

MESOSCALE CIRCULATION OVER THE ANDAMAN ISLANDS : NUMERICAL SIMULATIONS

by

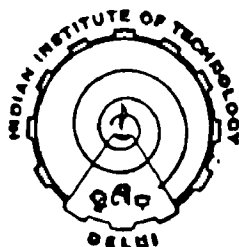
SARAT CHANDRA KAR

Thesis submitted

in fulfillment of the requirements

for the degree of

DOCTOR OF PHILOSOPHY



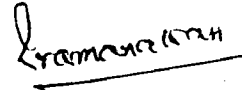
Centre for Atmospheric Sciences
INDIAN INSTITUTE OF TECHNOLOGY, DELHI

MAY, 1989

TO MY PARENTS

CERTIFICATE

This is to certify that the thesis entitled "Mesoscale Circulation over the Andaman Islands: Numerical simulations", being submitted by Sarat Chandra Kar for the award of degree of DOCTOR OF PHILOSOPHY, is a record of the original bonafide research work carried out by him. He has worked under my guidance and supervision and has fulfilled the requirements for the submission of this thesis. The results presented in this thesis have not been submitted in part or full to any other University or institute for award of any degree/diploma.



(N. Ramanathan)

Senior Scientific Officer-I
Centre for Atmospheric Sciences
Indian Institute of Technology, New Delhi

ACKNOWLEDGEMENTS

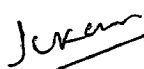
I express my deepest sense of gratitude to my advisor Dr. N. Ramanathan for his painstaking guidance and constant encouragement throughout the research work.

I am extremely grateful to Prof. M.P. Singh, Head, Centre for Atmospheric Sciences for his encouragement and providing all facilities during the course of this work.

I am also grateful to Prof. P.K. Das for his comments which were of immense value in this work.

My sincere thanks goes to all my friends who extended a hand of support as and when needed. In particular, I wish to express my cordial thanks to Mr. Alexander John, Mr. Mohan Kumar, Mr. Selva Kumar and Ms. Indu Jain for their support in various forms.

I take this opportunity to mention that without the constant encouragement and good wishes from my parents, brothers and sisters, this work could not have been completed.


(Sarat Chandra Kar)

ABSTRACT

Mesoscale atmospheric circulations such as air flow over islands are induced by the temperature contrast between the land and the surrounding oceans. These circulations are the characteristics of the location of the land mass and the prevailing atmospheric conditions. No mesoscale studies exist for any island in the Indian subcontinent. Inorder to identify various components of the mesoscale flow over a tropical island, namely the Andaman islands, numerical simulation studies were carried out.

A hydrostatic primitive equation mesoscale model was adopted for the purpose. This model uses a terrain following coordinate system and has detailed planetary boundary layer parameterisation. Atmospheric heating and cooling due to radiative flux divergence is considered.

Two dimensional numerical studies of the air flow over the Andaman islands indicated that the boundary layer air flow was not affected by the presence of an absorption layer at the model top. The model simulated better results when observed upper air wind was used to initialise the model. The land and sea breezes over the islands were simulated with and without topography. The depth of the sea breeze was about 500 m. The inland penetration of the sea breeze increased when topography was included.

A large scale precipitation scheme was included to simulate the effects of condensation on the mesoscale air flow. Two cases (a synoptically clear day and a rainy day) were considered. The latent heat release due to precipitation intensified the sea

breeze over the island. The model under-estimated the rainfall. The boundary layer wind was stronger than the observed one.

A multi-layer soil and a single level vegetation parameterisation schemes were described. In the soil scheme, soil moisture is computed by a prognostic equation assuming continuity at the air soil interface. Surface albedo is approximated as a function of available soil moisture. The foliage intercepts the insolation and re-radiates in longer wave lengths. The boundary layer is modified by the changes in the sensible and latent heat fluxes in the presence of vegetation. One dimensional sensitivity studies were carried out to test the schemes and various parameters of the model for Indian data.

These schemes were incorporated into the mesoscale model and two dimensional simulation of air flow over the Andaman islands were carried out to study the influences of moisture and heat fluxes upon the mesoscale circulations. The simulated lower level wind compared well with the available observation, when the forest cover was included in the model. A statistical analysis of the errors in the simulated results was made to test the applicability of the model. The magnitude of the errors reduced when the model physics was improved.

