Observation of Convection on the Coriolis Platform

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Journée de la convection
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Oceanic convection ≡ Boussinesq Dry Atmospheric convection

Similarities

Same equation inverted in the z axis

- **Atmosphere:**
  - Triggered by heating in the lower layer
- **Ocean:**
  - Triggered by Cooling on the surface

Differences

- **Atmosphere:**
  - Shear stress at the surface $\rightarrow$ **Dissipation** of momentum
- **Ocean:**
  - Shear stress at the surface $\rightarrow$ Input of momentum $\Rightarrow$ **Forcing**

Note : This presentation does not present results but a project of experiment of Boussinesq dry convection that we interpret as oceanic convection

Atmospheric/Ocean Convection: Data set differences

Observation of convection Event

- Observations more accessible in the atmosphere than in the ocean
- Large observation database for the Atmosphere / Very poor for the Ocean

Numerical model

Atmospheric community 20 years ahead in convection parameterisation

Lab Experiments

- Necessary step to study Oceanic convection
- Might be **useful for the atmosphere**
  - Fill the gap between observation and modelling

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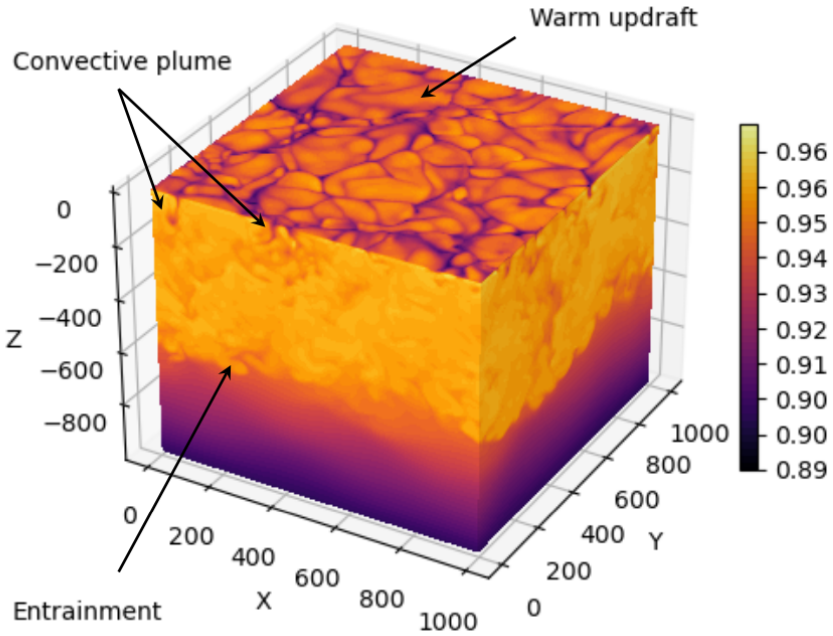
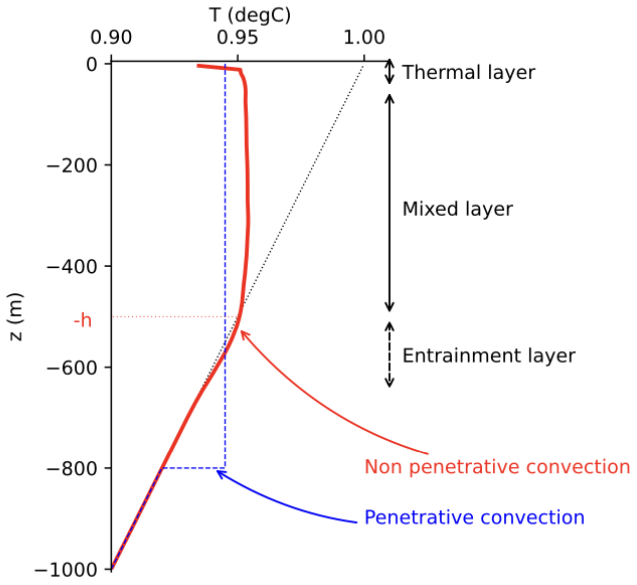
Observation of the organisation of the turbulent structures in a convective boundary layer





