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

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and
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and all site PIs
„Learning from observations for better process understanding“

„Improving model representations of ecosystems“

Mahecha, 2009
Observing at the interface between ecosystem and atmosphere: a good tool: eddy covariance

Flux = speed x concentration

Photo: Baldocchi
World-wide eddy covariance collaborations

- Fluxnet-Canada
- Ameriflux
- LBA
- CarboEurope/NECC
- TCOS
- CarboAfrica
- Afriflux
- Cinaflux
- USCCC
- Asiaflux
- KoFlux
- Ozflux

Logos: MPI-BGC Jena, AfriFlux, ChinaFLUX, OxFlux, LBA, NECC, USCCC, MDI-BGC.
The global FLUXNET data base

- >950 site-years from >250 sites
model data integration

model  data

Meeting Point
Convergence in general statistical approach

- Simplified (Bayesian) maximum likelihood estimation:

Objective function

\[
J = \frac{1}{2} \sum_{j=1}^{M} \sum_{i=1}^{N(j)} \left( \frac{f_{i,j}(p) - OBS_{i,j}}{\sigma_{obs,i,j}^2} \right)^2 + \frac{1}{2} \sum_{k=1}^{O} \left( \frac{p_k - \hat{p}_k}{\sigma_{P,k}^2} \right)^2
\]

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
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

<table>
<thead>
<tr>
<th></th>
<th>Real fluxes</th>
<th>Observed fluxes</th>
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<tbody>
<tr>
<td></td>
<td>Day-time uptake</td>
<td>Day-time uptake</td>
</tr>
<tr>
<td></td>
<td>Night-time release</td>
<td>Night-time release</td>
</tr>
<tr>
<td></td>
<td>Net uptake</td>
<td>Net uptake</td>
</tr>
<tr>
<td></td>
<td>1000 g m(^{-2})</td>
<td>1000 g m(^{-2})</td>
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<tr>
<td></td>
<td>990 g m(^{-2})</td>
<td>900 g m(^{-2})</td>
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<tr>
<td></td>
<td>10 g m(^{-2})</td>
<td>100 g m(^{-2})</td>
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<tr>
<td></td>
<td></td>
<td>9% error</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1000% error (or 0.8 Pg)</td>
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</tbody>
</table>
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

Fast decay of autocorrelation

Almost no cross-correlation

Lasslop et al. (2008)
selective systematic error leads to selective parameter errors...

... but could be attenuated by multiple constraints...

Lasslop et al. (2008)
Uncertainties by semi-empirical „u*-correction“

![Graph showing uncertainty range and NEE distribution]
u* - based uncertainties across sites

<5% of sites: uncertainty > 200 gC m\(^{-2}\) yr\(^{-1}\)
>80% of sites: uncertainty < 80 gC m\(^{-2}\) yr\(^{-1}\)
flux partitioning

GPP: \( r^2=1.00 \) (\( y=-10.30+1.00x, \ p=0.000, \ N=7 \))

NEE: \( r^2=0.98 \) (\( y=-2.04+0.95x, \ p=0.000, \ N=7 \))

TER: \( r^2=0.99 \) (\( y=-0.94+0.99x, \ p=0.000, \ N=7 \))

Annual integrated flux acc. Lasslop et al. (2009)

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

\[ \text{Non steady state } [\text{NEP}<0] \]
\[ \text{Steady state } [\text{NEP} \approx 0] \]
\[ \text{Non steady state } [\text{NEP}>0] \]
Model Data Integration

• Net ecosystem exchange fluxes at the ecosystem scale
• Model: Carnegie-Ames-Stanford Approach
• Optimize the CASA against NEP observations
• Model drivers:
  – site meteorological data;
  – remotely sensed fAPAR and LAI;
MDI approach

- Relaxation of the steady state assumption

[Carvalhais et al., 2008, GBC]
MDI results

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

![Graph showing the relationship between NEP (gC.m⁻².a⁻¹) and the difference in ε* (gC.MJ⁻¹ APAR)].

- P/P
- SE/SE
- ↑NPP
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

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

Just NEP

different sites

different scenarios
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 $\rightarrow$ role of empirical upscaling (e.g. MTE)

- Parameter optimization
  - Selective systematic biases in the data $\rightarrow$ systematic and selective parameters biases
  - Challenging model structures and/or general assumptions $\rightarrow$ model performance and parameterization
  - Multiple constraints $\rightarrow$ addressing equifinality
FLUXNET time line

Notion of need of a global standard dataset

Data ‘collection’ and processing from networks/PIs

LaThuile workshop, β-data set version

Release of 1st data version at fluxdata.org (60% more site years)

60 proposals for data analysis submitted (online)

Re-evaluation of processing scheme (e.g. u*, fluxpart); uncertainty analysis; work on proposed scientific questions

Workshop on data-uses @ Asilomar, opened policy planned

New data policies in place “LaThuile”, “Opened”, “Free-fair”
PIs to select

Dec 1st, data subsets available to users

Workshop on model eval, data assim etc. (iLEAPS collab.)

2005 2006 2007 2008 2009 2010 2011
FLUXNET policies

• **Underlying rule:** Site PIs are the data owners and souverain 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; acknowledgements

• **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 facilitate the use of the data? Requirements? QC of interest?