NATIONAL TRANSPORTATION SAFETY BOARD

Office of Aviation Safety
Washington, D.C. 20594

October 16, 2018

Attachment 10 – JetBlue Radar Training Tool (Excerpt)

OPERATIONAL FACTORS

DCA16IA215

Weather Radar

Training Tool

Introduction

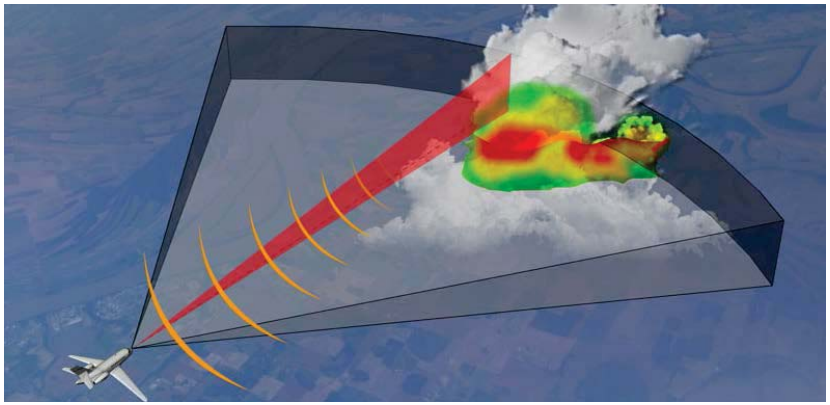
While both the A320 and the E190 are equipped with modern airborne weather radar, pilots must operate this equipment properly to prevent incursions into hazardous convective weather. Such incursions can lead to injuries and aircraft damage, and must be avoided.

Purpose

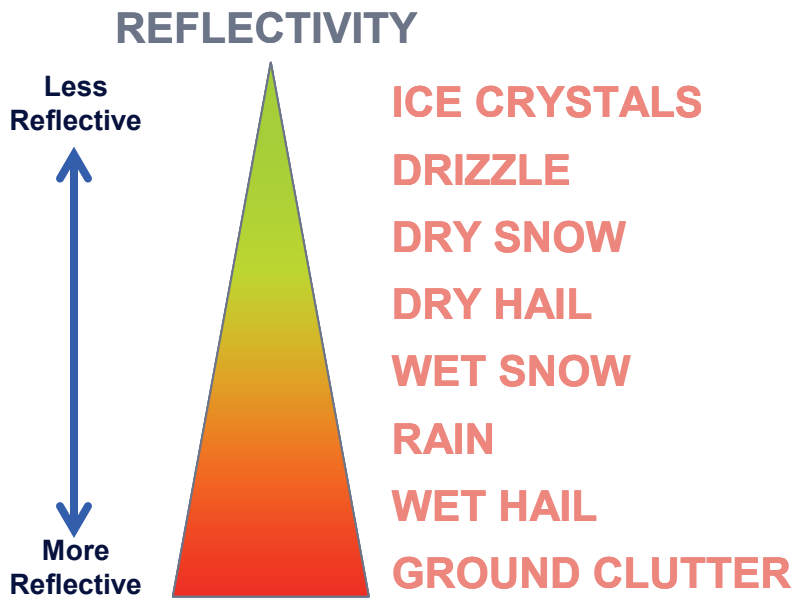
- The objective of this presentation is to provide essential information about operating in areas where the threat of convective weather exists. The following topics are included:
  - Radar Basics
  - Radar Controls
    - Tilt, Range, and Gain
  - Operational perspectives and strategies for radar usage
  - Aircraft type-specific details

Radar Basics - What Your Radar "Sees"

- Weather Radar works by sending out signals that reflect off objects and return to the aircraft. These returns are displayed to the pilot on the radar screen.



- The amount of radar signal returned and displayed to you depends on the reflectivity of the object struck by the radar beam.
- The chart on the right shows the relative reflectivity of various objects.



What Your Radar "Sees"

- Additionally, the reflectivity of precipitation droplets is dependent upon their…
  - Size: The larger the droplet, the better the reflectivity
  - Number: The higher the concentration of droplets, the better the reflectivity
  - Composition: The greater the liquid water content (i.e., "wetness") of the droplet, the better the reflectivity

What Your Radar "Sees"

Here's a simple summary:

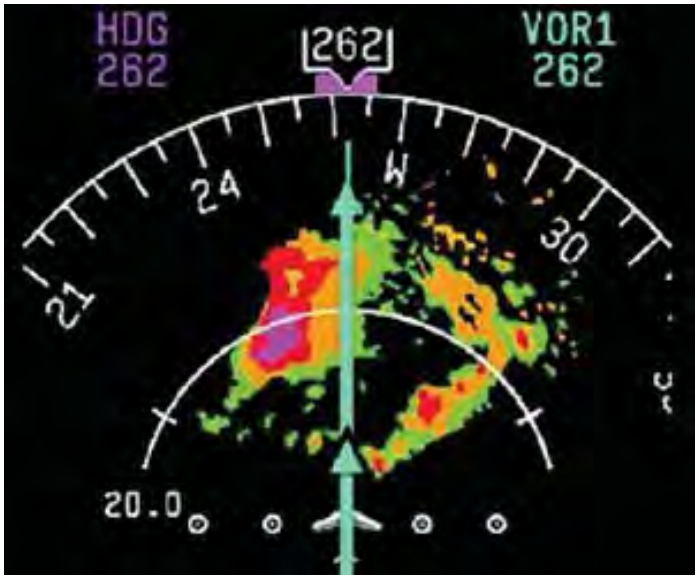
- Radar is **good** at detecting:
  - Particles with high liquid content (rain, wet snow, wet hail, etc.)

- Radar is ***unlikely*** to detect:
  - Particles with little or no liquid content (Ice crystals, dry hail and dry snow)

- Radar ***does not*** detect:
  - Clouds or fog (droplets are too small)
  - Volcanic Ash or dust (no water at all)
  - Clear air turbulence or wind (no particles)

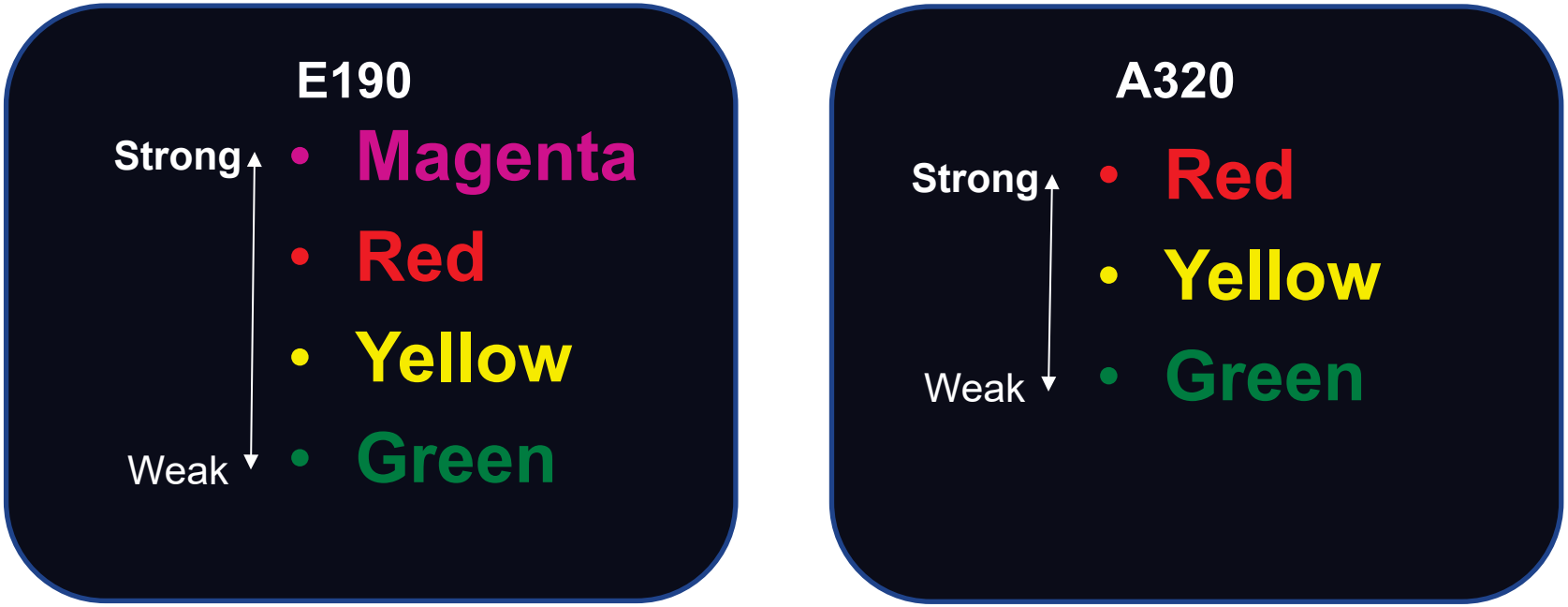
Radar Display

- Different colors are used on the radar display to depict the differences in intensity of the reflected radar signal.



Radar Display

- It should be noted that different types of radar equipment use different color scales
- For instance, in the E190, magenta represents the strongest return
- However, in the A320, this is displayed in red



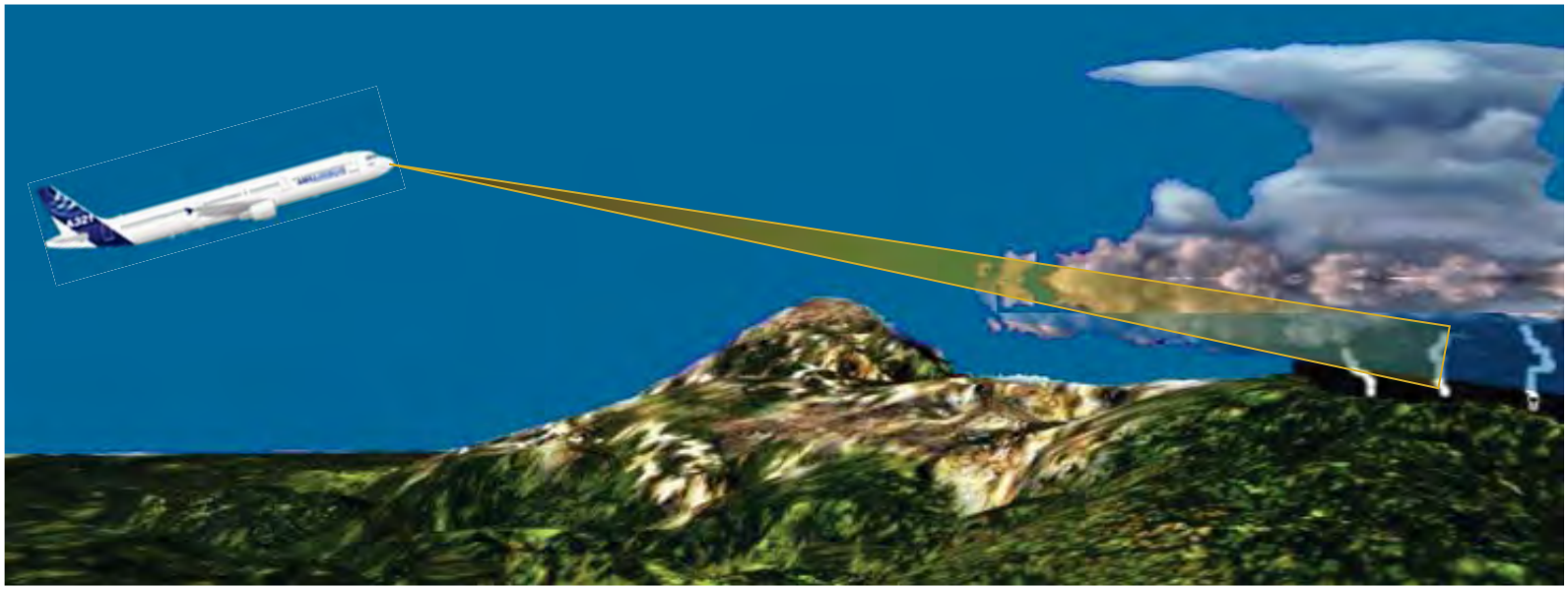
Operating the Radar

- The flight crew utilizes three primary controls to operate the radar:
  - **Tilt** is the vertical adjustment of the angle between the center of the beam and the horizon.
  - **Range** is the distance from the aircraft to the radar returns being displayed. (This is determined by the range setting of of the ND/MFD map display).
  - **Gain** is the sensitivity adjustment of the radar receiver. (Should usually be set to AUTO)

- In the following slides, we'll discuss each of these controls.

