JP4J.4 SOME 3D ASPECTS OF A STRIATED CLOUD HEAD OVER NEW ZEALAND INCLUDING RADAR AND RAINGAUGE DATA

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1. INTRODUCTION

One of the most damaging extratropical cyclones over central New Zealand occurred on 15/16 February 2004. Although late summer in the Southern Hemisphere (SH), it resulted from a polar outbreak more typical of wintertime (Fig. 1).

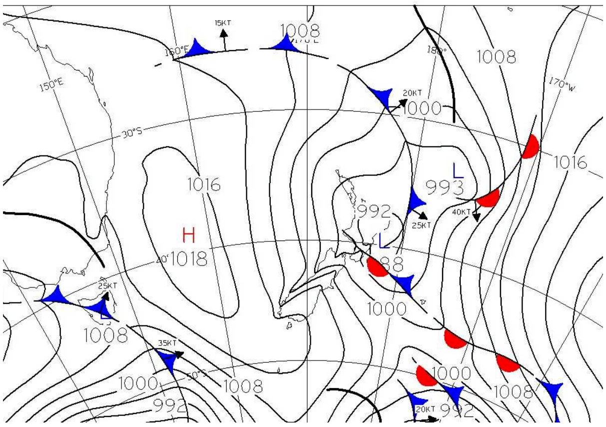

Figure 1. MSL analysis 00 UTC 15 February 2004 (noon NZST).

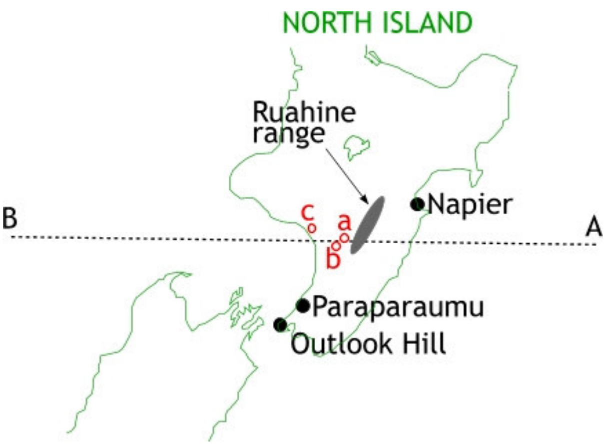

Figure 2. Location map for the southern North Island of New Zealand.

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Prolonged heavy rain with a return period of 150 years or more affected the southern North Island (Fig. 3).

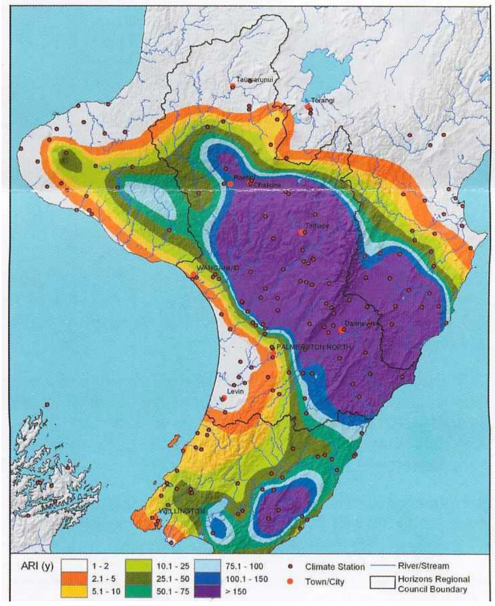

Figure 3. 24 hour rainfall recurrence intervals for the storm prepared by National Institute of Water and Atmosphere (NIWA) for Horizons Regional Council (HRC) and including their raingauge data. Purple area is in excess of 150 years.

Flood waters damaged bridges, swept away livestock and inundated farmland, leaving large amounts of silt in their wake. Severe southerly gales also affected coastal areas of central New Zealand.

There were several unusual mesoscale aspects to this storm:

(a) extent of the heavy rain; there was almost as much in the lee (western) side of the Ruahine range (Fig. 2) as on the upwind (eastern) side
(b) striated cloud head over the southern North Island capped by a dry intrusion and very low tropopause, as well as a prominent striated delta further east
(c) moving bands of radar echoes and fluctuations in rainfall rates in phase with the more prominent cloud striations.

2. INTRUSION OF DRY, HIGH IPV AIR ALOFT

Cyclogenesis was associated with a large negative IPV anomaly (cyclonic in the SH) as low as –6 PV units at about 400hPa which moved from the Southern Ocean and reached the North Island on 15 February. See Billingsey, for an explanation of the theory. It coincided with an intrusion of very dry air aloft with RH down to 40% or less (Fig. 4) similar to the case described by Young et.al. (1987).

