CLOUD HEADS — PRECURSORS TO RAPID CYCLOGENESIS

Mark Pascoe

Meteorological Service of New Zealand Ltd, Wellington, New Zealand

ABSTRACT

The cloud head has been known about for several years, and has been found to be precursor to the development of depressions containing hurricane force winds. The appearance of a cloud head preceded such notable British events as the 'Great Storm' of October 1987, and the 'Burns Day Storm' of January 1990.

It is shown that cloud heads are not uncommon in the New Zealand area. Often however, some of the essential features are only weakly present. In such cases, 'rapid' cyclogenesis will occur, without necessarily the development of hurricane force winds.

INTRODUCTION

The cloud head was first described by Bottger et al. (1975). The Bottger team found 22 cloud heads in the Atlantic Ocean in the period 1968-73. In every case without exception, the cloud head developed into a depression containing hurricane force winds.

The main features were described as follows:

1. An unusually large, dense slab of cloud.
2. A well-defined, anticyclonically-curved rear edge.
   This suggests that the upper flow turns strongly anticyclonic after it emerges from the upper trough to the rear of the system. In other words, there is strong cyclonic vorticity advection (CVA) over the cloud system.
3. Open cell cloud entering the rear edge.
   This suggests increasing baroclinicity within the system.

The above are the three features essential for the identification of a cloud head.
Sometimes also, the following two features are also present:

4. A dry slot within the main cloud sheet.
   This indicates the descent of rapidly-moving air from high altitudes.
5. An area of enhanced cumuliform cloud to the rear of the cloud sheet, indicating further CVA.

NORTHERN HEMISPHERE EXAMPLES

In October 1987, there occurred in Britain what became known as the 'Great Storm', described in the March 1988 edition of *Weather*. The 'Great Storm' developed from the cloud head shown on page 133 (Figure 4) of that publication. This picture was taken about 24 hours before the storm struck southern Britain. One can see that the three essential features are there, also a dry slot, and an area of enhanced cumuliform cloud to the rear.

A few months later, a feature very similar to the above appeared in the Atlantic Ocean. This feature can be seen in McCallum and Young (1989) (Figure 2). As with the previous situation, Numerical Weather Prediction (NWP) models did not suggest that strong gradients would develop, and forecasters did not predict severe gales on this occasion either. This time, the forecasts were correct. However, 24 hour pressure falls at the centre of the system were about the same as they had been for the Great Storm — about 21 hPa in 24 hours. Pressures before and after intensification were about 30 hPa higher on this occasion, and as the system evolved, the upper trough did not move eastwards with the surface depression, but remained well back. Winds of no more than 40 knots resulted.

What may be the critical difference is that in this latter case, although it is apparent that there is relatively cold air to the rear of the main cloud sheet, there is no open cell cloud actually entering this rear edge. We will return to this discussion later.

On 8 November, 1989 the cyclogenesis event described by Woodroffe (1990) occurred in the Atlantic Ocean. The cloud system from which this developed can be seen in Figure 7(a) of his publication. Note the area of enhanced convection within the cold air, indicating a CVA maximum. Originally, the models were predicting only weak development. Then one run predicted strong development, and severe gale warnings were issued for parts of Britain. However, the next run, shortly before this picture was taken, reverted to the non-developmental pattern. Forecasters persisted with their predictions of severe gales however, which is what in fact occurred.

The models played a similar trick before the Burns Day Storm of 25 January, 1990 (McCallum and Norris 1990). This storm developed from another good example of a cloud head. Widespread severe gales were experienced in Britain on this occasion. These were well forecast, but again forecasters had to contend with a 'rogue run' predicting only weak development.

EXAMPLES FROM THE NEW ZEALAND AREA

In the New Zealand area, winds of hurricane force are rare, and are usually associated with disturbances which have either originated in the tropics, or which have had tropical air incorporated into them. These are outside the scope of this paper — what we are concerned with here are the true extra-tropical developments. A search through the Victoria University satellite loop revealed a surprising number of interesting features. The signature is usually present for only three to six hours, so is very easy to miss.

