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Off-season carbon dioxide exchange of a temperate mountain grassland

Georg Wohlfahrt

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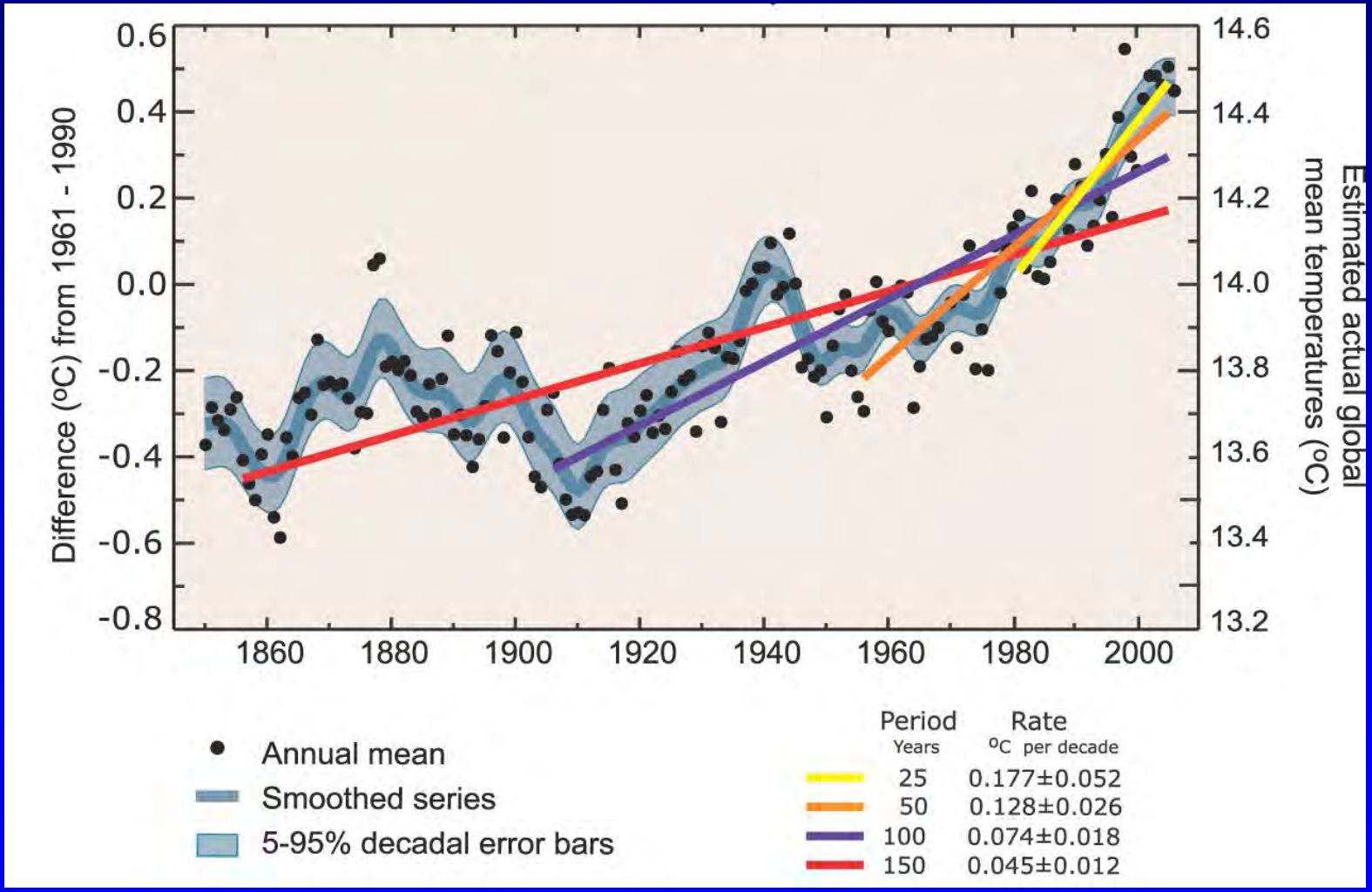
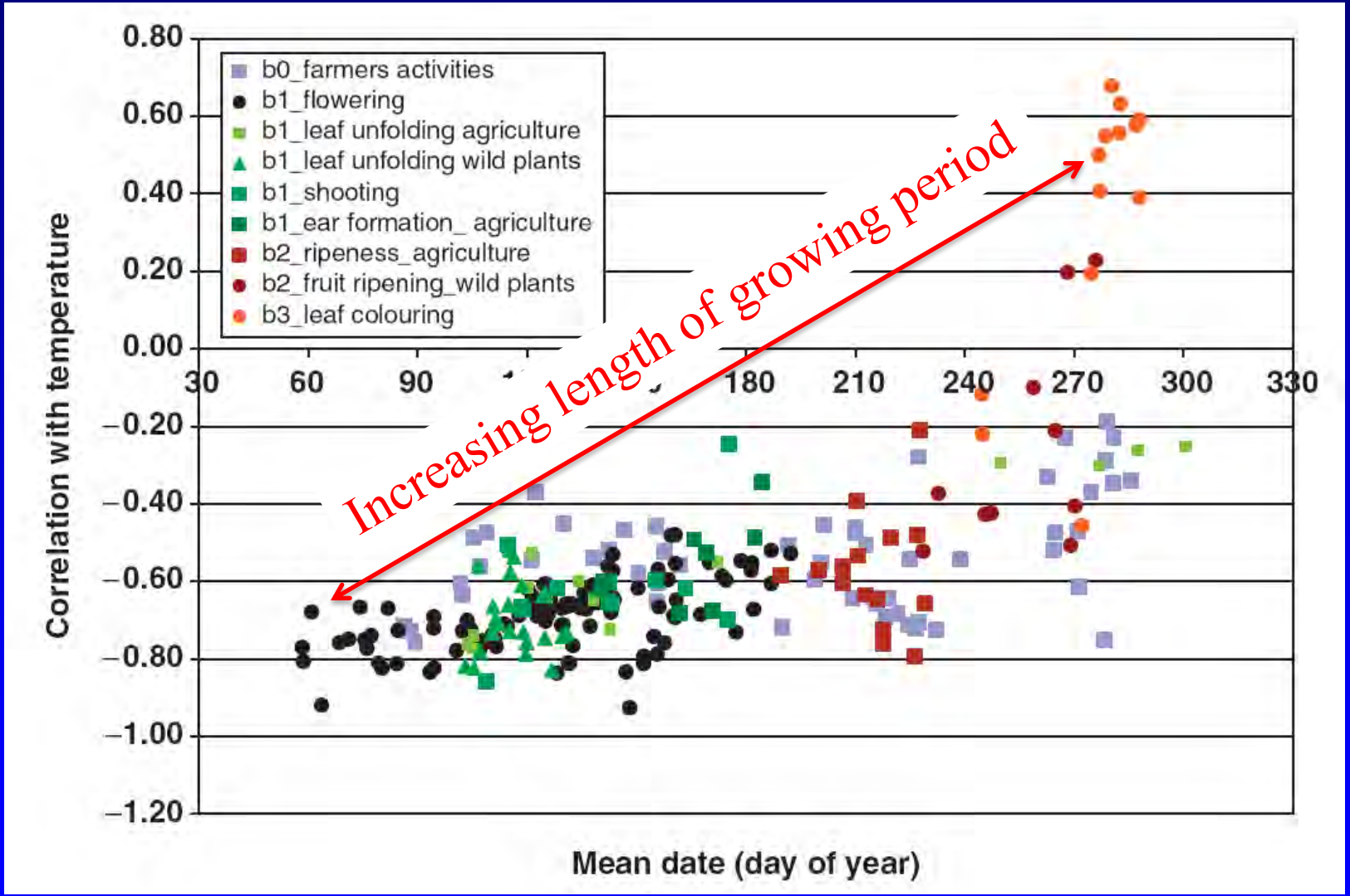
Warming up ...



