Aust. Met. Mag. 34 (1986) 1-11 551.557.2(945)

Upper winds and mesoscale easterly flows in the Latrobe Valley*

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(Manuscript received November 1984; revised November 1985)

Upper air data for heights up to 3 km in the Latrobe Valley area have been examined. The prevailing winds are westerly at all levels due in part to the topography of the area. A three-level flow structure is indicated on about one morning in four with slope or drainage flows, generally shallow, but occasionally as deep as 100 m, an intermediate flow (low-level easterly) above these from about 100 m to as much as 700 m, and the synoptic flow becoming predominant above this level. Ambient Froude Numbers on these occasions are typically about 1. The intermediate flow is from the east with upper-level winds from the northwest and appears to be due to a mesoscale interaction of the synoptic pressure gradient and the local topography producing a diversion of the low-level flow towards low pressure.

Introduction

Local wind fields and associated temperature structure in valleys may vary considerably from those expected using observations from a synoptic-scale meteorological network, as indicated by recent reviews such as Atkinson (1981), Barry (1981) or DeMarrais and Clark (1982). Katabatic or slope flows have received considerable study (Atkinson 1981). Channelling of ambient flows by valleys has also been studied both observationally (e.g. Gunn and Furmage 1976) and, more recently, using numerical modelling approaches (e.g. Wipperman and Gross 1981). Considerable observational and theoretical studies have been made of mountain lee waves, for example Corby (1954) and Smith (1979). However the related lee trough, while a well-known synoptic feature, has received less attention so that the associated wind fields and temperature structure are not well described or understood (e.g. Atkinson 1981 and Smith 1982).

The Latrobe Valley of Victoria is currently the site of a major air quality study (Hart 1981) one aim of which is to develop the ability to predict effects of large industrial plants, such as power stations, on air quality in the region. Computer models are currently being developed for this task. It is important in determining model input data and in assessing results to know how uniform actual wind fields may be in either the horizontal or vertical planes.

This study will examine aspects of the wind structure in the Latrobe Valley in the first kilometre or so and, in particular, characteristics of some low-level easterly flows.

Upper wind climatology

The Latrobe Valley of Victoria is a region some 100 km long by 50 km wide near the southern extremity of the Great Dividing Range (see Fig. 1). The valley runs east-west with the floor at an elevation of 50 m to 100 m. The Range to the north of the valley rises to typically 1000 m (with peaks to 1500 m) with a coastal range rising to typically 500 m (with peaks to 760 m) forming the southern edge of the region. The valley opens to the east but on the western extremity land rises to only about 150 m. Thus although the Latrobe River, the main river of the valley, rises in the Great Dividing Range to the north, the area known as the Latrobe Valley does not have a well-defined head. It is more of a channel with the southern part of the Great Dividing Range along its northern side and hence is more open to mesoscale pressure effects than would be a normal valley which is enclosed on three sides.

Bureau of Meteorology stations making upper air observations are located at Laverton, near Melbourne, some 195 km west-northwest of Traralgon and at Sale (East), some 65 km east of Traralgon (see Fig. 1). The State Electricity Commission in conjunction with the CSIRO Division of Atmospheric Research (then Atmospheric Physics) carried out a two-year program (April 1975 to April

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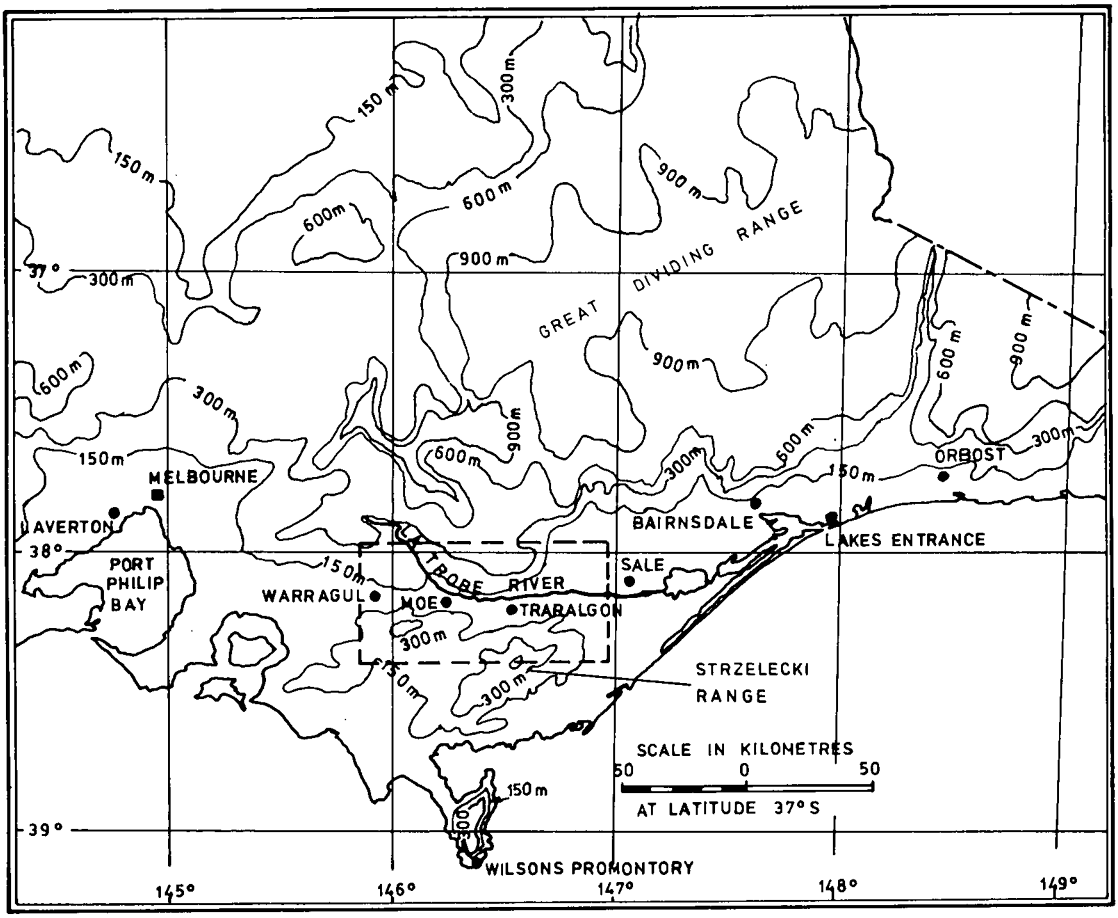
*This paper was presented in a preliminary form to the International Conference on Mesoscale Meteorology held in Melbourne, 6-10 February 1984.

