基于分解思路的生产力的调控机理认识及其对模型的启示

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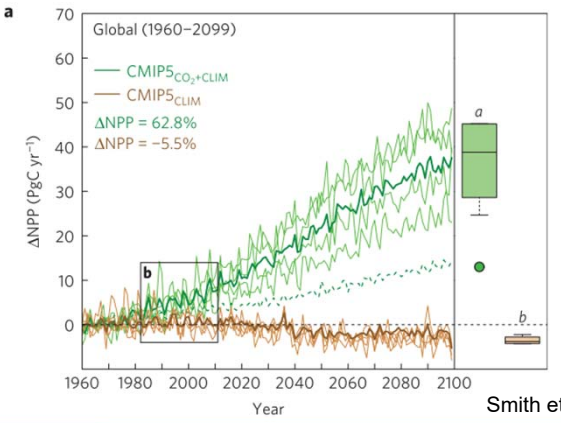
背景I：

模型是评估和预测植被生产力动态变化的基本手段，但不同模型对于生产力年际变异的模拟差异巨大



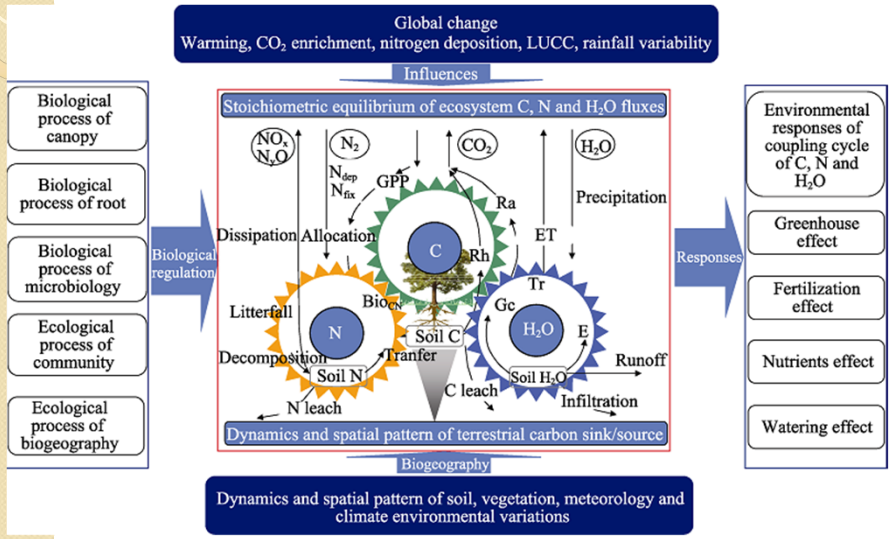
Smith et al., 2016

nature climate change
LETTERS
PUBLISHED ONLINE: 7 DECEMBER 2015 | DOI: 10.1038/NCLIMATE2879

Large divergence of satellite and Earth system model estimates of global terrestrial CO_2 fertilization

