

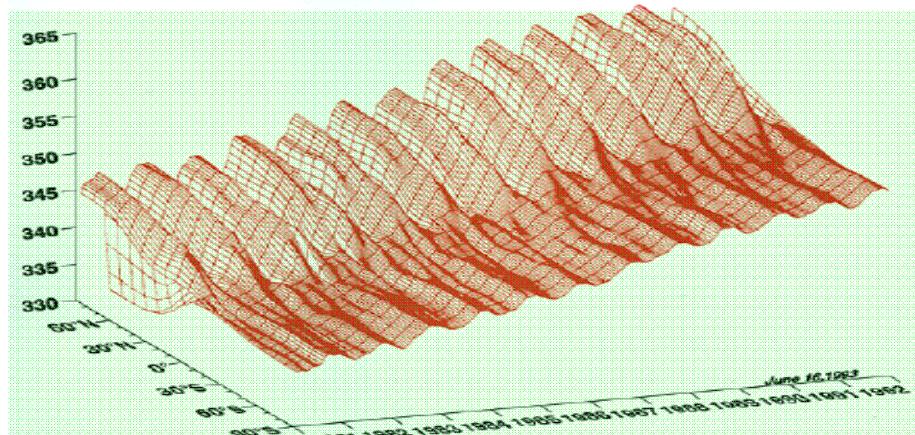
Change in vegetation growth and its driving factors over the past three decades

Shilong Piao

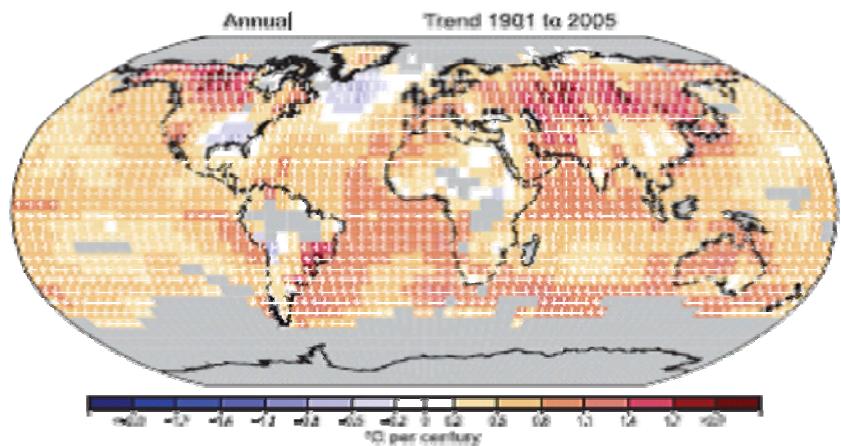
Peking University



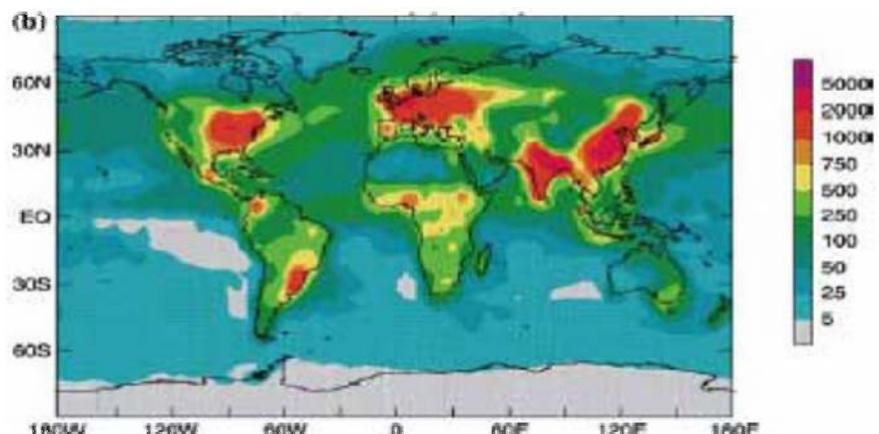
Change in climate and atmospheric components



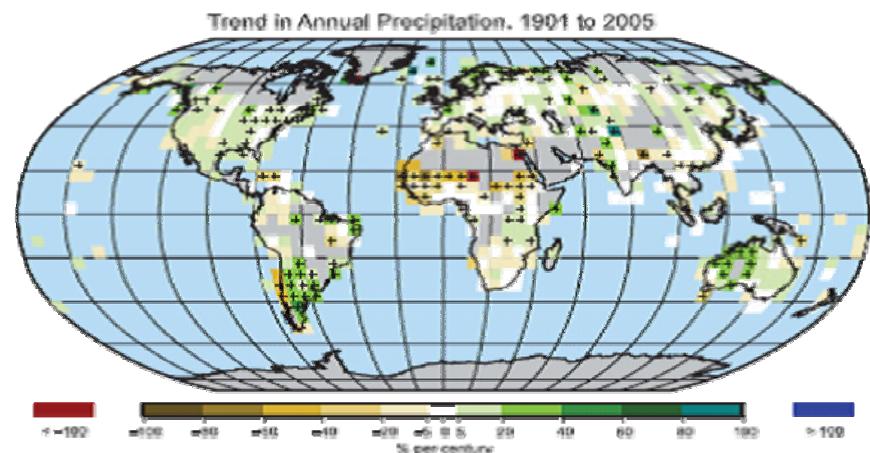
CO₂ increase



Temperature change

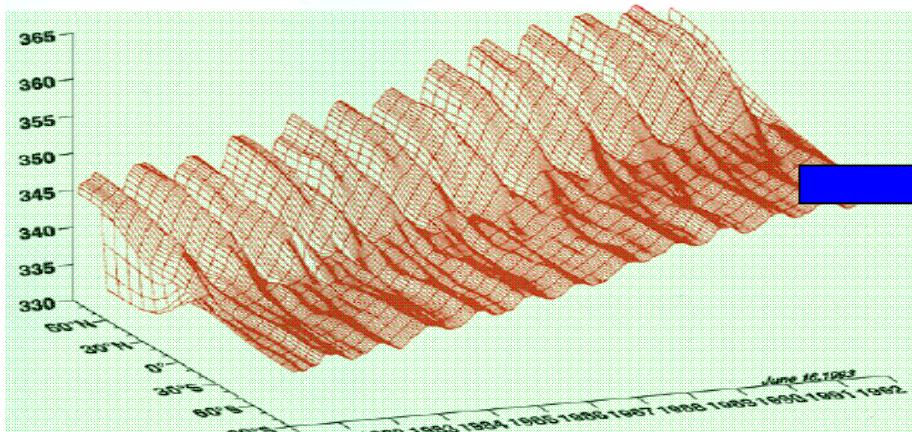


Nitrogen deposition

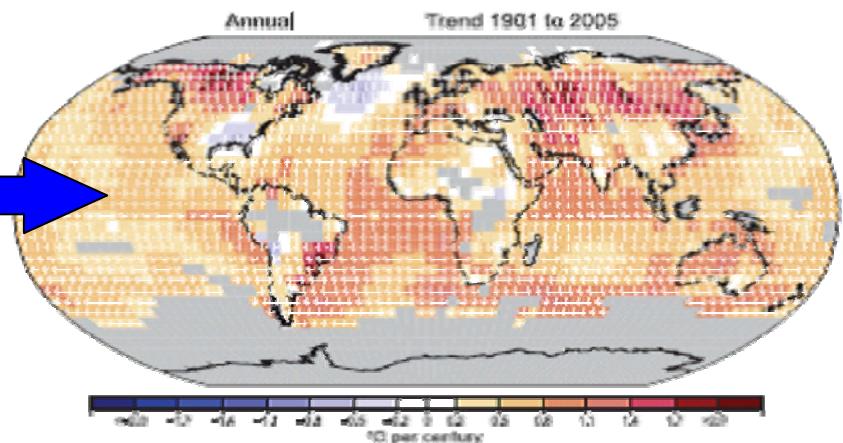


Precipitation change

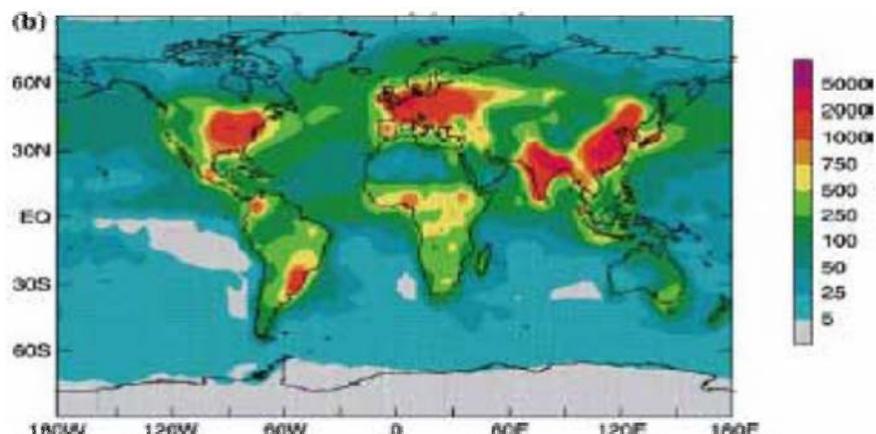
Atmospheric Scientists have established:



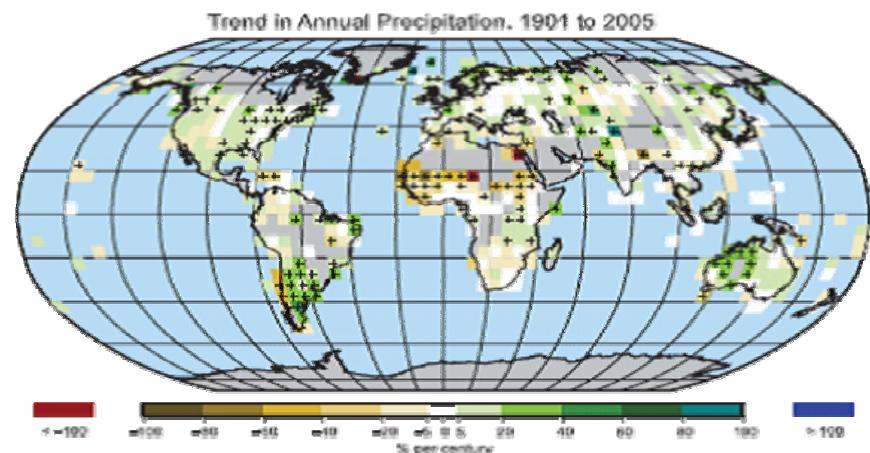
CO₂ increase



Temperature change

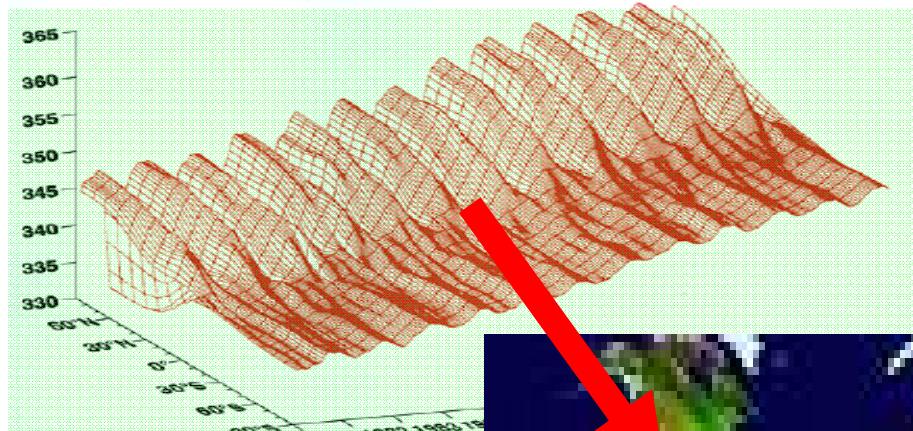


Nitrogen deposition

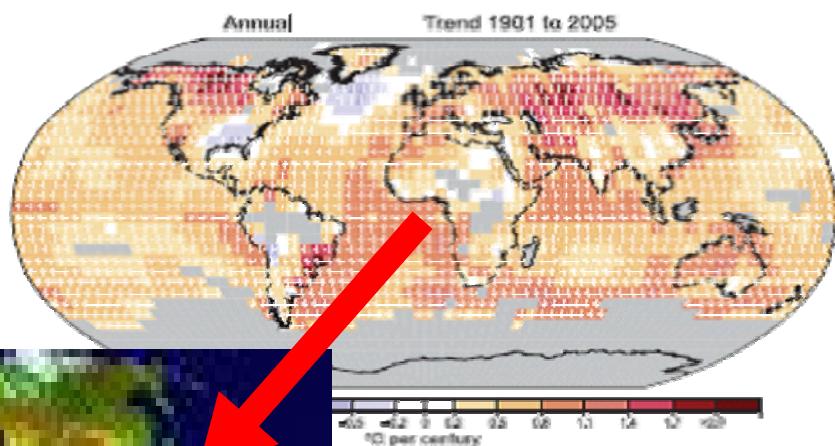


Precipitation change

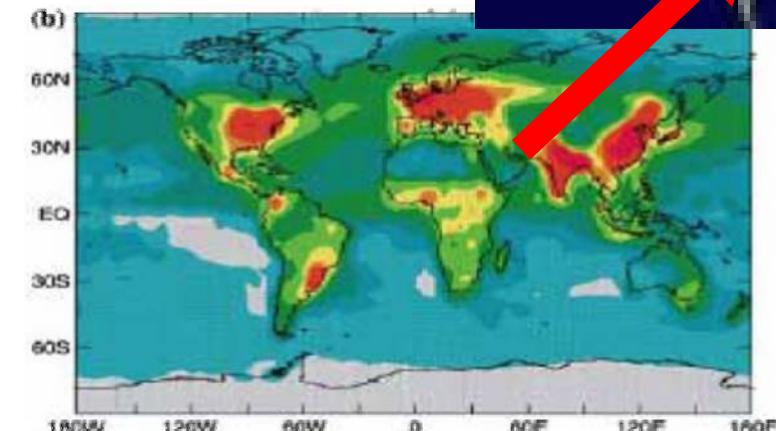
What is the response of vegetation growth to these changes?



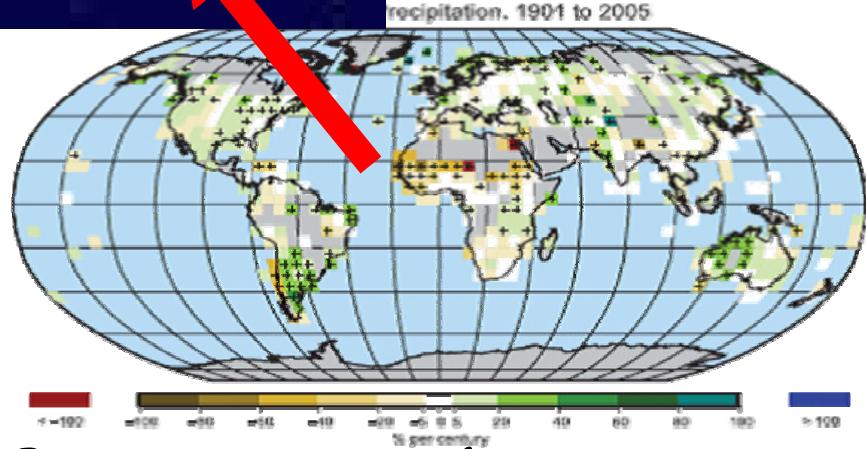
CO₂ increase



Temperature change



Nitrogen deposition



Precipitation change

conformational change upon adsorption is observed for Cu-TBPP on Ag(110) (Fig. 3d), where the single adsorption state is characterized by a dihedral angle of 30°.

From this analysis we conclude that the molecular conformation of Cu-TBPP is driven by the nature of the molecule–surface interaction. This conformational adaptation within the molecules occurs in addition to the general tendency for an adsorbate molecular lattice to rotate with respect to the substrate in order to minimize the inequivalent number of adsorption sites¹⁸. It also goes beyond the observation of a gauche conformation in molecular layers¹⁹. The saturated hydrocarbon group on the DBP substituents interacts with the surface by a weak chemisorption and permits molecular mobility¹⁹. Small deviations of the Cu-TBPP conformation ($\sim 90 \pm 10^\circ$) result from modification of the weak chemisorption in response to the atomic corrugation and spacing. In contrast, larger conformational adaptations ($\sim 45^\circ$ and more) are dominated by stronger π -metal interaction at close proximity (typically $\ll 0.5$ nm) of the delocalized electron system of the phenyl and the porphyrin components to the metal.

Conformational analysis of adsorbed molecules permits a semi-quantitative analysis of the adsorbate molecular interaction energy. The degree of rotation of the phenyl-porphyrin bonds balances the intramolecular steric hindrance with the molecule–surface interactions. The rotational barrier for one phenyl-porphyrin bond of tetra-aryl porphyrins in liquids has been measured by thermally activated isomerization of specific isomeric forms (isolated

22. Dirks, J. W., Underwood, G., Matheson, J. C. & Gust, D. J. *J. Org. Chem.* **44**, 2551–2555 (1979).
23. Gottwald, L. K. & Ullman, E. F. *Tetrahedron Lett.* **56**, 3071–3074 (1969).
24. Hatono, K., Anzai, K., Nishino, A. & Fujii, K. *Bull. Chem. Soc. Jpn.* **58**, 3653–3654 (1985).

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Correspondence and requests for materials should be addressed to T.A.J. (e-mail: thomas.jung@psi.com).

Increased plant growth in the northern high latitudes from 1981 to 1991

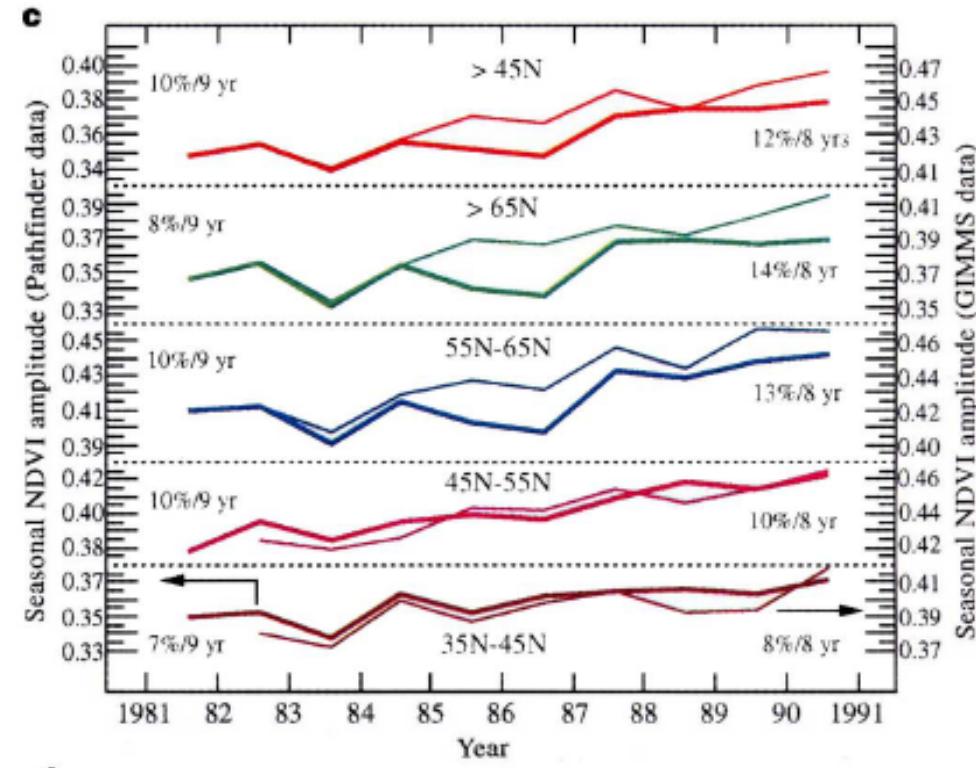
R. B. Myneni^{*}, C. D. Keeling[†], C. J. Tucker[‡], G. Asrar[§] & R. R. Nemani^{||}

^{*} Department of Geography, Boston University, Commonwealth Avenue, Boston, Massachusetts 02215, USA

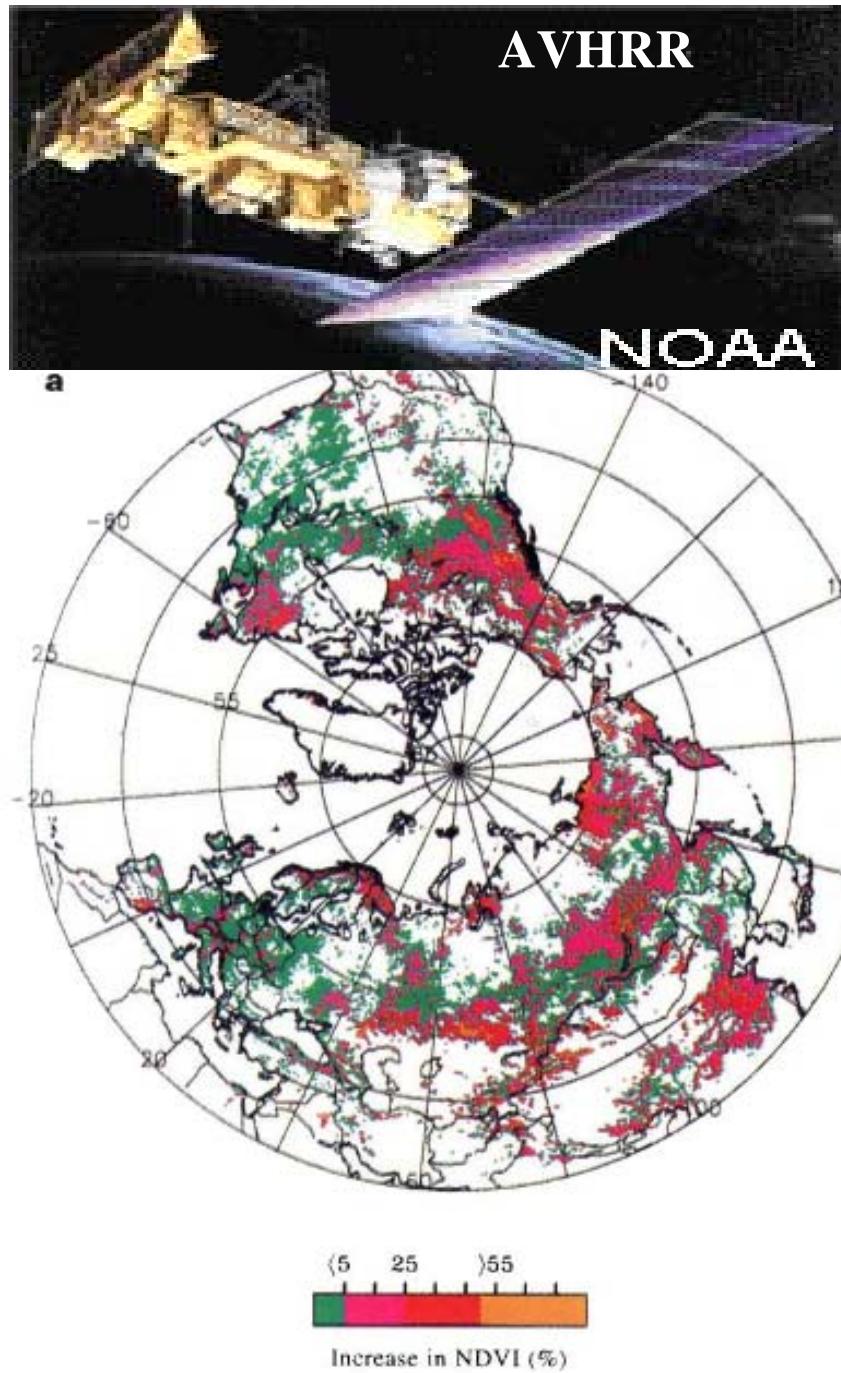
[†] Scripps Institution of Oceanography, La Jolla, California 92093-0220, USA

