



HAL
open science

Impact of climate change on fungal diseases of agroecosystems

Laurent Huber, Marie-Odile Bancal, Marie Launay

► **To cite this version:**

Laurent Huber, Marie-Odile Bancal, Marie Launay. Impact of climate change on fungal diseases of agroecosystems. International conference ANSES The impact of global change on the emergence of plant diseases and pests in Europe, Apr 2018, Paris, France. hal-01799549

HAL Id: hal-01799549

<https://hal.science/hal-01799549>

Submitted on 5 Jun 2020

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons Attribution - ShareAlike 4.0 International License



Impact of climate change on fungal diseases of agroecosystems

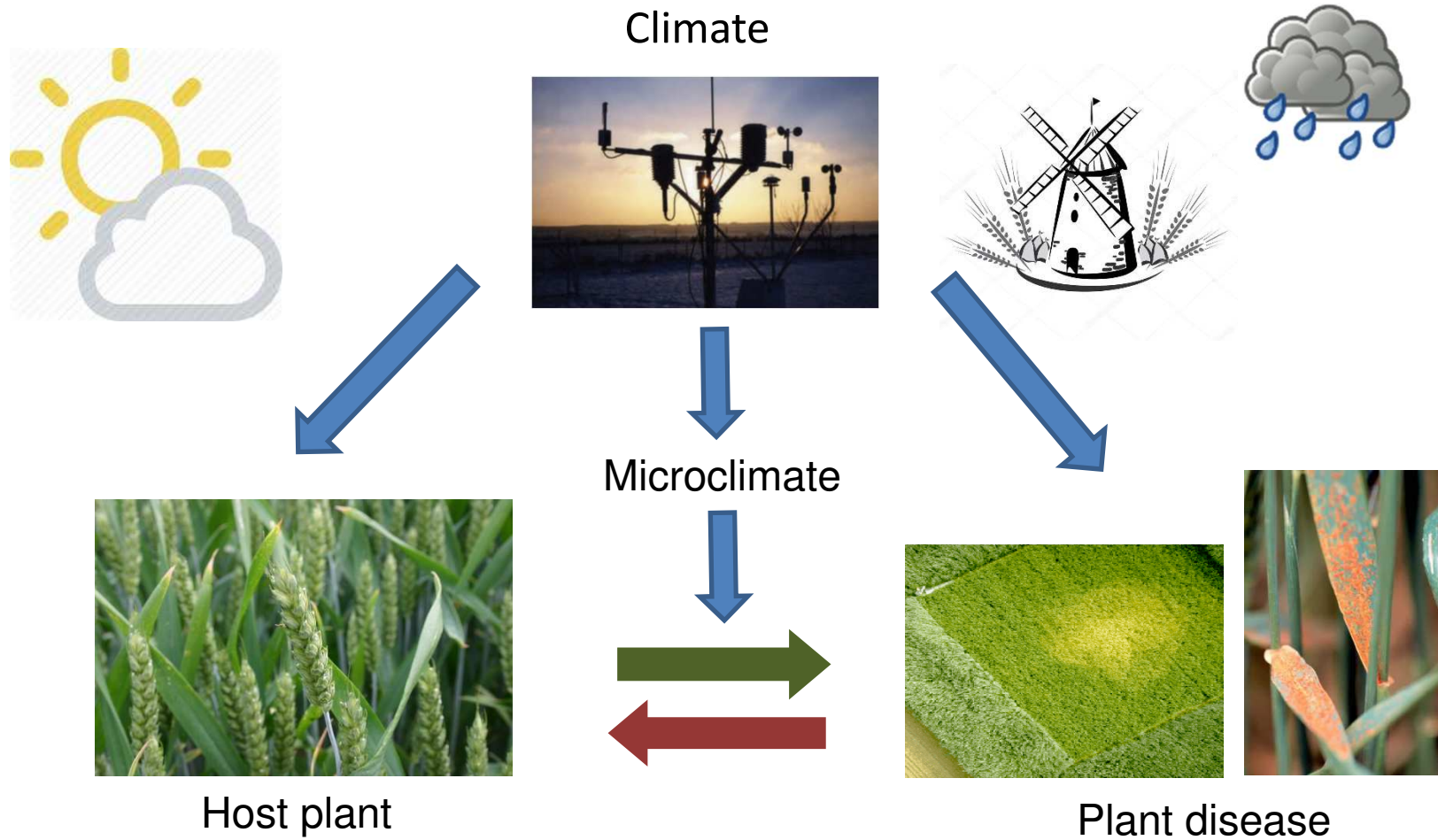
L. Huber¹, M.-O. Bancal² and M. Launay³

¹INRA, Joint Research Unit EcoSys, Thiverval-Grignon, France

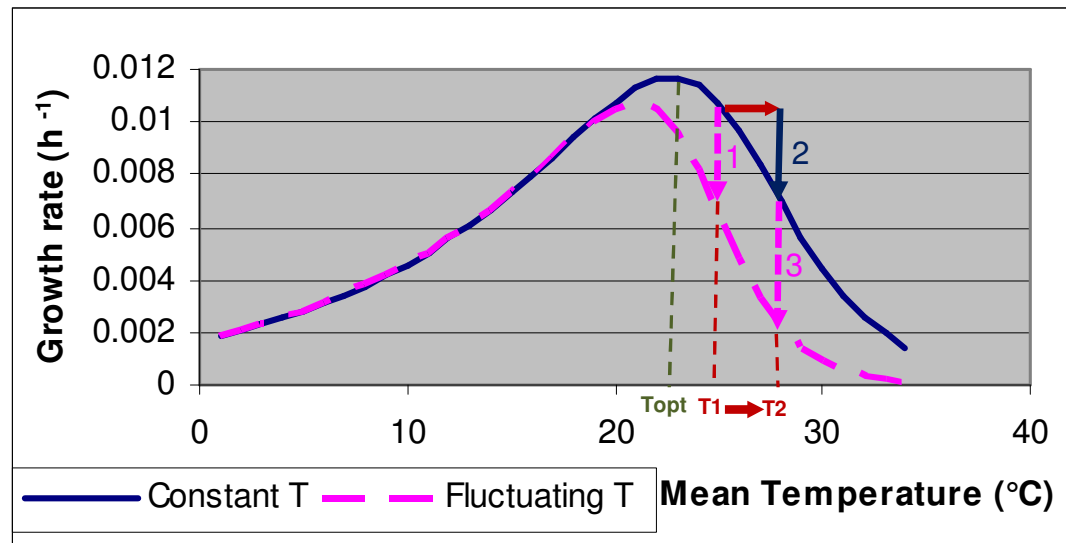
²AgroParisTech, Joint Research Unit EcoSys, Thiverval-Grignon, France

³INRA, AgroClim Unit, Avignon, France

Past and recent climate : temporal and spatial variability



Fungal growth response to temperature



For $T_{\text{mean}} > T_{\text{opt}}$:

1. At T_1 under fluctuating T
⇒ Growth rate ↓

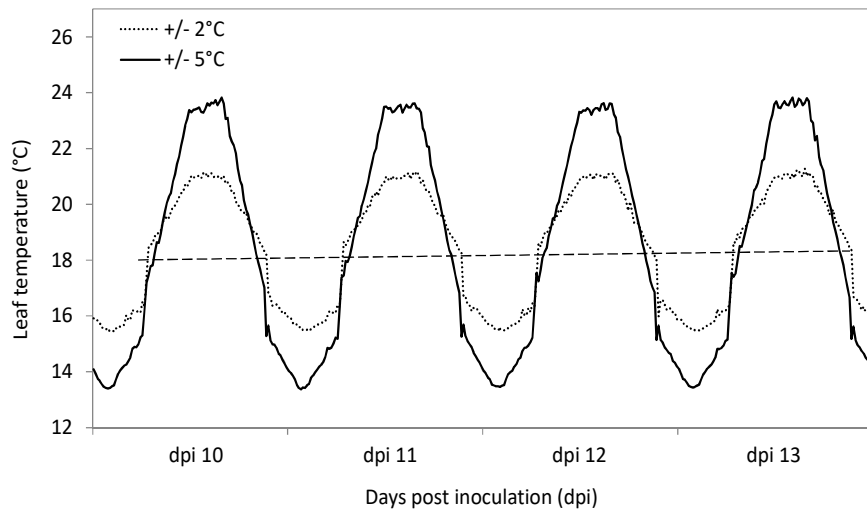
2. From T_1 to T_2 at Constant T
⇒ Growth rate ↓

