MEMBER REPORT [Republic of Korea]

ESCAP/WMO Typhoon Committee
14th Integrated Workshop
Guam, USA
4 – 7 November 2019

CONTENTS

I. Overview of tropical cyclones which have affected/impacted Member's area since the last Committee Session

1. Meteorological Assessment (highlighting forecasting issues/impacts)

Twenty typhoons have occurred up until 18 October 2019 in the western North Pacific basin. The number of typhoons in 2019 was below normal, compared to the 30-year (1981−2010) average number of occurrences (25.6). The Republic of Korea has been experienced an active typhoon season this year. Seven out of 20 typhoons, such as DANAS (1905), FRANCISCO (1908), LEKIMA (1909), KROSA (1910), LINGLING (1913), TAPAH (1917) and MITAG (1918) influenced the Korean Peninsula from July to October. FRANCISCO (1908), LINGLING (1913) and MITAG (1918) made landfall on the Korean Peninsula. The tracks of typhoons affected the Peninsula are presented in Fig. I-1.

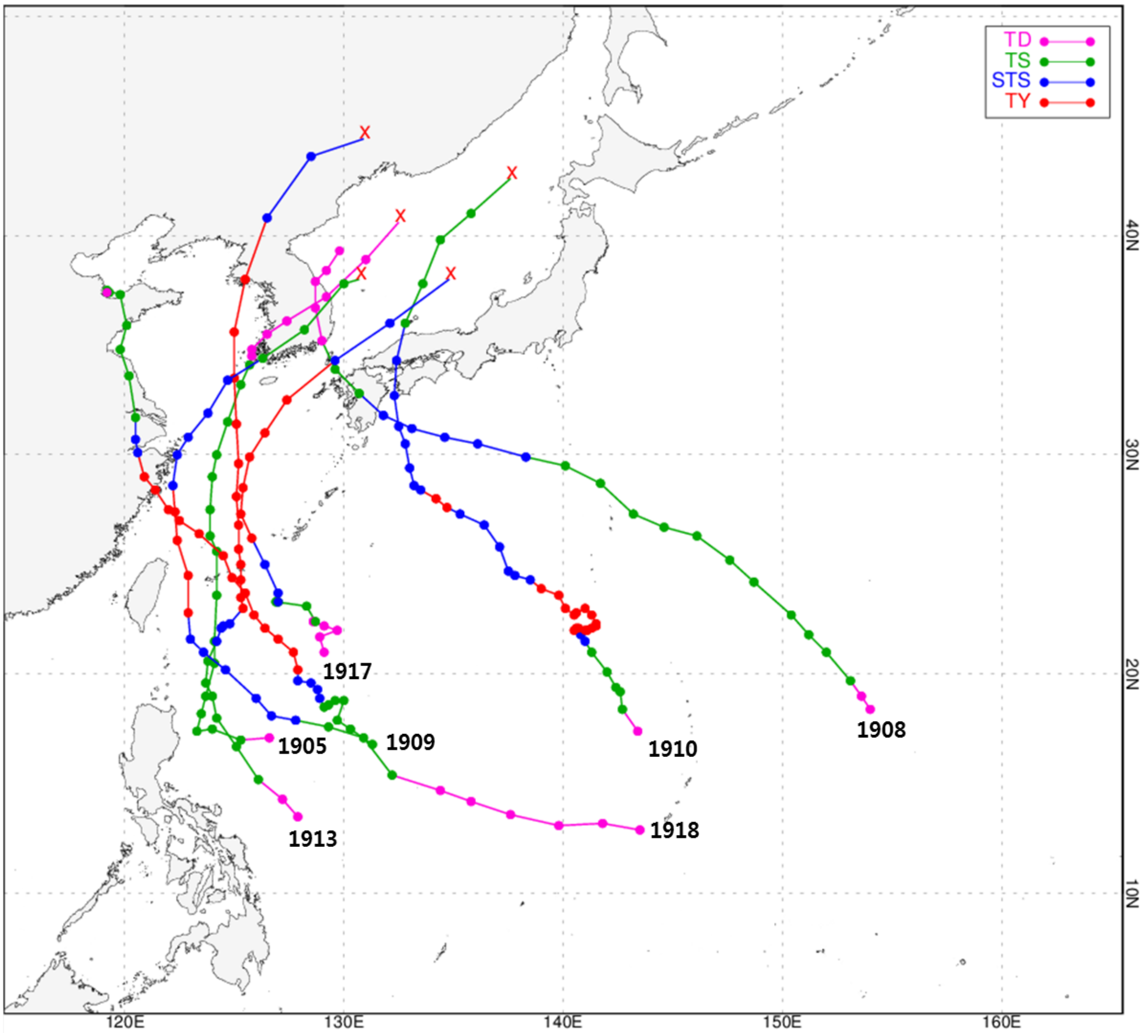


Fig. I-1. TC tracks that affected the Korean Peninsula in 2019

DANAS (1905) passed over the western sea of Jeju on 20 July and brought a huge amount of rainfall with strong wind, heading towards the southern-west part of the Korean Peninsula. It made landfall in the southwestern part of the Korean Peninsula after the KMA downgraded DANAS (1905) to a tropical depression. Then it crossed through the Korean Peninsula as a tropical depression on 21 July.

Heavy rainfall was concentrated in Jeju Island, recording over 965 mm during the period from 19 to 20 July. The heavy precipitation was recorded around the tops of Mt. Halla due to orographic effects. Gust also exceeded 34m/s on top of Mt. Halla.

FRANCISCO (1908) passed through Kyushu, Japan and headed to the southern part of Korea. It made landfall near Busan, Korea on 6 August, and then it moved northward, passing South Korea after weakening to a tropical depression and decayed over the ocean to the east of the Korean Peninsula. During the TC passage, heavy rainfall of over 230 mm was recorded in the eastern part of South Korea during the period from 6 to 7 August. Gust exceeded 25m/s in the southern-east part of Korea.

LEKIMA (1909) affected some parts of KMA's marine area of responsibility (AOR) as it made landfall in China and passed the southern-east coast of China on 11 to 12 August. Heavy rainfall was recorded over 570 mm around the tops of Mt. Halla during 11−12 August. Gust exceeded 35m/s in the island near the southern-west part of Korea.

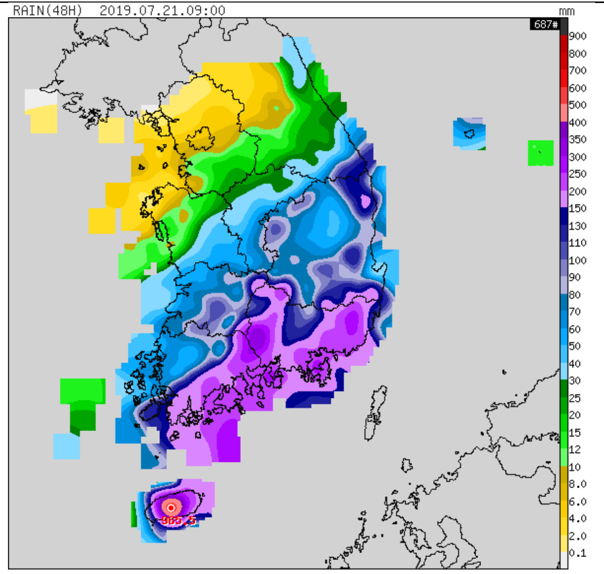
KROSA (1910) passed through Kyushu, Japan, passed nearby Dok-do and finally transferred into extratropical cyclones over the southern-west sea of Sapporo, Japan. It affected some parts of marine forecast zones of South Korea and the eastern part of the Korean Peninsula on 15 August.

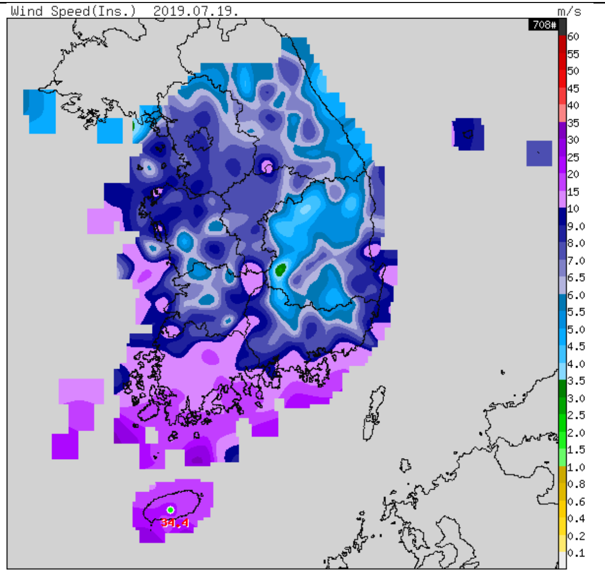
LINGLING (1913) passed through the western sea of Jeju on 7 September and moved into the West Sea of Korea, then it made landfall in North Korea. During the TC passage in the West Sea of Korea, heavy rainfall of over 416 mm was recorded around the tops of Mt. Halla during the period from 6 to 7 September. Gust exceeded 54m/s in the Heuksando Island in the West Sea of Korea.

TAPAH (1917) passed by the southern-east sea of Jeju and moved north-east ward, approaching nearby Busan on 22 September. During the TC passage, heavy rainfall of over 773 mm was recorded around the tops of Mt. Halla during the period from 21 to 22 September. Gust exceeded 42 m/s in Yeosu in the southern part of Korea.

