Authors Responses

To the *Interactive comments on* manuscript titled "Simple insect removal algorithm for 35- GHz cloud radar measurements", M C R Kalapureddy et al. *Atmos. Meas. Tech. Discuss., doi:10.5194/amt-2017-254, 2017*

At the outset, we are grateful to the Editor(s) and all Editorial team for their services/help and untiring timely support and cooperation. We are also equally thankful to all the three Anonymous Referees, for their hearty services in rendering experience and knowledge based comments, those are valuable to us for improving the quality and the focus of the paper.

The point-to-point AR2 responses of the authors are as below:

Anonymous Referee #2 (AR2)

AR2-Comment: I think the NER algorithm should be removed from this paper. There are much more general ways for thresholding between signal and "salt and pepper". I should be done by the radar software. so that it adapts automatically to the processing parameters.

Response: NER curves are potential part of the used algorithm required to identify the cloud peak at first place and then backtracked for to its weakly echoing boundary regions. Thus, NER curves are required for complete recovery of cloud structure (see latest figure 2 for point and volume target NER curves). Moreover, the developed algorithm is the part of our automatic off-line data processing software for the quality control of the cloud radar data. And it will also be useful for those who want to use it in the post processing data set.

AR2-Comment: I think the TEST algorithm for filtering insect echoes from the radar data is helpful if it is used in combination with LDR-filtering and or dual frequency filtering. The author comes to this conclusion in the lines around 285 and I agree to it. In the rest of the paper the algorithm is described as a standalone alternative to LDR or dual-frequency filtering. It should be clearly said that this does not work as in regions with much insects the insect signatures are as smooth as butter. There they are volume filling targets.

Response: It has been found with our numerous examples that LDR threshold alone is not able to remove all the biota (e.g., added Figure 13) but inauspiciously affecting the weak cloud portions that are not sufficient enough to excite the cross pol. channel weakest returns due to the cross-pol. isolation restriction of the antenna on the LDR values (see figure 10 and 11 and related discussions at pg 8). Therefore, TEST+LDR filtering is definitely helping for the cases when biota density is more (added Figure 14, pg 37 and its discussion at pg 10) or biota echo co-exists inside the cloud (Figure 13). Still, pure cloud returns are noted to be not possible even by TEST+LDR besides that this combination was also severely affecting the weak cloud portions. Thus, the TEST alone is found to fulfill the requirement significantly of both biota removal as well as recovery of weaker cloud

portions using NER curves excepted to cases of high number density of biota or biota existing within the cloud. The NER curves hold the key again here. However, after TEST process, to eliminate further those portions of Z values which are possible biota contamination within cloud inferring from the both LDR and SW thresholds for the preserving the true cloud returns (see Figure 13i, pg 36).

AR2-Comment: The theoretical background of the algorithm should be explained more general: actually the signal from insects has a longer de-correlation time than signal from volume filling targets.

Response: That could be apparently true if one have high density insect presence with course resolution observations. For our case, insect density is observed to be moderate and that the echo de-correlation time found to be very much shorter than cloud duration. This can be evidently seen with added figure 13, figure 14 and figure A3. Most importantly we demonstrated now with Figure 15 that cloud de-correlate longer than biota those discussion can be seen at page 11 before section 4.

AR2-Comment: The signal from volume targets is a sum of many signals with statistical phases and amplitudes which causes noise with normal distribution (central limit theorem). Therefore even if the volume is filled with stationary targets (droplets falling with different speeds, some exiting the volume, some entering) each line of of the un-averaged complex spectra is normal distributed noise with zero mean and a variance corresponding to the power in the doppler spectrum. The doppler spectra are the abs-square of the complex spectra and therefore they are still noisy. Due to squaring the distribution is transformed from normal to exponential. After averaging over 1 s this noisiness has smoothed out by 1/sqrt(nave). In contrast the signal from a single insect is not noisy at all if its SNR is large. But there is another reason causing variance in the biota signals. Typically the insects are advected through the radar beam, entering with apparent downward velocity and leaving with apparent upward velocity. The pass through time depends on beam width (deg), height, and wind speed. this causes a spiky spectra. if there are not too many insects, then there is a maximum in the variance spectrum of biota signals at 1/(pass through time). For this reason the variance spectrum of volume targets is white and for biota with moderate densities it has a maximum at the frequency corresponding to the 1/(pass through time). The TEST-procedure extracts the variance caused by biota by cancelling the high frequency variance of the volume targets by 1 second averaging and by cancelling the low frequency variance with high pass filtering the variance of reflectivities. The remaining medium frequency componets of the variance spectrum is dominated by the beam passing of the single insects, and therefore it can be used for recognising if the signal is from biota or clouds. Without understanding the author found that the test method works in many cases. In cases with too high or too low wind speed this simplified filtering may fail.

