Regionalization of the key carbon storage parameter within the Carbon Cycle Data Assimilation System (CCDAS)

Quantifying and Understanding the Earth System

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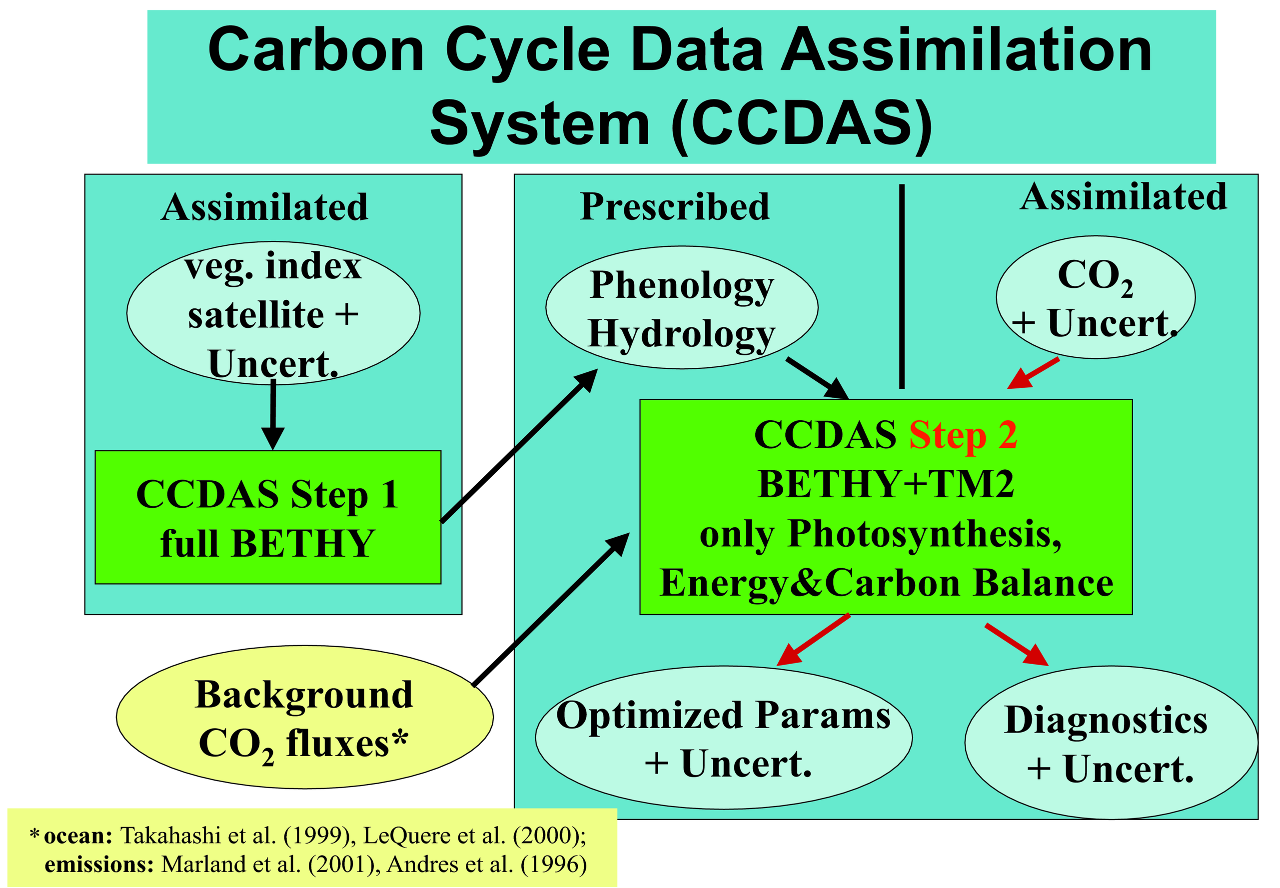

Figure 1: Schematic representing information flow in CCDAS. In each of the steps, parameters of the Biosphere Energy-Transfer Hydrology scheme (BETHY) are optimally adjusted to match observations. Ocean and anthropogenic CO_2 fluxes are represented as background fields.

