5B.2 NUMERICAL WEATHER PREDICTION IN EAST ANTARCTICA

Neil Adams*
Antarctic CRC and Australian Bureau of Meteorology

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1 INTRODUCTION

The need for a high resolution numerical model to be run routinely over East Antarctica and the Southern Ocean has partially arisen out of the proposed long range inter-continental flying between Australia and bases in East Antarctica. The potential for hazardous flying conditions around the Antarctic coast makes such flights weather critical, and access to accurate and timely weather forecasts essential. The current global models don't have the resolution to adequately model some of the more adverse weather conditions that arise due to topographic influences around the steep Antarctic coastal escarpment. These inadequacies surfaced some years ago when trying to support field operations and long range intra-continental helicopter flying, with forecasters having mixed results in trying to infer likely adverse weather from the broad scale features depicted in the global model fields. The Australian Bureau of Meteorology's limited area prediction scheme, (LAPS), was chosen for the Antarctic study because it has been in development for some years, employs full data assimilation, is globally relocatable, and has proven robust in operational forecasting in the Australian region since July 1996. The following paper briefly discusses the model, including changes made to better simulate the Antarctic environment, then presents some statistical results on model performance and a case study highlighting the forecast improvements possible with a high resolution grid point model. Ongoing work and future studies are then briefly outlined.

*GPO Box 421 Kent Town
SA 5071 Australia. Email N.Adams@bom.gov.au
Ph +61 8 8366 2686 Fax +61 8 8366 2742

2 THE MODEL

LAPS is implemented on a latitude/longitude horizontal grid using sigma coordinates in the vertical. The domain has a resolution of 0.25^o of latitude by 0.50^o of longitude, with boundaries from 0^oE to 180^oE and 80^oS to 35^oS and 29 vertical sigma levels, ranging from 0.9988 near the surface to 0.05 at the model upper boundary. A full description of the model is given by Puri et al. (1998) but in essence the governing equations are the multilevel primitive equations for momentum, mass, temperature and moisture, written in advective form, except for the mass equation which is in flux form. The model runs on an Arakawa A grid employing fully explicit Miller-Pearce time differencing. High order spatial differencing is used where ever possible to ensure accuracy to at least that of second order C grid models. The physical parameterisation schemes are the same as used in the Australian global assimilation and prediction system (GASP), as described by Puri et al. (1998). The analysis system is a limited area adaptation of the global multivariate statistical interpolation (MVSI) used by GASP and is described by Seaman et al. (1995). The model is run every 12 hours with two analysis cycles. The first analysis is performed at -6 hours from the forecast start time, with the first guess field extracted from the current global model data. The analysis is integrated forward 6 hours to the zero time of the current model run. The second analysis is then performed on the +6 hour forecast and the model integrated forward 48 hours, producing output every 3 hours. Surface and upper air data, along with TOVS soundings are using in the analyses and appear to have a positive impact on the model output.

Several changes to the operational version of

LAPS have been made in order to better represent the Antarctic environment. Daily sea ice concentrations from NCEP are used to improve the land-sea-ice mask and to also alter the surface temperature field. If the sea ice concentration is higher than 95% then the surface is treated as land and the topography and surface temperature updated accordingly (with height set to 2.0 m). If the sea ice concentration is less than 30% then the surface is set to water with a temperature of -1.5^{o}C. Surface temperatures over sea ice are set to -1.96^{o}C. The albedo field generated in the Antarctic version of LAPS continues to use the work of Hummel and Reck (1979) but in a manner that more accurately sets albedo values in the high resolution domain. The entire continent is set to the continental value, except for a small zone near the coast which reduces uniformally to a set coastal fringe value of 65%. Albedos are kept at 65% for high sea ice concentrations but reduce to the Hummel and Reck (1979) seasonal open ocean values as the ice concentration reduces to zero. Changes are also made to the calculation of surface temperature south of 45^{o}S. In the Antarctic version, if there is a positive lapse rate ($T_{\sigma 2}$ - $T_{\sigma 1}>$ 0.0) then the surface temperature is calculated as a linear extrapolation of the first 2 sigma levels, otherwise the surface layer is made isothermal with the surface temperature set to the first sigma level air temperature. Points north of 45^{o}S continue to have a surface temperature set marginally warmer than that at the first sigma level. A more realistic simulation of the surface flow has been achieved by setting the surface roughness to a fixed value of 0.001m over the continent, rather than using the effective roughness implementation of Wood et al. (1993), as used in the Australian LAPS code.

