COMPARISON BETWEEN ELECTROMAGNETIC SCATTERING BY A RAIN INDUCED SEA SURFACE ROUGHNESS AND FIELD DATA

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1. INTRODUCTION

Rain falling on a water surface can dramatically modify its roughness and hence its reflectivity. When a single raindrop hits a quiet water surface, it generates a crater with a crown which collapses to form a stalk ofwater, and then subsides to generate rings of gravity-capillary waves. These effects introduce biases on wind speed estimates from scatterometers and modify SAR images. Rain can also damp the sea waves if the rain intensity is high enough.

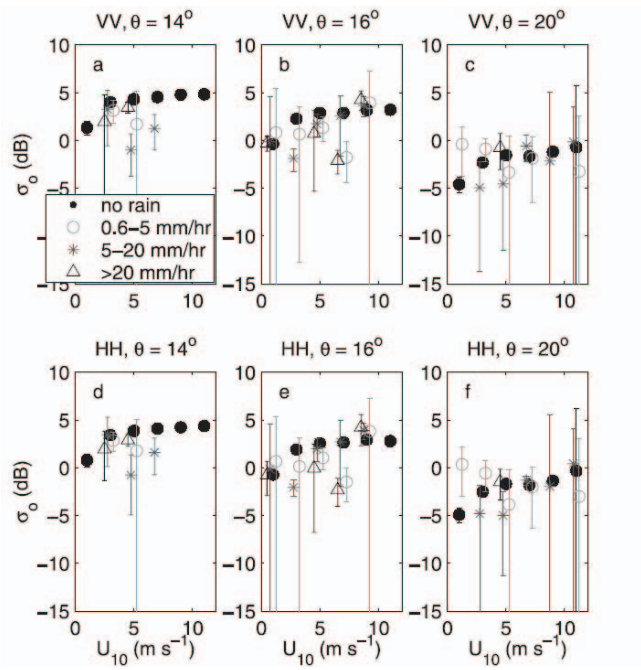
Wavetank experiments have been performed at the single-drop level, as well as for full-rain events. Experiments to analyze the drop size dependence of different surface and scattering features have been conducted as well [1,2]). These have shown that, at scatterometric incidences (30° from nadir), the dominant features of backscattered power due to the impact of drops are not the stalks but the generated ringwaves. They yield a component in the surface elevation spectrum, in addition to to the surface spectrum dueto instantaneous wind speed and wind history.

Multifrequency and multipolarisation scatterometric measurements, in laboratory as well as in open field, along with rain data confirmed the previous results [3]. The dominant scattering mechanism of a rain-roughnened water surface observed at all incidence angles at VV polarization is Bragg scattering from ringwaves. For HH polarization, the radar backscattering mechanisms are dependent on incidence angle: at steep incidences Bragg scattering from ringwaves is dominant, while this effect decreases for increasing angles and scattering from non propagating splash products, like stalks, becomes more visible. From Ku-band open-field measurements [4,5], it has been concluded that VV backscatter during rain is mainly due to ringwaves, while HH backscatter is also from ringwaves at moderate incidence angles (20°-60°) but contains substantial contributions from stationary splash products at high incidence angles. The approximative additive law for spectra due to rain and due to wind allowed the retrieval of both wind and rain fields from SeaWinds data [6]. On the contrary, for higher incidence angles, it is probably the combined effect of both ringwaves and stalks may cause significant increases in sea surface radar cross section as can be suggested from the data collected by Weissman and Bourassa [7].

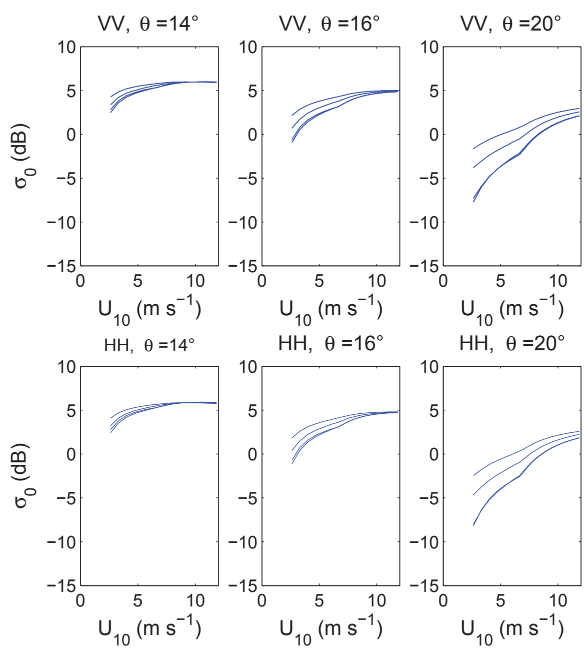
The focus of this paper is to compare the radar signature of the rain-perturbed sea surface calculated with a model developed previously [8] with data for different sea state conditions. Only a very limited amount of well documented data of the surface backscattering coefficient are available. For instance [4] present a set of figures showing the scattering coeffient σ° vs. wind and rain at various incidence angles (from 14 to 76), while in [7] satellite data along with ground based weather informations are presented. Analyzing the evolution of σ° versus wind and rain toward nadir, we see that the change due to rain becomes smaller and smaller and even changes sign. These authors also report that data near nadir below 13.5 were discarded as they suffer from ship obstruction; they are thus cautious with near-nadir incidences. From their results at high incidences the conclusions are clear; however the dependence of σ° versus rain rate below 20 is negligible or small, and difficult to read as can be seen in the attached figure (part (a)) quoted from [4](fig.10)).

