Impacts of atmospheric [CO2] doubling on climate, water balance, carbon balance and growth of maritime Pine in southwestern France

INRA

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LTEEF

Long - **T**erm regional **E**ffects
of climate change on **E**uropean **F**orests

Introduction

- **The *Landes de Gascogne* Forest :**

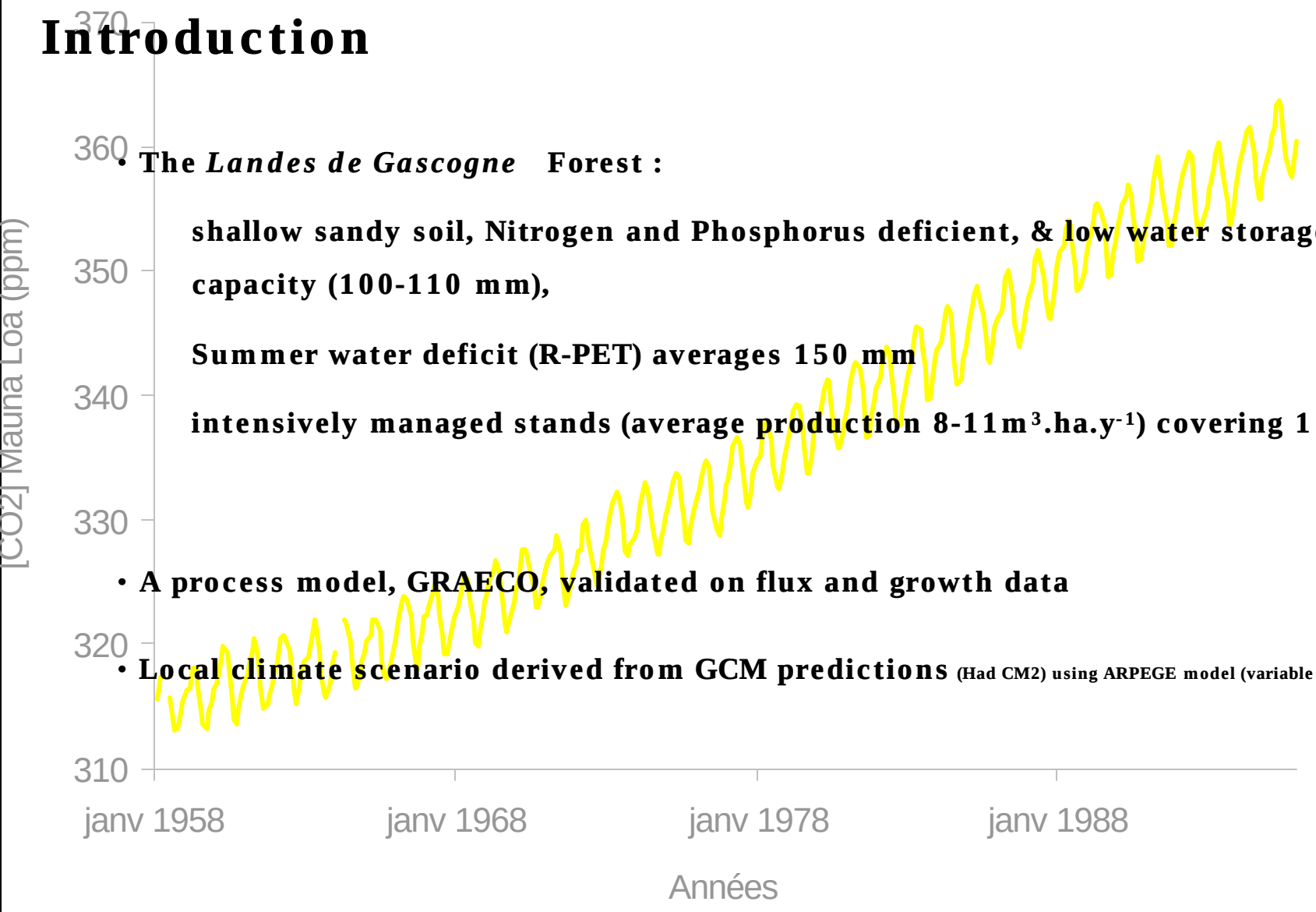
  shallow sandy soil, Nitrogen and Phosphorus deficient, & low water storage capacity (100-110 mm),

  Summer water deficit (R-PET) averages 150 mm

  intensively managed stands (average production 8-11m^3.ha.y^{-1}) covering 1 M Ha.

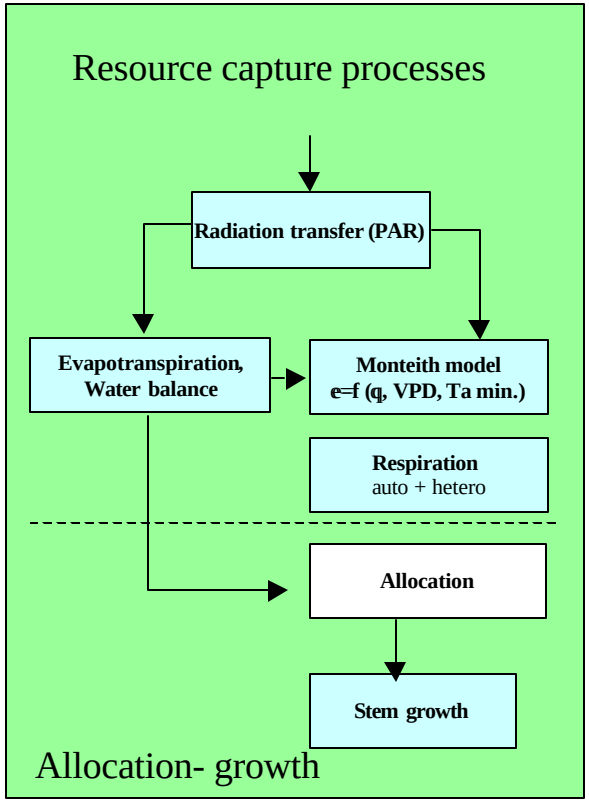
- **A process model, GRAECO, validated on flux and growth data**

- **Local climate scenario derived from GCM predictions** **(Had CM2) using ARPEGE model (variable cell grid)**

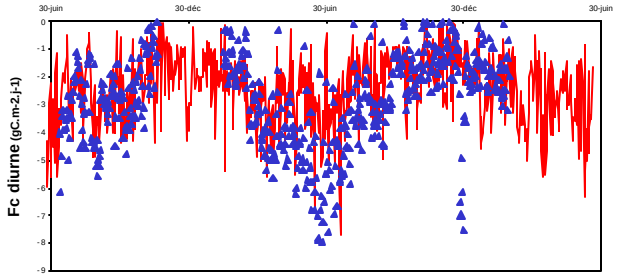


Source : Keeling, C.D., Institution of oceanography, University of California

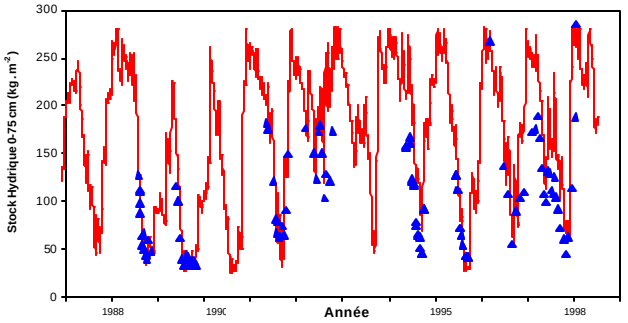
Model GR.A.Eco (see poster of Porté et al.)



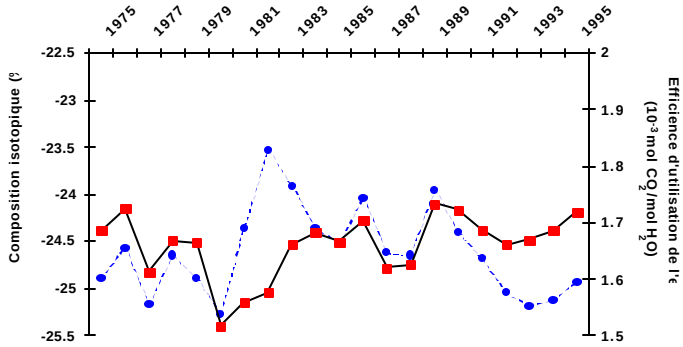
CO2 fluxes (hour-day-1y)



Soil water balance (10 years)



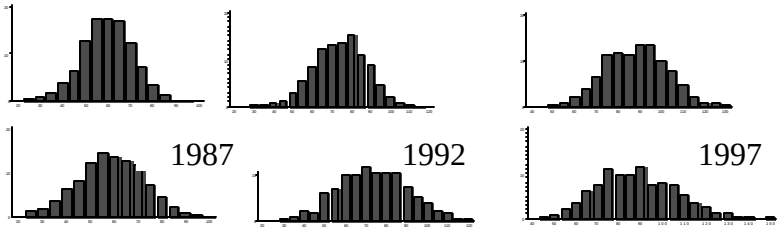
Tree rings, carbon isotopes (50 years)



