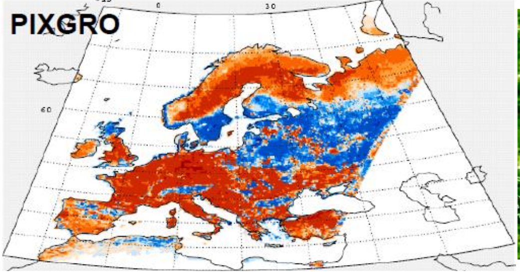
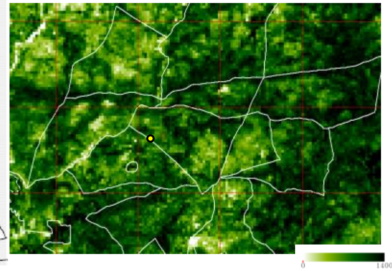
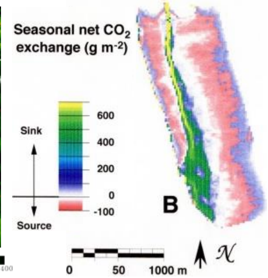
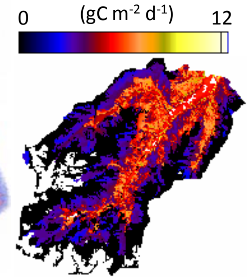


2003 Reduction in European GPP

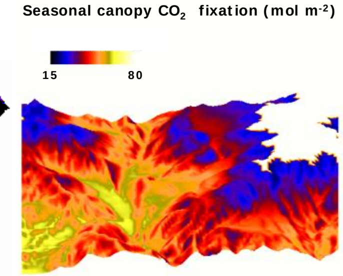

Herdade de Mitra 2002 GPP



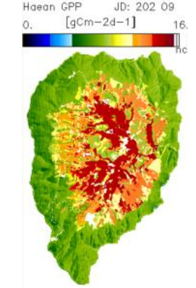
Imnaviat Creek, Alaska



Stubai Valley, Austria



IBP Sites, Naeba Mountains, Japan


Haean, South Korea

Linking ecosystem physiology to hydrology in different environments and at different scales: An important resource management challenge.

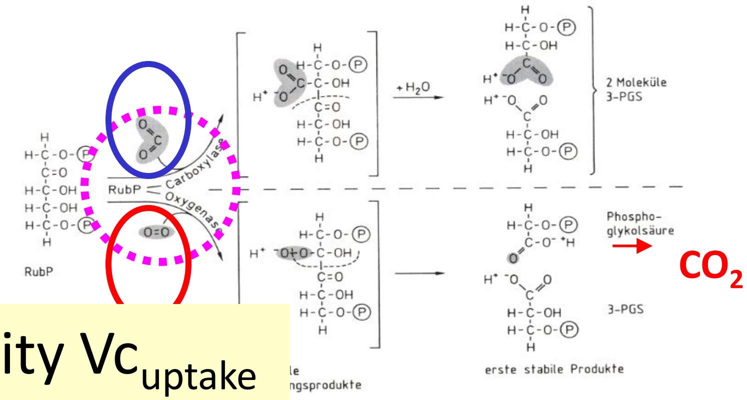
John Tenhunen

Bayreuth Center of Ecology and Environmental Research University of Bayreuth, Germany

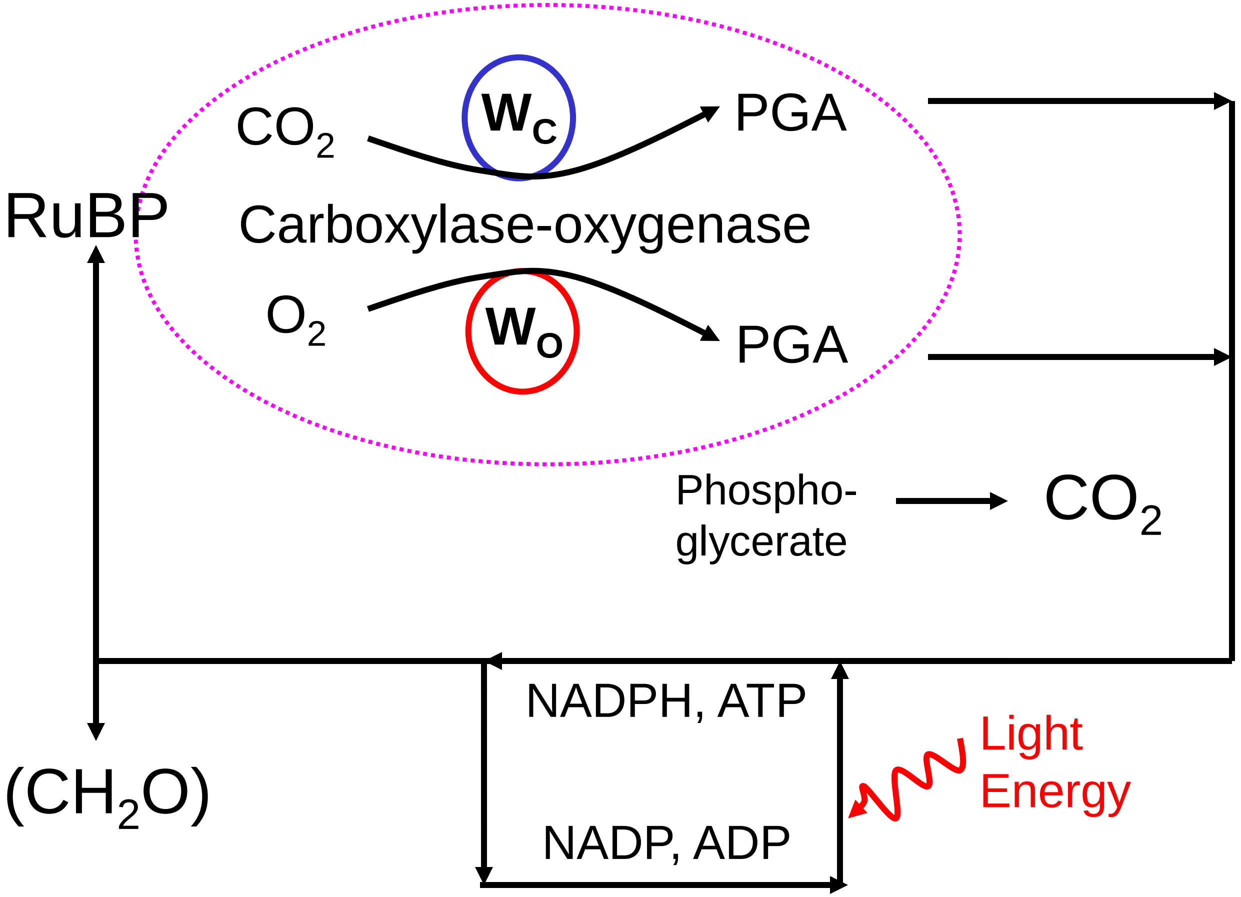
Ecohydrology Seminar
Kyoto University, Japan, April 10, 2015

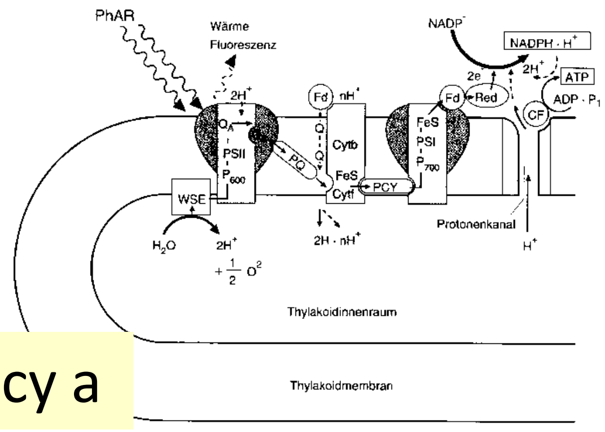
C_3 - Photosynthesis

and NP-Dependencies

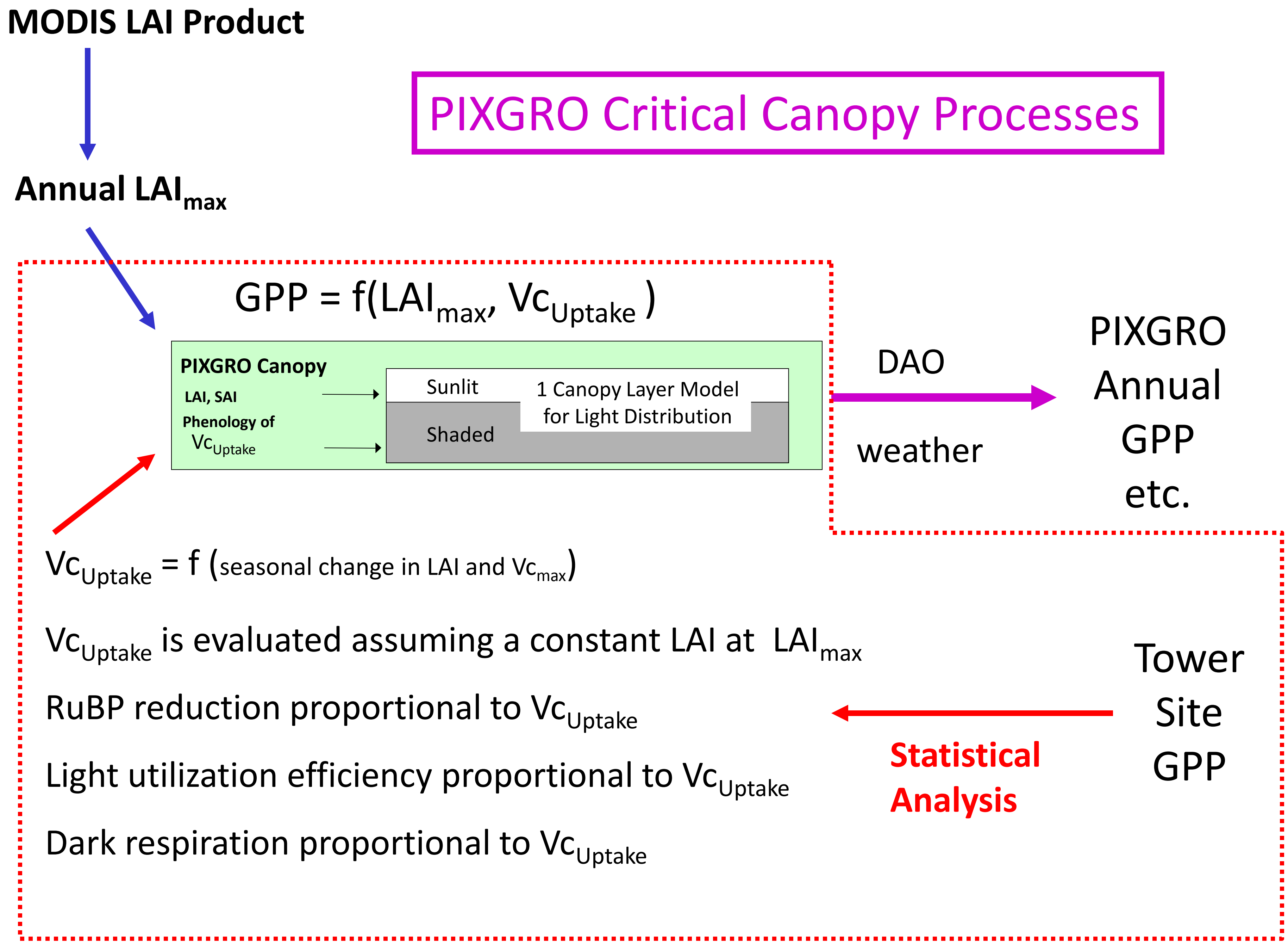


Critical Parameter: Carboxylation Capacity Vc_{uptake}

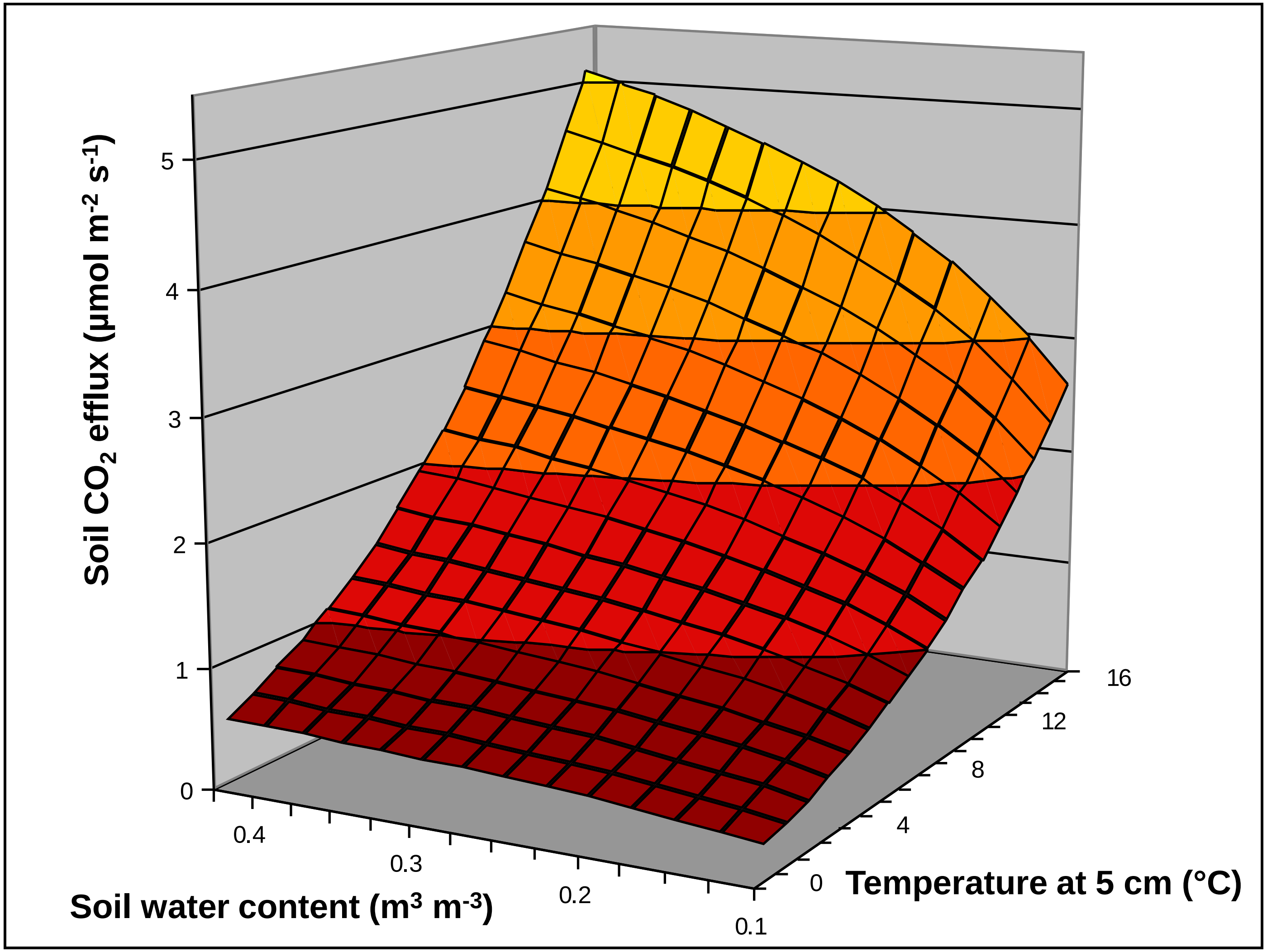




Critical Parameter: Light Utilization Efficiency a

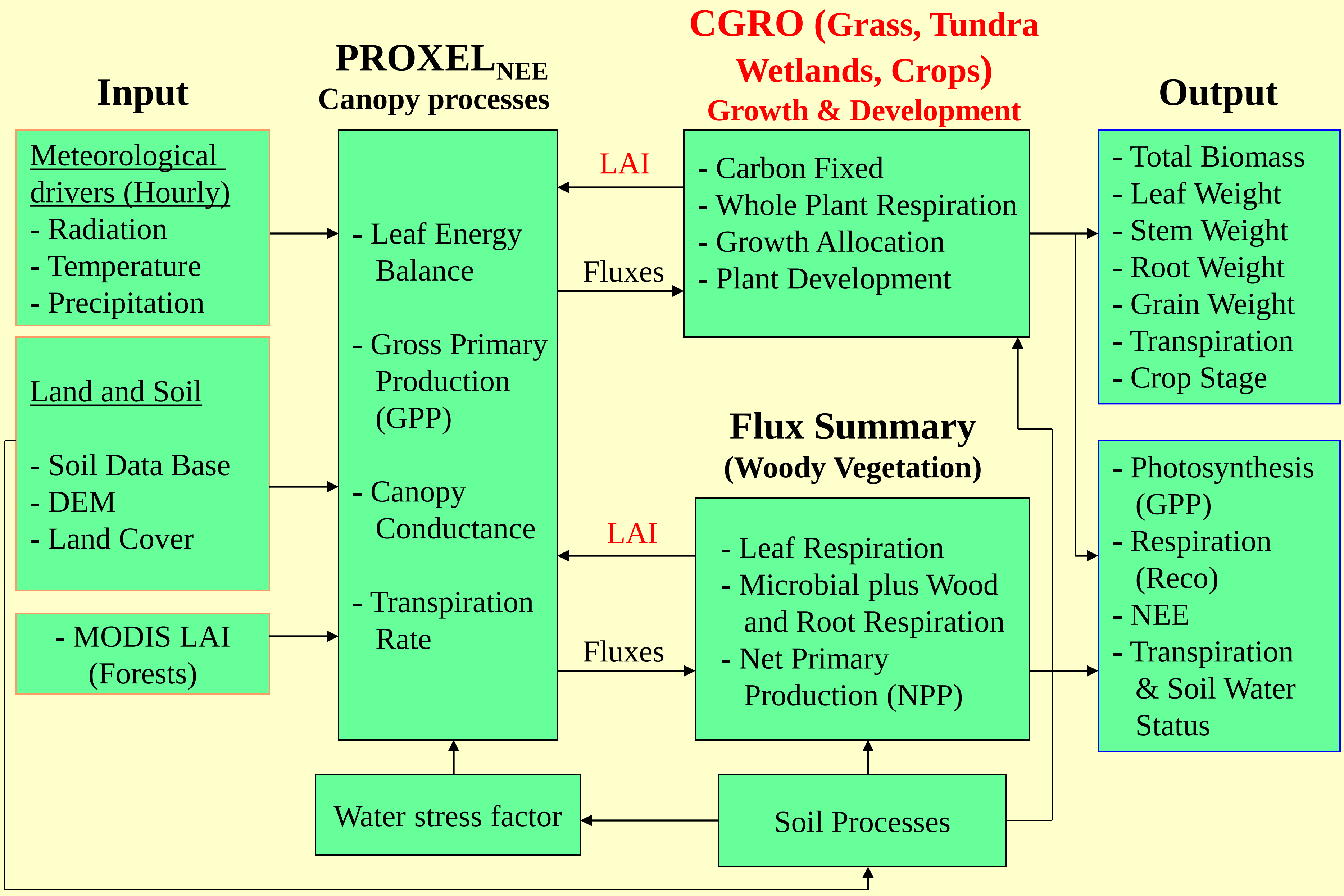

MODIS LAI Product
PIXGRO Critical Canopy Processes
Annual LAI_{max}
$GPP = f(LAI_{max}, Vc_{Uptake})$
PIXGRO Canopy
LAI, SAI
Phenology of Vc_{Uptake}
Sunlit
Shaded
1 Canopy Layer Model for Light Distribution
DAO
weather
PIXGRO Annual GPP etc.
Vc_{Uptake} = f (seasonal change in LAI and Vc_{max})
Vc_{Uptake} is evaluated assuming a constant LAI at LAI_{max}
RuBP reduction proportional to Vc_{Uptake}
Light utilization efficiency proportional to Vc_{Uptake}
Dark respiration proportional to Vc_{Uptake}
Tower Site GPP
Statistical Analysis

Temperature and SWC dependence of soil CO_2 efflux



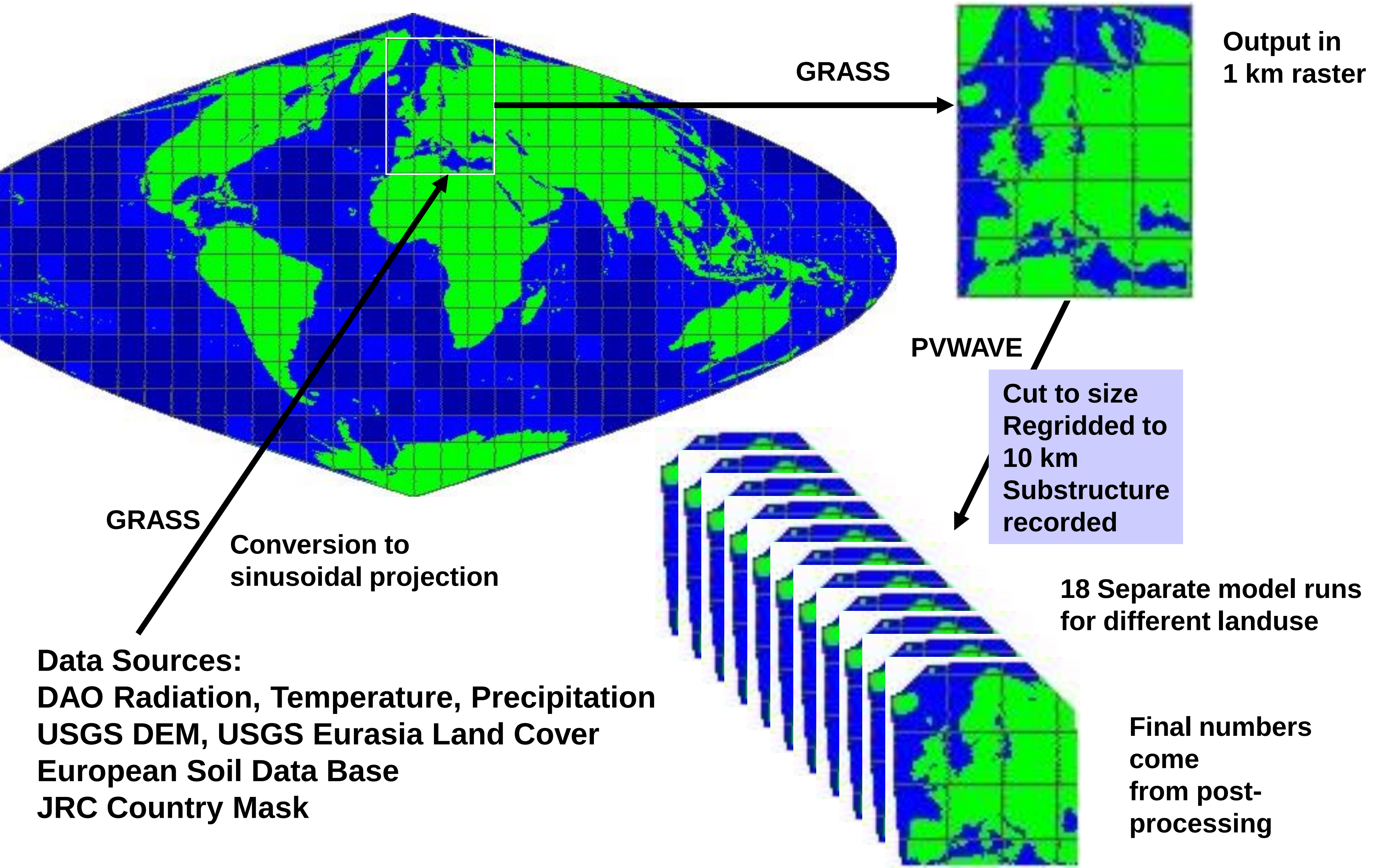
Empirical Description

The Model PIXGRO



PIXGRO Strategy - fine grain / high resolution version

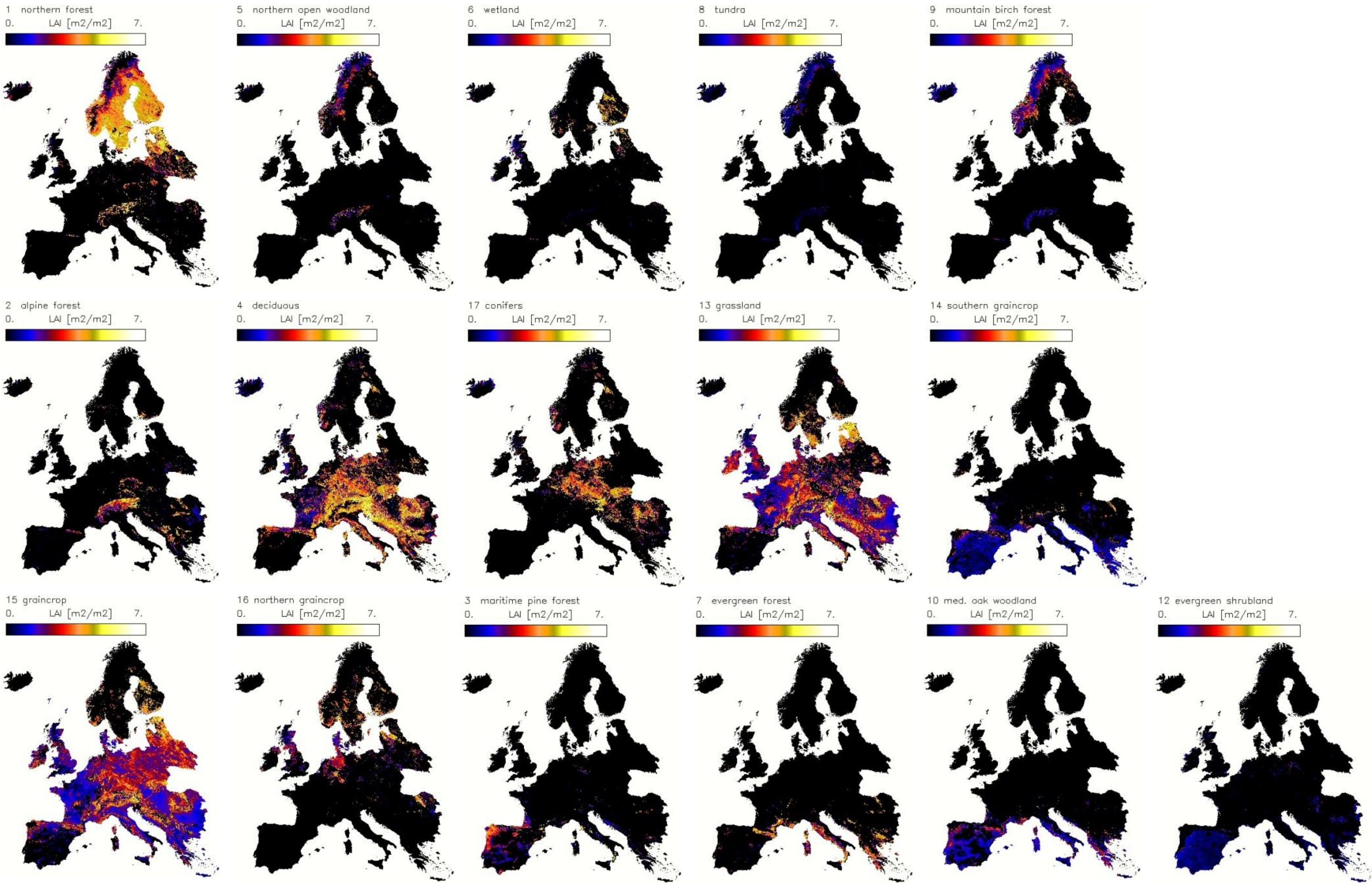
MODLAND Sinusoidal Grid10 degree Tiles (LAI, other data)



