

# CHAPTER 1 INTRODUCTION

## 1.1 Rationale / Problem

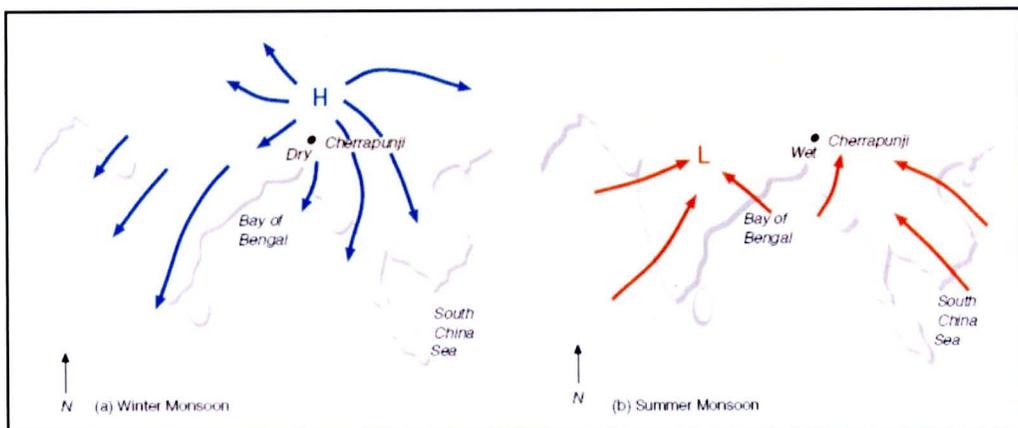
In Southeast Asia, cold surge is one of the most obvious features of the winter monsoon. Its impact on weather events that pose a distinct threat to agriculture industry and human health in this region remains underexplored. Every year during the winter monsoon period over Southeast Asia between mid October to mid February, cold surge plays an important role in the winter climate over Thailand and the surrounding area. Along with the foundation of the winter monsoon, cold air outbreaks propagate southward, bringing with them severe weather such as large temperature drops, high winds, and thunderstorms. The Intergovernmental Panel on Climate Change - IPCC (2007) reports that in the past century, the average temperature of the world increase 0.6-0.8 degree Celsius. The increase in global temperature will lead to global climate change. In order to mitigate from the disaster associated with severe weather, model simulations have been used. Winter monsoon forecast should concern all related variables. These variables are, for example, wind velocity and geopotential height. In order to obtain various patterns of weather, numerous scenarios should be generated from an initial observation and these scenarios are then used as input for a prediction model. Ensemble forecasting technique is based on the recognition of the fact that any error in initial conditions or model formulation shall lead to loss of predictability after a finite period of time. This technique entails running a simulation model a number of times with slightly perturbed initial conditions, to assess the forecast uncertainty due to errors in the initial conditions and possibly in model formulation. In this research, the shallow water model called "Single Level Primitive Equation Model" (SILEPE) is used to simulate the patterns of cold surge over Southeast Asia under the influence of global warming. This is done using an ensemble forecasting technique in order to reveal the pattern of cold surge under global warming.

## 1.2 Monsoon and Cold Surge

### 1.2.1 Monsoon

The word monsoon derives from the Arabic mausim, which means seasons. A monsoon wind system is one that changes direction seasonally, blowing from one direction in summer and from the opposite direction in winter. This seasonal reversal of winds is

especially well developed in eastern and southern Asia. During the winter, the air over the continent becomes much colder than the air over the ocean. A large, shallow high-pressure area develops over continental Siberia, producing a clockwise circulation of air that flows out over the Indian Ocean and South China Sea. Sinking air of the anticyclone and the down slope movement of northeasterly winds from the inland plateau provide eastern and southern Asia with generally fair weather and the dry season. Hence, the winter monsoon means clear skies, with winds that blow from land to sea (Donald, 2000) (Figure 1.1a).

