modextreme

agriculture facing extreme climatic events

Impacts of extreme events in grasslands models

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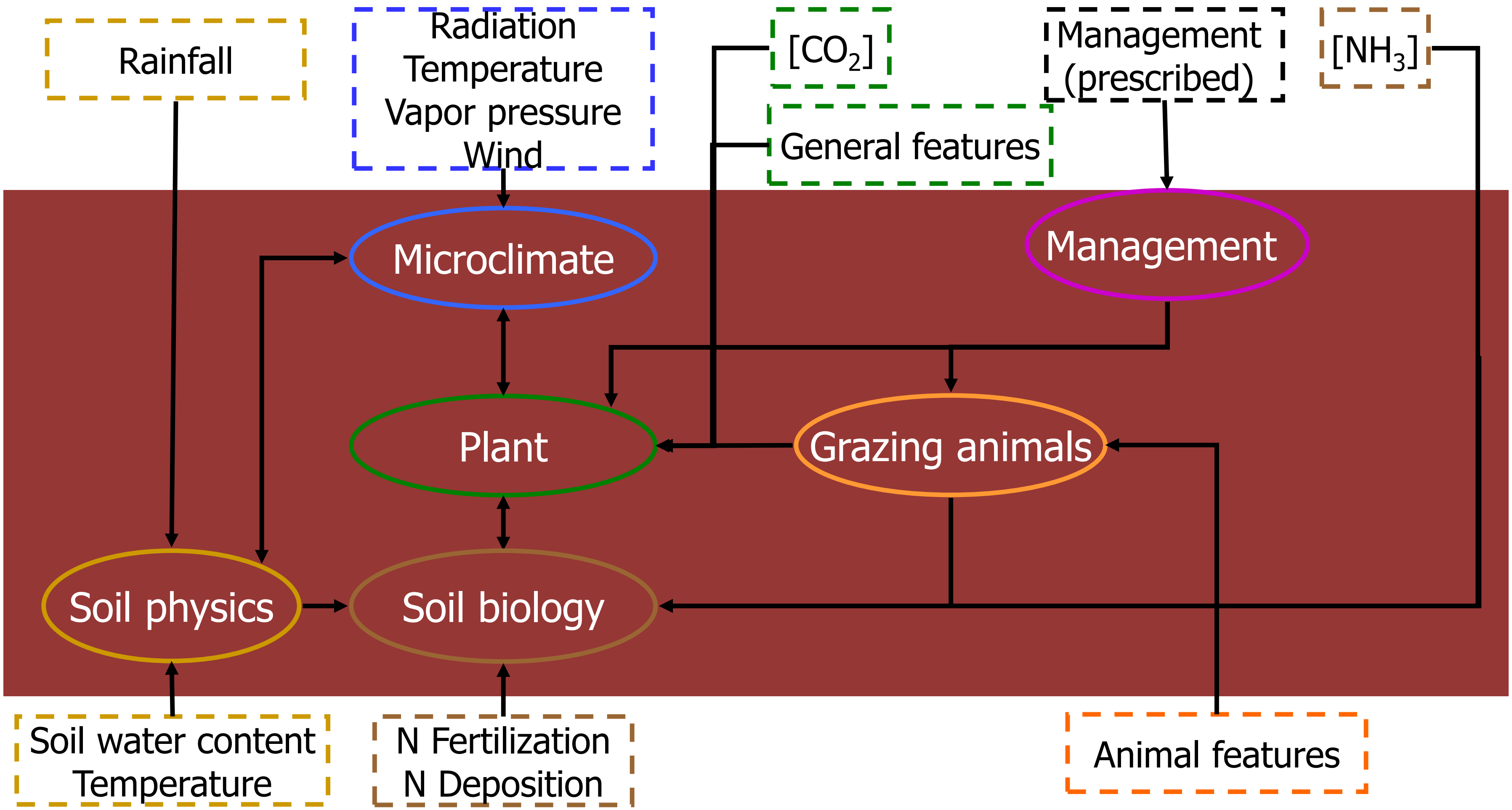
Outline

- **Context**
  - PaSim – Pasture Simulation model
  - Limitations of the model
- **Photosynthesis process in PaSim**
  - Adaptation to acclimatation
- **PaSim within modelling platforms**
  - RECORD, BioMA

