SUMMER CONVECTION OVER THE SOUTHERN NORTH ISLAND

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INTRODUCTION

In summer, when meteorological conditions are favourable, daytime solar heating of the Earth's surface and subsequently the air in contact with it, results in a decrease in atmospheric stability. The reduced stability can lead to the formation of convective clouds which typically reach their peak development in the late afternoon. Sometimes these clouds produce showers which, under optimum conditions, are torrential and accompanied by thunderstorms.

Hills and mountain ranges, which provide heated ground at higher elevations and upslope winds along their flanks, are favoured localities for the formation of these convective clouds and showers. However, other influences can dictate precisely where, and to some extent when, the major convection occurs on any particular day. For example, subsidence related to upper level wind patterns can hinder or prevent daytime convective activity; again, low level convergence of air into a region of vigorous convection in one place will create divergence in a nearby locality and inhibit convection there.

Conditions favourable for daytime heating and convective activity over the southern part of the North Island prevailed during six consecutive days in mid-February 1990. Throughout this time (13-18 February) the general weather situation changed very little, thus providing a unique opportunity to observe from day to day the location and intensity of the peak convection, and to speculate on why this should be so.

The detailed observations of cloud and wind patterns, without which this study could not have been attempted, were made by the authors — one located at Paraparaumu, the other at Masterton (locations shown in Figure 1a). In the prevailing cloud and visibility conditions, it is believed that these observations reliably recorded cloud and precipitation within some 30km of a line joining the two sites. The observations were also used for the construction of vertical cross sections across the island for key times of the day. Because of the strong solar influence on the events studied, all times of day and dates are in N.Z. Standard Time, since this corresponds most closely to 'sun time'. A few technical terms used when describing clouds are explained in Appendix 1.

Overview

Following the passage of a weak cold front northward over central New Zealand on 12th February 1990, a high pressure ridge extending from an anticyclone (central pressure 1027hPa) located south of the Tasman Sea extended northward to cover the seas between New Zealand and the Chatham Islands, a position it continued to occupy through to the 18th. Meanwhile a depression, off the New South Wales coast on the 12th, drifted as far as the central Tasman Sea by the 14th, where it too became stationary from then until it decayed away on the 17th ahead of a trough advancing from Australia (Figure 2).

This isobaric pattern indicated that there was a gentle northeasterly airflow at low levels over central New Zealand from the 13th to the 18th. However, the northeasterly was very shallow and from just above the surface winds were predominantly west or northwesterly throughout the low and middle troposphere, rarely reaching 20 knots (see the vertical time section of winds at Paraparaumu: Figure 3). Only in the upper troposphere did speeds approach or exceed 50 knots. A general indication of winds over New Zealand in the high troposphere (at 250hPa, approximately 10,500m) is given in Figure 4. Significant trough passages (when winds changed from northwest to southwest) occurred on the 12th and about midnight on the 18th. In be-

