Vision for Meteorological Services in 2030

Public-focused meteorological service development against a background of increased disaster occurrence and societal change

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Proposal Outline

Changes observed in recent years in Japan have included an intensification in the scale of natural disasters (such as the heavy rain event of July 2018) along with demographic aging and a declining birthrate. At the same time, a concept known as Society 5.0 has been advocated as a national target, with the expansion of information and communications technology (ICT) to various fields. In light of these developments, five specific discussions have been held on meteorological services with a medium- to long-term perspective for the next 10 years, and recommendations for the Japan Meteorological Agency (JMA) have been compiled as outlined below.

Direction of meteorological services focusing on science and technology toward 2030

- Meteorological services in 2030
  - Ever-greater roles for meteorological services by 2030 for protection of life/property and quality of life
  - Ongoing innovation and improvement of observation and forecasting techniques via constant incorporation of cutting-edge technology; further utilization of meteorological information/data as an integral part of soft infrastructure and as a common public asset

- Protection of life/property and quality of life supported by meteorological services
  - Appropriate disaster mitigation and response to extreme phenomena
  - Ideal lifestyles for all
  - Innovation in economic activity and other areas

- Direction of meteorological services
  - In consideration of changes in natural/public environments and technological progress expected by 2030, JMA development efforts for disaster risk reduction with a twin-pronged approach toward improved observation/forecasting accuracy and enhanced utilization of meteorological data

Priority issues

Meteorological service provision based on the science and technology of 2030 requires 1. technological development in observation and prediction as major elements of meteorological services, 2. promotion of meteorological information usage in various fields, and 3. enhancement of disaster management and support with JMA as the core government body. The relevant targets are outlined below.

- Development of technologies to improve accuracy in observation and forecasting

1. Weather and climate
    - Enhanced accuracy of meteorological observation and forecasting for immediate evacuation and public safety
    - Improved forecast accuracy for disaster mitigation measures up to 12 hours in advance
    - Improved forecast accuracy for typhoons, torrential rain and other phenomena to support wide-area evacuation in preparation for large-scale disasters several days in advance
    - Improved forecast accuracy with lead times of several months to help reduce climate risk and improve productivity
    - Provision of information with lead times of up to a century to support policy decisions on global warming countermeasures and adaptation

2. Earthquakes, tsunamis and volcanoes
    - Provision of simple information on status and outlooks for earthquakes to support appropriate evacuation/mitigation and related rescue/recovery
    - Provision of data on expected timing of initial and largest tsunami waves, outlooks for the lifting of warnings to support appropriate evacuation
    - Issuance of eruption warnings based on accurate predictions of volcanic activity, and higher precision volcanic ash fall forecast, to support long-term disaster mitigation

- Promotion of meteorological data/information usage

1. Establishment of environments for access to meteorological information

- Promotion of efficient distribution for meteorological information as a common public asset via combination with various types of big data and other channels
- Expansion of basic meteorological data and improvement of environments for ready acquisition
- Improvement of information accessibility
- Review of systems in response to technological innovation (e.g., deregulation)

2. Improvement of information literacy
    - Enhancement of meteorological literacy for appropriate disaster response and public safety
    - Promotion of meteorological information usage in economic activity

- Promotion of public disaster mitigation for life and property
    - JMA's public-agency performance of a central role in improving weather information using advanced technologies and promotion of understanding and utilization of weather information for synergistic effects toward increased public disaster awareness

Basic and cross-sectional measures for initiative promotion

- Ongoing verification and improvement based on public demand

- Sustained and effective efforts via public-private-academia/international collaboration

- Strengthening of institutional structure and technological infrastructure

Outline

I. Introduction

The provision of meteorological services in Japan began in 1875, when the Tokyo Meteorological Observatory (the predecessor of today's Japan Meteorological Agency (JMA)) began observing weather and earthquakes.

In 1959, JMA became the first government agency to use a large computer for scientific calculations, and started numerical forecasting to predict atmospheric conditions using physics equations. This was followed by observation using the first Himawari meteorological satellite in 1978 and the introduction of Earthquake Early Warnings in 2007. The Agency engages in constant development to incorporate cutting-edge expertise in natural science and technology in the fields of computing and information/communications. JMA's comprehensive observation network allows constant nationwide monitoring of weather, climatic conditions, oceans, earthquakes, tsunamis and volcanoes, as well as analysis and prediction of phenomena using supercomputers with capacity a trillion times faster than the first-generation machines. Observation and forecasting activities are also expanding in the private sector.

Results from observation and numerical forecasting, as well as information such as warnings and forecasts (referred to here simply as *meteorological information*) from JMA and private operators, are provided to the general public to support disaster mitigation, everyday living and socio-economic activity, and are today seen as common public property.

The roles played by meteorological services in disaster mitigation, traffic safety and commercial prosperity necessitate ongoing development of observation and forecasting techniques. As meteorological information must meet consumer need to be effective, there is also a requirement for more sophisticated and diversified data for today's natural/social environments and the requirements of the times.

The natural environment continues to change. In recent years, as seen with the torrential rains of August 2014 and those in northern Kyushu in July 2017, rainfall has become more localized, more concentrated and more intense. In the Heavy Rain Event of July 2018, unprecedentedly heavy rain fell over wide areas, resulting in extensive landslides and flood damage. Other extreme conditions have also caused damage in many areas, including heavy snowfall in the Hokuriku region in 2018 and heatwaves that have brought unprecedented summer temperatures to many parts of Japan from July onward. Ongoing global warming brings concerns that the frequency of disastrous heavy rainfall and extremely high temperatures will further increase, in addition to disasters caused by earthquakes, tsunamis and volcanic eruptions such as the 2011 Great East Japan Earthquake, the 2016 Kumamoto Earthquake and the 2014 eruption of Mt. Ontake. Future disasters may cause tremendous damage, including the predicted Nankai Trough Mega Earthquake, a potential Tokyo Inland Earthquake directly under the capital, and associated volcanic activity.

Japan has a declining birthrate and an aging demographic that may negatively affect local disaster preparedness as the number of community leaders decreases and the number of disaster-vulnerable people increases. It is important to improve productivity in light of the declining working-age population, and international factors such as an increased number of visitors and residents from overseas are expected to take on even greater importance.

In advanced technology, the 5th Science and Technology Basic Plan advocates the ideal of an Ultra-smart Society 5.0 with ICT applied in various fields for universal quality of life. This heralds the start of an era of great change.

In consideration of the natural environment, social change and expected technological advancement, the Meteorological Subcommittee under the Council of Transport Policy embraces a medium- to long-term vision to ensure that meteorological services provided by JMA and various other organizations continue to develop. This is intended to contribute to the resolution of meteorology-related issues and further progress in various fields such as disaster mitigation, everyday living and economic activity. To these ends, five specific discussions have been held on meteorological services with a medium- to long-term perspective for the next 10 years, and recommendations for JMA have been compiled.

This report outlines current status and issues related to observation/forecasting technology for weather, climate, earthquakes, tsunamis, volcanoes and other phenomena, and utilization of the meteorological information produced. The content also suggests potential directions for meteorological services toward the science and technology environment of 2030, and highlights priority issues in this regard.