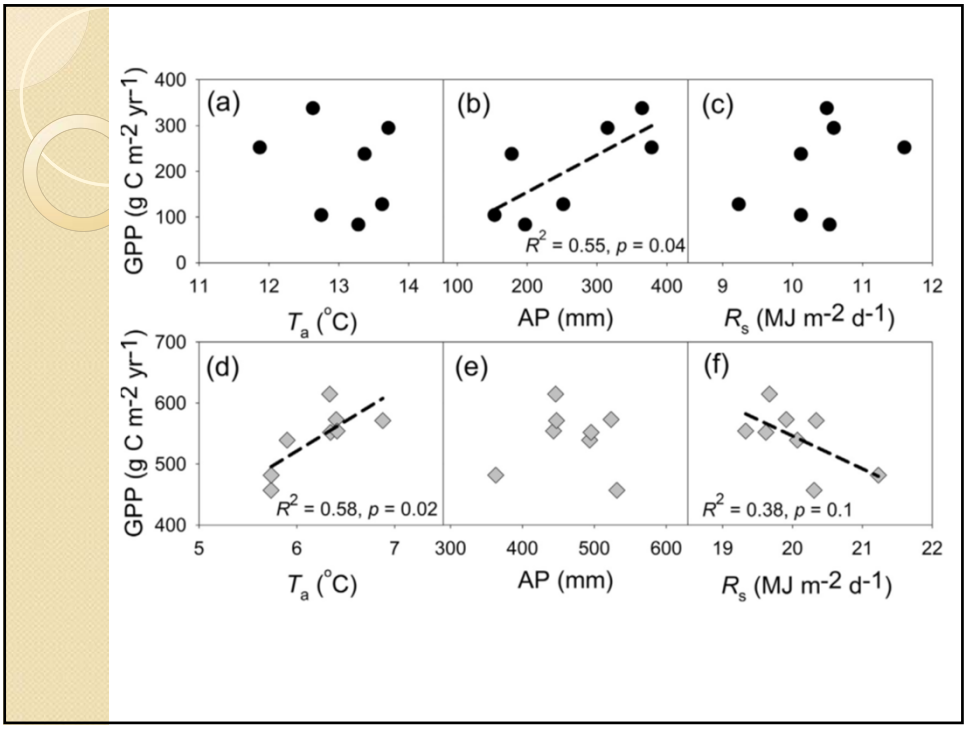
背景2:

生态系统碳水过程复杂交错，难以厘清其时空变异的主控因子



解决思路

- 传统方法：与不同生物环境因子建立统计关系，从而解析主控因子。
- 新的思路：对生产力进行拆分，找出影响生产力的关键过程，进而改进模型



PERSPECTIVE
PUBLISHED ONLINE: 21 MAY 2015 | DOI: 10.1038/NCLIMATE2621
nature climate change

Using ecosystem experiments to improve vegetation models

Belinda E. Medlyn[1,2*], Sönke Zaehle[3], Martin G. De Kauwe[1], Anthony P. Walker[4], Michael C. Dietze[5], Paul J. Hanson[4], Thomas Hickler[6], Atul K. Jain[7], Yiqi Luo[8], William Parton[9], I. Colin Prentice[1,10], Peter E. Thornton[4], Shusen Wang[11], Ying-Ping Wang[12], Ensheng Weng[13], Colleen M. Iversen[4], Heather R. McCarthy[8], Jeffrey M. Warren[4], Ram Oren[14,15] and Richard J. Norby[4]

Box 1 | Examples of analyses used in the assumption-centred approach.

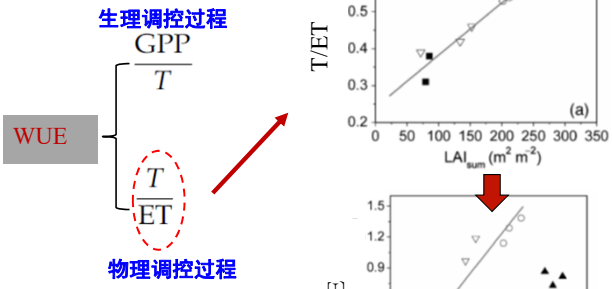
Model simplification. One technique is to compare all outputs for a given process against those from a 'lowest common denominator' simple model. For example, 10 of the 11 models considered here applied similar representations of stomatal conductance. All used different versions of the stomatal conductance model of Ball, Woodrow and Berry[64]. The simplest possible application of this model predicts that WUE, defined as canopy assimilation divided by transpiration, should be proportional to the C_a, independent of model parameterization. We therefore compared modelled WUE against this simple prediction. In two of the models, the difference from the simple model could be attributed to the fact that they used structurally different variants of the Ball, Woodrow and Berry model, which do not yield the same proportional response to C_a. Leaf-level gas exchange data from both experiments supported the simplest possible model rather than the variants[29]. Thus, this approach allowed us not only to identify an important difference among the assumptions of the models and outline their importance for predicting the ecosystem-level consequence of CO_2 fertilization, but also to identify which of these assumptions were supported by observations.

