Mobile Polar Highs over Australia: Origins and Effect on Rainfall

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Abstract
Mobile Polar Highs (MPHs) are masses of cold air that move out aperiodically from the Antarctic Icecap and eventually cross Australia. Their movement from the Weddell Sea and the Lambert Glacier was monitored between 26 March and 20 July 2004 using daily satellite images and synoptic charts. Their leading edge appears on these images as a distinct arced cloudband. The patterns of MPHs were then linked to significant rainfall events—>50 mm in 24 hrs—in southeastern Australia. Although most of this area of Australia was in drought over the study period, three major rainfall events resulted from the passage of three of the eleven MPH events mapped. All three events either originated or received cold air injections from the Lambert Glacier. Analysis of MPHs between January and March 2000 also indicated that polar air originating from this latter location could be linked to major rainfall events over southeastern Australia. If this relationship holds over time, then the tracking of MPHs offers a prognosis by several days for heavy rainfalls in southeastern Australia. MPHs appear to be another dynamic element of southern hemisphere circulation influencing the rainfall of southern Australia.

Introduction
The purpose of this paper is to analyse the movement of Mobile Polar Highs (MPHs), which are defined as huge rotating pools of dense cold air originating from downward air motion over Polar Regions and subsequently moving outwards to mid-latitudes as cold air anticyclones (Leroux, 1993). These pools of cold air eventually extend over 1000s of kilometres; yet, they are shallow being less than 1.5 km thick. The importance of high-pressure systems in the Australia region, and their effect on seasonal patterns of atmospheric circulation and rainfall is widely appreciated throughout the meteorological literature (Hobbs, 1998). However, their Antarctic link is poorly researched (Leroux, 1993, 1996; Bouveyron, 2001). In addition, MPHs may have some control on rainfall as they pass over the Australian continent. Certainly, in the northern hemisphere, MPHs produce inclement weather as much as they do fine weather depending on the season and local geography (Leroux, 1996).

This paper aims to add to the limited research about the behaviour of MPHs in the Southern Hemisphere as follows:

- To map the movement of MPHs from satellite images as they leave the Weddell Sea or Lambert Glacier in the Antarctic until they cross the Australian continent over a four-month period between late March and July 2004;
- To match these maps with any significant daily rainfall events, which produced more than 50 mm of rain over a 24-hour period in southern Australia over the same period. Based on climatology records between 1961-1990, NSW, Victoria, and Tasmania reach this threshold an average of 2-3 days per year;
- To determine the characteristics and origin of southern hemisphere MPHs that may produce significant rainfall; and
- To provide another possible forecasting mechanism for rain events in southern Australia using the identification of MPHs on satellite images.

