An Observational Study of Jumping Cirrus with Ground-based Visible Cameras and X-band Radar

*Takafumi Seguchi[1], Suginori Iwasaki[1], Masashi Kamogawa[2], Tomoki Ushiyama[3], Hajime Okamoto[4]

1. NDA of Japan, 2. GCARR, University of Shizuoka , 3. ICHARM, PWRI, 4. RIAM, Kyushu University

Jumping cirrus (JC) is a cirriform cloud which literally jumps up from the anvil cloud of deep convective storms and appears to transport water vapor atop the anvil through its partial sublimation. Some research using a satellite observation indirectly suggests that JC can moisten the lower stratosphere above a thunderstorm. Thus, JC is likely to contribute to the total amount of stratospheric water vapor.

Numerical studies indicated that JC is generated by the breaking of gravity wave which a sinking overshooting top creates. On the other hand, our knowledge of the physical characteristics of JC is not sufficient to confirm the mechanism of JC. This is partly because past observations were insufficient. JC has been rarely observed because of its small optical thickness. Space-borne imagers cannot identify JC directly since they do not have vertical information. Only a few cases where JC was observed by a ground-based camera, aircraft, and space-borne cloud radar, have been reported, but there were no quantitative studies. This study is the first work focusing on the observation-oriented analyses for multiple cases of JC using ground-based visible camera and weather radar.

During the summer in 2016, 2017, and 2018, we found 28 cases of JC around the Kanto area in Japan by ground-based visible cameras. The ground-based observation by visible cameras has an advantage that they can record the consecutive change of horizontal and vertical development of clouds. In our observation, many cases tended to be observed in the mountainside, which is reasonable for the cumulonimbus occurrence by the forcible rising of the air.

Combined with the data from the infrared band of the geostationary meteorological satellite Himawari-8 and radiosonde, the motion and scale of JC, such as height and width, and environmental atmospheric conditions of JC occurrence were investigated. From radiosonde, we calculated the altitude of tropopause and defined if the JC reached the tropopause or not. Also, environmental wind shear and convective available potential energy (CAPE) were examined. For the detection of water vapor in the lower stratosphere, we calculated the brightness temperature difference (BTD) value by subtracting the black body temperature of the IR band (10.4 μm) from that of the water vapor absorption band (6.2 μm) of Himawari-8. If the detectable amount of water vapor exists in the lower stratosphere where the air temperature is warmer than the one at the anvil top layer in the UT, the black body temperature of the water vapor absorption band is higher than that of the cloud top, and thus, the BTD value is positive.

The results indicated 6 cases of JC entered the lower stratosphere. However, water vapor in the lower stratosphere was not detected for all cases. Compared with the case of JC in the United States (US) reproduced by a 3-dimensional non-hydrostatic cloud model simulation, our cases show the smaller value of CAPE and environmental vertical wind shear above the anvil, while the height, vertical speed, and duration to disappear of JC show similar scales on average. It means that JC can occur even if the underlying convection is relatively weak like a single cell storm, not a supercell thunderstorm in the US case. Our studies showed the scale of JC varied with cases and was not correlated with the CAPE, anvil size, and environmental wind shear.

C-band radar (5.3GHz) operated by Japan Meteorological Agency is used to investigate the relation between the storm severity and JC. We found that the thunderstorms causing JC were accompanied with heavy rain which was more than 100 mm/h. For further works, the data from X-band radar network (as known as XRAIN) operated by the Ministry of Land, Infrastructure, Transport and Tourism, Japan, whose wavelength is 9.7 GHz, will be examined to understand the vertical structure of JC and the underlying deep convections. There is a previous study where JC was observed by the Cloud Profiling Radar on the CloudSat satellite, whose wavelength is 94 GHz and smaller than X-band. By comparing those radar data from various bands, we can estimate the size of cloud or precipitation particles of JC, which is likely to be ice particles at higher altitudes.

Keywords: jumping cirrus, convective cloud, overshooting top, ground-based observation, XRAIN