MEMBER REPORT

(2011)

ESCAP/WMO Typhoon Committee

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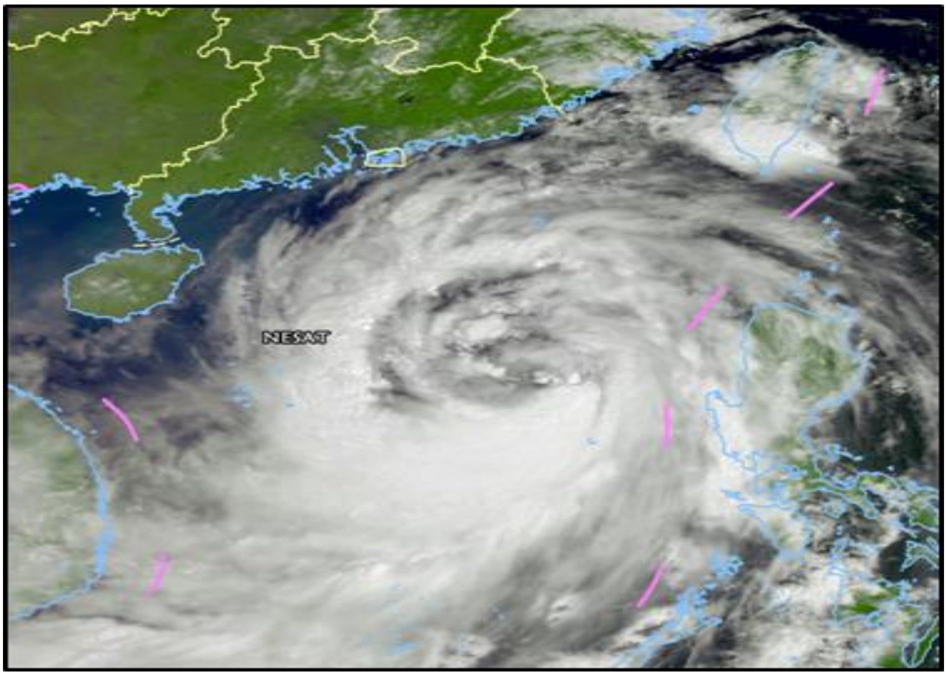

China

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I. Overview of tropical cyclones which have affected/impacted Member's area in 2011

1.1 Meteorological Assessment

In 2011, totally 21 tropical cyclones (including tropical storms, severe tropical storms, typhoons, severe typhoons and super typhoons) formed over the western North Pacific Ocean and the South China Sea (Fig1.1). Among them, 7 TCs landed on China's coastal areas (Fig1.2), namely Tropical Storm *SARIKA* (1103), Tropical Storm *HAIMA* (1104), severe tropical storm *MEARI* (1105), severe tropical storm *NOCK-TEN* (1108), super typhoon *NANMADO*L (1111), severe typhoon *NESAT* (1117) and severe typhoon *NALGAE* (1119).

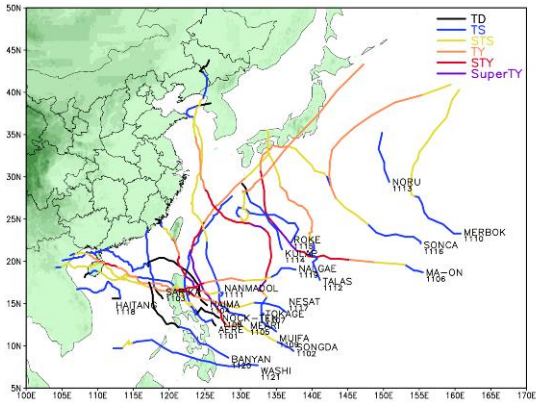


Fig 1.1 The tracks of TCs over the western North Pacific and the South China Sea in 2011

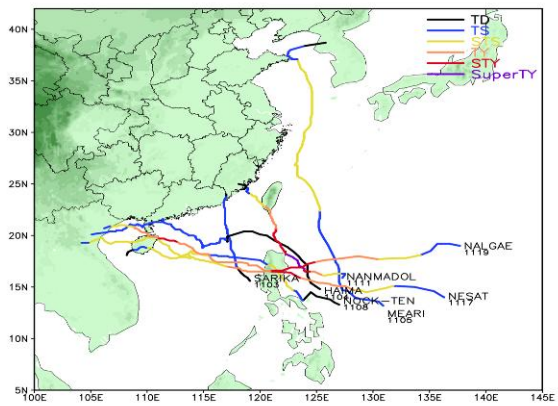


Fig 1.2 The tracks of TCs that landed on China's coastal area in 2011

1.1.1 The characteristics of tropical cyclones in 2011

The characteristics of the tropical cyclones in 2011 are as follows:

1) Less and weaker TCs than normal

In 2011, 21 TCs formed over the western North Pacific and the South China Sea. The number was obviously less than the normal average (27.1). 9 of them developed into typhoons or beyond, accounting for 43% of the total; the percentage was also lower than the normal average (62%). And the average intensity of all 21 TCs was 33.4m/s, which was lower than the normal average (40.7m/s).

2) TC genesis region tended to be located further north and east

In 2011, 10 TCs formed over the sea to east of the Philippines, 8 TCs were located over the waters north of Guam and Marshall Islands and 3 TCs (normal 5) generated over the South China Sea. Compared with the normal positions, TC genesis region was located further north and east.

3) Landing TCs' intensity was weaker than normal

In 2011, 7 TCs made their landfalls over the China's coastal areas. The landing TC number was almost equivalent to the annual average (6.9). But the average intensity of all landing TCs was only 33.4m/s, which was weaker than the normal average (40.7m/s).

4) Early landing time for the first landing TC

Tropical Storm *Sarika* (1103) was the first landing TC on China in 2011. It landed on Shantou/Guangdong on 11 June. Its landing time was 18 days earlier than usual (June 29).

Severe Tropical Storm *Meari* (1105) made its landfall on Rongcheng, Shandong on 26 June. The landing time was 23 days earlier than Super Typhoon *Billie* (7303), which was the earliest landing TC on Shandong province in records

5) Frequent binary TCs

During the 2011 typhoon season, there were 8 binary TCs over the western North Pacific and the South China Sea. They were *Haima* (1104) vs. *Meari* (1106), *Ma-on* (1106) vs. *Tokage* (1107), *Nock-ten* (1108) vs. *Muifa* (1109), *Muifa* (1109) vs. *Merbok* (1110), *Nanmadol* (1111) vs. *Talas* (1112), *Talas* (1112) vs. Noru (1113), *Roke* (1115) vs. *Sonca* (1116) and *Nesat* (1117) vs. *Haitang* (1118) respectively.

6) Weaker rainfall volume with stronger local rainfall

In 2011, the total TC-related rainfall was weaker across all China's coastal and inland areas and it was mainly distributed in Hainan, Guangxi and Guangdong provinces. But there was stronger local rainfall in some coastal areas. For example, during the affect of *Nanmadol* (1111) on the Fujian province, 443.4mm accumulated rainfall in 9 hours was observed in Linqiao, Putian, Fujian from 18 UTC, 31 August to 03 UTC September. During the impact of *Nesat* (1117) on the Hainan province, 904.6mm accumulated rainfall was observed in Wangxia, Changjiang, Hainan from 12 UTC 28 September to 22 UTC 29 September. During the period when the *Nalgae* (1119) was affecting the Hainan province, 333.6mm accumulated rainfall in 24 hours was observed in Haikou Hainan from 12 UTC,4 October to 12 UTC 5 October. These stronger local rainfalls caused severe floods in the above areas.

7) Relatively weaker impacts on China's inland and lighter losses from TC-induced disasters

During 2011, there were relatively heavier impacts by strong wind and rain only in the eastern coastal areas and the southern China. There were lighter impacts on inland areas. About 18.128 million people were affected by landing TCs, 29 people were killed or missing, direct economic loss is about 23.71 billion RBM Yuan. The number of death toll and missing people was the least since 2000 (283 people died or missed since 2000 on average). The direct economic loss was less than the average since 2000 (CNY 31.82 billion since 2000).

1.1.2 Operational Forecasts

In 2011, the China Meteorological Administration (CMA) continued to improve its observation and forecasting system. The National Meteorological Centre (NMC) of CMA established an objective TC positioning and intensity estimation system using FY2C/D/E and MTSAT infrared channel 1 data and products from the Regional Typhoon Numerical Prediction Model (GRAPES-TYM), which was based on GRAPES_MESO model, and NMC continued to improve its multi-model consensus TC track prediction system, super ensemble TC track prediction system based on TIGGE data and its Typhoon Information Processing System (TIPS). In 2011, the 24h, 48h, 72h, 96h and 120h mean distance errors of NMC/CMA subjective TC forecasts were about 113, 187, 277, 398 and 509km respectively (Table 1.1).

Table.1.1 Mean distance errors of NMC subjective TC forecasts in 2011 (km)

Forecast time	24h	48h	72h	96h	120h
2009	119	205	299	392	514
2010	107	199	296	387	499
2011	113	181	277	398	509

1.1.3 Narrative on Tropical Cyclones

8) *SARIKA (1103)*

SARIKA emerged as a tropical depression over the eastern part of the South China Sea at 06:00 UTC 9 June 2011. It moved northwest afterwards and developed into a tropical storm at 18:00 UTC 9 June. Then it turned north-northwest. *SARIKA* approached gradually to the eastern coast of the Guangdong province. It landed on Shantou of the Guangdong province at 21:45 UTC 10 June with the maximum wind at 18m/s near its centre. After landfall, *SARIKA* moved north with its intensity being weakened gradually. It turned into a tropical depression in Fujian province, where it disappeared at 06:00 UTC 11 June.

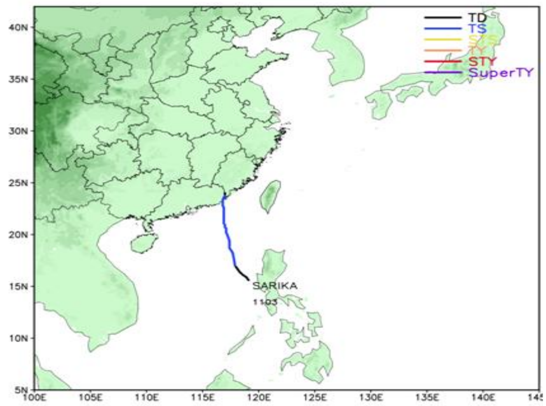


Fig 1.3a Track of *SARIKA* (1103)

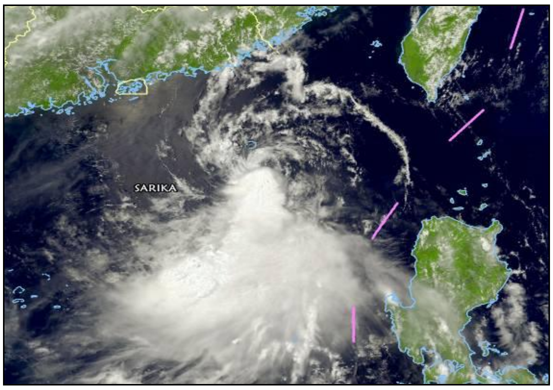


Fig 1.3b FY-3B image at 05:35 UTC 10 June 2011

9) *HAIMA (1104)*

It firstly turned out as a tropical depression over the east off the Philippines at 09:00 UTC 18 June 2011. It moved northwest afterwards and developed into a tropical storm over the northeastern part of the South China Sea at 18:00 UTC 20 June. It approached gradually to the western coast of the Guangdong province. *HAIMA* landed at a site between Dianbai and Yangxi of the Guangdong province at 02:10 UTC 23 June with the maximum wind at 20m/s near its centre. Later it landed again on Wuchuan of the Guangdong province at 08:50 UTC 23 June with the maximum wind at 20m/s near its centre. After its second landfall, it turned southwest and entered the Beibu Gulf. It landed for the third time on the northern Vietnam on 24 June. It was weakened rapidly and became a tropical depression at 18:00 UTC 24 June. At last, it disappeared over northern Vietnam at 21:00 UTC 24 June.

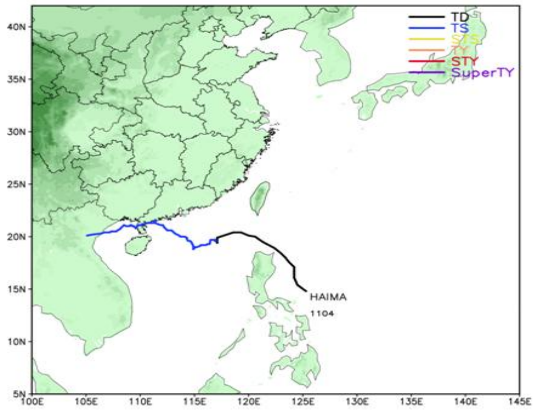


Fig 1.4a Track of *HAIMA* (1104)

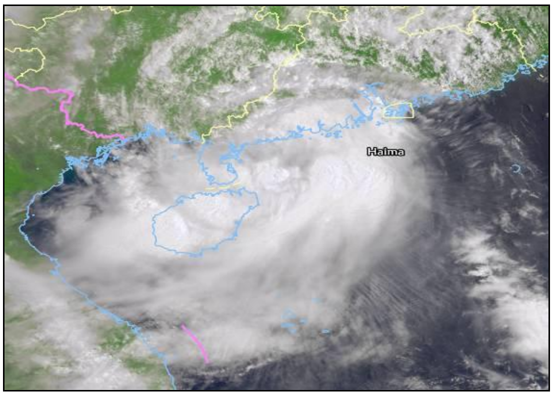


Fig 1.4b FY-3A image at 02:50 UTC 23 June 2011

10) *MEARI (1105)*

Tropical storm *MEARI* was formed at 06:00 UTC 22 June 2011 over the western North Pacific. Later it moved northwest. Then it turned north-northwest. It reached a severe tropical storm level at 09:00 UTC 24 June. It approached gradually to the eastern coast of the Shandong province. *MEARI* landed on Rongcheng of the province at 13:10 UTC 26 June with the maximum wind at 23m/s near its centre. After its first landing, it turned northeast and approached to the western coast of the Korean Peninsula. It became a tropical depression at 21:00 UTC 26 June over the Yellow Sea. *MEARI* landed again on the western coast of the Korea Peninsula on 26 June. At last it faded away over there at 03:00 UTC 27 June.

