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IMPACTS OF LAND-USE IN CHINA ON REGIONAL CLIMATE: AN AUSTRALIA-CHINA BILATERAL PROJECT ON CLIMATE CHANGE

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1. INTRODUCTION

It has been widely recognized that land-surface processes and land-use form an essential component of the study of the Australia-Asian monsoon system and its potential changes in future climate (Fu et al., 2002). China, as the most populated country in the world, is currently experiencing rapid economic development and modernization. In recent years, more and more research has been devoted to studying the impacts of human activities in China and East Asia on local and regional climate. Almost all the published results point to the conclusion that land-use vegetation change can affect local and regional climate. On the other hand, it is also widely acknowledged that large uncertainties exist in model-simulated climatic impacts of land-use. There are, as yet, very few published studies exploring uncertainty in climate model simulations of land-use impacts and identifying potential causes of such uncertainties. The lack of such studies is of particular concern in the Australian-Asian monsoon region due to the complexity of its weather and climate processes.

Prompted by these considerations, An Australia-China climate change bilateral project between the China Meteorological Administration (CMA/China) and Bureau of Meteorology Research Centre (BMRC/Australia) has been established to address the following scientific issues: simulating local and regional climate impacts of land-use in China and assessing the extent of uncertainty in model-simulated impacts due to land-surface parameterization; exploring the impacts of land-surface processes in the Eurasian and Australian continents on climate variability in the Australian-Asian region; exploring the relative role of land-use to other anthropogenic forcing in affecting climate variability and climate change in the region; and diagnosing potential climate change in the Australian-Asian region simulated by current state-of-art climate models.

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2. MODEL EXPERIMENTS

This study presents results from a series of Australian Bureau of Meteorology Research Centre (BMRC) climate model simulations of land-use in China on regional climate and Australia-Asian monsoon system. The climate impacts of land-use are assessed by applying two sets of surface vegetation datasets in the model: one represents current vegetation coverage in China and the other approximates its potential vegetation coverage without human intervention. The imposed surface parameter changes include changes in surface albedo, surface roughness, vegetation fraction and leaf-area-index (LAI). Experiments conducted in this research are centralised by a pair of the model integrations using the most complex mode in its multi-mode land-surface scheme and forced with observed SSTs for the period of 1948-2002. Following that, four extra pairs of experiments are conducted using another four different complexity modes in the model land-surface scheme to explore model uncertainties caused by land-surface modelling. In addition, a pair of the model integrations using climatological SSTs is conducted to isolate climate change signal due to land-use vegetation change from the model variations due to varying SST forcing.

3. IMPACTS ON REGIONAL CLIMATE

This study shows moderate but statistically significant regional impacts caused by land-use vegetation change. In the northern winter season (DJF), there are consistent patterns of changes in surface climate between the five pairs of 55-yr integrations, including a reduction of precipitation in the south/southeast region and a cooling in large parts of the country. The cooling effect is primarily due to the increase in surface albedo while the reduction in precipitation is associated with an enhanced southward penetration of dry and cold air due to reduced surface roughness. The model experiments

also reveal moderate impacts of land-use change on summer (JJA) monsoon rainfall and temperature, with a 10-20% reduction in summer rainfall and above 0.5°C warming in the south/southeast region. The warming in the summer season is largely the result of a reduction in surface evaporation and the rainfall decrease is consistent with changes in the model atmospheric dynamics and physics responding to vegetation change. The fundamental processes contributing to such impacts are the changes in surface albedo (Figure 1) and surface roughness.

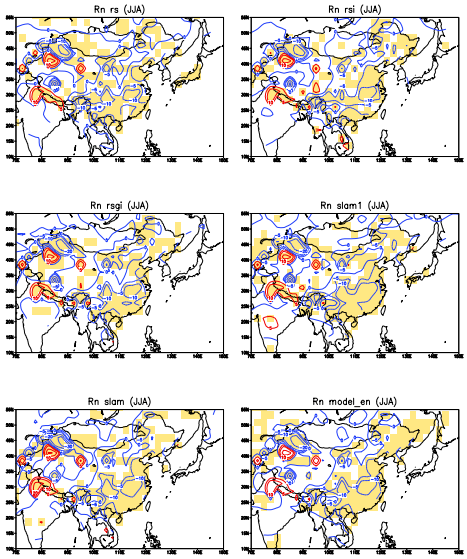

Figure 1: Changes of surface net radiation (Wm^{-2}) in JJA from five pairs of BMRC model results using five different modes in its land-surface scheme. Statistically significant changes are shaded by orange colour. The sixth panel shows model ensemble averages.

