

# Preface

This book would not have been written if not for the generosity of the funding agencies, providing sufficient amounts of monies from 2004 - 2008 to buy the computer equipment and most significantly, to support two capable PhD students and two M.Sc graduate students. With one of these recent PhDs, Dr. Xueru Ding, and another PhD student, Dr. Joseph Nebus, we now record the results and products of our work over the last four years, which is informed by several years of earlier works in the subject matter of the book. We would like to acknowledge therefore the program officers, Dr. Chris Arney of the Army Research Office, and Dr. Walt Polansky and Dr. Gary Johnson of the United States Department of Energy.

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With Dr. Timothy Andersen, we have several fruitful collaborations in the past and a few exciting on-going projects; with Dr. Junping Shi, we have published a paper on a related topic; with Rajinder Singh Mavi, we

have a paper on a topic relevant to chapter 8 in this book and more exciting on-going projects; with Nuwan Silva Induruwege, we have another paper, relevant to this book, to be published; and with Syed M. Assad, we have several papers in this area.

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The focus of this monograph is a physically sound and rigorous, qualitative theory for the end-states or statistically-stationary asymptotic flow states of the forced-damped rotating shallow water equations, with applications to the super-rotation of slowly-rotating terrestrial planets and major moons and the key large-scale features of the Gas Giants in our solar system. Emphasizing the self-organized emergence of these astrophysical atmospheric structures through first and second order phase transitions, the spin-lattice models under Gibbs canonical constraint on the Lagrangian of the underlying dynamics and various microcanonical constraints on total circulations (sums) and enstrophies (square-norms) of relevant physical quantities, are simulated by Monte-Carlo methods, analyzed by mean-field techniques, and rigorously integrated in closed-form where possible by the non-Gaussian non-mean-field spherical model method. In a 2007 survey of Venusian atmospheric dynamics [87], the retrograde super-rotation of its lower atmosphere, up to 100 km, and also that of Titan, is viewed as a continuing enigma, and all attempts known to the authors of that survey, have so far failed to explain this phenomenon in simple and rigorous physical terms. The Barotropic Vorticity Model which is solved in closed-form by Lim, motivated by the detailed simulation results of Ding and discussed in the first part of this book, offers rigorous predictions on the asymmetry between super-rotation and anti-rotating zonal flows, stating that a slowly-rotating planet can support a super-rotating vertically-averaged barotropic atmosphere at high enough energies, but such coupled atmosphere-planet systems cannot have an anti-rotating barotropic atmosphere unless the planet's spin-rate is fast enough.

Analyzed by rigorous qualitative methods, based on the shallow water equations total mechanical energy, theoretical work independently predict

(and further explain the simulation results) the four key Jovian features, namely, (a) anticyclonic predominance, (b) north-south asymmetry of the highest anticyclonic spots, (c) high rim velocity in the circumferential band of Jupiter's Red Spot, and (d) the alternating zones-belts or Limaye bands. In providing this qualitative theory for end-states, by-passing often difficult and costly dynamical simulations of the underlying initial value problems at Jovian parameter sets it is oft asked what is the physical meaning of the statistical models' temperature. We hope to have given here sufficiently detailed discussions of the meaning of this notion in the context of macroscopic flows where subgrid scales could be 1000 km in wavelengths and widely-separated in physical effects from molecular notions of temperature.