The role of microclimates in climate change responses: ecologists need climatic data with high resolution

Sylvain PINCEBOURDE

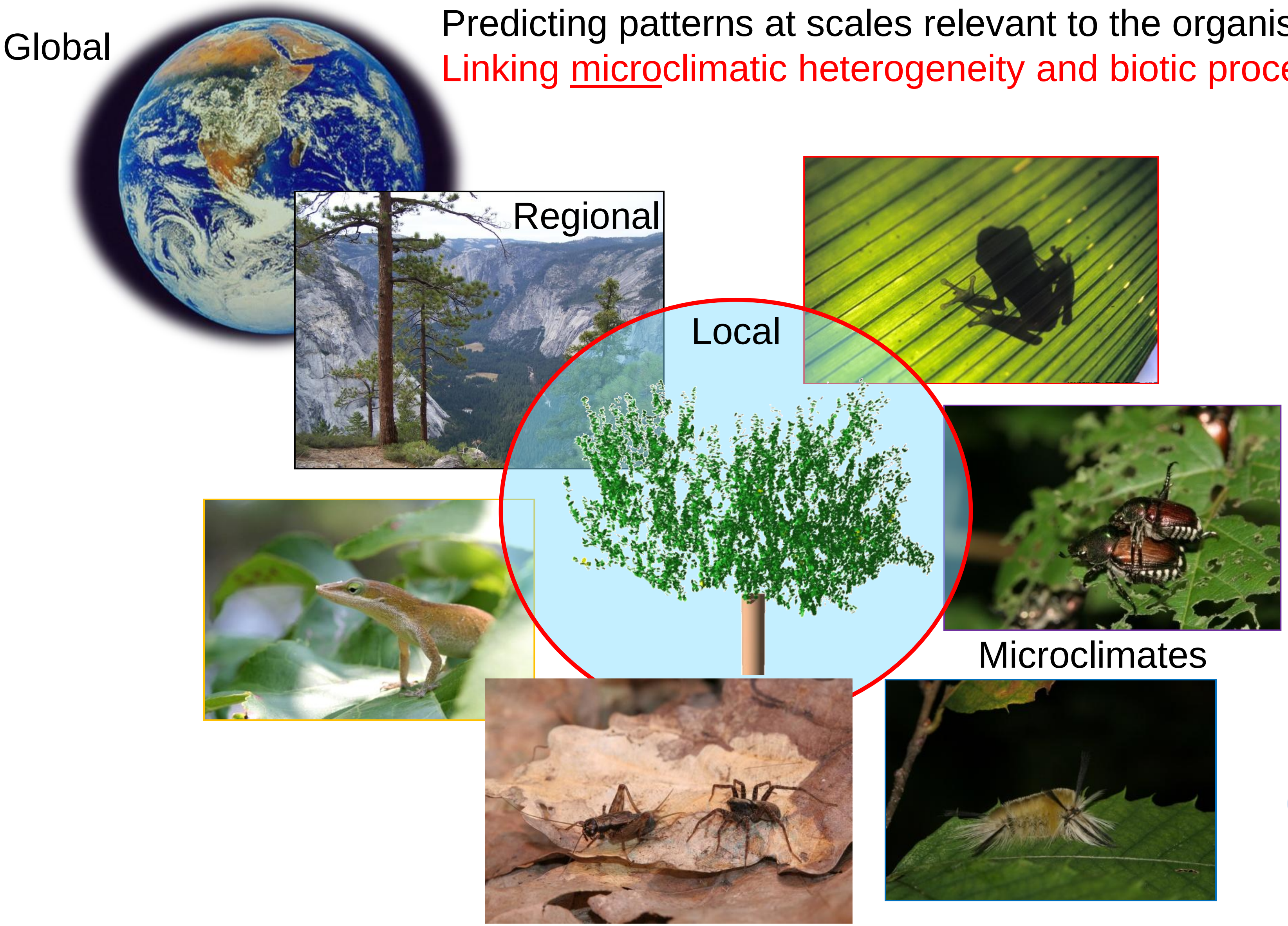
Research Institute on Insect Biology (IRBI), CNRS, Tours, France

SWGEN, Avignon, September 16-19, 2014

Microclimates: a key role in climate change responses

Predicting patterns at scales relevant to the organism

Linking <u>micro</u>climatic heterogeneity and biotic processes



Microclimates: a key role in climate change responses

Framework

Weather / Climate

↓

Microclimates/body temperatures

↑ ↓

Thermal adaptations

Do microhabitats buffer or amplify climate fluctuations?

What is the level of heterogeneity at small scale?

How organisms modify or find another microclimate depending on their needs?

Example of a micro-habitat

Up-scaling heterogeneities

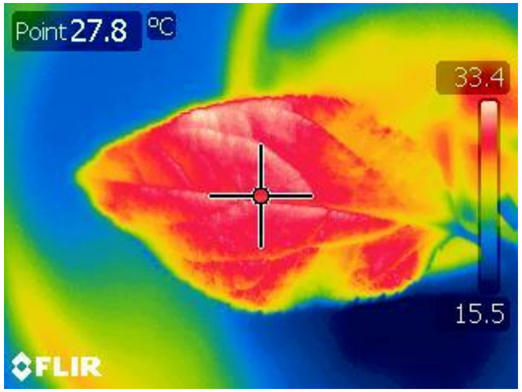
My aim here is to show you:

→Why ecologists need fine scale meteorological data, and how fine should it be?

→How (some) ecologists are trying to 'upscale', starting form the organism body (while *climatologists* are downscaling, starting from GCMs – when will we meet?).

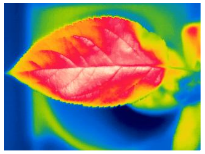
Living in the leaf microclimate

- Plant leaves host an important biodiversity
- The leaf filter is dynamic
- It can be altered by herbivores

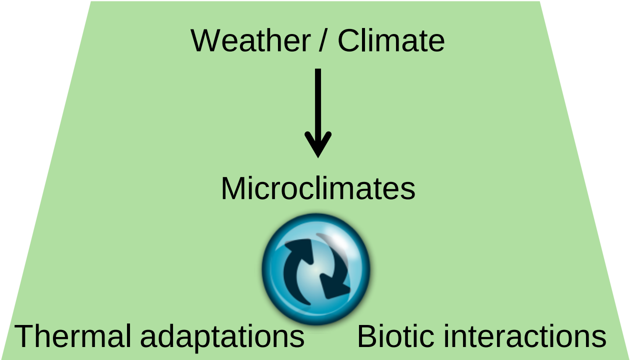


Caillon et al. 2014, *Functional Ecology*

Living in the leaf microclimate



The link between leaf microclimate, insect thermal adaptation and the importance of manipulations : studying an extreme scenario to understand general patterns