Tree growth, Size classes distribution,

observed

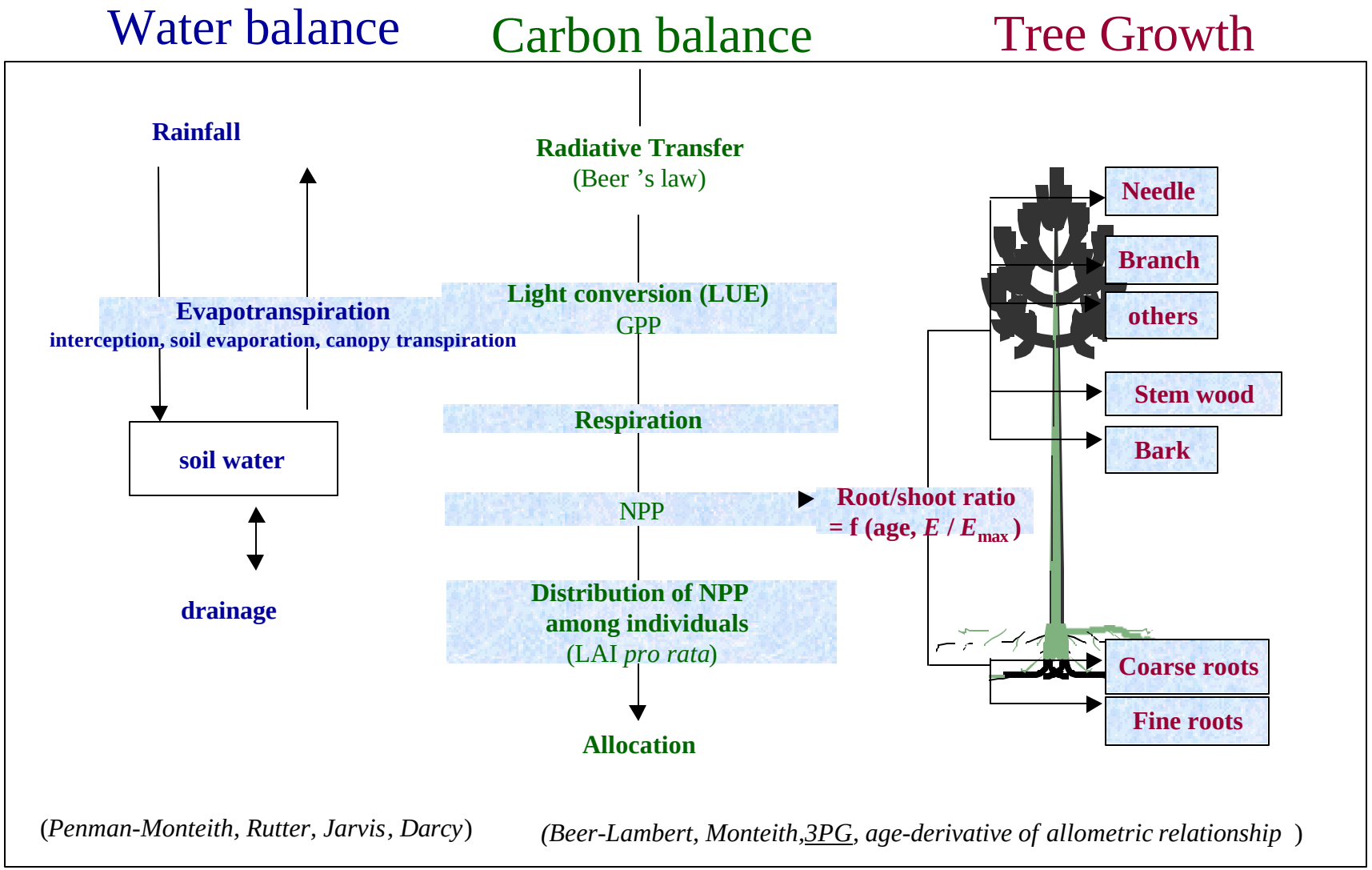
predicted



Model

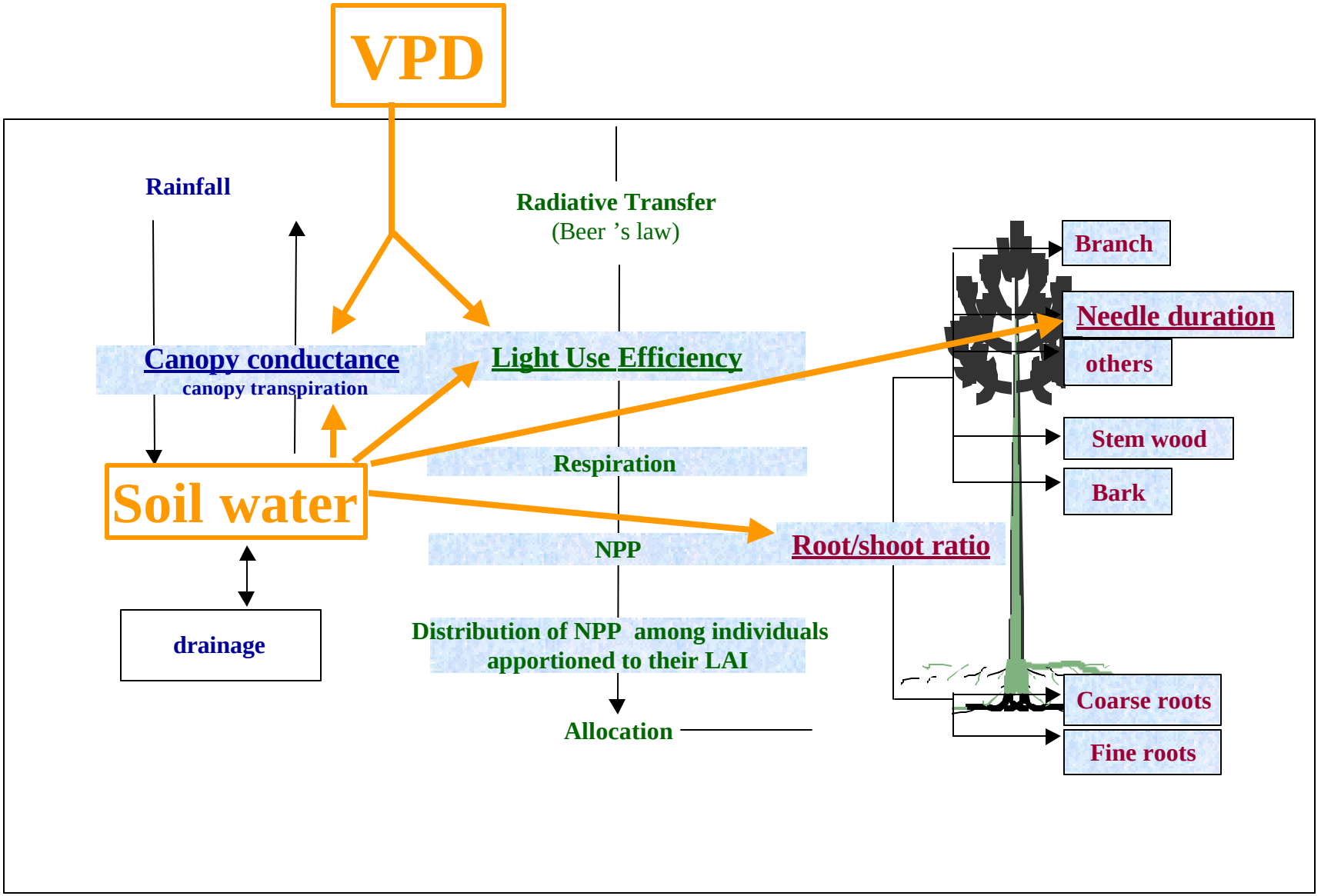
Model: 2-layer canopy

(only the pine canopy layer is shown)



Model

Direct impacts of water stress variables on biological parameters



Model

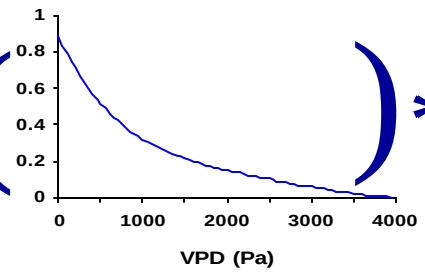
Light Use Efficiency (e)

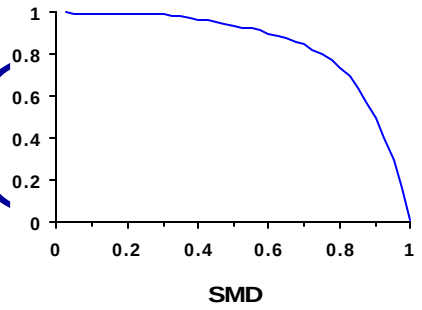
$$e_3 = e_{max} \cdot g(VPD) \cdot g(SMD) \cdot g(T_{air}) \cdot g(\text{age})$$

with g= theoretical function derived from a coupled Farquhar (A) - Jarvis (g_s) model parameterised from gas-exchange data:

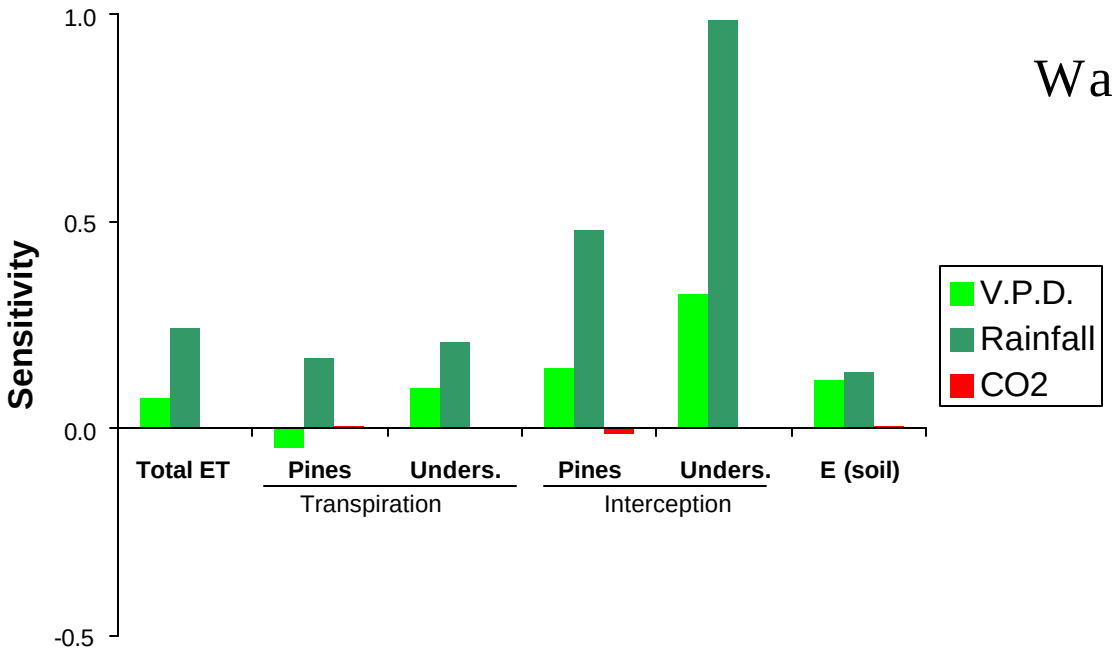
$$\left.\begin{aligned} A &= (1 - \Gamma^* / c_i) \cdot \min(W_C, W_J) - R_d \\ c_i &= c_a - \frac{A}{g_s} \\ g_s &= g_{smax} \cdot u(D) \cdot u(SMD) \cdot u(age) \end{aligned}\right\}$$