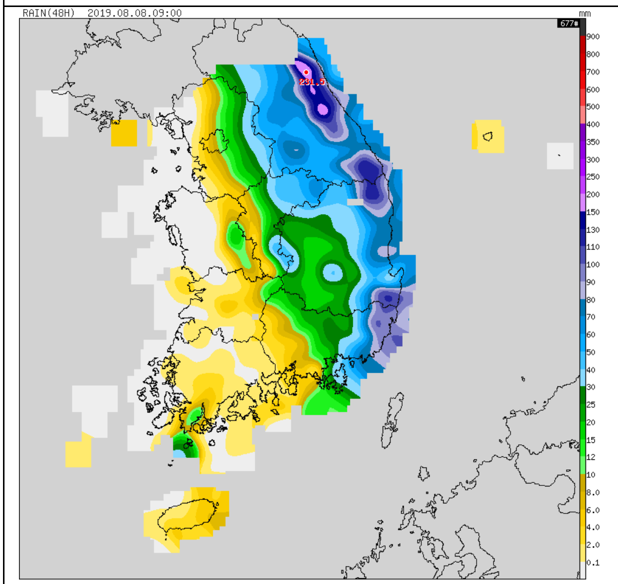
MITAG (1918) passed by the west sea of Jeju and moved north-east ward, then it made landfall near Mokpo. Afterwards the typhoon passed through the southern part of the Korean Peninsula and moved out to the East Sea on 2 October. During the TC passage, a huge amount of rainfall poured down: more than 555 mm for Uljin in the eastern part of Korea; 100−400 mm for the southern and southeastern parts of the Korean Peninsula during the period from 1 to 2 October.

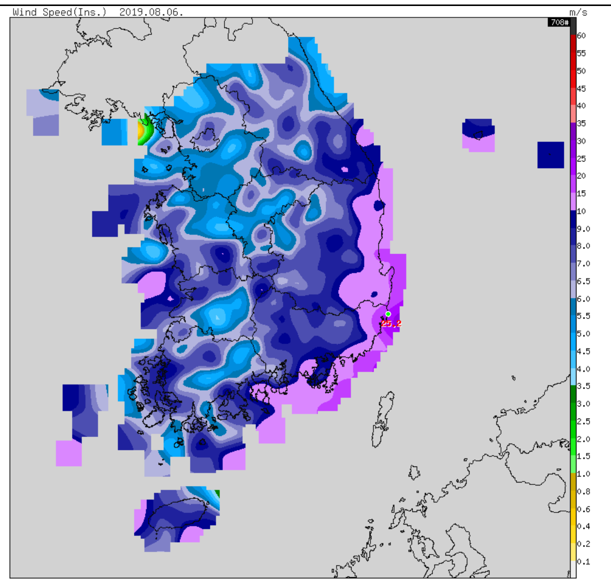
No. 5 DANAS (19−20 July)



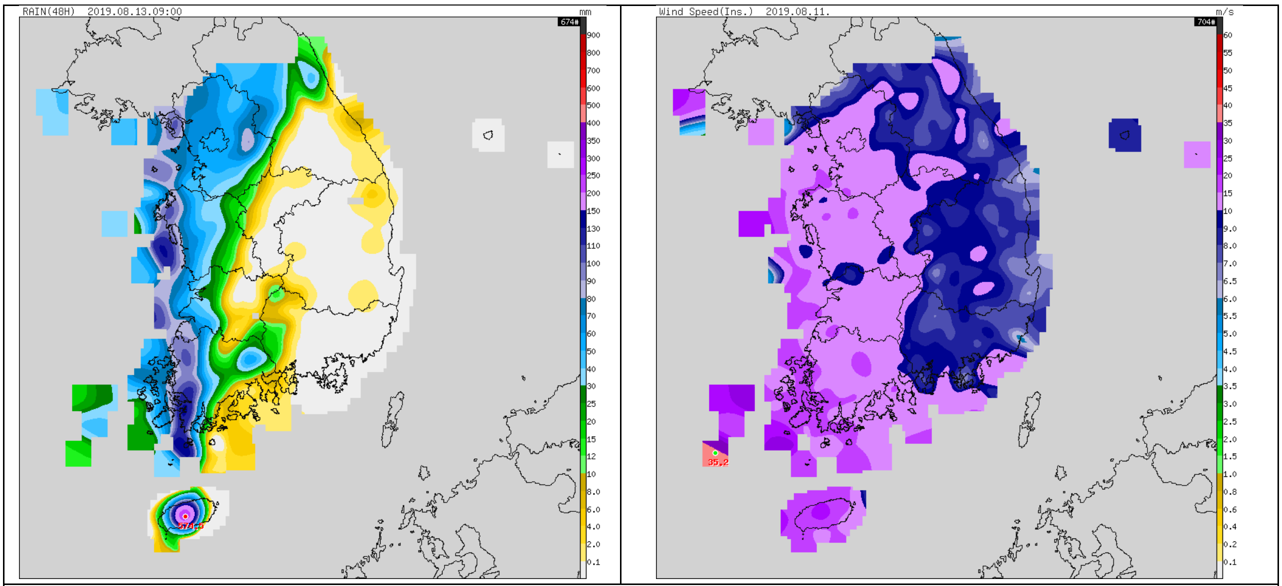


No. 8 FRANCISCO (6−7 August)

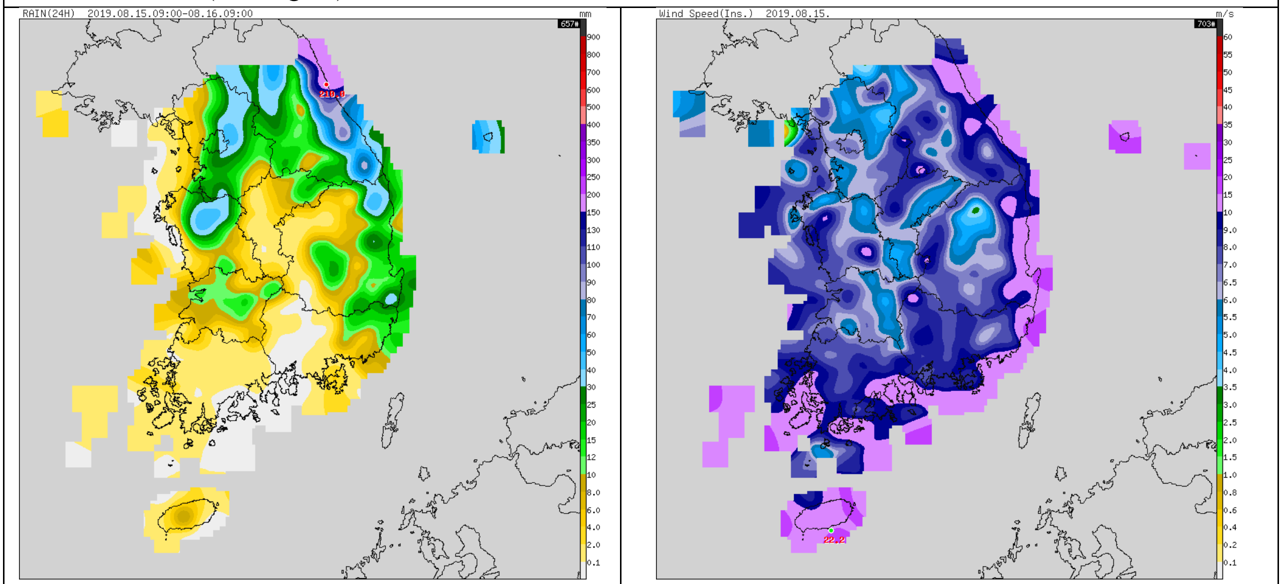




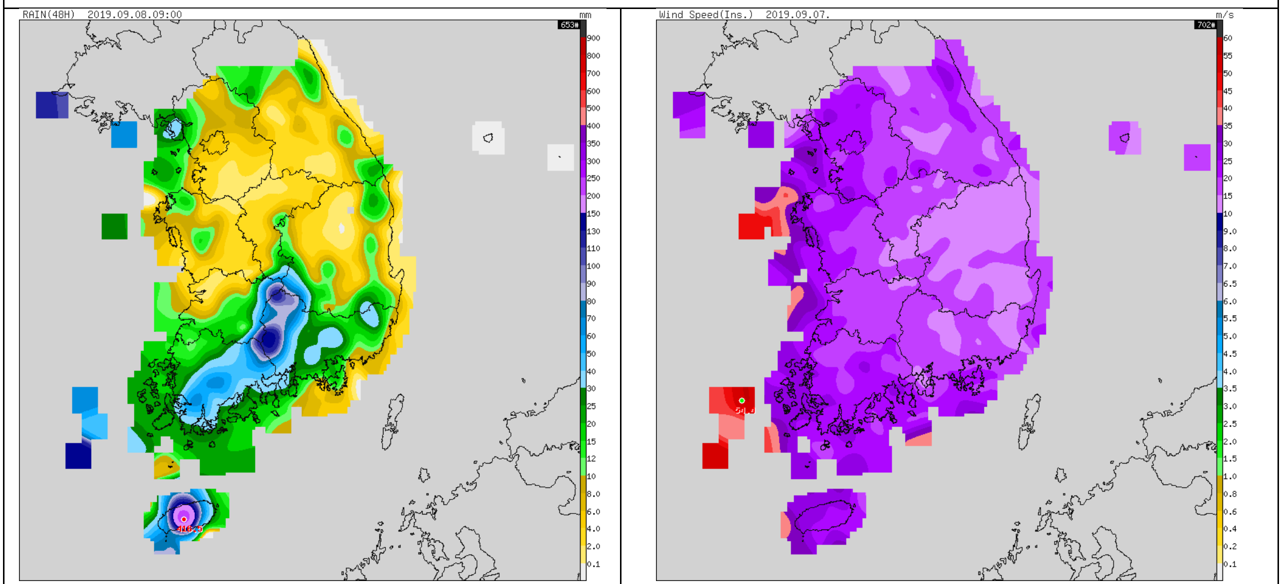
No. 9 LEKIMA (11−12 August)



