SYNTHESIS OF CARBON FLUXES SENSITIVITIES TO HEAT AND DROUGHT IMPACTS IN NORTH AMERICA FORESTS

Bing Xu and M. Altaf Arain

School of Geography and Earth Sciences, McMaster University
Email: xub12@mcmaster.ca

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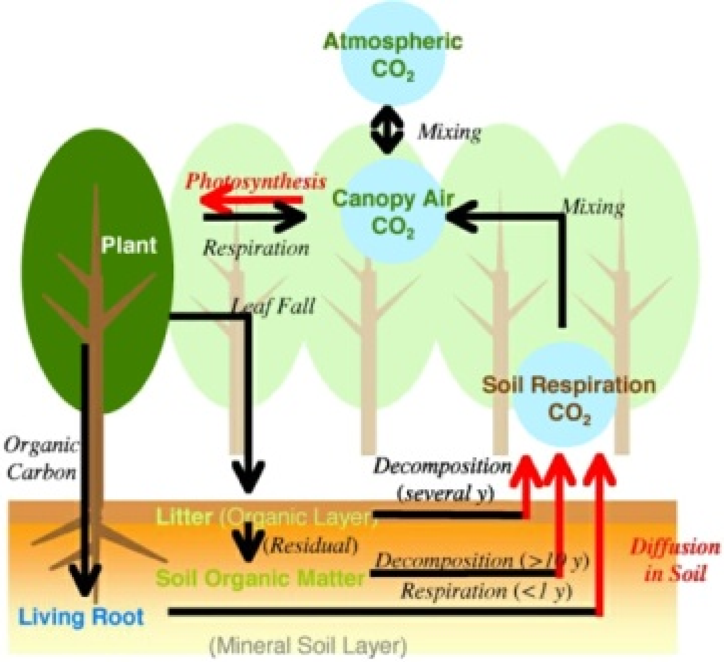
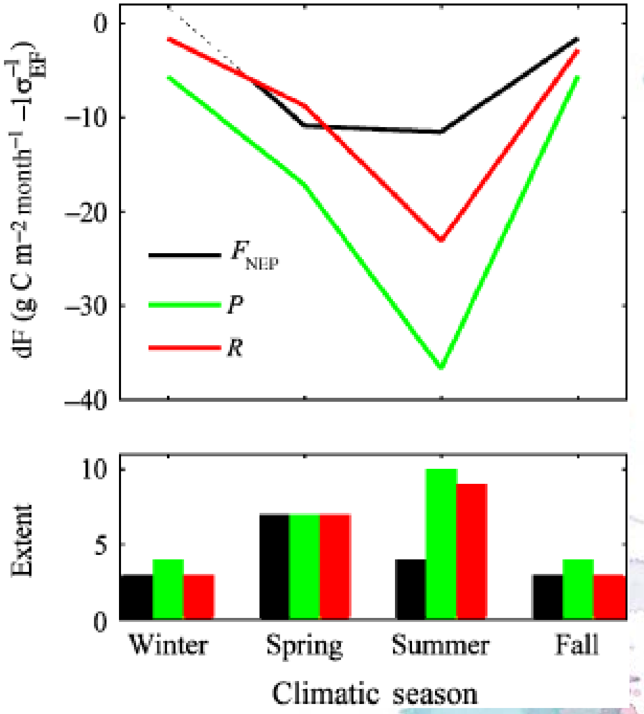
INTRODUCTION

- Exchange of carbon between forest ecosystem and atmosphere is an important pathway in global carbon cycle. The processes of carbon fluxes are strongly controlled by climate variations.
- Climate extreme events such as heat and drought are projected to occur more frequently in the future and will have a large impact on forest carbon and water cycles.





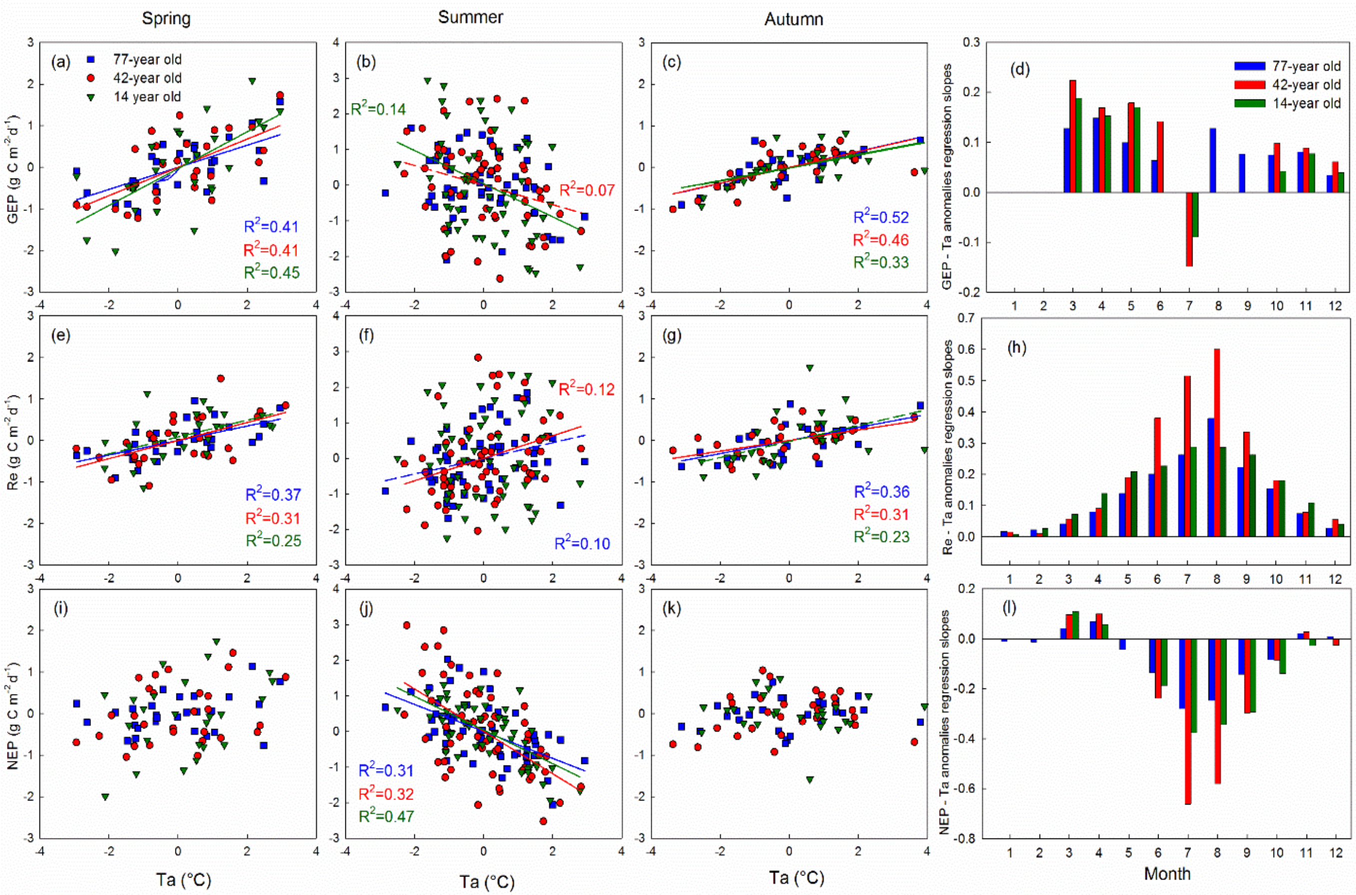
(Schwalm, et al. 2010, GCB)

