Understanding the Associated Effects of Temperature and Soil Moisture on Summer Carbon Fluxes of Forest Ecosytems in the Contiguous United States

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Introduction

Individual effects of temperature and soil moisture on plants are well studied. Higher temperature below an optimal value increases Gross Primary Productivity (GPP). Ecosystem Respiration (ER) increases with warming. Higher soil moisture increases both GPP and ER until saturation. However, the associated effects of temperature and soil moisture on forest ecosystems are more complex. The correlations between carbon fluxes and temperature or soil moisture are categorized as: 1) negative, negative; 2) negative, positive; 3) positive, negative; and 4) positive, positive. Based on the climate and description of each forest, we propose the following mechanisms to explain the respective correlations: 1) soil moisture limits GPP or ER; 2) temperature surpasses the optimal GPP; 3) GPP or ER changes as expected; and 4) temperature dominates GPP or ER. The Net Ecosystem Productivity (NEP) is determined by the direction and magnitude of changes in GPP relative to ER.

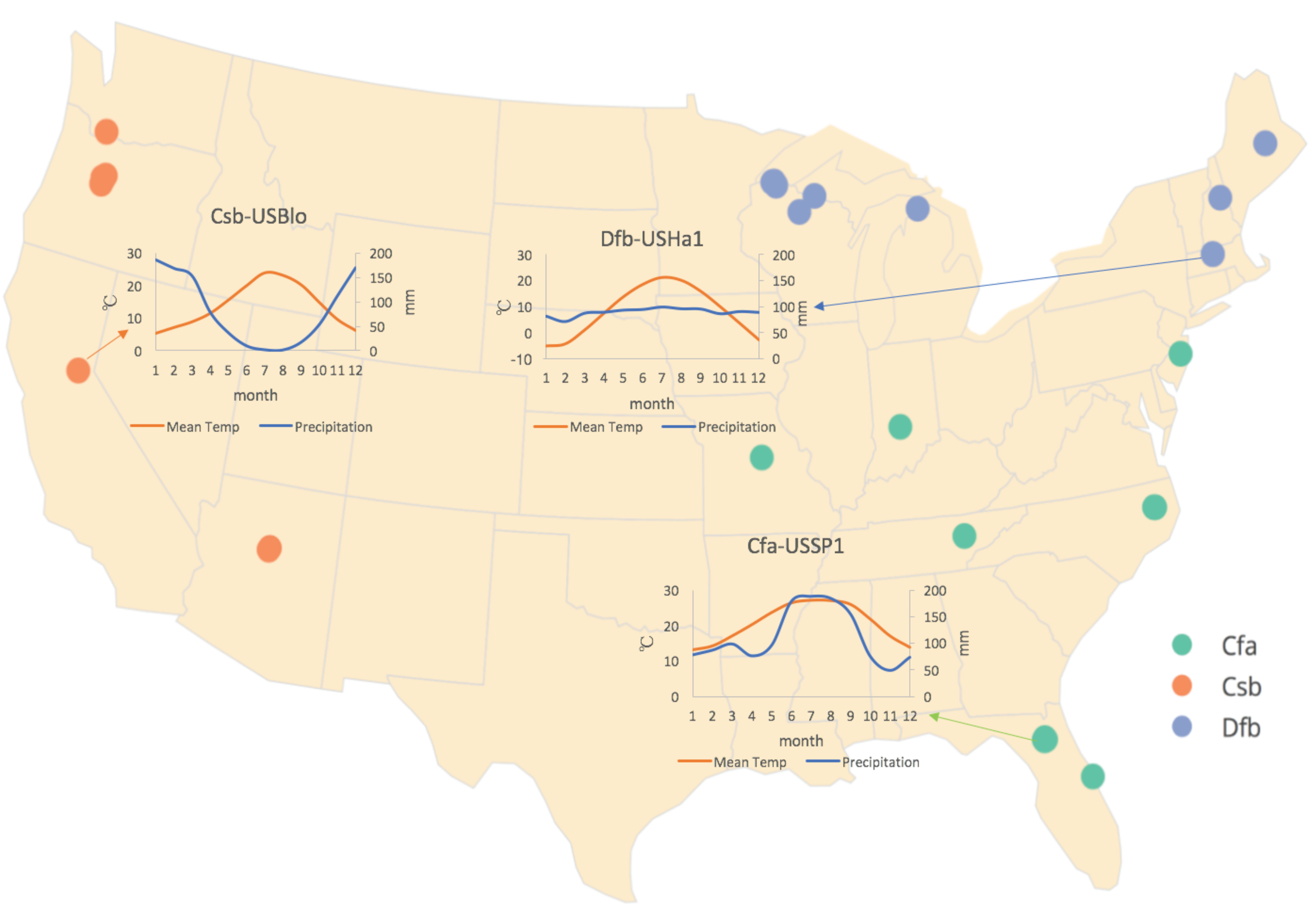

Figure 1. Eddy Covariance towers with their climate categories. Cfa = humid subtropical climate; Csb = Mediterranean climate; Dfb = humid continental climate.

