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MONTHLY ANTICYCLONICITY AND CYCLONICITY IN THE SOUTHERN HEMISPHERE: AVERAGES FOR MARCH AND SEPTEMBER

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ABSTRACT

Geographical distributions across the Southern Hemisphere of 15-year averages (23-year averages in the Australian region) of monthly anticyclonicity and cyclonicity as well as monthly anticyclone and cyclone immobility times, for the months of March and September for the years 1973-1987 (1965-1987 in the Australian region) are presented in the form of maps.

Comparisons are made with an existing atmospheric climatology of the Southern Hemisphere by the National Climate Centre of the Bureau of Meteorology, Melbourne covering the period 1976-1990 calculated from numerical analyses, and with relevant climatologies contained in the World Survey of Climatology. References are made to past works relating to the climatology of the Southern Hemisphere and synoptic features of the climatology are discussed.

INTRODUCTION

An excellent account of the early history of synoptic meteorology and climatology is given by Klein (1957) with references to the tracking and frequency of cyclones and anticyclones in the Northern Hemisphere. By the end of the nineteenth century many studies of cyclone frequency and tracks were made not only for the U.S. but for Europe, the Atlantic, India, the west Indies and the Far East. The first thorough investigation for the Northern Hemisphere was completed in 1894 which contained the average frequency of cyclones during each of the 12 months and their principal tracks.

During the twentieth century notable work on various aspects of synoptic climatology in the Southern Hemisphere has been completed. Streten and Troup (1973) developed a classification scheme for observed cloud vortices. Streten (1980) developed a series of indices relating to the subtropical highs, the westerlies, the sub-Antarctic trough and the high pressure region south of the sub-Antarctic trough and Streten and Pike (1980) applied these monthly indices to the year of the first GARP global experiment (FGGE) of 1978-79. Trenberth (1984) studied the interannual variability of the Southern Hemisphere circulation as represented by the FGGE year. Le Marshall et al. (1985) produced ten-year monthly mean sea level pressure charts based on 10 years of daily numerical analyses (1972-1982) for both January and July, and a comparison of these charts with averages of anticyclonicity and cyclonicity for the Australasian region (90°E-180°E) are discussed by Leighton and Deslandes (1991). A comprehensive account of the history of the study of blocking in the Southern Hemisphere is given by Trenberth and Mo (1985). Trenberth (1991) provided a description of atmospheric variables which have a strong signature in baroclinic storm tracks in the Southern Hemisphere. Jones (1991) used a principal components regression scheme on station mean sea level pressure data to reconstruct gridded data back to 1951 and 1911.

For the Australian region (including New Zealand) the method of representation of the surface circulation for long periods (i.e. months, season, etc) by charts of anticyclonicity and cyclonicity was developed during 1951-53 in connection with the problem of extended and long-range forecasting in Australia. Later charts of 7-year averages (1946-1952) of monthly and seasonal anticyclonicity and cyclonicity and their description were published by Karelsky (1954). Charts of monthly and seasonal anticyclonicity and cyclonicity for the Australian region for 15 years (1946-1960) were published by Karelsky (1961). Leighton and Deslandes (1991) published monthly charts for 23 years (1965-1987) for the Australian region including the eastern Indian Ocean.

ANTICYCLONICITY AND CYCLONICITY

The term **anticyclonicity (cyclonicity)** is defined as the time in hours during which anticyclone (cyclone) centres occupied a given 5° cell during a given period (i.e., week, month, season, etc.). (South of 55°S cells are 5° latitude by 10° longitude.)

Cyclonicity and anticyclonicity were computed from the plotted locations of cyclone (anticyclone) centres at 00 UTC and 12 UTC and, assuming a uniform speed of movement, the systems could be tracked. Single centres which were not part of a track were assigned a lifetime of 6 hours.

Cyclones whose centres were tracked fitted into one or more of the following classes: identifiable closed circulation with or without an associated front, wave lows which developed into closed circulations, thermal (heat) low, tropical lows and tropical cyclones.