INTRODUCTION

Example from Turkey Point Flux Station

14 years of flux measurements (2003-2014)

3 different age (77-yr, 42-yr and 14-yr old) forests site



(1) Forest response to climate anomalies vary with season and stand age

(2) Indexes of sensitivity to stress are needed to compare fluxes among sites

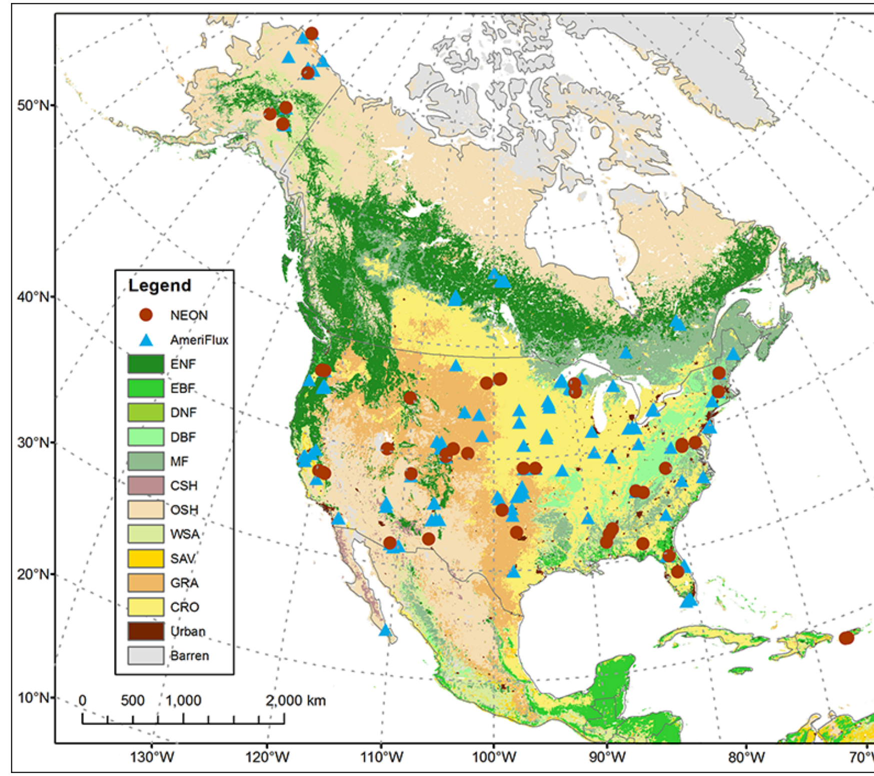
What about other forest sites ？

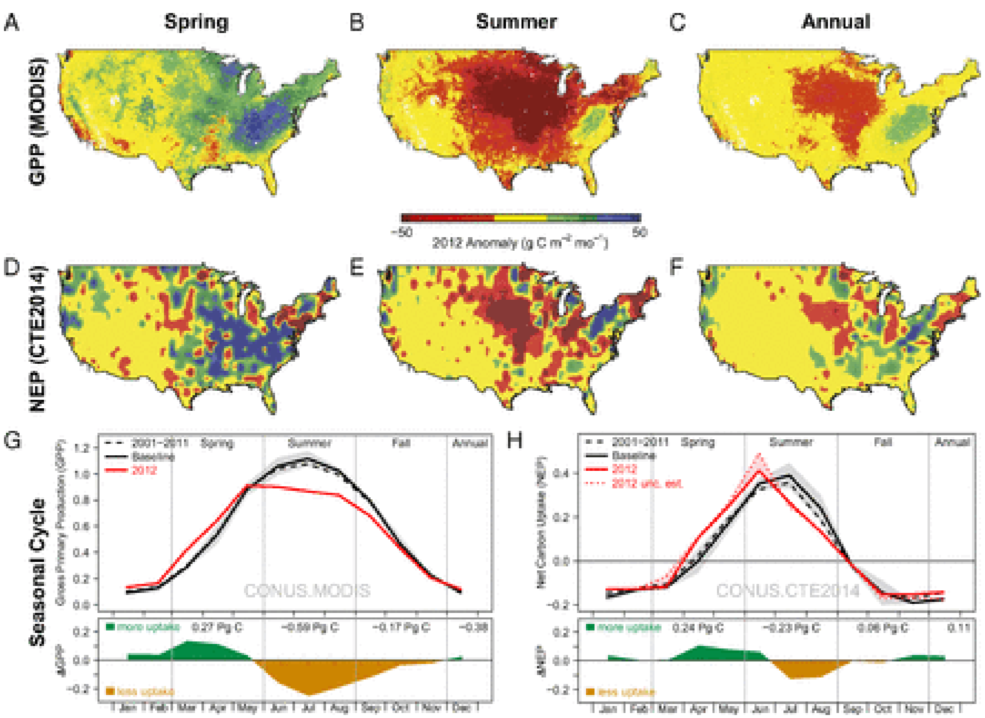
INTRODUCTION

- The FLUXNET provides continuously measured meteorological and C fluxes data:
  - Net Ecosystem Productivity (NEP)
  - Gross Ecosystem Productivity (GEP)
  - Ecosystem Respiration (RE)

    NEP = GEP-RE

(Xiao, et al. 2016, EOS)





(Wolf, et al. 2016, PNAS)

Questions:

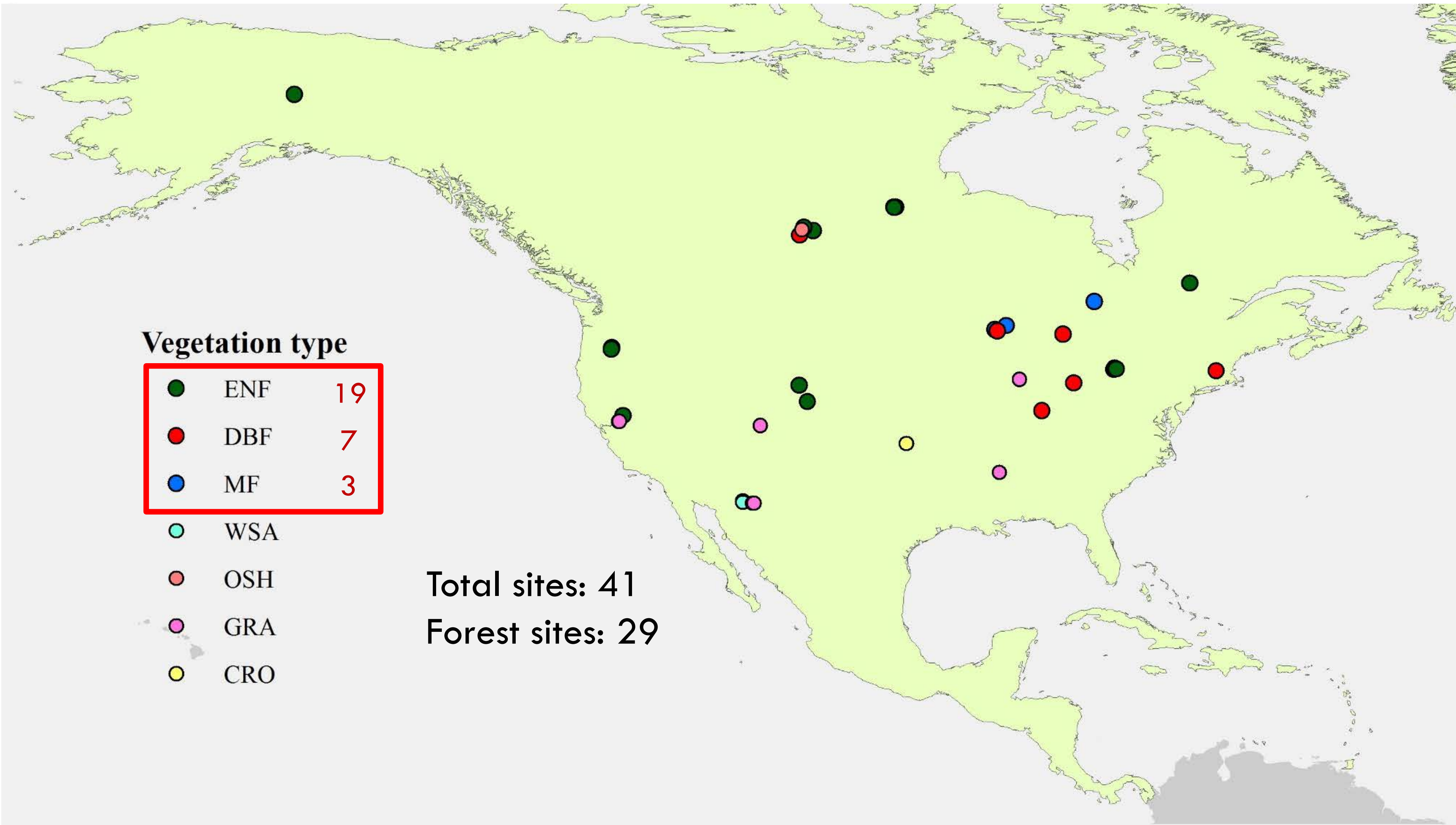
1) How do the seasonal pattern of sensitivity of forest carbon fluxes to heat and drought stress change among the FLUXNET sites in North America?

