Divergent Apparent Temperature Sensitivity of Terrestrial Ecosystem Respiration

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Supplementary Information

Table S1. Main site characteristics, climatic index, and studied period of Flux sites in this analysis.

Site name	Latitude*	Longitude*	Biome	Climate	Year	Reference
AT-Neu	47.12	11.32	GR	TEM	02-06	(Wohlfahrt *et al.* 2008)
AU-Tum	-35.66	148.15	EBF	TEM	01-06	(van Gorsel *et al.* 2008)
AU-Wac	-37.43	145.19	EBF	TEM	05-07	--
BE-Bra	51.31	4.52	MF	TEM	97-06	(Carrara *et al.* 2004)
BE-Lon	50.55	4.74	CR	TEM	04-06	(Moureaux *et al.* 2006)
BE-Vie	50.31	6.00	MF	TEM	96-06	(Aubinet *et al.* 2001)
BW-Ma1	-19.92	23.56	WSA	TEM	99-01	(Veenendaal *et al.* 2004)
CA-Ca1	49.87	-125.33	ENF	TEM	97-05	(Humphreys *et al.* 2006)
CA-Ca2	49.87	-125.29	ENF	TEM	00-05	(Chen *et al.* 2006)
CA-Ca3	49.53	-124.90	ENF	TEM	01-05	(Chen *et al.* 2006)
CA-Gro	48.22	-82.16	MF	TEM	03-05	(McCaughey *et al.* 2006)
CA-Let	49.71	-112.94	GR	TEM	98-05	(Flanagan and Adkinson 2011; Flanagan and Syed 2011)
CA-Man	55.88	-98.48	ENF	BOR	94-03	(Dunn *et al.* 2007)
CA-Mer	45.41	-75.52	WET	TEM	98-05	(Lafleur *et al.* 2003)
CA-NS1	55.88	-98.48	ENF	BOR	02-05	(Goulden *et al.* 2006)
CA-NS2	55.91	-98.52	ENF	BOR	01-05	(Goulden *et al.* 2006)
CA-NS3	55.91	-98.38	ENF	BOR	01-05	(Goulden *et al.* 2006)
CA-NS4	55.91	-98.38	ENF	BOR	02-04	(Goulden *et al.* 2006)
CA-NS5	55.86	-98.49	ENF	BOR	01-05	(Goulden *et al.* 2006)
CA-NS6	55.92	-98.96	ENF	BOR	01-05	(Goulden *et al.* 2006)
CA-NS7	56.64	-99.95	OSH	BOR	02-05	(Lafleur *et al.* 2003)

CA-Oas	53.63	-106.20	DBF	BOR	97-05	(Black *et al.* 2000)
CA-Obs	53.99	-105.12	ENF	BOR	99-05	(Bergeron *et al.* 2007)
CA-Ojp	53.92	-104.69	ENF	BOR	99-03,05	(Howard *et al.* 2004)
CA-Qcu	49.27	-74.04	ENF	BOR	01-06	(Giasson *et al.* 2006)
CA-Qfo	49.69	-74.34	ENF	BOR	03-06	(Giasson *et al.* 2006)
CA-TP2	42.77	-80.46	ENF	TEM	03-05	(Peichl and Arain 2006)
CA-TP3	42.71	-80.35	ENF	TEM	03-05	(Peichl and Arain 2006)
CA-TP4	42.71	-80.36	ENF	TEM	03-05	(Peichl and Arain 2006)
CA-WP1	54.95	-112.47	MF	BOR	03-05	(Flanagan and Adkinson 2011; Flanagan and Syed 2011)
CH-Oe1	47.29	7.73	GR	TEM	02-06	(Ammann *et al.* 2007)
CH-Oe2	47.29	7.73	CR	TEM	2005	(Ammann *et al.* 2007)
CN-Anh	33.00	117.00	DBF	TEM	05-06	--
CN-Bed	39.53	116.25	EBF	TEM	05-06	--
CN-Cha	42.40	128.10	MF	TEM	2003	(Guan *et al.* 2006)
CN-Do1	31.52	121.96	WET	SUBT	2005	(Chen *et al.* 2004)
CN-Do2	31.58	121.90	WET	SUBT	2005	(Chen *et al.* 2004)
CN-Do3	31.52	121.97	WET	SUBT	2005	(Chen *et al.* 2004)
CN-Du1	42.05	116.67	CR	TEM	05-06	(Chen *et al.* 2009)
CN-Hny	29.31	112.51	DBF	TEM	05-06	--
CN-Ku1	40.54	108.69	EBF	TEM	05-06	(Wilske *et al.* 2009)
CN-Xfs	44.13	116.33	GR	TEM	04-06	(Chen *et al.* 2009)
CZ-BK1	49.50	18.54	ENF	TEM	01-06	(Reichstein *et al.* 2005)
DE-Bay	50.14	11.87	ENF	TEM	96-99	(Staudt. and Foken 2007)
DE-Geb	51.10	10.91	CR	TEM	04-06	(Anthoni *et al.* 2004)
DE-Gri	50.95	13.51	GR	TEM	05-06	(Gilmanov *et al.* 2007)
DE-Hai	51.08	10.45	DBF	TEM	00-06	(Knohl *et al.* 2003)
DE-Har	47.93	7.60	DBF	TEM	05-06	(Chen *et al.* 2010)
DE-Kli	50.89	13.52	CR	TEM	04-06	(Chen *et al.* 2010)
DE-Meh	51.28	10.66	GR	TEM	03-06	(Don *et al.* 2009)
DE-Tha	50.96	13.57	ENF	TEM	96-06	(Valentini *et al.* 2000)
DE-Wet	50.45	11.46	ENF	TEM	02-06	(Rebmann *et al.* 2010)
DK-Lva	55.68	12.08	GR	TEM	05-06	(Gilmanov *et al.* 2007)
DK-Ris	55.53	12.10	CR	TEM	04-05	(Chen *et al.* 2010)
DK-Sor	55.49	11.65	DBF	TEM	96-06	(Pilegaard *et al.* 2003)
ES-Es1	39.35	-0.32	ENF	SUBT	99-02,04-06	(Reichstein *et al.* 2005)
ES-Vda	39.35	-0.32	ENF	SUBT	04-06	(Migliavacca *et al.* 2011)
FI-Hyy	61.85	24.29	ENF	BOR	96-06	(Suni *et al.* 2003)
FI-Kaa	69.14	27.30	WET	BOR	00-06	--

