Harnessing dynamical seasonal climate forecasts for agricultural applications in Australia

Andrew Schepen[1], Yvette Everingham[2], Andries Potgieter[3], QJ Wang[4], Jason Brider[3], Graeme Hammer[3] and David Robertson[5]

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GCMs are increasingly providing skilful and reliable seasonal climate forecasts. In Australia, however, agro-climate decision support tools rarely make use of GCM forecasts. We are linking GCM forecasts and crop models through GCM forecast post-processing, unlocking the potential for GCM forecasts to become the primary driver of Agro-climate forecasting models in Australia.

Background

Seasonal climate forecasts are valued by farmers as an indicator of crop yield and to inform decisions around planting, fertilising and irrigating. In Australia, the Bureau of Meteorology makes seasonal forecasts using a dynamical climate model (GCM). However, quantitative agro-climate forecasts in Australia still frequently rely on SOI-phase forecasts, which have been found to be outperformed by GCM forecasts (Rodriguez et al. 2018).

We have been working on systematically linking seasonal GCM forecasts and crop models to produce reliable outlooks for industry.

Application 1: Sugar yield forecasts

- ECMWF Sys4 forecasts of rainfall, temperature and surface solar radiation are downscaled to a local weather station (Figure 1)
- Meteorological forecasts are augmented up to 12 months ahead by generating climatology-like sequences beyond the GCM run
- The meteorological forecast ensemble is used to drive an APSIM sugarcane model (Figure 2)
- We find that GCM-driven yield forecasts are skilful compared to climatology forecasts (Figure 3) and are reliable in ensemble spread (Figure 4)

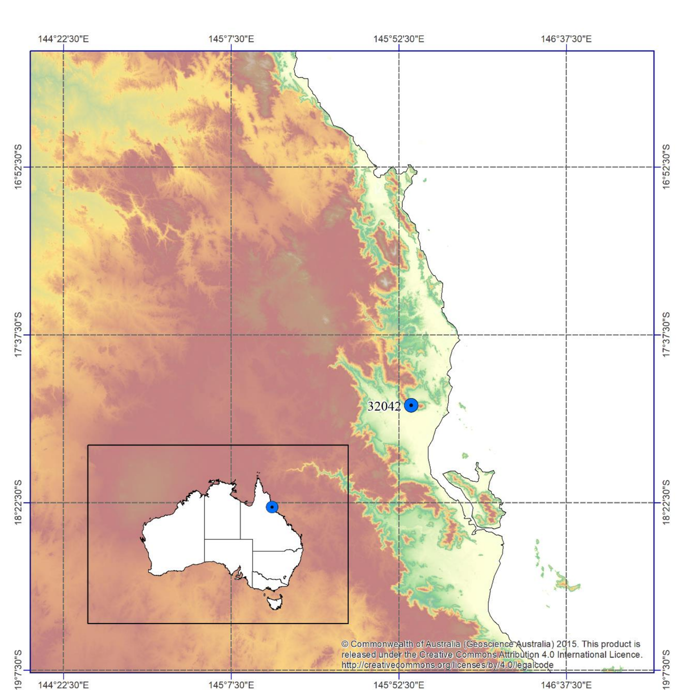

Figure 1: Location of the Tully Mill weather station in northeast Australia and position within an ECMWF Sys4 grid cell. The station resides in one of Australia's wettest regions, dominated by summer rainfall.

