NEAR-REAL-TIME SIGNIFICANT WAVE HEIGHTS IN HURRICANES FROM A NEW AIRBORNE KA-BAND INTERFEROMETRIC ALTIMETER

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ABSTRACT

During the 2020 hurricane season, scientists at the National Oceanic and Atmospheric Administration (NOAA)/National Environmental Satellite, Data, and Information Service (NESDIS)/Center for Satellite Applications and Research (STAR) Ocean Surface Winds Team (OSWT) operated the Ka-band Interferometric Altimeter (KaIA) from the NOAA WP-3D aircraft in collaboration with Remote Sensing Solutions (RSS). KaIA is a nadir-looking Ka-band radar altimeter that is capable of measuring the first three Doppler moments. This paper shows significant wave height (SWH) retrievals from the 2020 hurricane season and compares them to the IFREMER Wavewatch3 model.

Index Terms— Sea measurements, Ka-band, altimetry, remote sensing, cyclones

1. INTRODUCTION

Beginning in the 2019 hurricane season, scientists at the National Oceanic and Atmospheric Administration (NOAA)/National Environmental Satellite, Data, and Information Service (NESDIS)/Center for Satellite Applications and Research (STAR) Ocean Surface Winds Team (OSWT) have installed and operated the Ka-band Interferometric Altimeter (KaIA) on the NOAA WP-3D Hurricane Hunter aircraft. KaIA remained on the P-3 for flights through winter extratropical cyclones as part of the OSWT Ocean Winds field experiment in January and February of 2020, and was installed again for the 2020 hurricane season. It has always been collocated with the Imaging Wind and Rain Airborne Profiler (IWRAP) [1] and Stepped Frequency Microwave Radiometer (SFMR) [2] instruments, which should prove to be scientifically interesting for studying the air-sea interface at extreme winds. Table 1 lists basic information about the storms KaIA has sampled in these two hurricane seasons.

KaIA is a nadir-looking Ka-band radar altimeter capable of measuring the first three Doppler moments with a range gate spacing of 5 cm. In the 2020 hurricane season, it provided real-time significant wave height (SWH) retrievals for

Table 1: Tropical Cyclones Sampled by KaIA 2019–2020

Date	Storm Name	Saffir-Simpson Category
2019-09-13	TD 9	TD
2019-09-14	TD 9	TD
2019-09-15	TD 9	TD
2019-09-16	Humberto	1
2019-09-22	Jerry	1
2019-09-29	Lorenzo	4
2019-09-13	Paulette	1
2019-09-14	Sally	1
2019-09-17	Teddy	4
2019-09-18	Teddy	3
2019-09-22	Teddy	2
2019-10-03	Gamma	TS
2019-10-06	Delta	4
2019-10-07	Delta	2
2019-10-08	Delta	2
2019-10-09	Delta	3
2019-10-25	Zeta	TS, TS
2019-10-26	Zeta	TS, 1
2019-10-27	Zeta	TS
2019-10-28	Zeta	1
2019-11-06	Eta	TD
2019-11-07	Eta	TS
2019-11-08	Eta	TS, TS
2019-11-10	Eta	TS
2019-11-11	Eta	1

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the National Hurricane Center (NHC) and Ocean Prediction Center (OPC) to use in their forecasts. A version of the plots presented below were posted as the flight was occurring at `https://manati.star.nesdis.noaa.gov/datasets/AircraftData.php`. While not exploited yet, KaIA also has the capability of retrieving mean squared slope (MSS), relative ocean height, and wind speed estimates at low wind speeds. A Ku-band channel is being added for the 2021 winter storm season, which will allow for rain rate retrieval and correction of rain effects on the surface.

The instrument was built using Phase 3 funding as part of the NOAA Small Business Innovation Research (SBIR) project for the Debris and Small Object Mapping radar system (DSOM) in order to achieve the high-precision altimetry required by DSOM. DSOM is a multi-phase-center interferometric synthetic aperture radar (SAR) that will provide extremely fine-scale measurements of the ocean-surface reflectivity and motion.

2. OBSERVATIONS AND DISCUSSION

Figure 1 shows a map of the 20201009H1 NOAA WP-3D flight track through Hurricane Delta when the storm was off the coast of Louisiana. Two satellite altimeters, Jason-3 and AltiKa, are also shown as colored significant wave height values in feet along their flight track. The time of the satellite measurement corresponding to the measurement lowest in latitude is shown near the bottom of the plot adjacent to the track. NOAA buoy locations are labeled with their numeric identifier and a colored marker showing the last SWH measurement made near the time KaIA passed over it.

