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13. ABSTRACT *(Maximum 200 words)*

Research investigations on the interaction of surface waves, wind and currents in stratified ocean layers have been carried out. The research program involves the development of appropriate models for general physical situations (e.g., systems of coupled nonlinear partial differential equations) as well as the analysis of these models for certain specific problems such as Langmuir circulations and double-diffusive convection. During the period of the report, two papers were published and four papers were accepted for publication. Some of the results obtained and the methods used in these papers are outlined in this report.

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Subtitle: **Langmuir Circulations in Ocean Surface Layers**

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I. Summary of Research Activities.

(1) Various Couette-Poiseuille problems for viscous spiral flows were considered in [1] (see the list of publications in part II below). Periodic waves were shown to exist and their expansions were obtained to lowest order. The existence of periodic waves in such problems had been conjectured but never proved.

(2) The bifurcation and stability properties for rotating plane Couette flow were obtained in [2] and [3]. These are the first results on the bifurcation and stability properties of viscous spiral flows. Results of the type obtained provide the only qualitative explanation to date for the occurrence of turbulent-like flows in well-known experiments on rotating plane Couette flow. New methods involving singular operators were developed in [2] to solve the problem and a more general approach using center manifolds was developed in [3].

(3) A general method for reducing certain singular problems for Navier-Stokes type equations to regular finite-dimensional Hopf bifurcation problems is described in [4]. The method is based upon singular implicit function theorems in infinite-dimensional spaces.

(4) The basic equations for wind-driven, double-diffusive convection in ocean surface layers were derived in [5]. A set of coupled partial differential equations was obtained that describes the interaction of surface waves, wind, ocean currents and the diffusivity of temperature and concentration as a single system driven ultimately by the wind. In the case of rolls when the Rayleigh numbers for heat and solute are sufficiently small, it was shown that the basic state always undergoes Hopf bifurcation losing stability to an asymptotically stable, periodic traveling wave. The presence of such traveling waves, in turn, leads to traveling wave corrections to the density in the layer. Thus, various physical models for ocean surface layers based upon constant layered density properties (e.g., certain acoustical models) may have to be re-evaluated in physical situations in which there is a mean current present that is not aligned with the wind.

(5) The basic equations for Langmuir circulations in upper-ocean mixing problems when the Stokes drift has a cross-wind component were developed and analyzed in [6]; the set of partial differential equations were derived from a rational model that describes the development of mean currents and Langmuir circulations as a single system driven by a prescribed wind stress and a prescribed surface wave field. In special situations where there is no cross-wind component of the Stokes drift and one seeks only roll-like solutions independent of the wind direction, the equations in [6] reduce to those derived previously by other investigators. The equations in [6] are derived by the use of multiple time scales related to the relative magnitudes of surface waves, wind and currents. The results in [6] provide the only rational theoretical explanation to date of observed phenomena in Langmuir circulations such as cross-drift of Langmuir cells and the rapid breakdown of Langmuir cells under a change in wind direction.

II. Publications and Papers Accepted for Publication.

The following papers were published or accepted for publication during the period of the Progress Report. Preprints and reprints have been forwarded to ONR.

[1] *Symmetry in rotating plane Couette–Poiseuille flow*, (with George H. Knightly), Lectures in Applied Mathematics, Vol. 29, Exploiting Symmetry in Applied and Numerical Analysis, (E. Allgower, et al., eds.), American Mathematical Society, Providence, 1993, 299–306 (refereed article).

[2] *Singular Hopf bifurcation problems and rotating-sliding spiral flows* (with G. Knightly), Inequalities and Applications, (R. Agarwal, ed.), World Scientific Publishing Co., Singapore, 1994, 345–360.

[3] *Continua of periodic waves in rotating plane Couette flow* (with G. Knightly), European J. Mech. B/Fluids, 1994, 16 journal pages (in press).

[4] *Reduction of a singular equation of Navier–Stokes type to a regular Hopf bifurcation problem* (with G. Knightly), Proceedings Volume for the International Conference on Advances in Geometric Analysis and Continuum Mechanics (K. Lancaster, ed.), International Press, 1994, 10 pages (in press).

[5] *Wind-driven, double-diffusive convection in ocean surface layers* (with G. Knightly), Proceedings of the Chapman Conference on Double–Diffusive Convection (A. Brandt, ed.), American Geophysical Union, Washington, D.C., 1995, 20 pages (to appear, refereed article).

[6] *Langmuir circulations when the Stokes drift has a cross-wind component* (with G. Knightly), Arch. Rational Mech. Anal., 1995, 37 manuscript pages (to appear).

III. Invited Symposia Lectures.

Chapman Conference on "Double–Diffusive Convection," sponsored by ONR and the American Geophysical Union, Phoenix, November 3–6, 1993.