INTRODUCTION

The Carbon Cycle Data Assimilation System (CCDAS) [1] allows the current fluxes of CO_2 to the atmosphere to be mapped and the evolution of these fluxes into the future to be predicted [2]. Here we concentrate on the calibration mode of CCDAS where an optimal parameter set is derived from 21 years of atmospheric CO_2 concentration observations using an adjoint approach. The terrestrial biosphere model BETHY [3], which is combined in the assimilation system with the atmospheric transport model TM2 [4], has 20 parameters for each plant functioning type (PFT). There is a total of 3462 grid cells within the model and each of the 20 parameters can be assigned to one global control parameter via a mapping routine (global description). It is also possible to assign each of the 20 parameters to one control parameter for each of the 13 PFTs or to one control parameter for each PFT occurring in each of the 11 Transcom land regions. In the base case, 17 of the 20 parameters are applied globally, mainly those concerning the soil model or general plant physiology. The key photosynthetic parameters (maximum electron transport and maximum carboxylation rate) and the key carbon storage parameter β vary with PFT, which gives a total of 57 control parameters.

The focus of this work is on incorporating the differences in the long-term carbon balance in various regions of the earth by considering 11 land regions as defined in the Transcom 3 Level 2 Atmospheric Inversion Intercomparison Experiment [5]. Therefore, in a second configuration the key carbon storage parameter β is also allowed to vary by both land region and PFT, which results in an extended set of 155 control parameters.

	PFT	Regionalised soil carbon balance parameter												Standard inversion
		North American boreal (1)	North American temperate (2)	South American tropical (3)	South American temperate (4)	Northern Africa (5)	Southern Africa (6)	Eurasian boreal (7)	Eurasian temperate (8)	Tropical Asia (9)	Australia (10)	Europe (11)	Σ	Σ
1	Tropical broadleaved evergreen tree	----	0	429	-3	382	220	----	12	21	0	----	**1060**	**2298**
2	Tropical broadleaved deciduous tree	----	30	1450	-646	-408	471	----	-118	-39	0	----	**739**	**349**
3	Temperate broadleaved evergreen tree	----	0	----	----	0	0	----	9	----	-11	0	**-2**	**0**
4	Temperate broadleaved deciduous tree	1	141	0	-127	5	----	186	155	0	0	-82	**278**	**-82**
5	Evergreen coniferous tree	187	-335	-29	-28	----	----	-3	301	27	-30	-148	**-57**	**-285**
6	Deciduous coniferous tree	----	----	----	-----	----	----	288	----	----	----	----	**288**	**1402**
7	Evergreen shrub	-8	0	-6	0	-4	29	148	118	-1	-34	-8	**234**	**308**
8	Deciduous shrub	0	4	-2	-6	-5	-4	6	-9	0	2	1	**-12**	**-1815**
9	C3 gras	-245	-287	-111	-976	5	24	828	388	0	92	-319	**-601**	**-3814**
10	C4 gras	0	576	269	-74	274	-483	3	-253	92	197	-17	**584**	**0**
11	Tundra vegetation	-18	0	----	0	----	----	-358	5	----	0	-89	**-461**	**-569**
12	Swamp vegetation	-40	----	0	-2	----	0	13	0	----	----	0	**-28**	**0**
13	Crops	0	210	0	-8	0	-3	33	234	0	0	-278	**189**	**4420**
	Σ	**-121 (120)**	**340 (224)**	**2000 (333)**	**-1870 (271)**	**249 (222)**	**254 (233)**	**1140 (309)**	**843 (273)**	**100 (184)**	**215 (131)**	**-939 (272)**	**2210**	
	Standard inversion Σ	**-364 (62)**	**454 (101)**	**1100 (219)**	**-881 (131)**	**77 (76)**	**-106 (141)**	**476 {196}**	**907 (150)**	**689 (72)**	**-232 (30)**	**96 (146)**		**2211**

Table 1: NEP (TgC/year) for each PFT and land region using the extended set of 155 parameters. The last column to the right and the bottom row present the results using the standard set of 57 parameters (base case). Sources are highlighted in red and sinks are highlighted in blue. Uncertainties (1 σ) resulting from the uncertainty in β alone are given in brackets for each Transcom region.

