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On the Origin and Generation Mechanism of Large-Scale Vortices in Tidal Estuaries

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Abstract: ***Large scale vortices in strong tidal currents have been found on the tranquil sea surface at Western Port, Melbourne, Australia. Aerial observation of dye patches reveals sometimes remarkably regular honeycomb arrangement in a manner in which they are distributed over the sea surface. In the field, flow visualization by two color dye patches, and sea bed survey in terms of a side-scan sonar have been done, while in the laboratory, extensive towing experiment has been conducted to demonstrate the constant, accelerated and/or decelerated flows over each dune model for simulating cycle of tidal currents. On the basis of field and laboratory experiments, the nature, origin, and generation mechanism of the vortices are scrutinized. In general, it is possible that vortices on the sea surface have various origins such as thermal convection (Bénard cell) and wind shear stress (Langmuir cell). Contrary to these ordinary origins of vortices, it has been concluded that they are generated by the interaction of tidal currents and sand dunes at singular time: When tidal currents change from acceleration to deceleration and vice versa, the fluid body in the re-circulatory flow region (cavity) behind each dune crest is changed into a pair of vortices by being ejected. Then, the paired vortices are transported to the sea surface in experiencing a series of change in the structure, and finally form the cellular vortices on the sea surface. It is inferred that this new finding is critical to understand any oscillating flow over the roughness with the separation in nature and laboratory accompanying the cyclical change from acceleration to deceleration and vice versa.***

Keywords: Cellular Vortex, Tidal Current, Cavity, Oscillating Flow, Dune, Turbulence.

Introduction

Well over the last 50 years, it has been known by fishermen, seamen, oceanographers and others in Japan, USA, Italy, UK, and/or Norway that intriguing vortices similar to Bénard cell appear on the tranquil sea surface of estuaries. This enhances us to investigate into those vortices at Western Port, Australia.

Observation made during dye release has shown the existence of large-scale vortices in strong tidal currents as shown in Fig.1(a). These observations, made in tidal estuaries in Western Port, Australia by Hinwood and his students (Pollock, 1973; Chandler & Berzkalns, 1977: Nakagawa & Hinwood, 1978; Hinwood, 1978; Nakagawa, 1979a) have been extended by the study of aerial photographs of bays and tidal inlets in other Australian States, Delaware Bay, U.S.A, Naruto Strait in Seto-inland Sea, Japan (Fig.1(b)) and so forth. These vortices were coined by anonymous Japanese as 'Uzushio' (Tidal Vortex, 渦潮) in earlier than the tenth-century: In the historical book, named "Tosa Nikki", Tsurayuki Kino(1912) referred to "Uzushio" observed during his journey in 935 returning to Kyoto from Tosa province across the Naruto Strait. Very recently, it is realized that vortices observed at Western Port are quite similar to those at Naruto Strait in their origin and mechanism of generation. This prompts us to investigate the vortices with a renewed interest. Despite the widespread occurrence of these vortices, very little is known about their origin and mechanism of generation. It is evident that the vortices alter the rate of diffusion or dispersion of effluents within the water and may influence the rate of sediment transport and of dissipation of tidal energy, hence a sound understanding of the vortices is essential to the study of flow in estuaries and tidal inlets.

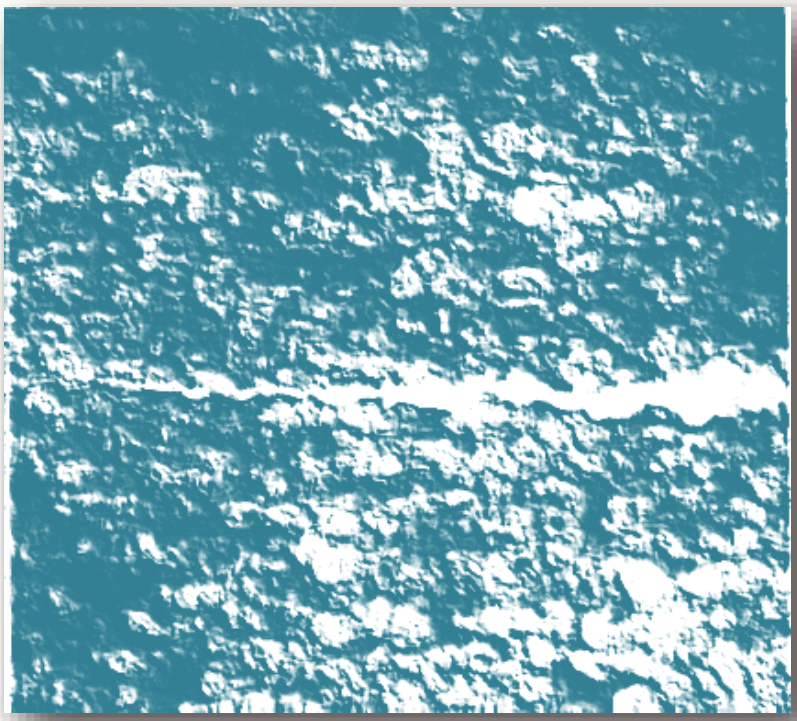
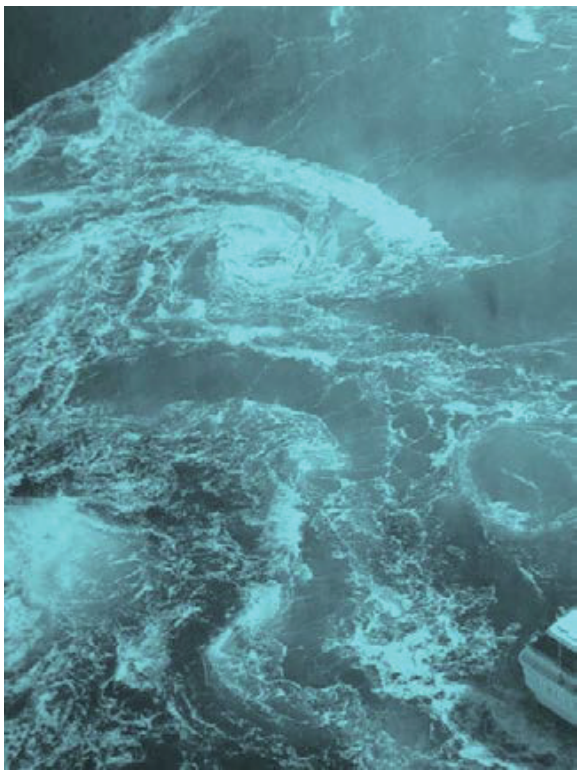


Fig.1(a) Aerial photograph of large-scale vortices in Western port, Victoria, Australia. After Pollock, 1973.



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