OUTSIZED CONTRIBUTION OF THE SEMI-ARID ECOSYSTEMS TO INTERANNUAL VARIABILITY IN NORTH AMERICAN ECOSYSTEMS

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BACKGROUND

- Over the past 60 years, flask and in situ CO_2 measurements at surface sites have revealed large scale features of the global carbon cycle.

- Driven by increasing observational density, much of the current top-down research emphasizes estimating surface-atmosphere CO_2 fluxes on smaller spatial and temporal scales.
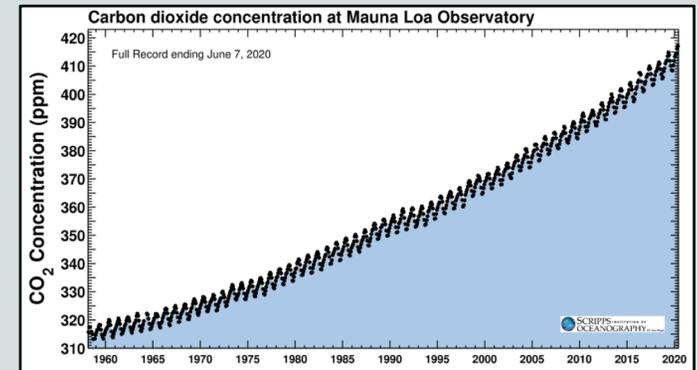
Figure 1. CO_2 measured at Mauna Loa, Hawaii (Keeling et al., 2001).
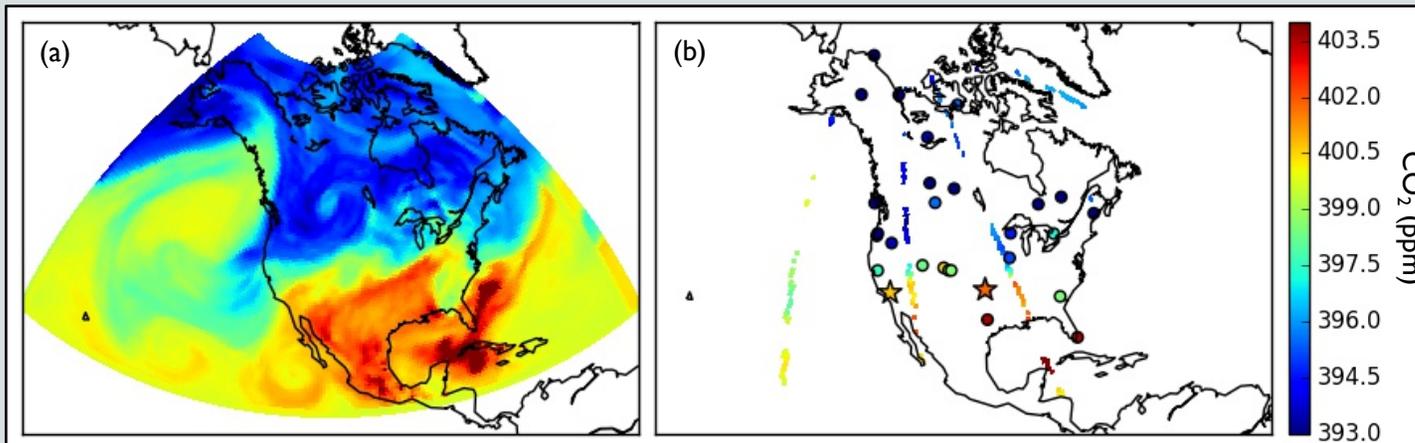
Figure 2. (a) Simulated XCO2 and (b) measurements from flask and in situ sites (circles), TCCON (stars) and OCO-2 (tracks) over North America on 17 July 2015.

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COMBINING SURFACE AND SPACE-BASED MEASUREMENTS

- Assimilating both surface- and space-based CO_2 measurements in a flux inversion fills in observational gaps.

- We performed a set of six-year flux inversions (2010-2015) assimilating CO_2 measurements from GLOBALVIEW+, TCCON, and ACOS b7.3 GOSAT (nadir only). Performed ensemble of inversions three times applying different prior NEE constraints (with no prior interannual variability).

