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Modelling short-term variability in carbon and water exchange in a temperate Scots pine forest

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1. Calculation methods for plant available water (*wr*)

For the daily calculation of the plant water supply (S, Eq. (4)), LPJ-GUESS offers different methods to calculate available soil moisture in the rooting zone (*wr*), which is the ratio between current soil water content (*wcont*) and plant-available water capacity (*AWC*). The latter is dependent on soil type and texture, values for this study are provided in Sitch et al. (2003). The soil is represented using a simple bucket model with two layers. The upper layer (l_1) is 50 cm deep, and the lowest layer (l_2) is 100 cm deep. Water uptake (f_{uptake}) is calculated for each layer, taking into account foliar projective cover on each patch with scaling factor $fpc_{rescale}$, and then summed to calculate *wr*:

$$wr = \frac{wcont}{AWC} = f_{uptake[l_1]} + f_{uptake[l_2]} \quad (1)$$

The calculation of *wr* in each of the model setups S1 – S3 (Fig. S1)) is done as follows:

S1: *wr_rootdistr*

Uptake depending on root distribution (*rootdistr*) of the PFT. Values for root distributions of C_3 grass and *Pinus sylvestris* can be found in Table 1.

$$f_{uptake} = \min(wcont * AWC * fpc_{rescale}, E_{\max} * rootdistr) / E_{\max} \quad (2)$$

E_{max} being maximum possible transpiration rate under well watered conditions (5 mm/day). This uptake parameterization takes the minimum of two limiting processes: Plant water uptake is either limited by the current water content (*wcont*), or when water content is sufficient, uptake from each layer is a relative fraction of E_{max} depending on PFT root distribution.

S2: *wr_speciesspecific*

Uptake is species specific. More drought tolerant species have higher relative uptake rates. Values for drought tolerance ($drought_{tol}$) of C_3 grass and *Pinus sylvestris* can be found in Table 1. To limit the uptake of C_3 grass, a maximum relative uptake is defined as

$$f_{\max\_relative\_uptake} = wcont^{0.2} \quad (3)$$

$$f_{uptake} = rootdistr * \min(wcont^2 * drought_{tol}, f_{\max\_rel\_uptake} * fpc_{rescale}) \quad (4)$$

This uptake parameterization takes the minimum of two limiting processes: Plant water uptake is either limited by the current water content (*wcont*) and the species' drought tolerance, or when water content is sufficient, uptake from each layer is the maximum relative uptake corrected for foliar projective cover.

S3: *wr_wcont*

Uptake scales linear with water content and is depending on root distribution, similar to Haxeltine and Prentice (1996b).

$$f_{uptake} = rootdistr * wcont * fpc_{rescale} \quad (5)$$

This uptake parameterization always takes the current water content of a layer and multiplies this with species PFT root distribution and correcting for foliar projective cover.

The effect of these different uptake parameterizations on the errors for modelled daily GPP and AET are visualized in Fig. S2, by plotting the residuals (modelled minus observed fluxes) against *wcont* (depicted as Θ).

