P1.28 ANTARCTIC MESOSCALE PREDICTION SYSTEM (AMPS): A CASE STUDY FROM THE 2000/2001 FIELD SEASON

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1. INTRODUCTION

The United States Antarctic Program (USAP) operating out of McMurdo Station, Antarctica, relies heavily on weather forecasts for the coordination of short-term local field logistics, as well as flight operations from Christchurch, New Zealand. Flights from New Zealand take up to 8 hours to reach McMurdo – enough time for the weather to change dramatically in this terrain-dominated area with coastal mountains in excess of 4,000m high. This has the potential to endanger passengers and cargo, and can be very expensive in the case that flights must turn back to Christchurch. As a result, the need for more accurate, longer-range forecasts has been recognized. Therefore, a numerical weather prediction program, AMPS (Antarctic Mesoscale Prediction System), has been implemented in the 2000-2001 field season. AMPS employs the Polar MM5, a hybrid version of the Pennsylvania State / NCAR Mesoscale Model 5, modified to represent parameterizations over extensive ice sheets (Cassano et al., 2001). One element of AMPS is to assess the performance and accuracy of the Polar MM5 by employing case studies of unique weather events. This is one such study, which will focus on a cyclone that formed and developed over the western Ross Sea (Fig. 1) between Jan 13-16, 2001, causing precipitation, strong winds, and low visibility at McMurdo. The storm is assessed at both the surface and upper levels. The surface analysis utilizes data from automatic weather stations (AWS), ship observations, and satellite images. The upper level analysis makes use of NCEP/NCAR Reanalysis-I model output (Kalnay et al., 1996), as well as rawinsonde data from McMurdo Station and the Italian base at Terra Nova Bay (TNB). The goals of this study are to determine what caused the formation of the system, its course (track), the skill of the Polar MM5 in forecasting the storm, and what improvements might be made to the model to insure more accurate forecasts in the future.

2. FORMATION

At first glance, the cyclogenesis of the system appears to be similar to that described in *Bromwich* (1991) and *Carrasco and Bromwich* (1996), which is linked to katabatic outflow in the vicinity of TNB. This mechanism deserves mentioning, as it is one of the most common types of cyclogenisis in the western Ross Sea. In this type of system, a steep baroclinic zone forms offshore as cold continental air flows over

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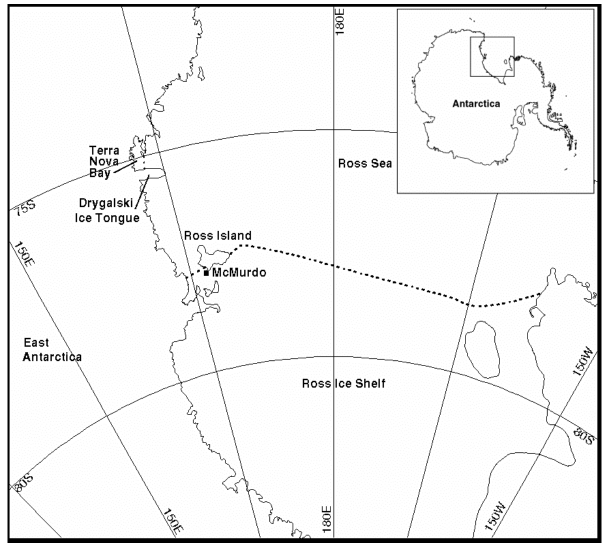

Figure 1. Study area for weather system occurring Jan. 13-18, 2001.

(relatively) warm maritime air. In addition, horizontal wind shear caused by the fast-moving air mass increases cyclonic vorticity. These two elements are important factors in cyclone formation.

Indeed, a katabatic event during the period of cyclogenesis is suggested in Figure 2, which shows wind speed and direction at Zoraida AWS, on the Priestley Glacier near TNB. A significant increase in wind speed (~25 kts) begins on Jan 13 at 1200 UTC and continues through Jan 16 at 1200 UTC. Throughout the event, the wind direction stays nearly constant (NW). This is characteristic of the intense, consistent winds associated with a katabatic episode.

However, during the Antarctic summer katabatic winds are infrequent, and the onset of a katabatic event generally requires some form of synoptic forcing (Bromwich et al., 1993). Therefore, it is worth considering other mechanisms that may be at work. For example, these winds might be forced by a low-pressure center out in the Ross Sea.

