



Optimum use of weather radar

In recent years, there have been a number of flights where passengers or crew suffered injuries due to severe turbulence. In some other instances, the aircraft structure was substantially damaged following a hailstorm encounter. Clearly adverse weather can pose a threat to the safe and comfortable completion of a flight, thus it needs to be detected and avoided in a timely manner.



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The airborne weather radar system is an essential tool for pilots to assess the intensity of convective weather ahead of the aircraft. In this respect, it enables the strategic and tactical planning of a safe flight trajectory.

Weather radar technology has evolved significantly in the last few years and a range of enhanced products is now available. If properly used, they permit pilots workload to be significantly reduced while substantially reducing encounters with adverse weather.

This article offers an overview of the existing weather radar technologies, and provides information and tips on how to tune the system and correctly interpret the available displays.

WEATHER RADAR PRINCIPLE AND OPERATION

The weather radar system installed on-board aircraft provides the pilot with the necessary information to avoid - not penetrate - adverse weather.

To obtain the maximum benefit from the weather radar system requires

the crew to carefully optimize its use. This relies primarily on a good meteorological knowledge of weather phenomena, along with a good understanding of the available radar functions.

Flying in adverse weather: lessons learned

The aviation industry experience shows that although aircraft are equipped with airborne weather radars, incursions into very active convective cells still occur, resulting in injuries or substantial

aircraft damage **(fig. 1)**.

These events have led us to wonder why such encounters happen, and clearly show that prevention through anticipation is essential.



(fig.1)

Radome and windshield after hail encounter

When it comes to understanding why aircraft fitted with technologically advanced weather radars can end up flying in such unfavorable weather patterns, we have to consider that getting the best out of technology onboard is just a part of the answer. A key element of adverse weather avoidance strategies

is the active monitoring of the overall meteorological situation by the crew, in addition to the optimum use of the weather radar and correct understanding of the information displayed. We must not forget that weather radar is of help, but the crew overall assessment of the weather situation plays the central role.

“ Prevention through anticipation is essential. ”

“ Weather radar is of help, but the crew overall assessment of the weather situation plays the central role. ”

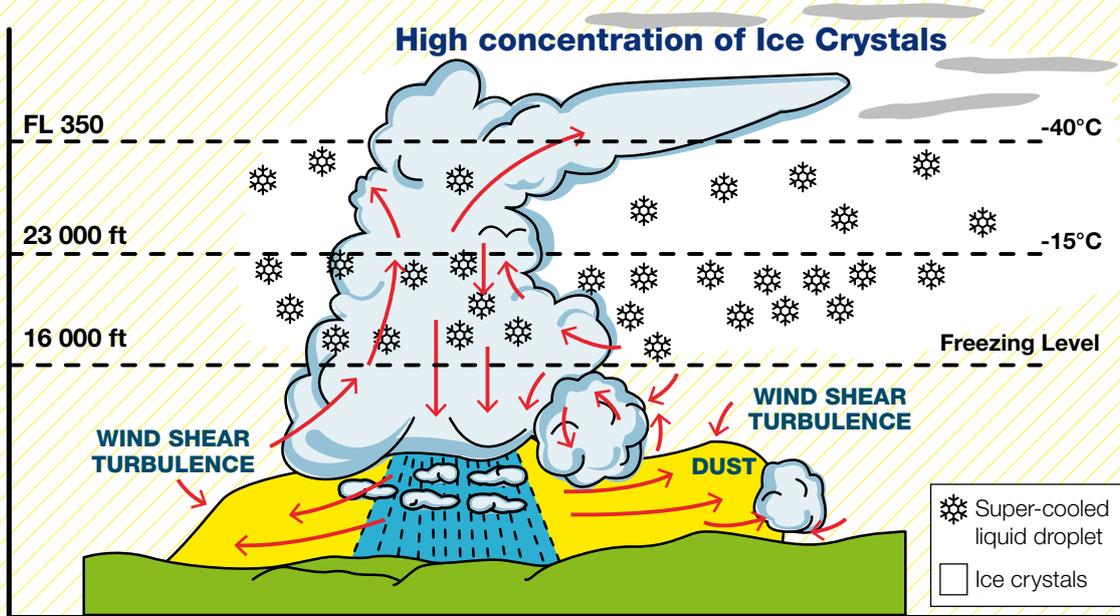
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Optimum use of weather radar

HOW IS A CUMULONIMBUS, OFTEN CALLED "THUNDERSTORM", STRUCTURED?

Three common threats to aircraft are turbulence (which is caused when two masses of air collide at different speeds), hail and windshear. All three of these are by-products of thunderstorms.

Understanding how a cumulonimbus cloud is structured and evolves is key in dodging the associated weather disturbances.



Turbulence:

Turbulence associated with a cumulonimbus is not limited to inside the cloud. Therefore, when flying in an area where cumulonimbus clouds have developed,

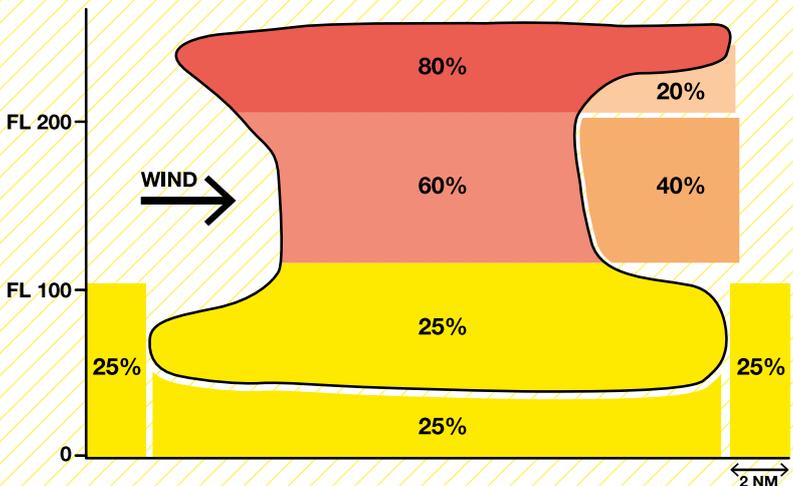
it is necessary to apply recommendations for weather avoidance as summarized in this article.

Hail:

The presence of hail within a cumulonimbus varies with altitude and wind:

- Below FL 100, hail is equally likely to be encountered under the storm, in the cloud or around it (up to 2 NM).
- Between FL 100 and FL 200, approximately 60 percent of hail is encountered in the cumulonimbus and 40 percent is encountered outside the cloud, under the anvil.
- Above FL 200, hail is most likely to be encountered inside the cloud.

Risk of encountering hail relative to cumulonimbus cloud position



When hail is encountered outside the cloud, usually the threat of hail is greater downwind of the cumulonimbus because moisture is

driven upward within the cloud by strong drafts. It then freezes and is transformed into hail before being blown downwind. Paradoxically, there

is less risk of hail in humid air than in dry air. In fact, moisture in the air behaves as a heat conductor, and helps to melt the hail.

