Long (and really long!)-Term Terrestrial Carbon Fluxes & Uncertainties in Ecological Forecasting with Model-Data Fusion

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Perspectives

- Bev Law

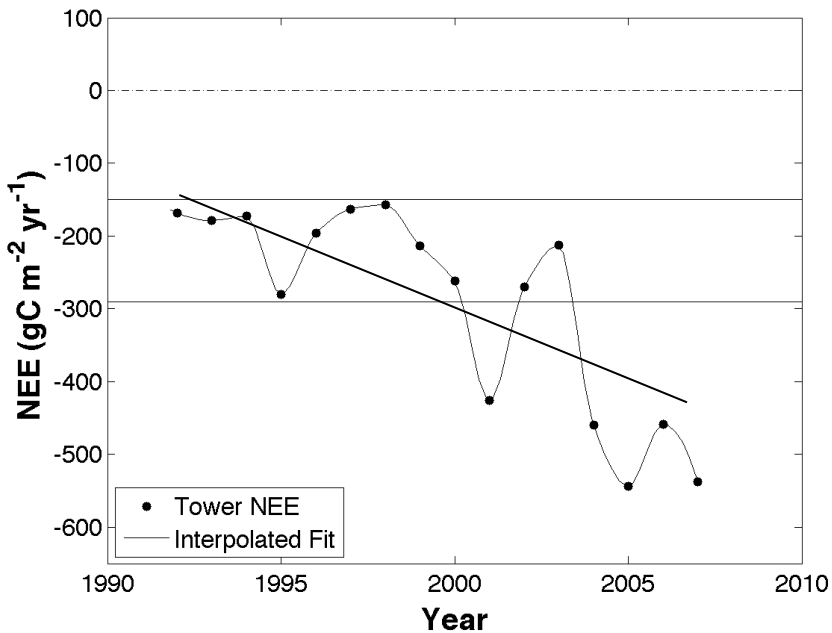
"Long-term data are needed to calibrate models"

"Do we have the science to inform policy makers?"

- Michael Kuperberg

"We need a predictive understanding."

Objectives:



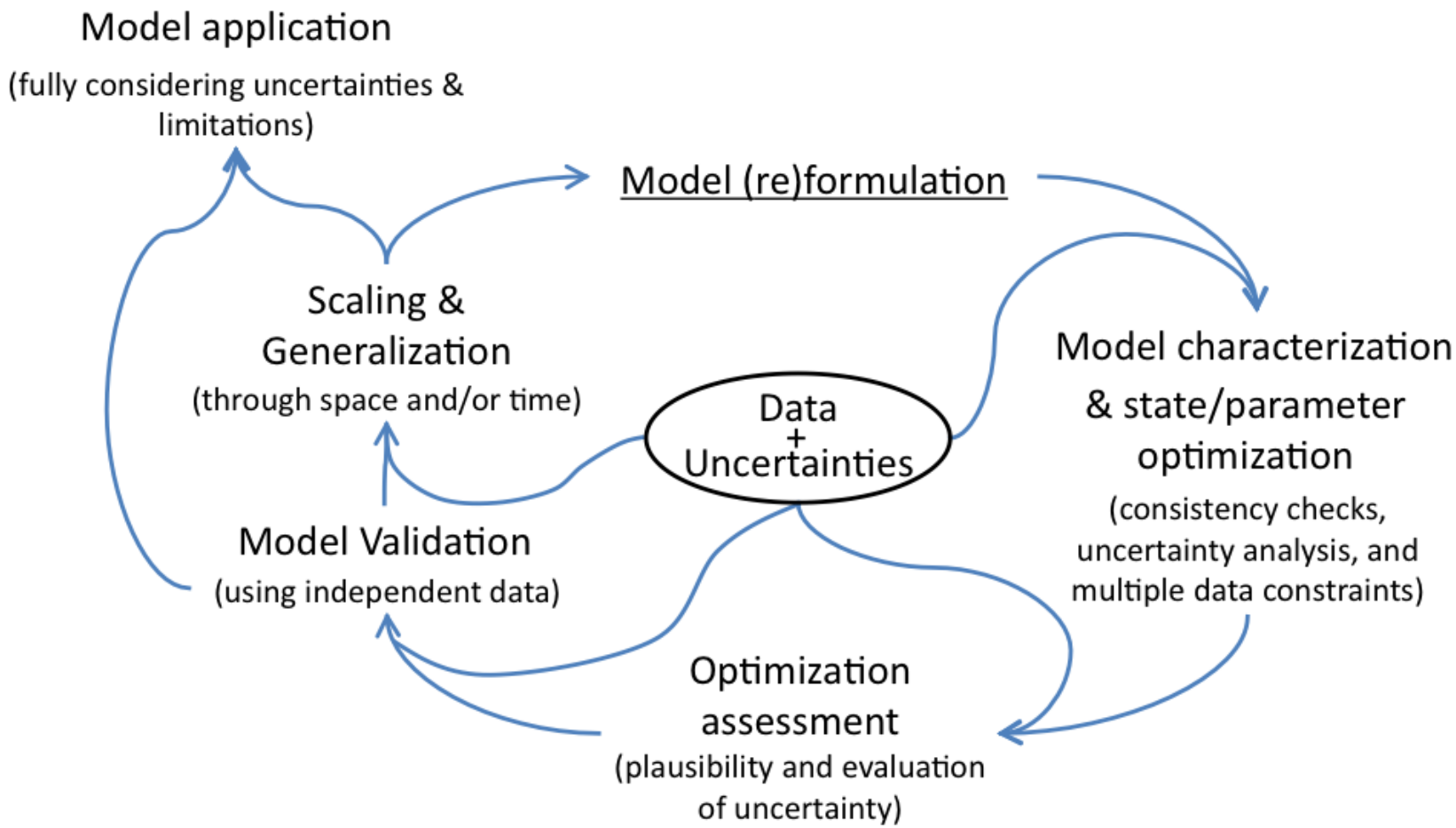
– Long term trends in C cycling at Harvard Forest.

– Assess the ability of integrated data streams to constrain process-based model uncertainty.

– The propagation of model uncertainty into future projections.

How? – Using a forest C-cycle model in a Model-Data Fusion framework.

