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ANNUAL REPORT FOR ONR FOR WORK DONE UNDER THE MBL ARI

submitted to G. Geernaert Jan. 20, 1994

Principal Investigator: John C. Wyngaard, Penn State University

Title of proposal: Research in Marine Boundary Layer Intermittency. Total funding $480,069. Duration: 1 July 1992 to 30 June 1995.

Papers submitted: On the response of a turbulent-pressure probe and the measurement of pressure transport. To appear in Boundary-Layer Meteorology, 1994.

Abstract: Wind-tunnel calibrations of turbulent-pressure sensors usually reveal deviations from ideal response. These deviations are typically reported in dimensional form (e.g., in microbars) or as a fraction of the dynamic pressure. Neither presentation gives a direct indication of the reliability of pressure statistics measured in a turbulent flow.

We derive a general response equation for a turbulent-pressure probe. The coefficients in the equation are obtainable from standard wind-tunnel calibration results. The form of the response equation makes it straightforward to relate the errors in measured pressure statistics to the statistics of the turbulence. We demonstrate this by evaluating the reliability of measurements of some important pressure covariances, including the pressure-transport term in the turbulent kinetic energy (TKE) budget in the unstable surface layer. The preliminary finding is that the Nishiyama-Bedard sensor is capable of measuring pressure transport of TKE there to within 10-20%.

Postdocs supported: Keith Wilson, 100%.

Graduate students supported: Andrew Siegel, Meteorology, 100%.

Book chapters published: "Large-eddy simulation in geophysical turbulence parameterization: An overview", with Chin-Hoh Moeng. In Large-Eddy Simulation of Complex Engineering and Geophysical Flows, B. Galperin and S. A. Orszag. Eds., Cambridge, 1993.

Significant presentations: "Effects of fluctuating subgrid-scale stresses on mean velocity profiles in large-eddy simulations of boundary-layer flows", with B. Kosovic and L.J. Peltier, presented at International Workshop on Large-eddy Simulations of Turbulent Flows in Engineering and the Environment, September 26–28, 1993, Montreal.

Major accomplishments:

A. LES CODE DEVELOPMENT

1. We have made improvements in Moeng's LES code that allow it to run faster and use less storage. We have expanded it to a 15 × 15 × 1 km domain, 192 × 192 × 42 grid resolution. Empirical orthogonal function (EOF) analysis of data from runs for nearly neutral conditions shows clear evidence of boundary-layer roll circulations. Their

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contributions to fluxes are being evaluated.

The spectra show that the large-scale roll circulations in the LES slowly decrease in lateral wavelength over many large-eddy turnover times. This suggests that it may not be possible to achieve a strictly statistically stationary state for LES over reasonable integration times.

We have computed one-dimensional bispectra of the LES velocity fields for both the streamwise and cross-stream directions. They show that the bicoherency is much higher in the cross-stream direction. The meaning of this result is currently being studied.

2. In an attempt to improve the traditional drag-law formulation in LES, we have derived a conservation equation for the subgrid-scale temperature flux near the surface. It (and its extensions to momentum and mass) contains the physics of the surface exchange coefficients and, hence, is the basis of a "dynamic drag law". We are studying key terms in this equation with data from surface-layer experiments.

3. A variable-mesh LES (with higher resolution near the surface) has been written and is currently being debugged.

B. ASSIMILATING AIR-SEA INTERACTION PHYSICS

1. We are studying the inclusion of the wavy, time-dependent air-sea interface into the "dynamic drag law" formulation described in A2 above.

2. We are studying the intermittency of heat fluxes in the marine surface layer off Scripps pier with wavelet-transform techniques. Preliminary results indicate that

a) Over 75% of the heat flux is contained in several highly concentrated regions in wavelet space corresponding to structures of 10 to 300 m scale. This is only weakly sensitive to the wavelet basis. The concentration of momentum fluxes is less extreme and agrees well with the Mahrt-Howell findings (JFM, 1994).

b) The wavelet coefficients are comparably non-Gaussian in the Scripps pier data and in the LAMEX data over land.

C. INTERACTIONS WITH OTHER GROUPS

1. With J. Wilczak of NOAA/WPL we completed an analysis of the dynamical response of the Nishiyama-Bedard pressure probe. We found that it can measure turbulent pressure statistics in the surface layer with good accuracy. Thus, it should be a valuable addition to the air-sea interaction experiments planned under the MBL ARI.

2. We are analyzing terms in the "dynamic drag law" equation with turbulence time series obtained from surface-layer experiments carried out by NCAR/ATD.

3. We are complementing NCAR's efforts in surface-layer LES mesh refinement with two efforts, one using a increasing number of horizontal Fourier modes near the surface, and (through interactions with our URI program at Penn State) one using a one-way nested grid in the surface layer.

4. We are analyzing a number of LES data sets from NCAR with EOF techniques, searching for large, characteristic structures.

5. We obtained data sets from the Scripps pier and LAMEX experiments through L. Kristensen and Finn Hansen of Riso.

Key words describing research: turbulence, air-sea interaction, large-eddy simulation, intermittency, atmospheric boundary layer, roll vortices.

New research areas identified:

1. We did some preliminary experimentation with auto-regressive and maximum entropy techniques for extending two-dimensional fields to smaller scales. We believe these have potential in subgrid-scale parameterization if their effect on the energetics can be clarified.

2. We have encouraging evidence that averaging of time series can be an adequate surrogate for the horizontal area averaging required in the dynamic-drag law theory discussed in A2 above. This opens the possibility that conventional, in-situ turbulence measurements in the marine surface layer can be used to develop a dynamic drag model.

Papers published in non-refereed journals: none.

Technical reports: none.

Books published: none.

Patent applications: none.

Honors and awards: none.