MECHANISMS UNDERLYING THE FORMATION OF CROSS-SHORE PARALLEL TIDAL CHANNEL SYSTEMS

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INTRODUCTION
Worldwide, tidal channel systems exhibit various planform morphologies, including dendritic, distributary, braided, interconnected, and parallel channels. Among these, complex dendritic channel network systems have been extensively studied, with a focus on their remarkable tree-like morphology and associated scaling properties. In contrast, parallel channel systems that are prevalent in many coastal and estuarine environments worldwide, have received comparably little attention (Hughes, 2012; Perillo, 2019).

METHODS
We conducted comprehensive morphological analyses of 275 parallel channels selected from 20 sites worldwide, encompassing diverse geomorphological settings, including estuaries, lagoons, and open coasts. Moreover, to gain deeper insights into the physical processes underlying parallel channel inception, we performed morphodynamic simulations to disentangle the influence of alongshore tidal currents and bed topography.

RESULTS AND DISCUSSION
Different from the distributary channel networks in river deltas, whose mean bifurcation angle is close to 72°, our analysis reveals the presence of two distinct groups of parallel channel systems according to channel angles. The first group consists of channels characterized by both the mean intersection angles α and the mean trend angles β close to 90º. We will refer to these channels as “perpendicular channels”. The second group comprises channels that exhibit greater variability in angle measurements, with mean intersection and/or trend angles falling outside the 80°-100° range and typically being smaller than 90°.
In agreement with the observation of various natural systems worldwide, our model results demonstrate that parallel tidal channels can be formed by a combination of alongshore tidal forcing and alongshore uniformity in bed topography (e.g., similar bed profile shape and local topographic relief magnitude in the alongshore direction). The creeks present on fringing tidal flats originate at the transition zone between the milder-slope upper and steeper-slope lower flats where the highest ebb velocities and largest velocity gradients tend to occur. The parent channel provides a conduit for the alongshore flow constrained within the banks, and the lateral gradient of bed elevation controls the bend of the flow direction. Therefore, parallel tidal channels usually occur as “first order” branches of a parent channel, while for sub-branches, the local bed geometry, local topographic relief, and flow field are often not uniform alongshore and thus do not meet the prerequisite of the formation of parallel sub-channels. In fact, individual parallel channels may further branch into lower-order creeks, preferentially with dendritic patterns, because the condition of the alongshore uniformity is not satisfied anymore. The alongshore uniformity of the bed topography and the magnitude of local topographic relief may also influence the drainage processes on the tidal basin and the spacing of channel systems, which need further analysis in the future.

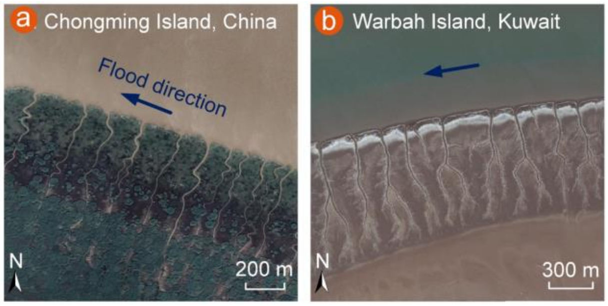

Figure 1 - Examples of parallel tidal channels

CONCLUSIONS
We investigate the mechanisms by which alongshore tidal currents generate cross-shore parallel tidal channels. Through analysis of a large number of satellite imagery from coastal regions worldwide, we find that parallel channel branches often intersect shorelines or parent channels at near 90° angles, distinct from typical dendric tidal or fluvial channel networks. Numerical simulations demonstrate that this characteristic channel orientation arises from the abrupt turning of alongshore currents at the interface where a sudden change in bed elevation occurs. This flow pattern is dictated by a friction-dominated tidal regime under shallow water. The turning of alongshore currents is pronounced where the transition in bed elevation around the mean sea level are sharp. In contrast, gradual profile shapes lead to smoother flow transitions and channel intersection angles less than 90°. We suggest that alongshore uniformity in bed topography, hydrodynamic forcing, and local topographic relief govern the pervasive regularity of parallel channels, especially near lower-order channels adjoining major tidal conduits. This work provides insight into factors controlling observed morphological variability in channel networks around the world and aids in the management and preservation of tidal environments.

REFERENCES
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