Lagrangian Floats for CBLAST

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LONG-TERM GOALS

I seek to understand the dynamics of the ocean boundary layer beneath hurricanes and the resulting air-sea fluxes which drive it with the goal of improving ocean models at high wind speed.

OBJECTIVES

To measure turbulence properties and fluxes in the ocean boundary layer beneath hurricanes and relate them to hurricane properties and fluxes measured by others. To model the measured boundary layer properties using Large Eddy Simulation (LES) techniques with the twin goals of testing the models and investigating the boundary layer physics using the models.

APPROACH

Measurements. Neutrally buoyant Lagrangian floats were air-deployed into hurricanes during the 2002, 2003 and 2004 hurricane seasons. The floats are designed to be used in energetic turbulent flows such as those found in the top and bottom boundary layers of the ocean. A combination of accurate ballasting, compressibility matched to that of seawater and high drag is used to make these floats follow the motion of water parcels accurately (D'Asaro 2003). Water velocity is inferred from the motion of the floats; high frequency fluctuations in velocity can be used to infer dissipation rate (Lien and D'Asaro, 2006) and covariance of vertical velocity with scalars can be used to compute heat and other fluxes (D'Asaro, 2004).

Modeling. The LES modeling work is being conducted by Ramsey Harcourt and Eric D'Asaro. Our starting point is a standard LES scheme using a subgrid closure with active kinetic energy as implemented in Harcourt et. al (2002). The standard implementation of vortex force interaction between surface wave Stokes drift (Skyllingstad and Denbo, 1995; McWilliams *et al*, 1997) is modified to simulate the mean Lagrangian velocities measured by floats in the ocean. Careful attention has been paid to the role of surface waves in forcing boundary layer turbulence. This model includes the ability to simulate the trajectories of both perfectly Lagrangian and realistically imperfect floats.

WORK COMPLETED

Work during FY08 focused on finishing the analysis of existing data and synthesizing the results over a wide range of wind speeds including hurricanes. It has been done jointly by Eric D'Asaro and Ramsey Harcourt. The work has focused on two questions:

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14. ABSTRACT
To measure turbulence properties and fluxes in the ocean boundary layer beneath hurricanes and relate them to hurricane properties and fluxes measured by others. To model the measured boundary layer properties using Large Eddy Simulation (LES) techniques with the twin goals of testing the models and investigating the boundary layer physics using the models.

15. SUBJECT TERMS

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- How well can Lagrangian floats measure ocean boundary layer turbulence? Although Lagrangian floats are excellent tools for measuring boundary layer processes, they are imperfect. The major cause of error is the buoyancy of the float, caused either by imperfect ballasting of the float or air bubbles attached to the float. This causes the float to spend more time near the surface and thus biases turbulence statistics measured from the float.

- What do LES models predict for turbulence levels in hurricanes? The prevailing paradigm for ocean boundary layer turbulence is that it is forced by both surface wind and waves. However, we do not have a quantitative understanding of the turbulence properties in such a boundary layer.

Both of these questions were addressed using LES modeling. An ensemble of LES model simulations spanning a wide range of oceanic conditions, including hurricanes, and including forcing by wind and surface waves via the Craik-Leibovich coupling. Lagrangian floats with realistic sizes, virtual masses, drag and a wide range of buoyancies were also simulated as in Harcourt, (2002). The wind stress and wave spectrum were forced to be consistent with the those of a pure wind sea. These simulation results were used to develop scaling laws for both the true properties of the ocean turbulence and the errors in float measurements of these properties. These are the two crucial components to rigorously assessing whether the float observations agree with the simulations. This final comparison will be completed under other funding.

RESULTS

How well can Lagrangian floats measure boundary layer turbulence?

Fig. 1 shows a typical result of many. Neutrally buoyant floats are mixed across the mixed layer by the energetic large turbulent eddies and rapidly become uniformly distributed in depth. Buoyant floats are not uniformly mixed, but rather spend more time near the surface. This biases the average vertical kinetic energy measured by floats high both because the kinetic energy is higher near the surface and because buoyant floats spend more time in the strongest-downward going plumes. Fig. 1 compares this bias, scaled by the measured vertical kinetic energy, to a simple measure of the depth distribution of the floats, the depth skewness. A good correlation exists. Since the skewness is an easily measured quantity, this result can be used to correct real observations. Under hurricane conditions, the skewness, and resulting bias, is typically quite small because the boundary layer turbulent velocities are very high. This adds strength to the previously reported good agreement between the float observations and model predictions in Hurricane Frances.