Fig. 1 Eastern Victoria showing topography and the Latrobe Valley study area (— — —).



1977) of radiosonde releases at the Minniedale Road (MR) air monitoring station, some 5 km east-southeast of Traralgon (Spillane and Wren 1978). Upper winds and temperatures were collected at 0800 h Eastern Standard Time (EST) except during Eastern Daylight Saving Time* when they were collected at 0700 EST. Observations were made on weekdays excluding public holidays.

Climatological upper wind frequency distributions were examined for Laverton and Sale East (Latrobe Valley Airshed Study Steering Committee 1981) and these illustrated the effect of the topography on wind direction. At the surface at 0900 EST both stations showed the effects of local drainage flows and channelling by the Great Divide, i.e. from the north of Laverton and from the west to northwest at Sale East. At 950 mb (about 550 m) channelling effects were still evident although at Sale East the wind rose was broader to the west than for the surface case. At greater heights the wind direction distributions at the two stations became more alike, but it was not until about 750 mb (about 2500 m) that they could be said to be comparable — mainly due to a reduction in the easterly wind components at Sale East and an increase in the westerly wind components at Laverton.

Wind roses at different heights derived from radiosonde data at MR over two years at 0800 EST (or 0700 EST during EDST) in Fig. 2 showed the prevailing westerly to northwesterly wind direction at all levels with east to northeasterly winds the next most frequently occurring group. There was good agreement between 900 mb (approximately 1000 m) wind direction at Sale East and the corresponding 1000 m wind direction at MR so that spatial uniformity of upper wind direction in the Latrobe Valley area is evident.

The height dependence of the frequency of occurrence of easterly (northeast to southeast, inclusive) winds at MR at 0800 EST is shown in Table 1. The maximum frequency of easterlies occurred at some 50 m above ground and it was not until some

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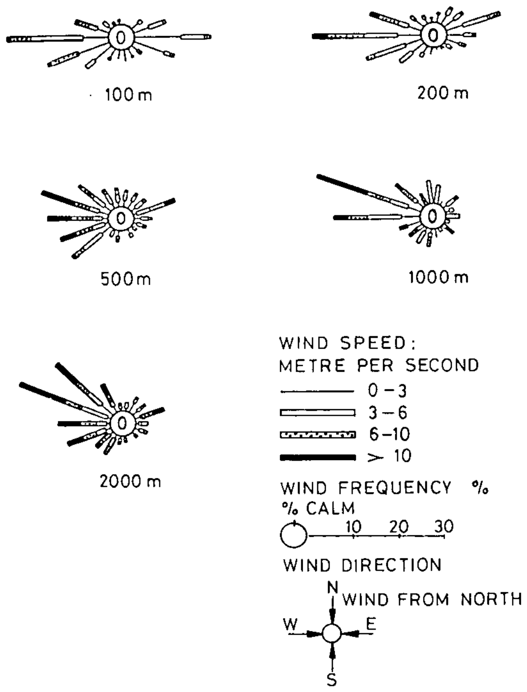
*Eastern Daylight Saving Time (EDST) occurs from the last weekend in October to the first weekend in March when clocks are advanced one hour relative to Eastern Standard Time. Eastern Daylight Saving Time = Greenwich Mean Time + 11 hours.

Fig. 2 Wind roses for various heights at Minniedale Road, 0800 EST (April 1975-April 1977).



300 to 400 m that the frequency was similar to that at ground level. A decrease with height in the frequency of easterlies would be expected due to the generally westerly flow at this latitude becoming more pronounced with height. The maximum in the frequency of easterly winds above ground level is thought to be due to the occurrence of surface calms (10 per cent) and surface drainage flows which have a marked southerly component at this site (Tapp and Hoy 1980). Examination of more recent data from four meteorological towers in the Latrobe Valley (between Warragul and Rosedale) shows a steady increase in the frequency of easterly winds between 10 m and 110 m, averaged over all hours of the day (Table 2). At Sale East climatological data for the surface, 500 and 1000 m showed a maximum in the frequency of easterlies at the 500 m level.

Figure 3 shows the relationship between wind direction in the layer 100 to 150 m, and at 1000 m for all available MR wind soundings. The data used were the original, observed (layer-averaged) winds rather than those of Spillane and Wren (1978). Figure 3 shows the prevalence of easterly flows at both levels and westerly flows at both levels due to the topography of the Latrobe Valley. However, there is also a group of points indicating easterly flows at 100 to 150 m with upper flows between west and north, and a further few points indicating westerly flows at 100 to 150 m with northeasterly flows aloft.

