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**NUMERICAL SIMULATION OF GOLD SURGE OVER SOUTHEAST
ASIA UNDER THE INFLUENCE OF GLOBAL WARMING**

MISS JERRAWAN SARLAO

**A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF DOCTOR OF PHILOSOPHY (APPLIED MATHEMATICS)
DEPARTMENT OF MATHEMATICS
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KING MONKUT'S UNIVERSITY OF TECHNOLOGY THONBURI
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of Global Warming

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A Thesis Submitted in Partial Fulfillment of the Requirements for
the Degree of Doctor of Philosophy (Applied Mathematics)

Department of Mathematics

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Thesis Title	Numerical Simulation of Cold Surge Over Southeast Asia Under the Influence of Global Warming
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Department	Mathematics
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Abstract

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Winter monsoon cold surge events over Southeast Asia under A2 global warming scenario are simulated by the Single Level Primitive Equation (SILEPE) model. The objective is to reveal the pattern of cold surge associated with the 500hPa geopotential height. The SILEPE model is first tested for its capability in cold surge simulation using 2 selected events in the years 2002 and 2005. There is a large error at the upper right corner of the study domain due to strong geopotential gradient associated with the surface high pressure area. However, the model provides acceptable simulation for upto 4 days. A breeding method is then applied to the SILEPE model to generate 50 ensemble forecast members for the 5 selected events of cold surge under A2 scenario. These 5 events are in the years 2049, 2056, 2058, 2059 and 2062. The initial perturbation is calculated from the 500 hPa geopotential height difference between the model initialized data and A2 scenario. This initial perturbation is then used in a 14-day simulation by the SILEPE model. The model outputs of geopotential height for every 6 hr are normalized by the norm of the initial perturbation to generate 50 new perturbations or bred vectors. Four-day ensemble simulations with the bred vectors show that the cold surges over Southeast Asia can be identified from a pattern of longwave trough in geopotential field at 500hPa.

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หัวข้อวิทยานิพนธ์	การจำลองเชิงตัวเลขของคลื่นอากาศหนาวเหนือเอเชียอาคเนย์ภายใต้อิทธิพลของภาวะโลกร้อน
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เหตุการณ์คลื่นอากาศหนาวเหนือเอเชียอาคเนย์ภายใต้ทัศนภาพภาวะโลกร้อน A2 ได้รับการจำลองโดยใช้แบบจำลองสมการปฐมฐานระดับเดียว (SILEPE) วัตถุประสงค์เพื่อแสดงรูปแบบของคลื่นอากาศหนาวที่เกี่ยวข้องกับความสูงของจีโอโพเทนเชียล 500 hPa เริ่มแรกแบบจำลอง SILEPE ได้รับการทดสอบสมรรถนะในการจำลองคลื่นอากาศหนาวโดยใช้เหตุการณ์คลื่นอากาศหนาว 2 เหตุการณ์ในปี ค.ศ. 2002 และ 2005 มีความผิดพลาดมากที่มุมขวางบนของพื้นที่ศึกษา เนื่องจากเกรเดียนต์ความสูงของจีโอโพเทนเชียลกำลังแรงซึ่งเกี่ยวเนื่องกับความกดอากาศสูงที่ผิวพื้น อย่างไรก็ตามแบบจำลองให้ผลการจำลองที่ยอมรับได้สำหรับไม่เกิน 4 วัน จากนั้นประยุกต์วิธีบลิตดิงกับแบบจำลอง SILEPE เพื่อสร้าง 50 สมาชิกของการพยากรณ์แบบรวมชุด สำหรับคลื่นอากาศหนาว 5 เหตุการณ์ที่ได้เลือกไว้แล้ว ภายใต้ทัศนภาพ A2 เหตุการณ์ทั้งห้าอยู่ในปี ค.ศ. 2049, 2056, 2058, 2059 และ 2062 ค่าเริ่มต้นของเพอร์เทอร์เบชันคำนวณจากความแตกต่างของความสูงของจีโอโพเทนเชียลระหว่างข้อมูลเริ่มต้นจากแบบจำลองและทัศนภาพ A2 จากนั้นใช้ค่าเริ่มต้นของเพอร์เทอร์เบชันนี้ในการจำลอง 14 วัน โดยแบบจำลอง SILEPE ผลที่ได้จากแบบจำลองทุก 6 ชั่วโมงจะถูกทำให้เป็นบรรทัดฐานโดยนอร์มของค่าเริ่มต้นของเพอร์เทอร์เบชันเพื่อสร้างเพอร์เทอร์เบชันใหม่หรือเบรคเวกเตอร์ 50 ค่า การจำลองแบบรวมชุดด้วยเบรคเวกเตอร์ระยะ 4 วัน แสดงว่าคลื่นอากาศหนาวเหนือเอเชียอาคเนย์สามารถระบุได้จากรูปแบบของร่องในคลื่นยาวของสนามจีโอโพเทนเชียล ที่ระดับ 500 hPa.

