Addressing Data Quality Challenges of the NCMS Dual-Polarization Radars in the UAE

NCAR is sponsored by the US National Science Foundation

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Introduction

The UAE has a challenging environment for weather radar observations. An unusually large fraction of the radar echoes in the country are caused by non-meteorological targets. These include:

- anomalous propagation (AP) from atmospheric ducting – causing intermittent ground clutter returns
- sea clutter – also affected by AP conditions
- chaff
- interference from wireless routers for local area networks (RLAN)
- insects – biological scatterers, clear-air echoes

Anomalous Propagation - AP

Anomalous propagation (AP) results from vertical gradients in refractive index, which are in turn related to the vertical profile of moisture content, particularly close to the surface.

Figure 1 shows the reflectivity from an AP case at Abu Dhabi. Figure 2 shows that the radial velocity is generally close to 0 in AP cases over land.

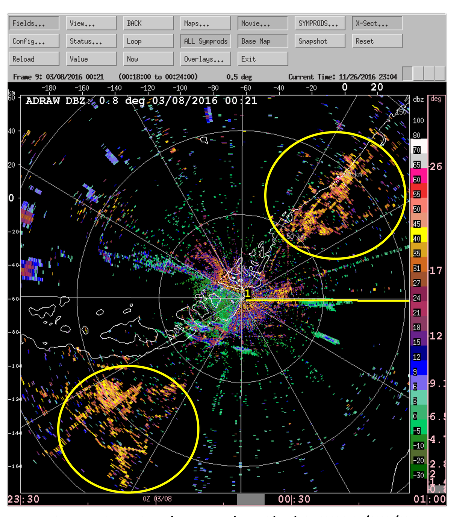


Figure 1: AP echoes, Abu Dhabi, 2016/03/08 00:21 UTC

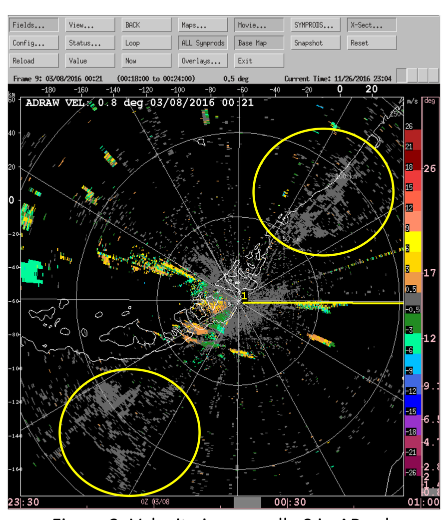


Figure 2: Velocity is generally 0 in AP echoes because these are ground returns.

Figure 3 shows that the same locations are free of clutter just 45 minutes later, probably due to a change in the vertical gradient of moisture close to the surface.

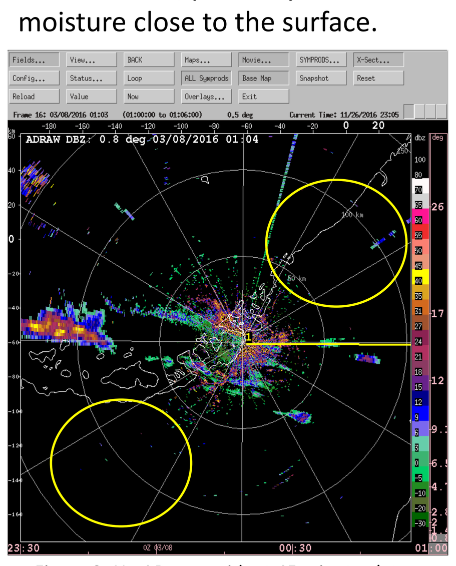


Figure 3: No AP was evident 45 minutes later.

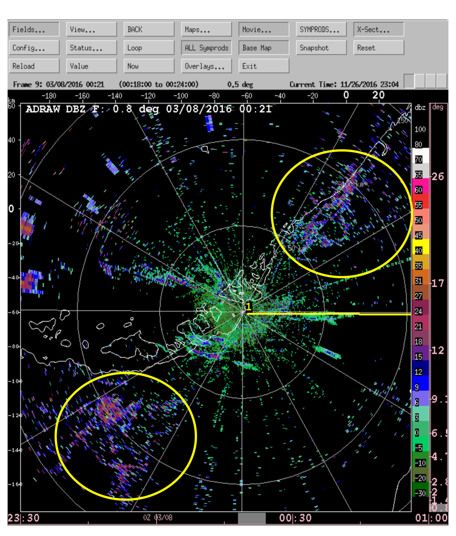


Figure 4: The clutter filter running on the time series data at the radar can be quite effective at filtering out AP returns.