Model-Data Fusion

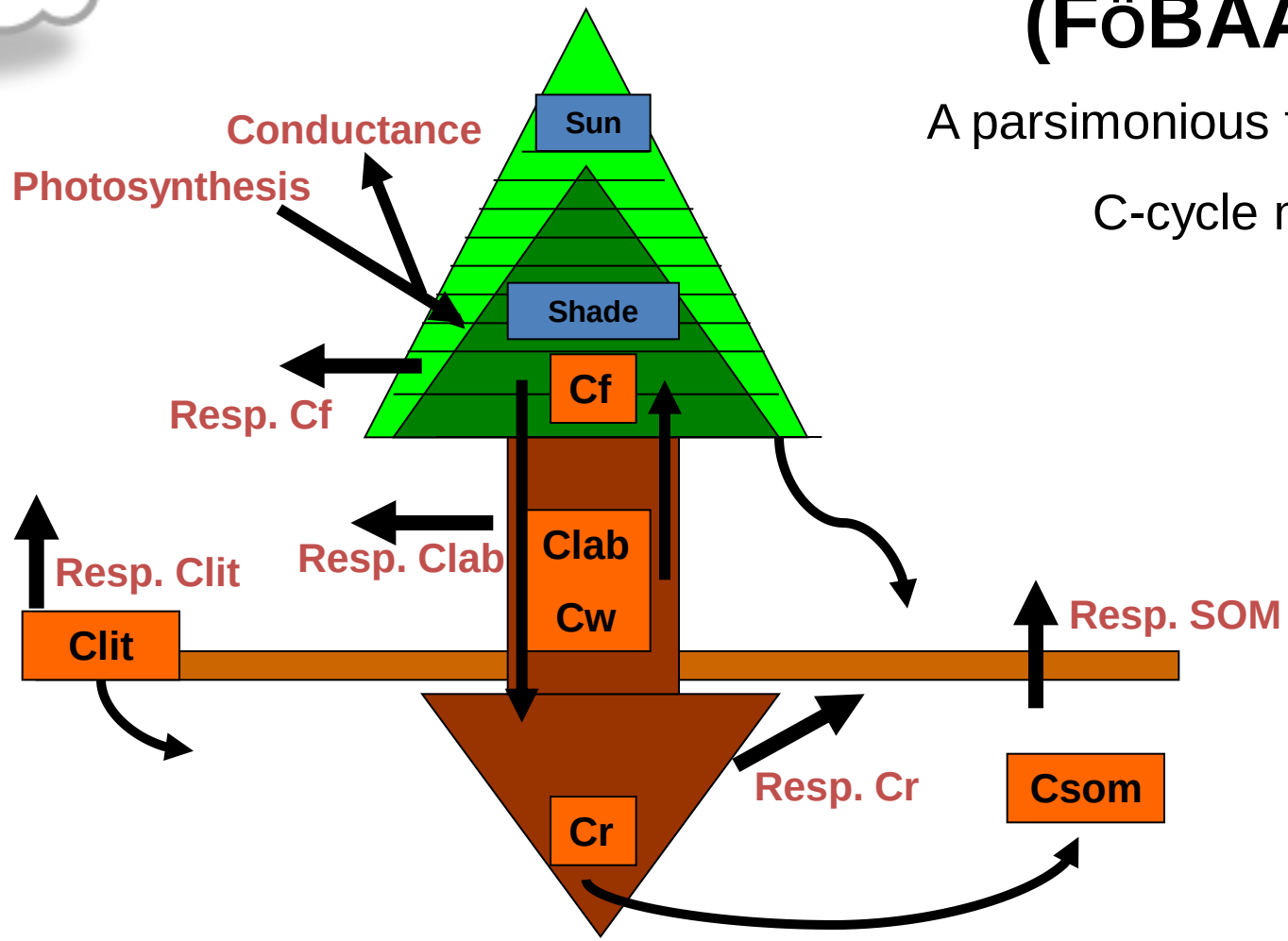


Keenan et al. (in review)

Forest Biomass Assimilation Allocation and Respiration (FöBAAR)

A parsimonious forest C-cycle model

Drivers:
PAR
Air Temp.
Soil Temp.
VPD
CO_2



6 Pools, 29 Parameters, 3 dataset harmonization parameters = 38 p's optimized

The Six Commandments for a good model-data fusion study

	Code of best practices for model-data fusion analyses
1.	**Data uncertainties should be openly acknowledged**
2.	**Model structural error should be assessed**
3.	**Multiple data constraints should be implemented**
4.	**The MDF framework should be tested against synthetic data**
5.	**Validate the optimized model against independent data.**
6.	**Confidence intervals (posterior distributions) on model parameters, states, and predictions should be estimated in a transparent manner**.

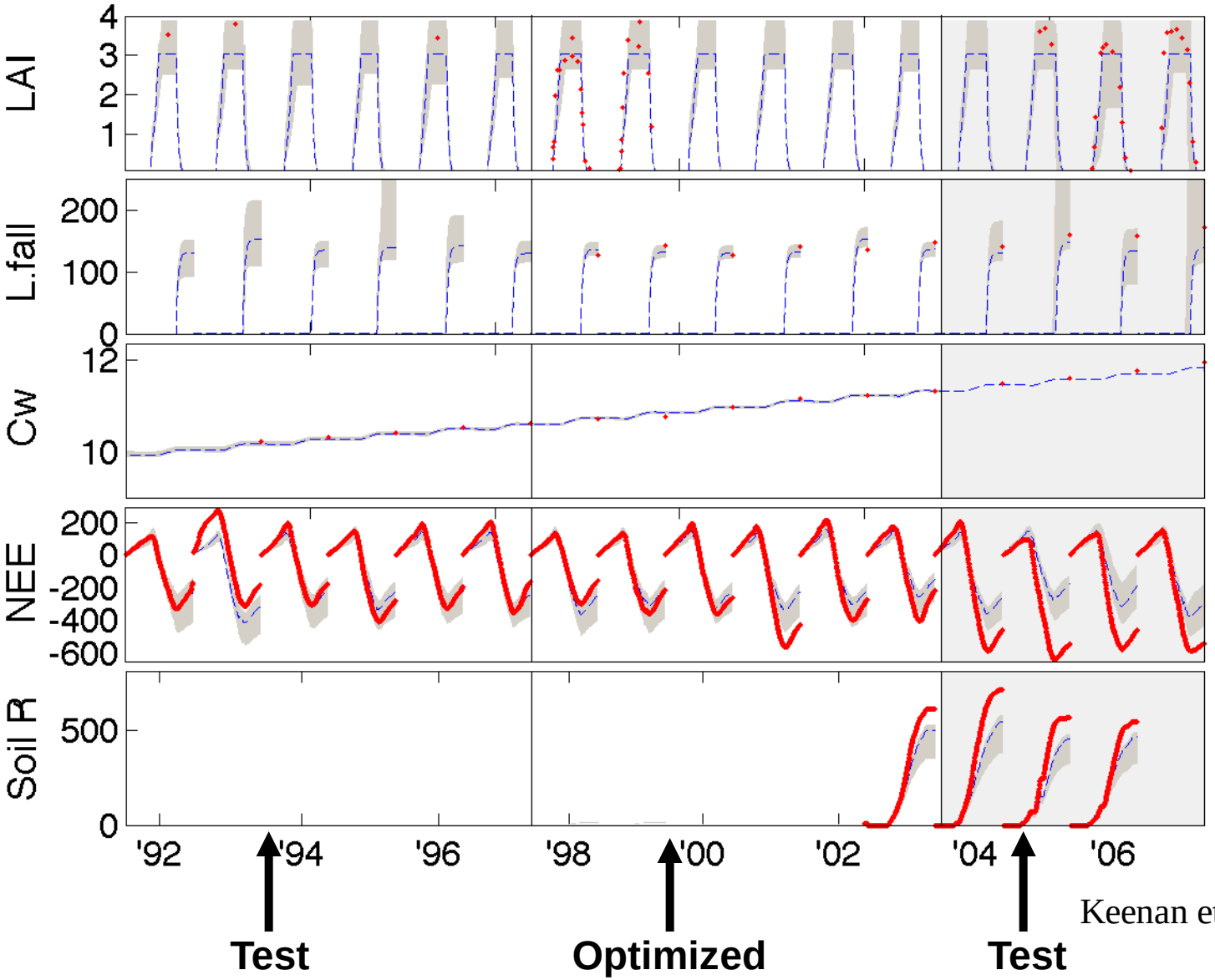
Keenan et al. (in review)

Constraints

- NEE (hourly, no gap filled data)
  - Distinction between day & night
  - Monthly & annual incremental values