3. At T_2 under fluctuating T
⇒ Growth rate ↓ ↓

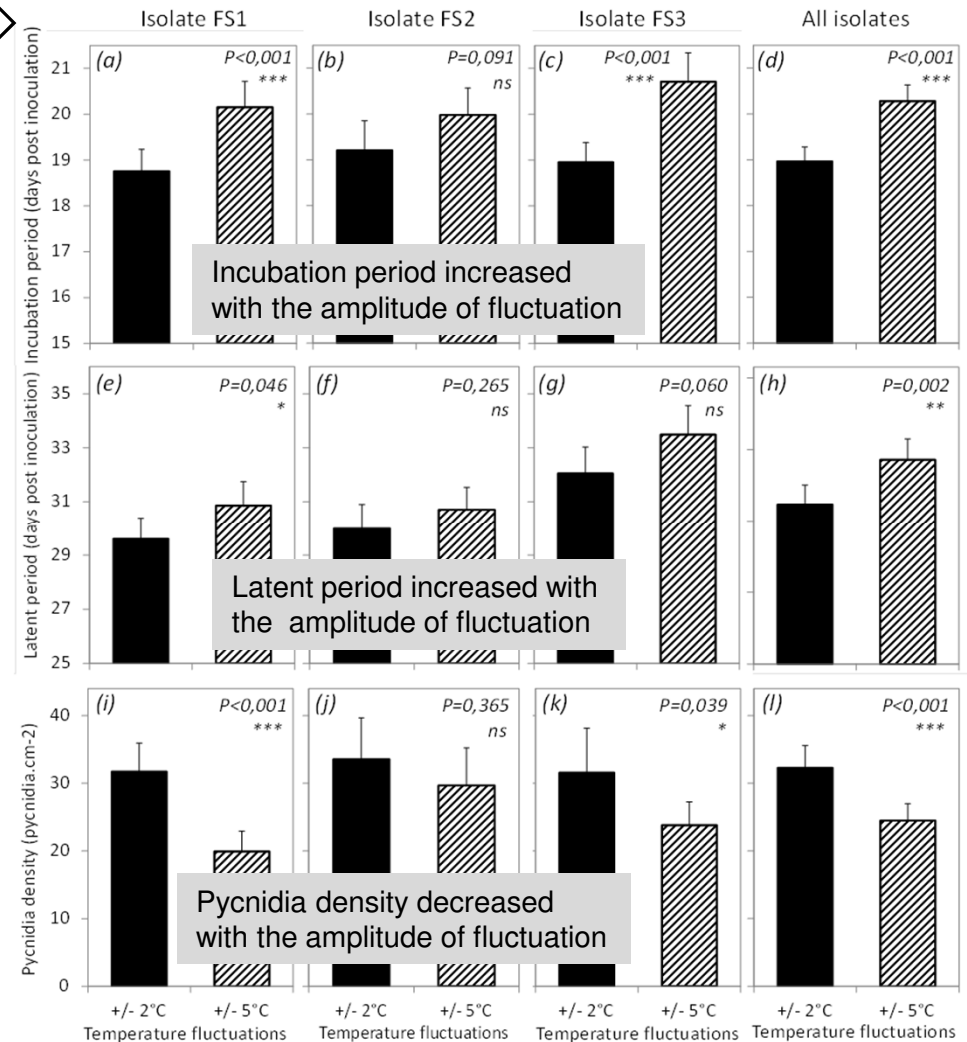
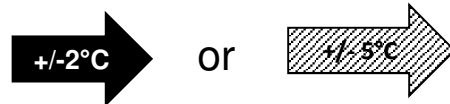
Experiments under controlled conditions of **constant** or **fluctuating** temperature and **global warming** $T_2 - T_1$ (→)

Fungal growth response to the leaf temperature fluctuating around optimal temperature

Fungal pathogen :
Zymoseptoria tritici with 3 isolates

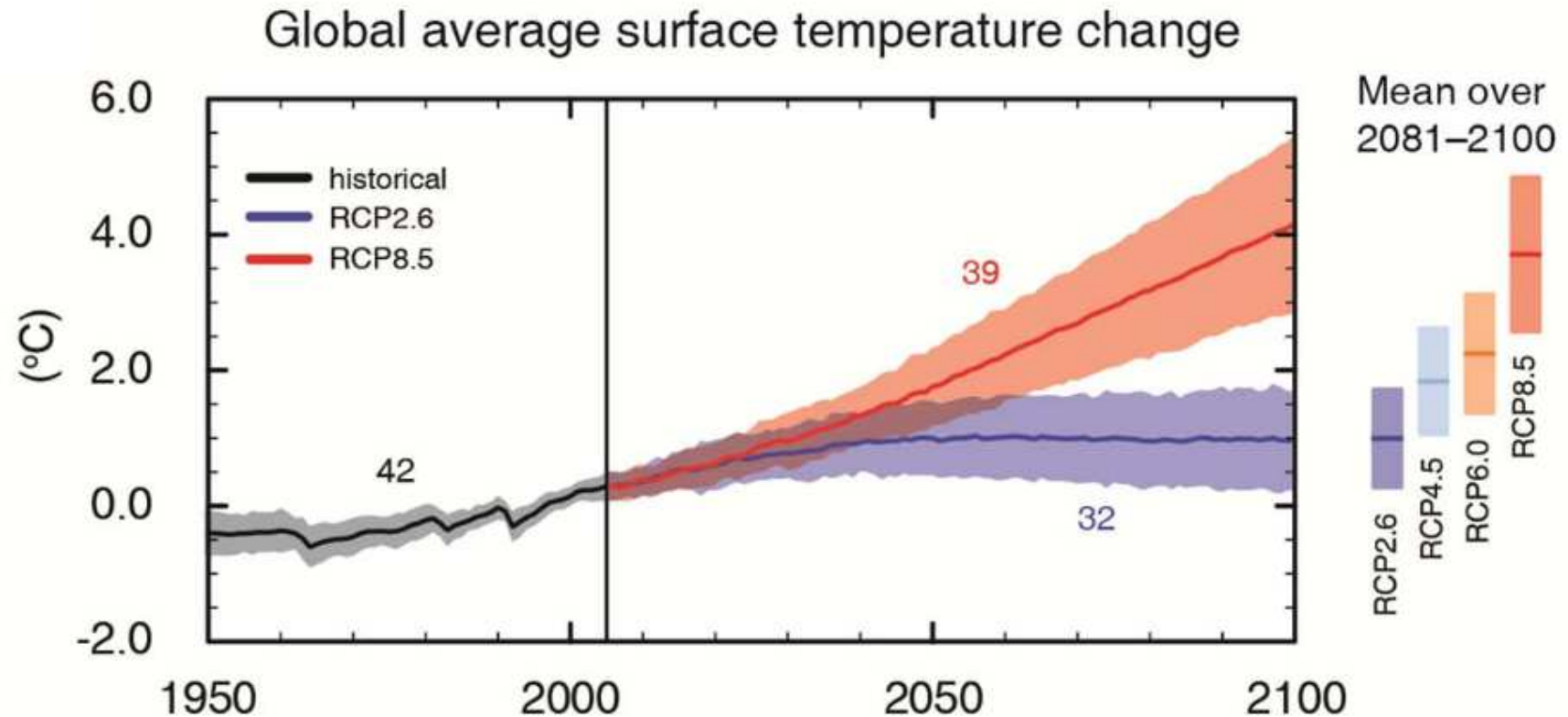


Experiments under controlled conditions on adult wheat plants
 T_{optimal} = T_{mean} = 18 °C with fluctuations of temperature



