JMA's NWP Strategic Plan Toward 2030

NWP innovation to ensure the safety and security of the people,

and to realize a vibrant society

Executive Summary

Japan Meteorological Agency

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Meteorological Operation Focusing on Science and Technology Toward 2030 (a recommendation formulated by the Meteorological Subcommittee under the Council of Transport Policy implemented by Japan's Ministry of Land, Infrastructure, Transport and Tourism) is intended to help prevent and mitigate natural disasters and improve socioeconomic productivity. Based on the direction suggested in this Recommendation, *JMA's NWP Strategic Plan Toward 2030* has been established aiming to promote strong and steady technical development in the area of numerical weather prediction as part of social information infrastructure in disaster prevention and related fields.

The plan covers numerical weather prediction for weather and climate.

1 Current situation surrounding meteorological services

i) Changes in natural disaster characteristics

Japan has experienced a variety of natural disasters related to torrential rain in recent years, including the Heavy Rain Event of July 2017 in Kyushu Hokubu (torrential rain in Northern Kyushu) and the Heavy Rain Event of July 2018. Future events on a scale comparable to those of the devastating Typhoon Kathleen (1947) and the Ise-Bay Typhoon (1959) could cause serious damage in Japan, including loss of life, significant damage to property and long-term urban function paralysis.

The severity of natural disasters caused by extreme weather conditions in Japan has increased in recent years, and global warming may exacerbate the situation further. Against this background, there is strong demand for

the provision of reliable weather information to help prevent and mitigate natural disasters.

ii) Rapid changes in social conditions

Japan's aging society, declining birthrate and shrinking population give rise to concerns over dwindling local disaster prevention capacity caused by reduced manpower and a greater number of people needing special attention in disaster situations. Demographic aging also requires productivity improvement for appropriate maintenance of social functions as the working-age population decreases.

At the same time, the widespread adoption of ICT (information communication technology) such as IoT (the Internet of Things) and AI (artificial intelligence) has progressed rapidly, and further use of meteorological information and datafor various purposes is anticipated.

Accordingly, the utilization of meteorological informationand data is keenly expected to contribute to society and economic wellbeing, not only in helping to prevent disasters but also in supporting the establishment of a super-smart society (referred to as Society 5.0), with adoption by individuals and contribution to decision-making and business process improvement in industry.

iii) Dramatic advances in science and technology

Numerical weather prediction involves various processes ranging from observation data collection to predictive simulation for calculation of future atmospheric states based on various physical and chemical equations. Recent years have seen dramatic advances in scientific technology

supporting numerical weather prediction, such as the development of supercomputers and simulation technology. In addition, the development and proliferation of sensor technology heralds an era of big data from earth observation and the ability to analyze atmospheric and oceanic conditions with higher accuracy than ever.

International competition in technological development for numerical weather prediction is rapidly accelerating, and national meteorological services in many countries are taking active measures to secure appropriate human resources and budgets in addition to promoting the installation of high-performance supercomputers. At the same time, great strides are being taken in international collaboration to help address issues common to many countries under World Meteorological Organization (WMO) and regional frameworks.

2 JMA's vision for numerical weather prediction

In consideration of today's meteorological service landscape, JMA is positioning "NWP innovation to ensure the safety and security of the people, and to realize a vibrant society" as its vision for NWP.

Numerical weather prediction is a cornerstone of meteorological and climate prediction, and represents part of the social infrastructure necessary for safe, secure and affluent living. It is placed as a major pillar and a new national shared asset in the realization of a safe, resilient and vibrant society targeted for the year 2030 with enhanced technology and accuracy for standards that meet public needs in disaster prevention and other areas.

