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THE SHOWALTER INDEX AND ASSOCIATED WEATHER

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Abstract: At Queensland radio-sonde stations for the period September 1957 to May 1958, stability indices for 800 aerological soundings indicative of the air mass types over the State were compared with subsequent weather, and classified into air mass and frontal types. The resulting frequency analyses for the respective stations are given in tabular and graphical forms.

The particular value of the use of stability indices for "border-line" cases is discussed, and some suggestions given for forecasting changes in stability index.

1. INTRODUCTION

An index developed by Showalter (1946) gives a simple parameter for determining atmosphere stability. This index is defined as the difference between the 500 mb environmental temperature and that of an 850 mb "parcel" lifted dry-adiabatically to saturation, and then pseudo-adiabatically to the 500 mb level. A negative value indicates instability, while a positive value is indicative of stability. This holds true, however, only when no marked inversions are present.

A modification of the Showalter Index (S.I.) is the Lifted Index (L.I.) which is deduced in a similar manner, but takes into account an average dew point in the lower layers (say between the surface and 850 mbs), and also an estimated maximum surface temperature. These are illustrated in Figure 1.

The purpose of this project was to construct simple graphs for each radiosonde station, showing the relationship between occurrence and non-occurrence of showers and thunderstorms, and stability indices with respect to non-frontal weather situations.

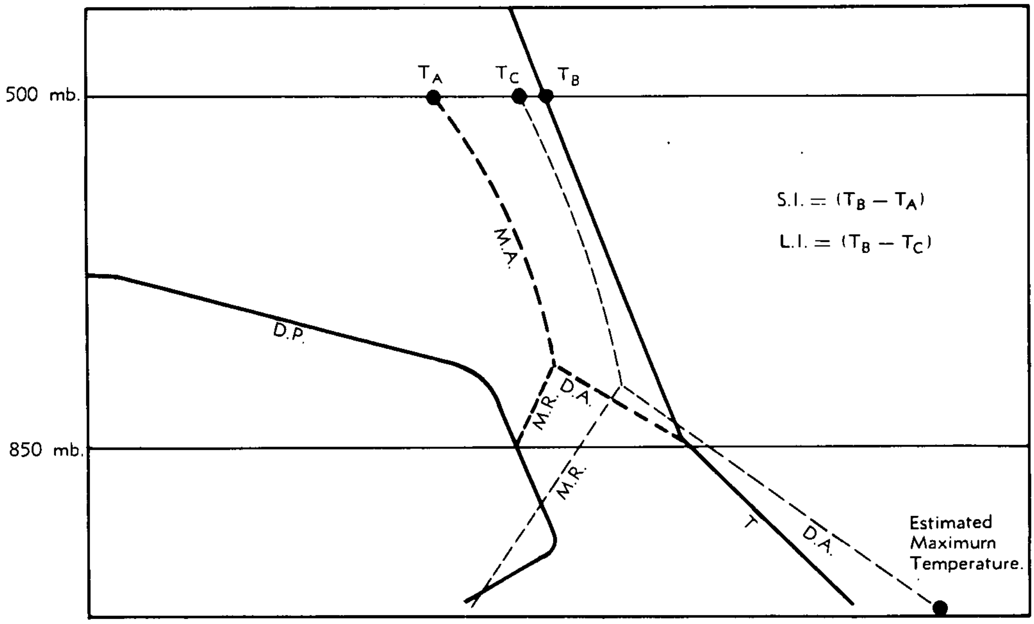

Fig. 1. Illustration of the method of finding the Showalter Index $(T_B - T_A)$ and Lifted Index $(T_B - T_C)$. T and D.P. denote temperature and dew point soundings. M.R., D.A. and M.A. denote Mixing Ratio Lines and Dry and Moist Adiabatics respectively.

2. METHOD OF INVESTIGATION

Both the S.I. and L.I. were calculated daily from the four Queensland radiosonde soundings at Eagle Farm, Charleville, Cloncurry and Townsville for the period September 1957 to May 1958. In all some 800 soundings were used, and the stability indices and respective weather patterns occurring within visual distance of respective stations for 24 hours following the taking of the sounding were recorded. Cases of occurrence and non-occurrence of phenomena were separated into air mass and frontal classes, and a frequency analysis made. Stability indices in excess of +5°C were disregarded as, in practically all cases, air masses with such values of the index exhibited absolute stability and were unassociated with precipitation except when a marked change in air mass properties occurred within 24 hours of the time of the sounding.

