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THE IMPACT OF FRACTIONAL VEGETATION COVER AND LEAF AREA INDEX ON WARM SEASON PRECIPITATION VARIABILITY IN GLOBAL ENSEMBLE SIMULATIONS

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1. INTRODUCTION

The land component of climate models represents many important processes that control the transfers of water and energy to the atmosphere. Because the absorption of solar energy is a dominant process, surface properties that are related to this absorption, such as the presence of vegetation, must be included in some detail.

Fractional vegetation cover (FVC) is an important surface property, namely because it determines the size of the vegetated portion of the land surface that will be communicating with the atmosphere. This vegetated fraction can transpire, evaporate, absorb radiation, and store energy depending on the area of leaves per area of ground, a property known as leaf area index(LAI).

The inclusion of remotely-sensed land properties results in a more realistic representation of the land surface (Bonan et al. 2002a). Satellite-based observing systems are able to continuously monitor surface conditions globally. This global aspect of the observations is vital to the improvement of land surface boundary conditions in global climate models.

2. Data

Fractional vegetation cover was calculated using the normalized difference vegetation index (NDVI) from the Advanced Very High Resolution Radar (AVHRR) reflectance in the visible and near-infrared channels. The global 1-km, AVHRR data are available from April 1992 to March 1993. The FVC is related to NDVI by using a linear contribution of NDVI from vegetated and non-vegetated surfaces:

$$FVC = \frac{NDVI_{max} - NDVI_s}{NDVI_v - NDVI_s}$$

where the subscript *max* indicates the maximum NDVI observed during the 12-month period, the subscript *v* indicates the NDVI value that corresponds to 100% vegetation cover for each of the seventeen International Geosphere-Biosphere Program (IGBP) land cover types, and the subscript *s* indicates the NDVI value for bare soil.

For more information and detail regarding the process of calculating FVC from the AVHRR reflectance, see Zeng et al. 2000.

3. Model

To assess the impacts of this new high-resolution global FVC dataset on the modeling of seasonal summertime precipitation, the National Center for Atmospheric Research Community Climate System Model (CCSM) was used. The CCSM is a multi-component model consisting of separate atmospheric, land, ocean, and sea ice models.

The atmospheric model (Community Atmosphere Model; CAM2) has a horizontal resolution of 2.8° x 2.8° (Gaussian T42 grid) and 26 vertical levels. The parameterization of the land surface is performed in the Community Land Model (CLM2). The horizontal grid for the CLM is the same T42 grid as the CAM. The specification of land surface properties in the CLM is described in Bonan et al. 2002a and Bonan et al. 2002b.

Each grid cell in the CLM is divided into five separate units, one each for vegetated land, wetland, glacier, lake, and urban. The vegetated fraction is further divided into a maximum of four plant functional types (PFTs).

There are 7 primary and 15 total PFTs in the CLM. The primary PFTs (needle-leaf evergreen and deciduous tree, broadleaf evergreen and deciduous tree, shrub, grass, and crop) are defined based on 1-km IGBP land cover dataset

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and University of Maryland tree cover dataset. These primary types are expanded to climate regimes (arctic, boreal, temperate, and tropical), using temperature and precipitation-based rules, to obtain the 15 total PFTs. A limitation of the current version of the CAM/CLM model is that only four PFTs for each grid cell are used (the CLM code does allow for up to 16 PFTs). The four PFTs chosen for each grid cell are the PFTs with the highest percent coverage of area. This method does allow for the most accurate representation of the land surface under the constraint of a maximum of four PFTs. The CLM does allow for barren land (bare soil) if it is one of the most prevalent land use types. However, if bare soil is not one of the four most prevalent, then no bare soil is assumed.

Figure 1 shows the CLM grid cells (black) that have a bare ground fraction of the cell greater than zero. Except for the large desert regions and arctic tundra, very few grid cells have any bare ground fraction. As Figure 2 shows for the Southwestern United States, only very little of the desert Southwest contains any bare soil. This is an unrealistic representation of the landscape of Arizona and New Mexico.

To remedy this issue, a fractional vegetation dataset has been created for the T42 Gaussian grid using the method described in section 2 above. This dataset is shown in Figure 3. It is clear that low fractions of vegetation, or equivalently, high fractions of bare soil do prevail over much of the Sahara desert, Arabian peninsula, Tibetan highlands, and other regions shown to have bare soil in Figure 1. However, it is evident that significant portions of the west and southwest United States are also barren even though the model representation of this region does not indicate any bare land.