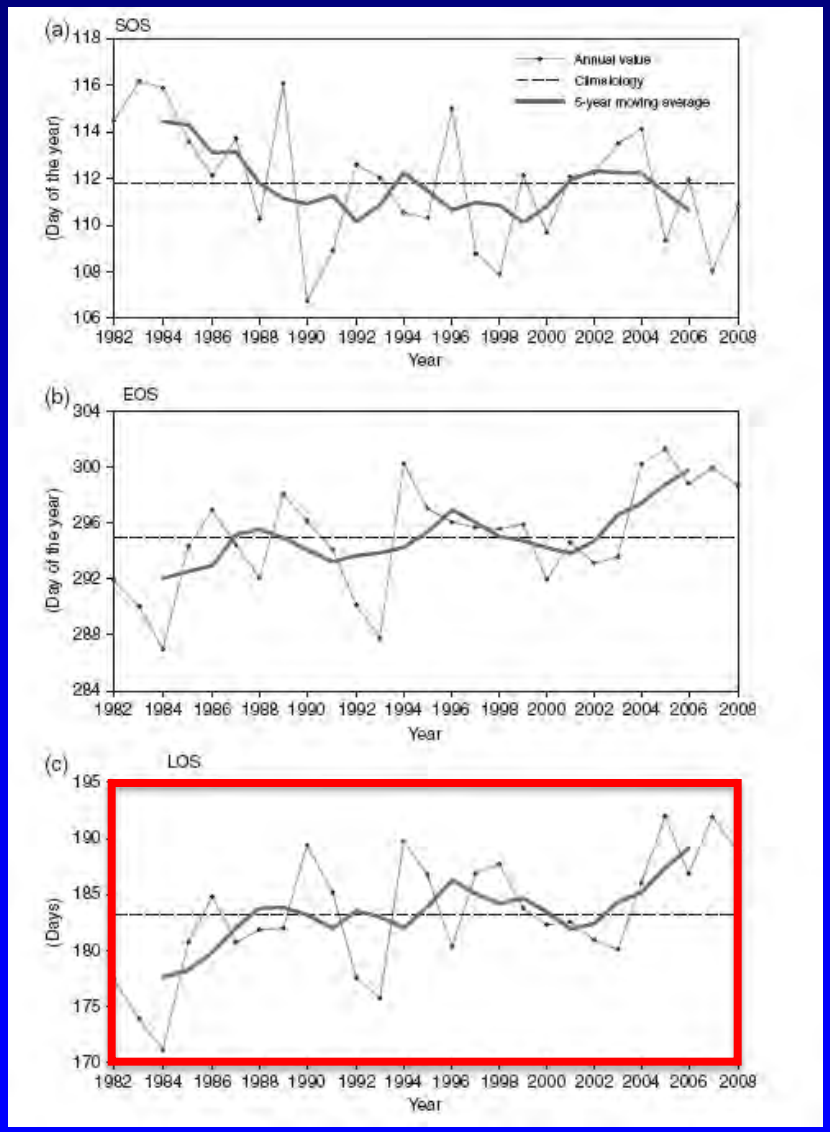
FAQ 3.1 Fig. 1, WG1 IPCC, 2007

Plant development and temperature



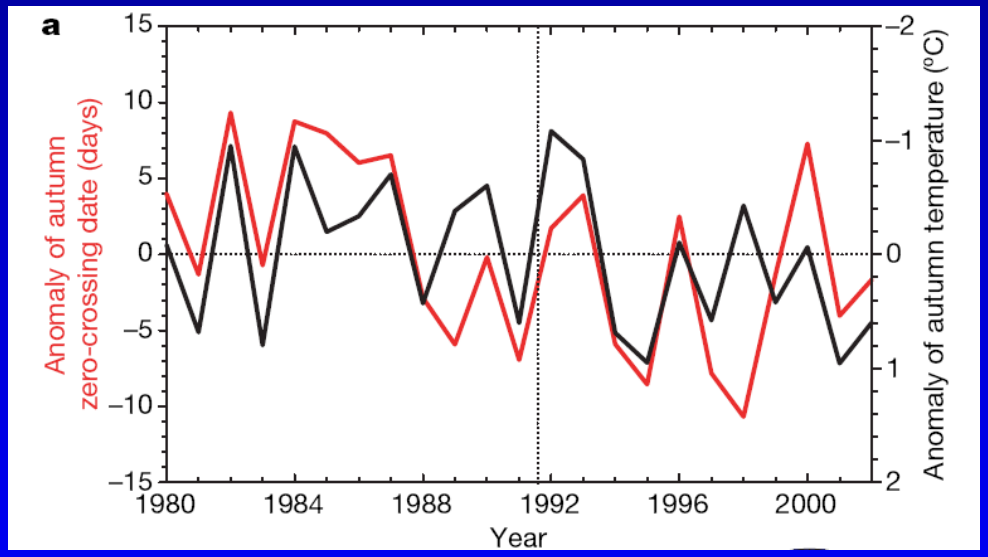
Menzel et al. (2006)

