Using OCO-2 column XCO_2 retrievals to rapidly detect and estimate extreme terrestrial biosphere carbon anomalies

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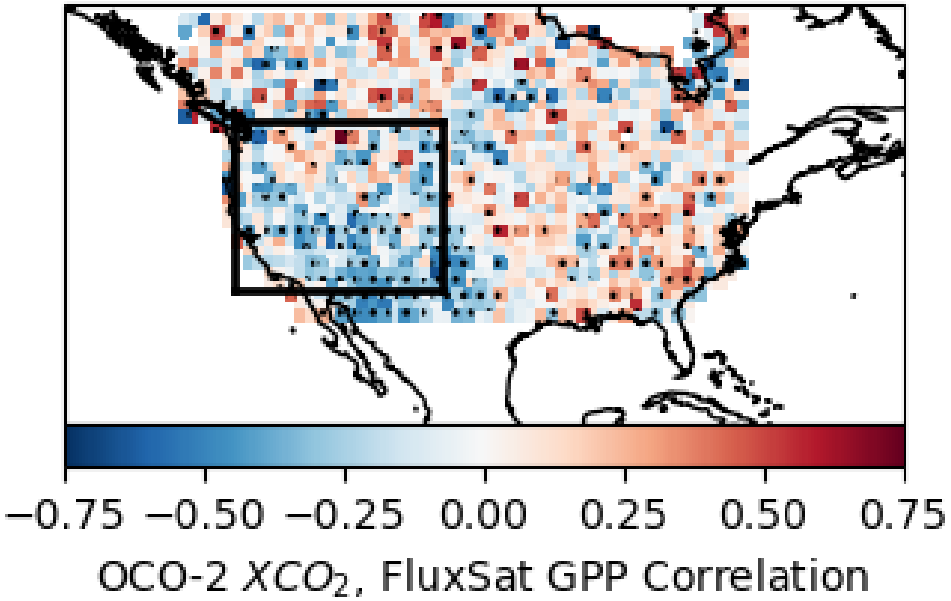
Background

- Greenhouse gas satellites (like OCO-2) were designed to provide a constraint on seasonal to interannual carbon cycle variability

- Many recent investigations show these satellites' sensitivity to smaller spatiotemporal scale surface fluxes

- Can satellite XCO_2 be used to directly monitor monthly surface CO_2 flux anomalies from the terrestrial biosphere?
  - How about estimate them?
  - Under what conditions?



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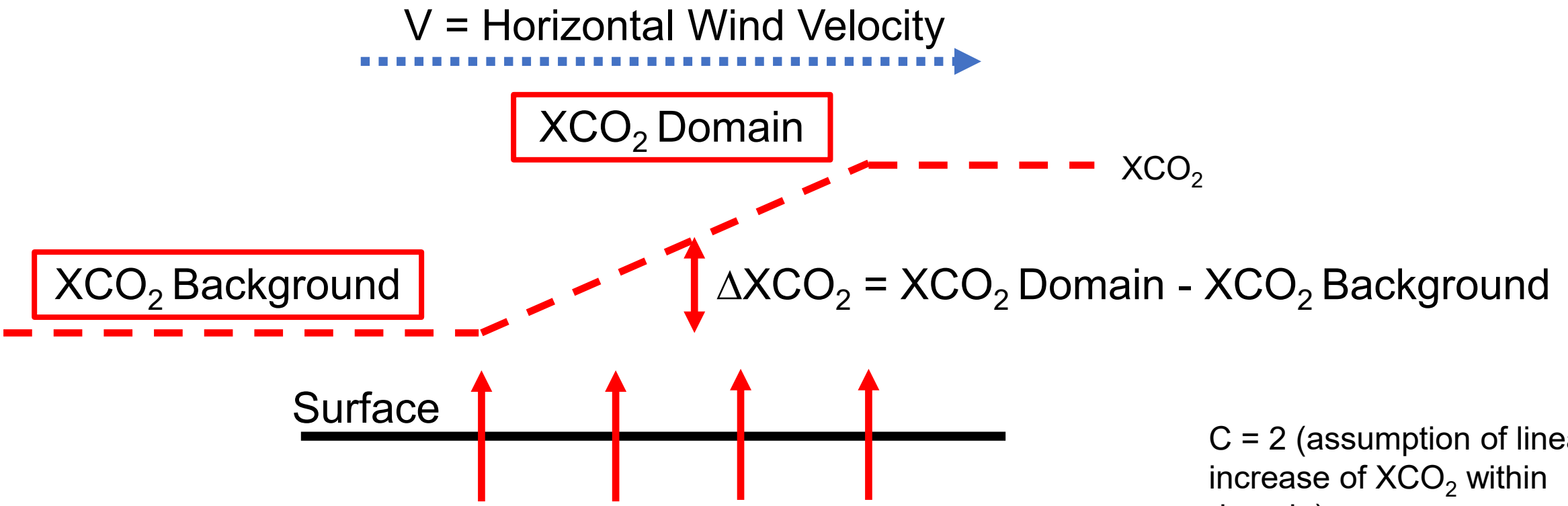
Simple Mass Balance Method: “Pixel Source Mass Balance”

