Site-level synthesis of modeled and measured carbon, water, and energy fluxes across North America: Evaluation of model and measurement uncertainty

Sponsors/Support: CCIWG, AmeriFLux, Canadian Carbon Program, Microsoft, and many other institutions

Site-level model-measurement synthesis: Objectives

- Starting at the spatial scale of individual sites, establish quantitative framework that allows NACP investigators to answer the question:
  - **"Are the various measurement and modeling estimates of carbon fluxes consistent with each other - and if not, why?"**
- Improve quantification of uncertainty for forward models and site-based measurements.
- Identify strengths and weaknesses in models and measurements.
- Migrate new knowledge up-scale in coordination with regional and continental-scale efforts.

Approach

- Anchor the comparison at flux measurement sites
  - Multiple years of energy, water and carbon fluxes
  - Ancillary physical and biological measurements (“template” exists, encourage site PIs to fill it in)
- Introduce additional data sources as available.
- Measurement teams produce their own best estimates of fluxes and flux uncertainty at each site.
- Modeling teams produce their own best estimates of fluxes and flux uncertainty at each site for each model.
- Evaluate overlap (or lack thereof) in confidence intervals to answer main science question: are the measurements and model predictions different?

Current Status

- Sites
  - 36 first-priority sites
  - 11 second-priority sites (chronosequences)
  - 11 third-priority sites (incomplete ancillary data)
- First-priority sites: representation by veg type:
  - CRO(5), GRA(4), DBF(7), ENFB(4), ENFT(6), MF(3), WSA(1), SHR(1), TUN(2), WET(3)
- ~25 models have contributed results.
  - CLM4 simulations are running now, using latest code tag within modified ModelFarm.

Flux Tower Sites

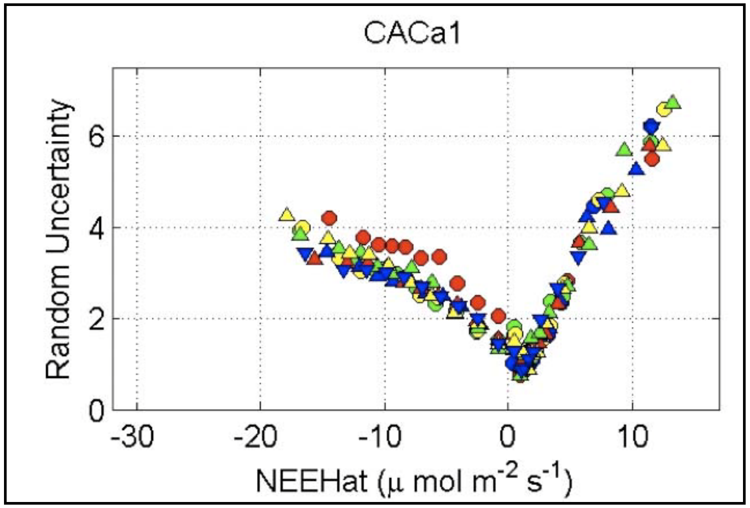
Flux measurement uncertainties

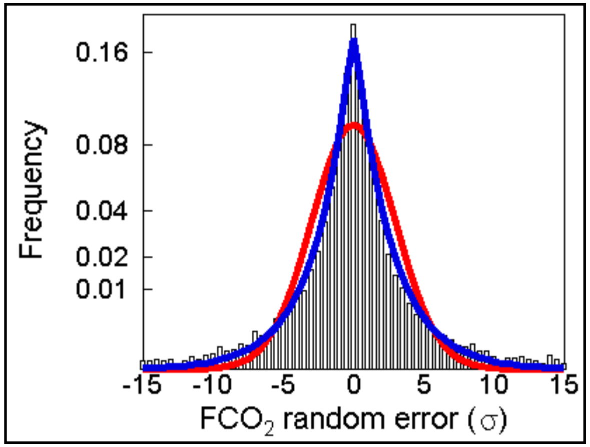
- Must consider both random and systematic uncertainties
- Systematic: here, consider effect of processing algorithms (other sources: advection, possibly energy balance closure, etc.)
  - Evaluate by comparing processing methods (e.g., u* threshold, gap filling algorithm, NEE/GPP/RE partitioning algorithm)
  - Gap filling uncertainty: across an ensemble of methods, ± 30 g C m-2 y-1 (95% CI, based on reanalysis of Moffat et al. 2007 results) at annual time step; ± 15% at half hourly time step
  - Flux partitioning: across an ensemble of methods, ± 10% for annual GPP, ± 15% for annual RE (95% CI, based on reanalysis of Desai et al. 2008 results); at half-hourly time step, algorithmic uncertainty is (approximately) a similar percentage of the estimated flux