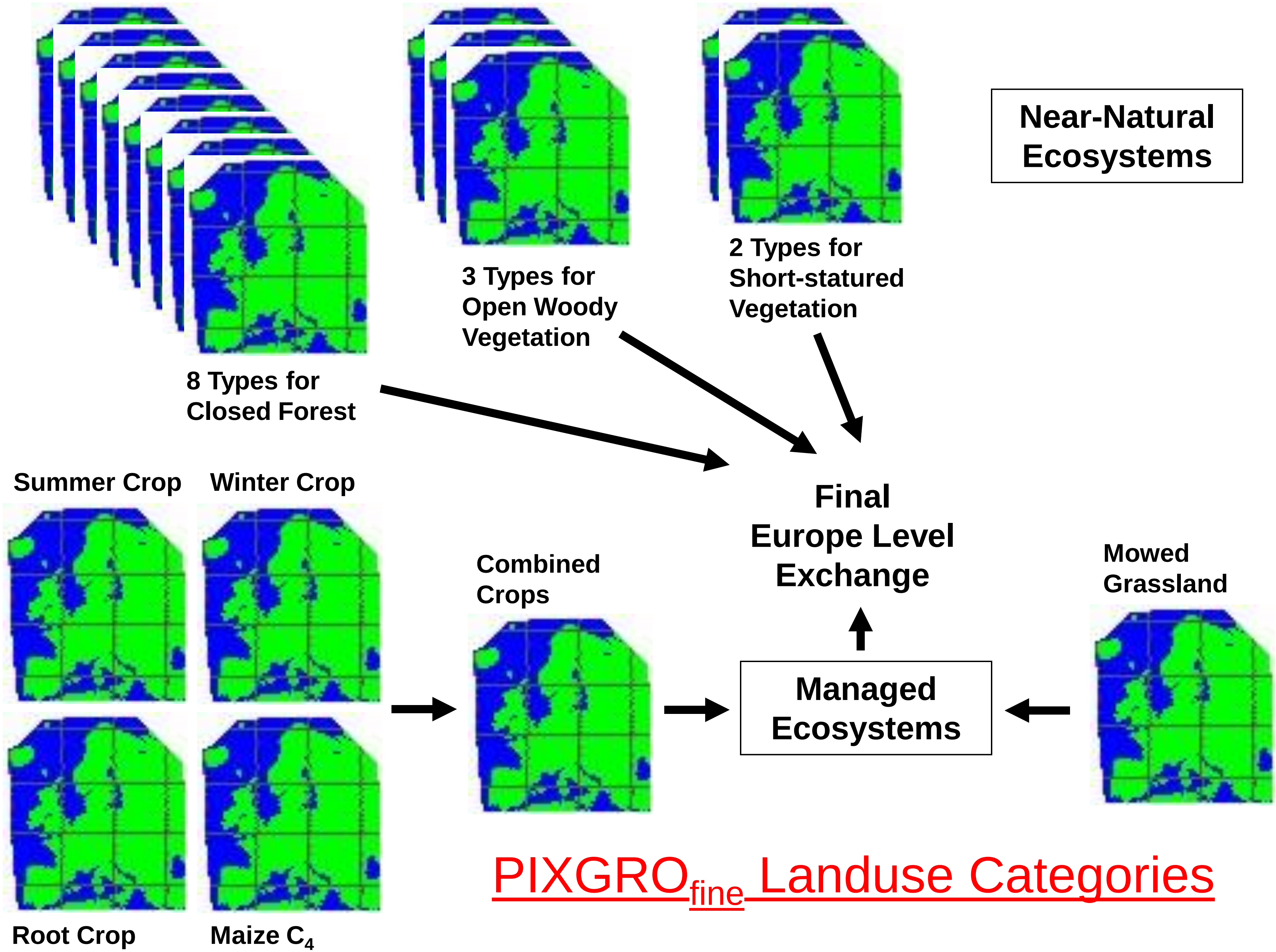
Data Sources:
DAO Radiation, Temperature, Precipitation
USGS DEM, USGS Eurasia Land Cover
European Soil Data Base
JRC Country Mask

FTs from USGS Eurasia land cover data base based on 1-km AVHRR

Maximum LAI determined from analysis of MODIS summer values

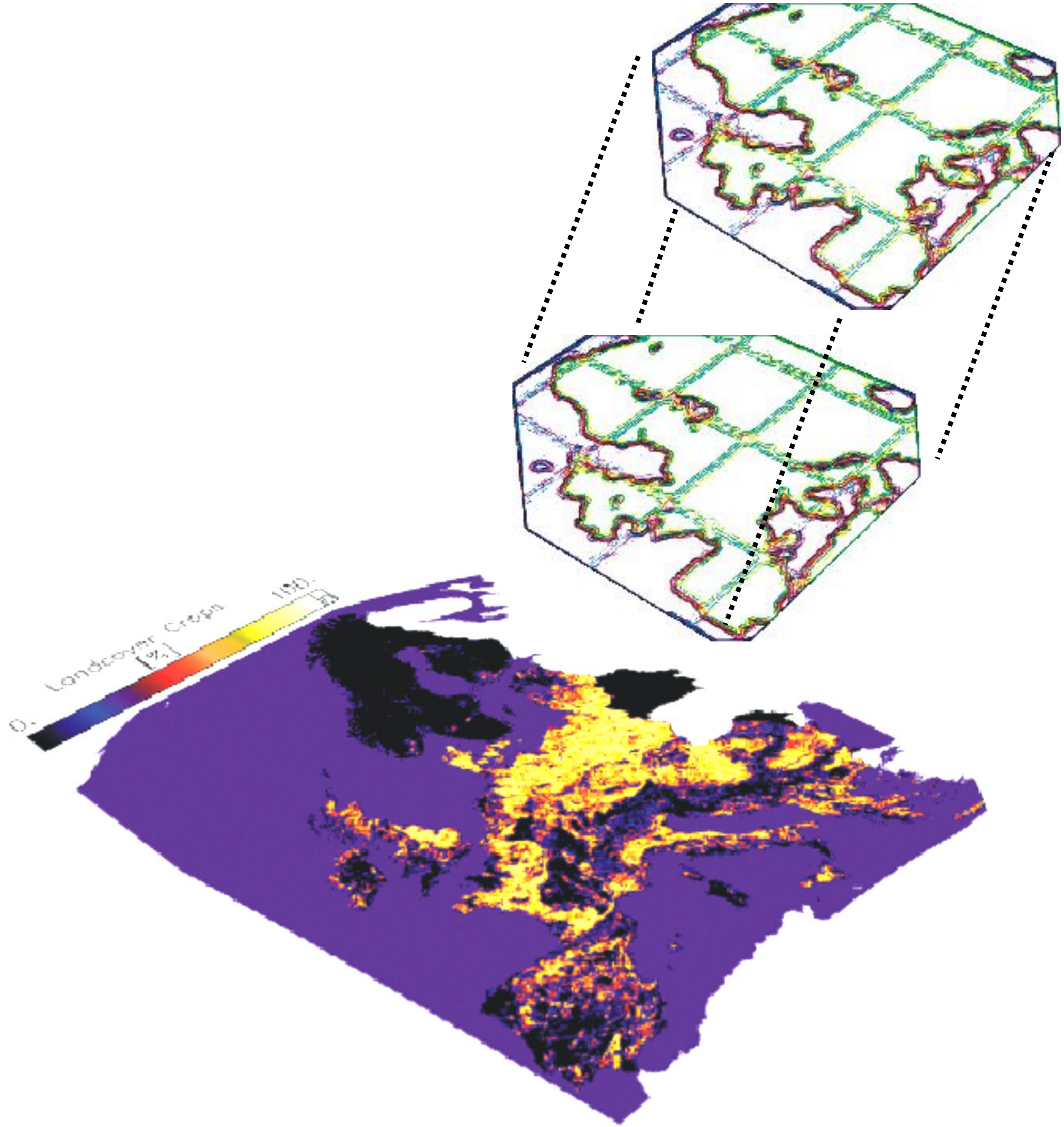


Landuse Type in $\text{PIXGRO}_{\text{fine}}$	**km^2**	**percent**
Closed Forest Types		
Alpine Forest	5.33×10^4	1.0
Coniferous Forest	4.17×10^4	0.8
Deciduous Forest	5.16×10^5	9.8
Maritime Pine Forest	9.15×10^4	1.7
Mediterranean Evergreen Forest	6.10×10^4	1.2
Mountain Birch Forest	1.20×10^4	0.2
Northern Forest	8.30×10^5	15.8
Pinus mugo Scrub	4.59×10^3	0.1
Open Woody Vegetation		
Northern Open Woodland	4.39×10^4	0.8
Mediterranean Woodland	1.99×10^5	3.8
Evergreen Shrubland	2.92×10^5	5.5
Short-statured Vegetation		
Tundra	9.05×10^4	1.7
Wetland	2.28×10^4	0.4
Grassland with Mowing	8.89×10^5	16.9
Crops	2.12×10^6	40.2


Near-Natural Ecosystems
8 Types for Closed Forest
3 Types for Open Woody Vegetation
2 Types for Short-statured Vegetation
Final Europe Level Exchange
Summer Crop
Winter Crop
Root Crop
Maize C_4
Combined Crops
Managed Ecosystems
Mowed Grassland
PIXGRO$_{fine}$ Landuse Categories

You Need Some Kind of

"Management"

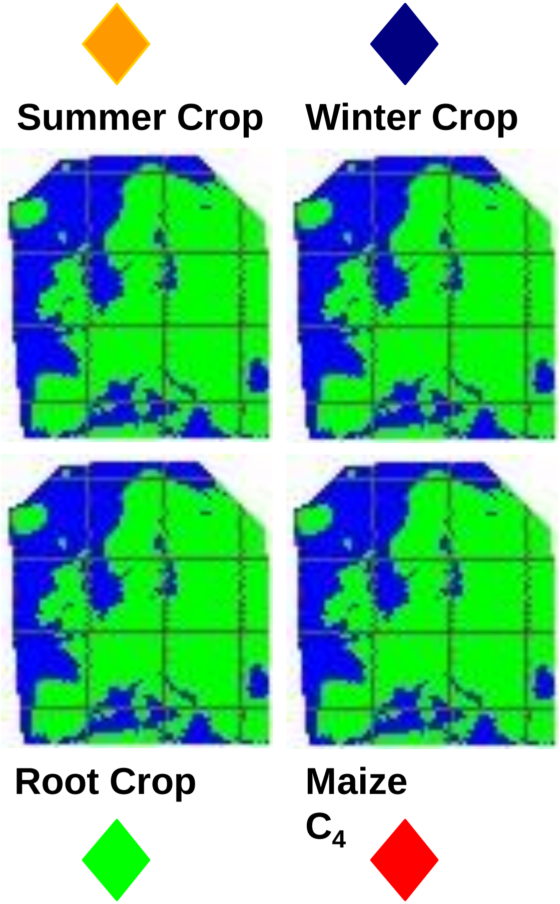


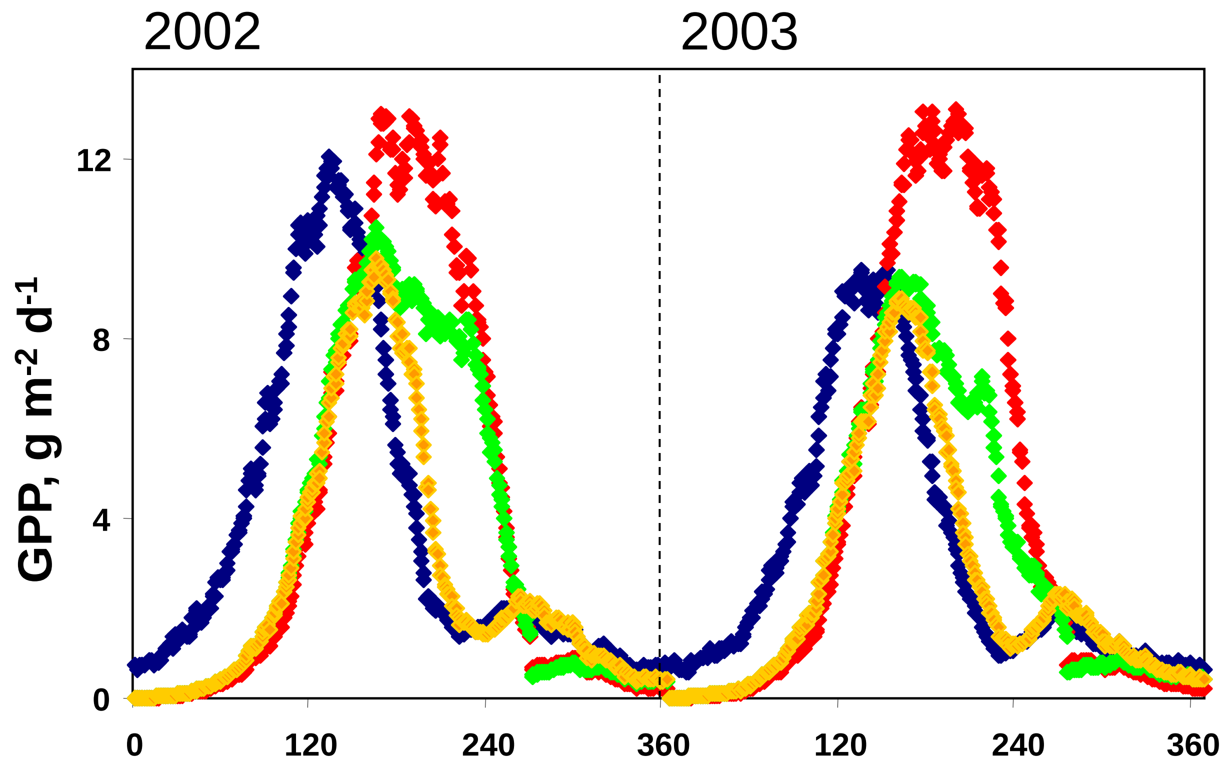
Masks from Remote Sensing or Statistical Data

Crop- or grassland-type cover
Planting date
Fertilization date
Irrigation date
Harvest date

Management specific behavior at pixel level for crop and grass-land types

Average PIXGRO$_{fine}$ Response Across Europe





Mix according to cover and management →

Combined Crops

→ **Final numbers**

You Need Some Kind of

“Up-scaling”

Exactly what you need is not clear.

Classification from a 1km-Layer to a 10km-Layer

soils type

3	3	2	2	3	3	4	4	3	2
3	3	2	3	3	3	3	3	2	2
1	3	1	1	1	4	3	3	2	2
1	2	1	2	2	3	3	3	2	2
3	3	3	2	2	3	5	5	5	5
2	3	3	3	3	3	4	4	4	4
4	2	2	3	4	3	4	5	3	3
3	3	3	4	5	5	3	4	3	3
2	2	4	4	5	4	3	3	3	3
1	2	4	5	4	3	3	3	2	3

Where(veg = 4,13,15 or 17)

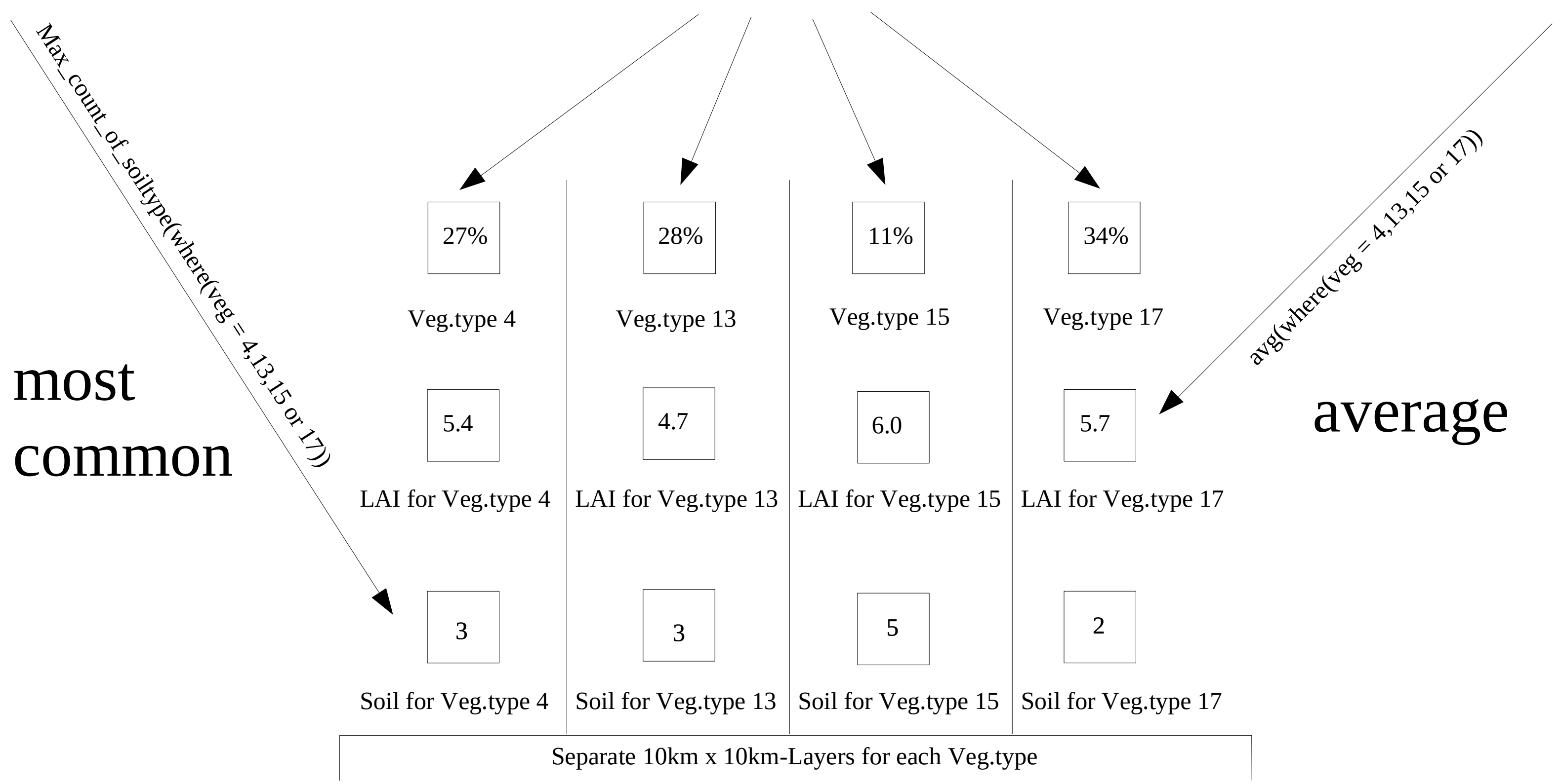
vegetation

13	13	17	17	17	17	17	13	13	17
13	13	13	17	17	17	13	13	17	17
13	13	17	17	17	4	13	13	17	17
17	13	17	17	17	4	13	13	17	17
17	17	17	17	4	4	13	17	4	17
17	17	17	4	4	4	4	4	4	13
4	17	17	4	4	13	13	15	13	13
4	4	17	4	15	15	13	15	13	13
4	4	4	15	15	15	13	13	4	4
4	4	4	15	15	15	13	15	4	4

Where(veg = 4,13,15 or 17)

forest LAI

4.2	4.3	5.2	6.1	5.2	5.3	5.7	4.2	4.2	6.2
4.1	4.0	4.2	5.9	4.2	4.2	4.8	4.4	6.2	6.9
4.2	4.2	5.8	5.4	4.8	4.2	5.0	5.2	5.8	6.1
6.2	4.2	5.3	5.1	4.2	4.6	5.5	4.2	5.7	5.4
5.9	6.2	6.0	5.8	4.2	5.2	5.4	6.2	5.5	5.8
5.6	7.0	6.2	5.2	6.2	6.2	5.3	5.9	5.4	4.2
6.2	6.5	5.7	4.6	4.2	4.2	4.5	6.2	4.2	4.8
6.1	5.2	5.3	4.8	6.1	6.0	5.2	5.8	5.2	5.8
6.0	6.1	4.2	6.2	5.9	5.7	6.3	4.2	6.2	5.9
5.9	5.3	4.8	5.9	5.9	5.8	6.8	4.2	5.8	6.4



You Need “Phenology”

Synthesis of phenological information is very poor, but . . .

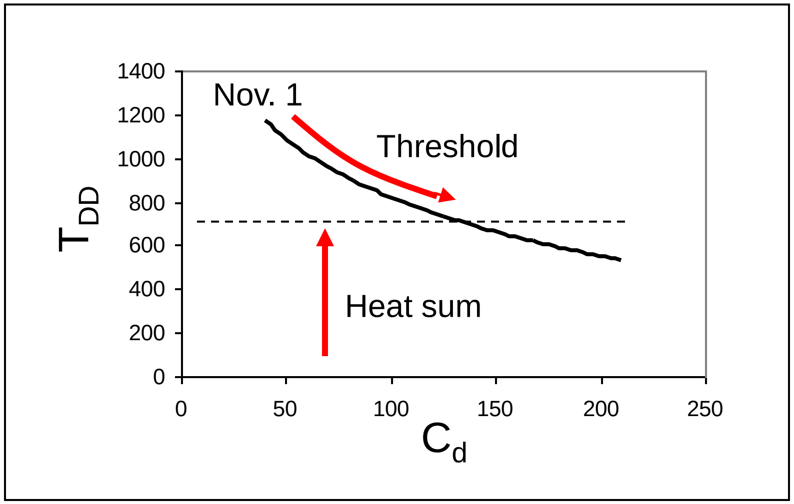
you must start somewhere!

