SUPPLEMENTARY MATERIAL RELEVANT FOR THE FOLLOWING PAPER

Quantifying the constraint of biospheric process parameters by CO_2 concentration and flux measurement networks through a carbon cycle data assimilation system

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Note 1:

BETHY NEE diurnal variations against observations

1. Introduction

The above mentioned paper investigates the sensitivity of the process parameters of the biosphere model BETHY (Knorr, 2000) to choices of atmospheric concentration network, high frequency terrestrial fluxes, and the choice of flux measurement network by using a carbon cycle data assimilation system. For the flux measurements, we used BETHY generated fluxes as a proxy of the observations. To ensure that BETHY fluxes are reasonable, this note aims to compare BETHY net flux (NEE) to observations obtained from some selected sites of the FLUXNET network (e.g., Baldocchi, 2003 and Papale et al., 2006; see the dedicated website: http://www.fluxnet.ornl.gov). In fact, to infer the uncertainties in the model process parameters, we use the classical linear error propagation via the Jacobian of the model. This does not require the use of either real or synthetic data, but the uncertainties in these data.

2. Methodology

BETHY simulates only a diurnal variation of NEE for each month of the year. To compare these simulations to the observations, we first derived a mean diurnal cycle (hourly basis) from FLUXNET semi-hourly NEE data having a 'Free Fair Use" data policy (see http://www.fluxdata.org). We selected 20 sites that are located in a great part of the globe (Figure A1). The details (station names, ID, and coordinates (longitude/latitude)) of these sites are given in the Table A1. The comparisons of BETHY NEE to the FLUXNET observations are made mainly for the year 2001.

3. Results

This note does not intend to discuss the sources of the differences between the observations and the modeled fluxes, but to give only the main differences between the two data sets. Overall, BETHY NEEs confronted to the observations obtained from the 20 selected FLUXNET sites do show 5 main characteristics (see Figures A2 to A8):

- The phasing of the diurnal cycle of modeled NEE is generally in a fairly good agreement with the ones derived from the observations
- The amplitudes of the modeled NEE are larger than the observed ones for most of the selected cases during spring and summer seasons
- The use of the optimized parameters of BETHY as performed in Koffi et al. (2012), when using only CO_2 concentrations to constrain the process parameters of BETHY, decreases the amplitudes of modeled NEE at some sites. Moreover, as expected, in some cases, the optimized parameters improve the fitting of the modeled fluxes to the observations (e.g., cases of AU-Thum and BE-Vie (Fig. A2), SE-Fla (Fig.A6), US-Los (Fig. A7), and US-SP2 (Fig.A8)). Note also that in some cases (e.g. US-Blo in Fig. A7), the optimization process decreases the model performance.
- The simulated onset of the growing season is delayed at most of the sites (e.g., FR-Pue and IT-Ro1 (Fig. A5), SE-Fla (Fig. A6), and UK-Gri (Fig. A7)).
- Finally, in general the model seems to perform equally for the different selected PFTs

These results are encouraging and can be expected to be significantly improved. Indeed, in the present study, the BETHY fluxes are obtained by using daily meteorological, phenological, and soil data averaged over a large grid cell (2x2 degrees latitude/longitude) and also this cell can contain only up to 3 PFTs. Consequently, by using fine meteorological, phonological, and soil data measured at each of these sites would undoubtedly improve the results.

4. Conclusions

BETHY fluxes compare quite well to the observations, hence the use of these simulated fluxes as a proxy of the measurements is reasonable. The modeled fluxes are generally found to be larger than the observed ones, hence the uncertainties in the flux as characterized in this work can be overestimated in some cases and then render the conclusions of the work enough robust. Indeed, we have considered the uncertainties in flux to be 25% and 75% of the modeled fluxes. For more details, see the manuscript of the paper.

Table A1: The names, IDs, and the coordinates (longitude and latitude) of 20 selected FLUXNET sites are given. The dominant PFT in the cell of BETHY that encompasses the FLUXNET site together with their percentage of coverage relative to the total area of the cell are also reported. The PFTs of BETHY are defined in Figure 2 of the paper.

FLUXNET				BETHY	
Station Name	**Station ID**	**Longitude (o)**	**Latitude (o)**	**Dominant PFT of BETHY cell**	**Percentage of coverage of the dominant PFT**
Howard Springs	AU-How	131.152	-12.494	10	0.54
Tumbarumba	AU-Tum	148.152	-35.656	9	0.60
Vielsalm	BE-Vie	5.997	50.306	13	0.54
Santarem-Km83-Logged Forest	BR-Sa3	-54.971	-3.018	1	0.9
Maun- Mopane Woodland	BW-Ma1	23.56	-19.916	10	0.49
UCI-1930 burn site	CA-NS2	-98.524	55.906	5	0.9
Bily Kriz- Beskidy Mountains	CZ-BK1	18.538	49.503	9	0.72
Hainich	DE-Hai	10.452	51.079	13	0.60
El Saler	ES-ES1	-0.319	39.346	9	0.39
Hyytiala	FI-Hyy	24.295	61.847	5	0.46
Puechabon	FR-Pue	3.596	43.741	9	0.44
Roccarespampani 1	IT-Ro1	11.93	42.408	9	0.38
Fyodorovskoye wet spruce stand	RU-Fyo	32.923	56.461	4	0.40
Zotino	RU-Zot	89.350	60.800	5	0.77
Flakaliden	SE-Fla	19.457	64.113	5	0.65
Griffin- Aberfeldy-Scotland	UK-Gri	-3.798	56.607	13	0.55
CA - Blodgett Forest	US-Blo	-120.633	38.895	4	0.42
WI - Lost Creek	US-Los	-89.979	46.083	4	0.65
FL - Slashpine-Mize-clearcut-3yr,regen	US-SP2	-82.245	29.765	4	0.52
Skukuza- Kruger National Park	ZA-Kru	31.497	-25.02	10	0.47