Random uncertainties

Main source: turbulence sampling errors

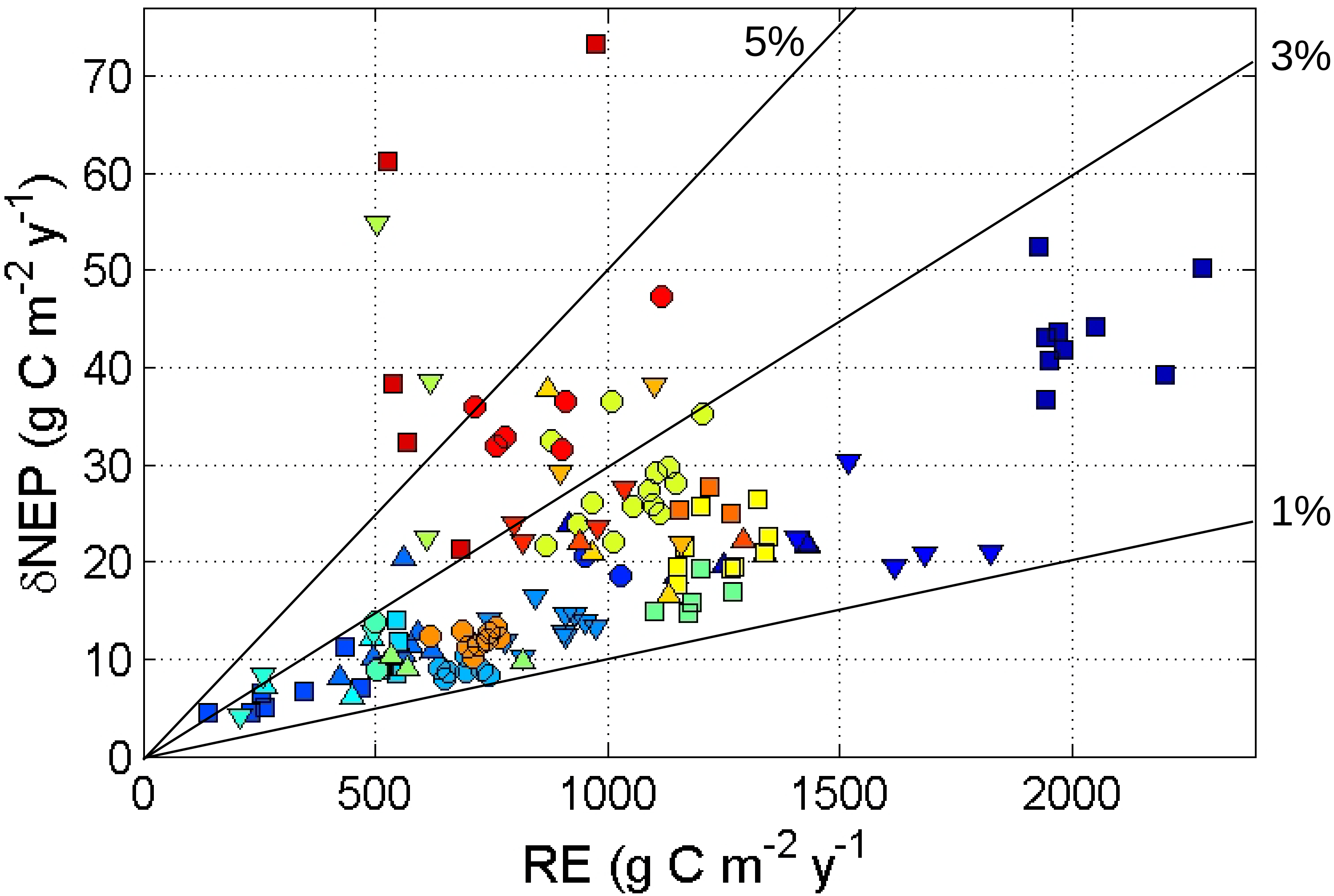
- Evaluate using statistical analyses of measured fluxes (e.g., two tower, paired difference, model residual approaches; see Richardson et al. 2006, 2008)
- Non-Gaussian (Laplace distribution), standard deviation of uncertainty increases with flux magnitude (≈20% during day; ≈50% during night)
- Half-hourly uncertainties propagate to gap filled values, too. Random errors DO NOT “cancel out”: integrated uncertainty IS SIGNIFICANT at annual time step
- Integrated over year: ±10-40 g C m^{-2} y^{-1}, at 95% confidence (depends on site characteristics, flux magnitude, and extent and timing of gaps)