[‡] NASA Goddard Space Flight Center, Code 923, Greenbelt, Maryland 20771, USA

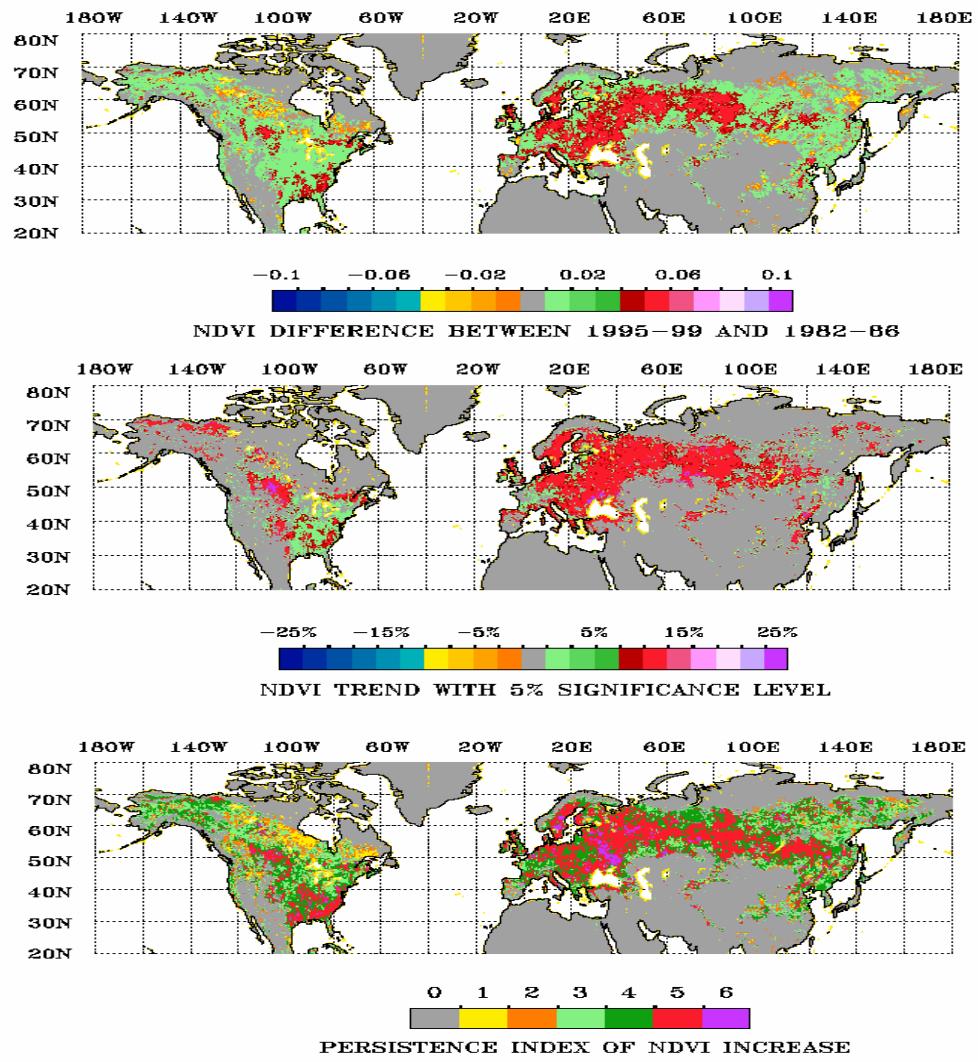
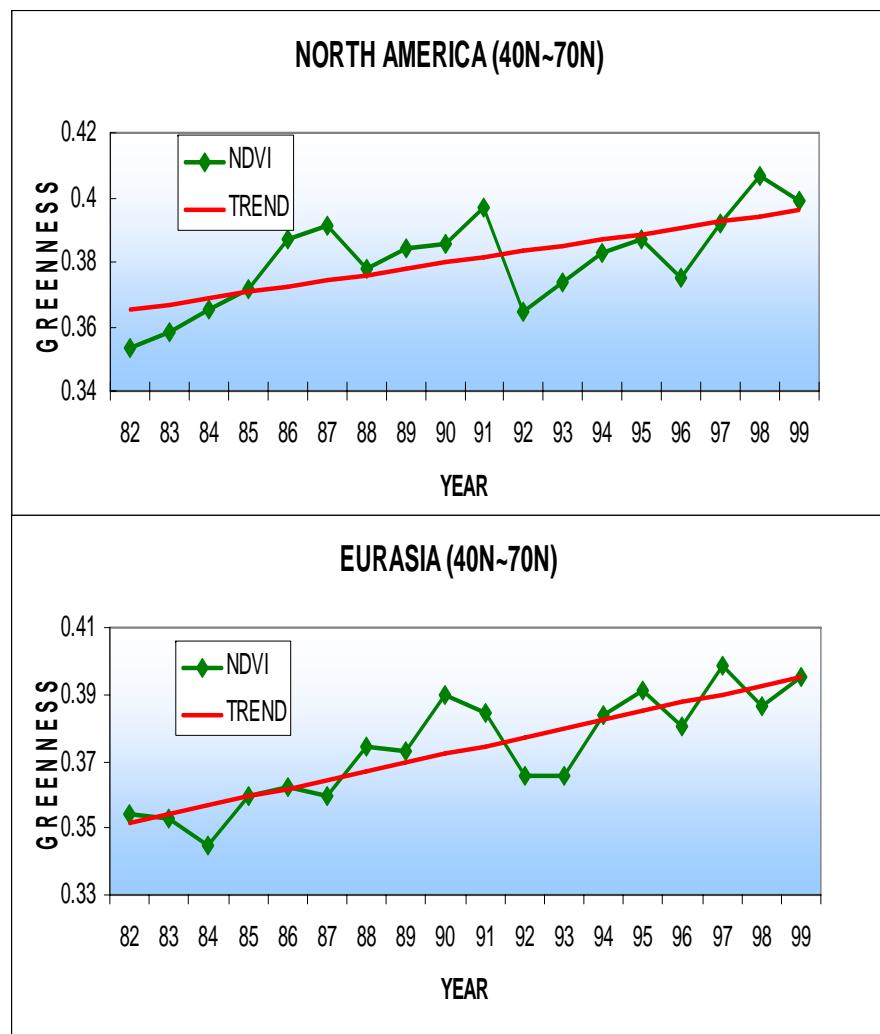
[§] Office of Mission to Planet Earth, NASA Headquarters, Washington DC 20546,



d Myneni et al. (1996)



Increase in NDVI Magnitude from 1982 to 1999



Role of temperature change - statistic application

Zhou et al. (2001)

detrending the original time series. To estimate the relation between NDVI and temperature, we estimate the regression model

$$Y = \beta_0 + \beta_1 X + \beta_2 \text{time} + \varepsilon, \quad (11)$$

where Y is the dependent variable, time is the deterministic variable, X is the independent variable, β_0 , β_1 and β_2 are regression coefficients, and ε is a stochastic error term. This



Greening of NH was chiefly driven by rising **temperature**

Zhou et al. (2002)

$$\text{NDVI} = \beta_0 + \beta_1 \text{time} + \beta_2 \text{temp} + \beta_3 \text{CO}_2 + \varepsilon, \quad (2)$$

Ahlbeck et al. (2002)

[2] To confirm Ahlbeck's results, we estimate the following equation:

$$\text{NDVI} = \beta_0 + \beta_1 \text{temp} + \beta_2 \text{CO}_2 + \varepsilon, \quad (1)$$

with data from North America and Eurasia. Here temp denotes temperature. To determine whether CO_2 or temperature has a statistically measurable effect on NDVI, we use a t statistic to test the null hypothesis that the



Greening of NH was chiefly driven by rising **atmospheric CO₂**

There is little doubt that changes in these factors affect vegetation growth. The real question is that how much each factor contributes to the observed signals.

Role of temperature change - modeling application

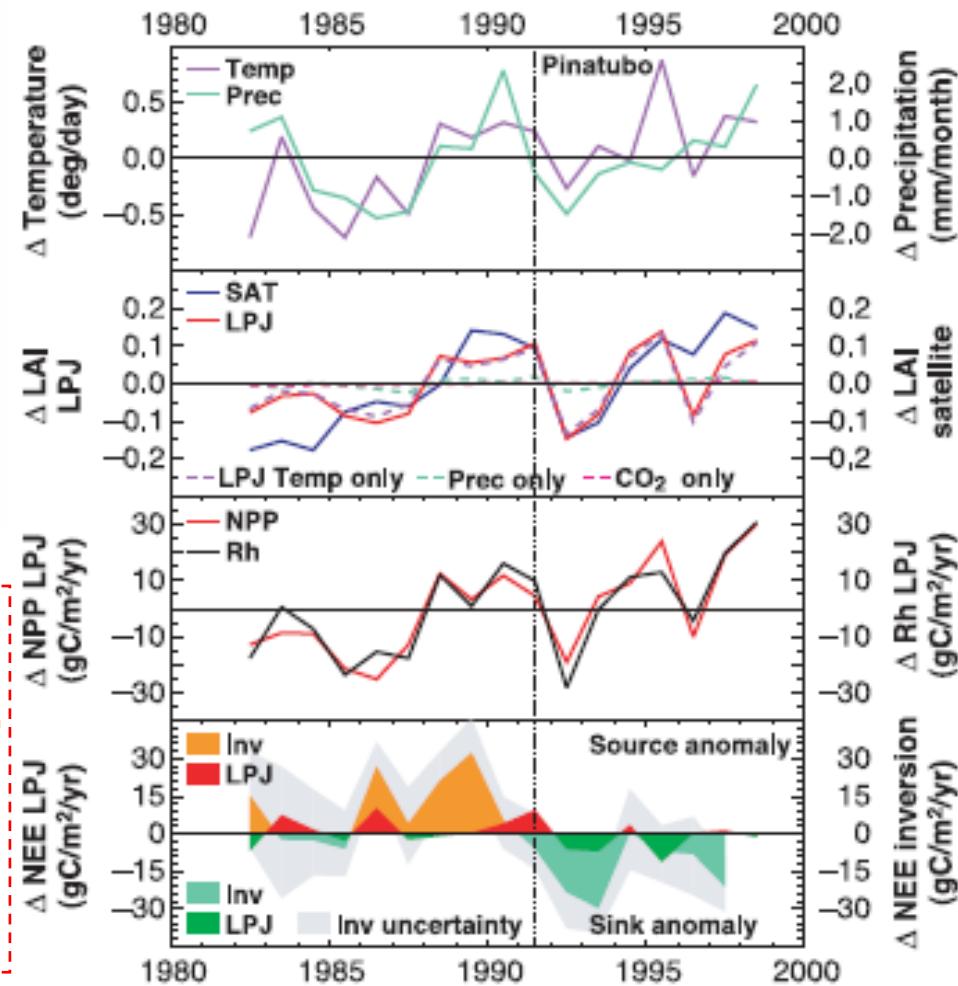
REPORTS

Climatic Control of the High-Latitude Vegetation Greening Trend and Pinatubo Effect

Wolfgang Lucht,^{1*} I. Colin Prentice,² Ranga B. Myneni,³ Stephen Sitch,¹ Pierre Friedlingstein,⁴ Wolfgang Cramer,¹ Philippe Bousquet,⁴ Wolfgang Buermann,³ Benjamin Smith⁵

A biogeochemical model of vegetation using observed climate data predicts the high northern latitude greening trend over the past two decades observed by satellites and a marked setback in this trend after the Mount Pinatubo volcano eruption in 1991. The observed trend toward earlier spring budburst and increased maximum leaf area is produced by the model as a consequence of biogeochemical vegetation responses mainly to changes in temperature. The post-Pinatubo decline in vegetation in 1992–1993 is apparent as the effect of temporary cooling caused by the eruption. High-latitude CO₂ uptake during these years is predicted as a consequence of the differential response of heterotrophic respiration and net primary production.

Greening of NH was chiefly driven by rising temperature, and the effect of rising atmospheric CO₂ can be ignored.



Role of temperature change - modeling application

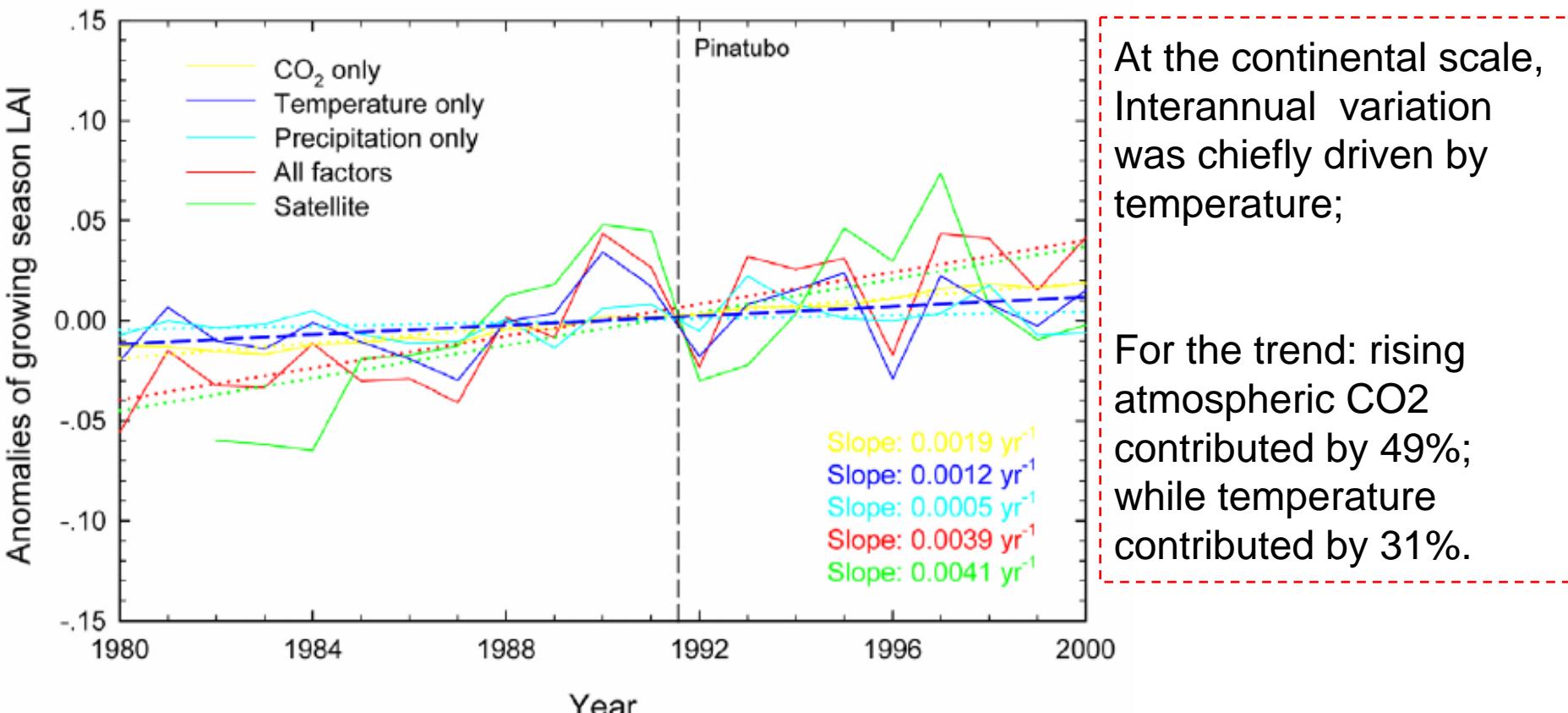
GEOPHYSICAL RESEARCH LETTERS, VOL. 33, LXXXXX, doi:10.1029/2006GL028205, 2006



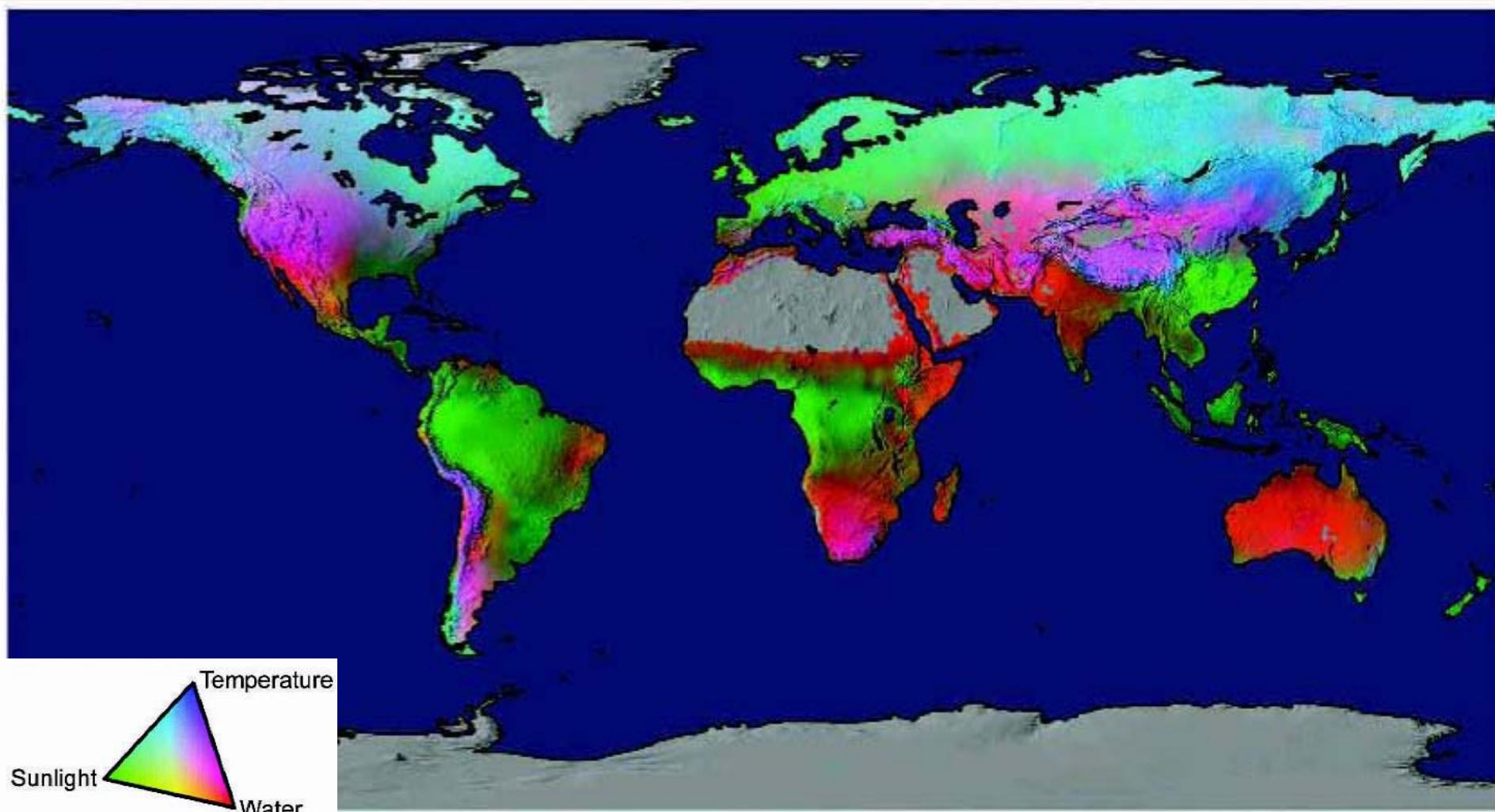
Effect of climate and CO₂ changes on the greening of the Northern Hemisphere over the past two decades

Shilong Piao,¹ Pierre Friedlingstein,¹ Philippe Ciais,¹ Liming Zhou,² and Anping Chen³

Received 18 September 2006; revised 24 October 2006; accepted 27 October 2006; published XX Month 2006.



Potential climate limits to plant growth derived from long-term monthly statistics of minimum temperature, cloud cover and rainfall.

