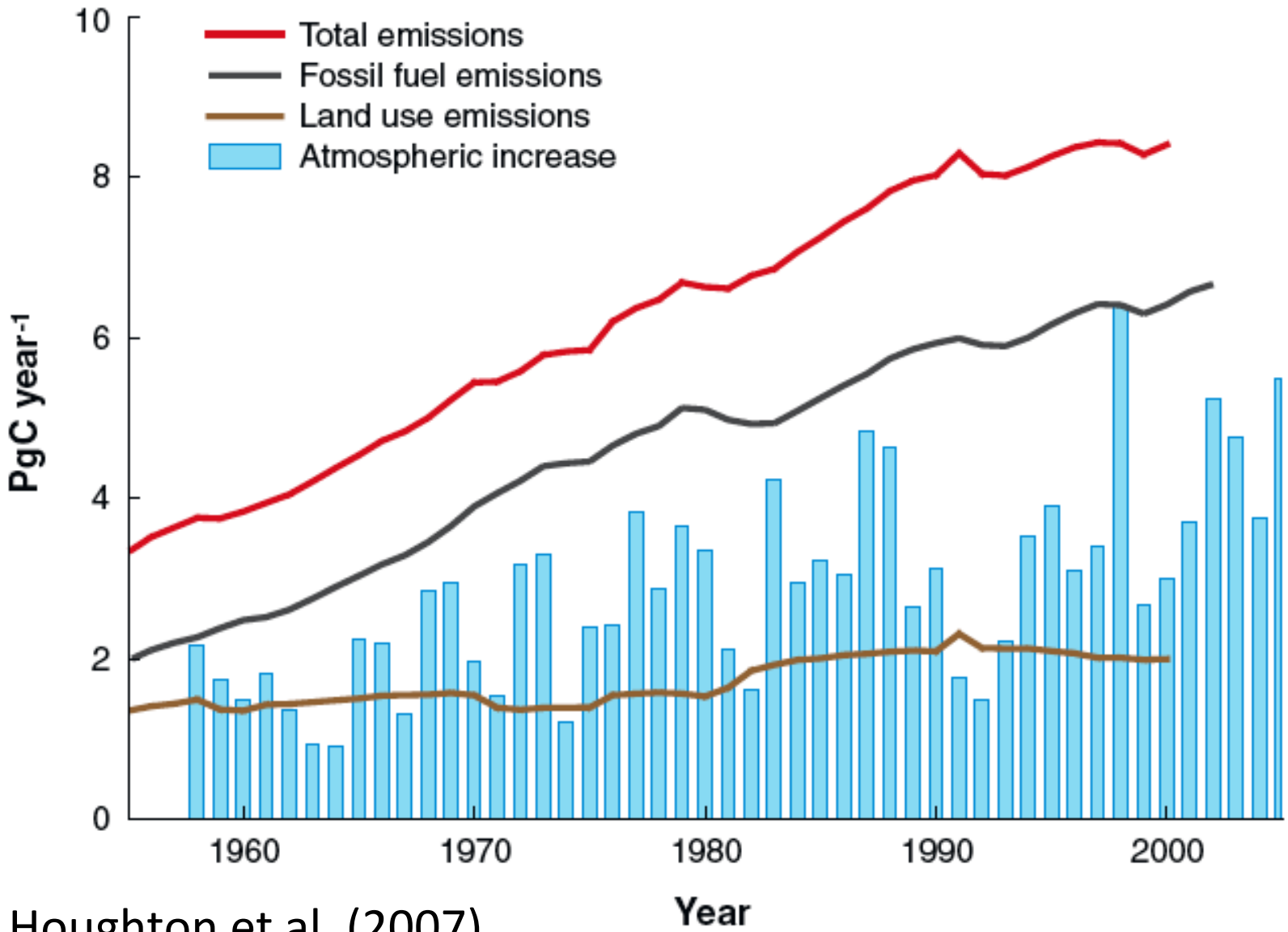
Synthesis, model validation, and data-assimilation on centennial time-scales

Michael Dietze, Jason McLachlan, Steve Jackson, Simon Goring, Chris Paciorek, Jack Williams, and PalEON team members

February 5, 2013

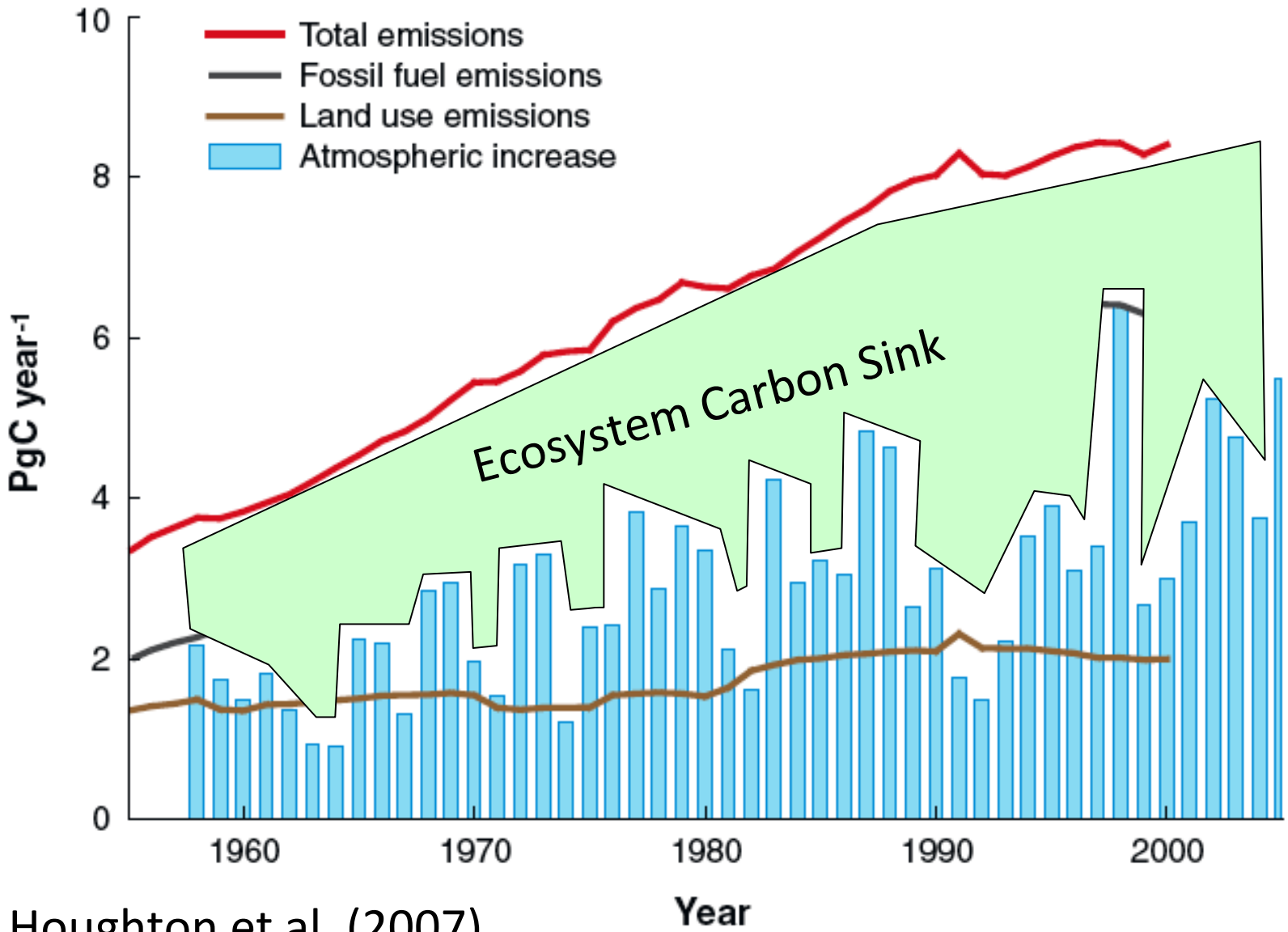
NACP 4th All Investigators Meeting, Albuquerque, NM

Biology drives Physics

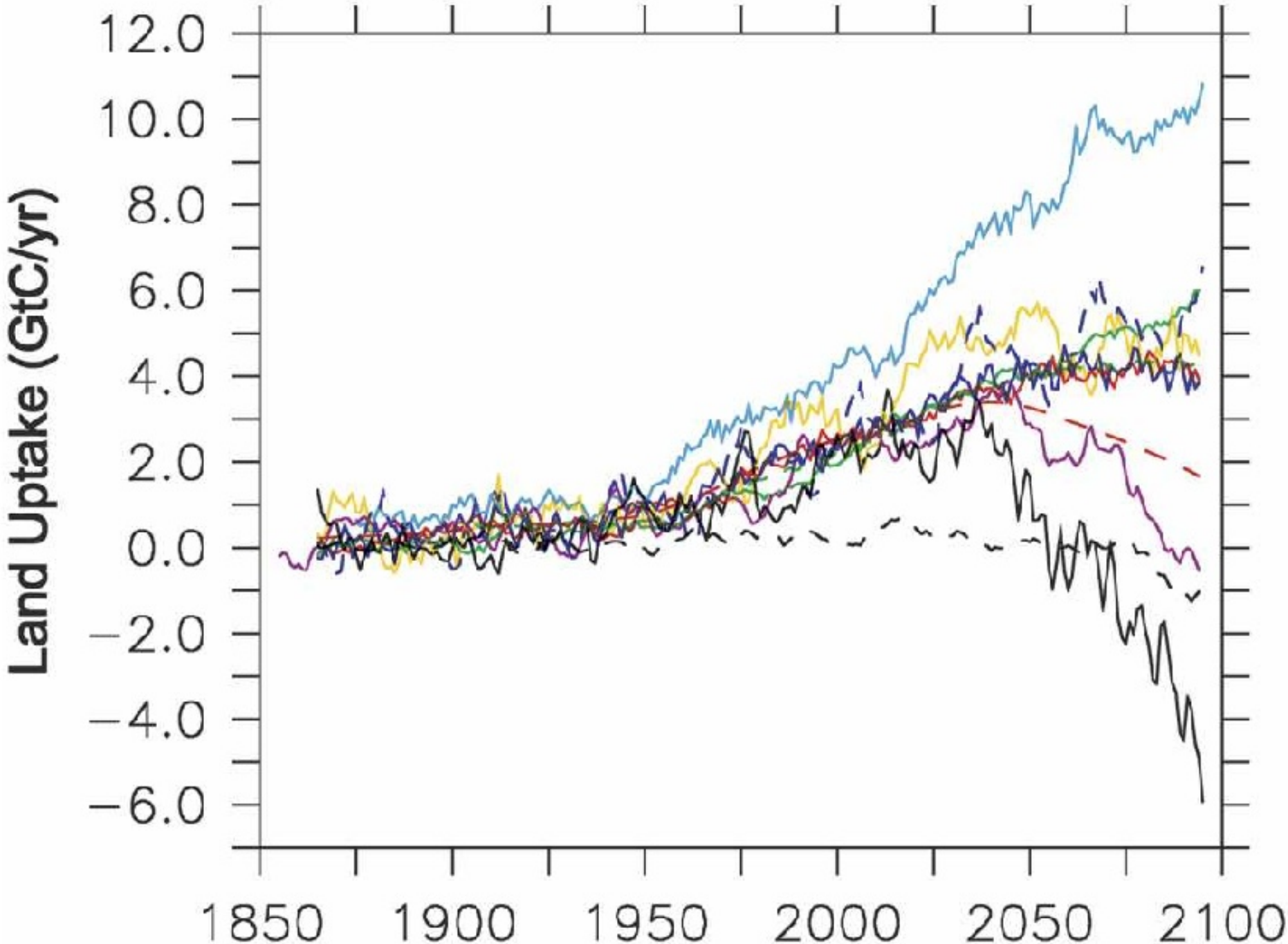


Houghton et al. (2007)

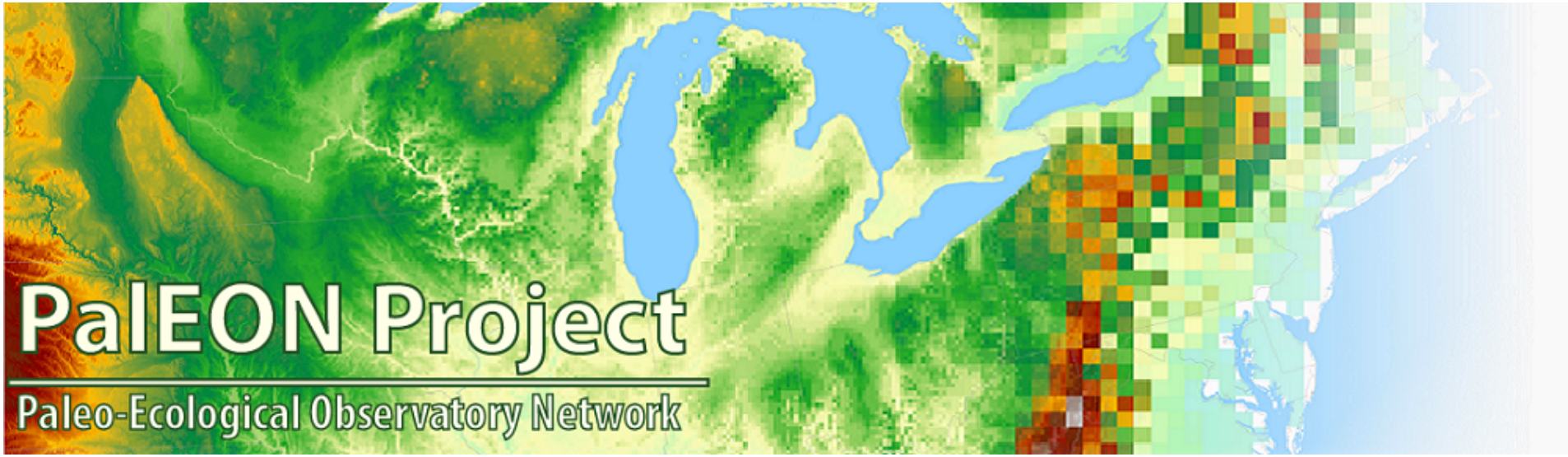
Biology drives Physics



Houghton et al. (2007)



Friedlingstein et al 2006



Jason McLachlan	Notre Dame
Michael Dietze	Boston University
Steve Jackson	U. Arizona
Chris Paciorek	UC Berkeley
Jack Williams	U. Wisconsin

60+ PalEON team members

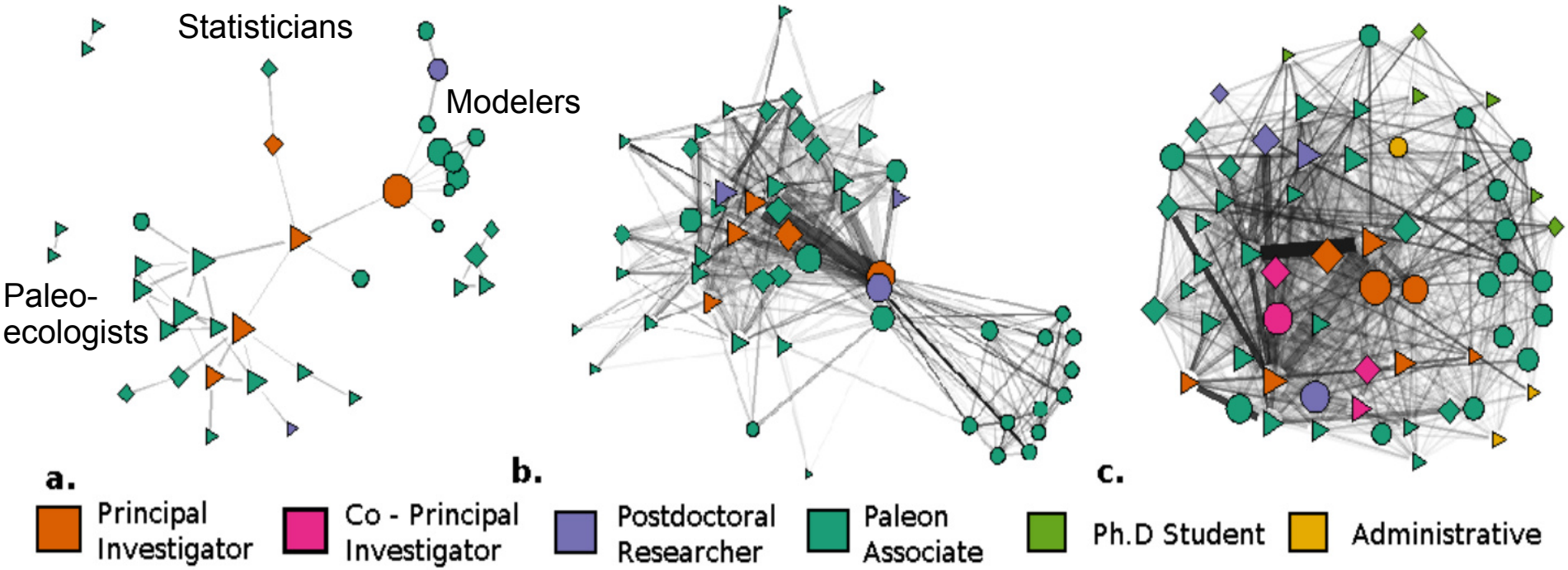
NSF grants #1065848, #1055732, #1065702, #1065656, and #1065646 & Notre Dame Environmental Change Initiative