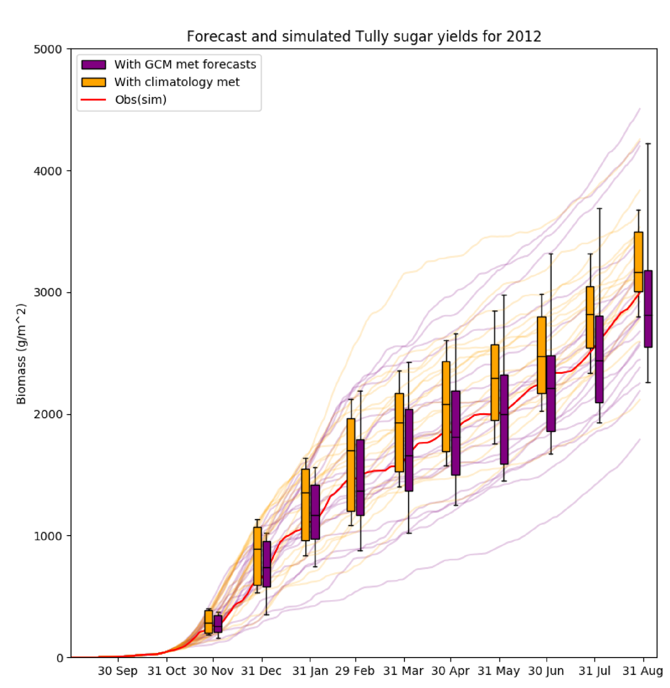

Figure 2: Long-range ensemble forecasts of yield for the 2012 sugar harvest, initialised on 1 Nov 2011. 20 randomly selected ensemble members are plotted. Boxplots show the IQR and [0.1-0.9] quantile range.

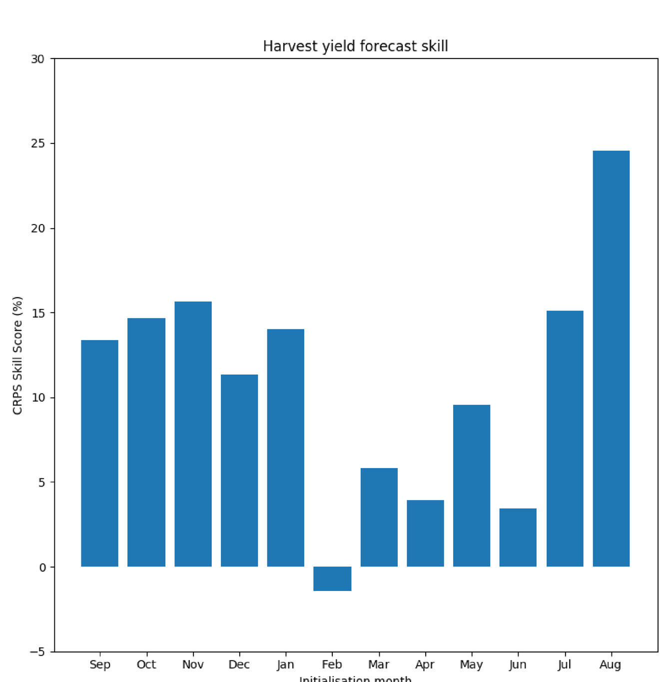

Figure 3: CRPS skill scores for the GCM-based harvest yield forecasts. A higher score indicates lower error. The skill scores are evaluated using leave-one-year-out cross-validation for 1981-2016.

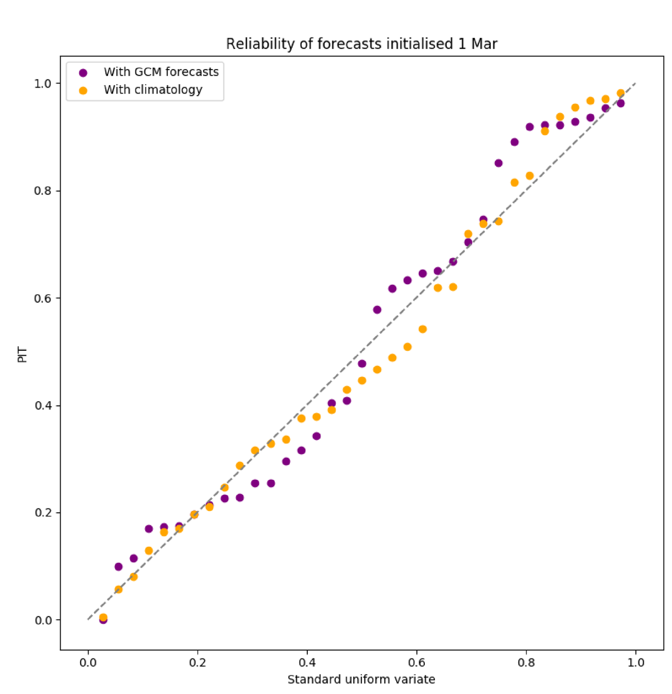

Figure 4: Reliability diagram for harvest yield forecasts initialised on 1 Mar. Points aligning with the 1:1 line indicate a reliable forecasting system.

Application 2: Regional wheat yield outlooks

- Sys4 forecasts are downscaled to 32 regional weather stations (Figure 5)
- Pan evaporation is predicted using GCM outputs in the downscaling process
- GCM, SOI-phase and climatological meteorological ensembles are used to drive the Oz-Wheat stress index model (Figures 6 and 7).