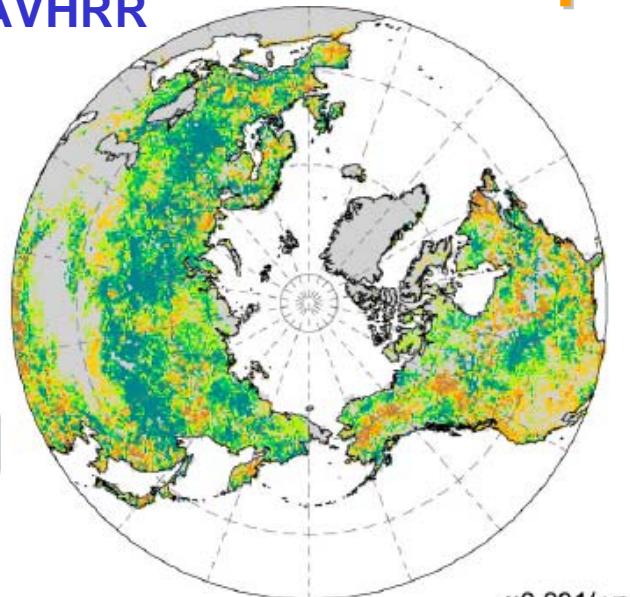


Water = 40%, Temperature = 33%, Radiation = 27%

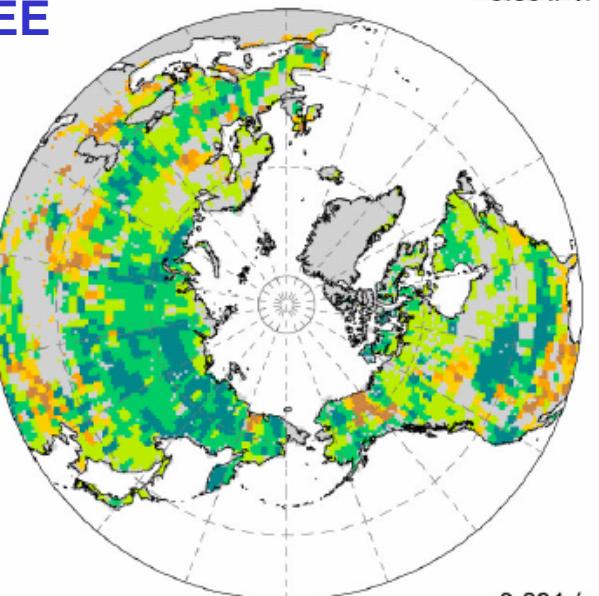
Nemani et al., 2003

Spatial patterns

NOAA/AVHRR

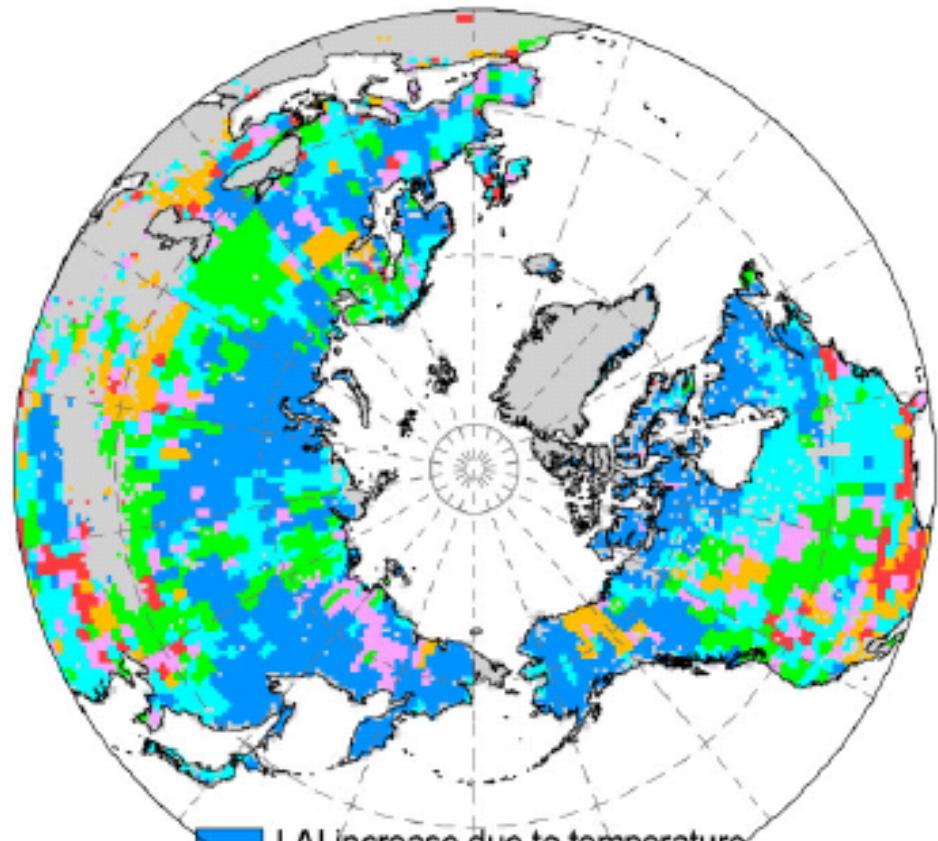


$\times 0.001 / \text{yr}$

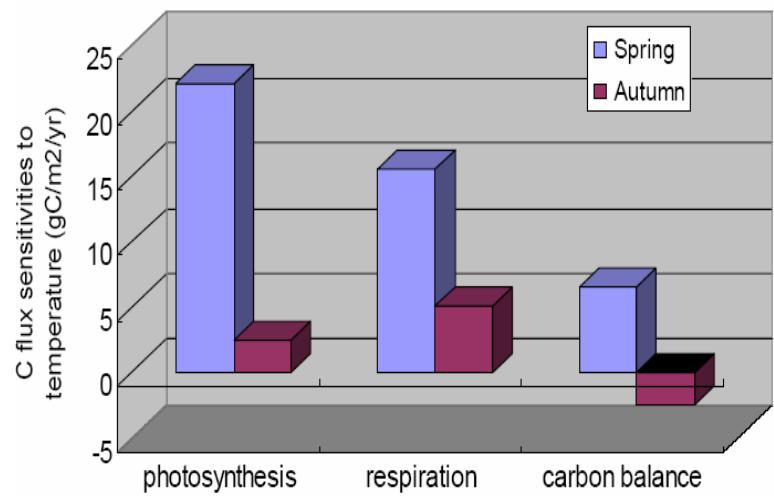
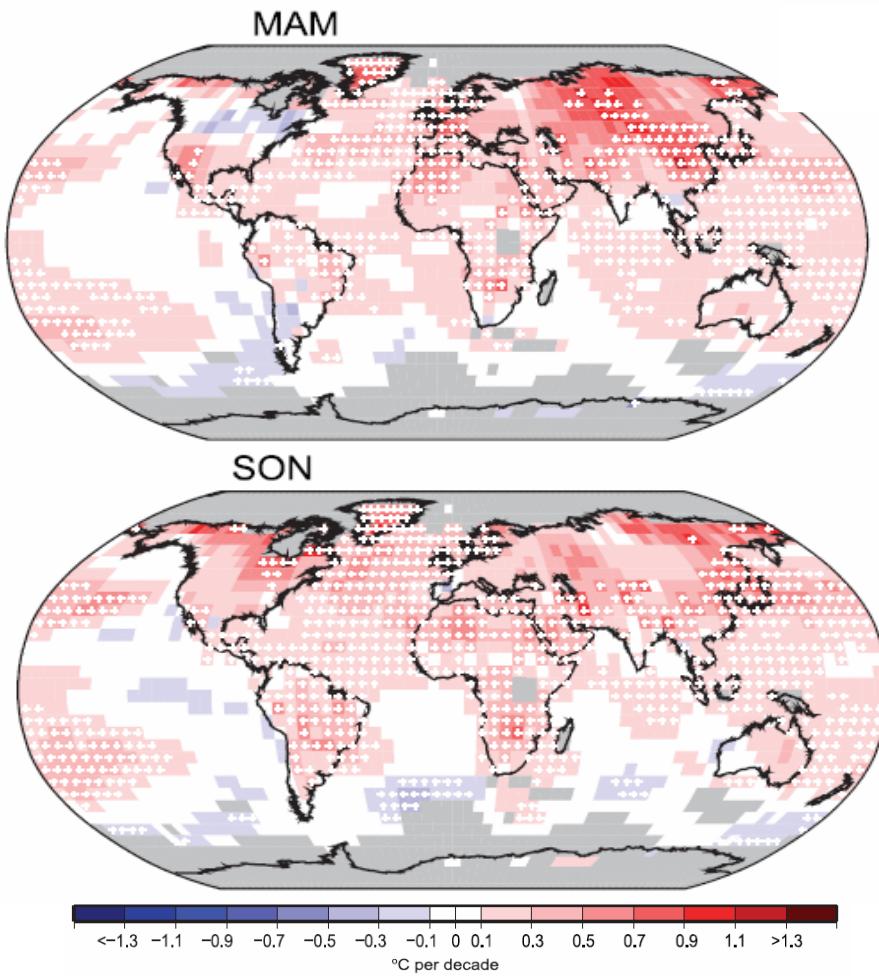


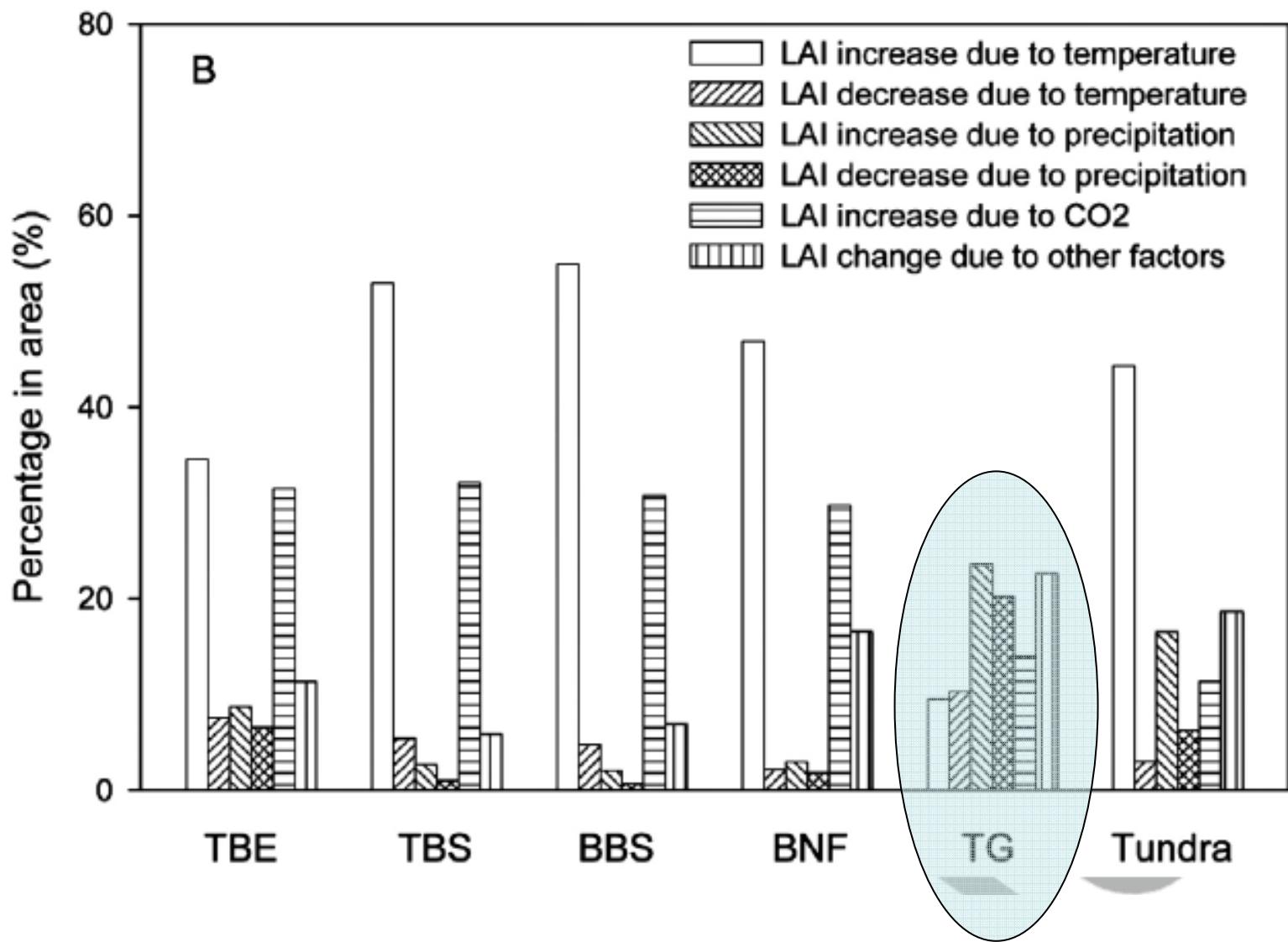
$\times 0.001 / \text{yr}$

<-8 -4 -1 1 4 >8



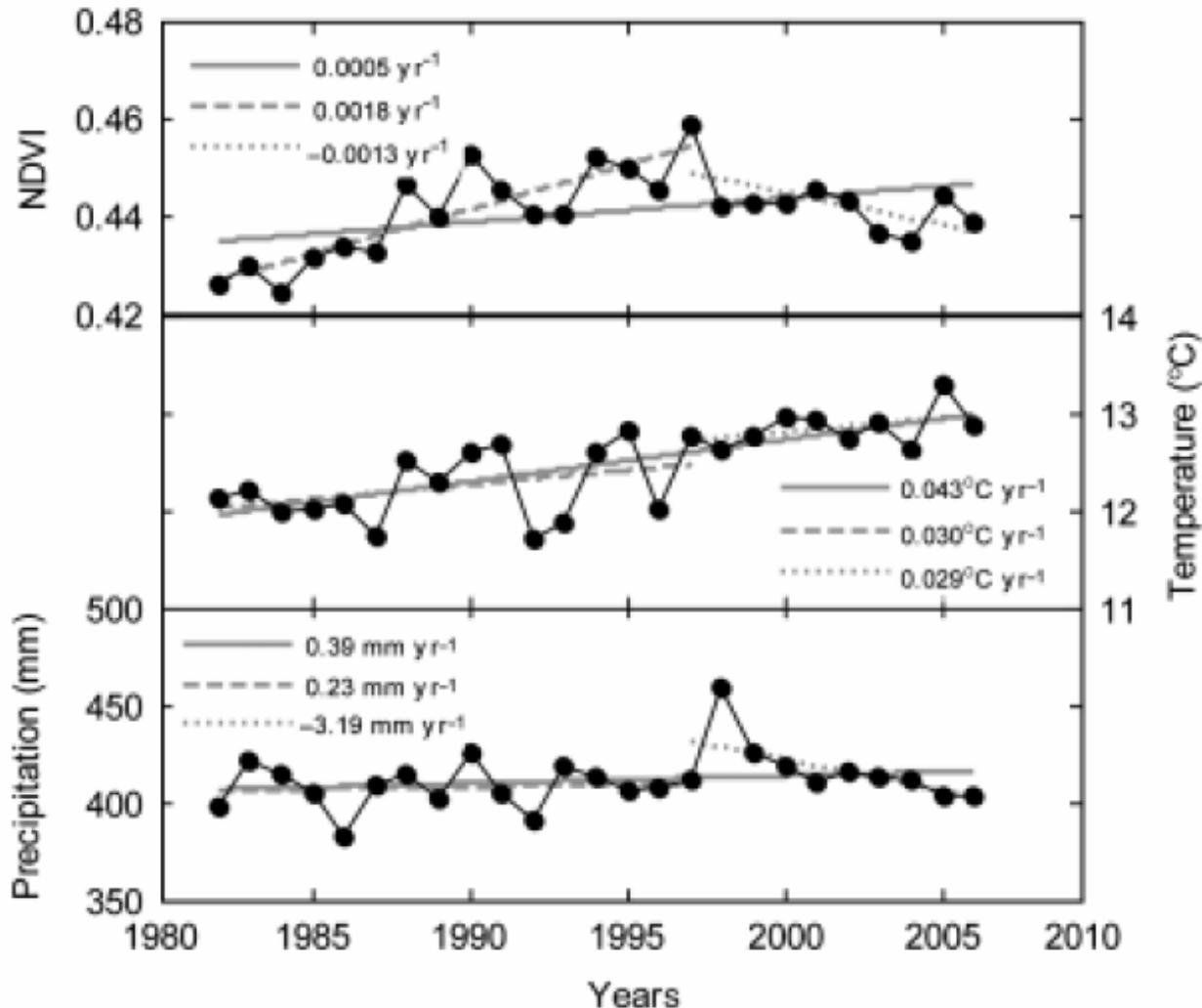
- LAI increase due to temperature
- LAI increase due to precipitation
- LAI increase due to CO₂
- LAI decrease due to temperature
- LAI decrease due to precipitation
- LAI change due to other factors





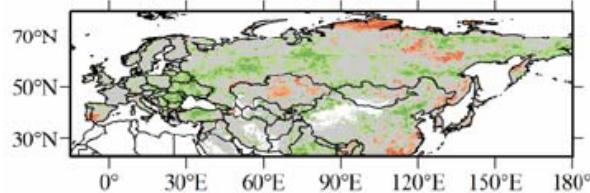
问题： 1980s-1990s显著增加的植被生长趋势最近10年是否还在持续？

生长季(4-10月) NDVI变化趋势

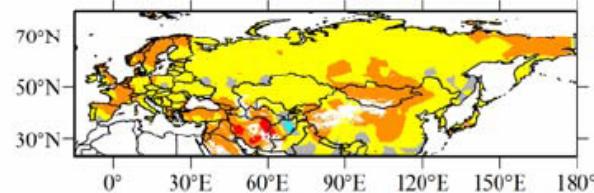


生长季(4-10月) NDVI变化趋势的空间分布

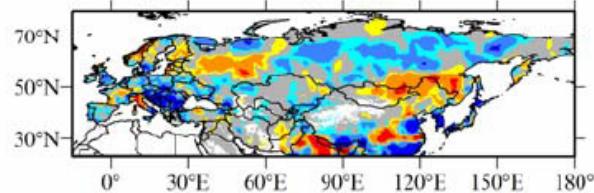
a Growing season NDVI trend during 1982-2006



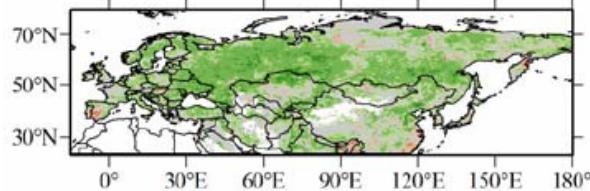
d Growing season temperature trend during 1982-2006



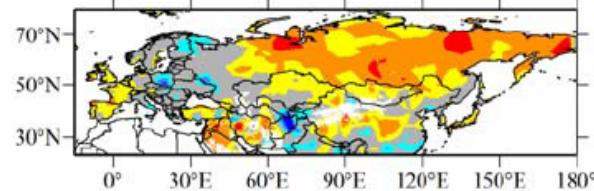
g Growing season precipitation trend during 1982-2006



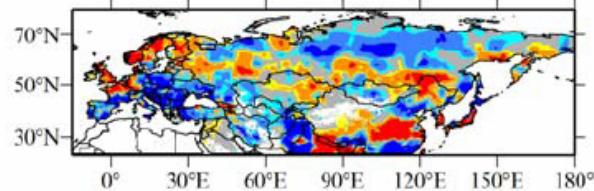
b Growing season NDVI trend during 1982-1997



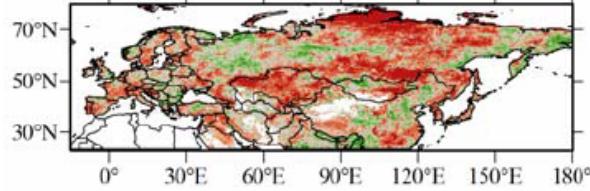
e Growing season temperature trend during 1982-1997



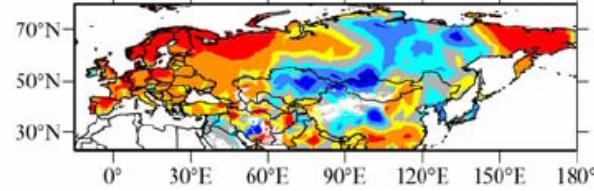
h Growing season precipitation trend during 1982-1997



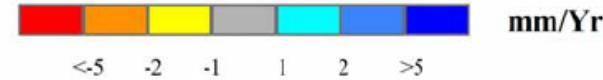
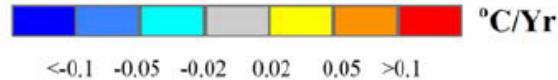
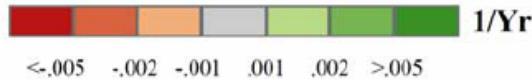
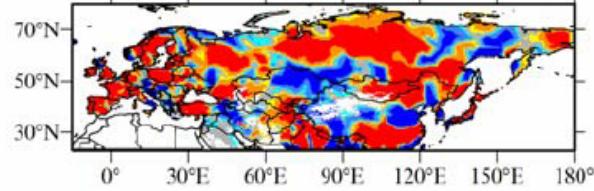
c Growing season NDVI trend during 1997-2006



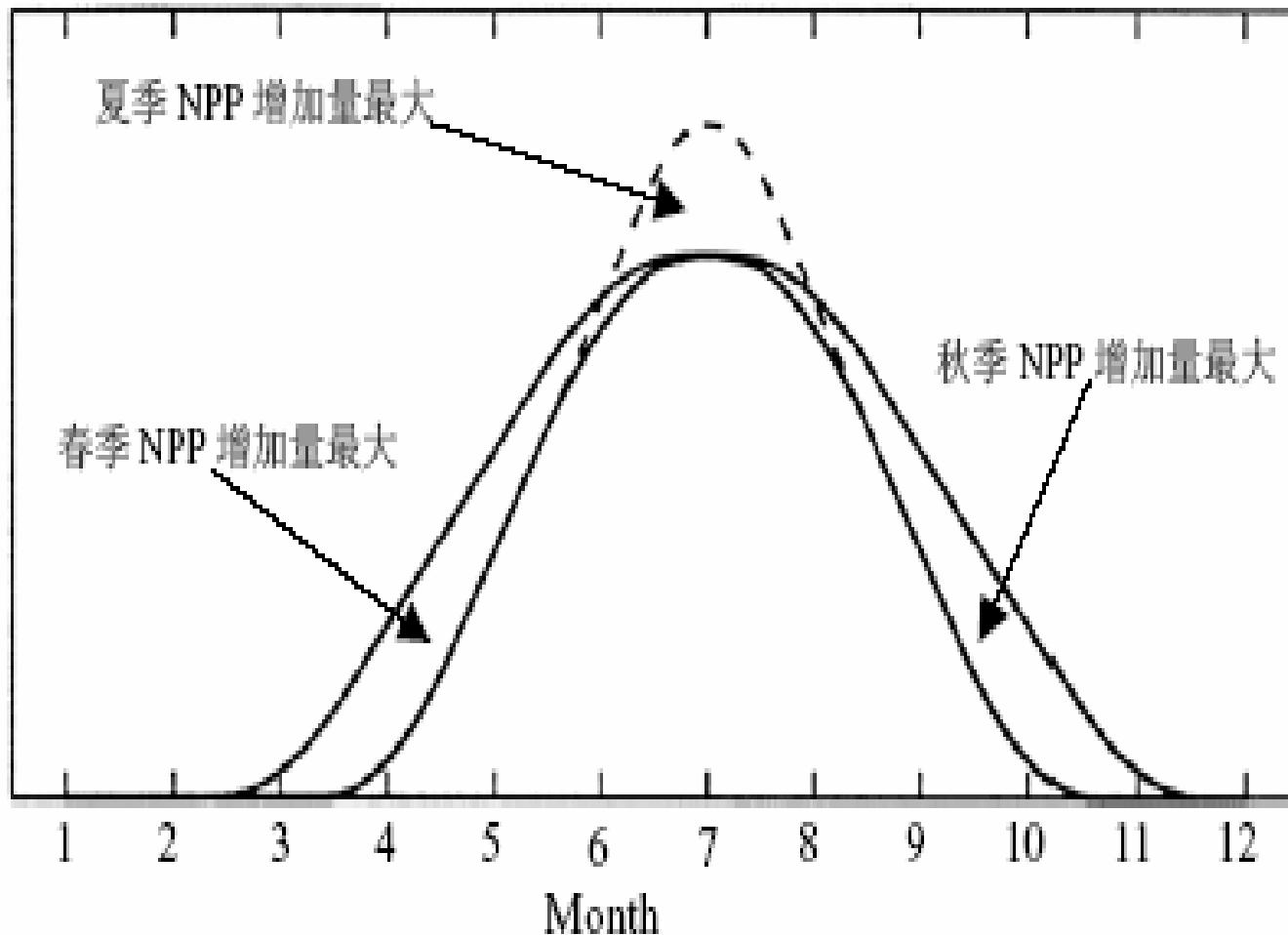
f Growing season temperature trend during 1997-2006



