발간등록번호
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ANNUAL REPORT 2017

KOREA METEOROLOGICAL ADMINISTRATION

Korea Meteorological Administration

Contents

The Korea Meteorological Administration (KMA) is committed to providing weather information in a prompt and accurate manner, to ensure that people can enjoy a safe and comfortable way of life and economic benefits. Also, when an earthquake or other natural disaster is predicted, we make every effort to promptly deliver earthquake and disaster-related information to the public to help them avoid being placed in danger and reduce economic losses.

"Watching the Sky Friendly, Serving the People Faithfully."— This is what we always keep in mind.

KMA

Message from the KMA Administrator

Watching the Sky Friendly,

Serving the People Faithfully

It is a great pleasure to publish the 2017 Annual Report of the Korea Meteorological Administration (KMA), which reviews the KMA's achievements and performance from 2017.

In 2017, the second warmest year on record globally, we saw several destructive weather and earthquake events on the Korean Peninsula. An increased frequency of the extreme weather events, such as localized rainfall, drought, and extreme heat waves, caused by climate change led to the loss of life and property.

Particularly, during the monsoon season, large regional differences in precipitation resulted from heavy rain concentrated in the central part of the country. In July, the number of heat wave days has increased by 5.5 days nationwide from last year, which was also related to the prolonged severe drought in the southern region.

A massive earthquake of magnitude 5.4 hit the city of Pohang on November 15, 2017, which terrified the public with strong shaking and hundreds of aftershocks. The earthquake in Pohang took place before the country was recovered from the shock and damage resulting from the 2016 earthquake in Gyeongju.

These two consecutive strong earthquakes were major challenges that threatened our valuable resources, but they also raised awareness of earthquake-led disasters and drove us to take precautions against future earthquakes. In an attempt to improve natural disaster preparedness, there have been a wide range of efforts by the KMA. In close cooperation with relevant organizations and media, we helped the public better respond to the earthquake with prompt emergency alert texts and press briefings. We also reduced the earthquake warning issuing time from 50 seconds to 5-15 seconds, while expanding the earthquake observation network and enhancing equipment

since the 2016 earthquake in Gyeongju.

The efficiency and the capacity of weather forecasts has been improved by reforming the forecasting process. The enhanced forecasting process enabled the capacity development in response to unusual weather events. Additionally, a weather-specific website was launched separated from the existing KMA website for better public access to weather information.

In addition to these measures, the KMA contributed to a successful 2018 PyeongChang Winter Olympic Games and Paralympics. As part of our efforts for the Olympics, we finished the preparation for weather monitoring and support. Forty-five forecasters, who were trained in a specialized programme over the last four years, produced and provided venue-specific weather information during the pre-operational period. High-resolution observation network was established at the venues as well.

During the year of 2017, the KMA made an all-out effort to improve its weather and earthquake services. However, we should not be complacent but make a next step forward for better services. In 2018, we will implement five core values — safety, basics, people, future, and the world — to fulfill the 2018 policy goal of "Working to provide weather and earthquake services focused on public safety and security", as well as being faithful to basic duties of forecasting and observation. Furthermore, we will make an effort to be well prepared for the future, in particular, by taking advantage of the fourth industrial revolution technology for the existing meteorological infrastructure. We will also spur our preparation for impact-based forecasting which aims to be launched in 2020.

We have been working closely with other meteorological agencies to exchange weather data and produce more accurate forecasts and warnings toward informed decision making and public safety. In the context of multilateral cooperation, the KMA has represented the government of the Republic of Korea as a member of the World Meteorological Organization (WMO) since 1956. As a leading country in the meteorological society, we will make continued efforts to more contribute to the development of human resources and infrastructure in developing countries through various training programs and projects.

Lastly, I hope that the KMA staff members, many related agencies, and people around the globe find this annual report useful. I take this opportunity to thank all our employees for their dedicated work on the publication of this report.

Administrator
Korea Meteorological Administration
Jong seok Kim

김 종 석

Vision & Goals

Become a leader in preparing for the future and ensuring public safety

Mission

Offer prompt, accurate, and valuable weather services

Vision

Provide reliable weather information that meets the public's needs

Goals

- Increase speed and accuracy of weather forecasts
- Expand the application of weather & climate information to create added value
- Secure cutting-edge meteorological technologies and experts

Five Core Values

- A leader in public safety
- Strong and well-founded services
- In touch with the public
- Preparing for the future
- Working together with the international community

2017 NEWS HIGHLIGHTS

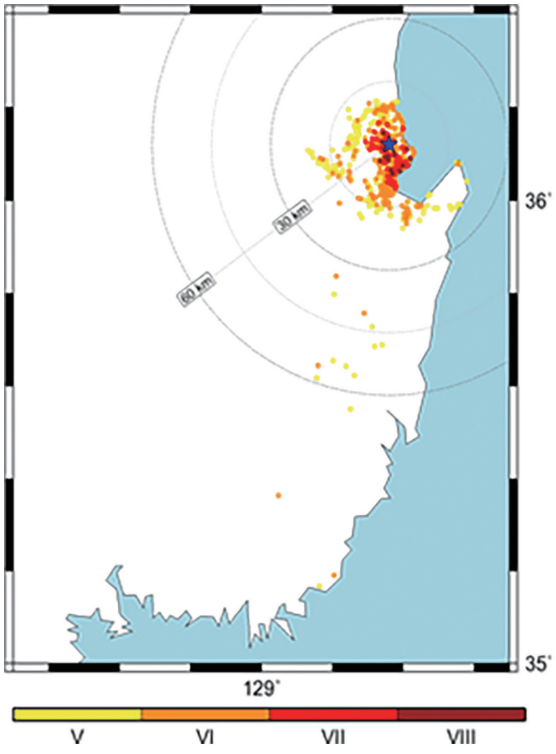
NEWS 1

Pohang hit by second most powerful earthquake in Korean history

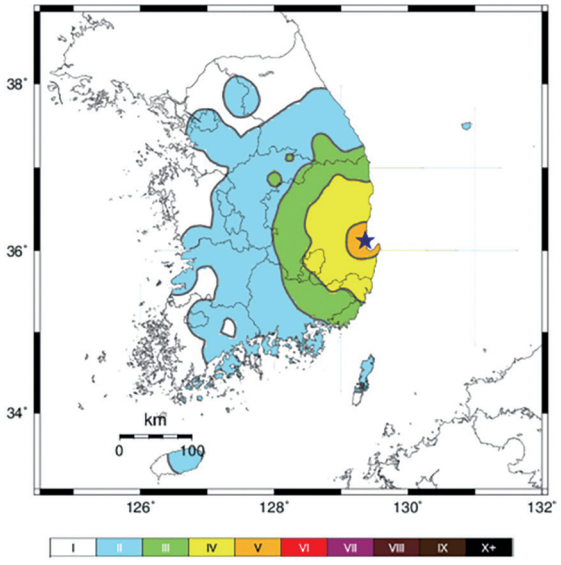
A magnitude 5.4 earthquake struck the South Korean city of Pohang, North Gygeongsang Province on November 15, 2017. It was the second largest earthquake since the country officially began recording seismic data. The Korea Meteorological Administration (KMA) issued earthquake an early warning 19 seconds after the initial quake was detected, and sent an emergency alert text to the public nationwide. People who were in areas far from the epicenter were quickly informed of the earthquake occurrence as they received the text alert before feeling the shaking.

The seismic intensity of up to Ⅵ was detected in North Gyeongsang Province including Pohang, and in particular, the intensity of 5 or more was centered on areas within 15 – 20 km of Pohang. This indicated that the second–largest earthquake caused more damage to a narrow range of areas as compared to the Gyeongju earthquake on September 12, 2016 which damaged a wide range of areas within a 30 km–radius of the epicenter. The 5.4 magnitude earthquake in Pohang resulted in 135 injuries, 1,797 people left homeless, and 67.3 billion KRW in property damage according to the assessment by the Ministry of the Interior and Safety.

Before the main quake there were two foreshocks with a magnitude of 2.2 and 2.6 in the region, respectively, and there were 76 aftershocks with at least a magnitude of 2.0 throughout the year of 2017.



Intensity map based on earthquake damage



진도	진도 등급별 현상 (Ⅰ ~ Ⅵ)
Ⅰ	대부분 사람들은 느낄 수 없으나, 지진계에는 기록된다.
Ⅱ	조용한 상태나 건물 위층에 있는 소수의 사람만 느낀다.
Ⅲ	실내, 특히 건물 위층에 있는 사람이 현저하게 느끼며, 정지하고 있는 차가 약간 흔들린다.
Ⅳ	실내에서 많은 사람이 느끼고, 일부가 잠에서 깨며, 그릇, 창문 등이 흔들린다.
Ⅴ	거의 모든 사람이 진동을 느끼고, 그릇, 창문 등이 깨지기도 하며, 불안정한 물체는 넘어진다.
Ⅵ	모든 사람이 느끼고, 일부 무거운 가구가 움직이며, 벽의 석회가 떨어지기도 한다.

