A January and July climatology of the southern hemisphere based on daily numerical analyses 1973–1977

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(Manuscript received December 1980; revised June 1981)

A limited climatology has been developed using the unique data set afforded by five years (1973–77) of World Meteorological Centre (WMC) Melbourne’s operational hemispheric analyses. The climatology differs from Taljaard et al. (1969) in respect of an upper-tropospheric ridge over the western Pacific at lower latitudes. Other differences appear in the lower levels over Antarctica and certain ocean areas. Distributions of cyclones and anticyclones, which to date have largely been based on studies performed during the International Geophysical Year (IGY) (1957–58), have been re-calculated.

Introduction

Monthly mean and annual mean conditions have been derived from the Australian Bureau of Meteorology archives for the period 1973–1977 inclusive. Daily numerical analyses for 0000 GMT have been used to construct these means because they generally have a more extensive data base than the 1200 GMT charts. This paper contains a review of the January and July means, as these indicate seasonal contrasts, and because January and July are the most modelled months. A climatological atlas detailing all months is in preparation.

The archived analyses are held on a 47 × 47 hemispheric grid giving an effective resolution of approximately 500 km. They relied on initial specification of the mean sea level pressure and 1000 to 500 mb thickness by manual analysis methods. These methods made use of the conventional observation network, and also cloud picture interpretation (Guymon 1978) which gave deviations from Taljaard’s climatology (Taljaard et al. 1969) to extend the data base into no-data areas. The conventional data base used in the analysis was that arriving at WMC Melbourne within seven hours of analysis time. The coverage of these observations was often incomplete: for example it was unusual for upper-air observations from some Chilean and Antarctic stations and Easter Island to be used in the analyses. Satellite imagery available during analysis came from US polar-orbiting satellites (Automatic Picture Transmission (APT) and Weather Facsimile (WEFAX) data) and GOES-E and GOES-W since January 1977. Of course from 1978 onwards the Geostationary Meteorological Satellite has augmented this data base.

In the analysis scheme first guess fields between 1000 and 500 mb were a combination of twelve-hour prognosis and Taljaard’s climatology. First guess fields above 500 mb were a combination of prognosis fields, Taljaard’s climatology, and fields based on correlations between lower and upper-tropospheric parameters, and generated by using predictors and predictands which were deviations from Taljaard’s climatology (Seaman 1972). All observations at each level were then analysed using a successive correction method, with the manual 1000 to 500 mb analysis being statistically broken down to provide standard level values below 500 mb. It can be seen as a result of this procedure that WMC analyses will show some bias towards Taljaard’s climatology.

The conventional data base has been supplemented since 1976 between 20°S and 60°S by Vertical Temperature Profile Radiometer (VTPR) data, in part locally reduced (Kelly et al. 1976).

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The anticipated difficulties (Streten 1977) in using the archive period as a compatible continuous series, due to the introduction of VTTR data during the archive period, have been investigated by analysis of the 1976 January data with and without VTTR data. These archived analyses have already been the basis of several studies, Trenberth (1979, 1980a, b), Streten (1980) and van Loon (1980), which with some reservations indicate this data set to be probably the best available to describe broadscale southern hemispheric features. Differences between this and Taljaard’s climatology will be outlined and where necessary related to differences in the observational networks used, differences in analysis methods (Taljaard et al. computed means from conventional observations and analysed these), and real differences between the periods.

Hemispheric means

The mean January and July charts of mean sea level pressure, geopotential and temperature are in most areas similar to those of Taljaard et al. (1969), see for example Figs 1 and 2. This suggests the five years of data (about 150 days) represent a stable estimate despite serial correlation.

At MSLP the salient differences between the WMC means (Figs 1(a) and (c)) and those of Taljaard et al. (1969) (Figs 1(b) and (d)) are over Antarctica, where the different technique for reduction to sea level is a contributing factor. Some differences are seen in the Circumpolar Trough (CPT) for January, an area with a significant inter-annual variability, although it appears that in both five-year and individual January means a closed 990 mb isobar usually lies off the coast of East Antarctica centred around 80°E and the circumpolar trough is usually broken by higher pressure at Drake Passage.

The standard level monthly mean geopotential analyses also differ from Taljaard’s means around Antarctica. The increase in geopotential shown above Antarctica is due to both the increased surface pressure and also to a warmer lower troposphere during this period (Trenberth 1979). The lower-tropospheric (anticyclonic) regions associated with the Sub Tropical Ridge (STR) also show a general increase in geopotential. A salient difference revealed by this study is an upper-tropospheric ridge near 20°S, 140°W at 100 mb and 200 mb (Fig. 3). Although not fully consistent with long-term mean station winds at Tahiti (18°S, 150°E) and Raratonga (21°S, 200°E) it is

Fig. 1 (a) Average January MSLP (mb) chart from WMC archives (1973–1977).