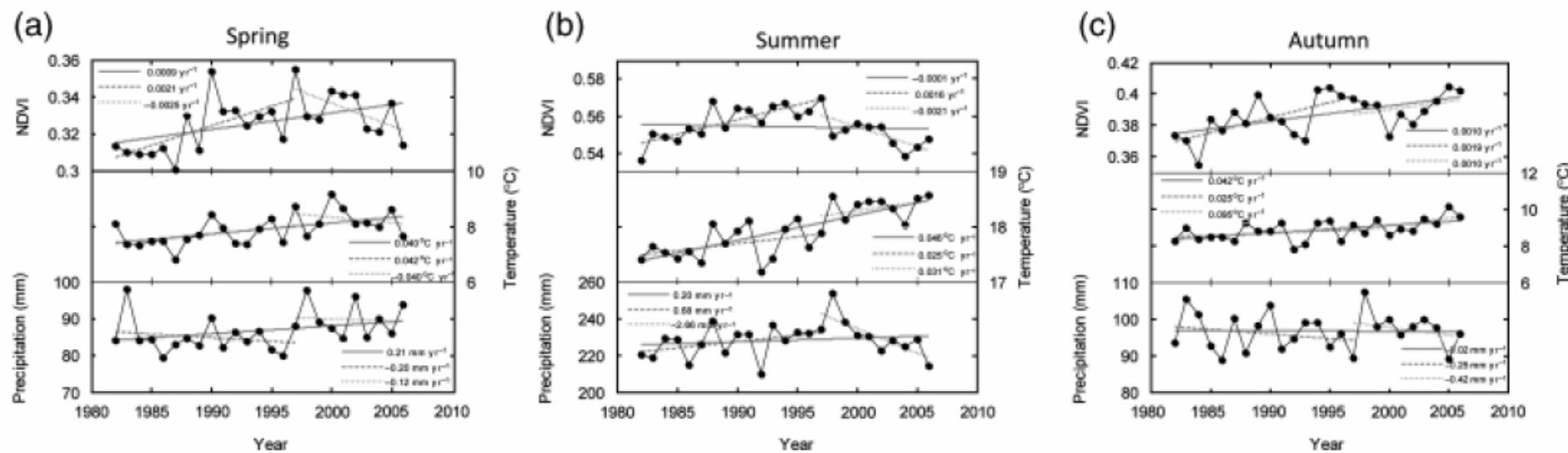
i Growing season precipitation trend during 1997-2006



生长季平均NDVI增加机制

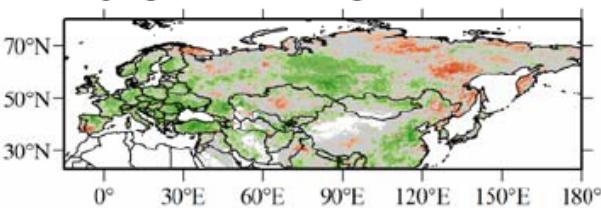


不同季节 NDVI 变化趋势

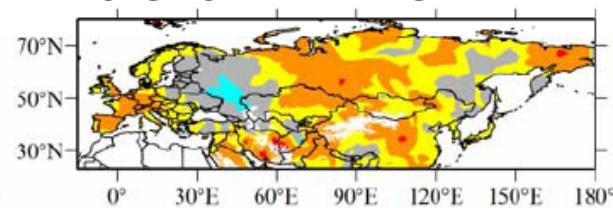


春季 NDVI 变化趋势的空间分布

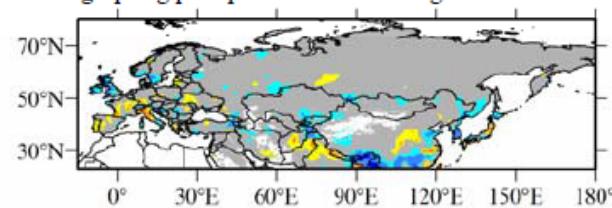
a Spring NDVI trend during 1982-2006



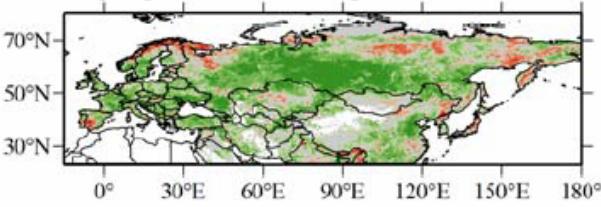
d Spring temperature trend during 1982-2006



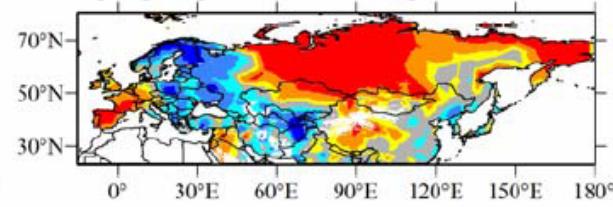
g Spring precipitation trend during 1982-2006



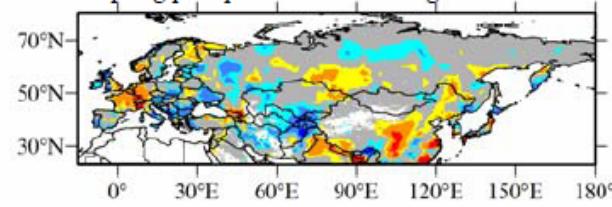
b Spring NDVI trend during 1982-1997



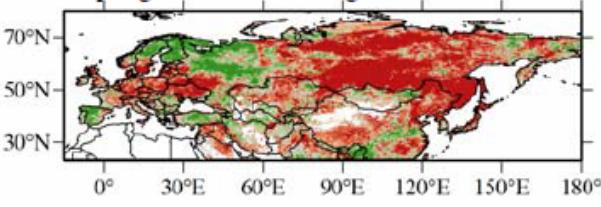
e Spring temperature trend during 1982-1997



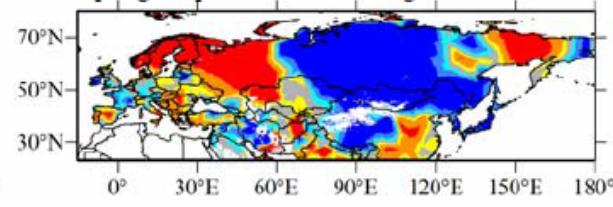
h Spring precipitation trend during 1982-1997



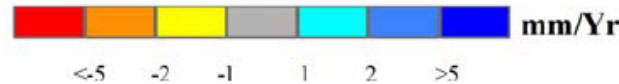
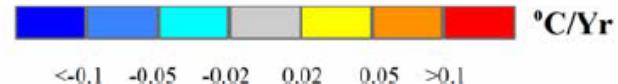
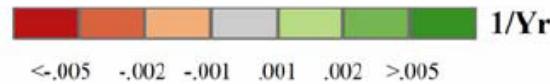
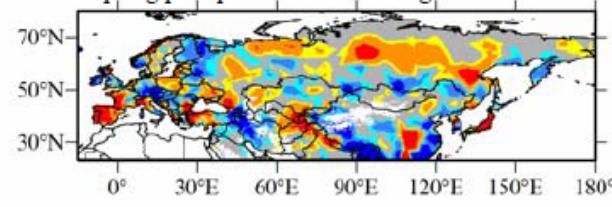
c Spring NDVI trend during 1997-2006



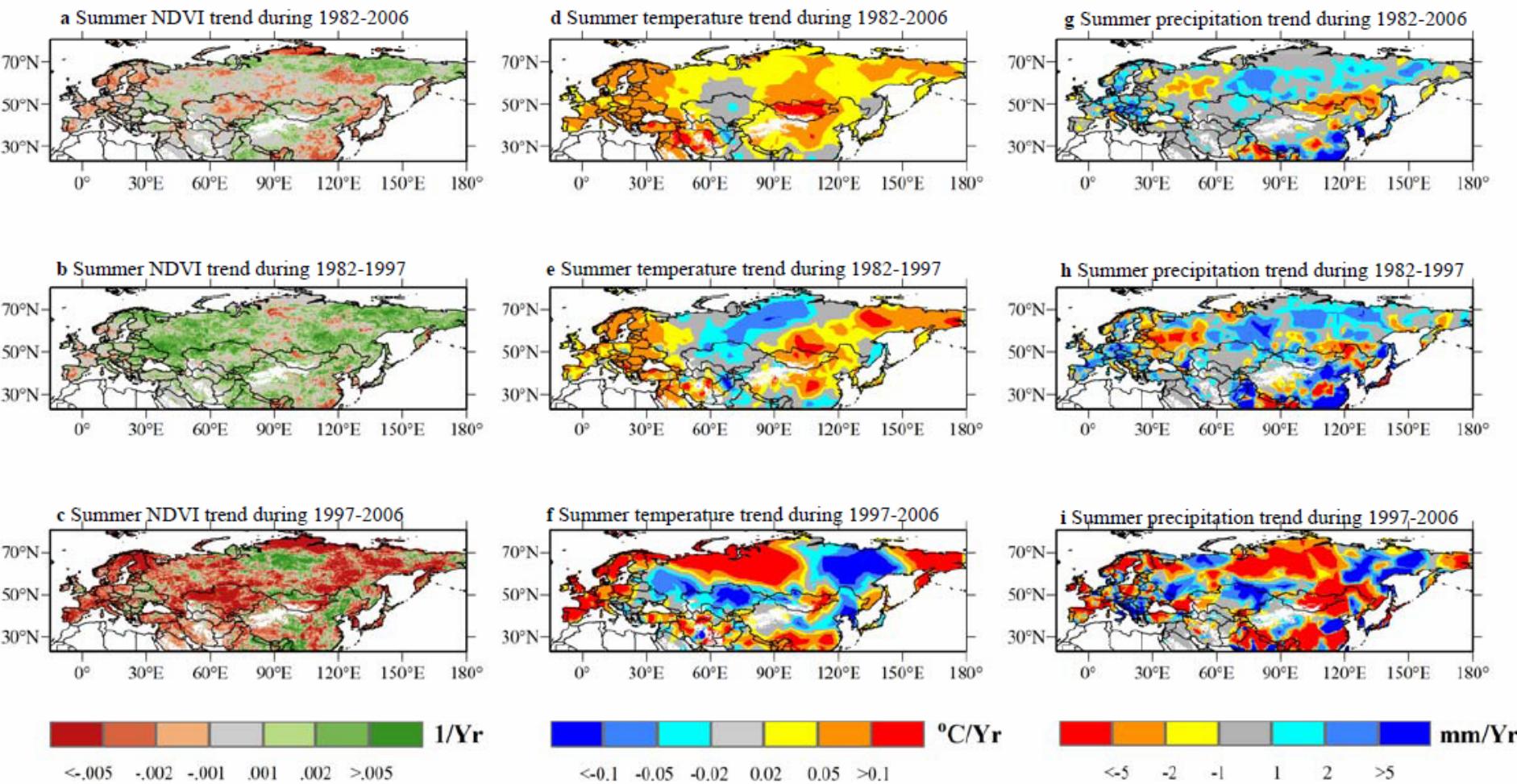
f Spring temperature trend during 1997-2006



i Spring precipitation trend during 1997-2006

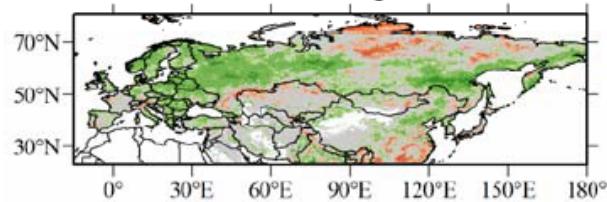


夏季 NDVI 变化趋势的空间分布

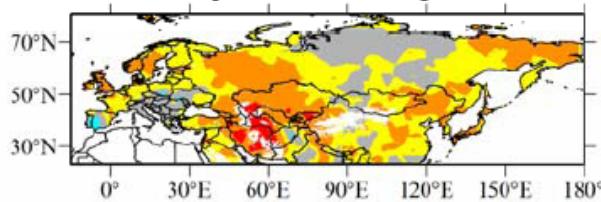


秋季 NDVI 变化趋势的空间分布

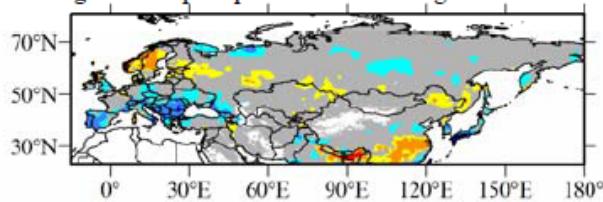
a Autumn NDVI trend during 1982-2006



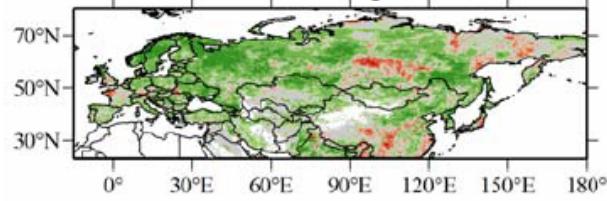
d Autumn temperature trend during 1982-2006



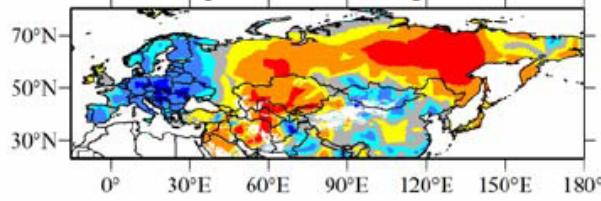
g Autumn precipitation trend during 1982-2006



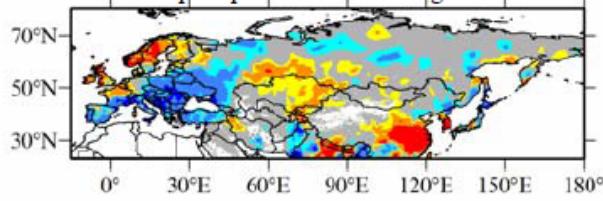
b Autumn NDVI trend during 1982-1997



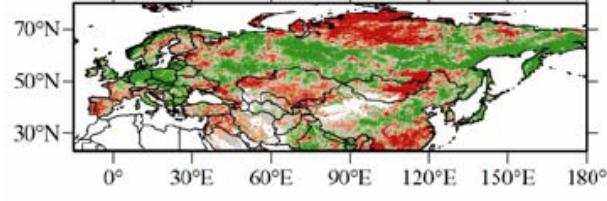
e Autumn temperature trend during 1982-1997



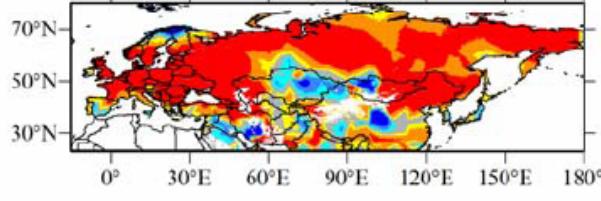
h Autumn precipitation trend during 1982-1997



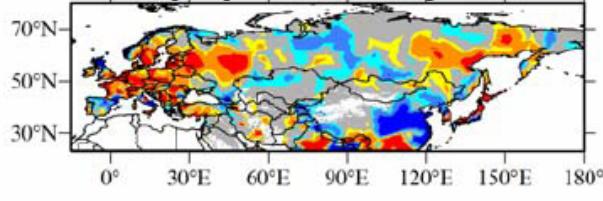
c Autumn NDVI trend during 1997-2006



f Autumn temperature trend during 1997-2006



i Autumn precipitation trend during 1997-2006

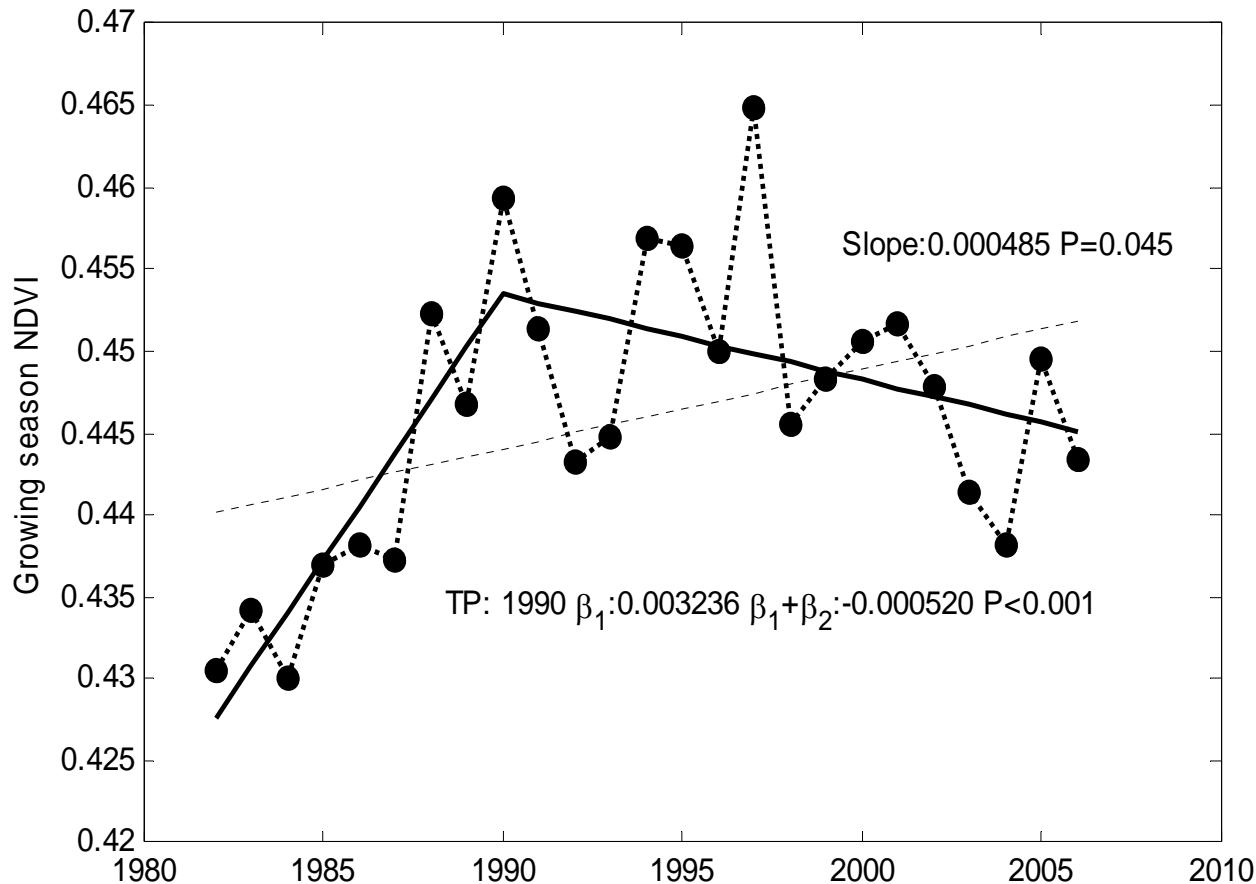


- 1980s-1990s显著增加的植被生长趋势
最近10年发生了变化

- 1980s-1990s显著增加的植被生长趋势
最近10年发生了变化

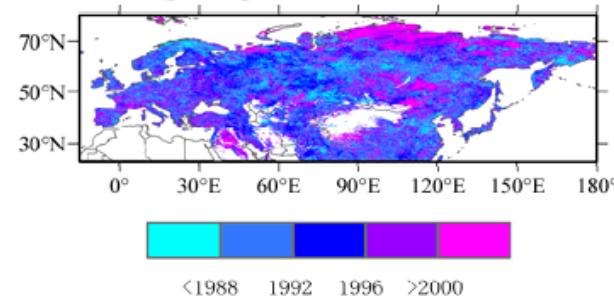
问题：那么什么时候开始发生这一变化？
它的空间变化是怎样？

Piecewise linear regression

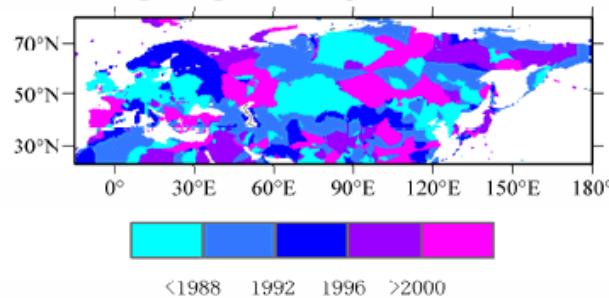


Piecewise linear regression

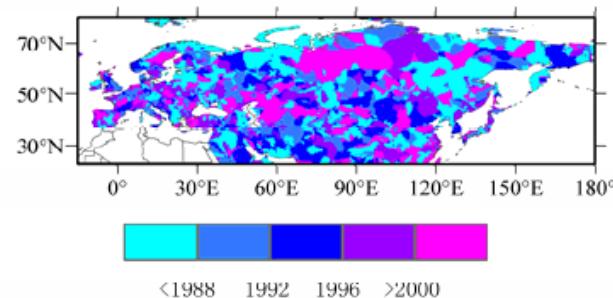
a TP of growing season NDVI



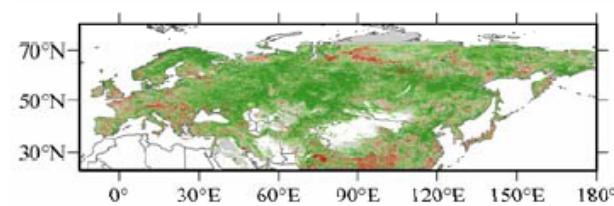
b TP of growing season temperature



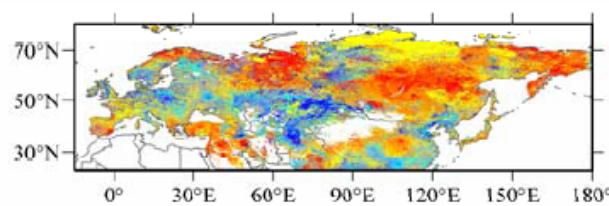
c TP of growing season precipitation



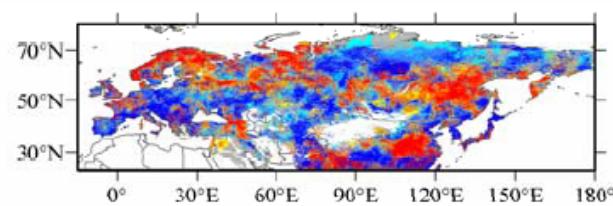
d Growing season NDVI trend before TP of NDVI



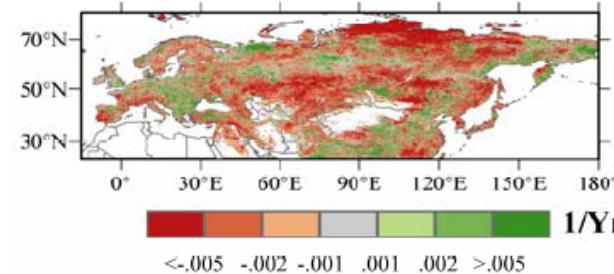
f Growing season temperature trend before TP of NDVI



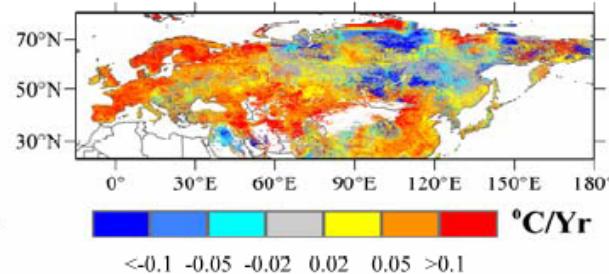
h Growing season precipitation trend before TP of NDVI



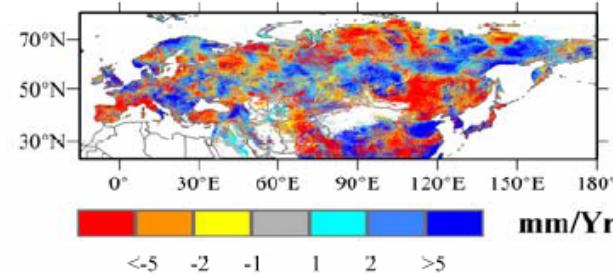
e Growing season NDVI trend after TP of NDVI



g Growing season temperature trend after TP of NDVI



i Growing season precipitation trend after TP of NDVI



Impact of 1998–2002 midlatitude drought and warming on ecosystem and the global carbon cycle

Ning Zeng and Haifeng Qian

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Received 15 September 2005; revised 19 October 2005; accepted 25 October 2005; published 26 November 2

[1] A rare drought occurred from 1998 to 2002 across much of the Northern Hemisphere midlatitude regions. Using observational data and numerical models, we analyze the impact of this event on terrestrial ecosystem and the global carbon cycle. The biological productivity in these regions was found to decrease by 0.9 PgC yr^{-1} or 5% compared to the average of the previous two decades, in conjunction with significantly reduced vegetation greenness. The drought led to a land carbon release that is large enough to significantly modify the canonical tropically dominated ENSO response. An atmospheric inversion

2003. Although the yearly growth was less than during the short-term relaxation with increasing temperature and solar radiation, allowing an upward trend in NPP from the 2001–2003 growth was higher than in 1982 through 1999. The past decade (2000 to 2009) has been the warmest since instrumental measurements began, which could imply continued increases in NPP; however, our estimates suggest a reduction in the global NPP of 0.55 petagrams of carbon. Large-scale droughts have

[3] In the meantime, the reduced regional NPP, and a drying trend in the Southern Hemisphere has decreased NPP in much of the Northern Hemisphere area, counteracting the increased NPP over the Northern Hemisphere. A continued decline in the mean annual precipitation in the Southwest Asia, eastern Europe, and Central America has contributed to the recent increase in the frequency and severity of the region's droughts (Hoerling and Kumar 2002; Hoerling and Kumar 2004). The projected increase in the frequency and severity of the region's droughts (Hoerling and Kumar 2002; Hoerling and Kumar 2004) is expected to further reduce regional NPP, and a drying trend in the Southern Hemisphere has decreased NPP in much of the Northern Hemisphere area, counteracting the increased NPP over the Northern Hemisphere. A continued decline in the mean annual precipitation in the Southwest Asia, eastern Europe, and Central America has contributed to the recent increase in the frequency and severity of the region's droughts (Hoerling and Kumar 2002; Hoerling and Kumar 2004). The projected increase in the frequency and severity of the region's droughts (Hoerling and Kumar 2002; Hoerling and Kumar 2004)

Maosheng Zhao* and Steven W. Running

(C5) 8-day composite 1-km fraction of photosynthetically active radiation (FPAR) and leaf area index (LAI) data from the MODIS sensor (9) as remotely sensed vegetation property dynamic inputs to the algorithm. Data gaps in the 8-day temporal MODIS FPAR/LAI caused by cloudiness were filled with information from accompanying quality-assessment fields (SOM text S2) (10). For daily meteorological data required to drive the algorithm, we used a reanalysis data set from National Center for Environmental Prediction (NCEP) (SOM text S3) (11). A Palmer Drought Severity Index (PDSI) (12) at 0.5° resolution was used as a surrogate of soil moisture (13) to measure environmental water stress by combining information from both evaporation and precipitation (SOM text S4). A lower PDSI generally implies a drier climate.