3. GENERAL

To an operational forecaster, the most important decision to make regarding thunderstorm development is the one in which the chances of occurrence equal those of non-occurrence, and it was with this in view that the various categories of stability indices were selected. For example, with a stability index of say +8°C, temperature values aloft are usually comparatively high while the low level moisture content is, in most instances, very small - in such a case it is obvious that the probability of thunderstorm occurrence is very small. On the other hand, the other extreme lies in situations where a large negative value of Showalter Index, with its associated cold temperatures aloft and considerable low level moisture, is almost certain to produce thunderstorm activity. "Border-line" cases, however, lie somewhere in between, and these are the cases that require special detailed examination of the following:-

1. Presence of inversions
2. Cold-air advection aloft (or surface warm air advection)
3. Depth of moisture (for consideration of entrainment - this is most important)
4. Proximity of ridges, fronts and troughs
5. Rising or falling pressures
6. Areas of divergence or convergence aloft
7. Areas of surface convergence
8. Topography
9. Preferred areas of thunderstorm development
10. Air mass advection
11. Isotherms

Hail and Severe Squalls

In all cases studied, hail and severe squalls were limited to areas of strong surface convergence associated with moist tropical air-masses exhibiting instability such that the S.I. and L.I. were -1.0°C or less. The L.I. in all cases of hail or severe squalls was numerically greater than the S.I. and occurred during the afternoon. The agents causing strong surface uplift consisted of fronts, small closed "heat lows", troughs and strongly converging northerly isobars.

The most notable cases of hail and wind damage are shown in Table 1.

Table 1 - Stability Indices and Synoptic Situations associated with Damage due to hail or wind

Date	Raob	Convergence Agents	Locality of Damage
6/2/1958	<u>Cloncurry</u> S.I. -1.5 °C L.I. -3.5°C D.P. 72°F <u>Charleville</u> S.I. -1.5°C L.I. -1.6°C D.P. 63°F Both traces showed considerable moisture to great heights.	(1) Upper trough (2) 1008 mb "low" in SW Q'ld. (3) Surface trough from Urandangie to Charleville to NE New South Wales.	(1) <u>Dalby</u> (i) Sheds lifted like matchwood. (ii) 5 mile path cut through scrub. (11) <u>SE Darling Downs</u> Damage by hail to fruit crops.
7/2/1958	<u>Cloncurry</u> S.I. -1.0°C L.I. -3.0°C D.P. 71°F (for 48 hrs) Trace relatively moist.	(1) 1004 mb closed "low" in NW of State. (2) Associated surface trough extended to the south-east.	<u>Camooweal</u> Damage by wind-gusts to 100 mph
11/2/1958	<u>Eagle Farm</u> S.I. -1.0°C L.I. -1.5°C D.P. 70°F	(1) Trough ahead of front.	<u>Isisford</u> and <u>Ipswich</u> Structural Damage

Table 1 (continued)

Date	Raob		Convergence Agents	Locality of Damage
11/2/1958	Charleville S.I.	-2.5°C	(1) Trough ahead of front.	Isisford and Ipswich
	L.I.	-4.2°C		Structural Damage
	D.P.	69°F		

4. FRONTAL THUNDERSTORMS

From a forecasting point of view, frontal changes in the late spring and summer months usually produce thunderstorms, or weather of some kind, and present little difficulty. From Table 2, which gives the occurrence and non-occurrence of air-mass and frontal thunderstorms or showers with various stability indices, it is evident that in very few cases was precipitation of some kind not associated with a frontal passage in air masses exhibiting a stability index less than +2°C. All cases of non-occurrence of showers or thunderstorms in this category were either due to the front moving through during the night or to the atmosphere becoming more stable in the period that elapsed from the time of the sounding to the actual time of frontal passage. Thus it can be deduced that, for all values of S.I. or L.I. less than +2°C, thunderstorms should occur with a frontal passage. Also, for air more stable and showing an index of between +2°C, and +5°C showers or weak thunderstorms are possible.