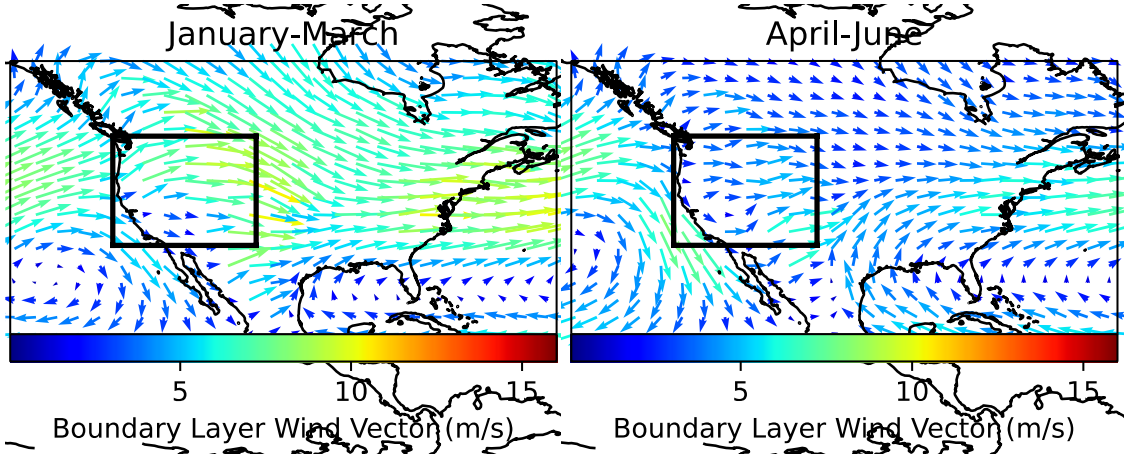


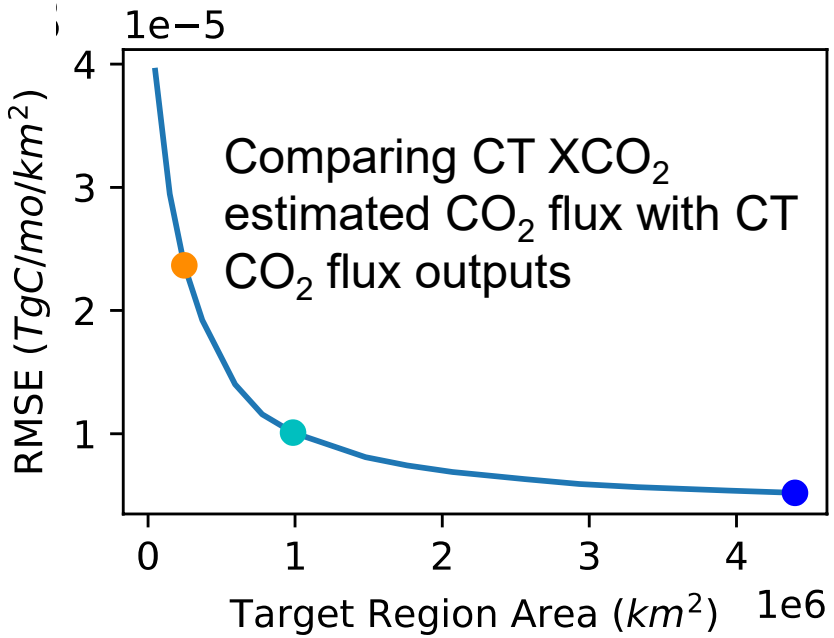
Pandey et al. (2021); Buchwitz et al. (2017)

$$Q = (\Delta XCO_2)(V)(L)(C)\left(M_{exp}\right)(M)$$

C = 2 (assumption of linear increase of XCO_2 within domain)
M = Conversion from carbon mixing ratio to total column mass
M_{exp} = Ratio of atmospheric to surface pressure

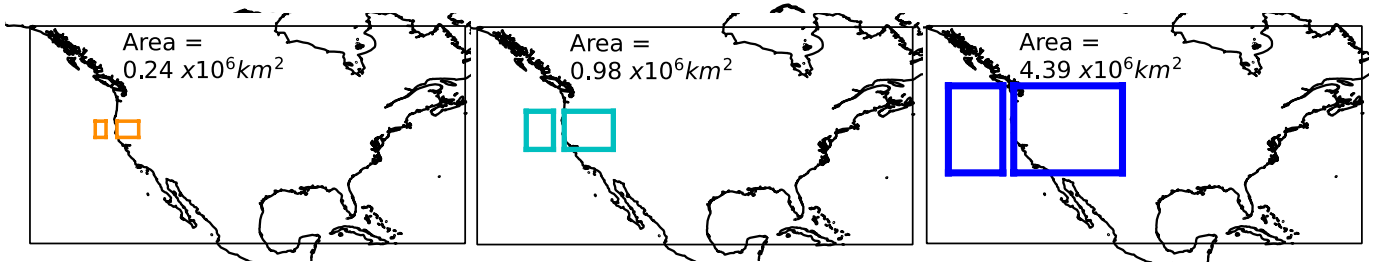
CarbonTracker Reanalysis Tests: Wind and Areal Conditions