PalEON Goals

- Validation
  - *How well do current models simulate decadal-to-centennial ecosystem dynamics when confronted with past climate change, and what factors most limit model accuracy?*
- Inference
  - *What net carbon fluxes are compatible with an observed species composition and disturbance regime? Was the terrestrial biosphere a carbon sink or source during the Little Ice Age and Medieval Climate Anomaly?*
- Initialization
  - *How sensitive are ecosystem models to initialization state and equilibrium assumptions? Do data-constrained simulations of centennial-scale forest dynamics improve 20th-century simulations?*
- Improvement

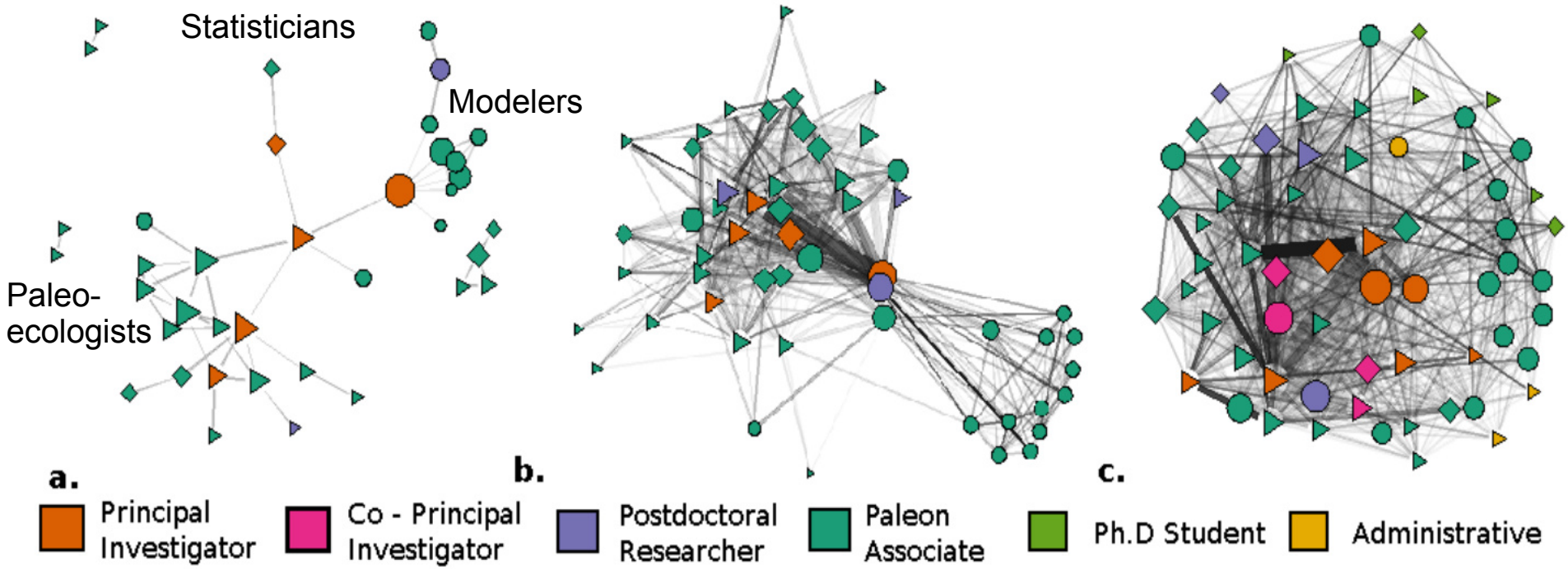
PalEON Approach

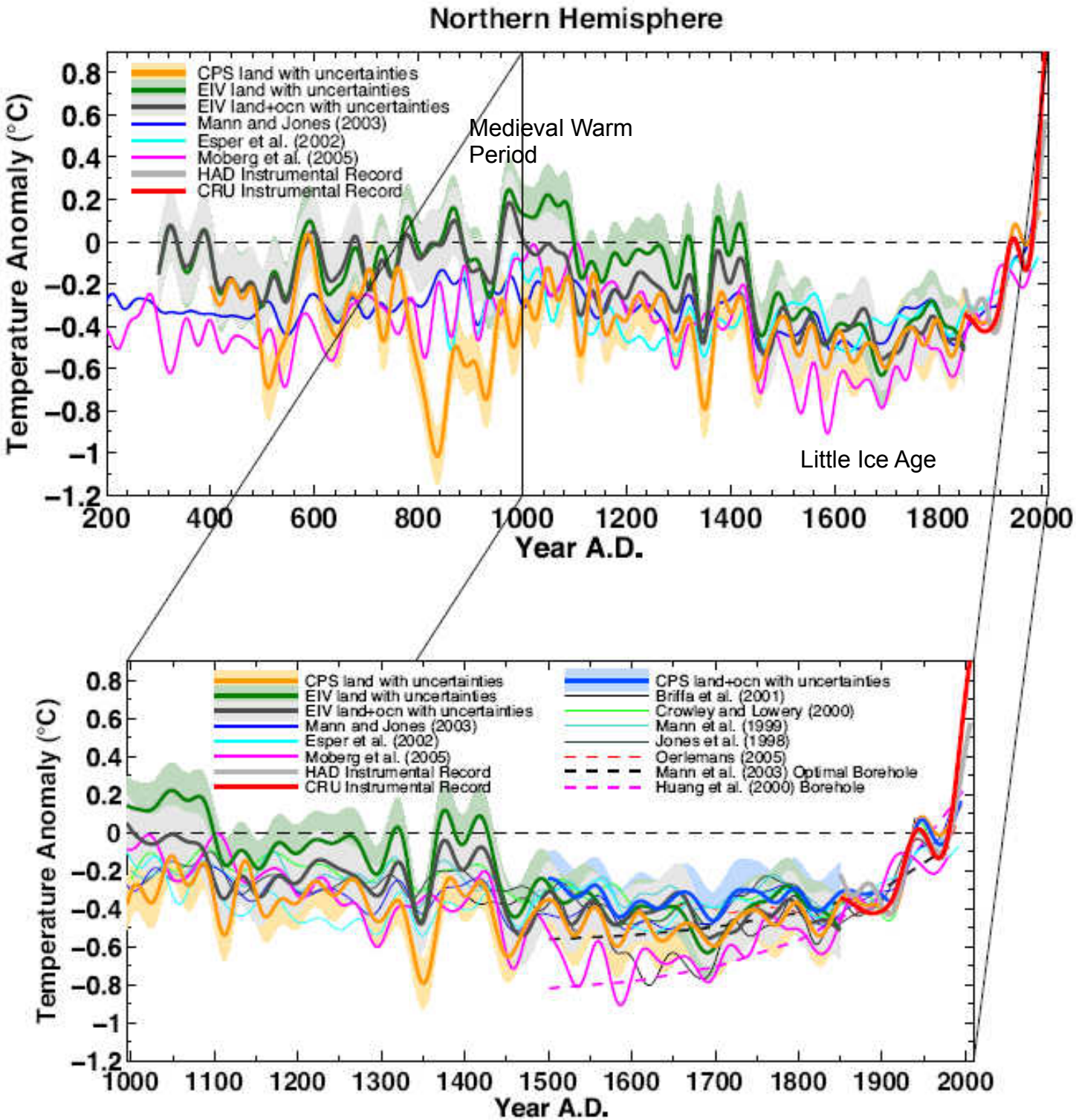
Pre-PalEON



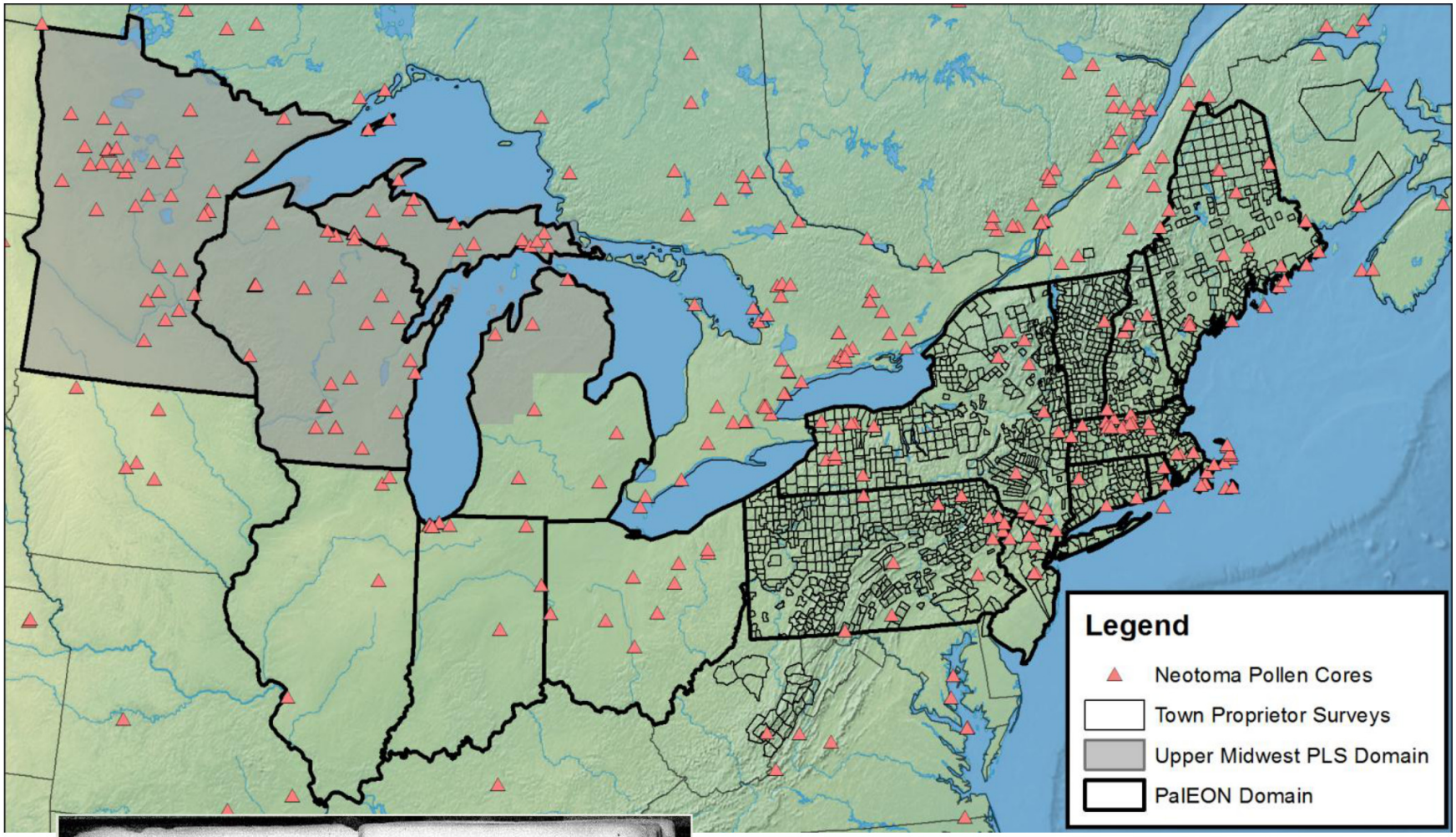
PalEON Approach

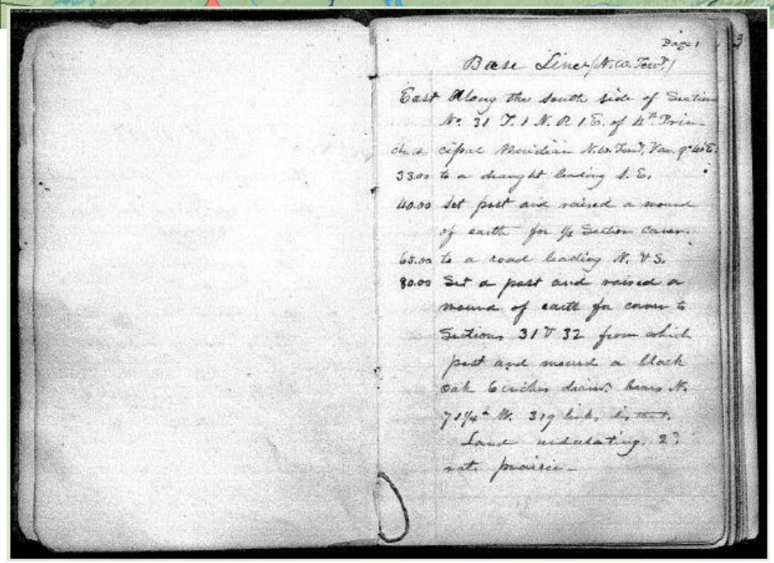
Pre-PalEON | **Current** | **PalEON 2** *(proposed)*