Using the current method in the CLM, the four predominant PFTs (Figure 4) will still be used to determine the vegetated makeup of each grid cell. However, instead of specifying a fraction bare soil only if it was a predominant type, a fractional vegetation will be associated with each PFT on each grid cell. Figure 5 shows the combination of the fractional vegetation dataset with the IGBP land cover type dataset. It is clear that most land cover types, especially forest, have a nearly constant FVC. Some types such as Mixed Forest and Grassland, however, have significant global variation. This method allows for the realistic inclusion of a bare soil fraction in each climate grid cell.

4. Ensemble Simulations

To assess the statistical significance of the inclusion of fractional vegetation cover in the CCSM framework, a series of ensemble simulations will be conducted. Each ensemble set will consist of 10 ensemble members differing only in their initial conditions.

Analysis of the results will concentrate on the impacts that inclusion of FVC will have on summertime precipitation, especially in the United States.

5. References

Bonan, G.B., S. Levis, L. Kergoat, and K.W. Oleson, 2002a: Landscapes as Patches of Plant Functional Types: An Integrating Concept for Climate and Ecosystem Models, *Global Biogeo. Cycles* **16(2)**.

Bonan, G.B., K.W. Oleson, M. Vertenstein, S. Levis, X. Zeng, Y. Dai, R.E. Dickinson, and Z. Yang, 2002b: The Land Surface Climatology of the Community Land Model Coupled to the NCAR Community Climate Model, *J. Climate* (submitted).

Zeng, X., R.E. Dickinson, A. Walker, M. Shaikh, R.S. DeFries, and J. Qi, 2000: Derivation and evaluations of global 1-km fractional vegetation cover data for land modeling, *J. Appl. Meteor.* **39**, 826-839.

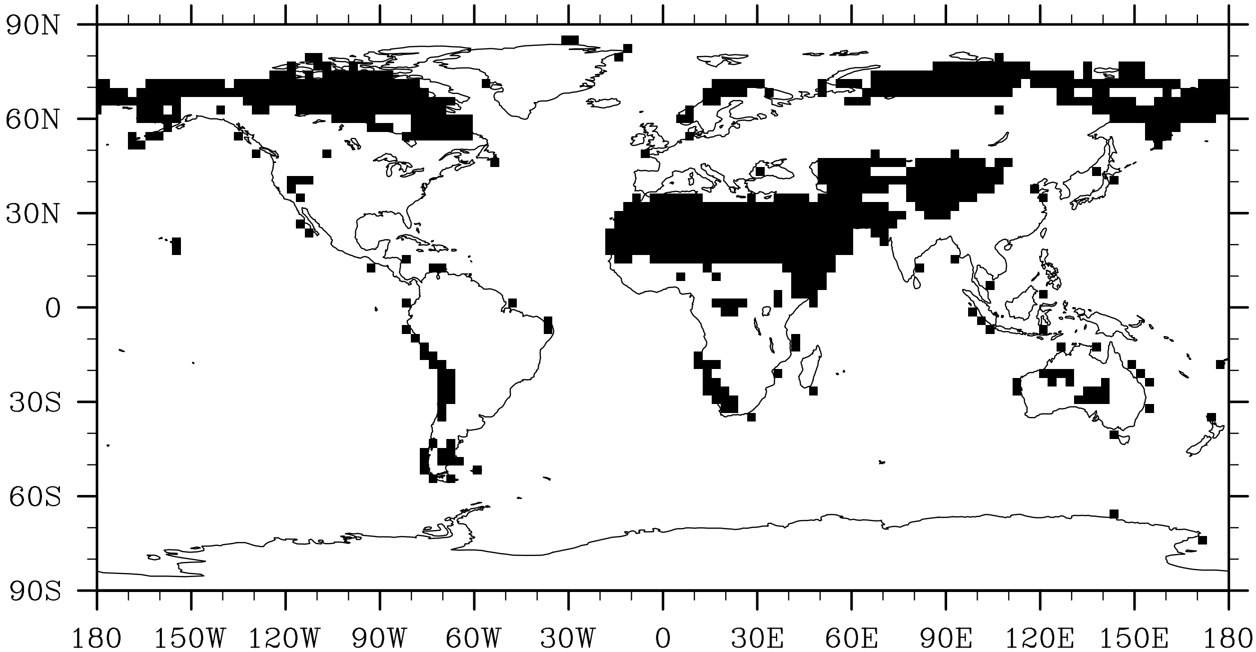

Figure 1. CLM grid cells (black) with a bare ground fraction greater than zero.