Anticyclones in general covered much larger areas than cyclones. On occasions when anticyclones were shown to have a double centre, both centres were considered when **budding** (an anticyclone centre forming in a ridge which is extending from an established anticyclone) was the obvious cause. Centres in ridges were taken into account when there was an identifiable outflow, or when they were seen as a prelude to anticyclogenesis.

In general the cut-off value for weak cyclones was about 1008 hPa except in cases when cyclogenesis was evident. For anticyclones, weak cells below 1018 hPa in tropical regions and in high-latitude ridges were taken into account, but for mid latitudes these cells were considered only when anticyclogenesis was apparent. A certain amount of identification of centres relates to the pressure of the centre compared with that of surrounding areas rather than the absolute pressure value of the centre.

Manually drawn archive charts prepared by the National Meteorological Centre of the Australian Bureau of Meteorology were used to obtain means of cyclonicity, anticyclonicity, and immobility for March and September from 1973-1987 (1965-1987 in the Australian Region (90°E-180°E)). Charts of mean monthly anticyclonicity, anticyclone immobility, cyclonicity, and cyclone immobility are presented in Figs. 1a-d and 2a-d.

CHARTS OF ANTICYCLONE (CYCLONE) IMMOBILITY

Immobility of an anticyclone (cyclone) centre is defined as the time taken by the anticyclone (cyclone) centre to traverse a 5° cell. The average immobility of anticyclone (cyclone) centres across a 5° cell was calculated by dividing the anticylonicity (cyclonicity) of a 5° cell by the number of anticyclone (cyclone) centres which have occupied that square during the same period.

ACCURACY OF CHARTS OF ANTICYCLONICITY AND CYCLONICITY

Cloud satellite photos were available from 1965 for the Australian Region and from 1973 for the Southern Hemisphere, greatly increasing the data base for synoptic analyses. Additional data has been supplied by drifting buoys deployed at various times since 1978 at differing locations in the oceans around the Southern Hemisphere. The author believes that the ability of analysts to identify centres of lows from cloud photos could affect the accuracy of the charts. Wave lows forming under heavy cloud cover may not be obvious until the clouds display a definite wave or hook shape. Old lows can be difficult to assess because an apparent circulation may remain visible in the cold air after the surface low itself has decayed. Lows situated under clouds associated with warm air advection may give no visible evidence of formation, particularly in the initial stages of development. Surface lows in the monsoon trough are difficult to determine due to lack of data. Areas showing

