Geophysical Research Abstracts
Vol. 20, EGU2018-7140, 2018
EGU General Assembly 2018

Wave and tidal controls on headland bypassing

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Headland bypassing involves the transport of sediment around rocky headlands by wave and tidal action, and is often associated with high energy conditions. Bypassing is a key component in the sediment budget of many coastal compartments, yet the processes involved remain under-researched. This study aims to quantify the primary forcing controls on headland bypassing for a single high-energy, macrotidal headland, including: wave generated currents, tidal currents and water levels. The case study is then used as an example to develop a parameter for headland bypassing that may be more broadly applicable. Currents and water levels were measured off the headland of interest in 18 m and 26 m depth from July to August 2016, and waves were observed by a directional buoy, including a storm with peak significant wave height of 4.5 m. Bathymetry was obtained by merging single-beam and multibeam-echosounder bathymetry, and topographic surveys. Observations were used to calibrate a coupled *Delft3D* morphodynamic model in 2D-mode (Brier Skill Scores $>$ 0.74). The numerical model was run for observed conditions, then for 'zero-tide' and 'zero-wave' scenarios. Additionally, a sensitivity test was conducted for a range (72 scenarios) of wave conditions (height, period, direction) and tidal conditions (springs, neaps, no tide). Wave height was found to be the primary control on bypassing, with flux rates over an order of magnitude greater in storm conditions ($\sim$2000 m^3/day) relative to modal conditions ($\sim$100 m^3/day). Wave direction modulates bypass, with bypass rate a function of the sine of the wave angle relative to shore-normal. Bypassing is minimised for shore-normal waves, and is maximised at high wave angle (which is limited on the observed coastline). For the observed macrotidal beach, water level and tidal currents were significant controls on bypassing rates. Bypassing was mostly restricted to low tide, and a residual northward current (0.2 m/s) strongly biased transport toward that direction, even under an opposing wave direction. A "Headland Bypass Parameter" was developed to estimate sediment volumes bypassing the headland as a function of easily determined boundary conditions: wave height, wave direction and water level. The contributions of waves and water level were effectively parameterised to predict bypass on the observed headland (R^2=0.85). Given further observations, the coefficients of this parameter could be modified to apply to other headlands globally, thus allowing simplified prediction of bypassing rates.