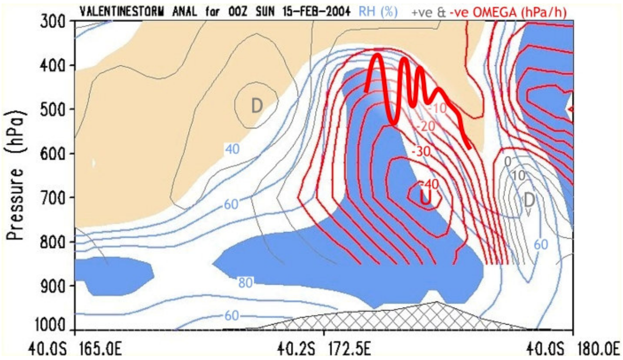

Figure 4. Cross section along BA (Fig. 2) at 00 UTC 15 February of RH (blue shading 80% or more, tan 40% or less), omega (thin red lines denote ascent, thinner black lines descent) from NCEP data. Height of cloud top striations (thick wavy red line), see also Fig. 6.

The nose of the dry intrusion was still descending as confirmed by HYSPLIT trajectory plots but there was weak ascent at high levels by this time.

3. WARM CONVEYOR BELT

Fig. 4 also shows an inclined zone of ascent sloping up from low levels east of the main ranges, peaking near 700hpa over the Ruahine range but reaching up to about 400hPa further west. Moisture convergence (not shown) peaked below the core of strongest ascent.
Radiosonde flights from Paraparaumu revealed that south to southwest winds at low levels were over ridden above about 750hPa by air with potential wet bulb temperatures (PWBT) 2C or more higher coming from the easterly quarter.

A picture thus emerges of an airstream which started at 2000m or less but rose rapidly to middle levels of the atmosphere over the southwestern parts of the North Island. It had the characteristics of a warm conveyor belt which carried moist, strongly ascending air across the ranges and ascent continued on the lee (western) side (Fig. 5).

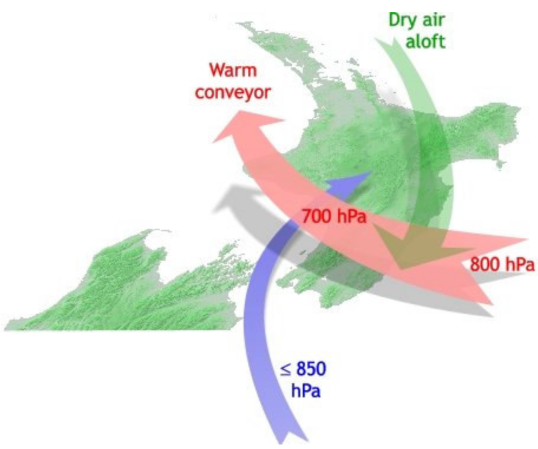

Figure 5. Schematic 3D flows showing warm conveyor rising above a wedge of low level southerly winds and overlain by an intrusion of dry air aloft.

4. STRIATED CLOUD HEAD

The cloud associated with the warm conveyor took the form of a striated cloud head on the morning of 15 February, with bands oriented approximately from north-northwest to south-southeast near the centre of Fig. 6.
The striations were not apparent before 19 UTC. By 21 UTC they were numerous and spaced about 7km apart. By 23 UTC the striations became fewer, broader, and further apart. The more prominent ones were moving westwards.
Also shown on the right of Fig. 6 is a portion the cirrus shield of a larger striated delta. Feren (1995) associated the latter type of cloud system with major cyclogenesis but the focus here is on the cloud head.

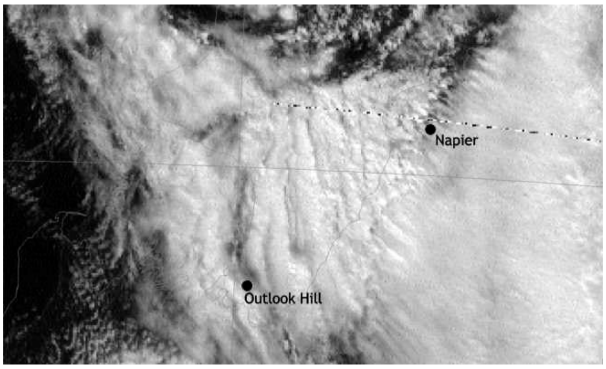

Figure 6. Visible geostationary satellite picture over southern North Island at 23 UTC 14 February. Napier and Outlook Hill are correctly positioned but the coastline is in error.

The striations of the cloud head took the form of wavelike undulations of the cloud tops (Fig. 7).

