Deriving process information on the terrestrial carbon cycle from earth observations

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Challenges in estimating terrestrial carbon fluxes

- Heterogeneous landscapes
  - Uncertain current states
  - Uncertain process rates
- Non-steady state dynamics
  - Spin-up assumptions
- Complex models
  - Challenging to create confidence estimates

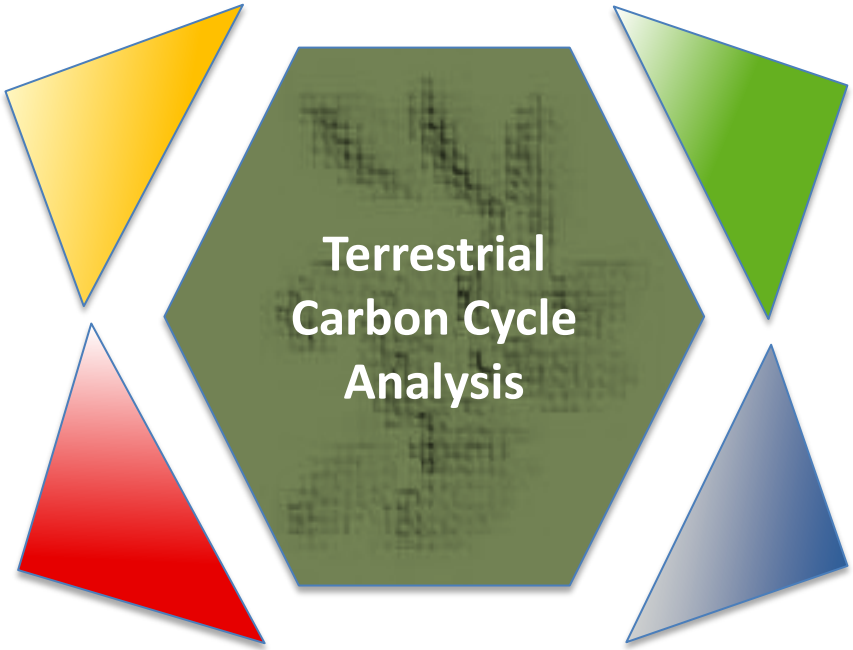
CARDAMOM - CARbon DAta MOdel fraMework

MODEL

DALEC: Data Assimilation Linked Ecosystem Carbon model

DRIVERS

Global ERA interim analyses



DATA

MODIS LAI time series, Biometric Satellite data, Eddy flux tower data, Plant trait data.

OPTIMIZATION

Metropolis-Hastings Markov Chain Monte Carlo

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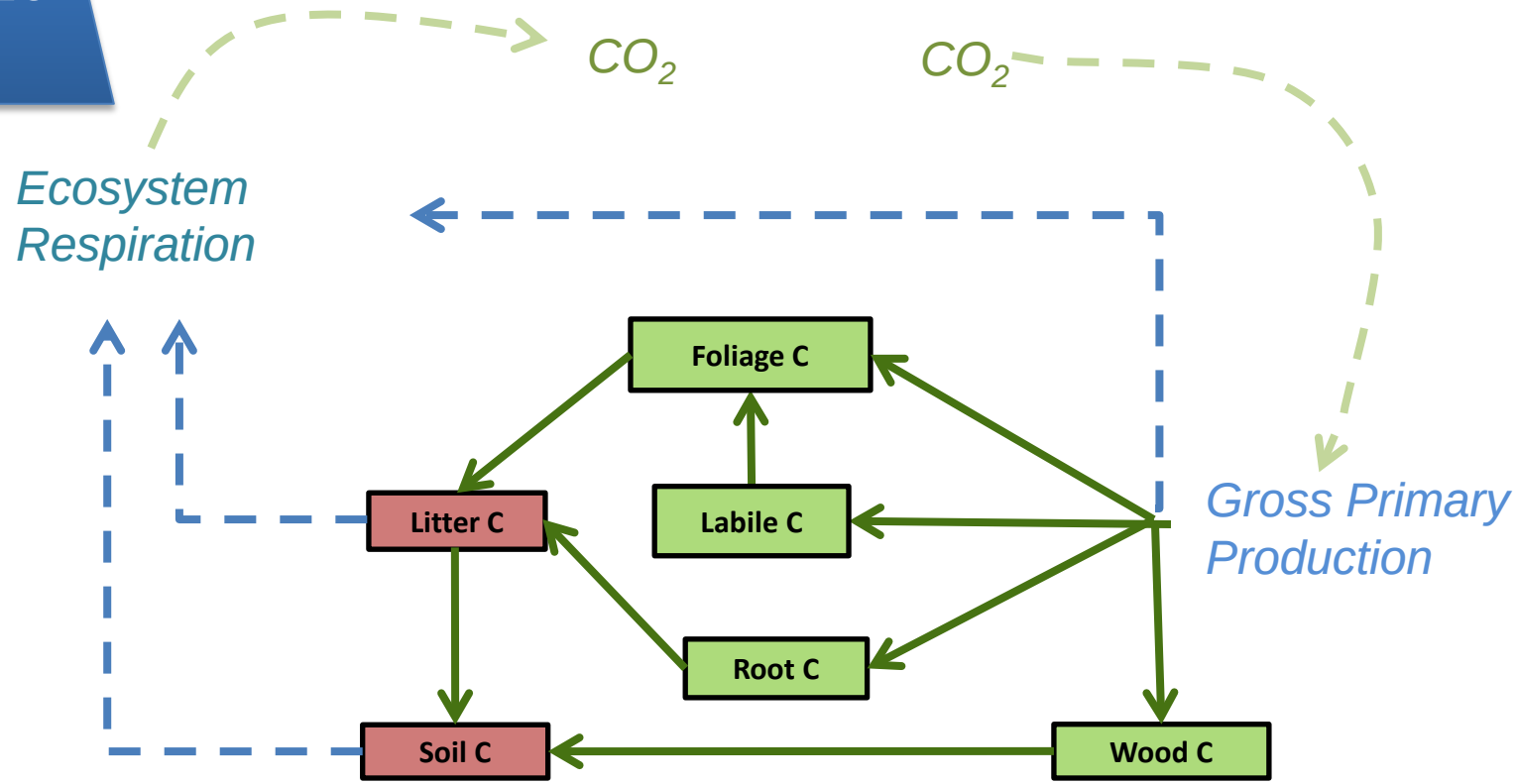
Data Assimilation Linked Ecosystem Carbon model

DALEC



DALEC carbon pools and fluxes: 23 parameters describe pool allocation, phenology and turnover rates in ecosystem carbon cycling.

