

Monsoon Disturbances Over Southeast and East Asia and the Adjacent Seas

C.-P. Chang

Department of Meteorology

Naval Postgraduate School, Code MR/Cp

Monterey, CA 93943

Telephone 831-656-2840, e-mail cpchang@nps.navy.mil

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LONG TERM GOALS

To study weather disturbances over the Southeast and East Asian monsoon region and adjacent seas using Navy research and operational analysis and forecast models. The primary goal is to advance the understanding of the weather-producing systems in the region, in order to improve forecast capabilities.

OBJECTIVES

The objectives are: (1) to study the structure and the dynamic and thermodynamic properties of the disturbances in the vicinity of the Southeast and East Asian monsoon region that stretches from Indian Ocean to the tropical western Pacific, including the South China Sea and Yellow Sea, which are of particular interest to naval operations; and (2) to study the ability and sensitivity of Navy operational numerical models in analyzing and predicting these disturbances.

APPROACH

Observational studies/Data analysis: Use archived gridded data from global NWP outputs (including NOGAPS and NCEP model analyses) and satellite data to determine the structure of mesoscale and synoptic disturbances in various local regions for the different seasons. Use composite and principal component approaches to perform statistical analysis of the data.

Dynamic modeling: Use dynamic models to study the interaction of western tropical Pacific monsoon circulation and synoptic tropical disturbances.

Numerical modeling: Perform sensitivity and simulation studies of the observed monsoon disturbances with Navy's regional research and operational models. Cold start with NOGAPS fields and continued integration using update cycles. Carry out sensitivity studies with respect to physical parameterizations, grid sizes, and data impacts. Verify model forecasts and analyze model results with results of observational study using diagnostic tools.

WORK COMPLETED

Conducted a study of the formation of Typhoon Vamei what occurred near Singapore on 27 December 2001. With its circulation center at 1.5°N and a radius of convective cloud area of about 200 km, the

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storm circulation was on both sides of the equator. This was the first-ever recorded tropical cyclone formation at such equatorial latitude. We analyzed the NOGAPS and NCEP wind analyses, QuikSCAT winds and satellite data, and carried out a statistical study of northeast monsoon cold surges and the synoptic scale vortices near Borneo during boreal winter, to understand this rare event.

RESULTS

Typhoon Vamei formed near Singapore on 0600 UTC 27 December 2001. With its circulation center at 1.5°N and a radius of convective cloud area of about 200 km (Fig. 1 left panel), the storm circulation was on both sides of the equator.