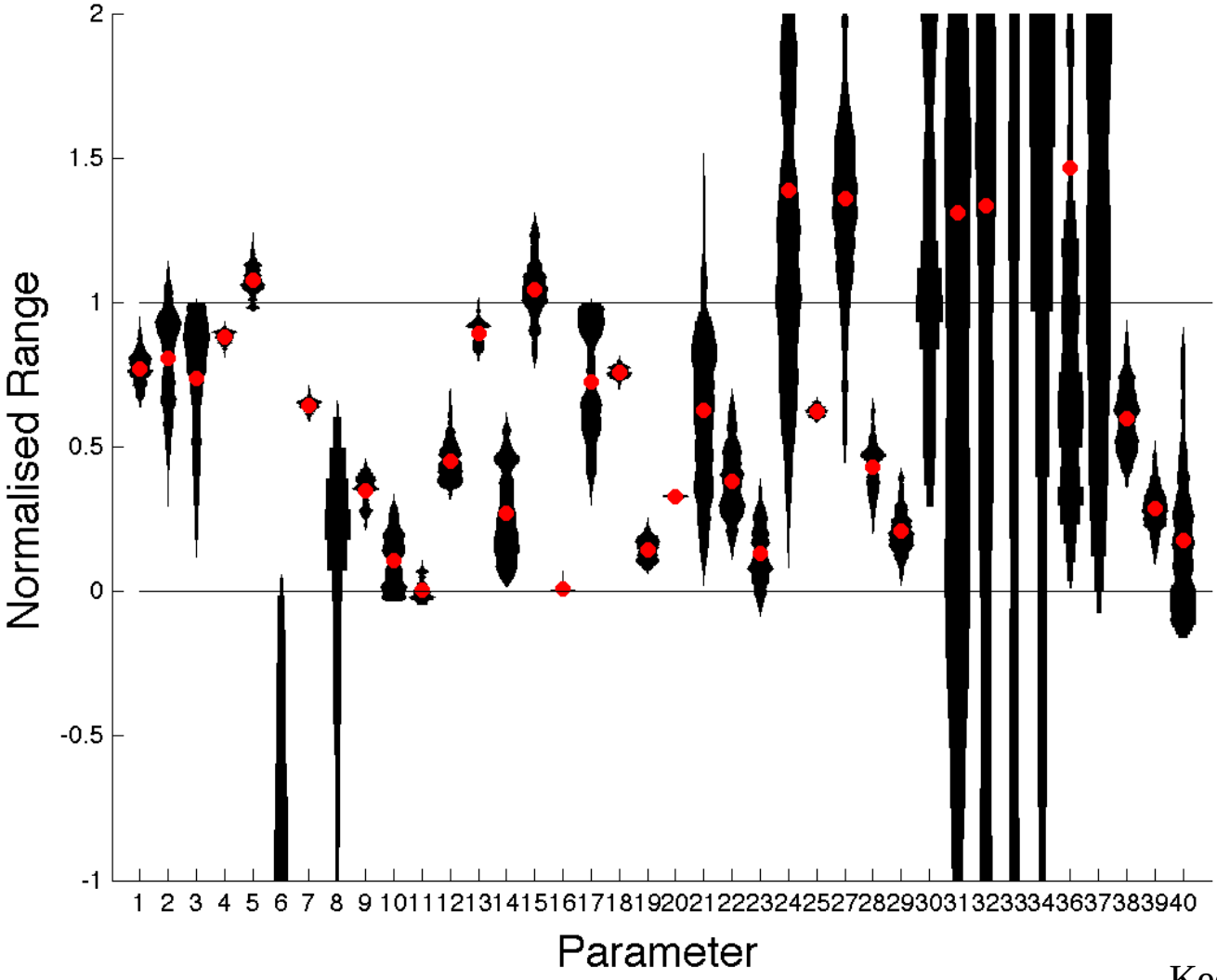
- Soil Respiration (3 different data sets, day & night)
- LAI
- Leaf litterfall
- Carbon in wood (both measured & increment)
- Phenology –leaf out and leaf in
- % Soil respiration from autotrophic

Results:



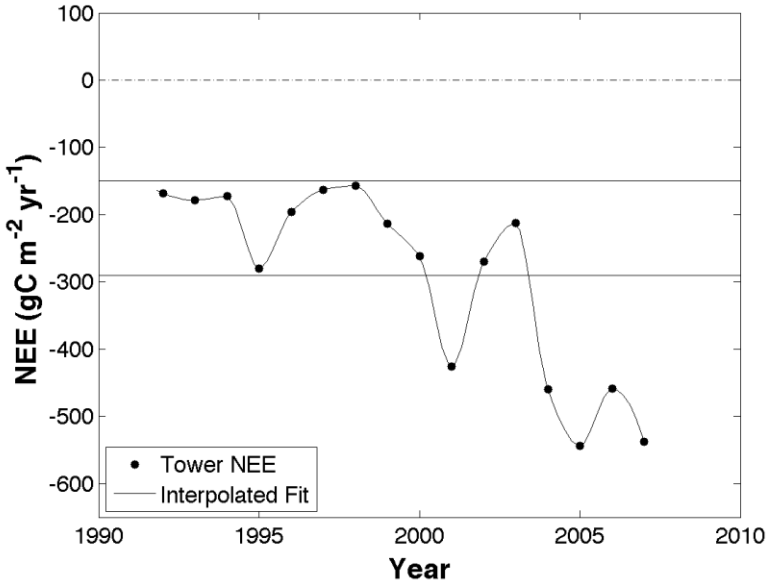
Keenan et al. (in prep.)

Confidence in parameters…



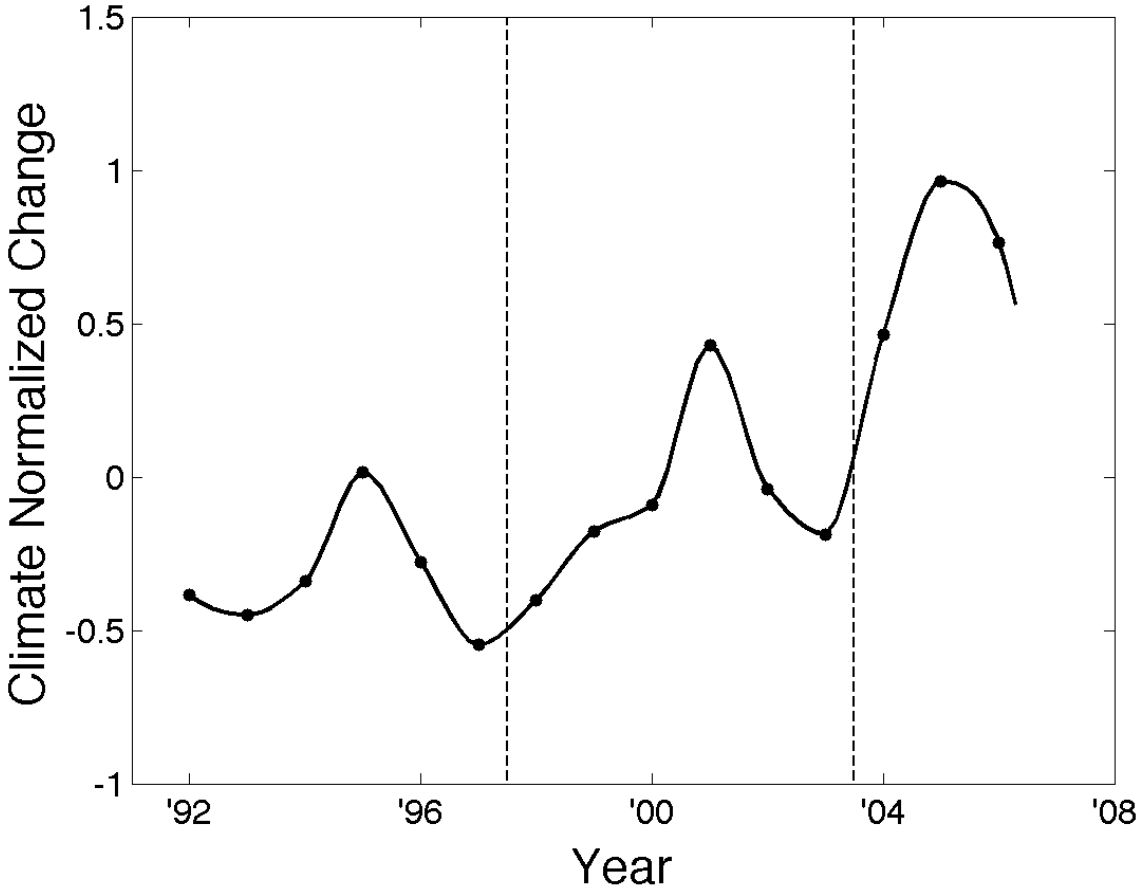
Keenan et al. (in prep.)

- What have we learned?
  - The model gets it, but doesn't get it.
  - Model structural error?
  - Lack of sensitivity to a changing climate?
  - Data error?



