Divergent long-term trends and interannual variation in ecosystem resource use efficiencies of a southern boreal old black spruce forest 1999–2017

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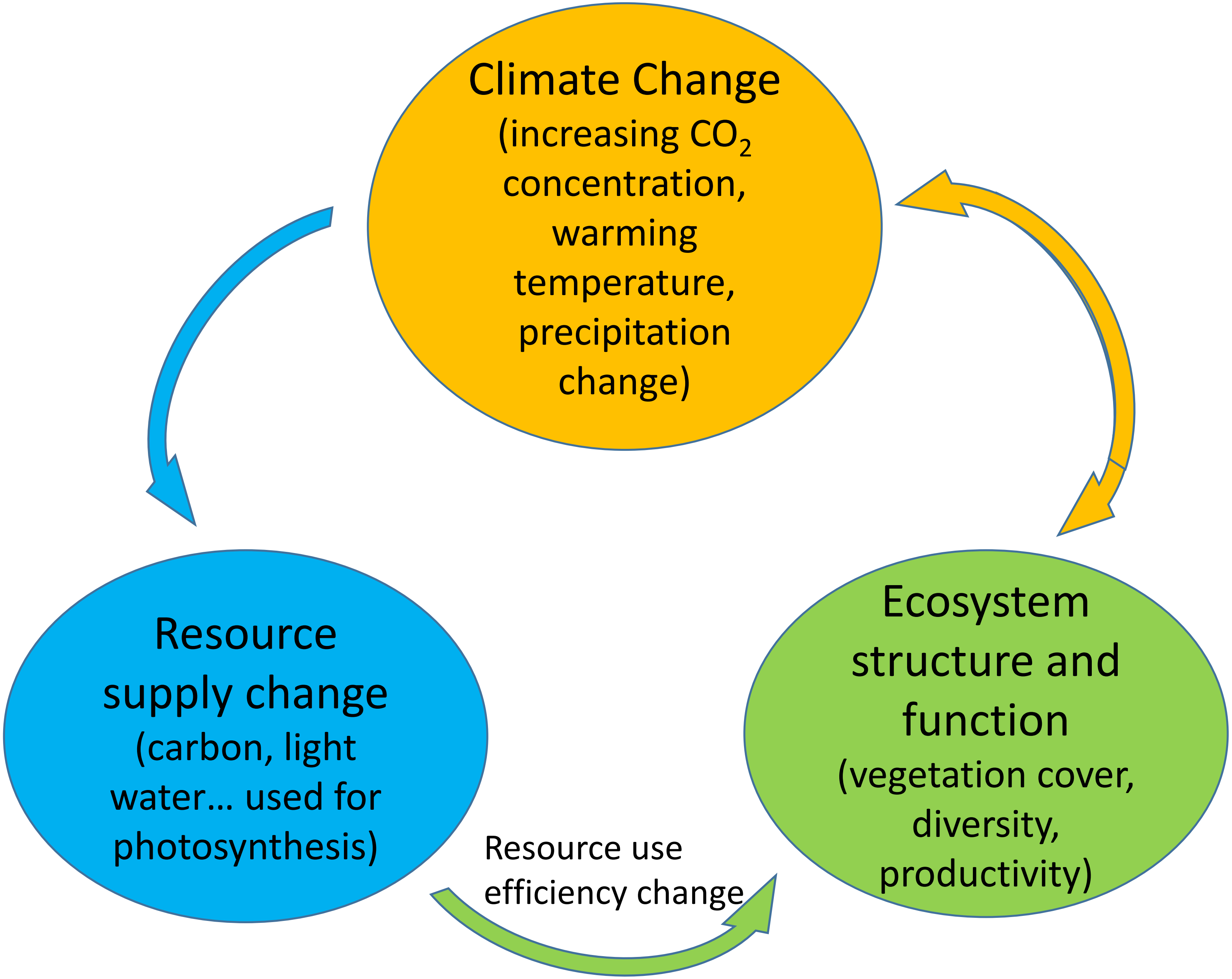
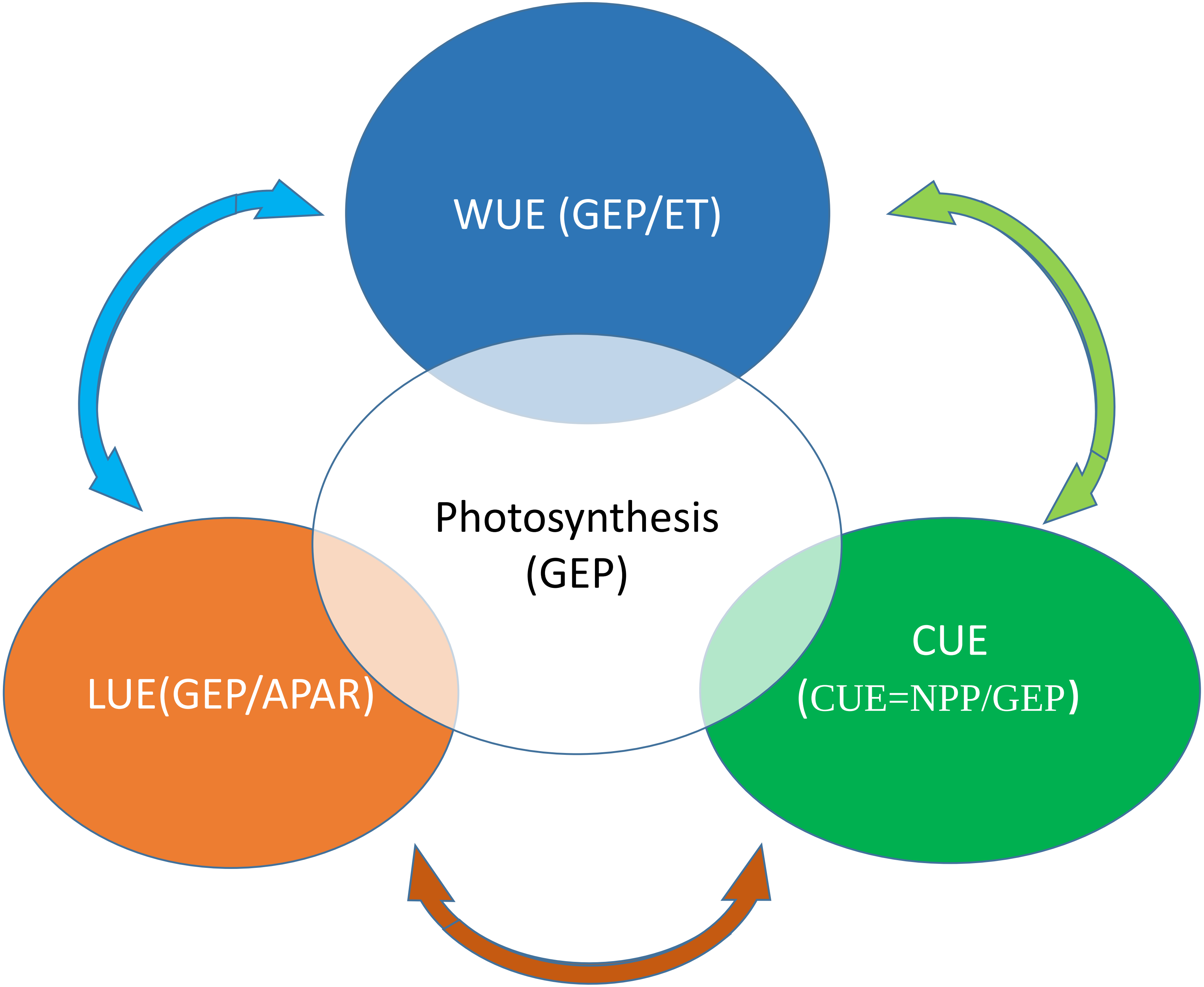
2019.07 USCCC