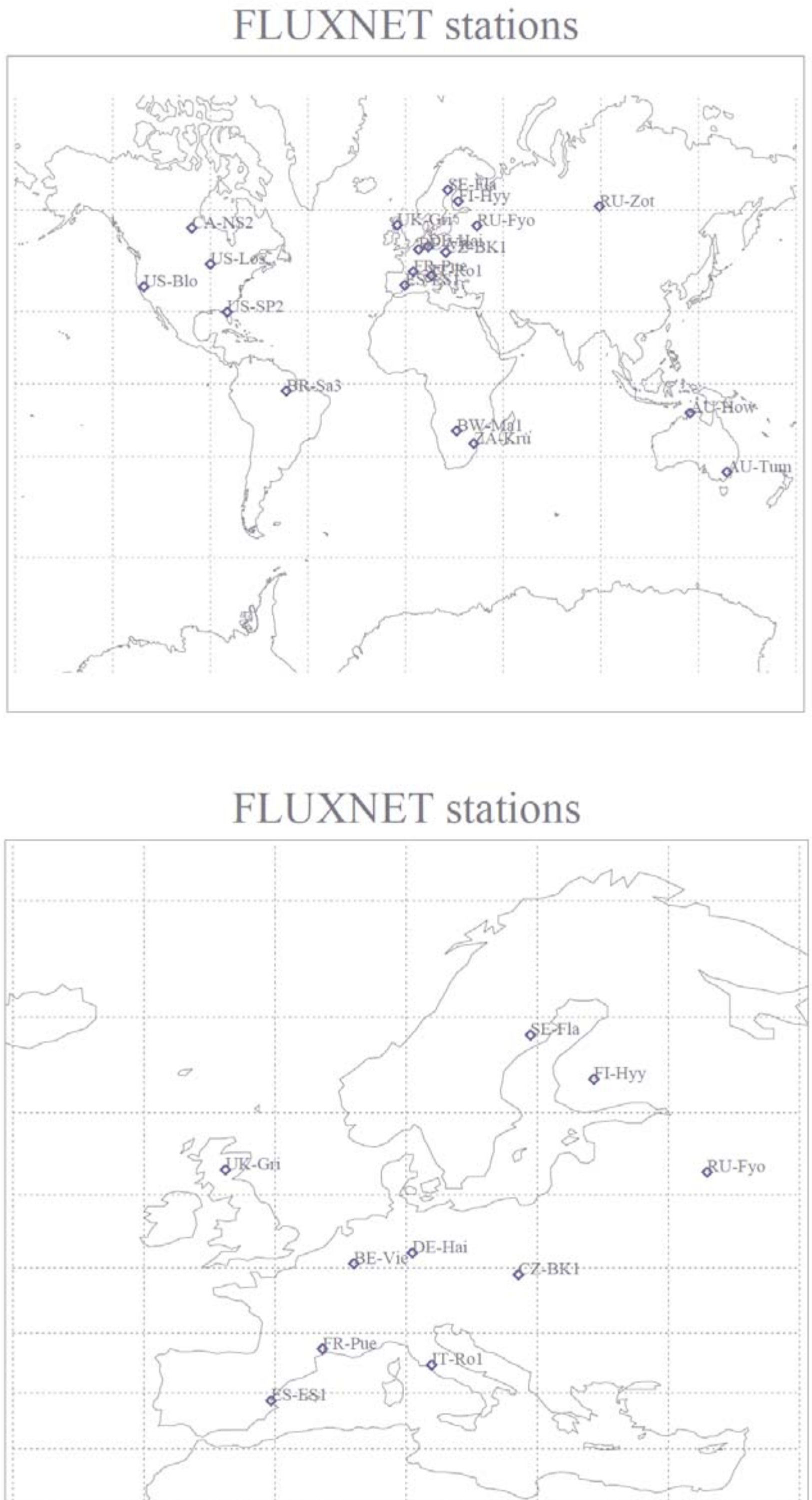

Figure A1: Locations of the selected 20 FLUXNET sites used for the comparison. The stations' IDs are shown. The station names together with the coordinates are described in the Table A1.