Table 1. Height dependence of the frequency (%) of easterly winds (northeast to southeast, inclusive) at Minniedale Road, based on all morning radiosonde data.

	Height (m)											
	Sfc*	50	100	150	200	300	400	500	800	1000	1500	2000
Freq. (%)	26.6	39.4	37.9	34.5	28.8	27.3	25.2	23.6	20.4	17.7	13.5	15.0
No. of obs.	500	393	388	383	377	359	352	349	308	276	224	99

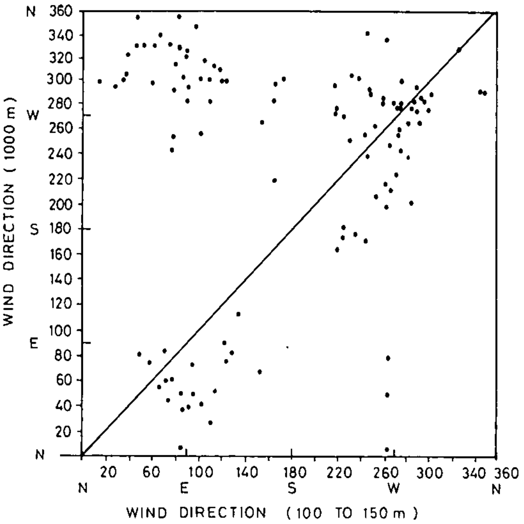
*Surface data based on observer estimates or 8 m height wind vane observations as available.

Table 2. Frequency (%) of easterly winds (34° to 146° inclusive) at Latrobe Valley meteorological tower sites, averaged over all hours of the day.

Meteorological tower (lat., long.)	February 1983			June 1983		
	Measurement Height (m)			Measurement Height (m)		
	10	110	Δ(110-10)	10	110	Δ(110-10)
Flynn (38°12', 146°40'E)	57.0	65.9	8.9	22.7	25.0	2.3
Yinnar (38°19'S, 146°23'E)	40.0	51.5	11.5	15.1	25.5	10.4
Thoms Bridge (38°11'S, 146°24'E)	55.2	61.5	6.3	21.8	29.4	7.6
Trafalgar (38°12'S, 146°08'E)	53.6	60.1	6.5	27.7	34.0	6.3

Δ means difference

Fig. 3 **The relationship between wind direction in the layer 100 m to 150 m, and wind direction at 1000 m.**



The 1000 m wind directions are indicative of the wind direction expected from sample surface pressure charts that were examined, even though the Great Dividing Range is higher than 1000 m in this area.

Some studies have already been made of likely mesoscale circulations in the Latrobe Valley. Drainage flows and sea-breezes have both been identified (Tapp and Hoy 1980). Manins and Sawford (1979 a,b) have studied drainage flows in the valley of Traralgon South Creek, near Calignee in the Strzelecki Range. Manins (1983) has also commented that, for the broader Latrobe Valley, drainage flows would be generally shallow, in the nature of slope flows, and only reach a depth of one hundred metres or so on a few occasions annually. Physick (1982) has studied easterly sea breezes in the valley in some detail using surface data. The sea breeze does not reach the Morwell area until late afternoon. A separated reverse circulation has also been suggested to explain some air pollutant observations (Bureau of Meteorology 1981).

Wind direction data from different heights were analysed to determine those cases where wind direction was within ±90° at both levels, using only morning flights and these results are summarised in Table 3. In 85 per cent of cases wind direction at 100 and 350 m agreed to within ±90° whereas only 68 per cent of cases agreed within these limits between 100 and 1000 m.

Discussing the cases comparing wind direction between 100 to 150 m and 1000 m, there were 32 cases (29 per cent) where easterly winds occurred beneath northwesterly winds and three cases (3 per cent) where westerly winds occurred beneath northeasterly winds. These 32 cases were examined more closely to see whether some synoptic effect was contributing and six cases were eliminated where the geostrophic wind over the Latrobe Valley area showed an easterly component. This left 26 examples of low-level easterly flows, implying a frequency of occurrence of about one day in four. Cases with a deep easterly flow resulting from the synoptic situation would not have been considered as the wind directions at both levels would have been within ±90°. No afternoon cases were considered as these could have been influenced by sea-breeze effects.

Table 3. **Relationship between wind direction at two heights at 0800 EST.**

	100 m and 1000 m		100 m and 350 m	
	Number	(%)	Number	(%)
WD ±90°	74	(68)	115	(85)
NW/E (1)	32	(29)	16	(12)
NE/W (2)	3	(3)	4	(3)
TOTAL	109	(100)	135	(100)

