OCEAN SURFACE CURRENTS AND WINDS USING DOPPLERSCATT

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ABSTRACT

DopplerScatt is a Ka-band pencil-beam Doppler scatterometer developed under NASA's ESTO Instrument Incubator Program (IIP) to serve as a demonstrator for future spaceborne instruments to measure ocean surface currents and winds simultaneously. We review the capabilities of the DopplerScatt instrument, and present results from multiple airborne campaigns. One of our primary results will be the development of Ka-band Geophysical Model Functions (GMFs) to translate backscatter and Doppler measurements into surface winds and currents.

Index Terms— Ocean currents, ocean winds, radar, scatterometer, Doppler

1. INTRODUCTION

Ocean surface vector winds and currents are intrinsically coupled essential climate variables. The recent US National Academies Decadal Review for Earth Observation from Space [1] has recently identified these coincident measurements as a priority for observations from space in the next decade. The DopplerScatt instrument, developed under the NASA ESTO IIP, is a demonstrator instrument for a potential spaceborne measurements of these variables from space. The instrument architecture builds on rotating pencil-beam scatterometers and adds Doppler estimation, enabling global simultaneous measurements of winds and current vectors on a daily basis, thanks to the ultra-wide swaths ($\sim$ 1800 km) achievable by rotating pencil beam systems.

The DopplerScatt instrument was completed in 2016 and participated in several field campaigns, including the Submesoscale Processes and Lagrangian Analysis on the Shelf (SPLASH) campaign conducted by the CARTHE consortium at the mouth of the Mississippi River, during which hundreds of surface drifters were deployed coincident with DopplerScatt flights. Although simultaneous winds and Doppler have been explored at C[2, 3], our results are the first collected at Ka-band. Here, we demonstrate the ability to retrieve winds and currents using Ka-band returns, and derive Geophysical Model Functions (GMFs) for both winds and currents. We show that, unlike the C-band results, the Ka-band wind-driven surface current signature does not show a strong variability with winds, for a large wind speed range.

The research presented in the paper was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautic and Space Administration.

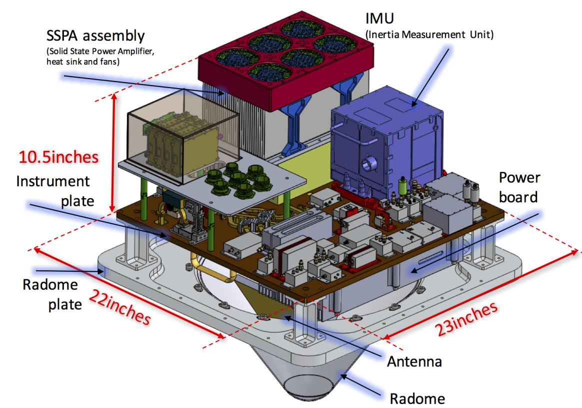

Fig. 1. Schematic of the DopplerScatt instrument.

2. DOPPLERSCATT INSTRUMENT OVERVIEW

DopplerScatt is a vertically polarized single-beam Ka-band coherent scatterometer using a rotating pencil-beam antenna to illuminate circular regions that can be built into a continuous swath, similar to the principle of the NASA's Seawinds Instrument on QuikSCAT [4]. The 12 RPM rotation rate of the antenna is set so that, for a given range, every point in the swath is observed from at least two different directions. The data are recorded coherently onboard and processed on the ground to estimate radial velocities by using pulse-pair phase differences and normalized radar backscatter cross sections, σ_0. The azimuth diversity of the measurements allows for inversion of both vector surface velocities and winds. The antenna beam boresight is set at a nominal incidence angle of 56°, which, at a nominal flight altitude of 8.53 km, results in a ground scan radius, R, of approximately 12.5 km, for a total observation swath of about 25 km. The system is highly configurable in terms of the inter-pulse period, the burst repetition interval, and the system bandwidth, allowing for operation at multiple altitudes. Table 1 presents the configuration that was used to obtain the results presented here and an instrument schematic is presented in Figure 1.