Change in onset, end and duration of growing season

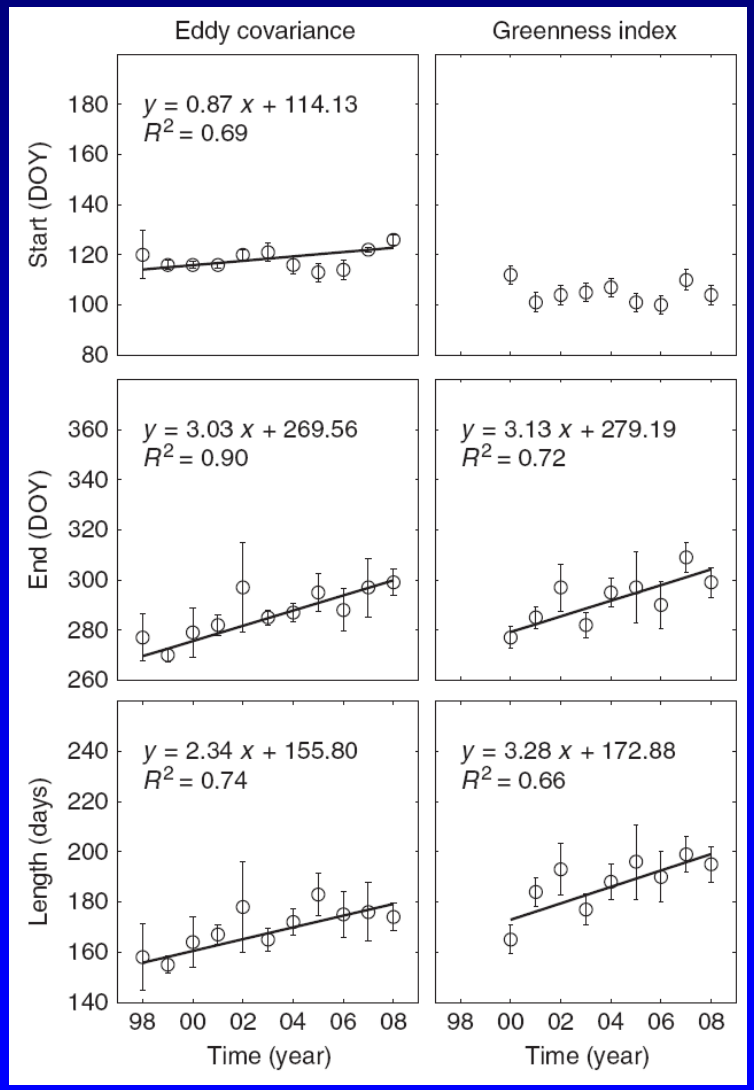


Jeong et al. (2011)

Does this lead to more net CO_2 uptake?



Piao et al. (2008)

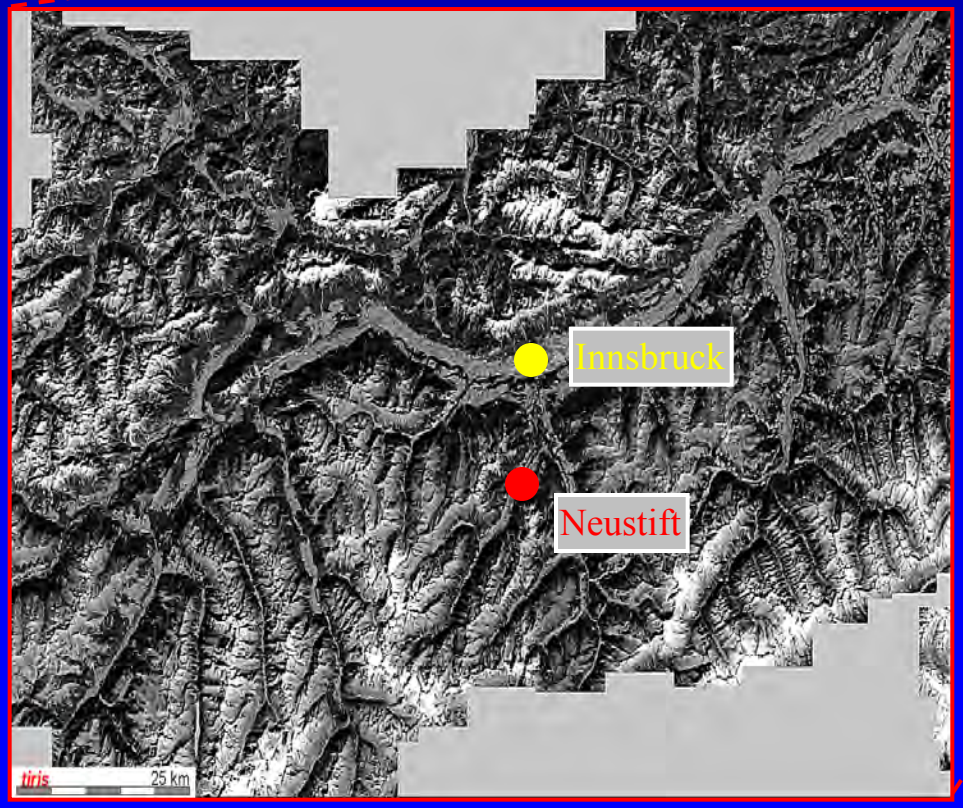


Dragoni et al. (2011)

Objectives

- Quantify the sensitivity of the off-season CO_2 exchange of a seasonally snow-covered ecosystem to temperature.
- Predict off-season CO_2 exchange under warmer future conditions.
- Determine limits of warming effects on growing season length and off-season CO_2 exchange imposed by day length.

