Impacts of the weather radar's design on operations

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Purpose of this Article:

Operators sometimes get reports from their flight crews related to the weather radar. Examples of reports are listed below:

- “We have spurious returns above stratiform layers”
- “Sometimes the weather seems significant at 80 NM, we initiate avoidance, and when reaching 40 NM it seems to be less active than initially planned”
- “On-path weather sometimes becomes off-path when approaching the convective cell”
- “The radar said that there was no precipitations close to the ground whereas it was not true”
- “The radar seems to be less effective for stratiform layers with embedded cumuliform weather”

All of these reports can be due to the design of the radar itself. The aim of this article is to explain with more details some of the radar’s features, in order to give a possible explanation to the reports listed above.

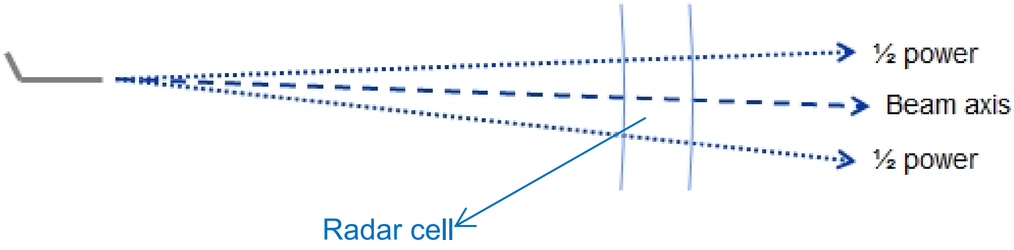
Applicability:

All Aircraft

1. GENERAL

All the weather radar systems perform scans with a beam, which has the shape of a cone. Depending on the power returns that it receives, the radar system deducts the reflectivity at different ranges to display it on ND/VD (direct relation between reflectivity and displayed colors).

For a given range and beam, the radar computes the average power return (and so, reflectivity) of a small area that is named “radar cell”. Each “radar cell” is a portion of space defined by the angular and range resolutions:

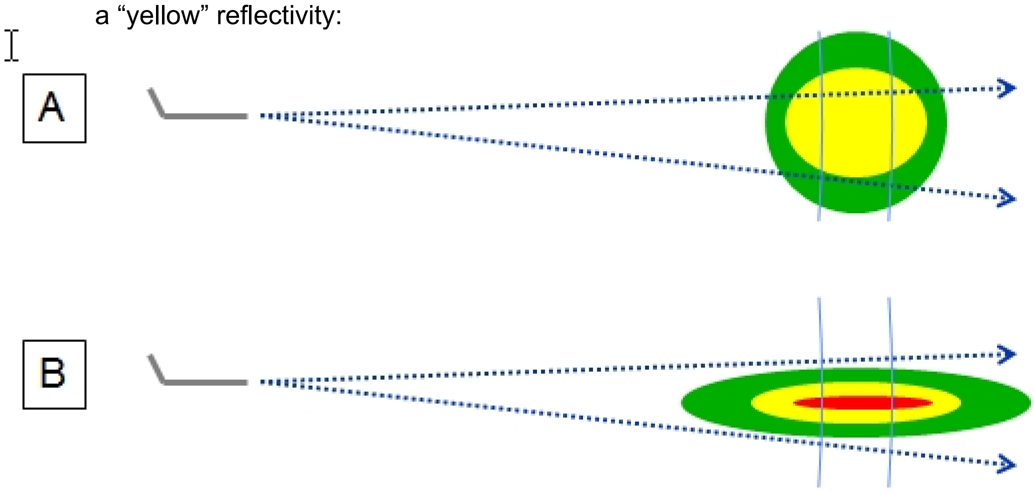


2. EFFECT OF THE RANGE ON THE RESOLUTION

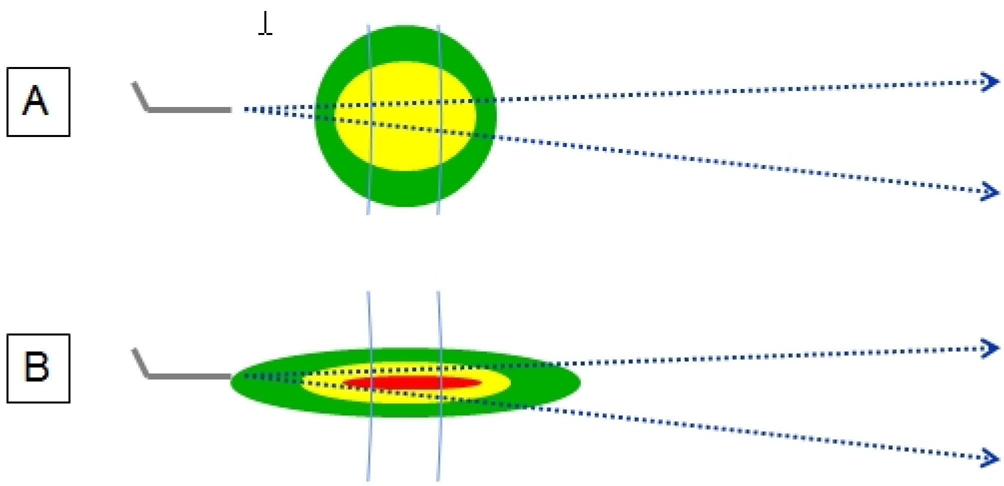
The width of the beam is fixed by the design of the antenna (3°). As a consequence, the higher the range, the bigger the size (volume) of the "radar cell".

