

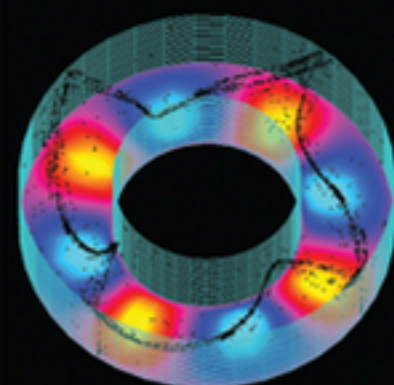
Marcello Lappa

Rotating Thermal Flows

in Natural
and Industrial
Processes



 WILEY



Rotating Thermal Flows in Natural and Industrial Processes

Rotating Thermal Flows in Natural and Industrial Processes

MARCELLO LAPPA
Naples, Italy

 **WILEY**

A John Wiley & Sons, Ltd., Publication

This edition first published 2012
© 2012 John Wiley & Sons, Ltd

Registered office

John Wiley & Sons Ltd, The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, United Kingdom

For details of our global editorial offices, for customer services and for information about how to apply for permission to reuse the copyright material in this book please see our website at www.wiley.com.

The right of the author to be identified as the author of this work has been asserted in accordance with the Copyright, Designs and Patents Act 1988.

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording or otherwise, except as permitted by the UK Copyright, Designs and Patents Act 1988, without the prior permission of the publisher.

Wiley also publishes its books in a variety of electronic formats. Some content that appears in print may not be available in electronic books.

Designations used by companies to distinguish their products are often claimed as trademarks. All brand names and product names used in this book are trade names, service marks, trademarks or registered trademarks of their respective owners. The publisher is not associated with any product or vendor mentioned in this book. This publication is designed to provide accurate and authoritative information in regard to the subject matter covered. It is sold on the understanding that the publisher is not engaged in rendering professional services. If professional advice or other expert assistance is required, the services of a competent professional should be sought.

The publisher and the author make no representations or warranties with respect to the accuracy or completeness of the contents of this work and specifically disclaim all warranties, including without limitation any implied warranties of fitness for a particular purpose. This work is sold with the understanding that the publisher is not engaged in rendering professional services. The advice and strategies contained herein may not be suitable for every situation. In view of ongoing research, equipment modifications, changes in governmental regulations, and the constant flow of information relating to the use of experimental reagents, equipment, and devices, the reader is urged to review and evaluate the information provided in the package insert or instructions for each chemical, piece of equipment, reagent, or device for, among other things, any changes in the instructions or indication of usage and for added warnings and precautions. The fact that an organization or Website is referred to in this work as a citation and/or a potential source of further information does not mean that the author or the publisher endorses the information the organization or Website may provide or recommendations it may make. Further, readers should be aware that Internet Websites listed in this work may have changed or disappeared between when this work was written and when it is read. No warranty may be created or extended by any promotional statements for this work. Neither the publisher nor the author shall be liable for any damages arising herefrom.

Library of Congress Cataloging-in-Publication Data

Lappa, Marcello.

Rotating thermal flows in natural and industrial processes / Marcello Lappa.
pages cm

Includes bibliographical references and index.

ISBN 978-1-119-96079-9 (hardback)

1. Heat – Transmission. 2. Rotating masses of fluid. I. Title.

QC320.2.L37 2012

536'.2 – dc23

2012008650

A catalogue record for this book is available from the British Library.

Print ISBN: 978-111-996-0799

Typeset in 10/12pt Times-Roman by Laserwords Private Limited, Chennai, India.