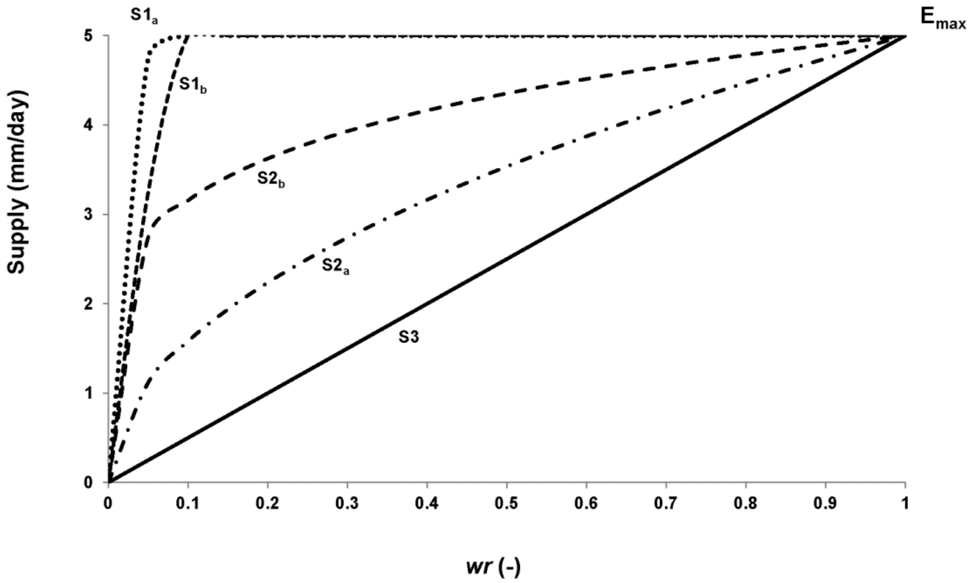


Fig. S1. Response curves for water uptake as a function of available soil moisture for selected plant species. S1a) *Pinus sylvestris*, uptake according to root distribution; S1b) C_3 grass, uptake according to root distribution; S2a) *Pinus sylvestris*, species specific uptake; S2b) C_3 grass, species specific uptake; S3) linear uptake (equal to original parameterization in Sitch et al. (2003)).

