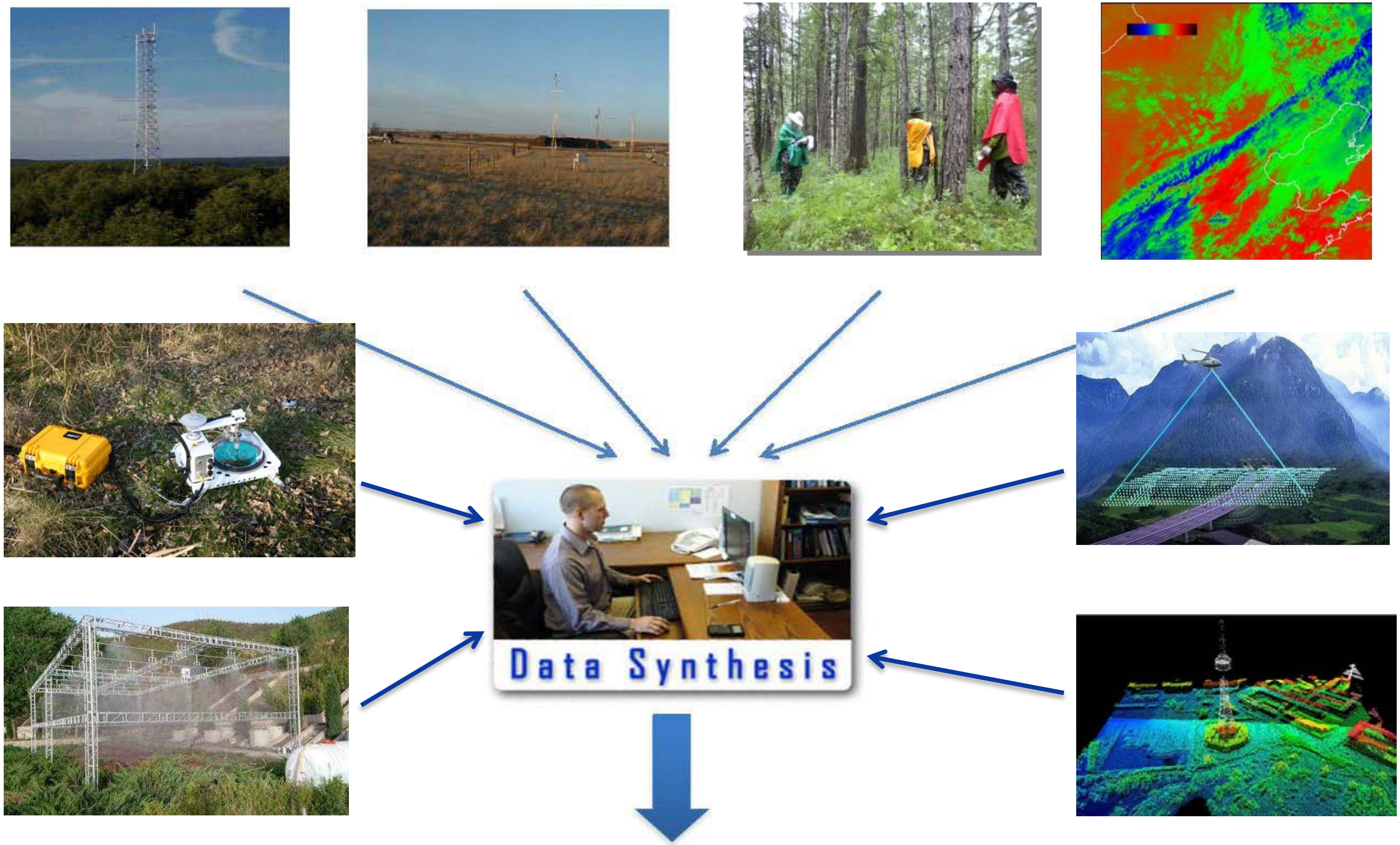
中国科学院地理科学与资源研究所
Institute of Geographic Sciences and Natural Resources Research, CAS

基于通量数据的集成分析

报告人：陈　智

ChinaFLUX第13次通量观测理论与技术培训
2018-07-19

Key Laboratory of Ecosystem Network Observation and Modeling



“new or enhanced information about ecosystems” ,
(across sites, biomes, regions/zones)
reveal the large scale patterns and mechanisms

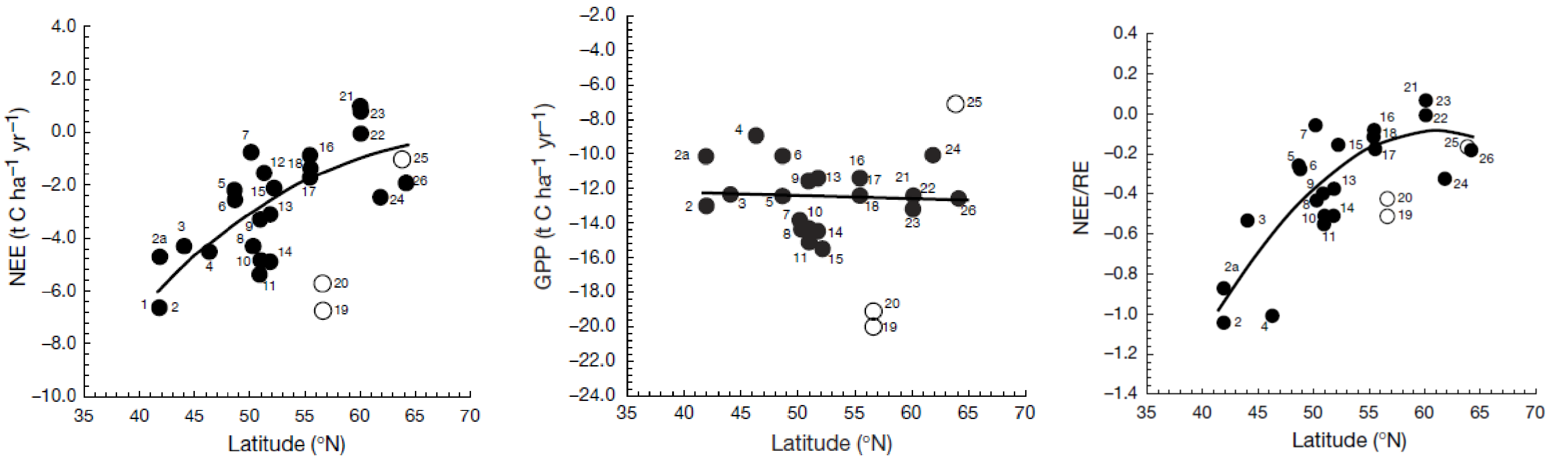
Data synthesis methods

- Cross-site synthesis
- Upscaling analysis
- Data-model synthesis

General patterns

Respiration as the main determinant of carbon balance in European forests

R. Valentini[1], G. Matteucci[1], A. J. Dolman[2], E.-D. Schulze[3,4], C. Rebmann[3,4], E. J. Moors[2], A. Granier[5], P. Gross[5], N. O. Jensen[6], K. Pilegaard[6], A. Lindroth[7], A. Grelle[8], C. Bernhofer[9], T. Grünwald[9], M. Aubinet[10], R. Ceulemans[11], A. S. Kowalski[11], T. Vesala[12], Ü. Rannik[12], P. Berbigier[13], D. Loustau[14], J. Guðmundsson[15], H. Thorgeirsson[15], A. Ibrom[16], K. Morgenstern[16], R. Clement[17], J. Moncrieff[17], L. Montagnani[18], S. Minerbi[19] & P. G. Jarvis[17]

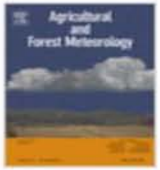


Response to environmental change

Agricultural and Forest Meteorology

Volume 113, Issues 1–4, 2 December 2002, Pages 97–120

FLUXNET 2000 Synthesis



Environmental controls over carbon dioxide and water vapor exchange of terrestrial vegetation

B.E. Law[a,*], E. Falge[b], L. Gu[c], D.D. Baldocchi[c], P. Bakwin[d], P. Berbigier[e], K. Davis[f], A.J. Dolman[g], M. Falk[h], J.D. Fuentes[i], A. Goldstein[c], A. Granier[j],

Abstract

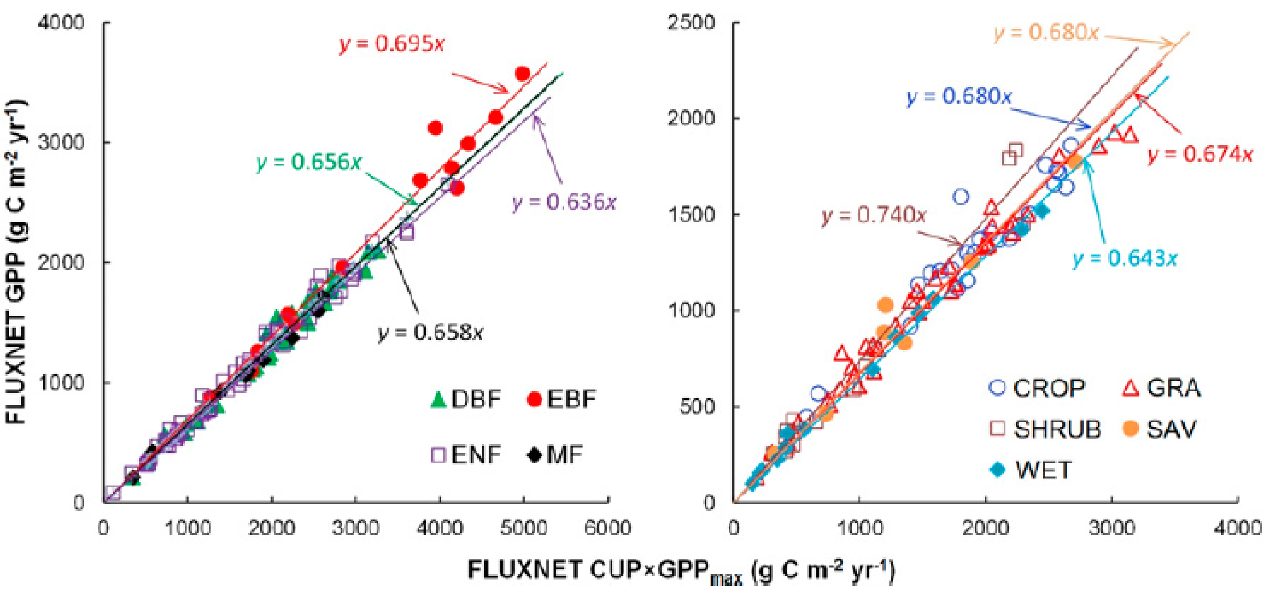
The objective of this research was to compare seasonal and annual estimates of CO_2 and water vapor exchange across sites in forests, grasslands, crops, and tundra that are part of an international network called FLUXNET, and to investigating the responses of vegetation to environmental variables. FLUXNETs goals are to understand the mechanisms controlling the exchanges of CO_2, water vapor and energy across a spectrum of time and space scales, and to provide information for modeling of carbon and water cycling across regions and the globe. At a subset of sites, net carbon uptake (net ecosystem exchange, the net of photosynthesis and respiration) was greater under diffuse than under direct radiation conditions, perhaps because of a more efficient distribution of non-saturating light conditions for photosynthesis, lower vapor pressure deficit limitation to photosynthesis, and lower respiration associated with reduced temperature. The slope of the relation between monthly gross ecosystem production and evapotranspiration was similar between biomes, except for tundra vegetation, showing a strong linkage between carbon gain and water loss integrated over the year (slopes = 3.4 g CO_2/kg H_2O for grasslands, 3.2 for deciduous broadleaf forests, 3.1 for crops, 2.4 for evergreen conifers, and 1.5 for tundra vegetation). The ratio of annual

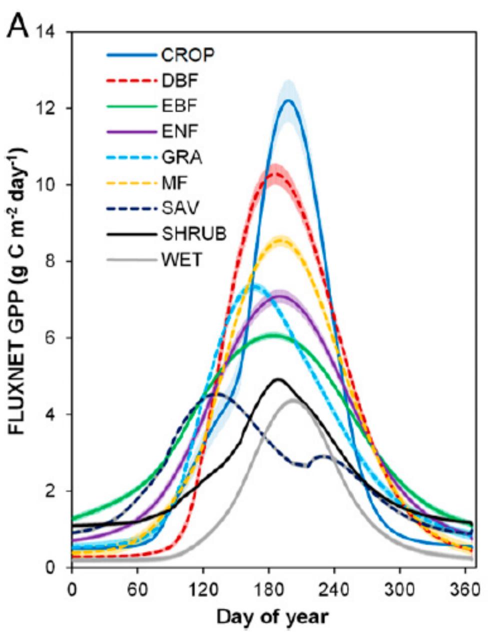
Forming mechanism

PNAS

Joint control of terrestrial gross primary productivity by plant phenology and physiology

Jianyang Xia[a,1,2], Shuli Niu[b,1,2], Philippe Ciais[c], Ivan A. Janssens[d], Jiquan Chen[e], Christof Ammann[f], Altaf Arain[g], Peter D. Blanken[h], Alessandro Cescatti[i], Damien Bonal[j], Nina Buchmann[k], Peter S. Curtis[l], Shiping Chen[m], Jinwei Dong[a], Lawrence B. Flanagan[n], Christian Frankenberg[o], Teodoro Georgiadis[p], Christopher M. Gough[q], Dafeng Hui[r], Gerard Kiely[s], Jianwei Li[a,t], Magnus Lund[u], Vincenzo Magliulo[v], Barbara Marcolla[w], Lutz Merbold[k], Leonardo Montagnani[x,y], Eddy J. Moors[z], Jørgen E. Olesen[aa], Shilong Piao[bb,cc], Antonio Raschi[dd], Olivier Roupsard[ee,ff], Andrew E. Suyker[gg], Marek Urbaniak[hh], Francesco P. Vaccari[dd], Andrej Varlagin[ii], Timo Vesala[jj,kk], Matthew Wilkinson[ll], Ensheng Weng[mm], Georg Wohlfahrt[nn,oo], Liming Yan[pp], and Yiqi Luo[a,qq,1,2]