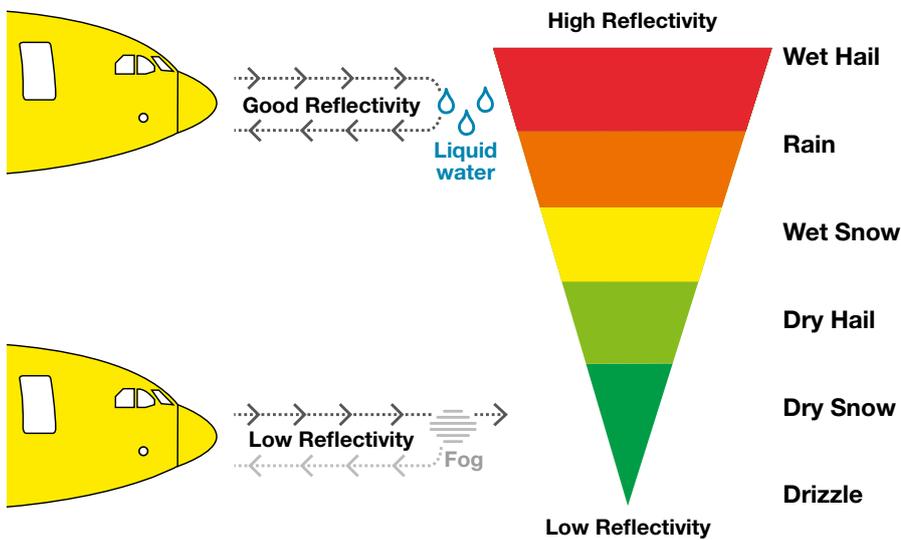
Weather radar principle

A knowledge of the radar principle is paramount in order to accurately tune this system and interpret the weather radar display correctly.

Reflectivity

Weather detection is based on the reflectivity of water droplets (fig.2). The weather echo appears on the Navigation Display (ND) with a color scale that goes from red (high reflectivity) to green (low reflectivity).

The weather radar echo returns vary in intensity as a function of the drop-let size, composition and quantity. For example, a water particle is five times more reflective than an ice particle of the same size.



“ On the Airbus fleet, all weather radars have full capability to allow wet turbulence detection. ”

(fig.2) Weather radar principle

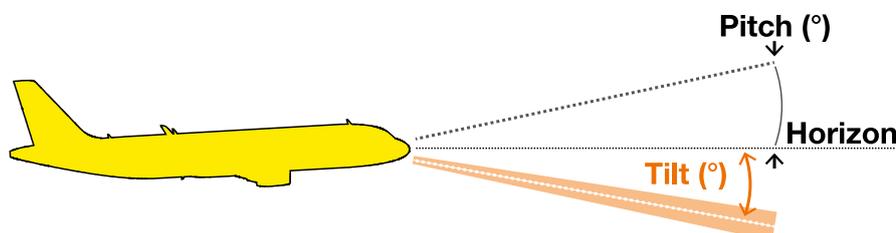
Some weather radars are fitted with a turbulence display mode. This function (the TURB function) is based on the Doppler effect and is sensitive to precipitation movement. Like the weather radar, the TURB function needs a minimum amount of precipitation to be effective. An area

of light rainfall, depicted in green in normal mode, is shown in magenta when there is high turbulence activity. The TURB function is on most weather radars only active within a range of 40 NM (Doppler measurement capability) and should only be used in wet turbulence.

Weather radar operation

The flight crew uses four features to operate the radar:

- **Antenna tilt:** this is the angle between the centre of the beam and the horizon (fig.3).
- **Range control of the ND:** this has an essential influence on the optimum tilt setting.
- **Gain control:** this adjusts the sensitivity of the receiver.
- **Radar modes:** weather (WX) or weather + turbulence (WX + T).



DID YOU KNOW

Each type of weather radar has its own particularities. To get all the information on the characteristics, limitations and operational recommendations of each weather radar model, the user guide of the radar manufacturer needs to be studied.

(fig.3) Definition of the TILT

“ Reflectivity is not directly proportional to the level of risk that may be encountered. ”

Weather radar limitations

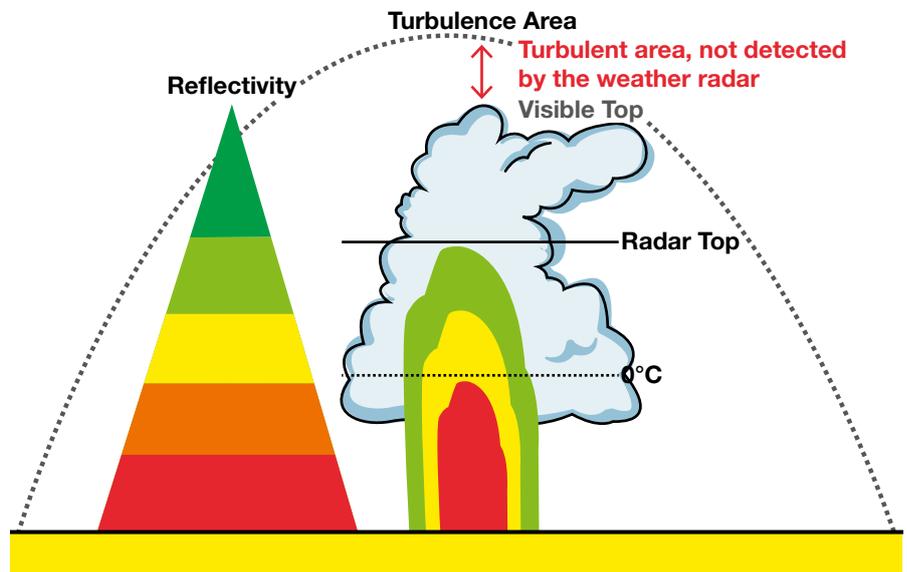
Weather radar detection capability

One of the weather radar limitations is that it indicates only the presence of liquid water. The consequence is that a thunderstorm does not have the same reflectivity over its altitude range because the quantity of liquid water in the atmosphere decreases with the altitude **(fig.4)**. Yet, the convective cloud and associated threats may extend significantly above the upper detection limit of the weather radar (called ‘radar top’). This means that reflectivity is not directly proportional to the level of risk that may be encountered: a convective cloud may be dangerous, even if the radar echo is weak.

This is particularly true for equatorial overland regions where converging

winds produce large scale uplifts of dry air. The resulting weather cells have much less reflectivity than mid-latitude convective cells. However, turbulence in or above such clouds may have a higher intensity than indicated by the image on the weather radar display. On the other hand, air close to the sea can be very humid. In this case, thermal convection will produce clouds that are full of water: these clouds will have a high reflectivity, but may not necessarily be a high threat.

Consequently, limitations of weather radars must be well understood and complemented by basic meteorological knowledge of the crew and, where possible, visual observation.



(fig.4)
Reflective image of a cumulonimbus

The weather radar detects:	The weather radar does not detect:
<ul style="list-style-type: none"> - Rainfall - Wet hail and wet turbulence - Windshear 	<ul style="list-style-type: none"> - Ice crystals, dry hail* and snow - Clear air turbulence - Sandstorms (solid particles are almost transparent to the radar beam) - Lightning*

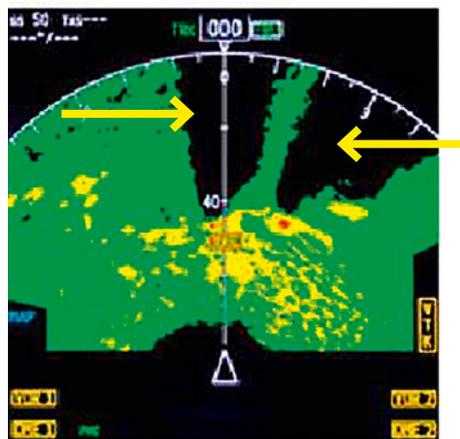
* The latest generations of weather radars offer hail and lightning prediction functions (see the following sections).

The beam attenuation phenomenon

Another limitation of the weather radar is called 'shadowing' or 'attenuation'. The weather radar display depends on signal returns: the more intense the precipitation, the less distance the radar can see through. Therefore when the radar echo is unable to make the two way trip through heavy precipitation, a 'shadowing' effect occurs.

The result is twofold. First, the size, shape

and intensity of that weather may not be accurately displayed to the pilot. What appears to be a thin or inexistent band of precipitation (**fig.5**) could in fact be the leading edge of a much larger area of precipitation. Secondly, any weather behind such strong shadowing cells will not be detected. This can result in unexpected weather unfolding only after the cell has been circumnavigated. ■



“ A black hole behind a red area on a weather radar display should always be considered as a zone that is potentially very active and shadows weather further down the scanned path. ”

(fig.5)

Attenuation caused by moderate to extreme precipitation

WEATHER RADAR TECHNOLOGY: THE DIFFERENT TYPES OF WEATHER RADAR

In cooperation with its suppliers, Airbus has continuously and pro-actively supported weather radar technology evolution over the years.