Methods

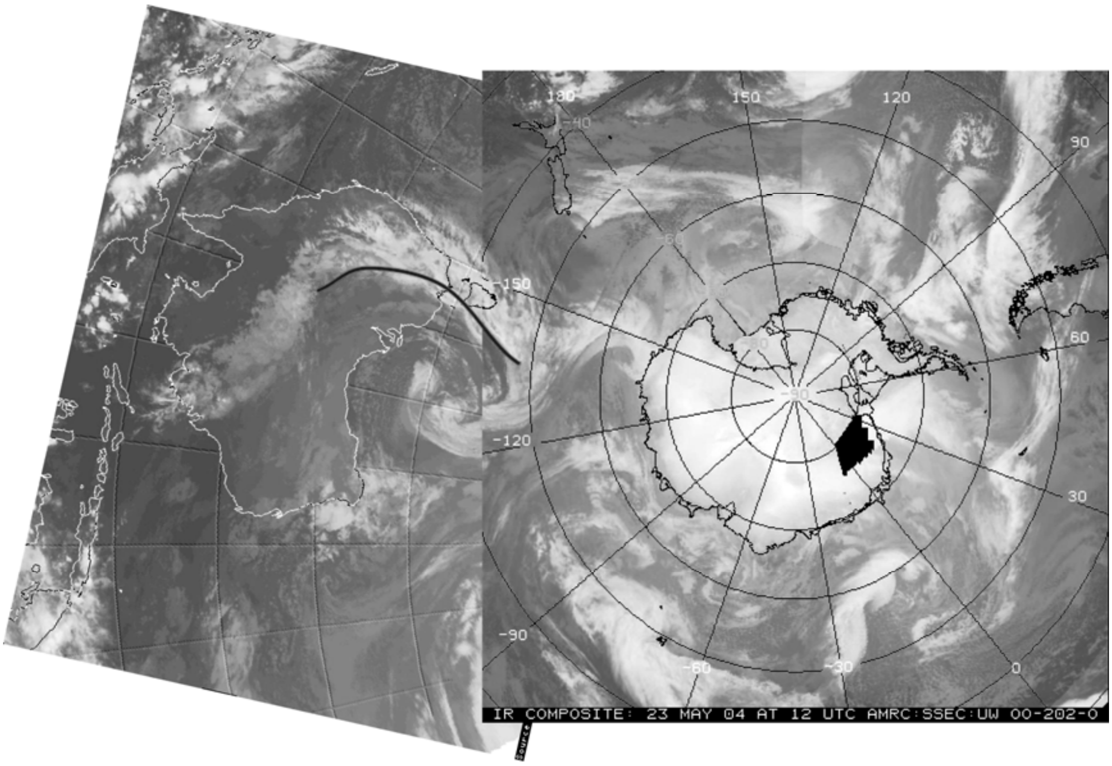
Mapping of Images

This study formed the basis of a short-term BSc Honours project. For this reason, Mobile Polar Highs were mapped only for the period 26 March to 20 July 2004. Infrared satellite images of MPHs were downloaded each day at 12UTC (Coordinated Universal Time) from the University of Wisconsin Space Science and Engineering Data website (**www.ssec.wisc.edu/datacenter**) where they are archived for only a month. No attempt could be made to look at MPH behaviour over a longer period and hence seasonal differences in pathways were not investigated. The current study is therefore only representative of autumn/winter MPH movement in the southern hemisphere. Events were identified by the cold, leading edge, arc-shaped, cloudband within a day of leaving the Antarctic continent. They were then tracked daily until they passed over the eastern seaboard of Australia. Once they reached Australia, a second infrared satellite image of the Australian region was downloaded from the Bureau of Meteorology website (www.bom.gov.au/weather/satellite) at 11:25 UTC, the closest time to the 12:00 UTC Antarctic image. To complement these satellite images, mean sea level pressure charts of the Indian Ocean were also used. These charts showed the synoptic features such as the exact centre of the MPH and the associated poleward displaced low on the leading edge. Finally, daily rainfall amounts over southern Australia were obtained from the Bureau of Meteorology website.

Adobe Illustrator CS was used to map the movement of MPHs identified from satellite images by their characteristic arc-shaped, leading cold front and the presence westward of speckled cloud indicating cold air (Figure 1). This cold air is evident at the centre of the high, which is generally located further to the north of the arc-shaped cold front. The stronger the strength of cold air intrusion, the more well defined the arc-shaped cloudband. These antecedent cloudbands were traced daily and overlain on a single map. Once cloudbands reached Australia, they were mapped using the more detailed satellite image and synoptic chart. An example of the latter is shown in Figure 1. The cloudbands formed a log-spiral shape that tended to bulge either northwards or eastwards as the Mobile Polar High crossed the Indian Ocean. Paths were observed as being flat, intermediate or peaked. A flat pathway showed the Mobile Polar High travelling a consistent distance from the Antarctic continent south of Australia. An intermediate pathway saw the MPH moving gradually away from Antarctica and across Australia. A peaked pathway showed rapid movement from Antarctica and a slow drift southwards in the Australian region. The latitude and longitude of the leading bulge in the cloudband was determined each day. From this, the daily speed and acceleration of each Mobile Polar High were calculated using the following formulae:

Speed (km hr^{-1}) = (1/24) (location (i+1) – location (i))
Acceleration (km hr^{-2}) = (1/24) (speed day(i+2) – speed day(i+1))
where i = day of MPH mapped

Figure 1: An example of the traced cloudband preceding the arrival of a Mobile Polar High over eastern Australia on 24 May 2004 (Commonwealth Bureau of Meteorology, 2004). Note the pattern of speckled cloud over the Bight, indicative of an infusion of cold air over the continent following the passage of the cloudband.