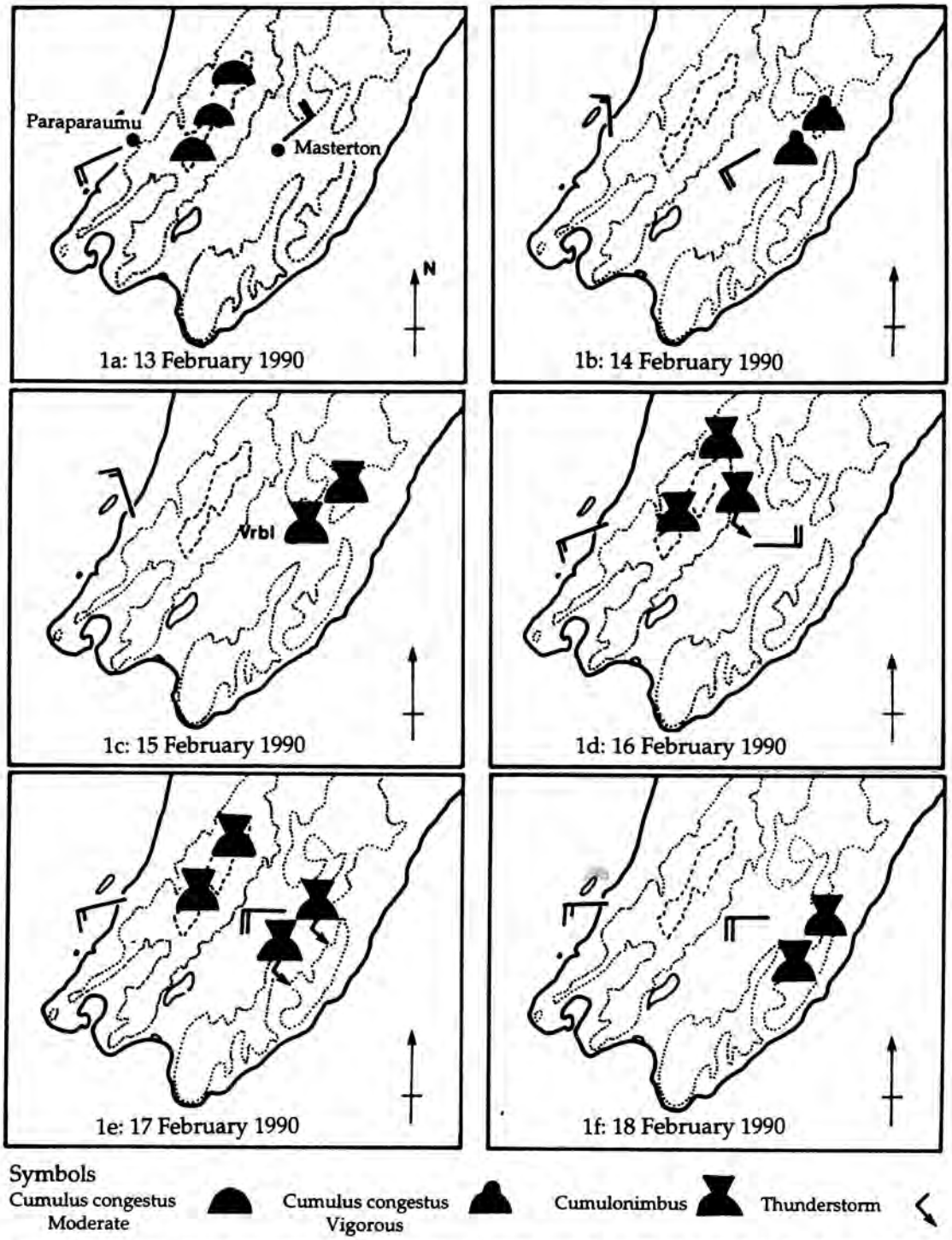

Figure 1: Location and peak intensity of daily convective activity over the southern part of the North Island during 13-18 February 1990. Height contours are shown at 300 metres (dotted) and 900 metres (dashed).

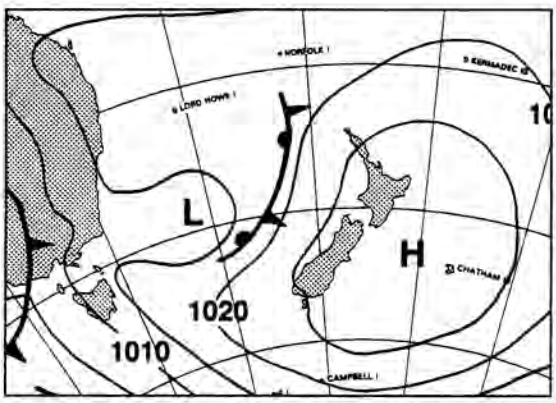

Figure 2: Mean sea level analysis, 0000 17 February 1990.

tween there were two minor, rather poorly-defined troughs, one late on the 13th and the other late on the 15th. As will be seen diurnal convection became progressively more vigorous from the 13th to the 17th, and so it is assumed that neither minor trough produced any noticeable effect on stability. However, accompanying features in the lower troposphere, also poorly defined, probably contributed to changes in the distribution of convection.

