

Interaction between a free-surface flow and an emerging obstacle : Dynamics of the laminar horseshoe-vortex.

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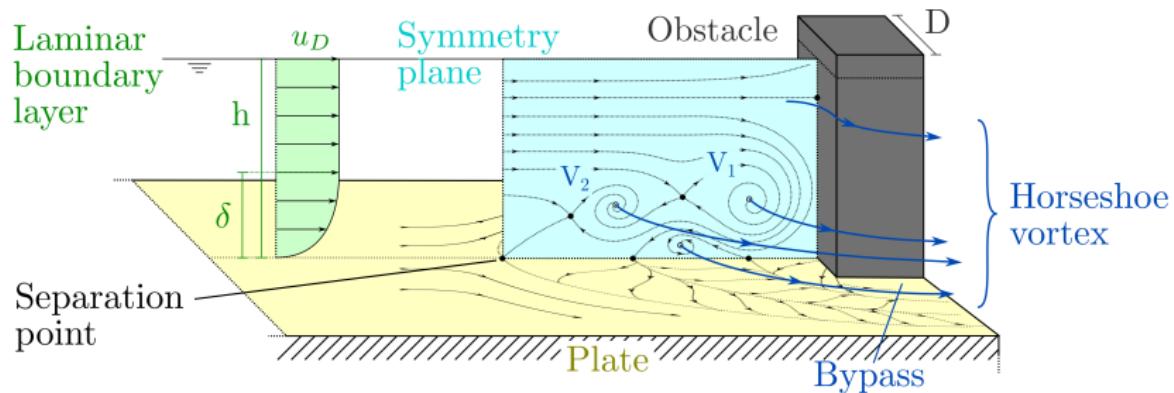
Laboratory : LMFA
Supervisors : R. Perkins (Pr. ECL)
: N. Rivière (Pr. INSA)
: E. Mignot (M.d.C. INSA)

September 14, 2016



Introduction

Context



Scouring



Source : www.usgs.com

Urban floods

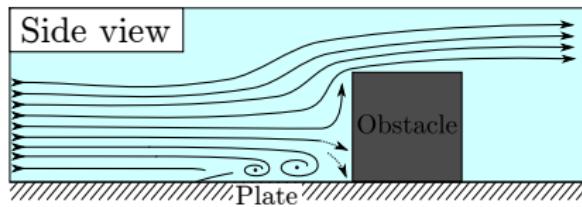


Source : www.gallery4share.com

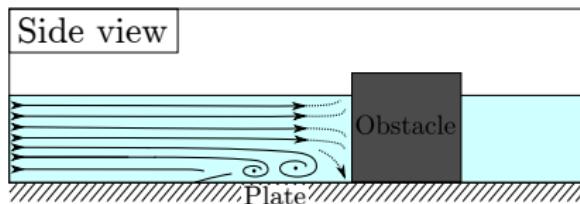
Introduction

State of the art and goal

Immersed obstacle



Emerging obstacle



- Abundant literature
 - Baker (from 1978 to 1991)
 - Ballio et al. (1995)

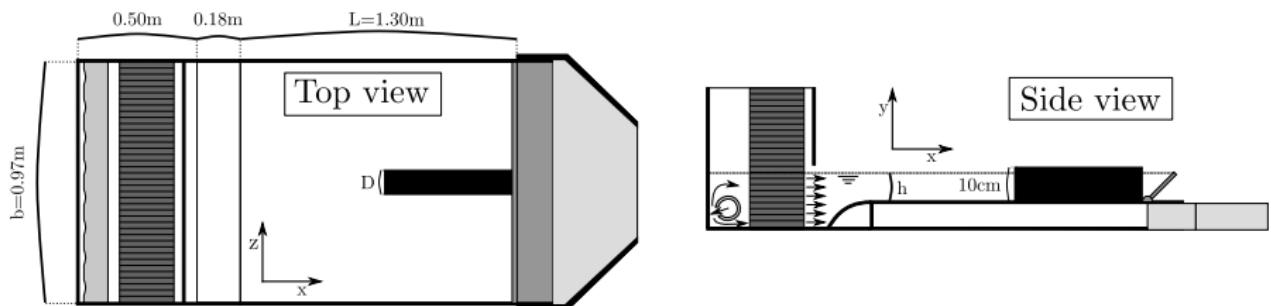
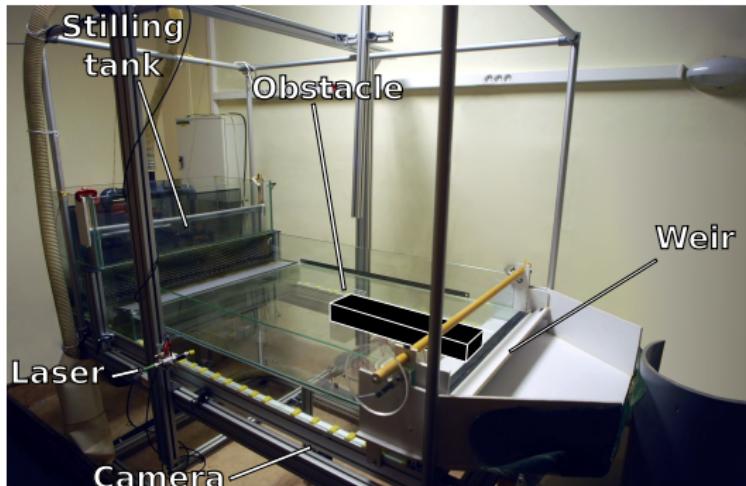
- No comprehensive studies
- Lack of studies for wide obstacles