II. Current status and issues in meteorological services

JMA and private operators collect data on weather, climate, oceans, earthquakes, tsunamis, volcanoes and other natural conditions via observation and various instruments. The resulting information is processed using supercomputers for analysis, prediction and development of information for provision to local governments, news organizations and private entities for disaster mitigation and various purposes in the public and commercial sectors.

In this context, JMA works to ensure the sound development of meteorological services based on observation and forecasting, provision of resulting information, promotion of related work by local governments, media organizations and private enterprises, and utilization in various areas of socioeconomic activity.

This chapter reports on current status and issues related to observation/forecasting technology and utilization of meteorological data.

1. Observation and prediction technology

(1) Weather and climate

<u>Status</u>

While Japan enjoys various blessings from the varied weather of its four distinct seasons, meteorological phenomena such as typhoons, a marked rainy season and heavy snowfall can cause tremendous damage. Due to the country’s steep and complex topography and geology, heavy rainfall can also cause significant flood damage and landslides, and weather can be changeable and unpredictable.

Against this background, JMA’s comprehensive core observation network is leveraged to provide a three-dimensional picture of atmospheric conditions. The system optimally combines wide area observation using remote sensing technology (such as the Himawari geostationary meteorological satellite and weather radar) with direct observation using the AMeDAS regional meteorological monitoring system and radiosondes. The Agency provides a variety of meteorological information on precipitation, such as high-resolution nowcasts with a 250-meter mesh resolution and analysis every five minutes, along with forecasts up to an hour ahead and information on estimated weather distribution accompanied by hourly temperature and weather data calculated with a fine 1-km mesh resolution.

Data are also collected from various related organizations. These include information from rain/snow gauges and weather radars operated by Japan's Ministry of Land, Infrastructure, Transport and Tourism and local governments, GNSS observation data from the Geospatial Information Authority of Japan (used for estimating atmospheric water content) and satellite data from domestic and international organizations.

Information is also gathered from private meteorological service providers. These private operators, as well as various private enterprises such as electric power, transportation and telecommunication companies, conduct meteorological observation for their own needs. The rapid progress of IoT in recent years has enabled real-time collection of observation data from their sensors.

JMA uses supercomputers in processing these data and analyzing atmospheric conditions to support numerical forecasting as a fundamental technology. Multiple numerical prediction models (e.g., local, mesoscale and global) with lead times ranging from several hours to six months are operated along with different prediction areas from domestic to global, and ensemble forecast models for typhoons and seasons are used to statistically diagnose prediction accuracy based on multiple prediction. While accuracy in such numerical prediction models is among the world's highest, the accuracy of the global model lags behind that of cutting-edge prediction centers in Europe and the United States. Based on these forecasts and data representing weather conditions, precipitation probabilities and other variables (generally known as *guidance*) and mesh information highly relevant to disaster occurrence (e.g., various indices and risk distribution information), weather forecasts, forecasters issue warnings and other types of meteorological information. JMA also provides information on notable high and low temperatures up to two weeks in advance as well as forecasts up to six months in advance in consideration of global atmospheric and oceanic phenomena such as El Niño.

JMA products such as meteorological information, observation data and numerical forecasts are also provided to the private sector for use with in-house forecasts and information and for application in various fields such as disaster mitigation and commerce.

Future issues

To provide ever-more accurate real-time analysis of weather conditions, JMA should continually upgrade its observation network as technology progresses. The use of meteorological observation data from various organizations, as well as huge amounts of data from smartphones and other terminals associated with IoT development, is currently limited in this regard. It is necessary to improve the information environment so that these data can be widely distributed and effectively used in various fields.

The accuracy of JMA's numerical prediction models improves year by year, and it is essential to keep enhancing precision for extreme phenomena causing significant disasters such as the Heavy Rain Event of northern Kyushu in July 2017 and the Heavy Rain Event of July 2018. Accordingly, it is necessary to maintain cutting-edge accuracy in global models and further improve precision in mesoscale and other models. For example, with torrential rain and localized downpours caused by linear precipitation belts, residents need to be aware of the need to prepare for disasters based on their location and situation (e.g., presence in a hazard zone such as a flood-prone area or a landslide disaster warning area, and the status of heavy rain). It is necessary to further improve accuracy in prediction by specifying times and locations several hours in advance to enable individual evaluation and effective use of information for immediate evacuation where necessary. For the prediction of widespread phenomena caused by typhoons and stagnation of rainy-season fronts, timelines used by local governments to prepare for large-scale flooding require accurate and region-specific evacuation from around three days in advance. Accordingly, it is necessary to further improve accuracy in forecasting for typhoon paths and rainfall (such as total precipitation forecasts focused on specific areas) with lead times of up to three days.

Forecasts with lead times ranging from a week to several months (which help to mitigate damage in agriculture/logistics and improve productivity in production, distribution, sales and other fields) also need to be improved. Other needs include soft-infrastructure measures (such as improved accuracy in heavy-rainfall forecasting) to address the increasing impacts of heavy rainfall, extremely high temperatures and other effects of global warming. Global warming forecast information also requires optimization as a basis for hard-infrastructure measures (such as disaster mitigation and social infrastructure development) by national and local government bodies.

Observation/forecasting technology is essential in meteorological services. Significant improvement of related sophistication and accuracy requires promotion of public-private-academia collaboration and international correspondence, as well as cutting-edge technologies such as artificial intelligence (AI).

(2) Earthquakes, tsunamis and volcanoes

Status

Subduction of the Oceanic Plate under the Continental Plate produces complex interacting forces around the island nation of Japan. Surrounded by the sea, the country has been severely damaged by earthquakes and tsunamis. It is also home to 111 active volcanoes.

JMA monitors seismic activity, tsunamis and volcanic activity 24 hours a day using observation data from seismometers, seismic intensity meters, tsunami observation facilities and other sources nationwide, as well as seismometers, tiltmeters, GNSS and surveillance cameras around volcanoes. The Agency collects and utilizes its own data as well as information from observation equipment operated by the Ministry of Land, Infrastructure, Transport and Tourism, local governments and research institutes.

JMA uses such data and the results of surveys and research to issue various types of earthquake information, tsunami warnings, volcanic warnings, volcanic ash fall forecasts and other output to contribute to disaster mitigation response by national/local government bodies and the public.

The Earthquake Early Warning System, internationally recognized as the first facility of its type, was launched in 2007 to warn people of approaching strong tremors based on immediate analysis and prediction of observation data from seismographs near earthquake epicenters. Around 70 years after the large-scale Showa-Tonankai and Showa-Nankai earthquakes, a large-scale earthquake over the entire Nankai Trough is expected to occur and cause enormous damage. The Report on Disaster Mitigation Measures Based on Earthquake Observation and Assessment along the Nankai Trough (produced by the relevant working group of the Disaster Mitigation Executive Committee of Japan’s Central Disaster Management Council) suggested the issuance of Information Related to Nankai Trough Earthquakes when assessment indicates increased risk, and a system for such issuance was introduced in November 2017. Related government agencies and research institutes also collaborate under the framework of the Headquarters for Earthquake Research Promotion.

