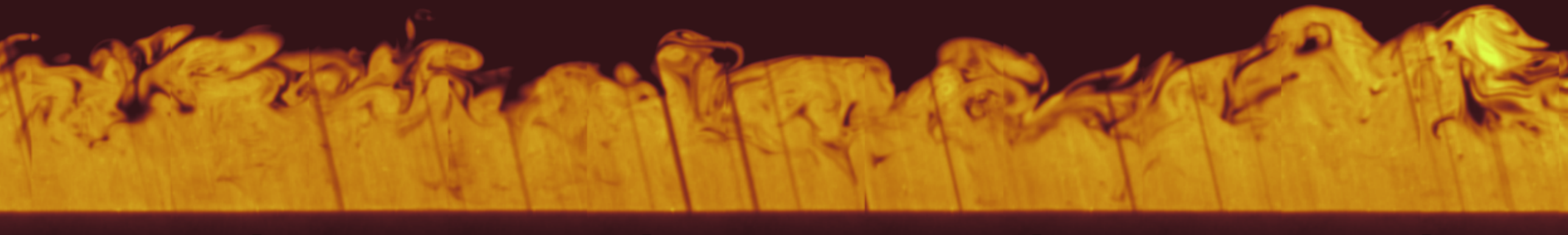
Journées annuelles du GdR Défis Théoriques
pour les Sciences du Climat
29 Mai 2026

# Laboratory observation of a transient turbulent Ekman layer

Max Coppin, Bruno Deremble, Joel Sommeria, Eletta Negretti,
Thomas Valran, Samuel Viboud



# Context

Wind stress at the ocean surface

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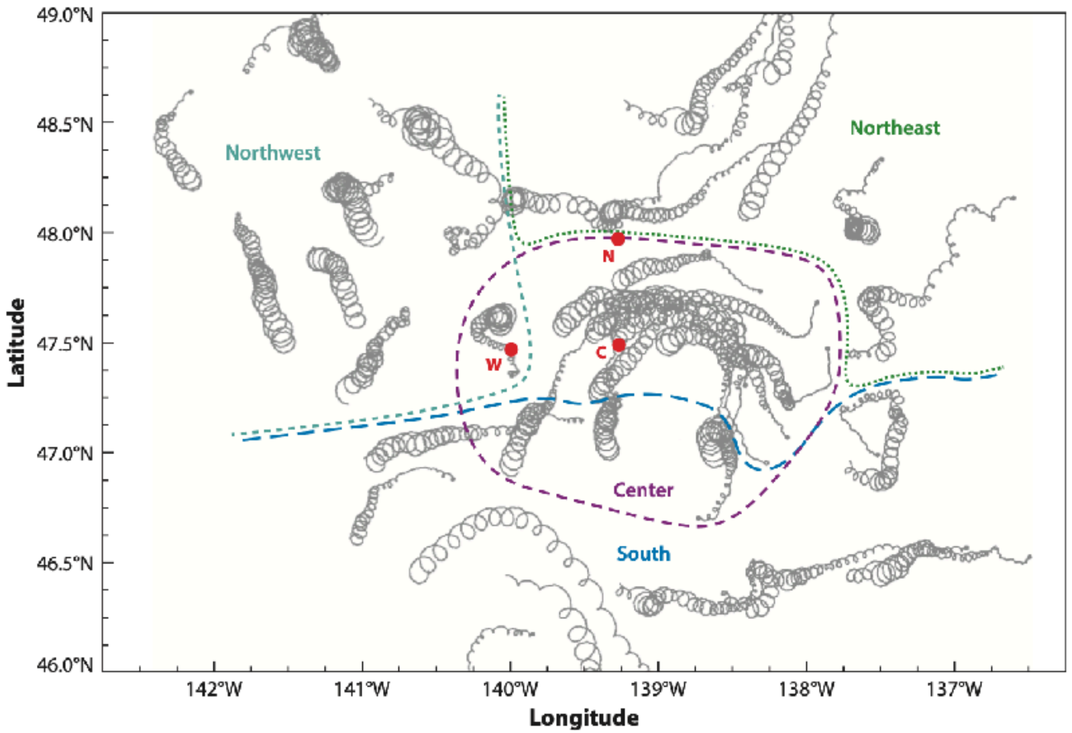
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**Turb. Ekman Layer**

**DNS:** Marlatt et al. (2012). J. Atm. Science

**Experiments:** Sous et al. (2012). Phys. Fluid

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Float trajectory during a storm:

Each loop $\approx$ 13 hours

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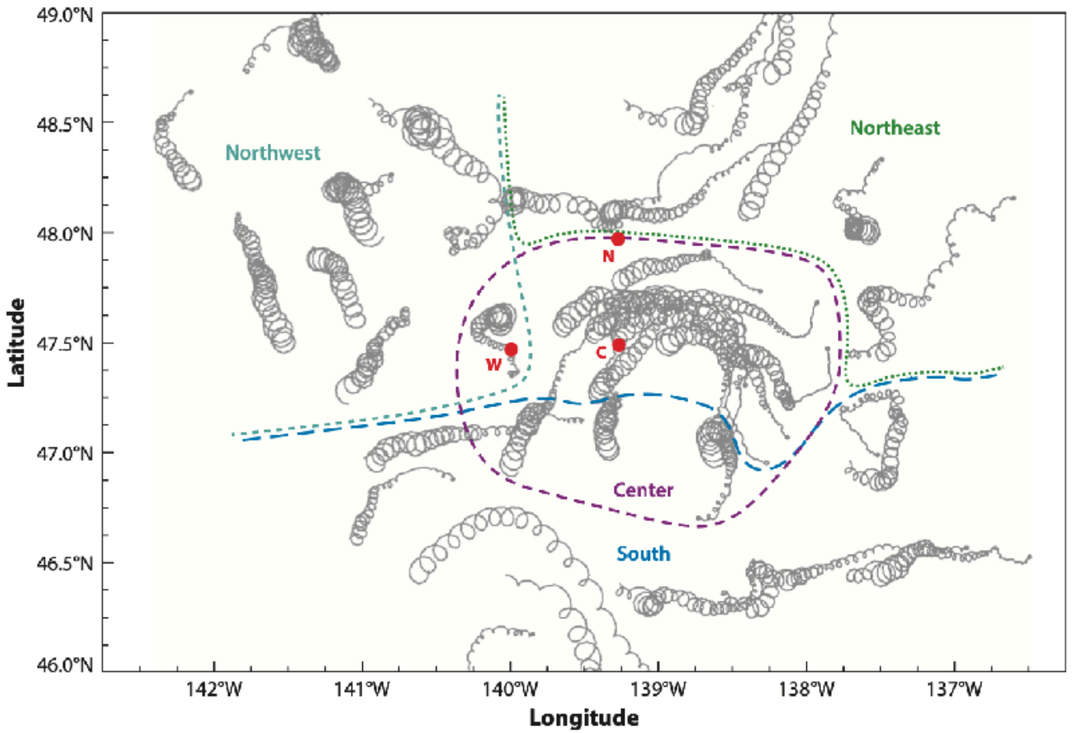
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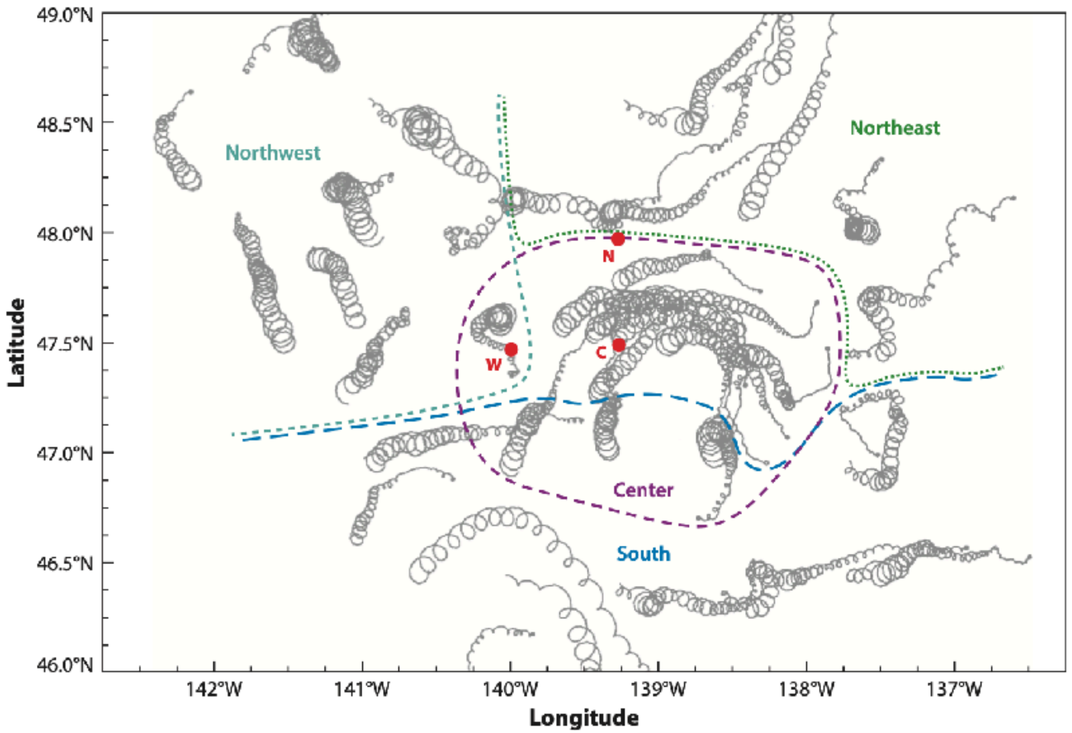
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**Inertial oscillations are key to the energy budget of the ocean boundary layer**

