Typhoon Maemi and Impacts on Lower Nakdong River, South Korea

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Abstract. In South Korea, the average annual frequency of typhoons over 30 years, from 1971 to 2000, is 26.7 per year. Among the annual typhoons, Typhoon Maemi of September 12, 2003 was the worst typhoon to hit South Korea for more than a decade, causing wide damage from the Nakdong Rver basin to the port of Pusan and the populated areas in the southeast of the peninsula. More than 110 people were killed in Korea. Several bridges collapsed and about 18,000 buildings were either destroyed or damaged by the typhoon. The characteristics of Typhoon Maemi, on the Nakdong River basin, and flood damages are analyzed using the satellite data and field measurements of hydrologic and hydraulic conditions.

1. Typhoon Maemi Track and Characteristics

A tropical depression was formed about at 3 PM on September 6th 2003 near Guam. It developed into a severe tropical storm at 3 AM on September 8th and rapidly became a typhoon at 9 AM on September 9th 2003. It approached to the south coast of the Korean peninsula at 8 PM on September 12th 2003 (Figures 1 and 2). It lasted only 6 hours in the South Korea and brought localized windstorms (Table 1) and torrential rainfall and windstorm. The most particular characteristic of Typhoon Maemi is that it moved through Korean peninsula even though it was very late in the season (September). One of the reasons for this phenomenon is attributed to the maintenance of high temperature of the North Pacific seawater and the increased seawater temperature by about 3℃ in the Southern Sea of the Korean peninsula. As a result, Typhoon Maemi was supplied the energy from the sea. Typhoon Maemi caused extensive damage with extremely flashy hydrographs from over 400mm. Table 1 shows the comparison with other historic typhoons in South Korea.

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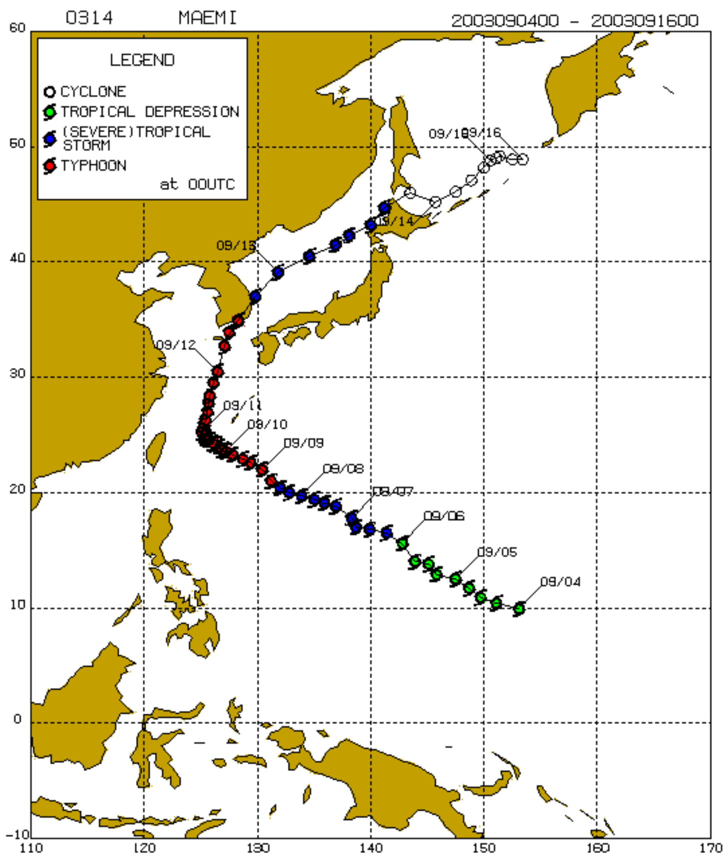

Figure 1. Passage of Typhoon Maemi (Typhoon Research Center, TRC)