Figure 3 shows the path of the R/V Italica as it cruises toward TNB on Jan 13-14. Note, on January 13 at 1800 UTC the southerly winds begin to increase, and quickly become in excess of 30 knots. The magnitude and direction of these winds suggest a depression lies to the east of the ship (we are unsure of its origin at this point). This argument is further reinforced by considering the sea-level pressure on the ship compared with AWS sites in the TNB region. In Figure 4a (a snapshot of the state of the system on Jan 14 at 0600 UTC), the sea-level pressure on the R/V Italica is 2-3 hPa lower than the AWS sites in TNB, implying

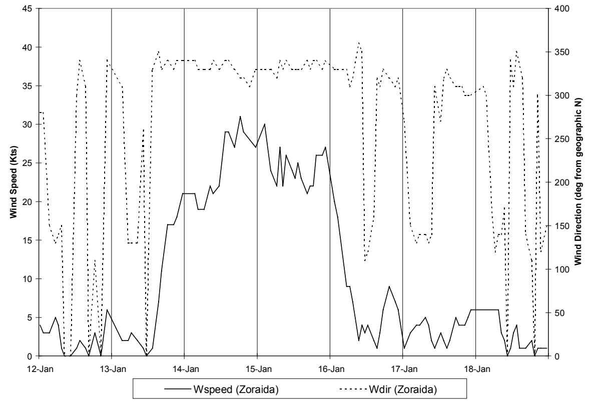

Figure 2. Wind Speed / Direction at Zoraida AWS on the Priestley Glacier Near TNB.

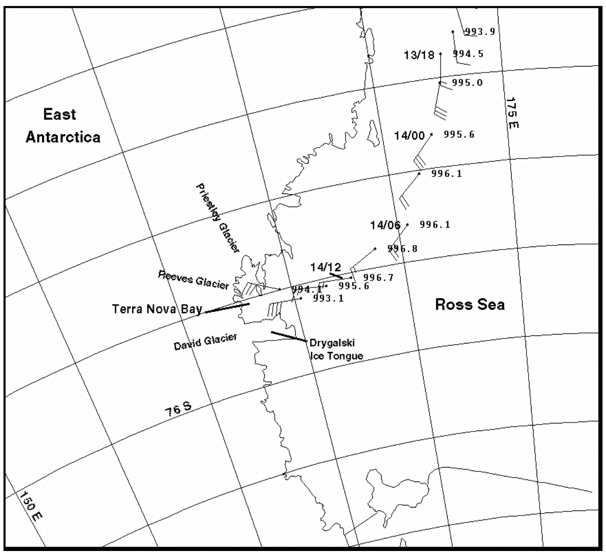

Figure 3. Track of R/V Italica, showing wind speed (kts) and direction, and sea level pressure (hPa), Jan 13-14, 2001. 13/18 = Jan 13 at 1800 UTC.

the center of the low is to the east of the ship. Several coastal AWS sites also indicate a depression in the vicinity of the ship. For example, at 0600 UTC on Jan 14, winds are southerly at Alessandra and Silvia AWS (the two sites north of TNB in Fig. 4a).

In the near future, high-resolution (1km) AVHRR data from the Italian base in TNB will be analyzed to confirm the presence of a depression in the Ross Sea during this period. For the purpose of discussion, we will assume the center of the low is to the east of the R/V Italica on Jan 13-14, and is responsible for the katabatic wind event observed at Priestley Glacier in Figure 2.

At the same time, another low-pressure center is forming to the west of Ross Island, as indicated by the AWS pressure analysis in Figure 4a. This depression may be a result of upper-level divergence as evidenced by a trough at the 500 hPa level over East Antarctica (Figure 5a).

Both depressions (one forming to the NE of TNB, near the R/V Italica, and the other propagating away from East Antarctica) are part of the same, general low-pressure area lying over the western Ross Sea. However, each is a distinct entity, forming under different conditions, intensifying for different reasons, and taking a different path. This will be examined in the following section.

3. TRACK

At 0600 UTC on Jan 14 (Fig. 4a), the 996 hPa depression to the east of the R/V Italica and TNB (henceforth, 'Low-N') is intensifying as it moves SW. As discussed above, forcing from Low-N most likely triggers a katabatic wind event in the TNB region. Data suggest this event exerts positive feedback on the system – serving to strengthen the low by increasing baroclinicity and cyclonic vorticity. This is apparent 12 hours later at 1800 UTC on Jan 14 (Fig. 4b) which shows Low-N intensifying to 994 hPa as it moves inward toward TNB. Twenty-four hours later, at 0600 UTC on Jan 15 (Fig. 4c), the system moves inland of TNB, merging with another weak depression. For reasons yet to be determined, Low-N stays in TNB for the remainder of the period, and eventually dies out as (relatively) high-pressure moves in. This is not the system that causes adverse weather at McMurdo.