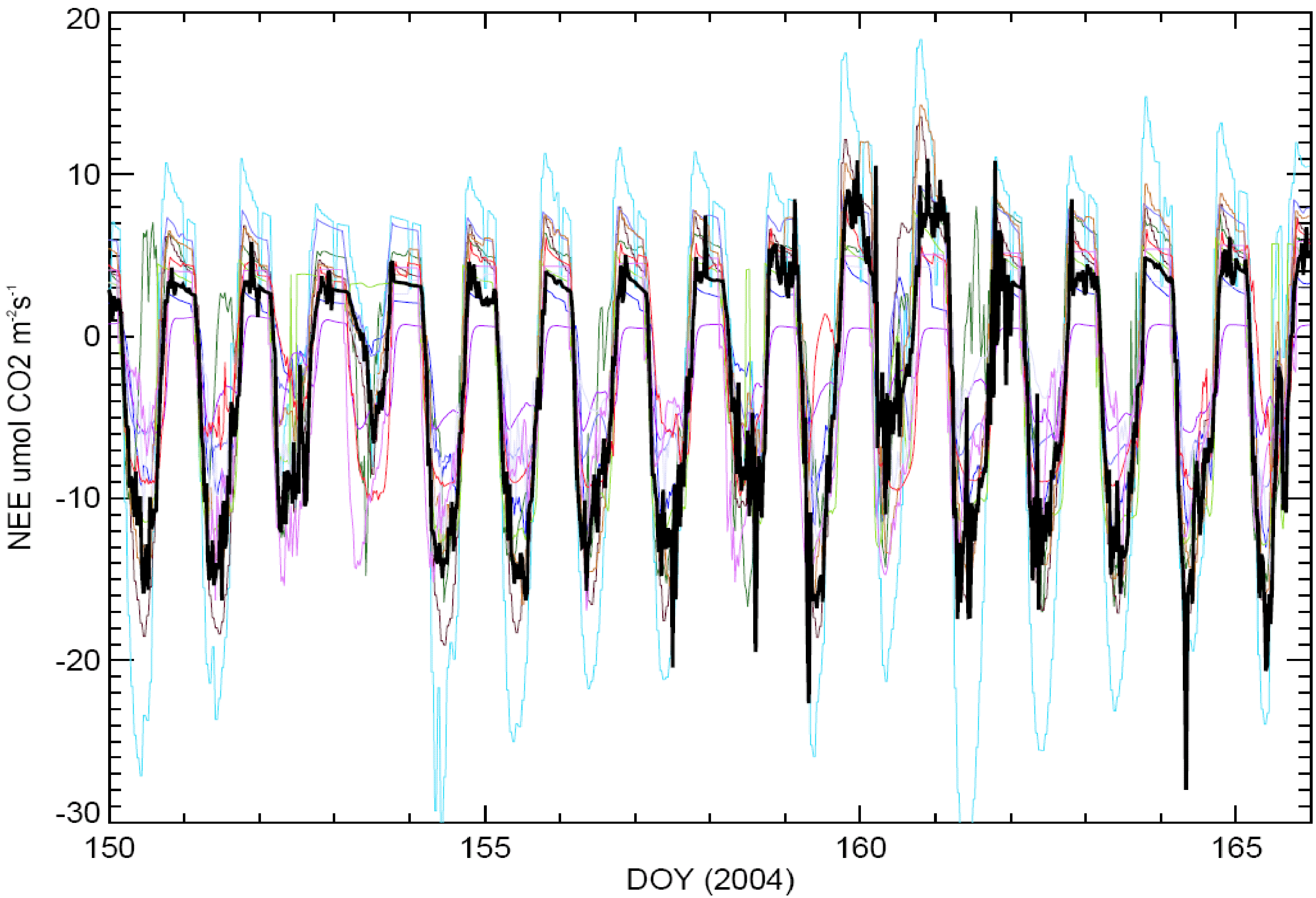


Random Uncertainty (95% CI) in Measured Annual Net Ecosystem Production vs. Ecosystem Respiration

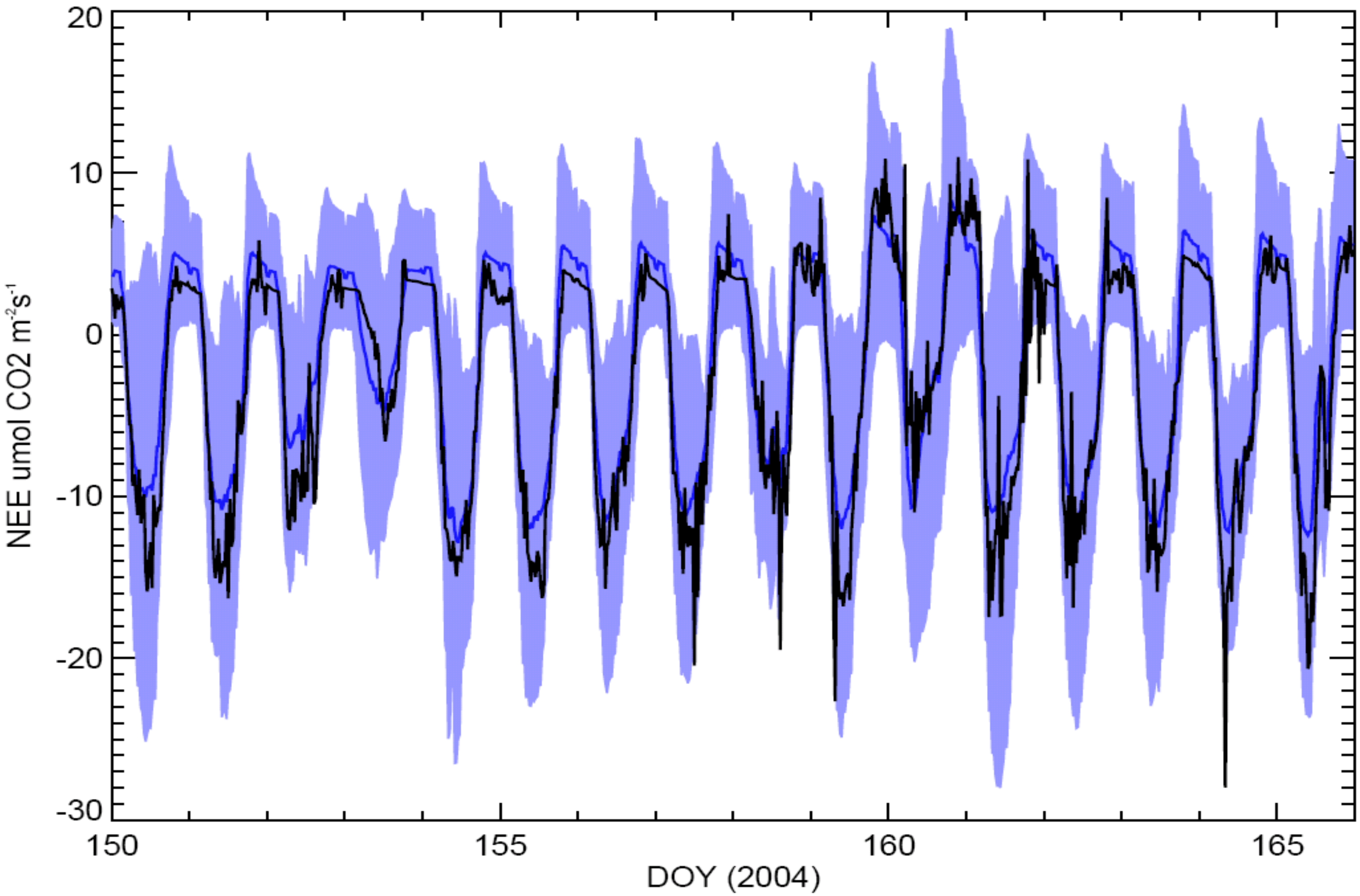
(following Richardson et al. 2008, NACP synthesis sites, FCRN gap-filling)



