IMPORTANCE OF MARINE DATA TO SEASONAL FORECASTING IN AUSTRALIA

Scott Power*, Dean Collins and Grant Beard, National Climate Centre, Bureau of Meteorology, Australia

1. INTRODUCTION

Each month, Australia's Bureau of Meteorology issues a seasonal climate outlook of rainfall outlooks throughout the country for the coming three months (see http://www.bom.gov.au/au/climate/ahead for further details). This site depicts a small but important subset of the forecast information we provide. A much larger set is provided on a cost-recovery basis to hundreds of subscribers from around the country. Forecast information is also disseminated via the mass media through the radio, newspapers (national, state and rural), and more recently via satellite television to over 300,000 subscribers in rural Australia, on a weekly basis.

These outlooks, together with estimates of their reliability, are useful to a wide range of users, including farmers, water managers, banking groups, and scientists, and many other users connected with the rural sector.

The outlooks are based on the statistical relationships between rainfall and patterns of sea surface temperature (SST) anomalies in the region (Drosdowsky and Chambers, 1998). A similar scheme for Australian temperature forecasts has also been developed (Jones, 1998). Over the longer term, we also provide forecasts of NINO3 out to nine months using an intermediate coupled model (Kleeman, 1993). The Bureau is also moving towards forecasts based on coupled general circulation models (Power *et al.*, 1998; Wang *et al.*, 1999). In this paper we will outline the fundamental importance of marine data sets for both the statistical and numerical prediction schemes.

In addition, we will describe research which suggests that the predictability of seasonal rainfall anomalies over Australia associated with ENSO, waxes and wanes from generation to generation and this variability may be associated with the "Interdecadal Pacific Oscillation" (Power *et al.*, 1999). Additional marine observations may be required to ensure that variability of this kind is adequately represented in future coupled models used for seasonal forecasting.

