use of eddy covariance data from FLUXNET for parameter estimation and model evaluation

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and

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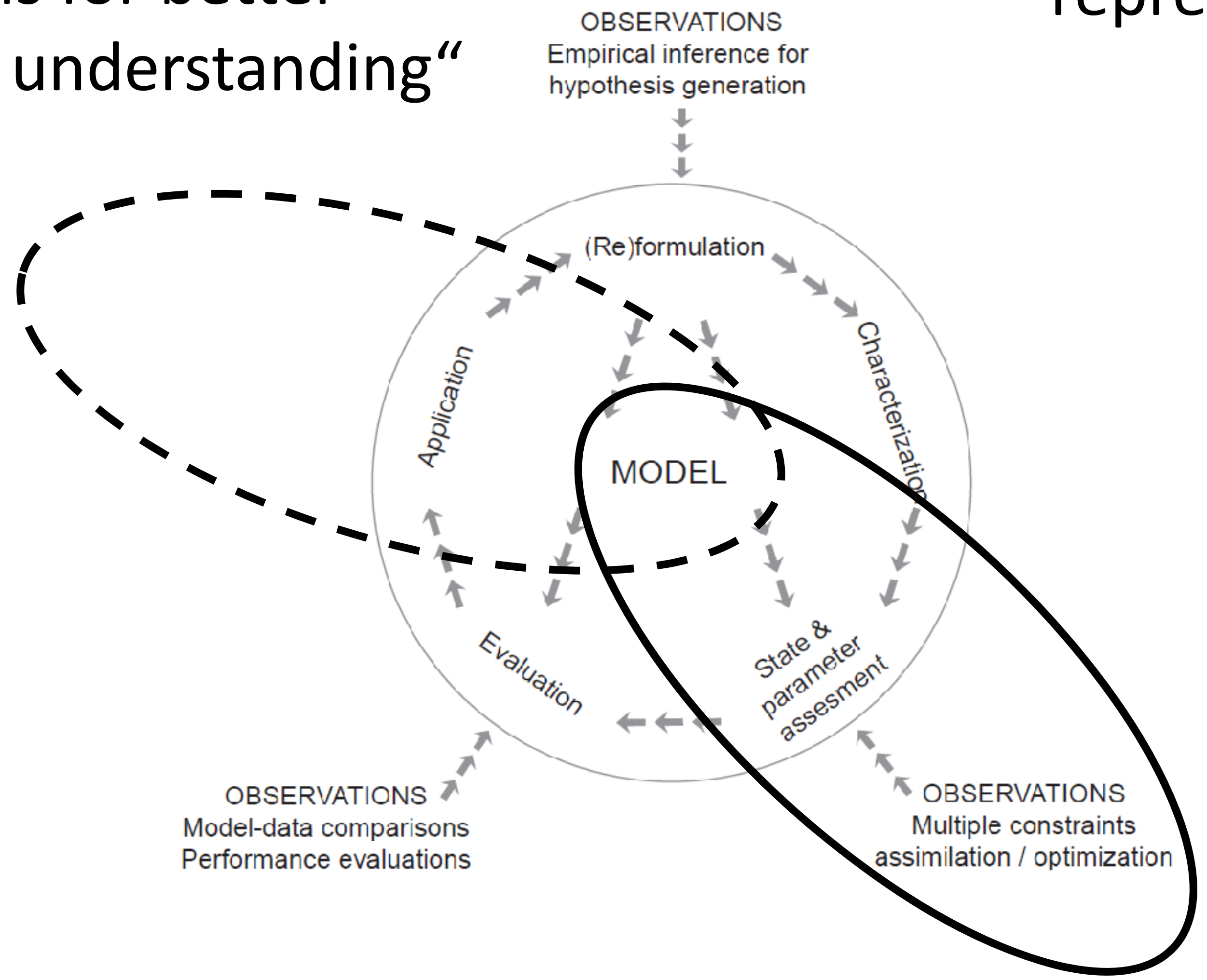
„Learning from obs-ervations for better process understanding“

„Improving model representations of ecosystems“



Mahecha, 2009

Observing at the interface between ecosystem and atmosphere: a good tool: eddy covariance

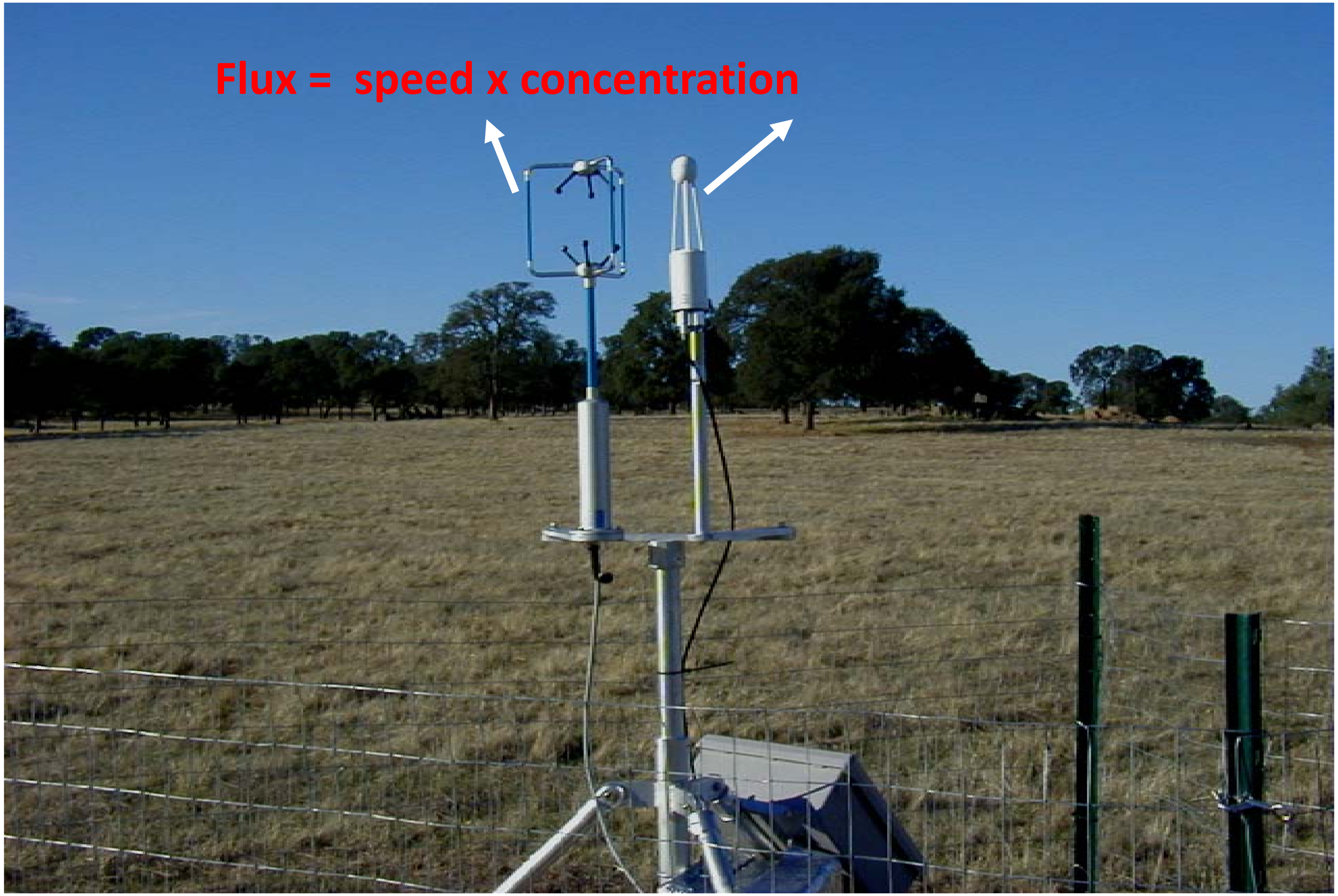
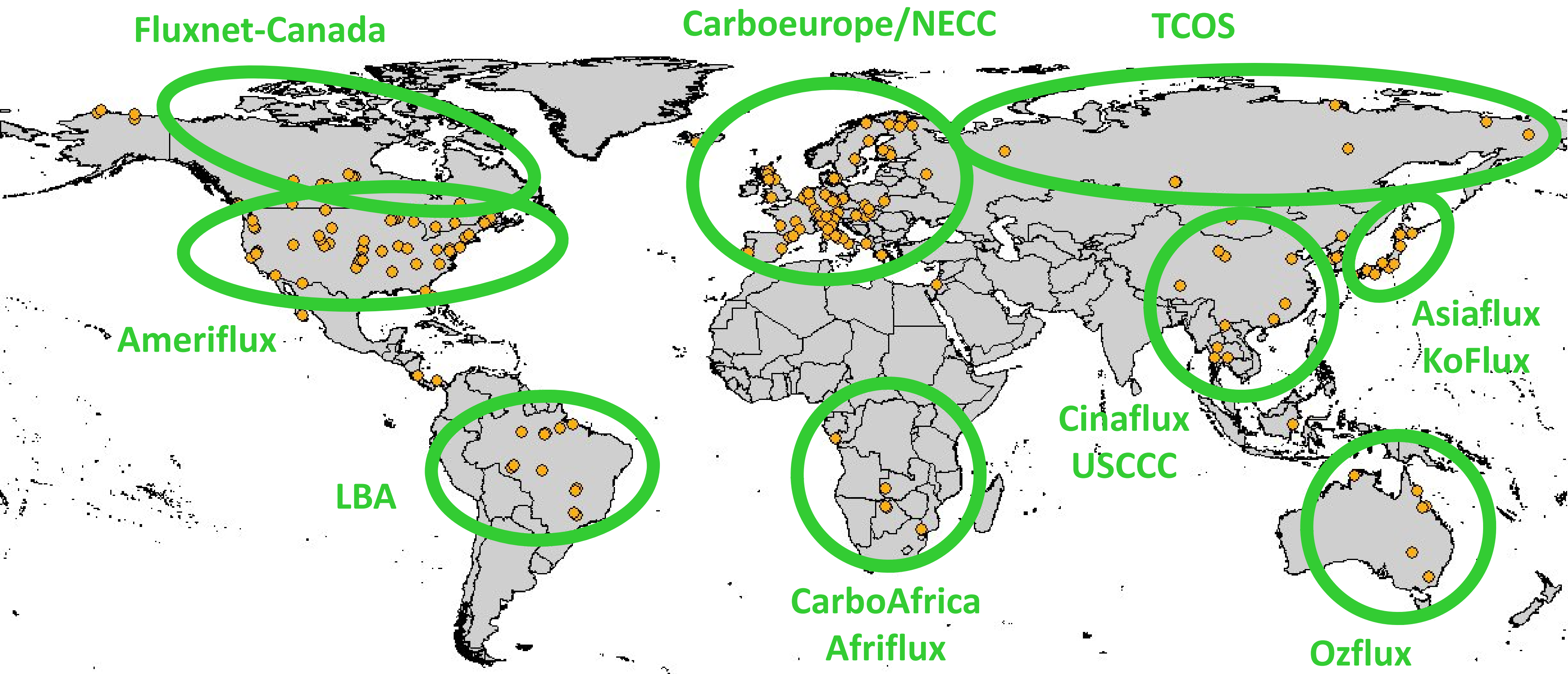
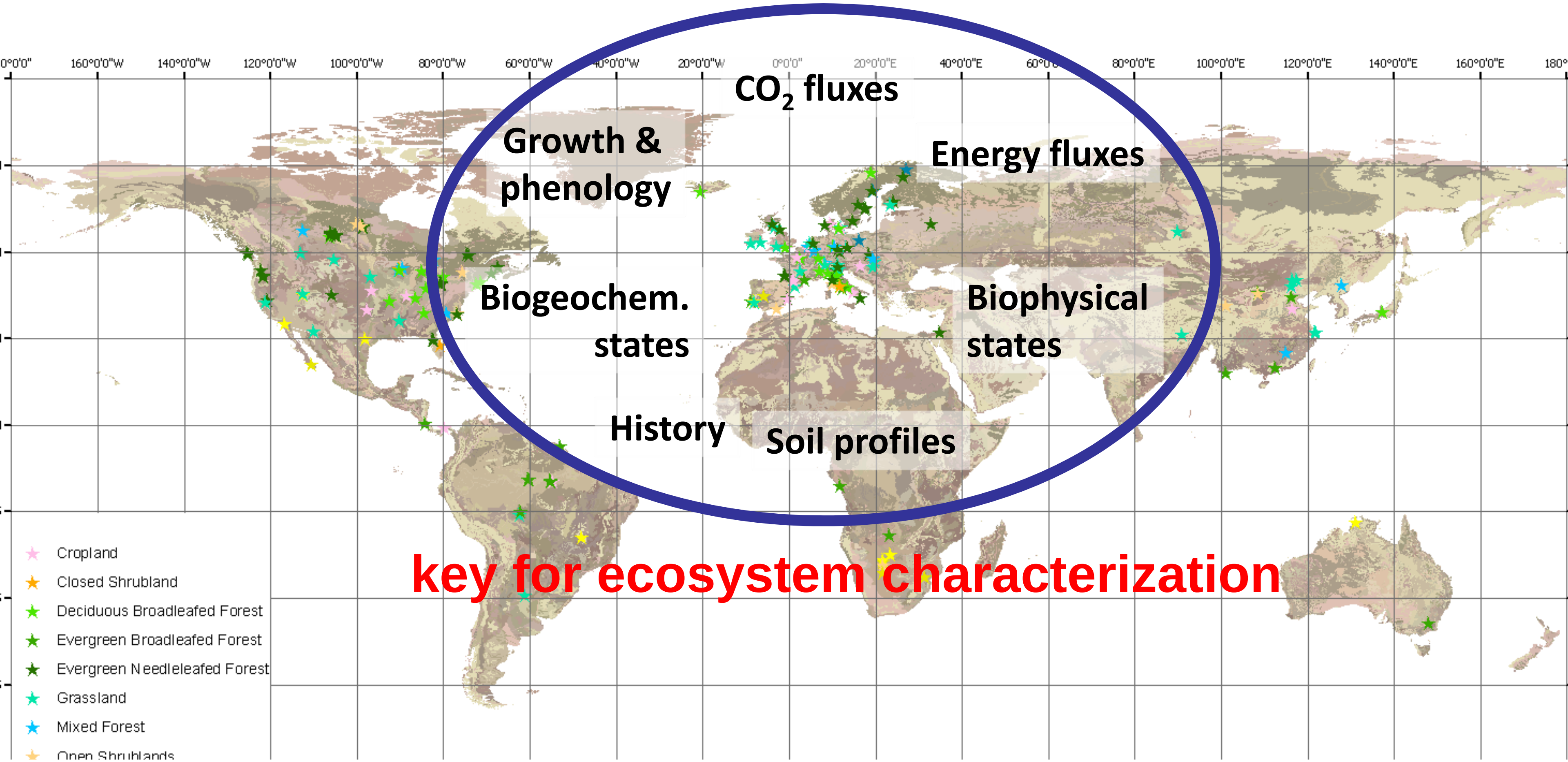


