The Development of a Numerical Weather Prediction Climatology and it's Application to Antarctic Weather Forecasting.

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1 Introduction

Researchers at the Antarctic Climate and Ecosystems Cooperative Research Centre (ACE CRC) are involved in the development of a sea-ice analysis and forecasting system that ultimately will provide the Australian Antarctic community with an operational sea-ice analysis and forecasting tool to assist navigation at sea, and local Antarctic sea-ice research. The core of the forecasting system is version four of the Los Alamos National Laboratory's Community Ice (CICEv4) model (Hunke et al. 2008). The system is primarily designed to run in a coupled mode with global climate and ocean models. However, it can be run in a stand-alone mode, and the ACE CRC development team have implemented the CICEv4 code as a regional sea-ice model covering only the southern hemisphere, using the same polar-stereographic grid as employed by the Australian Bureau of Meteorology's polar-stereographic Limited Area Prediction System - polarLAPS (Adams in press). The rationale behind employing the same grid as the polarLAPS model is the ease with which atmospheric forcing data can be ingested by the sea-ice model. The data assimilation system under development for the sea-ice model is based on the Bluelink Ocean Data Assimilation (BODAS) system (Oke et al. 2007), with the initial version expected to assimilate only sea-ice concentration data. BODAS is an optimal interpolation system requiring error covariance matrices for each of the state variables, and these matrices need to be generated from a suitably long climate run of the sea-ice forecast system. To provide the atmospheric forcing data for the climate run polarLAPS was run from 1 January 1998 to 31 December 2008, nested within NCEP-DOE Reanalysis-2 data (Kanamitsu et al. 2002). Although these model runs were primarily performed to provide forcing data for the sea-ice forecasting system they also have the potential to provide a wealth of data to Antarctic weather forecasters. With 11 years of model data it is possible to carefully look at model statistics in the form of model biases and errors and to also provide forecasters with a unque data-set over those parts of Antarctica for which there are no long term surface or upper air observational records. The follow paper introduces some of the analysis undertaken to describe the polarLAPS model climatology, and potential benefits to Antarctic weather forecasting.

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2 The modelling system

PolarLAPS is a polar-stereographic implementation of the ALAPS model (Adams 2004) and designed to overcome some of the more serious short-comings of ALAPS resulting from converging meridians towards the southern boundary and the proximity of the domain boundaries to the main forecast areas of interest. In it's current form polarLAPS runs as a down-scaling system and in forecast mode is nested within output from the National Centers for Environmental Prediction Global Forecast System (NCEP-GFS) (www.emc.ncep.noaa.gov/modelinfo/index.html).

For the climate runs the NCEP-DOE Reanalysis-2 data (Kanamitsu et al. 2002) was used to provide initial and boundary conditions for the forecast runs, and over the 11 year period the model was re-initialised every 24 hours at 0000 UTC, with model output from +12 hours out to +36 hours saved from each run. The 11 year climatology was then constructed from hourly surface forecasts and three hourly upper-level forecasts from between the +12 hour time-step and +35 hour time-step. The initial 12 hours of model output was discarded in order to give the model adequate spin-up time. Figure 1 shows the domain employed by the polarLAPS system in the climate run mode.