Global Change Biology (2004) **10**, 1133–1145, doi: 10.1111/j.1365-2486.2004.00784.x

Climate controls on vegetation phenological patterns in northern mid- and high latitudes inferred from MODIS data

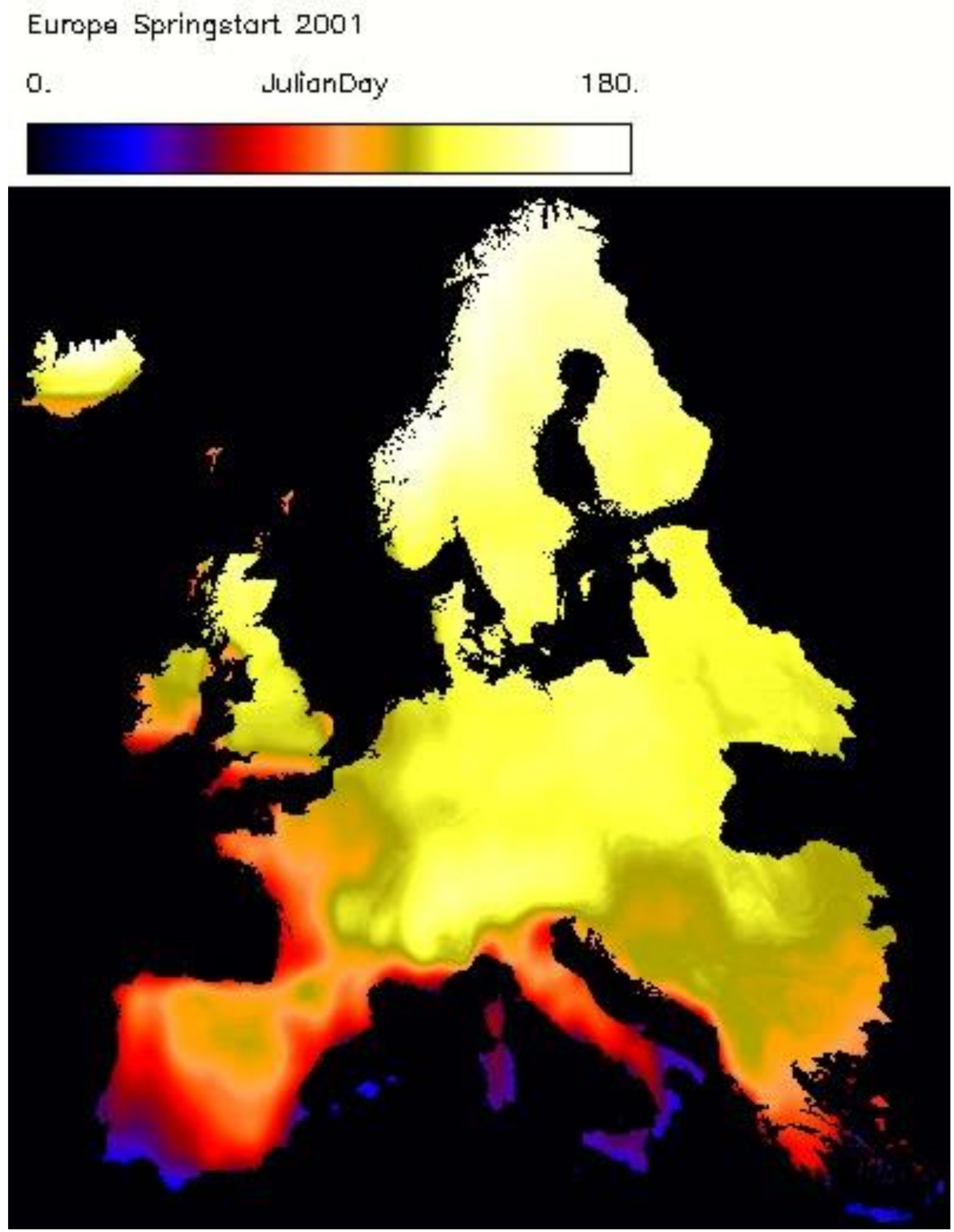
XIAOYANG ZHANG, MARK A. FRIEDL, CRYSTAL B. SCHAAF, ALAN H. STRAHLER
Department of Geography, Center for Remote Sensing, Boston University, 675 Commonwealth Avenue, Boston, MA 02215, USA

Phenology, e.g, springtime greenup, is estimated according to Zhang et al. 2004 considering chilling time and heat sums.

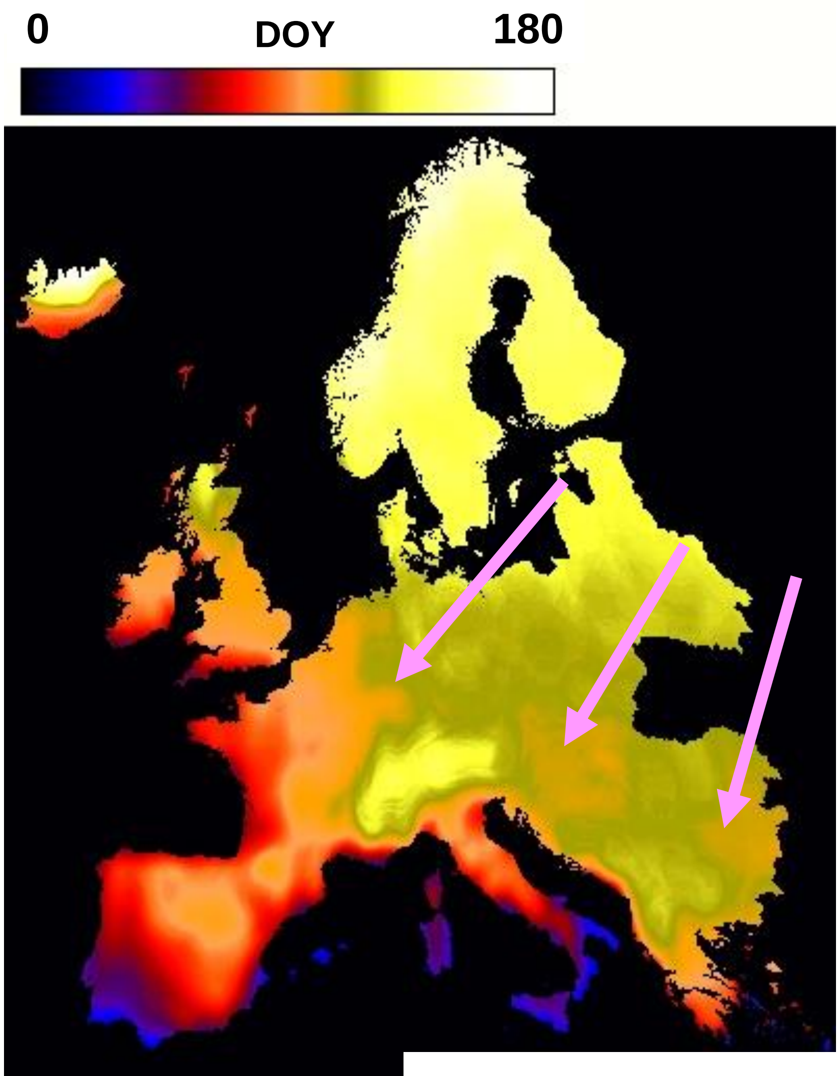


$$T_{DD} = \alpha + \beta e^{-\gamma C_d}$$

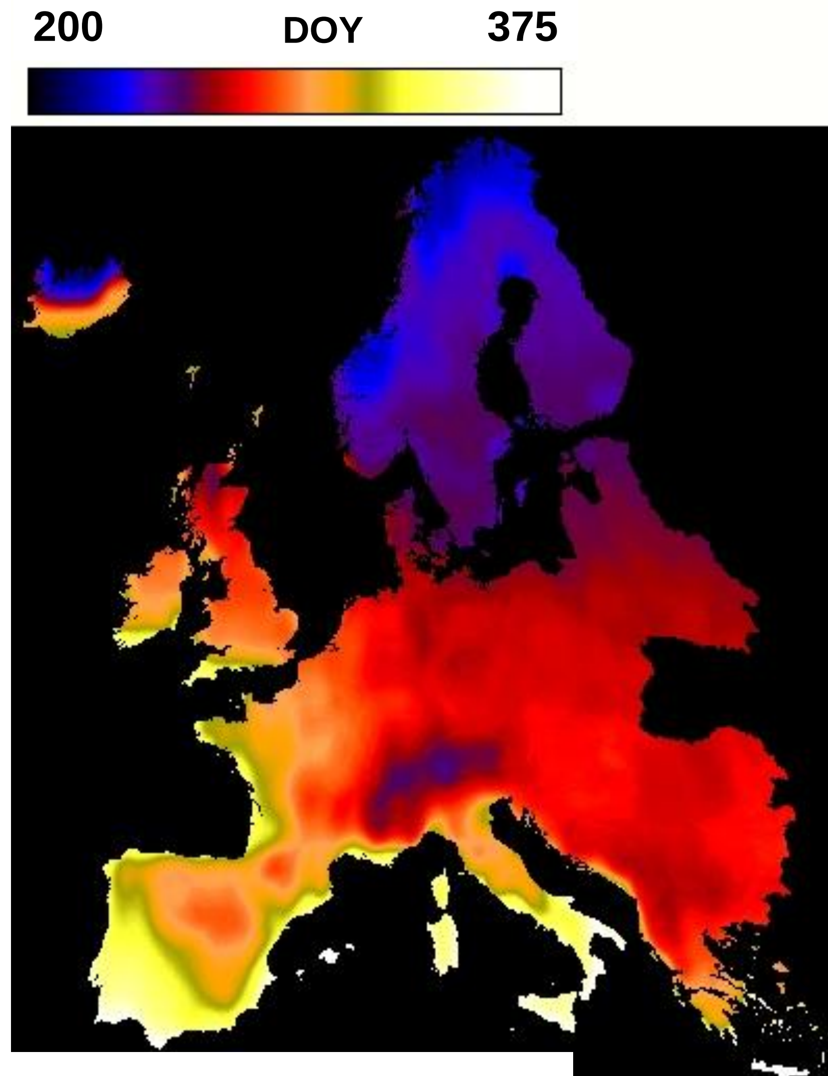
Locally climate specific with annual variation.



Spring Activity Increase



Fall Activity Decrease



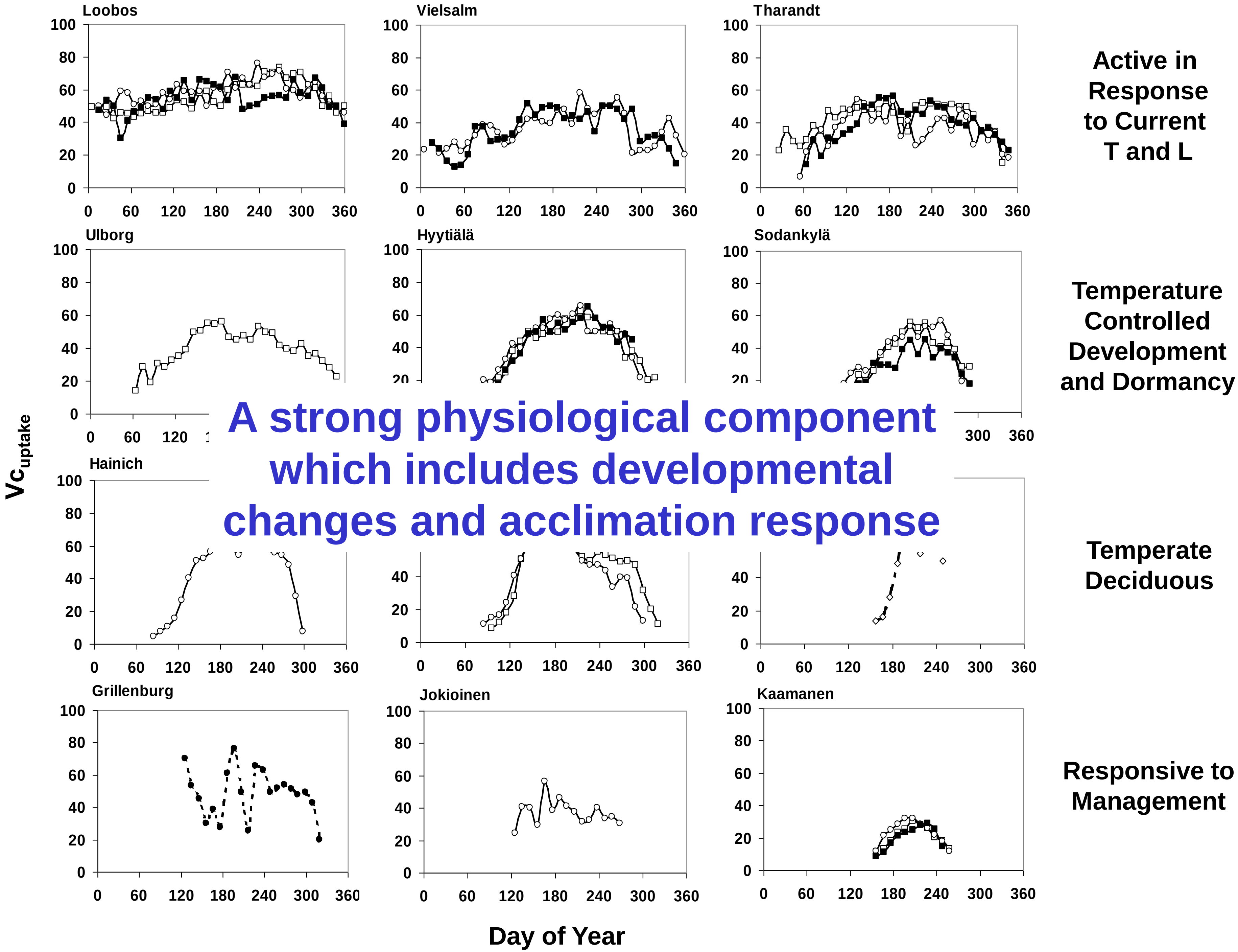
2003 earl ner

Calibration according to observations at eddy covariance sites is possible!

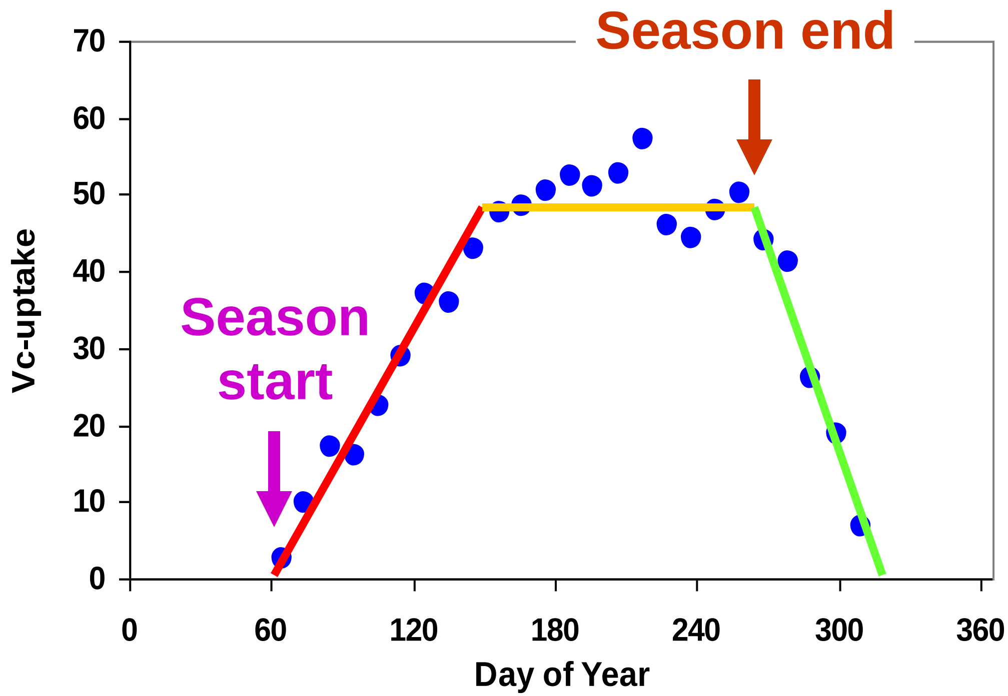
You Need Physiology

“Critical Behavior of Canopies”

We know the principles but spatial generalization if difficult.



Loobos
Vielsalm
Tharandt
Active in Response to Current T and L
Ulborg
Hyytiälä
Sodankylä
Temperature Controlled Development and Dormancy
Hainich
Temperate Deciduous
Grillenburg
Jokioinen
Kaamanen
Responsive to Management
Vc uptake
Day of Year
A strong physiological component which includes developmental changes and acclimation response



Critical PIXGRO Phenology

DAO weather → PIXGRO Annual GPP
Canopy model

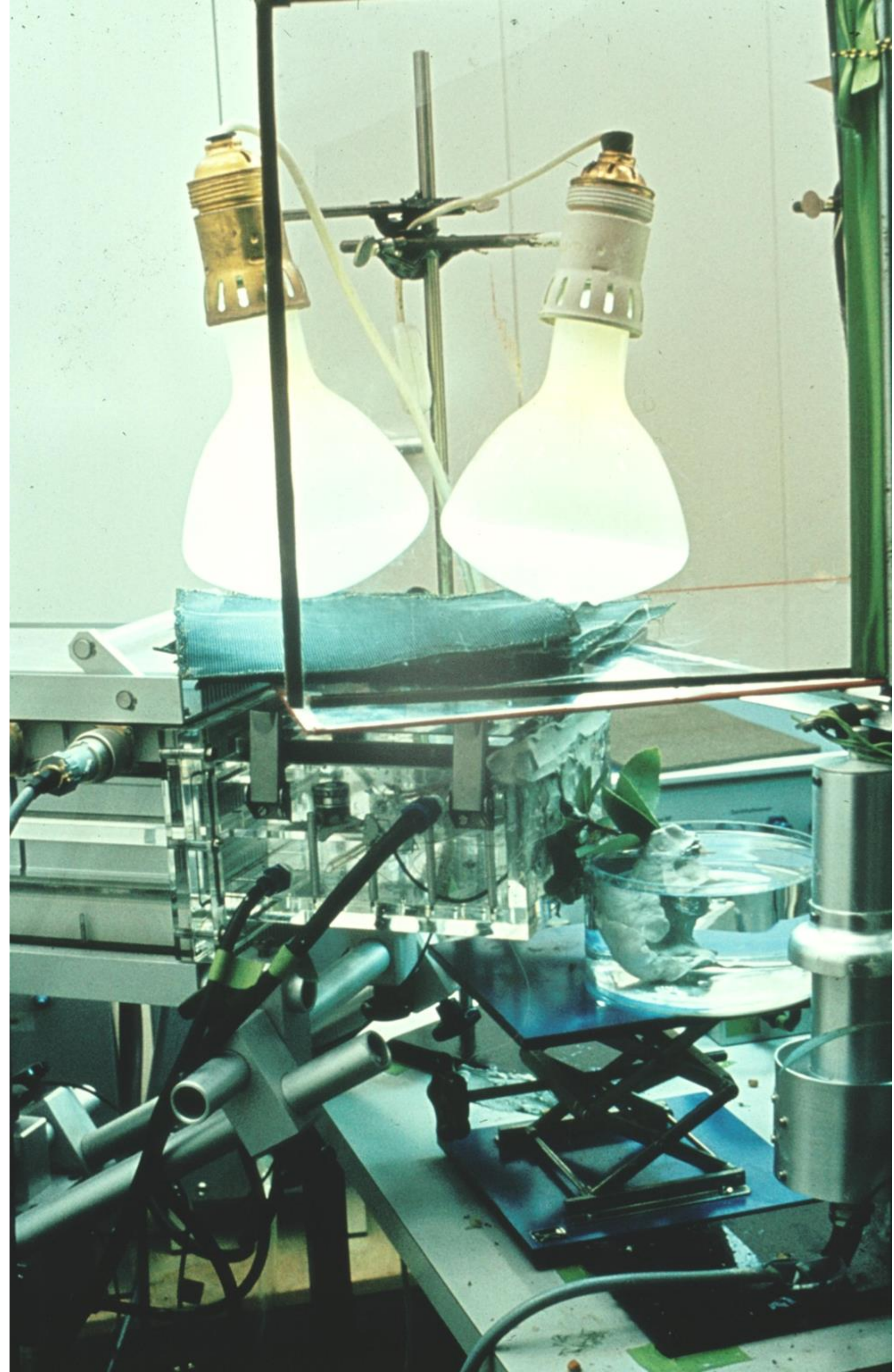
Vc_{Uptake} is characterized <u>for each vegetation class</u> by:

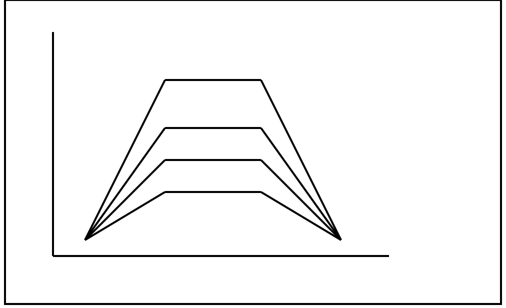
1) rate of spring increase
2) maximum achieved during mid - growth - period
3) rate of fall decrease
4) day on which springtime increase begins = f (temperature climate)
5) day on which fall decrease begins = f (temperature climate)

You Need Sensitivity to

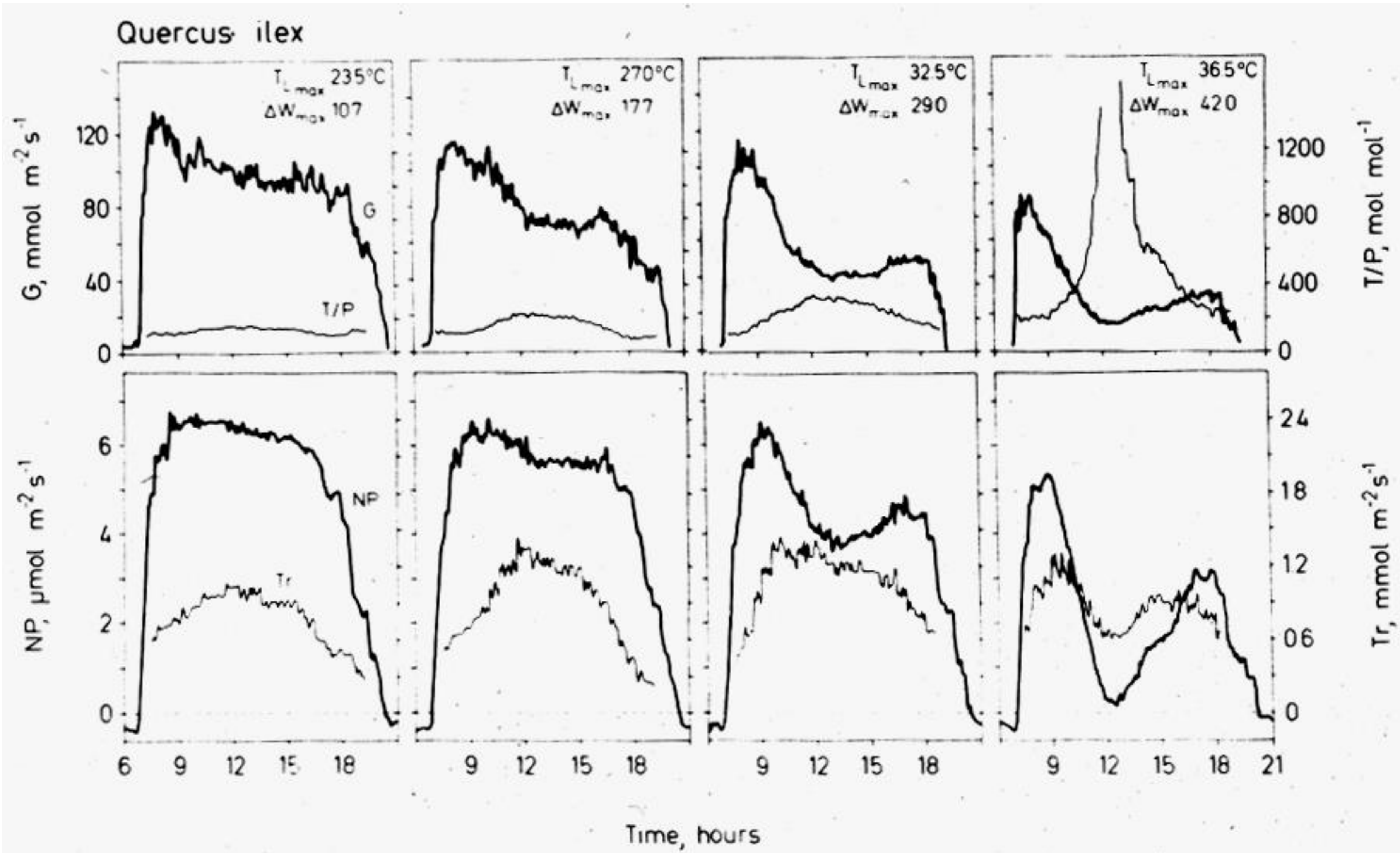
"Critical Environmental Factors"