Study sites



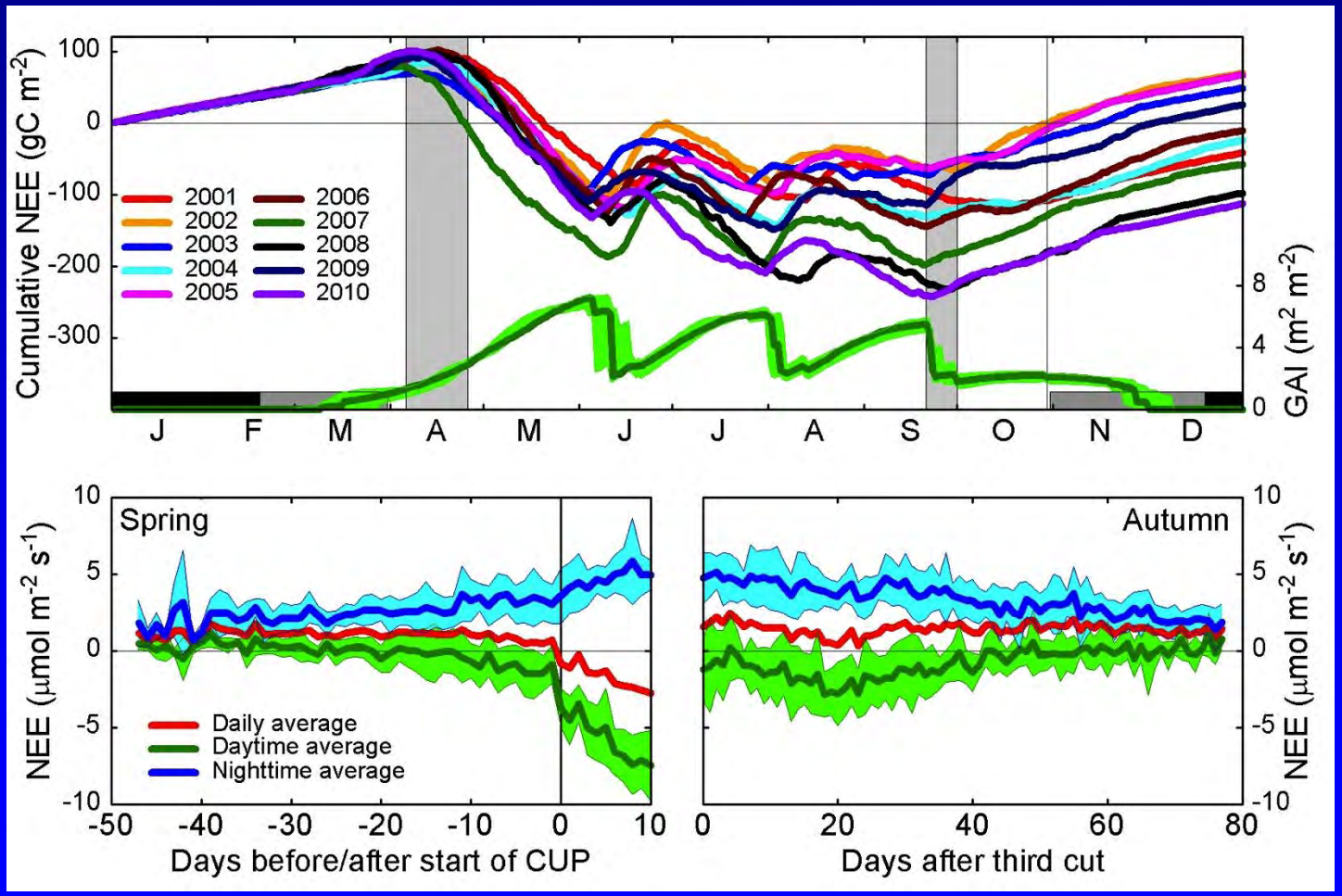
Study site

- temperate mountain grassland
- MAT 6.5° C, MAP 852 mm
- 3 cuts/year
- CO_2 and energy flux measurements: 2001-ongoing

Results

Overview of CO_2 exchange

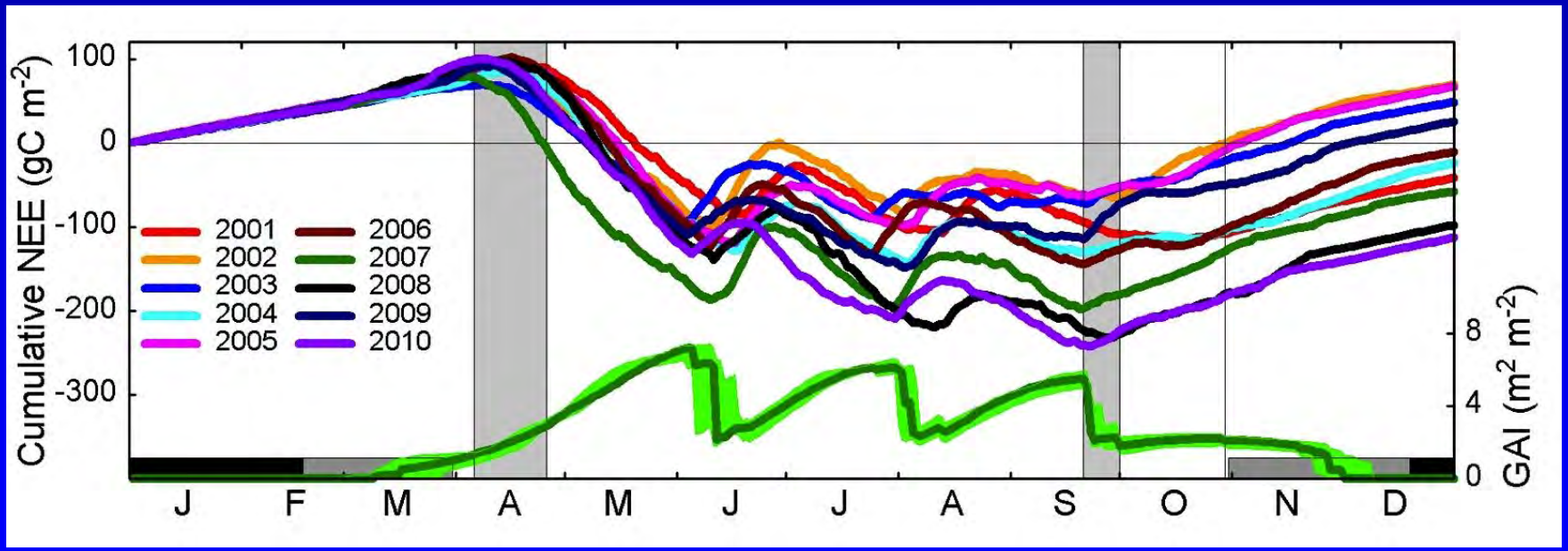
$$NEE = \overline{NEE_d} t_d + \overline{NEE_n}(1 - t_d)$$



