Session 1 – Overview of Ceiling and Visibility

Hello and welcome to this series of sessions on ceiling and visibility for aerodrome forecasts. My name is Harrison Burns-Fabb and I'm an aviation service improvement lead at the Bureau of Meteorology in Australia.

This is the first of three pre-recorded sessions. In this session we will cover an overview of ceiling and visibility, including definitions, hazards to operators, and the most common causes of low ceiling and visibility. Session two will cover the forecast process. Session three will cover processes for effective weather watch.

Let's start with some definitions. Ceiling is defined as a layer of cloud above the surface, the base of which is the ceiling height. The amount of cloud, the type of cloud and the height all factor into whether it is of concern to the safe operation in and out of the aerodrome. Ceiling is usually an issue when the amount is broken or overcast, and the bases are in the lowest few 1000 feet of the atmosphere. I should also note that there can be a ceiling present of smoke or haze suspended in a layer above the surface, but we will be discussing cloud. Visibility is defined as the distance at which an object can be clearly distinguished and is caused by a number of phenomena such as fog, smoke, haze, and precipitation. The fact that meteorological visibility is assessed at eye level on the ground is worth emphasizing an air traffic controller in the tower and the pilot on finals will have a very different view of that. For example, in shallow for mist or fog patches, the ground level visibility may be significantly less than that from the tower.

Why can lower ceiling and reduce visibility be hazardous? When cloud base or visibility full below acceptable values, the pilot is in a situation where there won't be sufficient time to take avoiding action. Should an obstacle be cited, that obstacle may be natural, such as the hill or simply the ground. It may be a structure such as a building or tower or another aircraft. If this situation occurs, collisions are possible. Pilots who are not qualified to use the instruments or flying poorly equipped aircraft may become disorientated when confronted with poor visibility and or low cloud. Whether or not a pilot can land at an aerodrome depends on three factors, the equipment on board, the aircraft, the qualifications of the pilot, and the visibility or cloud present. So how do we prevent this happening? We have defined limits of usability for an aerodrome as stipulated by the International Civil Aviation Organization Annex 6, Part 1. Each aerodrome will have different aerodrome operating minima. The landing and take-off as each aerodrome are unique in the topography around it, the runway size and orientation, and the availability of other navigational aids. There are also different types of operating minima depending on the flight crew, the aircraft, and the equipment on board. This has a few flows on effects. If an aircraft can't land due to the ceiling or visibility below minima, then airborne holding may occur, which imposes a safety risk and the economic cost as the aircraft is still airborne and burning fuel. If the aircraft does not have enough fuel to hold then it must divert to an alternate aerodrome so delays and missed connections can then occur from this and also reduce aircraft acceptance rates. Visibility may also lead to airport closures.

Let's go through some of the phenomena that can cause low ceiling and reduce visibility. Ceiling is usually an issue when the amount is broken or overcast, and the bases are in the lowest few 1000 feet of the atmosphere as I stated before. The main cause is a layer of cloud above the aerodrome, below minimum height and of sufficient coverage. We will focus on stratus and stratocumulus for this session as they are the cloud types most likely to produce hazardous low cloud conditions. Reduced visibility is caused by a number of phenomena. Fog and mist are common causes of low visibility and can remain at an aerodrome for long periods of time, and very low visibility in fog can occur. Precipitation also often reduces the visibility, and the reduction in visibility is related to the particle size and type and intensity. the duration of reduced visibility is also a key forecast decision regarding precipitation. Some precipitation can hang around for long periods, like significant rain bands. Others can pass through quickly, like showers. Smoke, dust and haze also reduce visibility, the difference being they are not water droplets. The particle type, size and concentration can all factor it into the forecast.

Let's now go through a quick overview on low cloud formation. Cooling of moist air to its condensation point will often lead to the formation of cloud. The formation of low cloud frequently occurs overnight due to nocturnal cooling. Another cooling mechanism occurs due to the saturated adiabatic expansion of rising moist air. This occurs due to the temperature of rising air initially decreasing according to the dry adiabatic lapse rate. As it cools, the relative humidity increases and eventually saturation is reached. Further cooling produces condensation and visible cloud forms. So, condensation releases latent heat, which serves partly to warm the rising air. When the temperature contrasts between rising air and the surrounding environment is not significant. Air is allowed to rise slowly over a large air, and the whole air mass is cooled at the same rate at the same time, leading to more of a layer cloud such as Stratus. Addition of water vapour occurs from moist air advection, evaporation of precipitation below existing cloud post precipitation, moisture remaining in the lower levels, evaporation of surface water and mixing of air masses of different moisture content and temperature. When these processes occur at low levels in the atmosphere, low cloud may result. Low cloud dissipates when sufficient warming and drying of the air mass occurs. Low cloud is commonly dispersed by the advection of warmer air or drier air, or by the mixing of air due to insolation. Low Cloud may also dissipate when the process responsible for the cloud diminishes, for example when winds ease or change direction and the forcing of air upwards at a mountain range decrease or ends.