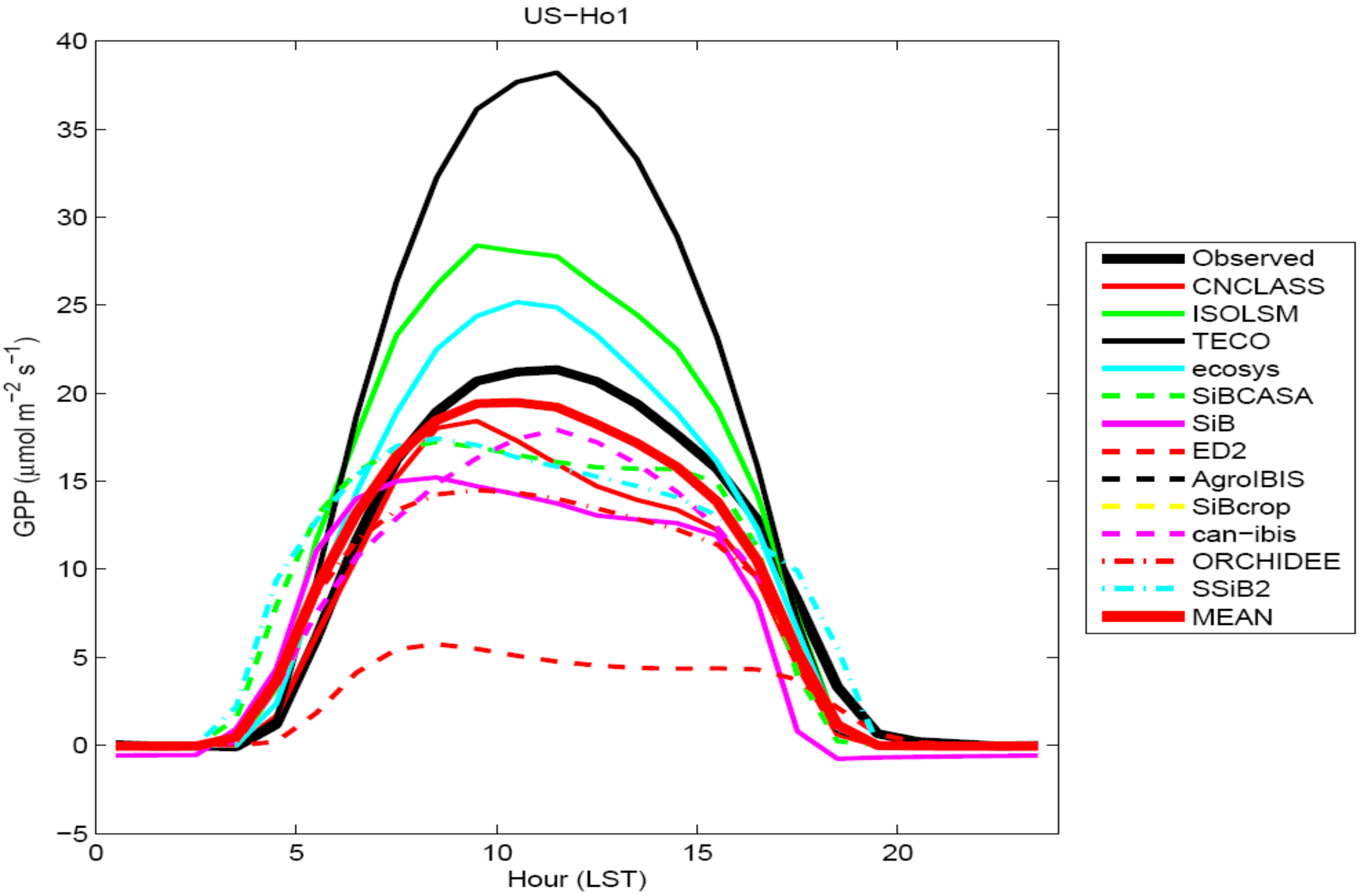
Multi-model comparison: diurnal cycle (Howland)



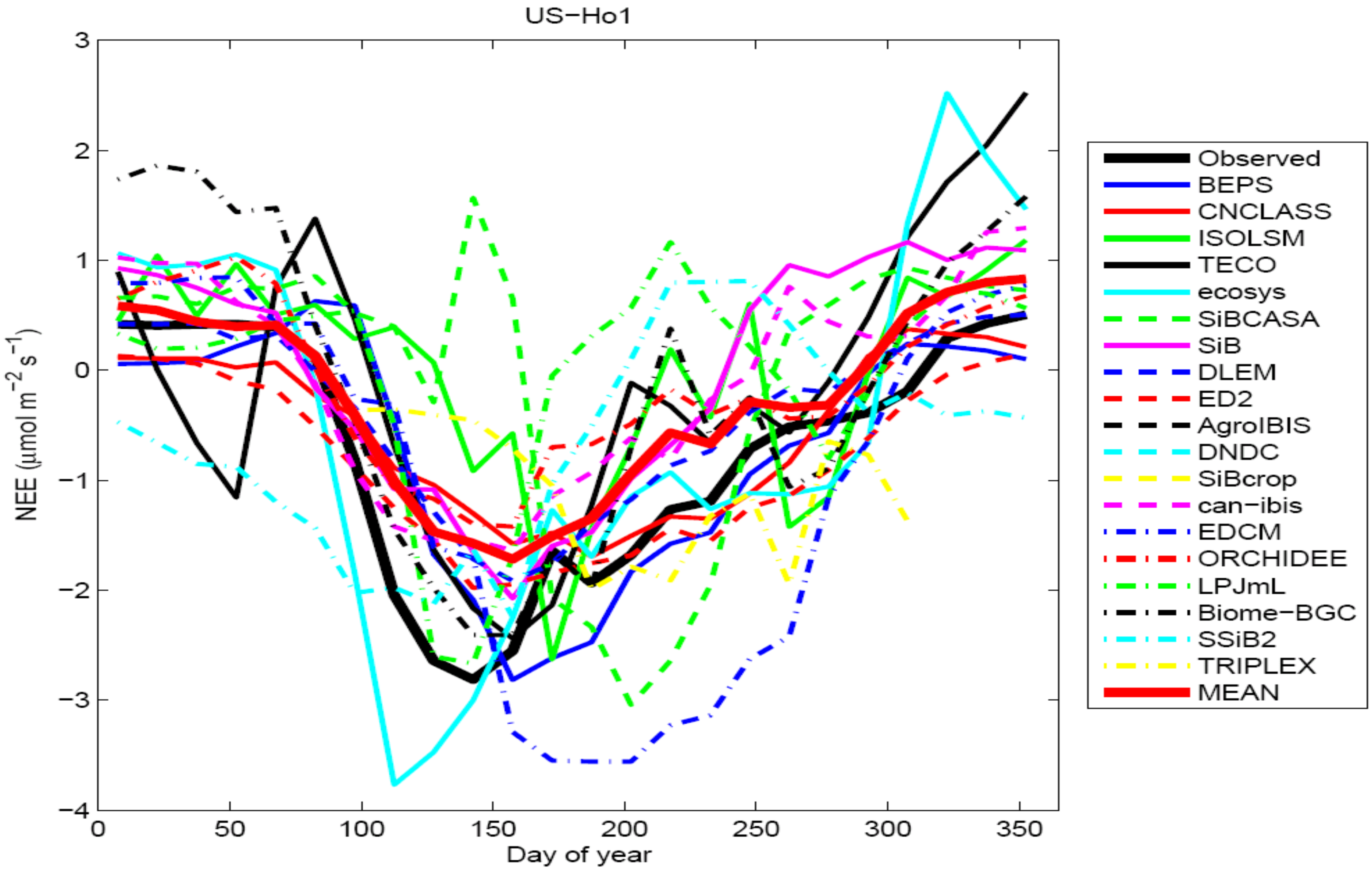
Multi-model comparison: diurnal cycle (Howland, with model 95%CI)