3 Priority goals for 2030

Toward the realization of the NWP vision, JMA will set priority goals for 2030 based on changes in the characteristics of natural disasters and social conditions, and on advances in science and technology.

i) Prevention of disasters caused by heavy rain

Aim: To enable more confident prediction of the possibility of occurrence of torrential rain by improving the prediction of stationary linear mesoscale convective systems characterized by elongated precipitation areas with spatial scales covering around 100 km. This would support early warning and evacuation, particularly during the daytime.

ii) Prevention of disasters caused by typhoons

Aim: To improve the accuracy of prediction for phenomena such as heavy rain associated with typhoons and fronts. This would enable reliable disaster prevention operations involving wide-area evacuation several days before extreme winds, flood damage and storm surge disaster conditions arise.

iii) Contribution to socioeconomic activity

Aim: To enhance long-range forecasts with lead times of up to six months and improve related accuracy. This would enable contribution to productivity in socioeconomic activity via reduced climate risk and optimization of product distribution and production planning.

iv) Adaptation to global warming

Aim: To provide Japanese consolidated projections on global warming with higher-resolution meshes in collaboration with relevant organizations. This would contribute to the formulation of global warming adaptation measures implemented by local governments and the private sector.

4 Promotion of technological innovation

Toward the priority goals for 2030, technological innovation should be promoted for the following three items as keys to improving prediction accuracy.

i) Application of big data from earth observation using next-generation technology

Aim: To apply big data from sources such as satellite observation conducted with next-generation sensors and related utilization technology. This would help to clarify current atmospheric and oceanic conditions and support more confident prediction with regard to the dynamics of moist atmospheric air in the environmental field that produces stationary linear mesoscale convective systems, the state of the atmosphere and ocean areas around typhoons, and other considerations.

ii) Weather simulation for areas over Japan with world-leading precision and resolution

Aim: To utilize the latest supercomputer and cutting-edge simulation technology in weather simulation. This would enable the prediction of weather for areas over Japan with world-leading accuracy and resolution from planetary-scale phenomena such as heat and cold waves to mesoscale

phenomena such as cumulonimbus clouds constituting typhoons and mesoscale convective systems.

iii) Decision support based on a fusion of probability prediction and AI technology

Aim: To realize technology for the conveyance of information on projection/prediction uncertainty to users in an easy-to-understand manner. This would contribute to decision-making on evacuation during torrential rain events and to adaptation measures for global warming.

5 Reinforcement of development management

Technical development in the area of numerical weather prediction will be actively promoted by reinforcing development management to realize technological innovation.

i) Promotion of wide-ranging collaborative efforts

Aim: To realize all-Japan industry-academy-government partnerships and strengthen international collaboration. This would strongly promote research and development in the area of numerical weather prediction

ii) Training and securement of staff for model development

Aim: To foster sophisticated experts and development leaders by promoting the success of diverse staff to realize development based on world-leading science and technology.

iii) Establishment of bases for research and development

Aim: To intensively strengthen cutting-edge hardware and software resources such as supercomputers, base software components including AI,

observation platforms including satellites, and development frameworks to support research and development.

6 Development plan

JMA development guidelines

Software applications for numerical weather prediction are called numerical weather prediction models (referred to here simply as “models”). The promotion of model development stands at the core of realizing innovation in such prediction.

These models are aggregates of huge and complex programs based on advanced science and technology. To promote their development, everybody involved in related efforts must share not only the relevant vision and priority targets but also the development guidelines outlined below.

i) Prioritization

Aim: To prioritize development and promote the sharing of priorities among those involved based on analysis of prior R&D with consideration of development and operation costs. This would enable enhanced developments contributing to the achievement of the goals.

ii) Empirical evidence-based development

Aim: To ensure the traceability of development based on empirical evidence and emphasis on scientific discussion, and to promote systematic development based on common evaluation methods.

iii) Optimization of development as a whole

Aim: To optimize and strengthen the whole scope of development in order to promote R&D by creating infrastructure software that supports the development process and ensuring an appropriate environments for related work.

Development plan for priority-goal achievement

The current status and direction of development toward achievement of the priority targets are discussed below along with related challenges.

i) Prevention of disasters caused by heavy rain

Current status and related issues

- Even with the Local Forecast Model, which has the finest horizontal resolution of any JMA model, it is still difficult to predict the precise timing and location of elongated areas of heavy precipitation caused by stationary linear mesoscale convection systems with a lead time longer than around 12 hours, and prediction uncertainty is high.
- Even the current resolution of 2 km is still insufficient to resolve individual convective clouds. Physical processes suitable for high-resolution models are also necessary.
- More accurate initial states for water vapor and wind fields over sea areas are necessary.

