The Impact of Typhoon Usagi（2013）Simulation

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Abstract

Typhoon Usagi was a tropical cyclone which brought heavy damage to Taiwan. Formed in the eastern part of Philippines and began to intensify 3 days later. Afterwards, Usagi moved through the Bashi Channel and made landfall over Guangdong. The typhoon caused an estimated NT$37.22 million in agriculture losses in Taiwan.

This case was studied by using weather research and forecasting(WRF)system 3.7. Simulation was initialized on 1200 UTC 20 September and proceeded for 48 hours, the final date was on 1200 UTC 22 September. The results of rainfall simulation on eastern part of Taiwan were closed to observed rainfall which was about 300 mm. Also, the surface pressure of simulation was similar to observation.

Keywords: Typhoon rainfall, model simulation

1. Introduction

Typhoon Usagi（2013）caused severe damages to Taiwan, Philippines and China. Formed as a tropical storm near Philippines on September 16, Usagi intensified on September 19 and ultimately became a super typhoon. Based upon satellite images of intensity by the National Aeronautics and Space Administration（NASA）, within 24 hours Usagi began to intensify by 33.3 m/s and reached a maximum wind speed of 69.4 m/s（Chen et al., 2015; Zhao et al., 2016）.

On September 16, the system was formed in the eastern part of Philippines and began to intensify 3 days later. After the intensification, typhoon Usagi weakened on September 21 while crossing through the Bashi Channel. The system eventually made landfall over Guangdong on 22.

Typhoon Usagi was downgraded by JMA as it weakened while moving cross Guangxi. On September 24, the system eventually dissipated.

The purpose of this case study is to discuss the impact of typhoon Usagi（2013）by using WRF model.

In section 2, the synoptic analysis from observation data are described. The simulation results are presented in section 3. Finally, we will discuss the final results in section 4.

2. Synoptic Analysis

Usagi crossed through the Luzon Strait separating the Philippines and Taiwan on September 21, bringing heavy rainfalls and strong winds to island communities. Figure 1 shows the weather chart by the Central Weather Bureau（CWB） on 0000 UTC, September 21. We can see that Usagi was developed into a severe typhoon. The lowest center pressure was 915 hPa and the maximum wind speed was approximately 53m/s.

Typhoon Usagi went through rapid intensification（RI）in 24 hours, starting from 1200 UTC September 18 to 1200 UTC September 19. RI is usually defined as over 30 knots（15 m/s）intensification in 24 hours（Kaplan and DeMaria, 2003）.

The variation of the minimum pressure and maximum wind speed of typhoon Usagi provided by CWB showed that the wind speed had increased from 33 m/s on 1200 UTC September 18 to 53 m/s on 1200 UTC September 19, which was nearly 20 m/s（38 knots） intensification in 24 hours. The intensity of typhoon Usagi also upgraded to severe typhoon on 1200 UTC September 19. Below is the wind speed and pressure chart of typhoon Usagi provided by CWB.

Since the intensification of the energy source（i.e., air-sea fluxes）comes from the ocean, i.e., ocean is a necessary condition in intensification（Emanuel, 1999）.

Therefore, even if the atmospheric conditions are favorable, yet without sufficient flux supply from the ocean, it is not possible for intensification to take place（Lin et al., 2009）.

Figure 4 and 5 are sea surface temperature（SST）and depth of 26 °C on September 18 2013. As they clearly indicated that the average temperature of sea surface was 29-30 °C when typhoon Usagi began to rapid intensified. Also, the depth of 26 °C was approximately 150 m. These two factors were favorable condition to support the intensification of typhoon Usagi.

Figure 6 is MODIS（Moderate Resolution Imaging Spectroradiometer） acquired by NASA’s Aqua satellite, on the same date as Figure 1 shown above. The cloud structure was very solid and well-organized. Satellite maps acquired from CWB（Figure 7）also indicated the structure of typhoon Usagi remained solid while approaching eastern part of Taiwan. Therefore, the circulation of the cloud and rain band had caused torrential rainfall and slope disasters mostly in eastern part of Taiwan（Figure 8）.

As the daily accumulated rainfall and radar reflectivity（Figure 9）suggested that, during the movement of typhoon Usagi on September 21, the eastern part of typhoon began to received light precipitation. While the typhoon moved gradually across Bashi Channel, we can see that the structure was well organized and the eyewall of typhoon Usagi was clearly seen on the radar map. The maximum rainfall on September 21 was 521.5 mm in Taitung.

Figure 10 is the best track of typhoon Usagi made by CWB. The intensity of Usagi is also included.