DALEC Parameter vector = [M_r, f_a, f_f, f_r, L_L, t_w, t_r, t_{lit}, t_{SOM} T_{rate}, C_{eff}, B_{day}, f_{lab}, R_r, F_{day}, R_f, LMA, C_{LA},C_{FO}, C_{RO}, C_{WO}, C_{LI}, C_{SO}]

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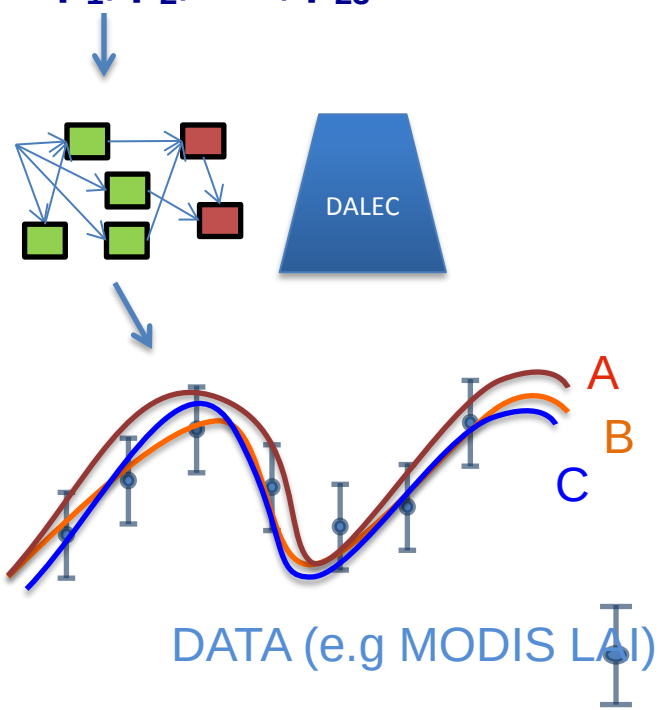
Model Data Fusion (MDF)

Random Sampling of DALEC parameters

A. $p_1, p_2, \ldots, p_{23}$

B. $p_1, p_2, \ldots, p_{23}$

C. $p_1, p_2, \ldots, p_{23}$



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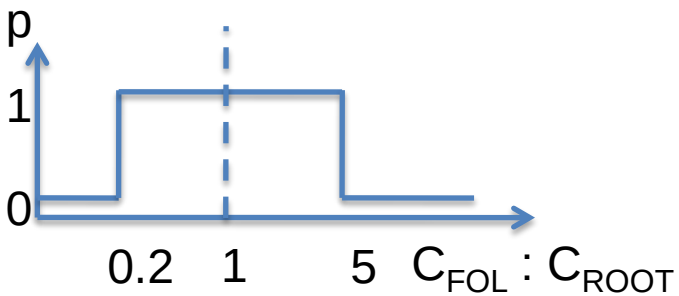
Ecological and Dynamic Constraints (EDCs)

DALEC Parameter vector = [M_r, f_a, f_f, f_r, L_L, t_w, t_r, t_{lit}, t_{SOM} T_{rate}, C_{eff}, B_{day}, f_{lab}, R_r, F_{day}, R_f, LMA, C_{LA},C_{FO}, C_{RO}, C_{WO}, C_{LI}, C_{SO}]