The UAE radar processing software includes a clutter filter that runs on the time series (I/Q) data at the radar sites. This is an effective strategy for dealing with AP echoes. Figure 4 shows the result of running the clutter filter on the echoes from Figure 1. The echo power is reduced considerably by the filter.

Sea Clutter

Sea clutter echoes occur when the radar beam, or part of it, is reflected by the sea surface. Near to the shore this can occur simply because the radar has a direct view of the water out to some distance. In the UAE, however, sea clutter echoes can be significantly enhanced due to anomalous propagation (AP).

Sea clutter case - Dubai

Figure 5 below shows the reflectivity at 0.8 degrees elevation for a sea clutter case from the Dubai radar at 17:09 UTC on 2017/03/09. There is a large area of clutter to the NW of the radar over the sea.

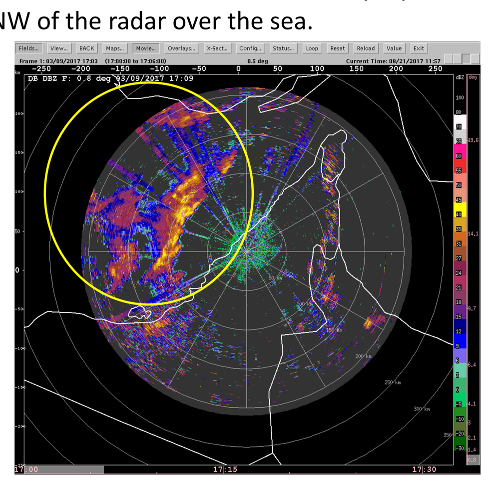


Figure 5: Sea clutter case, Dubai, reflectivity at 0.8 degrees elevation.

Figure 6 shows the radial velocity for the same case. Notice that the velocity is not close to zero as it was in the AP case (figure 2). Instead, the velocity as measured by the radar indicates the fact that the waves and the sea spray are moving and therefore show up as a non-zero velocity. Because of this, the normal AP-type clutter filter is not effective with sea clutter.

Instead, we need to make use of the dual polarization quantities to identify sea clutter. Figure 7 shows PHIDP, which is very noisy in range. Figure 8 shows the RHOHV field, which is quite low, less than 0.5. And figure 9 shows the reflectivity at 1.4 degrees, which is much reduced compared to that in figure 5, indicating that there is a strong gradient of reflectivity with height.

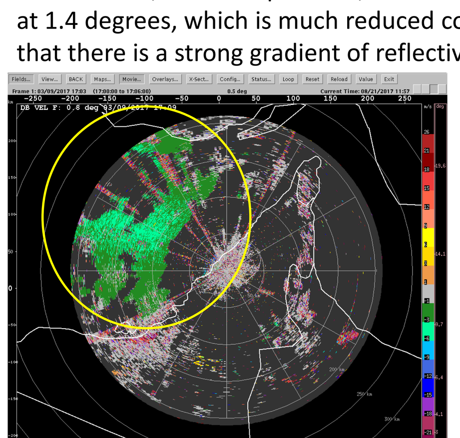


Figure 6: Sea clutter case, Dubai, radial velocity.

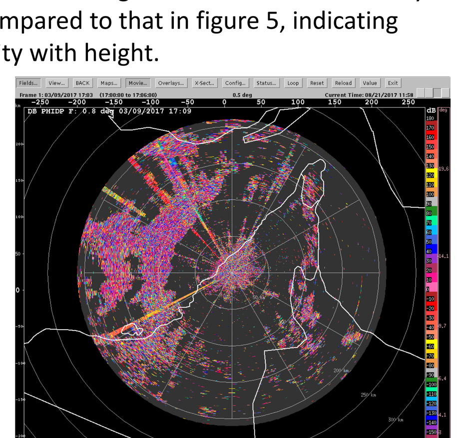


Figure 7: Sea clutter case, Dubai, PHIDP (noisy)

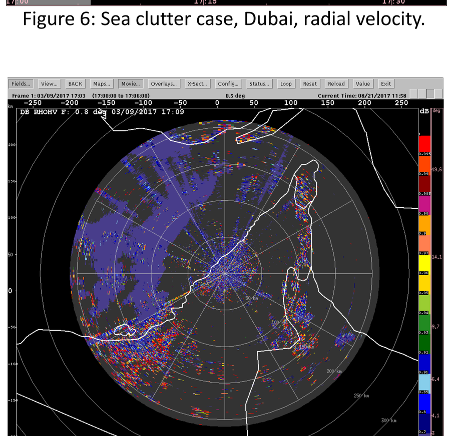


Figure 8: Sea clutter case, Dubai, RHOHV (< 0.5)

