ASPECTS OF SUMMER TROUGHS IN WESTERN AUSTRALIA

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Abstract: Three cases are examined of troughs developing in the summer of 1953-4. The first represents a rapid development and eastward movement characteristic of early and late summer; the second a more persistent type occurring frequently in midsummer; and the third a variation of the second. The cases considered are typical of troughs which present problems of prognosis, but they do not cover the whole field. Their significance in relation to forecasts of temperature in the Perth region is brought out, and the article draws attention to some criteria which the author has found useful in indicating when the trough would commence a steady eastward movement.

1. INTRODUCTION

In Western Australia during summer, the most significant feature of the synoptic charts is a trough development, either near the west coast or over the inland divisions.

This trough directly controls the weather over the State, and the prognosis of its development and movement is most important as regards both regional and aviation forecasting, and is a prime factor in the estimation of the maximum temperature for various areas.

In the hot dry summer of the southern half of Western Australia, the estimation of the maximum temperature is significant with regard to fire hazard forecasts, which cover both forest and agricultural districts; and it may be added that the general public is more interested in the estimated maximum temperature than in general terms such as 'warm', 'hot' etc., and frequent requests for an estimated maximum temperature are received from wide localities.
2. **SOME CHARACTERISTICS OF THE SUMMER TROUGH**

The inland trough is more characteristic of early or late summer, and does not normally give rise to much difficulty as regards forecasting the maximum temperature for Perth; but the trough which develops along the west coast frequently leads to difficult forecasts and it is this latter kind which will be considered here.

The trough lind shows a tendency to move inside the west coast during the day, and seawards beyond the coast at night. This movement is often referred to as the movement of the so called 'coastal front', and is significant with regard to forecasting day to day land and sea breezes. Diurnal variation of the surface temperature difference between land and sea is probably the chief cause of the oscillation.

Another notable factor influencing the diurnal movement is the katabatic easterlies off the escarpment in the morning. These may have the effect of retarding the eastward movement of a surface trough.

Figs. I and II show the development of a typical west coastal trough. In Fig. I, the high pressure ridge moving along the south coast is causing a southerly stream of maritime origin over the southern divisions of the State.

The air is progressively warmed in its passage over the land. Sea breezes are influencing the temperatures along the west coastal strip, but this strip, between, say, Geraldton and Perth, represents the region of greatest surface warming of the air. This warming and consequent convection on the first day of a cool change is generally sufficient to destroy the subsidence inversion associated with the advancing high pressure ridge.

When the warming of the lower layers is accompanied by divergence aloft (500 mb. level) over the west coast, the development of a surface trough may be expected on the following day. The 500 mb. charts show that the surface trough developments are often preceded by the formation of an upper trough aloft, considerably west of the coast (see Figs. V and VI). Divergence aloft over the west coast is usually discernible, but not always obvious. Further, it is found that the intensity of the upper trough and the degree of divergence may be used to give an indication of the intensity of the surface trough which will develop on the following day. The main upper trough remains semi-stationary west of the coast until the surface trough begins its permanent eastward movement.
Another factor to be considered is the relative surface pressure changes, which will occur over the southern half of the State during the night. Surface pressure along the west coast during the night generally falls slightly; but the relatively large pressure rise over the south-eastern divisions of the State (which occurs with such situations, as in Fig. VI), has the effect of enhancing the west coastal trough development by 0600 W in the morning. The over-night pressure rise over the south-eastern part of the State is due to the intensification of the anticyclone in the Bight, especially along its north-westerly edge.

The gradual deepening of the surface trough along the coast usually allows an accurate sequence of maximum temperature forecasting; and the deepening continues until a critical stage is reached at which the trough will begin to move steadily eastward from the coast within thirty-six (36) hours: but whether this movement will begin during the early morning, or during the late afternoon is usually difficult to determine; (the arrival of a sea breeze may cause a sharp fall in temperature prior to the actual passage of the trough).

If the former occurs, the maximum temperature in Perth will be about 80°F, while if the latter occurs, a century may be reached before the arrival of the cool change. It is the existence of these two possibilities which is responsible for most of the difficulties regarding maximum temperature estimation during summer or early autumn. If and when a solution to the problem is found, forecasting maximum temperatures in Perth and the south west coastal districts will take a significant step towards greater accuracy.