คำสำคัญ : คลื่นอากาศหนาว / ภาวะโลกร้อน / การพยากรณ์แบบรวมชุด / เทคนิคบลิตดิง

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CONTENTS

	PAGE
ENGLISH ABSTRACT	ii
THAI ABSTRACT	iii
ACKNOWLEDGEMENT	iv
CONTENTS	v
LIST OF TABLES	vi
LIST OF FIGURES	viii
LIST OF SYMBOLS	xi
LIST OF TECHNICAL TERMS AND ABBREVIATIONS	xiii
CHAPTER	
1. INTRODUCTION	1
1.1 Rationale/Problem	1
1.2 Monsoon and Cold Surge	1
1.2.1 Monsoon	1
1.2.2 Cold Surge	3
1.3 Global Warming	4
1.4 Simulation	4
1.5 Ensembles Forecast	5
1.6 Literature Review	5
1.7 Objective	8
2. THEORY	9
2.1 Shallow Water Equations	9
2.2 Closed Domain Invariants of the Shallow Water Equation	12
2.2.1 Mean Potential Vorticity	12
2.2.2 Mean Geopotential Height	14
2.2.3 Mean Total Energy	15
2.3 Specification of Initialization	17
2.3.1 Static Initialization	17
2.3.2 Dynamic Initialization	17

2.4	Ensemble Forecasting Techniques	18
2.4.1	Singular Vector Method	19
2.4.2	Monte Carlo method	21
2.4.3	Breeding Technique	22
2.4.4	Kalman Filter Method	23
2.4.5	Extended Kalman Filter Method	28
3.	METHODOLOGY	32
3.1	Single Level Primitive Equation (SILEPE) Model	32
3.2	The Data	34
3.2.1	The Data for Testing the Model	34
3.2.2	The Data for Breeding Method	35
3.3	Breeding Case Selection	36
3.4	Domain	39
3.4.1	Study Domain	39
3.4.2	Experiment Domain	40
3.5	Breeding Method for Generation of Initial Perturbation	40
3.6	Ensemble Forecasting from Bred Vector	43
4.	RESULTS AND DICUSSION	44
4.1	Performance of SILEPE Model	44
4.2	Bred Vector	46
4.3	Ensemble Forecast	51
4.4	Domain Invariant of Ensemble Forecast	57
4.5	Ensemble Forecast Probability	60
5.	CONCLUSION AND RECOMMENDATION	66
5.1	Conclusion	66
5.2	Recommendation	67
	REFERENCES	68
	APPENDIX A ENSEMBLE FORECAST PROBABILITY OF GEPOTENTIAL HEIGHT	72
	BIOGRAPHY	86

LIST OF TABLES

TABLE		PAGE
3.1	Summary of cases for testing the model	35
3.2	The Special Report on Emissions Scenario (SRES) data and Non-SRES for the Atmospheric Environment	36
3.3	Experiment cases for testing the generation of initial perturbations in breeding process	37
3.4	Example of data for the experiments	38
4.1	The experiment setting for testing the performance of SILEPE model	44
4.2	The outline of experiment setting for ensemble forecasts using bred vector	51
4.3	Domain invariants of the control run (CTL) and the mean of 50 ensemble members (mean EM)	57
4.4	Example of counting the number of ensemble member that corresponds to the event at each grid point in Case 1 for 24-hr forecast	60
4.5	The pattern of cold surge from the ensemble forecast probability of geopotential height at 500 hPa.	65