Photo: Baldocchi

World-wide eddy covariance collaborations



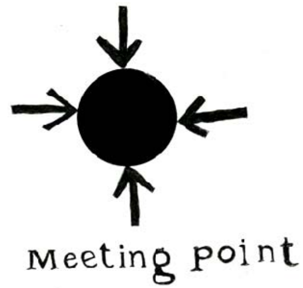
The global FLUXNET data base



- >950 site-years from >250 sites
- Standardized u*-filtering, gap-filling, flux-partitioning and uncertainties (Aubinet et al. 2001, Foken et al. 2003, Reichstein et al. 2005, Richardson et al. 2006, Papale et al. 2006, Moffat et al. 2007, Desai et al. 2008, Lasslop et al. 2008)

model data integration

model



data

Convergence in general statistical approach

- Simplified (Bayesian) maximum likelihood estimation:

Objective function

$$J = \underbrace{\frac{1}{2}\sum_{j=1}^{M}\sum_{i=1}^{N(j)}\frac{\left(f_{i,j}(\mathbf{p})-OBS_{i,j}\right)^2}{\sigma_{obs,i,j}^2}}_{\text{Trust in data}} + \underbrace{\frac{1}{2}\sum_{k=1}^{O}\frac{\left(p_k-\hat{p}_k\right)^2}{\sigma_{P,k}^2}}_{\text{Trust } \textit{in apriori} \text{ model parameters}}$$

Trust in data

Trust *in apriori* model parameters

examples

- Wang et al 2001: limits of model data fusion
- Reichstein et al 2003: effects of drought on ecosystem fluxes
- Knorr and Kattge 2005, Santaren et al 2006: address parameters
- Sacks et al 2006: seasonal controls on carbon fluxes
- Richardson et al 2006: model structure evaluation
- Williams et al 2005: multiple constraints

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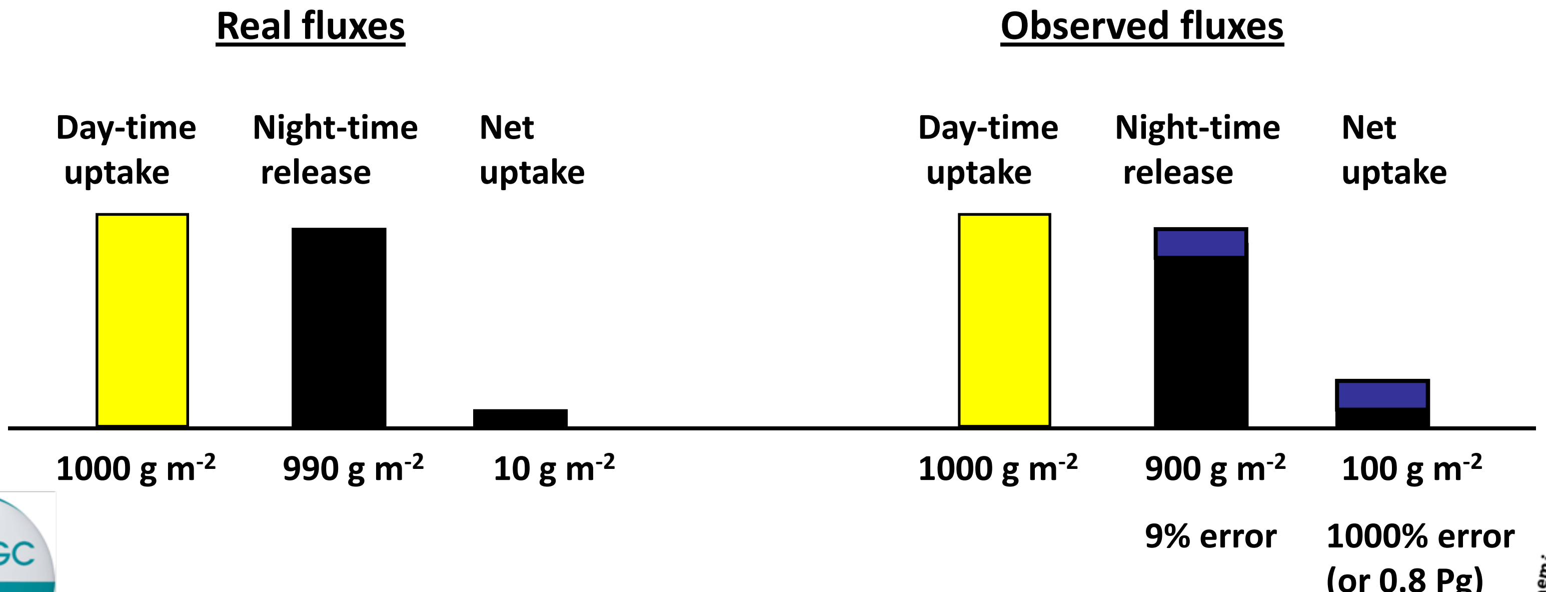
issues

