The present state of the water exchange through the Strait of Gibraltar

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The present two-way exchange through the Strait of Gibraltar stems from the fresh water deficit of the Mediterranean basin. The size of the exchanged flows is the outcome of the climatology over the basin and the morphology and internal hydraulics of the Strait. Its highly constraining topography imposes an upper bound to the flows that cannot be exceeded, a limit known as maximal exchange, which is associated with the minimum salinity difference (density, in fact) between the inflowing (Atlantic) and outflowing (Mediterranean) waters. A relevant question is whether or not the present exchange has achieved this limit. A simple steady-state model of the Mediterranean Sea and Strait of Gibraltar system in which the deep water formation rate is balanced by the Mediterranean outflow, strongly suggests that the exchange is quite close to (or, indeed, it is) maximal. The Strait topography requires two hydraulic control sections for this limit to be achieved, which could be thought as if one of them controls the outflow (the section of the main sill of Camarinal) and the second one the inflow (the narrowest section or Tarifa Narrows, to the east of the main sill). Oceanwards of Camarinal, the outflow accelerates and settles as one of the fastest and brisk bottom currents of the world ocean. East of Tarifa Narrows the inflow becomes a swift jet, the Atlantic Jet, which enters the Mediterranean Sea and sets up the basic features of the Alboran Sea surface circulation.

The steady exchange so far depicted is not realistic. The flows undergo large fluctuations at different time scales, which modify the former description drastically. Of special importance are the tides and associated tidal flows, which can be up to 5 times greater than the long-term averaged flows. Under such huge fluctuations, the hydraulic control in Camarinal sill is periodically lost about two hours before high water, during the rising tide, when the tidal currents still head toward the Atlantic Ocean. The flooding of the control is revealed by the release of a vast internal hydraulic jump that progresses towards the Mediterranean Sea while evolving into a regularly shaped train of great amplitude internal waves that carry away part of the tidal energy accumulated nearby the sill during the rising tide. Whenever the hydraulic control at Camarinal is lost, a second sill located to the west (Espartel sill, the westernmost gateway of the Strait) takes over the control of the Mediterranean outflow. The hydraulic control at Espartel is very seldom flooded, which is a fundamental fact for understanding the internal dynamics of the exchange under large barotropic fluctuations. Without this sill, the Strait dynamics would be very different. It is behind the powerful, but periodically inverting, bottom currents nearby Camarinal sill and the also strong, but already unidirectional, bottom currents in Espartel sill and beyond, a reason for which this sill might well be considered as the proper source of the Mediterranean plume in the Atlantic Ocean.