Figure 2 shows the significant wave height retrieved from KaIA during the 20201009H1 flight through Hurricane Delta as a time series. In the top panel, modeled wave heights from the IFREMER Wavewatch3 model are shown as orange + symbols. Model wave heights from the Meteo-France MFWAM model are shown as magenta circles. The two models were linearly interpolated in time and space to the location and time of the KaIA measurement. The bottom panel shows SFMR retrievals from [3].

Nearby buoy measurements are shown as colored `X` symbols according to the distance of the WP-3D from the buoy. These buoys are labeled with the NOAA buoy identifier. Since the buoys take a 20 min average, the time during which this average is taken may be different from when the aircraft was nearest the buoy location. The sampling time of the buoy is shown on the horizontal axis as a purple rectangle, and the buoy measurements from this sampling time are “tied” to the center of the rectangle.

The first observation we can make is that there is good agreement between the general shapes of the model and the KaIA retrievals. This is not always the case with the storms this season, but there tends to be better agreement in stronger cyclones. Occasionally rain corrupted the surface observations too much to make a valid retrieval. Compare the spikes in the rain rate (bottom panel of fig. 2) with missing SWH retrievals.

The measurements according to the buoys near the middle of the flight (42002 and 42019) indicate that the SWH was stable when KaIA sampled near the buoy, so the time difference is not significant. Figure 2 shows these two buoys report SWH within 0.1 m (0.3 ft) and 0.4 m (1 ft) in consecutive sampling periods for 42002 and 42019, respectively. As can be seen in fig. 2, the aircraft passed almost directly over 42002 but was only within 40 km to 50 km of 42019. Still, the agreement between both buoys and the nearest KaIA retrievals in space are good. This is due to the concentric circle structure of significant wave heights with respect to the center of the storm. KaIA observed the same section of the storm as the buoy did at KaIAs point of closest approach to the buoy.

Just after the third eyewall penetration, the Jason-3 satellite altimeter passed over part of the track KaIA observed from early in the flight. Though this was about 4 hours earlier, the correlation between sensors is good due to its distance from the storm. The AltiKa satellite altimeter made its overpass at approximately the same time as KaIA was flying the downwind leg of the pattern between the southernmost and easternmost points. Unfortunately, the satellite retrievals appear to be corrupted—though they do generally increase as the sensor samples closer to the storm.

3. CONCLUSIONS

The Ka-band Interferometric Altimeter (KaIA) is a new airborne satellite altimeter that has been used for near-real-time significant wave height retrieval during the 2020 hurricane season. Though there are few validation opportunities available, comparisons have been made above for the storm flight through Hurricane Delta with buoy and satellite altimeters. In general, the KaIA retrievals match well with other sensors and wave models.

This work is in progress and it is anticipated that we will be able to improve retrievals as we develop the processing software further. In particular, there is a small aircraft attitude dependence that remains to be accounted for in the SWH retrieval. Additionally, attenuation and impact from rain can modify the Ka-band signal enough to change the apparent leading-edge slope. This could be mitigated or flagged in the future with the addition of a Ku-band channel.