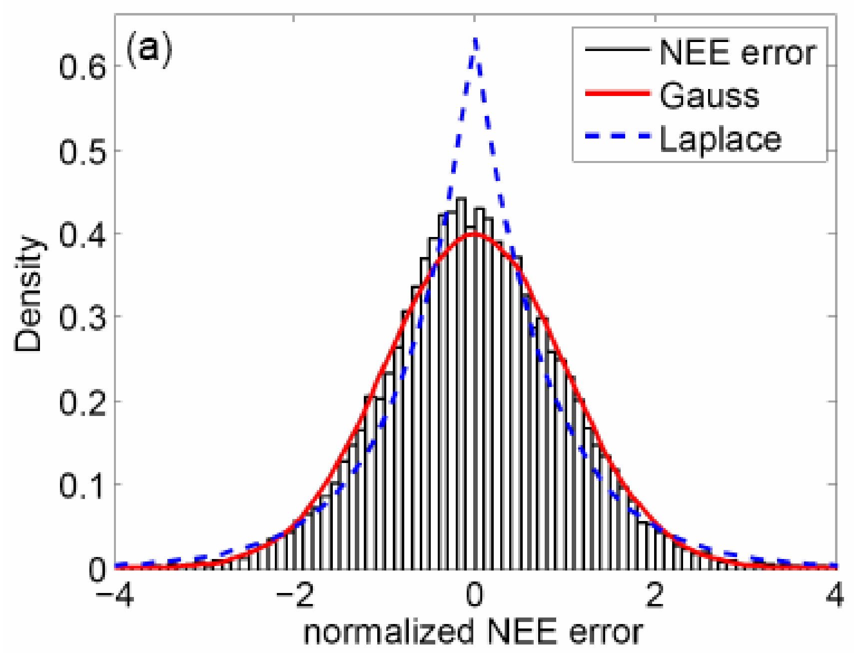
1. Formal versus real data uncertainties (cf. eddy covariance, Lasslop et al. 2008) → Data ensembles
2. Data representativeness & scale errors → data oriented up-scaling
3. Model structural biases affects parameters (Carvalhais et al. 2008) → challenge model structures;
4. Equifinality → multiple constraints approaches (Carvalhais et al., cond. acc)

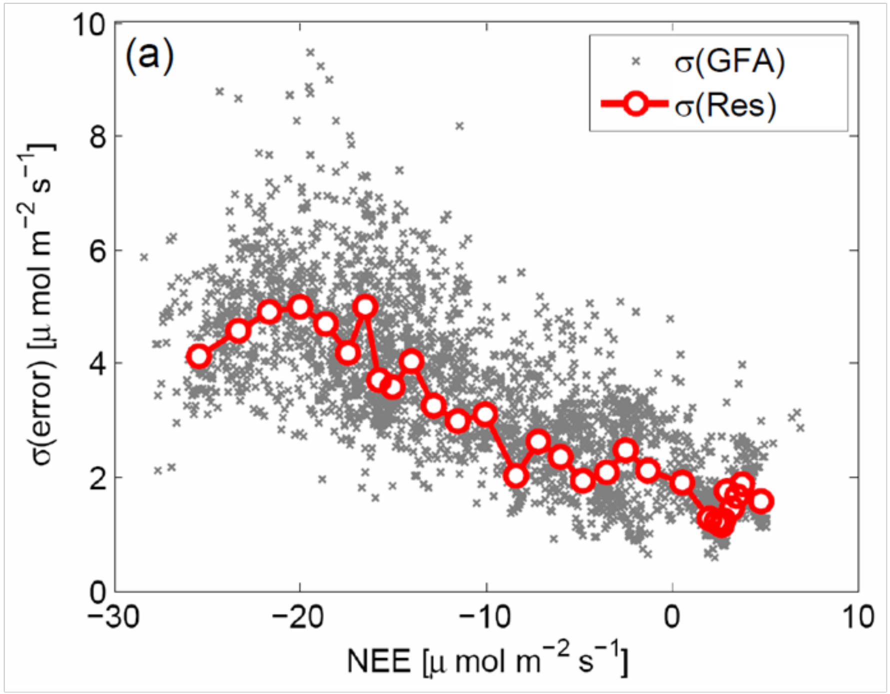
Errors in eddy covariance data (Moncrieff et al. 1996)

- Random errors (large for the half-hourly flux)
- Systematic errors (must/can be largely controlled/avoided)
- Selective systematic errors
  - Conditions where the theory does not apply:
    - Low turbulent conditions (night-time)
    - Advection



characterization of the random error



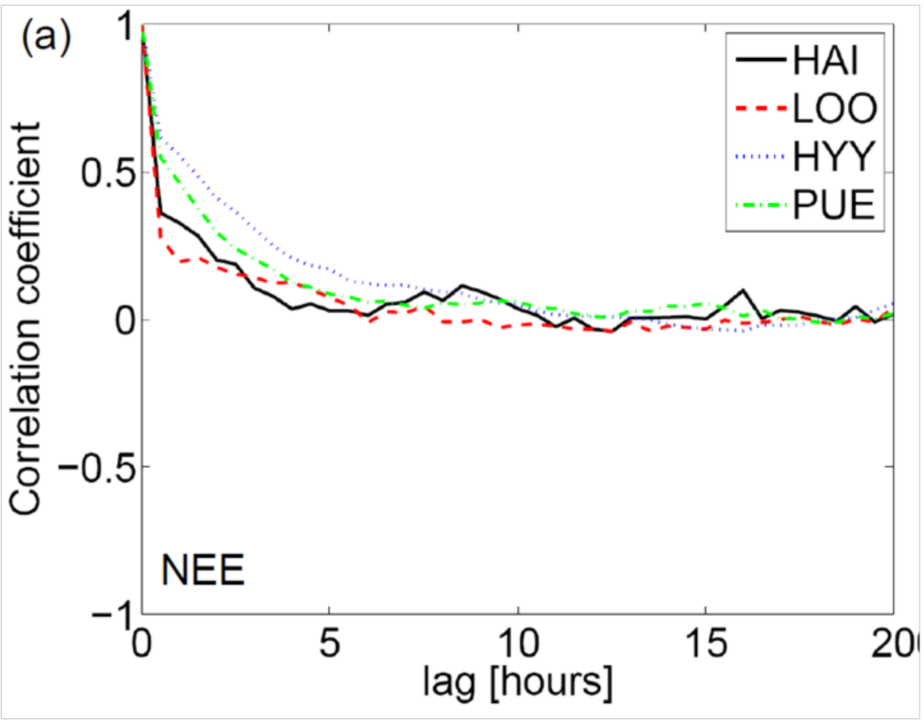


Almost normal distribution in most cases

Random error scales with magnitude of the flux (heteroscedastic)

Lasslop et al. (2008)

characterization of the random error



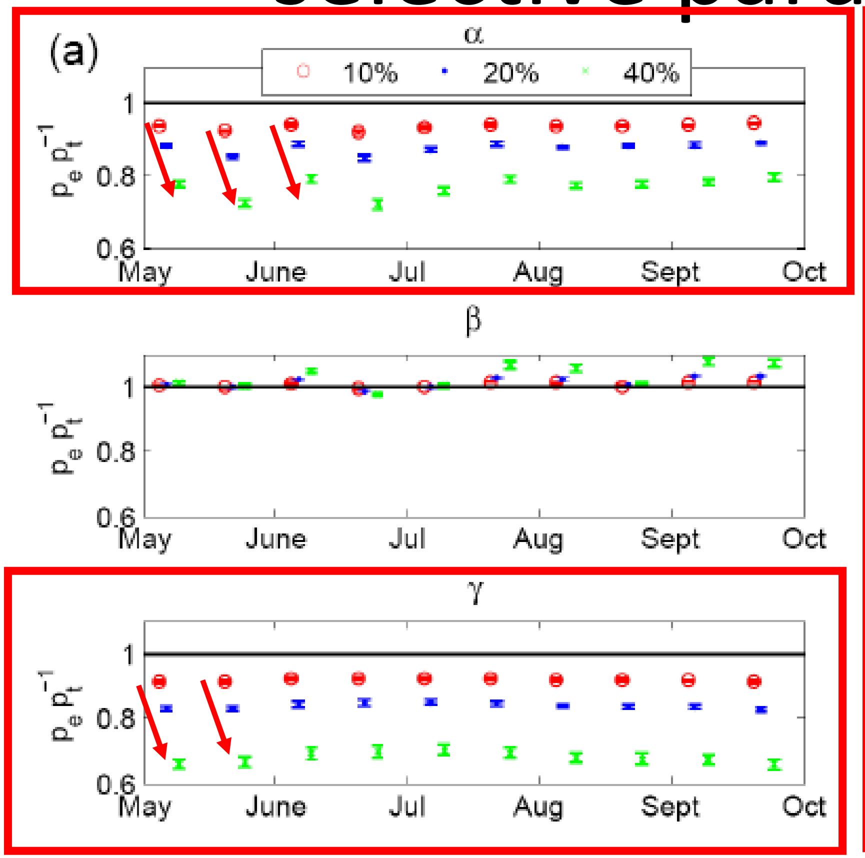
R^2 of *NEE* and *LE* errors										
Data period	1.– 15.5	16.– 31.5	1.– 15.6	16.– 30.6	1.– 15.7	16.– 31.7	1.– 15.8	16.– 31.8	1.– 15.9	16.– 30.9
HAI	0.089	0.004	0.176	0.192	0.088	0.136	0.202	0.007	0.077	0.097
LOO	0.004	0.029	0.059	0.086	0.031	0.000	0.004	0.024	0.030	0.010
HYY	0.197	0.033	0.139	0.128	0.021	0.012	0.023	0.049	0.000	0.003
PUE	0.093	0.244	0.038	0.033	0.068	0.003	0.012	0.018	0.019	0.031