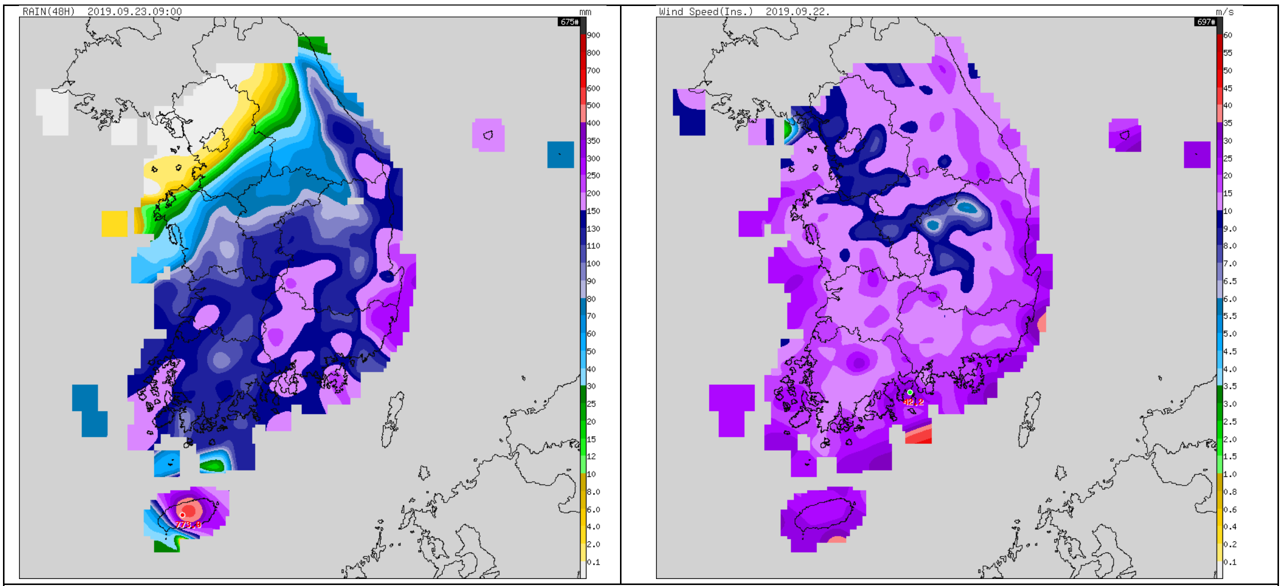
No.10 KROSA (15 August)



No.13 LINGLING (6−7 Sepetmber)



No.17 TAPAH (21−22 September)



No.18 MITAG (1−2 October)

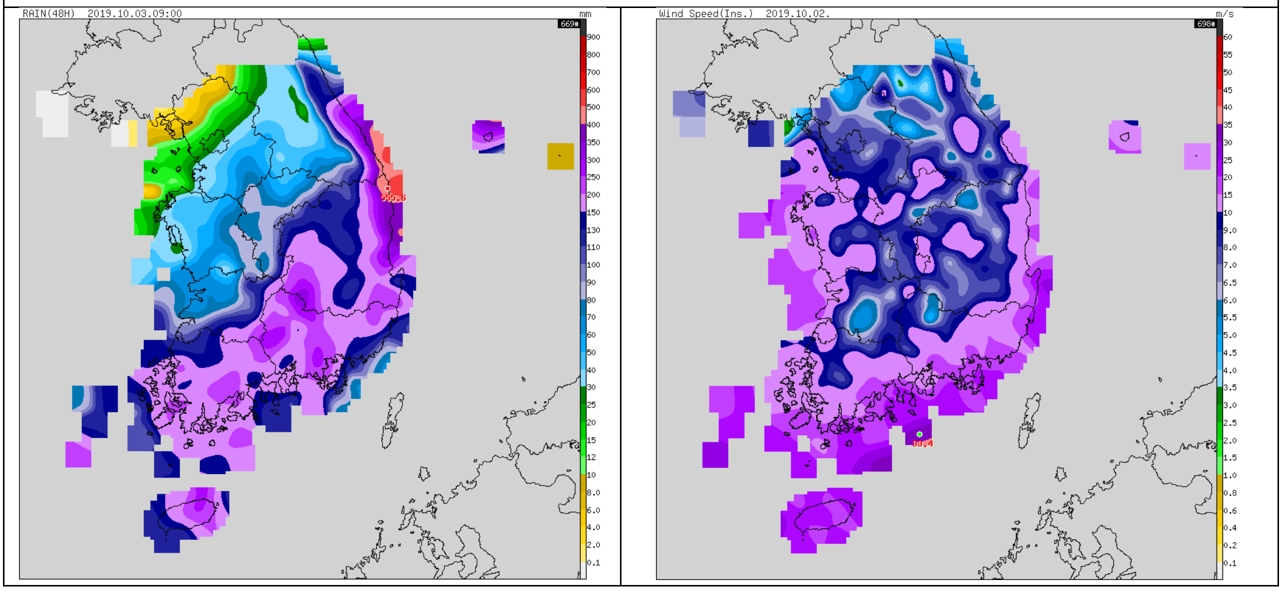


Fig. I-2. Distribution of accumulated rainfall (left) and gust (right) during the passage of seven typhoons affecting the Korean Peninsula

2. Hydrological Assessment (highlighting water-related issues/impact)

There were seven typhoons that directly or indirectly affected South Korea from July to early October 2019, which is a record high in the past 60 years. After September, in particular, three typhoons affected the country with heavy rain. In the case of Typhoon No.13 LINGLING and No.7 TAPHA, the actual trajectory of these typhoons was slightly different from the predicted route, causing some casualties in unexpected areas.

Typhoon No.5 DANAS abruptly dissipated after reaching the southwestern sea of Seogwipo City, Jeju Island, South Korea at dawn on 20 July. Then it disappeared as a tropical low pressure at about 50 km west of Jindo-gun, South Jeolla province, South Korea. Typhoon No.8 FRACISCO landed in Busan Metropolitan City on 6 August at around 8 p.m. and turned into a tropical low pressure on the same day at 9 p.m. Typhoon No.10 KROSA affected the eastern part of South Korea in August as well. This brought heavy rain in the east of Gangwon province.

In addition, Typhoon No.13 LINGLING passed by sea at around 6 a.m. on 7 September, around 140 km west of Mokpo city, South Jeolla province, South Korea. Typhoon LINGLING drove a record-breaking strong wind of 54.4 m per second, the fifth-strongest in Korean history, with 27 casualties nationwide. Typhoon No.17 TAPHA was located at sea about 330 km south of Seogwipo city, Jeju Island in South Korea on 22 September, and some parts of Jeju experienced a heavy rain of 30 mm per hour. On the night of 22 September, Typhoon TAPHAS was close to Busan Metropolitan City at 95 km southeast of Busan, South Korea. After passing through the Korea Strait without landing on South Korea, Typhoon TAPHAS rapidly traveled northeast toward the East Sea, transforming into an extratropical cyclone. As a result, daily precipitation of 262.5 mm was recorded in Geoje city, South Gyeongsang province on 22 September. Typhoon TAPHA brought heavy rain of up to 700 mm and a maximum instantaneous wind speed of 42.2 m per second. Recently Typhoon No.18 MITAK was close to Jeju Island at 3 p.m. on 2 October at about 170 km west of Seogwipo. Because of its close proximity to Jeju Island, it has been moving north rapidly and landed on Haenam-gun, South Jeolla province, South Korea on the afternoon of 2 October. Over 260 mm of heavy rain was sprayed on the entire area of North Gyeongsang province and continued north-east, passing through Uljin-gun, North Gyeongsang province on 3 October. After passing through Uljin-gun, the typhoon moved in the north-east direction. On the morning of 3 October, Typhoon MITAG moved to the East Sea, about 57 km northwest of Ulleung-gun, North Gyeongsang province, and then was weakened. Typhoon MITAK caused more than 10 casualties, collapse of houses and landslides.

In 2019, the Flood Control Office issued 17 flood alerts nationwide: two alerts by the Yeongsan River Flood Control Office due to the heavy rain caused by a monsoonal front; two alerts by the Nakdong River Flood Control Office and the Yeongsan River Flood Control Office, respectively, affected by the typhoon TAPHA; and 13 alerts by the Nakdong River Flood Control Office, affected by the typhoon MITAG. In addition, the level of crisis warning was subdivided into four levels to disseminate flood risks through cell phone text messages. A text message service was also provided for the management of facilities located along the streams and rivers.

3. Socio-Economic Assessment (highlighting socio-economic and DRR issues/impacts)

There were a total of seven typhoons that affected the Republic of Korea this year (Table I-1). The year 2019 has become the year most affected by typhoons since 1959. Six of them — DANAS, FRANCISCO, KROSA, LINGLING, TAPAH, and MITAG — caused casualties and economic losses. LINGLING and MITAG were the most damaging typhoons on record to hit the Republic of Korea in 2019.

Table I-1. List of typhoons that affected the Republic of Korea in 2019

No.	Typhoon Name	Duration
1905	DANAS	16 to 20 July 2019
1908	FRANCISCO	02 to 06 August 2019
1909	LEKIMA	04 to 12 August 2019

1910	KROSA	06 to 16 August 2019
1913	LINGLING	02 to 08 September 2019
1917	TAPAH	19 to 23 September 2019
1918	MITAG	28 September to 03 October 2019

(By the courtesy of KMA web site, www.weather.go.kr)

DANAS (1905) started to affect Jeju Island on July 18th. The Minister of the Ministry of the Interior and Safety (MOIS) held an emergency meeting and declared 'Emergency Stage 1'. As of July 21st, the accumulated rainfall was 1,145 mm in Jeju Island and it was reported that 2,454 ha of farmland and 3 apartment complexes were flooded by the torrential rain.