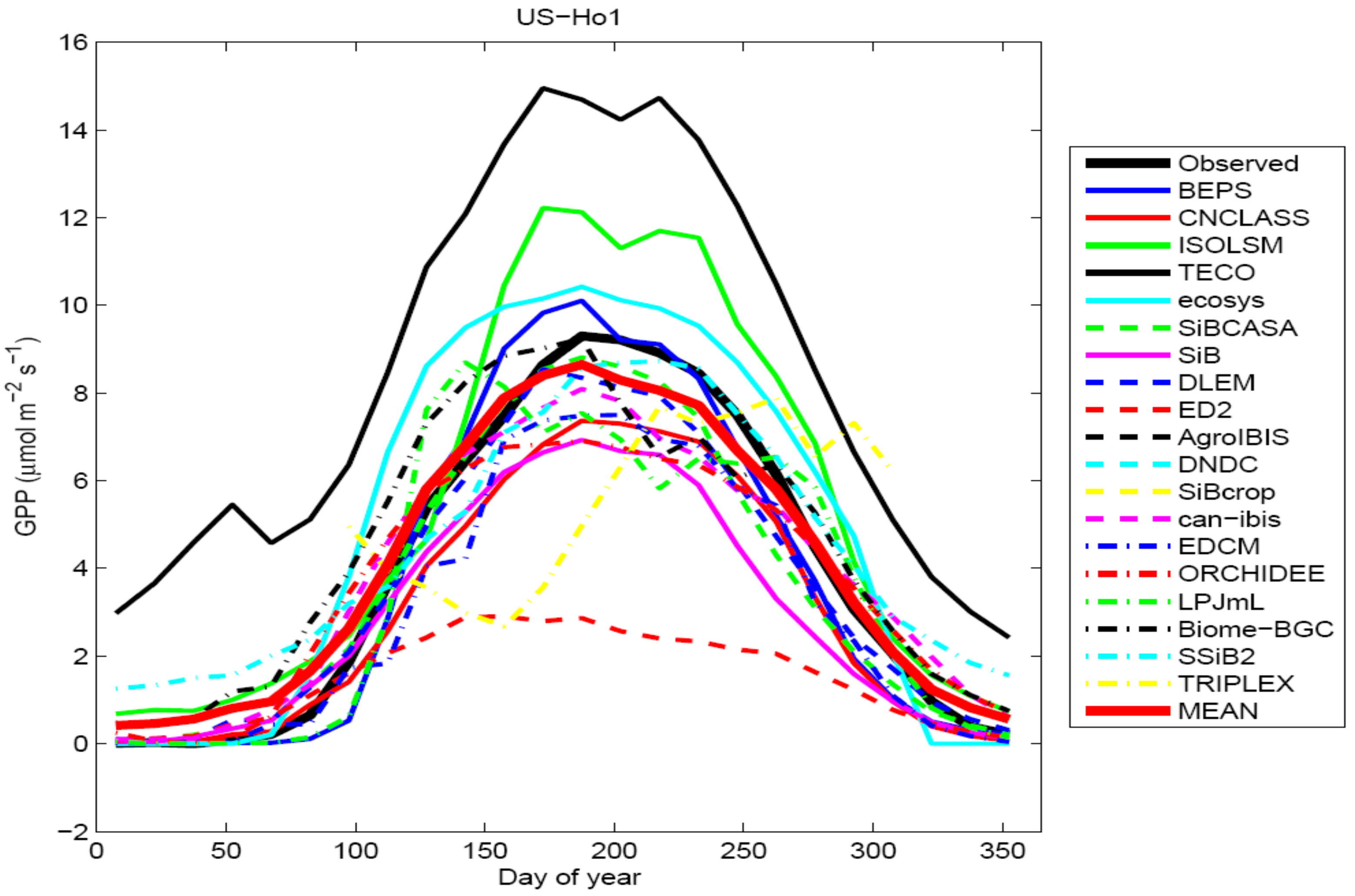
Multi-model comparison: diurnal cycle (Howland growing season mean)