Fast decay of autocorrelation

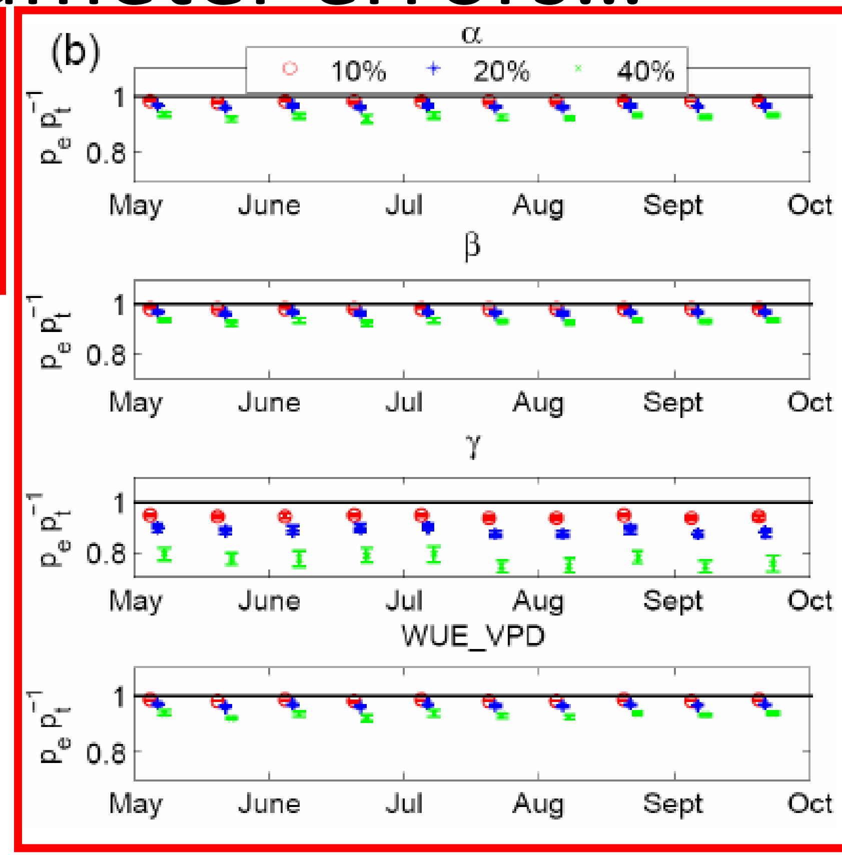
Almost no cross-correlation

Lasslop et al. (2008)

selective systematic error leads to selective parameter errors…



CO_2 flux constraint only

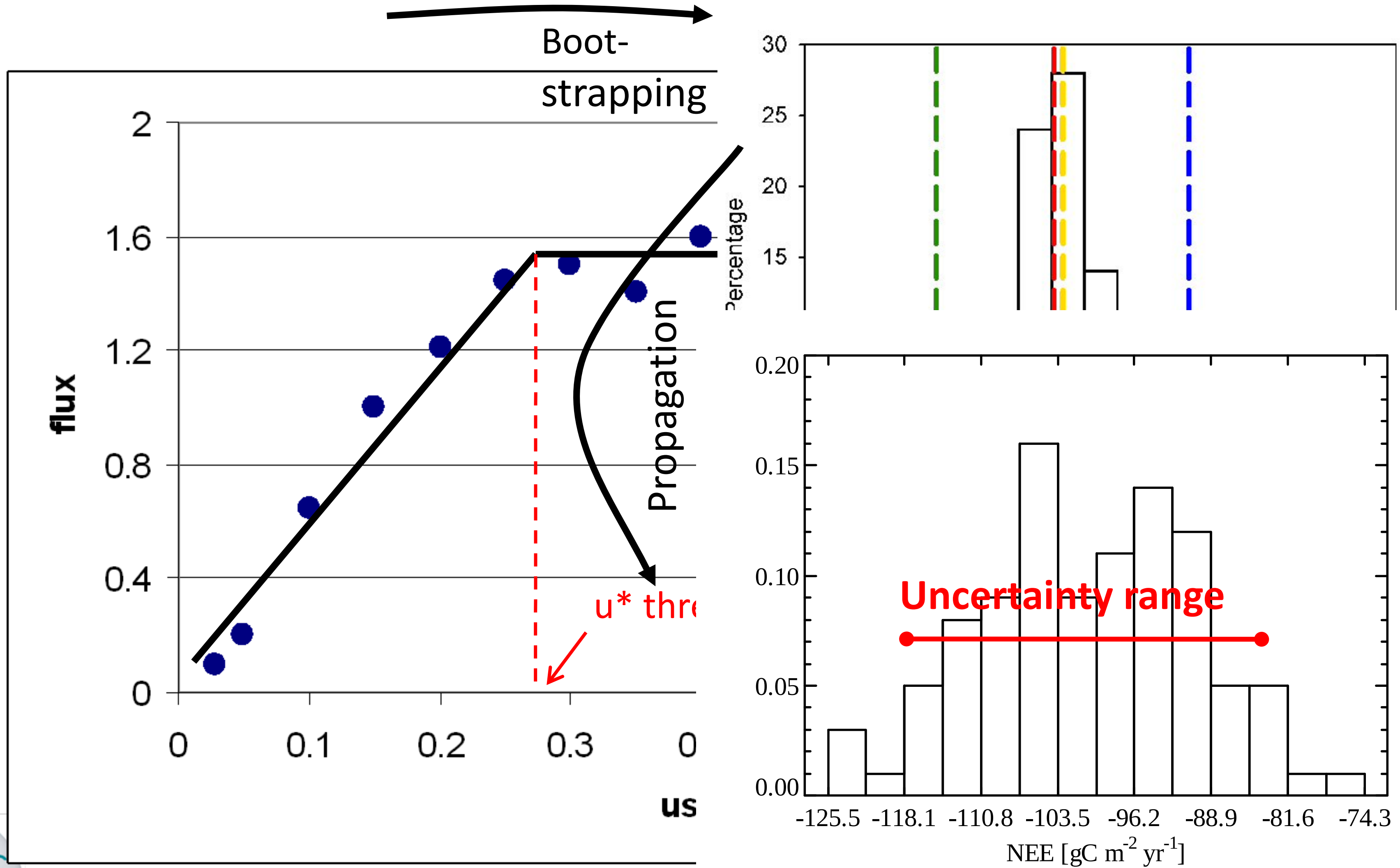


CO_2 and H_2O constraint

… but could be attenuated by multiple constraints…

Lasslop et al. (2008)

