# Utilization of Meteorological Model WRF for New Prediction of Heavy Rain that can Cause Sediment-related Disasters

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## BACKGROUND AND PURPOSE

A large number of sediment-related disasters have occurred recently in Japan due to record rainstorms exceeding a cumulative rainfall of 1,000 mm or torrential rains with an hourly rainfall of 100 mm, caused by long-staying fronts or powerful typhoons, including a large-scale. Recently, information on sediment-related disaster warnings has been announced by each municipality in order to brace residents for frequent sediment disasters. However, since the existing sediment disaster warning information is on the basis of observed rainfalls or the CL (critical line) exceedance of the snake curve based on the soil rainfall index, there are some problems such as inadequate time to let residents evacuate because warnings are often made just before the actual disaster occurs.

On the other hand, as Japan has many mountainous areas, there has been a lot of research about relationship between rainfall and topography from the meteorological and hydrological viewpoints. It has eventually been clarified that the topography has a big impact on the rainfall with a relatively long time scale such as daily or total rainfall, and orographic rainfall phenomena, such as long-stationing heavy rainfall, tends to occur in a windward slope or a high altitude area.

From these backgrounds, it is effective to evaluate and organize relationships between risks of sediment disaster occurrence and rainfall factors or meteorological conditions in each topographic feature and each area in advance and to judge situations of sediment disaster occurrence by using the organized relationships and existing information on sediment disaster warnings and so on.

In order to clarify the wind direction and velocity conditions that tend to develop the growth of orographic rainfall for each area, this research involves to perform the orographic rainfall simulation by using the numerical calculation meteorological model of Weather Research and Forecasting (WRF) and to evaluate the validity of the simulation results in comparison with the actual rainfall phenomena. In addition, it is discussed about a methodology to predict orographic rainfall that would cause sediment disaster at an early stage, such as two to three days in advance, based on the simulation results.

## METEOROLOGICAL MODEL

The simulation by using the meteorological model was implemented in 32 cases of 16 wind directions and 2 wind velocities in order to identify areas where orographic rainfall tends to develop by the wind direction and velocity. The WRF model is used as the numerical calculation model, and a calculation area is in between 134° 30′ and 143° in the east longitude and 33° and 40° 30′ in the north latitude. **Table 1** shows conditions of simulation. An interval of the horizontal grid is set to 2 km to enhance reproducibility of the orographic rainfall. For the initial conditions, aerological observation data at Wajima immediately before heavy rainfall in Niigata and Fukushima in July 2011 are evenly set in the horizontal

**Table 1**: Calculation setting conditions

| Calculation conditions | Settings |
|---|---|
| Horizontal grid interval | 2 km |
| No. of horizontal lattices | 375 in east-west and 425 in north-south |
| No. of vertical layers | 50 |
| Calculation integration time | 4 hours |
| Calculation time step | 10 sec. |
| Lateral boundary conditions | Periodic boundary |
| Distribution of temperature and humidity | Temperature and humidity data at the Wajima Aerologic Observatory (Observation data at 9:00, Jul. 28, 2012) |
| Soil water content | 0.30 ($m^3/m^3$): uniform |
| Soil temperature | 290 K: uniform |
| Wind direction | 16 cases (16 directions) |
| Wind velocity | Two cases: (1) 15 m/s (stationary front assumed) (2) 30 m/s (typhoon rainfall assumed) |

direction as a vertical profile.

## RESULTS OROGRAPHIC RAINFALL SIMULATION

**Fig. 1** shows the results of orographic rainfall simulation in Toyama area. Toyama area is greatly affected by the North Alps of Japan, therefore, when the wind direction is north-northwest to west-northwest, the orographic rainfall develops in the Joganji River catchment area at the windward side due to the influence of the steep topography. On the other hand, when the wind direction is south-southeast to east-southeast, the orographic rainfall develops on the southern to eastern slopes of the North and Central Alps, while it does not develop in the Joganji and Kurobe River catchment areas at the leeward side.

## COMPARATIVE REVIEW OF CALUCULATION RESULTS AND ACTUAL PHENOMENA

The following 3 heavy rainfall events were used for verification of the model: the heavy rainfall by the large and slow-moving Typhoon No. 12, which caused a large-scale and deep-seated landslide in the Kii Peninsula in September 2011; the concentrated heavy rainfall by the baiu front associated with the approach of Typhoon No. 8, which caused debris flows along the Nashizawa mountain stream in Nagisomachi in July 2014; and the heavy rainfall from the band-shaped rainfall formed by the influence of Typhoon No. 18, which caused debris flow damage in Serizawa, Nikko in September 2015. The simulation results were compared with aerological observation data from actual rainfall events and radar/raingauge-analyzed precipitation maps, and validity of the orographic rainfall simulation was reviewed.

Comparing the radar/raingauge-analyzed precipitation distribution map for the heavy rainfall by Typhoon No. 12 (3:00, Sept. 3) with the simulation result when the southeasterly wind blew at a velocity of 30 m/s revealed heavy rainfall areas occurred at the same positions around the Omine Mountains and the Daikou Mountains. In the comparison between the radar/raingauge-analyzed precipitation map of when the Nashizawa debris flow occurred (12:00 to 24:00, Jul. 9) and the simulation result of the south-southwesterly wind blowing at a velocity of 15 m/s, it is confirmed that such same phenomenon is obtained as a local heavy rainfall area appeared in Nagisomachi. Comparison with the Kanto and Tohoku Heavy Rainfall that caused debris flow damage in Serizawa, Nikko also shows that a band-shaped rainfall occurred exactly at the same position as in the simulation for the case of south-southeasterly wind at a velocity of 30 m/s and good reproduction with an actual rainfall condition.

## DISCUSSION AND CONCLUSION

As verified with the heavy rainfall events cited in this paper the WRF-based rainfall simulation based on wind direction and velocity reproduces rain area development conditions that are similar to the actual rainfall conditions. We can conclude that the simulation results are precise enough to help clarify areas where orographic rainfall occurs and, therefore, sediment-related disasters are likely to occur as well.

As discussed above, it is logical to say that analysis and understanding of sediment disaster occurrence conditions and occurrence sites based on the orographic rainfall simulation is effective for disaster risk prediction. It is also indicated that when predicting orographic rainfall using WRF on a real-time basis (hourly rainfall) and applying the prediction results to the actual rainfall or snake curve for cases of major sediment disasters such as landslide dams, it can assist in early warning against rainfall likely to cause sediment disasters.

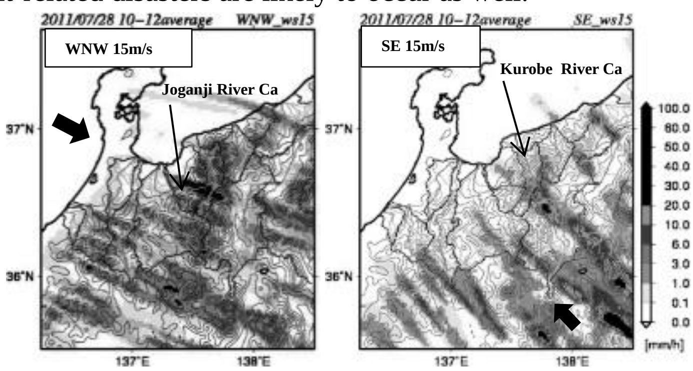


**Fig. 1**: Orographic rainfall simulation results

**Keywords**: meteorological model WRF, orographic rainfall, rainfall prediction, sediment disaster