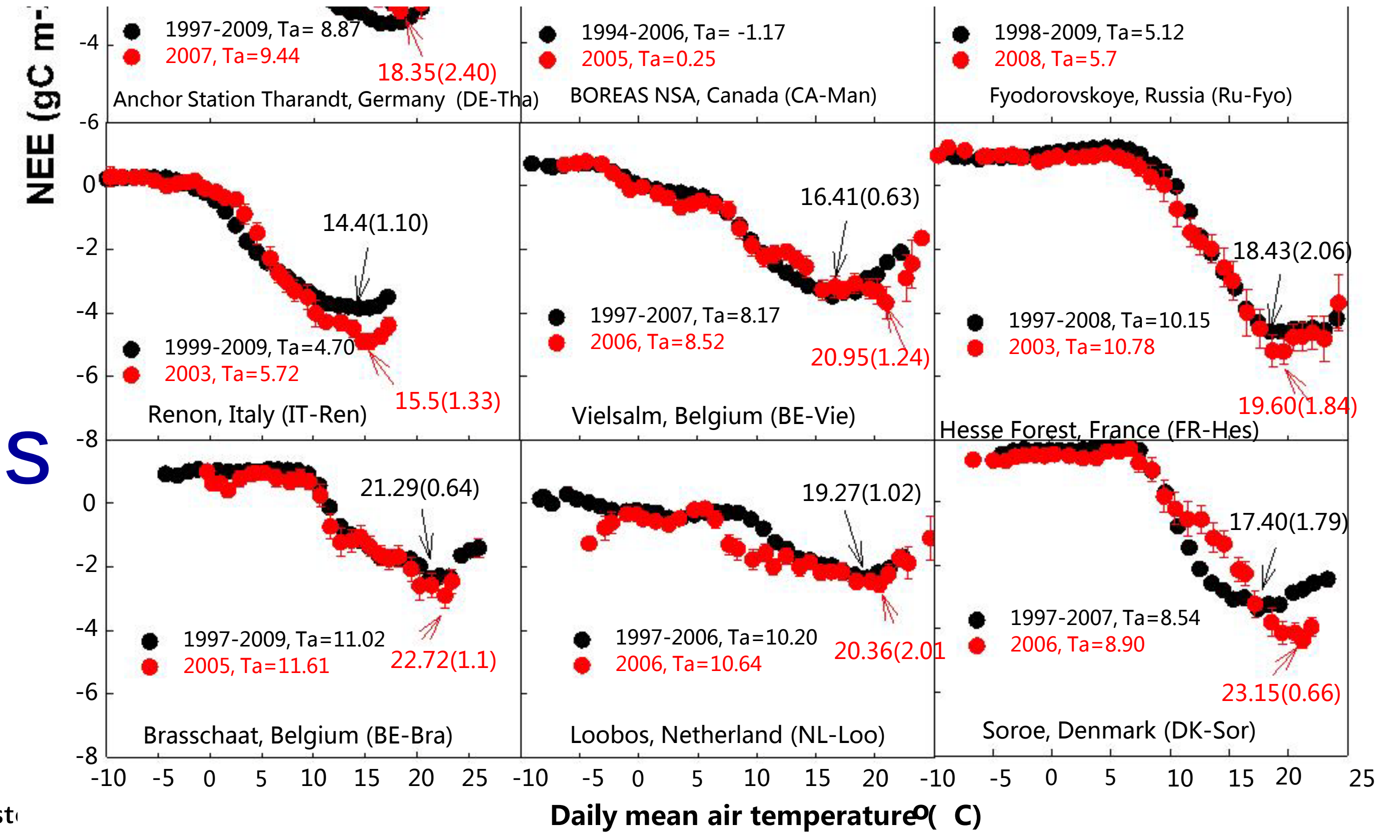
Global Change Biology

Global Change Biology (2011) **17**, 3102–3114, doi: 10.1111/j.1365-2486.2011.02459.x

Seasonal hysteresis of net ecosystem exchange in response to temperature change: patterns and causes

SHULI NIU*,†, YIQI LUO*, SHENFENG FEI*, LEONARDO MONTAGNANI‡§, GIL BOHRER¶, IVAN A. JANSSENS‖, BERT GIELEN‖, SERGE RAMBAL**, EDDY MOORS†† and GIORGIO MATTEUCCI‡‡

Seasonal hysteresis



Key Laboratory of Ecosyst

Drought effects

nature
International journal of science

LETTERS

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

Ph. Ciais[1], M. Reichstein[2,3], N. Viovy[1], A. Granier[4], J. Ogée[5], V. Allard[6], M. Aubinet[7], N. Buchmann[8], Chr. Bernhofer[9], A. Carrara[10], F. Chevallier[1], N. De Noblet[1], A. D. Friend[1], P. Friedlingstein[1], T. Grünwald[9], B. Heinesch[7], P. Keronen[11], A. Knohl[12,13], G. Krinner[14], D. Loustau[5], G. Manca[2]†, G. Matteucci[15]†, F. Miglietta[16], J. M. Ourcival[17], D. Papale[2], K. Pilegaard[18], S. Rambal[17], G. Seufert[15], J. F. Soussana[6], M. J. Sanz[10], E. D. Schulze[12], T. Vesala[11] & R. Valentini[2]

Table 1 | Changes in climate and ecosystem CO_2 fluxes between 2002 and 2003 at eddy covariance sites

						July–September						Annual			
Site Code	Name	Vegetation, main genus	Country	Latitude	Longitude	ΔT	ΔP	ΔGPP	ΔTER	ΔNEP	s.e.*	ΔGPP	ΔTER	ΔNEP	s.e.*
SA	El Saler	ENF, pine	SP	39.28	0.33	1.7	−34	−33	−63	30	7	−94	−460	366	43
CP	Castelporziano	EBF, oak	IT	41.71	12.38	3.5	−42	−47	−21	−26	11	−17	16	−33	86
RO	Roccarespampani	DBF, oak	IT	42.39	11.92	2.3	−118	−117	−89	−28	15	−130	−287	158	95
SR	San Rossore	ENF, pine	IT	43.71	17.28	1.8	−120	−87	−47	−40	11	−344	−292	−51	25
BX	Bray	ENF, pine	FR	44.72	−0.77	2.9	−4	29	21	8	14	180	−114	294	77
LA	Laqueuille	GRA, grass	FR	45.64	2.75	3.5	−15	−25	−19	−6	4	−†	−†	−†	−†
PI	Pianosa	OSH, juniper	IT	42.58	10.07	3.2	−69	5	9	−4	16	−†	−†	−†	−†
PU	Puéchabon	EBF, oak	FR	43.73	3.58	2.2	+3	−52	−24	−28	6	−206	−91	−115	32
HE	Hesse	DBF, beech	FR	48.67	7.08	2.0	−53	−115	−42	−73	9	−291	−187	−104	46
VI	Vielsalm	MF, beech and fir	BE	50.30	6.00	1.4	−18	−20	−37	+17	15	−95	−203	108	75
TH	Tharandt	ENF, spruce	GE	50.95	13.57	1.0	−121	−41	−10	−31	7	−208	−53	−155	53
HA	Hainich	DBF, beech	GE	51.07	10.5	1.8	−30	−82	−25	−57	6	−195	−125	−70	48
SO	Soroe	DBF, beech	DK	55.48	11.63	0.3	−57	−15	−14	−1	7	−158	−183	26	66
HY	Hyytiälä	ENF, pine	FI	61.85	24.28	−0.1	−5	−3	10	−13	5	−52	48	−100	30

Science

Test traditional theory

Global Convergence in the Temperature Sensitivity of Respiration at Ecosystem Level

Miguel D. Mahecha, Markus Reichstein, Nuno Carvalhais, Gitta Lasslop, Holger Lange, Sonia I. Seneviratne, Rodrigo Vargas, Christof Ammann, M. Altaf Arain, Alessandro Cescatti, Ivan A. Janssens, Mirco Migliavacca, Leonardo Montagnani and Andrew D. Richardson

Global Convergence in the Temperature Sensitivity of Respiration at Ecosystem Level

Miguel D. Mahecha,[1,2*] Markus Reichstein,[1] Nuno Carvalhais,[1,3] Gitta Lasslop,[1] Holger Lange,[4] Sonia I. Seneviratne,[2] Rodrigo Vargas,[5] Christof Ammann,[6] M. Altaf Arain,[7] Alessandro Cescatti,[8] Ivan A. Janssens,[9] Mirco Migliavacca,[10] Leonardo Montagnani,[11,12] Andrew D. Richardson[13]

The respiratory release of carbon dioxide (CO_2) from the land surface is a major flux in the global carbon cycle, antipodal to photosynthetic CO_2 uptake. Understanding the sensitivity of respiratory processes to temperature is central for quantifying the climate–carbon cycle feedback. We approximated the sensitivity of terrestrial ecosystem respiration to air temperature (Q_{10}) across 60 FLUXNET sites with the use of a methodology that circumvents confounding effects. Contrary to previous findings, our results suggest that Q_{10} is independent of mean annual temperature, does not differ among biomes, and is confined to values around 1.4 ± 0.1. The strong relation between photosynthesis and respiration, by contrast, is highly variable among sites. The results may partly explain a less pronounced climate–carbon cycle feedback than suggested by current carbon cycle climate models.

Data synthesis

- Cross-site synthesis
- Upscaling analysis
- Data-model synthesis

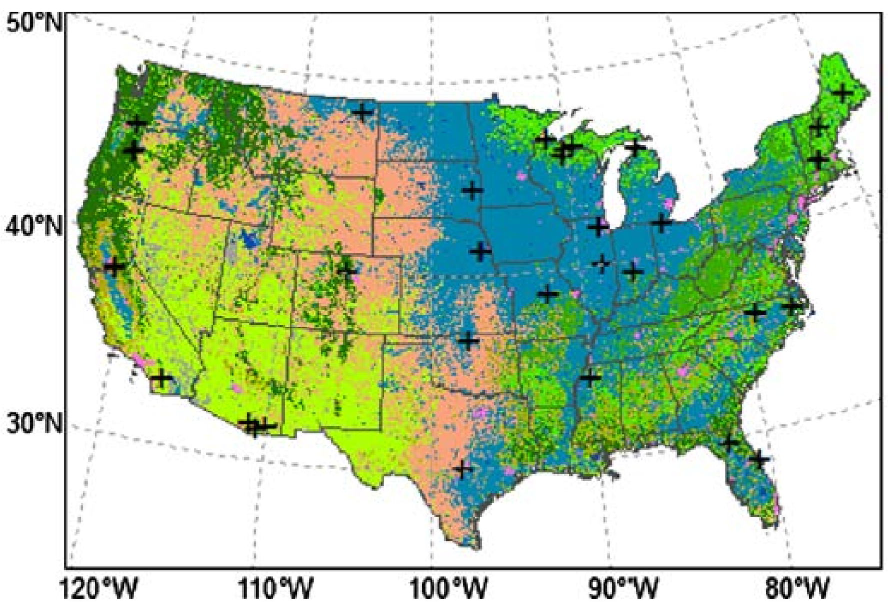
Examples for upscaling analysis

3.1. *Model development*

The best model contained the following explanatory variables: surface reflectance bands 1–6, EVI, daytime and nighttime LST, and NDWI (relative error = 0.64, average error = 0.986, $r = 0.73$). This model achieved slightly higher performance than the full model (relative error = 0.66, average error = 1.01, $r = 0.72$). The selected model consisted of five committee models, each of which was made of a number of rule-based submodels. For example, the first committee model was made of 26 rule-based submodels:

Rule 1: if land cover = croplands, daytime LST > 30.07, EVI > 0.40, then

$$\text{NEE} = 20.24 - 430.3B_3 + 431.7B_4 + 80.8B_1 - 108.7B_5 - 23.4\text{EVI} + 0.22L_d + 11.4\text{NDWI} - 27.6B_6 + 4B_2$$



Rule 2: if land cover in {deciduous forests, savannas}, $B_2 > 0.34$, NDWI $<= -0.36$, $L_d > 18.06$, $L_n > 11.13$, then

$$\text{NEE} = -5.94 + 47.2B_4 - 35B_1 - 12.7B_2 - 7B_3 - 3.6\text{NDWI} + 8.4B_6 + 4.4B_5 - 0.4\text{EVI}$$

⋮

Rule 25: if land cover in {deciduous forests, mixed forests, croplands}, NDWI > 0.02, $L_n <= 9.68$, then

$$\text{NEE} = 0.40 - 37.6B_4 + 15.1B_1 + 8.9B_2 + 0.046L_n + 0.9B_5 + 0.4B_3$$

Rule 26: if land cover in {deciduous forests, mixed forests, croplands}, NDWI > 0.02, $L_n > 9.68$, then

$$\text{NEE} = -2.86 + 56.5B_5 - 50.5B_6 + 14.9\text{NDWI} - 2.9B_1 - 0.5B_4 - 0.5B_2$$

AGRICULTURAL AND FOREST METEOROLOGY 148 (2008) 1827–1847

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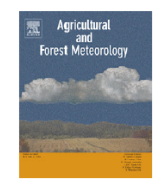


