Eyewall Evolution of Typhoons
Crossing the Islands:
An Observational Study

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Outline:
- Overview of the scenario of eyewall oscillation
- Historic statistics of TC passed the Philippines and Taiwan
- The oscillation eyewall depicted from the microwave and radar imager and rain gauges data
- Concluding remarks
The interesting eyewall evolution of Typhoon Zeb (1998) before, during, and after its landfall at Luzon was documented from both the satellite observation and numerical simulation. It is proposed that the terrain plays a critical role in leading to such evolution: first the eyewall contraction just before landfall, a following breakdown, and then the eyewall reformation after the storm returned to the ocean.
In Typhoon Zeb (1998), the original eyewall contracted and broke down due to enhanced surface friction after landfall. The outer eyewall was triggered near the western coastal region of Luzon and formed as a result of axisymmetrization well after the dissipation of the inner eyewall convection.

The numerical results indicate that the availability of sensible and latent heat from the underlying ocean is crucial for the eyewall and intensity evolution of a landfalling typhoon.
Eyewall evolution depicted by the ASCAT wind

Typhoon Megi (2010)

KNMI ASCAT wind in 12.5 km resolution
Eyewall evolution for TC passing the Taiwan


Eyewall evolution for TC passing the Taiwan


WRF simulation in 3.3 km resolution

Hovemoller diagram of azimuthally averaged tangential wind
Motivation:

- To document the statistical characteristics of the eyewall evolution crossing Philippines islands and Taiwan.
- To examine the difference between the typhoons with and without reorganization of the outer eyewall when typhoons reentered the ocean.
- To identify the differences in eyewall evolutions between the typhoons crossing the Philippines and those crossing the Taiwan.
How frequent for TC passing the islands?

- JTWC best track from 1945-2010 are analyzed.
- TS: $34 \leq V \leq 63$ knots; TY: $V \geq 64$ knots
- On average each year about 2.2 tropical storms and 3.0 typhoons made landfall at and crossed the Philippines, which accounts for about 20% of the total number of TCs.
- Among all the TCs crossing Taiwan, about 0.7 tropical storms and 1.3 typhoons made landfall and crossed Taiwan respectively, which accounts for 8% of the total number of TCs in the WNP.
The microwave images are analyzed for 23 typhoons that crossed Philippines from 2000-2010.

In most (87%, 20/23) of the cases, the outer eyewall reappeared when the storms were about to leave the land and reenter the ocean.

Over half (57%, 13/23) of typhoons experienced reorganization of the outer eyewall.

Obvious reorganization eyewall case: Ex: Megi (2010)

Non-obvious reorganization eyewall case: Ex: Mitage (2007)
What factors control the reorganization of the outer eyewall?

- The environmental conditions between the obvious and non-obvious reorganization eyewall cases are examined.
- The former appears to be embedded in an environment with smaller vertical wind shear, higher low-level relative humidity, and higher sea surface temperature than the later.
- These three environmental factors are rather consistent with the necessary conditions of tropical cyclone genesis proposed by Gray (1968).
The microwave images are analyzed for 19 typhoons that crossed Taiwan from 2000-2010.

In about 89% (17/19) cases, the major convective ring shifted from the central area to the outer area of the storm.

The reorganization of the outer eyewall is rarely observed because the storms generally pass through the Taiwan Strait and make landfall over Mainland China within short periods of time.

Before landfall | After landfall
---|---
|-obvious reorganization eyewall case: Ex: Nondectateable


- 07 Sepat
- 09 Morakot
The oscillation eyewall depicted from radar images for TY passing the Taiwan

- A quantitative analysis is preformed based on radar images with high spatiotemporal resolution (0.0125° in horizontal, 10 min. in temporal).
- Following the subjective definition of the outer eyewall by Kossin and Sitkowski (2009), the major convective ring is identified when there is at least 75% of a complete circular band with 0.5 degree width.
- These results are consistent with the eyewall evolution as depicted by the microwave images.
The oscillation eyewall depicted from radar images for TY passing the Taiwan

- Hovemoller diagram of radar reflectivity for typhoons crossed Taiwan during 2005-2010.
- Over half of typhoons (58%, 7/12) showed the contraction of inner eyewall before landfall over Taiwan.
- Most typhoons (83%, 10/12) experienced the inner eyewall breakdown and reorganization of outer eyewall when passed Taiwan.
- Except for Sinlaku, Jangmi, and Fanapi, the reorganized eyewall did not contract when the storms cross the Taiwan Strait.
The oscillation eyewall depicted from automatic rain gauges for TY passing the Taiwan

- Hovemoller diagram of rainfall rate calculated from rain gauges for typhoons crossed Taiwan during 2005-2010.
- Except for Pabuk and Kalmaegi, the areas with larger rainfall rate were always located within a 0.5 degree radius from the storm center.
- The locations of the maximum rainfall rate shifted outward to a 1.0-2.0 degree radius when the storms left Taiwan.
- The results are consistent with the analyses of the radar images.
The rainfall pattern evolution caused by the terrain effect

Typhoon Sepat (2007)

Corr.(Ref, RR), 0-48h = 0.43
Corr.(Ref, RR), 6-36h = 0.57
Concluding remarks

• Based on the analyses of JTWC best track data from 1945-2010, it is found that annually at least 3.0 typhoons passed through the Philippine islands and 1.3 through Taiwan.

• For 23 typhoons crossing the Philippine islands from 2000-2010, the results indicate that the radius of the eyewall increased during landfall in 87% of the landfalling typhoons, while in 57% of the cases the radius of the eyewall contracted when the typhoon reentered the ocean.

• Analyses of large-scale environmental conditions show that small vertical wind shear, high low-level relative humidity and sea surface temperature are important for the reorganization of the outer eyewall and the subsequent eyewall contraction when the typhoons reentered the ocean.

• For 19 typhoons crossing Taiwan, it is found that 89% of cases show an expansion of the eyewall during the landfall period, while reorganization of the outer eyewall is seldom observed due to the limited time the typhoon spends over the Taiwan Strait.

• In addition, observed rainfall shows an expansion in the rainfall area induced by terrain.
Future works

- Some issues remain unsolved and are yet to be addressed in future studies.
  (1) How is such an eyewall evolution influenced by the size of the land, the height of the terrain, and the size and intensity of the landfalling storm?
  (2) What determines the timing for the inner eyewall to break down after the storm makes landfall?
  (3) What is the relationship between land with different surface roughness, latent heat flux supply, and topography?

- It is expected that more insight can be obtained from more well-designed sensitivity numerical experiments with high-resolution cloud-resolving models.