

A COMPARISON OF GEOSTROPHIC AND OBSERVED UPPER WINDS \*

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The jet streams in the upper troposphere have been discussed in recent years almost exclusively in terms of geostrophic (or gradient) rather than directly observed winds. A striking example is the use of winds derived from the hydrostatic pressure field only by Palmén and Newton (1948) in their classical study of the polar front jet stream over North America. These authors concluded that "direct verification of results is difficult since wind observations at high altitudes are much too scanty and particularly unreliable in case of strong winds".

If this described the position in the dense network of U. S. radiosonde stations a direct verification of derived winds must obviously be even more difficult in a region like Australia. Yet it is here that such a verification would be especially desirable. It would establish how far the observations from a few widely scattered stations permit a detailed representation of especially the momentary (rather than the average) flow conditions in the upper troposphere. A special aspect of this general problem concerns the errors introduced in a meridional cross section by the use of all available stations, irrespective of moderate differences in their longitudes. The use of this procedure by Loewe and Radok (1950) was criticized by Hutchings (1950) and again recently by Gibbs (1952). Against this Grant and Radok (1951) pointed out that the zonal scatter of the stations used in a meridional cross section can often be taken into account, i.e. whenever the meridional height profiles of the isobaric surfaces tend to sway northwards and southwards with little change in shape. Clearly this is an argument which could be settled by comparisons between derived and observed winds.

A chance for such a comparison presented itself following the construction of a series of momentary cross sections by the present writer. While as a whole these cross sections will be discussed elsewhere one of them has been singled out because subsequently three sets of trustworthy upper wind observations were discovered which had been made not far from the latitude of the strongest cross section winds on the day in question (29th July 1949).

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Despite a number of shortcomings a comparison between the derived and observed winds for that day seemed of interest, and the results form the subject of this note.

Figs. 1 - 3 give auxiliary information and require little discussion. Thus fig. 1 shows the 500 mb contours for 0800 Z on July 29th, 1949; the locations of the radiosonde and upper wind observations used in the following are also indicated. Over eastern Australia the contours are approximately straight and zonal so that there exists no obvious objection to the use of all stations for the cross section. The latter is given in fig. 2, the thermal field being represented by the isentropes. The tropopause has been drawn so as to fit the most plausible estimates for the individual stations; it cannot be decided with certainty whether the transition from the high to the low tropopause was continuous, as shown, or whether a tropopause "break" existed around latitude  $35^{\circ}\text{S}$ .

The cross section shows a jet stream with a maximum velocity of 190 m.p.h. just below the 200 mb level in latitude  $32^{\circ}\text{S}$ . As a check the velocities at the 300 mb. level were integrated and the resulting height profile was compared with the directly computed 300 mb heights for the individual radiosonde ascents (cf. Grant and Radok 1951). The result is shown in fig. 3. The fit obtained seems very good, but there are signs of a slightly steeper gradient in the western part of the region under consideration (between stations 659 and 677). Finally fig. 4 gives the information of principal interest here, viz. the comparisons between the geostrophic (thin lines) and observed (heavy lines) west-east velocity components for three stations.

The first set of upper wind observations consists of two rawins for Auckland (112). While these observations were made at a considerable distance from the region of the cross section they are at any rate representative in time, having been started four hours before and two hours after the time of the cross section. The observed velocities agree fairly well with those derived from the cross section for the same latitude, both being only moderately large. The observed wind directions in this case fluctuated between  $260^{\circ}$  and  $280^{\circ}$ .

The second set of observed winds, one of the series of rawins discussed by Edwardes (1952), was made almost six hours before the time of the cross section at Sydney (767).

Here the strongest winds, between 35,000 and 45,000 ft., were from the west, whereas the remainder had a slight northerly component ( $284^\circ$ ) at all levels up to 94,000 ft. This incidentally amounts to a confirmation of the observed velocities which are seen to be considerably below the derived values; with the latter the balloon would have moved out of range long before it actually did. The cross section velocities therefore are quite definitely excessive in this case.

The third and final set of upper winds to be discussed was observed by means of double theodolite procedure even closer to the centre of the jet stream in fig. 2. Apart from a shallow layer (20,000 - 25,000 ft.) with a weak southerly component the direction of the wind was from  $270^\circ$  at all levels above 5,000 ft. The agreement between derived and observed velocities is reasonably good. It should be noted that the maximum observed velocity of 195 m.p.h. agrees closely with that of the jet stream centre shown in fig. 2 at a slightly higher latitude.

