Quantifying and Understanding the Earth System

University of BRISTOL

Local-scale carbon cycle data assimilation using satellite-derived FAPAR with a generic phenology model

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Objectives

- Demonstrate the assimilation of optical reflectance data from satellites into a new generic model of leaf phenology (Fig. 1)
- Assess the reduction in uncertainty of carbon fluxes after simultaneous assimilation of satellite-data at multiple sites
- Explore suitability for global-scale applications

Results

- Efficient algorithm finds optimum for all 6 sites simultaneously after ~60 iterations, producing good fit to observed FAPAR (Fig. 1)
- For 6 sites, FAPAR data constrain most phenology parameters (Table 1).
- Limited constraint for parameters related to photosynthesis (≤7%).
- Only small constraint on carbon fluxes (Fig. 3).

Outlook

- Algorithm fast enough for global applications.
- Since one set of parameters is used across multiple sites, adding more grid cells will increase constraint on parameters from satellite data.
- Expect significant constraint on carbon fluxes if model is applied globally.

References

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2-Gobron, N., et al. (2008), Uncertainty estimates for the FAPAR operational products derived from MERIS - Impact of top-of-atmosphere radiance uncertainties and validation with field data, *Remote Sens. Eviron.*, *112*, 1871-1883.

3-Knorr, W. (2000), Annual and interannual CO_2 exchanges of the terrestrial biosphere: process-based simulations and uncertainties, *Global Ecology and Biogeography*, 9, 225-252.

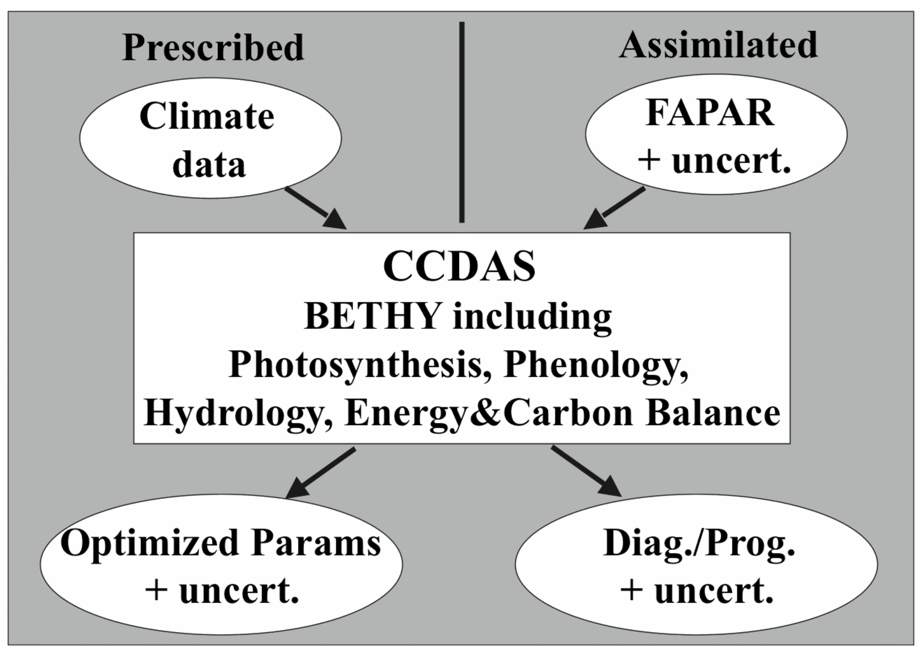

Figure 1: Revised CCDAS scheme.

Table 1: The 14 parameters for the new phenology scheme as optimised in CCDAS. An additional 24 Parameters were optimised from the original CCDAS, with uncertainty reductions of up to 7%.

Parameter	PFTs[1]	Prior value	Posterior value	Uncert. reduction [%]
$\tilde{\Lambda}$ maximum LAI	all	5.00±0.25	4.36±0.23	6
T_φ temperature threshold	4, 5	10.00±0.50	9.34±0.27	46
T_φ "	8	6.00±0.50	8.11±0.50	0
T_φ "	9, 10	2.00±0.50	1.53±0.41	18
T_r spatial variability of T_φ	1, 2, 4, 5, 8	2.00±0.10	2.04±0.10	1
T_r "	9, 10	0.50±0.10	0.52±0.10	0
t_c day length threshold	4, 5, 8	10.50±0.50	13.73±0.43	14
t_r spatial variability of t_c	4, 5, 8	0.50±0.10	0.46±0.10	0
ξ see Equ. (1)	all	0.50±0.10	0.52±0.10	0
k_L=1/τ_L see Equ. (1)	all exc. 5	0.100±0.050	0.058±0.012	76
k_L=1/τ_L see Equ. (1)	5	$3.0±1.5×10^{-3}$	$3.3±8.9×10^{-4}$	40
τ_W water-limited leaf longevity	1	360±180	1114±192	61
τ_W "	2	50±25	112±19	62
τ_W "	9, 10	50±25	28±12	9

[1]1: tropical evergreen trees, 2: tropical drought-deciduous trees; 4: temperate cold-deciduous trees; 5: evergreen conifers; 8: deciduous understorey shrub; 9: C3 grass; 10: C4 grass. The PFTs exist at the following sites: Sodankylä (5, 4), Zotino (5, 4), Loobos (5, 8, 9), Hainich (4, 9), Manaus (1, 10) and Maun, Botswana (2, 10).

