Abstract View

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Large-Eddy Simulation of the Diurnal Cycle of Deep Equatorial Turbulence

Dailin Wang, James C. McWilliams, and William G. Large

National Center for Atmospheric Research, Boulder, Colorado

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ABSTRACT

The deep diurnal cycle of turbulence at the equator is studied using the technique of large-eddy simulation (LES). Based on a scale-separation hypothesis, the LES model includes the following large-scale flow terms: the equatorial undercurrent (EUC), zonal pressure gradient, upwelling, horizontal divergence, zonal temperature gradient, and mesoscale eddy forcing terms for the zonal momentum and the heat equations. The importance of these terms in obtaining a quasi-equilibrium boundary layer solution is discussed. The model is forced with a constant easterly wind stress and diurnal cooling and heating. It is found that boundary-layer turbulence penetrates as deep as 50 m below the mixed layer during nighttime cooling. The diurnal variation of turbulence dissipation and mixed layer depth are within the range of observations. The gradient Richardson number (Ri) of the mean flow shows a diurnal cycle but the amplitudes decrease with depth. Within the mixed layer and just below the layer, Ri can be lower than the critical value of 0.25 at night. During the day, Ri > 0.25 below the mixed layer. Well below the mixed layer (below about 40 m), Ri is always greater than 0.25 because of the initial vertical profiles of EUC and temperature chosen. However, the flow is still highly nonlinear, or turbulent, as indicated by the order one ratio of fluctuating temperature gradient (root-mean-square) to the mean gradient. The authors find that this deep turbulence cycle from the model is closely related to local shear (or Kelvin–Helmholtz) instability. Distribution of local (pointwise) gradient Richardson number shows a diurnal cycle, which is the cause of the diurnal cycle of turbulence well below the mixed layer as evidenced by high levels of turbulent kinetic energy at local Richardson numbers in the range of [0, 0.25]. Eddy viscosity and diffusivity are computed from the LES solutions and are compared with observationally derived values.

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Headquarters: 45 Beacon Street Boston, MA 02108-3693
DC Office: 1120 G Street, NW, Suite 800 Washington DC, 20005-3826
amsinfo@ametsoc.org Phone: 617-227-2425 Fax: 617-742-8718
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