The Pasture Simulation model

- Mechanistic, biogeochemical model (Riedo et al., 1998)
- Simulation of fluxes of water, energy, C and N at the soil-plant-animal atmosphere interface
- Simulation of permanent (cut / grazed) grassland systems
- Time resolution: ~30 minutes
- Reference grassland model in several projects:
  - Europe: EU FP7 AnimalChange, FACCE-JPI MACSUR
  - International: AgMIP, FACCE-JPI CN-MIP and Model4Pasture

Graphical overview of PaSim



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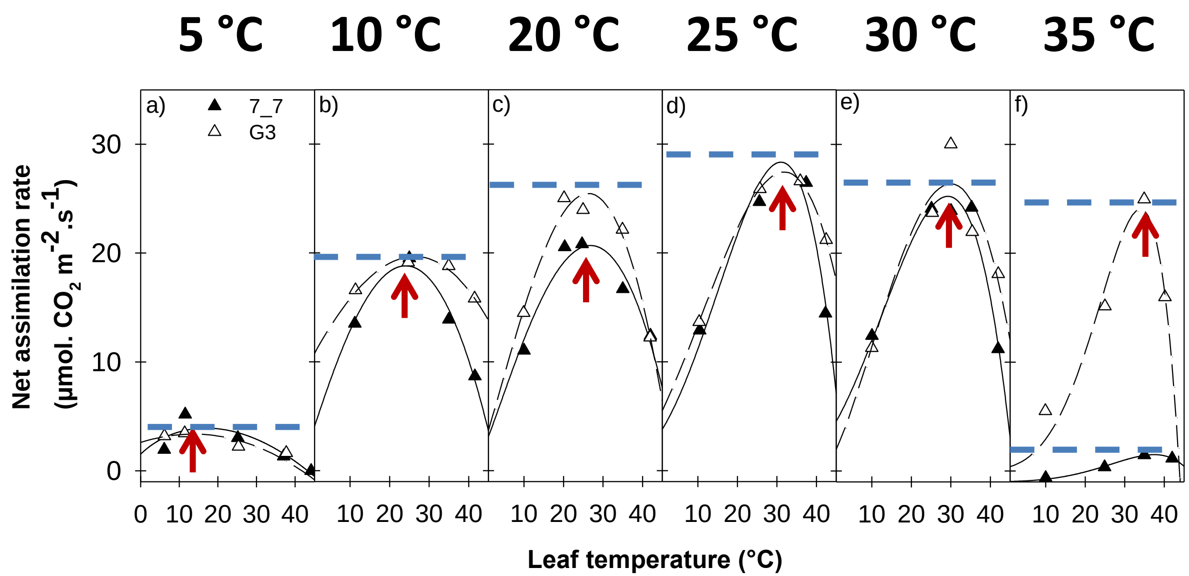
Limitations of the model

- Soil C pools averaged over the whole soil profile
- Homogeneous herds (type, age) of grazing animals
- No explicit representation of plant communities
- Limited sensitivity to extreme events (e.g. regrowth after heat and water stress)
- …