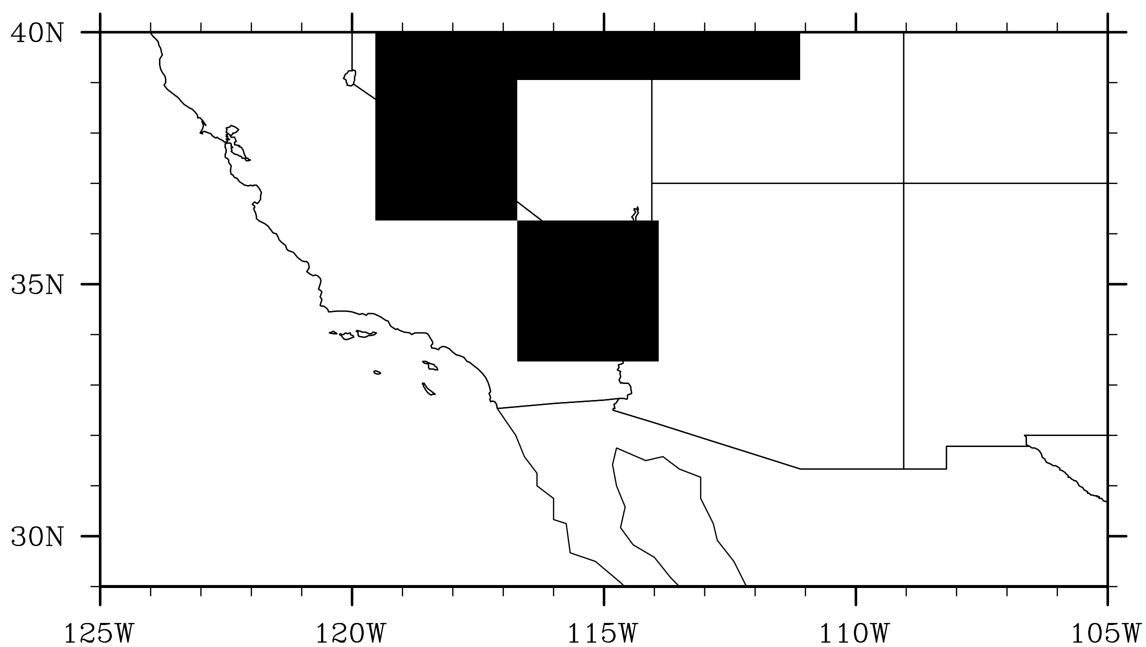

Figure 2. Enlarged view of Figure 1 for the Southwest United States.