Earthquake location & Instrumental intensity

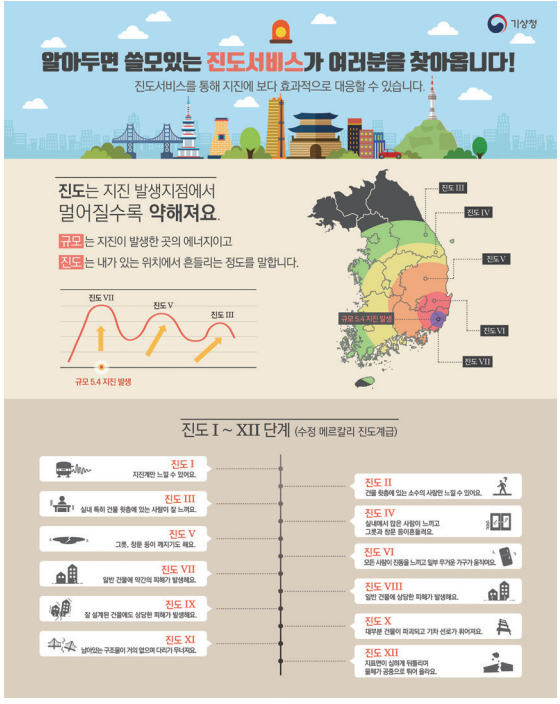
NEWS 2

Earthquake alert service improved

From July 2017 KMA greatly improved its earthquake alert service and implemented more prompt earthquake dissemination system. To ensure the timeliness and accuracy of earthquake information, the KMA divided earthquake service into two types: prompt information (earthquake early warning, earthquake early information) and detailed information (earthquake information). Prompt information delivers seismic information that is automatically estimated using P–waves, which travel faster than any other seismic waves, to focus more on the speed of information distribution than on the accuracy of the information. The KMA reduced the early warning time from 50 to 15–25 seconds, and earthquake early information from five minutes to 60100 seconds, after the first detection. Detailed information is provided within five minutes with comprehensive analytical information by earthquake analysts, to increase the accuracy of the prompt information.

In addition, seismic intensity (expected and instrumental intensity) and the focal depth will be added to the existing earthquake information (origin time, epicenter, magnitude). Seismic intensity information service, which was offered to relevant agencies in 2017 as part of a pilot project, will be expanded to the general public in 2018. The KMA will continue its efforts to improve earthquake services to minimize the damage from future earthquakes.

Earthquake alert service



Seismic intensity service

NEWS 3

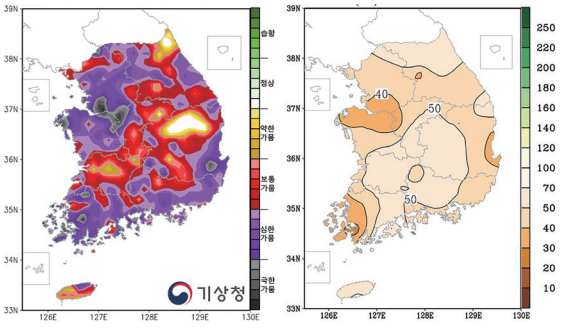
Nationwide drought in 2017

Most parts of Korea had below–normal precipitation in 2017. The national average precipitation in 2017 was 967.8 mm, accounting for 74.2 % of normal precipitation of 1307.7 mm. In particular, some southern areas and Jeju Island received very small amount of precipitation, with 56.8 % of normal in South Gyeongsang Province, 65.5 % in South Jeolla Province, and 60.5 % in Jeju Island.

The national precipitation in the first half of the year (January to June) only amounted to a half of the normal, the lowest cumulative precipitation since the observation began in 1973. May and June, particularly, had lesser rain with 29 % and 39 % of the normal, respectively, resulting in an extreme drought in spring. Dry dams and reservoirs in some parts of South Chungcheong and Gyeonggi Province and West Sea region unveiled submerged areas. Water level in the Boryeong dam reached the lowest level of 8.5 % (as of June 30), leading to difficulties supplying water to the western part of South Chungcheong Province. The drought had lasted across the country until June, but it was relieved in the central part of the nation as the region had more rain than normal with the strong monsoon rain front. The drought, on the other hand, continued in the eastern part of Gangwon Province and southern part of the country, with the dry and sunny weather influenced by high pressure.

Drought index distribution map (Jun. 30)

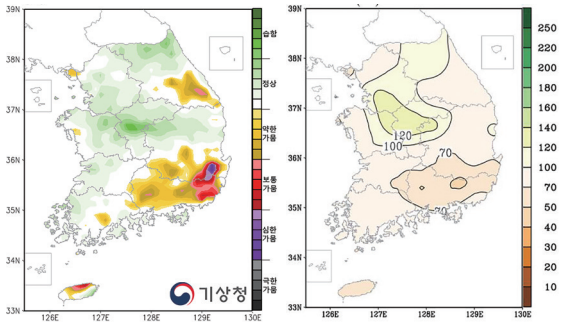
Percent of normal precipitation for the 6 months (Jan. 1-Jun. 30)



Drought in June 2017

Drought index distribution map (Dec. 31)

Percent of normal precipitation for the 6 months (Jul.1-Dec. 31)



Drought in December 2017

Over the past five years Korea has frequently experienced localized droughts, and the intensity of the droughts is expected to increase because of climate change–induced global warming. To proactively respond to droughts, the KMA plans to issue drought forecasts starting from November 2018. It will continue to make its effort to offer highly credible region–specific drought information.

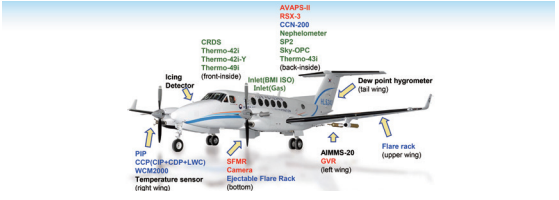
NEWS 4

Korea's first meteorological research aircraft adopted

KMA adopted Korea's first meteorological research aircraft on November 8, 2017. The aircraft is King Air 350 HW, part of a line of utility aircraft made by Beechcraft, a U.S. company. Equipped with 14 types of 25 cutting–edge meteorological observation instruments, it can fly for up to six hours and reach altitudes of around 32,000 ft or 10 km. King Air was designed to observe severe weather events such as typhoon, heavy rain, and heavy snow; to measure atmospheric quality including air pollutants, Asian Dust, and fine dust particles; to monitor greenhouse gases and other substances causing climate change and physical characteristics of clouds, with an aim of carrying out experiments of artificial rainfall and snowfall. While the first meteorological research aircraft was designed for about four years and six months (from May 2013 to November 2017), the process for adopting the aircraft was concluded from purchasing the aircraft and meteorological instruments to remodeling the aircraft by equipping it with instruments, obtaining a supplementary type certificate (STC) from the U.S. Federal Aviation Administration (FAA) to assure the aircraft safety, registering with the Ministry of Land, Infrastructure and Transport, and obtaining and airworthiness certificate.

The operation of the aircraft will be managed by the National Institute of Meteorological Sciences (NIMS) and an external service provider specialized in aircraft operation, maintenance, and meteorological observation. Based in Gimpo Airport, Korea's first meteorological research aircraft aims to fly for 400 hours on average per year to perform its missions. Along with ground observation network, weather satellite (COMS), and meteorological research vessel (Gisang–1), the first research aircraft will contribute to making the observation network for the Korean Peninsula more comprehensive and multi–dimensional. In addition, as the most cutting–edge meteorological equipment flying in the sky, the aircraft is expected to help enhance understanding of meteorological disasters and improve disaster response, and going further, take the lead in the field of aircraft–based meteorological observation in the North–East Asia region.

Meteorological research aircraft at Gimpo airport (Aug. 30, 2017)



Instruments mounted on the aircraft

Inaugural ceremony of the aircraft (Dec. 20, 2017)

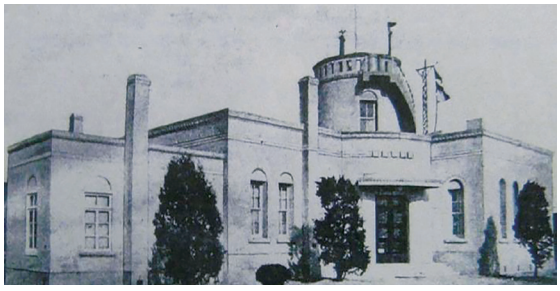
The aircraft in the hangar at Gimpo airport

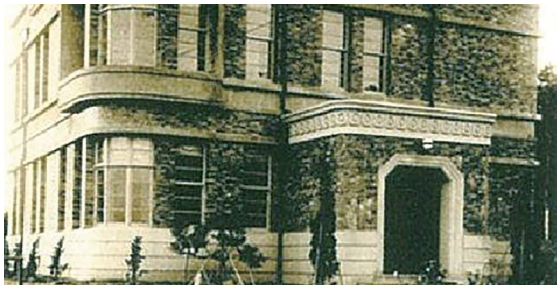
NEWS 5

Seoul and Busan Observatories awarded WMO Centennial Observing Stations status

Seoul Observatory and Busan Observatory of the Korea Meteorological Administration, which were founded in 1907 and 1904, respectively, were recognized as a Centennial Observing Station by the World Meteorological Organization. This accreditation is significant because it demonstrates that the international community recognized Korea's stable and credible meteorological observations and measurements over the past 100 years despite all historic hardships and amid rapid modernization. There are 13,000 meteorological observatories around the world, and 60 of them were accredited as WMO Centennial Observing Stations. Now Korea has the second most Centennial Observing Stations in Asia after China (3 stations). To be accredited as Centennial Observing Stations, stations must meet a list of requirements. For instance, the observing station should be founded at least 100 years ago; the inactive periods of the station should be less than 10 years; the station should be in operation in compliance with WMO observation standards; data quality from the station is continued to be controlled; observation data from the station should be open. Since a station can be recognized only when it meets WMO's strict criteria, Centennial Observing Stations are regarded as cultural and scientific heritage of mankind in the field of meteorology.

The Seoul and Busan observatories had their name listed on the Centennial Observing Stations at the 69th Session of the WMO Executive Council in Switzerland in May. This served as an opportunity for Korea's meteorological observation and its history to be recognized by the international community and to reaffirm the international status of Korea on the global stage in the field of meteorology.