- **Background**
- **Trend and variation**
- **Controlling factors**
- **Conclusion**


Climate Change
(increasing CO_2
concentration,
warming
temperature,
precipitation
change)
Resource
supply change
(carbon, light
water… used for
photosynthesis)
Ecosystem
structure and
function
(vegetation cover,
diversity,
productivity)
Resource use
efficiency change


WUE (GEP/ET)
Photosynthesis
(GEP)
LUE(GEP/APAR)
CUE
(CUE=NPP/GEP)

Increased WUE in response to CO_2 concentration

LETTER

doi:10.1038/nature12291

Increase in forest water–use efficiency as atmospheric carbon dioxide concentrations rise

Tre
& A

Geophysical Research Letters

RESEARCH LETTER
10.1002/2016GL070710

Increased light-use efficiency in northern terrestrial ecosystems indicated by CO_2 and greening observations

Key Points:
- Current terrestrial biosphere models underesti
cycle amp
- Models ca
trends an
of light by
- Reconcilin

Global Ecology and Biogeography, (Global Ecol. Biogeogr.) (2014) **23**, 144–155

RESEARCH PAPER

Climate-driven global changes in carbon use efficiency

Yangjian Zhang[1*], Guirui Yu[1], Jian Yang[2], Michael C. Wimberly[3], XianZhou Zhang[1], Jian Tao[1], Yanbin Jiang[1] and Juntao Zhu[1]

Decreased WUE in response to CO_2 concentration

Global Change Biology

Primary Research Article

Change in terrestrial ecosystem water-use efficiency over the last three decades

Me
Xia

OPEN

How is water-use efficiency of terrestrial ecosystems distributed and changing on

SUBJECT AREAS:

PL
ECOSYS

Pol. J. Environ. Stud. Vol. 27, No. 4 (2018), 1-10

DOI: *10.15244/pjoes/76912* ONLINE PUBLICATION DATE:

Original Research

Dynamics and Controls of Carbon Use Efficiency across China's Grasslands

Inconsistent and inconclusive

Global Change Biology

Global Change Biology (2017) **23**, 2755–2767, doi: 10.1111/gcb.13626

Emergent climate and CO_2 sensitivities of net primary productivity in ecosystem models do not agree with empirical data in temperate forests of eastern North America

PNAS

Forest response to elevated CO_2 is conserved across a broad range of productivity

Richard J. Norby[a,b], Evan H. DeLucia[c], Birgit Gielen[d], Carlo Calfapietra[e], Christian P. Giardina[f], John S. King[g], Joanne Ledford[a], Heather R. McCarthy[h], David J. P. Moore[i], Reinhart Ceulemans[d], Paolo De Angelis[e], Adrien C. Finzi[j],
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Science
Agricu
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New Phytologist

Full paper | Open Access

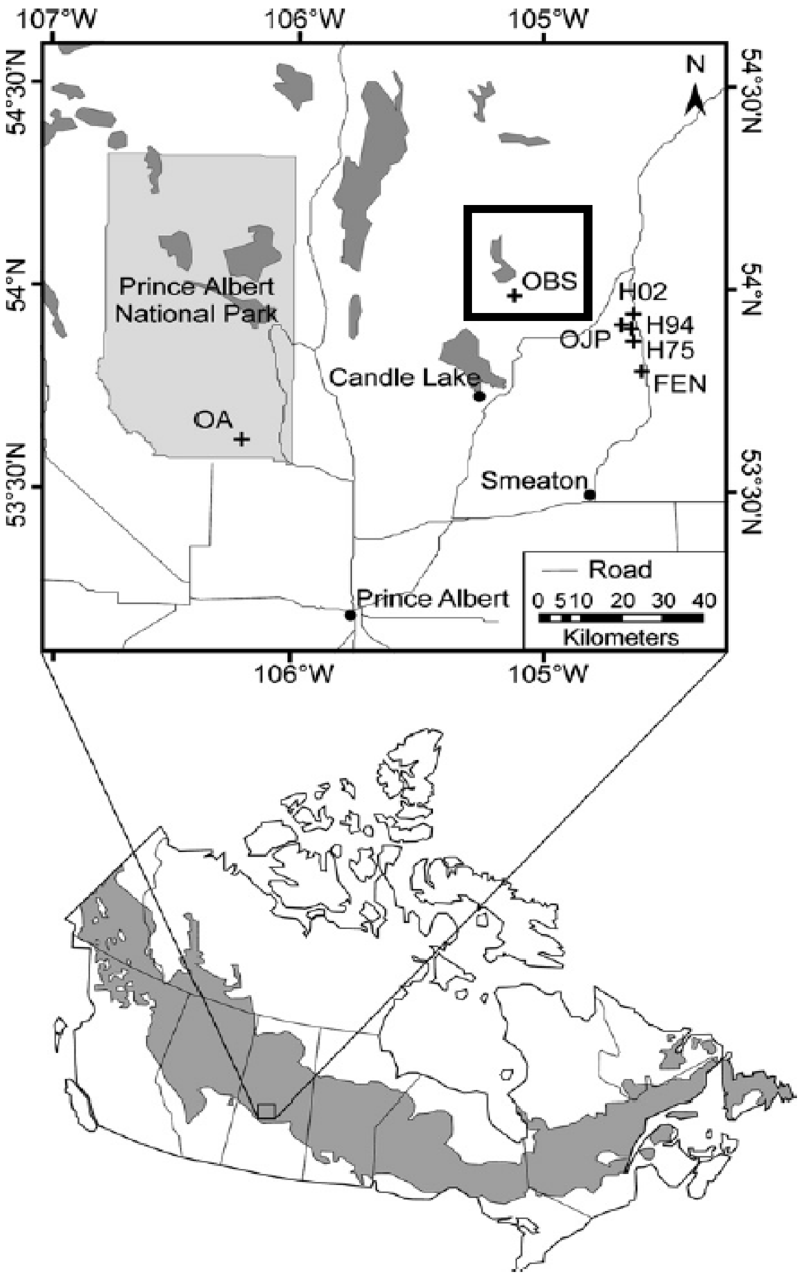
Where does the carbon go? A model–data intercomparison of vegetation carbon allocation and turnover processes at two temperate forest free-air CO_2 enrichment sites