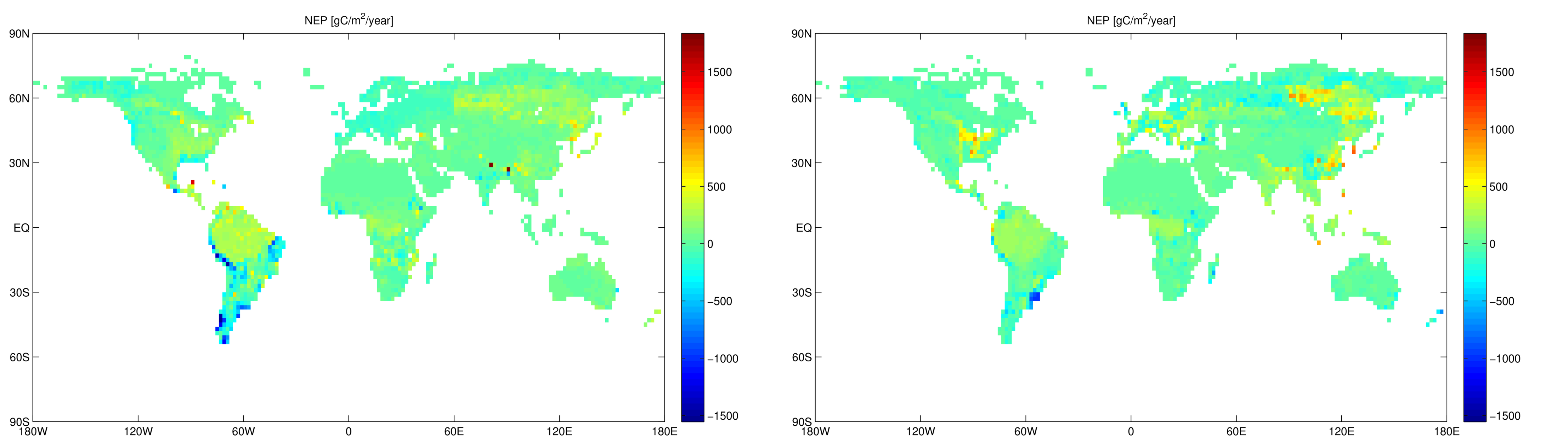

Figure 2: NEP (TgC/year) using the extended set of 155 parameters (left) and the standard set of 57 parameters (right).

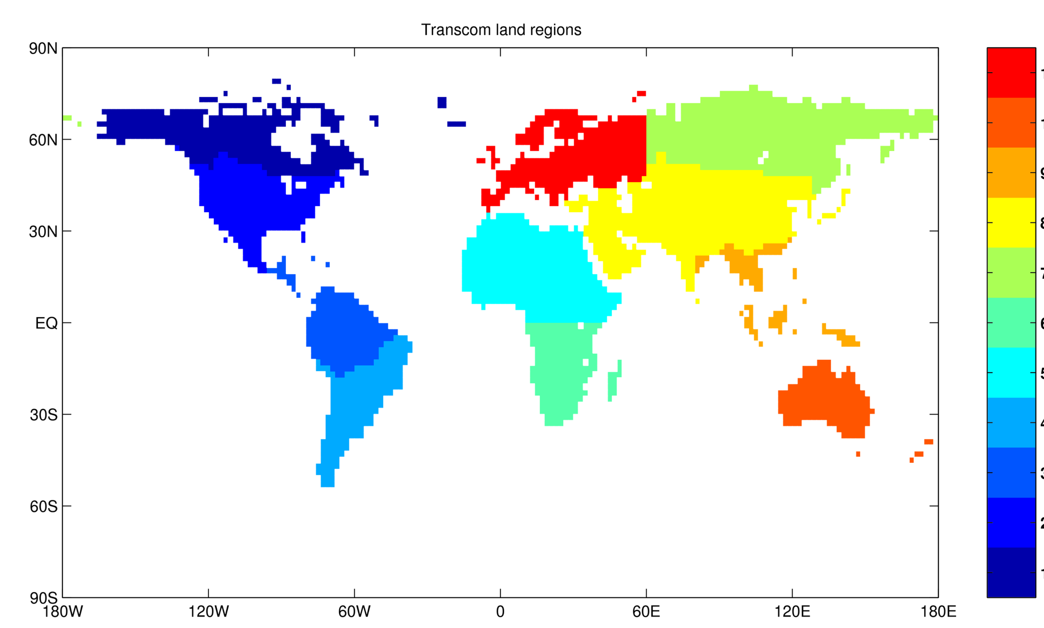

Figure 3: Set up of the 11 land regions as defined in the Transcom 3 Level 2 Atmospheric Inversion Intercomparison Experiment. Land region labels are given in Table 1.

