Notes from the forecast room: Wellington snow event 10 August 2023

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ABSTRACT

Snow is a relatively rare event in the Wellington region, and there are subtleties in forecasting all aspects of it (timing, spatial distribution, and the level it falls to). For most residents of the Wellington region, snow is of novelty value, but it can occasionally prove a nuisance when it threatens the Remutaka Road Summit. The key synoptic ingredients for snowfall in the Wellington region are discussed.

A recent Wellington snow event on 10 August 2023 is then used as a real-world example, to examine whether all meteorological ingredients were present, including a comparison to observations. This note was written because there was a high level of forecaster interest in this snowfall event, due to synoptic complexity.

1. INTRODUCTION

It is difficult to get snow in Wellington. Even on the surrounding hills, we may only see it a few times a year, and there are some winters where the local hills never see snow.

Our snow challenges are common to most coastal locations in New Zealand – we have a lot of relatively mild sea between us and our source of cold air, and our source of cold air is quite a long way away. This combination allows for a lot of potential modification of incoming polar outbreaks, which means that only the very coldest bursts tend to be of interest.

This is not our sole difficulty though: even when we can access cold air from either Antarctica or the Southern Ocean quickly enough to minimise modification, we need the remainder of the atmosphere to play its part.

One typical factor that can spoil our snow is if the wind direction in the lower levels of the atmosphere is southwesterly. In these setups, we have seen snow to low levels elsewhere, even on the West Coast of the South Island, but Wellington finds itself orographically sheltered by the South Island landmass and ranges. The result can be clear, crisp days, but perhaps a sense of squandered opportunity.

The weather situation in August 2019 (Figure 1) saw the South Island's West Coast experience some of its coldest

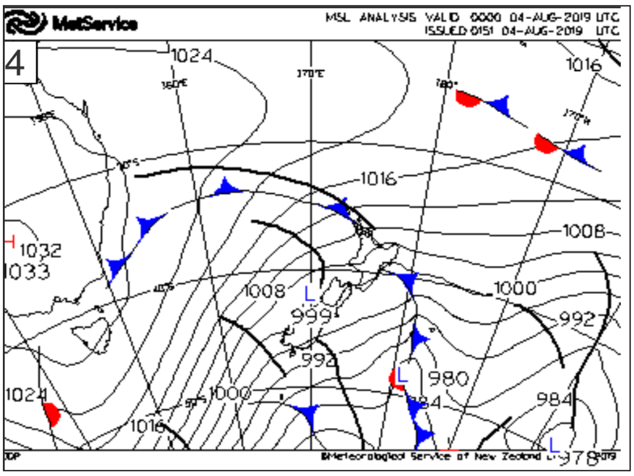

Figure 1: Mean sea level pressure analysis at noon 4 August 2019, showing a cold southwesterly outbreak over New Zealand. No snow was observed in Wellington during this event.

August days on record, with snow down to 200m above sea level (asl). Even though the same airmass affected Wellington, the southwesterly flow prevented any showers from reaching the region.

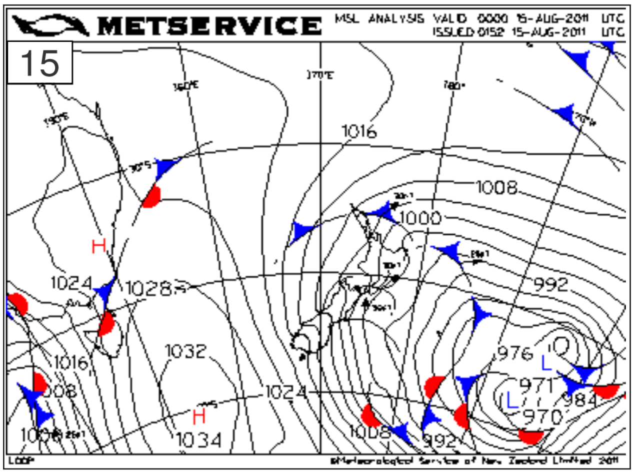

Figure 2: Mean sea level pressure analysis at noon 15 August 2011, showing a very cold southerly outbreak over New Zealand. This event produced significant snow in Wellington.

If the wind direction in the lowest levels of the atmosphere is direct southerly, any sheltering is removed, and abundant showers reach Wellington (Figure 2).

However, we need more ingredients than just especially cold air and a southerly wind direction – and for this we must investigate the full vertical reaches of the atmosphere.

To produce snow, atmospheric processes must be creating snowflakes. For this to happen, there must be sufficient moisture at levels in the atmosphere where snowflake production is accelerated. This happens inside a temperature range which is usually referred to as the dendritic zone – where temperatures are between around -12°C and -18°C. Typically in winter snow situations like this, these temperatures occur between approximately 2000m and 4000m asl.