Drier summers cancel out the CO₂ uptake enhancement induced by warmer springs

A. Angert*, S. Biraud*, C. Bonfils*, C. C. Henning*, W. Buermann*, J. Pinzon*, C. J. Tucker*, and I. Fung*

*Berkeley Atmospheric Sciences Center, University of California, Berkeley, CA 94720-4767; and ^aNational Aeronautics and Space Administration/Goddard Space Flight Center, Greenbelt, MD 20771

Edited by Christopher B. Field, Carnegie Institution of Washington, Stanford, CA, and approved June 14, 2005 (received for review March 1, 2005)

An increase in photosynthetic activity of the northern hemisphere terrestrial vegetation, as derived from satellite observations, has been reported in previous studies. The amplitude of the seasonal cycle of the annually detrended atmospheric CO₂ in the northern hemisphere (an indicator of biospheric activity) also increased during that period. We found, by analyzing the annually detrended CO₂ record by season, that early summer (June) CO₂ concentrations indeed decreased from 1985 to 1991, and they have continued to decrease from 1994 up to 2002. This decrease indicates accelerating springtime net CO₂ uptake. However, the CO₂ minimum concentration in late summer (an indicator of net growing-season uptake) showed no positive trend since 1994, indicating that lower net CO₂ uptake during summer cancelled out the enhanced uptake during spring. Using a recent satellite normalized difference vegetation index data set and climate data, we show that this lower summer

CO₂ concentration time series. The first is the atmospheric CO₂ concentration in early summer (June), which is indicative of net CO₂ uptake (photosynthesis CO₂ uptake minus the CO₂ release from heterotrophic respiration and biomass burning) in spring. The second indicator is the CO₂ seasonal minimum concentration, which is reached in late summer and indicates net CO₂ uptake during the growing season (March through August). These two indicators will be referred to onward as "net spring CO₂ uptake" and "net growing-season CO₂ uptake," respectively. They have been calculated after Thoning *et al.* (10) by using monthly zonal concentrations from the GLOBALVIEW (11) "reference marine boundary layer matrix" (12) from 1985 onward [when the number of operating CO₂ stations was sufficient to allow robust study of interannual variations (13)]. The values of the two indicators were then averaged for the entire

Europe-wide reduction in primary productivity caused by the heat and drought in 2003

Ph. Ciais¹, M. Reichstein^{2,3}, N. Viovy¹, A. Granier⁴, J. Ogée⁵, V. Allard⁶, M. Aubinet⁷, N. Buchmann⁸, Chr. Bernhofer⁹, A. Carrara¹⁰, F. Chevallier¹, N. De Noblet¹, A. D. Friend¹, P. Friedlingstein¹, T. Grünwald⁹, B. Heinesch⁷, P. Kerone¹¹, A. Knöhl^{12,13}, G. Krinner¹⁴, D. Loustau⁵, G. Manca^{2,†}, G. Matteucci^{15,†}, F. Miglietta¹⁶, J. M. Ourcival¹⁷, D. Papale², K. Pilegaard¹⁸, S. Rambal¹⁷, G. Seufert¹⁵, J. F. Soussana⁶, M. J. Sanz¹⁰, E. D. Schulze¹², T. Vesala¹¹ & R. Valentini²

Future climate warming is expected to enhance plant growth in temperate ecosystems and to increase carbon sequestration^{1,2}. But

ecosystem respiration (TER) are separated from CO₂ net fluxes (net ecosystem exchange, NEE), using the same method for each

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Published online 29 October 2010 | Nature | doi:10.1038/news.2010.571

News: Explainer

Drought strikes the Amazon rainforest again

Climate change may explain why history is repeating itself in Brazil.

Jeff Tollefson

Five years ago, vast areas of the Amazon were hammered by a historic drought, which destroyed trees, impacted the livelihoods of fishermen and others who are dependent on the river and presented scientists with what was seen as a rare opportunity to investigate the world's largest



A severe drought is affecting the Amazon for the second time in five years.

Stories by subject

- Earth & Environment
- Developing world
- Ecology

Stories by keywords

- Amazon
- Remote sensing
- Ecology
- Climate change
- Global warming

This article elsewhere

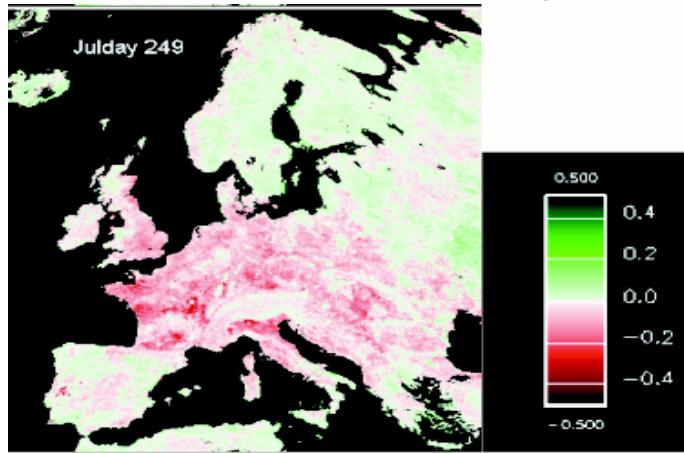
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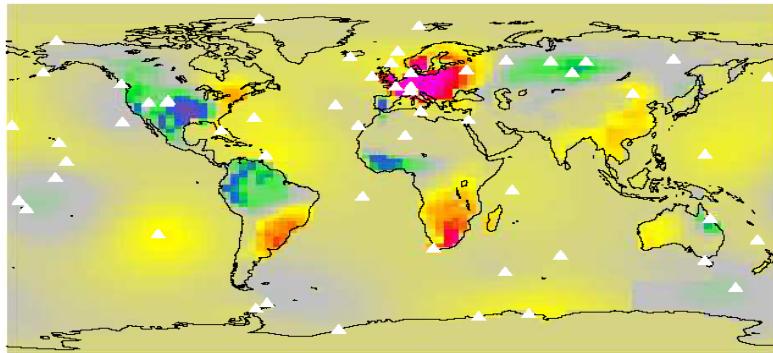
Year 2003 in Europe

The largest productivity crash of the past 100 years

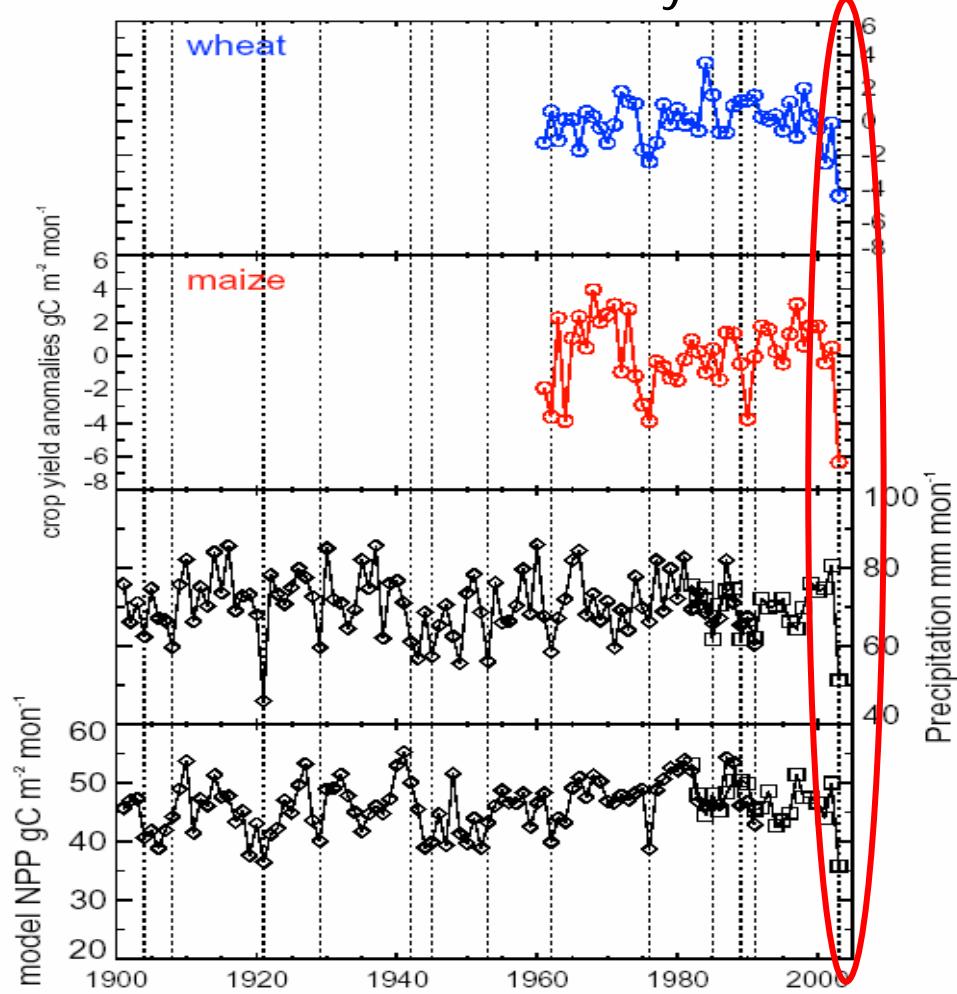
fAPAR Anomaly



CO₂ Anomaly

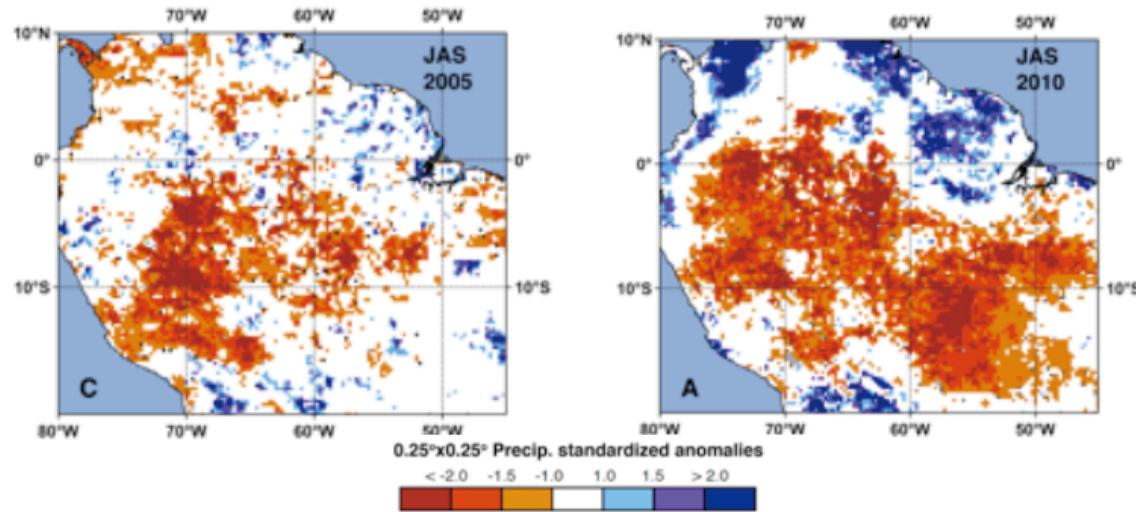


Plant Productivity

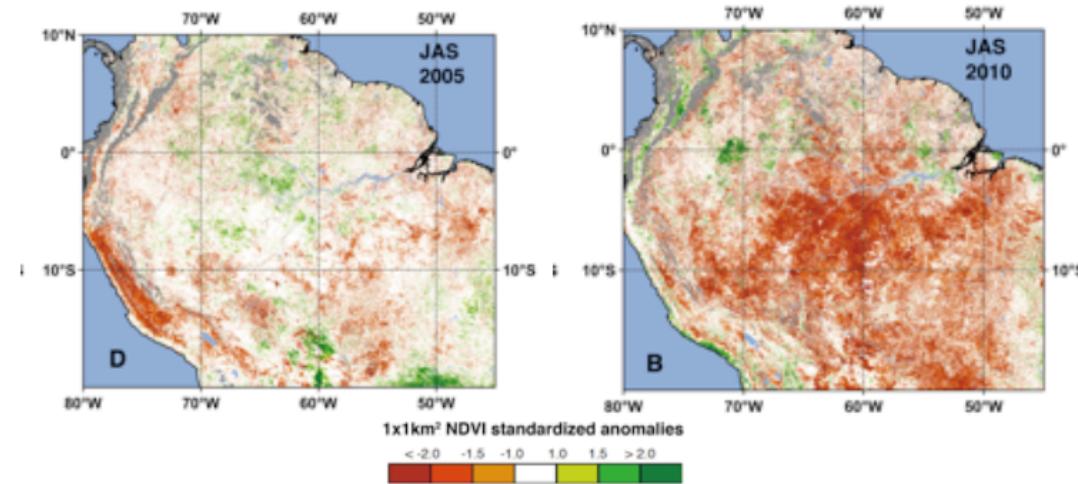


Ciais et al. 2005, Peylin et al., unpublished

Precipitation Anomalies



MODIS Normalized Difference Vegetation Index Anomalies



问题：最近十年的植被生长下降只取决于干旱？

Decline in vegetation growth over the last decade

Drier summers cancel out the CO₂ uptake enhancement induced by warmer springs

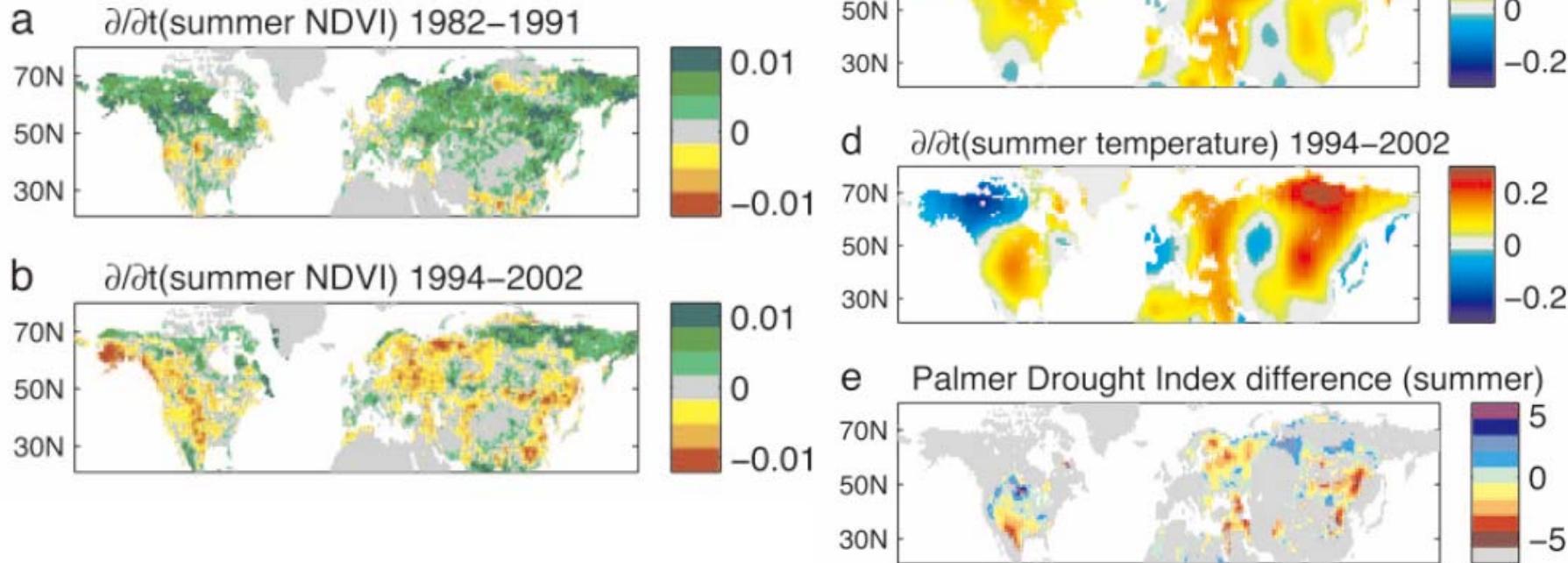
A. Angert*, S. Biraud*, C. Bonfill*, C. C. Henning*, W. Buermann*, J. Pinzon*, C. J. Tucker*, and I. Fung*

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CO₂ concentration time series. The first is the atmospheric CO₂ concentration in early summer (June), which is indicative of net CO₂ uptake (photosynthesis CO₂ uptake minus the CO₂ release from heterotrophic respiration and biomass burning) in spring. The second indicator is the CO₂ seasonal minimum concentration, which is reached in late summer and indicates net CO₂ uptake during the growing season (March through August). These two indicators will be referred to hereafter as "first series."