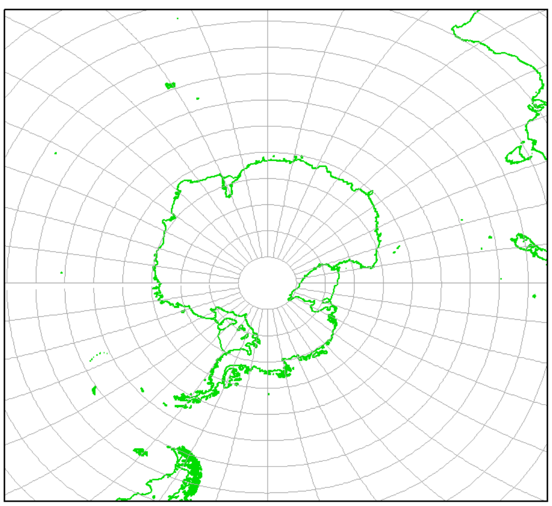

Figure 1: PolarLAPS domain used in climate system

The modelling method employed was designed for speed of processing as a strict time-line of achieving results was in place, with the 11 years of data taking seven months on an NEC SX6 super-computer. There were some issues with the modelling system employed. A bug in the set-up code resulted in monthly mean one degree sea surface temperature data being used rather than weekly data. The 12 hour spin-up for the model runs was most definitely too short given the interpolation of 250 km resolution reanalysis data directly to the 27.5 km resolution polarLAPS domain. Recent studied of the polarLAPS model skill (Adams in press) showed that polarLAPS nested within the 100 km resolution NCEP-GFS output took around 16 hours of spin up before the model skill improved sufficiently to out-perform the same model code but nested within the 75 km resolution Australian global Model (GASP) output. The 16 hour spin up was considered a direct result of the shock to the model system from the interpolation process. Given the much coarser resolution of the reanalysis data it would be expected that the spin-up would be some what longer than 16 hours. Ideally, such a down-scaling process would be more functional if the system was re-started every 6 hours with model output from between +24 hours and +29 hours from each model run used to construct the climatology. However, the aim of the system was not to provide accurate regional climate data, but 11 years worth of polarLAPS data from which to force a sea-ice modelling system to generate error covariance matrices.

3 Performance of the polarLAPS climatology

The initial testing of the model performance involved a comparison of model biases, root mean square errors (RMSE) and bias corrected RMSE for screen temperature, surface pressure and near surface wind speed at Casey, Mawson and Vostok. Biases and RMSE (not shown), were in general improved in polarLAPS over the reanalysis data used to initialise polarLAPS. Although, the wind statistics at Mawson were slightly degraded in bias and RMSE over the reanalysis output. However, the bias corrected RMS errors from polarLAPS were better for all locations and variables (Table 1). The down-scaled polarLAPS bias corrected RMS errors were only marginally worse than the statistics from the real-time forecast runs of the model, nested within the NCEP-GFS data, where the temperature bias corrected RMSE was 2.4 K, pressure 3.1 hPa and wind speed 5.1 ms^{-1}.

General features of the Antarctic atmosphere were

bC-RMSE	Temp (K)	SLP (hPa)	Wind (m/s)
	L - N	**L** - N	**L** - N
Casey	**3.0** 4.7	**4.7** 34.7	**5.9** 7.4
Mawson	**2.9** 3.7	**3.9** 34.3	**5.7** 6.6
Vostok	**3.1** 5.4	-	**2.8** 4.4

Table 1: Model bias correct RMSE for temperature, pressure and wind speed at Casey, Davis and Vostok. (L - polarLAPS, N- Reanalysis-2).

well captured in the down-scaling process. Figure 2 shows the aggregate monthly mean temperatures

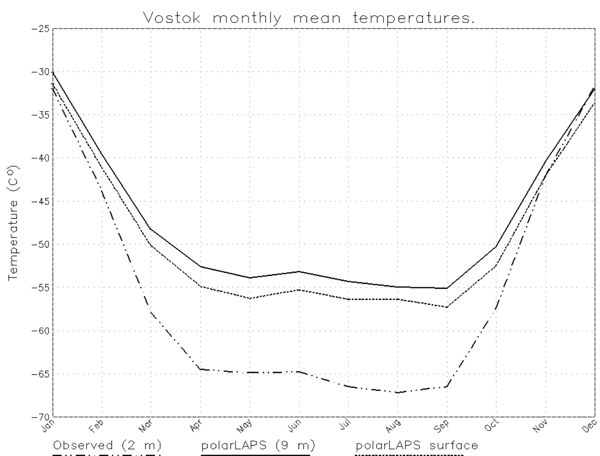

Figure 2: Mean monthly Vostok temperatures for the period 1998 - 2008. Solid line is the polarLAPS 9 m data, dashed line the Vostok observations, and the dotted line the polarLAPS surface temperature.

