Evaluating interannual variability in CASA-GFED3 modeled global carbon fluxes

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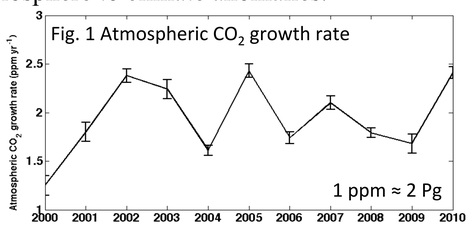
1. Introduction:

Large interannual variability (IAV) in global terrestrial biospheric carbon (C) fluxes has been inferred from observations of atmospheric CO_2 variability (Fig. 1, data from NOAA). It's likely that most of this variability is caused by the response of the terrestrial biosphere to climate anomalies.



2. Motivation:

- **Investigate the ability of our version of CASA-GFED3 (Carnegie-Ames-Stanford Approach - Global Fire Emissions Database, v3) to capture the IAV in terrestrial biospheric C fluxes.**

3. Method:

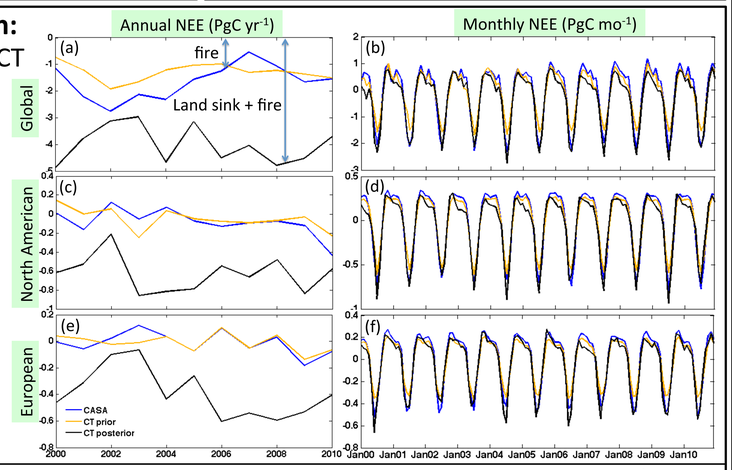
- Compared the driver data and results of our version of CASA-GFED3 (CASA hereafter, ½°) to atmospheric CO_2 inversion (CarbonTracker, CT, prior ½° and posterior 1°) and to published eddy covariance (EC) data for documented large scale climate anomalies (Ciais et al., '05; Delpierre et al., '09; Kljun et al., '06).

4. Results and discussion:

4.1 CASA independent of CT

Fig. 2(a-f) Global (a-b), North American (c-d) and European (e-f) annual and monthly net ecosystem exchange (NEE, excluding fire) of CASA, CT prior and CT posterior.

Our CASA results are independent of the CT posterior results despite that CT uses another version of CASA-GFED3 as prior. Similar to CT posterior, we show higher seasonal amplitude than CT prior. CASA and CT prior spinup with no sink. Global fires ~2PgC/yr.



4.2 Impacts of extreme climate anomaly events on C fluxes : comparing CASA, CT (prior and posterior) and eddy covariance (EC) results

4.2.1 2003 summer (Jun-Sep, JJAS) drought event in south central Canada

Fig. 3(a-f) Comparison of '03 JJAS anomalies in the driver data of CASA (a-c) and CT prior (c-e), and between ½° FPAR (fraction of absorbed photosynthetically active radiation, c) and 8km NDVI (normalized difference vegetation index, f). Base period: 2000-2010. Red and blue squares: EC sites.