The feature seen south of Tasmania in Figure 1 is a classic example of a cloud head. The subsequent pressure fall was 30 hPa in 36 hours. This is approximately equal to the criterion for hurricane force winds (1 bergeron) as suggested by, for example, Sanders and Gyakum (1980), where

$$1 \text{ bergeron} = \frac{(\text{pressure fall per 24 hours})}{24} \times \frac{\sin(\text{latitude})}{\sin 60}$$

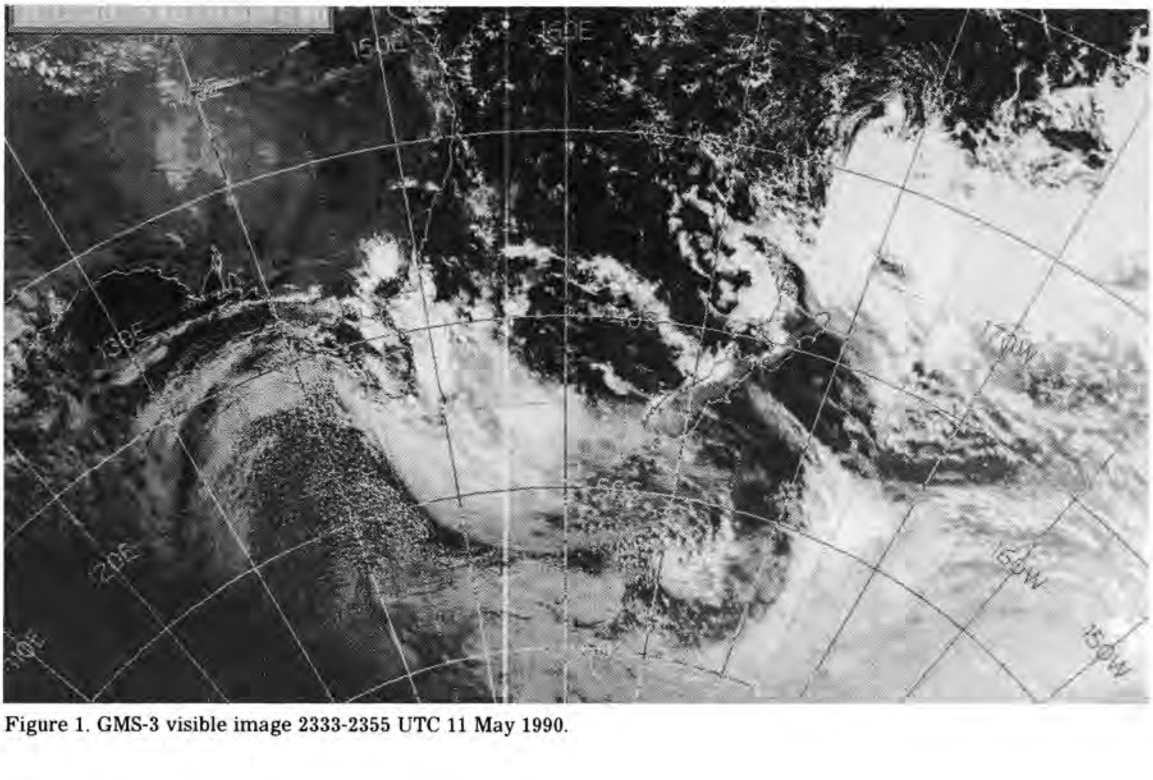

Figure 1. GMS-3 visible image 2333-2355 UTC 11 May 1990.

In data-sparse areas, such as that around New Zealand, it is often difficult to verify whether or not a depression contains hurricane force winds. However, in this case, a very deep depression eventuated, and it appears likely from an inspection of the relevant charts, that hurricane force winds were present.

A very similar feature was seen in the same area a few days later (not shown). This system was slightly smaller than the previous example, and the convection to the rear was less active. The resulting depression was not quite as deep as that in the previous example.