Wohlfahrt et al. (in preparation)

Overview of CO_2 exchange

$$NEE = \overline{NEE_d} t_d + \overline{NEE_n} (1 - t_d)$$



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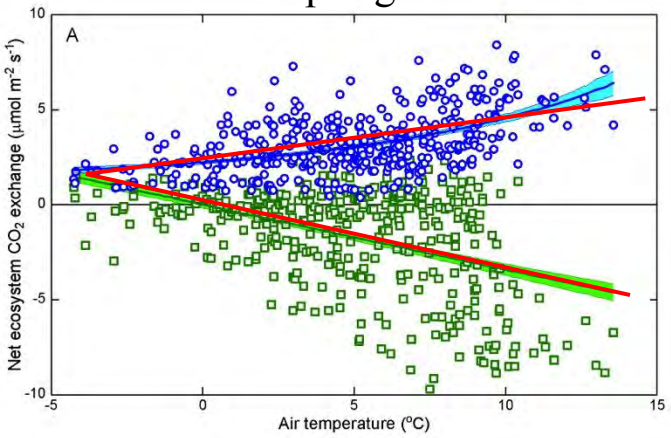
Results

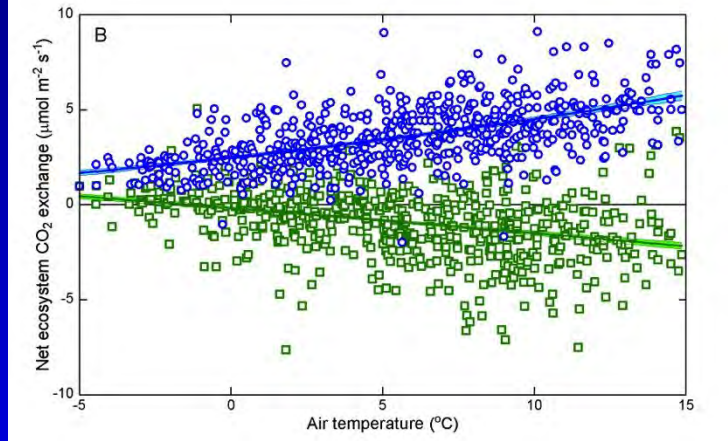
Spring and autumn CO_2 exchange

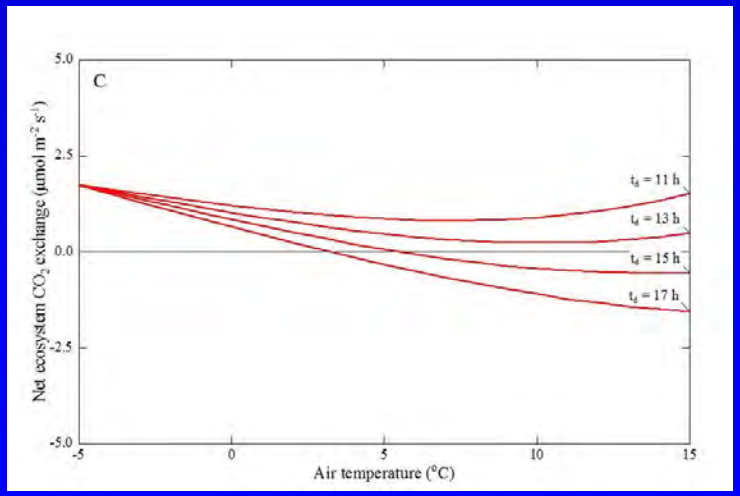
$$\overline{NEE} = a + b\, e^{cT_a}$$