FRANCISCO(1908) started to affect the southest of Korea on August 5th. MOIS held emergency meeting on August 3th. The accumulated rainfall was 128 in Ulsan. There was no casualties but typhoon FRANCISCO made 82 flights and 5 ferries canceled. Also 2 roads were blocked and 5 trees were uprooted.

KROSA (1910) was developed near Guam and affected the east side of Korea. A high seas watch was issued for the east coast. The accumulated rainfall was 255.5 mm in Sokcho. Damage caused by Typhoon KROSA was relatively minor. But one house was flooded, and a highway was affected by soil runoff (The above information is based on reports and press releases published by the MOIS).

LINGLING (1913), formed near the Philippines as a midget typhoon, became a huge typhoon when it passed through the west side of Mokpo in Korea on 7 September. In order to prepare for the arrival of the typhoon, the MOIS held a situational awareness meeting and raised its emergency level from ATTENTION to CAUTION. On 8 September, the MOIS released an emergency alert. It was reported that the maximum instantaneous wind speed was 54.4 m/s in Heuksan Island. In result, 4 people were dead, 7,900 public facilities including schools, cultural properties, and roads were damaged. Also, 1,516 private facilities were damaged (Fig. I-3). The total amount of damage was estimated at 28 million USD (Table I-2) (The above information is based on reports and press releases published by the MOIS).

	
Damaged house (Incheon)	Collapsed greenhouse (Incheon)

Collapsed farmland by wind
(Incheon)

Wrecked aquaculture facilities
(South Jeolla)

Damaged warehouse
(South Jeolla)

Damaged fishing port
(South Jeolla)

(By the courtesy of MOIS Official Press Release on 30 September)

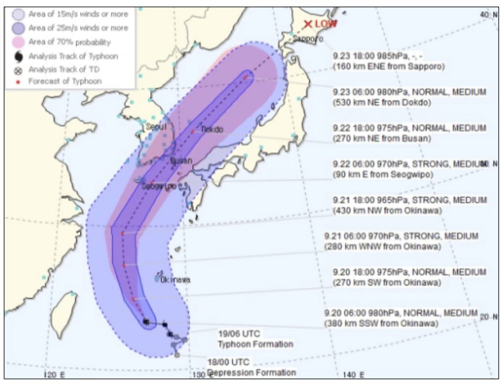
Fig. I-3. Pictures of major damage in a special disaster area by Typhoon LINGLING

Table I-2. Facility damage and recovery costs by Typhoon LINGLING

Name of province	Damage costs of facilities (USD)			Recovery costs (USD)
	Subtotal	Private	Public	
Incheon	8,754,946	6,651,511	2,103,435	7,906,468
South Jeolla	6,482,027	4,377,473	2,104,554	60,465,899
Gyunggi	4,962,153	3,532,677	1,399,476	8,493,819
South Chungcheong	4,794,347	4,373,791	420,556	33,807,081
North Jeollaand others	3,112,120	2,691,534	420,556	23,048,452
Total	**28,119,222**	21,609,350	6,509,872	133,797,068

(By the courtesy of MOIS Official Press Release on 30 September)

TAPAH (1917), which went through between the Korean Peninsula and Japan from 21 to 23 September, brought human and economic losses. Although it did not directly hit Korean territories, its instantaneous wind speed was approximately 36 m/s and the accumulated precipitation



(By the courtesy of KMA)

Fig . I-4. Track of typhoon TAPAH

recorded in Jeju Island was about 783.5 mm for three days. Because of these intense wind and rain, about 3,000 ha of farmland and 60 roads were flooded, and 71 public facilities including traffic lights, power poles, and seawalls were significantly damaged. In addition, nearly 28,000 households were blacked out due to the impact of the typhoon. In total, 1 person was dead. To prepare for and respond to TAPAH, the Korean prime minister convened an emergency meeting on 18 September, which was 2 days before TAPAH started to affect Korea, and more than 30,000 local government officers remained on standby for immediate response and recovery work (The above information is based on reports and press releases published by the MOIS).

MITAG (1918) started to affect the southern part of Korea, including South and North Jeolla provinces from 1 October. It was expected that MITAG would be a huge typhoon, which led the MOIS to activate the Central Emergency Operation Center on 1 October and start early typhoon monitoring with related ministries. The alert was released on 3 October. It was reported that the accumulated rainfall in Uljin was 556.3 mm. Consequently, 15 people were dead. 1,835 public facilities and 3,700 private properties were damaged. The typhoon also caused a power outage at 48,673 houses. Typhoon MITAG caused enormous damage on the Republic of Korea. For this reason, the MOIS designated some of the most affected areas, such as Samcheok, Uljin, and Yeongdeok, as special disaster areas (Fig. I-5) and expanded its public assistance. The MOIS deployed a Central Disaster Damage Investigation Group (about 100 experts including members of NDMI) to the special disaster areas from 11 to 17 October to analyze the causes of damage. The investigation using drones will be also conducted in some areas, which are difficult for investigators to approach.

Also, the MOIS is planning to utilize an additional fund and reduce utility rates such as electricity bills to provide further assistance for residents whose houses and workplaces got damaged (The above information is based on reports and press releases published by the MOIS. Further detailed information will be added when the investigation is finished).

	
Loss of bridge (Yeongdeok)	Damaged road (Yeongdeok)

Damaged road
(Yeongdeok)

Inundated farmland
(Yeongdeok)

Inundated farmland
(Yeongdeok)

Inundated stream
(Yeongdeok)

Washed stream
(Uljin)

Inundated street
(Uljin)

	
Inundated village (Samcheok)	Sediment runoff (Samcheok)
	
Loss of bridge (Samcheok)	Inundated village (Samcheok)
	
Landslide (Busan)	Landslide (Busan)

(By the courtesy of MOIS Official Press Release on 10 October and NDMI Investigator)

Fig. I-5. Pictures of major damage in special disaster areas by Typhoon MITAG

II. Summary of Progress in Priorities supporting Key Result Areas

1. The Web-based Portal to Provide Products of Seasonal Typhoon Activity Outlook for TC Members (POP1)

Main text:

The Korea Meteorological Administration (KMA) has issued a seasonal outlook for typhoons occurring in the western North Pacific basin on its website (http://gtaps.kma.go.kr/TSP/index.php) since 2014. The information about the number of typhoons and track pattern is provided based on the results of three types of models: multi-regression model, global dynamical model and hybrid model of statistical and dynamical method (Fig. II-1). In 2019, the KMA provided TC Members with a seasonal outlook for western North Pacific typhoon-activities on the website. The seasonal outlooks for summer and fall were issued in late May and late August, respectively. In the summer seasonal outlook (Jun. to Aug.), 11 to 13 typhoons were forecasted to occur. In the fall seasonal outlook (Sep. to Nov.), 8 to 15 typhoons were forecasted to occur. Storm frequency would be above normal in the southern Sea of Japan and near the Korean Peninsula, and below normal in the South China Sea and near the Philippines.

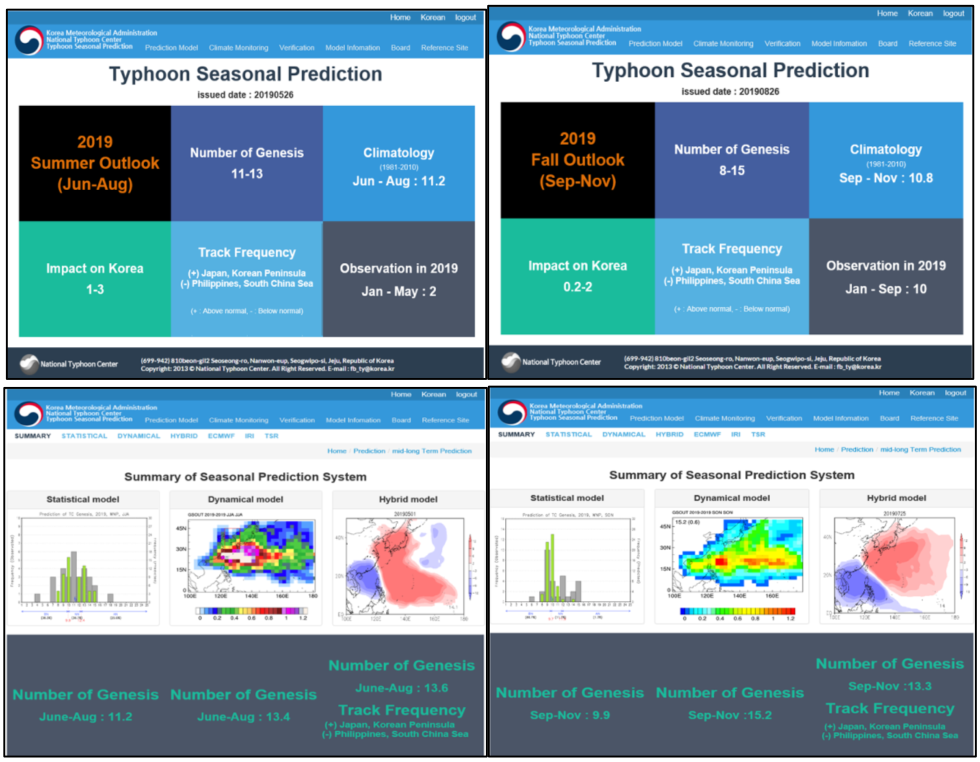


Fig. II-1. Sample pages of the website for the KMA's seasonal typhoon activity outlook: Summer (Top left), Model prediction result during Jun. to Aug. (Bottom left), Fall (Top right), Model prediction results during Sep. to Nov. (Bottom right)

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2. Technology Transfer of Typhoon Operation System (TOS) to the Macao Meteorological and Geophysical Bureau (POP4)

Main text:

The NTC/KMA carried out a transfer of Typhoon Operation System (TOS) technology to the Macao Meteorological and Geophysical Bureau from 16 to 18 October, 2019. This system allows forecasters to produce typhoon information with multi ensemble function for intensity and track forecasting by using NWP data in the TOS DB. TOS optimally covers all member countries' responsible areas and displays their stations. Recently, a new feature of TD forecast has been added as requested. Three staff members of the NTC and two engineers visited the Macao to install the TOS system on the Linux server and train the TOS (Fig. II-2). During the visit period, the KMA staff introduced the TOS and performed demonstration of typhoon forecasts using TOS. The visit was made by TCTF support.

