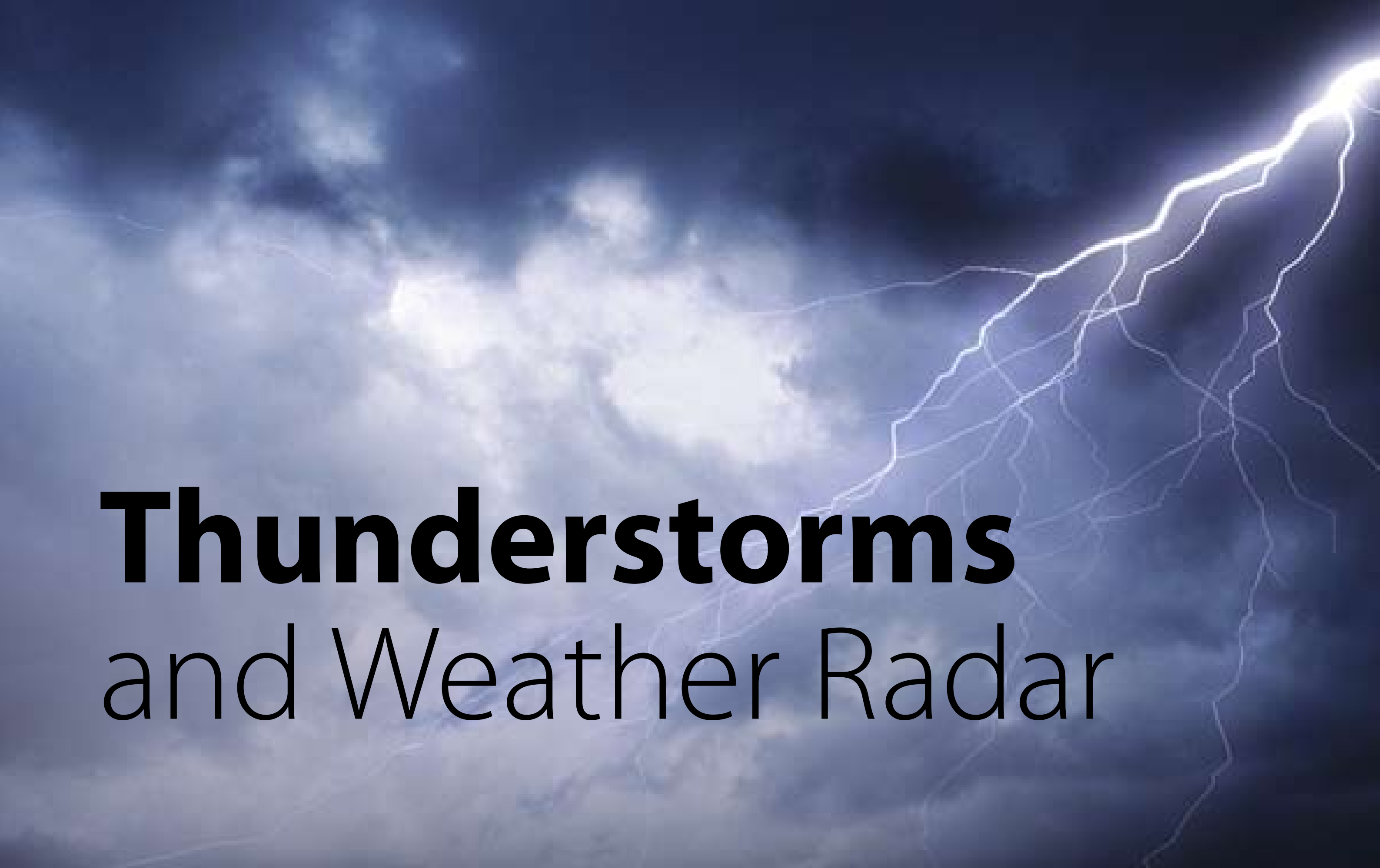


Thunderstorms and Weather Radar

Lightning strikes can cause significant damage to the structure and control surfaces of an aircraft, and the electrical and avionics systems.

