Detection, Analysis and Mitigation of Sea Clutter in Polarimetric Weather Radar

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***Abstract*- The presence of sea clutter introduces error in weather radar observations over sea. Since the characteristics of sea clutter are different from stationary ground clutter, conventional clutter mitigation techniques produce unsatisfactory results. Hence, study of sea clutter properties and its mitigation is important. Over the last few decades, various research communities have studied and modelled sea clutter using different statistical distributions. This paper discusses identification of sea clutter in a weather radar using fuzzy logic technique. Time series data from an C-band dual-pol weather radar has been used to identify sea clutter in presence of precipitation. Spectral properties and distributions of sea clutter are also studied and a modified GMAP technique has been implemented for the sea clutter suppression.**

I. INTRODUCTION

The SEAPOL (SEA-going POL-arimetric) radar has been a part of NASA's SPURS-2 campaign from the year 2016. The radar works with a uniform Pulse Repeating Frequency (PRF) of 300-1800 Hz and a pulse width of 0.4-2µs. It is equipped with both Horizontal and Vertical Polarization channels. The radar is capable of scanning in both azimuth and elevation. The PPI scan is restricted only to a 240-degree sector sweep. In this paper, results from one of the PPI scans are shown. The data were collected in the Eastern Tropical Pacific region where different precipitation events were captured over the sea surface. Radar Reflectivity (Z) and Velocity (V) along with various dual-pol moments such as Differential Reflectivity (Z_{dr}), Differential Phase (φ_{DP}) and Co-pol Correlation (ρ_{HV}) were processed from the time series data. Case study of a particular event showing the dual-pol characteristics of weather and sea-clutter has been presented. The main aim of this paper is to identify sea clutter in presence of precipitation and study its characteristics in both time and spectral domain. Ryzhkov at el showed a fuzzy logic approach of discriminating sea clutter using textures of Differential Phase and Signal Power [1]. Moisseev at el showed that it is possible to identify ground clutter mixed with precipitation using textures of Spectral Differential Reflectivity and Spectral Differential Phase [2]. In this paper, Co-pol Correlation, textures of Differential Phase and Differential Reflectivity are used for classification. One particular azimuth was chosen and spectral decompositions of Z, Zdr, φ_{DP} and ρ_{HV} were done. Range-Azimuth spectrographs were generated showing the characteristics of weather and sea clutter echoes.

II. OBSERVATIONS

Radar Reflectivity and Velocity were observed from a sector PPI scan. Figure 1 shows the data collected from a precipitation event on 9th November 2017 over the East Pacific region. The

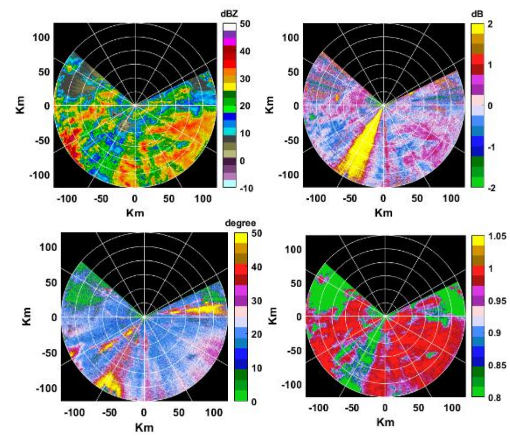


Fig. 1 From top clockwise PPI plots of of Reflectivity (Z), Differential Reflectivity (Z_{dr}), Copol Corrlation (ρ_{HV}) and Differential Phase (φ_{DP}) from 9th November 2017 data.

observations showed stratiform echoes with mixtures of heavy and light rain. Various dual-pol moments are also shown in Figure 1.The Z field shows that the region is having a mixture of moderate to heavy rain.The Zdr field shows the occurrence of mixture of large and small drops. The larger drops contribute to the high positive value reaching to a maximum value around 2 dB. The smaller drops however are almost circular in shape and hence contributes to lower values close to almost zero. A possible beam blockage is observed from 205 to 215 degree azimuth.

III. ANALYSIS OF SEA CLUTTER PROPERTIES

The membership functions used for fuzzification are constructed from the statistical distributions of the input parameters. Additional references are taken from the membership functions as used in [1] and [3].