Response to growth temperature

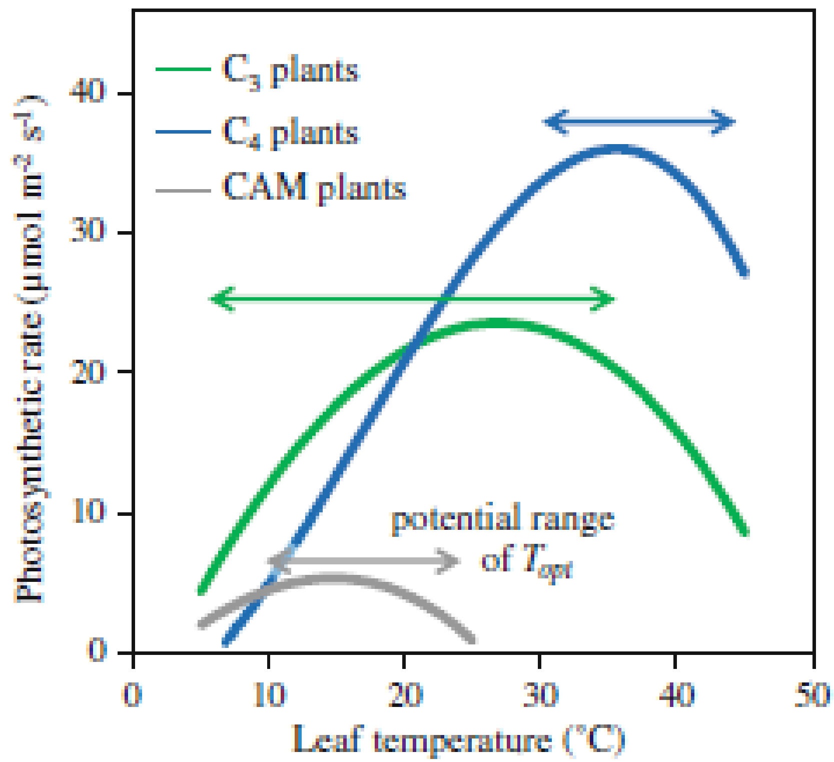


Shift of optimum temperature over a broad range of temperatures

Homeostasis of maximum photosynthetic rate over a limited range of temperatures

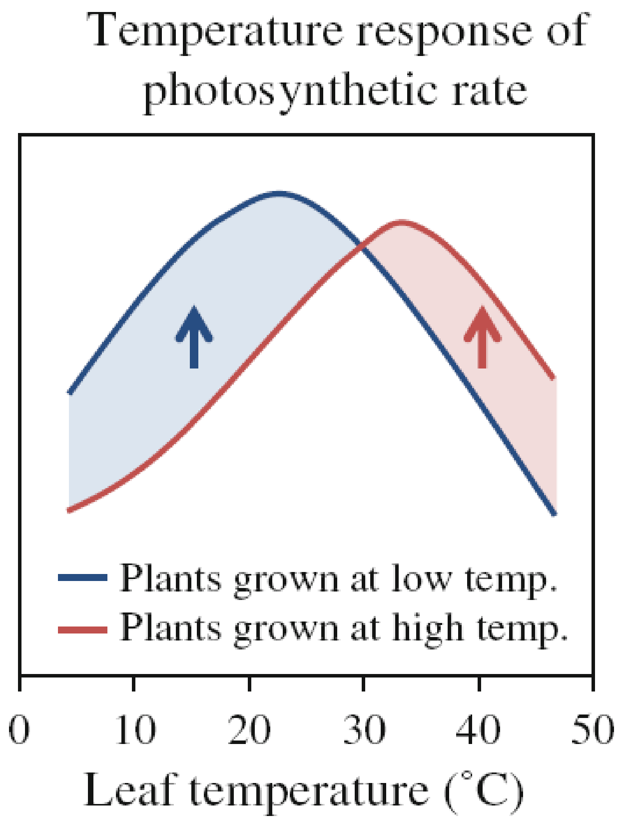
Alfalfa (Mediterranean▲ vs temperate∆ cv.)

Acclimatation of photosynthetic response / 1



Yamori et al. (2014)

Acclimatation of photosynthetic response / 2



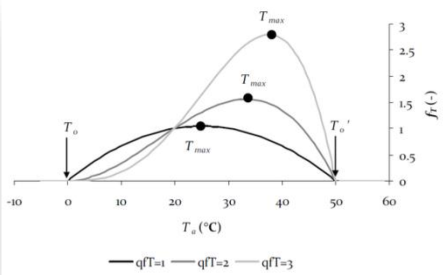
Increase of optimum temperature with increasing growth temperature

Growth temperature acts as a modifier of the response curve of assimilation

Yamori et al. (2014)

Farquhar scheme (photosynthesis)

$$f_t = \left(\frac{T - T_0}{\boxed{T_{opt}} - T_0}\right)^{\boxed{q}} . \left(\frac{T_0' - T}{T_0' - \boxed{T_{opt}}}\right)$$



($P_{max,20}$)
Max photosynthesis at 20 °C

(f_T)
Temperature factor

$$P_{max} = P_{max,20} f_T P_{m,CO_2T} P_{mN} P_{mC}$$

(P_{m,CO_2T})
CO_2-temperature interaction

(P_{mN}, P_{mC})
Functions of plant N and C concentrations

$$P_{m,CO_2T} = V_{cmax} \frac{A_{max}}{A_{max,350}}$$

V_{cmax} = maximum catalytic rate of the enzyme Rubisco
A_{max} = Light-saturated photosynthetic rate
(functions of CO_2 compensation point and CO_2 concentration in the intercellular air spaces)

Farquhar and von Caemmerer (1982)

Adaptation of photosynthesis to acclimatation

- Optimum temperature T_{opt} as a function of growth temperature:

(q/T)