- Posterior CO_2 fields were extensively evaluated against aircraft based CO_2 measurements and gave data-model differences similar to inversions assimilating surface-only or GOSAT-only observations (Byrne et al., 2019, *ESSOAr,* 2019; email me for latest version).
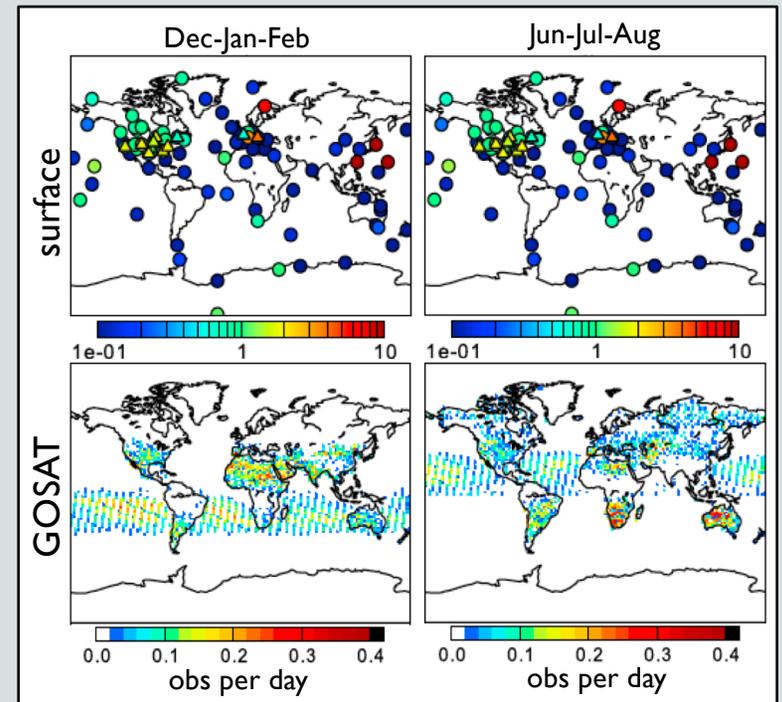
Figure 3. Number of measurements per day for surface-based (Obspack PROTOTYPE) and space-based (GOSAT) observing systems (Byrne et al., *JGR-A,* 2017).

INTERANNUAL VARIABILITY OVER NORTH AMERICA

- From the six-year posterior NEE fluxes we can examine the anomalies about a mean year:

$$\Delta NEE_{year} = NEE_{year} - \frac{1}{N}\sum_{i=0}^{N} NEE_i$$

- Inversions assimilating different combinations of datasets show differences in interannual variability (IAV).
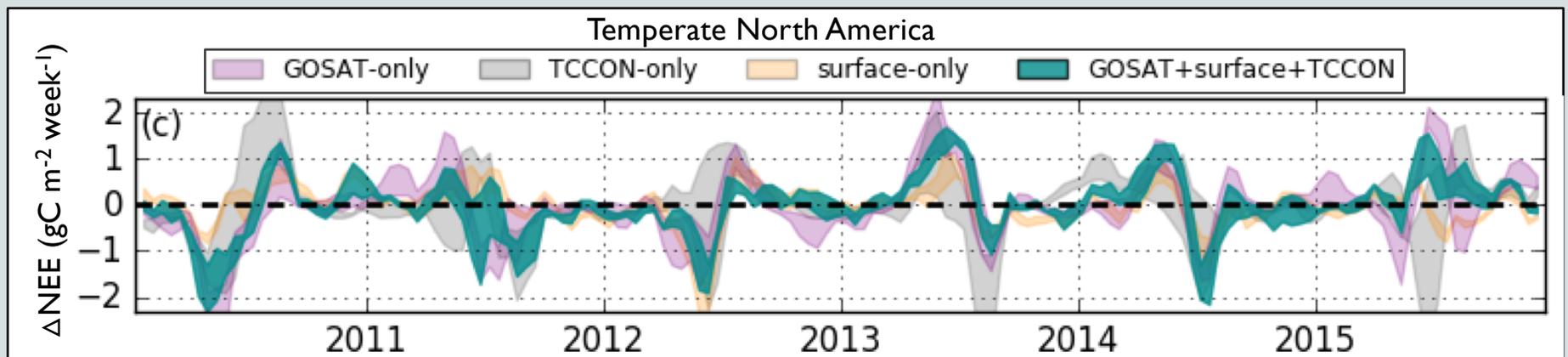
Figure 4. Two-week NEE anomalies over temperate North America for posterior NEE fluxes from inversions combining multiple datasets (green) and from inversions assimilating single datasets (Byrne et al., *ESSOAr,* 2019; email me for latest version).

