Upslope vs downslope asymmetric bedforms at the head of a submarine canyon

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Sediment transport from shelf to deep ocean is mostly controlled by gravitational flows, but this simple pattern can become more complex in the vicinity of submarine canyons. Here we document uncommon asymmetric bedforms that are interpreted to represent a pattern of both upslope and downslope flows connecting the upper reaches of the Whittard Canyon to the outer shelf on the northern Biscay margin. During the JC125 CODEMAP expedition, funded by ERC Starting Grant 258482 and the NERC MAREMAP programme, high-resolution data were collected from two sandwave fields along the outer shelf adjacent to the head of Whittard Canyon. Data include shipboard MBES bathymetry (5 m res) and sub-bottom profiles, AUV sidescan sonar (0.15 m res), 3 ROV-mounted vibrocores, and 2 box cores, allowing a multi-resolution analysis of the mapped bedforms in both space and time. The sandwave fields are 7 km apart, occur at 170-220 m depth, and display wavelengths ranging from 300 to 700 m and wave heights of 3 to 8 m. One field of well-developed sandwaves has an unusually pronounced upslope asymmetry, facing the shallower regions of the shelf. Contrastingly, the second sandwave field has similar morphometric characteristics but shows a downslope asymmetry, facing the head of the canyon. AUV sidescan sonar mosaics show, with unprecedented quality, spectacular trains of fresh megaripples with an average wavelength of 10 m, overprinting the large sandwaves. The megaripples reflect the same asymmetric trends, suggesting a constant hydrodynamic regime in the region. AUV-derived images also show unusual lenticular features along the wave crests, which have not been described previously. Comparison with a bathymetric grid acquired 15 years earlier does not reveal any significant migration of the sandwaves. Nonetheless, differences in sediment grain size and composition between crests and troughs suggest that the crests may be controlled by active processes. The spatially-variable regime of the internal tide may be one of the mechanisms involved in the generation and maintenance of the mapped sandwaves. Concurrent hydrographic observations within the canyon using an autonomous ocean glider indicate large-amplitude semidiurnal internal tides are present, possibly transitioning to asymmetrical-shaped internal bores in the upper reaches. Moreover, preliminary results from a numerical model of the semidiurnal internal tide within the canyon suggest a dynamic environment with internal tide energy fluxes directed both up- and down-canyon. This work highlights the local importance of uncommon and still not fully characterized sedimentary dynamics, which are likely related to a complex interaction between canyon morphologies and tidally-driven oceanographic regimes. These results challenge traditional notions of gravity-driven processes being dominant in canyon head environments, and have implications for geo-hazard assessment of mobile substrates in outer shelf settings and quantification of offshore sediment and carbon fluxes.