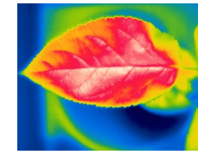


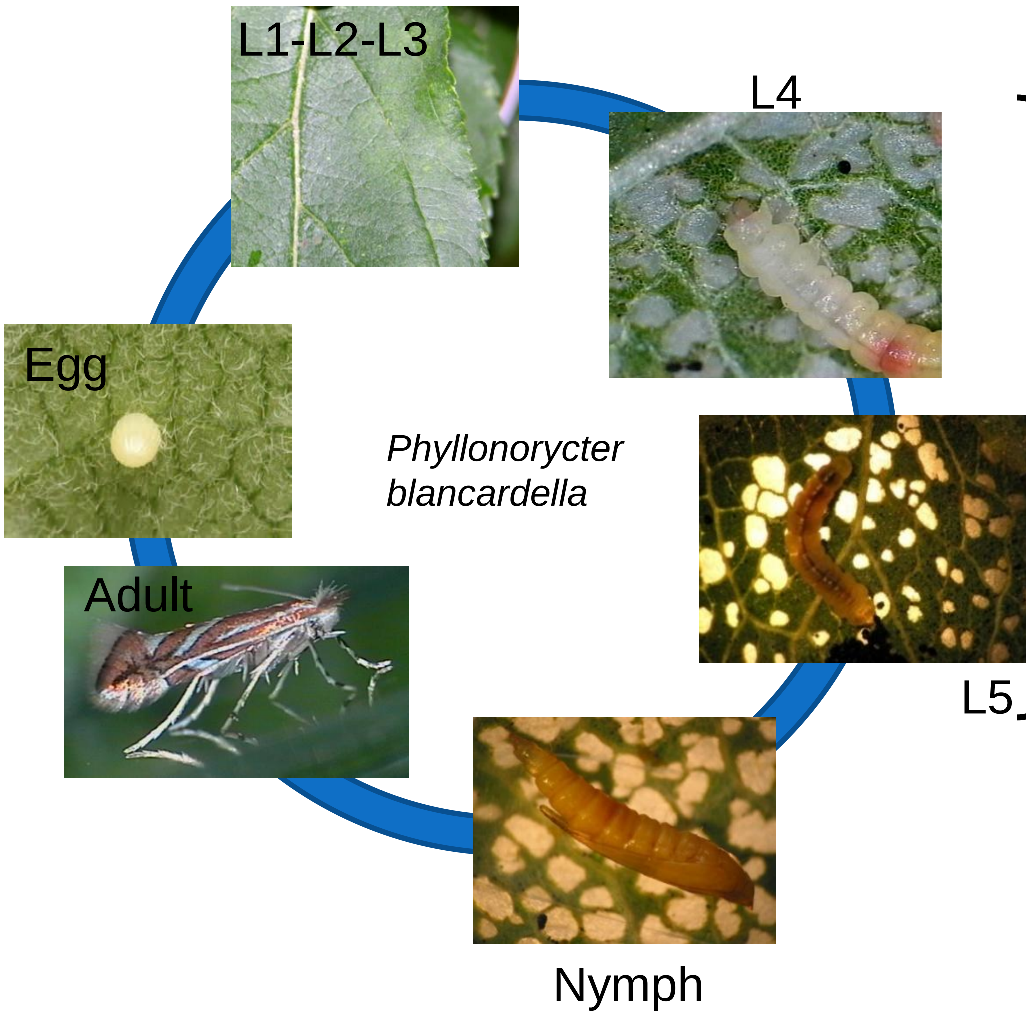
Leaf miners as a model system to study the inter-relationship between these 3 factors

- Modifications of plant tissues
- The microclimate within a mine
- Relationship between thermal tolerance and mine microclimate

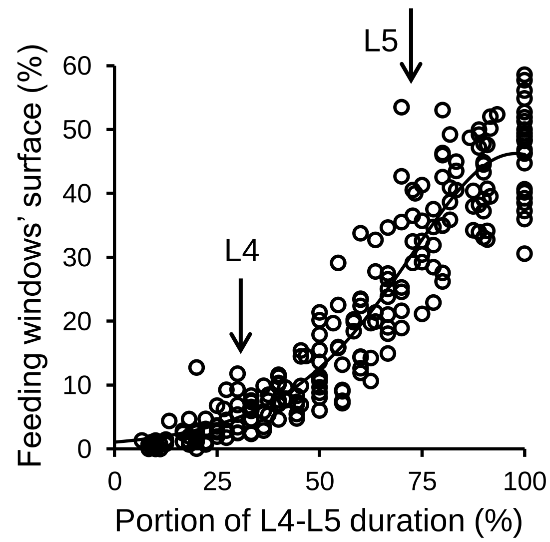
Biophysical modeling approach
Across ontogeny