To a red rose

Contents

<i>Preface</i>	xiii
<i>Acknowledgements</i>	xvii
1 Equations, General Concepts and Nondimensional Numbers	1
1.1 The Navier-Stokes and Energy Equations	1
1.1.1 The Continuity Equation	2
1.1.2 The Momentum Equation	2
1.1.3 The Total Energy Equation	2
1.1.4 The Budget of Internal Energy	3
1.1.5 Closure Models	3
1.2 Some Considerations about the Dynamics of Vorticity	5
1.2.1 Vorticity and Circulation	5
1.2.2 Vorticity in Two Dimensions	7
1.2.3 Vorticity Over a Spherical Surface	8
1.2.4 The Curl of the Momentum Equation	10
1.3 Incompressible Formulation	10
1.4 Buoyancy Convection	13
1.4.1 The Boussinesq Model	13
1.4.2 The Grashof and Rayleigh Numbers	14
1.5 Surface-Tension-Driven Flows	14
1.5.1 Stress Balance	15
1.5.2 The Reynolds and Marangoni Numbers	16
1.5.3 The Microgravity Environment	18
1.6 Rotating Systems: The Coriolis and Centrifugal Forces	19
1.6.1 Generalized Gravity	20
1.6.2 The Coriolis, Taylor and Rossby Numbers	21
1.6.3 The Geostrophic Flow Approximation	22
1.6.4 The Taylor–Proudman Theorem	23
1.6.5 Centrifugal and Stratification Effects: The Froude Number	23
1.6.6 The Rossby Deformation Radius	24
1.7 Some Elementary Effects due to Rotation	25
1.7.1 The Origin of Cyclonic and Anticyclonic flows	25
1.7.2 The Ekman Layer	26

1.7.3	Ekman Spiral	28
1.7.4	Ekman Pumping	28
1.7.5	The Stewartson Layer	30
2	Rayleigh-Bénard Convection with Rotation	33
2.1	Rayleigh-Bénard Convection with Rotation in Infinite Layers	34
2.1.1	Linear Stability Analysis	35
2.1.2	Asymptotic Analysis	36
2.2	The Küppers-Lortz Instability and Domain Chaos	38
2.3	Patterns with Squares	41
2.4	Typical Phenomena for $Pr \cong 1$ and Small Values of the Coriolis Number	42
2.4.1	Spiral Defect Chaos and Chiral Symmetry	42
2.4.2	The Interplay between the Busse Balloon and the KL Instability	45
2.5	The Low- Pr Hopf Bifurcation and Mixed States	48
2.5.1	Standing and Travelling Rolls	50
2.5.2	Patterns with the Symmetry of Square and Hexagonal Lattices	52
2.5.3	Other Asymptotic Analyses	54
2.5.4	Nature and Topology of the Bifurcation Lines in the Space of Parameters (τ, Pr)	56
2.6	Laterally Confined Convection	58
2.6.1	The First Bifurcation and Wall Modes	60
2.6.2	The Second Bifurcation and Bulk Convection	63
2.6.3	Square Patterns Driven by Nonlinear Interactions between Bulk and Wall Modes	64
2.6.4	Square Patterns as a Nonlinear Combination of Bulk Fourier Eigenmodes	67
2.6.5	Higher-Order Bifurcations	69
2.7	Centrifugal Effects	71
2.7.1	Stably Thermally Stratified Systems	71
2.7.2	Interacting Thermogravitational and Centrifugally Driven Flows	74
2.7.3	The Effect of the Centrifugal Force on Domain Chaos	84
2.8	Turbulent Rotating RB Convection	87
2.8.1	The Origin of the Large-scale Circulation	87
2.8.2	Rotating Vortical Plumes	89
2.8.3	Classification of Flow Regimes	92
2.8.4	Suppression of Large-scale Flow and Heat Transfer Enhancement	99
2.8.5	Prandtl Number Effects	103
3	Spherical Shells, Rossby Waves and Centrifugally Driven Thermal Convection	107
3.1	The Coriolis Effect in Atmosphere Dynamics	107
3.1.1	The Origin of the Zonal Winds	107
3.1.2	The Rossby Waves	110
3.2	Self-Gravitating Rotating Spherical Shells	114
3.2.1	Columnar Convective Patterns	115
3.2.2	A Mechanism for Generating Differential Rotation	119
3.2.3	Higher-Order Modes of Convection	121