It is reasonably common for Wellington to experience both very cold southerlies and showers, but with the showers themselves not deep enough to be good snow producers due to insufficient moisture in the dendritic zone. In these setups, Wellington finds itself dendritically deprived, and we miss out on snow again. This often happens during the latter part of cold events as the atmosphere slowly stabilises while cold air remains at the surface.

There are additional critical factors higher in the troposphere. In these regions we are primarily sleuthing for anything that can give us significant upward motion. Upward motion is the true essence of operational meteorology – the thermodynamic processes acting on rising air lead to condensation of water vapour, clouds and ultimately: precipitation.

In the mid-levels (approximately 3000m to 7000m), upward motion is typically driven by cyclonic vorticity advection (CVA). As per quasi-geostrophic theory, an increase in CVA with height promotes upward motion in the atmosphere. Cyclonic vorticity itself can be found near the axis of troughs, and the advection of it occurs downstream of the trough.

We can start to put all the synoptic ingredients together by looking at a recent event in August 2023. This event did not bring snow to extremely low levels but was notable in producing some large totals above 500m asl in the Wellington region.

2. METEOROLOGY OF THE 10 AUGUST 2023 WELLINGTON SNOW EVENT

On 10 August 2023, a cold airmass had been entrenched over the lower South Island for a few days, and a developing low pressure system to the east was expected to advect cold air towards Wellington. The primary cold front was forecast to lie from approximately Napier to Raglan, at midday on the 10th (Figure 3).

Freezing levels (not shown) were forecast to lower to around 800-900m over the Capital and remain static for many hours – a good start. Usually for Wellingtonian eyes to light up, we'd need to see a freezing level lower than around 1200m. Snow can fall significantly lower than the free air freezing level. This is because in the absence of thermal advection, the melting effect, which is usually an order of magnitude less than sublimation, can become

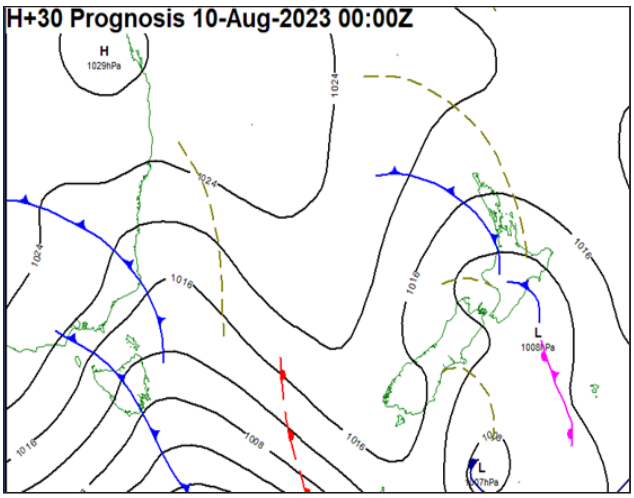

Figure 3: Mean sea level pressure prognosis for noon on 10 August 2023.

the primary mechanism for cooling the atmosphere. The melting effect is the processes of snowflakes melting as they fall, progressively cooling the surrounding air, and allowing subsequent snowflakes to fall even lower.

We can split this event into two halves: what comes with the cold front, and what comes after the cold front.

With the cold front:

At the time that the cold front was close to Wellington itself (about 6am), forecasters analysed a following trough sitting just to the south of Wellington (Figure 4).