Table 1. DopplerScatt nominal parameters.

Parameter	Value
Peak Power	100 W
3dB Azimuth Beamwidth	3°
3dB Azimuth Footprint	800 m
3dB Elevation Beamwidth	3°
3dB Elevation Footprint	1.4 km
Nominal boresight angle	56°
Burst Repetition Frequency	4.5 kHz
Inter-pulse Period	18.4 μsec
Chirp length	6.4 μsec
Pulses per burst	4
Pulse Bandwidth	5 MHz
Azimuth Looks	100
Range Resolution	30 m
Resolution in Elevation	36.2 m
Resolution in Azimuth	485 m
Nominal Platform Altitude	8.53 km
Nominal Swath	25 km
Scan Rate	12 RPM
Noise Equivalent σ_0	-37 dB

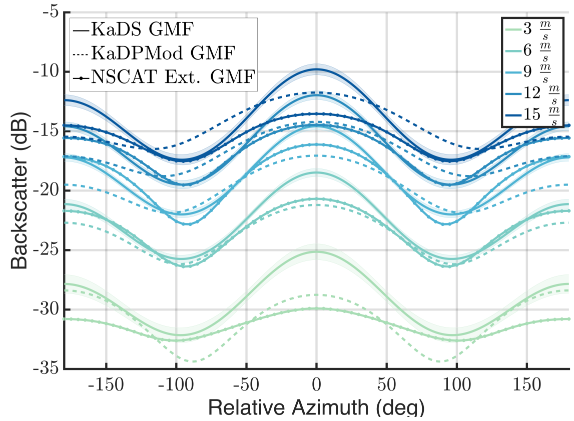

Fig. 2. comparison between the KaDPMod wind GMF (dashed lines), NSCAT (lines and + signs), and the DopplerScat Ka-band wind GMF (solid lines). Shaded regions again represent 95% confidence intervals for the DopplerScatt wGMF. The relative azimuth for the wind GMF is taken with the origin in the ***upwind*** direction.

3. GEOPHYSICAL MODEL FUNCTIONS

In order to convert Ka-band backscatter measurements into winds, one traditionally uses a model function that relates mean backscatter as a function of elevation and azimuth angles to wind speed and direction. Here, we train a GMF based on comparisons of extensive flight data to high-resolution weather forecasting models from multiple sources, and compare our results against obtained at Ku-band by the NSCAT/QuikSCAT scatterometers and tower measurements conducted in the black sea by Yurovsky et al. [5]. An overview of the Ka-band wind GMF is shown in Figure 2. This figure shows that Ka-band has wind speed sensitivity similar to Ku-band, and the upwind-crosswind ratios are greater than at Ku-band, leading to greater direction sensitivity. This sensitivity of the Ka-band backscatter cross section shows promise for spaceborne wind estimation using Ka-band data.

Although the DopplerScatt Doppler signatures can be translated directly to an along-track radial velocity, this radial velocity contains, in addition to the surface currents of interest, the intrinsic motion of the Bragg scatterers, as well as aliasing of orbital velocities due to differential radar brightness due to large-wave effects [2]. To disentangle these effects, we average surface currents that are not driven by the simultaneous winds by bining Doppler velocities as a function of wind speed and azimuth angle relative to the wind direction. This process will isolate Brag and wave driven effects, but will also include Stokes and surface drift currents. In Figure 3, we show the result of this binning. From these results, we can infer the modulation transfer function [6] and estimate the contribution due to orbital velocity aliasing. We attribute the remaining component to resonant Bragg waves and see that it behaves mostly as expected as a function of wind speed and direction. We also note that the orbital wave contamination is nearly constant for a large fraction of the wind speed range, unlike similar results for C-band [3]. This implies that removing the wind driven component will be more robust to wind speed errors than at C-band. The simultaneous wind speeds and directions from the σ_0 data allows an accurate removal of these wind-driven effects.