→ Representation in numerical models remains a challenge

→ Experiments allow realistic boundary layers

# Laminar Case: oscillating Ekman layer

**Momentum Equ.**

$$\frac{\partial u}{\partial t} - fv = \nu \frac{\partial^2 u}{\partial z^2}$$

$$\frac{\partial v}{\partial t} + fu = \nu \frac{\partial^2 v}{\partial z^2}$$

**Boundary Cond.** $t > 0\,, \quad z = 0$

Imposed stress: $\nu \frac{\partial v}{\partial z} = -u_*^2\,, \quad \nu \frac{\partial u}{\partial z} = 0$
(Free-slip)

Imposed velocity: $v = v_0\,, \quad u = 0$
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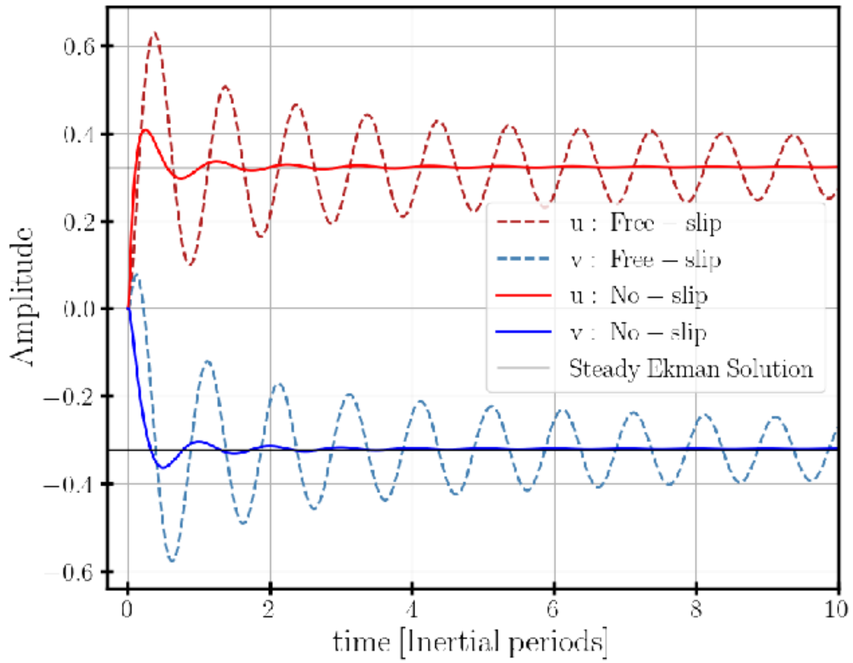
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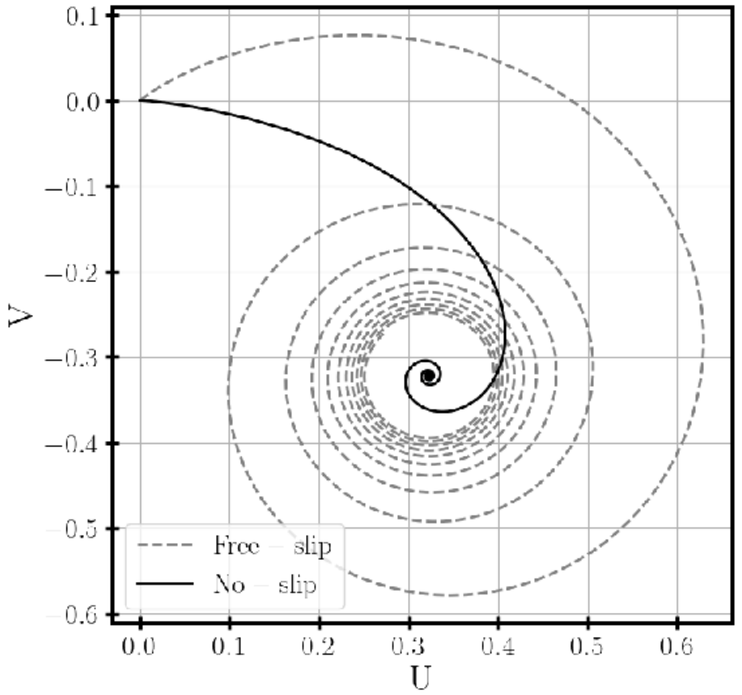
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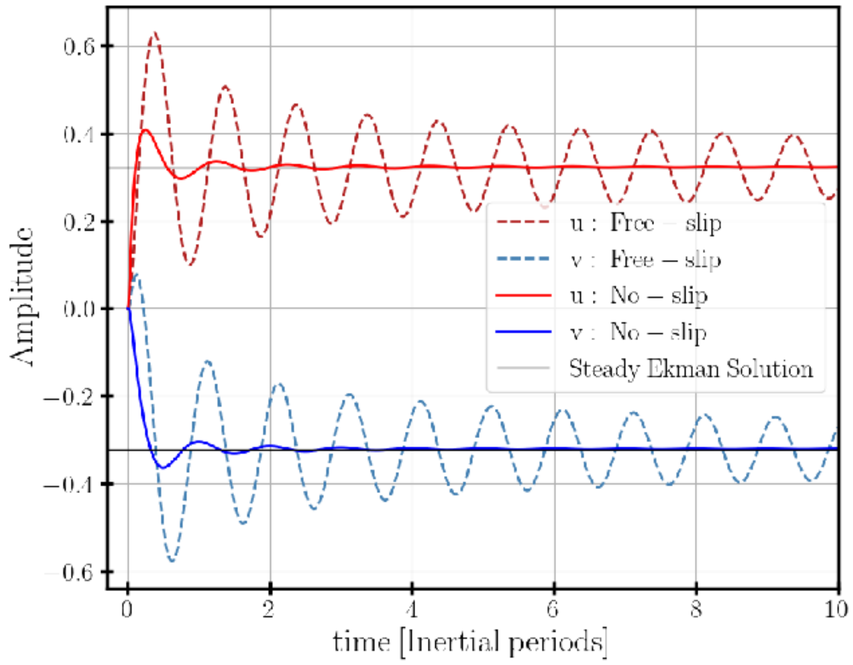
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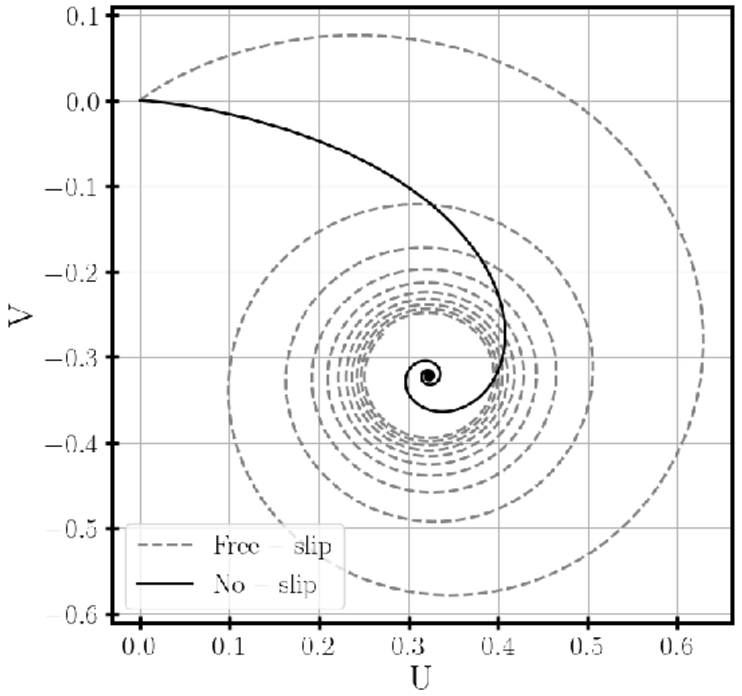
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| Free-slip | No-slip |
|---|---|
| Weaker dissipation | Stronger momentum extraction |
| → longer-lived oscillations | → faster damping of inertial oscillations |