Based on lessons learned from the 2011 Great East Japan Earthquake, the capacity for issuance of appropriate warnings for tsunamis caused by earthquakes with magnitudes exceeding 8 has been enhanced. In this context, offshore tsunami observation data can be used to quickly inform and warn residents of tsunamis with updates as necessary.

In response to the eruption of Mt. Ontake in 2014, the government strengthened the observation system around the crater and upgraded the volcanic activity assessment system with efforts for visualization of subterranean structures and other measures. As a member of the Volcanic Disaster Mitigation Council (composed of representatives from relevant national organizations, local prefectures, municipalities and elsewhere) based on the Act on Special Measures Concerning Active Volcanoes, JMA provides information on eruption scenarios and assessment/forecasting of volcanic activity as a basis for consideration of disaster mitigation measures.

Future issues

Since disastrous earthquakes, tsunamis and volcanic eruptions are rare, the mechanisms behind them remain largely unexplained, and prediction often involves technical difficulties. However, due to the very short time between their occurrence and the onset of disaster conditions, it is necessary to further promote efforts for prompt prediction and communication based on observation, including Earthquake Early Warnings, Tsunami Warnings and Volcanic Warnings. In consideration of today’s forecasting technology, efforts should be made to elucidate the mechanisms of phenomena in collaboration with related organizations. It is necessary to provide simple and timely information on the trends and prospects of seismic and volcanic activity.

Ongoing observation of huge earthquakes and accompanying tsunamis must be complemented by further collaboration with research institutes and related organizations. It is also necessary to develop monitoring and evaluation technologies for large-scale tremors (such as the expected Nankai Trough Earthquake) in consideration of potential disaster-mitigation application of information on uncertain phenomena such as transitions and occurrence potential.

Volcanic eruption assessment should be based on expertise regarding subsurface structures in consideration of physics, chemistry, geology and various other factors. The sheer uncertainty of the potential for volcanic activity creates a need for optimal communication in the field.

2. Utilization of meteorological information

Status

JMA provides meteorological information to the public via government bodies, disaster mitigation organizations, media outlets and other channels, as well as to the public at large and to private commercial operators and other parties online and via the Japan Meteorological Business Support Center (a corporation under Article 24-28 of the Meteorological Service Act). The private sector also supplies weather information to the general public. In recent years, IT companies have begun to provide a wide range of information via smartphone apps and other media as part of basic soft infrastructure supporting disaster mitigation, everyday living and socio-economic activity. Such information is today seen as common public property.

JMA promotes meteorological information literacy (rather than mere data provision) in order for such information to be utilized appropriately.

In the area of disaster mitigation, JMA references the 2017 report of the Study Group on Regional Meteorological and Disaster Mitigation Services to promote regional collaboration, and makes efforts during normal times to support local-government literacy in regard to meteorological information for decisions on disaster mitigation. In commercial meteorological market development, utilization of meteorological information in the private sector is promoted by the Weather Business Consortium (WXBC, established in March 2017 via public-private-academia collaboration) based on inter-sector dialogue incorporating new consumers expected to contribute to development in the industry. The Consortium also seeks to clarify private-sector needs and related issues, and to provide meteorological information as necessary.

Future issues

Today’s capacity for real-time online interconnection has created a mainstream environment for the provision of services to meet increasingly diverse public demands using the latest AI technology and IoT, along with information tailored to individual locations, situations, behaviors and interests, using smartphones and other devices. In line with the Basic Act on the Advancement of Public and Private Sector Data Utilization, data distribution via the Internet and other media is promoted to help resolve issues via the creation of new businesses and services using a variety of big data managed by national/local government bodies and private enterprises. Meteorological information is already being distributed and used to a certain extent in society. However, today's conditions necessitate further promotion of new services by facilitating access to weather information and related utilization in combination with various forms of publicly available big data. This requires enhanced provision of various services by the private sector, etc., improvement of JMA website accessibility, and promotion the distribution of meteorological information and enable system review as necessary.

As meteorological information become~~s~~ more diversified and sophisticated, the Government of Japan should promote related literacy and utilization in socio-economic activities such as disaster mitigation, agriculture and tourism via active dialogue and collaboration with local governments, disaster mitigation-related organizations and various commercial and other consumers. This will support mutual action to address meteorology-related problems and create new commercial activity. In this field of disaster mitigation, the intensification of natural disasters caused by recent environmental change requires enhanced mitigation capability (i.e., self-help and mutual assistance) for regional support. Public understanding and utilization of such information is based on provision and solid awareness on weather and earthquakes, forecast accuracy and interpretation of related information. In this context, the reduced scientific knowledge necessitates measures to ensure that education on meteorology and disaster mitigation takes root in schools and in efforts to train related staff. Efforts are also necessary to ensure that information is conveyed, properly understood and utilized by overseas visitors and residents in Japan, whose numbers are expected to increase, to enable appropriate disaster mitigation and positive travel experiences.

III. Direction of meteorological services toward the science and technology of 2030

As 2030 approaches, the environment surrounding meteorological services is expected to undergo major transformation, including changes in the natural environment and societal conditions, and further development of advanced technologies.

This section describes the current outlook for this environment, ideal visions for meteorological services in 2030, and the public contribution of such services based on the status and challenges outlined in Chapter 2.

1. Natural/social environments and technology in 2030

Natural environment

Rainfall in recent years has become more localized, concentrated and intense, causing frequent disaster conditions such as those observed in the Kanto and Tohoku regions in September 2015, the Tohoku region in association with Typhoon No. 10 in 2016, and the northern Kyushu region in July 2017. Record rainfall in July 2018 over western Japan and other areas also caused extensive damage. Notably heavy snowfall and heatwaves have additionally caused damage in many areas in recent years, including snow in the Hokuriku region and other areas in the winter of 2018 and heatwaves that have brought unprecedented temperatures to many parts of Japan from July onward.

Ongoing global warming may further increase the frequency of heavy rainfall and extreme high temperatures, which may result in more natural disasters and cause adverse effects in fields such as agriculture and water provision.

Disasters are also caused by earthquakes and tsunamis, as seen in the 2011 Great East Japan Earthquake and the 2016 Kumamoto Earthquake, and volcanic activity such as the 2014 eruption of Mt. Ontake. The Earthquake Research Committee reports a 70 – 80% probability that a magnitude 8 – 9 earthquake will occur along the Nankai Trough and a 7 – 40% probability that a magnitude 8.8 or greater earthquake will occur along the Kuril Island Trench within the next 30 years. There are also concerns over potentially disastrous phenomena such as an earthquake directly below the Tokyo metropolitan area and volcanic eruptions.

Social environments

Japan has a declining birthrate and an aging demographic that will exacerbate its population shrinkage. The working-age population will also decline, and some local governments (especially in rural areas where depopulation is particularly marked) may become unsustainable or even disappear. In local communities, the number of people involved in disaster mitigation is decreasing as the number disaster-vulnerable people increases, which raises concerns regarding capacity to handle disaster conditions. It is important to improve productivity in light of the declining working-age population and to maintain/supplement service functions essential for everyday living using advanced technology and other resources.