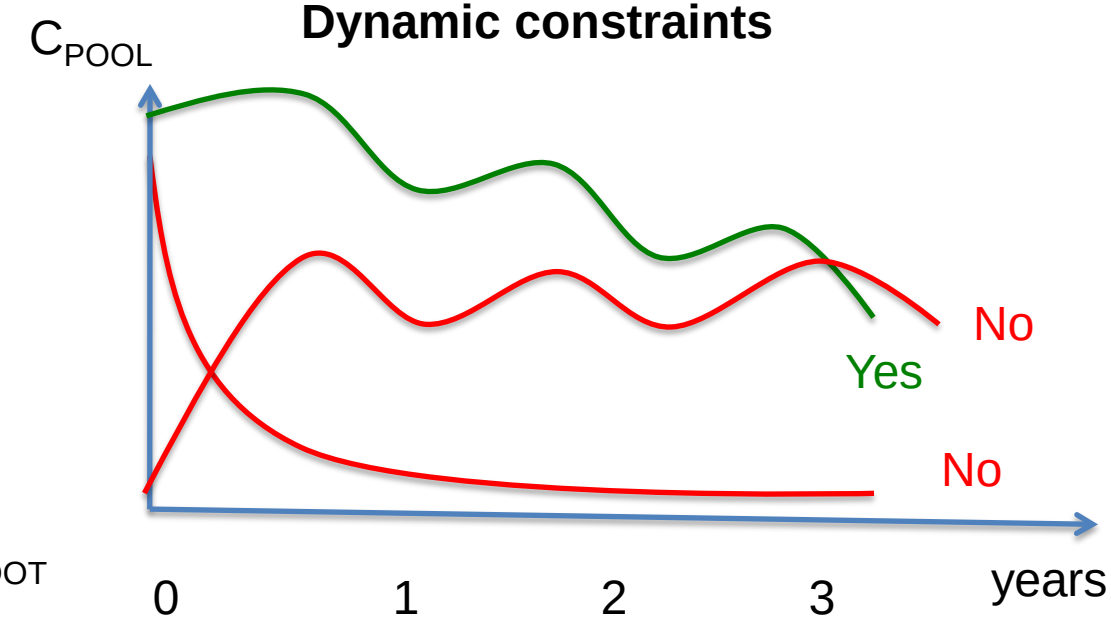
Turnover constraints

$t_{SOM} < t_{litter}$ & $t_{wood} < t_{foliar}$

C_{root}: C_{fol} ratio

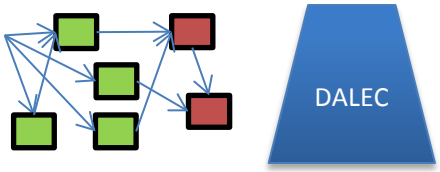


Dynamic constraints



Analytical dynamic constraints

$GPP_{mean}*f_{som}/(t_{som}*\exp(T_{fac}*T_{mean}))$~ factor of 4 of C_{som}



In total: 14 checks

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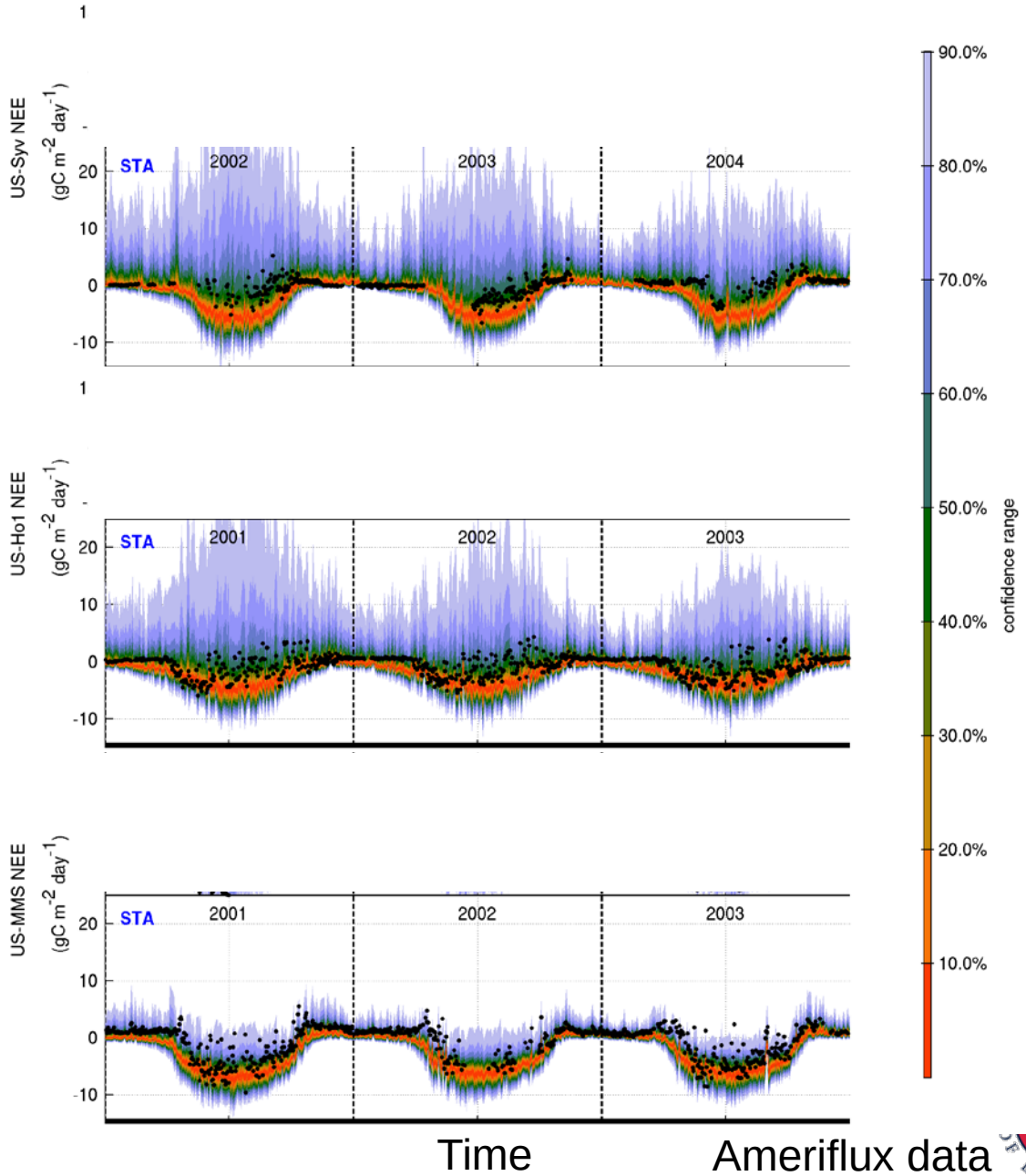
Independent tests at flux sites indicate value of EDCs

Assimilate MODIS LAI, HWSD soil C

Sylvania
(Mixed forest)

Howland
(Evergreen forest)

Morgan Monroe
(Decid. Broadleaf)



Ameriflux data

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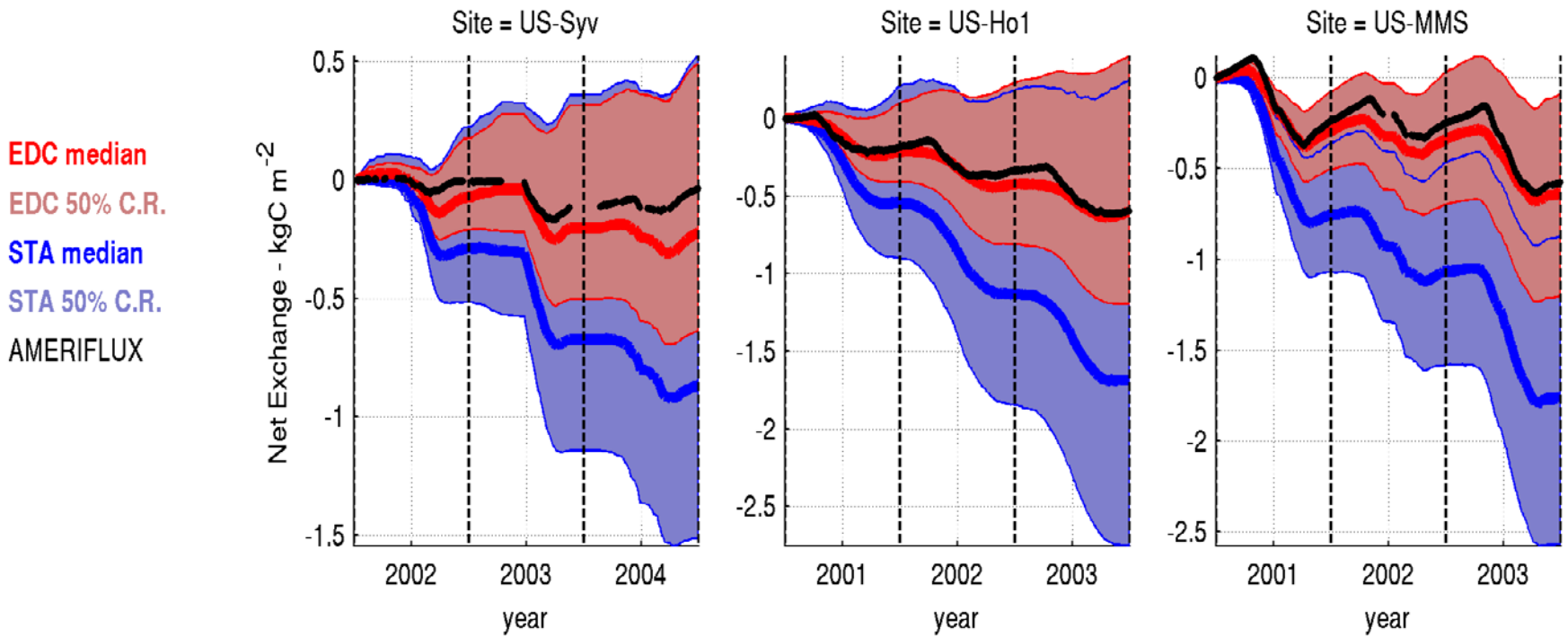
Independent tests of cumulative NEE at Ameriflux sites