Data & Method

Table 1. Data Sources

Data set	Source	Grid resolution	Time range	reference
Precipitation (P) Temperature (T) Penman-Monteith PET	CRU3.23	0.5 ° x 0.5 °	1901 – 2014	[Harris et al., 2014]
PDSI	CRU3.10	0.5 ° x 0.5 °	1901 - 2009	[G. van der Schrier et al., 2016]
ER, GPP, NEP	Ameriflux	Level 4 gap-filled sites	Varies	[RDA at NCAR]

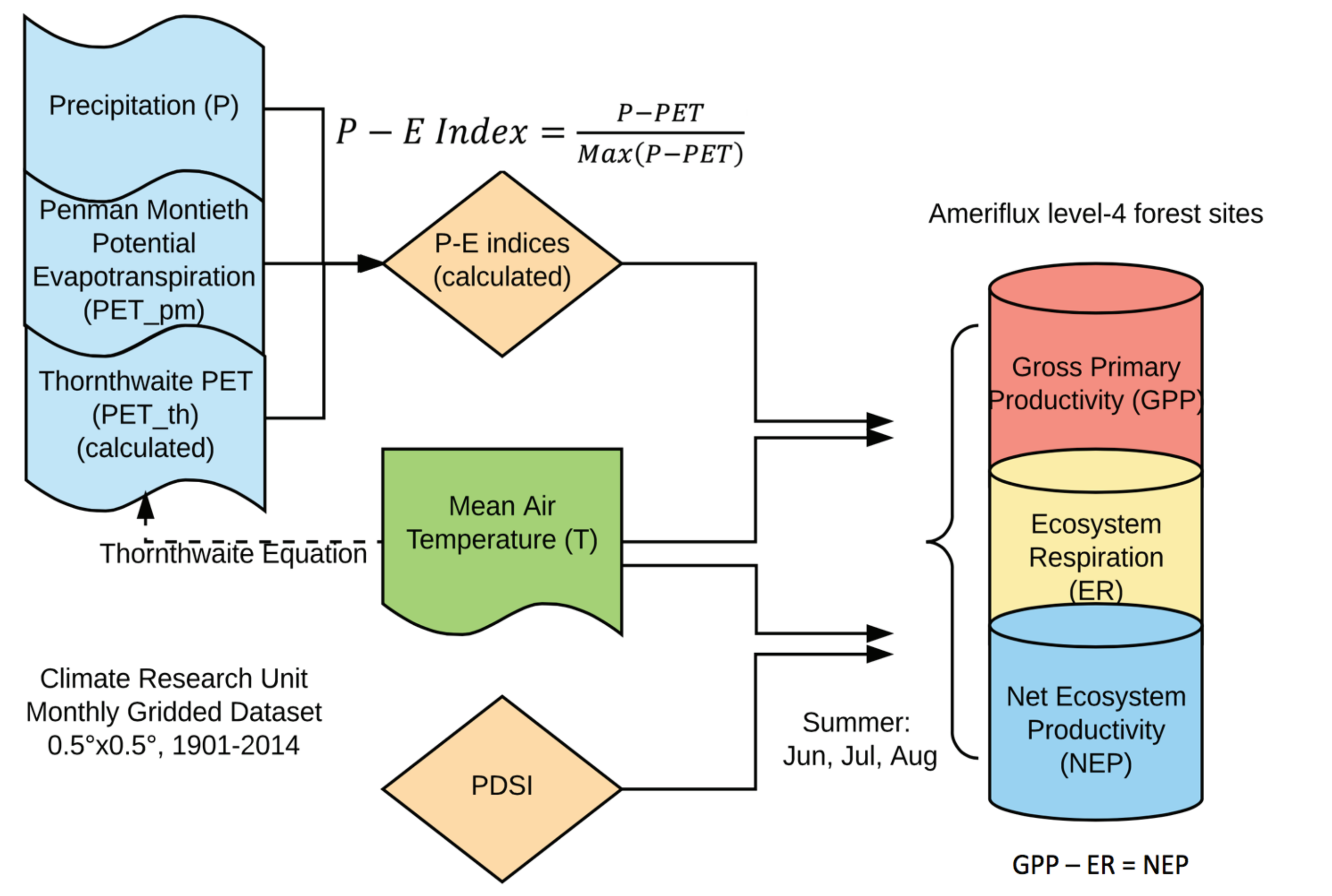

Figure 2. Process of data analysis. Thornthwaite PET (PET_th) is derived from gridded mean air temperature (T) by Thornthwaite Equation [Willmott et al, 1985]. Derived P-E indices represent short term droughts, while Palmer Drought Severity Index (PDSI) shows long term droughts. Summer temperature and drought indices are correlated with carbon fluxes from Ameriflux level-4 gap filled forest sites [RDA at NCAR, 2016].