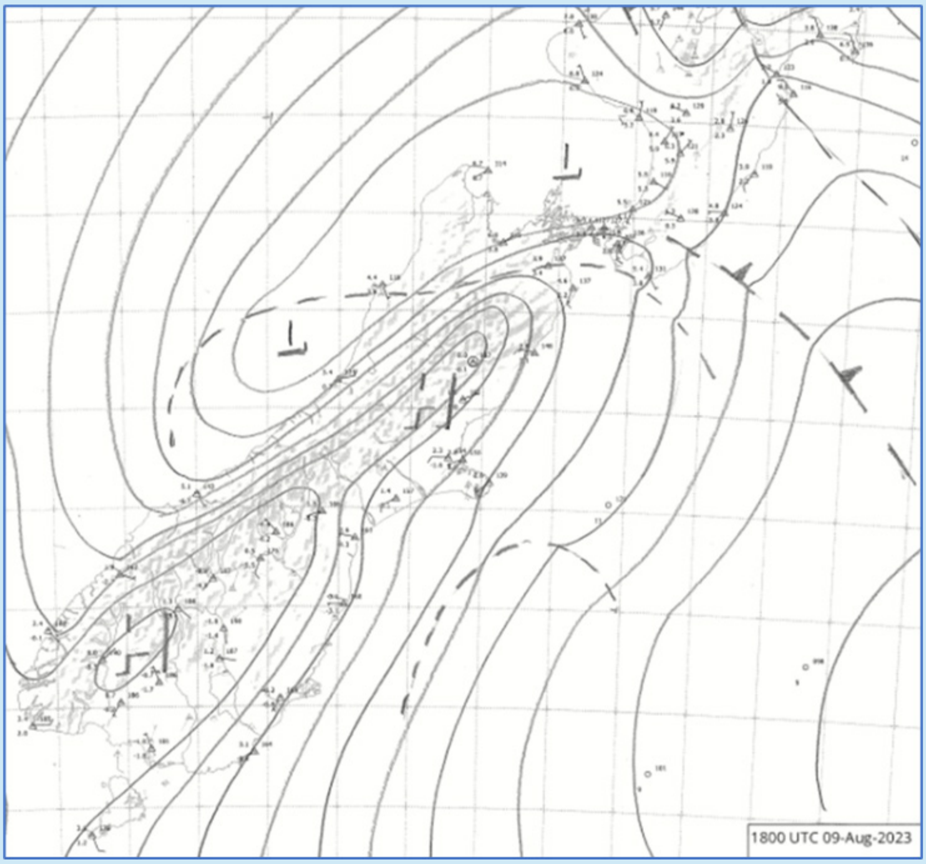

Figure 4: Hand-drawn mean sea level pressure analysis at 6am 10 August 2023.

At this time, forecast models indicated robust upward motion (not shown) along the surface front and trough. Surface fronts and troughs are associated with surface convergence, which leads to low-level upward motion. The upward motion can be enhanced through a greater depth of the atmosphere if we have further factors in favour.

In this event, strong cyclonic vorticity advection (Figure 5) was in play in the middle atmosphere (500hPa) as the upper trough approaches Wellington. This was the main driver of upward motion through the middle atmosphere.

Additionally, the relatively "slack" pressure gradient east of New Zealand under the broad trough indicates that this is a mature, slow-moving system which is very close to being "vertically stacked". Vertically stacked lows are defined to be in the same position at all heights of the atmosphere, not tilted with height. They are slow moving and this assists the relatively long lived low freezing levels mentioned prior.

The gauge corrected radar accumulations are useful to see what happened around dawn on 10 August 2023 (Figure 7).

During this time, is it likely that snow was falling and settling over the southern Remutaka Range – and sleet was reported in Karori at a height of 200m asl. Figure 6 clearly shows the largest rainfall accumulations were confined to the southern part of the Wellington region during the first half of this event, due to the stalled front. Measured rainfall totals in low lying gauges were five times higher than for areas further north during this period. For example, around 25mm in Karori compared with 5mm in various locations near Upper Hutt.