3. Simulation Results

This case study used NCEP global data as analytical sources. Adopting WRF V3.7 to process FNL（final analysis）data. WRF numerical model processes the initial data and boundary conditions created by the information from the US Environmental Prediction Center（NCEP） operations.

The global forecast system（Global Forecast System, GFS）final analysis data（Final Analyses, FNL）, the data time is every 6 hours（0000 UTC, 0600 UTC, 1200 UTC and 1800 UTC）, the horizontal space resolution is 1.0 × 1.0 °, vertical space resolution from the surface at 1000 hPa to high altitude at 10 hPa with 32 isobaric, and nearly 100 kinds parameters for analysis.

Using GrADS（The Grid Analysis and Display System）and variety of graphics technology to display the simulation results, different data and draw longitude, latitude, vertical and time（4-D）.

Two domains with grid resolution of 25 KM and 5 KM were adopted in this case study（Figure 11）. The physic schemes were listed in Figure 12.

The simulation started on 1200 UTC, September 21 and ended on 1200 UTC, September 22. A total of 48 hours until Usagi made landfall over China.

First, we compared the simulated surface pressure to observed ones and Figures are presented as follow.

Figure 13（a）indicated the typhoon's location as well as the pressure of its center（946hPa）. With a slightly discrepancy of observed sea surface pressure on the exact date（925hPa）. Figure 13（b）better captured the pressure（973hPa）compared with observed one（975hPa）.

The accumulated rainfall from September 21 to 22, a total of 24 hours simulation is shown below.

The observed rainfall distributed mainly on eastern part of Taiwan with maximum rainfall of 300 mm in Taitung and Pingtung. Compared with simulated rainfall, the maximum rainfall also located in eastern part of Taiwan and the accumulated rainfall was 300 mm.

As the CWB best track of Usagi suggested, the typhoon didn't make landfall over Taiwan. Indicating the impact of terrain was limited（Lo, 2013; Liao, 2017）. During the movement of Usagi, it had brought heavy rainfall to eastern part of Taiwan, causing severe flooding and casualties among local citizens.

Therefore, we conducted the vorticity, vertical profiler and vector simulation to better understand the heavy rainfall distributed by Usagi.

The vector simulation on 0000 UTC 21 September and 1800 UTC 22 September indicated that the wind direction on eastern Taiwan remained east to southeastern wind during the passage of Usagi. Which induced heavy rainfall on windward area of eastern Taiwan.

Figure 17 shows the simulated 700 hPa vorticity on 0000 UTC 21 September, there was positive vorticity over eastern Taiwan with maximum of $10x10^{-5}$ s^{-1}.

Finally, the simulated vertical wind profiler on 0000 UTC 21 September is shown below（Figure 18）.

As we can see, the maximum rain water amount was 9 g/kg, and the uplifting wind on both side from 500 hPa to 100 hPa.

4. Conclusion

Though typhoon Usagi did not made landfall directly over Taiwan, it still caused heavy rainfall mostly on eastern part of Taiwan. By using WRF 3.7 to conduct simulation of typhoon Usagi, results are listed as following:

（1）The simulated rainfall and observed one were closed, with maximum rainfall over 300 mm in eastern Taiwan.

（2）The heavy rainfall on 21 September was induced by typhoon's circulation and the effects of local topography with east to southeastern wind on the windward side of eastern Taiwan.

（3）The simulated vorticity on 0000 UTC 21 September over eastern Taiwan was $10x10^{-5}$ s^{-1}, indicating positive vorticity and unstable atmospheric condition.

（4）The rain water amount inside typhoon Usagi on 0000 UTC 21 September was over 9 g/kg, and the uplifting wind on both side from 500 hPa to 100 hPa.