Knowledge gaps

- **How are the long-term trends in multiple ecosystem resource use effiencies (RUEs)?**
- **What are the key controlling factors on RUEs over a long-term period?**

Material & Methods

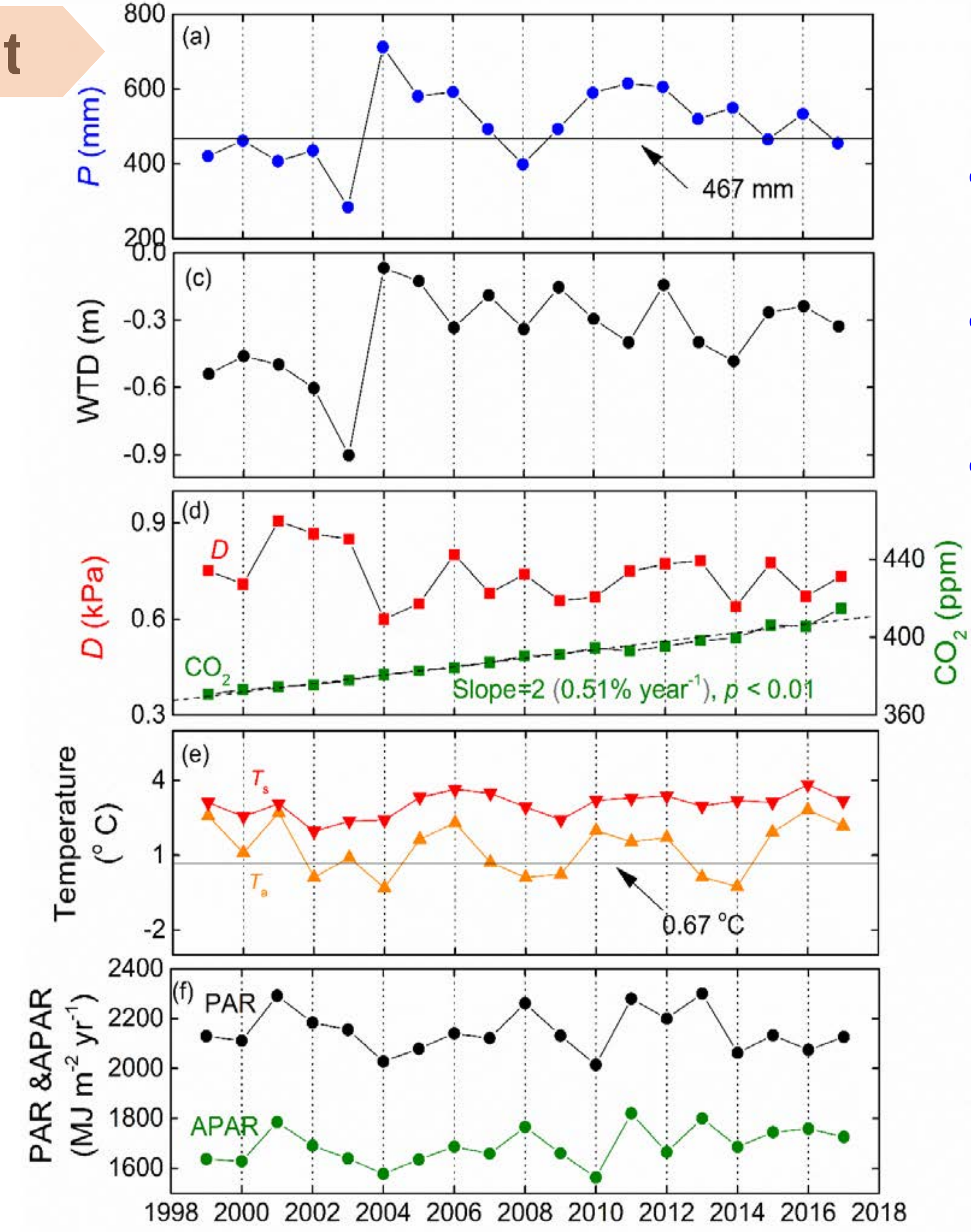
Site location (Old black spruce)



Site name	OBS
Year established	1999
Elevation (m)	629
Location	53.9 °N, 105.1 °W
MAT(°C)	1
MAP(mm)	480

Canopy Height (m)	16
Leaf area index	4.2
Depth of organic (cm)	20-30
Soil carbon (kg C m-2)	39.2
Stand density (stems ha-1)	5900

Result



Environmental conditions

- **Long-dry period in 2001-2003**
- **Cold Ta in 2002 and 2004**
- **CO_2 concentration increasing with a slope of 0.5%**