Matching of MPH events to Rainfall

Maps showing rainfall amounts exceeding 50 mm per day for southeastern Australia were obtained from the Bureau of Meteorology (2004). Significant areas of rain were then matched to the nearest Mobile Polar High and its antecedent cloudband to see if the passage of a Mobile Polar High was responsible for the rainfall event. Synoptic charts were used to confirm that rain was due to the passage of the cold front or processes associated with the body of the high-pressure system. Only three rainfall events in the 2004 period of study met the criteria for a significant event. To extend this coverage, a study on Mobile Polar Highs carried out between January and March 2000 in the southern hemisphere (Bouveyron, 2001) was incorporated into the analysis. Three out of nine MPHs over this latter period produced significant rainfall events.

2004 MPH Pathways

The results show that of the eleven MPH events mapped between 26 March and 20 July, eight originated from the Weddell Sea and three from the Lambert Glacier. Figures 2 and 3 illustrate typical movement of MPHs from the Weddell Sea and Lambert Glacier regions respectively. All eleven events monitored in the 2004 study originated in either of these regions. Thick lines on these figures denote the daily position of the leading cloudband. Weddell Sea events were more common, occurring on average every eight days. However, the frequency of outbursts ranged between 6 and 17 days. The time that these events took to reach southeastern Australia varied from seven to twelve days with eleven days being the most common. The paths of the leading cloudband varied, with intermediate ones being the most common, followed by peaked ones. Only one flat path was recorded (26 March). This gradual movement of MPHs away from Antarctica is characteristic of MPH behaviour during summer and autumn months (Leroux, 1993).

Figure 2: Passage of a MPH originating on 8 May, 2004 from the Weddell Sea. Its pathway is flat showing minimal change in latitude. An additional feature is a northwest cloudband originating in the tropics of the Indian Ocean and moving southeast across Australia.