3.2.4	Equatorially Attached Modes of Convection	126
3.2.5	Polar Convection	127
3.3	Centrifugally Driven Thermal Convection	128
4	The Baroclinic Problem	135
4.1	Energetics of Convection and Heuristic Arguments	136
4.2	Linear Stability Analysis: The Classical Eady's Model	139
4.3	Extensions of the Eady's model	148
4.4	Fully Developed Nonlinear Waveforms	154
4.5	The Influence of the Prandtl Number	162
4.6	The Route to Chaos	166
4.7	Hybrid Baroclinic Flows	172
4.8	Elementary Application to Atmospheric Dynamics	175
4.8.1	Spiralling Eddy Structures	176
4.8.2	The Baroclinic Life-Cycle and the 'Barotropization' Mechanism	177
4.8.3	The Predictability of Weather and Climate Systems	179
5	The Quasi-Geostrophic Theory	183
5.1	The Potential Vorticity Perspective	183
5.1.1	The Rossby-Ertel's Potential Vorticity	183
5.1.2	The Quasi-Geostrophic (QG) Pseudo-Potential Vorticity	184
5.2	The Perturbation Energy Equation	189
5.3	Derivation of Necessary Conditions for Instability	191
5.3.1	The Rayleigh's Criterion	192
5.3.2	The Charney–Stern Theorem	193
5.4	A Generalization of the Potential Vorticity Concept	195
5.4.1	The Origin of the Sheets of Potential Vorticity	196
5.4.2	Gradients of Potential Vorticity in the Interior	199
5.5	The Concept of Interlevel Interaction	201
5.6	The Counter-Propagating Rossby-Wave Perspective on Baroclinic Instability	205
5.6.1	The Heuristic Interpretation	206
5.6.2	A Mathematical Framework for the 'Action-at-a-Distance' Dynamics	208
5.6.3	Extension and Rederivation of Earlier Results	211
5.7	Barotropic Instability	215
5.8	Extensions of the CRW Perspective	218
5.9	The Over-reflection Theory and Its Connections to Other Theoretical Models	222
5.10	Nonmodal Growth, Optimal Perturbations and Resonance	225
5.11	Limits of the CRW Theory	229
6	Planetary Patterns	231
6.1	Jet Sets	232
6.2	A Rigorous Categorization of Hypotheses and Models	236

6.3	The Weather-Layer Approach	237
6.4	The Physical Mechanism of Vortex Merging	238
6.4.1	The Critical Core Size	240
6.4.2	Metastability and the Axisymmetrization Principle	241
6.4.3	Topology of the Streamline Pattern and Its Evolution	242
6.5	Freely Decaying Turbulence	246
6.5.1	Two-dimensional Turbulence	246
6.5.2	Invariants, Inertial Range and Phenomenological Theory	247
6.5.3	The Vortex-Dominated Evolution Stage	250
6.6	Geostrophic Turbulence	254
6.6.1	Relationship with 2D Turbulence	254
6.6.2	Vortex Stretching and 3D Instabilities	256
6.7	The Reorientation of the Inverse Cascade into Zonal Modes	258
6.7.1	A Subdivision of the Spectrum: Rossby Waves and Turbulent Eddies	258
6.7.2	Anisotropic Dispersion and Weak Nonlinear Interaction	259
6.7.3	The Stability of Zonal Mean Flow	262
6.8	Baroclinic Effects, Stochasting Forcing and Barotropization	262
6.9	Hierarchy of Models and Scales	264
6.9.1	The Role of Friction	264
6.9.2	The One-Layer Perspective and the Barotropic Equation	265
6.9.3	Classification of Models	266
6.9.4	Characteristic Wavenumbers	267
6.10	One-Layer Model	268
6.10.1	Historical Background	268
6.10.2	The Wavenumber Sub-space	276
6.11	Barotropicity, Baroclinicity and Multilayer Models	278
6.11.1	Eddy Variability and Zonally Averaged Properties	279
6.11.2	Polygonal Wave Structures	283
6.12	The Ocean–Jupiter Connection	286
6.13	Wave–Mean-Flow Dynamics	287
6.13.1	The Barotropic Instability of Rossby Waves	288
6.13.2	The Transition from Inflectional to Triad Resonance Instability	291
6.13.3	Destabilization of Mixed Rossby–Gravity Waves	296
6.13.4	Relaxation of the Triad Resonance Condition	299
6.13.5	Interaction with Critical Lines	300
6.14	Solitary Vortex Dynamics	302
6.14.1	The Zoo of Vortex Instabilities on the f -Plane	302
6.14.2	Free Vortices on the β Plane	309
6.14.3	β Gyres and Rossby-Wave-Induced Gradual Vortex Decay	311
6.14.4	The Influence of Zonal Flow on Vortex Stability	317
6.15	Penetrative Convection Model	322
6.15.1	Limits of the Shallow Layer Approach	322
6.15.2	Differential Rotation and Deep Geostrophic Convection	323
6.16	Extension and Unification of Existing Theories and Approaches	329
6.16.1	The Classical Bowl-Based Experiment	330
6.16.2	Models with β Sign Reversal	332

