The role of the polar jet in modulating the surface weather around coastal Antarctica - A case study.

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1 Introduction

Much has been made of the dominance of the near surface wind flow on the weather around Antarctica. Indeed the near surface wind over Antarctica shows the highest persistence on earth (Parish and Bromwich 1987)

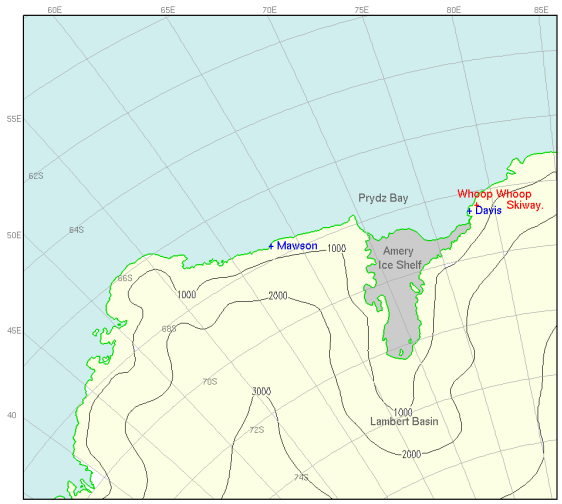

Figure 1: *Lambert Basin Map showing, Mawson, Davis and the Whoop Whoop Ski-way.*

with the orography of Antarctica exerting a strong control on the circulation in the lower levels (Parish and Bromwich 2007). Stations such as Mawson in East Antarctica, and the Davis Ski-way at Whoop Whoop (Figure 1), are dominated by the outflow off the high continental interior. Figure 2 shows the

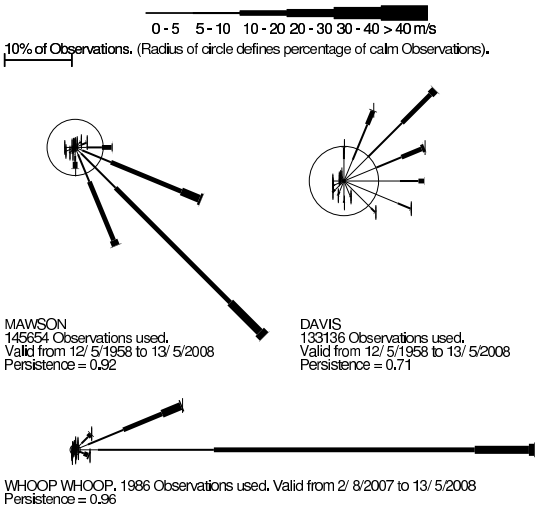

Figure 2: *Wind rose data from Mawson, Davis and the ski-way at Whoop Whoop.*

wind rose diagrams for Mawson, Davis and the Davis ski-way at Whoop Whoop. The dominance of the southeast flow at Mawson, and the easterly flow at Whoop Whoop are further exemplified by the very high persistence[1] values of 0.92 and 0.96, re-

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[1] $P = \sqrt{\bar{u}^2 + \bar{v}^2}/\bar{s}$, where $\bar{s}$ = mean wind speed, $\bar{u}$ = mean zonal, and $\bar{v}$ = mean meridonal wind component.

spectively. The weather at Mawson is all the more remarkable in as much as the prevailing wind direction of 135^{O}(true), is maintained under weak pressure gradients, where the katabatic flow dominates, and under very strong pressure gradients associated with the passage of deep low pressure systems through the polar trough; re-enforcing the ideas of Parish and Bromwich (2007), in as much as the Antarctic orography dominates the near surface flow. Davis Station is located near the coast in the Vestfold Hills, some 25 km from the ice plateau, and experiences a more maritime climate, however the persistence in the northeast flow is still comparatively high at 0.71. Davis is fairly immune to the katabatic flows associated with the steep icy slopes of the Antarctic escarpment.

With the increase in the amount of local flying occurring in the Australian sector over the last decade, routine high resolution regional scale modelling of the Antarctic and surrounding Southern Ocean has become a fundamental component of the forecast process, and finer scale and more detailed forecasts are being demanded. One result of the increased focus on meso-scale meteorology is the identification of weather events that don't fit the normal pattern of local weather, and the negative impact these events have on forecast accuracy and local flying operations. One such event, already described, is the relatively infrequent strong southerly surface flow at Casey Station (Adams 2005). This paper will briefly look at two more such events. Firstly, the passage of a hydraulic jump across Davis Station, and the second a strong southerly wind event at Mawson. Both these events are rare, and have a detrimental affect on flying operations. It will be argued that such events have their origins in the upper tropospheric flow and are intimately linked to the passage of the polar jet, and may be more readily forecast when upper level wind forecasts are more closely scrutinised.