2) Which variables can explain the spatial variation of the sensitivities?

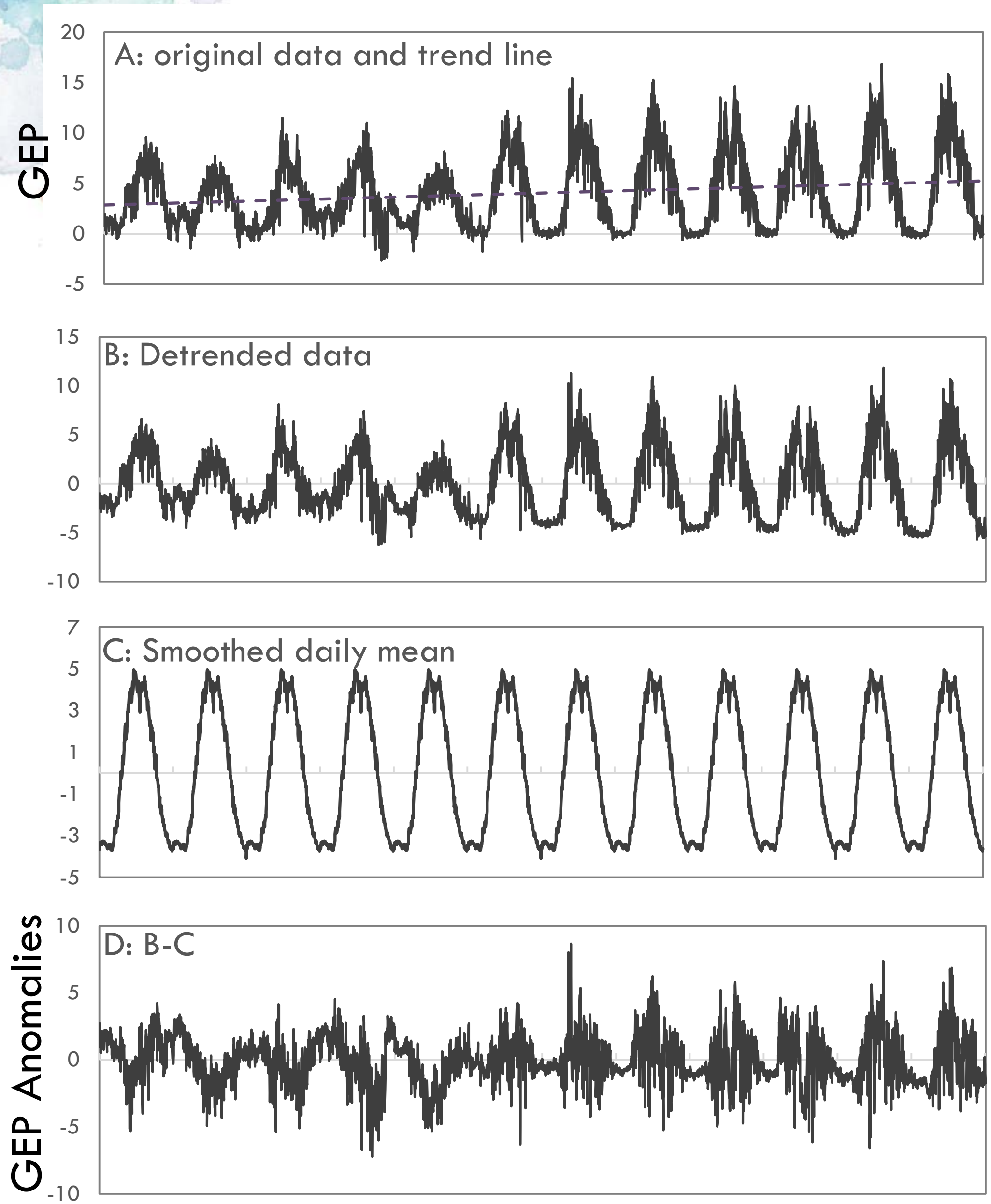
METHODS

Data Base: FLUXNET2015

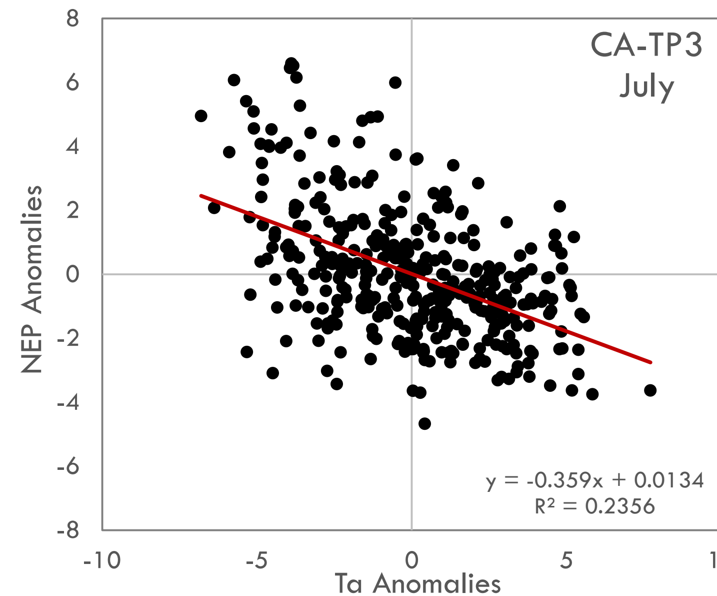
Criteria: more than 5 yrs continuous measurements of NEP, GEP, RE, Ta, LE, H and SWC