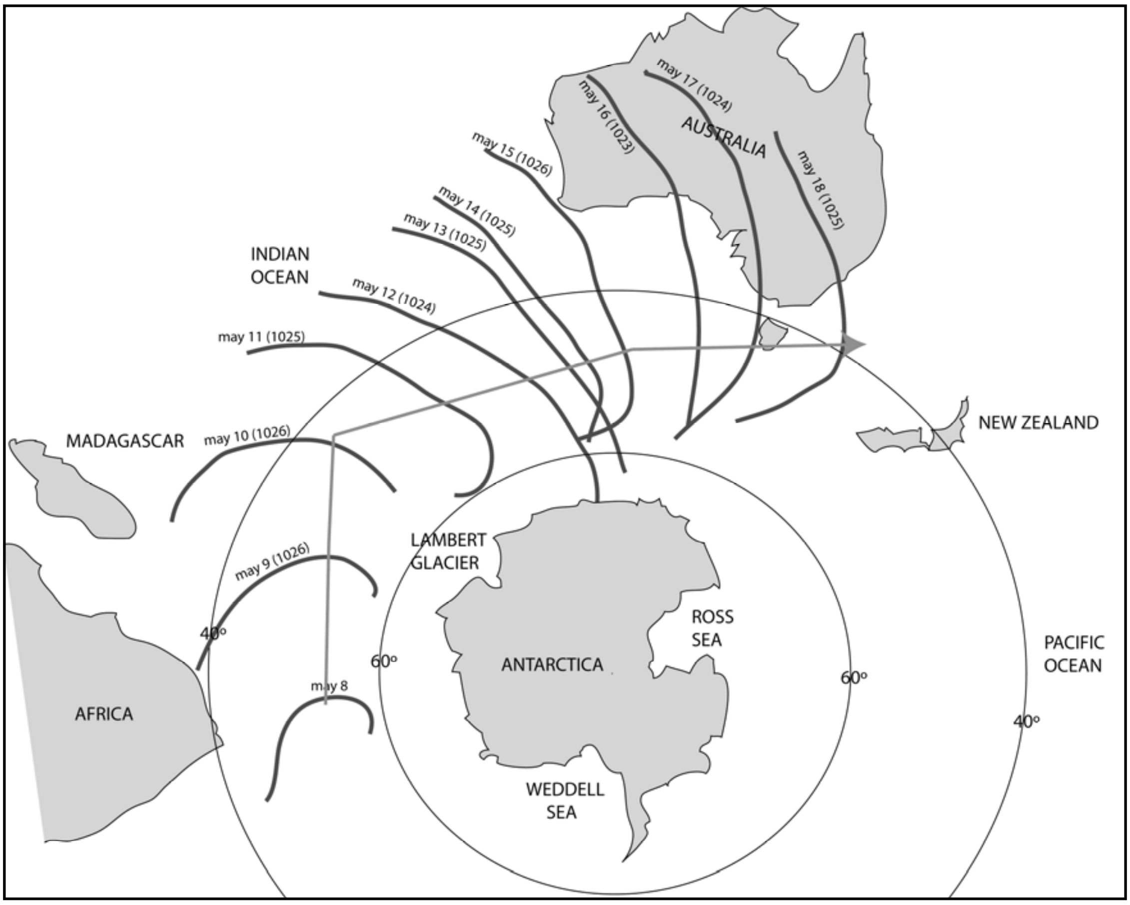
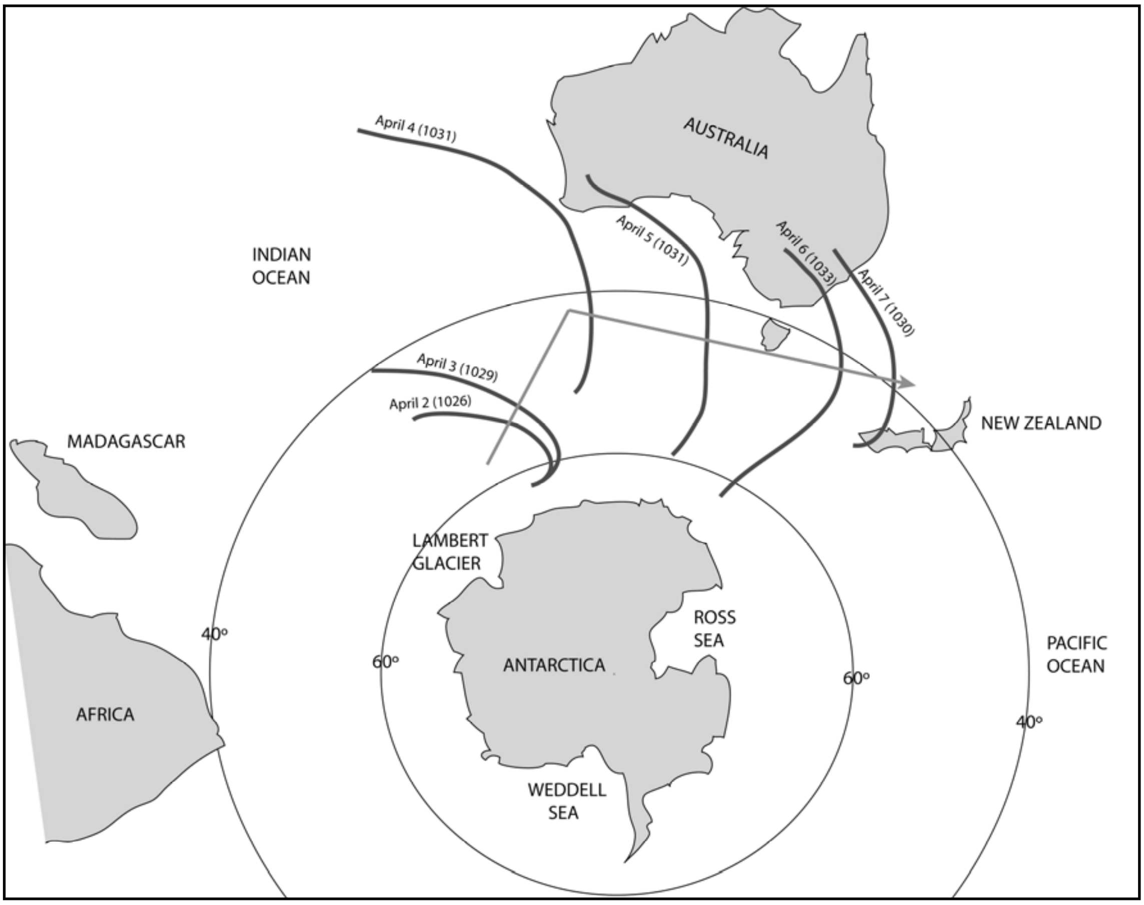


