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Exploring the impacts of land surface characteristics and water availability on regional weather and climate extremes

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1 Introduction

Bureau is now developing the JULES to better represent Australia's hydrological and plant-physiological conditions for the next generation of operational water information services. This involves developing regional high-resolution ancillaries specific to Australian land surface and transient characteristics and enhancing model physics for soil hydrology, river routing, and vegetation phenology. The development of an Australian regional coupled system that allows us to assess how changes in land surface impact on atmospheric modelling over weeks to months is incredibly valuable. Here we showcase the recent development of a new land-atmosphere "coupled" suite capable of testing the impacts of land parameter changes in regional simulations at various resolutions.

2 Suite design & Capability

The HM suite is an extension to the well-established Regional Nesting Suite (RNS) and allows long-period simulations (i.e. months or years long) in "free-running" mode. The HM suite does not have data assimilation (DA) but is constrained at boundaries by reanalysis; BARRA-R2 for atmosphere and ERA5 sea surface temperature (SST) (Figure 1).

The benefit of this new suite is that we can now test land configuration changes over long periods, constrained by reanalysis, and without soil and atmosphere states being reinitialized at each new "cycle". This is useful as land states have much longer timescales for change than the atmosphere, so the impact of changes to land configurations can be more easily assessed.

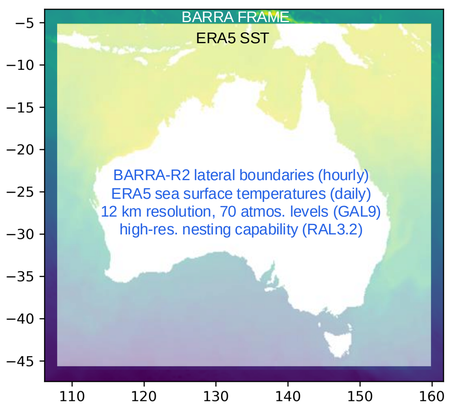


Fig. 1: Regional configuration

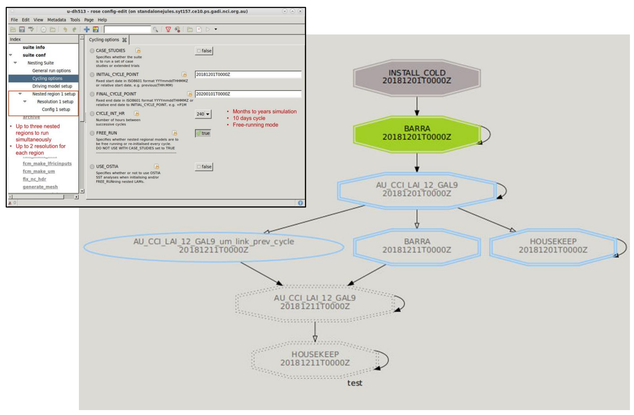
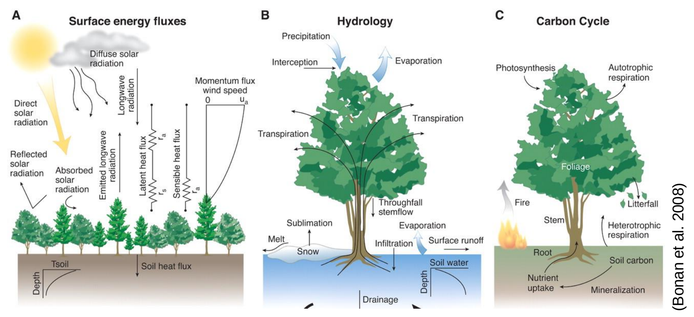


Fig. 2: HM suite GUI and graph

The suite maintains the GUI and backwards compatibility with the RNS. It also incorporates functionality developed for long-running BARRA and BARPA suites, e.g. "shortstep" fallback if a forecasting cycle fails, and SU logging. The suite has successfully been run for 13 months.

3 Experiments



(Bonan et al. 2008)

The area of leaves in the plant canopy, measured as leaf area index (LAI), modulates key land-atmosphere interactions, including the exchange of energy, moisture, carbon dioxide (CO2), and other trace gases and aerosols, and is therefore an essential variable in predicting terrestrial carbon, water, and energy fluxes.

Fig. 3: biogeophysical regulation of climate by vegetation through albedo, roughness, energy and water fluxes

The LAI climatology currently used in the global and coupled models were derived from 5 years MODSI product over the period of 2005 – 2009. This period was during the millennium drought over Australia. Here we calculated the climatology of LAI over a 20 years period from 2000 – 2020 to evaluate the impact on regional weather simulation using our HM suite.