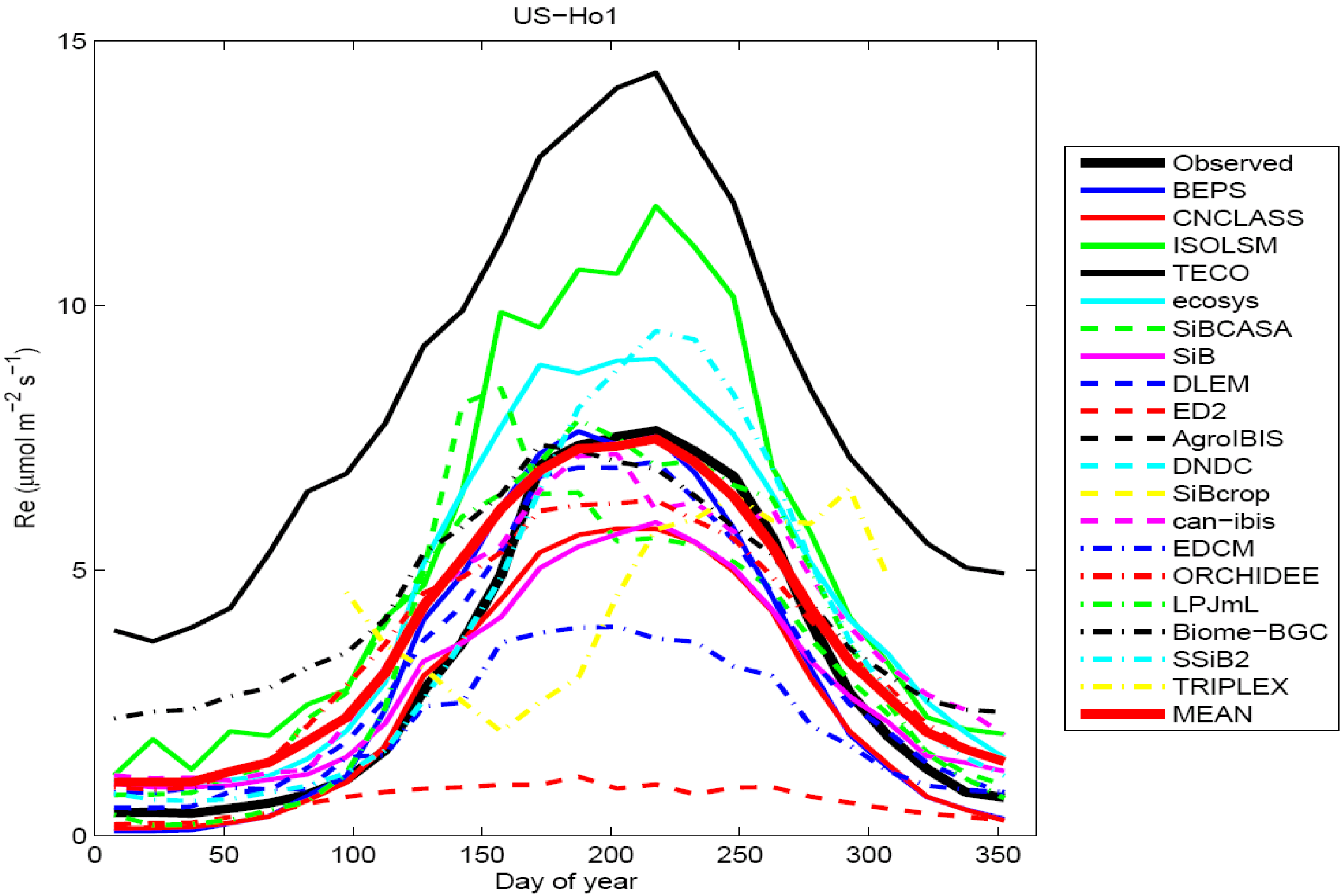
Multi-model comparison: seasonal cycle (Howland, NEE)



Multi-model comparison: seasonal cycle (Howland, GPP)



Multi-model comparison: seasonal cycle (Howland, Re)



Conclusions

- We’re about 50% of the way to a publishable analysis
- Building a valuable data and analysis resource for the broader community
- Highlighting many data and model quality issues along the way
- Better understanding of measurement uncertainty than model uncertainty