Northwesterly and westerly winds in the middle and upper troposphere carried cloud, generated within the Tasman Sea depression, across central New Zealand. Initially (on the 13th) this cloud was dense enough to reduce the solar heating but thereafter the cloud arrived in a progressively dissipated state and daytime temperatures on the plains of Wairarapa daily reached the upper 20s or low 30s Celsius. That the atmosphere was in a state conducive to deep convection was revealed by elements of this cloud which displayed castellanus features (see Appendix 1). Castellanus indicates the presence of instability in the upper troposphere which, in this case, contributed to the vigorous nature of the daytime convection.

The convective period

On each of the six days from the 13th to the 18th of February 1990, daytime heating produced a cycle of convective activity, which began in the morning, reached a peak in the late afternoon, and died out in the evening. With light winds throughout the low and middle troposphere and very little vertical wind shear, convective clouds moved only slowly and were nearly vertical.

This section of the report focuses attention on the intensity, location, and possible reasons for each day's peak convection; a more detailed description of weather conditions, day by day, is given in Appendix 2.

13th February 1980 — (Figure 1a):

Cloudiness in the high and middle troposphere reduced daytime heating: this, and a subsidence inversion in the lower troposphere (associated with the recently-arrived high pressure ridge), limited peak convection to modest cumulus congestus over the Tararua range. Further east cloud tops spread out to form a stratocumulus layer located beneath the inversion.

14th February 1990 — (Figure 1b):

Vigorous cumulus congestus reached peak development over hilly ground east and northeast of Masterton. Earlier in the day, cumuli were developing most prominently both there and over the Tararua range; however, in the afternoon subsidence spread from the west causing the cumulus over the Tararua range to decay. Those further east continued to develop for an hour or two before reaching peak activity which culminated in a small shower; the subsequent decay that took place towards evening would have been driven, at least in part, by the normal diurnal heating cycle but could have been assisted by the arrival of the region of subsidence that earlier affected the region of the Tararua range. No satisfactory explanation can be offered for the region of subsidence; it is known that winds in the high troposphere over central New Zealand were anticyclonically curved and cyclonically sheared, much as they were on the previous day (see Figure 3a).

15th February 1990 — (Figure 1c):

As on the 14th convection developed over both the Tararua range and the hills northeastward of Masterton; however, after midday, for reasons unknown, clouds to the northeast of Masterton had become the more vigorous and proceeded during the afternoon to evolve into cumulonimbus. The cumulonimbus cloud tops, reaching greater altitudes than had yesterday's cumulus congestus, entered the much stronger upper tropospheric westerlies (Figure 4b) and were carried away east-