6.16.3	Models with Scaling Discontinuities	337
6.16.4	Open Points and Future Directions of Research	343
7	Surface-Tension-Driven Flows in Rotating Fluids	345
7.1	Marangoni–Bénard Convection	346
7.1.1	Classical Patterns and Theories	346
7.1.2	Stationary and Oscillatory Flows with Rotation	347
7.2	The Return Flow	352
7.3	The Hydrothermal Instability	354
7.3.1	A LSA Including the Effect of Rotation	356
7.4	The Annular Pool	360
7.4.1	Liquid Metals and Semiconductor Melts	363
7.4.2	Travelling and Stationary Waves	364
7.4.3	Transparent Organic Liquids	366
7.4.4	Modification of the Fundamental Hydrothermal Mechanism	369
8	Crystal Growth from the Melt and Rotating Machinery	371
8.1	The Bridgman Method	372
8.2	The Floating Zone	381
8.2.1	The Liquid Bridge	383
8.2.2	Rotating Liquid Bridge with Infinite Axial Extent	385
8.2.3	Rotation, Standing Waves and Travelling Waves	386
8.2.4	Self-Induced Rotation and PAS	390
8.3	The Czochralski Method	394
8.3.1	Spoke and Wave Patterns	396
8.3.2	Mixed Baroclinic-Hydrothermal States	399
8.3.3	Other Effects, Cold Plumes and Oscillating Jets	406
8.3.4	Geostrophic Turbulence	411
8.4	Rotating Machinery	413
8.4.1	The Taylor–Couette Flow	413
8.4.2	Cylinders with Rotating Endwalls	422
9	Rotating Magnetic Fields	431
9.1	Physical Principles and Characteristic Numbers	432
9.1.1	The Hartmann, Reynolds and Magnetic Taylor Numbers	432
9.1.2	The Swirling Flow	434
9.2	Stabilization of Thermo-gravitational Flows	438
9.3	Stabilization of Surface-Tension-Driven Flows	442
9.4	Combining Rotation and RMF	446
10	Angular Vibrations and Rocking Motions	449
10.1	Equations and Relevant Parameters	450
10.1.1	Characteristic Numbers	453
10.1.2	The Mechanical Equilibrium	454

10.2	The Infinite Layer	454
10.2.1	The Stability of the Equilibrium State	455
10.2.2	Combined Translational-Rotational Vibrations	460
10.3	The Vertical Coaxial Gap	462
10.4	Application to Vertical Bridgman Crystal Growth	467
	References	473
	Index	511

Preface

The relevance of self-organization, pattern formation, nonlinear phenomena and non-equilibrium behaviour in a wide range of fluid-dynamics problems in *rotating systems*, somehow related to the science of materials, crystal growth, thermal engineering, meteorology, oceanography, geophysics and astrophysics, calls for a concerted approach using the tools of thermodynamics, fluid-dynamics, statistical physics, nonlinear dynamics, mathematical modelling and numerical simulation, in synergy with experimentally oriented work.

The reason behind such a need, of which the present book may be regarded as a natural consequence, is that in many instances pertaining to such fields one witnesses remarkable affinities between *large-scale-level processes* and the same entities on the *smaller* (laboratory) *scale*; despite the common origin (they are related to ‘rotational effects’), such similarities (and the important related implications) are often ignored in typical analyses related to one or the other category of studies.

