Geophysical Research Abstracts,
Vol. 10, EGU2008-A-00476, 2008
SRef-ID: 1607-7962/gra/EGU2008-A-00476
EGU General Assembly 2008

Formation and long-term evolution of beach cusps

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One of the most observed swash zone morphological patterns on coarse-grained beach are beach cusps. For decades, many scientists and engineers have attempted to explain how beach cusp patterns develop and to investigate the formation of beach cusps. Many researchers tried to reconcile the formation of beach cusps with standing edge wave theory, self-organisation theory, or both of them, but these previous works either ignored the role of sediment or simplified the water motion. Following *Dodd et al. (to appear in J. Fluid Mech.)* this study uses process-based morphodynamical equations including nonlinear shallow water theory to simulate beach change in the swash zone in order to understand the long-term formation and evolution of beach cusp patterns.

In this study, we aim to investigate the long-term evolution of beach cusps and to understand the effect of incoming wave conditions on beach cusp formation. Therefore, here we simulate the occurrence of beach cusps started from plane-sloped beach with the different incoming wave periods and beach permeabilities until the beach cusp patterns have formed and have reached an equilibrium stage. The incoming wave conditions and beach permeability induce the variation of swash excursion (S_e) and the reflection coefficient ($|R|$). Then, these components also have an impact on the characteristics of beach cusps (cusp spacing (λ_c) and growth rate (σ)) during the formation and long-term evolution. The predicted beach cusps are not completely regular, so the growth rate needs to be determined using the discrete Fourier analysis to find the dominant wavelength. Then, the growth rate is computed from the logarithm of the absolute value of the Fourier coefficient for the particular mode which corresponds to the dominant wavelength at the final state.

The resulting of cusp spacing and swash excursion allow computation of the constant f of self-organisation theory. The impermeable beach has the same range of f coefficient as *Coco et al.(1999, 2000)*. On the other hand, the permeable beach has slightly higher f than *Coco et al.*'s work. The occurrence of beach cusps at various wave periods can relate with the reflection coefficient. The beach cusps can be found when $|R| < 0.4$, and they disappear when $|R|$ is higher. For the long-term evolution of beach cusps, the permeable beach has more regular cusp formation than the impermeable beach and it can reach the equilibrium stage. These dynamics will be further discussed in the presentation.