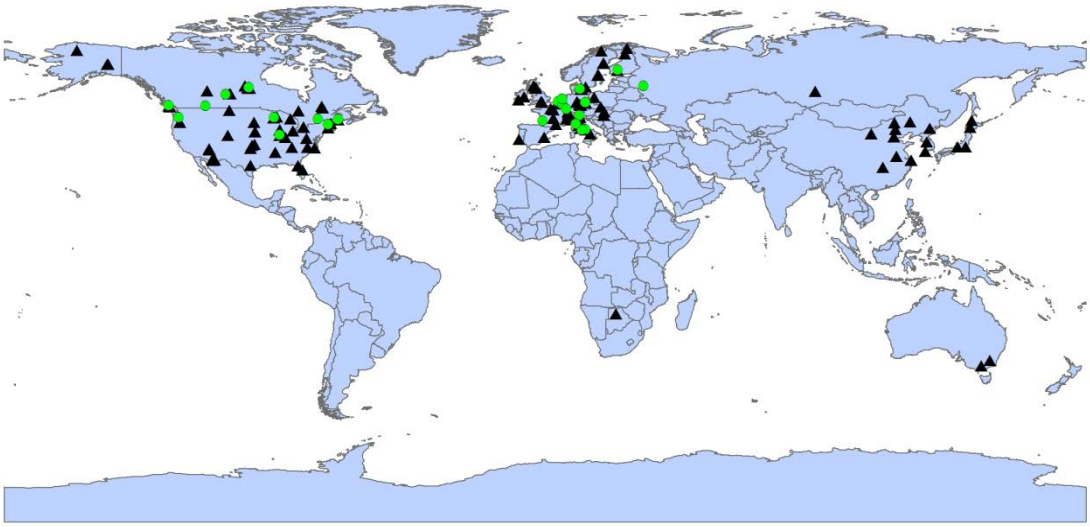
FI-Sii	61.83	24.19	ENF	BOR	04-05	--
FI-Sod	67.36	26.64	ENF	BOR	00-06	(Suni *et al.* 2003)
FR-Fon	48.48	2.78	DBF	TEM	05-06	(Migliavacca *et al.* 2011)
FR-Gri	48.84	1.95	CR	TEM	05-06	(Migliavacca *et al.* 2011)
FR-Hes	48.67	7.06	DBF	TEM	97-06	(Granier *et al.* 2000)
FR-Lbr	44.72	-0.77	ENF	TEM	96-00,03-06	(Berbigier *et al.* 2001)
FR-Lq1	45.64	2.74	GR	TEM	04-06	(Gilmanov *et al.* 2007)
FR-Lq2	45.64	2.74	GR	TEM	04-06	(Gilmanov *et al.* 2007)
FR-Pue	43.74	3.60	EBF	SUBT	00-06	(Rambal *et al.* 2004)
HU-Bug	46.69	19.60	GR	TEM	02-06	--
HU-Mat	47.85	19.73	GR	TEM	04-06	(Pinter *et al.* 2008)
IE-Ca1	52.87	-6.92	GR	TEM	04-06	(Gilmanov *et al.* 2007)
IE-Dri	51.99	-8.75	GR	TEM	03-05	(Jaksic *et al.* 2006)
IT-Amp	41.90	13.61	GR	SUBT	02-06	(Gilmanov *et al.* 2007)
IT-Bci	40.52	14.96	CR	SUBT	04-06	(Eugster *et al.* 2010)
IT-Col	41.85	13.59	DBF	SUBT	96-06	(Van Dijk and Dolman 2004)
IT-Cpz	41.71	12.38	EBF	SUBT	97,00-06	(Garbulsky *et al.* 2008)
IT-Lav	45.96	11.28	ENF	TEM	00-02,04,06	(Marcolla *et al.* 2003)
IT-Lec	43.30	11.27	EBF	SUBT	05-06	(Groenendijk *et al.* 2011)
IT-Lma	45.58	7.15	GR	TEM	03-06	--
IT-Mal	46.12	11.70	GR	TEM	03-06	(Gilmanov *et al.* 2007)
IT-Mbo	46.02	11.05	GR	TEM	03-06	(Migliavacca *et al.* 2009)
IT-Non	44.69	11.09	DBF	SUBT	01-02,03,06	(Reichstein *et al.* 2005)
IT-Pt1	45.20	9.06	DBF	SUBT	02-04	(Gilmanov *et al.* 2007)
IT-Ren	46.59	11.43	ENF	TEM	99-06	(Montagnani *et al.* 2009)
IT-Ro1	42.41	11.93	DBF	SUBT	00-05	(Rey *et al.* 2002)
IT-Ro2	42.39	11.92	DBF	SUBT	02-06	(Tedeschi *et al.* 2006)
IT-Sro	43.73	10.28	ENF	SUBT	99-06	(Chiesi *et al.* 2005)
IT-Vig	45.32	8.85	DBF	SUBT	04-05	--
JP-Mas	36.05	140.03	CR	SUBT	02-03	--
JP-Tak	36.15	137.42	DBF	TEM	99-04	--
JP-Tef	45.06	142.11	ENF	TEM	01-02,04-05	(Migliavacca *et al.* 2011)
JP-Tom	42.74	141.52	MF	TEM	01-03	(Groenendijk *et al.* 2011)
KR-Hnm	34.55	126.57	DBF	TEM	04-06	--
KR-Kw1	37.75	127.16	ENF	TEM	04-07	(Kang *et al.* 2003)
NL-Ca1	51.97	4.93	GR	TEM	03-06	(Gilmanov *et al.* 2007)
NL-Hor	52.03	5.07	GR	TEM	04-06	(Jacobs *et al.* 2007)
NL-Loo	52.17	5.74	ENF	TEM	96-06	(Dolman *et al.* 2002)

