OIST SEMINAR

Date: June 10th, 2016 (Fri)
Time: 1:00 pm – 2:00 pm
Venue: D015, Lab1 Level D
Speaker: Prof. Tamer A. Zaki (Johns Hopkins University)

Boundary layer transition beneath free-stream turbulence: Linear precursors of nonlinear breakdown

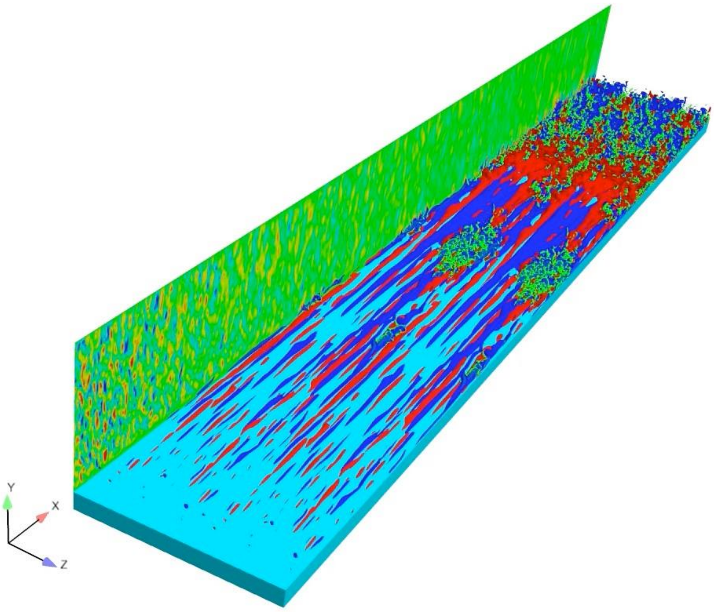

Figure 1: Snapshot of a boundary layer undergoing bypass transition beneath free-stream turbulence. Red and blue isosurfaces are high- and low-speed streaks. Localized turbulent spots are identified by isosurfaces of the λ2 criterion.

Abstract

The manner in which infinitesimal disturbances can cause organized fluid motion to become chaotic is an intriguing phenomenon. In addition to being of great theoretical interest, laminar-to-turbulence transition is of significant engineering importance due to its role in heat transfer, its influence on momentum mixing, and its effect on drag. In this work, we present complementary theoretical analysis and high-fidelity direct numerical simulations of transition to turbulence in boundary layers. The proceedings of transition are not unique, and various pathways can ultimately lead to boundary-layer turbulence. These pathways have traditionally been grouped in two classes: the orderly and the bypass routes. Orderly transition has its origin in classical linear stability theory, which predicts a slow transition process starting from weak Tollmien-Schlichting instability waves. In engineering applications, the presence of free-stream disturbances promotes early breakdown to turbulence, and transition is said to “bypass” the classical Tollmien-Schlichting route. Numerical simulations of bypass transition reveal that high-frequency disturbances from the free stream are expelled by the boundary-layer shear – a phenomenon known as shear sheltering. Using asymptotic analysis, we develop a physical understanding of the mechanics of shear sheltering, and explain how low-frequency free-stream perturbations can permeate the mean shear. These elongated disturbances force the boundary layer resonantly and lead to the amplification of streaks. While the majority of the laminar streaks are innocuous, a small proportion undergoes a localized instability and breaks down to turbulence. Reports in the literature present conflicting views on the origin of streak breakdown – a matter that we address by performing secondary instability analyses of realistic streaks. The predicted streak instabilities are shown to cause breakdown to turbulence in complementary direct numerical simulations.

Contact information: Fluid Mechanics Unit

Kaori Egashira: (Tel) 098-966-8683 (e-mail) e-kaori@oist.jp