Estimation of net ecosystem carbon exchange for the conterminous United States by combining MODIS and AmeriFlux data

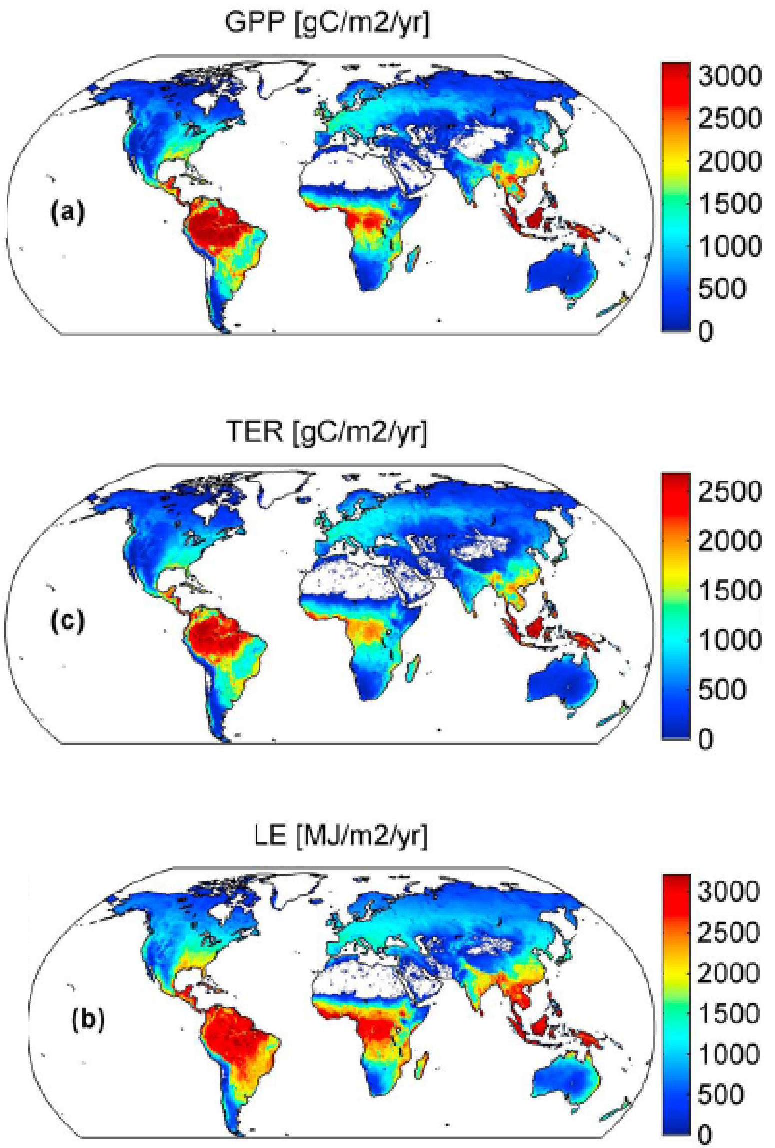
Examples for upscaling analysis

Global patterns of land-atmosphere fluxes of carbon dioxide, latent heat, and sensible heat derived from eddy covariance, satellite, and meteorological observations

Martin Jung,[1] Markus Reichstein,[1] Hank A. Margolis,[2] Alessandro Cescatti,[3]

Table 1. List of Explanatory Variables Used for the Training of MTEs[a]

Variable	Type	Type of Variability
	Climate (for Data Stratification)	
Mean annual temperature	Split	static
Mean Annual precipitation sum	Split	static
Mean annual climatic water balance	Split	static
Mean annual Potential evaporation	Split	static
Mean annual sunshine hours	Split	static
Mean annual number of wet days	Split	static
Mean annual relative humidity	Split	static
Mean monthly temperature	Split	Monthly but static over y
Mean monthly precipitation sum	Split	Monthly but static over y
Mean monthly climatic water balance	Split	Monthly but static over y
Mean monthly potential evaporation	Split	Monthly but static over y
Mean monthly sunshine hours	Split	Monthly but static over y
Mean monthly number of wet days	Split	Monthly but static over y
Mean monthly relative humidity	Split	Monthly but static over y
	Vegetation Structure	
Maximum fAPAR of year	Split	yearly
Minimum fAPAR of year	Split	yearly
Maximum–minimum fAPAR	Split	yearly
Mean annual fAPAR	Split	yearly
Sum of fAPAR over the growing season	Split	yearly
Mean fAPAR of the growing season	Split	yearly
Growing season length derived from fAPAR	Split	yearly
Sum of fAPAR × potential radiation of year	Split	yearly
Maximum of fAPAR × potential radiation of year	Split and regression	yearly
IGBP vegetation type	Split	static
	Meteorology	
Temperature	Split and regression	monthly
Precipitation	Split and regression	monthly
Potential radiation	Split and regression	Monthly but static over years
	Vegetation Status	
fAPAR	Split and regression	monthly
fAPAR × potential radiation	Split and regression	monthly



Data synthesis

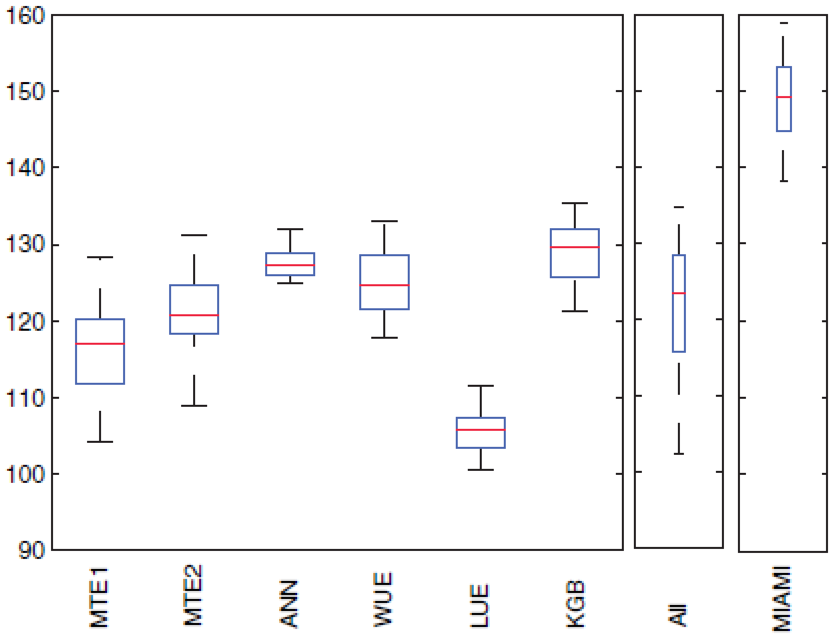
- Cross-site synthesis
- Upscaling analysis
- Data-model synthesis

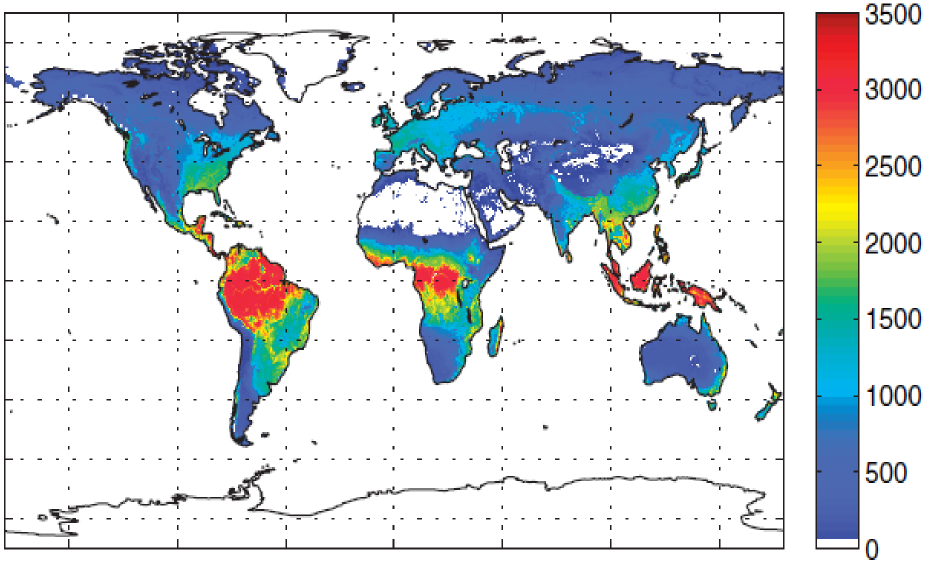
Data-model synthesis

Terrestrial Gross Carbon Dioxide Uptake: Global Distribution and Covariation with Climate

Christian Beer *et al.*

Science **329**, 834 (2010);
DOI: 10.1126/science.1184984





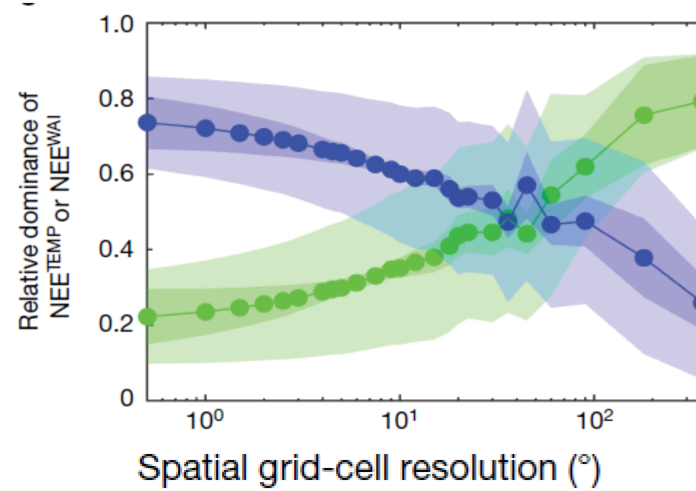
LETTER

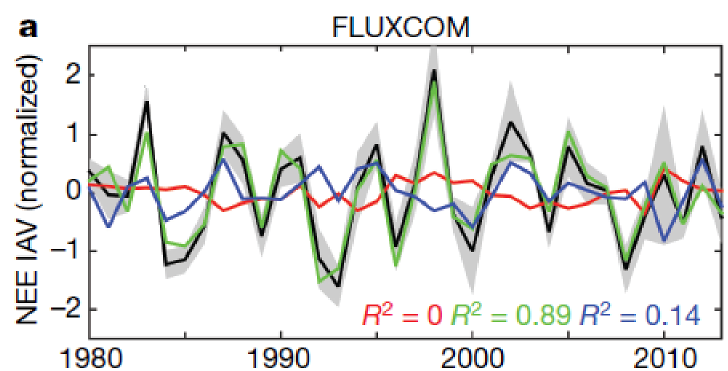
doi:10.1038/nature20780

Compensatory water effects link yearly global land CO_2 sink changes to temperature

Martin Jung[1], Markus Reichstein[1,2], Christopher R. Schwalm[3], Chris Huntingford[4], Stephen Sitch[5], Anders Ahlström[6,7], Almut Arneth[8], Gustau Camps-Valls[9], Philippe Ciais[10], Pierre Friedlingstein[11], Fabian Gans[1], Kazuhito Ichii[12,13], Atul K. Jain[14], Etsushi Kato[15], Dario Papale[16], Ben Poulter[17], Botond Raduly[16,18], Christian Rödenbeck[19], Gianluca Tramontana[16], Nicolas Viovy[10], Ying-Ping Wang[20], Ulrich Weber[1], Sönke Zaehle[1,2] & Ning Zeng[21,22]

spatial and temporal scales[3–14]. Here we use empirical models based on eddy covariance data[15] and process-based models[16,17] to investigate the effect of changes in temperature and water availability on gross primary productivity (GPP), terrestrial ecosystem respiration (TER) and net ecosystem exchange (NEE) at local and global scales. We find that water availability is the dominant driver of the local interannual variability in GPP and TER. To a lesser extent this is true also for NEE at the local scale, but when integrated globally, temporal NEE variability is mostly driven by temperature fluctuations. We suggest that this apparent paradox can be explained by two compensatory water effects. Temporal water-driven GPP and TER variations compensate locally, dampening water-driven NEE variability. Spatial water availability anomalies also compensate, leaving a dominant temperature signal in the year-to-year fluctuations of the land carbon sink. These findings help to reconcile seemingly contradictory reports regarding the importance of temperature and water in controlling the interannual variability of the terrestrial carbon balance[3–6,9,11,12,14]. Our study indicates that spatial climate covariation drives the global carbon cycle response.





