Australian Storm Spotters' Guide

The guide presented here is adapted from "The Storm Spotters' Handbook" published by the Bureau of Meteorology, Australia in 1995.

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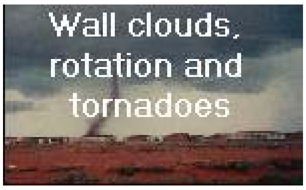

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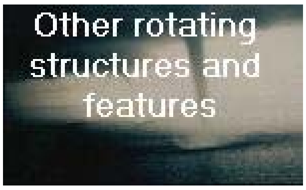

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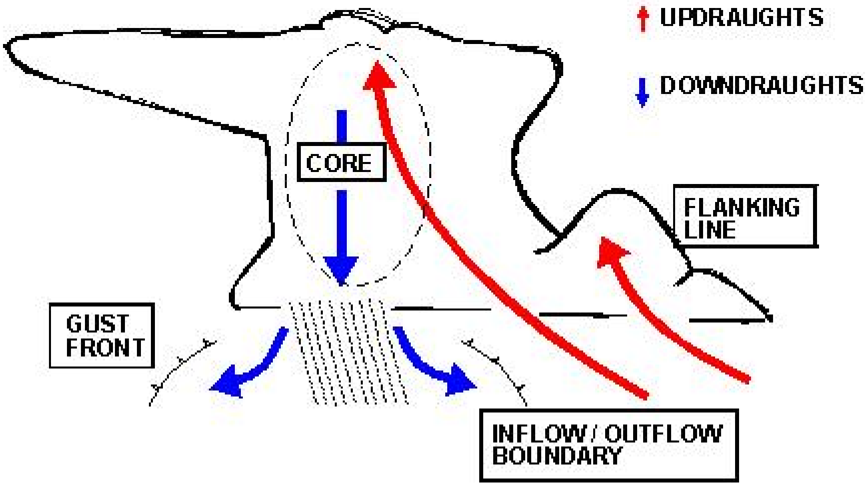
1. Thunderstorms and their main parts

Severe thunderstorms are very localised events that don't usually affect as wide an area as tropical cyclones and floods. Often, their devastating impact in Australia is under-estimated. However, severe thunderstorms are responsible for more insured loss (on average) than tropical cyclones, earthquakes, bushfires and floods combined and may result in death and injury.

This spectacular photograph (1.1) taken from an aircraft provides a "birds-eye" view of a thunderstorm over Point Lookout in NSW. The isolation of the storm system is a fairly common feature of severe thunderstorms.

1.1 Photograph by P. Mackey.

Thunderstorms have a three-dimensional structure, but it is best to think of them as a constantly evolving process, rather than just an object. The diagram below represents a vertical cross-section through a thunderstorm moving towards the left of the screen. Each storm, or cluster of storms, is a self-contained system (1.2) with organised regions of upward moving air, known as updraughts, and downward moving air, downdraughts. The warm, moist air which fuels updraughts, typically rises in successive cumulus towers along a flanking line that leads to the storm's main core. As air rises within the core, it cools and condenses into rain or hail which then falls in the downdraught. Near the ground, the downdraught spreads out in what is known as the outflow region. Often, the leading edge of the outflow is marked by an abrupt, cool wind surge, the gust front.



1.2 diagram of a thunderstorm.

This photograph (1.3) from Gladstone, Queensland shows a good example of a flanking line. Note how the towers grow progressively larger towards the main storm updraught which is off to the left of the photograph.

1.3 Photograph by P. Kearton.

The top of a thunderstorm cloud, known as an anvil, is seen as bright and tall, reaching up to an altitude of 10-16 kilometres. It may appear to be "boiling" with cauliflower-shaped lumps but more often has a fibrous, frozen appearance because it is primarily composed of ice crystals. This photograph (1.4) from Brisbane shows a crisp thunderstorm anvil which is a good indicator of a strong updraught.