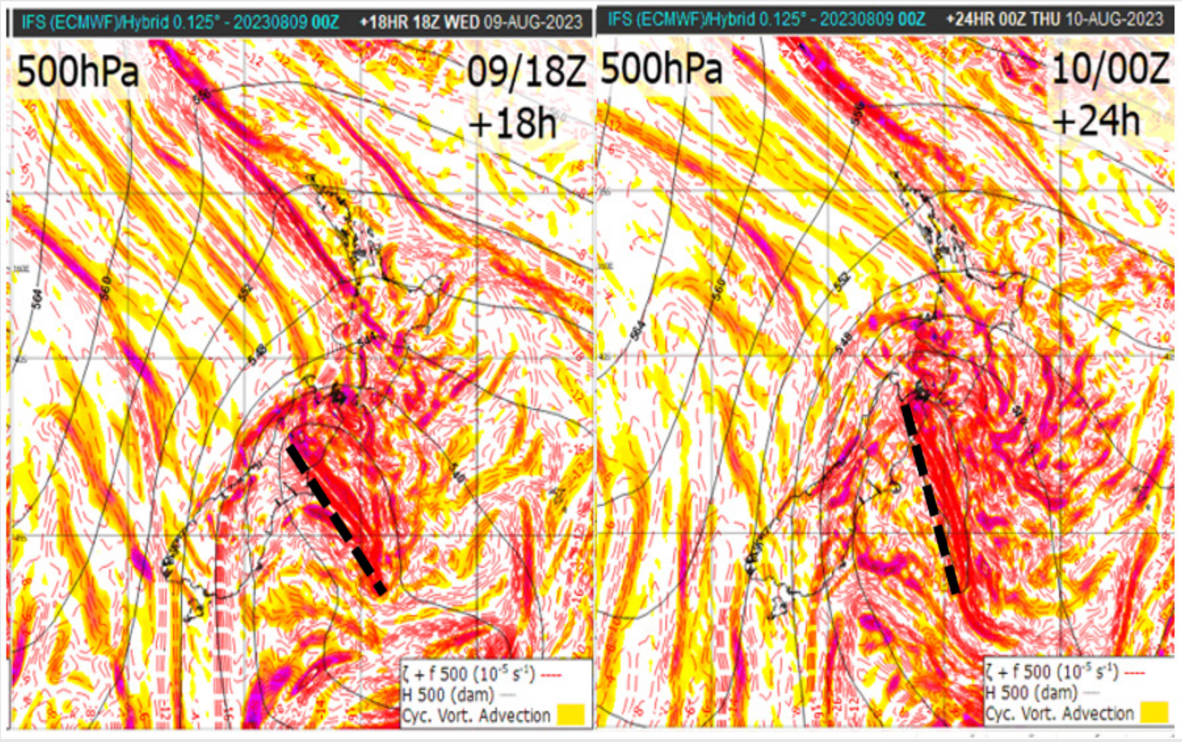

Figure 5: ECWMF 500hPa modelled fields identifying cyclonic vorticity (marked with black line) at 6am 10 August (left) and advecting towards Wellington at noon 10 August 2023 (right).

Figure 6: Identifying a few locations of interest in this event.

After the cold front:

For the second half of the event, the surface low gradually moves eastwards and allows a showery, strong southerly wind flow to push continuously through Wellington.

Of course, when we're looking at showers, we are very interested in these becoming deep enough to reach the aforementioned dendritic zone. There are various ways we can do this, but one important contributing factor is the 500hPa temperature field. If this is sufficiently cold, it can enhance the buoyancy of rising air from below, and again assist with our all important upward motion.

The modelled 500hPa temperature at midnight 10 August 2023 was still expected to be colder than -30°C, still being close to the axis of the cold upper trough (Figure 8). We would not expect showers to ease or become shallower until that cold trough has moved away from Wellington, and this proved to be the case (Figure 9).

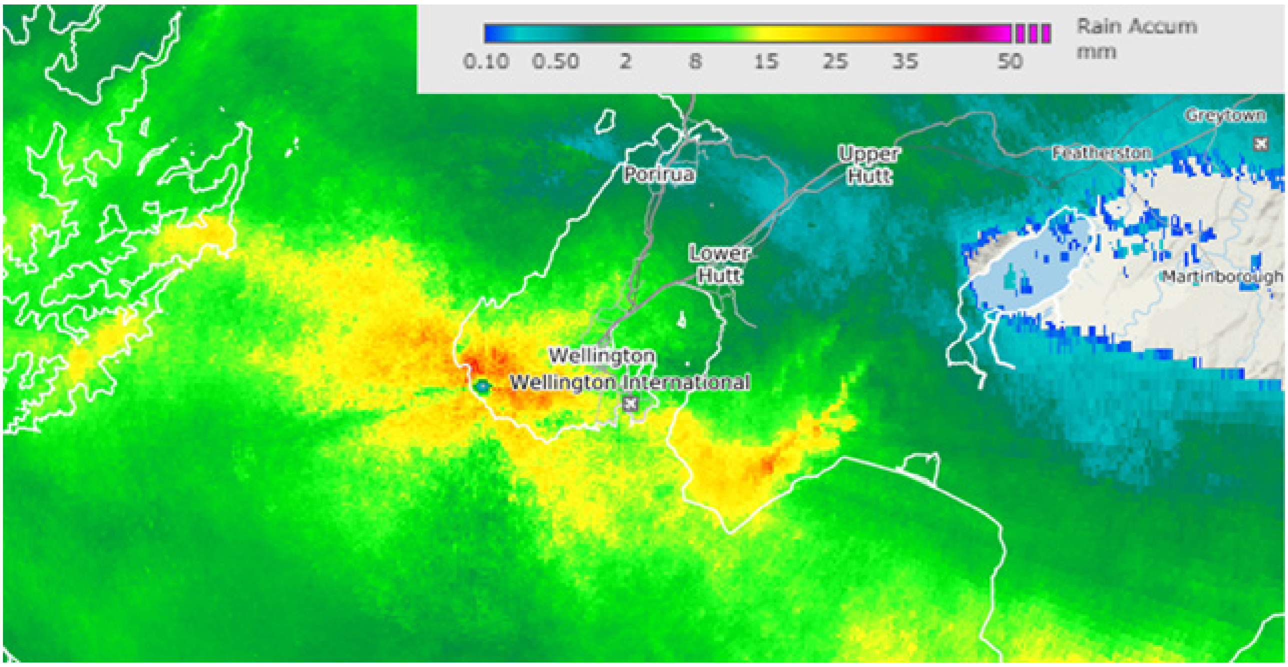

Figure 7: Wellington radar gauge corrected accumulations for 3 hours between 4am and 7am 10 August 2023. Orange colours indicate totals 15-25mm, with red colours indicating totals of 25-40mm.

