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Mesoscale Coastal Behavior of a Deltaic Barrier Island: Storm-Driven Evolution and Morphodynamic Feedbacks

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Barrier islands and spits are among the most dynamic and vulnerable coastal features. Sacalin formed at the southernmost Danube mouth (Sfântu Gheorghe arm), representing the youngest downdrift island/spit of the Sfântu Gheorghe deltaic lobe, which previously formed several similar downdrift barrier islands during its cyclic pattern of long-term development (1400 BP – present). In this study, we document a 120 yr record of coastal changes that occurred since the emergence of Sacalin Island (1897), following a major flood, occasioned by its development through constant elongation (towards south) and backwards migration. The barrier island/spit is frequently breached in the central part (narrow inlets) and it experiences episodes of large elongation and retreat rates (up to 300 m/year and 60 m/year).
Using successive georeferenced maps, satellite images and field measurements, we derived several morphodynamic indices which were analysed in correspondence with the storm climate. The coastal storms temporal variability shows four active intervals (1962-1972, 1975-1977, 1995-1998, 2002-2004) with highly intensive erosional and accretional processes, and three calm periods (1989-1994, 1999-2001, 2005-2015), with a decrease of 40-70 % of the shoreline migration rates. On the other hand, the successive barrier configurations show a distinct evolutionary pattern of its central sector, controlled by the (subaerial) barrier widths. Thus, following an extraordinary high storm (or storm season), the narrower barrier sectors will benefit from a new generation of breach deposition and washover fans. They will further contribute to the reconfiguration of the barrier on a backward position, where it attains significantly larger widths (250-500 m for the subaerial part) which for a while will inhibit the new large overwash formation able to expand the barrier into the lagoon. After such a "widening episode", the time intervals of barrier backline stability (i.e. unaffected by overwash) are of 10-30 years, depending on the storm climate. Therefore, the multi-decadal transformations of the central Sacalin depend on the interplay between storm regime and barrier widths, which points to a major influence of the morphodynamic feedbacks in modulating the storm morphological impact and imposing a rhythmic evolution of the barrier, with the narrow sectors becoming wide and vice-versa.
Nevertheless, large oscillations in storm regime may induce unusual barrier morphodynamics. It was the case of the last calm interval (2005-2015), in fact an exceptional negative anomaly, when the storm frequency decreased to half of the multi-decadal average. As a consequence, the formation of washover fans was inhibited and restricted to only a few small-size fans, contributing to the unprecedented central barrier narrowing. In these conditions, during 2012-2013 winter, an atypical southern storm (December 2012), very short but intense, produced a high storm surge which caused massive overtopping in the central part of the spit, favoured by the small width of the island in this sector, creating an exceptional large breach (of ca. 2 km). In the next two months, even low storms enlarged the breach, transforming it into the biggest breaching (3.5 km wide) ever recorded in more than 100 yr of Sacalin evolution. This case documents how a prolonged low storminess interval may trigger barrier island destabilisation or even destruction.