Ameriflux data

Bloom and Williams, in review

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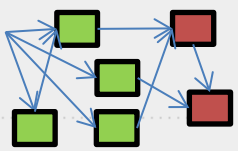
CARDAMOM DALEC: a terrestrial ecosystem carbon cycle analysis

Posterior Parameter Probability
1° x 1° Pixel Scale Parameter, Flux & carbon pool estimates

C state likelihood function = observation likelihood & parameter priors
No spin-up
No PFTs
No Steady state

Drivers:

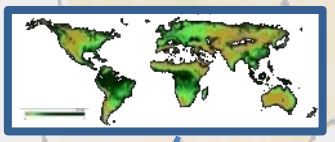
ERA-interim 1° x 1° resolution 8-day time-step 2001-2010



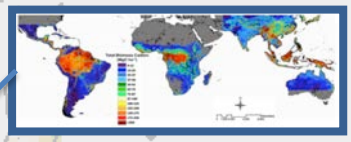
DALEC

Biometric Data Constraints

MODIS LAI



Pan-Tropical Biomass



Saatchi et al. 2011

HWSD Soil Organic C

Hiederer & Köchy, 2012

$$p(x|c) \propto p(c|x)\, p(x)$$

Dynamic & ecological constraints

Parameter probability **p(x|c)** at each pixel derived using a Metropolis-Hastings MCMC algorithm

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Bloom & Williams, in prep.

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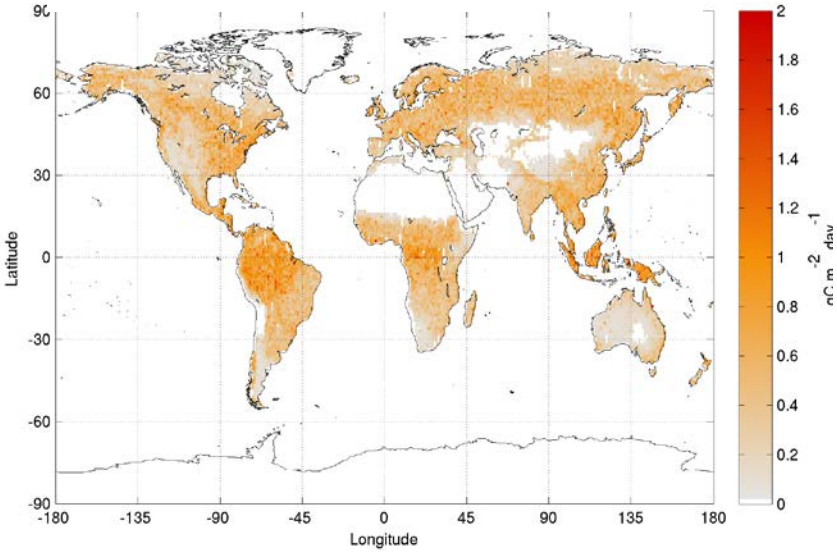
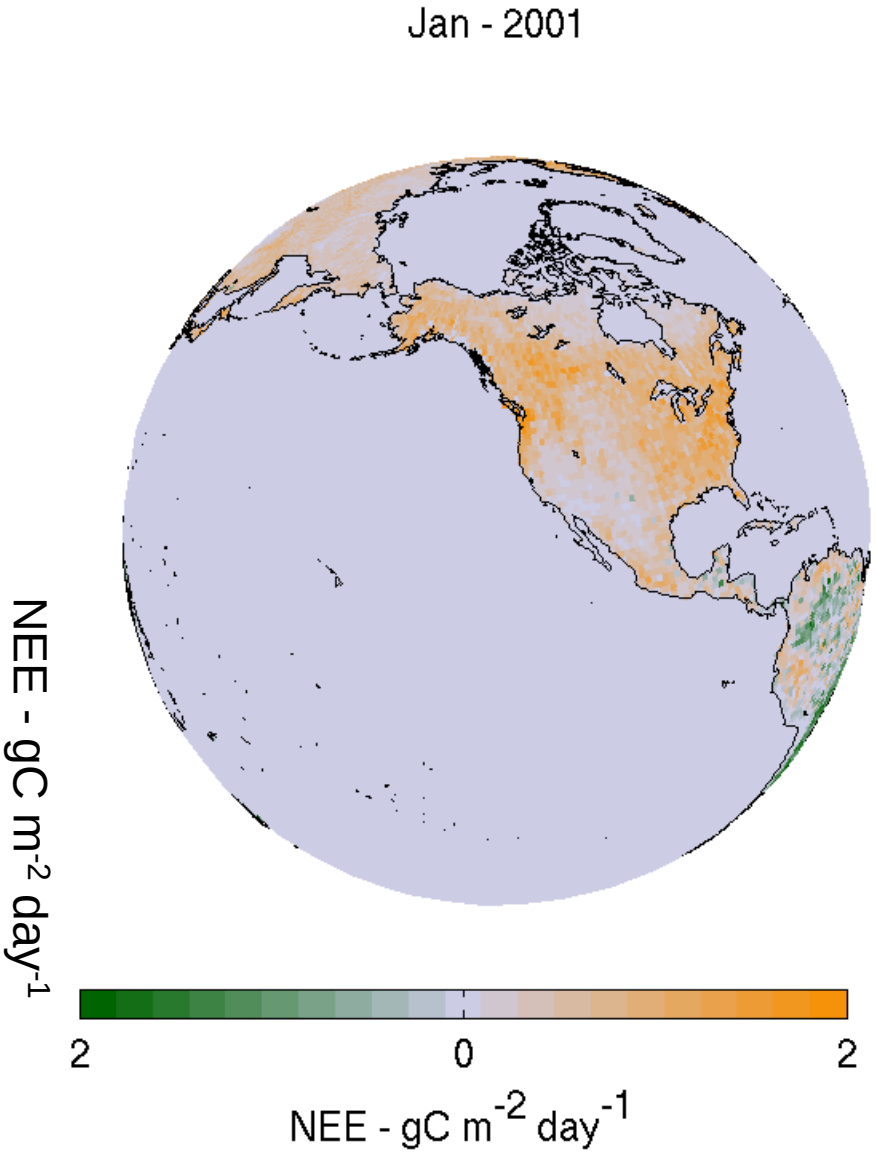
Mean monthly NEE at 1° x 1°