5. AIR-MASS THUNDERSTORMS

By way of contrast to frontal thunderstorms, however, air-mass thunderstorms, and especially when traces exhibit a S.I. of between +2°C and 0°C, are the most difficult to forecast; but as the value approaches zero, the chance of larger convective build is obviously increased.

Stability Index (+2°C to +5°C)

It was found that for all four stations when both S.I. and L.I. were between +2°C and +5°C that some showers and isolated thunderstorms did occur, but the chances of non-occurrence of precipitation greatly exceeded those of occurrence. It is

Table 2 - Occurrence and non-occurrence of air-mass and frontal showers or thunderstorms with various stability indices

	AIR MASS												FRONTAL											
	EAGLE FARM			CHARLE-VILLE			CLON-CURRY			GARBUTT			EAGLE FARM			CHARLE-VILLE			CLON-CURRY			GARBUTT		
	Shrs	T/S	No Precip.	Shrs	T/S	No Precip.	Shrs	T/S	No Precip.	Shrs	T/S	No Precip.	Shrs	T/S	No Precip.	Shrs	T/S	No Precip.	Shrs	T/S	No Precip.	Shrs	T/S	No Precip.
S.I. (>+2°C to +5°C)																								
No. of cases	17	0	23	4	1	34	0	8	30	21	4	31	4	7	1	0	9	0	1	7	0	1	2	0
Percentage of occurrence	43	0	57	10	2	88	0	21	79	37	7	56	33	58	9	0	100	0	13	87	0	33	67	0
L.I. (>+2°C to +5°C)																								
No. of cases	18	0	28	5	0	29	0	2	33	16	1	30	1	4	1	1	1	0	1	3	0	2	0	0
Percentage of occurrence	39	0	61	15	0	85	0	5	95	34	2	64	17	66	17	50	50	0	25	75	0	100	0	0
S.I. (+2°C to 0°C)																								
No. of cases	6	5	8	7	12	9	4	23	9	13	4	6	2	2	0	1	2	0	0	3	1	0	0	0
Percentage of occurrence	32	26	58	25	43	32	11	64	25	57	17	26	50	50	0	33	67	0	0	75	25	0	0	0
L.I. (+2°C to 0°C																								
No. of cases	13	4	9	4	8	17	2	9	24	13	3	10	1	1	0	2	2	0	2	3	0	2	0	0
Percentage of occurrence	50	22	28	14	28	58	6	25	69	50	12	38	50	50	0	50	50	0	40	60	0	100	0	0

Table 2 (continued)

	AIR MASS												FRONTAL											
	EAGLE FARM			CHARLE-VILLE			CLON-CURRY			GARBUTT			EAGLE FARM			CHARLE-VILLE			CLON-CURRY			GARBUTT		
	Shrs	T/S	No Precip.	Shrs	T/S	No Precip.	Shrs	T/S	No Precip.	Shrs	T/S	No Precip.	Shrs	T/S	No Precip.	Shrs	T/S	No Precip.	Shrs	T/S	No Precip.	Shrs	T/S	No Precip.
S.I. Negative values to -2°C																								
No. of cases	2	8	1	0	14	0	1	11	3	8	7	0	0	0	1	0	1	0	0	1	0	0	0	0
Percentage of occurrence	18	73	9	0	100	0	7	73	20	53	47	0	0	0	100	0	100	0	0	100	0	0	0	0
L.I. Negative values to -2°C																								
No. of cases	3	5	8	5	10	3	3	17	4	11	8	16	0	1	0	0	3	0	0	1	0	0	0	0
Percentage of occurrence	19	31	50	28	56	16	12	72	16	31	23	46	0	100	0	0	100	0	0	100	0	0	0	0
S.I. (< -2°C)																								
No. of cases	0	0	0	0	5	0	1	3	0	0	3	0	0	1	0	0	1	0	0	0	0	0	0	0
Percentage of occurrence	0	0	0	0	100	0	25	75	0	0	100	0	0	100	0	0	100	0	0	0	0	0	0	0
L.I. (< -2°C)																								
No. of cases	0	6	1	0	6	0	1	9	0	4	7	2	0	1	1	0	1	0	0	0	0	0	0	0
Percentage of occurrence	0	86	14	0	100	0	10	90	0	31	54	15	0	50	50	0	100	0	0	0	0	0	0	0
L.I.< S.I.<0°C																								
No. of cases	1	6	0	0	8	0	1	10	0	7	8	0	0	1	2	0	0	0	0	0	0	0	0	0
Percentage of occurrence	14	86	0	0	100	0	9	91	0	47	53	0	0	33	67	0	0	0	0	0	0	0	0	0