P: Precipitation

WTD: water table depth

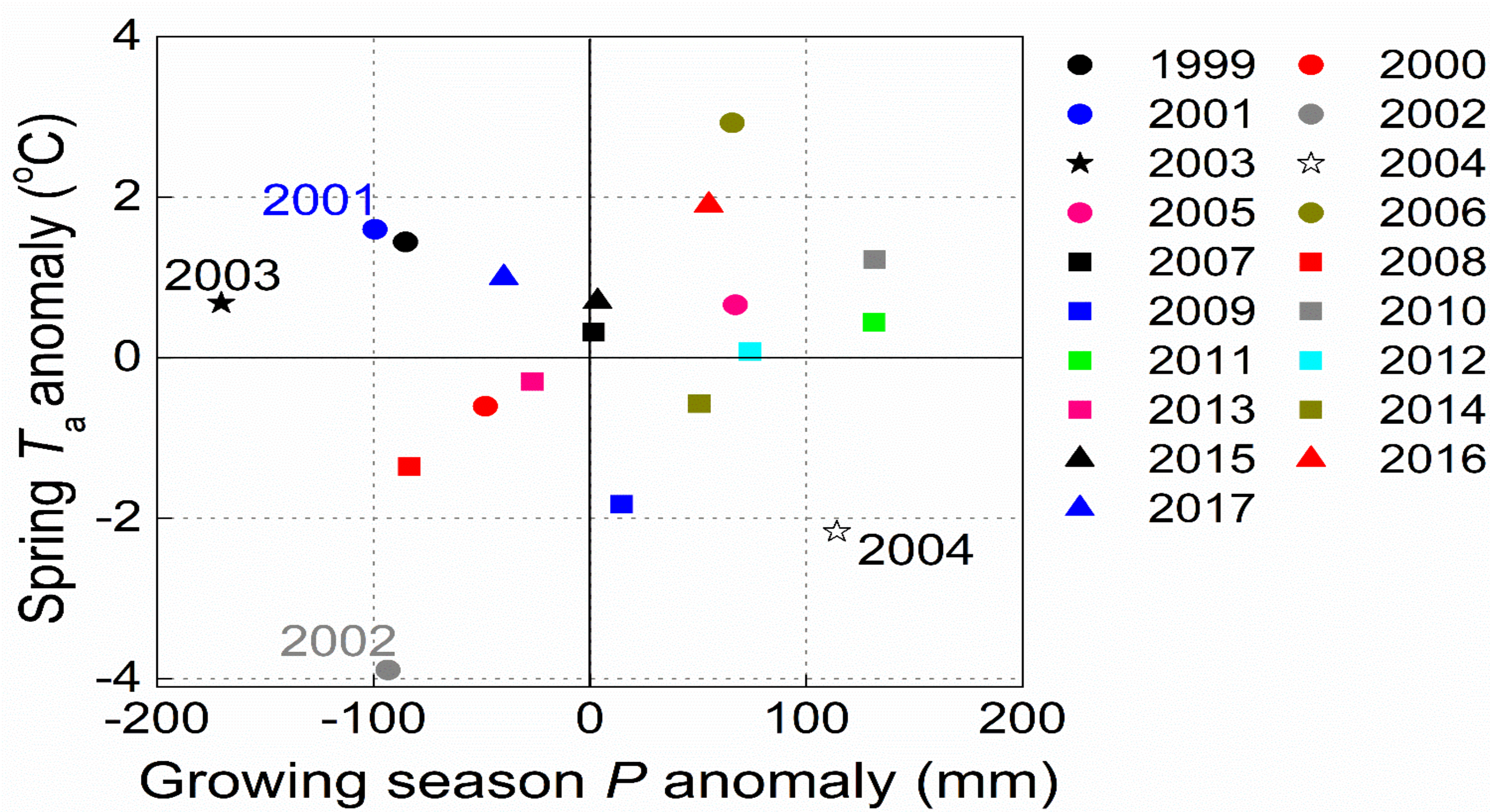
D: vapor press deficit

Ta: air temperature

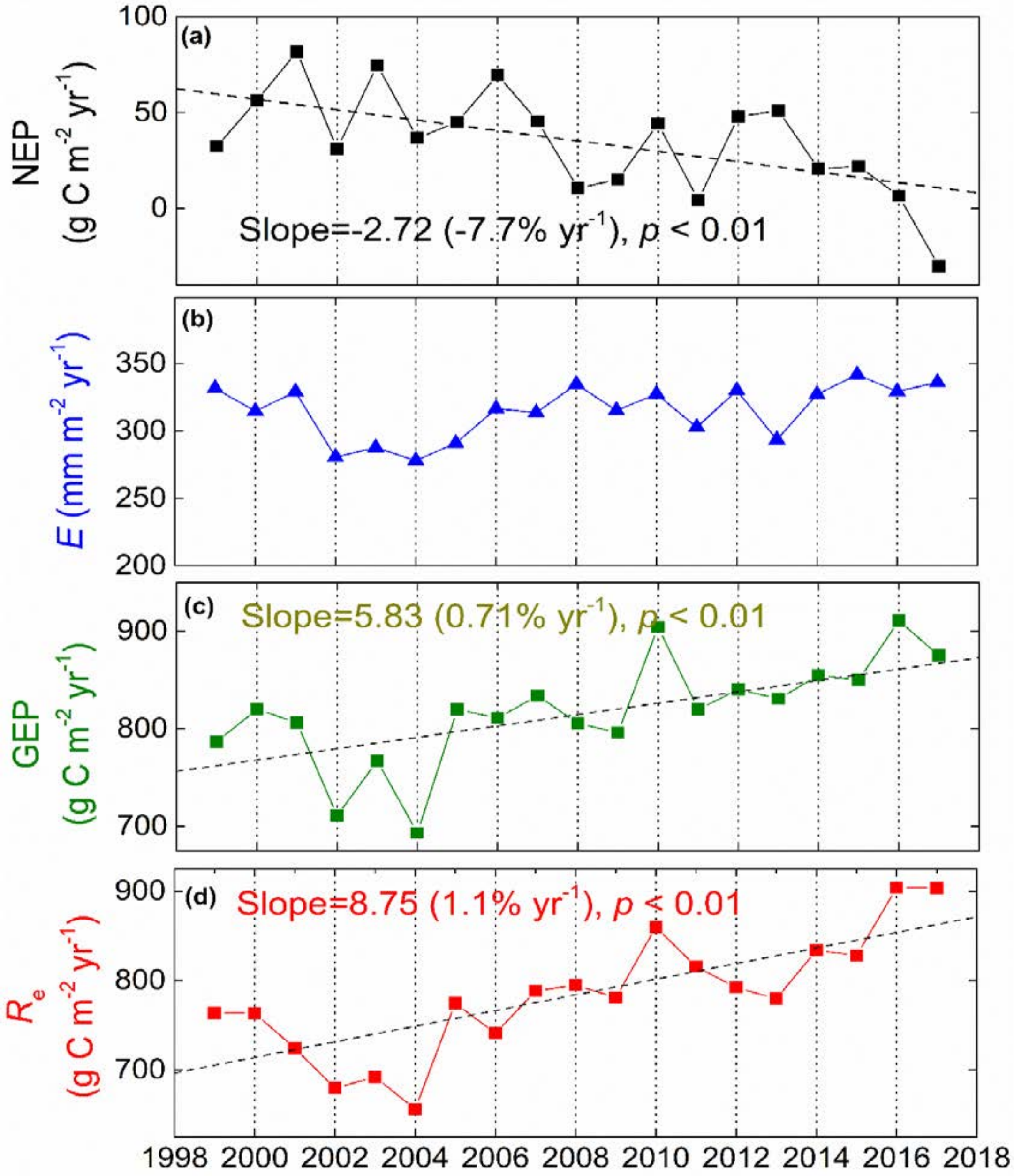
Ts: soil temperature

APAR: absorbed PAR