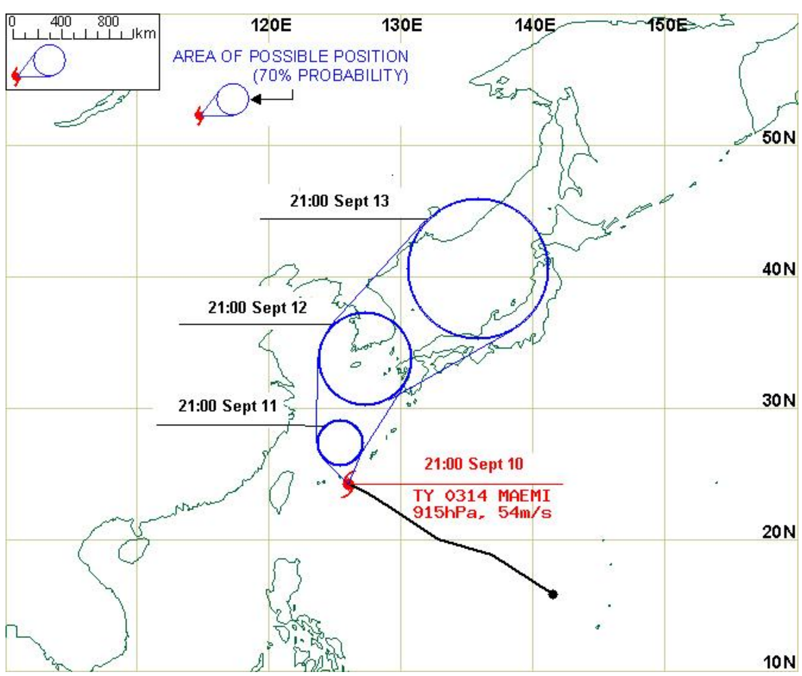

Figure 2. Area of possible position on the passage of Typhoon Maemi (Korea Meteorological Administration, KMA)

Table 1. Comparisons of the major typhoons in South Korea (KMA)

	Sarah 1959 (9/15/1929)	**Thelma 1987 (7/15/1987)**	**Rusa 2002 (8/30/2002)**	**Maemi 2003 (9/12/2003)**
Maximum Sustained Winds(m/s)	52.7(Pusan)	40.3(Yeosu)	39.7(Yeosu)	60(Jeju)
Lowest Pressure (hPa)	952(Pusan)	972(Yeosu)	970(Yeosu)	954(Tongyoung)

The satellite view of Tropical Rainfall Measuring Mission (TRMM) which is a joint mission between NASA and the Japanese space agency NASDA provided valuable images of Typhoon Maemi. It formed as a minimal typhoon of the Philippines to a super typhoon with winds over 155 mph as it was approaching the southern Ryuku Islands. Figures 3 and 4 are the images of the satellite which monitored Maemi on the southeast coast of South Korea.

2. Rainfall and Floods

Figure 3 taken at 12:24 UTC on 12 September 2003 is the condition of Maemi just after it made landfall near Pusan on the Korean peninsula. Significantly heavy rainfall ranged from the north of the center with a large area of greater than 2 inch per hour rates and it was classified as a Category 2 typhoon of the Saffir-Simpson Scale with winds of 105 mph at this time. The Saffir-Simpson Scale (Table 2) is the scale for dividing hurricanes to 5 categories by the magnitude of destruction in United States. Considering the maximum sustained wind, Typhoon Maemi ranges to Category 4.

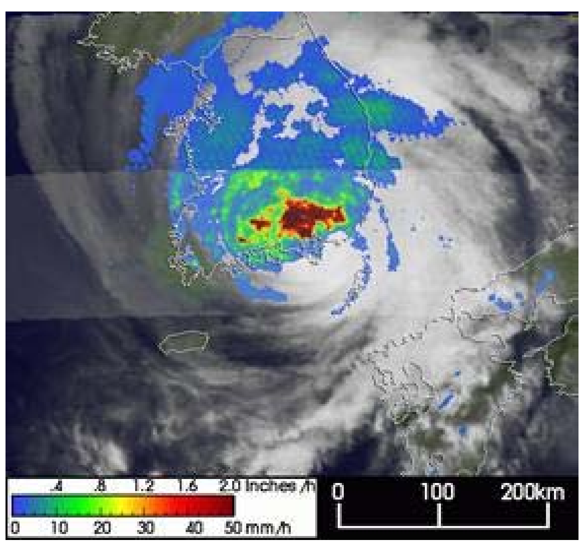

Figure 3. Rainfall distribution of Typhoon Maemi on the Korean peninsular (9/12/2003)

Table 2. Saffir-Simpson Scale

Scale No.	Central Pressure	Winds	Surge	Damage
1	>28.94" (980 mb)	74-95 mph (119-153 km/hr)	4-5 ft (1.2-1.7 m)	Minimal
2	28.91-28.50" (979-965 mb)	96-110 mph (154-177 km/hr)	6-8 ft (1.8-2.6 m)	Moderate
3	28.47-27.91" (964-945 mb)	111-130 mph (178-209 km/hr)	9-12 ft (2.7-3.9 m)	Extensive
4	27.88-27.17" (944-920 mb)	131-155 mph (210-249 km/hr)	13-18 ft (4-5.5 m)	Extreme
Super Typhoon		>150 mph (241 km/hr)		Catastrophic
5	<27.17" (920 mb)	>155 mph (249 km/hr)	>18 ft (5.5 m)	Catastrophic

Figure 4 shows the total amount of rainfall which is near-real time Multi-satellite Precipitation Analysis (MPA) at the NASA Goddard Space Flight Center for the period 8-13 September 2003. The southern coast of Korea received upwards of 12 inches of rainfall and all of the rest of South Korea received over 4 inches. Tropical cyclone symbols mark the positions of Meami every 6 hours.