Changes relating to globalization, such as an increased number of visitors and residents from overseas, are also expected. Japan's government expects 60 million overseas visitors by 2030, and the number of foreign nationals living in Japan was approximately 2.5 million as of January 1, 2018 (Current Population Survey of the Ministry of Internal Affairs and Communications) with an expected trend of growth. Visitors in tourism and commerce will interact with people in various parts of Japan on a daily basis, and may even remain in the long term. These need to be addressed.

Technology

The Fifth Science and Technology Basic Plan proposes an ideal Ultra-smart Society 5.0, in which ICT is expanded to various fields. This follows the historical cultural progression of hunting (Society 1.0), agriculture (Society 2.0), commerce (Society 3.0) and information (Society 4.0). Society 5.0 is intended to leverage value via the use of ICT (such as IoT, AI and big-data analysis) and to overcome issues such as a declining birthrate, an aging population and disparities in rural areas. This is expected to support quality of life, improved productivity and sustainable economic growth via the use of autonomous robots and other types of commercial equipment.

The realization of this ultra-smart society is also expected to support the Sustainable Development Goals (SDGs), with a target date of 2030, as proposed at the September 2015 United Nations Sustainable Development Summit.

Worldwide adoption of IoT technology is expected to promote automatic and advanced control in the field, as well as information collection from a vast number of sensors as well as advanced, complex and rapid analysis using big data.

2. Direction of meteorological services toward the science and technology of 2030

(1) Roles of meteorological services in 2030

In view of changes in natural and social environments and further technological development toward 2030, the roles of meteorological services are expected to become even more important in protecting life and property and supporting quality of life.

As such services are based on observation and forecasting technology, there is a need for constant cutting-edge innovation and improvement along with promotion of public use of meteorological information as an indispensable part of soft infrastructure and a common public asset.

(2) Protection of life/property and quality of life supported by meteorological services

<u>Appropriate disaster management for major phenomena</u>

Importance should be placed on promoting understanding and utilization of highly accurate meteorological information produced using advanced technologies and large volumes of observation data to enable appropriate disaster mitigation measures. This should be done a way that is friendly to individual entities (such as local governments, residents, the elderly, visitors to Japan and commercial operators).

Examples

- Precise early evacuation instructions and other disaster mitigation measures by local governments and related organizations
- Timely and appropriate evacuation by residents with a sense of personal responsibility; safe, early evacuation for the elderly and other vulnerable people
- Appropriate disaster mitigation for visitors to Japan

- Appropriate, resilient disaster mitigation measures and continuity of corporate activity in large-scale disasters
- Promotion of disaster mitigation awareness against a background of intensified disaster conditions caused by heavy rainfall and extreme temperatures associated with global warming
- Promotion of adaptation measures (such as disaster mitigation and systematic development of social infrastructure) based on global warming forecasts

Universal quality of life

Quality of life can be improved via the collection of personalized information relating to individual situations.

Examples

- Quality of life with linked-up home-appliance functionality based on weather and temperature
- Real-time wellbeing management in relation to heatwaves and other phenomena
- Safety and convenience in travel based on pinpoint destination information

Innovation in economic activity and other areas

Meteorological information is expected to be used in combination with various types of big data and advanced technologies in the envisaged Society 5.0 to create diverse services and improve productivity in commercial fields such as transportation, agriculture, forestry, fisheries, infrastructure, logistics, retail and tourism.

Examples

- Safe, pleasant traffic conditions with automatic driving based on road conditions, and safe, efficient maritime navigation and aviation
- Appropriate power supply-and-demand planning with solar/wind power and other forms of energy
- Smart, ultra-labor-saving agriculture for high production
- Development of optimal value chains in manufacturing, logistics and retailing

(3) Direction of meteorological services

JMA’s responsibilities include independent observation/forecasting as well as provision of meteorological information and promotion of related public application. The Agency has a duty to determine and respond to public demand, and to take the following measures as necessary:

- To support the provision of technology-based meteorological information, observation/forecasting accuracy should be developed with incorporation of cutting-edge science and technology in conjunction with public-private-academia operators and international contributors.
- The government should support extensive distribution and usage of meteorological information as a basic element of soft infrastructure in socioeconomic activities (such as disaster mitigation, everyday living and economic activity). Efforts should be made to improve public information literacy in regard to such data.
- Efforts should be made to promote meteorological services for contribution to disaster mitigation, everyday living and economic activity with synergies in technological development and application. In particular, JMA must fulfill its government-agency role in disaster mitigation and promote related public awareness in direct relation to life and property.

IV. Priority issues

Toward the direction of meteorological services in line with the science and technology for 2030 as outlined in Chapter 3, it is essential to focus on (1) further advancement and improvement of observation/forecasting technology as a basis for meteorological services, and (2) efforts to ensure that meteorological information provided to the public by JMA and private-sector companies is fully utilized in various fields as an indispensable part of soft infrastructure and common public property.

Technological development and promotion of related utilization requires a non-independent integrated approach with focus on disaster mitigation, everyday living and economic activity. As a national agency, JMA should play a central role in disaster management based on its direct relation to life and property, and actively promote outcomes in collaboration with related organizations.

The next section outlines related priority issues, specific goals for technological development toward 2030 based on public demand, efforts to promote public utilization of meteorological information, and the promotion of disaster preparedness and support.

1. Development of technologies to improve accuracy in observation and forecasting

Observation and prediction technologies cover the areas of weather/climate and earthquakes/tsunamis/volcanoes. Specific goals of related development in each field for 2030 are outlined below.

(1) Weather and climate

JMA should significantly improve accuracy in its numerical weather and climate forecasts, which underpin various public meteorological services including disaster mitigation efforts, and ensure that such information is provided to the public and fully utilized to stimulate socioeconomic activity. Information of current weather conditions and prediction with lead times of up to 100 years must meet various needs in disaster mitigation, everyday living and economic activity based on numerical forecasts, while considering the difficulty of detailed and accurate quantitative forecasting with longer forecasting periods.

Specific goals

i. Improved accuracy in weather observation and forecasting for prompt evacuation and public safety

To support prompt evacuation and various measures (including efforts related to heatstroke, traffic safety and commercial development), real-time spatially detailed analysis is performed to clarify the status of weather phenomena such as rain, snow, wind, temperature, humidity, solar radiation, lightning and tornadoes. Accurate weather nowcasts with lead times of up to an hour are provided.

In 2030, Severe Storm Alerts will be provided for extreme phenomena such as torrential rain, thunderstorms and strong winds, with accurate forecast information up to an hour in advance to warn of hazardous conditions and encourage self-protection measures. Phenomena including snowfall, humidity, solar radiation and wind will also be added to weather analysis map to be provided every 5 – 10 minutes, and forecasts with lead times up to an hour will be added. Weather and temperature forecast accuracy will also be enhanced for more effective application in everyday living, including measures against heatstroke. These efforts will promote understanding of local weather conditions and outlooks for application in heatstroke countermeasures and traffic safety, as well as promoting the use of various services in combination with a range of data.

ii. Improvement of prediction accuracy relating to disaster mitigation with a 12-hour lead time

Forecasting accuracy for torrential rainfall caused by the stagnation of linear mesoscale convective systems will be greatly improved to support early evacuation and other disaster mitigation measures.