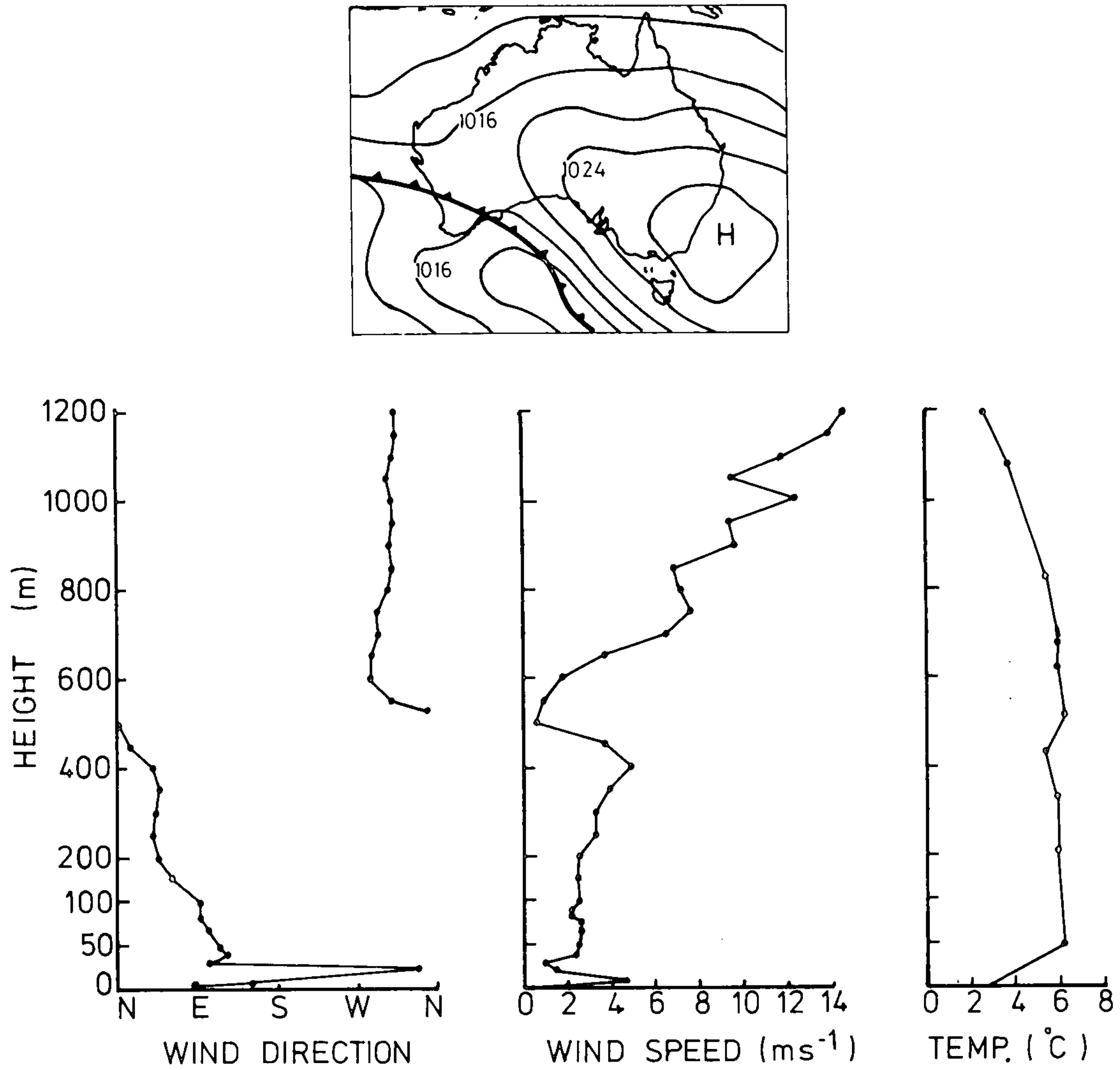
1. Upper wind direction is northwesterly while 100 m wind direction is easterly.
2. Upper wind direction is northeasterly while 100 m wind direction is westerly.

Case studies of low-level easterly flows

A good example of a low-level easterly event occurred on 8 August 1975. Upper wind and temperature profiles are presented for this day in Fig. 4. It was selected to represent most clearly the structures in question, namely the change from easterly to northwesterly flow at heights of a few hundred metres. The synoptic chart closest to the time of the sounding showed the prevailing broadscale north to northwest geostrophic flow. Figure 4 showed three different regimes: a drainage flow in the first 20 m or so; the easterly flow above between about 30 and 500 m; and the northwesterly flow above that. Most profiles were not detailed enough in the first 50 m or so to show detail of drainage winds.

A second example on 13 January 1977 is shown in Fig. 5. It showed generally similar structure compared with the event on 8 August 1975 except that the wind speed did not become zero at the height of the pronounced direction change as in Fig. 4. Other cases showed a mixture of these two types of wind speed profiles. Figure 6 shows mesoscale pressure fields for southern Victoria for these two days. Comparison of Fig. 6 with the broadscale synoptic situations of Figs 4 and 5 shows some trough formation is apparent south of the Great Dividing Range, in the vicinity of the Latrobe Valley on both days. The definition of mesoscale pressure fields in the vicinity of the Latrobe Valley is limited by the few observing stations in the area.

Fig. 4 Radiosonde data for 0800 EST, 8 August 1975 at Minniedale Road and surface pressure chart for 1000 EST.