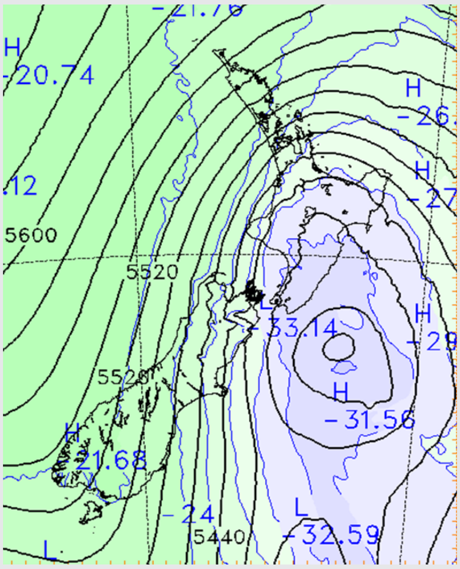

Figure 8: The modelled 500hPa temperature at midnight 10 August 2023. Blue colours depict 500hPa temperatures below -30°C.

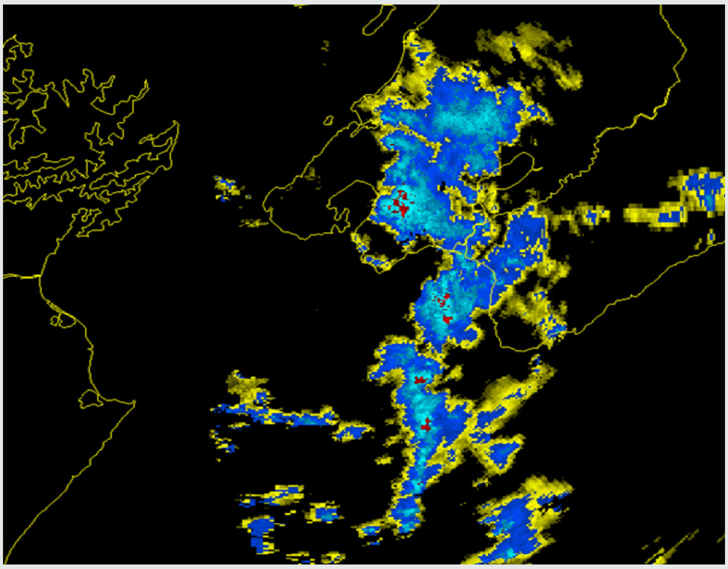

Figure 9: A radar snapshot shortly after midnight 10 August 2023 shows heavy showers tracking into the Remutaka Range, bringing snow to some higher parts of the ranges.