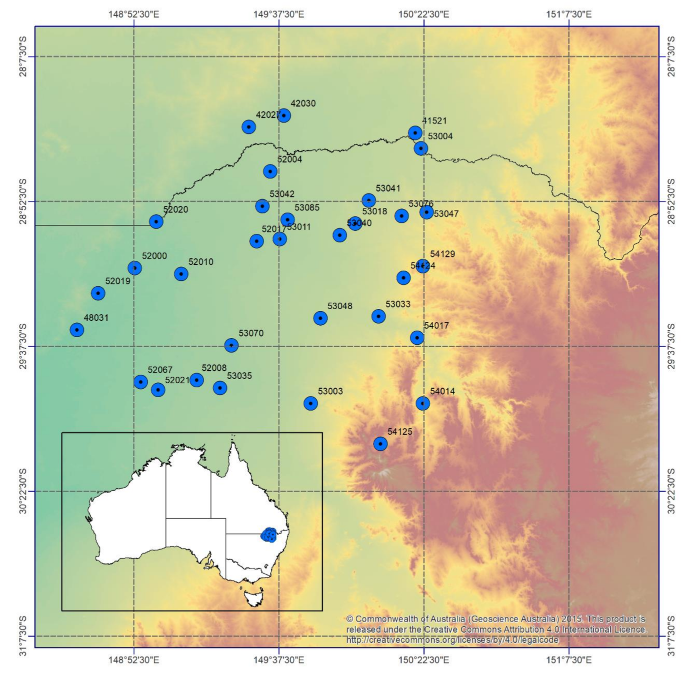

Figure 5: The location of the 32 weather stations contributing to the Moree wheat yield outlook

- GCM-driven wheat outlooks for Moree are reliable and show greater skill than SOI-phase-driven forecasts, albeit SOI-phase-driven forecasts are sharper

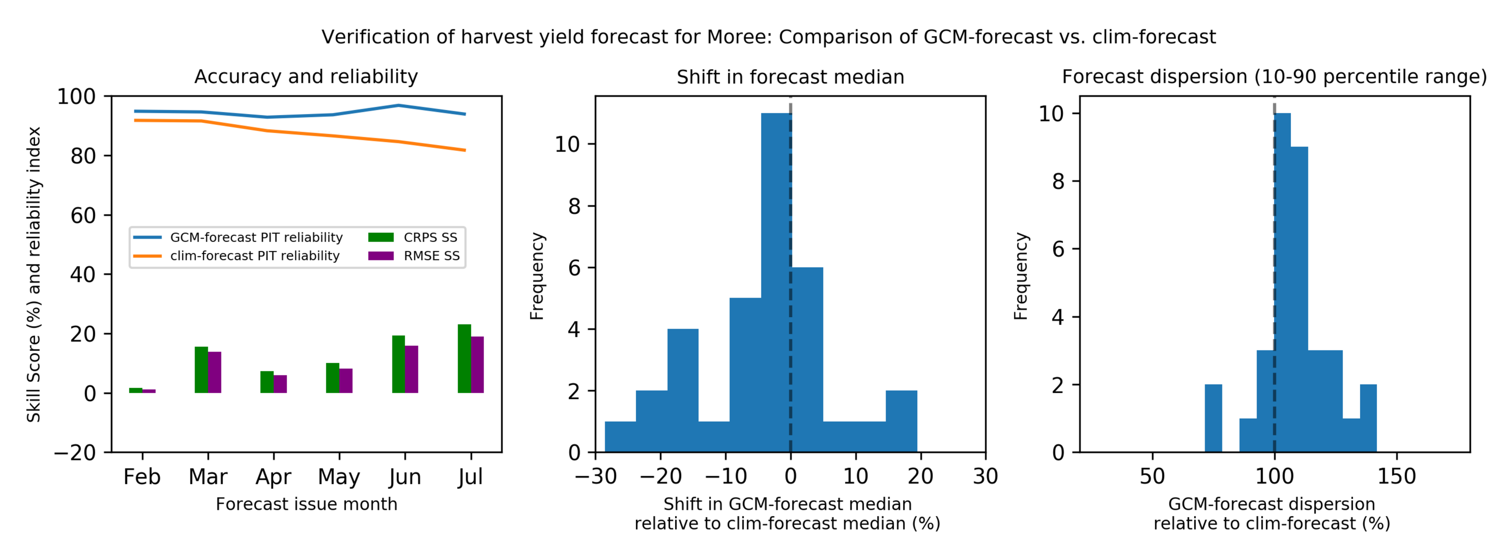

Figure 6: Verification metrics for the performance of GCM-driven wheat outlooks relative to climatology-driven wheat outlooks.