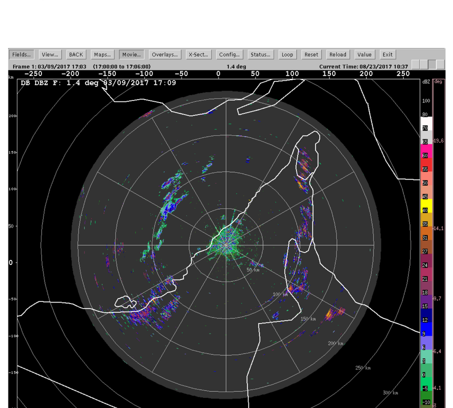
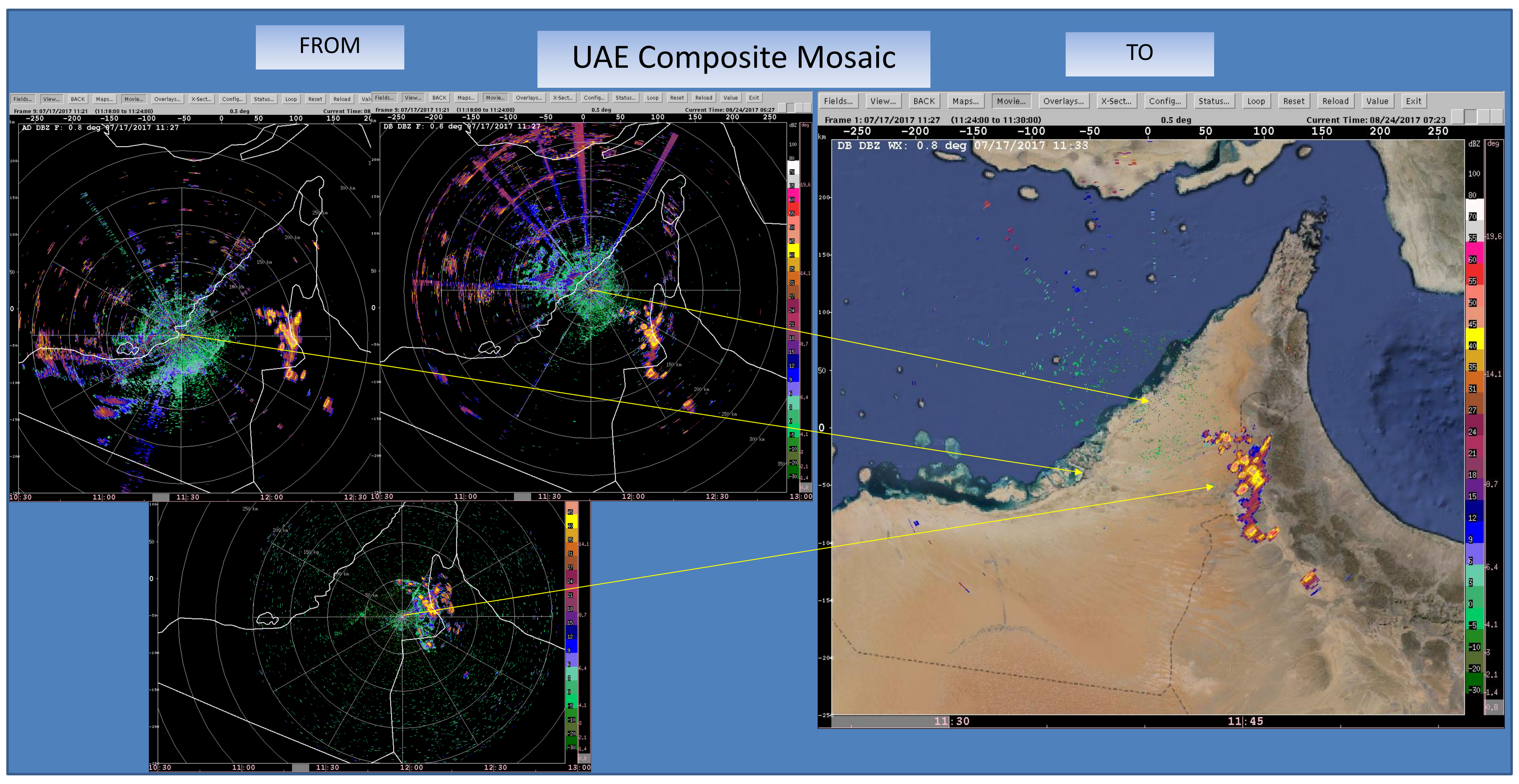


Figure 9: Sea clutter case, Dubai, reflectivity at 1.4 degrees elevation, rapid decrease with height.

