THE HIGH ALTITUDE MMIC SOUNDING RADIOMETER ON THE GLOBAL HAWK – FROM TECHNOLOGY DEVELOPMENT TO SCIENCE DISCOVERY

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1. INTRODUCTION

This paper presents results from the High Altitude MMIC Sounding Radiometer (HAMSR) during three recent field campaigns on the Global Hawk Unmanned Ariel Vehicles (UAV), focusing on the enabling technology that led to unprecedented observations of significant weather phenomenon, such as thermodynamic evolution of the tropical cyclone core during rapid intensification and the high resolution three dimensional mapping of several atmospheric river events. HAMSR is a 25 channel cross-track scanning microwave sounder with channels near the 60 and 118 GHz oxygen lines and the 183 GHz water vapor line [1]. HAMSR was originally designed and built at the Jet Propulsion Laboratory as a technology demonstrator in 1998. Subsequent to this, HAMSR participated in three NASA hurricane field campaigns, CAMEX-4, TCSP and NAMMA. Beginning in 2008, HAMSR was extensively upgraded to deploy on the NASA Global Hawk (GH) platform and serve as an asset to the NASA sub-orbital program. HAMSR has participated on the Global Hawk during the 2010 Genesis and Rapid Intensification (GRIP) campaign, the 2011 Winter Storms and Atmospheric Rivers (WISPAR) campaign and is currently participating in the NASA Ventures Hurricane and Severe Storm Sentinel (HS3) campaign (2011-2015).

2. HAMSR INSTRUMENT TECHNOLGOY

The recent upgrades to the HAMSR instrument have made it into a state-of-the-art microwave sounder for the NASA sub-orbital program. Continued upgrades are planned based on the recent campaign experience recognizing the capabilities of the Global Hawk. This paper will highlight the past technology upgrades and the plans for the future as the system is optimized for the new and unique capabilities offered by the Global Hawk platform. The state-of-the-art features of the instrument are the front-end LNA technology, developed by JPL through the MIMRAM project, which have been incorporated in the 118 and 183 GHz receivers, reducing the noise in these bands to less than 0.1K at the sensor resolution (~2km) and enabling HAMSR to observe much smaller scale temperature and water vapor features. Another feature is an enhanced data system that provides on-board science processing capability and real-time data access. Recently, the HAMSR ground data system (GDS) was upgraded for the Ventures HS3 campaign to take full advantage of this real-time capability and provide timely information for not only the mission but the National Hurricane Center (NHC). These products included real time storm center positioning, intensity estimates and displays of the eyewall convective structure for each eye overpass. This reconnaissance information is invaluable not only for underway mission flight planning but also for tropical cyclone now-casting and forecasting.

3. HAMSR VALIDATION

During the WISPAR and HS3 campaigns, dropsondes were flown on the Global Hawk with HAMSR. The dropsondes provide in-situ observations of temperature and water vapor co-incident in time with the HAMSR measurements providing an excellent data source for validating the HAMSR calibration and retrieval algorithms. The current number of co-incident dropsondes is over 250, providing a statistically significant sample set over a wide variety of atmospheric and surface conditions, from summer tropical, to mid-latitude winter to arctic. As an example, the comparison between the dropsonde derived and HAMSR retrieved integrated water vapor (IWV) is shown in Figure 1 for all co-incident observations during the WISPAR campaign. Excellent agreement is observed over the range of atmospheric conditions sampled. In addition to a statistical comparison, and perhaps more important, is a comparison of the observations during several atmospheric river crossings. An example is shown in Figure 2. Statistical comparisons do not provide insight the performance particular to the events being studied. These data in Figure 2 show that the HAMSR data can provide complementary information to the dropsondes, and reveal the true structure of the atmospheric river that could not be obtained accurately from the under sampled dropsondes. In this paper, we will summarize the HAMSR retrieval validation of temperature and water vapor profiles and integrated quantities, such as IWV, using the dropsondes from WISPAR and HS3.

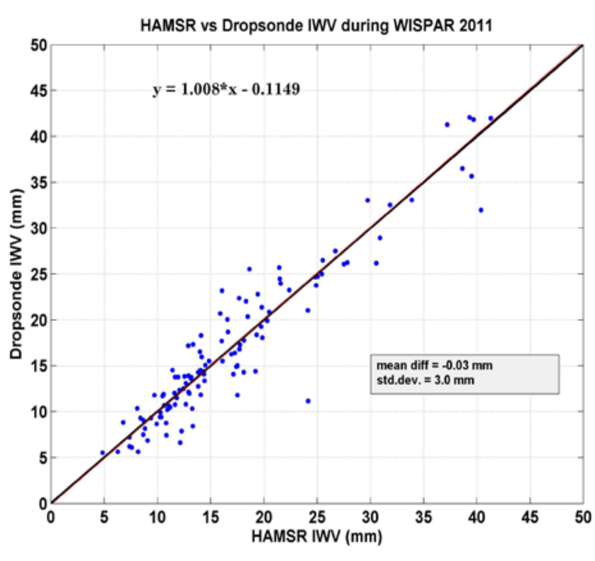

Figure 1. HAMSR retrieved IWV compared to co-incident dropsondes during WISPAR.