from Vostok between 1998 and 2008 from polarLAPS, with the near surface (~9 m) temperature plotted as a solid line, and the modelled surface temperature as a dotted line. The observed (2 m) temperatures are shown as dashed line. The polarLAPS climatology has under-estimated the winter-time temperatures by some 10 to 12 °C, which is a significant departure from observed. The model grid point is at an elevation of 3470 m with the actual station height at 3488 m so height differences are unlikely to significantly contribute to the error. The model surface temperatures are also too warm, suggesting that the initialisation of the model surface temperature field was in error and forcing near surface air temperatures to be too warm. Where the polarLAPS climatology did perform well was in modelling the core-less winter and the slight warming around June associated with the build up of the strong winter-time surface outflow.

Closer examination of the time series data also highlighted the relatively good performance of the down-scaling process. Figure 3 shows a time-series

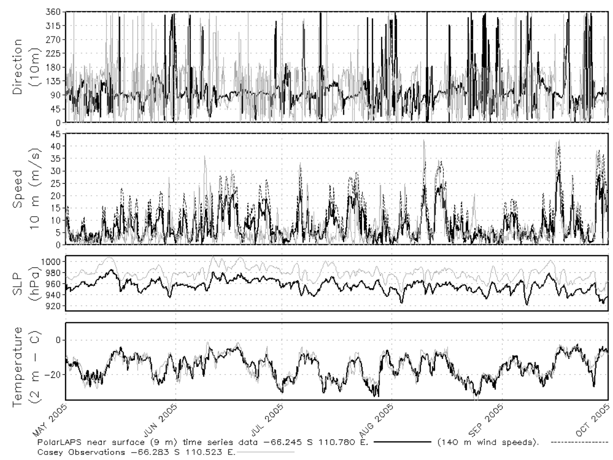

Figure 3: Time series plot of polarLAPS data and Casey observational data for the period 1 May to 1 October 2005. Solid black lines are polarLAPS 9 m data, thin grey line Casey observational data and thin dashed line the polarLAPS 140 m wind speed.

plot of three hourly data from the grid point closest to Casey Station (66º 17' S, 110º 31.4' E). Model data from the 0.9988 sigma level (~9 m) are shown in black, and Casey observations in grey. Wind speed data from the polarLAPS 0.9820 sigma level (~140 m) are shown as a dotted line. Temperatures match very well, and the profile of pressure also matches very well, but with an obvious bias resulting from the model grid point being at an elevation of 234 m and the station barometer at a height of 42.3 m. Close inspection of the wind speed time series shows the polarLAPS climate runs picked the majority of strong wind or storm events, although under-estimated their strength. The polarLAPS winds from 140 m better captured the storm events although slightly over-estimated wind speeds between events. The wind direction record is somewhat difficult to interpret, although the model has bias towards east to northeasterly flow and appears not to capture the southerly events that are evident in the observational record. The anomalies in the modelled winds are best compared through the use of wind speed and direction frequency analyses. Figure 4a shows the frequency analysis from the polarLAPS 9 m winds, with Figure 4b the analysis from the observational data. Figure 4c is the polarLAPS 140 m frequency analysis. The bi-modal nature of the Casey 10 m wind is quite apparent in Figure 4b with a predominance of light (~5 ms^{-1}) northeasterly and south to southeasterly flow. The polarLAPS prevailing 9 m flow is a light east to northeasterly. Storm events at Casey have a prevailing direction around 85^{o} true, where as the polarLAPS storms at both 9 m and 140 m are from around 95^{o} true. The reasoning behind the biases needs further investigation but it would appear that the specified friction within the polarLAPS dynamics has been set too high, resulting in a retardation of the modelled surface flow and an increase in the down-slope direction of the wind.

