Surface transport in the Ria de Vigo - Transport barriers in a tidal estuary

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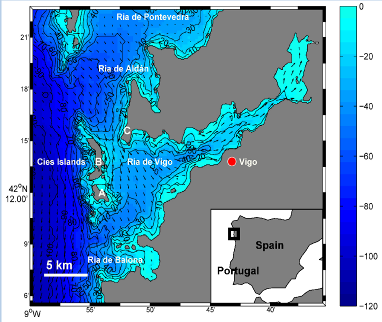
Ria de Vigo – study area

The Ria de Vigo is an estuary with tidal and wind-driven dynamics. In the outer part the flow dynamics are determined by the interaction of the tides with the flow on the shelf leading to chaotic flow patterns. Upwelling favorable conditions with southward winds are typically observed in summer and downwelling favorable conditions with northward wind in winter. Yet, circulation patterns are highly variable and coupled to the meteorological forcing with time scales of several days.

Water exchange with the shelf strongly influences the primary production in the estuary. On the one hand, an extensive seafood industry takes advantage of large nutrient fluxes connected with upwelling, on the other hand, harmful algae blooms (HAB) occur regularly. Especially, in some retention zones high persistent chlorophyll concentrations are measured.

Additionally, contaminations from the busy harbour and ship traffic may threaten the ecosystem. In order to prevent damage to the ecosystem a detailed knowledge of the surface circulation is necessary.



How are water masses exchanged with the shelf?

What are the typical Lagrangian patterns in the surface flow?

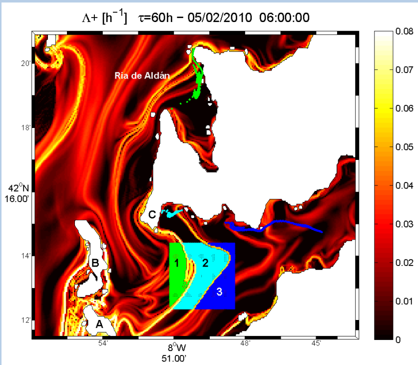
Data and methods

Model

3-D hydrodynamic nested baroclinic model MOHID (IST Lisbon), horizontal resolution of 300 m, wind forcing, tidal forcing, river outflow

Lagrangian Coherent Structures (LCS)

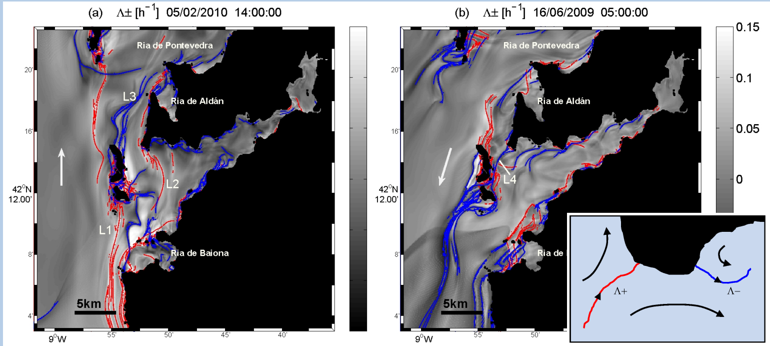
LCS are lines that define dynamically different water masses. They can be estimated as ridges in fields of the Finite-Time Lyapunov Exonent (FTLE), the exponential separation rate between initially close fluid particles.



Instantaneous FTLE field in the Ria de Vigo computed from trajectories of arificial fluid particles in the model surface flow. Different water masses (1,2,3) are defined between sharp ridges of the FTLE field, corresponding to distinct final positions of the particles.

LCS separate dynamically different water bodies in the model flow

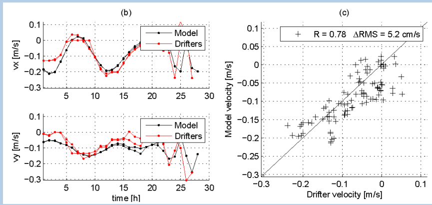
Lagrangian transport patterns



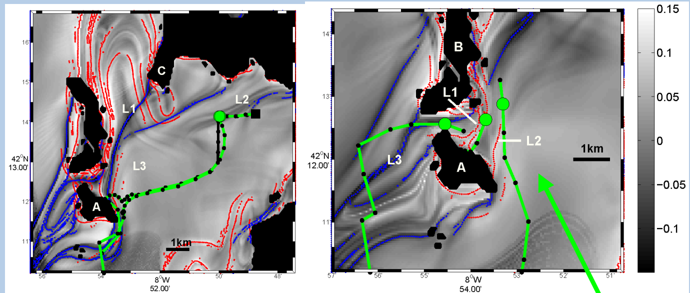
Attracting (blue) and repelling (red) LCS reveal a detailed picture of the surface flow in two typical meteorological conditions: a) northward wind, b) southward wind. LCS are attached to prominent coastal boundaries, indicating that the geometry of the flow is dominated by coastal boundaries rather than by turbulent flow features. The water body entering the estuary can easily be defined and can be distinguished from the water body drifting by on the shelf. Known retention zones (Ria de Aldán, Ria de Baiona) are cut off from the ambient circulation which could be an explanation for high plankton concentrations in these regions.

Visualize geometry of flow exchange

Comparison with surface drifters



Trajectories of coastal surface drifters are used as ground truth data to validate the transport barriers extracted from the model flow. Drifter trajectories largely stay in the water bodies defined by those transport barriers. In some cases drifters slightly cross the barries, so a uncertainty in the position of LCS of about 1 km can be estimated.



Model transport patterns agree with drifters

Conclusions

Lagrangian Coherent Structures (LCS) define global transport patterns of the surface flow

Flow separates at prominent coastal boundaries

Water masses separated by LCS coincide with drifter trajectories

References

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