Photosynthesis and phenology developments

→ Estimating the spatial and temporal variability of photosynthesis parameters: Implementation of the **photosynthesis coordination theory**

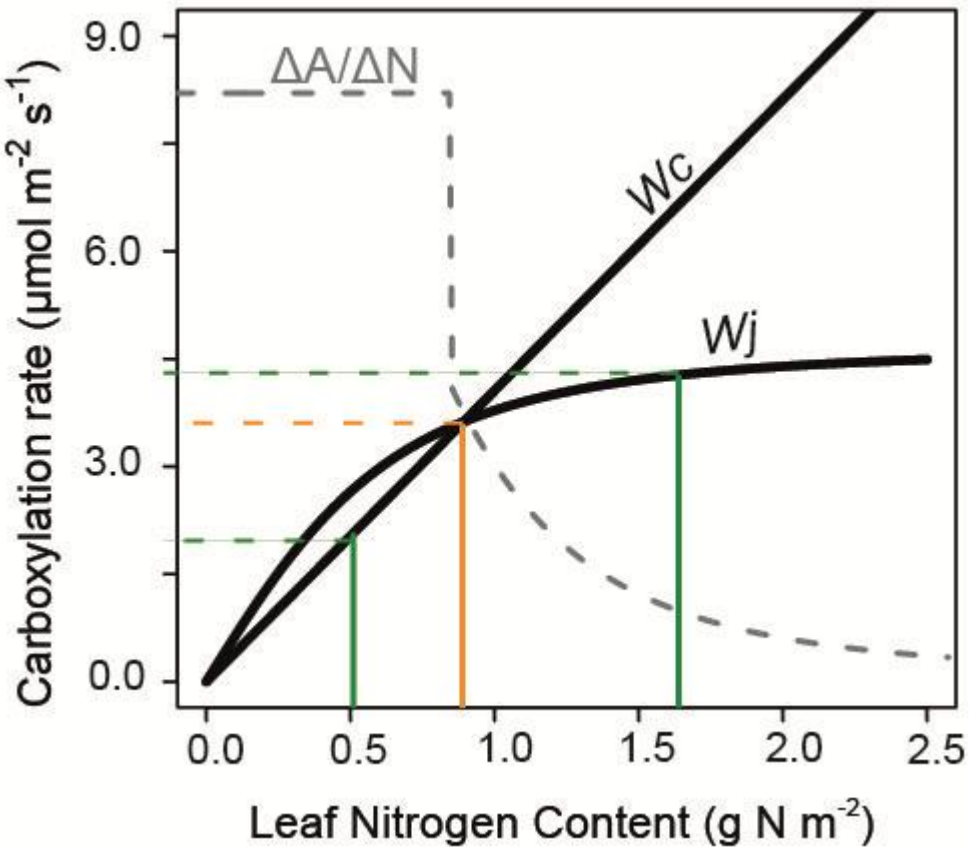
→ Representing an explicit phenology for evergreen coniferous: Implementation of a **new phenology module that represent needle budburst and senescence**

The coordination of leaf photosynthesis

→ The two main photosynthesis parameters in ORCHIDEE:
- The maximal rate of CO2 assimilation limited by CO_2 : **Vcmax**
- The maximal rate of CO2 assimilation limited by light : **Jmax**

→Vcmax and Jmax vary spatially and temporally
→Vcmax and Jmax are strongly correlated
→But Vcmax and Jmax are constant for each PFT in ORCHIDEE