Figure 2 shows an interesting area of cloud in the western Tasman Sea. In this case, there is no open cell cloud to the rear, and neither does the rear edge have anticyclonic curvature. However, pressures fell at the rate of about 1 bergeron within this system as a small depression developed just off the coast. This development may have been assisted by the strong sea surface temperature gradient usually present off the Australian east coast. This example has been included to show that explosive cyclogenesis may still occur even if the criteria for a cloud head have not been met.

In the feature seen in Figure 3, there is open cell cloud to the rear, although it has been suppressed somewhat by the land. As far as the influence of topography is concerned, it seems likely that, as well as tending to spoil the visual effect somewhat, the land also does inhibit cyclogenesis to some extent. This extent probably depends on the height of the topography, (but needs to be offset by the effects of lee cyclogenesis). The feature shown in Figure 3 is very large, however, and the beginnings of a dry slot can also be seen. Pressures fell by 35 hPa in about 30 hours, and very strong gradients were produced, with winds probably up to or approaching hurricane force.

Figure 4 shows an example of a feature that is *not* a cloud head. There is plenty of open cell cloud entering the rear edge of the system. However, the back edge down not have anticyclonic curvature. Although this system had become somewhat more organised 24 hours later, there was in fact little pressure fall.

The feature shown in Figure 5 is quite small, but there is the anticyclonic curvature, open cell cloud entering the rear edge, and

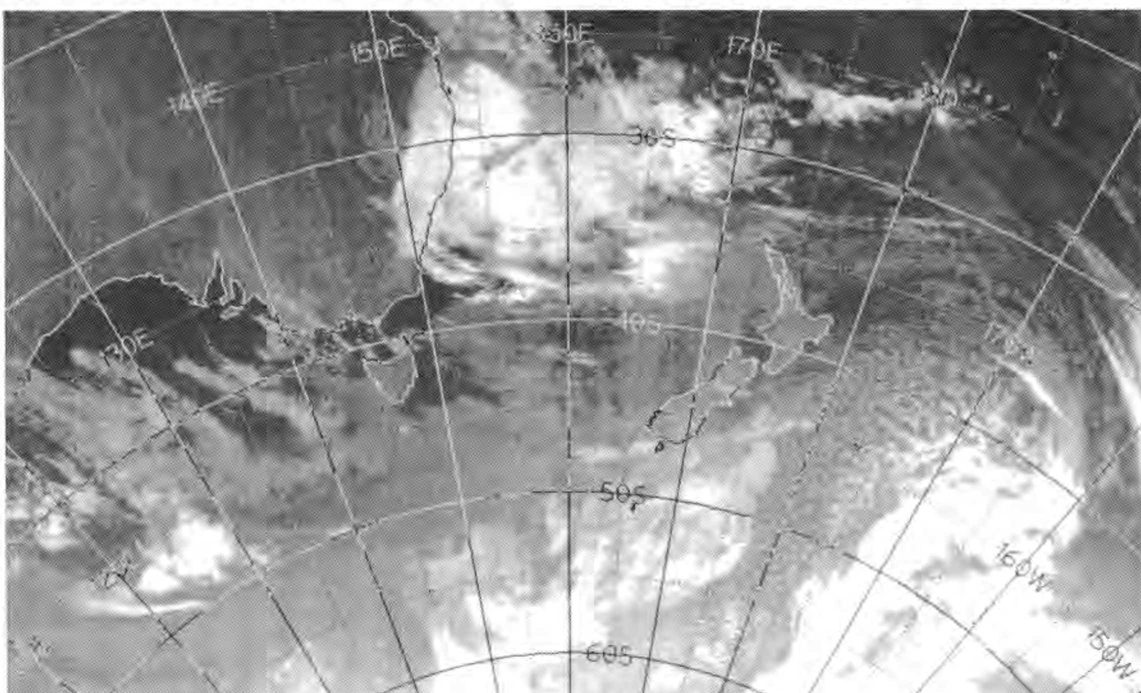

Figure 2. GMS-3 infrared image 1732-1755 UTC 27 May 1990.