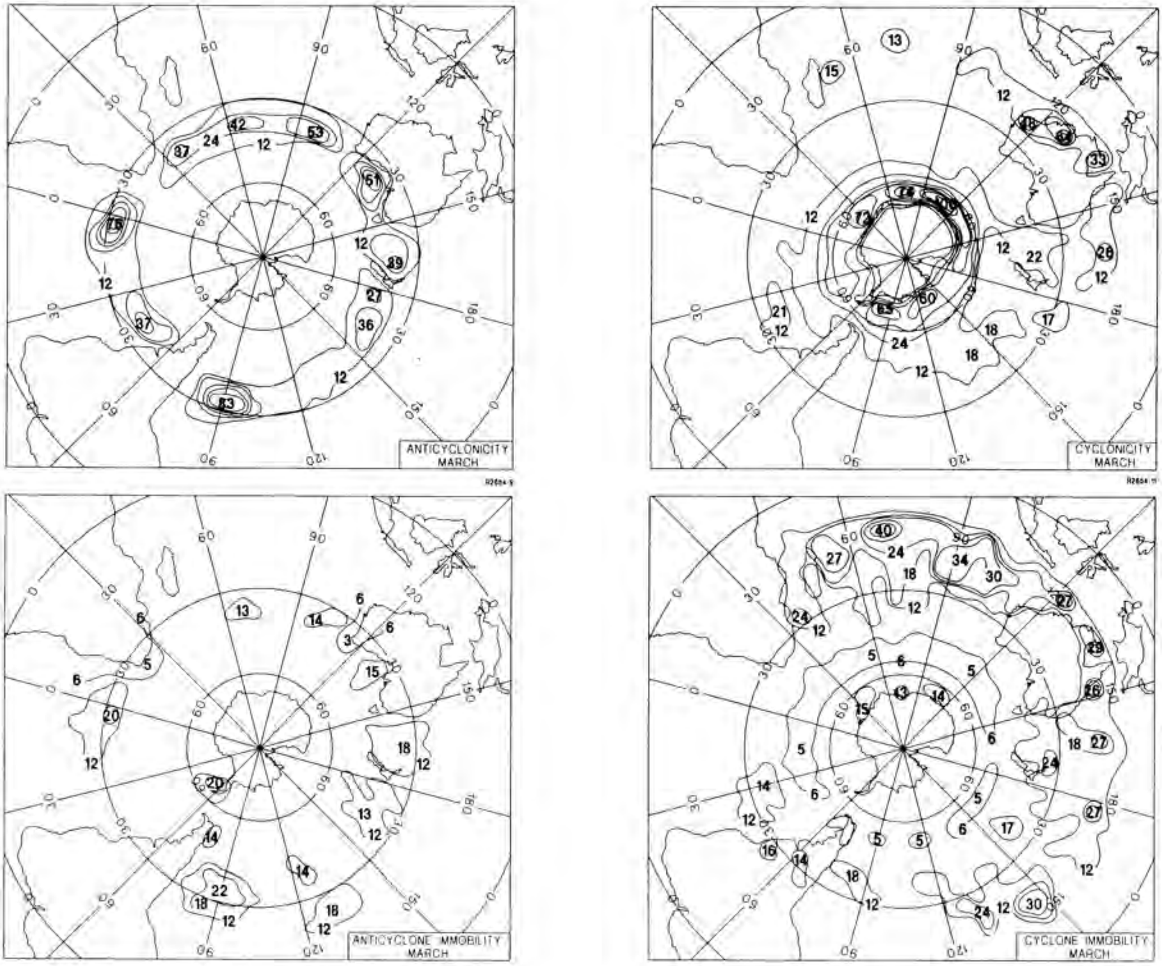
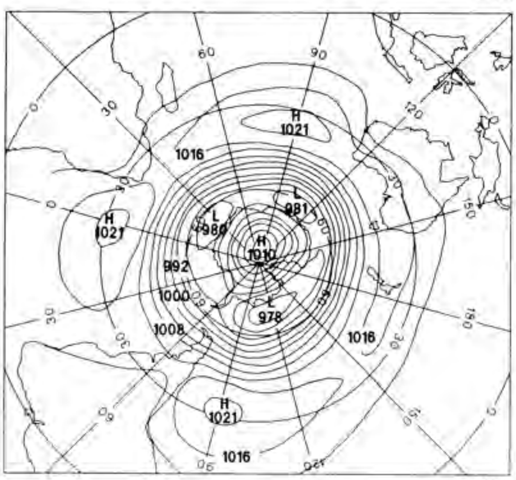
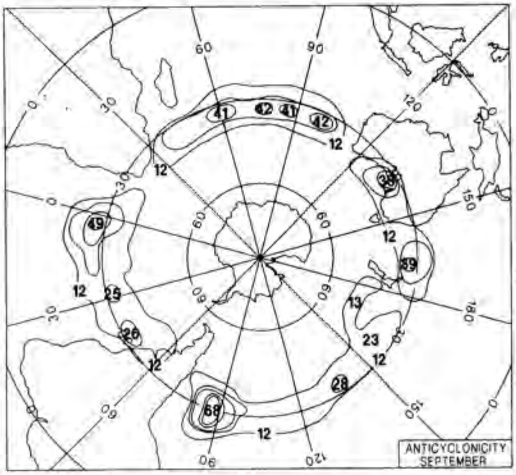
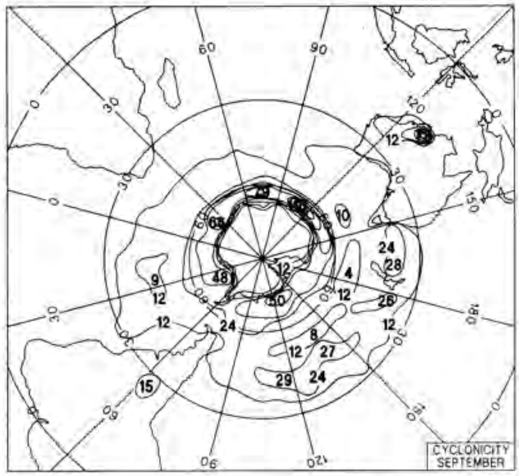
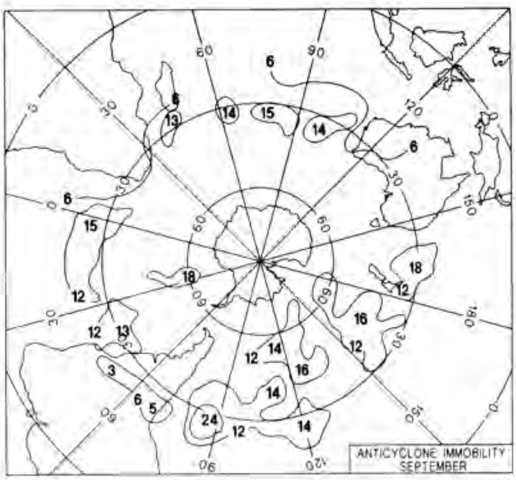