Uncertainties by semi-empirical „u*-correction“



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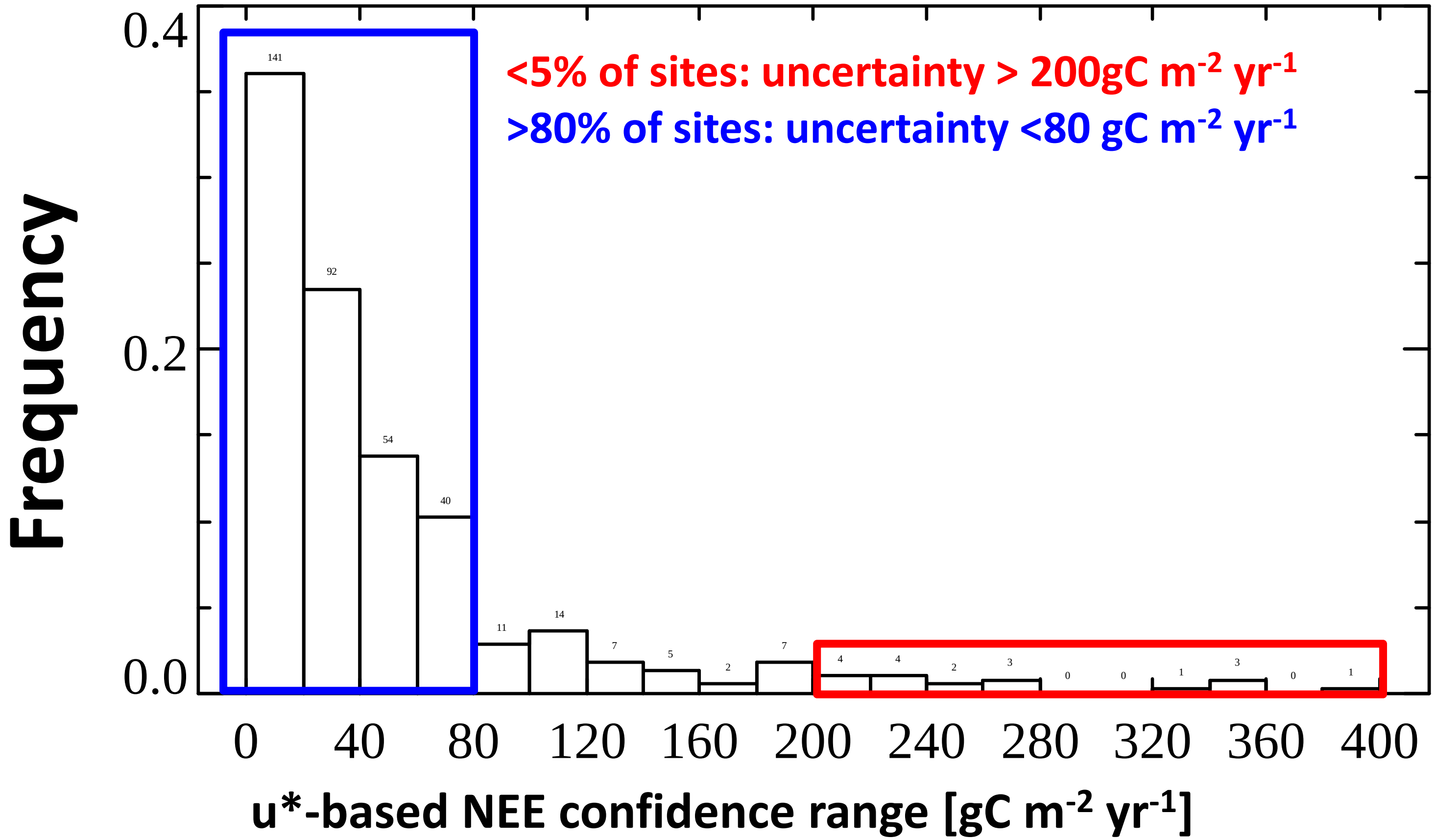
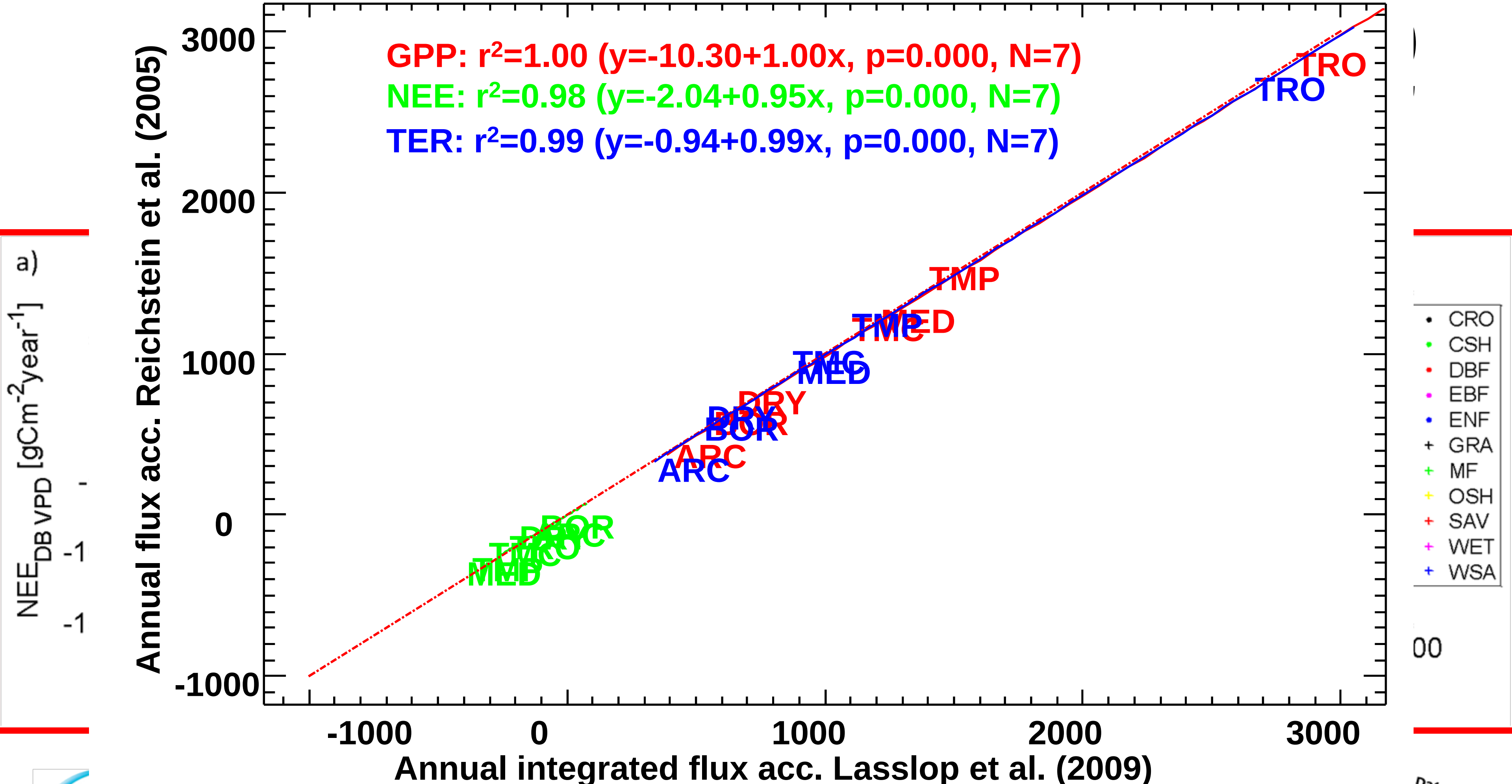
u* - based uncertainties across sites



flux partitioning

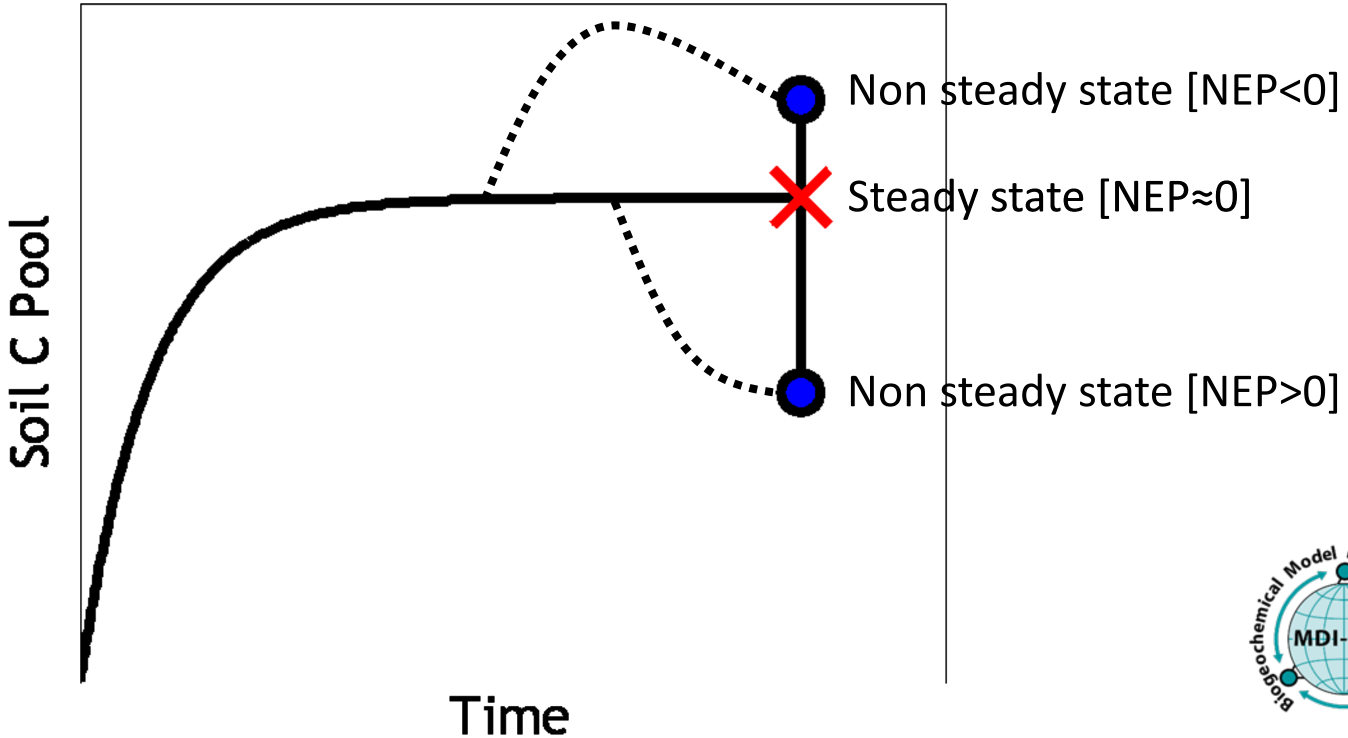


Lasslop et al, in press

learning about model structure
--
testing common model assumptions

the Steady State Assumption

- Problem:
  - initial conditions of the ecosystem C pools
- Common approach:
  - Spin up runs until equilibrium

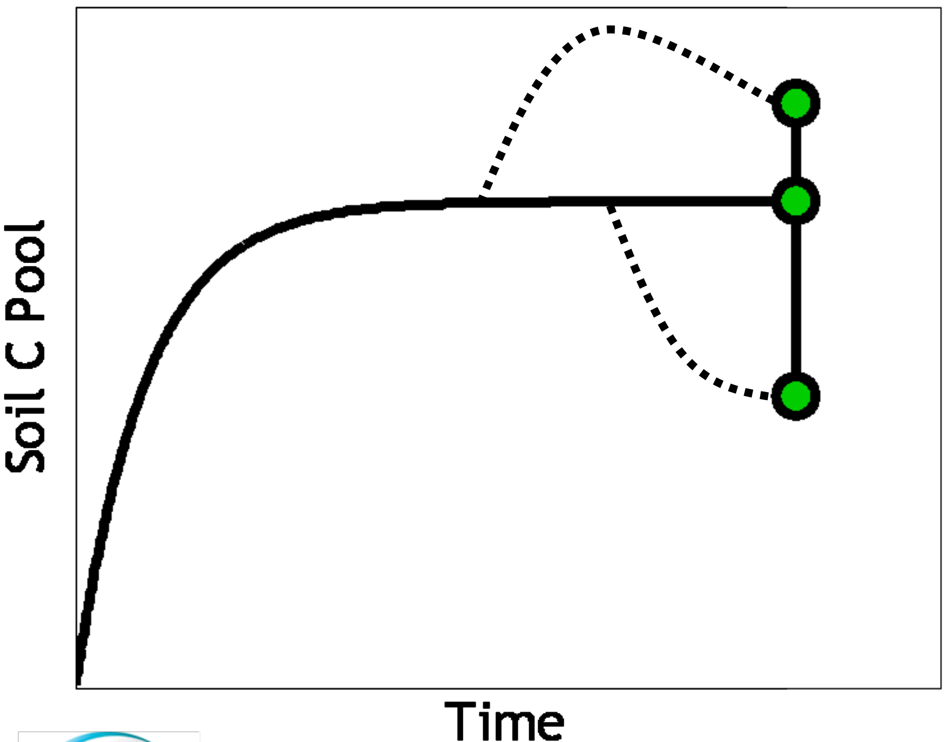


Model Data Integration

- Net ecosystem exchange fluxes at the ecosystem scale
- Model: **C**arnegie-**A**mes-**S**tanford **A**pproach
- Optimize the CASA against NEP observations
- Model drivers:
  - site meteorological data;
  - remotely sensed *f*APAR and LAI;