Seoul Observatory

Busan Observatory

NEWS 6

Weather Forecast Support for 2018 PyeongChang Olympic test events

The KMA provided weather forecast support for 13 Olympic test events (10 for Olympics, 3 for Paralympics) in Pyeongchang and Jeongseon, Gangwon Province from November 2016 to March 2017, in preparation for 2018 PyeongChang Winter Olympic Games. The 65–member team[1] performed a variety of weather support, including producing and issuing venue–specific real–time weather information, communicating with venue operation staff, providing mobile upper air observations, and conducting ICE–POP 2018[2]. Through this experience the Olympic weather forecast support team was able to test weather forecast service at the Olympic site, and identify and figure out where and how to improve the service to make sure that the team itself is fully prepared for the biggest winter sports event in the world.

» Weather forecast support

Field	Observation	Forecast	Service
Support	- Build/operate/inspect observation network · 9 types of 103 observation instruments, including integrated meteorological sensor, visibility and present weather sensor, AWS, etc. -Special observation of surface, upper-air, and marine environment with mobile observing vehicle and meteorological research vessel Gisang 1 -International collaborative observation network · Snow monitoring equipment from Taiwan, Spain, and Canada	-Weather forecasters for the Olympics · 25 for WFC[3], 11 for WIC[4] · 3 types (24h, short, and mid-term forecast) of forecasts for 7 venues and 14 forecasting sites - Real-time NWP data · Very short, 24h, short, and mid-term data · Operating RSD[5]	-Smart weather support system on PC and mobile platform · http://pc2018.kma.go.kr · http://m.pc2018.kma.go.kr - The Road Weather Hazzard Information (Good/Rain/Snow/Fog) for 4 points on the Yeongdong Expressway

Weather forecast support for test events

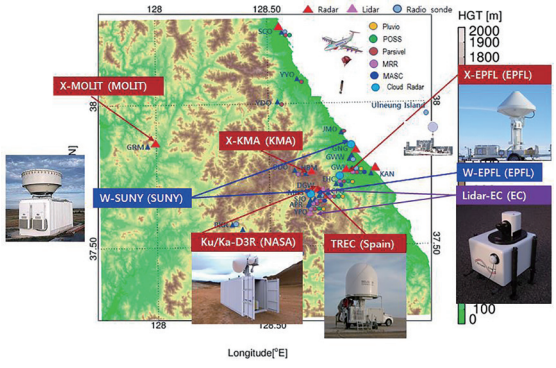
1) 36 for weather forecast support, two for numerical weather prediction, three for observation network operation, six for mobile observation, three for organizing, 15 for volunteers
2) ICE-POP 2018 : International Collaborative Experiments for Pyeongchang 2018 Olympic and Paralympic winter games
3) Weather Forecast Centre (WFC) is responsible for generating and notifying venue-specific weather forecasts, adjusting work duties, and monitoring severe weather events at night.
4) Weather Information Centre (WIC) is responsible for weather forecast support for venues, on-site forecast briefing, and communication with venue operation staff.
5) Research Support Desk (RSD) supports NWP model data and advanced observations of ICE-POP 2018 for forecasters.

NEWS 7

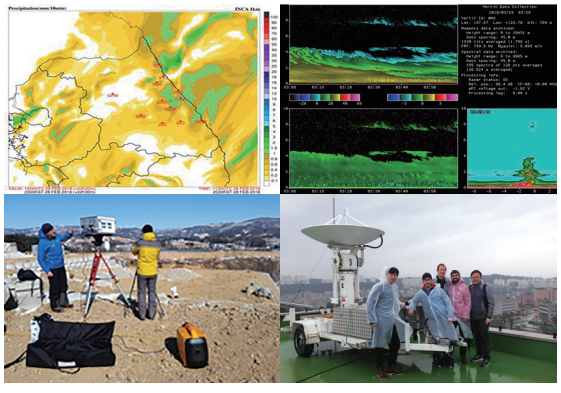
ICE-POP 2018 implemented for 2018 Winter Olympics in Pyeongchang

The KMA organized and led International Collaborative Experiments for Pyeongchang 2018 Olympic and Paralympic winter games (ICE–POP 2018) to successfully provide weather forecast support for the games. The project approved by the World Meteorological Organization (WMO) in 2016 was designed as part of Research and Development and Forecast Demonstration Projects (RDP/FDP) of WMO's World Weather Research Program (WWRP). ICE–POP 2018 was voluntarily joined by 29 agencies from 12 countries, including KMA Numerical Prediction Center, National Institute of Meteorological Sciences, National Weather Radar Center, National Meteorological Satellite Center, NASA, Swiss Federal Institute of Technology in Lausanne, and Meteorological Service of Canada. These participating agencies, with cutting–edge instruments, jointly observed and measured winter meteorological conditions in complex mountainous terrain in Pyeonchang in terms of precipitation, very short–range NWP model, and model verification, to enhance the predictability of NWP models.

For intensive precipitation observation, the project monitors and produces surface and three–dimensional precipitation distribution data in real time by using advanced instruments such as cloud and precipitation radar, lidar, disdrometer, multi–angle snow–flake camera, and weighing type rain gauge from December 2017 to March 2018. In terms of NWP, different forecasting models from several participants, including KMA's NWP model, Austria's nowcasting model INCA, and NASA's NU–WRF model, produce NWP data. Data from intensive precipitation observation and NWP model during the project will continue to be improved, and this is expected to serve as a good opportunity to upgrade Korea's winter weather forecasting and to set as a good example of successful intensive observation.



Major observation instruments



Intensive observation, NWP model, and verification

KEY ACTIVITIES OF 2017

- Forecast
- Observation
- Climate
- Meteorological Industry
- Information & Telecommunication
- International Cooperation
- International Training and Education

Forecast

Operations of Numerical Weather Prediction System

The NWP system of the Korea Meteorological Administration (KMA) consists of Global Data Assimilation and Prediction System (GDAPS), Ensemble Prediction System for Global (EPSG), Regional Data Assimilation and Prediction System (RDAPS), Local Data Assimilation and Prediction System (LDAPS), Limited area ENsemble prediction System (LENS), Korea Local Analysis and Prediction System (KLAPS), Very short range Data Assimilation and Prediction System (VDAPS), and several application systems for such as marine meteorology, Asian Dust, and statistics.

The KMA uses the Unified Model (UM) as its operational model since it adopted from the UK Met Office in 2010, and updates it to the latest version once or more every year. The major areas improved during 2017 were (1) application of the latest versions of model and data assimilation, (2) application of Variational Bias Correction (VarBC) of satellite data in global model, and (3) adding a soil moisture perturbation to the ensemble model. These improvements increased the model's predictability up to 1 to 2 % and 6 to 8 % for summer and winter season, respectively, on the basis of the northern hemisphere (500 hPa geopotential height RMSE*).

* RMSE: Root Mean Square Error

Status of Korean Numerical Weather Prediction (NWP) Model Development

The KMA has been carrying out a 9-year project developing Korea's own NWP model since 2011, with an aim of reducing its 30-year dependence from foreign NWP models and generating its own numerical prediction data. The project, which started from developing basis and source technology, is now moving toward to developing operational system. Korean NWP model, named KIM (KIAPS Integrated Model), will be operated in parallel with the current model in 2018, in trial operation in 2019, and in full operation in 2020.

For the successful launch of KIM in 2020, the KMA improved the model resolution from 25 km to 12 km, adopted the cutting-edge four-Dimensional Ensemble Variational (4DEnVAR) formulation, and expanded the model's vertical resolution from 50 to 91 layers in 2017. As for dynamics, a variety of sensitivity tests were performed to reduce numerical noise resulted from the increase in resolution and to stabilize the model. It was shown that the increased resolution improved the performance of synoptic predictability and the simulation of low atmospheric pressure in the west sea of the Korean Peninsula.

» Forecast system of Korea's own NWP model

Type	Forecast System
Horizontal Resolution	Approx. 12 km
No. of Grids	3,110,402 in horizontal direction
Vertical Resolution / Top layer	91 layers / 0.01 hPa, Approx. 80 km
Time Step	20 secs
Data Assimilation	4DEnVar
Cycle / DA window / cutoff	6-hour cycle 6 hours (±3 hours) DA window Cutoff time: 7 hours 30 minutes (late observation)
Observation data	Surface (Synop, METAR, Ship, Buoy), Sonde (TEMP, PILOT, Windprofiler, Drop-Sonde), Aircraft (AMDAR, AIREP), GPS-RO, AMSU-A, MHS, ATMS, IASI, CrIS, AMV, ScatWind, TCBogus

» Operations of NWP system at KMA (As of December 2017)