- **Plentiful *P* and low spring Ta in 2004**
- **Below average P in 2001-2003**

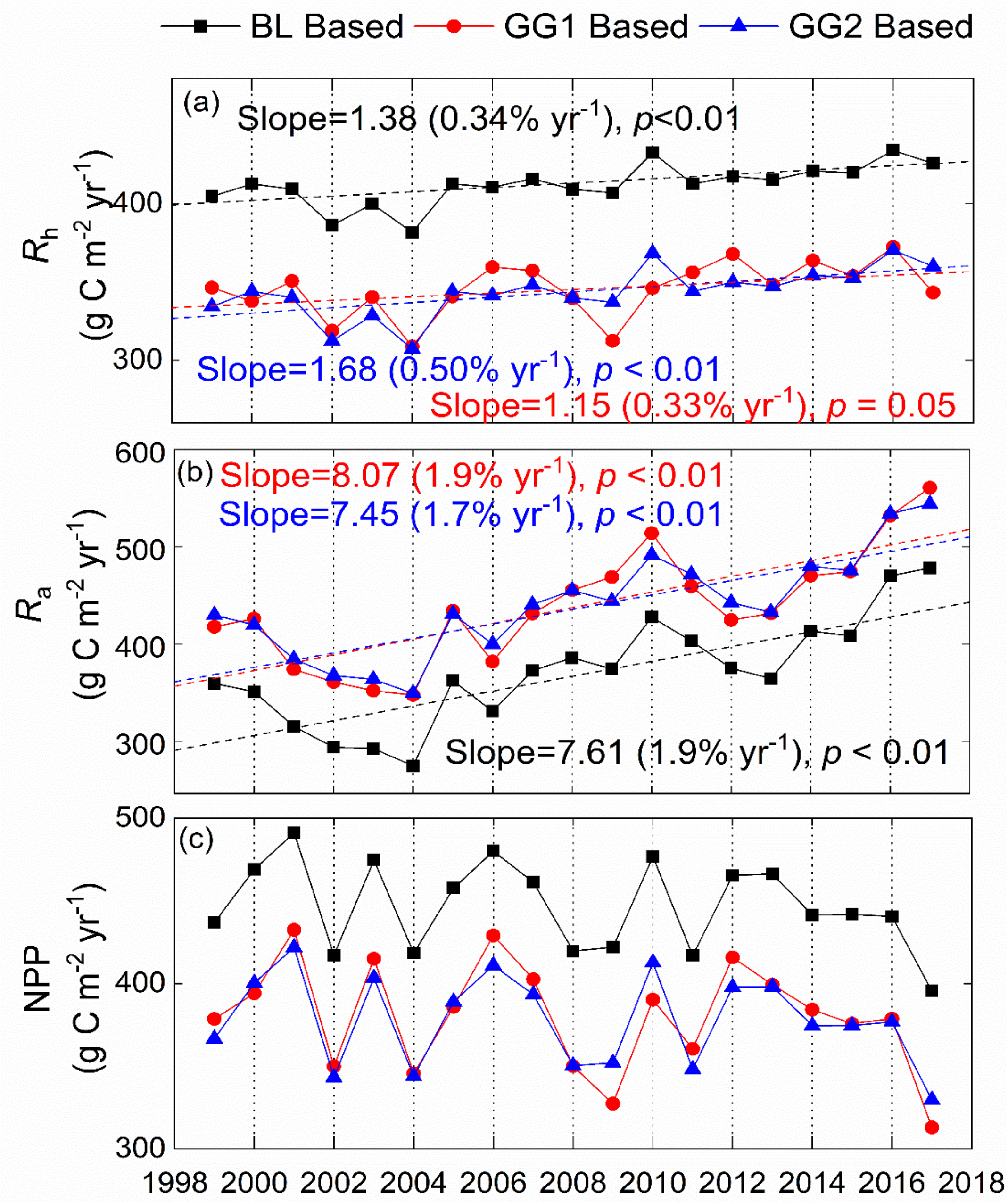


Annual of spring T_a and growing season *P* during the study years 1999–2017.



