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

Development of Prediction Methods for Meteorological and Climatic Impact on Power Facilities

Background and Objective

Disasters have occurred at a higher frequency, associated with super typhoons, rapidly-developed low pressure systems, localized heavy rainfall/snowfall or tornado wind blasts, etc. There is concern that global warming could possibly be related to the occurrence of extreme events.

In this project, we aim to assess the variety of hazards for meteorological phenomena and oceanography, and to evaluate the impact of global warming. For this purpose, a long-term high-resolution meteorological database is produced. This database is anticipated to be utilized as fundamental data for considering each hazard during the design of electric power facilities. Another important issue is the development of techniques that are needed for preventing the occurrence of damage or supporting the quick restoration of damaged components. A forecasting method for severe storms up to a week in advance and their associated highly-convenient systems will then be developed for various lead-times.

Main results

1 Development of a high resolution, long-term weather and climate database

The numerical weather forecasting and analysis system, NuWFAS, has been improved as a regional climate model for applying to a long-term regional climate prediction around Japan (Fig. 1). Through a physical downscaling with this model and two global reanalysis datasets provided by the European Centre for Medium-range Weather Forecasts (ECMWF), a database, CRIEPI-RCM-Era2, was developed by compiling the hourly product of downscaling during the period from FY1958 to FY2010 (N13004). The database is composed of meteorological variables including surface wind, temperature, and precipitation from surface to 20 km aloft with a horizontal resolution of 5 km. The fine spatiotemporal resolution is good enough to use for the practical purposes of evaluating the impact of extreme weather conditions on electric power equipment, in particular distribution facilities (Fig. 2).

2 Short-range rainfall forecasting for prevention of hydropower facility disasters

A radar data assimilation system developed based on VDRAS*1 can assimilate routine observation data from domestic Doppler weather radars in order to improve the accuracy of the initial condition of a numerical weather prediction (NWP) model. This assimilation technique results in more accurate forecasts of rainfall and wind fields for heavy rainfall cases, even if it is difficult to forecast such cases by only using the NWP model (Fig. 3). In the line of research, a short-term rainfall prediction system was developed, in which the product from very short-range (up to 2 hours ahead) nowcasting based on the extrapolation of sequential radar echo images and the product from short-term (up to 6 hours ahead) rainfall forecasting using NuWFAS are combined.

3 Assessment of storm surges and high waves for the design of seaside power plants

A model to predict and estimate a storm surge due to a typhoon was constructed using ROMS*2. The sea level elevation and duration of the storm surge predicted by the model are consistent with the tide gauge observations (Fig. 4). These results confirmed that the model (including a conceptual typhoon model using atmospheric pressure, the radius of the region where winds over 25 meters per second, and traveling speed of typhoon) allowed us to estimate the impact of the storm surge due to a typhoon. The database of ocean waves around the Japanese coast, CRIEPI-OWCM05, was also developed by the ocean wave model using CRIEPI-RCM-Era2 as physical wind forcing. This database is useful to evaluate the impact of high waves on the design of seaside power plants.

4 Assessment of the impact of tornadoes on the design of nuclear power plants

Regions prone to supercell tornadogenesis were specified from a map based on CRIEPI-RCM-Era2 (Fig. 5). This map is useful in determining the regions to be considered for hazard assessment. The probabilistic method developed can estimate an exceedance hazard curve from past observations. The design wind speed estimated is used for assessing the behavior of tornado missiles. Furthermore, the maximum of the missile speed, and the horizontal and vertical travelling distances can be assessed by a code called TONBOS (Fig. 6). As a countermeasure to mitigate the impact load of a tornado missile, a method for the construction of high-strength metal mesh was also proposed, as well as a design for an energy absorption method (N13014). These research results have been used to assess the safety of nuclear power plants according to the new national regulatory standard.

*1 Variational Doppler Radar Assimilation System developed by the National Center for Atmospheric Research.
*2 Regional Ocean Modeling System has been developed by Rutgers University and UCLA and other academic institutions.

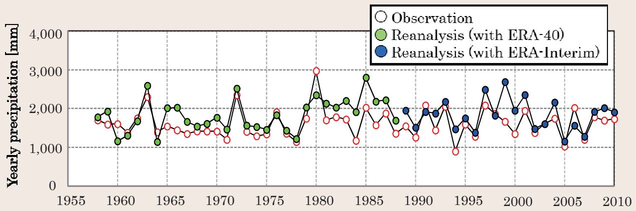


Fig. 1: Temporal variation of yearly precipitation over 53 years

ERA-40 and ERA-Interim reanalysis datasets provided by ECMWF are used for this 53-year reproduction run. This result indicates that numerical errors do not accumulate with time and that yearly accumulated precipitation reproduced is in good agreement with observations.

