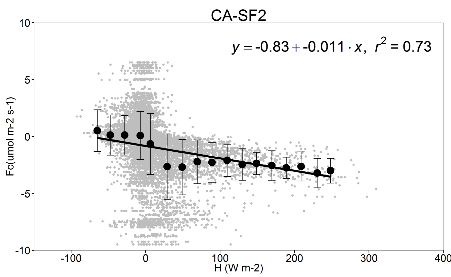
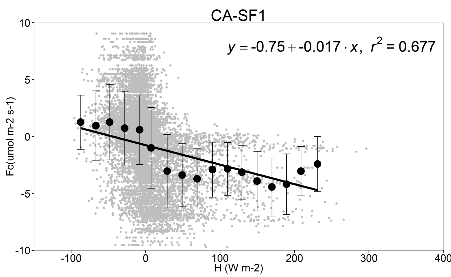
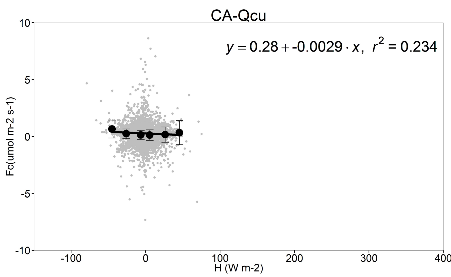
**Supplementary information**

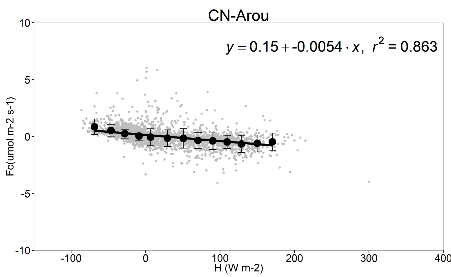
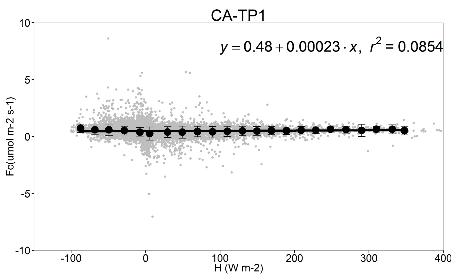
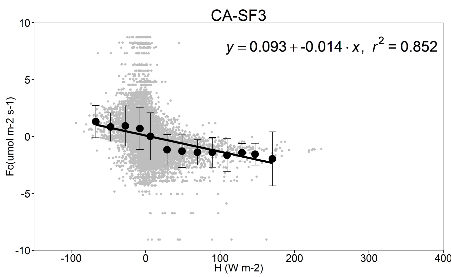
Table S1. Summary statistics of the relationship between wintertime CO2 flux (*F*c,a, umol m−2 s−1) and sensible heat (*H*, W m−2) and meteorological conditions at the 64 eddy flux sites.