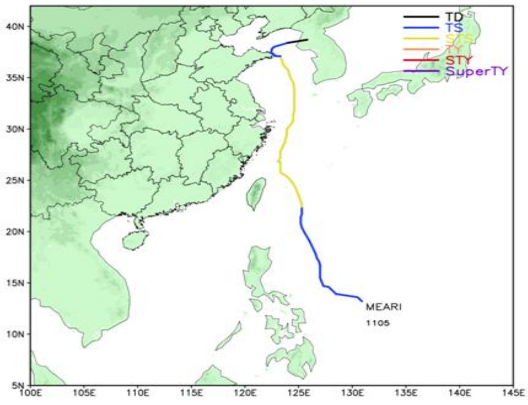


Fig 1.5a Track of *MEARI* (1105)

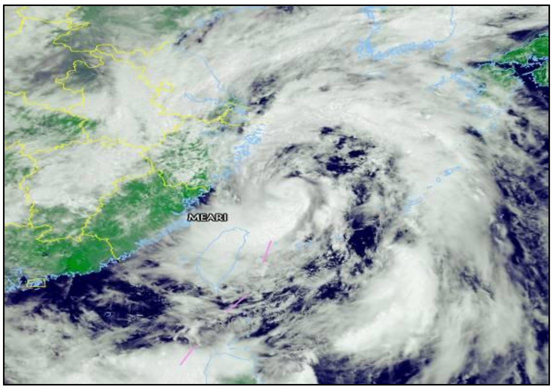


Fig 1.5b FY-3A image at 02:15 UTC 25 June 2011

11) *NOCK-TEN* (*1108)*

NOCK-TEN appeared as a tropical depression over the east off the Philippines at 06:00 UTC 25 July 2011. Moving northwest, it became a tropical storm at 00:00 UTC 26 July. It intensified gradually and turned into a severe tropical storm at 15:00 UTC 26 July. Then it approached to

Luzon, the Philippines. *NOCK-TEN* landed on the eastern coast of Luzon on 27 July, it weakened rapidly to a tropical storm. Then it moved west-northwest and entered the South China Sea. As it was approaching to the coast of the Hainan province, it became a severe tropical storm again. *NOCK-TEN* landed again on Wenchang of the Hainan province at 09:40 UTC 29 July with the maximum wind reaching 28m/s near its centre. After landfall, *NOCK-TEN* turned west and entered the Beibu Gulf. It landed for its third time on the eastern Vietnam on 30 July. It weakened to a tropical depression at 15:00 UTC 30 July. At last, it disappeared over northern Vietnam on 30 July.

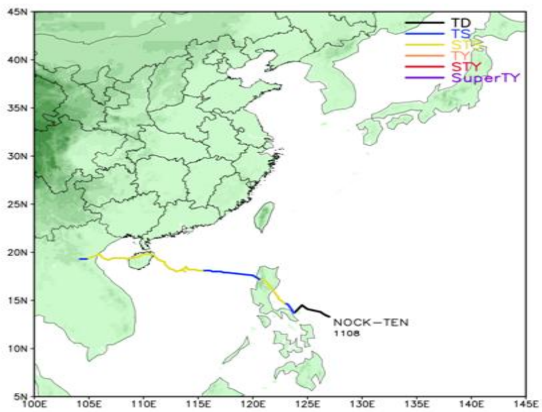


Fig 1.6a Track of *NOCK-TEN* (1108)

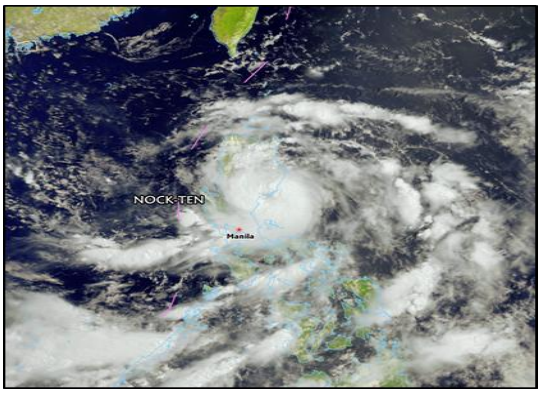


Fig 1.6b FY-3A image at 02:15 UTC 27 July 2011

12) *NANMADOL (1111)*

Tropical storm *NANMADOL* formed at 12:00 UTC 23 August 2011 to the northeast off the Philippines. It moved west after its genesis. Its intensity reached a severe typhoon category at 12:00 UTC 25 August. It developed into a super typhoon at 00:00 UTC 26 August. As it was approaching to the northeastern coast of Luzon, the Philippines, its intensity was reduced to a severe typhoon. It first landed on the northeastern coast of Luzon on 27 August. Then it entered the Bashi Channel and it moved toward the southern coast of the Taiwan province. Later it landed again on Taidong of Taiwan province at 20:25 UTC 28 August with the maximum wind up to 33m/s near its centre. After its second landfall, it moved northwest with its intensity being reduced. It became a tropical storm over the Taiwan Strait at 21:00 UTC 29 August. It landed for its third time on Jinjiang of the Fujian province at 18:20 UTC 30 August with the maximum wind at 20m/s near its centre. After landing, its intensity was weakened quickly. It became a tropical depression in the Fujian province, where it disappeared at around 09:00 UTC 31 August.

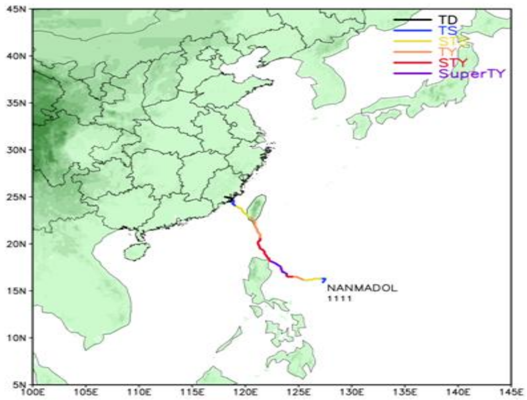


Fig 1.7a Track of NANMADOL (1111)

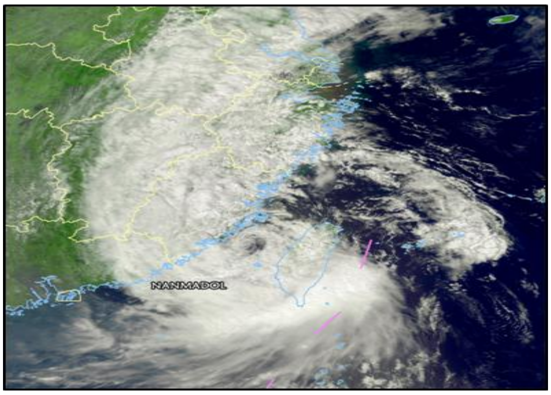


Fig 1.7b FY-3B image at 05:05 UTC 30 August 2011

13) *NESAT (1117)*

Tropical storm *NESAT* appeared at 00:00 UTC 24 September 2011 over the western North Pacific. Then it moved west-northwest. Its intensity reached the severe typhoon category at 15:00 UTC 26 September. It was gradually approaching to the eastern coast of Luzon, the Philippines. It landed on the eastern coast of Luzon on 26 September. After its landfall, it continued to move west-northwest with its intensity being reduced. It became a typhoon at 03:00 UTC 27 September. Then it crossed Luzon and entered the South China Sea. It approached gradually to the northeastern coast of the Hainan province. Later *NESAT* landed again on Wenchang of the Hainan province at 06:30 UTC 29 September with the maximum wind up to 42m/s near its centre. After its second landfall, it moved northwest and entered the Beibu Gulf. Its intensity was reduced gradually. It became a severe tropical storm over the Beibu Gulf at 21:00 UTC 29 September. *NESAT* landed for its third time on the northern coast of Vietnam on 30 September. At last it faded away over northern Vietnam on 30 September.

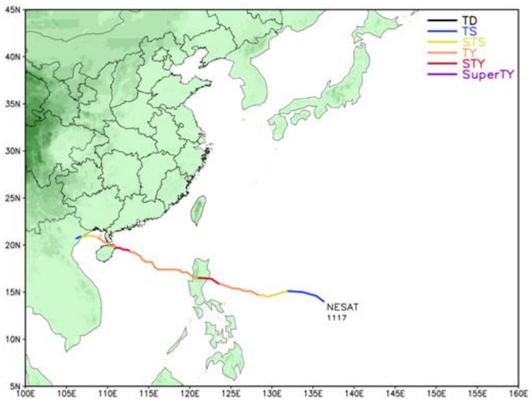


Fig 1.8a Track of *NESAT* (1117)

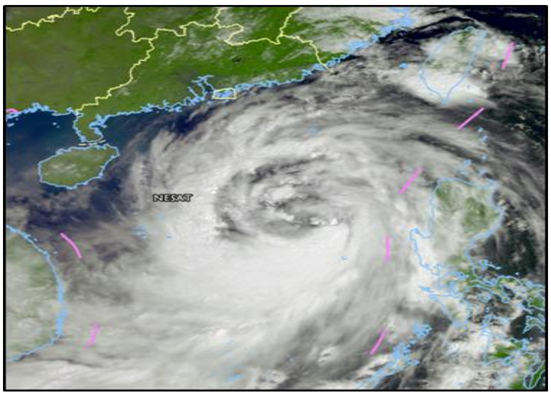


Fig 1.8b FY-3A image at 02:25 UTC 28 Sept. 2011

14) *NALGAE (1119)*

Tropical storm *NALGAE* formed at about 18:00 UTC 27 September 2011 over the western

North Pacific. It moved west after its genesis. Then it turned west-southwest. It approached gradually to Luzon, the Philippines with its intensity being increased gradually. Its intensity increased into the severe typhoon level at 15:00 UTC 30 September. *NALGAE* landed on Luzon on 1 October. After landfall, it moved west. Then it crossed Luzon and entered the South China Sea. Then, it turned west-northwest and it gradually approached to the southeastern coast of the Hainan province. Eventually, *NALGAE* landed on Wanning of the Hainan province at 04:30 UTC 4 October with the maximum winds at 25m/s near its centre. After landfall, it moved southwest with its intensity being weakened quickly. It became a tropical depression at 15:00 UTC 4 October. At last it disappeared over the southern Beibu Gulf at around 00:00 UTC 5 October.

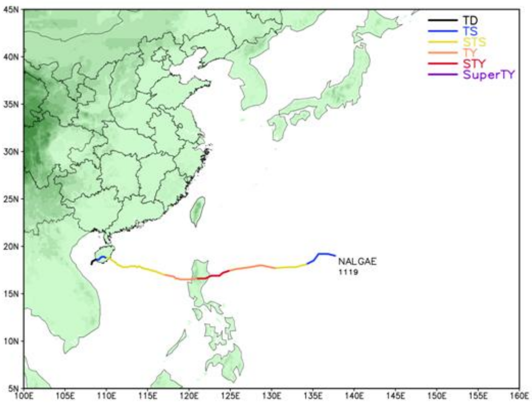


Fig 1.9a Track of *NALGAE* (1119)

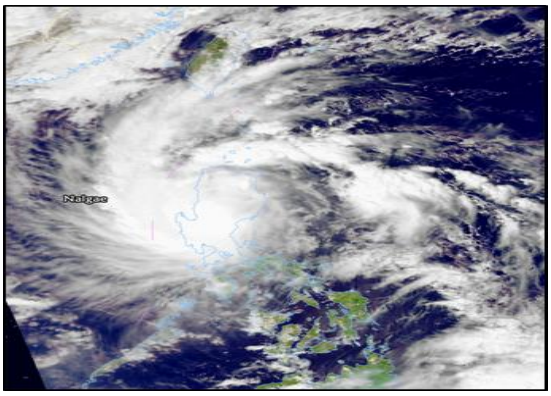


Fig 1.9b FY-3B image at 05:00 UTC 1 October 2011

1.2 Hydrological Assessment (highlighting water-related issues/impact)

In 2011, climate was abnormal in China. In general, rainfall was less than normal, with uneven spatial and temporal distributions showing distinct stages. The water levels of major rivers were generally stable. In the flood-prone season, there were two major flood peaks in China. One was in June when floods occurred in a number of rivers to the south of the Yangtze River; another one was in September when severe autumn floods occurred in Jialing River, Han River and Wei River. More than 260 rivers across the country exceeded their warning lines, and overwhelming floods occurred in more than 50 rivers, and record-breaking floods occurred in 11 rivers. The severest flood occurred in the Qiantang River since 1955. Totally there were 88 days when the water level of the Taihu Lake was above its warning line. At the same time, since the beginning of flood season, rainfall was significantly less than normal to the south of the Yangtze River; severe droughts occurred in Yunnan, Guizhou and Chongqing; and the minimum water level relative to the same period in history occurred in Xi River in Wuzhou. In 2011, seven typhoons or tropical storms landed on China's coastal areas.

In flood season, the inflow of seven national major rivers was generally 30% to 90% less than normal, out of which the inflow of the Huai River was nearly 90% less than normal; but the total water storage of large reservoirs was better than normal, 20% more than that in the same period in history.

In 2011, the nationwide rainfall and hydrological condition had the following features:

1) Overall, the rainfall was less than normal, and floods were followed by droughts or vice versa in some regions. From May to September, rainfall was generally less than normal, and drought was more severe than flood. The nationwide average rainfall was 382.4 mm, 6% less than the same period of normal year (406.9 mm), thus ranking the 9th in rainfall deficiency since 1961. Among them, a serious summer-autumn drought occurred in the Southwest China; after winter-spring drought in the middle and lower reaches of the Yangtze River, 5 strong rainfall processes occurred in the early June, with drought turning into flood.

2) The spatial and temporal distribution of rainfall was uneven, with autumn floods being prominent. From the temporal perspective, there were clear periodic rainfalls. In May-August, rainfall was generally less than normal, and in June-September, rainfall was more than normal. From the spatial perspective, in most parts to the south of the Yangtze River, especially in Yunnan, Guizhou and Guangxi, rainfall was generally less than normal. In the early flood season, local rain was extremely heavy. For example, 8-hour rainfall reached 309 mm at Zuogang rainfall station in the Tongcheng County, Hubei Province; 1-hour rainfall was 122.5 mm at Xingtong in the Wangmo County, Guizhou Province, with the frequency of one in 200 years. In the early and mid September, 3 heavy rainfall processes occurred in the upper reaches of Han River, Jialing River, and Yellow River's Jing-Luo-Wei River Basin, where local rainfall ranked the first relative to the same period since 1961.

3) Typhoon landed earlier with weak intensity, and the phenomenon of "binary typhoons occurring concurrently" was evident. On 11 June 2011, the first typhoon landed on China, which was 15 days earlier than normal (26 June); tropical storm "*Meari*" landed on Shandong Province on 26 June, being the earliest landing typhoon in the North China on record since 1949. Among seven landing typhoons, only one typhoon landed on mainland China with wind force exceeding force 12, two strong tropical storms reached force 10, and the remaining four storms were at force 8-9. Overall, the intensity of landing typhoons was significantly lower than normal. The phenomenon of "binary typhoons occurring concurrently" was often. Of 21 typhoons, 14 were 8 binary tropical cyclones in the typhoon season, doubling the historical average (4).

4) The water level of major rivers was generally stable, with fewer rivers exceeding their warning water levels. Among the main streams of the major rivers, floods exceeding the warning level occurred only in the Taihu Lake. Floods beyond warning level only occurred in Jialing, Han and Lean Rivers in the Yangtze River Basin, Wei and Yiluo Rivers in the Yellow River Basin, Qiantang River in Zhejiang-Fujian and the upper reaches of West Liao River. In other major rivers and major rivers, no floods surpassing warning water level occurred.

5) Most floods surpassing warning water level occurred in medium- and small-sized rivers with larger magnitude. Approaching to the end of 2011, more than 260 rivers (mostly medium- and small-sized rivers) surpassed their warning lines, of which nearly 50 were beyond their water retention capacities, 11 rivers including the upper reaches of Lushui River in Hubei, Lean River in

Jiangxi and Qujiang River in Sichuan broke their records, and the most severe flood occurred in Qiantang River in Zhejiang since 1955.