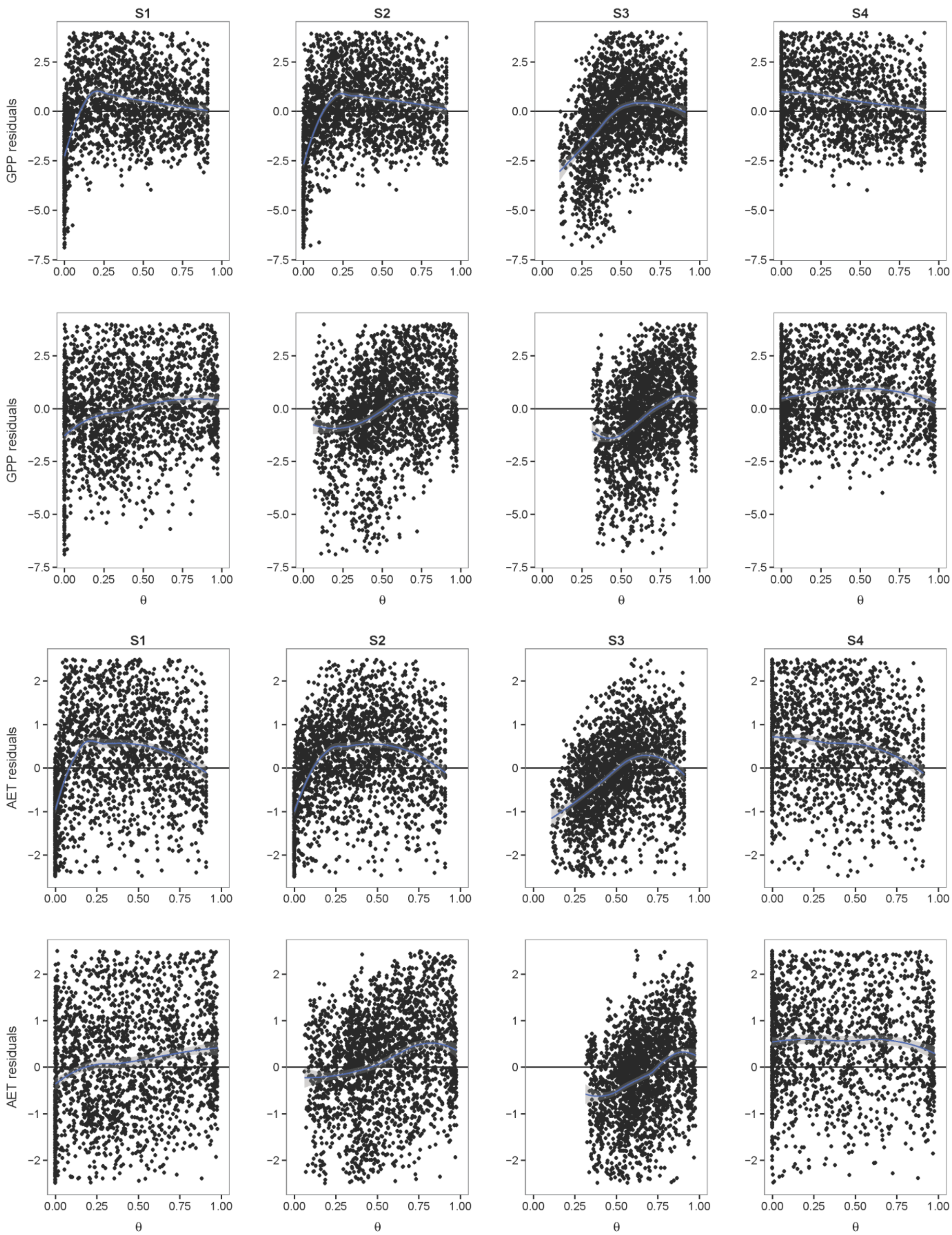
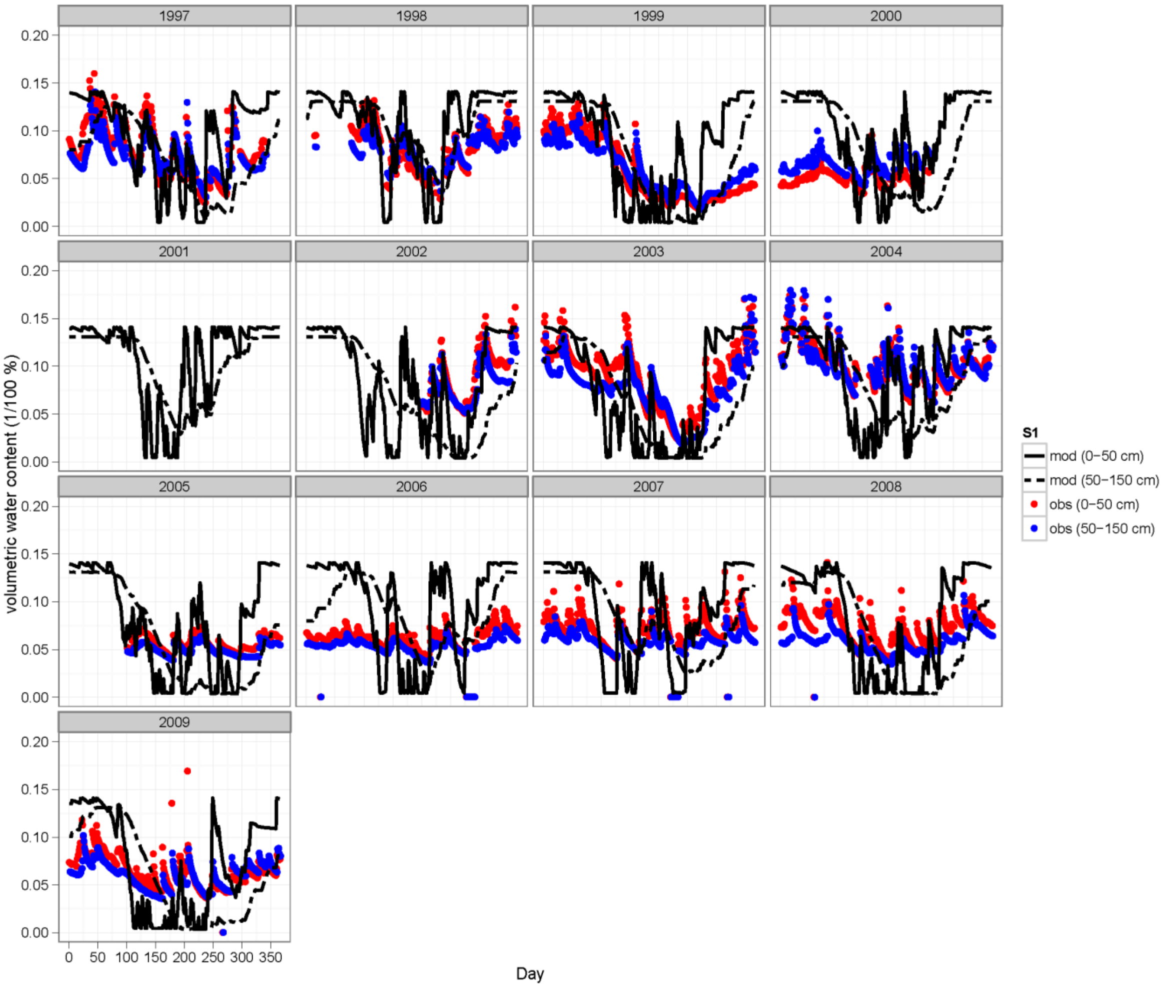