RESULTS

The key carbon storarage parameter β is sensitive to the regionalization process as shown in Table 1 and Figure 2. There is a disagreement in the direction of the net fluxes for region 6 (Southern Africa), 10 (Australia) and 11 (Europe). In the base case (standard inversion, 57 control parameters) region 6 and 10 were identified as CO_2 sources and region 11 as a carbon sink. The optimization considering the regionalization of the β parameter leads to the opposite results for those regions. However, taking the uncertainties for mean NEP into account region 6, for example, could be a source or a sink in both cases. Disagreement can also be found in the value and direction of the net fluxes for the PFTs. For example, PFT 13 (crops) was identified as a CO_2 sink in both cases. However, the net flux in the base case is more than 20 times higher than the net flux using the extended set of control parameters.

The regionalization leads to a smaller cost function value (c=5385) in comparison to the case where β was only allowed to vary with PFT (c=5921), which indicates a better fit to the observations. Additionally, the rate of convergence is about twice as high for the extended set of parameters. The results presented here demonstrate that the key carbon storage parameter β is not a universal and robust parameter, but changes significantly with the regionalization.

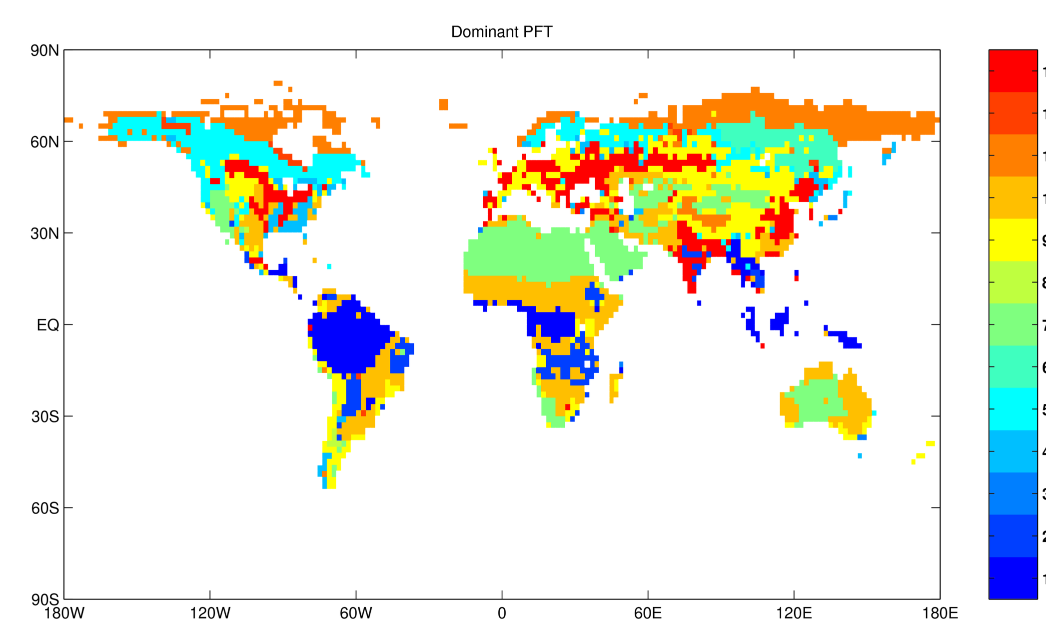

Figure 4: Distribution of the dominant PFT per grid cell. PFT labels are given in Table 1.

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[4] Heimann, M. (1995), The global atmospheric tracer model TM2, *Tech. Rep.* 10, Dtsch. Klimarechenzentrum, Hamburg, Germany.

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