These continuous improvements have allowed the crew to be provided with optimized observation features and weather threat assessment functions.

Radars with manual controls

Full manual control radars

Early generations of radars are not equipped with an automatic tilt function; therefore the antenna tilt needs to be manually adjusted up and down as the flight progresses according to the aircraft's altitude,

the expected weather on path and the ND range selection. Then the pilot needs to analyze and understand the individual radar slices of weather displayed in order to get an overall picture.



NOTE

Early generation of full manual controlled radars without auto tilt are: Rockwell Collins WXR-701X family up to weather radar transceiver Part Number 622-5132-624 and Honeywell RDR-4B family up to weather radar transceiver Part Number 066-50008-0407.

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Optimum use of weather radar

Autotilt radar (Honeywell RDR-4B family PN 066-50008-0409)

Honeywell introduced the first weather radar featuring an automatic tilt computation named "Autotilt". When in Autotilt mode, the radar uses

the EGPWS terrain database and automatically adjusts the antenna tilt based on the aircraft position, altitude, and the selected ND range **(fig.6)**.

(fig.6)
Honeywell Autotilt



“ Automatic radars optimize weather detection and decrease significantly the pilots’ workload. ”

Fully automatic radars

The next generation of radars included automatic functions, which:

- Scan airspace ahead of the aircraft with multiple beams
- Feature a three dimensional (3D) buffer to store weather data
- Automatically compute and adjust the antenna tilt

- Offer independent pilot control and display selection.

These new radars optimize weather detection and decrease significantly the pilots’ workload necessary to understand the complete picture of the weather ahead.

A320 & A330 families:

Multiscan radar (Rockwell Collins WXR-2100 family)

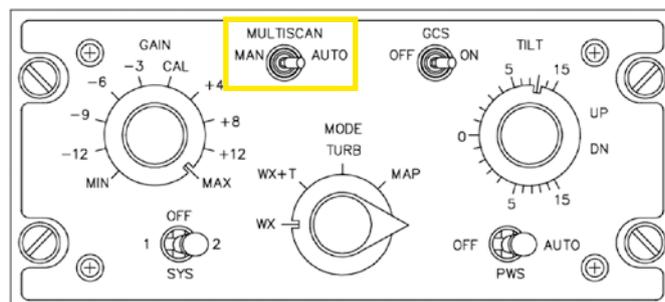
The WXR-2100 Multiscan weather radar is part of this new generation of weather radars that offers an automatic computation of tilt and gain control at all ranges, all altitudes and all times **(fig.7)**.

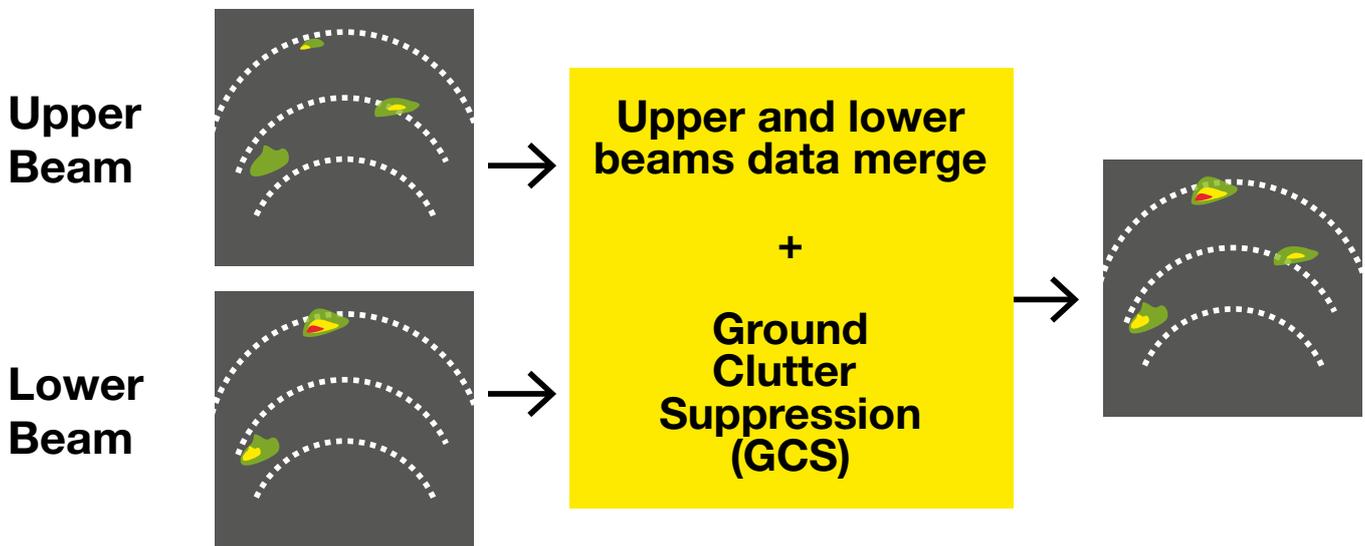
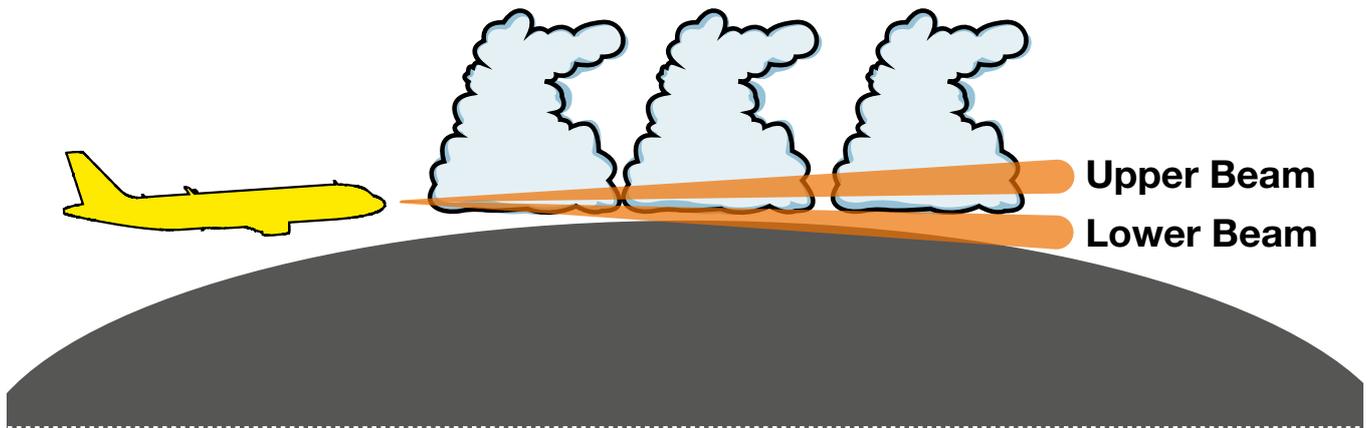
This weather radar is designed to work in Multiscan automatic mode. Pilots select only the desired range for the display and the radar alternatively scans at two

antenna tilt settings. The image that is displayed on the ND is the result of the stored and combined information from each beam.

The radar automatically adjusts the gain and tilt based on various parameters (aircraft altitude, geographical area, season, time of the day) to obtain the best weather display in each geographic region.

(fig.7)
Rockwell Collins Multiscan





A320 & A330 & A350 & A380 families: Honeywell RDR-4000

The Honeywell RDR-4000 model is part of the new generation of weather radars including a 3D volumetric buffer.