MDI approach

- Relaxation of the steady state assumption



Fix Steady State

$\eta > 1$

$\eta = 1$

$\eta < 1$

$$C_{ns} = C_{ss} \cdot \eta$$

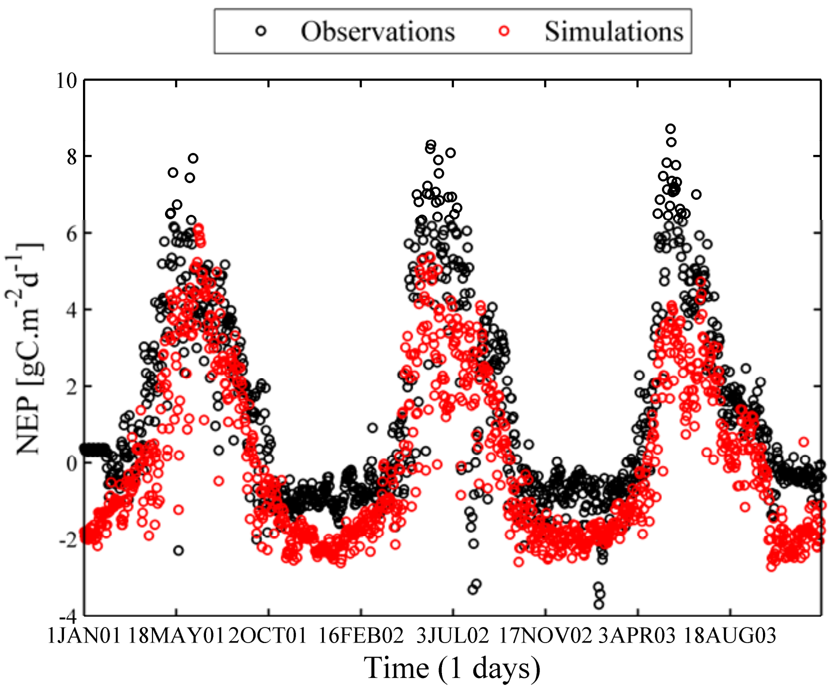
A_{ws} Q_{10} ε^* T_{Opt} $B_{w\varepsilon}$ η

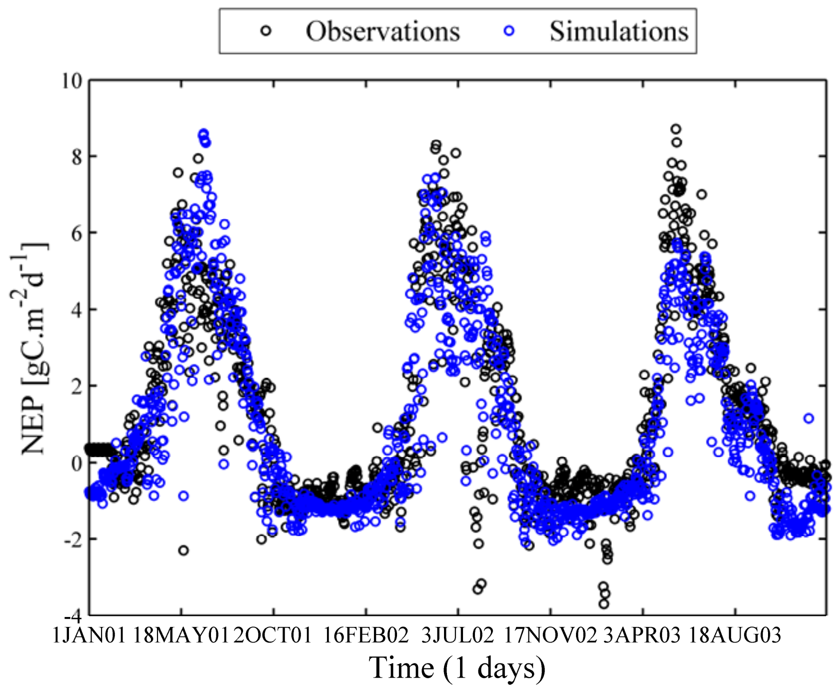
Relaxed Steady State

[Carvalhais et al., 2008, GBC]

MDI results

IT-Non [sink: 542gC m-2 yr-1]





adding η

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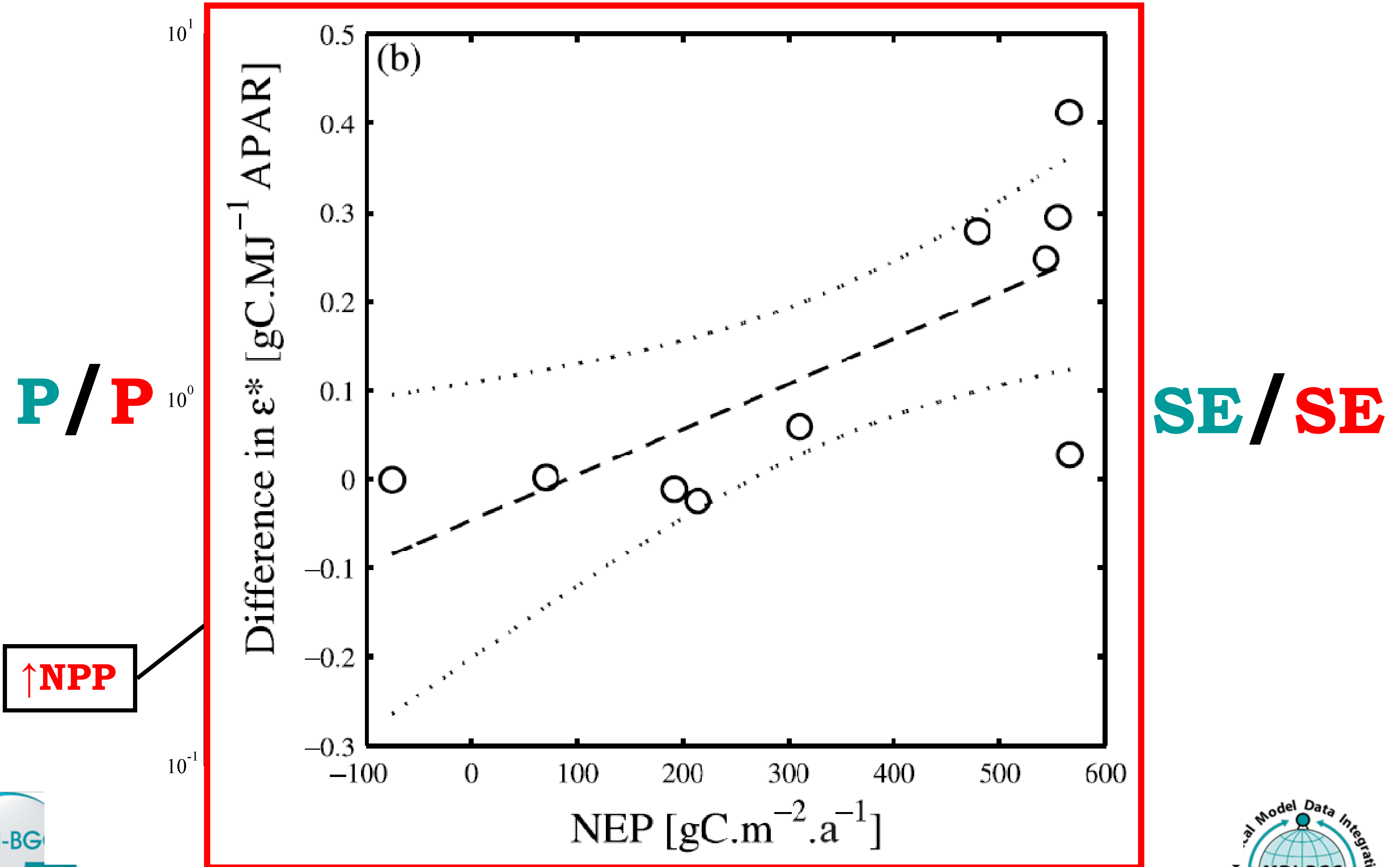
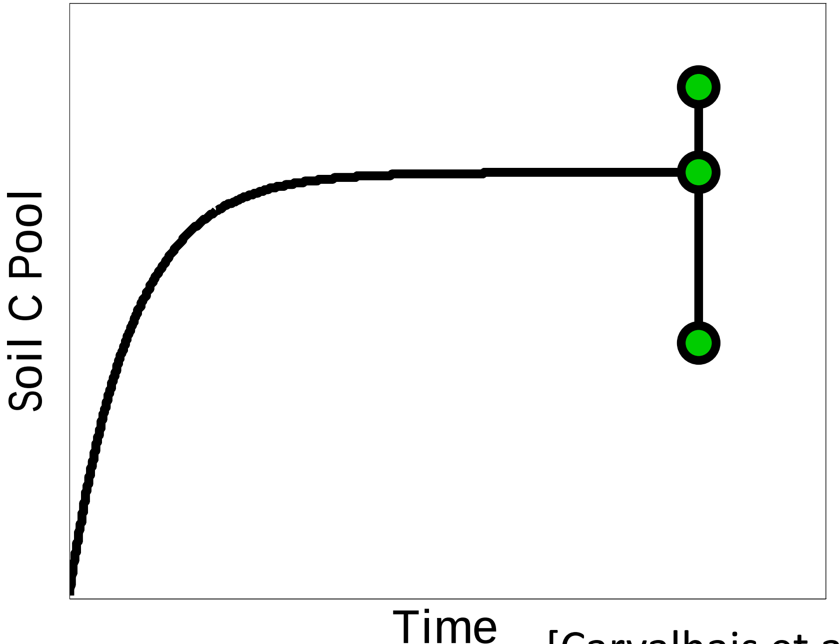
changes in parameters