Fig. 1 (c) Average July MSLP (mb) chart from WMC archives (1973–1977).

Fig. 1 (b) Average January MSLP (mb) after Taljaard et al. (1969).

Fig. 1 (d) Average July MSLP (mb) after Taljaard et al. (1969).
reasonably consistent with mean station height data (Figs 3(a) and (b)), which were not used in Taljaard’s analyses. These station data were checked during 1977 by a comparison of southern hemisphere sonde station and coincident VTPR soundings, which showed no anomalous bias in the South Pacific. The ridge was also present in the post-1976 analyses and the March to June analyses in 1979, where VTFR and the first few months of TIROS-N data respectively, helped to define its southern edge. Unfortunately its form is

influenced by the data distribution, and is a result of analysis using limited data from a number of island stations within a data-void area. This upper air climatology, particularly to the east of this feature, is now being re-evaluated using second generation sounding data from polar-orbiting satellites. The ridge, however, is not inconsistent with the surface discontinuity in the mid-latitude anticyclone indices of Streten (1980) at around 130°W, and may be related to the mid-Pacific cloudband (see e.g. Streten 1973).
Mean temperature fields which in data-void areas are diagnosed from geopotential indicate a warmer lower troposphere over Antarctica. A warmer lower troposphere has been diagnosed over large oceanic areas (particularly the eastern sections) while in January a cooler troposphere is apparent over the continents. Generally the five-year means are much less zonal than the long-term averages of Taljaard et al. (1969).

To gauge the impact of VTPR data on the WMC means, the analyses for January 1976 were repeated with and without VTPR data. Little change was found in the resulting monthly mean even at 200 mb where some change in jet structure from the additional soundings might be anticipated. It appears that although VTPR data may enhance jet structure and other features for particular analyses (see Fig. 4, in particular the isotach analysis over the southern Indian Ocean), and is therefore important in the forecast context (Kelly 1976 — unpublished), it has little effect on the long-term means. This result is not unexpected as the statistical technique used for generation of standard-level data above 500 mb in 'no data' areas should show no bias in the mean and hence be consistent with climatology. The results also allow confidence in using the archive data as a compatible continuous series.

Variability

The average daily standard deviations (SD) of the five Januaries and Julys from 1973 to 1977 about their respective monthly means have been calculated for all levels. At mean sea level (Figs 5(a) and (b)) the area of maximum variability appears to lie in a band near 55°S (the westerlies) with three local maxima in this band to the southeast of the major land masses. This band of maximum variability effectively defines the boundary (or maximum overlap) of the mean cyclone and anticyclone densities (Fig. 7). It appears more intense and shows some southward displacement in winter.

The local maxima in the band occur in the three regions of preferred blocking for the southern hemisphere (van Loon 1956). In these regions large deviations can be recorded by slow-moving or stationary highs well south of the STR, deflecting the normal westerly current well to the south of its mean course. However, the influence of the distribution of island station data on the positioning of maxima in this band (i.e. its influence on manual analysis) may be significant, and will not be resolved at least until a full analysis of floating buoy data is completed. In fact initial analysis of the distribution of variance
Based on FGGE data, where oceanic data were augmented by floating buoys, indicated a more zonal distribution (Guymer and Le Marshall 1980). Other areas of high variability include the regions to the northeast and northwest of Australia in January, reflecting tropical depression and tropical cyclone activity (Bureau of Meteorology 1976). Above MSL the annulus of maximum variability is centred near 50°S at 500 mb and 45°S at 200 mb with local maxima in approximately the same longitudes as at MSL.

The SD of the monthly means, about the 1973–77 mean, are shown in Figs 5(c) and (d).

Although less smooth because of the small sample used in calculating the SD, they are clearly similar to the daily standard deviations. The positions of two of the maxima illustrated correspond to the two regions of maximum regional variability in zonal flow quoted by Streten (1977). He estimated zonal flow using monthly mean pressure differences between station pairs and found maximum variability north of the Weddell Sea and southeast of Australia. Again the impact of island stations on the distribution may be significant. The figures, however, give some idea of the pattern of year-to-year variability of monthly means, and are a useful adjunct when comparing simulated monthly means from a general circulation model with climatology. The upper-air data are generally consistent with the long-term station standard deviations in Taljaard et al. (1969), but of course extend through the data-sparse areas.

Distribution of synoptic systems

Meridional profile of cyclones

The meridional profiles of cyclone frequency per 5° latitude band have been constructed from daily analyses (Figs 6(a) and (b)). The profiles peak in the CPT and show minima on the Antarctic continent, and in January in mid-latitudes. The contribution in lower latitudes in January includes a substantial number of heat lows. The distributions are consistent with those of Taljaard (1967) for the IGY summer and winter. The mean July peak is broader with less amplitude and further south than the January peak and indicates a larger number of cyclones in the 30°S to 50°S zone. One feature is the similarity from year to year in the
polar regions, where the southern boundary of the CPT confines the distribution to a narrow range.