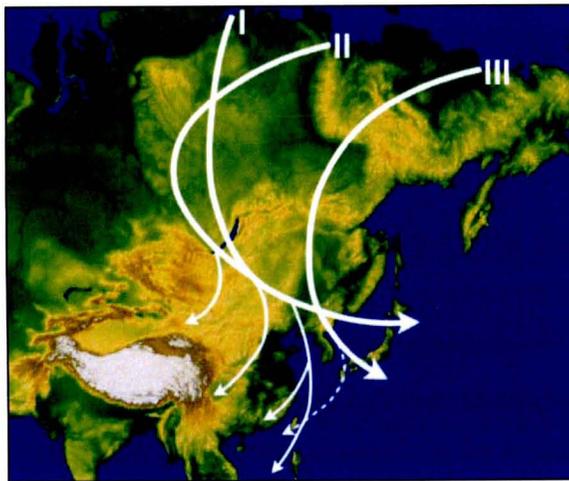


**Figure 1.1** Changing annual wind flow patterns associated with the winter and summer Asian monsoon (Donald, 2000).

In summer, the wind flow pattern reverses itself as air over the continents becomes much warmer than air above the water. A shallow thermal low develops over the continental interior. The heated air within the low rises, and the surrounding air responds by flowing counterclockwise into the low center (Figure 1.1b). This condition results in moisture-bearing winds sweeping into the continent from the ocean. The moist air converges with a drier westerly flow, causing it to rise; further lifting is provided by hills and mountains. Lifting cools the air to its saturation point, resulting in heavy showers and thunderstorms. Thus, the summer monsoon of southeastern Asia means wet, rainy weather (wet season) with winds that blow from sea to land (Donald, 2000).

### 1.2.2 Cold Surge

In winter monsoon period, cold air masses moved from the Siberian-Mongolian high pressure system will generate large anticyclones flows moving southward to low latitudes. Figure 1.2 shows that after the cold surge begins, the center tends to move along one of three main tracks. Each of these tracks shows an initial southward movement, then a turn to the east towards Japan. Cold air, branching off of the tracks, pushes the cold front southward along the eastern periphery of the Tibetan Plateau. These surges quite often reach the South China Sea (COMET, 2010).



**Figure 1.2** The three primary and multiple secondary tracks for cold surge (COMET, 2010).

A cold surge begins with the establishment of a northwesterly flow over the Lake Baikal region. An upper-level shortwave trough will move east towards a longwave trough positioned along the coast of Asia. As the shortwave passes through the longwave, it intensifies and initiates surface cyclogenesis over the East China Sea. As this surface low deepens the pressure gradient between the low and the Asiatic High increases and initiates a cold surge.

A cold surges are progressive, starting in the far north and moving south over time. They occur at intervals of four to twenty days, and a major surge may take six or seven days before its influence is apparent at near-equatorial locations. Cold surges bring extremely dry and cold weather to Mongolia, China, and Korea. The associated weather

includes high winds, abrupt temperature drops, severe frost, freezing rain, heavy snow, and even sandstorms (COMET, 2010).

Sometimes the outflow from the high pressure system intensifies causing a widespread outbreak of cold continental air, rapidly increasing surface pressure accompanied by strong northeasterly winds and a sharp drop in daily temperature which can extend to Southeast Asia. This cold surge is associated with strong gusty winds, widespread heavy rain and sometime severe thunderstorms over Southeast Asia. Consequently, forecasting the exact intensity, timing, and resulting weather in the cold surge is very interesting and important for Southeast Asia. A cold surge is over Thailand when the 1020 hPa isobar reached the border of Thailand.

### **1.3 Global Warming**

Human activities of all kinds whether in industry, in the field (e.g. deforestation) or concerned with transport or home are resulting in emissions of increasing quantities of gases, in particular carbon dioxide, into the atmosphere. Every year these emissions add to the carbon already present in atmospheric carbon dioxide a further seven thousand million tons, much of which is likely to remain there for a period of a hundred years or more. Because carbon dioxide is a good absorber of heat radiation coming from the Earth's surface, increased carbon dioxide acts like a blanket over the surface, keeping it warmer than it would otherwise be. With the increased temperature the amount of water vapor in the atmosphere also increase, providing more blanketing and causing it to be even warmer. According to the IPCC (2007) during the past century, the average temperature of the world increased 0.6-0.8 degree Celsius. The increase in global temperature will lead to global climate change. If the change were small and occurred slowly enough it would almost certainly that human would be able to adapt to it. However, with rapid expansion taking place in the world's industry the change is unlikely to be either small or slow (Houghton, 2009). Intensive research is needed to improve the confidence in climate change predictions.

