Predicting summer rainfall in coastal NE Australia for improved farming practices in sugar cane

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Abstract
Reliable summer rainfall forecasts in coastal northeast Australia can empower sugar cane growers to better manage their farm, including tailoring nitrogen applications for the coming climate, which will reduce damage to the Great Barrier Reef. We evaluated the ability of a seasonal climate forecasting model (ACCESS-S) to predict summer rainfall for the wet tropics region of northeastern Australia. We found that ACCESS-S was unable to capture the rainfall variability, primarily due to not being able to capture the extreme events.

Key Words
Rainfall variability, ACCESS-S climate model, austral summer rainfall

Introduction
Seasonal rainfall forecasts are of great significance for northeast Australia's sugar cane farmers. Knowledge of the upcoming weather can influence many decisions in sugarcane farming, including fertiliser applications (Everingham et al. 2002; Skocaj et al. 2013; Thorburn et al. 2011). Dissolved nitrogen discharged from cropped lands harms the Great Barrier Reef, and nitrogen fertiliser applications are an important cause of these discharges (Kroon et al. 2016). Thus skilful rainfall forecast methodologies are an important aid in decision-making around improving farm management to alleviate damage to the Great Barrier Reef.

For northeastern Australia, rainfall in the wet season (November to April) can vary year to year and the variability in wet season rainfall has clearly been linked to the El Niño Southern Oscillation (ENSO) phenomenon (Allan 1988). La Niña events are strongly associated with above average rainfall. Conversely, El Niño events are associated with below average rainfall, although the rainfall decrease from average during El Niño is less pronounced than the increase during La Niña events (Cai et al. 2010; King et al. 2013). Since the ENSO effect on summer rainfall is pronounced in northeast Australia, ENSO-based indices using Southern Oscillation Index and sea surface temperature have been used to make seasonal rainfall predictions, e.g. (Everingham et al. 2002).

With the emerging skill of seasonal climate models, it is timely to explore whether they can enhance the predictive skill of summer rainfall beyond the ENSO indices currently used. The Bureau of Meteorology (Bureau) uses a dynamical model called ACCESS-S to make seasonal rainfall predictions up to 6 months into the future. Since the ACCESS-S model is the backbone of Australian national weather and climate forecasting, it is worth exploring how skillful it is at predicting rainfall for this application. We do this by assessing the skill of ACCESS-S over the summer (December-January-February; DJF) focussing on the sugarcane growing regions of the wet tropics region of northeast Australia (NEA).

Data and Methods
Five BoM weather stations in the wet tropics region were selected for the study, namely Babinda, Gordonvale, Ingham, Innisfail, and Tully. Our analysis focused on the austral summer (December-January-February; DJF, where year of summer refers to year of December), which is the main rainfall season in the study region. The observed daily rainfall data was obtained from the SILO database (Jeffrey et al. 2001) for the period 1980-2017.

Rainfall data over these years at these five locations were also obtained from the BoM's Australian Community Climate Earth-System Simulator Seasonal (ACCESS-S) model hindcast (Hudson et al. 2017). The ACCESS-S forecasts were made up of 11 ensemble members, where each ensemble member had different initial conditions to generate a forecast, at a 5 km x 5 km resolution.

For each year, the data were averaged across the five stations to obtain a single time series that gave us the average condition of the region. Over 1990-2012, the average DJF rainfall across the five stations was 1288 mm and standard deviation was 607 mm.

To evaluate the prediction accuracy of ACCESS-S model, we compared DJF total rainfall from two forecast initialisation dates (1st of October and 1st of November) with observed DJF rainfall. The seasonal observed rainfall was grouped in terms of terciles where lower tercile indicated low rainfall, middle tercile indicated average rainfall and upper tercile indicated high rainfall. For each year we assessed when the ACCESS-S model forecast had two-terciles-out error where it predicted high rainfall but the observed rainfall was low, and vice versa. We termed this as an 'incorrect' forecast. We also assessed when the rainfall forecast by ACCESS-S was in adjacent tercile to the observed; for instance, when model predicted rainfall in the middle tercile but the observation was either in upper or lower tercile. We termed this a 'one-tercile-out' forecast.

As well as the categorical forecasts, we compared the frequency of daily rainfall forecast by the ACCSESS-S model with observations.

Results and Discussion

Understanding how well the ACCESS-S national climate model generates DJF rainfall forecasts can help us examine its limitations, and hence improve its prediction capability. Results show that the model forecasted rainfall in the middle tercile in 16 (14) of the 23 years for the 1st October (1st November) initialisations, (Fig. 1). However, the observed rainfall was in the middle tercile, by definition, in only 7 years. This suggests the model generally predicts middle tercile DJF rainfall when in ~70% of the years the observed rainfall was not in the middle tercile. Encouragingly, there were only two instances where ACCESS-S model forecasts were incorrect (i.e. two-terciles-out) for each initialisation (1993 & 2012 for 1st October and 1990 & 2011 for 1st November) as shown in Fig.1 and Table 1. However, there were several years when the observed rainfall was in either the high or low tercile while the model predicted rainfall in the middle tercile (i.e. 'one-tercile-out' error).