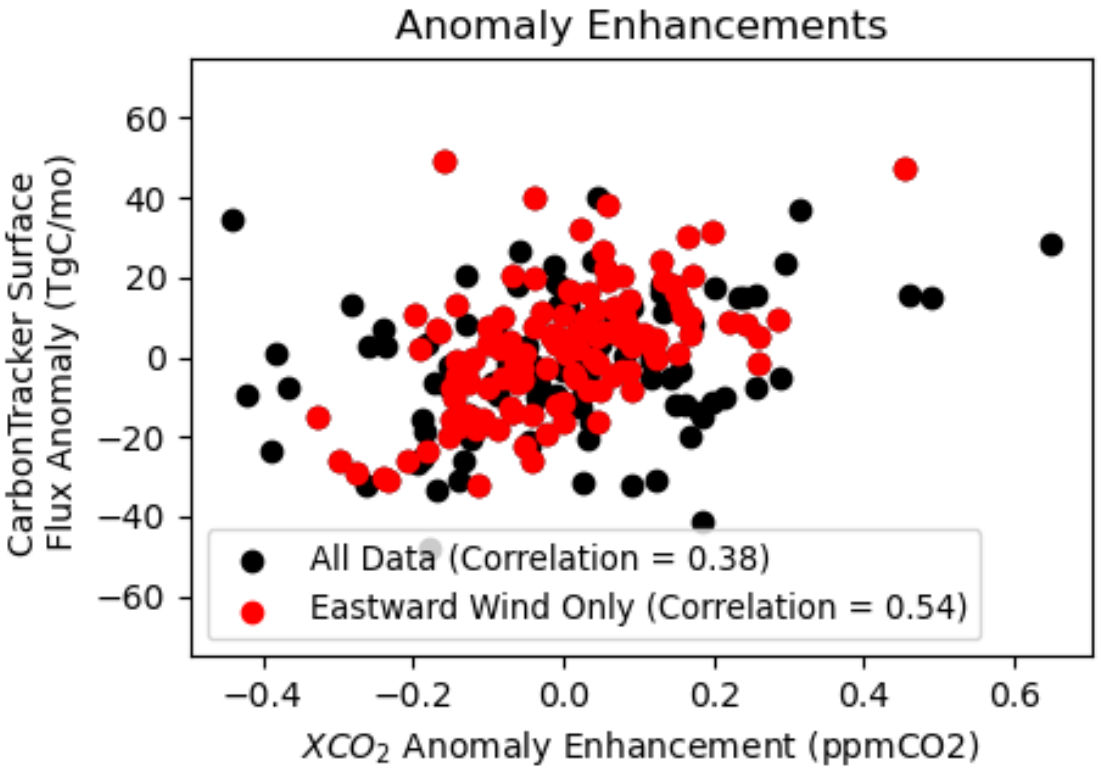
Winds:

- Consistently originate from same background region
- Flow consistently through region

