The satellite observation of the aerosol emissions and the reaction of the clouds with the atmospheric wave from Hunga-Tonga Hunga-Ha'apai volcanic eruption

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The Hunga Tonga-Hunga Ha'apai submarine volcano began volcanic activity on December 20, 2021, and the massive explosion eruption occurred on January 15, 2022. This eruption caused global impacts such as tsunami, atmospheric wave, and emission of the plumes and aerosols. Satellite observation from space is useful for such large-scale events that are difficult to observe directly on site. In this study, we show the characteristics of the emitted aerosols captured by the Second generation GLobal Imager (SGLI) onboard GCOM-C, and the reaction of the clouds with the atmospheric wave analyzed with the Advanced Himawari Imager (AHI) onboard Himawari-8.

The SGLI is a sensor capable of 19-channel observation from near-UV to thermal infrared wavelengths with spatial resolutions of 250 m or 1 km. Since the 1.38 μm channel (shortwave infrared) is within the strong water vapor absorption band, light from the ground surface and the lower layer of the atmosphere cannot be seen due to the absorption by the water vapor in the lower atmosphere. By utilizing this characteristic, it is possible to extract the scattered light from clouds and aerosols in the upper atmosphere. As for the aerosols emitted along with the Tonga volcanic eruption, we found that the aerosols spread westward and returned to the same region in about three weeks.

SGLI also has a function that turns the telescope along orbital direction (approximately +/- 53 degrees from the zenith direction on the Earth's surface). By using the parallax of the observation target based on the slant view angles just like a stereoscopic view, it is possible to estimate the approximate altitude of the targets. As a result, the estimated aerosol altitudes were about 28 km for the three regions, around Tonga, northeastern Australia, and the Indian Ocean. On the other hand, the altitude of clouds was about 15 km or less, which corresponds to the top altitude of the troposphere, suggesting that aerosols are distributed in the stratosphere above the troposphere.

The AHI, the optical imager, has 16 channels and can observe the full Earth disk seen from about 141E geostational orbit with a temporal resolution of 10-minute. Because of the powerful shock wave, the atmospheric wave (Lamb wave and internal gravity waves) propagated across the Pacific Ocean. Since the temperature of the water vapor in the atmosphere could be increased by the adiabatic compression due to the atmospheric wave, the propagation of the atmospheric wave can be visualized by the time difference images of the channel of the water vapor in the upper level (6.2 μm) of Himawari-8. By using this method, we investigated the response of the cloud optical thickness (Himawari-8, Level2 product) to the atmospheric wave propagation. As a result, the cloud optical thickness instantaneously changes with the propagation of the atmospheric wave as well as the brightness temperature at 6.2 μm. In addition, we found that there was a clear negative correlation between the amount of change in cloud optical thickness and in brightness temperature at 6.2 μm. The decrease in cloud optical thickness can be explained by the evaporation of water droplets due to the increase in temperature with adiabatic compression. Conversely, when atmospheric waves pass through, adiabatic expansion causes the temperature to decrease and water vapor condenses, resulting in a larger cloud optical thickness.

This study shows the satellite-based analyses of the atmospheric phenomena of the Tonga eruption. To estimate these sudden and large-scale impacts on the climate, it is important to continue monitoring with the global observation satellites such as GCOM-C, Himawari-8 and -9.

Keywords: Hunga Tonga–Hunga Ha'apai, volcanic eruption, GCOM-C/SGLI, Himawari-8/AHI, atmospheric wave, aerosol

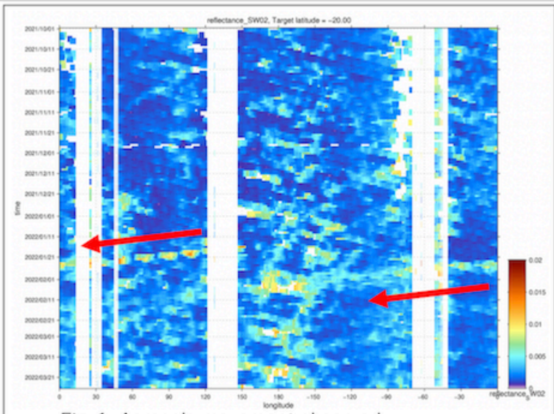

Fig. 1 Aerosols movement observed by 1.38 μm wavelength channel of GCOM-C/SGLI

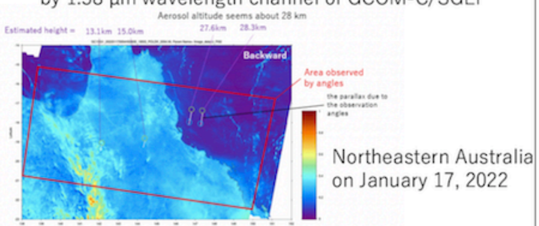

Fig.2 Estimation of aerosol altitude by multidirectional observation of GCOM-C/SGLI

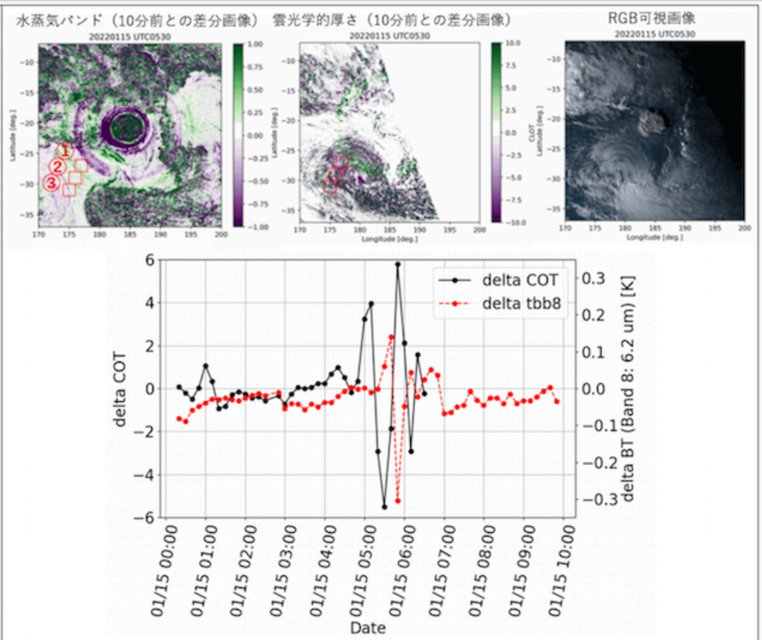

Fig.3 The response of the Cloud optical thickness and brightness temperature at water vapor channel analyzed with Himawari-8/AHI.