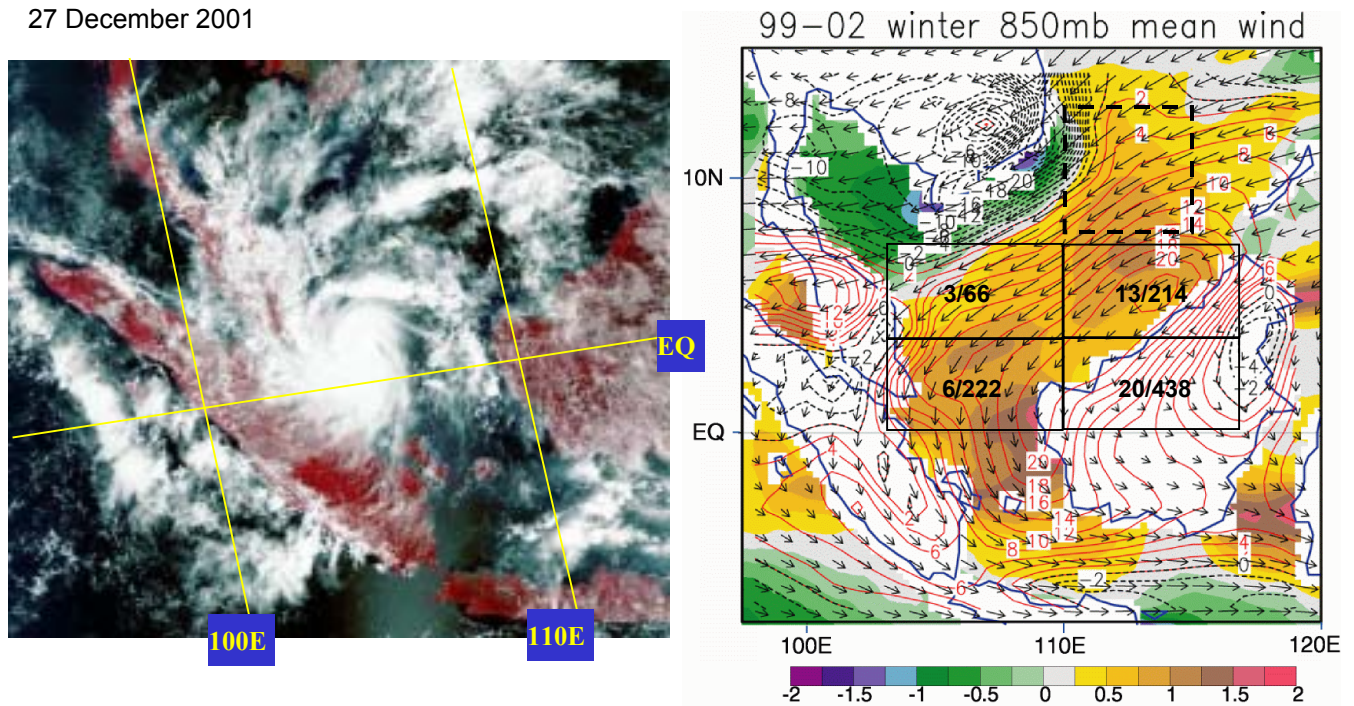


Fig. 1. (Left) MODIS satellite picture of Typhoon Vamei, Dec 27, 2001. (Right) 1999/2000 –2001/02 boreal winter (DJF) mean of 850 hPa NOGAPS $1^{\circ}\times 1^{\circ}$ wind and vorticity (contours: solid positive, dashed negative, interval $2\times 10^{-5} \text{ s}^{-1}$), and surface vorticity based on 25 km resolution QuikSCAT winds (yellow positive, green negative). The first number in each box along the northwestern Borneo coast indicates frequency of persistent 925 hPa cyclonic circulation center that lasted for 96 h or more, based on 1951/52–2001/02 DJF NCEP/NCAR $2.5^{\circ}\times 2.5^{\circ}$ reanalysis. The second number is total number of days a center is identified. The heavy dashed box indicates the area in which the northeasterly component of QuikSCAT winds is averaged to produce the surge index.

The development was the result of two interacting systems, a weak Borneo vortex (Chen et al 1986, Johnson and Houze 1987) that drifted into the southern tip of the South China Sea and remained there for four days, and a strong and persistent cold surge (Chang et al. 1983, Chang and Chen 1992) that created the large background cyclonic vorticity as the flow crosses the equator. The Borneo vortex is a persistent feature of the northern winter monsoon. Because most of the time a significant part of its

circulation is over land, even when a vortex drifts to northern Borneo between 5°N-7°N, it is very difficult for the vortex to develop into a tropical cyclone. The narrowing of the South China Sea at the equator appears to be an important factor for the rare occurrence of the typhoon formation. On the one hand, the channeling and strengthening of the cross-equatorial surge winds helps to produce the background cyclonic vorticity at the equator. On the other hand, the open water region of approximately 5° longitude is just sufficient to accommodate the diameter of a small tropical cyclone, but is too limited for most pre-existing synoptic disturbances to remain over water for a few days. In the case of Vamei, the Borneo vortex migrated to this narrow region and stayed for more than 96 h to become the pre-existing disturbance for the formation.

The 850 hPa NOGAPS wind analysis and vorticity (Fig. 2) depict the southwestward movement of the vortex from along the Borneo coast toward the equator. By 21 December, the center of the vortex had moved off the coast to be over the narrow ocean region. Meanwhile, the strong northeasterly surge persisted, and was slightly deflected to the northwest of the vortex. Consequently, the cross-equatorial flow wrapped around the vortex and the net result was a spinning up of a rapid counter-clockwise circulation that is similar to the spinning of a top played by a child, and this led to the development of Typhoon Vamei.