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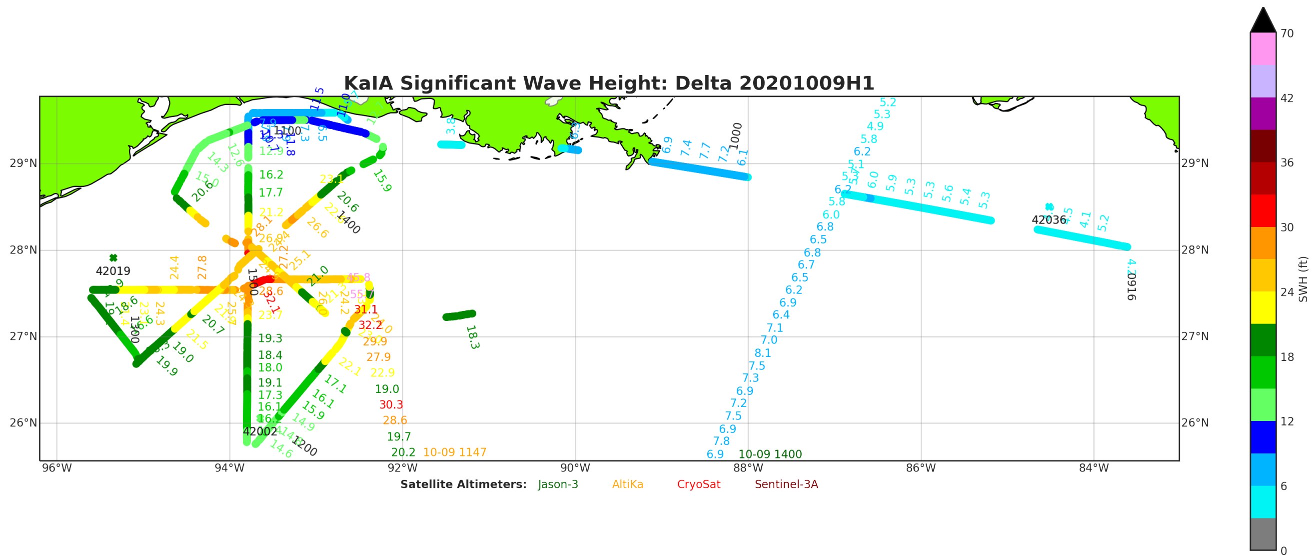

Fig. 1: Map showing KaIA significant wave height retrievals from the 20201009H1 flight through Hurricane Delta, when it was off the coast of Louisiana. Also shown are two satellite altimeter overpasses and NOAA buoy locations.

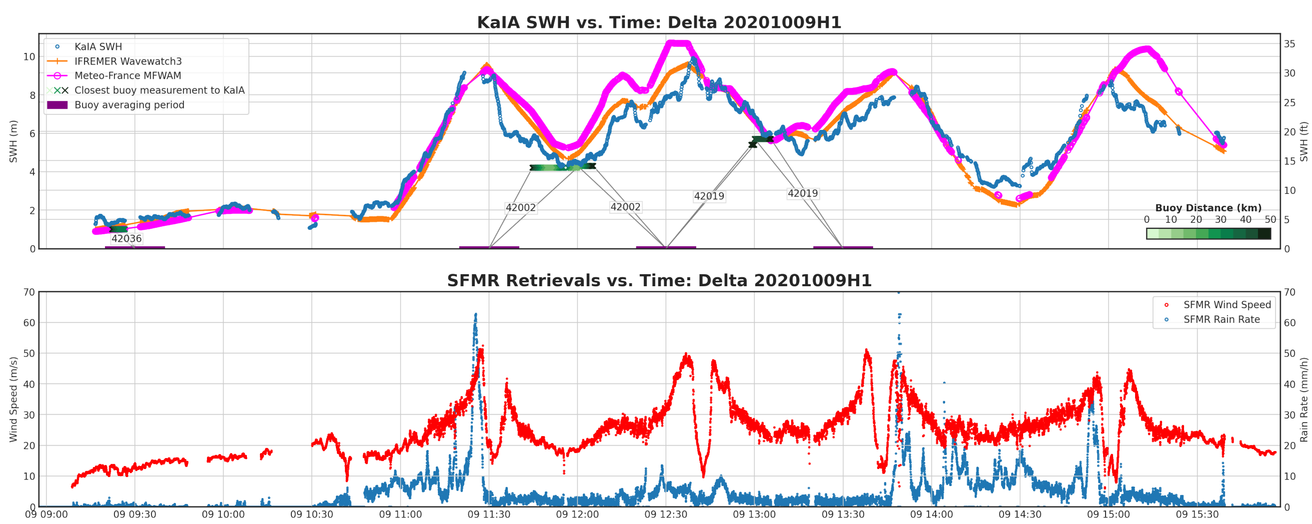

Fig. 2: Time-series of KaIA significant wave height retrievals (top) and SFMR retrievals (bottom) from the 20201009H1 flight through Hurricane Delta. In the top panel, model SWHs from the IFREMER Wavewatch3 model are shown as orange + symbols and model SWHs from the Meteo-France MFWAM model are shown as magenta circles. Nearby buoy measurements are also shown as colored X symbols according to the distance of the WP-3D from the buoy. The sampling time of the buoy is shown on the horizontal axis as a purple rectangle, and the buoy measurements from this sampling time are "tied" to the center of the rectangle. The bottom panel shows SFMR retrievals from [3].

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5. REFERENCES

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