The cool change in Perth is normally experienced as follows:--

The north-east winds back to the northwest, thus causing temperatures to fall; but conditions remain warm and humid until the arrival of the south-west stream when the effect of the cool change is felt.
In the diagram, A is a diffuse boundary line, which often becomes less discernible in its passage over the land; but B takes on the characteristics of a cold front, especially if the surface low (or trough) deepens appreciably and the advancing south-west stream continues to move eastwards as a cold front, which rapidly occupies the position of the original trough line. Cold fronts which are generated in this way frequently become very active over the Goldfields and Eucla divisions, giving rise to thunderstorms and dust-storms.

It has been suggested that A and B are the remains of old trailing fronts which become re-activated, but this seems unlikely because it is considered that such trailing fronts are subject to marked frontolysis by the continuous and prolonged surface heating which occurs over the land.

It is proposed to investigate three examples of recent west coastal troughs which caused forecasting difficulties. These cases are typical of troughs which present problems of prognosis, but they are by no means representative of the whole field.

3. CASE I

The period covered is 8th-11th December, 1953 (see Figs. I-IV). It is a case of a rapid trough development on the west coast, followed by an early eastward movement of the trough line.

Referring to Fig. II, the problem is to estimate the position of the trough at 100400Z, and hence to estimate the maximum temperature for Perth on 10/12/53. If the trough remains semi-stationary on the coast, and does not begin its steady eastward movement until the late afternoon, a temperature approaching 100°F will be reached. However, if the trough begins its eastward movement during the early morning (by 0600W) at the usual velocity of 5-10 knots, Perth's maximum temperature will be about 80°F.

The isallobaric sequence seemed to suggest that the anticyclone in the Bight, although slowly weakening, would be sufficiently intense to favour the former prognosis; but a substantial compromise was made, and a maximum of 88°F was estimated. The trough actually moved eastwards by 0600W and thus a maximum of only 80°F was attained in Perth. (See Figs. III & IV).
A significant feature of Fig. II is the intensity of the anticyclonic cell in the northern Bight. The anticyclones of early and late summer are generally centred towards the northern Bight, are fast moving, and do not show a tendency to intensify during the night as do those of mid-summer. The pressure changes to be expected may be determined by close attention to isallobars, while the rate at which the upper winds over the west coast back to the north-west gives a further clue to the rate at which the trough will move.

This rapid developing type of trough of early and late summer may be distinguished by the following characteristics:

(a) The short sojourn on the west coast.

(b) The surface pressure at the vertex, or at the low pressure centre which forms at the vertex, does not fall appreciably below 1010 mbs. before the trough moves eastwards. This pressure is usually in the range 1010-1015 mbs.

(c) The low pressure centre normally moves eastwards, or south-eastwards, from a position on the coast north of Geraldton.

(d) Maximum temperatures in the inland divisions are mainly higher than on the coast. (see Fig. II). Since the trough-line tends to move (other things being equal) towards the region of highest surface temperature, it may be expected to be located considerably east of the coast next day at 0400Z.

This trough development occurs several times during any one summer-autumn season. Dates of other occurrences were 14th March, 1954 and 28th March, 1954. Recognition of the type is, of course, a considerable aid in extended period forecasting.

4. CASE II

The period covered is 6th-11th January, 1954. (see Figs. VI-XI). This is an example of the more persistent type of trough which occurs frequently in mid-summer. The trough was semi-stationary along the coast for four days, and caused heat wave conditions over the southern half of the State. On two occasions over the period, the prognosis of the trough differed considerably from the actual position.
Little difficulty was encountered in the forecasting sequence until the 9th January, 1954 (see Fig. IX). On this day, the three-hourly isallobars suggested that the low centre (1005 mbs) just north of Geraldton and the trough-line, would move south-eastwards early on the following afternoon. This appeared to be indicated by the anticyclone in the Bight continuing to move eastwards, and the upper winds at Guildford and Geraldton showing a tendency to back north-west.

Hence a cool change was forecast for the west coastal districts for the afternoon of the 10th January, 1954; and it was thought that the widespread middle level cloud along the coast associated with the low, would keep the maximum temperature below 90°F.

As may be seen (Fig. X), the intensification of the anticyclone in the Bight was clearly evident on the early morning charts.

An anticyclonic centre in the southern Bight frequently intensifies over night, particularly at its north-western edge. The increase in surface pressure is usually of the order of 2-5 mbs. over the south-eastern divisions of the State. This occurs mostly during mid-summer, and is considered to be caused mainly by subsidence in the south-east to east stream accompanied by inflow aloft (500 mb. level).

