Detecting drought impact on terrestrial biosphere carbon cycle over US in the context of carbon-climate interannual variability

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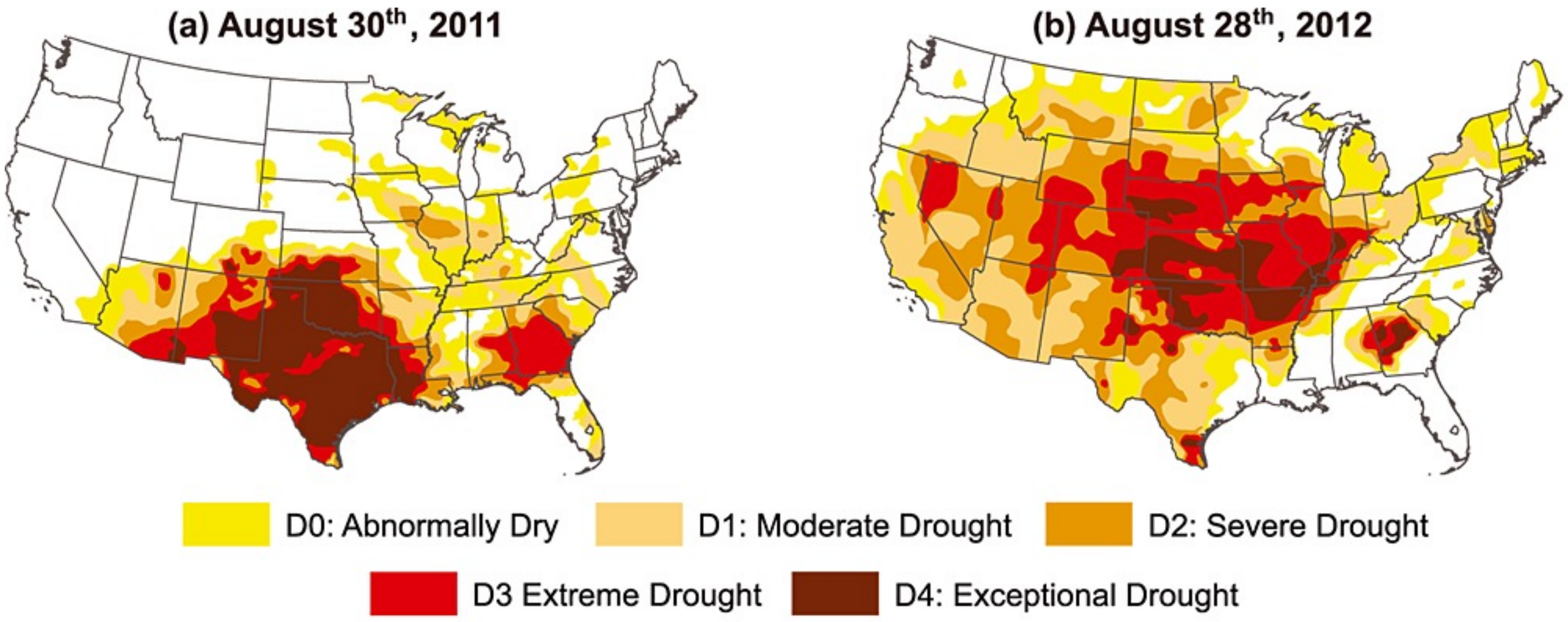
2011 Texas and 2012 central great plain drought



Sun et al., 2015

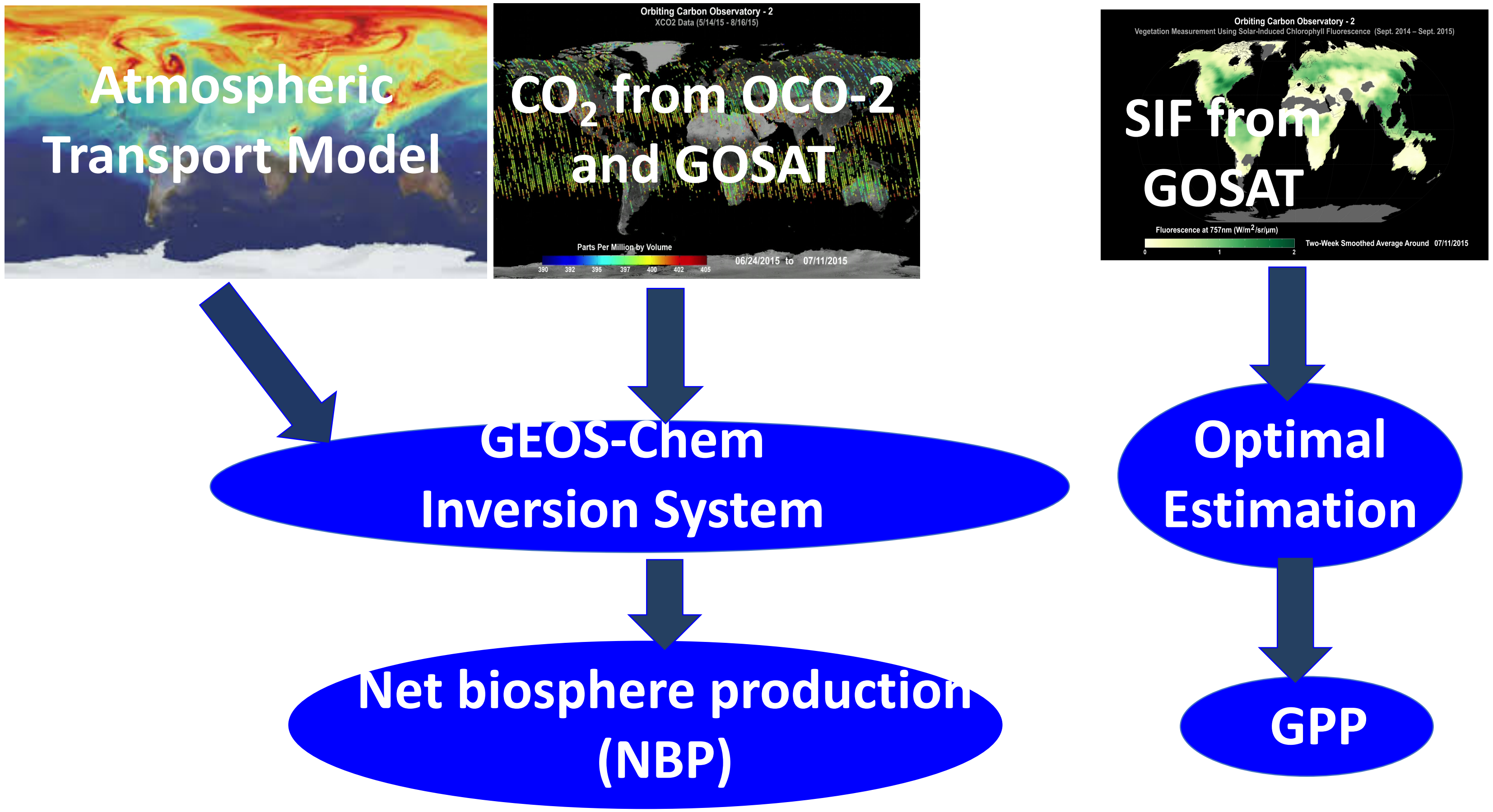
- The 2011 dry spell in Texas was the worst one-year period of drought since 1895.
- The area span of 2012 summer drought was comparable to the dust bowl era (1930s and 1950s).
- Crop and livestock loss from 2011 Texas drought was worth of $7.62 billion
- The 2012 drought has cost more than $35 billion in the Midwest, reduce GDP by 0.5-1%, equivalent to $75 - $150 billion.

Questions

- Can satellite observations detect the impact of these large climate anomalies on terrestrial biosphere carbon cycle in spite of possible biases in satellite observations?

  - How do these two drought events differ in their seasonal progression in terms of climate drivers and carbon flux responses?
  - What are the general relationships between carbon flux anomalies and climate state anomalies?
  - How significant are drought impact on carbon fluxes relative to regional fossil fuel emissions?