Model decomposition. A second technique is to decompose a process into its components to identify which of several underlying assumptions is causing intermodel differences[28,65]. For example, ref. 28 decomposed net primary production (NPP, gC m^{-2} yr^{-1}) into N use efficiency (NUE, gC per gN) and N uptake (N_{up}, gN m^{-2} yr^{-1}):

$$NPP = NUE \times N_{up}$$

Using this decomposition, ref. 28 showed that, although several models correctly estimated the eC_a effect on NPP, they did so for the wrong reason: effects of eC_a on NUE were overestimated, whereas effects on N_{up} were underestimated.

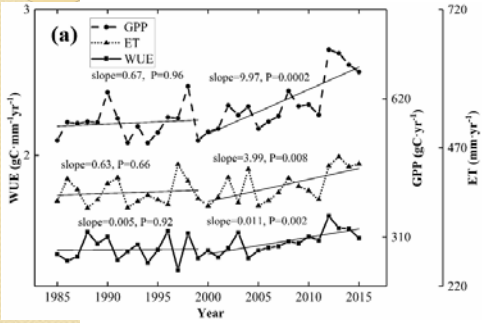
案例1：生态系统水分利用效率的调控机制

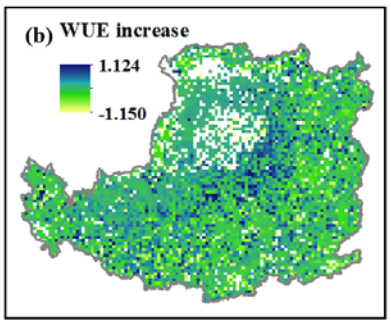