Decline in vegetation growth over the last decade

Drier summers cancel out the CO₂ uptake enhancement induced by warmer springs

A. Angert*, S. Biraud*, C. Bonfill*, C. C. Henning*, W. Buermann*, J. Pinzon*, C. J. Tucker*, and I. Fung*

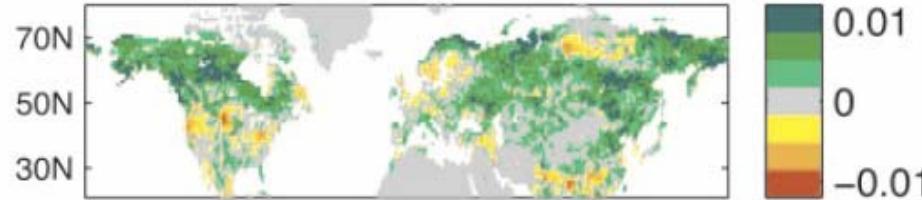
*Berkeley Atmospheric Sciences Center, University of California, Berkeley, CA 94720-4767; and *National Aeronautics and Space Administration/Goddard Space Flight Center, Greenbelt, MD 20771

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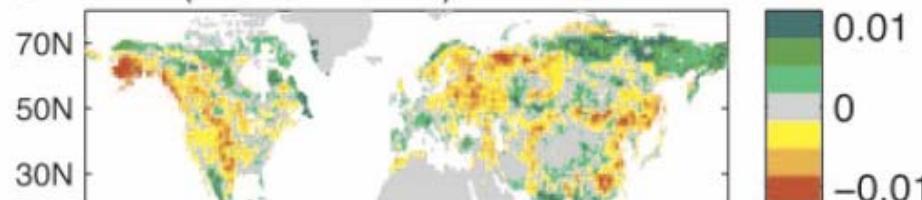
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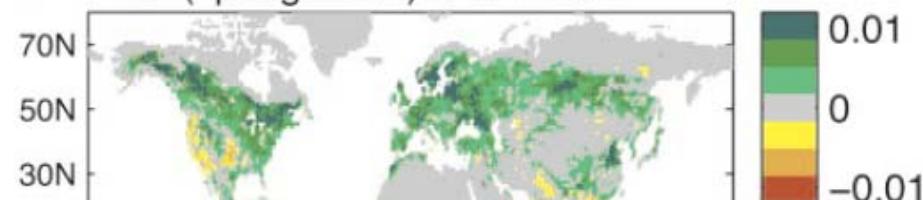
a $\partial/\partial t(\text{summer NDVI})$ 1982–1991



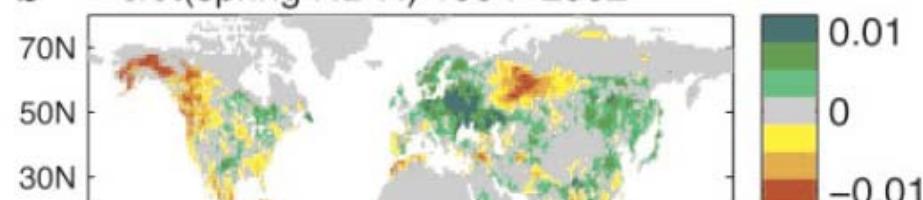
b $\partial/\partial t(\text{summer NDVI})$ 1994–2002



a $\partial/\partial t(\text{spring NDVI})$ 1982–1991

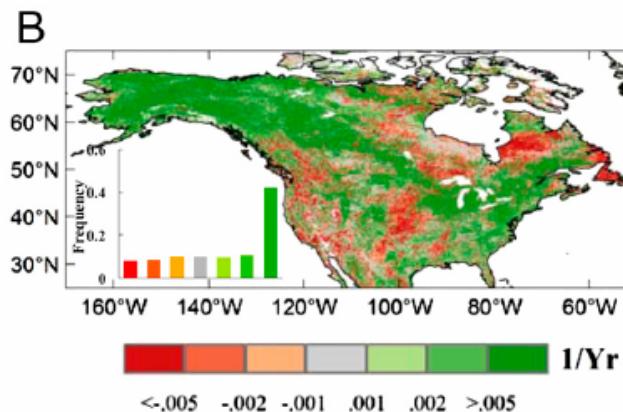


b $\partial/\partial t(\text{spring NDVI})$ 1994–2002

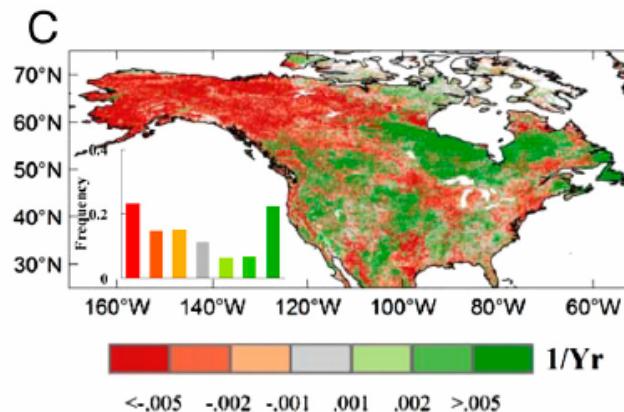


Trend in spring vegetation growth and temperature

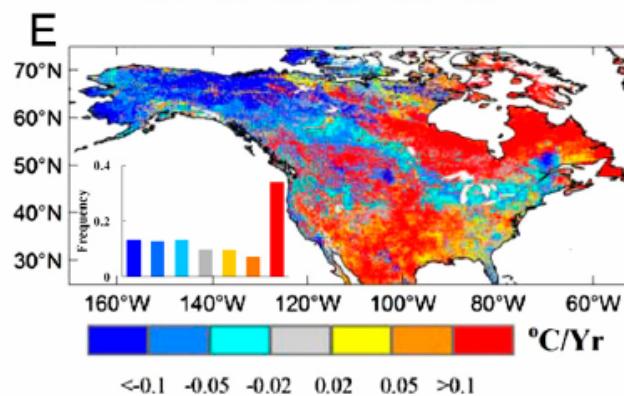
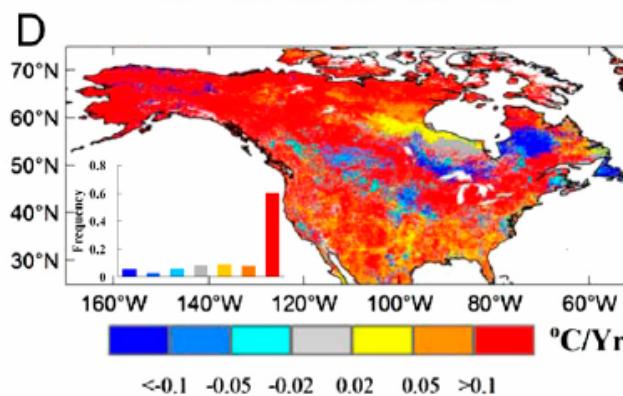
Before TP



After TP



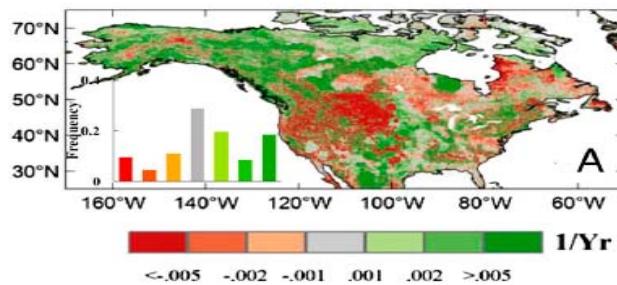
Spring
NDVI



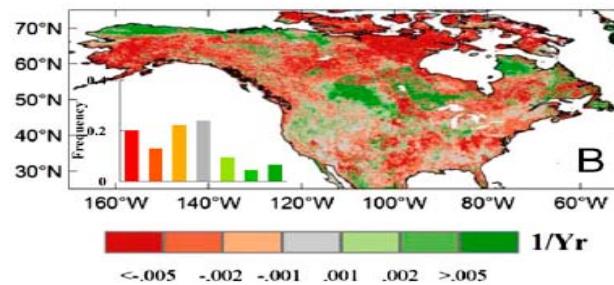
Spring
Temperature

Trend in summer vegetation growth

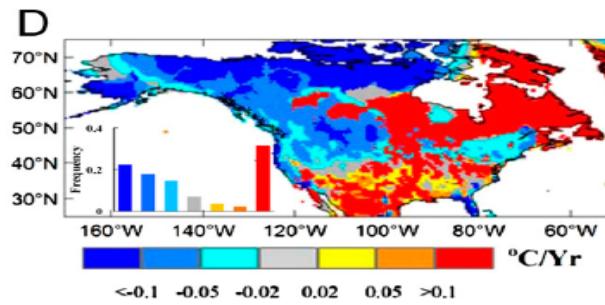
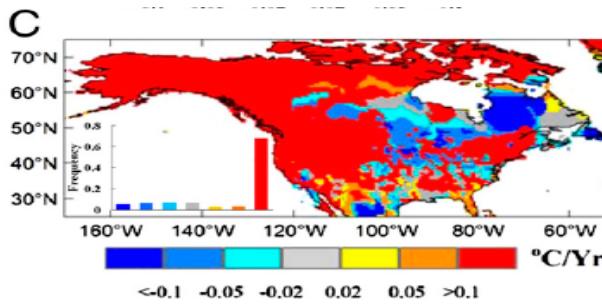
Before TP



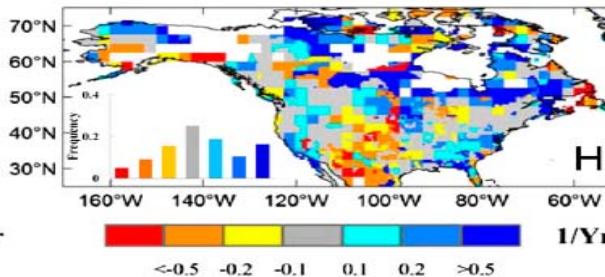
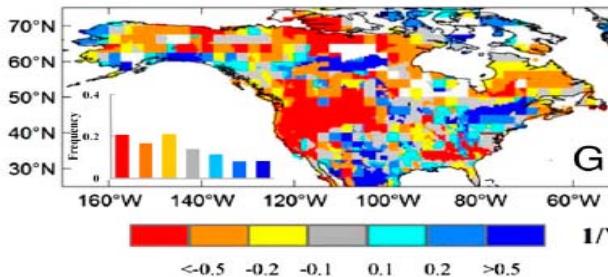
After TP



Summer
NDVI

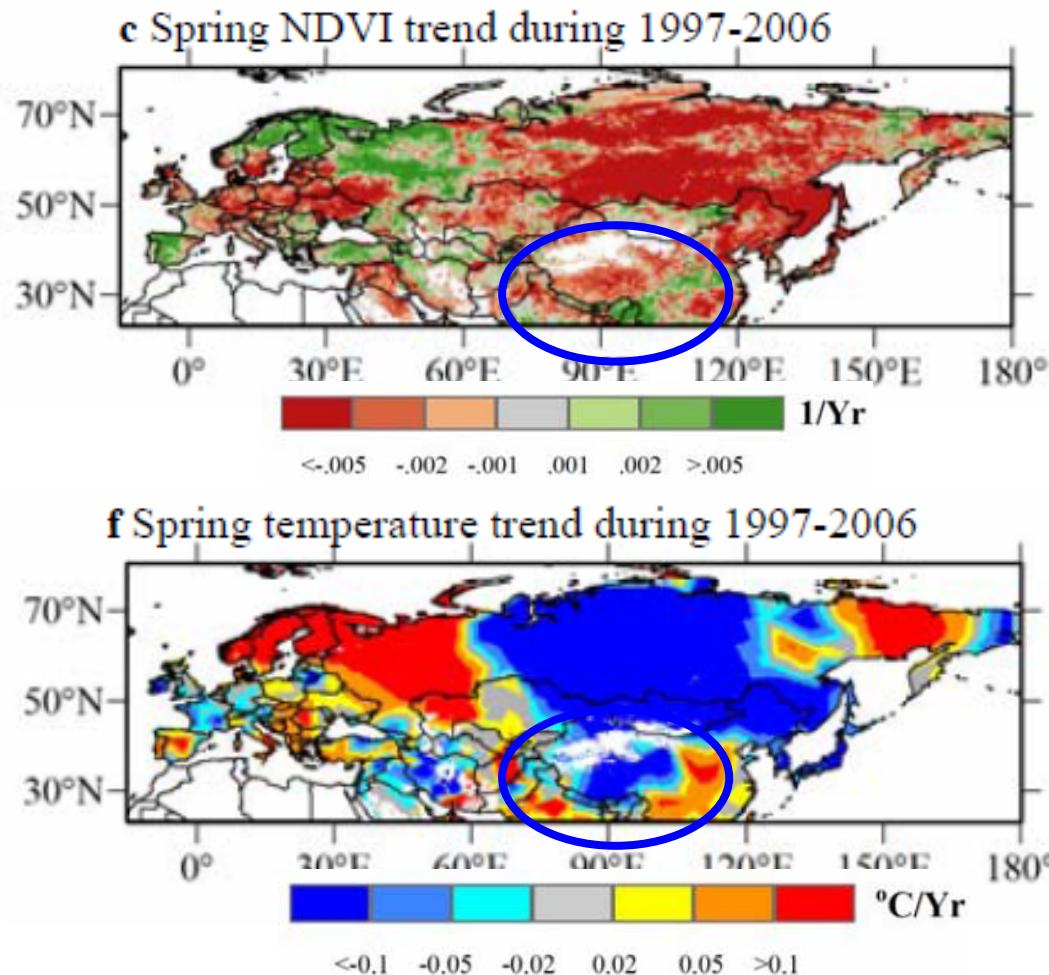


Spring
temperature



Summer
PDSI

Decline in spring vegetation growth due to cooling



Spring phenology change in Qinghai-Xizang

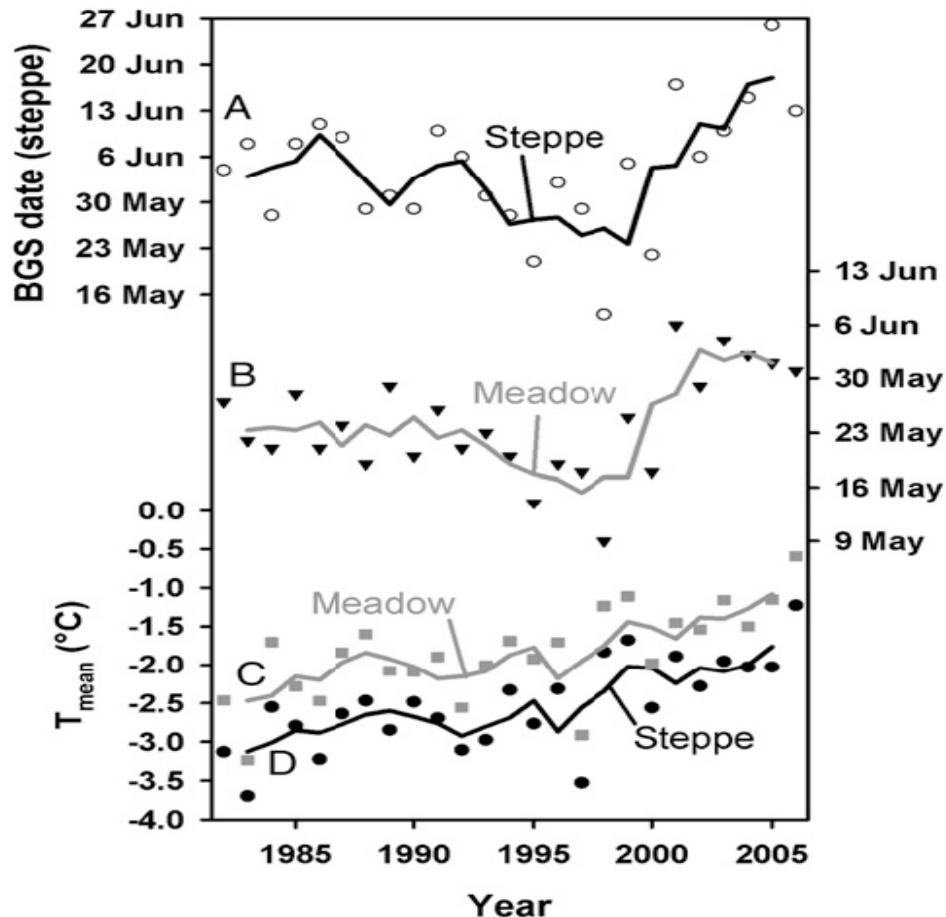
Winter and spring warming result in delayed spring phenology on the Tibetan Plateau

Haiying Yu^{a,b}, Eike Luedeling^c, and Jianchu Xu^{a,b,1}

^aKey Laboratory of Biodiversity and Biogeography, Kunming Institute of Botany, Chinese Academy of Sciences, Kunming 650204, China; ^bWorld Agroforestry Centre, East-Asia Program, Kunming 650204, China; and ^cWorld Agroforestry Centre, Giri, Nairobi 00100, Kenya

Edited by F.

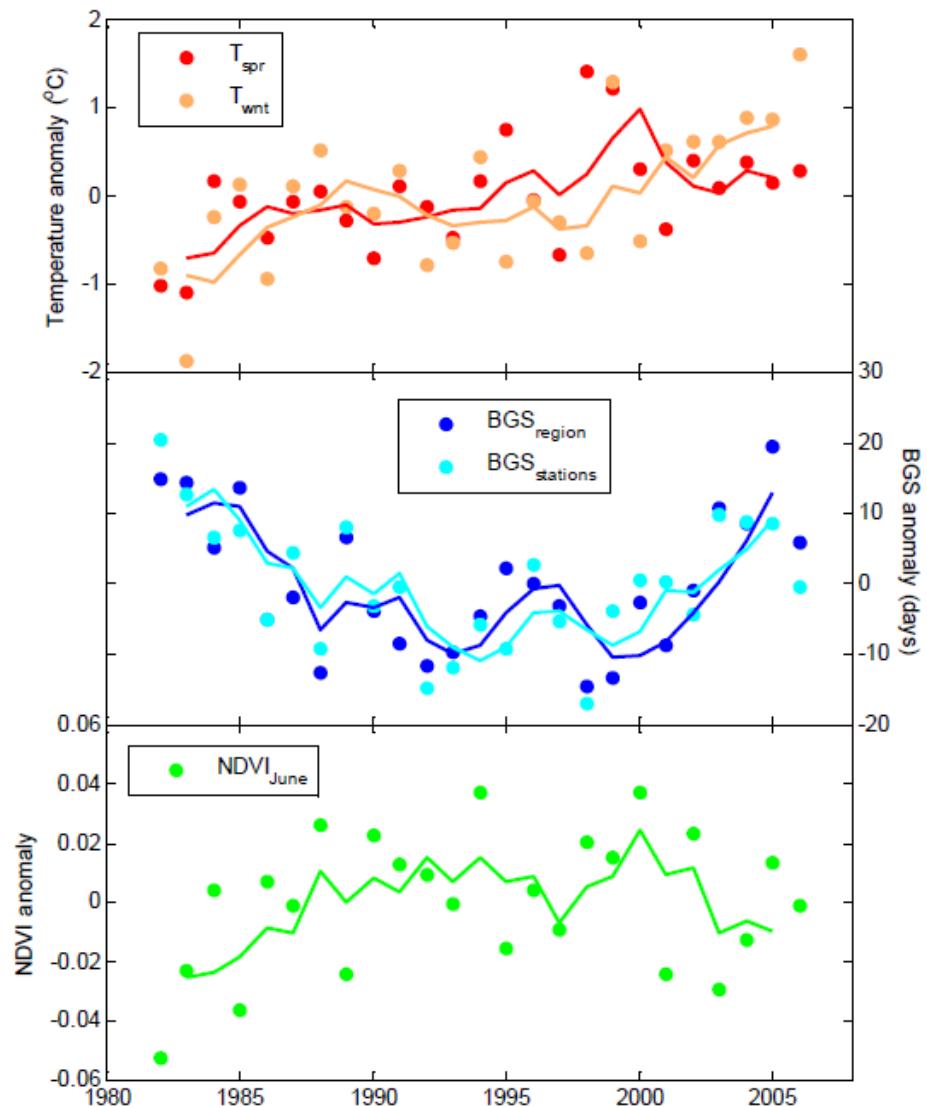
Climate change species. The slow the full phenology regions that characterize this hypothesis. Index ratio the growth Tibetan Plateau correlated



August 23, 2010

nset of spring phases. The large have shown advancing phenology effects of rising spring temperatures ies that are particularly sensitive ose at high latitudes or altitudes m those in more temperate climat are experiencing particularly recent remote sensing analysis of Northern latitudes found a delay-

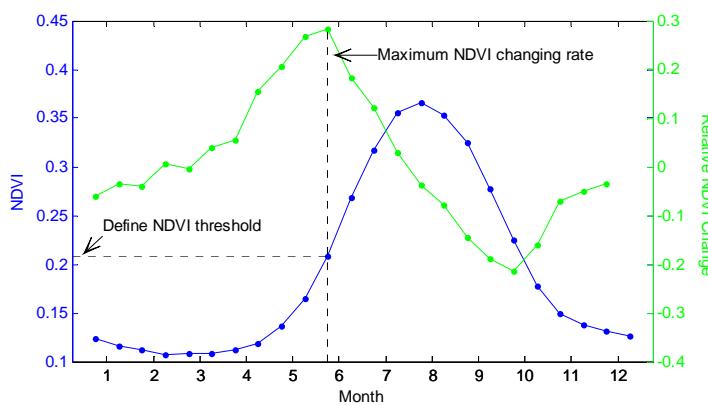
Spring phenology change in Qinghai-Xizang



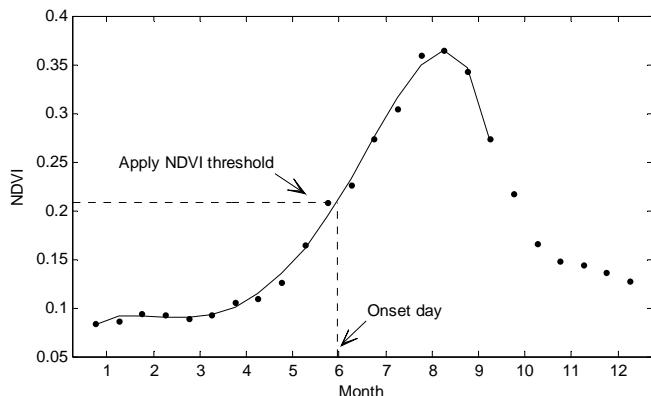
如果**1998-2006**年的冬季温度上升导致该地区物候推迟的话，为什么**1998年之前**，春季物候提前？

Spring phenology change in Qinghai-Xizang

Method to detect changes in the vegetation green-up date



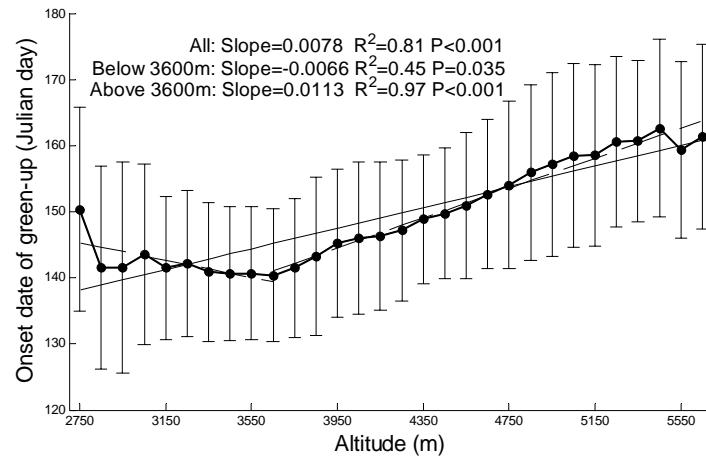
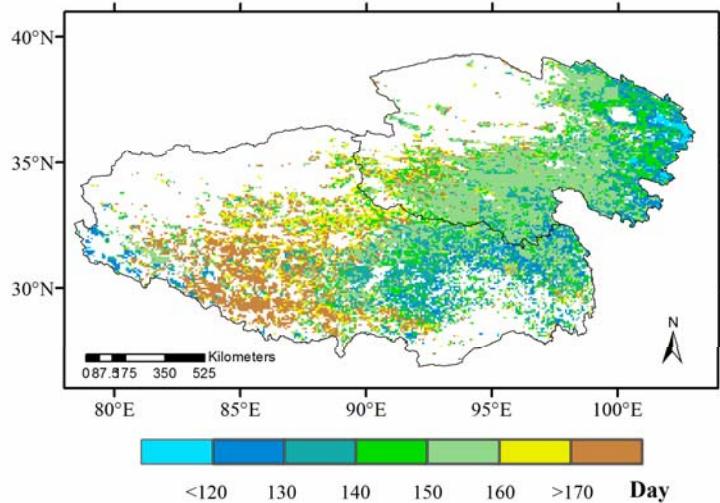
- Firstly, we calculate the averaged annual NDVI time series curve during 1982-2006 to determine the NDVI threshold of vegetation green-up in each pixel.
- The threshold over 1982-2006 is defined as the NDVI value with the highest positive relative NDVI seasonal change;



- We performed a least square regression analysis between NDVI data and the corresponding day of year (Julian day)
- Finally, the annual green-up date is calculated as the day when interpolated daily NDVI crosses the corresponding threshold upwards .