Fig.II-2. TOS introduction and typhoon forecast practice at SMG

Identified opportunities/challenges, if any, for further development or collaboration:
We will continue TOS technology transfer to Member countries when requested.

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3. 2019 TRCG Research Fellowship Scheme by KMA

Main text:

The NTC/KMA hosted the Typhoon Research Fellowship Program of the Typhoon Committee Training and Research Coordination Group (TRCG) for the ESCAP/WMO Typhoon Committee Members. This year, the program duration was extended from two to four weeks, taking place from 20 May to 14 June 2019. The Program was joined by two participants from the Philippine

Atmospheric Geophysical and Astronomical Services Administration (PAGASA) and the National Center for Hydro-Meteorological Forecasting (NCHMF) of Viet Nam. The two forecasters conducted research on: multi-model ensemble forecast of tropical cyclone tracks with bayesian model averaging, and comparison of the track forecast by NCHMF with that by NTC. They were also offered training sessions, including typhoon forecasting using numerical model, seasonal typhoon forecast, typhoon genesis monitoring system, and typhoon information production using TOS. The event ended with a technical visit to the KMA headquarters, National Meteorological Satellite Center, and National Meteorological Center of Supercomputer.

Fig.II-3. Typhoon Committee TRCG Research Fellowship at KMA in 2019

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4. Co- Hosted the 12th Korea-China Joint Workshop on Tropical Cyclones

Main text:

The 12th Korea-China Workshop on Tropical Cyclones was held at the Shanghai Meteorological Service of the China Meteorological Administration (SMS/CMA), China, from 20 to 24 May 2019. The workshop included four sessions and a cooperative conference where the delegates from both agencies had a discussion about analysis of extra-tropical cyclone transition, exchanging experts, and validation of best-track data as well as exchanging typhoon forecasters and observational data.

Fig.II-4. Photos of 12th Korea-China Joint Workshop on Tropical Cyclone: Group photo (Top), Opening Address by director of NTC (bottom left), Discussion between NTC and STI (Bottom right)

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5. Improved KMA's Typhoon Intensity Classification

Main text:

The Korea Meteorological Administration (KMA) has changed its TC intensity classification. The existing classification, released on the KMA website, used four categories based on typhoons' sustained wind speed — Weak, Moderate, Strong, and Very Strong. Tropical cyclones with sustained winds exceeding 17m/s (34 knots) were considered as weak typhoons, but they are still dangerous and have potential to cause significant damage to people and property. In this regard, the KMA removed "Weak" category from the Typhoon Intensity Scale as of 29 March 2019 to prevent any misinterpretation. The new intensity classification was firstly applied to SEPAT (1903) as follows:

Table II-1. Typhoon intensity classification of KMA

Scale	Maximum Sustained Wind Speed
-	More than 17m/s (34 knots) − Less than 25m/s (48 knots)
Moderate	More than 25m/s (48 knots) − Less than 33m/s (64 knots)
Strong	More than 33m/s (64 knots) − Less than 44m/s (85 knots)
Very Strong	More than 44m/s (85 knots)

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6. Operational Service of GEO-KOMPSAT-2A

Main text:

The KMA began operating GEO-KOMPSAT-2A (GK2A) at 00UTC on 25 July 2019, continuing the COMS' mission after carrying out 7-month In-Orbit-Test (IOT) from its successful launch on 4 December 2018. The KMA operates three different observation areas with 10-minute schedule. The GK2A's AMI (Advanced Meteorological Imager) observes Full Disk (FD) once, Extended Local Area (ELA) five times, and Local Area (LA) five times every 10 minutes. In particular, LA mode can be used for target area observation, covering a 1000 km X 1000 km area every 2 minutes with flexibility for location changes. The KMA utilized target area observation to monitor five typhoons (5th DANAS, 9th LEKIMA, 13th LINGLING, 17th TAPAH, and 18th MITAG) which affected the Korean Peninsula in 2019. It improved the accuracy of Tropical Cyclone (TC) center position and reduced the TC analysis time by providing better insight about the evolution of convective clouds around the center TC within one minute after the end of observation. Fig. II-5 shows visible images of the circulation of low-level clouds in the eye region, taken by COMS and GK2A which has four times higher spatial resolution than COMS. The official request for target area observation every 2 minutes will be available via a designated web page (or email) within next year to support national and international services over the Asian Pacific region (RA II and RA V). However, the first priority is disaster monitoring over the Korean Peninsula, such as typhoon, wild fire.

Level 1B data of GK2A have been released via internet as well as broadcast since 25 July 2019. The KMA broadcasts meteorological observations from all 16 bands with full resolution using UHRIT (Ultra High Rate Information Transmission), and maintains HRIT (High Rate Information Transmission) broadcast corresponding to COMS 5 channels. LRIT (Low Rate Information Transmission) broadcast will be replaced by meteorological service for ship-board small antenna. The KMA disseminates GK-2A level 1B data via landline, too. The full disk data from 16 bands, about 2.25 GB volume, are provided by FTP in real time. Considering the network bandwidth limitation, the FTP account is issued one account per one country. Currently nine countries are registered, namely, Australia, Bangladesh, Hong Kong, India, Japan, Malaysia, Nepal, Singapore, and Vietnam. GK-2A level 1B and level 2 products in netCDF format are available on the NMSC website (http://nmsc.kma.go.kr/enhome/html/main/main.do) and at the DCPC-NMSC (http://dcpc.nmsc. kma. go.kr). The data requested by users can be downloaded in non-real time. User registration is needed for accessing this service.

a) COMS (15min, 1km resolution)   B) GK2A (2min, 0.5km resolution)

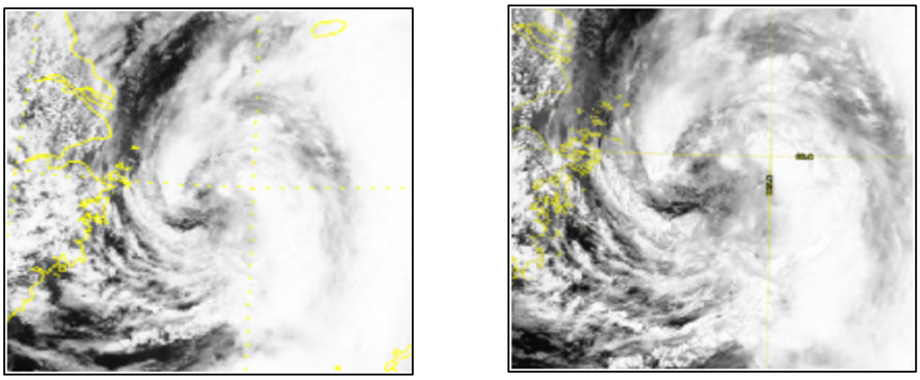

Fig.II-5.The comparison of visible images between COMS and GK2A for the 5th typhoon DANAS at 03UTC on 19 July 2019

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7. Developing Typhoon Analysis Technique for GEO-KOMPSAT-2A

Main text:

The National Meteorological Satellite Center (NMSC)/KMA has developed various typhoon analysis techniques to provide better information of tropical cyclones based on satellite observation, especially when TCs are approaching to the Korean Peninsula. To automatically provide more accurate TC center position and intensity information than the current ADT ver. 8.2.1 before the Subjective Dvorak Technique (SDT) analysis, the KMA has developed Korean-Advanced Dvorak Technique (K-ADT) by introducing the modified algorithm of TC center location, the ensemble TC intensity number algorithm, and the new wind speed/pressure conversion algorithm. Unlike the current ADT using the combination of Spiral Centering (SC) and Ring Fitting (RF) methods, when T# is greater or equal to 3.5, K-ADT has developed pattern-based TC centering algorithm by applying RF method for eye TCs and SC method for non-eye TCs even if they are weak. Only if the TC center determined by SC algorithm is out of the normal forecast error range (1.5° within 24hours), the storm forecast center position is used in K-ADT. To reduce the uncertainty in TC intensity caused by the errors in the TC center, K-ADT calculated the ensemble CI number from the distance-weighted averaged CI value using nine different TC center locations. K-ADT also implemented the relationship equation between CI-maximum wind speed and CI-minimum pressure using best-track data and CI# by the KMA, which is based on the methodology outlined in Knaff and Zehr (2007) and Courtney and Knaff (2009), to consider different stages, positions and moving speed of TCs and environmental background. Fig. II-6 shows the preliminary results of TY1913 LINGLING by K-ADT, compared with those from existing ADT ver. 8.2.1 and SDT by the KMA. CI number, minimum pressure and center position estimated by K-ADT correspond better to those by SDT than those by ADT ver 8.2.1, though it has a relatively big difference at the beginning and decaying stage. K-ADT will be pre-operated to complement ADT ver. 8.2.1 in 2020 after optimizing K-ADT algorithm to the Korean Peninsula in 2019.