All of these fields provide clues to the presence of sea clutter. By combining the information from these fields using fuzzy logic we can generate a 'sea clutter flag' as shown in figure 10. Note that it does flag areas that are not over the sea, but this is a benign error because it is also including areas of AP and chaff, which should be removed anyway.

The management and forecasting groups need a quality-controlled radar product that only shows true weather echoes for the mosaic and the web. (http://www.ncms.ae/en)



Sea clutter case – Dubai - continued

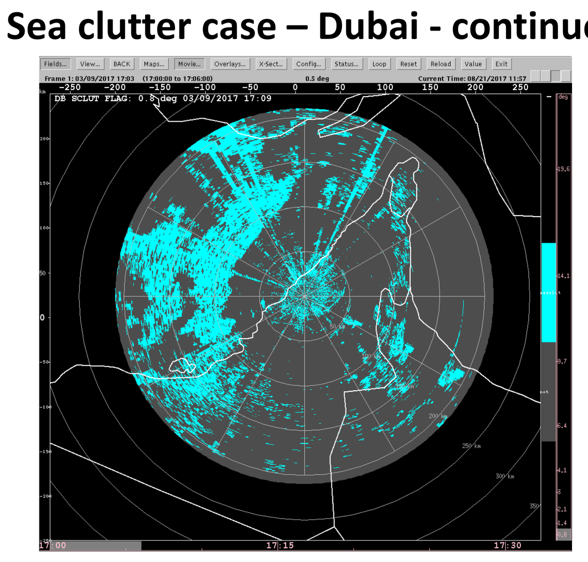


Figure 10: Sea clutter case, Dubai, sea clutter flag

Figures 11 through 13 below show the interest maps that are used for the identification of sea clutter using fuzzy logic. An interest map converts a measured value (feature field) into an interest value between 0 and 1. This approach allows us to combine various fields in a normalized manner, and to produce a weighted average of the interest fields. If the weighted average exceeds some threshold, usually 0.51, we consider that the desired phenomenon has been identified. Table 1 shows the constraints that are placed on the variables for sea clutter.

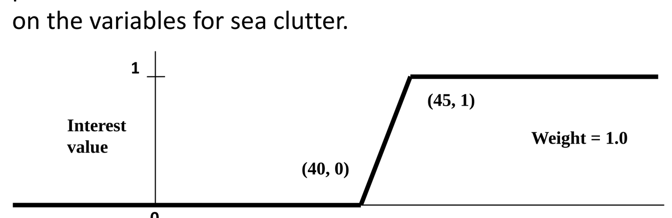


Figure 11: Sea clutter interest map for standard deviation of PHIDP

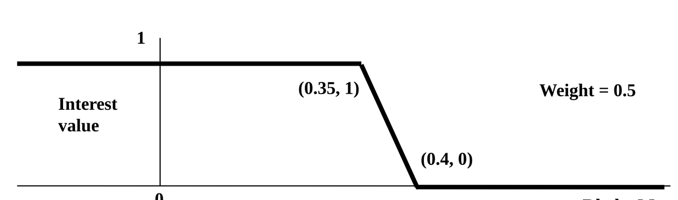


Figure 12: Sea clutter interest map for mean of RHOHV

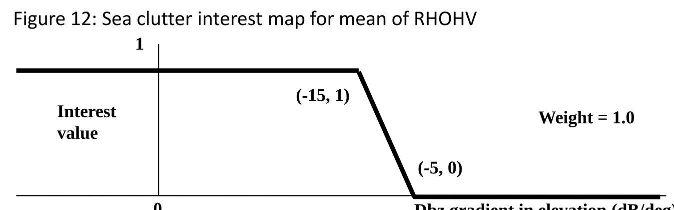


Figure 13: Sea clutter interest map for the vertical gradient of reflectivity, with respect to elevation angle.