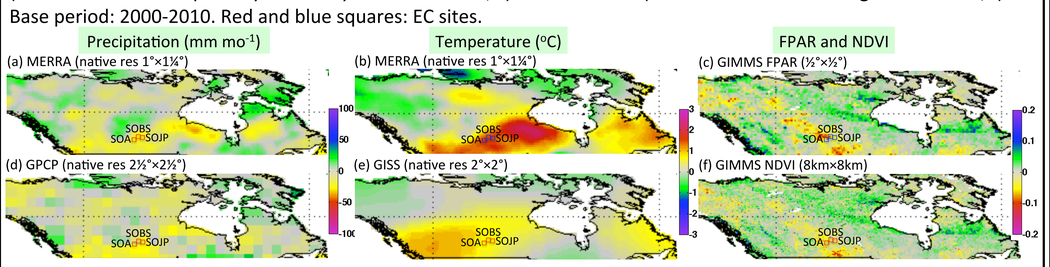
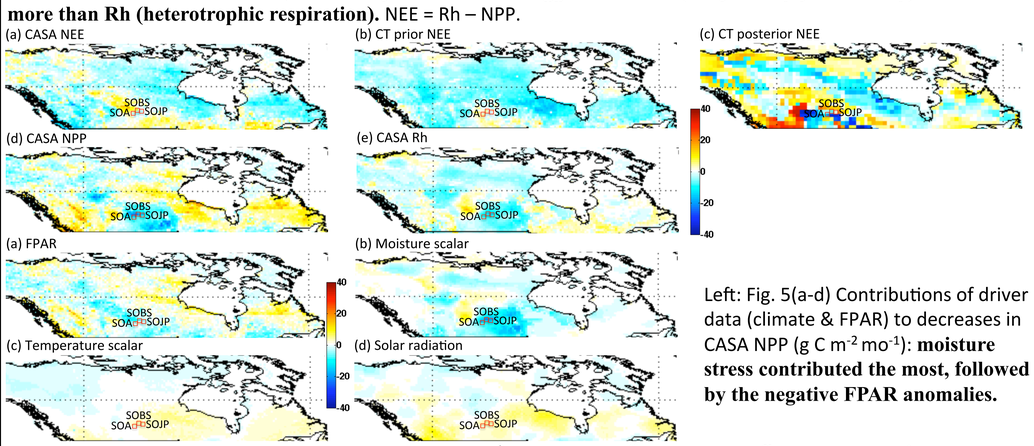
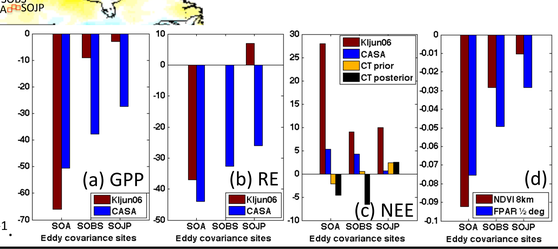


Fig. 4(a-e) '03 JJAS carbon flux anomalies (g C m^{-2} mo^{-1}, base period 2000-2010). **CASA and CT prior show bigger C source in south central Canada, while CT posterior shows bigger sink. NPP (net primary productivity) decreased more than Rh (heterotrophic respiration).** NEE = Rh – NPP.



Left: Fig. 5(a-d) Contributions of driver data (climate & FPAR) to decreases in CASA NPP (g C m^{-2} mo^{-1}): **moisture stress contributed the most, followed by the negative FPAR anomalies.**

Fig. 6(a-d) Change in 2003 JJAS GPP (gross primary productivity, a), RE (ecosystem respiration, b), NEE (c), and FPAR and NDVI (d) at EC sites. **For NEE, CASA agrees better with EC (Kljun et al., '06) than CT. Mismatch in the size of GPP changes (a) is due in part to the coarser resolution driver data (d) and model.** Change = '03 – '00. Ra=NPP, GPP_{CASA}=NPP+Ra =2xNPP, RE_{CASA}=Rh+Ra, NEE=RE-GPP. Units: gC m^{-2} mo^{-1}.



4.2.2 2003 summer (Jul-Sep, JAS) drought and heatwave event in EU

Fig. 7(a-i) Comparison of '03 anomalies in the driver data of CASA (a-c), CT prior (c-e) and figures taken from Ciais'05 (g-i), and between ½° FPAR (c) and 8km NDVI (f). **Coarser resolution driver data dampen the fine scale extremes in anomalies. This will underestimate the stresses in the models.** Precipitation and temperature: '03 – '98-'02 means; FPAR and NDVI: '03 – '00-'02 means. Red squares: EC sites.