CMS-Flux to Estimate Net CO_2 fluxes and its Component Fluxes

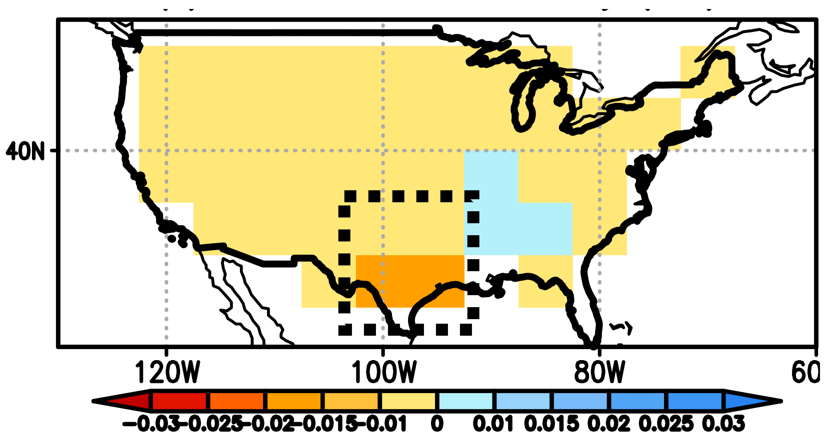


- Net biosphere production (NBP)= GPP - Respiration
- Assimilate ACOS-GOSAT b7.3 from July 2009 to Dec 2015
- Baseline years: 2010, 2013-2015

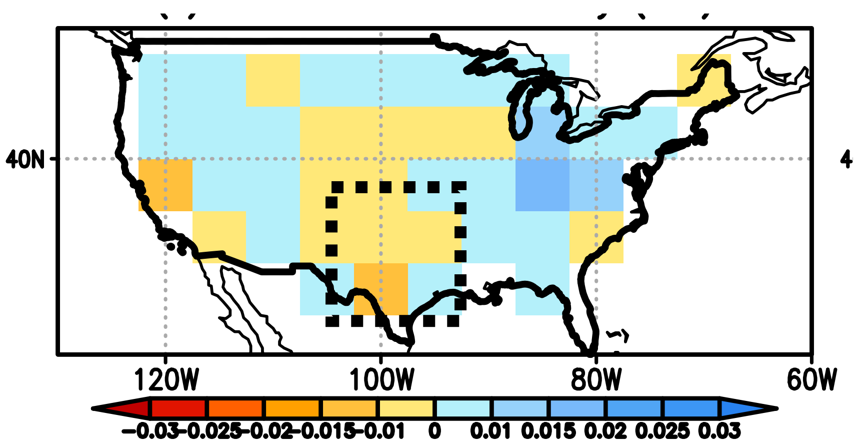
Liu et al., 2014; 2017
Parazoo et al., 2015

Reduced net carbon uptake and growth in 2011 spring vs. increased net carbon uptake and growth in 2012 spring

2011 MAM NBP anomaly (GtC)



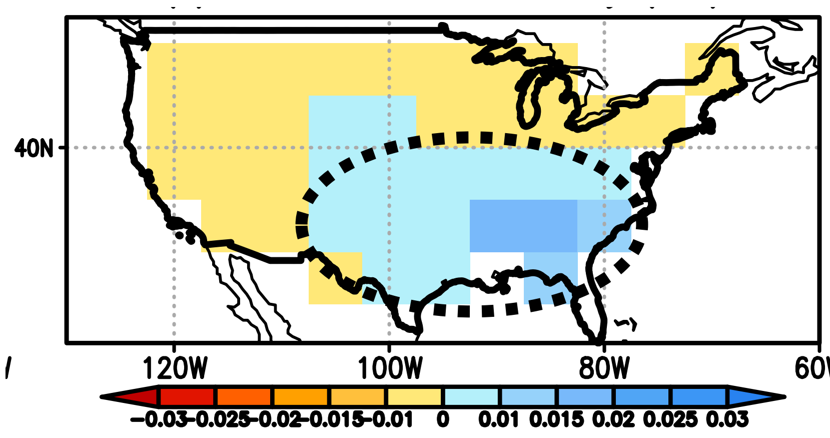
2011 MAM GPP anomaly (GtC)



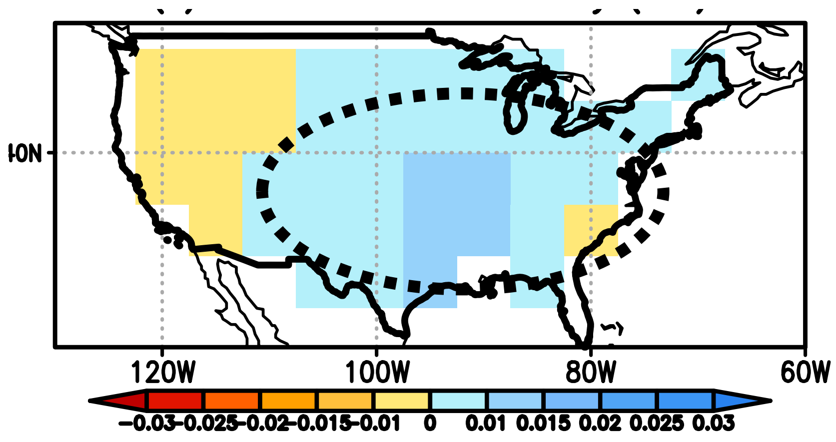
- NBP reduced by 0.06 GtC (60%)
- GPP reduced by 0.01

=> NBP reduction was dominated by increase of respiration

2012 MAM NBP anomaly (GtC)



2012 MAM GPP anomaly (GtC)



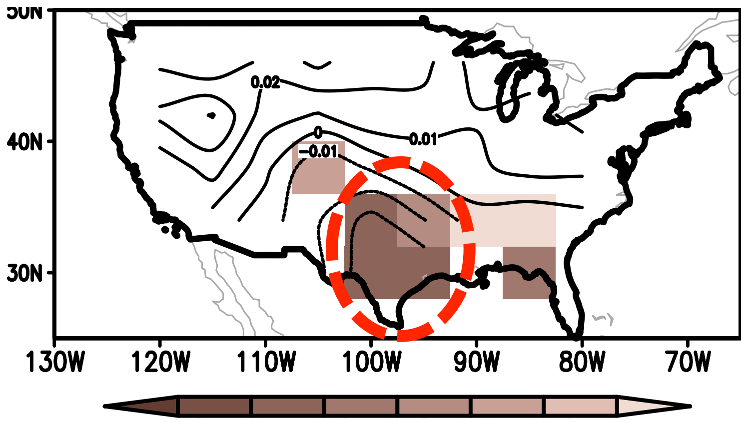
- NBP increased by 0.1 GtC (50%)
- GPP increased by 0.1 GtC