It can probe hundreds of miles ahead (up to 320 NM on A320 & A330 families and up to 640 NM on A350 and

A380) to show the en route weather picture, as well as automatically scan from the ground up to 60 000 feet to provide information targeted at various altitudes. The required display data are then accessed from the 3D buffer (fig.8 and 9).



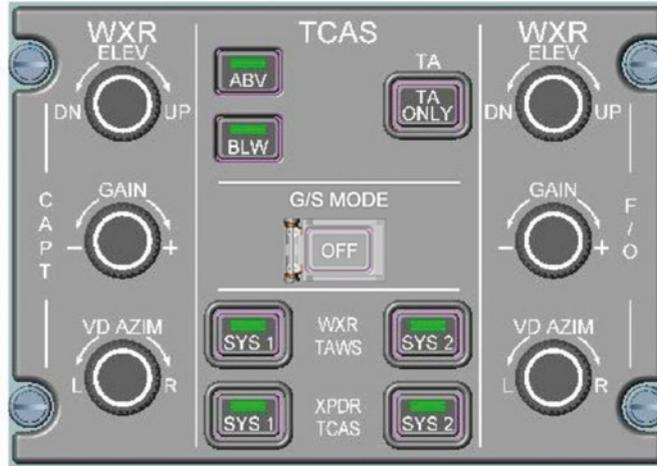
(fig.8)
Honeywell RDR-4000 control panel on A320 & A330 families

OPERATIONS

Optimum use of weather radar

(fig.9)

Honeywell RDR-4000 control panel on A350 & A380



When it is activated in the automatic mode, the radar RDR-4000 takes into account a vertical trajectory envelope (nominally +/- 4000 ft) along the vertical flight path of the aircraft based on the flight path angle. It then defines if the weather echo is inside this envelope (relevant 'ON PATH') or not (secondary

'OFF PATH') depending on the flight profile. Weather conditions along the plane's trajectory are displayed in solid colors, while more distant vertical echoes are shown in striped pattern to help pilots determine whether weather avoidance maneuver or rerouting is necessary **(fig.10)**.

(fig.10)

Honeywell RDR-4000 display



NOTE

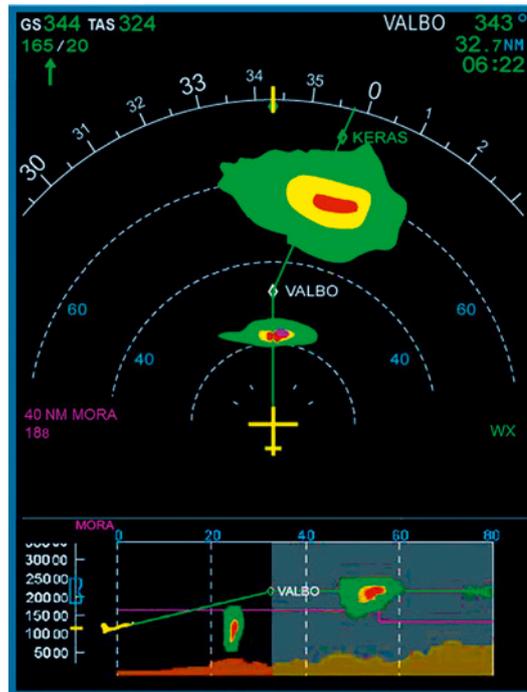
These enhanced weather radars are provided at Entry Into Service for new programmes (A380, A350) and as a retrofit option for A320 and A330 families.

The RDR-4000 can also be used in manual mode (elevation mode) as a tool for analyzing weather at user-selected altitudes and thus, assess the vertical expansion and structure of convective clouds.

This system is available on the A380 and also on the A350 with an additional 'weather ahead' alerting function. On these aircraft, the weather displayed is a computed image on:

- the ND, for views along the vertical flight path (in AUTO mode) or along the selected altitude (in ELEVN mode) or along the selected tilt angle (in TILT mode)

- as well as on the Vertical Display (VD) for views along the lateral flight path (in AUTO mode) or along the selected azimuth (in AZIM mode) **(fig.11)**.



(fig.11)
Weather information displayed on the Vertical Display

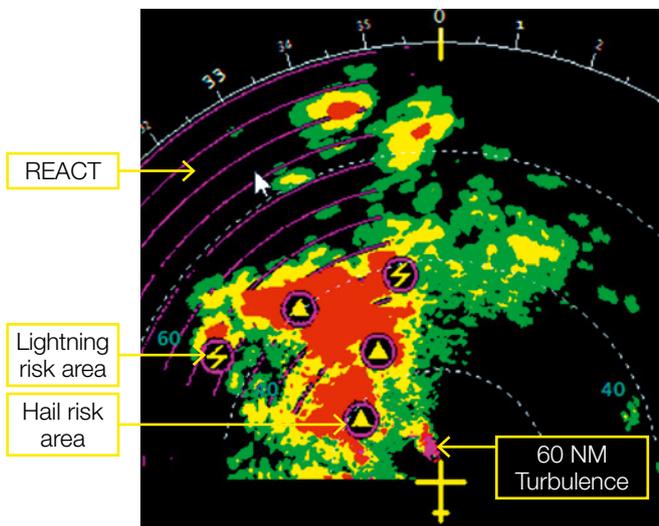
Hail and lightning prediction: the new functions introduced by ‘step 2’ automatic radars

In continuity of RDR-4000 and Multiscan WXR-2100, a new step of development recently introduced:
 - Hail and lightning prediction
 - Improved weather information.

» **Honeywell RDR-4000 (V2)** includes new features to improve weather hazard assessment by automatically providing the following additional information **(fig.12)**:
 - Weather alerting (‘WEATHER

AHEAD’) to alert the crew when the ND is not in weather mode

- **Hazard functions** offering:
 - Lightning and hail prediction
 - Rain Echo Attenuation Compensation Technique (REACT): this function indicates areas where the intensity of the radar echo has been attenuated by intervening weather.
 - Extended turbulence detection (up to 60 NM instead of 40).



(fig.12)
Honeywell RDR-4000 V2 display

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Optimum use of weather radar

» **Rockwell Collins Multiscan WXR-2100 (V2)** includes an automatic weather threat assessment (“Track While Scan” function). In continuity of the Multiscan, the aim of this version is to provide not only a depiction of the reflectivity of surrounding weather cells, but also a threat assessment for each cell detected.

Weather cells are first tracked and then, additional vertical scans are performed automatically to assess

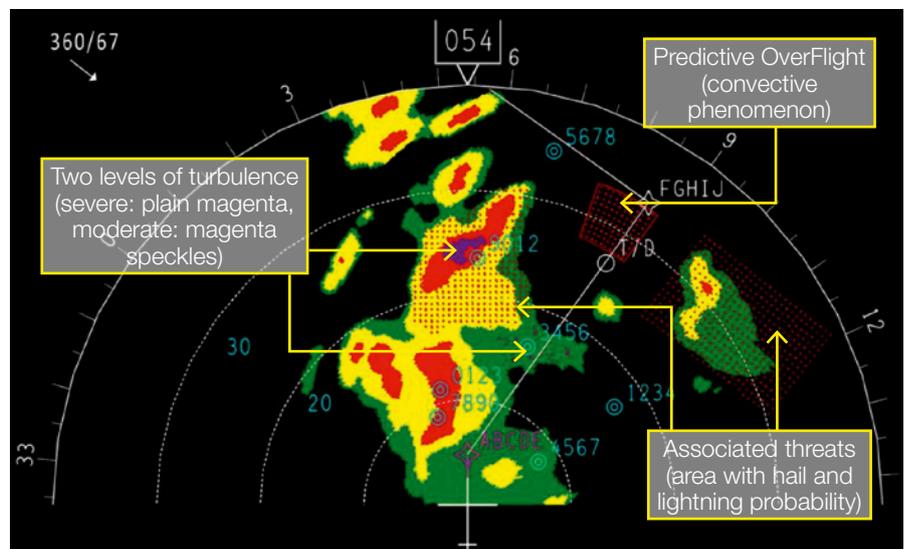
the corresponding threat based on reflectivity characteristics (**fig.13**).