The main discrepancy then is that found at Sydney. The observed winds for that station agree roughly with those found at Auckland, 3 degrees of latitude further south, while having a weak northerly component; this suggests a slight meandering of the jet stream, with a trough just west of Sydney. Alternatively there might have been a fanning-out of the contours near the Australian east coast, leaving the fairly shallow layer of stronger west winds mentioned earlier as the only trace of the jet stream further to the west. Both these interpretations lead to difficulties, however. In the first case the height of the 300 mb surface would have been expected to be relatively lower at Charleville (510) than at Amberley (575) whereas fig. 3 shows them to fit well into the same meridional profile. The second interpretation implies a strongly diffluent jet stream (Sutcliffe and Forsdyke 1950) and spectacular dynamic consequences in the "delta" region (Scherhag 1948), say between longitudes  $140^\circ$  and  $150^\circ$ E, which however did not materialize subsequently.

The inescapable impression gained from the above is that important details in the high-level flow were not brought out by the radiosonde observations available in this case. This would also hold true if the latter had been used to construct a set of constant pressure charts instead of the cross section in fig. 2. In

particular fig. 3 gives no reason to suspect that the accuracy of the derived winds has suffered through the use of stations differing by up to 20 degrees in longitude.

Finally it must be stressed that the few comparisons given would not have been conclusive if agreement between the derived and observed winds had been obtained in every case. On the other hand the discrepancy found seems conclusive evidence that a great many more reliable upper wind observations - such as have recently begun to come forward - are required for a detailed representation of the high-level flow over the Australian region, especially under jet stream conditions.

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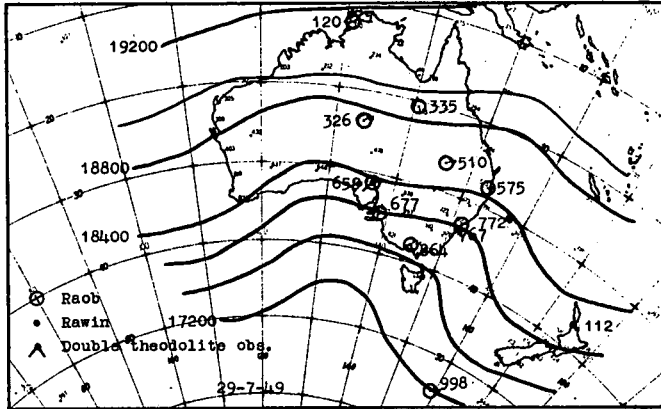


Fig. 1. 500 mb contours for July 29th, 1949, 0800Z.

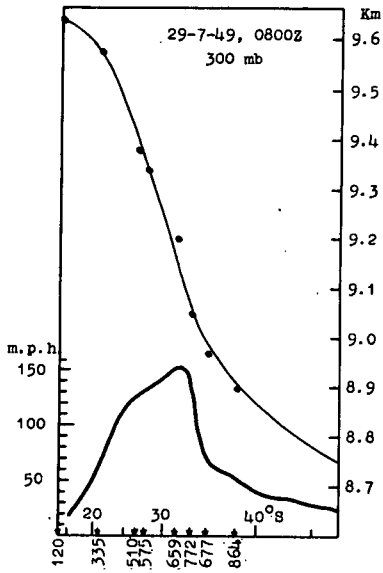


Fig. 3. 300 mb height and velocity profiles from the cross section in Fig. 2.  
 — height profile.  
 - - - velocity profile  
 • observed heights  
 The height profile was obtained by integration of the velocity profile and located so as to reduce the sum of the observed height deviations to zero.

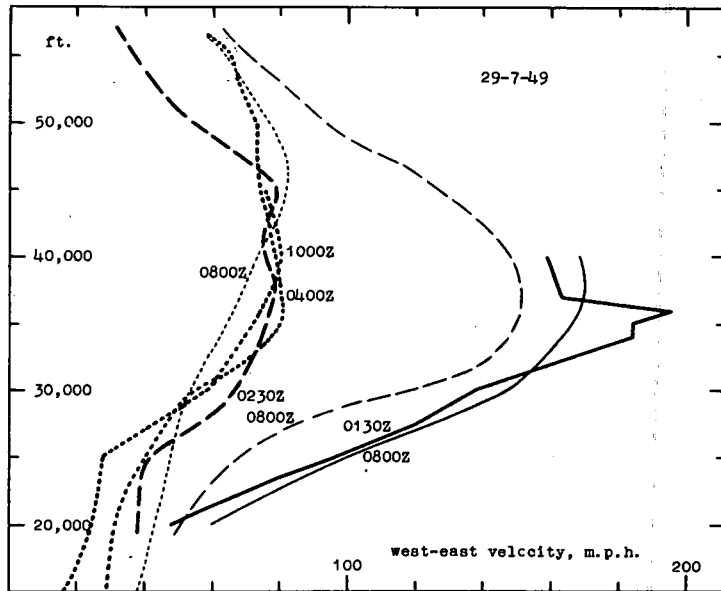


Fig. 4. Comparisons of observed and geostrophic zonal velocity components for July 29th, 1949.

