Structural Features of Typhoon RUSA's Center Revealed by Three-Hourly Upper-Air Observation Data

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The Center for Severe Weather Monitoring and Observation, established by the Meteorological Research Institute, Korea Meteorological Administration is located at the Haenam Weather Observatory (34° 33’N, 126° 35’E). Its principal project, called the Korea Enhanced Observing Period (KEOP), is to produce intensive observation data of severe weather conditions which occur during the summer, such as heavy rainfall and typhoons, through intensive field-based experiment in which high-tech, sophisticated meteorological equipments are deployed. The intensive observation data analysis and its application studies will be used to provide better understanding of various severe weather structures and developments, as well as improve the short-range forecasting of severe weather events.

In keeping with the Center's view of applying high-tech meteorological equipments to intensive field-based experiments, the Meteorological Research Institute initiated the purchase of Vaisala's Autosonde in 2000. The Autosonde has been operating continuously for the purposes of researching severe weather conditions, such as heavy rainfall and typhoons, since the middle of January 2001.

The Autosonde was especially successful in the KEOP-2002 project in 2002. The main mission of KEOP-2002 was to produce spatial and temporal high-resolution upper-air observation data over the southwestern part of the Korean peninsula and clarify the structure of severe weathers and the mechanism of their genesis and development trough intensive observation data. The equipment used in the project included a portable rawinsonde system, the Autosonde, and the Korea Meteorological Administration (KMA) upper-air observation network.

In enhancing the utilization and application of the Autosonde and the assessment of its steadiness against maximum wind speeds of over 20 m/s, valuable three-hour upper-air observations were made from 09 UTC on August 29th to 21 UTC on September 1st, 2002. During this period, the Center was able to capture Typhoon RUSA, which had caused record-breaking damage to lives and properties in Korea, as the typhoon approached the Korean peninsula and hit a south coastal region near the Haenam Weather Observatory at 06 UTC on August 31st, 2002. Using the temporal high-resolution upper-air observation data obtained by the Autosonde, the Center for Severe Weather Monitoring and Observation was able to delineate and analyze the characteristics of the atmospheric vertical structure around Typhoon RUSA's center.
There has been previous research done in other countries on the analysis of atmospheric vertical structure around the typhoon’s center using wind profilers and drop windsondes in other countries (Sato, 1992; May, 1993; Willoughby, 1998). However, such studies in Korea remain very limited due to the difficulty of maintaining effective three-hour upper-air sounding observations under the influence of strong winds and heavy precipitation and the fact that only a few of the well-organized typhoons that have been observed have hit the Korean peninsula. Thus, the research done on Typhoon RUSA is very unique and meaningful in enhancing our perspective and understanding of this severe weather system structure.

The time-altitude cross-sections of various meteorological elements (temperature, relative humidity, equivalent potential temperature and wind vectors) using the data from the 21 UPT Autosonde upper-air observation are shown below. The red typhoon symbol on the bottom of the graph indicates the time when Typhoon RUSA hit the southern coastal region of Korea. The time of the typhoon was determined with consideration to the position of the typhoon’s center, obtained from the best track of Typhoon RUSA issued by RSMC (Regional Specialized Meteorological Center) of Tokyo, the shortest distance between the typhoon and the Haenam Weather Observatory, and the lowest surface pressure at the observatory. The blank areas of the figures below indicate that no observation data were collected due to the strong surface winds that were created as the typhoon passed. Generally, during Autosonde observations, a more expensive helium gas is used instead of the normal hydrogen gas to enhance operation safety. In this particular Autosonde observation (shown below), 200g weather balloons were used instead of the regular 800g or 1,000g balloons in order to reduce costs by decreasing the amount of gas needed in the process.

Time-altitude cross-sections of (a) temperature, (b) relative humidity, (c) equivalent potential temperature, and (d) wind vectors observed by the Autosonde from 09 UTC August 29th to 21 UTC September 1st, 2002
In Figure a, the lower level temperatures started to decrease gradually while the higher level temperatures increased as the typhoon approached the Korean peninsula. The interface height of the decreasing and increasing temperature regimes was about 2.5 km. The decrease in the lower level temperature regimes can be explained partly by the adiabatic expansion of air parcels under which the pressure was lower than the environment and the cooling effect induced by precipitation.

Relative humidity was characterized by high humidity associated with a cloud band ahead of the typhoon, low humidity derived from the increase of temperature by adiabatic compression around the typhoon center, and the effect of the synoptic weather system after the typhoon passed (Fig. b). High equivalent potential temperature at the typhoon passage time appeared due to the increase in the amount of cloud at regions where it was relatively warmer than the environment (Fig. c). The easterlies before the typhoon abruptly changed to westerlies after the typhoon passed (Fig. d).

The change in the wind speed magnitude, shown in altitudes of 2 to 3 km, was relatively small compared to the change of wind direction. In addition, there was a divergent region above 8 km. From the temporal high-resolution upper-air observation data obtained with the Autosonde, the warming core associated with the adiabatic compression of air parcel and low humidity at mid to high levels could be seen. Weak wind speeds which were typical characteristics of the typhoon center could also be seen since the observation site at Haenam was located within the typhoon center which was ill-organized and wide after it had hit the peninsula.

From the tangential velocity computed from the Autosonde, four maximum tangential velocity areas could be seen at altitudes of 3 to 4 km. These corresponded with the rainfall peaks at Haenam. The satellite images showed that the first maximum tangential velocity at 07 UTC on August 30th was influenced by the second cloud band formed ahead of the typhoon. The second area was at 00 UTC on August 31st, just before the typhoon passed, when there was strong cyclonic and convergent circulation in the typhoon’s inner eyewall. The third velocity was located at the eyewall of the ill-organized typhoon center (see below).

Maximum rainfall at Haenam occurred when a strong cyclonic circulation, associated with the outer eyewall of the typhoon, appeared at the observation site. However, due to the influence of the ill-organized and wide typhoon center, there was no rain and the sky was clear at Haenam.

The relationship between azimuthal velocity and Haenam rainfall (left panel), and the structure of Typhoon RUSA’s eye and associated convective cloud systems (right panel) analyzed by high-resolution upper-air soundings from Autosonde and the corresponding satellite images.
Looking at the analyses done in this project, it can be said that Vaisala’s Autosonde played an important role in obtaining useful data about Typhoon RUSA. While providing sufficient three-hour upper-air observations in conditions where maximum wind speeds were 20 m/s, the Autsonde helped clarify the structure, genesis, and developmental mechanism of the typhoon.

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