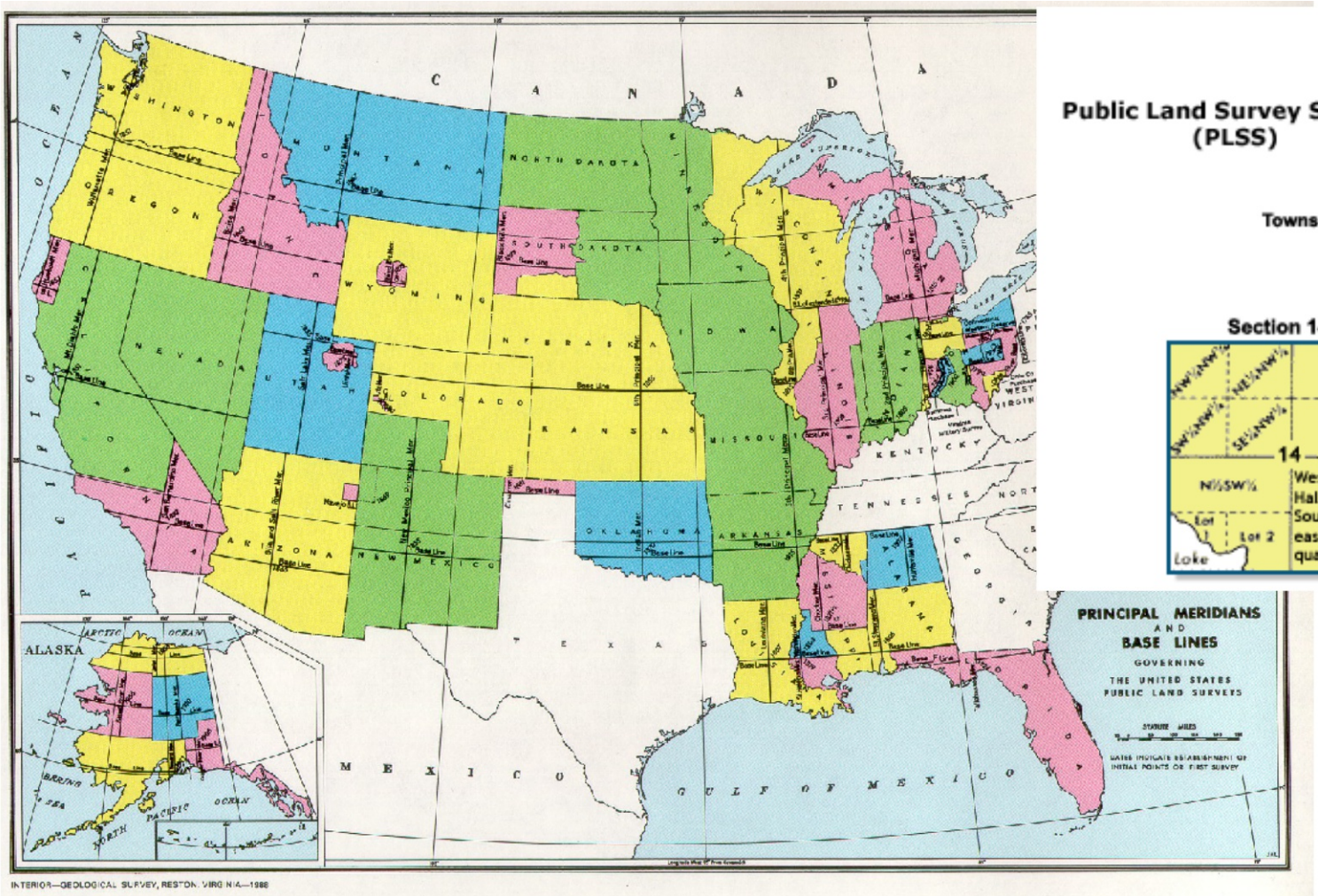


Mann et al 2008 PNAS

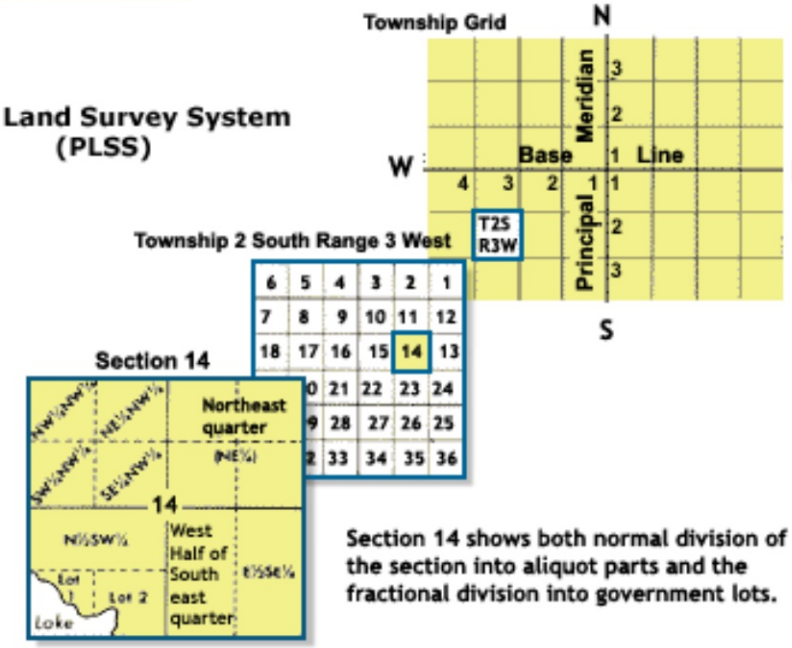




(Goring, Mladenoff, Cogbill)

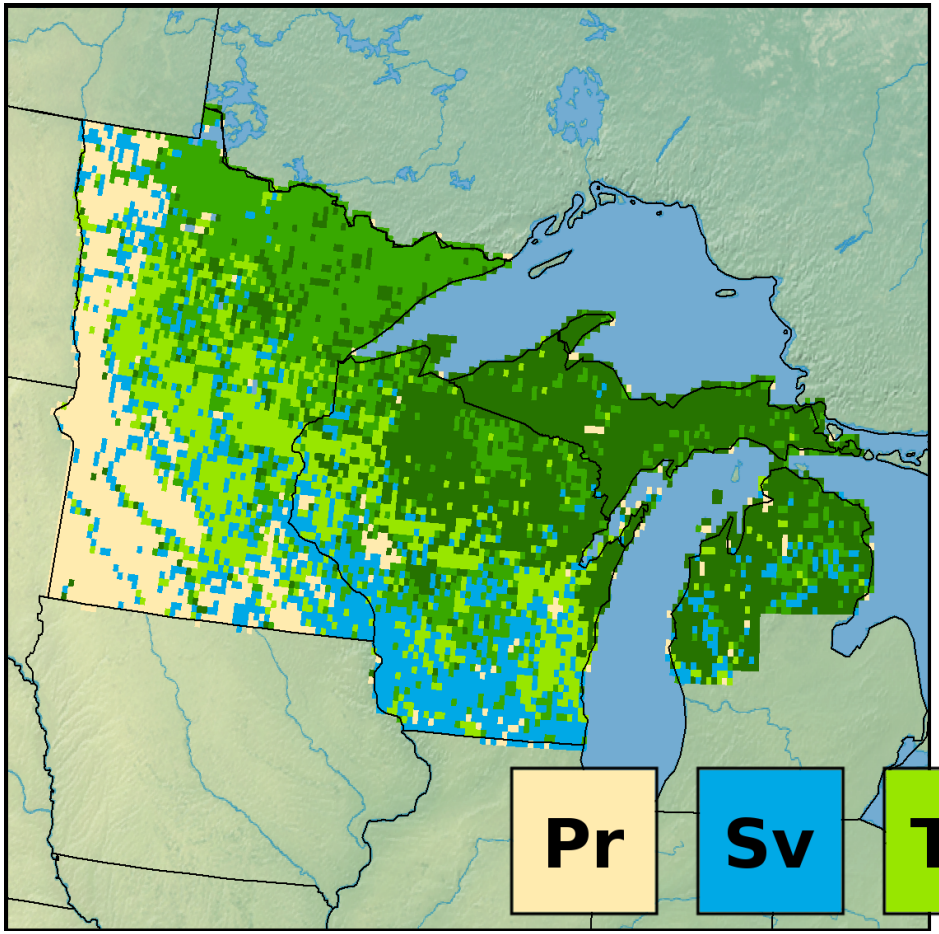


Public Land Survey System (PLSS)



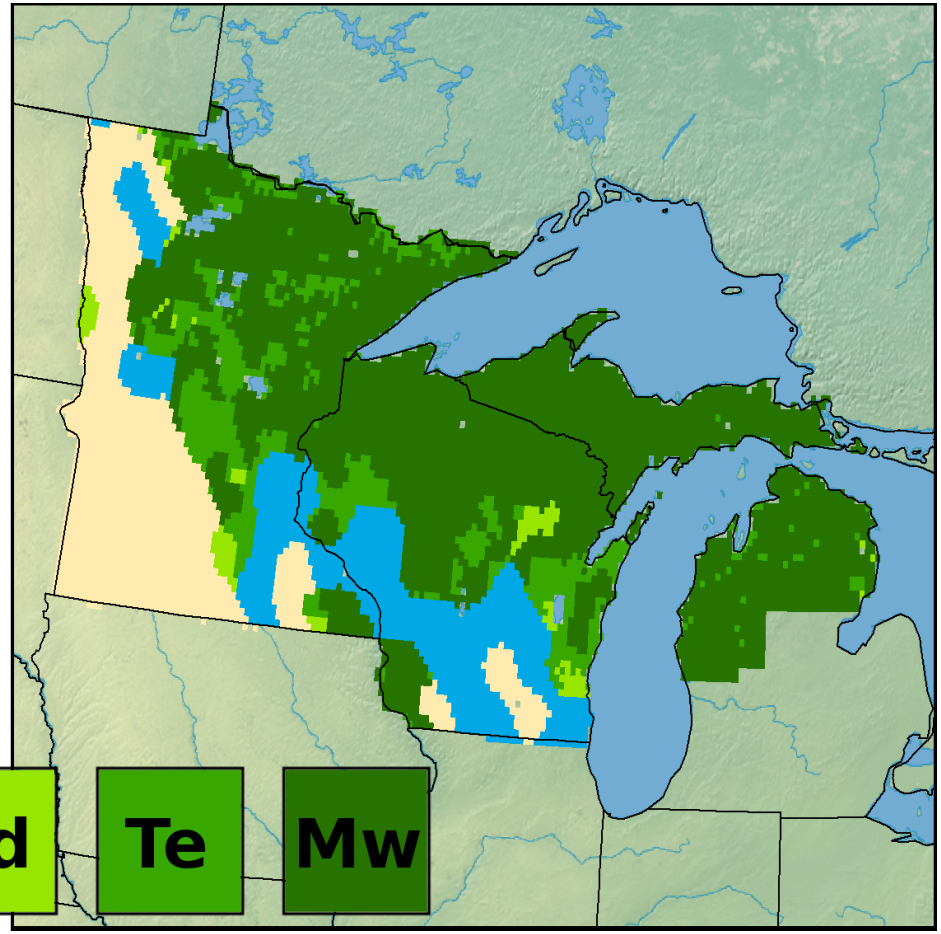
Section 14 shows both normal division of the section into aliquot parts and the fractional division into government lots.