PL-Wet	52.76	16.31	WET	TEM	04-05	(Chojnicki *et al.* 2007)
PT-Esp	38.64	-8.60	EBF	SUBT	02-04,06	--
RU-Fyo	56.46	32.92	ENF	TEM	98-06	(Kurbatova *et al.* 2008)
RU-Ha1	54.73	90.00	GR	BOR	02-04	(Chevallier *et al.* 2006)
SE-Abi	68.36	18.79	ENF	BOR	2005	--
SE-Deg	64.18	19.55	WET	BOR	01-05	(Sagerfors *et al.* 2008)
SE-Faj	56.27	13.55	WET	TEM	05-06	(Lund *et al.* 2007)
SE-Fla	64.11	19.46	ENF	BOR	96-98,00-02	(Lindroth *et al.* 2008)
SE-Nor	60.09	17.48	EBF	TEM	96-99,03,05	--
SE-Sk1	60.13	17.92	ENF	TEM	2005	--
SE-Sk2	60.13	17.84	ENF	TEM	04-05	--
UK-Ebu	55.87	-3.21	GR	TEM	04，06	(Yi *et al.* 2010)
UK-Esa	55.91	-2.86	CR	TEM	03-05	(Groenendijk *et al.* 2011)
UK-Gri	56.61	-3.80	ENF	TEM	97-98,00-01,05-06	(Rebmann *et al.* 2005)
UK-Ham	51.12	-0.86	DBF	TEM	04-05	--
UK-Pl3	51.45	-1.27	DBF	TEM	05-06	--
US-Arb	35.55	-98.04	GR	TEM	05-06	(Migliavacca *et al.* 2011)
US-Arc	36.93	-96.68	GR	SUBT	05-06	(Yi *et al.* 2010)
US-Arm	36.61	-97.49	CR	SUBT	03-06	(Fischer *et al.* 2007)
US-Aud	31.59	-110.51	GR	TEM	02-06	(Yi *et al.* 2010)
US-Bar	44.06	-71.29	DBF	TEM	04-05	(Jenkins *et al.* 2007)
US-Bkg	44.35	-96.84	GR	TEM	04-06	(Gilmanov *et al.* 2005)
US-Bn1	63.92	-145.38	ENF	BOR	2003	--
US-Bn2	63.92	-145.38	ENF	BOR	2003	--
US-Bn3	63.92	-145.74	ENF	BOR	2003	--
US-Bo1	40.01	-88.29	CR	TEM	96-07	(Migliavacca *et al.* 2011)
US-Bo2	40.01	-88.29	CR	TEM	04-06	(Migliavacca *et al.* 2011)
US-Cav	39.06	-79.42	GR	TEM	04-05	(Groenendijk *et al.* 2011)
US-Dk1	35.97	-79.09	GR	SUBT	01-05	(Oren *et al.* 2006)
US-Dk2	35.97	-79.10	DBF	SUBT	03-05	(Pataki and Oren 2003)
US-Dk3	35.98	-79.09	ENF	SUBT	01-05	(Pataki and Oren 2003)
US-Fmf	35.14	-111.73	ENF	TEM	05-06	(Dore *et al.* 2008)
US-Fpe	48.31	-105.10	GR	TEM	00-06	(Yi *et al.* 2010)
US-Fr2	29.95	-98.00	WSA	SUBT	04-06	(Heinsch *et al.* 2004)
US-Fuf	35.09	-111.76	ENF	TEM	05-06	(Dore *et al.* 2008)
US-Fwf	35.45	-111.77	ENF	TEM	05-06	(Dore *et al.* 2008)
US-Goo	34.25	-89.87	GR	SUBT	02-06	(Yi *et al.* 2010)
US-Ha1	43.54	-72.17	DBF	TEM	01-06	(Urbanski *et al.* 2007)
US-Ho1	45.20	-68.74	ENF	TEM	96-04	(Hollinger *et al.* 2004)