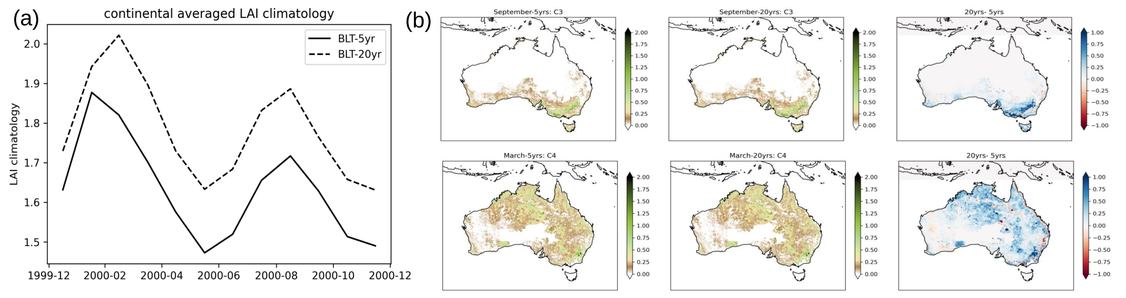
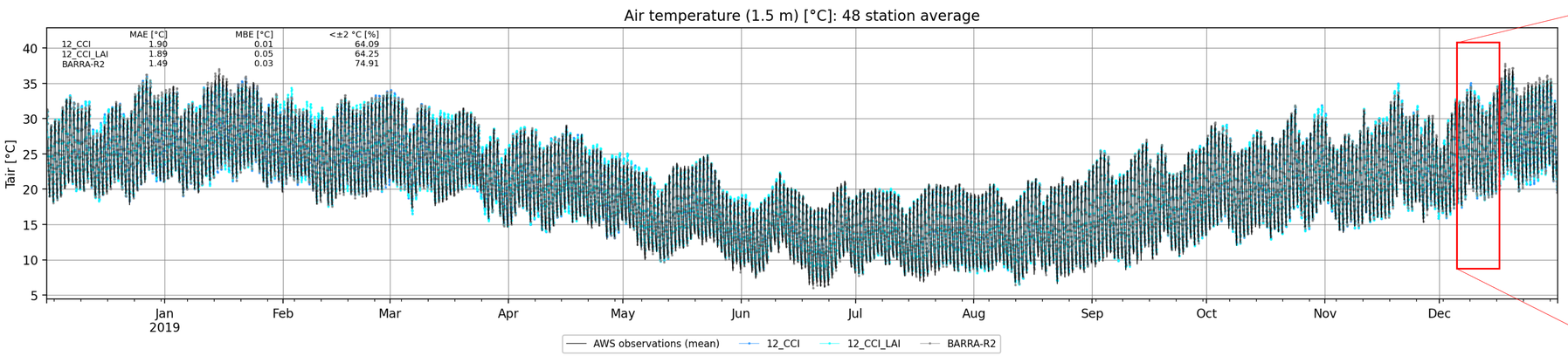


Fig. 4: (a) continental averaged LAI for broadleaf tree from 20 and 5-year climatology; (b) difference in LAI climatology for C3 and C4 over March and September in each climatology

4 Results



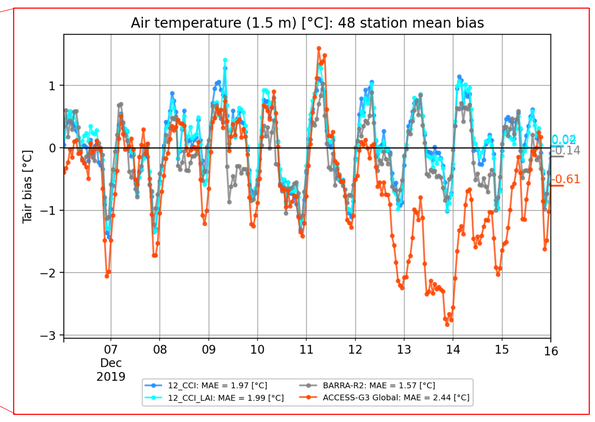


Fig. 5: Site-averaged 2 m air temperature compared with BARRA-R2 at 48 AWS sites (see Fig. 7 for site locations). Air temperature throughout the 13-month free-running simulation remains close to BARRA-R2 and AWS observations indicating the suite has suitable boundary forcing and that observed weather patterns are broadly captured.

Fig. 6: After 13 months HM simulations (blues) compare reasonably with BARRA-R2 (grey: reanalysis) and ACCESS-G3 (red: operational NWP), which does not have the benefit of hourly DA and starts to diverge.