6) More severe autumn floods occurred concurrently in multiple rivers, which were rare. Since September 2011, affected by 3 heavy rainfall processes, more severe autumn floods occurred concurrently in the tributary streams of the Yangtze River (e.g. Jialing and Han Rivers) and the Yellow River (e.g. Wei & Yiluo Rivers), which were historically rare. Among them, 1-in-100 year flood occurred in Qu River (a tributary stream of the Jialing River), overwhelming flood occurred in the main stream of the Jialing River, 1-in-20-year flood occurred in the upper reaches of the Han River, and the most severe flood continuously occurred in Wei River since 1981.

7) The inflow of rivers was less than normal and the water storage of large reservoirs was slightly more than normal. Compared with the same period of normal year, the inflow of nationwide major rivers was generally 30% to 90% less than normal, in which the inflow of the main stream of the Huai River was 90% less than normal, and the inflow of the Xi, Xiang and Gan Rivers as well as other major rivers was 40% to 50% less than normal. According to statistics, on 1 October 2011, the total water storage of 422 large reservoirs across the country reached 220 billion m^3, about 20% more than normal, 50%-70% more than normal for reservoirs in Shandong, Jiangsu and Qinghai, but 40%-60% less than normal for those in Inner Mongolia, Chongqing, Guizhou and Yunnan.

1.3 Socio-Economic Assessment (highlighting socio-economic and DPP issues/impacts)

TCs brought abundant rainfall to China and abated the agricultural droughts and impact of hot weather on the most southern areas in the middle and lower reaches of the Yangtze River and in the Southern China, and TCs increased the reservoir water storage. However, the high winds, heavy rain and associated astronomical tides also brought about heavy losses in the coastal areas in 2011. Comparing with the economic losses caused by TCs with those in the last 10 years, the economic losses in 2011 were less severe. According to the preliminary statistics, 18.128 million people were affected. 29 people were killed or missing, with the direct economic loss of about CNY 23.71 billion.

Table 1.2 Impacts & losses by TCs in China in 2011
(Source: Ministry of Civil Affairs & National Commission for Disaster Reduction)

TC Name (Number)	**Landing Date**	**Landing Place**	**Maximum Wind at landing**	**Affected Provinces**	**Affected People** (in ten thousand)	**Death & Missing People**	**Direct Economic Losses** (in CNY 0.1 billion)
Sarika (1103)	10 Jun.	Shantou, Guangdong	18m/s	Fujian	4.1	7	1.3
Haima (1104)	23 Jun.	Yangxi & Dianbai, Guangdong	20m/s	Guangdong Guangxi	14.4	0	0.3
	23 Jun	Wuchuan, Guangdong	20m/s				
Meari (1105)	26 Jun.	Rongcheng, Shandong	23m/s	Liaoning, Zhejiang	17.6	0	5.8

				Shandong			
Nockten (1108)	29 Jul.	Wenchang, Hainan	28m/s	Guangxi Hainan	63	2	3.3
Muifa (1109)	No Landfall			Liaoning, Shanghai, Jiangsu, Zhejiang, Shandong	516.5	0	62.5
Nanmadol (1111)	28 Aug.	Taidong, Taiwan	33m/s	Taiwan Fujian	133.4	10	9.5
	30 Aug	Jinjiang, Fujian	20m/s				
Nesat (1117)	29 Sep.	Wenchang, Hainan	42m/s	Hainan, Guangxi, Guangdong	962.5	9	138.8
	29 Sep	Xuwen, Guangdong	35m/s				
Nalgae (1119)	4 Oct.	Wanning, Hainan	25m/s	Hainan Guangxi	111.3	1	15.8
Total					**1822.8**	**29**	**237.3**

Totally 7 TCs landed on China's coastal areas and brought rainfall inland in 2011. One TC influenced China (*Muifa*). The intensities of landed TCs were relatively lower. Meteorological departments enhanced the TC disaster risk management. For the high-risk areas of TC disaster, such as Guangdong, Guangxi, Fujian, Zhejiang and Hainan, the TC disaster risk management had been made in advance, including pre-assessment and early warning of TC risks to reduce TC impact on the urban population, agriculture, transportation, electricity and dam safety. Considering different risk areas and TC risk categories, disaster prevention and mitigation measures were proposed for the government agencies in charge of TC disaster emergency responses for mitigating the impact of TC disasters, which provided useful information for decision-making. (Source: National Climate Centre)

1.4 Regional Cooperation Assessment (highlighting regional cooperation successes and challenges)

In 2011, the Ministry of Civil Affairs actively participated in the international cooperation in disaster prevention and reduction, and it played an active role in collaborating with the Beijing Office of the United Nations Platform for Space-based Information for Disaster Management and Emergency Response (UN-SPIDER Beijing Office) under the International Charter - "Space and Major Disasters", and with the International Centre for Drought Risk Reduction, and MCA promoted the overall technological exchanges and experience-sharing in disaster reduction and relief in association with the relevant UN organizations, regional organizations and relevant countries through exchanges in space technology applications, emergency responses, assessments and technology sharing for disaster information management. In 2011, the National Disaster Reduction Centre of China (NDRCC) received about 260 person-times visits from 70 countries, 16 international and non-governmental organizations. NDRCC also sent 30 delegations abroad (37 person-times), including the attendance to the 43rd session of the ESCAP/WMO Typhoon Committee. Through mutual visits and exchanges, the mutual understanding between China and other countries and international organizations has been increased, experience and practices are shared, and a solid foundation has been laid for future cooperation in this field.

II. Summary of progress in Key Result Areas

2.1 Progress in Key Result Area 1: Reduced Loss of Life from Typhoon-related Disasters

2.1.1 Meteorological Achievements/Results

1) Typhoon-related Disaster Emergency Response initiated by CMA (Source: NMC/CMA)

In 2011, 7 TCs landed on China coastal areas with another influencing China, China Meteorological Administration (CMA) had launched different categories of Typhoon-related Disaster Emergency Response Plans (Table 2.1). About 2.715 million people were evacuated from TC impacted areas.

During the severe typhoon *Nesat* (1117), Hainan, southern Guangdong and southern Guangxi experienced heavy rain from 28 to 30 September under combined effects of *Nesat* and cold air, the Nandu River in Hainan rose above the alert water level in the whole river basin and caused the most severe flood in 2011. Typhoon emergency plans were initiated in Hainan, Guangdong, Guangxi and Fujian to take emergence response measures for minimizing the damages of *Nesat*. A working group from the China Meteorological Administration led by Deputy Administrator Mr. SHEN Xiaonong went to the Hainan province to inspect the typhoon forecasts and meteorological services. Several special teleconferences for typhoon forecasting were held by the National Meteorological Centre, Hainan and Guangdong Meteorological Services. As a result, water storage was increased by 1.5 billions m^3 in the local medium and large reservoirs in Hainan.

Table 2.1 Meteorological disaster emergency actions initiated by CMA in 2011 in response to 7 landing TCs.

TCs' Name (Number)	**Emergency Response Actions**		**Landing Time/Date**	**Warning Lead-time**
	Category	Action Time		
Sarika (1103)	IV	04:00 UTC 10 June	21:45 UTC 10 June	17h 45min.
Haima (1104)	IV	03:00 UTC 21 June	02:10 UTC 23 June 08:50 UTC 23 June	47h 50min.
Meari (1105)	IV	11:00 UTC 24 June	13:10 UTC 26 June	50h 10min.
Nockten (1108)	III	09:35 UTC 28 July	09:40 UTC 29 July	24h 5min
Muifa (1109)	III II	03:00 UTC 4 Aug. 03:30 UTC 5 Aug.	No landfall	——

Nanmadol (1111)	IV	01:00 UTC 29 Aug.	20:25 UTC 28 Aug. 18:20 UTC 30 Aug.	41h 20min.
Nesat (1117)	III II	10:00 UTC 27 Sep. 03:00 UTC 28 Sep.	06:30 UTC 29 Sep. 13:15 UTC 29 Sep.	44h 30min.
Nalgae (1119)	IV	01:00 UTC 3 Oct.	04:30 UTC 4 Oct.	27h 30min.

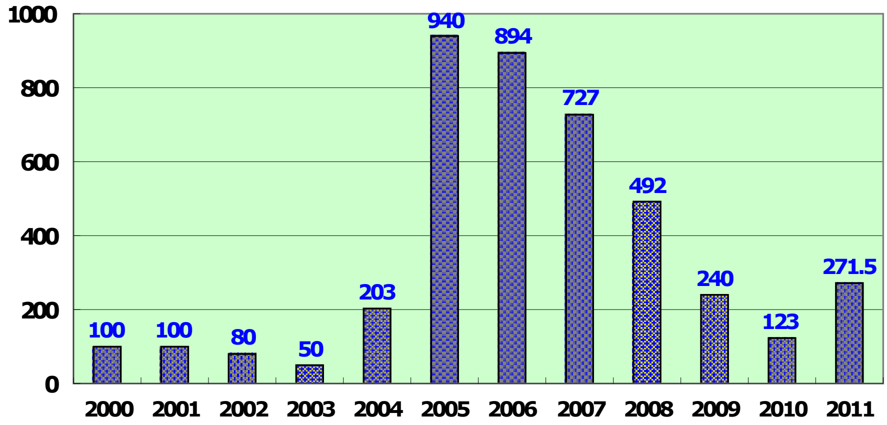


Fig 2.1 Evacuated population exposed to TC threats in 2000-2011

2) Well organized and timely emergency responses

Meteorological departments participated in meetings convened by civil defense authorities to discuss how to get prepared for forthcoming typhoons, on the occasion of which they provided information on monitoring and warning and advice on typhoon preparedness. They initiated the high impact meteorological disaster emergency response plans, under which task teams were dispatched to the scenes for guidance. The on duty practice was emphasized to ensure the presence of executives at the forecasting desk to keep local decision-makers and authorities informed of the latest and next development of a typhoon. In a word, every effort was made to deliver the best possible forecasts and warnings.

3) Forecast and warning messages were produced and issued in a timely fashion

CMA has always given top priority to typhoon events in flood season in its agenda. Facing the 21 typhoons appearing in 2011, resources including 6 meteorological satellites, 164 next-generation Doppler weather radars, 383 local weather monitoring radars, 2419 surface stations, 34000 automatic weather stations were used to closely track their evolution and promptly disseminate information on TC positioning, forecasting, warning and service delivery. Altogether 21 tropical cyclones were numbered in 2011, particularly the 7 typhoons landed on China. 42 blue, 25 yellow, 15 orange and 2 red warning messages were released in total. The Central Meteorological Office (CMO) of CMA issued a red warning message for rainstorm when the typhoon '*Nesat*' was approaching, the first alarm of this level since the National Meteorological Disaster Emergency

Response Plan was announced in 2010. As many as 72 bulletins were submitted to the CPC Central Committee, State Council and other relevant authorities in support of their decisions.

CMO, in coordination with meteorological services in such provinces as Hainan, Guangdong, Guangxi, Fujian, Zhejiang and Shandong, released timely updates on typhoon warning through SMS, web site and TV. At present, meteorological service-providers have as many as 128 million SMS users, 80000 loudspeakers, 70 thousand electronic screens, 39400 rural weather information points, 490000 rural weather information communicators. Meanwhile, meteorological service-providers own 7 marine weather radio stations that broadcast relevant information to all coastal and off-shore regions of China. In 2011, the Hainan Provincial Meteorological Service issued 63 red warnings for typhoon, using a variety of channels and means. When the impacts of such typhoons as '*Haima*', '*Nock-Ten*' and '*Nesat*' were being felt, the Guangdong Provincial Meteorological Service intensely broadcast the latest developments and marine weather forecasts and warnings, using the Maoming Marine Meteorological Service Radio to alert fishermen at sea. 827 warning messages outreached in these areas while 500 million pieces of SMS messages were sent to the public.

4) Timely and efficient inter-agency coordination

Before and when the impact of a typhoon is felt, meteorological service-providers keep other sectors well informed such as civil defense, land, transport, tourism and education and issued forecasts and warnings in association with other agencies concerned to enhance the efficiency of inter-agency coordination. By implementing the relevant requirements of the National Meteorological Disaster Response Plan, meteorological departments enhanced the communication, cooperation and interaction with other agencies. The inter-ministerial liaison meeting on meteorological disaster warning is held when necessary involving 24 agencies. A partnership agreement has been signed with the Ministry of Civil Affairs. Classified and graded warning messages on such disasters as typhoon and rainstorm are sent to the 39 State Council ministries and other relevant agencies in a timely manner through SMS, e-mail and fax. Forecasts and warnings are jointly issued with the Ministry of Land and Resources to avoid geological disasters. Road condition forecasts and warning are co-produced and co-issued with the Ministry of Transport. Such an inter-agency partnership contributes to the synergy against meteorological disasters.

2.1.2 Hydrological Achievements/Results

In the field of water in 2011, focusing on flood and drought control, China took actions to enhance the institutional development of hydrological information and forecasting, the water monitoring and forecasting, the water information in service of flood and drought control, the research into and application of new water technologies, the water system upgrade, reprocessing of water information and extension of water service and products, the development of hydrological monitoring systems for small and medium-sized rivers to further promote flash flood control and hydrological emergency monitoring.

1) The Hydrological Information and Forecasting Centre set up

Hydrological information and forecasting are essential to decisions on flood and drought control. In recent years, as a result of a booming economy in China and the global climate change, flood and drought have increased in type, frequency, intensity and damage in China, making hydrological information and forecast more necessary.

On 8 June 2011, the Hydrological Information and Forecasting Centre of the Ministry of Water Resources was officially inaugurated in Beijing, an initiative to help strengthen the institutional development as a firm groundwork to fully address the climate change and worsening flood and drought, integrate meteorological and water operations across the sector to improve hydrological information and forecasting in terms of timeliness, relevance, range and accuracy, and strengthen sector guidance for a rapid progress in this connection at national level.

Fig 2.2 Inauguration of the Hydrological Information and Forecasting Centre

2) Enhanced hydrological regime monitoring and forecast

The hydrological departments always give top priority to the hydrological regime forecasting services for flood prevention and drought relief. They made every effort in the following areas: 1) enforcing routine work shifts watching rainfalls and water levels, starting from mid March, which was earlier than usual. The 24-hour work shifts began from mid May, making 6 observations and short-message predictions per day; 2) producing more relevant information and materials. The statistics show that throughout the year, more materials were produced than previous years, including 166 *Rainfall and Water-level Report*, 129 *Rainfall and Water-level Bulletin*, 36 Hydrological Forecast, and submitted more than 150 Reports on Integrated Hydrological Regime Analysis; 3) delivering timely high-impact rainfall and water-level forecast and analysis. In 2011, 4 *Trend Analysis Reports on Rainfall and Water-level in the Flood Season* were prepared, over 10 specific hydrometeorological predictions and analyses on heavy rainfall were issued, and over 200 station/time real-time flood forecast were delivered, all of which provided scientific basis for decision making by top leaders of the Ministry of Water Resources (MWR) and the Office of the State Headquarters for Flood Prevention and Drought Relief (SHFPDR); 4) Expanding the scope of rainfall and water-level services. In response to the request by the Office for SHFPDR, *Drought Analysis Report* is submitted every Tuesday, with analysis on soil moisture being added for assessing drought status, which provided a basis to the decision making.

3) Application of new techniques for exchanging rainfall and water-level information

The review and approval of two standards, namely the *Architecture and Identifiers for Real-time Rainfall and Water-level* (SL323-2011) and *Rainfall and Water-level Code* (SL330-2011), were accomplished. These two standards were issued and took effect as of 12 July 2011.