US-Ho2	45.21	-68.75	ENF	TEM	99-04	(Oren *et al.* 2006)
US-Ib1	41.86	-88.22	CR	TEM	05-07	(Hollinger *et al.* 2004)
US-Ib2	41.84	-88.24	GR	TEM	04-07	(Hollinger *et al.* 2004)
US-Ivo	68.49	-155.75	WET	BOR	03-06	(Epstein *et al.* 2004)
US-Ks2	28.46	-80.67	ENF	SUBT	00-06	(Li *et al.* 2003)
US-Lph	42.54	-72.19	DBF	TEM	02-05	(Li *et al.* 2003)
US-Me2	44.45	121.56	ENF	SUBT	03-05	(Sun *et al.* 2004)
US-Me3	44.32	-121.61	ENF	SUBT	04-05	(Sun *et al.* 2004)
US-Mms	39.32	-86.41	DBF	SUBT	99-05	(Schmid *et al.* 2000)
US-Moz	44.32	-121.61	ENF	SUBT	04-06	(Gu *et al.* 2006)
US-Nc1	35.81	-76.71	OSH	SUBT	05-06	(Noormets *et al.* 2010)
US-Ne1	41.17	-96.48	CR	TEM	01-05	(Richardson *et al.* 2006)
US-Ne2	41.16	-96.47	CR	TEM	02-05	(Richardson *et al.* 2006)
US-Ne3	41.18	-96.44	CR	TEM	01-05	(Richardson *et al.* 2006)
US-Nr1	40.03	-105.55	ENF	BOR	99-00,02-03	(Monson *et al.* 2002)
US-Oho	41.55	-83.84	DBF	TEM	04-05	(DeForest *et al.* 2006)
US-Pfa	45.95	-90.27	MF	TEM	96-00,03	(Davis *et al.* 2003)
US-Sp1	29.74	-82.22	ENF	SUBT	00-01,05	(Migliavacca *et al.* 2011)
US-Sp2	29.76	-82.24	ENF	SUBT	98-04	(Migliavacca *et al.* 2011)
US-Sp3	29.75	-82.16	ENF	SUBT	99-04	(Migliavacca *et al.* 2011)
US-Srm	31.82	-110.87	WSA	TEM	04-06	(Scott *et al.* 2009)
US-Syv	46.24	-89.35	MF	TEM	02-06	(Desai *et al.* 2005)
US-Umb	45.56	-84.71	DBF	TEM	99-03	(Gough *et al.* 2008)
US-Wbw	35.96	-84.29	DBF	SUBT	95-99	--
US-Wcr	45.81	-90.08	DBF	TEM	99-06	(Cook *et al.* 2004)
US-Wkg	31.74	-109.94	GR	TEM	04-06	(Scott *et al.* 2010)
US-Wrc	45.82	-121.95	ENF	TEM	98-06	(Falk *et al.* 2008)

Ecosystem type: DBF: deciduous broadleaf forests; EBF: evergreen broadleaf forests; ENF: evergreen needle leaf forests; GR: grasslands; CR: croplands; MF: mixed deciduous and evergreen forests; WSA, woody savannas; OSH: open shrub; WET: wetlands. Climate types: TEM: temperate, BOR: boreal, SUBT: subtropical. *Positive value indicates north latitude. *Negative value indicates west longitude. The data in the table came from www.fluxdata.org.