$$e = e_{max} * \left(\right) * \left(\right)$$



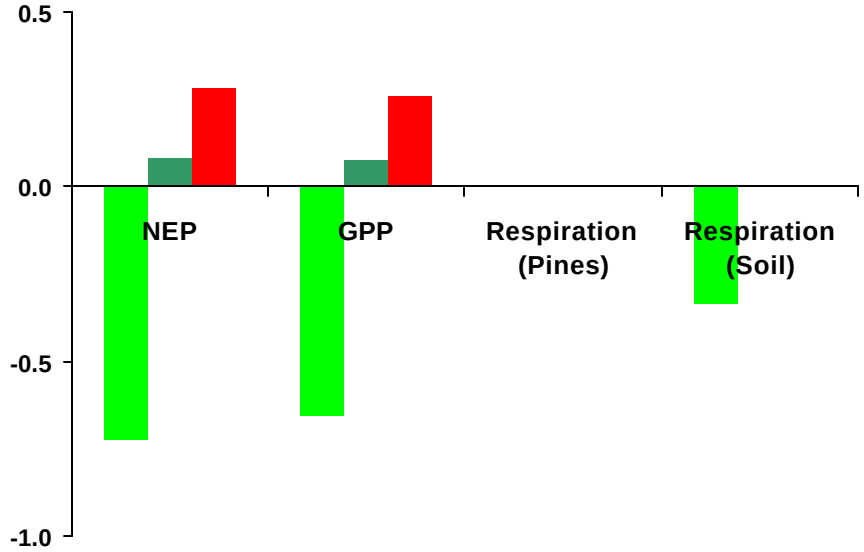


Analysis of the model Sensitivity to Rainfall, VPD and CO2



Water balance components

Rainfall> VPD > CO2

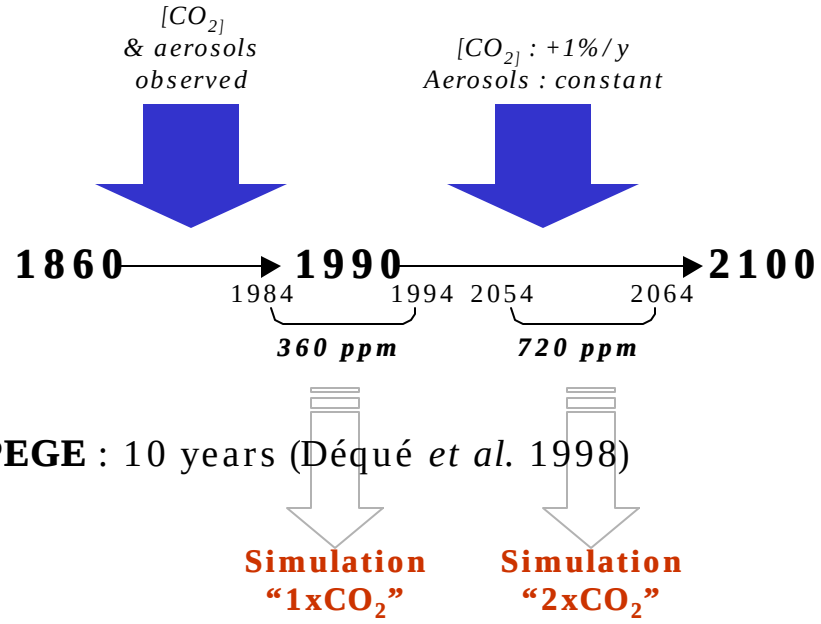


Carbon fluxes

VPD> CO2 > Rainfall

Climate scenarios

• **HADCM2** : 240-year period simulated

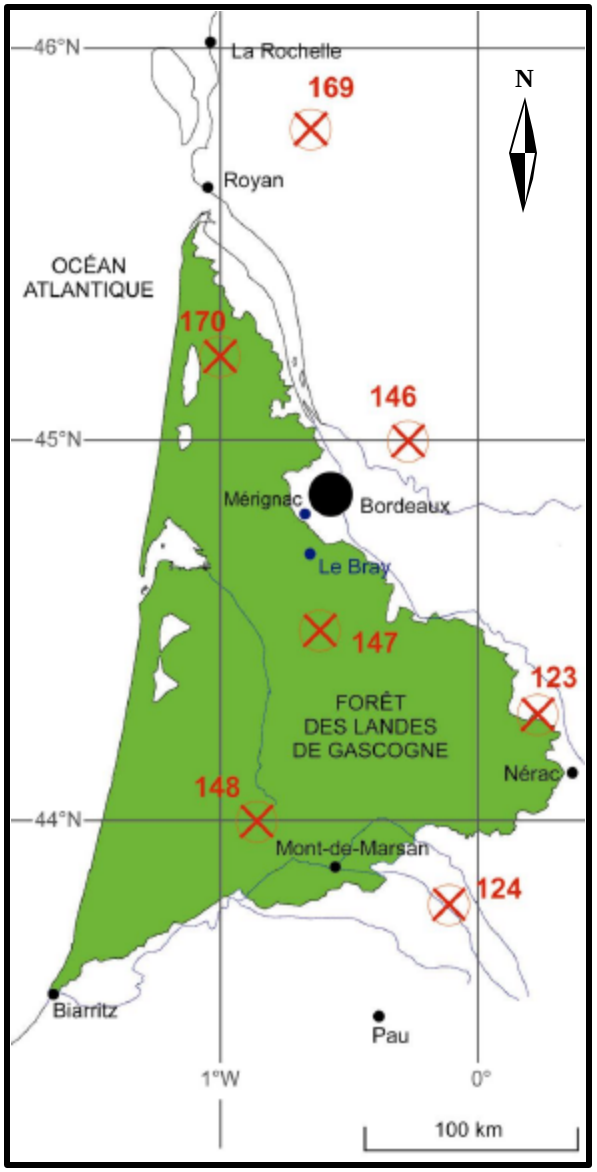


• **ARPEGE** : 10 years (Déqué *et al.* 1998)

variable cell grid : 60 km over Europe,

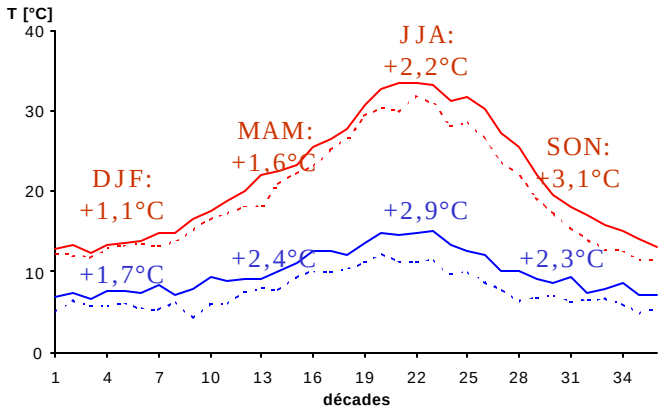
700 km over Pacific ocean

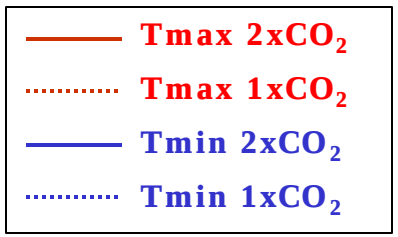
-->224 grid points over Europe
7 points over the maritime Pine forest in southwestern France