**Meridional profile of anticyclones**
(Figs 6(c) and (d))

The profiles of anticyclones are similar from year to year with a strong maximum about the STR and also over the semi-permanent but artificial Antarctic anticyclone. Seasonal differences are evident with a northward shift of the mid latitude profile peak, and an increase in the number of intense anticyclones in the STR in July. The profiles are similar to those for the IGY summer and winter, and as Taljaard (1967) states: "The peak frequencies of anticyclones occur 2–3° poleward of the mean ridge axes... This is no doubt due to persistence of high pressure in the less disturbed northern parts of the high pressure belt, while troughs and ridges or closed anticyclones follow each other in rapid succession in the southern parts of the belt."

The meridional profiles of zonal mean MSLP are displayed in Figs 6(e) and (f). They show for July the northward movement and intensification of the STR and the southward movement and intensification of the CPT, which is consistent with the seasonal changes in the meridional profiles of cyclones and anticyclones.

**Normalised frequency of cyclones**

The mean monthly frequencies of cyclones per 5° latitude by 10° longitude block (normalised to 45°S) are presented in Figs 7(a) and (b). In January, the continental heat lows dominate the mean chart in sub-tropical latitudes. A further band of high frequency is found about the CPT with local maxima in this band being related to pressure minima in the monthly mean MSLP (Fig. 1(a)).

This frequency distribution is similar to the IGY summer (Taljaard 1967) even to the extent that with a different choice of contour interval, it also shows an increase in frequency near 130°W in the mid Pacific (near Pitcairn Island). One difference, however — even though we are comparing a January to a summer mean — is the frequency maximum in the Tasman Sea, which appears on the IGY-based frequencies and is now
found to the northeast of New Zealand. However, there is a very great variation in cyclonic activity from year to year, particularly at New Zealand longitudes and longer-term records may reveal this as a short-term lessening of Tasman Sea activity. Mainland Australia also exhibits a different frequency distribution with a lessening of frequencies indicated in the northeast sector.

In July the frequency of continental cyclones is substantially lessened by the reduction in heat low contribution, while the circumpolar cyclone belt extends further north. In the circumpolar distribution the higher frequencies group closer to the Antarctic coast in July than January.

The distribution is very similar to the IGY winter although the spiral ‘arms’ of high frequency in the IGY study appear somewhat truncated in the five-year mean, making this distribution a little more zonal.

Normalised frequency of anticyclones (Figs 7(c) and (d))

In January the sub-tropical ridge and the polar anticyclone dominate the distribution. Comparison with IGY summer data indicates a similar frequency distribution within the STR although the January mean — as with most individual monthly means for January — displays twin frequency maxima in the central Indian Ocean where the IGY data indicate a single maximum. The polar anticyclone situated near 89°E, 83°S appears as a narrow distribution. Mean and standard deviation data show it to be strong, relatively unmoving, with high variability within the month and from month to month. However, the uncertainties associated with data sparsity and reduction to MSL should be remembered.

In July a general broadening and northward movement of the distribution associated with the
STR is evident and the anticyclone distribution encroaches upon the now cooler continents. The polar anticyclone again appears as a narrow distribution with the characteristics described previously. The distribution is similar to the IGY winter, although some detailed differences are apparent, particularly over Australia.

Concluding remarks
A summary has been presented of the salient features of the January and July climatology generated from WMC Melbourne 1973–77 analyses. The differences between these and Taljaard’s means can generally be ascribed to different data bases and real differences between the two periods. The use of VTPR data late in the period had little effect on the monthly means. Certain characteristics of the WMC analysis scheme should be remembered. These include an inbuilt bias towards Taljaard’s climatology through its contribution to the analysis first guess fields, and loss of data because of operational ‘cutoffs’. In addition it should be remembered that thickness, wind and temperature have been diagnosed from MSLP and 1000 to 500 mb thickness, determined from cloud picture analysis in data-sparse regions. Despite these limitations, some differences between the WMC and Taljaard climatologies, for example the upper-tropospheric ridge over the Pacific at lower latitudes, may indicate a refinement to previous long-term means.

The study of cyclone and anticyclone distributions adds to an area where the bulk of the information was previously based on the IGY period (1957–58), and strongly illustrates seasonal contrasts. It also augments recent studies of southern hemisphere synoptics by Streiten (1980).

The mean data, combined with the analyses of variance within the month and from month to month, also have immediate utility in two areas. The first is validation of daily observations. The second is in the evaluation of both simulations of the general circulation of the southern hemisphere and extended range (up to ten days) forecasts by examination of means, variance, and cyclone and anticyclone distributions.

Acknowledgments
We wish to thank the operational staff of NMAC for their help and comments. We also wish to thank Mrs S. Ickeringill, Mrs D. Bulner and Ms G. Burt of the ANMRC for their technical assistance.

References