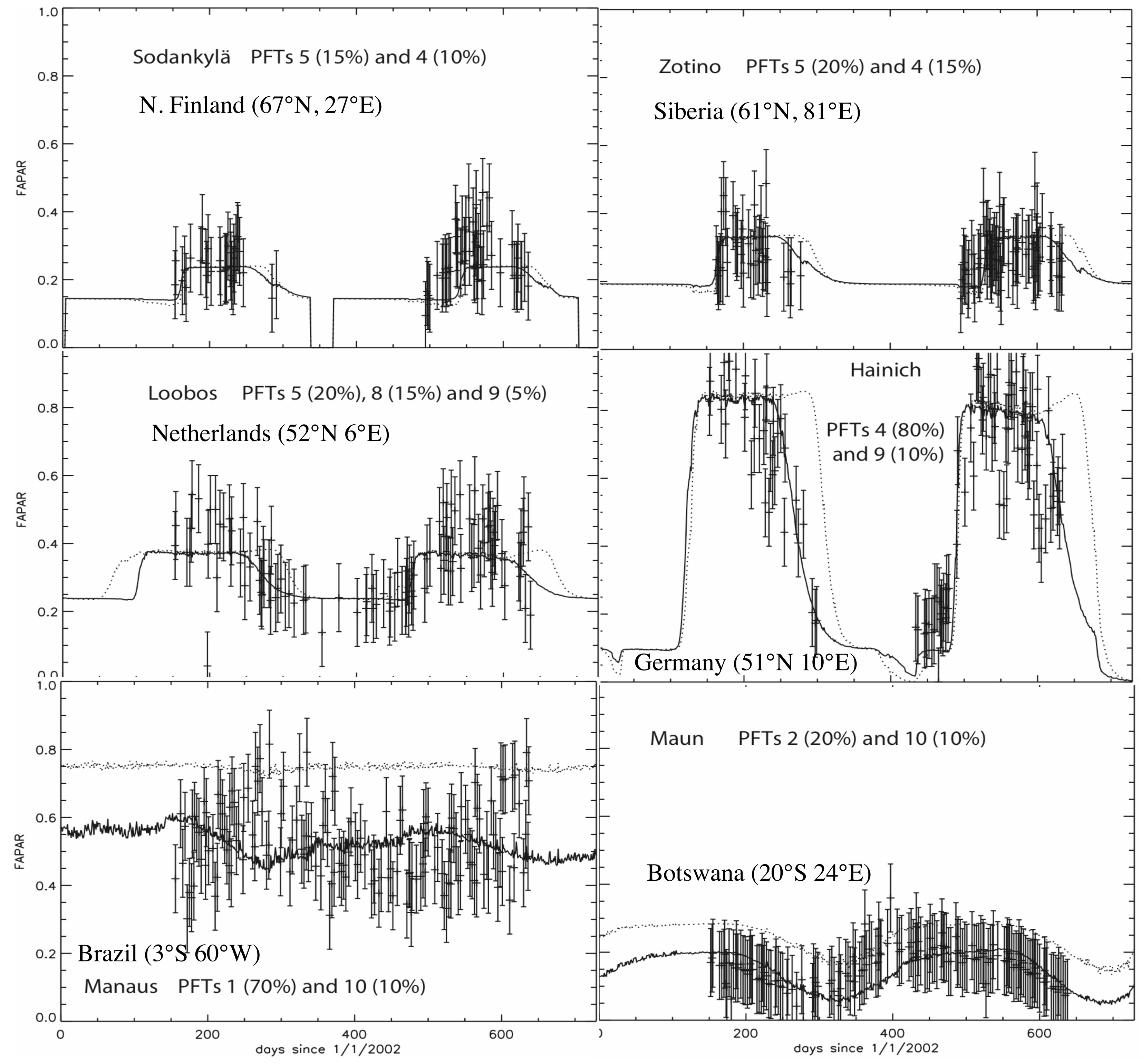

Figure 2: *a priori* (dotted) and *a posteriori* (solid) FAPAR simulated with BETHY at the 6 sites. Satellite data are shown with error bars.