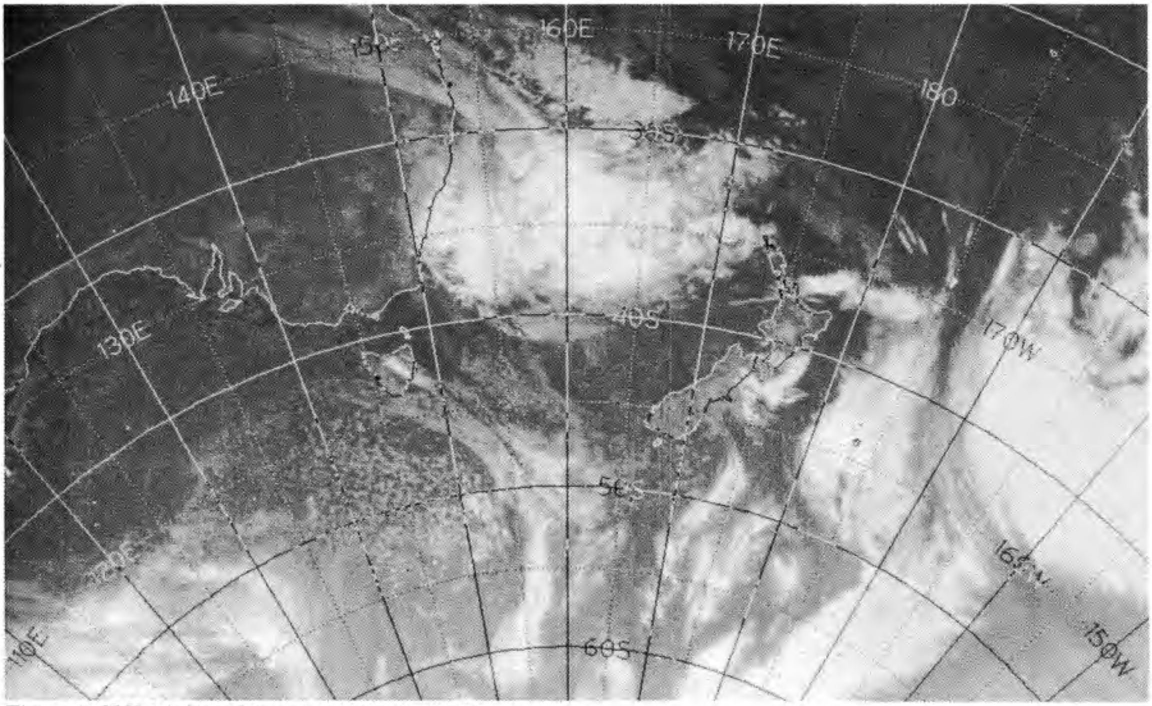

Figure 3. GMS-3 infrared image 0833-0856 UTC 27 July 1990.