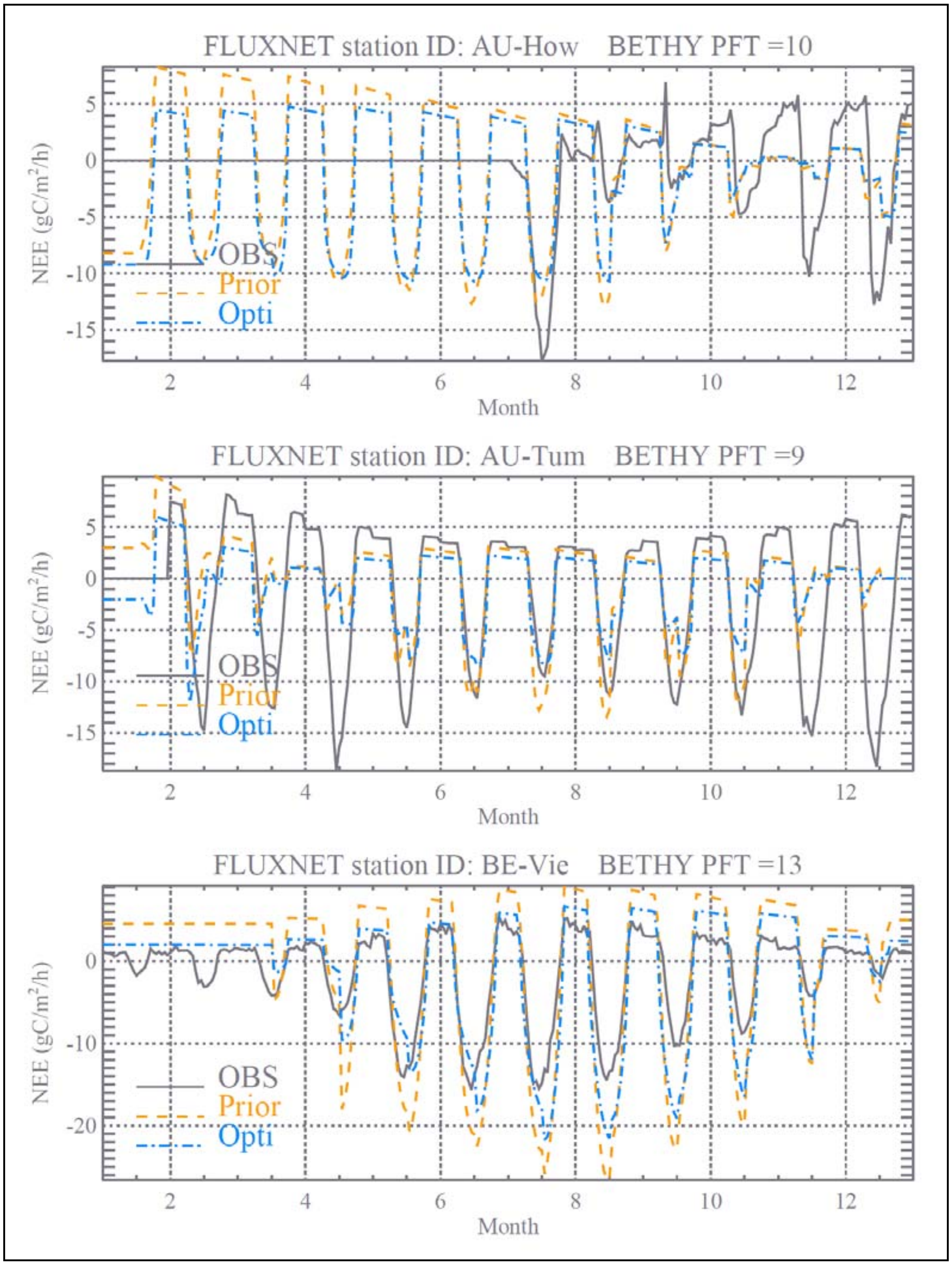

Figure A2: Mean diurnal variations of NEE at some selected FLUXNET sites. The observed NEE (black solid line), the BETHY simulations by using the prior values (orange dashed line) and optimized values (blue dashed dot line) obtained by using only observed CO_2 concentrations (Koffi et al., 2012) of the process parameters are shown. The FLUXNET station details (i.e., station name, ID, and location latitude and longitude) are described in the Table A1. The FLUXNET station ID and the PFT of BETHY that encompasses the FLUXNET site are given. The year 2001 is considered.