References:

Carbon Dioxide Information Analysis Center/Environmental Sciences Division/Oak Ridge National Laboratory/U. S. Department of Energy (2012), AmeriFlux Gap-Filled Data from Selected Sites, http://rda.ucar.edu/datasets/ds387.0/, Research Data Archive at the National Center for Atmospheric Research, Computational and Information Systems Laboratory, Boulder, Colo.

Harris, I, P. D. Jones, T. J. Osborn, and D. H. Lister (2014), Updated high-resolution grids of monthly climatic observations – the CRU TS3.10 Dataset, Int. J. Climatol, 34, 623-642, doi:10.1002/joc.3711.

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NSF IBSS project
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Results

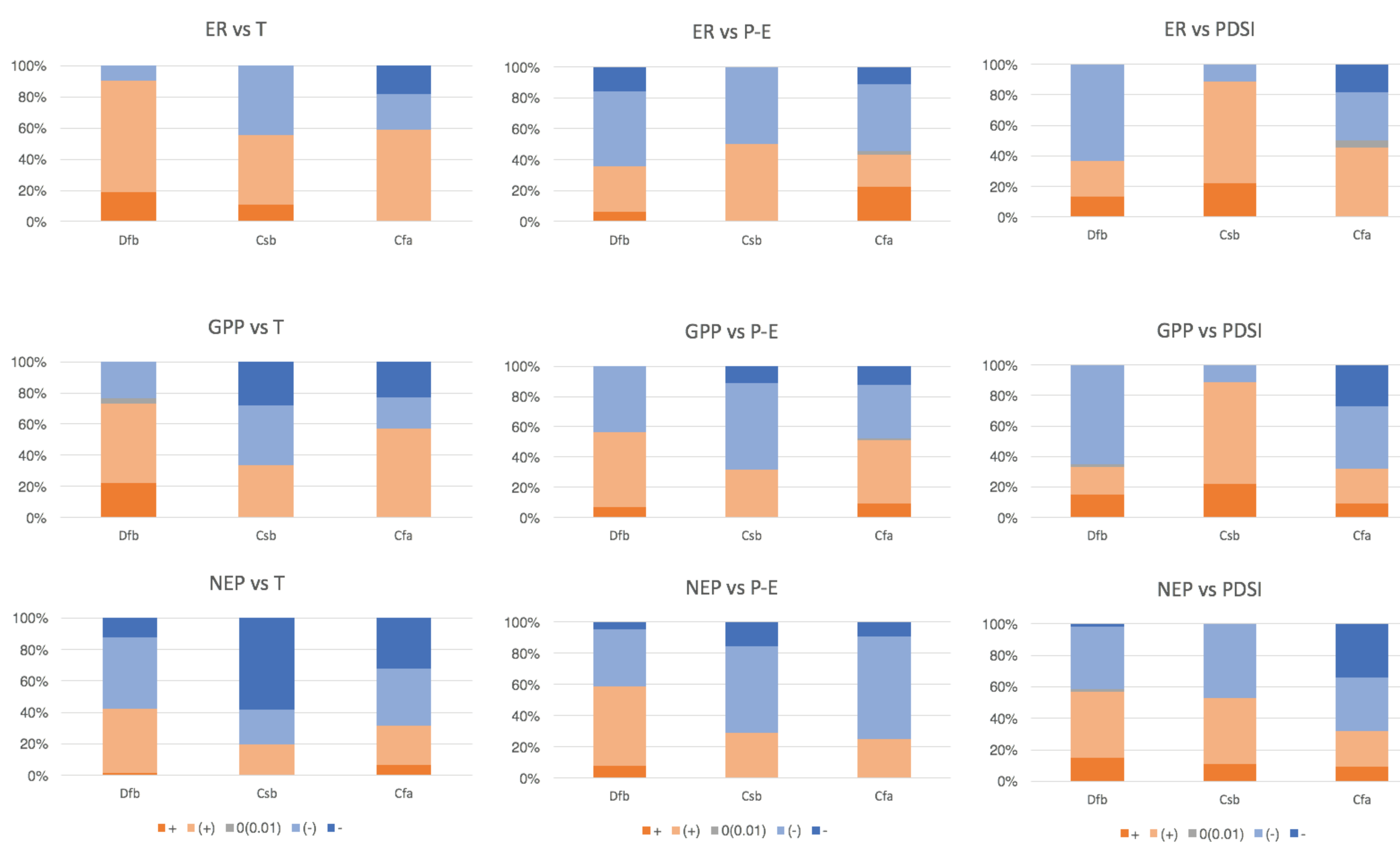


Figure 3. Percentage of sites with significant positive[+], insignificant positive[(+)], insignificant negative[(-)] and significant negative[-] correlations. The correlations are between carbon fluxes (ER, GPP, and NEP) with temperature (T), short term drought (P-E) and long term drought (PDSI). P < 0.1.

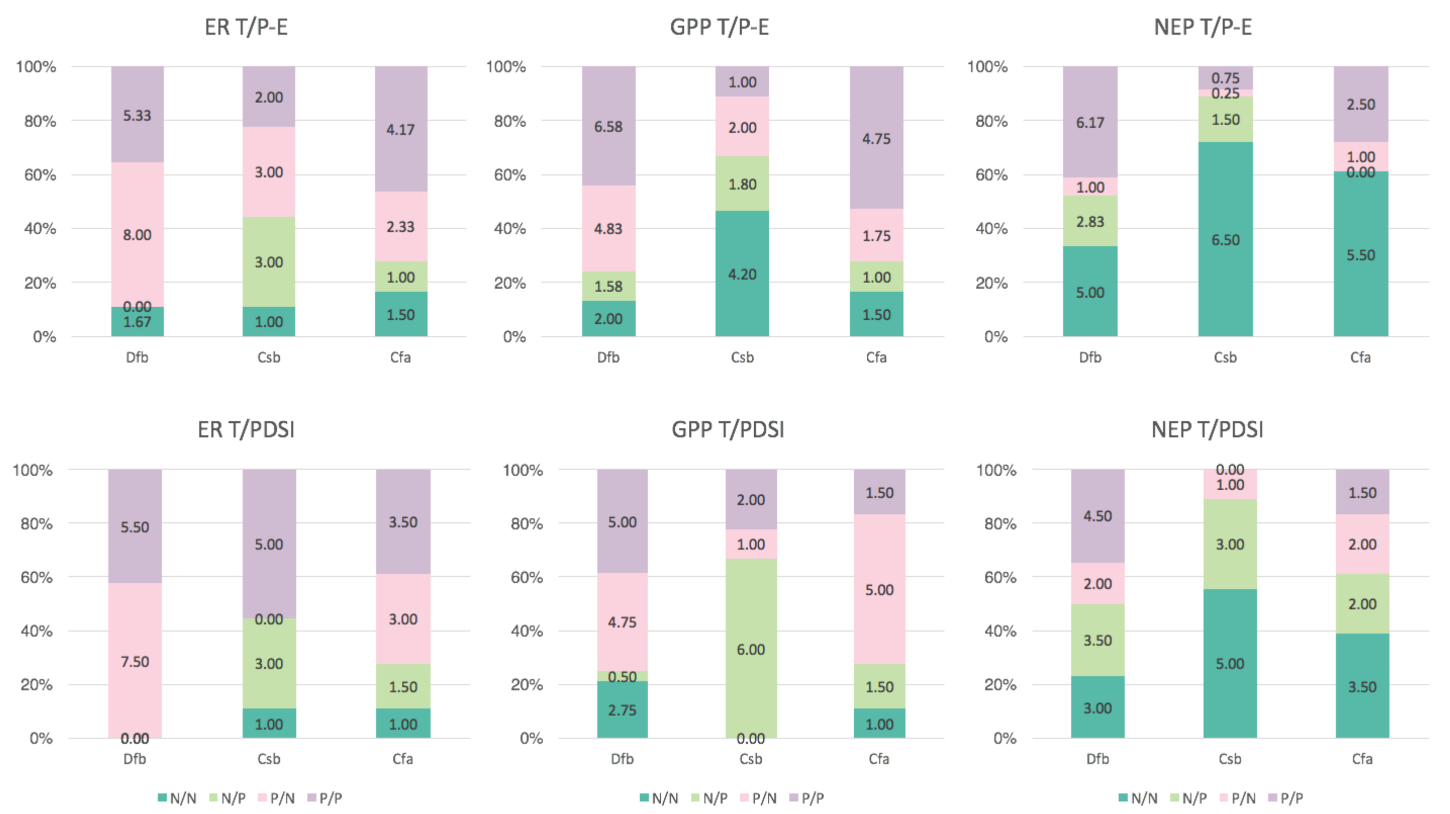
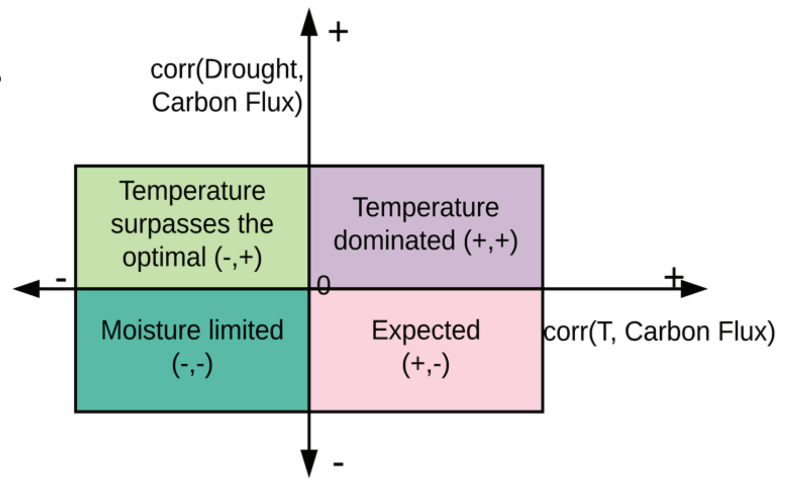