2 Background

During early April of 2008 both Mawson and Davis experienced unusual weather. Figure 3 shows the operational ensemble forecast for Mawson, valid from

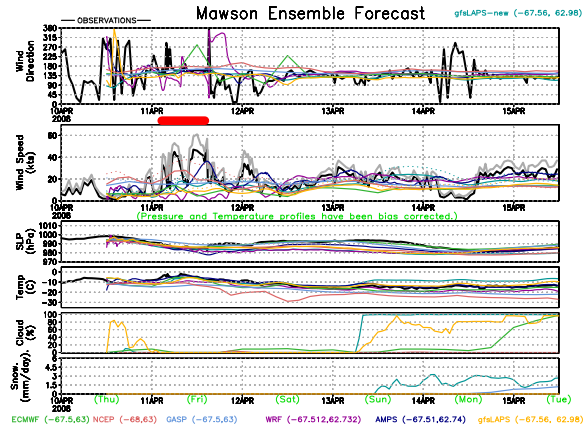

Figure 3: *Ensemble forecast for Mawson valid from 1200UTC 10 April 2008. Mawson surface observations overlaid in black.*

1200 UTC on 10 April 2008, with forecasts of near surface wind direction, wind speed[2], surface pressure, near surface air temperature, total cloud and precipitation from the European Centre for Medium-range Weather Forecasting (ECMWF), Australia's Global ASsimilation and Prediction (GASP) system (Seaman et al. 1995), the National Centers for Environmental Prediction (NCEP) Global Forecast System (GFS), and regional models, including the 20 km MM5 version of the Antarctic Meso-scale Prediction System (AMPS) (Bromwich et al. 2003), the new 20 km WRF version of AMPS, and two versions of the polar-stereographic implementation of the Australian Limited Area Prediction System (polarLAPS), based on the ALAPS model (Adams 2004), and nested within the NCEP-GFS model (gfsLAPS). In these diagrams, ECMWF is plotted in bright green, GASP in light blue, NCEP-GFS in red, AMPS-MM5 in dark blue, AMPS-WRF in purple, gfsLAPS in yellow, and gfsLAPS-new in drab green. Time series output are extracted from each model using the closest grid point to the forecast location. Bias corrections for pressure and air temperature are applied based on observations taken over the first 9 to 12 hours of

[2]Please note, this is an operational product and wind speed is measures in knots, rather than ms^{-1}.

each model run. As part of the post-analysis the surface observations from Mawson have been overlaid on the ensemble forecast, with all observations plotted in black, apart from observed gust strengths plotted in grey. The Mawson surface observations between 0300 UTC and 1500 UTC on 11 April (marked) were quite unusual as the surface wind direction during the period of strong ($>$ 40 knots, or 20 ms^{-1}) wind was from 160°true, rather than the prevailing 135°true. The deviation in direction was not large but the local weather affects were. Blowing snow and stratus streaming off the plateau directly over Mawson immediately prior to the onset of the strong surface wind was testament to the turbulence associated with what appeared to be a hydraulic jump moving across the station. Satellite imagery from the time of the event (Figure 4) showed relatively clear skies around

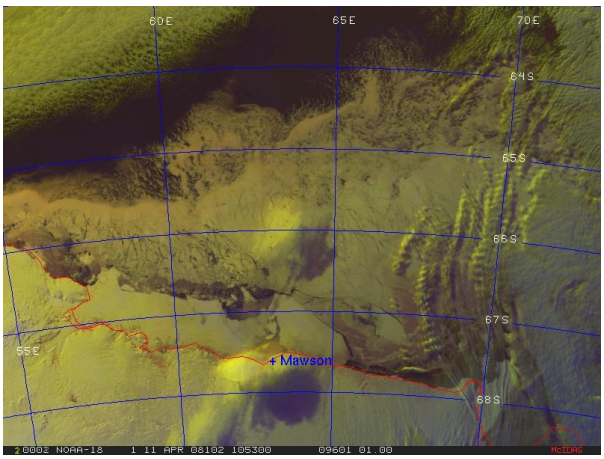

Figure 4: *NOAA-18 False Colour Image valid 1053 UTC 11 April 2008.*

Mawson, apart from some high cloud over the station and out to sea. The WRF version of AMPS forecast the second wind maxima during the event, and the NCEP-GFS model the first, but in general the NWP forecasts were not good.