1. Benchmark the model – Artificial Neural Network
2. Test the data – independent gap filling

Climate-independent change in uptake



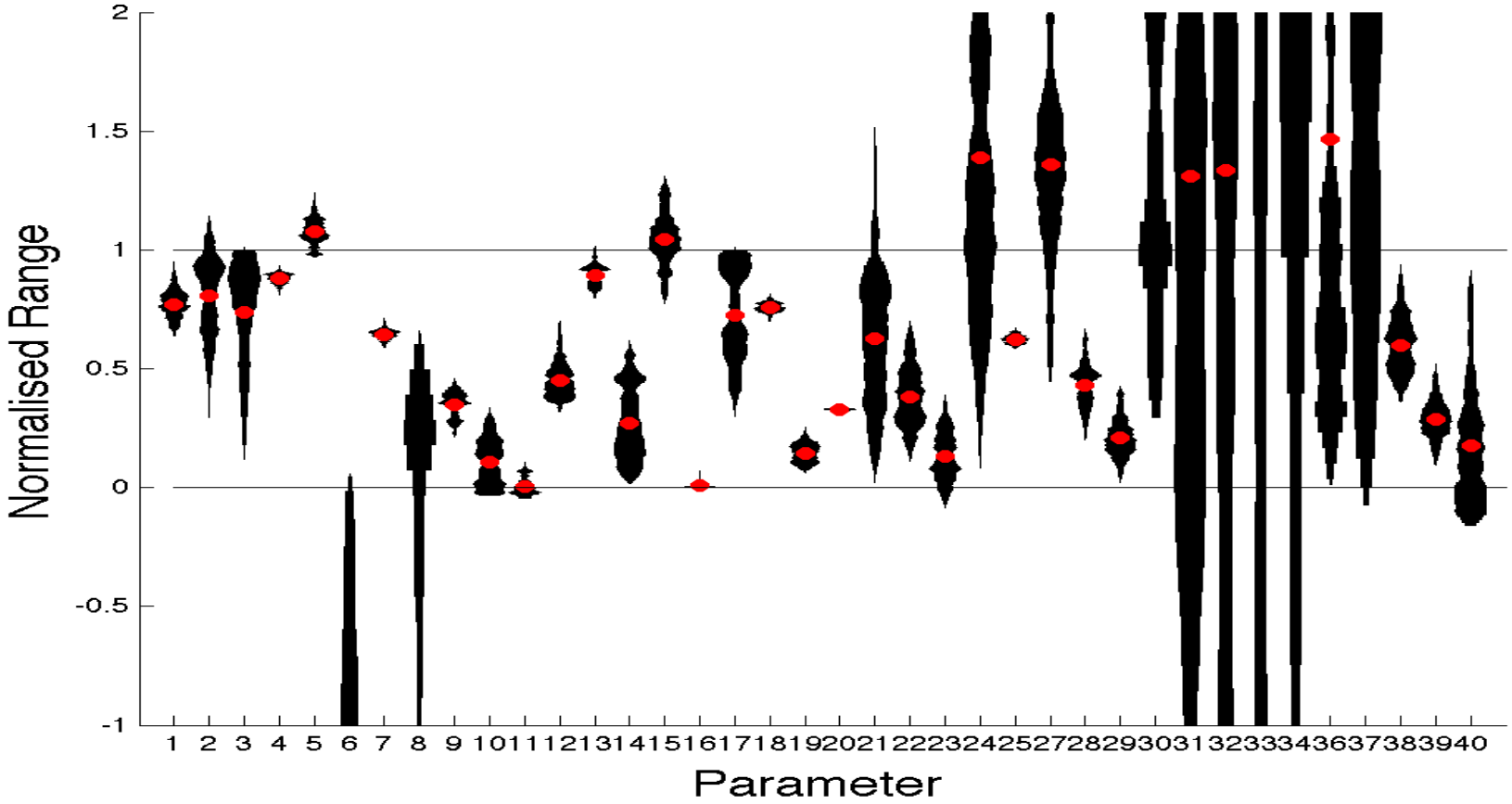
What's going on?

- 1. Change in ecosystem climate sensitivity with respect to late '90s mean?
  - Can ecosystem structural changes explain the necessary ~20% increase in GPP?
- 2. Systematic measurement error?
  - If it is not the gap-filling….then?

to be continued…

Back to the Future….

FöBAAR & Ecological Forecasting



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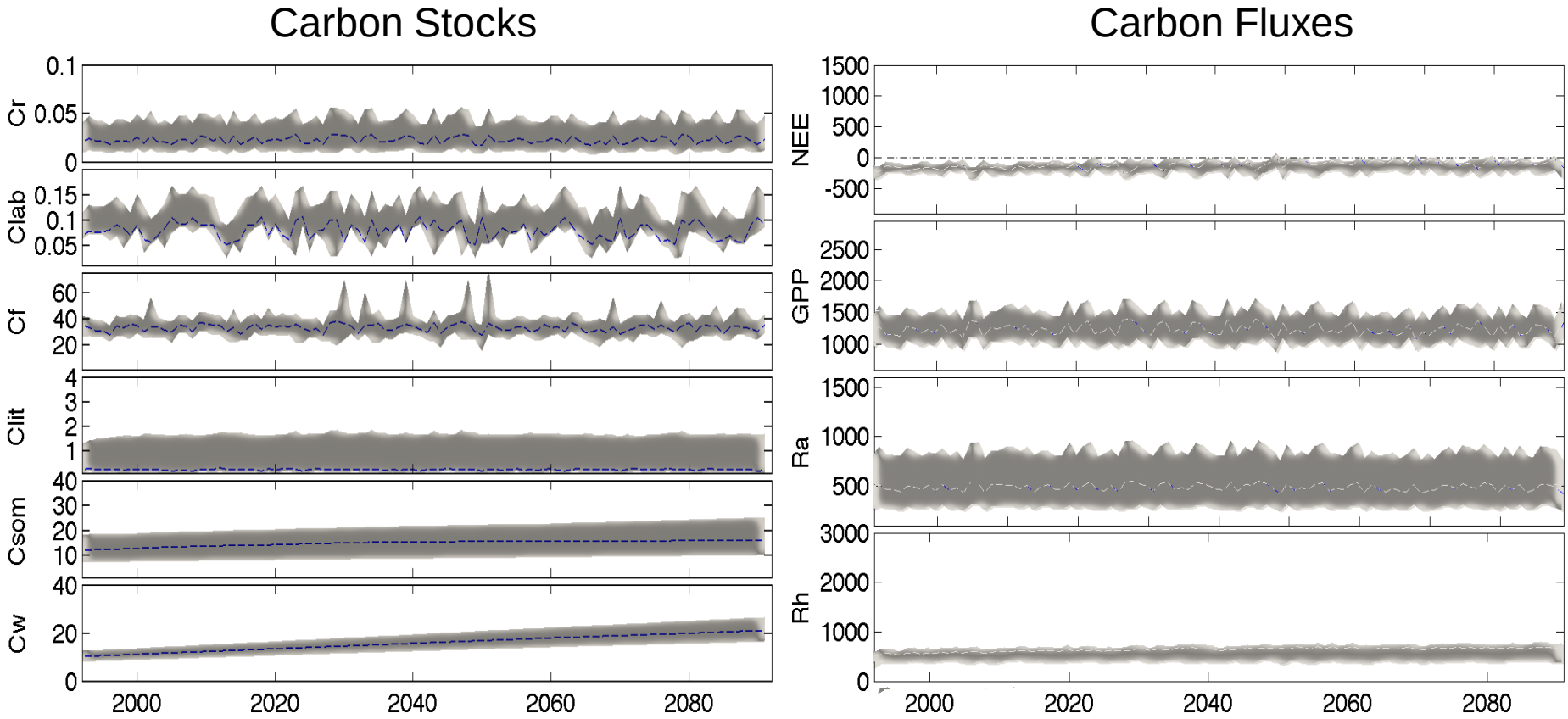
Back to the Future….