=> NBP increase was dominated by increase of GPP

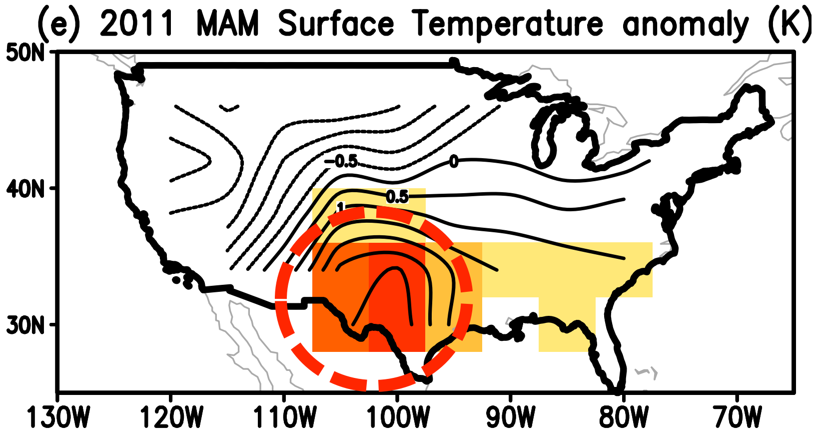
Liu et al., 2018, in review

Soil moisture and temperature anomaly in 2011 and 2012 springs

2011 MAM surface soil moisture anomaly (m^3/m^3)

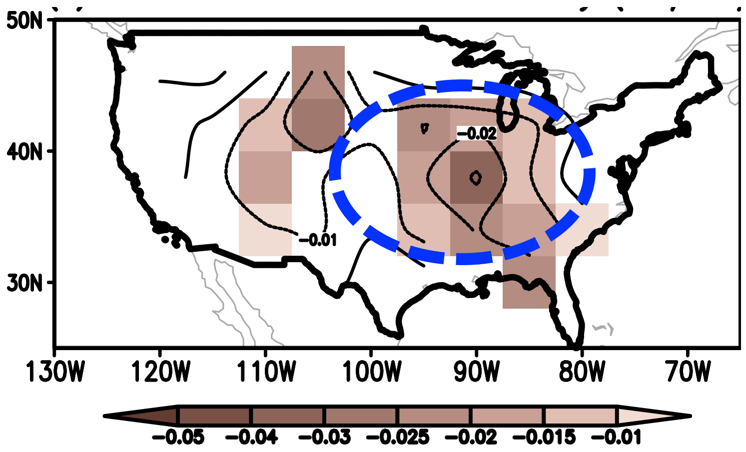


2011 MAM surface

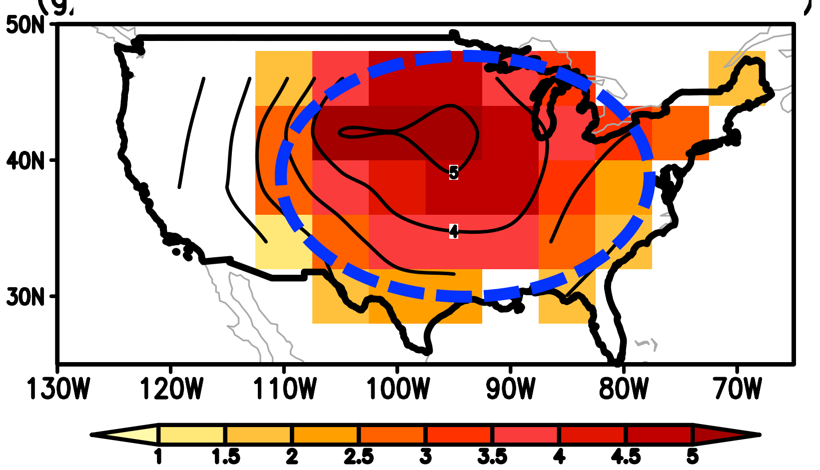


- Soil moisture negative anomaly over Texas in 2011 was about 2.8 times of soil moisture anomaly over mid west in 2012

2012



2012

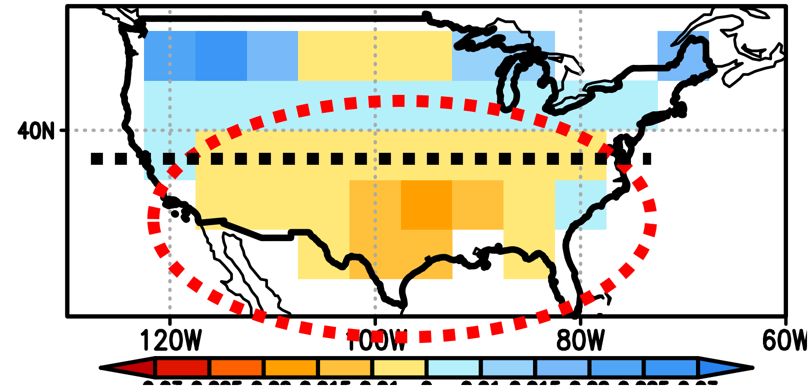


- Surface temperature anomaly was 1.9 ℃ (mean is ~20℃) over Texas in 2011, while it was 3. 3 ℃ (mean is ~13 ℃) over mid west in 2012

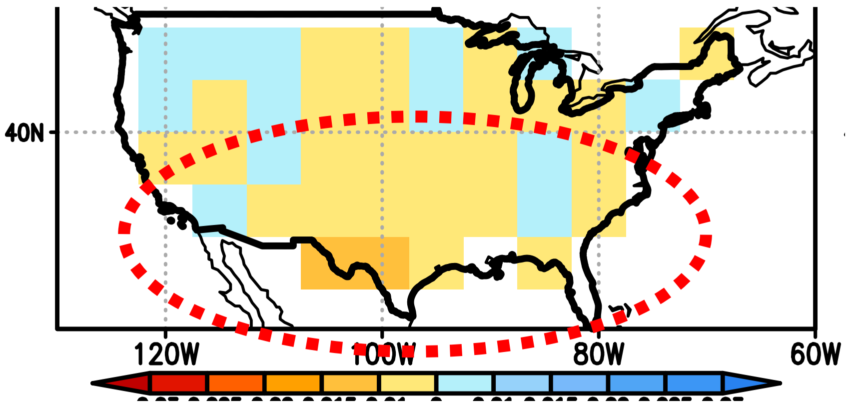
- Warm and drought in 2011 spring => Increased soil decomposition;
- Much warmer spring and not much water deficit in 2012 spring => increased growth

The NBP and GPP were greatly reduced during both 2011 and 2012 summer droughts

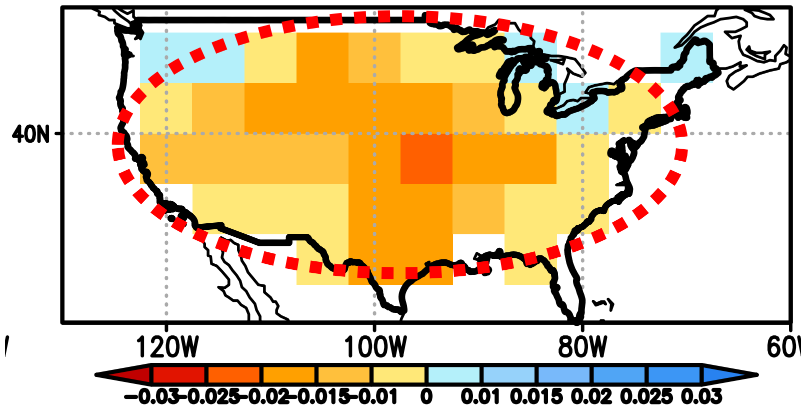
2011 JJA NBP anomaly (GtC)



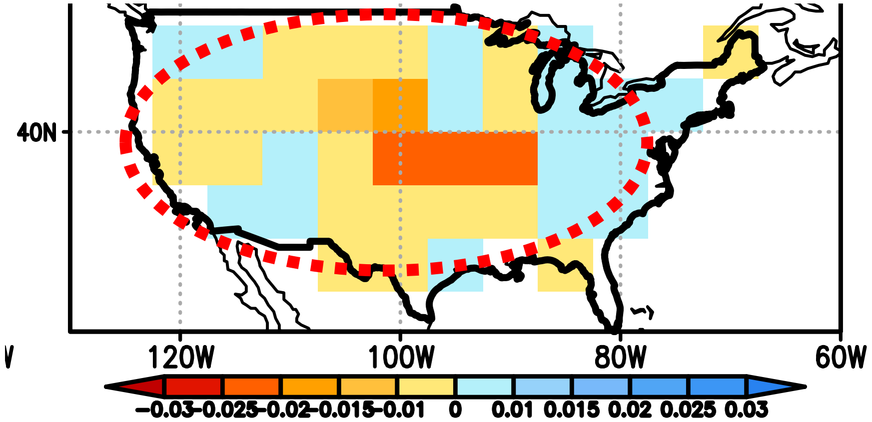
2011 JJA GPP anomaly (GtC)