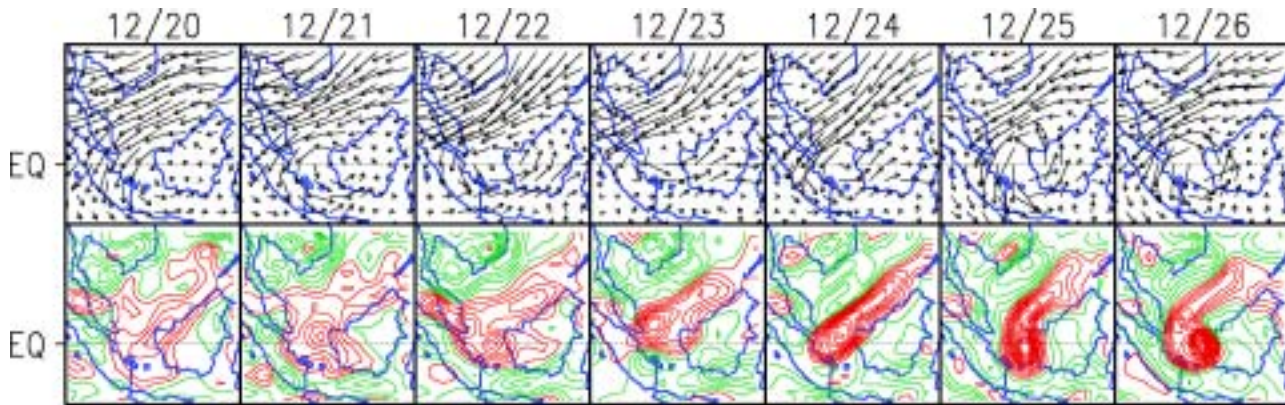


Fig. 2. Three-hourly GMS infrared images from 00 UTC – 18 UTC, 25 December 2001. The latitude and longitude lines indicate the equator and 110°E, respectively. Typhoon Vamei developed from cluster C in the 12 UTC frame, while cluster B in the preceding (09 UTC) frame dissipated.

The right panel of Fig. 1, based on the NCEP/NCAR reanalysis, shows the distribution of the frequency of a boreal winter 925 hPa cyclonic circulation center in the vicinity of Borneo since December 1951. There were only six occurrences of a Borneo vortex center that stayed continuously for 96 h in this narrow equatorial sea region in the 51 boreal winters. An increase in the 200 hPa divergence over the region was also observed from 19 to 22 December, but the tendency and maximum magnitude are no greater than many other events during boreal winters.

Based on a statistics of the duration and frequency of cold surges and those of Borneo Vortex centers staying over the southern tip of the South China Sea from the NCEP/NCAR data of 1951/52-2001/02, we estimate the probability of the “spinning top effect” to be available about 2-4% during boreal winters. Whether a pre-existing disturbance develops into a tropical cyclone depends on background vertical shears of wind and vorticity, upper level divergence, and a variety of environmental factors

(Anthes 1982, McBride 1995) In the more favored tropical cyclone basins of the western Pacific and North Atlantic, the percentage of pre-existing synoptic disturbances developing into tropical cyclones during their respective tropical cyclone seasons ranges between 10-30%. Thus, if the conditions that led to the formation of Vamei are required, we estimate the probability for a typhoon to develop in the equatorial South China Sea to be about once every 100-400 years. Since cold surges are strongest and penetrate deepest into the tropics in the South China Sea, it is unlikely that such a tropical cyclone formation scenario can take place elsewhere along the equator.

IMPACT

During northern winter cold surges in the South China Sea and monsoon disturbances in the maritime continent are significant events that impact naval operations. Typhoon Vamei's maximum sustained surface wind of 39 m s^{-1} and gust wind of up to 54 m s^{-1} caused damages to the carrier USS Carl Vinson and an accompanying ship. Its development is interesting both scientifically and to naval operations.

TRANSITIONS

None

RELATED PROJECTS

NSF Project on Asian Monsoon at NPS.

SUMMARY

Due to the diminishing Coriolis effect, the belt 300 km either side of the equator has been considered tropical cyclone-free. Typhoon Vamei, developed near Singapore on 27 December 2001, was the first recorded tropical cyclone formation within 1.5 degrees of the equator. The development was the result of two interacting systems, a weak Borneo vortex that drifted into the southern tip of the South China Sea and remained there for four days, and a strong and persistent cold surge that created the large background cyclonic vorticity at the equator. The probability of a similar equatorial development is estimated to be once every 100-400 years.

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