Effect of Precipitation on Sea Surface Wind Scatterometry

Jilong Yang[1], Xuehu Zhang[1], Xiuwan Chen[1], Daniel Esteban[2], David McLaughlin[2], Jim Carswell[2], Paul Chang[3], Peter Black[4], Yinghai Ke[1]

[1] Institute of Remote Sensing and Geographic Information Ssytem, Peking University, P. R. China

[2] University of Massachusetts at Amherst, USA

[3] NOAA NESDIS, USA

[4] NOAA HRD, USA

yangjl@water.pku.edu.cn

Abstract: A set of microwave remote sensing data collected with the newly developed UMass Imaging Wind and Rain Airborne Profiler (IWRAP) during the 2002 Atlantic Hurricane Season was analyzed to further our understanding of the effect of precipitation on scatterometer wind vector retrieval. Coincident surface wind speed and precipitation measurements were provided by the UMass Simultaneous Frequency Microwave Radiometer (SFMR). The differences between the wind estimations from IWRAP and SFMR under precipitation conditions of 0-100mm/hr and wind speed of 0-60m/s was calculated, from which the effect of precipitation on the wind vector retrieval using scatterometry is analyzed qualitatively.

Keywords: Ocean Wind Scatterometry, Hurricane Remote Sensing, Airborne Radar, Precipitation Effect

1. Introduction

Knowledge of wind velocity over the ocean is of critical importance for understanding and predicting many oceanographic, meteorological, and climate phenomena. Satellite-borne microwave scatterometers can measure ocean wind vectors on a global scale. However, precipitation has been shown to limit the accuracy of scatterometer ocean wind ocean wind vector retrievals within tropical cyclones (TCs) and severe ocean storms [1]. Light to medium rain rates (0.5 – 5 mm/hr) are absorptive and have significant attenuation (up to about a dB) at Ku-and (13 GHz). Heavy rains (> 10 mm/hr) exhibit both absorption and scattering of radar signals and can cause a total bias of several dB's for ocean scatter measurements [2]. These effects of rain on NRCS (Normalized Radar Cross Section) measurements will affect the scatterometer wind retrievals [3]. The effect of rain should be quantified in order to improve the usefulness of satellite ocean wind scatterometry. Current methods tried to identify those cells contaminated by rain by providing an estimate of conditional probability of rain [4]. For example, a multidimensional histogram rain-flagging (MUDH) technique was adopted by the QuikSCAT science team to provide a rain flag with the wind vector estimates during the calibration/validation phase of SeaWinds wind products [5]. Some rain events are missed and some cells are rain flagged when rain is not present. In order to improve forecasts and atmospheric models, the data set coming from scatterometer measurements should remove or at least minimize the undesirable degradation due to precipitation.

This paper presents preliminary analysis results of a set of microwave remote sensing data collected with the newly developed UMass Imaging Wind and Rain Airborne Profiler (IWRAP) during the 2002 Atlantic Hurricane Season. Meanwhile, UMass Simultaneous Frequency Microwave Radiometer (SFMR) provided coincidental surface wind speed and precipitation measurements. The differences between the wind estimations from IWRAP and SFMR under precipitation conditions of 0-100 mm/hr and wind speed of 0-60 m/s was calculated, from which the effect of precipitation on the wind vector retrieval using scatterometry is presented qualitatively.

2. IWRAP Instrument

IWRAP is a dual frequency (C/Ku Band) dual polarized airborne radar that profiles the volume and surface backscatter and Doppler simultaneously at 30, 35, 40 and 50 degrees incidence, while conically scanning at 30 to 90 rpm. Its range resolution can be set at 15, 30, 60 or 120 m. During the 2002 Atlantic Hurricane Season, the slant resolution of IWRAP is set at 30 m From these measurements the ocean surface wind field, 3-D boundary layer winds within rain bands can be mapped. IWRAP was flown onboard the NOAA N42RF P-3 aircraft during the 2002 NOAA/NESDIS/ORA Hurricane Ocean Winds Experiment, which was conducted in conjunction with the 2002 NOAA/AOML/HRD Hurricane Field Program (HFP). A total of 13 flights were carried out with 358 GB of data collected.