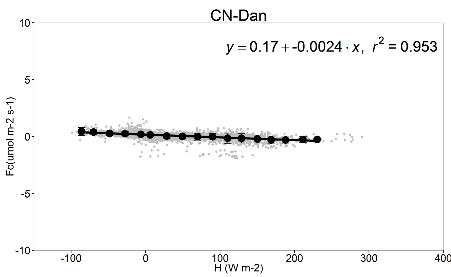
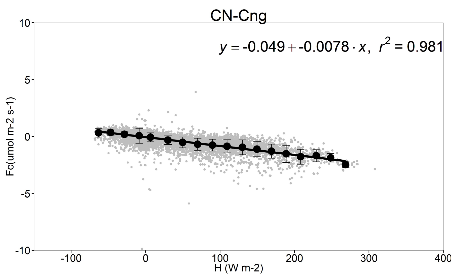
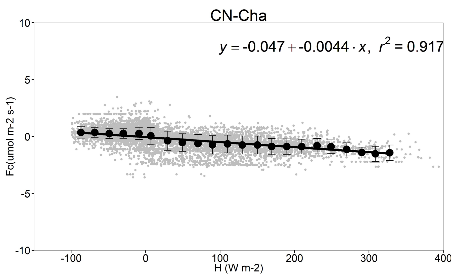
| Site ID | Slope | R2 | Air temperature  (℃) | Absolute humidity  (g m-3) | Equipment | Vegetation type | Reference |
| --- | --- | --- | --- | --- | --- | --- | --- |
| CA-Qcu | −0.003 | 0.23 | −15.47 |  | LI-7500+CSAT3 | ENF | Giasson(2006) |
| CA-SF1 | −0.017 | 0.68 | −14.99 | 1.76 | LI-7500+CSAT3 | ENF | Amiro (2010) |
| CA-SF2 | −0.011 | 0.73 | −16.82 | 1.44 | LI-7500+CSAT3 | ENF | Amiro (2010) |
| CA-SF3 | −0.014 | 0.85 | −14.39 | 1.71 | LI-7500+CSAT3 | OSH | Amiro (2010) |
| CA-TP1 | 0.0002 | 0.09 | −6.51 |  | LI-7500+CSAT3 | ENF | Peichl (2010) |
| CN-Arou | −0.005 | 0.86 | −12.74 | 3.23 | LI-7500+CSAT3 | GRA | Liu et al. (2011) |
| CN-Cha | −0.004 | 0.92 | −12.57 | 1.27 | LI-7500+CSAT3 | ENF | Yu et al. (2006b) |
| CN-Cng | −0.008 | 0.98 | −13.48 | 1.04 | LI-7500+CSAT3 | GRA | Yu et al. (2006b) |
| CN-Dan | −0.002 | 0.95 | −8.41 | 1.02 | LI-7500+CSAT3 | GRA | Yu et al. (2006b) |
| CN-Du2 | 0.001 | 0.70 | −14.21 | 1.16 | LI-7500+CSAT3 | GRA | Zhang et al. (2007) |
| CN-Gebi | −0.007 | 0.90 | −6.34 | 6.46 | LI-7500+CSAT3 | BAR | Liu et al. (2011) |
| CN-Ha2 | −0.005 | 0.84 | −13.09 | 0.97 | LI-7500+CSAT3 | OSH | Zhang et al. (2016) |
| CN-HaM | −0.001 | 0.26 | −13.68 | 1.04 | LI-7500+CSAT3 | GRA | Zhang et al. (2016) |
| CN-Huazhaizi | −0.003 | 0.84 | −10.39 |  | LI-7500+CSAT3 | ENF | Liu et al. (2011) |
| CN-Hunhelin | −0.014 | 0.95 | −7.73 | 4.25 | LI-7500+CSAT3 | ENF | Liu et al. (2011) |
| CN-Huyanlin | −0.011 | 0.94 | −8.00 | 0.93 | LI-7500+CSAT3 | DBF | Liu et al. (2011) |
| CN-Kub\_f | −0.010 | 0.94 | −8.41 | 1.47 | LI-7500+CSAT3 | DBF | This study |
| CN-Kub\_s | −0.014 | 0.98 | −8.45 | 1.43 | LI-7500+CSAT3 | OSH | This study |
| CN-Shenshawo | −0.015 | 0.70 | −7.21 | 0.19 | LI-7500+CSAT3 | BAR | Liu et al. (2011) |
| CN-Sw2 | 0.008 | 0.74 | −17.57 | 0.97 | LI-7500+CSAT3 | GRA | Shao et al. (2013) |
| CN-Xilinguole | −0.002 | 0.11 | −13.15 |  | LI-7500+CSAT3 | GRA | Yu et al. (2006b) |
| CN-Yucheng | −0.015 | 0.73 | −3.30 |  | LI-7500+CSAT3 | CRO | Yu et al. (2006b) |
| DE-SfN | −0.018 | 0.77 | −2.89 | 3.88 | LI-7500+CSAT3 | WET | Hommeltenberg et al. (2014) |
| DE-RuS | −0.037 | 0.94 | −2.05 |  | LI-7500+CSAT3 | CRO | Schmidt et al. (2012) |
| IT-CA3 | −0.003 | 0.65 | −1.39 | 3.34 | LI-7500+CSAT3 | DBF | Stojanov et al. (2013) |
| IT-Noe | −0.007 | 0.86 | −1.15 | 3.94 | LI-7500+CSAT3 | OSH | Marras et al. (2011) |
| IT-Tor | −0.010 | 0.93 | −5.64 | 2.11 | LI-7500+CSAT3 | GRA | Migliavacca et al. (2011) |
| US-Bn2 | 0.0004 | 0.02 | −11.62 | 1.49 | LI-7500+CSAT3 | DBF | Liu et al. (2005) |
| US-Bn3 | −0.004 | 0.40 | −11.12 | 1.49 | LI-7500+CSAT3 | OSH | Liu et al. (2005) |
| US-Br1 | −0.008 | 0.24 | −9.50 | 2.24 | LI-7500+CSAT3 | CRO | Gilmanov et al. (2014) |
| US-Br3 | −0.004 | 0.38 | −9.41 | 2.23 | LI-7500+CSAT3 | CRO | Gilmanov et al. (2014) |
| US-CRT | 0.005 | 0.58 | −4.67 | 2.95 | LI-7500+CSAT3 | CRO | Chu et al. (2014) |
| US-ICh | 0.011 | 0.76 | −13.43 |  | LI-7500+CSAT3 | OSH | Euskirchen et al. (2012) |
| US-ICs | −0.008 | 0.82 | −14.53 |  | LI-7500+CSAT3 | WET | Euskirchen et al. (2012) |
| US-KUT | −0.005 | 0.64 | −11.22 | 2.99 | LI-7500+CSAT3 | GRA | Hiller et al. (2011) |
| US-Oho | −0.010 | 0.82 | −5.63 | 3.78 | LI-7500+CSAT3 | DBF | Noormets et al. (2008) |
| US-Wi2 | −0.012 | 0.49 | −7.04 | 3.01 | LI-7500+CSAT3 | ENF | Desai et al. (2008) |
| US-Wi3 | 0.003 | 0.02 | −7.30 | 3.51 | LI-7500+CSAT3 | DBF | Desai et al. (2008) |
| US-Wi4 | 0.001 | 0.01 | −4.80 | 3.64 | LI-7500+CSAT3 | ENF | Desai et al. (2008) |
| US-Wi5 | −0.051 | 0.34 | −5.39 | 3.42 | LI-7500+CSAT3 | ENF | Desai et al. (2008) |
| US-Wi9 | 0.013 | 0.68 | −7.48 | 3.93 | LI-7500+CSAT3 | ENF | Desai et al. (2008) |
| JP-SMF | −0.010 | 0.83 | −1.37 | 3.13 | LI-7500+DAT540 | ENF | Saigusa et al. (2010) |
| AT-Neu | −0.030 | 0.71 | −4.94 | 2.82 | LI-7500+Gill | GRA | Haslwanter et al. (2009) |
| AU-Tum | −0.023 | 0.41 | −1.40 |  | LI-7500+Gill | ENF | Van Gorsel et al. (2007) |
| CH-Cha | −0.014 | 0.38 | −3.36 | 3.59 | LI-7500+Gill | GRA | Zeeman et al. (2010) |
| CH-Fru | −0.007 | 0.64 | −4.41 | 3.35 | LI-7500+Gill | GRA | Zeeman et al. (2010) |
| FR-Fon | −0.009 | 0.81 | −2.34 |  | LI-7500+Gill | DBF | Delpierre et al. (2015) |
| IT-CA1 | 0.013 | 0.72 | −1.38 | 3.38 | LI-7500+Gill | DBF | Stojanov et al. (2013) |
| IT-La2 | 0.000 | 0.00 | −3.22 | 2.44 | LI-7500+Gill | ENF | Cava et al. (2008) |
| IT-Lav | −0.010 | 0.85 | −3.47 | 2.79 | LI-7500+Gill | ENF | Cava et al. (2008) |
| RU-Cok | −0.002 | 0.02 | −33.29 | -0.15 | LI-7500+Gill | OSH | Parmentier et al. (2011) |
| NL-Hor | −0.010 | 0.92 | −1.84 |  | LI-7500+Gill | ENF | Hendriks et al. (2008) |
| RU-Ha1 | −0.009 | 0.98 | −17.11 | 1.04 | LI-7500+Gill | GRA | Marchesini et al. (2007) |
| US-Ne1 | −0.003 | 0.23 | −7.09 | 2.52 | LI-7500+Gill | CRO | Suyker et al. (2004) |
| US-Ne2 | −0.002 | 0.22 | −7.50 | 2.52 | LI-7500+Gill | CRO | Suyker et al. (2004) |
| US-Ne3 | −0.004 | 0.24 | −7.09 | 2.46 | LI-7500+Gill | CRO | Suyker et al. (2004) |
| US-Sdh | 0.007 | 0.71 | −5.38 | 4.69 | LI-7500+Gill | GRA | Billesbach and Arkebauer (2012) |
| CN-Daman | −0.009 | 0.69 | −7.89 | 6.02 | LI-7500A+CSAT3 | CRO | Liu et al. (2011) |
| CN-Nongtian | −0.013 | 0.94 | −8.02 |  | LI-7500A+CSAT3 | CRO | Liu et al. (2011) |
| CN-Shidi | −0.017 | 0.90 | −6.30 | 9.02 | LI-7500A+CSAT3 | WET | Liu et al. (2011) |
| CN-Sidaoqiao | −0.003 | 0.50 | −7.52 | 5.61 | LI-7500A+CSAT3 | DBF | Liu et al. (2011) |
| IT-CA2 | −0.014 | 0.77 | −1.33 | 3.39 | LI-7500A+CSAT3 | CRO | Stojanov et al. (2013) |
| CN-Tarim | −0.017 | 0.75 | −7.14 | 4.04 | LI-7500A+Gill | DBF | Wang et al. (2016) |
| CN-Tarim2 | −0.019 | 0.94 | −8.08 | 2.20 | IRGASON+Gill | DBF | Wang et al. (2016) |

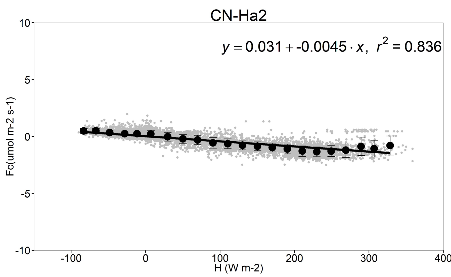
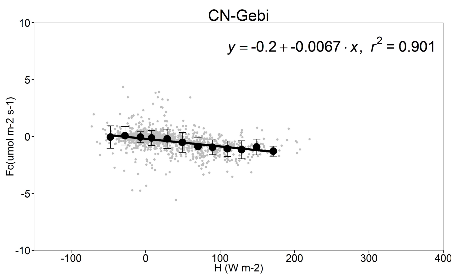
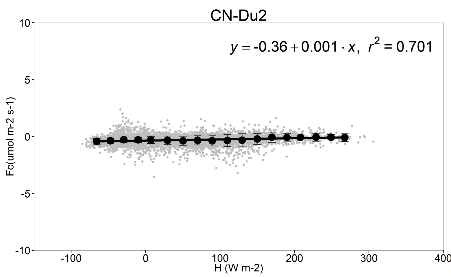
Table S2. Detail information about the open-path eddy covariance sites used in this study. MAP: mean annual precipitation; MAT: mean annual temperature.