Water Stress Response

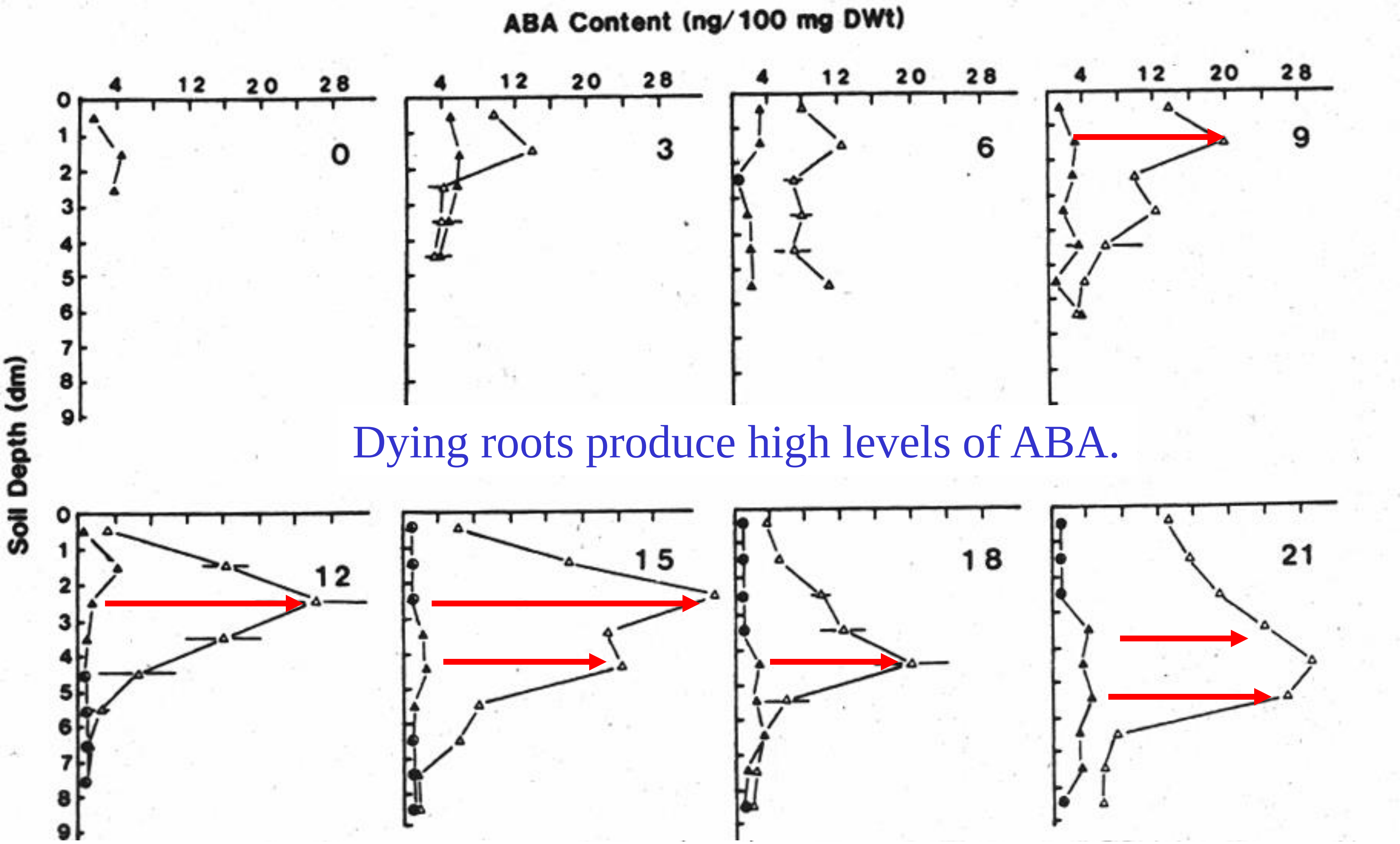





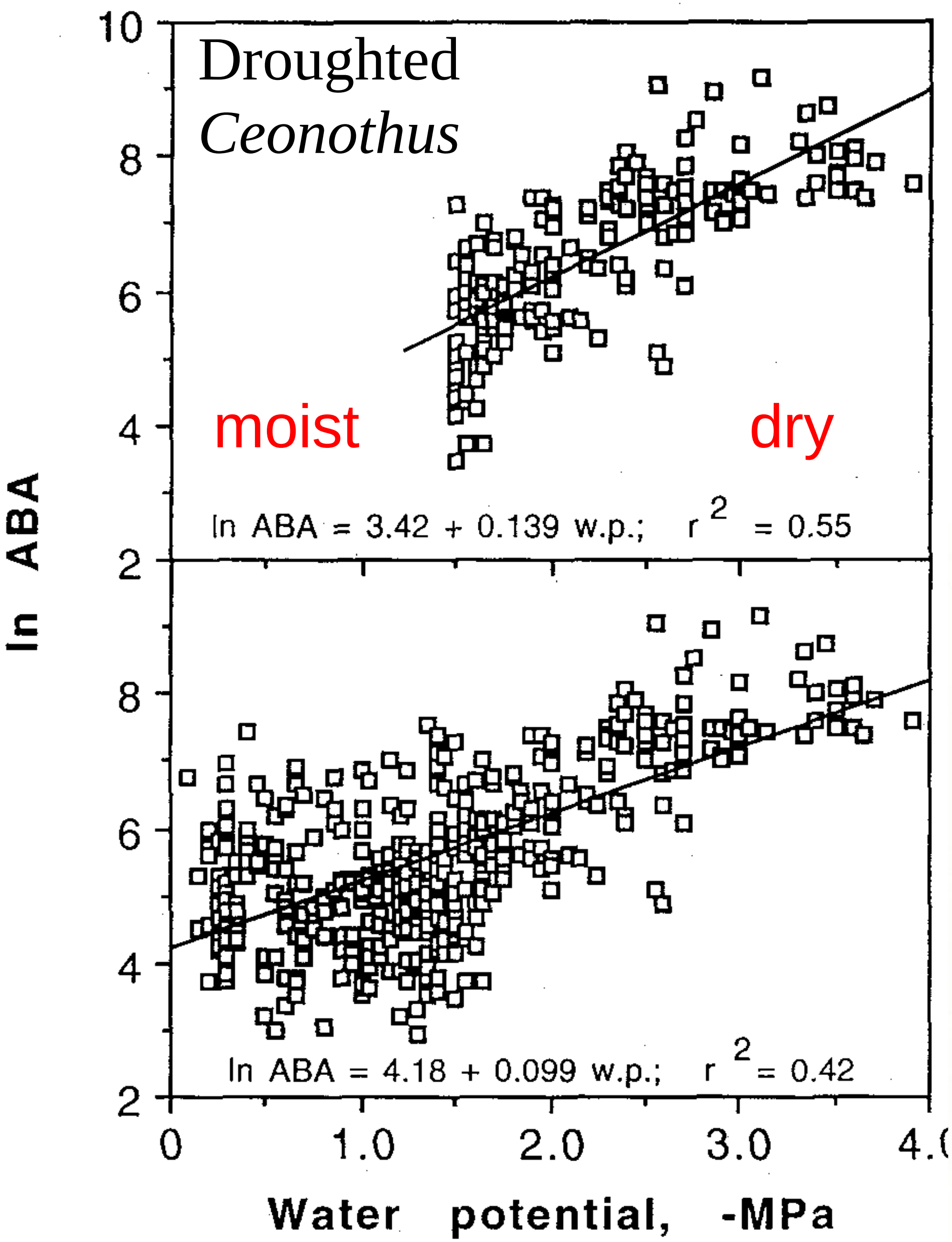
Progressive Increase in Maximum Temperature

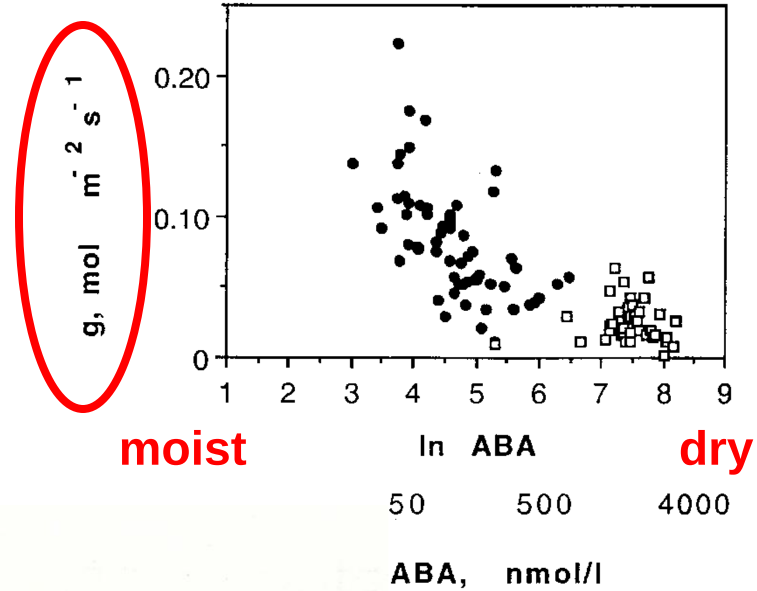


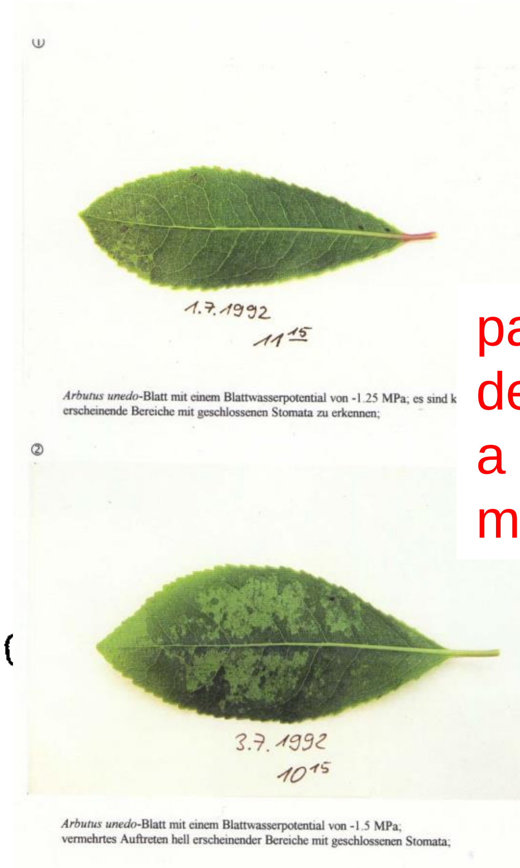
Maize plants planted in Cylinders



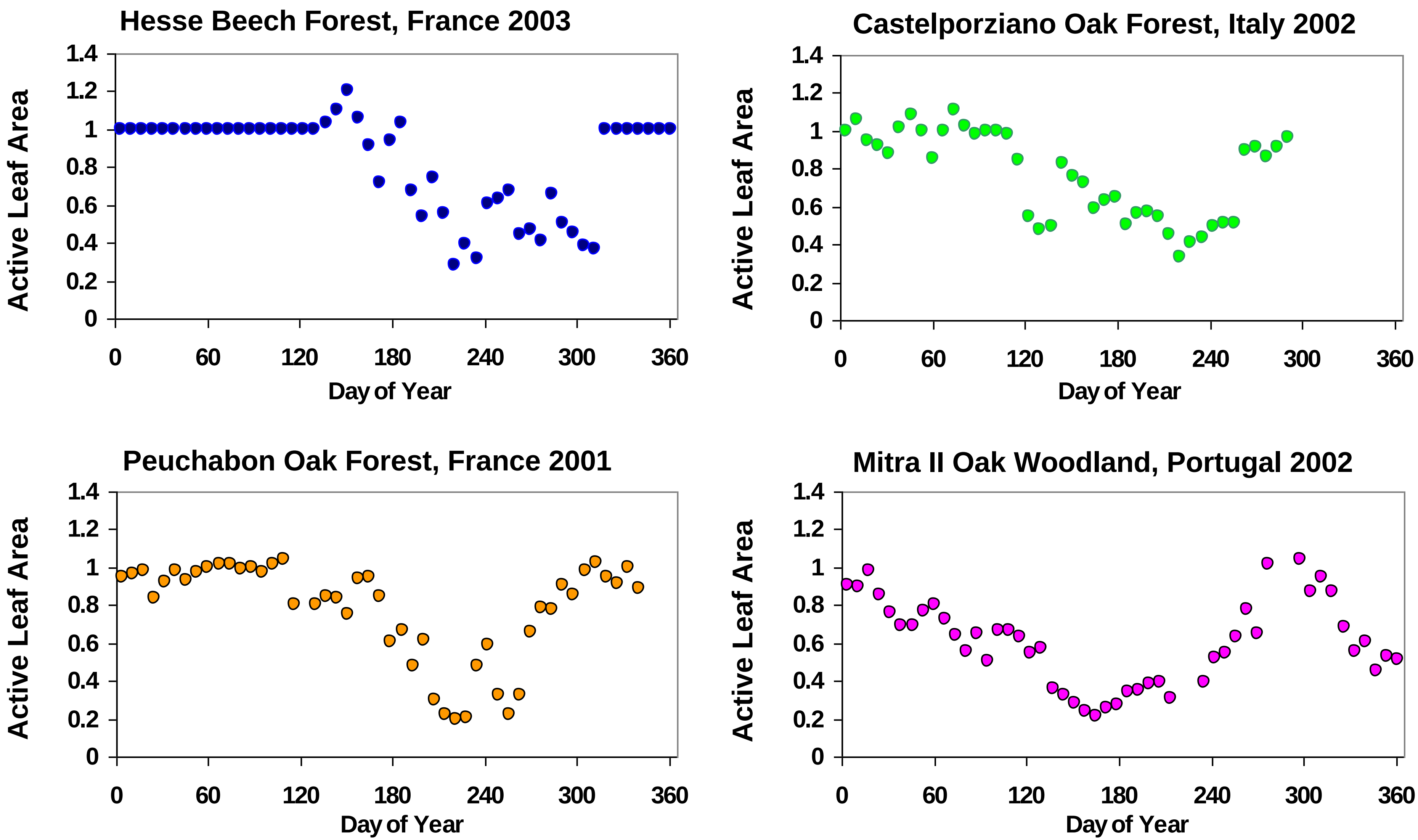
Dying roots produce high levels of ABA.







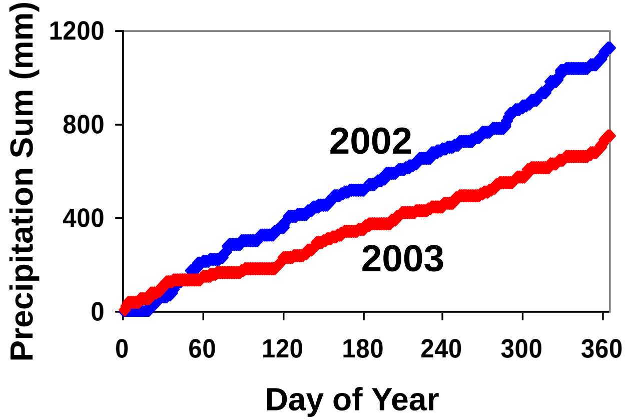
patchy water delivery may be a general control mechanism



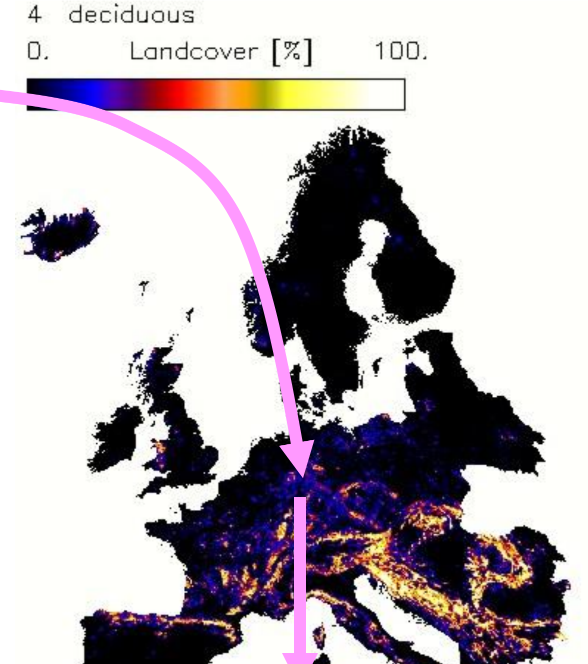
Stomatal factor: assume that carboxylation capacity is known then carry out a second model inversion to estimate patchy stomatal behavior.

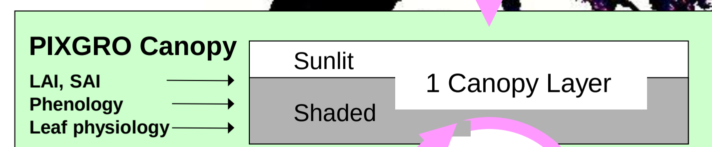
Downscaled DAO Climate

Test Pixel Input



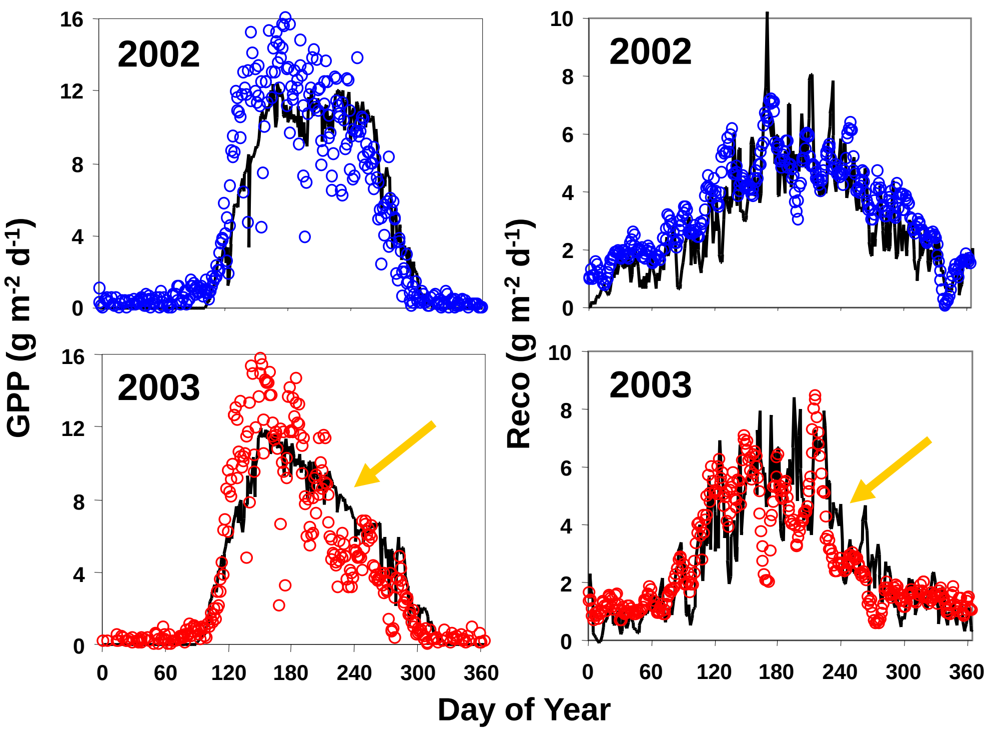
PIXGRO Framework



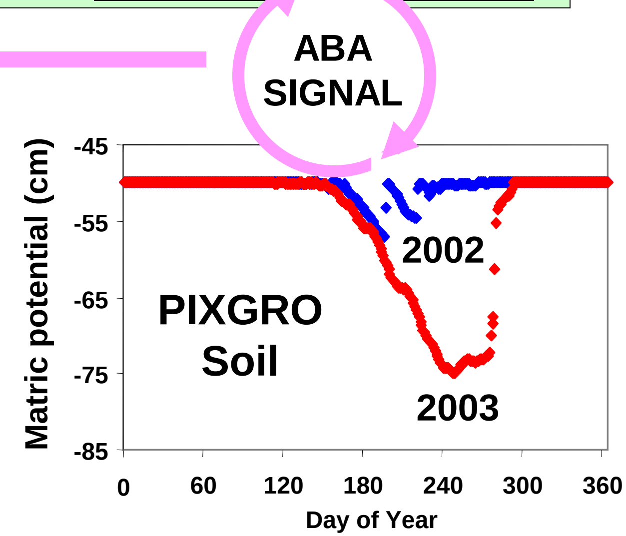


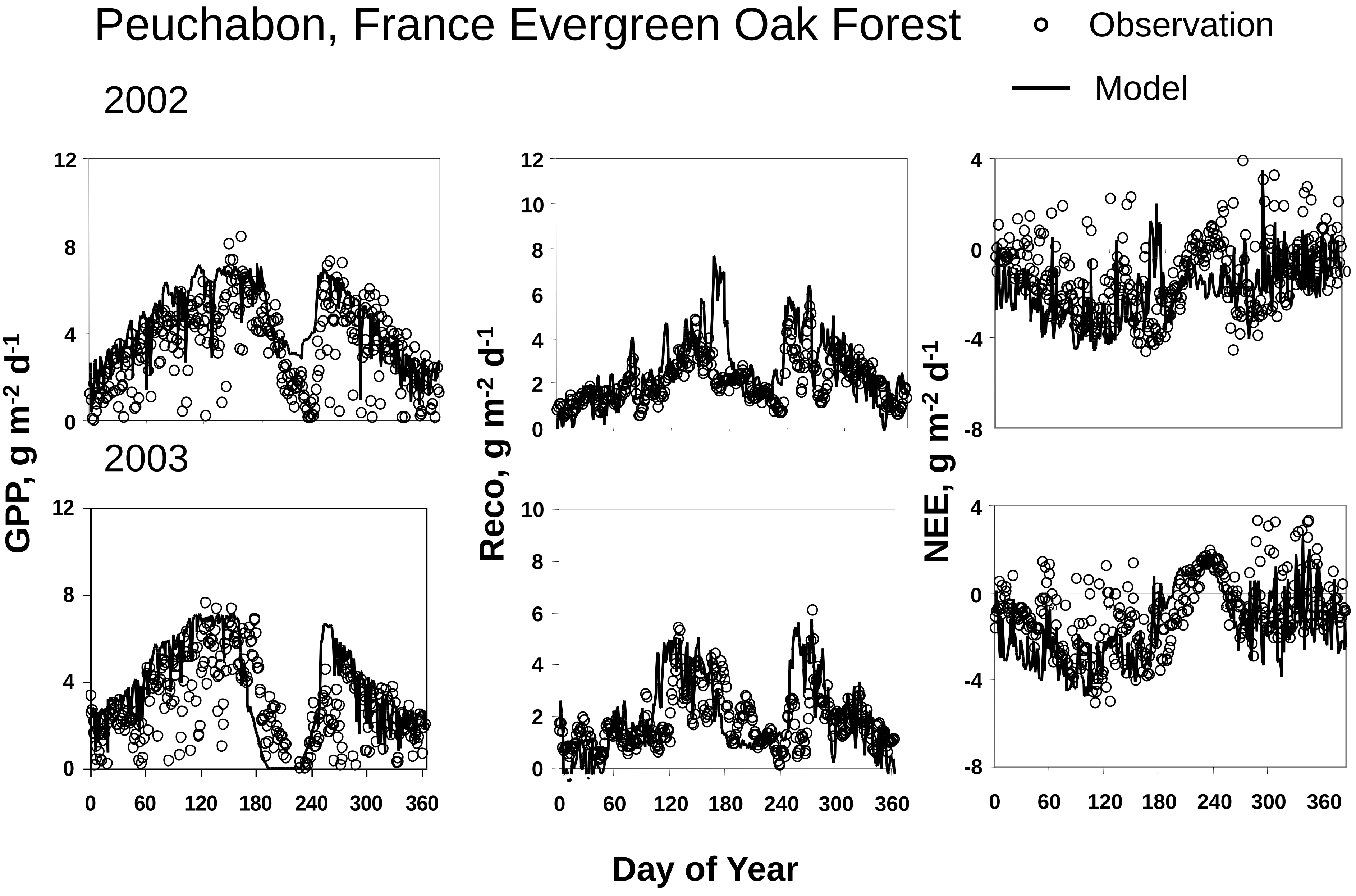
Deciduous Forest Test Site Hesse, etc.