5. References

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6. **Charts**

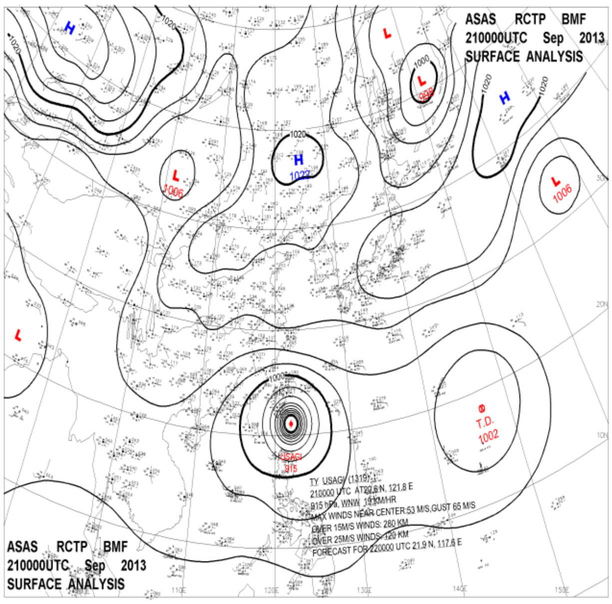


Figure 1. 21 September weather chart by CWB

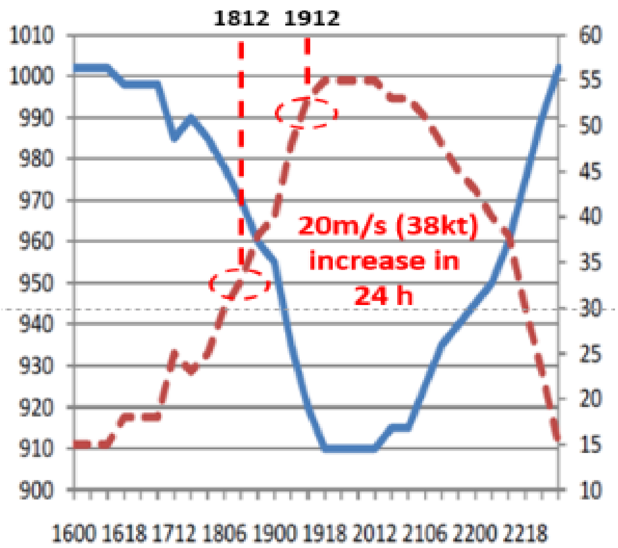


Figure 2. Wind speed and pressure chart by CWB

