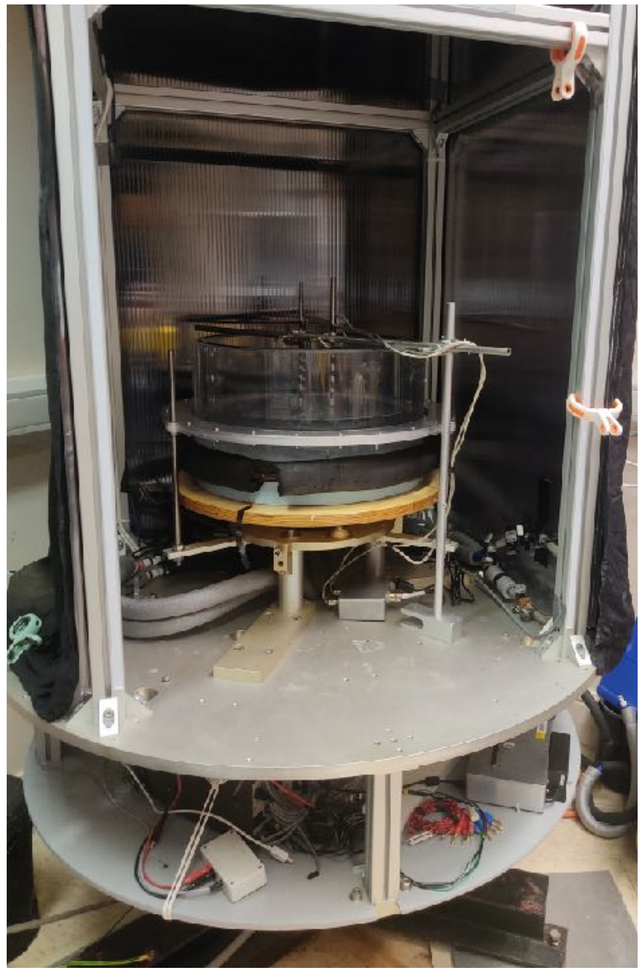
- Array of thermistances
- High frequency acquisition

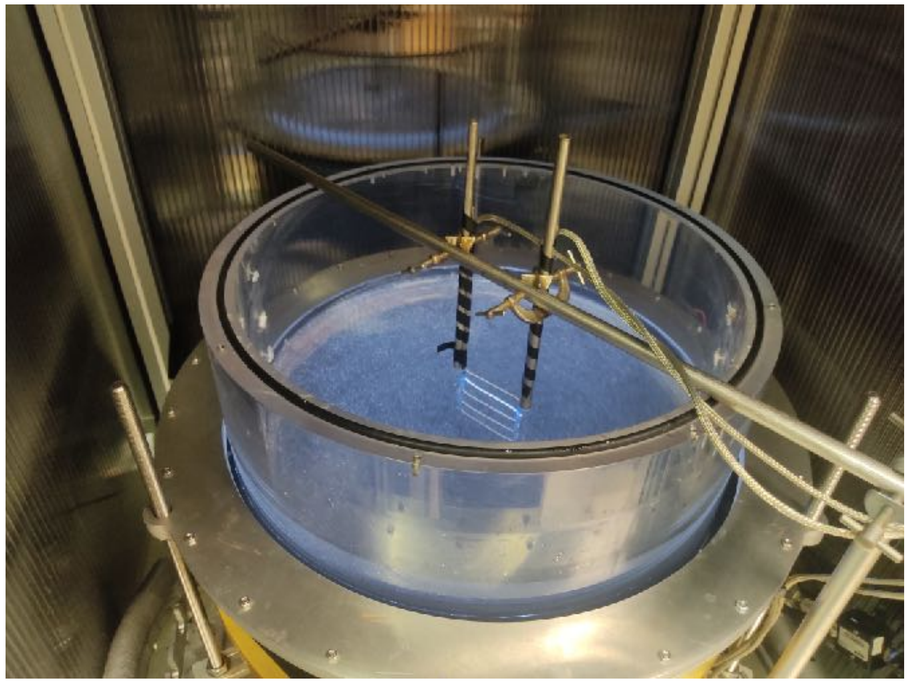
$T = \overline{T} + T'$ (plume signature)