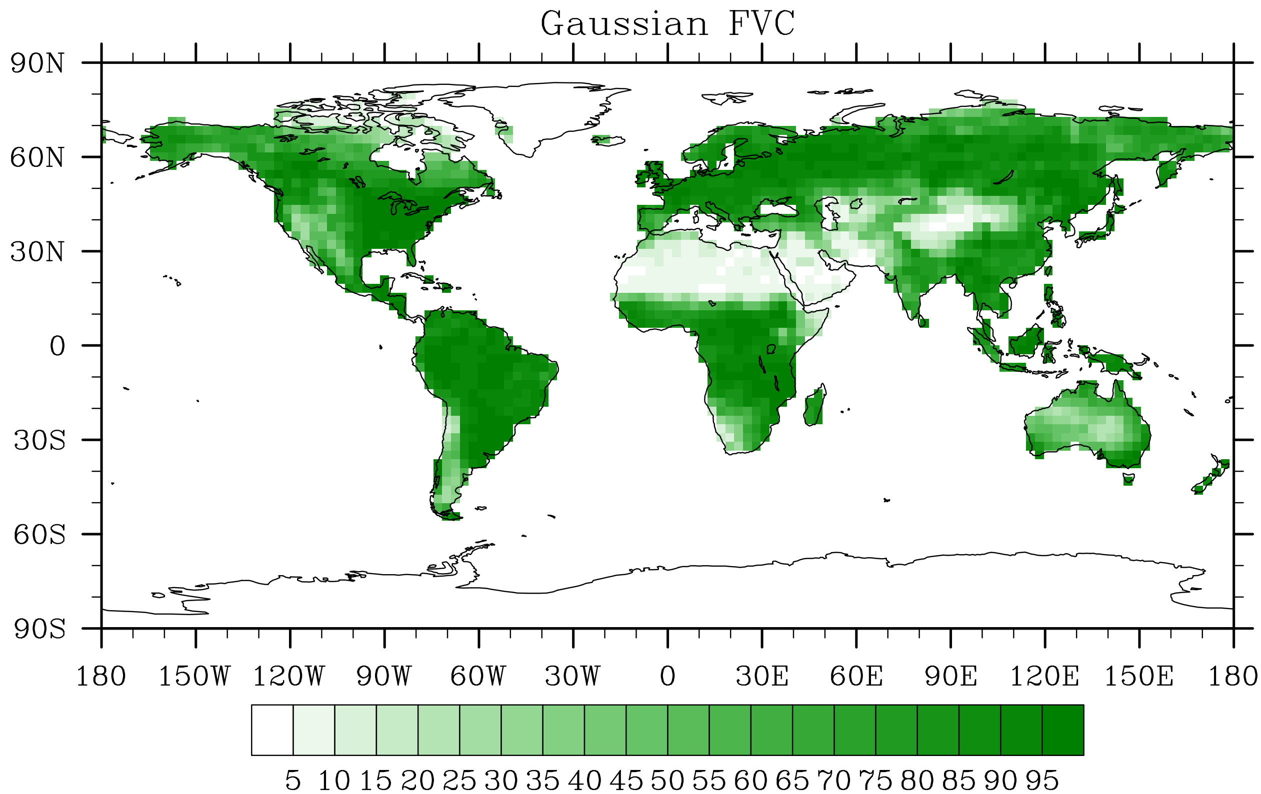

Figure 3. Fractional vegetation cover for each Gaussian T42 CLM grid cell.