Tilt - Basics

- By adjusting the tilt, the pilot controls where the radar is "looking" vertically

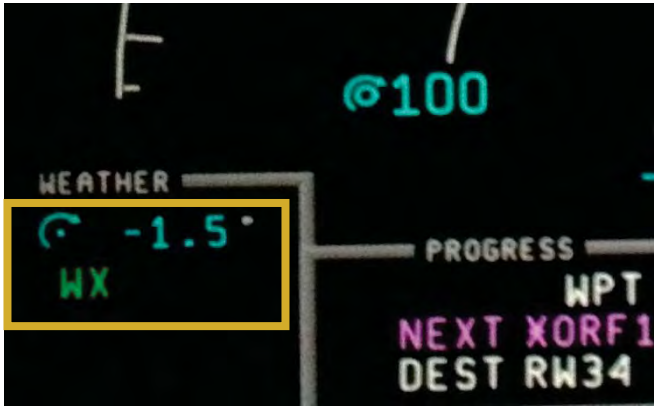


jetBlue AIRWAYS

Tilt - Basics

- Tilt angle is displayed on the ND (A320) / MFD (E190).
  - Both aircraft have a +/- 15 degree range of tilt available

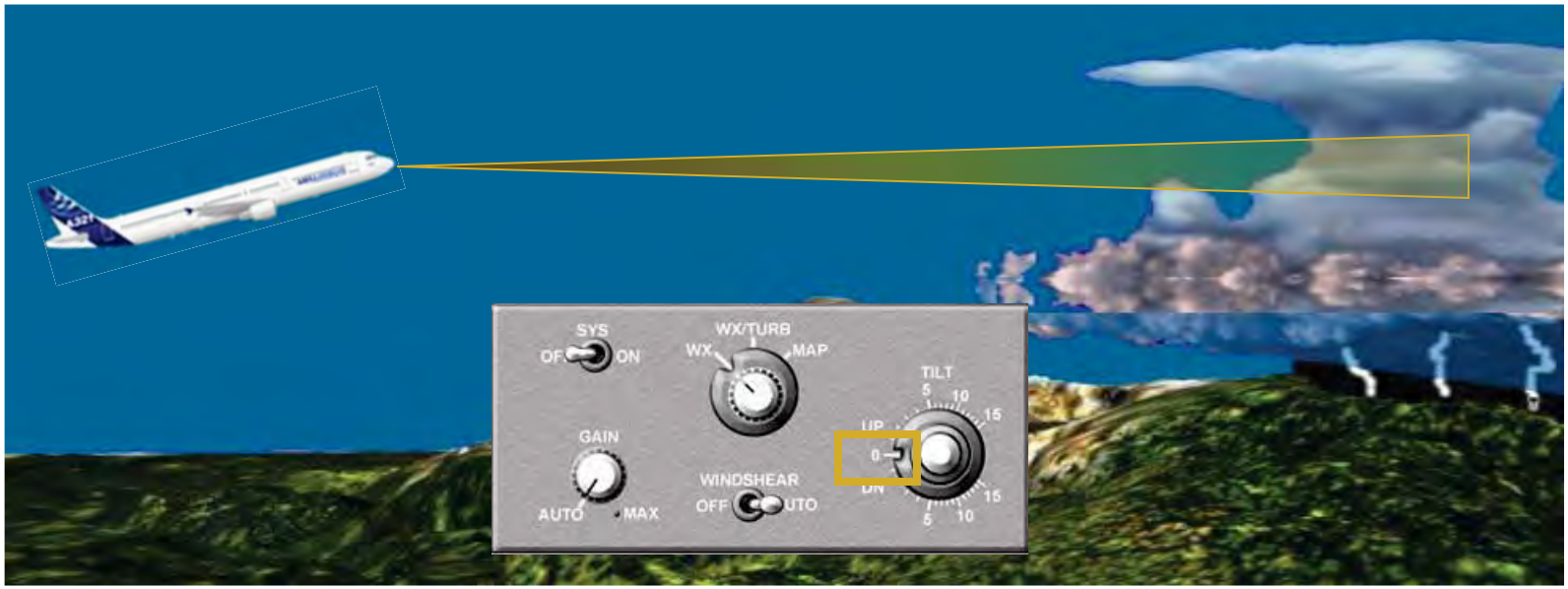
A320



E190

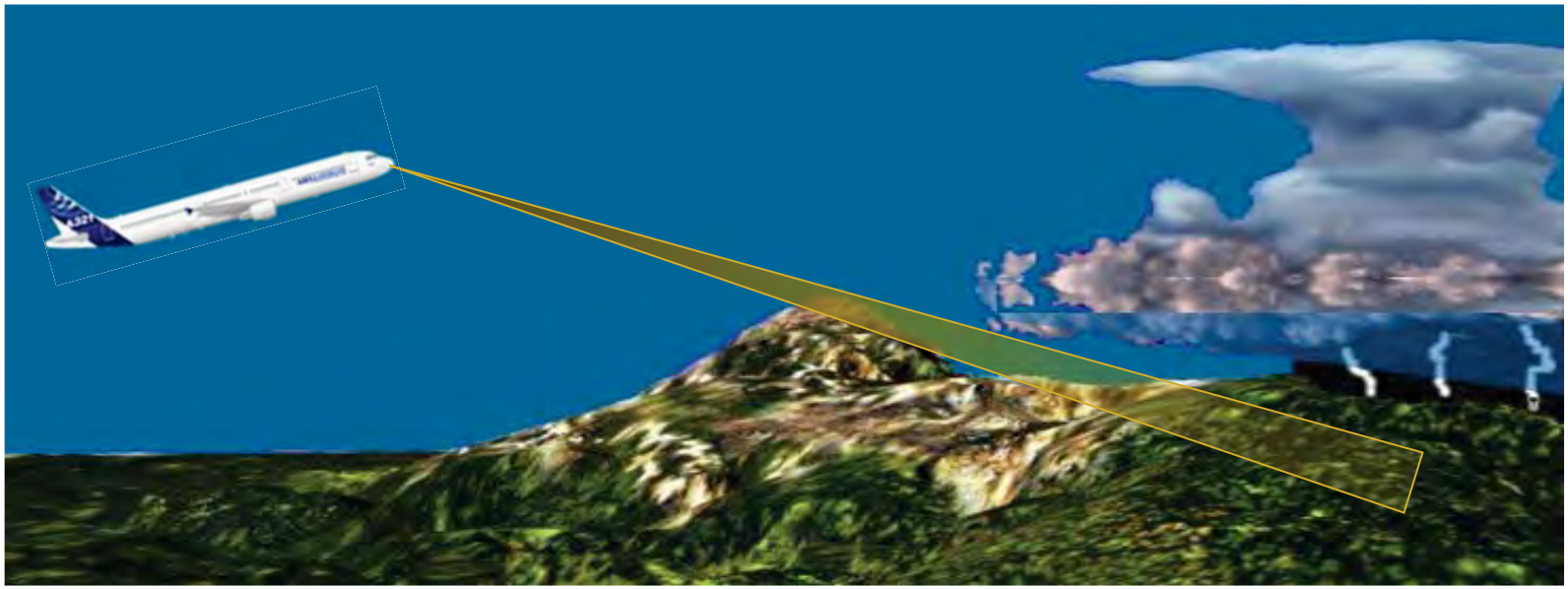
Tilt - Basics

- All tilt control adjustments are calibrated relative to the horizon, not the aircraft attitude. In the below example, note that the tilt control is set to 0 degrees. The aircraft has a nose-up attitude yet the beam center is level to the horizon.



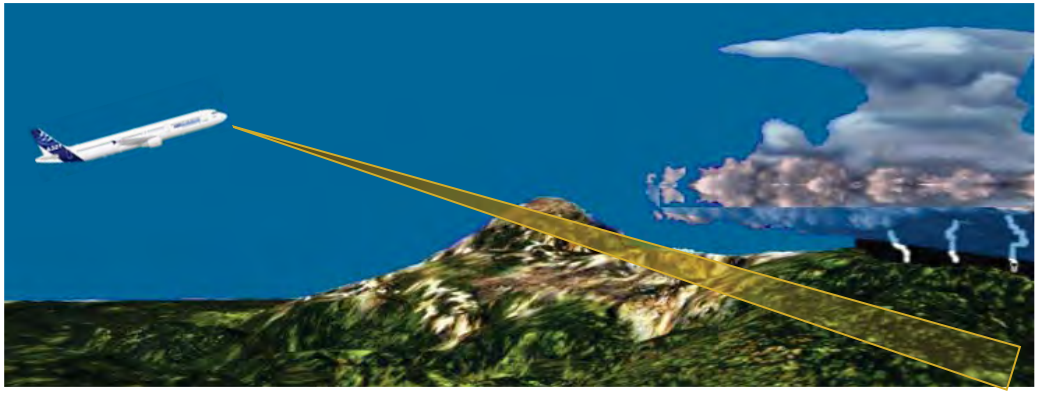
Tilt – Under Scanning

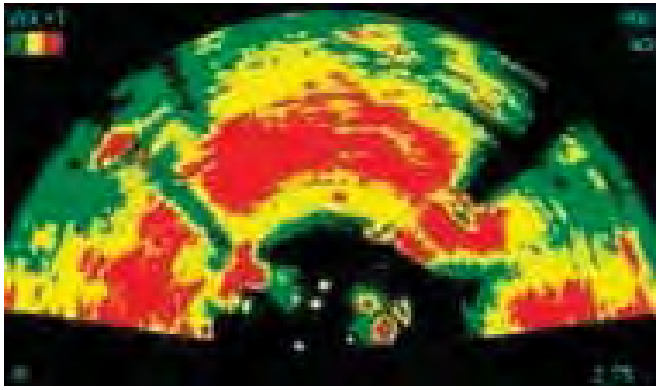
- “Under scanning” occurs when tilt is adjusted too low. As shown below, this means that the radar beam misses the intended weather target because it is pointed under it, so the radar displays only ground returns.



Ground Returns

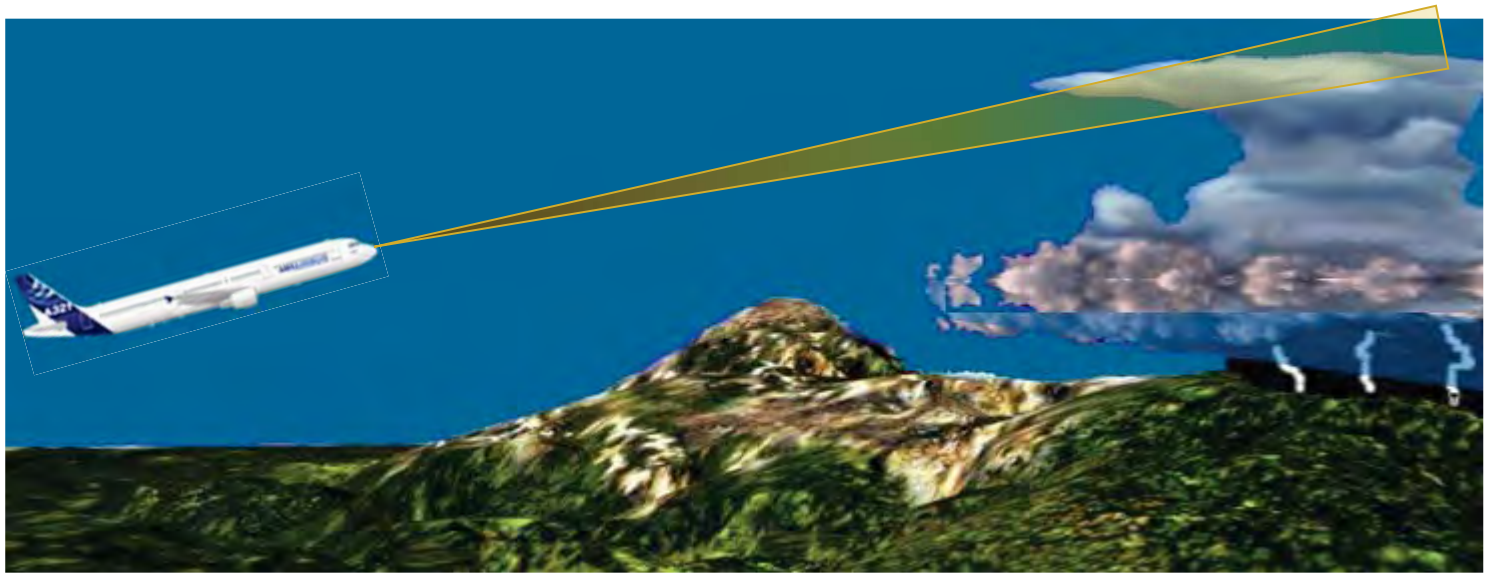
- When the radar beam is pointed at the ground, it will create a strong return.
- This can be misinterpreted as a strong storm or can prevent the radar from displaying weather threats effectively.





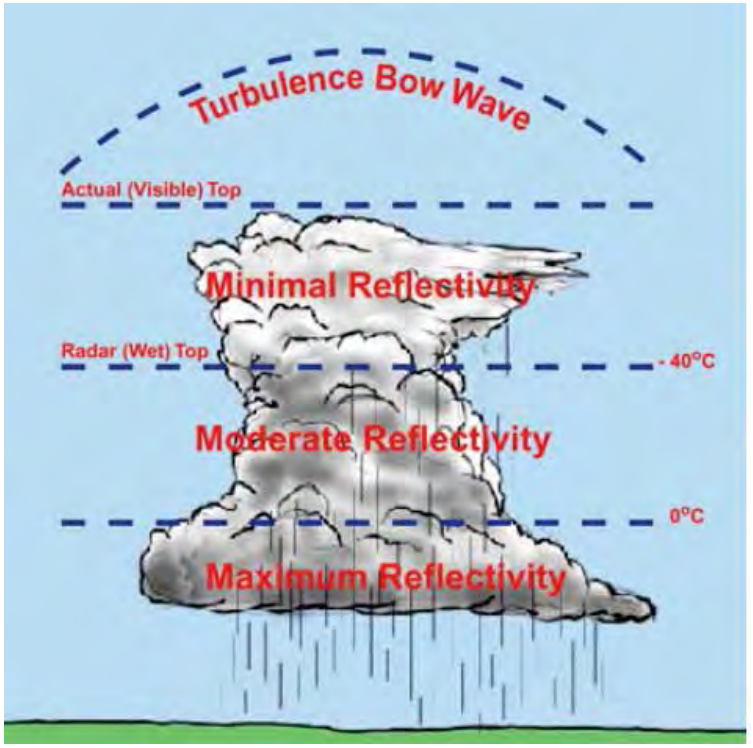
Tilt – Over Scanning

- “Over scanning” occurs when tilt is adjusted too high. As shown here, this means that the beam is pointed above the intended weather target, resulting in no returns being displayed on the radar screen.



