Role of Model-Data Fusion in Analyzing/Quantifying Uncertainty (D. McGuire and H. Genet)

- Sources of Uncertainty in Models
- Traditional Parameter Uncertainty Analysis
- Model-Data Fusion

Sources of Uncertainty in Modeling

- Conceptual Uncertainty
  - Compare dynamics of alternative models
- Formulation Uncertainty (equations)
  - Compare models with different equations
- Parameter Uncertainty
  - Various approaches to analyzing uncertainty
- Application Uncertainty
  - Jeremy Littell's presentation

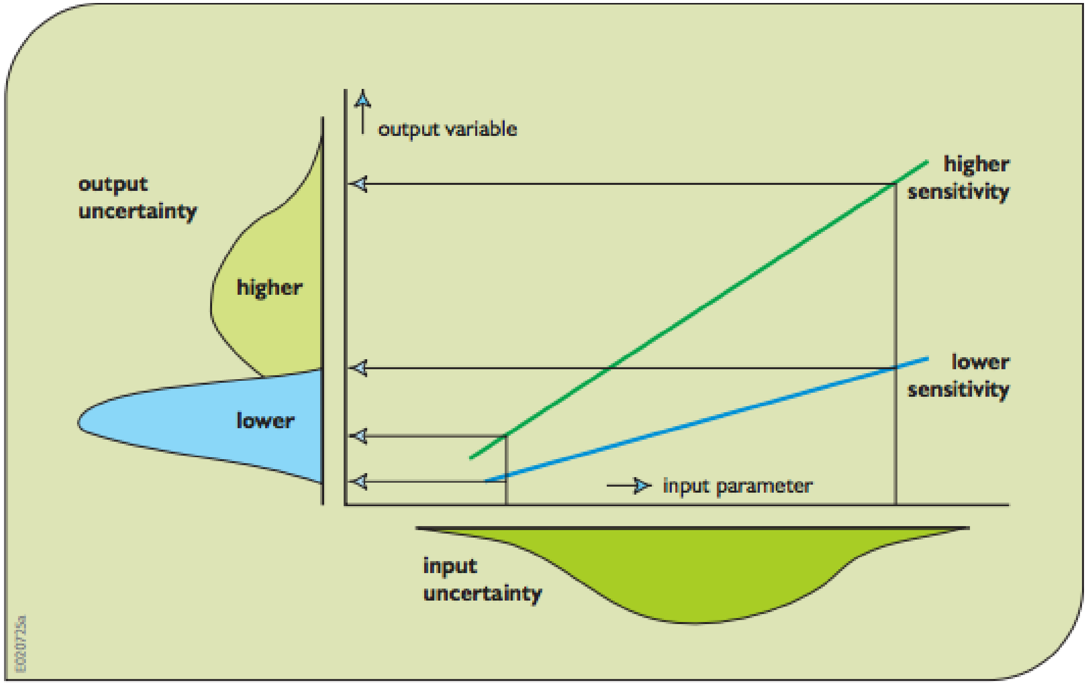
Parameter Estimation

- Literature-based estimation
- Experimentally based estimation
- Calibration

Traditional Parameter Uncertainty Analysis

- Definition

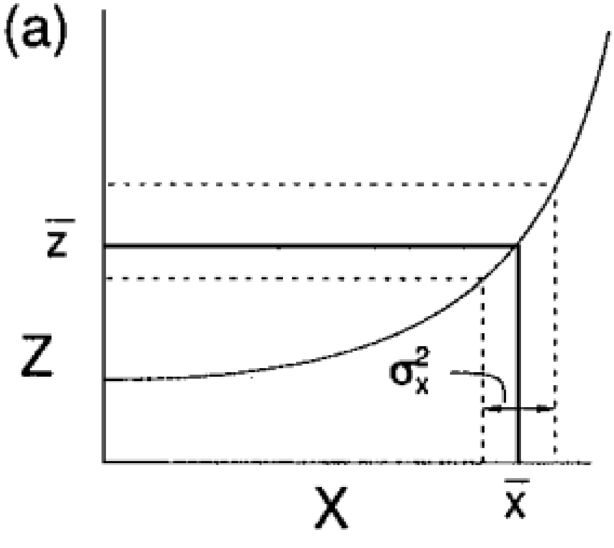
  Relates the variability of model predictions to uncertainty in parameter estimates.