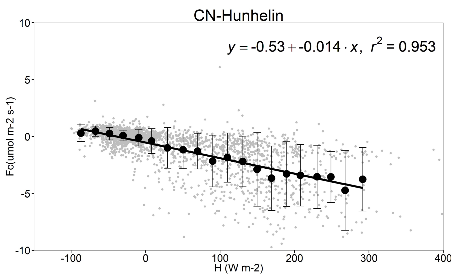
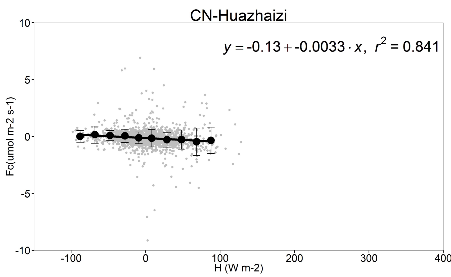
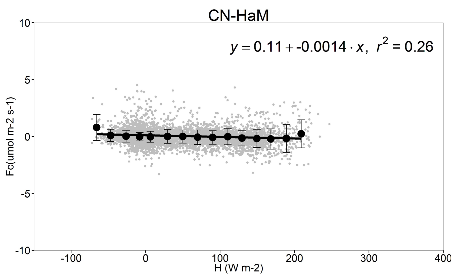
| Site ID | Site name | MAP  (mm) | MAT  (°C) | Latitude (degrees) | Longitude  (degrees) | Years of data |
| --- | --- | --- | --- | --- | --- | --- |
| CA-Qcu | Quebec - Eastern Boreal, Black Spruce/Jack Pine Cutover | 950 | 0.13 | 49.2671 | −74.0365 | 2001-2010 |
| CA-SF1 | Saskatchewan - Western Boreal, forest burned in 1977 | 470 | 0.4 | 54.485 | −105.818 | 2003-3006 |
| CA-SF2 | Saskatchewan - Western Boreal, forest burned in 1989 | 470 | 0.4 | 54.2539 | −105.878 | 2001-2006 |
| CA-SF3 | Saskatchewan - Western Boreal, forest burned in 1998 | 470 | 0.4 | 54.0916 | −106.005 | 2001-2006 |
| CA-TP1 | Ontario - Turkey Point 2002 Plantation White Pine | 1036 | 8 | 42.6609 | −80.5595 | 2002-2015 |
| CN-Aro | Arou |  |  | 38.0473 | 100.4643 | 2008-2009 |
| CN-Cha | Changbaishan |  |  | 42.4025 | 128.0958 | 2003-2005 |
| CN-Cng | Changling |  |  | 44.5934 | 123.5092 | 2010 |
| CN-Dan | Dangxiong |  |  | 30.4978 | 91.0664 | 2004-2005 |
| CN-Du2 | Duolun grassland |  |  | 42.0467 | 116.2836 | 2007-2008 |
| CN-Gebi | Heihe Gebi |  |  | 42.0012 | 101.1374 | 2014 |
| CN-Ha2 | Haibei shrubland |  |  | 37.6086 | 101.3269 | 2003-2005 |
| CN-HaM | Haibei Alpine |  |  | 37.3700 | 101.1800 | 2002-2004 |
| CN-Huazhaizi | Heihe Huazhaizi |  |  | 38.7652 | 100.3186 | 2014 |
| CN-Hunhelin | Heihe mixed forest |  |  | 41.9903 | 101.1335 | 2014 |
| CN-Huyanlin | Heihe Populus euphratica |  |  | 41.9928 | 101.1236 | 2014 |
| CN-Kub\_f | Kubuqi Populus |  |  | 40.5383 | 108.6936 | 2006-2008 |
| CN-Kub\_s. | Kubuqi shrubland |  |  | 40.3808 | 108.5486 | 2006-2008 |
| CN-Shenshawo | Heihe Shenshawo |  |  | 38.78917 | 100.4933 | 2014 |
| CN-Sw2 | Siziwang Grazed |  |  | 41.7902 | 111.8971 | 2010-2012 |
| CN-Xilinguole | Xilinguole |  |  | 44.1333 | 116.3000 | 2004-2005 |
| CN-Yucheng | Yucheng |  |  | 36.9583 | 116.6406 | 2004-2005 |
| DE-RuS | Selhausen Juelich | 700 | 10 | 50.86591 | 6.447169 | 2011-2014 |
| DE-SfN | Schechenfilz Nord | 1127 | 8.6 | 47.80639 | 11.3275 | 2012-2014 |
| IT-CA3 | Castel d'Asso 3 | 766 | 14 | 42.38 | 12.0222 | 2011-2013 |
| IT-Noe | Arca di Noe - Le Prigionette | 588 | 15.9 | 40.60613 | 8.15146 | 2004-2014 |
| IT-Tor | Torgnon | 2.9 | CO2−E/C | 45.84444 | 7.578055 | 2008-2013 |
| US-Bn2 | Bonanza Creek, 1987 Burn site near Delta Junction |  |  | 63.9198 | −145.378 | 2002-2004 |
| US-Bn3 | Bonanza Creek, 1999 Burn site near Delta Junction |  |  | 63.9227 | −145.744 | 2002-2004 |
| US-Br1 | Brooks Field Site 10- Ames | 842 | 8.95 | 41.6915 | −93.6914 | 2005-2011 |
| US-Br3 | Brooks Field Site 11- Ames | 847 | 8.9 | 41.9747 | −93.6936 | 2005-2011 |
| US-CRT | Curtice Walter-Berger cropland | 849 | 10.1 | 41.6285 | −83.3471 | 2011-2013 |
| US-ICh | Imnavait Creek Watershed Heath Tundra | 318 | −7.4 | 68.6068 | −149.296 | 2007-2011 |
| US-ICs | Imnavait Creek Watershed Wet Sedge Tundra | 318 | −7.4 | 68.6058 | −149.311 | 2007-2011 |
| US-KUT | KUOM Turfgrass Field | 777 | 7.9 | 44.995 | −93.1863 | 2005-2009 |
| US-Oho | Oak Openings | 849 | 10.1 | 41.5545 | −83.8438 | 2004-2013 |
| US-Wi2 | Intermediate red pine (IRP) |  |  | 46.6869 | −91.1528 | 2003 |
| US-Wi3 | Mature hardwood (MHW) |  |  | 46.6347 | −91.0987 | 2002-2004 |
| US-Wi4 | Mature red pine (MRP) |  |  | 46.7393 | −91.1663 | 2002-2005 |
| US-Wi5 | Mixed young jack pine (MYJP) |  |  | 46.6531 | −91.0858 | 2004 |
| US-Wi9 | Young Jack pine (YJP) |  |  | 46.6188 | −91.0814 | 2004-2005 |
| JP-SMF | Seto |  |  | 35.2617 | 137.0788 | 2002-2006 |
| AT-Neu | Neustift | 852 | 6.3 | 47.11667 | 11.3175 | 2003 |
| AU-Tum | Tumbarumba |  |  | −35.6566 | 148.1517 | 2001-2014 |
| CH-Cha | Chamau | 1136 | 9.5 | 47.21022 | 8.410444 | 2006-2012 |
| CH-Fru | Früebüel | 1651 | 7.2 | 47.11583 | 8.537778 | 2006-2012 |
| FR-Fon | Fontainebleau-Barbeau | 720 | 10.2 | 48.4764 | 2.780142 | 2005-2014 |
| IT-CA1 | Castel d'Asso1 | 766 | 14 | 42.38041 | 12.02656 | 2011-2014 |
| IT-La2 | Lavarone2 | 1150 | 7.2 | 45.9542 | 11.2853 | 2000-2002 |
| IT-Lav | Lavarone | 1291 | 7.8 | 45.9562 | 11.28132 | 2003-2014 |
| NL-Hor | Horstermeer | 800 | 10 | 52.24035 | 5.071301 | 2004-2011 |
| RU-Cok | Chokurdakh | 232 | −14.3 | 70.82914 | 147.4943 | 2003-2013 |
| RU-Ha1 | Hakasia steppe | 360 | 0.5 | 54.7252 | 90.0022 | 2002-2004 |
| US-Ne1 | Mead - irrigated continuous maize site | 790 | 10.07 | 41.1651 | −96.4766 | 2001-2013 |
| US-Ne2 | Mead - irrigated maize-soybean rotation site | 789 | 10.08 | 41.1649 | −96.4701 | 2001-2013 |
| US-Ne3 | Mead - rainfed maize-soybean rotation site | 784 | 10.11 | 41.1797 | −96.4397 | 2001-2013 |
| US-Sdh | Nebraska SandHills Dry Valley |  |  | 42.0693 | −101.407 | 2004-2009 |
| CN-Daman | Daman |  |  | 38.8555 | 100.3722 | 2014 |
| CN-Nongtian | Heihe cropland |  |  | 42.0048 | 101.1338 | 2014 |
| CN-Shidi | Heihe wetland |  |  | 38.9751 | 100.4464 | 2014 |
| CN-Sidaoqiao | Heihe Sidaoqiao |  |  | 42.0012 | 101.1374 | 2014 |
| IT-CA2 | Castel d'Asso2 | 766 | 14 | 42.37722 | 12.02604 | 2011-2013 |
| CN-Tarim | Tarim Populus euphratica |  |  | 40.4331 | 88.0261 | 2013 |
| CN-Tarim2 | Tarim Populus euphratica |  |  | 40.4331 | 88.0261 | 2013 |