2001-2010: global terrestrial carbon cycle analysis.

NEE UNCERTAINTY



Bloom & Williams, in prep.



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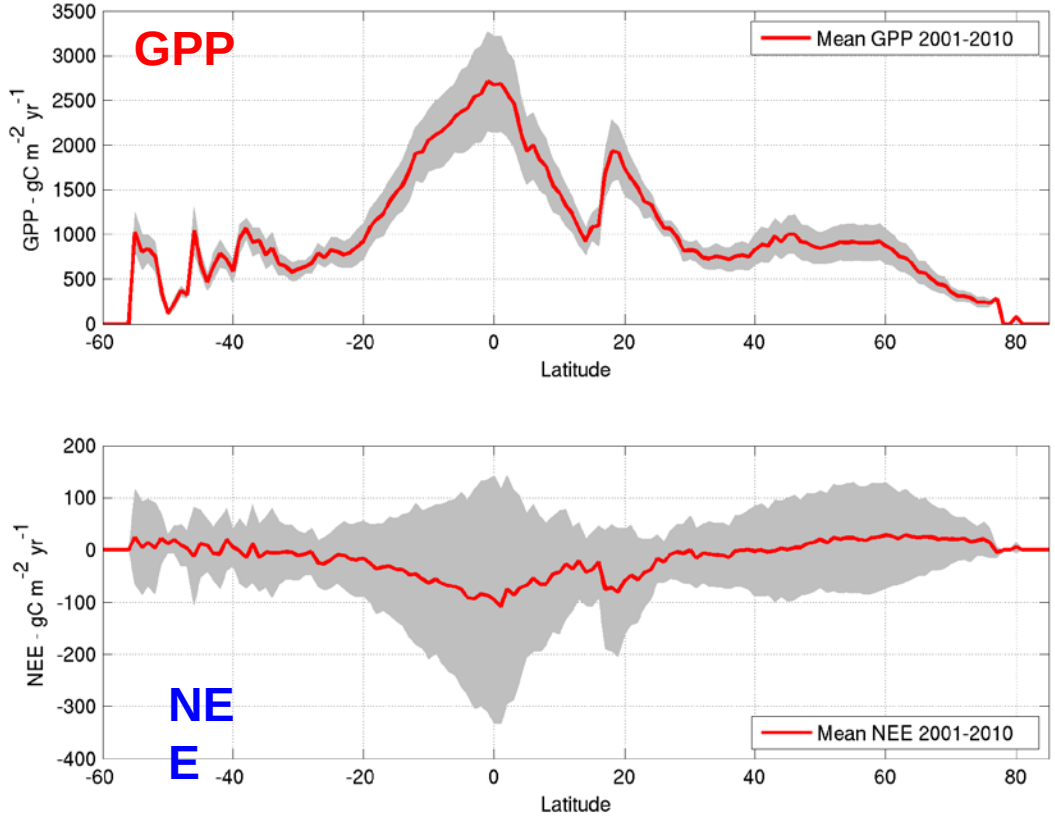
CARDAMOM fluxes 2001-2010: key results

(A) Global carbon flux estimates



Gross Primary Production

$GPP_{01\text{-}10} = 123.2 \pm 7.5$ PgC yr^{-1}

Net Ecosystem Exchange

$NEE_{01\text{-}10} = -1.8 \pm 2.7$ PgC yr^{-1}

Global carbon pool totals

Labile = 4 ± 2 Pg C

Foliar = 11 ± 7 Pg C

Fine Roots = 16 ± 12 Pg C

Wood = 535 ± 298 Pg C

Litter = 17 ± 14 Pg C

SOM = 1415 ± 735 Pg C

Bloom & Williams., in prep.