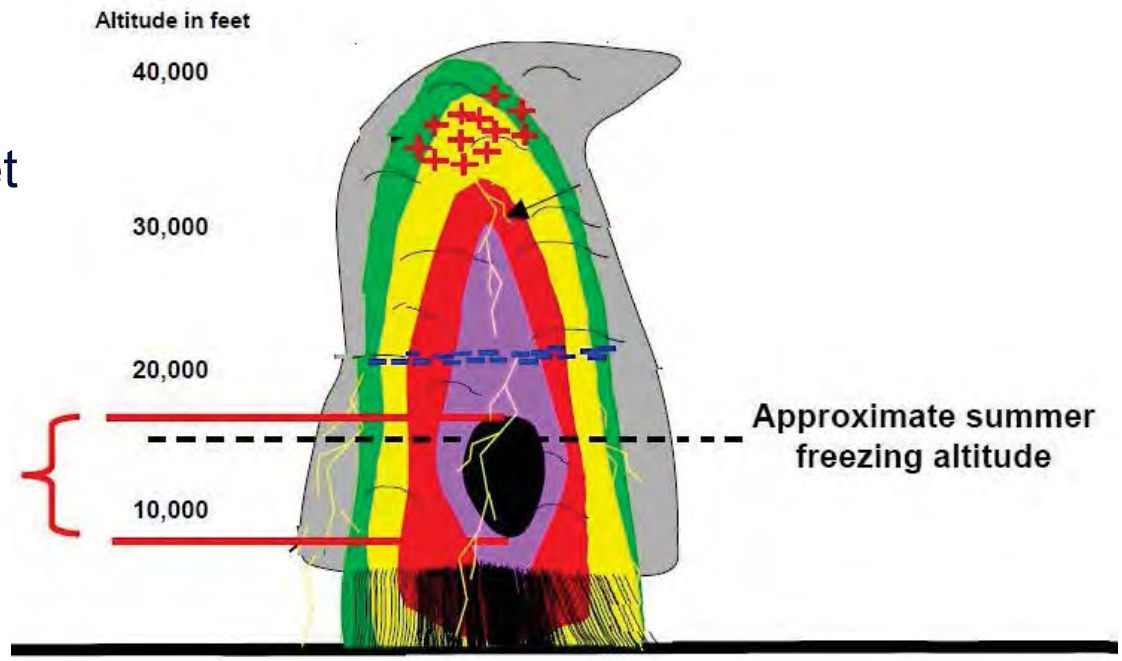
Tilt
Where to “look” for the best returns

- Because the precipitation changes in size and composition with altitude, a typical thunderstorm will have different levels of radar reflectivity at different altitudes
- In general, the area from the base of the storm to the freezing level of the storm contains the greatest amount of liquid moisture, and will provide you with the best reflectivity



Tilt
Where to “look” for the best returns

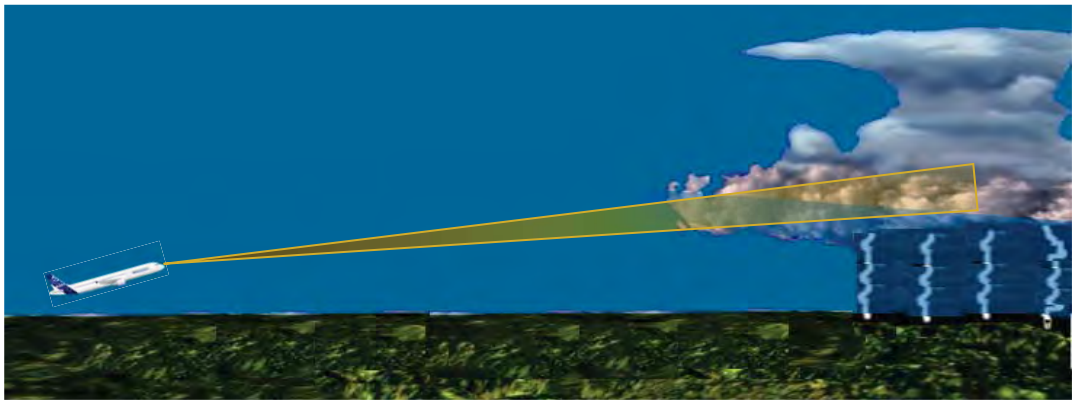
- With a typical summer thunderstorm, the area of highest reflectivity is the zone from approximately 10,000 feet to 18,000 feet



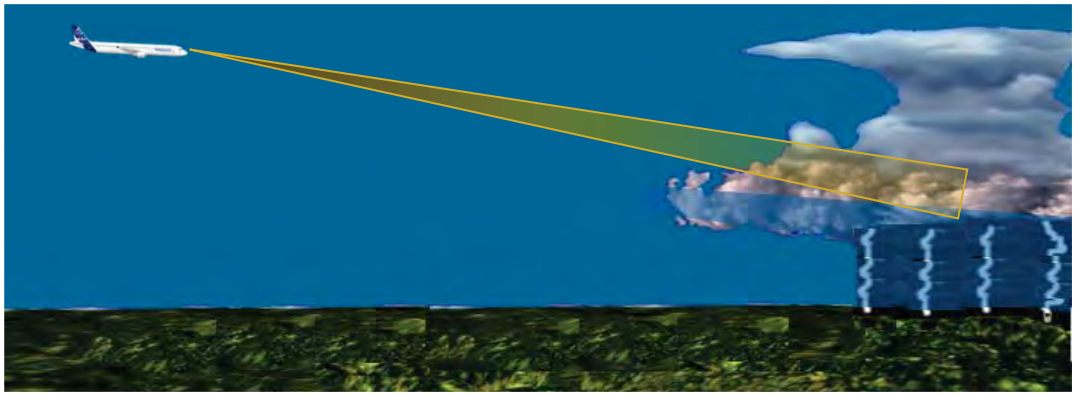
Tilt
Where to "Look"

Simply stated, our goal is to ensure that the radar beam is aimed at the area of highest reflectivity

From **low** altitudes, tilt should be set to "look" **up**.



From **high** altitudes, tilt should be set to "look" **down**.



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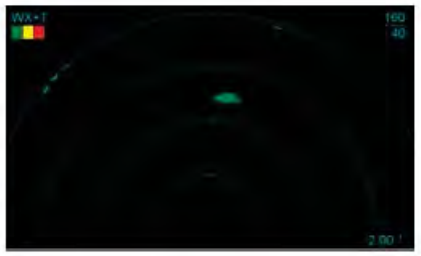
Tilt
Parked Position

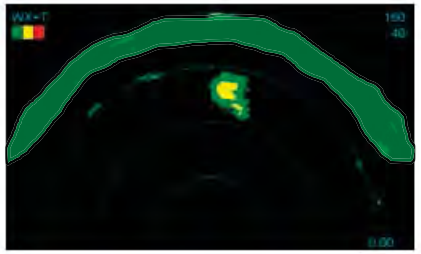
Here's a valuable technique:

- To simplify your tilt adjustments, use the "***Parked Position***"
- To set the "parked" position, adjust the tilt so that ground returns are painted ***on the outer edge*** of the radar display
  - *While the exact fraction of ground-return coverage is not important, anywhere between approx 10% and 30% of the outer range of the screen is generally appropriate.*

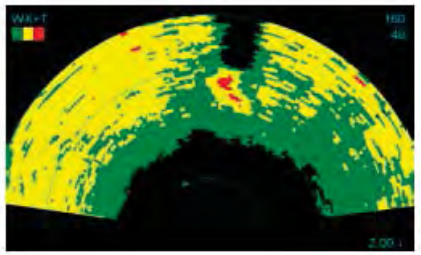
Overscanning



Parked Position



Underscanning



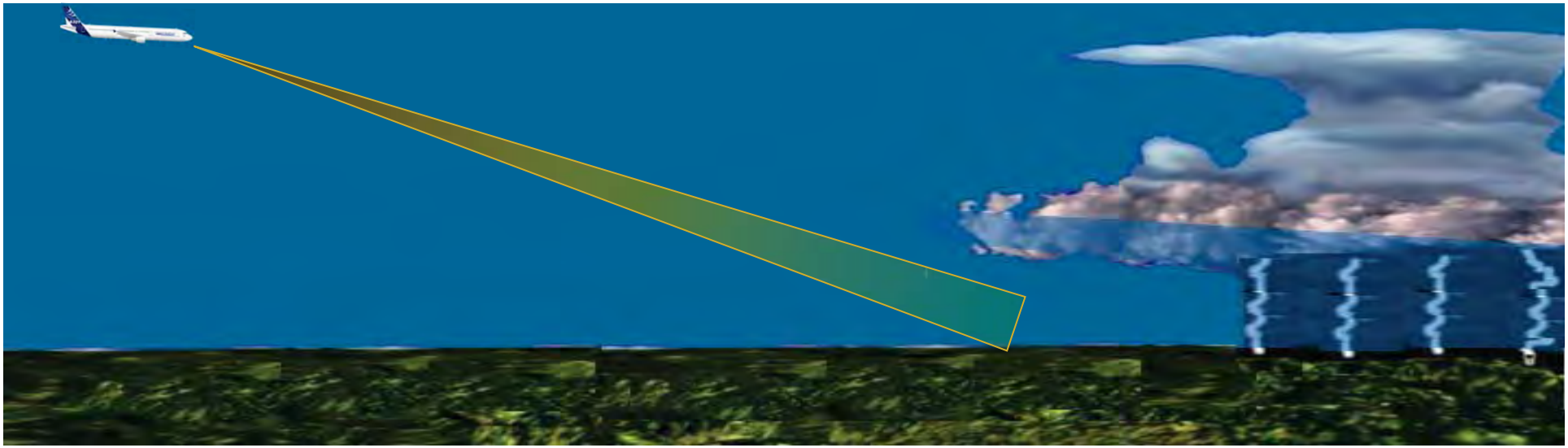
jetBlue AIRWAYS

Tilt
Parked Position

- By using the “Parked” position with proper range control, you ensure…
  - That the radar is working properly (by evidence of ground returns)
  - That you’ll detect any hazardous weather containing precipitation along your route (helps avoid over scanning and under scanning)

Tilt
Parked Position

- The parked position is particularly useful when operating above 10,000 feet
  - By pointing the radar so that the outer edge of the display shows ground returns, we allow the radar beam the ability to intercept the most reflective part of the storm with sufficient time to react



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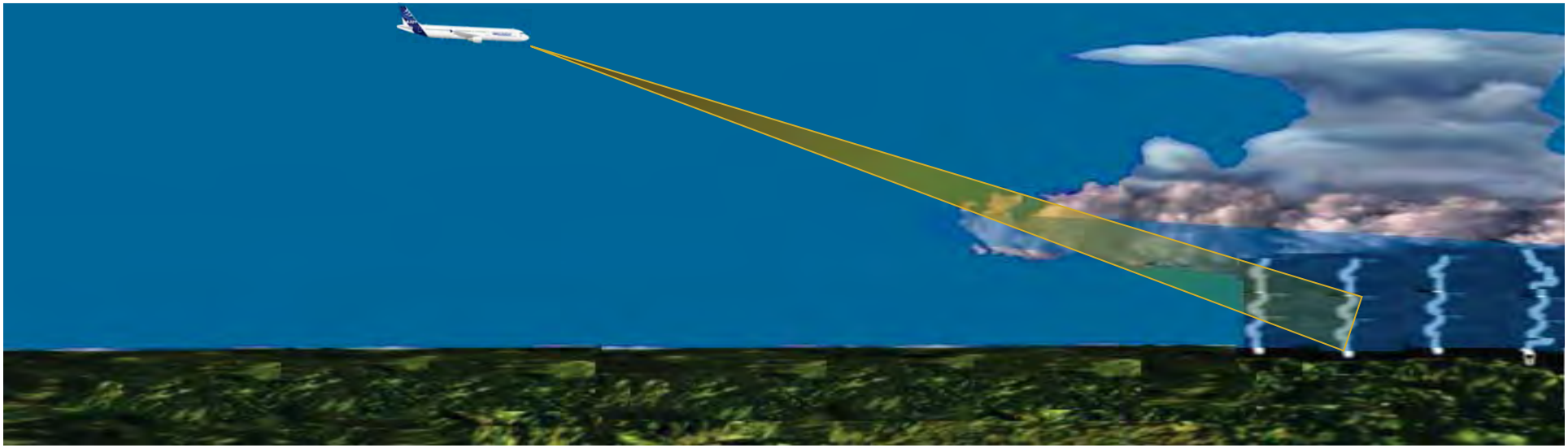
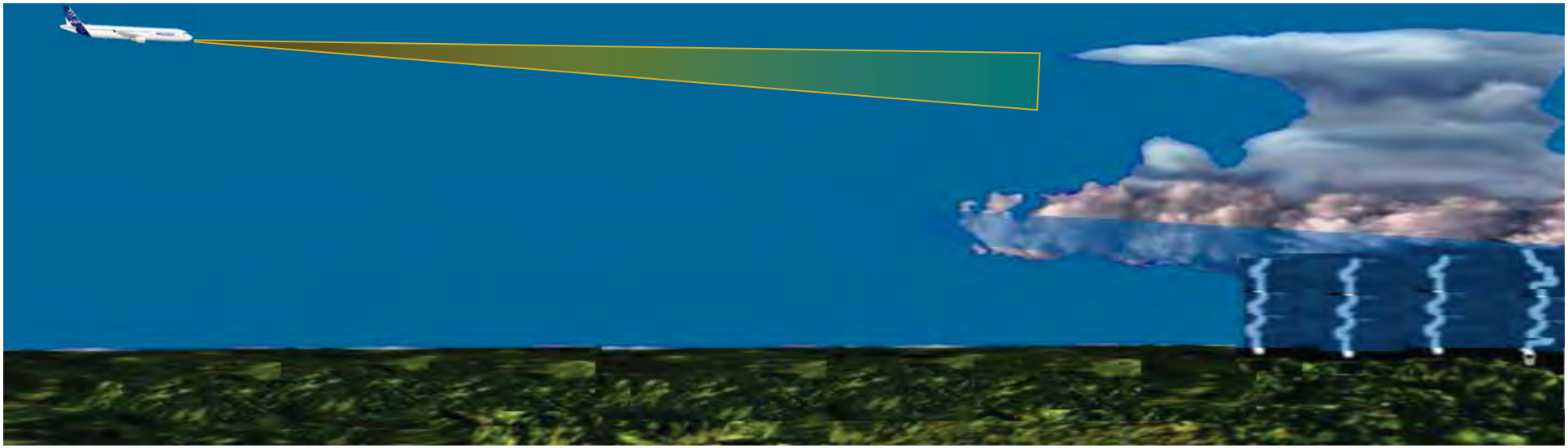