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- The combined inversion show seasonal compensation features.
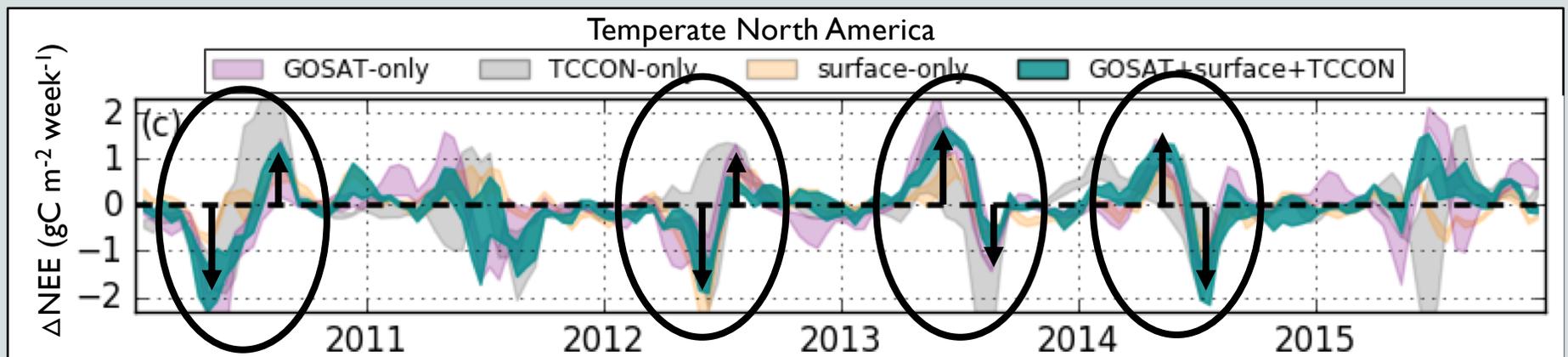
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SEASONAL COMPENSATION OBSERVED IN △GPP

- Studies have found seasonal cycle compensation in △GPP based on NDVI, SIF, flux tower, and phenology measurements.

- Does seasonal compensation in △NEE correspond to seasonal compensation in △GPP?

Earlier springs decrease peak summer productivity in North American boreal forests

Wolfgang Buermann[1], Parida R Bikash[2], Martin Jung[3], Donald H Burn[4] and Markus Reichstein[3]

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Cropland Carbon Uptake Delayed and Reduced by 2019 Midwest Floods

Yi Yin ✉, Brendan Byrne ✉, Junjie Liu, Paul O. Wennberg, Kenneth J. Davis, Troy Magney, Philipp Köhler, Liyin He, Rupesh Jeyaram, Vincent Humphrey, Tobias Gerken, Sha Feng, Joshua P. Digangi, Christian Frankenberg ... See fewer authors ∧

The timing of autumn senescence is affected by the timing of spring phenology: implications for predictive models

TREVOR F. KEENAN[1] and ANDREW D. RICHARDSON[2]

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Widespread seasonal compensation effects of spring warming on northern plant productivity

Wolfgang Buermann[1,2]*, Matthias Forkel[3], Michael O'Sullivan[1], Stephen Sitch[4], Pierre Friedlingstein[5], Vanessa Haverd[6], Atul K. Jain[7], Etsushi Kato[8], Markus Kautz[9], Sebastian Lienert[10,11], Danica Lombardozzi[12], Julia E. M. S. Nabel[13], Hanqin Tian[14,15], Andrew J. Wiltshire[16], Dan Zhu[17], William K. Smith[18] & Andrew D. Richardson[19,20]

Satellite observations reveal seasonal redistribution of northern ecosystem productivity in response to interannual climate variability

Zachary Butterfield [a] ✉, Wolfgang Buermann [b, c], Gretchen Keppel-Aleks [a]

SEASONAL COMPENSATION AND AMPLIFICATION

- Examine six-year IAV in GOSAT+surface+TCCON posterior NEE (2010-2015) over North America.

- Examine 17-year of IAV in FluxSat GPP (2001-2017). FluxSat is a GPP product primarily using MODIS NBAR measurements and is calibrated using Fluxnet and SIF measurements (Joiner et al., 2018).

