Observational and modelling analysis of land-surface processes on influencing Australian climate variations

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Introduction

Along with the studies of tropical and global SSTs on influencing the Australian climate variability and predictability, investigating the potential impacts of continental land-surface processes on the Australian climate variations has become one of the research foci in recent years. This study summarise results from some recent observational and modelling analyses. They have been designed to explore whether soil storage of precipitation water (and other meteorological forcing) can lead to some slow-varying land-surface processes that could in turn affect the mean state and the variability of the atmosphere at monthly or even longer scales and modulate the atmospheric responses to SST forcing. It comprises of three components. At first, it assesses if there are observational signals suggesting land-surface conditions affecting climate variability in the Australian region. Then, by comparing a suite of AMIP2 model simulations, it analyses whether land-surface modelling affects the model simulated climate variability and predictability over this region. Finally, some BMRC atmospheric model (BAM) experiments are conducted to explore the relevant role of SST forcing and land-surface processes in determining the model climate variability in the region and the potential impacts of different coupling approaches land-surface scheme in the model on its behaviour.

Observational analysis

In this section, the Bureau of Meteorology observed monthly mean rainfall, monthly mean daily maximum (Tmax) and minimum (Tmin) surface air temperatures over the fifty-year period of 1950-1999 are used in the observational analysis (Zhang 2004). A simple linear regression method is used to largely remove the ENSO influence from 50-year observational surface temperature and precipitation datasets. Then, lag and partial correlations of the residuals are analysed. The impacts of precipitation on the forthcoming surface temperature variations are largely attributed to the soil storage of precipitation water and the slow-varying soil moisture process. Figure 1 shows the partial lag correlations of monthly averaged daily Tmax and precipitation after removing the SOI component in the observed time series using linear regression. For instance, results in July are the correlations between Tmax anomaly residual in July with observed precipitation anomaly residual in June. Numbers in the title of each diagram are the total number of grid points passing the local significant test at 95% confidence level. The correlation field is statistically significant above 95% confidence level if there are more than 28 points passing the local significant test. Such results, by and large, show the persistence of Tmax anomalies due to soil moisture responses to anomalous precipitation forcing.

AMIP2 model analysis

After the analysis of observational results, sixteen AMIP2 AGCM simulations over the Australian region have been analysed to assess if different land-surface schemes used in these models can affect the model simulated climate variability over the region. Figure 2 (a) shows the relationship between areally averaged instantaneous correlations of surface evaporation and soil moisture from sixteen AMIP2 models (presented by A to P) and the soil moisture autocorrelation one-month decay rate. Fig 2b shows areally-averaged soil moisture two-month auto correlation decay rate and that of surface evaporation. Furthermore, Fig2c displays relationship between soil moisture and surface temperature autocorrelation decay rates. Lag-correlation analysis reveals that "climatic memory" of soil moisture has different features in the sixteen models. Models with simple bucket-type schemes (O and P) tend to have a rapid decay rate in the retention of soil moisture anomalies and show rapid feedback between land-surface and the overlying atmosphere, with a much weaker influence of soil moisture conditions on surface climate variations. Models with higher correlations of surface evaporation and soil moisture tend to have weaker soil moisture memory because soil moisture can be rapidly evaporated in those models and leading to a low soil moisture retention. Furthermore, weaker soil moisture memory leads to weaker surface temperature persistence and therefore low predictability of surface temperature in those AMIP2 models.

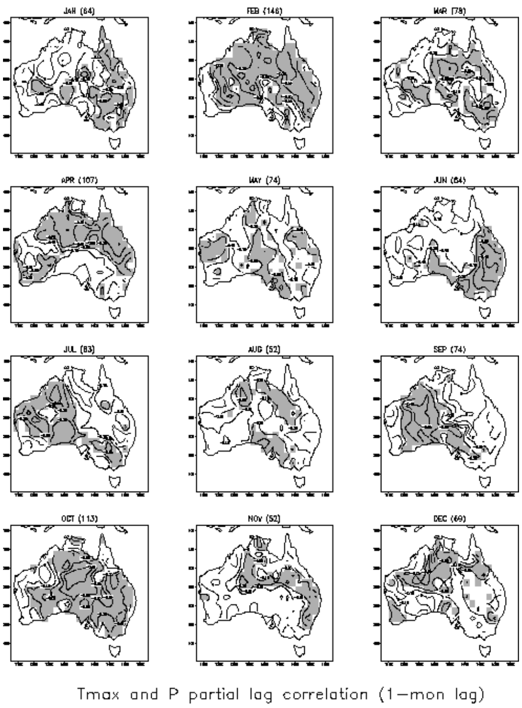

Fig 1. One-month partial lag correlations between observed Tmax and Pr.

