Improving Forest Ecosystem Models to Simulate Responses to Global Change

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Looking at Global Change

- Global CO_2 concentration has risen by 30% since pre-industrial times

- Over the same period tropospheric ozone (O_3) has risen by 36%

But we want more ozone, right?

- Tropospheric ozone is *surface* level ozone created downwind from metropolitan areas due to the action of sunlight on nitrous oxides and volatile organic compounds

- On the surface O_3 is harmful animals and plants

Independent Effects of CO_2 and O_3 on Forests

- Elevated CO_2 stimulates photosynthetic productivity in trees

- O_3 is detrimental to forest growth and productivity

Forests at Risk

- Currently, a quarter of the Earth's forests are at risk from peak level O_3
- It has been estimated that half of the Earth's forests will be subjected to risk level O_3 in the near future

What will be the combined effect?

- It is largely uncertain how exactly CO_2 in combination with O_3 will interact on mature forest ecosystem functioning and productivity

FACTS II (Aspen FACE)

- Three replicate 30 diameter rings for each treatment

- Four treatments: control (ambient CO_2 and O_3), elevated CO_2, elevated O_3, elevated CO_2 + O_3

- Two O_3 intolerants (*Populus tremuloides* and *Betula papyrifera*) and one tolerant (*Acer saccarum*)

FACTS II (Aspen FACE)

Established in 1997 it is the first site in the world to use open air elevation of CO_2 and O_3 alone and in combination

Modeling the response of forests to changes in CO_2 and O_3

- Objective to use five years of extensive data from FACTS II to parameterize established forest ecosystem models PnET and GTEC

Hypothesis

- Omitting increases in O_3 from forest ecosystem models will lead to overestimation of the enhancement in growth stimulated by elevated CO_2

Testing and development

- Parameterize models with data from control and elevated CO_2 treatments
- Develop a mechanistic model to predict the processes within the O_3 treatments in addition to the interactions of the CO_2 + O_3 treatments
- Use the extensive FACTS II data to examine how well the models are predicting observed responses

Previous research

- Modeling canopy photosynthesis for POPlar Free Air CO2 Enrichment (POPFACE)