1.4 Photograph by A. Smallegange.

The boundary between cool storm outflow, here indicated (1.5) by heavy precipitation on the left, and rising warm inflow, here on the right, is sometimes marked by spectacular shelf cloud (or Arcus). Sometimes this cloud feature may become detached and move out ahead of a storm as a horizontal roll cloud.

1.5 Photograph by A. Husted.

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2. Types of Storms

There are three simplified thunderstorm types: the single-cell, the multicell, and the supercell. Of these, it is the multicell which is the most common.

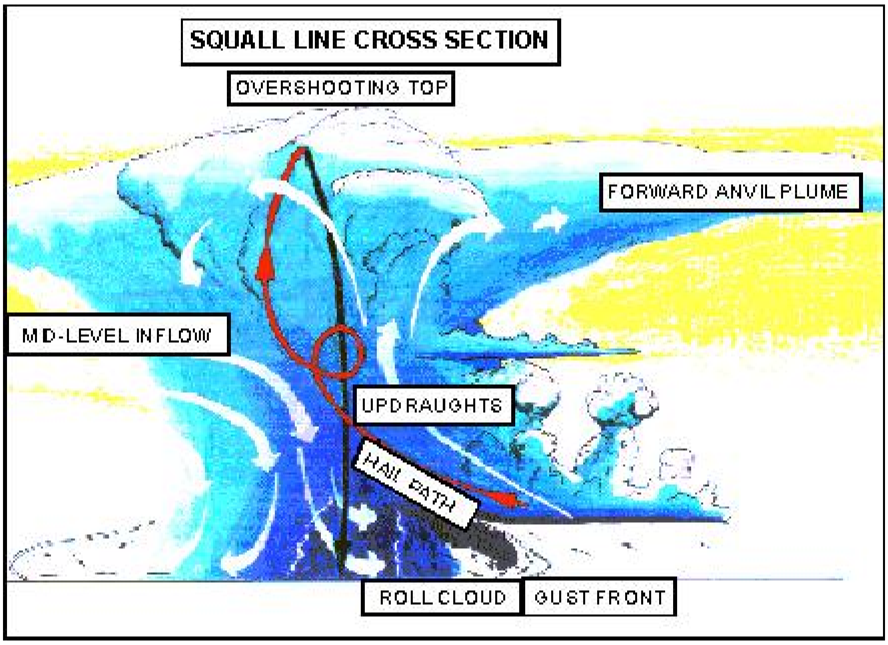
This photograph (2.1) of a multicell storm near Tamworth, NSW, illustrates many of the features we discussed in Section 1. The flanking line can be seen extending from the lower right of the photo in a series of steps up to the well defined anvil in the top left. Rain falls below a relatively flat base in the form of a diffuse rain curtain. Although on first appearance, this storm is unlikely to be severe, multicells have been known to produce all the severe effects, but cause tornadoes only infrequently.

2.1 Photograph by G. Garradd.

A supercell thunderstorm is a special storm type which maintains an intense steady-state for many hours. This photograph (2.2) shows a supercell storm near Fiskeville, Victoria. Note the high, crisp anvil, which indicates a very strong, sustained updraught. Supercells are a fascinating but dangerous cloud complex and they account for most of the serious thunderstorm events we experience.

2.2 Photograph by P. Baker.

Thunderstorms don't always occur as single entities. Often, many storm cells will group together in a line, aligned with a cold front or a low pressure trough. These storm complexes are referred to as squall lines because of the strong, squally winds they can produce. Sometimes they also generate tornadoes, particularly in southern parts of Australia during the cooler months. This diagram (2.3) shows a vertical cross-section of a squall line storm cell which is moving quickly towards the right of the screen. The gust front moves along with the storm, helping to fuel the updraught and prolong the storm's life. A shelf or detached roll cloud is a common feature of these storms.



2.3 Painting by B. Rolstone.

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3. A day to watch

Altocumulus castellatus is an indicator of atmospheric instability and a common precursor to thunderstorm development. The example (3.1) below was photographed during mid-morning above the city of Melbourne. Instability is shown by separate towers, or turrets of cloud, rising from a flat middle level base.

