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THREE-DIMENSIONAL MODULATION OF TURBULENT SHEAR STRESS OVER OBLIQUE MOVING WAVES

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The objective of this paper is to address the tangential stress at an undulating and oblique moving surface.
This study considers a wave field in near steady-state rather than focusing on the initial growth of surface wave under the action of the local shear flow.
The main interest is, in particular, the local modulation of surface stress along the phases of an underlying long wave profile. This exercise is of prime importance to ocean surface remote sensing since electromagnetic scattering is often correlated with the presence of small surface perturbations and riding upon the background wave. This surface roughness is highly influenced by the local stress acting on the surface. The approach taken is to linearise the Reynolds-averaged Navier-Stokes (RANS) equations including two important generalisations. The first is a second-order expansion in surface slope for the two-dimensional problem. It is shown that, for this second order, the equation reduces to an Orr-Sommerfeld like equation coupled with an Orr-Sommerfeld at first order for the vertical component of the mean flow velocity. Under three-dimensional flows we consider a mere linearisation to first order only because of the complexity of the equations. It is demonstrated that, in this three-dimensional case, the Orr-Sommerfeld equation at first order is now coupled with a second-order ordinary differential equation for the transversal mean flow velocity. These

equations, to second order in surface slope and for three-dimensional flow, are solved by means of the pseudo-spectral method based on Chebyshev interpolants. Recent theoretical papers by Miles(1996) and Cohen & Belcher (1999) are revisited and compared with present results. It appears that both recent theories are inadequate for describing the local stress modulation at the moving surface. The present approach seems more accurate in defining the depth of the constant shear stress sublayer in the inner region.
One direct result of this approach is a clear definition of the amplitude and phase of the surface stress. The model is amenable for generalisation to more complex situations ranging from non-linear expansions in surface slope to three-dimensional flows and to inclusion of higher-order turbulent schemes.