Condition	Threshold or value
Min SNR	-5 dB
Max elevation	2.5 deg
Interest threshold for detection	0.51

Table 1: Constraints applied to sea clutter identification

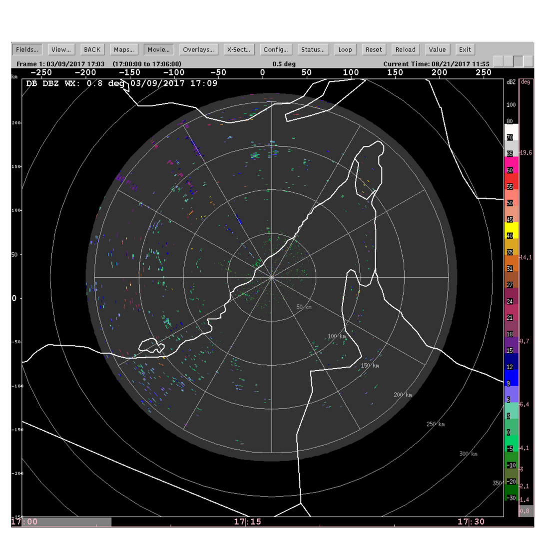


Figure 14: Sea clutter filtered reflectivity.

Figure 14 shows that after censoring at the locations at which sea clutter is identified, the reflectivity field is cleaned up significantly. In this case there was no weather present, so almost all of the reflectivity field has been filtered and removed.

Sea clutter case – Abu Dhabi

Figure 15 below shows the same sea clutter case as viewed by the radar at Abu Dhabi.

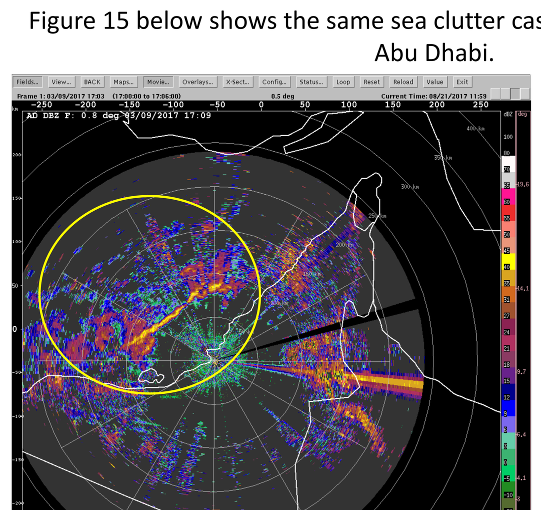


Figure 15: Sea clutter case, Abu Dhabi, reflectivity.

Figure 16 below shows that the radial velocity is also not zero in that case.

And finally figure 17 shows the cleaned up reflectivity for the Abu Dhabi radar for this case. Once again there was no weather present, so almost all of the reflectivity pixels have been reduced.

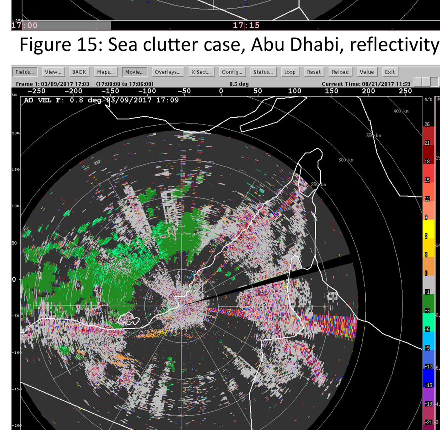


Figure 16: Sea clutter case, Abu Dhabi, radial velocity

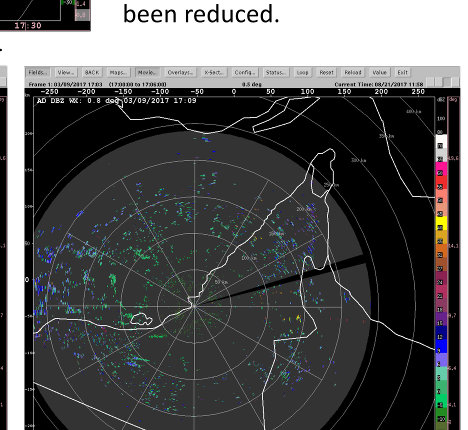


Figure 17: Sea clutter case, Abu Dhabi, filtered reflectivity

Chaff and R-LAN echoes

The UAE radars detect military chaff on a regular basis. The chaff issue has been documented in a separate report to the NCMS. Some material in the following section has been copied from that report.

Also, the presence of Radio LAN interference (R-LAN) has been increasing over time. Many countries have been experiencing significant R-LAN interference at C-band.

What is Chaff?

The use of chaff dates back to 1932. Chaff was developed to create false echoes on radars. In 1942 it was found that aluminum foil strips 27 by 2 cm worked well. Later thin glass fibers coated with a metal was found to be the best. Chaff fibers are finer than the thickness of a human hair (i.e., generally 25 – 30 microns in diameter), and range in length from 7.6 mm to over 50 mm.