Living in the leaf microclimate

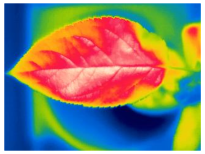


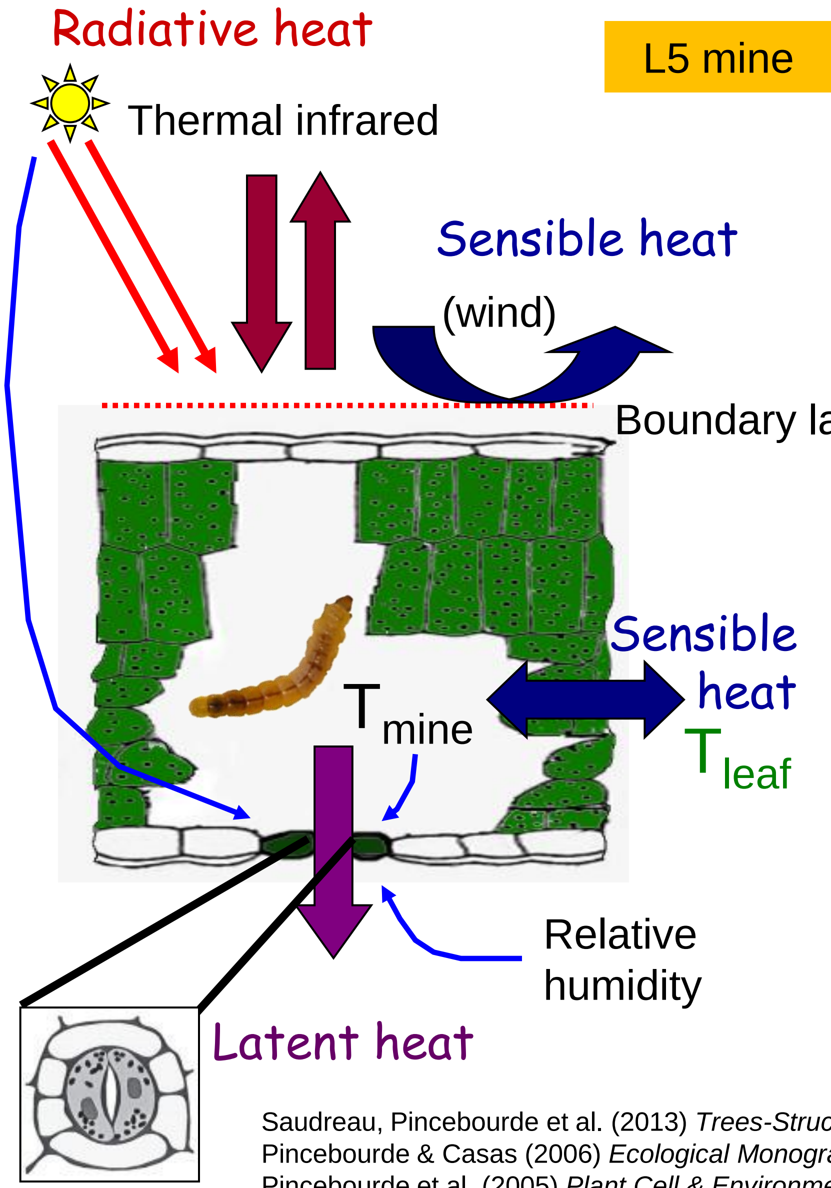


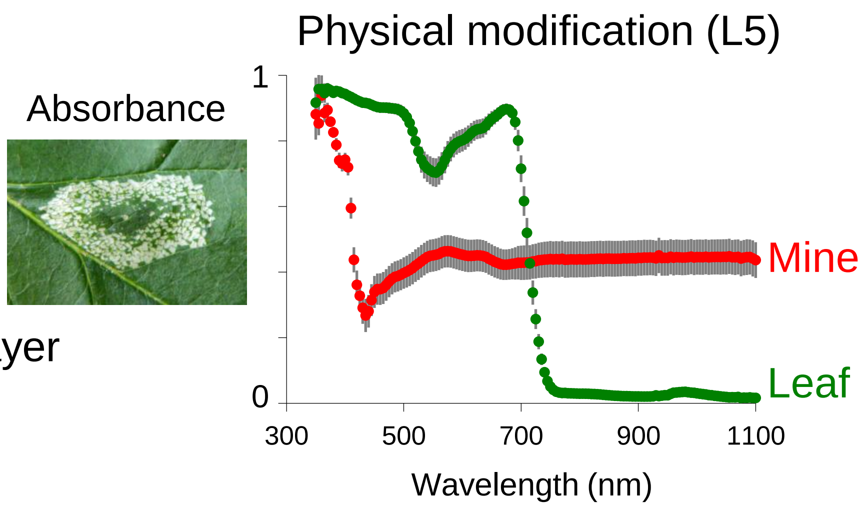
Characterize the mine microclimate along larval development

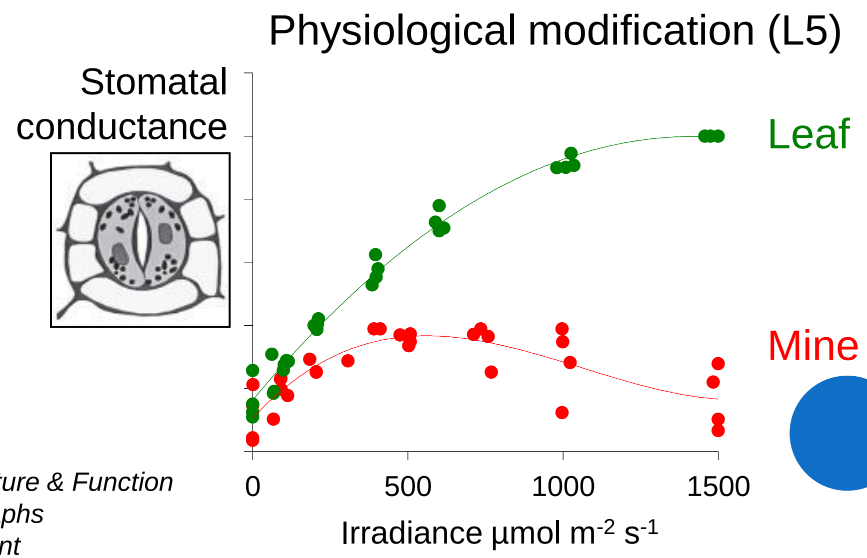


Living in the leaf microclimate









Saudreau, Pincebourde et al. (2013) *Trees-Structure & Function*
Pincebourde & Casas (2006) *Ecological Monographs*
Pincebourde et al. (2005) *Plant Cell & Environment*
Pincebourde & Casas (2006) *Journal of Insect Physiology*

The heat balance model

Radiative heat

Sensible heat

Latent heat

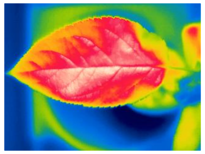
$$\left(a^{vis}I^{vis}+a^{nir}I^{nir}+a^{tir}I^{tir}-\varepsilon\theta T_M^4\right)-\left(0.135c_p\sqrt{\frac{u}{d}}\left(T_M-T_{air}\right)\right)-\left(\lambda\left(\frac{0.5}{\frac{1}{0.147\sqrt{\frac{u}{d}}}+\frac{1}{g_{vs}}}+\frac{0.5}{\frac{1}{0.147\sqrt{\frac{u}{d}}}+\frac{1}{g_{ve}}}\right)\left(\frac{e_s(T_M)-e_a}{P}\right)\right)-\left(0.05c_p\left(\frac{T_M-T_L}{Ep}\right)^{0.25}\left(T_M-T_L\right)\right)=0$$

Jarvis model (1976) for stomatal conductance

$$g_{vs}=g_{smax}\,f(Q)\,f(VPD)\,f(T_M)$$

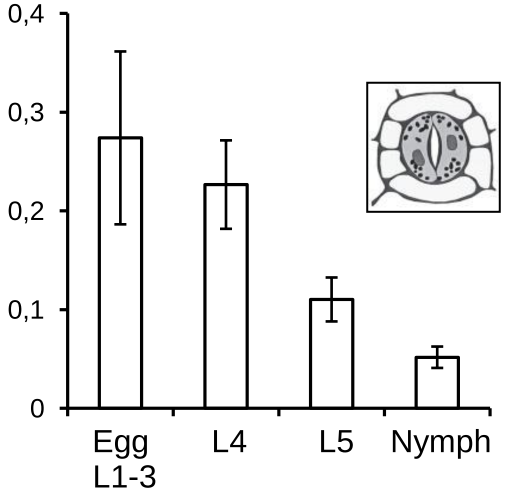
Pincebourde & Casas 2006, Ecological Monographs