Organisation of the structure of the convection

- Atmospheric community has deeply study **organisation of the convection**
- We want to scan the parameters which influence the structure of the organisation of convective plume
  - Observe the Temperature T' and vertical fluctuation w'

Parametrisation

We'd like to model turbulent closure on that used for the atmosphere

- **Model** $k - \epsilon$
  - Turbulence is assumed fully described locally by the two quantities (k the kinetic energy - ϵ the dissipation

$$\text{eddy viscosity} \quad \nu_t \sim u' l = C \frac{k^2}{\epsilon}$$

- **Mass flux scheme closure**

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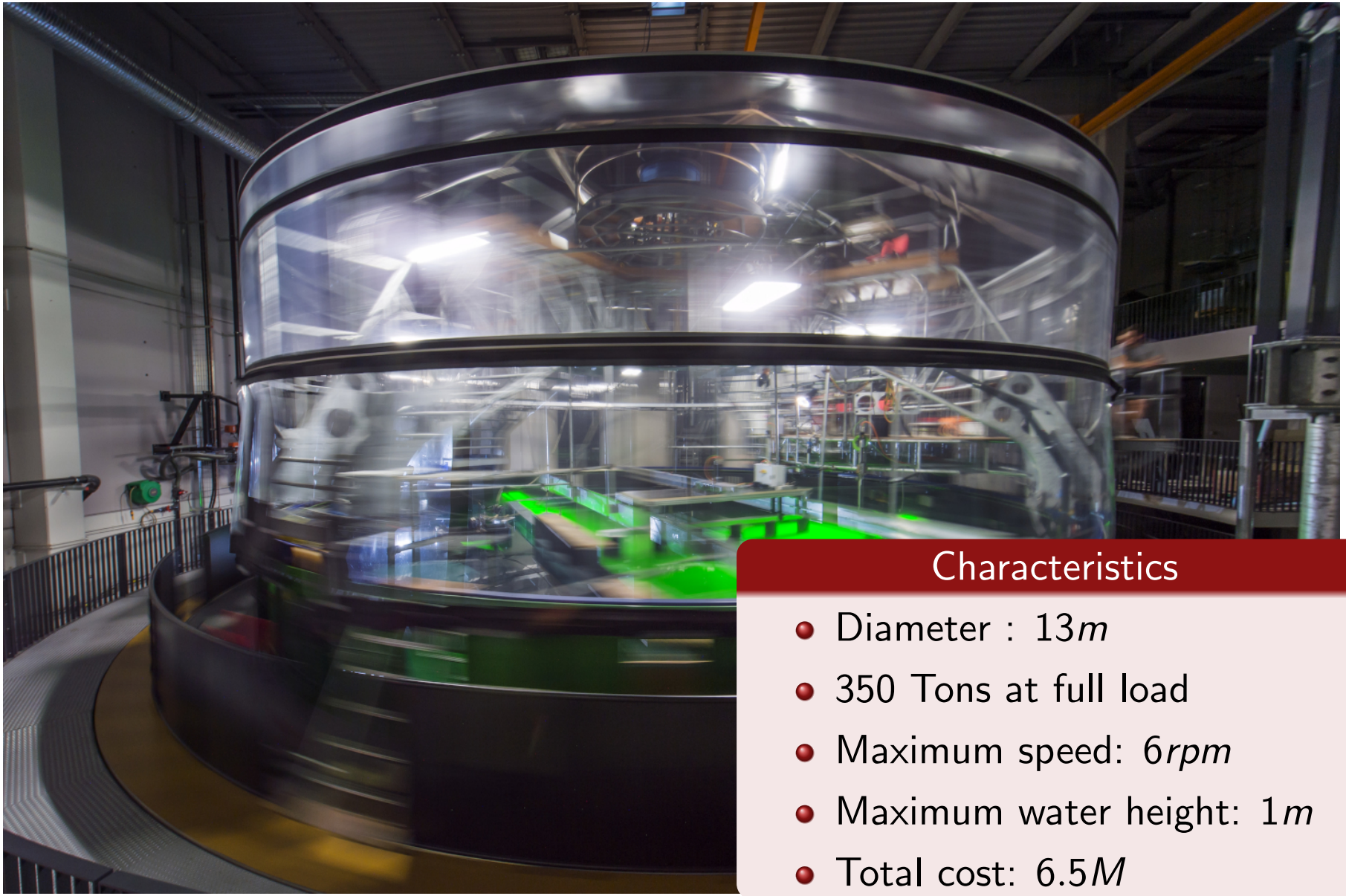
Coriolis Platform: World's largest rotating water tank