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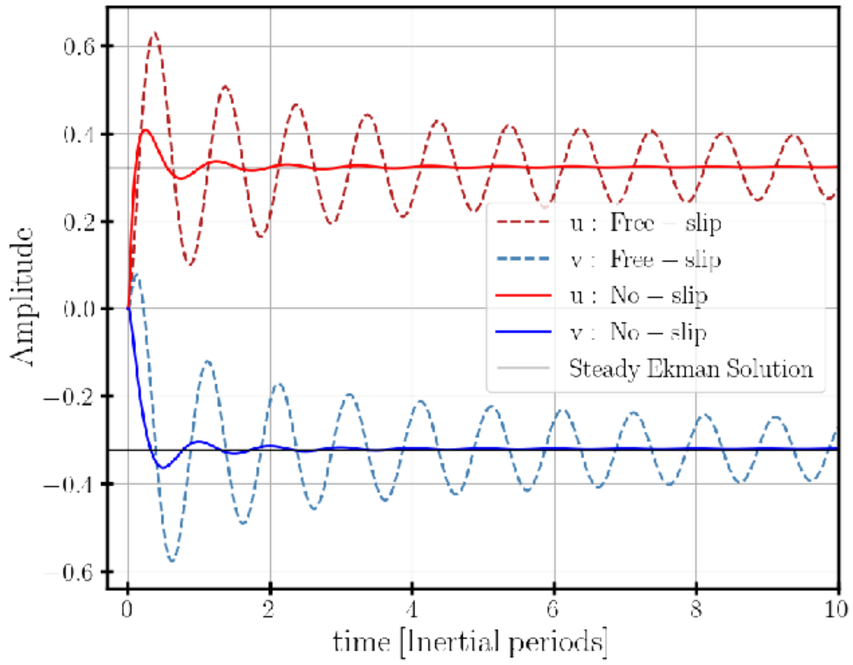
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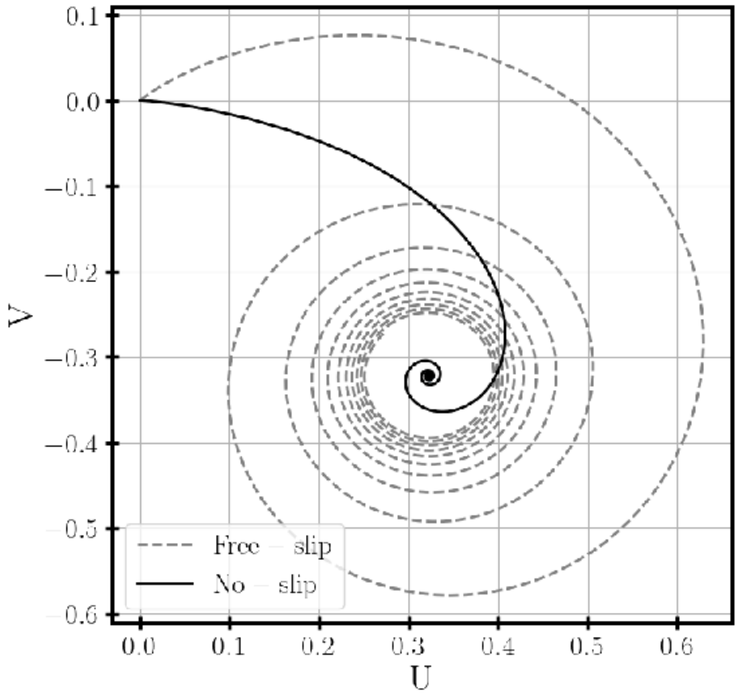
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Free-slip $\Leftrightarrow$ No drag
Weaker dissipation
$\rightarrow$ longer-lived oscillations

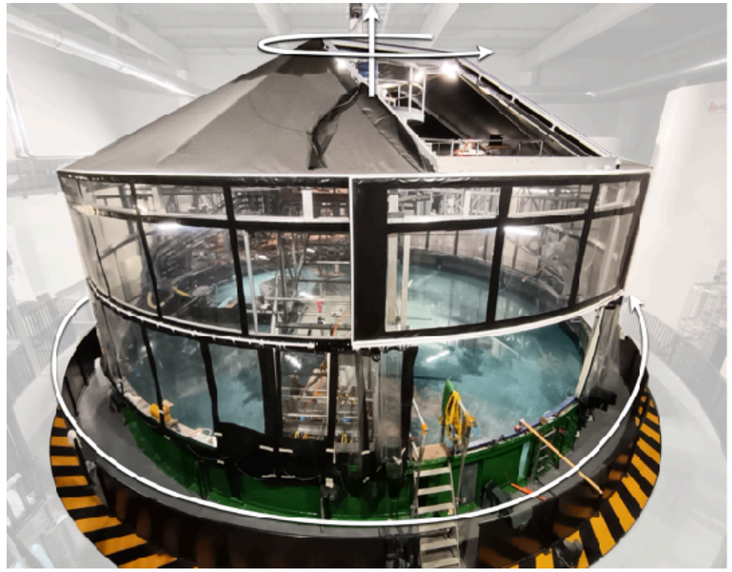
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Stronger momentum extraction
$\rightarrow$ faster damping of inertial oscillations