Project goals for 2021 – 2023 incorporate the provision of mesh information on the probability of heavy rainfall for emergency warnings with lead times of around 12 hours from upgraded forecasting for the occurrence and stagnation of linear mesoscale convective systems. This will be based on mesoscale ensemble forecasting scheduled to start operating in the next fiscal year and cutting-edge AI technology, and will support accurate disaster mitigation measures such as daylight evacuation ahead of torrential nighttime rain.

Using the latest AI technology along with significant upgrading of numerical weather prediction technology, improved and high resolution 12-

hour prediction for torrential rainfall associated with the occurrence and stagnation of linear mesoscale convective systems is also expected by 2030. This prediction will support improved information on risk maps for heavy rainfall and flood warnings. Such data on hazards relating to landslides, flooding and potential inundations resulting from downpours will be provided with a lead time of around 12 hours, and will help local governments and residents to understand current conditions independently and take appropriate disaster mitigation measures such as early evacuation.

iii. Improvement of forecast accuracy for typhoons, torrential rain and other phenomena requiring advance wide-area disaster evacuation

Focus will be placed on accuracy in forecasting with lead times of several days for heavy rainfall, storm surges and high waves in association with phenomena such as typhoons and widespread unprecedented rainfall from rainy-season fronts (such as the heavy rains of July 2018) and supporting disaster mitigation measures such as wide-area evacuation by local governments based on timelines and other information.

With predicted application in 2021 or so, lead times for mesoscale model will be extended from 39 to 78 hours for approaching typhoons or expected unprecedented rainfall over wide areas for comprehensive coverage, and information for total rainfall up to three days will be provided in advance. Storm surge prediction model will be upgraded to issue longer term, more accurate and higher resolution forecast.

By 2030, based on significant advancements in numerical weather prediction technology, typhoon track forecast errors three days ahead will be improved to around 100 km (similar to that of current one-day forecasts), and the accuracy of heavy rainfall prediction associated with the stagnation of the rainy season front up to three days will also be improved, thereby the accuracy of rainfall prediction for large river basins and storm surges will be greatly improved. This will support disaster mitigation activities such as appropriate wide area evacuation operations by local governments.

iv. Improvement of accuracy in predictions up to several months in advance to reduce climate risk and improve productivity

To support the early application of measures against heatstroke, snow damage and other phenomena, and to help reduce climate-related risk/productivity impairment in various industries (such as logistics, agriculture, forestry and fisheries), focus will be placed on comprehensive improvement of numerical forecast models used to predict heatwaves, cold waves and other significant phenomena exerting significant public impacts. Advanced technologies such as the Earth System Model will also be applied to predict extreme phenomena with a high degree of accuracy.

In 2030, accurate forecasts of strong winds, heavy snowfall and other prominent phenomena creating significant public impacts are expected to be made up to two weeks in advance for divisions of each prefecture. Weekly forecasts with lead times of up to a month will warn of extreme high/low temperatures associated with heatwaves, cold waves and other phenomena. Accuracy in forecasts of extreme high/low temperatures three months ahead will also be improved to the same level as current one-month forecasts.

v. Centennial-scale information to support policy decisions and adaptation to global warming

In addition to raising public awareness of today's apparent and worsening global warming, efforts will be made to provide related information in collaboration with relevant organizations. This will contribute to policy decisions and the formulation/promotion of plans for adaptation in various fields, such as the development of dams/levees, high temperature-resistant crop varieties and cultivation management. To these ends, focus will be placed on providing an integrated overview of global warming conditions, including forecast uncertainty, and forecast information in collaboration with relevant organizations.

By 2030, the project will generate detailed global warming projections necessary for national and local governments to formulate adaptation measures, as well as projections several decades into the future. Information will also be provided on the frequency and intensity of extreme events such as typhoons and heavy rainfall caused by global warming, and ocean-related projections for phenomena such as sea level rise.

In collaboration with related organizations, focus will be placed on raising public awareness of disaster mitigation incorporating a shared sense of urgency in relation to intensified heavy rainfall. This will support adaptation measures such as increased recognition of the disaster mitigation and promotion of the disaster related social infrastructure development.

Specific action toward goal attainment

i. Improvement of weather-monitoring technology

JMA's core comprehensive observation network will be further enhanced and upgraded. For Himawari meteorological satellites, focus will be placed on increasing observation frequency and resolution from the current 0.5 km to 2 km every 10 minutes, and to increase the number of observation bands (elements) from the current 16. There will also be promotion for phased introduction of next-generation weather radars such as dual polarization types (with enhanced accuracy in observation of precipitation intensity and discrimination of precipitation particles) and phased-array types enabling three-dimensional observation with periods of 1 – 2 minutes as opposed to the current 5 – 10 minutes. For ground-based meteorological observation, JMA will work to determine weather conditions at AMeDAS sites in real time via web cameras and AI analysis technology for imagery.

The Agency will also collect and utilize meteorological observation data from various entities, including local governments, research institutes and private enterprises (such as electric power, transportation and telecommunications companies). The vast body of meteorological data available (including information from smartphones and other gadgets as well as AI-processed information) is expected to support clarification of current situations, thereby greatly improving accuracy in actual and short-term forecasts of heavy rainfall.

ii. Improvement of numerical weather prediction technology

To support the core of forecast information, JMA will improve the accuracy and resolution of numerical weather prediction models and applied technology (guidance, risk distribution, etc.) based on the development of supercomputer capacity and AI technology. For improved precision in torrential rain prediction, ensemble forecasting will be introduced for short-term forecasting, and the results will be translated into simple probability information using cutting-edge AI. For improved precision in long-term forecasting and global-warming forecasting, an Earth System Model will be used with hierarchical incorporation of atmospheric, oceanic and other factors relevant to climatic prediction. Focus will also be placed on collaboration with research institutes and overseas organizations via active discussion and provision of research data, and on significant improvement of numerical forecasting for Japan's meteorological characteristics based on domestic and international expertise.

The application of cutting-edge AI technology to weather forecasting requires collaboration with research institutes and other expert organizations. Accordingly, JMA will continue to accumulate expertise toward application in observation and forecasting, and will promote active discussion and collaboration in providing research data.

(2) Earthquakes, tsunamis and volcanoes

Information on earthquakes, tsunamis and volcanoes is extremely important for disaster mitigation because these relatively infrequent phenomena can cause large-scale damage. The difficulties involved in related forecasting (especially for earthquakes and volcanic eruptions) using current science require efforts to improve related technology and information provision.

To this end, JMA will use internal and external observation data, survey outcomes, research results and cutting-edge ICT to clarify the ever-changing nature of these phenomena, and will provide detailed, clear information on related status. This information should be made available in a timely manner to meet user needs and means of acquisition. Development of scientific expertise and technological development should also be promoted to enhance information on forecast and improve related mitigation awareness.

Specific goals

i. Earthquakes

Simple information on tremors will be provided to support public disaster mitigation. To allow long-term disaster management efforts when a major earthquake hits, ongoing changes in seismic activity and crustal movement will be monitored and evaluated. Information on the outlook for seismic activity, which is subject to uncertainty, is needed in consideration of a public need for safety measures.

