Supplemental Materials for:
Impacts of land-use change and elevated CO_2 on the interannual variations and seasonal cycles of gross primary productivity in China

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1 Models and data

In this study, we used twelve terrestrial biosphere models (TBMs) that participated in the Multi-scale Synthesis and Terrestrial Model Intercomparison Project (MsTMIP) (Huntzinger *et al*., 2013; Wei *et al*., 2014a, 2014b) to investigate the effects of climate change, land use and land cover change (LULCC), and rising CO_2 concentration on the temporal changes in GPP. These models are Community Land Model version 4 (CLM4), CLM4 with Variable Infiltration Capacity Runoff

Parameterization (CLM4VIC), Dynamic Land Ecosystem Model (DLEM), Global Terrestrial Ecosystem Carbon model (GTEC), Integrated Science Assessment Model (ISAM), Lund-Potsdam-Jena Dynamic Global Vegetation Model, Swiss Federal Research Institute WSL modification（LPJ-wsl), Organizing Carbon and Hydrology in Dynamic Ecosystems (ORCHIDEE-LSCE), Simple Biosphere version 3 by Jet Propulsion Laboratory (SiB3-JPL), SiB3 with Carnegie-Ames-Stanford Approach (SiBCASA), Terrestrial Ecosystem Model version 6 (TEM6), Vegetation Global Atmosphere and Soil version 2.1 (VEGAS2.1), and Vegetation Integrative SImulator for Trace gases (VISIT), respectively (Table S1). They were all forced by the same climate drivers, LULCC, and CO_2 data. The climate forcing data set was generated by combining the Climate Research Unit (CRU) data and the National Center for Environmental Prediction and National Center for Atmospheric Research (NCEP/NCAR) Reanalysis product (hereafter CRU-NCEP). Time-series data for atmospheric CO_2 concentration derived from observations were applied to SG3, and other simulations used constant CO_2. A merged product derived from a static satellite-based land cover product, SYNergetic land cover MAP (SYNMAP) (Jung *et al.*, 2006) and the time-varying land use harmonization version 1 (LUH1) data (Hurtt *et al.*, 2011) from the fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) were used to describe historical LULCC.

2 Analysis methods

The nonparametric Mann-Kendall method was used to determine the statistical significance of trends in Chinese and regional GPP (area-weighted), where the Sen median slope (Sen, 1968) was considered as the trend value in this paper. Trend analysis was based on annual values averaged from monthly values. The first step was to test for statistical significance of trends by computing the Mann-Kendall statistic *S*. Each data value was compared with all subsequent data values as follows:

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sgn(GPP_j - GPP_k), \tag{1}$$

$$sgn(GPP_j - GPP_k) = \begin{cases} 1, GPP_j > GPP_k \\ 0, GPP_j = GPP_k \\ -1, GPP_j < GPP_k \end{cases}, \tag{2}$$

where *n* is the length of the record for a given grid cell or region. The variance of *S* (Eq. (3)) was then calculated to test for the presence of a statistically significant trend using the *Z*-value (Eq. (4)):

$$var(S) = \frac{1}{18}\left[n(n-1)(2n+5) - \sum_{p=1}^{q} t_p(t_p-1)(2t_p+5)\right], \tag{3}$$

$$Z = \begin{cases} \frac{S-1}{\sqrt{var(S)}}, S > 0 \\ 0, \quad\quad S = 0 \\ \frac{S+1}{\sqrt{var(S)}}, S < 0 \end{cases}. \tag{4}$$

where q is the number of tied groups and t_p is the number of data values in the p^{th} group. The statistic Z was compared with a tolerable probability (the default significance level was set to 0.05 in this study). If a linear trend was statistically significant, then the change per unit time was estimated using a simple nonparametric procedure developed by Sen (1968):

$$b_{sen} = Median\left(\frac{GPP_j - GPP_k}{j-k}\right), j > k \ . \quad (5)$$

If there were n values of GPP_j in the time series, as many as $n(n-1)/2$ slope estimates could be obtained, and b_{sen} was taken as their median.