Historical Vegetation



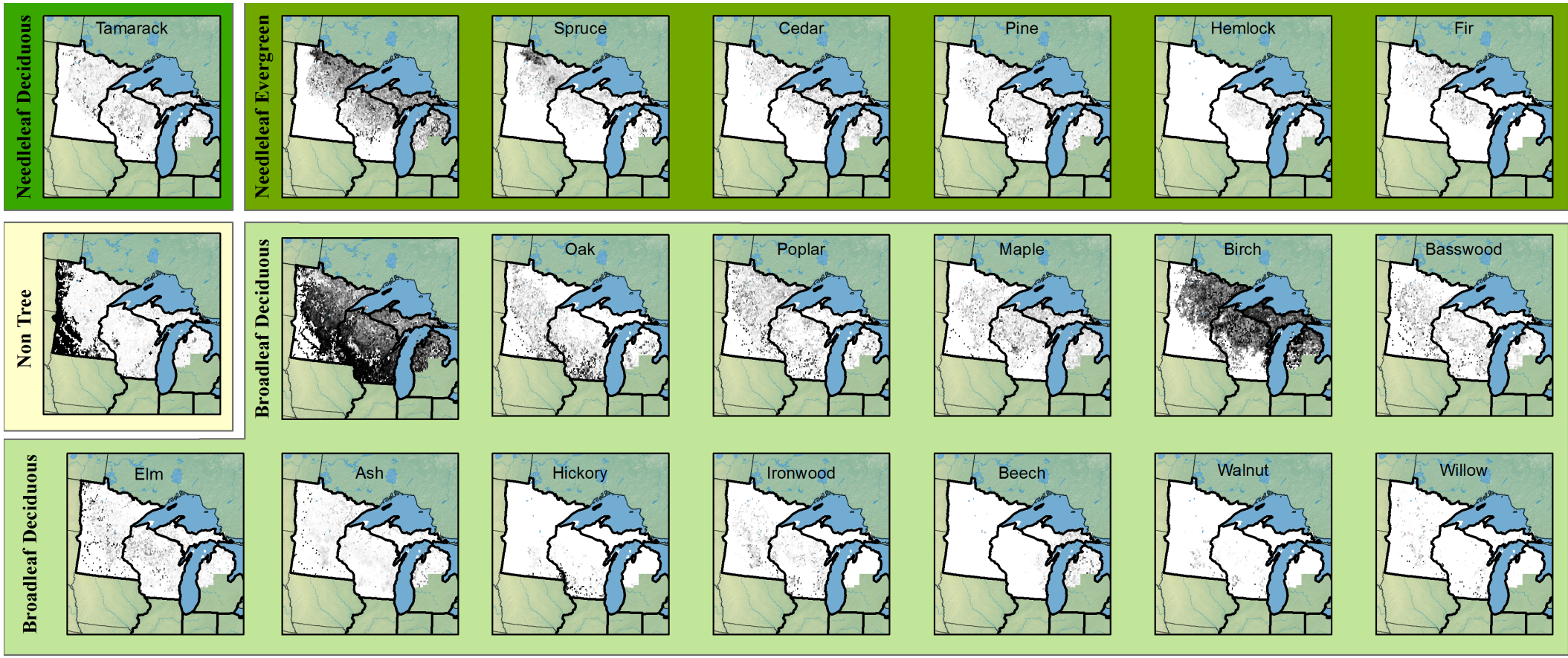
Goring in prep

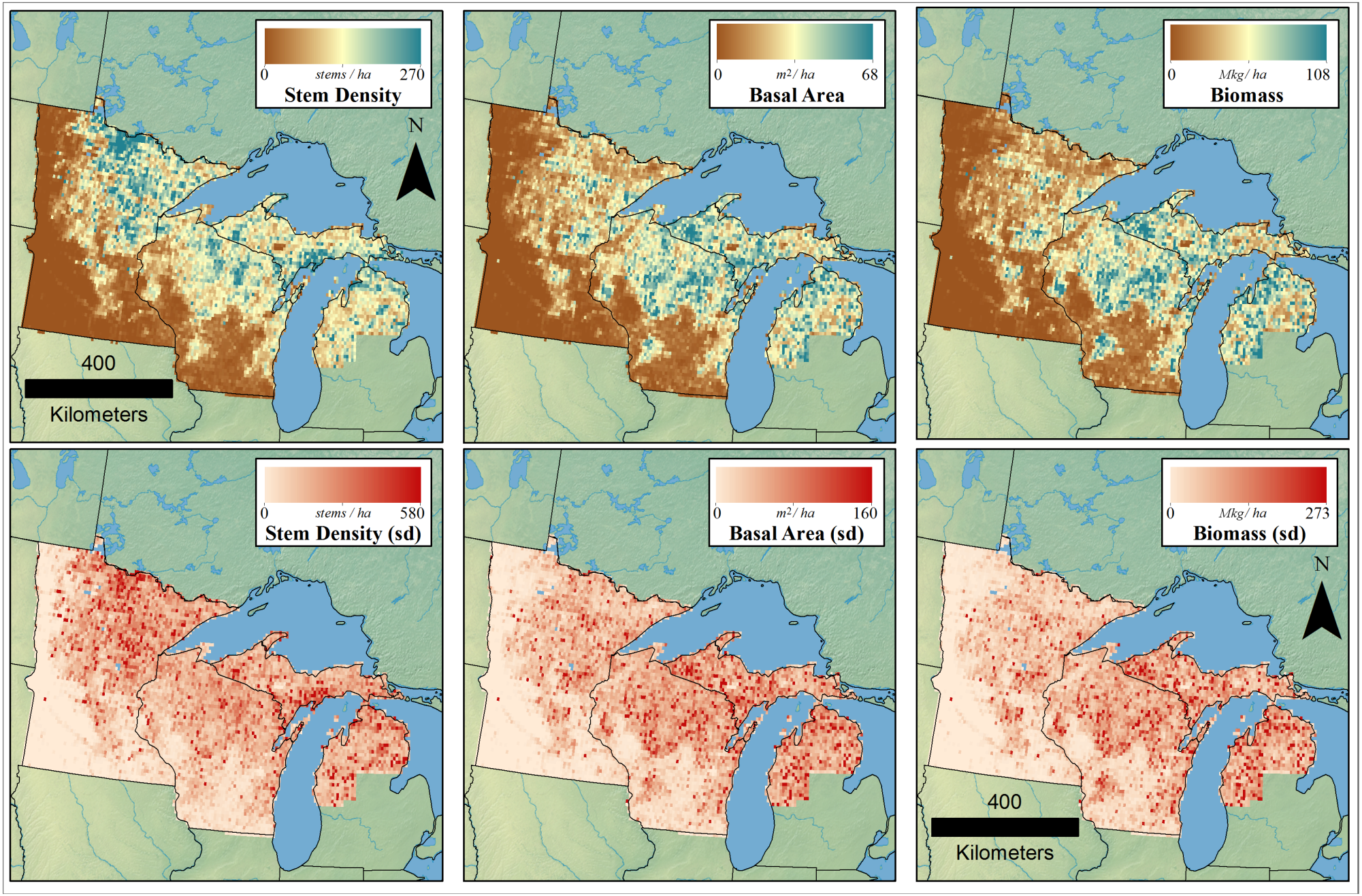
Potential Vegetation



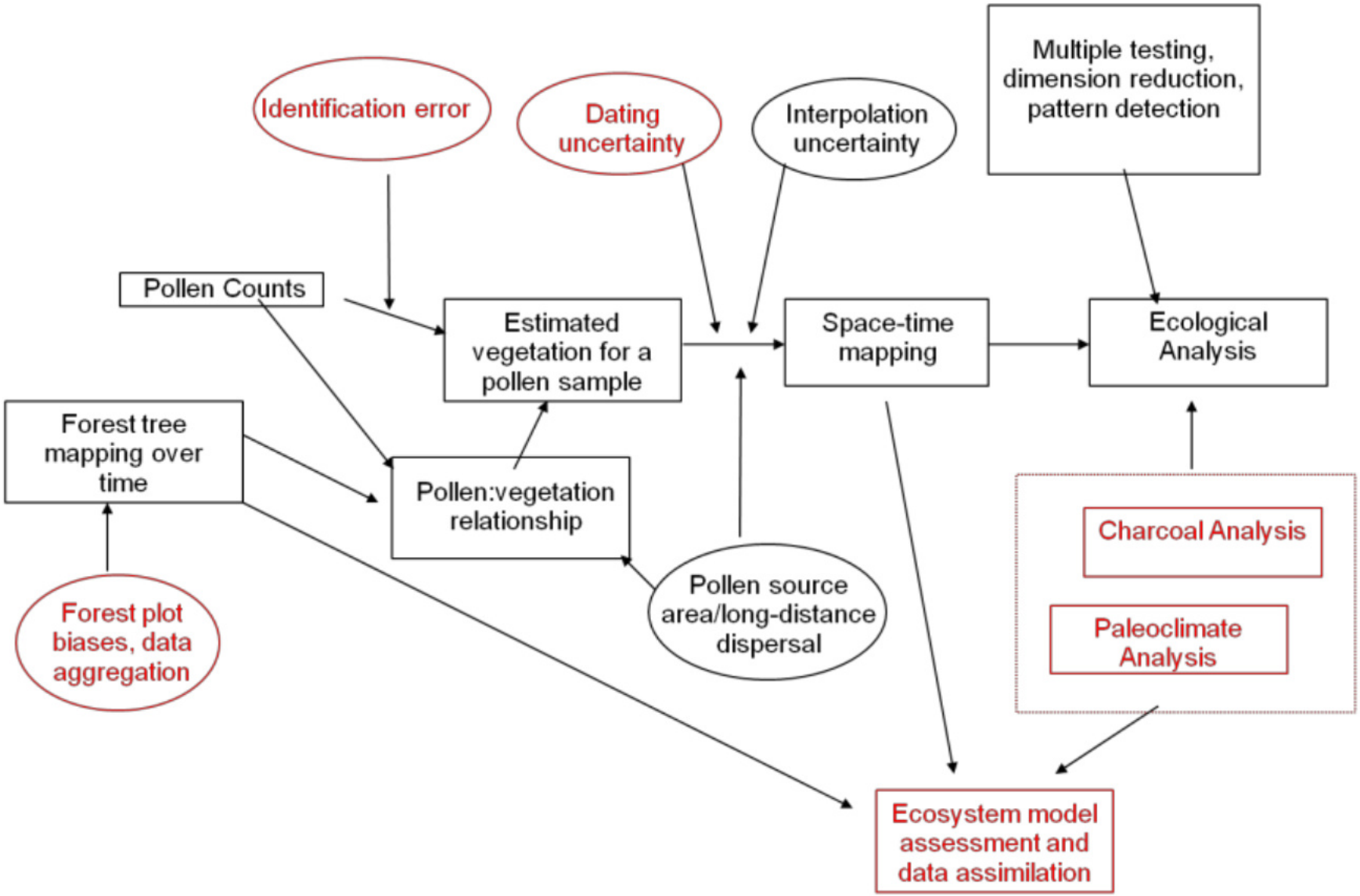
Ramankutty & Foley

Species Composition

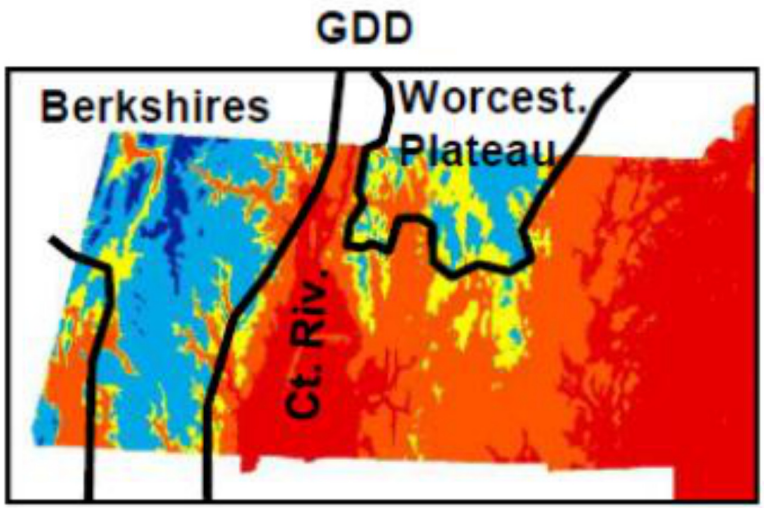



0
stems / ha
270
Stem Density
N
400
Kilometers
0
m2/ ha
68
Basal Area
0
Mkg/ ha
108
Biomass
0
stems / ha
580
Stem Density (sd)
0
m2/ ha
160
Basal Area (sd)
0
Mkg/ ha
273
Biomass (sd)
N
400
Kilometers

STEPPS

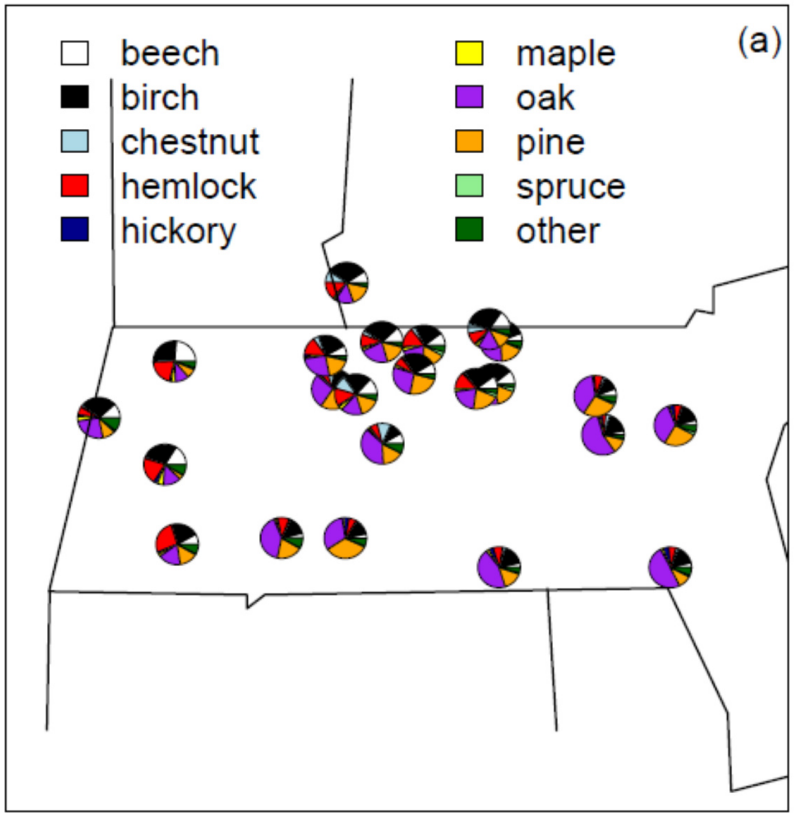

Identification error
Dating uncertainty
Interpolation uncertainty
Multiple testing, dimension reduction, pattern detection
Pollen Counts
Estimated vegetation for a pollen sample
Space-time mapping
Ecological Analysis
Forest tree mapping over time
Pollen:vegetation relationship
Charcoal Analysis
Paleoclimate Analysis
Pollen source area/long-distance dispersal
Forest plot biases, data aggregation
Ecosystem model assessment and data assimilation

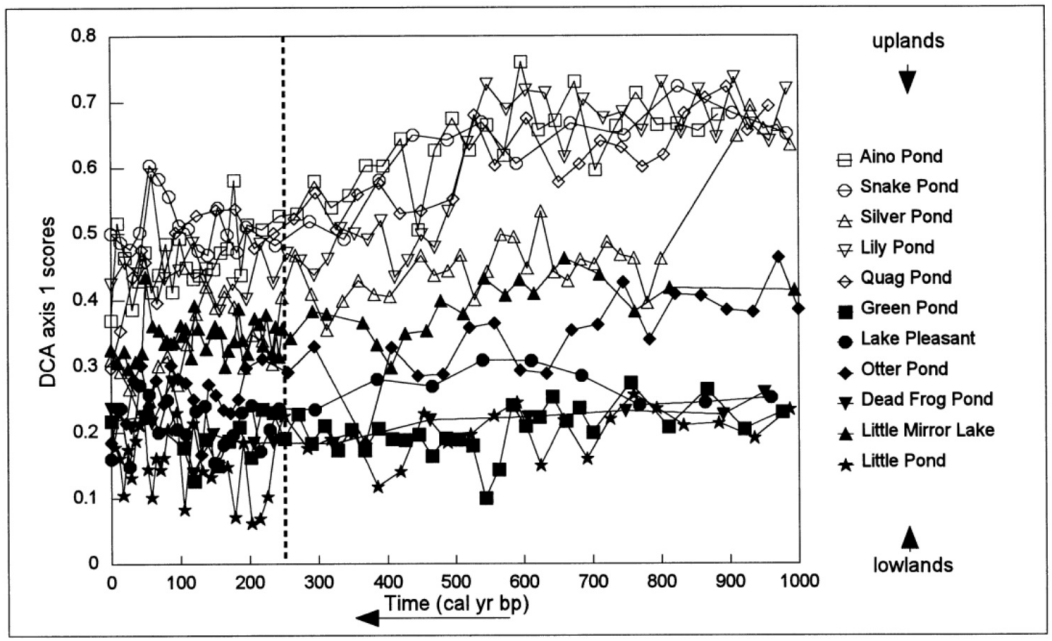
An example from New England



Key features of past 2000 years

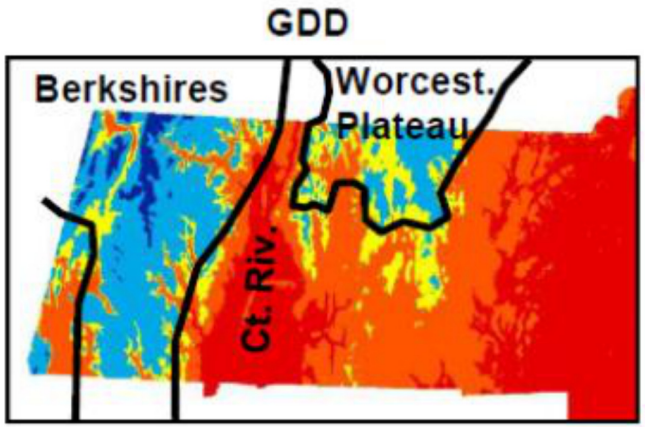
- Arrival of American chestnut
- Decline in beech and hemlock
- Spatial persistence of ecotone
- 19th century land-use impact

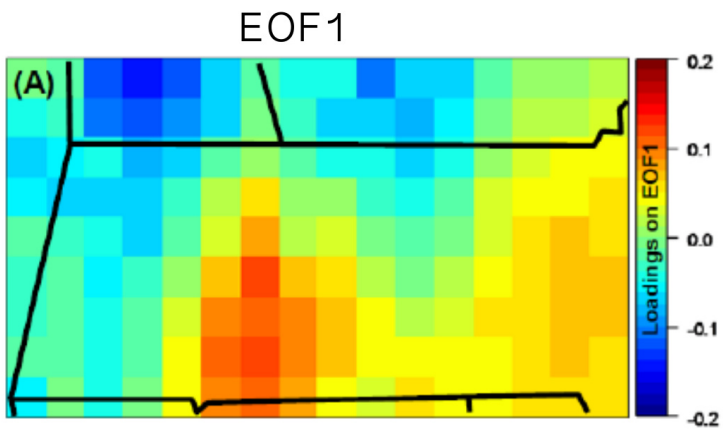


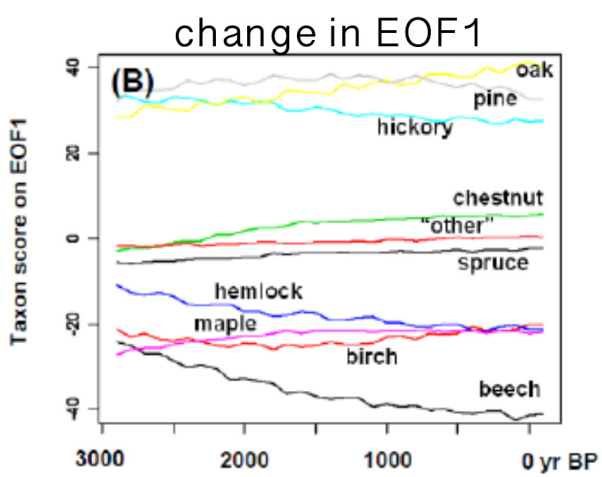


(Fuller et al 1998)

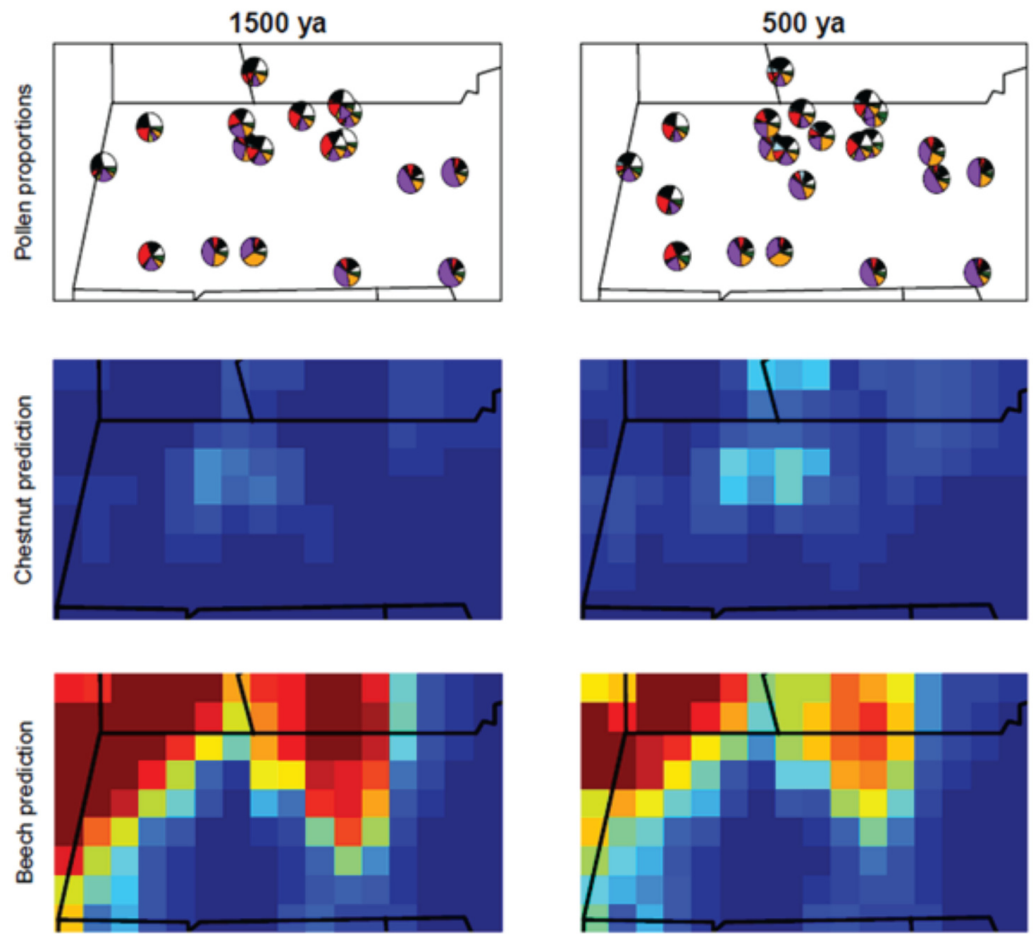
Statistical estimates of changing forest composition