Surprisingly, lightning strikes are often triggered by the aircraft itself. A study conducted by the NASA Storm Hazards Program in the 1980s showed that an aircraft flying into a strong electric field often triggers the lightning that strikes it. In the decaying stage of a thunderstorm, an extended anvil forms containing strong electric charges. This is the most likely place for an aircraft to trigger a strike, because a metal aircraft intensifies the cloud's electric field, becoming a likely source of lightning initiation.

An aircraft will attract lightning if it is not at a similar potential to the surrounding air mass (due to local charge build-ups). To minimise the potential of being struck, all aircraft parts should be properly bonded, and during your pre-flight make sure all static wicks are serviceable. This will create a low resistance path for lightning to exit the aircraft, preventing heat build-up and reducing the potential for damage.

The more frequently lightning flashes in a storm, the lower the probability of being struck if you fly into it. On the flip side, a higher flash rate means a greater potential for encountering severe turbulence, heavy rain, and hail in the storm.

The NASA research involved 1500 flights between 5000 feet and 40,000 feet. Most of the 714 strikes received occurred in light rain and light turbulence conditions. Lightning strikes were encountered at nearly all temperatures and altitudes – so there is no safe place to be in a thunderstorm.

The best policy is to avoid Cumulonimbus clouds (Cbs) like the plague, but by how much, and how do you find them?

Weather Radar

Airborne weather radar is an excellent tool for avoiding Cbs, however pilots must understand how the technology works, its limitations, how to use their system, and how to interpret the radar display, in order for weather radar to successfully keep them out of trouble.

Avoid Them

Put as much distance as practicable between you and active Cb cells. Avoid areas of red and magenta as these indicate intense rainfall and turbulence, generally associated with Cbs. If possible, a minimum of 5000 feet vertically and 20 NM laterally should be applied to reduce the chance of encountering severe turbulence. Frontal Cbs often form in a line. They are easier to divert around than convective Cbs, which are random in distribution and constantly moving and changing.

Determine a heading change that will allow you to bypass a Cb by a safe lateral distance. In some instances it may be possible to climb above one, but Cbs in New Zealand generally extend to FL250 (or higher in late summer around Auckland). Thunderstorms tend to travel in the direction indicated by the 10,000 foot wind. New cells generally form on the downwind side of a thunderstorm, and turbulence with be encountered in downwind eddies created by the storm obstructing the windflow. So it is safest to detour to the upwind side of a Cb.

How Does it Work?

Radar works on the premise that some of the energy in radio waves is reflected by the objects they strike. If you want to locate something and learn something about it, you can throw radio waves at it, then measure the strength of the energy that comes back and the amount of time it takes to return.

In the case of weather radar, the objects that reflect radio waves are precipitation droplets. Radar will detect rain, wet hail, ice crystals, dry hail, and dry snow – however, the last three will only give small reflections. Water particles are five times more reflective than ice particles of the same size. Radar echo returns are proportional to droplet size and intensity. Radar cannot detect clouds, fog, or wind, as the droplets are too small or don't exist. It cannot detect clear air turbulence or windshear, as there is no precipitation associated with these, except in a microburst.

Avoid areas of red and magenta.

Limitations

There are several limitations of weather radar, the most significant being attenuation. Dennis Newton describes the problem of attenuation in the book *Severe Weather Flying*.

