A probability based sea clutter suppression method for polarimetric weather radar systems

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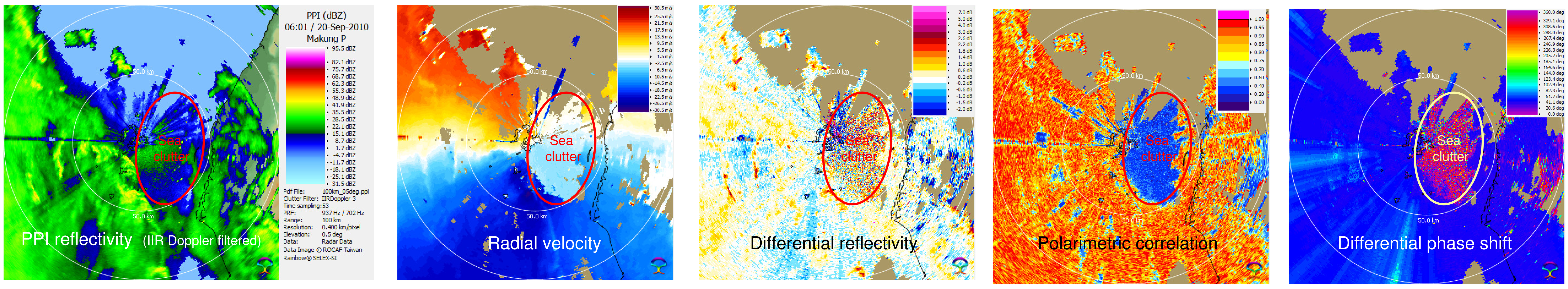
Introduction

In the past decade, an increasing amount of operational weather radar systems has been equipped with polarimetric measurement capabilities. A particular focus of polarimetric radar data applications is on the identification and removal of non-weather radar signals. Echoes from moving non-weather targets often pass signal processor thresholds and may eventually affect radar data processing algorithms. One type of radar target which usually cannot be filtered effectively by Doppler filters is sea clutter: waves on the sea surface cause a signal which is typically as strong as that of weak to moderate precipitation and is usually not removed by Doppler filters due to the waves' motion with typically several meters per second.

Signatures of sea clutter and weather echoes

Parameter	Typical range for sea clutter	Typical range for weather echoes	
Reflectivity (Z)	low to moderate	low to high	☹
Texture of Z	moderate to high	low to moderate	😐
Vertical Gradient of Z	negative	variable	😐
Radial Velocity	variable	low	😐
Texture of ZDR	moderate to high	low	☺
Texture of Φ_{dp}	high	low	☺
Correlation ρ_{hv}	low to moderate	high	☺
Spatial Area	over sea; mostly low-level	anywhere	😐

Observation Example



0.5-degree PPIs scanned with a METEOR 1500 CDP C-band radar West off Taiwan on 20-Sep-2010, during tropical cyclone "Fanapi". Data Images copyright © of ROCAF, Taiwan.

Algorithm description and results

The first seven parameters of those listed in the above table are available for every range gate of a radar scan. The corresponding measurements are converted into conditional probabilities p_{ij} ($0 \le p_{ij} \le 1$) for the corresponding parameters (i = 1,…,7) and for each of the assumed echo types (j = 1 for sea clutter; j = 2 for weather echoes). The values of p_{ij} are equal to one for the typical ranges given in the table, and zero outside these ranges (with a linear change in a small transition interval).

The conditional probabilities of all seven parameters are combined to conditional probabilities P_j by