GPP and Reco

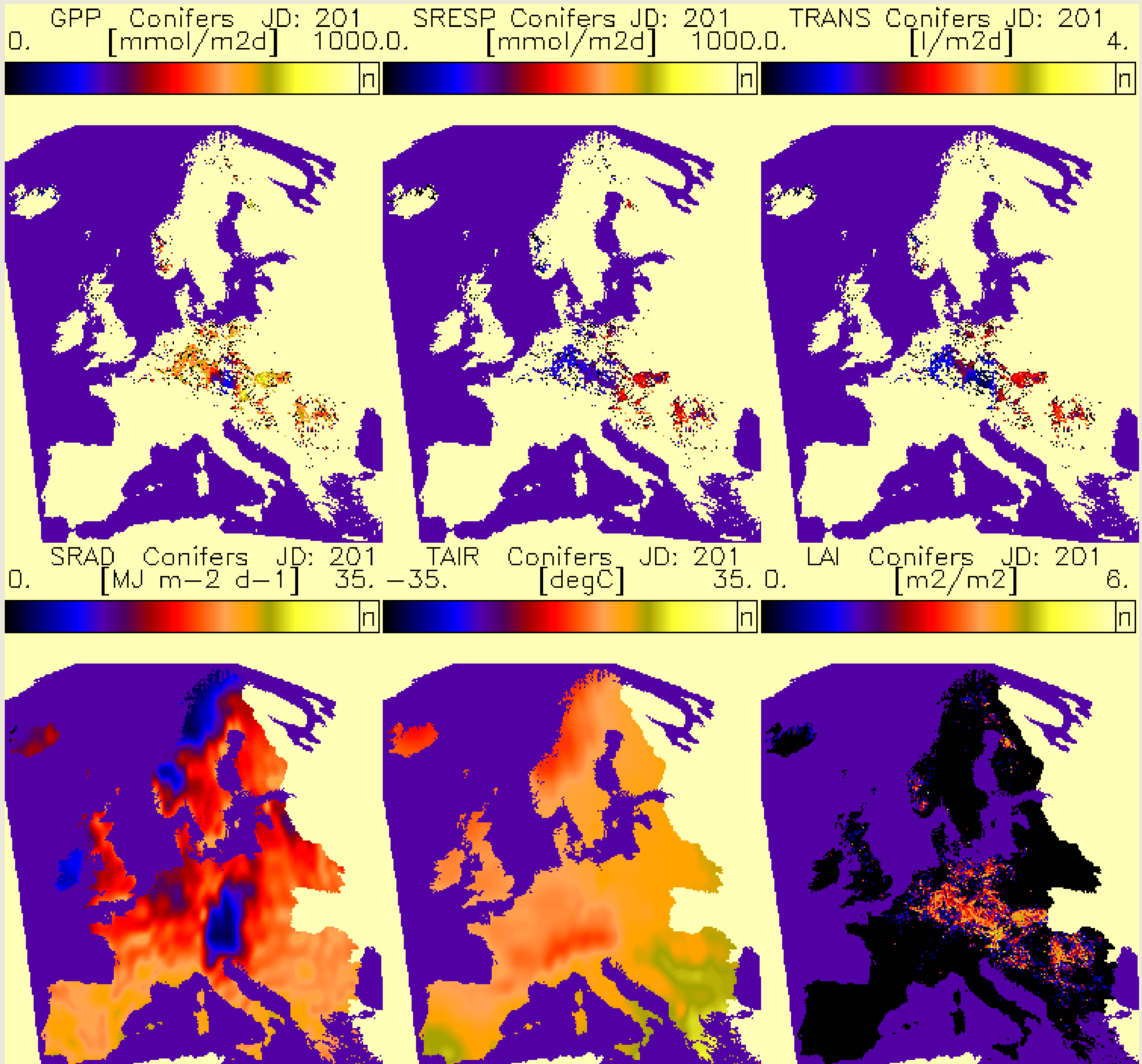


10x10 km pixel output





Peuchabon, France Evergreen Oak Forest
Observation
Model
2002
2003
GPP, g m-2 d-1
Reco, g m-2 d-1
NEE, g m-2 d-1
Day of Year
0
60
120
180
240
300
360



Included:

"Ecosystem physiology from tower sites"

Radiation and temp. response

MODIS max. LAI as constant

DAO weather

Phenology

Elevation influences

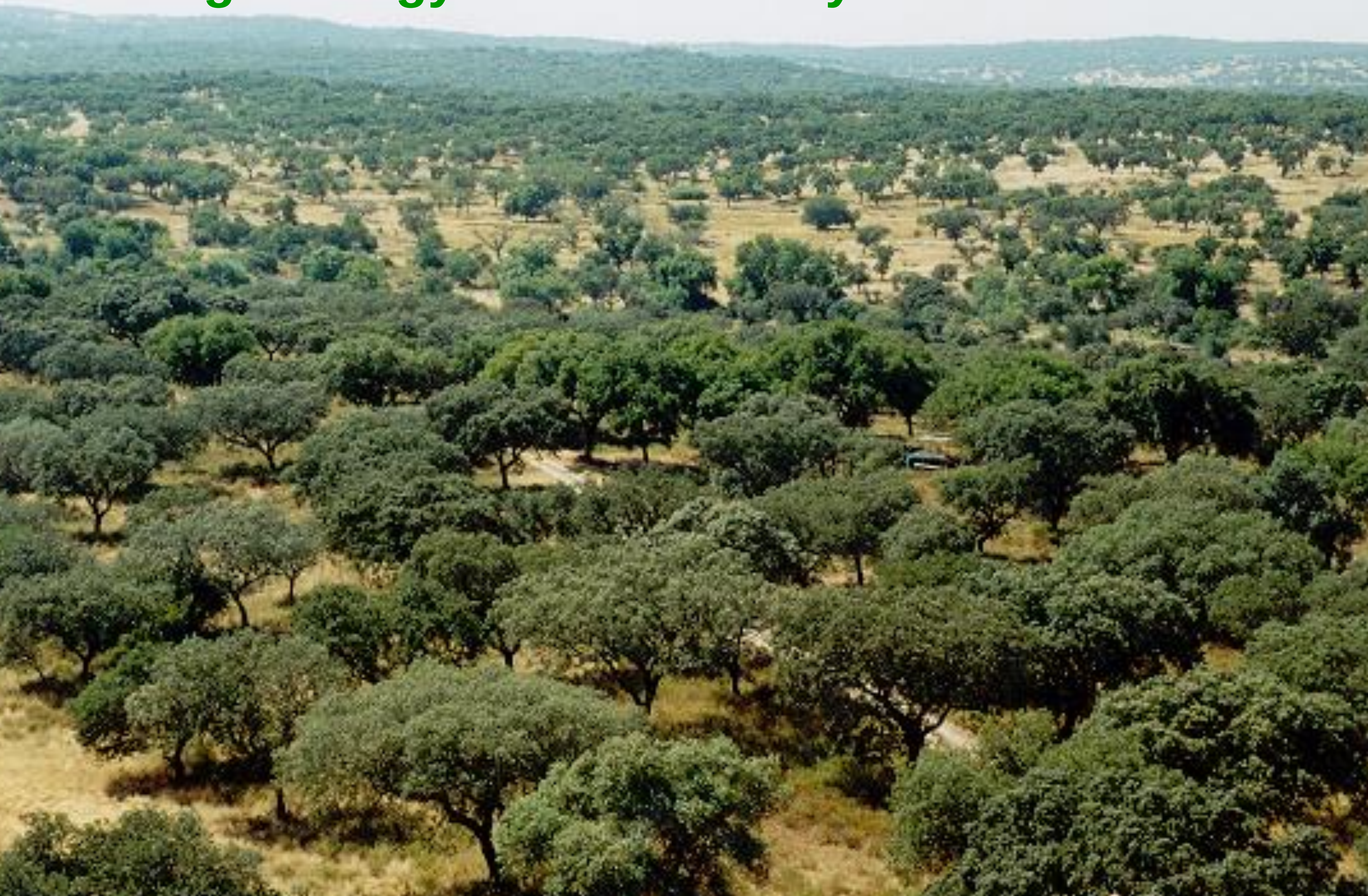
Soil coupling

Water stress

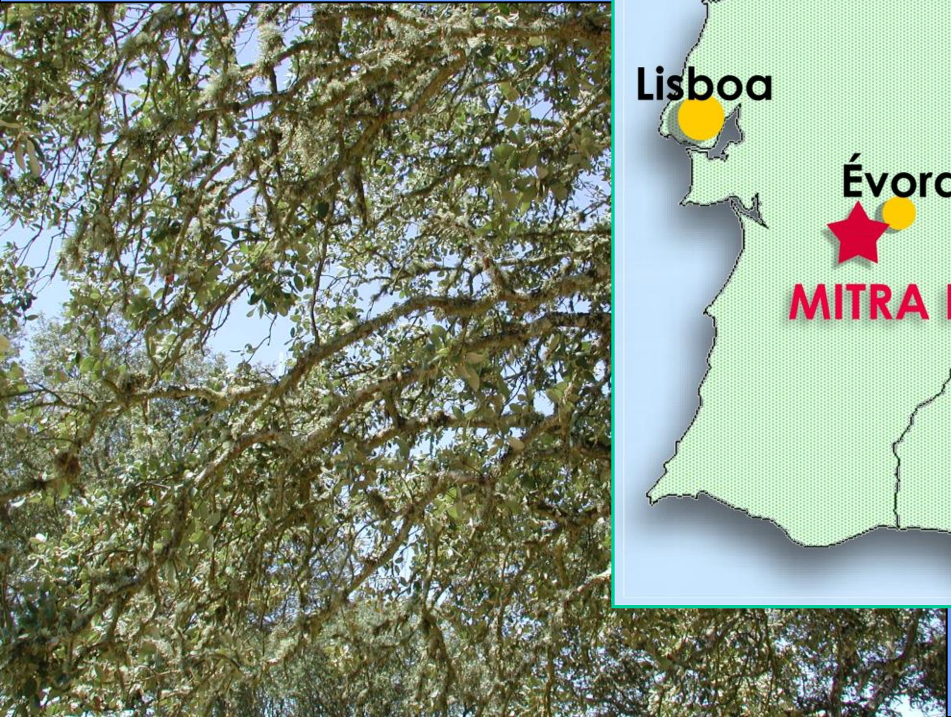
Spatial influence on soil CO_2 efflux

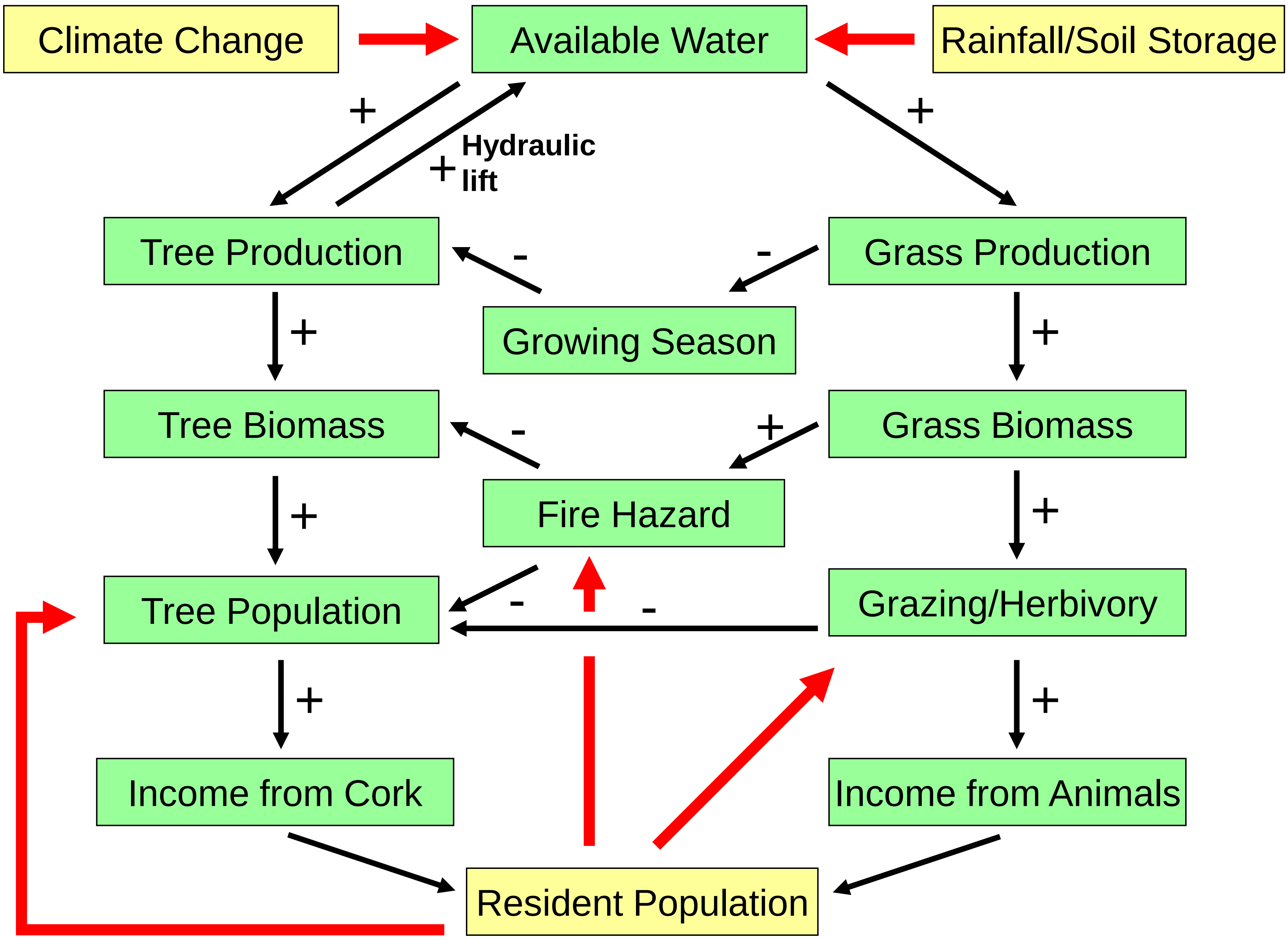
Acclimation!

Controls on Ecosystem Level Fluxes in Savanna: Relating Ecology to Vulnerability of the Montado

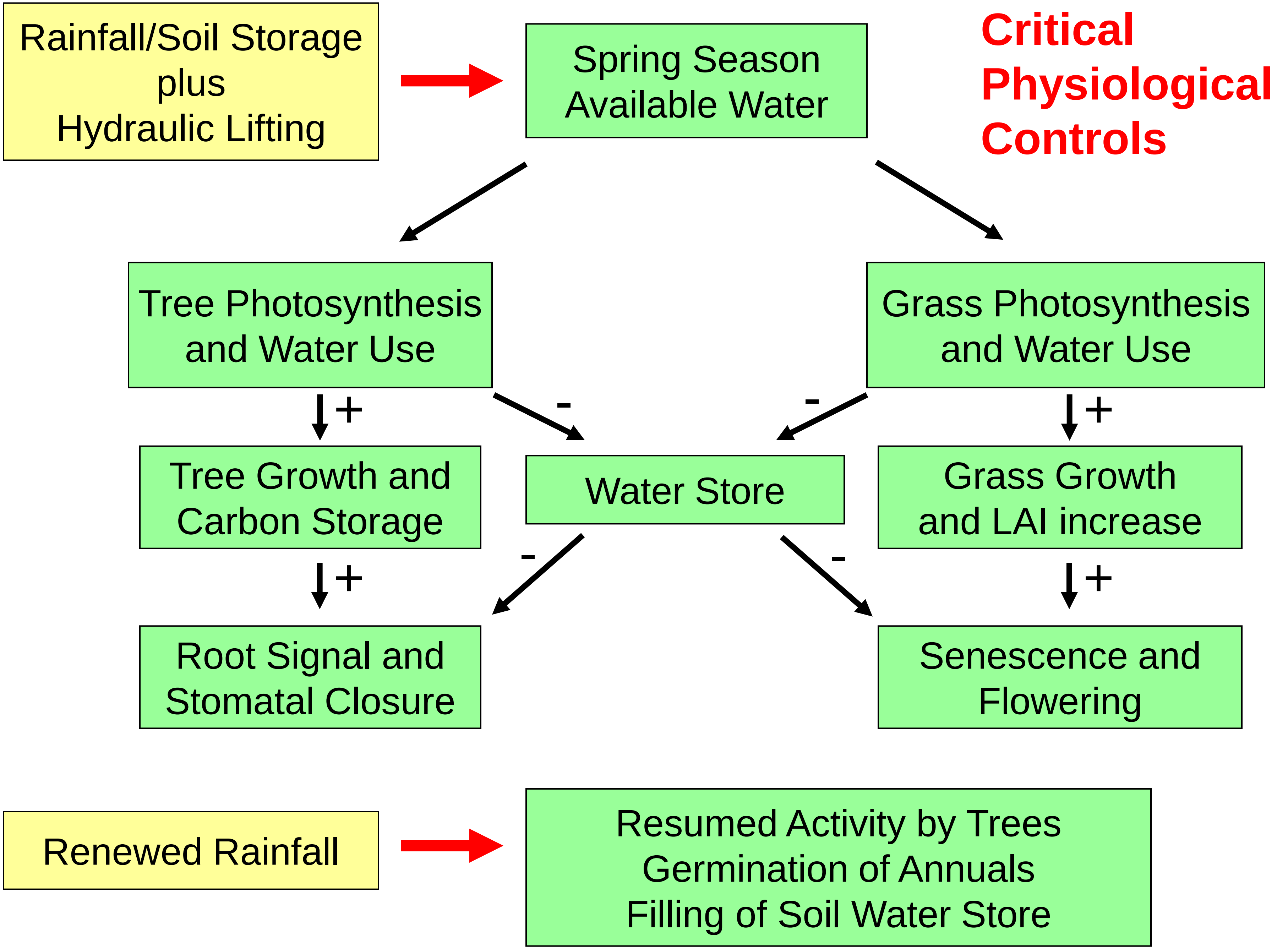


Montado at Herdade de Mitra

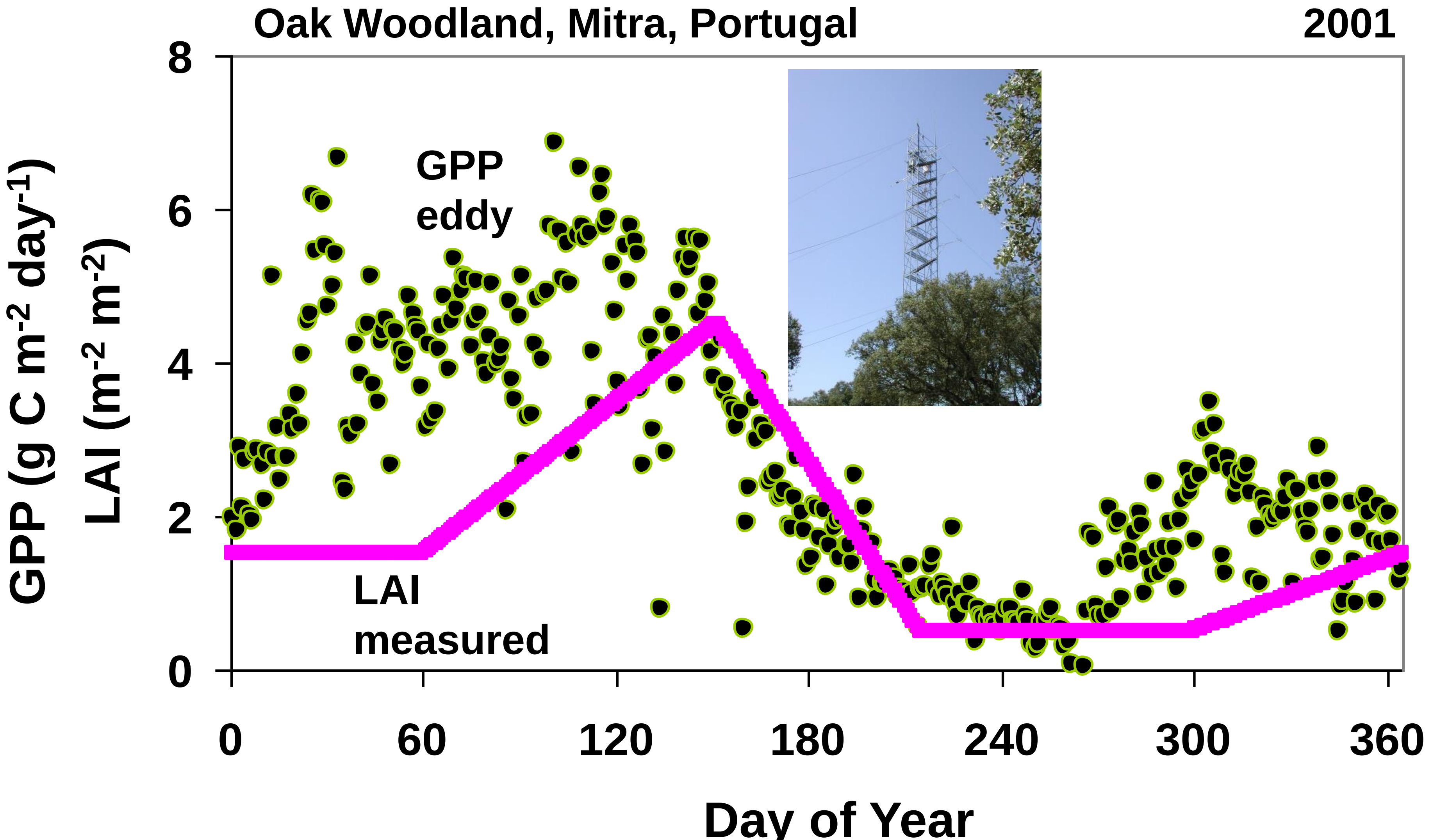




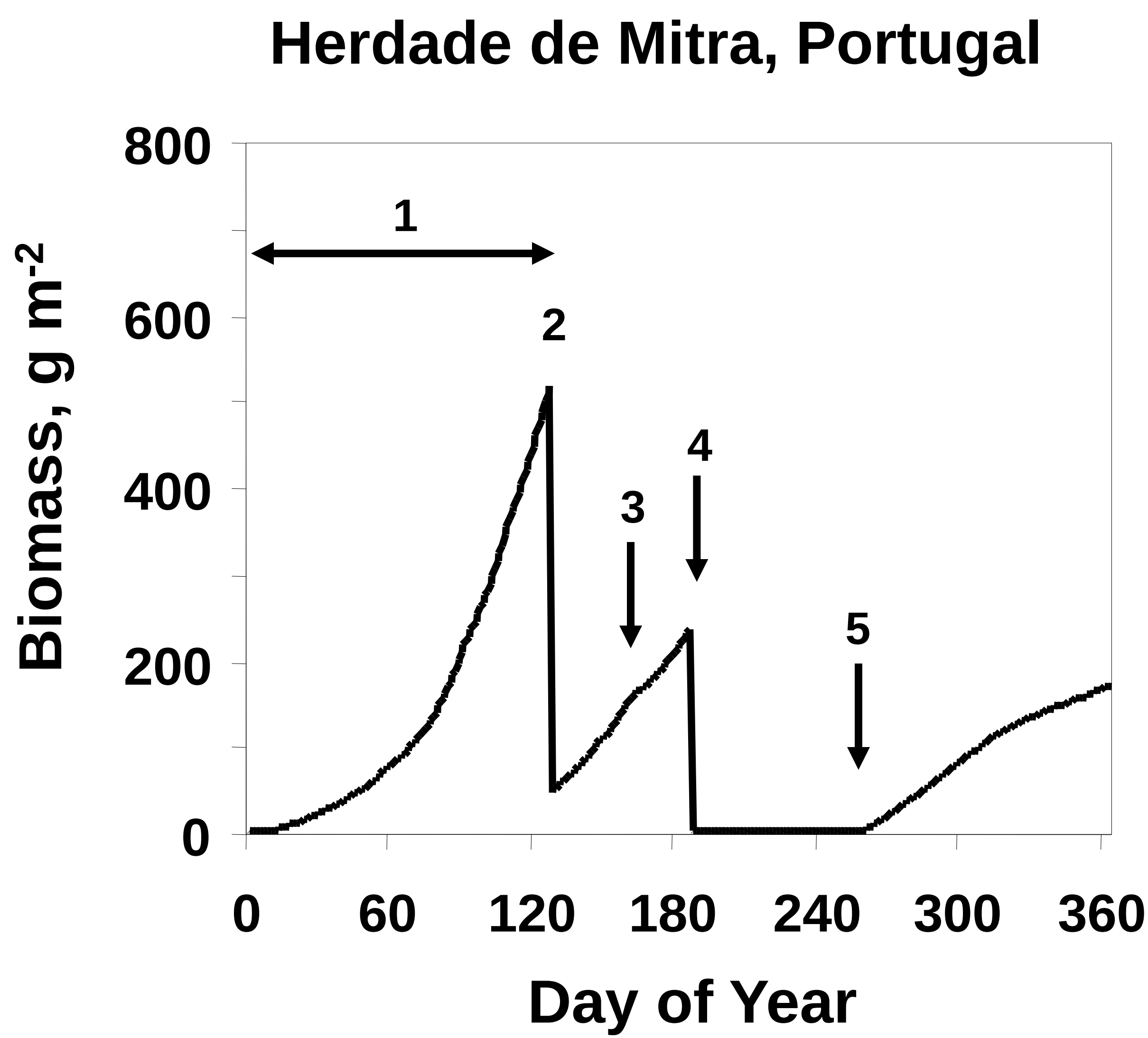
Climate Change
Available Water
Rainfall/Soil Storage
+
Hydraulic
lift
+
+
Tree Production
-
-
Grass Production
+
Growing Season
+
Tree Biomass
-
+
Grass Biomass
+
Fire Hazard
+
-
-
Tree Population
Grazing/Herbivory
+
+
Income from Cork
Income from Animals
Resident Population