3.1 Photograph by A.Treloar.

Low level moisture is also essential in thunderstorm development. This can sometimes be indicated by the presence of low clouds or haziness in the morning and/or many small cumulus clouds later. Here (3.2) we see a field of small cumulus clouds in the Simpson Desert of South Australia.


3.2 Photograph by A. Charles.

On a typical late spring or summer storm day, a few small clouds may become briefly larger but their tops soon evaporate. At some point however, the number of clouds decreases, and fewer, larger ones remain. Several of these may sprout tall towers, (towering cumulus) as shown above (3.3) in Brisbane.


3.3 Photograph by A. Smallegange.

4. Assessing severity from storm features

Once a thunderstorm develops, various features can be assessed as a guide to its potential severity. The anvil, for instance, can tell us many things about the age, strength and organisation of the storm system. Unevenness on top indicates erratic growth, and a diffuse edge suggests weak updraughts, hence a weaker system. This photograph (4.1) from Brisbane is a good example of a weak, fibrous anvil from a non-severe storm.

4.1 Photograph by A. Smallegange.

The anvil on a long-lived, regenerating storm may be very extensive, with small notches or dents along the edge which correspond to the separate updraught pulses. Notches can be seen here (4.2) on the right edge (or front) of this thunderstorm in Wellington, New Zealand.

4.2 Photograph by G. Trelaggan.

The top of an anvil is normally restricted by the tropopause (the stable layer at the top of the weather-producing part of the atmosphere) and blown forward on strong winds aloft. However, when the main updraught within the storm is very strong, a portion of the anvil may push upward above the general level. This feature is known as an overshooting top and can be seen above on the top left of the photograph as an upward "bulge".

When the overshooting top becomes prominent, as in this case, and persists for longer than several minutes, it can be regarded as an excellent sign of storm severity. Other characteristics of severe thunderstorms illustrated well in this photograph (4.3) near Tamworth, NSW, are:

- a high anvil with a crisp edge;
- a steep, almost vertical mass of boiling towers at the rear of the storm (here on the left of the photograph; and
- a tendency for the anvil to push back against the prevailing winds (a back-sheared anvil).


4.3 Photograph by G. Garradd.

Advancing outflow air acts like a plough, mixing the cool, moist air at its boundary with warmer inflow air and forcing it to rise. As we have seen, this can result in the spectacular low cloud bank called shelf cloud (or arcus) near the leading edge of the storm. The shelf often has a smooth, laminar or banded surface and black, turbulent base. Here (4.4) we see a smooth shelf cloud near Tewantin, Queensland. The rain curtain beneath the core can be seen in the left background. Very humid conditions will promote a thick, low cloud bank. A sharp, strong gust front will cause the lowest part of the leading edge of the shelf to be ragged and lined with rising scud cloud.


4.4 Photograph by L. Lloyd.

Wind squalls may also be generated by downbursts, concentrated, severe downdraughts usually accompanied by a descending deluge of precipitation. These induce an outward (horizontal) burst of damaging wind at the surface. On a smaller scale, this wind feature is known as a microburst. The rain curtain below this storm (4.5) has a "foot" which extends to the right, close to the ground. Outwardly curved rain shafts such as this, are a good sign of strong downburst or microburst winds and the steeper the angle, the stronger the flow. Note the rising rain or dust well to the right. (Tamworth, NSW)


4.5 Photograph by G. Garradd.

There are other clues to storm severity that can be found in the rain curtain. If it is dark and smooth, such as in this photograph (4.6) near Tamworth, very heavy rain is likely. Rainfall in severe storms will generally become progressively heavier, and sometimes mixed with hail whilst in weaker storms, rainfall will be patchy or confined to short downpours.
This photograph is also interesting as it shows lightning under the main storm updraught. Severe storms are likely to have multiple bolts of lightning under the main updraught and sometimes a strobe-like flashing high up in the cloud.