Option for T-dependent exponent

$$f_t = \left(\frac{T-T_0}{T_{opt}-T_0}\right)^{\boxed{q/T}} . \left(\frac{T_0'-T}{T_0'-T_{opt}}\right)$$

$$T_{opt} = \frac{1}{1+\frac{q}{T}.\left(T_0+\frac{qT'_0}{T}\right)} = \boxed{a.T_{m,20}+b}$$

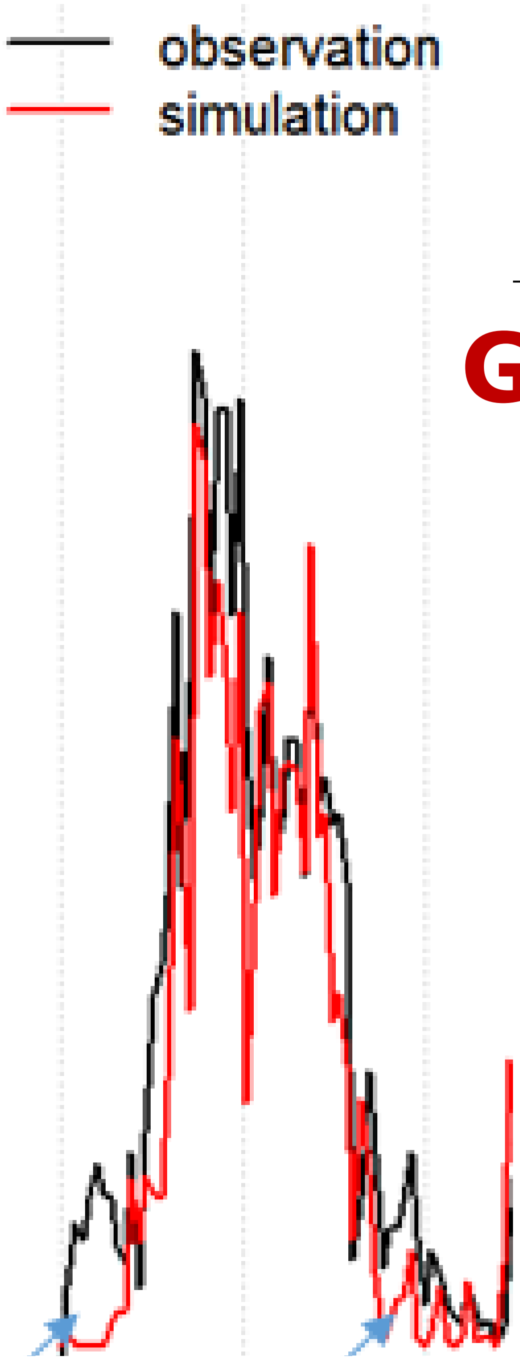
$(T_{m,20})$

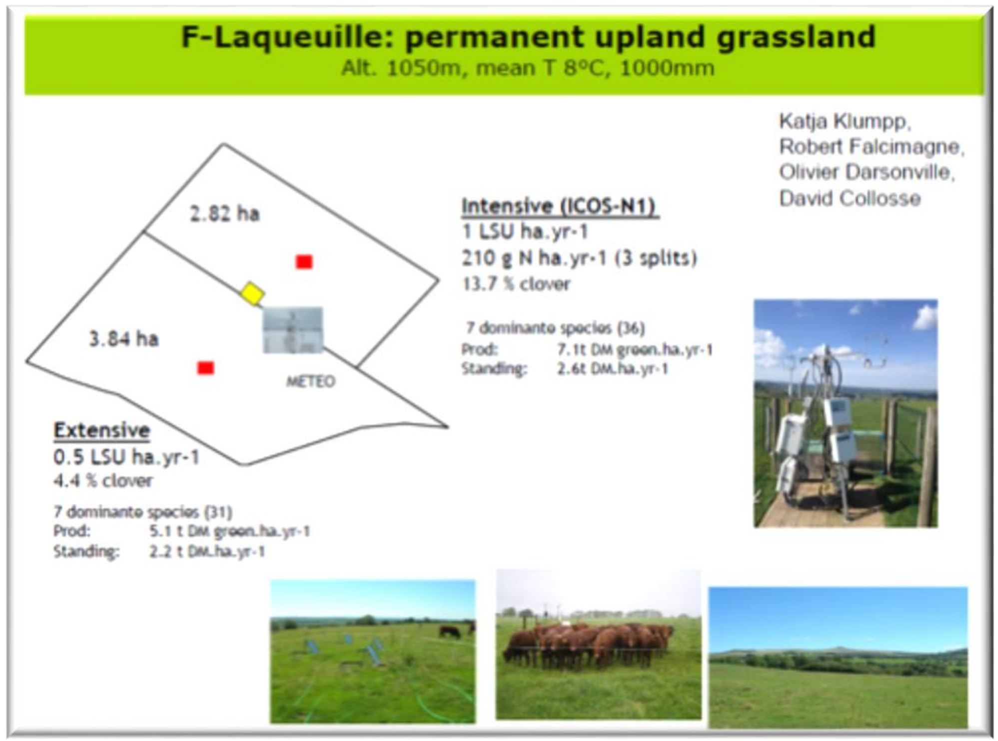
Average air temperature over the previous 20 days