### **1.4 Simulation**

There are several types of model. Each type of model has many variables such as temperature, pressure, rain, and wind, etc. If artificial data are used as initial conditions

instead of observed data, this model run is called “simulation”. If several sets of initial condition are used to simulate a phenomenon to reveal more possible scenarios, this is call “ensemble forecast”. Up to now there is no study about the effect of global warming on the cold surge that utilized the ensemble technique. Thus, in this study an ensemble technique is applied to investigate the effect of global warming on the cold surge associated with the northeast monsoon over Southeast Asia.

### **1.5 Ensembles Forecast**

Ensemble forecast is a numerical prediction method that is used to generate representative samples of the possible future states of a dynamical system. Ensemble forecast is a form of multiple numerical predictions that are conducted using slightly different initial conditions. The quality of ensemble forecasts highly depends on the method of ensemble initialization as it influences the subsequent evolution of the simulations. Ensemble initialization procedures have been developed to enforce the ensemble spread growth in such a way that these represent the uncertainties as well as possible. But since the number of ensemble forecast members is strongly limited by computational cost, it is important that this limited number of perturbations optimally sample the initial error probability distribution. Several techniques are used for the generation of the initial perturbation of analysis fields. Considering the problem of numerical weather prediction, ensemble forecasts are now commonly used at most of the major operational weather prediction facilities worldwide, including the National Centers for Environmental Prediction (NCEP), the European Centre for Medium-Range Weather Forecasts (ECMWF), the United Kingdom Meteteorological Office, Meteo France, Environment Canada, the Japan Meteorological Agency, the Bureau of Meteorology (Australia), the China Meteorological Administration, and the Korea Meteorological Administration.

### **1.6 Literature Review**

Houtekamer, et al. (1996) generate an ensemble to simulate the process of error growth in a forecast model. For each perturbation, an independent 6-hr assimilation cycle is performed. For this the available observations are randomly perturbed. The perturbed observations are integrated for 6 hr with a perturbed version of the T63 forecast model,

using perturbed surface fields, to obtain a perturbed first guess for the next assimilation. After cycling for 4 days it is found that the ensemble statistics have become stable. Toth and Kalnay (1997) use the breeding method for two concurrent forecasts rather than a time-lagged forecast and a current analysis, to calculate raw perturbation at  $t = 0$ . The difference is then scaled down and added to or subtracted from the current control initial condition. In this way, one can create as many members as required to have a large size ensemble as long as one can create enough initial random seeds or use other approaches in the beginning to initiate or have enough different forecasts to start with. The predictability of a cold-air outbreak over eastern North America during January 1985 has been studied with ensemble forecasts from the NCAR Community Climate Model version 2 run at T42 horizontal resolution by Colucci (1999). The results suggest that the forecast details of a cold air outbreak may depend upon the subtle balance between diabatic and adiabatic processes.

Hu, et al. (2000) use the simulation of a single atmosphere-ocean general circulation model (AOGCM) under global warming to show that the intensity of the East Asian winter monsoon (EAWM) will be weakened while interannual to decadal variability in EAWM will remain the same.

Anthony (2001) examines the climatological, large-scale, and synoptic-scale aspects of South American cold surges using NCEP–NCAR gridded reanalyses for the 1992–1996 period. Three common cold surge types are identified on the basis of a thickness (1000–850 hPa) criteria: type 1—a transient surge associated with weak anticyclone development east of the Andes in the absence of ridging aloft, type 2—a strong and persistent surge associated with dynamic anticyclogenesis aloft and strong surface anticyclone development east of the Andes, and type 3—a surge east of the Brazilian coastal mountains. Cold surges are most common during the winter and spring (Jun–Nov), accounting for 189 of the 256 events (74%).