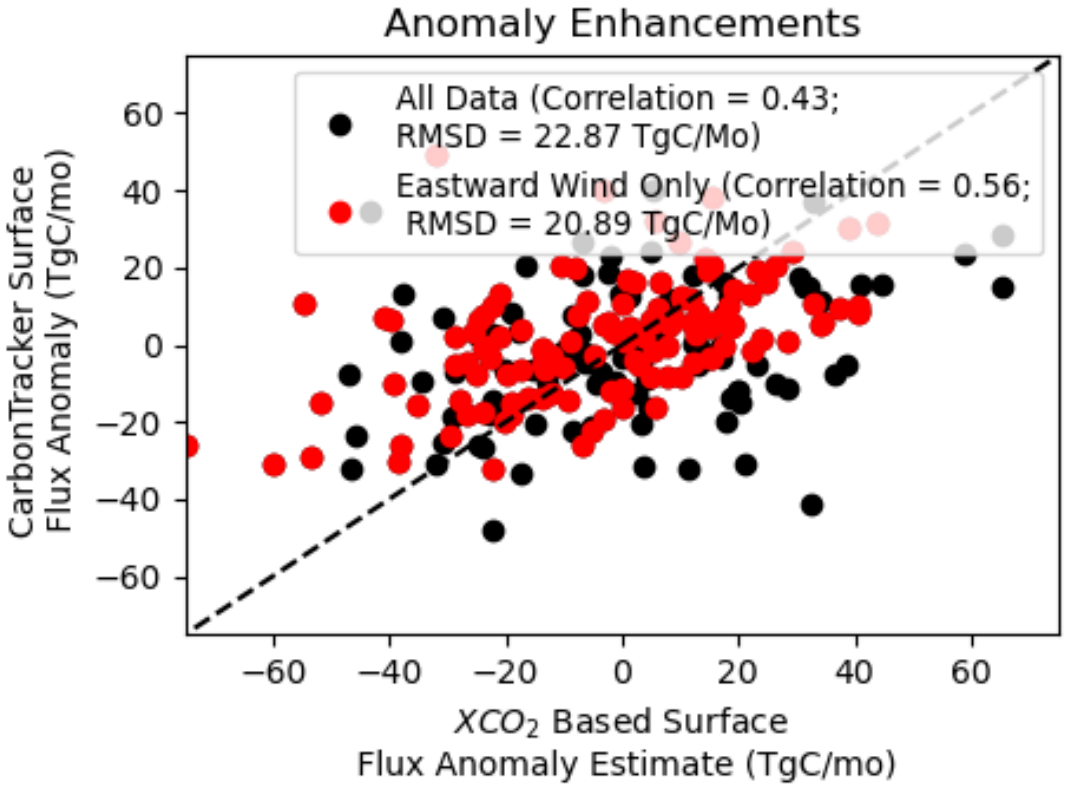


Larger domain area reduces effects of turbulent mixing at monthly scales

CarbonTracker Reanalysis Tests: Wind and Areal Conditions



XCO_2 enhancement anomalies correlate with surface flux anomalies

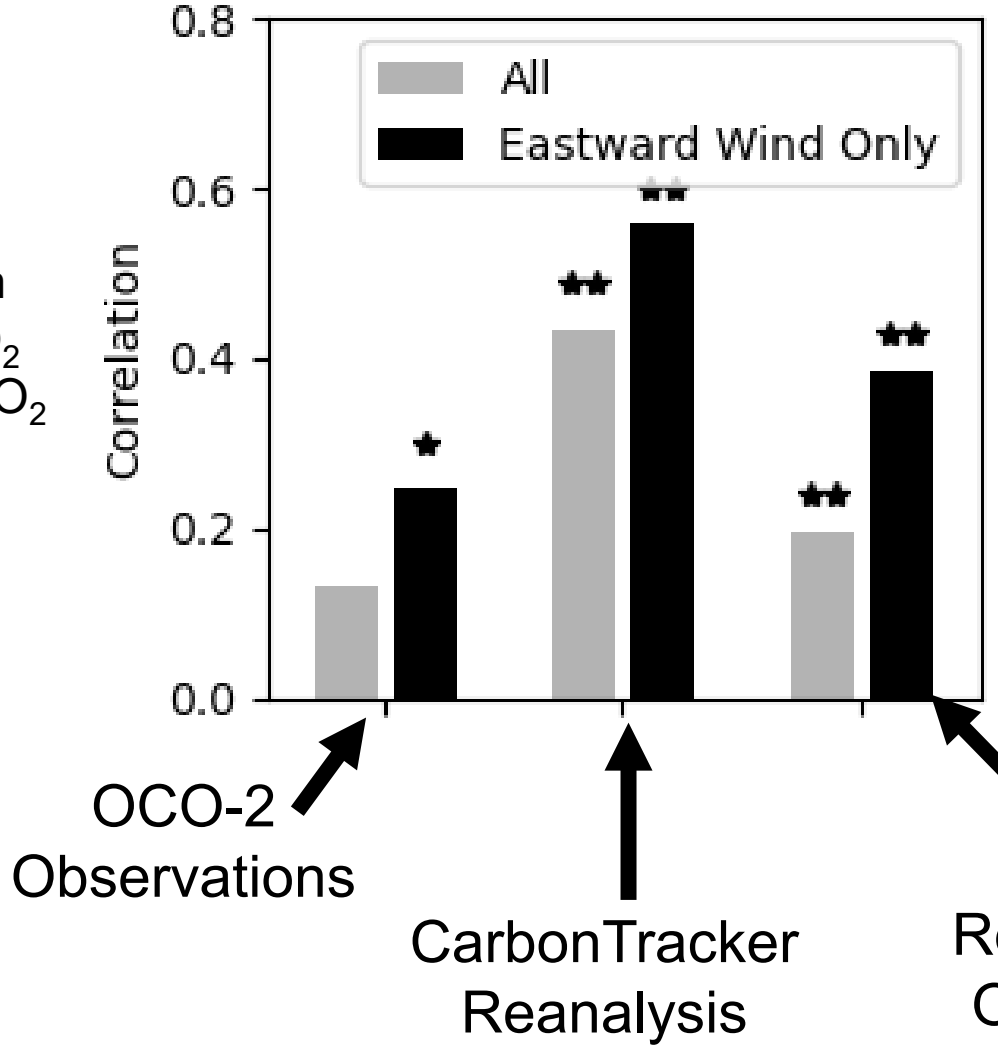


Mass balance method with XCO_2 can provide first order estimate of surface flux anomalies

Eastward = months with winds <60° angle from east

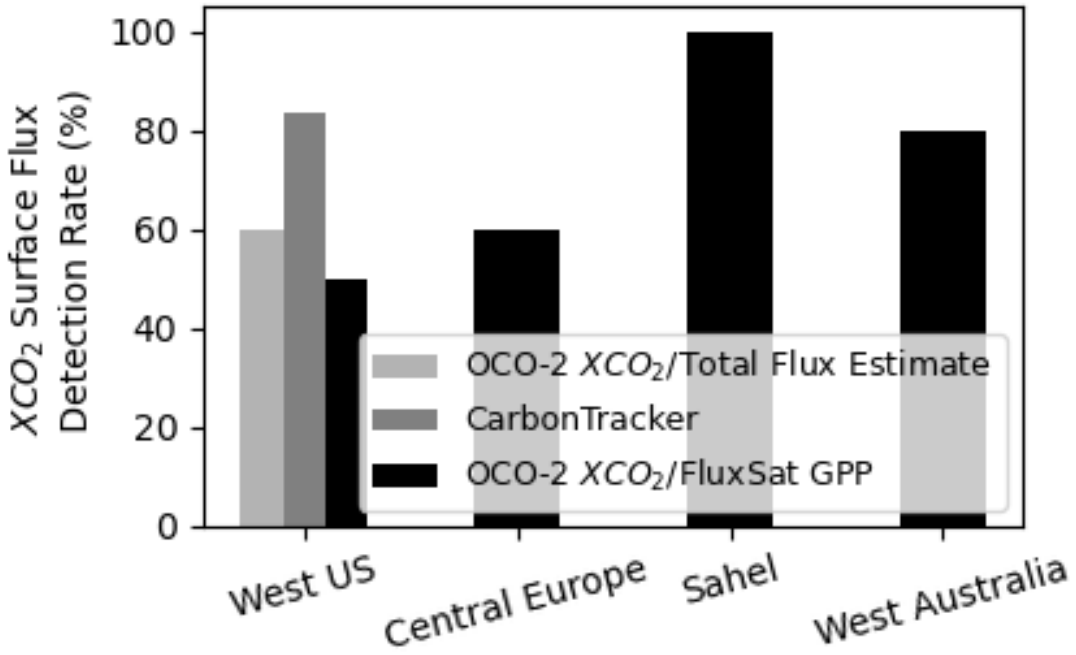
OCO-2 Observations: observation error can hinder surface monthly flux estimation