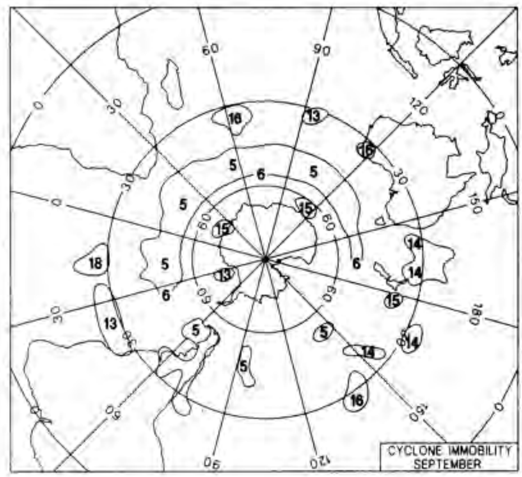
Fig. 1: March average
(a) anticyclonicity (c) cyclonicity
Isopleths are hours for each 5° square
(b) anticyclone immobility index (d) cyclone immobility index
Isopleths are hour/system for each 5° square.
(e) Hemispheric mean sea level pressure











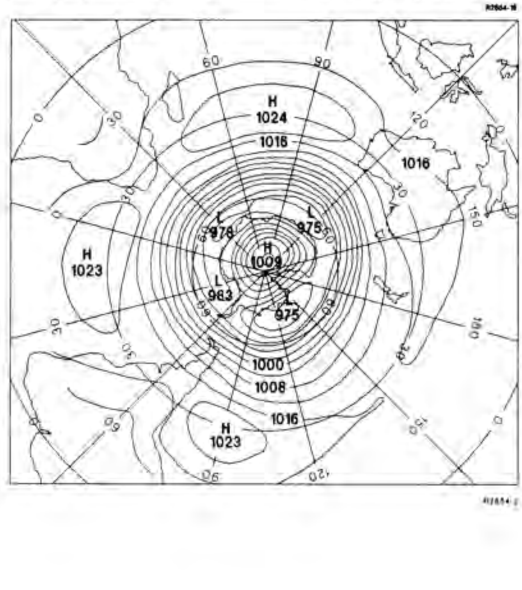


Fig 2: September average
(a) anticyclonicity (c) cyclonicity
Isopleths are hours for each 5° square
(b) anticyclone immobility index (d) cyclone immobility index
Isopleths are hour/system for each 5° square.
(e) Hemispheric mean sea level pressure

large cloud masses of convective activity in the tropics are regarded as regions of potential surface low development. On occasions analyses identify ephemeral centres in these areas.