The coordination of leaf photosynthesis



$$W_c = \frac{CV_{c\max}}{C + K_c\left(1 + O/K_o\right)},$$

$$W_j = \frac{J}{\left(4 + 8\Gamma^*/C\right)},$$

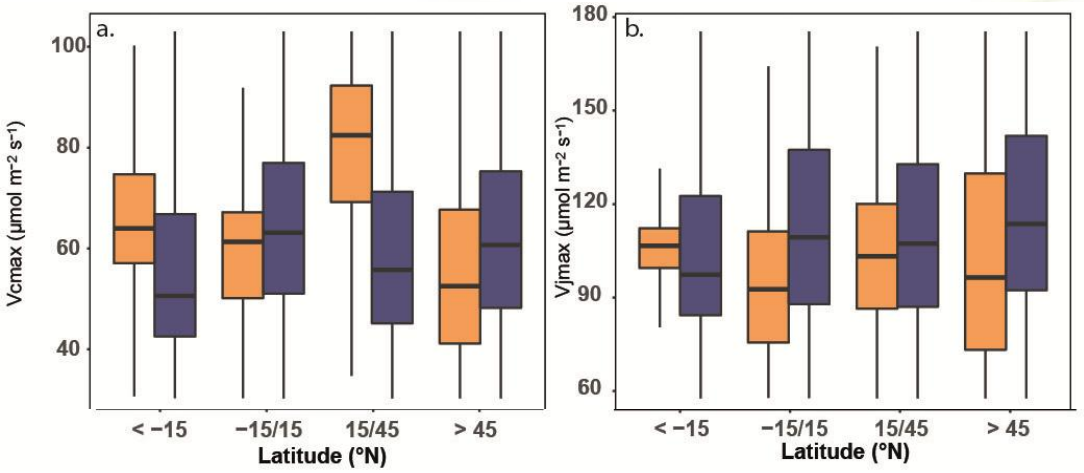
$$J = \frac{4\cdot\alpha\cdot PPFD}{\left(1 + (4\cdot\alpha\cdot PPFD)^2 \Big/ \left(J^r_{\max}\cdot\Phi_{J_{\max}}\right)^2\right)^{1/2}}$$

$$J^r_{\max} = J^{atc}_{fac}\cdot V^r_{C_{\max}}$$

→Initially Implemented in ORCHIDEE TRUNK v.1.9.6

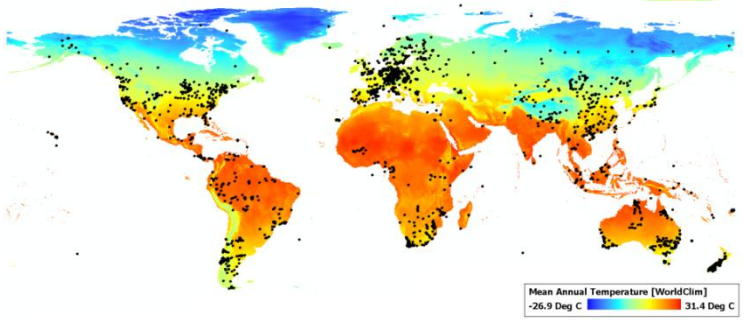
→Vcmax and Jmax estimated from light, humidity, temperature and CO_2