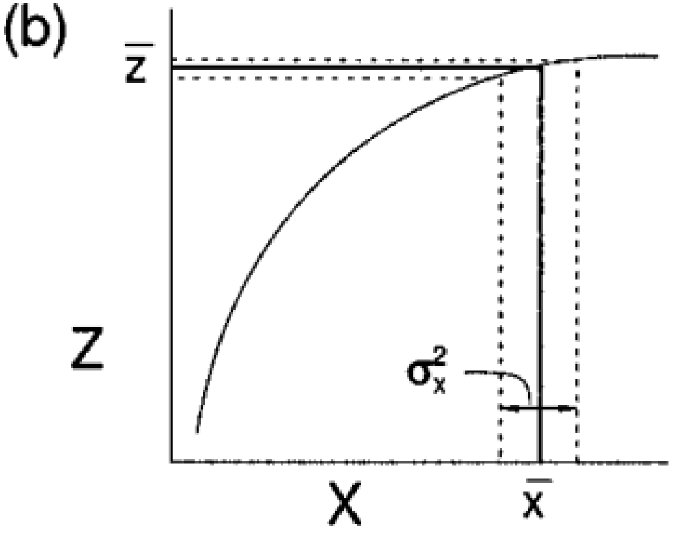
Uncertainty analysis is analyzing the effect of the ***variance*** of a parameter to the model predictions.