Let's go through some common situations where you may find low cloud. A common example is air mass in contact with a colder surface where there's some low-level wind present. In this situation, air is cooled to its dew point when it comes into contact with a cold surface. Nocturnal cooling is the most common instance. A well-recognized example of condensation due to nocturnal cooling is the formation of fog during clear, almost calm nights when the ground is cooled by radiation to form a radiation fog. If there are more than a few knots of wind present in the low levels, then low cloud will tend to form in the first instance as opposed to fog. Stratus due to lifted or dissipating fog can also occur. The primary fog dissipation mechanism is via turbulent mixing and heating. After sunrise, warming initiates weak convective mixing and the transfer of heat from the ground into the lowest portion of the fog layer. As warming progresses, humidity decreases, droplets begin to evaporate, and the fog thins. From the base upward, the fog essentially becomes Stratus. A great majority of clouds are formed in rising air, and low cloud is no different. A common lifting mechanism for low cloud is forced lifting of air by topography, surface convergence, or by a synoptic system such as a trough or a front. So, to forecast this low cloud, we will need to check a few things. We need to analyse the instability, as this will give an indication of whether that air mass is likely to be lifted or whether it will remain at level, and whether there may be an inversion present to prevent further lifting. The lifting condensation level as determined from an atmospheric sounding can give you a good first guess of ceiling heights. Low level wind speed is critical in determining the degree of mixing and the depth to which occurs. In general, the stronger the wind, the greater the depth of the mixed layer. In stable situations, the decision between fog and low cloud is often based on the gradient wind. Stronger winds will give rise to a deeper depth of mixing and will be more likely to be associated with Stratus. A prerequisite of low cloud formation is the presence of near saturated conditions in the lower levels, so we need to analyse the moisture levels throughout the lower levels of the atmosphere. Local effects such as topography may cause orographic lifting. As seen in this diagram on the right, we need to check the area around the aerodrome we are forecasting for.

For fog or mist to form, we need the air mass at the surface to be saturated, and we also need sufficient condensation nuclei for water vapor to condense to form water droplets, which is common in the lower layers of the atmosphere. So, to create fog, we need to either decrease the air temperature, increase the moisture content, or both. Let's look at these processes, radiative cooling of the surface temperature to the dew point temperature. Forced ascent and adiabatic cooling as we mentioned earlier for cloud. Conductive or turbulent transfer a cooling of air moving over a cool surface, also known as advection. Or turbulent mixing of nearly saturated air. The most common processes that lead to moistening are evaporating from a moist surface, just as we mentioned in the low cloud formation section. or precipitation prior to or possibly at formation time.

There are many types of fog named according to their formation mechanism. If we have a good idea of the formation mechanism, we can then know what to look for to diagnose the potential for fog when we come to produce our forecasts. A pure radiation fog forms and completes its lifecycle in situ. It initially forms in response to radiative cooling of the surface temperature to close to or equal with the dew point in calm or very light winds. Essential ingredients for radiation fog formation are the potential for low level air to be cooled to its dewpoint by contact with a radiatively cooled surface with a sufficiently clear sky. The existence of a sufficient depth of moisture, sufficient fog, top cooling and condensation to deepen the fog. Advection fog develops as warm, moist air moves over a cooler surface. Radiative processes frequently assist in the formation of maintenance of advection fog. For example, this is likely to occur when remnant moisture from a sea breeze moves inland and passes over terrain that as undergone substantial radiative cooling during the night. Not to be confused with the previous fog advected fog forms in a different location and moves into and modifies or displaces the original amass that was not conducive to fog formation. They're often affected by local winds, such as katabatic winds down a valley, and usually appear later in the morning than radiation fogs. Sea fog occurs when moist air flowing over relatively cold-water cools to saturation. A likely scenario is for moisture to be captured from a warm surface current prior to being advected over cooler water surfaces. This can be likened to both an advected fog and an advection fog. Sea fogs can be widespread and also persist throughout the day. It's also worth noting that salt spray from the ocean is an effective condensation nucleus. Steam fog is caused by the evaporation from water into cooler overhead air. This can remain in situ or be affected away from the surface. Unlike sea fog, post rain fog more commonly occurs during the evening or overnight when radiative cooling increases. Precipitation enhances the ground level moisture, much like low cloud formation, and this evaporates, raising the low-level moisture. After the precipitation forming cloud has moved away, radiative cooling can occur. Upslope fog is caused by adiabatic cooling to the dew point temperature of air rising and flowing over a barrier. Fog formation will occur on the slope at and above the lifting condensation level. It's important to note that a large hill or mountain is not a necessity for upslope fog to occur. A gentle slope will suffice. And lastly, we have valley fog. Hilltops are often observed to be fog free while adjacent valleys are enshrouded in fog, even though available moisture may be similar at both locations. The main reason for the disparity is the difference in the depth of cool air. Thick and deep fog is more likely in the valleys because katabatic winds funnel cool air downwards, inhibiting the depths of cooling on hilltops.