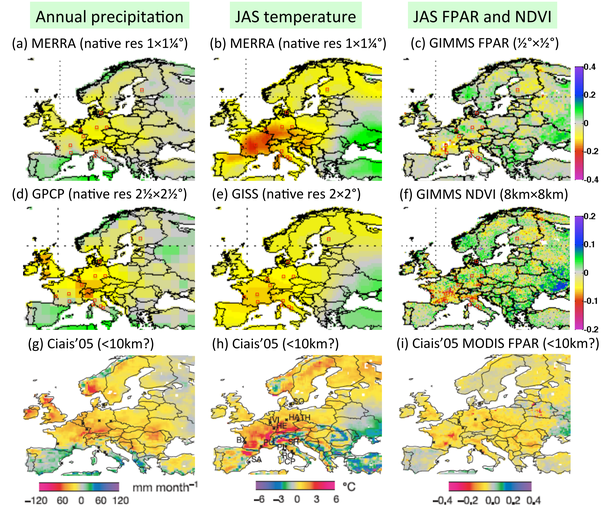


Fig. 8(a-e) '03 JAS carbon flux anomalies (g C m^{-2} mo^{-1}, base period 2000-2010). **Both CASA and CT show reduction of carbon sink in S and NE Europe. Both NPP and Rh decreased.**

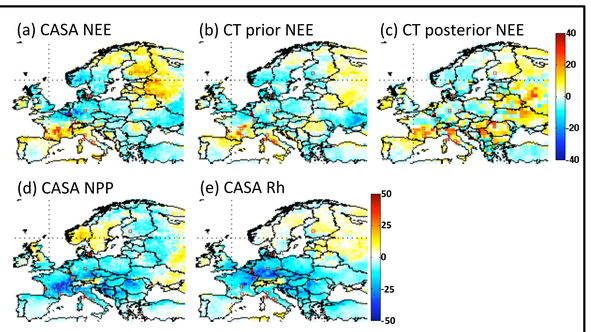


Fig. 9(a-d) Contributions of driver data to the reduction of CASA NPP (g C m^{-2} mo^{-1}): **moisture stress contributed the most, followed by the negative FPAR anomalies.**

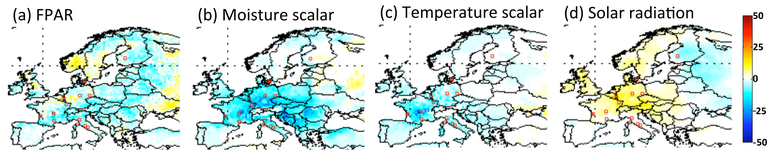
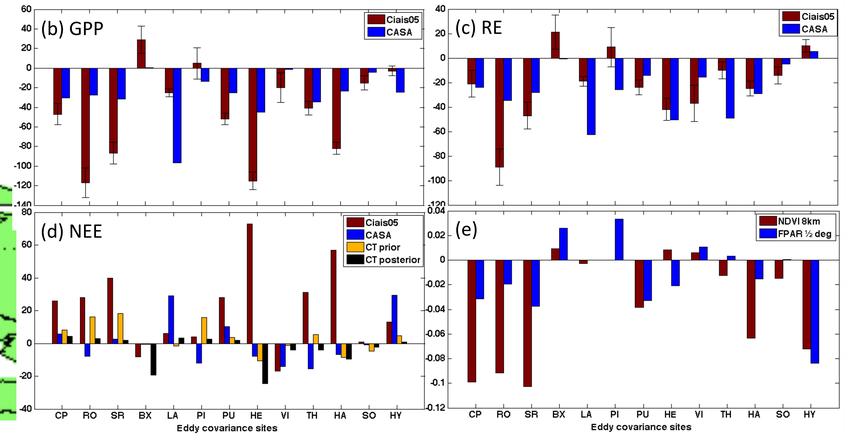


Fig. 10(a-e) Change in 2003 JAS GPP (b), RE (c), NEE (d), and FPAR and NDVI (e) at EC sites (a). **CASA agrees with EC (Ciais et al., '05) in the direction of GPP and RE changes. Disagreement in NEE is probably due to the smaller footprint of EC sites compared to model resolutions and the dampening of climate anomalies in coarser resolution driver data (e and Fig. 7).** Change = '03 – '02. Units: gC m^{-2} mo^{-1}.



4.2.3 2007 spring (Jan-May, JFMAM) warming event in EU

Fig. 11(a-g) Comparison of '07 JFMAM anomalies in the driver data of CASA (a-c) and CT prior (c-e), between ½° FPAR (c) and 8km NDVI (f), and snow cover anomalies (g) (base period: 2000-2010). Red squares: EC sites.