2012 JJA NBP anomaly (GtC)



2012 JJA GPP anomaly (GtC)

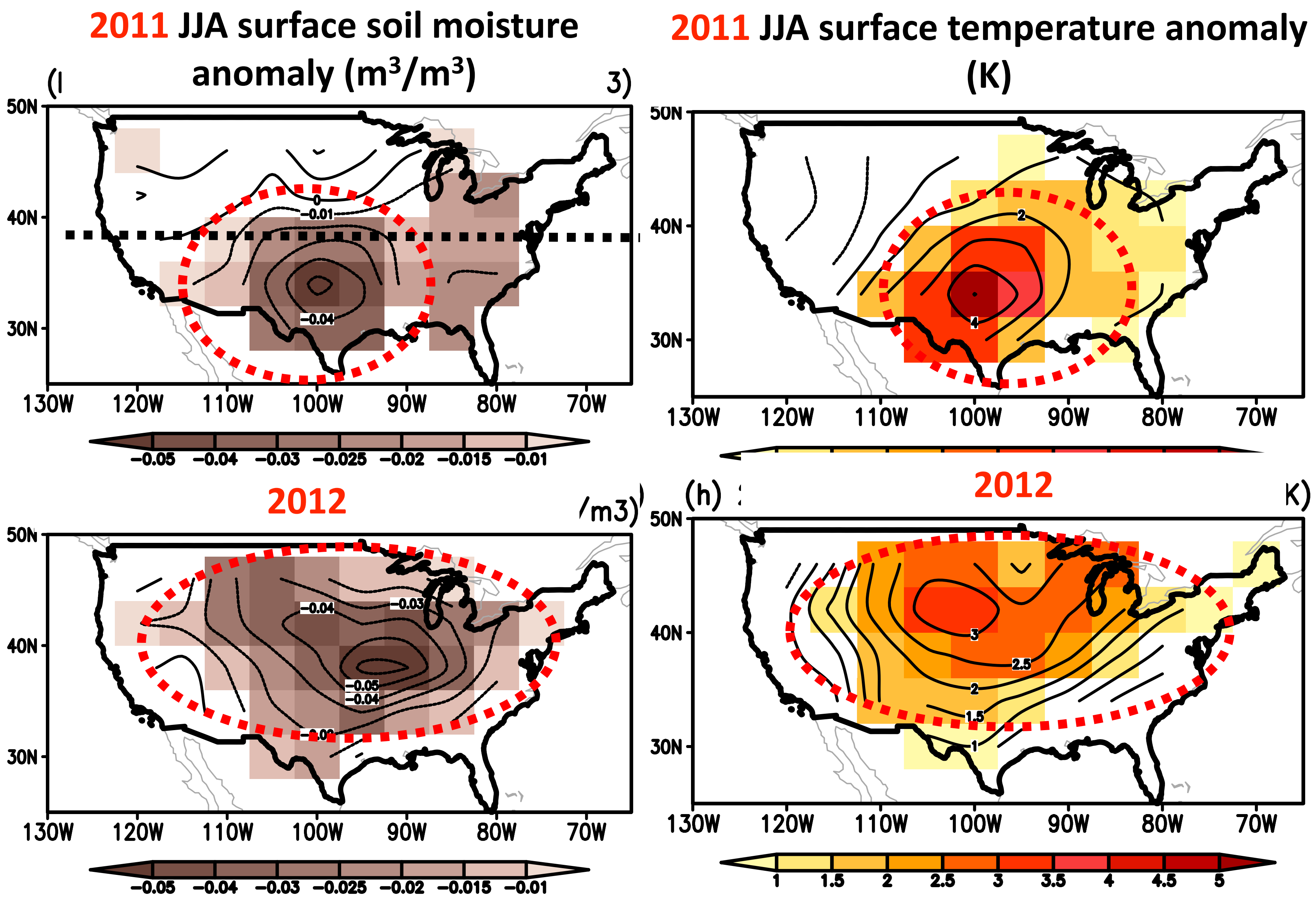


- NBP reduction: 0.14 GtC (25% of mean) over S. CONUS in 2011;
- NBP reduction: 0.39 GtC (30% of the mean) over CONUS in 2012

- GPP reduction: 0.10 GtC over S. CONUS in 2011;
- NBP reduction: 0.17 GtC over CONUS in 2012

- NBP reduction during 2011 and 2012 summer drought was due to both GPP reduction and respiration increase.

Reductions of NBP and GPP during summer correspond to drought and high temperature

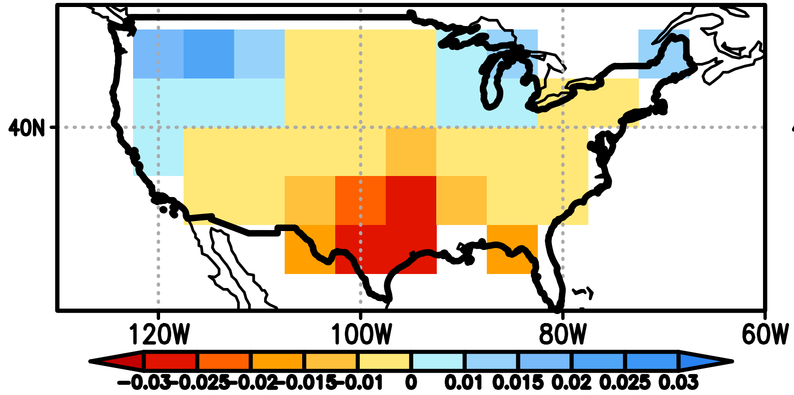


- Negative soil moisture anomaly was comparable between S. CONUS in 2011 and CONUS in 2012

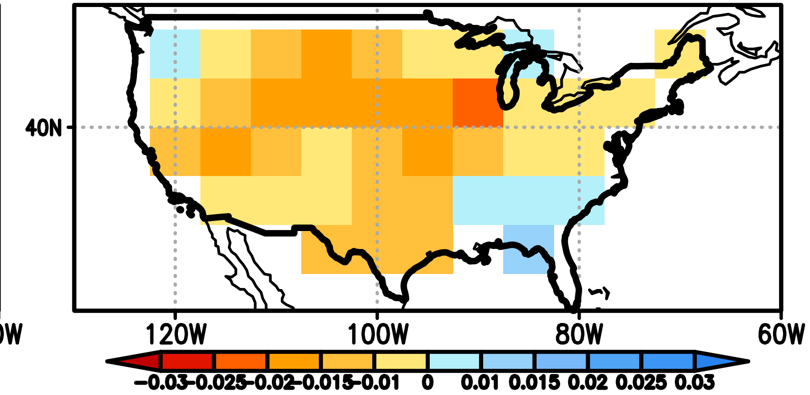
- T anomaly is 1.3 ℃ over S. CONUS in 2011
- T anomaly was 1.1 ℃ over CONUS in 2012

Total NBP and GPP anomaly between March and August

2011 NBP anomaly (March-August)

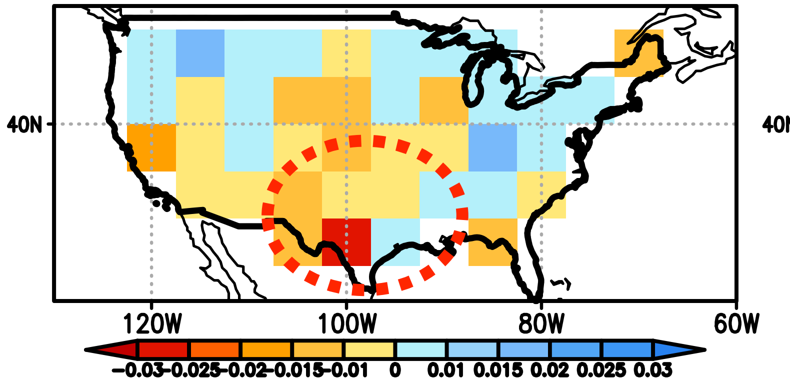


2012 NBP anomaly (March-August)

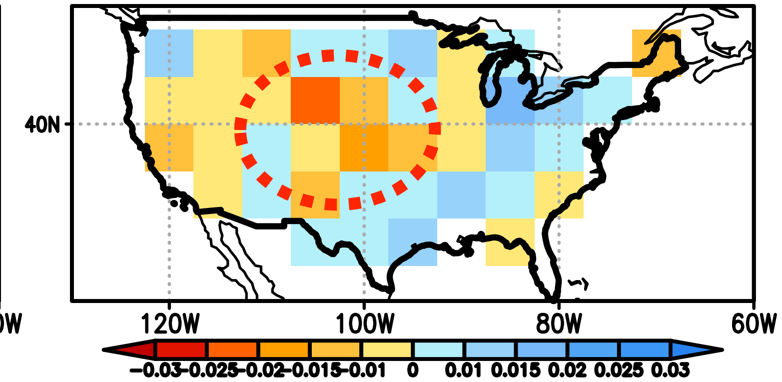


- NBP reduced by 25% over S. CONUS, but by 50% over Texas region in 2011;
- NBP reduced by 25% over CONUS between March and August in 2012

2011 GPP anomaly (March-August)

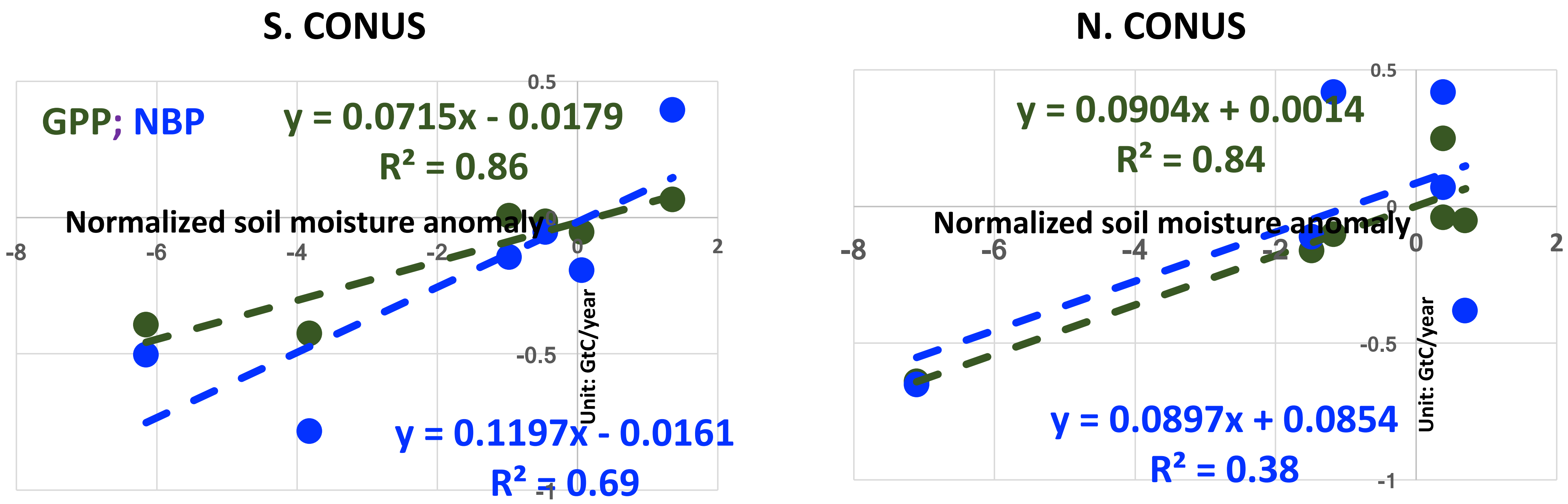


2012 GPP anomaly (March-August)



- GPP reduction was the driver for NBP reduction over regions with large NBP reduction

