EUTROPHIC WATER BODY

T. YUAN, J. C. LI and J. F. ZHOU, *Institute of Mechanics, CAS, China*, In eutrophic waters, phytoplankton or unicellular microalgae can grow rapidly to very high concentrations under favorable environmental conditions, occasionally resulting in harmful algal blooms. This kind of extreme environmental events have been worsening marine ecosystems and causing great economic loss. A dynamic eutrophication model is described to simulate algal growth and nutrient cycling during algal blooming in the present paper. It involves crucial influential factors including water temperature, nutrient supply and light density. Moreover, it takes non-predatory mortality, endogenous respiration and settling into consideration as controlling factors for alga decay. We have endeavored to elucidate the influence of some of these factors on algal blooming including temperature and the two crucial nutrient factors (P, N) by numerical results. In addition, nonlinear qualitative analysis is used to study the mechanism of the algal blooms occurrence. To begin with, we only focus on the examination of the most important nutrient element, phosphorus (P) effect. Based on numerical simulations, the threshold of phosphorus at different temperature may be delineated by the 3D isoquant contours of algal growth rate. It is apparently seen that the larger the phosphorus concentration, and the higher the water temperature, the greater the algal growth rate is, which may explain why alga blooming disasters are prone to occur in polluted water body in a fine summer day. Furthermore, the threshold is reduced when half-saturation constant K_{MP}, a parameter to indicate algae ability to digest nutrient, decreases. The result means that such kind of algae with smaller half-saturation constant grows faster and very probably becomes overwhelming species during algae blooms. The analysis on the phase plot clearly exhibits nonlinear behavior of the system during the process and further verifies the conclusions drawn by numerical simulation. Then, an additional nutrient element, namely nitrogen (N) is involved. Both nonlinear analysis and numerical simulation demonstrate the influence of the initial N/P ratio on the nutrient limitation. Three regions of nitrogen limitation, transitional and phosphorus limitation are identified as the ratio of N over P is rising. In the water body having higher ratio, phosphorus becomes a crucial factor and the algal growth is mainly limited by less supply of P. However, the role of N can't be neglected any more as this ratio drops. The fact means that P limitation is gradually replaced to N limitation, which is in accord with what was found by Sakamoto. In summary, we have investigated the effects of ambient water temperature and nutrients supply on algae blooming. In addition, half-saturation constant is also a decisive factor affecting algae blooming and selecting overwhelming species. Usually phosphorus is a decisive nutrient though, the role of nitrogen should be considered when the ratio of N over P drops to a certain amount in this kind of marine ecosystem disaster.

W-4E-3. A NUMERICAL STUDY OF THE ROLE OF VERTICAL STRUCTURE OF VORTICITY DURING TROPICAL CYCLONE GENESIS

T. N. VENKATESH, *National Aerospace Laboratories, Bangalore, India,* J. MATHEW, *Indian Institute of Science, Bangalore, India,* Understanding the processes leading to tropical cyclone genesis presents a challenge to fluid dynamicists. Of particular interest is the role of mid-level vorticity during early stages of cyclone genesis. An eight-level axisymmetric model with simple parameterizations for clouds and the atmospheric boundary layer was developed to examine the evolution of vortices that are precursors to tropical cyclones. The effect of vertical distributions of vorticity has been studied. To obtain a reasonable representation of the flow structure and physics, axisymmetry is assumed and hydrostatic and gradient wind balance approximations made. The effects of clouds, radiation, boundary layer and sea-surface are parameterized. The prognostic equations in the interior for the azimuthal velocity and the saturation equivalent potential temperature are solved. A Poisson equation is solved for the secondary flow. Non-linear terms are integrated using the second-order Adams-Bashforth scheme and the diffusion terms treated implicitly. The basic model has been validated with analytical results available for the spin-down of vortices. With the inclusion of the cloud and boundary layer parameterizations, the evolution of deep vortices into hurricanes and the subsequent decay is simulated quite well. The finite amplitude nature, dependence on various parameters, like sea surface temperature, Coriolis parameter, initial vortex strength etc. have been studied and these compare well with other simulations. The novel feature of this study is that the evolution of mid-level vortices has been studied. A new finding is the manner in which mid-level vortices decay and how, on simulated merger of these mid-level vortices, the resulting vortex amplifies to hurricane strength in a realistic time-frame. These results form an important part of the evidence in favour of the authors' model for tropical cyclone genesis.

W-4E-4. IN WHAT SENSE IS A LOW-REYNOLDS MIXING LAYER STABLE?