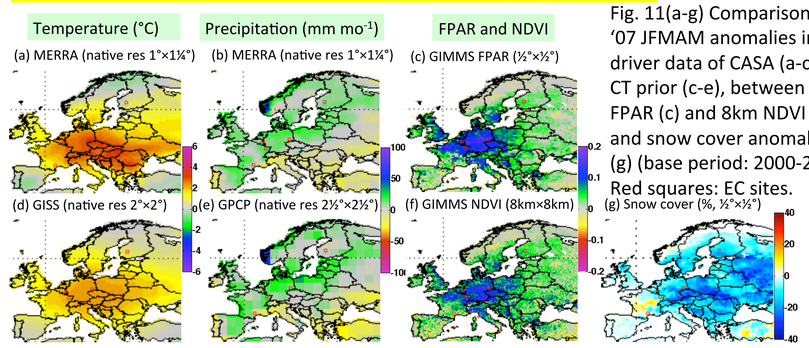
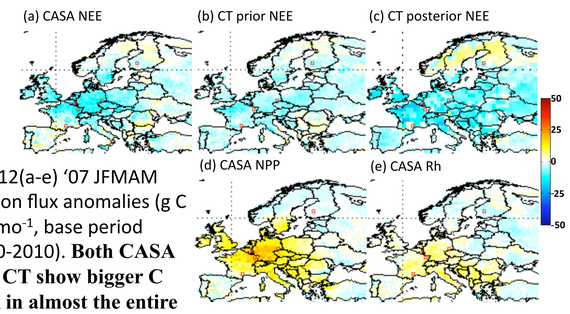


Fig. 12(a-e) '07 JFMAM carbon flux anomalies (g C m^{-2} mo^{-1}, base period 2000-2010). **Both CASA and CT show bigger C sink in almost the entire Europe. NPP increased more than Rh.**



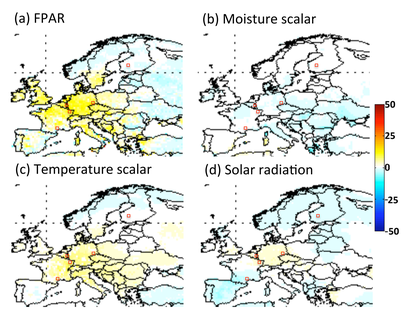
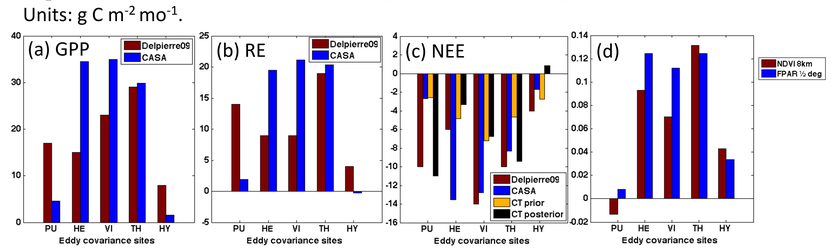


Fig. 13(a-d) Contributions of driver data to increases in CASA NPP (g C m^{-2} mo^{-1}): **FPAR increase contributed the most, followed by increases in temperature stimulation of NPP.**

Fig. 14(a-d) Change in 2007 JFMAM GPP (a), RE (b), NEE (c), and FPAR and NDVI (d) at EC sites (see Fig. 10a for location). **Model results generally agree well with EC results (Delpierre et al., '09) in the direction of changes. Slight mismatch in the size of GPP changes (a) is due in part to coarser resolution driver data (d) and model.** Change = '07 – '00-'07 means. Units: g C m^{-2} mo^{-1}.



5. Conclusions:

- CASA produced gross flux anomalies (GPP and RE) that are generally consistent with EC observations for these 3 regional climate anomaly events. CASA also captured the effects of drought in Canada and warm spring in EU on the sign of the net flux (NEE) anomalies from EC data. CASA NEE was not as consistent with EC data for the EU drought which showed greater reductions in GPP relative to RE than CASA.
- CT inversion derived NEE was less consistent with CASA and EC data for the 2 drought events.
- NDVI (or FPAR) played a major role in determining flux anomalies in CASA.

Acknowledgements:
This work was funded by NASA Carbon Cycle Science.

References:

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