Du and Tracton (2001) show that the breeding method is a simple assumption (using full nonlinear primitive-equation based model) and easy to implement, has little cost in computing power and gives good ensemble spread. It is widely used and tested by many centers such as NCEP ensemble systems.

Ming, et al. (2003) use the breeding method to obtain the bred vectors (BV) of the Zebiak–Cane (ZC) atmosphere–ocean coupled model. Bred vectors represent a nonlinear, finite-time extension of the leading local Lyapunov vectors of the ZC model. The spatial structure and growth rate of bred vectors are strongly related to the

background El Nino/La Nina-Southern Oscillation (ENSO) evolution of the ZC model. Potential applications of bred vectors for ENSO predictions are explored in the context of data assimilation and ensemble forecasting under a perfect model scenario. It is shown that when bred vectors are removed from random initial error fields, forecast errors can be reduced by up to 30%. This suggests that minimizing the projection of the bred vectors on the observation-minus-analysis field may be a beneficial factor to an operational forecast system.

Wang and Bishop (2003) study Ensemble Transform Kalman Filter (ETKF) approach for generating ensemble. The ETKF forecast perturbations are put into analysis perturbations by multiplying a transformation matrix. Using observational information, the magnitude of the analysis perturbations was adjusted before the perturbations are added to a control analysis to initiate an ensemble of forecasts. The transformation matrix used can also guarantee all perturbations to be orthogonal to each other, a desired property for ensemble forecasting.

Masatake and Hiroaki (2006) study an impact of global warming on the EAWM by using nine coupled atmosphere-ocean general circulation models (AOGCMs). The models are mostly successful in simulating the basic features of the EAWM with varied location of where monsoon northwester lies. Under the global warming scenario, most models show a weakening of the EAWM accompanied by a strong anticyclonic anomaly over the North Pacific corresponding to a weakened and/or the northern shift of the Aleutian Low (AL). Response in Sea Level Pressure (SLP) also shows the weakening of both the AL and the Siberian High (SH), which gives rise to a weakened pressure gradient along the eastern coast of the Eurasian continent. Among other factors, weakening of the tropical local Hadley circulation was found to substantially weaken the East Asian Jet and the resultant EAWM.

Wei (2005) studies the impact of increasing greenhouse gases on the Asian monsoon by using coupled atmosphere-ocean models. It is found that the variability of the monsoon associated with ENSO phenomena will vary more.

Rosangela and Haroldo (2008) apply bred vectors for the Lorenz system, and a model for three coupling waves for solar activities connected to the space weather process. The bred vector growth can be used to predict which will be the last orbit in each of the two regimes and how long will the next regime last.

Jun, et al. (2008) present the effectiveness of an Ensemble Kalman Filter (EnKF) for the Gulf of Maine using observing system simulation experiment. Perfect and imperfect

model experiments are considered to mimic different scenarios in the Northeast Channel. In the perfect model experiment, the models for the false ocean run is identical to the one used for the true ocean. The initial ensemble members of the false ocean are constructed from long term unconstrained model simulations. Current velocity, temperature and salinity from the true ocean state are then assimilated into the false ocean run. The analysis root-mean square errors are reduced by more than 75% at the end of day 10. In the imperfect model experiment, the model deficiency is mimicked through perturbing meteorological forcing (wind stress and heat flux) so that the false ocean is contaminated by both initial error and model forcing error. The assimilation results show that in winter scenario EnKF is highly sensitive to the wind stress perturbations but not sensitive to the heat flux perturbations, whereas in summer scenario both wind stress and heat flux perturbations become significant. Although all experiments are made with EnKF only, the results could be applicable in general to all other ensemble-based data assimilation methods.

Tossavainen et al. (2008) present a state estimation method for 2D shallow water equations in river hydraulics using Lagrangian measurement data. The solution method is based on the state augmentation and the use of ensemble Kalman filter. By using state augmentation it is possible to use the drifter positions as measurements directly without any mappings to Eulerian flow variables. The state augmentation approach has been earlier successfully introduced to oceanography.

## **1.7 Objective**

To reveal the pattern of cold surge over Southeast Asia under the influence of global warming.