interesting to note, however, the 21 per cent probability of thunderstorm development at Cloncurry when the S.I. was between +2^{o}C and +5^{o}C. Also, the coastal soundings indicated a much higher percentage frequency of showers than did the soundings taken at the inland stations.

Stability Index (+2^{o}C to 0^{o}C)

When an aerological sounding indicates instability which falls into this category, all available forecasting aids should be scrutinised before a decision is made as to whether or not weak thunderstorms or showers will result. However, it is evident from Table 2 that when an atmosphere has a stability rating between +2^{o}C and 0^{o}C, the development of thunderstorms rather than showers is much more likely at the inland stations of Charleville and Cloncurry than at Eagle Farm and Garbutt. On the other hand, showers rather than thunderstorms are more probable at Eagle Farm and Garbutt with air masses in this category.

Negative Values of Stability Index

It is evident from Table 2 that development of thunderstorms rather than showers is much more likely as the negative value of the indices increases numerically. Thus on a negative S.I. alone a thunderstorm forecast is warranted. This is particularly true if pressures are falling. On the other hand, rising pressures tend to nullify the high instability indicated by negative values of stability index; this has been noted on a number of occasions in south-east Queensland, where a southeasterly surge along the coast has intensified a high pressure ridge thus preventing the necessary surface triggering action.

L.I. > S.I. numerically and both negative

This is the category of severe thunderstorms, and in nearly all cases, such instability was associated with strong surface convergence such as due to "heat lows" or to that immediately ahead of a front. Local strong squalls and structural damage should be indicated in forecasts for areas having such instability

6. PRACTICAL APPLICATION OF STABILITY INDICES

Figs. 2 to 5 give a simple graphical relationship between percentage occurrence of non-frontal showers and thunderstorms and stability indices for the four Queensland radiosonde stations. When either the S.I. or the L.I. has been calculated from an upper air

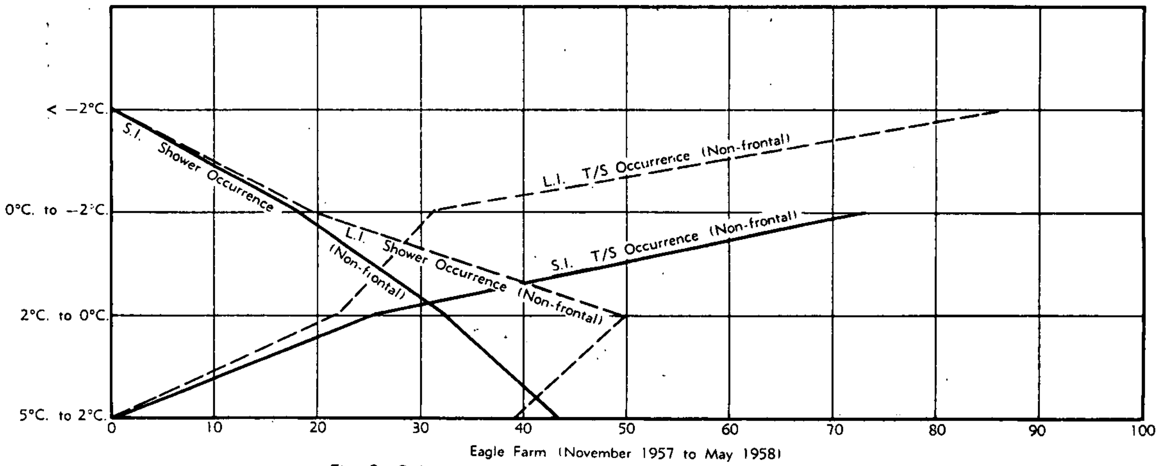

Fig 2. Relation between percentage occurrence of non-frontal showers and thunderstorms and stability indices.