This new radar also provides **hazard functions**, namely:

- Lightning and hail prediction
- Predictive OverFlight (this function alerts the crew to growing cells that are potentially on the aircraft trajectory)
- Improved turbulence detection able to display an additional level of moderate turbulence.

(fig.13)

Rockwell Collins Multiscan V2 threat detection and analysis



NOTE

Honeywell RDR-4000 V2 and Rockwell Collins Multiscan WXR-2100 V2 weather radars were certified in July 2015 for A320 and A330/A340 families and are available as retrofit options.



Coming next... the future evolution of weather information

Airbus in cooperation with weather radars suppliers, maintain their efforts in designing and producing new weather surveillance functions. Today, at a research level, a strong focus is placed on three main dimensions with the aim to improve pilots' awareness of the weather ahead.

1. High Altitude Ice Crystal (HAIC) detection to avoid flying in ice crystals areas.

There are multiple threats attributed to ice crystals; for example, engine vibrations, engine power loss, engine damage or icing of air data probes. In fact, the formation of ice crystals at high altitude and their effect on aircraft performance is recognized as an industry wide issue. Airbus in particular is leading the HAIC research project with several partners. This project aims to characterize and identify the environmental conditions of ice crystals, to improve aircraft operations through the development of appropriate detection and awareness technologies to be fitted

on aircraft. The next generation of weather radars is expected to benefit from this research work and enable the detection of ice crystals to avoid convective weather linked to ice crystal icing.

2. Weather display fusion to offer a single display of weather data covering all weather threats.

The feasibility of collecting all "weather on board" information together with weather information collected by the radar (reflectivity, turbulence and hazards) and merging them in a single display is currently being studied.

3. 3D weather analysis: automatic re-routing

Work is also being carried out to allow the automatic computation of an optimized deviation route based on: the actual weather (weather on board and radar data), the ongoing traffic and the stored flight plan. Such a function is expected to facilitate pilot's decision making and re-routing planning if needed. Additionally it improves comfort. ■

PUTTING THEORY INTO PRACTICE: HOW TO MAKE AN OPTIMUM USE OF THE AIRBORNE WEATHER RADAR

The weather radar is a tool for detecting, analyzing and avoiding adverse weather and turbulence. As with any other tool, adequate skills and the crew's involvement are needed in order to use it efficiently. In fact, the management of adverse weather still relies primarily on the crew to actively monitor the meteorological situation throughout the flight, and make a full use of the available technology thanks to:

- Awareness of weather radar capabilities and limitations, according to the specificities outlined in the FCOM and the manufacturer's user guide.
- Preflight briefing (knowledge of the route climatology and weather forecast –

charts and online simulation) and during flight (update on weather information)

- Adapted use of the weather radar, with the crew regularly assessing the range, gain and tilt, and making use of weather threat assessment functions when available in order to display an optimum weather radar picture on the ND.
- Regular manual vertical and horizontal scanning by the crew to increase situation awareness.
- Correct understanding of the radar image displayed.
- Adequate strategic (mid-term) and tactical (short term) decision making for trajectory planning.

How to optimally tune the weather radar and manage flights in convective weather?

Flight planning: the importance of weather briefing and weather reports

Weather avoidance already starts in the briefing room before commencing the flight, with a thorough assessment of en-route weather and decisions on possible mitigation means.

Before boarding, a weather briefing should reveal areas of predicted significant weather activity. Equally, this briefing should include the assessment of typical weather patterns in the area. For example in the tropics, cumulonimbus intensity and development is greater at certain times of the day. The crew have the opportunity at this stage to plan a route to avoid active weather based

on both the weather briefing and their knowledge of local climatology. Changing the flight route could be an option as well as taking additional fuel for enhanced strategic and tactical options in flight.

Once airborne, the weather radar should be used and tuned regularly in combination with all available information, e.g. pre-flight briefing, pilot's knowledge and experience of the area's typicality, reported turbulence, updated weather reports... If possible, the weather information should be updated in flight regularly. Information sought by ATC of turbulence encounters are an additional means.

“ Once airborne, the weather radar should be used and tuned regularly in combination with all available weather information. ”



INFORMATION

Safe operation in convective weather requires good theoretical knowledge of meteorology, particularly on the formation, development and characteristics of convective clouds in different regions of the world. This knowledge is usually provided in pilot licencing and operational training and is not covered by aircraft documentation (FCOM and FCTM).

Weather radar antenna tilt

Effective management of the antenna tilt along with an appropriate ND range selection, are key tools to obtaining an informative weather radar display on the ND.

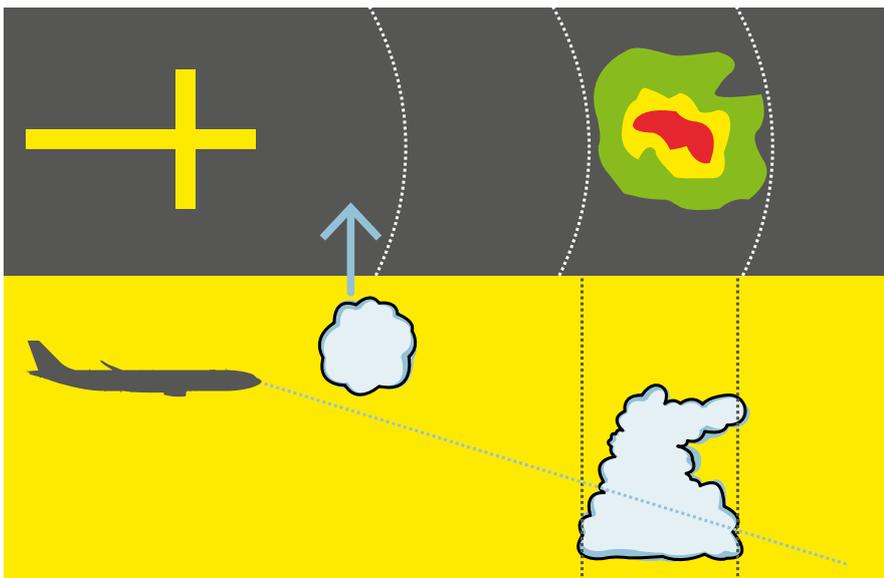
The ND might not display cells at aircraft flight level, only cells that are cut by the radar beam are shown **(fig.14)**. For this reason, the antenna tilt needs to be adjusted up and down regularly to scan weather ahead, and it needs to be adjusted to the ND range selection (except with the most recent radar models where this adjustment is made automatically).

The flight crew needs to periodically scan:

- Vertically, using the antenna tilt function
- Horizontally, using the range change.

If available, the automatic mode should be used as the default mode (unless mentioned differently in the FCOM), for detection and initial evaluation of displayed weather. Then, if adverse weather is suspected (e.g. according to information gathered during the pre-flight briefing), manual control should be used regularly and actively to analyze the weather ahead.

“ The automatic mode should be used as the default mode, for detection and initial evaluation of displayed weather. Then, manual control should be used periodically to analyze the weather. ”



(fig.14)

Display along radar beam



BEST PRACTICE

Even when the tilt is adjusted automatically, pilots are advised to reverse to the manual mode “MAN” regularly in order to scan the immediate weather ahead. This action allows the crew to assess the vertical structure and expansion of convective clouds.

Factors that can affect the relevancy of the ND display and that should trigger a tilt adjustment are:

- A heading change
- An altitude change, or even a regular flight profile change (e.g. from climb to cruise)

- The shape of thunderstorms
- A pilot report from another aircraft in the vicinity.