Case studies on spatial pattern of carbon fluxes data across sites

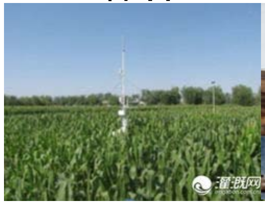
研究数据

1. 北半球碳通量数据

涡度相关

森林

草地



农田

湿地

收集发表的采用涡度相关技术测定的生态系统碳通量数据

↓

建立数据集

A	B	C	D	E	F	J	K
站点	站点简称	所属国家	Climate (	Climate (	纬度N/(°	生态系统	林型
Pasoh Forest Reserve (PSO		马来西亚	Af	Tropical	2.966667	森林	Tropical
Lambir		马来西亚	Af	Tropical	4.333333	森林	针阔混交林
Sakaerat		泰国	Aw	Tropical	14.48333	森林	常绿阔叶林
Mae Klong		泰国	Am	Tropical	14.58333	森林	落叶阔叶林

↓

数据筛选

↓

1. 经过校正
2. 至少一个完整年监测
3. 近10年未受强烈的干扰破坏

校正包括：

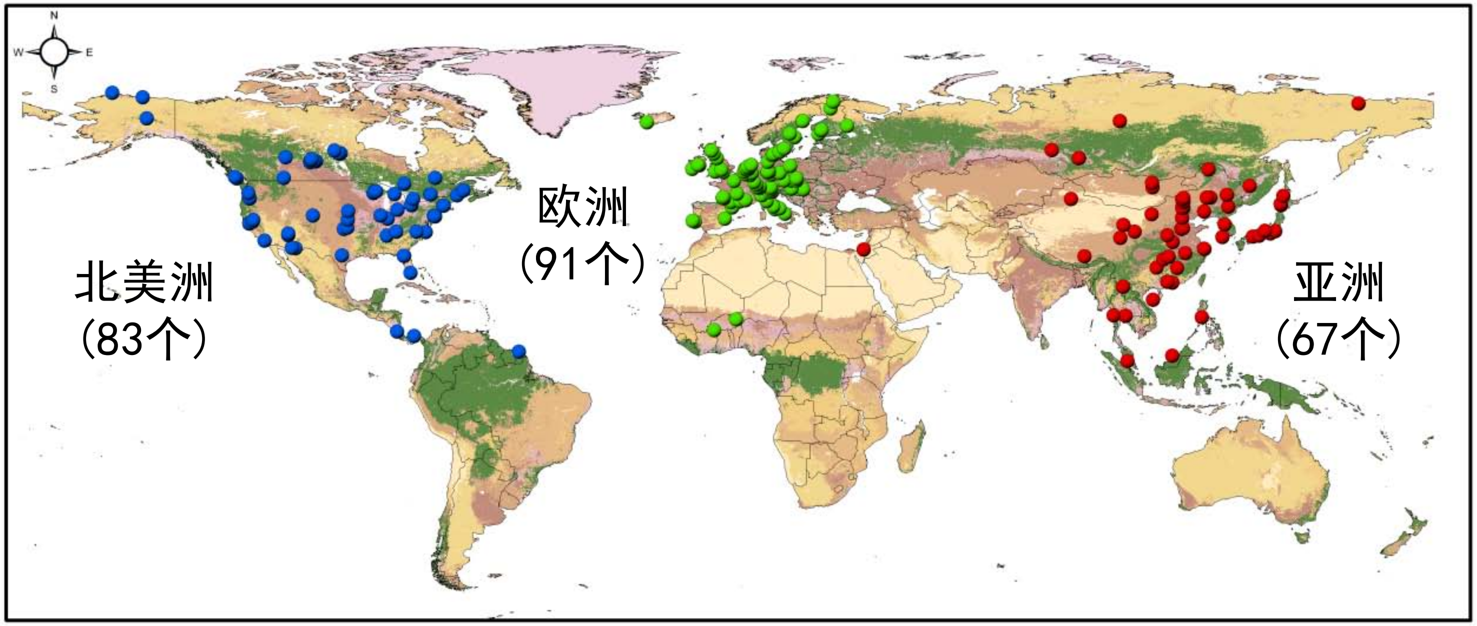
1. 坐标轴旋转
2. WPL校正
3. 储存项计算
4. 夜间数据校正
5. 缺失数据插补
6. 通量组分拆分

↓

计算每个站点的多年平均碳通量

研究数据

2. 北半球碳通量数据分布

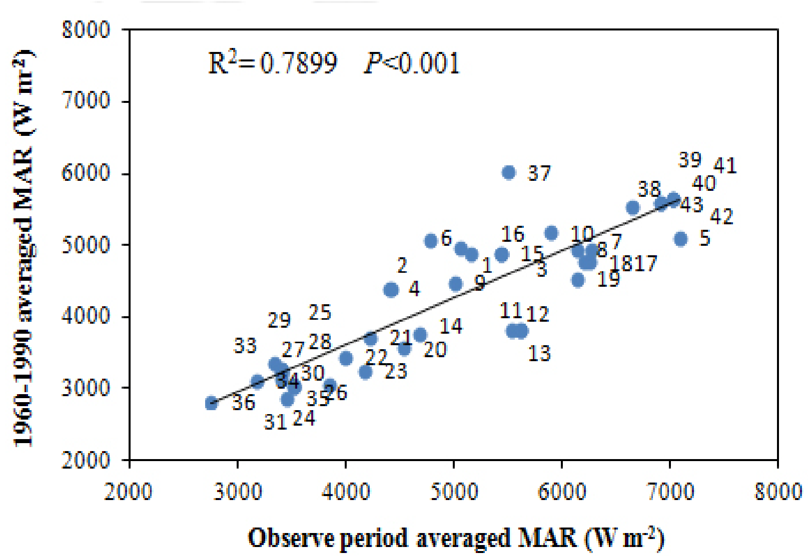


- ✓ 获取位于北半球的241个通量站点的861条有效的站点年碳通量数据。
- ✓ 涵盖了热带、亚热带、温带、北方林带、极地带和高山带六个气候带。
- ✓ 包括了常绿阔叶林(13)、常绿针叶林(64) 、落叶阔叶林(25) 、落叶针叶林(5) 、针阔混交林(12) 、草地(60) 、农田(34)和湿地(28)八类生态系统。

研究数据

3. 气候、土壤和植被数据

- **年均温和年总降水量**—通量塔监测与全球地表气象数据的插补
- **年总辐射**—月尺度气象数据集(CRU05)的30年年均太阳总辐射



- **土壤有机碳含量**—全球归一化土壤数据集的0-30 cm和30-100 cm层土壤有机碳含量
- **植被EVI**—MOD13Q1的250 m空间分辨率，16天时间分辨率的全球EVI数据

$$\text{Pix} = \begin{cases} 1 & if \quad pixel\ reliability = 0, 1; \\ 0 & if \quad pixel\ reliability = 2, 3; \end{cases}$$

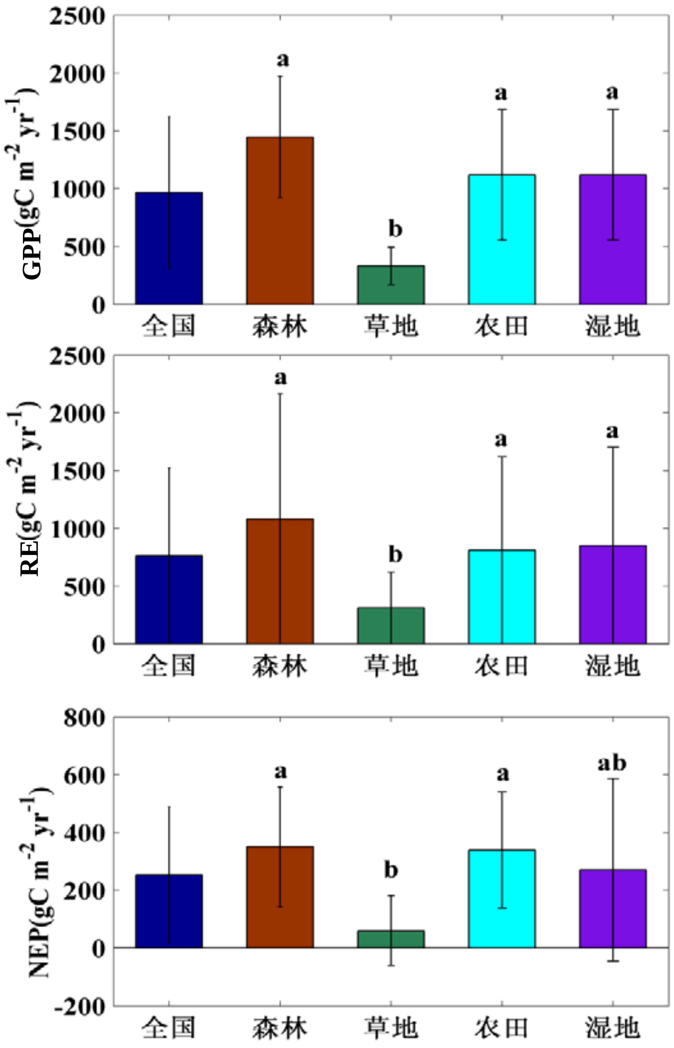
$$\text{n}_{i,j} = count\,(Pix = 1);$$

$$i = 1, 17, 33, \cdots\cdots 353; \quad j = 2000, 2001, \cdots\cdots 2010;$$

$$EVI_i = \begin{cases} \dfrac{\sum_{n=1}^{n_{i,j}} EVI_n}{n_{i,j}} & if \quad n_{i,j} \geq 0.25N \quad (N = 81); \\ missing & if \quad n_{i,j} \leq 0.25N \quad (N = 81); \end{cases}$$

$$\overline{EVI_i} = \frac{\sum_{i=1}^{353} EVI_i}{23} \qquad i = 1, 17, 33, \cdots\cdots 353;$$

1. 中国区域陆地生态系统碳通量特征



中国区域生态系统碳通量特征比较

中国区域平均（g C m^{-2} yr^{-1}）：

GPP：965.45 ± 665.53

RE： 760.84 ± 473.38

NEP：252.88 ± 234.23

中国区域是强净碳吸收区

生态系统类型间：

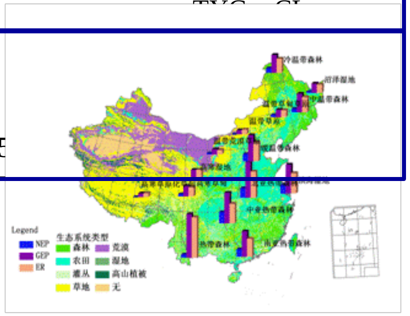
森林、农田 ＞ 草地

Yu et al. 2013. GCB

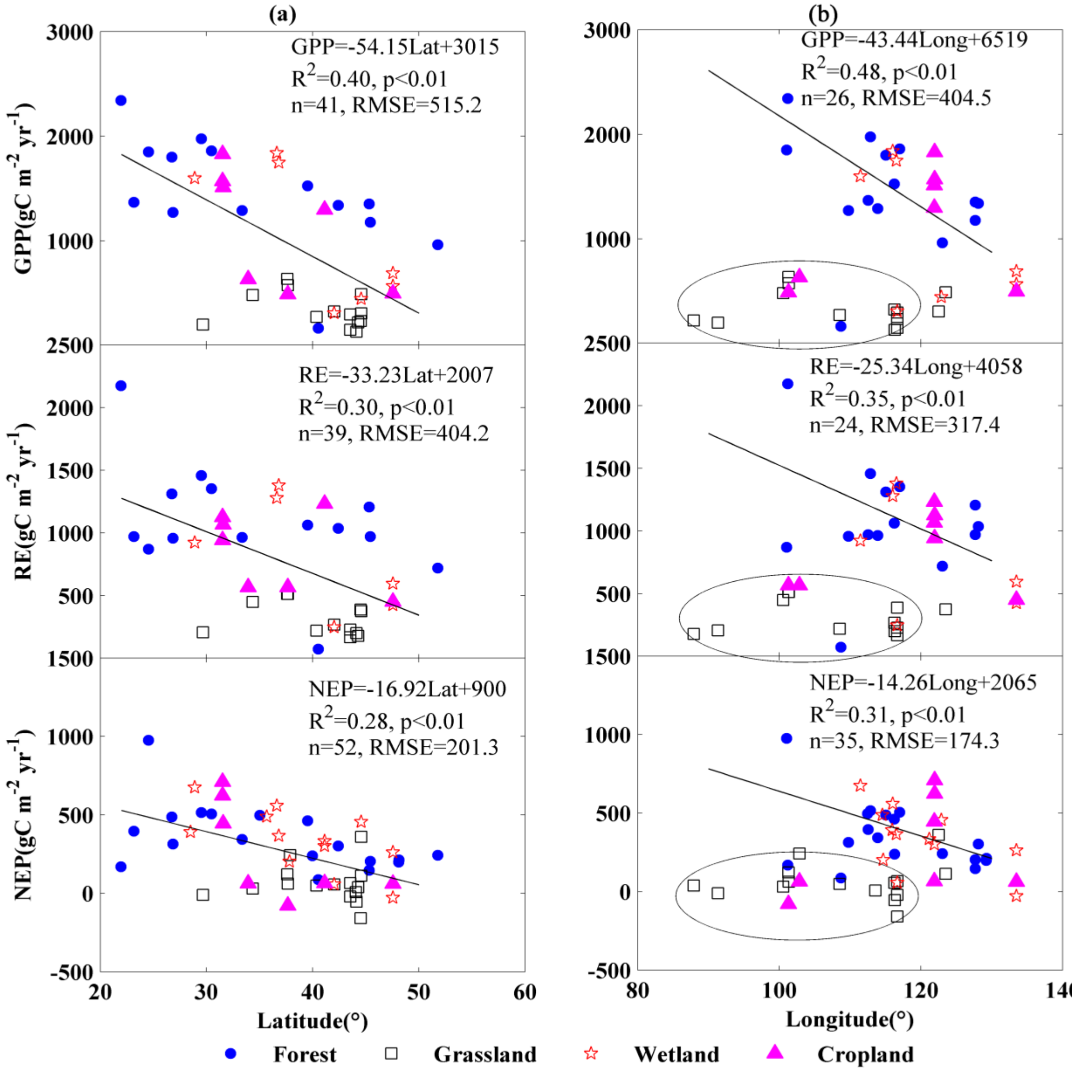
1. 中国区域陆地生态系统碳通量特征

表 中国重要区域的森林、草地和湿地生态系统碳通量的统计特征

生态系统类型	气候区	年平均GPP（g C m^{-2} yr^{-1}）	年平均RE（g C m^{-2} yr^{-1}）	年平均NEP（g C m^{-2} yr^{-1}）	数据来源的观测站信息
森林	寒温带森林	962.75	760.40	242.35	**HZ**
	中温带森林	1007.15±568.54	822.85±507.74	191.75±72.03	YCF、YCF2、CBS、LS、KBQF、MES
	暖温带森林	1406.55±167.51	1013.85±69.51	385.36±117.81	DXF、XLD、XP、HD
	北亚热带森林	1917	1406.13	510.88	AQ、YY
	中亚热带森林	1639.69±319.39	1047.20±232.57	592.36±343.59	QYZ、ALS、HT
	南亚热带森林	1367.26	971.31	395.95	DHS
	热带森林	2342.67	2173.83	168.83	XSBN
草地	青藏高原中部高寒草地	197.46	207.65	-10.18	DX
	青藏高原东缘草甸草原	563.14±77.75	492.19±36.54	113.65±93.33	SJY、HB、HBGC、HTC
	温带荒漠草原	270.18	221.01	49.17	KBQG
	温带典型草原	225.80±85.93	251.91±85.59	-17.65±82.47	XLHT、NM、XLF、XLD、DLG、XLGL
	温带草原	396.41	375.8	112.35	TYG、GL
湿地	三江平原湿地	497	453	61.67	
	青藏高原湿地	560.03±100.29	567.90	-7.86	
	滨海湿地	1552.61±218.64	1092.34±120.80	460.94±285	



