Predicting the extreme 2015/16 El Nino event

Lerato E. Mpheshea[1, 2] and Willem A. Landman[1, 2]

[1]Council for Scientific and Industrial Research, Natural Resources and the Environment, Pretoria, South Africa

[2]Department of Geography, Geoinformatics and Meteorology, University of Pretoria, Pretoria, South Africa

Abstract

A strong El Niño phenomenon is expected to develop during the austral summer. This study seeks to address the two main questions. 1) How strong will the 2016 event be? 2) With how much skill and confidence can a really strong event be predicted? A state-of-the-art coupled ocean-atmosphere model's Niño3.4 SST forecast for January 2016 is presented, followed by an evaluation of the model's ability to have predicted events of similar magnitude in the past. The January forecast, initialized in July 2015, shows a Niño3.4 SST anomaly larger than the 75th percentile of the observed climatological record. Verification over 18 years of Niño3.4 SST hindcasts suggest that such forecasts may be made with high confidence even at several months lead-time.

Key words: El Niño, coupled model, verification

Introduction

The anomalous fluctuations of sea-surface temperatures (SSTs) in the tropical Pacific Ocean have considerable global impact on inter-annual climate variability (e.g. Ropelewski and Halpert, 1987). In southern Africa, anomalously warm (cold) SSTs in the tropical eastern Pacific Ocean are strongly linked to drier (wetter) than normal seasons (Lindesay et al., 1988; Lindesay and Vogel, 1990; Rouault and Richard, 2003). In an event of a dry season, agricultural production tends to be impacted negatively and water scarcity tends to be exacerbated especially in the rural areas. Since the 1990's when seasonal forecasting became operational in South Africa, decision makers are informed ahead of time whether the coming season is likely to be drier, near-normal or wetter (Landman, 2014). Such forecast, however, work best in the presence of an El Niño or a La Niña event (Landman and Beraki, 2012). The July El Niño advisory issued by the USA's Climate Prediction Center states that the "consensus is in favour of a significant El Niño in excess of +1.5°C in the Niño-3.4 region." The aim of this study is to analyse the ability of a state-of-the-art coupled ocean-atmosphere model to predict such extreme El Niño events at lead-times up to 6 months. Our analysis indicates an exceptionally strong El Niño to occur and since such predictions have skill then southern Africans may have to brace themselves for a summer drought in 2015/16.

Data and Method

Verification data

The monthly Optimal Interpolation Sea Surface Temperature (OISST) data (Reynolds, et al., 2007) are used for verification. The months considered are November, December, January, February and March from 1982 to 2014 in order to capture the mature phase of ENSO.

Model validation

The model used is the GFDL-CM2.5-FLOR-B01 fully coupled model of the North American Multi-model Ensemble (Kirtman et al., 2014). Monthly hindcast global data from March 1980 to the present are available at a 1°x1° latitude-longitude resolution for 12 ensemble members and for lead-times up to 11 months. We consider only lead-times of 6 months which is typical for seasonal forecasting in South Africa. The model validation methods applied in this study are achieved by using the Climate Prediction Tool (CPT) statistical software of the International Research Institute for

Tel nr: +27(12) 841 2946 Email: lmpheshea@csir.co.za

Climate and Society. To assess model performance, a retroactive forecast procedure is employed so as to obtain realistic estimation of its prediction skill (Mason & Mimmack, 2002). The training period is initially set as 15 years (1982-1996) with a training period update interval of one year. We do not do a recalibration or downscaling of model output to the OISST grid, but rather only correct for the mean and biases of the model while interpolating to the nearest gridpoint of the OISST. These settings allow the optimal model to produce a set of 18-year retroactive predictions. The above- and below-normal events are defined at the 25% extreme tails of the climatological distribution of SSTs. Relative operating characteristic (ROC) areas (Mason, 1982; Mason and Graham, 1999) are computed to evaluate the discrimination in the forecasts more specifically. For the purpose of assessing the reliability the resolution slope is computed. The verification results presented in the following section are only for the upper 25% tail. This threshold represents extreme El Niño events in terms of Niño3.4 SST anomalies.

Results and Discussion

Fig. 1a shows a time series of the hindcast and the observed SSTs for the Niño3.4 region. These series represent area averages. Hindcasts have a bias of about 1°C which is subsequently removed. These forecasts compare well with the observations. The 2002/03 and 2009/10 events resulted in the wide spread dry conditions in southern Africa (Rojas, et al., 2014). The impact of the 1997/98 event on the rainfall over southern Africa was much less than anticipated (Rojas, et al., 2014). Many studies attribute the modification of ENSO/rainfall to the variability SSTs in the South Indian Ocean (e.g. Reason, 2001). In general, El Niño events are associated with dry summers. If the re-forecast appears to satisfactorily agree with the observed data as seen in fig. 1a, it is plausible to have confidence in the forecast system to predict the future events. In this case, the upcoming season is predicted to be amongst the most intense El Niño events. The January forecast of the SSTs in the Niño3.4 domain lies above the 75th percentile of the observed climatological data (see fig. 1a). The probabilistic forecast for each of the three outcomes (La Niña, Neutral and El Niño) for January Niño3.4 SST is shown in Fig. 2. The figure shows a 92% chance of an extreme El Niño condition (in terms of SST) to occur in January 2016. So not only is the prediction for a strong event to occur, the likelihood of this happening is also large.