4.6 Photograph by G. Garradd.

One small cloud feature which is particularly valuable in assessing a thunderstorm's severe potential, can sometimes be found beneath the rain-free cloud base toward the rear of the storm. This localised cloud-base lowering occurs at the site of the main, focused updraught into the system. It forms when cool, moist air from the rain area, is drawn into the updraught and condenses below the main cloud base in a process similar to that which forms shelf cloud at the leading edge of the storm.
Lowerings that become organised, complete and circular are known as wall clouds and may be a precursor to tornadoes. This photograph (4.7) of a wall cloud near Tamworth shows a typical "prong" extending towards the rain curtain, which is out of picture on the left.

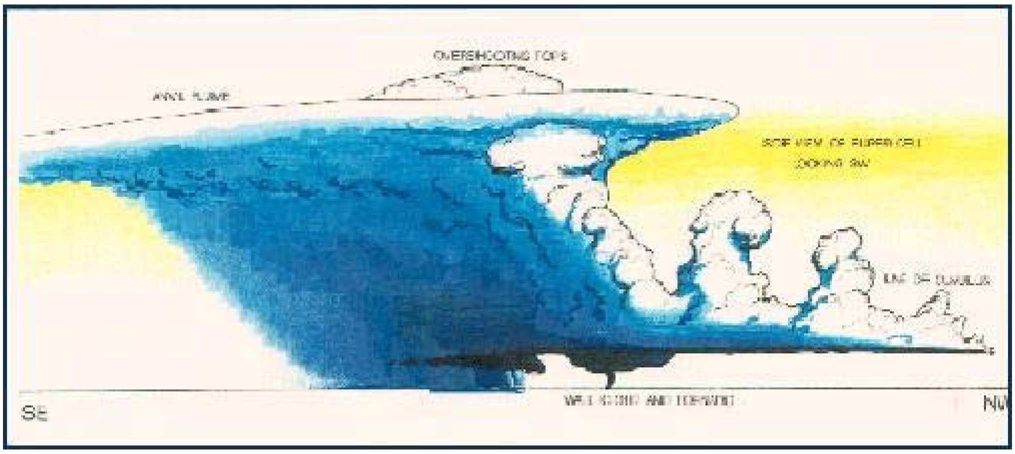
4.7 Photograph by G. Garradd.

Before moving on to discuss tornadoes in more detail, we will summarise the storm features seen so far that may give indications of thunderstorm severity. It must be stressed that these are indicators only and should not be used as the basis of storm spotter reports.

Assessing severity from storm features

	Stronger if:	**Weaker if:**
ANVIL	• crisp edge, long and thick • spreads back against upper flow (usually to the west)	• diffuse edge
CORE	• Large, solid, boiling cloud mass • cloud top overshoots anvil • rear of cloud almost vertical	• soft edged, no detail • rear of cloud leans forward
RAIN CURTAIN	• dark and smooth • strong outward spreading near the surface • rain becomes progressively heavier	

This diagram (5.8) of a supercell thunderstorm illustrates many indicators of storm severity that we have discussed. The storm is moving towards the left of the screen and we are viewing it from the northeast looking towards the southwest.



5.8 Painting by B. Rolstone.

Updraughts along a flanking line of cumulus clouds, lead to a solid, boiling cloud mass which is the main core of the storm. The anvil above is high and crisp, with an overshooting top and back-sheared rear edge. Beneath the storm, precipitation falls in a dark, smooth rain curtain which becomes progressively heavier towards the core. The boundary between storm inflow and outflow is marked by a low ragged shelf cloud, whilst beneath the core, a tornado touches down below the wall cloud.

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5. Wall clouds, rotation and Tornadoes

As a thunderstorm becomes stronger and develops an organised inflow, its main updraught may begin to rotate slightly. This is sometimes seen as broad rotation of the cloud base beneath the main updraught or in the circular nature of the wall cloud. An example of a rotating cloud base is shown here (5.1) from near Adelaide. In most cases in the southern hemisphere, rotation will be in a clockwise direction when viewed from a distance. If however, you are looking directly upward, changing perspective will make this rotation appear anti-clockwise.