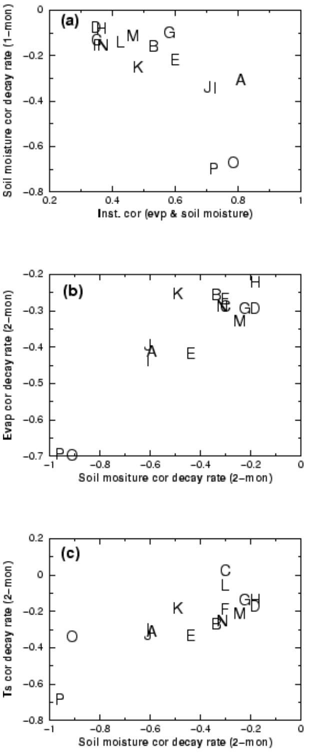

Fig 2. Lag correlation of 16 AMIP2 models

BMRC model experiments

Impacts of soil moisture initialisation

Using a version of the BMRC AGCM, Zhang and Frederiksen (2003) investigated the model's sensitivity to different soil moisture initial conditions in its experimental dynamically extended seasonal forecasts fro the season of JJA1998, with focus on the south and northeast China regions where severe floods occurred. By imposing soil moisture percentile anomalies derived from a reanalysis data into the BMRC model initial condition, the regional features of the seasonal precipitation and temperature anomalies were modulated. The impacts on the model's surface temperature forecasts were attributed to localised interactions between land-surface and the overlying atmosphere. Nevertheless, the model's sensitivity in its forecasts of rainfall anomalies was primarily caused by non-local impacts of the soil moisture conditions.

Role of SST forcing and land-surface process

As part of the BMRC climate variability study, as well as BMRC model experiments used for an Australia-China bilateral project on climate change study (Zhang et al., 2005), numerical experiments have been conducted by forcing a version of BMRC atmospheric model (BAM) with observed SSTs for the period of 1949-2002 and contrasting the model results with another set of the model experiment using monthly SST climatology. Such experiments allow us to assess the relative impacts of SST forcing and land-surface processes in the model simulated climate variability in the region. Figure 3 shows the ratio of temperature and precipitation standard deviations between the one using observed SST forcing and that with prescribed SST monthly climatology. Significant climate variations still remain when forcing the model with SST climatology. Part of the variations is caused by the inherent atmospheric variation, while further analysis suggests part of the variations reflects the contribution from land-surface processes.

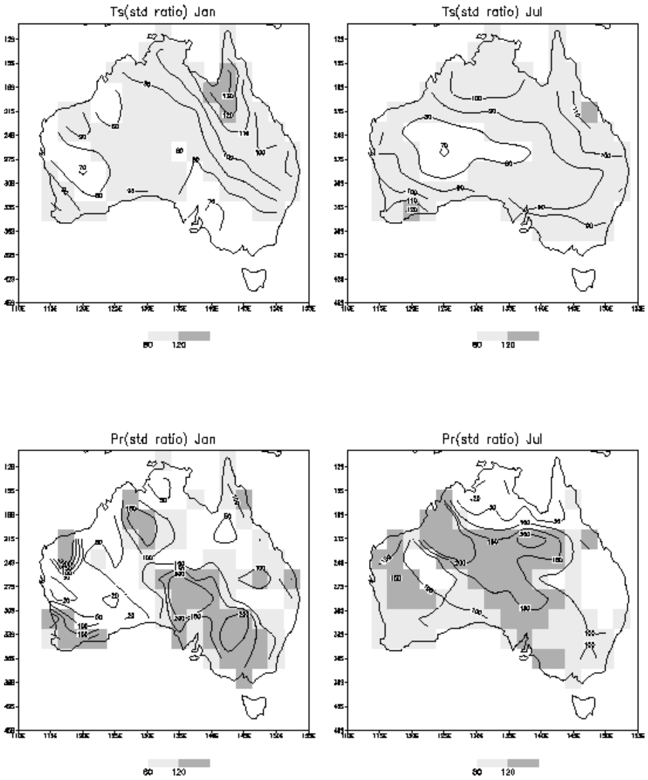

Fig 3. Ratio of standard deviations of surface temperature (Ts) and precipitation (Pr) from 54-yr model integrations using prescribed climatological SST and observed SST forcing.

Impacts of land-surface-atmosphere coupling

There are increasing number of studies investigating the impacts of different numerical approaches used in coupling land-surface scheme within a climate model. Similar studies have also been conducted using BMRC model. Preliminary results clearly demonstrate the significant impacts of land-surface coupling algorithm used in the model. Impacts of such coupling on the model-simulated climate variability are also analysed.

Conclusions

The presentation has summarised some recent studies on the potential impacts of land-surface processes on the climate variability in the Australia region. Both observational and modelling evidences have illustrated the importance of maintaining the ongoing efforts in improving the parameterisation of continental land-surface and hydrological processes in weather and climate modelling and studying the role of land-surface and hydrological processes in understanding the climate variability and predictability in the region. This can also eventually benefit the potential applications of weather and climate model forecasts for hydrometeorological applications.

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