> "Consider what happens as the radar antenna pulses and sends out a scouting party of skilled and dedicated photons to search for a storm. Let's suppose the scouts run into a really big one…some of them fortuitously run into water drops near the closest edge of the storm, and they dutifully rush back to report what they found. This results…in a paint on the screen of the leading edge of the storm at pretty much correct intensity.
>
> Meanwhile, however, some of the photons have made it farther into the storm before they hit anything. Now, in order to report their findings, they have to fight their way back out. Most of them make it, but some of them run into more drops before they get out and are bounced back in again. The ones that get out add thickness to the storm picture on the scope, but may or may not paint at the correct intensity. This process continues, with the return from deeper in the storm getting weaker and weaker.
>
> Now consider the really intrepid scouts who get deep into the storm and smack into Level 7 rain. 'Holy Kemo Sabe,' they think, 'this thing's deadly. We gotta get back and warn the boss!' But what happens when they try? Alas, they can't get out. They keep getting bounced back by other drops on the way…the hapless individual is the pilot who mindlessly believes the radar, because there is no paint at all from that distance into the storm or through it. That makes it look a whole lot thinner and a whole lot less intense than it really is."

Since the weather radar display depends on signal returns, heavy rain may conceal even worse weather behind it, and the aft part of a storm may be displayed as green (appearing as less threatening) or as a black radar shadow (implying no threat at all). Modern weather radars are able to apply a correction to a signal when it is suspected to have been attenuated. This reduces the phenomenon, but a black hole behind a red area should always be considered active.

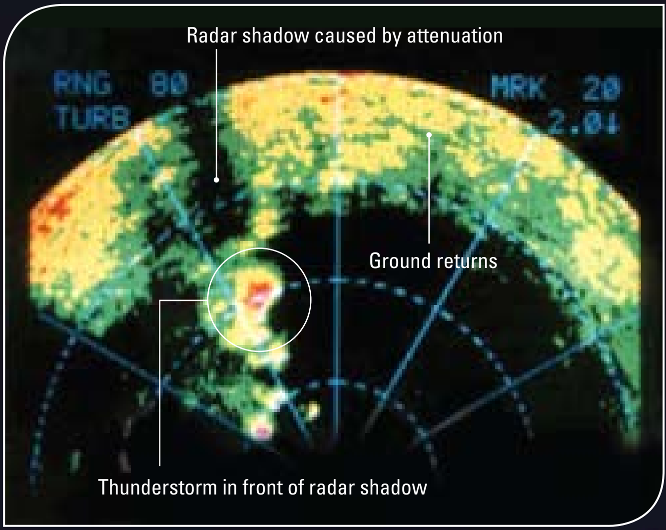


Photo courtesy of Honeywell ©

Antenna Tilt

Terrain will also reflect energy back to the antenna. The resulting ground clutter makes it more difficult to interpret weather radar, as weather echoes and ground clutter can be difficult to differentiate.

In August 2008, a Q300 was struck by lightning on climb out of Palmerston North. The aircraft entered a light hail shower and then received a strike to the nose area. No system malfunctions were experienced. The weather radar was on and adverse weather in the area was observed on the screen, but as the aircraft was still low, the crew stated they were uncertain if what they saw on the screen was actual weather or ground clutter off the ranges.

The key to determining weather echoes from ground clutter is antenna tilt.

Modern weather radars generally have flat antennae and use X-Band frequencies (8000 to 12,500 MHz). The antenna is swept left and right automatically. The tilt of the antenna up and down, however, can be controlled by the pilot. Zero tilt of the antenna equates to the longitudinal axis of the aircraft. With tilt set to zero, the attitude of the aircraft will determine whether the beam is pointing above, below, or straight ahead, of the aircraft. Some systems have an automatic attitude correction function.

Changing the tilt will change the shape and colour of ground clutter, eventually causing it to disappear. It is a good idea to have a small amount of ground return showing at the edge of the display. This shows the system is working, and allows radar shadows to be seen. If the tilt angle is too high or too low however, the radar beam will miss weather directly ahead of the aircraft. Ideally, the centre of the beam should be aligned with the flight path.

One degree of tilt up or down moves the beam centre 1000 feet up or down at a distance of 10 NM from the aircraft. Effective management of antenna tilt enables you to estimate the vertical extent of Cbs. The following formula can be used to determine the top of a Cb in height above or below the aircraft's altitude.

Distance of the weather (NM) x Tilt angle required for the weather to disappear from the display x 100.