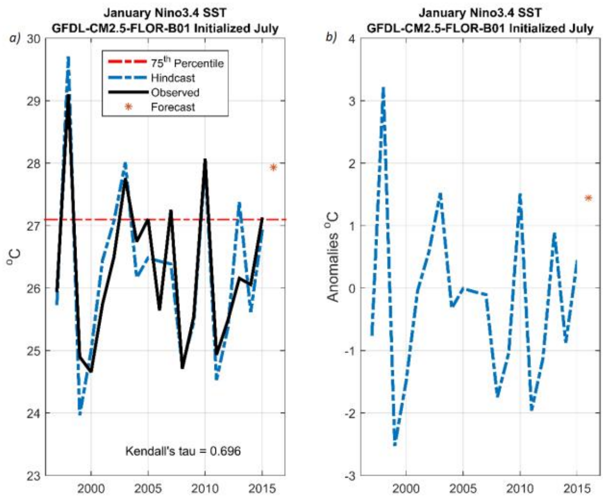

Figure 1: a) Area averaged hindcast and observed SSTs in the Niño3.4 region [5° N- 5 °S; 120° W – 170 °W] presented in blue and black respectively. The SST forecast for January is represented by an asterisk. The red dashed line marks the 75th percentile of the observed climatological record. b) Shows the anomalies of the SST hindcast (dashed line) and forecast for January (asterisk) in the Niño3.4 domain

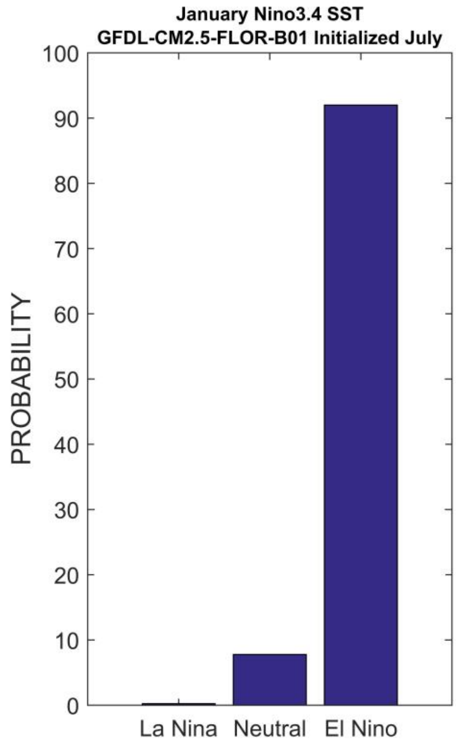

Figure 2: Probabilistic forecast of January 2016 Niño3.4 SST in terms of La Niña (0.2%), Neutral (7.8%) and El Niño (92%) occurrence.

Fig. 3 shows the ROC area scores for the model to discriminate the above normal SST events (El Niño) from the near – and below normal (La Niña) events in the tropical eastern Pacific Ocean. At all months considered here (i.e. Nov-Mar), from 1-month to 6-months lead the forecast system demonstrates a strong ability to differentiate El Niño events from neutral and La Niña events. ROC values are relatively higher for the Dec-Jan period and lower for March. This skill pattern also resembles the typical ENSO cycle – develops in April- June reaches its maximum peak in December to January and dissipates around March. The similar pattern is evident in the analysis of forecast's resolution presented in fig. 4. Although spring predictability barrier is a known feature in ENSO prediction, our analysis does not include this period. The highest resolution scores are observed for November and December forecasts issued a month and two months prior to the event, respectively. For instance, let us consider the case of an extreme El Niño event occurring in December, say such event is predicted in October (2-month lead) we can be confident enough say that the event will occur based on the fact that forecast system is good at predicting the occurrence of such events with probabilities that are substantially different from climatological frequencies (see fig.4) and that has an ability to distinguish this event from all other possible events (see fig.3).

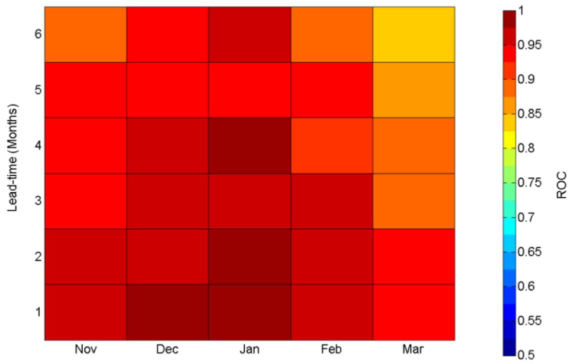

Figure 3: ROC scores for the probabilistic forecast of above normal SST events in the Niño3.4 domain. The scores are presented for November to March at lead-time 1- to 6-month.

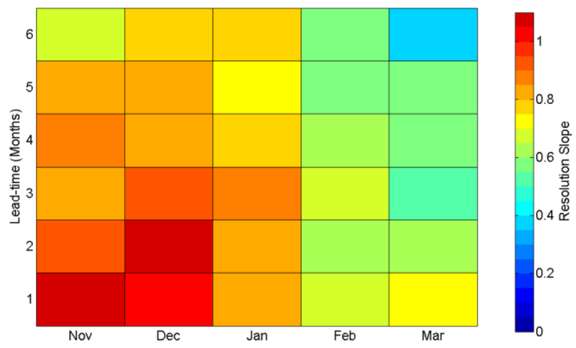

Figure 4: Resolution scores for forecast of above normal SST events in the Niño3.4 region for the target months – November to March for at lead- time 1- to 6-month.

Conclusion

The coupled model, initialized in July 2015, predicts very strong El Niño type SST anomalies for January

2016. This 2016 anomaly is similar to the 2^{nd} and 3^{rd} largest positive anomalies (El Niño events) of the 18-year verification period. In fact, the anomaly is likely to be larger than the 75^{th} percentile of the observed climatological record. Forecast verification shows that such strong El Niño events can be discriminated successfully from other (Neutral and La Niña) events and can be predicted reliably. We should expect southern Africa's coming summer season's rainfall and temperatures to be influenced by a strong El Niño event and that often means droughts and associated high temperatures over the subcontinent.

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