We performed comparative simulations for as similar as possible environmental conditions, with our rain ringwave model, along with a two-scale EM surface-scattering model and two different spectral models of the sea surface vs wind. In the sea surface model we have to specify along with wind speed, the sea state development through the significant slope and the peak wave number of the gravity waves on which wind waves appear, and the fetch, or by default we have to assume fully developed sea state conditions. We compared the mentioned data with our simulations for several combinations of the unknown sea state parameters. First, of all our simulations are consistent with the data, regarding the orders of magnitude of the measured σ° due to rain for these environmental conditions (for the known parameters) , taking into account the spread of the values within the errors bars shown in [4](fig.10). We also observe a slight decrease of σ° just at nadir, while in the off-nadir results presented in the attached figure (part (b)) we observe a slight increase with rain rate, i.e. in the opposite direction to the slight changedenoted in the data. On the contrary, for other combinations of the sea development parameters, we obtain a rather constant level or a slight decrease of $\sigma°$ with rain rate (i.e. in the same direction as in the data, and with similar amplitudes). At nadir, the results are consistent with the fact that any roughening of the sea surface (due to wind as well as due to rain) decreases the mirror effect of the surface, while at slant incidences (14° to 20°) the unknown development of the sea surface can lead to either an increase of a decrease of $\sigma°$.

2. COMPARISON OF SCATTERING COEFFICIENTS



a) Data from [4](fig.10)



b) The EM model used in this paper.

Fig. 1. Comparison of the backscattering coefficients obtained with the model used in this study, with 14 GHz radar data from [4] (Fig.10) for identical environmental conditions. σ_0 curves increase with rain rates respectively of 0, 5 , 20 and 40 mm/hr at incidences of 14, 16 and 20, VV and HH polarisations.

3. REFERENCES

[1] Bliven F.L. , Sobieski P. , Craeye C. (1997), Rain generated ringwaves: measurements and modeling for remote sensing, *International Journal of Remote Sensing*, **18**, 221—228.

[2] Lemaire D., Bliven L.F., Craeye C., Sobieski P. (2002), Drop size effects on rain-generated ringwaves with a view to remote sensing applications, *International Journal of Remote Sensing*, **23**, 2345—2357.

[3] Braun N. and Gade M. (2006), Multi-frequency scatterometer measurements on water surfaces agitated by artificial and natural rain, *International Journal of Remote Sensing*, **27(1)**, 27—39.

[4] Contreras R.F., Plant W.J., Keller W.C., Hayes K., Nuysten J.A. (2003), Effects of rain on Ku-band backscatter from the ocean, *Journal of Geophysical Research*, **108(C5)**, 3165, DOI:10,1029/ 2001JC 001255.

[5] Contreras R.F. and Plant W.J. (2006), Surface effect of rain on microwave backscatter from the ocean: Measurements and modeling, *Journal of Geophysical Research*, **111**, C08019, DOI:10,1029/ 2005JC 003356.

[6] Draper D.W. and Long D.G. (2004b), Assessing the Quality of SeaWinds Rain Measurements, *IEEE Transactions on Geoscience and Remote Sensing*, **42(7)**, 1424-1432.

[7] Weissman D.E and Bourassa M.A. (2008), Measurements of the effect of rain-induced sea surface roughness on the QuikSCAT Scatterometer Radar Cross Se'ction, *IEEE Transactions on Geoscience and Remote Sensing*, **46(10)**,I, 2882—2894.

[8] Lemaire D., Sobieski P., Craeye C., Guissard A. (2002b), Two-scale models for rough surface scattering: Comparison between the boundary perturbation method and the integral equation method, *Radio Science*, **37(1)**, 1001, DOI:10.1029/ 1999RS002311.