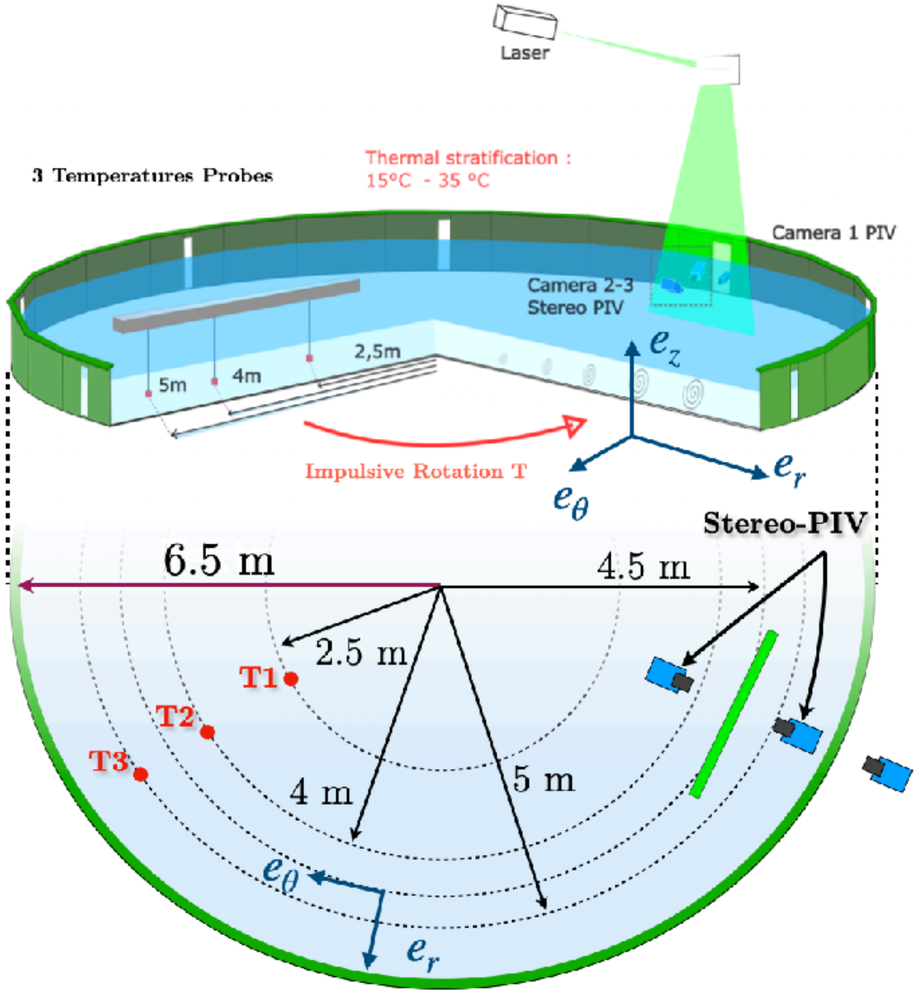




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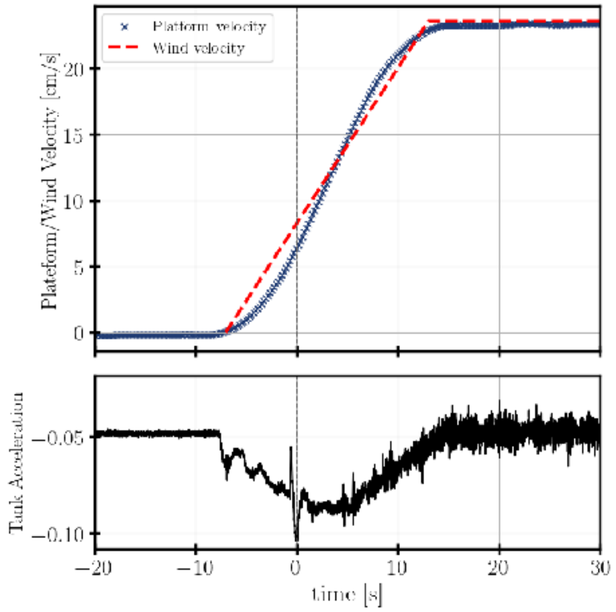
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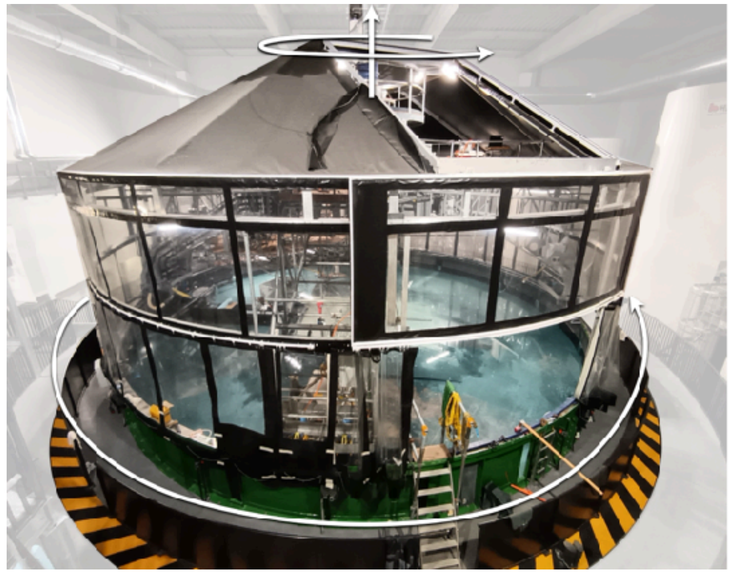


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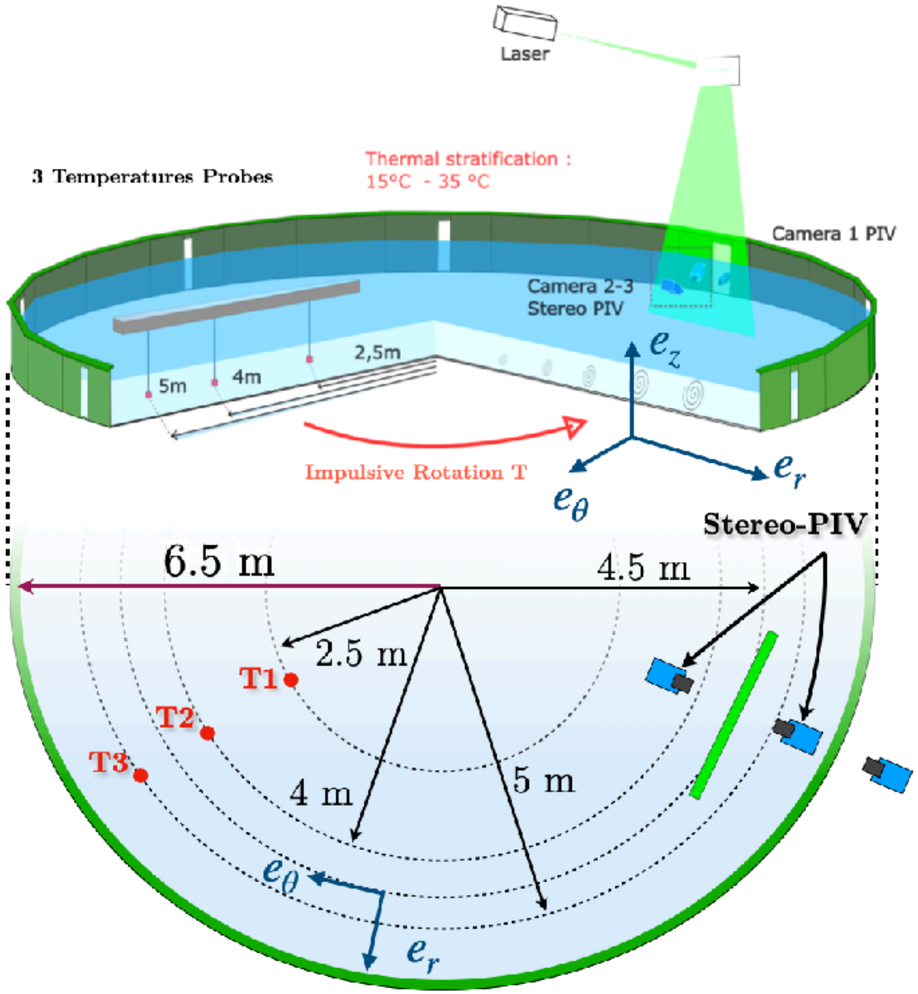