Error Propagation

- Amplification
- Compensation



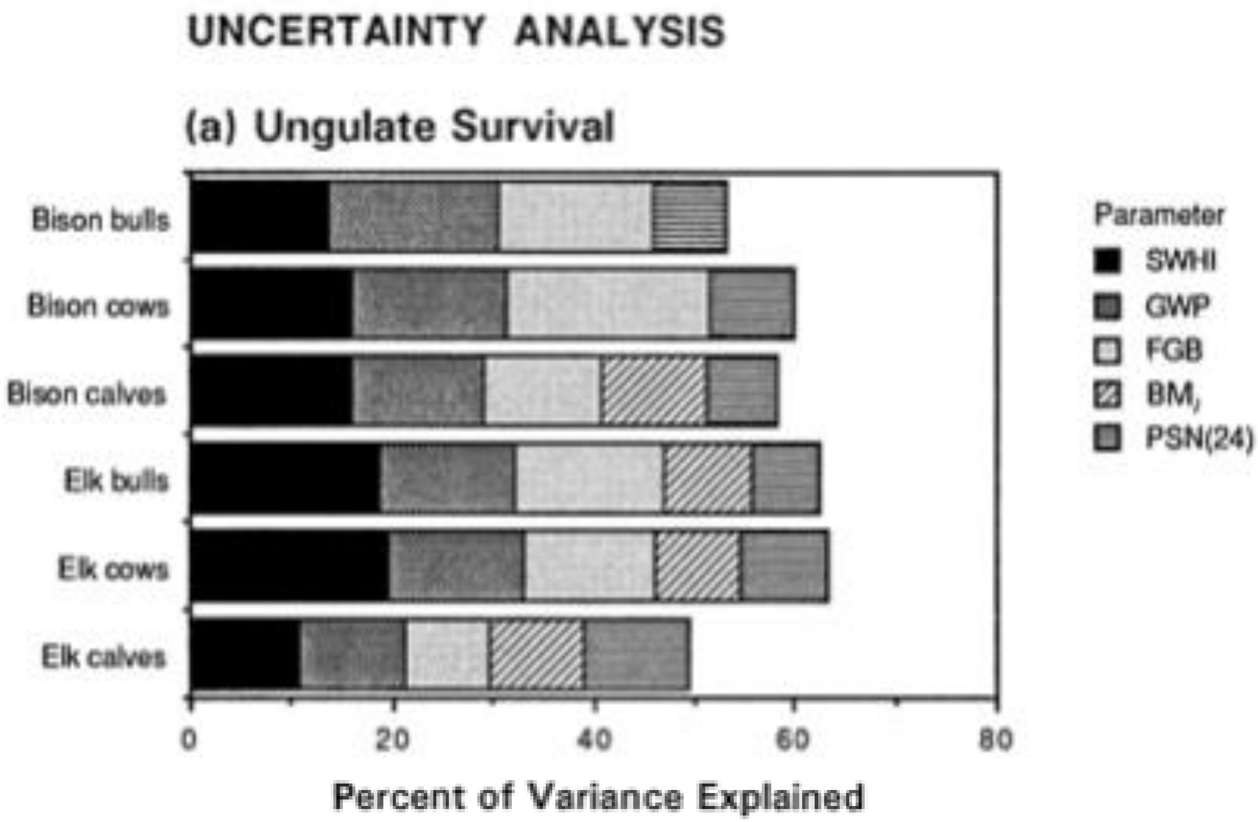
Error amplified : $\sigma_z > \sigma_x$



Error compensated: $\sigma_z < \sigma_x$

Multiple parameter uncertainty analyses:

100 independent sets of parameters value using Monte Carlo iterations applied to 43 parameters varying within an "acceptable" range, assuming a uniform probability density function for each parameter.