Examination of the charts over the last few years has shown that with these persistent developments, when the low pressure centre is north of Geraldton, the intensification of the anticyclone in the Bight during the night becomes the controlling influence, and the low pressure centre will persist on the west coast for at least-thirty-six (36) hours. Close attention to isallobars at 1600Z is a valuable aid in detecting this intensification.

Referring to the surface analysis 100400Z (Fig. X), it was apparent by the isallobars, that the low centre would move down the coast towards the col region during the succeeding twenty-four hours. Thus a cool change was expected to reach Perth during the latter part of the morning (about 1000W). With a high morning minimum temperature, it was thought that a maximum of about 96°F would be reached before the cool change brought relief.

However, the centre accelerated its south-easterly movement towards the Bight, and the cool change passed through the west coastal districts in the early morning. (See Fig. XI). The day-time maximum was only 78°F.
Charts over the last few years have shown that such a centre below about 1008 mbs located near the coast between Geraldton and Perth, moves towards the Bight within twenty-four (24) hours. The movement occurs most frequently in the early morning and the centre accelerates to about 15 knots. The cool change is marked and passes through Perth during the early hours of the morning (by 0600W). This pressure of 1008 mbs may be regarded as a critical pressure, below which the centre does not remain semi-stationary on the west coast.

A sharp increase in strength of the north-east to north winds from the surface to 10,000 ft, which occurs at this time, (about 1600Z) indicates that the low pressure centre near Perth is deepening, and that these winds will back rapidly north-west thus bringing an end to the heat spell within a few hours. It is incorrect to think that the strengthening of the north-easterlies is indicative of intensification of the anticyclone in the Bight, and a continuation of the hot weather.

The arrival of this hot and less dense northerly air is probably the main cause of the sharp fall in surface pressures over the lower south-west; and it is the deepening of the low pressure centre which hastens the arrival of the south-west stream over the south-west coastal districts.

The acceleration of the low pressure centre usually becomes evident at 1600Z by the increased negative isallobars at coastal stations on the south-west coast. Recognition of this tendency by close attention to the isallobars would assist the prognoses of these low pressure centres. Remarkably similar situations occurred over the periods 1-2 January, 1954 and 10th-12th March, 1954.

This trough, which develops into a low pressure centre off the west coast, is the most common type, and is responsible for most of the extended spells of hot weather over the west coastal districts. Errors of forecast of maximum temperature may be reduced by anticipation of the accelerated movement of the centre when it is on the lower west coast between Geraldton and Perth and below about 1008 mbs.
The period covered is 4th-7th March, 1954, (see Figs. XII - XV). This case is of interest because of its differences from Case II. Little difficulty in forecasting arises until the 5th March, 1954 (see Fig. XIII). With a deep trough along the west coast, and a comparatively weak anticyclone in the Bight, it may be considered that the situation is similar to Fig. X, and that a cool change will move through the west coastal districts during the following day, probably in the late morning. However, there are at least two differences, viz:—

(1) The closed low is located over the land well north of Geraldton and is not sharply defined.

(2) An investigation of the isallobaric sequence, particularly at 1600Z, did not indicate any rapid movement of the low.

Hence a cool change was not expected on the following day. Some allowance was made in case of possible error, and a temperature of 95°F was forecast. The actual maximum was 103°F, the highest March reading for 19 years.

In Fig. XIV it may be seen that the low pressure centre off the coast near Perth is below the critical pressure (1008 mbs) and cannot remain semi-stationary on the coast for more than twenty-four (24) hours, (cf. Fig. X). The rapid movement of the centre towards the Bight was confidently expected, with a cool change in Perth during the early morning of 7th March, 1954. The actual maximum temperature was 79°F (80°F forecast).

This discussion is concerned entirely with the summer or early autumn type of trough. In late Autumn and Winter, troughs develop in a similar way, but the trough line remains considerably west of the coast; and pressures fall rapidly - the trough developing usually into an intense depression off the south-west coast. A typical example occurred in the period 25th-26th May, 1954. Winter depressions of this kind are frequently responsible for general rains over the southern half of the State. They may be distinguished from the depressions which develop on cold fronts approaching the south-west coast; with the latter type, the rain is normally confined to the south-west of the State and is less heavy.
6. **CONCLUSION**

In conclusion, it may be stated that forecasting the time of arrival of cool changes over Perth and the south-west coastal districts may be facilitated by an investigation of summer trough types and that, in particular, the position and the M.S.L. pressure of the surface low pressure centre have a considerable bearing on the timing and intensity of the cool changes.