## Impulsive Rotation $\Delta\Omega$



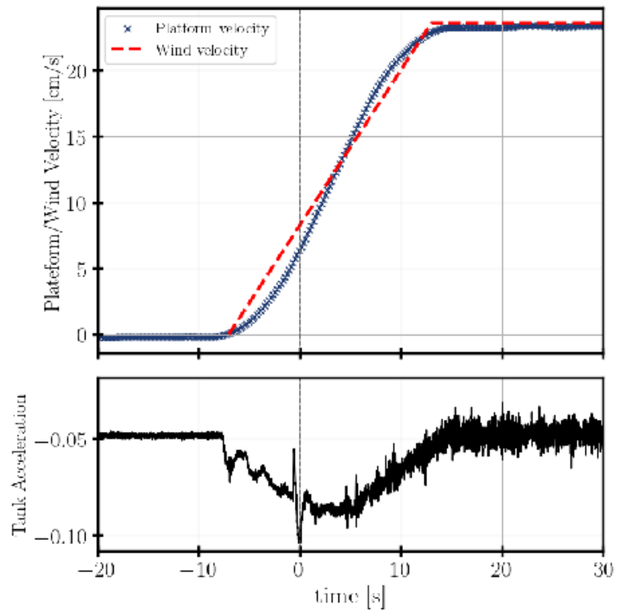



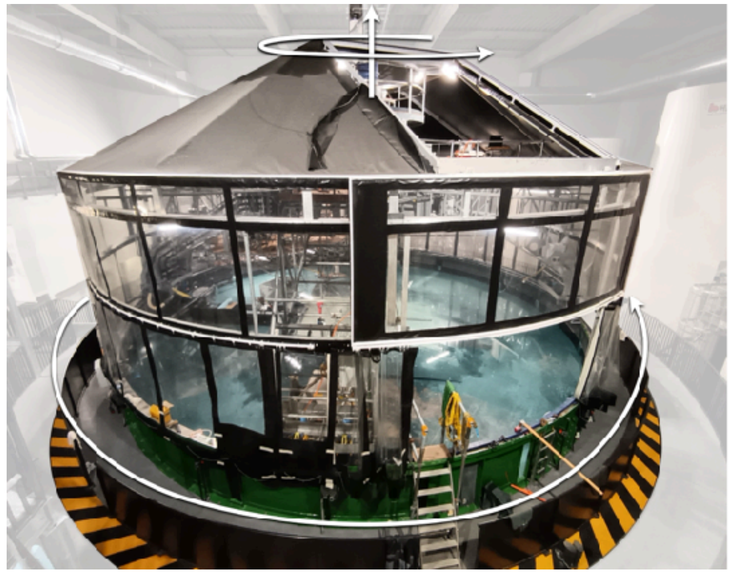
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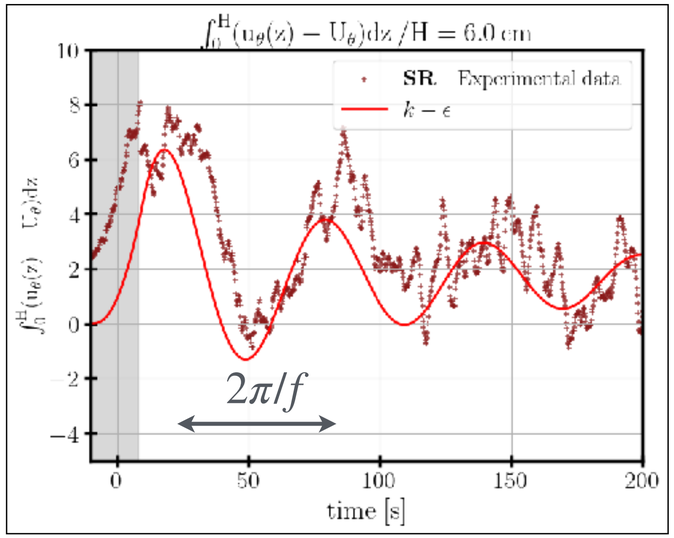



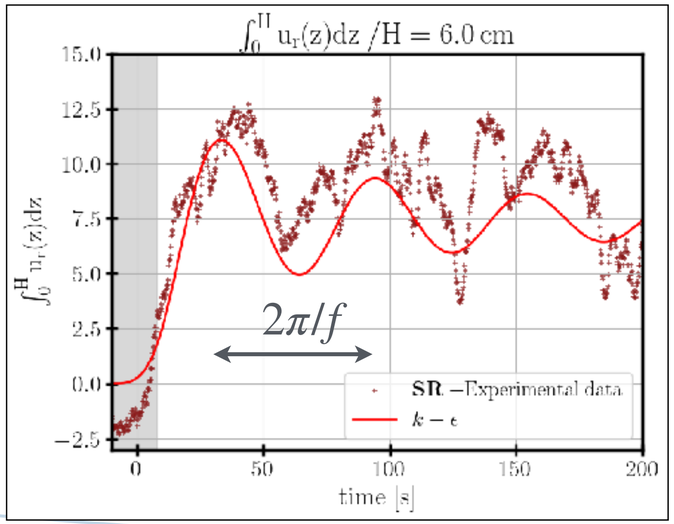
| Friction velocity | Aspect Ratio | Reynolds number (based on BL thick.) |
|---|---|---|
| $u_* \approx 1$ cm/s | $a = r/H = 9$ | $Re_\delta = \dfrac{r\Delta\Omega}{\sqrt{\nu\Omega_i}} \approx 10^3$ |
| **Mean flow velocity** | **Coriolis parameter** | **Friction Rossby number** |
| $\langle U_\theta \rangle \approx 23$ cm/s | $f = 2\Omega_i \approx 0.1\ s^{-1}$ | $Ro_* = \dfrac{u_*^2}{f\nu} \approx 10^3$ |


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# Inertial oscillations in a turbulent case

**Turb. regime**



# Inertial oscillations in a turbulent case

## Turb. regime

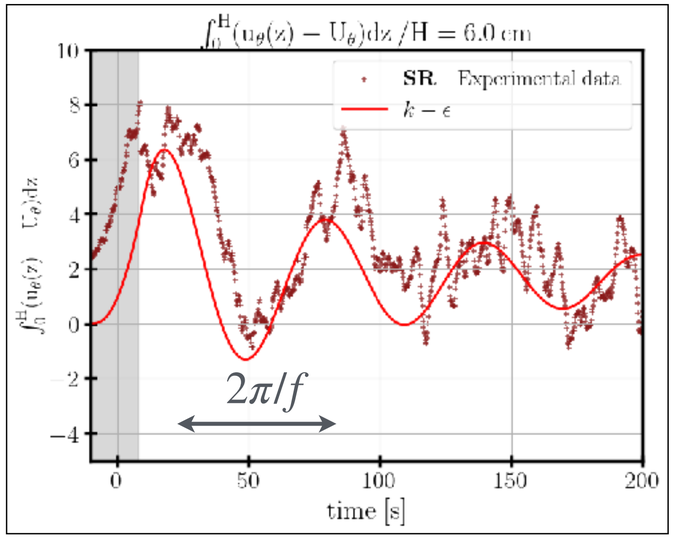
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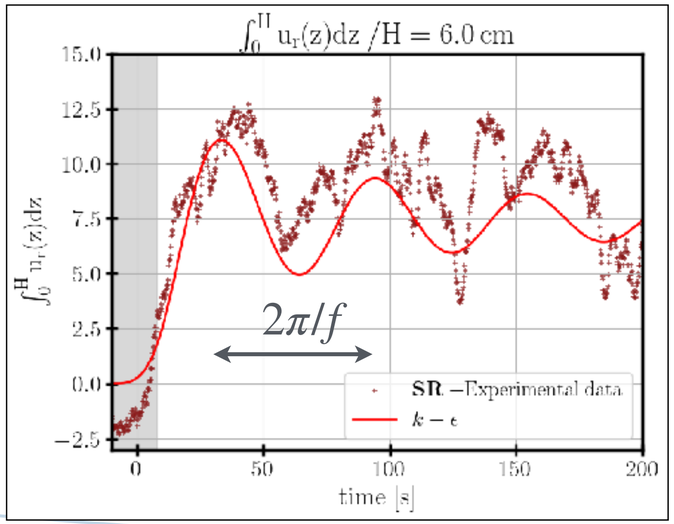
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$C_f = 2.5 \times 10^{-3}$