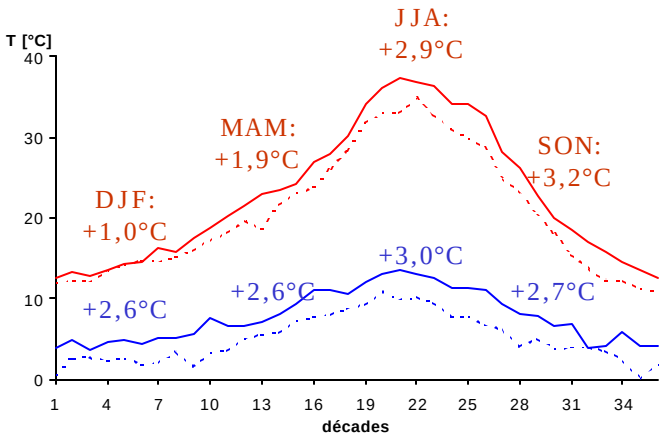


ARPEGE local climate scenarios

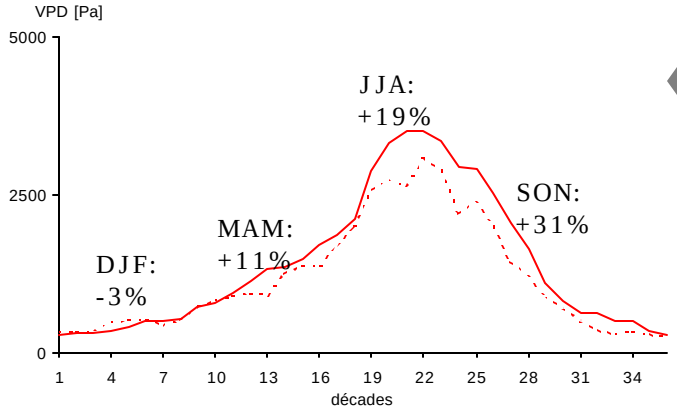
TEMPERATURES

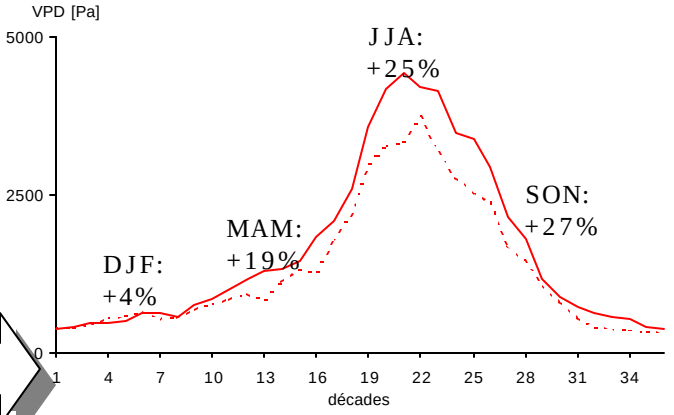




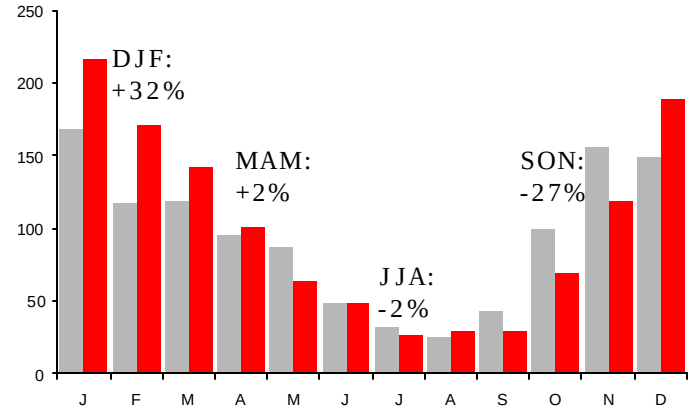


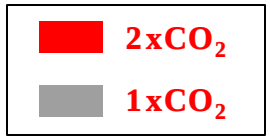
Maximum V.P.D.