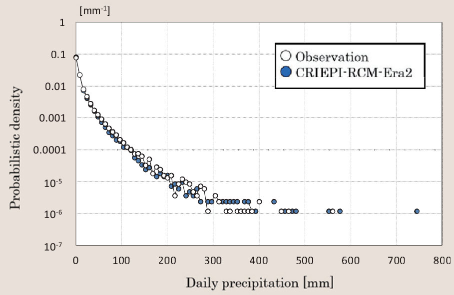


Fig. 2: Probability density distribution of daily precipitation

The probability density patter from the obtained database is compared with the one from observation. It is suggested that this database is sufficiently accurate for the hazard analysis of extreme weather events.

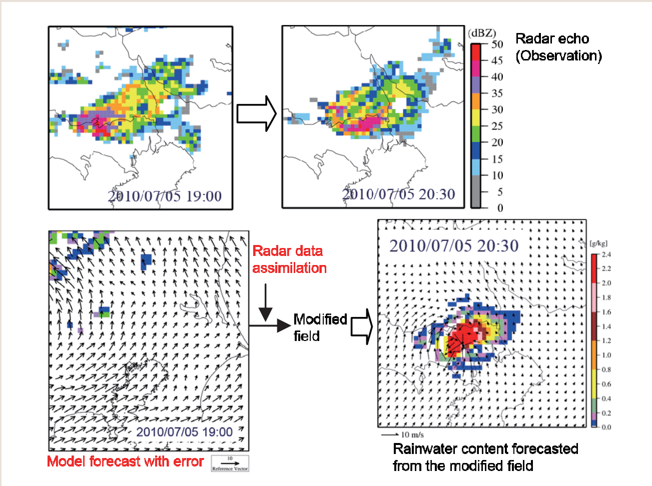


Fig. 3: Improving the accuracy of short-range rainfall forecasting using NCAR VDRAS

Errors in the initial condition and forecasting result of the meteorological model make forecasting of torrential rainfall difficult. Modification of the initial field or the forecasted field by assimilating four-dimensional radar data during a time window can enhance the capability of forecasting such severe storms.

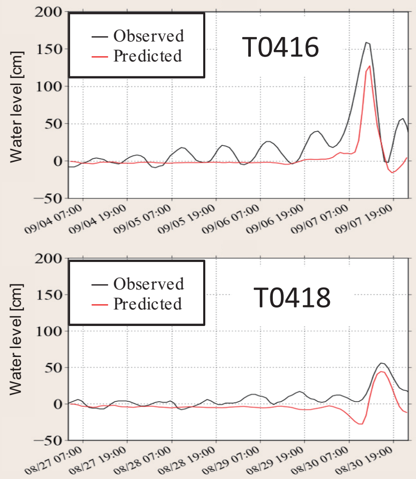
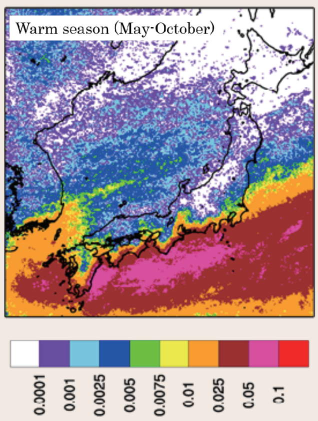


Fig. 4: Comparison of predicted and measured sea level changes of storm surges

The sea level changes of storm surges caused by the 16th and 18th typhoons in 2004 are compared with tide gauge measurements. With the exception of the semi-diurnal oscillations, predicted sea level changes agree with the measurements.



Storm-relative helicity (SReH) and convective available potential energy (CAPE) are calculated hourly from the database CRIEPI-RCM-Era2. Thresholds set for the above two indices are considered as a condition of the occurrence of supercell tornadoes.

Fig. 5: A map of probabilistic likelihood of the occurrence of F3 and larger tornadoes [%]

An analysis is made of the frequency that both thresholds are exceeded, set for two indices relating to vorticity transported to cloud and atmospheric instability. The result suggests that the frequency tends to increase over coastal areas on the Pacific side and around Kyushu. Regions with high frequency include almost all locations where F3 tornadoes occurred.

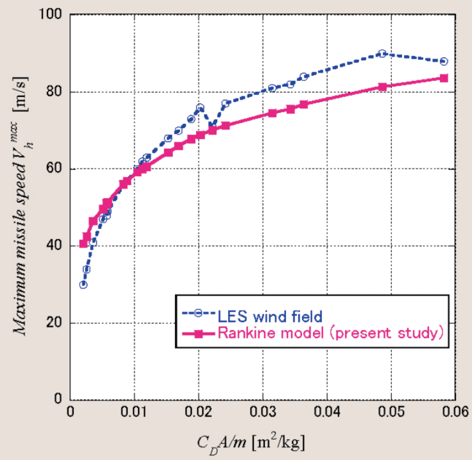


Fig. 6: Example of the maximum missile speed assessed under the two wind fields

The maximum travelling speed of a tornado missile, which begins to travel from a location 40 m above the ground level, depends on the material property represented by a drag coefficient C_D, cross section A, and mass m. The effect of the wind field is relatively smaller than the material property.