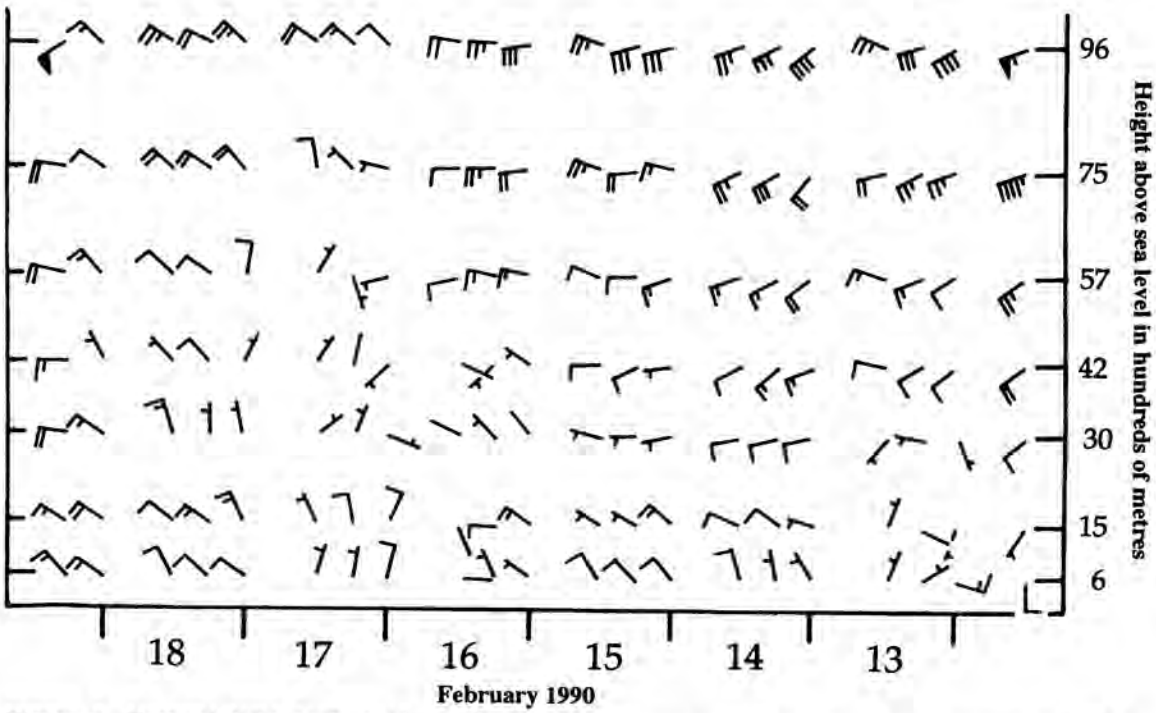

Figure 3: Vertical time section of winds over Paraparaumu.

wards. Meantime, new cumulus congestus towers, rising in their stead, evolved into cumulonimbus whose tops in turn were advected away.

16th February 1990 — (Figure 1d):

Active cumulus congestus formed over both the Tararua range and the hills to the northeast of Masterton. In the afternoon cumulonimbus clouds developed over the Tararuas but the cumulus northeast of Masterton ceased developing and then decayed as a "sea breeze" from the east coast terminated convective currents in its wake. In all probability the easterly brought about increased low level convergence towards the foothills of the Tararua range northwest of Masterton where convection intensified and a brief thunderstorm took place before the evening decay of convective cloud.

17th February 1990 — (Figure 1e):

Convection over the Tararua range evolved steadily to produce a bank of cumulonimbus along the full length of the range by early afternoon. Up to that time convection to the east of Masterton had proceeded only as far as moderately active cumulus congestus. After this time, clouds over the Tararuas edged out over western Wairarapa, gradually decaying; only isolated active convection persisted over the range. However, to the east and southeast of Masterton, vigorous cumulus congestus evolved into a large cumulonimbus which produced almost continuous thunder for half an hour followed by less frequent peals for a further half-hour. This most active convective phenomenon of the period occurred at a time when winds throughout the troposphere were unusually light (Figure 3) and in circumstances particularly favourable for intense convection — a diffluent region with pronounced cyclonic curvature and cyclonic shear at 250hPa (Figure 4c).

18th February 1990 — (Figure 1f):

The cumulus congestus which formed over the Tararua range reached, at its afternoon peak, no more than moderate intensity. It was near midday before cumulus congestus eventuated northeast and east of Masterton; during the afternoon this area of convection slowly receded eastwards, evolving into cumulonim-