Living in the leaf microclimate

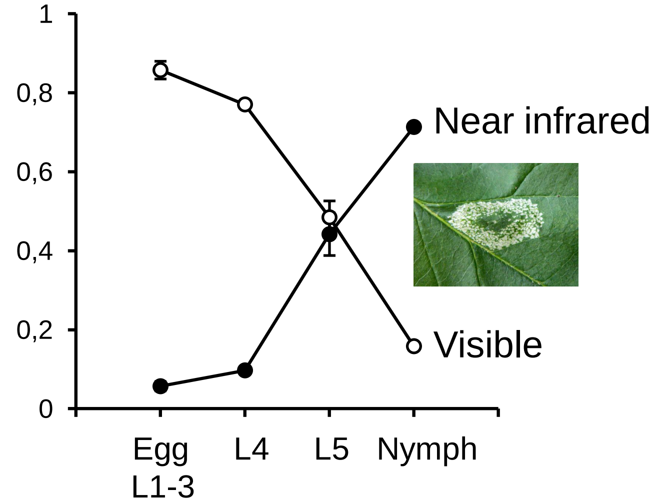


Physical and physiological modifications across ontogeny

Maximal stomatal conductance
(*gsmax*, mol m^{-2} s^{-1}) @ 25°C

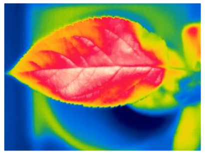


Absorbance



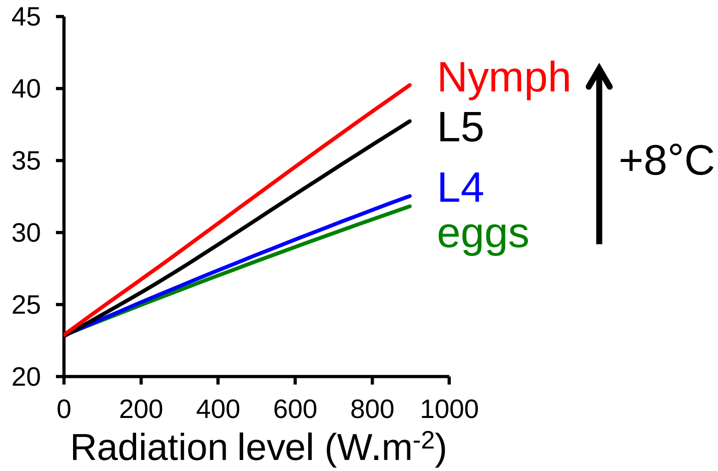
Pincebourde & Casas, 2015, Ecology

Living in the leaf microclimate

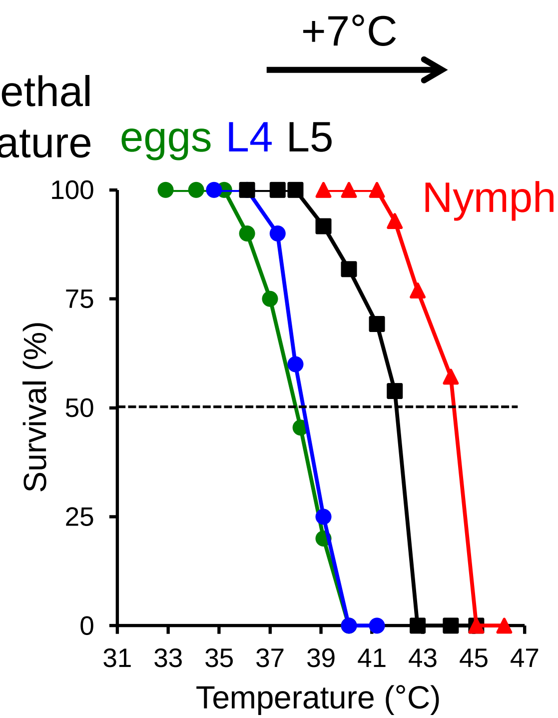


Mine temperature and upper thermal tolerance across leaf miner ontogeny

Biophysical model predicts mine temperature (°C) at ambient air 25°C



Upper lethal temperature

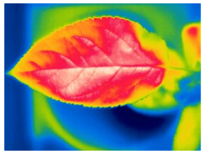


The older … the warmer … the more tolerant

Naïvely : The nymph is at risk because it is in a warm microclimate

Or eggs and L4 are at risk because they are less tolerant

Pincebourde & Casas, 2015, Ecology



Living in the leaf microclimate

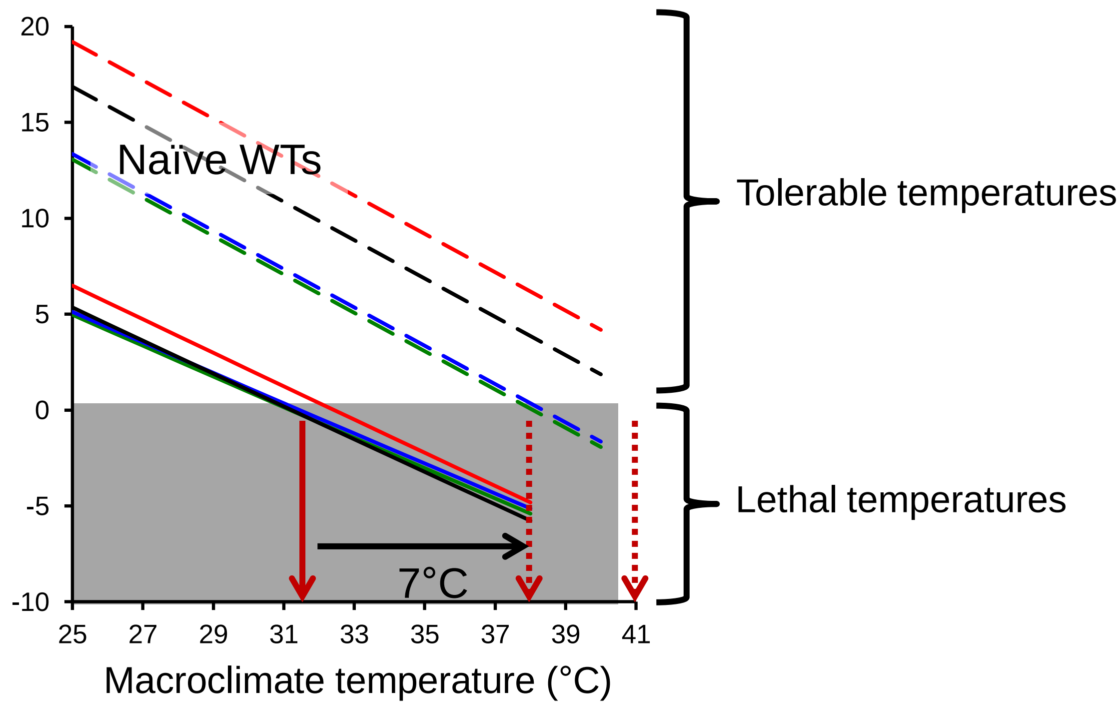
Integrating mine temperature and upper thermal tolerance to forecast ‘warming tolerance’ across ontogeny

Warming tolerance (°C) = lethal threshold minus mine/air temperature

Well-informed WT

Naïve WT

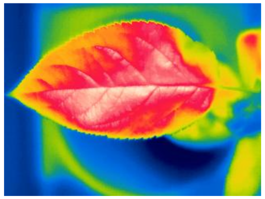
(biophysical model simulations)

