

## Reconstructing Three-Dimensional Models of Clouds by the Philippines' First Microsatellite, DIWATA-1

\*Ellison Caparas Castro<sup>1,2</sup>, Tetsuro Ishida<sup>1</sup>, Yukihiro Takahashi<sup>1</sup>, Kaye Kristine Vergel<sup>2</sup>, Francisco Miguel Felicio<sup>2</sup>

1. Hokkaido University, 2. Institute of Environmental Science and Meteorology, University of the Philippines Diliman

The Philippines' first microsatellite, DIWATA-1, is a 50-kg-class Earth Observation Microsatellite was launched by the International Space Station (ISS) on 27 April 2016 to an orbit of 400 kilometers altitude and an inclination of 51 degrees. Two of its cameras on-board are the Space-borne Multispectral Imager (SMI) and the High Precision Telescope (HPT). The SMI is attached to a Liquid Crystal Tunable Filter (LCTF) and has a spatial resolution of 60 meters, while the HPT has four bands, three for the visible spectrum and one for the near-infrared, and has a spatial resolution of 3 meters. Together with these cameras, DIWATA-1 is capable of target-pointing, that is capable of capturing stereo-images.

The Philippines is one of the most vulnerable countries to natural disasters; on average, about 18 –19 typhoons hit the Philippine area of responsibility, the main objective of DIWATA-1 is to assist in disaster monitoring and natural resource management. Although projecting the path of hurricanes for better forecasting has been successful, the strength of hurricanes is less likely predicted. Floods and damages in communities and even human lives are at risk depending on the strength of the hurricanes, and by carefully estimating the strength of an upcoming hurricane, necessary precautions and preparations can be made beforehand to mitigate disasters. An indicator of hurricane strength is the storm clouds' cloud-top height and growth. In this paper, the cloud monitoring capability of DIWATA-1 will be introduced, along with reconstructing three-dimensional models of clouds to estimate their cloud-top height and growth, which could be one of the powerful approaches to catch the precursor of natural disasters.

Unlike cloud observations from conventional satellites and radars, DIWATA-1, with its target-pointing capability, can capture cloud images for at least every 200 milliseconds. It can monitor the growth of clouds of specific areas, which radars may not reach, with high temporal and spatial resolution. Using the captured images through target-pointing, three-dimensional models can be reconstructed, which can exhibit the cloud-top height by using the height of the satellite as a parameter. By having several of these models, with images captured at separate times, the growth of the clouds can be estimated. An initial result of this methodology is an image captured in Iloilo, Philippines on 5<sup>th</sup> August 2017 with a local time of 12:40. Visually, the image consists of several cumulus clouds. The cloud-top heights of these clouds reached to approximately 4,000 meters, with most of the clouds within the 2,000-meter range. The cloud-top heights of the clouds were verified by locating the cloud and its corresponding shadow in the image, in addition with the solar zenith angle at the time and location of the images. The average error of the three-dimensional models in comparison with this verification is approximately 200 meters. Due to the interpolation in reconstructing three-dimensional models, the ground resolution of the models is higher than that of the actual images which can vary depending on the model.

The three-dimensional models reconstructed through this methodology will play a role in the SATREPS project ULAT "Project for development of extreme weather monitoring and alert system in the Philippines", complemented by ground-based lightning networks which estimates lightning activity to establish a very detailed semi-real-time information of thunderstorms and typhoons which may contribute

in the prediction of disasters and for a better alert system.

This work was supported by Japan Society for the Promotion of Science (JSPS), Core-to-Core Program, B. Asia-Africa Science Platforms, by Japan Science and Technology Agency (JST) together with Department of Science and Technology (DOST) of the Republic of the Philippines under the e-ASIA Joint Research Program, and by Japan International Cooperation Agency (JICA) and JST, SATREPS.

Keywords: DIWATA-1, Cloud-top Height, Three-dimensional Model