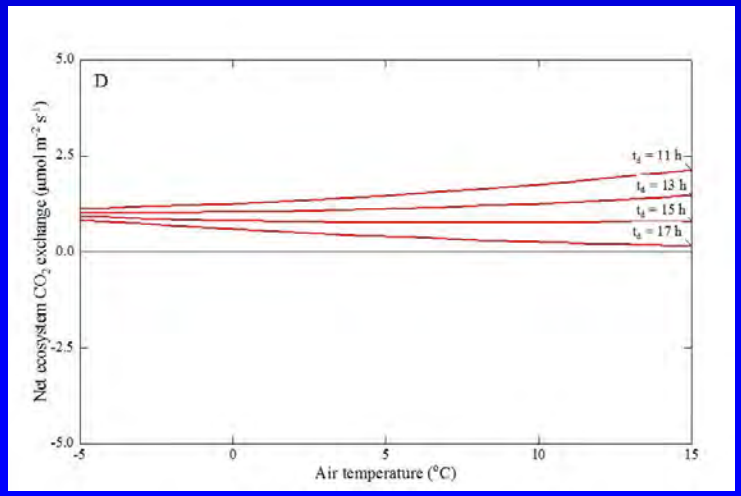
Spring



Autumn







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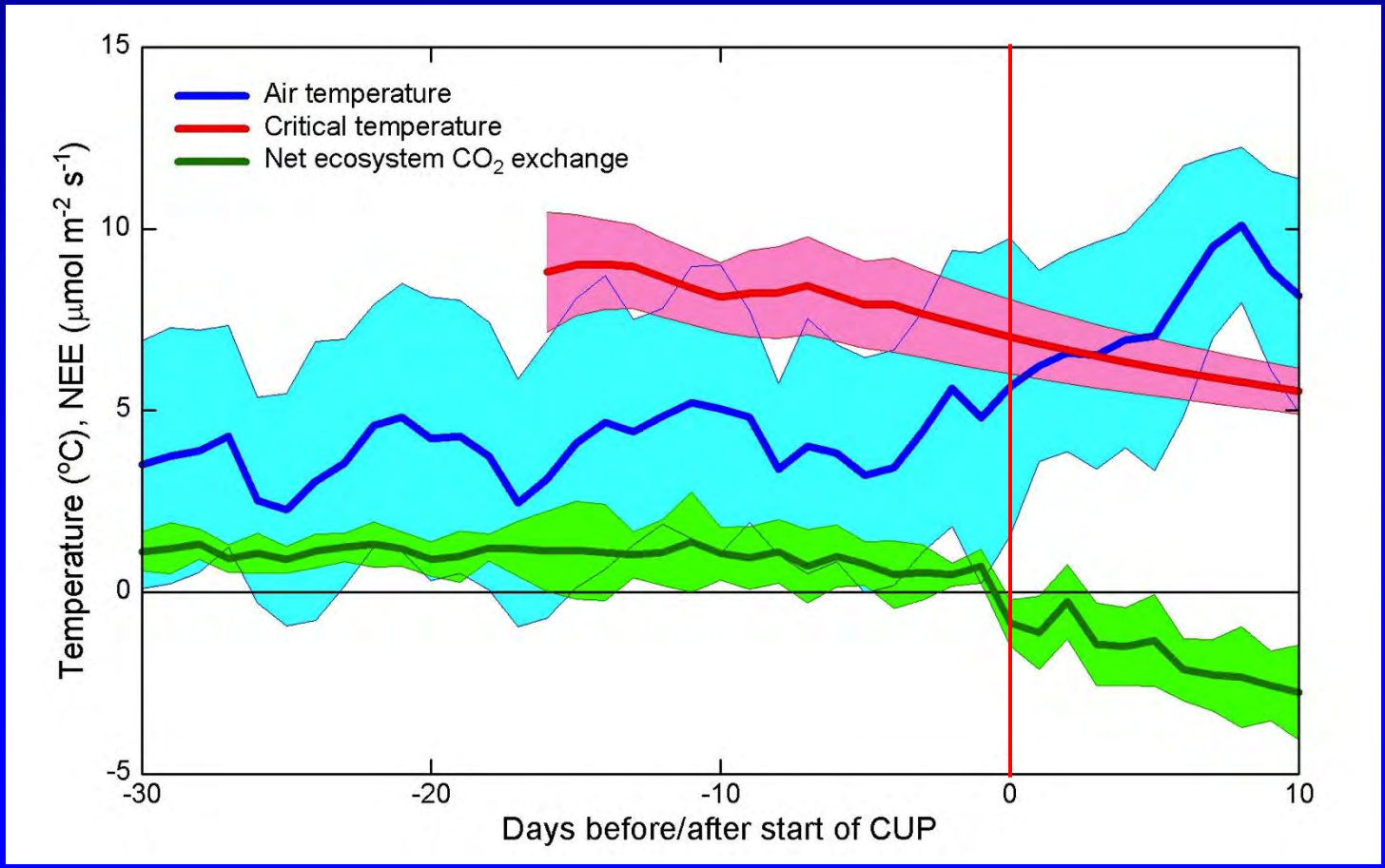
Results

Limits to warming effects

$$-\frac{\overline{NEE_d}}{\overline{NEE_n}} > \frac{(1 - t_d)}{t_d}$$



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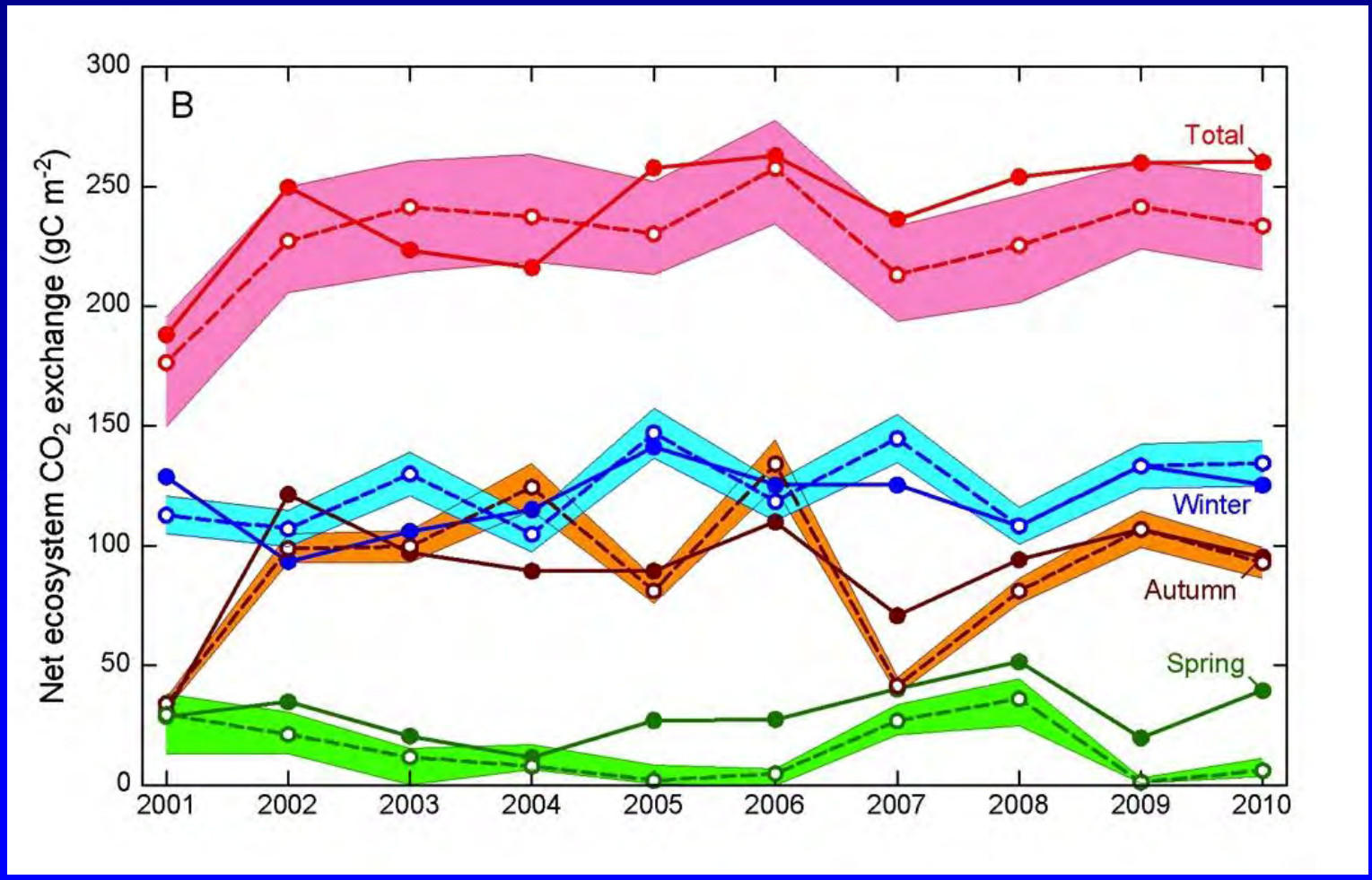
Model validation