Study plan

- Parametric study of the laminar HSV evolution
- Detailed study of the flow dynamic regimes

Experimental device

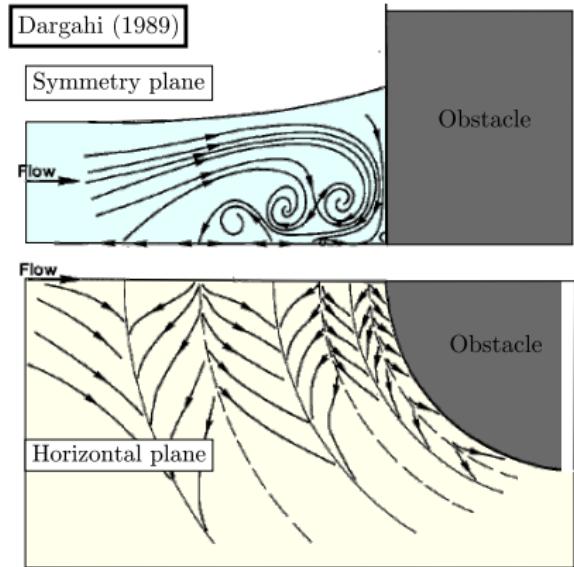
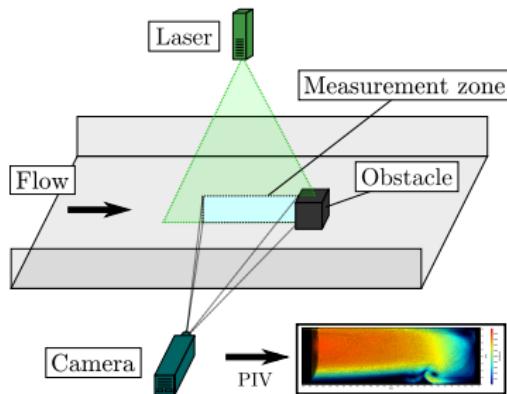
Water table



Experimental device

Measurements

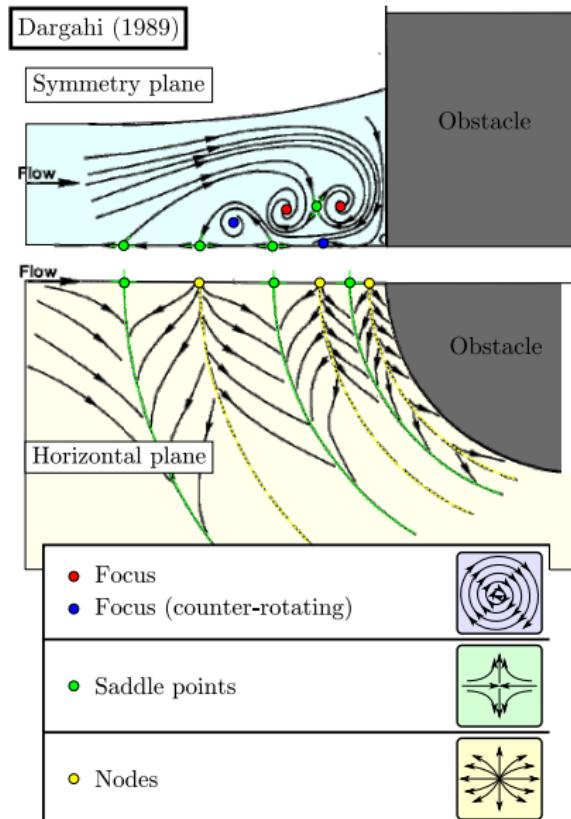
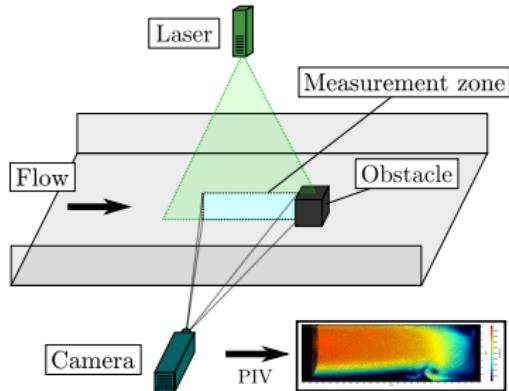
- Optical measurements
 - Trajectographies
 - TR-PIV