Rainfall/Soil Storage
plus
Hydraulic Lifting
Spring Season
Available Water
Critical
Physiological
Controls
Tree Photosynthesis
and Water Use
Grass Photosynthesis
and Water Use
+
-
-
+
Tree Growth and
Carbon Storage
Water Store
Grass Growth
and LAI increase
+
-
-
+
Root Signal and
Stomatal Closure
Senescence and
Flowering
Renewed Rainfall
Resumed Activity by Trees
Germination of Annuals
Filling of Soil Water Store

Relating System Level Fluxes to the Grass Component



The Understory


Herdade de Mitra, Portugal
Biomass, g m-2
800
600
400
200
0
1
2
3
4
5
0
60
120
180
240
300
360
Day of Year

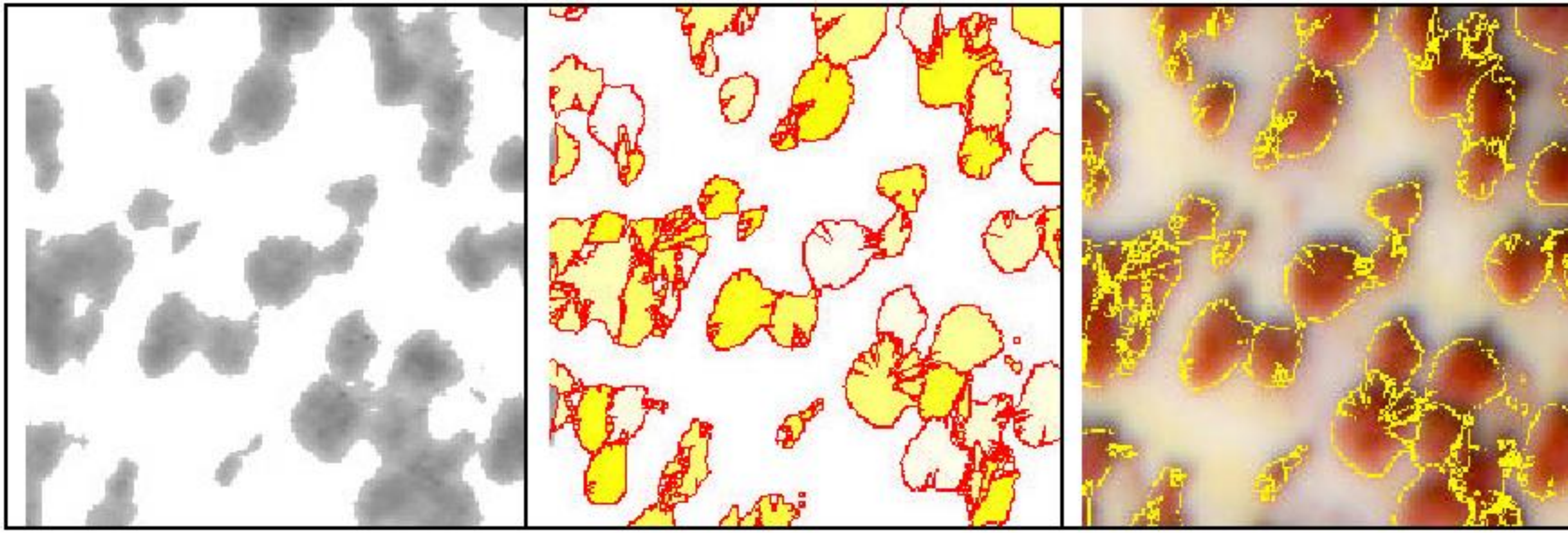
USING THE MODELS:

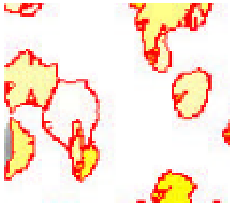
Working Across Scales with

the Aid of Remote Sensing

Surový, Ribeiro et al.

The Mosaic



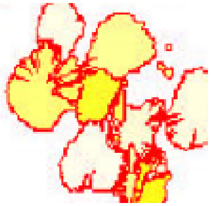


35

Under-story Trees

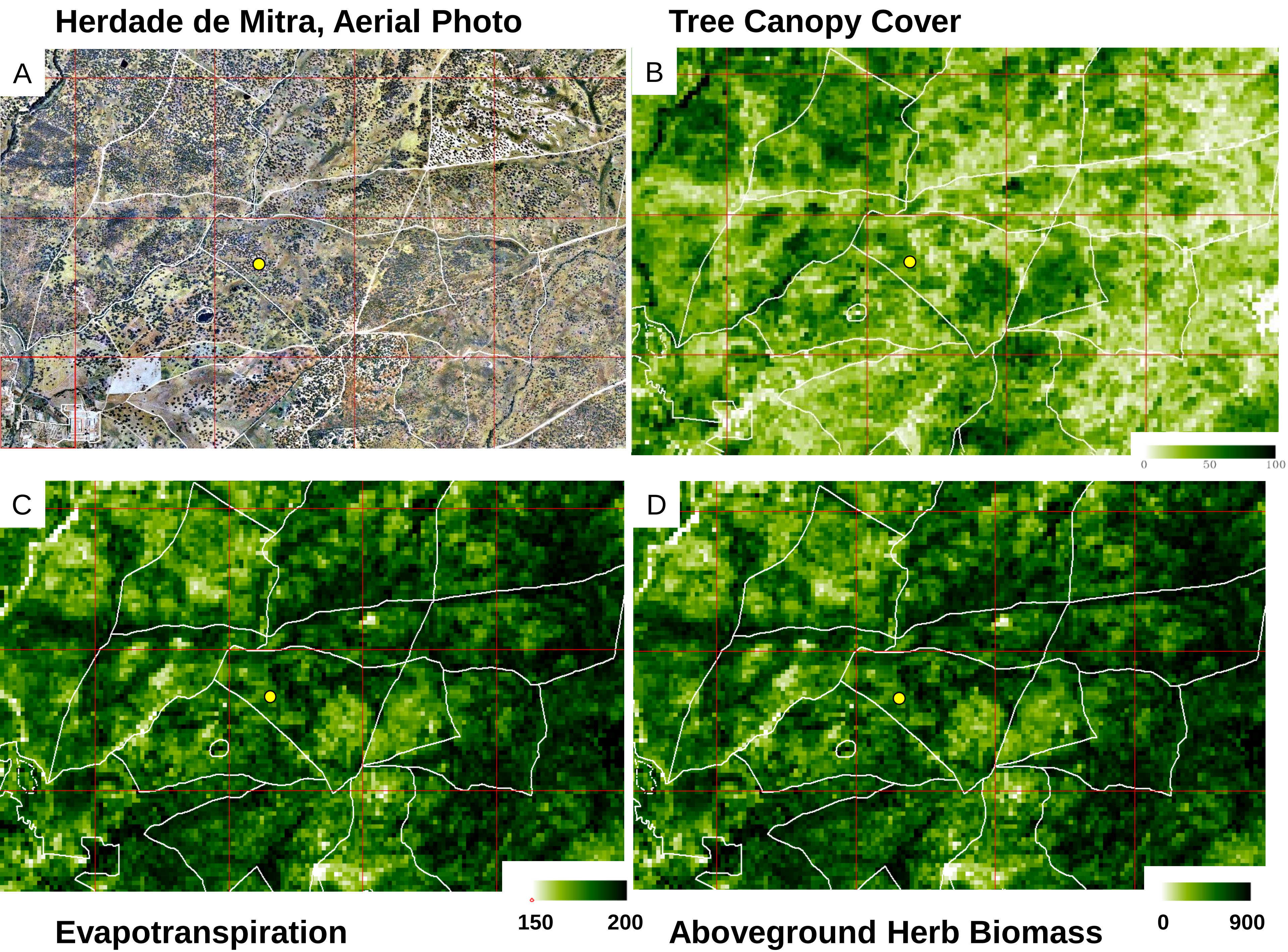
50

Under-story Trees



65

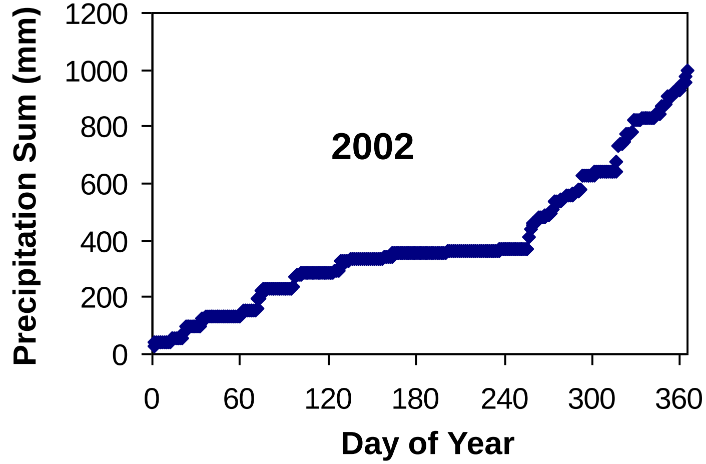
Under-story Trees



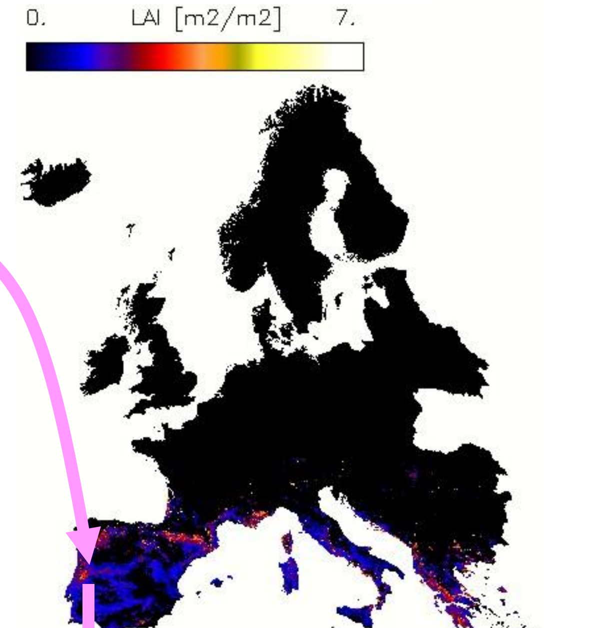
Herdade de Mitra, Aerial Photo
Tree Canopy Cover
A
B
0
50
100
C
D
150
200
0
900
Evapotranspiration
Aboveground Herb Biomass

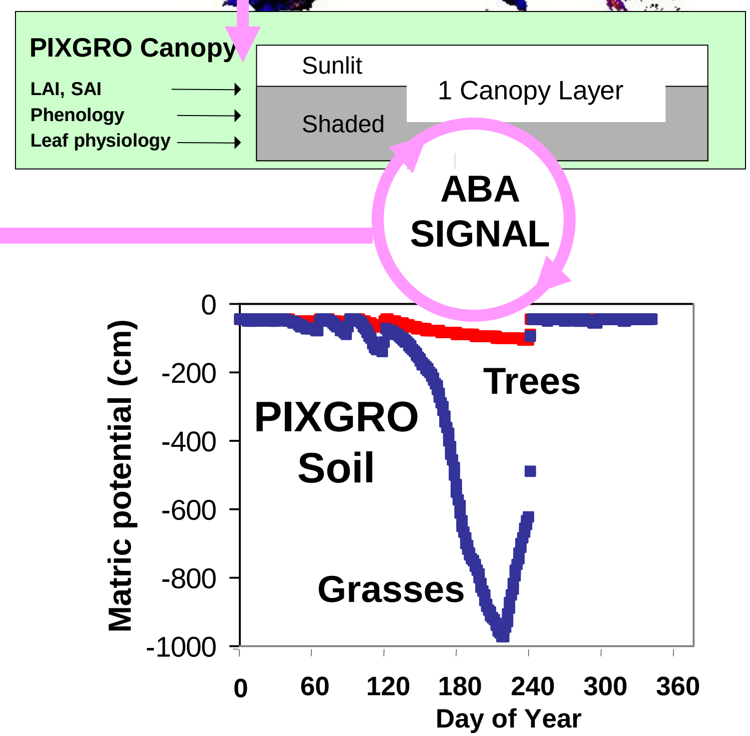
Downscaled DAO Climate

Test Pixel Input



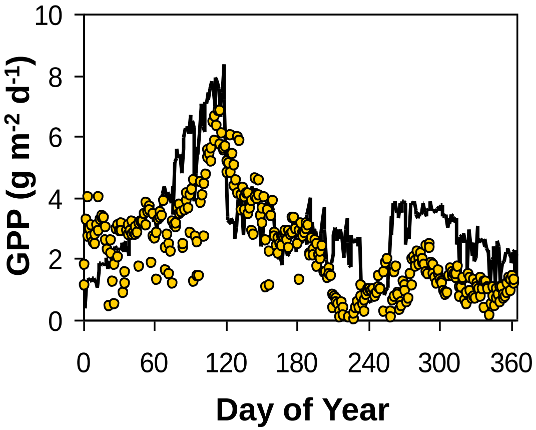
PIXGRO Framework





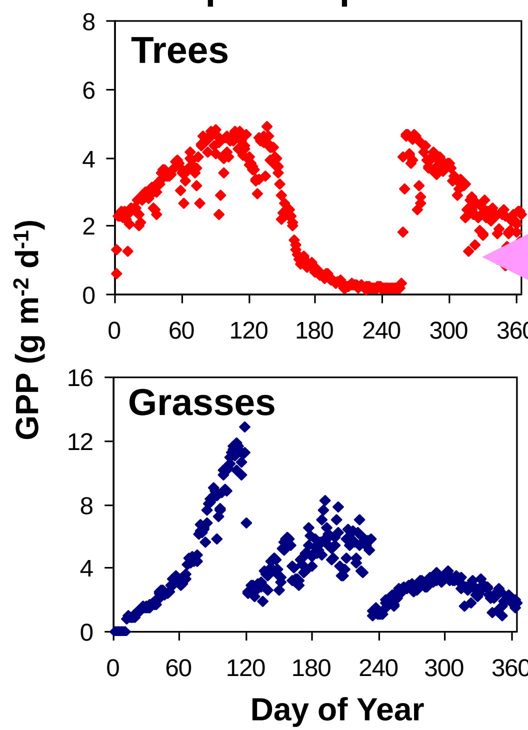
GPP at Mitra II in Evora, Portugal
10 x 10 km pixel output