Figure S1 Geographical distribution of the eddy flux tower sites involved in this study. The green ones are the sites analyzed for interannual variability.



References

Ammann C, Flechard CR, Leifeld J, *et al.* (2007) The carbon budget of newly established temperate grassland depends on management intensity. *Agr Ecosyst Environ* **121**:5-20.

Anthoni PM, Knohl A, Rebmann C, *et al.* (2004) Forest and agricultural land-use-dependent CO_2 exchange in Thuringia, Germany. *Glob Change Biol* **10**:2005-2019.

Aubinet M, Chermanne B, Vandenhaute M, *et al.* (2001) Long term carbon dioxide exchange above a mixed forest in the Belgian Ardennes. *Agr Forest Meteorol* **108**:293-315.

Berbigier P, Bonnefond JM, Mellmann P (2001) CO_2 and water vapour fluxes for 2 years above Euroflux forest site. *Agr Forest Meteorol* **108**:183-197.

Bergeron O, Margolis HA, Black TA, *et al.* (2007) Comparison of carbon dioxide fluxes over three boreal black spruce forests in Canada. *Glob Change Biol* **13**:89-107.

Black TA, Chen WJ, Barr AG, *et al.* (2000) Increased carbon sequestration by a boreal deciduous forest in years with a warm spring. *Geophys Res Lett* **27**:1271-1274.

Carrara A, Janssens IA, Yuste JC, *et al.* (2004) Seasonal changes in photosynthesis, respiration and NEE of a mixed temperate forest. *Agr Forest Meteorol* **126**:15-31.

Chen B, Ge Q, Fu D, *et al.* (2010) A data-model fusion approach for upscaling gross ecosystem productivity to the landscape scale based on remote sensing and flux footprint modelling. *Biogeosciences* **7**:2943-2958.

Chen JM, Govind A, Sonnentag O, *et al.* (2006) Leaf area index measurements at Fluxnet-Canada forest sites. *Agr Forest Meteorol* **140**:257-268.

Chen SP, Chen JQ, Lin GH, *et al.* (2009) Energy balance and partition in Inner Mongolia steppe ecosystems with different land use types. *Agr Forest Meteorol* **149**:1800-1809.

Chen ZY, Li B, Zhong Y, *et al.* (2004) Local competitive effects of introduced Spartina alterniflora on Scirpus mariqueter at Dongtan of Chongming Island, the Yangtze River estuary and their potential ecological consequences. *Hydrobiologia* **528**:99-106.

Chevallier F, Viovy N, Reichstein M, *et al.* (2006) On the assignment of prior errors in Bayesian inversions of CO_2 surface fluxes. *Geophys Res Lett* **33**.

Chiesi M, Maselli F, Bindi M, *et al.* (2005) Modelling carbon budget of mediterranean forests using ground and remote sensing measurements. *Agr Forest Meteorol* **135**:22-34.

Chojnicki BH, Ukbaniak M, Jozefczyk D, *et al.* (2007). Measurements of gas and heat fluxes at Rzecin wetland. . In Okruszko T, et al. (eds) *Wetlands: Monitoring, modeling and management*, London: Taylor & Francis Group, 125-132.

Cook BD, Davis KJ, Wang WG, *et al.* (2004) Carbon exchange and venting anomalies in an upland deciduous forest in Northern Wisconsin, USA. *Agr Forest Meteorol* **126**:271-295.

Davis KJ, Bakwin PS, Yi CX, *et al.* (2003) The annual cycles of CO_2 and H_2O exchange over a northern mixed forest as observed from a very tall tower. *Glob Change Biol* **9**:1278-1293.

DeForest JL, Noormets A, McNulty SG, *et al.* (2006) Phenophases alter the soil respiration-temperature relationship in an oak-dominated forest. *International Journal of Biometeorology* **51**:135-144.

Desai AR, Bolstad PV, Cook BD, *et al.* (2005) Comparing net ecosystem exchange of carbon dioxide between an old-growth and mature forest in the upper Midwest, USA. *Agr Forest Meteorol* **128**:33-55.

Dolman AJ, Moors EJ, Elbers JA (2002) The carbon uptake of a mid latitude pine forest growing on sandy soil. *Agr Forest Meteorol* **111**:157-170.

Don A, Rebmann C, Kolle O, *et al.* (2009) Impact of afforestation-associated management changes on the carbon balance of grassland. *Glob Change Biol* **15**:1990-2002.