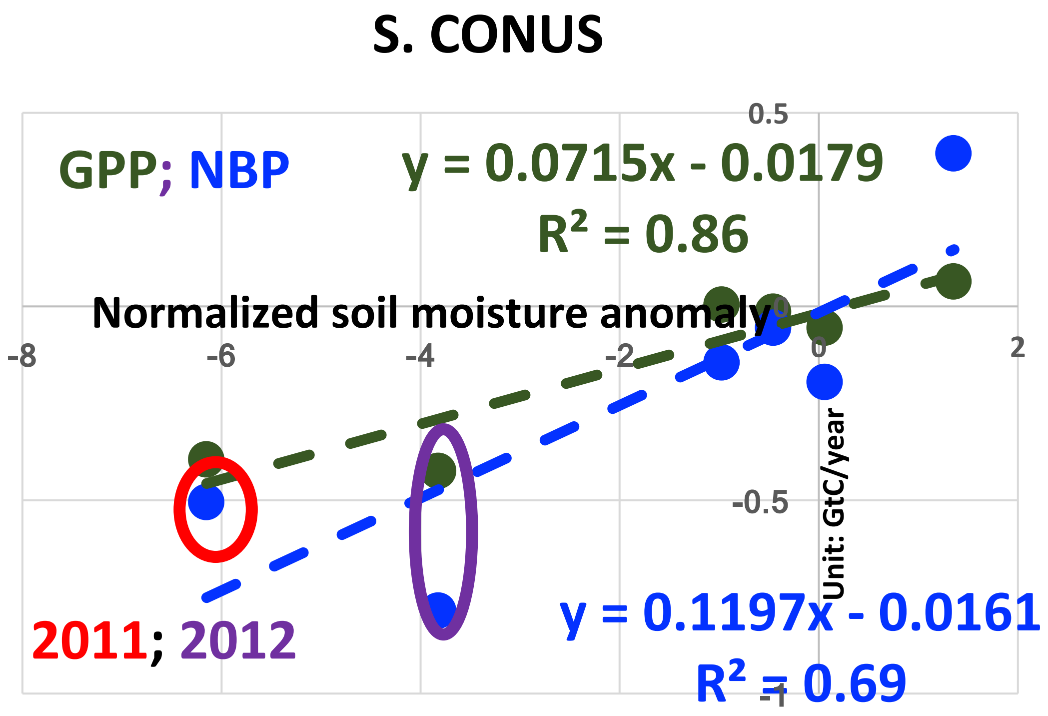
The relationship between soil moisture anomalies and NBP/GPP interannual variability in summer

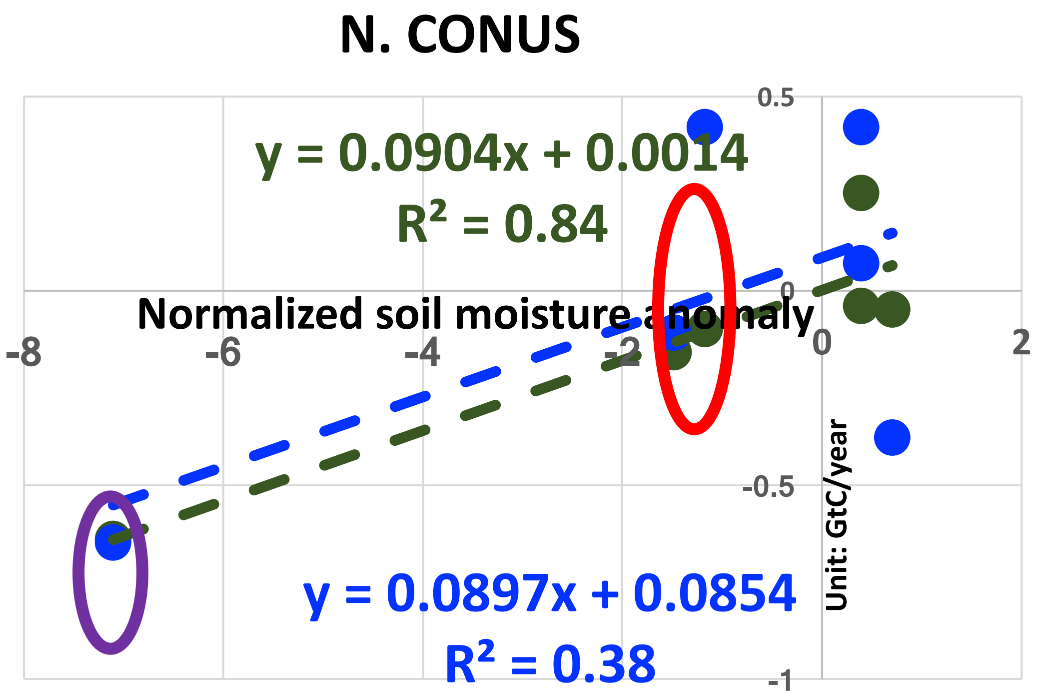


- Soil moisture anomalies explain more than 80% of summer GPP interannual variability in both S. CONUS and N. CONUS

- The relationship between soil moisture anomaly and NBP anomaly is not as good.

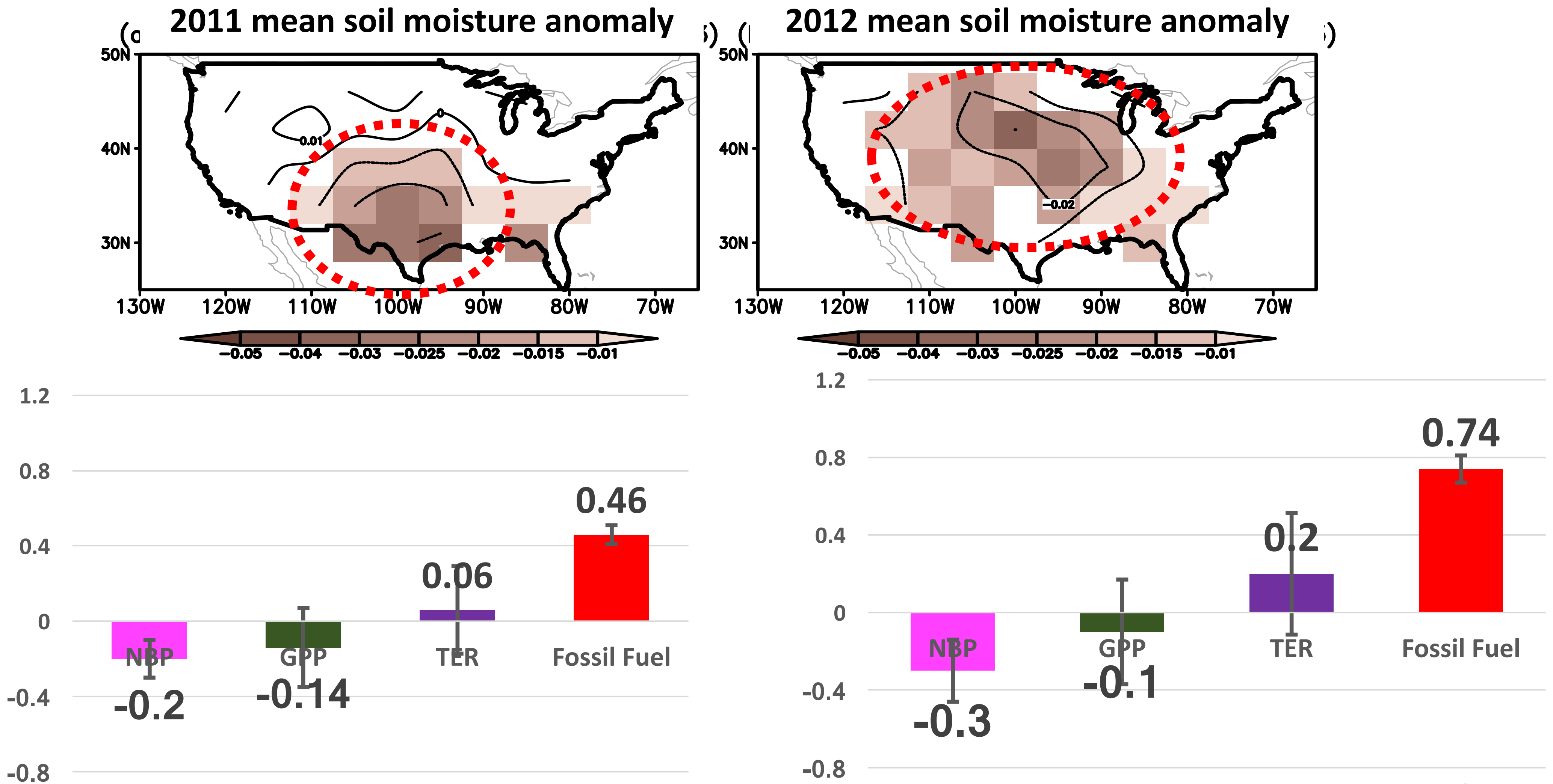
The relationship between soil moisture anomalies and NBP/GPP interannual variability in summer





