Measurements of upper-tropospheric water vapor and cloud ice at a variety of local times are critically needed to address current limitations of microwave sensors in sun-synchronous orbits. Such global measurements would improve currently limited understanding of upper tropospheric / lower-stratospheric (ULTS) processes in general circulation models (GCMs), improving both climate predictions and knowledge of their uncertainty. Clouds and Aerosols

• Clouds represent the largest uncertainty in predictions of climate models. Clouds in polluted environments tend to have smaller water droplets and ice crystals than those in cleaner environments. As shown in Figure 1, they are less likely to generate rainfall, increasing the cloud water content, and have higher albedo than clean clouds.

Ice Cloud Particle Size

• NASA's A-Train provides limited cloud particle size information. Sub-millimeter wave radiometry can fill the gap between large particle sizes from CloudSat's 94-GHz radar and small particle sizes from Aqua MODIS 10-µm infrared radiometer.

• Sub-millimeter wave radiometry can provide cloud particle size information between approximately 25 µm and 1 mm.

• High atmospheric opacity at sub-millimeter wavelengths allows the measurement of high cirrus clouds through scattering.

• Brightness temperatures decrease below the ambient water vapor continuum by different amounts at different frequencies, depending on ice particle size, as shown in Figure 2.

TWICE Instrument Top-Level Design

TWICE was managed by the NASA Earth Science Technology Office under the Instrument Incubator Program. TWICE is a collaborative effort led by Colorado State University (CSU) in partnership with the NASA Jet Propulsion Laboratory (JPL) and Northrop Grumman Corporation (NGC). TWICE is intended to provide global measurements of ice particle size through band-limited radiometric measurements performed at 240 GHz, 310 GHz, 670 GHz, and 850 GHz as well as provide temperature and humidity profiles using 118 GHz (temperature), 183 GHz (water vapor), and 380 GHz (upper tropospheric water vapor) sounding channels.

TWICE instrument is designed for deployment in a 6U-Class satellite and has a mass of 7.3 kg.

For a CubeSat deployment from the International Space Station into an orbit with 400 km altitude and 51.6° inclination:

• TWICE conically scans the scene with a nominal incidence angle of 53°, viewing the Earth scene swath over a scan angle range of 110°.

• TWICE has a swath width of 650 km and a scan-to-scan along-track displacement of 7.2 km, assuming a scan duration of 1 s. The relative sizes and locations of the geo-projected footprints are shown in Figure 8.

CONCLUSIONS

• The Tropospheric Water and Cloud ICE (TWICE) is a 6U-Class satellite instrument to enable global measurements of cloud ice particle size distribution and water vapor profiles in the upper-tropospheric/lower stratosphere (ULTS) at a variety of local times.

• TWICE performs measurements at 16 frequencies from 118 GHz to 850 GHz to yield cloud ice particle size information and total ice water content as well as atmospheric profiling of temperature and water vapor.

• Conical scanning preserves the polarization basis and enables end-to-end calibration at 16 frequencies using cosmic microwave background and an ambient blackbody calibration target.

• The TWICE instrument meets the size, weight and power (SWaP) requirements for deployment in a 6U-Class satellite.