Application and impacts of the GlobeLand30 land cover dataset on the Beijing Climate Center Climate Model

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Abstract. Land cover (LC) is a necessary and important input variable of the land surface and climate model, and has significant impacts on climate and climate changes. In this paper, the new higher-resolution global LC dataset, GlobeLand30, was employed in the Beijing Climate Center Climate System Model (BCC_CSM) to investigate LC impacts on the land surface and climate via simulation experiments. The strategy for connecting the new LC dataset and model was to merge the GlobeLand30 data with other satellite remote sensing datasets to enlarge the plant function types (PFT) fitted for the BCC_CSM. The area-weighted up-scaling approach was used to aggregate the 30m-resolution GlobeLand30 data onto the coarser model grids and derive PFT as well as percentage information.

The LC datasets of GlobeLand30 and the original BCC_CSM had generally consistent spatial features but with significant differences. Numerical simulations with these two LC datasets were conducted and compared to present the effects of the new GlobeLand30 data on the climate. Results show that with the new LC data products, several model biases between simulations and observations in the BCC climate model with original LC datasets were effectively reduced, including the positive bias of precipitation in the mid-high latitude of the northern hemisphere and the negative bias in the Amazon, as well as the negative bias of air temperature in part of the southern hemisphere. Therefore, the GlobeLand30 data are suitable for use in the BCC_CSM component models and can improve the performance of climate simulations.

1. Introduction

As one of the necessary and basic variables/elements of numerical models, Land Cover (LC) plays an important role in modulating complex biogeophysical and biogeochemical processes at the land surface and in land-atmosphere interactions through LC distribution and related parameters (such as canopy height, albedo, roughness).

There have been several global LC datasets produced and available for the models due to the development of satellite remote sensing techniques, such as the USGS/DISCover, LC data of the University of Maryland and Boston University, GLC2000/JRC of the EU, and GLOBCOVER/ESA. The 30m global land cover dataset, GlobeLand30, was produced by Chinese scientists and donated to the UN at the New York climate summit at September 2014. The GlobeLand30 is the first global 30-m resolution LC map with two time periods (year 2000 and 2010) using the same classification, w ith an overall classification accuracy higher than 80% (Chen et al., 2015).

In this paper, effects of the GlobeLand30 dataset on global climate simulations are tested with the Beijing Climate Center Climate System Model (BCC_CSM, Wu et al., 2014). The GlobeLand30 dataset was first transformed to the classification system and resolution of the BCC_CSM model to produce a new GlobeLand30-based applicable LC dataset. The new dataset was introduced in the model system via the land surface component model of BCC_CSM and affected the simulated climate through land-atmosphere coupling processes. The objectives of this study were to assess the effects of the LC data updates on the simulated global climate.

2. Model and LC dataset introduction

2.1 The BCC_CSM climate model

The climate model used here is the BCC_CSM developed at the Beijing Climate Center (BCC) of the China Meteorological Administration (CMA). The BCC_CSM is a fully coupled global climate system model including atmospheric, land surface, ocean, and sea ice component models, which interact with one another at their interfaces (coupler) through fluxes of energy, momentum, and water. The BCC_CSM has participated in the Coupled Model Inter-comparison Project Phase 5 (CMIP5) and is preparing for the simulation experiments of the CMIP6. It has also been applied in short-term climate predictions (Wu et al., 2014).

The LC datasets were mostly introduced in the model system through land surface models. The Beijing Climate Center Atmosphere-Vegetation Interaction Model (BCC_AVIM) is the BCC_CSM land surface model, which was developed on the basis of NCAR/CLM3 (Oleson et al., 2004) and the IAP/AVIM2 (Wu et al., 2014). The Beijing Climate Center Atmospheric General Circulation Model (BCC_AGCM) is the atmosphere component model of BCC_CSM. It is based on the NCAR/CAM3 and developed by introducing a unique dynamical framework, a reference atmosphere, and new parameterization schemes of cloud and cumulus convection (Wu et al., 2010).