a=0.48, b=17.4 °C for C3 species

- Modulation of maximum photosynthetic rate at 20 °C, $P_{max,20}$, as a function of growth temperature

Gross primary production
Laqueuille, France (2004)





Underestimations in winter time (with constant T_{opt})

Ma et al. (2015)

Improving the photosynthetic process in PaSim

- Integration of these new equations in the BioMA-oriented MODEXTREME component for extreme events (developed by University of Milan)

- Use of the component to create a modified solution of PaSim

BioMA components

Weather libraries

AirTemperature, EvapoTranspiration, LeafWetness,
SolarRadiation, Rainfall, Wind
Climatic indices
Weather Generators (ClimGen, CLIMAK)

Abiotic stresses

Heat damage, Rice cold shocks, Lodging

Biotic stresses

Generic air-borne diseases
simulator (Diseases, Magarey),
Generic soil-borne diseases growth (SBD),
CornBorer simulator (MYMICS)

Chemicals

Chemicals dynamics (AgroChemicals)

Plant libraries

Generic crop simulators (Wofost, CropSyst, STICS)
Generic tree simulator (Tree)
Rice (WARM)
Sugarcane (CaneGro)
Grain quality (AgPro-Q)

Soil libraries

Soil water runoff and erosion (CN, Eurosem),
Soil water redistribution (Cascading, FiniteDifferences)
Soil surface and profile temperature,
Soil nitrogen (SoilN)
Pedotransfer functions (SoilPAR)

Agricultural management

Rule-based modelling
(AgroManagement)

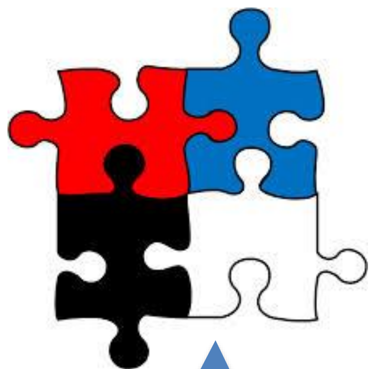
PaSim into platforms (RECORD and BioMa)

- Recoding of PaSim in C++ modules (RECORD) and externalization of the core of the model in a C++ library

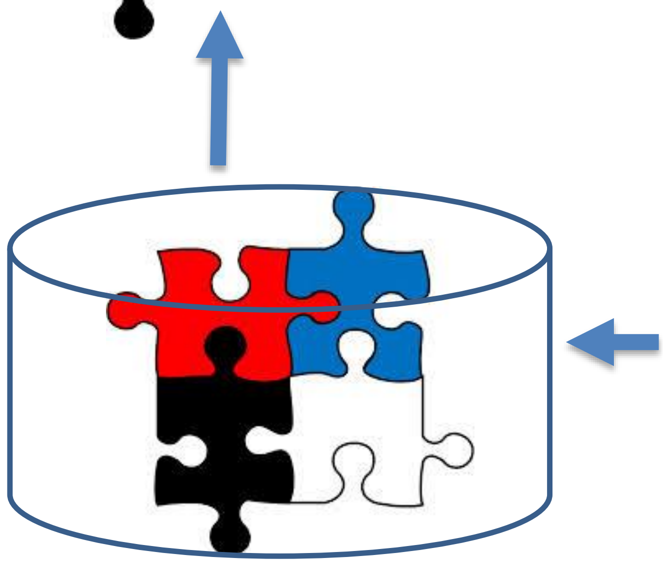
- Advantages:
  - Use of the oriented-object paradigm
  - Platform independency
  - One library to maintain different projects
  - Development of a stand-alone version

- Drawbacks:
  - Need of dedicated wrapper for BioMA
  - Consistency of the model time step with the platform
  - Need to define a satisfactory granularity