3. Description of Data Processing

The data utilized in the paper are composed of the C-band, vertically polarized NRCS measurements from IWRAP, and wind speed, rain rate estimations from SFMR. Sea surface wind vector was retrieved using a modified Geophysical Model Function (GMF) for high wind – CMOD4HW [6], and compared with coincidental wind measurements from SFMR. The differences between the wind estimations from different instruments under precipitation conditions of 0-100 mm/hr and wind speed of 0-60m/s were calculated, from which the effect of precipitation on the wind vector retrieval using scatterometry is derived for various wind and rain conditions.

The following data processing is carried out to obtain the results:

1) Exterior calibration using data collected by IWRAP during its calibration flight around a buoy station.

2) NRCS of the ocean surface are then calculated from the corresponding received power measurements of IWRAP using the calibration constants obtained in Step 1.

3) Wind vectors are then calculated from the NRCS measurements by using the CMOD4HW GMF. In order to decrease the NRCS fluctuation, 10 scans of data are averaged for each wind estimate.

4) Collocate the wind vector estimates from IWRAP with the wind speed and rain rate estimates from SFMR. Then compare the wind from IWRAP and SFMR retrievals under different rain rate and different wind speed.

5) Finally, analyze the relation between wind difference and rain rate under various wind speed.

4. Results

The wind retrieval from IWRAP under clear-sky is fairly agreeable. Base on the result arrived from the calibration flight of IWRAP, the average wind speed difference between IWRAP (C band, Vertical polarization) and collocated in situ data (buoys) was less than 1m/s under rain-free conditions.

Fig. 1 shows the difference between the wind estimations from IWRAP and SFMR under rain-free conditions. The average wind difference is only 0.6 m/s, which shows the wind retrieval ability between IWRAP and SFMR under no rain condition is very close.

Fig. 2 and Fig. 3 indicate that the discrepancy of wind speed retrieved from IWRAP and SFMR has a trend of growing with rain rate. This shows that the heavier the rain, the stronger the influence of precipitation on the scatterometer wind retrieval.

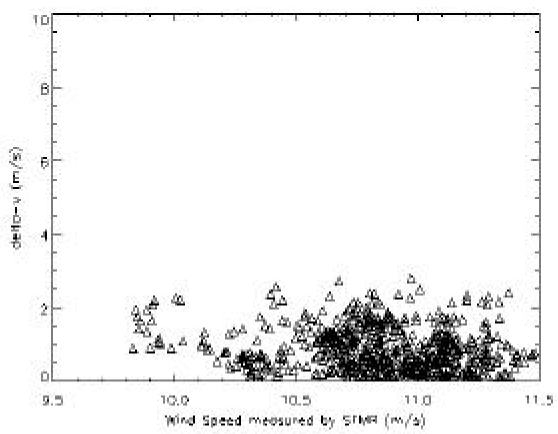

Fig.1 Difference between wind retrievals from IWRAP and SFMR vs. Wind speed measured by SFMR under moderate wind

It is also noticeable that even low precipitation would put significant influence on the wind retrieval of IWRAP. There can be a wind speed bias of 3-10 m/s. At a rain rate of approximately 1.0 mm/h, the wind difference is up to 5 m/s, while under heavy rain(>20 mm/h), the wind difference between IWRAP and SFMR would be increased to about 15 m/s.

In addition, Fig. 2 shows that under low to moderate wind (0-30m/s), rain rate is less than 18 mm/h. This is due to the fact that heavy rain is often accompanied with strong wind.