Climate change in the near and far future

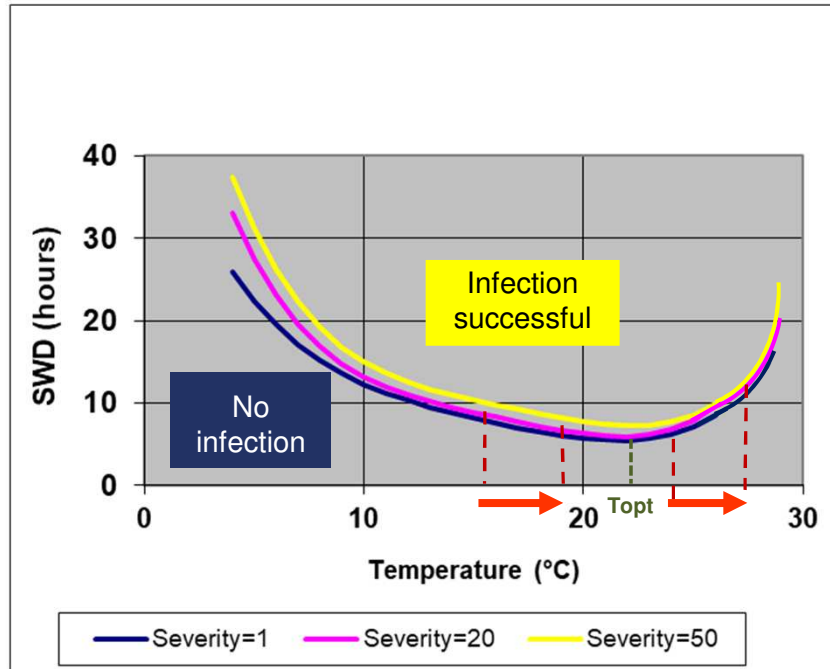
1. Solutions for continuous variables such as temperature



2. What about intermittent variables such as rainfall and leaf wetness duration ?

(IPCC, 2014)

Temperature-dependent response of fungal infection to leaf wetness duration



For $T < T_{optimal}$:

$T \nearrow \Rightarrow SWD \searrow$

\Rightarrow Potential opportunity for the pathogen

For $T > T_{optimal}$:

$T \nearrow \Rightarrow SWD \nearrow \nearrow$

\Rightarrow Potential threat for the pathogen

Experiments on infection efficiency under controlled conditions of temperature and Surface Wetness Duration with **virtual global warming of + 3 °C (\rightarrow)**

Criteria for predicting apple scab infection periods
Leca et al, Agricultural and Forest Meteorology, 2011
McHardy and Gadoury, Phytopathology, 1989

Brown rust and yellow rust on wheat seedlings
de Vallavieille-Pope et al, Phytopathology, 1995, 2002

