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Sheared free-surface flow over three-dimensional obstructions of finite amplitude

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The surface of flowing water, for example in rivers, is modulated by unevenness in bathymetry. This type of problem was first studied by Lord Kelvin in 1886, assuming small, two-dimensional perturbations and a uniform current profile. Our study analytically examines currents whose unperturbed velocity profile U(z) follows a power law zq above a three-dimensional bed. This particular form of U, which can nevertheless model a miscellany of realistic flows, allows explicit analytical solutions to be obtained.
Three-dimensional vorticity-bathymetry interaction effects are evident in the case of flow over, and at an oblique angle with, a sinusoidally corrugated bed. Streamlines are found to twist and the fluid particle drift is redirected away from the direction of the unperturbed current.
Furthermore, a perturbation technique has been developed which satisfies the bottom boundary condition also for large-amplitude obstructions which penetrate well into the current profile. This essentially introduces higher-order harmonics relative to the bathymetry. States of resonance for first and higher order harmonics are easily calculated and provide an observable relationship between bathymetry, current profile and the shape of the surface.
All expressions are analytically explicit and fast Fourier transformation ensures quick and easy computation for arbitrary three-dimensional bathymetries. A method for separating near and far fields ensures computational convergence under the appropriate radiation condition