Recent studies in the CMIP5 simulations shown that current dynamic vegetation models have serious weaknesses in reproducing the observed vegetation dynamics and contribute to bias in climate simulations. We have developed the Simplified Simple Biosphere Model version 4 (SSiB4)/Top-down Representation of Interactive Foliage and Flora Including Dynamics (TRIFFID) based on water, carbon, and energy balances, which are different from most current dynamic vegetation models. The surface heat, water, and carbon assimilation, and snow and soil moisture conditions are produced by SSiB4 and the allocation of net primary productivity among different plant functional types, vegetation cover, and plant structure are derived from TRIFFID. This model has been extensively evaluated through the two dimensional global simulations from 1948-2008 and compare the results with satellite data for the simulation over the past three decades. The model reproduces the main features of the global distributions of dominant vegetation types, the vegetation fraction, and leaf area index (LAI), including its seasonal, interannual, and decadal variability. The simulated North American LAI shows a general increasing trend after the 1970s in responding to warming. Both simulation and satellite observations reveal LAI increased substantially in the southeastern U.S. starting from the 1980s. The effects of the severe drought during 1987-1992 and the last decade in the southwestern U.S. on vegetation are also evident from decreases in the simulated and satellite-derived LAs. The coupling and testing with CFS/SSiB2 have also been conducted, which includes the photosynthesis processes and terrestrial carbon flux in the model under specify the vegetation condition. The CFS' lowest model thickness has been modified to be consistent with tree heights. The simulations from 1979 through 2010 have been conducted with different land surface parameterizations and land data. In general, the CFS/SSiB2 is able to reproduce the main features of large-scale mean precipitation and surface temperature. Larger precipitation biases are found in the equatorial zone along the ITCZ, while larger temperature biases are located at higher latitudes especially in the northern hemisphere. Meanwhile, the model predicts reasonable global SST spatial distribution, the tropical mixing layer and thermocline as well as global warming trend after the 1979. However, the model shows deficiency in simulated the trend of the thermal gradient between the northern and southern hemisphere oceans, which affect the global monsoon development during the past decade. Sensitivity to the land process will be briefly discussed.