In the case of a change in heading or altitude, leaving the antenna tilt on auto may induce a risk of overlooking weather or underestimating the

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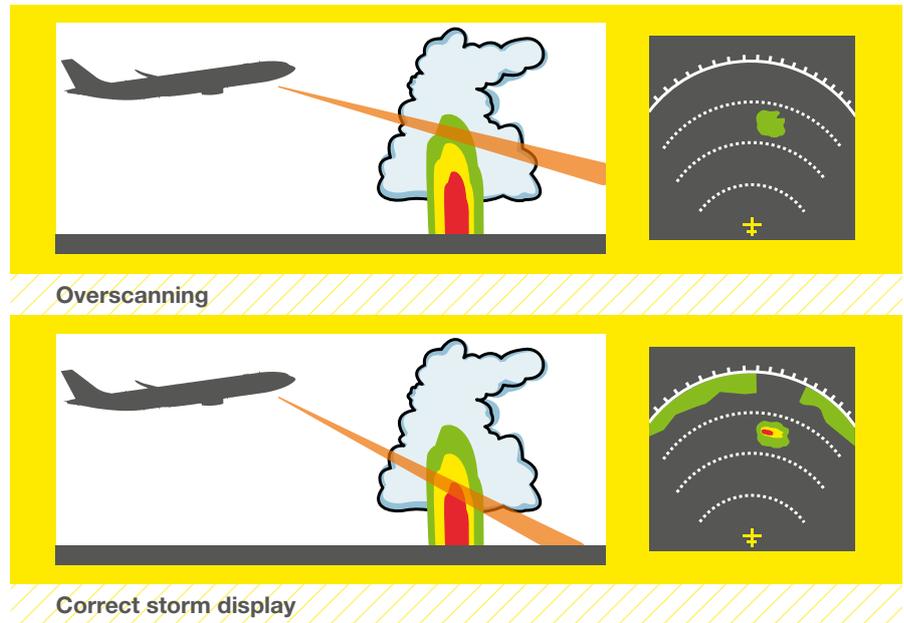
Optimum use of weather radar

(fig.15)

Weather radar display at different tilt settings

severity of the weather. For example, at take-off or in climb, the tilt should be set up if adverse weather is expected above the aircraft. **Figure 15** is an example of radar overshooting a

convective cell because the tilt is set incorrectly (too high in this case) while in the auto-tilt mode. When the antenna is tilted down, the ND shows a much stronger activity.



“ Presence of yellow or green areas at high altitudes, above a red cell, may indicate a very turbulent area. ”

To analyze a convective cell, the flight crew should use the tilt knob to obtain a correct display and point the weather radar beam to the most reflective part of the cell. At high altitude, a thunderstorm may contain ice particles that have low reflectivity. If the tilt setting is not adapted, the ND may display only the upper (less reflective) part of the convective cloud (overscanning). As a result, the flight crew may underestimate or not detect a thunderstorm. In order to get accurate weather detection, the weather radar antenna should also be pointed toward lower levels (i.e. below freezing level), where water can still be found. If a red area is found at a lower level, the antenna tilt should

then be used to scan the area vertically. Presence of yellow or green areas at high altitudes, above a red cell, may indicate a very turbulent area.

In most cases in flight, the adequate antenna tilt setting shows some ground returns at the top edge of the ND, which may be difficult to differentiate from genuine weather echoes. A change in antenna tilt rapidly changes the shape and color of ground returns and eventually causes them to disappear. This is not the case for weather echoes. Some weather radars are fitted with a Ground Clutter Suppress (GCS) function. When turned ON, it suppresses the ground return from the display.

Display range management

To maintain a comprehensive situation awareness, the flight crew needs to monitor both the short-distance and long-distance weather. To this end, the crew should select different ranges on the Pilot Monitoring (PM) and Pilot Flying (PF) ND.

To avoid threatening convective weather, the flight crew should make deviation decisions while still at least 40 NM away;

therefore, the following ranges should be selected on the NDs:

- Pilot Monitoring (PM) adjusts ranges to plan the long-term weather avoidance strategy (in cruise, typically 160 NM and below).
- Pilot Flying (PF) adjusts ranges to monitor the severity of adverse weather, and decide on avoidance tactics (in cruise, typically 80 NM and below as required).

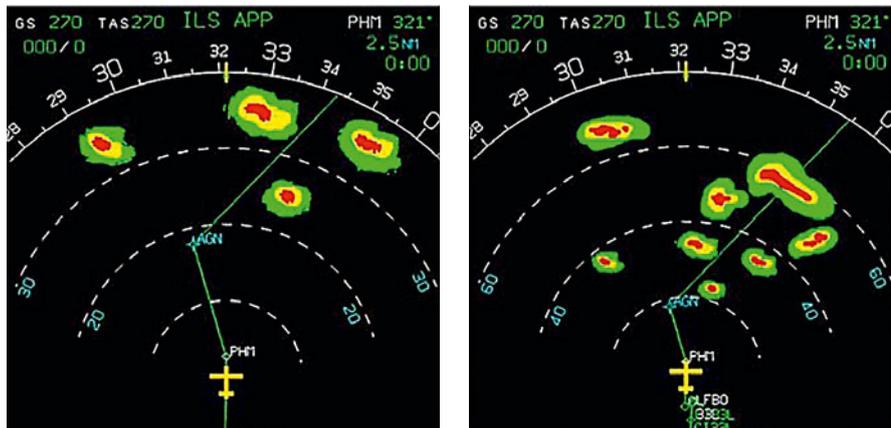


DID YOU KNOW

The FCTM provides useful guidance to correctly tune the weather radar in accordance with the flight phase.

Course changes to avoid adverse weather should be determined using both displays. This prevents the “blind alley” effect: a course change that may

seem safe when using a low range ND display may reveal a blocked passage when observed at a higher range (fig.16).



“ The crew should select different ranges on the Pilot Monitoring (PM) and Pilot Flying (PF) ND. ”

(fig.16)
Blind alley effect

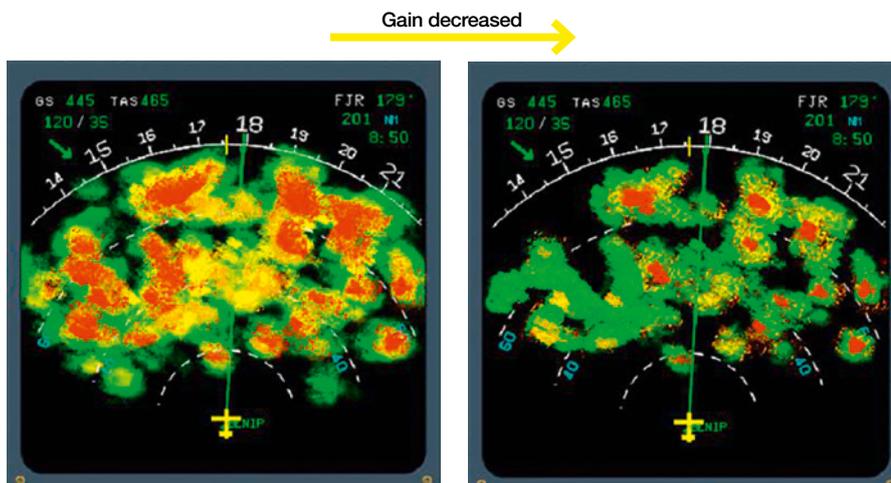
Gain adjustment

The sensitivity of the receiver may vary from one type of radar system to another. In the CAL (AUTO) position, the gain is in the optimum position to detect standard convective clouds. Manual settings are also available and can be used to analyze weather.

significant positive ISA deviations in a very humid atmosphere (typically the Indian monsoon). In these cases, slowly reducing the gain allows the detection of threatening areas: most red areas slowly turn yellow, the yellow areas turn green and the green areas slowly disappear. The remaining red areas – i.e. the red areas that are the last to turn yellow, - are the most active parts of the cell and must be avoided (fig. 17).