Visibility reductions due to precipitation can be complex and difficult to forecast. Let's look at a few things to assist with forecasting visibility in precipitation. The visibility occurring in precipitation correlates with the size and number of droplets in the precipitation. This is related to the precipitation type. For example, drizzle has very small droplets, but a high density as the surface is usually close to saturation, leading to very low visibility conditions. In contrast, a high based thunderstorm may have large droplets precipitating from it, but due to the amount of dry air underneath the storm, the droplets evaporate as they fall, and the visibility may not be reduced much at all. It's also worth noting that for different types of precipitation, the duration of the event will differ. A passing shower may only reduce visibility for 30 to 40 minutes, while a mid-level driven cloud band may produce ongoing rain lasting hours to days. Rainfall rate and intensity also has a large effect on the visibility as higher rates or more intense rainfall will lead to lower visibility drops. This is related to the instability of the atmosphere, so more unstable atmosphere can lead to more intense rainfall. Cloud depth has a large impact. Shallow cloud layers may not have sufficient depth of moisture to produce large amounts of precipitation when compared to deep cloud moisture levels, and sources are important when forecasting precipitation visibility. If there are dry slots in the atmosphere, this can cause the precipitation to evaporate before reaching the surface. And therefore, not reduce the visibility as much as a more moist atmosphere. Topography provides a lifting mechanism, therefore can enhance precipitation and therefore contribute to reduced visibility. To forecast the precipitation type and intensity, we need to do a few things. We should be checking observations upstream to compare forecast visibility amounts, while adjusting the forecast based on the comparison between the observed air mass and the air mass at your aerodrome. We also can compare to past events in your area, using climatology as a first guess. For visibility, forecasting can be useful as you can compare the current situation to past events and then tweak the forecast based on that comparison. For example, if you know rainfall this time of year often reduces visibility to 2000 metres, but this air mass is slightly drier, you know that your forecast visibility is likely to be higher than 2000 meters, so maybe 4 to 5000 meters. We also need to ground truth numerical weather prediction model visibility outputs against upstream observations, and check against climatology and against your local knowledge and understanding.

Visibility at aerodromes may be reduced by smoke from a variety of sources. Most significantly from fires occurring close to aerodromes. Files near aerodromes can produce dense smoke and reduce visibility where wind and atmospheric stability are favourable, such as when a low level inversion is present. Overnight fires may die down, but the smoke remaining can still be trapped below a nocturnal inversion close to the surface. Light winds overnight might not disperse the smoke as much as during the day. Smoke from remote sources may also affect visibility at aerodromes. A source of dust is the only non-meteorological condition required for dust causing visibility reductions. Dry bare soil is more likely to become airborne under a strong wind because plant cover reduces the speed of wind at soil level and moisture binds to the soil particles preventing lifting. If an appropriate source of dust exists, then the second ingredient from a dust storm is strong and gusty winds, with large vertical wind shear sufficient to lift soil particles high into the air. The next ingredient for a dust storm is an unstable atmosphere which enhances lifting and vertical motion, enabling dust particles to remain suspended in the air for longer periods. A stable boundary layer suppresses vertical motion, and a low level inversion limits the vertical extent of any dust lifting. The final meteorological ingredient for a dust storm is low atmospheric moisture. This reduces the likelihood of moisture condensing onto the dust particles forming cloud or rain, or binding dust particles into larger aggregates that cannot be supported by the existing art motions in the area. Haze also reduces visibility in similar ways to smoke, with the difference being the particles reducing visibility are often from burning of fossil fuels or salt particles originating from over the ocean.

To recap, in this session we covered an overview of ceiling and visibility, including definitions of ceiling and visibility. Ceiling and visibility hazards to operators and the most common causes of low ceiling and visibility. In the next session, we will be covering the forecast process, including the forecast funnel, ground truthing and how to add value as a meteorologist. Thanks for listening to this presentation. I want you to now think about how the material we covered applies to you and how it can assist in your role.

Session 2 – The Forecast Process

Hello, welcome to this series of sessions on ceiling and visibility for aerodrome forecasts. My name is Harrison Burns-Fabb. I'm an aviation service improvement lead at the Bureau of Meteorology in Australia. This is the second of three pre recorded sessions.

Session one covered an overview of ceiling and visibility. In this session, we will cover the forecast process including the forecast funnel ground truthing and adding value as a meteorologist. Session three will cover processes for effective weather watch.

Let's have a look at the forecast funnel. We'll go through this in more detail on the next few slides. But as an overview, we want to first look at the planetary scale, things like seasonal influences. Then we move down to the synoptic scale to dig deeper into the forecast challenges of the day and look at the key features present in our domain. And finally, we want to analyse the mesoscale, analysing things like topographic influences. This all funnels into the forecast, which in our case is an aerodrome forecast. To help illustrate the use of the forecast funnel, I will also be stepping through a case study to contextualize it to our topic of ceiling and visibility. This case study concerns low cloud in Adelaide in South Australia, as marked by the X on the map.