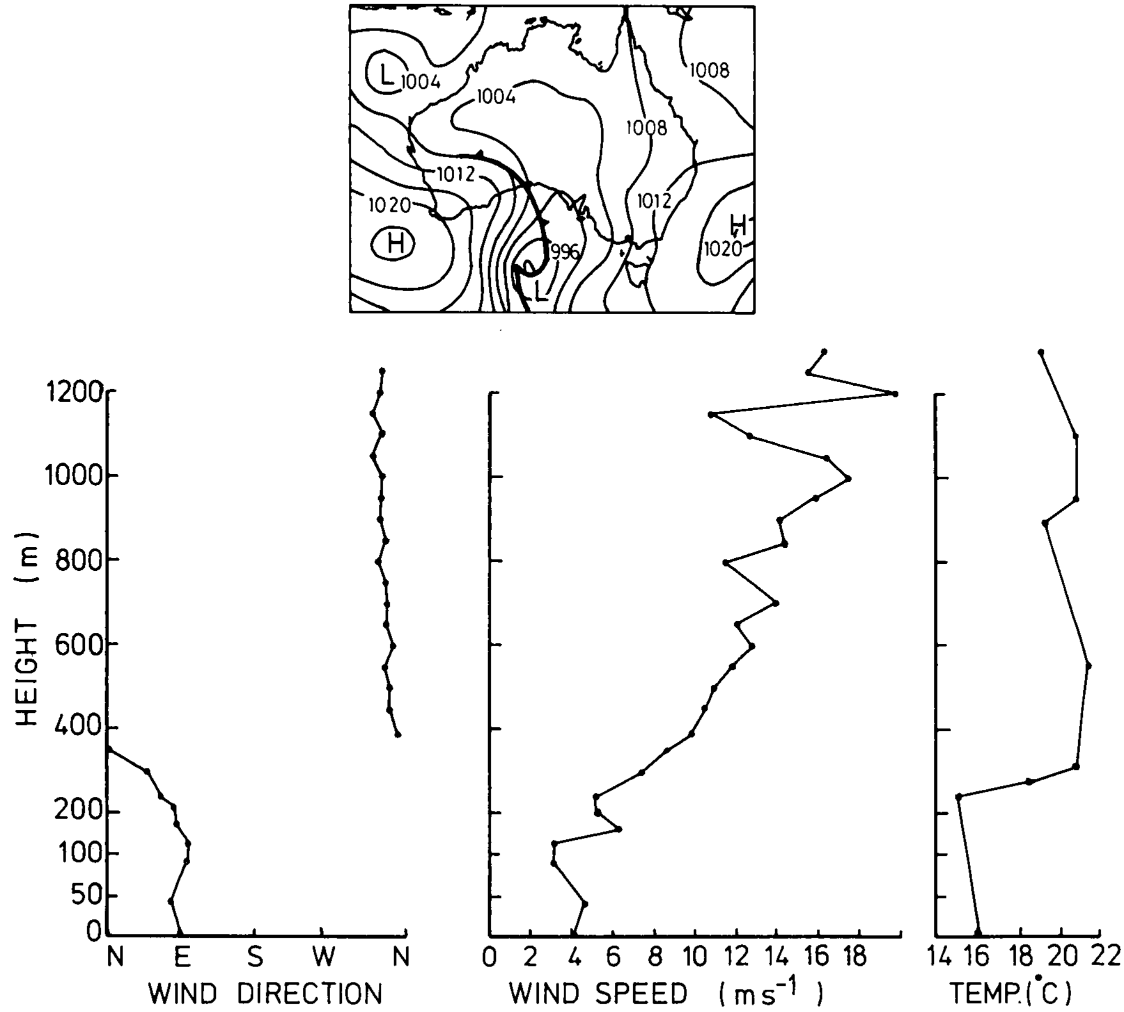
Characteristics of low-level easterly flows

Some characteristics of the 26 examples of low-level easterly flows are given in Table 4. The depth of the easterly flow was taken to be the height at which the wind backed through 0° (north). Table 5 shows that most flows were less than 400 m deep with the greatest number in the 200-299 m category. The maximum height of the Strzelecki Range is about 760 m and this height is similar to the top of the deepest case found (20 January 1977).

The cases of Table 4 show events in almost all months except October and November with the greater frequencies occurring in the cooler months May to September. The year 1975 also seems unusual in that seventeen cases, more than half the cases identified, occurred in that year between April and December whereas the other fifteen months of observations showed only nine cases. The mean easterly velocity components ranged from 1.1 to 5.4 m s^{-1} and the maximum easterly components ranged from 1.3 to 8.8 m s^{-1}.

For each of the 26 soundings there was at least one temperature inversion present and in two cases

Fig. 5 Radiosonde data for 0700 EST, 13 January 1977 at Minniedale Road and surface pressure chart for 1000 EST.



there were four inversions present in the sounding. Table 5 shows that the top of the easterly flows were located within an inversion layer in 16 out of 26 cases and were within ± 100 metres of an inversion layer in 24 out of 26 cases. Thus the low-level easterly is cut off from the overlying northwesterly winds associated with the prevailing synoptic situation.

In all cases geostrophic wind directions from the surface pressure charts were between WNW and NNW and the station level pressure differences between Sale East and Melbourne were positive. Allowing for the pressure difference between Sale East and Melbourne of 3.5 mb owing to the difference in station elevation (about 30 m), the pressure differences were still positive in almost all cases (see Table 4) suggesting the easterly winds were not geostrophic in nature. This easterly flow is also along the direction of channelling of the flows due to the east-west orientation of the Latrobe Valley. Hence flows, once established, would tend to persist in this direction. An easterly flow is also against the slope of the valley at the eastern end ruling out drainage flows as the cause of such flows.

The mean and maximum easterly wind components ($\bar{u}$ and u max) and the flow depth of Table 4 were correlated with the pressure difference —

$$\Delta p = \text{SLP (Sale East)} - \text{SLP (Melbourne)} - 3.5 \qquad \ldots 1$$

where SLP is station level presure (mb). The regression results are shown in Table 6. While the

Table 4. Data for low-level easterly days.