Models		Horizontal Resolution (Vertical Layers)	No. of Operations / Day	Duration of Prediction	Objective
Global (GDAPS)	Global Forecasting System (UM N768 L70)	17km (70)	4 times	12 days 87 hours	Global weather prediction, Digital forecast, Weekly forecast
Regional (RDAPS)	Regional Forecasting System (UM 12km (70)	12km (70)	4 times	87 hours	Weather forecast for Asia Digital forecast
Local (LDAPS)	Local Forecasting System (UM 1.5km L70)	1.5km (70)	4 times	36 hours	Weather forecast for the Korean Peninsula
Wave	Global Wave Model (GWW3)	Approx. 55km	2 times	12 days	Target: global wave Application: digital and mid-range ocean forecast
	Regional Wave Model (RWW3)	Approx. 8km	2 times	87 hours	Target: wave in East Asia Application: digital ocean forecast
	Local Coastal Wave Model (CWW3)	Approx. 1km	2 times	72 hours	Target: Daejeon, Gwangju, Busan, Gangwon, and Jeju Regional Office of Meteorology Application: Digital and local coastal ocean forecast
Storm Surge	Regional Storm Surge Model (RTSM)	Approx. 8km	2 times	87 hours	Application: storm surge in East Asia
	Local Coastal Storm Surge Model (CTSM)	Approx. 1km	2 times	72 hours	Target: Daejeon, Gwangju, Busan, Gangwon, and Jeju Regional Office of Meteorology Application: local coastal storm surge
Asian Dust / Haze	Asian Dust Aerosol Model (ADAM2)	25km (47)	4 times	72 hours	Application: prediction of Asian Dust
	Asian Dust and Haze Model (ADAM3)	25km (49)	4 times	72 hours	Application: haze prediction
Ensemble (EPSG)	Global Ensemble Prediction System (EPSG UM N400 L70 M49)	32km (70)	2 times	12 days	Target: global weather prediction Application: weekly forecast
Local Area (LENS)	Limited Area Ensemble Prediction System (LENS UM 3km L70 M13)	3km (70)	2 times	72 hours	Target: weather forecast for the Korean Peninsula Application: severe weather prediction
Very Short-range	Very Short-range Background Analysis (KL15)	15km (22)	8 times	-	Target: East Asia Application: generation of background fields for very short-range model
	Very Short-range Background Prediction (KLBG)	15km (40) 5km (40)	4 times	30 hours	
Very Short-range	Very Short-range Analysis (KL05)	5km (22)	24 times	-	Target: Korean Peninsula Application: three-dimensional analysis/ prediction
	Very Short-range Prediction (KLFS)	5km (40)	24 times	12 hours	
	Very Short-range Prediction System (VDPS) (UN 1.5km L70)	1.5km (70)	24 times	12 hours	Weather forecast for the Korean Peninsula

Observation

Weather Observation Standardization

The KMA has been carrying out a project since 2007 to standardize the weather observation across the country by improving the observing environment and avoiding duplicated installations of the same equipments, and thereby to increase the accuracy of the observation data as well as its collaborative applications. The KMA supports 27 public agencies conducting observations through training and workshops so that the agencies can diagnose their level of standardization and comply with the related laws and regulations.

To secure and maintain the best suitable observing environment of the observation facilities, the KMA obtained additional land through land purchase, free leasehold, and allowance to use government-owned properties, to build standardized observing sites, and thereby the share of standardized observing equipment installed on buildings' rooftop was reduced from 9.6 % at the end of 2015 to 6.3 % at the end of 2017.

Several meetings were held in 2017 to carry out observation standardization policies, such as Weather Observation Standardization Committee (twice) and Weather Observation Standardization Working Committee (twice), to come up with more reasonable collaborative frameworks.

The KMA also formed a Help Desk Team staffed with 26 members to instruct technologies related to observation standardization, promote the utilization of the joint application system, and successfully implement data quality rating system. In 2017, in particular, it analyzed and solved problems with telecommunication system and data processing to collect more data from other observing agencies, resulting in the average data collection rate as high as 94.8 % in 2017. Moreover, it had consultations with other observing agencies on evaluating observing environment and installation conditions before they install, replace or transfer observing equipment, in order to avoid duplication in equipment installation and support them in creating the optimized observing environment.

Operations of COMS and Data Service

Since April 1, 2011 the National Meteorological Satellite Center (NMSC) has provided basic satellite images and a variety of analysis images through real-time broadcasting service for about 2.2 billion people from approximately 30 countries in Asia and the Pacific, and real-time data service through landline networks for related agencies such as military, broadcasters, and disaster prevention institutions. The NMSC offers these data through various routes including website, web system of the intranet, and WMO's Data Collection or Production Centres (DCPC). It exerts its efforts to improve the quality of the service by conducting and assessing statistical results of the service and a satisfaction survey every year.

» Current satellite data service by COMS

	Route	Service
1	Satellite Broadcasting by COMS	• About 41 receivers (Domestic: 14, Overseas: 17) - Overseas: US Air Force (Guam, Okinawa), Vietnam Air Force, weather services of Sri Lanka, Taiwan, Japan, Laos, and the Philippines, and universities in Australia, Taiwan, and Thailand - Domestic: Air Force, Navy, National Institute of Fisheries Science, National Science Museum, Seoul Emergency Operations Center, National Disaster Management Research Institute, and related governmental agencies
2	Website (http://nmsc.kma.go.kr)	No. of subscribers: 1,661 in total (Internet: 1,436, Intranet: 225) Amount of Request and download data in 2017: 2,546 times, 1.1 TB
3	Partner agencies (Real-time FTP provided)	• Domestic: 19 agencies (via ICT division of the KMA) - Air Force, Navy, Ministry of Public Safety and Security, National Institute of Environmental Research, broadcasters (KBS, MBC, SBS), etc. • Overseas: 3 institution (Hong Kong Observatory, University of Wisconsin, and University of Colorado)
4	Joint Testbed -ETRI	• Amount of Himawari-8 data provided Himawari-8 to support the development of algorithms for the GK-2A: Approx. 187 TB
5	Off-line	• Amount of document: 18 times • Amount of data provided: Approx. 276 TB - Requested by academia, research institutes, industries, etc.

Climate

Integrated Climate Change Monitoring Information

The World Meteorological Organization is going ahead with the establishment of integrated information system on factors resulting in climate change while setting up a new Global Atmosphere Watch (GAW) Implementation Plan (20162023). Domestically, the need for more comprehensive climate change monitoring of the Korean Peninsula and the globe was raised for better understanding of climate change at the national level.

To shift gears from global atmosphere watch to an integrated climate change monitoring system, the KMA established Integrated Climate Change Monitoring Information Service Plan (2017-2021) for monitoring the causes, results and impacts of climate change, and developed a roadmap for service and its implementation based on the trends of climate change monitoring at home and abroad and the status of related service in different countries.

The information of eight variables – carbon dioxide, methane, aerosol, stratospheric ozone, temperature, precipitation, sea level, and sea ice – has been provided at the KMA's climate information portal site (http://www.climate.go.kr) since December 2017. The portal site also offers climatological significance and long-term impacts of each variable on the peninsula and related data analysis. Furthermore, the website gives users guidance on how to take advantage of the information to improve users' understanding and access to the provided contents.

Hydrometeorological Monitoring and Prediction Information

In recent years climate change has changed patterns of precipitation, and a big gap in precipitation by regions has led to an increase in the frequency and the intensity of hydrometeorological disasters in dams and rivers. To prevent hydrometeorological disasters in advance and actively respond to changes in the water environment, the KMA, the Ministry of the Interior and Safety (MOIS), and National Geographic Information Institute (NGII) have been working together since 2013 to implement and run Joint-Use National Hydrometeorological Disaster Information System (http://khazard.go.kr). This system consists of three systems – hydrometeorological drought information system (KMA), storm and flood damage prediction information system (MOIS), and joint-use spatial information system (NGII).

The information in the existing hydrometeorological prediction information system and comprehensive drought information system has been integrated into Hydrometeorological Drought Information System (http://hydro.kma.go.kr) since 2017 to increase the usability and convenience of users in the water management and disaster prevention agencies. Furthermore, the scope of hydrometeorological information was expanded from some parts of Seomjin river basin, Han river basin, and Nakdong river basin to the river basins nationwide. The period of climate statistics by river basin was also prolonged from the recent 10 years to 30 years or more (since 1973), and a method for calculating areal precipitation was changed from arithmetic mean method to Thiessen polygon method that considers a relative distance and density between observation points.

The KMA made a multi-model ensemble using KMA's operational model to offer areal precipitation estimates over various range of areas, and by using this multi-ensemble model, it developed Precipitation Index of standard river basins to take action in preparing for a flood. Moreover, it replaced the existing fixed image-based map with a GIS-based map enabling users to zoom in and out and move around the map so that users can search detailed information by river basin and administrative district.

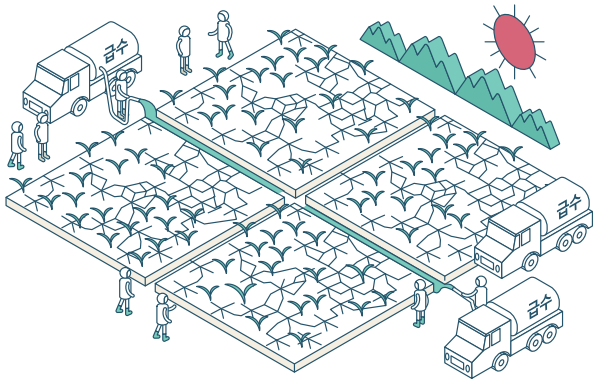
By improving the areal precipitation method considering characteristics of terrain and enhancing river basin precipitation index, the KMA is expected to not only contribute to protecting life and property from natural disasters, but also lay a foundation for the government's stable water management.

Meteorological Drought Monitoring and Prediction Information

Drought occurs more frequently in recent years in Korea. Localized drought, especially, has lasted for five years resulting from localized precipitation. The central part of the country, for instance, received significantly less precipitation between 2013 and 2016, and in 2017 the southern part of the nation experienced lack of precipitation.

The KMA expanded and improved meteorological drought information service for better use of drought information so that it can prevent drought disasters in advance and minimize the impacts. To this end, first, the KMA added river basin drought information (117 basins) to the existing drought information by administrative district to strengthen drought response, extended the period of Percent of Normal Precipitation (PN), and additionally provided Standardized Precipitation Evapotranspiration Index (SPEI). Second, the KMA developed a specification method of climate prediction models to reduce the uncertainty of climate prediction to shift from definitive drought forecasts to categorical probabilistic drought forecasts — for instance below, similar to, or above normal precipitation. In addition, it allowed its regional offices to directly generate and deliver region-specific drought forecasts to give local governments more assistance for their response to drought.