Methods

- Extend the Carbon Cycle Data Assimilation System (CCDAS)[1] to include hydrology and leaf phenology
- Incorporate satellite data of the Fraction of Absorbed Photosynthetically Active Radiation (FAPAR) from ESA's MERIS[2] instrument for 6 sites.
- Optimise process parameters of global vegetation model BETHY[3] for best agreement of model and satellite FAPAR.
- Use local information at the optimum to infer *a posteriori* uncertainties of parameters and compare to *a priori* uncertainties.
- Project *a priori* and *a posteriori* uncertainties from parameters to carbon fluxes.

Generic Phenology Model

$$\frac{d\Lambda(t)}{dt} = \xi[\Lambda_{max} - \Lambda(t)]f - \frac{\Lambda(t)}{\tau_L}(1-f) \quad \text{(Equ. 1)}$$

- Leaf area index (LAI): Λ
- Leaf sprouting rate: ξ
- Leaf shedding time: τ_L
- Water-limited LAI: Λ_{max}
- Fraction of plants in growth phase: f

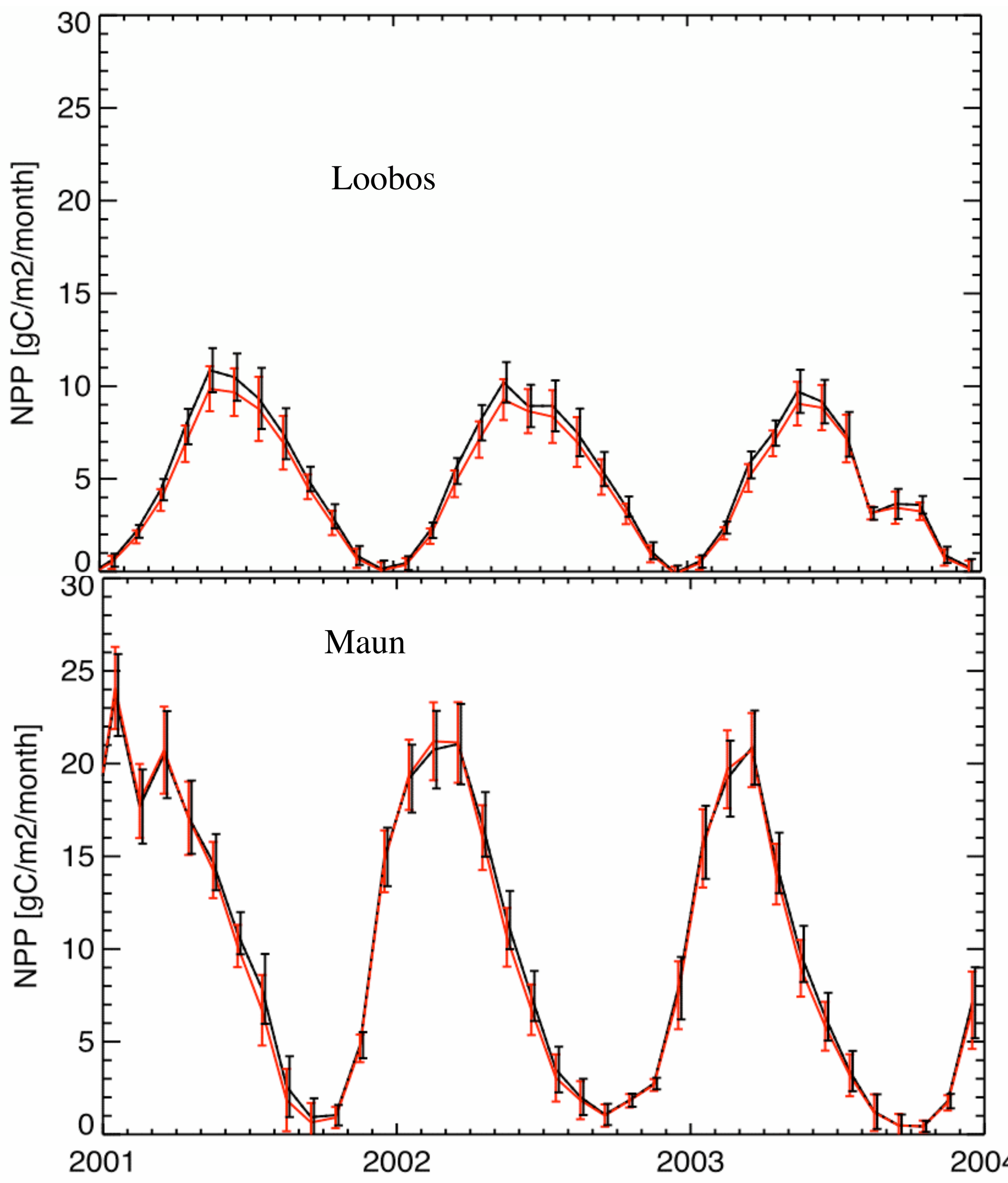

Figure 3: *a priori* (black) and *a posteriori* (red) NPP simulated with BETHY, with error bars.

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