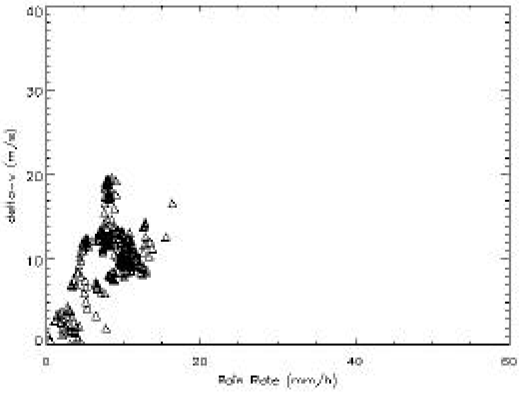

Fig.2. Difference between wind retrievals from IWRAP and SFMR vs. Rain Rate Under low to moderate wind (0-30m/s).

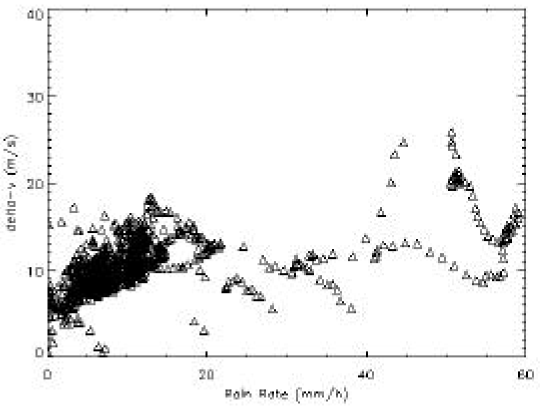

Fig.3. Difference between wind retrievals from IWRAP and SFMR vs. Rain Rate Under high wind (30-60m/s).

5. Summary

Preliminary analysis results of the effect of precipitation on ocean wind scatterometry are presented. Only C band, vertical polarization scatterometer measurements were used in the paper. The influences are qualified for 0-60m/s wind speed and 0-100 rain rate conditions. Future work will focus on a more accurate rain rate estimate using dual wavelength methods using the IWRAP C and Ku-band data. In addition, the GPS dropwindsondes measurements, which were conducted in the 2002 Hurricane Fied Experiment will also be considered in future studies.

ACKNOWLEGMENT

We appreciate the help from Microwave Remote Sensing Laboratory (MIRSL) at University of Massachusetts (UMass) for providing the data used in this analysis, as well as funding support for the processing work at PKU. Thanks also go to Unite States ONR, NOAA and NASA for supporting the UMass Hurricane Research Program at UMass.

References

[1] James R. Carswell, Paul S. Chang, Peter G. Black, 2001, Improving scatterometer wind vector retrieval in the presence of precipitation., Proposal submitted to NOAA, USA.

[2] W. Linwood Jones, Josko Zec. 1996. Evaluation of Rain Effects on NSCAT Wind Retrievals. OCEANS '96. MTS/IEEE. 'Prospects for the 21st Century'. Conference Proceedings, Volume: 3, pp. 1171 -1176.

[3] T. H. Guymer, J. A. Businger, W. L. Jones and R. H. Stewart, 1981. Anomalous wind estimates from the seasat scatterometer. Nature, Vol. 294, No. 5843, pp. 735-737.

[4] Connor, L. N., Chang P. S, 2000. Carswell, J. R. Identification and possible correction of rain contamination in QuickScat/SeaWinds wind retrievals. IGARSS 2000, Honolulu, Hawaii. IEEE.

[5] Huddleston, J. N., Stiles, B. W. A, 2000. multidimensional histogram rain-flagging technique for SeaWinds on QuickScat. IGARSS 2000, Honolulu, Hawaii. IEEE.

[6] Carswell, J. R., Castells A., Knapp E. J., Chang P. S., Black P. G. and F. Marks, 1999. Observed Saturation in in C and Ku-band Ocean Backscatter at Hurricane Force Winds. *Unpublish manuscript.*