To take proactive steps to prevent and minimize the impacts of regional droughts, the KMA plans to offer meteorological drought forecasts to the general public from November 2018.



Meteorological Industry

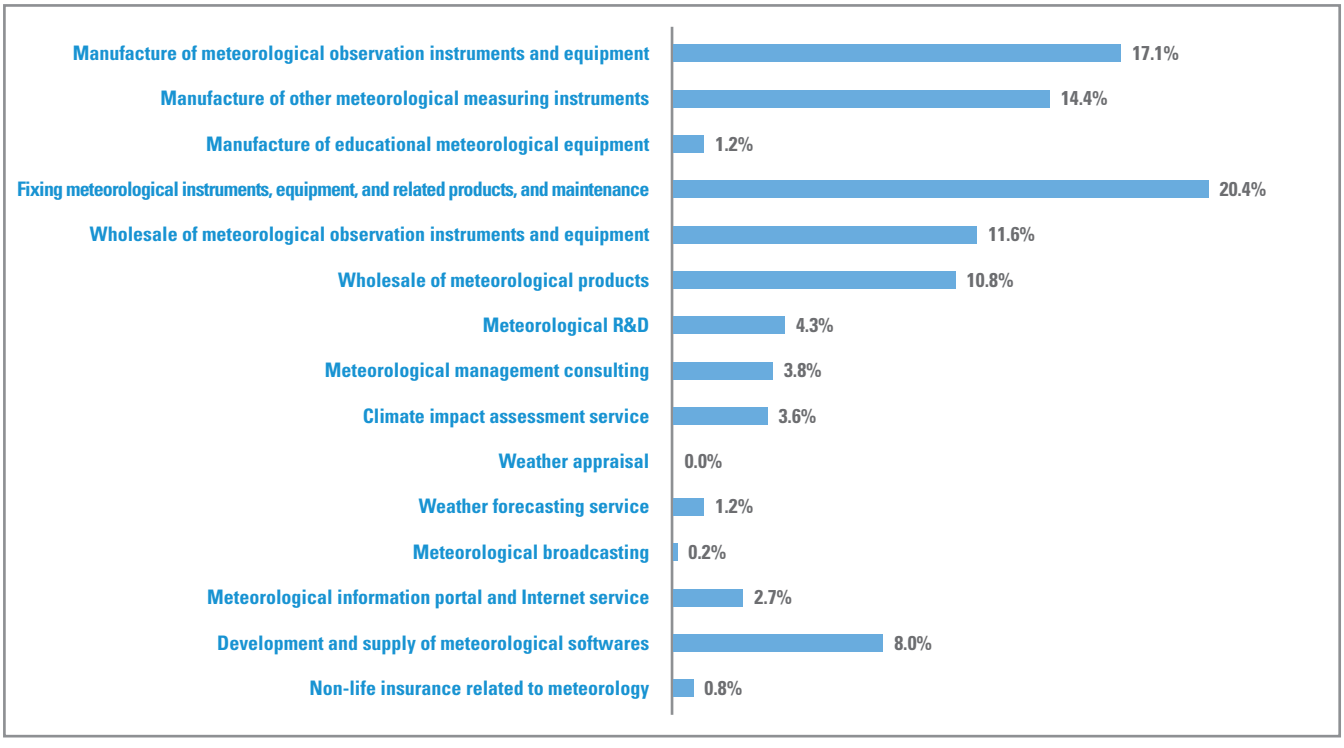
Meteorological Industry in Korea

The Korea Meteorological Administration focuses on discovering and promoting cases of using meteorological information in an effective and efficient manner to mitigate weather and climate risks and create economic values. It also provide supports for the opening and growth of meteorological businesses providing various services with meteorological information to increase the market and demand of meteorological services and enhance the capability of service suppliers.

With the advent of the fourth industrial revolution era, IoT (Internet of Things) sensor-based high-resolution weather observation system, artificial neural network or AI-based forecasting technologies have developed, and discussions over developing weather service fused with these new technologies are actively underway.

Number of Meteorological Businesses

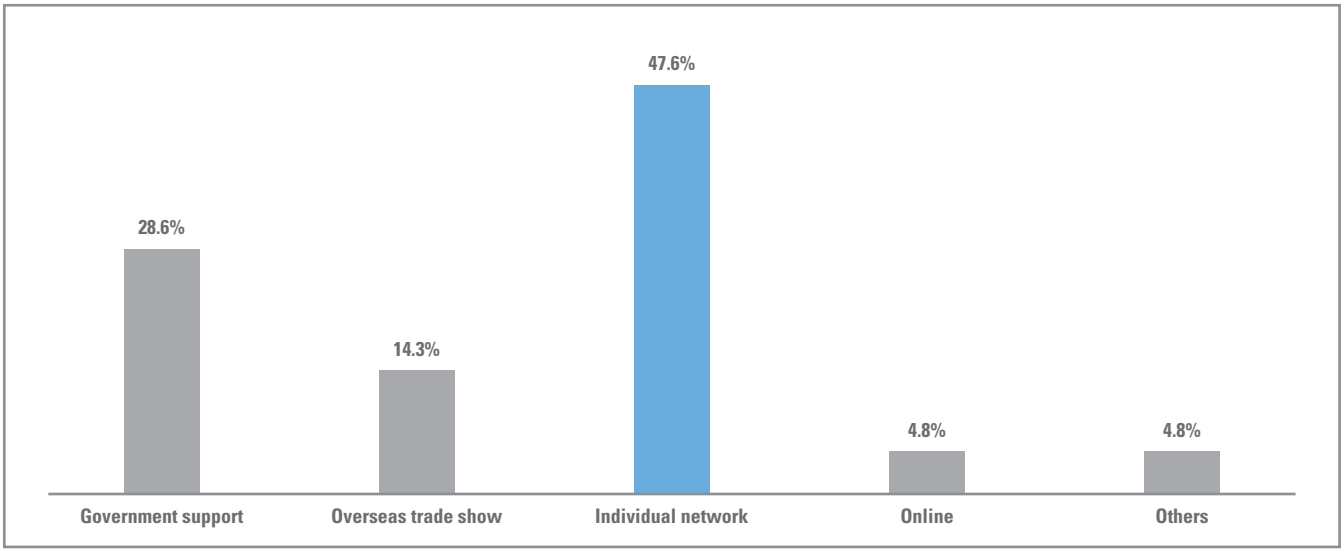
A survey showed that there are 603 meteorological enterprises across the country (as of December 2016) which fall into the definition and category (15 subcategories) of meteorological industry. One of the most representative types of business was fixing meteorological instruments, equipment and related products, and maintenance (20.4%), followed by manufacturing meteorological observation instruments and equipment (17.1%) and manufacturing other meteorological measuring instruments (14.4%).



Breakdown of meteorological industry in Korea (2016)

Import and Export in the Korean Meteorological Industry

The total values of imports and exports in the meteorological industry recorded at KRW 39.4 billion won and 10.8 billion won, respectively. Breaking down by business type, the business of manufacturing other meteorological measuring instruments represented the largest share in terms of export, followed by whole sale of meteorological products. On the other hand, wholesale of meteorological observation instruments and equipment accounted for the biggest share in terms of import, followed by whole sale of meteorological products. The main channels for export was individual network (47.6 %), governmental support (28.6 %), and overseas trade show (14.3 %).



Breakdown of export channels in the meteorological industry (2016)

Weather Industry Promotion Act

Even though demands for meteorological information from different industrial sectors have been growing and getting more specific, the size of the meteorological industry and market was smaller as compared to other industries. To invigorate the industry and market, the KMA enacted Weather Industry Promotion Act in 2009 which contains the provisions to support and foster the industry to lay a foundation for the growth of the weather industry in Korea and enhance its competitiveness. The Korea Meteorological Industry Promotion Agency (KMIPA), a subsidiary agency of the KMA, changed its name to Korea Meteorological Institute (KMI), and it redefined its role by unifying the work of planning, management, evaluation, and utilization in research and development projects. Eased regulations regarding the industry also contribute to revamping the economy.

New Steps to Promote Meteorological Appraisal Market

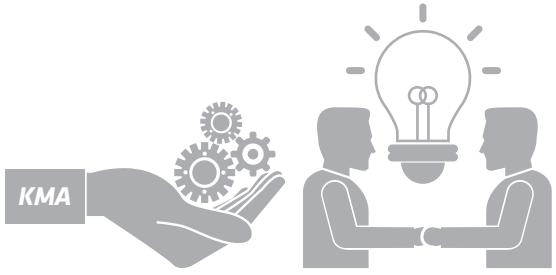
The KMA gave a definition of weather appraisal business in 2009, and adopted a license test for weather appraisers in 2012 to foster qualified professional weather appraisers. Also, it inserted a new provision in the Enforcement Decree of the Weather Industry Promotion Act with regard to the range of weather appraisal business in 2016, and then it enacted a Public Notice on Weather Appraisal Business Procedures in 2017.

In addition, as part of follow-up measures, the KMA developed a standard manual for weather appraisal to offer standards and examples and facilitate the business.

Technology transfer to Meteorological Businesses

The KMA has transferred its own meteorological technology to private weather enterprises to help strengthen their capability and technology. The transfer which began in 2005 includes software specialized in generating user-specific weather information, improvement reports, operational manual, etc.