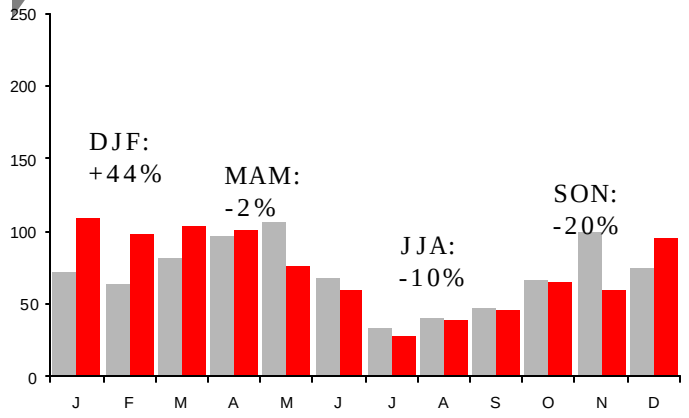




PRECIPITATIONS

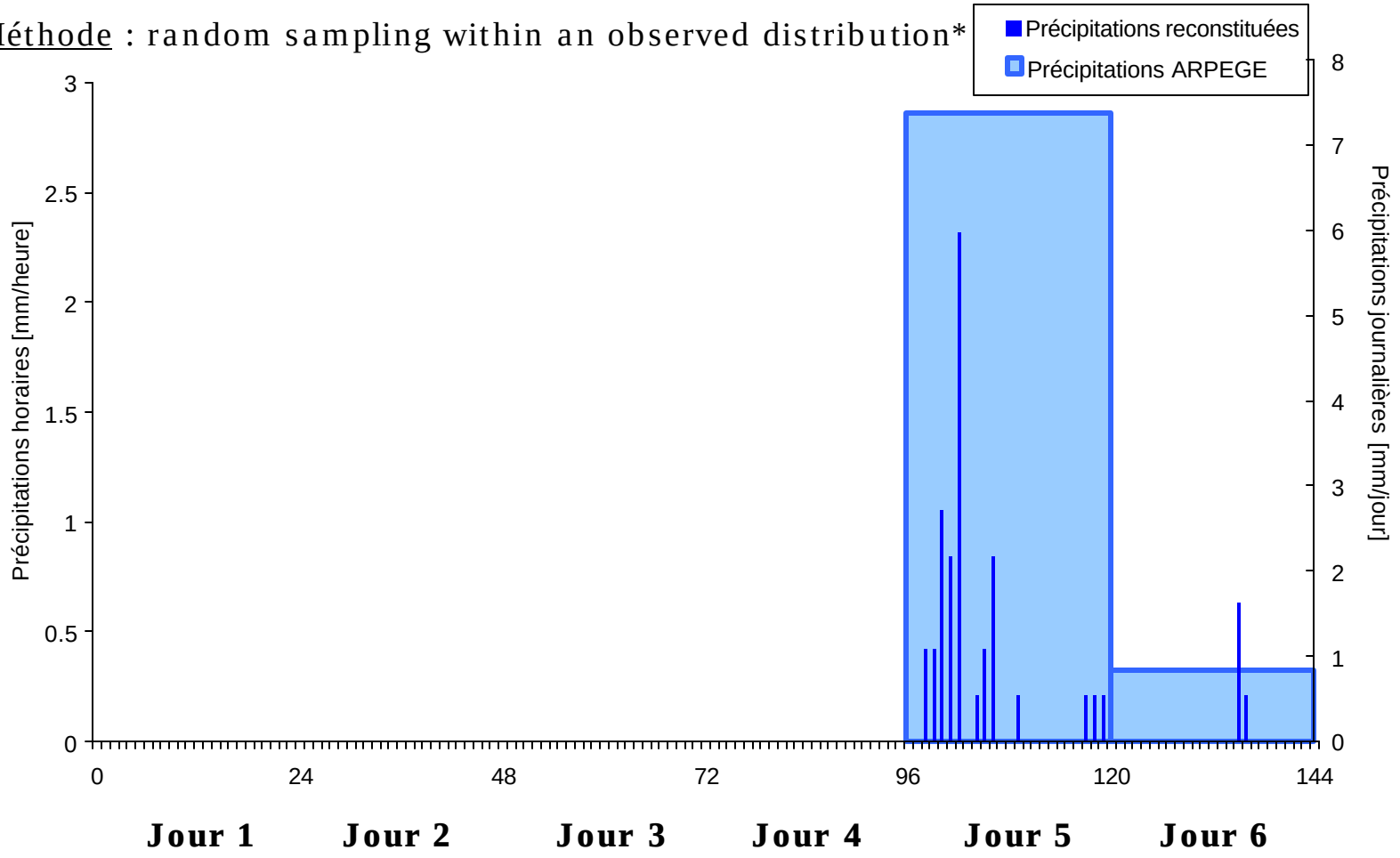






Hourly data reconstruction : precipitations

Méthode : random sampling within an observed distribution*

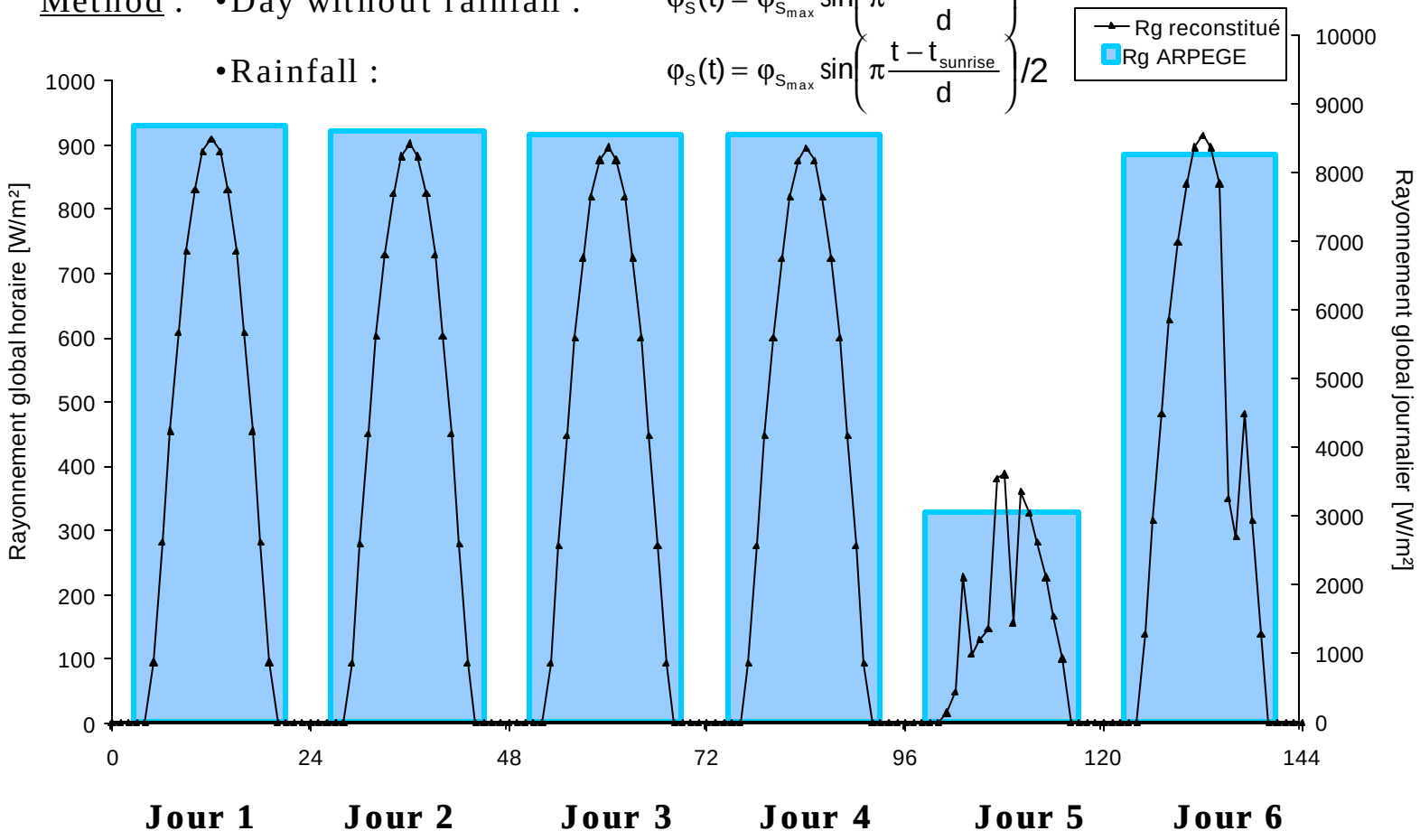


** French national network - Station Météo France de Bordeaux-Mérignac, 1993-1999*

Hourly data reconstruction: global radiation

Method : •Day without rainfall : $\varphi_S(t) = \varphi_{S_{max}} \sin\left(\pi \frac{t - t_{sunrise}}{d}\right)$

•Rainfall : $\varphi_S(t) = \varphi_{S_{max}} \sin\left(\pi \frac{t - t_{sunrise}}{d}\right)/2$

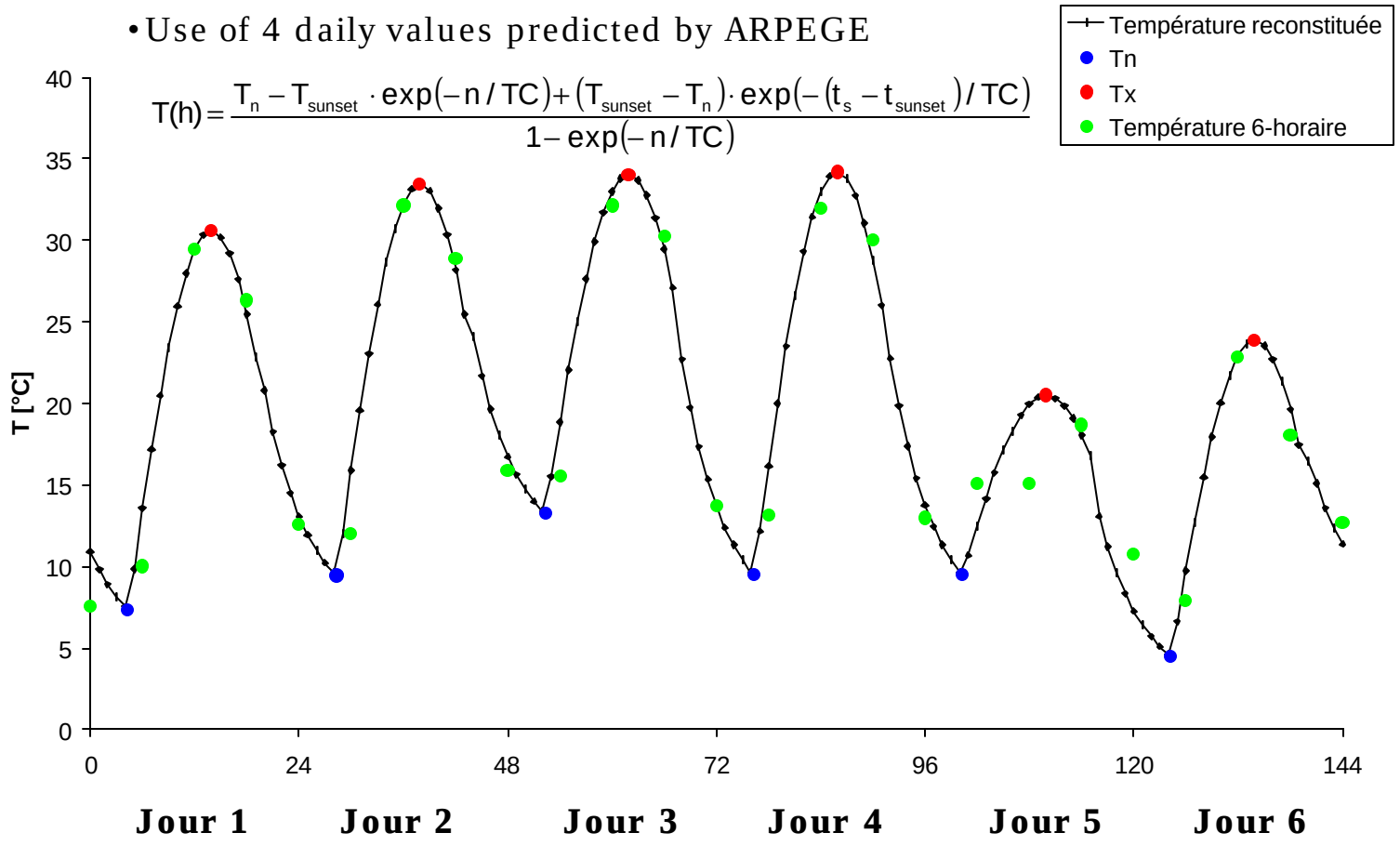


Hourly value interpolation: temperature

Method :

- Sine curve during day: $T(h) = T_n + (T_x - T_n) \cdot \sin\left(\pi \cdot \frac{t_s - 12 + d/2}{d + 2p}\right)$
- exponential dcrease at night:
- Use of 4 daily values predicted by ARPEGE

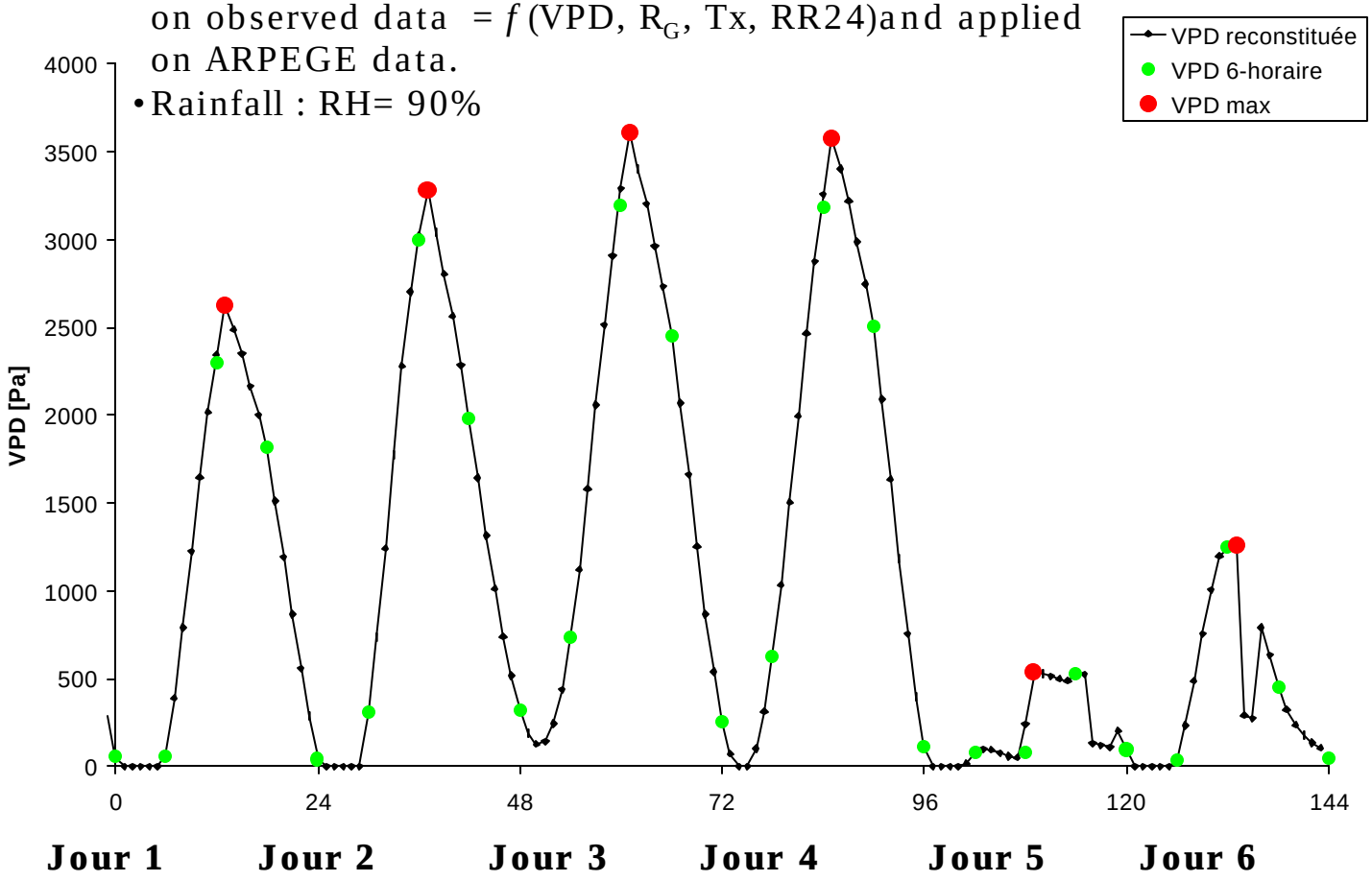
$$T(h) = \frac{T_n - T_{sunset} \cdot \exp(-n/TC) + (T_{sunset} - T_n) \cdot \exp(-(t_s - t_{sunset})/TC)}{1 - \exp(-n/TC)}$$