The model has been running every 12 hours since late December 2000, producing meteorological profiles at several locations around east Antarctica.

3 MODEL OUTPUT

The Antarctic version of LAPS has a resolution of around 25 km, which is significantly higher than the approximate grid point resolution of 75 km available from the GASP spectral model, making it possible to better model topographic influences on local weather. For example, in the GASP model Law Dome only appears as a ridge line jutting out into the Southern Ocean east of Casey, but at the higher resolution of LAPS, Law Dome appears as a regularly shaped dome to the southeast of Casey and is a good approximation of the real topography. The higher resolution now makes it possible for the forecaster to attempt single station forecasting from model data over a meso-scale domain but the availability of very high resolution data also introduces a challenge for the forecaster, in how to best display the data in a timely and efficient manner, and in a way that best represents the forecast weather. Several systems have been developed for displaying the model data, such as forecast aerological diagrams and time series of single station surface parameters (figure 1). More complex 4 dimensional cross sections tracking through the model domain are also available along with post processed fields such as model synthetic cloud.

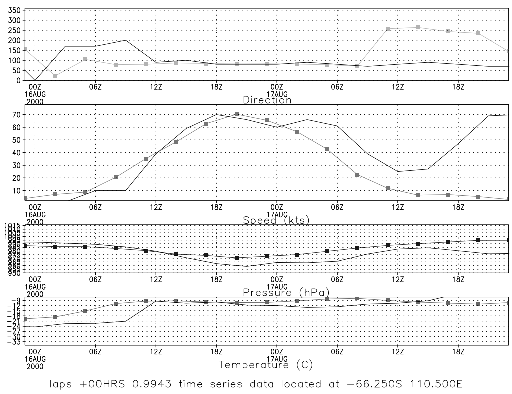

Figure 1: 48 Hour forecast with verifying station observations

4 MODEL PERFORMANCE

Traditionally, model output has been verified using SI skill scores (Teweles and Wobus, 1954), generated from the mean sea level pressure pattern, and verified against a control analysis. However, this method is no longer considered ideal and single station verification against actual synoptic observations has been chosen as a preferred method of verifying model performance. Within this study, numerical model data at 3 hourly intervals from the analysis out to +48 hours have been extracted at

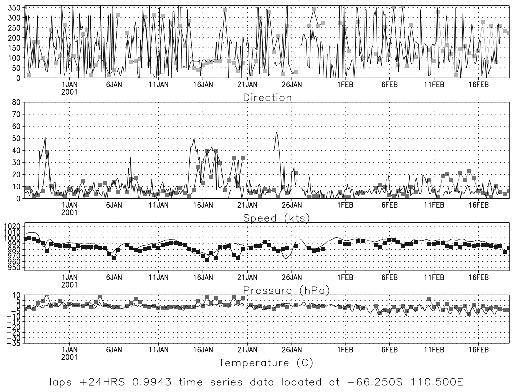

Figure 2: LAPS timeseries of +48 hour forecast surface data.

several key sites around Antarctica and the Southern Ocean, coincident with, or very close to, synoptic and upper air stations. Time-height profiles of temperature, wind, moisture, vertical motion and geopotential height were saved from each run

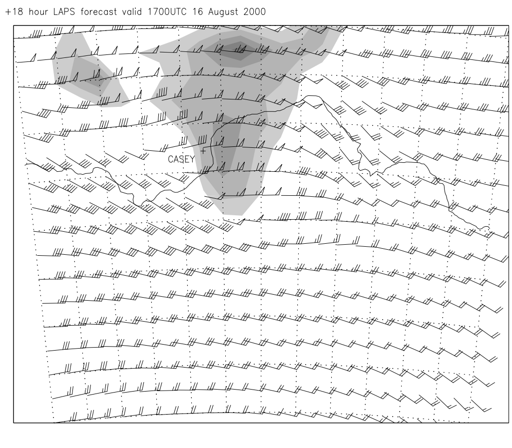

Figure 3: LAPS Forecast wind (~30m).