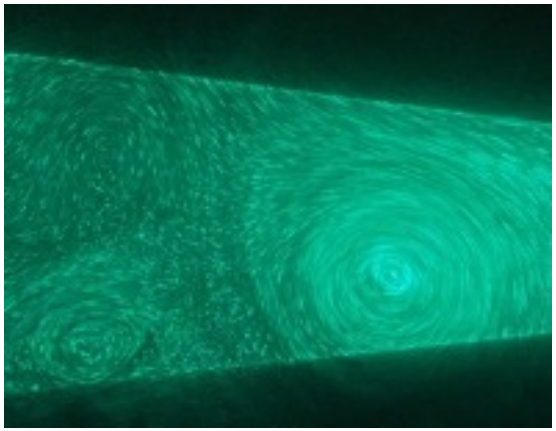
Characteristics

- Diameter : $13m$
- 350 Tons at full load
- Maximum speed: $6rpm$
- Maximum water height: $1m$
- Total cost: $6.5M$

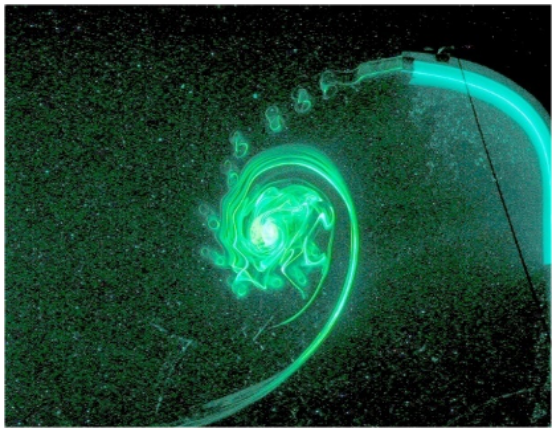
[1]