Spring phenology change in Qinghai-Xizang

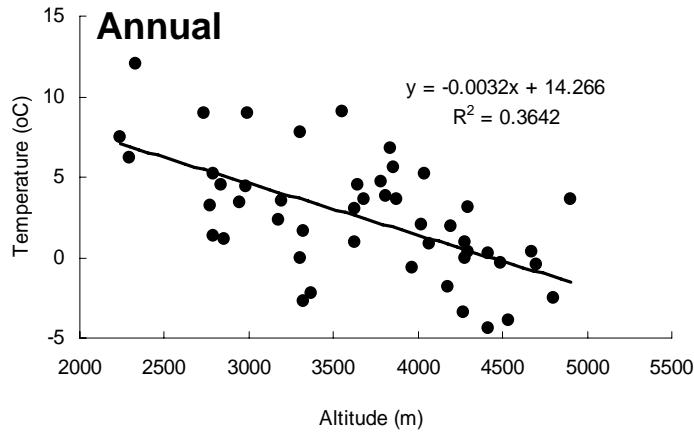
Spring vegetation green-up date vs. altitude



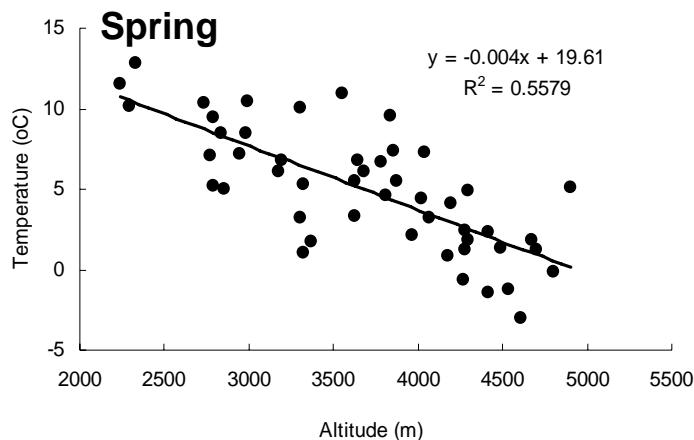
- Spatial patterns of spring vegetation green up date closely linked with altitude.
- Across the Plateau, in response to increase in elevation by 100m, the green-up date delays by **0.8 days**.

Spring phenology change in Qinghai-Xizang

Temperature vs. altitude



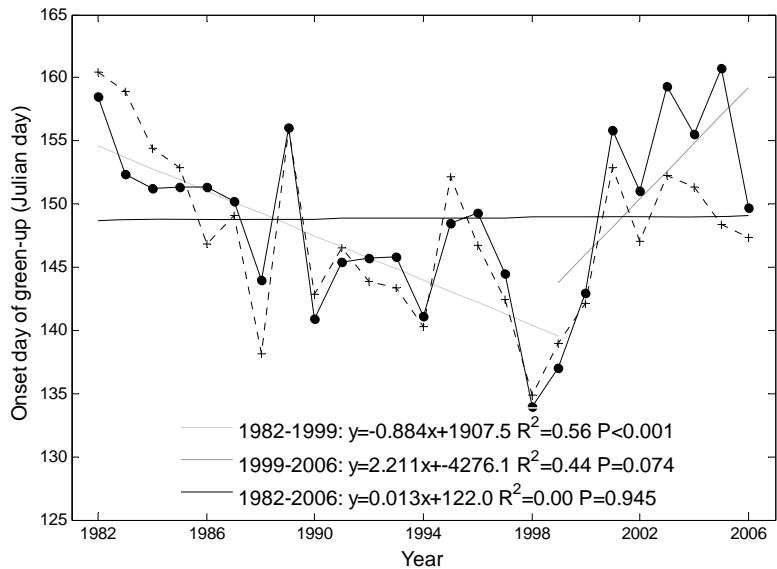
- Such a significant increase in green-up date with increasing altitude is coincident with decreasing temperature;



- Both annual and spring temperature is negatively correlated with altitude by 0.3 and 0.4 °C/100m, respectively.

Spring phenology change in Qinghai-Xizang

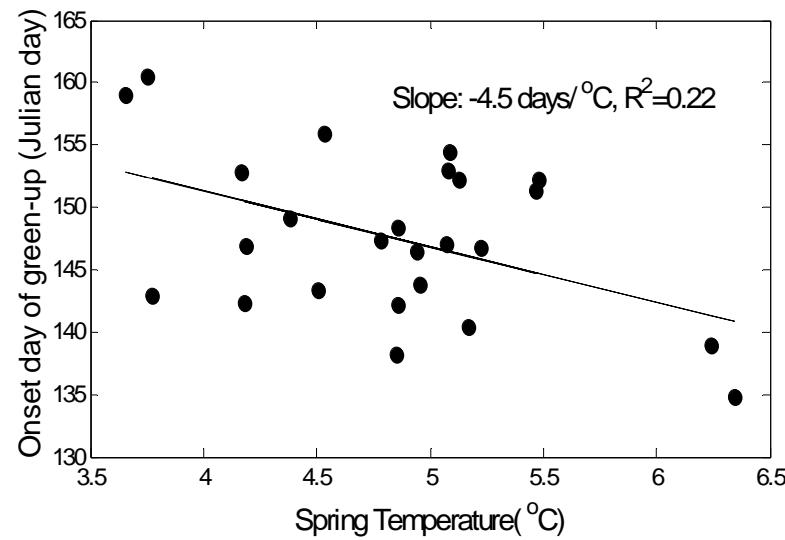
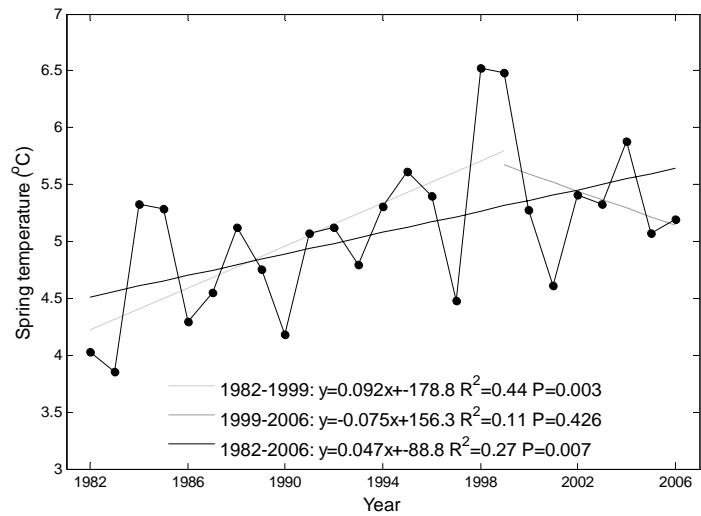
Temporal change in spring vegetation green up date



- The vegetation green-up significantly advanced by 0.9 days yr^{-1} from 1982 to 1999 ($R^2=0.56$, $P<0.001$);
- From 1999 to 2006, the green-up date marginally delayed with an overall rate of 2.2 days yr^{-1} .

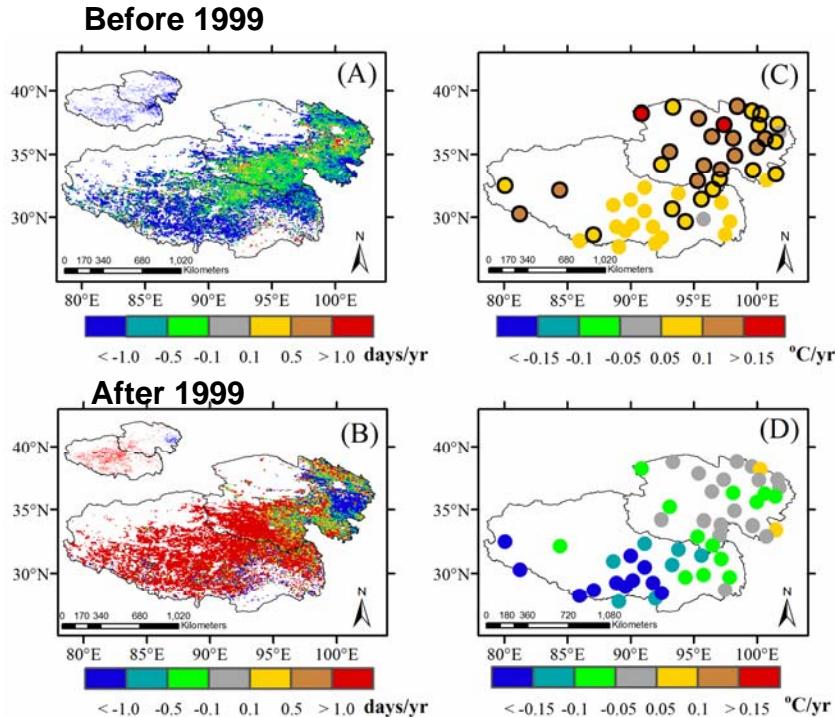
Spring phenology change in Qinghai-Xizang

Temporal change in spring temperature



Spring phenology change

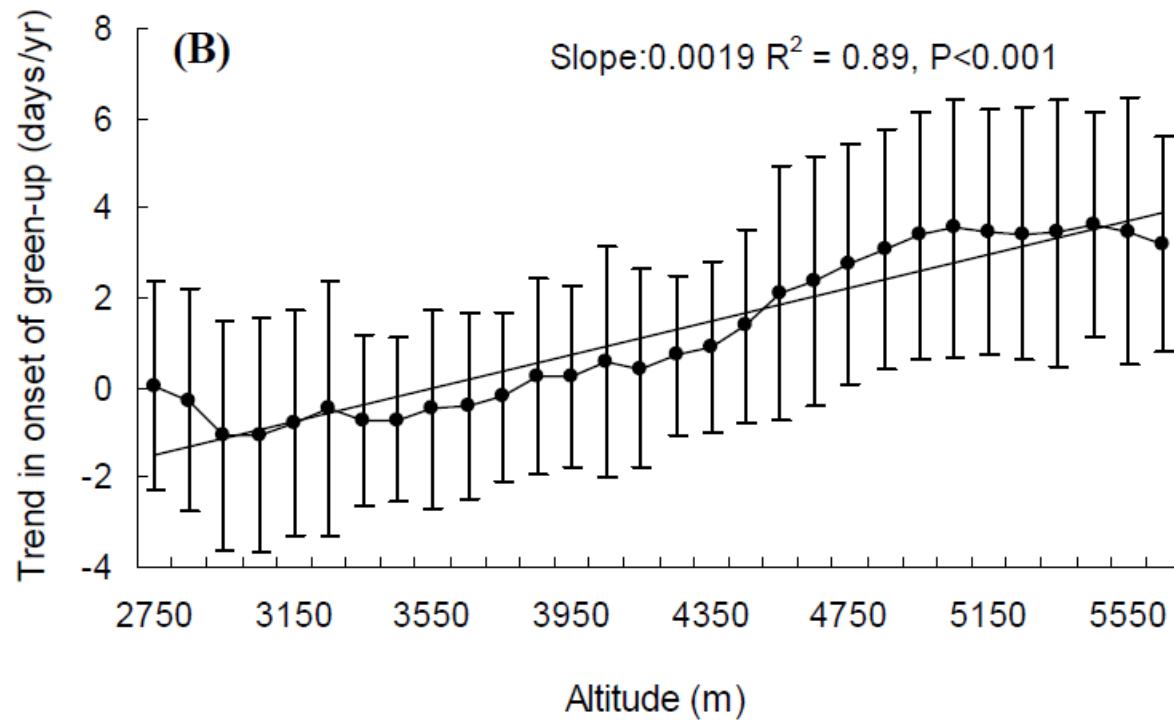
Trend in spring phenology and temperature



- Vegetation green-up significantly advanced in 29% of vegetated area, particularly in the southwestern parts;
- In contrast, during 1999-2006, the green-up date delayed (positive trends) in more than 75% of Qinghai-Xizang Plateau.

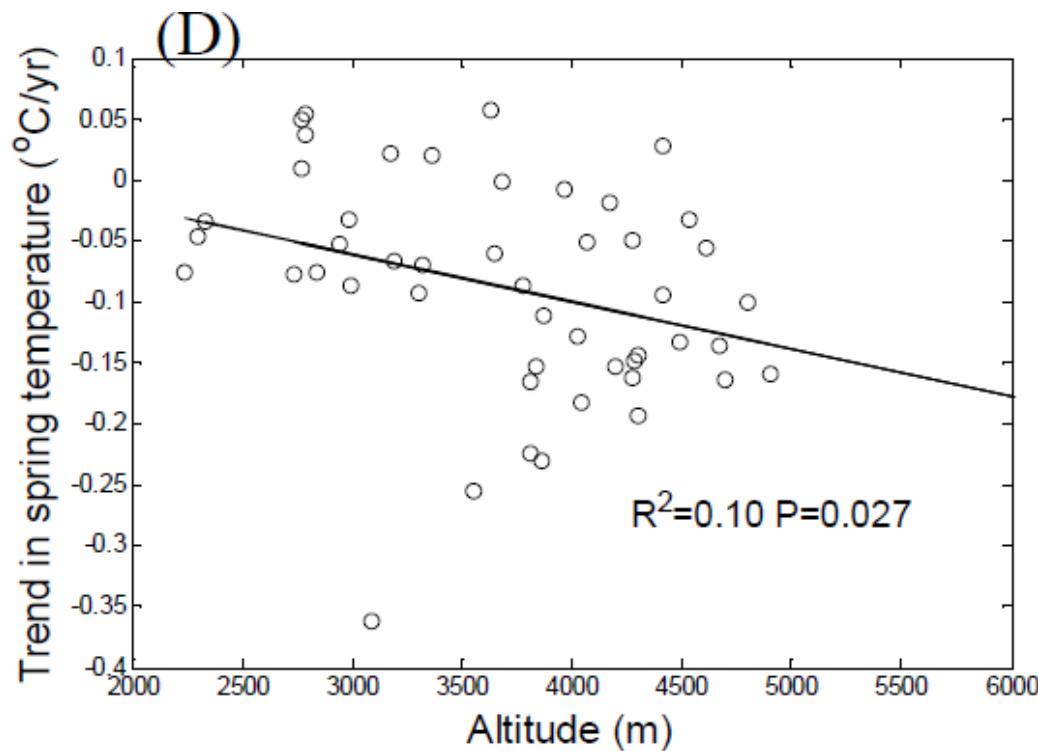
Spring phenology change in Qinghai-Xizang

1998-2006年间BGS变化趋势随海拔的变化



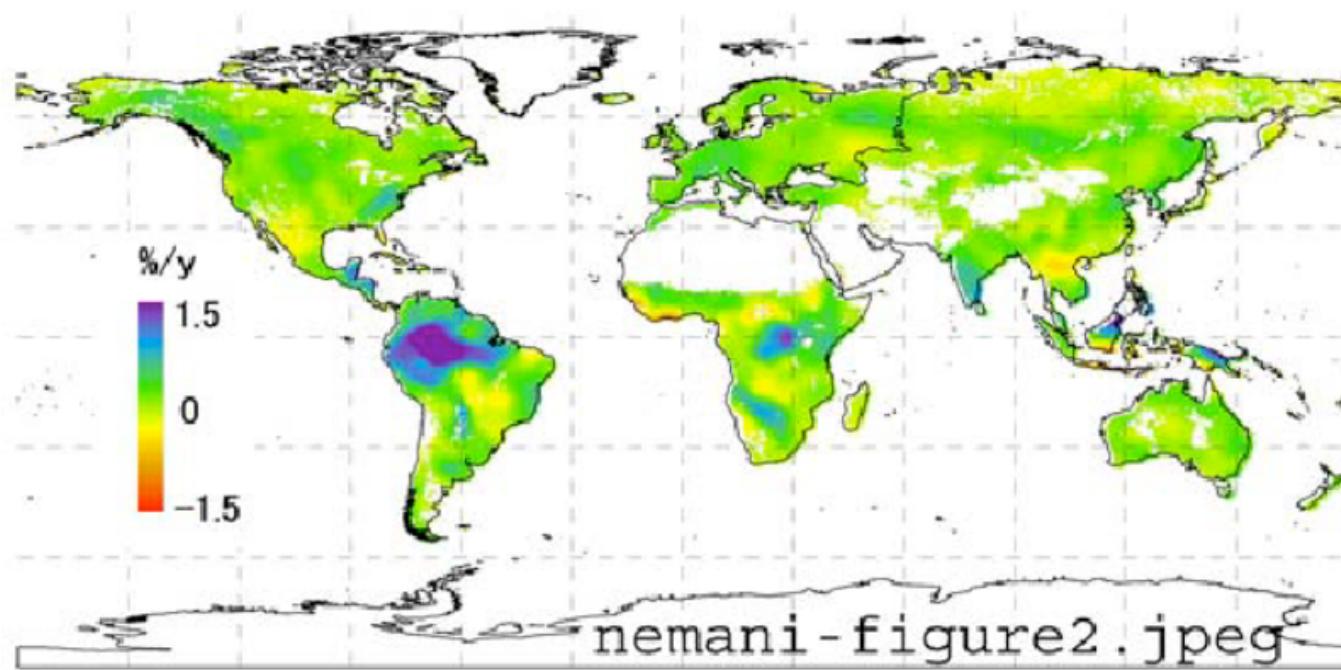
Spring phenology change in Qinghai-Xizang

1998-2006年间春季温度变化趋势随海拔的变化



生态系统过程模型？

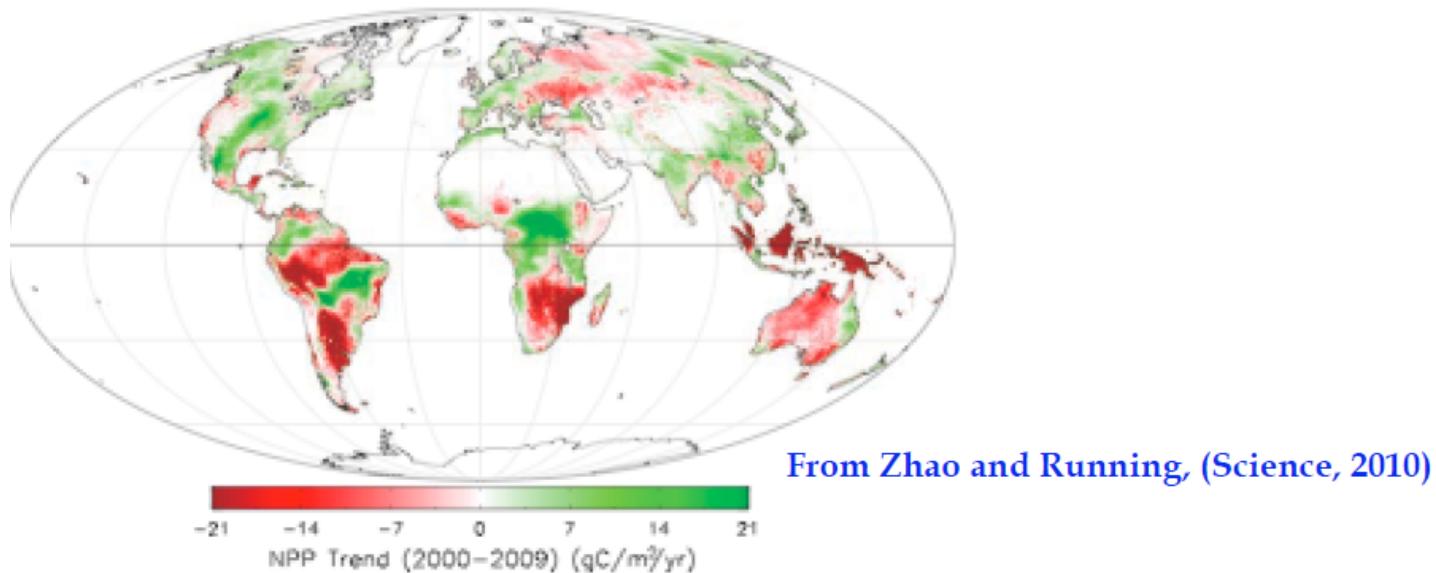
Changes in Vegetation Net Primary Production: 1982-1999



From Nemani et al., (Science, 2003)

- Trends in NPP are positive over 55% of the global vegetated area and are statistically more significant than the declining trends observed over 19% of the vegetated area

Changes in Vegetation Net Primary Production: 2000-2009



- Reduction in NPP of 0.55 billion tons of Carbon during 2000-2009
- Large droughts have reduced regional NPP (see, Amazon region for example)
- A drying trend in the **Southern Hemisphere** has decreased NPP there
- There was slight increasing trend in **Northern Hemisphere**

General Critique of Zhao and Running

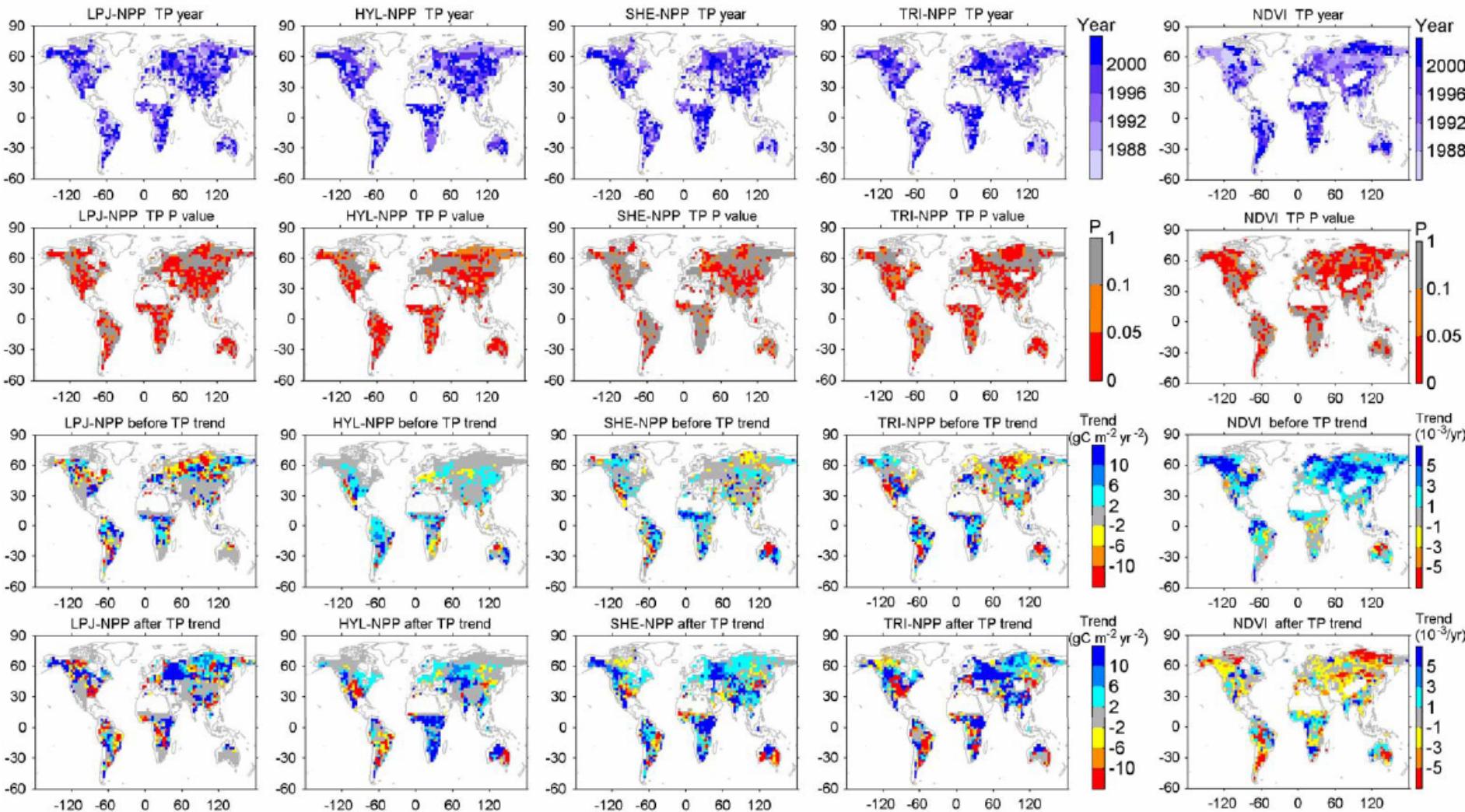
- Zhao and Running reported an extremely small reduction, 0.55 petagrams of carbon (Pg C), in global terrestrial net primary production of 535.21 Pg C over a ten-year period, or 0.1%.
- This decline is due to a drying trend in the Southern Hemisphere that decreased NPP by 1.83 Pg C (0.34%), and which was counteracted by increased NPP in the Northern Hemisphere by 1.28 Pg C (0.24%).
- These small changes raise the obvious question – how credible are these numbers and the reported regional patterns?
- The Amazonian forests present a good test case to assess Zhao and Running because of the wealth of field NPP measurements available to test the NPP model and the dominant role these forests play in NPP trends and interannual variability (66%).