At the planetary scale, we have a number of phenomena that influence the weather. We first need to consider what the seasonal influences are. So in the mid latitudes, this is associated with the shift of subtropical ridges, expectations of a change in frequency of frontal passages, changes in expectations of rainfall, snow and heat waves. In the tropics we see changes in atmospheric stability and the location of the monsoon which produces thunderstorms and heavy rainfall compared to the dry seasons or showers of the trade wind regime. The next thing to look at what are the cyclic ocean based phenomena that influence the weather? For example, the state of the El Nino Southern Oscillation Index can help determine the amount of rainfall for many countries bordering the Pacific Ocean. Next we want to look at the planetary scale, atmospheric phenomena that influence the weather in the mid latitudes. A large scale planetary wave known as a Rossby wave determines the development of weather phenomena being related to slow moving blocking highs, the development of low pressure systems including cut-off lows, that kind of thing. In the northern hemisphere, the North Atlantic Oscillation and the Arctic Oscillation influenced storm tracks and temperature trends. The Madden Julian Oscillation also influences the weather in tropical regions. To assess the planetary scale state of the atmosphere, we could use a number of diagnostics. Assessing means sea level pressure charts and geopotential height can give you a good picture of the state of the atmosphere at a planetary scale. Satellite imagery is often used to derive outgoing long wave radiation and therefore diagnose the presence of waves in the atmosphere at a planetary scale. Temperature and height anomalies are also useful in diagnosing the presence of waves in the atmosphere. In the case study for Adelaide, it's winter, so we know based on climatology that fog and low cloud are more common over large parts of Australia. We can also put these in context of the current winter. Have we experienced an average number of days with fog and low cloud this year and why is that? Synoptic features this time of year are further north than in summer, as the subtropical Ridge is further north, meaning that high pressure systems conducive to fog and low cloud are more likely to be present over our area. The state of the Indian Ocean dipole or El Nino Southern Oscillation Index can also influence our area. Although this has more of an influence on precipitation, it can assist with additional moisture in the atmosphere conducive to fog and low cloud.

At the synoptic level, the focus shifts to the problem of the day and impacts based forecasting. What are the key synoptic features that are driving ascent and descent in the atmosphere? So this includes high and low pressure systems, tropical cyclones and the patterns that are embedded in things like polar and subtropical jets and where moisture sources are and the movements of these air masses. As meteorologists, we'll rely on synoptic scale pattern recognition to quickly determine the possible problems of the day. Forecasters are aware that high pressure systems are characterized by stable conditions with light winds due to the associated subsidence in most seasons and locations. A key task here is identifying these features in satellite imagery and observations and understanding their past and expected future development using conceptual or mental models, and exploring future scenarios using numerical weather prediction. Let's go back to our Adelaide case study. There is a Ridge extending eastward into Central Australia, a common position for this time of year in winter. We can see the MSLP chart. There is a broad long wave trough in the Southern Ocean with a few embedded low pressure systems in it. This can often bring a cooler air mass with more moisture to southern Australia. Embedded in this long wave through, there's a weak cold front passing through WA and expected to move through the forecast area shortly. With this it looks like there's not a significant change in air mass, but given the predominant flow will be from the ocean, added moisture is likely in the lower levels.

So the mesoscale spans from just below the synoptic scale to spatial and temporal scales smaller than that of any individual thunderstorm. So understanding the mesoscale can add value to an understanding of the synoptic scale because local effects change the broader pattern. It will also allow forecasts to highlight important local impacts. For example, the presence of terrain will enhance ascent, leading to more enhanced precipitation, low cloud on the windward side. Likewise, wind flow over topography can generate turbulent motion, which is of concern particularly for aircraft operations. Surface influences on weather can also occur from boundaries such as land, water and rural urban interfaces. Mesoscale diagnostics include a variety of observations, from radar imagery to detect the location of boundaries or severe storm signatures to high resolution rapid scan satellite imagery. Numerical weather prediction models can run at mesoscale resolutions, and they can provide valuable information. Higher resolution numerical weather prediction models can capture things like the effect of topography on local wind flow, including orographic forcing of precipitation. Let's go back to our Adelaide case study. The topography in the immediate vicinity of Adelaide Aerodrome is flat. With a plain extending. coast to the Mount Lofty Ranges. This topography will have an effect on the overall westerly wind flow we are expecting. Therefore it will impact the ranges at a near perpendicular angle. Other local wind effects to check for would be the likelihood of a sea breeze and also katabatic winds overnight draining off the ranges.