DISCUSSION

Differing approaches to the climatology of synoptic systems for a region add detail to the understanding of the overall climatology of that region. Charts of (anti)cyclonicity help show how the centres of pressure systems can relate to the results of other climatological studies and indicate areas of fast or slow centre movement, thus suggesting regions favourable for the development of synoptic blocking patterns.

The 15-year (1976-1990) average hemispheric mean sea level pressure charts for March and September as produced by the National Climate Centre (NCC) of the Bureau of Meteorology, Melbourne appear in Figs. 1e, 2e. Climatologies contained in the **World Survey of Climatology** volumes 12 (Climates of Central and South America) and 15 (Climates of the Oceans) will be referred to as well as results from other works previously mentioned.

Anticyclonicity

The hemispheric mean sea level charts for both months show that the maximum pressures in the subtropical ridge are across the eastern half of the oceans. Anticyclonicity maxima coincide well with the maximum pressure values in the eastern Pacific Ocean and the eastern Atlantic Ocean in March. Around the hemisphere various other anticyclonicity maxima are located in the ridge mainly to the south of the ridge axis particularly in the western half of the oceans. In September the anticyclonicity centres are notably south of the high pressure ridge. The anticyclonicity maxima highlight where anticyclone centres are predominant in or near the ridge. Most anticyclones would appear to move eastwards to the south of the pressure ridge axis. This finding is consistent with Taljaard and van Loon (1984) when discussing the climate of the Indian Ocean south of 35°S, who state that the high pressure axis is located about 3 degrees equatorward of the core of highest anticylonic frequency. This is due to the fact that frontal or intercell troughs and occasional cyclones also occur in the anticyclonicity belt, in which cases the highest pressures (in the cols) are found well to the north.

Across the Australian region the anticyclonicity chart for March has distinct maxima at latitudes higher than 35°S in the Bight and the Tasman Sea. Notable maxima occur south of the west coast of Australia, across southeastern Australia and across New Zealand. Anticyclones located in the east Indian Ocean can extend a ridge under W.A. into the Bight where a new anticyclone centre forms in the ridge — a process known as **budding.** Anticyclones are known to remain in the Bight before a similar budding process occurs across southeastern Australia and anticyclone centres strengthen in the Tasman Sea. New Zealand is also a notable region for budding. In September the anticyclonicity maxima are located between 30°S and 35°S at longitudes similar to that of March.

East of New Zealand between 40°S and 50°S the anticyclonicity charts for both March and September have anticyclonicity maxima located at the highest latitudes around the hemisphere. The September maximum is small but distinct. The anticyclone immobility value for both months indicate that anticyclones tend to be slow moving when located in this region. Across the mid Pacific in March the anticyclonicity maxima values lie between 35°S and 45°S whereas in September the maxima are between 30°S and 40°S. In the eastern Pacific the anticyclones mostly are located between 30°S and 35°S near 90°W in March and between 25°S and 35°S east of 90°W in September. The anticyclone immobility values indicate that the less common anticyclones which are located at high latitudes across the Pacific can be slow moving particularly in September.

In the western Atlantic Ocean near 40°W the anticylonicity maximum in March is between 35°S and 40°S and in September between 30°S and 35°S. In the eastern Atlantic Ocean near 0° the March maximum lies between 30°S and 35°S whereas the September maximum is between 25°S and 30°S. The March maxima values are notably higher than the September values which is similar to the other oceans. The immobility values show that the irregular anticyclone centres which form off the Antarctic Peninsula north of the Weddell Sea are likely to be slow moving.