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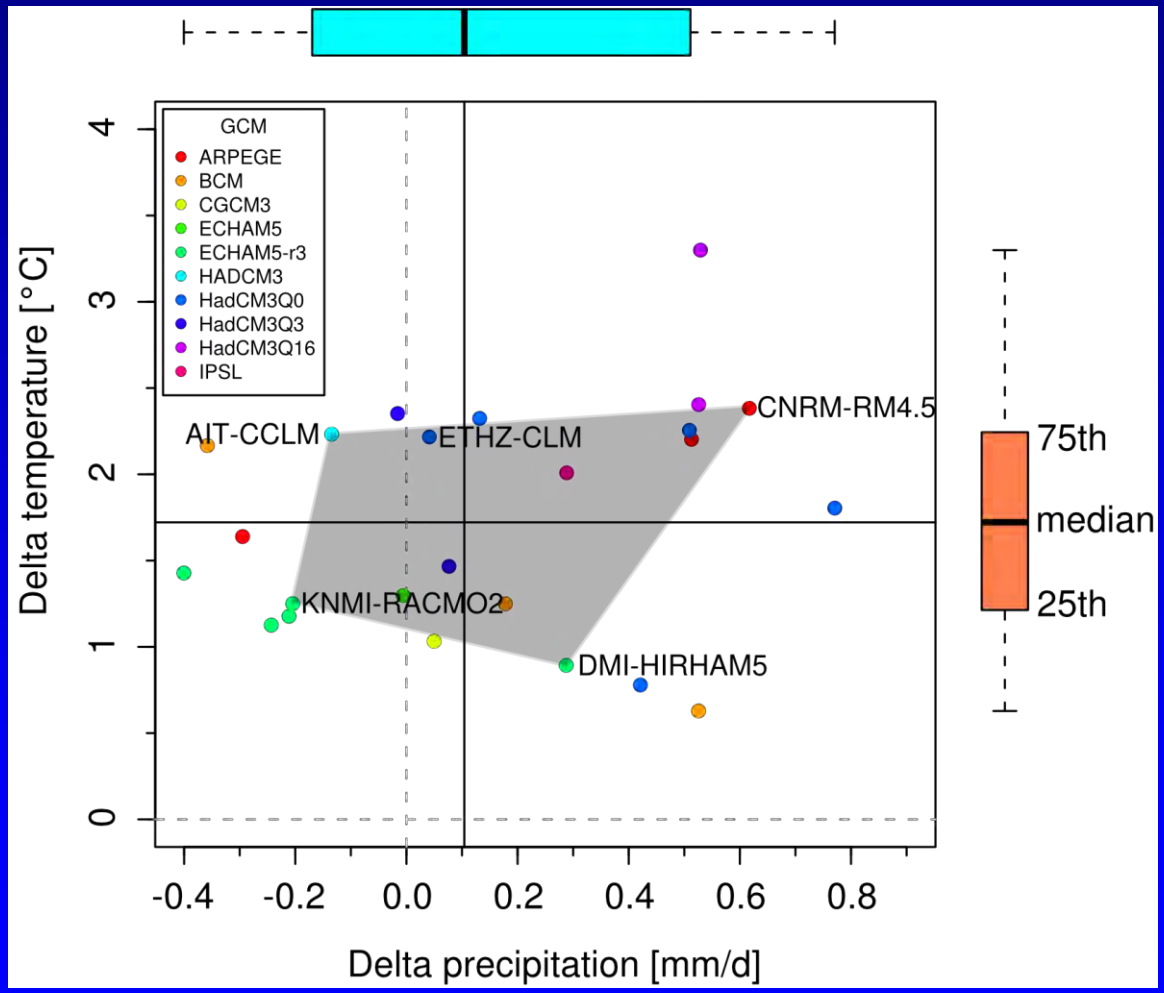
Climate scenarios

(A1B scenario, 1961-1990 *vs.* 2021-2050)



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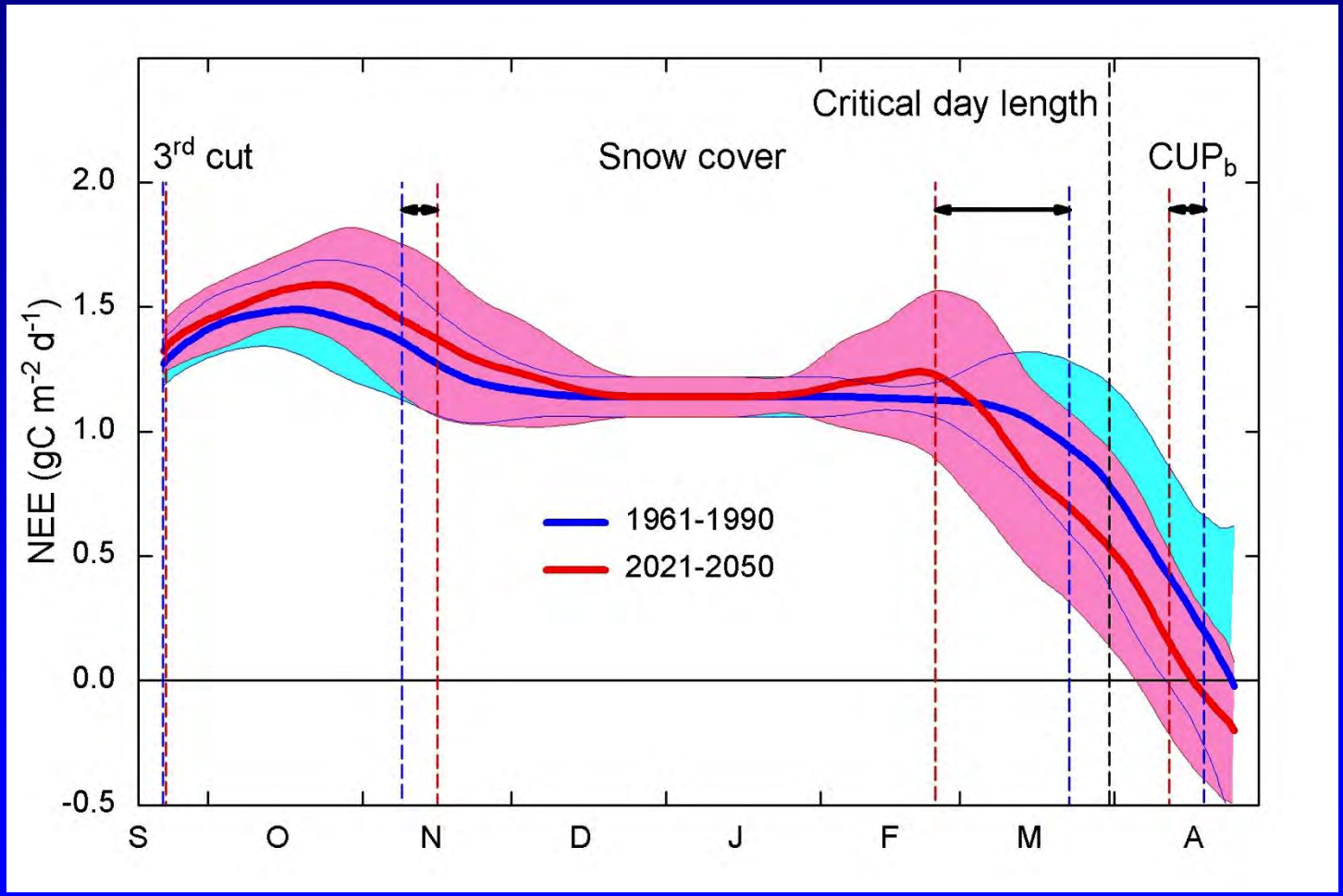
Results