Effects of climate change on pathogens, host plants and aerial diseases

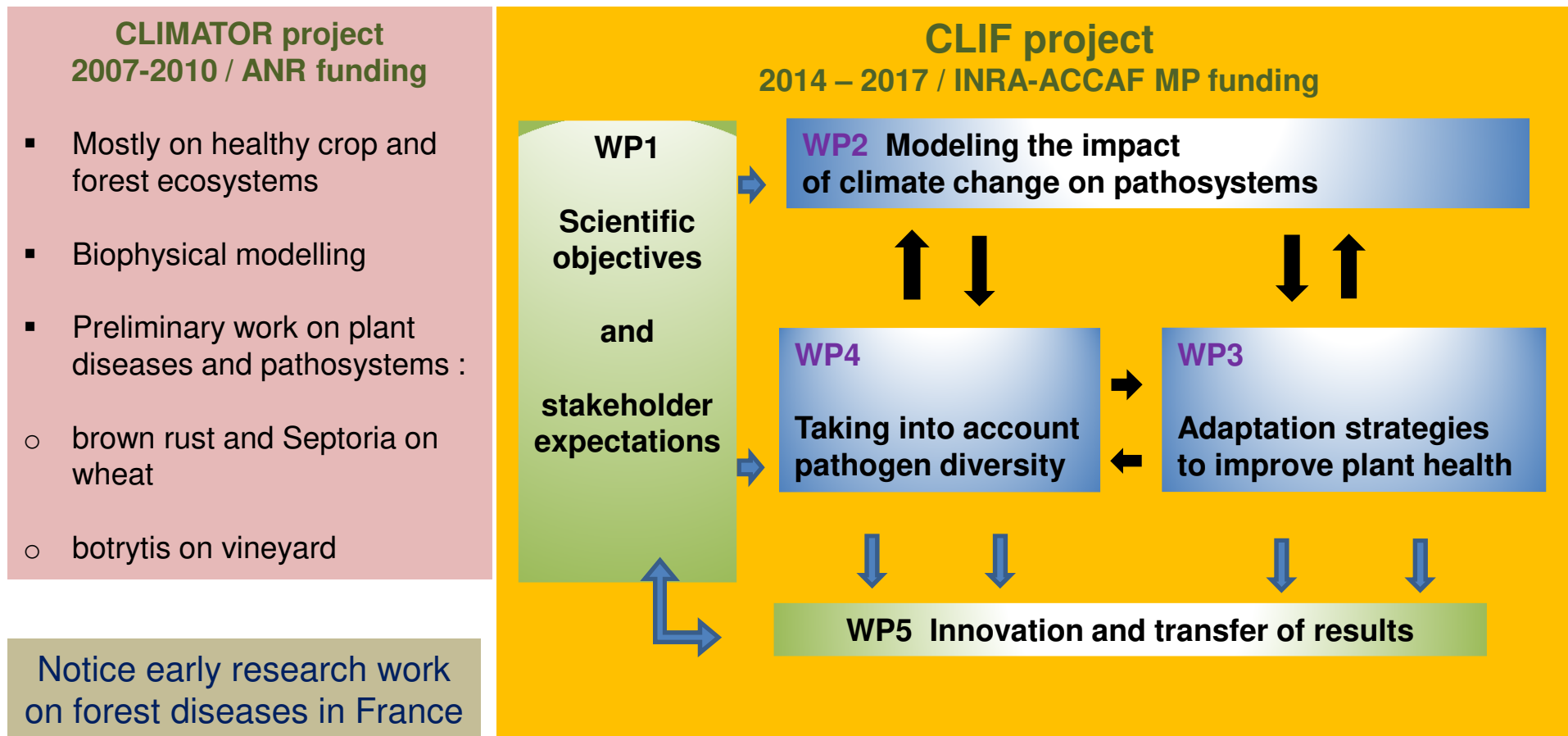
- ❖ Direct effects of climatic factors on epidemiological processes
 - effects of UV-B, CO₂, O₃, temperature, heat/water stress, rainfall, drought, ...
- ❖ Indirect effects of warming on pathosystems
 - shift in host phenology and spatial distribution
 - pathogen adaptation to host plant resistance
- ❖ Consequences for foliar plant diseases
 - allowing emergence of infectious diseases in new territories
 - varying incidence and severity of native diseases
 - filtering (or generating new) pathogens, pathotypes, races, ...
- ❖ Protection and prevention against diseases
 - no technological rupture in near-future tactical measures
 - manipulating biodiversity : possible long-term lever



Future distribution of vineyards in Europe ?

Effects of CC on crop diseases and pathosystems

Contribution of French research institutions and R&D organisations



Climate x Pathogen Climate x Pathogen x Host Climate x Pathosystem x Practices

WP2

Simulating Leaf Wetness Duration (LWD) to predict future fungal infection events

3 models to
estimate LWD

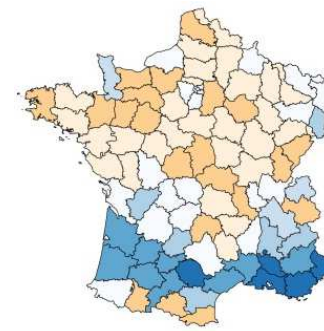
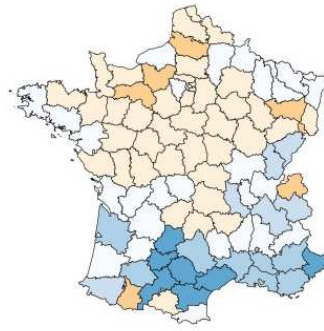
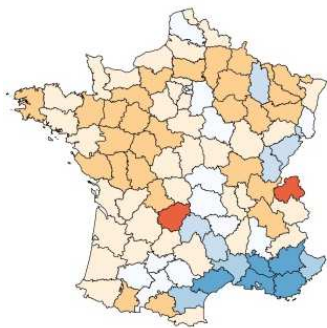
Huard F et al, AGU Fall Meeting, 2014

(Huber, Bancal, Launay, 2017. INRA-Accaf CLIF project, final report)

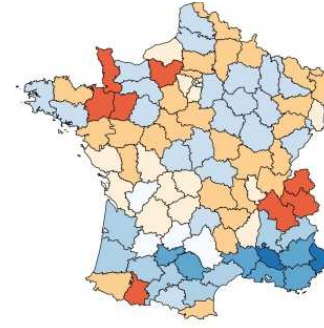
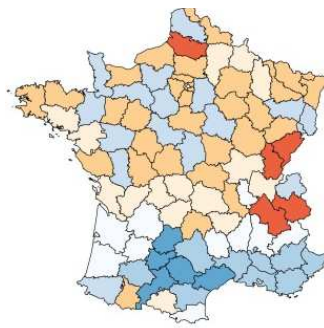
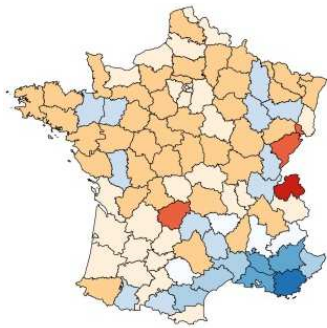
*LWD variation (%)
relative to the period
1976-2005*

