Assessing uncertainty of ecosystem models using AmeriFlux observations

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Uncertainty of ecosystem models

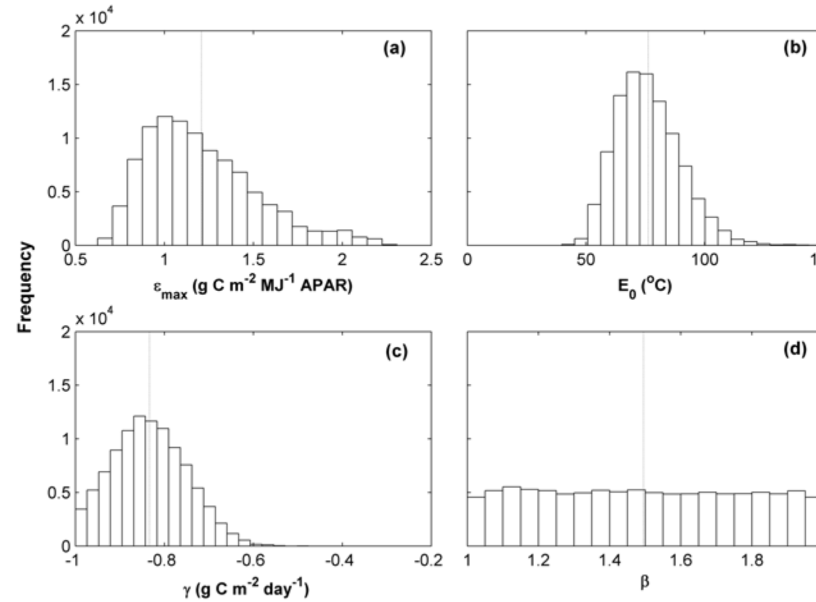
The uncertainty of modeled fluxes is from three main sources (Beck 1987):

- input variables (e.g., imperfect land cover or climate data)
- model parameters (e.g., imperfectly or poorly defined parameters due to lack of information)
- model structure (e.g., incomplete or flawed underlying processes and assumptions)

Parameter estimation

- Differential evolution (DE) *Xiao et al., JGR, 2011*
  - Easier to use
  - Single value
  - No uncertainty info

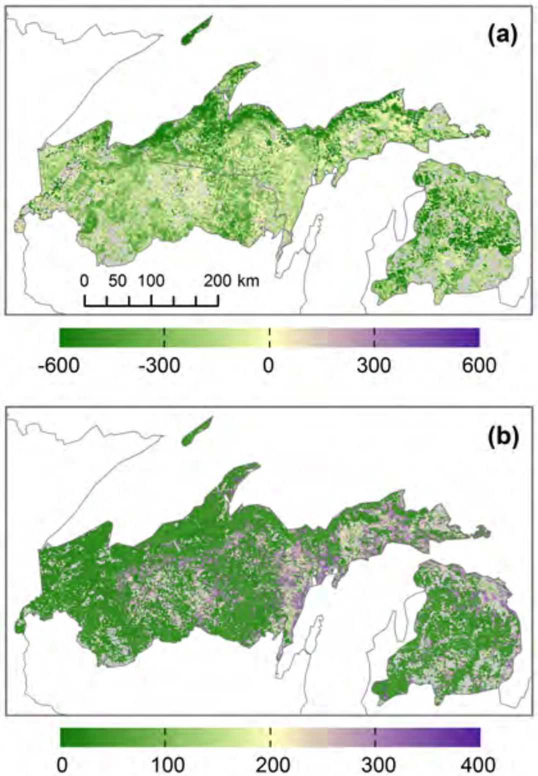
- Markov chain Monte Carlo (MCMC) *Xiao et al., AFM, 2014*
  - Probability density function (PDF)
  - Uncertainty analysis
  - Computationally demanding