Data Normalization



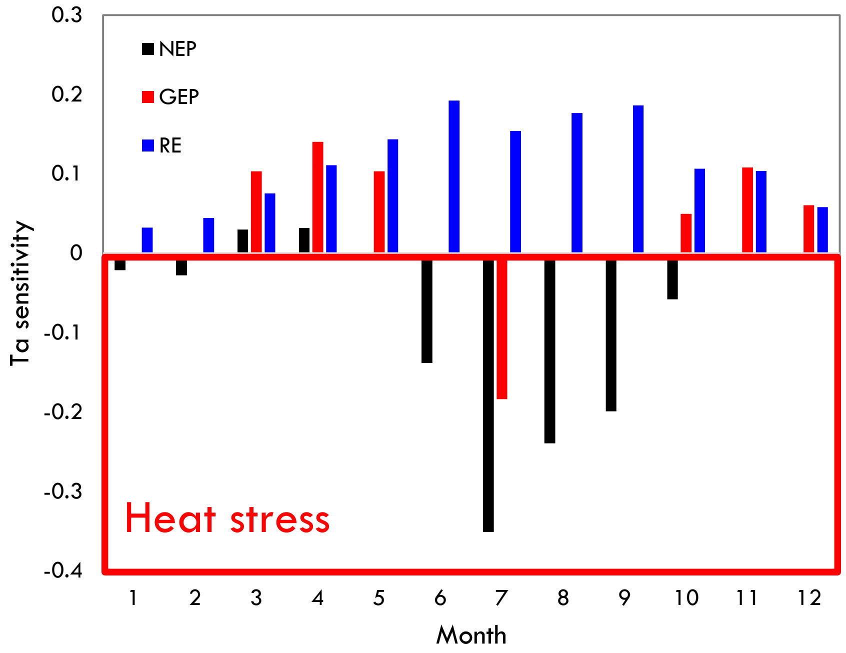
Example from Turkey Point Observatory 42-yr old site (CA-TP3)

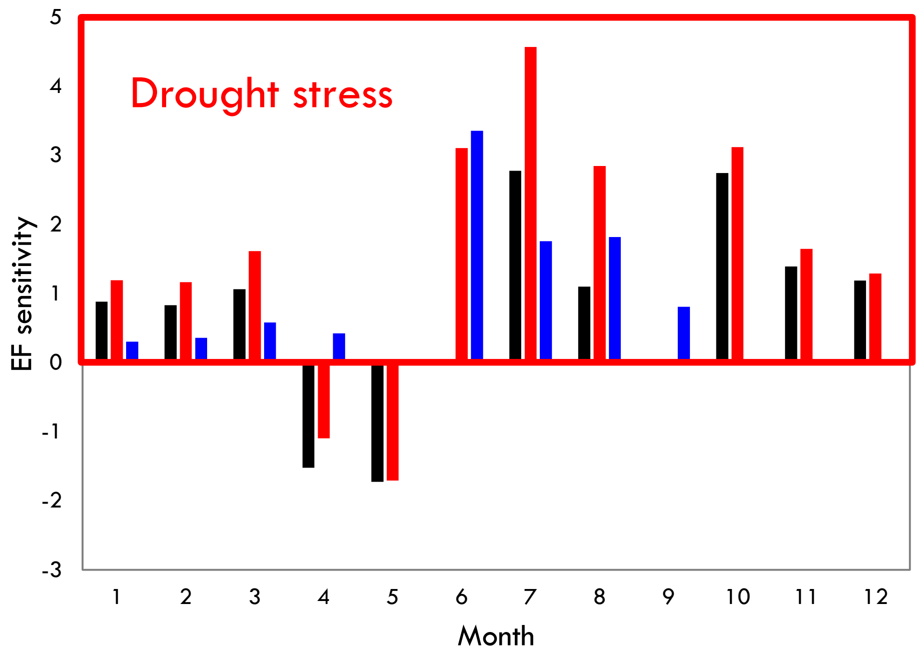


- Dryness index: Evaporative Fraction (EF) EF = LE/(LE+H)
- Daily data of NEP, GEP, Re, Ta and EF was normalized
- Linear regression between fluxes and environmental anomalies for each month
- Slopes of the regressions = index of sensitivity

METHOD

Example from Turkey Point Observatory, 42-yr old site (CA-TP3)



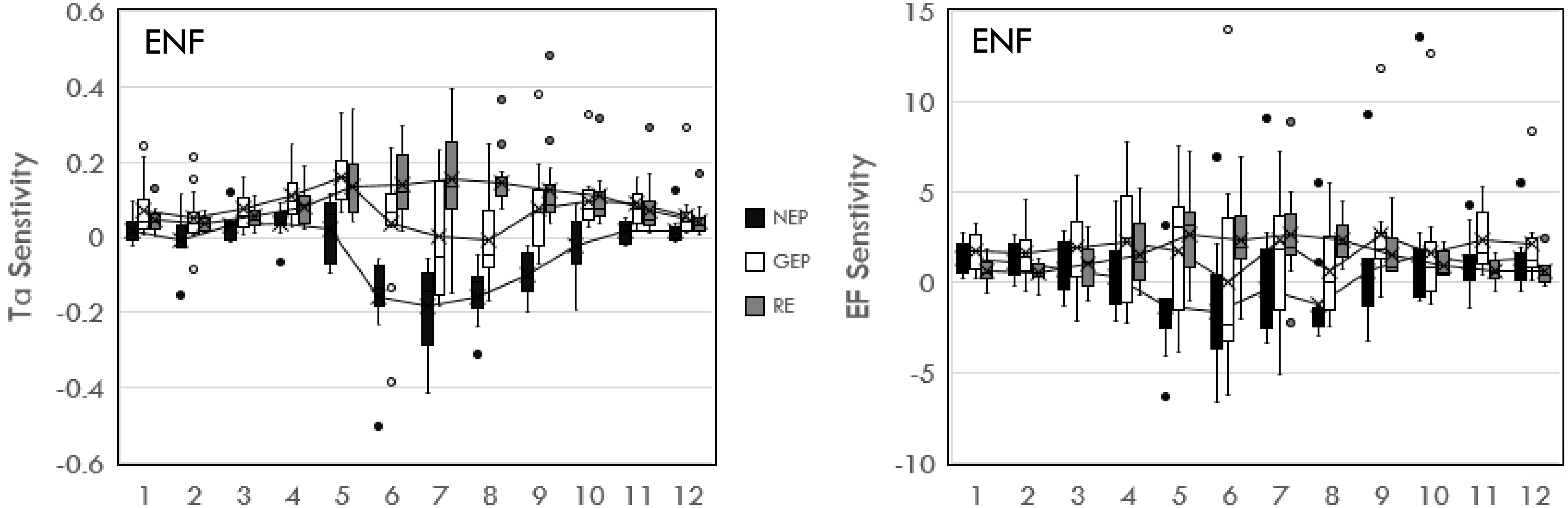


- **Monthly Indices of Sensitivity:**
  - Heat stress – TA (g C m^{-2} d^{-1}°C^{-1}) sensitivity <0
  - Drought stress – EF (g C m^{-2} d^{-1}) sensitivity >0
- **Explanatory variables:** forest type, climate zone, mean monthly temperature and precipitation, forest management, age classes, mean annual GEP, Water Use Efficiency.
- **Seasons:** defined by Koppen climate classification for each site

RESULTS: Forest Type (Conifer vs Deciduous)