FöBAAR & Ecological Forecasting



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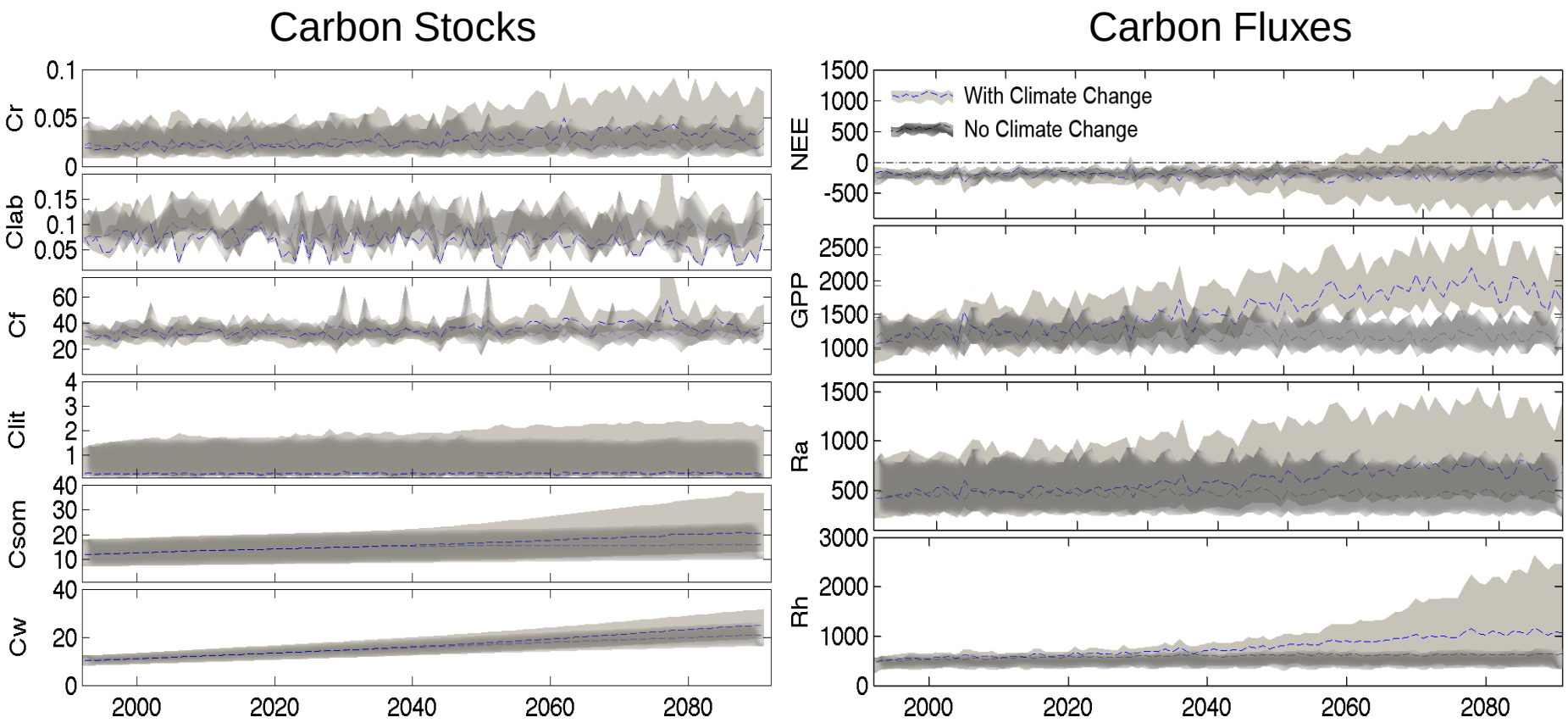
Back to the Future….

FöBAAR & Ecological Forecasting



Keenan et al. (in prep.)

Conclusions

- Modeling long-term trends is not trivial
- Multiple constraints can lead to a better constrained model
- Modeled really long-term (>50 years) fluxes shows strong sensitivity to initial conditions
- Techniques such as Model-Data fusion can help reduce this uncertainty.

Thanks…

Andrew Richardson

William Munger

Antje Moffat

Eric Davidson

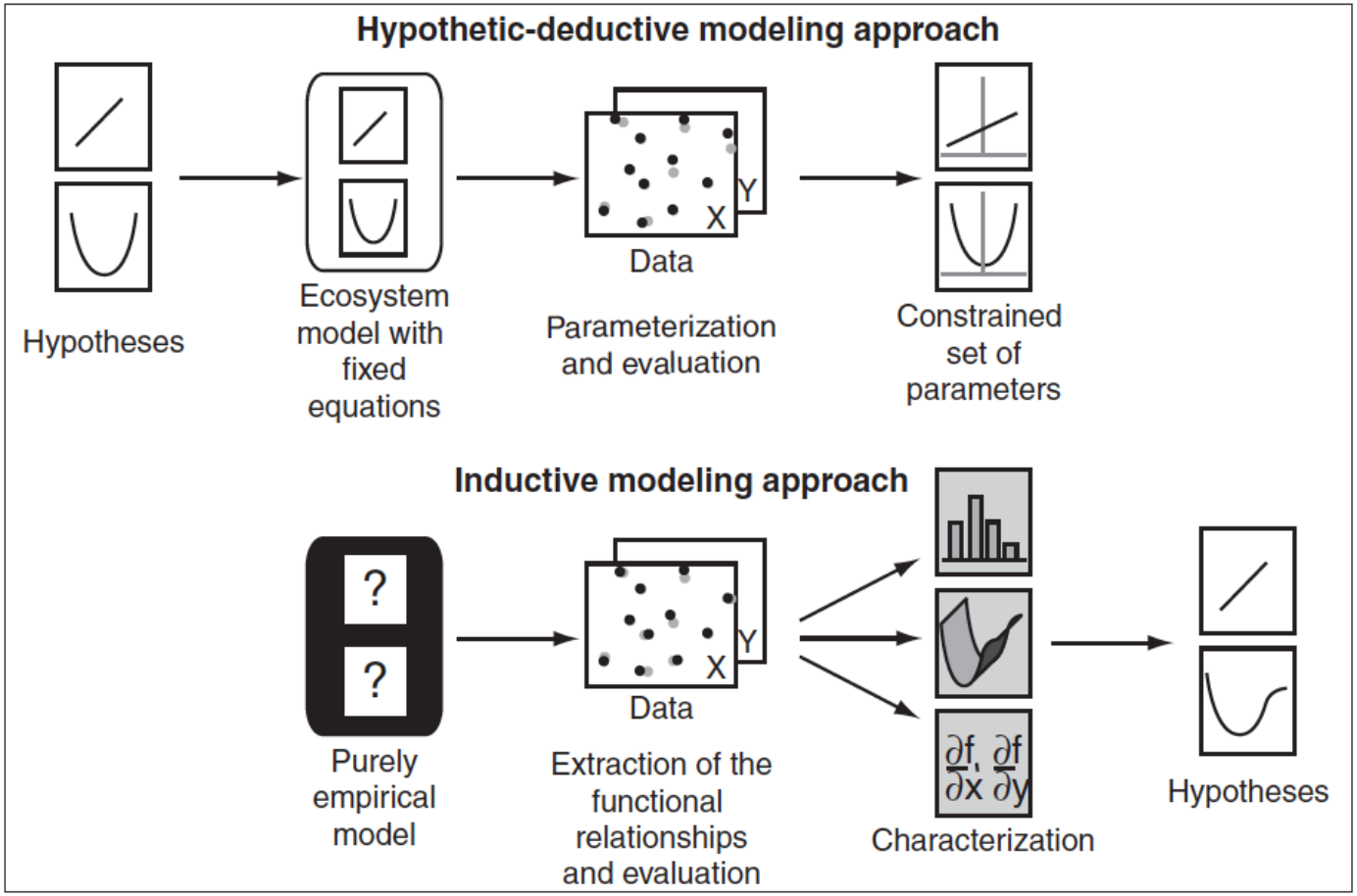
Kathleen Savage

Markus Reichstein

Extras…..