Date	Easterly wind velocity component			Δp^* (mb)	Upper wind direction category
	$\bar{u}$ (m s^{-1})	u max (m s^{-1})	Depth (m)		
29/4/75	3.6	6.3	400	2.6	NW
20/5/75	2.9	5.0	300	0.5	WNW
22/5/75	2.5	5.3	250	0.6	NW
23/5/75	2.3	4.8	200	0.5	NW
28/5/75	3.7	6.3	650	1.4	NW
27/6/75	1.3	1.9	100	0.9	WNW
17/7/75	1.4	2.5	100	1.1	WNW
18/7/75	1.1	1.6	250	1.3	WNW
8/8/75	2.4	4.0	550	1.0	NW
18/8/75	3.2	4.3	110	0.1	WNW
19/8/75	3.8	6.7	500	1.9	WNW
21/8/75	4.9	8.0	400	1.3	NW
26/8/75	3.3	6.0	350	2.1	WNW
2/9/75	1.5	2.1	230	0.7	WNW
9/9/75	2.5	3.5	300	1.3	WNW
12/9/75	2.4	3.5	200	2.3	NNW
11/12/75	1.6	4.6	330	1.5	NW
13/2/76	3.0	4.1	420	2.1	NW
20/8/76	3.0	4.2	250	0.9	NW
3/12/76	1.3	1.3	150	-0.3	NW
6/12/76	1.4	1.4	160	-0.3	WNW
22/12/76	2.5	4.1	300	1.6	NNW
13/1/77	4.2	6.2	380	2.4	NW
20/1/77	5.4	8.8	700	2.6	NW
4/2/77	2.4	2.9	260	1.8	NW
11/3/77	2.6	5.3	270	1.5	NW

* See Eqn 1.

Fig. 6 Pressure patterns for eastern Victoria for (A) 0900 EST, 8 August 1975 and (B) 0800 EST, 12 January 1977 based on Victorian Regional Forecast Centre analyses.

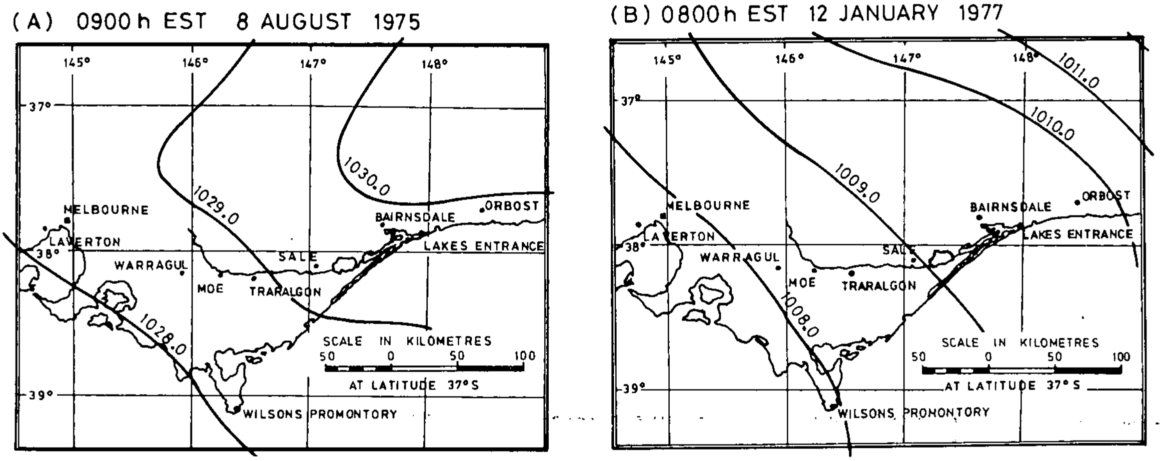


Table 5. Depths of easterly flows and association with temperature inversions.

Depth (m)	Number	Top of flow in inversion	Top of flow in inversion ± 100 m
0-99	0	0	0
100-199	5	5	5
200-299	8	4	7
300-399	6	4	6
400-499	3	1	2
500-599	2	1	2
600-699	1	0	1
700-799	1	1	1
⩾800	0	0	0
TOTAL	26	16	24

Table 6. Correlation of Δp with $\bar{u}$, u max and depth (for Equation $y = a x + b$, correlation coefficient r).

Coefficient in correlation	Variable		
	$\bar{u}$ (m s^{-1})	u max (m s^{-1})	Depth (m)
a	0.75	1.35	108.8
b	1.74	2.68	172.1
r	0.55	0.56	0.57

correlation coefficients of Δp with $\bar{u}$, u max and depth are significant at the 1 per cent level only some 30 per cent of the variance is explained. The relationship between $\bar{u}$ and Δp is shown in Fig. 7.

Examination of surface wind data at 0900 EST from Bureau of Meteorology stations in West Gippsland and Port Phillip Bay area for all days of Table 4 showed the following:

- the Latrobe Valley had either light easterly winds, drainage winds or calms;
- the Port Phillip Bay area and Wilsons Promontory Lighthouse showed light to moderate northeasterly to northwesterly winds. In the Melbourne area, drainage winds or blocking of the northwesterly winds by the Great Dividing Range would result in these directions.

At Laverton, moderate to strong north to west winds prevailed with no evidence of significant easterly components above 500 m. A small easterly component in the surface winds was sometimes evident, due to either drainage winds or low-level blocking of the northwesterlies by the Great Dividing Range. At Sale East the low-level easterly was only occasionally observed at 950 mb (500 m). Thus the low-level easterly flows exist in the Latrobe Valley area, but do not extend as far west as Laverton. They sometimes (11/26 cases) extend as far south as Wilsons Promontory.

Examination of surface pressure charts for the Australian region for days of low-level easterly occurrence typically showed a high pressure system over the Tasman Sea with a low pressure system to the south of the Great Australian Bight. Examination of corresponding synoptic charts for the Victorian region showed evidence of some trough occurrence to the south of the Great Dividing Range on about half the low-level easterly days.

