Temporally-Resolved Observations of Hurricanes, Tropical Cyclones and Severe Storms using Repeat-Pass Radiometry from 6U CubeSat Constellations

*Steven C Reising[1]

1. Microwave Systems Laboratory, Colorado State University, Fort Collins, CO 80523 USA

Global observations of clouds and precipitation are essential to improve monitoring and prediction of hurricanes, tropical cyclones and severe storms with substantial impacts on human life and property. For example, severe storms, tropical cyclones and hurricanes have caused more than 722 Billion USD of damage from 1980-2016 in the U.S. alone. To understand processes in clouds that lead to rain, snow, sleet and hail, global observations with rapid revisit times are essential. To this end, sensors on geostationary satellites have substantially improved weather prediction by providing visible and infrared measurements on the 5- to 10-minute time scale. However, to improve understanding of cloud and ice processes leading to the onset of precipitation on a global basis requires nanosatellite constellations using repeat-pass radiometry capable of penetrating into the storm to perform temporally-resolved observations of the radiative effects of scattering from cloud particles and hydrometeors.

At the same time, the use of nanosatellites to enable rapid access to space has grown exponentially in the past 3-5 years. In particular, CubeSats were introduced in 1999 as an educational satellite platform consisting of one or more units "U" of 10 cm cubes. CubeSats were originally used as teaching tools and for demonstration of space technology. However, rapid maturation of commercially-available nanosatellite technology and fast "fly-learn-refly" cycles have allowed CubeSats to produce high-value science, including remote sensing of the Earth's environment. As of the end of 2015, more than 425 CubeSats had been launched by 36 countries. More than 80% of all science-focused CubeSats have been launched from 2012 to 2016. The rapid development cycles of CubeSats of 2-3 years from funding to readiness to launch afford opportunities for rapid adoption of new technology. CubeSats typically benefit from low-cost launches as secondary payloads on missions of opportunity, e.g., free non-commercial U.S. launches provided by NASA's CubeSat Launch Initiative.

Nanosatellite constellations can provide rapid revisit times, including for sensing dynamic processes in the Earth’s atmosphere, including temperature, humidity, precipitation and cloud properties. An example is the Temporal Experiment for Storms and Tropical Systems (TEMPEST) mission concept. TEMPEST consists of a constellation of 5 identical 6U CubeSats measuring at 5 millimeter-wave frequencies with 5-minute temporal sampling to observe time-resolved severe storms and their transition to precipitation. 6U CubeSats are chosen due to their substantial margins on mass, power, satellite-to-ground communications and radiometer calibration capability. To achieve such a constellation requires (1) precision inter-satellite instrument calibration among the 6U CubeSats in the constellation and (2) orbital drag maneuvers to control the relative positions of 6U CubeSats in the constellation to achieve the required temporal spacing between successive observations.

Currently, the TEMPEST Technology Demonstration (TEMPEST-D) mission is under development to raise the TRL of the instrument and key satellite systems as well as to demonstrate the observational capabilities required to achieve such a 6U CubeSat constellation. A partnership among Colorado State University (Lead Institution), NASA/Caltech Jet Propulsion Laboratory and Blue Canyon Technologies,

TEMPEST-D will provide observations at five millimeter-wave frequencies from 89 to 183 GHz using a single compact instrument that is well suited for 6U CubeSats. The TEMPEST-D project started in August 2015 and passed CDR in July 2016, with planned delivery of the complete 6U CubeSat in Q3 of 2017. TEMPEST-D will be integrated by Nanoracks for launch to the International Space Station on a commercial resupply service (NASA ELaNa-23) in Q2 or Q3 of 2018, with deployment soon thereafter into a 400-km orbit with 51.6° inclination for a 90-day mission following on-orbit commissioning.

Keywords: Hurricanes, Tropical Cyclones and Severe Storms, CubeSats, Nanosatellites, Satellite Constellations, Microwave radiometry, Temporally-resolved observations