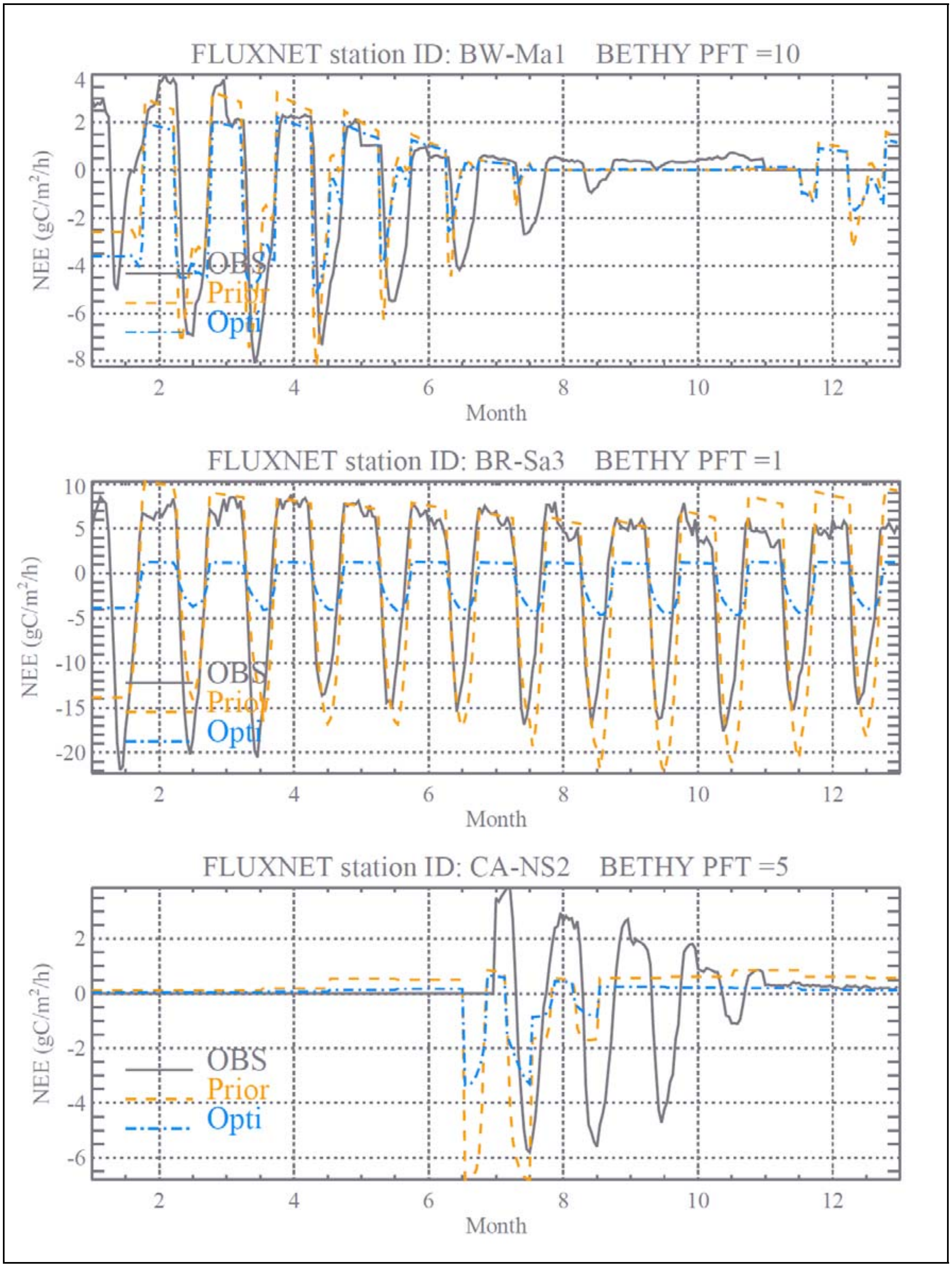

Figure A3: As Figure A2, but for other stations.

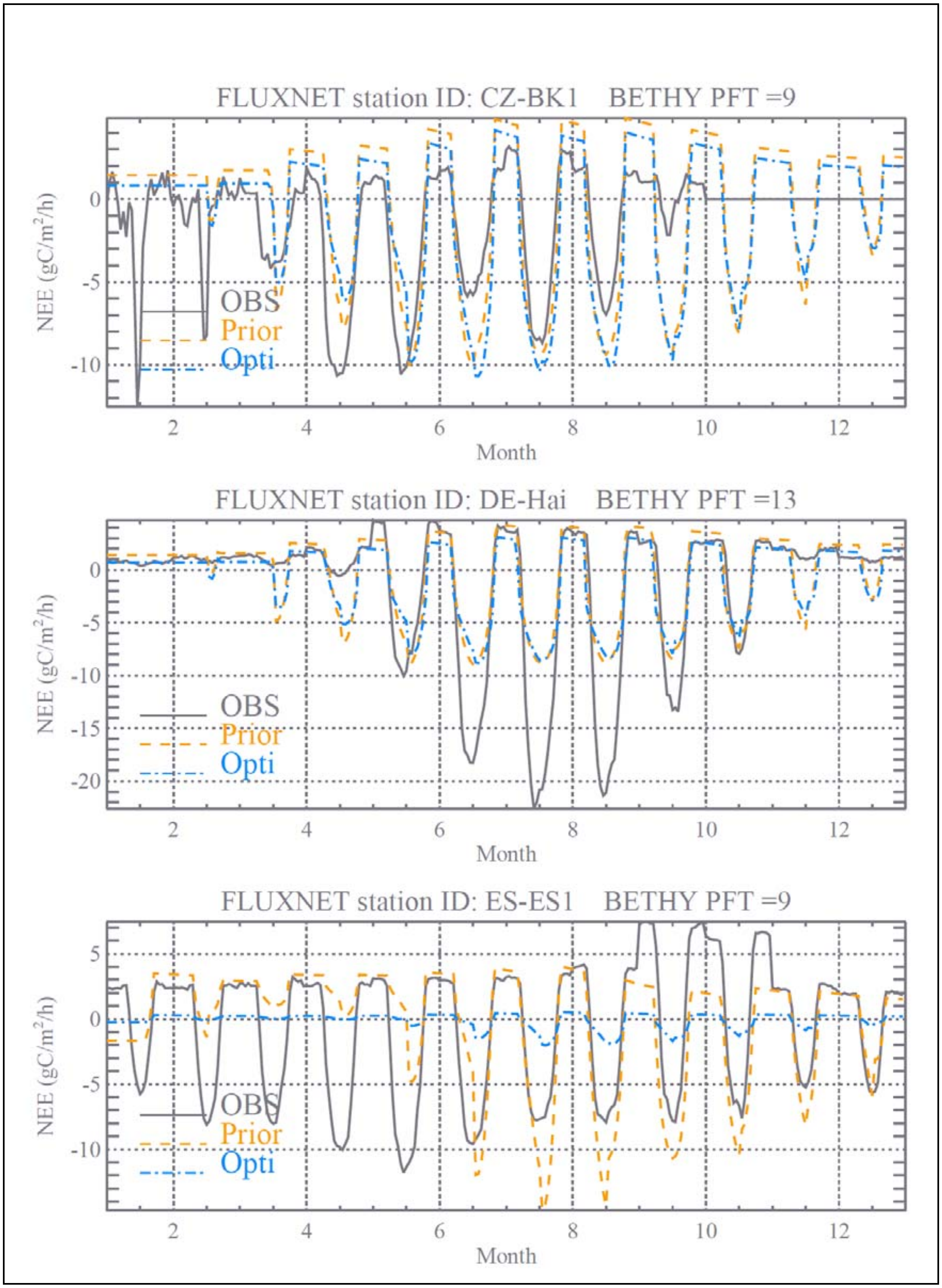

Figure A4: As Figure A2, but for other stations.