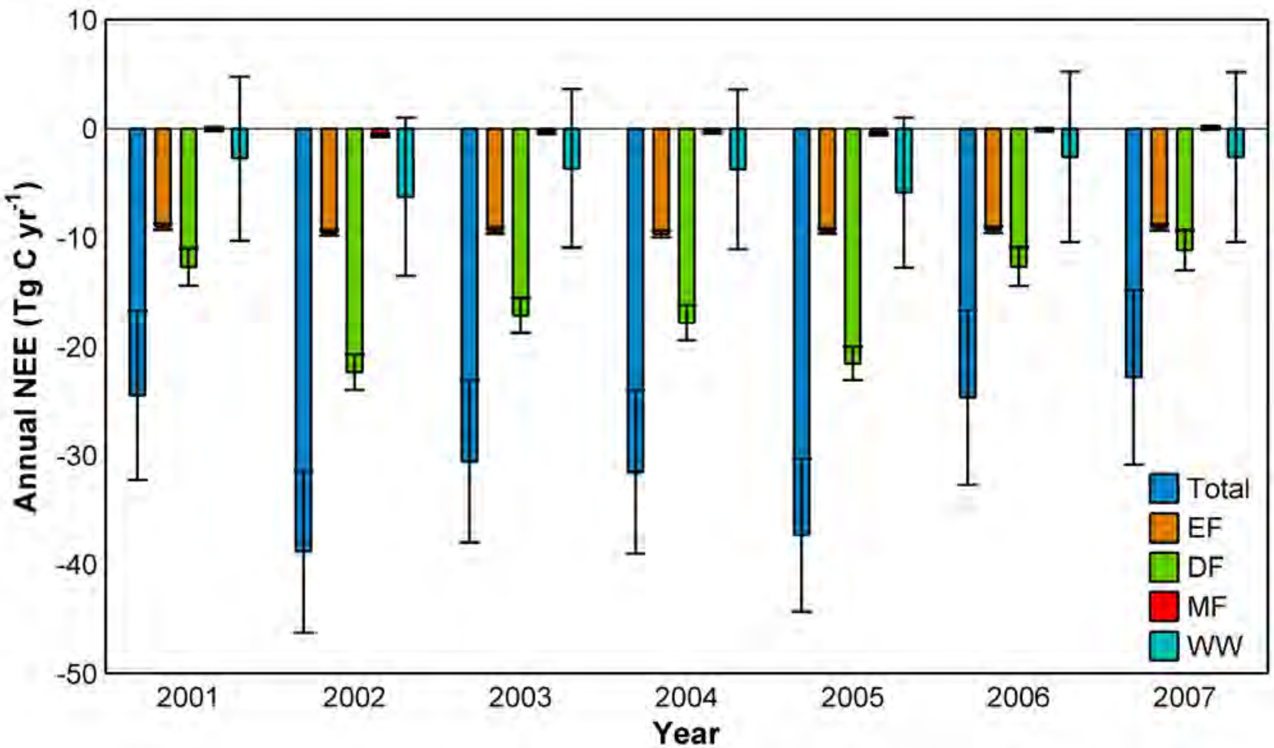


Parameter variability within a vegetation type

Site	ε_{max} (g C m^{-2} MJ^{-1} APAR)	α	β	R'_{ref} (g C m^{-2} d^{-1})	γ	λ (g C m^{-2} d^{-1})	E_0 (°C)	Slope	Intercept (g C m^{-2} d^{-1})	R^2	N
					Evergreen forests (EF)						
1	2.75	−0.30	1.85	13.12	−0.099	0.71	69.02	0.55	−0.40	0.04	4
2	1.15	−0.16	1.48	0.011	0.002	0.20	283.72	0.41	0.31	0.49	276
3	2.75	−0.30	1.85	16.85	−0.123	0.71	68.75	0.46	0.34	0.57	51
4	2.75	−0.30	1.85	15.77	−0.116	0.62	93.21	0.99	−2.89	0.48	131
5	2.05	0	1.85	13.33	−0.010	0.73	60.65	0.44	−1.36	0.66	97
					Deciduous forests (DF)						
1	2.70	−0.52	1.97	0	0.010	0.57	102.07	0.37	−1.73	0.61	20
2	1.93	−0.42	1.83	0	0.013	0.37	181.51	−0.13	2.21	0.16	20
3	2.01	−0.40	1.77	0	0.013	0.37	180.63	0.02	2.14	0.00	21
4	0.61	−0.65	1.66	0	0.003	0.04	500.00	0.21	0	0.66	518
5	2.36	−0.55	1.92	0	0.009	0.48	105.07	1.02	−2.40	0.33	68
					Mixed forests (MF)						
1	0.65	−0.34	1.86	2.61	−0.009	−0.06	309.85	0.44	0.12	0.44	390
2	0.71	−0.31	1.79	2.07	−0.005	−0.01	277.81	0.56	0.02	0.55	110
3	0.90	−0.35	1.74	7.01	−0.045	0.06	230.37	0.61	−0.47	0.37	771