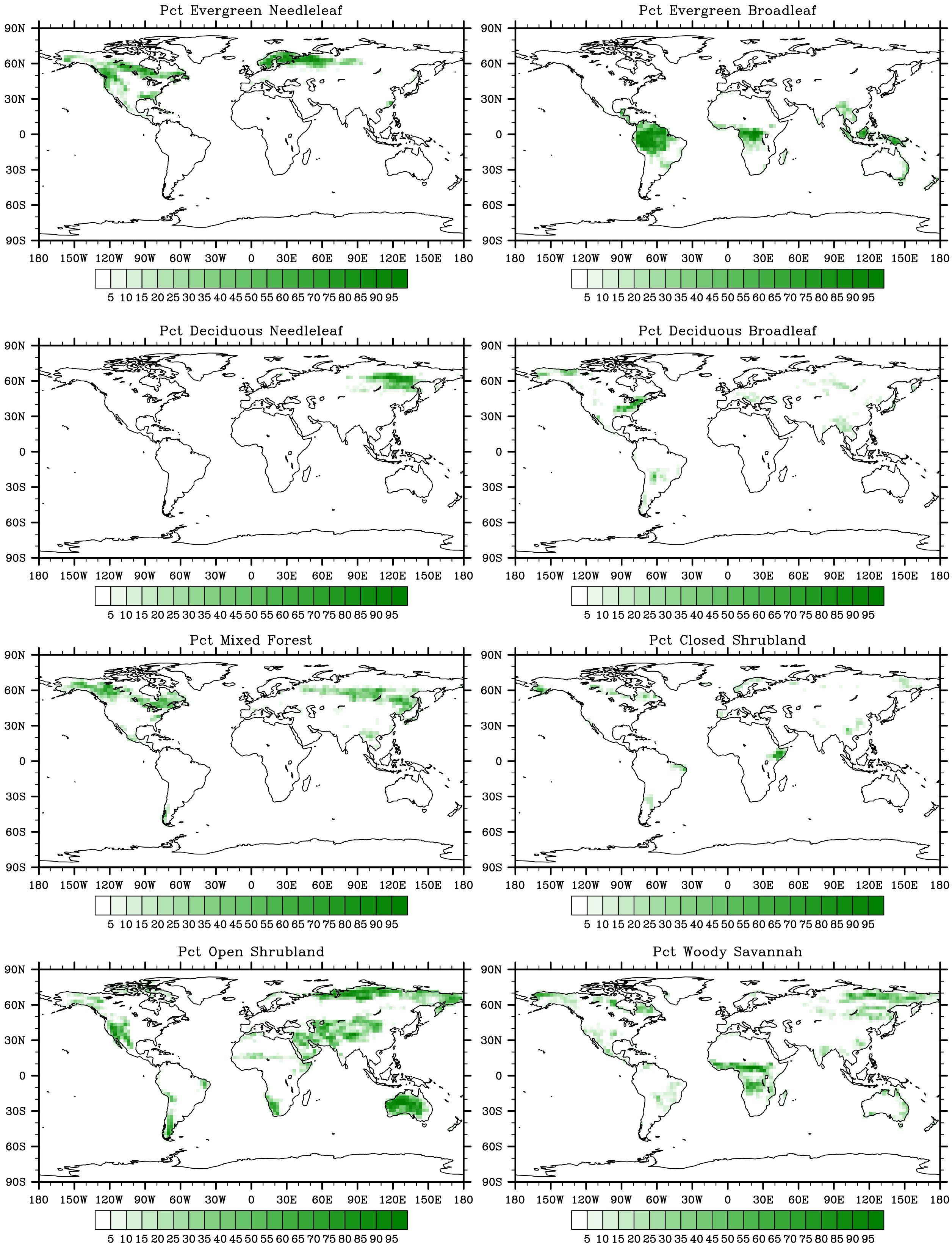

Figure 4. Fraction of each grid cell covered with each IGBP land cover type.