2.2 Land Cover Datasets

The GlobeLand30 comprises 30m-resolution LC datasets for the years 2000 and 2010, and can be downloaded from the website http://www.globallandcover.com/GLC30Download/index.aspx. The images used in the data production include multispectral images with a 30 meter resolution, like the TM5 and ETM+ of the America Land Resources Satellite (Landsat), and multispectral images of the China Environmental Disaster Alleviation Satellite (HJ-1) (Chen et al., 2015). It has 10 LC types: water bodies, wetland, artificial surfaces, tundra, permanent snow and ice, grasslands, barren lands, cultivated land, shrublands, and forests.

The original LC datasets in the BCC_CSM were presented by sub-grids, which include the glacier (IGBP DISCover, Loveland et al., 2000), wetland and lake (Cogley,1991), and PFTs from AVHRR (Bonan et al., 2002). The PFT included 16 types, as follows: 0-bare soil, 1-needleleaf evergreen tree -temperate,2-needleleaf evergreen tree- boreal, 3-needleleaf deciduous tree -boreal, 4-broadleaf evergreen tree -tropical, 5-broadleaf evergreen tree -temperate, 6-broadleaf deciduous tree -tropical, 7-broadleaf deciduous tree -temperate, 8-broadleaf deciduous tree -boreal, 9-broadleaf evergreen shrub -temperate, 10-broadleaf deciduous shrub -temperate, 11-broadleaf deciduous shrub -boreal, 12-C3 arctic grass, 13-C3 grass, 14-C4 grass, 15-crop.

The vegetation type is the main difference between GlobeLand30 and the AVIM_LC. The non-vegetation types (e.g., glacier, wetland, and lake) in the GlobeLand30 could be applied to the BCC_AVIM directly. The scheme proposed by Lawrence and Chase (2007) was used to enlarge the vegetation type from GlobeLand30 to the PFTS in the BCC_AVIM by merging with other remote sensing datasets (MODIS, GLC2000, C3 and C4 grass) and climate datasets (CRU). Besides LC types, the spatial resolutions also needed to be adjusted. The up-scaling methods of Yu et al. (2014) were applied to transfer the LC types and their fractions onto the coarser resolutions suitable for climate models.

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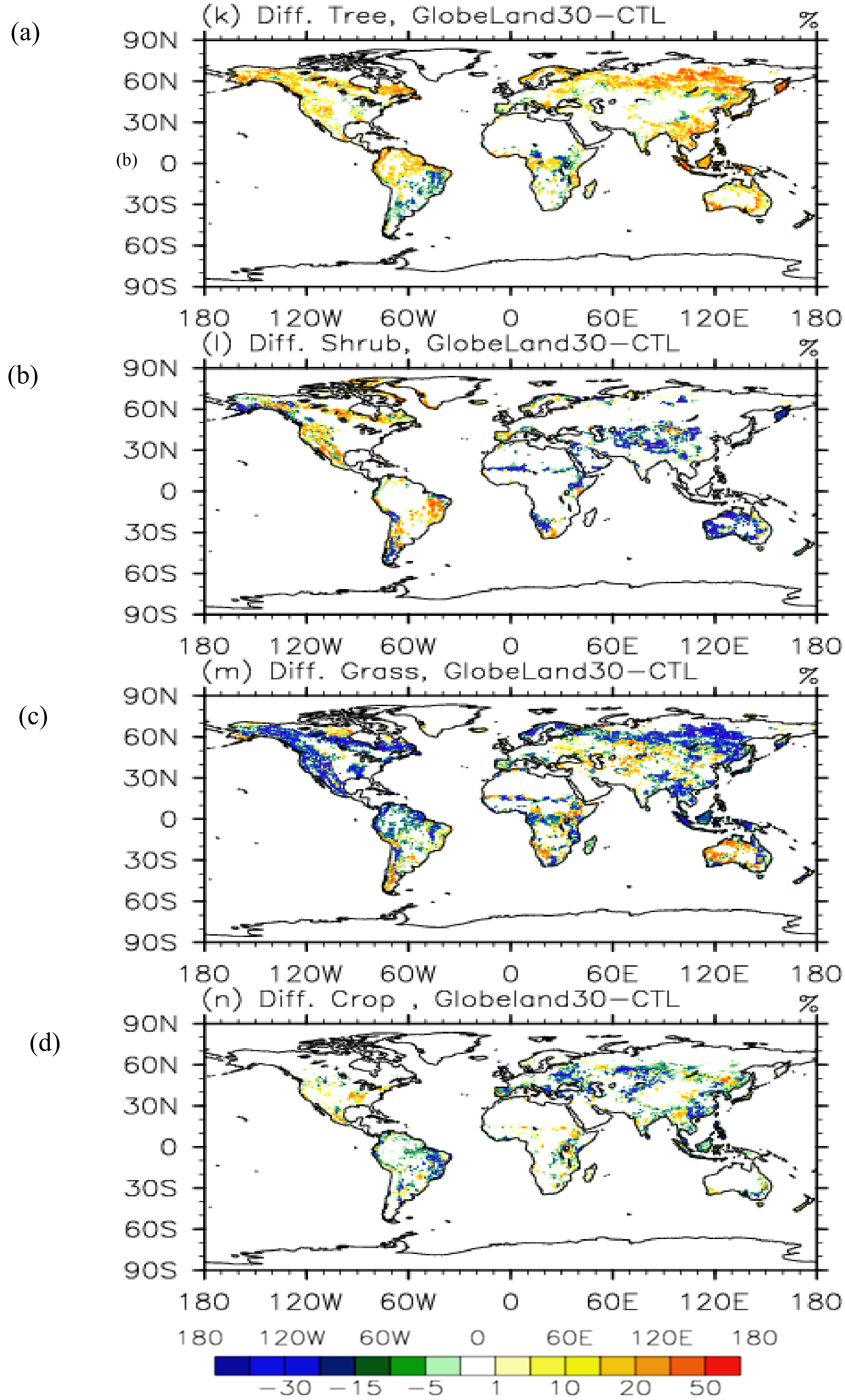