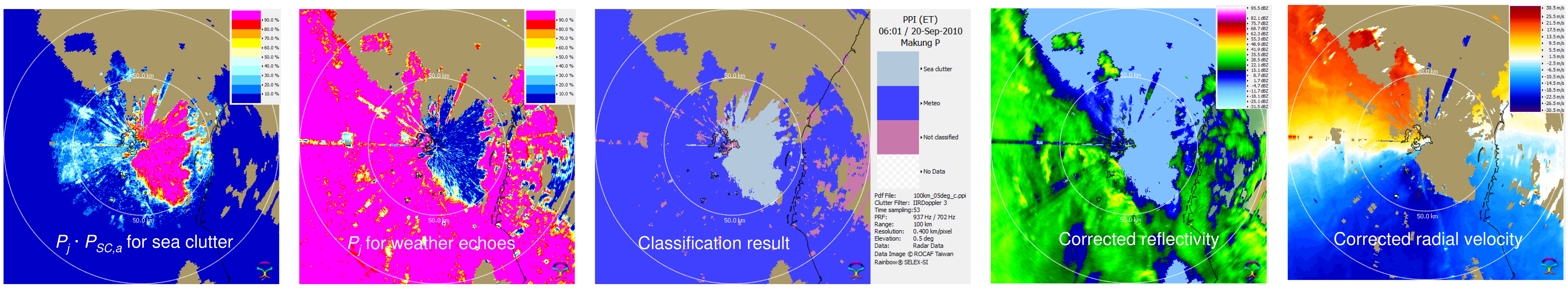
$$P_j = \sum_i w_i p_{ij} \Big/ \sum_i w_i$$

where the weight factors w_i ($0 \le w_i \le 1$) are higher for the useful parameters than for the others.

To reduce the amount of false alarms, i.e. echoes being identified as sea clutter which in reality are from meteorological targets, the combined conditional probability P_j for sea clutter is multiplied with an a-priori probability of sea clutter $P_{SC,a}$ between 0 and 1, depending on the range to the radar site, on the elevation angle, and on the earth surface (i.e. water or no water).

The combined conditional probability P_j for weather echoes is not modified.

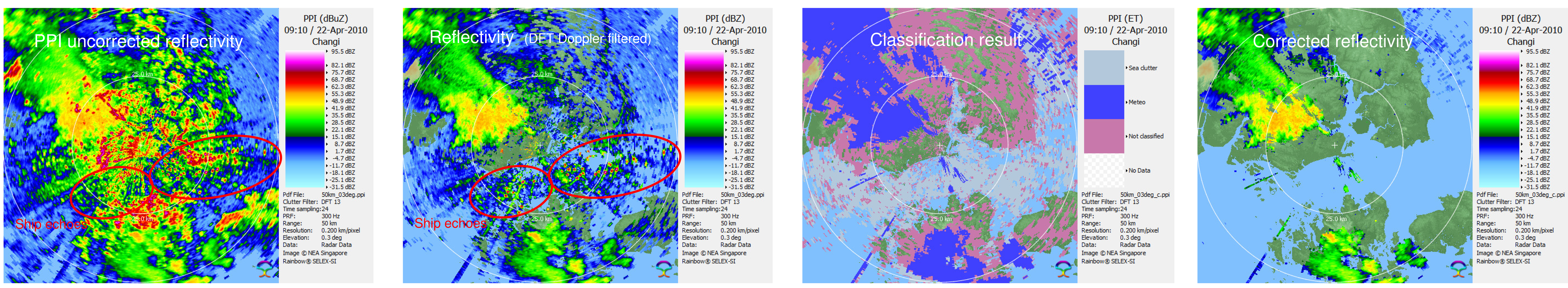
A radar measurement is finally classified as sea clutter, if the modified combined conditional probability P_j for sea clutter is larger than the combined conditional probability P_j for weather echoes; otherwise a measurement is classified as meteorological echo. If, however, both combined conditional probabilities are small, the measurement is not classified.



Probabilities, final classification result and corrected reflectivity and radial velocity for the above PPI scans. Data Images copyright © of ROCAF, Taiwan.

Removal of ship echoes

The algorithm can also be applied to remove echoes from ships and vessels. Similar to wave echoes, echoes of moving ships are not removed by a conventional Doppler filter. The figure below shows 0.3-degree reflectivity PPIs of a METEOR 1600 SDP S-band radar of the National Environment Agency, Singapore, located at Changi International Airport. The Doppler filter very effectively removes the ground clutter signals from the city of Singapore area, whereas echoes from ships are mostly kept. Intensities peak up to about 80 dBZ, and the signals appear sometimes as arch-like signatures due to side-lobe returns. The figure also shows the classification result (based on polarimetric data which are not shown) and the final reflectivity data after suppression of sea clutter signals.



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