Experimental device

Measurements

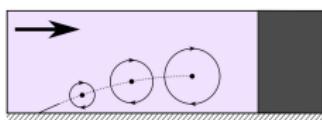
- Optical measurements
 - Trajectographies
 - TR-PIV
- Critical points extraction
 - Depardon et al. (2007)
 - Effenberg et al. (2010)



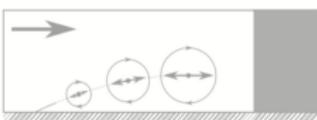
Laminar HSV Regimes

Stable regime

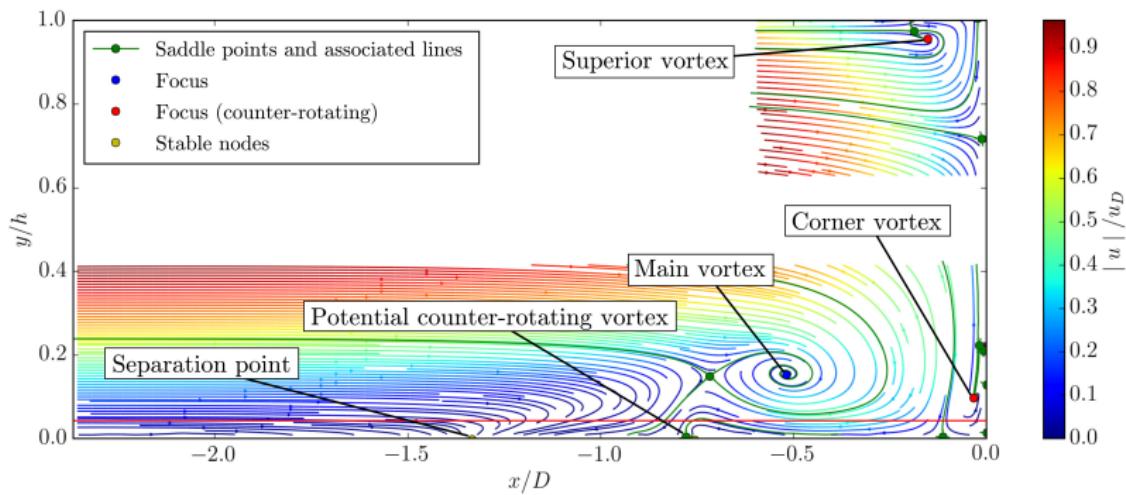
Stable



Oscillating

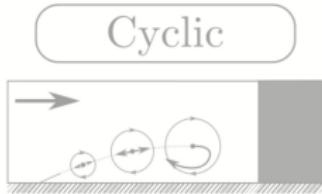
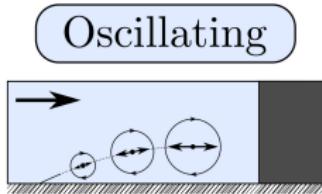
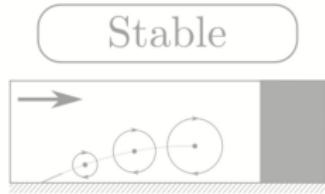


Cyclic

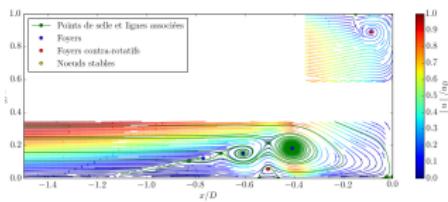


Laminar HSV Regimes

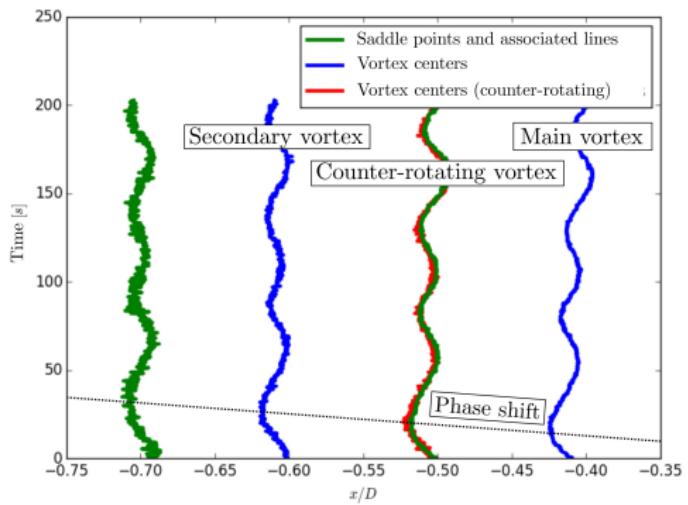
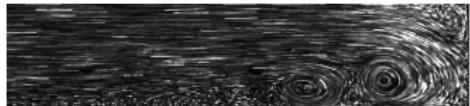
Oscillating regime