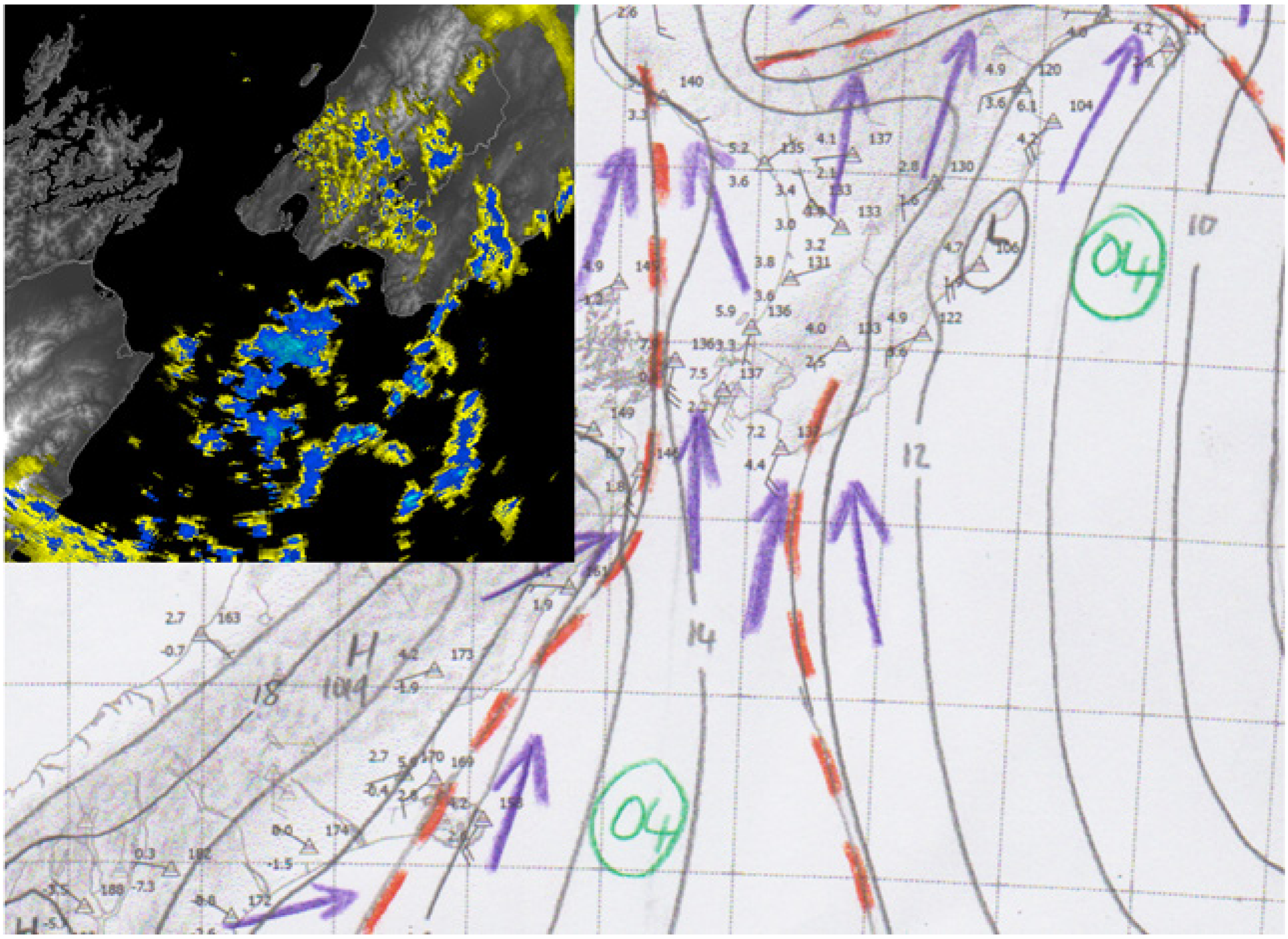

Figure 10: Surface analysis valid at 9pm on 10 August 2023 showing isobars, generalised wind flow (purple arrows) and analysed surface troughs (red dashed lines). Green numbers represent wet bulb potential temperatures.

During the post-frontal period, the precipitation was characterised by more meridionally oriented troughs within the broad southerly flow. These would enhance surface convergence and lead to periods of more organised showers. Outside of these troughs, showers would tend to be more sporadic. Figure 10 shows an indicative image of this period.

Two weather stations illustrate the divisions of this event effectively (Figures 11a, 11b). Kelburn (MetService), at 120m asl and Orongo Swamp (GWRC) at 420m asl. Both stations are at elevations where all precipitation would have fallen as rain. Kelburn received 28mm of rain from 3am on 10 August 2023 until 7am on 11 August 2023, and Orongo Swamp 33mm in the same time period, which are comparable amounts. However, Kelburn saw around 85% of its rainfall fall during the stalled frontal period, and just afterwards (up until 10am on 10 August). In contrast, Orongo Swamp received much of its rainfall during the post-frontal period, during prolonged showery conditions, leading to a more even distribution of its rainfall over time.

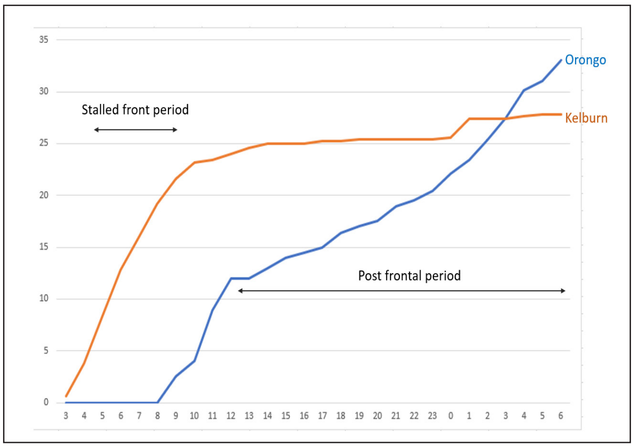

Figure 11a: Rainfall accumulation (mm, vertical axis) from 3am on 10 August to 6am on 11 August (horizontal axis) for Kelburn and Orongo Swamp weather stations.