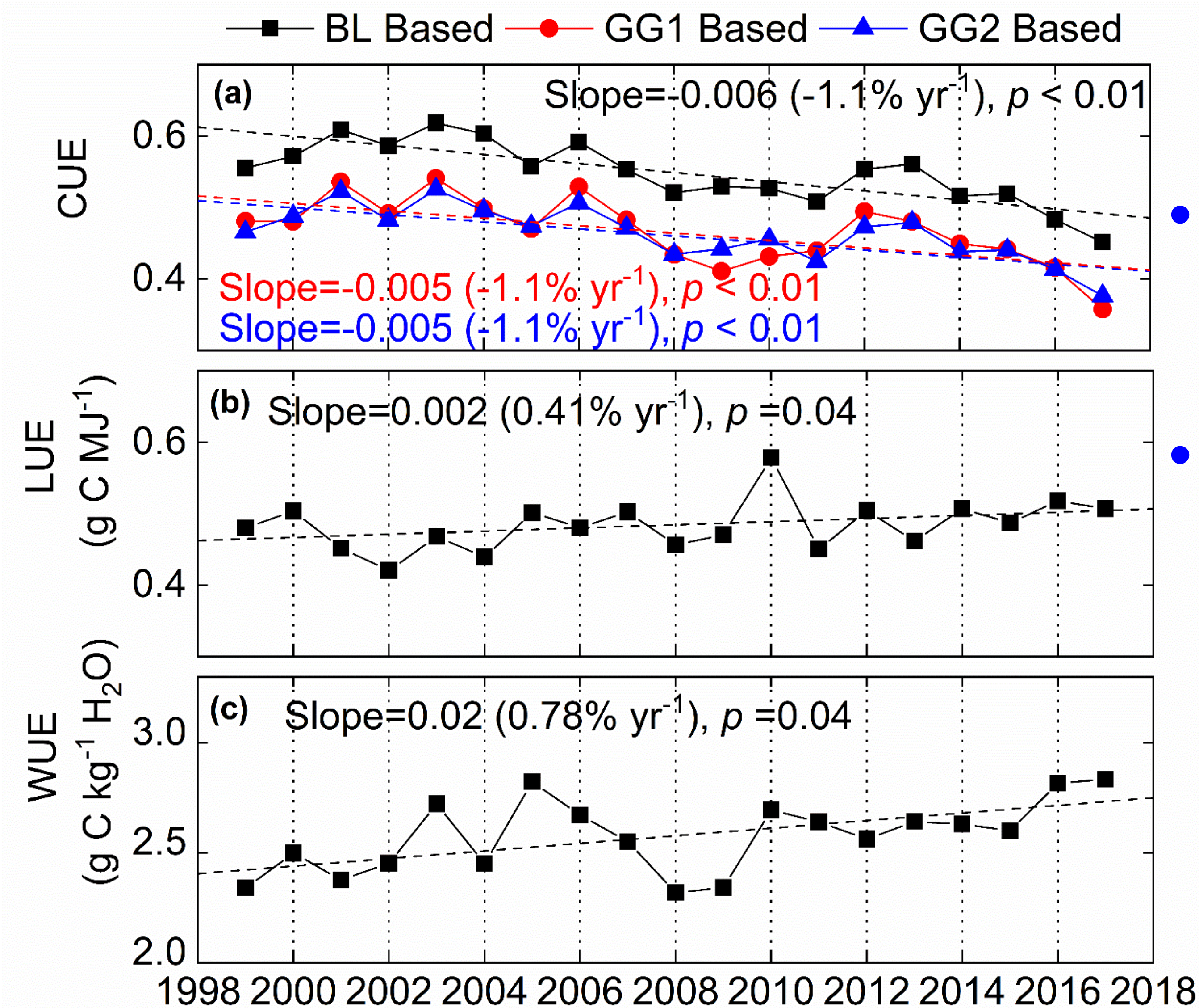
Interannual variation of annual C and water fluxes. The dashed lines denote interannual trends.

- **Re and GEP showed an increasing trend.**
- **Re had a greater increasing rate than GEP, causing NEP decrease significantly.**
- **E had no clear trend.**



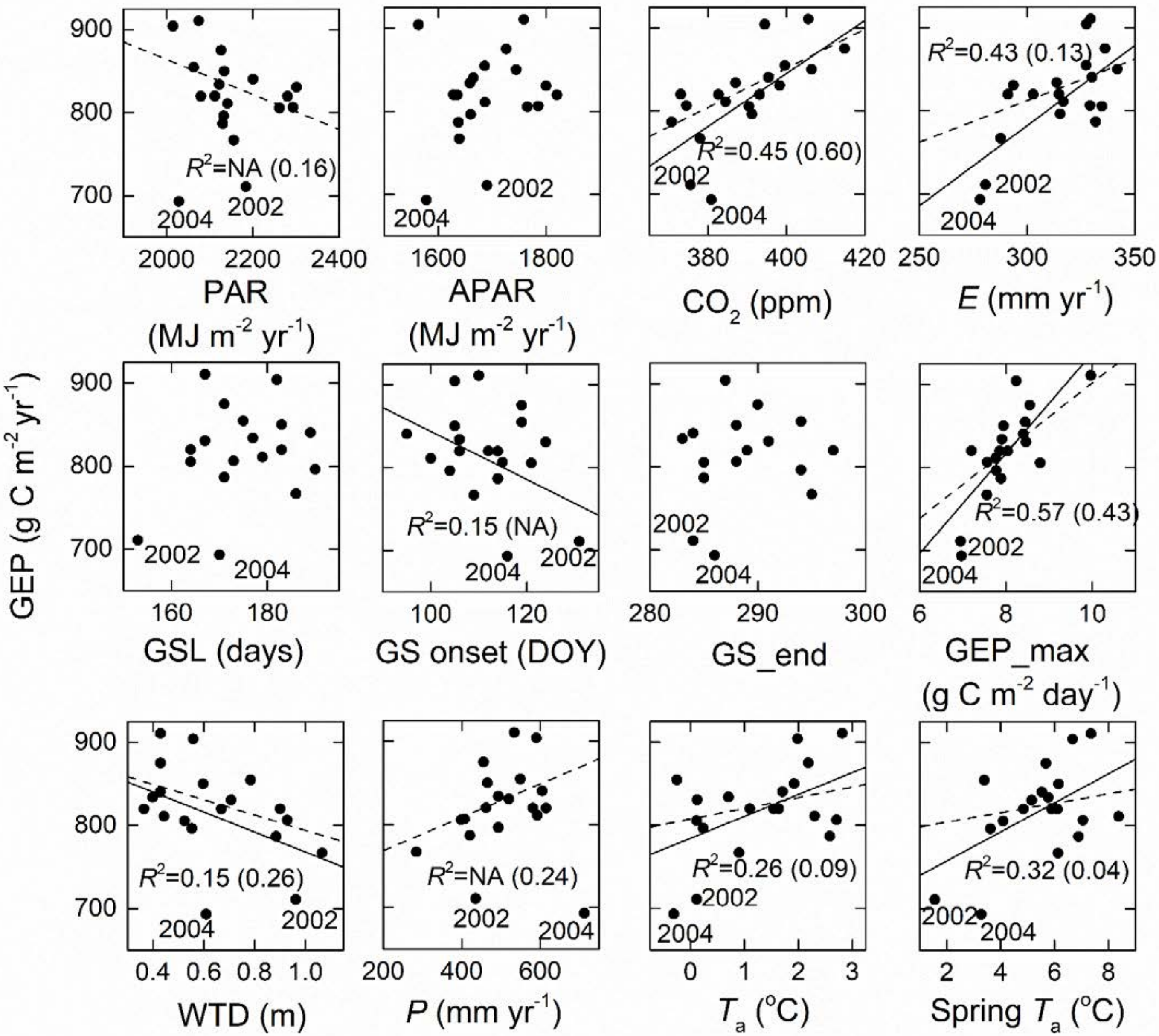
Interannual variation of annual C water fluxes. The dashed lines denote interannual trends.

