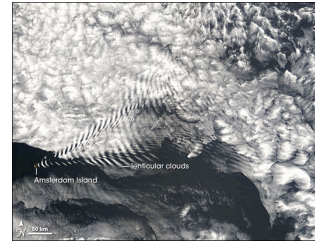


VORTEX IN HYDRODYNAMICS

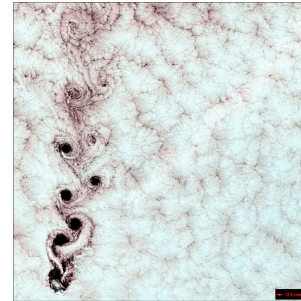
Maurice Rossi
CNRS,
Institut Jean Le Rond d'Alembert
Université Paris VI

Two types of motions in Fluid Dynamics

Waves



Vortices



Different scales

Ocean vortices	3000 km	1.5 m/s
Tornadoes	50m	150m/s
Trailing Vortices	1-3 m	10 to 100m/s
Dust Devils	3m	10m/s
Bathtub Vortex	1 cm	0.1m/s
Vortex in Biofluidynamics	0.1cm	1cm/s

Adapted from Lugt (1995)

Vortex Dynamics is a part of fluid mechanics.

Vortices are important objects for

1)practical reasons

2)theoretical reasons

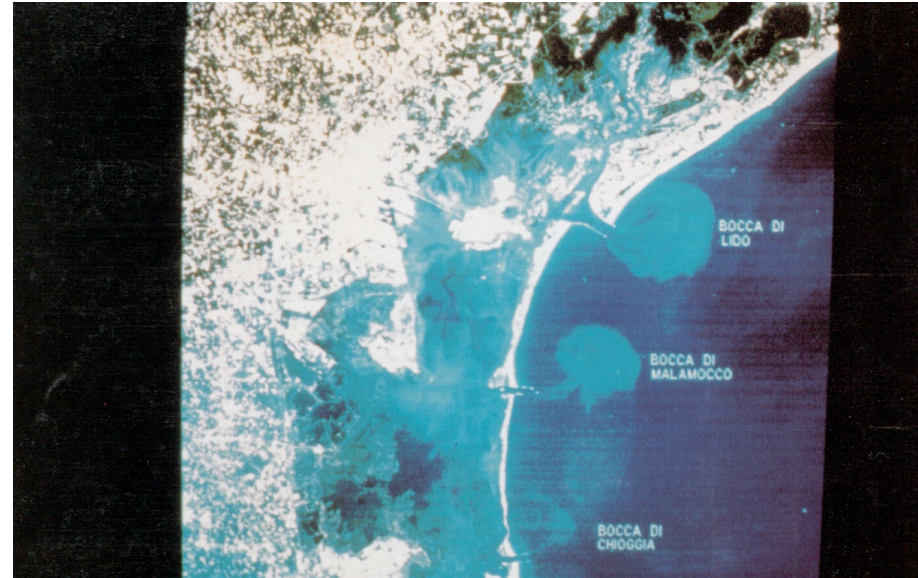
3)recent "historical" reasons

Practical reasons

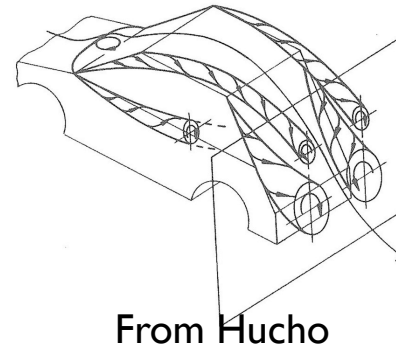
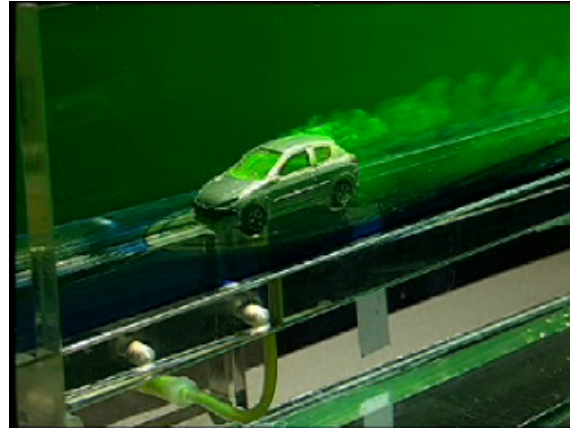
Role of Vortices in

- 1) Mass transfer for instance plankton transport
- 2) Mixing of particles, passive scalars or reactive scalars
- 3) Momentum transfer (impulsion) e.g. Drag or Lift
- 4) Energy transfer (tornado)

Mixing, transport of particles, passive or reactive scalars.



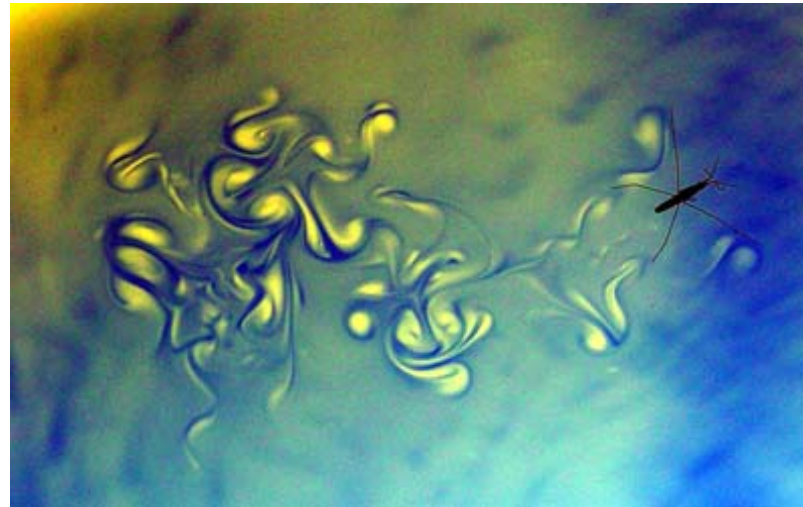
Momentum transfert Drag, Lift



Vortex generated behind a car

Momentum transfert Drag, Lift

Vortex dipole propulsing a Gerris (From J.Bush)