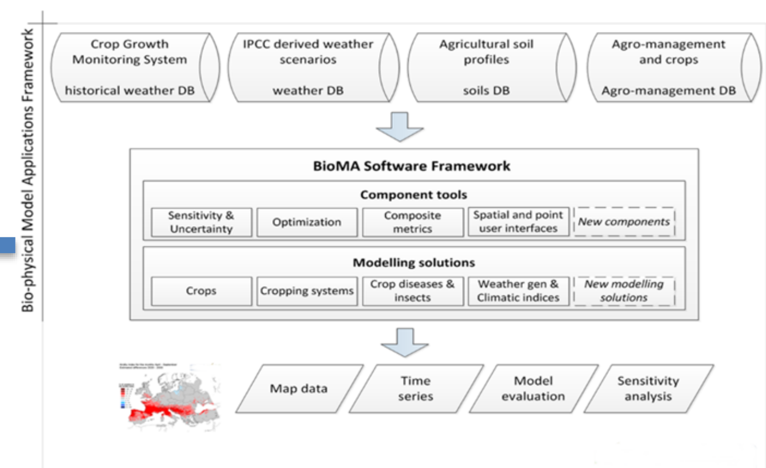
PaSim new design



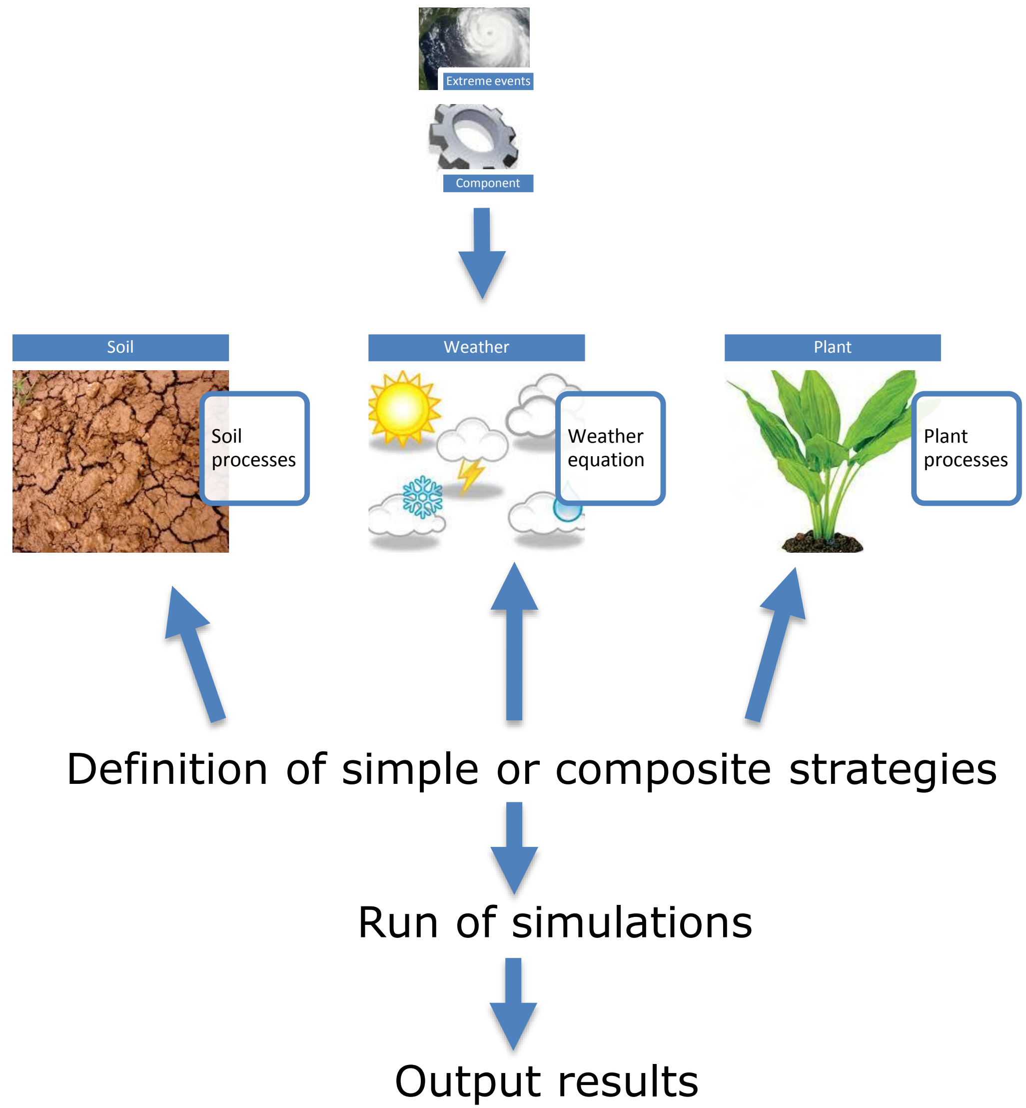
- Core of the model
- Modules can run independently
- Use of recent development techniques