Savanna ecosystem depending on cover %

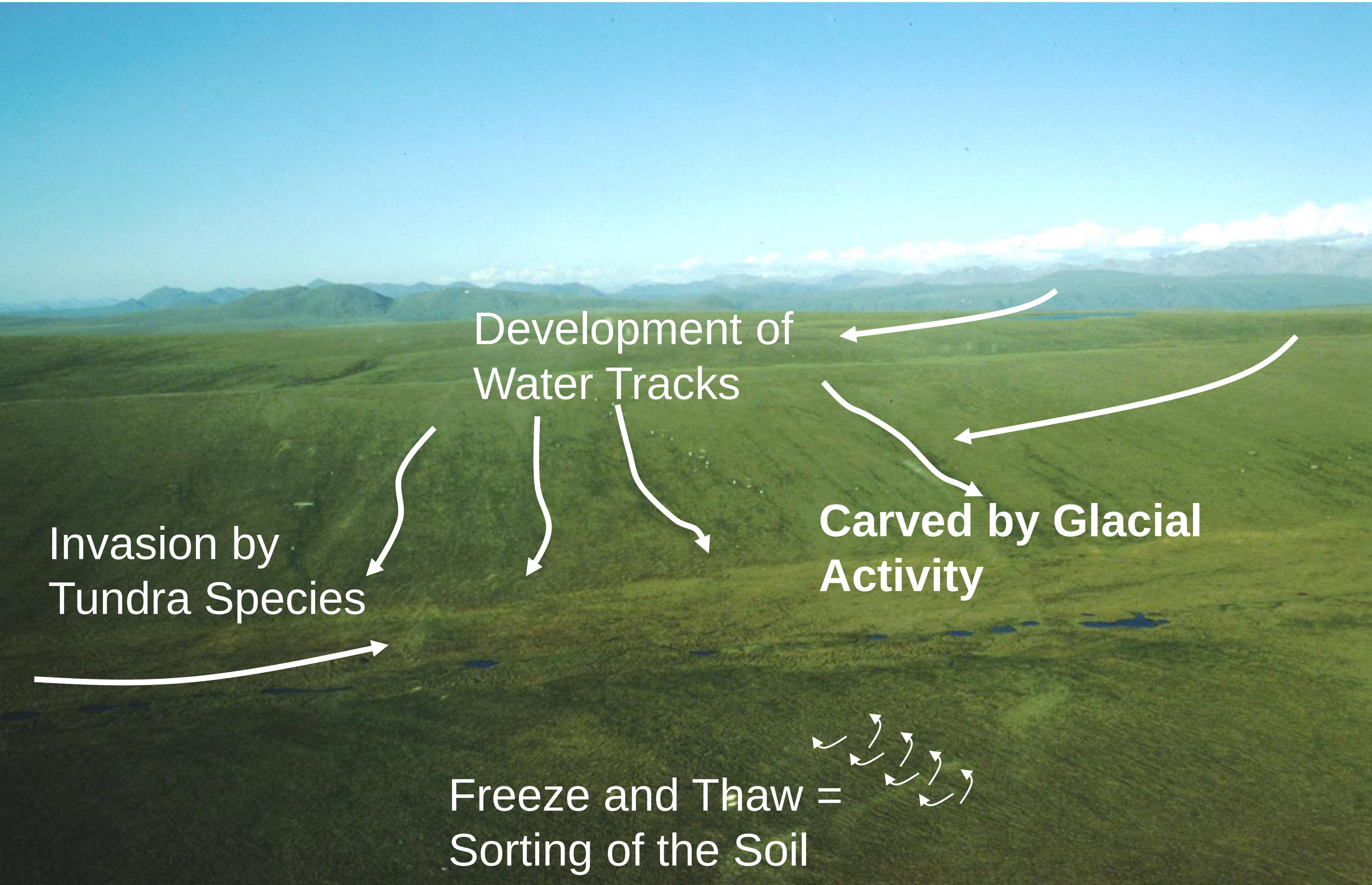


Solid line = observed
Symbols = modelled

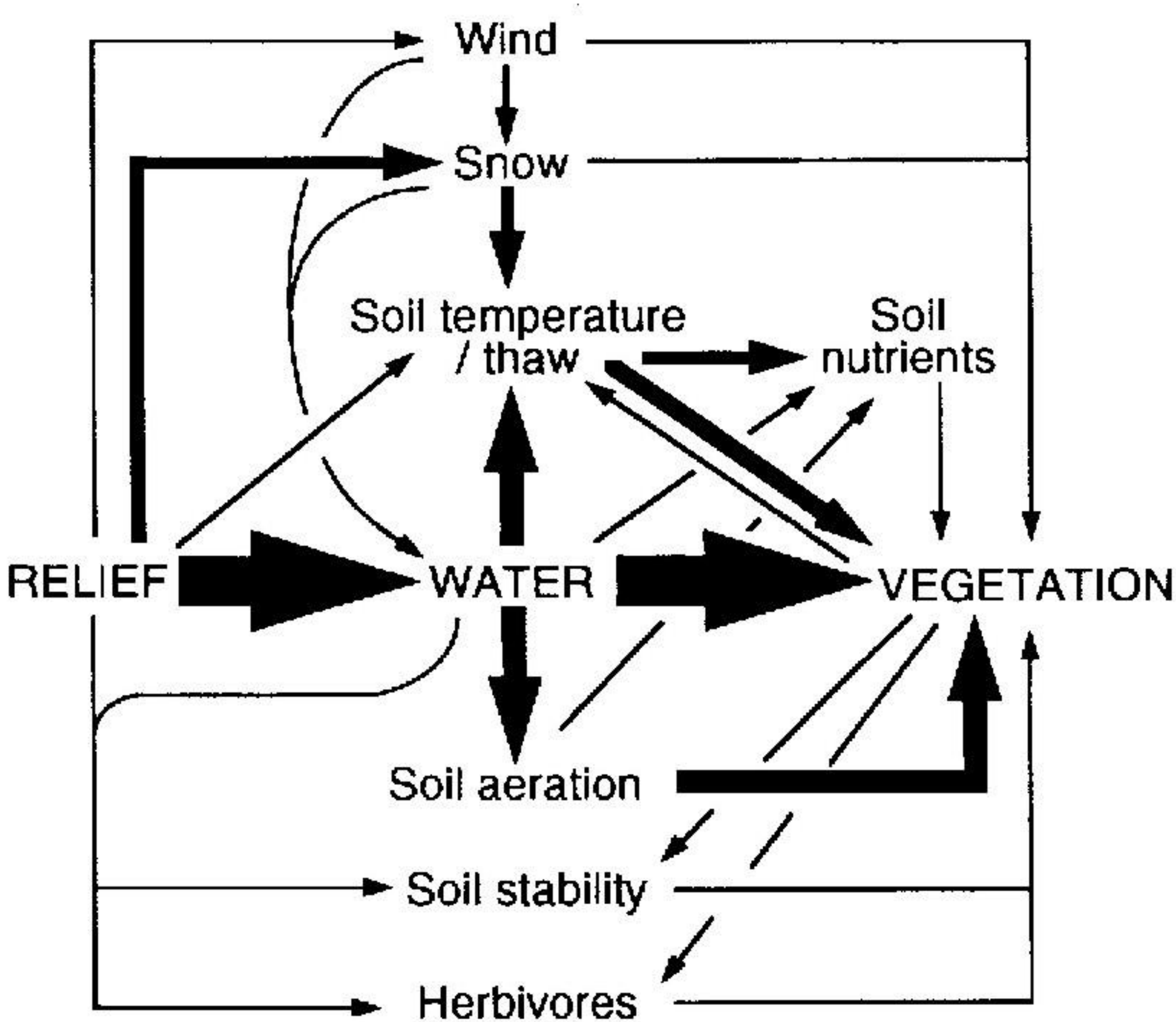
Component predictions



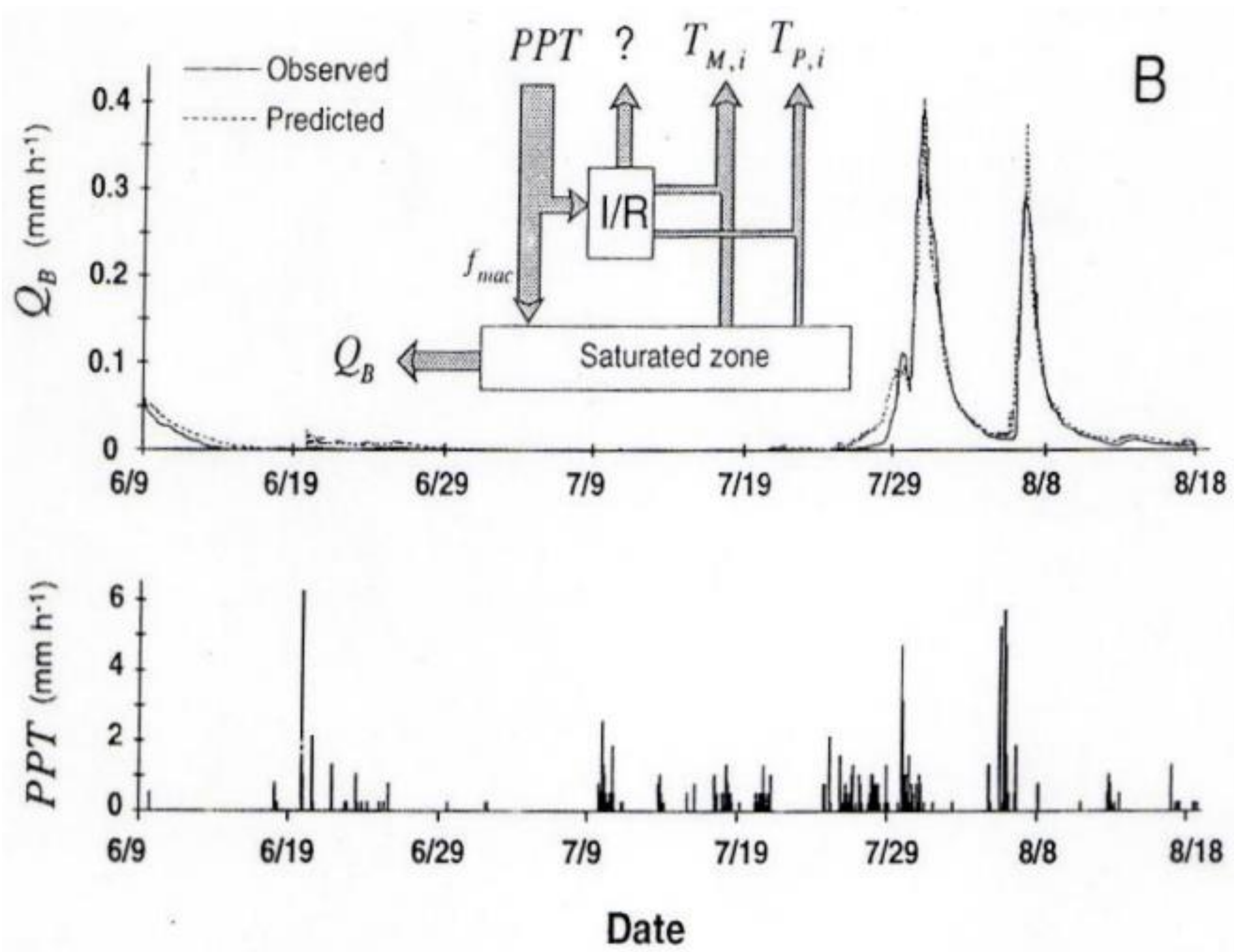
Controls on Ecosystem Level Fluxes in Tundra: Relating Ecology to Carbon Storage and Release

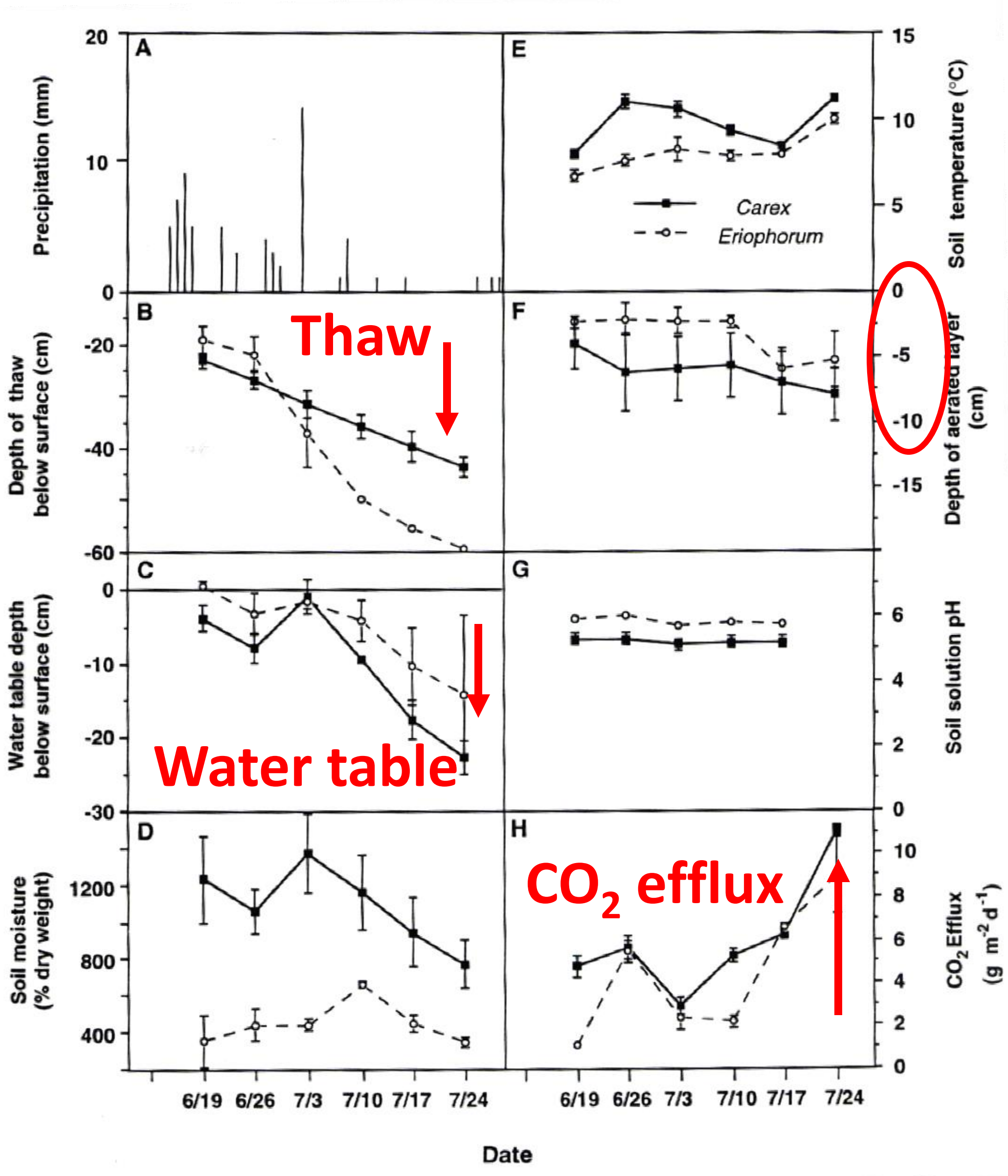


The Influence of Physical Factors on Ecosystem Processes in Tundra Regions



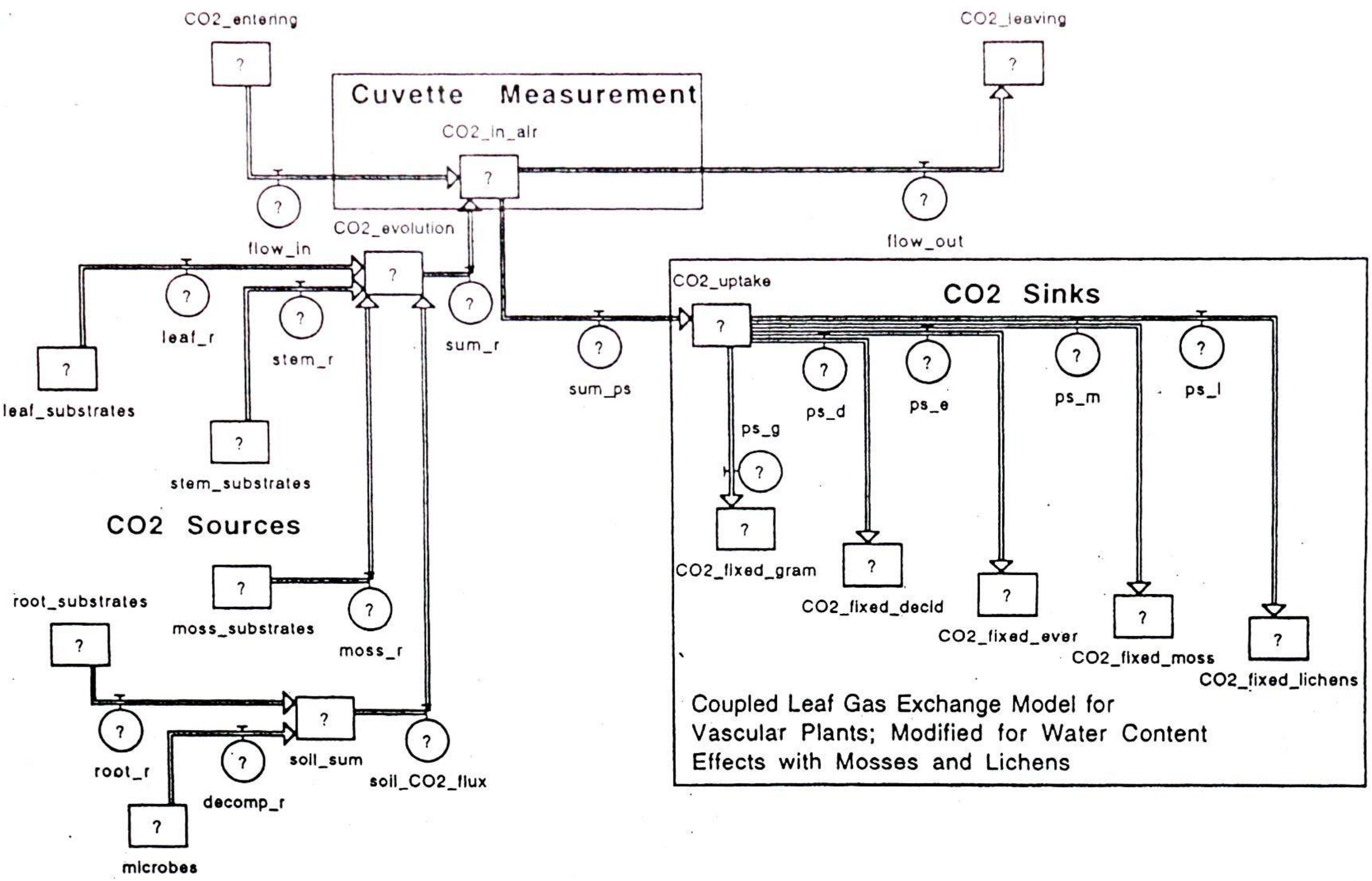
Hydrological modelling demonstrates the importance of moss (50% of green biomass - as in tropical forests) in controlling water balance.



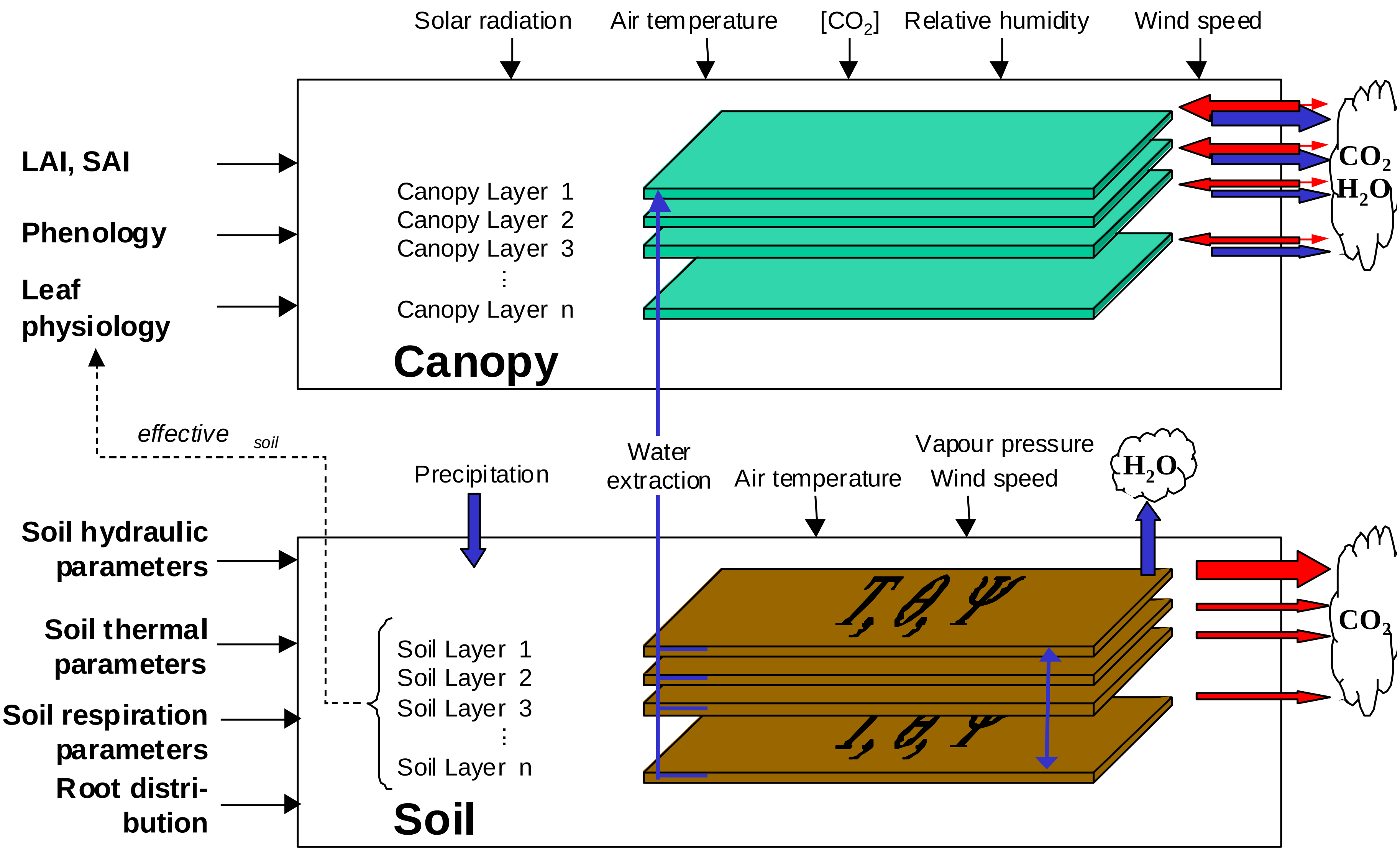


Local aeration of soil determines soil CO_2 efflux and carbon balance.

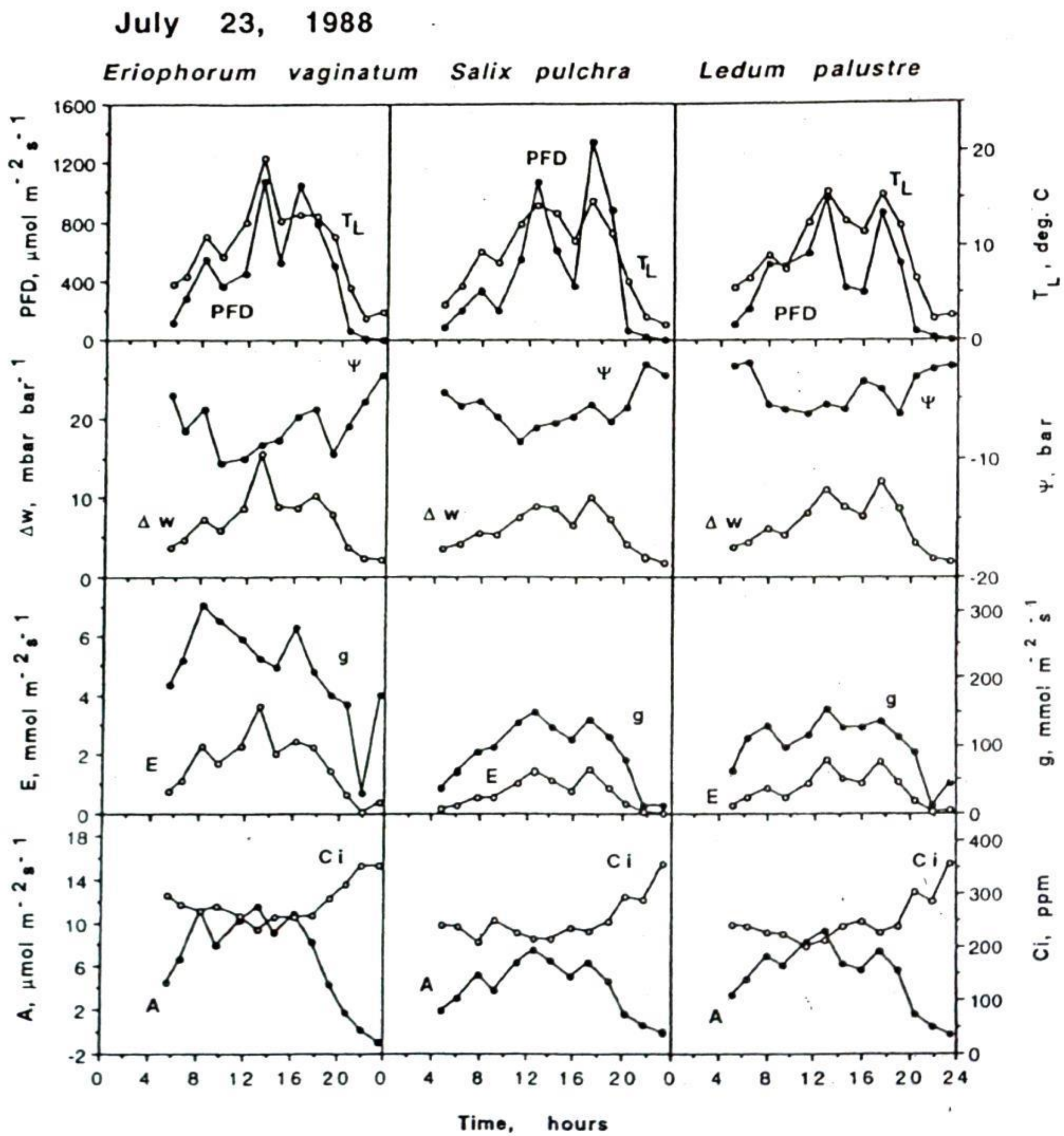
Stratified Stand Level Component - $PROXEL_{NEE}$



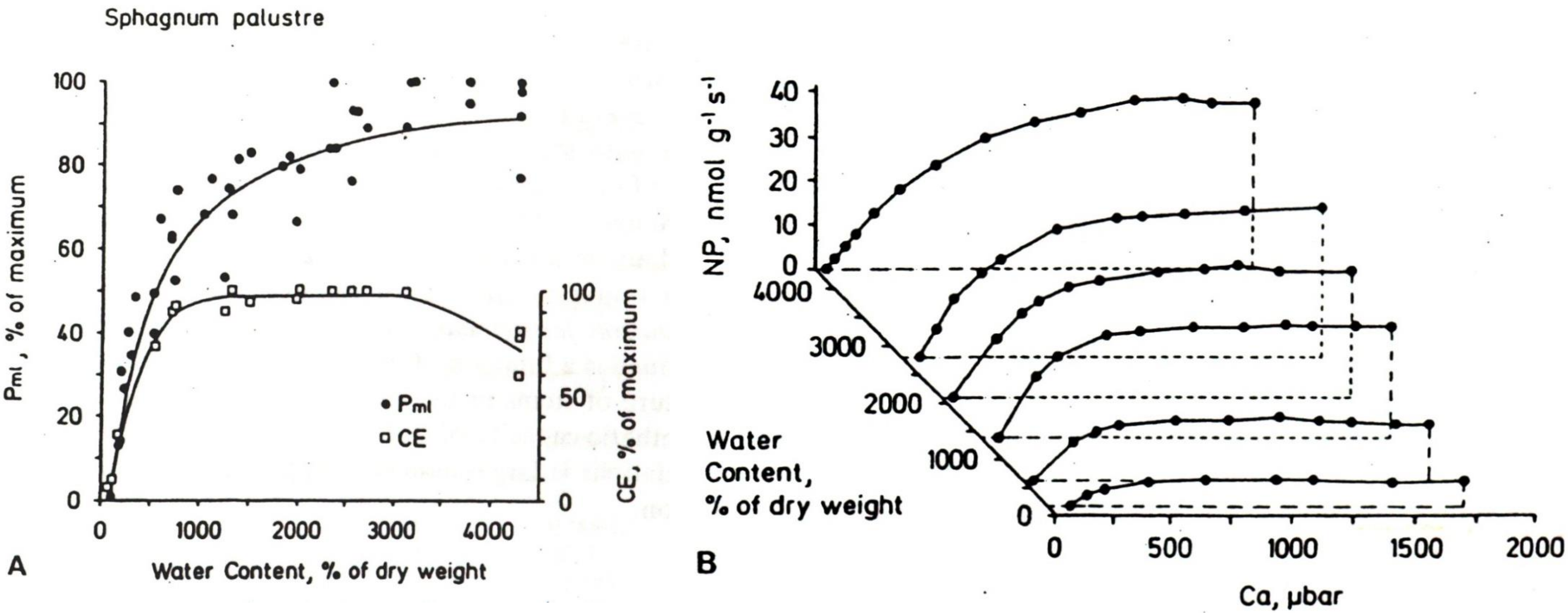
Stratified Stand Level Component - PROXEL$_{NEE}$