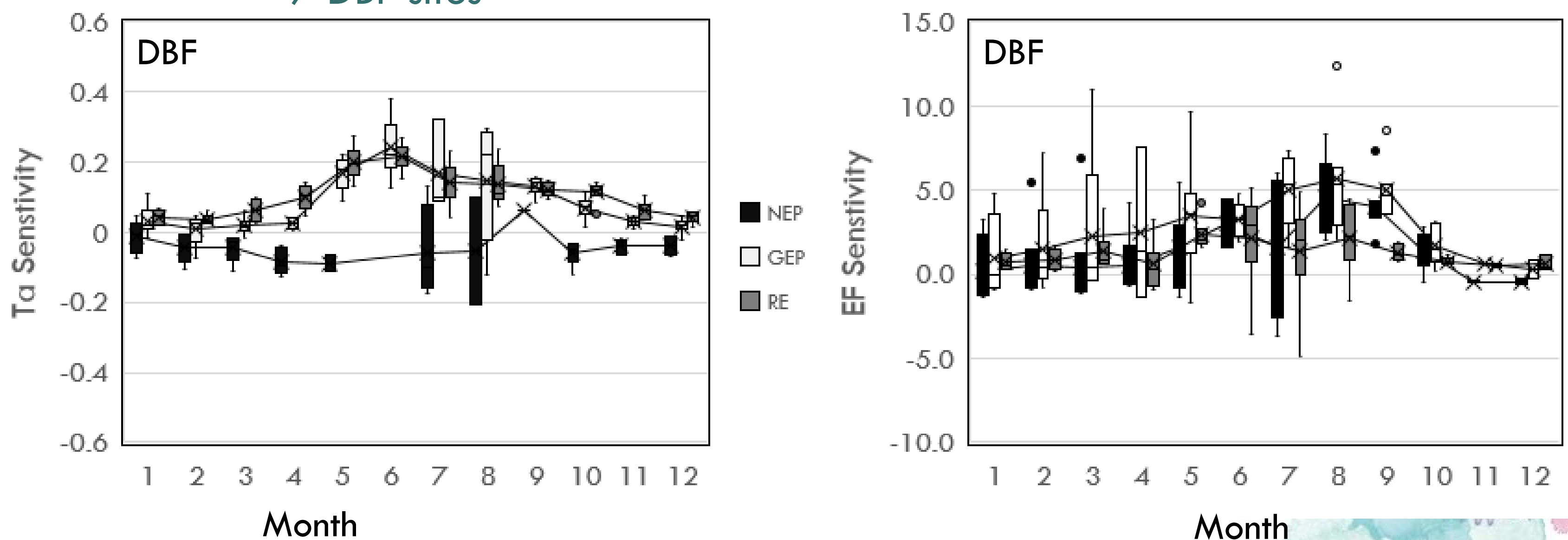
19 ENF sites

Conifer

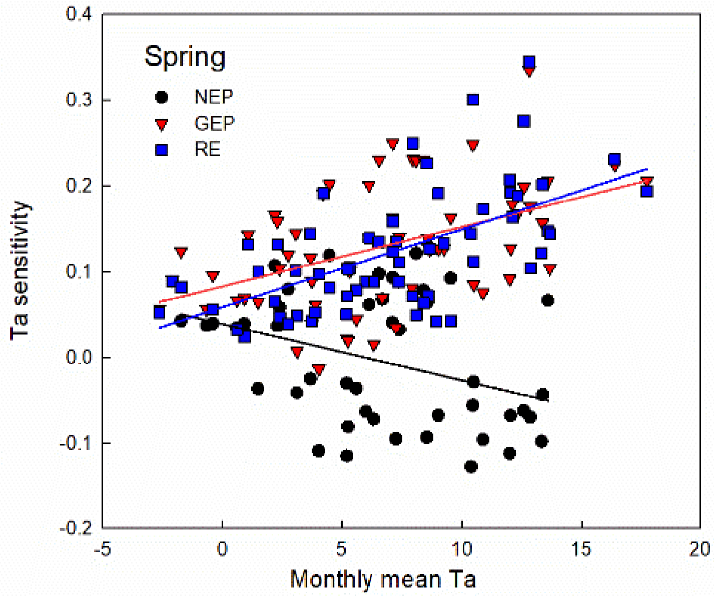


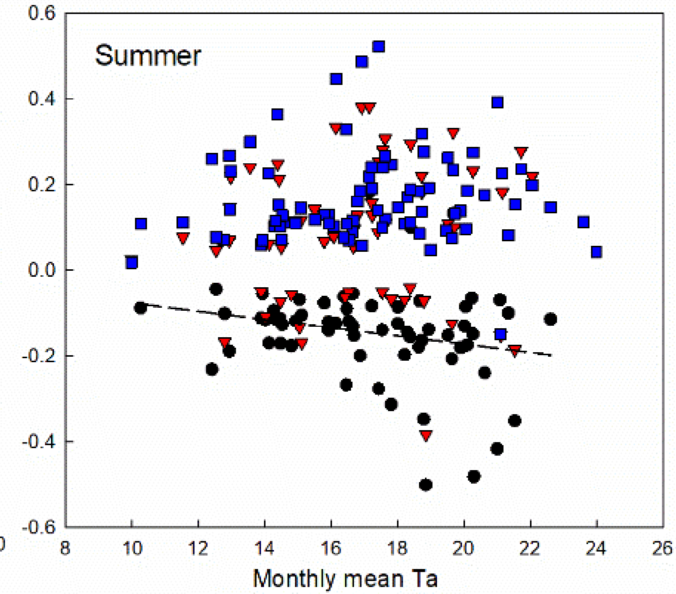
7 DBF sites

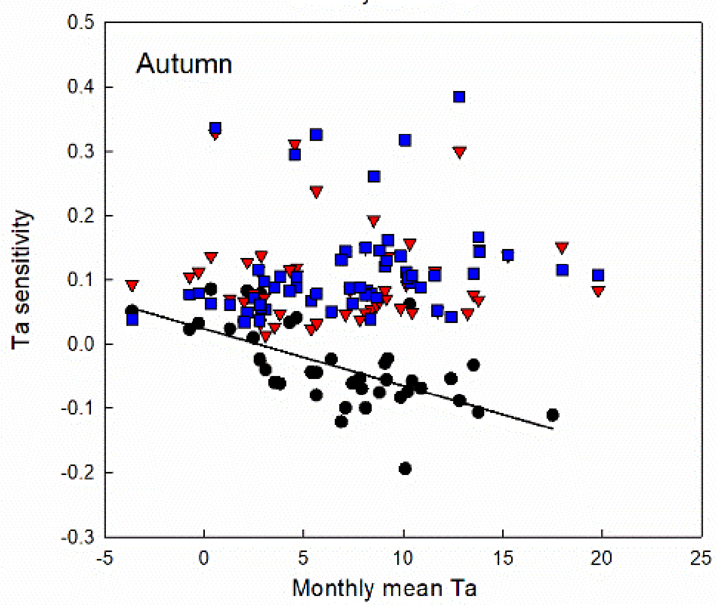
Deciduous



RESULT: Relationship with Temperate