Uncertainty of regional carbon fluxes





A process-based ecosystem model – PnET-CN

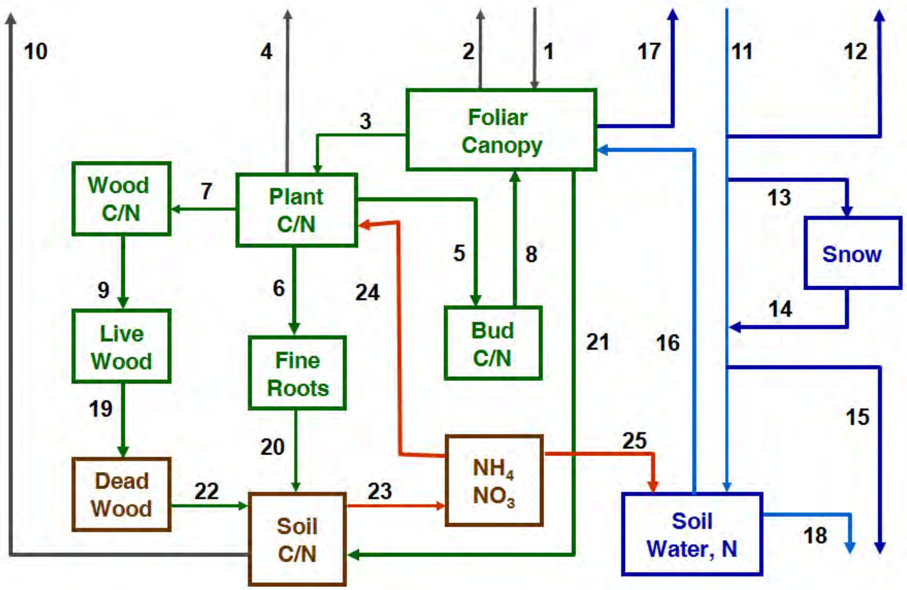


Figure 5. Structure of the PnET-CN model. Boxes represent pools and numbered arrows represent fluxes: (1) Gross photosynthesis & ozone uptake (2) Foliar respiration (3) Transfer to mobile pools (4) Growth and maintenance respiration (5) Allocation to buds (6) Allocation to fine roots (7) Allocation to wood (8) Foliar production (9) Wood production (10) Soil respiration (11) Precipitation & N Deposition (12) Canopy interception & evaporation (13) Snow-rain partitioning (14) Snowmelt (15) Macro-pore flow (16) Plant uptake (17) Transpiration (18) H2O Drainage (19) Woody litter (20) Root litter decay (21) Foliar litterfall (22) Wood decay (23) N Mineralization & Nitrification (24) Plant N uptake (25) N transfer to soil solution.