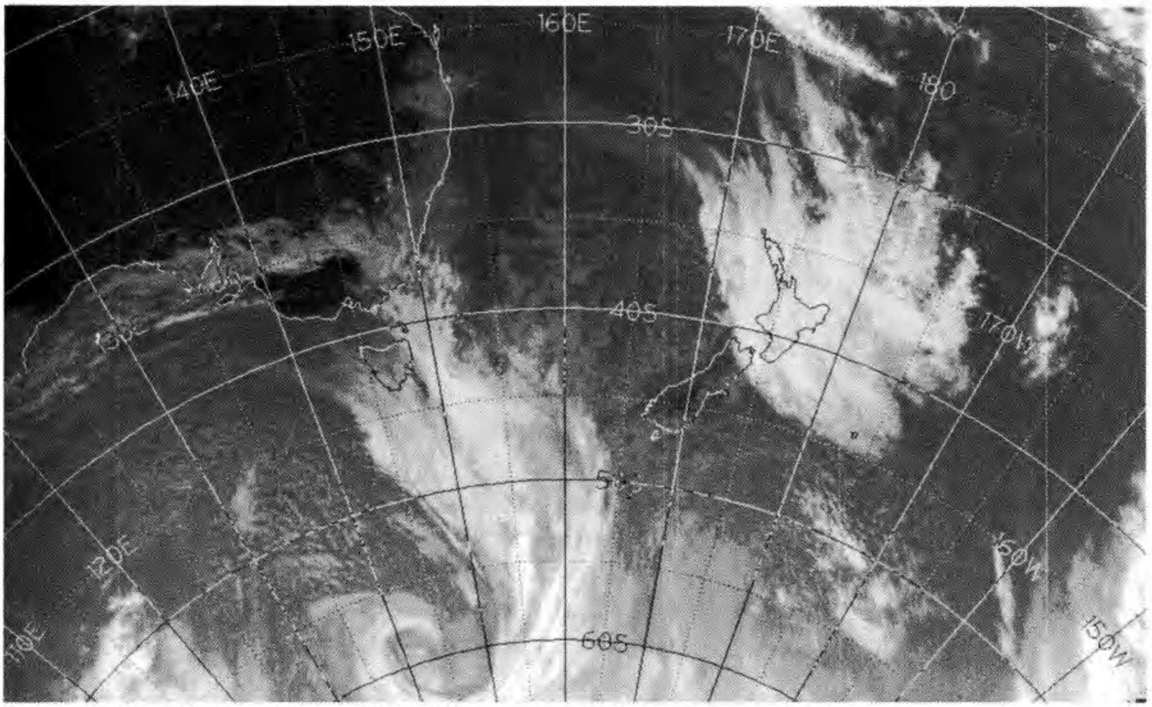

Figure 4. GMS-3 infrared image 0134-0157 UTC 28 February 1991.

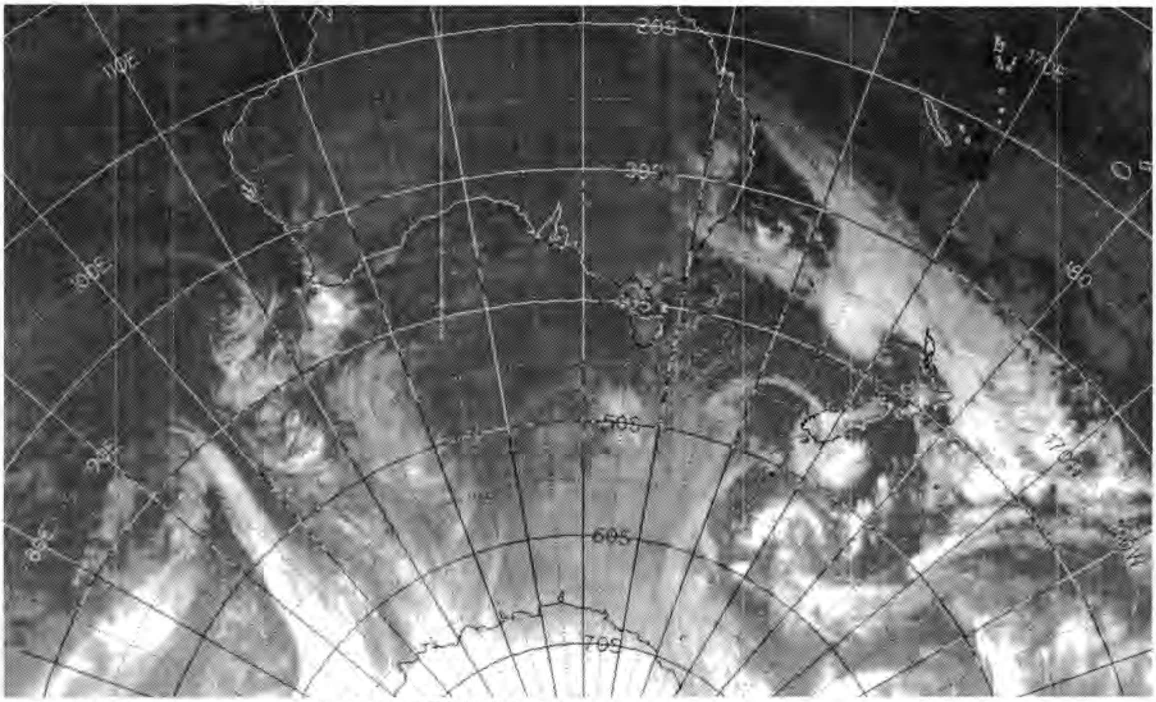

Figure 5. GMS-3 infrared image 1731-1754 UTC 22 July 1991.