[1] Credit:Cyril Fresillon/LEGI/CNRS Photothèque

Coriolis Platform: Instrument

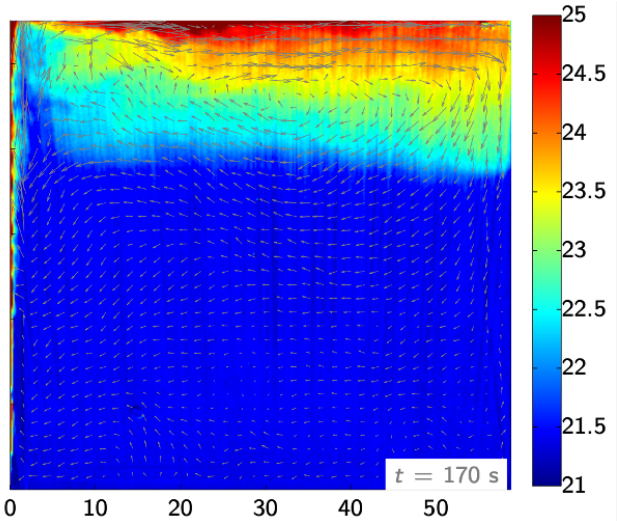


PIV

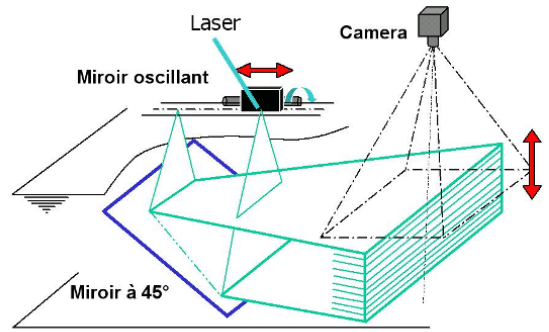


LIF

- **Imaging, 4 cameras:**
  - 12 bits, 60 images/sec, continuous data stream on computer disk.
- **Laser:**
  - 25 Watts - continuous Yag laser
- **Local probes:**
  - conductimetry + temperature, acoustic Doppler profiler



PIV-LIF for T



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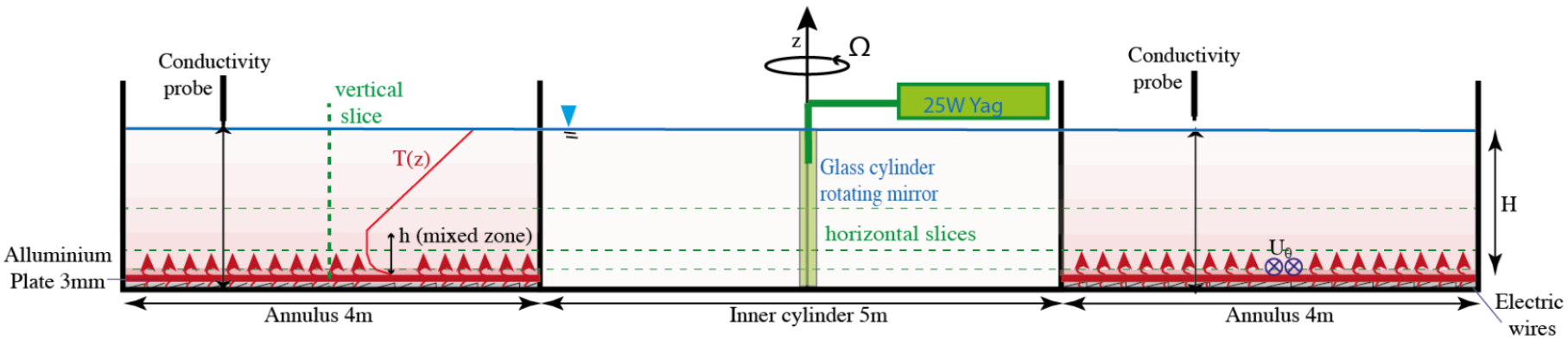
Apparatus

Apparatus

- Annulus (inner radius = 2.5m - outer radius = 6.5m)
- Water depth $H = 1$m
- Stratification in Temperature or/and in Salinity
- Typical azimuthal velocity : $U_\theta = 10$ cm.s^{-1}



Heating technique

- Grill-work of electrical wire embedded in a shallow water layer
- Separated by 3mm thick aluminium sheet
- Heat flux $H \sim 500$W.m-2

Dimensional parameter

Dimensional parameter

Our hypothesis is that convection is function of :

- The **thermal** forcing B
- The **mechanical** forcing τ (unlike atmosphere)
- The **stratification** N^2
- The **Mixed Layer depth** h

Influence of Earth's rotation

We suppose the **rotation** f to affect the organisation of turbulent structures

- True in the atmosphere
  - Tropical storms illustrate this on a macro scale

Non-dimensional parameters

Richardson number

- Quantify the impact of the plume on the stably stratified zone

$$\boxed{Ri = \frac{N^2 h^2}{w_*^2}} \qquad (1)$$

Natural Rossby number

$$\boxed{Ro = \frac{w_*}{hf}} \qquad (2)$$

It gives information on the impact of the earth rotation on convection.