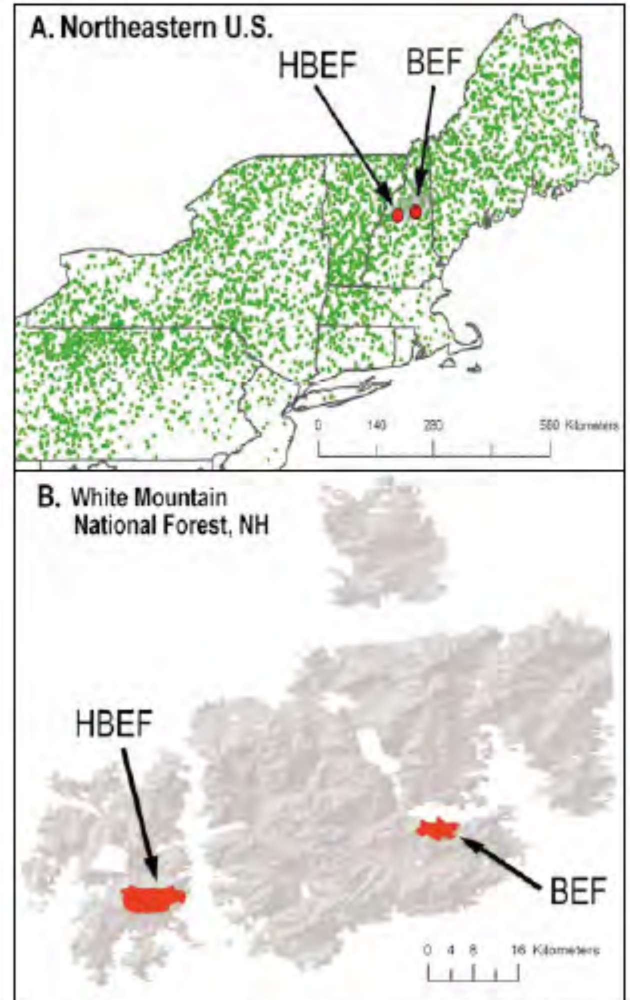


Figure 2. (A) BEF and HBEF locator map, with shading density illustrating the relative importance of maple-beech-birch stands in terms of county-level forest composition, as derived from Forest Service FIA data. (B) Location of BEF and HBEF within the White Mountain National Forest.