- - - - - observed (rawin) velocities, station 112
- - - - - geostrophic
- - - - - observed (rawin) velocities, station 767
- - - - - geostrophic
- - - - - observed (double theod.) velocities, station 659
- - - - - geostrophic

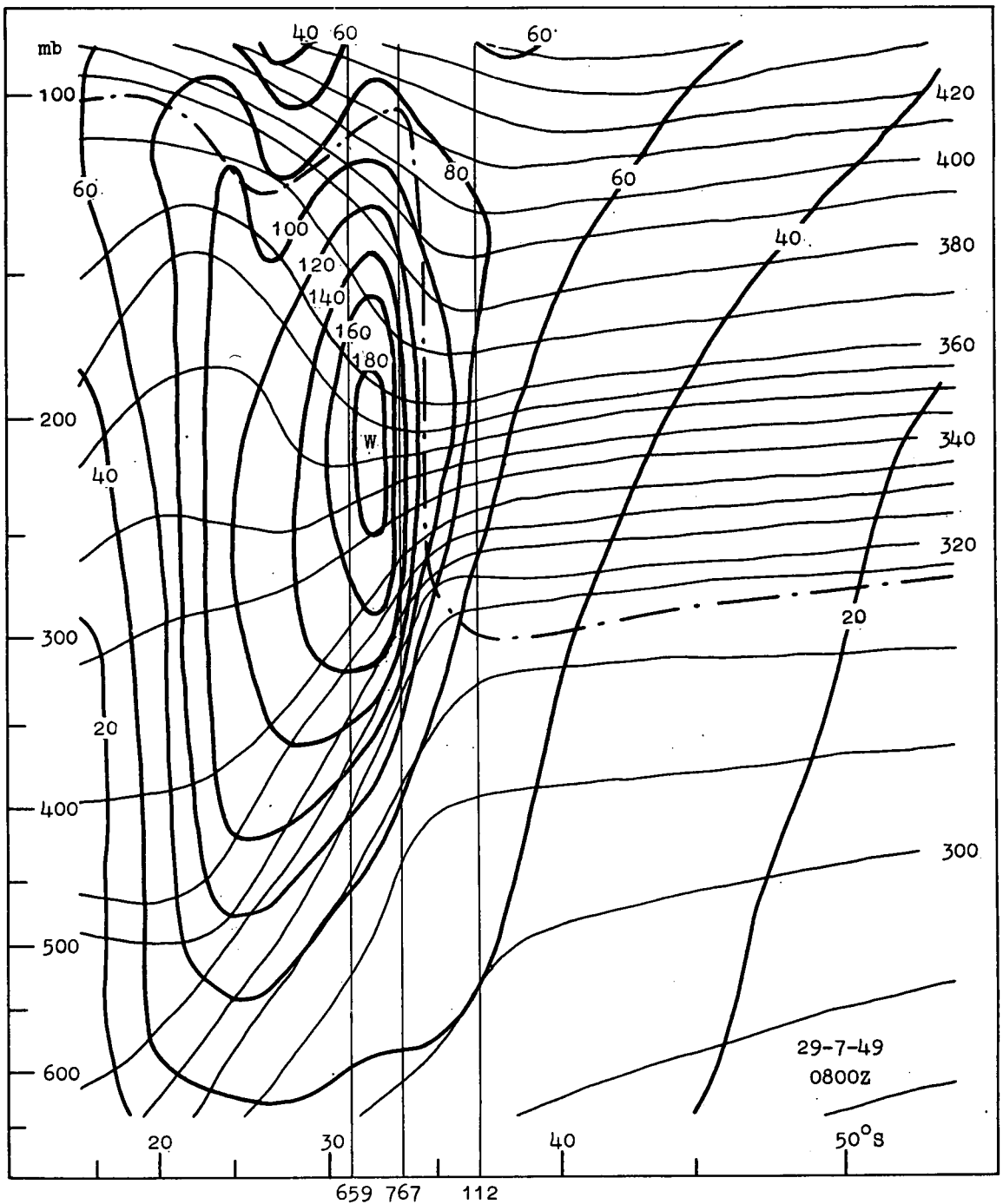


Fig. 2. Meridional cross section of potential temperature and zonal geostrophic wind for Eastern Australia; July 29th, 1949, 0800Z.

————— zonal velocity isopleths (m.p.h.)  
 ————— isentropes (°A)  
 - - - - - tropopause.