Concurrently, the depression that affects McMurdo (henceforth, 'Low-S') is emerging from East Antarctica immediately to the west of Ross Island. This is shown as a bow in the 998 hPa isobar at 0600 UTC on Jan 14 (Fig 4a). Evidence of this system is suggested by the wind fields near McMurdo, which flow southward (clockwise around the system). Twelve hours later (Fig 4b), Low-S has intensified to 992 hPa and moved just east of Ross Island. Note the winds at McMurdo have shifted 180 degrees, now flowing northward. This is indicative of clockwise flow around a low centered to the east. The upper-level support for Low-S is also strengthened. The (NCEP/NCAR Reanalysis-I) 500 hPa depression has moved NW over the Ross Island region, lowering geopotential by ~40 gpm from Jan 14 at 0600 UTC (Fig. 5a) to Jan 14 at 1800 UTC (Fig 5b). This decrease in geopotential is also apparent in the McMurdo rawinsonde data, which indicate a 45 gpm decrease in 500 hPa height from 0000 UTC to 1200 UTC on Jan 14 (Table 1).

At 0600 UTC on Jan 15 (Fig 4c), the center of Low-S has moved SE of Ross Island. However, it continues to intensify (990 hPa) as upper-level support moves overhead. The (NCEP/NCAR Reanalysis-I) 500 hPa depression falls by ~30 gpm from Jan 14 at 1800 UTC (Fig. 5b) to Jan 15 at 0600 UTC (Fig 5c). This is supported by the McMurdo rawinsonde data (Table 1), which indicate a drop of 43 gpm from 1200 UTC on Jan 14 to 0000 UTC on Jan 15. Note that although the NCEP/NCAR Reanalysis-I data is not quantitatively identical to the McMurdo rawinsonde data, it gives a reasonable qualitative look at upper-level conditions.

Table 1. 500 hPa rawinsonde data – Jan 14-16, 2001, McMurdo Station. GPM=geopotential meters, T=temperature (C^o), RH=relative humidity (%), Td=dew point (C^o), WD=wind direction (deg from geographic N), WS=wind speed (Kts). The final column is the interpolated NCEP/NCAR Reanalysis-I geopotential height over McMurdo. (*estimated)

Time	GPM	T	RH	Td	WD	WS	NCEP GPM
14/00	5127	-35	70	-39	349	34	5140
14/12	5082	-37	63	-42	343	30	5105
15/00	5039*	-38	34	-48	348	30	5075
15/12	4994	-40	33	-50	318	17	5050
16/00	5015	-41	39	-49	256	7	5050

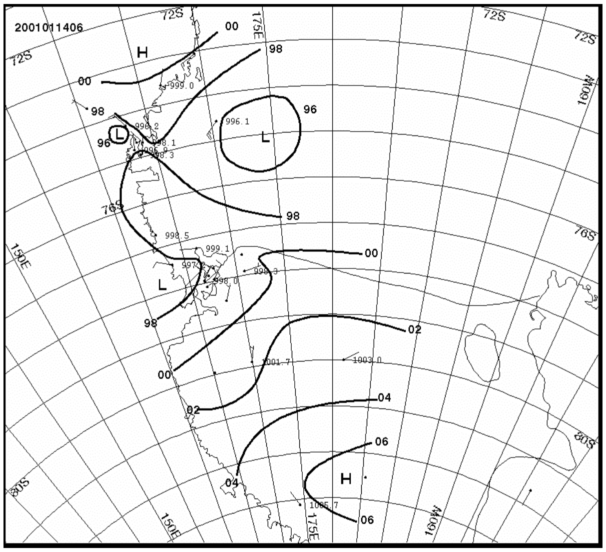

Figure 4a. Manual analysis of sea level pressure at 0600 UTC, Jan 14. 98=998 hPa, 04=1004 hPa. The R/V Italica is shown to the east of TNB at this time.