- **2011 has the largest negative soil moisture anomaly over S. CONUS, while 2012 had the largest negative soil moisture anomaly over N. CONUS.**

NBP reduction from 2011 and 2012 drought more than 40% of the regional fossil fuel emissions



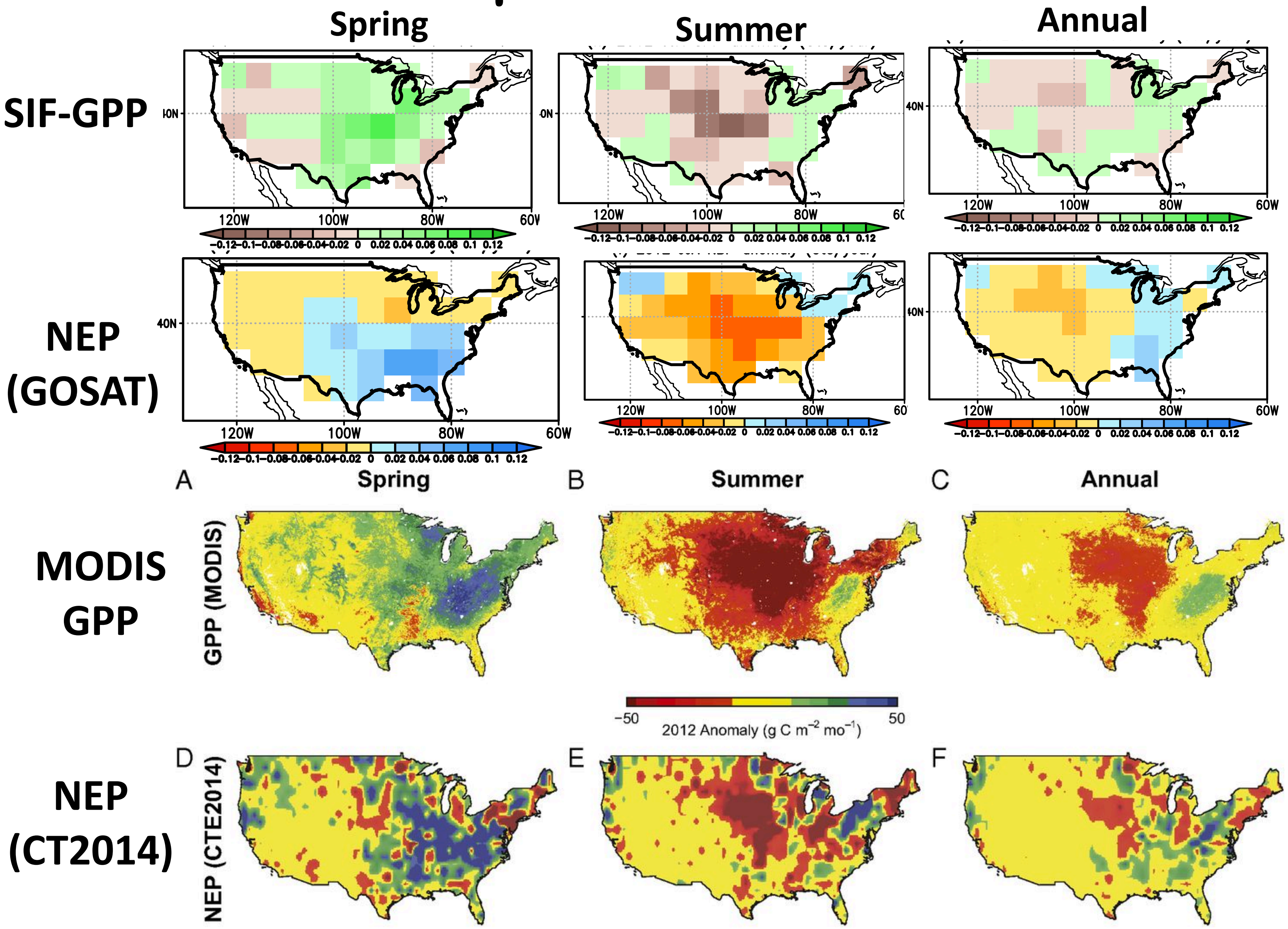
Unit: GtC/year

Conclusions

- **Flux inversions assimilating ACOS-GOSAT observations detected the 2011 and 2012 US drought impact on net biosphere carbon uptake.**
- **Due to the seasonal compensating effect, the annual mean impact of 2012 drought over CONUS is smaller than 2011 Texas drought.**
- **The NBP reduction was dominated by the reduction of GPP over the regions with most severe drought.**
- **Soil moisture anomalies and GPP anomalies have strong linear relationship in summer.**
- **NBP reduction from 2011 and 2012 drought more than 40% of the regional fossil fuel emissions, indicating that interannual variability and long-term change of NBP needs to be taken into account in designing any emission mitigation policy.**