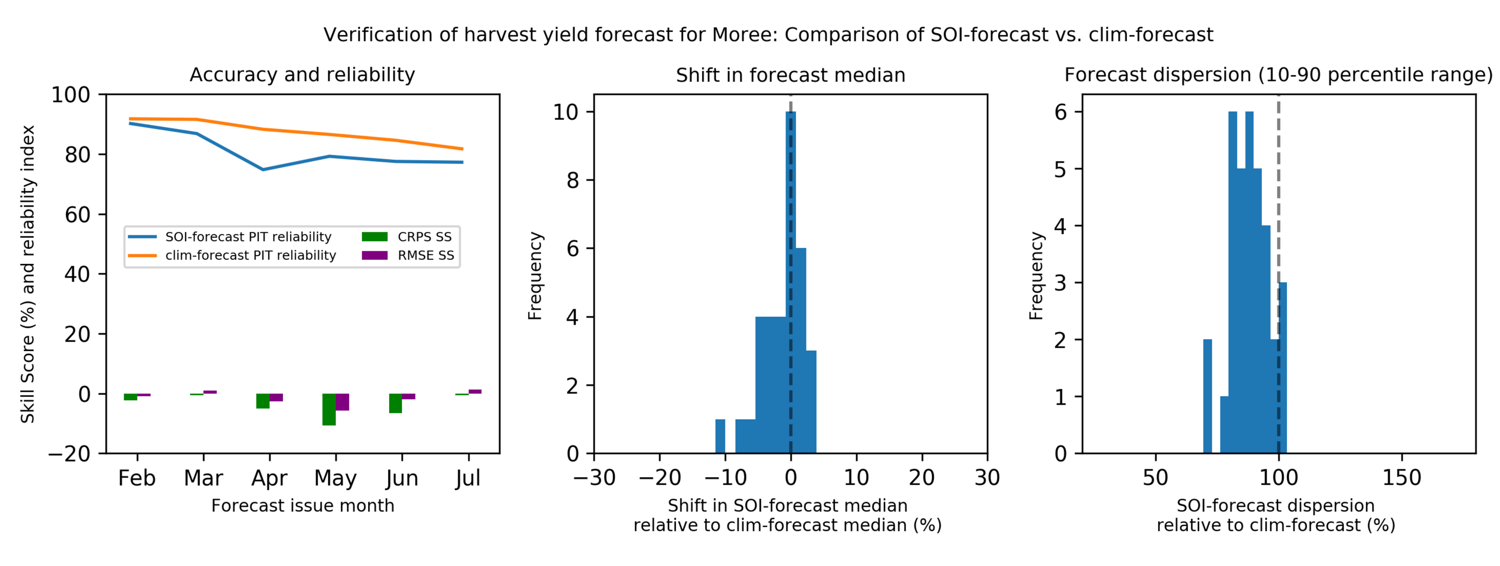

Figure 7: Verification metrics for the performance of SOI-Phase-driven wheat outlooks relative to climatology-driven wheat outlooks.

Conclusions and future research

- Post-processed GCM forecasts can be paired with different types of crop models to deliver skilful and reliable agricultural forecasts on seasonal time scales
- GCM-based forecasts are a viable alternative to purely statistical climate forecasts for crop modelling in Australia
- Further research is needed to further test the methods and to understand the value of uncertain forecasts for farmers

FOR FURTHER INFORMATION
Andrew Schepen
e Andrew.schepen@csiro.au
w www.csiro.au

REFERENCES
Rodriguez, D., P. de Voil, D. Hudson, J. N. Brown, P. Hayman, H. Marrou, and H. Meinke. "Predicting optimum crop designs using crop models and seasonal climate forecasts." *Scientific reports* 8, no. 1 (2018): 2231.

AFFILIATIONS
1 CSIRO Land and Water, Queensland, Australia
2 James Cook University College of Science and Engineering, Queensland, Australia
3 Queensland Alliance for Agriculture and Food Innovation, Queensland, Australia
4 University of Melbourne Department of Infrastructure Engineering, Victoria, Australia
5 CSIRO Land and Water, Victoria, Australia