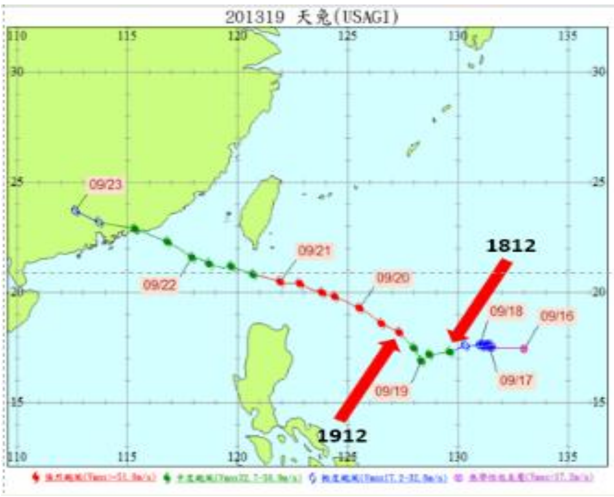


Figure 3. Intensity of Usagi in 24 hours

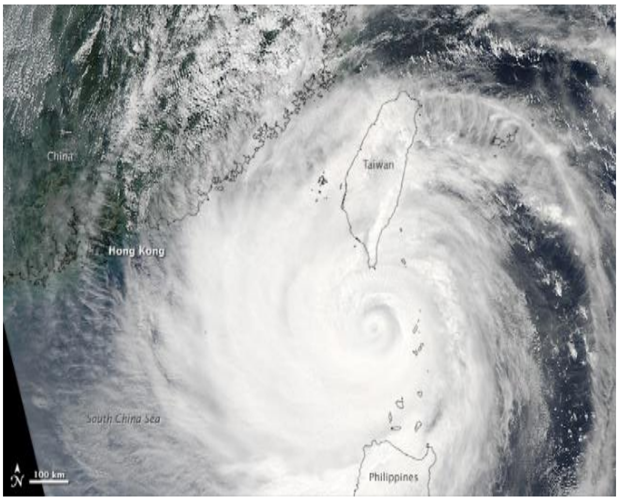


Figure 6. Satellite image by NASA

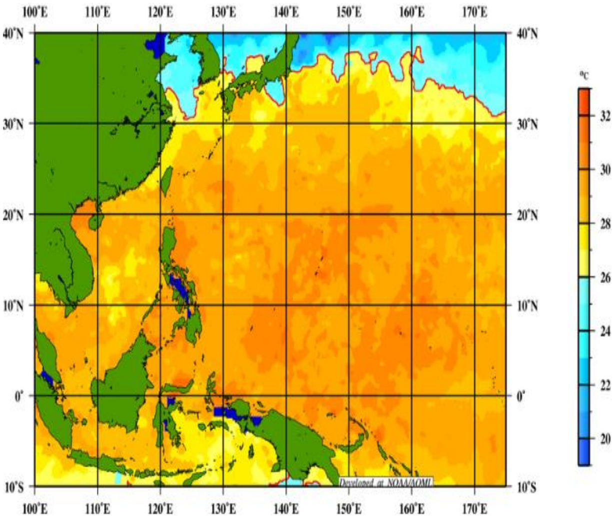


Figure 4. Sea surface temperature by NOAA

