Climatic Impact of Vegetation Change in the Asian Tropical Region

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Abstract

Using a global climate model which includes a realistic land surface model, several numerical simulations were performed to investigate the impact of Asian tropical vegetation changes on the climate. The morphological, physiological, and physical changes of the land surface vegetation in the Asian tropical region certainly induce statistically significant climate changes in these and the surrounding areas. That is, from the results of the bare soil and C_4 grass experiments, the decrease in the roughness length, and from the results of the green-less experiment, the decrease of the latent heat flux, exert strong influences on the horizontal and convective circulations of the atmosphere. Consequently, the distribution of precipitation will undergo change. Other energy and water balances at the land surface are also influenced by the vegetation changes, and the induced changes are generally statistically significant.

Keyword: Climate change, Land-atmosphere interaction, Vegetation change, Asian tropical region.

1. Introduction

Tropical vegetation controls the physical and biogeochemical interactions over climatically influential areas on the Earth, and plays important roles in the formation of the regional and global climates. Until recently, there have been numerous studies concerning the impact of vegetation change in the tropical region. There have been, however, few numerical impact studies that target the influence of vegetation change in the Asian tropical region. Using a global climate model which includes a realistic land surface model, several numerical simulations were performed to investigate the impact of Asian tropical vegetation changes on the climate. The control simulation, under conditions of the actual vegetation, and three vegetation change impact experiment simulations were performed, with the results of the impact experiments compared with those of the control. The horizontal resolution of the model used in these simulations was 1.875°, being finer than that of the models used in previous vegetation change impact studies. As a result, it was determined that the effects of vegetation changes in the Asian tropical region had spatially different features (Mabuchi et al. 2004a, Mabuchi et al. 2004b).

2. Experimental design

To investigate the impact of vegetation changes on climate in the Asian tropical region, three experimental areas were defined: the Indian subcontinent area (IND), the Indochina Peninsula area (ICP), and the maritime continent area (MTC). The IND, ICP, and MTC areas are mainly covered by the grassland, tropical seasonal forest, and tropical rain forest types of vegetation, respectively.

In the control integration, the actual global vegetation and climatic SST values were used. In order to estimate the initial values of soil water content, including the ice content in the soil and soil temperature, a 10-year spin-up calculation was carried out. Using the soil values obtained from the spin-up calculation, the control integration was continued for 20 years.

After the control integration, three vegetation change impact experiments were performed: the bare soil experiment (BS), the C_4 grass experiment (C4), and the green-less experiment (GR). In the BS experiment, it was assumed that the vegetation on the ground was almost removed. In the C4 experiment, while the morphological and physical parameters were set as C_3 grass type, the

physiological parameters associated with the photosynthesis processes for C_4 plants were used. In the GR experiment, the types of vegetation in the experimental areas were same as those in the control, but the greenness values of the vegetation in the areas were all set to zero. In the BS and C4 impact experiments, the actual vegetation types in the experimental areas (the IND, ICP, and MTC areas), were changed to a single vegetation type for each of the impact experiments. In each impact experiment, a 10-year spin-up integration was first performed, starting from the soil conditions at the end of the control run, and then the main experimental impact time integration was continued for 20 years under the changed vegetation conditions. The results of these three 20-year impact time integrations were compared with the results of the 20-year control integration.

3. Results

The morphological, physiological, and physical changes of the land surface vegetation in the Asian tropical region certainly induce statistically significant climate changes in these and the surrounding areas. That is, from the results of the bare soil and C_4 grass experiments, the decrease in the roughness length, and from the results of the green-less experiment, the decrease of the latent heat flux, exert strong influences on the horizontal and convective circulations of the atmosphere. Consequently, the distribution of precipitation will undergo change. Other energy and water balances at the land surface are also influenced by the vegetation changes, and the induced changes are generally statistically significant.

The vegetation changes were implemented only in the Asian tropical region. There were, however, possible influences of the vegetation change on the mid-latitude atmospheric circulation. It was considered that the vegetation changes from the forest type to grassland or bare soil induced modifications in the Hadley and Walker circulations. In particular, the divergence/convergence anomaly pattern that appeared at the upper atmospheric level in DJF in the C_4 grass experiment was very similar to that of an ENSO event. The height anomalies at the 500-hPa level were also similar to those found in an ENSO event. The possibility exists that the deforestation of the Asian tropical region could induce similar teleconnections as those associated with ENSO events.