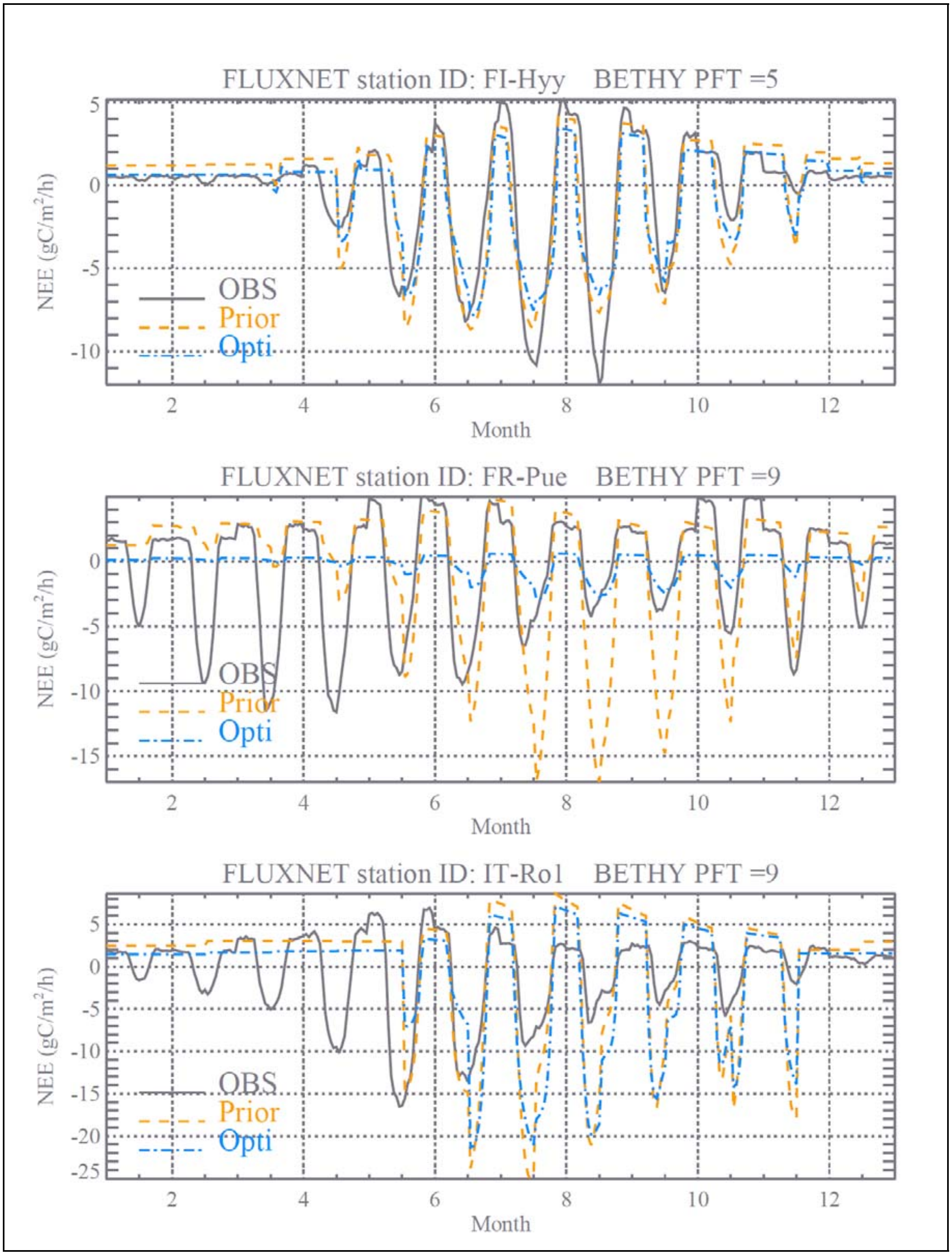

Figure A5: As Figure A2, but for other stations.