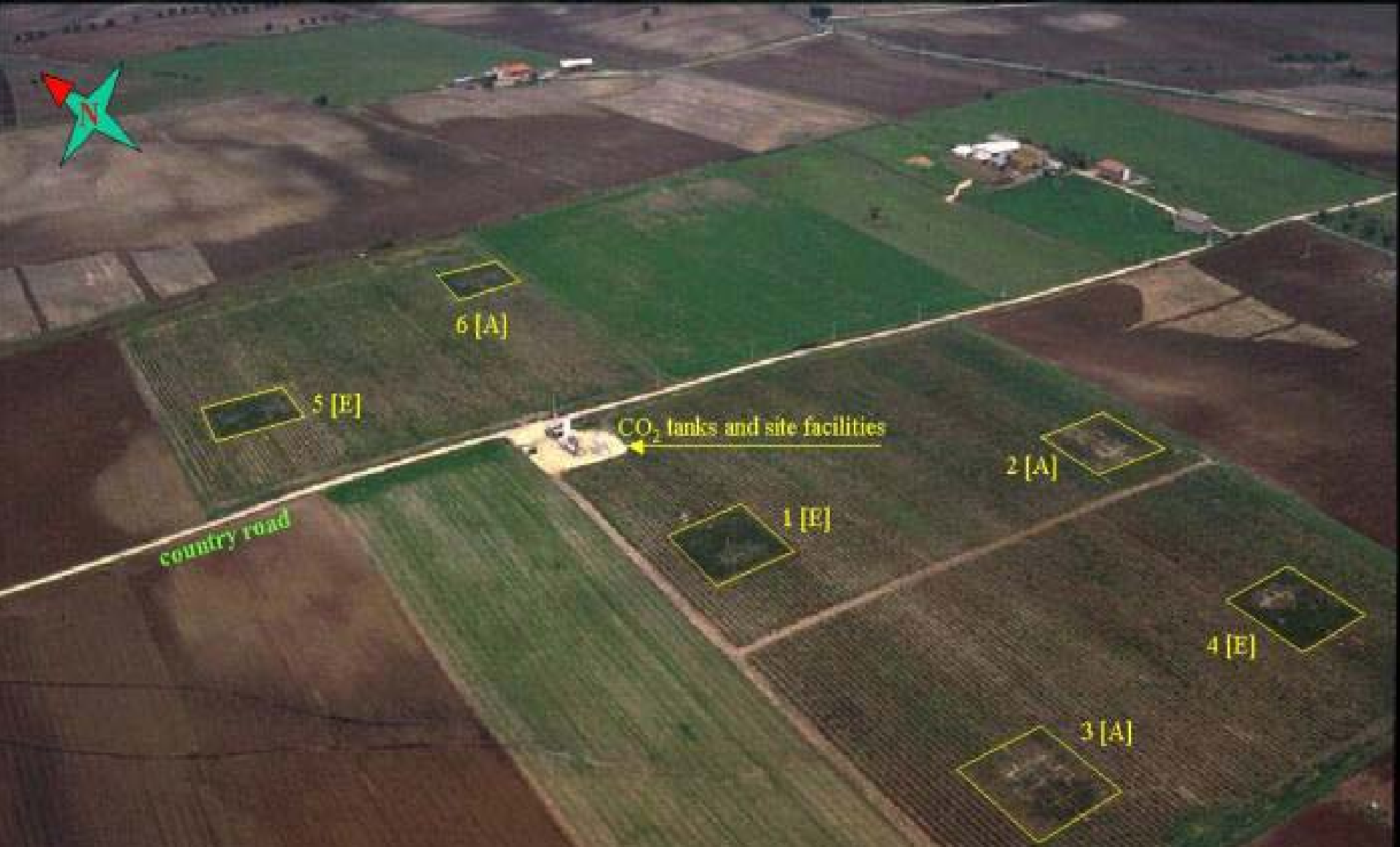
- Validation exercise of the University of Sheffield Conifer Model (USCM)

POPFACE

- Six plots planted with *Populus alba*, *P. nigra, and P. x euramericana*.