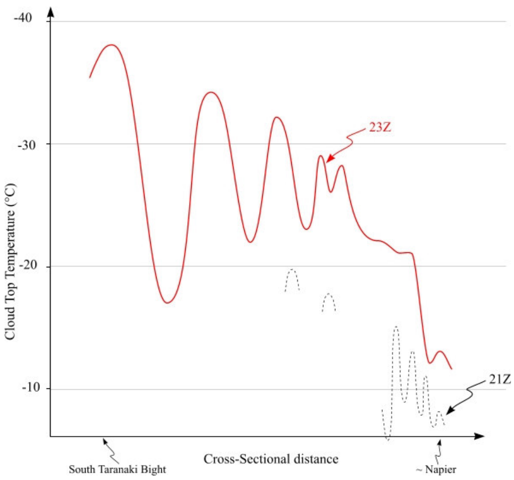

Figure 7. Simplified schematic cloud top temperature trace along a cross section of the cloud head. Note that this slice is oriented along about 240 degrees from near Napier at right, that is it crosses B-A at about a 30 degree angle. Solid red line at 23 UTC 14 February and partial dotted trace at 21 UTC.

This structure is similar to the Northern Hemisphere examples described by Dixon et.al. (2000). As the striations moved westwards, wavelength and amplitude tended to increase with time and distance downstream suggesting that energy was being fed into the system.

Note that the overall height of the striations increased with time, they were capped by the dry intrusion aloft and occurred near the top of the warm conveyor belt (see also Fig. 4).

5. RADAR AND RAINGAUGE DATA

Similar bands were also visible in scans from the Wellington weather radar (they are clearer in looped PPI images where they are visible east of the Ruahine range as well) and moved in phase with the more prominent cloud top striations (Fig. 8)

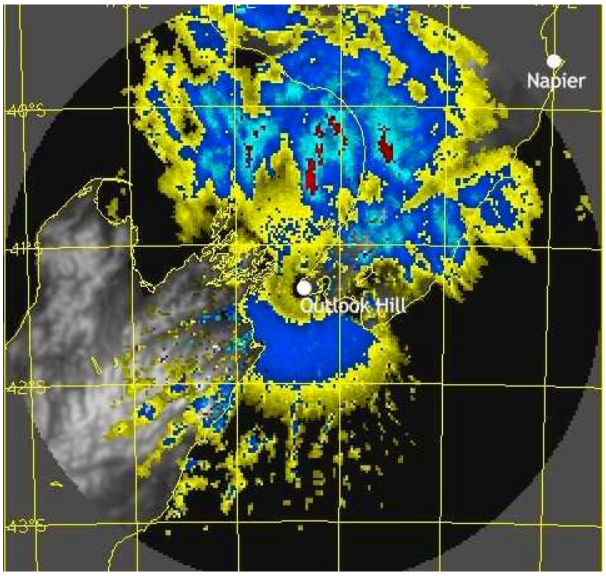

Figure 8. 0.5 degree elevation scan from Outlook Hill radar at the same time as Fig. 6 showing banding within the broad area of rain echoes north of the radar (they are more obvious in looped images). Blue is 20-30dbZ, light blue 30-40dbZ and red 40-45dbZ. The range is 240km.

The bands of stronger radar echoes correspond closely to the more obvious striations in Fig. 6, including a suggestion of double structure to the middle one.

A vertical slice across these half an hour later (Fig. 9) clearly shows three discrete bands with 20-30dbZ echoes as high as 7 or 8km. The central band is fairly symmetrical but the others are noticeably skewed. The strong cores within the bands suggest that there was embedded convection but although there was a lot of lightning over the North Island, none was detected within the striated part of the cloud head.

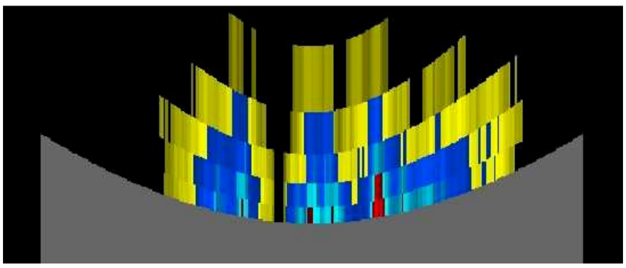

Figure 9. Radar cross section at 2330 UTC parallel to B-A but slightly further south through the strongest echoes. Height scale is 0 to 12km above the radar (altitude 0.5km) and range to edge of figure is 240km. Range to the image centre is about 100km where the curved base of the lowest beam is about 2km above the ground.