Tilt
Parked Position

- In contrast, if the display shows no ground returns, the radar beam may be pointed too high, i.e., overscanning. It may be set to an angle that does not “look” at the most reflective part of the storm and masks its intensity or position



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Tilt
Parked Position

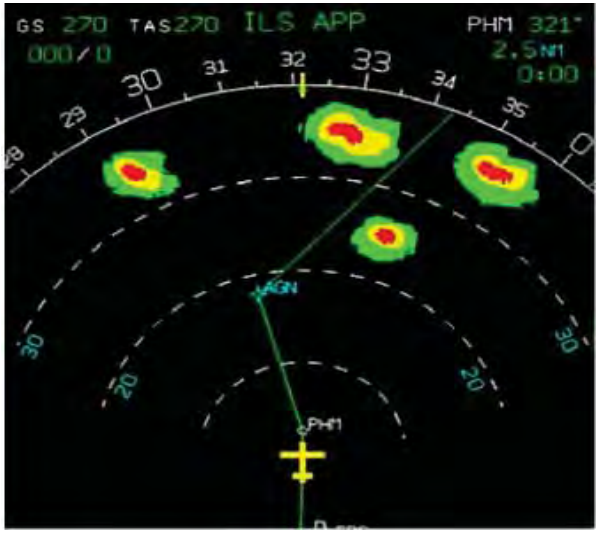
- However, if the radar display shows ground returns covering too much of the screen, you may be pointing too low, i.e., underscanning. This may not give us sufficient time properly avoid the storms as the ground returns may mask the storm until you are too close.

Tilt
Parked Position

- However, if the radar display shows ground returns covering too much of the screen, you may be pointing too low, i.e., underscanning. This may not give us sufficient time properly avoid the storms as the ground returns may mask the storm until you are too close.

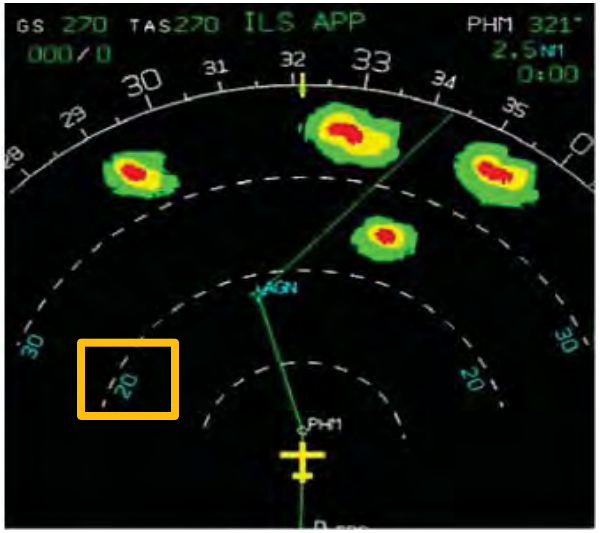
Range

- The range control allows you to view radar returns at different distances



Range

- The range control allows you to view radar returns at different distances
- The range is tied to the scale of the map where the radar returns are displayed

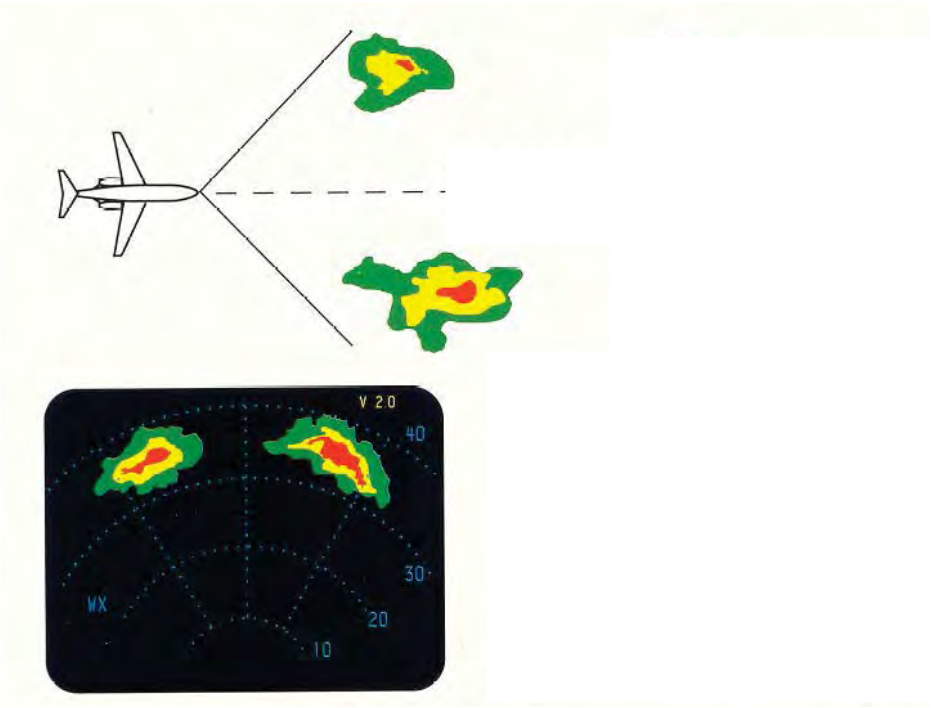


Range

- The range control allows you to view radar returns at different distances
- The range is tied to the scale of the map where the radar returns are displayed
- Managing your range setting allows you to properly evaluate the weather in front of you
  - Longer ranges are useful for strategic planning
  - Shorter ranges are useful when a more tactical approach is required

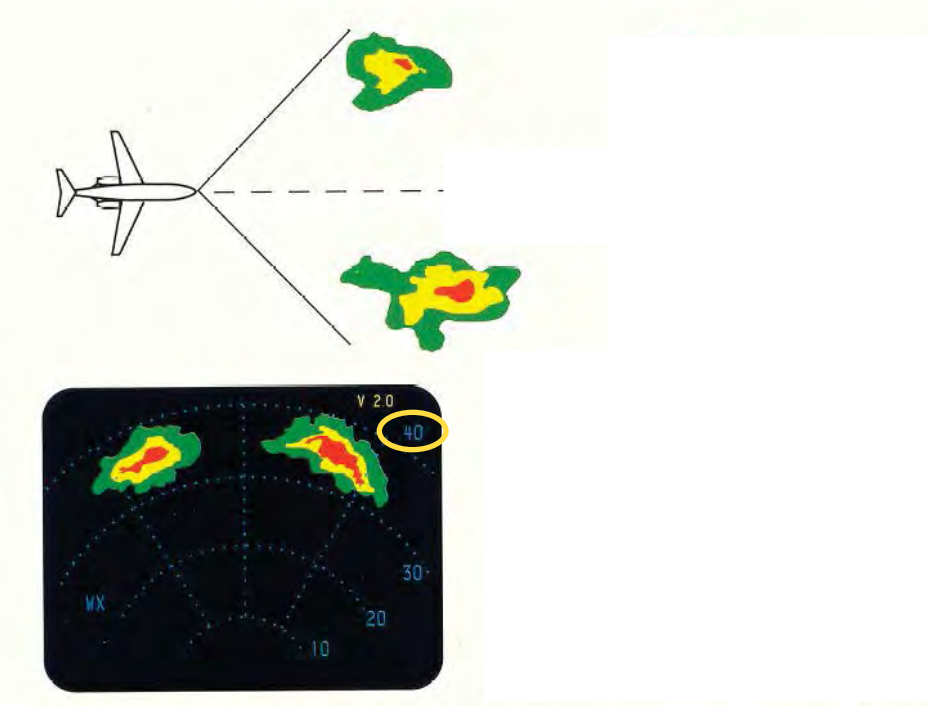
Range

- It is important to vary the range to avoid missing the big picture



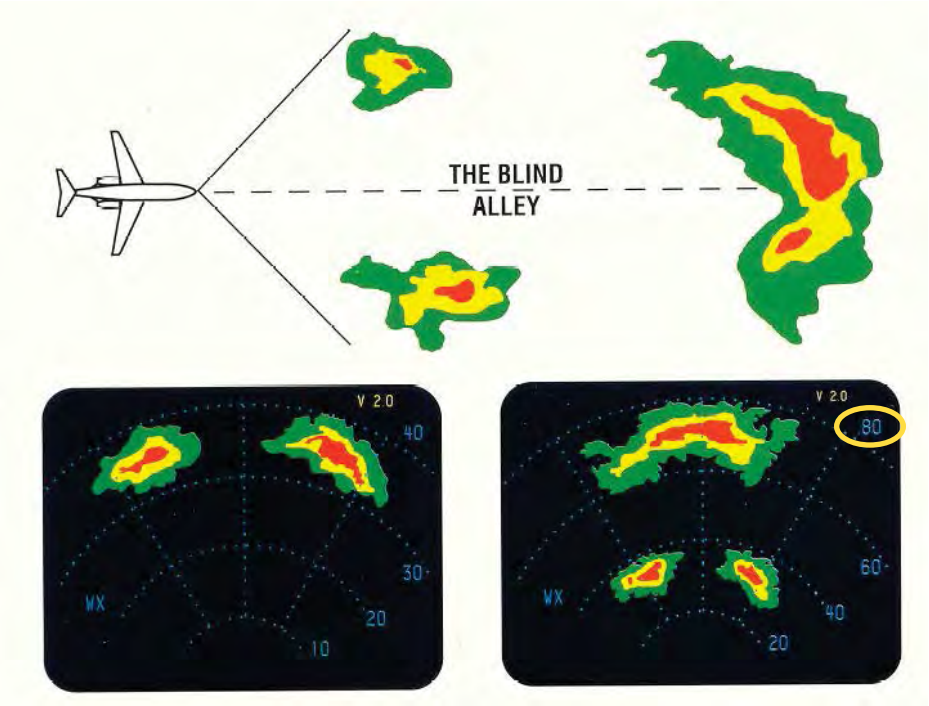
Range

- It is important to vary the range to avoid missing the big picture
- In this example, when the crew selects the 40NM range, it would appear that a safe course exists between these two cells



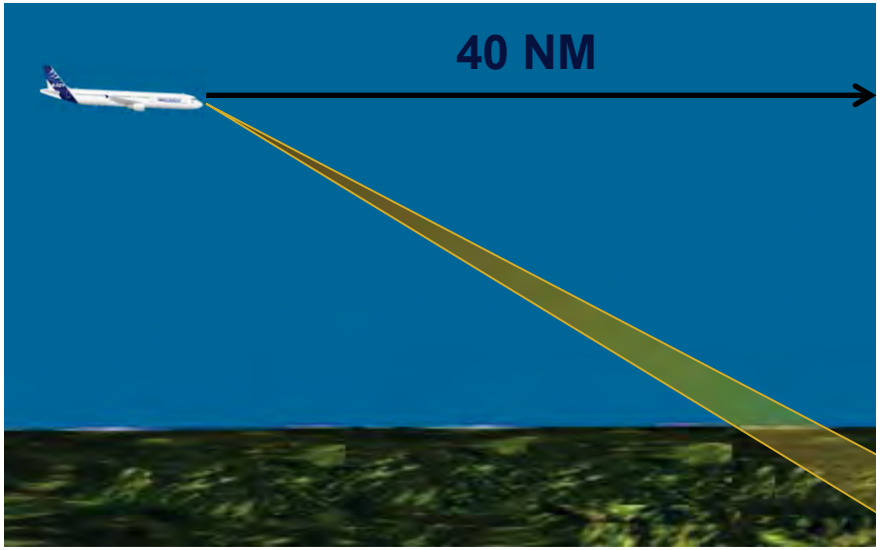
Range

- It is important to vary the range to avoid missing the big picture
- In this example, when the crew selects the 40NM range, it would appear that a safe course exists between these two cells
- However, it is quite evident when selecting the 80NM range that a deviation around the cells will be required



