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Fundamental Study for Real-Time Inundation Depth Estimation Using a New Weather Radar

Masahiko Osada[1*], Yuna Yoshinari[1] and Airi Shijo[1]

[1]Saitama University, Saitama, Japan

*(*Corresponding E-mail: osada@mail.saitama-u.ac.jp)*

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Abstract: To provide real-time inundation depth estimation for frequently occurring inland flooding events, we are advancing technological development utilizing new meteorological radar installed at Saitama University in 2017. This paper reports on the comparison between observed rainfall and analyzed rainfall, as well as the comparison between flood simulation results and actual inundation for the inland flooding occurred in Koshigaya City, Saitama Prefecture in 2023 as a case study.

Keywords: ***Inundation depth, Flood simulation, Multi-parameter phased array weather radar (MP-PAWR)***

Introduction

In recent years, increased typhoons and torrential rains have caused numerous inland floods across various regions. To address this, several real-time flood prediction systems are currently under development. However, despite the frequent inland floods, real-time flood prediction information is still not publicly available. Meanwhile, prefectures and municipalities have a need to quickly gather information, even at a rough level, on the extent of areas affected by above-floor and below-floor flooding. Recent research has begun attempting to predict road flooding 30 minutes in advance using the meteorological radar data employed in this paper (Kawai et al., 2025).

This study aims to develop real-time inundation depth estimation technology specifically tailored for inland flooding. It utilizes the all-sky rainfall distribution observed at 30-second intervals by the MP-PAWR (Takahashi et al., 2019; Kikuchi et al., 2020), installed at Saitama University and recognized as world-class. Particular emphasis is placed on actively incorporating micro-topography information specific to each region to construct region-specific specifications.

Target area

Specific microtopographic features are observed in inland areas prone to flooding. This study identifies these features using the inland flooding around Koshigaya City caused by a typhoon in June 2023 as a case study. Koshigaya City is located in eastern Saitama Prefecture and features a typical plain topography consisting of upland and lowlands. Figure 1 shows a location map and elevation map of Koshigaya City, Saitama Prefecture, presented as a color map. Elevations are below 10 meters, and microtopography such as natural levees, floodplains, and old river channels are well developed.

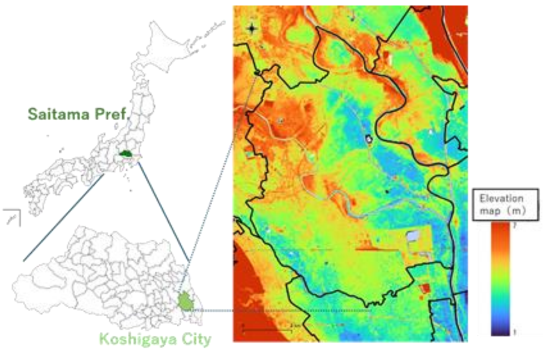

Figure 1, Location Map and Elevation Map (Source: GSI) of Koshigaya City, Saitama Prefecture.

Comparison of measured and analyzed rainfalls

Analytical rainfall observed by MP-PAWR is derived from the reflection intensity and falling velocity of raindrops at the lowest layer of the spatial mesh. First, we examine whether this analytical rainfall is comparable to actual rainfall measured at the ground.

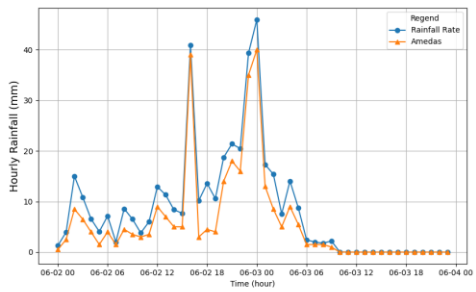

Figure 2, Location Map and Elevation Map (Source: GSI) of Koshigaya City, Saitama Prefecture.

Japan's Meteorological Agency operates the Automatic Meteorological Data Acquisition System (AMeDAS). An AMeDAS observation station is also located in Koshigaya City. Figure 2 compares the observed rainfall at this station with the rainfall rate (RR) from an analysis mesh that includes the AMeDAS observation station. The period compared was from June 2 to June 3, 2023, when flooding damage occurred.

As a result, although the rainfall analyzed shows slightly higher values, a good correlation has been obtained.

Comparison of actual inundation and flood simulation results

Flood simulation was conducted covering the entire area of Koshigaya City. Analysis utilized the flood simulation module in ArcGIS Pro. This module solves shallow water equations by setting rainfall intensity and infiltration rate into the ground. Here, to compare with actual rainfall measurements from AMeDAS, the simulated rainfall shown in the figure was applied across the entire analysis area.

Infiltration rates were set based on land use categories from the National Land Numerical Information Download Site: 5 mm/h for farmland and green spaces, and 0 mm/h for other areas (treated as paved surfaces where infiltration does not occur).

Simulations were conducted under these conditions for a 48-hour period starting at 0:00 on June 2, 2023. For comparison, analyses were also performed under the same conditions using rainfall intensity values derived from actual rainfall at the AMeDAS observation station.

Figure 3 shows actual flood inundation records and simulation results. Figure 3 (a) overlays the flood records onto the Geospatial Information Authority of Japan's flood control terrain classification map. The inundated areas are concentrated in floodplains and old river channels enclosed by natural levees. Figure 3 (b) shows one scene from the numerical results, depicting conditions at 1:00 AM on June 3, when rainfall peaked. Darker colors indicate deeper inundation depths. Comparing both figures, the areas with deeper inundation depths generally correspond to the actual flooded areas.

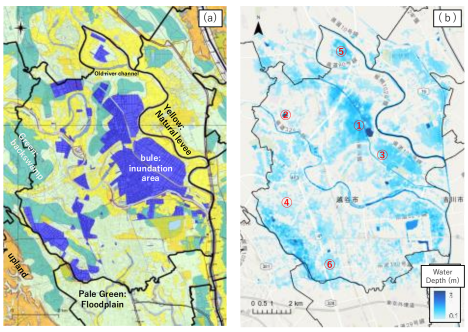

Figure 3, Comparison of Actual inundation and Flood Simulation Results. (a)Map showing inundation area on flood control terrain classification map (source: GSI), (b) Flood Simulation Results.

Figure 4 shows the time history of water depth at the six locations numbered in Figure 3(b). The water depth changes over time at all locations, the time at which the water depth begins to increase differs at each location, and the rate at which the water depth increases with increasing rainfall also differs. Furthermore, Location 2, which shows a water depth exceeding 4 m, is located in the regulating reservoir with a full water level of 4.41 m. Therefore, it was considered that flooding was not significant in its vicinity, indicating that the regulating function was working effectively.

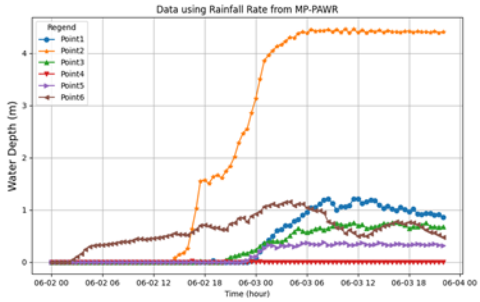

Figure 4, Time history of water depth at each location. Refer to Figure 3 (b) for the position number.

Summary

Using MP-PAWR rainfall intensity data, we conducted flood simulation for the 2023 Koshigaya flood. This reconfirmed that microtopography significantly contributes to inundation depth in the plains area. Moving forward, we plan to maximize MP-PAWR's capabilities and advance preparations toward developing a real-time system capable of issuing flood warnings before inundation occurs.

Acknowledgement

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