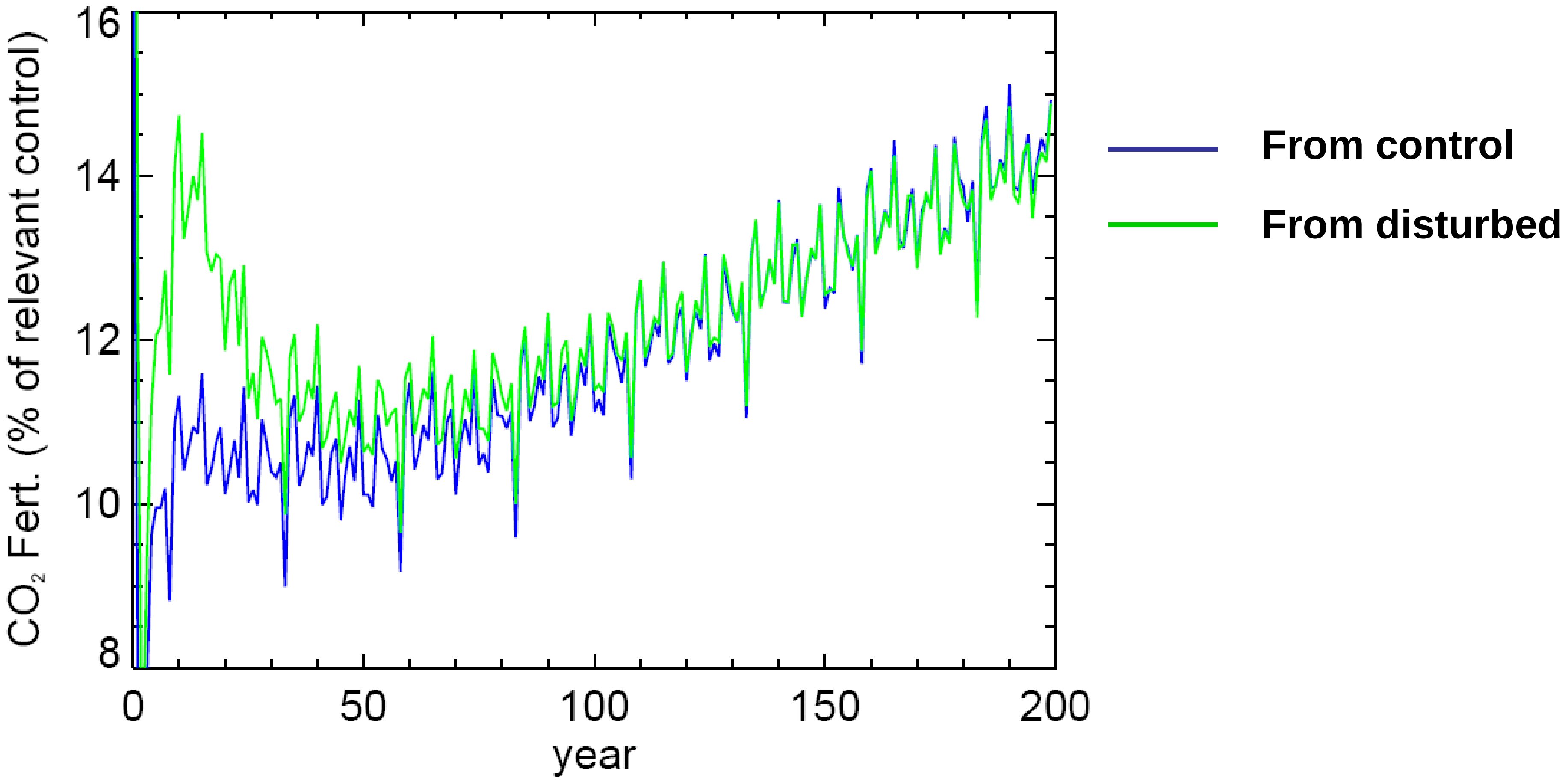
Conclusions (cont'd)

- Multi-model ensemble provides a useful way to analyze the structural component of model uncertainty
- Next steps:
  - Introduce disturbance history
  - Finalize measurement uncertainty analysis
  - Model parameterization uncertainty