*Future climate data obtained
using Aladin model, RCP 8.5,
and QQ method*

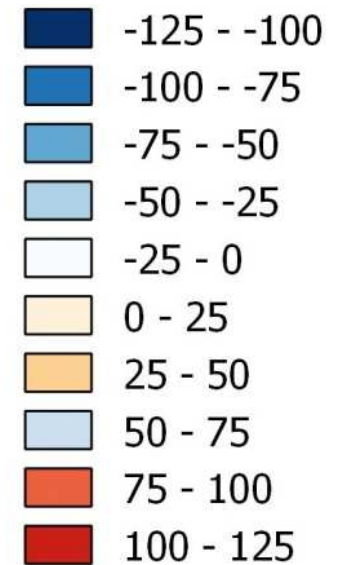
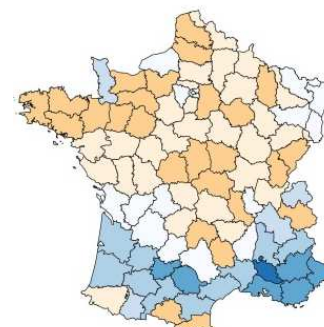
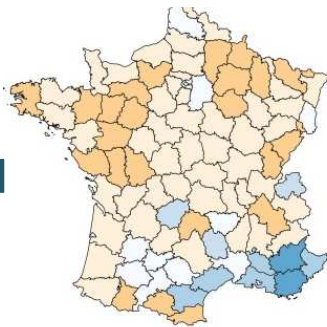
DPD
Vapour
pressure
deficit



CART
Decision
Tree



MEDHI
Statistical



2021-2050

2051-2070

2071-2100

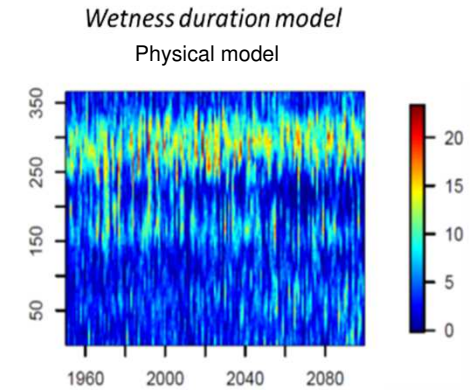
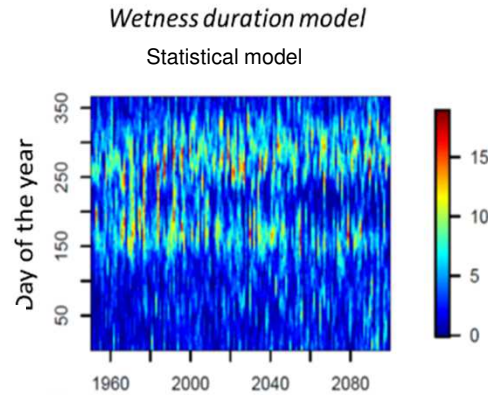
Estimating disease trends and uncertainties in relation to modeling assumptions

Case study : wheat infection by brown rust

Simulation of disease
infection risks based on :

- 2 LWD models
- 2 infection models

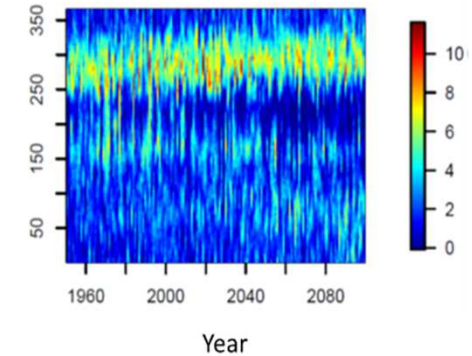
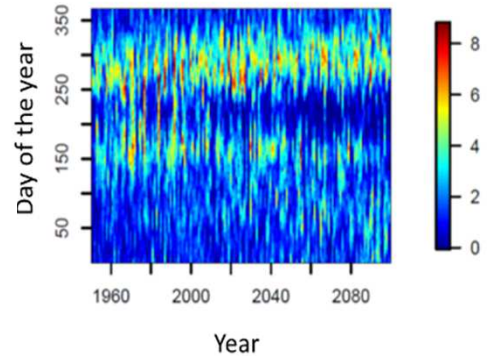
*Infection model
de Vallavieille-Pope*



Results

*Predicted infection values differ
significantly depending on both
LWD and infection models but
temporal trends are similar*

*Infection model
ClimInferR*



Disease infection risks :

- increasing in the fall and winter
- decreasing in summer

Huber, Bancal, Launay. 2017

NRA-Accaf CLIF project, final report

WP2 *Understanding disease trends according to climate and microclimate evolution*