Each region's relative contribution to the interannual variation (IAV) and seasonal cycle amplitude (SCA) of China's GPP was also calculated based on the method proposed by Ahlström *et al*. (2015) and Chen *et al*. (2017). The regional contribution R_j (j=1,2, ...,9) to the IAV of China's GPP was calculated using the following equations:

$$f_i = \frac{\sum_t \frac{A_i x_{i,t} |X_t|}{X_t}}{\sum_t |X_t|}, \quad (6)$$

$$X_t = \sum_i A_i x_{i,t}, \quad (7)$$

where $x_{i,t}$ is the GPP anomaly for region i in year t, A_i is the area of region i, and X_t is the area-weighted total GPP anomaly in the whole of China in year t. By this definition, f_i is the average relative area-weighted anomaly $A_i x_{i,t}/X_t$ for region i, weighted by the absolute regional area-weighted anomaly $|X_t|$. f_i ranges from -1 to 1. Higher positive f_i indicates that IAV in the region varies in phase with integral IAV and makes a larger contribution towards the IAV of China's GPP, whereas a smaller or negative f_i represents the opposite. In the same way, the regional contribution to the seasonality of China's GPP was calculated using Eq. (6), in which $x_{i,t}$ is the monthly GPP departure from the annual mean (seasonal anomaly) for region i in month t and X_t is the area-weighted total seasonal GPP anomaly for all China in month t.

Tables

Table S1. MsTMIP Terrestrial Biosphere Models (TBMs) used in this study including SG1, SG2, and SG3 simulations

Model		Simulation			References
		SG1	SG2	SG3	
1	CLM4	O	O	O	Shi *et al*. (2011), Mao *et al*. (2012)
2	CLM4VIC	O	O	O	Lei *et al*. (2014)
3	DLEM	O	O	O	Tian *et al*. (2011, 2012)
4	GTEC	O	O	O	Ricciuto *et al*. (2011)
5	ISAM	O	O	O	Jain *et al.* (2013)
6	LPJ-wsl	O	O	O	Sitch *et al*. (2003)
7	ORCHIDEE-LSCE	O	O	O	Krinner *et al*. (2005)
8	SiB3-JPL	O	O	O	Baker *et al*. (2008)
9	SiB3CASA	O	O	O	Schaefer *et al.* (2008)
10	TEM6	O	O	O	Hayes *et al*. (2011)
11	VEGAS2.1	O	O	O	Zeng *et al*. (2005)
12	VISIT	O	O	O	Ito and Inatomi (2012)

CLM4, Community Land Model version 4; CLM4VIC, CLM4 with Variable Infiltration Capacity Runoff Parameterization; DLEM, Dynamic Land Ecosystem Model; GTEC, Global Terrestrial Ecosystem Carbon model; ISAM, Integrated Science Assessment Model; LPJ-wsl, Lund-Potsdam-Jena Dynamic Global Vegetation Model, Swiss Federal Research Institute WSL modification; ORCHIDEE-LSCE, Organizing Carbon and Hydrology in Dynamic Ecosystems; SiB3-JPL: Simple Biosphere version 3 by Jet Propulsion Laboratory; SiBCASA, SiB3 with Carnegie-Ames-Stanford Approach; TEM6: Terrestrial Ecosystem Model version 6; VEGAS2.1, Vegetation Global Atmosphere and Soil version 2.1; VISIT, Vegetation Integrative SImulator for Trace gases.