Eighty types of meteorological technology were transferred to 54 meteorological businesses (459 times) from 2005 to 2017, contributing to the vitalization of the weather industry. In 2017, 26 kinds of technology (71 times) were transferred to 10 businesses. Among them, newly transferred technologies in 2017 were nine: prediction of Japanese flying squid per sea section; region-specific prediction of severe rainfall risks; advanced heat environment information for Busan; analysis of pollen from Japanese cedar in Jeju and specific wind fields; Danyang's aronia-specific weather information; development of biological weather information for supporting bee farming industry; quantification of Koreans' body heat stress; guideline for meteorological impact assessment; analysis of the validity of perceived temperature.



» **Transfer of meteorological technology to private weather businesses**

Year	'05	'06	'07	'08	'09	'10	'11	'12	'13	'14	'15	'16	'17	Total
Number of cases	12	48	7	4	4	11	24	24	45	51	99	59	71	459
Number of types	2	10	2	3	4	8	3 (6)	3 (6)	5 (10)	6 (18)	10 (22)	15 (11)	9 (17)	80
Number of businesses	6	4 (6)	(4)	(3)	1 (1)	2 (1)	4 (4)	3 (4)	7 (4)	6 (8)	6 (7)	5 (8)	10	54

* ( ): the number of overlapped technologies transferred in the past

Information & Telecommunication

The Global Telecommunication System (GTS) is a global network established in the 1960s for the transmission of meteorological data between WMO member countries. The GTS plays a key role in acquiring global meteorological data which is integral to the generation of weather charts and operation of numerical weather prediction models.

As the existing GTS showed its limitations in exchanging and accessing a large volume of (numerical model, satellite) meteorological data, the WMO has carried out developing a new concept of WIS (WMO Information System) since 2003, which can supplement the previous telecommunication system. The WIS not only has the existing functions of the GTS, but also provides Discovery, Access and Retrieval (DAR) service. Also, its governance consists of Global Information System Centre (GISC), Data Collection or Production Centre (DCPC), and National Centre (NC).

In June 2012, the GISC Seoul was designated as one of 15 GISCs. The GISC Seoul, which has come into full operation in March 2013, is responsible for operating three DCPCs (DCPC WAMIS, DCPC LC-LRFMME, DCPC NMSC) and one NC (http://gisc.kma.go.kr). In accordance with the WIS manual, the GISC Seoul manages the metadata of the three DCPCs and exchanges a total of 527 metadata with other 14 GISCs under the WIS community.

In addition, jointly working with the UK, France, Australia, the U.S. and Finland, the KMA, as a co-director has participated in the OpenWIS, a non-profit organization in the development of business strategies with open source-based software developers. Thereby, the KMA was recognized for its work in establishing government agencies-led business models for open software, contributing to the WMO community.

For the stable operation of the GISC Seoul, the OpenWIS, an operating software for WIS center, was upgraded to the latest version (v3.13.1 to 3.14.8). The newly established Real-time Monitoring System of Global Meteorological Data enables us to get statistical information on the routes and types of data acquired by the GISC Seoul. Moreover, the KMA launched the TDCF Conversion Service, which offers text files from TDCF (Table Driven Codes Form), in the GISC Seoul Portal in order to improve end users' utilization of the data.

Main page of GISC Seoul Portal site (http://gisc.kma.go.kr)

International Cooperation

Multilateral Cooperation

2017 was the year when the KMA enhanced its leading role and expanded the participation of Korean experts in the international community by actively getting involved in WMO technical commissions and a wide range of expert meetings. The KMA, as a member of WMO executive council, sent its delegates to major WMO meetings, such as the 17th Session of the Commission for Atmospheric Sciences (CAS), the 5th Session of the Joint WMO-IOC Technical Commission for Oceanography and Marine Meteorology (JCOMM), and the 16th Session of Regional Association II (RAII), to further contribute to the development of international meteorological policies. At the 17th Session of CAS, the former administrator of the KMA, Dr. NAM Jaecheol, was relected as the vice-president of the Commission.

The KMA also hosted several WMO-related meetings. For instance, it held 12th UNESCAP/WMO Typhoon Committee Integrated Workshop (IWS-12) from October 30 to November 3 in Jeju Island, which was joined by 137 participants from 12 out of 14 member countries, UNESCAP/WMO Typhoon Committee, WMO Secretariat, and other people concerned, to offer an opportunity to share typhoon analysis, damage assessment and achievements of each member state. Regional Workshop on Impact-based Forecasts in RAII was taken place from November 7 to 9 in Seoul, which served as a platform to share knowledge, technology and policies in NMHSs associated with impact-based forecast among around 100 experts from 24 countries and to promote the implementation of the impact-based forecasts. In addition, the KMA will host the 17th Session of Commission for Agricultural Meteorology in conjunction with Women's Agrometeorology Leadership Workshop attended by around 200 participants from 91 Member states, resulting in fruitful outcomes regarding its four focus areas and the reorganization of the WMO's technical commission structure.

As part of efforts to nurture international professionals, the KMA has also run a training course for Korean undergraduate and graduate students for the past 4 years. In 2017 it selected competent students and dispatched them to relevant international organizations, including WMO, Typhoon Committee (TC), Asian Disaster Preparedness Center (ADPC), International Centre for Water Hazard and Risk Management (ICHARM), and United Nations Economic and Social Commission for Asia and the Pacific (ESCAP).

The 69th Session of the World Meteorological Organization (WMO) Executive Council (June 2017)

Intergovernmental Panel on Climate Change (IPCC)

As a focal point for the IPCC of the Republic of Korea, the KMA plays a key role in coordinating international and domestic cooperation relevant to IPCC activities. The KMA attends an IPCC plenary which is held an average

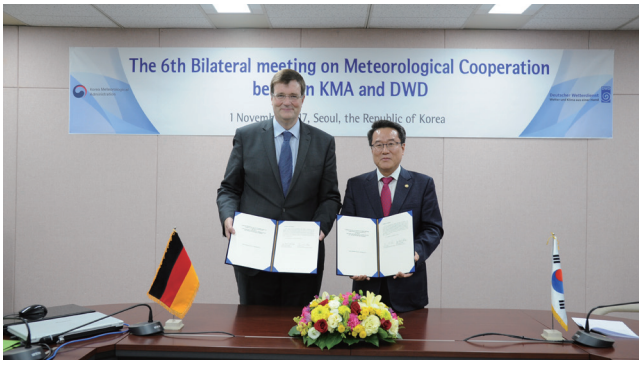
of twice a year to review and make key decisions of the IPCC with government representatives around the world. Korean specialists from different fields including government agencies and academia participated in the process of approving the outlines of the Special Report on the Ocean and Cryosphere in a Changing Climate (SROCC) and the Special Report on Climate Change and Land (SRCCL) at the 45th Session, as well as in three working group's contributions to the IPCC Sixth Assessment Report (AR6) at the 46th Session. Furthermore, two Korean experts will get involved in the preparation of these two special reports until 2019. The 48th Session of the IPCC will be held in Korea.

Global Framework for Climate Services (GFCS)

The Global Framework for Climate Services (GFCS), one of the priorities of the WMO, is aimed at developing and delivering science-based climate services in climate-sensitive areas to assist decision-making at all levels, in which the KMA has participated since its beginning stage as a member of the Management Committee. As contributions to the GFCS, the KMA has sponsored projects for the development of climate forecasting systems in East African countries, such as Rwanda, Uganda, Djibouti, Burundi and Tanzania, to improve their respective climate services in cooperation with the IGAD Climate Prediction and Application Centre (ICPAC).

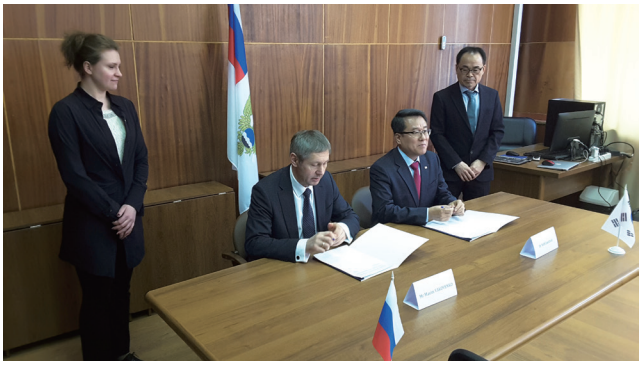
Bilateral Cooperation

A range of activities were carried out in 2017 to strengthen bilateral cooperation. The KMA renewed its bilateral agreement with the Met Office to continue cooperation between two agencies for the next five years. It also held regular meetings with a number of countries in a bilateral relationship — Taiwan, Russia,

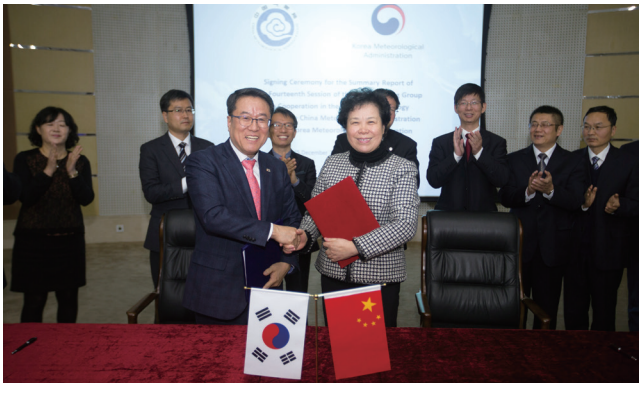


The 6th Bilateral Meeting between KMA and DWD

The 6th Bilateral Meeting between KMA and PAGASA



The 9th Bilateral Meeting between KMA and Roshydromet



The 14th Bilateral Meeting between KMA and CMA

the Philippines, EUMESAT, Germany, India, and China — to ensure coherent human and technical exchanges. The KMA advisors who have been dispatched to the Civil Aviation Authority of Qatar has continued to do their tasks toward the development of meteorological services in Qatar. In addition, the delegation of Nigeria headed by Administrator Sani Abubakar Mashi visited the KMA to discuss the ways to develop a cooperative relationship.