Figure 1. Differences of LC fractions between GlobeLand30 and the original LC data in BCC model. (a) for forest, (b) for shrub, (c) for grass, (d) for crops.

The revised GlobeLand30 can reasonably reproduce global LC spatial distributions, but its differences with the original LC data in the BCC model were significant. As shown in Figure 1, the forest fractions (types 1-8) were larger in northern mid-high latitude areas, southern Asia, and Australia, but less in South America and mid-southern Africa (figure 1a). Shrub cover (types 9-11) decreased (increased) in the eastern (western) hemisphere (figure 1b). Grass (types 12-14) showed significant differences between the two datasets: notably, an increase (up to 30%) appeared in western and north-eastern America, far east areas of Russia, and parts of southern Asia, while there were 20-30% decreases in mid-Europe and mid-western Australia (figure 1c). Cropland (type 15) differences ranged up to 20% (figure 1d).

Bare lands increased 10-40% in desert areas, and decreased in part of North America (figure 2a). The ice lands of GlobeLand30 increased at high terrain areas of the Tibetan Plateau and Andes, but slightly decreased on Greenland (figure 2b）. The lake fractions of GlobeLand30 were higher (lower) in Euro-Asian (North American) areas (figure 2c). Wetlands increased about 20% in North America and mid-Africa, but decreased in other regions, especially western Siberia and eastern China (figure 2c). These differences were related to the definition and period differences of the two LC datasets.

3. Impacts of GlobeLand30 data on the climate

The BCC_AGCM model, coupled with the BCC_AVIM, was used to assess the effects of LC on the climate simulation. The spatial resolution of the model was approximately 1.125° × 1.125°. The models were integrated from 1970 to 2008 under series of given forcing, including sea surface temperature, sea ice distribution, solar cycle, and observed aerosol and greenhouse gas conditions. The first 9 years were taken as the spin-up period, and simulation results between 1979-2008 were used to analyse the effects of the LC data. The simulation with the original LC dataset was labelled as the CTL experiment, while simulations with the GlobeLand30-based PFT types and all LC types datasets were labelled, respectively, as the PFT and ALL experiments.