C++ / CLI wrapper

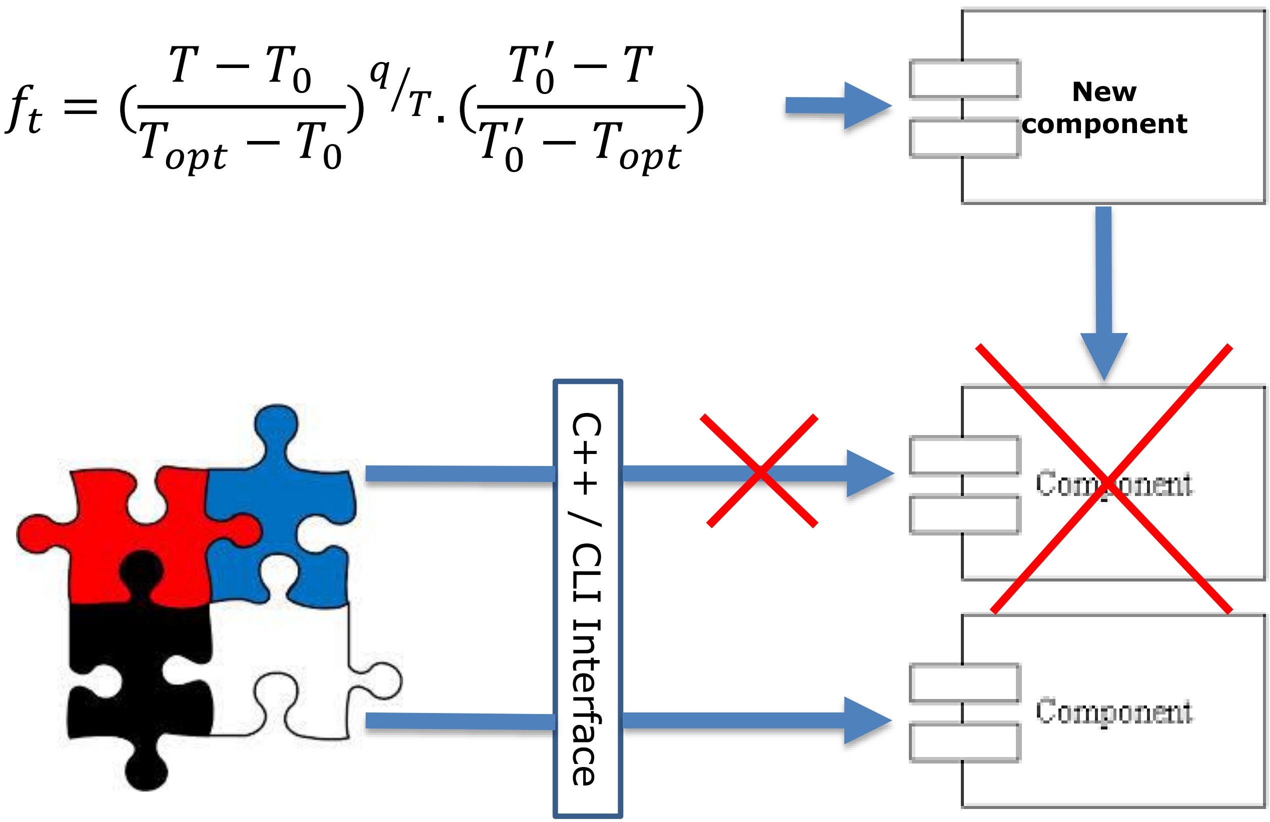


Modelling solutions in BioMA



Modelling solutions of PaSim

$$f_t = \left(\frac{T - T_0}{T_{opt} - T_0}\right)^{q/T} \cdot \left(\frac{T_0' - T}{T_0' - T_{opt}}\right)$$