With promulgation and implementation of the new standards, the hydrological authorities replaced the 40-year-old conventional information coding with alternative information exchange mode to exchange and share rainfall and water-level information, and to further promote the techniques for sharing rainfall and water-level information nationwide. On 1 June, the national rainfall and water-level information exchange system was officially put into operation for efficient exchanges of relevant information among the Bureau of Hydrology, provincial river basin authorities and over 200 prefecture-level hydrological offices, which further ensured the information consistency, increased the time validity of flood forecast, added more contents and improved the information transmission techniques. According to statistics, the Bureau of Hydrology under the Ministry of Water Resources received a total of more than 21,000 pieces of messages from flood gauging stations across China with the information variety, quantity, timeliness and consistence being significantly improved compared with those through coding and decoding.

4) Enhanced efforts to update the rainfall and water-level operational system

Learning from the service modalities of the U.S National Weather Service and the China Meteorological Administration, the MWR Hydrological Information & Forecasting Centre enhanced the efforts to update its operational hydrometeorological system, refined the hydrometeorological information analysis and processing, and increased its product lines. The Centre improved its operational meteorological system, integrated the consulting system for rainfall and water level forecasts, improved flash flood warning and flood forecasting system in China, and developed a national unified database maintenance and management system, which provided technical support to hydrometeorological services in 2011.

5) Completion of the 2011 Work Plan for preparedness and treatment of flash floods

In 2011, another 600 counties implemented the non-structural measures on flashflood preparedness and treatment, following the efforts in 2010 for 500 counties. Under the direction and leadership of the Office of the State Headquarters for Flood Prevention and Drought Relief, the hydrological authorities made multiple inspections on the development of the flash flood monitoring system.

6) Further enhanced emergency hydrological monitoring

To further build up the capacity in emergency responses to breaking hydrological events, and to improve the technical capability to address such events, the MWR Bureau of Hydrology prepared the *Measures on the Implementation of Emergency Hydrological Monitoring* and organized training workshops for the western China.

7) Construction of the small and medium river hydrological monitoring system

On 31 August 2011, MWR held a Workshop on the Construction of Hydrological Monitoring System for Small and Medium Rivers, for which the comprehensive plan was announced. In mid September, the National Development and Reform Commission approved the Investment Plan on Small and Medium River Hydrological Monitoring System in 2011. The approved total investment was about RMB 4.1 billion Yuan, among which 2.3 billion came from the central government. The major projects for 2011 included setup of 1,171 hydrological stations, 3,553 water-level stations, 30,347 rain gauge stations, 407 central hydrological information station and 32 mobile taskforces for emergency responses. In addition, a supporting document - *Measures on the Construction of Hydrological Monitoring System* will be prepared.

8) Solid work to implement various hydrological plans

The preparation of hydrological sections for three special plans (Small and Medium Rivers and Reservoirs Infrastructure Reinforcement, Flash Flood Prevention and Control, and Ecological Conservation in the Disaster-prone Regions) were completed, with a planned investment of CNY 16 billion in 3 years to set up a hydrological monitoring system watching China's small and medium rivers. The National Hydrological Infrastructure Construction Plan in the 12th Five-year Period was prepared, which incorporated all projects related to hydrological infrastructure construction, including small and medium river hydrological monitoring, phase-II national commanding system for flood prevention and drought relief, ground water and drought monitoring, etc. and amendment to the *National Hydrological Service Development Plan* is well under way.

2.1.3 Disaster Prevention and Preparedness Achievements/Results

Compared with the same periods in recent years since 2000, the number of typhoon-related fatalities (including those missing) reached minimum level, about 90.6% less than the average number in recent years.

1) Timely Effort of Disaster Emergency Response and Relief

In response to typhoon-induced disasters in 2011, the National Committee for Disaster Reduction and the Ministry of Civil Affairs successively launched 5 national emergency responses actions for natural disasters and 3 emergency response plans for disaster relief; working teams were sent to the disaster-stricken areas to check the availability of disaster relief materials and shelters and to assist and guide the local authorities in emergency relief work.

2) Raise Public Awareness of Disaster Prevention and Reduction

For the National Disaster Prevention and Reduction Day and the International Disaster Reduction Day, various outreach and education campaigns on disaster prevention and reduction were organized to raise public awareness of disaster prevention and mitigation. The outreach and education on relevant knowledge were conducted through various media such as the National Disaster Reduction Website (http://www.jianzai.gov.cn/) and the publication - *China's Disaster Reduction*

3) Enhance Communities' Capacity for Disaster Prevention and Reduction

More guidance was provided to different localities for building the "National Demonstrative Communities for Comprehensive Disaster Reduction". The fifth group of such communities was set up, i.e. 1,281 new demonstration communities were established in 2011. These communities are important for enhancing the capacity of local communities and grassroots units for disaster prevention and reduction and for emergency management.

2.1.4 Research, Training, and Other Achievements/Results

In order to reduce the loss of life from typhoon-related disaster, research work in 2011 mainly focused on unusual TC behaviors such as:

1) TC sudden turning in direction

Statistical studies show that sudden north turning in TC motion happens 1.4 times per year. The forecasting errors may increase by about 3 times larger in predicting a TC turning point. The sudden north turning is likely due to the enhanced synoptic-scale northwesterly steering flow associated with extension of the subtropical high, presence of monsoon gyres, their interaction with TCs and Rossby wave dispersion. Interactions of TC with upper level vortex may also lead to the sudden change of a TC track. A case study of Chanchu (2006) shows that changes in deep mean flow may play an important role in sudden TC track change.

Currently, numerical model of CMA (GRAPES-TYM) has been improved in both initialization and physical schemes. An ensemble forecast system is also being developed for stochastic forecast to capture the sudden change in TC tracks.

2) TC structure change

Study shows that the initiation and maintenance of convections outside the primary eyewall in the early stage of secondary eyewall formation (SEF) was related to the asymmetric forcing by outer spiral rain band. It may be also the result of the interactions within an inner eyewall, vortex Rossby waves (VRW), beta-skirt, and outer rain band. During the rapid intensification (RI) period that is beneficial to the SEF, PV generation was active in the outer spiral rain band. PV dipoles in an outer rain band move along the band and inward toward inner core region, and get asymmetrized by the pre-existed beta skirt. Asymmetric structures in the inner core are dominated by vertical hot towers and VRWs. Sheared VRWs propagate to their “stagnant radius” leading to the increase of mean tangential wind speed and outward expansion of the beta skirt.

In order to better understand the behavior of asymmetric TCs under varying thermodynamic conditions, some numerical experiments were conducted to test the sensitivity of TC *Talim*’s vortex structure to ambient moisture variations. In case of asymmetric TCs, a wetter environment tends to expand TC wind field and drier environment causes a TC to contract. For TCs with larger asymmetric rain band, the rain band growth is more sensitive to water vapor from the upwind side. More moist supply yields stronger rain band convections that is often coupled with eyewall replacement cycle, and less water vapor supply inhibits rain band growth and is favorable for rapid asymmetrization in rain band convections

Some landing TCs may be associated with preceding squall line, which causes strong wind and heavy rainfall. A squall line in front of TC may increase the possibility of flooding by saturating the soil before TC landing. A statistical study shows about 43% of Landing TCs are associated with pre-TC squall lines. The approaching TC provides moisture, enhances instability, and facilitates low-level meso-scale convergence and front-genesis for linear growth of the convection. Relative to mid-latitude squall lines, pre-TC squall lines have a weaker cold pool and a shorter life span.

3) TC Remote Precipitation

Tropical cyclones may produce heavy rainfall or torrential rainfall in an area in front of and away from the cyclone. We call this phenomenon as the Tropical-cyclone Remote Precipitation (TRP). The statistics in a paper show that TRP is a small probability event. It is difficult to predict this phenomenon in operational circumstance. The statistical analysis shows that 14.7% tropical cyclones could produce TRP events in 1971-2006 years. Most of such events would last more than two days. A number of TRPs have a wide distribution and high rainfall rate. High frequency of TRPs occurs in July and August. Statistical analysis also shows that there are two areas with the high TRP frequency, i.e, encircling Bohai Sea and adjacent area between Sichuan and Shanxi provinces.

A diagnostic study on comparison of 2 TRP dataset with non-TRPs dataset suggests that the prominent differences in the lower level are found in typhoon interactions with a westerly trough in TRP dataset and without it in non-TRP dataset but with northwesterly dry flow instead. On the other hand, the comparison shows tropical cyclones with TRP have strong southeasterly wet flow channel but the non-TRP cyclones do not have such a channel. (Source: Chinese Academy of Meteorological Sciences, CMA)

4) Development of Seasonal Dynamical Ensemble Prediction System

In the past year, National Climate Centre had conducted some research work to meet the demand for seasonal TC prediction, including use of hydrostatic prediction model for the track, intensity and TC genesis. Furthermore, it also developed a seasonal dynamical downscale ensemble prediction system for western North Pacific typhoon based on a WRF model.

2.1.5 Regional Cooperation Achievements/Results

1) The 4th China-Korea Joint Workshop on the Tropical Cyclones

The 4th China-Korea Joint Workshop on the Tropical Cyclones was held in Shanghai and Beijing on 18-23 December 2011, sponsored by CMA. 6 experts from KMA attended the event.

2) Expert Meeting on Assessment Report on Typhoon Climate Change

An expert meeting on assessment report on typhoon climate change was held in Shanghai, China on 21 and 22 November 2011, co-sponsored by the Typhoon Committee Trust Fund and Shanghai Typhoon Institute/CMA. The theme of the meeting was "assessment report of impact of climate change on tropical cyclone track and impact area". Members of the expert team, including those from China; Hong Kong, China; Japan; Macao, China; Republic of Korea; TCS; USA; and WMO attended the meeting.

Fig 2.3 Expert Meeting on Assessment Report on TC Climate Change in China

2.1.6 Identified Opportunities/Challenges for Future Achievements/Results

1) Urgent need to improve forecast of unusual change of TC intensity, track and rainfall

It may be at challenge for TC prediction: quick change in TC intensity, track, and rainfall associated with landing TCs. While these phenomena represent a relatively small percentage in TC forecasts, they are responsible for the largest errors in the TC track, intensity and rainfall predictions. Forecasters must have tools to enable them to recognize the potential rapid change in TC intensity, track and rainfall.

2) Improvement of high resolution numerical prediction

To improve prediction on TC structure change, higher horizontal resolution can help to capture more detailed characteristics of the TC structure. Findings also show that a higher resolution tends to over-estimate the rainfall. Another way to improve the structure simulation is to use radar data assimilation to reduce the errors in structure simulation.

2.2 Progress in Key Result Area 2: Minimized Typhoon-related Social and Economic Impacts

2.2.1 Meteorological Achievements/Results

The tropical cyclone frequency prediction issued in the early April 2011 was as follows: It is estimated that the tropical cyclones (max. wind near the centre ≥ 8 grade level), TC number would range from 24 to 26 in 2011 in the Western North Pacific and the South China Sea, less than normal (27 on average in 1971- 2000), and more than that in 2010 (total number: 14). The number of landing TCs on China would be from 7 to 9, more than normal (7). The first landing date would be earlier than normal (June 29), the ending landing date later than normal (Oct. 7).

In fact, the number of generated tropical cyclones is 21 in the Western North Pacific and the South China Sea in 2011, less than normal. The number of landing tropical cyclones is 7, near normal. The first landing date of tropical cyclone in China is 11June, earlier than normal.

2.2.2 Hydrological Achievements/Results

At the 42nd Session of the Typhoon Committee, the project "Urban Flood Risk Management (UFRM)" initiated and led by China was identified as a comprehensive cooperation project for the three working groups on meteorology, hydrology and disaster prevention and mitigation. In the 43rd Session of the Typhoon Committee, the UFRM project was once again the focus of attention.

To actively and effectively make smooth progress in the project, the Bureau of Hydrology (BOH) under the Ministry of Water Resources (MWR) actively organized a series of activities under the UFRM project in 2011, in order to successful complete the tasks undertaken by China on time.

1) Hosting small work meeting for the Project "Urban Flood Risk Management"

A small work meeting for UFRM project hosted by the MWR Bureau of Hydrology (BOH) was held in Beijing on 4 and 5 April 2011. The major participants were from the Typhoon Committee Working Group on Hydrology, Task Force on the project, some experts or consultants, including 13 representatives from the Typhoon Committee Secretariat, China, Japan, Korea, the Philippines, Thailand and Viet Nam. The meeting discussed and adopted the "Research Report on the Advanced Experiences of UFRM Pilot Cities" drafted by China, "Field Investigation Report on Project Pilot Cities" drafted by project consultants, and "Project Advisory Report" prepared by consultant experts together with China. The meeting further discussed a plan for writing the "Guidelines on UFRM Project" prepared by China, including its structure, chapters, contends, etc. The meeting identified the tasks and responsibilities for the Project Implementation Group and related staff in preparation of the "Guidelines on UFRM Project", and selected the authors of various chapters. The meeting also established the working procedures and timeline for preparation of the guidelines, with a deadline for submission of the report.

Currently, the first draft of the "Guidelines on UFRM Project" has been completed for discussion at the 44th Session of the Typhoon Committee.

Fig 2.4 Representatives attending a small work meeting on UFRM Project.

2) An field investigation at UFRM Project pilot city Shanghai

From18 to 20 May 2011, the MWR Bureau of Hydrology (BOH) arranged a visit of the experts from four Members of the Typhoon Committee and the Secretariat to Shanghai, a pilot city of the UFRM Project. 15 meteorological, hydrological, disaster prevention experts from the Philippines, Thailand, Viet Nam and Malaysia as well as hydrological representatives from the Typhoon Committee Secretariat participated in the field investigation. The delegation visited Shanghai Meteorological Service/CMA, MWR Taihu Basin Management Bureau, Shanghai Hydrological Information Centre and other departments, including a mobile meteorological observation vehicle, learning about the forecast platform, strong convective weather early warning systems & multi-hazard early warning systems, typhoon early warning system of the Shanghai Municipal Meteorological Service; they were given an overall presentation on the flood and typhoon prevention; they visited the hydrological remote sensing system in Shanghai, a typical hydrological stations, and a forefront seawall, flood control systems in Jinshan District and the command system for flood and typhoon prevention in the Taihu Lake Basin Management Bureau.

Fig 2.5 Representatives visiting the Shanghai Municipal Meteorological Service

Fig 2.6 Representatives visiting Shanghai Main Hydrological Station and Information Centre

Fig 2.7 Representatives visiting MWR Lake Taihu Basin authority and Jinshan hydrological station

3) Participation of Chinese experts in the "Training Seminar on QPE/QPF, Urban Flood Risk Mapping, Flood Forecasting and Assessment " in Thailand

From 8 to 10 August 2011, the MWR Bureau of Hydrology (BOH) sent Dr. WANG Jing from the China Institute of Water Resources and Hydropower Research (IWHR) to participate in the Training course on QPE / QPF, Urban Flood Risk Mapping, Flood Forecasting and Assessment " in Thailand, giving 2-day lectures on the theme - "establishment of urban flood simulation model and urban flood risk mapping" for the trainees in the Meteorological Department of Thailand, taking Hat Yai City (a pilot city) as an example, providing guidance on how to use GIS software in data pre-and post-processing and urban flood risk mapping. During the course, she also exchanged ideas on the flood issues in Hat Yai City and the progress in urban flood simulation techniques, and discussed on continual cooperation in the future, and even explored the possibility and approaches of applying the IWHR urban flood simulation technology in other cities in Thailand.