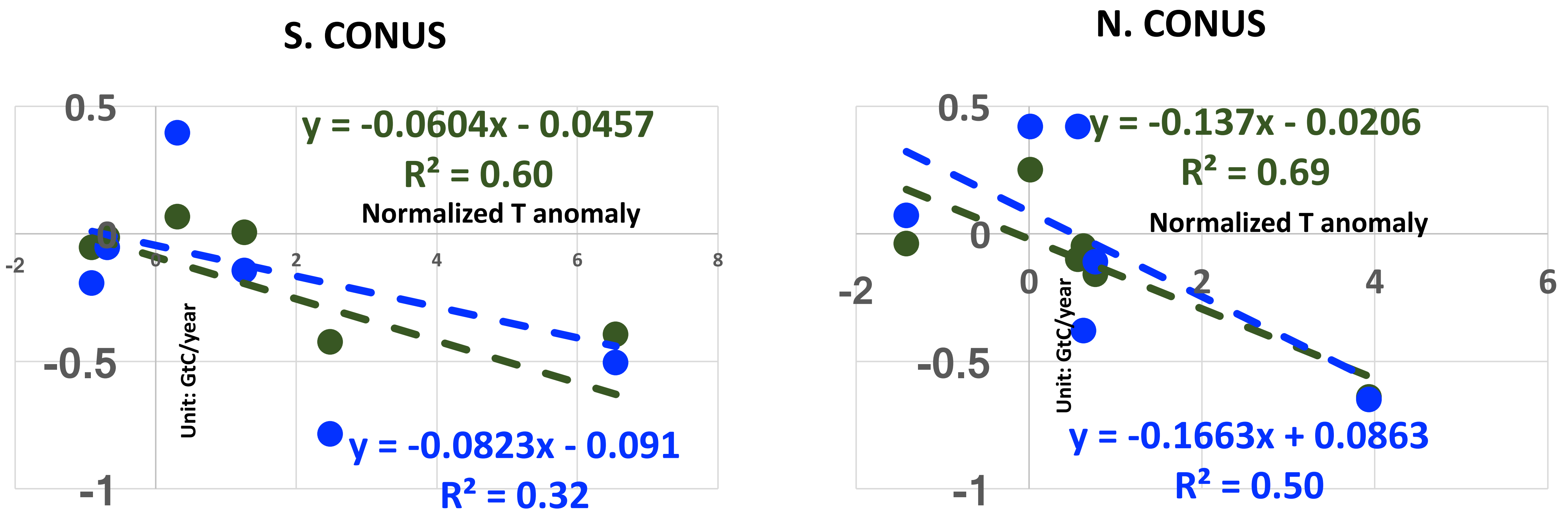
Back-up slides

Seasonal compensation effect of 2012 mid-west drought



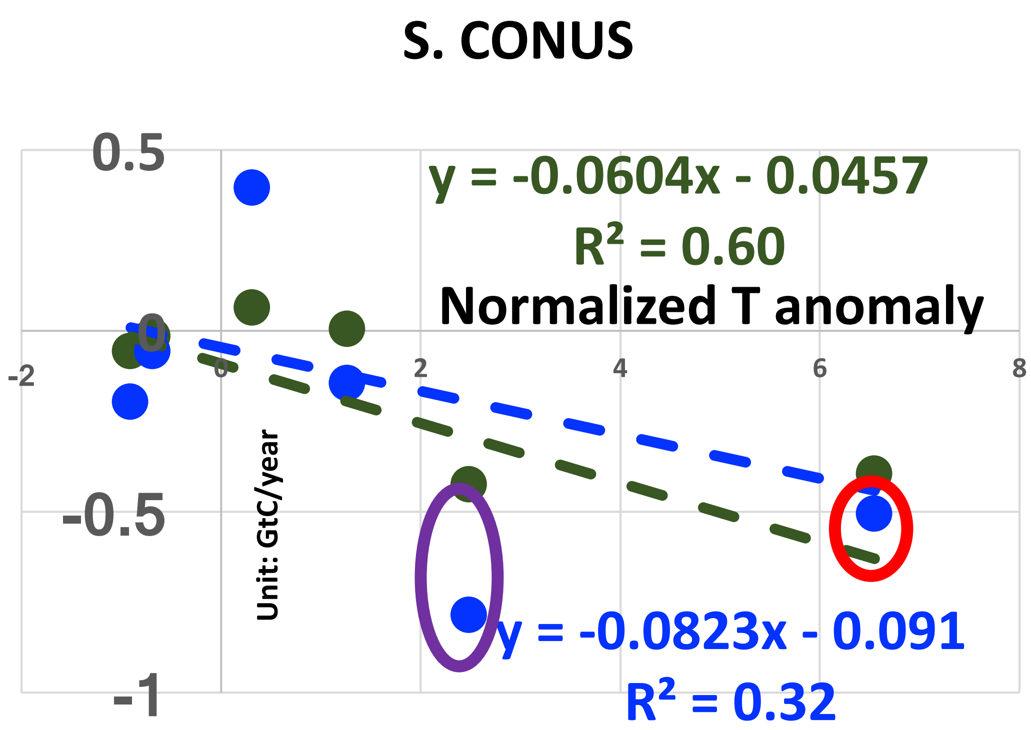
- Seasonal compensating effect is consistent with Wolf et al. (2016)

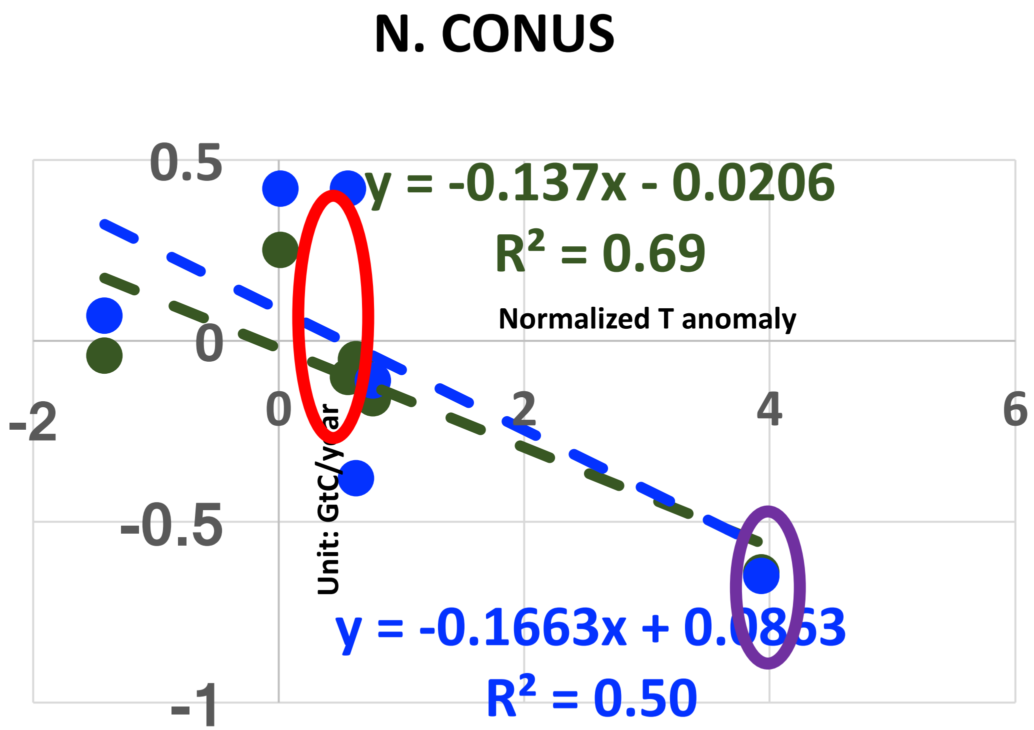
The relationship between T anomalies and NBP/GPP interannual variability in summer

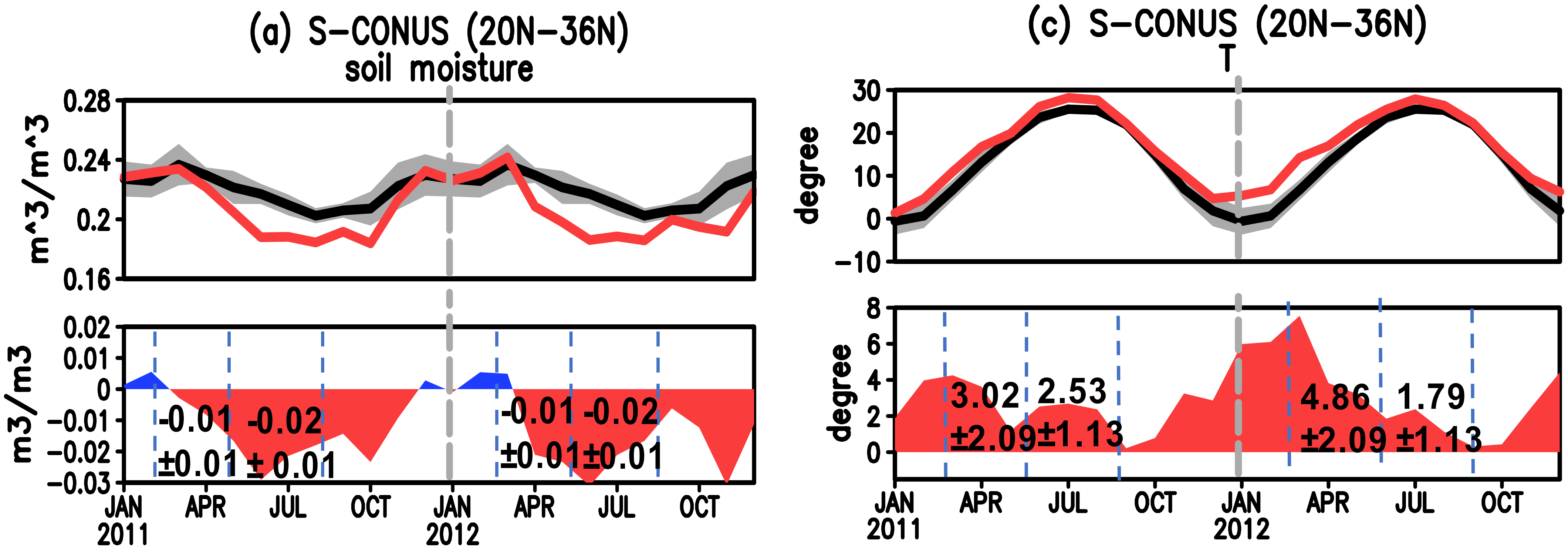


- T anomalies explain more than 60% of summer GPP interannual variability in both S. CONUS and N. CONUS,
- The relationship between T anomaly and NBP anomaly is not as good.