Core of PaSim

BioMA platform

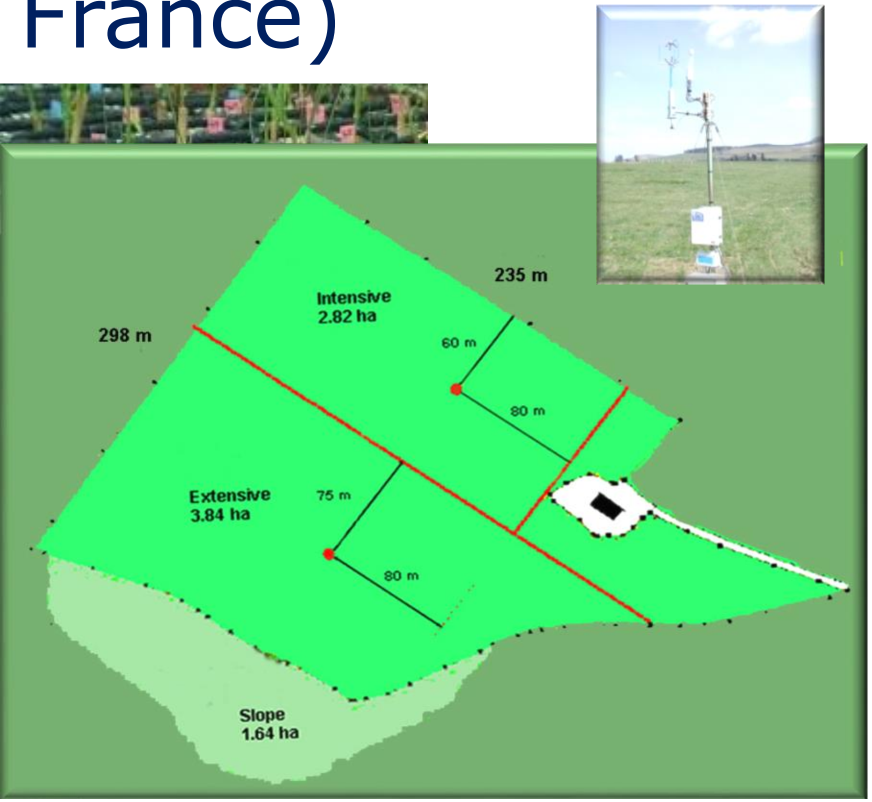
Concluding remarks

- The proposed strategies for photosynthesis and respiration will contribute to the MODEXTREME component of BioMA, for use within PaSim but potentially re-usable by other models

- Improving photosynthesis and respiration processes for acclimatation to temperature will likely improve the sensitivity PaSim to extreme events

- Modified PaSim modelling solutions will be evaluated with field data from grasslands systems provided by MODEXTREME partners

Permanent grassland sites (Massif Central of France)

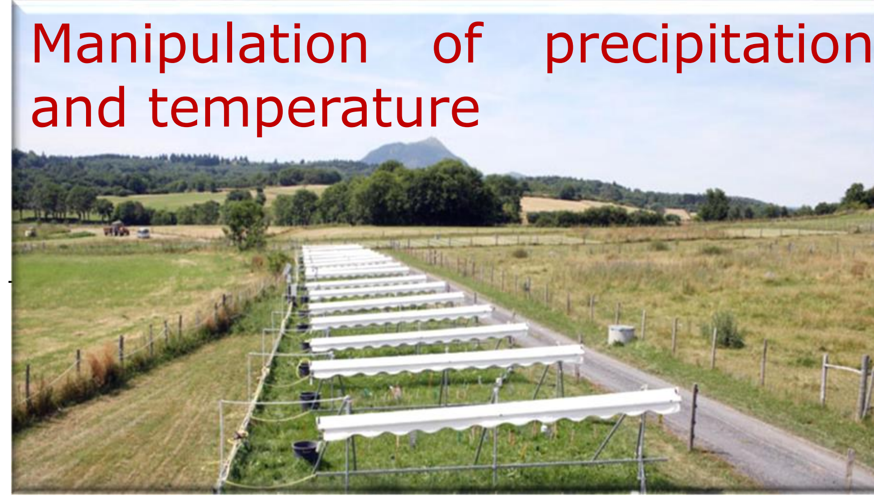


Laqueuille

1040 m a.s.l.

Mean annual temperature: 8.0 °C

Annual total precipitation: 1000 mm



Theix

880 m a.s.l.

Mean annual temperature: 8.7 °C

Annual total precipitation: 780 mm

Literature sources

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