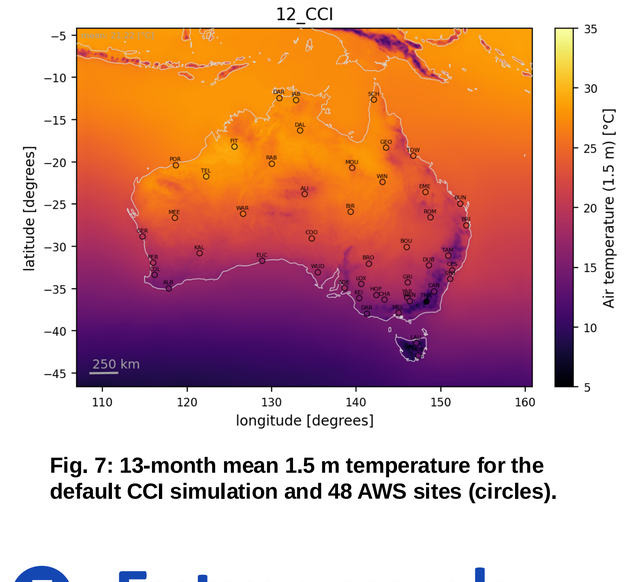


Fig. 7: 13-month mean 1.5 m temperature for the default CCI simulation and 48 AWS sites (circles).

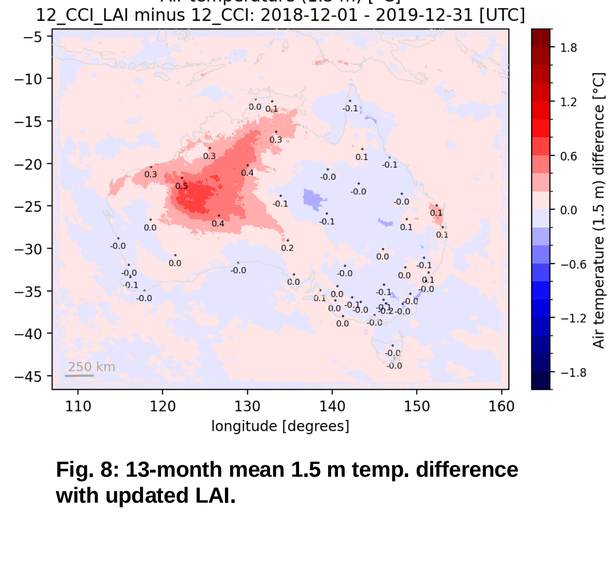


Fig. 8: 13-month mean 1.5 m temp. difference with updated LAI.

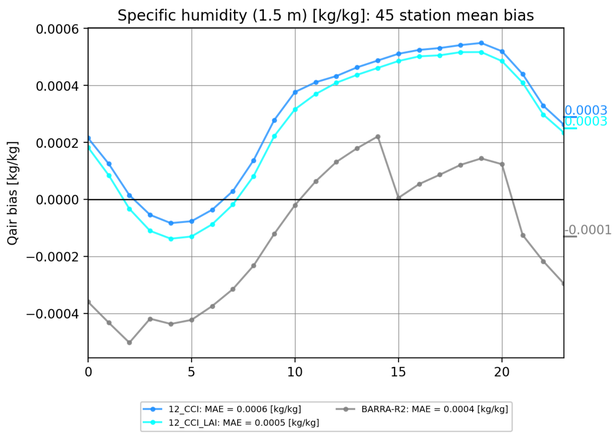


Fig. 9: 13-month hourly mean 1.5 m specific humidity

Conclusions

BARRA-R2 2 m air temperature and humidity errors are lower than the HM suite in this 13-month period. However, the data assimilation processes that keep reanalysis products (e.g. BARRA or ERA5) closer to observed quantities result in discontinuities between reanalysis simulation cycles (Fig. 9). Evaluation directly within an NWP system (Fig. 6) leads to divergence from observed states after several days, and/or discontinuities between concatenated cycles.

On the other hand, the HM suite is allowed to evolve freely while being driven towards observed states by the reanalysis at boundaries, making the impact of configuration changes physically consistent and simpler to analyse with direct observations.

Overall, the impact of the updated LAI climatology at national scales are small in these initial experiments. Additional testing will be undertaken (see future work).

5 Future work

These 13-month LAI runs are initial tests of the newly developed HM suite. Longer simulations (up to 5 years) will be undertaken at 12 km resolution, as will higher resolution (1.5 km) nested simulations over shorter periods. Other changes to land configuration (land cover, soil physics, climatology vs time-series ancillaries) will also be tested. Additional evaluation (e.g. with RES: the regional evaluation suite) will be undertaken. The Bureau will collaborate with 21st Century Weather to undertake and analyse future work.

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