Figure 3: MPH originating from the Lambert Glacier on 2 April 2004. Its pathway is peaked, moving rapidly over Australia and then drifting southward.



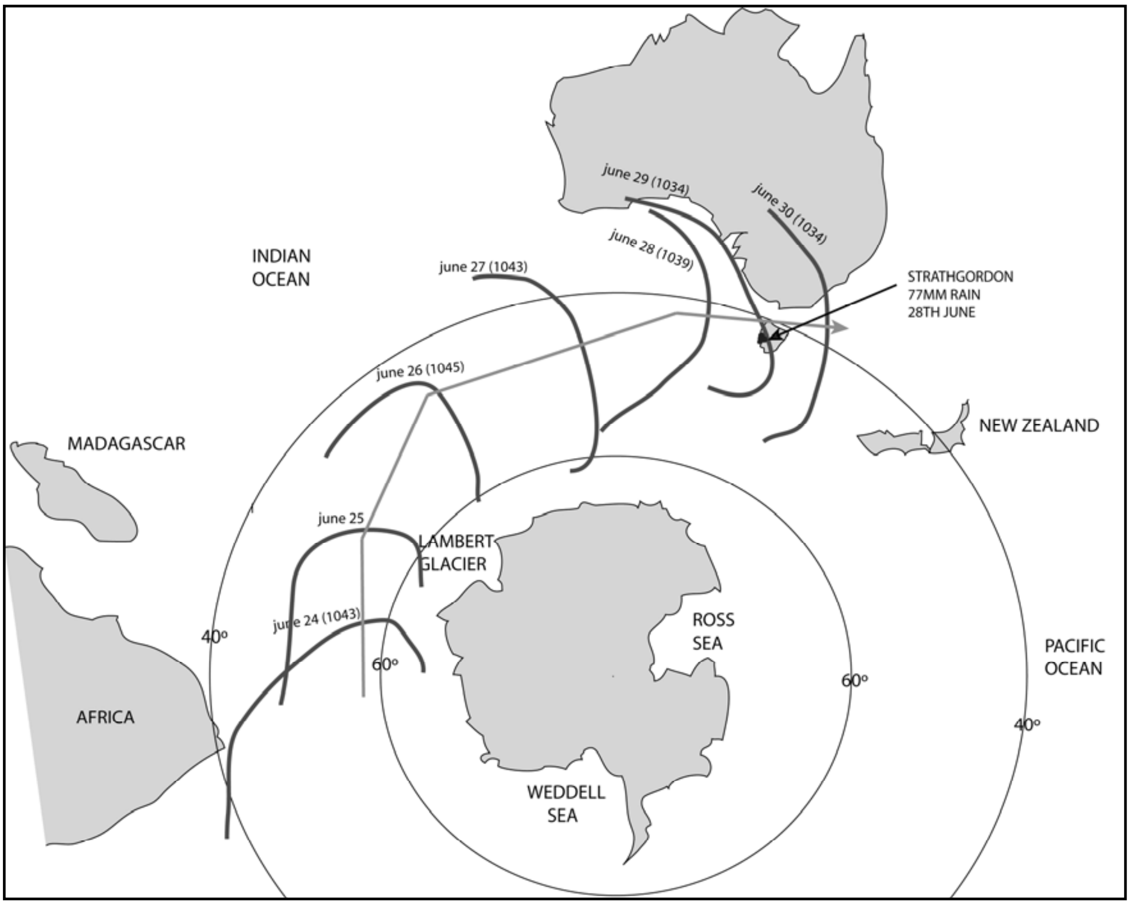
Maximum pressures during the journey of MPHs to southeastern Australia varied from 1026 hPa to 1045 hPa. However, the majority of events reached a maximum pressure in the 1030's. These values are higher than the long-term average for high pressure in the Australian region (Gentilli, 1971). Values greater than 1040 hPa are rare (Graham de Hoedt, Commonwealth Bureau of Meteorology, per comm.). The maximum latitude reached by the centre of the high varied between 29°S to 43°S. Both intermediate and peaked paths reached the maximum latitudes. Three of the eight MPHs from the Weddell Sea merged with a northwest cloudband (6 May, 14 May, and 30 June). Speeds of the Weddell Sea MPHs varied between 63 and 133 km hr^{-1}—these events being much faster than those originating from the Lambert Glacier. Cold air injections from the Lambert Glacier—a feature noted in five of the eight events—either increased the central pressure or accelerated the original Weddell Sea MPH.