of the model for comparison with surface and upper air observations, and also for inter-comparison with other numerical models. Only a short period of model output exists at the time of writing so drawing meaningful conclusions as to model performance is not yet possible. However, interesting trends (figure 2) and model strengths are beginning to show and perusal of LAPS model output shows a significant improvement in the forecast of onset and strength of storm force wind events (figure 3), when compared against forecasts from the global model used to initialise the high resolution run (figure 4).

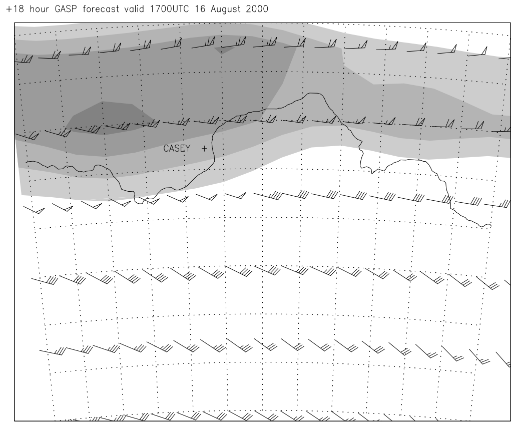

Figure 4: GASP forecast wind (~75m).

5 CASE STUDY

One of the key meteorological problems in the Casey area is forecasting the onset and strength of storm force wind events that are associated with the passage of extra tropical cyclones to the north of the station. Despite being able to track the passage of the low pressure systems with reasonable accuracy, and monitor the increasing wind speeds measured on the summit of Law Dome to the southeast of Casey, forecasting the onset of what is often hurricane strength wind has been difficult. Nowcasting techniques, involving the monitoring of fluctuations in the local wind, and visually monitoring the snow drift tails caused by increasing wind speed on the plateau inland of Casey, can assist in onset timing within an hour or so but reliably forecasting onset 12 to 36 hours in advance has not been possible. Several studies have been undertaken to assist in our understanding of the dynamics associated with the very strong wind events at Casey, ranging from studies by Murphy (1990), Wilson (1992), Adams (1996) and most recently by Turner et al. (2001) but in all of the studies no conclusive evidence was found to categorically define the dynamics associated with the onset and maintenance of what is a significantly super geostrophic flow at Casey. Lacking a meso-scale network of surface and upper air data in the area has limited the effectiveness of observational studies and it is in this respect that a high resolution atmospheric numerical model may be able to assist in providing a detailed description of the dynamics associated with the enhanced flow, and accurately forecast onset. Figure 5 shows

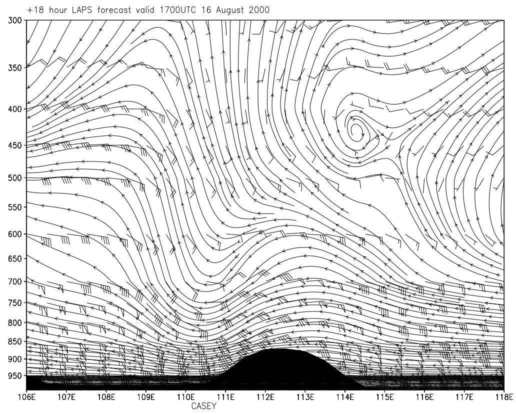

Figure 5: Cross section of flow over Law Dome.

a cross section of the flow over Law Dome at the latitude of Casey, highlighting the vertical structure of the wind regime and defining the accelerated downslope flow which is possibly associated with a stationary gravity wave.

6 FUTURE WORK

The Antarctic LAPS model at it's current resolution shows promise as a useful tool in forecasting high latitude weather systems and in exploring their dynamics. Future studies will focus on additional case studies to better understand the weather around Australian Antarctic bases, the continuation of single station verification studies, higher resolution simulations to further explore topographic influences on Antarctic weather systems and sensitivity studies on the impact of sea-ice variability in short term weather forecasting.

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