Fig2.8 A Chinese expert giving lectures in Thailand

2.2.3 Disaster Prevention and Preparedness Achievements/Results

The direct economic loss caused by typhoons in 2011 was 23.71 billion RMB Yuan, which was 21.3% less than the average for the same periods since 2000. Among the losses, the number of ruined houses by typhoons was a record low in the recent years, which was 85.8% less than the average number since 2010.

1) Disaster-related information reporting

The management of disaster-related information reporting has been enhanced and regulated: by calling local departments of civil affairs to designate the disaster information reporters, setting and refining the nature disaster emergency-on-duty mechanism, transforming the mechanism of disaster consultation and release, setting up a round-the-clock disaster-reporting hot line, and organizing operational trainings on a regular basis.

2) Typhoon disaster assessment

In 2011, significant progress had been achieved in typhoon disaster assessment, with the criteria of assessment increasingly expanded, assessment indicators, assessment methods and evaluation system gradually established, and the capabilities for disaster risk, emergency and loss assessments continuously enhanced. These achievements were instrumental to the decision-making, emergency responses and post-disaster rescue & relief.

3) Emergency response and post-disaster rescue & relief

Guidance was provided to local governments in the disaster-stricken areas to make proper emergency settlement for the disaster-affected people, to timely distribute disaster relief materials according to the needs in the disaster-affected areas, and to consult with the Ministry of Finance for timely allocation of disaster relief funds by the central government to effectively ensure the basic livelihood of the disaster-affected people.

2.2.4 Research, Training and Other Achievements/Results

See 2.1.4 for KRA1

2.2.5 Regional Cooperation Achievements/Results

The cooperative project between the Beijing Climate Centre and Met Office Hadley Centre, UK continues. The cooperation on the seasonal TC prediction over the Western North Pacific became an important topic, which would greatly improve the operational capability for seasonal typhoon prediction. (Source: National Climate Centre/CMA)

2.2.6 Identified Opportunities/Challenges for Future Achievements/Results

Based on the BCC-CSM2.0 climate prediction system and a multi-model ensemble prediction system, the second generation multi-model ensemble seasonal-interannual TC prediction system will be developed in the future.

2.3 Progress in Key Result Area 3: Enhanced Beneficial Typhoon-related Effects for the Betterment of Quality of life

2.3.1 Meteorological Achievements/Results

See 2.1.1 for KRA1

See 2.2.1 for KRA2

2.3.2 Hydrological Achievements/Results

For typhoon preparedness in 2011, through enhanced leadership, thoughtful deployments, scientific directives and clear-cut responsibilities, the Ministry of Water Resources (MWR) made good preparations for possible typhoon- induced floods, by evacuating people under risks to safety and minimizing damages and losses. On condition that preparatory work was well done to prevent and reduce typhoon-induced disasters, every opportunity was taken based on effective and timely forecasts to increase water storages for reservoirs and ponds in dry areas from typhoon rainfall.

In 2011, on the basis of flood forecasting schemes for 77 sections of 66 rivers in 8 provinces in China’s coastal regions, the MWR Hydrological Information and Forecasting Centre provided hydrological forecasts and early warnings for the regions that were likely affected by landing typhoons, enhancing forecasts/warnings, and improving accuracy and quality of the hydrological forecasts. Such information not only minimized damages, but also provided effective guidance for coastal provinces in making full use of favorable rainfall from typhoons for drought relief and water storage. According to primary statistics, the Hydrological Information and Forecasting Centre prepared and released more than 770 materials concerning rainfall and flood monitoring, prediction and forecast, as well as periodic summaries.

Many regions enhanced rainfall and flood monitoring for typhoon preparedness, convening more frequently consultations and interactive discussions, making in-depth analysis on flood trends, and issuing early warnings on time, to provide science-based information for decision-making in flood control. The Fujian Provincial Flood Control Office followed the practice of convening "consultations on affecting typhoon once a day, and on landing typhoon at least twice a day", deploying preventative works well in advance. Guangdong Province widely broadcasted typhoon information via news media, to increase public awareness of disaster prevention and mitigation and their self-rescue capability, and to reduce damages and losses caused by typhoons. Hainan Province closely watched typhoon motions, enhancing relevant consultations, proposing timely measures against typhoon, deploying preventative work in advance. It initiated 9 emergency responses in 2011, releasing 100 early warnings through its typhoon early warning system.

2.3.3 Disaster Prevention and Preparedness Achievements/Results

See 2.1.3 for KRA1

See 2.2.3 for KRA2

2.3.4 Research, Training, and Other Achievements/Results

See 2.1.4 for KRA1

2.3.5 Regional Cooperation Achievements/Results

1) IBTrACS and IWSATC Workshop

The 2nd International Best Track Archive for Climate Stewardship (IBTrACS) meeting and International Workshop of Satellite Application on TC (IWSATC) were held in Hawaii, USA from 11 to 16 April 2011. More than 30 participants attended the meeting. Experts from the Shanghai Typhoon Institute and Shanghai Satellite Remote-sensing and Measurement Application Centre participated in the events. The ,meetings summarized satellite analysis and best track procedures. All the participants joined the in-depth discussion on Dvorak exercise and training on objective satellite-based TC analysis methods.

Fig 3.1 IBTrACS and IWSATC Workshop held in US.

2) Workshop on Web-Based Typhoon Forum

The Workshop on Web-Based Typhoon Forum was held in Shanghai on 22 November 2011, which was co-sponsored by the Typhoon Committee Trust Fund and the Shanghai Typhoon Institute/CMA. The theme of the meeting was how to increase interactivity and influence of the forum on operational forecasts. Participants from the National Typhoon Centre of KMA, National Meteorological Centre, Shanghai Typhoon institute and China Eastern Regional Climate Centre/CMA attended the forum.

Fig 3.2 Workshop on web-based typhoon forum

2.3.6 Identified Opportunities/Challenges for Future Achievements/Results

NIL

2.4 Progress in Key Result Area 4: Improved Typhoon-related Disaster Risk Management in Various Sectors

2.4.1 Meteorological Achievements/Results

See 2.1.1 for KRA1

See 2.2.1 for KRA2

2.4.2 Hydrological Achievements/Results

In aspect of typhoon disaster risk management, the Ministry of Water Resources initiated emergency response mechanism and took emergency measures based on the changing flood situations to ensure people's safety.

During the Qiantang River flood, Zhejiang Province initiated the category l-1 emergency response plan (also the prevention and preparedness plan) against the exceptional flood like the one occurred in 1955 for the main stream of the Qiantang River. Lanxi city announced that it entered the urgent flood control period, mobilizing tens of thousands of people and soldiers to patrol the river dyke, having urgently built a 7-km secondary dyke before the flood peaked, replacing people at risk to safety.

When the historically rare flood occurred in Lean River in Jiangxi Province, the Zhushan and Changjiang districts of the Jingdezhen City urgently evacuated 31900 people within 12 hours. Leping City evacuated 91200 people in 18 hours. No one died under the serious conditions, during which the Xuhulian, Pailou and Xihulian dikes were partially overwhelmed by 1.5 meters.

To get prepared for the typhoon *Muifa*, Zhejiang, Shanghai and Fujian among others effectively avoided potential typhoon-caused damages by calling 62700 ships back to ports, evacuating 610,000 people from the areas under threats.

In Hunan, Yunnan and Jiangxi provinces, more than 900,000 people were evaculated in advance according to the early warnings on flash flood issued by taking the non-engineering measures developed in 2011, bringing about significant social benefits.

2.4.3 Disaster Prevention and Preparedness Achievements/Results

1) Human resources development for disaster prevention and reduction

In 2011, the Ministry of Civil Affairs made further progress in establishing disaster information liaison networks and formulating their mandates. At present, there are over 530,000 disaster information liaison officers in China, and the liaison networks have extended to provinces, municipalities, counties, townships and villages. Meanwhile, efforts have been made through training to enable liaison officers to better understand the relevant policies and regulations and to further build up their capabilities.

2) An enhanced Comprehensive Operational System for Natural Disasters

An improved comprehensive operational system for natural disaster is the precondition and foundation for effective disaster reduction and relief. At present, NDRCC under the Ministry of Civil Affairs has established sound systems and platforms for disaster information reporting, remote-sensing and on-the-spot disaster information collection, and it has set up stable emergency response mechanisms and sound decision-making supportive systems, and provided important technological support for the national decision-making in disaster emergency relief, etc.

3) Improvement of disaster management regulation and criteria

In 2011, the National Emergency Plans for Natural Disaster Relief was revised, making more detailed provisions for initiating 4-category emergency response plans. The Statistics Regulation on Natural Disaster was also revised, in which the reporting system was based on indicators such as flooded counties, cities, severely damaged houses to better adapt to the disaster management and new needs for disaster relief. Furthermore, the Basic Terminology for Natural Disaster Management was formally published, providing a basis for the scientific and standardized management of natural disasters.

4) Inclusion of typhoon-rainstorm disaster chain into the National Comprehensive Disaster Prevention and Reduction Plan (2011-2015)

On 26 November 2011, with the approval by the State Council, the National Plan for Comprehensive Disaster Prevention and Reduction (2011-2015) was formally promulgated. It is specified that the capacity-building for natural disaster risk management and scientific and technological supports for disaster prevention and reduction shall be enhanced, emphasizing research on large-scale natural disasters such as the typhoon-rainstorm disaster chain, etc.

2.4.4 Research, Training, and Other Achievements/Results

1) TC climate prediction model and climate prediction for WNP region in 2011 TC season

A climate model was developed for short term TC climate prediction. The preliminary tests were carried out. The TC activity prediction over the Western North Pacific (WNP) in 2011 was made in the spring. The results were the frequency would be below normal, the frequency of landfall TCs on China would be less than normal. The TC activities in 2011 validated this prediction.

2) TC disaster estimations in 2011

The disaster pre-estimation was made for every major TC impacting China in 2011. For those severe TCs, the disaster risk analyses were also made.

2.4.5 Regional Cooperation Achievements/Results

See 2.1.5 for KRA 1

2.4.6 Identified Opportunities/Challenges for Future Achievements/Results

NIL

2.5 Progress in Key Result Area 5: Strengthened Resilience of Communities to Typhoon-related Disasters

2.5.1 Meteorological Achievements/Results

See 2.1.1 for KRA1

See 2.2.1 for KRA2

2.5.2 Hydrological Achievements/Results

In October 2006, the State Council officially approved the "*National Plan for Flash Flood Prevention and Control*". In November 2007, the Ministry of Water Resources (MWR) completed the "*National Report on Implementation Schemes for the Pilot Counties in Flash Flood Prevention and Control*". In April 2009, MWR launched on a pilot basis the so-called non-engineering flash flood prevention and control measures in 103 counties in 29 provinces (autonomous regions or municipalities) including Xinjiang Autonomous Region production corps. In July 2010, the county-level non-engineering measures began fully. It is planned that a mechanism for implementation of non-engineering measures will be set up in 3 years in 1836 counties nationwide, aimed at outreaching early warnings, launching rapid responses and evacuations, effectively avoiding various risks, and providing reliable supports for people's safety and properties. The main elements of these measures include a survey on flash flood disasters; risk mapping; identifications of early warning indicators for threshold rainfall and water levels; buildup of flood monitoring and warning systems, accountability system; preparation and improvement of emergency flood prevention & preparedness plans, as well as public outreach, training and exercises among others.

Since 2010, the Ministry of Finance approved CNY 3.8 billion subsidies from central budget in two separate allocations for the project constructions in 1100 counties. In the late September 2011, it also approved subsidy budget plan for 2012 involving 736 counties.

In 2011, the flood monitoring & warning system and the joint prediction and prevention system under the project made significant social benefits in disaster prevention and mitigation. In Hunan and Jiangxi provinces, over 100,000 people were evacuated in advance in response to early warnings released by the systems for taking immediate non-engineering measures, which were established in 2009 and 2011 as pilot projects, having effectively avoided casualties.

2.5.3 Disaster Prevention and Preparedness Achievements/Results

The Ministry of Civil Affairs, in consultation with other relevant governmental departments, provides guidance to the local governments in the disaster-stricken areas in making plans for post-disaster recovery and reconstruction, so as to help the disaster-affected people rebuild their homes as soon as possible. In August 2011, the Ministry of Civil Affairs launched the *Regulation on Subsidy Fund Management for Reconstruction and Recovery of Ruined and Damaged Houses in*

Disasters to further enhance the subsidy fund management in rural areas, and to rebuild houses and recover normal life of affected people. The local departments of civil affairs at different levels must strictly abide by these procedures and proactively promote recovery and reconstruction of people's houses ruined in disasters.

2.5.4 Research, Training, and Other Achievements/Results

1) Typhoon Field Observation in 2011

From 09:10 pm 5 August 2011 to 07:46 am 7 August 2011, typhoon *Muifa* was tracked with the Mobile Typhoon-Monitoring System (MTMS) of the Shanghai Typhoon Institute, which is equipped with GPS, microwave radiometer, raindrop spectrometer, flat array sodar, AWS instruments and ultrasonic anemometers. The *Muifa* data from MTMS and coastal wind towers around Shanghai were analyzed with preliminary result being obtained. The characteristics of *Muifa* were compared with those of *Morakot*.

2) Review of the Web-based Typhoon Forum in 2011

The web-based typhoon forum (http://www.typhoon.gov.cn/en/bbs) has been created and operated by Shanghai Typhoon Institute/CMA, and it has been used online for two years. This forum includes 3 topic sessions: (1) TC real-time information and forecasts; (2) historical cases; and (3) forecast verifications. By the end of December 2011, 60 users from 11 Typhoon Committee Members participated in the forum. 18 topics and 74 posts were presented in the forum in 2011. A meeting on the forum development was held in Shanghai in November 2011. Some recommendations were made: Increasing users from the forecasting centres; outreaching the forum to all Typhoon Committee Members; enhancing exchanges of real-time observations; and improving the notification function of the forum.

2.5.5 Regional Cooperation Achievements/Results

NIL

2.5.6 Identified Opportunities/Challenges for Future Achievements/Results

NIL

2.6 Progress in Key Result Area 6: Improved Capacity to Generate and Provide Accurate, Timely, and understandable Information on Typhoon-related Threats

2.6.1 Meteorological Achievements/Results

1) Improvement in Satellite Observation System

A new polar-orbiting satellite (FY-3B) has been put into operation since 1 July 2011. FY-3A and FY-3B are operating in a network that covers both morning and afternoon orbits. They have improved China's meteorological observing and weather forecasting capabilities. The FY-3 series play an important role in monitoring natural disasters and environment, addressing climate change and disaster prevention and reduction.

In the typhoon season of 2011, the twin geostationary satellites were switched to intensified observations. Everyday, 96 images (15 min) were received from FY-2D and FY-2E satellites. Through these higher temporal resolution satellite data, the occurrences and evolution characteristic of TCs can be captured. It played important role in TC monitoring and forecasting.

2) Improvement in Marine Observing System

By the end of 2011, the surface observation network in marine composed of 191 shore-based stations, 99 AWSs on islands, 18 buoys, 1 storm surge station, 6 oil drilling platform-based stations and 5 ship stations, which greatly enhance the ability of coastal ocean observing ability.

3) Improvement in Radar Observing System

In 2011, 5 CINRAD radars were set up in Jiangsu, Fujian, Anhui, Hunan and Henan provinces. They further enhanced the capability for TC monitoring along the China's southeast coast among others. They have contributed to severe weather prevention and reduction in many provinces.

