



## **Tropospheric Water and Cloud Ice (TWICE) Millimeter and Sub-millimeter Wavelength Radiometer for 6U-Class Satellites: Enabling Global Observations of Ice Cloud Particle Size and Humidity in the Upper Troposphere/Lower Stratosphere**

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Ice clouds cover more than 33% of Earth's surface and play a significant role in the hydrological cycle by affecting atmospheric dynamics, precipitation and cloud processes. Global measurements of cloud ice particle size distribution and total ice water content, along with associated temperature and water vapor profiles, in the upper troposphere/lower stratosphere (UTLS) are critically needed to improve knowledge of the role of ice clouds in Earth's climate, precipitation and cloud processes. Such observations will enable improvement in cloud and moisture models including precipitation forecasting.

A recent study has developed a Bayesian-based simulation and retrieval system and applied it to the TWICE radiometer instrument with channels at a range of millimeter and sub-millimeter wavelengths. Results show that the TWICE instrument is capable of retrieving ice particle size in the range of approximately 50 to 1000 micrometers with better than 50% uncertainty, filling the gap in ice cloud particle size retrieval using existing space-borne remote sensing modalities. Results of these simulations show simultaneous retrieval of ice water content within 50%, temperature profiles within 1 K, and water vapor profiles within 20% [1].

To perform such observations on a global basis, a new millimeter and sub-millimeter wavelength radiometer is currently under development with mass, volume and power requirements suitable for deployment on 6U-Class satellites, also known as 6U CubeSats. The Tropospheric Water and Cloud ICE (TWICE) instrument is a wide-band radiometer measuring at 15 frequencies from 118 GHz to 670 GHz, including two orthogonal polarizations at the highest frequency. The TWICE instrument is designed to provide observations of upper tropospheric water vapor profiles, temperature profiles and ice particle size distribution in clouds on a global basis at a variety of local times. The TWICE instrument uses 25-nm InP High Electron Mobility Transistor (HEMT) low-noise amplifier-based (LNA) receiver front-ends to provide low-noise and low-power operation in a small form factor at millimeter and sub-millimeter wavelengths. TWICE radiometers perform conical scanning to preserve the polarization basis. End-to-end calibration is performed once per scan at all 15 frequencies by viewing both the cosmic microwave background (2.7 K) and an ambient calibration target at a known thermodynamic temperature. TWICE will meet the requirements for operation in a 6U-Class satellite with dimensions of 34 cm x 20 cm x 10 cm and mass up to 12 kg.

1. J. H. Jiang, Q. Yue, H. Su, S. C. Reising, P. P. Kangaslahti, W. R. Deal, E. T. Schlecht, L. Wu and K. F. Evans, "A Simulation of Ice Cloud Particle Size, Humidity and Temperature Measurements from the TWICE CubeSat, *Earth and Space Science*, July 2017, pp. 1-14, doi: 10.1002/2017EA000296.