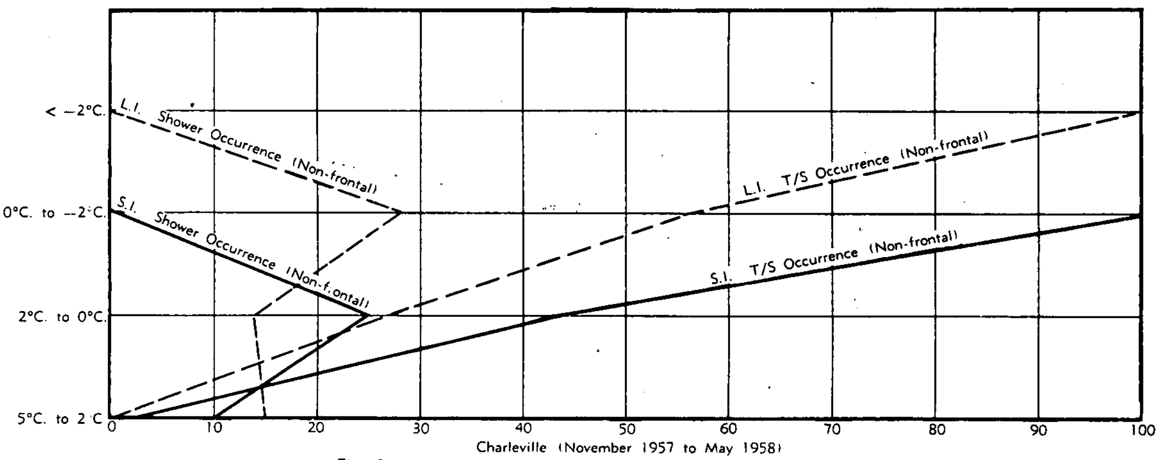

Fig. 3. Relation between percentage occurrence of non-frontal showers and thunderstorms and stability indices.

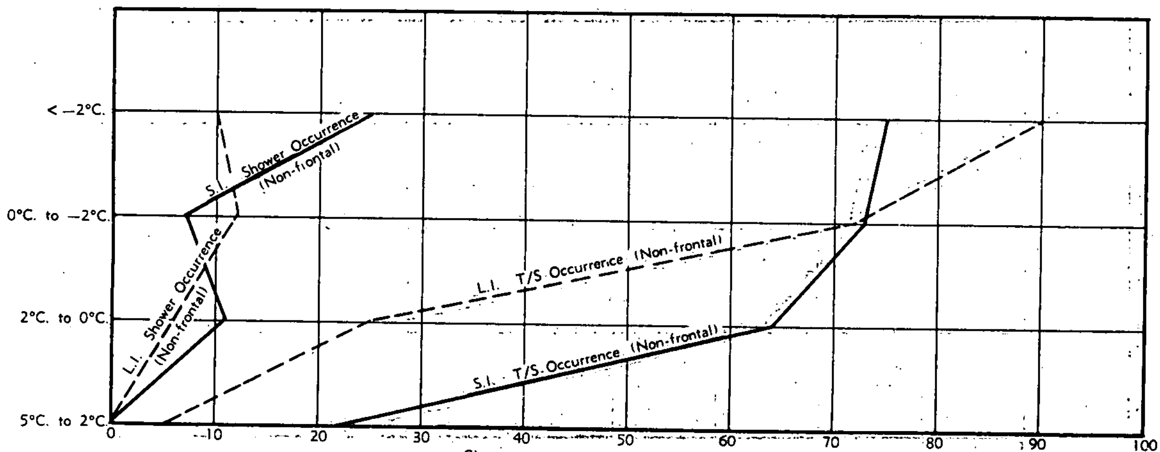

Fig. 4. Relation between percentage occurrence of non-frontal showers and thunderstorms and stability indices.