With the specific intent to extend the treatment given in an earlier Wiley text (*Thermal Convection: Patterns, Evolution and Stability*, Chichester, 2010, which was conceived in a similar spirit), the present book is entirely focused on *hybrid* regimes of convection in which one of the involved forces is represented by standard gravity or surface tension gradients (under various heating conditions: from below, from the side, etc.), while the other arises by virtue of *rotation*.

The analogies and kinships between the two fundamental classes of models mentioned above, one dealing with issues of complex behaviour at the laboratory (technological application) level and the second referring to the strong nonlinear nature of large-scale (terrestrial atmosphere, oceans and more) evolution, are defined and discussed in detail.

The starting point for such a development is the recognition that such phenomena share an important fundamental feature, a group of equations, strictly related, from a mathematical point of view, to model mass, momentum and energy transfer, and the mathematical expressions used therein for the ‘driving forces’.

Although other excellent monographs that have appeared in the literature (e.g. to cite the most recent ones: Marshall and Plumb, 2007, *Atmosphere, Ocean, and Climate Dynamics*, Academic Press; Vallis, 2006, *Atmospheric and Oceanic Fluid Dynamics*, Cambridge University Press) have some aspects in common with the present book, they were expressly conceived for an audience consisting of meteorologists.

Here the use of jargon is avoided, this being done under the declared intent to increase the book’s readability and, in particular, make it understandable also for those individuals who are not ‘pure’ meteorologists (or ‘pure’ professionals/researchers working in the field of materials science), thereby promoting the exchange of ideas and knowledge integration.

In this context, it is expressly shown how the aforementioned isomorphism between small and large scale phenomena becomes beneficial to the definition and ensuing development of an integrated comprehensive framework, allowing the reader to understand and assimilate the underlying quintessential mechanisms without requiring familiarity with specific literature on the subject.

A Survey of the Contents

In Chapter 1 the main book topics are placed in a precise theoretical context by introducing some necessary notions and definitions, such a melange of equations and nondimensional numbers being propaedeutical to the subsequent elaboration of more complex concepts and theories.

Chapter 2 deals with *Rayleigh–Bénard convection* in simplified (infinite and finite) geometrical models, which is generally regarded as the simplest possible laboratory system incorporating the essential forces that occur in natural phenomena (such as circulations in the atmosphere and ocean currents) and many technological applications (too numerous to list).

The astonishing richness of possible convective modes for this case is presented with an increasing level of complexity as the discussion progresses, starting from the ideal case of a system of infinite (in the horizontal direction) extent in which the role of centrifugal force is neglected (with related phenomena including the Küppers–Lortz instability, domain chaos, the puzzling appearance of patterns with square symmetry, spiral defect chaos and associated dynamics of chiral symmetry breaking), passing through the consideration of finite-sized geometries and the reintroduction of the centrifugal force, up to a presentation of the myriad of possible solutions and bifurcations in cylindrical containers under the combined effects of vertical (gravity), radial (centrifugal) and azimuthal (Coriolis) forces.

Similar concepts apply to the case of convection driven by internal heating in rotating self-gravitating spherical shells (Chapter 3), whose typical manifestation under the effect of radial buoyancy is represented by an unsteady *columnar mode* able to generate differential rotation under given circumstances. Exotic modes of convection (such as hexagons, oblique rolls, hexarolls, knot convection and so on) are also reviewed and linked to specific regions of the parameter space.

Then, attention is switched from rotating systems with bottom (or internal) heating to laterally heated configurations (temperature gradient directed horizontally, gravity directed vertically), which leads in a more or less natural way to the treatment of so-called *sloping convection* (Chapter 4), known to be the dominant mechanism producing large-scale spiralling eddy structures in Earth's atmosphere, but also eddy structures and wavy patterns in typical problems of crystal growth from the melt.

Apart from providing a general overview of so-called *quasigeostrophic theory*, Chapter 5 also gives some insights into the fundamental difference between the two main categories of fluid-dynamic instabilities in rotating fluids: one associated with problems for which the unstable modes essentially involve *mass and temperature redistribution* (e.g. Rayleigh–Bénard or Marangoni–Bénard convection considered in Chapters 2 and 7, respectively); and the other including problems such as stably stratified and unstratified shear instabilities, *barotropic and baroclinic instabilities*, which appear to be connected to the *self-excitation of waves* rather than to the direct redistribution of mass and temperature.

