Oceanic current flowing around topography
A numerical study of wake response to upstream flow perturbation

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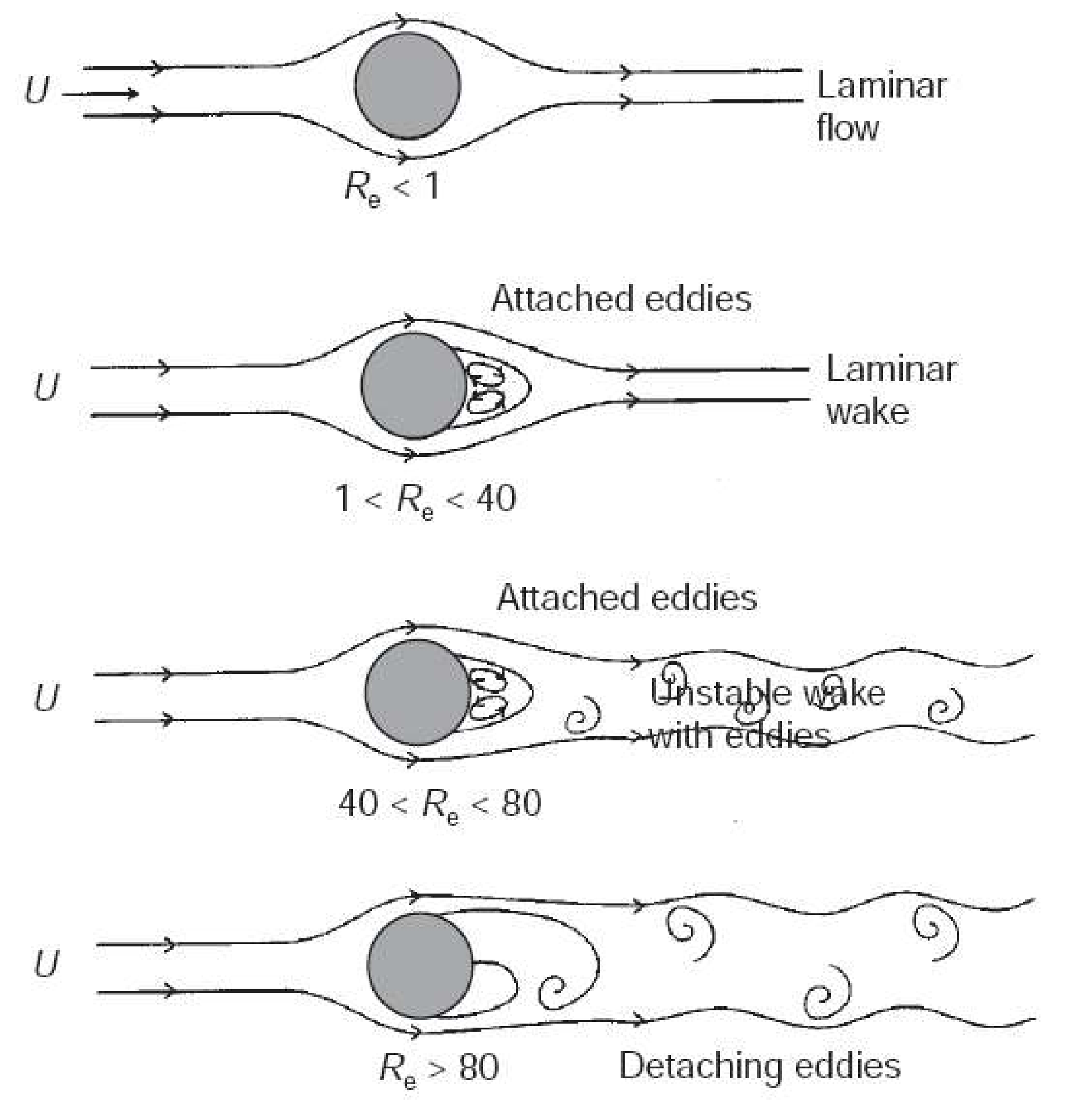
Oceanic currents flowing around topographic features such as an island, headland, reef or even a shallow seamount, usually involve strong wakes in which there is vigorous re-circulation after separation of the stream from the topography. The wake flows govern the dispersion of pollutants and nutrients, they generate vertical transport of nutrients from deeper water, and they influence the scouring and deposition of sediments. In fluid dynamics, flow separation and wakes have been extensively studied for smooth incident flows. However, geophysical flows are characterised by high incident levels of turbulence, and this strongly influences both the flow separation and the wake structure. In the coastal ocean, the incident turbulence can come from other topographic features, tidal currents, wind stress variability, larger scale current variability, ...