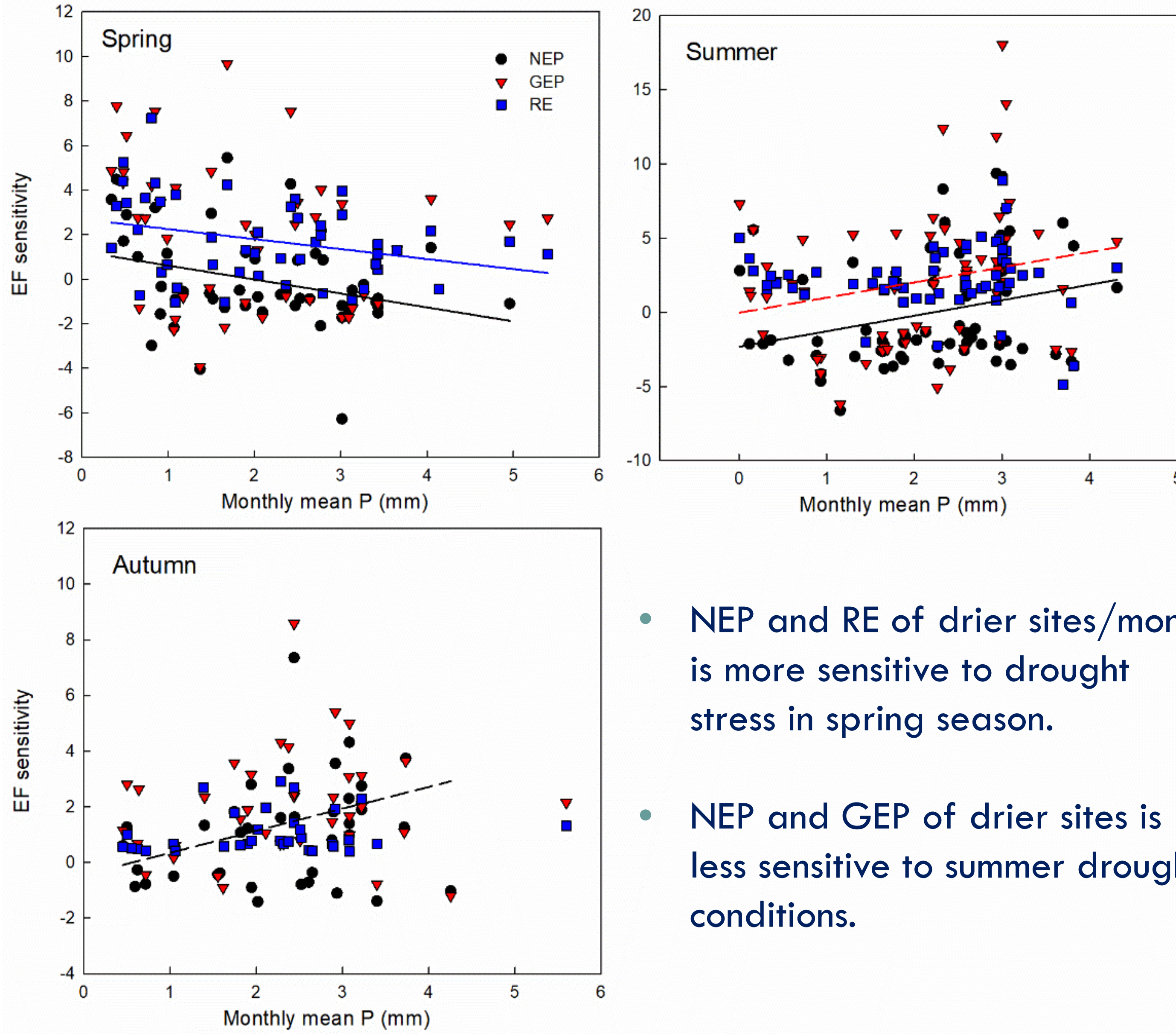






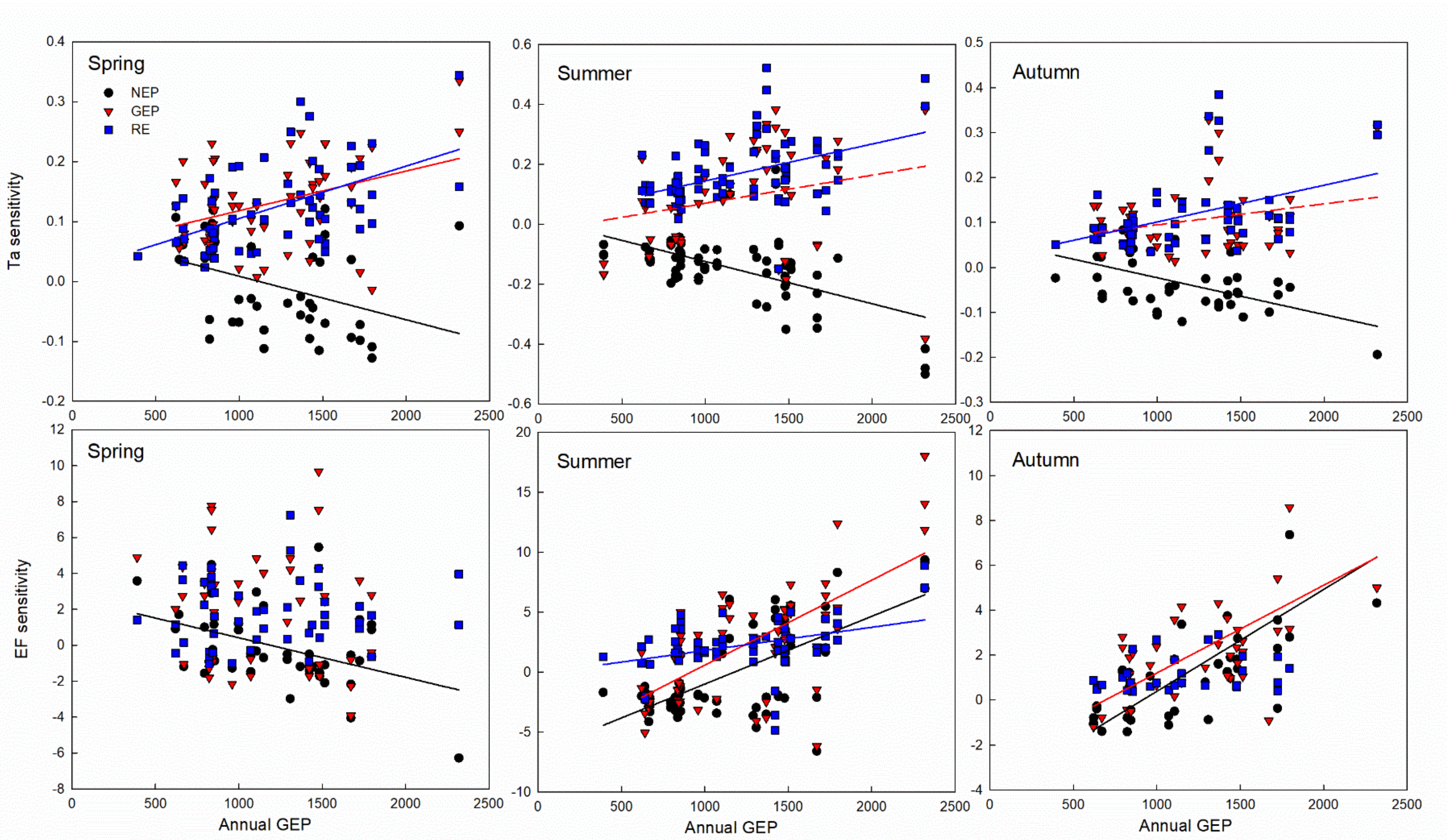
- NEP of warmer sites/month is more sensitive to heat stress in all three seasons.
- GEP and RE of warmer sites is more sensitive to high temperatures in spring season.