Horizon Regional Council raingauges a, b and c in Fig. 2 detected peaks in rainfall intensity which coincided with the passage of one or more bands of strong radar echoes above:

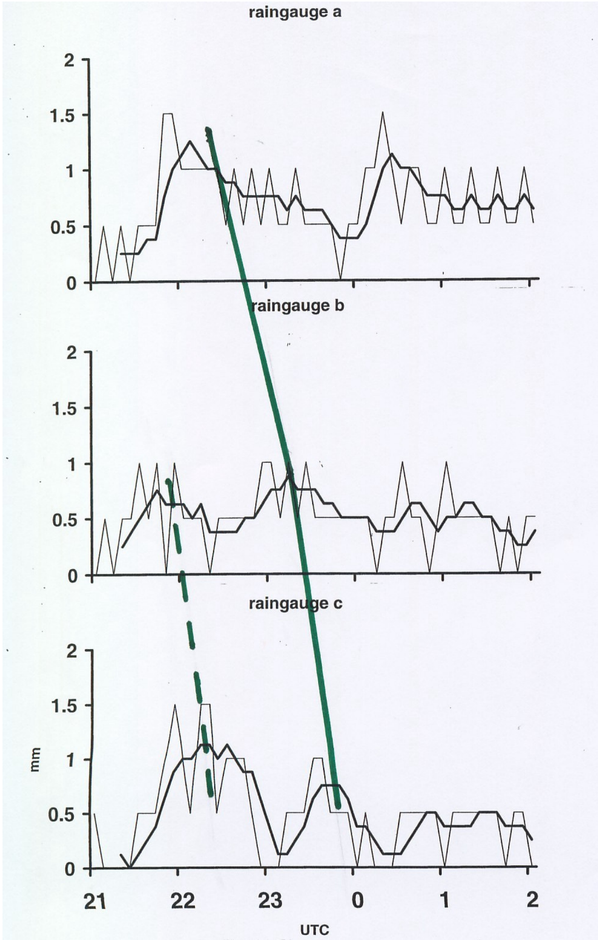

Figure 10. 6 minute rainfall in mm (thin lines) and running mean (thicker curves) from gauges a, b and c from 21 UTC 14 February to 02 UTC 15 February.

The thick green line in Fig. 10 corresponds to the righthand band of strong radar echoes in Fig. 9 and the dashed green line to the middle one.

7. MM5 CLOUD WATER REPRESENTATION

Vis5D was used to view MM5 output run over a restricted domain at 5km resolution to see if the mesoscale model could resolve any banding features. It is difficult to show clearly in one picture, but sequences of cloud water images showed the formation of bands stacked in a slantwise fashion sloping up to the left (west) before merging into a deeper area of cloud water. They can just be discerned immediately to the right of centre of Fig. 11. However, these bands were stationary and slightly further north compared with those observed.

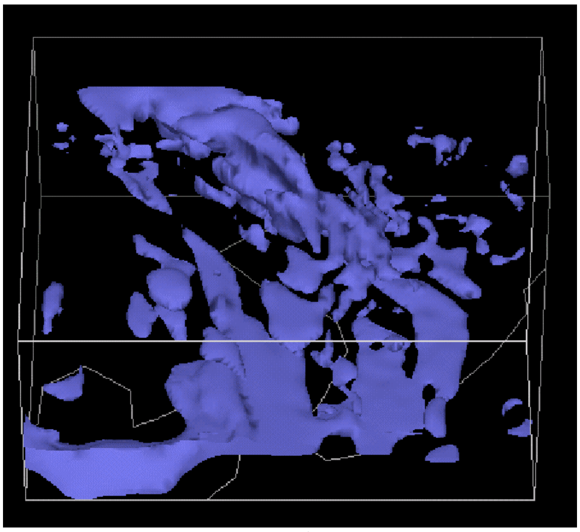

Figure 10. Vis5D display of MM5 cloud water at 2330 UTC February, 17.5 hours from the start of the model run. It is an oblique view looking down and to the north. The land area is approximately 70% of Fig. 2.

6. SUMMARY AND CONCLUDING REMARKS

A period of unusually widespread heavy rain over the southern North Island of New Zealand was caused by a slowmoving warm conveyor belt which carried ascent far across to the lee side of the main ranges.
A striated cloud head was associated with the warm conveyor. The striations took the form of westward moving wavelike undulations in the cloud tops. Wavelength and amplitude increased rapidly with time and distance downstream.
PPI radar loops showed that rain echoes were modulated in bands that coincided with the more prominent cloud top striations, and cross sections revealed strong convective type cores within the bands. Raingauge data also showed westward moving peaks in rainfall intensity up to about 10mm per hour. This implies that the vertical motions causing the cloud top striations extended through a substantial depth of the troposphere.
MM5 data at 5km resolution hinted at some of these features, namely an increasing depth of cloud water roughly along the warm conveyor and the development of transverse banding stacked slantwise along part of it. It shows that a three dimensional viewer such as Vis5D used in conjunction with high resolution model output has the potential to be a powerful operational tool for mesoscale forecasting and not just for case studies.

ACKNOWLEDGEMENTS

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