Direction of development – aims:

- To make the horizontal resolution of the Local Forecast Model finer than 1 km and improve various processes related to cumulus convection.

- To develop an ensemble prediction system that appropriately captures uncertainties in prediction of torrential rainfall using the Local Forecast Model.
- To further utilize big data collected via various observation types with spatially and temporally high density such as information from satellites, aircraft, radar, ship-based GNSS (Global Navigation Satellite System) and various IoT converting sensors.
- To develop all-sky satellite data assimilation methods for cloud and rain-affected observations, to introduce a hybrid data assimilation system incorporating state-of-the-art technology combining multiple methods, and to advance handling of observation error correlation.
- To improve the NWP system based on the up-to-date scientific deliverables by the research on the mechanism of weather events such as heavy rain.

ii) Prevention of disasters caused by typhoons

Current status and related issues

- To enable prediction of heavy rain and storm surges accompanying typhoons several days in advance, it is essential to efficiently make predictions over a wide range of scales from the entire globe to areas around Japan.
- It is necessary to significantly improve typhoon track forecasts via improved representation of environment steering flow (i.e., atmospheric flow affecting the course of typhoons) and typhoon structures.

- Accuracy in the initial state around typhoons requires particular improvement.

Direction of development – aims:

- To develop an optimal hierarchical system incorporating the Global Spectral Model, the Meso-Scale Model, the operational ocean-related models such as a storm surge model, the Global Ensemble Prediction System and other resources.
- To enhance horizontal resolution by increasing the grid interval of the global model used for typhoon prediction to 10 km or less, and to develop new physical processes more suitable for such a high-resolution model.
- To implement all-sky assimilation of microwave satellite radiances and infrared radiances, and to develop technology for the utilization of observation-related big data from sources including aircraft, atmosphere tracking winds, GNSS and scatterometers with higher resolution and frequency.
- To develop AI application technology that can be utilized for parameter optimization inside models, high-speed calculation for physical models, observation data quality control and the like.
- To improve typhoon forecasts based on the latest scientific deliverables via research on the mechanisms behind typhoon movement and development.

iii) Contribution to socioeconomic activity

Current status and related issues

- The accuracy of forecasts with lead times of up to around six months is insufficient for full utilization in socioeconomic activity, including optimization of production and product distribution plans.
- Technologies suitable for predicting target phenomena efficiently and effectively are needed. Particularly for predictions with lead times of two weeks or more, a model capable of adequately reproducing interaction among earth system components (such as the atmosphere and oceans, sea ice, ozone, aerosols and other components) is required.

Direction of development – aims:

- To develop hierarchical earth system models capable of predicting various phenomena and factors with high accuracy (such as heat waves, cold spells, sea surface temperatures and amounts of incoming solar radiation) and can provide these predictions on a practical basis.
- To develop a high-resolution ocean model capable of accurately reproducing ocean eddies to support forecasts with lead times of up to several months.
- To enhance the data assimilation system for the incorporation of various observation data on variables such as land surfaces, oceans, sea ice and aerosols in consideration of consistency among earth system components and models.

iv) Adaptation to global warming

Current status and related issues

- For the production of fine-grained projection information on global warming needed for decisions to be made by the national government and municipalities, highly accurate and detailed projection for Japan and its surroundings must be developed in collaboration with relevant organizations.
- It is necessary to improve the accuracy of global warming projection as a basis for detailed forecasting.

Direction of development – aims:

- To develop a high-resolution regional climate model for atmospheric and oceanic conditions in order to enable prediction of changes in extreme phenomena such as typhoons and heavy rain, changes in sea surface temperature and changes in sea water levels with lead times ranging from several decades to 100 years.
- To improve the accuracy of the earth system model for the projection of global warming.