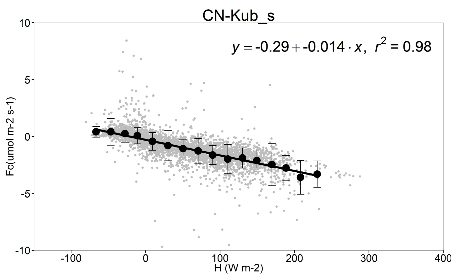
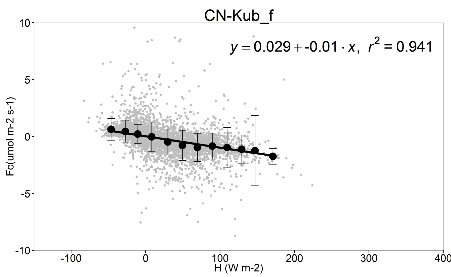
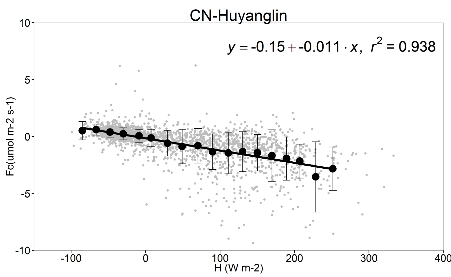


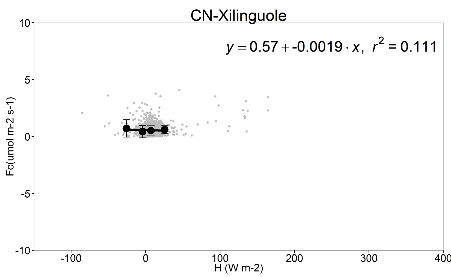
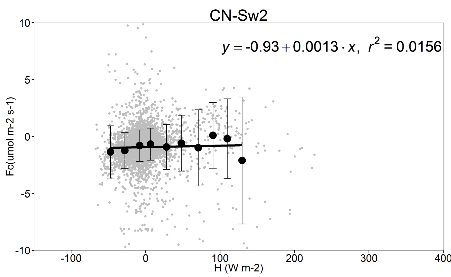
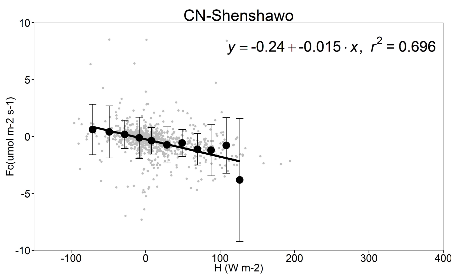


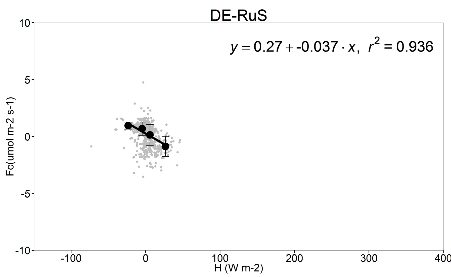
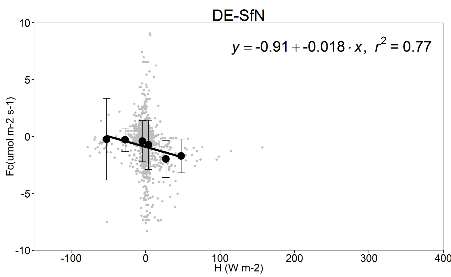
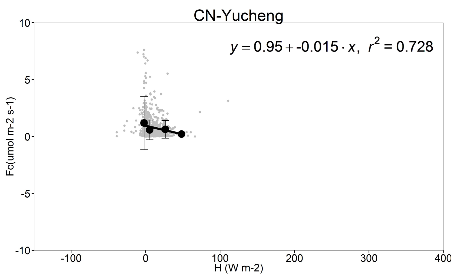


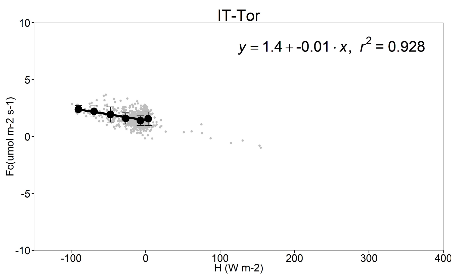
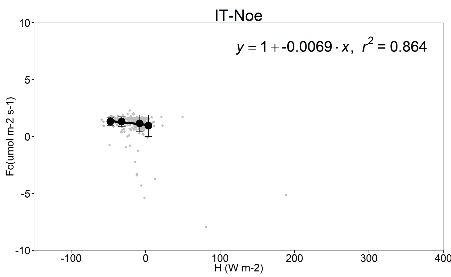
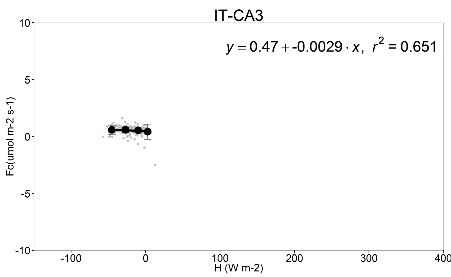