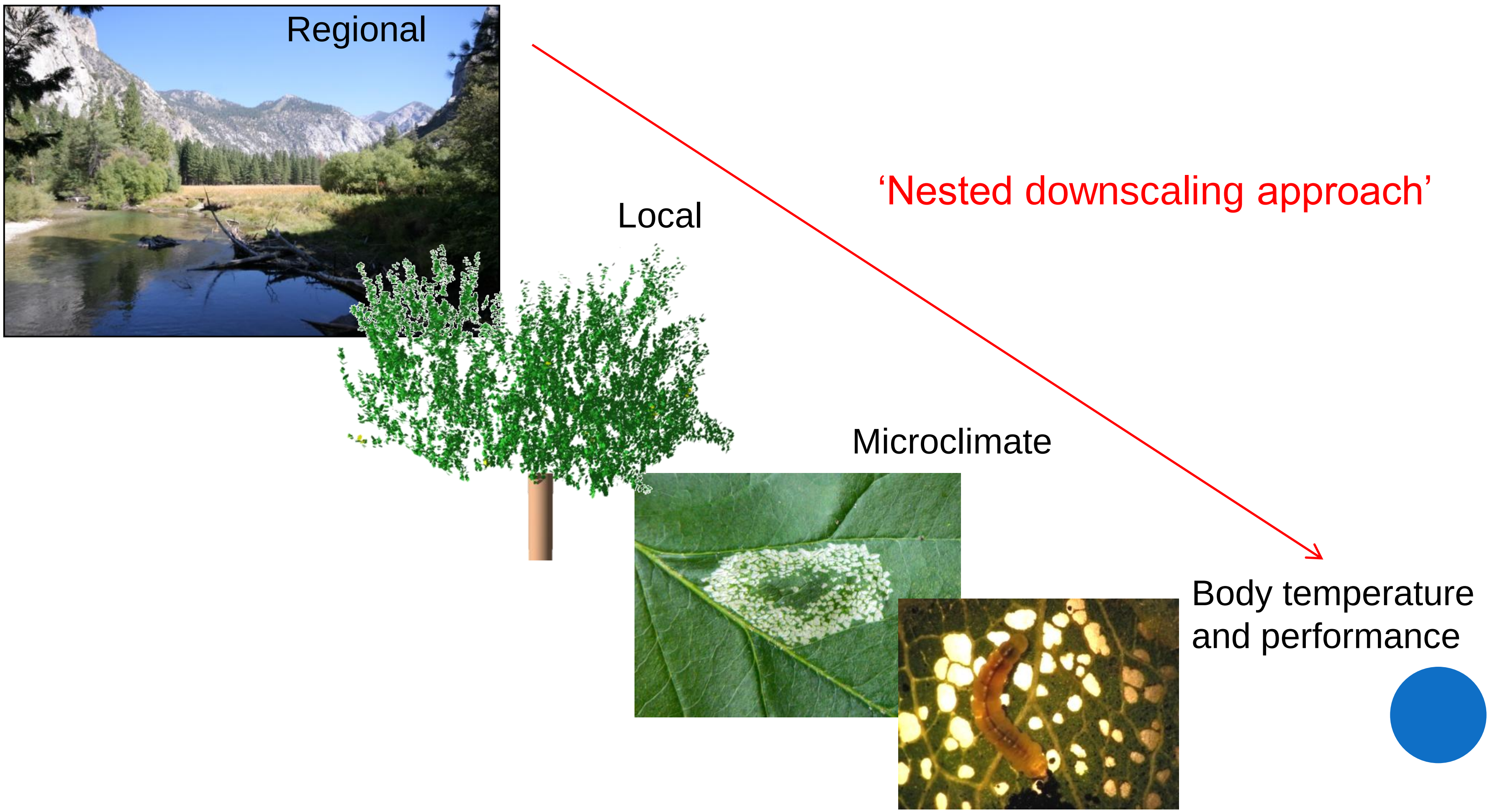


All stages are equally–and they are all–susceptible to ambient warming

Pincebourde & Casas, 2015, Ecology

Major errors are to be expected when forecasting the impact of global warming on species distribution if microclimates are neglected.





Climatic variable at local scale

↓

Model of radiation interception by plant canopies

↓

Microclimate of a leaf (Radiation)

↓

Heat budget of a mine

↓

Temperature within a mine

↓

Heat budget of a larva

↓

Body temperature of a larva

↓

Developmental rate model

↓

Performance of a larva (development)

Erreur de prédiction < 1°C

Pincebourde et al. 2007, Journal of Animal Ecology

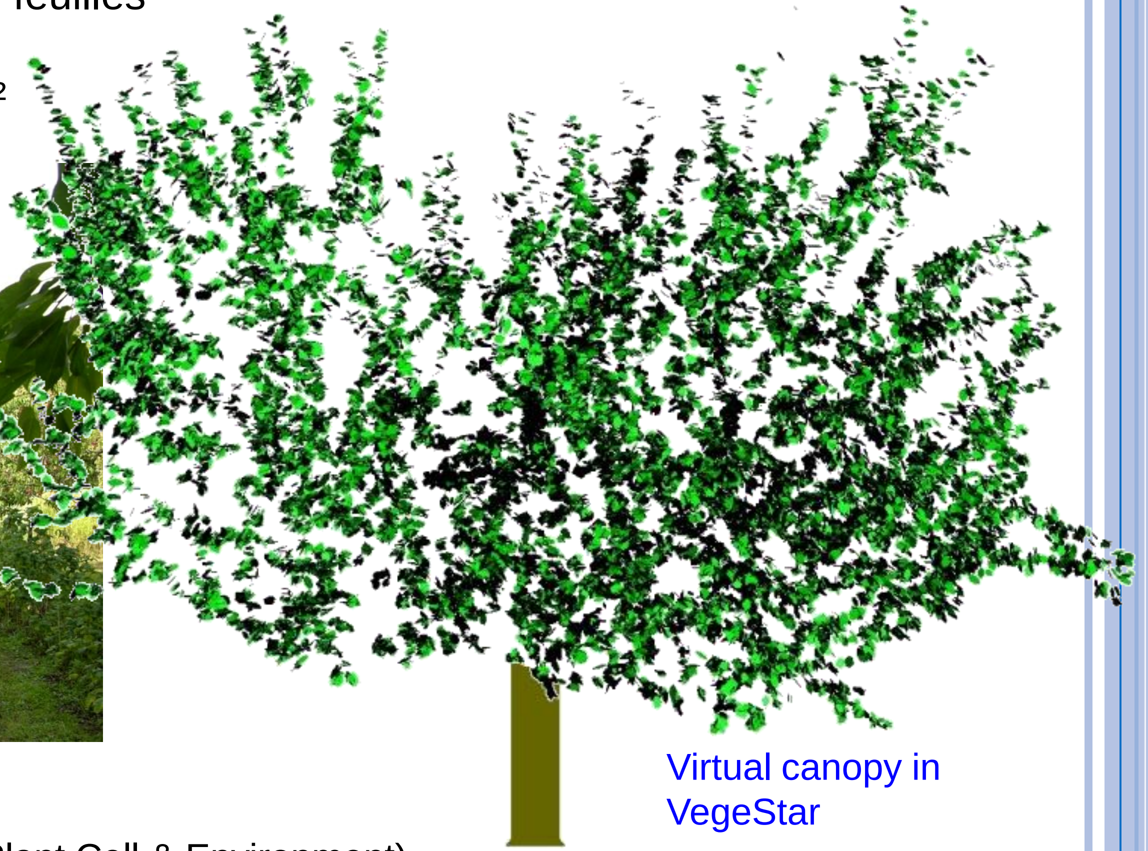
Parameterizing the model with canopy architecture

Electromagnetic digitizer

3D coordinates and angles for 26 281 feuilles

Leaf sizes

Total surface area of foliage: 37.01 m²



Virtual canopy in VegeStar

RATP model (Sinoquet et al. 2001, Plant Cell & Environment)