In 2011, six boundary wind profilers were set up in Anhui, Fujian, Jiangxi, Shandong and Zhejiang provinces.

4) Improvement of Telecommunication System

In 2011, CMA completed its new-generation data-broadcasting system - CMACast. The CMACast system is a satellite-based data broadcasting system that complies with DVB-S2 standard, substituting the present satellite data-broadcasting systems (PCVSAT, DVB-S & FENGYUNCast), which have 2400, 700 and 200 users respectively. The CMACast is a major component of the national meteorological data dissemination system, continuously broadcasting the real-time observational data and products crucial for the weather forecasts and related services for more than 2500 users. It is also the most effective way to share the various meteorological data and products with user communities in China. At present, the daily data volume is more than 150 GB, including national and international observations, CMA T639 NWP products, satellite data and products from FY2D/E, FY3A/B, EUMETSAT, etc.

CMACast is also a component of WMO IGDDS and GEONETCast systems. It substitutes the Regional GEONETCast Network Centre (GNC) of the FENGYUNCast, which was formerly integrated into GEONETCast in 2007 as a contribution of China to GEONETCast. Compared to the FENGYUNCast, CMACast has a higher bandwidth, more data contents, and improved user and data management. CMACast provides a full range of services within GEONETCast framework, especially for the users in the Asia-Pacific Region.

The Sixteenth World Meteorological Congress (Cg-16) designated Beijing as one of the Global Information System Centre (GISC Beijing). Following the trial operation over the year, the GISC Beijing started its operation as from 15 August 2011. Apart from continued provision of existing GTS data transmission and exchange services, GISC Beijing provides the Data Discovery Access and Retrieve (DAR) service, Data Subscription service and CMA's NWP products and FY satellite products. CMACast Users can also receive meteorological data and products from GISC Beijing within the limit of the telecommunication band and according to relevant data policy. The web site of GISC Beijing (http://wisportal.cma.gov.cn, email: giscadmin@cma.gov.cn) is now open to the users for registration.

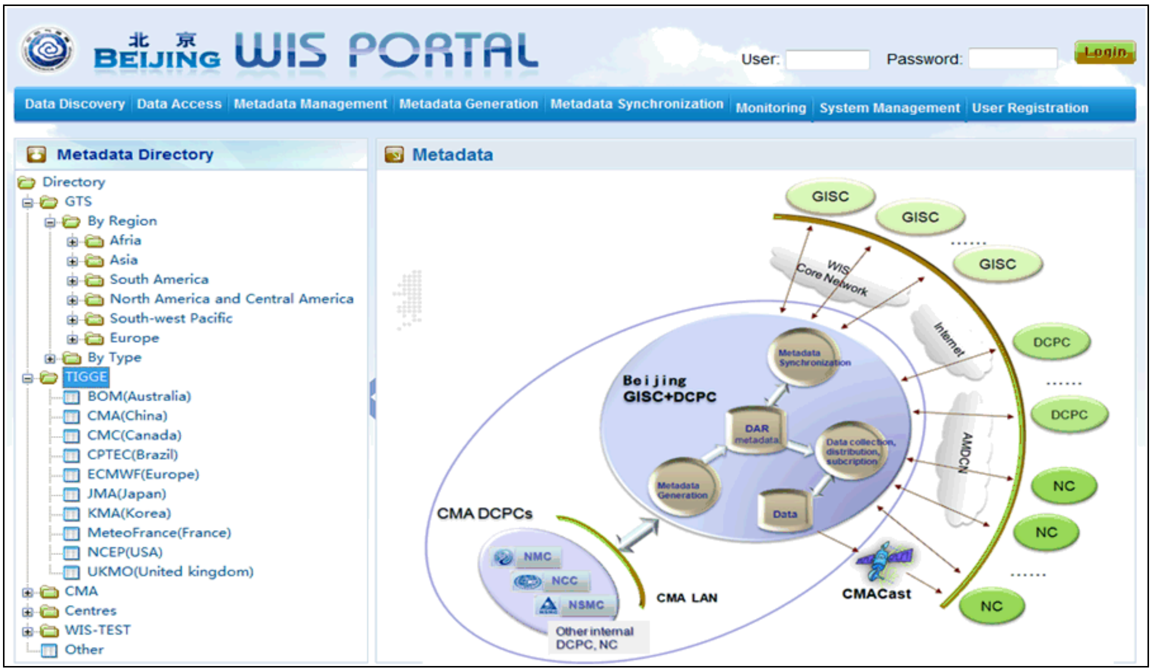


Fig 6.1 The WIS and CMAcast system

5) Rapid radar data assimilation and analysis system for landing typhoons

During the typhoon season in 2011, rapid radar data assimilation and analysis system for landing typhoons was established in National Meteorological Centre (NMC), CMA. The system is targeted to landing typhoons based on 3D-VAR data assimilation (ARPS3DVAR) and composite cloud analysis technique developed by Oklahoma University, incorporating inversed Doppler radar data and other data (conventional data & model outputs). Figure 2 gives the 10m wind fields of severe typhoon *Nesat* (1117) from the radar data assimilation and analysis. The product provides objective analyses for operational TC intensity and high wind forecasts.

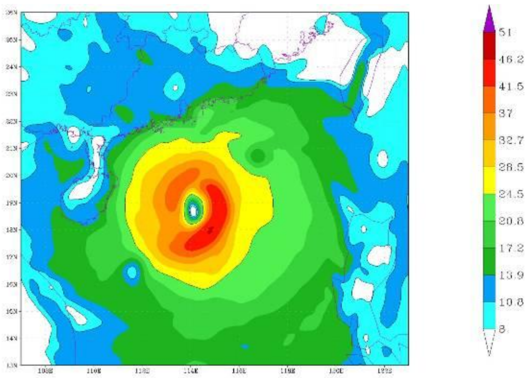


Fig 6.2a. 10m wind field of severe typhoon *Nesat* (1117) 21:00 UTC 28 Sep. 2011

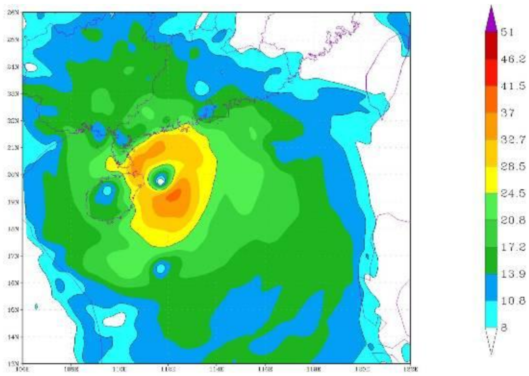


Fig 6.2b. 10m wind field of *Nesat* (1117) 06:00 UTC, 29 Sep. 2011

6) GRAPES Regional Typhoon Prediction Model (GRAPES-TYM)

GRAPES Regional Typhoon Prediction Model (GRAPES-TYM) is a mesoscale typhoon prediction model developed by NMC/CMA based on CMA GRAPES-MESO model. GRAPES-TYM has been put into operation since typhoon season 2011 as a main component of CMA typhoon forecast experiment. This model runs twice (00, 12 UTC) per day. Its 24, 48 and 72 h track forecast errors are 98, 181 and 311km respectively in 2011. Its skill is equivalent to that of the NMC/CMA T213 model.

GRAPES-TYM has improved TC vortex initialization scheme, physical process and dynamic framework. The vortex initialization scheme mainly uses the artificial vortex technique based on the nonlinear equilibrium model and combines with GFDL TC separation technique. Its work flow is shown in Fig 2. The main improvements in physical process and dynamic framework include improved surface heat flux calculation by correcting surface roughness parameter under strong wind conditions, improved model TC intensity prediction by introducing heat expansion from continuous equation, and adjustment of physical values in the model by introducing surface pressure from TC vortex initialization scheme.

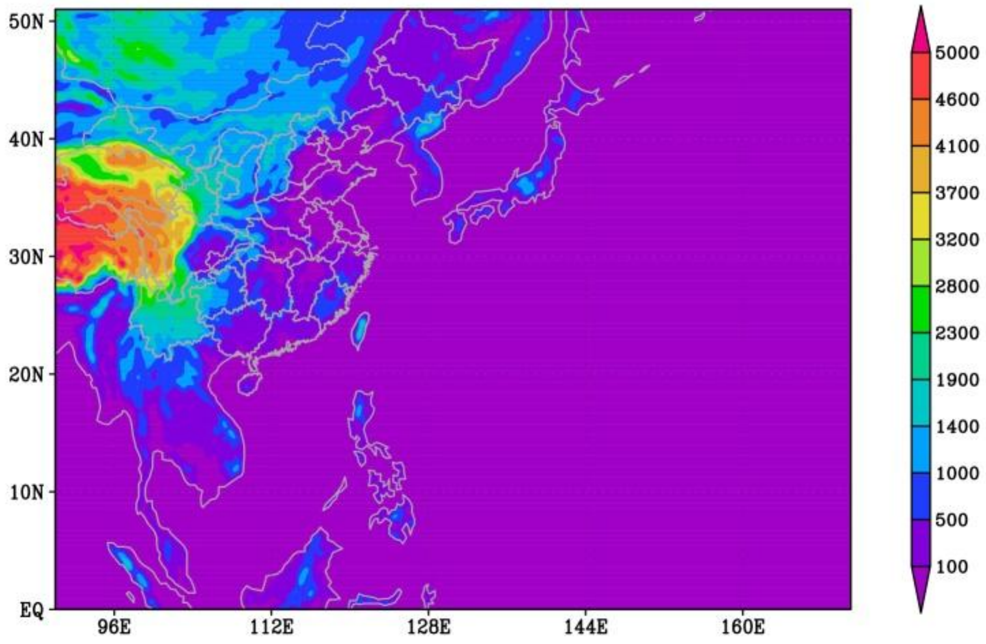


Fig 6.3 GRAPES-TYM domain (color shadow shows terrain heights)

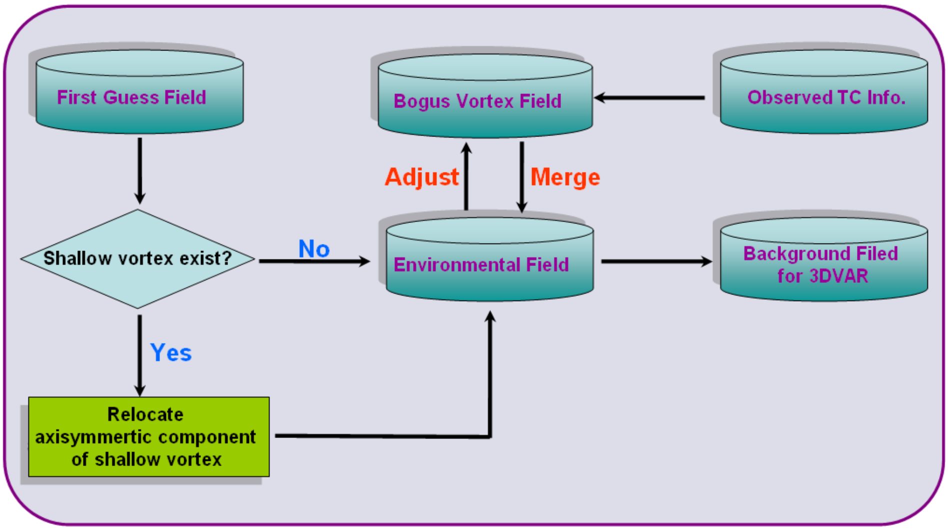


Fig 6.4 GRAPES-TYM work flow in TC vortex initialization scheme

7) Objective TC positioning and Intensity estimation system based on geostationary meteorological satellites

During the typhoon season in 2011, an objective TC positioning and intensifying system based on satellite TC data over Western North Pacific and the South China Sea was established and used on a trial basis. The objective TC estimation system was established by introducing the advanced objective Dvorak technique (AODT) developed by Cooperative Institute for Satellite Meteorological Studies (CIMSS) of the Wisconsin University. It can process FY2C/D/E and MTSAT infrared channel 1 data. The objective TC positioning system was established by using mathematical morphology, image processing and intelligent information processing technique. It now can process images from MTSAT satellite infrared channel 1 from Kochi University, Japan.

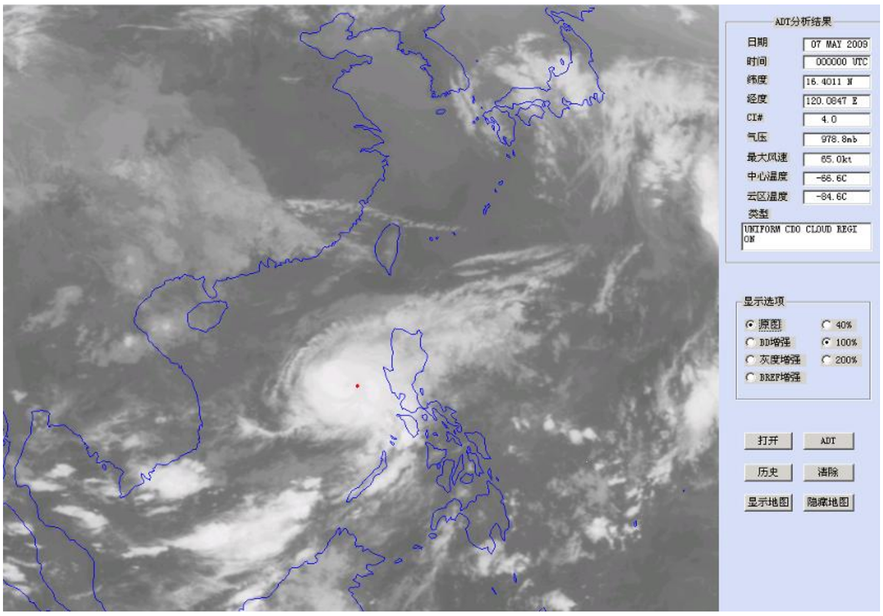


Fig6.5 The interface of objective TC intensity estimation system

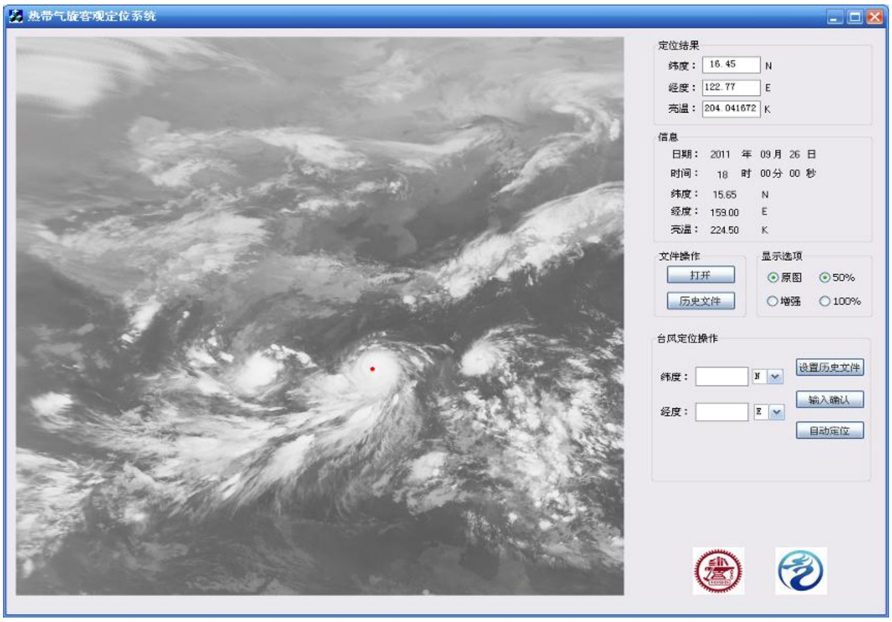
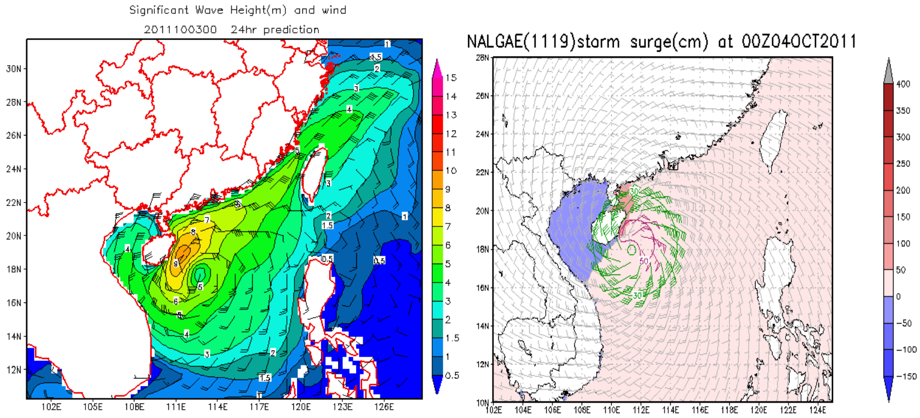


Fig 6.6 The interface of objective TC positioning system

8) Improvement of the South China Sea Typhoon Model (SCS-TM)

In 2011, SCS-TM developed by Guangzhou Institute on Tropical Marine Meteorology, CMA was operating in a stable manner. To address TC track and intensity forecast issues, based on its operational system, improvements were made in the moisture advection scheme, upstream physical processes, model boundary layer and dynamic framework, and a regional assimilation model was set up for the tropical South China Sea, which is a useful tool for the Southeast Asia region. A model for typhoon-induced sea wave was developed with SCS-TM as an atmospheric component.