- **Three methods-based Rh and Ra showed similar trends and variability.**
- **Three methods-based NPP were relatively constant over the long-term period.**



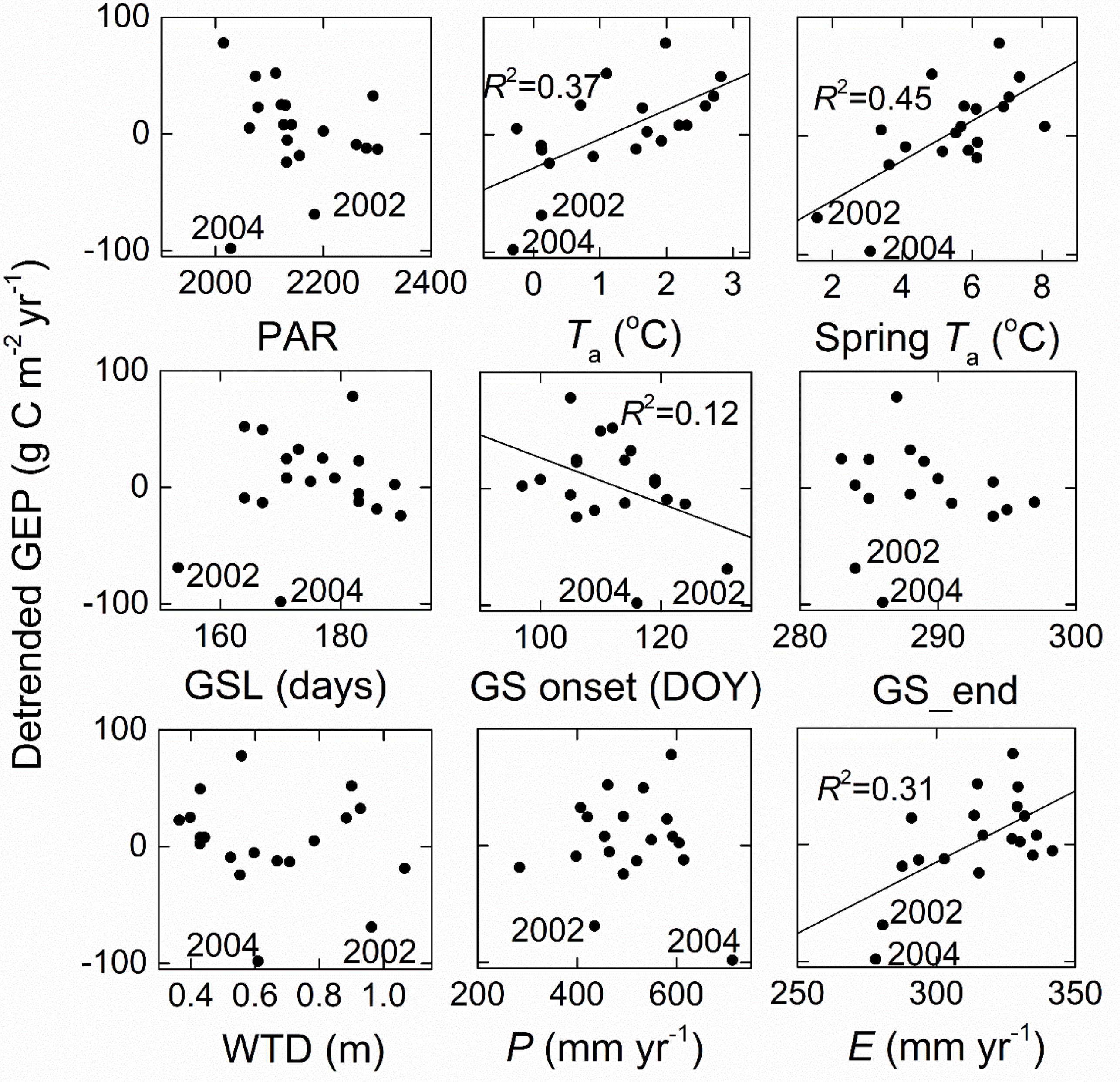
Interannual variation in annual RUEs.

- **CUE showed a decreasing trend**
- **WUE and LUE showed an increasing trend.**



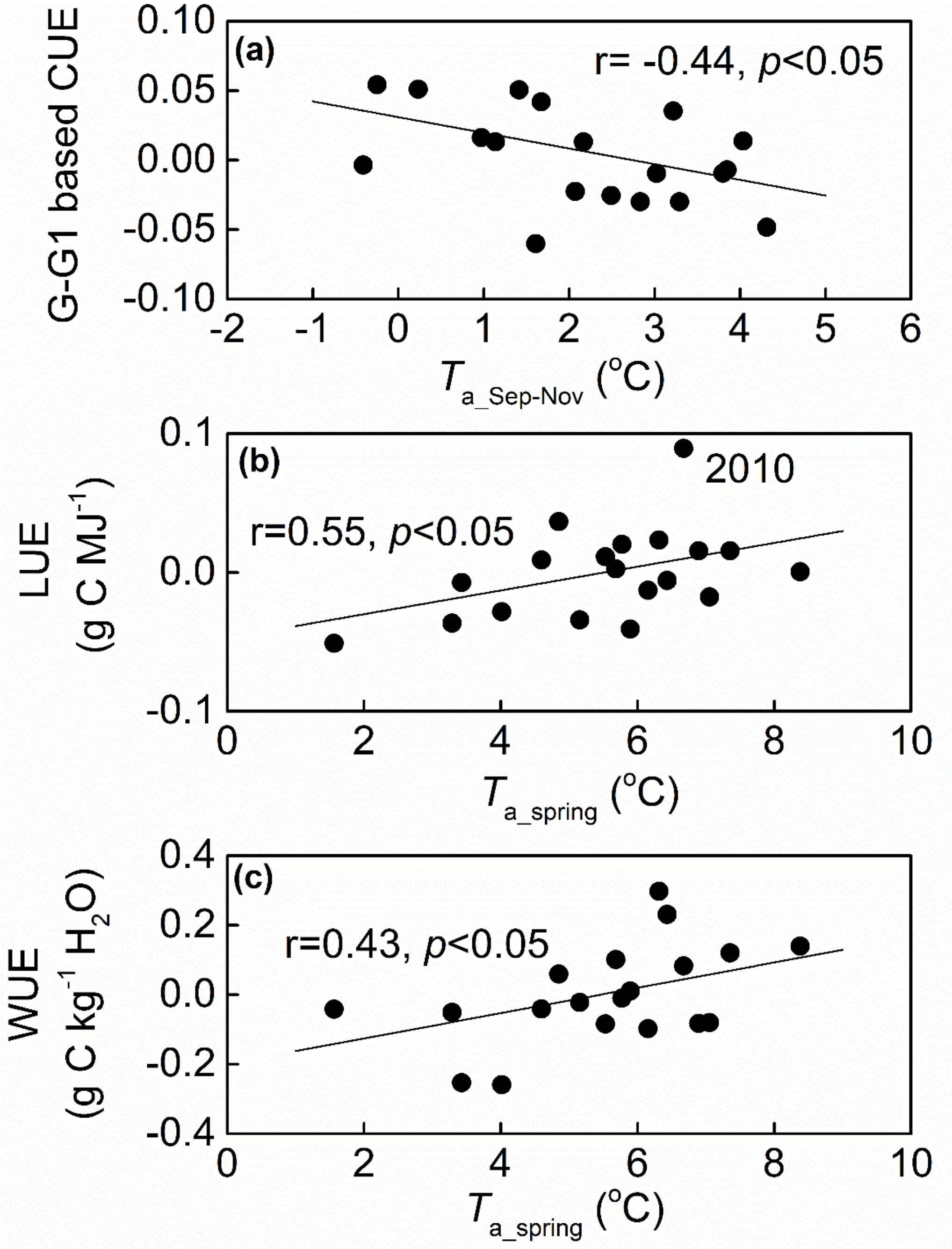
- **CO_2 was the most important factor in explaining annual GEP.**
- **Physiological factor (i.e. GEP_max) explained more than the phenological index (i.e. GSL,GS_onset).**