At Davis Station, some 36 hours earlier, a similar event was recorded. The ensemble forecast for Davis, valid from 0000 UTC on 9 April 2008 is shown in Figure 5. The event of interest occurred between 1800 UTC on 9 April and 0800 UTC 10 April

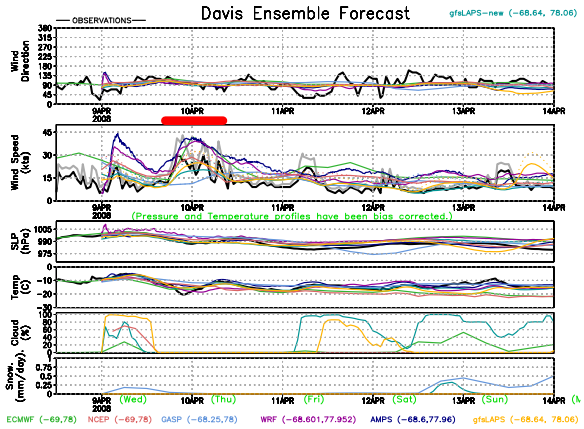

Figure 5: *Ensemble forecast for Davis valid from 0000UTC 9 April 2008. Davis surface observations overlaid in black.*

(marked), where a strong (30 knot, or 15 ms^{-1}) easterly flow occurred at the station. In the past, such rare events have caused the cessation of helicopter operations due to low level turbulence and reduced visibility in drifting snow, as happened on May 5 1998 with the last flights of the season attempting to return personnel to the ship for return to Australia. Such easterly events on the icy escarpment to the east of Davis are common, as evident in the wind rose for Whoop Whoop Ski-way in Figure 2. However, the strong easterly flow rarely moves off the plateau and out across the Vestfold Hills. The gfsLAPS forecast of the event was remarkably good, as was the NCEP-GFS forecast. Both AMPS models and the ECMWF forecast the event but over forecast the wind strengths.

These two events are considered rare, with Mawson experiencing a southerly wind in excess of 20 ms^{-1} on only 1% of occasions, and Davis an easterly wind in excess of 15 ms^{-1} on well less than 1% of occasions. Both events occurred in relatively clear skies, suggesting the phenomena were un-associated with any large scale weather systems.

3 Discussion

In the mean, the upper tropospheric flow over Antarctica is light, with the polar jet found some distance off the coast. The general flow pattern is shown in the 300 hPa NCEP-NCAR Reanalysis2 wind field

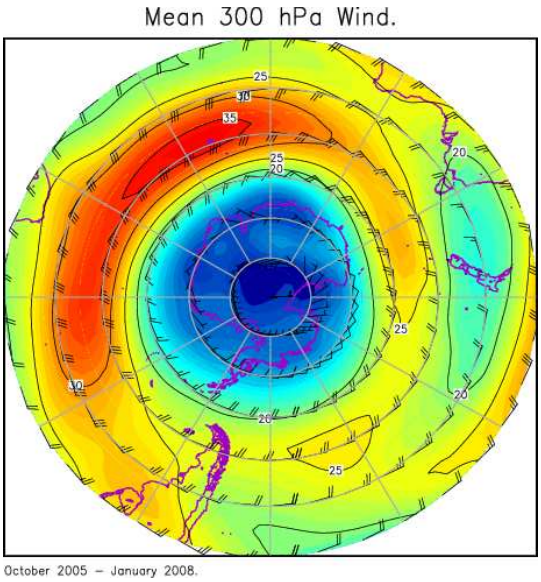

Figure 6: *Mean 300 hPa flow from the NCEP-NCAR Reanalysis2 for October 2005 to January 2008.*

in Figure 6, describing the mean flow for the period between October 2005 and January 2008. However, the mean field disguises strong anomalies that do arise in the upper level flow around the coastal regions of Antarctica. An analysis of upper air data collected from Mawson and Davis over the last two and a half years shows a small but significant number of events (3%), where the 300 hPa wind exceeded 40 ms^{-1}, indicative of an upper level jet. Wind roses compiled for the Mawson and Davis 300 hPa flow, over this period are shown in Figure 7. The Mawson wind rose highlights the predominance of west to southwesterly jets, whereas Davis also saw some easterly jets.