- Examine the relative magnitudes of amplification and compensation in IAV.

$$\Delta NEE_{comp} = \Delta NEE_{Jul-Aug-Sep} - \Delta NEE_{Apr-May-Jun}$$
$$\Delta NEE_{amp} = \Delta NEE_{Jul-Aug-Sep} + \Delta NEE_{Apr-May-Jun}$$

$$NEE_{RATIO} = \frac{\sum_{y=2010}^{2015} |\Delta NEE_{comp}|}{\sum_{y=2010}^{2015} |\Delta NEE_{amp}|}$$
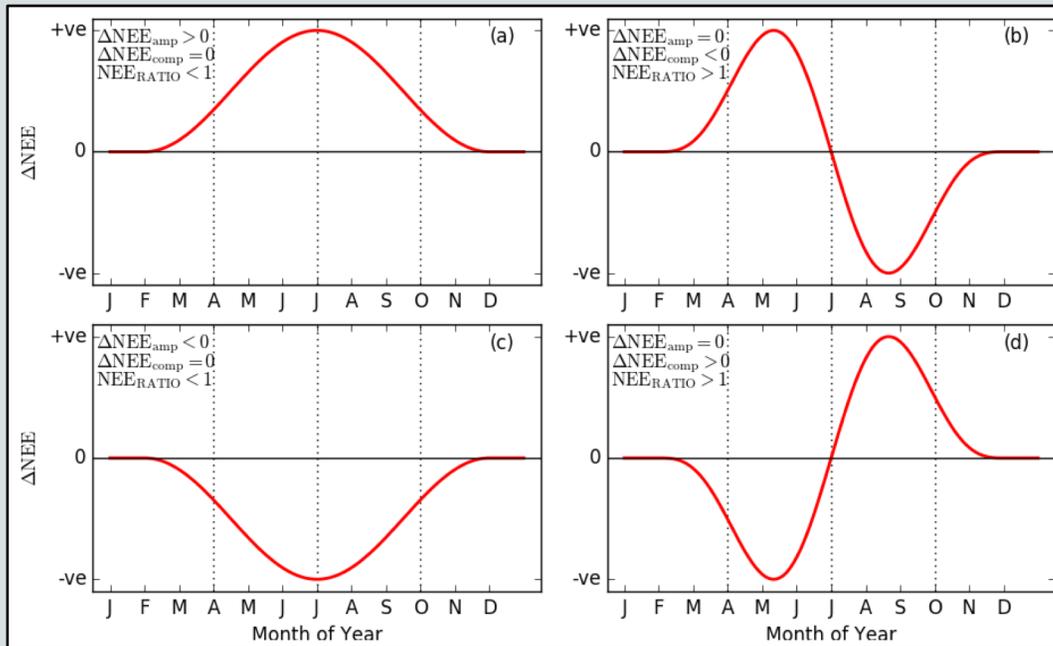
Figure 5. Illustration of amplification and compensation for NEE. (a) Positive amplification with no compensation, (b) no amplification with negative compensation, (c) negative amplification with no compensation, and (d) no amplification with positive amplification (Byrne et al., ESSOAr, 2020).

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SEASONAL COMPENSATION OBSERVED IN GPP

- We do not expect the flux inversions to capture IAV on $4^o \times 5^o$ grid. This provides a first look at the general spatial structures in $\triangle$GPP and $\triangle$NEE.

- In general, amplification dominates in West/Southwest and compensation dominates in East/Northeast.