even a CVA maximum to the rear of the system. It could be described as a 'mini' cloud head. Thirty hours later, the central pressure had fallen by 30 hPa.

The example shown in Figure 6 is similar to one of the Northern Hemisphere examples in that, although there is some open cell cloud behind the main cloud sheet, not much of it appears to be entering the back edge. The pressure fall in this example was 20 hPa in 36 hours, the deepening rate in this case being only 0.8 bergeron.

Figure 7 shows another *non*-example. In this case, most of the cold air is ahead of the system, and the system appears to be largely jet cloud. It was still just a weak wave 24 hours later. However, one needs to beware of systems that appear to be merely jet cloud. Careful examination of suspicious-looking cloud sheets, including the use of different enhancements, may reveal the presence of something more substantial underneath.

Figure 8 shows the system that helped produce the heavy snowfall in Canterbury in late August 1992. This is not really a classic pattern, but all the required features are present. There is anticyclonic curvature to the rear edge, and open cell cloud entering the rear edge, and even possibly a dry slot. The depression certainly deepened explosively.

Another classic example, similar to that shown in Figure 1, was seen south of Western Australia on 15th April, 1993 (this example not shown). The subsequent deepening rate was about 1 bergeron. A buoy near 59 south 146 east reported a pressure of 941.0 hPa shortly before the depression centre passed over it. Eight hours later, the pressure at the buoy had risen by 29.6 hPa to 970.6 hPa. A ship, 400 nautical miles from the depression centre when it was at its deepest, reported mean winds of up to 55 knots, and swells of 10 metres.

Another seven examples of cloud heads in addition to those mentioned herein have been observed in the New Zealand region.

CONCLUSIONS

It was found that in *all* cases where the three essential features were present together, rapid cyclogenesis was the result. In all but one case, there was a deepening rate in excess of the 'bomb' criterion.