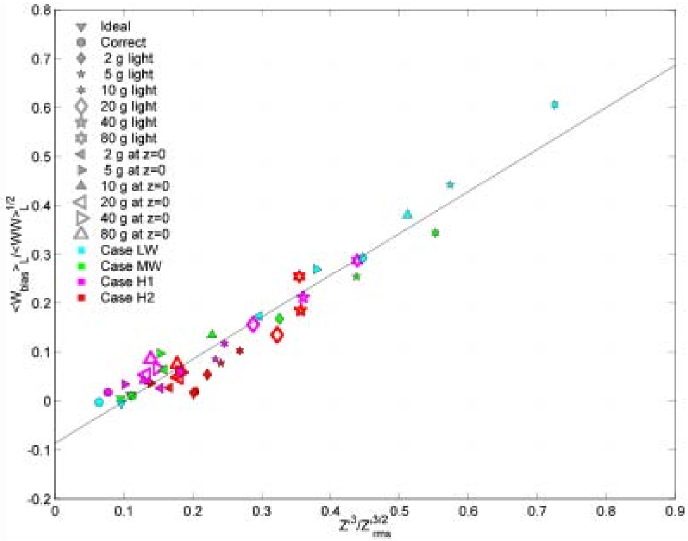

Fig. 1. Bias in float measurement of boundary layer average vertical kinetic energy (vertical axis) as a function of the skewness of float depth (horizontal axis) for floats with upward buoyancies ranging from neutral to 80g both uniformly distributed in depth and surface intensified. Forcing characteristics vary from typical mid-latitude conditions (cases LW and MW) to hurricane conditions (cases H1 and H2). The depth skewness is a good predictor of the measurement error.

What do LES models predict for turbulence levels in hurricanes?

The same ensemble of LES models was used to find scaling laws for the turbulence levels in wind and wave forced ocean boundary layers. The most important result in shown in Fig. 2. The mixed layer average vertical kinetic energy is found to accurately scale with a Langmuir number, the square root of the ratio of surface wave Stokes drift to wind stress, in which change in Stokes drift from the top 25% of the boundary layer to the bottom of the layer is used instead of the more usual surface Stokes drift. These results are also been used to predict the boundary layer turbulence level as a function of wind speed and wave age. These results have been published in JPO.

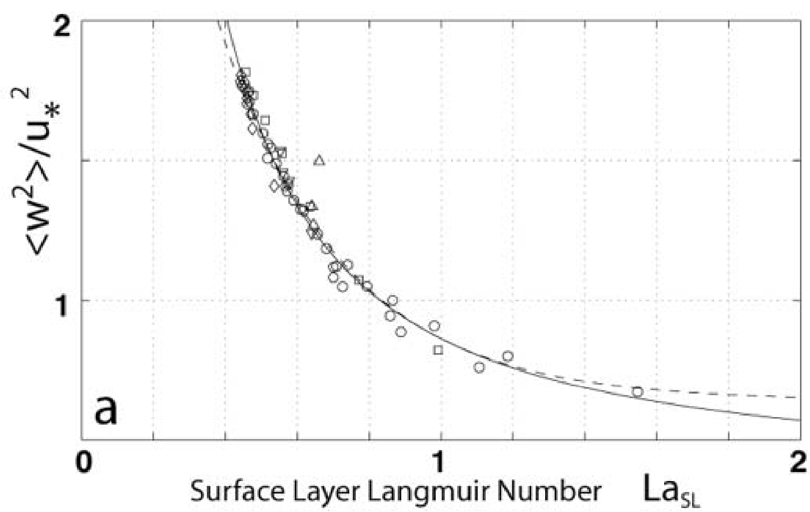

Fig. 2. Mixed layer average VKE from the ensemble of LES simulations scales accurately with the Surface Layer Langmuir number.

IMPACT/APPLICATIONS

The experimental and analysis techniques developed by this grant to study hurricanes continue to be used to study hurricanes under other funding and will be used in the upcoming ONR Typhoon Impact DRI.

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PUBLICATIONS

Harcourt, R, Eric D'Asaro, 2008, Large Eddy Simulation of Langmuir Turbulence in pure wind seas, *J. Phys. Oceanogr*., **38**, 7 pp. 1542–1562, DOI: 10.1175/2007JPO3842.1 PUBLISHED