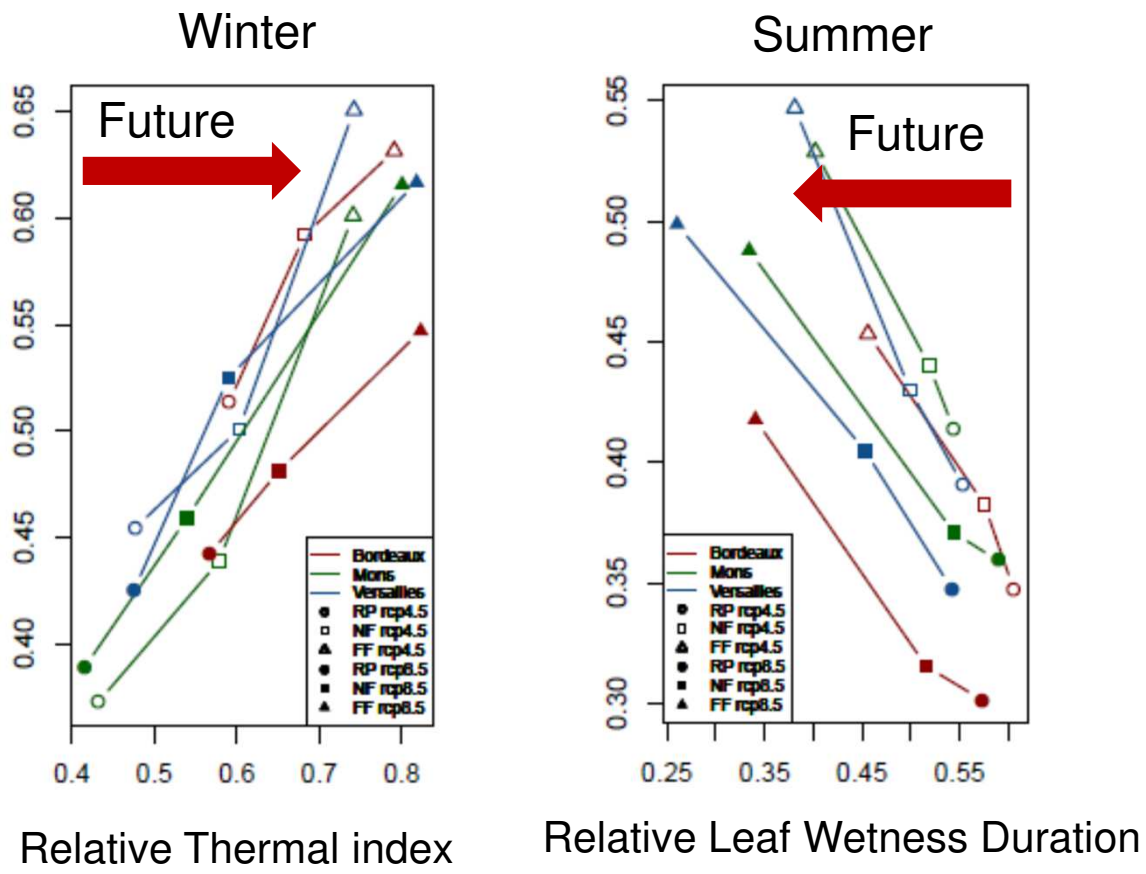
Case study : wheat infection by brown rust

Simulation of the relative number of days with infection efficiency > 5%

Results

Whatever the site (northern or southern France) and whatever the scenario (RCP 4.5 or 8.5):

- The number of infectious days is
- Significantly increased in winter by the expected warming
- Significantly reduced in summer by the predicted drought



