16. Dynamics at the land-sea interface

Patrick Marchesiello and Rafael Almar

The coastal zone is the interface between land and sea and is the site of some major societal challenges, with growing anthropogenic pressure (demography and use of resources) in a dynamic zone subject to significant natural hazards, principally erosion (Fig. 1) and submersion. These risks may intensify with rising sea levels or under the influence of more intense weather events. However, it is difficult to predict the evolution of the hydro-morphodynamic system that functions in a non-linear manner and where there are still many uncertainties. It is therefore vital that we improve our knowledge of the processes at work, and enhance the observation and modelling tools available, so that we can put forward integrated coastal management strategies.

From the deep ocean to the inner continental shelf

The continental margin needs can be scaled down to study the numerous circulation regimes and as many transitions from the ocean up to the shore. Contrary to the deep ocean, where the energy spectrum is largely controlled by the turbulent cascade, coastal dynamics are influenced by multiple types of forcing (wind, tide and waves) and constrained by bathymetry (cf. III.2). The continental slope is the outer boundary of this coastal interface. It is the source of strong vertical movements and generates internal tides that may reach the coast, as well as slope currents that form an effective barrier to land-sea exchanges.

This is especially true on the western boundaries of the oceans where Rossby waves accumulate and, through rectification, form major currents such as the Gulf Stream. On the other hand, on the eastern boundaries, persistent winds drive water masses away from the coast and prompt the upsurge of deep water, forming strong, turbulent streams, where shelf and ocean waters mix.

These upswellings have a major influence on the weather (*e.g.* sea breezes) and on coastal ecosystems. However, nearer the coast (from around 30 m deep), their dynamics are modified in a more frictional zone where the surface and deeper layers meet: the inner continental shelf.

From the inner continental shelf to the shore

On the inner continental shelf, winds tend to drive water masses in their direction (contrary to in deeper waters). In places, river plumes create marked stratification and dynamically active fronts (Fig. 2). The tide also generates intense currents, through resonance and through the concentration of energy in bays (funnel effect) and in

Fig. 1 – **The city of Hoi-An in central Vietnam is included on the UNESCO World Heritage List.** It used to be a prosperous city, thriving on maritime trade but its activity declined as its river silted up. Today, its beaches are subject to extreme erosion, requiring emergency but sustainable measures and therefore close understanding of the processes at work and predictive models. © R. ALMAR. ■

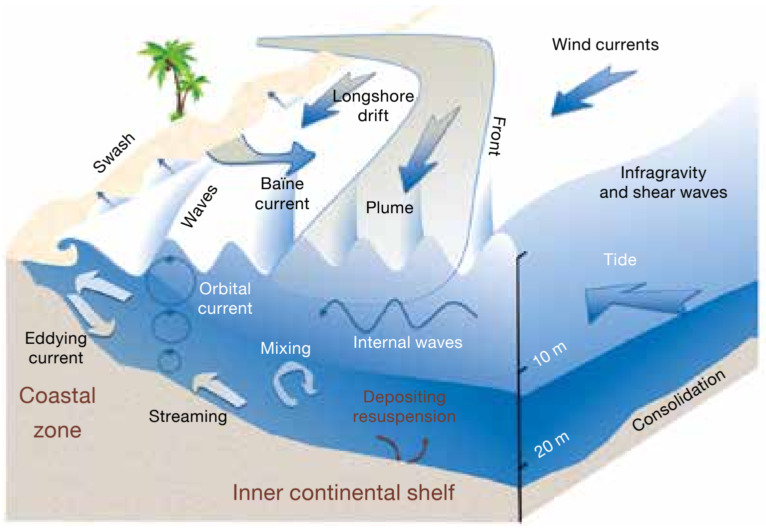

Fig. 2 – **Diagram showing circulation on the inner continental shelf and the coastal zone.** ■

shallows, slowing down the wave (as in the Bay of Mont Saint-Michel).

These currents have a residual component and, therefore, an effect on sediment transport and morphological evolution. At the same time, waves start to interact with the sea bottom (at depths of less than a quarter of their wave length). The speed of waves falls and their energy is concentrated in shorter but higher waves. Parallel to this, bottom friction has a dissipative effect and orbital speeds stir loose seabed material and move sediments.

Coastal hydrodynamics

Waves are the main component driving coastal dynamics. They disseminate the energy transferred by the wind at the ocean's surface from the offshore area towards the coast, often over several thousand kilometres. As they approach the coast, part of the waves' energy is dissipated by the swell. This energy is transferred to mean ocean circulation with currents that can exceed 1 m/sec (longshore drift, baine currents, eddying current), to waves with lower frequencies, known as infragravity waves (0.5 – 5 min), or to shear waves and instabilities (5 – 30 min). Setup, *i.e.* the increase in the mean water level due to the presence of wave swell (around 20% of wave height at peak swell), works in conjunction with the tide and wind to produce surges with a mean exceedance (over the wave period) of the high-tide water level. However, the maximum sea level is attained through transitory movements in the swash zone, which is the final interface with land, integrating every transformation of the wave from the time it was generated. Infragravity waves are especially active during storms, increasing submersion risks.