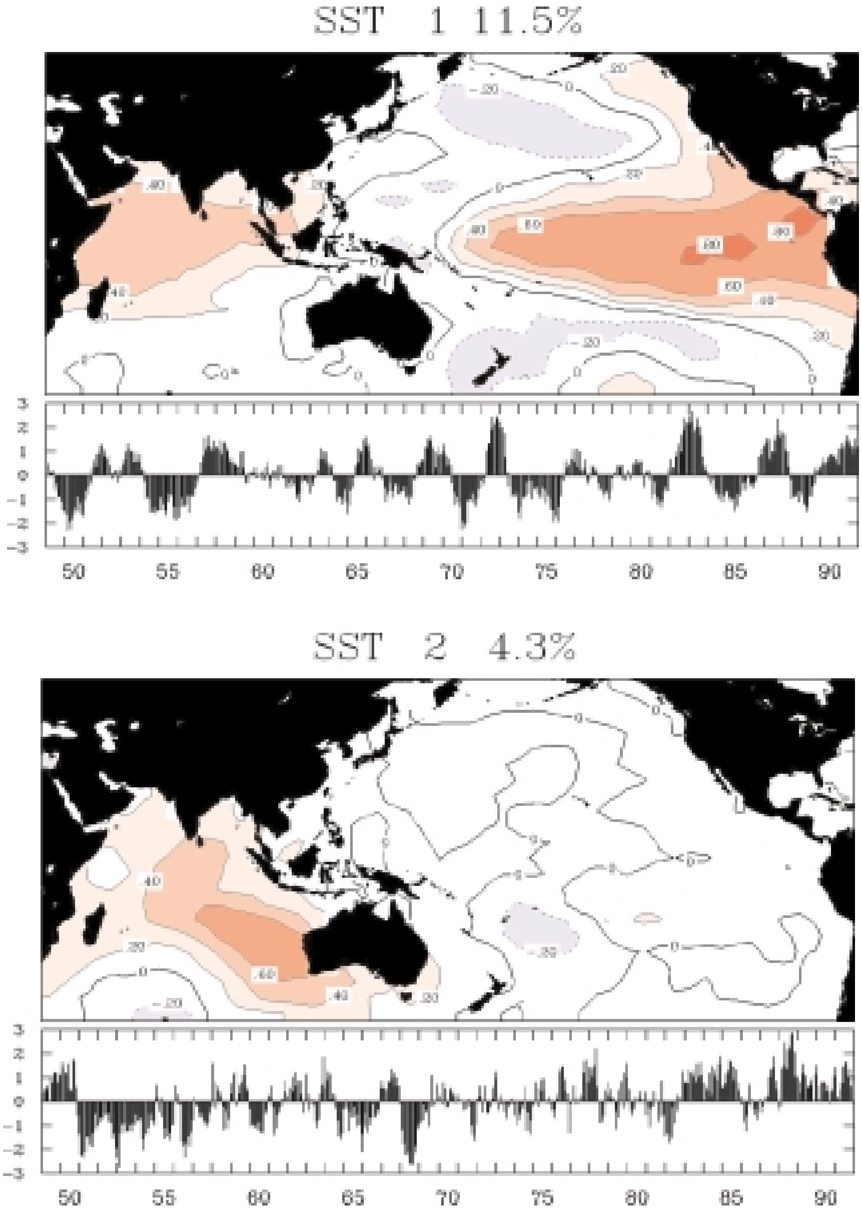
2. STATISTICAL PREDICTION SCHEMES BASED ON SEA SURFACE TEMPERATURE

The operational scheme currently used by the Bureau's National Climate Centre for rainfall prediction (Drosdowsky and Chambers, 1998) uses the lagged relationship between SST and Australian rainfall to provide estimates of the probability of total rainfall in the following season being above median, for example. The scheme uses Indian Ocean and Pacific Ocean SST patterns as predictors (Figure 1, from Drosdowsky and Chambers, 1998) and displays greater skill than previous operational schemes based on the SOI.

The marine data used to develop the statistical relationships for the rainfall prediction scheme were provided by a number of sources. SST data from 1949 to 1991 were provided by the UK Met Office Global Ice and Sea Surface Temperature data set (GISST, version 1.1; Parker *et al.*, 1995). To extend the data to the present, the National Center for Environmental Prediction optimum interpolation analyses (Reynolds and Smith, 1994) and the operational analyses of the Bureau of Meteorology (Smith, 1995) were used.

The Smith (1995) products are analyses of surface and subsurface tropical Pacific Ocean temperatures (Figure 2). The observational marine data used for these analyses primarily comes from the volunteer observing XBT programme (TWXXPPC, 1993) and the TOGA TOA array (Hayes *et al.*, 1991).

* Corresponding author's address: Scott Power, National Climate Centre, Bureau of Meteorology, GPO Box 1289K, Melbourne, AUSTRALIA, 3001; e-mail: s.power@bom.gov.au



Figugre 1—The first two principal components of SST variability that are used for seasonal prediction of Australian rainfall and temperature.

Further details on the ocean temperature analysis system can be found at: http://www.bom.gov.au/bmrc/mrlr/nrs/climocan.htm.

The differences between one observational estimate of SST and another are large enough to produce clear differences in the seasonal forecasts of rainfall that we are able to provide, and, therefore, efforts aimed at improving the accuracy of SST analyses are strongly supported.

A similar prediction scheme has also been developed to forecast seasonal temperature anomalies (Jones, 1998), and this is expected to be routinely disseminated to the general public soon. These temperature forecasts have been found to be more skilful than those for rainfall.

3. MARINE DATA AND SEASONAL FORECASTS BASED ON COUPLED OCEAN-ATMOSPHERE MODELS

3.1 INITIALIZATION

The use of subsurface analyses has been shown to significantly increase the hindcast performance of the BMRC (Bureau of Meteorology Research Centre) intermediate coupled model (Kleeman, 1993; Kleeman *et al.*, 1995) used to provide guidance of ENSO development for the coming nine months.

The surface conditions of the ocean component during the assimilation phase were specified by the wind stress derived from FSU wind data (Goldenberg and O'Brien, 1981) and the SST data set of Reynolds and Smith (1994). Subsurface ocean data were derived from a number of real-time and near real-time sources as well as some ocean experiment data sets and archives.