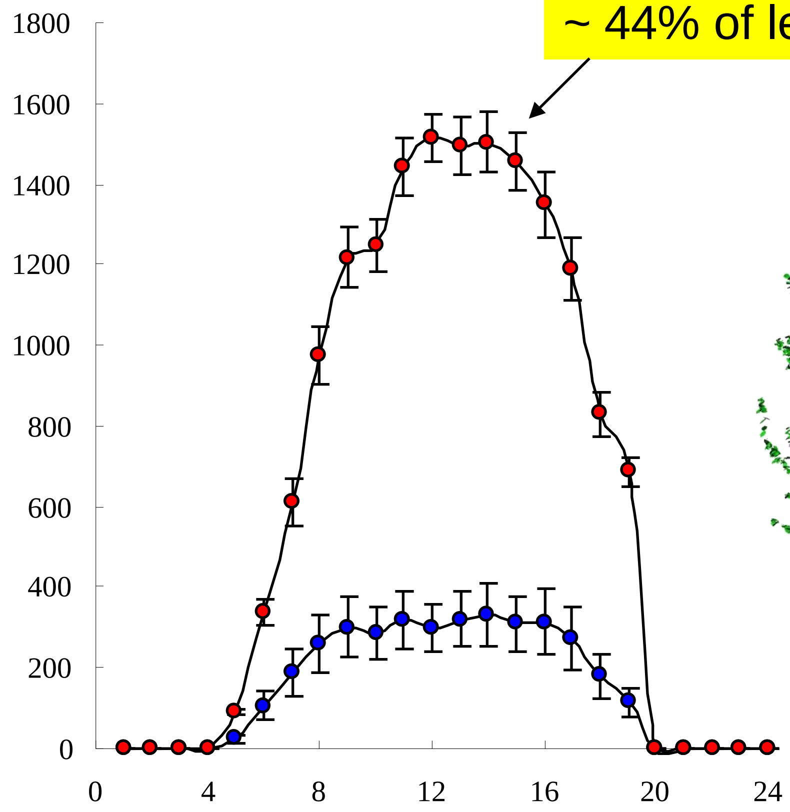
Sinoquet, Pincebourde et al. 2009, Ecology

Heterogeneity of the radiative environment

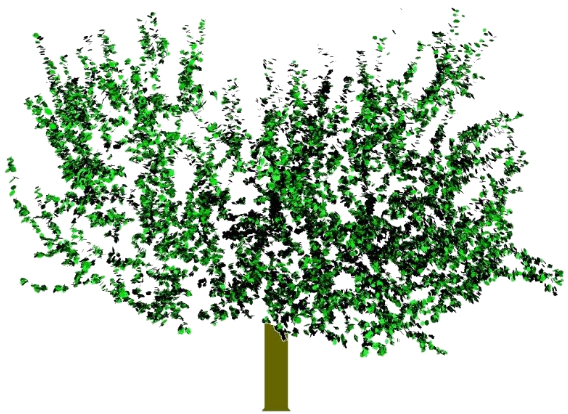
Simulation (RATP model) of the radiation level at leaf surfaces during a summer day with clear sky.

~ 44% of leaves

Radiation level at a leaf surface (µmol m^{-2} s^{-1})



Hour

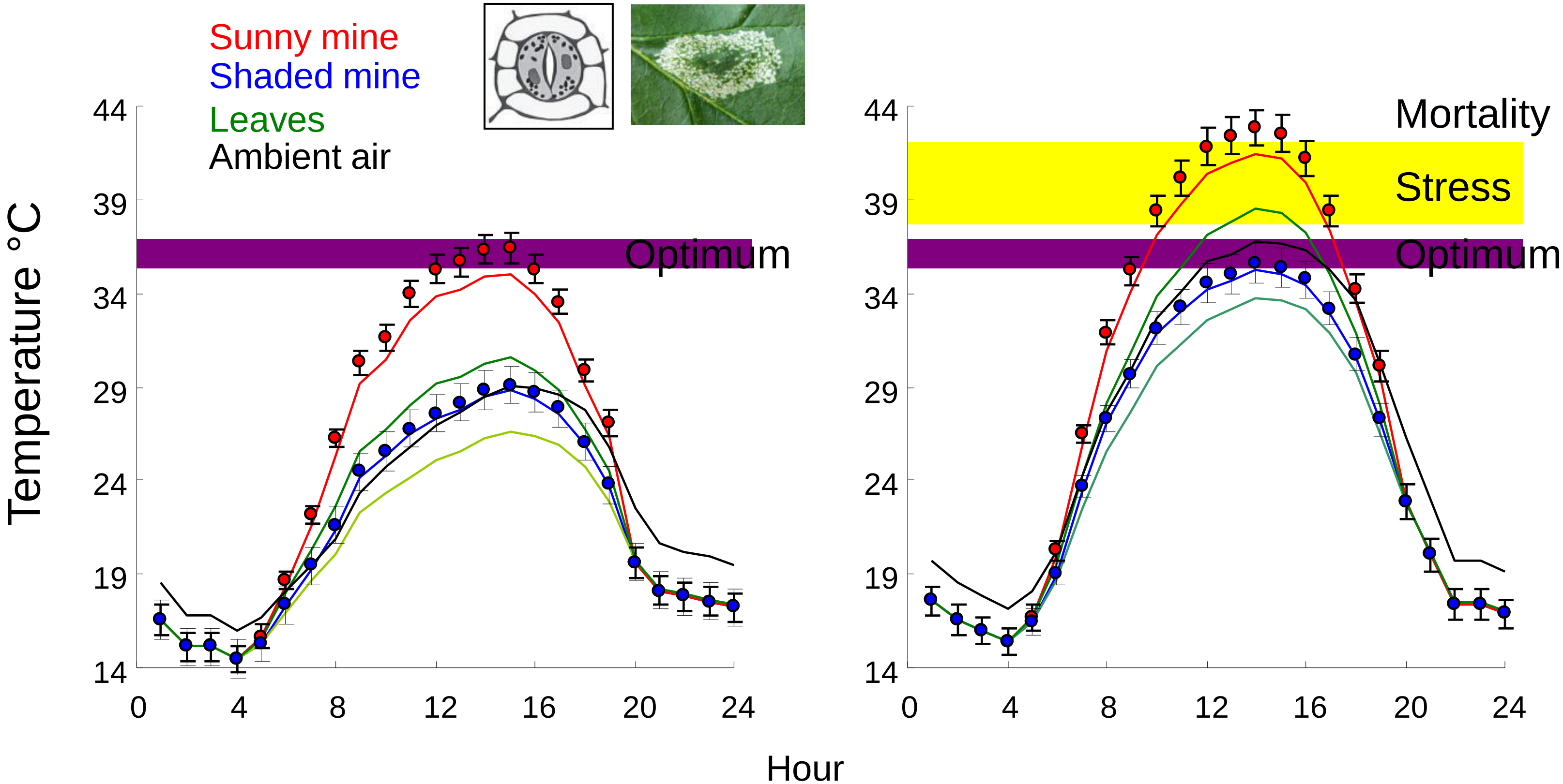


Strong dichotomy in the radiative environment: sunny leaves versus shaded leaves

Microclimatic heterogeneity within canopies

Moderate day, clear sky.
Tair up to 29°C.