Figure 3 shows observed and simulated rainfall and temperature distributions along latitudes. All of the simulation experiments with different LC datasets had consistent patterns and similar observations. The differences were most obvious at the equator and in mid-latitude areas. Compared to the observations, the simulated precipitation in CTL over-estimated rainfall (up to 0.5mm/day), which decreased slightly when using the GlobeLand30 datasets (figure 3a). The air temperature bias appeared strong at the mid-latitude areas of both hemispheres, and did not obviously diminish with GlobeLand30 (figure 3b). Additionally, the experiments with updated PFT types presented mostly similar patterns to those with all LC types of GlobeLand30, implying the significant roles of vegetation in the different land cover types (Shi et al., 2016).

4. Conclusions

The global 30m land cover dataset (GlobeLand30) was applied in the Beijing Climate Center climate model, and its impacts on the climate simulations were investigated. This is the first attempt to apply the GlobeLand30 data into the climate model, thus providing useful and valuable reference results for other model users. This work is a successful collaboration of researchers with expertise in atmospheric science, ecosystems, remote sensing, and geophysical information.

The conclusions are as follows: (1) The GlobeLand30 dataset can be usefully applied to the BCC_CSM model by enlarging the LC types with other remote sensing datasets and deriving the LC types and their fractions with up-scaling methods. (2) Climate features could be reproduced when using the revised LC datasets, and precipitation biases in the model simulations (higher at the mid-higher latitude of the northern hemisphere and lower at the Amazon) were effectively lessened with the GlobeLand30.