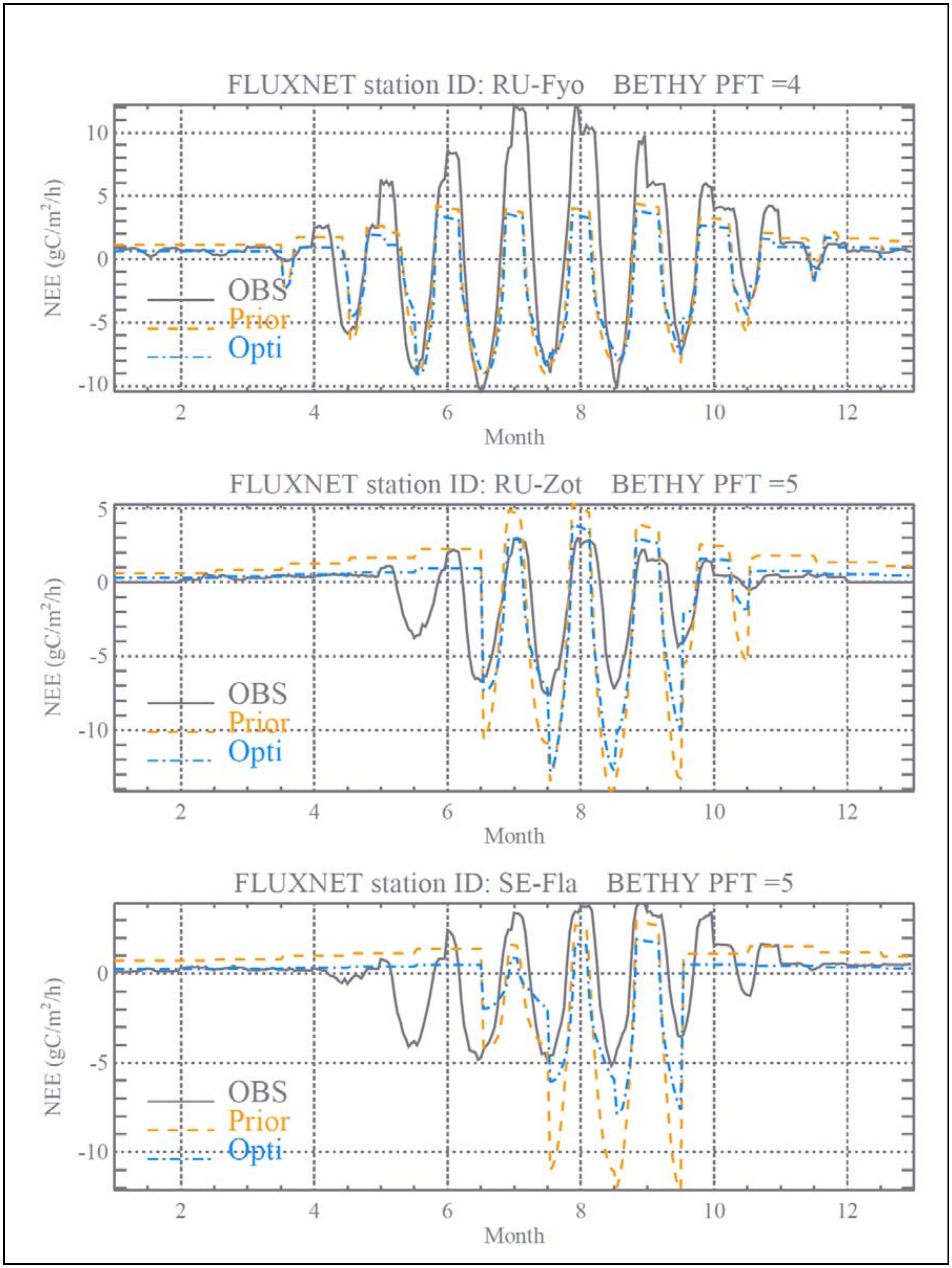

Figure A6: As Figure A2, but for other stations. Data for RU-Zot are for 2002.

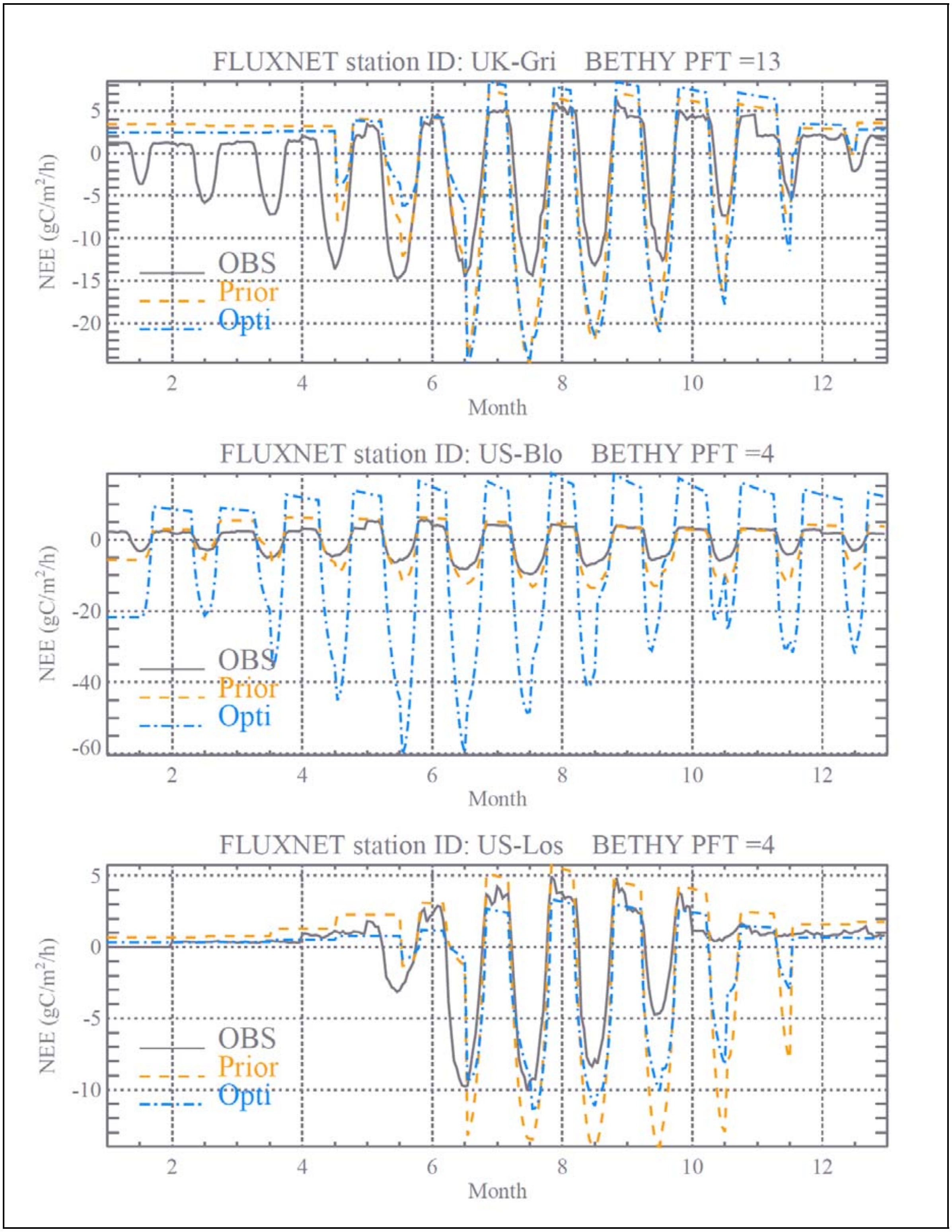

Figure A7: As Figure A2, but for other stations.