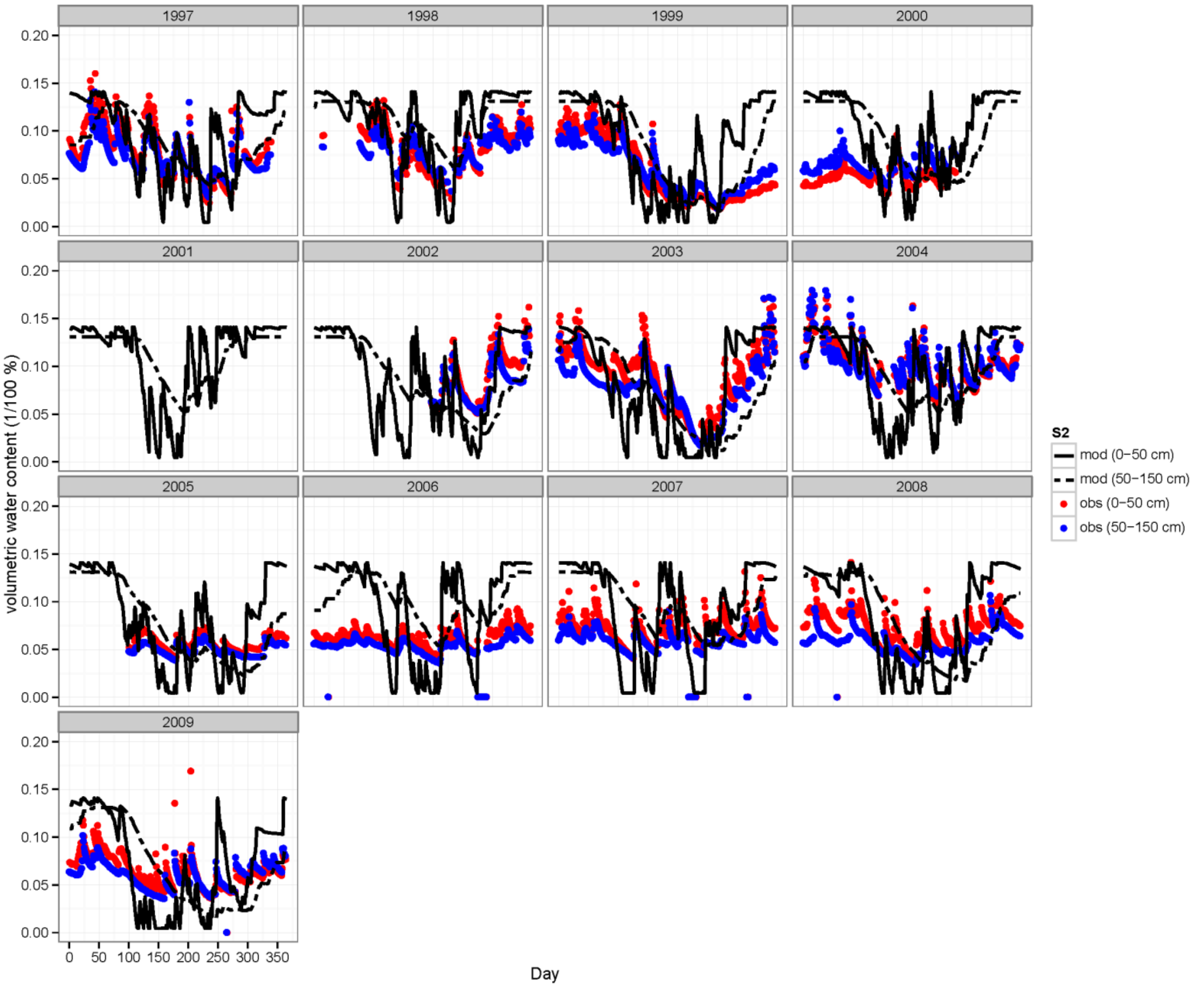