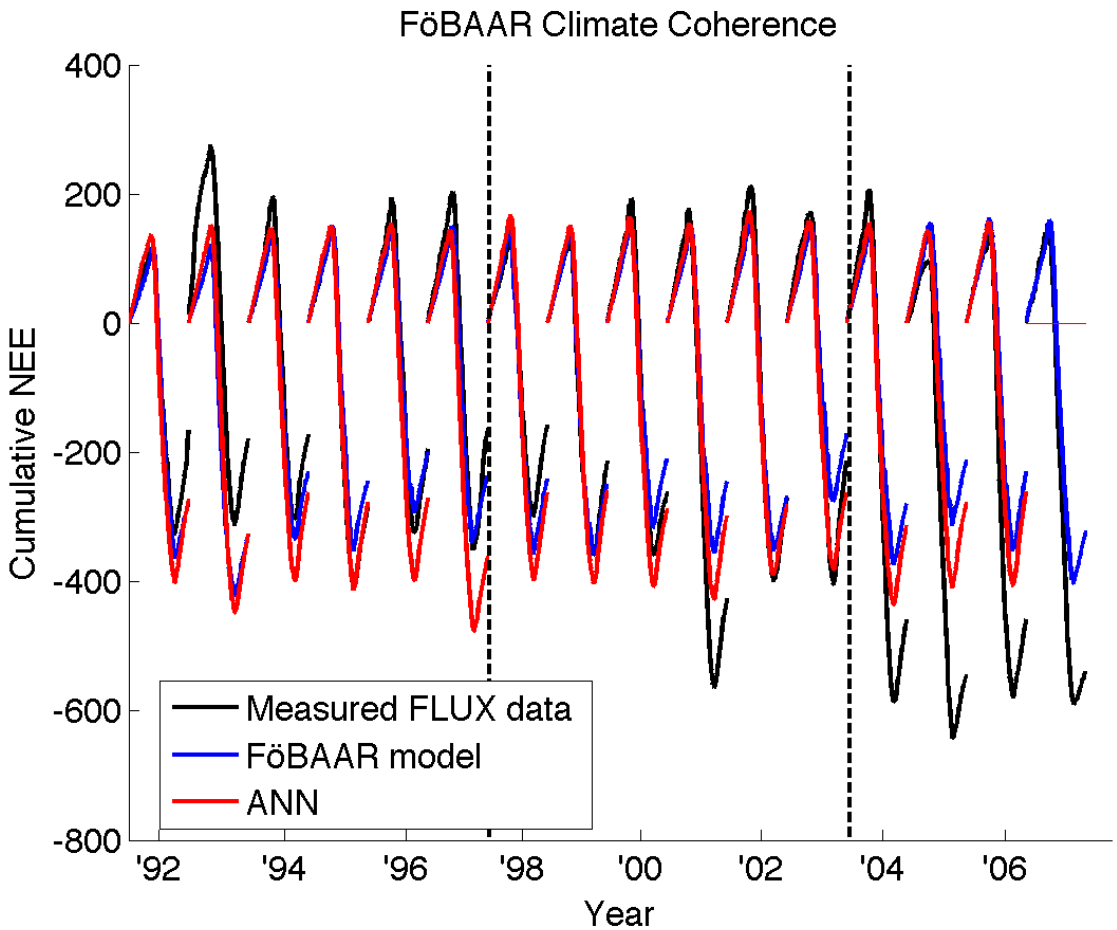
Artificial Neural Network

PAR
Rpot
VPD
Tair
Tsoil
CO_2
Phenology
Precipitation
u*
Wind

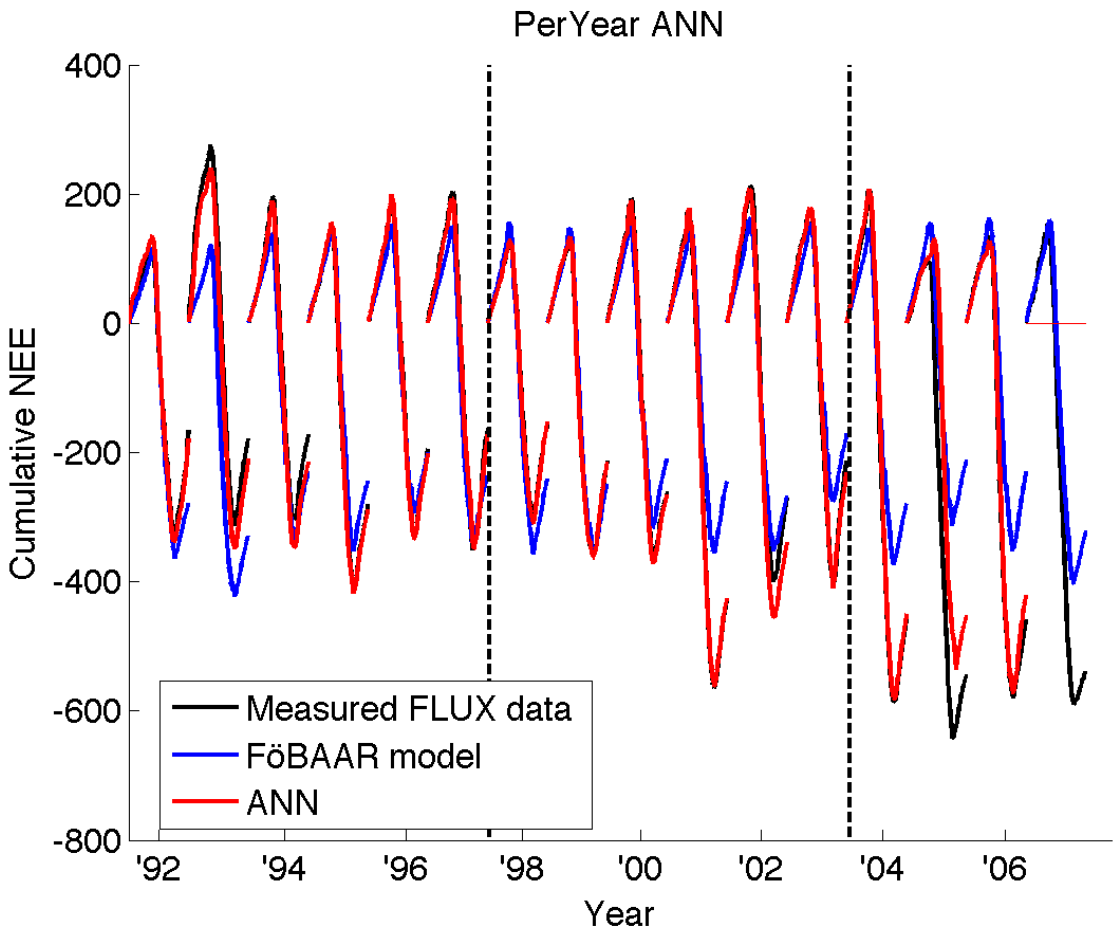


Moffat et al., 2010 GCB

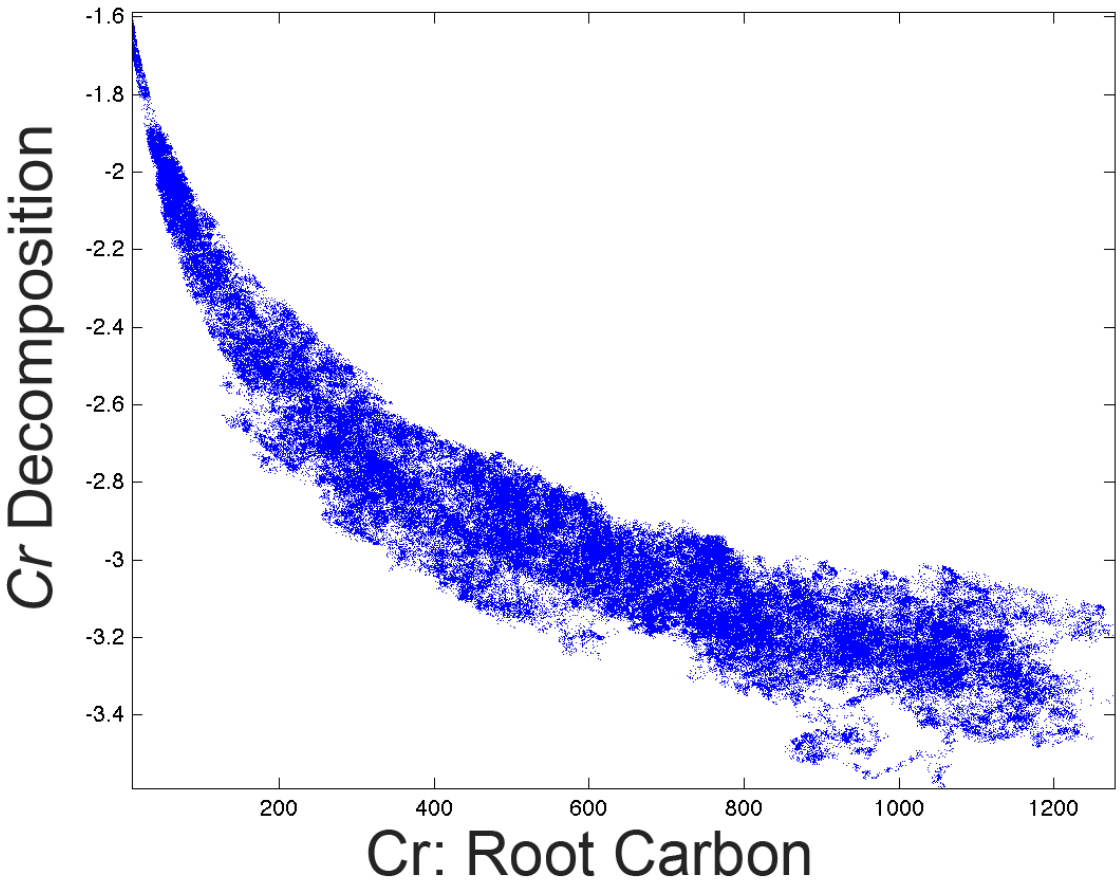
Is it the model?
Change in climatic drivers?



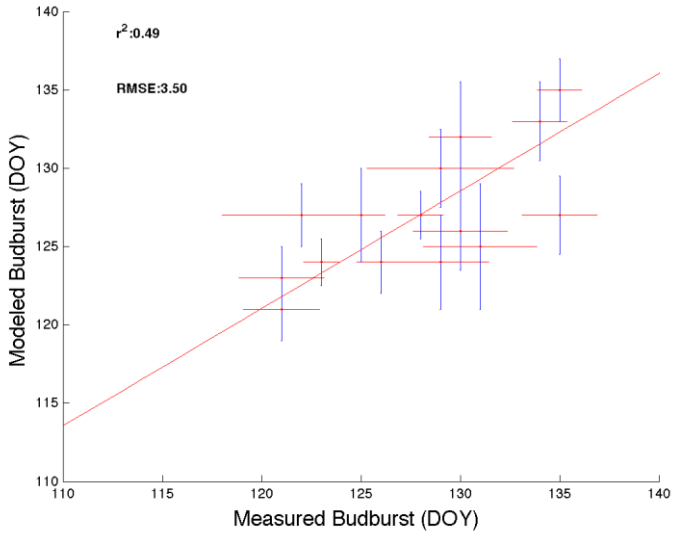
Is it the gap-filling?



Parameter Covariance:



Phenology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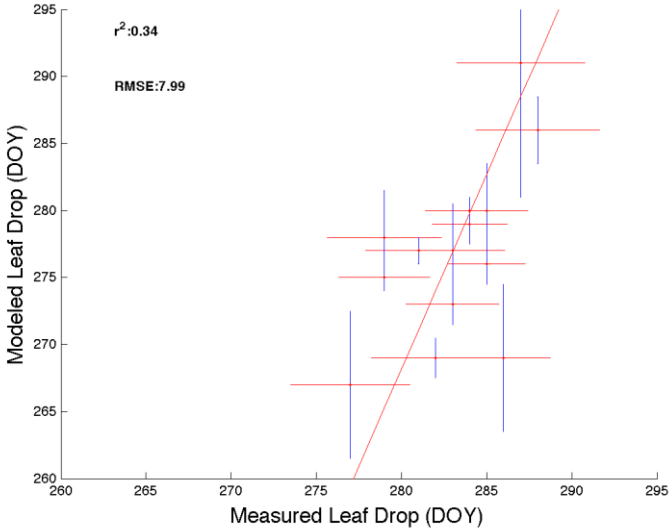
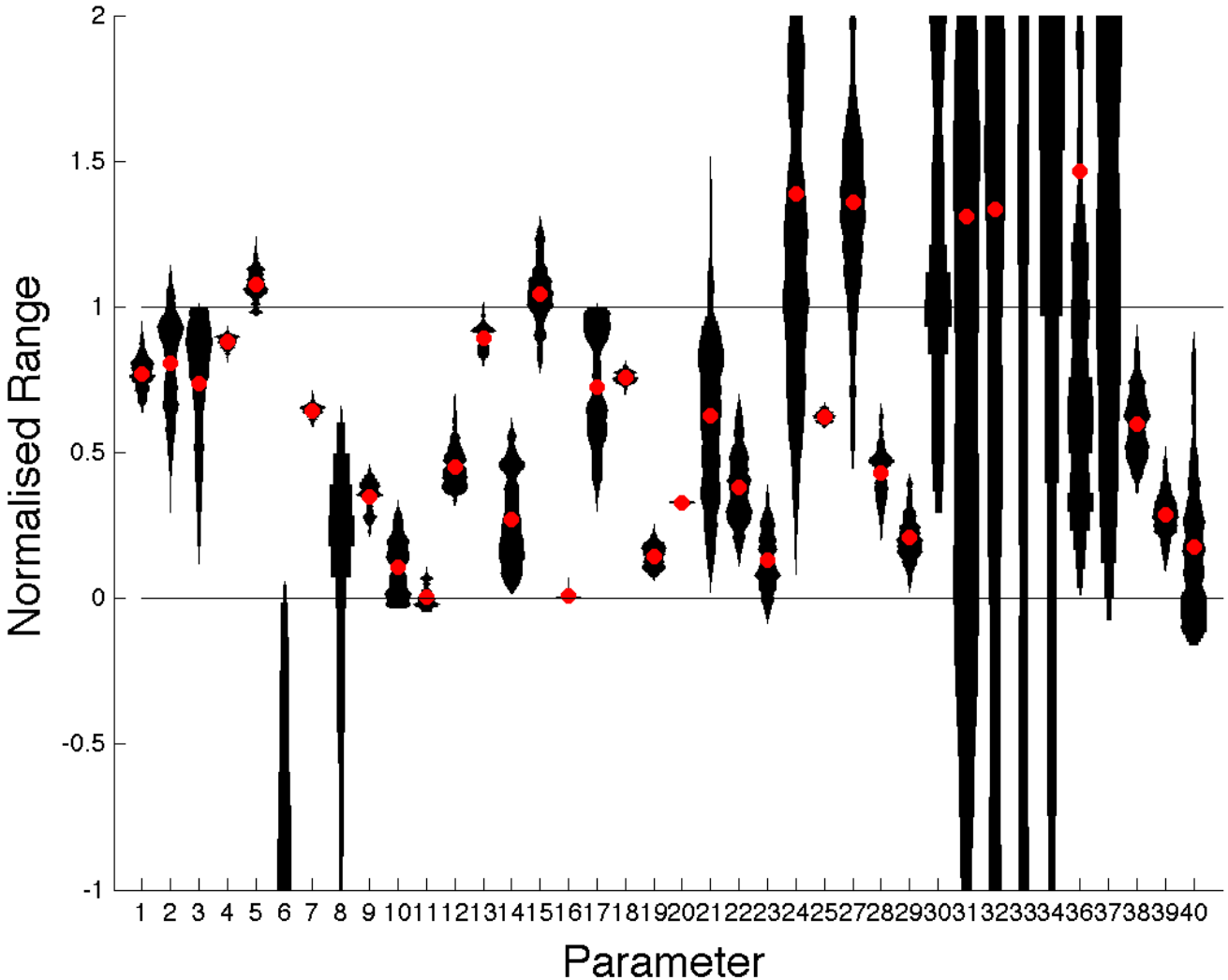
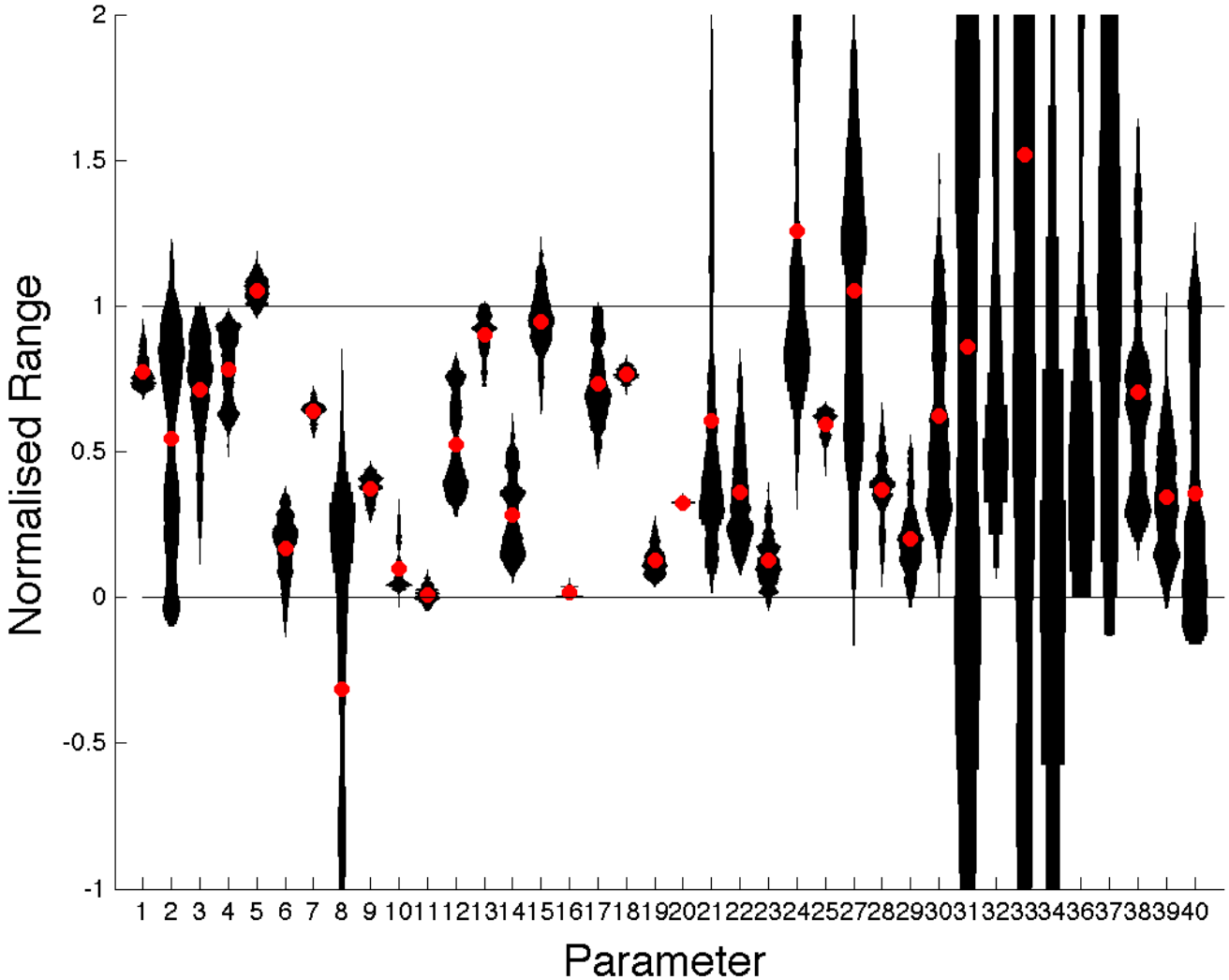
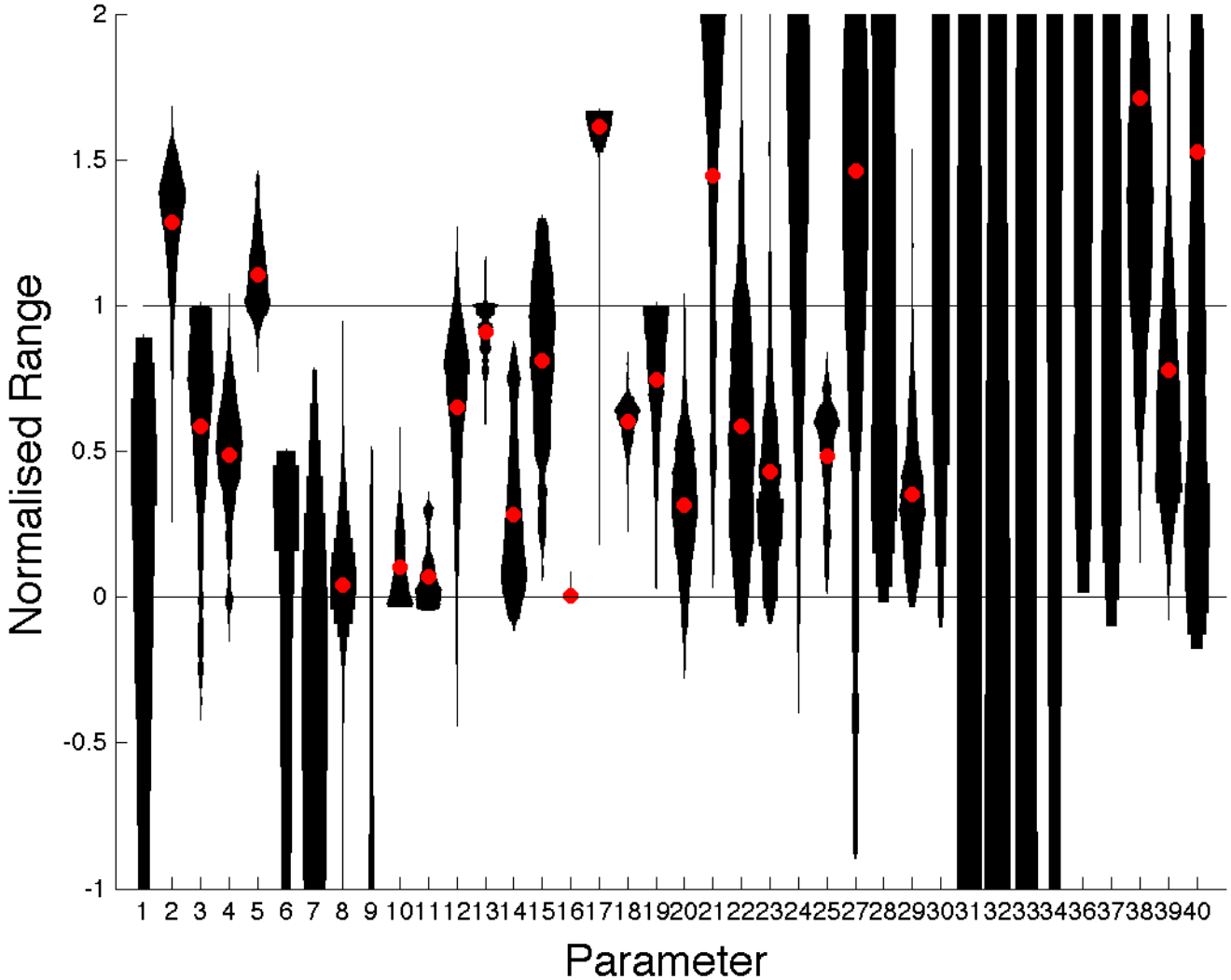
RMSE:3.50
Modeled Budburst (DOY)
Measured Budburst (DOY)
110
115
120
125
130
135
140


r2:0.34
RMSE:7.99
Modeled Leaf Drop (DOY)
Measured Leaf Drop (DOY)
260
265
270
275
280
285
290
295

Chi-square uncertainty…



MCMC Ji posterior search



Standard MCMC posteriors (Jtot exploration)