On the over-production of turbulence beneath surface waves in Reynolds-averaged Navier–Stokes models

In previous computational fluid dynamics studies of breaking waves, there has been a marked tendency to severely over-estimate turbulence levels, both pre- and post-breaking. This problem is most likely related to the prevailing exponential growth of the turbulent kinetic energy and eddy viscosity. While this problem has been known for nearly 20 years, a suitable and fundamentally sound solution has yet to be developed. In this work it is demonstrated that virtually all commonly used two-equation turbulence closure models are unconditionally, rather than conditionally, unstable in such regions. A new formulation of the – closure is developed which elegantly stabilizes the model in nearly potential flow regions, with modifications remaining passive in sheared flow regions, thus solving this long-standing problem. Computed results involving non-breaking waves demonstrate that the new stabilized closure enables nearly constant form wave propagation over long durations, avoiding the exponential growth of the eddy viscosity and inevitable wave decay exhibited by standard closures. Additional applications on breaking waves demonstrate that the new stabilized model avoids the unphysical generation of pre-breaking turbulence which widely plagues existing closures. The new model is demonstrated to be capable of predicting accurate pre- and post-breaking surface elevations, as well as turbulence and undertow velocity profiles, especially during transition from pre-breaking to the outer surf zone. Results in the inner surf zone are similar to standard closures. Similar methods for formally stabilizing other widely used closure models (K-ω and K- E variants) are likewise developed, and it is recommended that these be utilized in future RANS simulations of surface waves. (In the above is the turbulent kinetic energy density, is the specific dissipation rate, and is the dissipation.)

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