$$NEE_{RATIO} = \frac{\sum_{y=2010}^{2015} |\Delta NEE_{comp}|}{\sum_{y=2010}^{2015} |\Delta NEE_{amp}|}$$
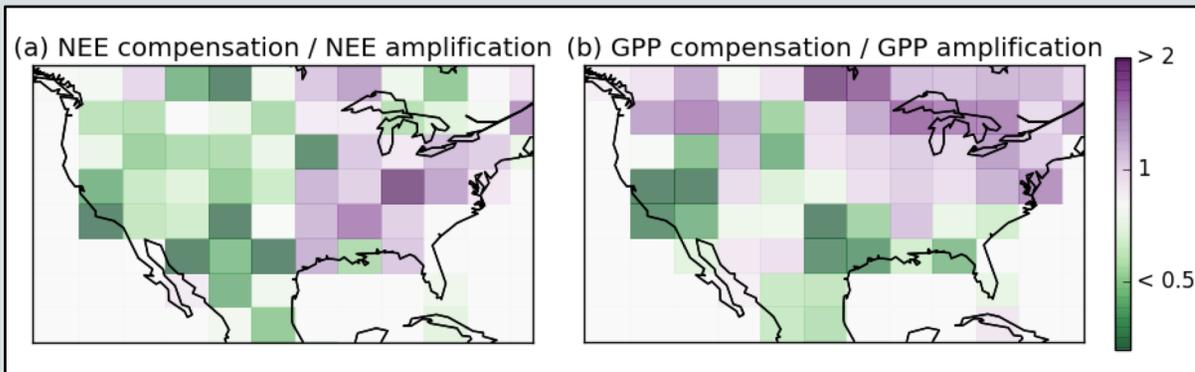
Figure 6. Relative magnitudes of seasonal compensation and amplification. (a) NEE$_{RATIO}$ over 2010–2015 and (b) GPP$_{RATIO}$ over 2001–2017 at $4^o \times 5^o$ spatial resolution (Byrne et al., ESSOAr, 2020).
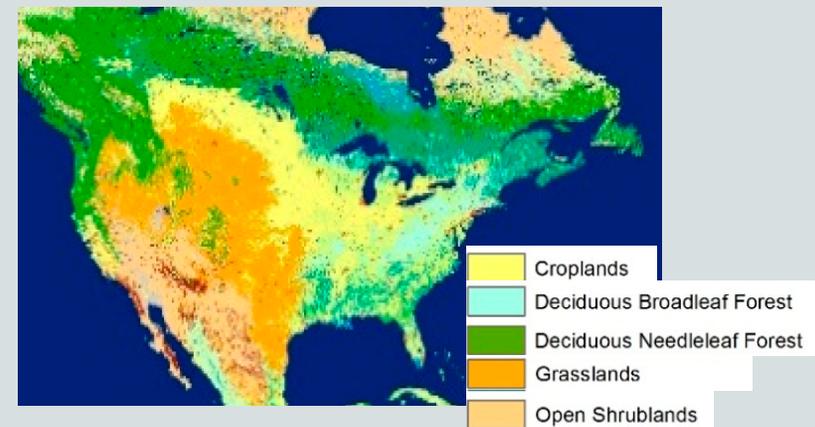
Figure 7. MODIS land cover types across North America

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DOMINANT MODES OF IAV

- Singular value decomposition (SVD) of month-by-year array of anomalies show the dominant modes of variability between years.

- SVD analysis show that amplification dominates in the west and compensation dominates in the east for both △GPP and △NEE.
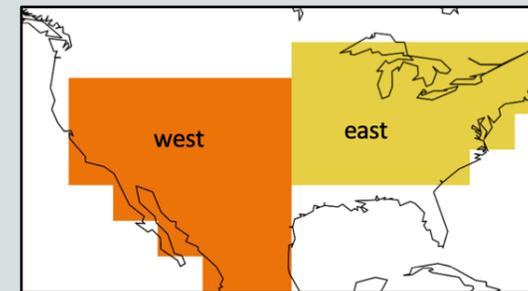
Figure 9. The spatial extent of western (orange) and eastern (yellow) regions of North America.

Figure 8. First and second singular vectors resulting from the decomposition of △GPP over 2001–2017 for the (i) western and (ii) eastern regions of North America, and △NEE over 2010–2015 for the (iii) western and (iv) eastern regions of North America (Byrne et al., ESSOAr, 2020).