Fig. S2. Residuals of daily GPP and AET against available water content (*wcont*, Θ) in the top soil layer (top panel) and lower soil layer (bottom panel) for model scenarios S1 – S4 during the growing season (1 April – 1 Oct, = DOY 90 – 272). Residuals were calculated by subtracting observed values from modelled ones, so that underestimations by the model compared to observations are represented with a negative sign. The blue line shows a local regression (lowess) through all data points.


1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
volumetric water content (1/100 %)
0.00
0.05
0.10
0.15
0.20
0 50 100 150 200 250 300 350
Day
S1
mod (0−50 cm)
mod (50−150 cm)
obs (0−50 cm)
obs (50−150 cm)


1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
0.20
0.15
0.10
0.05
0.00
volumetric water content (1/100 %)
0
50
100
150
200
250
300
350
Day
S2
mod (0−50 cm)
mod (50−150 cm)
obs (0−50 cm)
obs (50−150 cm)

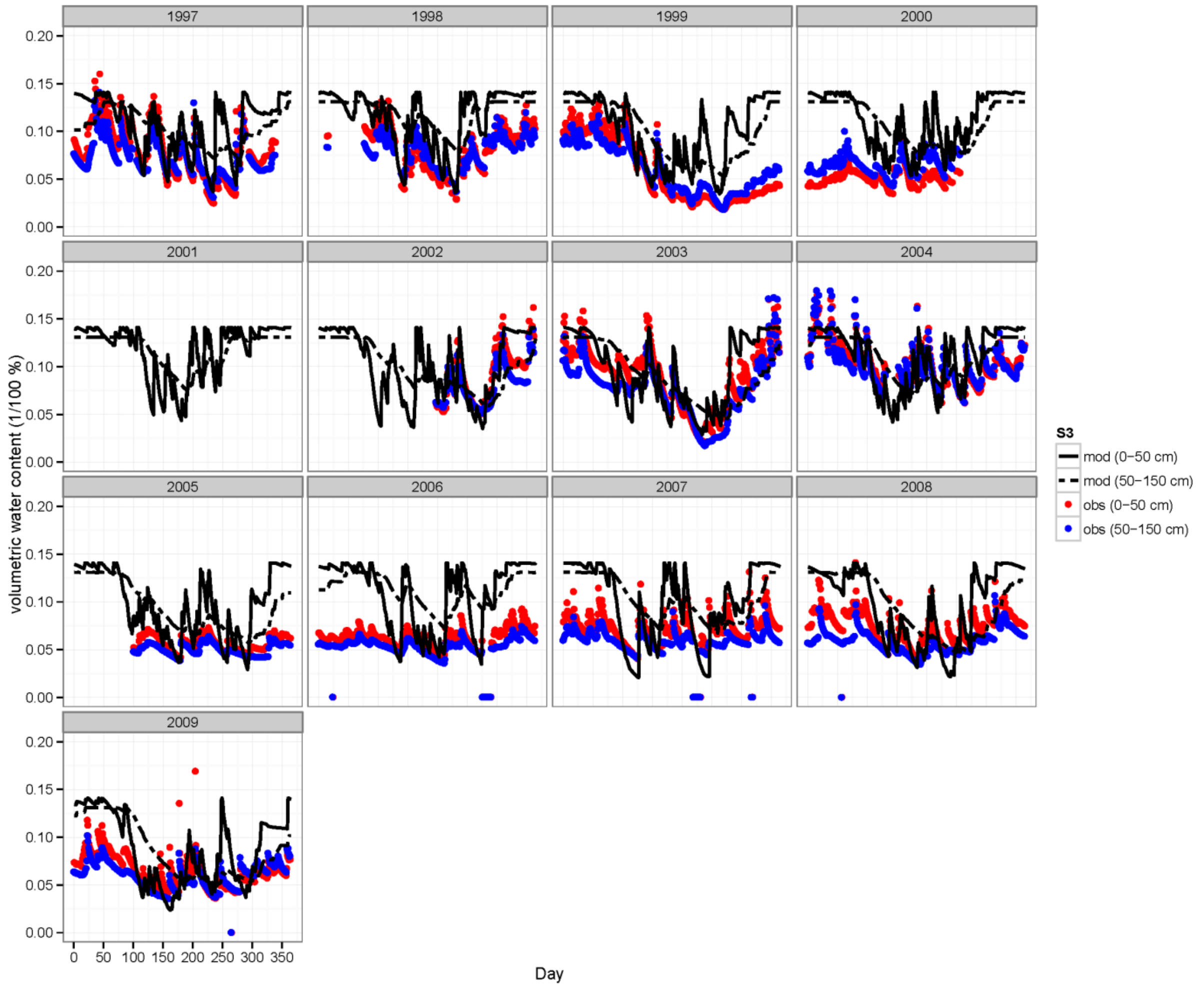


Fig. S3. Daily modelled (mod, black lines) and observed (obs, red and blue) soil moisture (as volumetric water content, 1/100%), for model scenarios S1 – S3. The two depths refer to the two soil layers in LPJ-GUESS: l_1 (0 – 50 cm) and l_2 (50 – 150 cm).