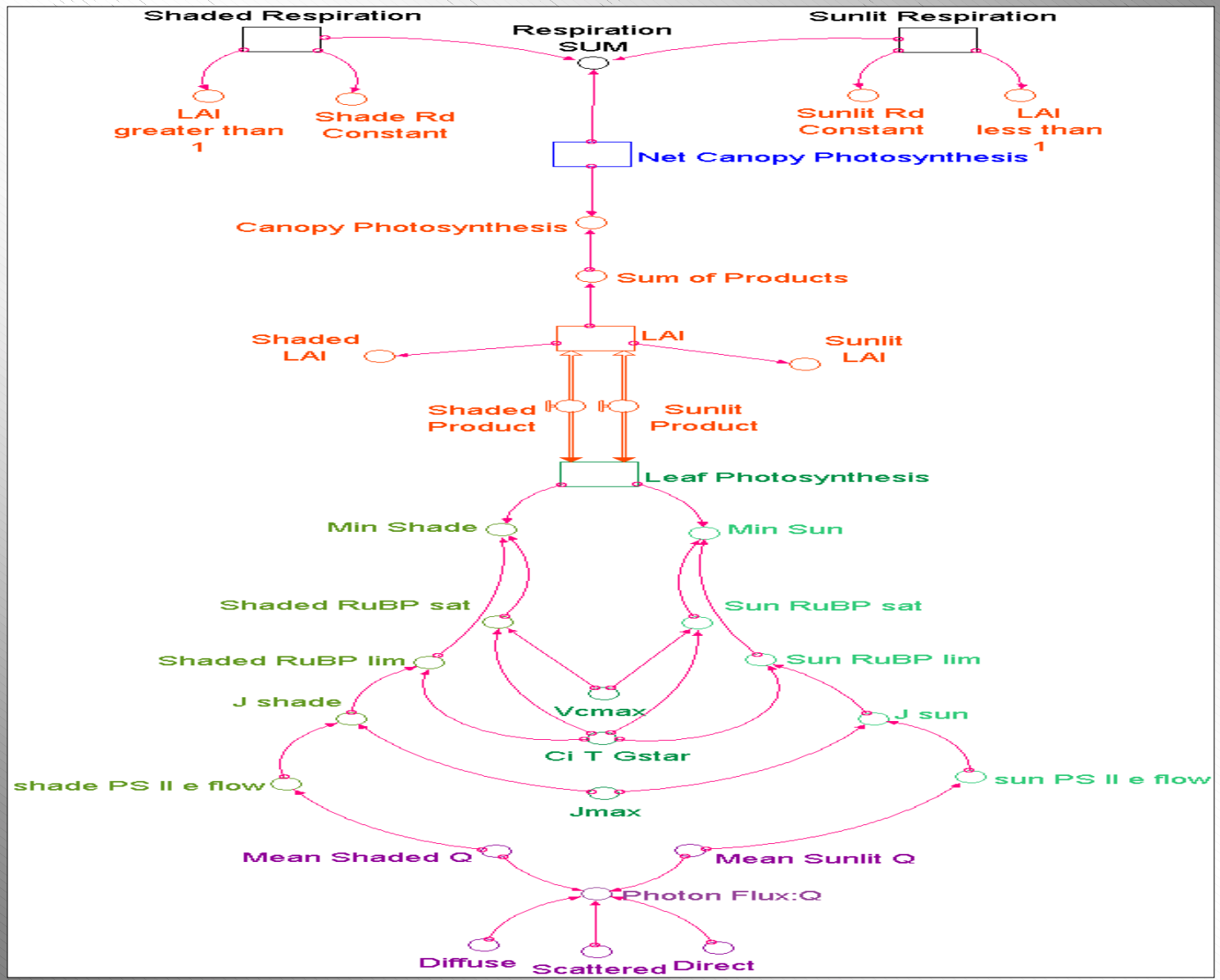
- Three plots enriched with [CO_2] (550ppm); three plots at ambient [CO_2] (~370ppm).