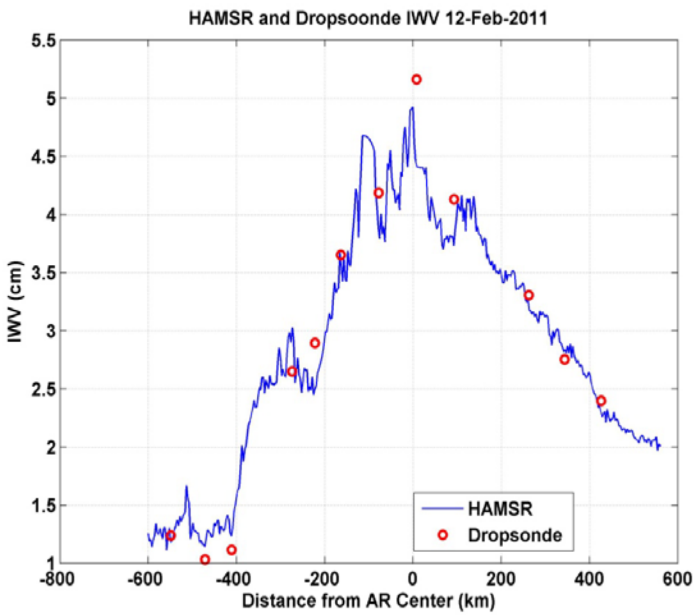

Figure 2. HAMSR retrieved IWV (blue line) compared to co-incident dropsondes (red circles) during an atmospheric river transect in WISPAR.

3. HAMSR SCIENCE

HAMSR on the Global Hawk has provided several first of their kind observations, including 12 hours of continuous reconnaissance of Hurricane Karl (2010) as it underwent rapid intensification from a category 1 to category 3 storm. The Karl data show the evolution of moist thermodynamic structure of the inner core. These unprecedented measurements show that the warm anomaly in Karl propagated downward as the storm intensified, with the largest temporal change near the 500 mb level. A comparison to numerical tropical cyclone models simulating rapid intensification show similar behavior. This example illustrates how these unique measurements contribute to ultimately improving tropical cyclone prediction by validating the model physics. The HAMSR observations also enable improvement and validation of satellite retrieval algorithms, particular for those that are observing features smaller than the radiometer footprint. For example, precipitation algorithms and tropical cyclone intensity estimation algorithms require beam-filling corrections. The high resolution HAMSR observations are used to validate the physical models that are used to account for the satellite sub-sampling of the phenomenon. For example, Figure 3 shows a comparison of the HAMSR high resolution observations of the upper tropospheric warm anomaly over Hurricane Karl compared to AMSU. The low-resolution of AMSU significantly reduces the warm anomaly signature (which is typically within 10-20km of the eye). The AMSU beam-filling correction algorithm from [2] is shown to fit the HAMSR data well, providing validation of this algorithm. The paper will highlight some of the more significant science results from the HAMSR observations of tropical cyclones and atmospheric rivers during the WISPAR and HS3 campaigns, including some of the first high spatial resolution maps of the vertical water vapor transport of an atmospheric river.

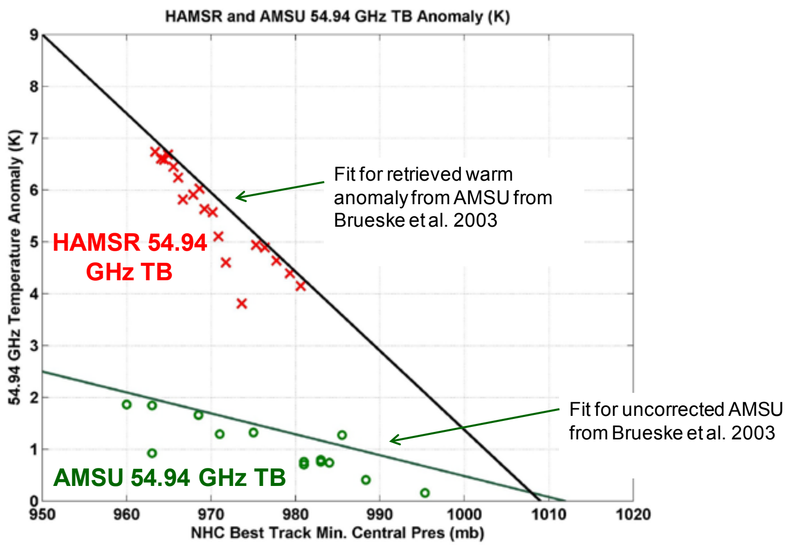

Figure 3. Comparison of HAMSR and AMSU upper tropospheric warm anomaly for Karl.

11. REFERENCES

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[2] Brueske, K. and C. Velden. 2003. Satellite-Based Tropical Cyclone Intensity Estimation Using the NOAA-KLM Series Advanced Microwave Sounding Unit (AMSU). 131. pp. 687-697.