3, OBSERVATIONS

In comparison to the rain observation network, there is a relative lack of direct, real-time snow observations through

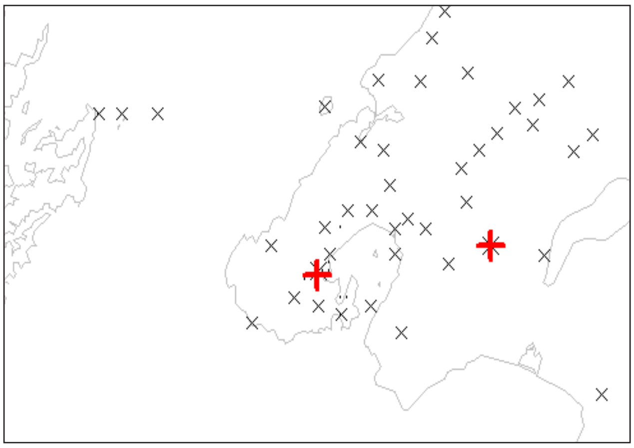

Figure 11b: Red crosses mark the location of Kelburn (left) and Orongo Swamp (right).

the Wellington region. Sometimes, field observations are the only way to gain feedback on an event. A former Meteorological Society member, Tom Adams, and his canine assistant Katla, mounted an expedition to assess the snowfall the following morning (11 August 2023). Tom measured 10-15cm of snow on Mt Climie in the Remutaka Range (Figure 13), at an elevation of approximately 900m asl with the smallest accumulations extending down to around 500-600m asl.

4. SUMMARY

This article is an overview of the most important factors relevant to Wellington snowfall, and then compared against a recent event. It has only really scratched the surface, but the author hopes it will elucidate some details. In this era, forecasters have access to a lot of sophisticated, highly derived NWP output. During the forecasting process, this guidance should be balanced with a physical understanding of the situation to assist in appropriate decision making.

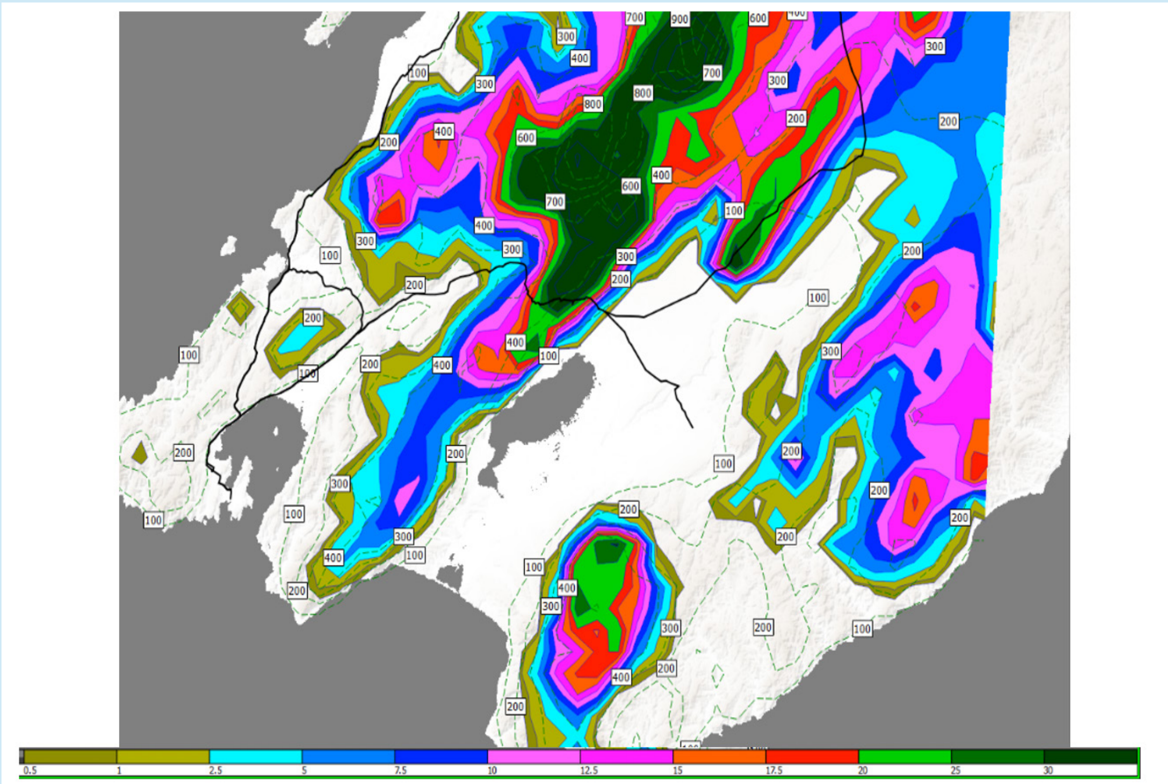

Figure 12: Derived snow accumulation guidance from an ECMWF IFS WRF 1.5km model. This shows 24hr snow accumulations (cm) up to midnight 10th August 2023.

