Monday, August 18

Plenary Lectures & Invited Lectures

PL-1. MECHANISMS OF CORE PERTURBATION GROWTH IN VORTEX-TURBULENCE INTERACTION

F. HUSSAIN and D. S. PRADEEP, *Department of Mechanical Engineering, University of Houston, Houston, TX, USA,* We study mechanisms of coherent structure decay via direct numerical simulations (DNS) of a vortex column interacting with external, fine-sale turbulence. Ensemble-averaged statistics show growth of strong core (Kelvin) waves induced by the external turbulence - surprising, given the stabilizing effect of rotation in the vortex core. We explore two potential mechanisms of perturbation growth and core transition: (i) resonant forcing of Kelvin waves by turbulence filaments wrapping the column, and (ii) growth of optimal transient perturbations. We demonstrate the possibility of ring-vortex wave resonance even for relatively weak rings. Resonance in the form of amplifying core dynamics results in sheath-like structures in the core, known to be unstable to a Kelvin-Helmholtz-like instability. However, this process requires sustained organized ring-like structures over several vortex turnover times. Amplification of core perturbations in optimal transient modes also occurs through resonant forcing. Several orders of magnitude growth is possible at even moderate Re ($\sim 10^4$) before the inevitable (linear) decay. We briefly examine the nonlinear evolution of optimal bending modes and show that such growth reproduces features of vortex interaction with turbulence: enhanced core diffusion, core perturbation growth, and circulation overshoot. Results from transient growth analysis suggest the importance of optimal transient modes in governing the decay of turbulent vortices.

PL-2. RECENT EXPERIMENTAL STUDIES ON MICROSCALE CHANNEL FLOWS

Jung Yul YOO, *School of Mechanical and Aerospace Engineering, Seoul National University, Korea*, Young Won KIM, *Institute of Advanced Machinery and Design, Seoul National University, Korea,* In this paper, we review recent studies on single-phase and multiphase flows in microchannels and their applications. First of all, overviews of physical phenomena of fluid flow in microchannels, and measurement techniques mainly in conjunction with the flow visualization, are given. As for the study of single-phase flows, the current state-of-the-art of electrokinetics and optofluidics is outlined. Electrokinetic flow has quite different characteristics from pressure-driven flow because the surface charge plays an important role. Optofluidics is currently a new emerging technology combining optics with microfluidics for creating highly versatile systems. Prominent examples of optofluidic devices are introduced. On the other hand, many microfluidic devices are operated in two-phase flow patterns, such as solid-liquid, liquid-liquid and gas-liquid flows in terms of their appropriate functionalities and applications. Most microfluidic systems often transport particulate samples, such as blood cells, bacteria, DNAs, and spherical particles, which possibly represents solid-liquid two-phase flow. In this situation, the solid particle may not necessarily follow fluid streamlines, and as a result, lateral migration of the particles occurs. However, this study has been poorly reported in microscale. We thus present a systematic evaluation of lateral migration, and propose a novel 3-D focusing method by controlling the lateral migration. It is also noted that the use of liquid-liquid flows on microfluidic device platform has various applications, such as bio/chemical reaction, droplet-based cell assay, and so forth. We review the droplet generation process (generation, merging and breakup) in microchannels. Finally, recent issues on gas-liquid flows are overviewed, particularly, focusing on pressure drop, void fraction, bubble speed and effect of channel size for straight microchannels and/or converging-diverging microchannels.