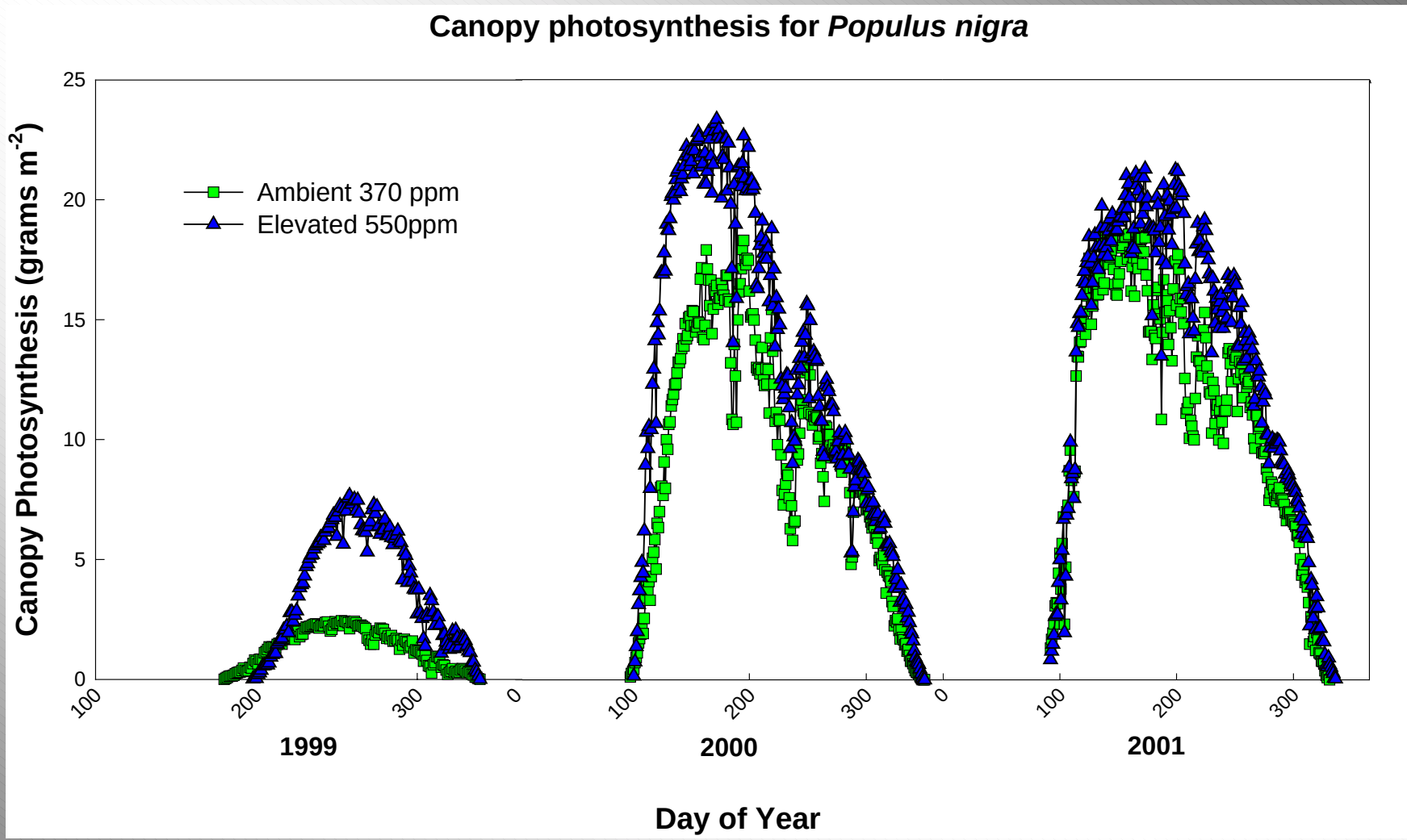
- The trees were planted late spring of 1999 grown through 2001 and coppiced in spring 2002.



The POPFACE facility is located in Tuscania, central Italy. Pictured here is one of three Free-Air CO_2 Enrichment (FACE) plots (top) in June 2002, after the spring coppice. The bottom two images are of *Populus alba* (bottom left) and *Populus nigra* (bottom right), two of the three *Populus spp.* planted in each of the six plots at POPFACE.

Synthesized three years of POPFACE data into a biochemical model of leaf photosynthesis scaled to the canopy level