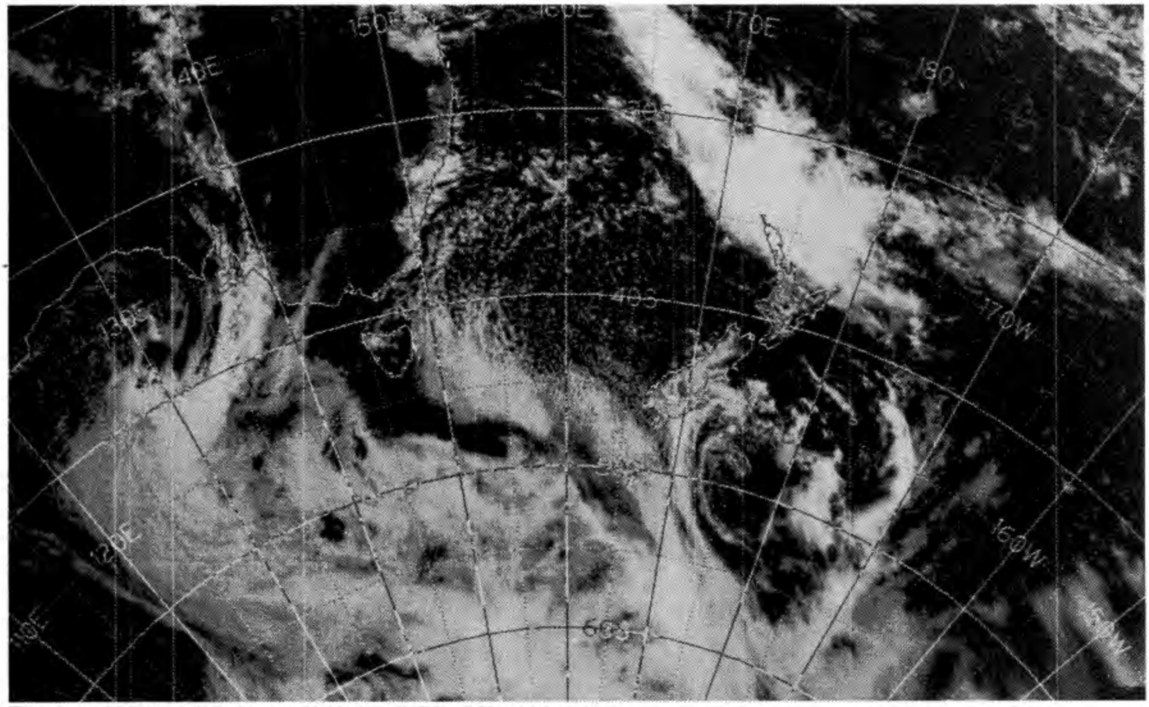

Figure 6. GMS-3 visible image 2226-2249 UTC 13 November 1991.

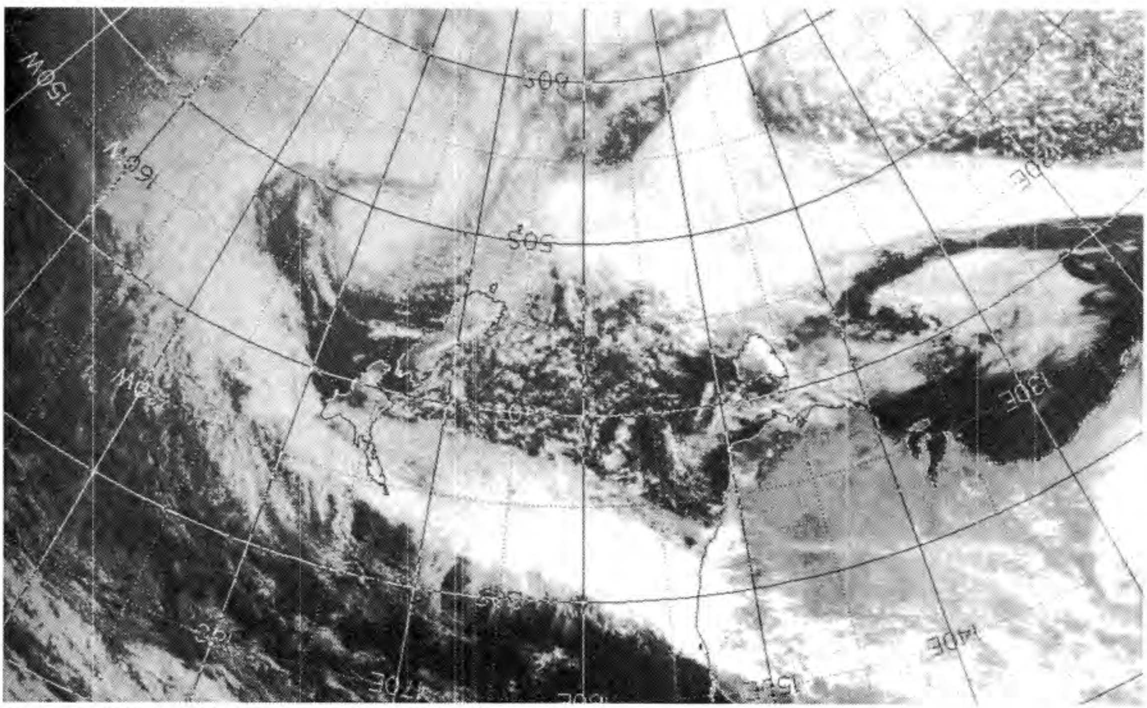

Figure 7. GMS-3 visible image 0426-0449 UTC 21 November 1991.