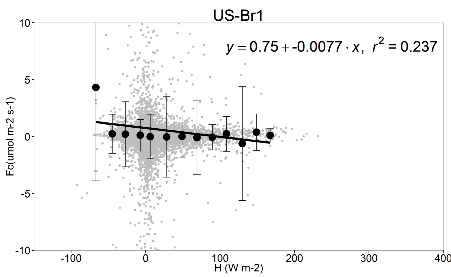
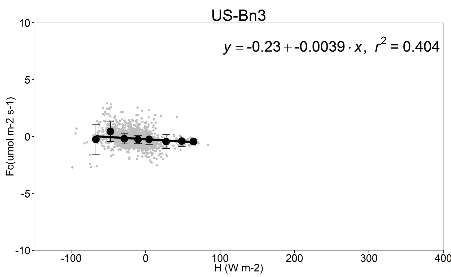
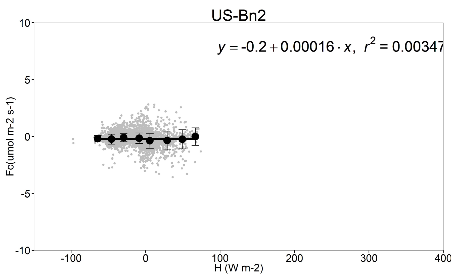


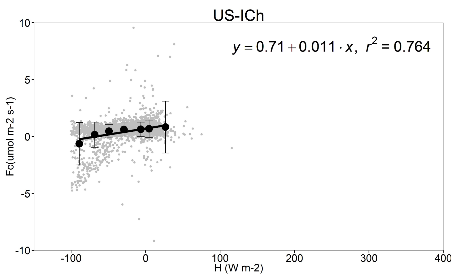
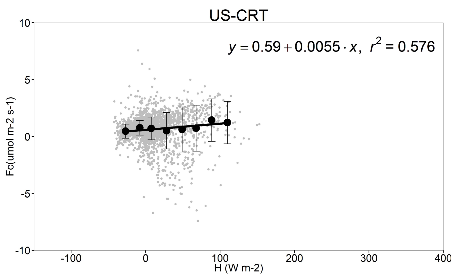
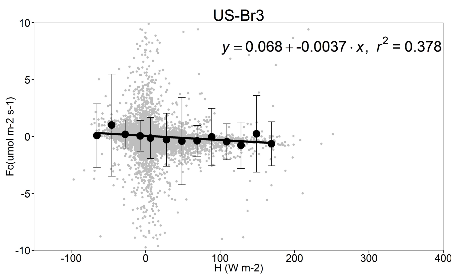


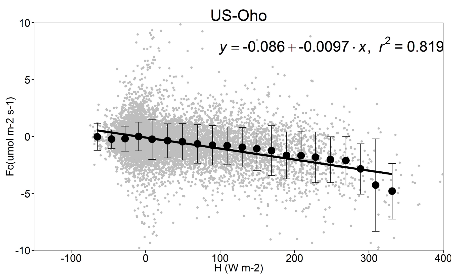
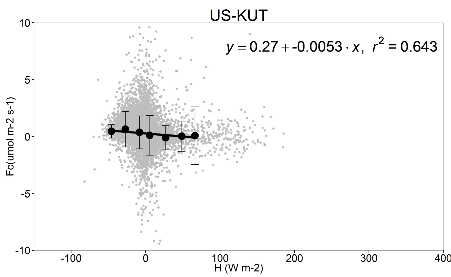
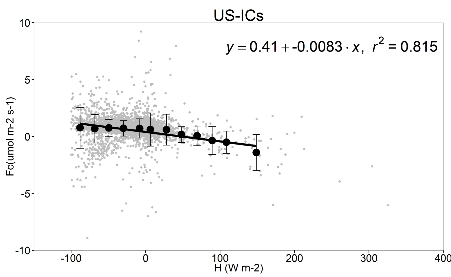


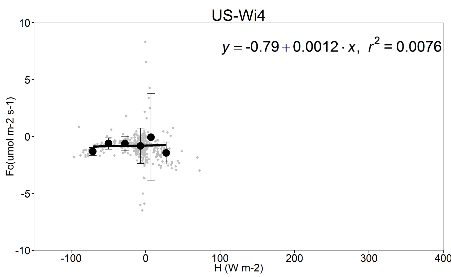
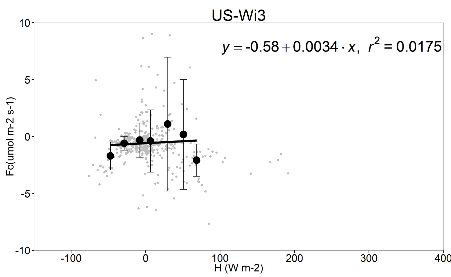
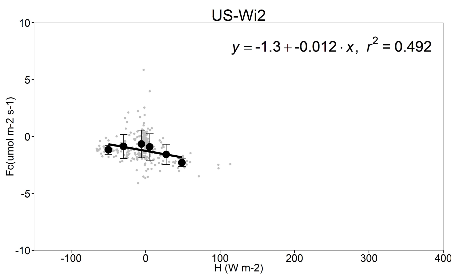


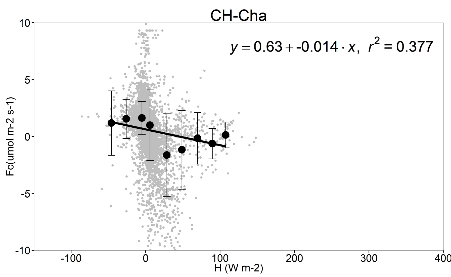
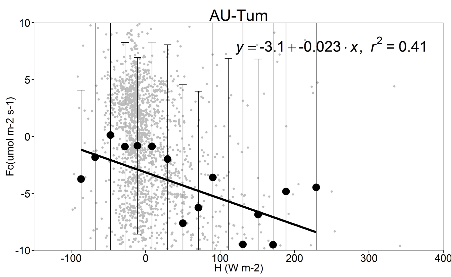
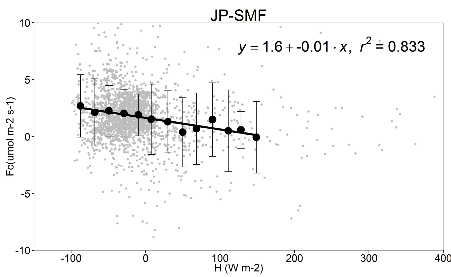
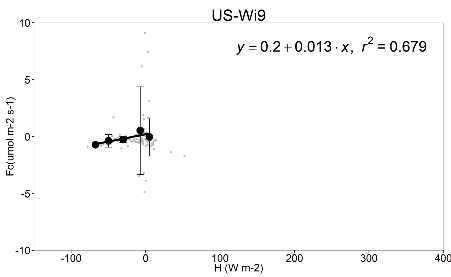
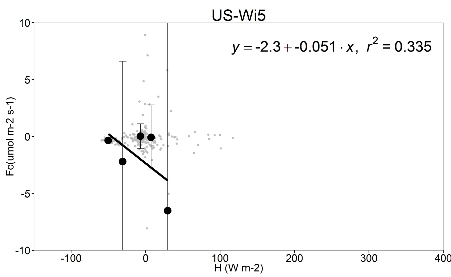