Incorporating TC conditions, the model was successful in forecasting sea waves in the Leizhou Peninsula and Qiongzhou Straits, which agreed well with the observations.



a) b)

Fig 6.7 24-h forecasts 0800 BT 3 October 2011 for wind and effective wave height (a, contours and shades represent effective wave height; and (b, shade shows water rise zone due to TC *Nalgae*).

9) The upgraded Typhoon Information Processing System (TIPS)

- **Improvement of operational TC forecasting platform**

  As an operational forecasting platform, MICAPS typhoon version provides visualized observations, interactive TC forecasts and graphics of TC track, intensity, wind and rainfall. The improved platform frees forecasters from repetitious hard work and makes weather analysis and forecasting more effective.

- **A statistical analysis system for forecast errors**

  In the typhoon season of 2011, NMC/CMA set up a real-time statistical forecast error analysis system, covering not only TC track and intensity forecast errors but also TC motion speed and direction errors. This system can be used to evaluate real-time forecast and lead to reasonable refinement of forecasting techniques.

- **A new version of the TC track retrieval system**

  To retrieve historical TC tracks and synoptic backgrounds, a new-version system has been built up based on CMA best track database. After a similar key area is located, past TC tracks together with a series of synoptic backgrounds can be provided. Another useful function of the system is to generate a sequence under given criterion.

10) GRAPES-based Regional TC Ocean-Atmosphere-Wave Coupled Model

A regional ocean-atmosphere-wave coupled model has been developed for TC prediction over the Western North Pacific. In this model, a multi-model coupler is introduced to accommodate the flux transfer and interaction among atmospheric, ocean and wave models. It has 4 major components: a regional typhoon model (based on GRAPES-TCM), an ocean module (ECOM), a wave module (WAVEWATCH III) and a multi-model coupler (OASIS). To reasonably describe the ocean-atmosphere-wave interactions, the physical processes in the coupled model have been investigated through numerical simulations of a number of typhoon cases. The results show this model runs stably and reproduces observed air-sea-wave processes, which evolve with the changing SST, sea surface flux (e.g., latent heat flux, sensible heat flux), which have impacts on TC intensity variation. Comparisons with model outputs without coupling (GRAPES-TCM) show better performance of the coupled model in simulating TC intensity, which is consistent with observations. The planned improvement of this coupled model will provide key support for TC predictions in China.

11) GRAPES model Improvement

The drag coefficient of boundary layer in the trial GRAPES model with higher resolution in Shanghai Typhoon Institute of CMA has been adjusted, and BOGUS data is assimilated with MC-3DVAR. The new typhoon initial state is more consistent, while calculating time is reduced compared with 4DVAR. For typhoon "*Muifa*", the 24-h mean track forecast error was reduced from 80 to 73 km (19 samples), and the 48-h mean track forecast error was reduced from 183 km to 147 km (16 samples).

2.6.2 Hydrological Achievements/Results

To improve the capability for hydrological information delivery, the MWR Bureau of Hydrology (BOH) upgraded the Integrated National hydrological Information and Flood Forecasting System in 2011. BOH had accomplished work of submitting the *Standard for Structure and Identifier in Real-time Hydrological Information Database* (SL323-2011) and *the Hydrological Information Code* (SL330-2011) for approval, promulgation and implementation. It also deployed the Hydrological Information Exchanging and Database Maintenance System, and organized the work to construct the National Flood Control and Drought Relief Database in the 3rd phase.

For typhoon-related services, BOH completed flood forecasting schemes for 77 flood sections of 66 rivers across 8 provinces (or municipalities) along China's coastal regions which are subject to typhoon impacts, and established the typhoon-related hydrological forecasting and performance assessment mechanism. Once a typhoon is numbered and has impacts on China, the hydrological departments will start forecasting. The departments in typhoon-impacted areas will make rolling predictions and forecasts on river water and tide levels according to real-time water and rainfall information and numerical weather forecasts. According to the Flood Forecasts Sharing Mechanism, these forecasts should be transmitted to BOH in time. According to preliminary statistics, in 2011 the MWR Hydrological Information & Forecasting Centre issued more than 10 hydrometeorological forecasts and analysis reports targeted to excessive rainfalls and over 200 real-time flood forecasts, which provided scientific information for the decision-making by MWR and the Office of State Flood Control and Drought Relief Headquarters.

2.6.3 Disaster Prevention and Preparedness Achievements/Results

At present, a Sky-Earth-Site 3D Disaster Monitoring System has been preliminarily set up, which consists of the Satellite/Aviation/Unmanned Aircraft remote-sensing platforms, network of surface observatories and the System for On-the-Spot Disaster Loss Information Collection in Disaster Zones.

1) Continuously Improved Information management system

Mechanisms and capacities for domestic and foreign information acquisition and sharing have been developed and enhanced. In 2011, National Natural Disaster Information Management System was operating in a stable manner, covering all provinces, prefectures, municipalities, counties and some pilot townships/towns in China with 8,000 users.

2) Remote sensing

NDRCC under the Ministry of Civil Affairs has established a relatively sound operational disaster remote-sensing products system for disaster monitoring, risk and disaster assessments as well as decision supporting. In response to the different relief demands at different TC stages, NDRCC is able to effectively monitor and assess disasters using various remote-sensing data from China and other countries.

3) Application of Emergency Telecommunication and Navigation Technologies

Making use of available communication resources, including satellite telecommunication, ground networks, emergency vehicles and handsets, the integrated space-air-ground information acquisition, transmission and support capabilities have been enhanced. To improve the telecommunications in emergency responses to natural disasters, the Ministry of Civil Affairs, National Disaster Reduction Center of China, Shanghai Civil Affairs Bureau co-organized a nationwide exercise on emergency telecommunication support at disaster-prone sites on 9 November 2011, during which the integrated satellite and conventional telecommunication approaches for emergency disaster relief were explored. Additionally, the system for information collection from PDAs has been put into operation, preliminarily realizing the real-time data transmission and sharing, including tables and forms, videos, audios and images between disaster management departments and disaster sites.

2.6.4 Research, Training, and Other Achievements/Results

1) Quantitative analysis of landing typhoon-induced rainfall: a case study on TC *Haitang* (2005)

A quantitative analysis of torrential rainfall associated with TC *Haitang* (2005) was made using a modified ageostrophic *Q* vector and outputs from Weather Research and Forecasting (WRF) model. 4 major factors determining the ascending motion associated with heavy rainfall were investigated: large-scale convection, condensation heating, topography and friction. The results show that the convective condensation heating played a major role in the heavy rainfall process after *Haitang* landing, but it was secondary before its landfall. The topographic lifting affects the formation of rainfall whereas the topographic friction had important impacts on the heavy rainfall after landing.

The rainfall amount as result of topographic friction and lifting showed similar horizontal distributions, but the magnitude of the former was found 2-3 times larger than that of the latter. The rainfall amounts due to topography (lifting and friction) and modified ageostrophic Q vector showed different horizontal distributions, with magnitude of the former was 2-5 times larger than that of the latter. Synthetic analysis showed that the typhoon rainfall may be driven by ageostrophic Q vector and enhanced by the topographic effects.

2) Correlation of the thermal helicity with rainfall of landing typhoons

This study utilized the MM5 mesoscale model to simulate the landing process of TC *Talim* (2005). The simulated typhoon track, weather patterns and rainfall process were consistent with the observations. Using the simulation results, the correlation of the second type thermal helicity (H_2) with rainfall induced by the landing *Talim* was analyzed. The results showed that H_2 could be used to predict the heavy inland rainfall in the early stage of the TC landfall. H_2 was highly correlated with rainfall of *Talim* in 1-h lead time. For 1-5 h lead time, H_2 also had a good correlation with rainfall, showing a good potential in forecasting rainfall intensity. Further analyses showed when *Talim* was in the early landfall stage: 200-850hPa vertical wind shear around the *Talim* centre was quite small (about 5 m s-1); the highest rainfall was to the right of the *Talim* track in an area with a 300-km radius around it, without showing obvious correlation with low-level temperature advection, low-level air convergence, and upper-level divergence; and the low-level relative vorticity reflected the rainfall change, which just explained why helicity had a better performance than H_2 in this stage. However, after *Talim* moved inland further, it was weakened gradually; the vertical wind shear was enhanced; 3) the vertical wind shear lay over the Lushan and Dabieshan mountains triggered a secondary vertical circulation, which caused the heavy rainfall; hence, H_2 showed a better capacity to reflect the rainfall change in this stage.

3) Application of generalized convective vorticity vector in a rainfall process induced by TC depression

A heavy rainfall caused by a landing tropical depression (TD) was studied in an experiment. It was found that contours of generalized equivalent potential temperature (θ^*) are almost vertical to horizontal surfaces near the TD centre and more densely distributed than those of equivalent potential temperature (θe). Because the atmosphere is non-uniformly saturated in reality, θ^* replaced θe in defining convective vorticity vector (CVV) so that a new vector, namely the generalized convective vorticity vector (CVV*), was applied in this study. Since CVV* could reflect both the secondary circulation and the variation of horizontal baroclinicity, the vertical integration of vertical component of CVV* can better reflect the rainfall areas in the TD case than potential vorticity (PV), moist potential vorticity (MPV), generalized moist potential vorticity (Pm), and CVV, with its large-value zone well corresponding to the heavy-rainfall area.

Through a sensitivity experiment on the effects of Hangzhou Bay, it was found that the CVV* was weaker than that in the experiment, resulting in less rainfall. Further analyses show that the Hangzhou Bay provides water vapor, surface latent and sensible heat fluxes to the TD system.

Therefore, the bay is very important for mesoscale cloud clusters' genesis and development around the TD and associated rainfall.

4) Study on the shear gradient vorticity associated with TC heavy rainfall

The shear gradient vorticity was introduced to diagnose heavy rainfall induced by some strong convective weather systems in this study. As an important component, the vorticity gradient can be used to study the merging process between different vortexes or the deformation of a vortex with a deep vorticity gradient. Vertical wind shear always represents the dynamical factor. Overall, it can represent the interaction between the environmental wind shear and the evolution of vortexes with a larger vorticity gradient. From this perspective, it seems to have the potential to diagnose some strong convective weather processes (e.g. Extratropical Transition (ET) of tropical cyclones or evolution of multi-cell storms) under combined effects of strong vorticity field and wind shear. In case TC *Toraji* (0108), SGV has showed better potential to forecast the distribution of heavy rainfall more accurately, especially in the frontal zone than helicity.

5) Typhoon vortex initialization with EnKF scheme for TC position and intensity assimilation

Taking into account TC characteristics of rotational and asymmetrical circulation, the ensemble Kalman filter (EnKF) with airflow-dependent background error covariance is more suitable for TC initialization. A new TC vortex initialization method based on direct TC position and intensity assimilations using the ensemble Kalman filter (EnKF) was investigated, in order to develop a dynamically balanced vortex without using any bogus-related schemes. A case study on TC *MORAKOT* with a WRF-EnKF system demonstrated that the intensity and rainfall forecasts with the EnKF analysis were improved significantly, while a positive impact on the track forecast was also noted by assimilating satellite observations of TC position and intensity.

6) Technique for determining the sensitive areas in TC intensity and track predictions

Sensitive area for target TC observation can be found through the conditional nonlinear optimal perturbations (CNOP). Sensitivity of different variables in the sensitive area has been studied. OSSE shows that CNOP is an effective approach for target TC observation. The differences between two different typhoon cases show that the way to select verification area is important. Wind is the most sensitive variable for TC forecast. The greatest improvement is found when wind is accompanied with humidity.

7) Sensitivity study on the uncertainty of convective parameterization schemes in typhoon intensity and rainfall predictions

The GRAPES-TCM is used to understand the uncertainty of convective parameterization schemes (KF: Kain–Fritsch; BMJ: Betts–Miller-Janjic) in typhoon intensity and rainfall predictions. Totally 44 typhoon cases have been investigated. The results show that the overall prediction with KF scheme is better than that with BMJ scheme. TC track prediction is slightly influenced by the difference of the two schemes. The influence of the convective schemes on the TC intensity and rainfall prediction depends on the initial TC intensity. The predicted TC rainfall magnitude is generally consistent with the TC intensities predicted with the two schemes. The difference in the simulated convection with the two schemes leads to different convective rainfall and latent heating, which ultimately determines the TC intensity. The difference of the latent heat leads to different TC intensities.

8) Study on operational forecast system for storm surge along the Yangtze River Delta coast and at the Huangpu River estuary

The operational storm surge forecast system over the Yangtze River Delta coast and at the Huangpu River estuary in Shanghai has been established based on the 3D hydrodynamic model (Estuarine Coastal Ocean Model) by Shanghai Typhoon Institute (STI), CMA. The resolution of the model is about 3 km and the finest resolution for the Huangpu River estuary is 17 meters. The astronomical tide process and its interaction with storm surge are also included. More than 10 TC-induced storm surge processes were simulated and the results showed good consistency with tide gauge measurements. The operational forecast system runs automatically from data acquisition and data processing to model output. It can provide 48-h water flow and water level forecasts twice a day, which are posted onto the website of the Shanghai Typhoon Institute, as well as comparisons of the daily forecasts with observations. The statistics show that the water level forecast is accurate. The graphic forecast products were given in the *Special Report of Typhoon Activity* issued by STI.

