Supplementary material - Uncertainty in the response of transpiration to CO_2 and implications for climate change

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Appendix A. Calculation of Water-Use Efficiency for Figure 4a

The UVic ESCM's (University of Victoria Earth System Climate Model) spatial resolution does not allow to calculate the water-use efficiency of a single plant or ecosystem. Hence the 'inherent' water-use efficiency (WUE_i) is calculated, which is used to compare water-use efficiencies between species and meteorological conditions [1]. For WUE_i the following equation is taken as a reference [2]:

$$WUE_i = (GEP * D)/E_e. \tag{A.1}$$

Here GEP is the gross ecosystem photosynthesis, representing the carboxylation rate minus photorespiration. D is the evaporative demand, and E_e is the ecosystem evapotranspiration. In order to derive the given equation, several assumptions were made [2]: "(1) vapour pressure difference between the leaf and the atmosphere can be approximated by measured atmospheric evaporative demand (D), assuming equal temperatures of leaves and atmosphere, (2) aerodynamic resistance between the canopy and the reference-height for the flux can be neglected, (3) under dry conditions, with no recent precipitation events, measured water vapour fluxes are equivalent to transpiration,[...] that is, evaporation contributes minimally".

To transfer the measured variables [2] into corresponding model variables, further assumptions had to be made and calculations had to be performed. For the observational-based derived variable GEP, the UVic ESCM variable describing the gross primary productivity of carbon was taken, $GPP_{UVic}(m)$.

In order to derive the model's evaporative demand, D_{UVic}, the saturated vapor pressure, SVP, was calculated with the following equation [3]:

$$SVP = 6.107 * 10^{7.5*T_{UVic}/(T_{UVic}+237.3)}. \tag{A.2}$$

Here T_{UVic} is the models' atmospheric surface temperature in °C. D_{UVic} then is defined as the difference between the saturation vapor pressure and the specific humidity, h_s, which is given as a model output variable.

$$D_{UVic} = (1 - h_s) * SVP. \tag{A.3}$$

In order to full fill assumption (3), excluded rain events were excluded [2] i.e. the day of rain and the day thereafter, in their analysis. The UVic ESCM however does not simulate weather fluctuations, hence this distinction can not be achieved. Furthermore, it was assumed that in this case soil and leaf evaporation contributes minimally [2]. To fulfil this assumption the terrestrial evapotranspiration from the UVic ESCM would have to be partitioned into its components. The applied scaling however would alter the partitioning of Evapotranspiration, since we increase the amount of vegetational transpiration. Therefore assuming the same partitioning for all runs would introduce an error in the calculations. To avoid these errors, we calculate the UVic ESCM's WUE using simply the model output variable of evapotranspiration E_{UVic}. We thereby do not fulfil the condition to exclude evaporation, and possibly underestimate the WUE.

$$WUE_{i,UVic} = (GPP_{UVic} * D_{UVic})/E_{UVic}. \tag{A.4}$$

This calculation was performed on a local scale and thereafter globally averaged, in order to produce Figure 4a.