Dore S, Kolb TE, Montes-Helu M, *et al.* (2008) Long-term impact of a stand-replacing fire on ecosystem CO_2 exchange of a Ponderosa pine forest. *Glob Change Biol* **14**:1801-1820.

Dunn AL, Barford CC, Wofsy SC, *et al.* (2007) A long-term record of carbon exchange in a boreal black spruce forest: Means, responses to interannual variability, and decadal trends. *Glob Change Biol* **13**:577-590.

Epstein HE, Calef MP, Walker MD, *et al.* (2004) Detecting changes in arctic tundra plant communities in response to warming over decadal time scales. *Glob Change Biol* **10**:1325-1334.

Eugster W, Moffat AM, Ceschia E, *et al.* (2010) Management effects on European cropland respiration. *Agr Ecosyst Environ* **139**:346-362.

Falk M, Wharton S, Schroeder M, *et al.* (2008) Flux partitioning in an old-growth forest: Seasonal and interannual dynamics. *Tree Physiol* **28**:509-520.

Fischer ML, Billesbach DP, Berry JA, *et al.* (2007) Spatiotemporal variations in growing season exchanges of CO_2, H_2O, and sensible heat in agricultural fields of the southern Great Plains. *Earth Interact* **11**.

Flanagan LB, Adkinson AC (2011) Interacting controls on productivity in a northern Great Plains grassland and implications for response to ENSO events. *Glob Change Biol* **17**:3293-3311.

Flanagan LB, Syed KH (2011) Stimulation of both photosynthesis and respiration in response to warmer and drier conditions in a boreal peatland ecosystem. *Global Change Biol* **17**:2271-2287.

Garbulsky MF, Penuelas J, Papale D, *et al.* (2008) Remote estimation of carbon dioxide uptake by a Mediterranean forest. *Glob Change Biol* **14**:2860-2867.

Giasson MA, Coursolle C, Margolis HA (2006) Ecosystem-level CO_2 fluxes from a boreal cutover in eastern Canada before and after scarification. *Agr Forest Meteorol* **140**:23-40.

Gilmanov TG, Soussana JE, Aires L, *et al.* (2007) Partitioning european grassland net ecosystem CO_2 exchange into gross primary productivity and ecosystem respiration using light response function analysis. *Agr Ecosyst Environ* **121**:93-120.

Gilmanov TG, Tieszen LL, Wylie BK, *et al.* (2005) Integration of CO_2 flux and remotely-sensed data for primary production and ecosystem respiration analyses in the northern Great Plains: Potential for quantitative spatial extrapolation. *Glob Ecol and Biogeography* **14**:271-292.

Gough CM, Vogel CS, Schmid HP, *et al.* (2008) Multi-year convergence of biometric and meteorological estimates of forest carbon storage. *Agr Forest Meteorol* **148**:158-170.

Goulden ML, Miller SD, da Rocha HR (2006) Nocturnal cold air drainage and pooling in a tropical forest. *J Geophys Res-Atmos* **111**:Doi 10.1029/2005jd006037.

Granier A, Ceschia E, Damesin C, *et al.* (2000) The carbon balance of a young beech forest. *Funct Ecol* **14**:312-325.

Groenendijk M, Dolman AJ, van der Molene MK, *et al.* (2011) Assessing parameter variability in a photosynthesis model within and between plant functional types using global fluxnet eddy covariacne data. *Agr Forest Meteorol*:22-38.

Gu Y, Liou KN, Xue Y, *et al.* (2006) Climatic effects of different aerosol types in China simulated by the UCLA general circulation model. *J Geophys Res-Atmos* **111**:Doi 10.1029/2005jd006312.

Guan DX, Wu JB, Zhao XS, *et al.* (2006) CO_2 fluxes over an old, temperate mixed forest in northeastern China. *Agr Forest Meteorol* **137**:138-149.

Heinsch FA, Heilman JL, McInnes KJ, *et al.* (2004) Carbon dioxide exchange in a high marsh on the texas gulf coast: Effects of freshwater availability. *Agr Forest Meteorol* **125**:159-172.

Hollinger DY, Aber J, Dail B, *et al.* (2004) Spatial and temporal variability in forest-atmosphere CO_2 exchange. *Glob Change Biol* **10**:1689-1706.

Howard EA, Gower ST, Foley JA, *et al.* (2004) Effects of logging on carbon dynamics of a Jack pine forest in Saskatchewan, Canada. *Glob Change Biol* **10**:1267-1284.

Humphreys ER, Black TA, Morgenstern K, *et al.* (2006) Carbon dioxide fluxes in coastal douglas-fir stands at different stages of development after clearcut harvesting. *Agr Forest Meteorol* **140**:6-22.