IAV IN CARBON FLUXES AND CLIMATE

(a) Western North America

(b) Eastern North America
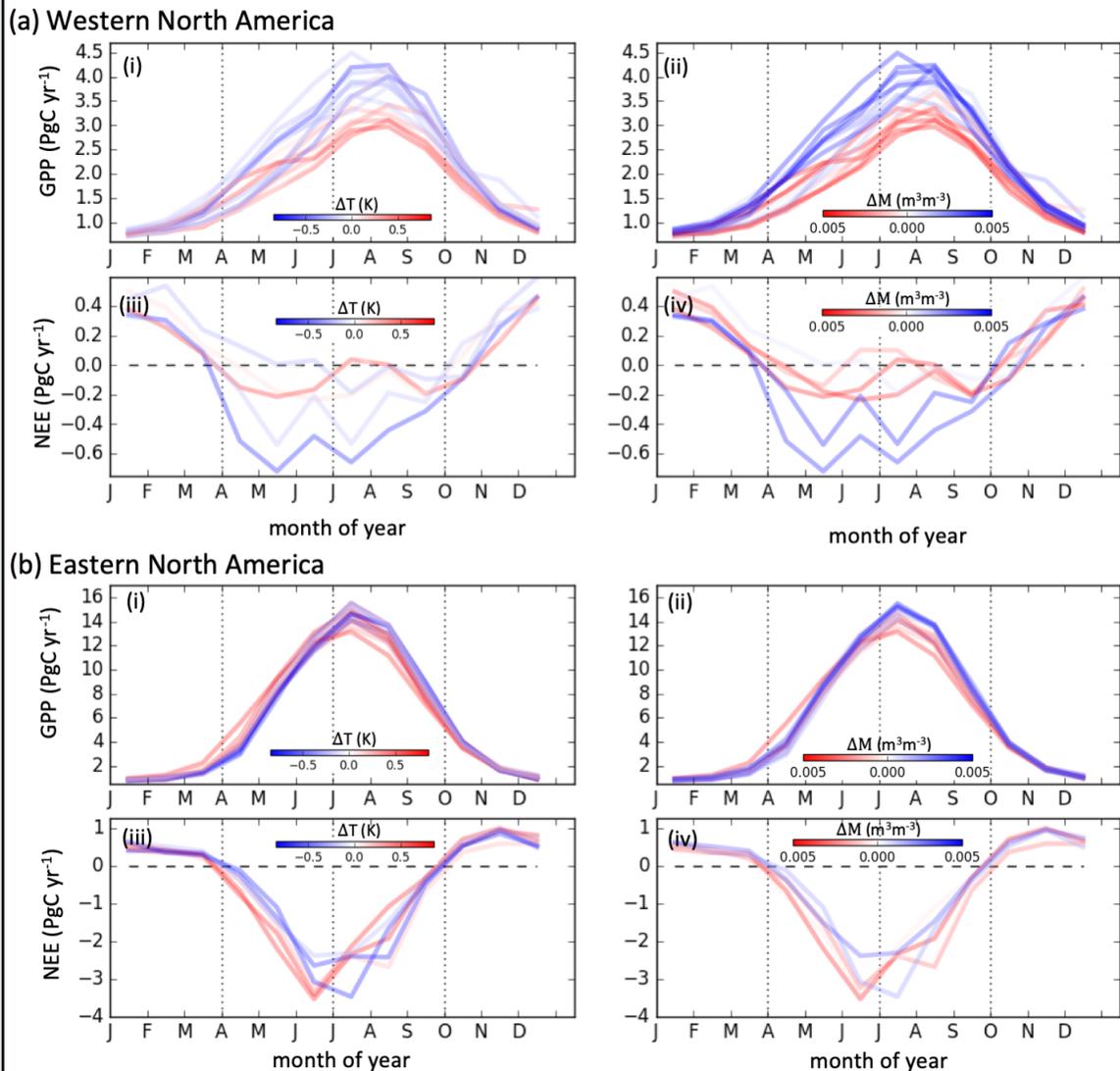
- In West, amplification is associated with wetter-cooler conditions.

- In East, shift to earlier in the year is associated with warmer spring.

- These differences in IAV between the east and west result in a similar magnitude of annual net △GPP (104% of east) and △NEE (127% of east), in spite of larger annual mean GPP and NEE in the east. (Byrne et al., ESSOAr, 2020).

Figure 10. Seasonal cycles of GPP (2001–2017) and NEE (2010-2015) over eastern and western North America. (a) Seasonal cycles of (i-ii) GPP and (iii-iv) NEE over western North America.(b) Seasonal cycles of (i-ii) GPP and (iii-iv) NEE over eastern North America. Colors indicate the Apr-Sep △T ((i) and (iii)) or Apr-Sep △M ((ii) and (iv)) (Byrne et al., ESSOAr, 2020).

CONCLUSIONS

- Increasing observational coverage from surface- and space-based CO_2 observing systems are driving advances in our ability to detect changes in surface-atmosphere fluxes.

- NEE constrained by surface- and space-based CO2 measurements suggest IAV in western North America is dominated by an amplification component while IAV in eastern North America is dominated by a compensation component.