The Froude Number Fr is useful to determine flow conditions, such as blocking, associated with flow obstructions. The Froude Number Fr is given by:

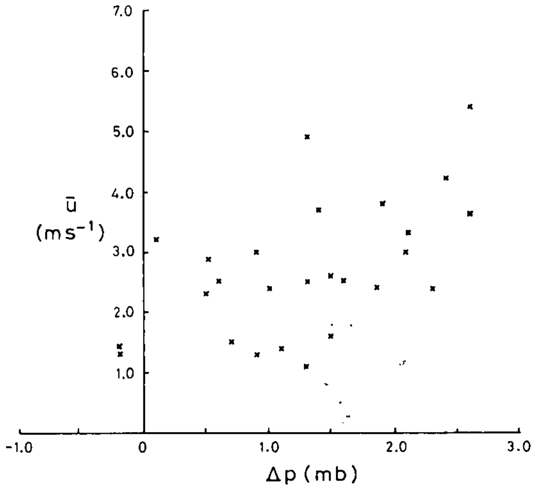
$$Fr = V (g \gamma/\theta)^{-0.5}/h \qquad \ldots 2$$

where V is the ambient wind speed, h is the obstruction height, g is the acceleration due to gravity, γ is the potential temperature gradient and θ is the potential temperature.

For comparison with modelling studies (Bell and Thompson 1980 or Smith 1982), an ambient or upstream Fr can be used to specify flow characteristics before interaction with the flow obstruction. For comparison with field studies (e.g. Manins and Sawford 1982 or Spillane 1978) an internal Fr, i.e. internal to the flow after interaction with the flow obstruction, can be used. Both Froude Numbers will be considered here.

In the present analysis of low-level easterly flows in the Latrobe Valley, upper-level northwesterly winds flow across the Great Dividing Range to the north of the valley and the Strzelecki Range to the south. The ranges to the north are about two to three times the height of those to the south which introduces uncertainties in choosing the appropriate obstruction or ridge height, the associated ambient wind speed (i.e. wind speed above ridge height) and ambient potential temperature gradient to use for determining Fr, particularly the internal Fr.

Fig. 7 Relationship between $\bar{u}$ and Δp for low-level easterly cases.



Laverton data were used to characterise ambient conditions in the prevailing northwesterly flows. Typical conditions at Laverton on days of low-level easterlies in the Latrobe Valley were wind speeds of about 16 and 15 m s^{-1} at 900 and 950 mb respectively and a potential temperature gradient of about 0.005 °C m^{-1} averaged from the surface to about 2000 m. Using the wind speed at 900 mb (about 1000 m) and a barrier height of 1000 m results in an ambient $Fr = 1.2$. Ambient Fr for individual days calculated in the same way ranged from 0.5 to 2.4.

Internal Froude Numbers for the two case studies of 8 August 1975 and 13 January 1977 using soundings from MR were calculated to be 1.2 and 2.4 respectively, using ridge heights of 500 m, ambient wind velocities just above the ridge line and an ambient potential temperature gradient. Alternatively using 1200 m as an upwind ridge height and appropriate wind speeds at greater heights and potential temperature gradients, internal Froude Numbers of 1.2 and 1.6 respectively were calculated. Allowing for the uncertainties of determining an internal Fr in this situation with differing and irregular ridge heights on either side of a valley, it could be said that values of Fr were typically between 1 and 2 and that these values are close to the critical values for distinguishing between sweeping and stagnating flows of Manins and Sawford (1982) or Bell and Thompson (1980).

Discussion

From discussions of mesoscale effects near mountains (such as Atkinson 1981 or Smith 1982) and, more locally, Manins (1983), possible mechanisms which may result in low-level easterly flows are:

- formation of a low pressure trough in the lee of the Great Dividing Range;
- formation of a mesoscale anticyclonic eddy in the lee of the Range; and
- interaction of topography, synoptic pressure pattern and low-level stability to induce an easterly surface flow.

A lee trough may be formed where strong winds flow across an extended mountain barrier. This occurs in the present situation with upper winds (~15 m s^{-1}) between WNW and NNW (Table 4) flowing across the Great Dividing Range which forms a continuous barrier oriented approximately ENE-WSW. Some trough occurrence was evident in Bureau of Meteorology surface pressure fields on about half of the 26 cases of low-level easterly flows. More closely spaced pressure observations than are routinely available in this area would be needed to determine definitely the existence or not of a lee trough.

Lee trough conditions associated with upper-level northwesterly winds occur in the Canterbury Plains area of the south island of New Zealand (Trenberth 1977 and McKendry 1984). Surface winds under these conditions are typically northeasterly, especially near the east coast, and thus show some similarity to low-level easterly conditions in the Latrobe Valley. Smith (1982) has proposed a theory to explain orographic effects on wind and pressure fields. The Fr used by Smith (1982) was about 0.7 (with $h = 3$ km and $V = 20$ m s^{-1}) and is within the range of Fr found in the present study. His theory did produce weak flows crossing the isobars toward low pressure at and just to the lee of his mountain ridge. Thus his theory and results provide some support to the idea that the low-level easterly could be caused by the flow deviation around the mountain barrier or the associated lee trough.

A mesoscale eddy may occur in the lee of a mountain range under suitable conditions of wind and stability. Spillane (1978) discussed eddy occurrence in the Melbourne area due to blocking of easterly flows by the Great Dividing Range with $Fr \leqslant 0.15$.