Modern chaff consists of small fibers that reflect radar signals and when dispensed in large quantities from aircraft form a cloud-like echo that temporarily hides aircraft from radar detection.

Chaff appears on the radar in a similar manner to that of a contrail to a human observer. Chaff in the atmosphere is not visible to the naked eye.

Chaff is dispersed by the prevailing wind and remains aloft in the atmosphere up to 10 hours.

Figures 18 and 19 below shows chaff before and after it is dispensed.

Figure 18: Modern US Navy RR-144 (top) and RR-129 (bottom) chaff countermeasures and container. Note how the strips of the RR-129 chaff (bottom) are of different widths, while those of the RR-144 (top) are all the same width. The RR-144 is designed to prevent interference with civil ATC radar systems. (Wikipedia)

Figure 19. Chaff fibers are normally between 25 and 30 microns in diameter. By comparison, human hair ranges in diameter from 30 to 100 microns.

Mitigating chaff and RLAN radar echoes

A chaff mitigation algorithm, based on the NCAR Particle ID (PID) algorithm, was introduced into the operational system for the NCMS radars during April of 2015. The goal of this algorithm was to remove non-meteorological echoes in the best possible manner, without removing true weather echoes. This procedure, though not perfect, did mitigate much of the worst contamination.

As an example of the results typical of this procedure, we can use the case from 2016/12/18 at 12:51 UTC, for the Abu Dhabi radar. This was a clear day with no clouds present.

Figure 20 shows the reflectivity for this case, with R-LAN and chaff echoes labelled. Figures 21 through 24 show the velocity, ZDR, RHOHV, and PHIDP fields for this case. It is these *feature* fields that provide the information required to filter out the non-weather echoes.

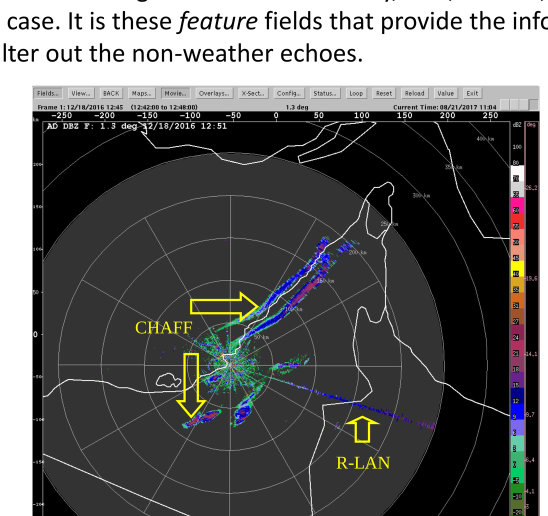


Figure 20. Reflectivity for Abu Dhabi chaff and R-LAN case, 2016/12/18.

As illustrated in figures 20 to 24 (above and top right), chaff has been shown to have the following dual polarization properties:

- reflectivity 0 dBZ to 35 dBZ
- ZDR either highly positive (horizontal alignment) or highly negative (vertical alignment)
- RHOHV is low, < 0.5
- PHIDP is noisy (random) in range – along the beam

References

Vivekanandan, J., D. S. Zrnic, S. M. Ellis, R. Oye, A. V. Ryzhkov and J. Straka, 1999: Cloud microphysics retrieval using S-band dual-polarization radar measurements. *Bull. Amer. Meteor. Soc.*, 80, 381 – 388.

Chaff and R-LAN case - continued

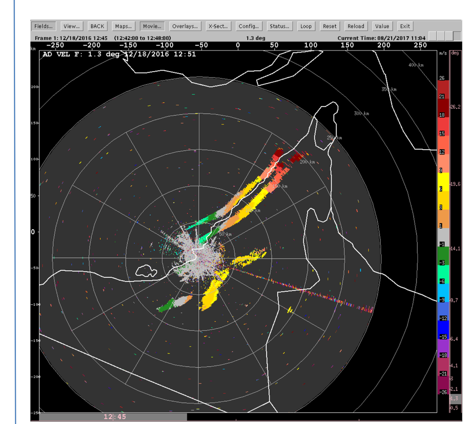


Figure 21. Velocity for chaff and R-LAN case, 2016/12/18. Chaff is carried downwind and descends to lower levels over time. RLAN velocity is random (noisy).