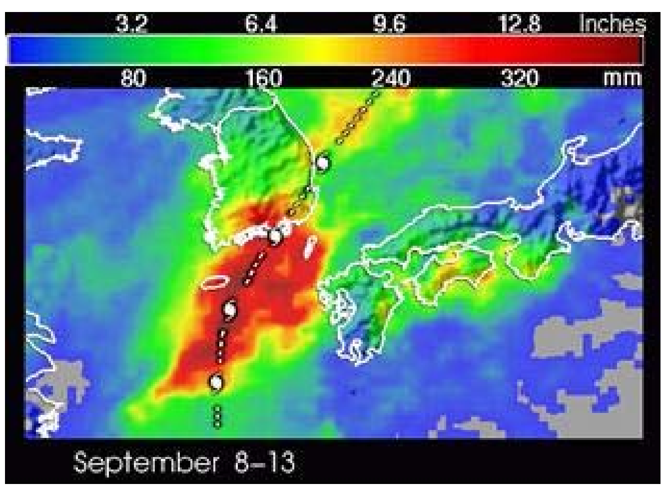

Figure 4. Total rainfall of Typhoon Maemi from 9/8/2003 to 9/13/2003

For the analysis focused on the Lower Nakdong River located in the area of the southeastern Korea near Pusan city, the precipitation data from Yangsan gauging station, and the water level and discharge data from Gupo bridge which was damaged by Typhoon Maemi were used.

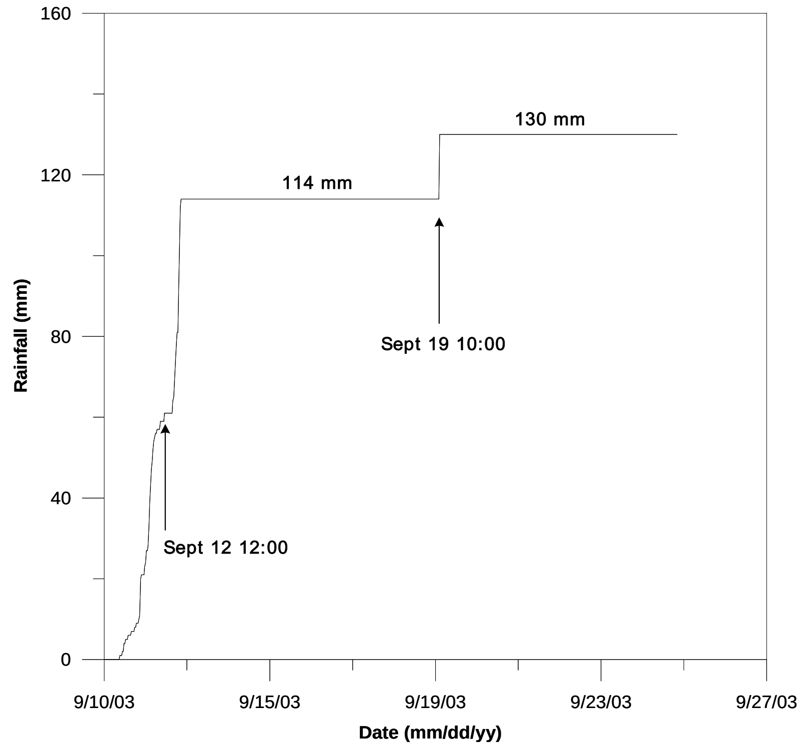

Figure 5. Mass rainfall curve at Yangsan gauging station (Source: Korea Water Resources Corporation, KOWACO)