Jacobs CMJ, Jacobs AFG, Bosveld FC, *et al.* (2007) Variability of annual CO_2 exchange from dutch grasslands. *Biogeosciences* **4**:803-816.

Jaksic V, Kiely G, Albertson J, *et al.* (2006) Net ecosystem exchange of grassland in contrasting wet and dry years. *Agr Forest Meteorol* **139**:323-334.

Jenkins JP, Richardson AD, Braswell BH, *et al.* (2007) Refining light-use efficiency calculations for a deciduous forest canopy using simultaneous tower-based carbon flux and radiometric measurements. *Agr Forest Meteorol* **143**:64-79.

Kang SY, Doh S, Lee D, *et al.* (2003) Topographic and climatic controls on soil respiration in six temperate mixed-hardwood forest slopes, Korea. *Glob Change Biol* **9**:1427-1437.

Knohl A, Schulze ED, Kolle O, *et al.* (2003) Large carbon uptake by an unmanaged 250-year-old deciduous forest in Central Germany. *Agr Forest Meteorol* **118**:151-167.

Kurbatova J, Li C, Varlagin A, *et al.* (2008) Modeling carbon dynamics in two adjacent spruce forests with different soil conditions in Russia. *Biogeosciences* **5**:969-980.

Lafleur PM, Roulet NT, Bubier JL, *et al.* (2003) Interannual variability in the peatland-atmosphere carbon dioxide exchange at an ombrotrophic bog. *Glob Biogeochem Cy* **17**:Doi 10.1029/2002gb001983.

Li JH, Dugas WA, Hymus GJ, *et al.* (2003) Direct and indirect effects of elevated CO_2 on transpiration from quercus myrtifolia in a scrub-oak ecosystem. *Glob Change Biol* **9**:96-105.

Lindroth A, Klemedtsson L, Grelle A, *et al.* (2008) Measurement of net ecosystem exchange, productivity and respiration in three spruce forests in sweden shows unexpectedly large soil carbon losses. *Biogeochemistry* **89**:43-60.

Lund M, Lindroth A, Christensen TR, *et al.* (2007) Annual CO_2 balance of a temperate bog. *Tellus B* **59**:804-811.

Marcolla B, Pitacco A, Cescatti A (2003) Canopy architecture and turbulence structure in a coniferous forest. *Bound-Lay Meteorol* **108**:39-59.

McCaughey JH, Pejam MR, Arain MA, *et al.* (2006) Carbon dioxide and energy fluxes from a boreal mixedwood forest ecosystem in ontario, canada. *Agr Forest Meteorol* **140**:79-96.

Migliavacca M, Meroni M, Busetto L, *et al.* (2009) Modeling gross primary production of agro-forestry ecosystems by assimilation of satellite-derived information in a process-based model. *Sensors-Basel* **9**:922-942.

Migliavacca M, Reichstein M, Richardson AD, *et al.* (2011) Semiempirical modeling of abiotic and biotic factors controlling ecosystem respiration across eddy covariance sites. *Glob Change Biol* **17**:390-409.

Monson RK, Turnipseed AA, Sparks JP, *et al.* (2002) Carbon sequestration in a high-elevation, subalpine forest. *Glob Change Biol* **8**:459-478.

Montagnani L, Manca G, Canepa E, *et al.* (2009) A new mass conservation approach to the study of CO_2 advection in an alpine forest. *J Geophys Res-Atmos* **114**:Doi 10.1029/2008jd010650.

Moureaux C, Debacq A, Bodson B, *et al.* (2006) Annual net ecosystem carbon exchange by a sugar beet crop. *Agr Forest Meteorol* **139**:25-39.

Noormets A, Gavazzi MJ, Mcnulty SG, *et al.* (2010) Response of carbon fluxes to drought in a coastal plain loblolly pine forest. *Glob Change Biol* **16**:272-287.

Oren R, Hseih CI, Stoy P, *et al.* (2006) Estimating the uncertainty in annual net ecosystem carbon exchange: Spatial variation in turbulent fluxes and sampling errors in eddy-covariance measurements. *Glob Change Biol* **12**:883-896.

Pataki DE, Oren R (2003) Species differences in stomatal control of water loss at the canopy scale in a mature bottomland deciduous forest. *Adv Water Resour* **26**:1267-1278.

Peichl M, Arain AA (2006) Above- and belowground ecosystem biomass and carbon pools in an age-sequence of temperate pine plantation forests. *Agr Forest Meteorol* **140**:51-63.

Pilegaard K, Mikkelsen TN, Beier C, *et al.* (2003) Field measurements of atmosphere-biosphere interactions in a danish beech forest. *Boreal Environ Res* **8**:315-333.

Pinter K, Barcza Z, Balogh J, *et al.* (2008) Interannual variability of grasslands' carbon balance depends on soil type. *Community Ecol* **9**:43-48.