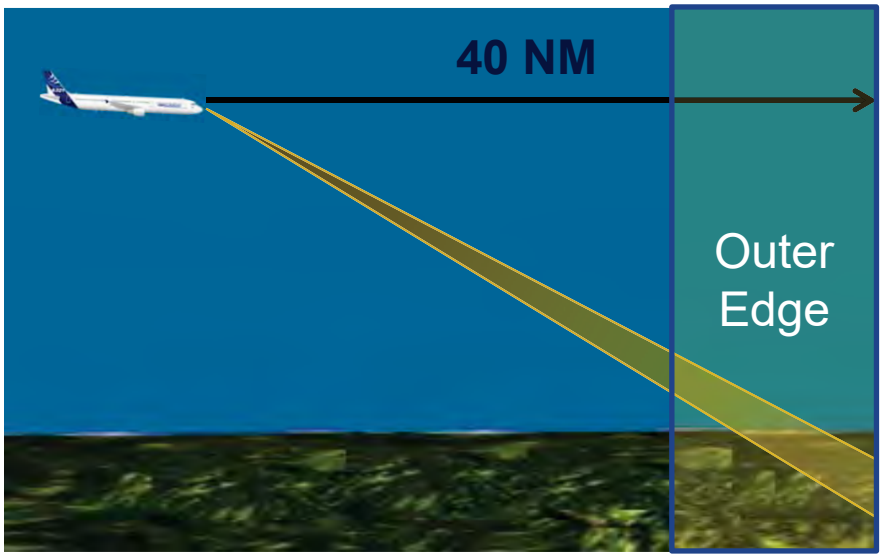
Tilt and Range Relationship

- As you vary the range, you will ordinarily need to also vary the tilt



Tilt and Range Relationship

- For example, to maintain the “parked” position:
  - As you increase the range, raise the tilt



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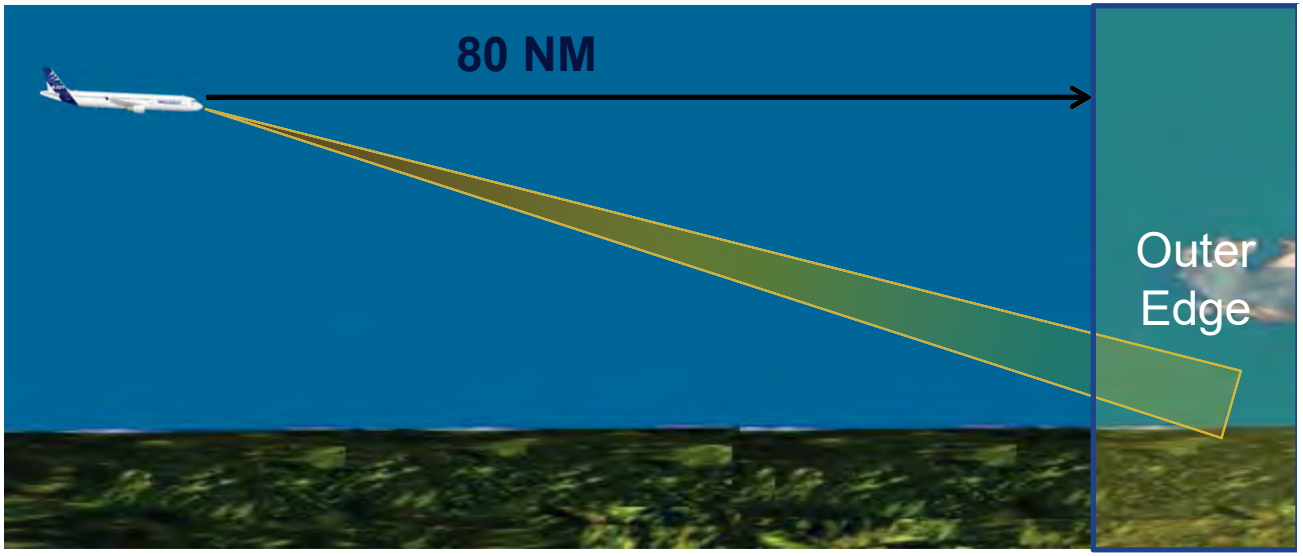

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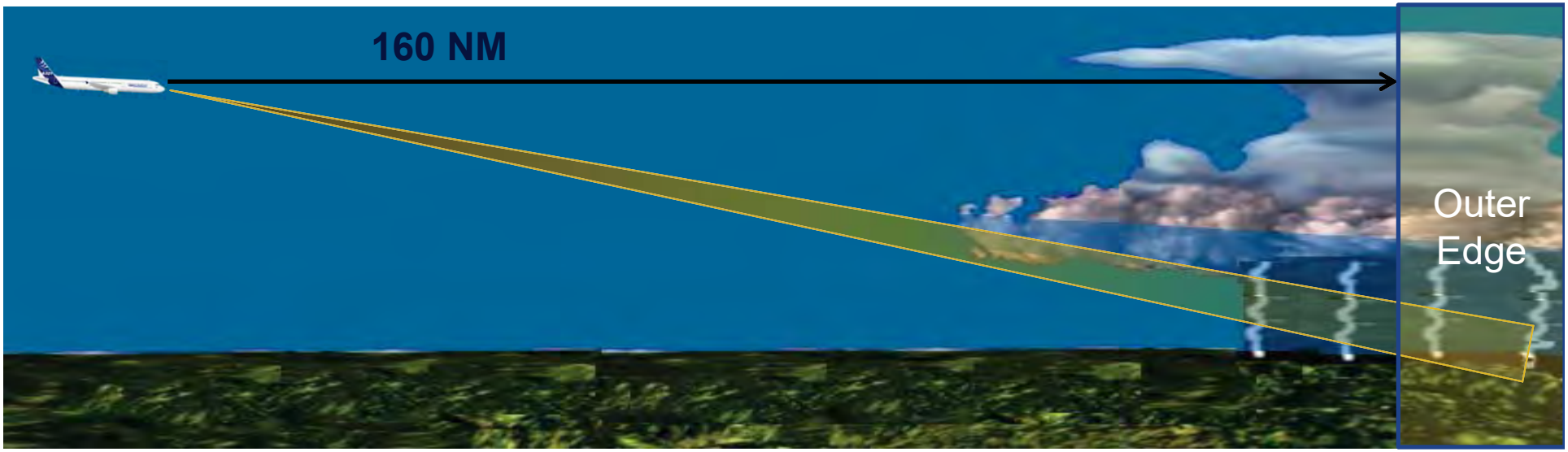
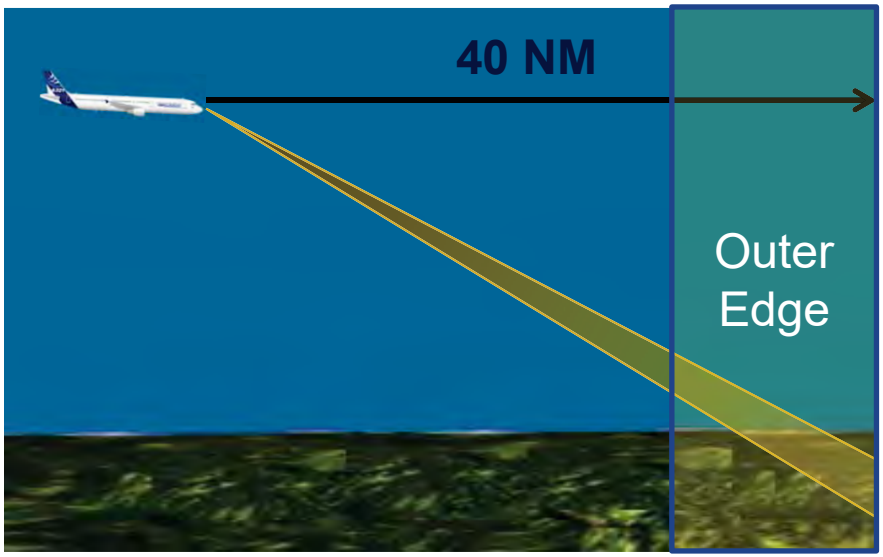


Tilt and Range Relationship

- For example, to maintain the “parked” position:
  - As you increase the range, raise the tilt
  - As you decrease the range, lower the tilt

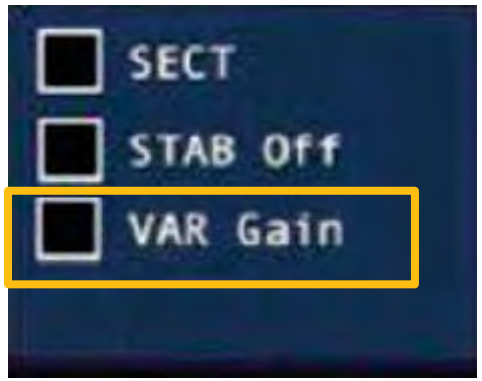


Gain

- The Gain control adjusts the sensitivity of the radar receiver
- **The Automatic mode should be the default setting for general radar usage**, and should always be used for the detection and initial evaluation of weather.
- However, in some instances, manual gain control can be used to further evaluate weather

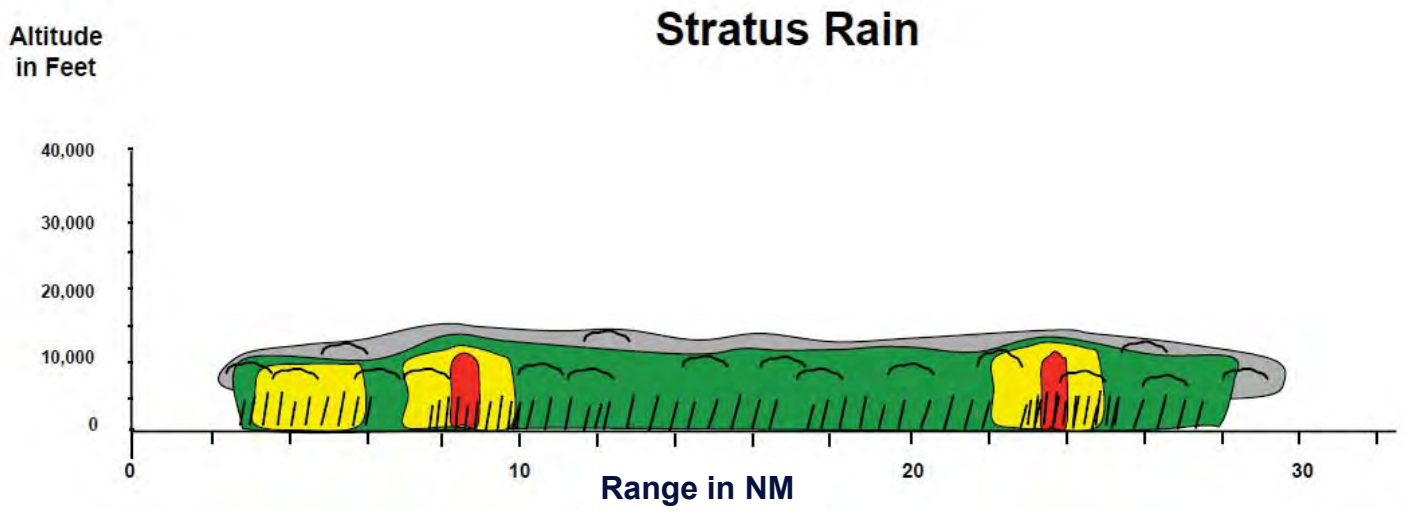
A320

E190



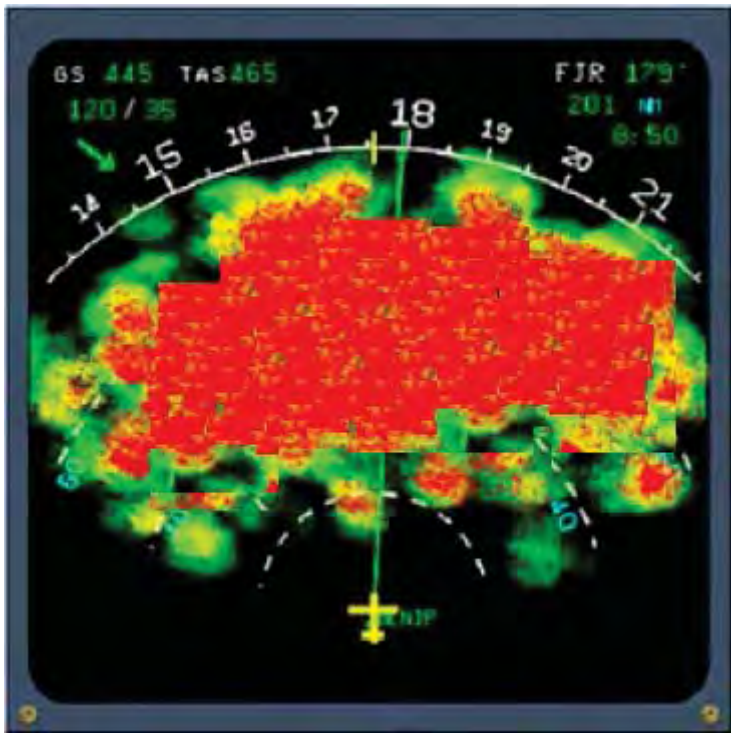
Gain

- One example of an appropriate use of manual gain would be when operating in areas of heavy rain associated primarily with stratus clouds