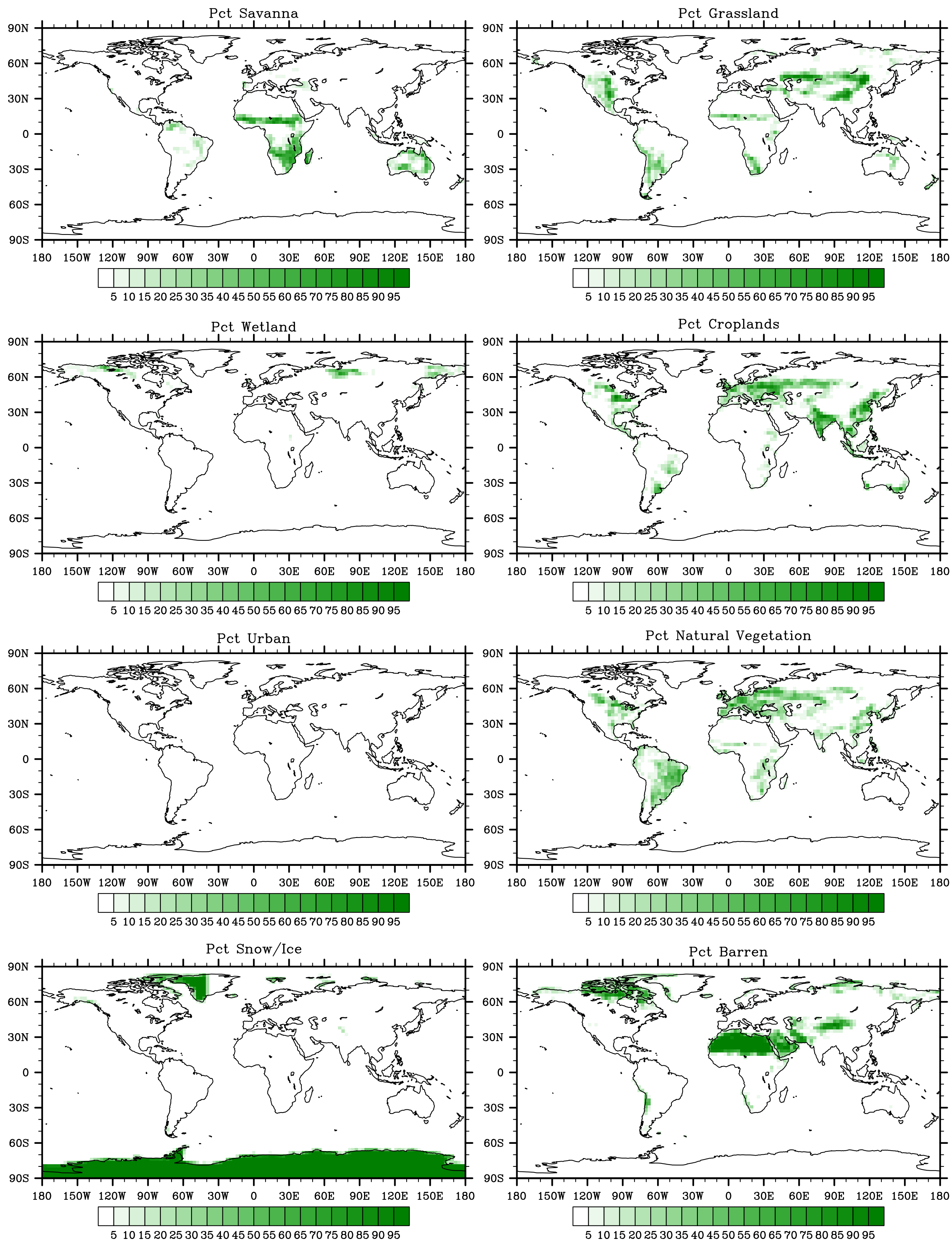

Figure 4 continued.

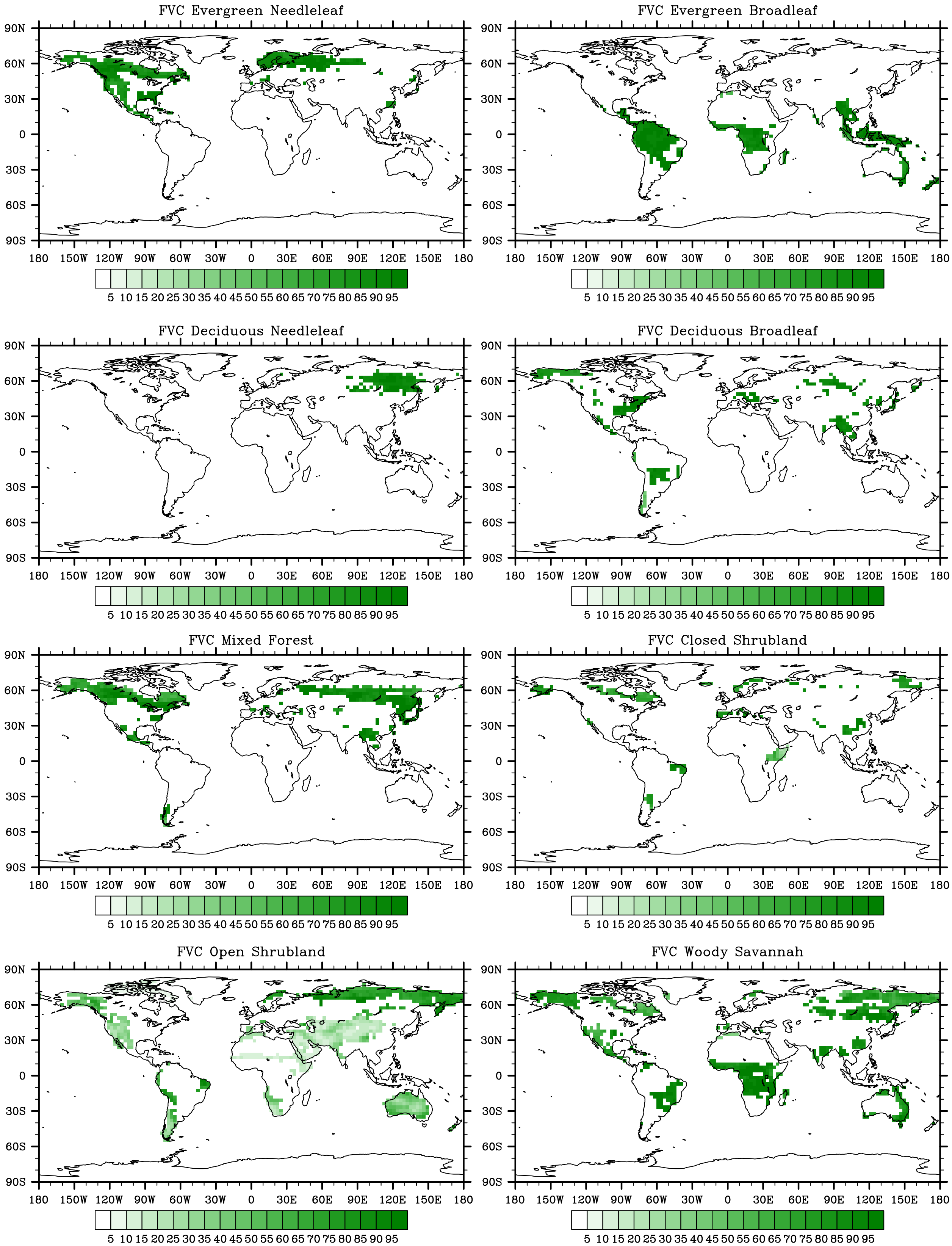

Figure 5. Fractional vegetation cover for each IGBP land cover type.

