Priority Subjects — **Establishment of Optimal Risk Management**

# Development of Prediction Methods for Weather/Climate Impact on Electric Power Facilities

## Background and Objective

The occurrence of natural disasters, associated with large-scale typhoons, rapid-developing low pressure systems, localized heavy rainfall and snowfall, and gusty winds due to tornados and downbursts, tends to be increasing. Recently, we have experienced extreme recorded events, raising concern regarding the influence of global warming. In this project, prediction methods of extreme meteorological disasters, methods for utilization of predicted products, and meteorological and oceanographic hazard evaluation methods are developed as techniques for supporting advance prevention of disasters in routine operations and for rapid restoration in the wake of disasters. The evaluation of the impact of tornadoes on nuclear power plants is another major topic. Results in this project are expected to contribute to improving the reliability of electric power facilities and the stability of power supply.

## Main results

### 1 Development of a short-range precipitation prediction system

In this system, two types of products are routinely predicted (Fig. 1). One is a product of 3-km prediction up to 9-hours in advance to cover the entire country. The other is a product of 2-km prediction up to 2-3 hours in advance to cover a particular region (e.g. Kanto area). The higher-resolution prediction is performed in a rapid update cycle (every 10-20 minutes). Both predictions utilize real-time weather radar data from the Japan Meteorological Agency (JMA) and Ministry of Land and Infrastructure, Transport, and Tourism, and surface observation data (e.g. AMeDAS and wind profiler, etc.) is processed automatically. Data assimilation of this data into our numerical weather forecasting and analysis system (NuWFAS) improved the accuracy of a short-range precipitation prediction.

### 2 Suggestion of a method to utilize JMA weekly ensemble forecasts*1

In order to conduct higher-resolution rainfall forecast based on weekly ensemble forecast data provided by JMA, the two techniques described below were developed. One is a method for 2-day prediction of hourly precipitation, which is based on a dynamical ensemble approach using NuWFAS, and the horizontal resolution is about 5-15 km (V14013). The other is a method for one-week prediction of daily precipitation using a pattern recognition technology (Fig. 2). Since both methods can estimate the range of fluctuations and time-lags for each weather variable, they can support end-users to make decisions in accordance with the reliability of the prediction.

### 3 Techniques for assessing the impact of tornadoes on nuclear power plants

A method to evaluate tornado parameters*2 is suggested for assessing the regionalization in terms of the frequency of favorable meteorological conditions which lead to the occurrence of tornadoes with the largest scale (F3*3) recorded in Japan or with larger scales. This method adopts a high-resolution and long-term reanalysis dataset called CRIEPI-RCM-Era2, and its applicability is verified from analyses of F3-F5 tornadoes which have occurred in Japan and the United States. A method for hazard assessment of tornado wind velocity, which is called TOWLA, is also developed, accounting for the likelihood that the majority of tornadoes have occurred in coastal areas of Japan. The usability of TONBOS, which is a tool for evaluating the velocity and the trajectory of tornado missiles, is also improved.

Concerning a countermeasure with high-strength wire mesh against the penetration of tornado missiles, the applicability of our method to evaluate the absorbed energy is examined through free drop tests using a heavy weight [1] (N14009). In addition, the effects of attaching additional wire mesh on the main wire mesh are verified to demonstrate the capability of resisting the penetration (N14018). Results and findings obtained in our research are significantly useful for the establishment of relevant guidelines by the Japan Society of Maintenology and the relevant standard by the Japan Society of Mechanical Engineers.

*1 An ensemble forecast is composed of forecast members, each of which is a forecast consisting of initial and boundary conditions with artificial perturbations. In this summary, the term “forecast” refers to public broadcasts by organizations such as JMA. Non-public information is, referred to as a “prediction”.

*2 Tornado parameters indicate atmospheric instability, wind shear, and other elements. Those parameters are used in issuing a warning or in nowcasting by JMA. In our method, tornado parameters such as convective available potential energy (CAPE), storm-relative helicity (SReH), and the energy helicity index (EHI; EHI=CAPE×SReH/160,000) are used.

*3 The Fujita scale is an index of tornado intensity estimated from the degree of structural damage. This is used to estimate the wind velocity. For example, the range of the velocity for F2 tornadoes is 50-69 meters per second (averaged in 7 seconds), and the range for F3 tornadoes is 70-92 meters per second (averaged in 5 seconds).

[1] K. Namba et al., J. Structural Engineering, Vol.61A, 958-969, 2015.