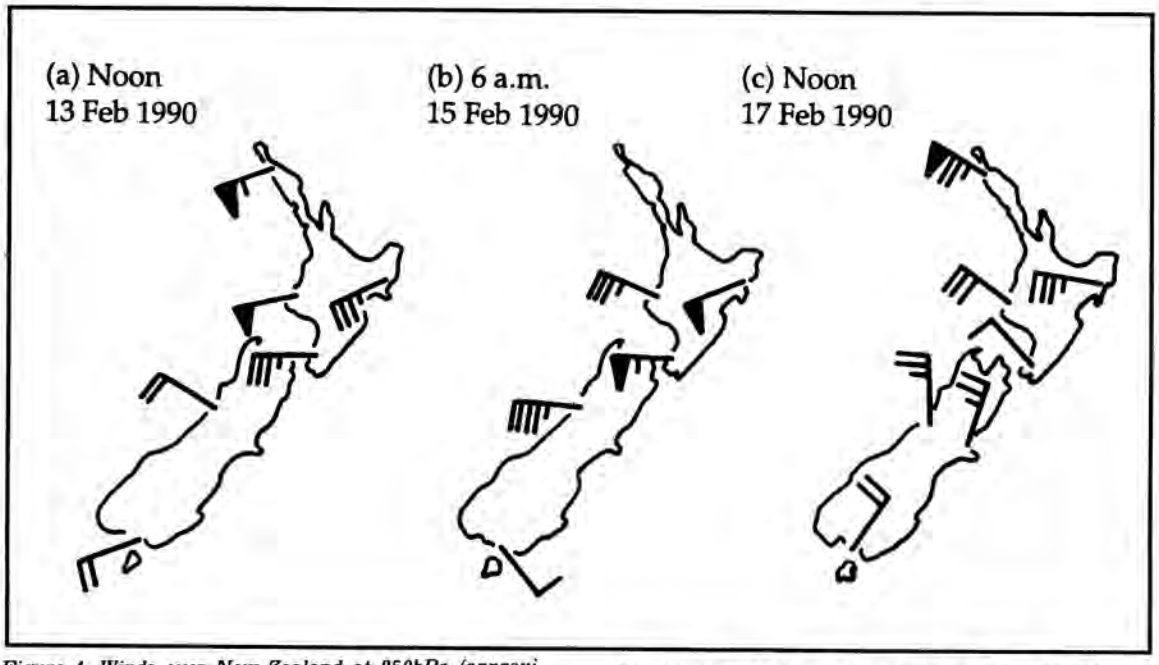

Figure 4: Winds over New Zealand at 250hPa (approximately 10,500m).

bus which probably did not reach peak activity until it was near the east coast. These events occurred at the time when the atmospheric conditions favourable for convection were moving eastwards off New Zealand.

SUMMARY AND CONCLUSION

In the synoptic weather regime which prevailed during the study period convection would be expected to occur over and in the lee of the main ranges (heat sources). This explains the comparative absence of convective activity on the west coast. Heavy convective precipitation was observed extending to the western foothills of the Tararuas on the 16th and possibly the 17th, the only time that the winds had an easterly component through a significant depth of the atmosphere, albeit weak (Figure 3).

Related to the above, the diurnal tendency for peak convection to occur progressively downwind on several of the days has been noted, a feature clearly brought out in the vertical cross sections (not shown). The main exception to this general pattern (on the 16th) appears to have resulted from subtle changes in the configuration of the anticyclone cells to the south which were driving the low-level windflow.

Further investigation of the factors controlling the distribution of convection would require more detailed and extensive data which were not readily available to the authors.

APPENDIX 1 Technical Terms

Congestus: Cumulus clouds which are **markedly sprouting** and are often of great vertical extent; their bulging upper part frequently resembles a cauliflower.

Castellanus:* Clouds which show, in at least some portion of their upper part, cumuliform protuberances in the form of turrets which generally give the clouds a crenelated appearance. The turrets, some of which are taller than they are wide, are connected by a common base and seem to be arranged in lines. The castellanus character is especially evident when the clouds are seen from the side.

* Some authorities favour the spelling Castellatus

APPENDIX 2 Detailed description of weather conditions

13 February 1990

Although cumulus developed rapidly over Wairarapa about midday, the presence of low

level stability associated with the onset of a ridge of high pressure and the lack of intense solar heating meant that most cumuli were contained below an inversion, beneath which a layer of high stratocumulus or altocumulus formed. Only over the main Tararua range was there a period of afternoon cumulus congestus. By late afternoon convection was declining everywhere. While moderate northeasterlies blew all day in Masterton, a moderate sea breeze developed by midday at Paraparaumu.