Development Cooperation

Modernization of Forecasting and Warning System for Natural Disaster in Myanmar (2017-2019)

The KMA established a master plan for modernizing national weather services in Myanmar from 2015 to 2016. As a follow-up project, the Korea Meteorological Institute (KMI), an implementing agency of the KMA, will carry out a pilot project for the next three years.

Installation of Automatic Weather System (AWS) in Mongolia (2017-2019)

By the request of Mongolia, the KMI, sponsored by the KMA, initiated this project to modernize surface observation system by installing automatic weather system (AWS) at 32 weather stations in the vicinity of the capital of Mongolia and changing manual systems.

Climate Data Rescue Project in Uzbekistan (2013-2018)

With the sponsorship of the KMA, the WMO has conducted Climate Data Rescue Project for Uzbekistan since 2013 which aims at transforming the climate data in paper format into image files. As of July 2017, it completed the transformation of four million pieces of paper and by the end of the project, another 6.5 million plans to be transformed and stored in the database.

Coastal Inundation Forecasting Demonstration Project-Fiji, Phase Ⅱ-Ⅵ (2016-2019)

The WMO plans to implement the next phase of this project based on the road map derived from the phase Ⅰ of the project which has been sponsored by the KMA. The next phase focuses on the development of coastal inundation forecasting model (wave, storm surge, river inundation, etc.), installation of associated equipment (buoys), publication of manuals, and education.

Cooperation between two Koreas

The KMA has accumulated meteorological technologies to acquire information about North Korean by analyzing the past and future climate, data, and forecasts. The KMA released 2016 Annual Weather Report of North Korea in 2017 using quality-controlled data of North Korea which were collected through the WMO's GTS. Also, the short- and medium-range forecasts have been produced for main regions in North Korea, just as have been done in South Korea. Additionally, an analysis of weather characteristics, extreme weather events, and earthquakes in North Korea has been provided to the KMA website on a monthly basis.

To be well prepared for the possible eruption of the Baekdu Mountain in North Korea, the KMA has been carrying out a R&D project on the prediction of volcanic activities by analyzing the transformation of surface and volcanic gases. Moreover, it has been operating a volcanic ash dispersion model in case of a volcanic eruption in East-Asia.

International Training and Education

International training course for improving weather services in WMO Member countries

The KMA was designated as a WMO Regional Training Center (RTC) in June 2015 at the 17th Session of the World Meteorological Congress. Then it signed a MoU with the WMO in June 2016 to better cooperate with global meteorological training and education. They shared a consensus on the need to enhance the capacity of meteorologists and meteorological technicians in member countries for respective public weather services, aviation, marine and hydrological forecasting, and climate services, as well as collaborating to establish the WMO Global Campus.

The RTC-Korea operated a variety of training courses, such as ICT for meterological services, weather radar operation and data utilization, weather forecast for foreign experts, to share meteorological technologies and know-how with a budget allocated to Official Development Assistance (ODA).

In addition, it joined a 2016 global capacity building program offered by the Korea International Cooperation Agency (KOICA) to provide training courses on weather forecasting and satellite data application using Information and Communication Technologies (ICT).

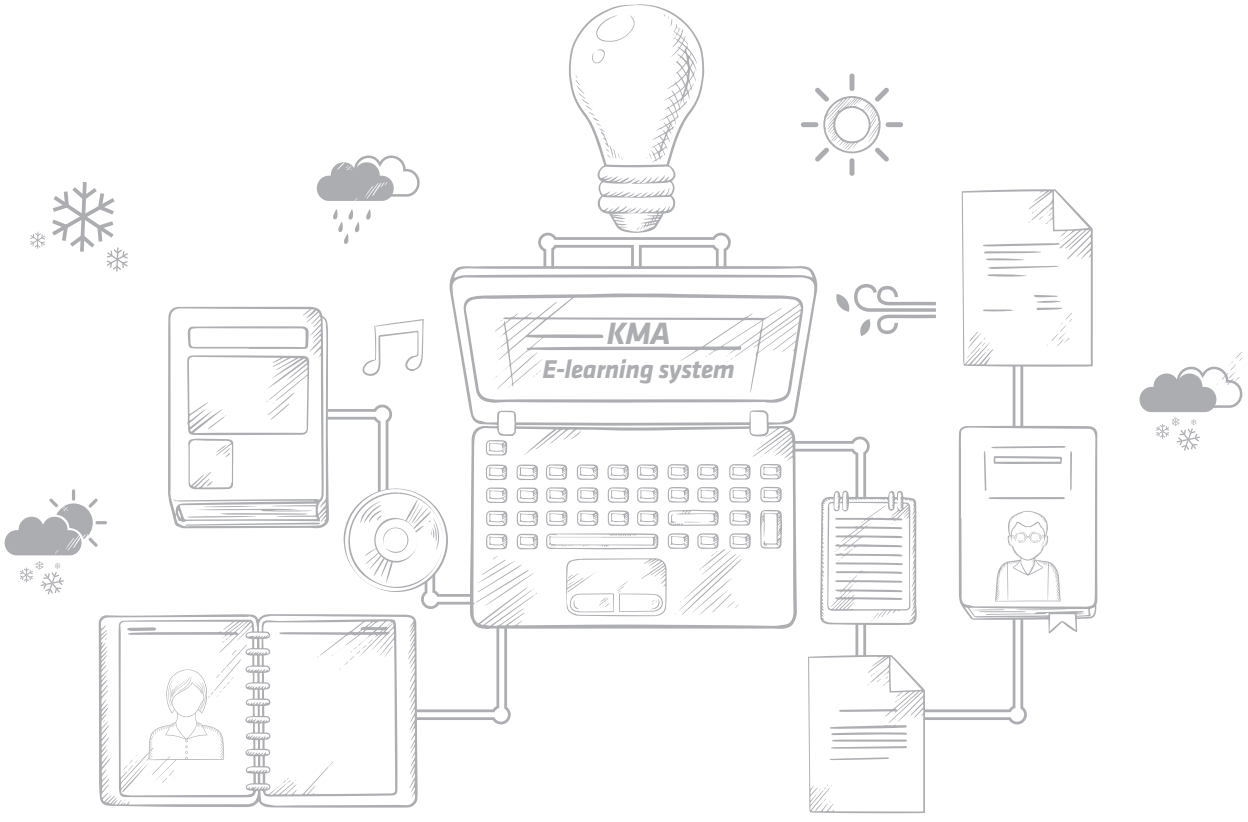
Sponsored by KOICA, the KMA signed a MoU with the Hankuk University of Foreign Studies to offer a master degree program in atmospheric sciences as one of the RTC-Korea programs. The program is aimed to give a chance up to 15 students from developing countries to allow them to acquire a master's degree and gain expertise required for public weather services. The KMA has been supporting the program by providing appropriate instructors and designating mentors for individual students, taking into consideration the topics of respective students' dissertations (www.hufs.ac.kr/gra).

» RTC-Korea Education Program for Developing Countries

Training Title	Year	Duration	Size	Region	Participants
ICT for Meteorological Services	2006~2017	21 days	15 persons	RA Ⅱ	211 persons
Meso-scale Numerical Weather Prediction	2007~2013	60 days	1~3 persons	RA Ⅱ	10 persons
Analysis of COMS data	2007~2017	28 days	13~19 persons	RA Ⅱ, RA Ⅲ, RA Ⅴ	132 persons
Weather Radar Operation and Data Utilization	2012~2017	14 days	16~19 persons	RA Ⅱ, RA Ⅴ	96 persons
Weather Forecast	1998~2017	26 days	14~25 persons	RA Ⅱ, RA Ⅴ	221 persons
Improvement of Meteorological Disaster Responsiveness	2009~2012	21 days	10~17 persons	RA Ⅰ	50 persons
Others					169 persons
Total					889 persons