Monin-Oboukhov scale L

$$\boxed{L/h} \quad \text{with} \quad L = \frac{\tau}{B} \qquad (3)$$

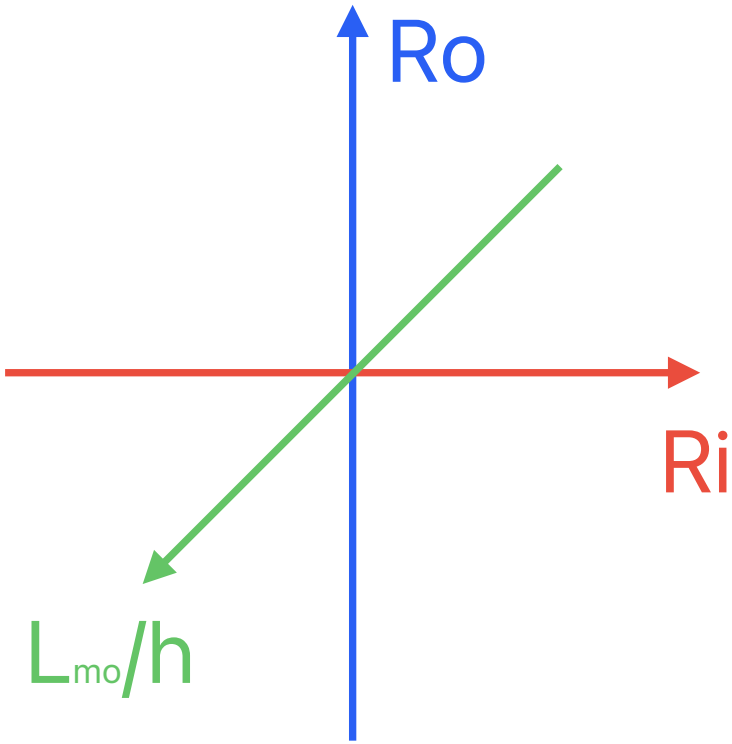
- Define when the turbulence is driven by wind shear ($L/h > 1$) or by the thermal convection ($L/h < 1$)

With B The buoyancy flux, h the MLD, w_* the velocity of the thermals, τ the shear

Non-dimensional parameters

Takes it to the limits

$$Ri = \frac{N^2 h^2}{w_*^2} \qquad Ro = \frac{w_*}{hf} \qquad L/h = \frac{\tau}{Bh}$$



Determine the nature of the organisation of convectives structures in this parameter space

Experiments 1 and 2

Exp 1: No rotation and no stratification

Interest

- High Ra at unique aspect ratio

Objectives

- Observe the large convective cells and plumes
- Reference experience

Exp 2: Stratification without rotation

Linear stable stratification

- In temperature (15K delta over 1m water height)

Objectives

- Influence of Ri

Experiments 3 and 4

Exp 3: Rotation and Stratification

Rotation

- Several rotating regimes
- Minimum period of rotation = 60s for negligible centrifugal effects