It's essential to understand whether the data sources you are using to create your forecasts have been representing the situation accurately. If they have, you can use them with more confidence. If not, then you have to add a lot more manual value. Observations of all types are needed to ascertain current atmospheric conditions and to evaluate the accuracy of numerical weather prediction models, analysis or forecast. Observations provide the ground truth data and are used to help assess the reliability of NWP model output and to make necessary adjustments. Observations are also collected to describe the initial state of the atmosphere. Comparing 1 numerical weather prediction model to another can work well in the short term if they are agreeing, but if the NWP models diverge then a more probabilistic approach may be needed. Intelligent use of these model outputs in the short term means that forecasters can decide if a model is performing well and whether or not a model has skill. Numerical weather prediction models are only representations of the atmosphere. The issue is not whether or not an NWP model is 100% correct, but whether or not they have skill. An NWP model with skill can provide the forecaster with information. That they would not otherwise have had in order to make decisions about forecasts. Knowing the limitations of the data you're working with is essential in understanding the outputs. More global NWP models may not represent small scale features well as they have not got the resolution to factoring things like topography or processes on short timescales. As a highly trained professional with conceptual models, experience, and access to observations, the human forecaster is able to intelligently use numerical weather prediction model output to formulate a forecast. Forecasters add value, particularly on timescales of less than 24 hours, to produce forecasts using a variety of tools. Forecasters can also use verification to refine their understanding of atmospheric processes and model output. Let's go back to our Adelaide case study. In this case we know that our fine scale access city NWP model usually does a good job at representing the blocked flow in the area. Other NWP outputs don't have enough resolution to distinguish this topographical influence. Here in the images you can see the cloud model fields which use relative humidity. As a proxy for cloud layers. At 18 UTC, pictured here, it's verifying relatively well spatially against the satellite image, although the cloud heights as predicted by the model are much lower than what is being observed. Other sources of data that we can use to check these cloud heights are the observed atmospheric soundings at Adelaide Airport. The surface conditions across the area and the observations upstream to check if the cloud may be lifting or lowering. Satellite plays a key role in this as the movement and development of the low cloud can be observed, especially when animated loops are created.

As Adelaide airport is a major International Airport in Australia it has multiple aerodrome operating minima. The standard minima is what we call the highest alternate minima, as stated here, which applies to all visual flights. So the threshold we are concerned with here is 1480 feet above ground level for ceiling if it's broken or more. In addition to this, we have a special alternate minima which only applies to some instrument rated aircraft with pilots who hold specialized qualifications, which is usually the larger airlines. Our threshold here is 850 feet above ground level for ceiling where the layer is broken or more. The models in this case are forecasting cloud down to below 3000 feet. If we just went with the model guidance, we would prevent landing for all operators and effectively shut down the airport. These thresholds are a key thing to take into account when choosing a ceiling height, as a slight difference in the forecast can have large impacts for the operators. As always, your job is to forecast the weather as accurately as possible, so don't just pick a value based on the operating minima. What you want to do is come up with the most likely cloud based and amount. And be conscious of whether it is either above or below minima. This means you will need to keep a very close watch on these values to ensure that if they pass above or below minima, that is reflected in the forecast. We will go through this in more detail in the next session.

As mentioned earlier, when we discuss ground truthing, there are a number of ways the meteorologist can add value. Let's have a look at a few examples related to our case study. Topography is a main factor in this case, as we can link this situation to known setups where fog all low cloud are often present. Topographic blocking is common in this situation, and given the height of the ranges one can use climatology to assess the likely cloud bases. Climatology, persistence, and the meteorologists experience from past similar weather events plays a big part in adding value to the forecast beyond just using NWP models. It is also useful to be able to identify the specific setup present and recognize what the most likely outcome is or what may be different to previous outcomes. To build up this knowledge, it's useful to keep logs or databases of previous events of significance as case studies, and use this to perform verification and research into the cause of the outcomes. As mentioned before, if ground Truthing has been performed you will already have an idea of the NWP model performance and may be able to get a consensus on NWP models biased towards those performing well or those tuned for this specific conditions present. In our Adelaide case study, the forecaster is using their experience, knowing the models generally forecast cloud bases a lot lower than what is observed and you can see as represented in the green relative humidity cross section here. The wind fields can also be assessed to see if they are strong enough to produce the specific type of blocking flow, which usually leads to low cloud in Adelaide. We can also use the observed atmospheric sounding to gain a greater appreciation of the vertical profile of the lower levels of the atmosphere. And compare this to the NWP model outputs. Here you can see a moist layer between about 1500 feet right up to about 9000 feet. With a lifting condensation level around 2000 feet at 12 Zulu.

As mentioned previously, as an experienced meteorologist, it's your job to impart your scientific knowledge and expertise into the forecast. In this case, blindly following the model would have led to a TAF forecast for cloud below minima from about 10 UTC right through to 03 UTC the next day. Instead, as you can see here, we produced a forecast for cloud below minima from 18 UTC right through to 03 UTC. Noting that from 16 to 18 UTC we had low cloud forecasts but only few.