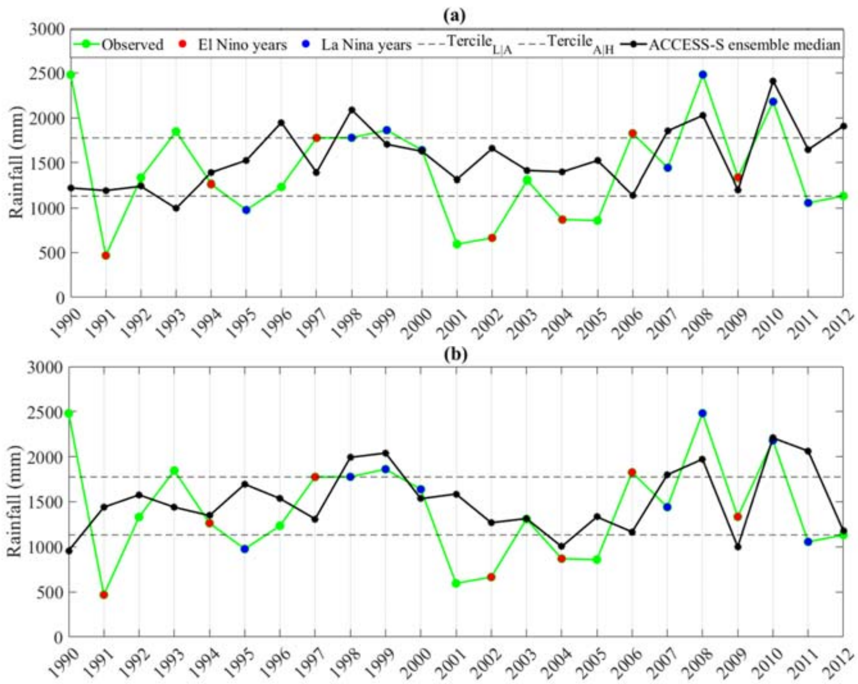

Figure 1: Comparison of DJF rainfall totals of observed against median of (a) 1st October and (b) 1st November initialisations of the ACCESS-S model. The grey dashed lines separate Low (L), Average (A) and High (H) rainfall terciles.

Table 1: Tercile of rainfall forecast on October 1st and November 1st initialisation compared to SILO.

Year	*Obs*	Oct Init.	Nov Init.	Year	*Obs*	Oct Init.	Nov. Init
1990	*High*	Avg.	Low	2001	*Low*	Avg.	Avg.
1991	*Low*	Avg.	Avg.	2002	*Low*	Avg.	Avg.
1992	*Avg.*	Avg.	Avg.	2003	*Avg.*	Avg.	Avg.
1993	*High*	Low	Avg.	2004	*Low*	Avg.	Low.
1994	*Avg.*	Avg.	Avg.	2005	*Low*	Avg.	Avg.
1995	*Low*	Avg.	Avg.	2006	*High*	Avg.	Avg.
1996	*Avg.*	High	Avg.	2007	*Avg.*	High	High
1997	*High*	Avg.	Avg.	2008	*High*	High	High
1998	*High*	High	High	2009	*Avg.*	Avg.	Low
1999	*High*	Avg.	High	2010	*High*	High	High
2000	*Avg.*	Avg.	Avg.	2011	*Low*	Avg.	High
				2012	*Low*	High	Avg.

The daily DJF distribution of rainfall is a further metric for model performance. It is expected that over a long hindcast, a model will accurately simulate the frequency distribution of daily rainfall. The model is predicting 2 – 4 mm daily rainfall more frequently (density between 0.10 – 0.11) compared to observed (density between 0.02 – 0.025) (Fig. 2). In other words, the predictions are dominantly <10 mm whereas the reality is generally >10 mm. In addition, the model never predicts daily rainfall of amounts > 15 mm hence missing the large rain events. This distribution towards drizzle is well known in climate modelling (Brown et al. 2018). It could be due models' inability to capture the features in large-scale climate drivers that tends to modulate the NEA rainfall.

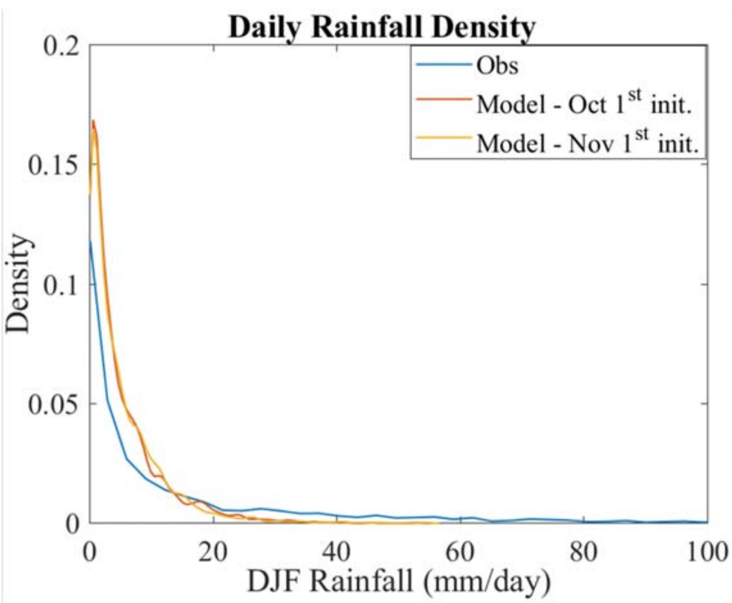

Figure 2: Density plot of daily observed and predicted DJF rainfall over 1990 - 2012.

Conclusion

This study shows that the ACCESS-S climate model cannot yet provide the level of skill for rainfall forecasts beyond what is currently obtained using SOI systems. Limitations include a predominance of predicting rainfall in the middle tercile. Part of this limitation occurs due to an under prediction of large rainfall events. From the findings in this study, it can be said that ACCESS-S is not a reliable model for predicting extreme rainfall for sugarcane farming region in NEA, especially with daily rainfall above 15 mm and DJF total in the lower or upper tercile. The future work will assess why the model is unable to capture the variability in summer rainfall and develop alternative approach consisting climate modes that tends to modulate the rainfall in the study region.

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