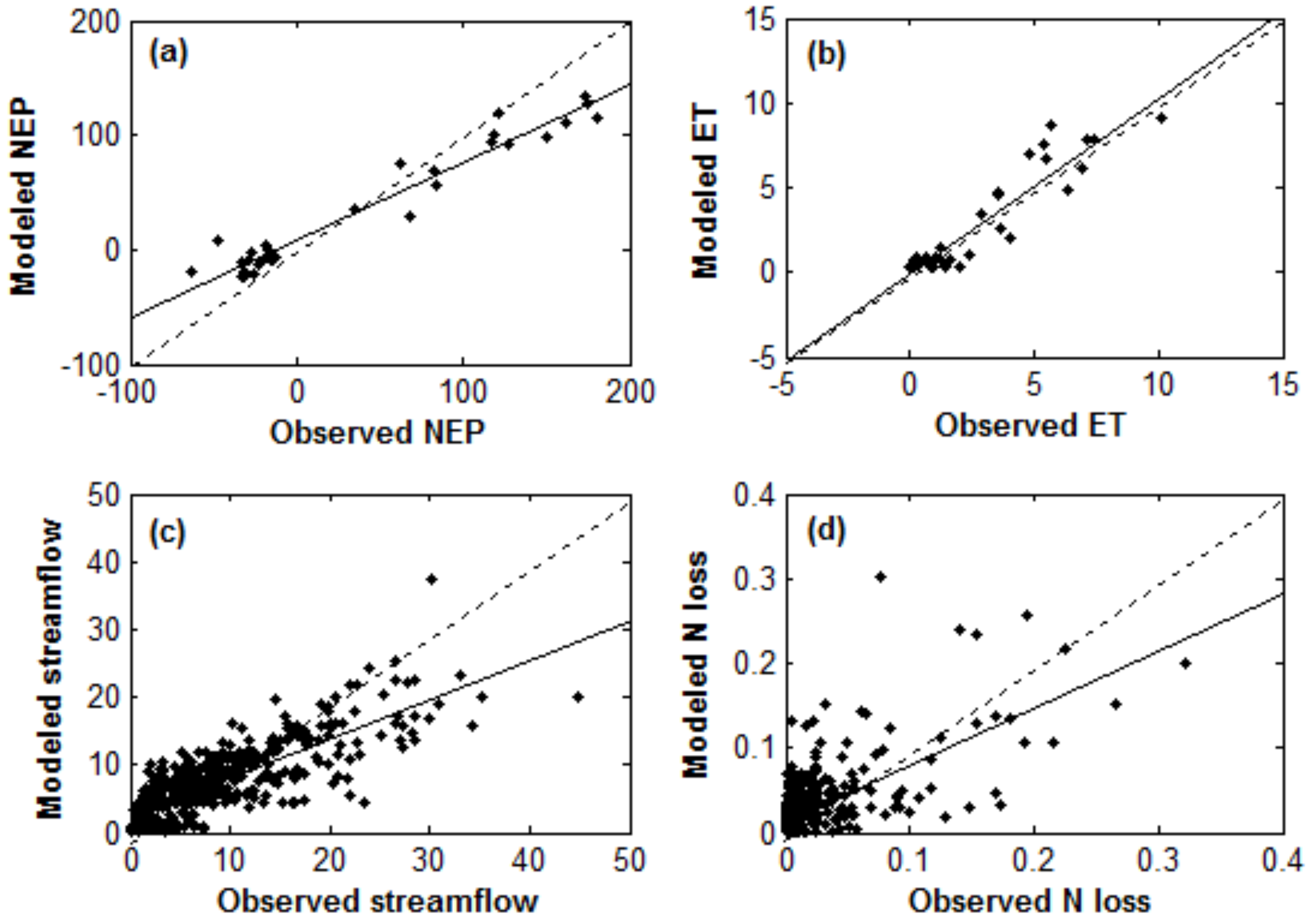
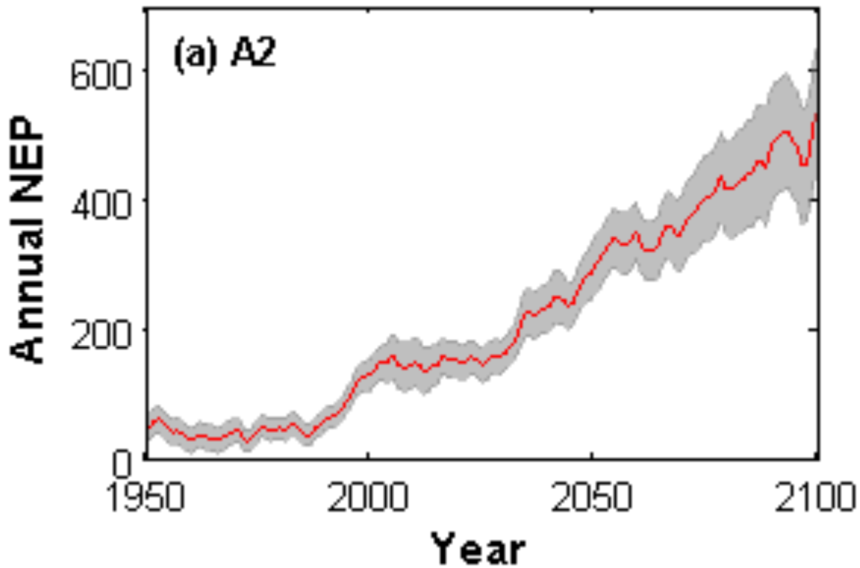
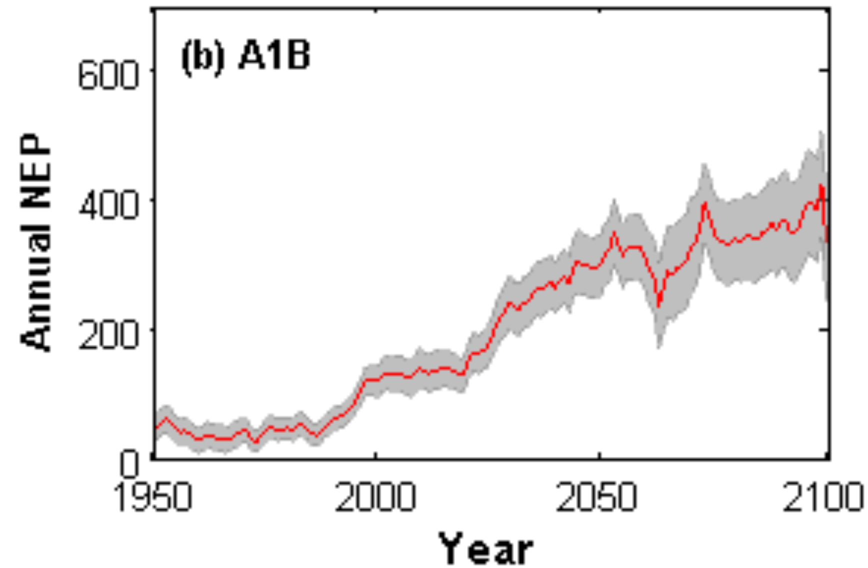


Figure 6. Observed fluxes versus modeled fluxes for **NEP, ET, streamflow, and streamwater chemistry**: (a) monthly ET (mm mo^{-1}); (b) monthly streamflow (mm mo^{-1}); (c) monthly N loss (g N m^{-2} mo^{-1}). Solid lines are the regression lines, and dashed lines are 1:1 lines.