The consequence is that the average power return for the "radar cell" could be the same for very different weather scenarios depending of the ranges of detection, as shown below:

- For a higher range: The average power return of the two following "radar cells" corresponds to a "yellow" reflectivity:

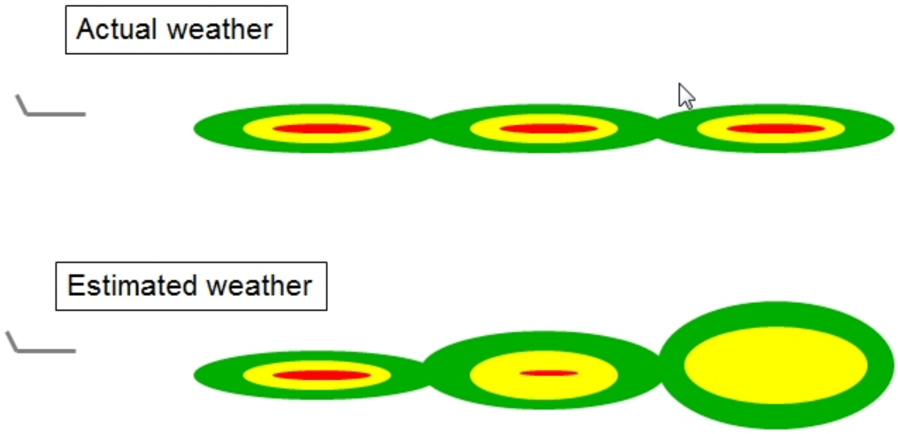


- For a lower range: The "radar cell" is smaller and enables to distinguish the red area:

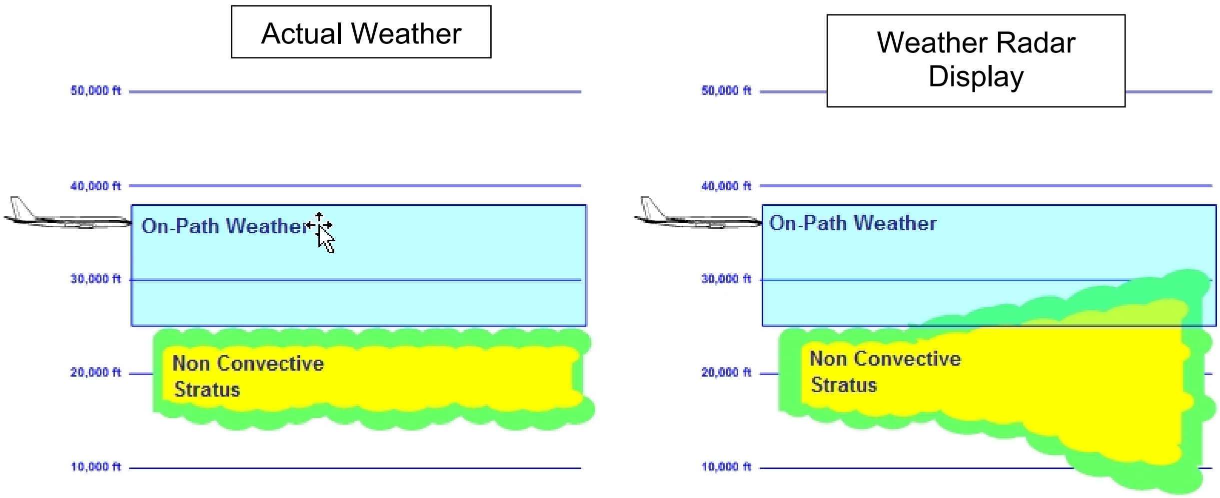


This explains why sometimes the ND may display yellow areas (for example) at long-range that will become red when the aircraft gets closer to the weather.

In addition, the estimated weather at a higher range may seem to be vertically higher than the reality because the average power return that the radar detects corresponds to a bigger “radar cell”, as shown below:

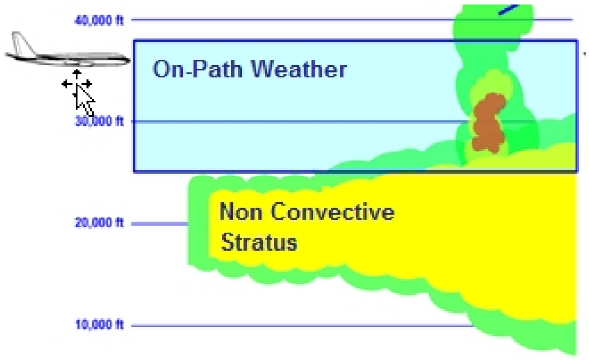


Another representation of this effect of angular resolution on range is given below, for aircraft fitted with on-path/off-path logic (Honeywell RDR-4000 on A320/A330/A340 family, and A350/A380 radars):



This explains why some on-path weather may become off-path when the aircraft gets closer to the weather and is sometimes called “ring effect”.