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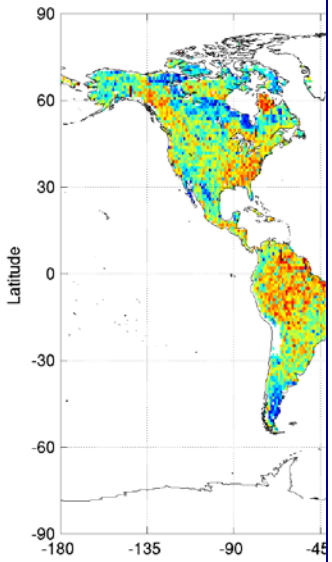
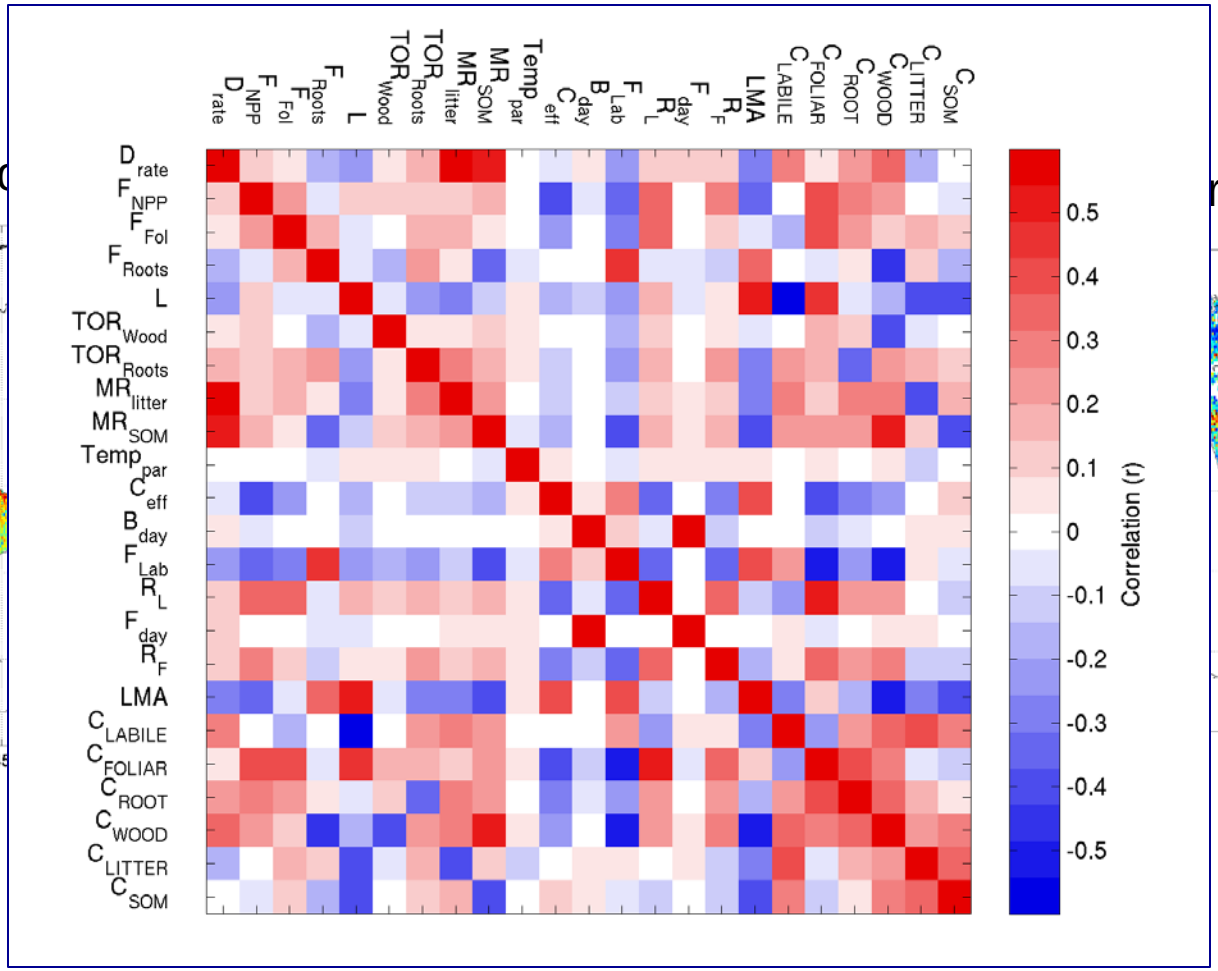
CARDAMOM DALEC – Posterior parameters

Soil turno





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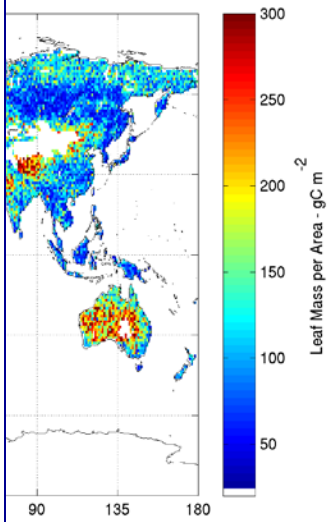

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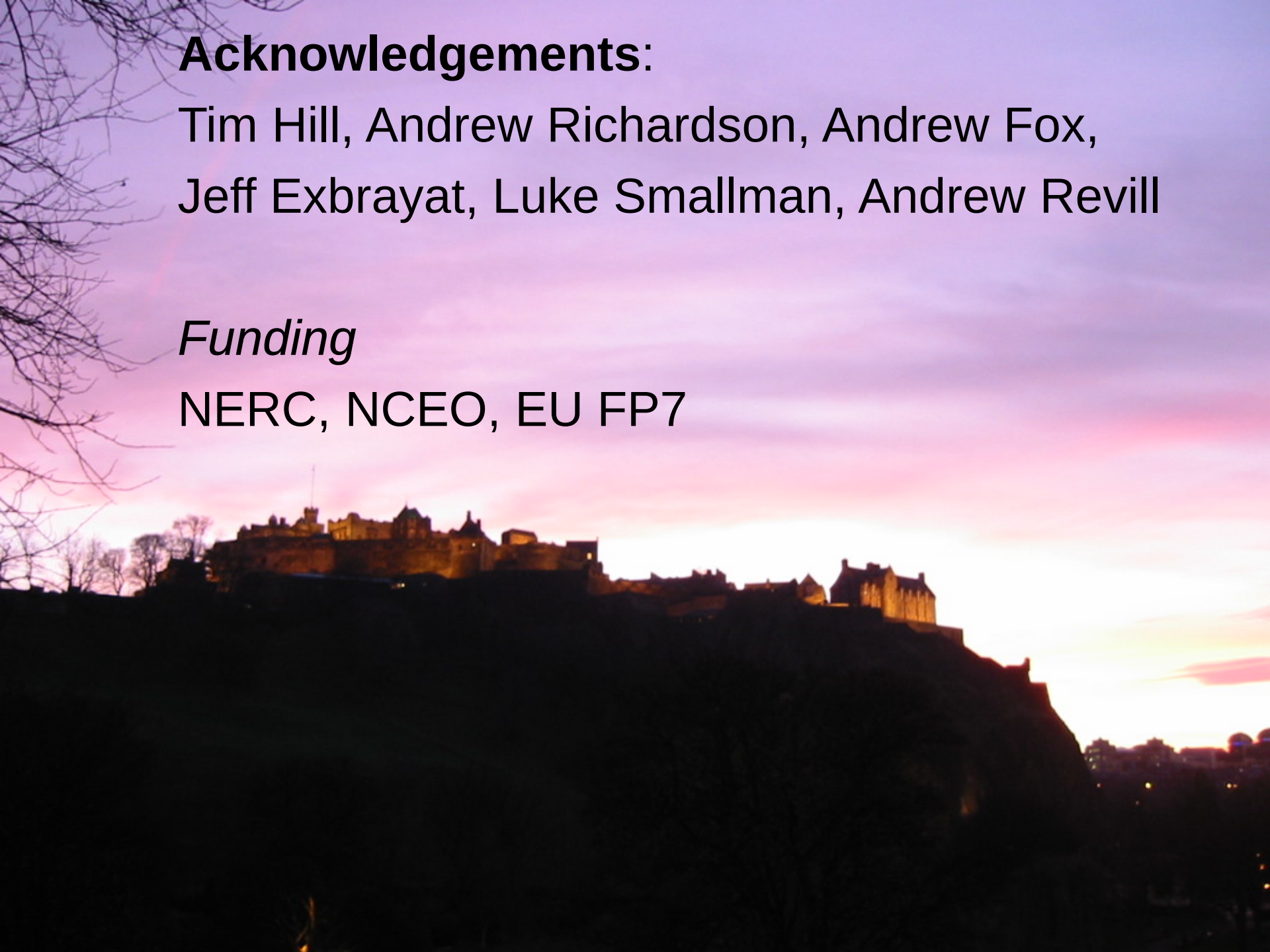
Conclusions