A sophisticated regional typhoon model has been set up, which is coupled with GRAPES mesoscale atmospheric model, ECOM ocean circulation model and WaveWatch III waves model. The parameterization schemes for sea surface roughness and heat flux have been improved. The preliminary results show that SST increase from ocean circulation model and the sea surface roughness variation given by the wave model can affect TC atmospheric boundary structure (Source: Shanghai Typhoon Institute)

9) Advanced Training Course on McIDAS-V Software Application in Satellite Meteorology

From 7 to 11 June 2011, CMA Training Centre and CMA National Meteorological Satellite Centre co-organized an advanced training course on McIDAS-V software application in satellite meteorology with 32 participants. The training course mainly covered: introduction and demonstration of McIDAS-V software, application of satellite images in McIDAS-V software, application of Hyperspectral remote sensing data in McIDAS-V software, uses of radar data, point data, and grid data in McIDAS-V software, etc.

The course was designed to help the trainees to improve their understanding of the U.S satellite data interactive processing application technique, to enhance research and development of human-computer interaction system, to improve the ability of analyzing and solving problems in the satellite data interactive processing applications, and to speed up China's human-computer interaction system development.

10) Advanced Workshop on the Theory and Application of Satellite Data Assimilation

The Advanced Workshop on the Theory and Application of Satellite Data Assimilation was held in 12-19 December 2011. Prof. ZOU Xiaolei from the Meteorological Department of the Florida State University, and Prof. WONG Fuzhong, a chief scientist from NOAA, were invited to give lectures, which covered techniques on satellite remote sensing, atmospheric spectroscopy and radiative transfer, microwave radiation, quality control of satellite data and its application in numerical weather forecast, basic theory and methods, influence of liquid and iced water in the cloud on GPS occultation data, FY 3 data quality evaluation, application of the satellite data in climate change studies and radiative transfer model - CRTM, 1D satellite data inversion system - MIRS, etc.

Over 70 professionals in the field of satellite data assimilation from CMA and its regional meteorological centres attended the workshop. Other participants include instructors from universities and researchers from scientific institutions. The trainees had an in-depth understanding of the basic theories such as characteristics of the satellite data, analysis methods and techniques for satellite data applications to models, with their ability being improved in the analysis and application of satellite data.

11) Training Course on the Application of Geostationary Meteorological Satellite Data in Weather Analysis and Forecasting

40 participants attended the training course on the Application of Geostationary Meteorological Satellite Data in Weather Analysis and Forecasting held at CMATC from 5-15 January 2011.

The training included basic principles of satellite meteorology, application of multiple observations in weather/climate analysis and forecasting, satellite monitoring and application of mesoscale systems, generation and application of TOVS data, cloud wind derived from geostationary meteorological satellites, typhoon positioning and intensity estimation from satellite imagery, rainfall estimation with satellite data, analysis and application of water vapor data, TBB analysis and application, OLR data generation and application, sandstorm monitoring by polar-orbiting and geostationary meteorological satellites, and analysis of large scale cloud system.

The participants grasped better knowledge of basic principles of satellite meteorology, theories and applications of various meteorological satellite products, which would enable them to better make use of FY2 data and products in weather analysis and forecasting.

12) Training Course on Applications of New Generation Doppler Weather Radar

From January to October 2011, China Meteorological Administration Training Centre (CMATC) held two training courses on Applications of New Generation Doppler Weather Radar for 88 trainees.

The training covered: Doppler radar theory, speed determination, radar data quality control, characteristics of convective storm echoes, radar product and algorithms, nowcasting for severe convective weather, hands-on case studies and relevant training seminars, etc.

Through the two training events, the trainees became familiar with basic analysis methods for analyzing strong convective weather with radar images, new generation weather radar theory, and they grasped basic knowledge and skills about applications of radar products as well as applications of new generation Doppler weather radar.

2.6.5 Regional Cooperation Achievements/Results

1) Verification of landfall typhoon forecasts in 2011

An English version website of the Typhoon Landfall Forecast Demonstration Project (TLFDP) , which was led by CMA, was launched in late June 2011 (http://tlfdp.typhoon.gov.cn). The application of the techniques and products in the Typhoon Committee region has been promoted. Most models show skills and some are comparable to or even better than official forecasts in certain aspects. The system for verifying tropical cyclone track and intensity forecasts, especially ensemble prediction and landfall forecasts, has been improved.

2) International Training Course on McIDAS-V Software Application in Satellite Meteorology

From 7 to 17 June 2011, CMA Training Centre, CMA National Meteorological Satellite Centre and University of Wisconsin-Space Science and Engineering Centre organized an International training course on McIDAS-V software application in satellite meteorology.

This training course was designed to help trainees learn how to use the sophisticated McIDAS software packages - McIDAS (Human-machine Interactive Data Access System), to acquire, display , analyze, interpret, and manage the geophysical data, such as satellite and radar imagery, in-situ observational reports, and gridded numerical forecasts. It was also designed to learn relevant expertise in satellite meteorology and China's FY series meteorological satellites and applications. This training course included both theory and case analysis. The participants' forum, field investigation and other learning activities combine studies with applications.

Out of 45 trainees, 13 were participants from different countries and regions, all engaged in weather and meteorological applications of satellite-related work, research and management. The overseas students were from Papua New Guinea, Thailand, Egypt, Oman, Niger, Rwanda, Poland, Yemen, Cayman Islands, Venezuela, Trinidad and Tobago, Mexico and Hong Kong, China.

3) RTH link upgrading

By the end of 2011, RTH Beijing has upgraded its transmission protocol for the dedicated link to RTH Tokyo. Thereafter, any urgent warning messages have a dedicated logical channel between the two RTHs. With this done, users can immediately receive the warnings on any regional natural disasters, such as typhoon and tsunami. RTH Beijing has also started to transmit the marine warnings to JCOMM members within the region since November 2011.

2.6.6 Identified Opportunities/Challenges for Future Achievements/Results

The progress of NWP depends on the knowledge of severe weather genesis mechanisms to improve parameterization schemes on one hand, and to use accurate observations in model assimilation systems on the other. As they are very complicated and challenging, continuous research is needed in the future.

2.7 Progress in Key Result Area 7: Enhanced Typhoon Committee's Effectiveness and International Collaboration

2.7.1 Meteorological Achievements/Results

1) Donation of CMACast and MICAPS 3.1 System and GISC Beijing

The China Meteorological Administration (CMA) donated CMACast and MICAPS systems (Meteorological Information Comprehensive Analysis and Processing System) to 19 developing countries in Asia (including DPRK, Laos, Malaysia, the Philippines, Thailand, and Viet Nam, which are TC Members) on 11 April 2011. Participants from those recipients also attended the 40th China Study Tour and the Regional WIS Training Seminar cosponsored by CMA and WMO from11to14 April 2011. CMACast is a new DVB-S2 standard satellite data broadcast system of CMA. It disseminates both the satellite data and routine meteorological data in C band (3400-4200GHZ) via AsiaSat 4 satellite (122.2°E) to its users. As mentioned before, MICAPS provides an effective means for forecasters to prepare and issue weather forecasts, including typhoon forecasts. It has more powerful functions for the forecasters to interactively view, analyze, use and prepare weather data.

Fig 7.1 The 40th China Study Tour and Regional WIS Training Seminar

Meanwhile, the Sixteenth World Meteorological Congress (Cg-XVI) designated Beijing as one of the Global Information System Centre（GISC Beijing）. Following the trial operation over the past years, GISC Beijing has started its operation since 15 August 2011 and its website (http://wisportal.cma.gov.cn) is now open for registration. Apart from continued provision of existing GTS data transmission and exchange services, GISC Beijing also provides the Data Discovery, Access and Retrieve (DAR) service, Data Subscription service as well as CMA's NWP products and FENGYUN satellite products. Registered Members of the Typhoon Committee can benefit from this new WMO Initiative.

2) On-job Training for Pilot Cities (8-19 August 2011, Shanghai, China)

STI/CMA conducted the UFRM on-job-training on QPE/QPF operation for 3 staffs from TMD, Thailand. The courses mainly focused on three parts: QPE (satellite, radar, GPS, Lidar, lightning), QPF (Data assimilation, GRAPES-TCM, ensemble), WENS (WMO Expo 2010 Nowcast Services Demonstration Project) and MHEWS Operational platform.

Fig 7.2 On-job Training for Pilot Cities

3) TC Research Fellowships Offered by CMA

Mr. Sukrit Kirtsaeng from Thailand was granted a TC Research Fellowship by CMA to work on the project - "Improvement of Prediction Method for the Rapid Intensification of Tropical Cyclones over the South China Sea" starting from 1 November to 30 December 2011. Another fellowship will be granted to Mr. Raymond Ordinario from the Philippines focusing on the project - "Application of Numerical Ensemble Prediction to Forecasting Typhoon Sharp Turning Tracks", which will start from 1 January to 28 February 2012.

Fig 7.3 Dr. Kirtsaeng presented a report on changing trend in heavy rainfall and TCs in Thailand at the National Meteorological Centre, CMA

4) Publication of Tropical Cyclone Review in 2011

At the 43rd TC Session, it was agreed to publish an international journal "Tropical Cyclone Research and Review", which focuses on tropical cyclone issues and topics, including operational forecast, scientific research, hydrological effects and disaster risk reduction. STI/CMA and Typhoon Committee established an editorial committee and an office for this journal. The sample edition has been delivered to the Typhoon Committee, with its International Standard Serial Number (ISSN) having been registered.

5) QPE/QPF workshop

A participant from CMA gave a keynote lecture on the QPE/QPF workshop held in Nha Trang, Viet Nam on 6 November 2011.

Fig 7.4 QPE/QPF workshop held in Nha Trang, Viet Nam.

2.7.2 Hydrological Achievements/Results

1) Hosting the Asia-Pacific Regional Workshop on Flood Forecasting and Early Warning

From 24 to 28 October 2011, the Asia-Pacific Regional Workshop on Flood Forecasting and Early Warning was held in the Nanjing Hohai University, cosponsored by WMO and BOH/MWR andthe Nanjing Hydraulic Research Institute. The Workshop was attended by over 30 trainees from China, Bangladesh, Nepal, Bhutan, Laos, Cambodia, Vietnam, North Korea, Thailand and the Philippines, as well as representatives and renowned experts from WMO, International Centre for Integrated Mountain Development, Danish Hydraulic Institute and the Bologna University of Italy.

The Workshop consisted of 3 segments: thematic presentations, discussions & exchanges, and hands-on model application practices. The topics included applications and practices of flood forecasting models, exchanges of flood forecasting and warning techniques in the Asia-Pacific Region, principles and application of the Xin'anjiang model, progress and outlook of flood forecasting and warning techniques in the world. The trainees also visited the experiment base at the Nanjing Hydraulic Research Institute and the national key laboratory in the Hohai University.

Fig7.5 The opening ceremony of and discussion during the Asia-Pacific Regional Workshop on Flood Forecasting and Early Warning

2) Sending technical personnel to Malaysia to attend the Seminar Tour of New Hydrological and Meteorological Technologies for Disaster Relief, held by the Typhoon Committee

From 20 to 24 September 2011, the Typhoon Committee held the Seminar Tour of New Hydrological and Meteorological Technologies for Disaster Relief in Malaysia. China was very interested in two of its topics: promoting urban flood management programs and the application of rainfall estimation/forecasting technologies in urban flood risk management. BOH, MWR recommended Hu Jianhua, senior engineer at the Guangdong Provincial Bureau of Hydrology to attend the seminar.

The participants of the meeting were from China; Hong Kong, China; Macau, China; Singapore; Thailand; Cambodia; Vietnam; the Philippines; Laos; Malaysia; etc. The theme of the meeting was Rainstorm and Flood Caused by Landfalling Typhoons. There were three subthemes: the Summary of Rainfall Estimation/Forecasting Technologies and their Hydrological Application, the Review of the Utility Systems of Typhoon Rain Estimation/Forecasting and Their Application and the Causes, Assessment and Management Of Floods Brought About by Typhoon Rains and Cyclones. The participants also visited the Malaysian Meteorological Department, SMART Tunnel, DID flood monitoring facilities and watched the demonstration of the monitoring and forecasting system.

Fig7.6 A roving training seminar on new hydrometeorological forecasting techniques for disaster reduction.

2.7.3 Disaster Prevention and Preparedness Achievements/Results

NIL

2.7.4 Research, Training and Other Achievements/Results

NIL

2.7.5 Regional Cooperation Achievements/Results

1) WWRP International Workshop on Rapid Changes in Tropical Cyclone Intensity and Track

WWRP International Workshop on Rapid Changes in Tropical Cyclone Intensity and Track was held in Xiamen China from 18 to 20 October 2011. The overall objective of this event was to improve understanding of "TC unusual changes" in operational forecasts. The workshop brought forecasters and researchers together to exchange empirical knowledge and research findings in this field.

2) International Training Course on Tropical Cyclone

An International Training Course on Tropical Cyclone, co-sponsored by both the China Meteorological Administration and the WMO/ESCAP Typhoon Committee, was held in Nanjing, China by the WMO RTC Nanjing from 5 to 16 December 2011 under the WMO VCP programme. A meeting on Tropical Cyclone Ensemble Forecasts was also held during the training course by WMO. The training courses, covering basic theory about tropical cyclone and TC ensemble prediction system and its applications, attracted more than 40 participants around the world and over 20

Chinese forecasters and researchers from coastal provinces. To have in-depth understanding of Ensemble Prediction System especially for TC forecasts, and to improve the ability to use EPS outputs, 7 NMC forecasters took part in the training. Dr. DUAN Yihong, Director General of NMC, gave a presentation on “Operational Tropical Cyclone Forecasting and Warning in China” for the participants.

Fig 7.7 International Training Course on Tropical Cyclone in Nanjing, China

3) Cooperation with HKO

During the 12th five-year national economic development plan, CMA’s Guangdong Institute of Tropical Maritime Meteorology will focus on the construction of NWP systems in its attempt to modernize meteorological course. Among its current work is the cooperation with Hong Kong Observatory to increase the accuracy and application of NWP products in the next few years.

2.7.6 Identified Opportunities/Challenges for Future Achievements/Results

NIL

III. Resource Mobilization Activities

3.1 To enhance typhoon research, and to provide better scientific & technical support to real-time operations, the Ministry of Finance approved the typhoon-related research projects in 2010-2012:

The research project on Offshore Typhoon Structure and Intensity Forecasting Techniques, with a fund of CNY 2.5 million, mainly includes (a) analytic study on the characteristics of TC boundary layer, mesoscale structural and intensity variation mechanism by using observational data, numerical simulations and diagnostic analyses in typical TC cases; (b) studies on various factors for

TC bogus and model physics, and TC structure and intensity changes based on the above analyses and research work; (c) establishment of a regional TC model for operational TC intensity prediction based on ARW-WRF.

3.2 Social mobilization in DPR

Guidance was provided and social participation was mobilized in disaster risk management, allowing experts to play a specific role in providing advices and recommendation for disaster prevention and reduction.

The 2nd Forum on Comprehensive Disaster Prevention and Reduction and Sustainable Development opened in Beijing took place on 7 May 2011, with nearly 300 participants including domestic experts and government officials in the field of disaster prevention and reduction. These participants provided their valuable opinions and proposals for enhancing China's capacity for comprehensive disaster prevention and reduction and building up a national system for comprehensive disaster prevention and reduction.

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