Lambert Glacier events were rarer, with just three events. Two of these followed a peaked path (2 April and 5 June) while the other date was intermediate. The 5 June MPH reached a latitude of 30°S, comparable to events originating from the Weddell Sea. Maximum speeds of the Lambert Glacier MPHs ranged from 53-85 km hr^{-1}. Two of these three events also accelerated as they journeyed towards southeastern Australia. Maximum pressure of the Lambert Glacier MPHs varied from 1032 hPa to 1045 hPa. Cloudbands of Lambert Glacier MPHs did not extend across the interior of the Australian continent, but affected only the southern states.

Rainfall Events

Rainfall events and the characteristics of the Mobile Polar Highs generating them are summarized in Table 1 for the 2000 and 2004 study periods. Two events from the Weddell Sea and one from the Lambert Glacier produced falls in excess of 50 mm in 24 hours in the 2004 study. All were associated with MPHs with extreme central pressures (1036 hPa, 1045 hPa, and 1042 hPa). Air movement from the Lambert Glacier directly or indirectly appeared crucial in triggering these higher rainfalls in southeast Australia. The two MPHs originating from the Weddell Sea both received cold air injections as they passed the Lambert Glacier, increasing in pressure and speed (Figure 4). MPHs associated with rain followed intermediate or flat pathways. Rainfall events were more common when MPHs moved gradually northward especially when they reached Australia. None of the MPH rain events merged with the northwest cloudband, itself a common rain-producing climate feature of Australia (Sturman and Tapper, 1993).

Figure 4: Rainfall events at Strathgordon, Tasmania on 8 June 2004. Note rapid acceleration of the MPH after it reaches the Lambert Glacier.



The 2000 study between January and March 2000, over the same length of time, produced seven events originating from the Lambert Glacier, three of which were linked to rainfall (Table 1). In addition, two of these events tended to stagnate over southeastern Australia and were associated with the generation of east coast lows. Leroux (1998) terms this stagnation process agglutination. Stagnation could have many causes, but it appears simply to be due to the loss of momentum in the eastward movement of the cold pool of air associated with the Mobile Polar High. Bryant (1997) stated that stagnation of high-pressure cells over eastern Australia is one of the prerequisites for the formation of east coast lows.