Wake structure depends mainly (but not only) on the Reynolds number Re. Classical stability theory fails to predict the correct Re regimes in most geophysical contexts. Field observations and laboratory experiments show that instability and transition to turbulence occur at lower Re. Wakes can be enhanced by incident turbulence through a property of the system known as non-normality (modes are not orthogonal). This means that linear interference of the modes can lead to significant transient growth of stochastically induced perturbations and an elevation of the system variance. This aspect of stochastically forced systems is embodied in the ideas of Generalised Stability Theory (GST) developed by **Farrel & Ioannou (1996)**. For example GST allows to compute initial perturbations which maximize linearly the energy over a given period.

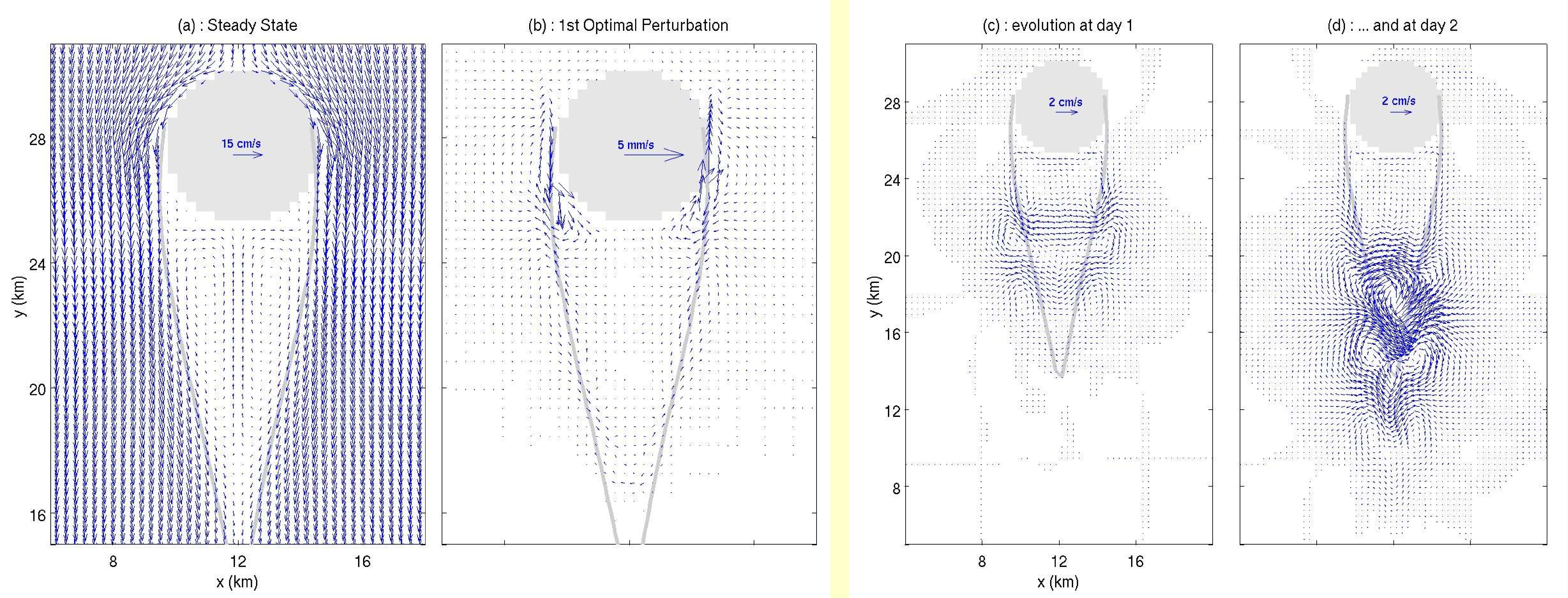
With a shallow water model **Aiken et al (2002, 2003)** have shown the relevance of using GST to study the wake sensitivity to upstream turbulence. We used the latest version of the Regional Ocean Modeling System (ROMS) which contains tools for invoking GST **(Moore et al, 2004)** to "reproduce" some Aiken et al experiments and to expand on these works with the addition of more realistic scenarios. A preliminary result on the addition of a varying bottom topography is presented below.

