CHAPTER 1 INTRODUCTION

1.1 Rational/Problem

Tropical cyclones can cause loss of life and severe damages to properties. One of the devastating factors in a tropical cyclone is very strong wind associated with the vorticity of the storm. This thesis formulates a numerical model for tropical cyclone formation in the Gulf of Thailand.

The Gulf of Thailand is a shallow water area, bounded by the coastlines of Vietnam, Cambodia, and connected to the South China Sea. The Gulf of Thailand is affected by tropical cyclone almost every year. Tropical cyclones have great effects on some long shore or offshore structures. Thus, it is of great importance to simulate tropical cyclone formation in the Gulf of Thailand by a numerical model.

In this thesis, Typhoons GAY (8929) and VAMEI (0126) are used in the model development. These are interesting cases because GAY occurred in the Gulf of Thailand and VAMEI occurred in the Gulf of Thailand near the equator which is very rare. A simulation model for the formation of the typhoons based on vorticity is presented. To increase weak observed wind speed of GAY and VAMEI, an asymmetric wind model is applied for wind bogussing. A shallow water model is used to simulated vorticity in typhoons GAY and VAMEI formation.

1.2 Tropical Cyclone

Tropical cyclone is a storm with very strong wind rotates into a low pressure center in counterclockwise direction in the Northern Hemisphere and clockwise direction in the Southern Hemisphere. Tropical cyclones can cause severe damage. This storm forms over the tropical oceans (except the South-Atlantic Ocean region) between latitude 23.5 degree North and South. The storms are called differently depend on the origin, such as:

- The Indian Ocean, Arab Sea and Bay of Bengal, called cyclone.
- The North-Pacific Ocean, the East Indies and South China Sea, called typhoon.
- The North-Atlantic Ocean, Gulf of Mexico, and the North-Pacific Ocean, called hurricane.

1.2.1 Classification of Tropical Cyclone

An average tropical storm system lasts about 12 days. If conditions are favorable, it may persist through three stages of formation (Ahrens, 2000).

- Tropical depression
  As convection intensifies and the surface pressure decreases further, a tropical disturbance begins to rotate. When the winds reach speeds over 17 ms^{-1}, the system is classified as a tropical depression.
- Tropical storm
  If a tropical depression intensifies, with wind speeds increasing to 32 ms^{-1} or higher, it is called a tropical storm, and is assigned a name. The eye of the storm may become visible.
- Typhoon
  When wind speeds exceed 33 ms^{-1}, the storm is classified as a cyclone or hurricane or typhoon. Distinct bands of thunderstorms rotate around the eye of

the storm. The eye is an area of calm surrounded by the eye wall, where the winds reach their maximum speed.

1.2.2 Features of Tropical Cyclone

In the mature stage, a tropical cyclone can have diameter around 400-800 kilometers. The period of life cycle is about 2-7 days, and maximum wind speed around the storm center is around 120-250 kilometer/hour (Australian Government Bureau of Meteorology, 2012).

The center of the storm is called eye, and the diameter of the eye is about 19-32 kilometers. The eye is a region of clear or mostly clear skies, little cloud, and calm wind. This is because the vertical motion in the eye is downward. The eye is surrounded by eye wall which is an intense band of thunderstorms. Eye wall is a region of bad weather, more cloud, dark skies and much rainfall, and sometimes thunderstorms. Generally, the storm has the movement speed around 20-30 kilometer/hour (Klaver, 2005).

1.2.3 Tropical Cyclone Formation

Some required conditions for the formation of tropical cyclone are as follows (Amanda, 2006):

- Warm ocean waters of at least 26.5°C throughout a sufficient depth (at least on the order of 50 m). Warm waters are necessary to fuel the heat engine of the tropical cyclone. This usually happens between 5° and 20º North and South.
- A minimum distance of at least 500km from the equator. For tropical cyclogenesis to occur, there is a requirement for non-negligible amounts of the Coriolis force to provide for near gradient wind balance to occur. Without the Coriolis force, the low pressure of the disturbance cannot be maintained.
- A wind pattern near the ocean surface that spirals air inwards.