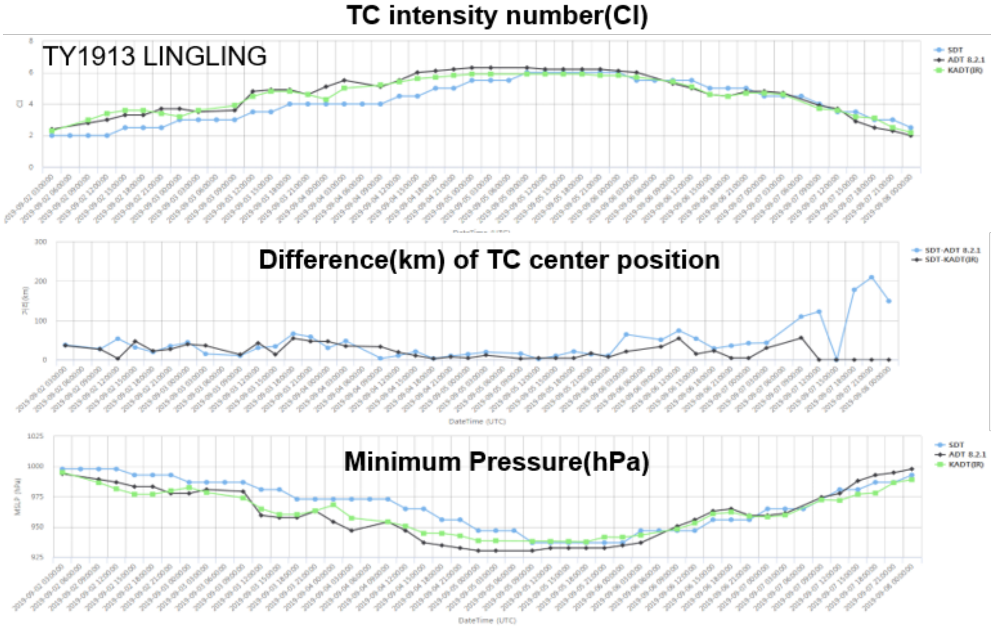

Fig.II-6 Preliminary TC information of TY1913 LINGLING calculated by K-ADT T, compared with those from existing ADT ver. 8.2.1 and SDT by KMA

On the other hands, the KMA has developed an algorithm to estimate 3D field of horizontal marine wind in and around a TC based on (near-) real-time multi-platform satellite data, such as cloud top temperature (CTT), atmospheric motion vectors (AMVs) of visible, infrared and water vapor bands on GK2A, microwave sounder (AMSU-A), and scatterometer (ASCAT, OSCAT). The algorithm consists of three main techniques shown in Fig. II-7.: IR winds, MW winds and multi-winds. IR winds are estimated based on the CTT from GK2A; MW winds from microwave sounder are used for modifying IR wind fields; and Multi-winds are finally retrieved by combining IR and MS winds, AMVs from GK2A and sea surface winds from scatterometers with moving windows for six hours using weighting functions optimized to minimize the root-mean square (RMS) difference with reanalysis winds as a function of the distance r from the TC center and altitude z. Using the combined 3D field, horizontal marine winds at multiple levels including sea-surface level and the radii of maximum wind (Rmax), 25 m/s (R25), and 15 m/s (R15) are extracted like shown in Fig. II-8, to support the TC intensity forecasting. The KMA will apply this algorithm to the 2019 Typhoons affected to the Korean Peninsula and validate the results using in-situ measurements or reanalysis data.

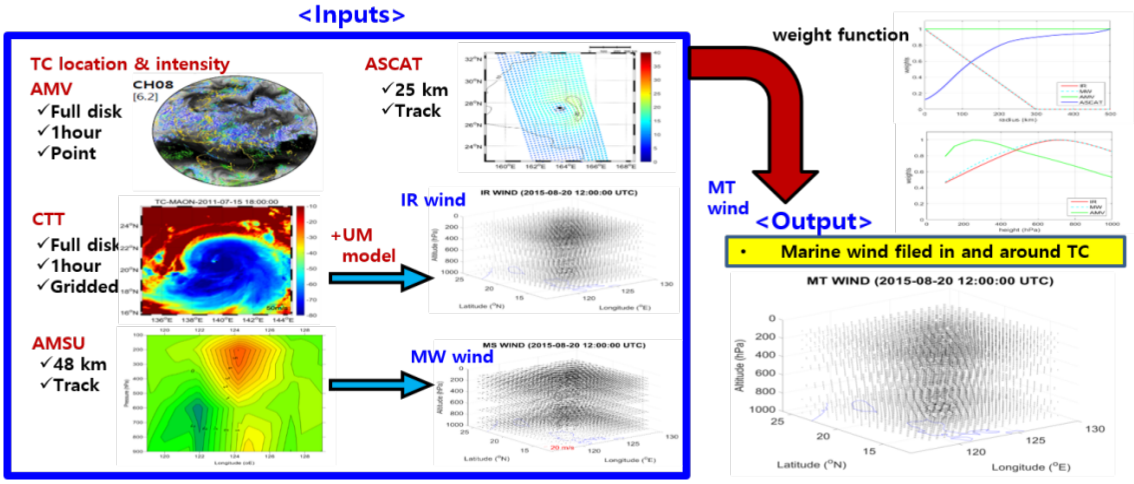

Fig.II-7. The flowchart to estimate 3D fields of horizontal marine winds in and around the tropical cyclone based on multi-platform satellite data

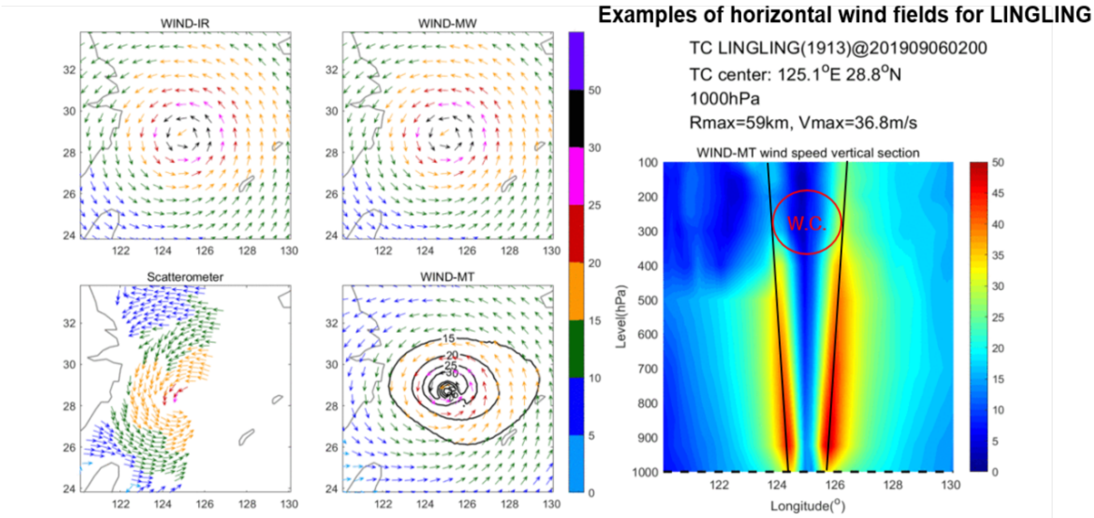

Fig.II-8. Example of horizontal wind fields at 1000hPa estimated from IR winds, MW winds and MT winds for the case of TY1913 LINGLING at 02UTC on 6 Sept. 2019

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8. Preliminary Research on Establishment of Hydrological Data Quality Control in TC Members

Main text:

The Republic of Korea has developed and operated a system for hydrological data quality control for major river watersheds including Han River basin, thereby improving the accuracy and efficiency of flood forecasting. The Han River Flood Control Office has to publish an annual hydrology data report using the national hydrology data quality control system and supply qualified hydrology data to the public on the public webpage.

The project for improvement of hydrological data quality control in TC members has been conducting for five years from 2018 to 2022. The objective of this project is to analyze the present state of the target country (Lao P.D.R, Malaysia, the Philippines, Republic of Korea, and Thailand), to provide direction and guidelines for the construction of hydrological data quality control system, and to develop the hydrology data quality control system in TC members. It is expected, eventually, that TC member countries will be able to improve flood forecasting performance by using high quality hydrological data.

Last year, preliminary studies were conducted on the hydrological data quality management for target countries in the TC region. This year, the first and second field surveys for the status analysis of target countries were conducted, suggesting the development direction of the system and methodologies for hydrological data quality control.

In 2020, a field survey meeting will be hosted by the Republic of Korea and a technical report on hydrological data quality control will be finalized.

Identified opportunities/challenges, if any, for further development or collaboration:

Capacity building for hydrological data quality control for TC members will be improved and high quality hydrological data can be published to the public and used for flood forecasting system.

Priority Areas Addressed:

Improve typhoon-related flood (including river flood, urban flood, mountainous flood, flash flood and storm surge) monitoring, data collection, quality control, transmission and processing.

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9. Task Improvement to Increase Effects in Flood Forecasting

Main text:

In Korea, the scope and work of flood forecasts (special flood bulletin and information) will incorporate the trend of unexpected heavy rainfall due to climate change to enable the diagnosis of flooding situation and respond rapidly. In this regard, as of 2019, 60 spots for special bulletins nationwide will be gradually expanded up to about 70.

