

Vasubandhu Misra

An Introduction to Large-Scale Tropical Meteorology

 Springer

Vasubandhu Misra
Department of Earth, Ocean and
Atmospheric Science
Florida State University
Tallahassee, FL, USA

ISSN 2194-5217
Springer Atmospheric Sciences
ISBN 978-3-031-12886-8
<https://doi.org/10.1007/978-3-031-12887-5>

ISSN 2194-5225 (electronic)
ISBN 978-3-031-12887-5 (eBook)

© Springer Nature Switzerland AG 2023

This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed.

The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

The publisher, the authors, and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publisher nor the authors or the editors give a warranty, expressed or implied, with respect to the material contained herein or for any errors or omissions that may have been made. The publisher remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Contents

1	A Synopsis of the Tropical Climate	1
1.1	Observational Features in a Zonally Symmetric Framework.....	1
1.2	A Reductionist Model.....	4
1.3	Theory on the Maintenance of the Zonally Symmetric Circulation	6
1.4	Application of the Concepts of Zonally Symmetric Circulation ...	9
1.5	Limitations of the Zonally Symmetric Framework	11
2	The Monsoon	15
2.1	The Asian Monsoon	15
2.2	Broad-Scale Features of the Asian Monsoon	17
2.3	The Evolution of the Indian Summer Monsoon	19
2.4	The Tropical Indian Ocean.....	23
2.5	The Coupled Ocean-Atmosphere Phenomenon of the Monsoon ..	25
2.6	The Tibetan Plateau	31
2.7	The Asian Monsoon Variations	34
2.7.1	The Monsoon-ENSO Teleconnection	34
2.7.2	The Tropospheric Biennial Oscillation	37
2.7.3	The Indian Ocean Dipole	42
2.8	The Other Regional Monsoons	43
3	The Role of the Diabatic Heating in the Tropical Atmosphere	47
3.1	The Ubiquity of Convection in the Tropics	47
3.2	CISK vs. Quasi-equilibrium	54
3.3	Radiative-Convective Equilibrium	58
3.4	Matsuno-Gill Atmosphere	61
3.5	The Implication on the Oceans	78
3.6	The Weak Temperature Gradient Balance	79
3.7	Moisture Modes	81
3.8	Organization of Convection.....	82

4	Intertropical Convergence Zone	91
4.1	The Latitudinal Location of the ITCZ.....	91
4.1.1	The Role of the Coriolis Force	93
4.1.2	The Role of the Oceans	97
4.2	Regional ITCZ.....	98
4.2.1	Eastern Pacific ITCZ.....	98
4.2.2	Eastern Atlantic ITCZ	101
4.2.3	Indian Ocean ITCZ	101
4.2.4	The South Pacific and South Atlantic Convergence Zones	102
4.3	ITCZ as a Spawning Zone of Tropical Cyclones	104
5	The Western Pacific Warm Pool	111
5.1	What Is the Significance of the Warm Pool?.....	111
5.2	The Atmospheric Thermostat Theory for the Warm Pool	115
5.3	A Holistic Approach to Understanding the Regulation of the Warm Pool.....	118
5.4	The Surface Heat Budget of the Warm Pool	130
5.5	The Indonesian Throughflow	134
6	The Intraseasonal Variations.....	137
6.1	The Bridge Between Weather and Climate	137
6.2	The Structure of the Madden-Julian Oscillation	139
6.3	The Seasonality of the Intraseasonal Variations	143
6.4	Theories of the Madden-Julian Oscillation	146
6.5	Identifying the Madden-Julian Oscillation	150
6.6	The Impact of the Madden-Julian Oscillation	154
7	El Niño and the Southern Oscillation	157
7.1	ENSO Definition	157
7.2	Observing ENSO	161
7.3	ENSO Features	164
7.3.1	Seasonal Phase Locking of ENSO	166
7.3.2	The Bjerknes Feedback Mechanism of ENSO	169
7.3.3	ENSO Spectrum.....	170
7.3.4	ENSO Teleconnections	172
7.3.5	ENSO Diversity	175
7.4	ENSO Theories.....	176
7.4.1	Linear Stochastic Theory	176
7.4.2	Delayed Oscillator Theory.....	180
7.4.3	Recharge-Discharge Theory	187
7.4.4	Advection-Reflective Oscillator Theory	189
7.4.5	The Western Pacific Oscillator Theory.....	191
7.4.6	The Unified Oscillator Theory	191
7.5	ENSO Asymmetry	191

Contents	xiii
8 Tropical Atlantic Variations	197
8.1 A Broad Overview	197
8.2 Seasonal Cycle	198
8.3 Atlantic Niño I.....	201
8.3.1 The Structure of Atlantic Niño I	201
8.3.2 Theories for Atlantic Niño I	201
8.3.3 The Symmetry Between Atlantic Niño I and Atlantic Niña I.....	204
8.3.4 The Impact of Atlantic Niño I	204
8.3.5 Comparing Atlantic Niño I with ENSO Variations.....	207
8.4 Atlantic Niño II.....	209
8.5 Atlantic Meridional Mode	212
8.5.1 The Structure of Atlantic Meridional Mode	212
8.5.2 Theory for the Atlantic Meridional Mode	213
8.5.3 The Influence of ENSO.....	215
8.5.4 The Relationship with the North Atlantic Oscillation.....	218
9 Large-Scale Aspects of Tropical Weather Extremes	221
9.1 Attribution Science	221
9.2 Attribution to the Madden-Julian Oscillation	222
9.3 Attribution to El Niño and the Southern Oscillation.....	224
9.4 The Psi-Chi Framework.....	230
9.5 The Easterly Wave	243
9.6 Thunderstorms.....	245
9.7 Diurnal Variations	248
10 Climate Change	253
10.1 The Widening Tropics	253
10.2 The Upped Ante Scheme	255
10.3 ENSO Variability.....	256
10.4 The Tropical Atmospheric Circulation	262
10.5 The Tropical Atlantic Ocean	267
10.6 The Tropical Indian Ocean.....	268
Glossary	271
References	283
Index	307