Mean velocity field



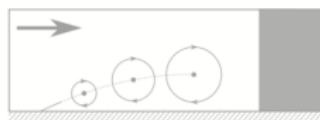
Trajectographie



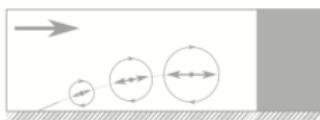
Laminar HSV Regimes

Cyclic regime

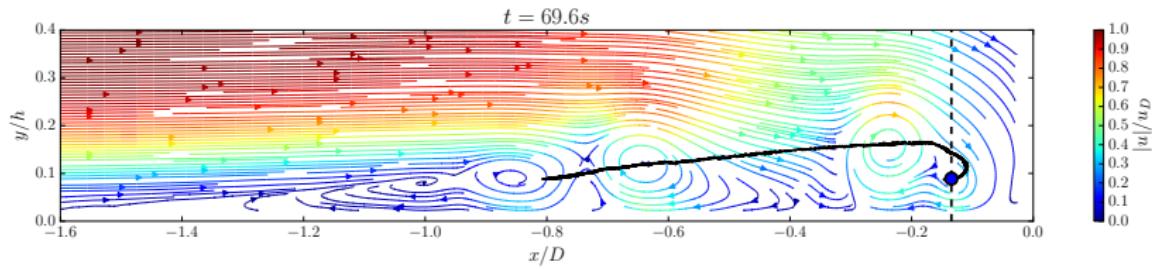
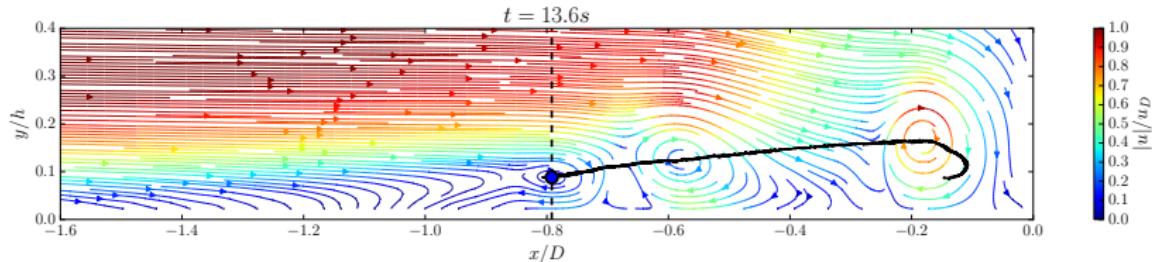
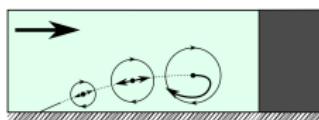
Stable