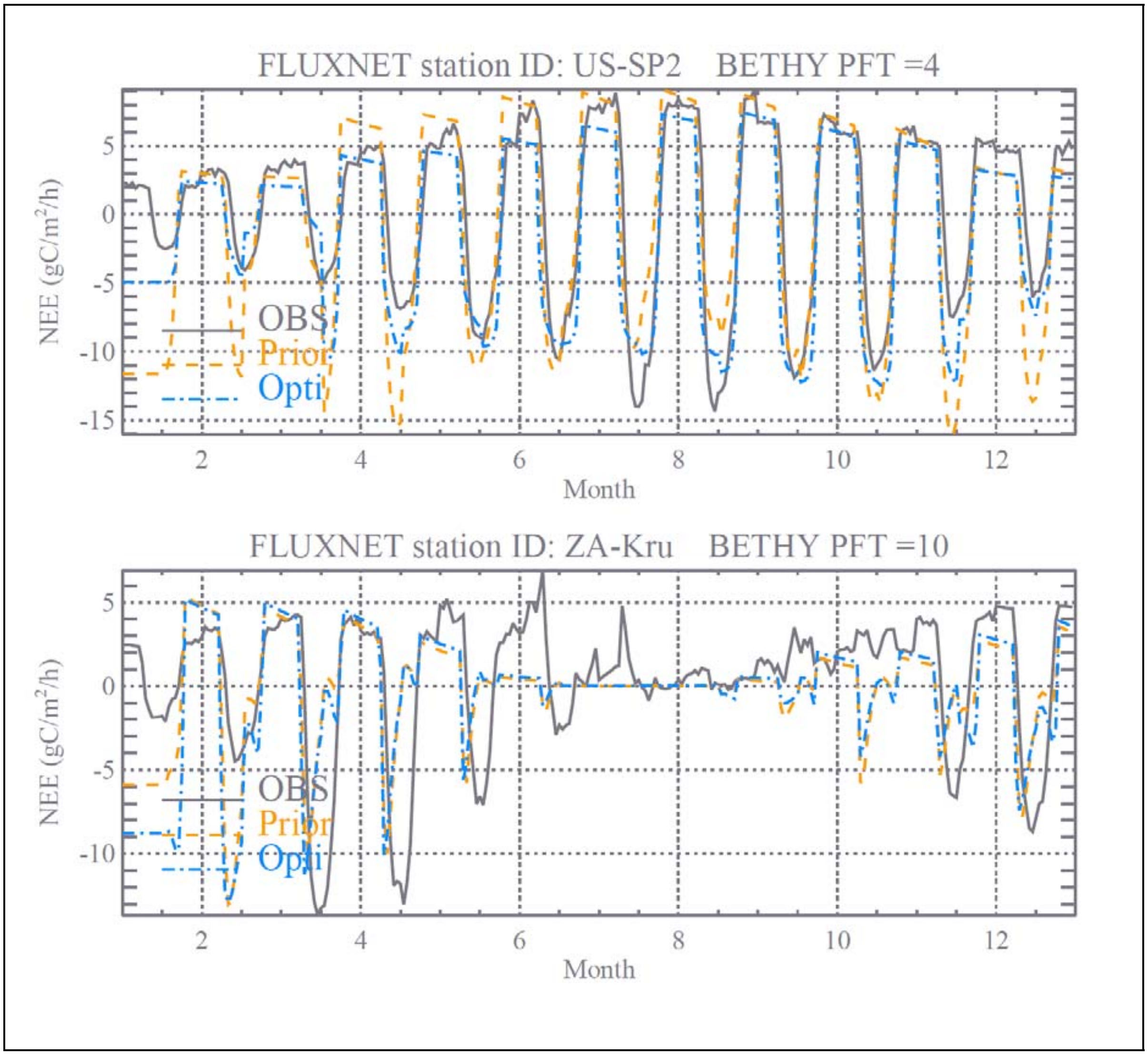

Figure A8: As Figure A2, but for other stations.

References

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Note 2:

CO2 measurements

We summarize the characteristics of flask and continuous measurements for the stations used for CO_2 concentrations. We are using:

- 77 flask measurements among which 62 are common for CCDAS (i.e., M_{TM3}) and PYVAR (i.e., M_{PYV}). The remaining 15 sites are only for PYVAR (PYV and PYV_{all}). See the text of the paper (Section 5 for the different acronyms. We used full-day averages of flask measurements. The uncertainties in these measurements including model errors are summarized in Table A2.
- 27 sites with continuous measurements used only by PYVAR among which 9 sites have also flask measurements. We average data from continuous sites into 3 hour windows in the PYVAR system.
- The measurement uncertainties which here represent both the model and observation uncertainties are provided in the supplementary material (Table A2) for all the sites used in this study.

Table A2: The acronyms of the CO_2 measurement stations, their coordinates (longitude and latitude), their type of measurements (FM: flask measurements; CM: continuous measurements), and the uncertainties assigned to the concentrations are given. FM* stand for flask measurements, but only used in the PYVAR system. Note that the observational uncertainties included both the model and observation uncertainties. CCDAS used the pre-computed Jacobians of the transport model TM3. PYVAR is built around the transport model LMDz. For more details, see the text of the paper.