Table 1: **Summary of characteristics of rainfall events during the 2000 and 2004 study periods.**

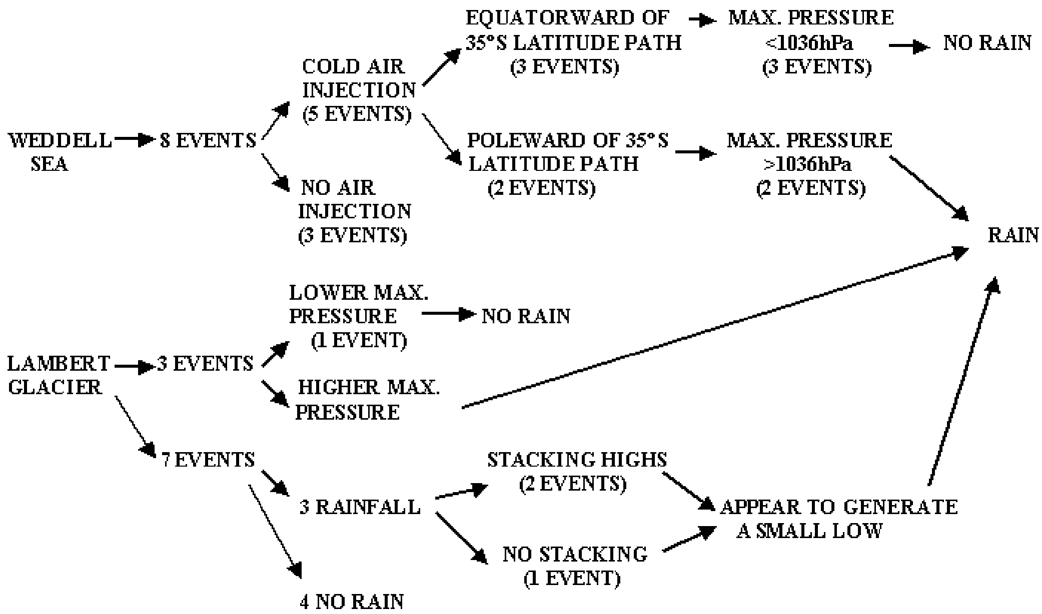
Year	Date of rainfall event	Location	Maximum rainfall (mm) in 24 hours	Source of MPH	Maximum pressure (hPa)
2000	14 January	North coast NSW	119	Lambert Glacier	1029
	27 January	Central Qld, NSW, and Victoria	>100	Lambert Glacier	1025
	8-9 March	NSW, south Qld	>200	Lambert Glacier	1033
2004	4 April	South coast NSW	>100	Weddell Sea-Lambert Glacier enhancement	1036
	24 June	Strathgordon, Tasmania	77	Weddell Sea-Lambert Glacier enhancement	1045
	28 July	Central Coast, NSW	73	Lambert Glacier	1042

Proposed Model

Using these results from two different years, a model linking significant rainfall events to Mobile Polar Highs was constructed (Figure 5). Rain-producing MPH events in the 2004 study originated from both the Weddell Sea and the Lambert Glacier; however, rain-producing MPHs originated only from the Lambert Glacier. Significantly, rain-bearing MPHs from the Weddell Sea during the 2004 study all received cold air injections from the Lambert Glacier. In 2004, Mobile Polar Highs brought in excess of 50 mm of rain within 24 hours somewhere in southeastern Australia, if the high was associated with cold air from the Lambert Glacier, took a path poleward of 35°S, and had a maximum central pressure that reached 1036 hPa or greater. In both 2000 and 2004, MPHs from the Lambert Glacier produced a greater percentage of events linked to rainfall. Stagnation—over southeastern Australia—of cold air masses originating from the Lambert Glacier was associated with the formation of an east coast low with its attendant rainfall. MPHs that advance quickly over the continent do not appear to be associated with extreme rainfall events.