Manins (1983) has produced an easterly flow beneath an upper-level northwesterly flow in experiments where a model of southern Victoria was towed in a water tank which simulated a stably stratified atmosphere with $Fr = 0.3$. The eddy in the tank experiments was centred off the coast and hence would be of considerable size (radius of order 100 km). This was consistent with the results of surface data examined as all Latrobe Valley and Central Gippsland stations (at least as far east as Sale) show effects consistent with eddy formation. However, observations from Bairnsdale, Lakes Entrance and Orbost (all to the east of Sale) were consistent with an anticyclonic eddy on only seven of the 26 cases. This could mean that the eddy did not exist at all, did not exist at the observation height but may have existed higher up, or did exist offshore but not onshore at these sites. The tank experiments, while simulating the geostrophic flow associated with a particular synoptic pressure gradient, did not include the effect of the synoptic pressure gradient explicitly. This is a weakness in the simulation as the low-level easterly flow was correlated with the pressure gradient (Table 6). Examination of more recent wind data from the oil rigs and island stations in Bass Strait on days when the low-level easterly existed in the Latrobe Valley did not support the occurrence of a mesoscale eddy (Manins, Private communication 1985).

The third mechanism provides a description of how a low-level easterly flow could occur in an area such as the Latrobe Valley. A northwesterly synoptic flow would be often associated with little cloudcover in the Latrobe Valley. Overnight radiative cooling of the ground surface of the valley could result in increasing stability in the lowest hundred metres or so of the valley. This increased stability could allow decoupling of this layer from the synoptic northwesterly flow aloft, with a temperature inversion separating the relatively warmer continental air aloft from the relatively cooler air below. The air below the inversion could then move along the valley in response to the remaining pressure forces. A weak westerly drainage flow, caused by the slight slope to the east along the axis of the Latrobe Valley (1.5 in

1000), could develop in the absence of a synoptic pressure gradient. A flow could develop from an area of high pressure to an area of lower pressure as the result of a synoptic pressure gradient. The synoptic situations observed with the low-level easterly would result in an easterly flow in the Latrobe Valley when the pressure gradient force was sufficient to lift an air parcel along the slight slope of the valley floor. The easterly flow, once established, would continue to bring cool moist air from the east into the valley, thus maintaining stable conditions. Such a flow could persist through the day if the advection of cool air was sufficient to overcome the effects of solar heating and thus maintain the low-level stability.

The evidence available is sufficient to suggest that the low-level easterly is caused by a mesoscale interaction of the synoptic pressure gradient and the local topography, but is not sufficient to determine which of the three proposed mechanisms is the main cause.

Three cases with 1000 m wind direction between north and east and 100 m wind direction from the west were identified in Fig. 3 and occurred on 23 April 1975, 9 June 1975 and 22 October 1975. A possible further case occurred on 13 January 1976. These cases were harder to characterise due to the small number found. They occurred with generally weak pressure gradients and geostrophic wind directions suggested were either northeasterly or indeterminate. The pressure differences (Sale East-Melbourne) were between 3.3 and 4.1 mb which, allowing for the height difference of the stations, meant a net difference of between -0.2 and 0.6 mb (close to zero) and less than the cases of Table 4. Examination of surface and upper air data between Melbourne and Sale East suggested consistent low-level westerlies were confined to the Latrobe Valley area and wind speeds at 1000 m were typically 4 m s^{-1}. Froude Numbers ranged from 0.1 to 0.5. Manins (1983) was able to induce some weak, low-level westerlies in the Latrobe Valley area when upper wind direction was northeasterly. In these cases of low-level westerlies the mesoscale eddy or a well developed drainage flow seem to be the most likely explanations.

The low-level easterly circulations have implications for the local climate in terms of fog formation and air pollutant dispersion. Fog formation is favoured by the occurrence of light winds bringing in relatively moist air from the Tasman Sea even though the rest of southern Victoria is under the influence of relatively dry continental air.

Air pollutant modelling studies may be affected as these studies often employ wind field models which use surface wind data, generally at 10 m height, extrapolated to the greater heights of the plumes from large sources. It is clear that speed and direction may change several times with height on many days and hence plume transport and dispersion will be difficult to predict from such models on these days.

Temperature inversions associated with the occurrence of low-level easterlies may account for some of the 40 per cent greater frequency of inversions observed at MR compared with Laverton (Tapp and Hoy 1981).

Because of the relatively common occurrence of low-level easterlies (about one day in four), emissions from higher level sources in the Latrobe Valley are carried towards the west up to 12 per cent (based on Tables 1 and 2) more often than would be expected based on surface wind direction measurements as in Tapp and Hoy (1980). The effect will be of most importance for plume material in the height range 50 to 400 m and will be of negligible importance for plumes which rise to heights above 800 m. The circulation will not result in emissions from the Latrobe Valley reaching Melbourne as air travelling westward under these conditions will encounter north to northwesterly winds at the western end of the Great Dividing Range and so be swept southward.

Conclusions

The prevailing upper winds in the Latrobe Valley are westerly at all levels, due in part to the topography of the area. A comparison of morning wind directions at about 100 m and at 1000 m showed that 32 per cent of cases did not agree to within ±90° at both levels. The majority of these showed typically upper-level northwesterly winds with lower-level easterly winds. A three-level flow pattern is suggested on about one morning in four with slope or drainage flows in the height range 10 m to possibly 100 m, an intermediate (low-level easterly) flow pattern above these from about 100 m to possibly as much as 700 m, and the synoptic-scale flows becoming predominant above this level.

The low-level easterly flow is generally isolated from the overlying northwesterly geostrophic wind by a temperature inversion and the strength of the flow is proportional to the synoptic pressure gradient. Ambient Froude Numbers on days of low-level easterly occurrence are about 1. The low-level easterly is sometimes associated with the occurrence of a lee trough and appears to be due to a mesoscale interaction of the synoptic pressure gradient and the local topography producing a diversion of the low-level flow towards low pressure.

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