Gain

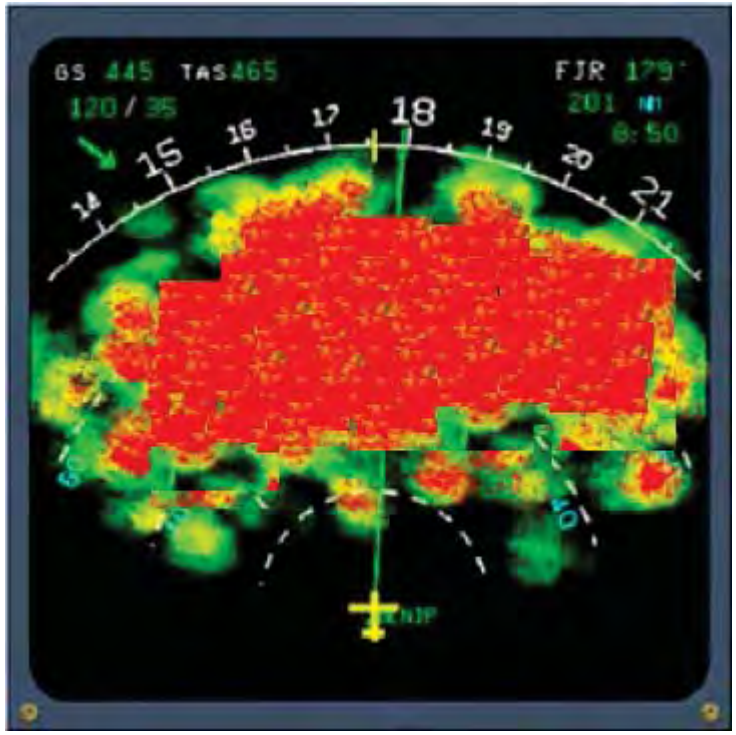
- In such a case, the radar display may be largely red, but you have good reason to believe that this is not indicative of one huge convective cell.
- In situations like this, manual gain control may help you evaluate the situation further



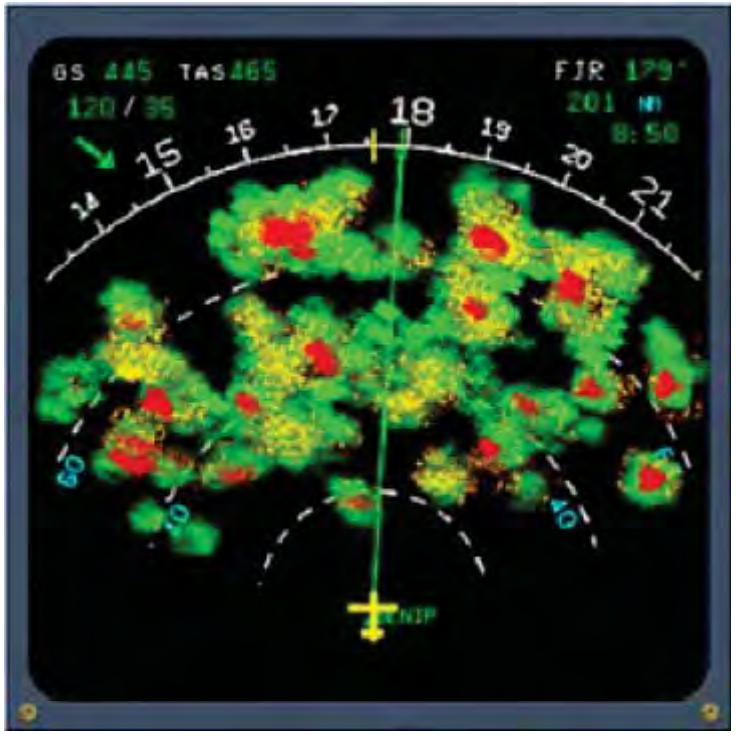
AUTOMATIC GAIN

Gain

- By carefully reducing the gain manually, you may be able to differentiate between stronger and weaker areas



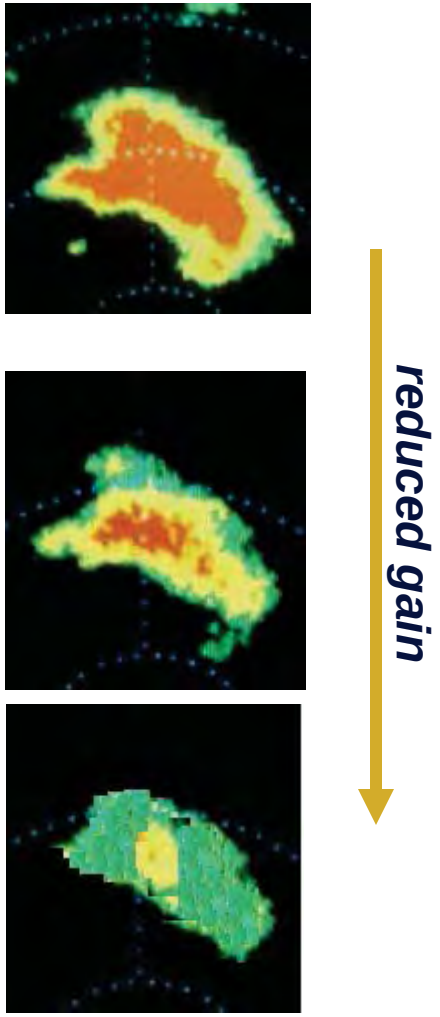
AUTOMATIC GAIN



MANUALLY REDUCED GAIN

Gain

- However, extreme care should be taken whenever manual gain control is used
  - When gain is reduced, the sensitivity of the radar is reduced
  - This may cause intense cells to look less intimidating and could lead you to underestimate a storm's strength
- After you have evaluated a return via manual gain control, RETURN THE GAIN TO AUTO.



Interpreting the Radar Display
Ground vs. Weather

- When interpreting weather radar, it is important to be able to differentiate between weather and ground returns

Interpreting the Radar Display
Ground vs. Weather

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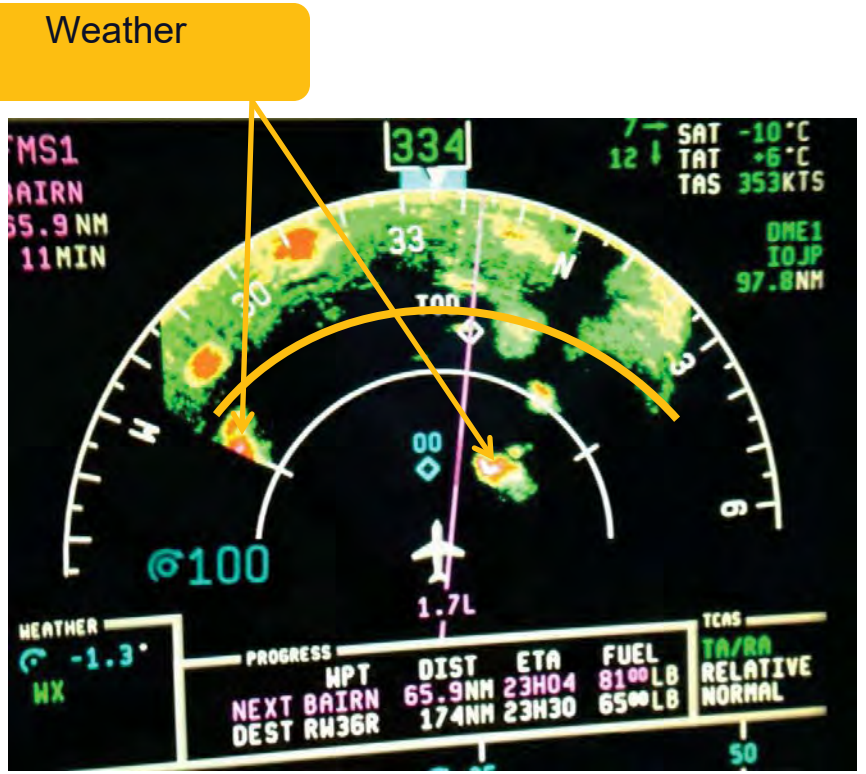
  - As tilt is lowered, ground returns will tend to match the arc of the range rings on the radar screen.

Interpreting the Radar Display

Ground vs. Weather

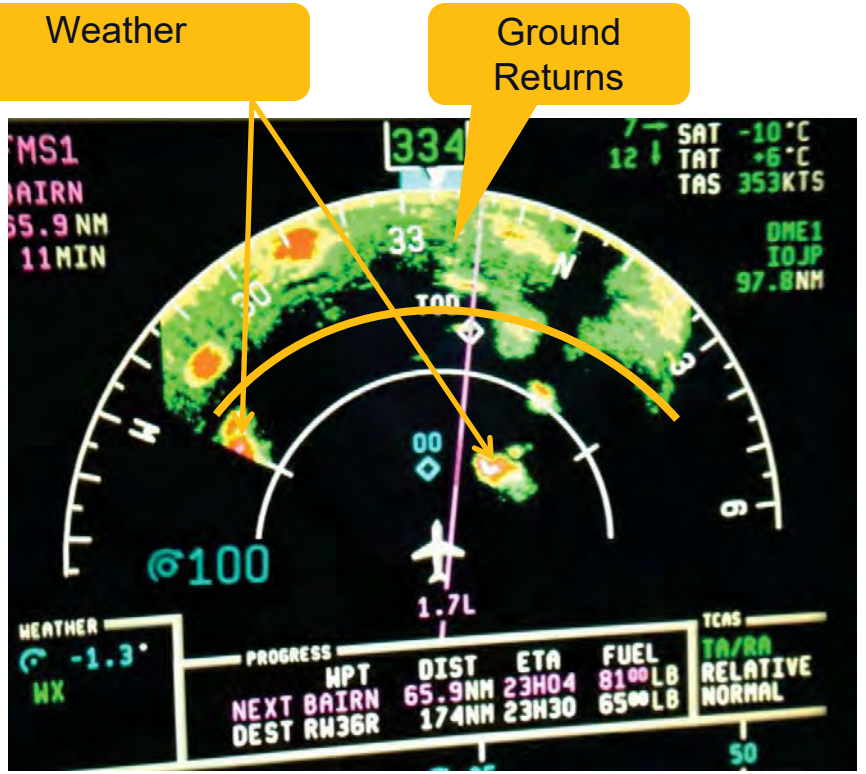
- When interpreting weather radar, it is important to be able to differentiate between weather and ground returns
  - As tilt is lowered, ground returns will tend to match the arc of the range rings on the radar screen.
  - Returns closer than this arc represent weather activity.



Interpreting the Radar Display

Ground vs. Weather

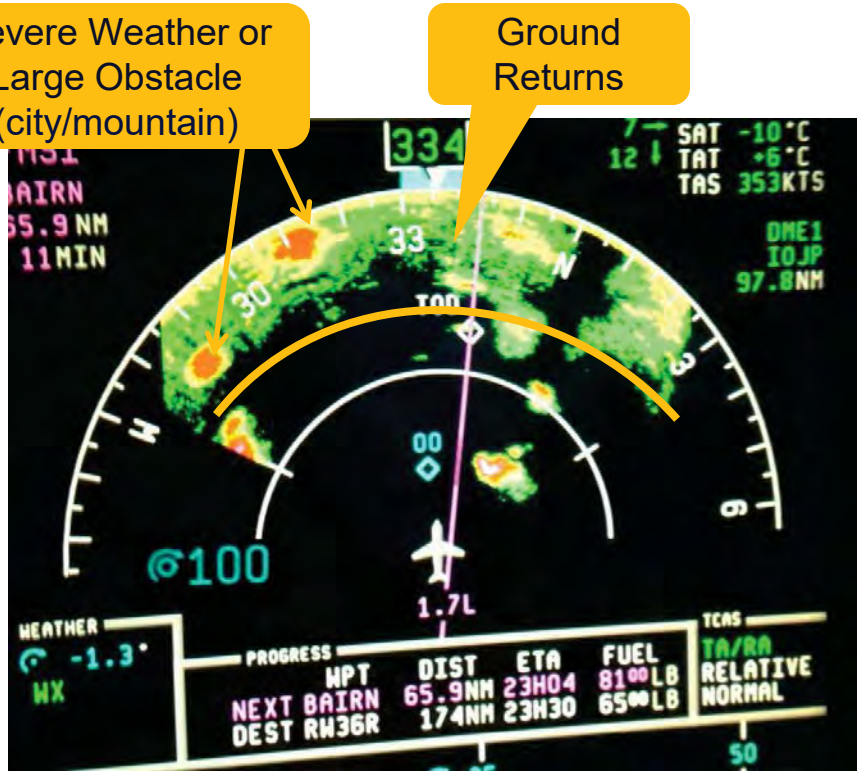
- When interpreting weather radar, it is important to be able to differentiate between weather and ground returns
  - As tilt is lowered, ground returns will tend to match the arc of the range rings on the radar screen.
  - Returns closer than this arc represent weather activity.
  - Returns beyond this arc are typically ground returns