Hourly values interpolation : VPD

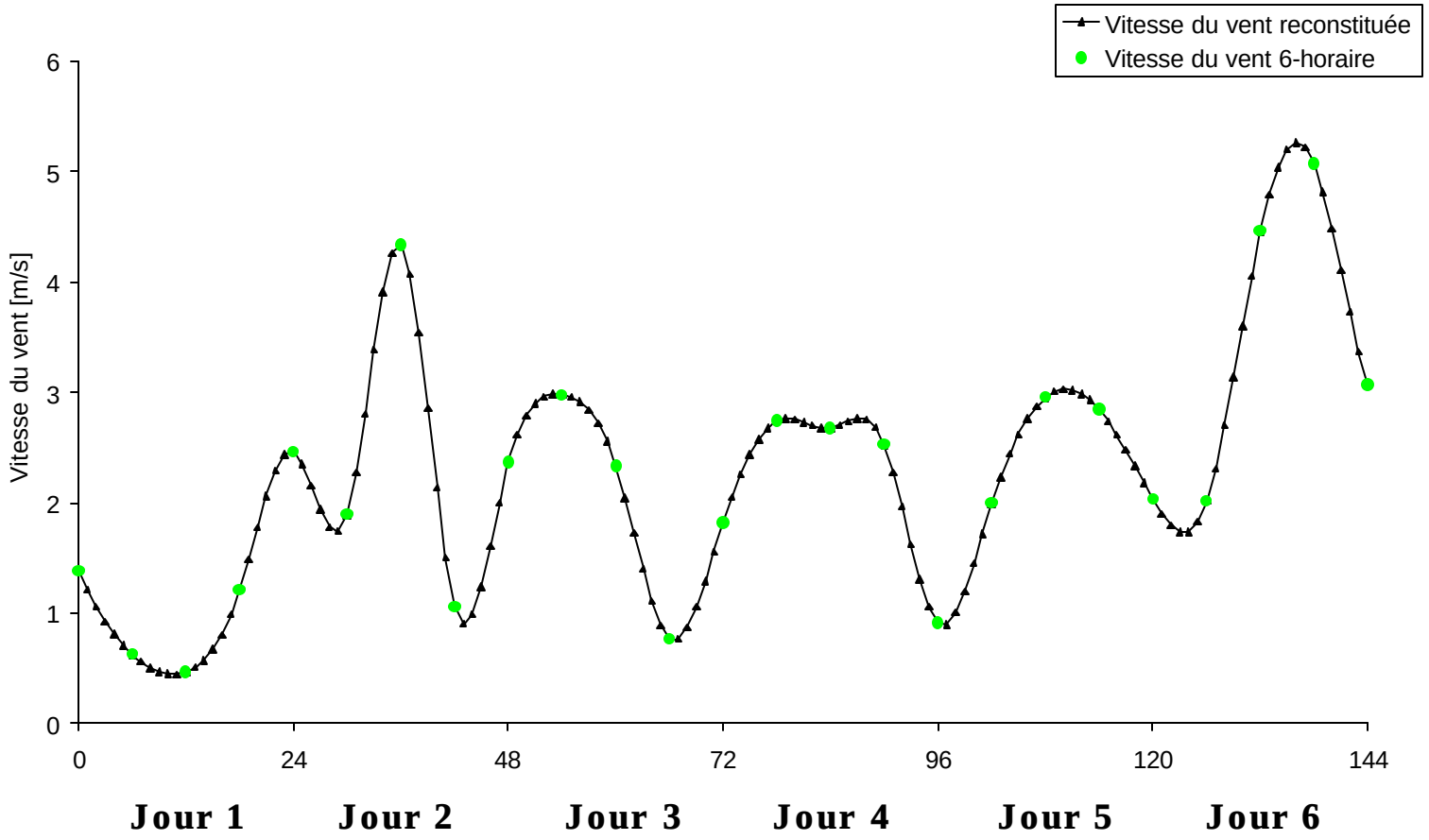
Method : • SPLINE through 4 daily values provided by ARPEGE+ VPDmax modelled on observed data = *f* (VPD, R_G, Tx, RR24)and applied on ARPEGE data.

• Rainfall : RH= 90%



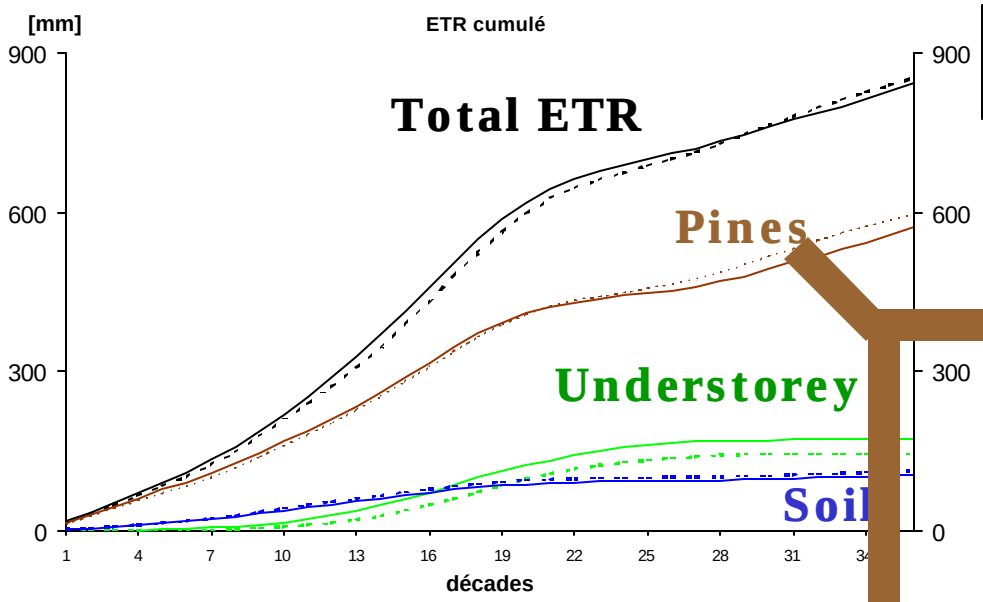
Hourly data interpolation: windspeed

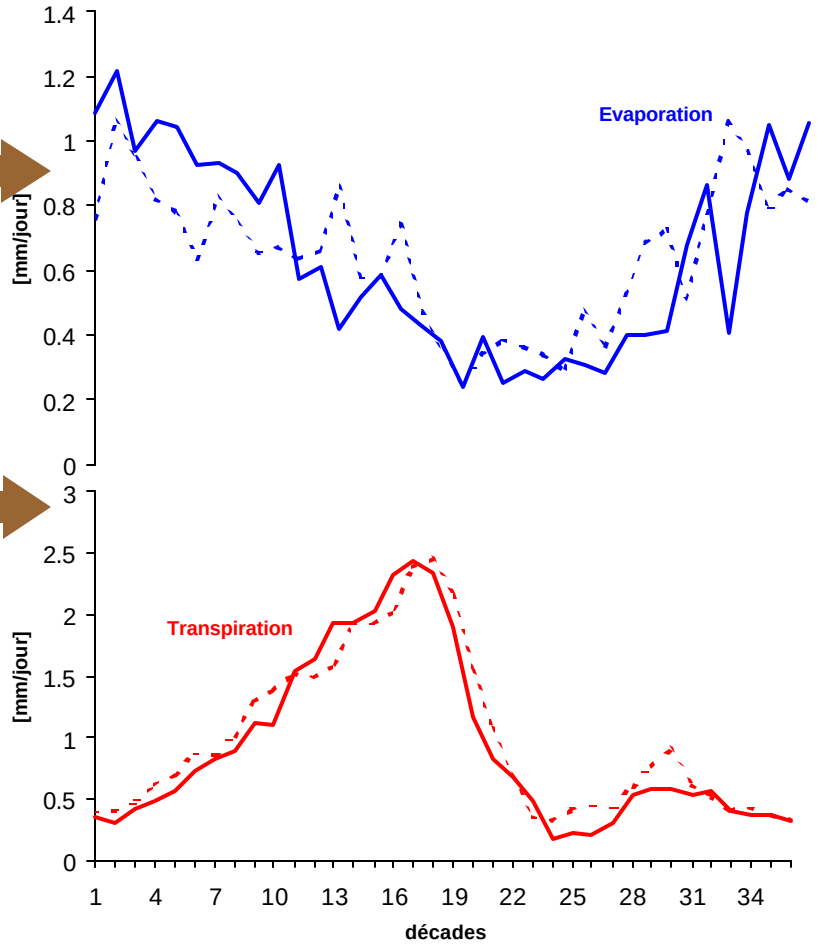
Method : SPLINE through the four daily values provided by ARPEGE