2. 中国陆地生态系统碳通量的空间格局特征



中国陆地生态系统碳通量的经纬度格局

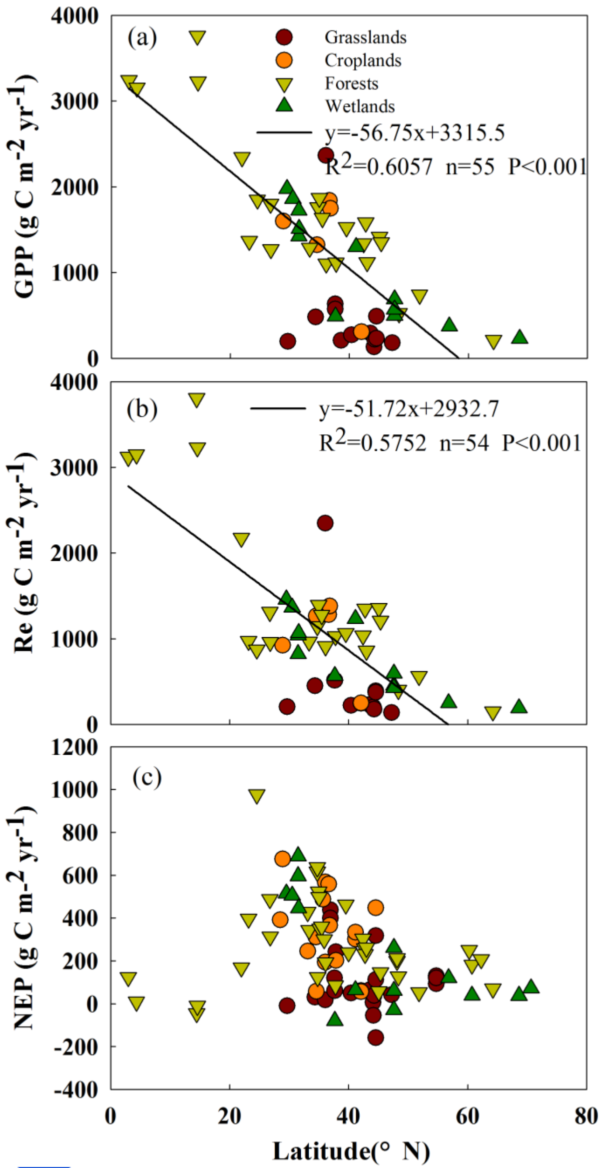
明显的纬向变化趋势：

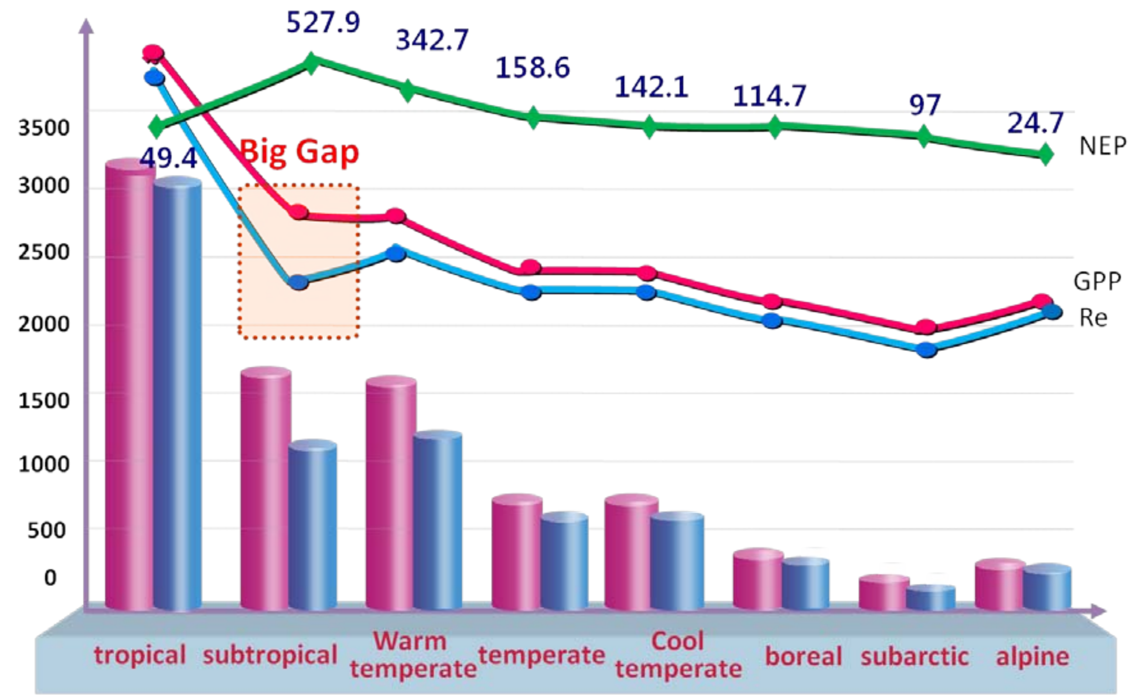
GPP, RE,NEP随着纬度的升高而降低

复杂的经向变化趋势

Yu et al. 2013. GCB

亚洲区域不同气候带碳通量空间分布特征



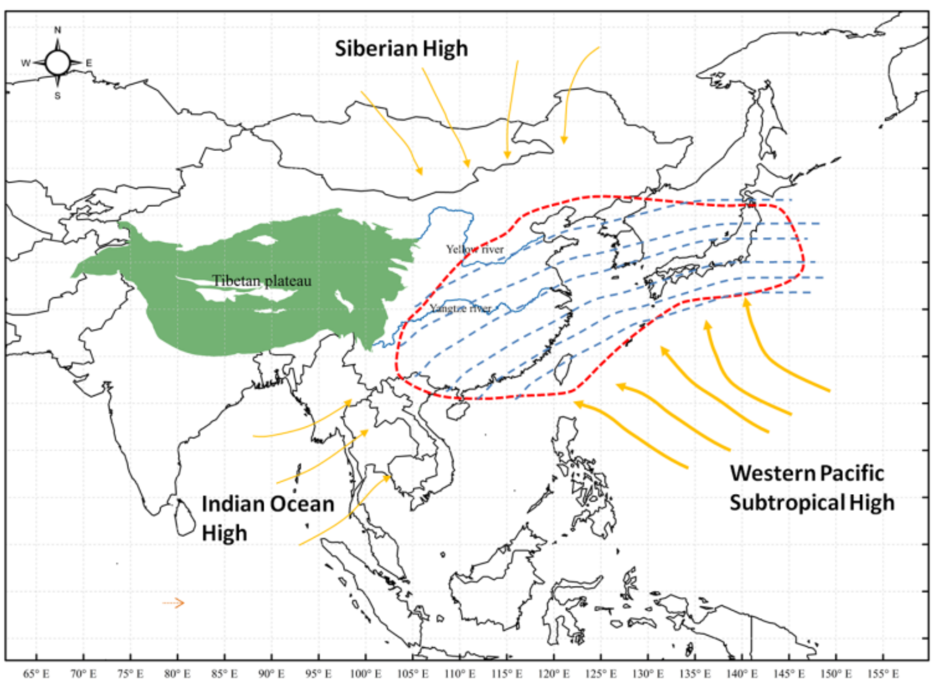


数据源：基于亚洲区域88个站点

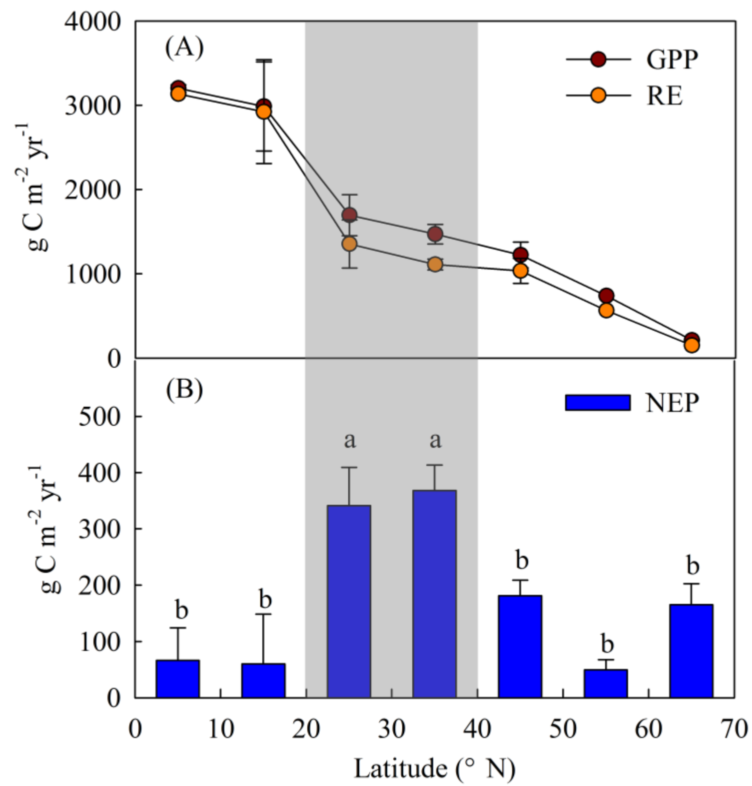
亚洲GPP和RE呈现显著的随纬度升高而降低的趋势，NEP无显著纬向变化趋势，但是亚热带区域NEP显著高于热带和温带的NEP。

3.东亚季风区森林高碳汇功能区

- 发现**东亚季风区亚热带森林**是个被长期忽视的高碳吸收功能区
- 东亚季风区森林碳吸收强度平均约为**362 ± 39 g C m^{-2} yr^{-1}**