Response: The proposed algorithm makes use of time series of 0^{th} moment profile data from the Doppler spectra. So, it is essentially off-line processing of 0^{th} moment time series data for running average of below 5 seconds window. So, there is much concern on biota (insects/birds) number density within the radar sample area than wind speed (observed to

be insignificant under light and moderately dense insect condition) as for as TEST performance on off-line moments data is considered. Thus, no need to involve the atmospheric wind or biota velocity details with TEST. To give more clairty further on it, we have chosen two contrasting wind speed day where low level jet (LLJ) shows strong (weak) winds at altitude of ~ 2 km AMSL derived from radar using VAD/VPP method (see belwo figure AR3) and found that TEST filtering working well during both high and low wind speed as well (see below figure AR(4, 5) for performance of TEST).

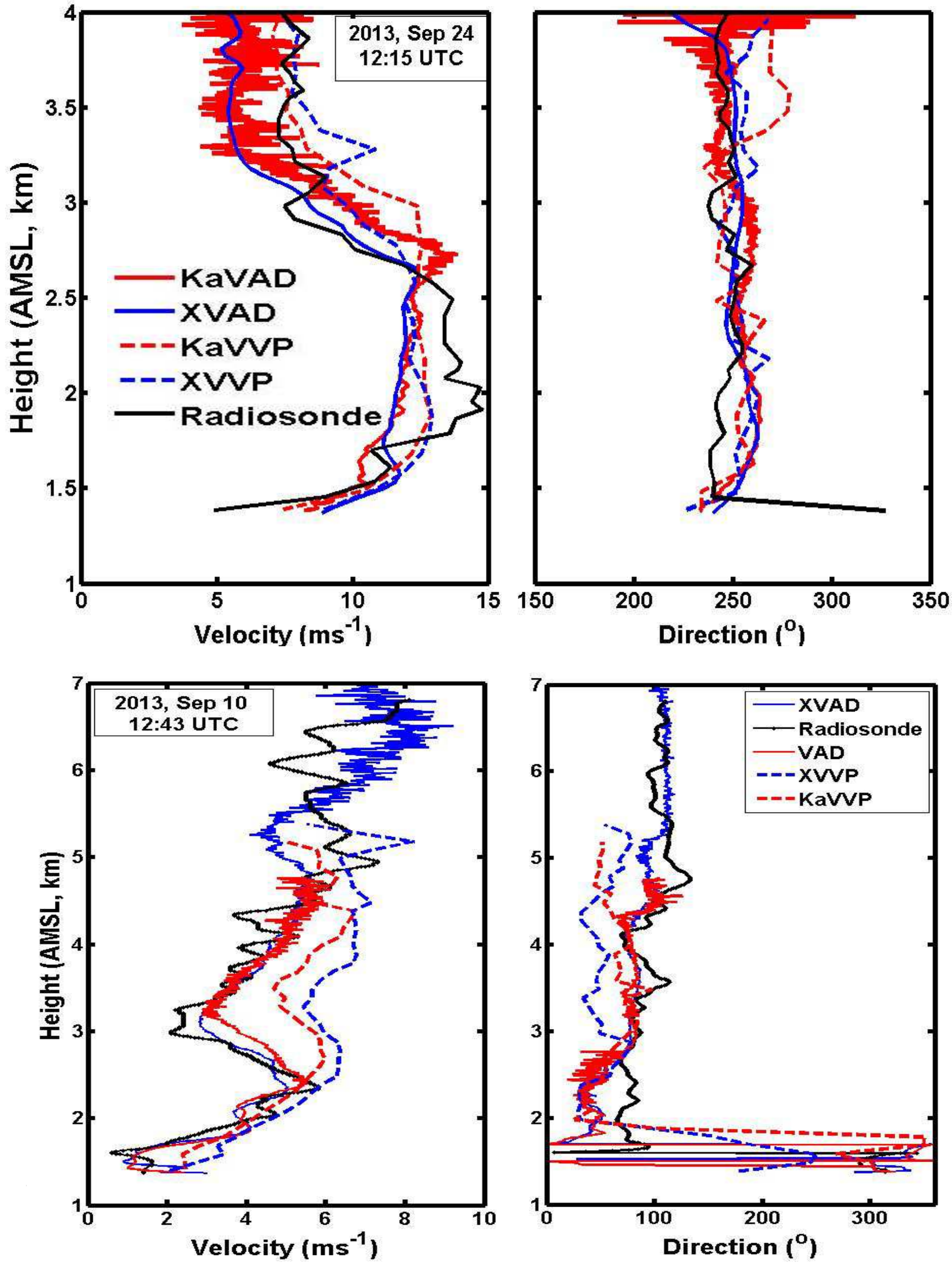

Figure AR3: VAD/VPP based wind profiles from KaSPR volume mode observations on 10 (weak ABL wind) & 24 (strong ABL wind) Sep.2013.