Interpreting the Radar Display

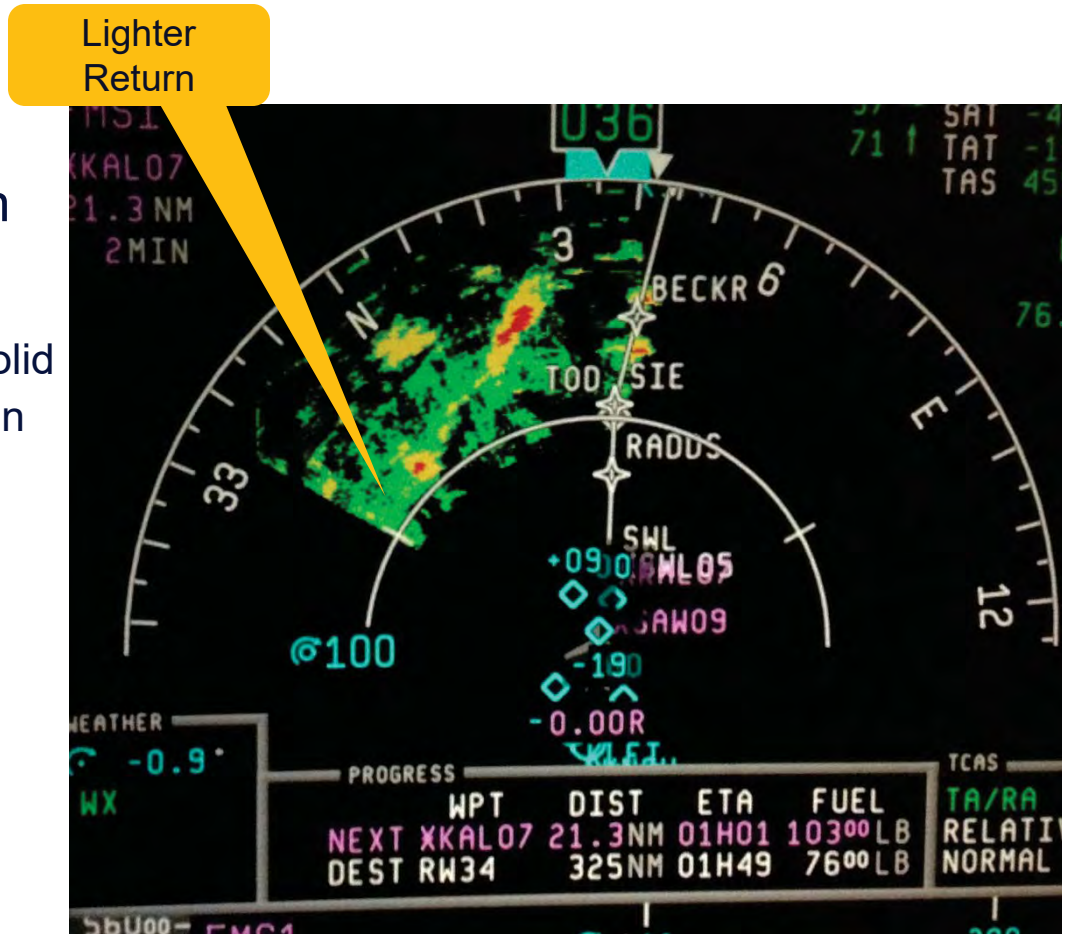
Ground vs. Weather

- Occasionally you will have strong returns embedded in the ground return.
- These returns represent severe weather or a large obstacle such as a city or mountain.
- Maintaining SA with surrounding terrain (EGPWS) and/or using ATC as a weather resource may help determine the difference.



Interpreting the Radar Display
Rain vs. Thunderstorms

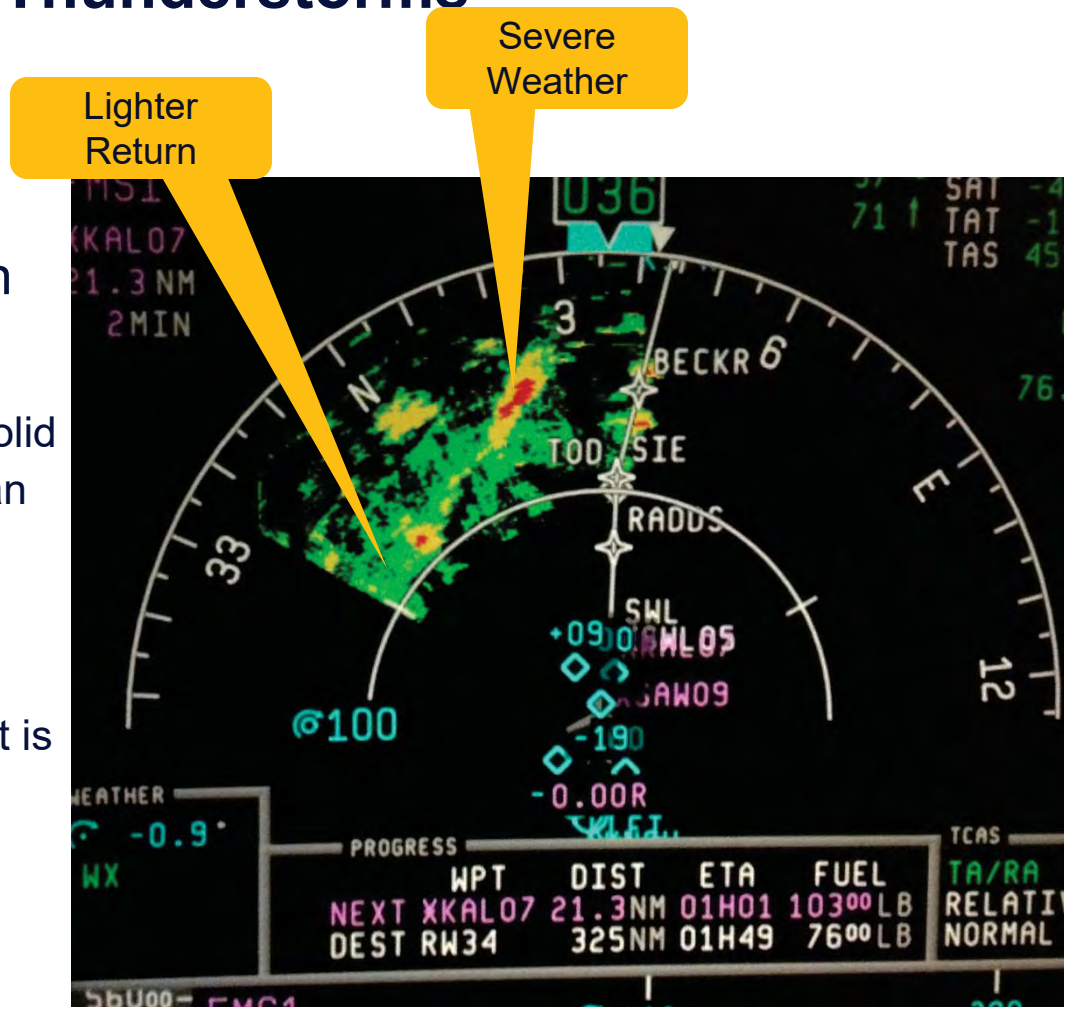
- Additionally, there are fundamental differences between the depiction of rain and thunderstorms
  - Rain is typically displayed as solid green (lighter returns) which can be separated from the ground clutter



Interpreting the Radar Display

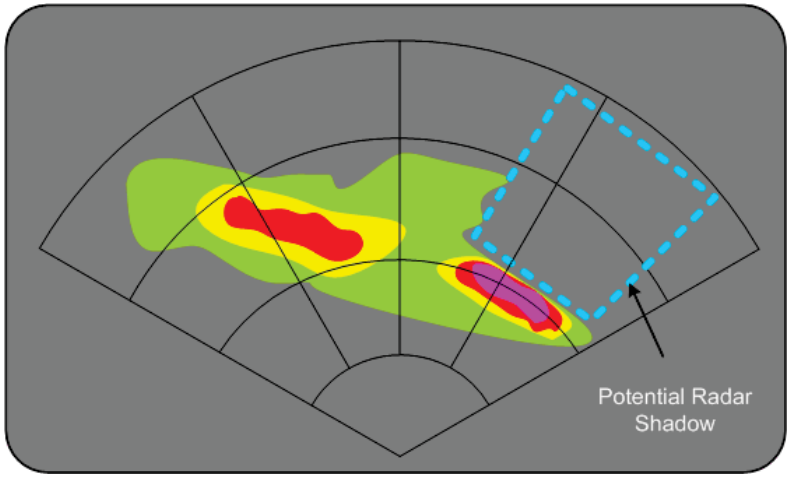
Rain vs. Thunderstorms

- Additionally, there are fundamental differences between the depiction of rain and thunderstorms
  - Rain is typically displayed as solid green (lighter returns) which can be separated from the ground clutter
  - Severe weather is typically shaded yellow and red when tilt is placed at the correct angle



Interpreting the Radar Display
Shadowing

- Radar returns can be masked by a strong return from a storm in front of another reflective object (the ground or another storm).
- The storm in front absorbs the radar energy and prevents the anything behind from being displayed. This is known as ***shadowing***.



Interpreting the Radar Display
Shadowing

- In this example, the ground returns are masked behind these storms.

Interpreting the Radar Display
Shadowing

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  - A radar shadow can be seen in the ground return.

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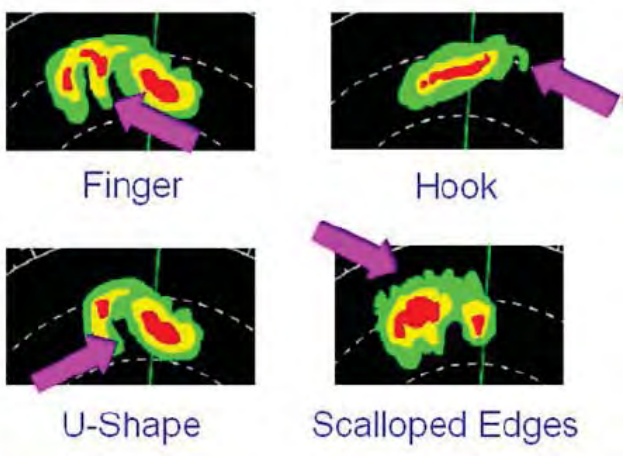
  - A radar shadow can be seen in the ground return.
  - Note the value of the parked position. If the tilt were set higher (showing no ground returns), the shadow effect would not be evident.

Interpreting the Radar Display
Shadowing

- In this example, the ground returns are masked behind these storms.
  - A radar shadow can be seen in the ground return.
  - Note the value of the parked position. If the tilt were set higher (showing no ground returns), the shadow effect would not be evident.
- **Warning: Always be aware that areas behind large storms may be shadowed**

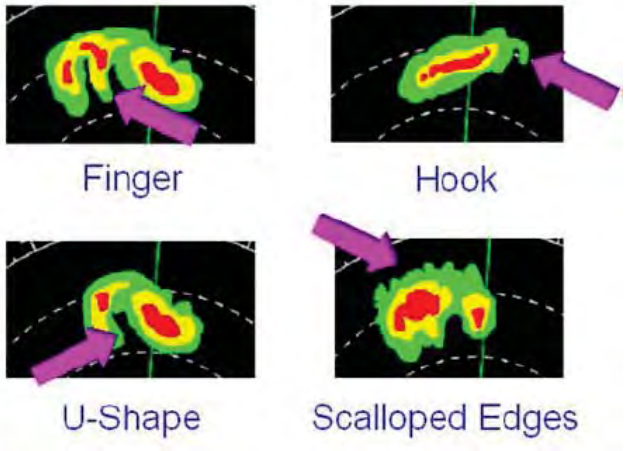
Interpreting the Radar Display
Weather Shapes

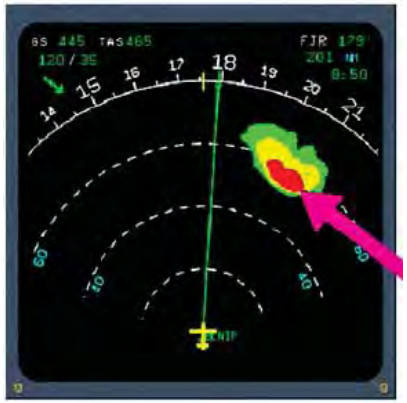
- The weather shapes shown here may contain clues that should alert the crew of potential extreme weather hazards (i.e. tornadoes or hail) that may require more than 20 NM of separation



Interpreting the Radar Display
Weather Shapes

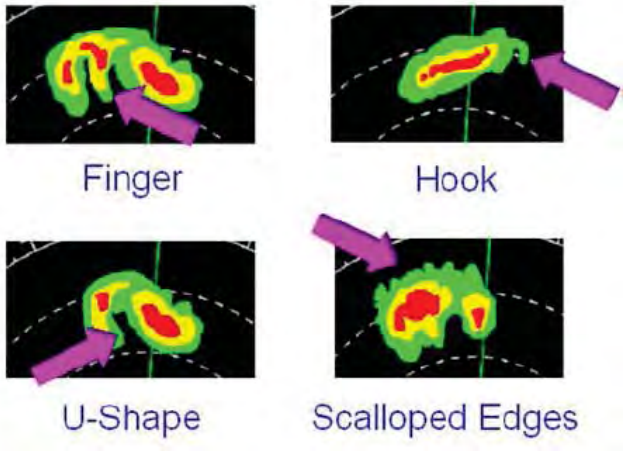
- The weather shapes shown here may contain clues that should alert the crew of potential extreme weather hazards (i.e. tornadoes or hail) that may require more than 20 NM of separation
- Closely spaced areas of different colors usually indicate highly turbulent areas