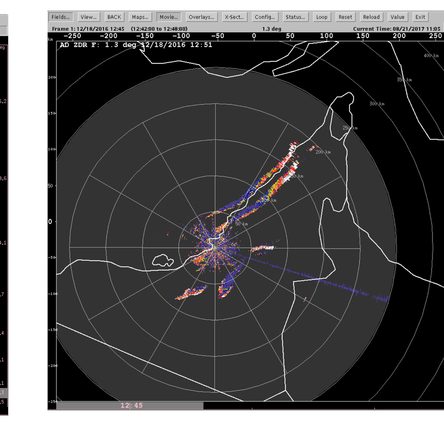


Figure 22. ZDR for chaff and R-LAN case, 2016/12/18. Chaff echoes have a mixture of highly negative and highly positive values.

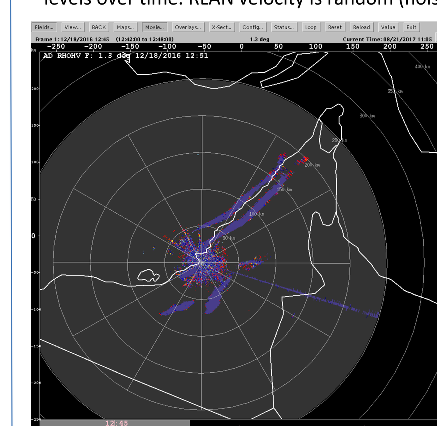


Figure 23. RHOHV for chaff and R-LAN case, 2016/12/18. All of the values are low, < 0.5.

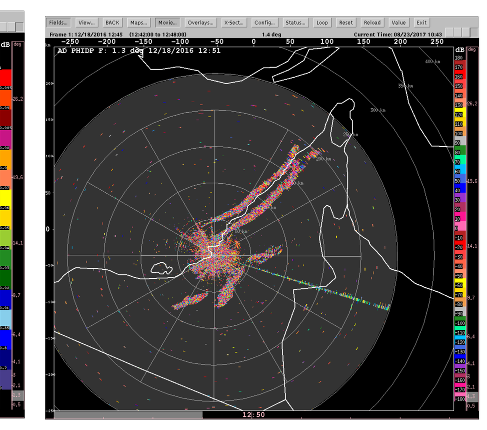


Figure 24. PHIDP for chaff and R-LAN case, 2016/12/18. This field is noisy in range for both chaff and R-LAN.

The NCAR PID algorithm was modified to identify chaff, based on these properties. Figure 25 shows the NCAR PID field for this case. The dark brown areas show those gates identified as containing chaff echoes, while the magenta areas are those gates identified as residual clutter. R-LAN tends to show up as residual clutter. Some chaff also shows up as residual clutter.

R-LAN interference can be identified in a similar way, given the radar signature for this type of interference. R-LAN echoes tend to show up over the entire range of the radar. Dedicated R-LAN code was added for identification of R-LAN interference. (RLAN was also removed in Figures 15&17)

Figure 26 shows the reflectivity that remains after the application of the filtering step, which removes both chaff and R-LAN gates. Since there is no real weather present at this time, almost all of the reflectivity echo is removed.

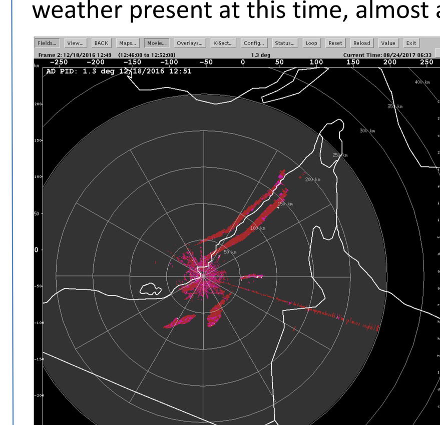


Figure 25. The PID for chaff and R-LAN case, 2016/12/18. Brown indicates chaff, and magenta indicates residual clutter.