In 2030, the Earthquake Early Warning System will provide forecasts of seismic activity over wide areas. Status will be reported simply using various indicators such as seismic intensity and long-period seismic motion in collaboration with related organizations to support related countermeasures in high-rise buildings. Focus will also be placed on improving prediction/application technology and provision of specific outlooks via integrated analysis of seismic activity and crustal deformation with evaluation of changes in phenomena. Such information will support effective disaster mitigation when the potential for a Nankai Trough earthquake is relatively high, or when seismic activity relating to short-term slow slip at plate boundaries is observed.

ii. Tsunamis

Tsunamis hitting coastal areas are often followed by larger subsequent waves, necessitating disaster mitigation measures such as evacuation until waves attenuate. However, current information on expected tsunami heights and times of arrival may cause local governments and residents to lower their vigilance once the estimated time of arrival for the first wave has passed.

By 2030, trends of timing from the first and largest waves to attenuation and the lifting of warnings and advisories will be provided after tsunami warning issuance based on actual situations and forecasts so that local governments and residents will know how to respond and how long evacuation orders should remain in effect. Information on tsunami heights will also be provided in consideration of astronomical tide levels. To ensure promptness, the first warning will be issued using a tsunami database created from simulation results based on location and earthquake scale. Focus will be placed on database developments such as refining simulation to further improve prediction accuracy, with results used to help enhance disaster mitigation awareness and promote proactive measures.

iii. Volcanoes

Volcanoes are a target for sudden disaster occurrence such as phreatic eruptions, and long-term disaster mitigation response. Support for residents, local governments and climbers in this regard requires efforts to raise awareness of volcanoes and related hazards, along with detailed information on expectations for periods during and after volcanic activity. This necessitates clarification of volcanic activity via various means of observation and active utilization of results from surveys and research on subterranean structures and eruption history by related organizations.

By 2030, enhanced expertise on the internal structures of volcanoes will enable more accurate prediction of activity and issuance of eruption warnings, thereby helping members of the Volcano Disaster Mitigation Council including local governments to more accurately address disaster mitigation needs. Assuming the potential for long-term eruptions, focus will be placed on improving local government expertise regarding related characteristics and disasters, and on contributing to appropriate disaster management with accurate assessment of volcanic trends and provision of detailed information.

Ashfall affects traffic, public health and power supplies, and can even damage buildings. Related classification is currently based on ash thickness, focus will be placed on improving accuracy in related prediction of extents and amounts to enable more specific measures.

By 2030, remote sensing technologies such as weather radar and satellites will be used for prompt evaluation of plumes and other eruption phenomena, and to assimilate the resulting data for more accurate prediction of ashfall extents and amounts.

Specific actions toward goal attainment

i. Improvement of observation and monitoring technologies

Focus will be placed on ongoing observation and monitoring with effective use of associated data from various entities, including JMA, universities and research institutes. For earthquakes and tsunamis, crustal deformation will be monitored along the Nankai Trough in collaboration with relevant organizations.

A volcanic observation system will be developed with utilization of research results from previous eruptions, and advanced IoT technology (such as web-based cameras and drones for mobile observation) will be promoted along with remote sensing via satellites and other technologies for ashfall prediction toward comprehensive volcano observation and monitoring.

ii. Improvement of forecasting and activity assessment techniques

Evaluation of seismic activity and crustal movement will be developed, and real-time simulation of tsunamis will be implemented. Techniques for immediate analysis of fault rupture and assimilation of observation data will be promoted.

Expertise on underground volcanic structures will also be developed, and results from academic research on eruption prediction will be incorporated. Efforts will also be made to assimilate volcanic plume observation data and improve ashfall simulation technology.

2. Promotion of meteorological information usage

Specific forms of public utilization for meteorological information can be summarized as below based on the vision outlined in Chapter 3.

Appropriate disaster management response and action for prominent phenomena

- Local-government promotion of appropriate disaster mitigation response via promotion of information awareness and utilization by building direct relations in normal times

- Provision of simple information to help residents, including the elderly, and visitors to Japan to take appropriate disaster mitigation action

Universal quality of life

- Personalized information acquisition and utilization in various aspects of life based on improved environments for the application of weather information

Innovation in economic activity and other areas

- Development of new technologies and services to meet diverse public needs via the development of environments for commercial promotion using meteorological information along with user dialogue and support

The promotion of meteorological information requires environments supporting related supply and usage, along with improved awareness and literacy for appropriate usage as outlined below.

(1) Establishment of environments for access to meteorological information

Recent years have seen a trend toward the creation of services and the acquisition of personalized information to meet increasingly diverse public needs based on advancing AI technology and IoT. Accordingly, meteorological information provided by various entities such as JMA and the private sector should be positioned as common public property and efficiently distributed as basic soft-infrastructure information for public services and use in combination with various forms of big data.

These goals require an environment in which basic meteorological information can be easily accessed and utilized, with focus on effective public utilization along with big data in consideration of governmental and societal trends.

Specific initiatives

i. Efficient distribution of meteorological information

A) Efficient distribution of vast amounts of observation data

In addition to data from conventional observation conducted by JMA, local governments, electric power companies, transportation operators and telecommunications providers, massive amounts of real-time information are expected from the public and various other entities due to the progress of IoT. This will enable the use of more dense and diverse bodies of data in line with user needs. However, any lack of user awareness in quality of these data may result in sub-optimal usage and provision.

Accordingly, focus will be placed on the development of an efficient environment for the distribution of meteorological observation data from various entities based on data quality visualization, such as for information on observation methods/environments affecting quality, and by making data easily comparable with basic JMA information. This will support understanding and appropriate application of various data types for purposes such as disaster mitigation, everyday living and economic activity.

Long-term focus will be placed on work to monitor the situation of meteorological observation data by various entities, and on research regarding institutional considerations and the establishment of an efficient distribution environment.

B) Expansion of basic meteorological data and improvement of environments for ready acquisition

Recent years have seen an increased need for further expansion of basic JMA meteorological data and environments facilitating acquisition to support its use by commerce, research institutes and the general public with advanced technology in combination with cutting-edge AI and other forms of big data. Some meteorological information provided by JMA is also intended for human use rather than machine reading.

Accordingly, historical and regional data (such as weather analysis map) provided on the JMA website and via the Japan Meteorological Business Support Center should be developed to support basic use for public services. JMA will also promote the development of environments for meteorological data acquisition in machine-readable and other formats, along with information on data access methods, in line with public and private open-data initiatives.

ii. Improvement of information accessibility

Now that data on smartphones and other devices have become a major source of reference, it is important to promote the distribution of reliable information via private-sector and other services to meet growing needs for personalized data.

Accordingly, JMA will strengthen the dissemination of primary information online, improve access to and the display of meteorological information on its website, and strengthen the provision of information via effective social media channels with attention to related characteristics. In collaboration with relevant organizations, the Government of Japan will promote disaster mitigation efforts to ensure that individuals are provided with essential location-based weather information. In connection with such efforts, the government will also promote the development of new private-sector meteorological services and the provision of information to meet individual needs via apps and other means.

iii. System review in response to technological innovation (e.g., deregulation)

To further develop meteorological commerce in response to technological advancement and societal change, the systems stipulated in the Meteorological Service Act and other laws should be reviewed and revised as necessary to ensure efficient distribution of meteorological information.