We will talk about steps to ensure your product is on track in the next session, but this is about verifying the event as a whole. This process should be holistic and should assess whether the models captured the situation well, whether the current forecast process was appropriate, or whether any extra forecast notes or guidance need reviewing. Let's review the case study briefly. Initial thoughts were there was a weak cold front moving by increasing low level moisture. We knew from experience this leads to moisture banking up on the ranges and producing low cloud for Adelaide. The model output initially suggested that low cloud would be present from 10 UTC till 03 UTC. We factor it in knowledge of local effects, previous forecast experience, and knowledge of model performance to produce the forecast. In the end, the forecast cloud heights and amounts verified relatively well, confirming the historical knowledge and local effects producing the cloud were accurate. The end time was not as well captured as you can see on the graph of cloud height here. Cloud did not lift to 2000 feet until after 03 or 04 UTC. This would be a trigger point to go back and review the numerical weather prediction output and also other conditions that may have prevented the cloud from clearing at the earlier time. Such as other higher cloud, present moisture levels throughout the atmosphere, etc. By reviewing and verifying forecasts like this on an individual basis, knowledge can then be shared with the rest of the team and processes can be improved upon. Verification can also take the form of longer term trend analysis, comparing forecast parameters to observations and identifying areas of improvement, but this is outside the scope of this presentation.

To recap, in this session we covered the forecast process, including the forecast funnel, ground truthing and how to add value as a meteorologist. In the next session, we'll be covering the process for effective weather watch, including maintaining situational awareness strategies to monitor incoming observations, proactive versus reactive weather watch and sending amendments. Thanks for listening to this presentation. I want you to now think about how the material we covered applies to you and how it can assist you in your role.

Session 3 – Process for Effective Weather Watch

Hello and welcome to this series of sessions on ceiling and visibility for aerodrome forecasts. My name is Harrison Burns-Fabb and I'm an aviation service improvement lead at the Bureau of Meteorology in Australia.

This is the third of three pre recorded sessions. Session one covered an overview of ceiling and visibility. Session two covered the forecast process. In this session. We will cover processes for effective weather watch, including maintaining situational awareness, strategies to monitor incoming observations, proactive versus reactive weather watch, and sending TAF amendments.

To be able to analyse and diagnose what is currently happening, we need to maintain situational awareness. This means that for your area of responsibility, you need to know what has happened in the past, what is happening currently, and you need to be able to understand why that has happened. The situation you initially forecast may rapidly change, and maintaining good situational awareness ensures you can recognise this change in a timely manner and react to it. To maintain situational awareness, we need to know what has happened and also what is happening right now. We can analyse the current situation by monitoring observations as they come in, which we will discuss further. Alerts as they come in. Which can be useful tools to notify you. We also need to be aware of the systems we are using and how they are running. We'll also discuss how to recognise erroneous data. We then need to diagnose the current situation, meaning we need to understand the reason behind why current events are happening. We do this by firstly interpreting the data. Then secondly, understanding the data, comparing it to conceptual models. Why should we maintain situational awareness? Picture this. You get a phone call coming into your forecast centre and the pilot asks when the fog will clear at the aerodrome you're responsible for. In this case, you haven't maintained situational awareness and you are unaware there was a fog patch rolling in about so you can't answer the pilot. Another reason is to be able to communicate with your colleagues to coordinate things like warnings, amendments and other products. And probably the two most important ones. We need to be able to send proactive amendments or warnings when specific thresholds are met.

To provide the best service we can, we need to be proactive in our weather watch. This means maintaining good situational awareness to understand what has happened, what is happening now, and using this knowledge to forecast for the next few hours. This enables you to keep a few steps ahead of the weather and avoid surprises, which can then lead to proactive amendments being sent before conditions are improving or deteriorating. Giving as much lead time as we can on changing conditions in the forecast can be very useful for our customers. Sometimes it's inevitable you will be caught out when a phenomena is already happening and that's just the way it is. Sometimes you have to react to things and send amendments as conditions deteriorate or improve. By doing this, though, we do not give our customers enough advance notice to plan for these changes. Let's think about a hypothetical example. It is 04 UTC. Your current TAF has fog forecast from 06 UTC, so in two hours time. You have been clipping a close eye on the satellite imagery and some other surface observations nearby your aerodrome. You notice that upstream the fog is thickening. Earlier than expected and the winds are weaker than initially forecast. This triggers you to dig deeper into the data, and you decide that the fog will now likely impact your aerodrome from 05 UTC. Therefore you send an amended TAF with the fog commencing from 05 UTC. And you send this at 04 UTC. Giving a full hours notice to the customer of the improvement. If, on the other hand, you are only reactive, you would only see the alert come in at 05 UTC as the fog rolls in. And then you would send an amendment giving the customer no advance notice of the deteriorating conditions. So how do we be more proactive? We need to monitor conditions closely. By doing this we can try and have identified trends in the data. We can also refer to all relevant data sources in a timely manner and keep in the back of your mind other possibilities such as fog developing earlier or later than initially forecast. So what are some causes of reactive weather watch? Only using single data sources may lead you to miss any trends evident in other data sources. Relying solely on alerting displays, which will only alert you to changing conditions as they happen. Not analysing the evolving trends in the data and also sometimes there can be a reluctance to change the forecast to better reflect the conditions. So we'll now go through a few tools for Weather Watch.

