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LES of Interfacial Dynamics in Air-Sea Systems

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Abstract

Large eddy-resolving numerical experiments for Air-Sea interfacial interactions have been conducted in order to explore the interaction of countercurrent air-sea flows, where the influence of the sea bed over interfacial turbulence has been considered. Results indicate that sea bed streaky structures have an influence in the shape of the *Reynolds stress* tensor on both sides of the interface.

1 Introduction

The interplay between the fluxes of both momentum and mass over the interface of highly stratified, i.e. seawater and air, play a major role in the turbulent mixing and transport of, say, the upper ocean layer and drag, or near-wall behaviour of turbulence of, say, air close to the ocean's free surface. Several researchers, see Fulgosi et al. (2003); Komori et al. (1993); Lombardi et al. (1996); Handler et al. (1993), have made direct numerical simulations related to interface turbulence in highly stratified flows where they have stressed the importance of the interfacial shear due to coherent structures produced in the near-interface region for the exchange processes occuring in large systems like deep lakes and deep oceans. These works have found that as the density ratio between the subdomains that comprise the coupled system rises (up to 900 for air-water coupling), interfacial turbulence motion in the lighter fluid resembles that of wall-bounded flows, where the streak-like coherent structures are driven by the mean shear; on the opposite side, turbulence is largely influenced by horizontal velocity fluctuations which, as shown by Lombardi et al. (1996), hinder 'sweeps' and 'ejections' which are the primary mechanisms for streak formation.

2 Governing Equations, Coupling, and Numerical Implementation

The non-dimensional, space filtered, incompressible Navier-Stokes equations are, in coordinate-free form:

$$\partial\langle\mathbf{u}\rangle/\partial t - 1/Re\Delta\langle\mathbf{u}\rangle + \langle\mathbf{u}\rangle\cdot\nabla\langle\mathbf{u}\rangle + \nabla\langle p\rangle + \nabla\cdot(\langle\mathbf{uu}\rangle - \langle\mathbf{u}\rangle\langle\mathbf{u}\rangle) = \langle\mathbf{f}\rangle$$

$$\nabla\cdot\langle\mathbf{u}\rangle = 0$$

And the interface jump conditions, as described by Delhaye (1973), for the non-iterative substructuring coupling between subdomains can be written as:

$$(1/\mathrm{Re})((\langle\tau_{liquid}\rangle - \langle\tau_{gas}\rangle)\cdot\mathbf{n})\cdot\mathbf{n} + \langle p_{gas}\rangle - \langle p_{liquid}\rangle = 0$$

$$\mathrm{u}_{gas} = (1/\mathcal{R})\mathbf{u}_{liquid}$$

$$\mathrm{R}=\sqrt{\rho_{liquid}/\rho_{gas}}$$

The numerical integration of the *incompressible Navier-Stokes* equations shown above is done via a fractional step method, as in Zang et al. (1994), where spatial derivatives are approximated using centered differences and time integration is carried out using an Adam-Bashford scheme for the advective terms and Crank-Nicholson for the diffusive terms. The unresolved velocity scales $\langle\mathbf{uu}\rangle$ are modelled using a Dynamic Lagrangian Smagorinsky Model, see Sagaut (2006).

3 Conclusions

An invariant analysis of the second-order correlation tensor of the velocity fluctuations shows that turbulence with a rod-like shape produced at the sea bottom does have an influence on the shape of turbulence at the interface towards a more 3-dimensional anisotropic state, and less towards a disk-like shape as shown by Lombardi et al. (1996), thus affecting the ejection-sweep coupling events produced at such interface. This occurs despite the fact that other statistical measures stay unchanged.

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