Simulated off-season CO_2 exchange

ETHZ-CLM



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Results

Off-season CO_2 exchange

		Air temperature (°C)			Snow cover		CUP	Net ecosystem CO_2 exchange (gC m^{-2})			
		ON	DJF	MA	Begin (DOY)	End (DOY)	Begin (DOY)	Autumn	Winter	Spring	Total
AITCCLM	1961-1990	4.4 ± 1.3	-2.6 ± 1.3	3.0 ± 1.3	313.2 ± 14.3	81.2 ± 13.3	109.1 ± 6.7	71.6 ± 23.4	151.6 ± 24.9	15.8 ± 11.6	239.0 ± 9.4
	2021-2050	6.1 ± 1.6	-1.0 ± 1.1	4.3 ± 1.6	322.3 ± 14.5	65.8 ± 15.8	102.1 ± 4.9	90.0 ± 26.1	123.8 ± 23.1	25.6 ± 19.1	239.3 ± 14.9
	Δ	1.6	1.6	1.4	9.0	-15.4	-7.0	18.4	-27.8	9.8	0.3 (-0.8)[a]
CNRMRM4.5	1961-1990	4.1 ± 1.4	-2.8 ± 1.3	3.0 ± 1.1	317.2 ± 16.6	81.9 ± 13.5	110.7 ± 7.9	76.3 ± 25.6	147.8 ± 24.9	14.9 ± 11.8	239.0 ± 10.0
	2021-2050	5.6 ± 1.0	-1.3 ± 1.0	4.0 ± 1.3	320.2 ± 15.2	71.1 ± 11.9	106.5 ± 6.6	84.2 ± 25.2	132.1 ± 22.6	20.9 ± 13.7	237.2 ± 7.2
	Δ	1.5	1.5	1.0	2.9	-10.8	-4.2	7.9	-15.7	5.9	-1.8 (-0.9)[a]
DMIHIRHAM	1961-1990	4.2 ± 1.3	-2.5 ± 0.8	3.1 ± 1.4	311.6 ± 13.9	79.2 ± 13.0	108.7 ± 7.1	67.7 ± 22.5	151.2 ± 21.4	17.5 ± 13.4	236.4 ±9.4
	2021-2050	5.4 ± 1.5	-1.6 ± 1.1	4.3 ± 1.3	315.6 ± 14.7	63.1 ± 15.8	106.0 ± 8.5	77.2 ± 24.3	128.3 ± 25.2	27.9 ± 17.9	233.4 ± 10.7
	Δ	1.2	0.9	1.1	4.1	-16.1	-2.7	9.5	-23.0	10.4	-3.0 (-0.6)[a]
ETHZCLM	1961-1990	4.4 ± 1.4	-2.4 ± 1.4	3.0 ± 1.5	312.7 ± 14.3	81.6 ± 15.6	108.7 ± 7.9	71.1 ± 23.4	152.6 ± 26.6	15.2 ± 13.1	238.9 ± 11.4
	2021-2050	6.2 ± 1.5	-0.6 ± 1.3	4.5 ± 1.8	319.8 ± 15.8	54.9 ± 21.2	102.5 ± 5.9	85.7 ± 27.4	114.2 ± 33.9	37.9 ± 27.3	237.8 ± 17.1
	Δ	1.8	1.8	1.5	7.1	-26.6	-6.2	14.6	-38.4	22.7	-1.1 (-0.7)[a]
KNMIRACMO	1961-1990	4.1 ± 1.2	-2.4 ± 1.1	3.4 ± 1.3	310.1 ± 14.7	77.6 ± 10.5	107.5 ± 6.7	65.7 ± 23.5	151.1 ± 20.3	17.4 ± 10.8	234.2 ± 10.7
	2021-2050	5.3 ± 1.5	-1.2 ± 1.0	4.3 ± 1.7	318.8 ± 14.0	63.8 ± 13.2	104.5 ± 8.2	81.4 ± 23.1	125.4 ± 22.7	27.3 ± 15.4	234.1 ± 10.6
	Δ	1.3	1.2	0.9	8.6	-13.9	-3.0	15.7	-25.6	9.9	0.0 (-0.6)[a]

[a] … number in parenthesis gives the additional amount of carbon (gC m^{-2}) that could be gained due to the earlier start of the CUP in 2021-2050 as compared to 1961-1990; autumn is defined between the third harvest (assumed to occur on DOY 265) and the establishment of a permanent snow cover, winter corresponds to the time of permanent snow cover and spring is defined between snow melt and the beginning of the CUP, and the column total refers to the sum of the three.

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Take-home message

- Grassland off-season CO_2 exchange resilient against climate change scenarios predicted up to 2050.
- End of CUP is determined by timing of final cut – will farmers adapt management in future?
- Advancement of start of CUP minor under climate change scenarios.
- A critical day length exists below which no net carbon gain occurs no matter what the temperature is.

Acknowledgements

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