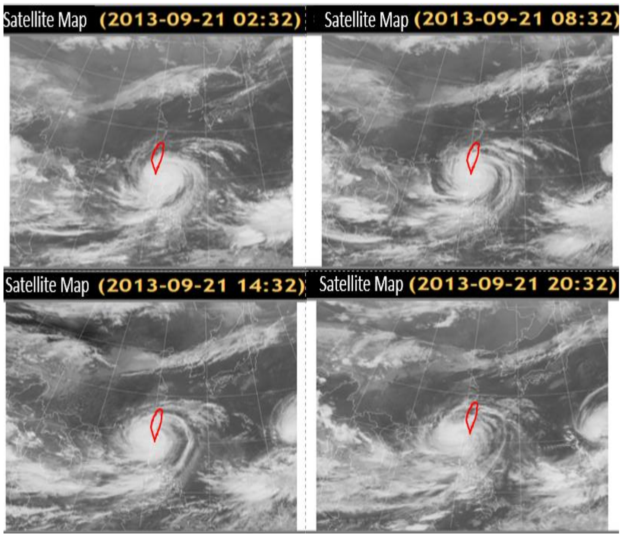


Figure 7. Satellite maps by CWB

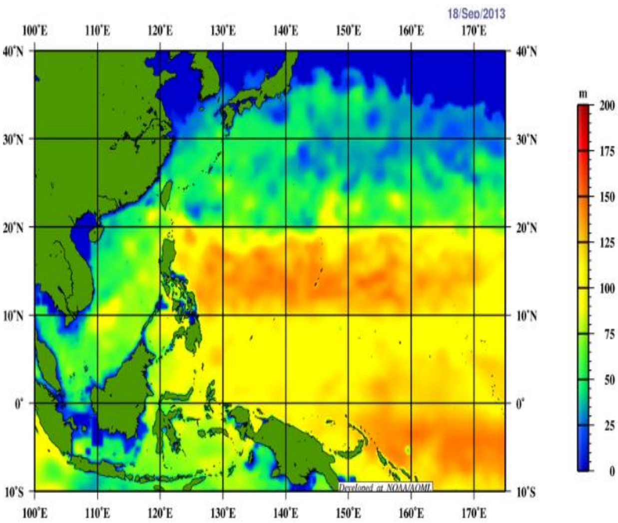


Figure 5. Depth of 26°C by NOAA

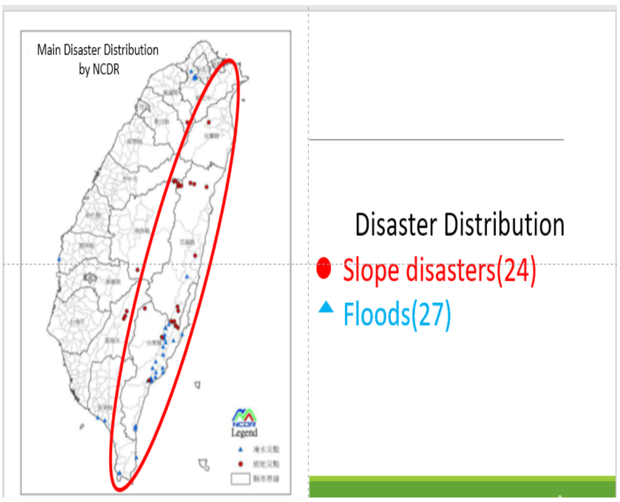


Figure 8. Disaster map by NCDR

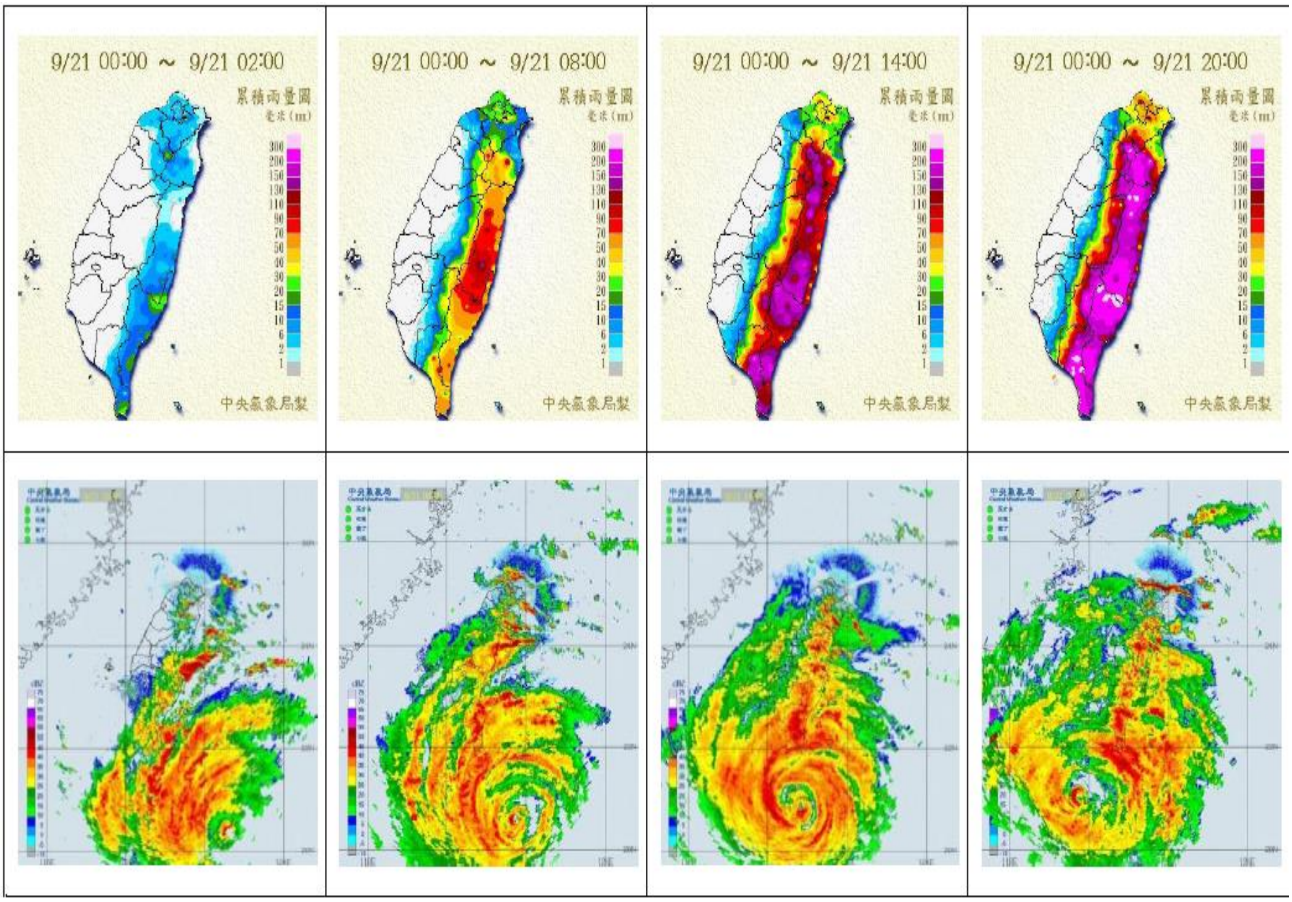