At low altitudes, reducing the gain might be justified for proper weather analysis. Due to increased humidity at lower levels, convective cells are usually more reflective and the weather radar display may have a tendency to show a lot of red areas. This can also be the case at higher altitude with

At high altitudes, water particles are frozen and clouds are less reflective. In this case, gain should be increased for threat evaluation purposes.



(fig.17)
Effect of gain reduction

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Optimum use of weather radar

“ The TURB function needs humidity; therefore clear air turbulence will not be displayed. ”

Turbulence and weather threats detection

Turbulence can be difficult to predict, but signs such as frequent and strong lightning and/or the specific shape of clouds (see the next section) can alert the crew to the likely presence of severe turbulence. If necessary and when available (according to the standard of weather radar onboard), the TURB function can additionally be used to confirm the presence of wet turbulence up to 40 NM (or 60 NM depending on

the radar standard) **(fig. 18)**. Remember that the TURB function needs humidity; therefore clear air turbulence will not be displayed.

In addition, the flight crew may be alerted by visual cues provided by the latest generations of weather radars that offer weather threat assessment functions, such as hail or lightning predictions.



(fig.18)

Turbulence detection (in magenta)



HOW TO CORRECTLY TUNE THE WEATHER RADAR AT A GLANCE



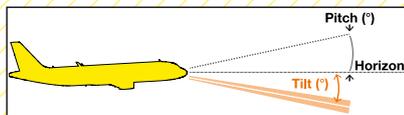
Before flight

Study the weather radar's specificities and limitations through the FCOM, FCTM and **weather radar user guide**.



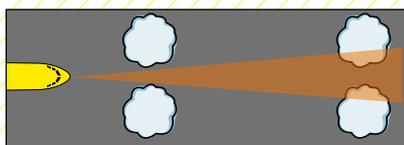
Before and during flight

Gather information about the **forecasted weather** and update regularly during flight: weather briefing, route climatology knowledge, reported turbulence...



During flight

Set the **antenna tilt** to auto as the default mode for detection and initial evaluation of weather, and periodically use the manual modes to scan and analyze the weather situation.



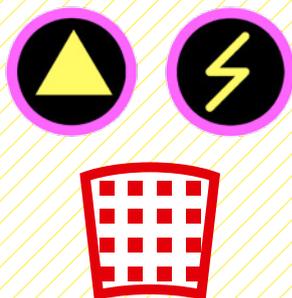
During flight

In cruise the combination of the following **ranges** provides good weather awareness and allows to avoid the "blind alley effect":
 - 160 NM on the PM ND
 - 80 NM on the PF ND.



During flight

Use **gain** in AUTO/CAL mode by default, then regularly reduce the gain for weather severity assessment.



During flight

Be attentive to the visual and oral cues provided by the **weather threat and hazard assessment functions** (as installed).

Weather radar data understanding: how to decide on an effective avoidance strategy?

Before any avoidance maneuver is initiated, the analysis the flight crew makes of the weather radar display is essential. Doing so, the crew is able

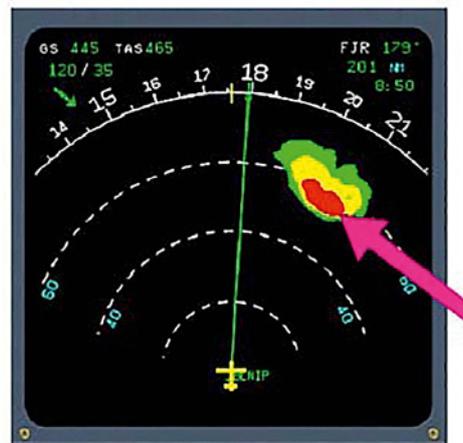
to conduct an in-depth analysis of the convective weather situation on-path and off-path and eventually, initiate action if needed.

Correctly understanding the weather display is paramount

After the weather radar has been tuned correctly, the data displayed should be supplemented with the available weather charts, reports and the meteorological knowledge of the pilot. Altogether these data enable the flight crew to get a complete weather picture and establish an “area of threat”. This “area of threat” corresponds to the zone where the flight crew estimates that the weather

conditions are too dangerous to fly in.

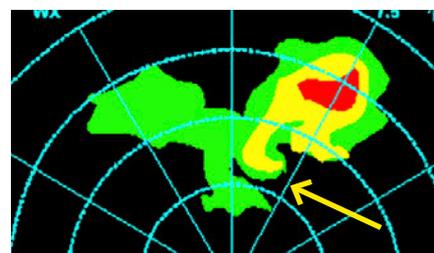
Some ND displays contain specific cues that should alert the flight crew. Clouds shapes, in addition to colors, should be observed carefully in order to detect adverse weather conditions. Closely spaced areas of different colors usually indicate highly turbulent zones **(fig.19)**.



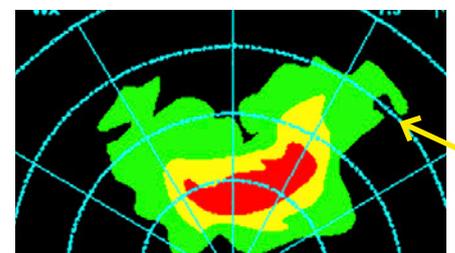
(fig.19)
Indication of a threat: closely spaced areas of different colors

Some shapes are good indicators of severe hail that also indicate strong vertical drafts **(fig.20)**. Finally, fast

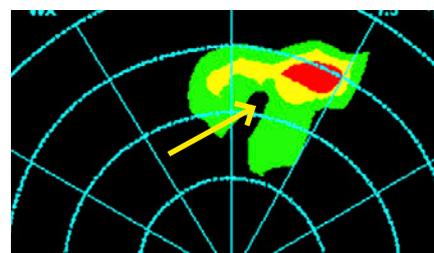
changing shapes, whatever the form they take, also indicate high weather activity.



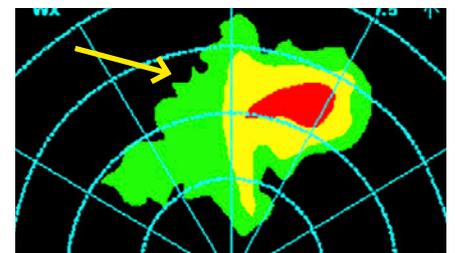
Finger



Hook



U-Shape



Scalloped Edges

(fig.20)
Shapes indicative of adverse weather

Avoidance strategy

The flight crew needs to remain vigilant and active in using and tuning the weather radar in order to be able to initiate an avoidance maneuver as early as possible. Indeed, weather radar information becomes more intense as the aircraft gets nearer the convective weather zone, thus making avoidance decisions more difficult. For this reason, crews should consider a minimum distance of 40 NM from the convective cloud to initiate the avoidance maneuver.

Once the decision to deviate course has

been taken, flight crews need to bear in mind the following advisory precautions and limits before actually deciding the trajectory of the avoidance maneuver.

If possible, it is preferable to perform lateral avoidance instead of vertical avoidance. Indeed, vertical avoidance is not always possible (particularly at high altitude) due to the reduction of buffet and performance margins. In addition, some convective clouds may have a significant build-up speed, that extends far above the radar visible top.