Deregulation of meteorological observation methods and equipment should be considered in order to facilitate the efficient distribution of vast and diverse bodies of data by various entities while ensuring quality visualization.

The nature of forecasting services has also changed, as research institutes and private enterprises can now provide short-term forecasts of precipitation based on improved observation/forecasting technology and computing capabilities, and such operators are increasingly licensed to publish the results of their research and development. Accordingly, the licensing system for meteorological forecasting will be examined, and revisions will be made as necessary in consideration of consistency with disaster mitigation information. There is also a need to expand the field of activities conducted by data analysts and other meteorological forecasters who digest weather data and other information in various fields. Such work involves predicting demand for weather-related products/services and promoting local weather phenomena (e.g., clouds that appear to form a “sea” when viewed from above in elevated locations) as a tourism resource. It also includes proposals and advice on related utilization, with experts in meteorological disaster prevention providing immediate assistance for municipal disaster mitigation.

(2) Improvement of information literacy

Effective public utilization of meteorological information in various fields such as disaster mitigation, everyday living and economic activity requires provision, support and promotion of awareness/application from a user perspective.

Accordingly, focus will be placed on supporting the understanding and utilization of meteorological information for socio-economic activity, including disaster mitigation and tourism (e.g., for overseas visitors to Japan) toward active promotion of dialogue and collaboration with users such as local governments, disaster mitigation-related organizations and various businesses, along with related problem resolution. The Government of Japan will also enhance public literacy for meteorological information by promoting application in collaboration with relevant organizations and raising safety awareness. Such efforts will include multilingual provision for visitors from overseas.

It should be noted that awareness and effective usage of meteorological information necessarily depend on the time scale of related phenomena.

Specific initiatives

i. Improved meteorological literacy for precise disaster management and quality of life

JMA will work to improve interest in the meteorological field and scientific literacy by promoting awareness of appropriate response actions and scientific expertise of weather and stochastic phenomena along with a sense of personal responsibility for action in the event of a disaster. This will involve the development of textbooks and supplementary reading materials to strengthen awareness in school education, and scientific research with public participation. JMA will also continue to work with local governments in disaster mitigation and education, and with schools to secure and develop human resources for next-generation meteorological services. To improve literacy and help eliminate inaccurate or confusing information from online and other sources, the Agency will use social media and other means to provide reliable comments on weather-related situations as well as forecasts and examples. Focus will also be placed on promoting public awareness of the purposes and details of the forecasting license system stipulated under the Meteorological Service Act and how to identify questionable weather forecasts.

For visitors to Japan, focus will be placed on enhancing simple information, promoting the display of maps and multilingual information, and providing highly accurate local weather services. Following its renovation in April 2020, the Meteorological Science Museum will be promoted as a tourist destination with a wide range of exhibits highlighting Japan's four distinct seasons, its natural environment and its weather conditions, and will also promote the concept of disaster preparedness.

ii. Promotion of weather information in economic activity

To promote 1. the public application of meteorological information in combination with various types of big data and advanced technologies in the context of Society 5.0, 2. commercial innovation, and 3. improved productivity, related needs must be clarified via dialogue with commercial operators, and an environment that facilitates the use of such information is required.

Against this background, various public needs will be identified via ongoing discussions among public/private/academic-sector operators and reflected in the establishment of environments for the provision and use of meteorological information. Seminars on information usage and training programs aimed at improving commercial application of meteorological data will also be conducted to develop human resources capable of meeting various needs by utilizing new technologies. To develop commerce combining meteorological information with big data, focus will be placed on promoting business matching and supporting new users of such information.

The Government of Japan will promote efforts to encourage weather forecasters to act as meteorological data analysts in order to promote the utilization of related information in combination with various types of public and private big data, with purposes such as corporate product-demand forecasting and utilization for local tourism.

3. Promotion of disaster mitigation response and support

The protection of life, property and universal quality of life requires meteorological services for disaster mitigation, everyday living and economic activity. This necessitates the application of synergistic effects rather than independent work on technological development and promotion of related utilization (as per the priority issues described in Sections 1 and 2 of this chapter).

In particular, recent years have seen natural disasters causing tremendous widespread damage (such as the Heavy Rainfall in Northern

Kyushu in July 2017 and the Heavy Rainfall in July 2018), remarkably heavy snowfall, heatwaves, notable volcanic eruptions, and seismic activity (such as the 2011 Great East Japan Earthquake). There are also concerns that global warming will cause increased incidences of heavy rainfall and extreme temperatures. Against this background, meteorological services play significant roles in raising public disaster awareness and related preparation.

As a national agency, JMA should play a central role in contributing to disaster mitigation, which directly affects life and property. The Agency should promote technological progress using advanced technologies and other tools, and develop meteorological information supporting local governments in issuing evacuation advisories, as well as promote the use of meteorological information for such advisories and evacuation actions by residents.

To these ends, JMA needs to provide weather information incorporating up-to-date technological developments (such as the risk maps introduced in July 2017) and continue to upgrade weather information with significantly improved accuracy in observations and numerical forecasts.

Efforts should also be made to support and promote literacy and utilization for advanced meteorological information so that related significance and limitations are understood and applied appropriately in disaster management. Specifically, based on the report of the Study Group on Regional Meteorological Services for Disaster mitigation (August 2017), local meteorological offices should strengthen collaboration with local disaster-prevention organizations and seek to ensure that meteorological information is understood and utilized by municipalities, as key operators in disaster mitigation, in making decisions on emergency response. These offices should promote the PDCA cycle as follows (Normal times, Disaster situations, and Post-disaster situations), and strengthen collaboration with local disaster management agencies. This will support identification of needs and areas for further improvement during these three stages and promote efforts/technological development for related awareness and utilization.

Normal times

- Establishment and development of direct relations between meteorological office directors and municipal leaders
- Implementation of practical training and drills for awareness and utilization of disaster-related meteorological information

Disaster situations

- Efforts to ensure that a sense of crisis is conveyed via hotlines, forecasting input and other channels
- Dispatch of JMA Emergency Task Team (JETT)
- Further proactive and integrated disaster reduction measures in collaboration with local disaster reduction agencies, large-scale flood mitigation councils, volcano disaster reduction councils and other bodies (timelines for large-scale floods and heavy snowfall, provision of information supporting road administration decisions for preventive traffic control and similar)

Post-disaster

- Joint situational reviews the emergency response by meteorological offices, municipalities and other bodies

In addition to disaster-preparedness among local governments and related bodies, the perspective of residents (essentially the main actors in safety-preservation activity) is extremely important in promoting public disaster awareness, as this greatly affects behavior in emergencies. Residents, districts and communities must enhance their self-help and mutual-help capabilities in collaboration with related organizations and community supporters. Accordingly, it is necessary to promote public awareness of disaster risks on a daily basis and the individual use of disaster mitigation information to help secure safety and evacuation when a disaster is imminent.