$u_s$ : First grid point

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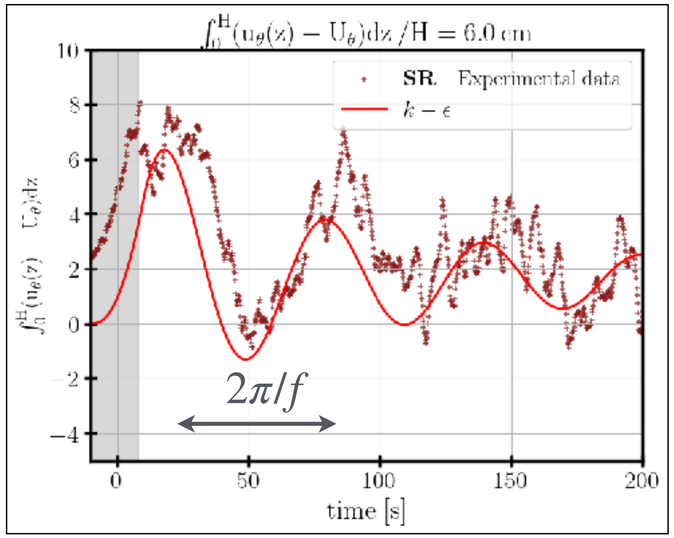
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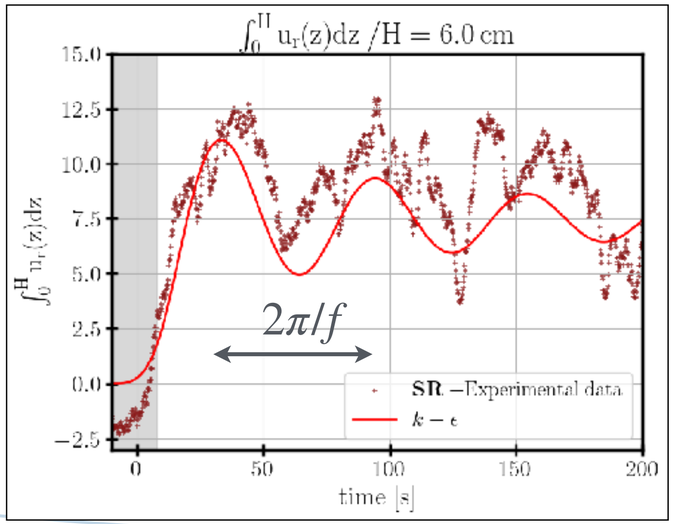
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→ **Oscillations at the inertial frequency on both velocity components**

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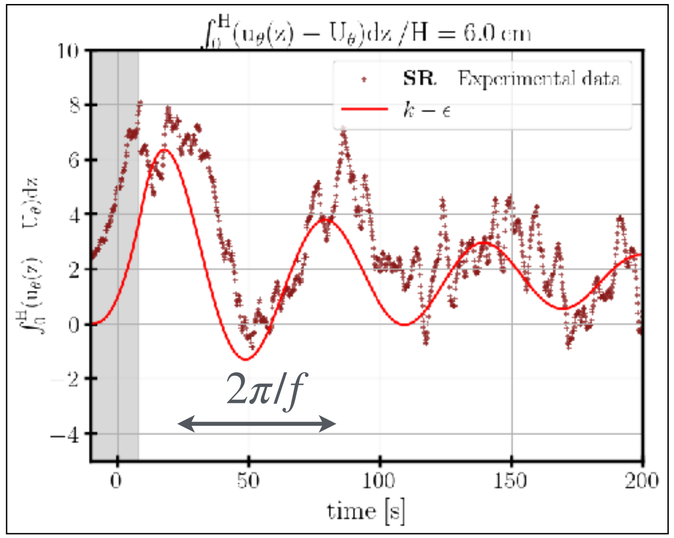
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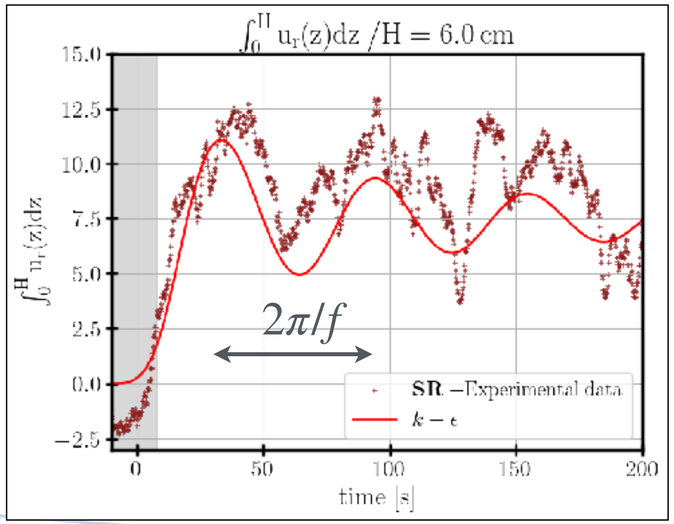
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→ **Oscillations at the inertial frequency on both velocity components**