Comparision of Model and Field NPP Measurements

Site	Period	Observed NPP	Zhao and Running (1)	
		(kg·C m ⁻² yr ⁻¹)	(kg·C m ⁻² yr ⁻¹)	Error (%)
KM67	2001	1.230	0.832	-32.36
KM67	2004	1.055	0.733	-30.52
ZF-2	2001	1.063	0.779	-26.72
ZF-2	2002	1.356	0.703	-48.16
UFAC	2001	1.343	0.997	-25.76
UFAC	2002	1.299	0.925	-28.79
BA712	2006	1.366	1.519	11.20
AGP (AGP-01 and AGP-02)	2004-2006	1.148	1.000	-12.28
CAX (CAX-06 and CAX-08)	2004-2006	1.396	0.737	-47.21
TAM (TAM-05 and TAM-06)	2005	1.534	2.028	32.20
ZAR-01	2004-2006	0.930	1.042	12.04

- Zhao and Running's NPP estimates differ from field measurements by 28%
- They generally underestimate by 31% and overestimate in a few cases by 18%
- This does not give confidence in their modeled NPP estimates

DGVMs derived NPP change

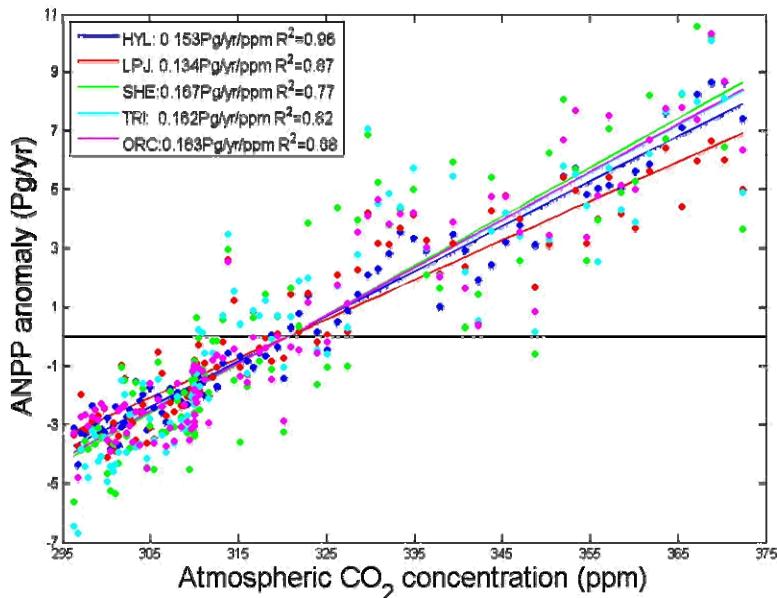
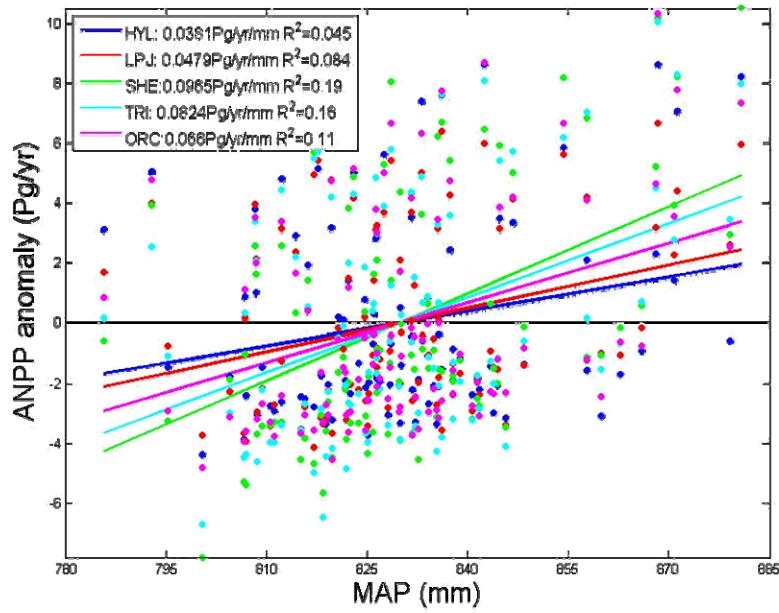
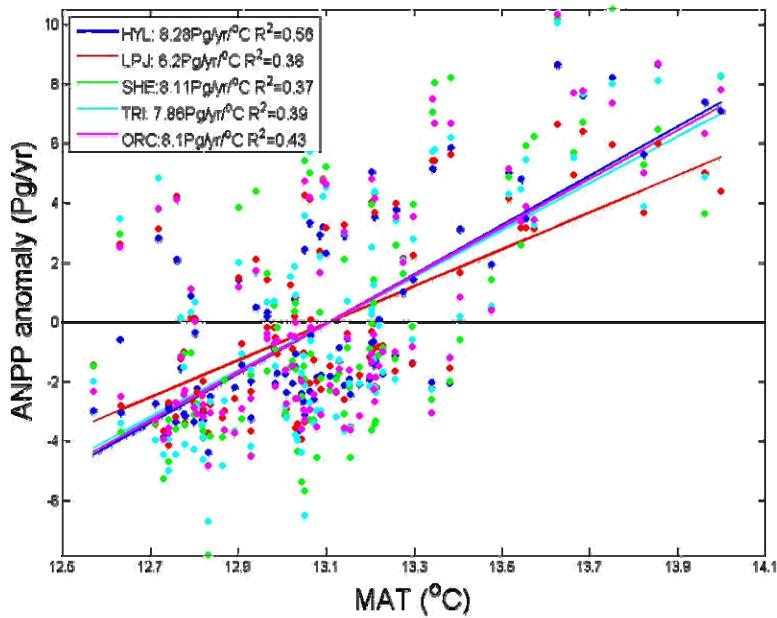


Uncertainties:

- **Missing processes**
 - N depositions.
 - Atmospheric O₃ pollution
 - Land Use Change (e.g. plantation, deforestation...)
 - Agriculture Irrigation & fertilization
- **Parameterizations**
- **Driving factors**

Temperature, precipitation, radiation and land cover map et al.

Uncertainties due to different parameterizations

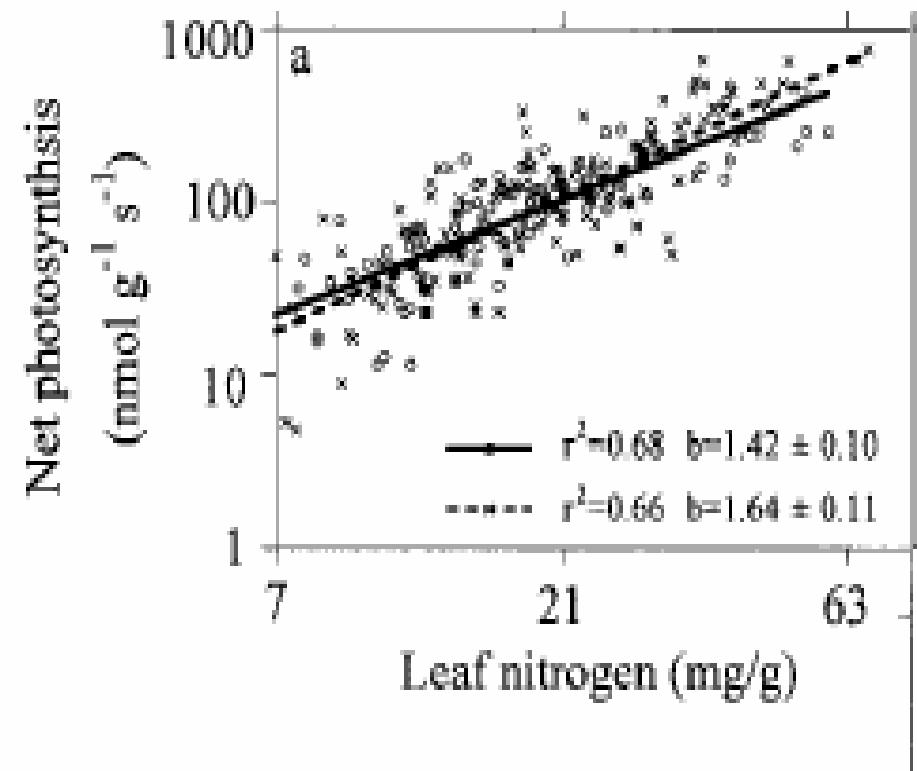
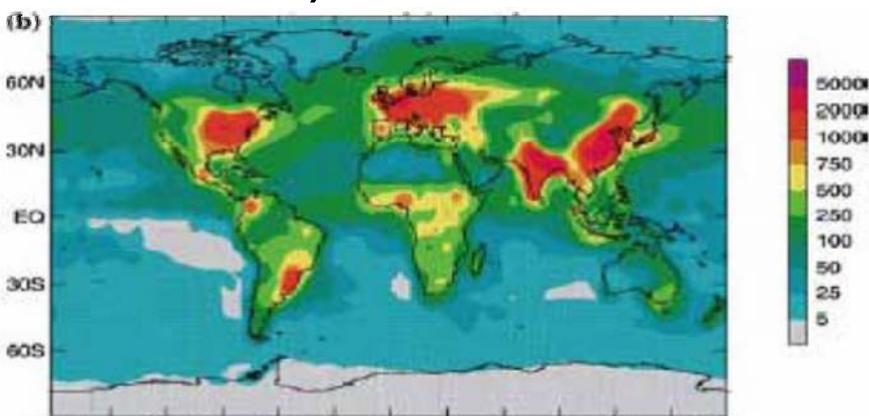


$$\text{NPP} = a\text{MAT} + b\text{MAP} + c\text{CO}_2 + d$$

	a Pg/yr/C	b Pg/yr/mm	c Pg/yr/ppm	R^2
HYL	-0.02	0.01	0.15	0.97
LPJ	-2.52	0.03	0.16	0.92
SHE	-2.46	0.07	0.18	0.89
TRI	-2.33	0.06	0.18	0.90
ORC	-1.79	0.04	0.18	0.92

Vegetation productivity and Nitrogen

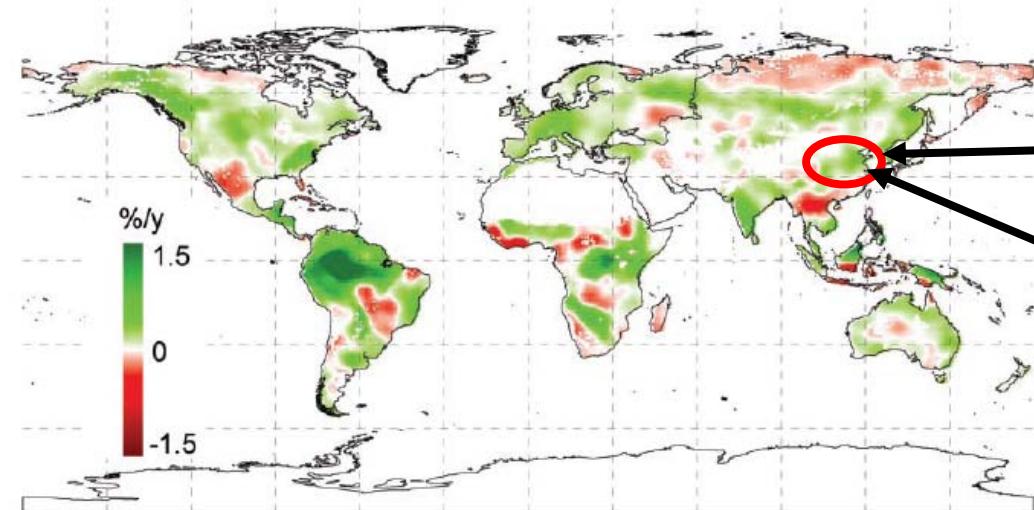
- Productivity of many land ecosystems is control by nitrogen availability (Vitousek, 2002, Reich et al. 1997, FACE results, etc.)



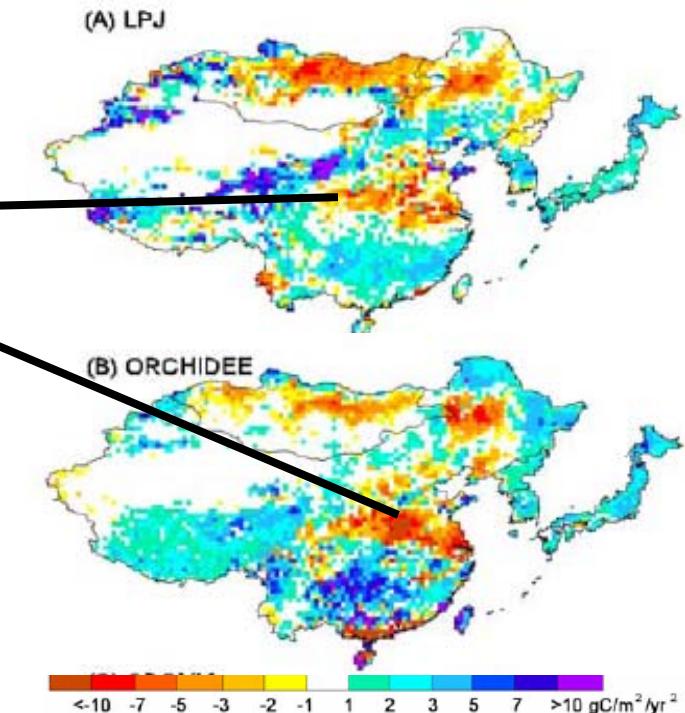
As mentioned above, fertilizer production is one of manifestations of N limitation on vegetation productivity
mobila.local, 2005-9-28

The effect of irrigation and fertilization on agriculture productivity

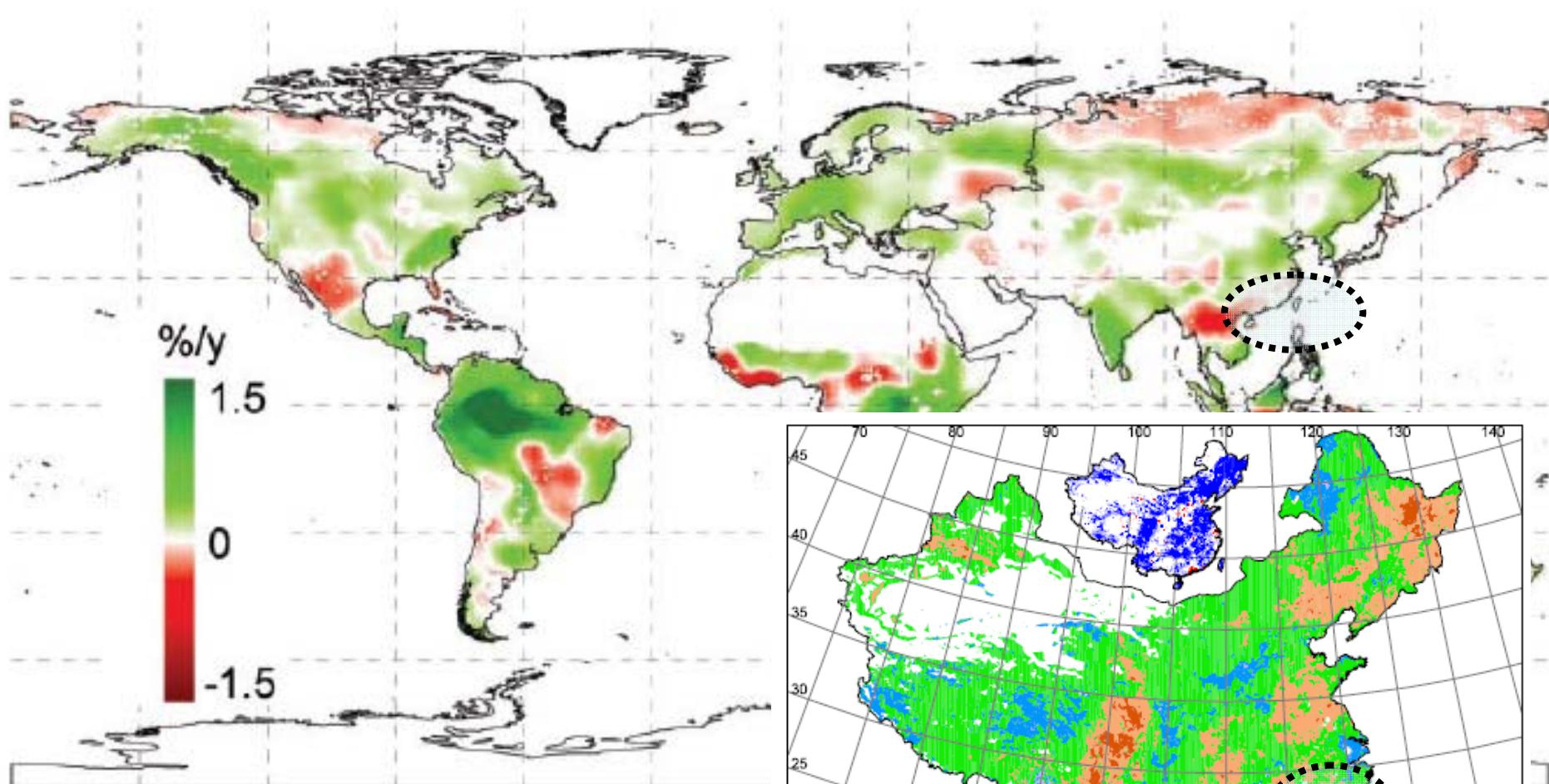
Satellite data based model



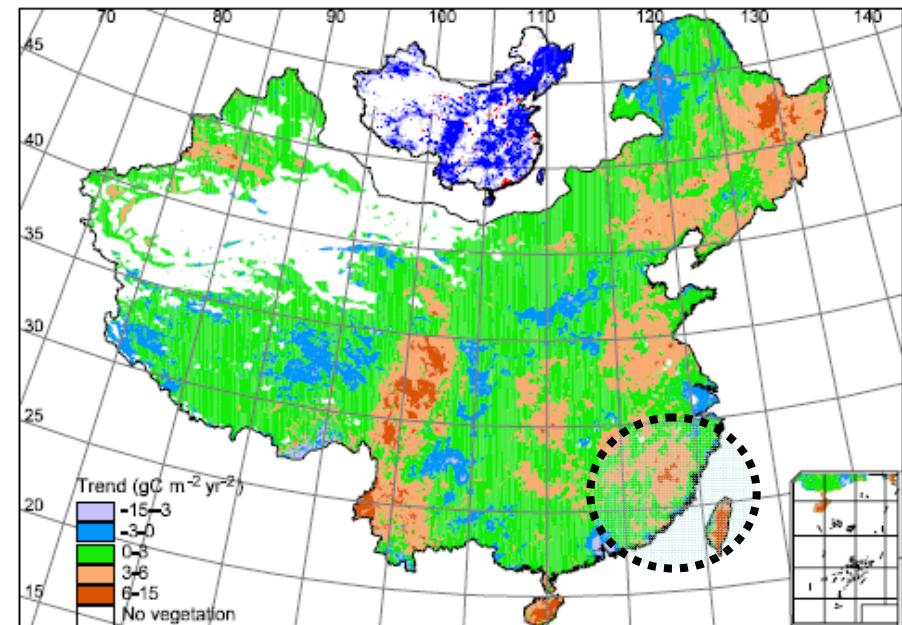
Only climate data based model



Uncertainties from driving factors

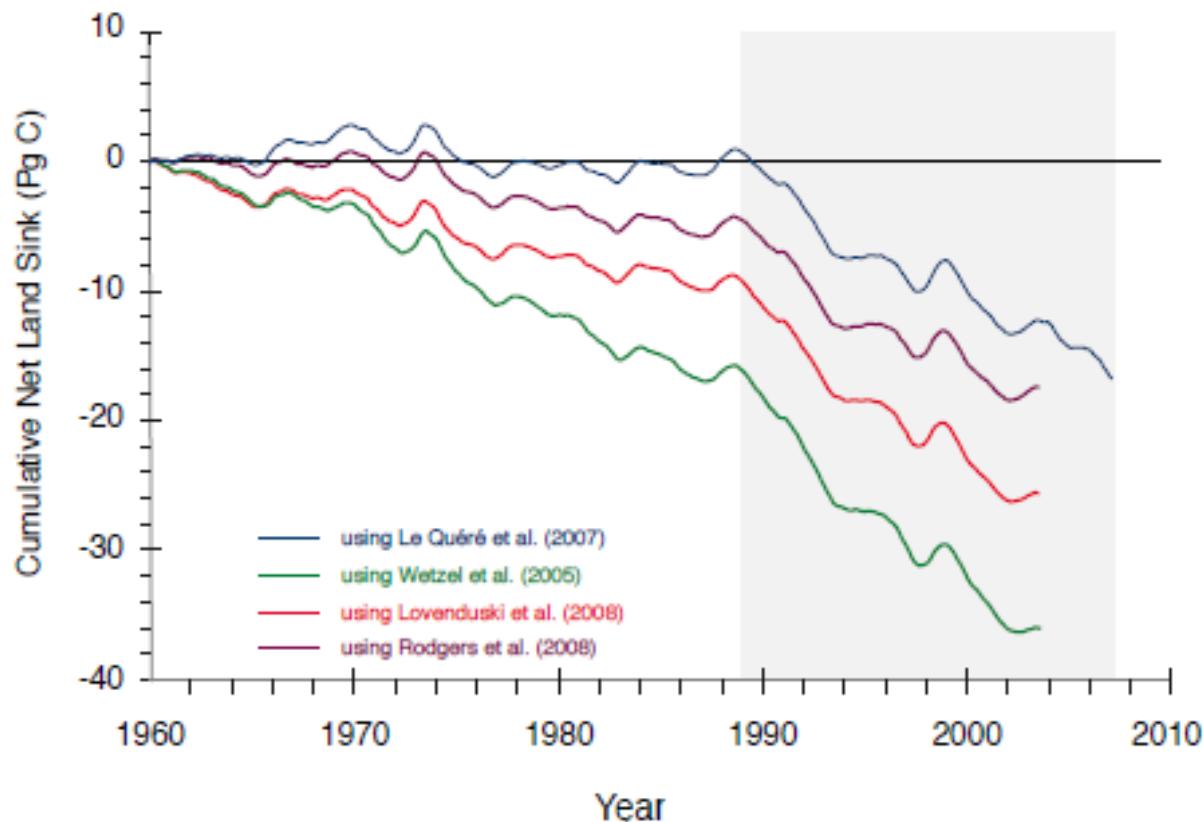


Nemani et al., 2003



Piao et al., 2005

Homework



Thanks !