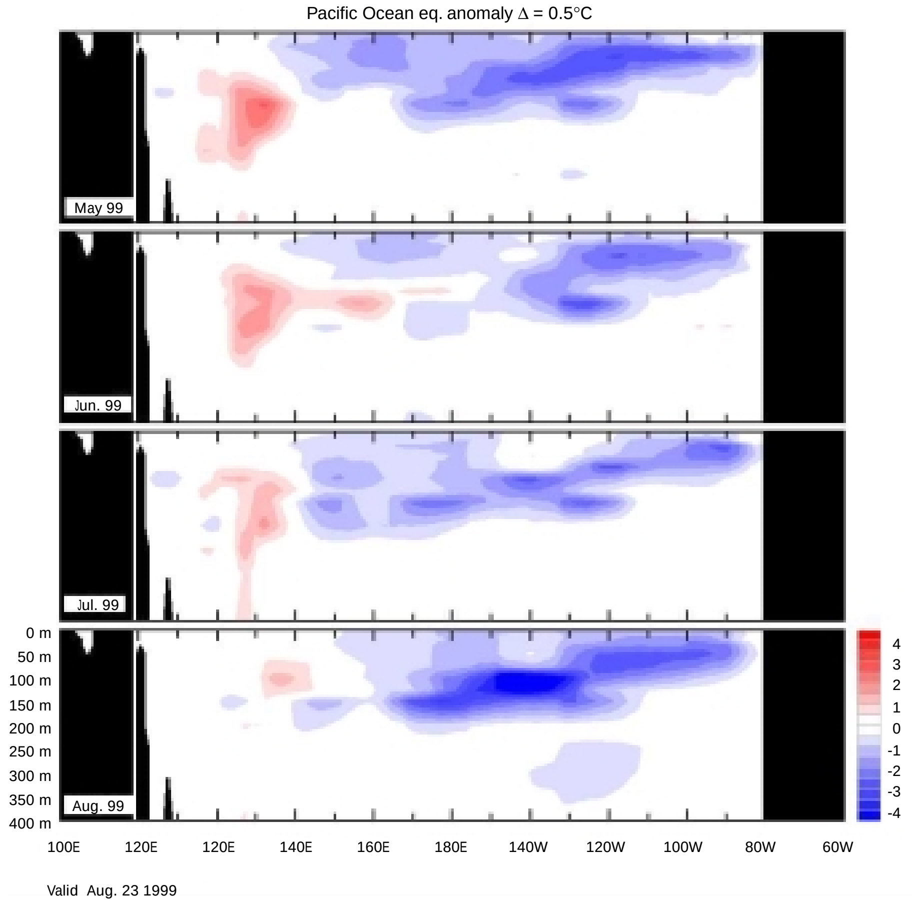


Figure 2—Incorporating analyses of subsurface ocean temperatures has significantly increased the skill of the Bureau's coupled model predictions.

As well as the operational prediction schemes, the Bureau of Meteorology Research Centre is currently developing a forecast scheme based on a coupled ocean-atmosphere general circulation model (CGCM; Power *et al.*, 1998; Wang *et al.*, 1999). Marine data have played a critical role in the development and verification of this model and will also be important in the routine running of the model once it has been implemented as an operational scheme.

Recent sensitivity studies of the model by Wang *et al.* (1999) indicate that the inclusion of ocean data is crucial to achieve higher skill in hindcasts. The fact that reliable subsurface analyses prior to the early 1980s are not available necessarily restricts the hindcast period for coupled models and, therefore, impedes our ability to verify CGCM hindcasts. Given that estimates of forecast reliability are very important for potential users, this limitation in our climatic database represents a major shortcoming. Efforts aimed at expanding the range of climatic variables or lengthening the period over which relevant data are available are, therefore, eagerly awaited by seasonal forecasters.

3.2 VERIFICATION

The verification of CGCMs requires a wide range of observational data sets. In fact, the WMO Commission for Basic Systems recently described a group of data sets which might be useful as part of an experimental long-range forecast verification project. These include :

(i) Sea surface temperature
Reynolds OI, with option for additional use of GISST

(ii) Precipitation
Xie-Arkin; GPCP data; ECMWF Reanalysis and operational analysis data

(iii) Mean sea-level pressure
ECMWF Reanalysis and operational analysis data; own centre operational analysis data if available; UKMO GMSLP data set.

The ideal verification data set for seasonal prediction would, in general, have global spatial coverage, would extend back at least a few decades and would also be available in real time so that both hindcast and real-time forecasts could be verified in a consistent fashion. In fact, the number of such data sets available is low and so many of the data sets suggested fall short of this ideal. This also represents a significant impediment to being able to provide assessments of seasonal forecasts that are as reliable and standardized as one might hope.