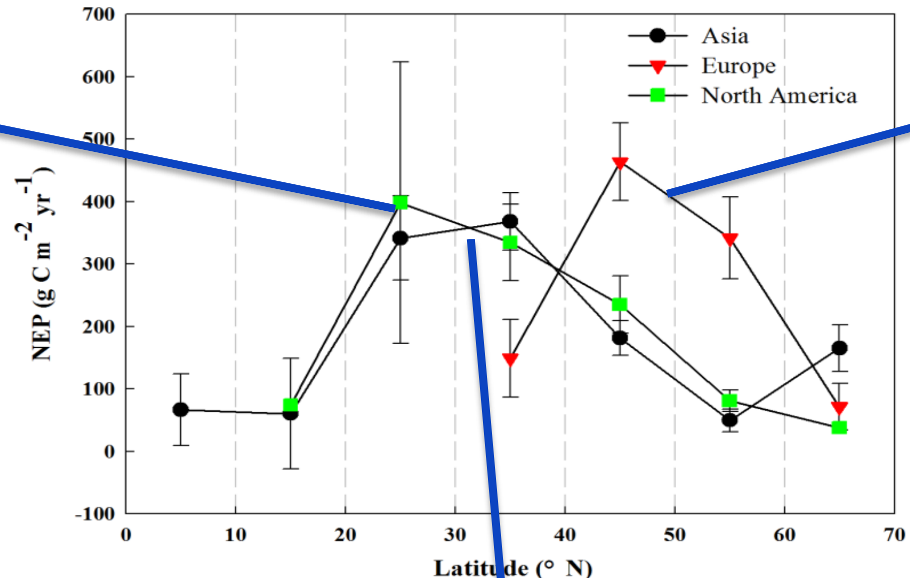


东亚季风区地理位置
（20-40° N, 100-145° E）

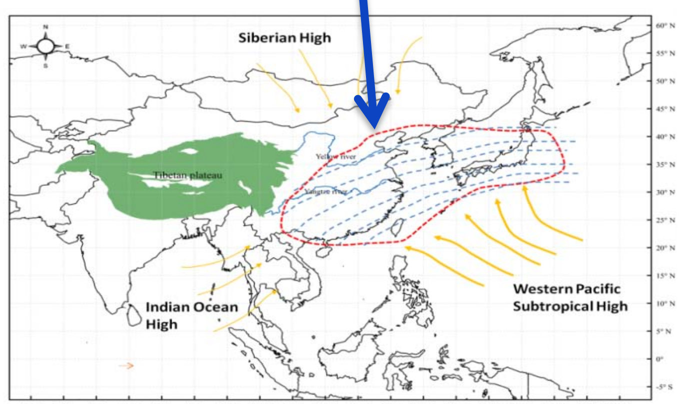


亚洲森林NEP的10° 纬度分布特征

东亚季风区森林高碳汇功能区

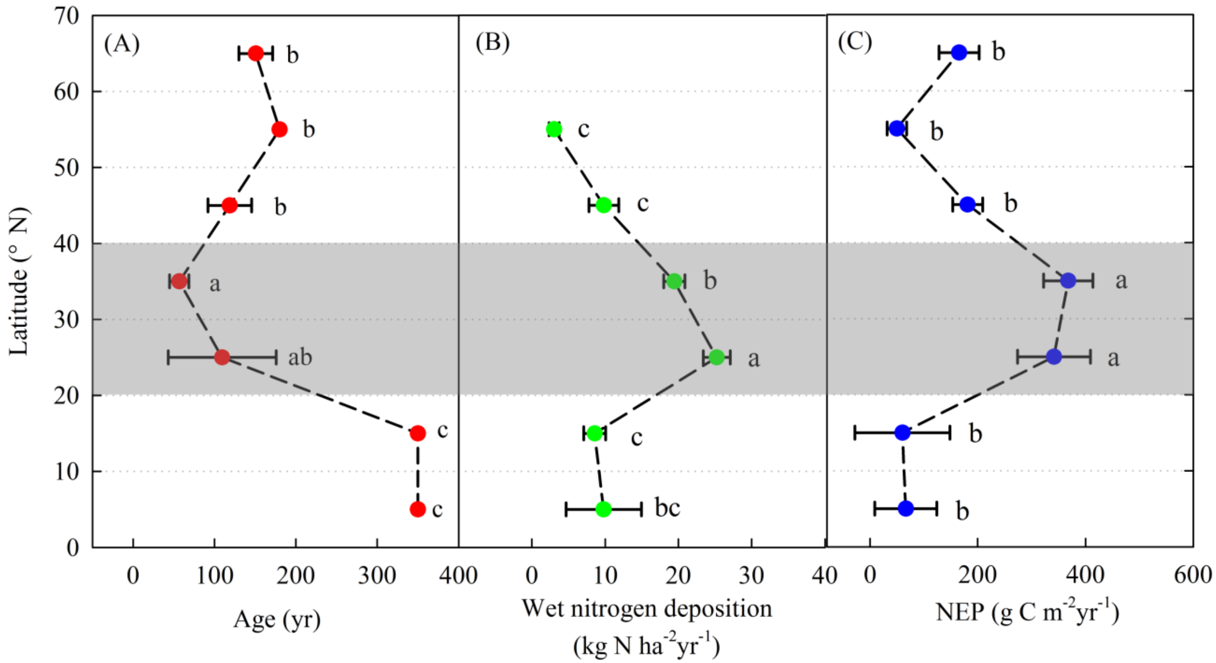


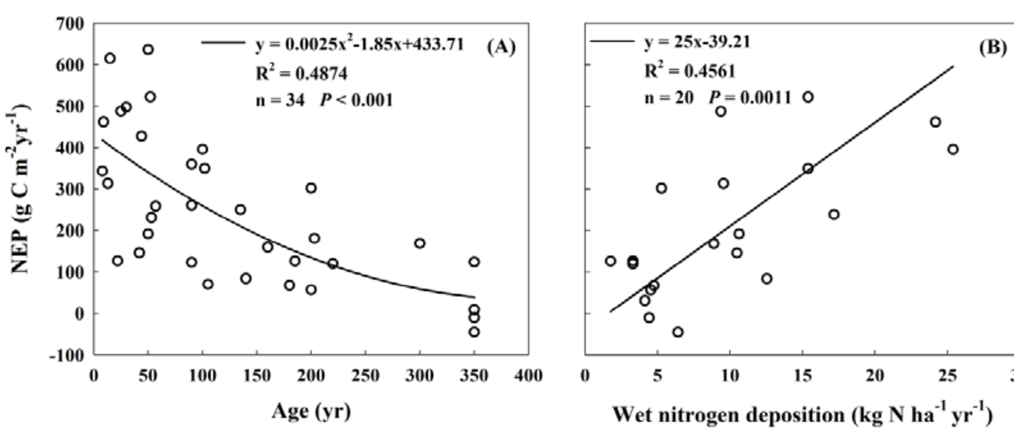
东亚季风区森林的碳吸收强度与被国际学术界广泛公认的两大碳汇区“北美和欧洲温带森林”的碳吸收强度相当。



挑战了过去仅认为欧美温带森林是主要碳汇功能区的传统观点

东亚季风区森林高碳汇功能区





形成机理分析：

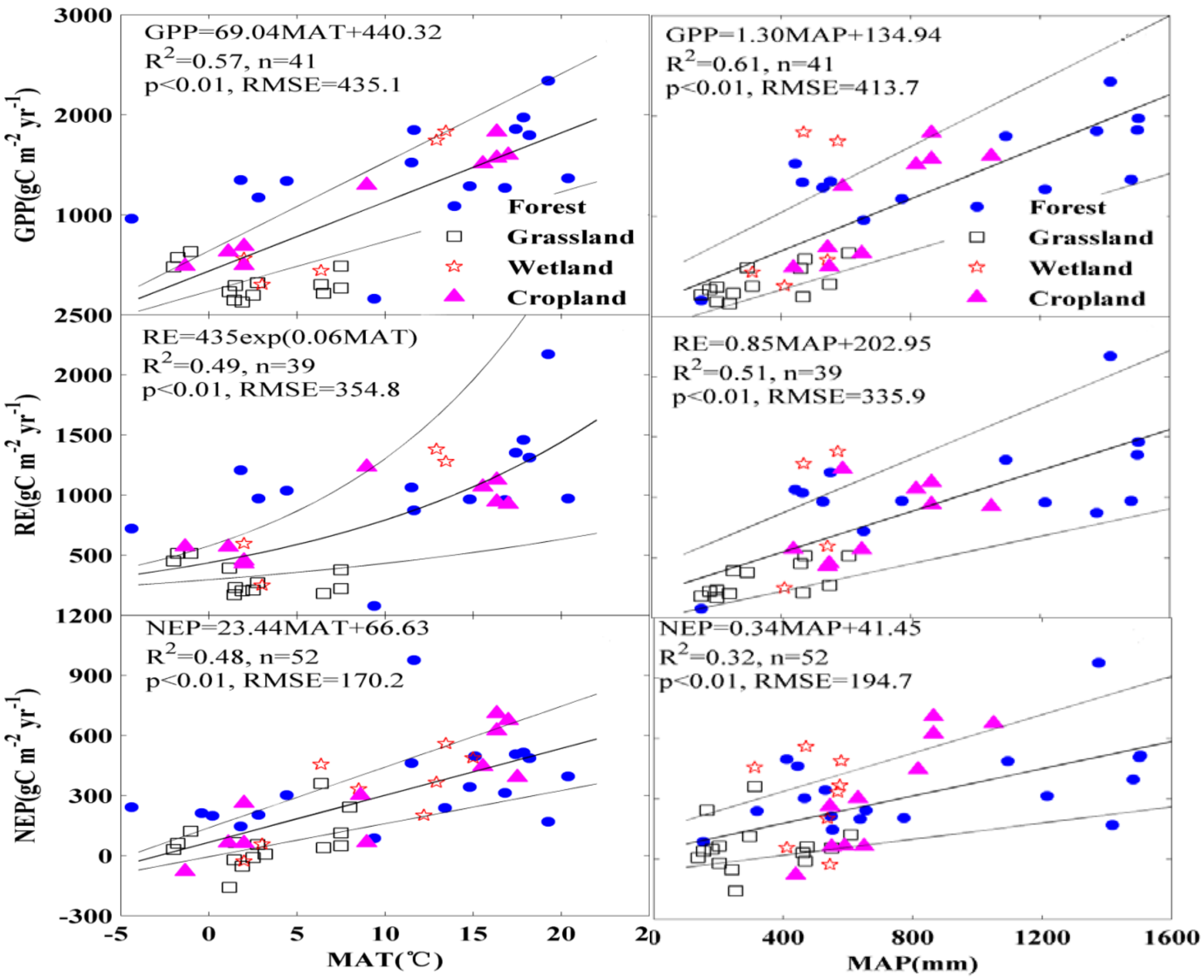
东亚季风区森林高碳吸收强度是

- 区域高氮沉降量
- 年幼的林龄结构
- 适宜的气候特征

叠加作用的结果

Yu and Chen et al., 2014, PNAS

4. 中国陆地生态系统碳通量空间格局的影响因子



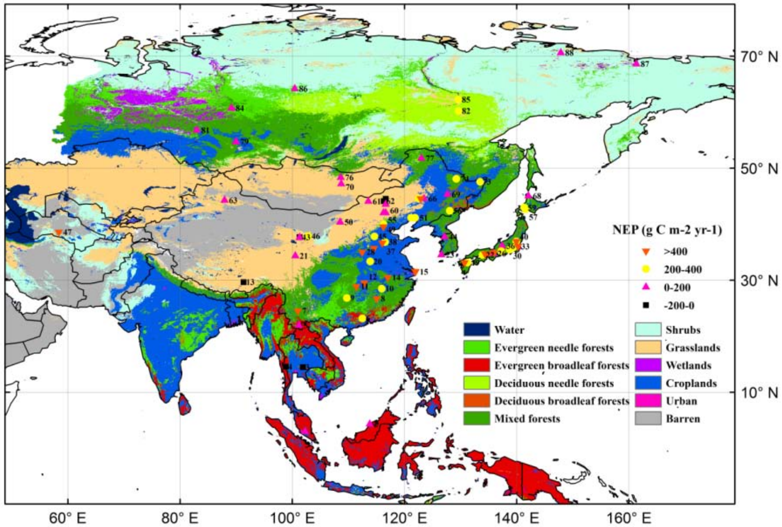
年均气温和年降水量对中国碳通量格局的影响

中国区域GPP、RE和NEP的空间变异均与年均温MAT和年总降水量MAP的空间格局显著相关。

GPP、RE和NEP在空间上分别随着MAT增加而线性或指数性增加。

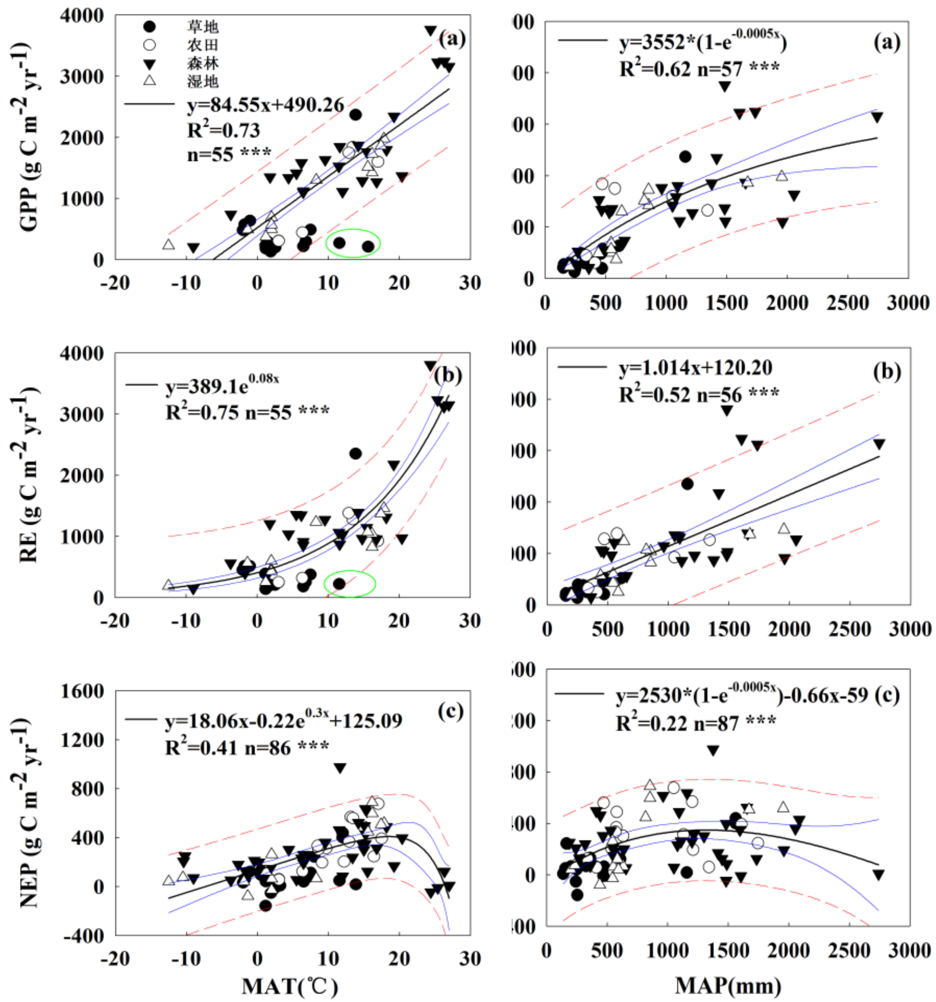
Yu et al. 2013. GCB

年均温和降水量对亚洲区域碳通量空间格局的影响



整合分析发现:

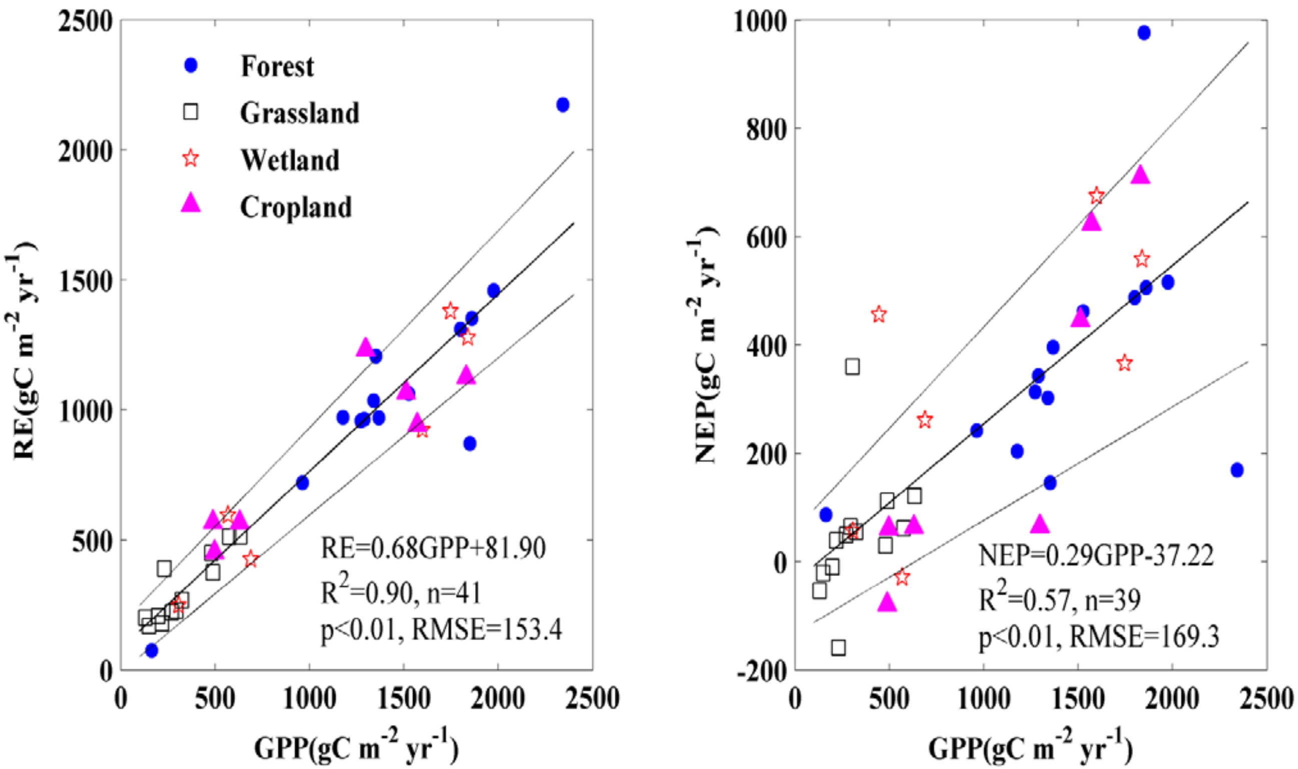
- 年均温度(MAT)和年总降水量(MAP)的空间格局也是亚洲陆地生态系统GPP、RE和NEP的空间变异格局的主要调控因子。
- MAT和MAP决定了亚洲区域GPP、RE和NEP的62-73%，52-75%和22-41%的空间变异性。



年均气温和年总降水量对亚洲碳通量空间格局的影响

Chen et al. 2013, AFM

4.中国区域GPP与RE和NEP空间格局上的耦联性



中国陆地生态系统碳通量间的空间耦联性

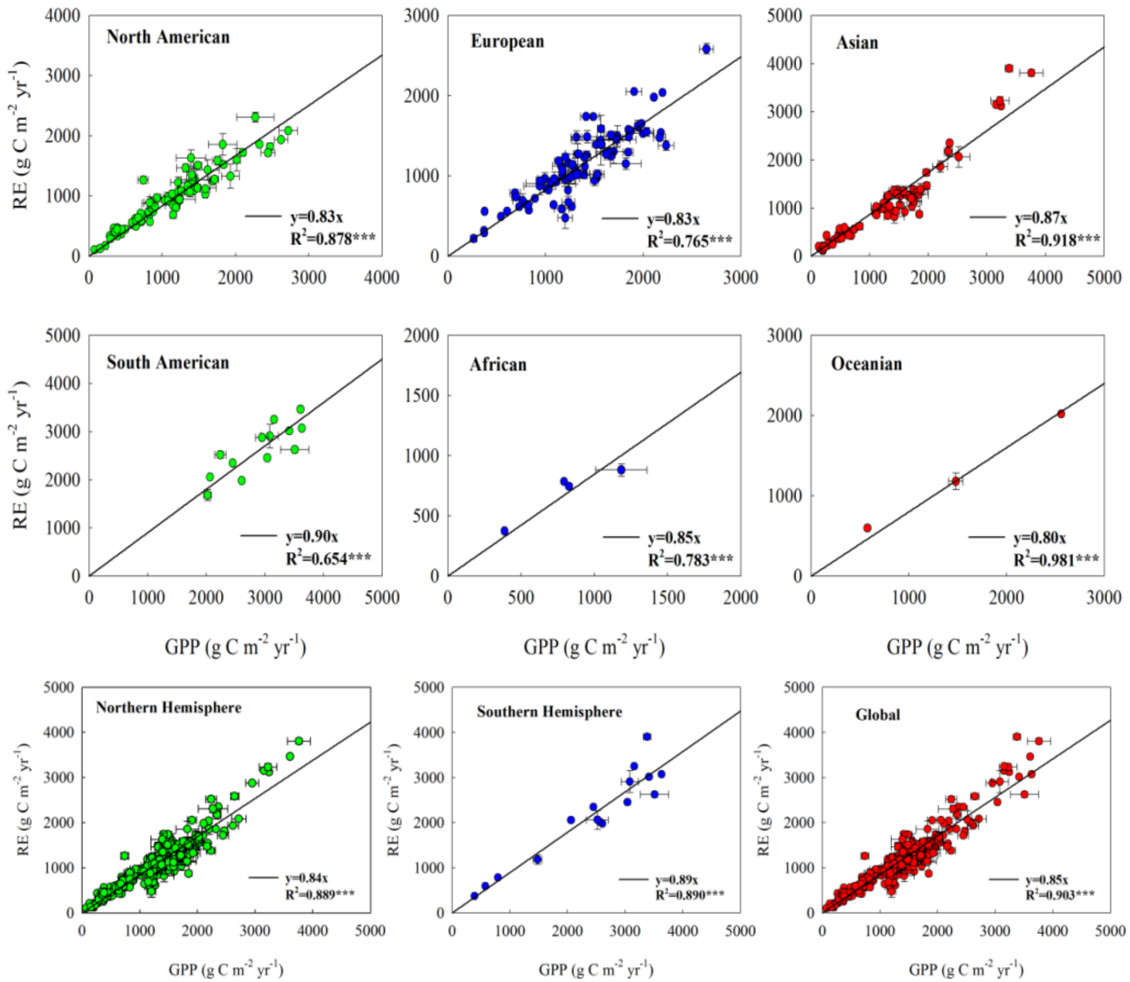
由森林、草地、湿地和农田生态系统构成的陆地生态系统的GPP与RE和NEP区域空间格局存在着严格的**“耦联性的同向共变现象”**

中国区域的陆地生态系统年均GPP水平决定了RE和NEP;

在空间格局变化上，单位GPP的变化对RE的贡献率为0.68，对NEP的贡献率为0.29。

Yu et al. 2013. GCB

全球GPP与RE在空间格局上的耦联性

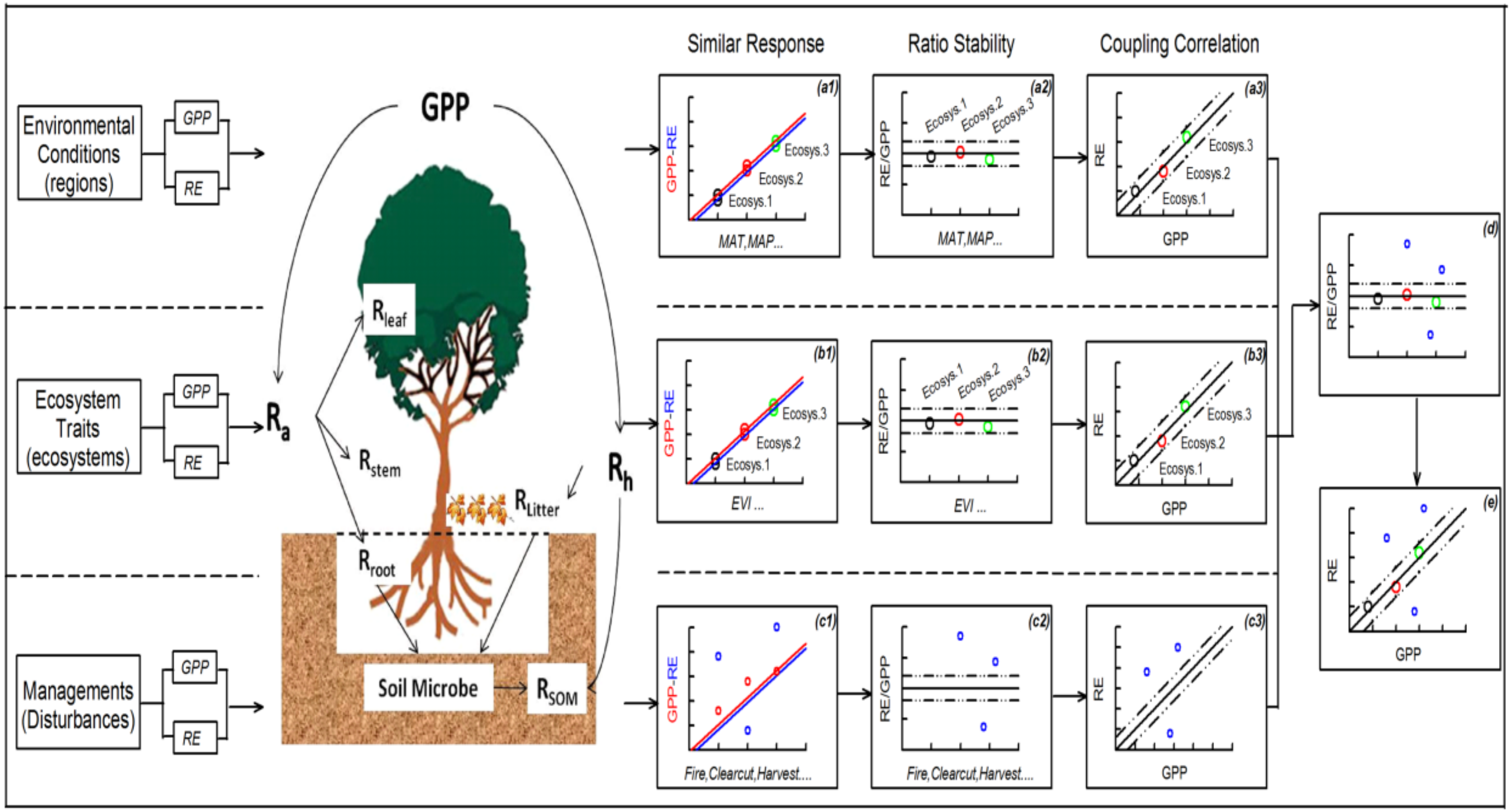


北美洲、欧洲、亚洲、南美洲、非洲、大洋洲、北半球、南半球和全球范围GPP与RE空间格局的偶联共变性

- 从区域-半球-全球尺度，生产力GPP与呼吸RE的空间变异格局呈现出一致的“同向耦联共变规律”。
- 回归斜率RE/GPP在六个区域之间以及南北半球之间均无显著差异。

Chen et al. 2015. AFM

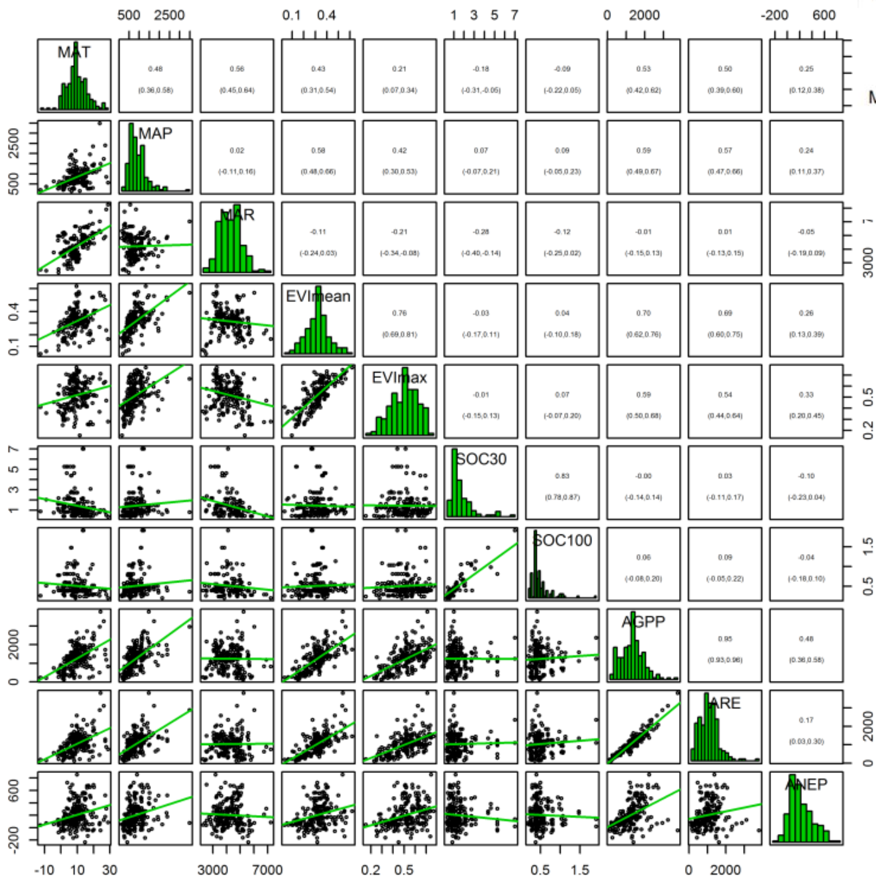
全球GPP与RE空间格局的耦联共变的形成机制



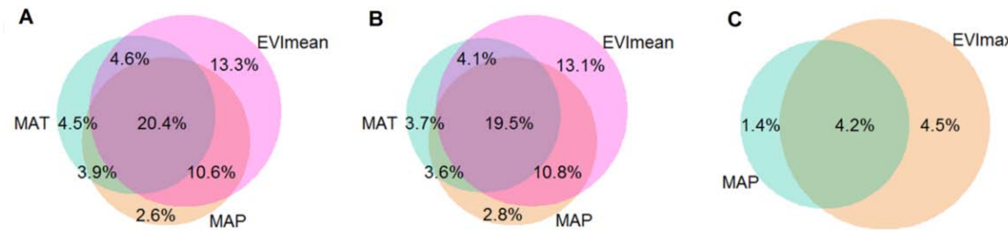
- 气候和生物因子对GPP和RE具有高度相似的同向驱动机制
- 生理学机理在于GPP是RE呼吸底物的根本物质基础

