Responses of the terrestrial carbon uptake to climate, CO_2, nitrogen deposition and land use changes simulated by CLM4VIC

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Motivation

▶ Understanding the responses of carbon uptake to various environmental factors is essential to research on global climate change.

▶This study attributes the variability of gross primary production (GPP) to prescribed environmental drivers (i.e., climate, atmospheric CO_2 concentration, nitrogen deposition, and land use change) over the period of 1901-2010 using a land surface model, CLM4VIC.

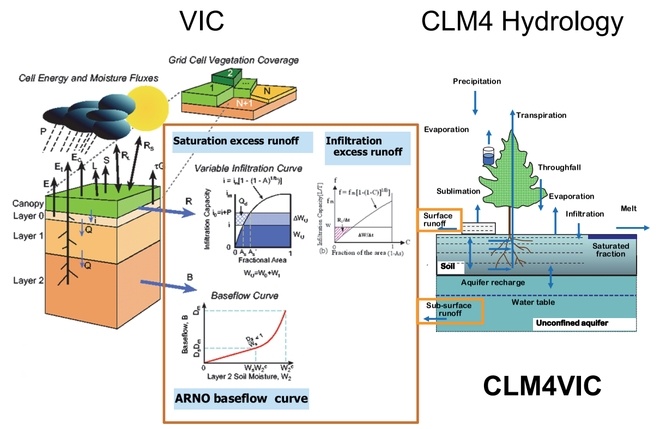
Input Data

Data Type	Temporal resolution	Source
Climate	6-hourly	Climate Research Unit (CRU) + National Centers for Environmental Prediction (NCEP) global climatology
CO_2 concentration	Monthly	GLOBALVIEW
Nitrogen deposition	Yearly	Dentener
Land cover change	Yearly	Synergetic land cover product (SYNMAP)+Hurtt's data
Soil	One-time	Harmonized World Soil Database (HWSD)

*The input data were from the North American Carbon Program (NACP) Multi-Scale Synthesis and Terrestrial Model Intercomparison (MsTMIP) project

Model Description

- Development of CLM4VIC: Runoff generation schemes from the Variable Infiltration Capacity (VIC) macroscale hydrologic model has been implemented in to CLM4;
- Hydrologic parameters: all parameters in the VIC runoff generation schemes were globally uniform in the study.



Experimental Design

Domain	Name	Climate Forcing (CLIM)	Land-Use History (LUC)	Atmospheric CO_2 (CO_2)	Nitrogen Deposition (NDEP)	Impact factor
Global (0.5°×0.5°)	RG1	Constant	Constant	Constant	Constant	ALL=BG1-RG1
	SG1	1901-2010	Constant	Constant	Constant	CLIM=SG1-RG1
	SG2	1901-2010	1901-2010	Constant	Constant	LUC=SG2-SG1
	SG3	1901-2010	1901-2010	1901-2010	Constant	CO_2=SG3-SG2
	BG1	1901-2010	1901-2010	1901-2010	1901-2010	NDEP=BG1-SG2

Calculation of Contribution

$$\text{Contribution}_i = \frac{\text{Slope}_i}{\text{Slope}_{ALL}},\ i=\text{CLIM, LUC, } CO_2\text{, or NDEP}$$

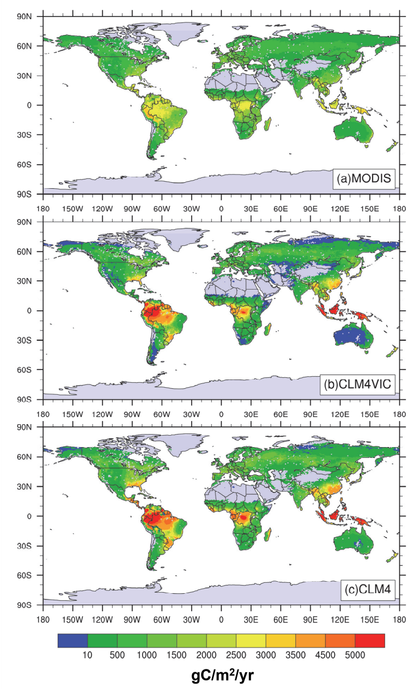
Slope_i: linear regression of annual GPP series on year series