A number of works are reviewed, which focus on the mechanism by which mechanical and wave signals interplay to control how individual convective structures decide whether to grow, differentiate, move or die, and thereby promote pattern formation during the related process. Moreover, starting from the cardinal concept of the *Rossby wave*, some modern approaches, such as the so-called CRW (counter-propagating-Rossby-wave) perspective, an ingenious application of what has become known as

‘potential vorticity thinking’, are also invoked and used to elaborate a specific mathematical formalism and some associated important microphysical reasoning.

As a natural continuation of preceding chapters, Chapter 6 develops the important topic of *geostrophic turbulence*.

The basic ideas of inertial range theory are illustrated and extended phenomenologically by incorporating ideas of vortex–vortex and vortex–strain interactions that are normally present in physical and not spectral space. Then, a critical analysis of the distinctive marks of geostrophic turbulence (and its relationship with other classical models of turbulence) is developed. The main theories for *jet formation* and stability are discussed, starting from the fundamental concept of turbulent ‘decascade’ of energy. Subsequent arguments deal with the role played in maintaining turbulence by baroclinic effects and/or other types of 3D instabilities and on the so-called *baroclinic life cycle*. An overview of the main characteristic wavenumbers and scales relating to distinct effects is also elaborated.

Similarities between Earth’s phenomena and typical features of *outer planet* (Jupiter and Saturn) dynamics are discussed as well. After the exposition of the general theory for vortex–vortex coalescence, a similar treatment is also given for phenomena of wave–wave and wave–mean–flow interference.

The remaining chapters are entirely devoted to phenomena occurring on the lab scale, thereby allowing most of the arguments introduced in earlier chapters *to spread from their traditional heartlands of meteorology and geophysics to the industrial field* (and related applications).

Along these lines, Chapter 7 is concerned with the interplay between rotation and flows induced by surface tension gradients (more specifically, *Marangoni–Bénard convection* and so-called *hydrothermal waves*, considered as typical manifestations of surface-tension-driven flows in configurations of technological interest subjected to temperature gradient *perpendicular or parallel*, respectively, to the liquid/gas interface).

The modification of the classical hydrothermal mechanism due to rotation, in particular, is discussed on the basis of concepts of system invariance breaking (due to rotation) and of the fundamental processes allowing waves to derive energy from the basic flow (an interpretation is given as well for still unexplained observations appeared in the literature).

Chapter 8 provides specific information on cases with important background applications in the realm of crystal growth from the melt, for example the Bridgman, floating zone and Czochralski (CZ) techniques, considering, among other things, the interesting subject of *interacting baroclinic and hydrothermal waves*, together with an exposition of the most recent theories about the origin of the so-called *spoke patterns*.

The CZ configuration is used as a classical example of situations in which fluid motion is brought about by different coexisting mechanisms: Marangoni convection, generated by the interfacial stresses due to horizontal temperature gradients along the free surface and gravitational convection driven by the volumetric buoyancy forces caused by thermally and/or solutally generated density variations in the bulk of the fluid, without forgetting the presence of phenomena of a rotational nature (baroclinic instability) and those deriving from temperature contrasts induced in the vertical direction by radiative or other (localized) effects.

The exposition of turbulence given in Chapter 6 about typical planetary dynamics is *extended* in this chapter to topics of crystal growth showing commonalities and differences due to ‘contamination’ exerted on the geostrophic flow by effects of surface-tension or gravitational nature (thermal plumes and jets).

Then a survey is given of very classical problems in rotating fluids which come under the general heading of *differential-rotation-driven flows*. This subject includes a variety of prototypical laboratory-scale

models of industrial devices (among them: centrifugal pumps, rotating compressors, turbine disks, computer storage drives, turbo-machinery, cyclone separators, rotational viscometers, pumping of liquid metals at high melting point, cooling of rotating electrical motors, rotating heat exchangers, etc.).