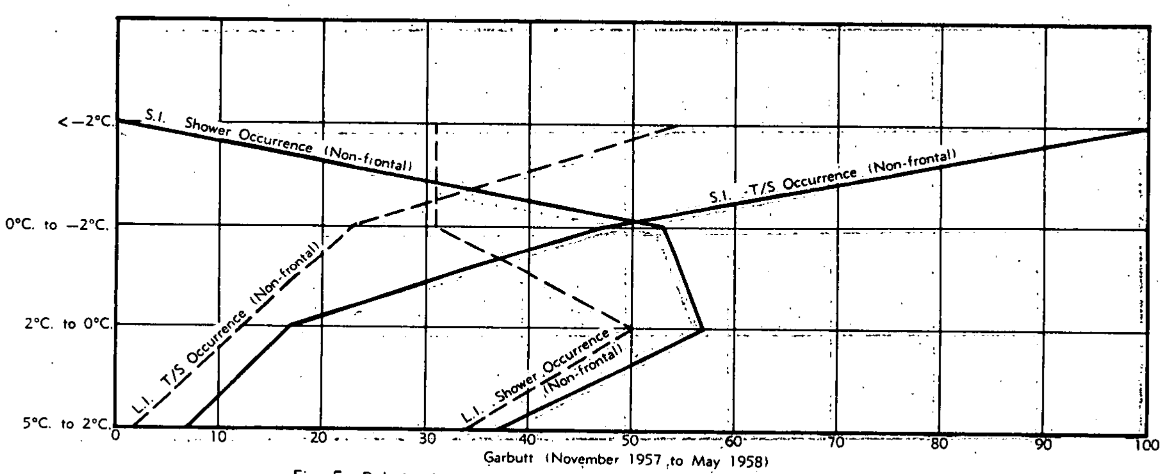

Fig. 5. Relation between percentage occurrence of non-frontal showers and thunderstorms and stability indices.

sounding, from a particular station, a good guide as to weather trend during the ensuring 24 hours can be obtained by applying this index to the graph for that station. In most cases the S.I. will be used because it is more readily deduced than the L.I. However, where the moisture decreases rapidly in the vicinity of the 850 mb level the S.I. is apt to indicate more atmospheric stability than will occur in actual practice. In such cases, the use of the L.I., which considers the average dew point up to 850 mbs, should be used in place of the S.I. Again, the L.I. rather than the S.I, should be used when a high diurnal variation of temperature is anticipated. In most instances this will apply only to the inland stations of Charleville and Cloncurry.

With regard to the forecasting of frontal weather, precipitation is possible at all stations having an air-mass with S.I. or L.I. as high as $+5^{\circ}C$. As the value approaches zero, it is obvious that thunderstorms are more probable than showers.

7. CHANGE IN STABILITY INDEX

On a number of consecutive days a decrease in stability index showed a linear relation to increase in surface dew point, but on the whole it was difficult to correlate the change of index with changing surface moisture. If we consider a static temperature field aloft and increased surface moisture, it is obvious that the instability should increase, but in actual practice temperature changes in the upper atmosphere do take place. In general, it is therefore inadvisable to estimate change of stability from day to day by using changes in surface dew point. Similarly, it is unwise to prognosticate the stability merely on historical sequence alone - changing surface pressure fields and upper air temperature advection are perhaps the most important factors to consider.

8. CONCLUSIONS

Air Mass Instability

(i) Probability of shower or thunderstorm development with respect to various instability parameters is readily obtained by reference to Figs. 2 to 5.

(ii) In general, thunderstorm development at the inland stations of Charleville and Cloncurry was greater than shower development for any particular stability index. The reverse was true of coastal stations for positive indices, but negative values indicated thunderstorms more likely than showers.

(iii) L.I. should be used in preference to S.I.

(a) When a large daily variation in temperature is forecast. This applies mainly to Charleville and Cloncurry.

(b) When a marked decrease in moisture occurs in the vicinity of 850 mbs.

Frontal Instability

(i) No thunderstorms occur when S.I. is greater than $+ 5^{\circ}C$ unless advection produces changes immediately ahead of the front.

(ii) Frontal thunderstorms are highly probable in all air-masses showing a Showalter Index of $+ 5^{\circ}C$ and less.

(iii) In cases studied, seven thunderstorms were accompanied by severe squalls and hail which caused structural damage. These violent storms were limited to air-masses in which $L.I. < S.I. < -1.0^{\circ}C$ when triggered by an agent of strong convergence or uplift - most severe storms occurred during the afternoon and in the month of February.

REFERENCES

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