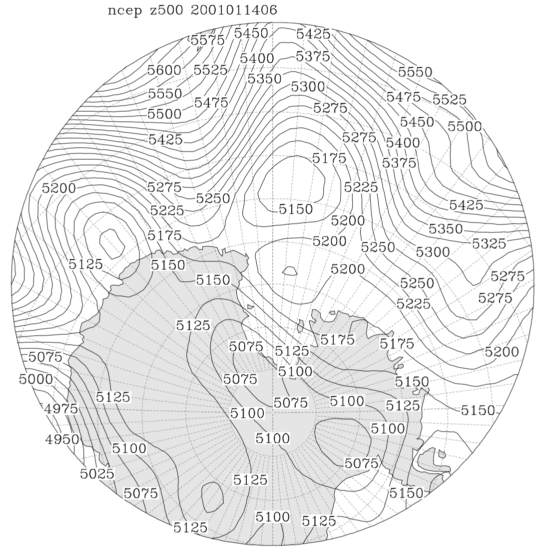

Figure 5a. 500 hPa height - Jan 14 at 0600 UTC. (NCEP/NCAR Reanalysis I data).

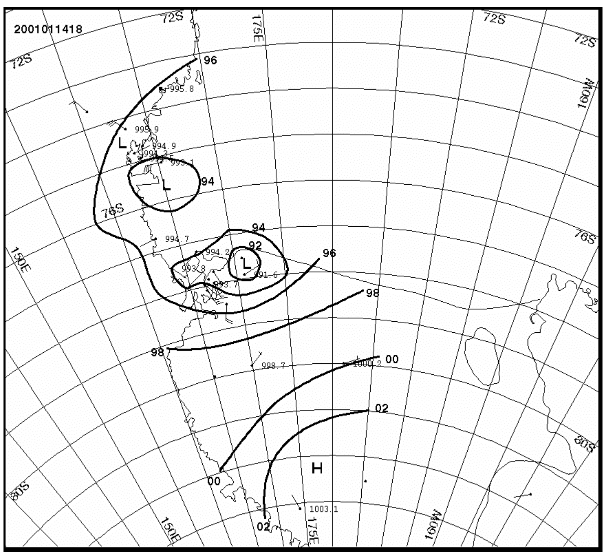

Figure 4b. Same as 4a, but for 1800 UTC, Jan 14.

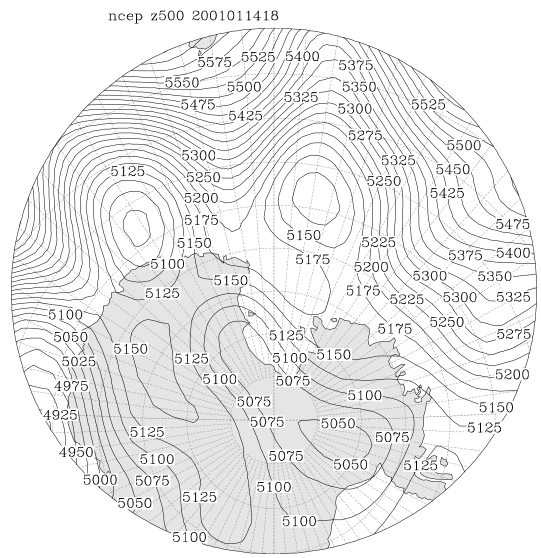

Figure 5b. Same as 5a, but for 1800 UTC, Jan 14.

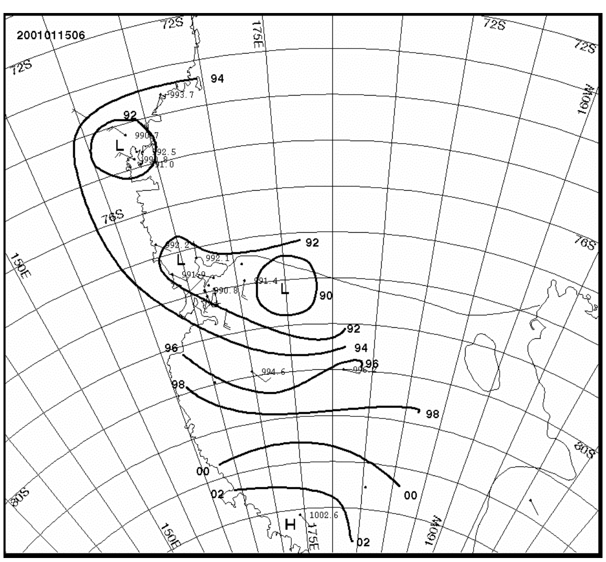

Figure 4c. Same as 4a, but for 0600 UTC, Jan 15.