- These results are supported by independent estimates of GPP IAV that give similar spatial and temporal variability.

- Both GPP and NEE suggest variability in the west is dominated by moisture availability, while variability in the east is most closely associated with temporal shifts in the seasonal cycle associated most closely with temperature.

ACKNOWLEDGMENTS

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- Mean summer GPP and net uptake are larger in the east than the west (7.6x for GPP, 3.5x for NEE)

- However, △GPP and △NEE similar in the west and east (1.04×for GPP and 1.27×for NEE).

- Therefore, anomalies are a much larger fraction of the mean in the west.
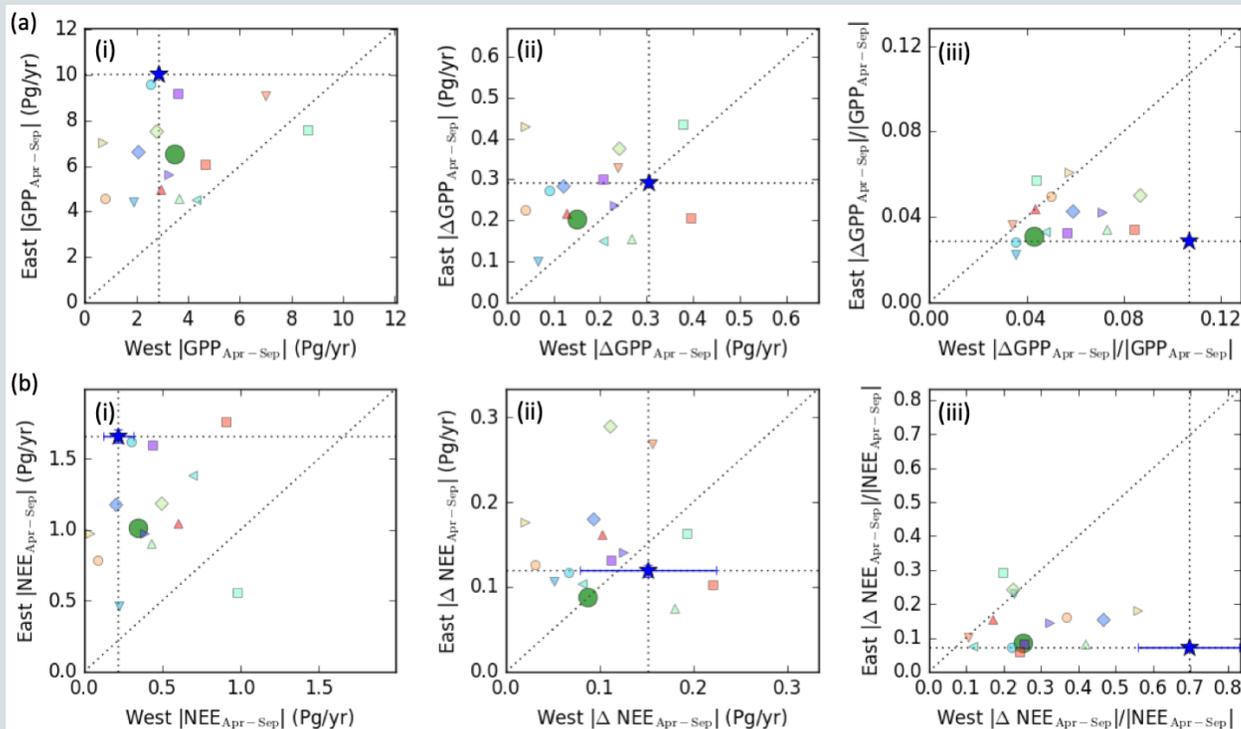
- MsTMIP models show similar east/west differences.

- MsTMIP models tend to underestimate the magnitude of the anomalies in the west relative to the mean

Figure 11. Scatter plots of (a) GPP and (b) NEE fluxes in eastern and western North America. The panels show (i) the magnitude of Apr-Sep mean fluxes, (ii) the magnitude of Apr-Sep mean anomalies, and (iii) the ratio of the anomalies to mean fluxes. The blue star shows the observationally-based estimates from FluxSat GPP and the flux inversion NEE. The error bars on the observationally-constrained NEE estimate show the range in these values between the three flux inversions. The large green circle shows the GPP and NEE estimate from the MsTMIP model mean. Small circles show the GPP and NEE estimates from individual MsTMIP models.

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