Oscillating

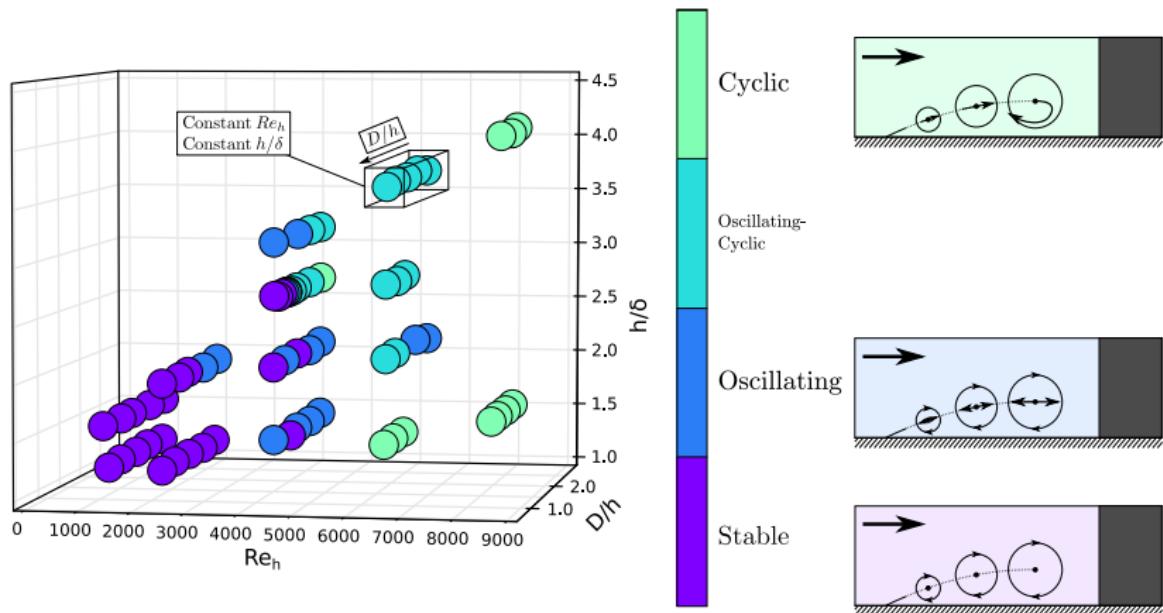


Cyclic



Laminar HSV Regimes

HSV Regimes evolution

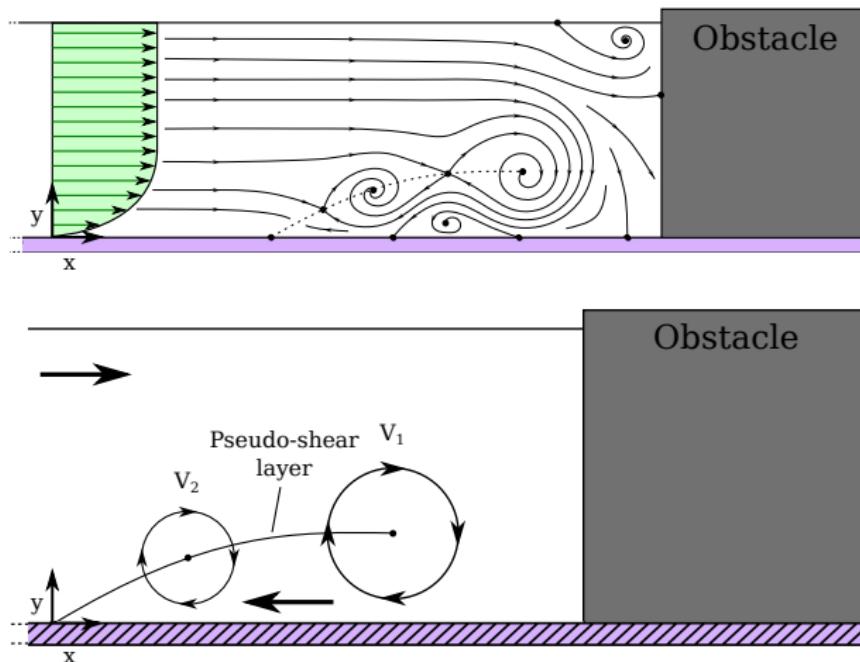


- Same typology as Lin et al. (2008) (for immersed obstacles)
- Detailed in Launay et al. (almost submitted)

Dynamic model

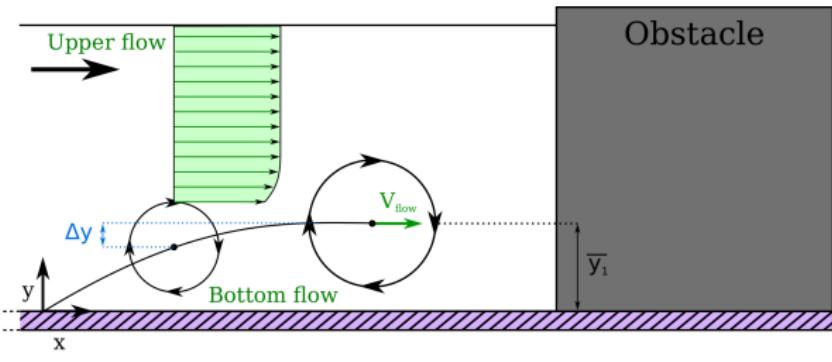
Introduction

- Conceptual model :

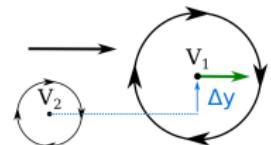


Dynamic model

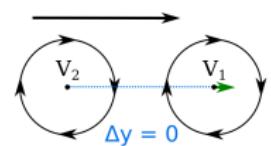
Velocity of the main vortex



Flow impact on V_1



Shielding effect

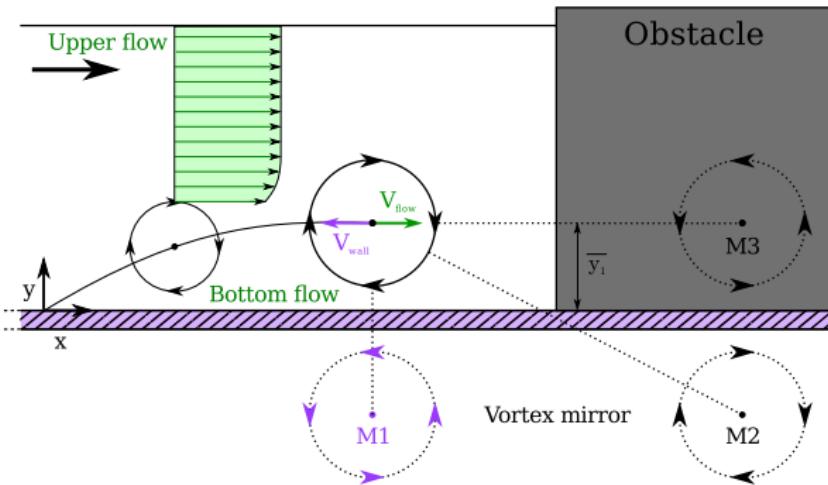


V_1 velocity model

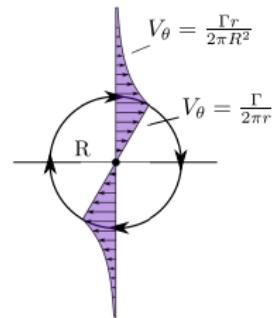
$$U_1 = U_{flow}(u_D, h, \delta, \bar{y}_1, \Delta y) +$$