Results
Comparison with trait observations



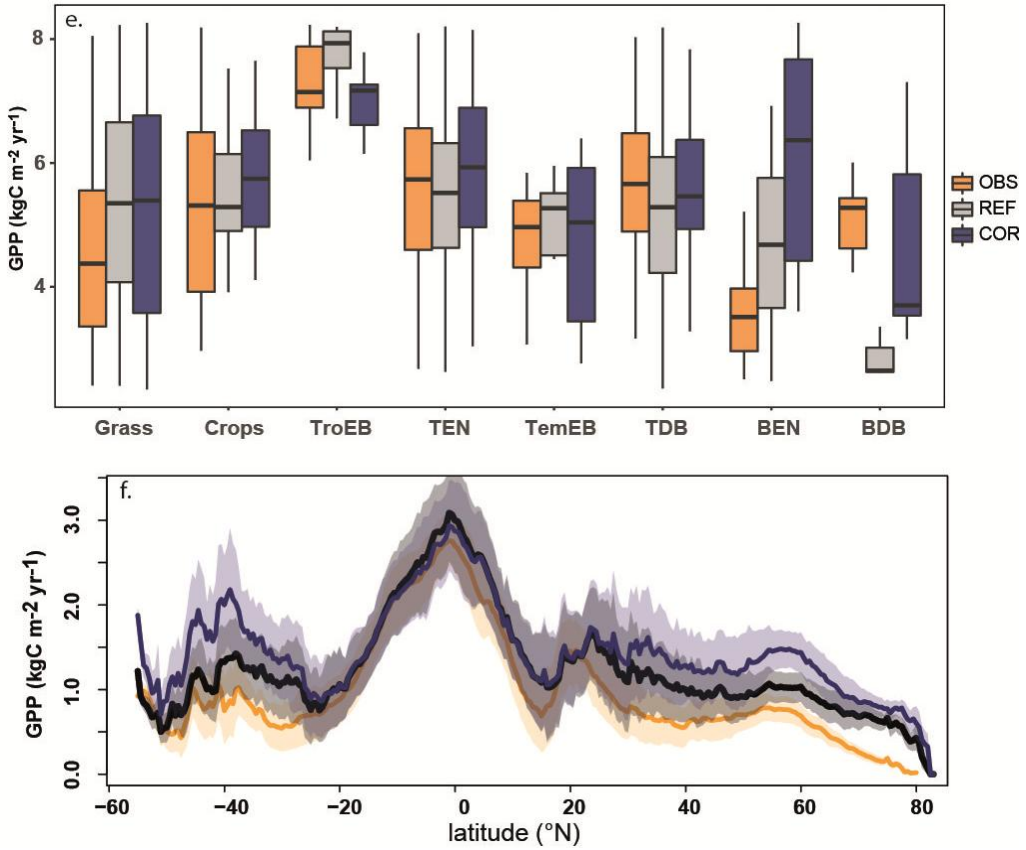
Interpolation from global observations

Trait simulated with the coordination (2000-2010)



(Kattge *et al.* ,2011)

Results
Comparison with GPP observations



e. FLUXNET observations
f. Jung et al. 2011

REF = ORCHIDEE TRUNK
COR= coordination

Average 2000-2010

	Global GPP
REF	145 PgC y^{-1}
COR	165 PgC y^{-1}
Literature	120 -170 PgC y^{-1}

Estimation of leaf CN variability

→Now implemented in ORCHIDEE-CNP

→Used to estimate leaf CN target

$$V_{C_{max}}^{r} = k_3^{ac} \cdot N_{pa}$$

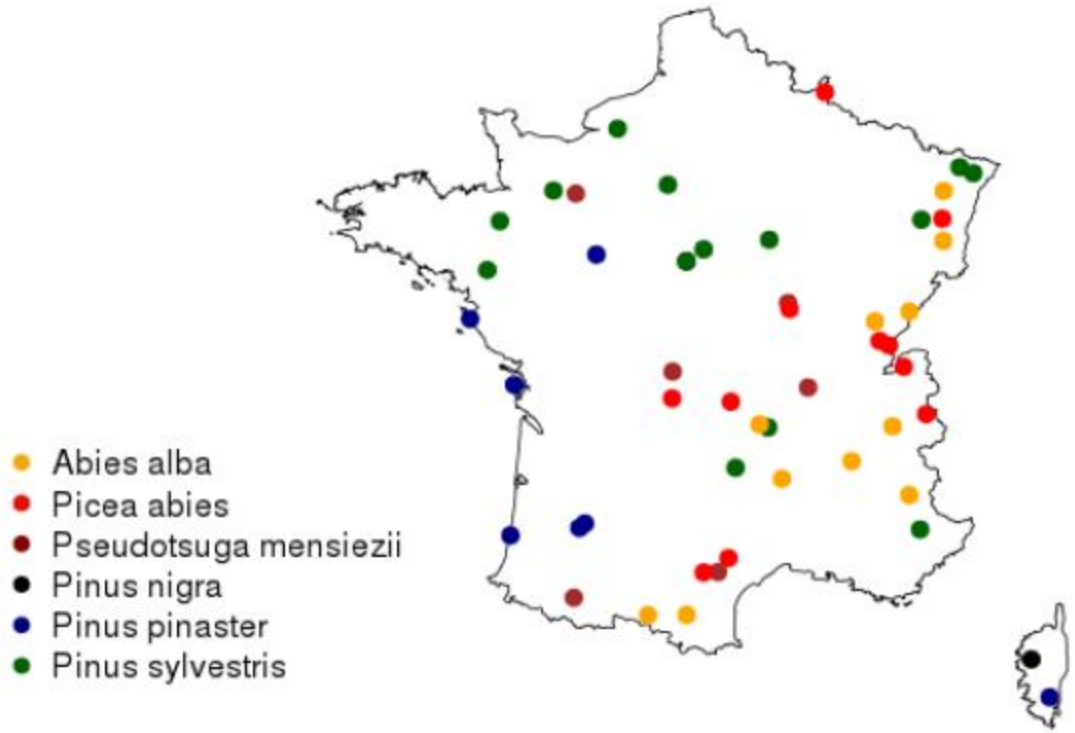
→Current work: Test the coordination hypothesis on FACE sites at eCO_2