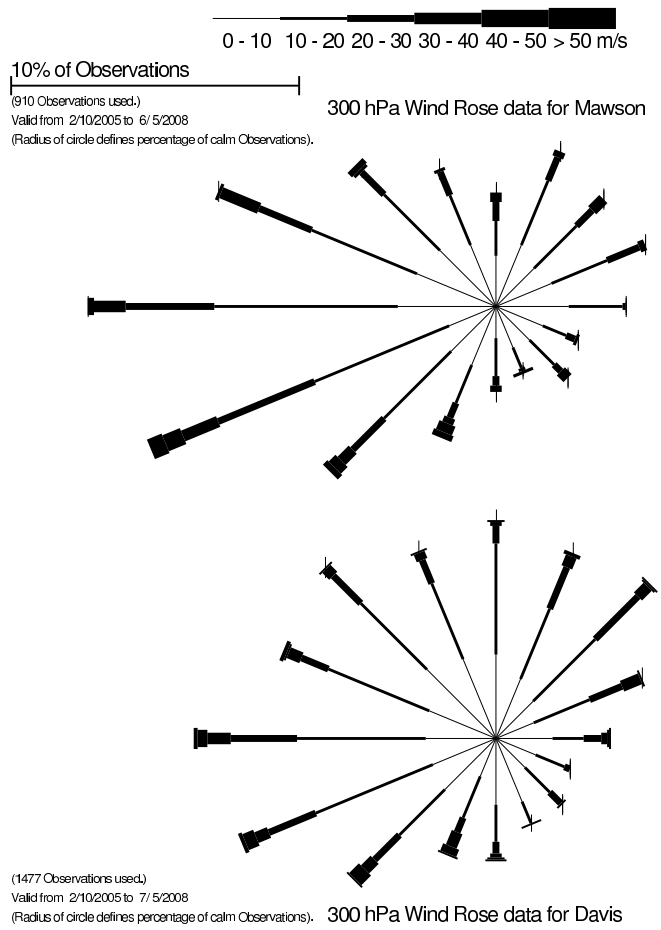

Figure 7: *300 hPa wind roses for Mawson (top) and Davis (bottom).*

An analysis of the upper level flow in early April 2008, showed a strong upper level anticyclone operating inland of Mawson and Davis. Figure 8 shows the 300 hPa flow over east Antarctica at 1200 UTC on 9 April, highlighting the strong (40-50 ms^{-1}) upper level jet associated with the circulation. The onset of the strong surface flow at Davis was around 0000 UTC on 10 April at which time the upper level southerly jet on the eastern side of the anti-cyclone was right over Davis (Figure 9). Similarly, at around 1200 UTC on 11 April when the strong southerly surface flow was affecting Mawson,