In the case of rivers, which have difficulties securing the lead time for water level forecasting, it is possible to provide the reference value based on observation data so that the risk situation can be identified in advance even before issuing a flood bulletin. Also, the total number of stations, which provides water level information in four levels (attention, warning, alert and severity), will be expanded.

In addition, research projects are underway to develop technologies for expanding the lead time for flood forecasting, which is the most important to respond to floods and estimate flash flooding and urban inundation in lowland.

When heavy rainfall caused by typhoons or fronts are expected, an increase in water level at 60 stations nationwide are estimated based on precipitation forecasting data and results of numerical forecasting model. This information, which is called "Flood Projection against Heavy Rainfall" data, is provided for related organizations and agencies to help preparations for typhoons and heavy rain in a practical field.

Identified opportunities/challenges, if any, for further development or collaboration:

Dissemination of examples, such as sharing preliminary information to prepare for flooding, can strengthen the capability of TC member countries to respond to flooding.

Priority Areas Addressed:

Enhance capacity to generate and provide accurate information about typhoon-related flood risk management.

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10.Enhancement of Flood Forecasting Reliability with Radar Rainfall Data

Main text:

In order to manage flash floods, it is necessary to have very dense, observable rainfall data. However, it is not practical to install a lot of rain gauge stations in the watershed to observe the amount of rain in terms of installation and maintenance costs. To solve these problems, a rainfall radar system is operated as a complementary measure.

With regard to the improvement of data observed in inland stations and impact assessment of climate change on water resources variability, a project was launched in 2018 to provide a methodology and technique to enhance flood forecasting reliability with radar rainfall data. The project aims to analyze the status of operation and flood forecasting with radar rainfall data and suggest a methodology for flash flood forecasting using radar rainfall data.

Specifically, four target countries (Lao P.D.R, Philippines, Republic of Korea, and Thailand) were selected to conduct a survey for the status of radar data application in those countries last year and operation rules for flood forecasting by utilizing radar rainfall data will be researched.
The first and second field surveys for the analysis status of target countries were conducted this year and suggested a direction for using radar rainfall data for flash flood forecasting links to Extreme Flood Forecasting System (EFFS). In 2020, a field survey meeting will be hosted by the Republic of Korea and a technical report on using radar rainfall data for flash flood forecasting will be finalized.

Identified opportunities/challenges, if any, for further development or collaboration:

TC members can use a practical methodology for flash flood forecasting using radar rainfall data.

Priority Areas Addressed:

Strengthen capacity to utilize advanced technology (including satellite data, GIS, RS, QPE/QPF, ensemble, parallel computing) in typhoon-related flood forecasting and early warning, and hydrological modeling.

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11.Flood Risk Mapping of Korea

Main text:

Developing a flood risk map of Korea was determined in 1999 as part of preliminary research planning working group for non-structural flood control measures. In 2001, a basic survey of flood risk mapping was conducted.

Rivers in Korea are divided into two types: national rivers directly managed by the central government and local rivers managed by local governments. A total length of national rivers is 2,332 km in 62 places, and 26,872 km in 3,776 local rivers. A flood risk map of national rivers was completed in 2016.

Since making a flood risk mapping of national rivers, the Han River Flood Control Office (HRFCO) of the Ministry of Environment, Republic of Korea has been developing a flood risk map to prepare for flooding in local rivers and urban flood inundation. The flood risk maps will be completed for all Korean rivers, which will have been legally managed by 2021.
Flood risk mapping for the Nakdong River area was launched in 2018, and flood risk mapping for the Geum River area is underway in 2019.

In addition, the HRFCO is operating production standards for the flood risk mapping to ensure the accuracy and quality of flood risk maps, and updating them to reflect the latest technological advances.

Identified opportunities/challenges, if any, for further development or collaboration:

It is determined that Korea's flood risk mapping know-hows and information provision system for flood risk prevention can be used to prevent flood disasters in TC member countries.

Priority Areas Addressed:

Enhance capacity in flood risk (hazard, inundation) information, mapping and its application

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12. Expert Mission

Main text:

At the 14th Annual Meeting of Typhoon Committee Working Group on Disaster Risk Reduction (TC WGDRR), representatives from TC Member countries and experts in the field of disaster management discussed a 2019 Expert Mission. The experts' mission was a knowledge exchange program between member countries, which was started from 2008. In order to exchange knowledge and experience on flood prevention and river management, at the meeting NDMI and the member countries discussed determining a hosting country for this year.

However, as there was no member country for the 2019 Expert Mission during the 14th Annual Meeting of Typhoon Committee Working Group on Disaster Risk Reduction, the TC WGDRR member countries suggested and agreed that if there is no country for the mission, the budget (6,000 USD) for AOP1 (Expert Mission) will be redirected for operating a plenary session of TC WGDRR during the Bosai Forum and to dispatch more representatives from TC WGDRR.

Identified opportunities/challenges, if any, for further development or collaboration:
The TC WGDRR will hold a plenary session during the BOSAI Forum in Sendai, Japan after the 14th Integrated Workshop. The result of holding a plenary session will be reported in the 52nd Session next year. In addition, the TC WGDDRR will discuss carrying forward an Expert Mission for 2020 with TC members during the 14th Integrated Workshop.

Priority Areas Addressed:

Strengthen partnership among TC member countries and promote sharing knowledge and experience about technical areas, such as disaster prevention, early warning systems and emergency operations

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13. Setting up Early Warning and Alert System in Lao PDR and Vietnam

Main text:

At the 9th Annual Meeting of TC WGDRR in 2014, Lao PDR and Vietnam had requested NDMI implements ODA projects in their countries. After conducting a feasibility study on these countries, NDMI implemented an ODA project in 2016 to strengthen their capability for flash flood preparedness.

The process of ODA project for installing Flood Alert System and Automatic Rainfall Warning System (ARWS[*]), which was carried by NDMI, consisted of three steps:

1) Conducting Field Survey
2) Installation and Inspection
   * Warning Post (WP), Rainfall Gauge (RG), Water Level Gauge (WG)
3) Operating Educational Program

In 2016, 2017 and 2018, NDMI had implemented an ODA project for both two countries, including field survey, installation and inspection, and educational program.

Table II-2. The Number of ARWS and FFAS installed in Lao PDR and Vietnam

Location	VangVieng	Oudomxay	
Year	2016	2017	2018
WP	2	2	4
RG	2	2	4
WG	2	2	4
FAS	1	1	1

<Lao PDR>

Location	Lao Cai		Yen Bai
Year	2016	2017	2018
WP	2	2	2
RG	2	2	2
WG	2	2	2
FAS	1	1	1

<Vietnam>

<Activities in Vietnam 2019>

Through the discussion with Vietnam Academy for Water Resources (VAWR) during the conducting field survey, NDMI had decided to install ARWS in Yen Bai to strengthen disaster management capability of the local community. Through the meeting with the VAWR and the local government of Yen Bai province, NDMI chose three places for WP, another three places for RG, and the other three places for WG in Nghia Lo, Yen Bai. Also, NDMI selected one place for Flood Alert System in VAWR (located in Hanoi). NDMI will inspect ARWS which will be installed in Nghia Lo, Yen Bai, and Flood Alert System which will installed in VAWR in November 2019. In addition, NDMI will operate an educational program in November 2019.

<Activities in Lao PDR 2019>

Through the discussion with the Department of Meteorology and Hydrology (DMH) during the conducting field survey, NDMI had decided to install ARWS in Bolikhamxay province to strengthen disaster management capability of the local community. Through the meeting with DMH and the local government of Bolikhamxay province, NDMI chose three places for WP and another three places for RG/WG in Borikhan, Bolikhamxay. Also, NDMI selected one place for Flood Alert System in DMH (located in Vientiane). NDMI inspected ARWS which had been installed in Borikhan, Bolikhamxay, and Flood Alert System which had been installed in DMH in October 2019. In addition, NDMI will operate an educational program in November 2019 after finishing the inspection and educational program in Vietnam.

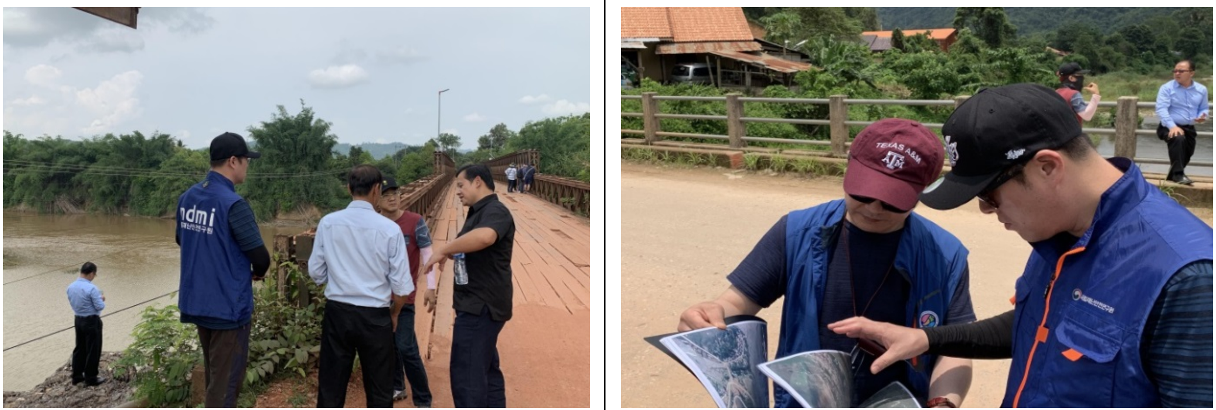

Fig. II-9. Photos of Field Survey in Lao PDR

Fig.II-10. Photos of Field Survey in Vietnam

Identified opportunities/challenges, if any, for further development or collaboration:

Next year NDMI will conduct maintenance on the ARWS and FFAS installed in the Philippines from 2013 to 2015. In addition, NDMI is planning to expand an ODA project to Lao PDR and the Philippines for 2021.