2. Winter fluxes at Loobos: half-hourly EC fluxes and leaf-level photosynthesis during frost days

In winter, the Scots pine vegetation at Loobos shows net carbon uptake in the few hours around noon (Dolman et al., 2002). Two days were selected (9 January 2003 and 18 December 2009), to demonstrate this phenomenon using half-hourly EC data from Loobos (dataset described in Sect. 2.1.2). Both days were cold and sunny, with average air temperatures between -4 °C and -14 °C, and incoming shortwave radiation peaks around noon > 200 Watts m^{-2}. The figures show GPP, NEE, and R_{eco} during daytime (Fig. S4) and GPP and NEE as a function of radiation and temperature (Fig. S5). Fig. S6 shows the result of a two-day measurement campaign at Loobos, where Scots pine leaf level photosynthesis was measured with a portable ADC- LCpro (ADC BioScientific, Hoddesdon, U.K.). We used ambient temperature, CO_2 and radiation for these measurements. January 30 2012 was a cold and snowy day, and February 2 2012 was a cold and sunny day.

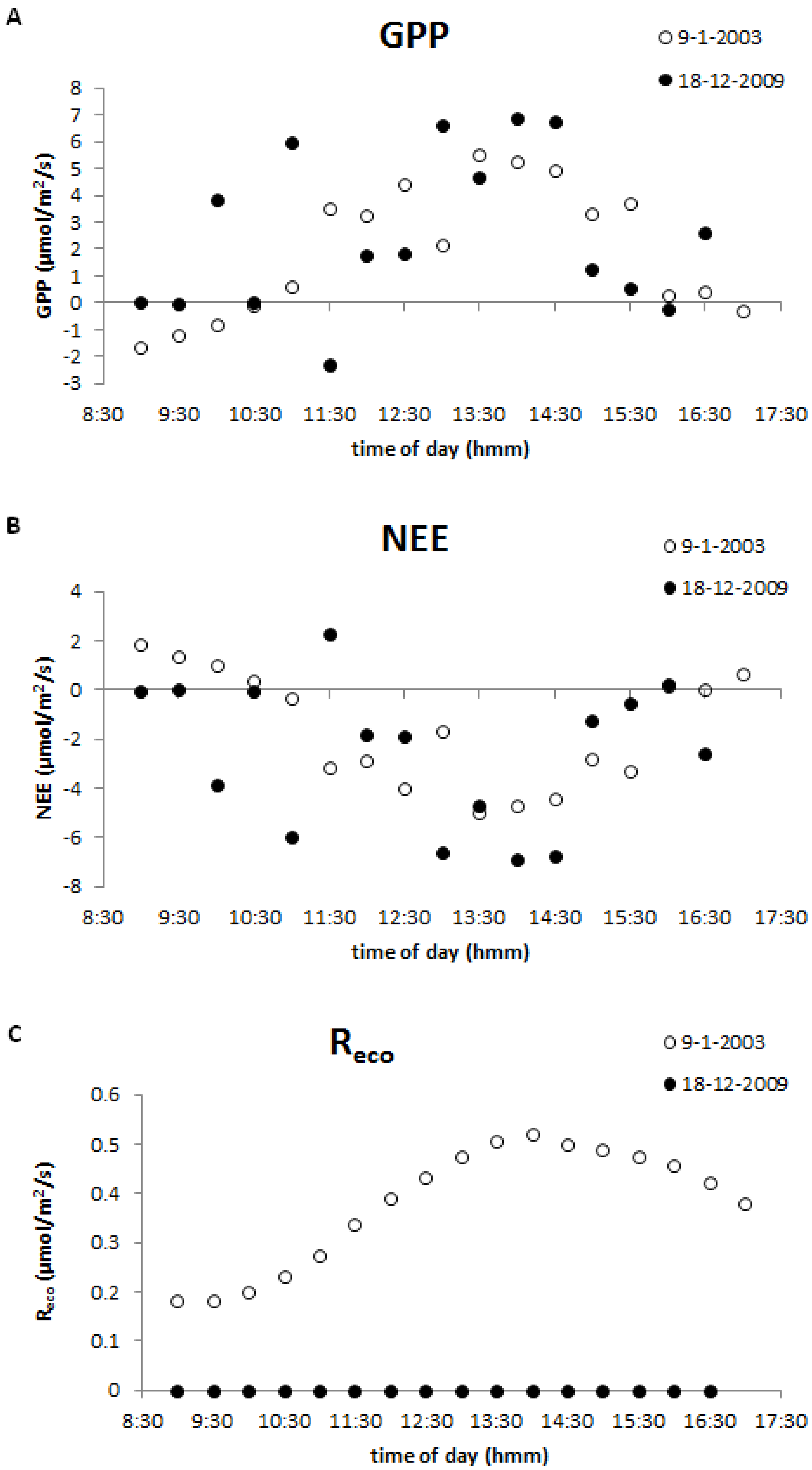


Fig. S4. Daytime fluxes of a) GPP b) NEE and d) R_{eco}, derived from half-hourly EC data measured at Loobos for two winter days between 9:00 and 17:00 local time.

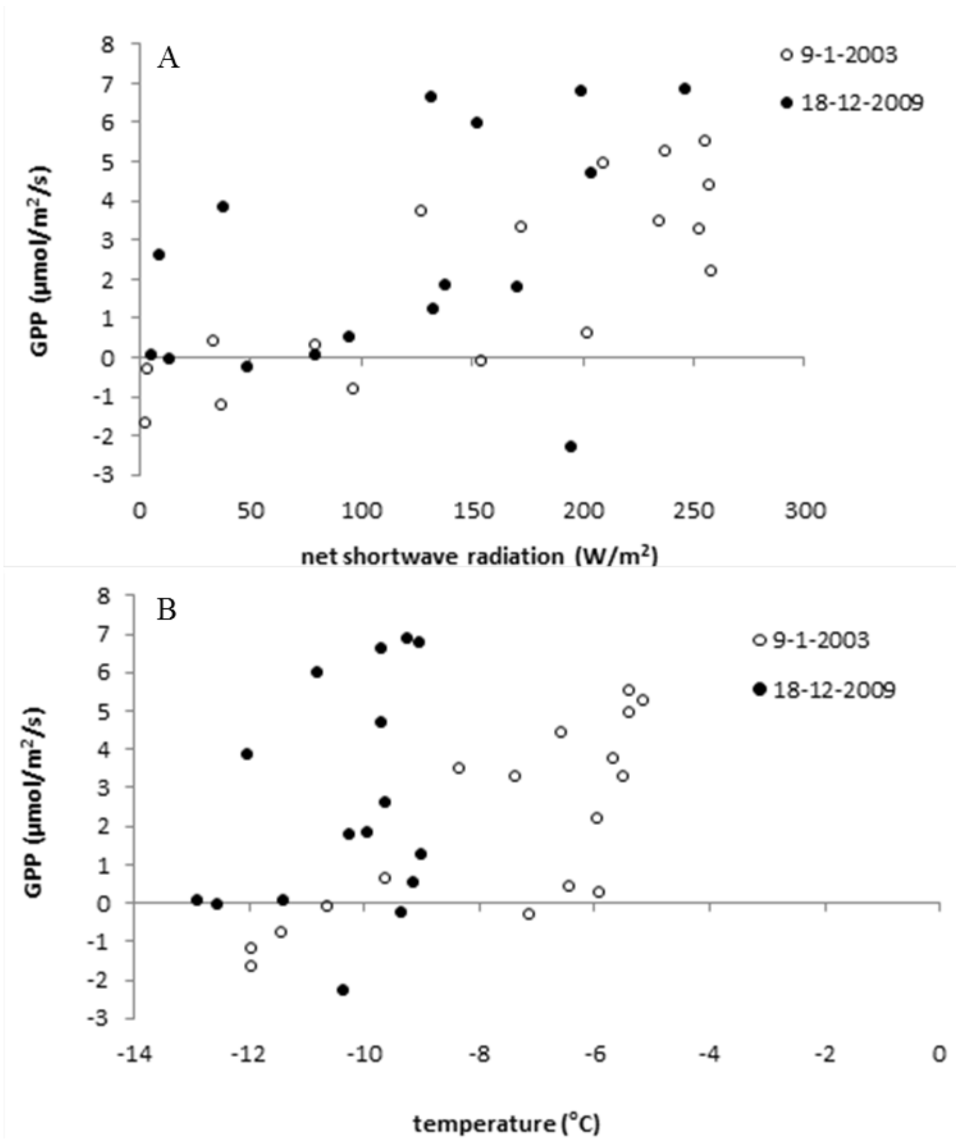


Fig. S5. GPP against incoming net shortwave radiation (A) and temperature (B), derived from half-hourly EC and meteorological data measured at Loobos for two winter days between 9:00 and 17:00 local time.