Figures

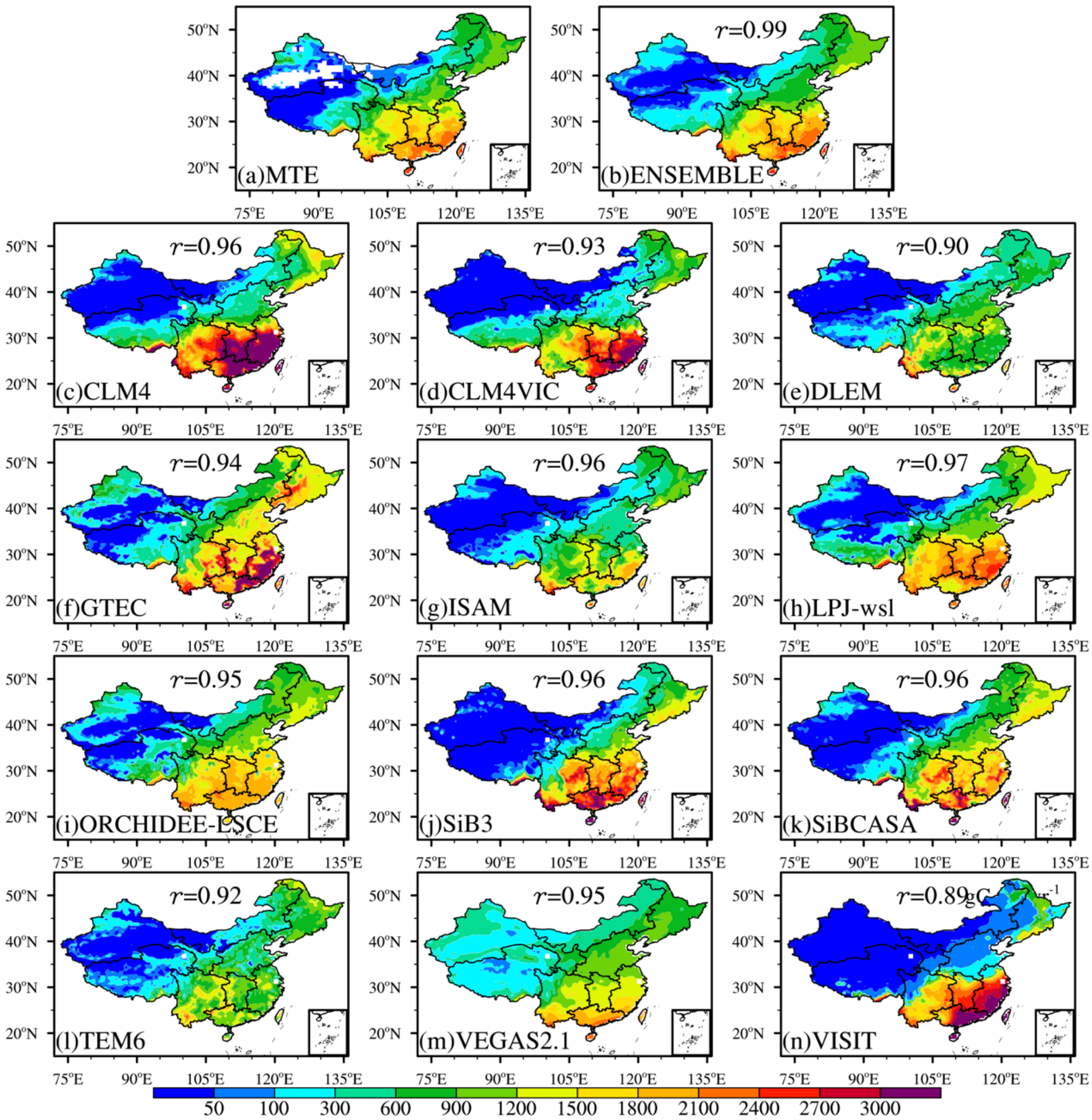

Figure S1. Annual terrestrial ecosystem gross primary production (GPP) from the MTE (1982–2010) and MsTMIP models (1981–2010 from SG3 simulation) over China. *r* is the spatial correlation coefficient with the MTE, and ENSEMBLE is the ensemble mean of the twelve MsTMIP models.