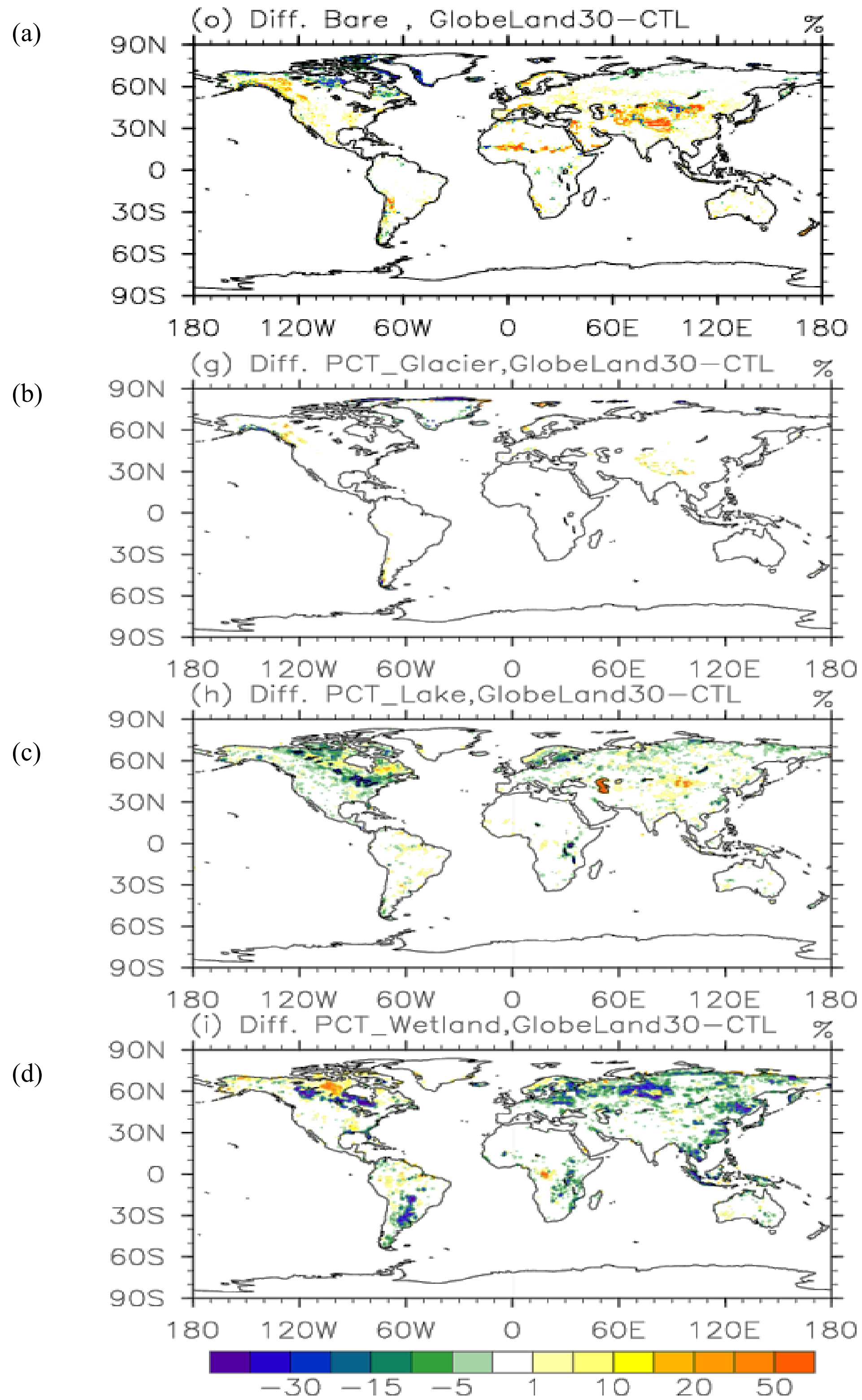

Figure 2. Differences of LC fractions between GlobeLand30 and the original LC data in BCC model. (e) for bare soil, (f) for ice lands, (g) for lake and (h) for wetland.

(a) (b)

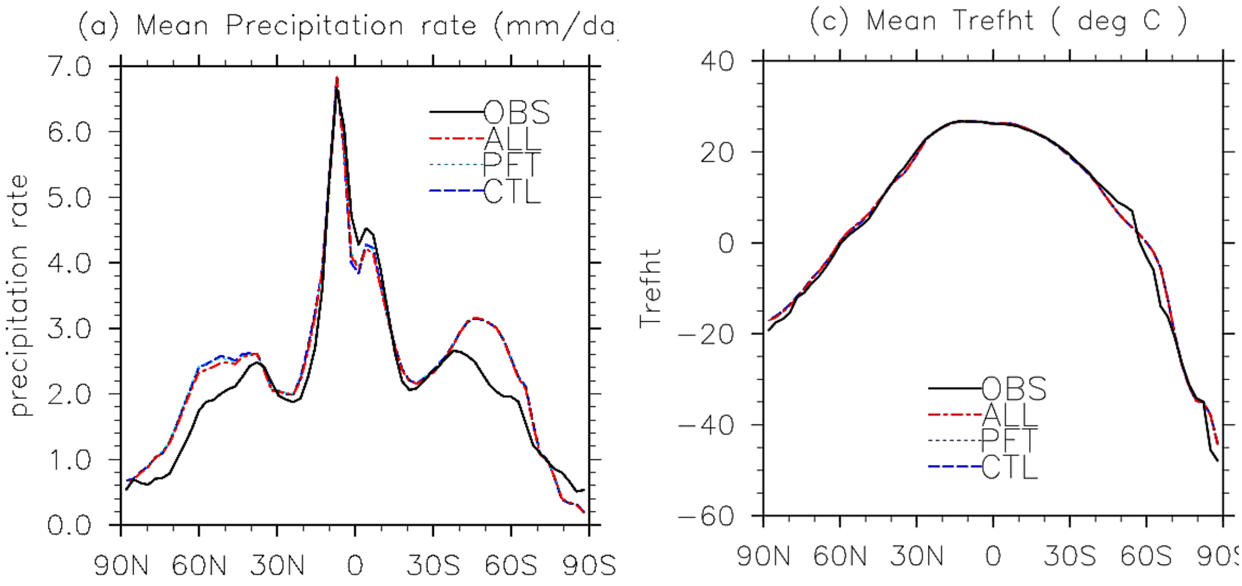

Figure 3. Observed and simulated precipitation (left) and air temperature at 2m (right) along latitude. Units of rainfall and temperature are m m/day and C, respectively.

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