4. UNCERTAINTY ASSESSMENT

Spatially averaged results over an area of south China are analysed to quantify uncertainty in the model experiments. By comparing the model results using different complexity modes in its land-surface scheme, one cannot see any coherent features to suggest that different complexity in land-surface modelling modes significantly affect the model-simulated climate change. To further test this conclusion, we have compared the spread from the five pairs of model experiments using different surface modes with the spread simulated from another five pairs of model experiments using the same land-surface mode but with different atmospheric initial conditions. The spread in the model-simulated climate changes among the experiments using different atmospheric initial conditions is comparable with the spread of the changes simulated by using different land-surface modelling complexity modes (Figure 2). Since the key physical processes such as the impacts of changes in surface albedo and surface roughness are presented similarly in the five surface modes in the model, this suggests that extra complexity in solving surface energy balance in the land-surface parameterisation does not make a significant difference to the model-simulated climate change due to land-use vegetation change.

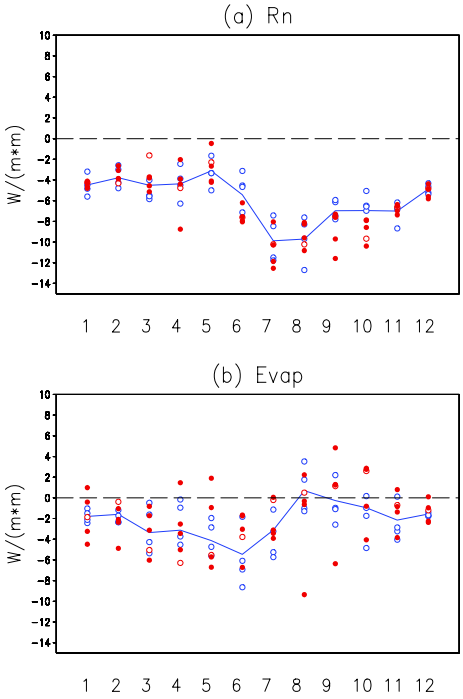

Figure 2: Areally averaged monthly changes of (a) surface net radiation (Wm^{-2}) and (b) surface evaporation (Wm^{-2}) over the area of 20 to 32.5°N and 105 to 120°E (25 model grid points) from the five pairs of experiment using different surface modes. Blue circles represent the spread of the model-simulated changes derived from five pairs of the runs using different land-surface modes. Red circles represent the spread of the model-simulated changes derived from five extra pairs of the runs using one of the surface modes but with different initial conditions. The spread caused by the model land-surface modelling complexity is insignificant compared to the model inherent variability.

Furthermore, we have analysed results from two sets of five-member ensemble results (one for current vegetation and the other for potential vegetation conditions) using one of the model surface modes (Figure 3). Results further demonstrate that the land-use impacts simulated by the model are significantly larger than inherent climate variability.

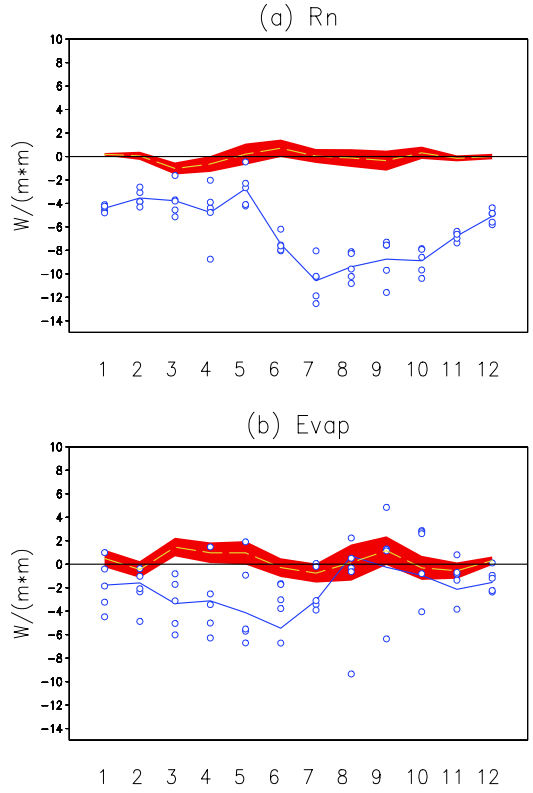

Figure 3: Areally averaged monthly changes of (a) surface net radiation (Wm^{-2}) and (b) surface evaporation (Wm^{-2}) over the area of 20 to 32.5°N and 105 to 120°E (25 model grid points) from five pairs of experiment using the same surface mode but with different initial conditions (blue circles). The changes are compared with the spread (4xSTD) *within* the model five land-use and five potential vegetation ensemble runs (red shaded area) which represents the model intrinsic noise.

5. CONCLUSIONS

A series of BMRC climate model simulations have been conducted to assess the impacts of land-use vegetation changes in China on regional climate. The model shows moderate impacts which can be explained by changes in the model physical and dynamical processes responding to the increase in surface albedo and reduction of surface roughness. Detailed analyses of uncertainties in the model simulations suggest that extra complexity in the model land-surface representations does not significantly affect the model results. Nevertheless, results from the current study are limited by a number of factors. High resolution and a fully-coupled climate system modelling approach is needed to the monsoon system.

6. ACKNOWLEDEMENT

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7. REFERENCE

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