challenging dynamics

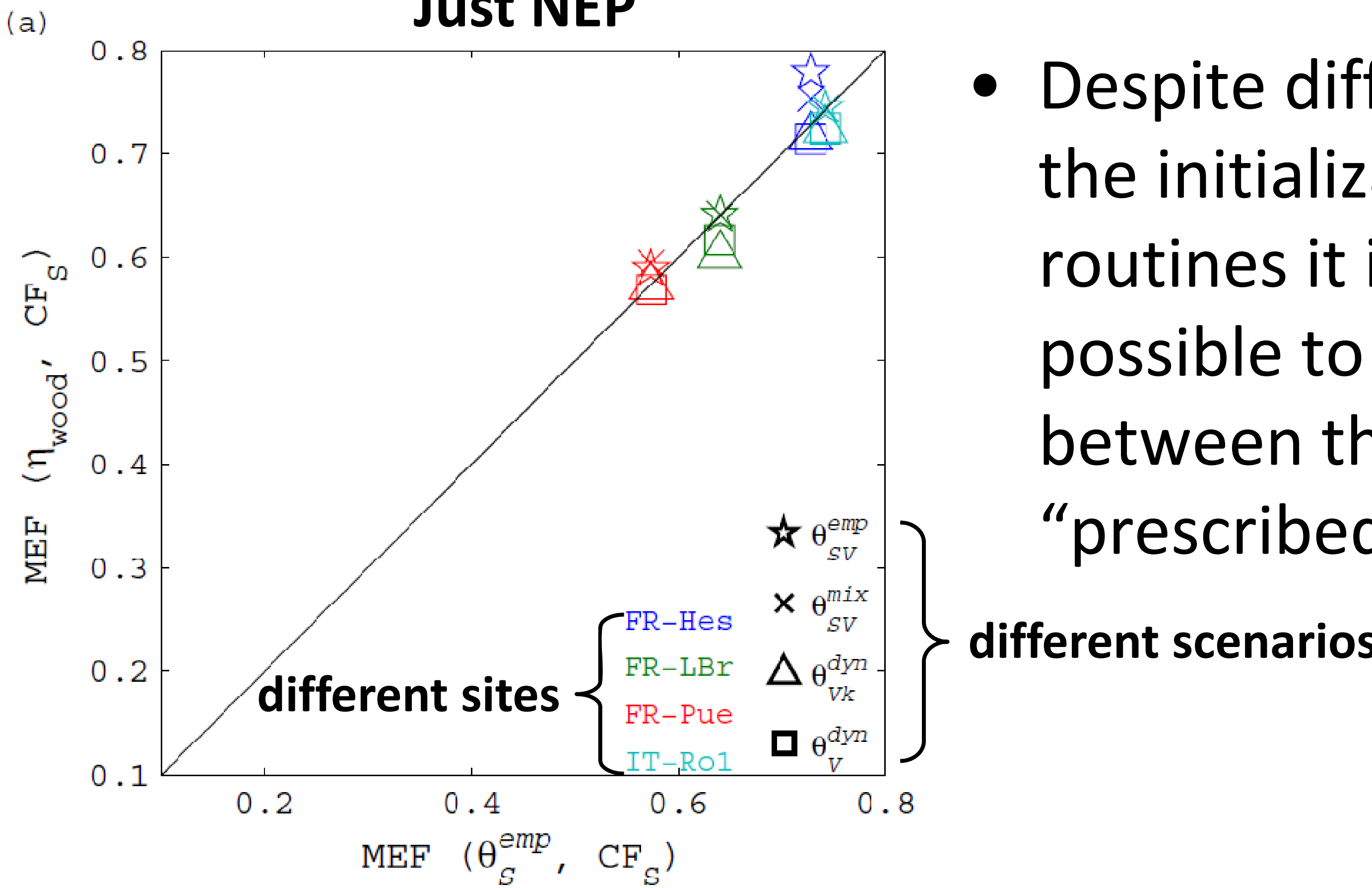
- The method is not informative on the underlying dynamics leading to the non-steady state conditions
- Experimental design:
  - Model evaluation for multiple scenarios



[Carvalhais et al., cond. Acc.]

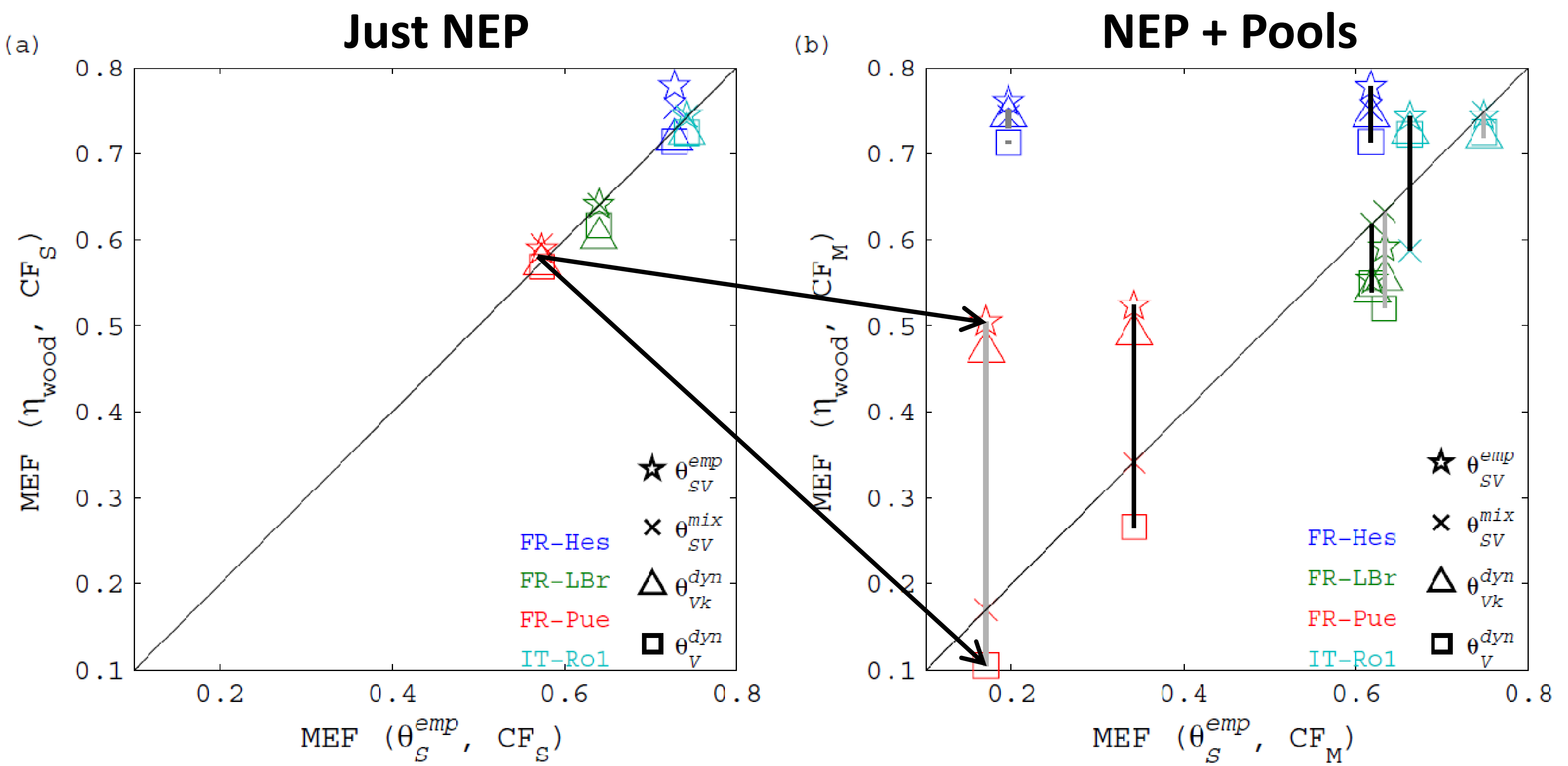
scenario differentiation

Just NEP

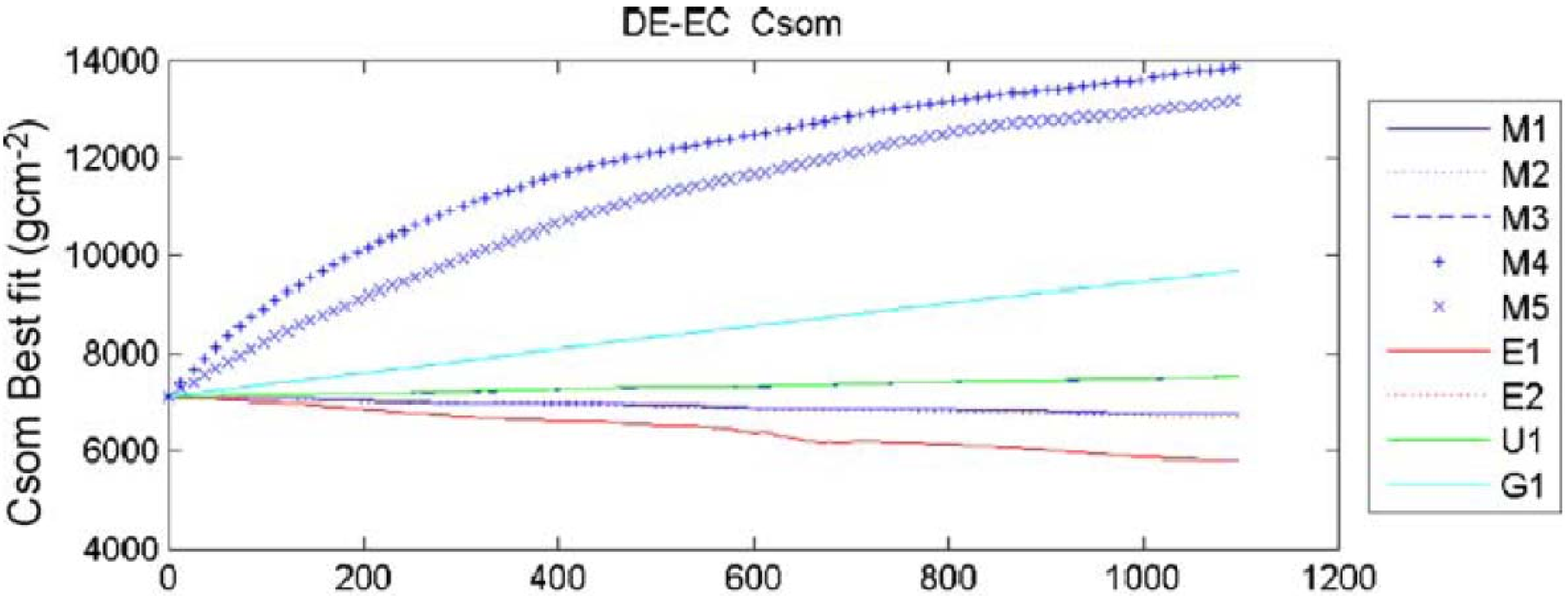


- Despite differences in the initialization routines it is not possible to distinguish between the different “prescribed dynamics”