→ **Damping of the inertial oscillation amplitude**

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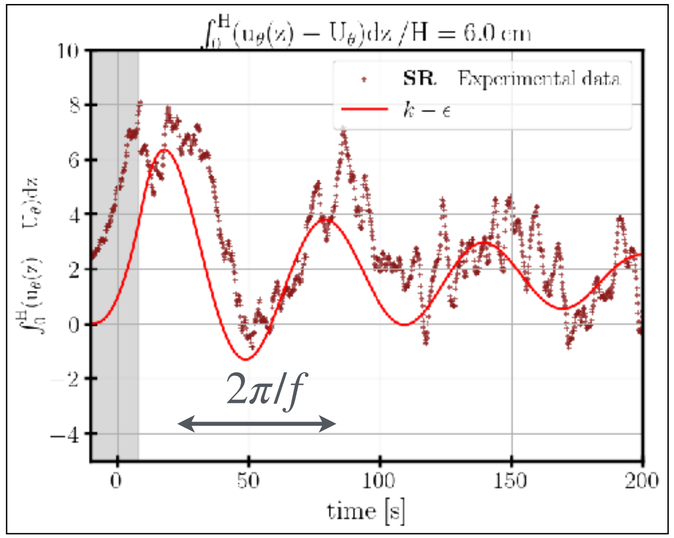
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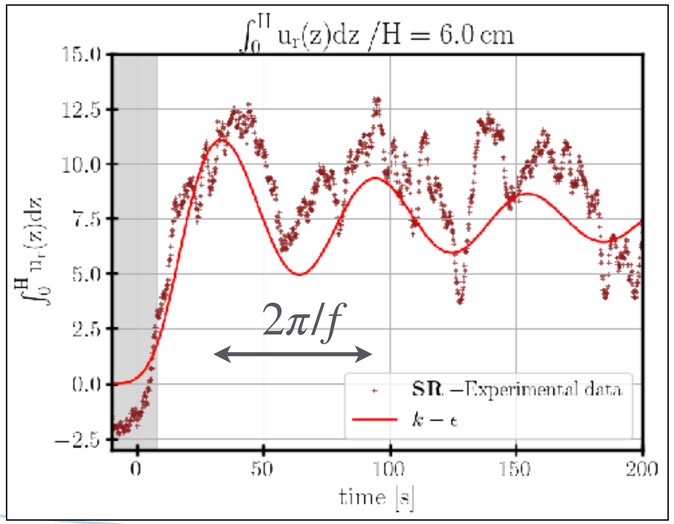
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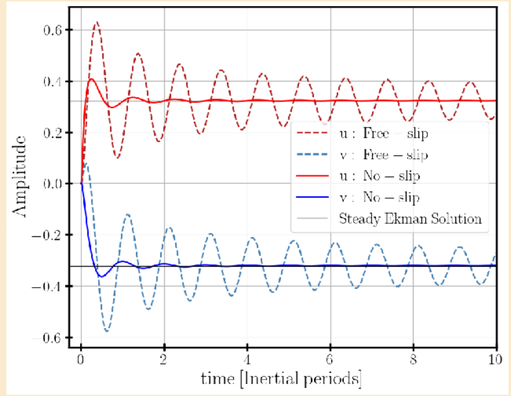

**Oscillations at the inertial frequency on both velocity components**

**Damping of the inertial oscillation amplitude**

## Vs Laminar

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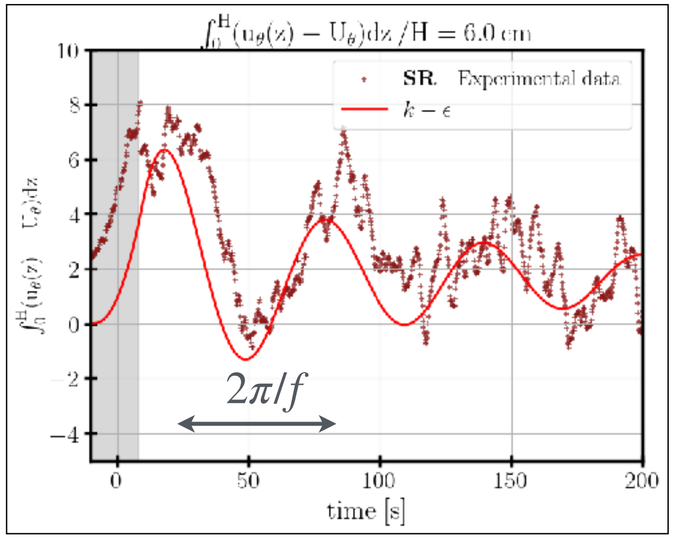
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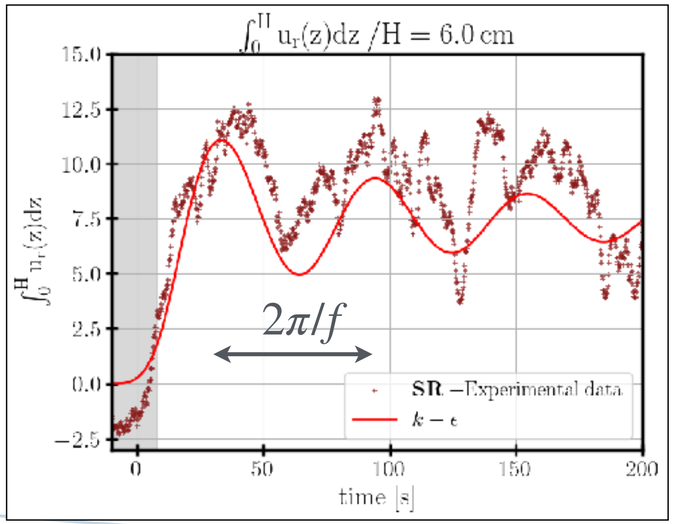
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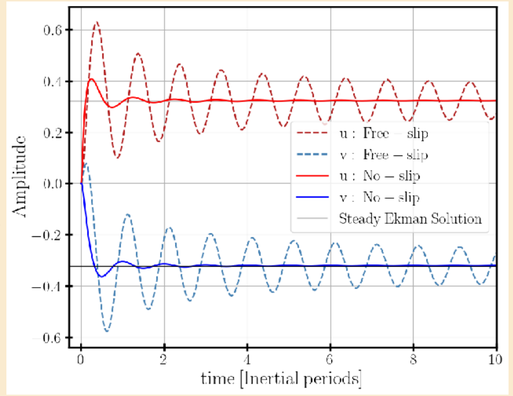
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Turbulent regime interpolates between these two extremes



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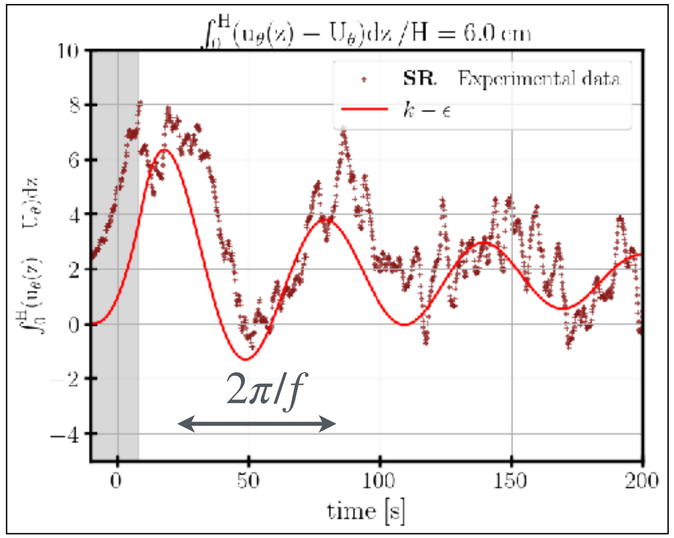
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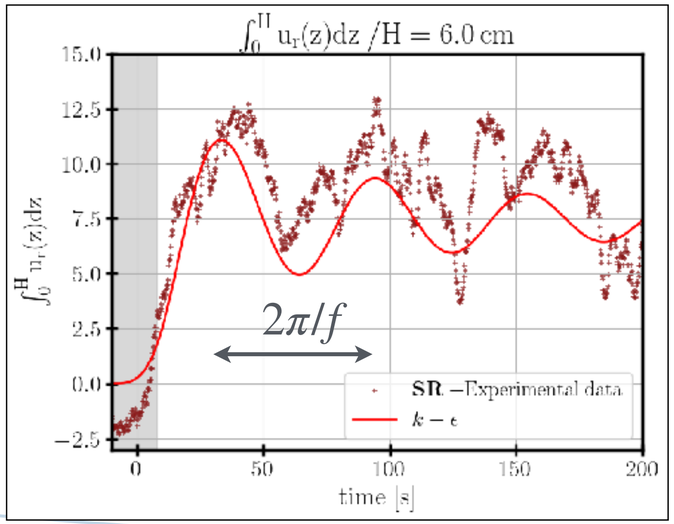
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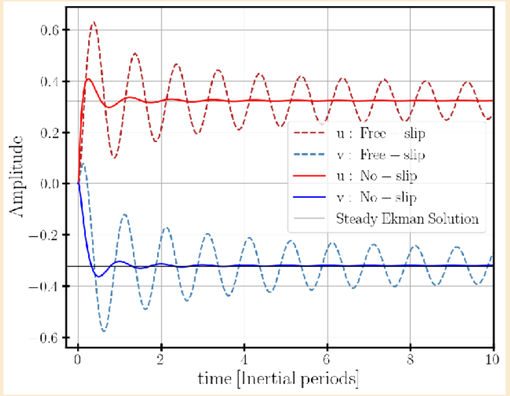
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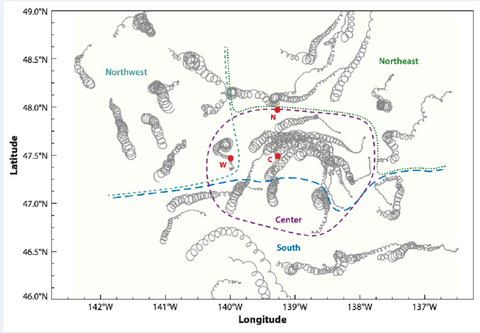
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## Vs Observations