Non-stationary trends in composition

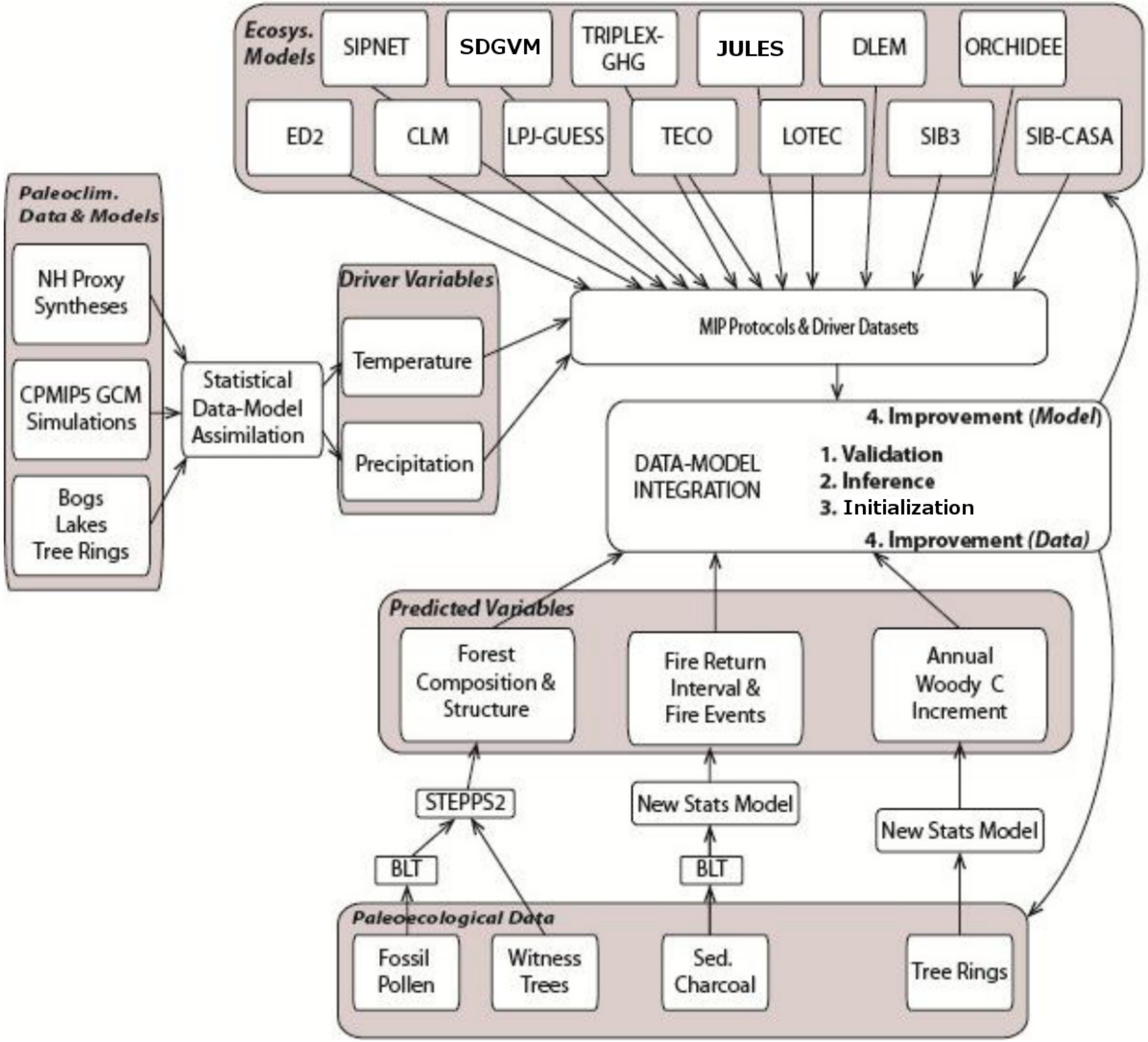


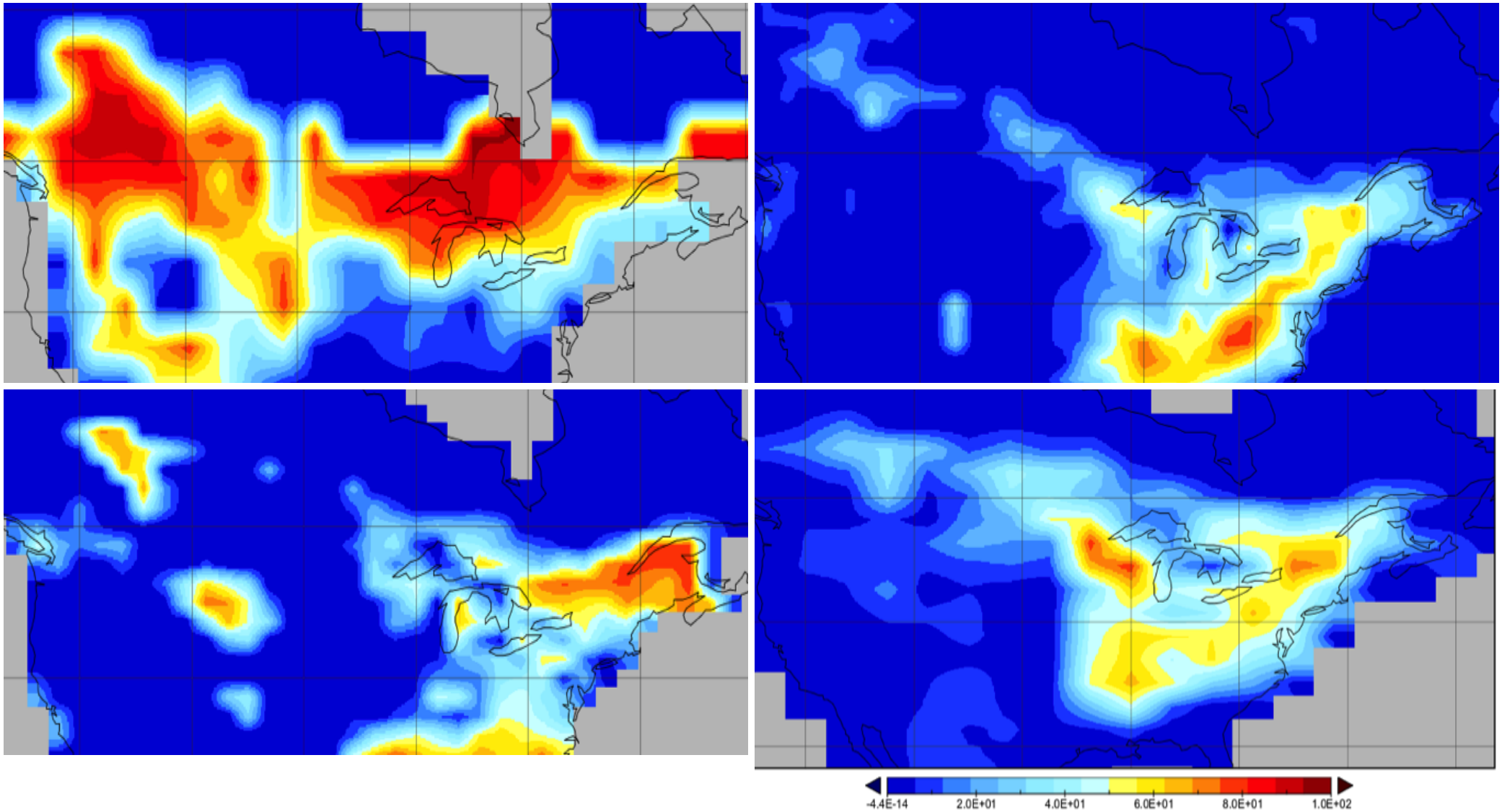
taxon %

0%

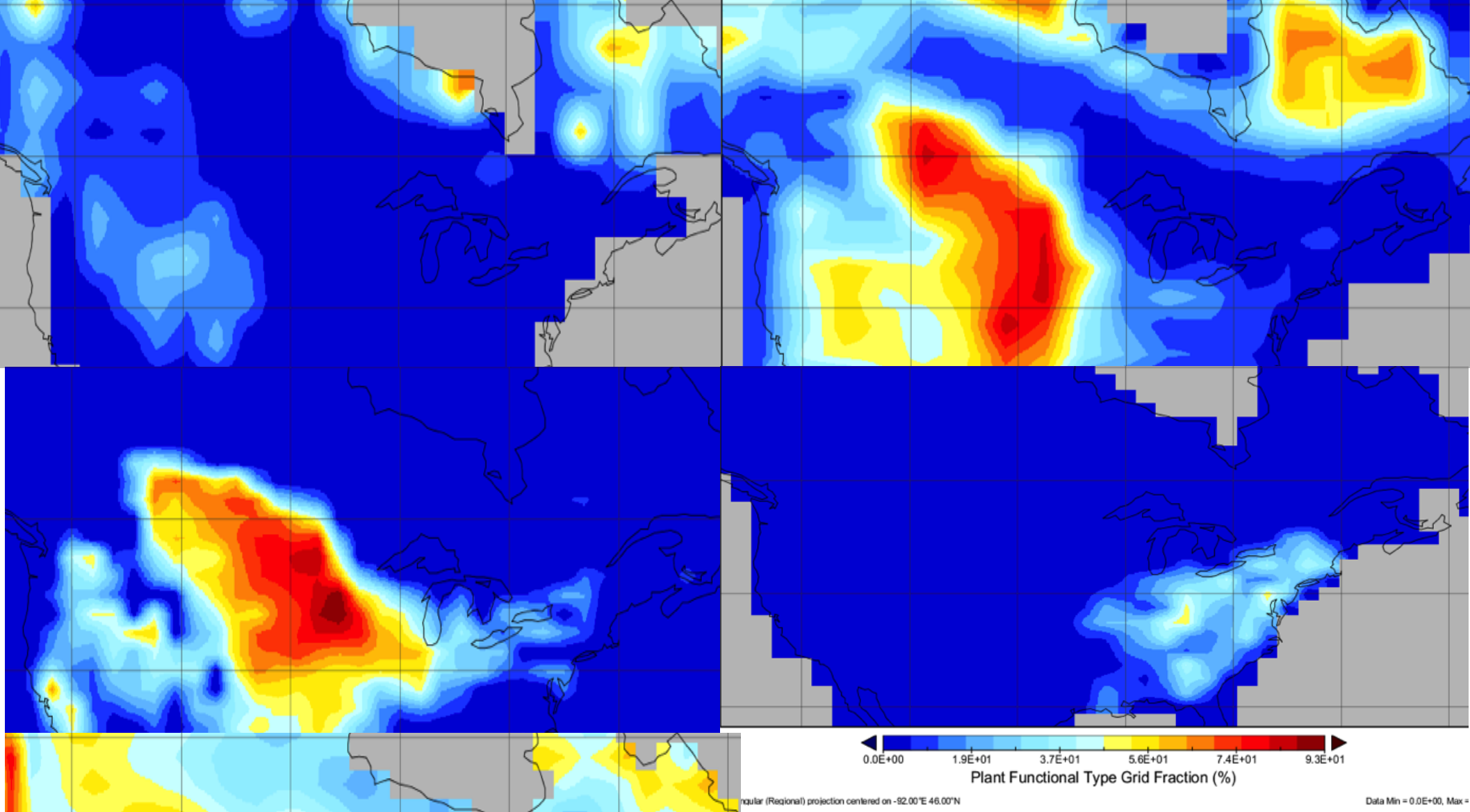
60%

Phase 1: Validation

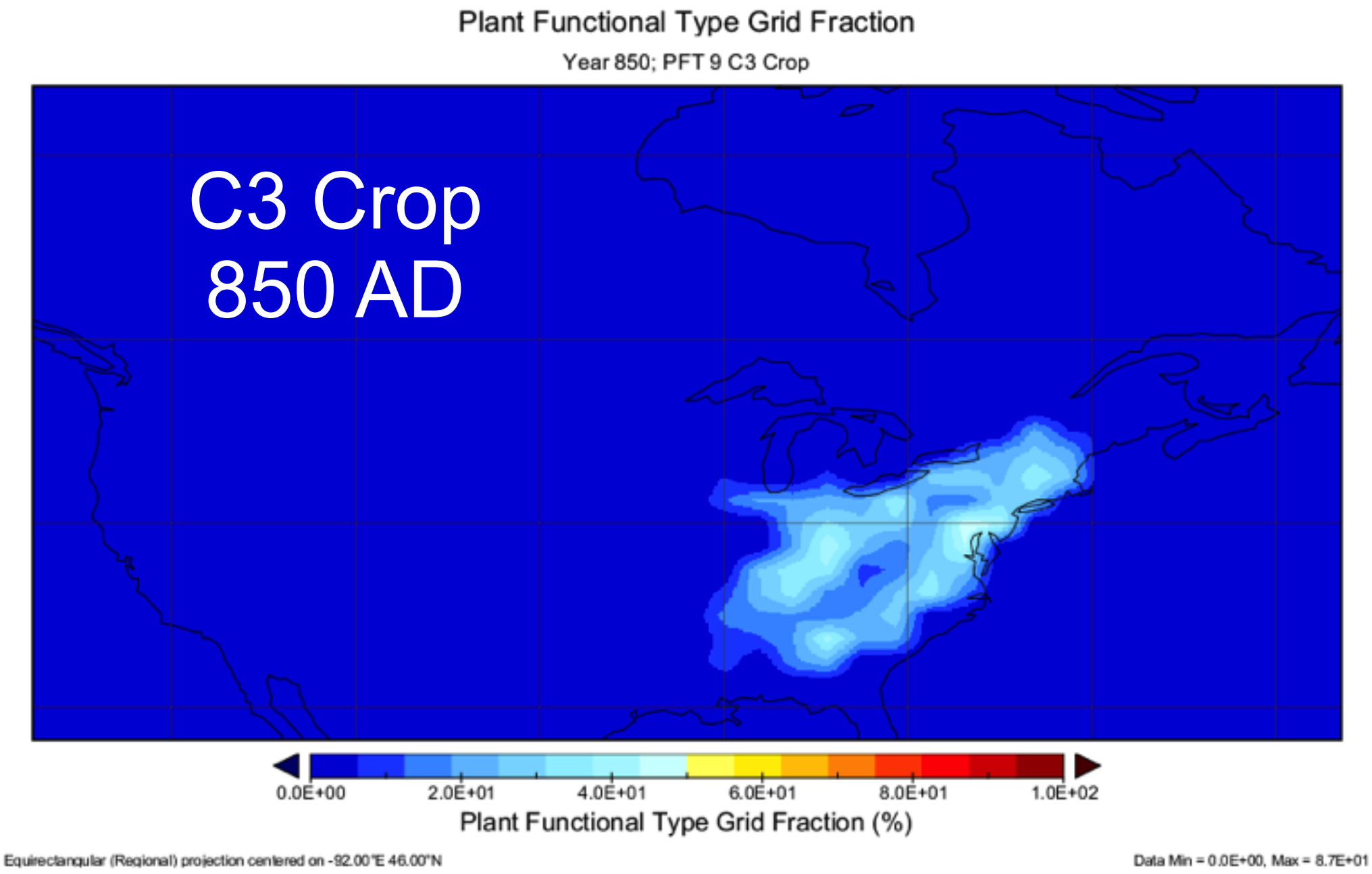

Ecosys. Models
SIPNET
SDGVM
TRIPLEX-GHG
JULES
DLEM
ORCHIDEE
ED2
CLM
LPJ-GUESS
TECO
LOTEC
SIB3
SIB-CASA
Paleoclim. Data & Models
NH Proxy Syntheses
CPMIP5 GCM Simulations
Bogs Lakes Tree Rings
Statistical Data-Model Assimilation
Driver Variables
Temperature
Precipitation
MIP Protocols & Driver Datasets
DATA-MODEL INTEGRATION
4. Improvement (Model)
1. Validation
2. Inference
3. Initialization
4. Improvement (Data)
Predicted Variables
Forest Composition & Structure
Fire Return Interval & Fire Events
Annual Woody C Increment
STEPPS2
New Stats Model
New Stats Model
BLT
BLT
Paleoecological Data
Fossil Pollen
Witness Trees
Sed. Charcoal
Tree Rings



Temperate Broadleaf Deciduous
850 AD
CMIP5/PMIP3 “Last Millennium”