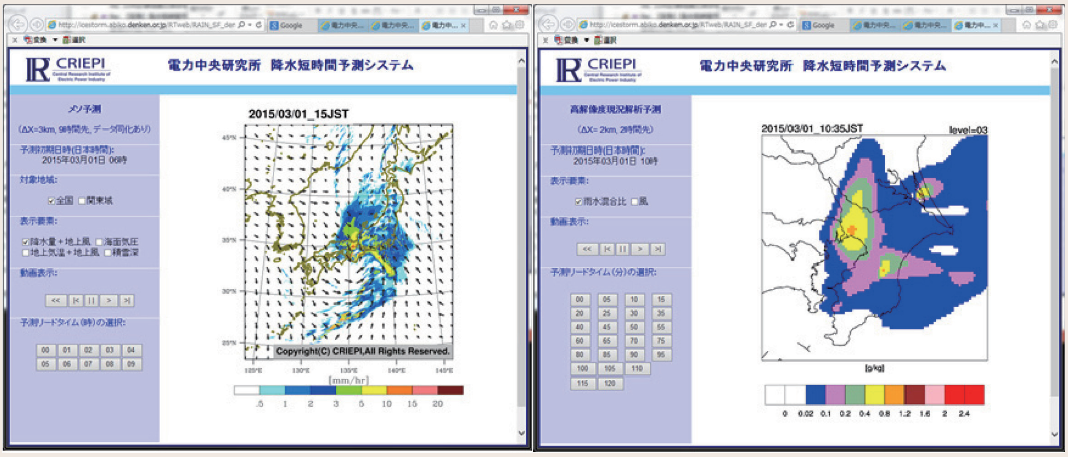



Fig. 1: Graphical user interface to browse products from our short-range precipitation prediction system (left: a full domain with 3-km horizontal resolution, right: a regional domain with 2-km horizontal resolution)

Our prediction system is developed for more quantitative precipitation predicted up to several hours in advance. Observed information such as radar data is incorporated into the result of 33-hour prediction from NuWFAS. In predictions covering the entire country, the use of three-dimensional variational data assimilation system (WRFDA) improves the accuracy of prediction up to 9 hours. In regional predictions, the rapid update cycle of a higher-resolution prediction is achieved with the four-dimensional variational radar data assimilation system (VDRAS), so that the quantitative prediction is improved even for a rapid-developing storm in a local area. Our system can be easily customized in terms of the duration of prediction, and the domain size according to the computational performance.

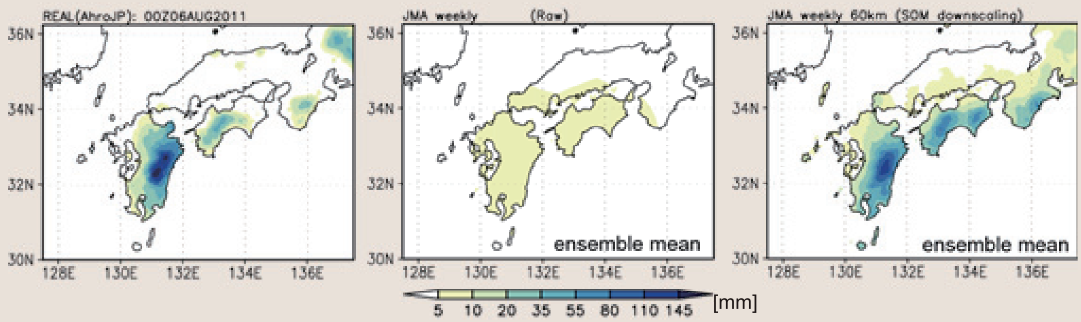
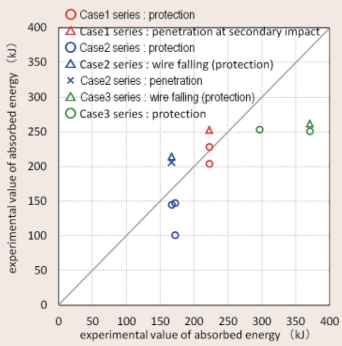
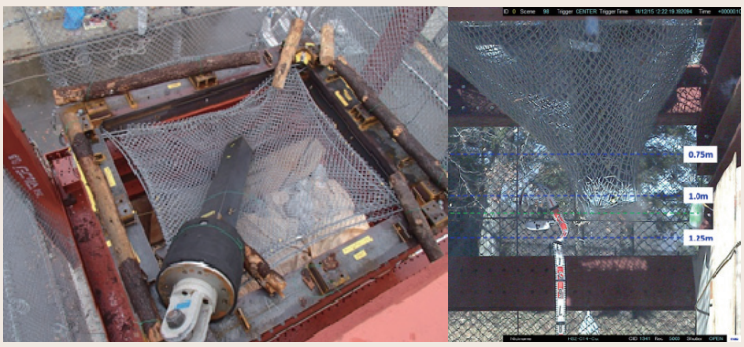



Fig. 2: Example of 1-week prediction of daily precipitation based on the developed method using the pattern recognition method (left: observation, middle: JMA ensemble forecast, right: our method)

A statistical pattern recognition technique called a self-organizing map is applied to reanalysis data and rainfall data. A few hundred weather patterns are identified, indicating the relationship between the spatial distribution of meteorological elements (e.g. the wind speed and the direction at 850 hPa height) with a lower-resolution and the rainfall distribution with a higher-resolution. This method enables us to predict immediately heavy rainfall area up to around 1-week in advance from a low-resolution JMA weekly ensemble forecast and its associated weather pattern, even if the original JMA forecast cannot predict heavy rainfall area.




Comparison of values of absorbed energy estimated with experimental values




Resisting a heavy weight simulating the impact of a pipe in a squared shape

Fig. 3: Examples of results of our study on the countermeasure with high-strength wire mesh against tornado missiles(left: observation, middle: JMA ensemble forecast, right: our method)

Our proposed method to evaluate the absorbed energy by the wire mesh is validated by comparison between estimated values and experimental values obtained from free drop tests (left panel). Moreover, it was confirmed that the performance of the wire mesh system is improved in terms of the catchment ability by attaching additional wire mesh. No local penetration of the falling heavy weight was found (right panel).