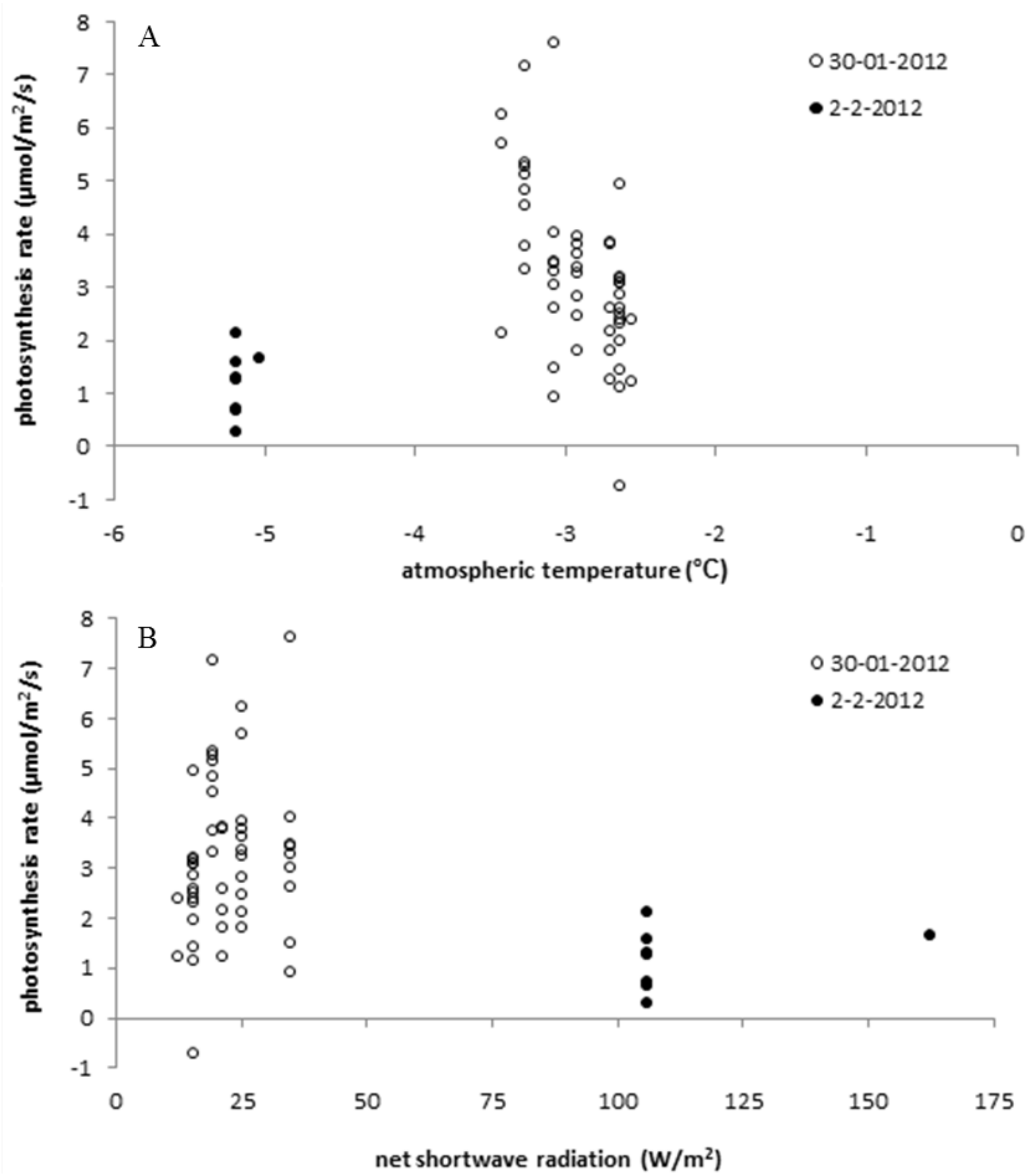


Fig. S6. Leaf-level photosynthesis (μmol m^{-2} s^{-1}) against atmospheric temperature (A) and incoming net shortwave radiation at top of the canopy (B), measured with a portable ADC-LCpro (ADC BioScientific, Hoddesdon, U.K.). January 30 2012 was a cold and snowy day with more diffuse radiation due to cloudiness, and February 2 2012 was cold and with clear sky.