Land-sea exchanges

Because currents on the coast and at sea have distinct scales and dynamics, they are usually measured and modelled separately, implicitly suggesting that there is little interaction between them. The study of continental shelf and offshore interchanges has developed widely over the last 15 years, but this is not the case for continental shelf/shore interchanges. Yet recent work has proven that bringing these historically distinct areas of study together can be very useful. For example, the stratification and vertical shear of currents are often neglected in studies of the shore area, as is the Coriolis Force. Nonetheless, three-dimensional processes appear to enable offshore propagation of eddies and facilitate exchanges between the shore and the continental shelf.

Hydro-morphodynamics

Finally, we cannot consider the coastal zone without referring to morphological changes, especially on sandy coasts (which account for 70% of coastlines in the world). The shoreline constantly adapts to very variable oceanic forcing and a balance is rarely, if ever, achieved. In turn, coastal morphology affects hydrodynamics. For example, the impact of a storm will be different if it comes on the back of another one, with natural self-protection mechanisms such as the formation of offshore sand bars, which dissipate wave energy. The shore areas are naturally resilient to oceanic climate change (waves and sea level), a quality that is considerably threatened by human developments (cf. V.15).

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AGATHE EUZEN
FRANÇOISE GAILL
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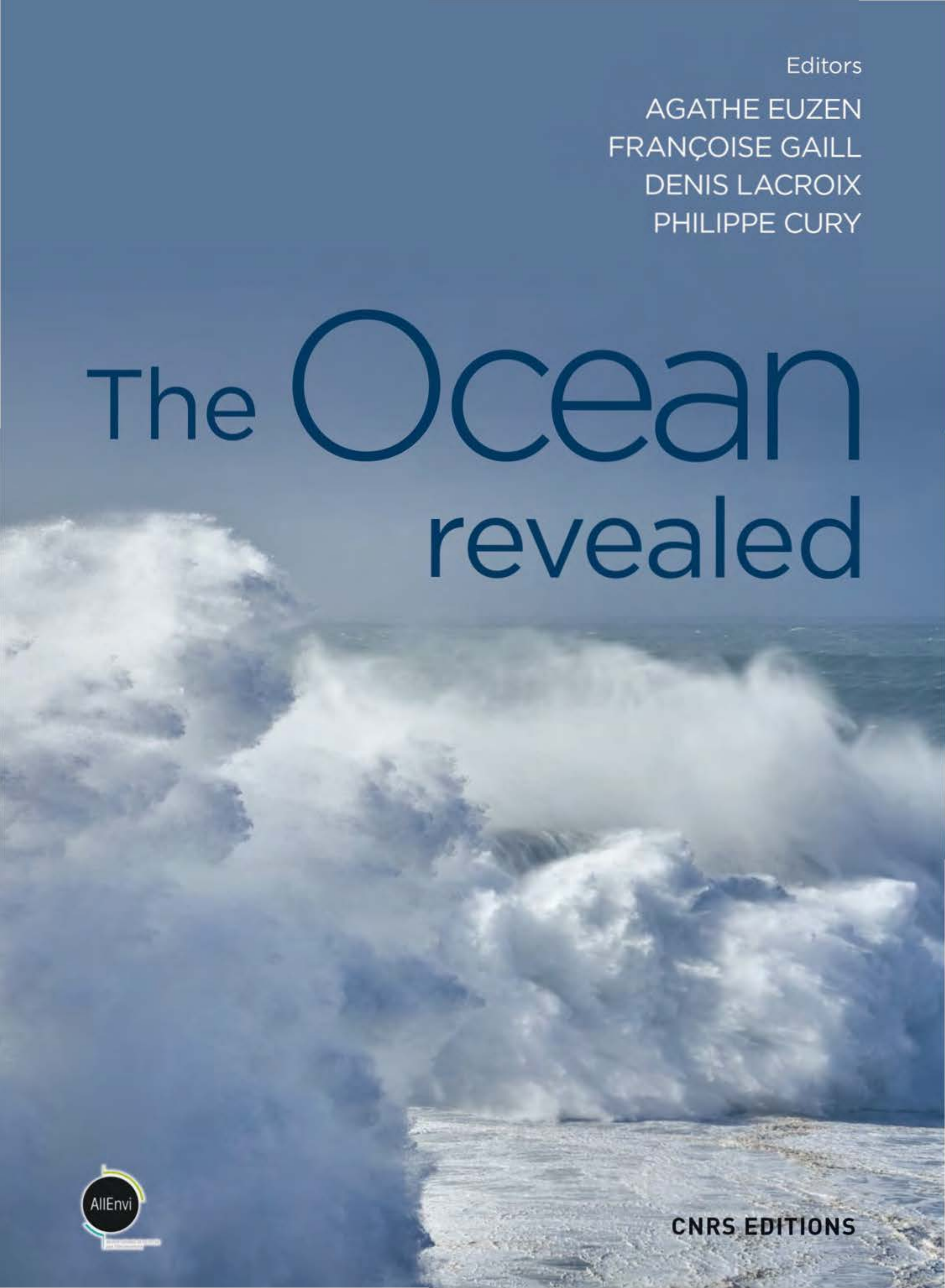
The Ocean revealed



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