Roddam NARASIMHA, Pinaki BHATTACHARYA, Rama GOVINDARAJAN, *Engineering Mechanics Unit, JNCASR, Bangalore, India*, The Orr–Sommerfeld equation governs the evolution of linear disturbance modes in a strictly parallel flow. For the plane incompressible mixing-layer this equation yields a critical Reynolds number equal to zero [1]. This result has been difficult to understand for a long time, for 'energy' theories indicate that there must be a non-zero Reynolds number (however small), below which viscosity would damp out any disturbance. Recently, we have used a non-parallel analysis to show that the critical Reynolds number *R*cr for the mixing-layer is not zero [2]. When expressed with the velocity difference D and vorticity thickness __ as velocity and length scales respectively, it is found that *R*cr is about 30. The analysis therein follows the minimal composite theory developed in [3]. We investigate here the physical behaviour of the disturbance kinetic energy in order to gain insight into the character of the stability of the flow. The mean flow in the incompressible mixing-layer we consider possesses a similarity solution. We simulate the flow as it might be observed in a wave-maker experiment. To this end a single disturbance mode, of dimensional frequency _*d*, is introduced into the flow at an appropriate station. The local kinetic energy density of the disturbance, averaged over one period, is denoted by <*kd*>, and fixing the amplitude level of the disturbance to be *A*0 at the location where it is introduced, we further define $\kappa \equiv \frac{\langle k_d \rangle}{|A_0|^2\Delta^2}$, as the non-dimensional disturbance kinetic energy. Two integral quantities are also defined as follows

$$K = \int_{-\infty}^{\infty} \kappa \, \mathrm{d}y,$$

$$\overline{K} = \int_{-\infty}^{\infty} \kappa \, \mathrm{d}\left(\frac{y_d \Delta}{\nu}\right), \qquad \frac{1}{\overline{K}}\frac{\mathrm{d}\overline{K}}{\mathrm{d}x} = \frac{1}{K}\frac{\mathrm{d}K}{\mathrm{d}x} + \frac{p}{R}.$$

where *p* is a constant depending on the velocity ratio parameter L = D/(2U_−D). As illustration we show the contours of _ in the two extremes of L = 49/50 and nearly shearless flow L = 1/39 is shown in figures 1 and 2. It is apparent that upstream (/downstream) of the streamwise location corresponding to R _ 39, there is hardly any streamline in the core of the flow along which energy decays (/grows) in the streamwise direction. Thus the picture is intuitively faithful to the concept of stability (/instability). For the same flows and the same frequency _d considered above, the variation of the two integrated kinetic energies is shown in figures 3 and 4. We see that *K* decays upto *R* _ 30 and then amplifies, but at a relatively slow rate. On the other hand amplifies monotonically at all *R*. These results show that the integral over *yd* grows continuously from very low *R*, and hence points towards instability. On the other hand integral *K* over the similarity coordinate y shows stability upto *R* _ 30. It is in this sense that the mixing-layer has a non-zero critical Reynolds number. Thus the maximum disturbance kinetic energy density _max may drop substantially over a given streamwise extent of the flow (figure 1), but its integral in *yd* may increase if the flow is rapidly thickening (see figure 3). Stability thus depends on how the norm is defined.

15:00 ~ 16:20 (Room106)

Convection and Buoyancy – Driven Flows (II)

Session Chair : Prof. K. Mansour, Amirkabir Univ of Tech/Iran

W-4F-1. OBERBECK CONVECTION IN CHIRAL FLUID THROUGH A VERTICAL CHANNEL IN THE PRESENCE OF TRANSVERSE MAGNETIC FIELD

NAGARAJU, *Department of Mechanical Engineering, Siddaganga Institute of Technology, Tumkur, India* B. M. RAJPRAKASH, *Department of Mechanical Engineering, University Visveswaraya College of Engineering, Bangalore, India* N. RUDRAIAH, *National Research Institute for Applied Mathematics, Bangalore, India,* Conventionally, fans and regular fluids are used to improve the cooling process in mechanical, electrical and electronic devices but they increase the device weight, size and bulk. These days the industries are changed to find the miniature and portable devices for this purpose. Therefore, there is an urgent need of suitable materials to overcome these thermal problems. At present nano and smart materials are becoming popular for use in such cases. As an alternative to these materials we propose in this paper the use of chiral material. At present solid chiral materials have been used to manufacture devices like antennas, but much attention has not been given to chiral fluids like turpentine, sugarcane solution, body fluids and so on. By definition chiral material is one which cannot be brought into congruence by its mirror image by translation and rotation having the property of either left-handed or right-handed, which can be efficiently used for cooling purposes involving effective heat transfer. The Oberbeck convection arising when temperature gradient is applied perpendicular to gravity in ordinary fluid saturated porous media has been investigated but much attention has not been given to its study in chiral fluids through a vertical channel in spite of its applications in many practical problems. The study of it, in the presence of transverse magnetic field, convective current and viscous dissipation, is the objective of this paper. The governing equations are solved analytically using regular perturbation method valid for small values of buoyancy parameter N. The velocity and temperature, mass flow rate, skin friction and rate of heat transfer are obtained for various values of electromagnetic thermal number w_1. We found that an increase in w_1 increases the velocity and the effect of N is to decrease the skin friction, heat transfer and the mass flow rate.