14 February 1990

With less upper cloud to hinder solar heating, convective activity was greater than on the previous day and enough to produce showers before convection was suppressed progressively from the west in the afternoon. Just as showers began over the Tararua range in the early afternoon, the first indication of subsidence occurred off the Kapiti coast. There a layer of high stratocumulus/altocumulus, which had temporarily thickened (with light precipitation) began clearing. Within an hour or two convection over the Tararua range was suppressed. A little later, by 4 p.m., intense convection that had occurred over the Wairarapa was declining in the west; but to the east and northeast of Masterton it remained strong enough to give a small, light shower on the nearby hills. After 5 p.m. convective clouds everywhere were decaying. At Paraparaumu there were gentle breezes from the northerly quarter. At Masterton, a light northeasterly changed to a moderate southwesterly between 3 and 4 p.m., less than an hour after convection over the Tararua range started to decay.

15 February 1990

Convective activity followed a typical diurnal cycle. Commencing mid-morning, cumulus became progressively taller until, by early afternoon, scattered cumulonimbus had evolved together with showers. Activity waned from 5 p.m. Whereas at their peak in early afternoon convective cloud over the Tararua range resulted in no more than cumulus congestus, convection peaked later over higher ground to the northeastward of Masterton, where cumulonimbus clouds with showers occurred late in the day. There were light or moderate north to northeast winds at Paraparaumu. At Masterton winds were variable, directions later in the afternoon being dictated by in- and out-flows associated with nearby convective activity.

16 February 1990

Cumulus began to develop in the morning; however, at least in Wairarapa, convection was less intense initially than on the 15th. Early in the afternoon cumulonimbus clouds developed more or less simultaneously over both the Tararua range and the foothills northwest of Masterton. The arrival over the Wairarapa plains of maritime air from the east at about 3 p.m. was followed by: a) the elimination of existing cumulus in its wake, and b) the intensification of the remaining convective clouds over Wairarapa — those over, or near, the Tararua range. There was a brief thunderstorm northwest of Masterton between 3 and 4 p.m. The usual late afternoon decay of cumulus and cumulonimbus was accompanied on this occasion by the presence of greater quantities of stratocumulus and suppressed cumulus than on previous days. At Paraparaumu a moderate sea breeze set in during the morning; at Masterton winds were very light until mid-afternoon, when there was a period of moderate, gusty easterlies.

17 February 1990

Convection was the most extensive and intense of the period. It began as usual in the morning and by midday cumulus congestus showed intense convection over the northern part of the Tararua range. Within two hours, cumulonimbus (and showers) formed a continuous bank along the length of the range. Further east, convection became concentrated in a bank along the hills adjacent to the eastern edge of the Wairarapa plains; by 2 p.m. showers began falling there. By 3 p.m. the cumulonimbus bank along the Tararuas was displacing eastwards; meanwhile the separate bank of very intense cumulus congestus east of Masterton evolved into a cumulonimbus complex with thunderstorms. Between 3 and 4 p.m. there was an initial 30-minute period of almost continuous thunder, then less frequent peals. Although by 6 p.m. there was much decayed cloud from degenerating cumulonimbus, scattered cumulus continued to build into cumulonimbus well on into the evening. At Paraparaumu a gentle northerly was interrupted at times by a sea breeze. A light morning northeasterly at Masterton was re-

placed in the afternoon by moderate variable winds whose directions were dictated by in- and out-flows associated with the intense convection.

18 February 1990

Convection over the Tararua range was much reduced in comparison to yesterday's; even in the afternoon it was never greater than moderate cumulus congestus. By late morning over Wairarapa, developing cumulus congestus had already reached moderate intensity. In the afternoon convection over the plains was suppressed progressively from the west; only over the hills east of the plains did it intensify; a cumulonimbus complex formed by mid-afternoon but by then lay over the hill country towards the east coast. By 5 p.m. most convective cloud had decayed. A sea breeze blew at times at Paraparaumu, replacing a light to moderate northerly. A light northerly drift at Masterton became a moderate westerly in the afternoon at the time when convection over the plains became suppressed.