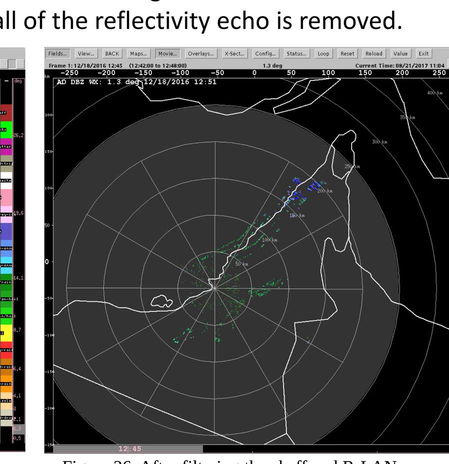
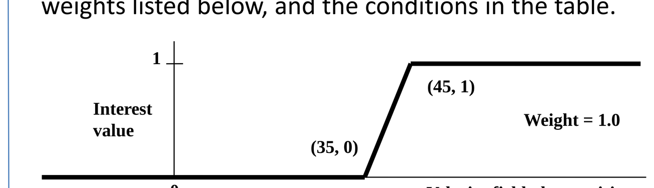
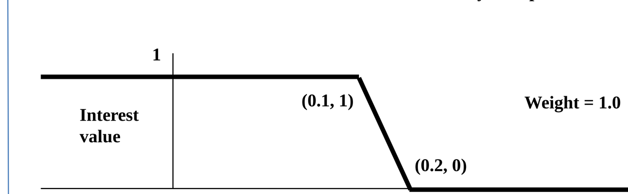


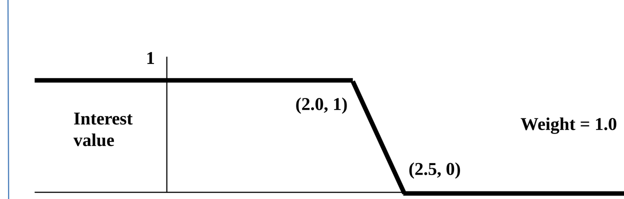
Figure 26. After filtering the chaff and R-LAN case, 2016/12/18. There was no weather at this time.

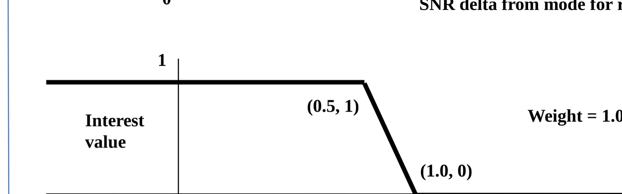
R-LAN Interest Maps and Constraints

R-LAN echoes are identified via fuzzy logic, using the interest maps and weights listed below, and the conditions in the table.





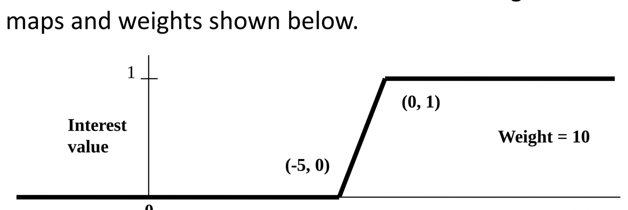


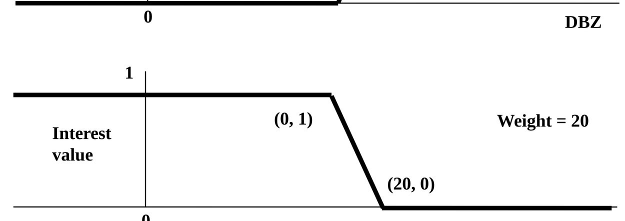


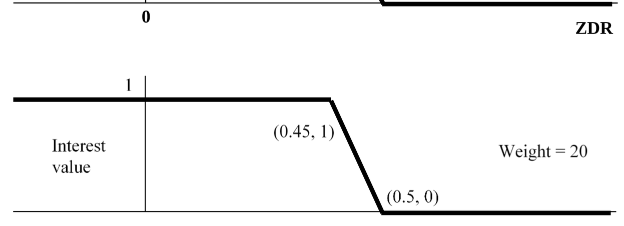
Condition	Threshold or value
Min SNR in ray	0 dB
Min valid fraction of ray	0.4
Max elevation	2.5 deg
Interest threshold for detection	0.51

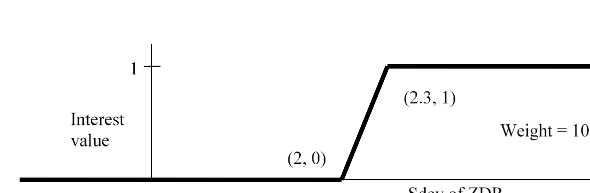
CHAFF Interest Maps

Chaff is identified from within the NCAR PID algorithm using the interest maps and weights shown below.









Processing details

Radar model used: ARC C250P

Software used for data processing: LROSE – Dsr2Radx and RadxQc (CfRadial)

Merge process: LROSE – Radx2Grid (MDV) and MdvMerge2

Future work: while the RadxQC program works very well to reduce non-hydrometeor radar echoes, there is still work to do with filter fine tuning. NCMS now has a CfRadial data set of over 8 months to test with.