V. Basic and cross-sectional measures for initiative promotion

The synergistic effects of the priority areas of technology development and utilization promotion (Chapter 4) should be applied to organically promote disaster management and support. Toward the application of meteorological services in disaster mitigation, everyday living and economic activity, these effects need to be realized with periodic reviews of science, technology and public demand, along with efforts to promote technology and its utilization in an integrated manner.

Effective achievement of these ends requires collaboration involving JMA, related ministries/agencies, universities and other research institutions, and private commerce. There is also a need for international collaboration among meteorological organizations.

Efforts should be made to strengthen the institutional structure and technical infrastructure of JMA and other organizations in order to promote such efforts.

The following sections describe basic and cross-sectional measures for the achievement of these priority initiatives.

1. Ongoing verification and improvement based on public demand

It is necessary to promote technological development and utilization in an integrated manner for meteorological services that meet public demand.

Accordingly, the PDCA (Plan-Do-Check-Act) cycle should be constantly applied and reviewed, organically linking technological development and utilization, with periodic checking of the status of science/technology and public demand (e.g., related development in areas such as AI and IoT, as well as changes in societal conditions and interest in data usage).

In this regard, there is a need to understand public demand in line with actual situations, and to consider trends and prospects in the field of cutting-edge technologies. In particular, in the event of large-scale natural disasters such as the Heavy Rainfall in July 2018, it is important to conduct joint verification involving JMA, relevant ministries/agencies and local governments supporting organic disaster mitigation efforts. For example, joint reviews of previous emergency response situations by the respective parties should be conducted, examining matters such as the type of information provided by meteorological offices and their technical limitations, and how municipalities and other organizations use such information in making disaster mitigation decisions. Assessments and advance measures also need to be reviewed using simulation based on forecasting technology for appropriate response to unprecedented situations caused by climate change and other factors.

To contribute to everyday living and economic activity, the Government of Japan should analyze annual surveys on the utilization of meteorological information and online feedback, as well as identify needs and issues in commercial sectors through the Weather Business Consortium and other bodies in a timely manner. This will support reviews of measures to promote the utilization of meteorological information.

2. Sustained and effective efforts via public-private-academia/international collaboration

In the field of meteorological services and closely related science and technology, JMA actively engages in cutting-edge research on IoT and AI along with universities, other research institutes and private operators. Future fusion and joint research combining meteorological information with big data from other fields (such as tourism and medicine) is expected. This should be promoted via the training of staff capable of combining meteorological services with cutting-edge science/technology and various fields of socio-economic activity. In promoting the utilization of meteorological information, relevant government ministries/agencies, local governments and media organizations play significant roles in enhancing information literacy for disaster mitigation and everyday living, as well as in improving the way information is conveyed. While effective measures against floods, volcanic eruptions and heatstroke are taken via council and inter-agency collaboration, it is necessary to further promote meteorological information usage in various other fields in collaboration with related organizations. There is also a need to collaborate with local governments in disaster mitigation/education and with schools to provide future human resources in the field.

Accordingly, related organizations should collaborate to promote technological development and utilization. JMA is in a position to play a central role as a national agency in this regard, especially in the area of disaster mitigation, with meteorological technologies including a core observation network with satellites, radar, AMeDAS and seismometers as well as numerical weather prediction models. In this context, JMA should collaborate with government ministries/agencies, local governments, universities and other research institutes, commercial operators and overseas meteorological organizations to incorporate state-of-the-art technological development into meteorological services, promote the utilization of meteorological information, and improve environments for organic creation of new value and services.

3. Strengthening of institutional structure and technology

infrastructure

To effectively implement these measures toward ideal meteorological services, it is necessary to consider strengthening JMA's institutional structure and technical infrastructure.

JMA as a whole (including the Meteorological Research Institute) needs to establish an effective development system and promote human resources toward technological development. It is also necessary to strengthen management for the formulation and implementation of strategic plans toward technological development based on public demand and technological progress, and to actively promote public/private/academic collaboration. In addition to these institutional structures, there is a need to maintain and build up core observation networks for weather, climate, oceans, earthquakes, tsunamis, volcanic activity and other phenomena. Such resources include the Himawari meteorological satellite series, weather radar, seismographs, supercomputers for numerical forecasting, and infrastructure systems for promoting the efficient distribution of vast amounts of meteorological information.

It is also necessary to improve environments so that meteorological information upgraded as a result of these technological developments and basic systems for observation/analysis can be fully utilized in fields such as disaster mitigation, everyday living and economic activity. In the field of disaster prevention, JMA needs to play a central role in promoting meteorological services as a national agency in collaboration with the public, private and academic sectors. It is also necessary to establish an institutional structure, including local meteorological offices, for providing more complete information on observations and forecasts, and for actively supporting the understanding and use of such information by local governments. At the same time, it is also important to promote human resource development at meteorological offices to contribute to the provision of such information and support. Support for national disaster mitigation and crisis management for the handling of large-scale disasters also needs to be researched.

VI. Conclusion

Meteorological services have been a part of people's lives since ancient times. As indicated by sayings such as "*Red sky at night, shepherd's delight; red sky in the morning, shepherd's warning,*" future weather conditions have historically been based on individual experience, known circumstances and available information. In daily living, people have embraced the wisdom and art of cohabitation in this regard, enjoying the seasonal expressions of Mother Nature and her blessings, and sometimes resisting her fury.

Meteorological services evolve to incorporate the rapid progress of science/technology and societal change. Observation networks have developed apace, and numerical weather prediction has enabled almost-objective weather forecasting. Cellphones now vibrate to alert users of imminent earthquakes even before the ground starts moving.

However, even in this day and age, further work is needed to achieve ideal observation and prediction conditions. Observation of natural phenomena necessarily involves some level of error, and the prediction of natural phenomena is accompanied by increasing uncertainty with longer lead times. Some of these problems can be addressed by the progress of science and technology, while others cannot.

Meteorological information based on observation and forecasting is today increasingly available, but at the same time is increasingly difficult to apply due to greater sophistication, diversity and complexity. As a result, public sensitivity to natural conditions may be reduced, along with the capacity for individual self-help in disaster conditions. The development of environments in which information is provided for use in daily living and activities also requires efforts to build awareness among a wide range of stakeholders (including those who produce and provide information) and work in collaboration with the public for meteorological service development to meet public need.

Despite the remarkable progress of meteorological services, natural disasters such as the Heavy Rain Event of July 2018 still cause many fatalities. Global warming is also exacerbating the severity of such disasters, and some situations cannot be handled from past experience alone. The relentless fury of nature must be respected even in the context of ongoing progress.

Global warming, along with Japan's declining birthrate and aging population, will accompany the development of advanced technologies such as IoT and AI. As the environment surrounding meteorological services evolves, related output will continue to develop and serve as a bridge between nature and society. These considerations underpin the production of this Scientific/Technological Application in Meteorology

Toward 2030 by the Meteorological Subcommittee under the Council of Transport Policy as a set of proposals to JMA.

The implementation of these recommendations is expected to promote the widespread application of meteorological information as common public property and the fulfillment of people's meteorological service expectations.