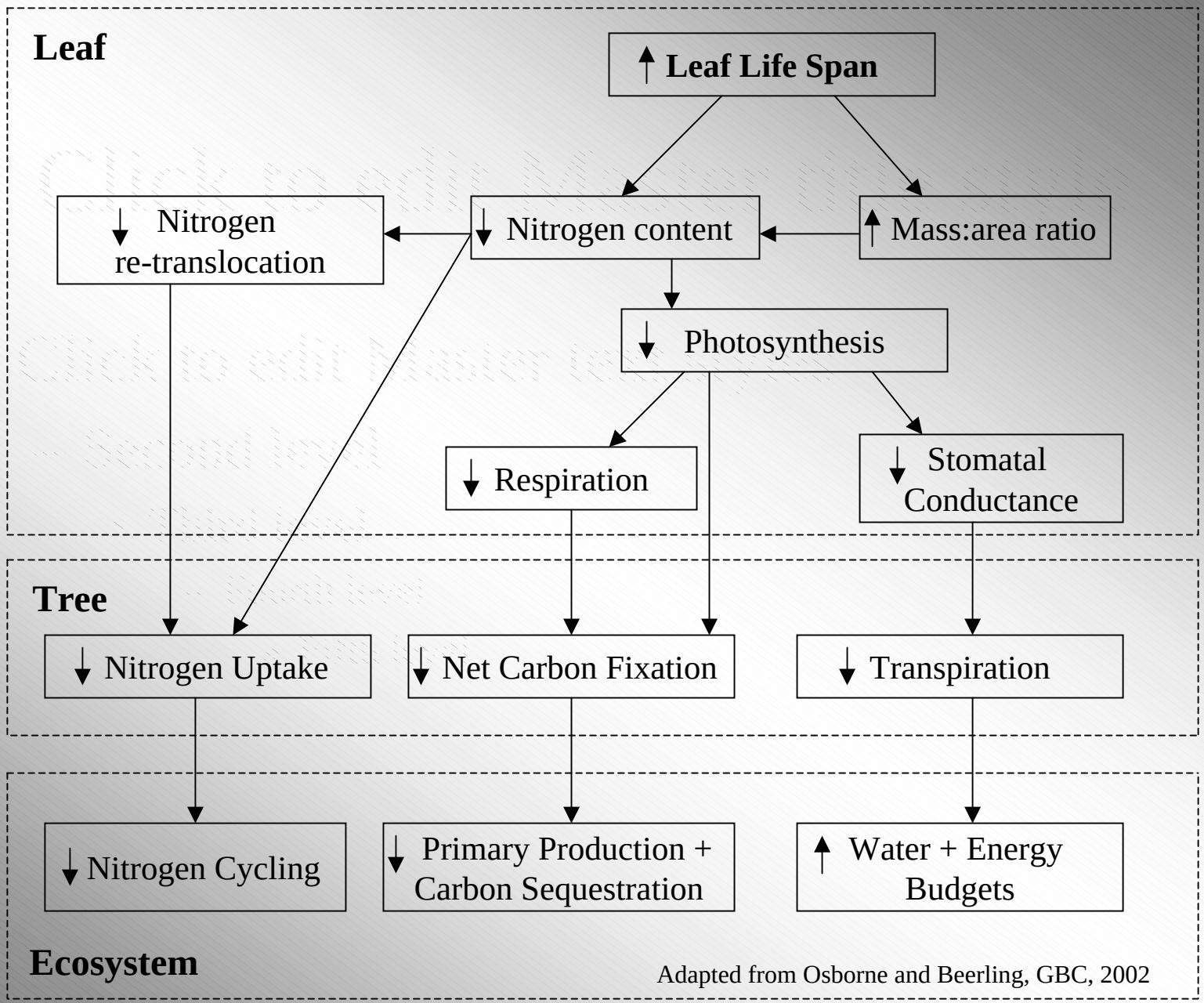
Example simulation of daily canopy photosynthesis for *Populus nigra* in CO_2 enriched plot 1 (550ppm) and ambient plot 2 (370ppm).

University of Sheffield Conifer Model (USCM)

- Simulates conifer forest carbon, nitrogen, and water fluxes
- Based on the relationship of leaf life span and function
- Useful for simulating forest growth in past, present and future climates

Leaf Life Span (LLS): the Driving Physiological Force of USCM

- A tool to explain distributions in Leaf Area Index and Net Primary Productivity at regional scales
- The link between ancient conifer forests in an elevated pCO_2 world and forests in the elevated pCO_2 world predicted for this century



Adapted from Osborne and Beerling, GBC, 2002

My Job: Validating the Coupling of USCM to CENTURY soil model

Selection of conifer forest research sites in the FLUXNET community comprehensively representing range of latitudes and coniferous species



Fluxnet: A global database of forest research using the Eddy-Covariance technique to determine carbon pools and fluxes

Limitations to Modeling

- No model can capture 100% of the natural system it represents
- Although imperfect, they are powerful tools that can be used to understand complex systems

Looking toward the future…

- To continue research in order to contribute to modern understanding of the way forests will respond to the interactive effects of CO_2 and O_3!

Thank You!

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