The influences of vegetation changes in the Asian tropical region were more complicated than those in the Amazon. One reason for this was that the Asian tropical region is strongly influenced by the Asian monsoon circulation; another reason being that the land-sea distribution and the distribution of vegetation in the Asian tropical region are not as simple as a tropical rain forest like the Amazon.

References

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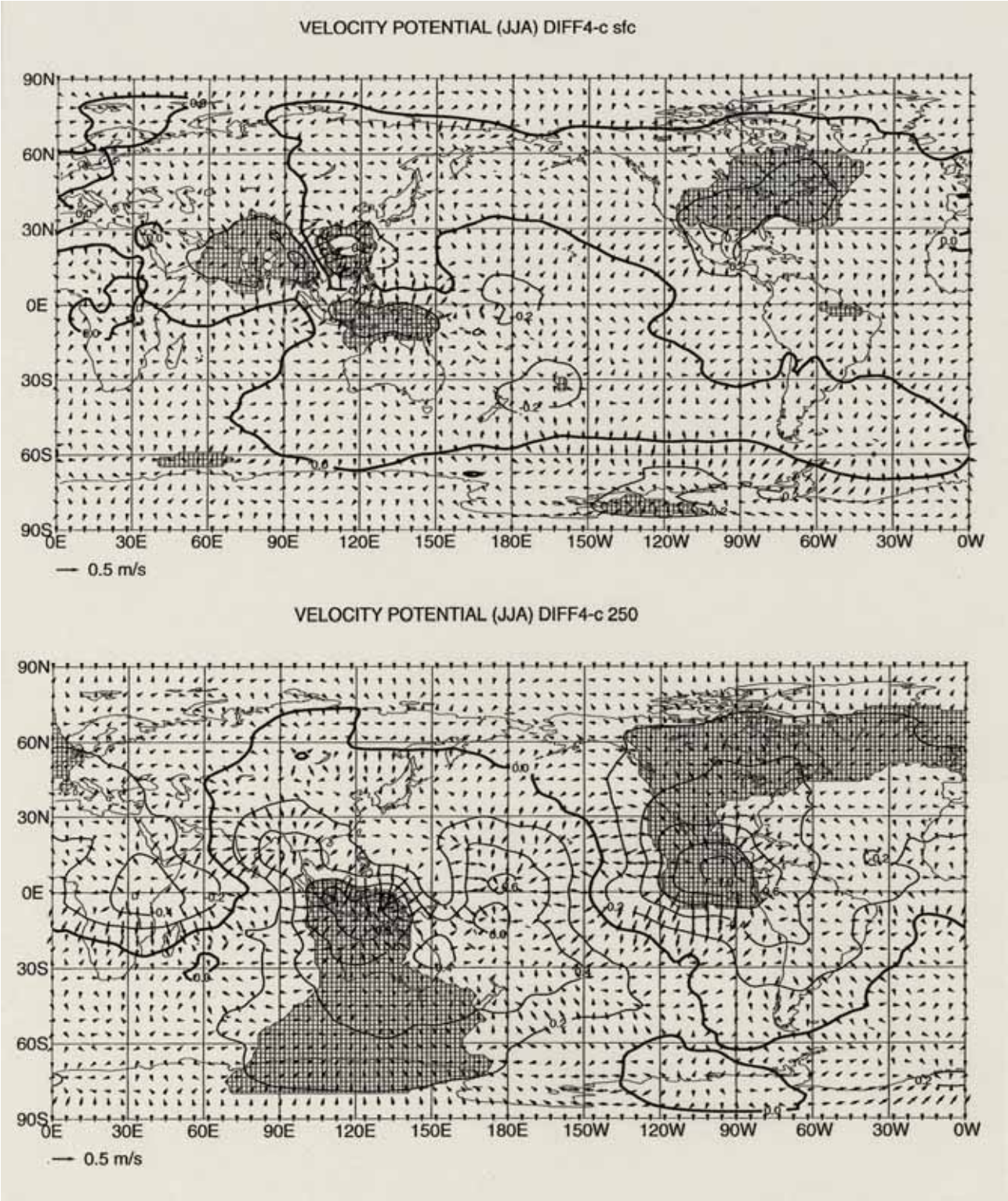

Fig. 1. Comparison of the JJA mean results of the impact experiments with those of the control integration (impact - control). The differences in the velocity potential (10^{6} m^{2} s^{-1}) and the divergence/convergence of wind vectors between C4 and CN are indicated. The upper panel indicates the results at the surface, and the lower panel those at the 250-hPa level. The areas where the Student's *t*-test values indicate statistically significant differences (at the 95 % level) are shaded.