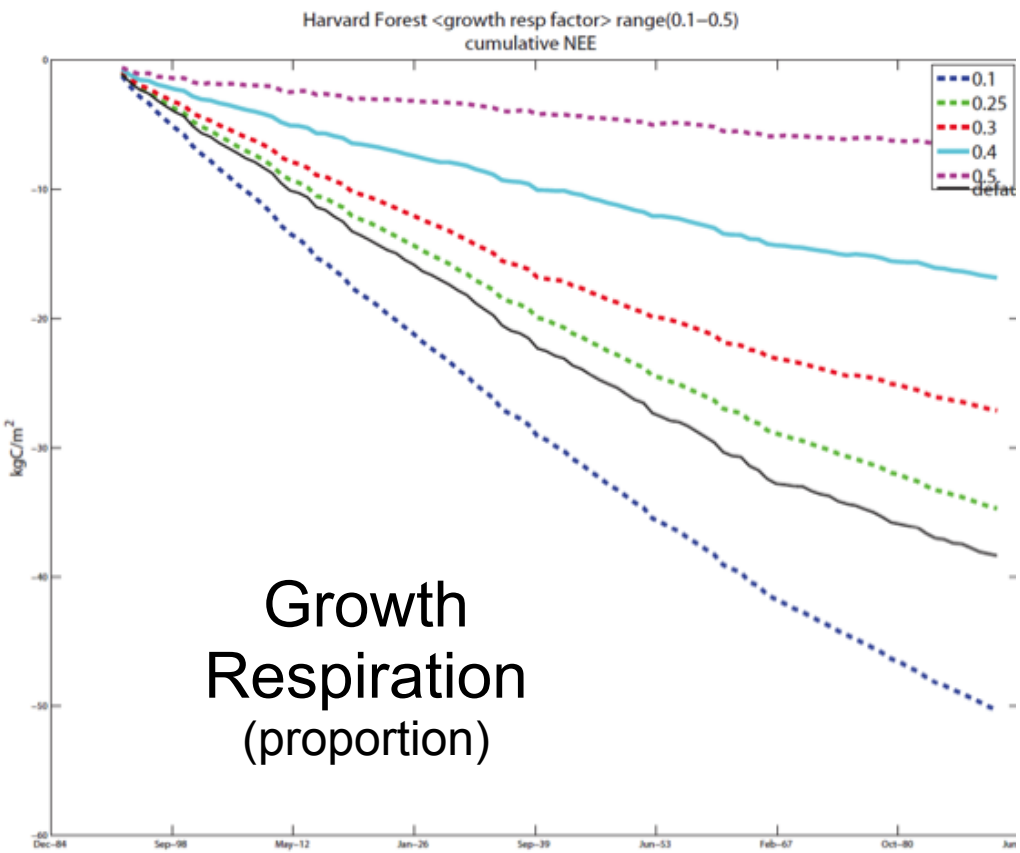


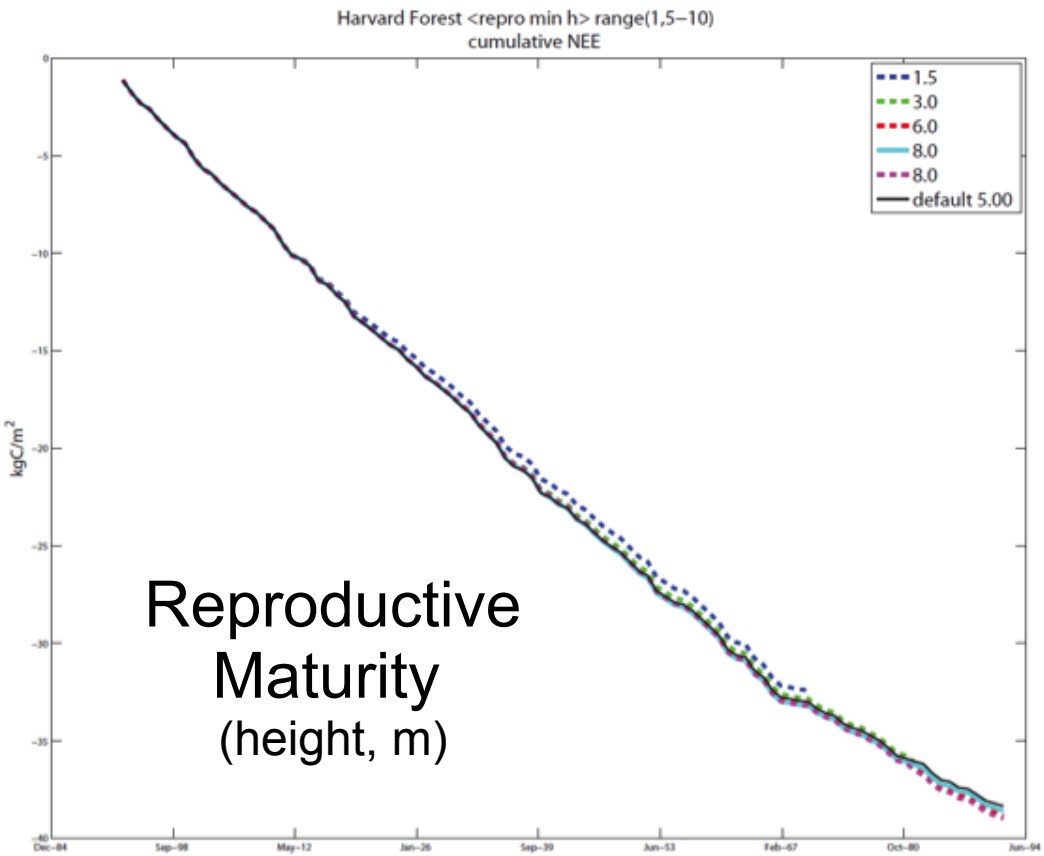
C3 Grass
850 AD


Plant Functional Type Grid Fraction
Year 850; PFT 9 C3 Crop
C3 Crop
850 AD
0.0E+00
2.0E+01
4.0E+01
6.0E+01
8.0E+01
1.0E+02
Plant Functional Type Grid Fraction (%)
Equirectangular (Regional) projection centered on -92.00°E 46.00°N
Data Min = 0.0E+00, Max = 8.7E+01

Centennial Sensitivity Analysis

ED2 model, Harvard Forest

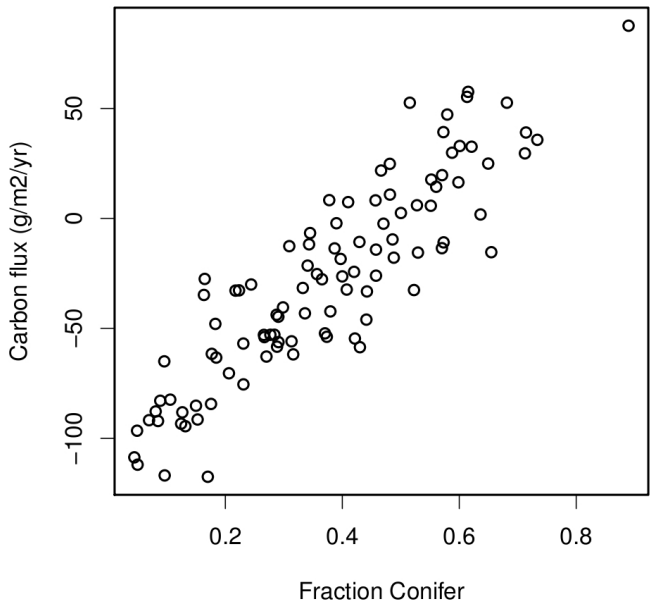


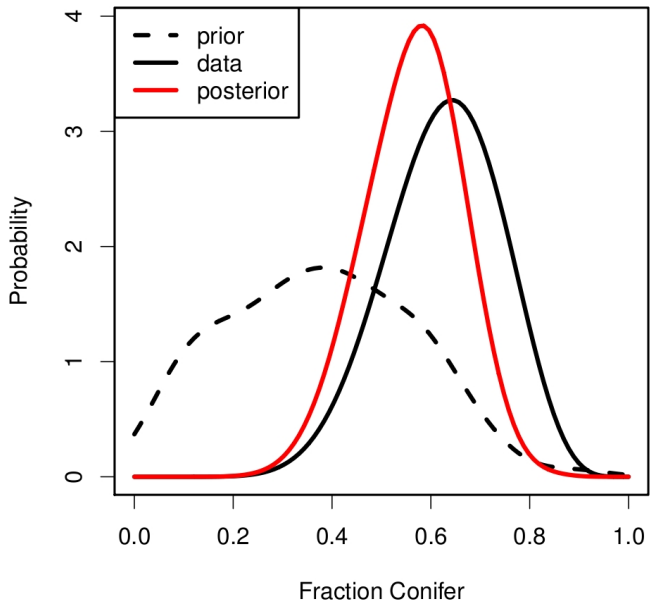


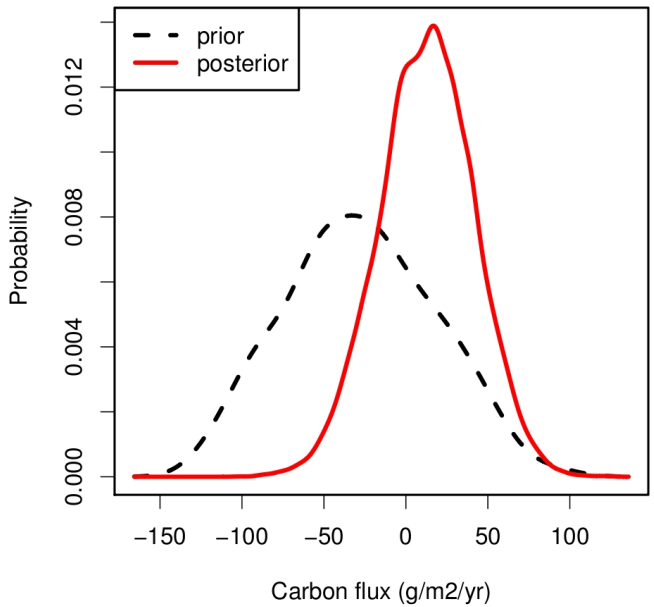
Brett Raczka & Ken Davis, PSU
See Poster 128

Phase 2: Assimilation

State-Variable Data Assimilation

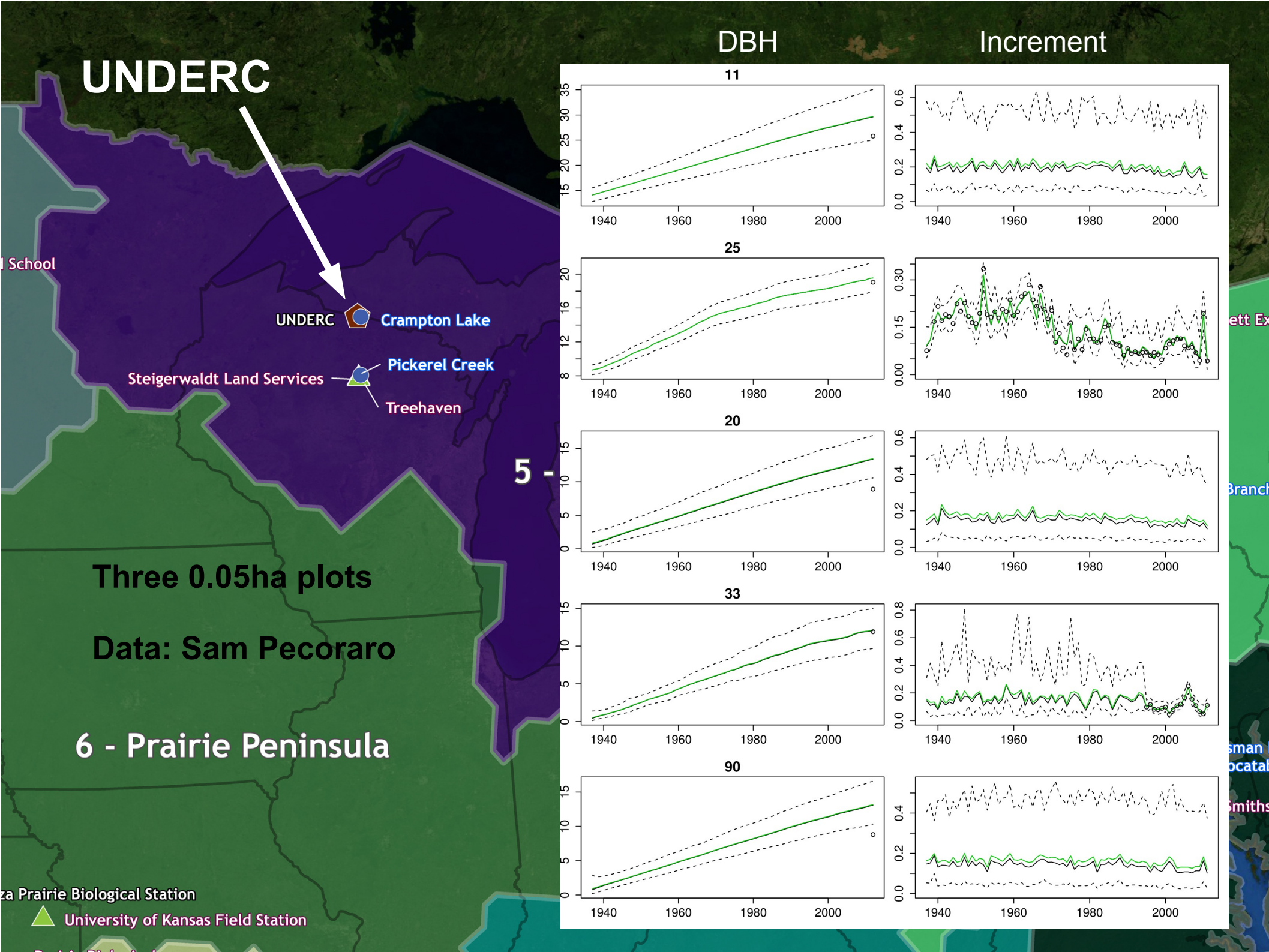






$$P(\theta|y) \propto P(y|\theta)\,P(\theta)$$

Updated State **Data** **Model**


UNDERC
DBH
Increment
UNDERC
Crampton Lake
Pickerel Creek
Steigerwaldt Land Services
Treehaven
5 -
Three 0.05ha plots
Data: Sam Pecoraro
6 - Prairie Peninsula
University of Kansas Field Station
11
25
20
33
90