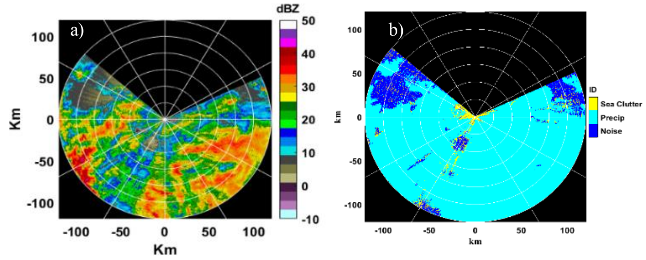


Fig. 2. PPI plots of Fuzzy logic output on the data from 9th November 2017 data.

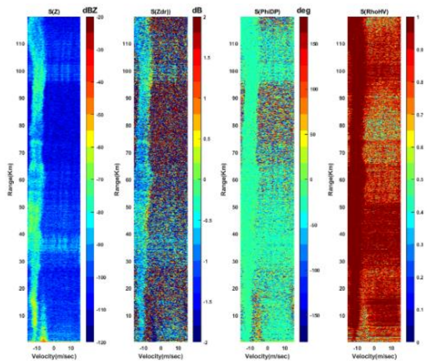


Fig. 3.Range Doppler Spectograph of Decompositions of Reflectivity (Z), Differential Reflectivity (Z_{dr}), Differential Phase (φ_{DP}) and Co-pol Corrlation (ρ_{HV}) at 125 degree azimuth from 9th November 2017 data

Figure 2 b shows the result after carrying out fuzzification on the PPI data.The sea clutter is mainly seen in the regions within 20 km from the radar. Errors in the output are seen where clutter has been identified in places of noise. The range bins, which are identified as precipitation matches with the observations fields.

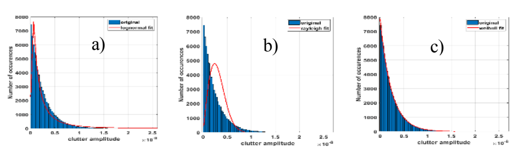
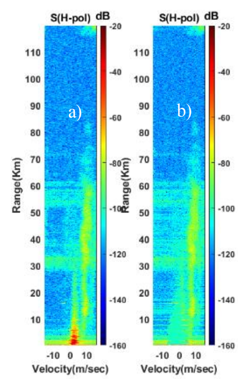


Fig. 4 a, b and c shows fitting of the original distribution of the data with three different distributions

A spectral decomposition of the Dual pol moments were done which revealed more information of the components in each range bin and azimuth. In Figure 3 spectral decompositions are show at 125° azimuth. Moissev at.el [2] showed that such spectral decompositions can help in discrimination of clutter from precipitation. The textures of the dual Pol spectral moments can also be taken into consideration in such cases. The spectrographs in Figure 3 show that the sea clutter is dominant in the ranges up to 15 km range while some effects of clutter can be seen around 35 to 40 km and from 100 to 110 km range. As seen from the fuzzy logic processing on the PPI data the region of clutter matches with the spectrograph. The mean velocity of the sea-clutter is non-zero, which indicates that sea-clutter is a non-stationary process. Traditional zero-Doppler notch filters cannot be used in this case. The spectral co-pol correlation $S(\rho_{HV})$ shows an expected high value for weather echoes. In the regions of high $S(\rho_{HV})$ the spectral Differential Phase is seen to be stable. Low ρ_{HV} and unstable φ_{DP} characterize the sea clutter regions. Figure 4 the distribution of the sea clutter fitted with three different probability density functions from the 9th November PPI scan data. A 2 sample K-S (Kolmogorov–Smirnov) test results performed between the actual clutter data distribution and the fitted distribution indicated that the clutter amplitude distribution is more likely to follow a Weibull distribution than the other distributions such as Rayleigh and Log-Normal.

IV. SEA CLUTTER MITIGATION-MODIFIED GMAP



Since the velocity spectrum of sea-clutter is not centered at zero, a modified GMAP approach has been proposed here which places the notch in the correct Doppler bin producing results as shown in figure 5 (b. Figure 5 (a) and (b) shows original and the filtered spectrum after using the modified GMAP respectively.

Fig. 5 (a) shows the original spectrograph of H-Pol PSD (b) shows the spectrograph after applying a modified GMAP filter.

CONCLUSION

Sea-Pol radar dual-pol radar moments were processed using pulse pair method. Fuzzification was done on the same data set and the classification results were obtained. Dual-pol spectral domain parameters were also generated and the range-Doppler spectrographs were studied. Sea clutter characterization and mitigation were successfully done.

ACKNOWLEDGEMENT

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