Velocity acquisition

- PIV methode

$\mathbf{u} = \overline{\mathbf{u}} + \mathbf{u}'$





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Temperature acquisition

- Array of thermistances
- High frequency acquisition

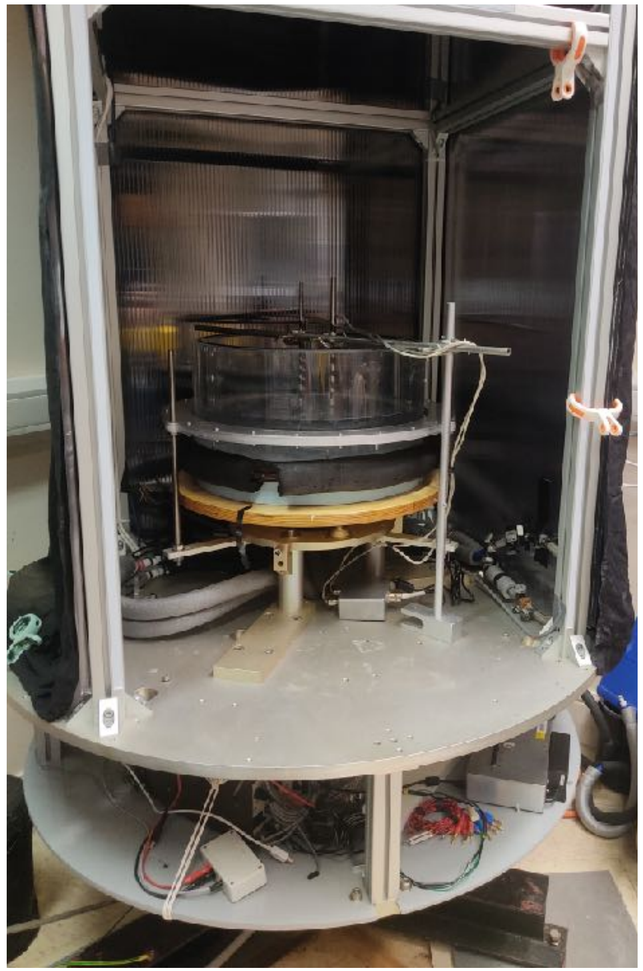
$T = \overline{T} + T'$ (plume signature)