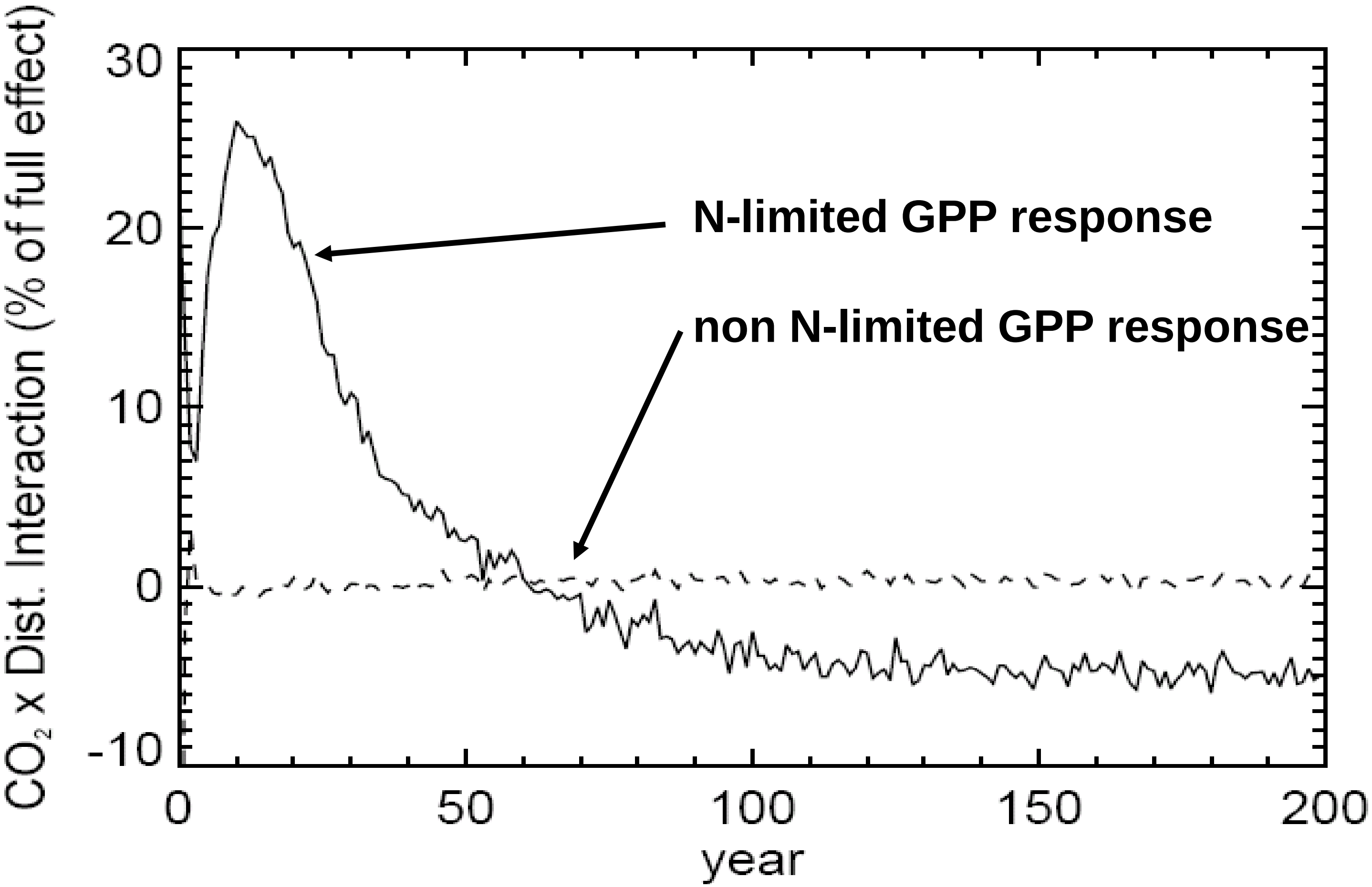
Three more LAMP pieces…

- NCEAS FACE analysis: model-measurement intercomparison at ORNL and Duke FACE sites.
  - Detailed model parameterizations to represent site conditions and experimental protocol.
- ^{15}N labeling experiments: Nadelhoffer et al., Zak et al., Stark et al. experiments. Recent review of experimental results by Schlessinger (2009).
  - Help trace the fate of N through plant, litter, and SOM pools
- Post/Matthews/Holland litter chemistry and decomposition database; Enriched Background Isotope Study (EBIS).
  - Evaluate organic carbon fluxes from litter sources to mineral-soil sinks. Should lead to improved model structure/parameterization.

%NPP Response to CO_2 fertilization (global response)



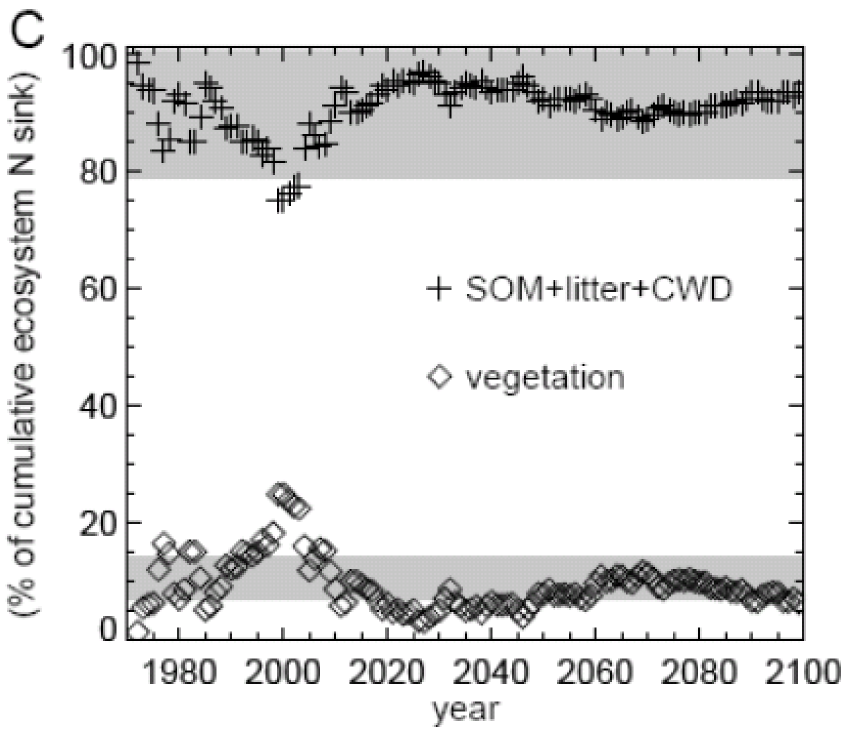
<u>Interaction effect</u> of +CO_2 and disturbance on GPP: (with and without N-limitation)

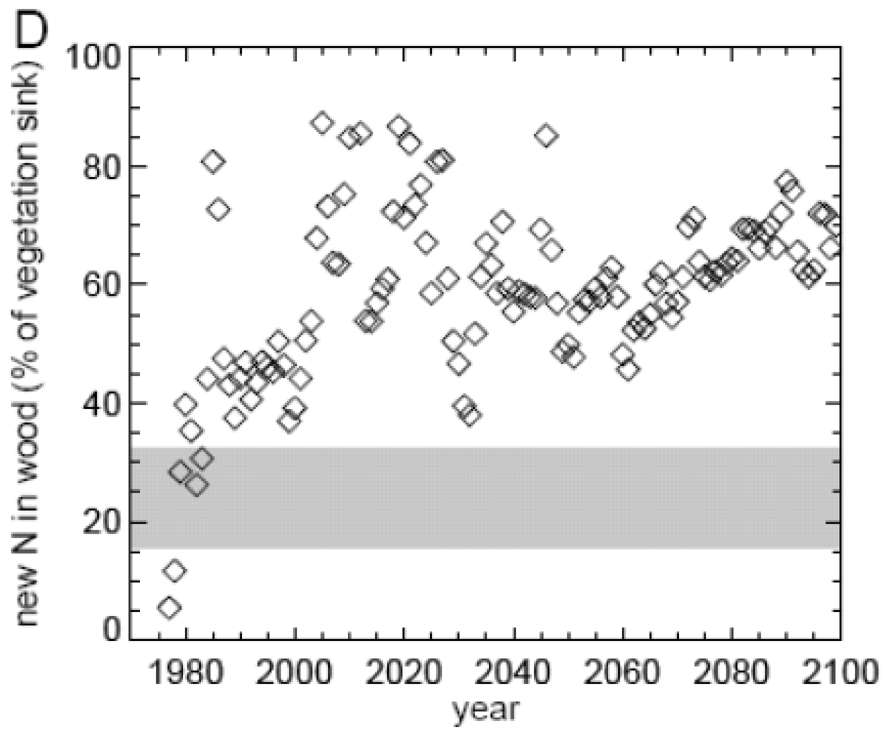


Comparison to ^{15}N tracer experiments:

Model captures the observed behavior: most new N ends up in litter and soil organic matter, smaller fraction in vegetation

Model predicts that the vegetation fraction will be increasingly dominated by wood over century time scale.





Thornton et al., 2009 (BGD)

EBIS plot and mesocosm experiments