4. EXAMPLE RESULTS DURING SPLASH

During the last year, DopplerScatt has participated in a variety of field campaigns that have allowed comparison of the retrieved geophysical values against models, *in situ,* and satellite data. As an example of typical data products, we show in Figure 4 examples of both retrieved winds and a component of the surface current at the Mississippi River Plume region in the Gulf of Barataria. These data compare well against model results, including the US Navy NCOM model. The surface currents show recirculation and a frontal region that were observed during the *in situ* campaign and by satellite sensors. As an example of the air-sea interaction effects, it is clear that the surface currents exert a strong influence on the retrieved winds. Although this phenomenon has been observed at large scales, these observations at 200 m resolution are the first synoptic observations of these phenomena at high resolution over extended areas. Additional examples and validation results will be presented in the fuller account.

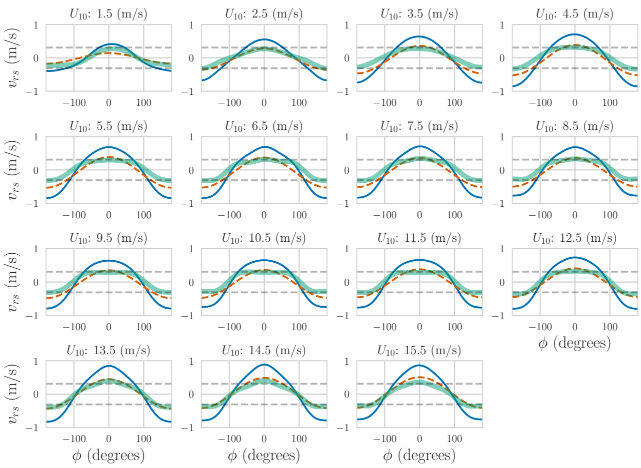

Fig. 3. (blue lines) Surface-projected radial velocities, binned by wind speed and azimuth angle relative to the wind direction; (dashed-red) Orbital velocity contamination predicted by modulation transfer function (MTF); (green) Residual "Bragg" contribution. (dashed gray) Free Bragg wave phase speed.

5. CONCLUSIONS

The DopplerScatt instrument presents an airborne platform that demonstrates the viability of making simultaneous wind and current measurements from space. Here, we outline the instrument implementation and some of the results obtained during campaigns conducted in the last year. These results include GMFs for winds and currents that demonstrate the capability of estimating both winds and currents from Ka-band backscatter data. We also present examples of data products. Validation of the measurements will form part of the fuller account.

6. REFERENCES

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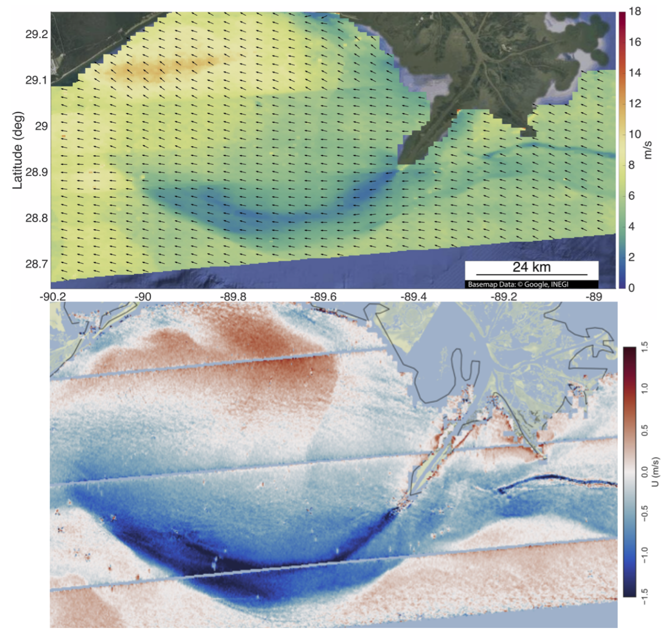

Fig. 4. (Upper panel) Estimated wind speed (color) and subsampled wind directions (arrows) for the Mississippi River plume and Barataria Bay; (Lower panel) Estimated east surface current component for the same region as a above.

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