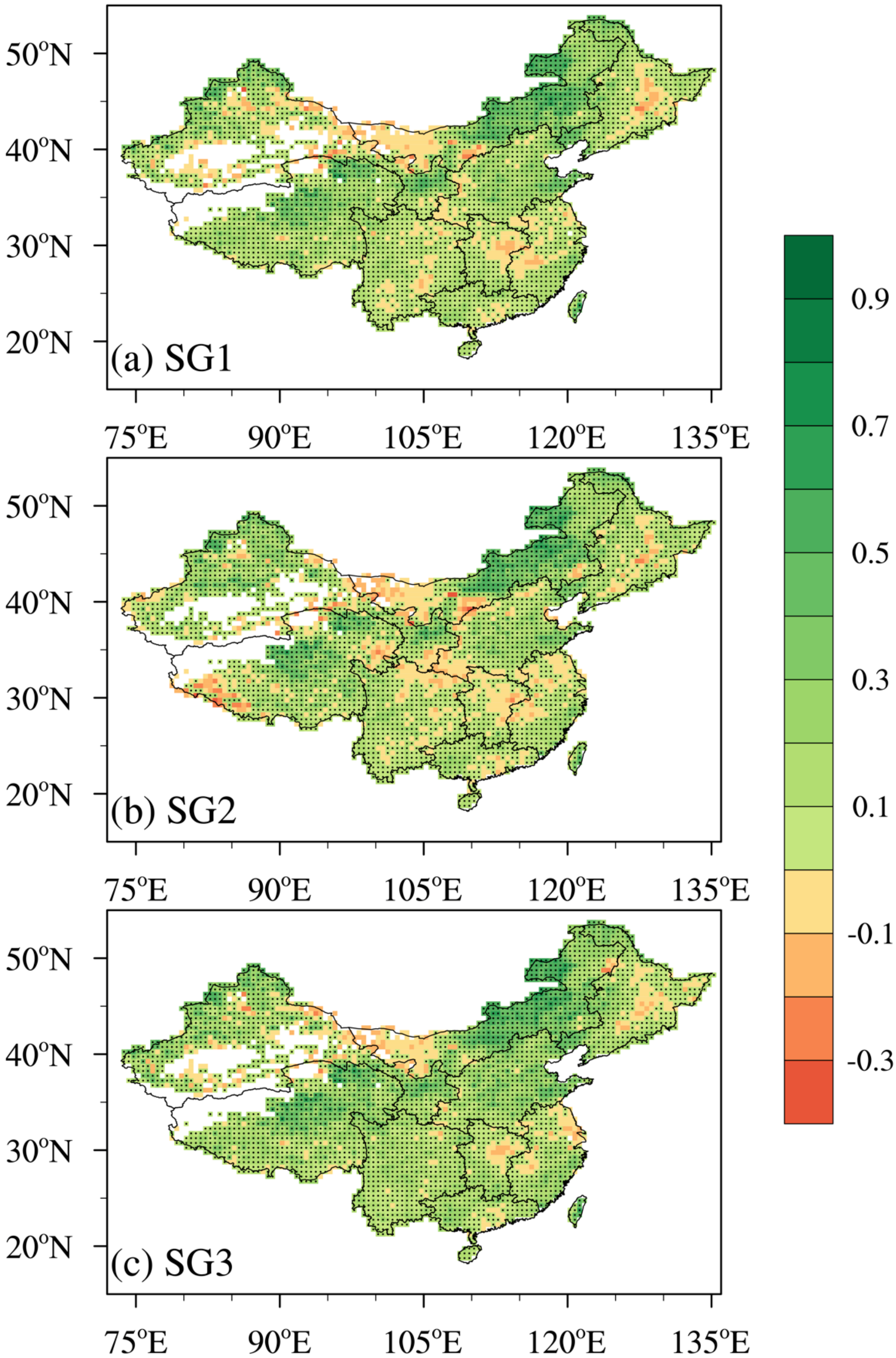

Figure S2. Spatial patterns of temporal correlation coefficients between annual GPP (1982–2010) from MTE and that from ensemble mean of MsTMIP simulations, including : (a) SG1, (b) SG2, and (c) SG3. Stippling highlights regions with significant correlations ($p < 0.05$).