E–learning system for meteorological eduction

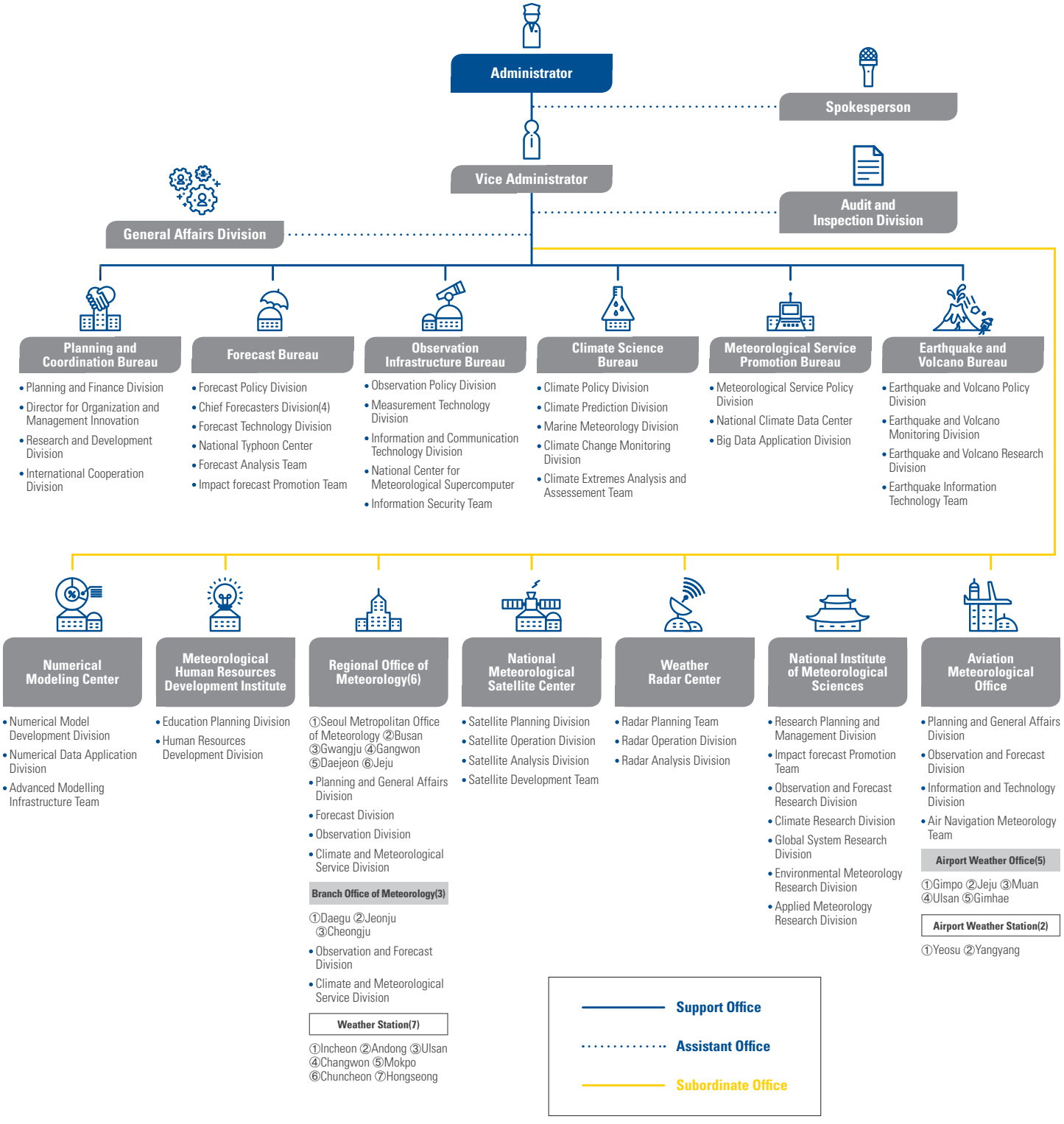
The KMA has been developing meteorological educational contents which reflect the latest trend and meteorological technologies to allow people at home and abroad to take lessons through KMA's e-learning and academic credit bank system. In 2017, it newly developed contents for synoptic meteorology, understanding of earthquake, tsunami and volcano, and general meteorology (in English). The KMA e-learning system offers an opportunity for anyone to obtain meteorological knowledge by taking advantage of the newest education materials. This academic system also continues to contribute to fostering professional personnel specialized in the field of meteorology and climate science, along with hands-on experiences.



APPENDIX

- Organizational Chart
- Staffing
- Budget

Organizational Chart (as of 1 December 2017)



Staffing

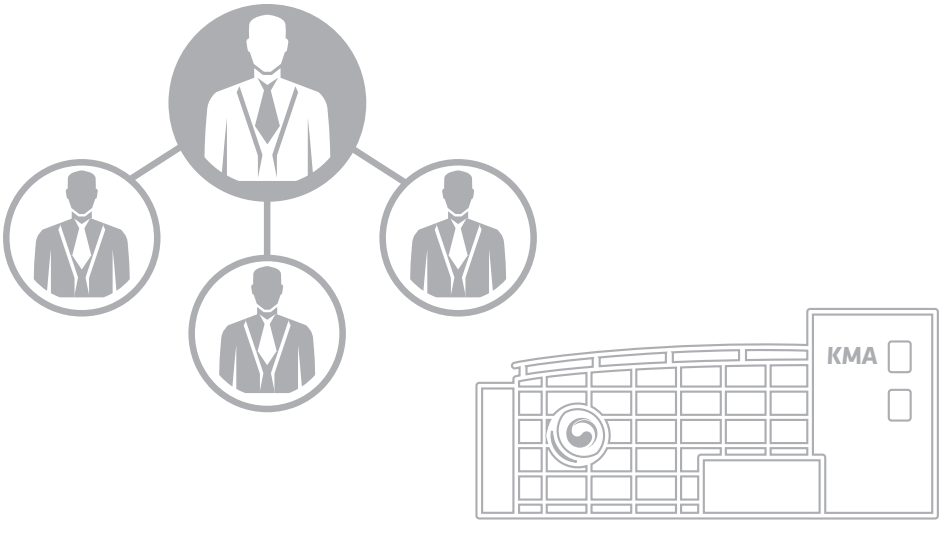
Number of staff members

(As of 31 December 2017)

Category	HQ	Regional Offices			NMC	MHRDI	NMSC	WRC	NIMS	AMO			Total
		Main (6)	Branch (3)	Station (7)						Main	Office (5)	Station (2)	
Quota	397	355	133	37	45	17	48	42	109	56	51	8	1,298
Current	415	378	142	40	46	17	47	40	108	56	51	8	1,289

Human Resources

Degree	Ph. D	Master	Bachelor	Diploma or lower	Total
Number of qualified workforce	129	367	809	193	1,498



Budget

The KMA's budget in 2017 was all complied into general accounts. The revenue was amounted to KRW 6,887 million, increased by KRW 1,116 million or 19.3%, while the expenditure was KRW 385,276 million, decreased by KRW 16,810 million or 4.2% compared to the previous year.

The expenditure can be divided into labor costs (KRW 90,742 million, increased by KRW 3,670 million or 4.2% YoY), basic expenses (KRW 18,740 million, the same as last year), and major project costs (KRW 275,794 million, decreased by KRW 20,480 million or 6.9% YoY). Of the total, these classified costs accounted for 23.6%, 4.9% and 71.6%, respectively.

The major project expenses consisted of general projects (KRW 97,732 million, 35.4%), R&D (KRW 116,926 million, 42.4%), IT (KRW 56,127 million, 20.4%) and ODA (KRW 5,009 million, 1.8%). Meanwhile, the budget for constructing new office buildings were transferred from the general accounts to the National Property Management Fund under the auspicious of the Ministry of Strategy & Finance (MOSF) from 2012, drawing up KRW 8,573 million for the Metropolitan Regional Office, Baekryeongdo, and Hongsung weather stations.

2017 Expenditure Budget for each Program

(unit: KRW million, %)

Program Classification	2016 Budget (A)	2017 Budget (B)	Up(△)Down (B-A)	Up(△)Down(%) (B-A/A*100)
Total	402,086	385,276	△16,810	△4.2
1. Weather forecast	8,784	8,669	△115	△1.3
2. Weather observation	73,245	86,023	12,778	17.4
3. Climate change sciences	26,090	27,491	1,401	5.4
4. Weather service promotion	15,738	15,505	△233	△1.5
5. Meteorological research	145,377	108,395	△36,982	△25.4
6. Performance-based agency operations	13,407	12,988	△418	△3.1
7. International Cooperation, Education and Training, and Public Relations	8,749	8,698	△51	△0.6
8. Administrative support	110,696	117,507	6,810	6.2

2017 Weather patterns over Korea

During the year 2017, the Korean Peninsula experienced a variety of significant extreme weather events such as abnormal high temperatures, draught, localized torrential downpour and heat waves.

The mean temperature in April and May were 13.9℃ and 18.7℃ which ranked the second highest and the most highest temperature, respectively, since 1973. In particular, for May, the top five highest temperatures in May have occurred since the 2000s — 2012, 2014, 2015, 2016, and 2017 — setting a new high for four consecutive years since 2014.

In May and June, severe drought has hit the country with precipitation of 29.5㎜ and 60.7㎜, respectively, accounting for 29% and 38% of the normal. This means these two months were the second and the third driest month since 1973. The national average number of days with precipitation in May was 5.7 days, 2.9 days less than the normal, which was the third fewest since 1973.

During the Jangma (Korean monsoon system) period in 2017, the average precipitation across the country was 291.7㎜, 81% of the normal, and there were big regional differences in precipitation because of frequent localized rainfalls. In particular, the difference of precipitation between the southern and middle part of the country was 254.9㎜ during the period, well above the normal of 17.8㎜. Among the middle parts of the country, Cheongju and Cheonan had heavy precipitation of 290.2㎜ and 232.7 , respectively, on 16 July, breaking the record of daily precipitation.

In July, the mean temperature was 26.4℃, 1.9℃ above the normal of 24.5℃, with heat wave of 6.4 days. Compared to the same period of the previous year, the number of heat wave days increased by 5.5 days, which is 1.5 times the normal (3.9 days). Moreover, heat waves were frequently witnessed across Gyeongsang Province, the eastern parts of Gangwon Province, and Jeju Island. Jeju Island, especially had a heat wave of 7.5 days, the highest number of heat wave days since 1973.

Climate extremes such as heat waves and localized heavy rainfall during the monsoon season caused damage to a wide range of fields such as agriculture, fishery, forest, environment, and health. The property damage was estimated at 87.2 million won in total, including flooding and broken underground pipes caused by localized heavy rain in the western parts of Gangwon Province and the middle part of the country, from July 2 to 11, and from July 14 to 16, respectively. The unprecedented heat waves and high temperatures of the seas around the Korean Peninsula resulted in 1,574 cases of heat-related illnesses and a 7% decline in fish catch.

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