Dynamic model

Velocity of the main vortex



Rankine vortex

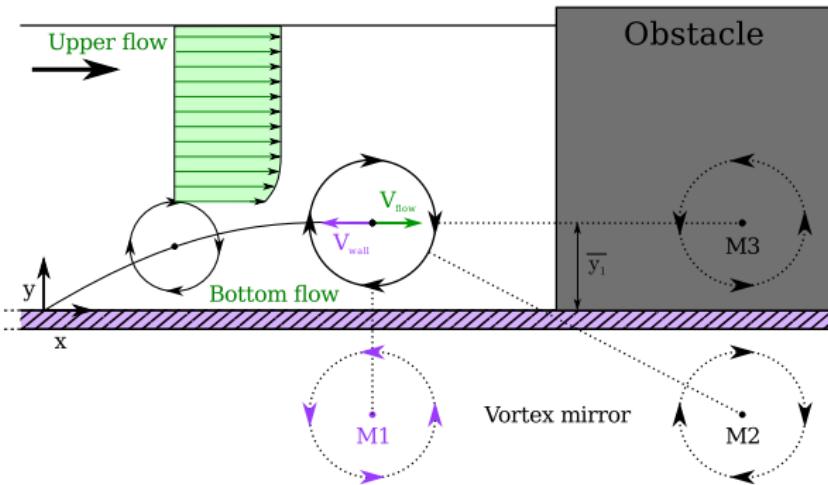


V_1 velocity model

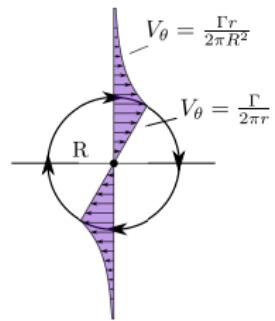
$$U_1 = U_{flow}(u_D, h, \delta, \bar{y}_1, \Delta y) - \frac{\Gamma_1}{4\pi\bar{y}_1}$$

Dynamic model

Velocity of the main vortex



Rankine vortex



V_1 velocity model

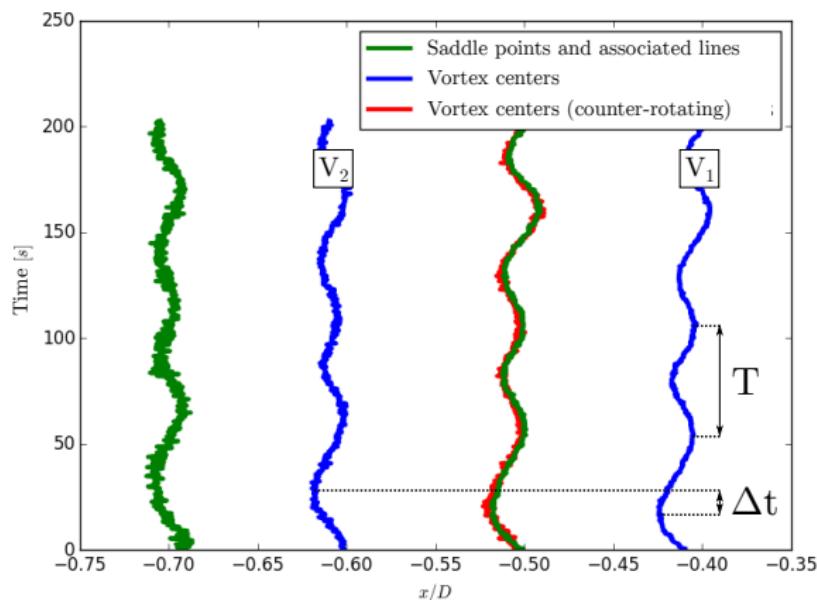
$$\frac{U_1(t)}{u_D} = P^2 \left(\frac{\Delta y(t)}{\overline{y}_1} \right) \left(\frac{h}{\delta} \right)^\alpha \left(\frac{\overline{y}_1}{h} \right)^\beta - \frac{\Gamma_1}{4\pi \overline{y}_1 u_D}$$

with $R^2 = 0.89$ on 15 cases (≈ 7000 points)

Dynamic model

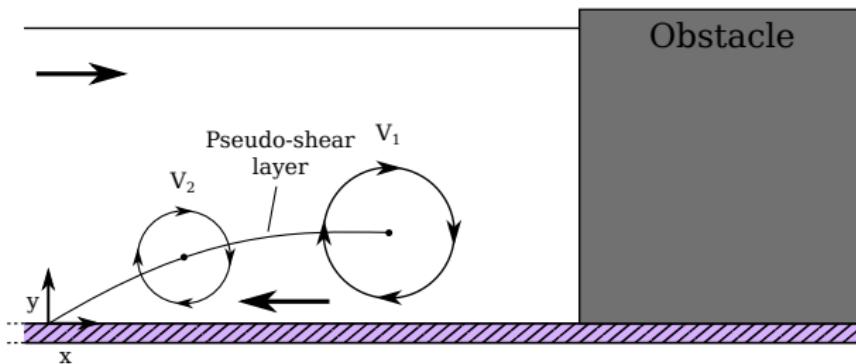
Velocity of the secondary vortex

- $U_2(t) = U_1(t) \rightarrow$ Vortex always stabilize
- $U_2(t) = U_1(t - \Delta t) \rightarrow$ Possible periodicity