$$WUE = \frac{GPP}{ET} = \frac{GPP}{T} \times \frac{T}{ET}$$

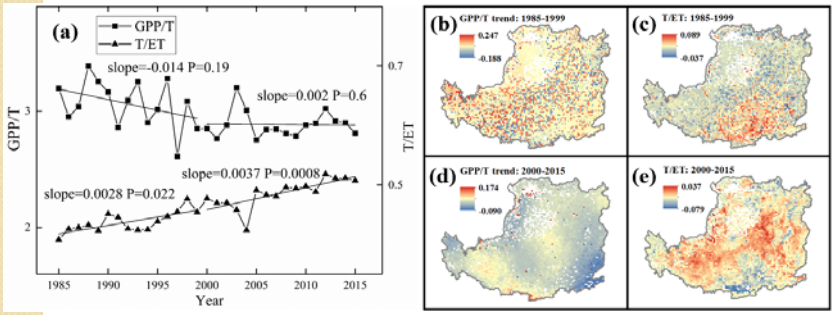
Hu et al. 2008. Global Change Biology

黄土高原WUE的变化与机理

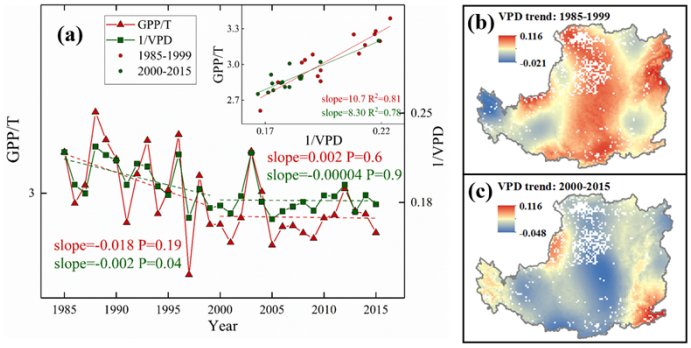




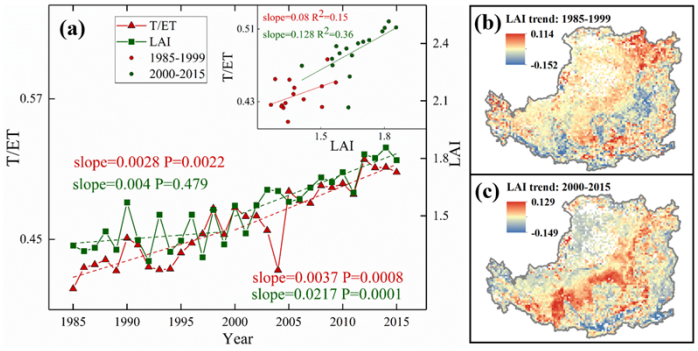
WUE=GPP/T × T/ET



GPP/T



T/ET

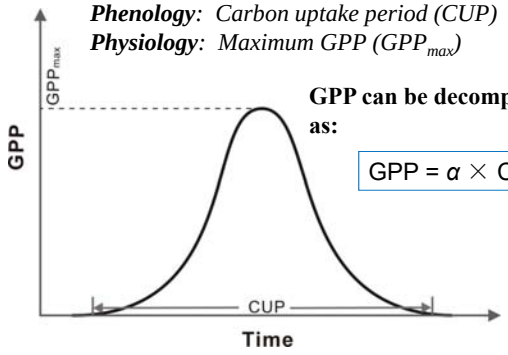


案例2：GPP的变异与机理

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[n], Lawrence B. Flanagan[o], Christian Frankenberg[p], Teodoro Georgiadis[q], Christopher M. Gough[r], Dafeng Hui[s], Gerard Kiely[t], Jianwei Li[a,1], Magnus Lund[u], Vincenzo Magliulo[v], Barbara Marcolla[w], Lutz Merbold[x],

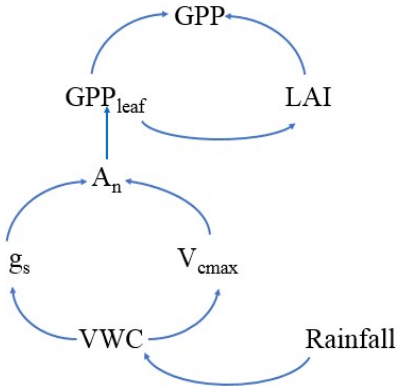
Phenology: *Carbon uptake period (CUP)*
Physiology: *Maximum GPP (GPP_{max})*



GPP can be decomposed as:

$$GPP = \alpha \times CUP \times GPP_{max}$$

GPP=GPP_{leaf}×LAI



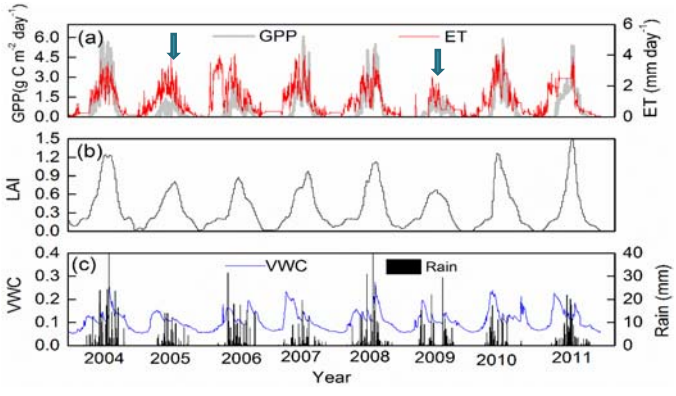
PRIMARY RESEARCH ARTICLE

WILEY Global Change Biology

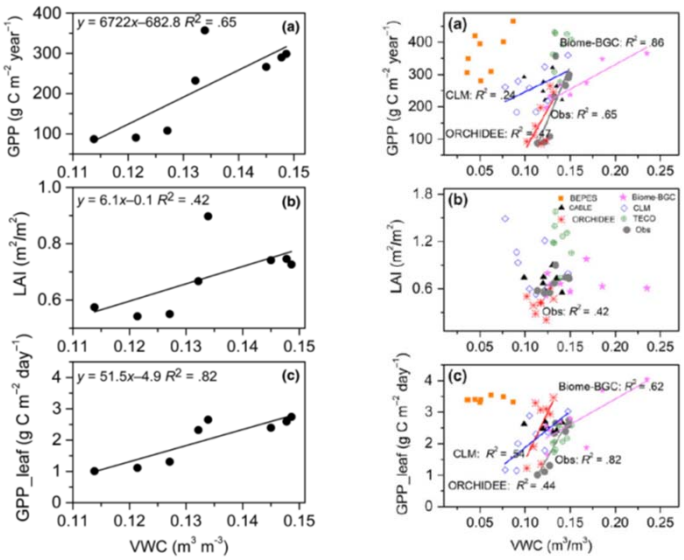
Joint structural and physiological control on the interannual variation in productivity in a temperate grassland: A data-model comparison

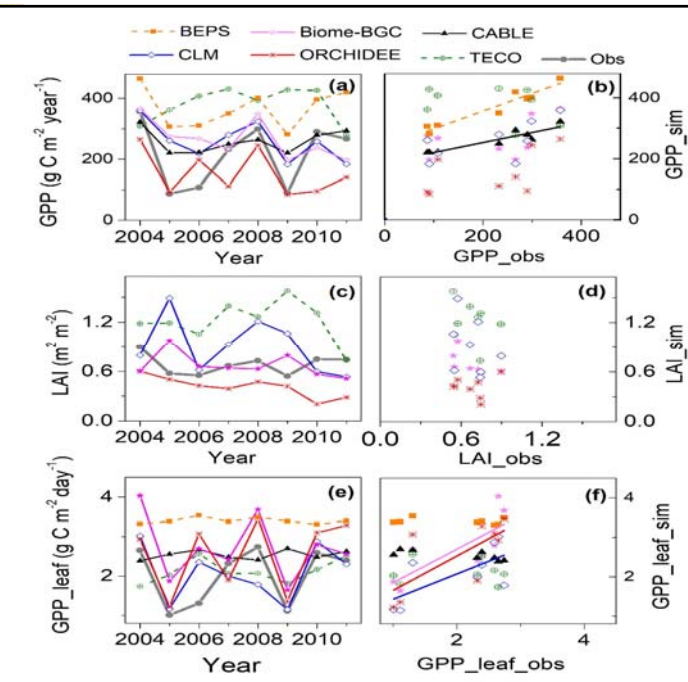
Zhongmin Hu[1,2,3,#] | Hao Shi[4,#] | Kaili Cheng[2,3] | Ying-Ping Wang[5,6] | Shilong Piao[7,8] | Yue Li[7] | Li Zhang[2,3] | Jianyang Xia[9,10] | Lei Zhou[11] | Wenping Yuan[12] | Steve Running[13] | Longhui Li[14] | Yanbin Hao[15] | Nianpeng He[2,3] | Qiang Yu[3,4,16] | Guirui Yu[2,3]

Observed pattern



Sharp reductions in GPP in drought years, but not so much for ET and LAI





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JGR Biogeosciences

Research Article | Full Access

Leaf Area Rather Than Photosynthetic Rate Determines the Response of Ecosystem Productivity to Experimental Warming in an Alpine Steppe

Fei Li, Yunfeng Peng, Dianye Zhang, Guibiao Yang, Kai Fang, Guanqin Wang, Jun Wang, Jianchun Yu, Guoying Zhou, Yuanhe Yang

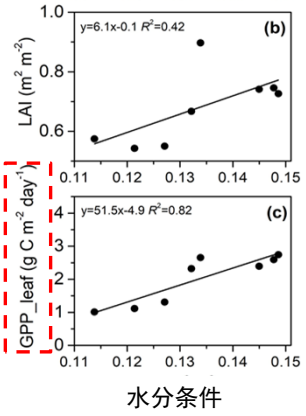
First published: 01 July 2019 | https://doi.org/10.1029/2019JG005193