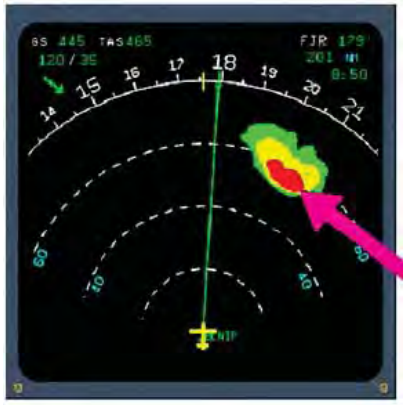




Interpreting the Radar Display
Weather Shapes

- The weather shapes shown here may contain clues that should alert the crew of potential extreme weather hazards (i.e. tornadoes or hail) that may require more than 20 NM of separation
- Closely spaced areas of different colors usually indicate highly turbulent areas
- **Warning: Fast changing shapes, in whatever form they take, indicate dangerous weather activity!**

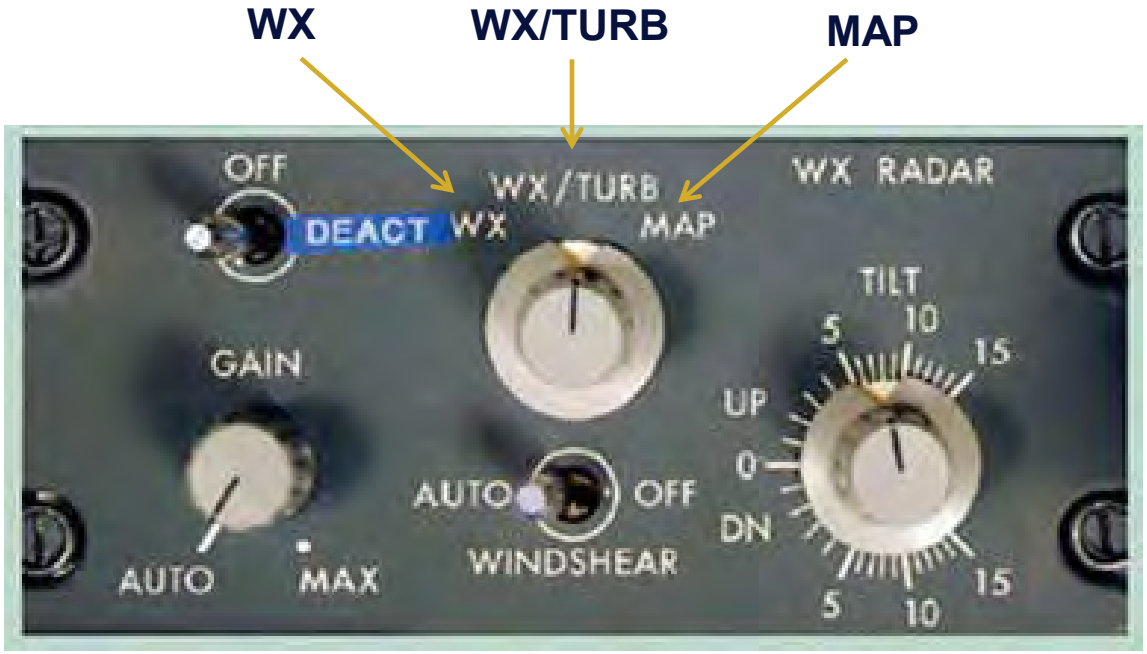




A320 Radar Operating Modes

There are three basic operating modes of the A320 radar:

- WX (Weather mode ***without*** Turbulence notification)
- WX/TURB (Weather mode ***with*** Turbulence notification). **(This is the normally-used mode)**
- MAP (Ground mapping mode. NOT to be used for navigation)



Ground Mapping (MAP) Mode

With the selector in the **MAP** position, the radar operates in ground mapping mode.

- This mode is rarely used in day-to-day operations. It is sometimes used to assist in differentiating between ground and weather returns, and occasionally used for geographical position awareness.
- In this mode, black indicates water, green indicates ground, and amber indicates cities and mountains.
- MAP mode is ***NOT*** to be used for navigation.

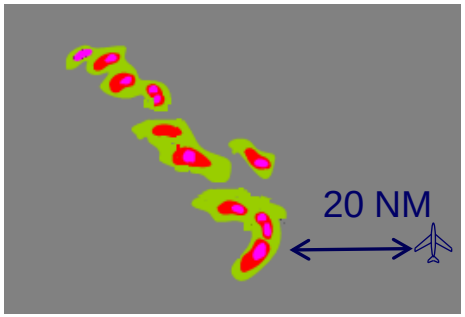
Radar Policy
Weather Avoidance

Key Policy Point: Your radar is to be used as a tool to ***avoid*** severe weather, not to penetrate it

Operational Strategies
Weather Avoidance

Treat every thunderstorm as **hazardous**!

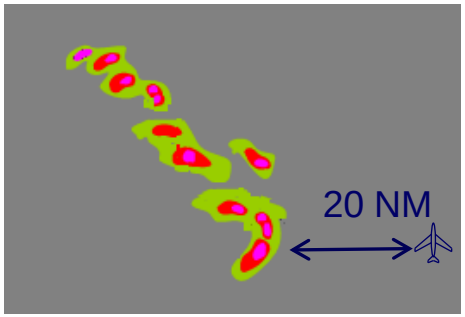
- Strive to maintain at least 20 NM lateral separation from severe weather



- When possible, deviate upwind instead of downwind
  - Avoid flying under the anvil

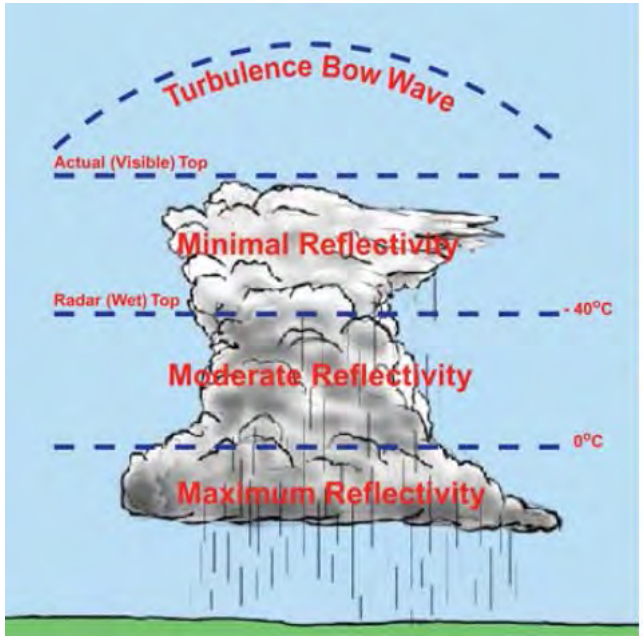
Operational Strategies
Weather Avoidance

Treat every thunderstorm as **hazardous**!



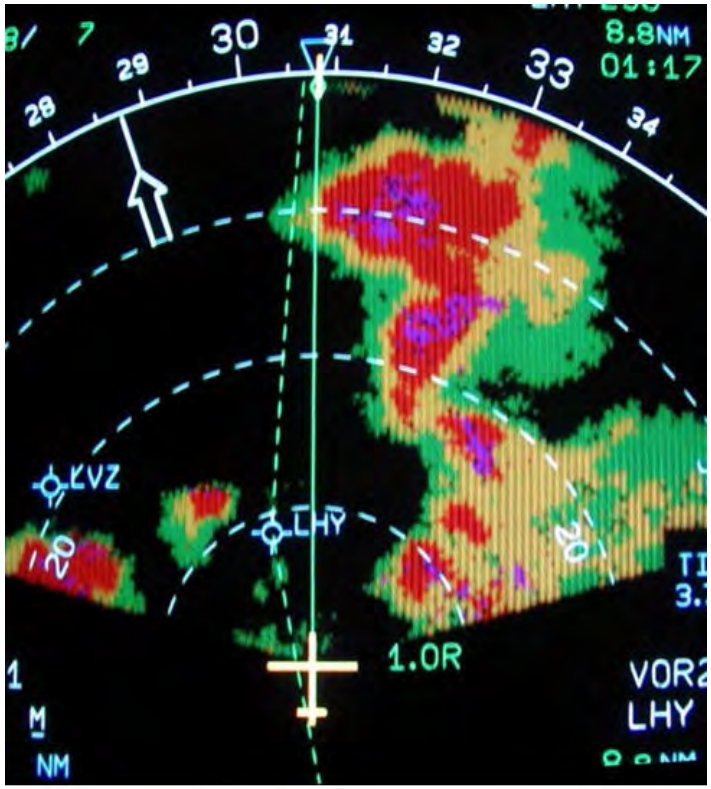
- Strive to maintain at least 20 NM lateral separation from severe weather

- When possible, deviate upwind instead of downwind
  - Avoid flying under the anvil
- Attempting to fly above a thunderstorm is not recommended.
  - Often, convective weather extends vertically to altitudes above the capability of our aircraft.
  - Severe turbulence can extend well above the detectible top of storm cells.
- It is best to go around, not over, storm cells.



Operational Strategies
Weather Avoidance

- Remember that radar is only one of the defenses in weather avoidance
- There are additional defenses that should be utilized such as:
  - ATC
  - Other Aircraft
  - Dispatch



Operational Strategies
Weather Avoidance

- Also, it is important not become so fixated on the radar display that you miss the big picture around you
- Whenever practical, navigate visually around storms
- In most cases, this simplifies your workload and provides a smoother ride for the customers

Color Display in WX and WX/TURB Modes

The **WX** and **WX/TURB** modes display the intensity of precipitation using these colors:

Heavy

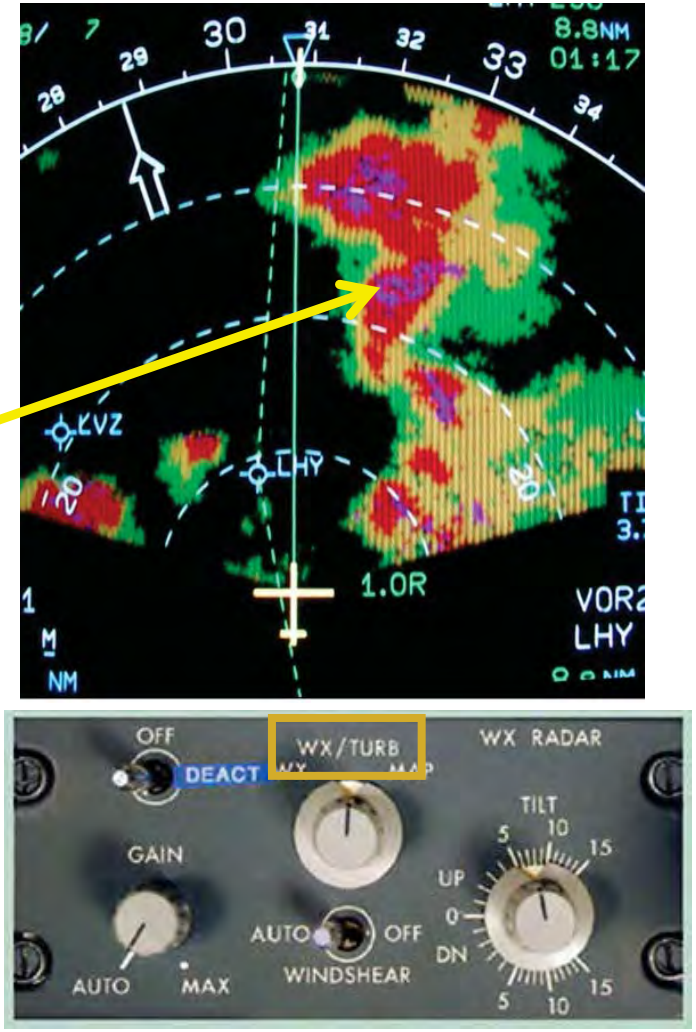
- **Red**
- **Yellow**
- **Green**

Light

WX/TURB Mode

WX/TURB (Turbulence) Mode

- This is the mode normally used in day-to-day operations.
- With **WX/TURB** selected, in addition to normal weather depiction, the radar also displays turbulent areas (within 40 NM).
- Areas of moderate to severe turbulence are displayed in **Magenta**
- **Note** that for the radar to detect and display turbulent areas, liquid water droplets are required. ***Clear Air Turbulence* CANNOT *be detected*** *(no reflective particles)*



Gain Control

GAIN Control

- The GAIN knob has a detent for AUTO when turned fully counter-clockwise.
- When out of the AUTO detent, clockwise rotation of the knob increases the gain (sensitivity) of the radar
- If the GAIN knob is rotated counter-clockwise, ***but not all the way into the AUTO detent***, the Radar Gain setting is at ***minimum!*** (At this setting weather returns would not be visible on the ND)

- As emphasized earlier in this presentation, ***AUTO should be the default position***