Results

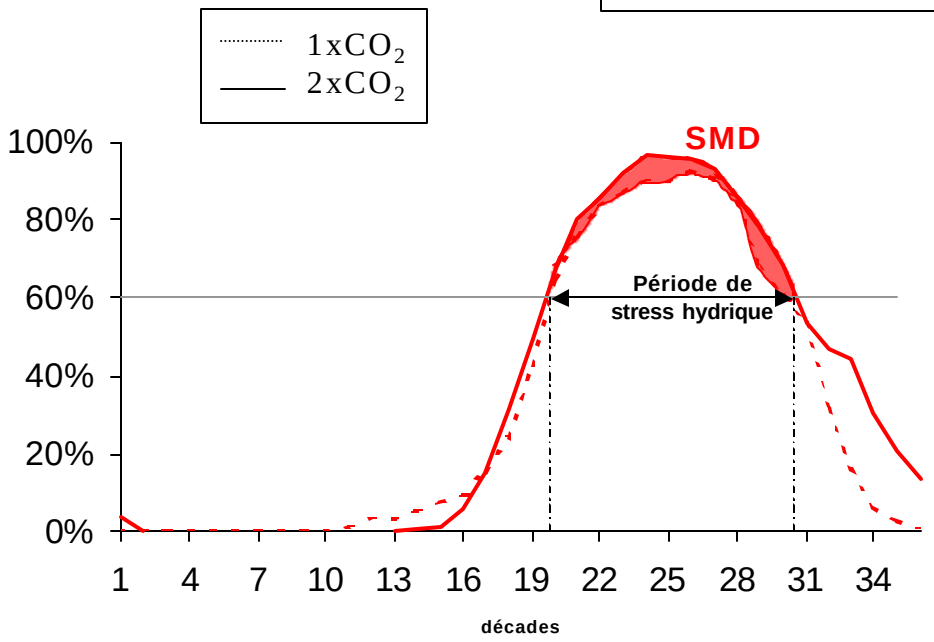
Water balance (average annual course,8 to 17 year-old stand, point 147)





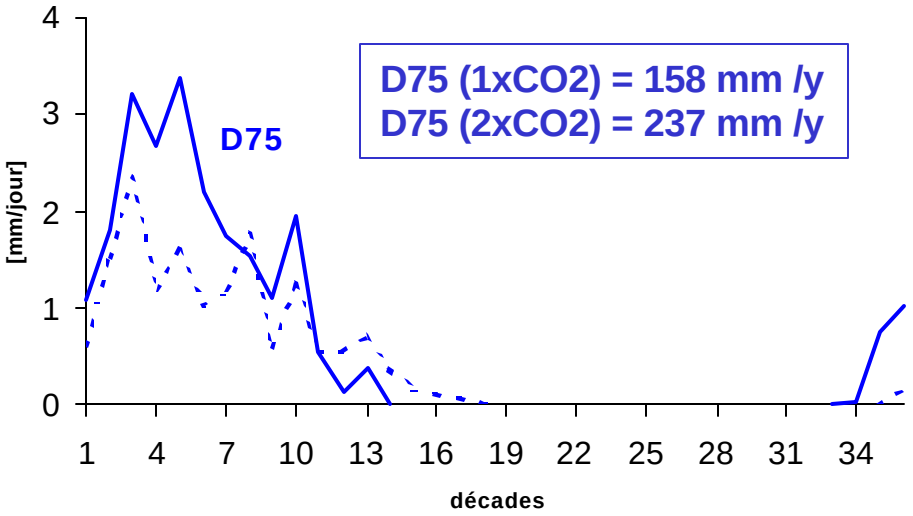
- Total evapotranspirtion unchanged
- Pine transpiration reduced by soil moisture deficit (stomatal closure)
- Understorey ETR enhanced by increased VPD

Annual water balance



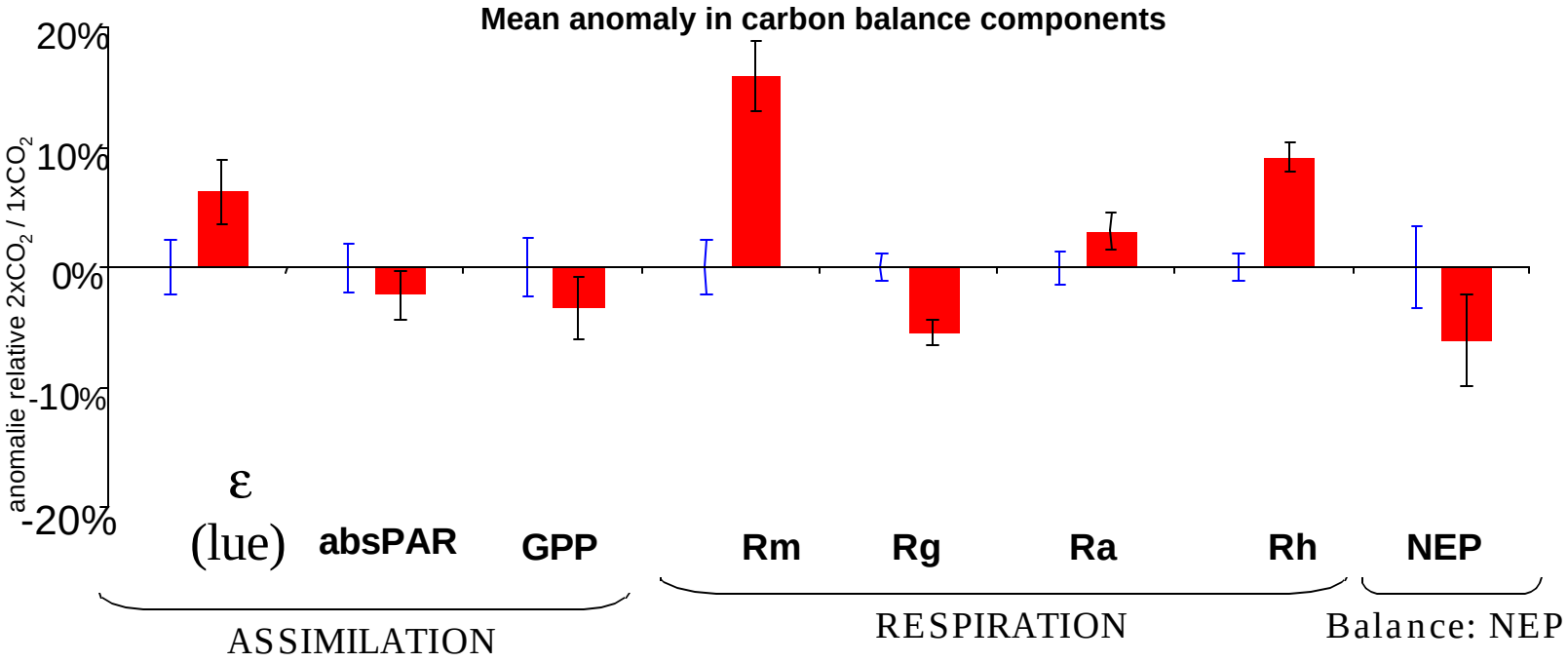
SOIL MOISTURE: seasonal shift in precipitation ==>