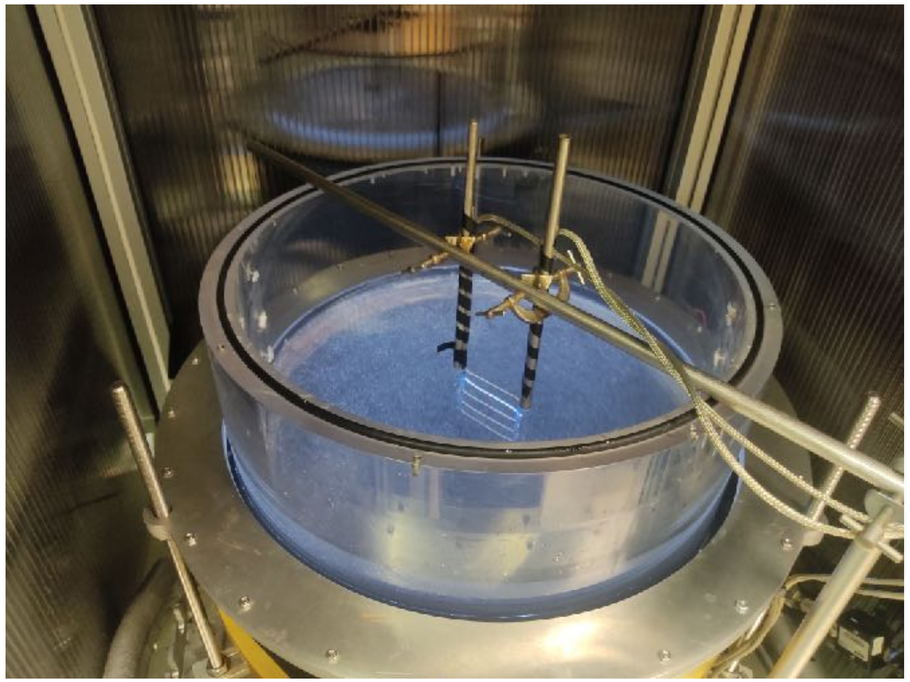
Velocity acquisition

- PIV methode

$\mathbf{u} = \overline{\mathbf{u}} + \mathbf{u}'$

Turbulent heat Fluxes: $\overline{\mathbf{u}'T'}$





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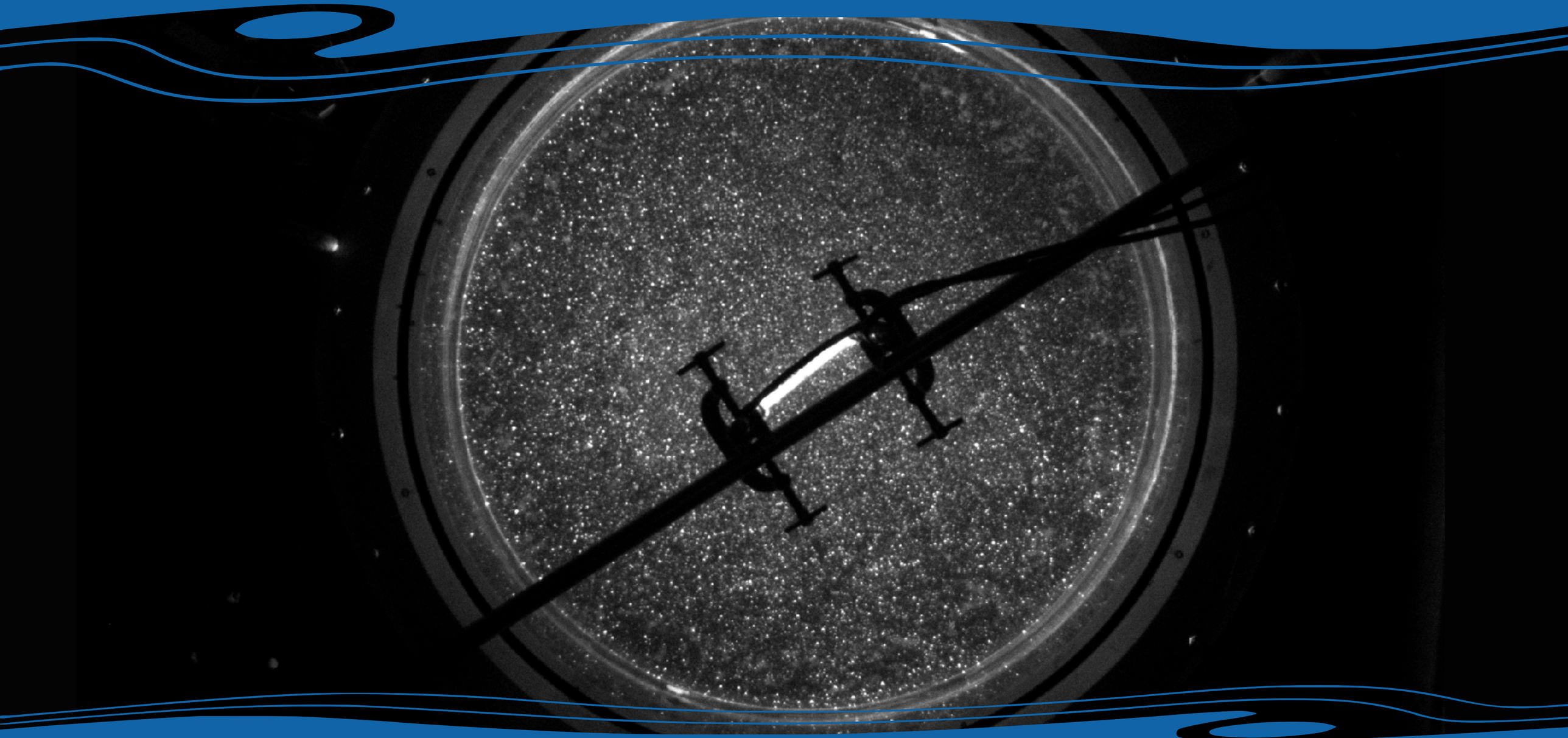

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