Figure 9. Accumulated rainfall and radar reflectivity on September 21

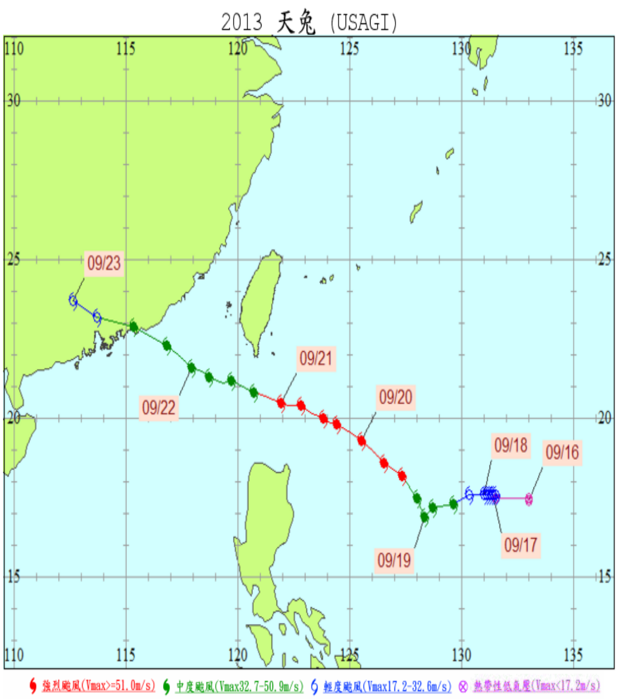


Figure 10. The best track of Usagi by CWB

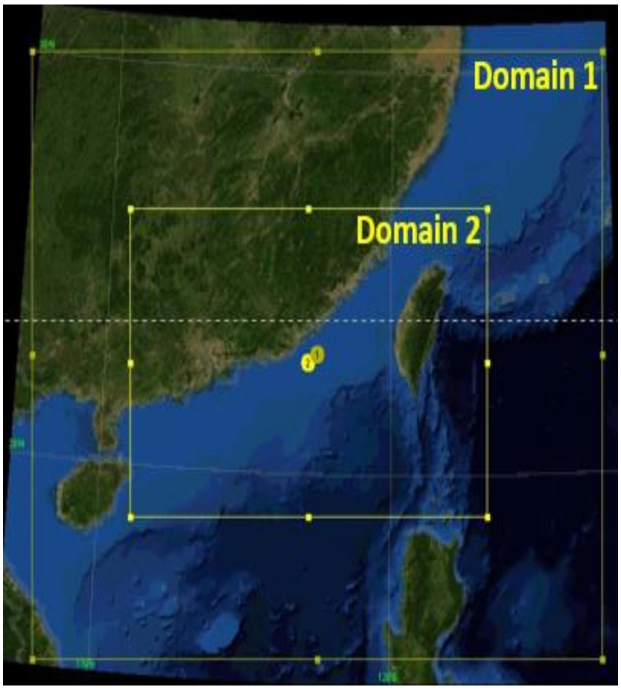
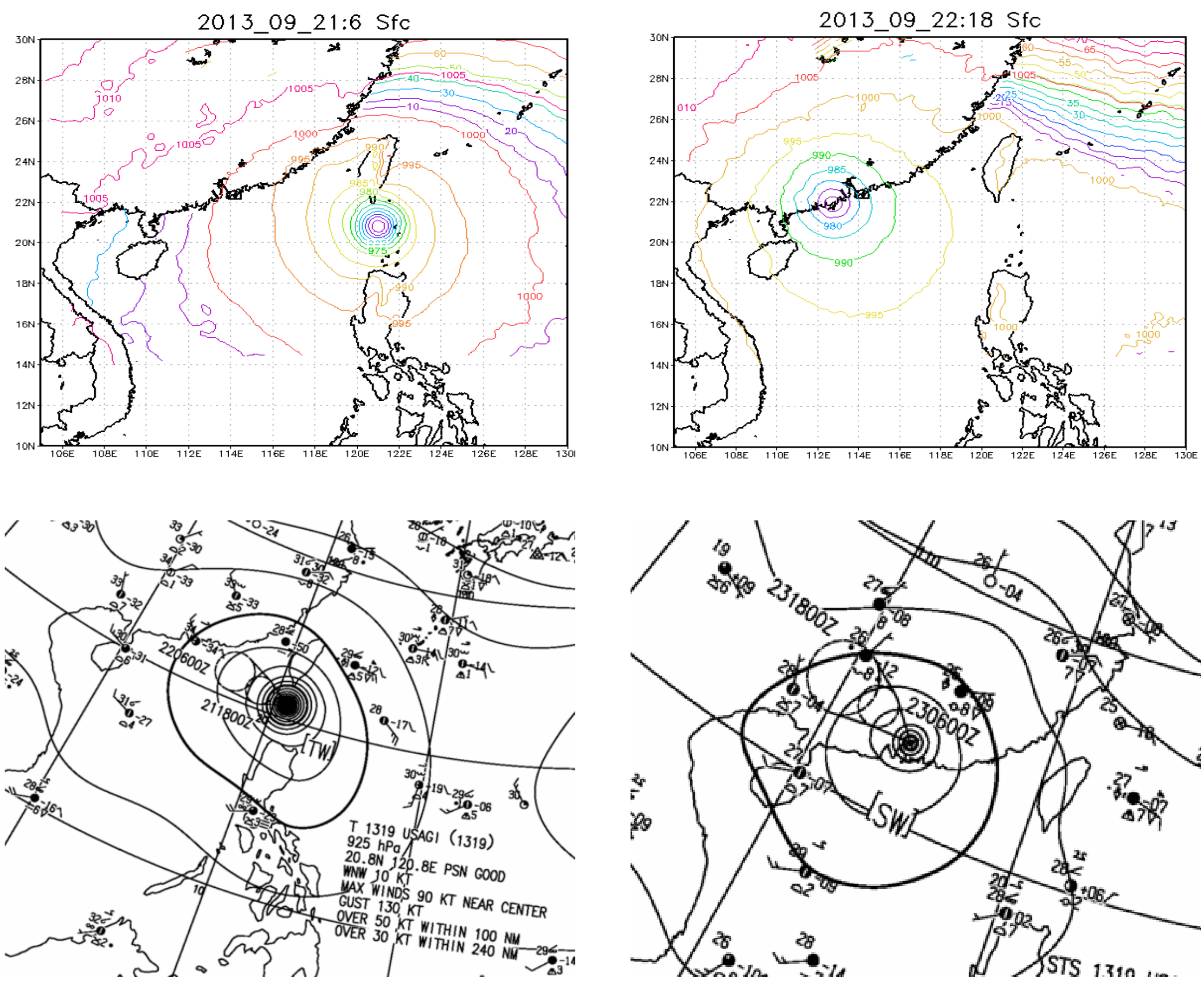