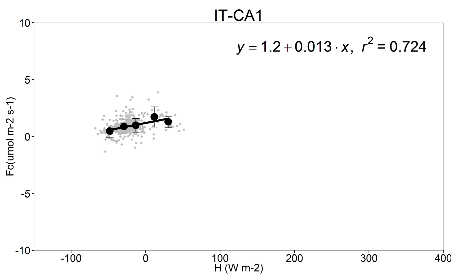
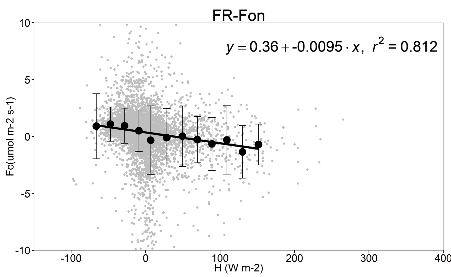
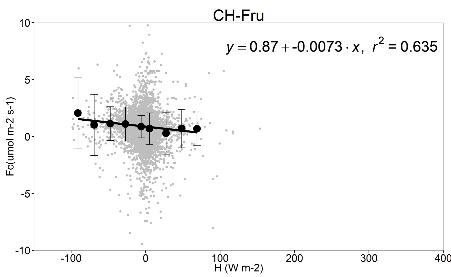


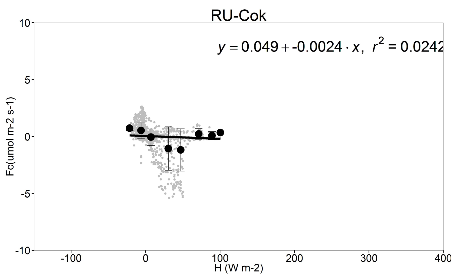
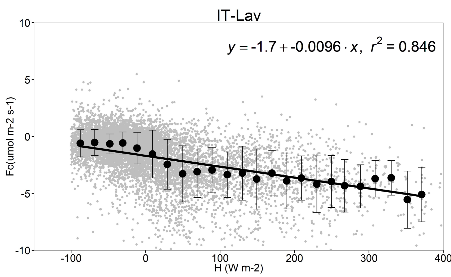
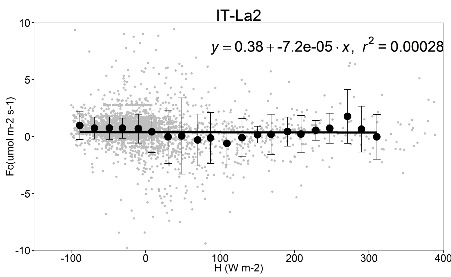


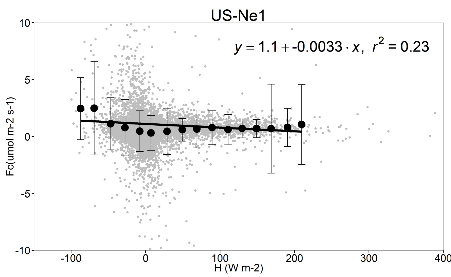
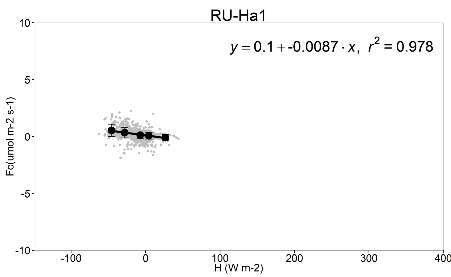
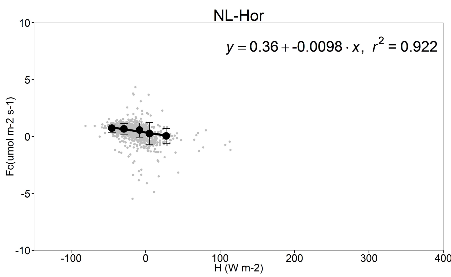


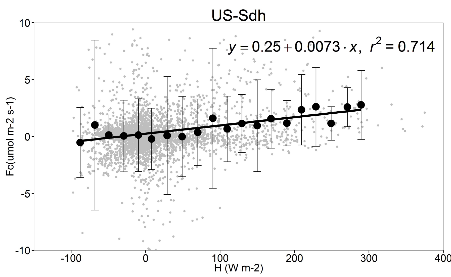
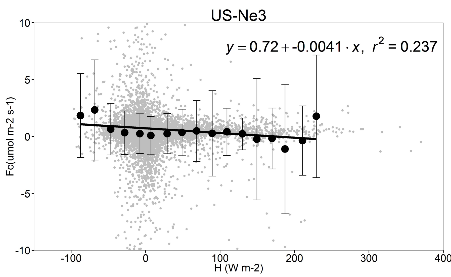
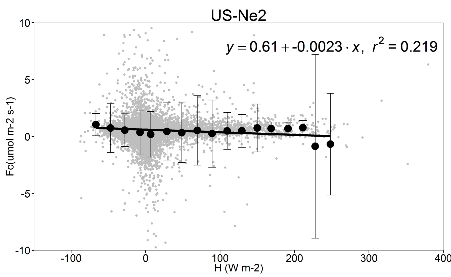


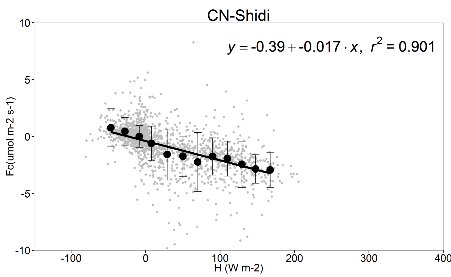
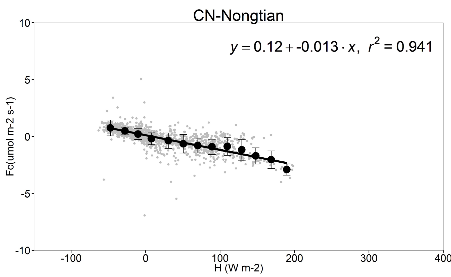
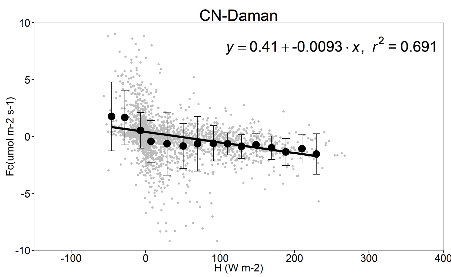