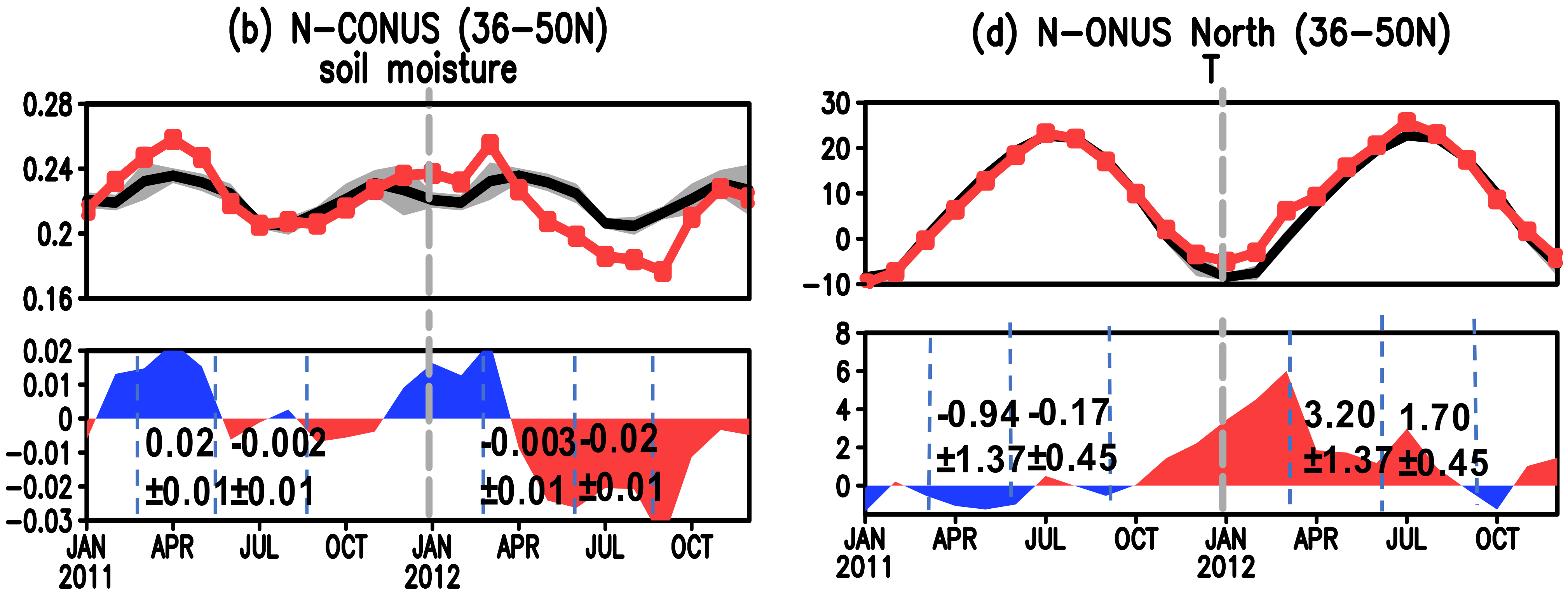
The relationship between soil moisture anomalies and NBP/GPP interannual variability in summer





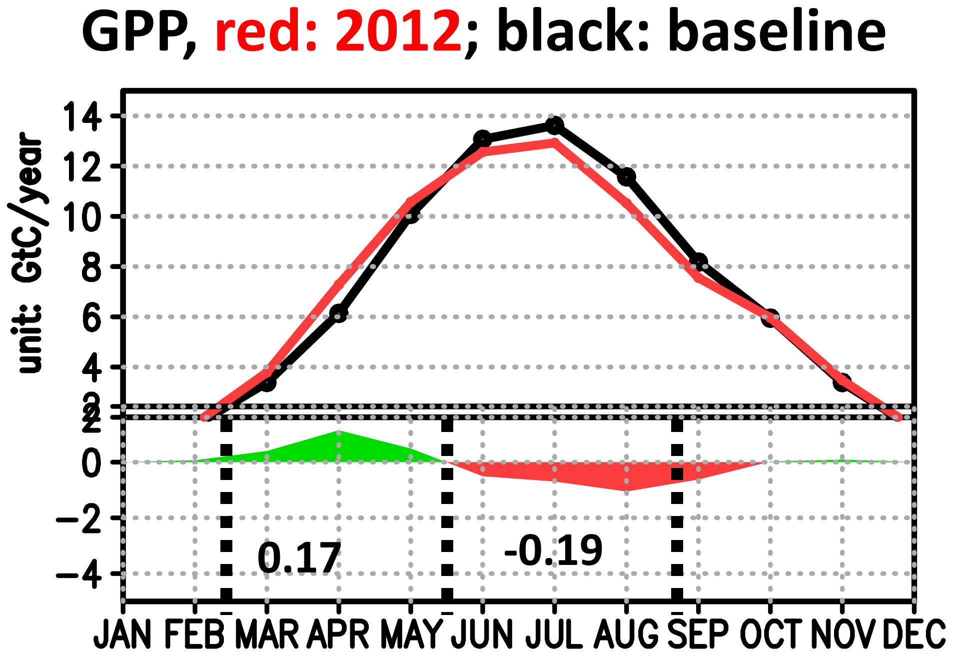


(a) S-CONUS (20N-36N)
soil moisture
m^3/m^3
0.28
0.24
0.2
0.16
m3/m3
0.02
0.01
0
-0.01
-0.02
-0.03
-0.01
±0.01
-0.02
± 0.01
-0.01
±0.01
-0.02
±0.01
JAN 2011
APR
JUL
OCT
JAN 2012
APR
JUL
OCT
(c) S-CONUS (20N-36N)
T
degree
30
20
10
0
-10
degree
8
6
4
2
0
3.02
±2.09
2.53
±1.13
4.86
±2.09
1.79
±1.13
JAN 2011
APR
JUL
OCT
JAN 2012
APR
JUL
OCT

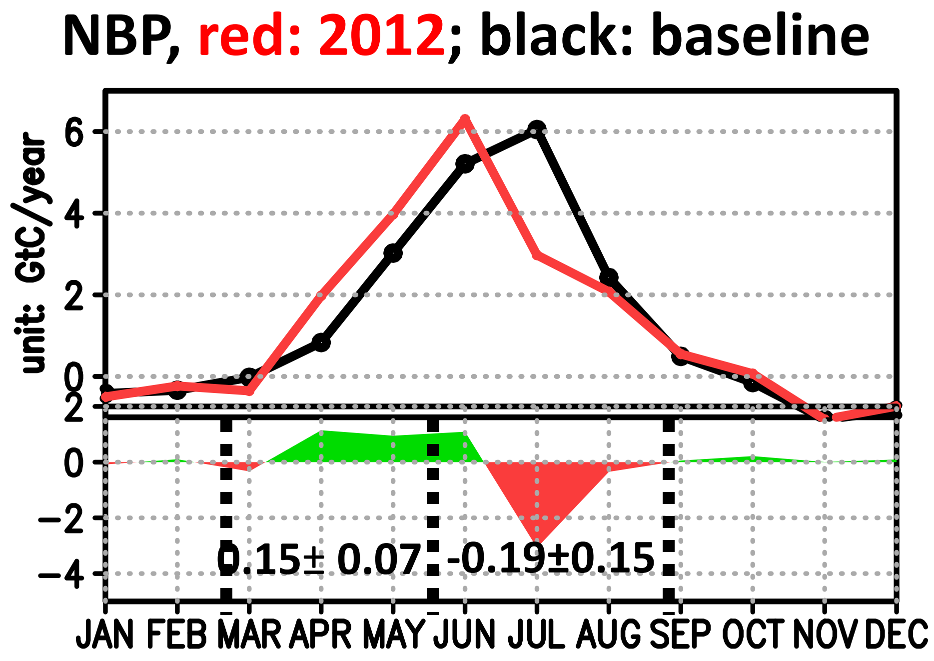


(b) N-CONUS (36-50N)
soil moisture
0.28
0.24
0.2
0.16
0.02
0.01
0
-0.01
-0.02
-0.03
0.02
±0.01
-0.002
±0.01
-0.003
±0.01
-0.02
±0.01
JAN 2011
APR
JUL
OCT
JAN 2012
APR
JUL
OCT
(d) N-ONUS North (36-50N)
T
30
20
10
0
-10
8
6
4
2
0
-0.94
±1.37
-0.17
±0.45
3.20
±1.37
1.70
±0.45
JAN 2011
APR
JUL
OCT
JAN 2012
APR
JUL
OCT

1.



GPP, red: 2012; black: baseline
unit: GtC/year
14
12
10
8
6
4
2
0
−2
−4
0.17
-0.19
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC



NBP, red: 2012; black: baseline
unit: GtC/year
6
4
2
0
−2
−4
0.15± 0.07
-0.19±0.15
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC

- 1.