Chen et al. 2015. AFM

5. 植被、土壤格局对碳通量空间格局的调控作用



碳通量与各个影响因子的相关性

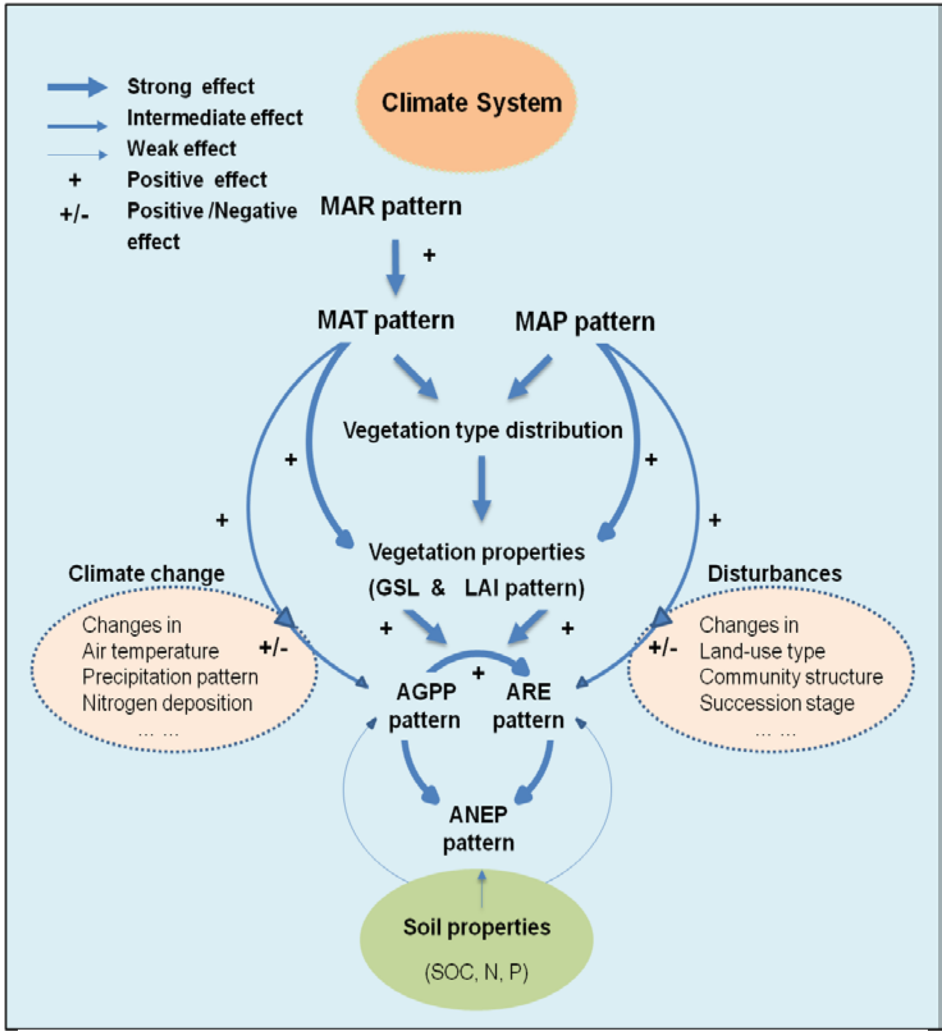


气候和植被因子对GPP、RE、NEP的调控作用大小

- MAT和MAP是GPP和RE空间格局的主要调控因子。
- 土壤有机碳含量对GPP和RE空间格局的调控作用较小。
- MAT和MAP通过调控EVI的空间变异决定了北半球60 % 的GPP空间变异和58 %的RE空间变异。

Chen et al., 2015, PLoS ONE

碳通量空间格局的生物地理生态学调控机制



生态系统碳通量空间格局的生物地理生态学调控机制

调控机理解析：

- 辐射+温度+降水→植被类型的地理分布
- 植被类型→植被生理生态学特征(叶面积大小LAI+生长季长度GSL) → GPP
- GPP → RE
- 土壤有机碳︱影响较小
- NEP ← GPP – RE + △ (△: 氮沉降、干扰…)

Chen et al., 2015, PLoS ONE

6.构建中国区域碳通量的地统计学评估模型

陆地碳收支评估的模式化方案

➢基于MAT和MAP对碳通量（GPP、RE和NEP）空间格局影响的模式化方案

$$Cflux = \min\{(A + B \times MAT), (C + D \times MAP)\} \quad (1)$$

$$Cflux = A + B \times MAT + C \times MAP \quad (2)$$

$$Cflux = A + B \times MAT + C \times MAP + D \times MAT \times MAP \quad (3)$$

（A，B，C和D为碳通量与MAT和MAP间的回归参数）

➢利用GPP、RE和NEP空间耦联关系的模式化方案

$$RE = 0.68 \times GPP + 81.90 \quad (4)$$

$$NEP = 0.29 \times GPP - 37.22 \quad (5)$$

➢基于NEP与GPP和RE理论关系的模式化方案

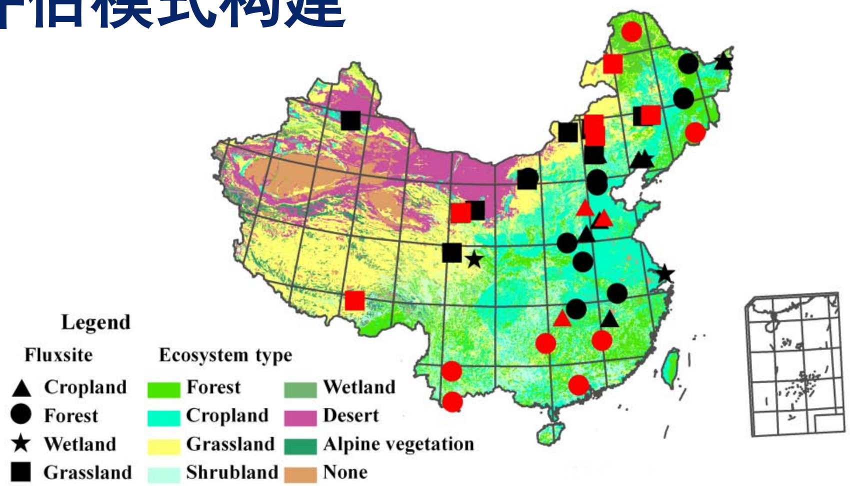
$$NEP = GPP - RE \quad (6)$$

碳收支评估模式

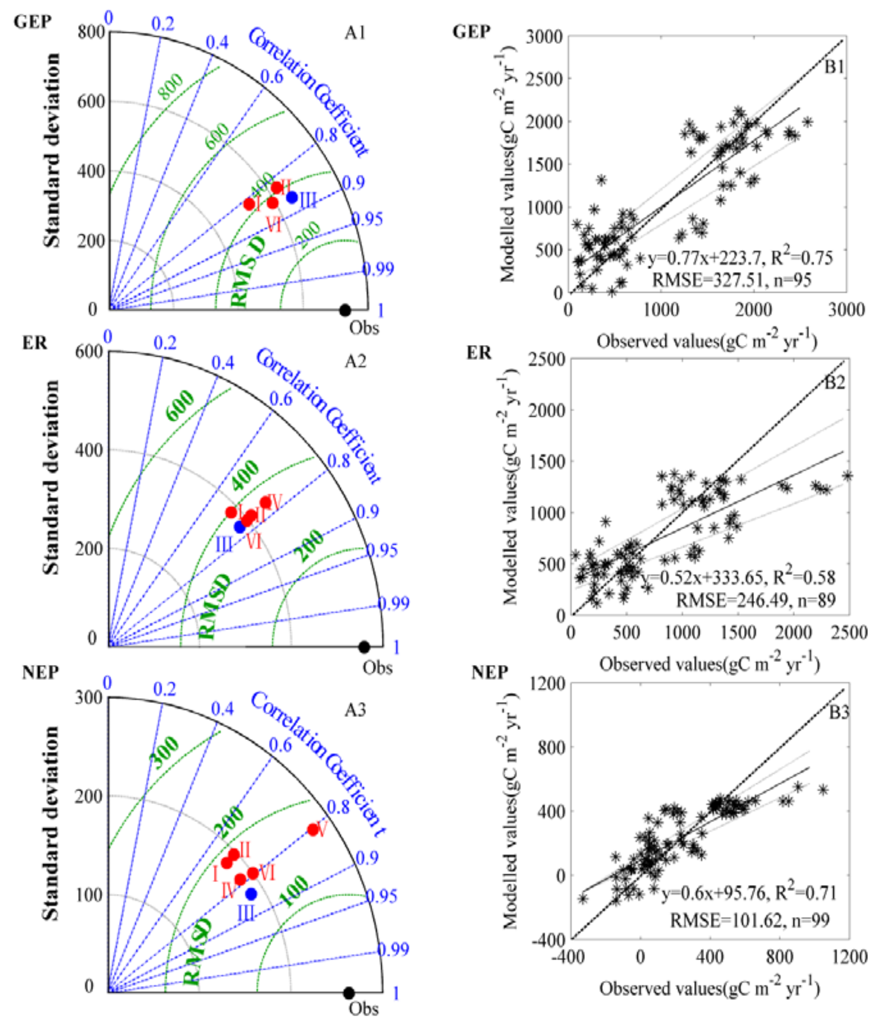
Cfluxes	GPP	RE	NEP
I	(1)	(1)	(1)
II	(2)	(2)	(2)
III	(3)	(3)	(3)
IV		(4)	(5)
V			(6)
VI	平均	平均	平均

构建中国区域碳通量的地统计学评估模型

评估模式构建



泰勒图　　Leave-one-out交叉验证



最优评估方案

$$GPP = A+B\times MAT+C\times MAP+D\times MAT\times MAP$$

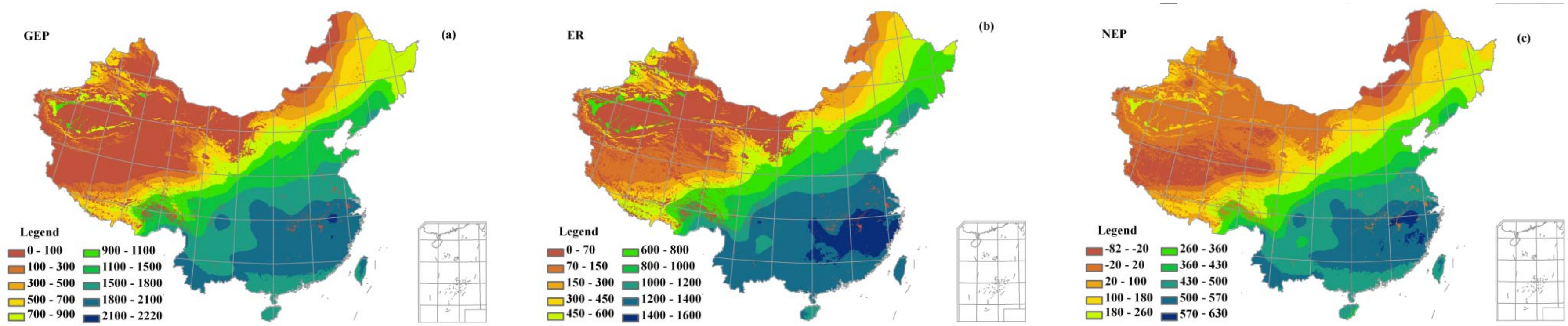
$$RE = 0.68\times GPP+81.90$$

$$NEP = GPP-RE$$

- 绝大多数点均匀分布在1:1线周围

Zhu et al. 2014. GPC

中国区域陆地生态系统碳通量评估



Cfluxes	Assessment schemes[b]						
	I	II	III	IV	V	VI	Mean (std)
GEP[a]	6.79	7.95	7.78	–	–	7.51	7.51 ± 0.51
ER	5.75	6.05	5.65	5.89	–	5.75	5.82 ± 0.16
NEP	1.79	2.15	1.71	1.99	1.89	1.91	1.91 ± 0.15

2001-2010年，中国区域**GPP**、**RE**和**NEP**分别为

7.78、5.89和1.89 Pg C yr^{-1}

Zhu et al. 2014. GPC

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谢　谢！

Thanks for your attention!