CO_2 – Exchange Behavior of Vascular Plants

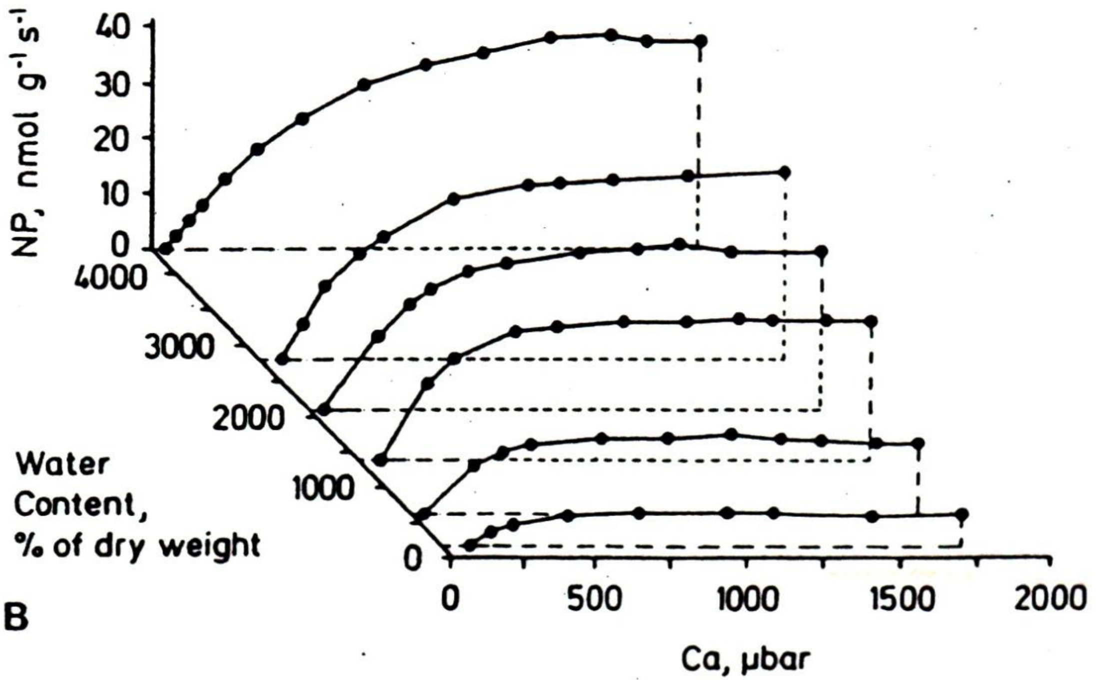


CO_2 – Exchange Behavior of Moss



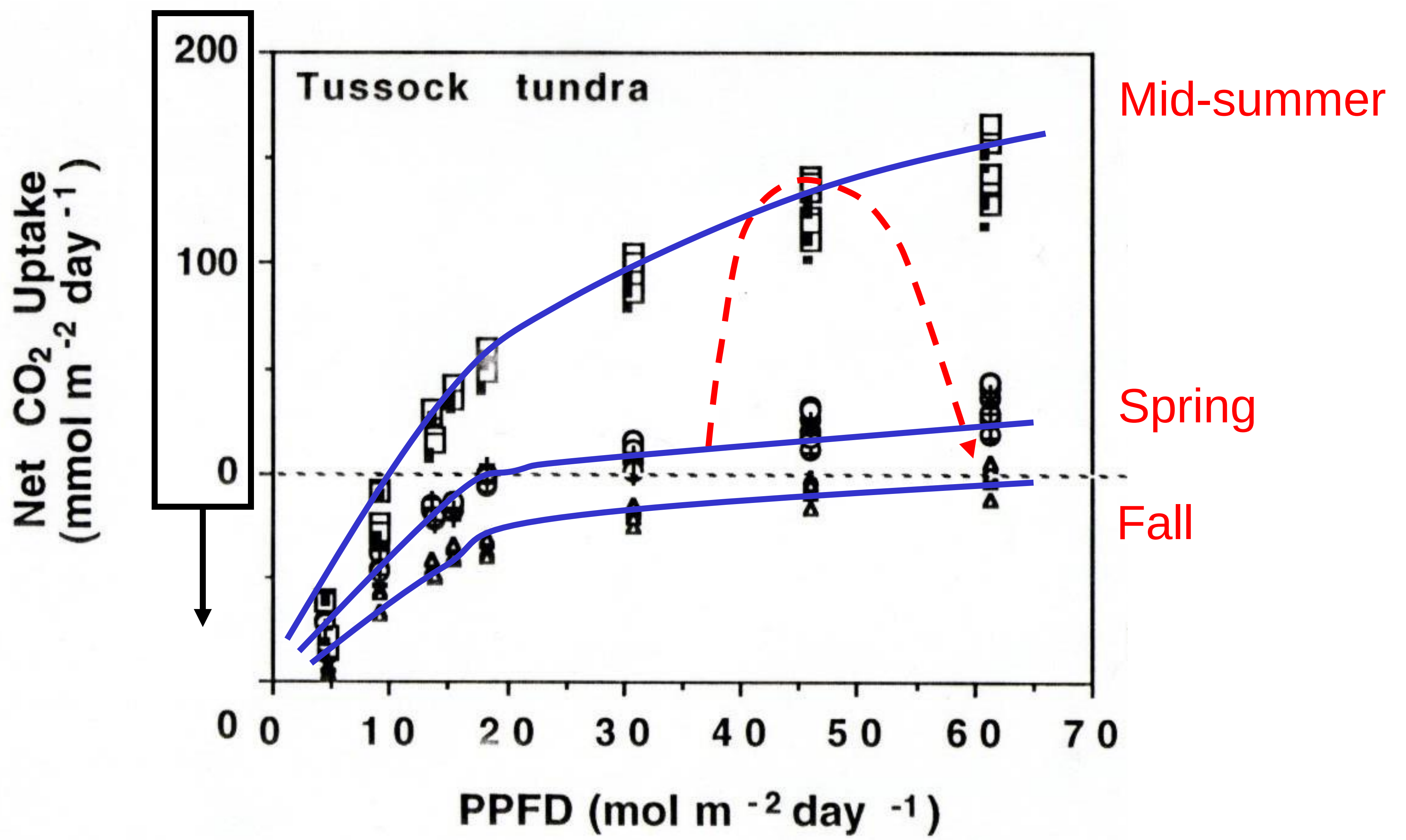
CO2 – Austausch bei wechselfeuchten Pflanzen

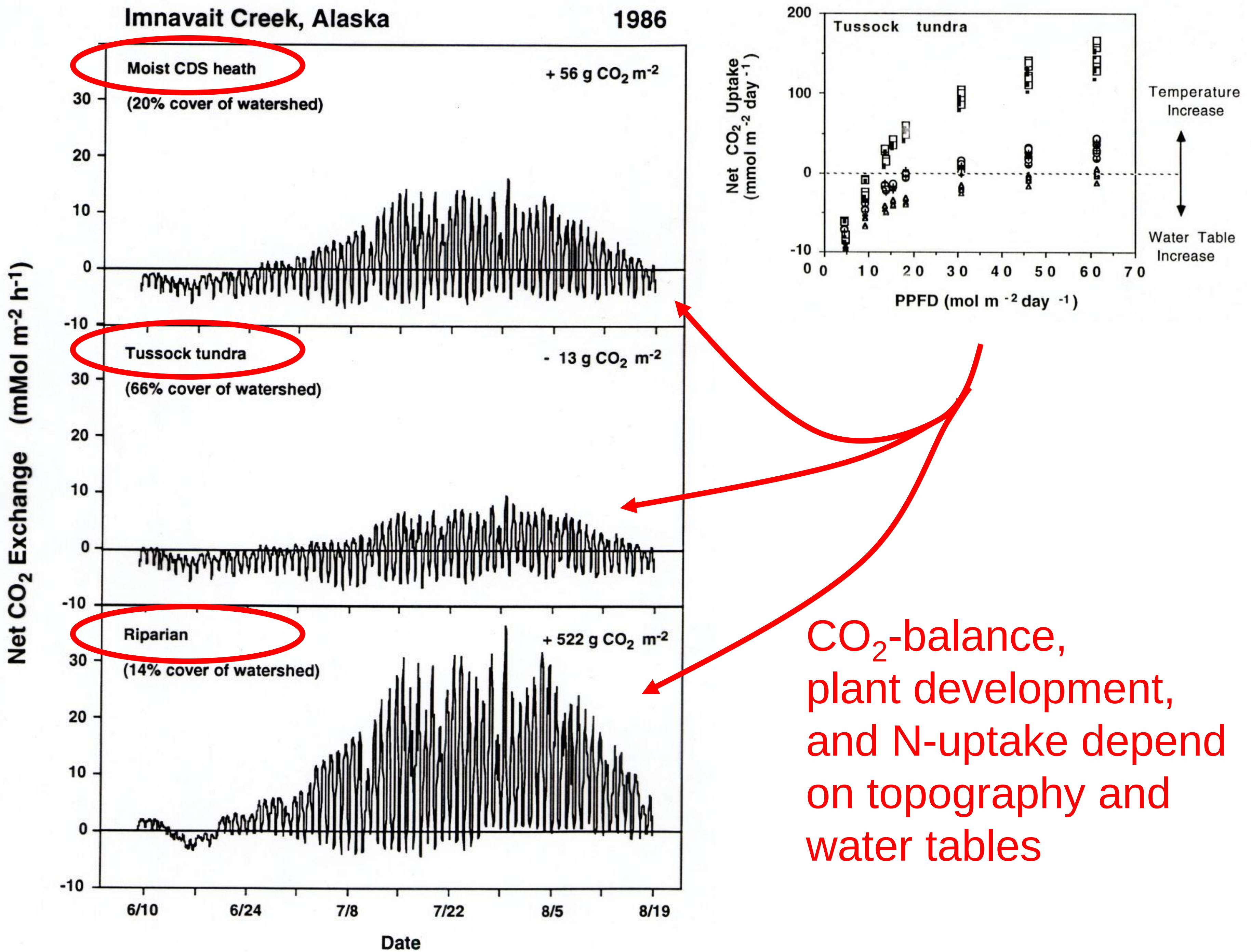
- Die Sphagnum-Sprösslinge wurden vertikal, aber getrennt angeordnet, um gleichmäßig zum Licht ausgerichtet zu sein
- Relative Luft-feuchtigkeit wurde nahe der Sättigung aufrecht-erhalten, sodass der Wassergehalt über eine längere Periode abnehmen konnte



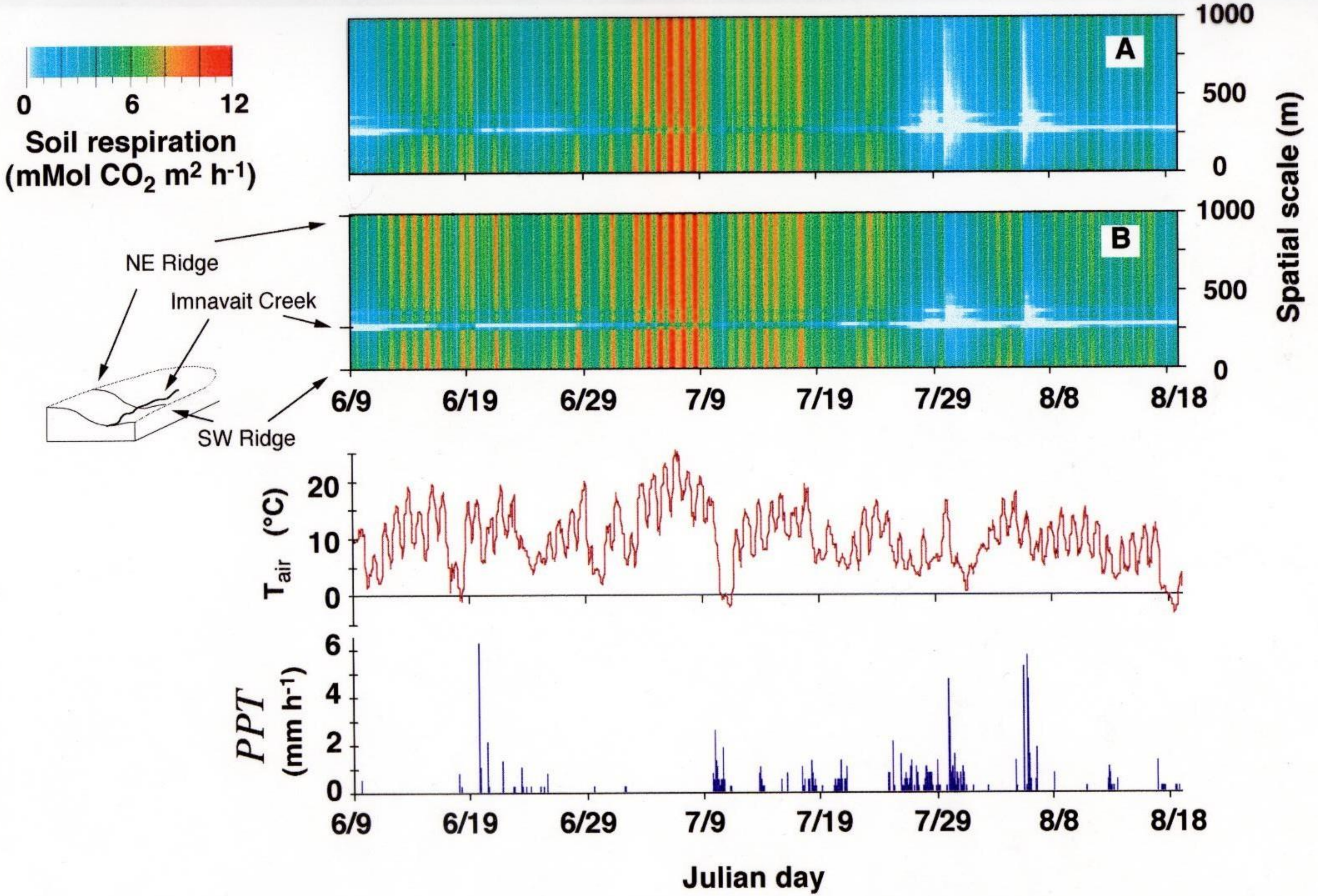
- NP = Nettophotosynthese, Ca = Antwort auf Luft-CO_2 Konzentration

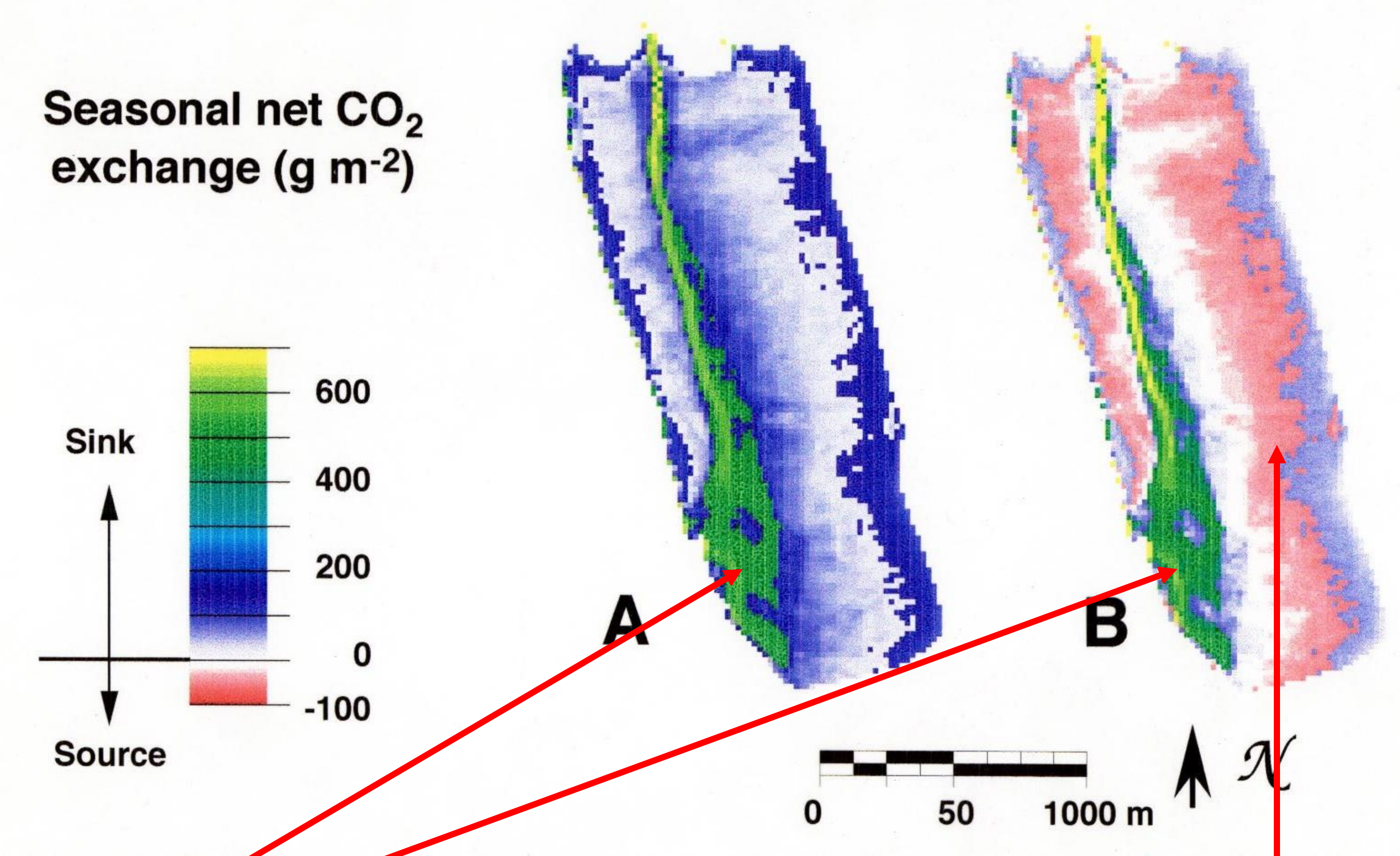
With seasonal development and with fluctuating water table, i.e., rainfall patterns





CO_2-balance, plant development, and N-uptake depend on topography and water tables


0
6
12
Soil respiration
(mMol CO_2 m^2 h^{-1})
A
B
1000
500
0
Spatial scale (m)
NE Ridge
Imnavait Creek
SW Ridge
6/9
6/19
6/29
7/9
7/19
7/29
8/8
8/18
T_{air} (°C)
20
10
0
PPT
(mm h^{-1})
6
4
2
0
Julian day



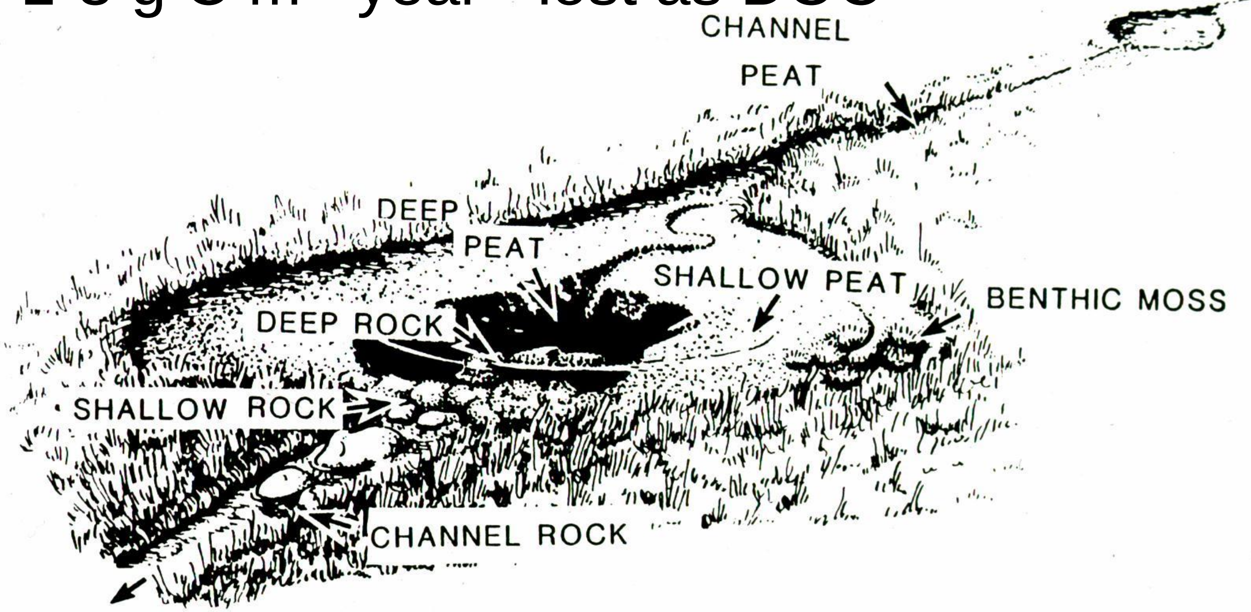
Strong CO_2 sink

Σ pixels = net balance

CO_2 source

ca. 10 g C m^{-2} $year^{-1}$

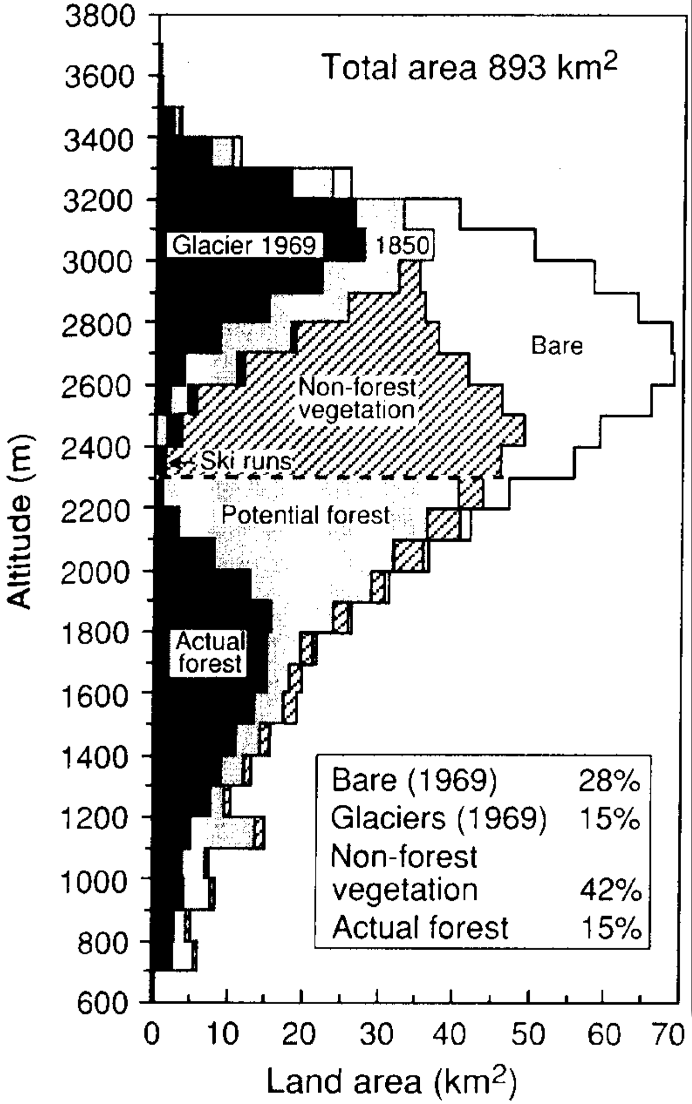
1-3 g C m^{-2} $year^{-1}$ lost as DOC



but net balance
also depends on
methane, peat and DOC:
<u>not yet evaluated</u>

In Complex Terrain: Gradients in Ecosystem Properties

Land Use and Change



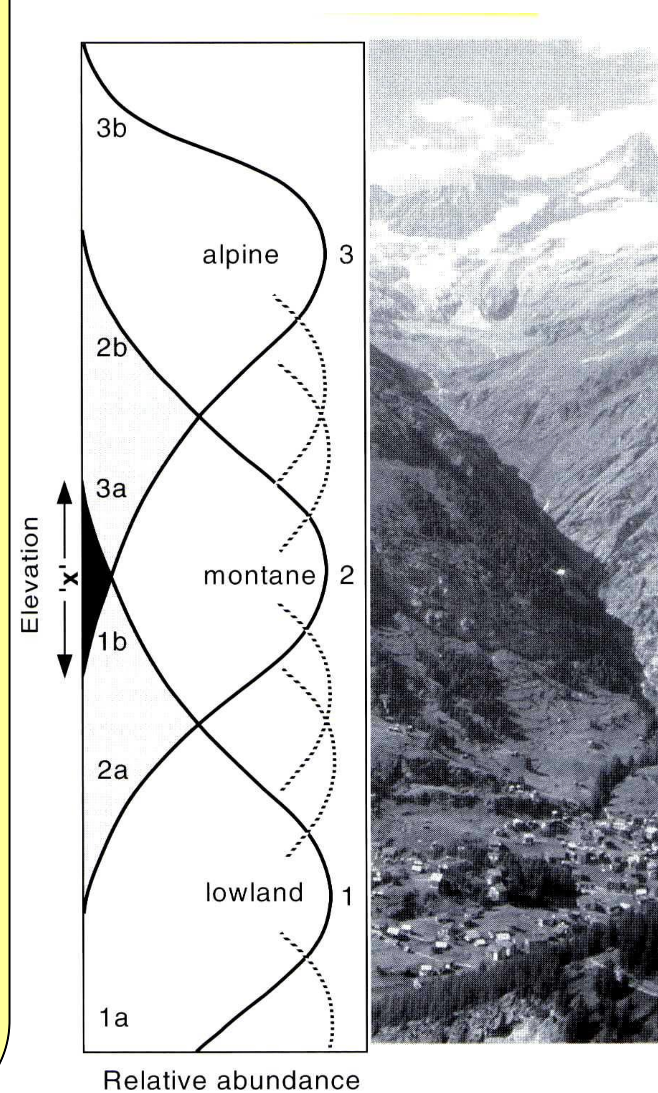
Shifts in Ecosystem Function with Elevation

Climate Factors
- radiation
  - shading
  - exposition
  - clouds*
- temperature
- humidity
- precipitation*
- drought
- CO_2 pressure

Plant Physiological Response
- photosynthetic capacity
- leaf respiratory capacity
- stomatal response
- cold stress response
- woody respiration
- phenology/season length
- allocation to LAI/roots
- reproductive output

Soil Characteristics
- soil temperature
- gas exchange
- nutrient availability
- N cycling, N forms
- microbial populations
- leaching

Organism Distribution



Thank You Very Much For Your Attention!

SOME RELEVANT LITERATURE

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