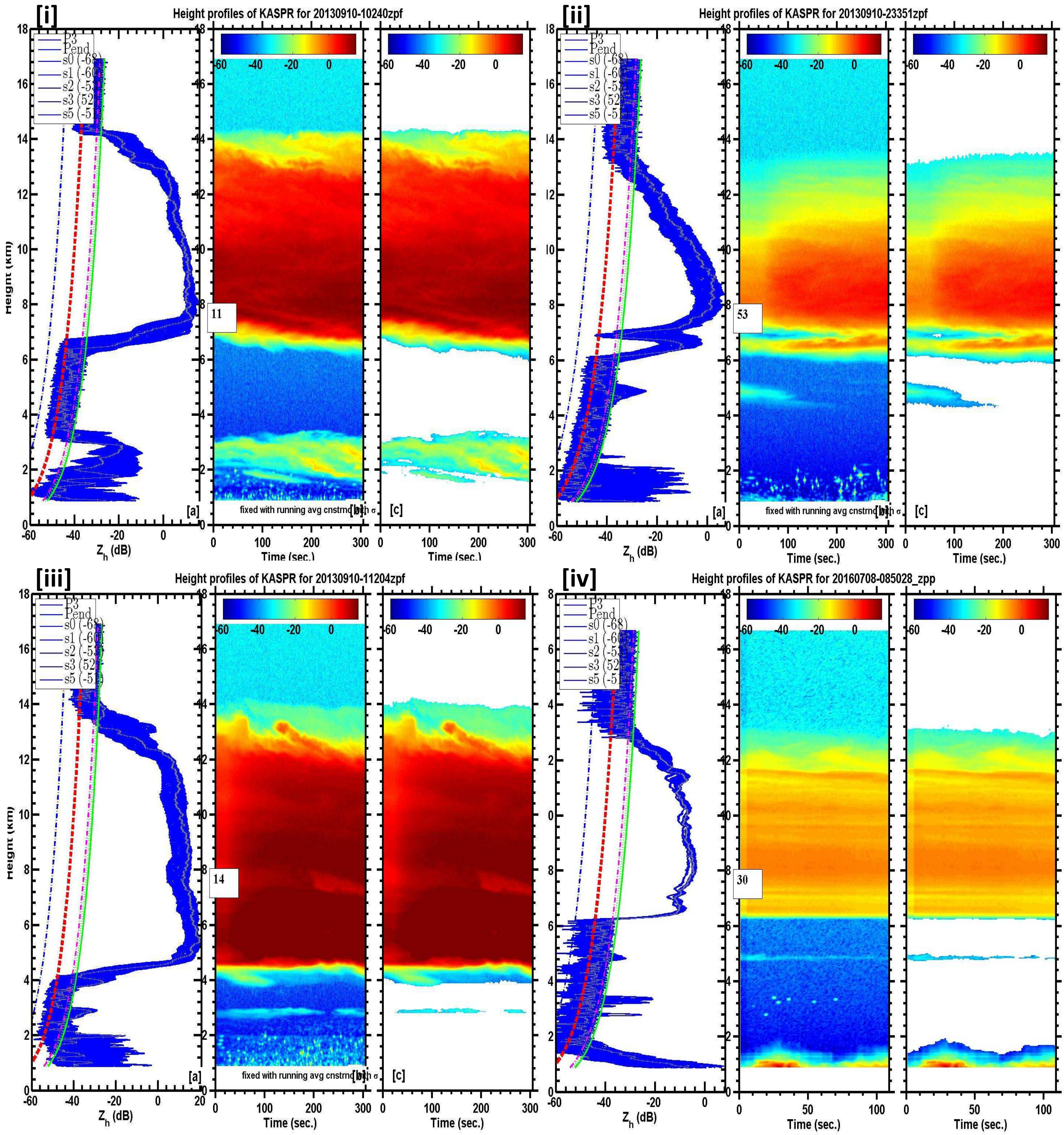

Figure AR4: TEST performance in filtering biota under strong low level Wind Speed (>10 m/s) day at 2.3 km AMSL for three cases on 10 Sep 2013 (i-iii) and case for active monsoon day on 08 Jul 2014 (iv).