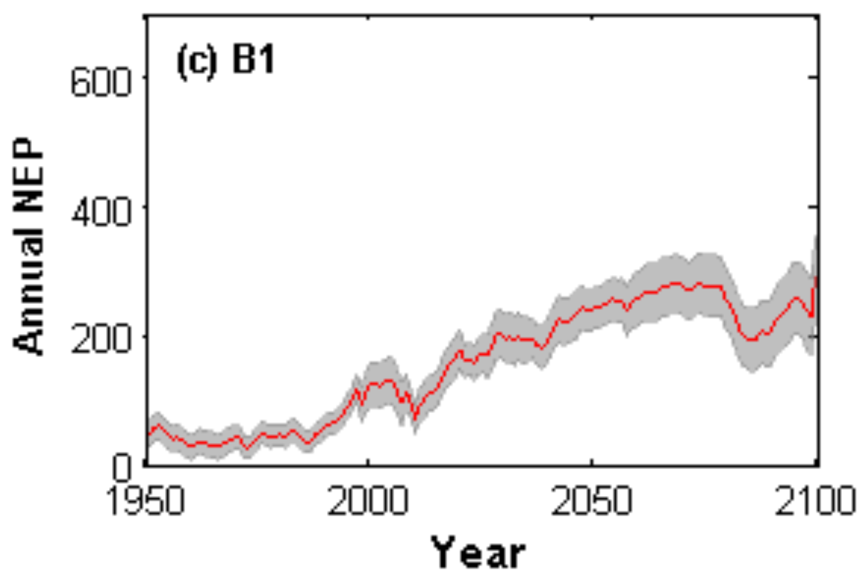


Figure 9. Uncertainty of historical (1950-1999) and projected (2000-2099) annual NEP under different emission scenarios (A2, A1B, and B1) at Bartlett Experimental Forest. For each scenario, the red line stands for the mean of annual NEP simulated with parameter PDFs, and the shade area stands for 2 standard deviations away from the mean.

Structural uncertainty

NACP Site Interim Synthesis

Model (click for submitted data)	Primary Contact	Sites simulated	Model Survey
Agro-IBIS	Chris Kucharik	5	
BEPS	M. Sprintsin, J. Chen		
Biome-BGC	Ryan Anderson	47	
Can-IBIS	David Price	28	X
CLASS-CTEM (TRIPLEX-Flux)	Changhui Peng	8	
CLM-CASA'	Forrest Hoffman		
CLM-CN	Peter Thornton		
CN-CLASS	Altaf Arain	33	
DAYCENT	Robin Kelly, Bill Parton		
DLEM	Hanqin Tian	36	X
DNDC	Christina Tonitto	5	X
ecosys	Robert Grant	40	X
ED2	Michael Dietze	30	X
EDCM	Shugang Liu	10	
EPIC	Cezar Izaurralde	2	
GTEC	Mac Post		
ISAM	Atul Jain	15	
ISO-LSM	Bill Riley	10	
LoTEC	Tony King	10	
LPJ_wsl	Ben Poulter	30	X
ORCHIDEE	Hans Verbeeck	36	X
SiB3	Ian Baker	31	X
SiBCASA	Kevin Schaefer	36	
SiBcrop	Erandathie (Erandi) Lokupitiya, Scott Denning	5	
SIPNET	Ankur Desai		
SSiB2	Alok Sahoo	47	
TECO	Ensheng Weng, Yiqi Luo	36	

PnET family of models

PnET-Day

PnET-II

PnET-CN

PnET-SOM

PnET-Farquhar

Summary

- Model parameters vary not only across plant functional types (PFT) but also within a given PFT