全球尺度LAI对GPP变异的解释能力如何？

$GPP = LAI \times GPP_{leaf}$

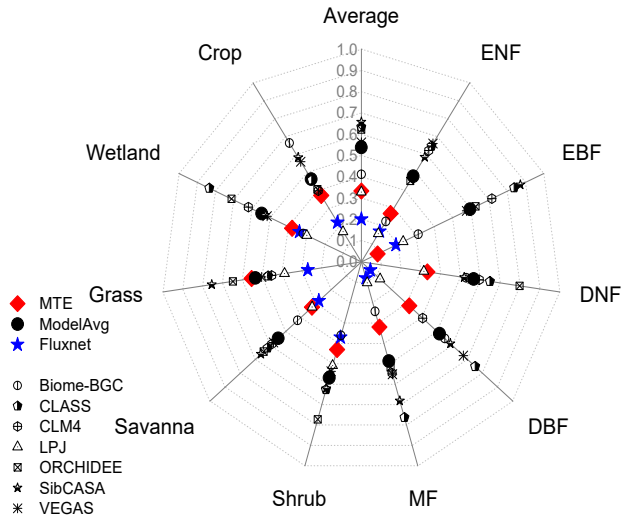
生产力 (GPP)

- LAI 结构属性
- GPP_{leaf} 生理属性

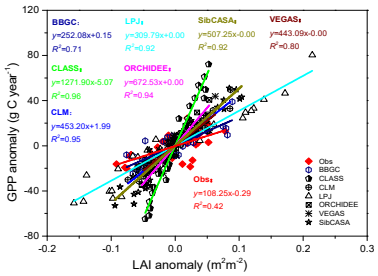


基于观测数据得到的LAI-GPP相关性低于模型模拟的LAI-GPP相关性

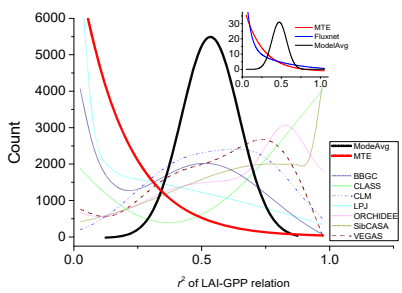
a

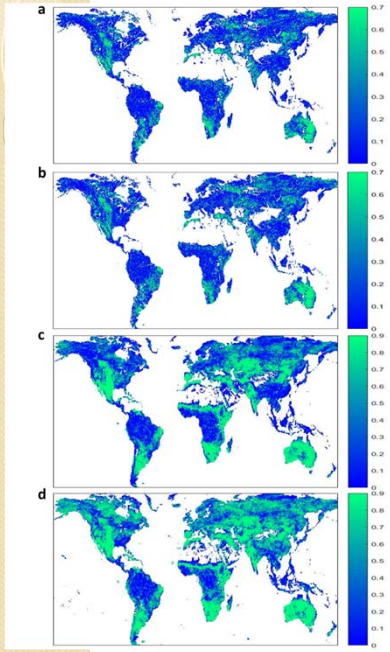


b



c





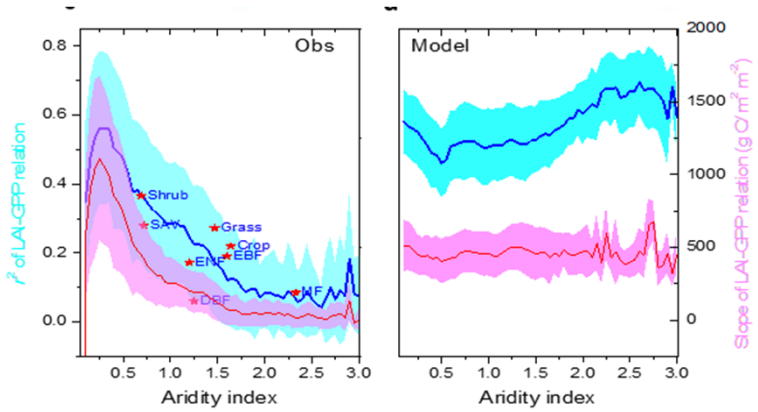
GIMMS 3g LAI-GPP MTE

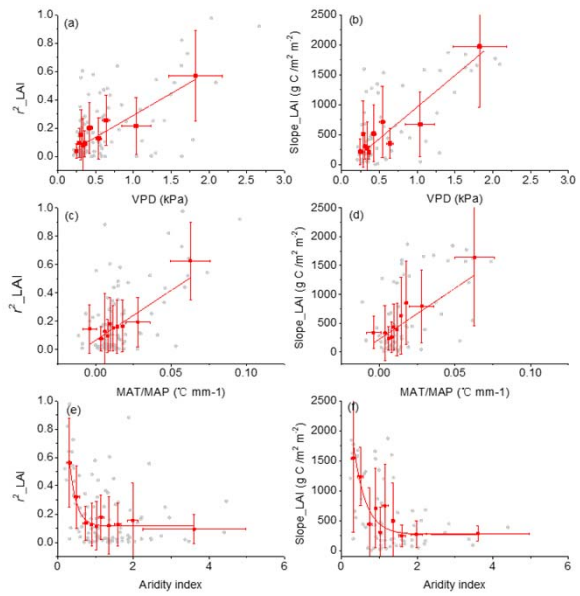