4. INTER-DECADAL VARIATIONS IN PREDICTIVE SKILL

It has been found that fluctuations in SST on inter-decadal time-scales seem to have a profound influence on the ability to predict ENSO-related seasonal rainfall anomalies in Australia (Power *et al.*, 1999). The success of an ENSO-based statistical scheme - and indeed the influence of ENSO on Australia in general - are shown to vary in association with a coherent, inter-decadal oscillation in SST over the Pacific Ocean.

When this Inter-decadal Pacific Oscillation (IPO) raises SSTs in the tropical Pacific Ocean, there appears to be no robust relationship between year-to-year Australian climate variations and ENSO. When the IPO lowers temperature in the same region, on the other hand, year-to-year ENSO variability is closely associated with year-to-year variability in rainfall, surface temperature, river flow and the domestic wheat crop yield. The contrast in ENSO's influence between the two phases of the IPO is quite remarkable and has serious implications for seasonal climate prediction in Australia, and possibly in other countries as well.

If subsequent research supports the need to ensure that variability of this kind is properly represented in future CGCMs, then additional data sets might be required, e.g. surface and sub-surface. This provides further evidence that marine data will continue to be vitally important for seasonal forecasting in the future.

5. SUMMARY

The success of the Bureau of Meteorology's forecast systems - both numerical and statistical, and operational and experimental - are critically dependent upon the ongoing availability of reliable marine data. The improvement in forecast skill of climate predictions depends, in part, on making greater use of existing and future marine data sets. From a seasonal forecasting perspective, therefore, efforts aimed at improving and extending existing data sets and expanding the range of appropriate climate data sets for use in statistical schemes, and for the verification and initialization of coupled atmosphere-ocean models, are highly valued and strongly supported.

REFERENCES

Drosdowsky, W. and L.E. Chambers, 1998: Near global sea surface temperature anomalies as predictors of Australian seasonal rainfall. *BMRC Res. Rep. No.* 65, Bur. Met., Australia.

Goldenberg, S.B. and J.J. O'Brien, 1981: Time and space variability of tropical Pacific wind stress. *Mon. Wea. Rev.*, 109, 1190-1207.

Hayes, S.P., L.J. Mangum, J. Picaut, A. Sumi and K. Takeuchi, 1991: TOGA TAO: A moored array for real-time measurements in the tropical Pacific Ocean. *Bull. Amer. Meteor. Soc.*, 72, 339-347.

Jones, D.A. 1998: The prediction of Australian land surface temperatures using near global sea surface temperature patterns. *BMRC Res. Rep.* No. 70, Bur. Met., Australia.

Kleeman R., 1993: On the dependence of hindcast skill on ocean thermodynamics in a coupled ocean-atmosphere model. *J. Clim.*, 6, 2012-2033.

Kleeman, R., A.M. Moore and N.R. Smith, 1995: Assimilation of sub-surface thermal data into an intermediate tropical coupled ocean-atmosphere model. *Mon. Wea. Rev*, 123, 3103-3113.

Parker, D.E., C.K. Folland, A.C. Bevan, M.N. Ward, M. Jackson and K. Maskerll, 1995: Marine surface data for analysis of climatic fluctuations on interannual-to-century time scales. In: *Natural Climate Variability on Decade-to-Century Time Scales*. Climate Research Committee, National Academic Press, Washington D.C., U.S.A., 241-252.

Power, S.B., F. Tseitkin, R.A. Colman and A. Sulaiman, 1998: A coupled general circulation model for seasonal prediction and climate change research. *BMRC Research Report* No. 66, Bur. Met., Australia.

Power, S., T. Casey, C. Folland, A. Colman and V. Mehta, 1999: Inter-decadal modulation of the impact of ENSO on Australia. *Climate Dynamics*, 15, 319-324.

Reynolds, R.W. and T.M. Smith, 1994: Improved global sea surface temperature analysis using optimum interpolation. *J. Climate*, 7, 929-948.

Smith, N.R. 1995: The BMRC ocean thermal analysis system. *Aust. Met. Mag.*, 44, 93-110.

TOGA/WOCEXBT/XCTD Programme Planning Committee 1993: Workshop on the use of sub-surface thermal data for climate studies (Brest, France). ITPO Rep. No.9/WOCE Rep. No. 110/93, WMO, 60 pp.

Wang, G., R. Kleeman, N. Smith and F. Tseitkin, 1999: Seasonal predictions with a coupled global ocean-atmosphere system at BMRC. *BMRC Res. Rep.* Bur. Met., Australia (in preparation).