Mini-symposium A9
Dynamical Systems Generated by 2D and Quasi-2D Navier-Stokes Flows

Organizer:

Hisashi Okamoto
Research Institute for Mathematical Sciences, Kyoto University
Email: okamoto@kurims.kyoto-u.ac.jp

A9-01 Keynote
Rotational effect on 2D Navier-Stokes flow
Michio Yamada
Research Institute for Mathematical Sciences, Kyoto University, 606-8502, Japan

Effect of rotation on 2D incompressible flows governed by the Navier-Stokes equation is discussed. The rotation has no effect in planar 2D case, but it is important when the flow domain is curved as the magnitude of Coriolis force is then not uniform. We focus our attention on the case of sphere, where rotation has a strong effect on the development of the flow pattern. If the flow is unforced, strong and westward circumpolar jets emerge in polar regions while the weak eastward flow is observed in low-latitudes. When the flow field is randomly forced at high-wavenumber region, plural zonal jets which are formed at an early stage of time-development gradually merge with each other, and finally only a few broad zonal jets survive in the flow field. When the flow is under a steady zonal forcing, the flow is globally stable or is unstable according to the structure of the forcing and the Reynolds number. However, for any steady zonal forcing, the corresponding steady zonal flow is globally stable if the rotation rate is large enough.

A9-02 Invited
On extremum statistics in dynamical systems and two dimensional flows
Shin-ichi Takehiro*, Michio Yamada
Research Institute for Mathematical Sciences, Kyoto University

Statistical property of extrema of physical variables in fluid phenomena is interesting from both theoretical and practical points of view, as it is related to a wide variety of subjects including, for example, turbulence dynamics theory and an assessment of a natural disaster in extreme weather events. The theory of extremum statistics has been established mainly for identical independent random events, as it is related to a wide variety of subjects including, for example, turbulence dynamics theory and an assessment of a natural disaster in extreme weather events. In this paper, we summarize difficulties in application of the extremum distributions to fluid phenomena, and then discuss an extremum statistics in two-dimensional fluids.

A9-03 Invited
Point vortex dynamics on the spheroid
Sun-Chul Kim
Chung-Ang University, Department of Mathematics, Seoul 156-756, Republic of Korea

Point vortex dynamics on the surface of a spheroid is studied. Exact governing equations are derived by computing the conformal metric which induces a modified stereographic projection. As an application, the motion of point vortices at the same latitude (called the point vortex ring) is investigated as an extension of the sphere case. The role of eccentricity to the stability of the rotating motion is analysed. The influence of a pole vortex is also discussed.


A9-04 Invited
Merging and disappearing processes of zonal jets in forced 2D Navier-Stokes turbulence on a rotating sphere
Kiori Obuse*, Shin-ichi Takehiro*, Michio Yamada
1 WPI-AIMR, Tohoku University, Sendai, Japan
2 RIMS, Kyoto University, Kyoto, Japan

In forced two-dimensional turbulence on a rotating sphere, it is well known that a multiple zonal-band structure, i.e. a structure with alternating eastward and westward jets, emerges in the course of time development. The zonal-band structure then experiences intermittent mergers and disappearances of zonal jets, and a structure with only a few large-scale zonal jets is realized as an asymptotic state. In this talk, the mechanism of merging and disappearing processes of zonal jets are discussed by using weakly nonlinear analysis

A9-05 Invited
Covariant Lyapunov analysis and its application to Navier-Stokes flows
Masanobu Inubushi*, Shin-ichi Takehiro*, Michio Yamada
1 NTT Communication Science Laboratories, NTT Corporation
2 Research Institute for Mathematical Sciences, Kyoto University

Covariant Lyapunov analysis developed by Ginelli et al. (2007) [Phys. Rev. Lett. 99, 130601 (2007)] can be used for understanding of chaotic behaviors of the Navier-Stokes flows. The covariant Lyapunov analysis gives not only Lyapunov exponents but also the magnitude of Coriolis force is then not uniform. We focus our attention on the case of sphere, where rotation has a strong effect on the development of the flow pattern. If the flow is unforced, strong and westward circumpolar jets emerge in polar regions while the weak eastward flow is observed in low-latitudes. When the flow field is randomly forced at high-wavenumber region, plural zonal jets which are formed at an early stage of time-development gradually merge with each other, and finally only a few broad zonal jets survive in the flow field. When the flow is under a steady zonal forcing, the flow is globally stable or is unstable according to the structure of the forcing and the Reynolds number. However, for any steady zonal forcing, the corresponding steady zonal flow is globally stable if the rotation rate is large enough.

A9-06 Invited
An application of interval arithmetic to certain dynamical systems arising in fluid mechanics
Hisashi Okamoto, Tomoyuki Miyaji, Alex. D. D. Craik
Research Institute for Mathematical Sciences, Kyoto University, Kyoto, Japan

We consider certain autonomous three-dimensional dynamical systems that can arise in mechanical and fluid-dynamical contexts. Extending a previous study in Craik & Okamoto Physica D, 164, (2002), pp. 168-186, to include linear forcing and damping, we find that the earlier four-leaf structure, and unbounded orbits, persist, but may be accompanied by three distinct period-doubling cascades to chaos, and by orbits that approach stable equilibrium points. This rich structure is investigated both analytically and numerically, distinguishing three main cases determined by the damping and forcing parameters.