Data for comparison

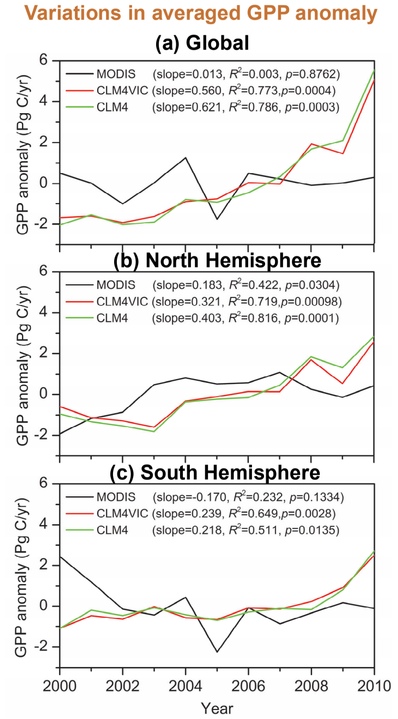
Name	Description	Source
CLM4 GPP	1901~2010, monthly, 0.5°×0.5°	MsTMIP
GPP	2000~2010, monthly, 0.05°×0.05°	MODIS

Results

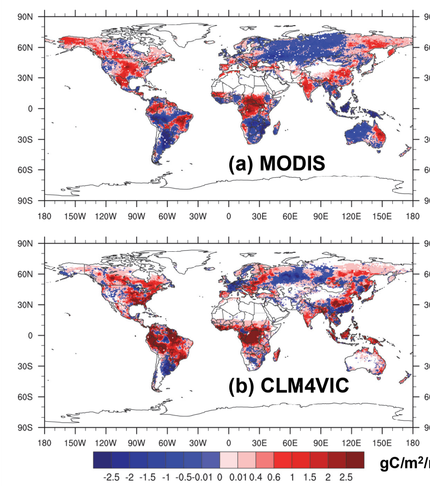
Global mean GPP by BG1 from 2000 to 2010



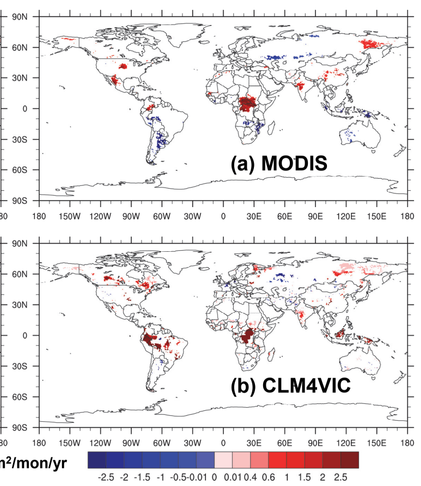
Variations in averaged GPP anomaly



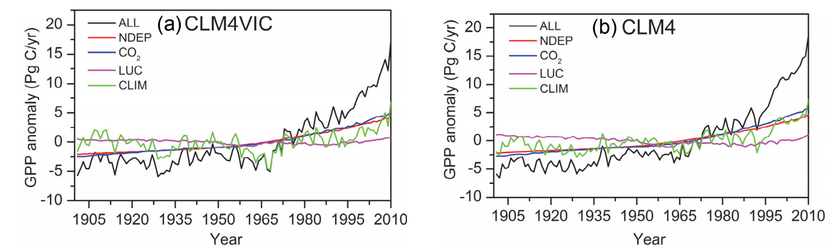
Changes in GPP from 2000 to 2010



Trend in GPP from 2000 to 2010 (*P*<0.05)