Figure 5. Percentage of sites with each of the four temperature and drought correlation combinations: 1) negative, negative [N/N]; 2) negative, positive [N/P]; 3) positive, negative [P/N]; and 4) positive, positive [P/P]. Numerical values are weighted number of sites.

Figure 4. Four categories of correlation combinations between carbon fluxes with temperature or drought indices and respective proposed reasons.



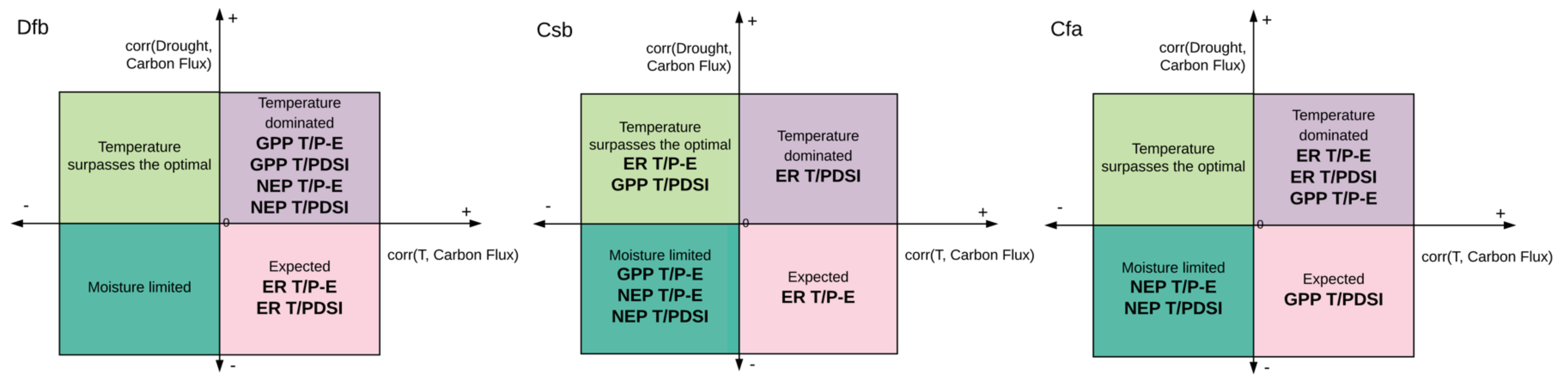


Figure 6. The most common combination in each climate.

Conclusions

- All three climates have warm summers and cold winters.
- Summer in Cfa is a wet season, while the Dfb has no wet and dry seasons.
- In Mediterranean climate (Csb), the correlations of GPP and ER with short term droughts differs significantly from long term drought (PDSI).
- For all three climates, insignificant correlations of GPP and ER with temperature or drought can result in a significant correlation of NEP with temperature or drought, and vice versa.
- None of the carbon fluxes in most Dfb sites are limited by soil moisture.
- Short term droughts limit the GPP of Csb sites, while long term droughts do not, possibly because vegetation in the Csb sites has adapted to dry conditions.
- Summer of Cfa sites is more humid than winter, therefore ER and GPP are dominated by temperature. However, the NEP is limited by soil moisture.