Representing an explicit phenology for coniferous

- No explicit representation of needle budburst nor senescence for evergreen species
- Overestimation of the growing season length (~335gC m^{-2} y^{-1}; Richardson et al., 2012)
- Impact on needle age, photosynthesis efficiency, LAI, needle turnover, litter, etc.…

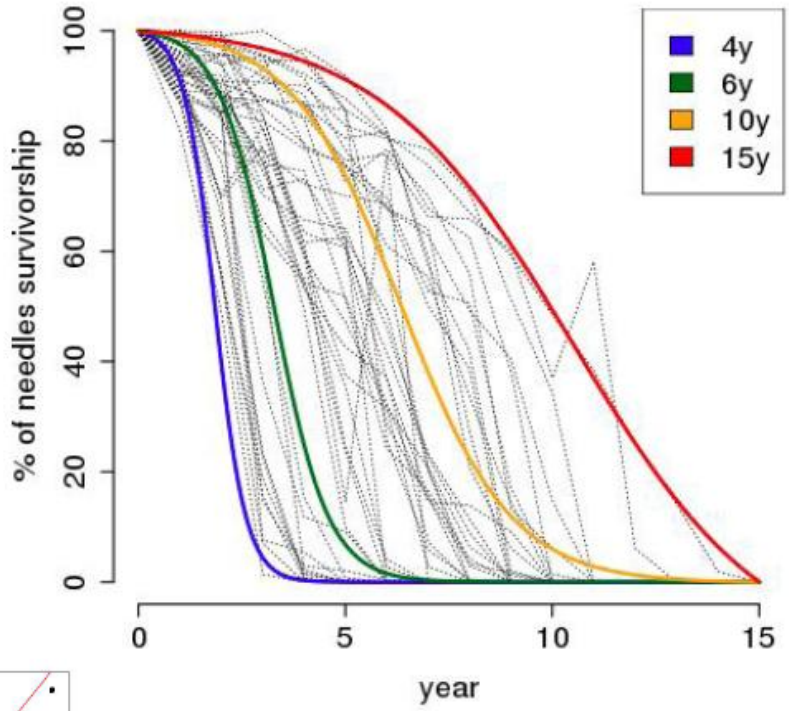
Needle budburst

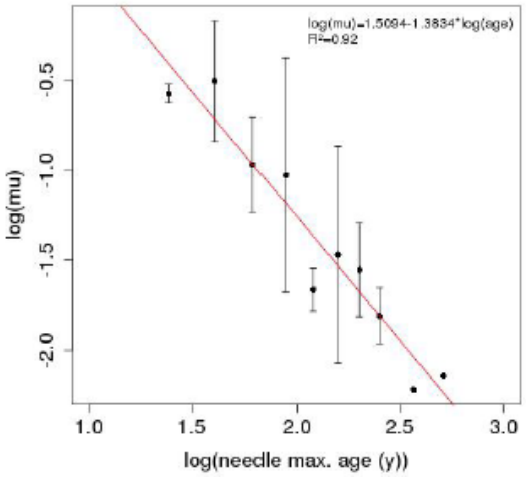
- 9 different budburst models fitted against observations from the French long-term monitoring network RENECOFOR (ONF)
- 6 dominant species
- The 9 models were implemented in ORCHIDEE trunk v.1.9.6
- 3 classes of model: GDD (spring forcing), NCD-GDD (chilling-forcing) and photoperiod (day length)

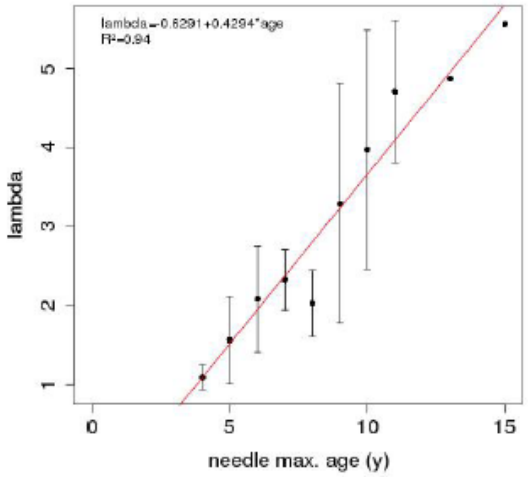


Needle Senescence

- Empirical logistic model derived from needle survivorship curves
- Model function of the needle lifespan
- In ORCHIDEE, continuous senescence all over the year







$$S(t) = \frac{1}{1 + exp(4\mu \cdot (\lambda - t) + 2)}$$

$$log(\mu) = 1.5094 - 1.3834 \times log(age_{crit}); R^2 = 0.92$$

$$\lambda = 0.6291 + 0.4294 \times age_{crit}; R^2 = 0.94$$

Modification of ORCHIDEE

Budburst:

All needle cohorts are represented

The new biomass is allocated to the new cohort only

At the end of the year cohort n=cohort n+1, etc....

Modification of Vcmax efficiency : Vcmax is optimal after 3 month and start to decline after 1y even for species with a needle lifespan of 10 years (Spruce)

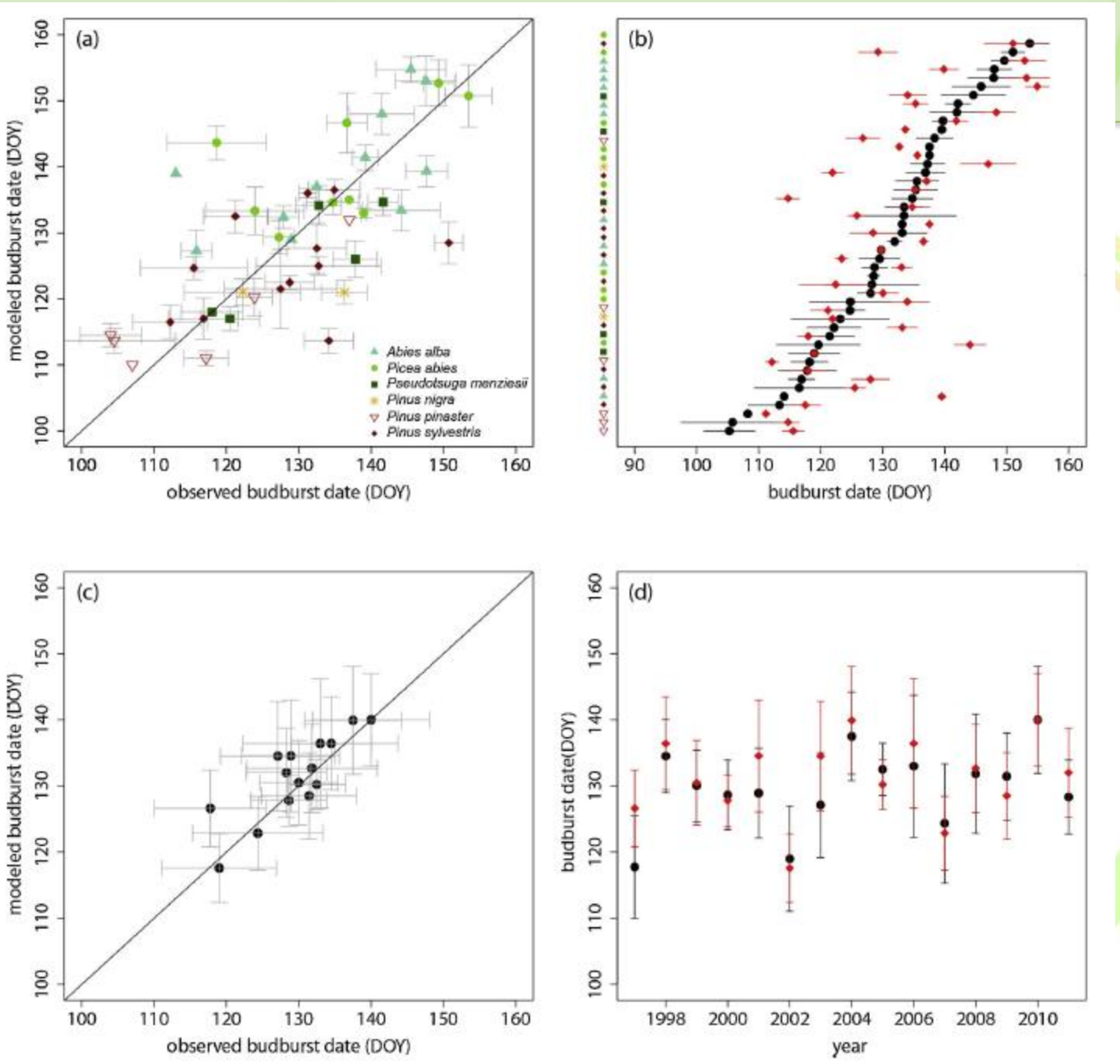
Calibrated for all species, groups of species and each species separately