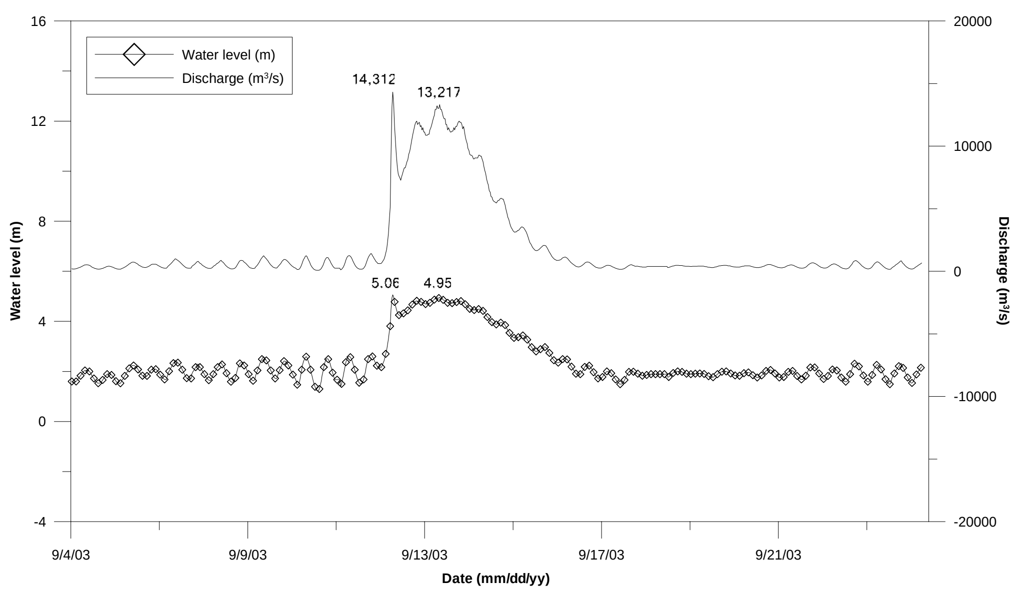

Figure 6. A water stage and discharge graph at Gupo bridge (Source: KOWAKO)

The Nakdong River has a basin area of 23,326 km^2 and the estuary barrage is lacated at the end of the river to reduce salt-water intrusion in the estuary and prevent a large flood due to high tides. The channel of Nakdong River was designed to convey a design flood of 18,300 cubic meters per second. Figure 5 show the mass rainfall curve at the Yangsan station and Figure 6 is the water level hydrograph during the passage of Typhoon Maemi with discharge data. During Typhoon Maemi, the water level significantly exceeded normal levels due to the strong westerly winds. The water level recorded at Gupo bridge reached maximum 5.06m on September 12, and the discharge of the Nakdong River peaked on September 14 at a value around 13,000 cubic meters per second. That is, the flood level exceeded the warning stage of 4m and the stage of 5 m corresponds to 70% of the project flood for the Nakdong River.

3. Flood Damages

According to the Korean research note, about 18,000 buildings were either destroyed or damaged by the strong winds (of up to 120 mph, or close to 200 km/h) and more than 110 people were killed in Korea by the impact of Typhoon Maemi. The typhoon also inflicted damages on heavy-duty shipping cranes and caused power outages for 1.5 million households. According to historical wind database figures (1950-2003), Typhoon Maemi made landfall from the southwest just like 60 percent of all previously recorded typhoons. At that moment, its sustained wind speed indicated a category 2 storm - the same level as Typhoon Sara in 1959. Both typhoons hit the southern city of Pusan and its surroundings.

Figure 7. Flood damages of Pusan of left, [AP] and Wah Yeon Beach on Geoje Island of right, [photo by Paul J. Riley]

In Figure 7, the left is the aerial view which shows a flooded rice field area after Typhoon Maemi hit Pusan on Saturday, Sept. 13, 2003 and the right shows the flood damages of Wah Yeon Beach on Geoje Island taken on Sept. 15. Figure 8 shows another damage that the ferry-shaped hotel is toppled over sideway after Typhoon Maemi hit Pusan Port, Pusan, Saturday, Sept. 13, 2003.

Figure 8. Damages of ferry-shaped hotel after Typhoon Maemi hit Pusan Port [AP]

One of the typical damage is the bridge collapse and it is shown in Figure 9. At this time, September 14, the 1.06 km-long Gupo bridge partially collapsed with the loss of 19th pier. It was due to high velocities in the river and bridge scour around the piers. The discharge of the Nakdong River peaked on September 14 at a value around 13,000 cubic meters per second.

Figure 9. Gupo bridge failure after Typhoon Maemi [Yonhap]

4. Summary and Conclusions

The Typhoon Maemi caused extensive damage including a bridge failure on the Nakdong River of South Korea. The data and information examined include satellite maps, rainfall intensity patterns, wind speed, etc. Typhoon Maemi caused extensive damage over the large area with extremely flash hydrograph of over 400mm of local precipitation and a severe storm surge. The water level recorded at Gupo bridge in Lower Nakdong River reached maximum 5.06m on September 12, and the discharge of the Nakdong River peaked on September 14 at a value around 13,000 cubic meters per second. Around 18,000 buildings were either destroyed or damaged by the strong winds and more than 110 people were killed in Korea. Gupo bridge on the Lower Nakdong River partially collapsed with the loss of 19th pier due to high velocities in the river and bridge pier scour. It is important ensure flood conveyance capability during floods and limit possible bed elevation changes. These conditions affect the stability of the bridges located near the Nakdong River Estuary Barrage.

Reference website

Korea Meteorological Administration (KMA), http://www.kma.go.kr

Korea Water Resources Corporation (KOWACO), http://www.kowaco.or.kr

Typhoon Research Center (TRC), http://www.typhoon.or.kr