Ecological Applications, 17(7), 2007, pp. 1942–1953
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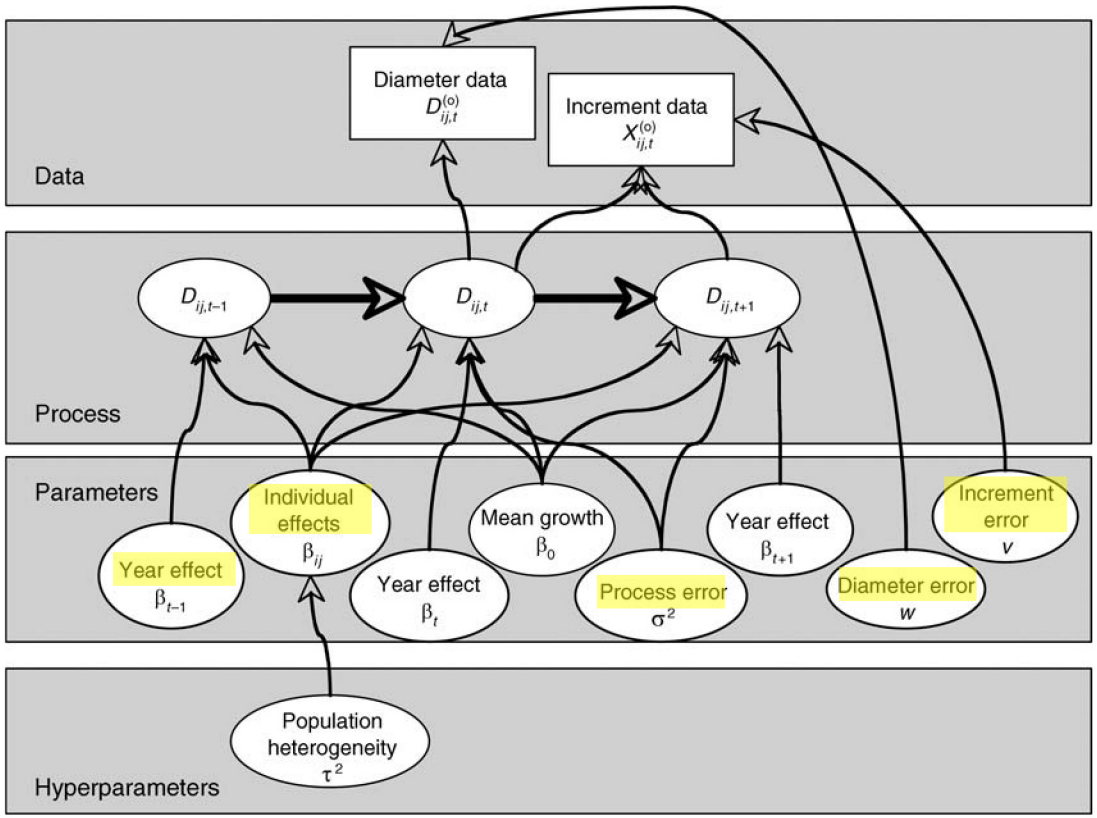
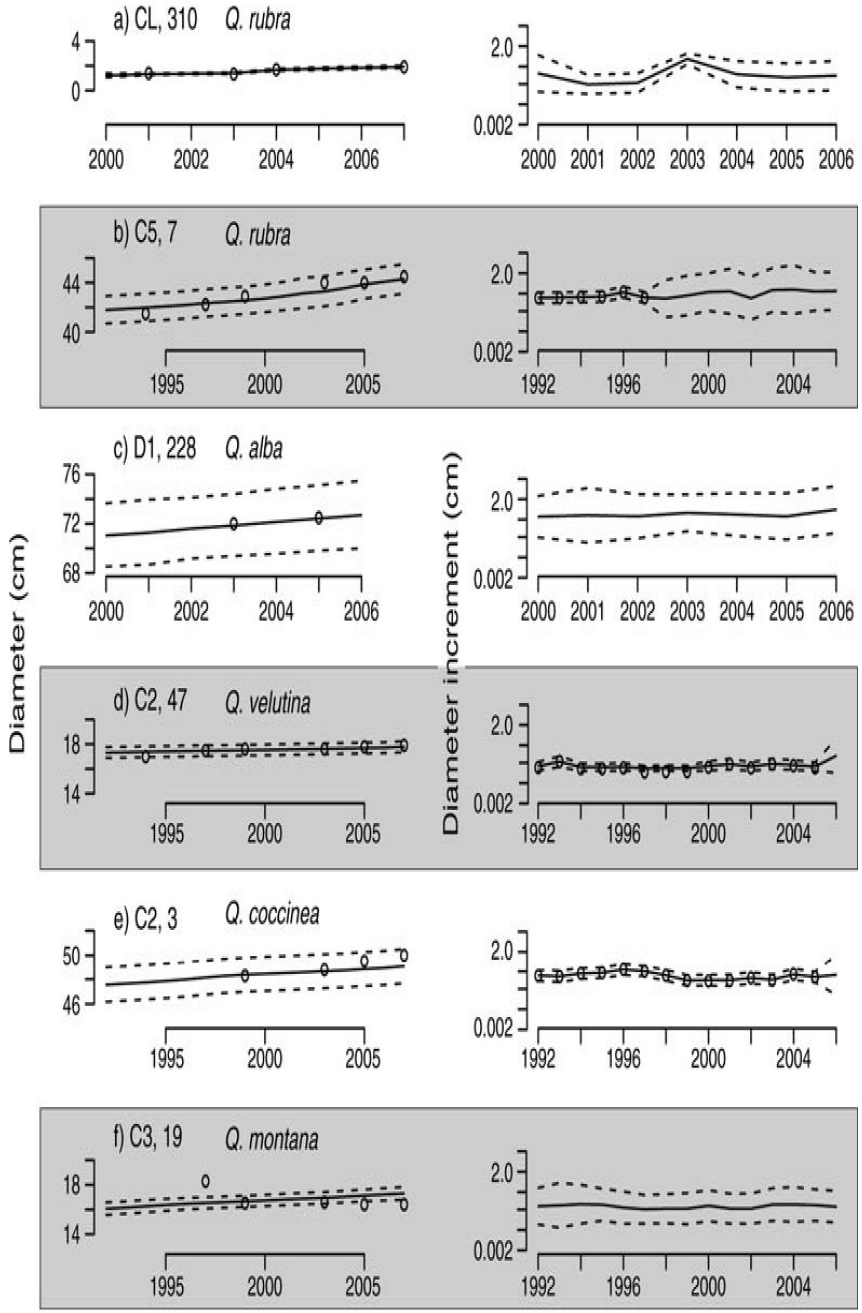
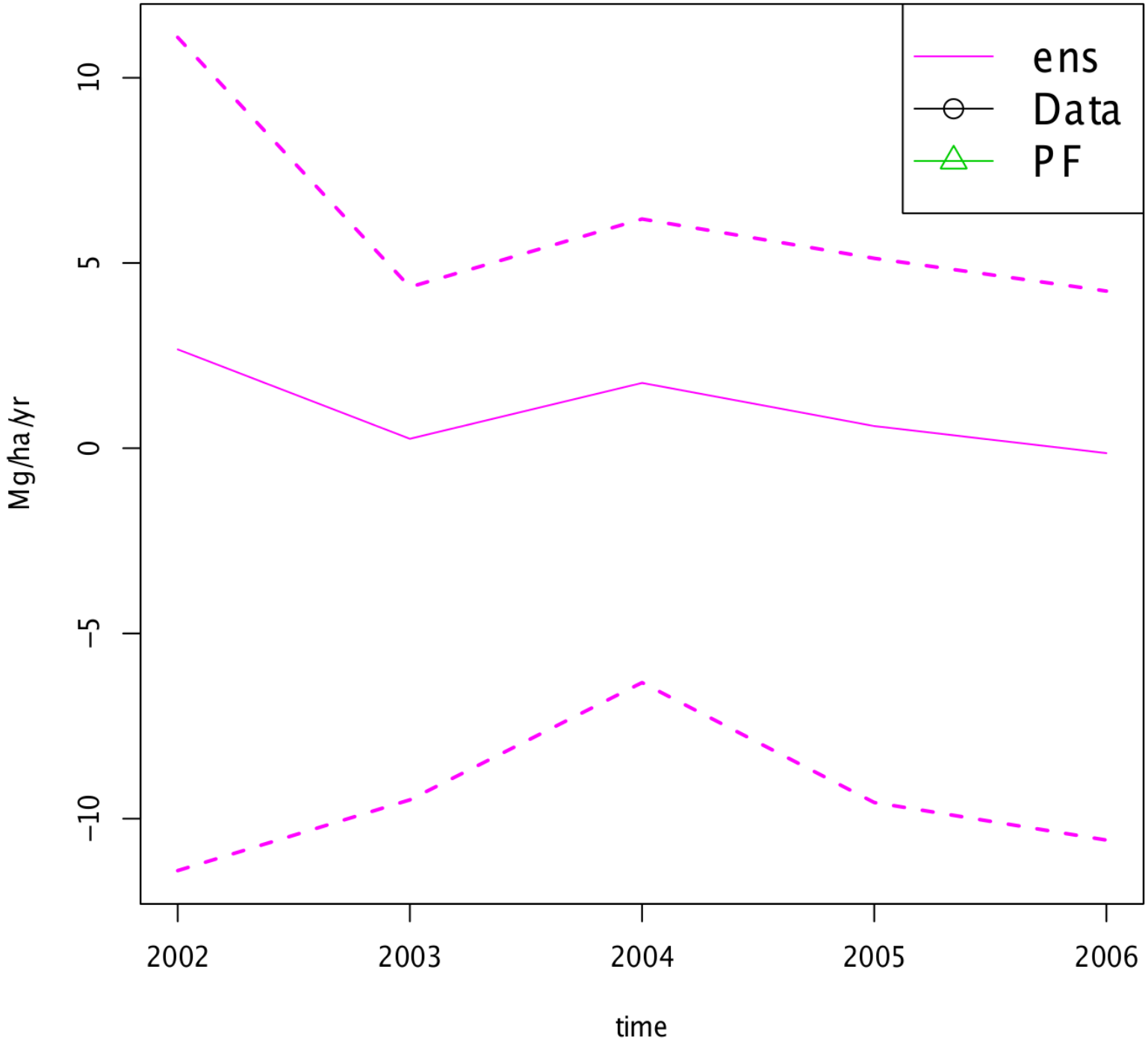
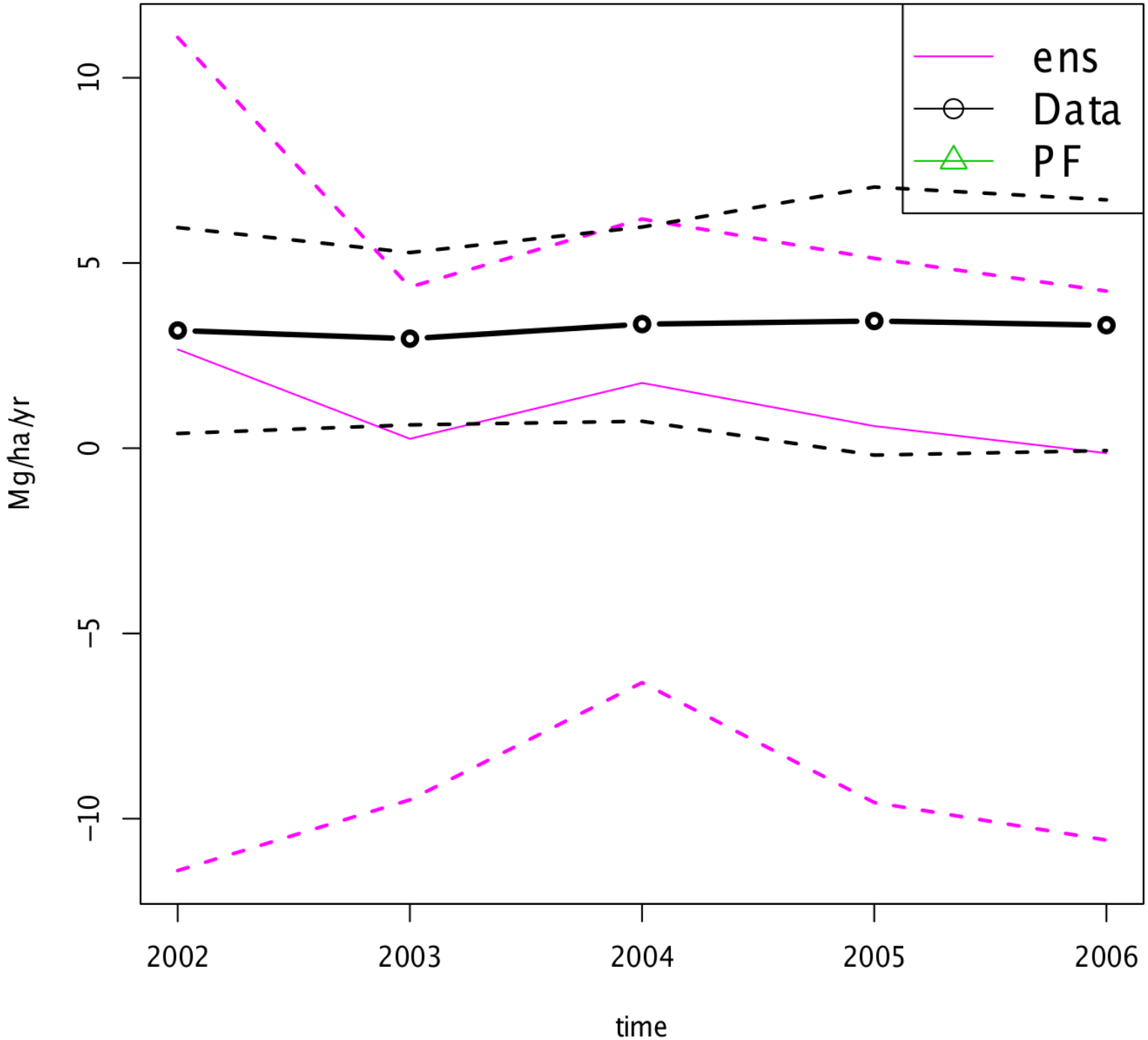
TREE GROWTH INFERENCE AND PREDICTION FROM DIAMETER CENSUSES AND RING WIDTHS

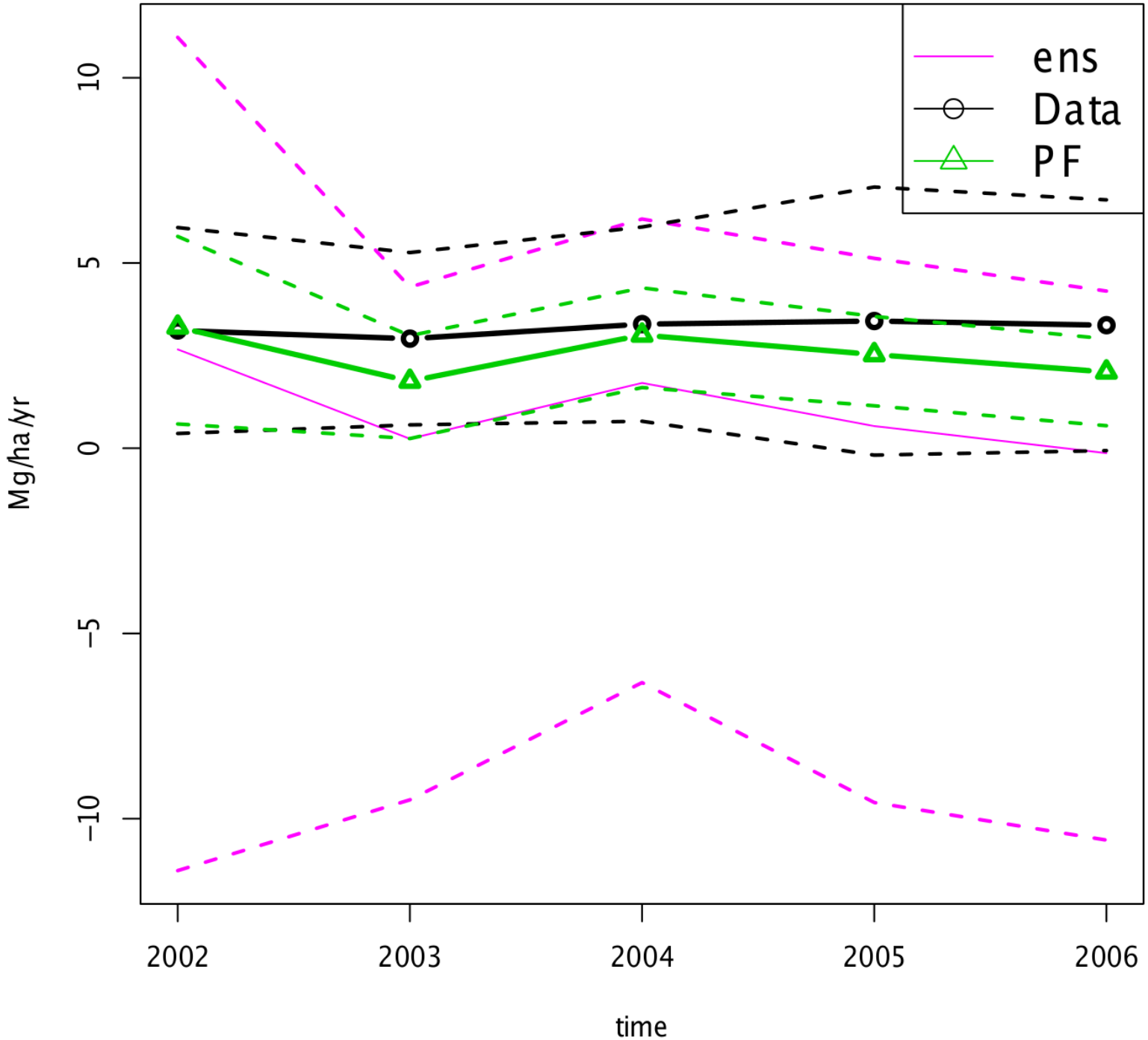
James S. Clark,[1,2,3,4,6] Michael Wolosin,[2,3] Michael Dietze,[2,3] Inés Ibáñez,[2,3] Shannon LaDeau,[2,3,7] Miranda Welsh,[1] and Brian Kloeppel[5]