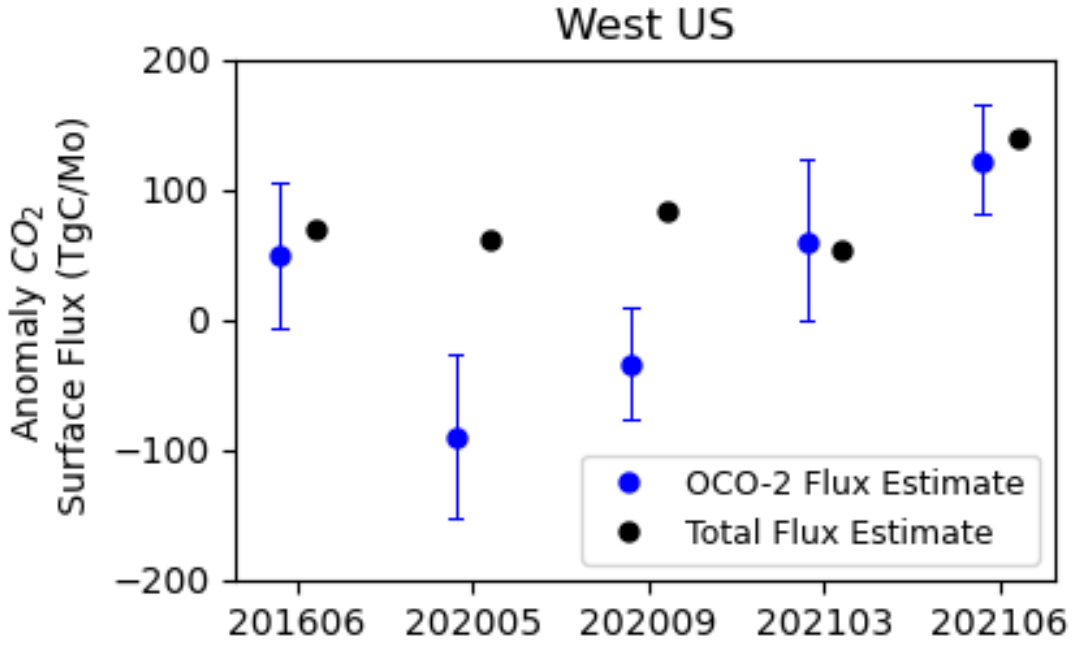
Correlation between XCO_2 estimated CO_2 flux and modeled CO_2 flux



Observation error is a large contribution to the reduction in ability of OCO-2 to monitor each month's surface flux anomaly

OCO-2 can detect and estimate more extreme surface carbon flux anomalies





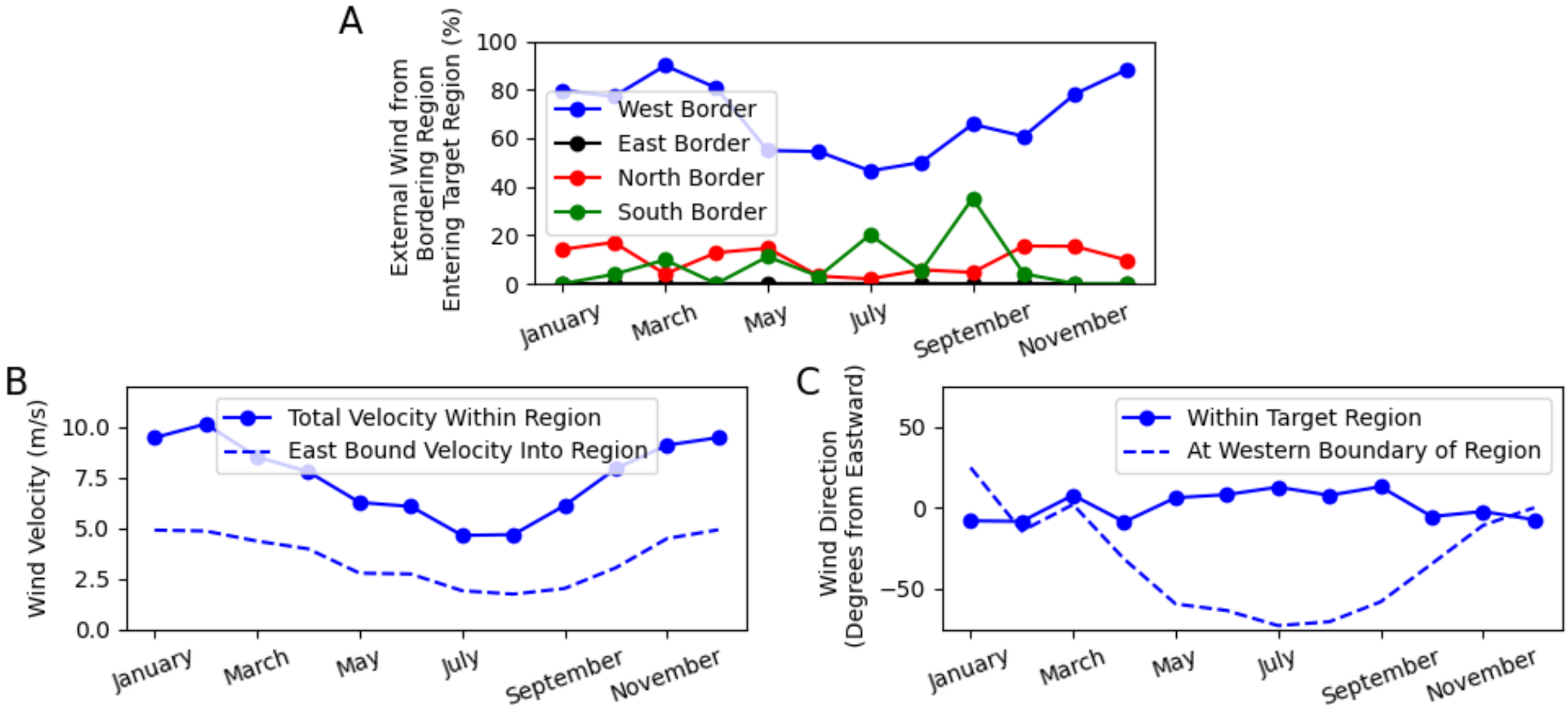
OCO-2 XCO_2 anomalies can frequently detect the largest surface fluxes