4 Summary and Conclusions

Eleven years of polarLAPS runs have been performed to provide atmospheric forcing data for a sea-ice forecasting system under development. However, these data provide a unique resource for weather forecasters operating in the Antarctic in as much as a model climatology is now available for data sparse locations across the Antarctic continent and Southern Ocean. The climatology is not perfect, with a very rudimentary down-scaling process employed, but careful analysis of the model output can be used to highlight model deficiencies that in turn can benefit the interpretation of the climatology. At present the climatology is quite short but this prototype system suggests that down-scaling is a worthwhile process and a modern NWP system coupled to a modern global

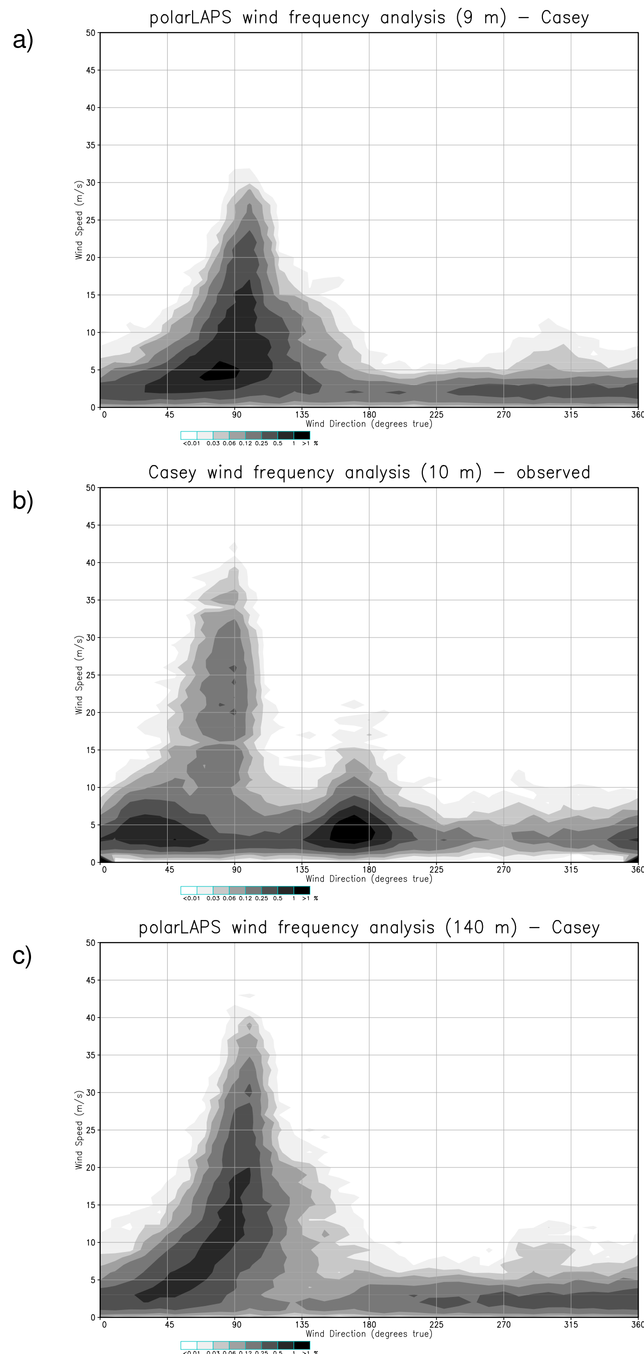

Figure 4: Wind speed and direction frequency analyses for a) polarLAPS 9 m data, b) Casey surface (10 m) observations and c) polarLAPS 140 m data.

reanalysis dataset may offer much in providing a high resolution long term Antarctic climate dataset.

5 References

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