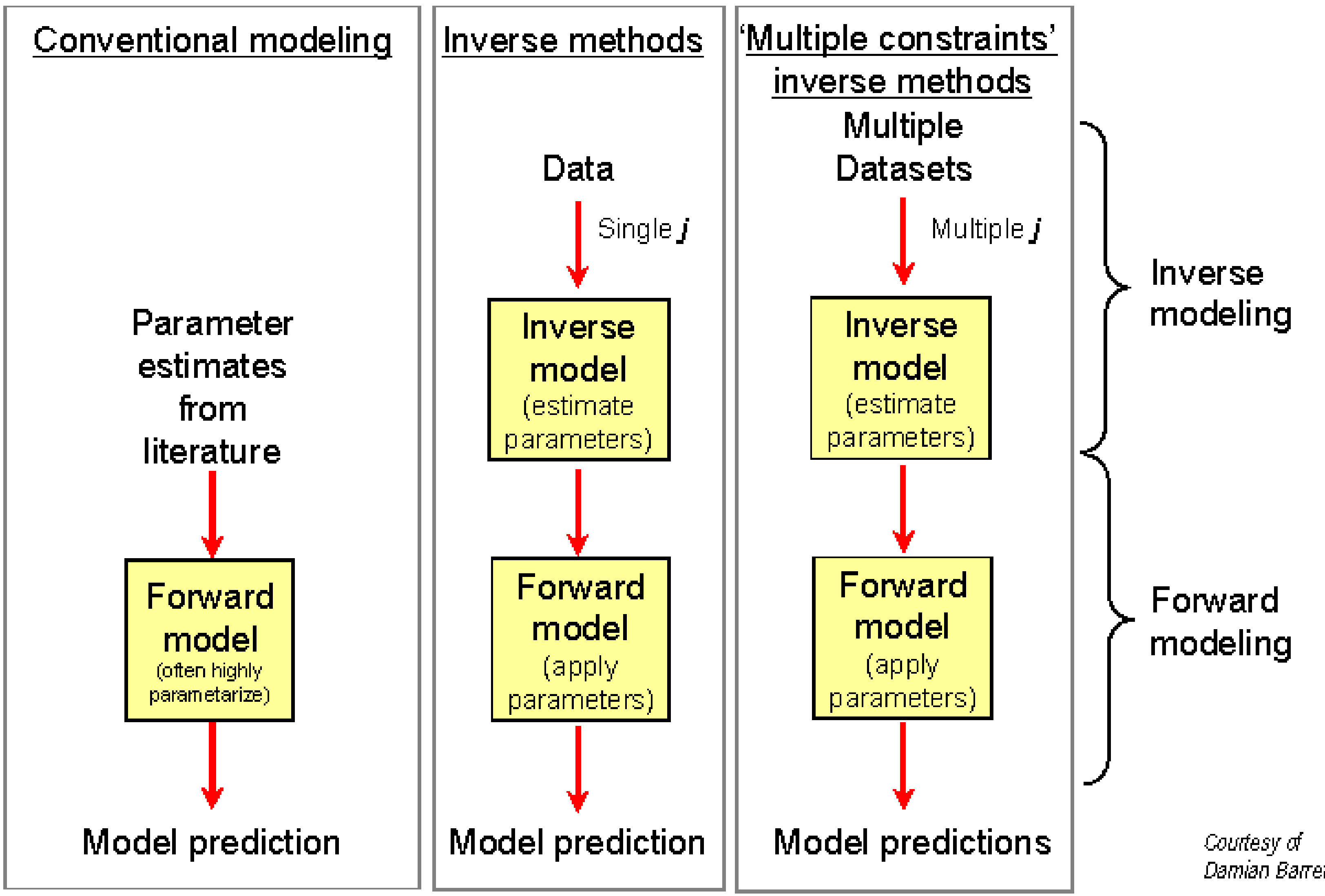


SWHi = Threshold snow water equivalent at which forage intake goes to zero for each ungulate category ; GWP = Water content per kg protein ; FGB = Forage intake per kg of body mass ; BMi = initial body mass for each ungulate category; PSN(24) = Snow depth in unburned forest. From Turner et al. (Ecological Applications).