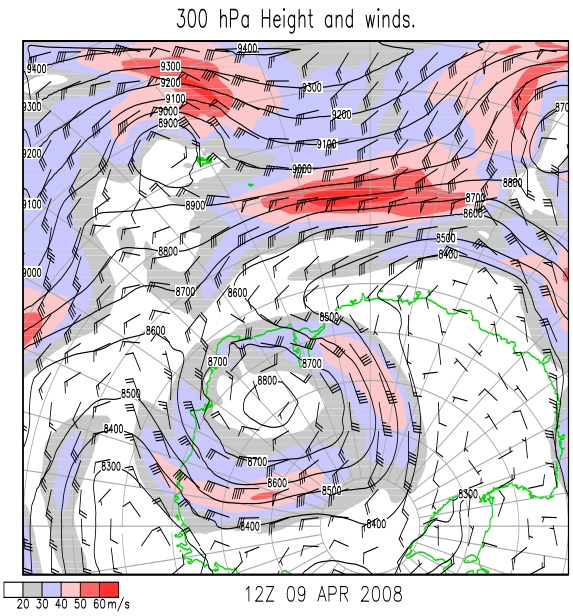

Figure 8: *300 hPa geopotential height and wind valid 1200 UTC 9 April 2008.*

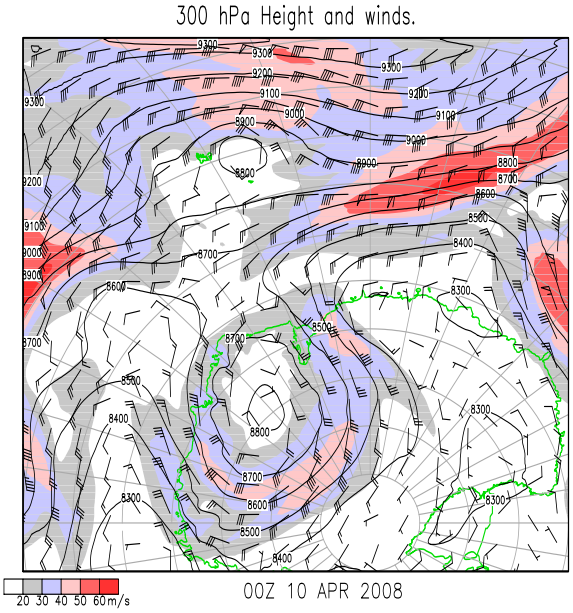

Figure 9: *300 hPa geopotential height and wind valid 0000 UTC 10 April 2008.*

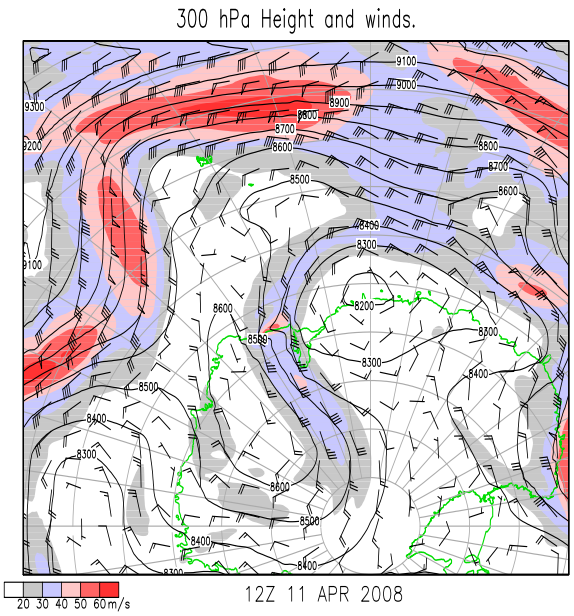

Figure 10: *300 hPa geopotential height and wind valid 1200 UTC 11 April 2008.*

the upper level southerly jet had advected westward over the station and reached in excess of 60 ms^{-1} (Figure 10). The flow regime at Mawson around this time was remarkably similar to the strong southerly events experienced at Casey (Adams 2005). Figure 11 shows a north-south cross-section along the Mawson longitude from the +24 hour gfsLAPS-new forecast valid at 1200 UTC 11 April, with the strong surface jet and shooting flow over the coast clearly linked to the upper level jet. In this model run the near surface shooting flow was still up-stream from Mawson (67.6^{o}S), where in reality it had moved offshore. However the model captured the dynamics well, with the strong upward vertical motion identifiable near 67.5^{o}S and 65.6^{o}S between 300 and 350 hPa, associated with the banner clouds visible on the satellite image in Figure 4.

At Davis the link between the upper level southerly jet and the occurrence of a surface easterly jet is not so clear and the dynamics still under review. However, just inland of Davis on the coastal escarpment, strong easterly flow is prevalent, as seen in the Whoop Whoop Ski-way surface wind (Figure 2). It is possible

that the upper level southerly flow was advecting the strong easterly surface flow from the south of Davis northward over the station.

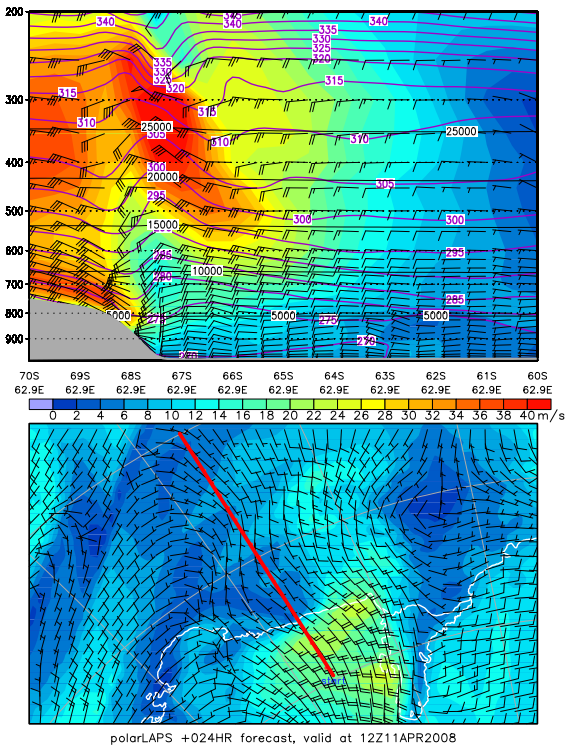

Figure 11: *Space-height cross section from 70°S to 60°S along 62.9^{o}E, valid 1200 UTC 11 April 2008.*

4 Summary

Hydraulic jumps and their associated dangers for local flying are a relatively rare event at Davis and Mawson, and inherently difficult to forecast. However, there is evidence for associating such events with the rare excursions of the polar jet southward over the Antarctic continent. A more detailed analysis of both unusual surface wind events and the movement of the polar jet needs to be undertaken, however if such a clear link is established then the forecasting of these surface events may become easier.

5 References

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