LIST OF FIGURES

FIGURE		PAGE
1.1	Changing annual wind flow patterns associated with the winter and summer Asian monsoon	2
1.2	The three primary and multiple secondary tracks for cold surge	3
2.1	A single-level shallow water system. $h = h(x, y)$ is the depth of the water column, H its mean depth	10
2.2	Schematic of the essential components of an ensemble of forecasts	19
2.3	Schematic of the method to generate bred vectors	23
2.4	The sequence of computational steps for the Kalman filter estimator	28
3.1	Flow chart showing sequence of running in SILEPE model	35
3.2	The breeding case of 12Z 07 DEC 2059 from a) A2 and b) COMMIT	36
3.3	The steps for preparing the data set from the WCRP CMIP3 multi-model database	37
3.4	The domain of study	39
3.5	The domain of experiment	40
3.6	Flow chart showing the steps of breeding method	43
4.1	Daily geopotential height (m) from a) NCEP b) Case A and c) Case B	45
4.2	The 500 hPa geopotential height for every of 24 hr of the control run of Case 4	46
4.3	The 500 hPa geopotential height at $t = 0$ (00 hr) after model initialization	47
4.4	The initial perturbation at $t = 0$	48
4.5	Spaghetti plot of 5700 m geopotential height for CTL (A2), +PRT, and -PRT at $t = 0$	49
4.6	The perturbation at $\delta t = 6$ hr	50
4.7	The new perturbations or bred vector for a) the plus bred vector (+BV) and b) the minus bred vector (-BV)	51
4.8	Spaghetti plots of 5800 m geopotential height for Case 4	52

LIST OF FIGURES

FIGURE		PAGE
1.1	Changing annual wind flow patterns associated with the winter and summer Asian monsoon	2
1.2	The three primary and multiple secondary tracks for cold surge	3
2.1	A single-level shallow water system. $h = h(x, y)$ is the depth of the water column, H its mean depth	10
2.2	Schematic of the essential components of an ensemble of forecasts	19
2.3	Schematic of the method to generate bred vectors	23
2.4	The sequence of computational steps for the Kalman filter estimator	28
3.1	Flow chart showing sequence of running in SILEPE model	35
3.2	The breeding case of 12Z 07 DEC 2059 from a) A2 and b) COMMIT	36
3.3	The steps for preparing the data set from the WCRP CMIP3 multi-model database	37
3.4	The domain of study	39
3.5	The domain of experiment	40
3.6	Flow chart showing the steps of breeding method	43
4.1	Daily geopotential height (m) from a) NCEP b) Case A and c) Case B	45
4.2	The 500 hPa geopotential height for every of 24 hr of the control run of Case 4	46
4.3	The 500 hPa geopotential height at $t = 0$ (00 hr) after model initialization	47
4.4	The initial perturbation at $t = 0$	48
4.5	Spaghetti plot of 5700 m geopotential height for CTL (A2), +PRT, and -PRT at $t = 0$	49
4.6	The perturbation at $\Delta t = 6$ hr	50
4.7	The new perturbations or bred vector for a) the plus bred vector (+BV) and b) the minus bred vector (-BV)	51
4.8	Spaghetti plots of 5800 m geopotential height for Case 4	52

4.9	Spaghetti plot of geopotential height at 5800 m for Case 1	53
4.10	Spaghetti plot of geopotential height at 5800 m for Case 2	54
4.11	Spaghetti plot of geopotential height at 5800 m for Case 3	55
4.12	Spaghetti plot of geopotential height at 5800 m for Case 5	56
4.13a	Mean potential vorticity ($\text{km}^2/\text{kg.s}$) for CTL and mean EM	58
4.13b	Absolute error of mean potential vorticity ($\text{km}^2/\text{kg.s}$) between CTL and mean EM	58
4.14a	Mean geopotential height (m) for CTL and mean EM	58
4.14b	Absolute error of mean geopotential height (m) between CTL and mean EM	58
4.15a	Mean total energy (m^3/s^2) for CTL and mean EM	59
4.15b	Absolute error of mean total energy (m^3/s^2) between CTL and mean EM	59
4.16	Ensemble forecast probability of geopotential height at 500 hPa for Case 1 at 24-hr forecast	61
4.17	Ensemble forecast probability of geopotential height at 500 hPa for Case 1 at 48-hr forecast	62
4.18	Ensemble forecast probability of geopotential height at 500 hPa for Case 1 at 72-hr forecast	63
4.19	Ensemble forecast probability of geopotential height at 500 hPa for Case 1 at 96-hr forecast	64
A.1	Ensemble forecast probability of geopotential height at 500 hPa for Case 2 at 24-hr forecast.	73
A.2	Ensemble forecast probability of geopotential height at 500 hPa for Case 2 at 48-hr forecast.	73
A.3	Ensemble forecast probability of geopotential height at 500 hPa for Case 2 at 72-hr forecast.	74
A.4	Ensemble forecast probability of geopotential height at 500 hPa for Case 2 at 96-hr forecast.	75
A.5	Ensemble forecast probability of geopotential height at 500 hPa for Case 3 at 24-hr forecast.	76
A.6	Ensemble forecast probability of geopotential height at 500 hPa for	77