IL-1. MODELING INDIAN OCEAN CIRCULATION: BAY OF BENGAL FRESH PLUME AND ARABIAN SEA MINI WARM POOL

P. N. VINAYACHANDRAN, J. KURIAN, *Centre for Atmospheric and Oceanic Sciences, Indian Institute of Science, Bangalore, India,* The Indian subcontinent divides the north Indian Ocean into two tropical basins, namely the Arabian Sea and the Bay of Bengal. The Arabian Sea has high salinity whereas the salinity of the Bay of Bengal is much lower due to the contrast in freshwater forcing of the two basins. The freshwater received by the Bay in large amounts during the summer monsoon through river discharge is flushed out annually by ocean circulation. After the withdrawal of the summer monsoon, the Ganga – Brahmaputra river plume flows first along the Indian coast and then around Sri Lanka into the Arabian Sea creating a low salinity pool in the southeastern Arabian Sea (SEAS). In the same region, during the pre-monsoon months of February – April, a warm pool, known as the Arabian Sea Mini Warm Pool (ASMWP), which is distinctly warmer than the rest of the Indian Ocean, takes shape. In fact, this is the warmest region in the world oceans during this period. Simulation of the river plume and its movement as well as its implications to thermodynamics has been a challenging problem for models of Indian Ocean. Here we address these issues using an ocean general circulation model – first we show that the model is capable of reproducing fresh plumes in the Bay of Bengal as well as its movement and then we use the model to determine the processes that lead to formation of the ASMWP. Hydrographic observations from the western Bay of Bengal have shown the presence of a fresh plume along the northern part of the Indian coast during summer monsoon. The Indian Ocean model when forced by realistic winds and climatological river discharge reproduces the fresh plume with reasonable accuracy. The fresh plume does not advect along the Indian coast until the end of summer monsoon. The North Bay Monsoon Current, which flows eastward in the northern Bay, separates the low salinity water from the more saline southern parts of the bay and thus plays an important role in the fresh water budget of the Bay of Bengal. The model also reproduces the surge of the fresh-plume along the Indian coast, into the Arabian Sea during northeast monsoon. Mechanisms that lead to the formation of the Arabian Sea Mini Warm Pool are investigated using several numerical experiments. Contrary to the existing theories, we find that salinity effects are not necessary for the formation of the ASMWP. The orographic effects of the Sahyadris(Western Ghats) and resulting reduction in wind speed leads to the formation of the ASMWP. During November – April, the SEAS behave as a low-wind heat-dominated regime where the evolution of sea surface temperature is solely determined by atmospheric forcing. In such regions the evolution of surface layer temperature is not dependent on the characteristics of the subsurface ocean such as the barrier layer and temperature inversion.

IL-2. THE FOSSILS OF ECTOPLASM IN A NUTSHELL: A BRIEF HISTORY OF THE CHALLENGES INTO THE AIR IN THE ANIMAL KINGDOM

T. SUGIMOTO, *Dept. Info. Systs. Creation, Kanagawa Univ., Japan,* Ectoplasm is a pair of condensation trails originating from the both wing-tips. The aim of this talk is from the mechanical point of view to look back upon the essential events in the origin of flight in the animal kingdom with special emphasis upon respiration and aerial locomotion. Each corresponds respectively to internal- and external-biofluiddynamics. The first flyers come from the insect group in the middle Carboniferous period, 310 million years ago. These are gigantic ancient dragonflies with more than one meter wing span. Insect wings derive from gills and have membrane structures. They breathe with the aid of the trachea system; this is a pneumatic pipe network spanned all over their bodies; delivery of oxygen is totally dependent on diffusion. The gigantism and the trachea system were possible, because dense oxygen existed in the Carboniferous atmosphere: oxygen percentage is estimated even up to 30% of the air, while the percentage of carbon dioxide was almost the same as the present value. The next dominant fliers are pterosaurs. They first appeared in the Triassic sky 220 million year ago. In the Mesozoic era oxygen had been as thin as 12% of the air, while carbon dioxide level had been 8 times higher than the present value. Pterosaurs are thought to have the lung system augmented by air-sacs, which is supported by the fact that fore-limb bones are pneumatic. A pair of air-sacs acts as tandem pumps to the lung in between; air flows in the lung against the direction of blood flow; this counter flow configuration makes the gas exchange more efficient than the parallel flow configuration found in the mammalian lung system. The fore-limbs and the elongated forth digits are the main structures that support pterosaurs' membrane wings. Experiments show that heaving such a wing induces lag in the trailing edge motion and that this passive feathering motion plays an important role in generation of thrust. Pterosaurs' gigantism cannot be accounted for, because the density of the air is lighter than today's value. The first birds *Archaeopteryx* appeared in the Jurassic sky more than 140 million years ago. They are covered with light-weight and flexible feathers suited for flight and warm-bloodedness. Birds have the lung system augmented by air-sacs. They are also adapted to thin oxygen in the Jurassic atmosphere, and hence they can fly over the Himalayas today. Bats appeared as the last active flyers. Their bones are fragile, and hence fossils are not well preserved; the oldest bat record dates back to 55 million years ago; in Tertiary oxygen level has risen up to 20% of the atmosphere. Bats have the typical mammalian lung system; they don't have air-sacs or pneumatic bones. Their feat of acrobatic flight owes largely to the wing structure; four of five digits