Figure 11. WRF domain setup

WRF Domain	D1	D2
Grid Points Distance	25km x 25km	5km x 5km
Terrain Data Resolution	30S	30S
Nest number X *Y	165 x 135	211 x 191
Microphysics	WSM5=1	
Cumulus Parameterization	Kain-Fritsch scheme=1	
Long-wave radiation parameters	RRTM=1	
Short-wave radiation parameters	Dudhia scheme=1	
Planetary Boundary layer	YSU=1	
Eta layer	41	

Figure 12. WRF physic schemes



（a）0600 UTC 21 September （b）1800 UTC 22 September

Figure 13. Simulated sea surface pressure and observed comparison（source from JMA）

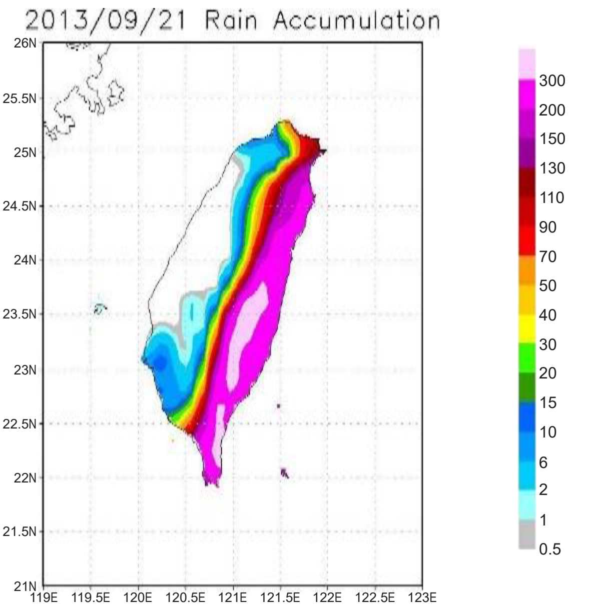


Figure 14. Simulated rainfall

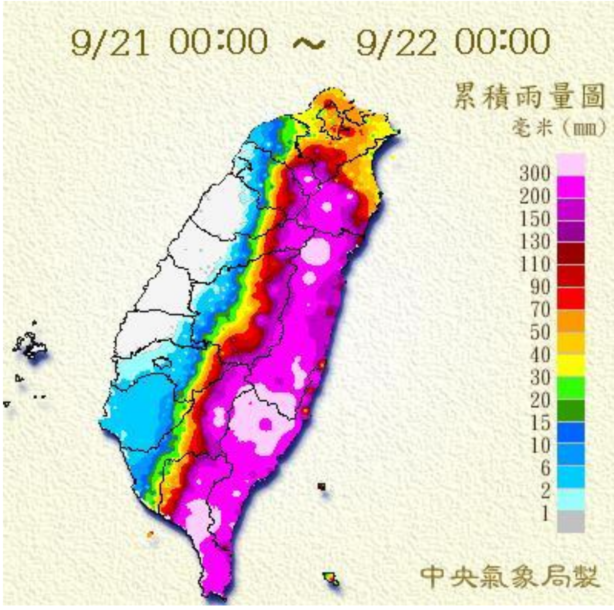
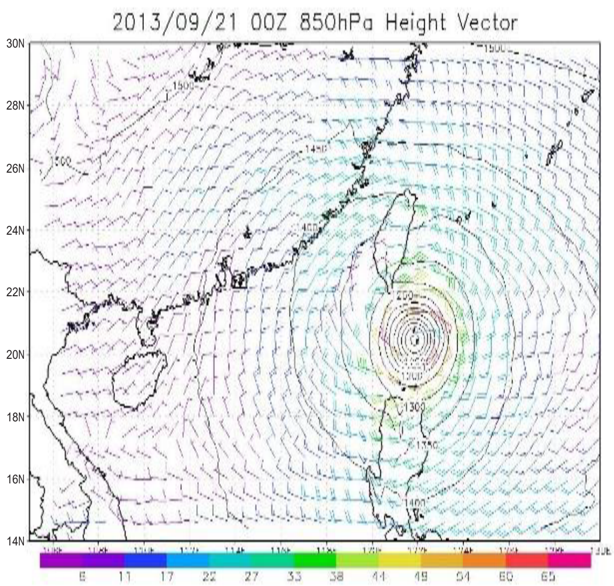
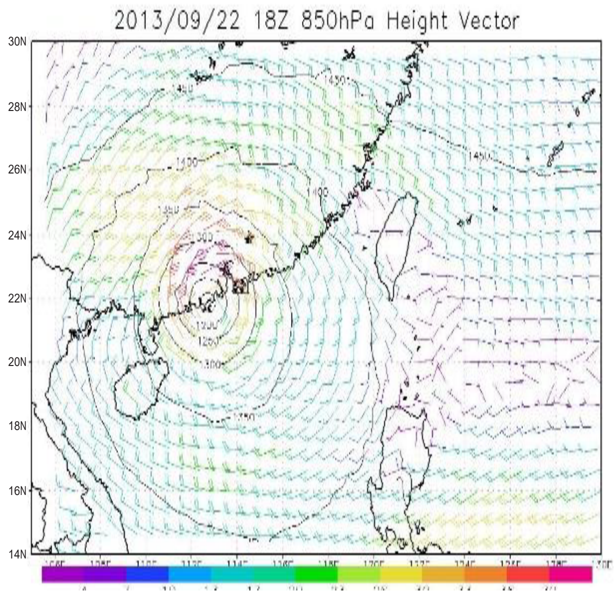