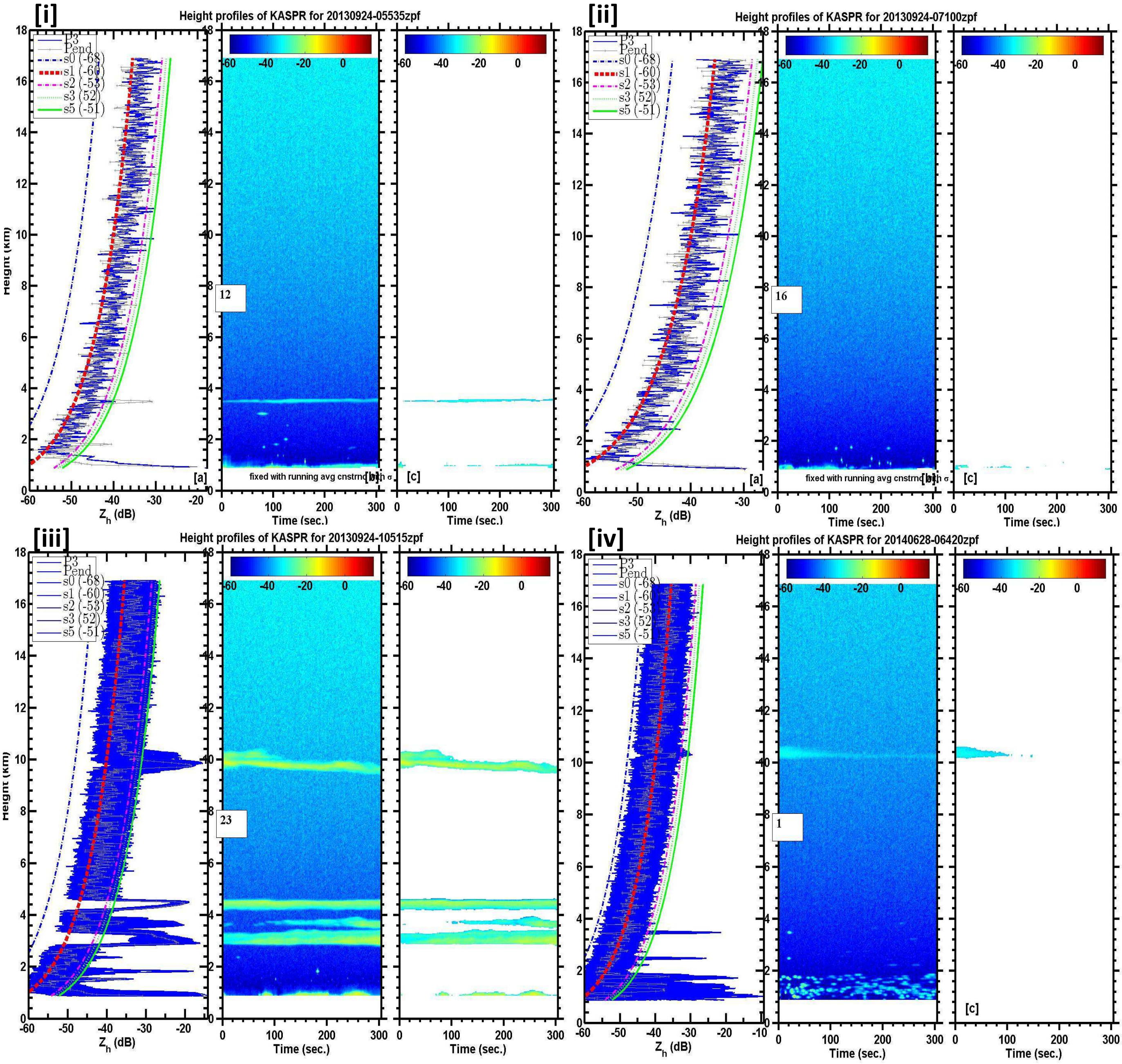

Figure AR5: TEST performance in filtering biota under weak low level Wind Speed (< 4 m/s) day at 2.3 km AMSL for three cases on 24 Sep 2013 (i-iii) and case for break monsoon day on 28 Jun 2014 (iv).

Some minor notes:

AR2-Comment:45: sensible âA˘T> sensitive

Response: Suggestion has well taken. However it cannot be seen now due to re-writing of Introduction.

AR2-Comment:56: to our experience the reflectivities of biota are below 0 dBZ, reflectivities of rain are above 0 or 5 dBZ.

Response: Okay! Correction made accordingly at line no 70.

AR2-95: T-matrics âA˘T> Rayleigh

Response: Thank you! Suggestion is implemented at line no 256.

AR2-Comment:96: I would change the sequence from large to small 1 droplets with .1 mm : -60 dBZ 64 droplets with 0.05: -60 dBZ 1e6 droplets with 0.01: -60 dBZ

Response: Thank you! sentence is modified now at line no 259.

AR2-Comment:I guess the author wants to say that hydro meteors are volume filling targets in most cases. For a single spectral component or say a single drop D size Z = N Dˆ6/V, where V is the radar volume which about 1000 to 25 000 mˆ2 depending on height, and N is the number of droplets in the radar volume. In case of single target N=1 and therefore Z_single target = Dˆ6/V or Z_volume traget » Dˆ6/V. As D can be inferred from the terminal falling velocity which is roughly the doppler velocity at least for larger droplets, it can be found by analysing data that hydrometeors are volume filling in the majority of cases. Sometimes large droplets in the beginning of a rain event are rather single targets.

Response: Yes, we assume that the hydrometeors are mostly volume filling / distributed targets. Agree that single big rain drop case could be point target but that yields very strong reflectivity where identification of cloud is much easy or exclusive in that sense that cloud echo can mask the weaker insect echo.