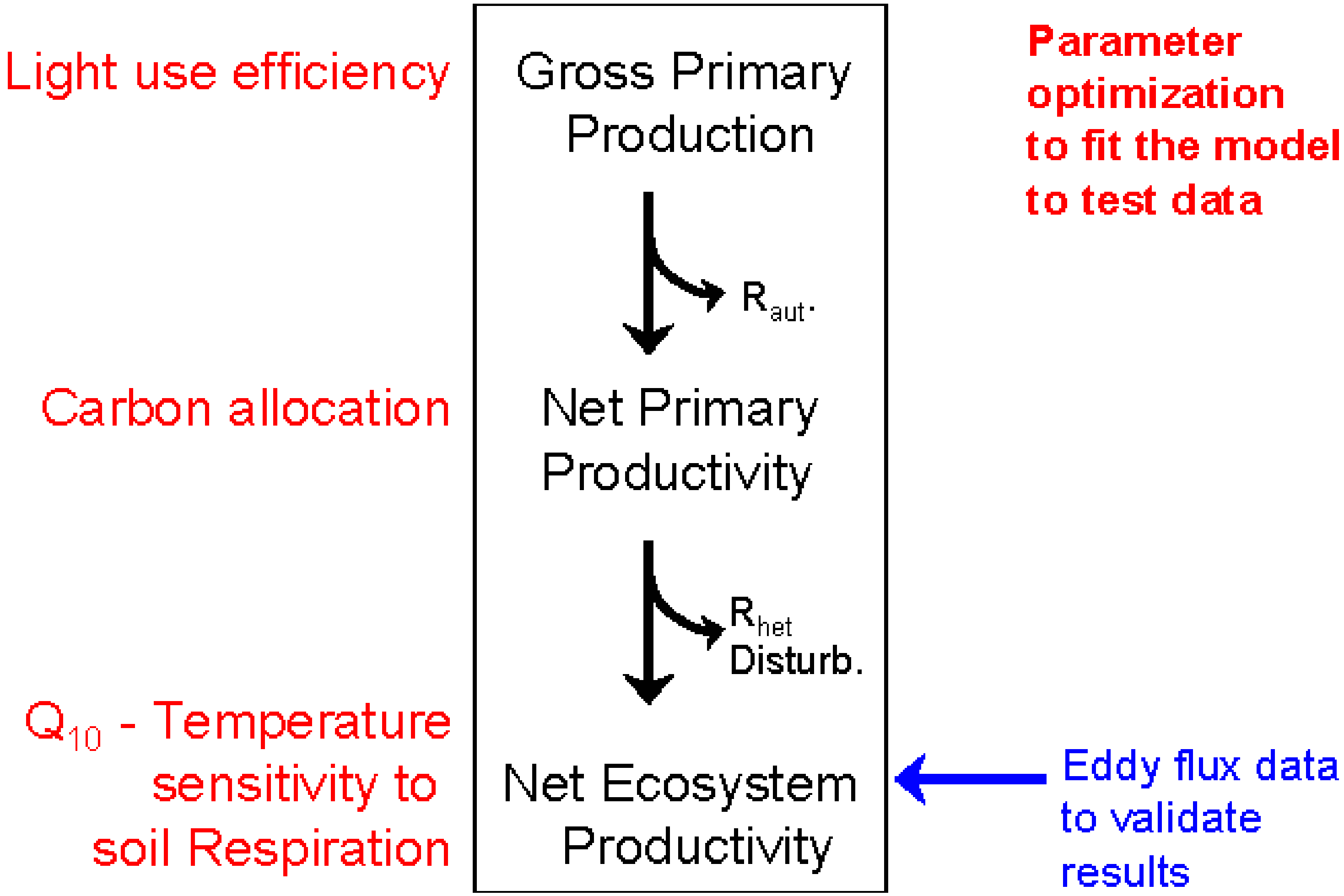
Model-Data Fusion

- **Model and data integration, also called model–data fusion or model–data synthesis**, is defined as combining models and observations by varying some properties of the model, to give the optimal combination of both (Raupach et al., 2005). Model–data fusion encompasses both **calibration and data assimilation**.
- **Model–data fusion** can be characterized as both an **inverse problem**, analyzing a system from observations, and as **statistical estimation**.