Figure 15. CWB observed rainfall



（a）0000 UTC 21 September



（b）1800 UTC 22 September

Figure 16. Simulated height and vector

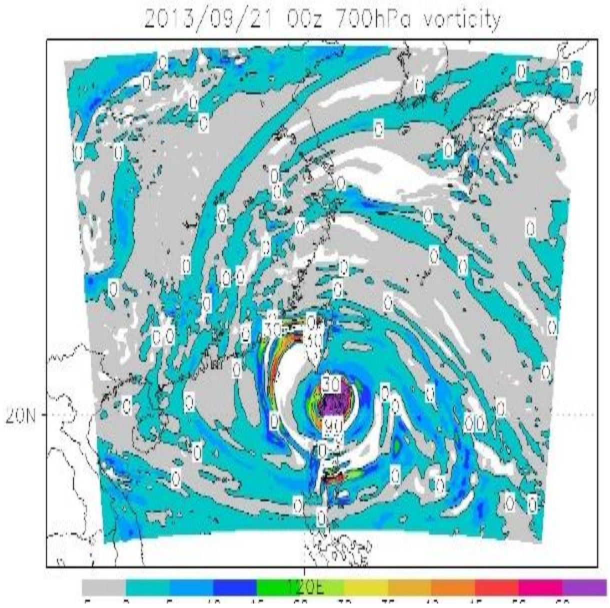


Figure 17. Simulated 700 hPa vorticity

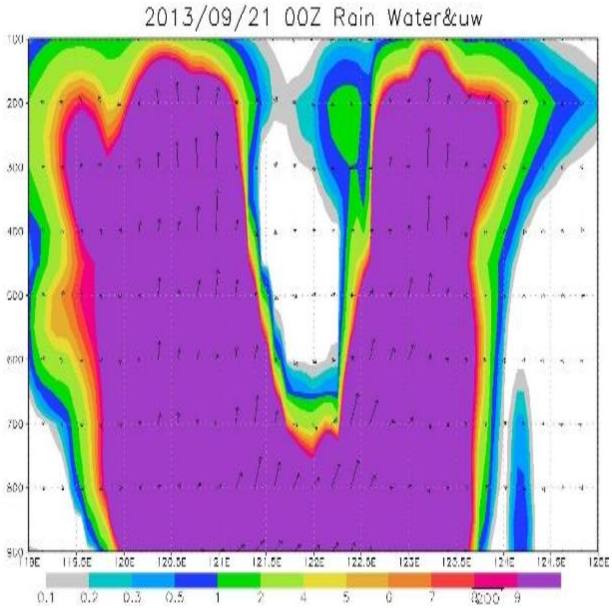


Figure 18. Simulated vertical wind profiler

天兔颱風（2013）影響臺灣之個案模擬

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摘要

天兔颱風原於2013年由熱帶性低氣壓自太平洋生成，至9月16日於菲律賓東部增強為輕度颱風，19日出現快速增強之情況並最終轉為強烈颱風。在增強為強颱後，颱風強度迅速減弱。天兔颱風於21日通過巴士海峽，並於22日登陸廣東。據估計，天兔颱風造成農產損失高達37.22億，並帶來不少災情。

本次個案使用天氣研究與預報模式（Weather Research and Forecasting，WRF）3.7進行模擬，起始時間為9月20日1200 UTC，總模擬時間為48小時，結束時間為9月22日1200 UTC。由模擬累積降雨與實際比較來看，造成嚴重災情的東部降雨狀況有成功模擬出來。除此之外，地面氣壓的模擬和實際情況也相當接近。

關鍵字：颱風降雨、模式模擬