	Case 3 at 48-hr forecast.	
A.7	Ensemble forecast probability of geopotential height at 500 hPa for Case 3 at 72-hr forecast.	78
A.8	Ensemble forecast probability of geopotential height at 500 hPa for Case 3 at 96-hr forecast.	79
A.9	Ensemble forecast probability of geopotential height at 500 hPa for Case 4 at 24-hr forecast.	79
A.10	Ensemble forecast probability of geopotential height at 500 hPa for Case 4 at 48-hr forecast.	80
A.11	Ensemble forecast probability of geopotential height at 500 hPa for Case 4 at 72-hr forecast.	81
A.12	Ensemble forecast probability of geopotential height at 500 hPa for Case 4 at 96-hr forecast.	82
A.13	Ensemble forecast probability of geopotential height at 500 hPa for Case 5 at 24-hr forecast.	83
A.14	Ensemble forecast probability of geopotential height at 500 hPa for Case 5 at 48-hr forecast.	84
A.15	Ensemble forecast probability of geopotential height at 500 hPa for Case 5 at 72-hr forecast.	85
A.16	Ensemble forecast probability of geopotential height at 500 hPa for Case 5 at 96-hr forecast.	86

LIST OF SYMBOLS

SYMBOL

u	x -component of the wind vector
v	y -component of the wind vector
w	z -component (vertical component) of the wind vector
f	Coriolis force
Ω	angular velocity of the earth
θ	latitude
ρ	Density
p	Pressure
h	depth of the water column
H	mean depth
g	acceleration due to gravity
x	state vector
M	time integration of the numerical scheme
L	tangent linear model
v_i	right singular vectors
u_i	left singular vectors
σ	variance of random errors
\hat{x}_k	state estimate of the system at time k
\hat{x}_{k-1}	state estimate of the system at time $k-1$
\hat{P}_k	estimation-error covariance matrix
w_{k-1}	random noise affecting the system at time $k-1$
z_k	vector of measurements at time k
v_k	random noise in the observation z_k at time k
K_k	Kalman gain
$W_{i,j}$	weights for the Lagrange interpolation scheme
t	time

Δt	time step size
$\tilde{Z}(x_i, 0)$	initial value of geopotential height
$\delta Z(x_i, 0)$	initial perturbation of geopotential height
$P_i(E)$	probability of the event E that have error in interested range of grid point i
$n(E)$	number of ensemble member that predict the event E of grid point i
$n(T)$	ensemble size

LIST OF TECHNICAL TERMS AND ABBREVIATIONS

AL	Aleutian Low
AOGCMs	Atmosphere-Ocean General Circulation Models
AR4	Fourth Assessment Report
BV	Bred Vector
BCCR	Bjerknes Centre for Climate Research
CMIP3	Coupled Model Intercomparison Project phase 3
CTL	Control Run
EAJ	East Asian Jet
EAWM	East Asian Winter Monsoon
ECMWF	European Centre for Medium-Range Weather Forecasts
EnKF	Ensemble Kalman Filter
EM	Ensemble Member
GHG	Greenhouse Gas
IPCC	Intergovernmental Panel on Climate Change
NCAR	National Center for Atmospheric Research
NCEP	National Center for Environment Prediction
NW	Northwesterly
OSSE	Observing System Simulation Experiment
PRT	Perturbation Run
SH	Siberian High
SILEPE	Single Level Primitive Equation Model
SLP	Sea Level Pressure
SRES	Special Report on Emissions Scenario
TLM	Tangent Linear Model
UTC	Coordinated Universal Time
WCRP	World Climate Research Programme
ZC	Zebiak–Cane