GIMMS 3g-GPP BESS

MODIS LAI-GPP MTE

MODIS LAI-GPP BESS.

LAI-GPP相关性沿气候梯度的规律



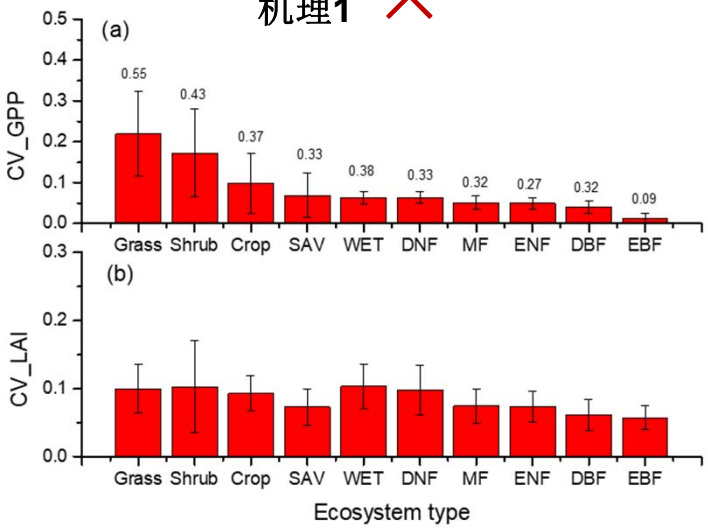


可能的机理

1. 湿润区（如热带雨林）冠层郁闭，LAI年际变异小，GPP的年际变异源于植物光合速率的变化：CV_GPP>CV_LAI

2. 湿润区LAI与GPPleaf之间的年际变异相反，即存在tradeoff：CV_GPP<CV_LAI

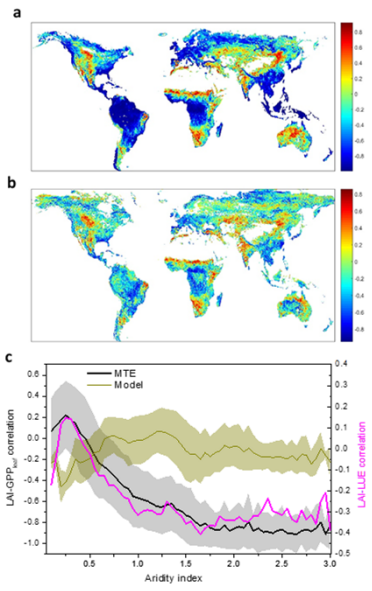
机理1 ×



机理2 √

随着气候湿润度的增加，**LAI-GPPleaf**之间的负相关关系增强

模型未捕捉到该关系的空间变化



小结

- 基于分解思路有助于揭示生产力时空变异的主要过程与机制
- 基于分解思路有助于明确模型不确定性来源并改进其相关模块

敬请指正!