- **Calibration**: Parameter estimation to produce desired outputs for a given input.
- **Data Assimilation**: observations are used to refine estimates of the evolving model state.
- **Model–data fusion brings together four components**:
  - external forcing,
  - a model that relates model parameters, state and external forcing to observations,
  - observations, and
  - an optimization technique.

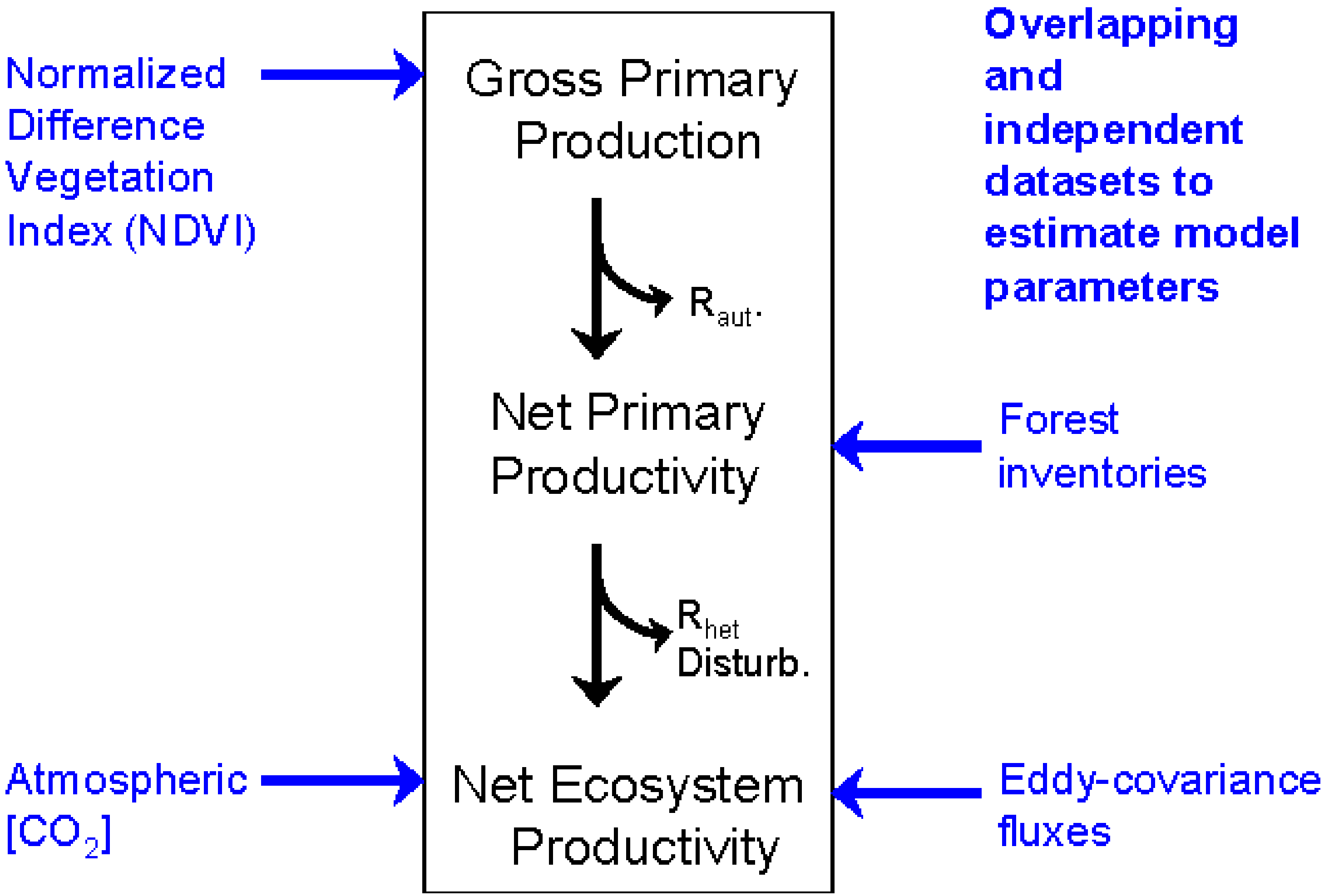
What is different from the more traditional modeling?