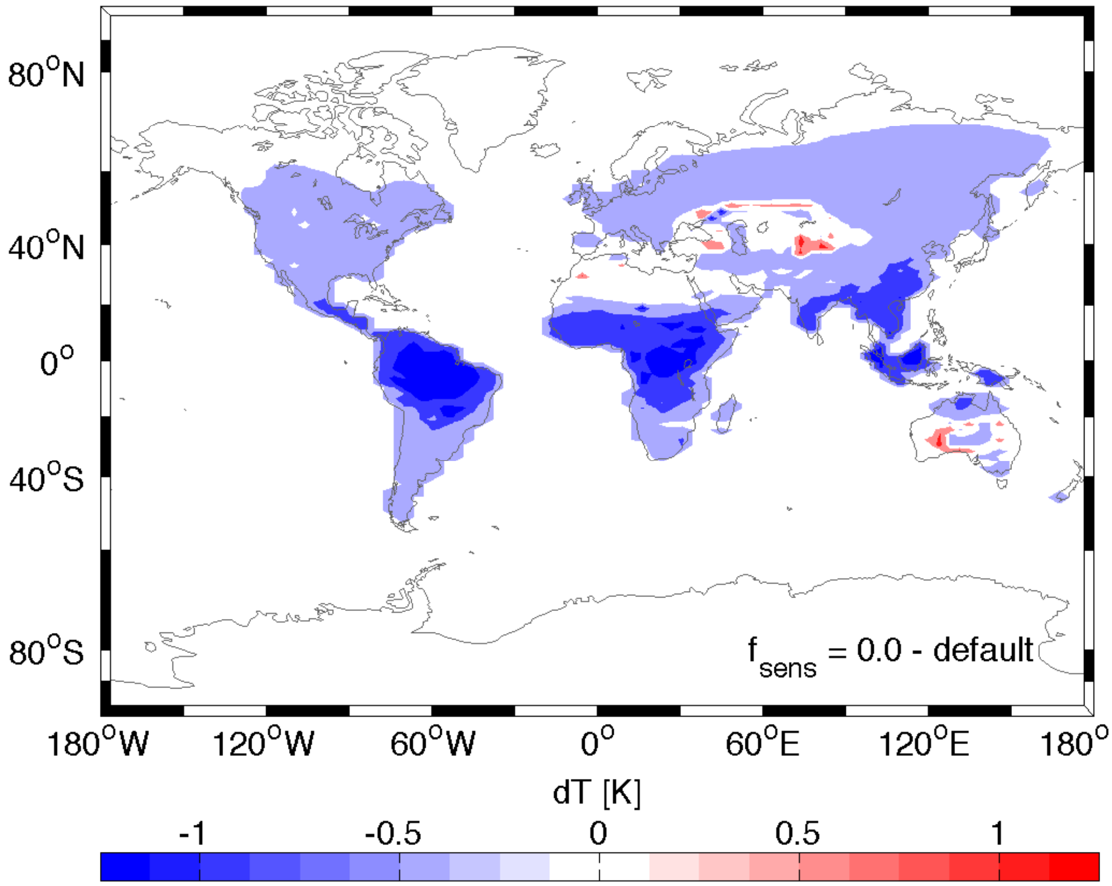

Figure B1. Map of soil temperature differences in the year 2100 between the sensitivity simulations $f_{sens} = 0.0$ and the default simulation ($f_{sens} = 1.0$) for the CO_2 forced simulations.

Appendix B. Map of Soil Temperature in 2100

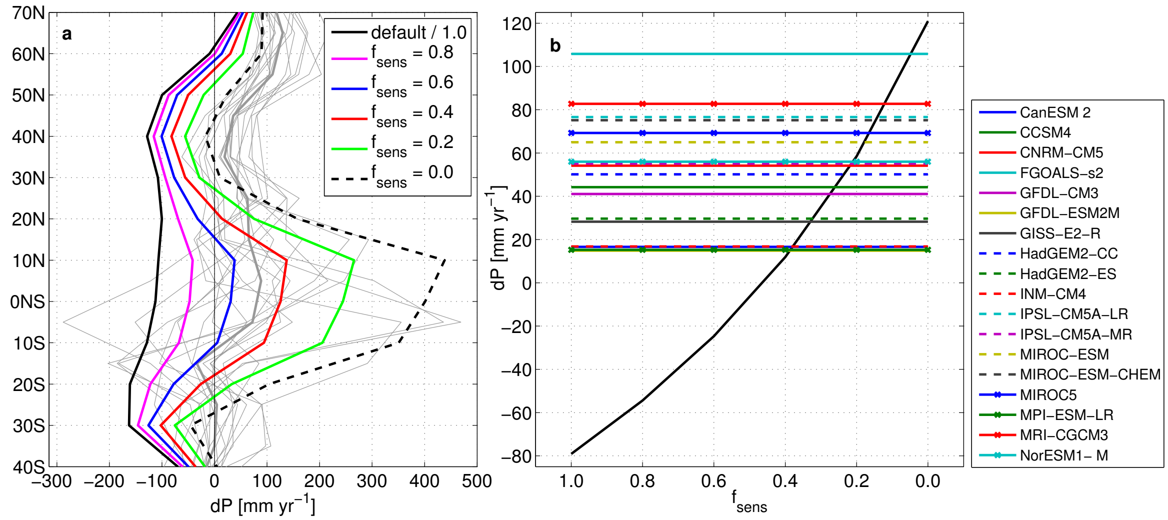

Figure C1. Same as Figure 3 in the main text but for the six simulations with an unperturbed terrestrial biosphere.

Appendix C. Same as Figure 3 from the simulations with CO_2 forcing only

Table D1. CMIP5 models and modelling groups [4].

Modelling centre (or group)	Institute ID	Model name
Canadian Centre for Climate Modelling and Analysis	CCCMA	CanESM2
National Center for Atmospheric Research	NCAR	CCSM4
Centre National de Recherches Meteorologiques/ Centre Europeen de Recherche et Formation Avancees en Calcul Scientifique	CNRM-CERFACS	CNRM-CM5
LASG, Institute of Atmospheric Physics, Chinese Academy of Sciences	LASG-IAP	FGOALS-s2
NOAA Geophysical Fluid Dynamics Laboratory	NOAA GFDL	GFDL-CM3
		GFDL-ESM2M
NASA Goddard Institute for Space Studies	NASA GISS	GISS-E2-R
Met Office Hadley Centre	MOHC	HadGEM2-CC
		HadGEM2-ES
Institute for Numerical Mathematics	INM	INM-CM4
Institut Pierre-Simon Laplace	IPSL	IPSL-CM5A-LR
		IPSL-CM5A-MR
Japan Agency for Marine-Earth Science and Technology, Atmosphere and Ocean Research Institute (The University of Tokyo), and National Institute for Environmental Studies	MIROC	MIROC-ESM MIROC-ESM-CHEM
Atmosphere and Ocean Research Institute (The University of Tokyo), National Institute for Environmental Studies, and Japan Agency for Marine-Earth Science and Technology	MIROC	MIROC5
Max Planck Institute for Meteorology	MPI-M	MPI-ESM-LR
Meteorological Research Institute	MRI	MRI-CGCM3
Norwegian Climate Centre	NCC	NorESM1-M

Appendix D. CMIP5 models and modelling groups used in Figure 3

[1] Beer C *et al.* 2009 Temporal and among-site variability of inherent water use efficiency at the ecosystem level *Global Biogeochemical Cycles* **23** 113

[2] Keenan T F *et al.* 2013 Increase in forest water-use efficiency as atmospheric carbon dioxide concentrations rise *Nature* **499(7458)**, 324-7.

[3] Murray F W 1967 On the Computation of Saturated Vapor Pressure, *Journal of Applied Meteorology*, **6** 203-204.

[4] Ahlström, A, Schurgers G, Arneth A and Smith B 2012 Robustness and uncertainty in terrestrial ecosystem carbon response to CMIP5 climate change projections *Environmental Research Letters* **7** 044008 (9pp).