

Preface

This book describes new theoretical advances made in recent years that yielded new analytical solutions of the rotating shallow-water equations. The intended readership of the book consists of graduate students and scientists in the fields of geophysical fluid dynamics, physical oceanography, dynamical meteorology, and applied mathematics who study or employ the shallow-water equations. The new dispersion relations and meridional amplitude structures of the waves derived in this book can be applied to observations in the atmosphere and ocean and they also provide alternatives to the spherical harmonics basis of global-scale spectral numerical models. The book originates from years of teaching courses in dynamical meteorology and physical oceanography at the Hebrew University of Jerusalem as well as at the University of Miami and Johns Hopkins University during my sabbatical stays there. In textbooks of Physical Oceanography and Dynamical Meteorology the theory of Kelvin, Inertia-Gravity (Poincaré) and Planetary (Rossby) Waves are developed starting from a different set of equations for each wave type instead of a single set of equations in which a certain parameter is set to a specific value or limiting value (e.g., zero, one, infinity). An additional issue with the traditional approach is that equatorial waves cannot be obtained from the mid-latitude waves by setting to zero the central latitude in the solutions for mid-latitude waves. This can be readily verified by realizing that the harmonic meridional structure of mid-latitude waves' amplitudes does not reduce to the Hermite functions structure of equator waves when the central latitude of the mid-latitude theory is set to zero.

In this book, I attempt to bridge the gap between equatorial wave theory and mid-latitude wave theory by developing a Schrödinger eigenvalue equation whose eigenvalues yield the phase speeds and the eigenfunctions yield the amplitude structure of both Inertia-Gravity and Planetary waves. This Schrödinger equation formulation was originally applied in 1966 by Taro Matsuno in his development of wave theory on the equatorial β -plane. The same approach is extended to mid-latitude wave theory which is traditionally developed on the f -plane for all waves except Rossby waves for which the theory is developed on the mid-latitude β -plane. In the unified approach, all waves are developed on the latter plain. In this

approach, Kelvin waves are a particular wave type that solves a degenerate case where the second-order eigenvalue problem degenerates to a first-order equation that determines the amplitude meridional structure, while the dispersion relation is determined from a wave equation in the zonal direction that is identical to the wave equation for gravity waves of the shallow water equations in one-dimension without rotation.

In contrast to Cartesian coordinates where the Schrödinger eigenvalue equation approach to shallow water waves offers an alternate (perhaps more elegant, general, and accurate) derivation to the traditional harmonic derivation, the application of this approach in spherical coordinates yields analytical results that cannot be derived otherwise. The first to recognize the importance of formulating an eigenvalue equation for the rotating shallow-water equations over a sphere was Michael S. Longuet-Higgins who successfully derived such equations in his seminal 1968 paper on “Laplace Tidal Equations Over a Sphere.” His detailed analysis and extensive numerical calculations (which is amazing considering the meager computing power that was available to him in the 1960s) of the exact equation make it clear that no progress can be made on the subject without first simplifying the eigenvalue equations. The necessary simplification was recently achieved for parameter values typical to earth by maintaining terms in the spherical problem that have counterparts on a plane. The accuracy of the solutions of the resulting simplified eigenvalue equation on a sphere provides the justification for the approximation more than the formal asymptotic expansion.

My research associate, Dr. Andrey Sigalov, along with my graduate students at the Hebrew University of Jerusalem, Shira Rubin, Yair De-Leon, and Ofer Shamir, have contributed greatly to the development of the ideas presented here and to the analysis and numerical calculations that are integral elements of the theory and its presentation to the readers of this book. I am indebted to them for their help in making the theoretical advances and consider them my partners in this endeavor. Though they share with me the major theoretical advancement, I am solely responsible for errors that have not been uprooted from this monograph. My colleague and close friend Prof. Hezi Gildor of the Hebrew University of Jerusalem encouraged me to write this book. I am grateful to him for the impetus he provided to me when the idea of writing this book was first conceived and for his encouragement during the time when this book was written. The Bogen Family Foundation supported my sabbatical stay at University of Pennsylvania during the spring semester of 2015 during which this book was completed.

Jerusalem
June 2015

<http://www.springer.com/978-3-319-20260-0>

Shallow Water Waves on the Rotating Earth

Paldor, N.

2015, VIII, 77 p. 32 illus., 19 illus. in color., Softcover

ISBN: 978-3-319-20260-0