Three additional points are implicated by the present study. First, below average rainfall over eastern Australian in the autumn and early winter of 2004 may be linked to the dearth of MPHs originating from the Lambert Glacier. Conversely, MPHs originating from the Weddell Sea appear to be associated with drought in eastern Australia unless these highs receive cold air injection from the Lambert Glacier. The fact that extreme rainfall events in 2000 were more widespread and all had an origin in air movement off the Lambert Glacier only reinforces this hypothesis. Second, there are common characteristics for MPHs that bring extreme rainfall to southeastern Australia. In the 2004 study period, all of these rain-bearing MPHs had central barometric pressures of 1036 hPa or more. These pressures are at the upper limit registered over Australia. Another common characteristic was the pathway traversed by these MPHs. Their centres never travelled closer to the equator than 34°S. Third, the behaviour of high-pressure cells originating from the Lambert Glacier may be a crucial determinant of extreme rainfall in southeastern Australia. If a MPH stagnates over eastern Australia, it is more likely to be associated with the development of an east coast low and higher rainfalls.

Figure 5: **Proposed model of MPH characteristics leading to rainfall production of >50mm in 24hrs in southeastern Australia, 2000 and 2004.**



Conclusion

There has been little research into Mobile Polar Highs in the southern hemisphere and none into their association with extreme rainfall events in southeastern Australia. This paper has looked at the Mobile Polar High—a cold air anticyclone originating from the Antarctic—and its link with significant daily rainfalls in southeastern Australia. MPHs affecting Australia were observed and mapped between March and July 2004 with the maps showing their origin and pathway towards southeastern Australia. These maps were then matched with significant rainfall events in southeastern Australia during the same three month period, events that brought >50 mm of rain in 24 hours. Given the limited amount of rainfall during this period, rainfall events for Mobile Polar Highs observed by Bouveyron (2001) between January and March 2000 were also included in the study.

The results indicate that the Lambert Glacier is a strong contributing factor to extreme rain events in southeastern Australia. The three Mobile Polar Highs bringing rainfall recorded during the 2004 study either originated from the Lambert Glacier or received a cold air injection as the MPH passed this location. MPHs in these cases had central pressures of 1036 hPa or more. The results of the 2000 study show that out of seven MPHs originating from the Lambert Glacier, three resulted in extreme daily rainfall. These events were associated with stalling of the high pressure cells over the eastern seaboard and the generation of east coast lows. The notion that an anticyclone cannot bring rainfall, as highs are usually associated with fine weather (Sinclair, 1996), is rendered questionable by the results of this study. MPHs can generate rainfall either in their leading cloudband or through the attendant generation of an east coast low. The timespan and number of Mobile Polar Highs used to develop this model of rainfall for southeastern Australia are limited. The tantalising association of extreme daily rainfall in southeastern Australia with Mobile Polar Highs originating or influenced by airflow off the Lambert Glacier begs further research. A longer study period and more extensive data collection would hopefully enable more definite conclusions to be reached.

References

Bouveyron, G. 2001. *La Dynamique des Anticyclones Mobiles Polaires Issus de L'Antarctique*. Laboratoire de Geographie, Laboratoire de Climatologie Risques Environnement, Universite Jean Moulin Lyon III, Lyon.

Bryant, E. 1997. *Climate Process and Change.* Cambridge University Press, Cambridge.

Bureau of Meteorology 2004. *South East Australian rainfall – Daily*. http://www.bom.gov.au/cgi-bin/climate/rainmaps.cgi?page=oldmap& variable=totals&period=daily&area=seaus&steps=2.

Gentilli, J. 1971. *Climates of Australia and New Zealand*. Elsevier Amsterdam.

Hobbs, J. A., Lindesay, J.A., and Bridgman, H.A. 1998. *Climates of the Southern Continents: Present, Past and Future.* Wiley, Chichester.

Leroux, M. 1993. The Mobile Polar High: a new concept explaining present mechanisms of meridional air-mass and energy exchanges and global propagation of palaeoclimatic changes. *Global and Planetary Change* 7: 69-93.

Leroux, M. 1998. *Dynamic Analysis of Weather and Climate: Atmospheric Circulation, Perturbations, Climatic Evolution*. Praxis, Chichester.

Sinclair, M.A. 1996. A climatology of anticyclones and blocking for the Southern Hemisphere. *Monthly Weather Review* 124(2): 245-264.

Sturman, A. and Tapper, N. 1996. The Weather and Climate of Australia and New Zealand. Oxford University Press, Melbourne.