Dynamic model

Full model

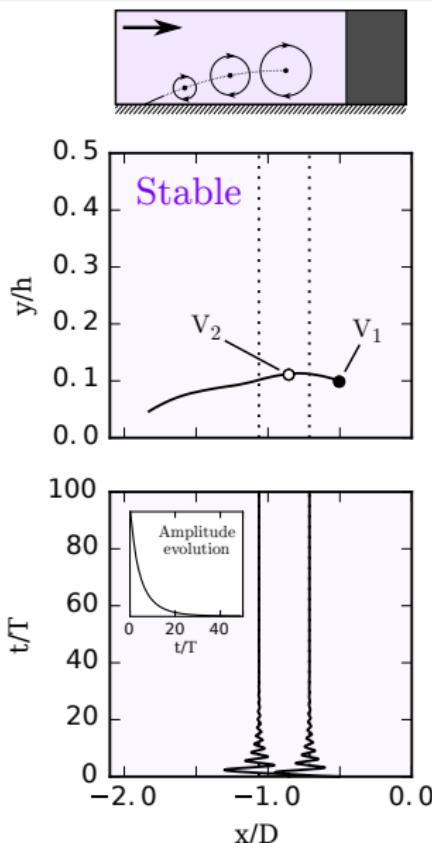


Vortex velocities

$$\frac{U_1(t)}{u_D} = P^2 \left(\frac{\Delta y(t)}{\bar{y}_1} \right) \left(\frac{h}{\delta} \right)^\alpha \left(\frac{\bar{y}_1}{h} \right)^\beta - \frac{\Gamma_1}{4\pi \bar{y}_1 u_D}$$
$$U_2(t) = U_1(t - \Delta t)$$