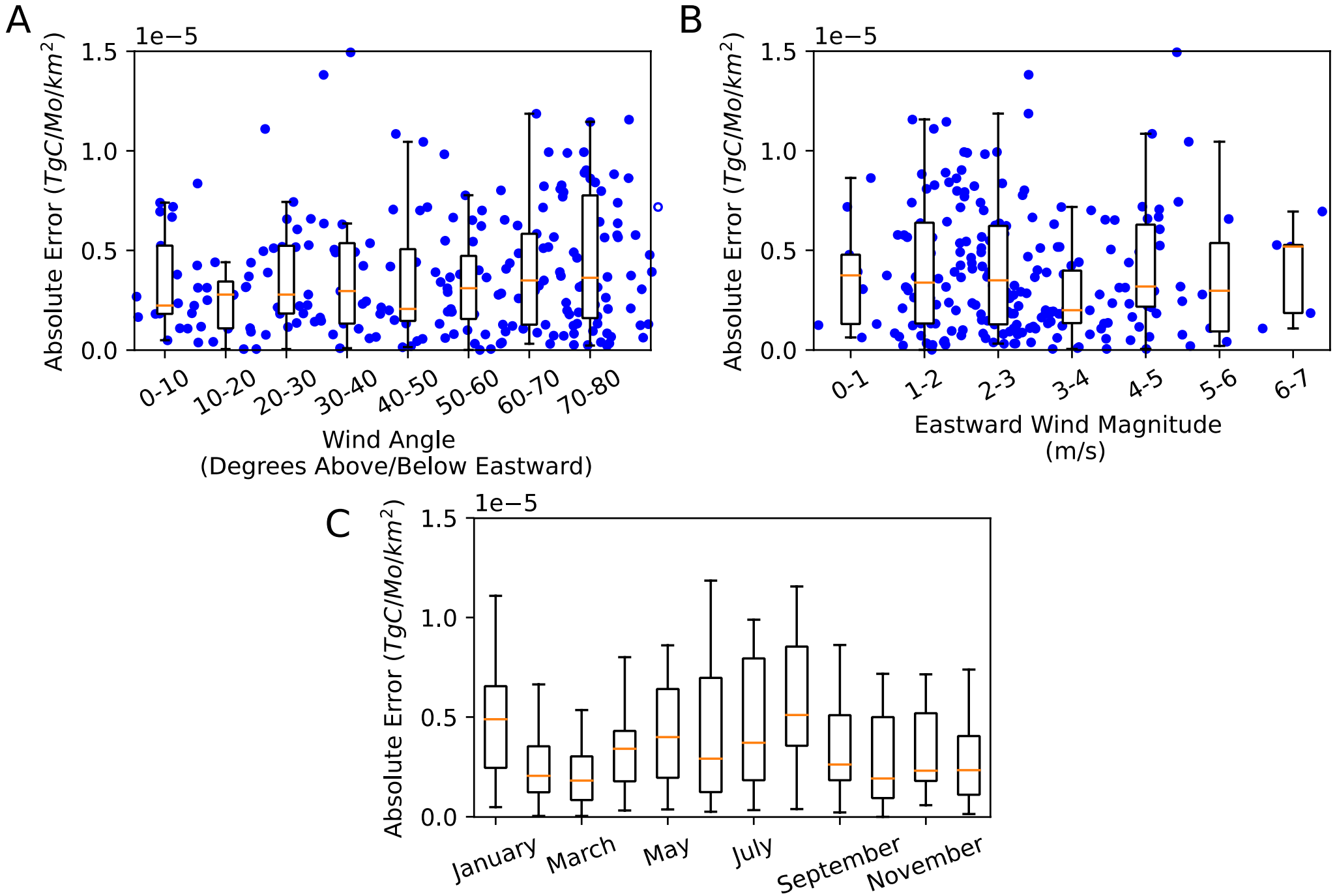
XCO_2-based flux estimates provide a first order estimate of large surface fluxes