Rambal S, Joffre R, Ourcival JM, *et al.* (2004) The growth respiration component in eddy CO_2 flux from a Quercus Ilex Mediterranean forest. *Glob Change Biol* **10**:1460-1469.

Rebmann C, Gockede M, Foken T, *et al.* (2005) Quality analysis applied on eddy covariance measurements at complex forest sites using footprint modelling. *Theor Appl Climatol* **80**:121-141.

Rebmann C, Zeri M, Lasslop G, *et al.* (2010) Treatment and assessment of the CO_2-exchange at a complex forest site in Thuringia, Germany. *Agr Forest Meteorol* **150**:684-691.

Reichstein M, Falge E, Baldocchi D, *et al.* (2005) On the separation of net ecosystem exchange into assimilation and ecosystem respiration: Review and improved algorithm. *Glob Change Biol* **11**:1424-1439.

Rey A, Pegoraro E, Tedeschi V, *et al.* (2002) Annual variation in soil respiration and its components in a coppice oak forest in central Italy. *Glob Change Biol* **8**:851-866.

Richardson AD, Hollinger DY, Burba GG, *et al.* (2006) A multi-site analysis of random error in tower-based measurements of carbon and energy fluxes. *Agr Forest Meteorol* **136**:1-18.

Sagerfors J, Lindroth A, Grelle A, *et al.* (2008) Annual CO_2 exchange between a nutrient-poor, minerotrophic, boreal mire and the atmosphere. *J Geophys Res-Biogeo* **113**.

Schmid HP, Grimmond CSB, Cropley F, *et al.* (2000) Measurements of CO_2 and energy fluxes over a mixed hardwood forest in the mid-western united states. *Agr Forest Meteorol* **103**:357-374.

Scott RL, Hamerlynck EP, Jenerette GD, *et al.* (2010) Carbon dioxide exchange in a semidesert grassland through drought-induced vegetation change. *J Geophys Res-Biogeo* **115**:Doi 10.1029/2010jg001348.

Scott RL, Jenerette GD, Potts DL, *et al.* (2009) Effects of seasonal drought on net carbon dioxide exchange from a woody-plant-encroached semiarid grassland. *J Geophys Res-Biogeo* **114**.

Staudt. K, Foken T (2007) Documentation of reference data for the experimental areas of the bayreuth centre for ecology and environmental research (bayceer) at the Waldstein site. *Arbeitsergebn, Univ Bayreuth, Abt Mikrometeorol*:35.

Sun OJ, Campbell J, Law BE, *et al.* (2004) Dynamics of carbon stocks in soils and detritus across chronosequences of different forest types in the pacific northwest, USA. *Glob Change Biol* **10**:1470-1481.

Suni T, Rinne J, Reissell A, *et al.* (2003) Long-term measurements of surface fluxes above a scots pine forest in Hyytiala, southern Finland, 1996-2001. *Boreal Environ Res* **8**:287-301.

Tedeschi V, Rey A, Manca G, *et al.* (2006) Soil respiration in a mediterranean oak forest at different developmental stages after coppicing. *Glob Change Biol* **12**:110-121.

Urbanski S, Barford C, Wofsy S, *et al.* (2007) Factors controlling CO_2 exchange on timescales from hourly to decadal at Harvard forest. *J Geophys Res-Biogeo* **112**:-.

Valentini R, Matteucci G, Dolman AJ, *et al.* (2000) Respiration as the main determinant of carbon balance in European forests. *Nature* **404**:861-865.

Van Dijk AIJM, Dolman AJ (2004) Estimates of CO_2 uptake and release among European forests based on eddy covariance data. *Glob Change Biol* **10**:1445-1459.

van Gorsel E, Leuning R, Cleugh HA, *et al.* (2008) Application of an alternative method to derive reliable estimates of nighttime respiration from eddy covariance measurements in moderately complex topography. *Agr Forest Meteorol* **148**:1174-1180.

Veenendaal EM, Kolle O, Lloyd J (2004) Seasonal variation in energy fluxes and carbon dioxide exchange for a broad-leaved semi-arid savanna (mopane woodland) in southern Africa. *Glob Change Biol* **10**:318-328.

Wilske B, Lu N, Wei L, *et al.* (2009) Poplar plantation has the potential to alter the water balance in semiarid Inner Mongolia. *J Environ Manage* **90**:2762-2770.

Wohlfahrt G, Hammerle A, Haslwanter A, *et al.* (2008) Seasonal and inter-annual variability of the net ecosystem CO_2 exchange of a temperate mountain grassland: Effects of weather and management. *J Geophys Res-Atmos* **113**:-.

Yi C, Ricciuto D, Li R, *et al.* (2010) Climate control of terrestrial carbon exchange across biomes and continents. *Environ Res Lett* **5**:1-10.