Rotating magnetic fields are also considered (Chapter 9) as a potential technological means for counteracting undesired flow instabilities. Some attention is also devoted to so-called *swirling flow* and related higher modes of convection (Taylor-vortex flow, Görtler vortices, instabilities of the Bodewadt layer, etc.).

Last, but not least, a synthetic account is elaborated for flows produced by *angular vibrations* (i.e. situations in which the constant rotation rate considered in earlier chapters is replaced by an angular displacement varying sinusoidally with time with respect to an initial reference position) and rocking motions (Chapter 10), which complements, from a theoretical point of view, the analogous treatment given in Wiley's earlier book on *Thermal Convection* (2010) of purely translational vibrations, and may be of interest for researchers and scientists who are now coordinating their efforts to conceive new strategies for flow control.

Acknowledgements

The present book should be regarded as a natural and due extension of my earlier monograph *Thermal Convection: Patterns, Evolution and Stability* (published by Wiley at the beginning of 2010) in which I presented a critical, focused and ‘comparative’ study of different types of thermal convection typically encountered in natural or technological contexts (thermogravitational, thermocapillary and thermovibrational), including the effect of magnetic fields and other means of flow control. That book attracted much attention and comments, as witnessed by the many reviews that have appeared in distinct important scientific journals (R.D. Simitev (2011) *Geophys. Astrophys. Fluid Dyn.*, **105** (1), 109–111; A. Nepomnyashchy (2011) *Eur. J. Mech. – B/Fluids*, **30** (1), 135; A. Gelfgat (2011) *Cryst. Res. Technol.*, **46** (8), 891–892; J. A. Reizes (2011) *Comput. Therm. Sci.*, **3** (4), 343–344).

The success of the 2010 book and the express requests of many referees to ‘complete’ the treatment of thermal convection, including the influence of Coriolis and centrifugal forces, as well as the development of turbulence, led me to undertake the present new work, for which I gratefully acknowledge also the many unknown reviewers selected by John Wiley & Sons, who initially examined the new book project, for their critical reading and valuable comments.

Following the same spirit of the earlier 2010 monograph, I envisaged to consider both natural and industrial processes, and develop a common framework so to promote the exchange of ideas between researchers and professionals working in distinct fields (in particular between the materials science and geophysical communities).

Along these lines, deep gratitude goes to many colleagues around the world pertaining to both such categories for generously sharing with me their precious recent experimental and numerical data (in alphabetical order): Prof. R. Bessaïh, Prof. F.H. Busse, Prof. R.E. Ecke, Prof. A.Yu. Gelfgat, Prof. N. Imaishi, Prof. A. Ivanova, Prof. V. Kozlov, Dr. R.P.J. Kunnen, Prof. I. Mutabazi, Prof. P.B. Rhines, Prof. P. Read, Prof. V. Shevtsova, Prof. I. Ueno.

In particular, I wish to express my special thanks to Prof. P. Read (Atmospheric, Oceanic and Planetary Physics, Clarendon Laboratory, University of Oxford, United Kingdom) and to Prof. N. Imaishi (University of Kyushu, Institute for Materials, Chemistry and Engineering, Division of Advanced Device Materials, formerly Department of Advanced Material Study, Fukuoka, Japan), for several relevant suggestions which significantly improved both the clarity and the accuracy of some arguments in Chapters 3–4 and 7–8, respectively. In addition, there were several people (too numerous to be listed here) who were instrumental in keeping me updated on the latest advancements in several fields relevant to this book, especially the many authors who over recent years published their work in the *Journal of Fluid Dynamics and Materials Processing (FDMP)*, for which I serve as the Editor-in-Chief.

Last but not least, I am also indebted to my wife Paola, to whom this book is dedicated. Writing is a solitary activity; nevertheless, her good humour, sensitivity and vitality have made this project a pleasure, especially in the evening and during weekends. This new treatise is largely due to her optimism, encouragement, and patience.

Marcello Lappa

Author contact information:

Marcello Lappa, Via Salvator Rosa 53, San Giorgio a Cremano (Na), 80046 – Italy

Email: marlappa@unina.it, lappa@thermalconvection.net, fdmp@techscience.com

Websites: www.thermalconvection.net, www.fluidsandmaterials.com, www.techscience.com/FDMP