Objectives

- Influence of Ro
- Observation of the organisation of convectives structures

Exp 4: Effects of surface shear

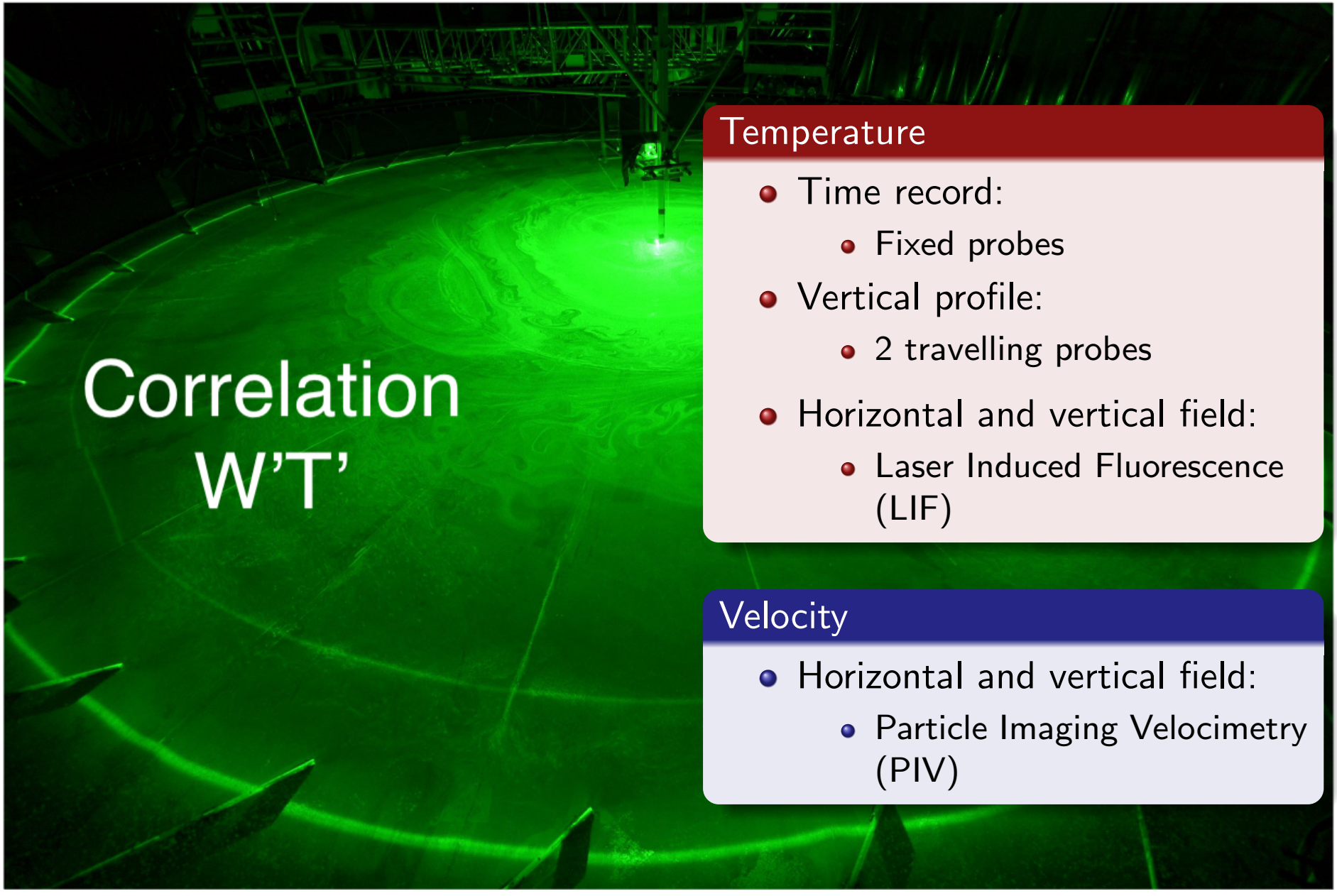
Shear

- Change in the tank rotation period

Objectives

- Influence of the Monin-Oboukhov scale

Measurements



Temperature

- Time record:
  - Fixed probes
- Vertical profile:
  - 2 travelling probes
- Horizontal and vertical field:
  - Laser Induced Fluorescence (LIF)

Velocity

- Horizontal and vertical field:
  - Particle Imaging Velocimetry (PIV)

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Data base

The database is designed to be shared and used by interested researchers

Organisation and distribution

- Follow the FAIR principle (Findable, Accessible, Interoperable and Reusable)
  - Creation of Metadata for each datasets (experimental set-up, numerical parameter parameters etc.)
  - Use of a version control system (git)
- Promotion of open-source software tools (Python) and standards-based data formats (NetCDF)

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Thanks

Thank you for your attention