Three dimensional air flow over the south Andaman islands was studied. The sea and land breezes were more intense where the island is the widest and the terrain height is maximum. A comparison of the two and three dimensional simulations with observations showed that the three dimensional model produced better results.

CONTENTS

	page no.
ABSTRACT	i
LIST OF FIGURES	iii
LIST OF TABLES	xi
LIST OF SYMBOLS	xiii
CHAPTER 1	
INTRODUCTION	
1.1 MESOSCALE CIRCULATION	1
1.2 HISTORICAL BACKGROUND	2
i) Observational studies	2
ii) Numerical studies	7
iii) Air flow over islands	12
iv) Applications of Pielke's Model	18
1.3 OBJECTIVE OF THIS INVESTIGATION	19
1.4 DESCRIPTION OF THE SIMULATED AREA	21
1.5 OUTLINE OF THE CHAPTERS	24
1.6 CONCLUSION	26
CHAPTER 2	
THE NUMERICAL MODEL	
2.1 INTRODUCTION	27
2.2 BASIC EQUATIONS	29
2.3 NUMERICAL TECHNIQUES	34
2.4 INITIALISATION PROCEDURE	36
2.5 PLANETARY BOUNDARY LAYER PARAMETERISATION	36
i) Vertical turbulent exchange	36
ii) Depth of the PBL	42
iii) Horizontal turbulent exchange	43

2.6	RADIATION PARAMETERISATION	44
	i) Short-wave radiation	44
	ii) Long-wave radiation	46
	iii) Surface energy balance	48
2.7	CONCLUSION	49
CHAPTER 3	TWO DIMENSIONAL SIMULATION OF AIR FLOW OVER ANDAMANS	
3.1	INTRODUCTION	50
3.2	NUMERICAL MODEL AND COMPUTATIONAL DOMAIN	53
3.3	INITIAL AND BOUNDARY CONDITIONS	55
3.4	RESULTS AND DISCUSSIONS	61
	i) Initialisation of wind above the PBL	62
	ii) Absorbing layer	62
	iii) Influence of topography	66
	iv) Comparison with observations	79
3.5	CONCLUSION	79
CHAPTER 4	INFLUENCE OF LATENT HEAT RELEASE ON MESOSCALE CIRCULATIONS	
4.1	INTRODUCTION	82
4.2	THE MODEL	85
	i) Numerical model	85
	ii) Precipitation Scheme	86
4.3	INITIAL AND BOUNDARY CONDITIONS	88
4.4	RESULTS AND DISCUSSION	89
4.5	CONCLUSION	107

CHAPTER 5	ONE DIMENSIONAL SENSITIVITY STUDIES WITH VEGETATION CANOPY	
5.1	INTRODUCTION	110
5.2	BACKGROUND	111
5.3	THE NUMERICAL MODEL	115
	i) The layered soil scheme	115
	ii) Vegetation parameterisation scheme	119
	iii) The atmospheric model	124
	iv) The numerical aspects	124
	v) Initial and boundary conditions	127
5.4	RESULTS AND DISCUSSIONS	129
5.5	CONCLUSION	146
CHAPTER 6	INFLUENCE OF VEGETATION AND SOIL MOISTURE ON AIR FLOW OVER ANDAMANS	
6.1	INTRODUCTION	149
6.2	THE MODEL, INITIAL AND BOUNDARY CONDITIONS	151
6.3	RESULTS AND DISCUSSIONS	154
6.4	ERROR ANALYSIS	177
6.5	CONCLUSION	179
CHAPTER 7	THREE DIMENSIONAL SIMULATION OF AIR FLOW OVER SOUTH ANDAMAN ISLAND	
7.1	INTRODUCTION	185
7.2	NUMERICAL MODEL AND COMPUTATIONAL DOMAIN	187
7.3	INITIAL DATA AND BOUNDARY CONDITIONS	191
7.4	RESULTS AND DISCUSSIONS	192
	i) Effect of soil moisture	193
	ii) Effect of topography	206

	iii) Changes due to vegetation canopy	209
	iv) Comparison of 2D and 3D simulation results	214
	v) Comparison with observations	219
7.5	CONCLUSION	223
CHAPTER 8	CONCLUSION AND SCOPE FOR FUTURE WORK	
8.1	CONCLUSION	226
8.2	SCOPE FOR FURTHER RESEARCH	229
REFERENCES		232