RESULT: Relationship with Precipitation



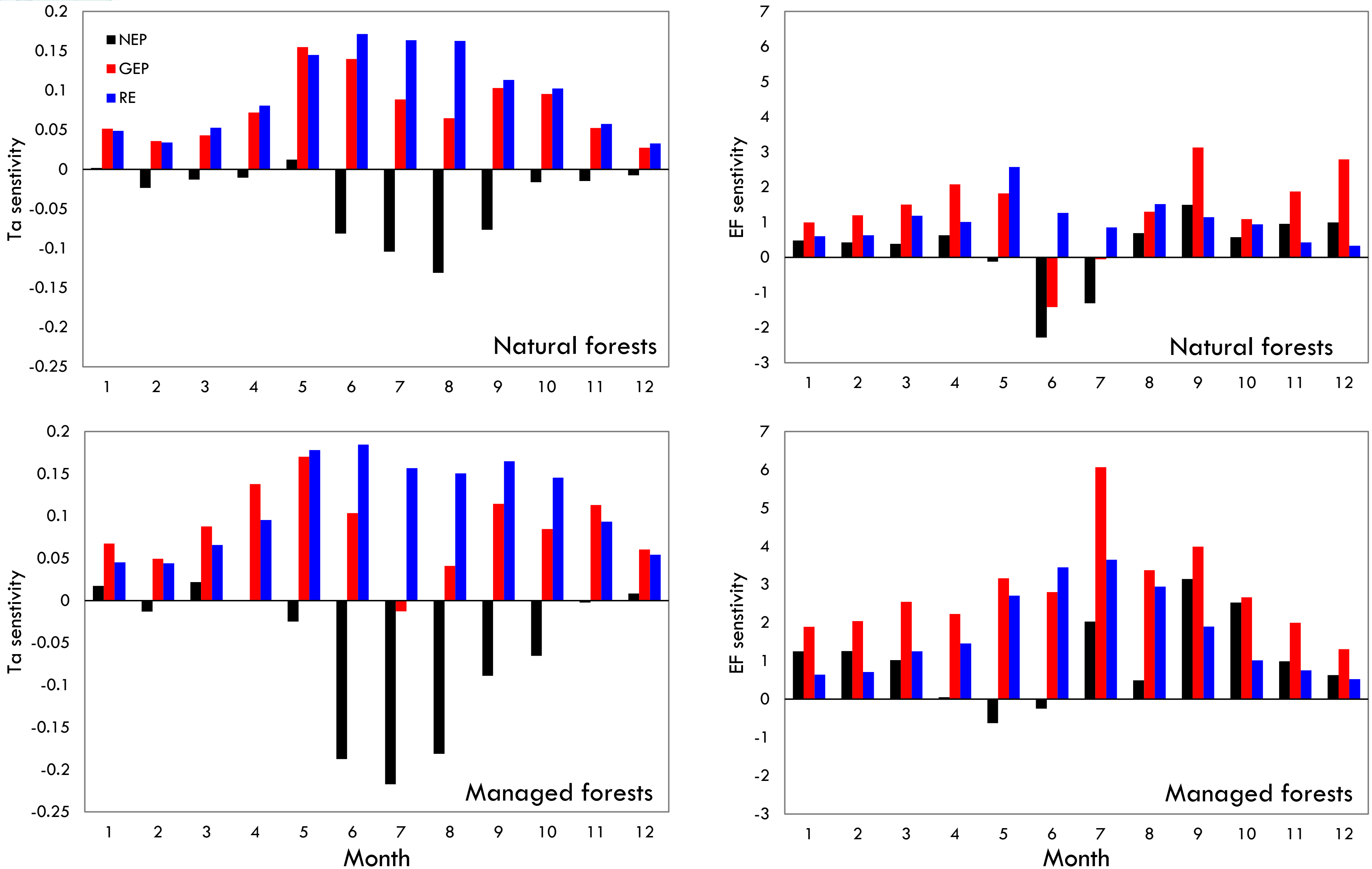
- NEP and RE of drier sites/month is more sensitive to drought stress in spring season.
- NEP and GEP of drier sites is less sensitive to summer drought conditions.

RESULT: Relationship with Productivity

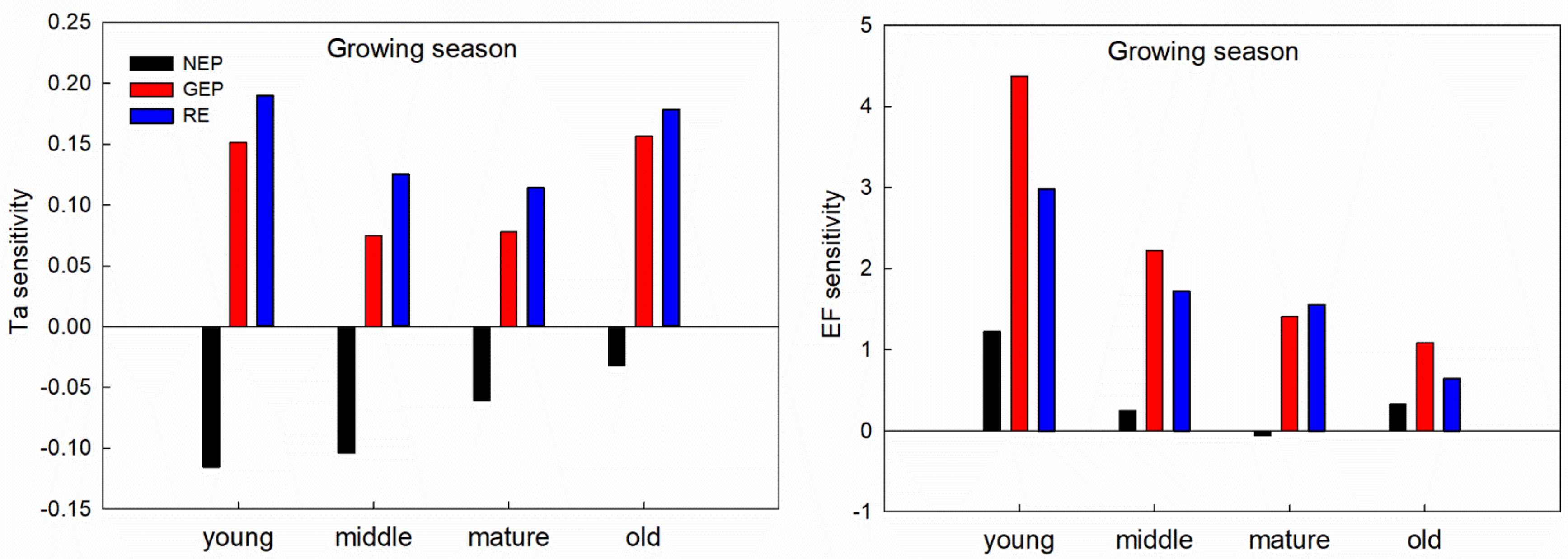


NEP in more productive sites are more sensitive Ta anomalies in all the three season; less sensitive to dryness in spring but more sensitive to dry condition in summer

RESULT: Management Impacts



RESULT: Forest Age Effects



- NEP are more conservative to temperature anomalies as forests grow older
- NEP in mature forests is least impacted by dryness in the growing season

CONCLUSIONS

1) The sensitivity of forest carbon fluxes to heat and drought stresses is highly dependent on the time of the stress.

2) GEP is more sensitive to drought anomalies, while RE is more sensitive to temperature anomalies.