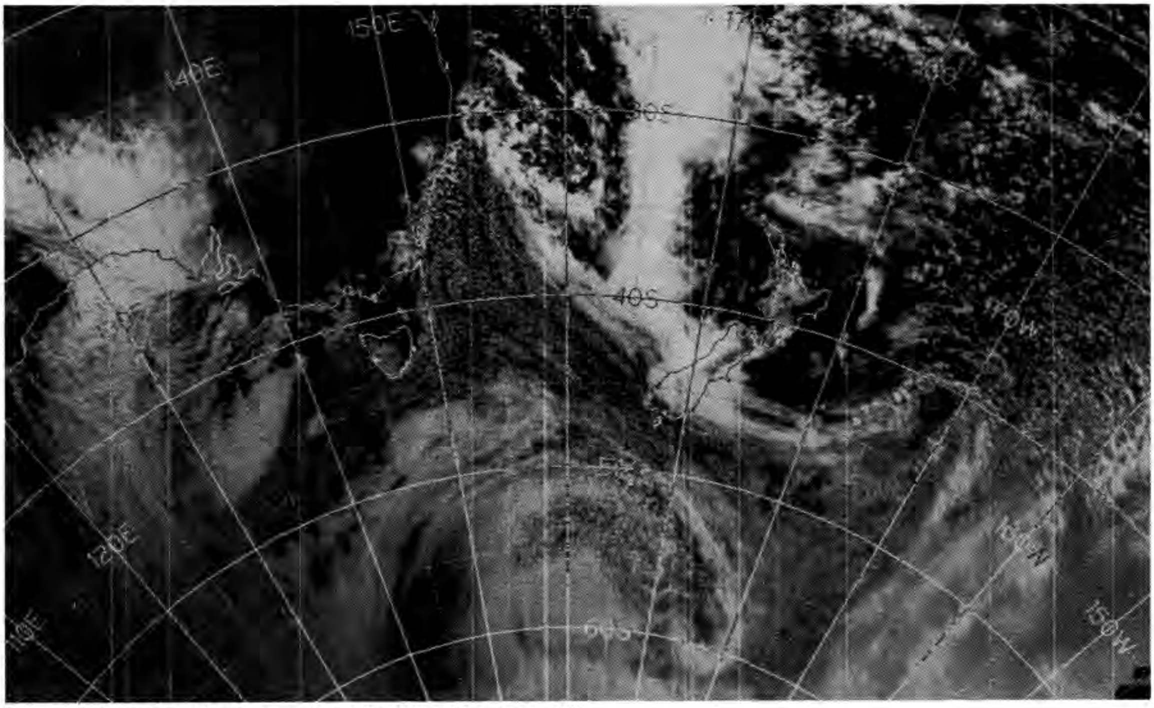

Figure 8. GMS-3 visible image 2333-2356 UTC 24 August 1992.

The following conclusions can therefore be made:

1. Cloud heads are not uncommon in the New Zealand area.
2. The three essential features are:
   a. An unusually large area of dense cloud.
   b. The area of cloud has a well-defined, anticyclonically-curved rear edge.
   c. Open cell cloud is entering the rear edge.
3. If the three essential features are all clearly present, then a depression containing hurricane force winds will develop from the cloud head.
4. If one or more of the essential features are only weakly present (that is, there is cold air evidently entering the rear edge, but *no actual open cell cloud* entering the rear edge, **or** the system is not unusually large), then one can expect to see 'rapid' cyclogenesis. This can be taken to be cyclogenesis close to or exceeding the 'bomb' criterion, but not necessarily hurricane force winds.

Little data on how the NWP models performed for the Southern Hemisphere examples has been gathered, but Northern Hemisphere experience would suggest that sometimes they predict the development successfully, and sometimes they do not, and sometimes both these scenarios can occur within the same event on different runs. Thus the conclusion must be that if a cloud head is seen, then rapid cyclogenesis must be predicted regardless of what the NWP models are indicating.

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