1.3 Literature Review

Trinh and Krishnamurti (1992) use a Rankin vortex initialization for typhoon track predictions with a single level primitive equation model. They present a vortex initialization for computing the tangential wind and geopotential height, expressions for computing typhoon initial movement and the merging of vortex bogus data into the initial data fields. Results of sensitivity studies on the above parameters in a synthetic idealized vortex show that the predicted track is sensitive to the initial size, intensity and direction and speed of motion of the storm.

Chang and Liu (2003) analyze the low-level wind fields to determine the roles played by monsoonal cold surge, pre-existing disturbances, and upper level divergence in typhoon VAMEI. The equatorial zone has been considered to be free from tropical storms. This is because tropical cyclones have rarely been observed to form equator ward of 5 latitude, where the diminishing Coriolis effect prevents effective generation of vorticity by horizontal convergence.

McConochie et al. (2004) use an asymmetric wind model and an interactive computer tool to developed wind fields of 64 historical tropical cyclones. Results from the study reveal that these wind fields are suitable to be applied to applications such as wave, storm surge and circulation modeling. The asymmetric double vortex wind field model is based on Holland (1980).

Singh et al. (2005) improve the initial condition of a tropical cyclone by design an initialization scheme to test with Orissa super cyclone (1999) over the Bay of Bengal using the Fifth-Generation Penn State / NCAR Mesoscale Model (MM5). They create an initial vortex that is more realistic in size and intensity than the storm that obtained from the National Center for Environmental Prediction (NCEP) analysis. It is found that for the bogus vortex to be effective, the radius of maximum wind of the bogus vortex has to be larger enough such that it can be resolved by the model.

Chambers et al. (2006) use a model to simulate and understand processes that led to the formation and intensification of a near-equatorial typhoon. The model simulation shows that a convectively driven vortex may be developed at near equatorial latitudes for a short period. The typhoon formation is marked by three rapid intensification periods, which are associated with the rapid growth of vorticity. A vorticity budget analysis reveals that the increases in low-level vorticity during the rapid intensification periods are attributed to enhanced horizontal vorticity fluxes into the storm vortex.

Giaiotti et al. (2006) propose a Rankine vortex model in cylindral coordinates. It can be expressed in a simple two-equation parametric description of a swirling flow, characterized by a forced vortex in the central core. The wind near the center of vortex circulates faster than the wind far from the center. The speed along the circular path of flow decreases as move out from the center. At the same time the inner streamlines have a shorter distance to travel to complete a ring. Wind speed of a vortex increasing with radial distance from the vortex center. The tangential wind speed varies inversely with the radial distance from the center of rotation, so the angular momentum is uniform everywhere throughout the flow. The two parameters of this model are the radius of maximum wind and the maximum wind speed.

Chang and Wong (2008) discuss a dynamic theory that may explain the formation of a near-equatorial typhoon VAMEI in which a strong cold surge event interacting with the Borneo vortex led to the equatorial formation. The cross-equatorial flow wrapped around the vortex and provided a background area of cyclonic vorticity.

Wang et al. (2008) compare two bogussing schemes, in one scheme a realistic bogus vortex is inserted into Fifth-Generation Penn State/ National Center for Atmospheric Research (NCAR) Mesoscale Model (MM5) while in the other scheme four-dimensional data assimilation is applied. The results show that the bogus scheme is more consistent with MM5 model but more expensive in terms of computational time.

Yavinchan et al. (2009) present a vortex bogussing method for improving tropical storm track prediction for Thailand using Weather Research and Forecasting (WRF) model. This research studies vortex bogussing based on analytic equations, which use tangent wind speed and geopotential height. Vortex bogussing is a method for improving initial data by correcting the position and intensity of the tropical storm before input them into the model. Tropical storm data from the Regional Specialized Meteorological Center (RSMC) Japan were used to correct initial position and movement of the tropical storm.

Holland et al. (2010) revise the original parametric wind model that utilizes central and environmental surface pressures, maximum winds, and radius of maximum winds. In the revision, additional wind observations at some radii within the hurricane are included. This new version provides a good representation of surface wind profile.

In the study of Samanworakit (2011), the genesis of typhoon GAY is simulated from collision of northeast monsoon wind and the prevailing easterly wind. The pattern of inflow spiral wind is obtained from the size, maximum wind and inflow angle of the spiral wind of the storm.

1.4 Objective

To simulate tropical cyclone formation in the Gulf of Thailand based on vorticity and a shallow water model.