Wind is intermittent

Oscillations are constantly triggered




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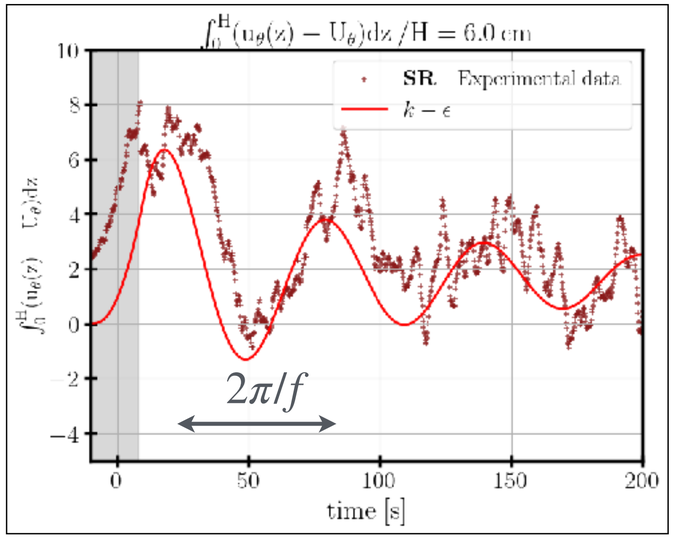
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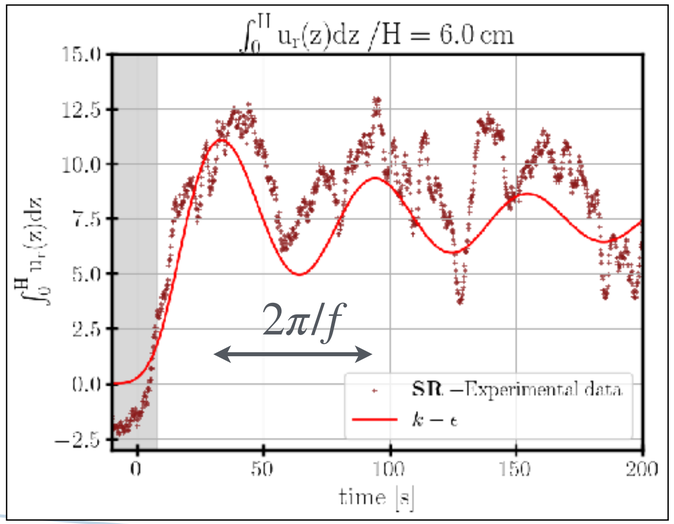
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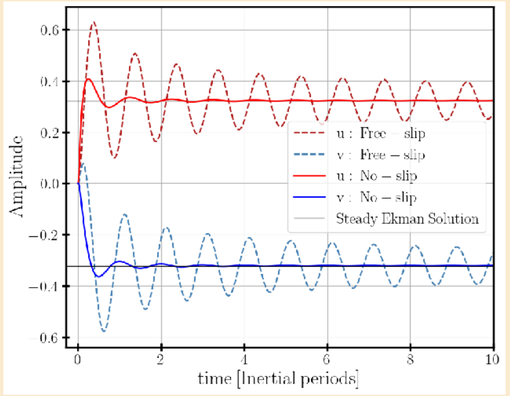
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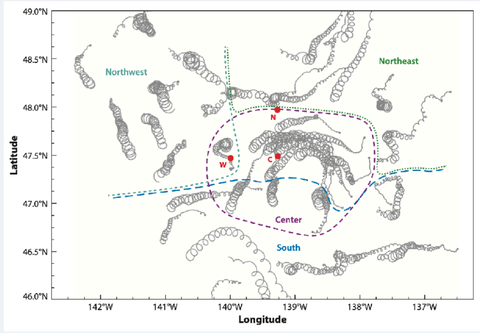



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Oscillations are constantly triggered

Need intermittent forcing

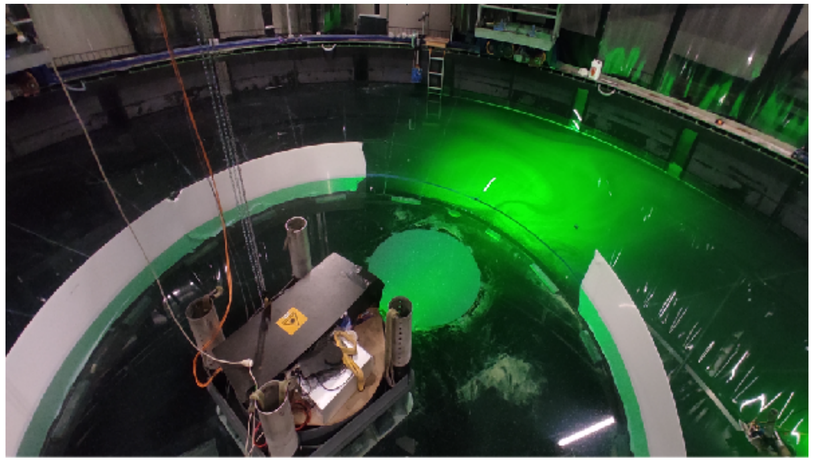


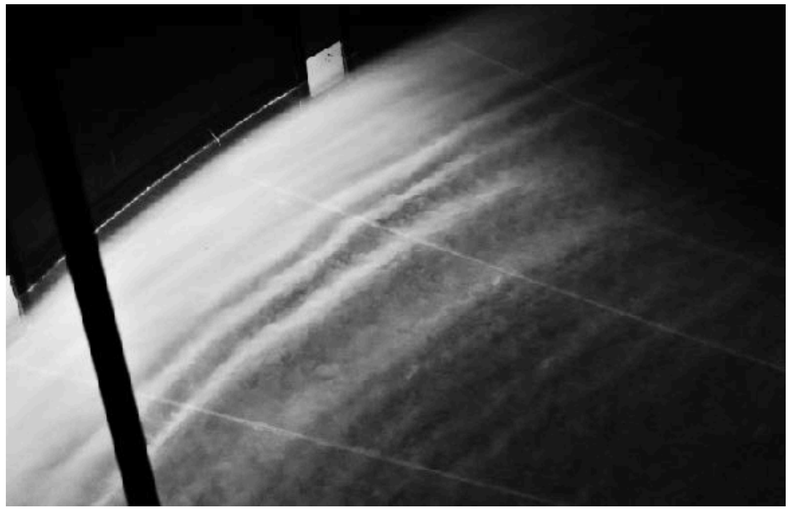

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# Take -Home Messages

## Results

- We observe the inertial oscillations in a fully turbulent regime
- Single column $k-\varepsilon$ model with an empirical drag coefficient successfully reproduces the transient turbulent Ekman dynamics
- The damping rate of inertial oscillations in turbulent regime lies within the two asymptotic laminar regimes set by the boundary condition





## Perspective:

**Spatial characterisation of inertial waves**

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