- Multiple data-streams combined with mass balance modelling allow estimation of ecologically-consistent fluxes, parameters and carbon pools.
- Dealing with dynamic and managed systems is the next challenge
  - See posters by Jeff Exbrayat [disturbances] and Andrew Revill [crops]



Acknowledgements:

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Jeff Exbrayat, Luke Smallman, Andrew Revill

Funding

NERC, NCEO, EU FP7

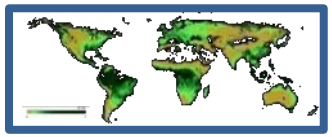
Next steps – beyond steady state

- Assimilating burned area data (MODIS)
- Assimilating deforestation time series (LandSat...)

- Objective: to produce analyses consistent with sequential biomass maps (ALOS...)
  - challenge to parameterise regrowth rates, emission factors, land use change

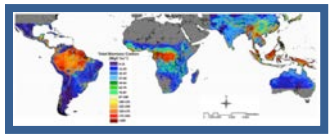
Ecosystem observations & terrestrial ecosystem carbon analysis

MODIS LAI



www.nasa.gov

Pan-tropical Biomass



Saatchi et al. 2011

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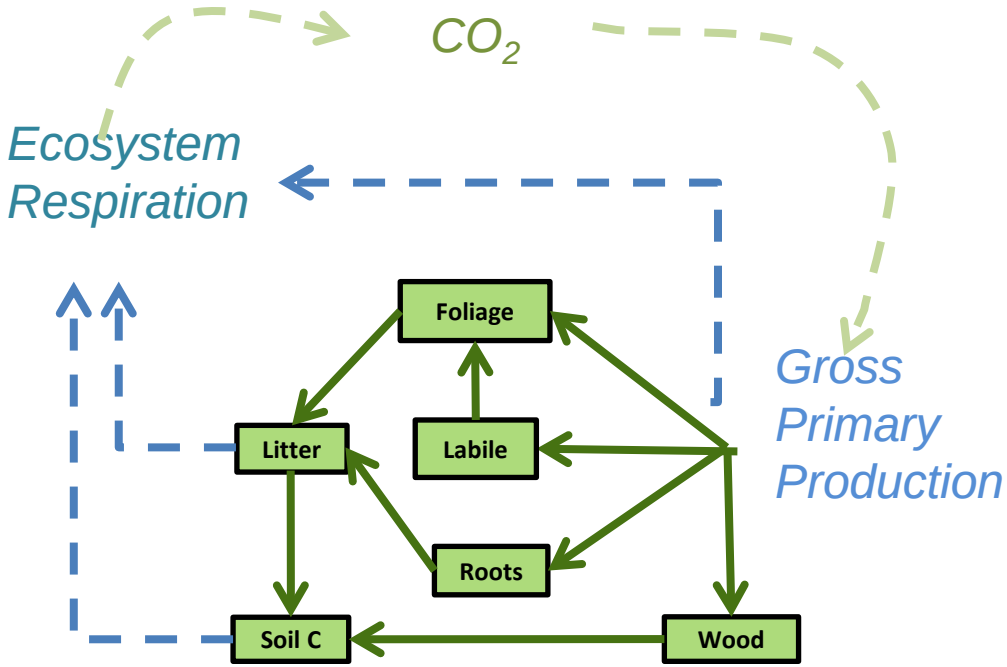
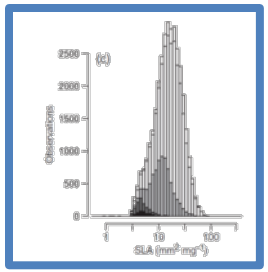
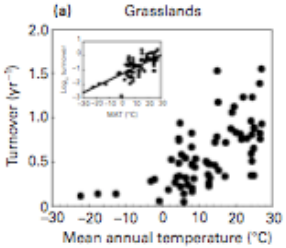