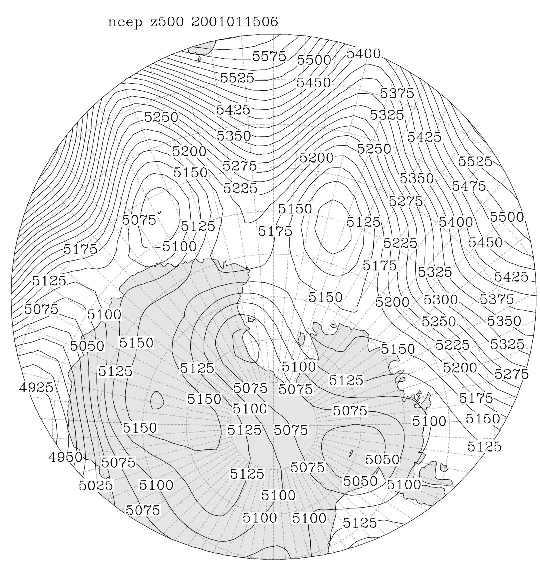

Figure 5c. Same as 5a, but for 0600 UTC, Jan 15.

After 0600 UTC on Jan 15, the surface low continues to track SE under the leading edge of the 500 hPa depression. The SE movement of this upper level depression is evident in the McMurdo rawinsonde data by the shift in wind direction from NW to W (clockwise around the low) between Jan 15 at 0000 UTC and Jan 16 at 0000 UTC (Table 1).

4. THE POLAR MM5

Several modifications have been made to the standard version of the PSU / NCAR MM5 model, in order to capture features unique to extensive ice sheets such as steep coastal margins and lack of conventional soil and vegetation types. To summarize briefly, changes include the representation of grid-scale cloud and precipitation processes by the Reisner explicit microphysics parameterization; sub-grid clouds resolved with the Grell cumulus parameterization; replacing the Fletcher equation for ice nuclei concentration with that of Meyers; using a modified version of the CCM2 radiation parameterization; atmosphere and atmosphere/surface turbulent fluxes represented by the 1.5 order turbulence closure parameterization from NCEP's ETA model; modified soil and thermal properties to represent snow and ice surfaces; and the addition of a sea ice surface type to the 13 types available in the standard version of MM5. These modifications are discussed in greater detail (including references for each of the parameterizations) in *Bromwich, et al*. (2001), and *Cassano et al*. (2001). The Polar MM5 is available in the public release version of MM5 (v. 3.5 or later).

The AMPS program employs three domains of the Polar MM5, as described in *Powers et al*. (2001). 1) A 90 km horizontal grid covers a large portion of the Southern Hemisphere, including all of Antarctica and New Zealand, and part of Australia and South America. 2) A 30 km grid covers Antarctica. 3) A 10 km grid covers the western Ross Sea, centered over McMurdo. Forecast length is 48 h for the 90 and 30 km grids, and 24 h for the 10 km grid. All grids have 29 sigma levels between the ground and model top (100 hPa). Initial and boundary conditions are derived from NCEP's global AVN model. Initialization times are at 00z and 12z.

A detailed investigation of the performance of the model is ongoing. Preliminary results show the model resolving the formation of a low-pressure system in TNB at the 14/00z and 14/12z initializations (Powers et al., 2001). However, contrary to the analysis in Sections 2 and 3, this system tracks SE to the Ross Ice Shelf. Further results will be presented as they become available.

5. SUMMARY

The goals of this case study are to determine the formation and track of a mesoscale cyclone occurring from Jan 13-16, 2001, to assess the skill of the Polar MM5 in forecasting the storm, and to formulate model improvements based on the assessment. Findings thus far are:

1) There is a general low-pressure area over the western Ross Sea between Jan 13-16. However, two distinct low-pressure systems (Low-N and Low-S) develop.
2) Low-N moves SW toward TNB and triggers a katabatic event that causes it to intensify briefly. It then moves inland of TNB where it eventually dies out.
3) Low-S moves out of East Antarctica and is amplified by upper-level support. It tracks over Ross Island then SE over the Ross Ice Shelf, and is responsible adverse weather at McMurdo.
4) Preliminary results show the Polar MM5 capturing the formation of a low in TNB in the 14/00z and 14/12z initializations. Contrary to the analysis in Sections 2 and 3, this system moves SE over the Ross Ice Shelf.

-The performance of the model is currently being examined in greater detail. Results will be published at a later date.

6. ACKNOWLEDGMENTS

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