Senescence :

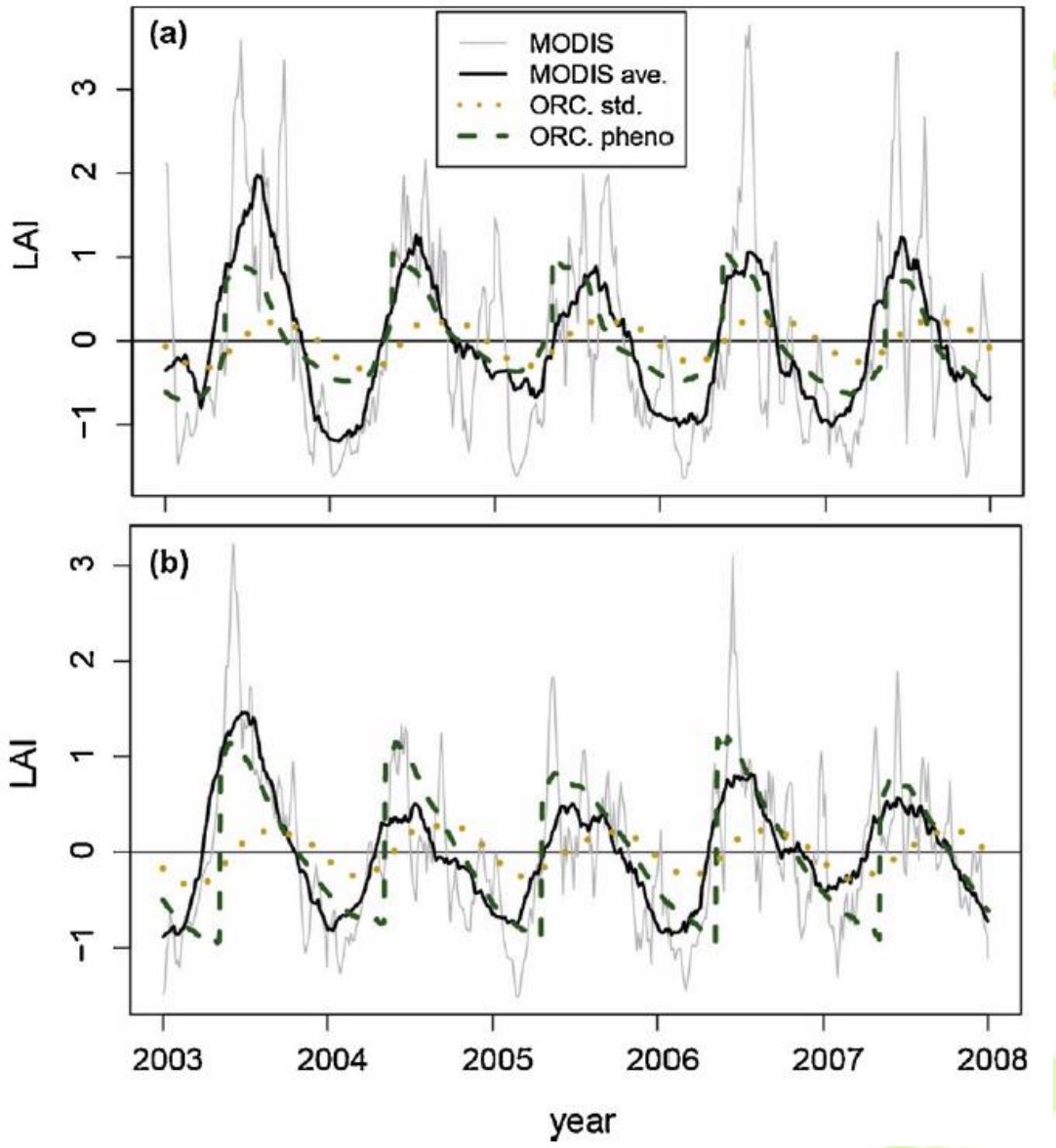
Continuous

Applied to each cohort

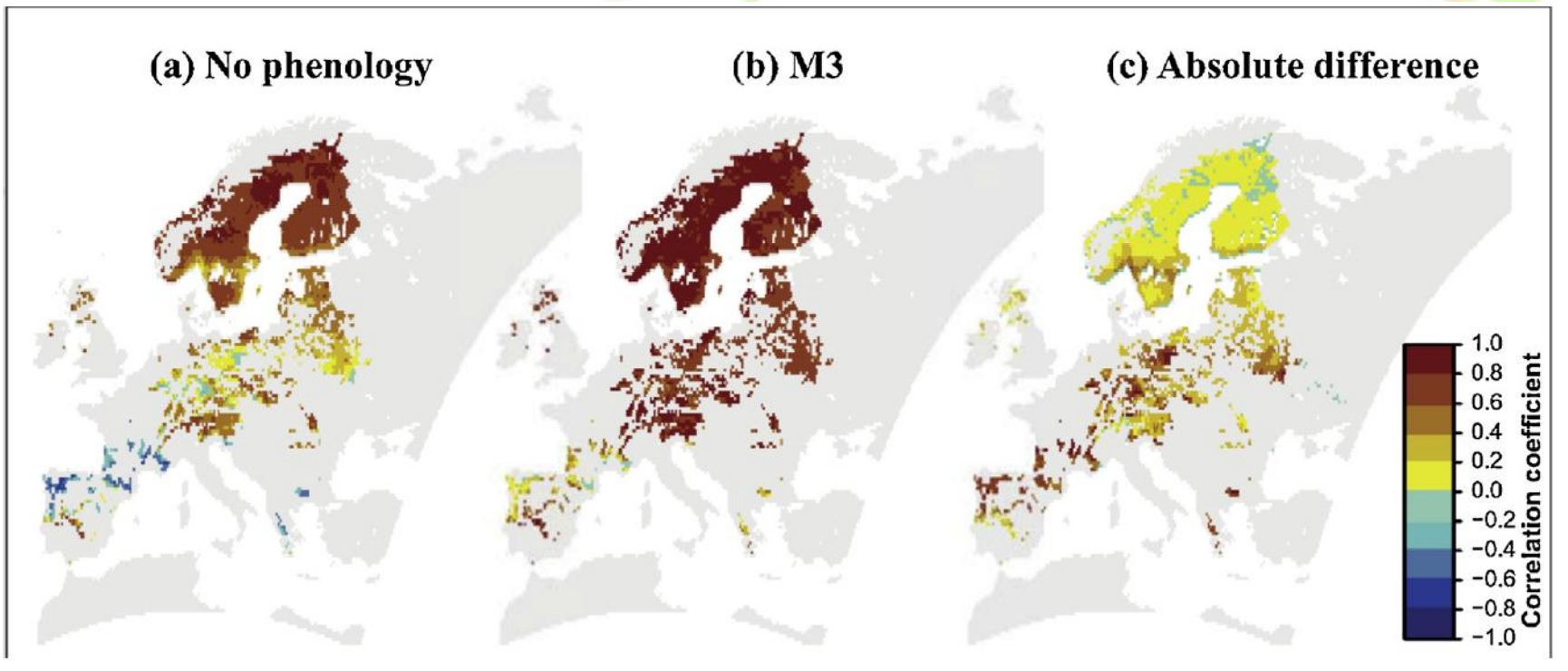
Calibrated for all species pooled together


(a)
modeled budburst date (DOY)
observed budburst date (DOY)
Abies alba
Picea abies
Pseudotsuga menziesii
Pinus nigra
Pinus pinaster
Pinus sylvestris
(b)
budburst date (DOY)
(c)
modeled budburst date (DOY)
observed budburst date (DOY)
(d)
budburst date(DOY)
year

Better representation of LAI dynamics



Better representation of LAI dynamics



Results

1) No real differences between the 3 types of model
2) Better representation of LAI dynamics
3) Better representation of litterfall (from -57 to +17 % in average)
4) Increase of GPP by 15% due to the faster renewal of needles compared to the standard version (higher Vcmax for young needles)