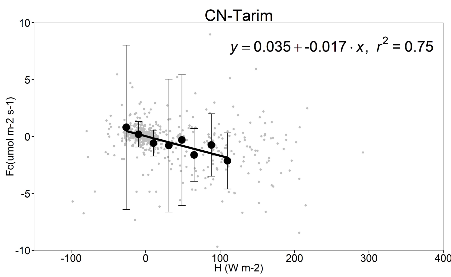
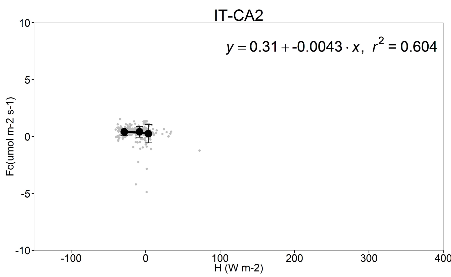
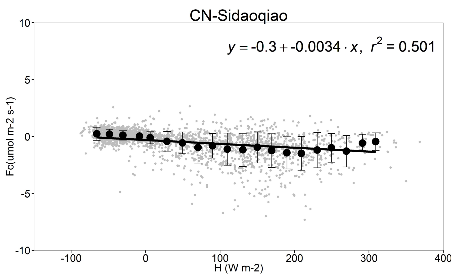












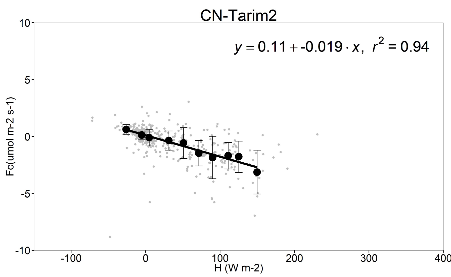


Figure S1. Relationship between wintertime CO2 flux (*F*c) and sensible heat (*H*). Grey dots represent half-hourly data, and black dots and error bars represent bin-average values and standard deviations.

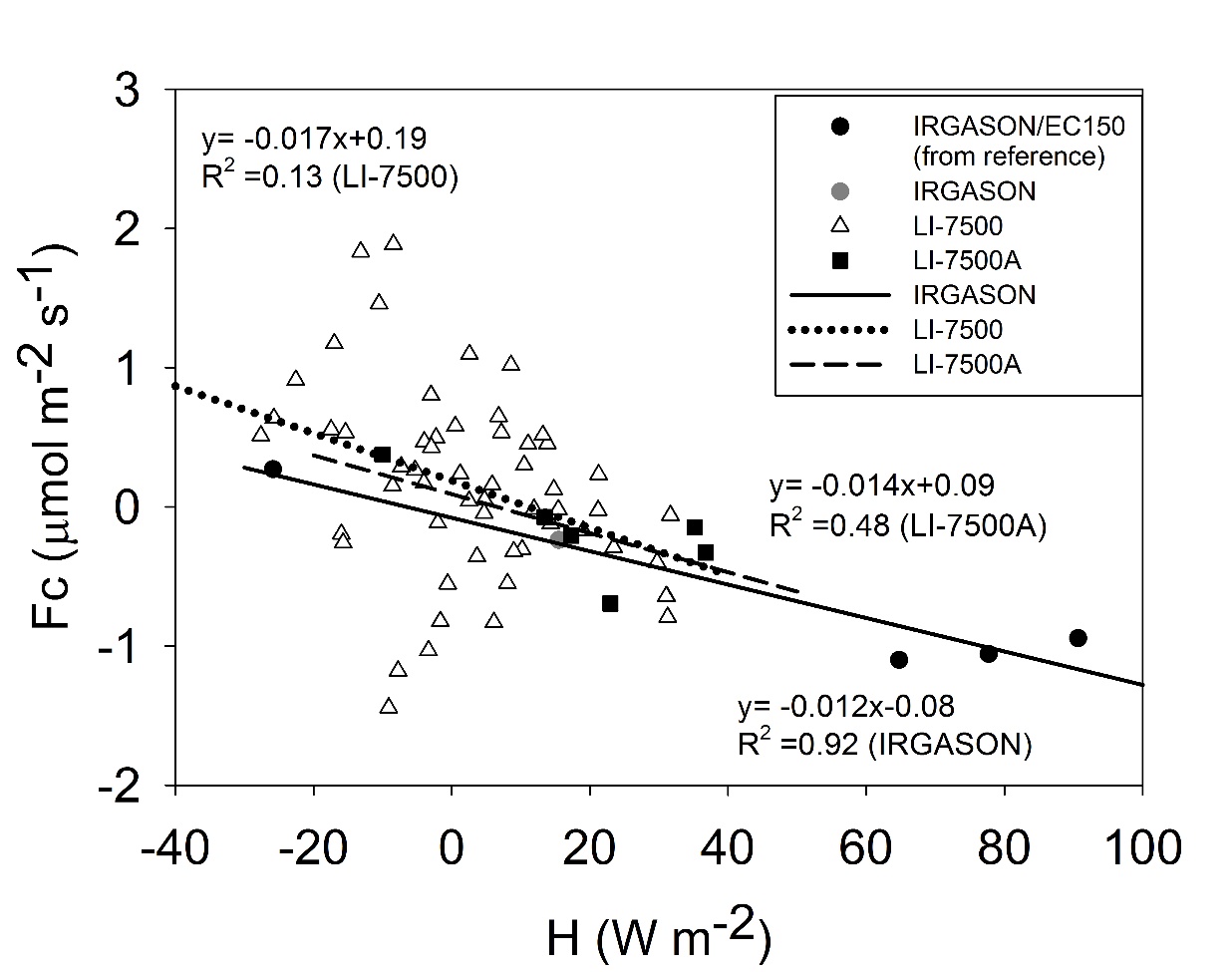


Figure S2. The site-mean CO2 flux versus the site mean sensible heat flux. Different symbols represent different analyzer types.