» Lateral avoidance

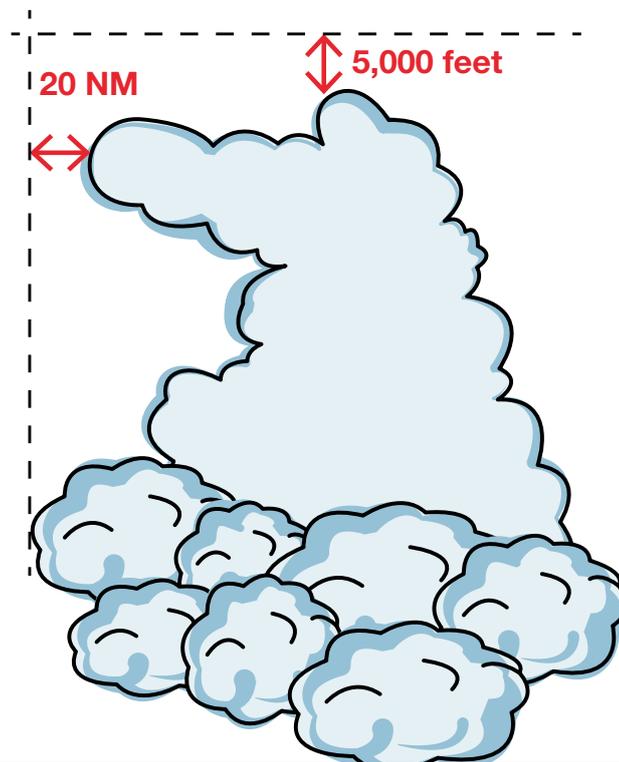
- When possible, it is advisable to try to avoid a storm by flying on the upwind side of a cumulonimbus. Usually, there is less turbulence and hail upwind of a convective cloud.
- The “area of threat” identified by the flight crew (e.g. a cumulonimbus cloud) should be cleared by a minimum of 20 NM laterally whenever possible
- If the aircraft trajectory goes between several convective clouds, if possible maintain a margin of at least 40 NM with the identified “area of threat”.

» Vertical avoidance

- Do not attempt to fly under a convective cloud, even when you can see through to the other side, due to possible severe turbulence, windshear, microbursts and hail. If an aircraft must fly below a convective cloud (e.g. during approach), then the flight crew should take into account all indications (visual judgement, weather radar, weather report, pilot’s report, etc) before they take the final decision.
- If overflying a convective cloud cannot be avoided, apply a vertical margin of 5 000 feet **(fig.21)**.

“ Consider a minimum distance of 40 NM from a threatening convective cloud to initiate the avoidance maneuver. ”

“ If possible, it is preferable to perform lateral avoidance instead of vertical avoidance. ”



(fig.21)

Lateral and vertical circumvention margins

Practical example: typical scenario of severe weather avoidance strategy

Figure 22 shows a typical weather radar display indicating multiple areas of severe weather. What route would look like the preferable option?

Route A:

this is the most direct route to destination but it navigates right through the most severe and active zone; therefore it is the path that carries the biggest risks and should not be an option.

Route B:

this route could be tempting since it requires little deviation to the mainstream route and it looks like the most active red areas are avoided. Nevertheless, this trajectory leads downwind of the convective area, thus increasing the risk of encountering severe weather. Additionally, the convective cells beneath might be developing fast and upwards, thus closing off the gap in between the red zones. Before this option is considered, the flight crew would need to tilt the radar antenna down to analyze weather and see what is below the apparent gap.

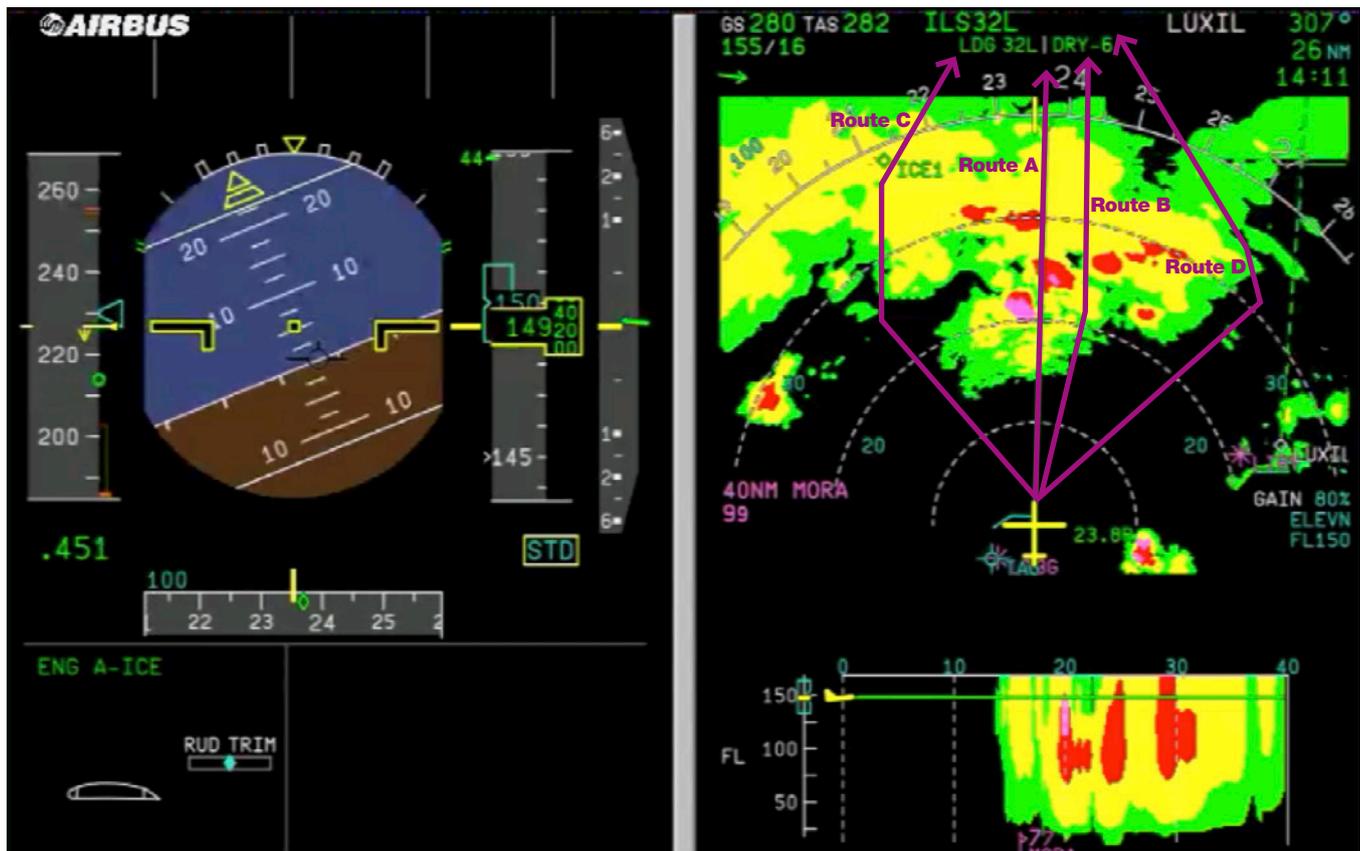
Route C:

this route looks like a possible escape route because it goes around most of the storms by a wide safety margin. However, while doing so, the flight crew would need to keep a look at the cell to the left of this route, and see whether it develops rapidly or not. In addition, this route leads away from the initial flight plan and therefore it could have operational implications such as fuel consumption or delays.

Route D:

this route would be the preferable option in terms of risks mitigation.

When faced with a situation where weather ahead reveals an extensive storm system, several options are always possible. Before the flight crew makes a decision, it is prudent to analyze weather carefully by scanning the vertical expansion of the various cells, and if possible, consider deviation to an alternate route. ■

**(fig.22)**

Available options to avoiding weather

Regardless of how you locate a severe weather area – visual, by radar, or from a report – a key parameter to successful route planning and avoidance strategy is time. The weather radar, and enhanced models more particularly, can help you to analyze and understand distant weather accurately and evaluate weather scenarios from a distance. This system is a key tool to planning ahead to avoid last-minute decisions, and making a decision on circumnavigating a nasty convective cell with a comfortable safety margin. In addition to technology, you need to stay active in maintaining situation awareness throughout the flight. Regularly complement the radar images displayed by a manual vertical scan of surrounding cells, as well as gain and tilt adjustments as required. Last but not least, adhere to your knowledge of meteorology basics, local climatology and weather briefing to adopt the best course of actions, and navigate safely, effectively and comfortably to destination.