In the Indian Ocean the anticyclonicity chart for March shows a broad maximum lying across the ocean between 35°S and 40°S. By contrast the anticyclonicity for September lies across the ocean between 30°S and 35°S. Peaks in the maxima are comparable in both months near 60°E and near 100°E. These months clearly show the seasonal shift in latitude of the paths preferred by anticyclones. The anticyclone immobility values in the Indian Ocean are lower than in the other oceans particularly in the eastern sector suggesting that the eastern Indian Ocean is not as great an anchor point for single anticyclones as the eastern Pacific or eastern Atlantic Oceans.

Cyclonicity

For both March and September the largest cyclonicity maximum is placed in the sub-Antarctic trough near the mean minimum sea level pressure value south of Western Australia. Other cyclonicity maxima coincide reasonably with minimum pressure values around the trough.

For both months in the New Zealand sector, both the Tasman Sea and the Pacific Ocean have cyclonicity maxima and cyclone immobility maxima indicating slow moving lows are common. These regions also favour slow moving anticyclones as suggested by the anticyclonicity and anticyclone immobility values which support the findings of Trenberth and Mo that the New Zealand sector is a primary location for the occurrence of blocking patterns.

Across the Pacific Ocean the cyclonicity chart for September shows distinct maxima between 40°S and 50°S and another strong maximum in the sub-Antarctic trough. A notable minimum is evident through the Ocean between 50°S and 60°S. The mid-Pacific cyclones which have originated in the Southwest Pacific or on the South Pacific Convergence Zone are usually separated from the large southern depressions by either a col region or occasionally a narrow latitudinal ridge located between 50°S and 60°S. In March the cyclonicity values across the central Pacific are less than in September and the latitudinal split in cyclonicity maxima is not as definite. These differences in cyclonicity values suggest that September is a more favoured month for cut-off lows to be located in the Pacific than March.

In the southwestern Atlantic Ocean cyclonicity maxima in both months are associated with cyclogenesis in the frontal zone off South America (Hoflich, 1984) and developments in easterlies over or near the South American continent. Both months show a cyclonicity maximum near 40°S 40°W indicating that cut-off lows are favoured in this region.

Across the Indian Ocean at high latitudes both months show cyclonicity maxima at the same locations, but cyclonicity at mid latitudes is less in the Indian Ocean than the other two oceans. For both months the Atlantic-Indian Ocean sector has an extended minimum cyclone immobility value along 50°S suggesting that movement of cyclones at this latitude is rapid. By contrast cyclone immobility minima in the Pacific Ocean are not continuous particularly in September indicating that cyclone movement can be slower than in the other oceans.

In both months the cyclonicity maxima across northwestern Australia and northern Argentina are related to heat lows. The Australian heat low is more evident than the corresponding heat low in South America because Schwerdtfeger (1984) states that the location in Argentina is over relatively high and dry terrain east of the Andes where the reduction of station level pressure to mean sea level pressure is a problematic procedure.

In March the cyclonicity maxima across tropical waters in the Indian Ocean, the Australian region and the western Pacific Ocean relate to tropical lows and cyclones. The cyclone immobility chart shows a large number of centres across these tropical regions but the author feels that a longer time average and a denser network of surface observations would be needed to confirm such a pattern of centres.

CONCLUSION

(Anti)cyclonicity and (anti)cyclone immobility averages supplement conventional climatologies by showing preferred locations of surface centres, regions of slow and rapid movement of centres and location of potential blocking areas. Averages for March and September show how positions of anticyclone and cyclone centres differ in contrasting seasons (in this case late summer and late winter). Some regions show a significant seasonal difference, for example latitudinal positions of anticyclones in subtropical regions and locations of lows in the tropics; whereas some regions do not, for example positions of lows off the coast of Antarctica. Blocking appears more common in the Pacific Ocean in September and speed of cyclone movement across the Atlantic-Indian Ocean sector near 50°S shows little difference between the two months. The averages could be useful for verifying the realism of Regional and Global Numerical Weather Prediction and the basic figures, being on a five degree grid, could be used as a data base in models. Anomalies can be calculated for ongoing current months and these could help in defining severe weather occurrences or possible climate change.

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