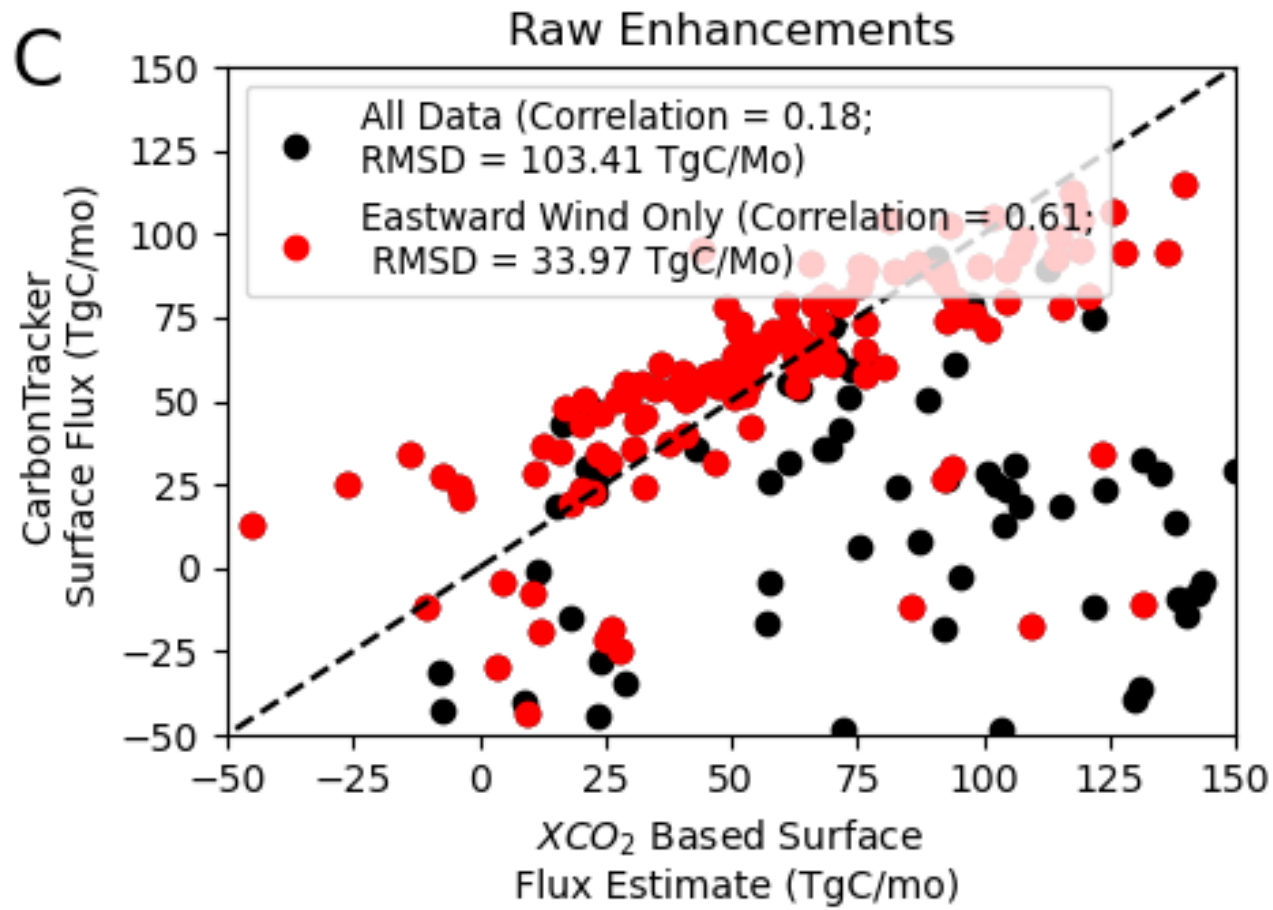
Summary

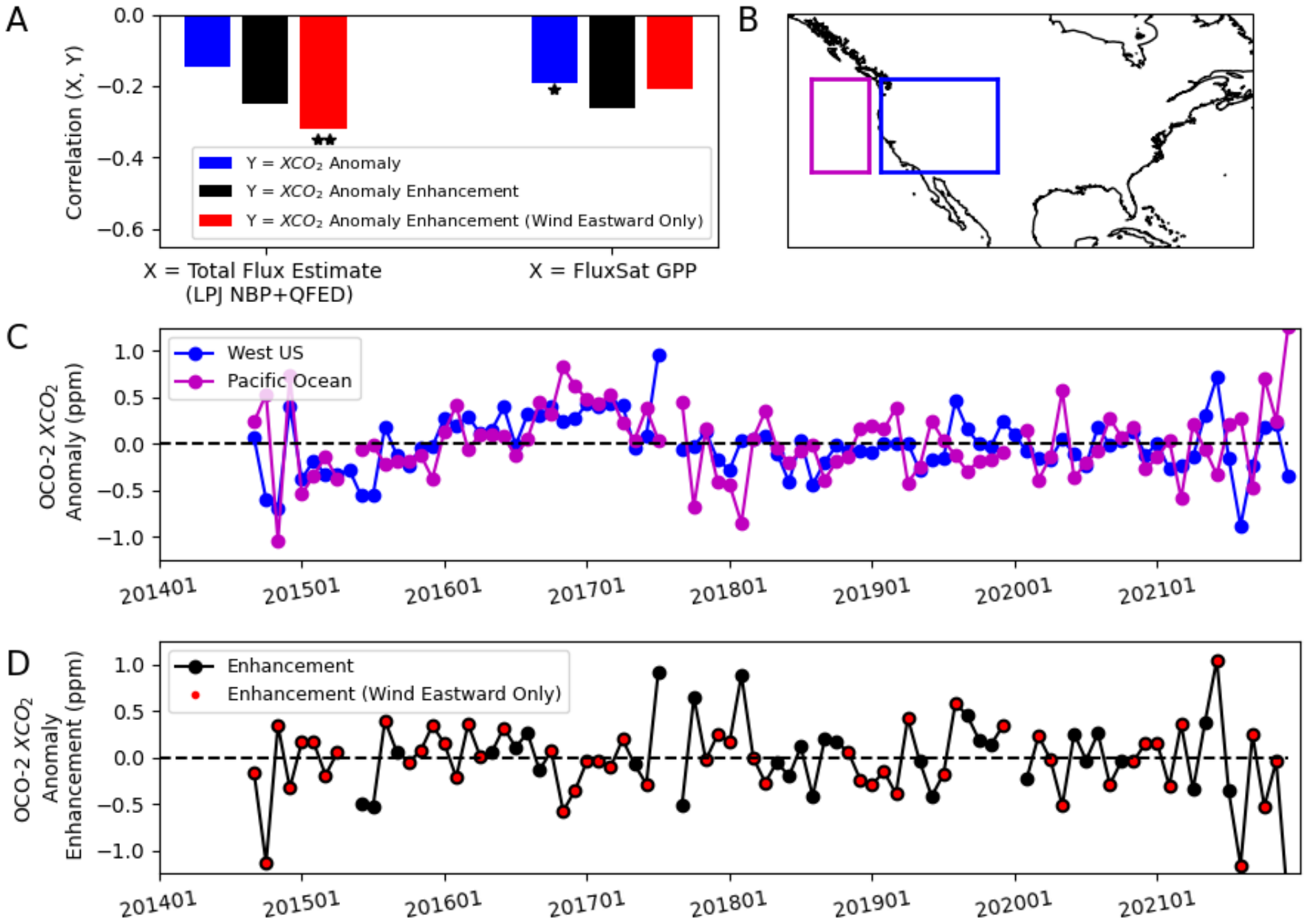
- Pixel source mass balance methods can viably be used to estimate surface fluxes from XCO_2
  - Observation error can hinder this approach
- Large carbon anomalies above instrument error can be detected and estimated with OCO-2
- Need large spatial domains and tractable advection conditions