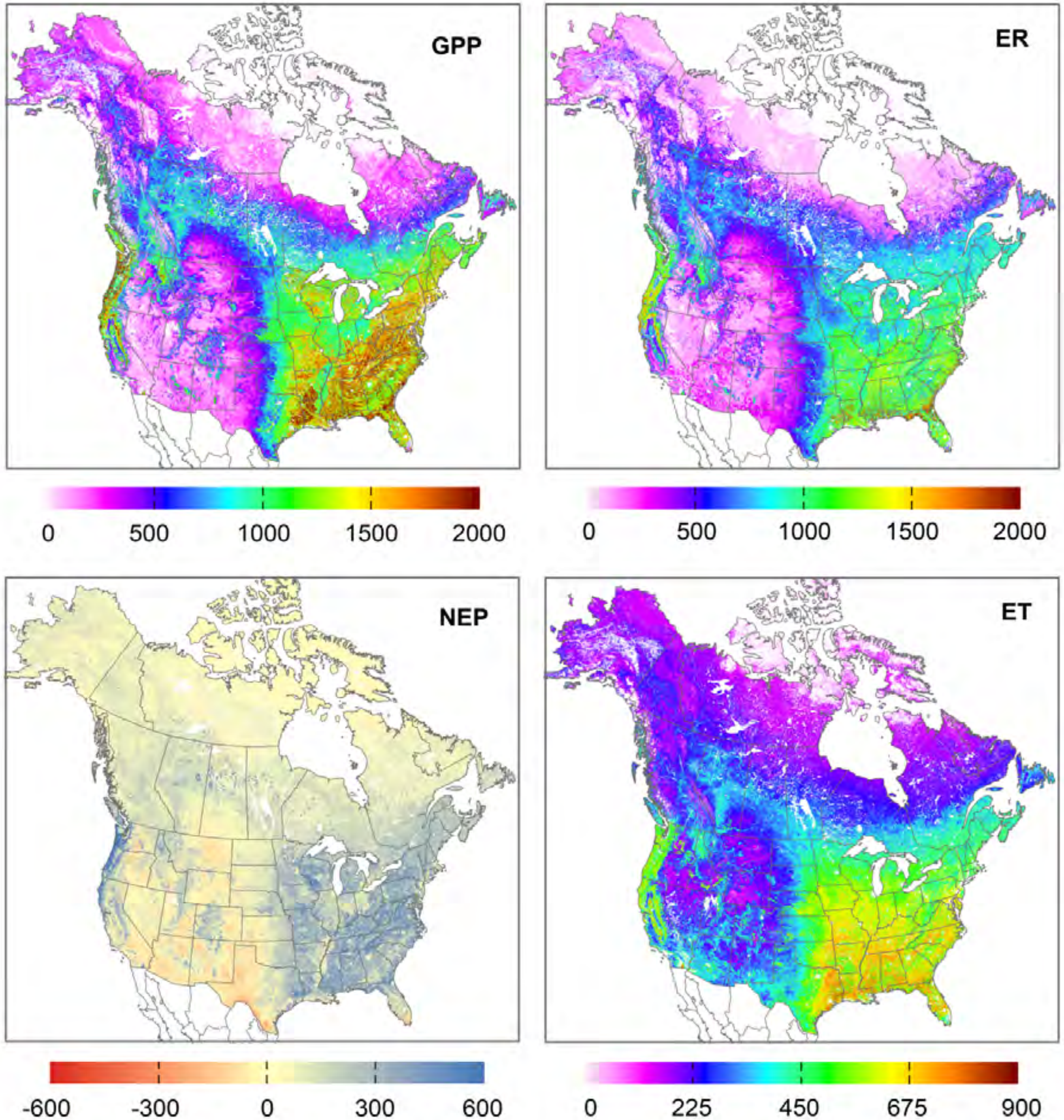
- Parameter estimates from a single site are not representative of the parameter values of a given PFT

- Cross-site (or joint) optimization using observations from multiple sites encompassing a range of site and climate conditions considerably improves the representativeness and robustness of parameter estimates

- Parameter uncertainty can lead to a large uncertainty in regional fluxes

- It remains a challenge to quantify structural uncertainty and to separate it from parameter uncertainty

- We plan to work towards assessing the full uncertainty of model simulations



Gridded, high-resolution (1km) flux estimates over North America (2000-2012)

Acknowledgements

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Published work on parameter and flux uncertainty

Xiao, J.F., Davis, K.J., Urban, N.M., Keller, K., and Saliendra, N.Z. (2011) Upscaling carbon fluxes from towers to the regional scale: Influence of parameter variability and land cover representation on regional flux estimates. *Journal of Geophysical Research - Biogeosciences*, 116, G00J06, doi: 10.1029/2010JG001568.

Xiao, J.F., Davis, K.J., Urban, N.M., Keller, K. (2014) Uncertainty in model parameters and regional carbon fluxes: A model-data fusion approach. *Agricultural and Forest Meteorology*, 189-190, 175-186.