To ensure you stay on top of any visibility reductions from precipitation, radar should be used frequently. Radar can also occasionally be used for detecting smoke plumes. If you have already gone through the forecast process, you should have a good idea of when and where precipitation may occur. These times and locations will be key areas you need to keep a close eye on. You can also use radar to assess the severity of precipitation and use this to compare with observations upstream or nearby. If the upstream observations have significantly different values for visibility, this may lead you to amend your visibility forecast in the precipitation expected at your aerodrome. If there is precipitation already on the radar, you need to monitor that closely for movement and development, and track individual cells relative to your aerodrome. This will give you a clearer picture of the likelihood of reduced visibility over your aerodrome in the short term. Knowing how often your radar data comes in will allow you to check immediately when there's new data. For example, if your radar has a 10 minute update cycle, you know to do a reanalysis of the radar imagery every 10 minutes.

Satellite imagery is a very powerful tool in maintaining situational awareness as it allows you to get a snapshot over your whole area at once. Here at the Bureau of Meteorology, our workstations are set up to show satellite images visible at all times. So while we are doing other work, we can glance at the imagery frequently to check for any developments. Satellite imagery can be used to monitor features such as low cloud and areas of low visibility for movement and development. For example, fog forming may show up as patchy, but then as it develops into a thicker blanket it will be a solid colour. Infrared imagery can be used to determine cloud top temperatures and then compare to atmospheric soundings to get cloud heights. Multiple satellite channels can give a wide range of data. Visible imagery is most useful for low cloud and fog, but is limited to the daytime. Infrared makes it difficult to detect fog and low cloud due to the small difference in the temperature of the phenomena versus the surface temperature. This is where satellite enhancements can come in handy. So here you can see a night-time multi spectral enhancement which computes differences in different satellite channels and highlights specific differences that it's tuned to, such as low cloud as evident here. As with radar, using loops can be very useful, such as smoke developing. In this loop we can see over Northern Australia. It gives a better understanding of movement and development of features, especially when you can access high frequency and high resolution data. Overlays such as lightning or weather stations can assist with gaining an appreciation beyond just what the satellite imagery captures.

Weather stations, either automatic or manual observations, are invaluable for monitoring and detecting ceiling and visibility. They're usually positioned at the aerodrome we are monitoring so can provide essential information on temperature, dew point, temperature, cloud bases and also visibility. We need to use this data as effectively as we can, as it's often the most detailed data source available. The first step is to compare the observations from weather stations in the form of meta or specie to the forecasts. This is a simple way to ensure your forecasts are within allowable thresholds, which will we discuss soon. As METARs only captured data at one point in time, sometimes with up to 60 minutes gap between them, we may miss important science. Conditions may be diverging from our forecasts. We then need to dig deeper into the trends in the data. At the Bureau of Meteorology we're able to analyse the data from weather stations every minute in an almost live feed. This gives us the ability to see trends before they may trigger a METAR or SPECI. We can then use this one minute data to construct media grams, which gives a visual display of current conditions, making it easy to identify trends. In this image you can see the temperature and the dew point temperature converging. As represented by the red and blue lines. Before they reach near saturation levels, you can clearly see the trend and this may prompt you to take action to review your forecast before the next METAR or SPECI, comes in. We can also represent this one minute data in ceilometer or vis-meter plots which make trends clearly visible here. On the bottom plot you can see the cloud base lowering over a few hours. As with any automated equipment, there are limitations. For example, the ceilometer sensor only samples a single point at the observation site, so may not accurately represent the cloud coverage over the whole celestial dome. Especially for slow moving cloud. Human observers may be able to overcome some of these limitations by providing you with more information of the whole picture. Often it's useful to call up the observer and discuss the observations, as there is only so much information they can put in the METAR/SPECI message.

In addition to the radar, satellite and weather station data, there are a number of other sources that can assist in maintaining proactive weather watch. The first is in the form of atmospheric soundings. Depending on the location of frequency of these, they can be very useful in the ground truthing process to compare the model NWP output and your forecast to the current situation. Webcams can provide extra detail on the surrounding areas, especially when a human observer is not at that location. Data from aircraft can also be used in a similar way to an atmospheric sounding as there are limited data sources above the surface. They can fill in gaps in the sounding network generated by balloon flights and assist with ground truthing and weather watch. As I mentioned previously, human observers can provide you with additional data. The instruments cannot. It's worth noting that air traffic control has also often provide you with information on the surrounding area if a dedicated weather observer is not available.