Shadings depict snow accumulation. Black lines are State Highways and dashed, labelled lines depict the model terrain heights (metres asl).

In operational environments, forecasters must assess this type of guidance and filter for the plausible and implausible. For example, in this case, the accumulations over the Remutaka Range and Tararua Range may be given more credibility than some of the spurious looking accumulations at near-sea level in the Wairarapa.

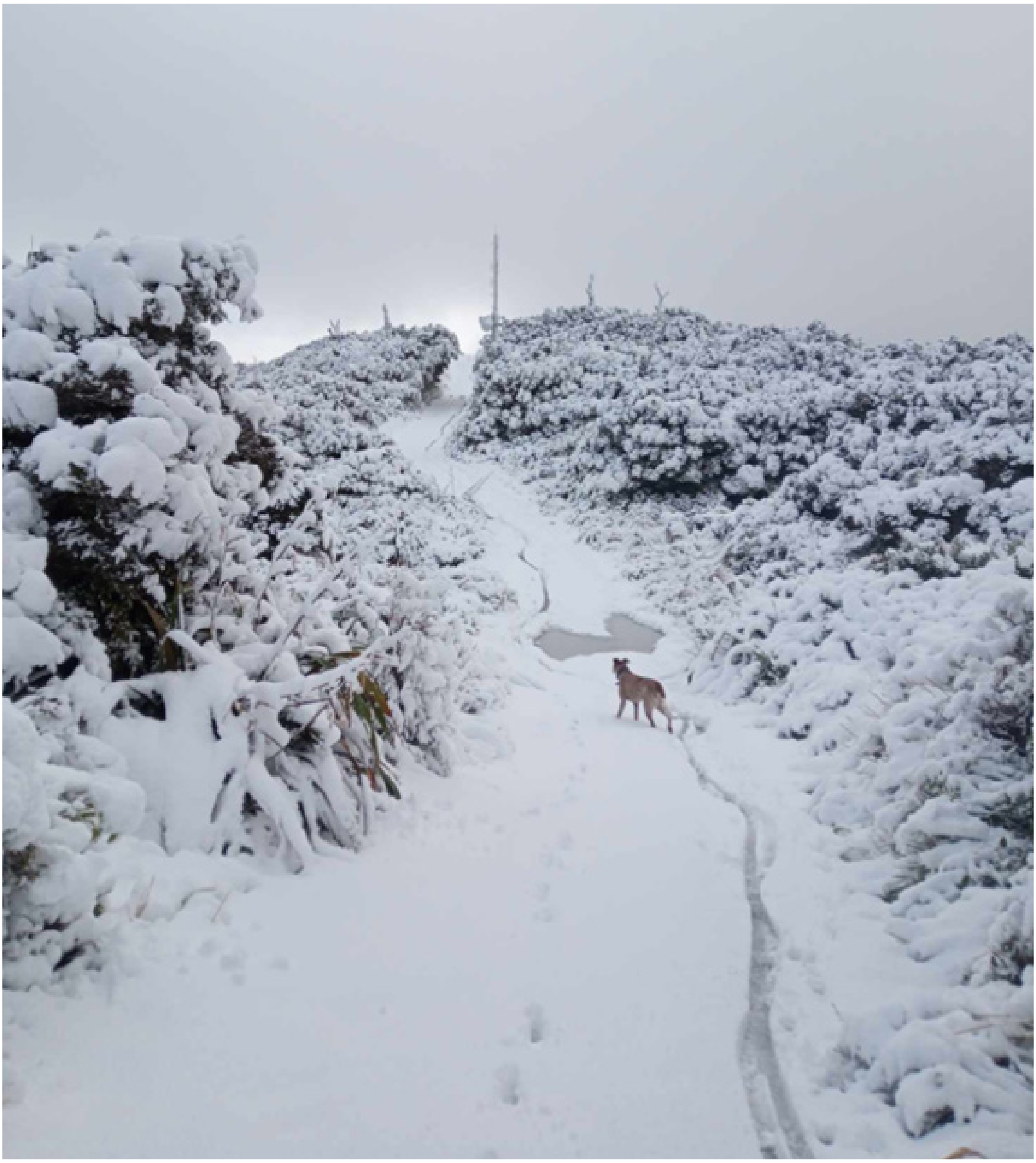

Figure 13: Katla and snowfall on Mount Climie, Remutaka Range. Photo credit: Tom Adams.