Station acronyms	Longitude (o)	Latitude (o)	Measurement type	Observational uncertainties (ppm)	
				CCDAS	PYVAR
alt	-62.52	82.45	FM	0.98	1.329
asc	-14.42	-7.92	FM	0.84	0.853
ask	5.4	23.1	FM	1.50	0.662
azr	-27.38	38.77	FM	2.79	2.112
bal	16.67	55.5	FM	4.99	6.078
bme	-64.65	32.37	FM	1.79	2.042
bmw	-64.88	32.27	FM	1.87	1.926
brw	-156.6	71.32	FM	1.24	1.922
cba	-162.72	55.2	FM	0.73	2.049
cgo	144.68	-40.68	FM	0.55	0.485
chr	-157.17	1.7	FM	0.65	0.695
cmn	10.7	44.1	FM	2.50	6.863
cmo	-123.97	45.48	FM	2.51	3.343
crz	51.85	-46.45	FM	0.61	0.848
eic	-109.45	-27.15	FM	0.81	1.805
gmi	144.78	13.43	FM	1.01	2.459
hba	-26.50	-75.58	FM	0.54	0.525
hun	16.60	46.9	FM	4.00	6.493
ice	-20.15	63.25	FM	1.12	1.584
itn	-77.30	35.3	FM	4.00	5.131
izo	-16.48	28.3	FM	0.97	2.621
key	-80.20	25.67	FM	1.14	4.632
kum	-154.82	19.52	FM	1.06	1.696
lef	-90.20	45.9	FM	4.00	12.45
maa	62.80	-67.6	FM	0.50	0.517

mbc	-119.35	76.25	FM	1.02	1.493
mhd	-9.90	53.33	FM	1.34	3.586
mid	-177.37	28.22	FM	1.11	1.309
mlo	-155.58	19.53	FM	0.82	0.997
mqa	158.90	-54.4	FM	1.5	0.517
nwr	-105.58	40.05	FM	1.4	1.964
pal	24.12	67.97	FM	3.00	3.22
poc000	-163.00	0.00	FM	1.50	1.164
pocn05	-158.00	5.00	FM	1.50	1.306
pocn10	-152.00	10.00	FM	1.50	2.054
pocn15	-147.00	15.00	FM	1.50	1.293
pocn20	-140.00	20.00	FM	1.50	1.827
pocn25	-134.00	25.00	FM	1.50	1.497
pocn30	-126.00	30.00	FM	1.50	1.551
pocs05	-168.00	-5.00	FM	1.50	0.794
pocs10	-174.00	-10.00	FM	1.50	1.294
pocs15	-178.00	-15.00	FM	1.50	0.893
pocs20	-178.50	-20.00	FM	1.50	0.932
pocs25	174.00	-25.00	FM	1.50	0.945
pocs30	169.00	-30.00	FM	1.50	0.814
prs	7.70	45.90	FM	4.00	5.268
psa	-64.00	-64.92	FM	0.54	0.518
rpb	-59.43	13.17	FM	0.80	1.361
sch	8.00	48	FM	1.50	4.414
sey	55.17	-4.67	FM	1.12	1.37
shm	174.10	52.72	FM	1.15	2.127
smo	-170.57	-14.25	FM	0.70	0.889
spo	-24.80	-89.98	FM	0.53	0.386
stm	2.00	66	FM	1.20	2.042
syo	39.58	-69	FM	0.50	0.522
tap	126.13	36.73	FM	0.50	5.822
tdf	-68.50	-54.9	FM	1.50	1.629
uta	-113.72	39.9	FM	2.01	2.53
uum	111.10	44.45	FM	1.9	2.354
wes	8.00	55	FM	3.00	23.653
wis	34.88	31.13	FM	2.36	2.408
wlg	100.90	36.29	FM	1.26	1.807
ams_ esrl	77.52	-37.78	FM*		0.44
cya_wdcgg	110.52	-66.27	FM*		0.37
cfa_ wdcgg	147.05	-19.27	FM*		1.88
csj_ wdcgg	-131.02	51.92	FM*		1.47
esp_ wdcgg	-126.53	49.37	FM*		2.53

kum_ esrl	-154.82	19.52	FM*		1.70
kzd_ esrl	75.57	44.45	FM*		3.25
kzm_ esrl	77.87	43.25	FM*		3.27
pta_ esrl	-123.72	38.95	FM*		5.79
scsn06_esrl	107.00	6.00	FM*		1.39
scsn09_ esrl	109.00	9.00	FM*		1.99
scsn12_ esrl	111.00	12.00	FM*		1.67
scsn15_ esrl	113.00	15.00	FM*		1.84
scsn18_ esrl	113.00	18.00	FM*		2.45
scsn21_ esrl	114.00	21.00	FM*		6.75
alt_wdcgg	-62.52	82.45	CM		3.60
amy_ wdcgg	126.32	36.52	CM		29.85
coi_ wdcgg	145.50	43.13	CM		7.78
cpt_ wdcgg	18.47	-34.35	CM		0.53
cya_ wdcgg	110.52	-66.27	CM		0.37
fsd_ wdcgg	-81.57	49.87	CM		10.36
hat_ wdcgg	123.78	24.05	CM		5.23
izo_ wdcgg	-16.50	28.3	CM		2.62
jbn_ wdcgg	-58.67	-62.22	CM		2.06
kot_ wdcgg	137.87	76.00	CM		2.02
kps_ wdcgg	19.55	46.97	CM		23.97
mlo_ esrl	-155.57	19.53	CM		1.00
mnm_ wdcgg	153.97	24.27	CM		3.51
ryo_ wdcgg	141.82	39.02	CM		11.73
snb_ wdcgg	12.93	47.03	CM		6.70
tkb_ wdcgg	140.12	36.03	CM		24.82
yon_ wdcgg	123.02	24.47	CM		7.02
cmn_ce	10.68	44.17	CM		6.90
hun0115_ce	16.63	46.95	CM		20.00
jfj_ce	7.98	46.53	CM		6.07
pal_ce	24.12	67.97	CM		9.70
prs_ce	7.70	45.92	CM		5.27
sch_ce	10.77	50.63	CM		4.41
smo_esrl	-170.57	-14.23	CM		0.89
spo_esrl	-24.80	-89.97	CM		0.39
wes_ce	8.32	54.92	CM		23.65
wkt_ esrl	-97.32	31.32	CM		11.93