"Classical" Re regimes for a flow past a cylinder ***(Barton, 2001)***



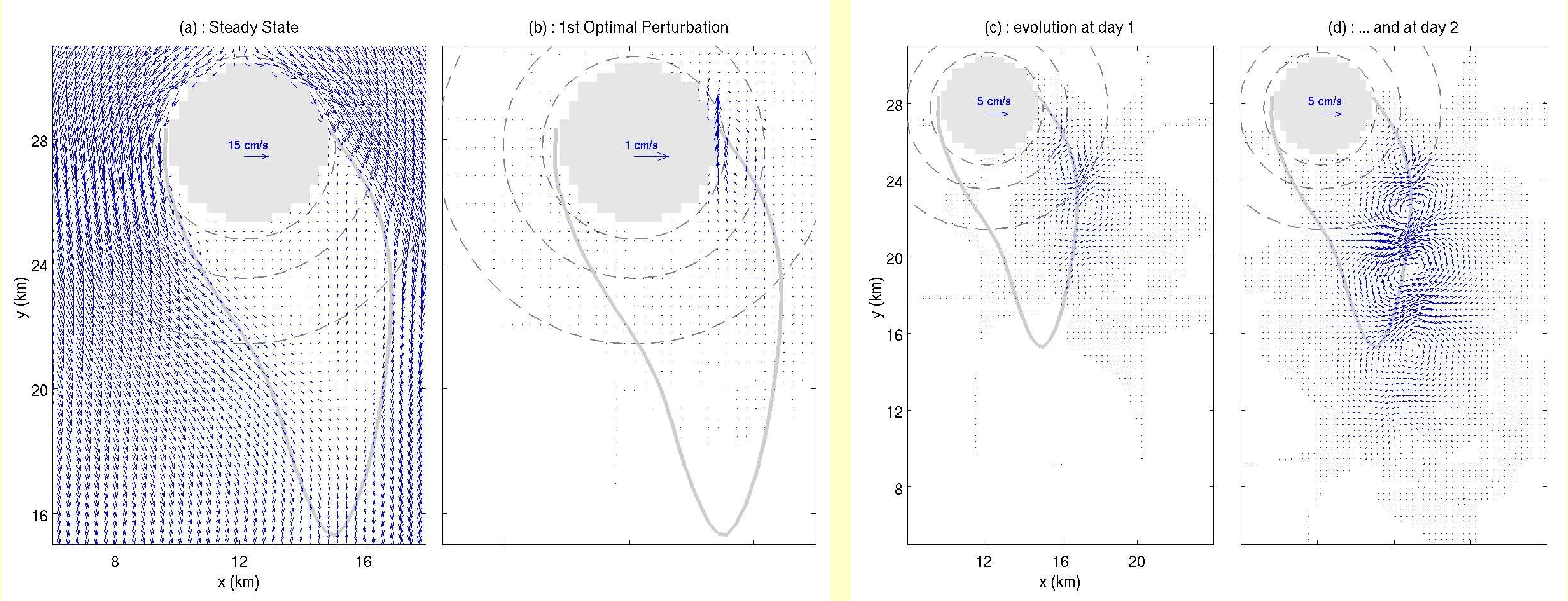
1st step : "reproduction" with ROMS of the 2D works of Aiken, Moore and Middleton (2002, 2003)

Example of a flat bottom (10 m) cylindrical island configuration initially at rest and forced with a constant southward flow (10 cm/s) from the northern boundary.
(a) : Steady flow after spinup (GST analysis are performed by linearization around this mean state) - (b) : First optimal perturbation for a 2 days optimal growth time
(this GST analysis invokes both Tangent Linear and Adjoint models) - (c) & (d) : Linear evolution of this perturbation (note that non linear evolution is similar)



2nd step : addition of more realistic scenarios (topography, vertical dimension, stratification, external forcings, ...)

Example of the addition of a gaussian bathymetry around the island on the previous configuration (dashed contours are 3, 6 & 9 m isobaths
and light gray contours delineate the wake region at steady state). Note that conservation of potential vorticity (in the southern hemisphere)
leads to a wake which is not symetrical anymore and the first optimal perturbation is then only located on one side of the island.



Perspectives

- "realistic" modeling
- coupling with biology
- field observations

References

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