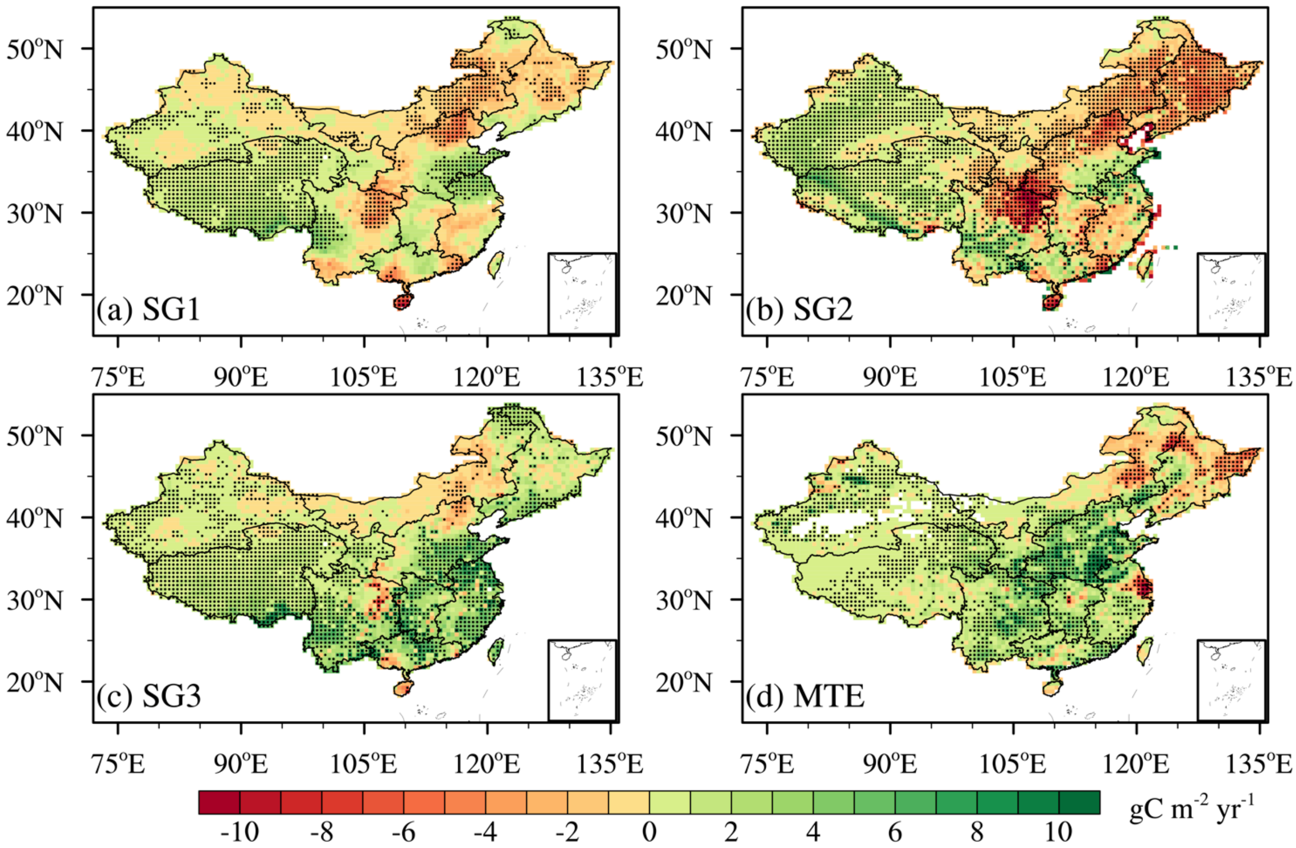

Figure S3. Trends in annual GPP (1982–2010) from the ensemble mean of MsTMIP simulations: (a) SG1, (b) SG2, (c) SG3 and (d) MTE. Stippling highlights regions with significant trend ($p < 0.05$).

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