DALEC model

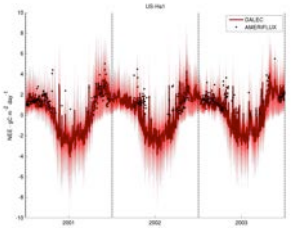
Plant trait data



Kattge et al., 2011



Fluxtower data



AMERIFLUX

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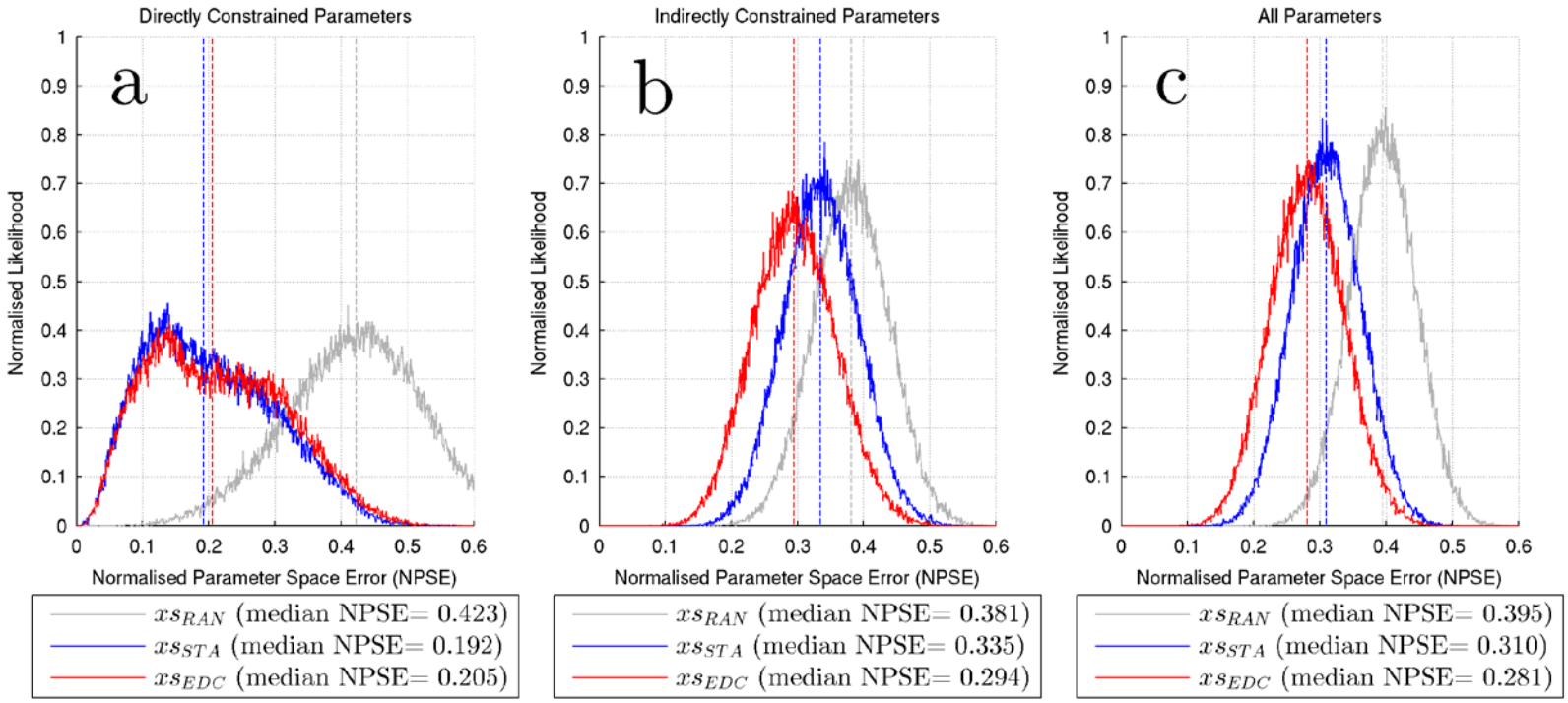
EDCs assist parameter constraint



Synthetic studies – 40 synthetic deciduous forests
Assimilate: LAI time series, singe soil carbon estimate

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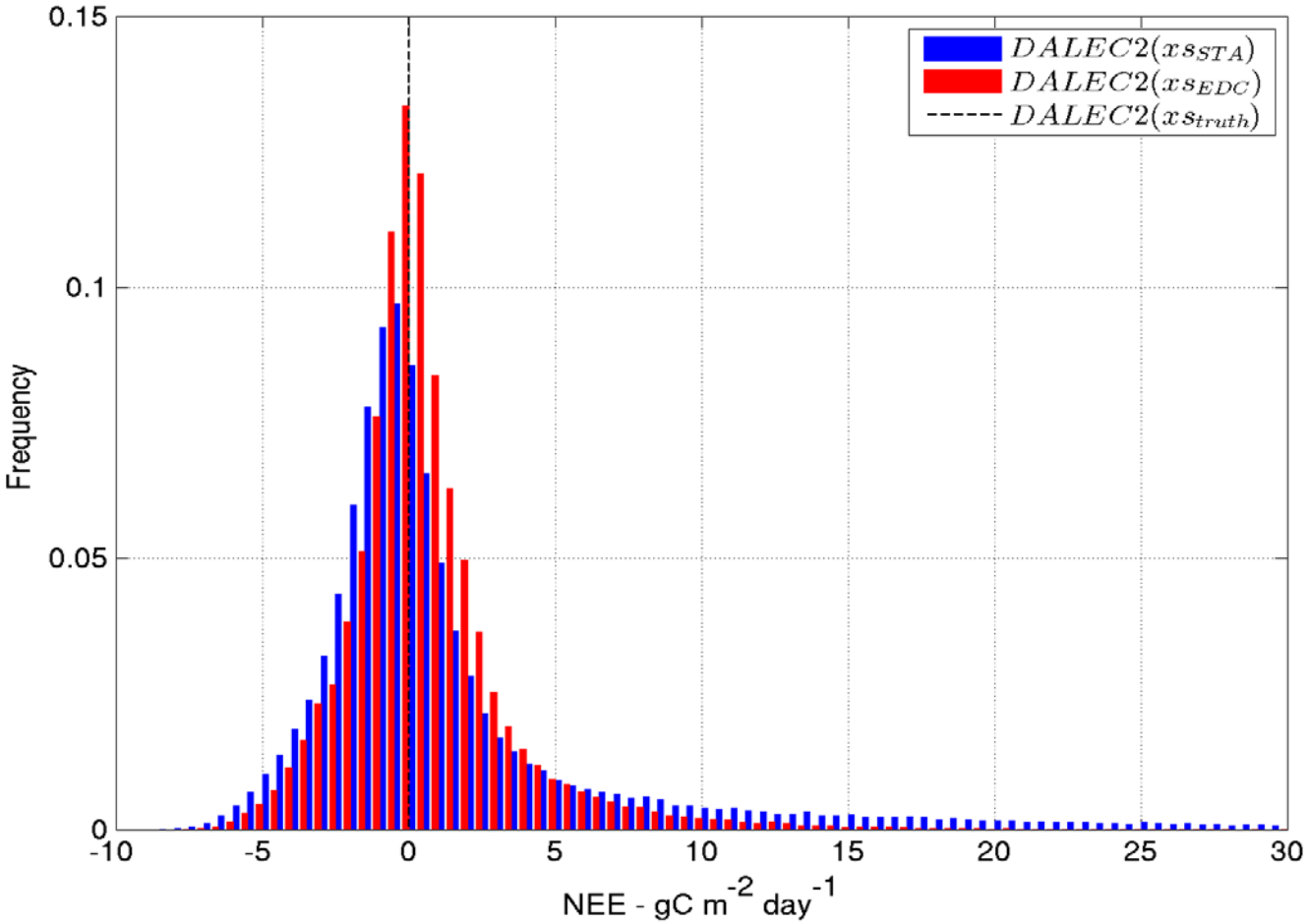
EDCs reduce model bias



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Synthetic studies

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