Relationships between the annual GEP and important climate variables.



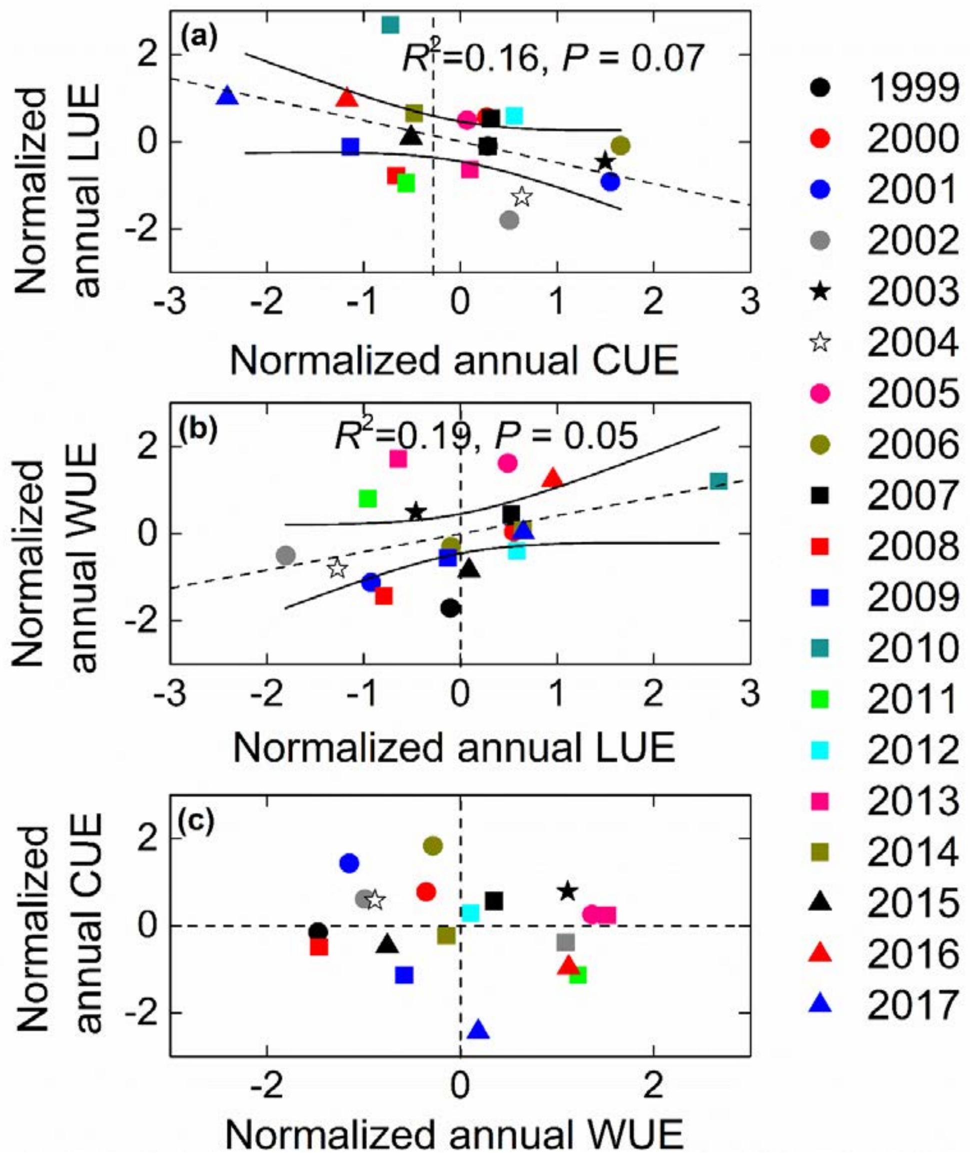
When including the cold years, spring Ta was the most important factor in explaining detrended annual GEP

Fig. 10 Relationships between detrended GEP and important climate variables.



Air temperature was a most important factor explaining annual detrended RUEs

Fig.12 Relationships between important climatic factors and detrended RUEs



- **Normalized CUE and LUE were negatively correlated,**
- **Normalized WUE and LUE were positively correlated.**

Normalized annual RUEs ($\frac{\mathrm{RUE}-\overline{\mathrm{RUE}}}{\sigma \mathrm{RUE}}$) during the study years 1999–2017; dashed lines and solid lines are the linearly fitted and the 95% confidence interval, respectively.

Summary

- **Annual GEP showed an increasing trend that was associated with CO_2. Inter-annual variation in annual GEP was positively related to spring Ta.**

- **Long-term trends in CUE, LUE and WUE, most likely caused by the 'CO_2 fertilization effect'. The inter-annual variability in the RUEs was most strongly related to air temperature.**

- **Annual LUE and WUE were positively correlated, while annual LUE and CUE were negatively correlated, and annual WUE showed no detectable relationships with CUE.**