Variations in global mean GPP anomaly from 1901 to 2010



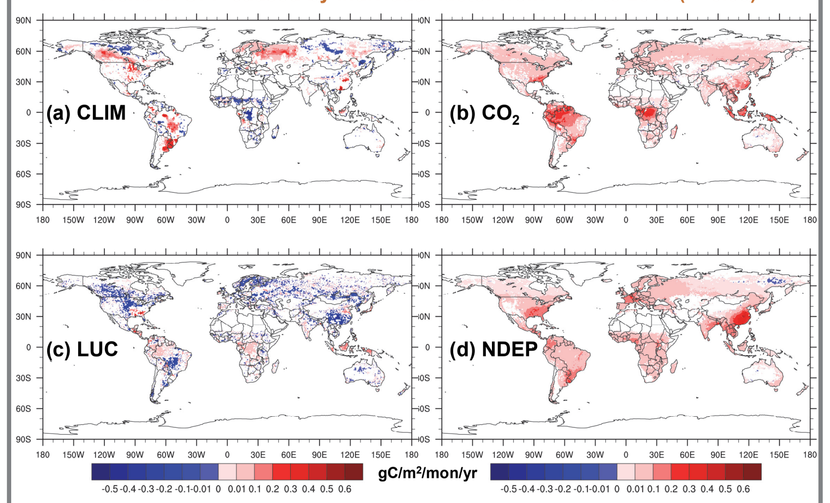
Annual trend of global mean GPP anomaly from 1901-2010

Factors	CLM4VIC			CLM4		
	Slope (PgC/yr²)	Contribution	*P*-value	Slope (PgC/yr²)	Contribution	*P*-value
ALL	0.1288	100.0%	0.0000	0.1508	100.0%	0.0000
NDEP	0.0547	**+42.5%**	0.0000	0.0565	**+37.5%**	0.0000
CO_2	0.0599	**+46.5%**	0.0000	0.0673	**+44.6%**	0.0000
LUC	-0.0040	-3.1%	0.0001	-0.0118	-7.8%	0.0000
CLIM	0.0182	+14.1%	0.0006	0.0387	+25.7%	0.0000

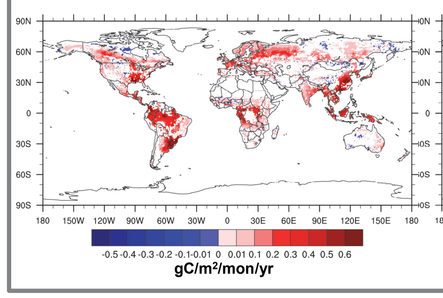
Annual trend of global mean GPP anomaly from 1960-2010

Factors	CLM4VIC			CLM4		
	Slope (PgC/yr²)	Contribution	*P*-value	Slope (PgC/yr²)	Contribution	*P*-value
ALL	0.3335	100.0%	0.0000	0.3545	100.0%	0.0000
NDEP	0.0919	+27.6%	0.0000	0.0943	+26.6%	0.0000
CO_2	0.1089	**+32.7%**	0.0000	0.1264	**+35.7%**	0.0000
LUC	0.0160	+4.8%	0.0000	0.0201	+5.7%	0.0000
CLIM	0.1166	**+35.0%**	0.0000	0.1138	**+32.1%**	0.0000

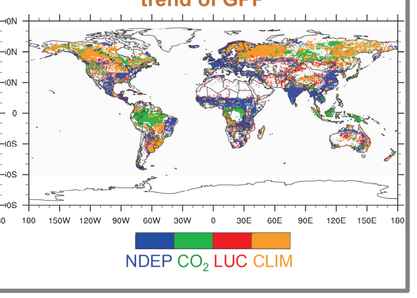
Trend in GPP caused by individual factor from 1901 to 2010 (*P*<0.05)



Trend in from 1901 to 2010 (*P*<0.05)



Dominant driving factors causing annual trend of GPP



Summary and Implications

▶GPP increased significantly in most of the areas over the past 110 years, with an accelerated rate of increase over the past 50 years. The change in GPP was larger in tropical regions than other regions.

▶Globally, CO_2 is the primary factor of GPP increase from 1901 to 2010, followed by NDEP. From 1960 to 2010, CLIM and CO_2 contributes approximately equally to the increasing trend in GPP.

▶The trend in GPP simulated by CLM4VIC is consistent with that in MODIS GPP over the North Hemisphere, but is opposite over the South Hemisphere and the Globe. However, CLM4VIC-based trend is consistent with CLM4-based trend. These inconsistencies imply that the underlying processes driving GPP should be further investigated.

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