W-4F-2. EXPERIMENTAL INVESTIGATION ON MICRO HEAT PIPES OF DIFFERENT CROSS-SECTIONS HAVING SAME HYDRAULIC DIAMETER

S. L. MAHMOOD, *IUT, Bangladesh,* M. A. R. AKHANDA, *IUT, Bangladesh,* Effect of micro heat pipe (MHP) cross-sections and orientations on its thermal performances are experimentally investigated in this study. Evaporator section of MHP is heated by electric heater and the condenser section is cooled by water circulation in an annular space between condenser section of MHP and water jacket. Temperatures at different locations of MHP are measured using five calibrated K type thermocouples. Heat supply is varied using a voltage regulator which is measured by a precision ammeter and a voltmeter. Tests are conducted using five different cross-sections (circular, semicircular, elliptical, semi elliptical and rectangular) of micro heat pipes having same hydraulic diameter of 3 mm placed at three different inclination angles (0º, 45º, 90º). Among all cross-sections of MHP circular cross-section exhibits the best thermal performance followed by semi elliptical, semicircular, elliptical and rectangular cross-sections. Moreover, maximum heat transfer capability tends to deteriorate as the flatness ratio is increased. Maximum heat transfer capability also decreases with decreasing of inclination angle. This implies that the action of gravity, which serves to speed up the flow of fluid from condenser to evaporator increases with increasing of inclination angle. A correlation is developed using all the gathered data of the present study to predict the heat transfer coefficient of micro heat pipes of different cross-sections placed at different inclination angles which correlates all the data within $\pm$7%.

W-4F-3. PLANFORM PLUME STRUCTURES IN HIGH RAYLEIGH NUMBER HIGH PRANDTL NUMBER NATURAL CONVECTION

Vivek N. PRAKASH, K. R. SREENIVAS, *EMU, JNCASR, Bangalore, India,* Jaywant H. ARAKERI, *Mechanical Engineering Dept., IISc, Bangalore, India,* High Rayleigh number (Ra) convection is important both in natural processes like in mantle-convection, atmospheric convection and in engineering applications like metallurgy. Very high Prandtl number (Pr) limit will be relevant in the geophysical context like mantle convection (Pr of the order of millions is common). Convection in the Earth's Mantle is responsible for volcanism, plate-tectonics and orography. The condition under which Rayleigh-Benard Convection (RBC) occurs in the mantle corresponds to a large Rayleigh number and in a medium of large Prandtl number. We are also motivated to study RBC in the limit of large Pr and high Ra to develop and extend the validity of the existing Nu-Ra correlations to the high Pr range. Using concentration difference to drive the convection, we simulate large Rayleigh number convection and study the effect of Prandtl number on the dynamics of convection and its structures. We create a viscosity contrast between the two fluid systems having different densities to mimic Mantle convection. The Ra covered in the present study are in the range of 10^9 to 10^{11} and Sc are in the range of 10^3 to 10^5. At low Sc, the near-membrane flow structures consist of line plumes. The planforms of these line plumes show a marked change in morphology as the viscosity of the upper fluid layer is increased. With the increase in viscosity the plume spacing increases and also there is a transition from line plumes to discrete blobs. We believe that the analysis of these planform convection structures leads to a better geophysical understanding of the dynamics of convection in the mantle offering better explanations to plate tectonics and the distribution of orographic features like hotspots on the surface of earth.

W-4F-4. A NUMERICAL SIMULATION OF HEAT TRANSFER FROM A CIRCULAR CYLINDER IN TURBULENT FLOW

Mohsen SAGHAFIAN, *Department of Mechanical Engineering, Isfahan University of Technology, Isfahan, Iran,* In this paper, heat transfer from a circular cylinder has been simulated numerically in sub critical Reynolds numbers. A nonlinear eddy – viscosity model with some adjustment is used, assuming incompressible and two dimensional flow. Local and averaged Nusselt numbers are presented and compared to experimental and other numerical results from the literature. The model can predict front stagnation region Nusselt number quite well but over predicts local Nusselt number in the wake region.