Classic modeling on Net Ecosystem Productivity

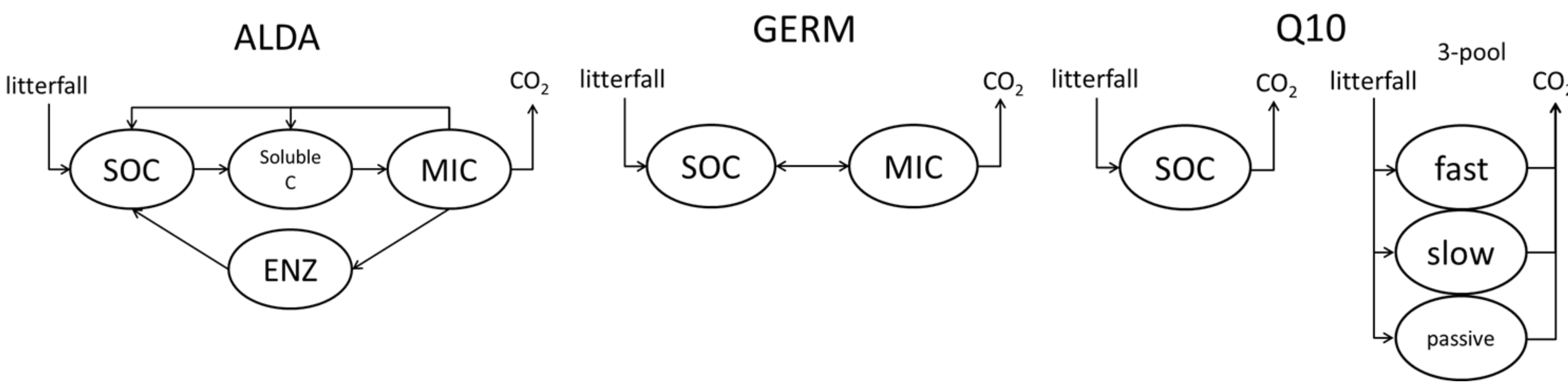


Multiple constraints on Net Ecosystem Productivity

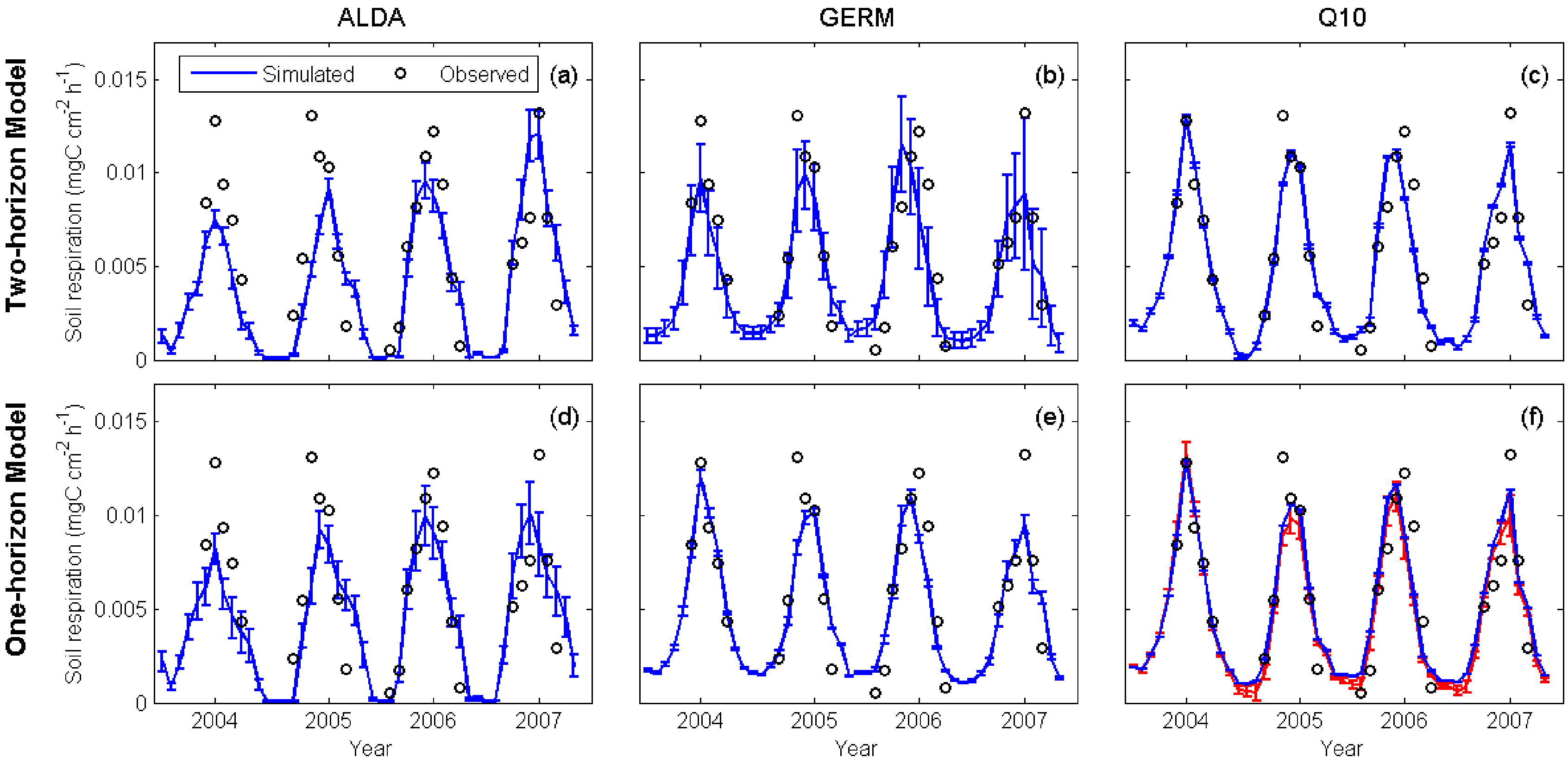


Example: Uncertainty in the fate of soil organic carbon: A comparison of three conceptually different decomposition models in a larch plantation (He et al. JGR-B in press)