So there are many ways to compare the forecasts to the observations, including a few automatic ways. Firstly, we can use simple alerting displays to compare forecasts to observations, such as this example from the Bureau of Meteorology. This is a basic viewer showing current observations and this viewer will highlight any observations. Of significance for your area so you can quickly glance at it and identify anything needing action. Another simple alerting display may be one that pops up on your desktop when specific criteria are met, and these can be audible or visual alerts. This alerting display, again from the Bureau of Meteorology, highlights when the TAF and the observations differ by more than the allowable thresholds. It places a coloured dot over the satellite imagery to visually notify you. This display can also highlight when conditions are close to thresholds, so you might have a little bit more time to investigate and amend before it's met. While these alerting displays are essential and very useful, they usually only provide alerts when conditions are changing, meaning they can only be reactive. One way to get around this reactive comparison is to introduce processes into your workflow that manually check observations against the products. Using the data we've mentioned already, you can be proactive by comparing your forecasts to observations, identifying trends, and keeping ahead of the changing situation.

Validating your observational data coming in is essential to know whether you can rely on that data or not. You may have an observation that just doesn't add up. A lot of the equipment we use can have limitations, such as a visibility sensor only sensing a small area which may not be representative of the aerodrome, or when a wasp makes a nest inside it and reduces the visibility. Another common one we get is when the grass is being cut around the weather station. There is often spurious observations reported by the automatic sensors. Human observers may also be limited by obstacles restricting the line of sight. If something doesn't add up, check multiple data sources. Use satellite to compare cloud cover to this cyclometer. Use webcams to verify low visibility. Use dew point temperature to check moisture levels. Let's have a quick look at one example. Here we have a SPECI for visibility dropping to 250 meters. This seems strange in the middle of the day when the dew point depression is 10 degrees. So we know it's not full or missed. It's unlikely to be precipitation as none is being recorded and it seems too dry. Could it be smoke or dust? The first thing you could do is call the observer if it's a manual observation, but in our case at Albury it's automated. Let's check the satellite image. There's nothing on the satellite image. There's looks like there's some cloud over the West and also a bit over to the east. In the valleys, there's no sign of dust or smoke. Let's check the webcam. It looks completely clear. You can see the visibility sensor right here in the front of the camera. If this was inconclusive or you didn't have a webcam or satellite imagery to confirm, you may also be able to call air traffic control to ask for a report. From here we know that the SPECI is incorrect and we would have to then log a fault report to get a technician to go out and check it. Something to note is that you may not have the same observations available as we do in the Bureau of Meteorology, but the key point here is to check other data sources.

Why do we amend TAFs? Amendments are a way to effectively account for unexpected conditions that arise before the next scheduled forecast is issued. So remember that the TAF should always reflect the observed and expected conditions. If ceilings or visibility changed significantly from the values that were forecast, we need to amend it. Likewise, if the timing and duration are different than what it is in the forecast, an amended TAF should be issued. TAFs are decision making tools and your aviation customers cannot make informed decisions without the most up-to-date whether information. Based on what you know about the event. Your delivery of accurate and timely TAFs based on significant weather changes is critical to aviation operations. Amendments are part of a high quality TAF service and should not be perceived as a negative thing. So here is an example priority list for the TAF product. TAF amendments for deterioration should always be prioritised as this can potentially pose safety risks. Next, TAFs for improving conditions as they can indicate conditions are not as they are on the previous TAF and therefore pilots can use this to plan accordingly. Both of these TAF amends are prioritised ahead of the routine TAF. Let's sum up by stepping through the procedures for amending a TAF. Firstly, by maintaining effective and proactive weather watch, we can assess the past, current and future expected situation. Once we recognize the need to send an amendment, we need to create our new TAF product in a timely manner. Then we need to send the product, which will often trigger alerts in systems used by our customers. This will then be disseminated to the end user and they can take action based on the content in the amendment. Sometimes it's worth calling your customers too, to notify them of an amendment. You may have specific local procedures for this.

Let's have a look at the amendment criteria for visibility. From the International Civil Aviation Organization, Annex 3, Appendix 5.1. When the visibility is forecast to improve and change to or pass through one of more of the following values. Or when the visibility is forecast to deteriorate and pass through one or more of the following values. We need to amend the tough. Let's go through the amendment criteria for ceiling, which is slightly more complex than for visibility. From the International Civil Aviation Organization, Annex 3, Appendix 5.1. The height of the base of the lowest layer or mass of cloud of broken or overcast extent is forecast to lift and change to or pass through one or more of the following values or lower and pass through one or more of the following values. In addition to this, when the amount of a layer or mass of cloud below 1500 feet is forecast to change from NSC / FEW / SCT to BKN / OVC or from BKN / OVC to NSC / FEW / SCT we will need to amend. It's also worth noting that there is a provision in Annex 3, Appendix 5.1, that notes any other criteria based on local aerodrome operating minima as agreed. Between the Meteorological authority and the operators concerned will also be an amendment criteria.

To recap. In this session, we covered the process for effective weather watch, including maintaining situational awareness strategies to monitor incoming observations, proactive versus reactive weather watch, and sending TAF amendments. This was the final of three sessions. Thanks for listening in and I want you to now think about how the material we covered applies to you and how it can assist you in your role.