AR2-Comment:98: is the PRF of this radar really adjusted to such a low value. this would allow for a maximum range of 300 km which is not useful in vertically pointing mode. a prf of 7 to 10 khz is more adequate in vertical mode. this allows a much larger velocity range. but this is not relevant for the scope or this paper.

Response: Yes. Thank you! We used near 5 kHz ie., prt is around 201 micro seconds with maximum range of 30 km. Necessary change made at line 260.

AR2-Comment:I cannot understand or even guess the mening of this sentence. 126: ..more than 2 m/s and the de-correlation

Response: Thanks you for letting us the missed clarity in writing. The mistake has been corrected at line no 290 and such needed clarity and correction can be seen with subsequent part of the MS. Regarding de-correlation, we are inferring indirectly with our time series echo coherence pertinent to biota and cloud using running average with a hypothesis (see line no 291-295) and subsequently presenting a shallow cumulus cloud presence with biota (figure 13a) case and proving the de-correlation time of biota and cloud echoes using ACF with figure 15.

AR2-Comment:137: This method will be fully explained in the following section âA˘T> It seems it is in the rest of this section and then in the section Results and discussion beginning in line 214

Response: Agree and implemented at line 321. Thank for the correction suggested.

AR2-Comment:139: fixing âA˘T> thresholding

Response: Yes, Implemented at line no 323.

AR2-Comment:227: This is not true for cyrus clouds. The have a very soft top.

Response: Hope AR2 means it cirrus clouds, even those clouds have soft top they have to come above the noise floor so it is equally applicable to cirrus clouds as well.