ens
Data
PF
10
5
0
−5
−10
Mg/ha/yr
2002
2003
2004
2005
2006
time


ens
Data
PF
10
5
0
−5
−10
Mg/ha/yr
2002
2003
2004
2005
2006
time


ens
Data
PF
10
5
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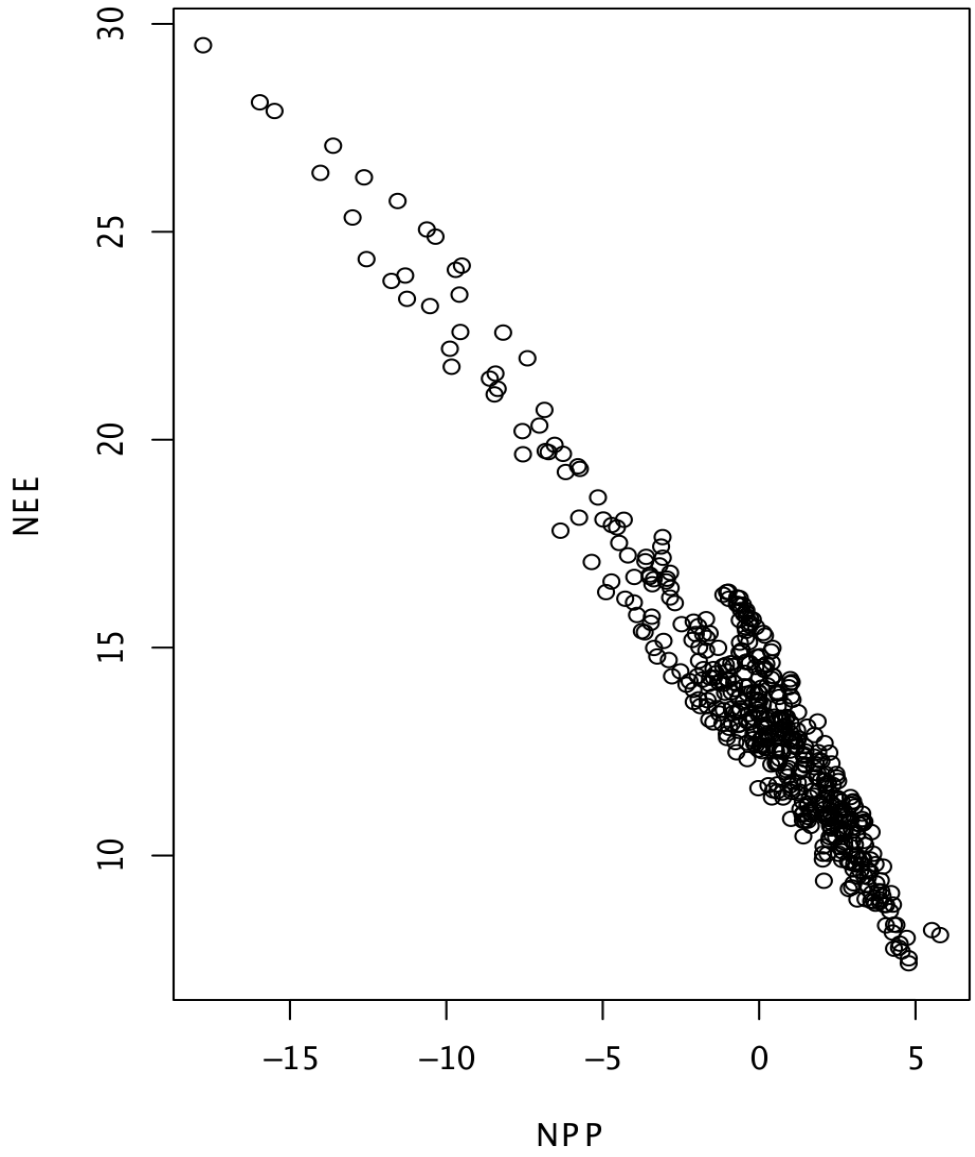
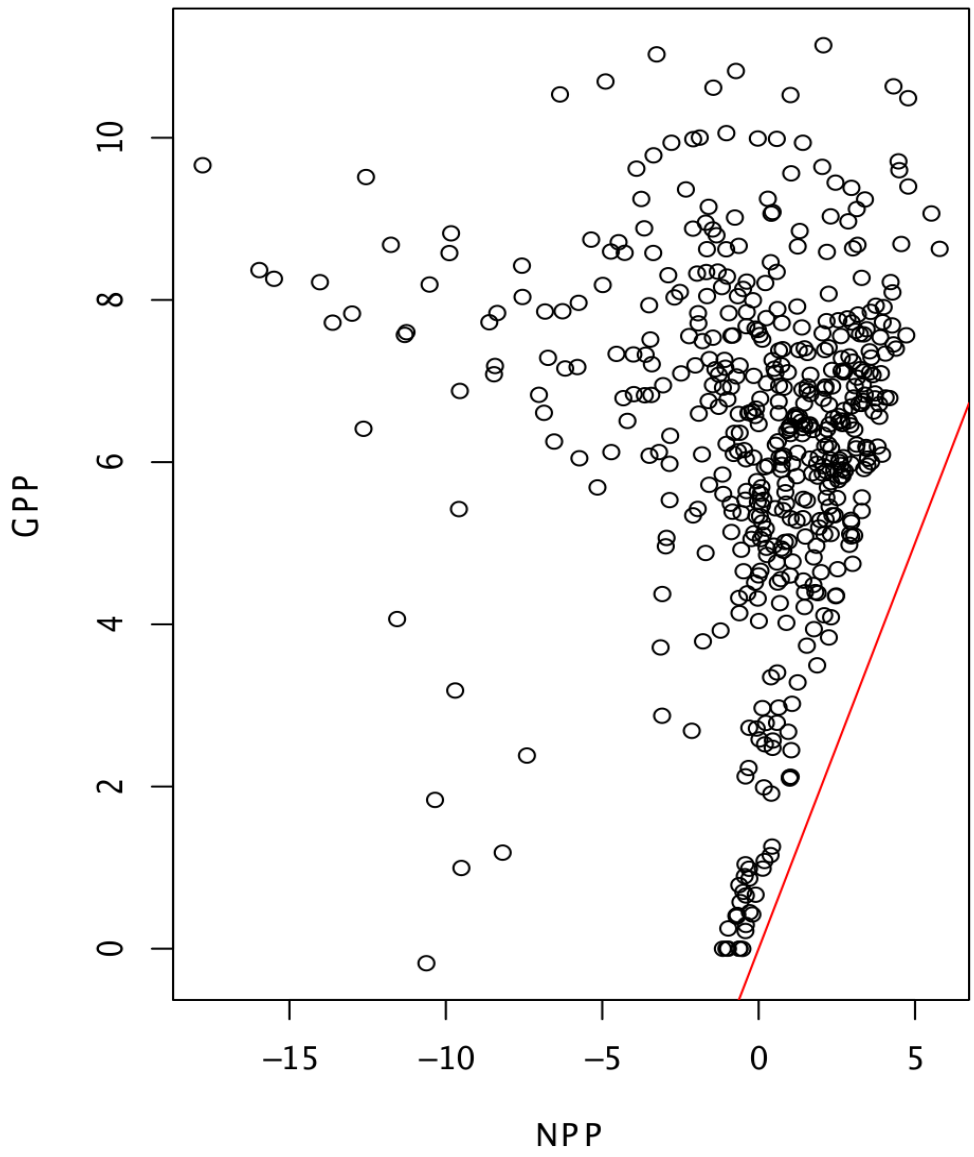
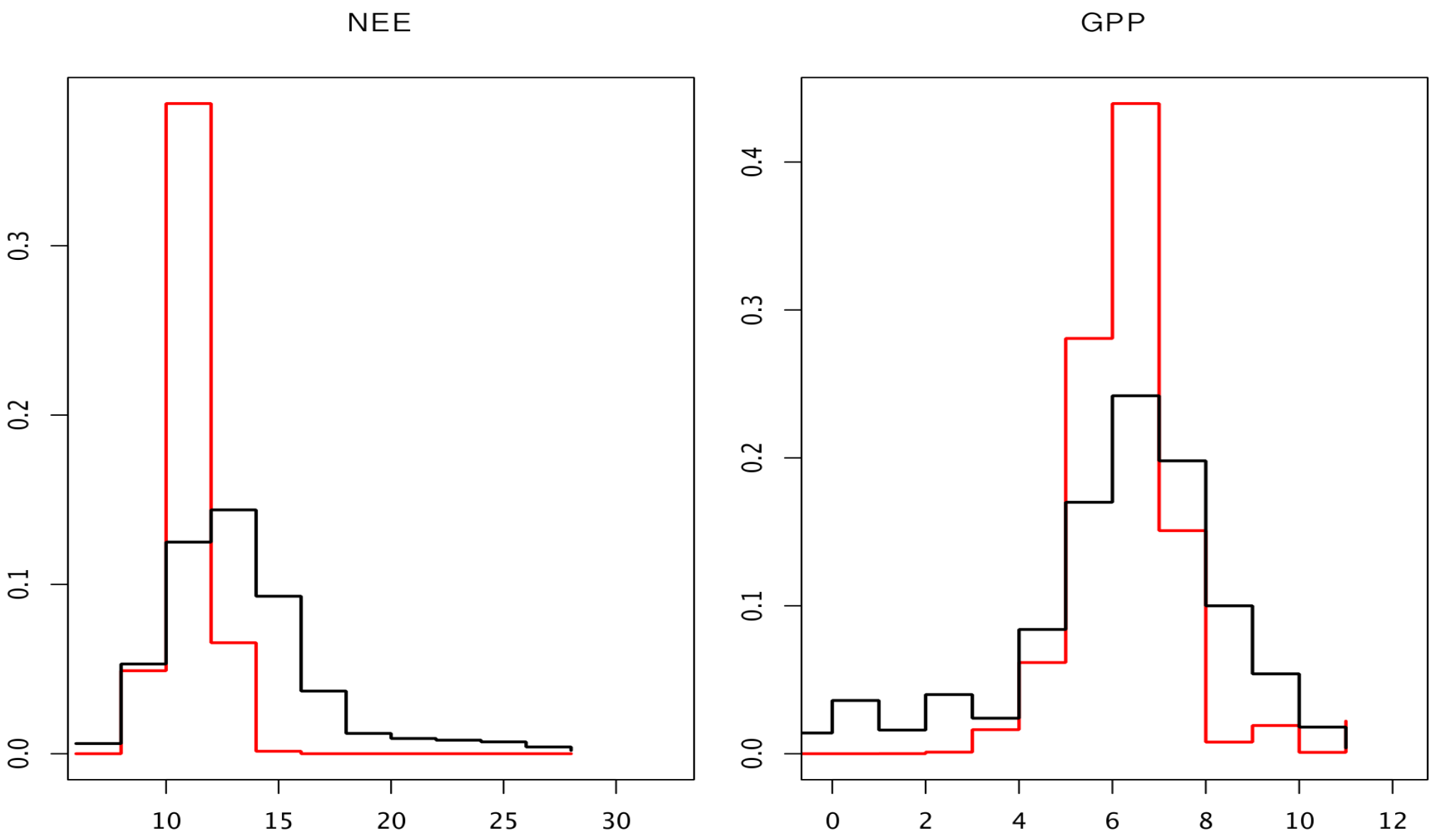
−5
−10
Mg/ha/yr
2002
2003
2004
2005
2006
time


NEE
NPP
30
25
20
15
10
−15
−10
−5
0
5


GPP
NPP
10
8
6
4
2
0
−15
−10
−5
0
5


NEE
GPP
0.0
0.1
0.2
0.3
0.4
10
15
20
25
30
0
2
4
6
8
10
12

Phase 2 Goals

- Proof of concept:
  Assimilate 1000+ yrs for 5 sites
  - Data: pollen proxy, tree rings, settlement & modern inventory
  - Drivers: CMIP5 GCM downscaled realizations
    - Ensemble of CMIP5 GCMs
    - Ensemble of downscaled realizations
- Expand to regional scale
  - Inference
  - Initialization for the modern

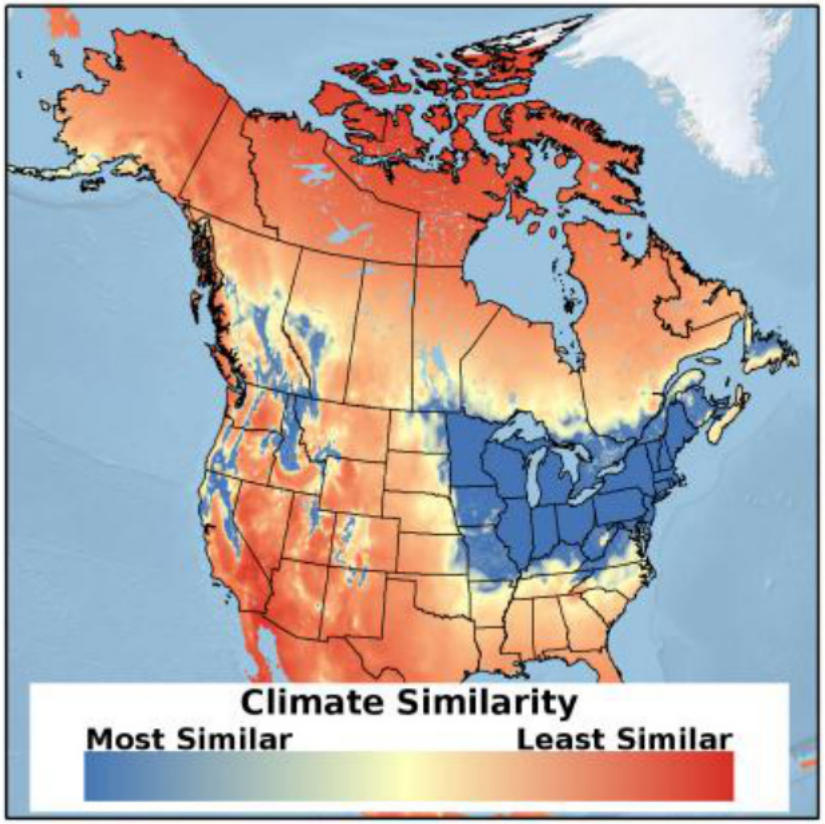
Where we are now...

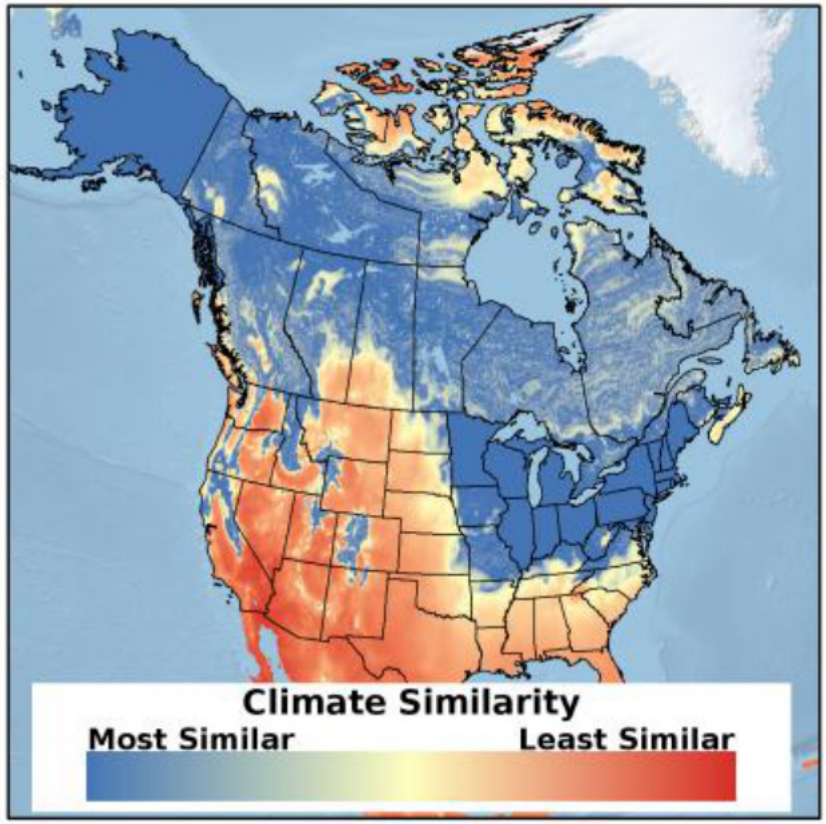
- GCM downscaling more complex and time consuming than anticipated...
- Very little proxy data independent of vegetation

PalEON2

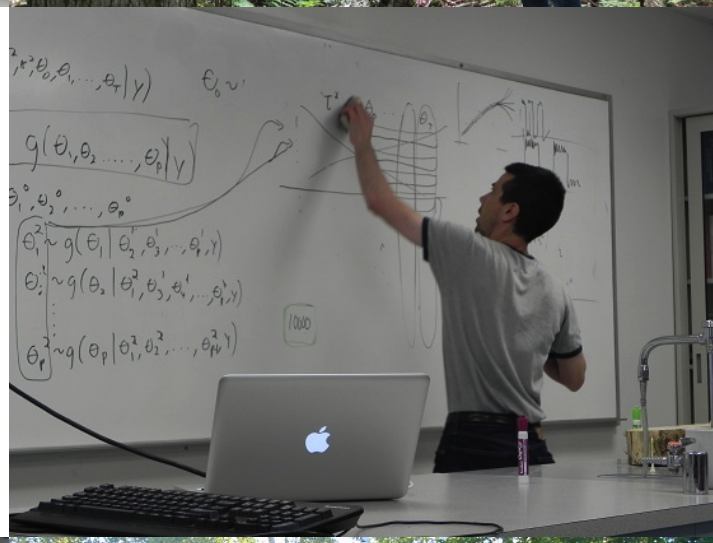
- New PLS
- Experimental design
- HIPS

- Tree rings
- Charcoal
- Paleo-climate





PaleoEcological Observatory Network

PalEON

Summer Course 2012