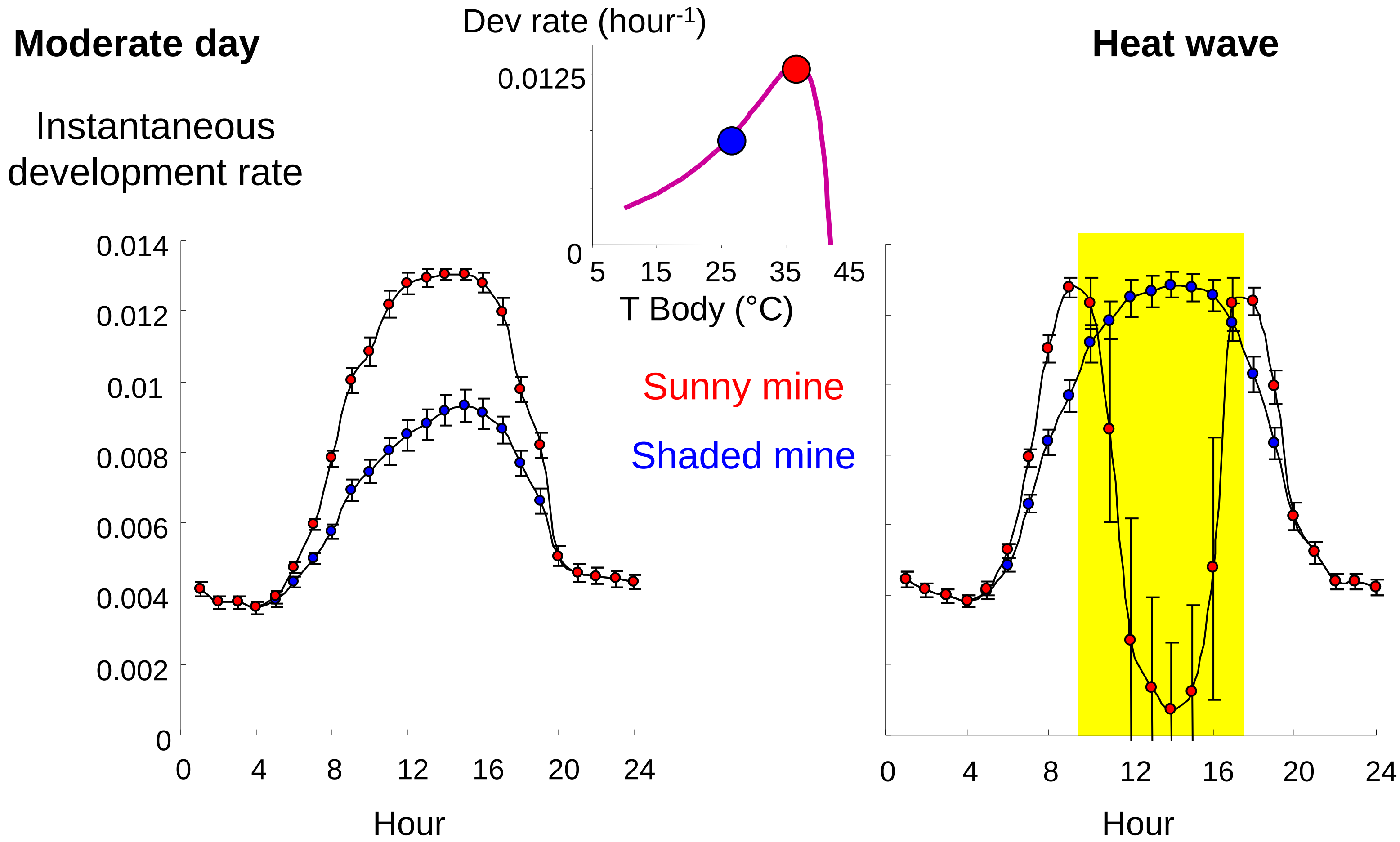
Exceptionally hot, clear sky.
Heat wave: Tair up to 36°C.



Strong microclimatic heterogeneity at local scale.

Pincebourde et al. 2007, Journal of Animal Ecology

Heterogeneity in insect performance within canopies

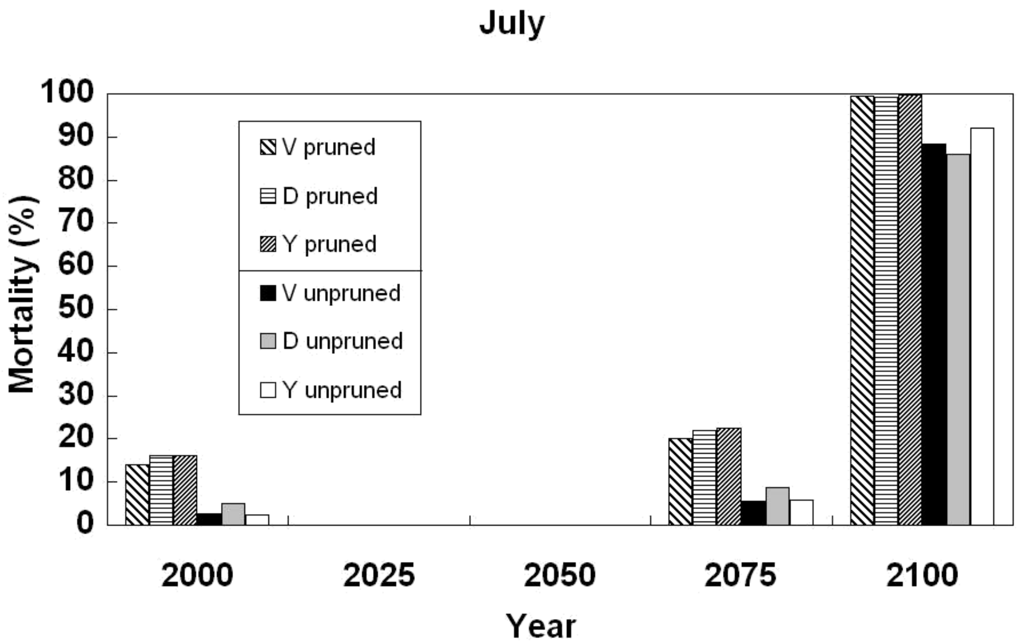


Biological effects are not the same everywhere within local scale

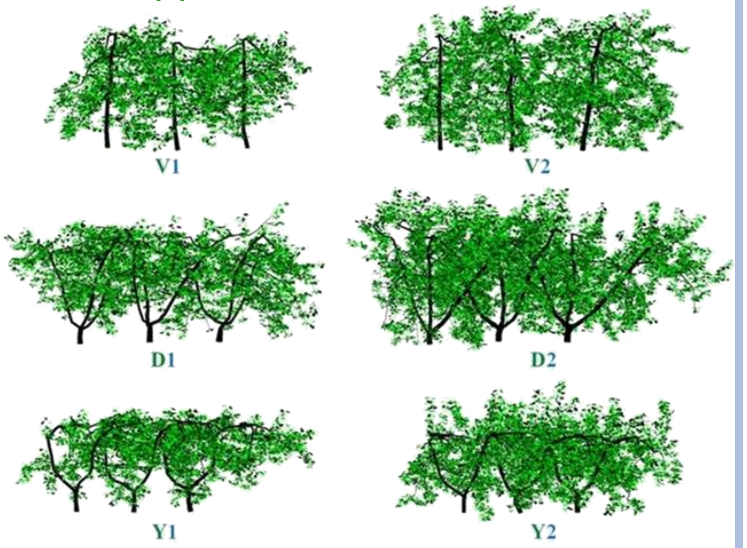
Pincebourde et al. 2007, Journal of Animal Ecology

Projecting warming effects on the leaf miner

Input: predicted daily meteorological data from the AGROCLIM (CLIMATOR) project (A1B SRES scenario). Sinusoidal change in Tair and radiation = hourly data. ARPEGE global model, coupled with statistical-dynamical downscaling method of Boé et al. 2006.