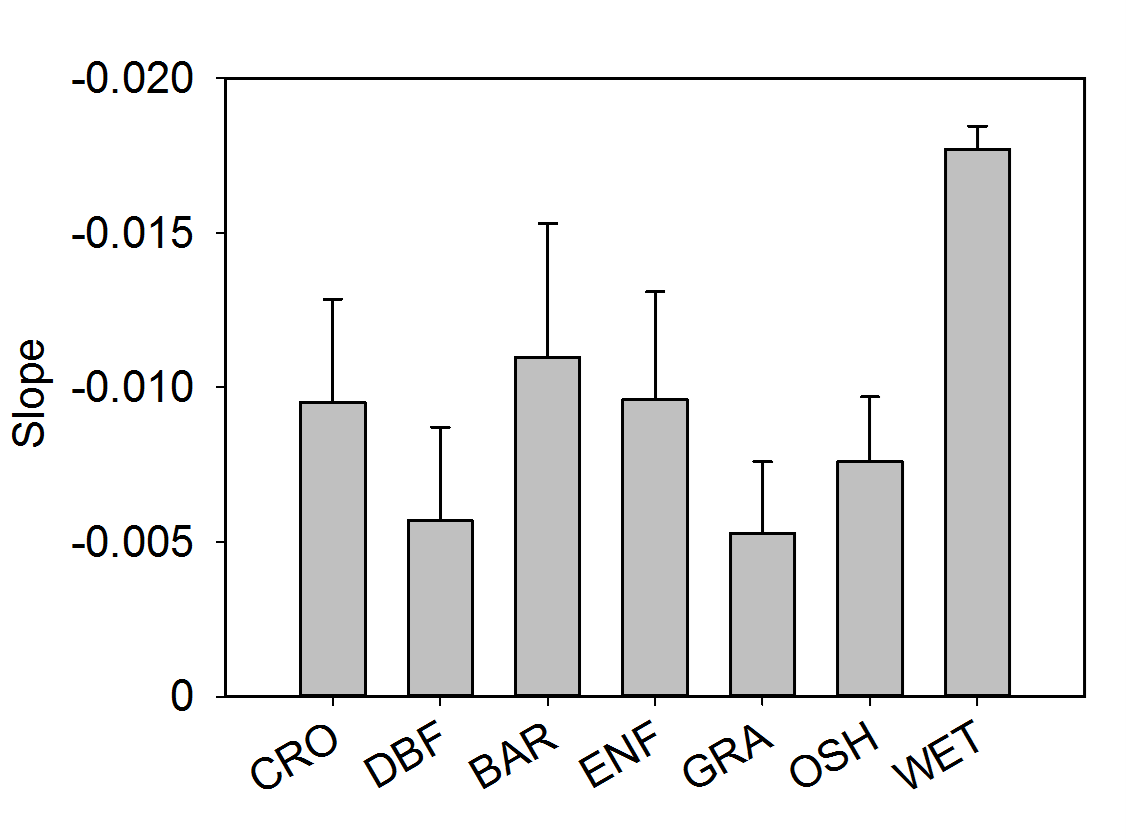


Figure S3. Comparison of the regression slope parameter *b* (μmol m−2 s−1 per W m−2) by vegetation type. Error bars are ± 1 standard error. CRO: Croplands (number of sites 11); DBF: Deciduous Broadleaf Forests (10); BAR: Barrens (2); ENF: Evergreen Needleleaf Forests (16); GRA: Grasslands (14); OSH: Open Shrublands (6); WET: Permanent Wetlands (2).

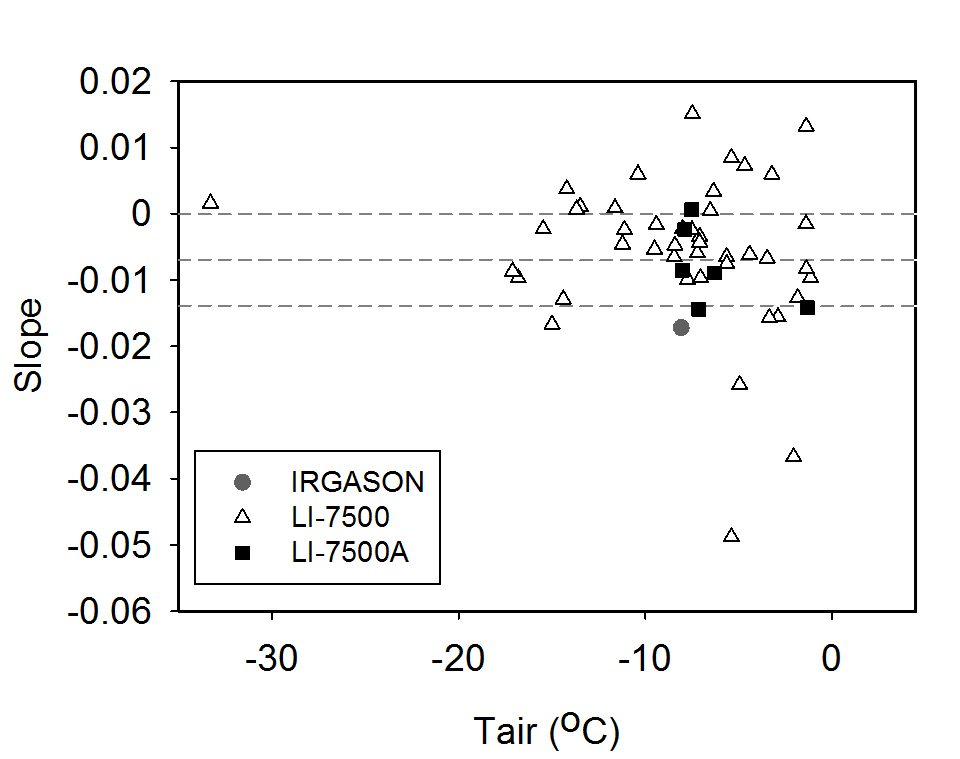


Figure S4. The regression slope parameter *b* (μmol m−2 s−1 per W m−2) with the effect of *ρ*c biases excluded versus air temperature.

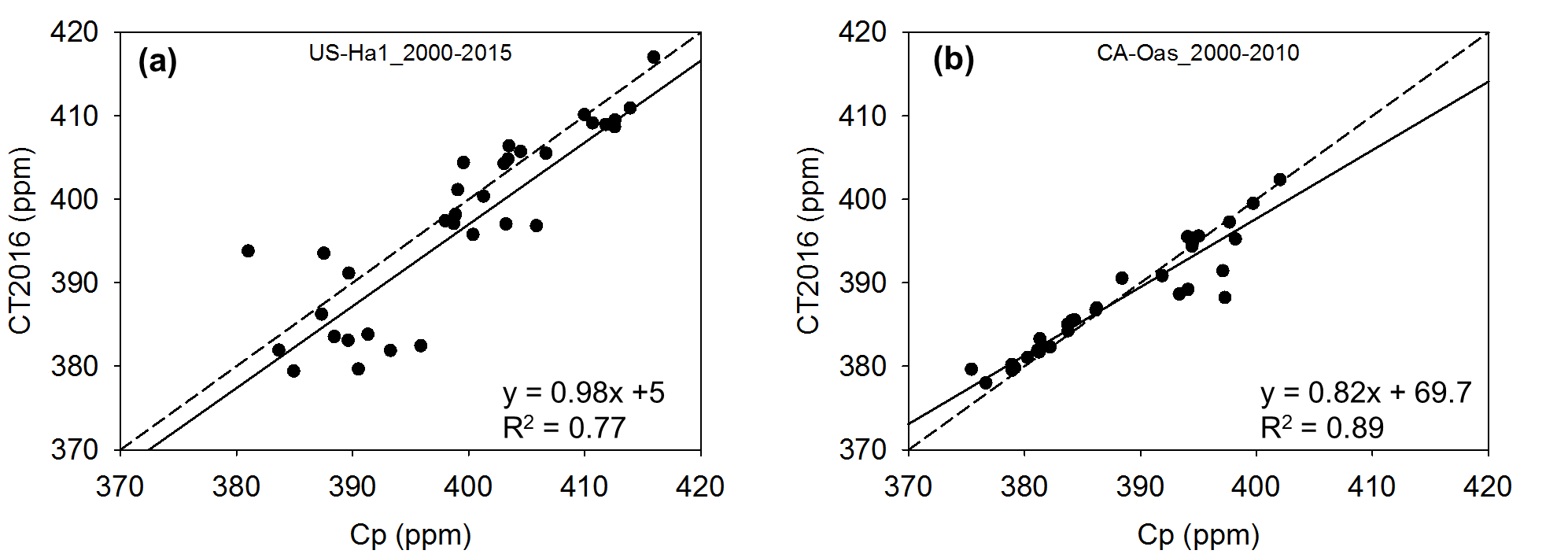


Figure S5. Comparison of the CarbonTracker surface monthly (December, January, February) mean CO2 mole fraction against the monthly CO2 mole fraction (in ppm) measured by close-path EC analyzers (Cp) at Harvard Forest, U.S. (panel a) and at Old Aspen, Canada (panel b). The periods of comparison are 2000-2015 for Harvard Forest and 2000-2010 for Old Aspen.

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