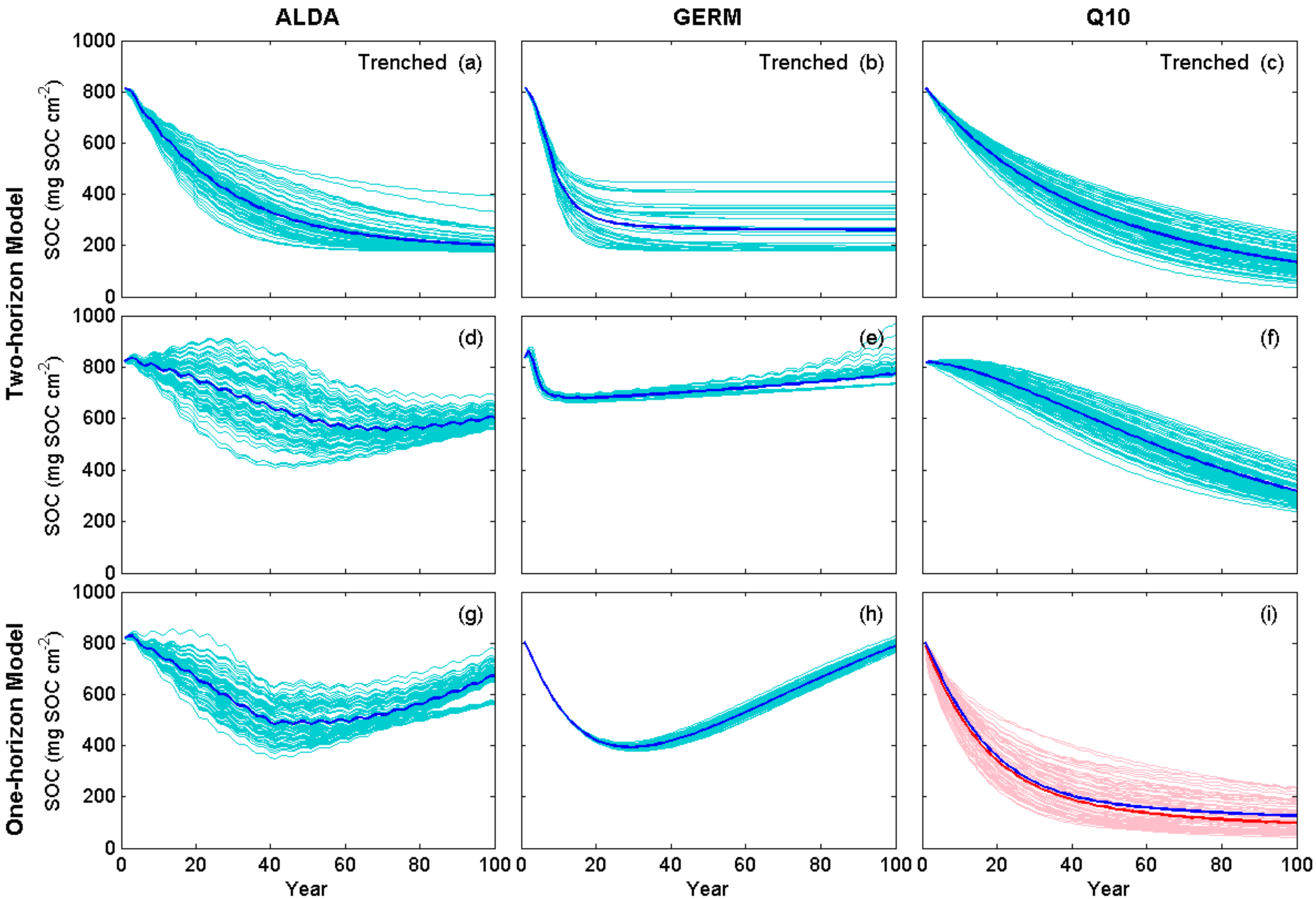
- Compared three structurally different soil carbon (C) decomposition models (one driven by Q10 and two microbial models of different complexity)
- The models were calibrated and validated using four years of measurements of heterotrophic soil CO_2 efflux from trenched plots in a Dahurian larch (*Larix gmelinii* Rupr.) plantation.
- Parameters in each model estimated using a Bayesian data assimilation framework



Model Validation



Differences in Model Dynamics and Uncertainty



Simulated 100 years responses of SOC stock for the three models. Top panel (a-c) is trenched plot simulation; bottom two panels (d-i) are model simulations under 4.8 °C progressive increasing soil temperature and litterfall. The deep blue and red lines (for 3-pool Q10 model) represent ensemble mean from the 100 independent optimization runs for each model, the light colored lines are the results from each ensemble member.