5.1 Photograph by R. Geytenbeek.

Weaker tornadoes are formed primarily by "tightening-up" of a rotating updraught. They occur as the storm intensifies to a maximum and are found right under the updraught core, sometimes without a significant wall cloud. Weaker tornadoes are most likely during mid-summer storms but may also accompany squall lines, mainly in southern parts of Australia. They are none-the-less significant events and may produce narrow strips of severe wind damage. This example (5.2) from Dimboola, Victoria occurred in December 1992.

5.2 Photograph by K. Reynolds.

Stronger tornadoes typically occur with late spring/early summer severe storms and have a more complex cause. It is speculated that at a certain stage in the storms life-cycle, a particularly intense updraught pulse partially blocks the prevailing wind aloft and deflects air down toward the surface. The downward surge interacts with the updraught to produce a tight rotational motion (in much the same way as rolling a pencil between your hands). This "spinning motion" is then tilted into an upright position and enhanced as it moves toward the ground as a tornado.

This photograph (5.3) of a strong tornado, accompanied by a well developed wall cloud, killed two people near Sandon in Victoria in 1976. The point of contact with the ground is marked by a cloud of dust and debris. The large "prong" attached to the left of the wall cloud later formed a second funnel.

5.3 Photograph by I. Kuiper.

The typical funnel shape of a tornado is formed when moist air condenses within the lower pressure of the rotating column of air. Under relatively dry conditions, a funnel cloud may not form and the presence of a tornado at the surface may only be indicated by a mass of debris. In this example (5.4) from Northam, WA, the tornado is made visible over pastoral land by a well defined dust funnel.


5.4 Photograph by J. May and C. Crane.

This interesting tornado (5.5) at Port Hedland, WA is made visible by an inner "inverted" dust funnel surrounded by an outer shell, most likely comprised of water vapour.


5.5 Photograph by P. Mudra.

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6. Other rotating structures and features

A waterspout looks like a slender tornado, but occurs over water. They are occasionally seen near the coast in the late summer and autumn when cool, unstable air passes over warmer waters. Nearby topography and other effects, allows local concentration (or convergence) of the airflow, which results in vigorous updraughts "tightening up" into spinning columns. This example (6.1) shows twin waterspouts over the warm waters of the Gulf of Carpentaria.

6.1 Photograph by T. Wallbank

A similar phenomenon over land is the landspout, seen here (6.2) below a large cumulus cloud near Cleve, South Australia. Note the lack of an anvil on the top of the cloud and the absence of any wall cloud. The mechanism which forms a landspout is similar to the waterspout except in this case, relatively cool air passes over hot ground.

6.2 Photograph by P. Foxwell

Whenever air rises rapidly at the edge of cool moist outflow, lower cloud fragments, known as scud, will form. Many low, dark patches of scud can be seen in the middle of this photograph (6.3) below a ragged shelf cloud. The rain curtain behind makes the scene appear even more ominous. Scud can best be distinguished from funnel clouds or tornadoes because it is less smooth-edged, more transient and rising (or moving in a straight line) rather than rotating.

6.3 Photograph by G. Garradd.

This "tornado-like" structure (6.4) was seen on the leading edge of a wind squall, located just ahead of a ragged shelf cloud. The feature lasted for several minutes but was not rotating and was most likely just an unusual feature of the shelf cloud itself.

6.4 Photograph by A.Treloar.

Another common deception is provided by distant shafts of falling precipitation, especially when silhouetted as here (6.5). Virga, or rain which evaporates before reaching the ground, often looks like dark, tapered extensions below a cloud base and thus, like a tornado. A closer inspection, however, shows they are diffuse and soft-edged.


6.5 Photograph by G. Garradd.

Another ominous-looking cloud feature, is mamma, or mammatus clouds. These rounded pouches or bulges protruding from an anvil base are shown here (6.6) in a good example from Brisbane. Mammatus have long been associated with severe weather, but their presence merely indicates descending pockets of small droplets or ice crystals from an anvil surface. In fact sometimes they can be observed below middle level cloud sheets.


6.6 Photograph by A. Smallegange.