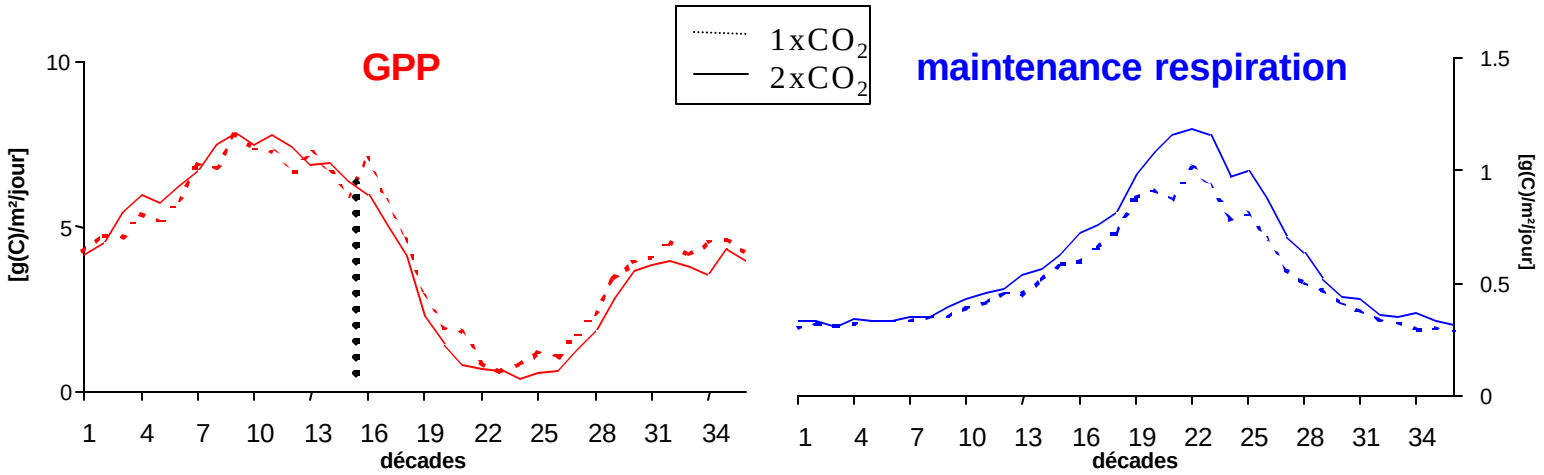
- **Water deficit increased in summer**



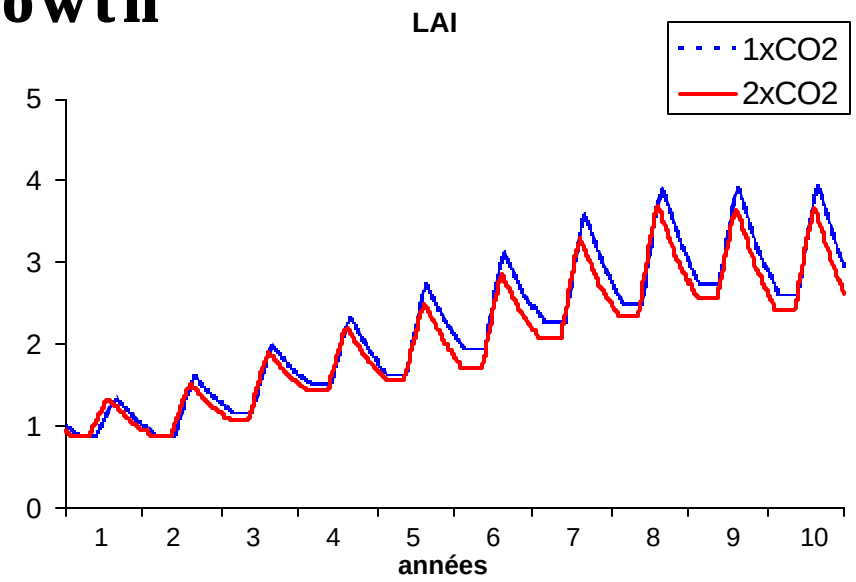
- **Drainage increased in winter**

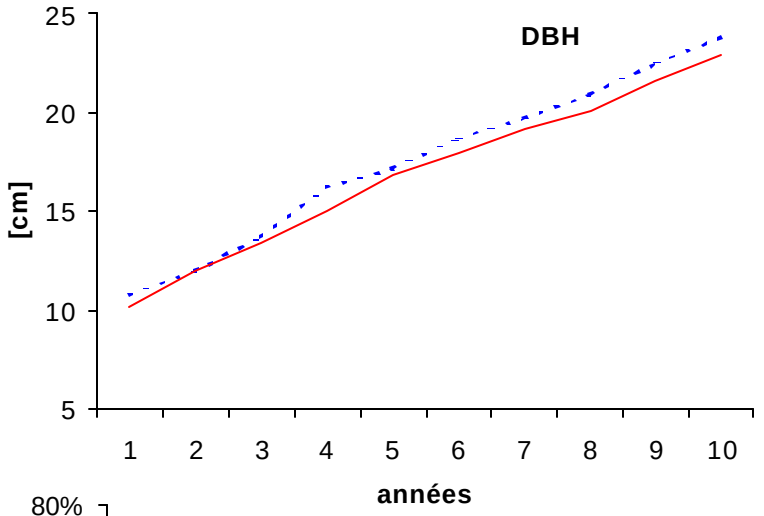
Carbon balance



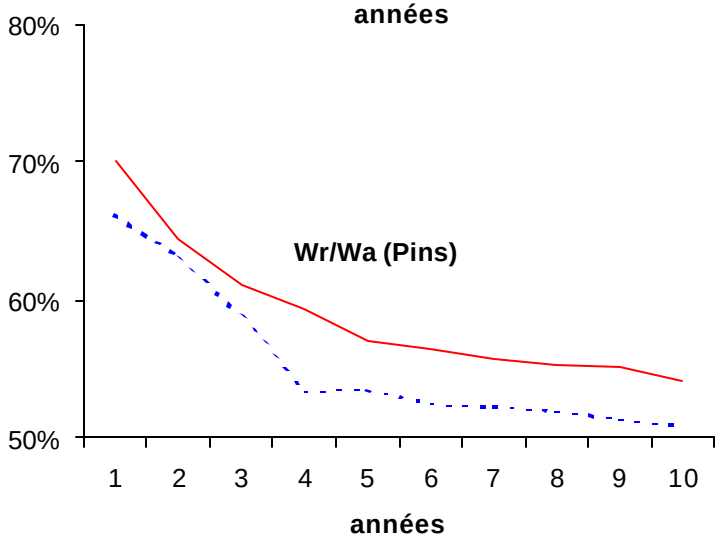


Growth

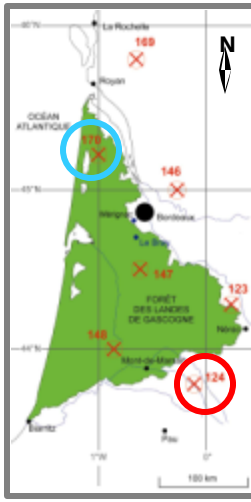


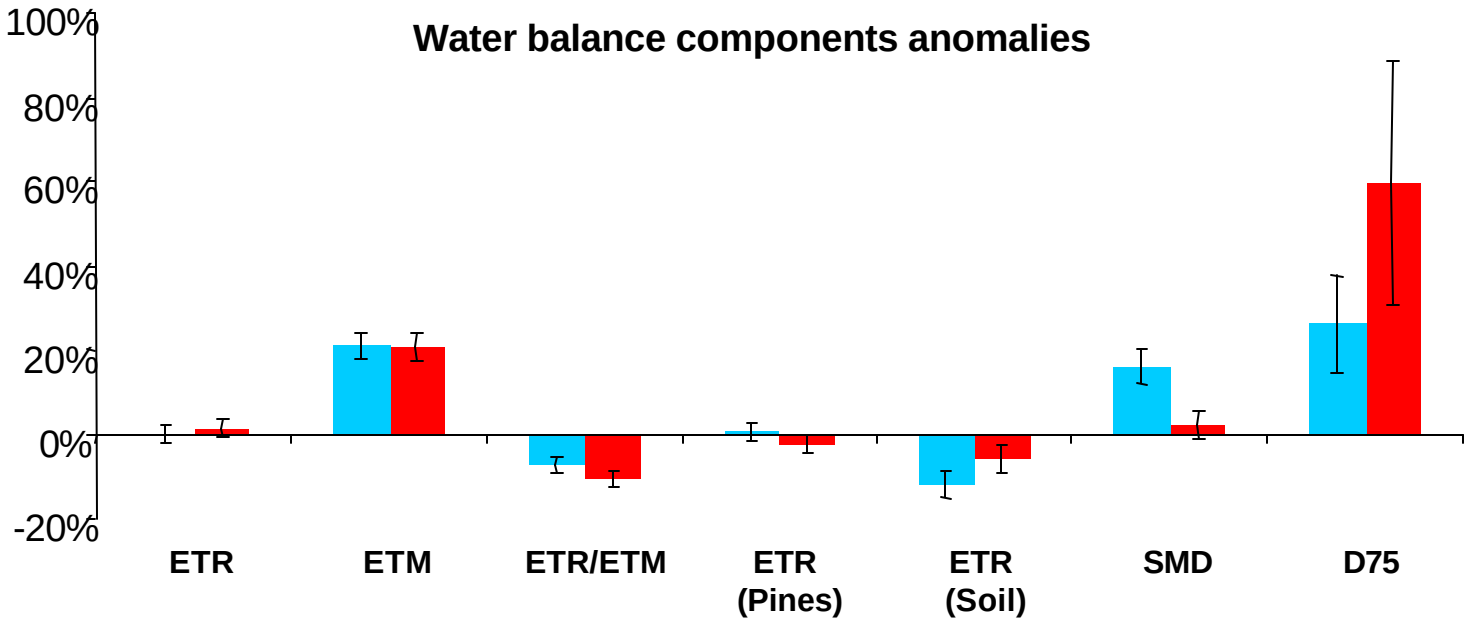


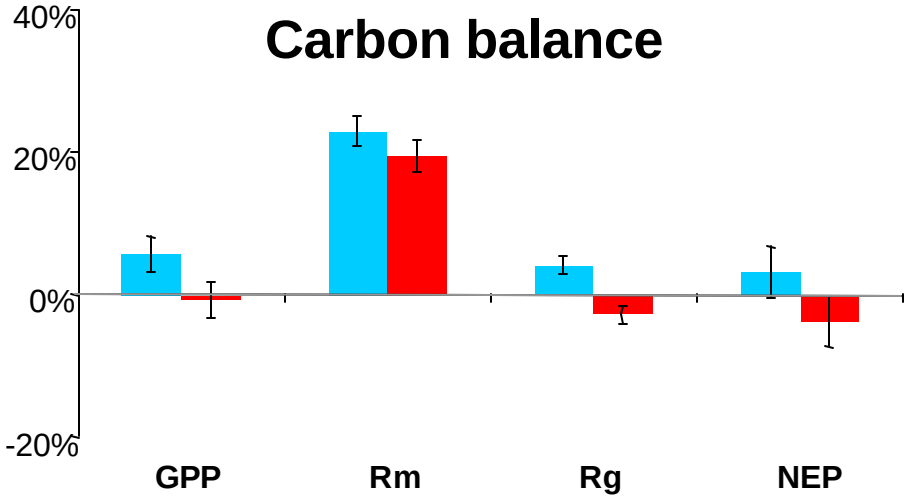
- Slight reduction in LAI
- Height and diameter growth reduced
- Root / Shoot ratio enhanced

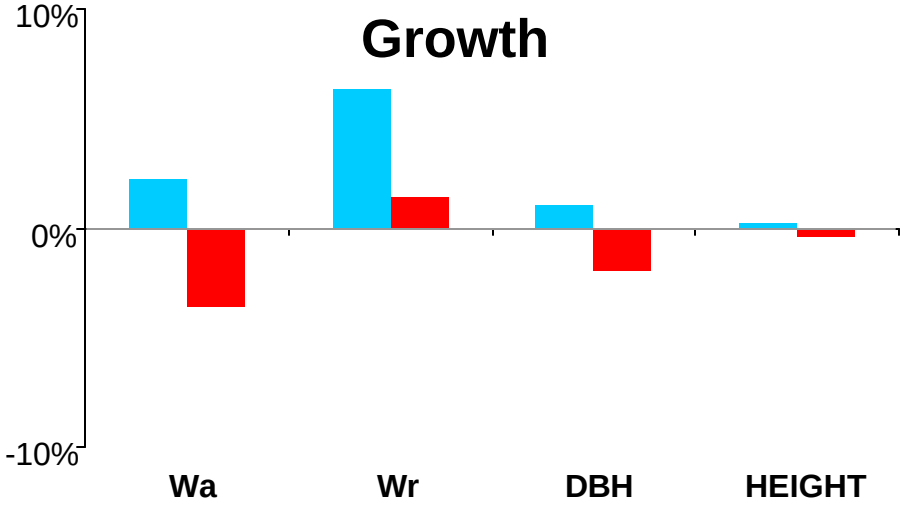


Local variations









Conclusions

- Importance of considering the seasonal and hourly variations in T, RH, Rainfall and VPD
- Significant local variations (50 km) in forest response due to climate
- Importance of soil characteristics (e.g. water holding capacity, nutrient availability)
- Under this particular scenario, the sensitivity to VPD might be more important than CO2.

Participants

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