3) In spring, NEP in deciduous forests is limited by heat stress but not in conifer stands; In summer, NEP in deciduous forests is more sensitive to drought stress as compared to conifer stands.

4) Warmer sites are more sensitive to heat stress. Dryer sites are more sensitive to water stress in spring, but less sensitive in summer.

5) High Productivity sites are more sensitive to heat and drought stress.

6) **Managed forests are more sensitive to drought stress.**

7) Sensitives of carbon fluxes decrease with forest age and development.

Thank you!

ACKNOWLEDGEMENT

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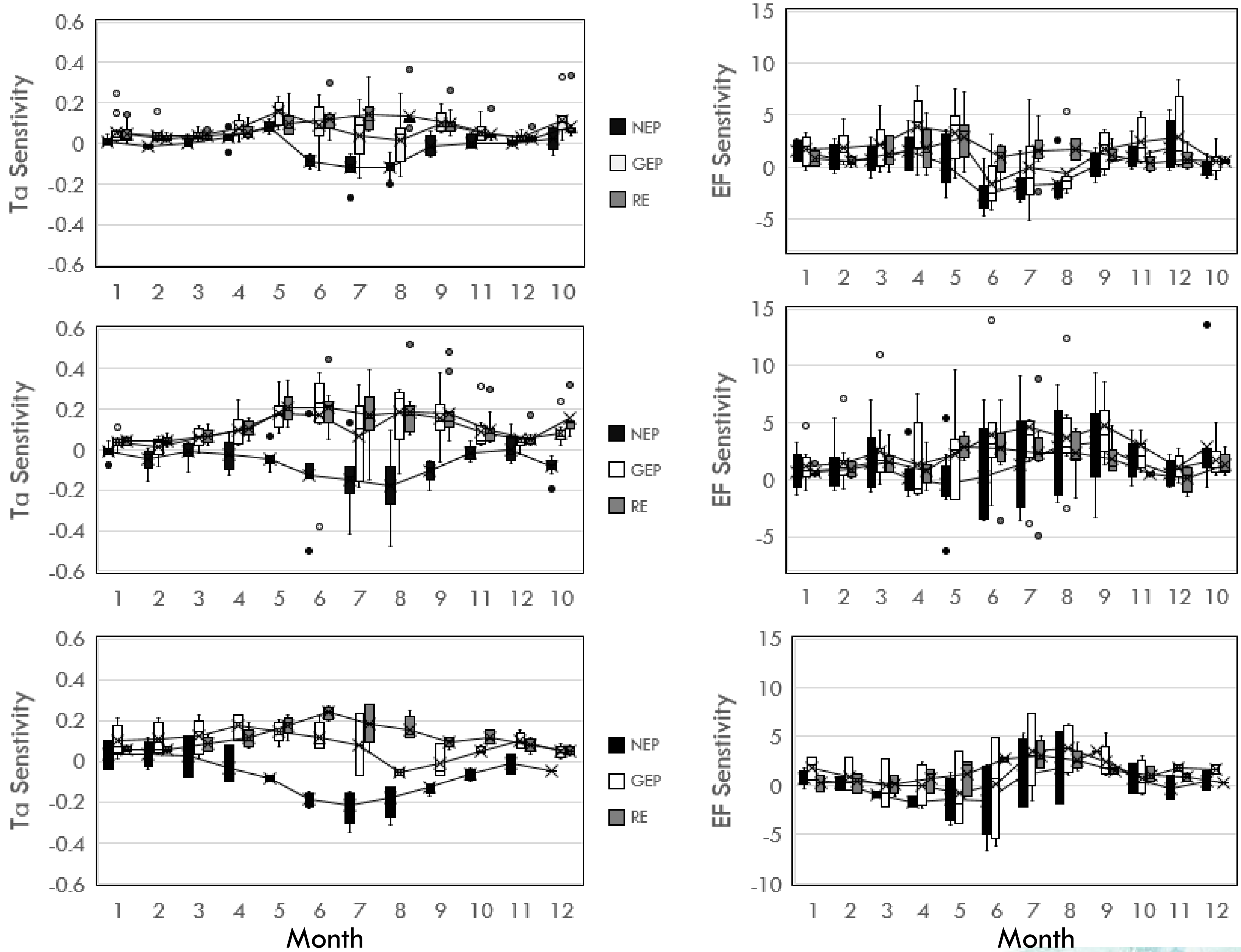
RESULT: Climate Zone

Total 29 forest sites

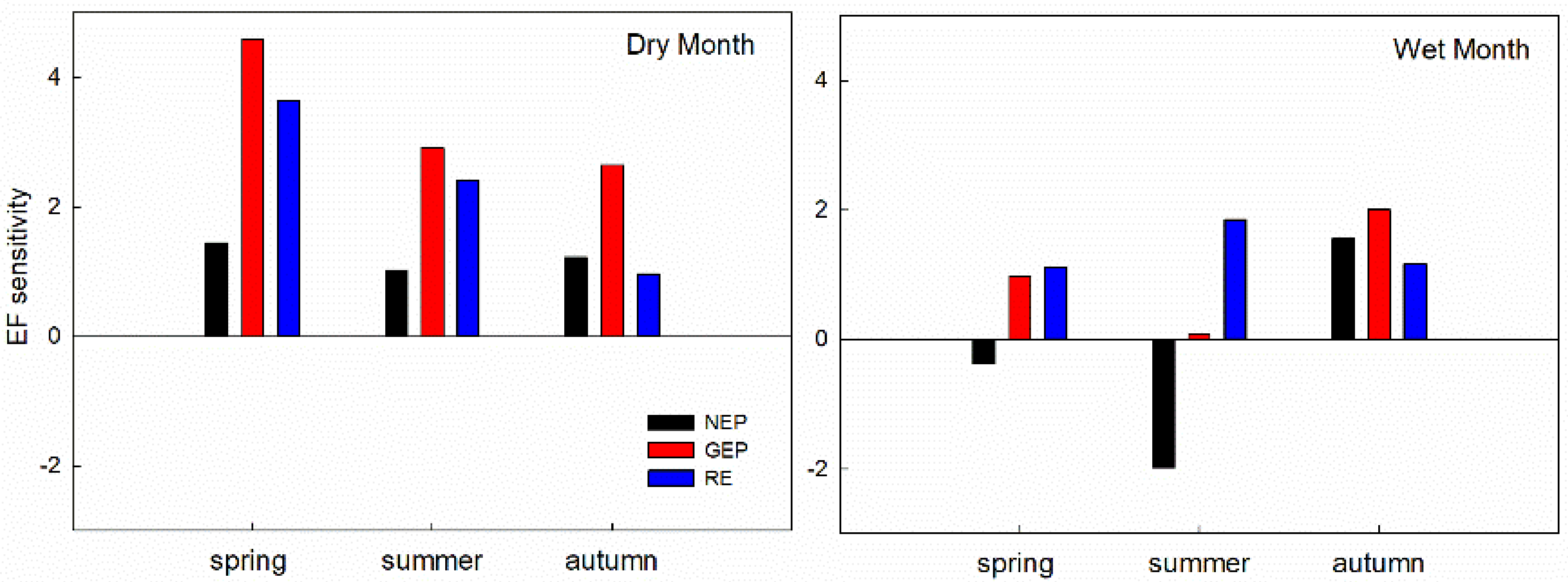
Subarctic

Continental

Subtropical



RESULT: Dry/Wet Season (or WUE)



Dryness in dry season are strongly correlated with forest carbon cycle;
In wet season, carbon fluxes are less sensitive to EF anomalies