POTENTIAL APPLICATIONS OF SMALL SATELLITE MICROWAVE OBSERVATIONS FOR MONITORING AND PREDICTING HURRICANES AND TYPHOONS

Fuzhong Weng
NOAA Center for Satellite Applications and Research, College Park, MD 20740

Yuan Ma, Hu Yang and Xiaolei Zou
Earth System Science Interdisciplinary Center, University of Maryland, College Park, MD 20740

ABSTRACT
A new constellation comprising of eight microwave small satellites is proposed in this study. This constellation is capable of covering the entire globe every two hours. With six more satellites added and properly arranged, a constellation is able to provide hourly observations of fast-evolving severe weather systems like hurricanes. Compared to current polar-orbiting satellite which normally carries one passive microwave instrument onboard, a small satellite constellation is more cost-effective, requires a shorter development cycle and has smaller failure impact. NOAA Center for Satellite Applications and Research (STAR) has built a full radiance transformation system (ARTS) that is applicable for small satellite calibration, validation and data processing. Hourly NWP forecast fields for tropical storm Debby (2012) will be produced and used as inputs to Community Radiative Transfer Model (CRTM) to simulate the designed microwave small satellite observations to demonstrate their values for monitoring and predicting hurricane and typhoon events.

Index Terms—Small satellite, Microwave instrument, Hurricane

1. INTRODUCTION
Remote sensing observations from space-borne microwave instruments on board polar-orbiting satellites have proved to be invaluable to numerical weather prediction. They can be used not only for observing temperature and water vapor throughout the atmosphere, but also cloud liquid water path and ice water path, in nearly all-weather conditions. However, the cost for a polar-orbiting satellite system is much higher than small satellite. This study aims at providing microwave observations for fast-evolving weather systems as well as entire globe using an optimally designed small satellite constellation.

Recent efforts for small satellites to carrying out microwave instruments include Microsized Microwave Atmospheric Satellite (MicroMAS) was deployed from International Space Station on March 4, 2015 and remained in communication for 5 days [1]; Microwave Radiometer Technology Acceleration (MiRaTA) and Earth Observing Nanosatellite (EON), which constitute both multi-band microwave sounder and GPS radio occultation (GPS-RO) sensor, are scheduled to be launched in near future [2]; the five-CubeSat constellation Temporal Experiment for Storms and Tropical Systems (TEMPEST) [3]. Besides engineering issues such as payloads and drags, proper calibration and cross calibration, complication of observations at a certain location from different scan angles, as well as quick data processing and stable data management are challenging for the development of any microwave small satellite constellation.
Figure 1. Simulated orbits for (a) COSMIC and (b) small satellite constellation on June 1, 2015.

Figure 2. Distribution of CRTM simulated brightness temperatures for ATMS on board the small satellite constellation during 0000-0136 UTC on June 1, 2015. The NCEP GFS fields at 0000 UTC June 1, 2015 are used as inputs to CRTM.

Figure 3. Global distribution of the total number of revisits within each 0.25°x 0.25° grid box during a one-day period for the small satellite constellation.

ATMS FOV geolocations are calculated. Brightness temperatures (TBs) at different FOVs are then simulated using the Community Radiative Transfer Model (CRTM) and the NCEP GFS forecast fields, which serve the inputs to CRTM simulations of ATMS brightness temperatures obtainable from the small satellite constellation. Global distributions of simulated TBs at ATMS channels 8 and 20 are shown in Fig. 2. As expected from a cross-track radiometer, a scan angle dependence of brightness temperature is seen clearly for temperature sounding channel 8 which is located around 250 hPa. For water vapor channel 20, small-scale features associated with low tropospheric water vapor distributions are captured. The entire globe is covered in less than two hours by
the small satellite constellation. A global distribution of the total number of revisits within each 0.25°x 0.25° grid box during a one-day period for the small satellite constellation is provided in Fig. 3. It is seen that more than 10 earth scenes are available within each 0.25°x 0.25° grid box.

4. SMALLSAT CAPTURING RAPID EVOLUTION OF HURRICANES

Orbits and FOV locations of microwave small satellite constellation can be generated in the area of fast-evolving systems such as hurricanes. A constellation comprising of 14 satellites is capable to provide hourly global observations. Geostationary Operational Environmental Satellite (GOES) data was used in grid point statistical interpolation (GSI) to produce initial condition for Hurricane Weather research and Forecasting Model (HWRF), and the model forecast for Debby (2012) was improved by this approach [4]. This forecast can be used to produce 1-hr input to CRTM. Together with FOV geolocations, ATMS brightness temperature observations can be generated for Debby. Limb correction should also be conducted in order to eliminate the effects of viewing a same location through different scan angles.

5. SUMMARY

Small satellites achieve high-frequency revisiting rates with a constellation consisting of eight small satellites. The entire globe is fully covered every two hours. A constellation comprising of 14 satellites could provide hourly global observations for monitoring the fast-evolving weather systems such as tropical cyclones. Compared to existing polar-orbiting satellites, the small satellite constellation is of low-cost, rapidly deployable and mission-flexible. NOAA STAR is now building the end-to-end calval system, such as ARTS, for small satellite calibration, validations and data processing. A core satellite for inter-calibration of small satellite data is needed, and the current JPSS ATMS is a great candidate. Hourly model forecasts for tropical storm Debby (2012) will be produced as inputs to CRTM to simulate ATMS observations to demonstrated the ability for small satellites to observed hurricanes or typhoons.

6. ACKNOWLEDGEMENT AND DISCLAIMER

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7. REFERENCES