Priority Areas Addressed:

Strengthen capability of flood preparedness in Lao PDR and Vietnam. Develop a strong partnership and collaboration between Republic of Korea and target countries of ODA projects.

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14. The 14th Annual Meeting of Typhoon Committee Working Group on Disaster Risk Reduction

Main text:

The 14th Annual Meeting of Typhoon Committee Working Group on Disaster Risk Reduction (TC WGDRR) was held in Ulsan, Republic of Korea from 18 to 2 June 2019. Around 40 representatives from international organizations, universities and TC member countries participated in the meeting and discussed international cooperation for reducing disaster risk around the world. The topic for the annual meeting was "Disseminating and Sharing of Data on Disaster Risk Reduction." In the meeting, TC members shared disaster management information, and current status of technology development related to disseminating and sharing disaster related information and data among its governmental organizations and to the public. In addition, the members discussed operational strategies for 2019 Annual Operation Plans (AOPs).

Table II-3. Annual Operations Plans (AOPs) with budget in 2019

No.	Items	Budget (USD)	No.	Items	Budget (USD)
1	Expert Mission	6,000	**2**	Setting up Early Warning and Alert System	-
3	TC WGDRR Annual Meeting	-	**4**	Promote TC-PTC Cooperation	-
5	Holding a Plenary Session in BOSAI Forum	8,000	**6**	Benefit Evaluation of Typhoon DRR	6,000
7	Supporting SSOP II Project	-	**8**	Sharing Information related to DRR	-
9	Making Educational Video	1,500	**Total Budget (USD)**		21,500

Fig. II-10. Photos of the 14th Annual Meeting of TC WGDRR

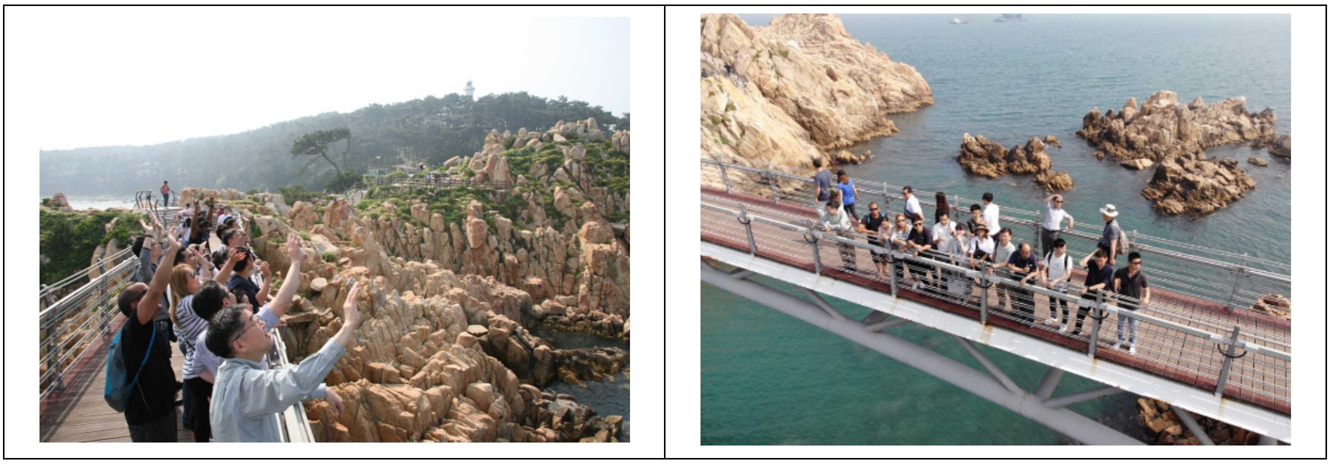

Fig. II-11. Cultural Tour at Daewangam Park, Ulsan Metropolitan City

Identified opportunities/challenges, if any, for further development or collaboration:

By holding the annual meeting, NDMI intended to promote sharing information and experience on "Disseminating and Sharing Data on Disaster Risk Reduction" between member countries. Also, the NDMI tried to establish strong cooperative ties with TC member countries.

Priority Areas Addressed:

Develop and enhance partnership among TC members and promote opportunity to share information and experience on "Disseminating and Sharing Data on Disaster Risk Reduction."

Strengthen the target "F" of Sendai Framework, which is "substantially enhance international cooperation to developing countries through adequate and sustainable support to complement their national actions for implementation of this Framework by 2030."

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15.Sharing Information Related to DRR

Main text:

As one of the AOPs of TC WGDRR, NDMI has been trying to share information related to disaster risk reduction at the ESCAP/WMO Typhoon Committee website. At the website, there is a Typhoon Committee (TC) Forum Session, which consists of two parts:

1. Shanghai Typhoon Institute Typhoon BBS: A discussion platform for typhoons, moderated by Shanghai Typhoon Institute (STI) and Typhoon Committee Secretariat (TCS)
2. Typhoon Committee Forum: A discussion platform among the working groups of TC
   * Three Working Groups: Working Group on Meteorology (WGM), Working Group on Hydrology (WGH), Working Group on Disaster Risk Reduction (WGDRR)

NDMI has been responsible for the WGDRR session to share information related to DRR.
The Topics in the session are:

1. ENFORCEMENT DECREE OF THE FRAMEWORK ACT ON THE MANAGEMENT OF DISASTER AND SAFETY
2. Framework act on the management of disaster and safety in the Republic of Korea
3. Thailand's Act 2007 and National Plan 2015

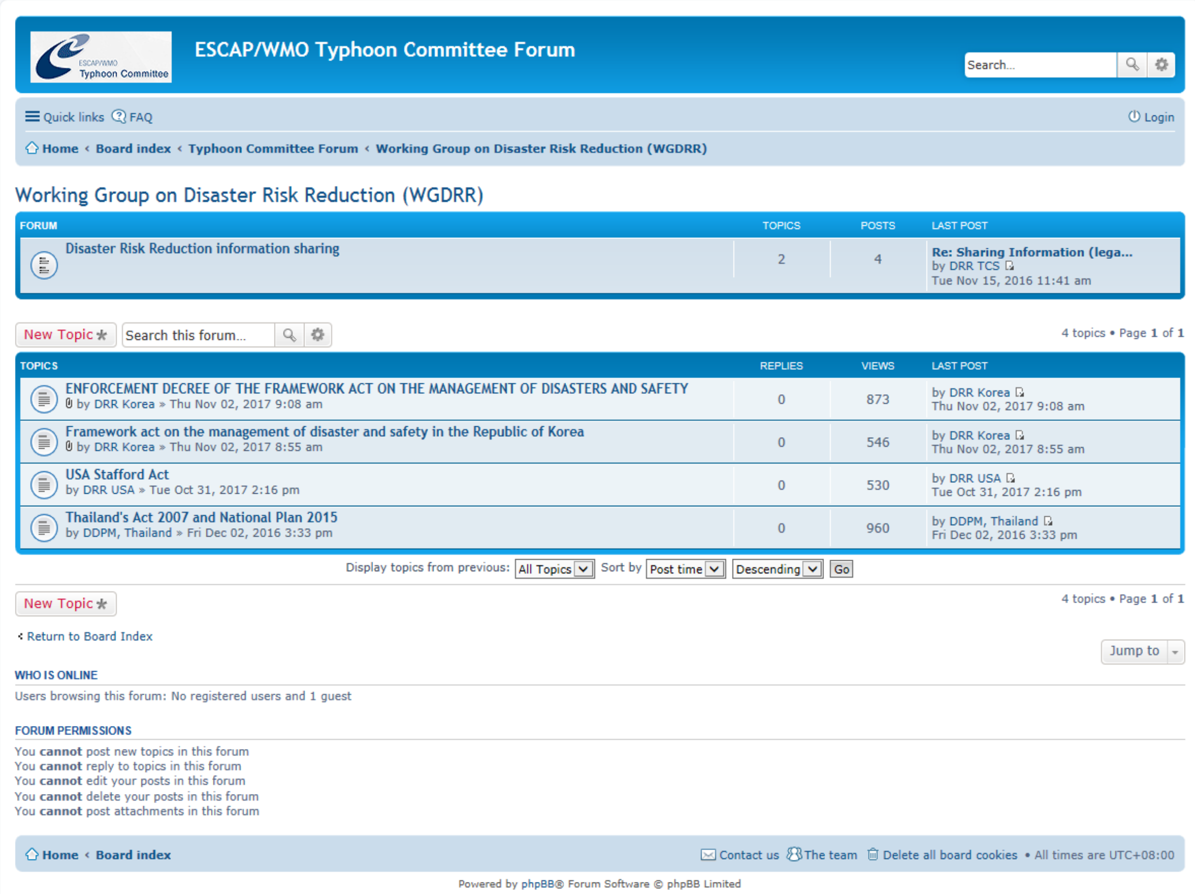

Fig. II-12. TC WGDRR Forum Website (http://www.typhooncommittee.org/forum/viewforum.php?f=12)

Identified opportunities/challenges, if any, for further development or collaboration:

Sharing information related to DRR through the TC forum website, a good framework to promote knowledge-sharing among TC member countries. Also, it could be a good opportunity to share information regarding disaster risk management to the public. Therefore, NDMI will keep promoting the use of the website so that all information about the related knowledge and experience from the TC members could be a good chance to draw continuous attention from the public in the field of disaster risk reduction.

Priority Areas Addressed:
Share knowledge related to DRR among TC member countries and strengthen capacity to make a strong partnership with not only TC members, but also international organizations.

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