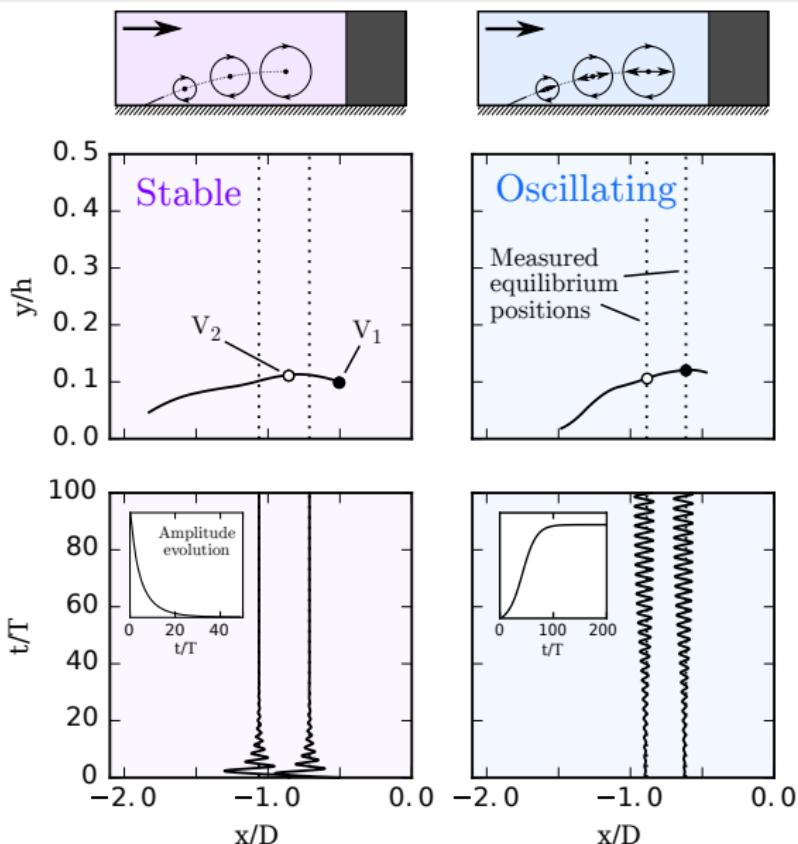
Dynamic model

Results



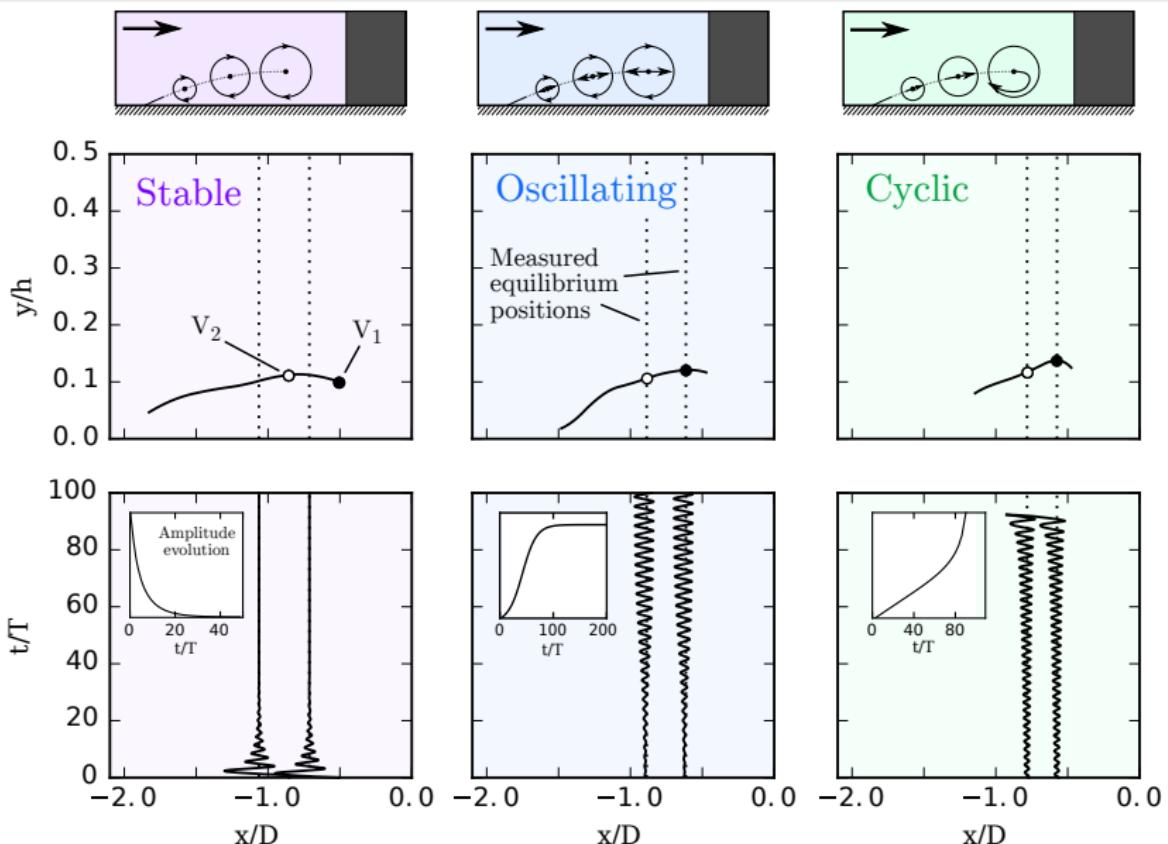
Dynamic model

Results



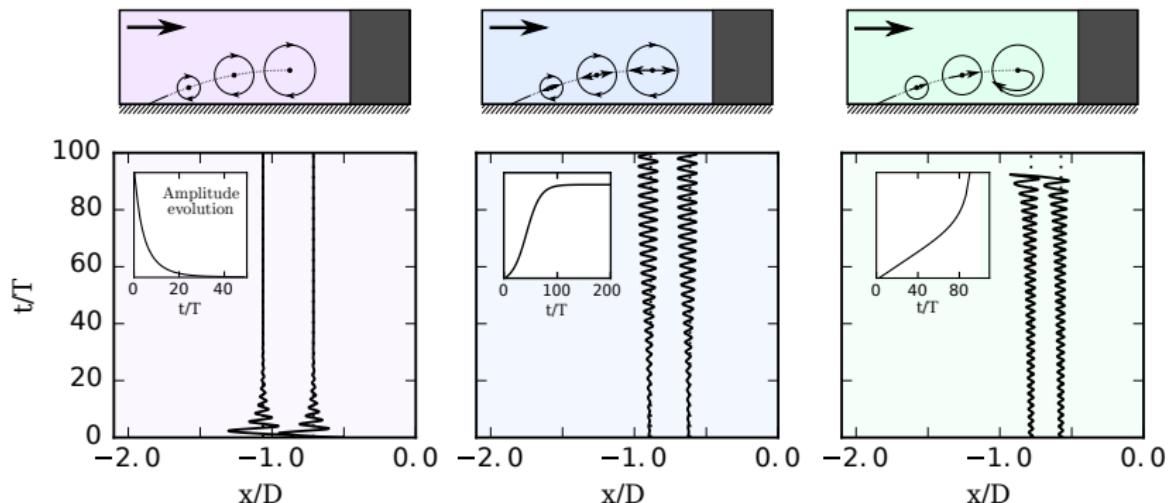
Dynamic model

Results



Dynamic model

Results



Model limitations

- Works only with amplified phase shift : $\Delta t' = 3\Delta t$
- Circulation constant with time

- Parametric study
 - Evolution of the HSV properties
 - Comparison with Immersed configuration

- Dynamics model
 - Complex dynamics requires :
 - Shielding effect
(V_2 influence on V_1)
 - Phase shift Δt
(between V_1 and V_2)
 - Enhancement :
 - Variable circulation
 - Consider merging