Continued over »

Continued from previous page

For example, a Cb disappearing at 50 NM with 1 degree of tilt down has a top located 5000 feet below the aircraft.

Most systems also have a Gain function. Temporarily selecting a lower Gain setting will allow more in-depth study of intense weather targets.

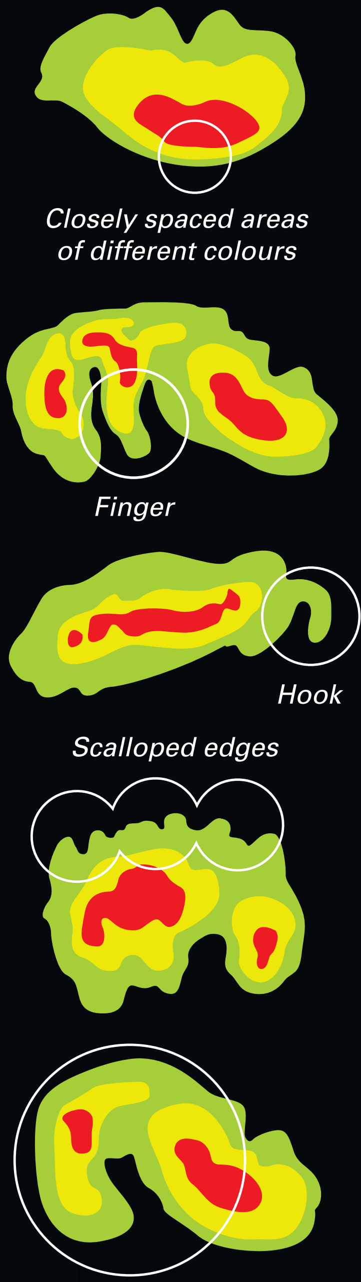
Antenna tilt should be adjusted throughout a flight, taking into account aircraft attitude, the expected weather, and the display range selected.

It is best practice to display longer ranges and periodically change to a lower range and tilt for a more in-depth look in front of the aircraft. This will give you time to evaluate weather changes. Thunderstorms grow rapidly and a course that is clear one minute may contain cells a few minutes later. Study both higher and lower range returns before deciding where to go.

Shapes painted on a radar screen are also an excellent indicator of severe weather. Fingers, hooks, u-shapes, scalloped edges, and fast changing shapes indicate areas to avoid. Closely spaced areas of different colours indicate highly turbulent zones.

Although most aircraft flying IFR are equipped with weather radar, flight into active Cbs still occurs, often resulting in damage. A thorough understanding of your particular weather radar system, and correct interpretation of the display, will help to reduce this possibility. Weather radar should never be used as a tool for penetrating severe weather, but as a means of avoiding active cells.

Shapes indicating adverse weather



Lightning Strikes in New Zealand

In the last 15 years there have been 25 lightning strikes in New Zealand with a severity classified as 'major'. Here are a couple:

Metro III – 5 May 1999

On approach to Wellington, the aircraft was struck by lightning and all electrical power was lost. The approach was discontinued and the aircraft climbed to where visual conditions could be maintained. Partial electrics were restored, but the left engine fire warning light illuminated. The crew shut the engine down and diverted to Woodbourne.

SAAB SF340A – 6 Oct 2000

On descent towards Nelson the crew were cleared for the VOR/DME 02 approach via the arc. They declined this approach due to thunderstorm activity showing on the radar. The strike occurred at 9700 feet as they were cleared to track direct to the Nelson VOR for the VOR/DME ALFA approach. Both generators tripped off line, the EFIS displays and autopilot failed. All systems were restored once the generators were reset. The crew operated on standby instruments during the 90 seconds it took to restore generator power. The standby compass was found to be 40 degrees out due to the strike magnetising the nose gear leg. The rudder, hydraulic pipe fairings, and aircraft skin, were also significantly damaged. ■

Photo courtesy of Honeywell ©