As a negative side-effect on aircraft fitted with on-path/off-path logic, if cumuliform weather is embedded in stratiform weather, the display of the cumuliform part is sometimes “drowned” into non-realistic on-path weather and more difficult to distinguish until the aircraft comes closer, as shown below:



This explains why cumuliform weather embedded in stratiform weather is difficult to see at high ranges.

3. GROUND EFFECT VS WEATHER

In addition to the weather reflectivity, the ground has also its own reflectivity. This ground reflectivity can be high, especially if there are water areas on the surface.

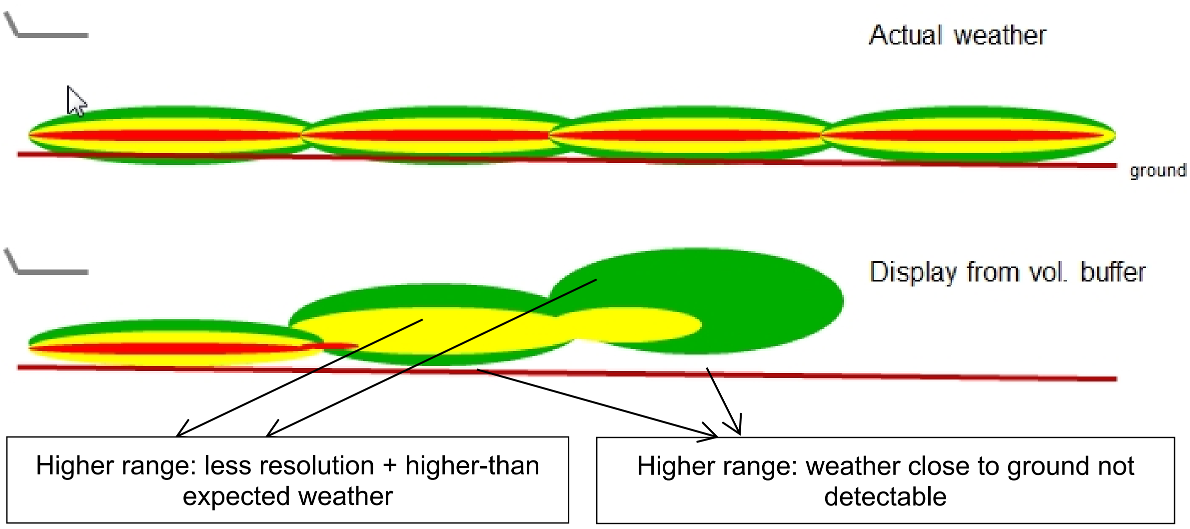
The radar system is designed to distinguish ground reflectivity from weather reflectivity. However, in areas where ground and weather returns are strongly mixed (i.e. clouds close to the ground), it is sometimes very difficult for the system to make this distinction.

This is why the weather close to the ground is sometimes not displayed to avoid displaying misleading ground reflectivity.

This explains why the weather located close to the ground, especially if it is stratiform and if the ground has a high reflectivity, is sometimes not detectable at high ranges.

4. COMBINATION OF ANGULAR RESOLUTION AND GROUND RETURN

The combination of the effects of angular resolution (section 2) and ground effect discrimination (section 3) has a direct impact on stratiform weather close to the ground, as shown on the picture below:



5. ALGORITHM TO CONVERT POWER RETURN INTO REFLECTIVITY

As explained in section 1.1, the radar has to convert, for each range, a power return into a reflectivity to be displayed on the ND/VD. The algorithm that makes this conversion takes into account some assumptions that come from experience on “standard” weather. The conversion model also depends on the range.

However, in reality, there is no “standard weather”. This means that sometimes the weather may have a stronger, or a weaker reflectivity than the “standard” assumption. This can make the algorithm too optimistic (or pessimistic) for a given range, and better for another range.

This explains why sometimes, depending on the range, the weather may seem to degrade or improve.

6. CONCLUSION

As a conclusion, we can say that some of the phenomena reported by operators on the radar may be due to the design of the radar itself, and particularly to:

- The angular shape of the beam that makes the resolution decrease naturally with the distance (effect on precision – “ring effect”, and also on the vertical size of sensed convective cells)
- The difficulty to discriminate the ground effect from the weather, in particular if the ground has a high reflectivity. This makes the close-to-the-ground weather difficult to see.
- The fact that the conversion of the power return into reflectivity takes into account standard assumptions, whereas there is no “standard weather”.