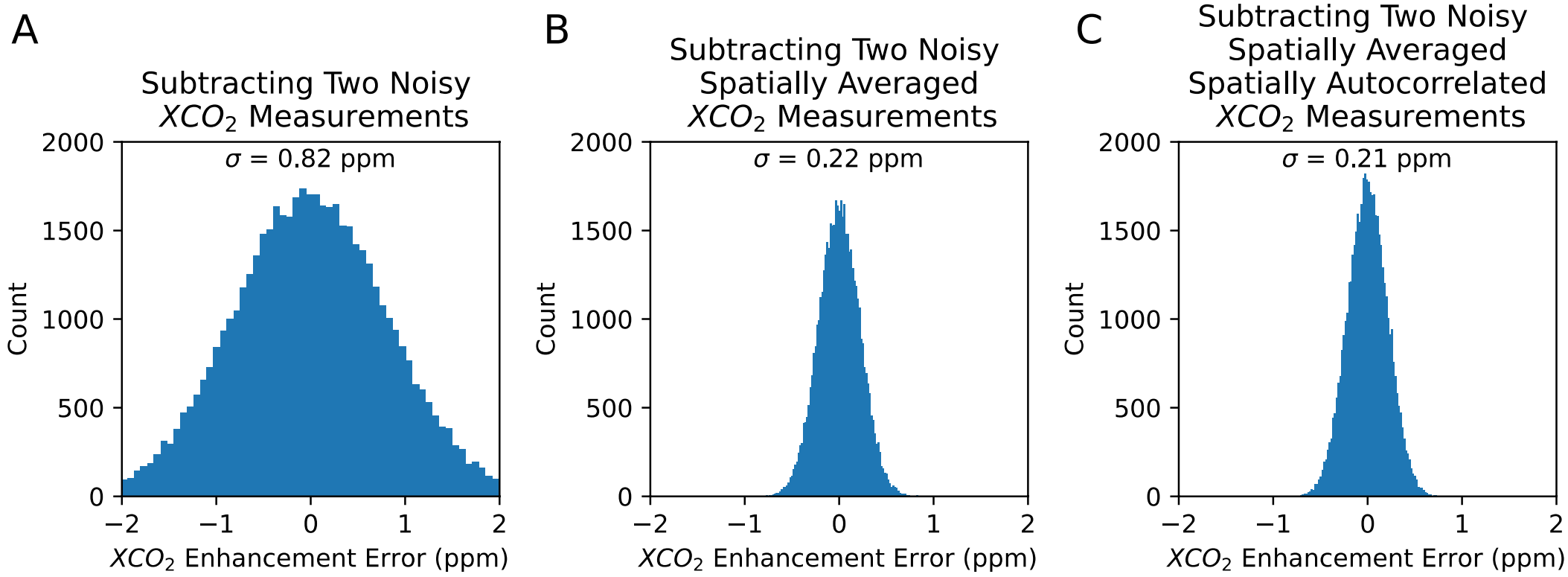
Supplemental Slides


A
External Wind from Bordering Region Entering Target Region (%)
100
80
60
40
20
0
West Border
East Border
North Border
South Border
January
March
May
July
September
November
B
Wind Velocity (m/s)
10.0
7.5
5.0
2.5
0.0
Total Velocity Within Region
East Bound Velocity Into Region
January
March
May
July
September
November
C
Wind Direction (Degrees from Eastward)
50
0
−50
Within Target Region
At Western Boundary of Region
January
March
May
July
September
November


A
1e−5
1.5
1.0
0.5
0.0
Absolute Error (TgC/Mo/km²)
0-10
10-20
20-30
30-40
40-50
50-60
60-70
70-80
Wind Angle
(Degrees Above/Below Eastward)
B
1e−5
1.5
1.0
0.5
0.0
Absolute Error (TgC/Mo/km²)
0-1
1-2
2-3
3-4
4-5
5-6
6-7
Eastward Wind Magnitude
(m/s)
C
1e−5
1.5
1.0
0.5
0.0
Absolute Error (TgC/Mo/km²)
January
March
May
July
September
November


C
Raw Enhancements
All Data (Correlation = 0.18;
RMSD = 103.41 TgC/Mo)
Eastward Wind Only (Correlation = 0.61;
RMSD = 33.97 TgC/Mo)
CarbonTracker
Surface Flux (TgC/mo)
150
125
100
75
50
25
0
−25
−50
−50
−25
0
25
50
75
100
125
150
XCO_2 Based Surface
Flux Estimate (TgC/mo)


A
0.0
−0.2
−0.4
−0.6
Correlation (X, Y)
Y = XCO_2 Anomaly
Y = XCO_2 Anomaly Enhancement
Y = XCO_2 Anomaly Enhancement (Wind Eastward Only)
X = Total Flux Estimate
(LPJ NBP+QFED)
X = FluxSat GPP
B
C
1.0
0.5
0.0
−0.5
−1.0
OCO-2 XCO_2
Anomaly (ppm)
West US
Pacific Ocean
201401
201501
201601
201701
201801
201901
202001
202101
D
OCO-2 XCO_2
Anomaly
Enhancement (ppm)
Enhancement
Enhancement (Wind Eastward Only)


A
Subtracting Two Noisy
XCO_2 Measurements
σ = 0.82 ppm
Count
2000
1500
1000
500
0
−2
−1
0
1
2
XCO_2 Enhancement Error (ppm)
B
Subtracting Two Noisy
Spatially Averaged
XCO_2 Measurements
σ = 0.22 ppm
Count
2000
1500
1000
500
0
−2
−1
0
1
2
XCO_2 Enhancement Error (ppm)
C
Subtracting Two Noisy
Spatially Averaged
Spatially Autocorrelated
XCO_2 Measurements
σ = 0.21 ppm
Count
2000
1500
1000
500
0
−2
−1
0
1
2
XCO_2 Enhancement Error (ppm)