scenario differentiation

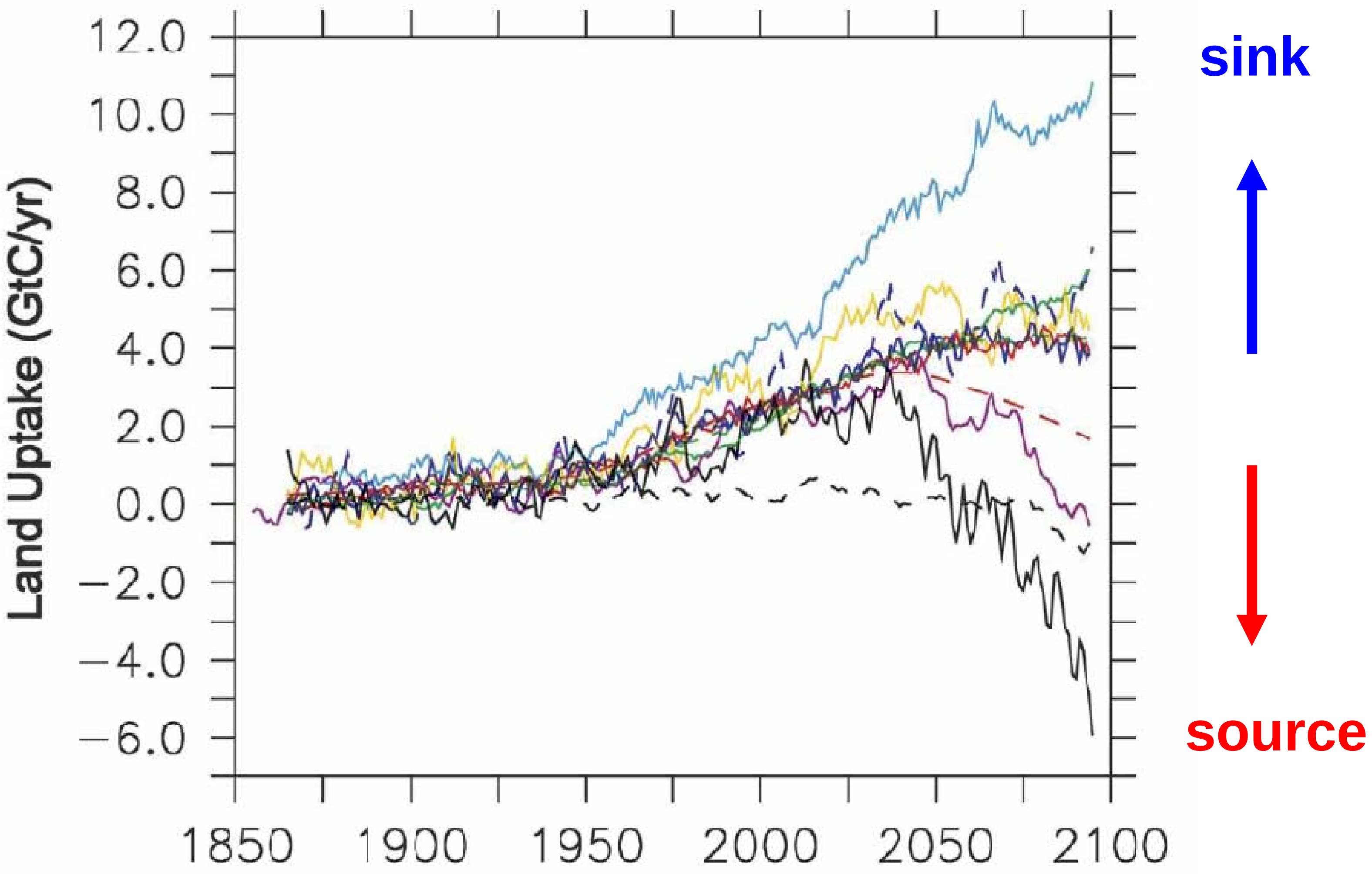


issues of equifinality



Fox et al., 2009

issues of equifinality

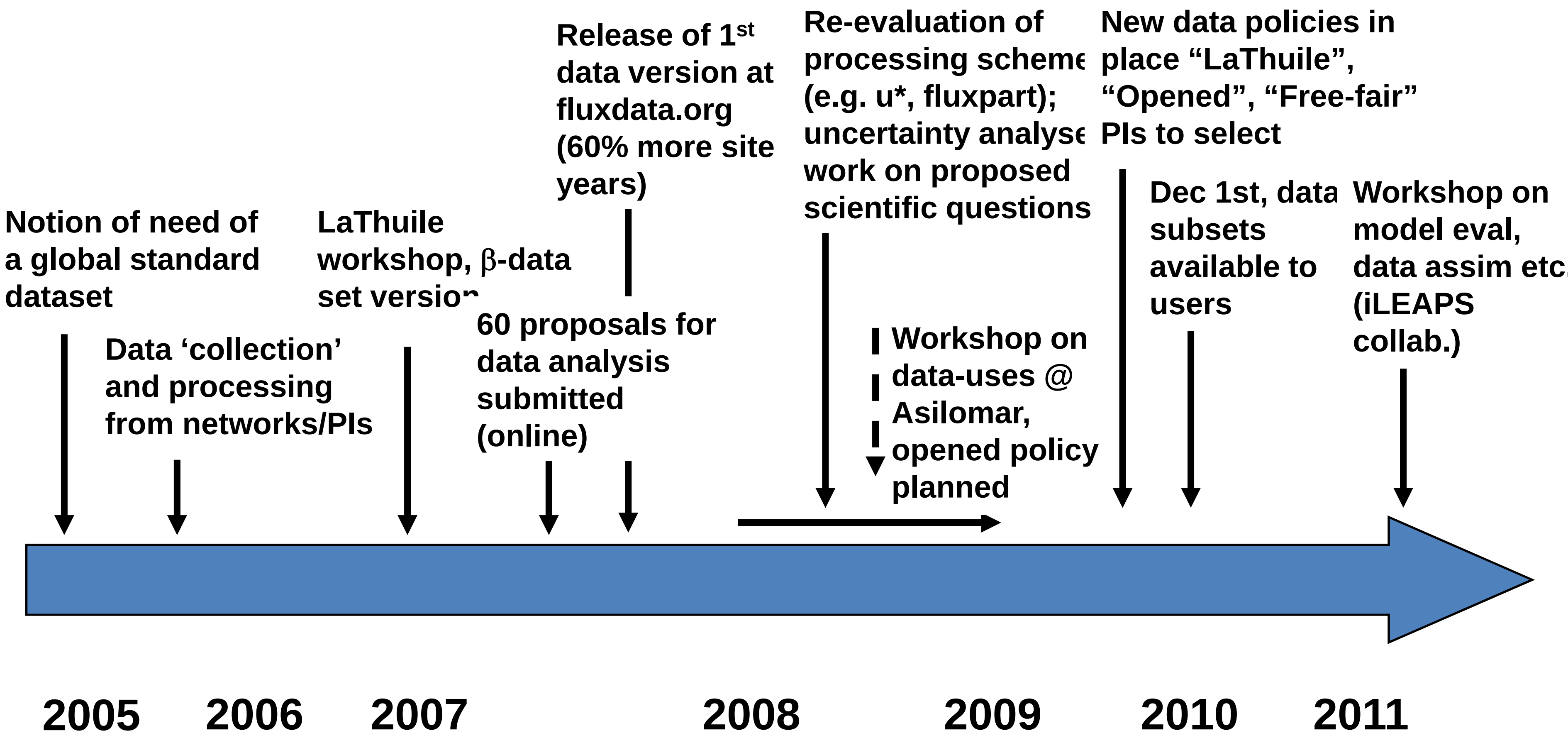


C4MIP, Friedlingstein et al. (2006)

Last slide!

- Data uncertainties
  - Random error is relatively well characterized
  - Systematic errors are still being addressed
- Overall, the FLUXNET data:
  - Informative and globally relevant
  - Spatial scale issues → role of empirical upscaling (e.g. MTE)
- Parameter optimization
  - Selective systematic biases in the data → systematic and selective parameters biases
  - Challenging model structures and/or general assumptions → model performance and parameterization
  - Multiple constraints → addressing equifinality

FLUXNET time line



FLUXNET policies

- Underlying rule: Site PIs are the data owners and souveraign to decide
- LaThuile policy: data available only to data providers, PIs „invited to give intellectual input“, which exclusively leads to co-authorship, 1-page proposals needed and checked for conflicts by SC with other ongoing studies (no censorship!, consensus solution sought for ➔ successful except in one case), group co-authorship
- Opened policy: as LaThuile policy but ‚world open‘ and co-authorship rules less strict on a case by case basis; models results to be documented/submitted upon acceptance of paper; acknowledements
- Free fair use policy: only free registration at web-site, normal scientific conduct, acknowledgments

Current state of site selection

- Pre-inquiry yielded 2/3 of site-years in Opened or Free policies
- Actual opening process active: so far 70 site-year ‘Free fair-use’, 40 ‘Opened’
  - Expectation: 400 site-years free or opened
- Questions:
  - Would you rather like fewer site open right now or wait and have more sites?
  - What would faciliate the use of the data? Requirements? QC of interest?