Apple tree architectures

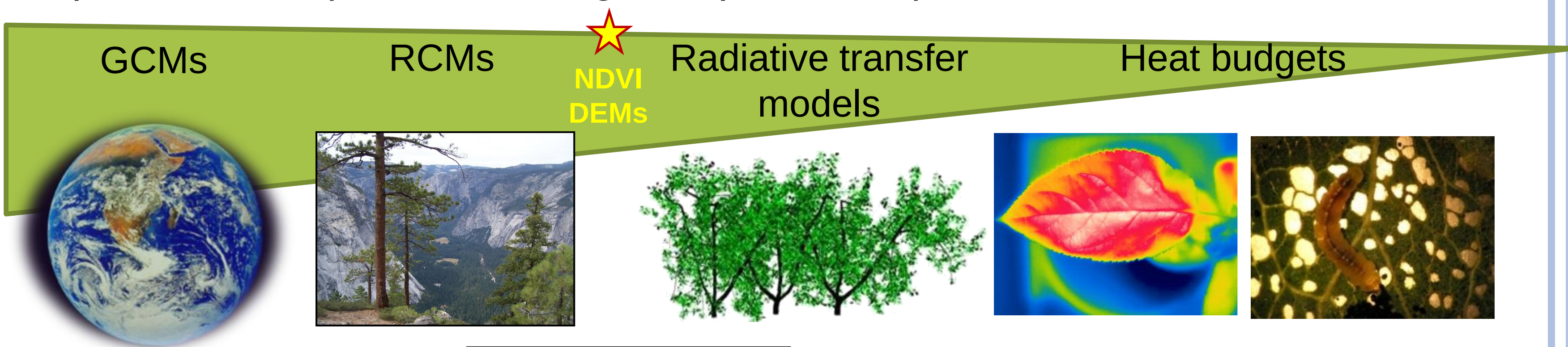


Architecture effects are ~negligible compared to effect of warming.

Saudreau, Pincebourde et al. 2013, Trees

Bridging regional and local scales: the potential of SWGs

- Spatial downscaling: ecologists need historical data/projections at fine spatial scales (connected to global processes).



The weakest link: regional-local models?

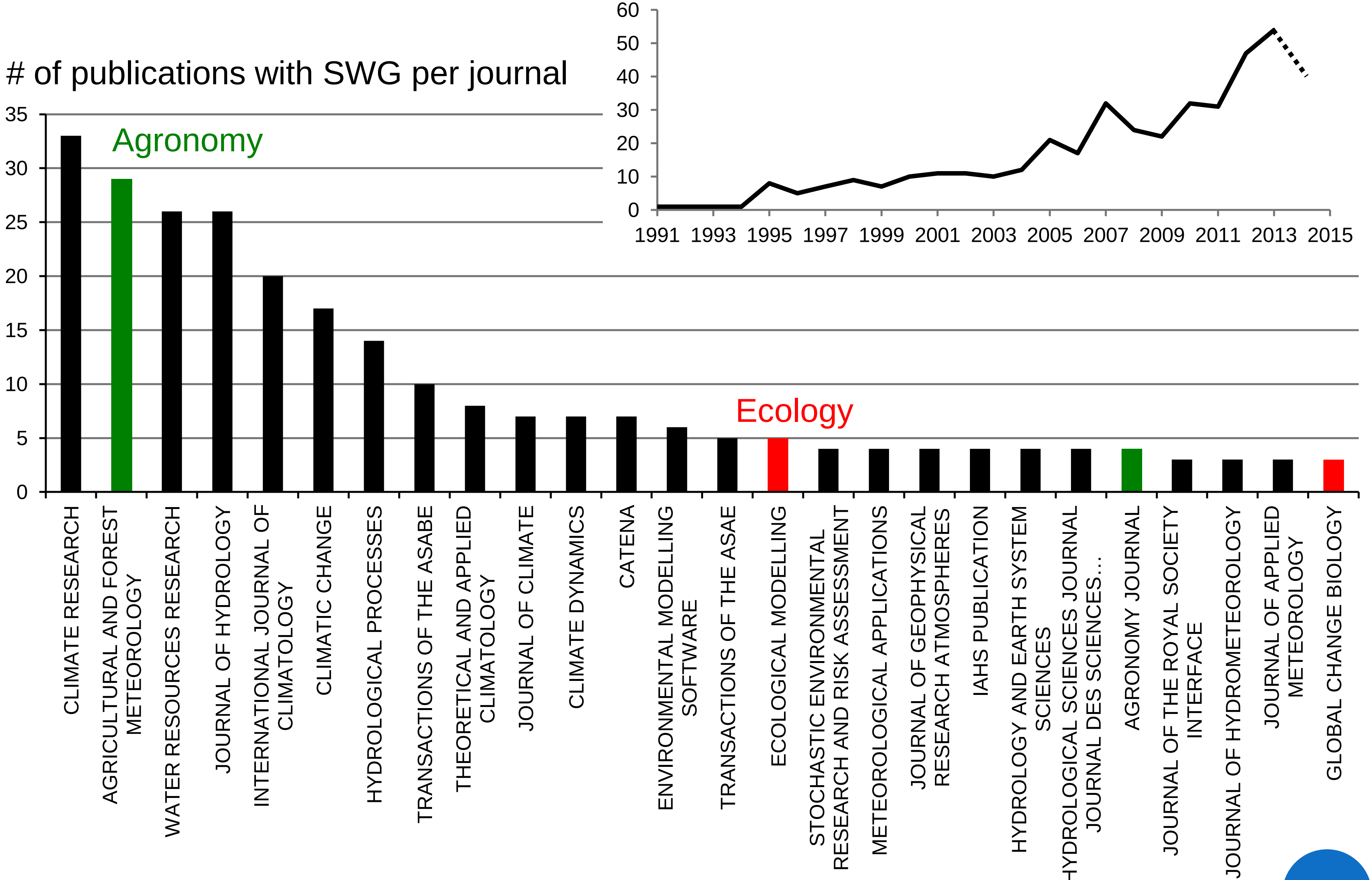
- Temporal downscaling: ecologists need hourly data to feed their biophysical models to get the precise daily maxima, to be compared to thermal limits.

- Coupling multiple stressors: temperature, precipitation (water balance, VPD), wind, CO_2, clouds etc.

→ 'Stochastic weather generator' in web of knowledge

N=114 records

# of publications with SWG per journal



Ecologists still need to discover SWGs …

Acknowledgements

Jérôme Casas
Christelle Suppo
Robin Caillon
Thomas Cahon
Amélie Ezanic

Marc Saudreau
Boris Adam

Arthur Woods
Kristen Potter

Funding:

ANR Microclimite (ANR-2010 BLAN-1706-02)

PEPS-2010 THERMALGAMES

Thank you for your attention !