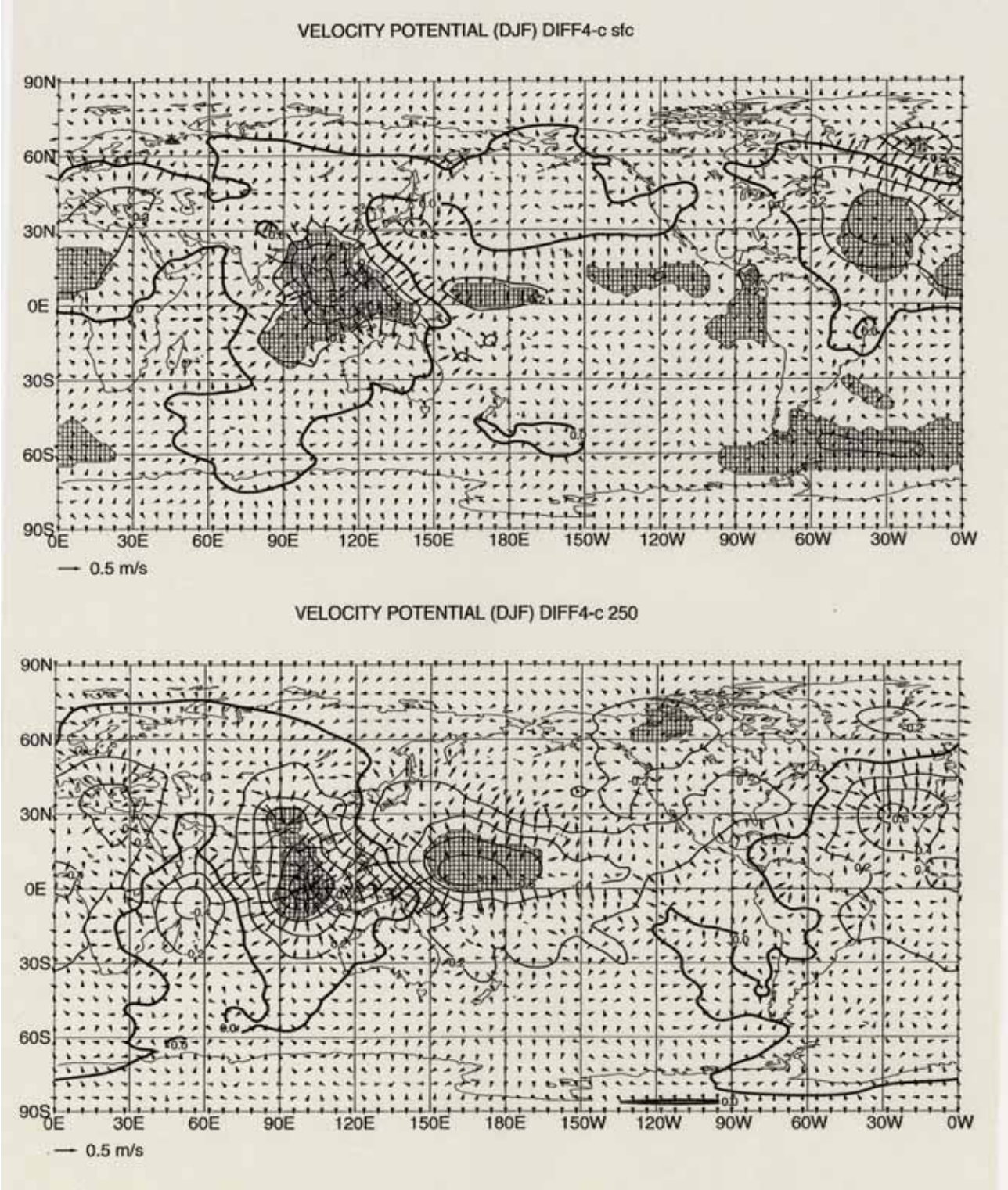

Fig. 2. Comparison of the DJF mean results of the impact experiments with those of the control integration (impact - control). The differences in the velocity potential (10^{6} m^{2} s^{-1}) and the divergence/convergence of wind vectors between C4 and CN are indicated. The upper panel indicates the results at the surface, and the lower panel those at the 250-hPa level. The areas where the Student's *t*-test values indicate statistically significant differences (at the 95 % level) are shaded.