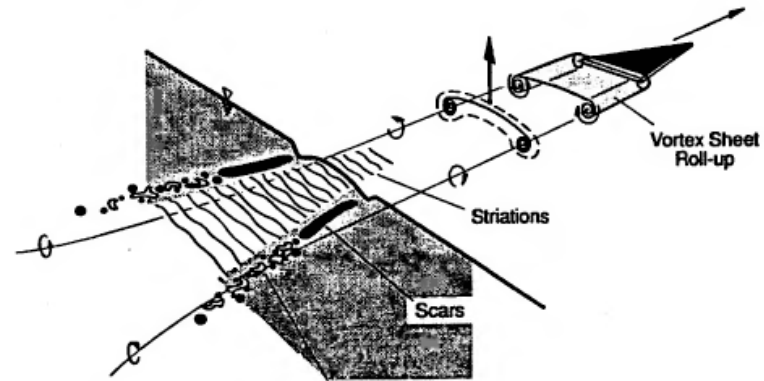
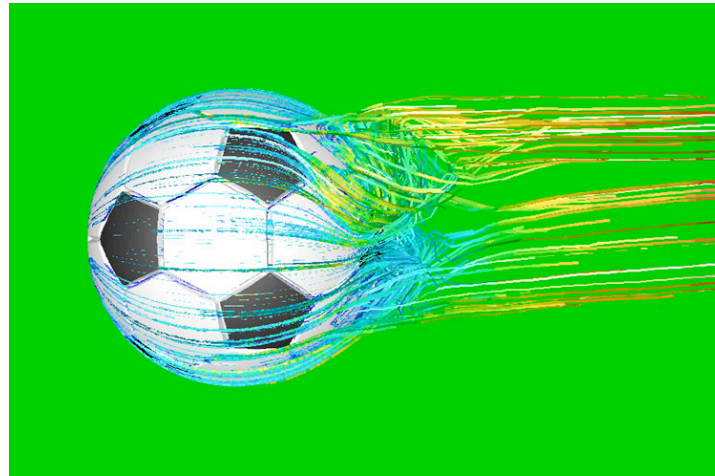


Fig. 15.4: Wave signatures due to a submerged vortex pair, generated by a body with negative lift and ascending to the surface (modified from Hirs et al. 1991).

Momentum transfert Drag, Lift



SPORT and VORTEX FLOW

ENERGY TRANSFER



Thermal to Mechanical Energy :
Thermodynamic Engine

Theoretical reasons

Role of vortex structures in characterizing complex flows such as turbulent jets, wakes... etc

**Order in a "chaotic" flows: determination of patterns, coherent structures

**Vorticity as an indicator of the flow topology (helicity)

Theoretical reasons : Helmholtz Laws

There exists a conservation Law for vorticity !

In experimental flows, this conservation law ensures
to follow structures

One can follow the vorticity in the flow !

Dust devil

Columnar vortex

Clear sky phenomenon:

Due to strong surface heating

Height:	50 – 500m
Diameter:	10 – 100m
Wind speed:	10 – 50km/h
Duration:	1 – 10 min.

(From P.Deitling)



Theoretical reasons

Dynamical Role of Vortices in laminar or turbulent flows

Coherent structures :

``Vortices are the sinews and muscles of fluid motion."''

$$\omega \longleftrightarrow \vec{u}$$

(Biot and Savart Law)

Theoretical reasons

Role of Vortices in turbulence

$U = \nabla\Phi$ is a potential flow (no vorticity)

It cannot be turbulent because it is a flow without history.

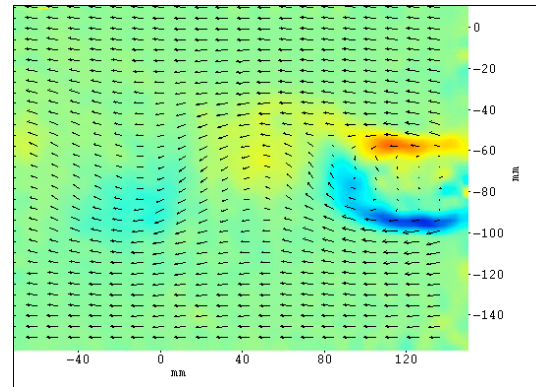
The number of degrees of freedom of a flow is very much increased when going from a potential to a rotational flow.

Recent historical reasons

Recently vorticity became a good quantity to analyze the flow :

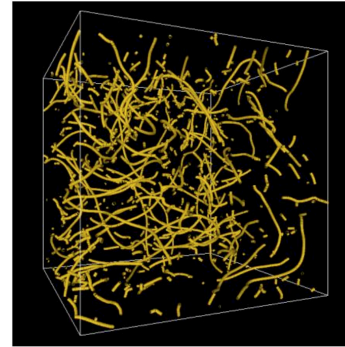
- 1) In numerical experiments : large amount of data provided by DNS
- 2) In real experiments : PIV, DPIV

In laminar or transitional flow



Experimental wake (PIV measurement)
from Olivier Cadot

In turbulent flows



Isotropic Homogeneous Turbulence
DNS from Kida