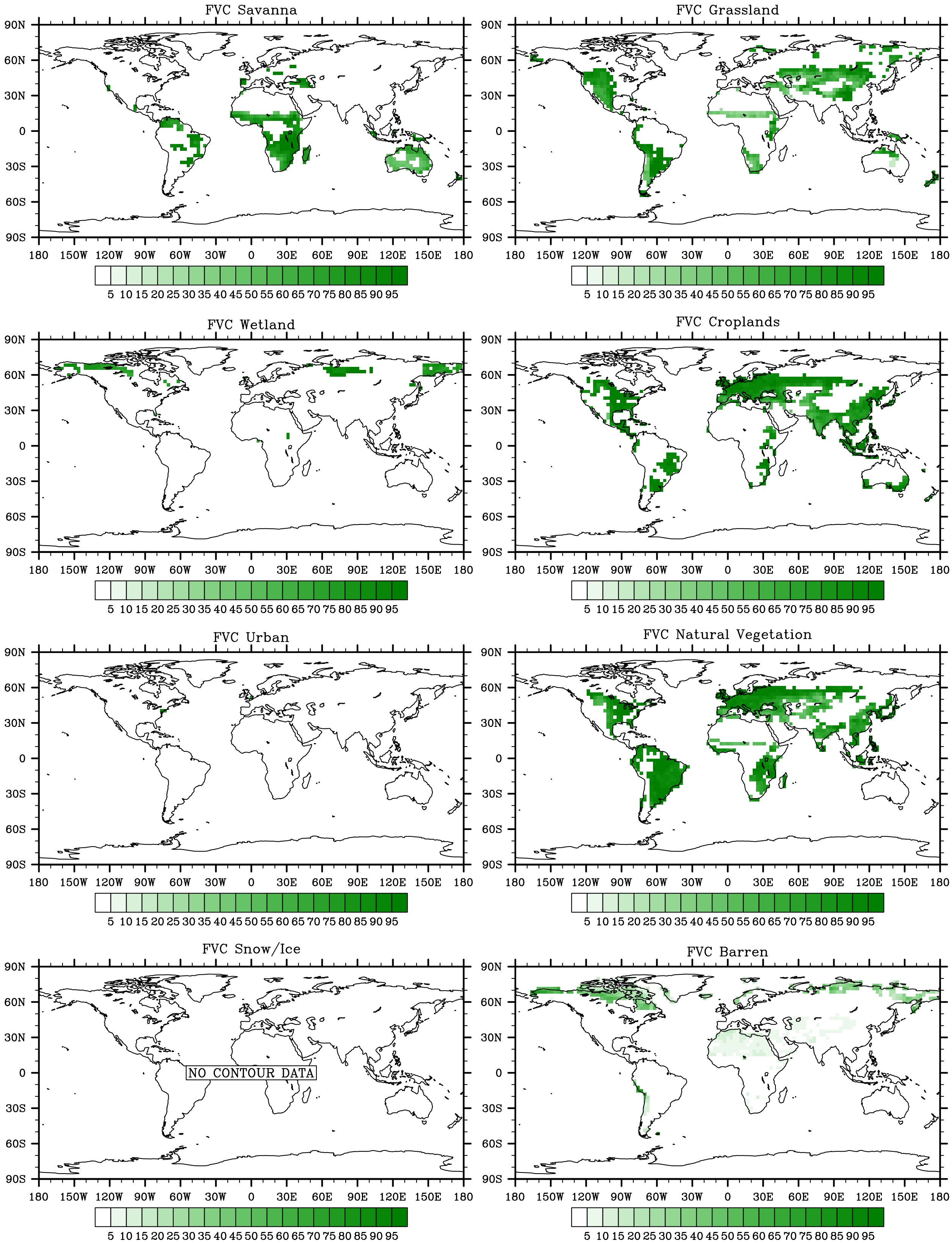

Figure 5 continued.