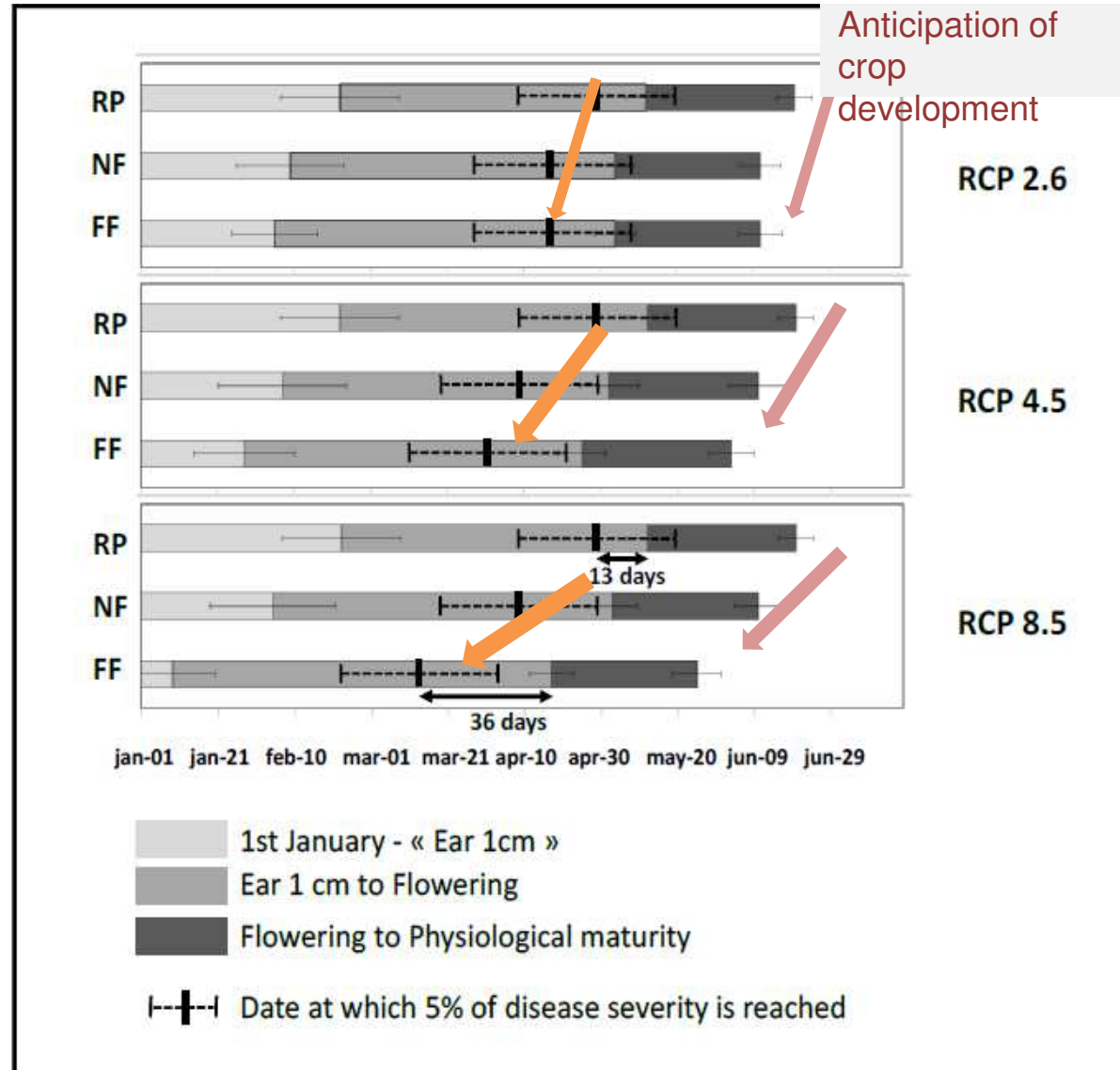
Huber, Bancal, Launay 2017
INRA-Accaf CLIF project, final report

| | | | | |
|--------------------------------------|------------|---|---|--|
| — | Bordeaux | ○ | ● | Recent past (1976-2005), RCP 4.5 and 8.5 |
| — | Mons | □ | ■ | Near future (2021-2050), RCP 4.5 and 8.5 |
| — | Versailles | △ | ▲ | Far future (2070-2099), RCP 4.5 and 8.5 |

Impact of Climate Change scenario on wheat crop growth and *Puccinia tritici* development



5% of disease severity is reached sooner in wheat under future climate

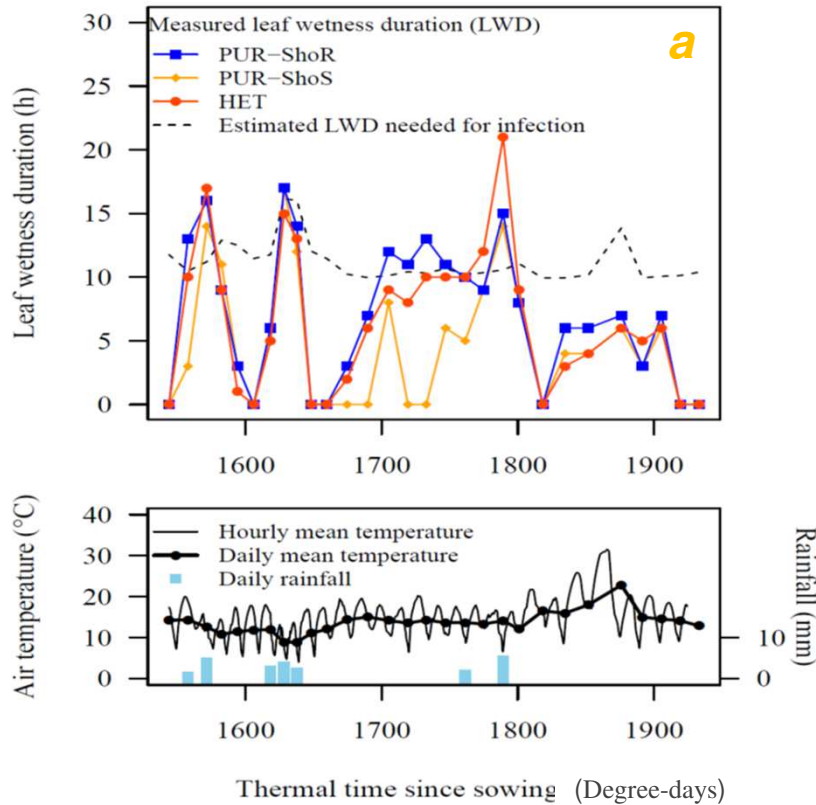


Caubel et al., 2017,
European Journal of
Agronomy

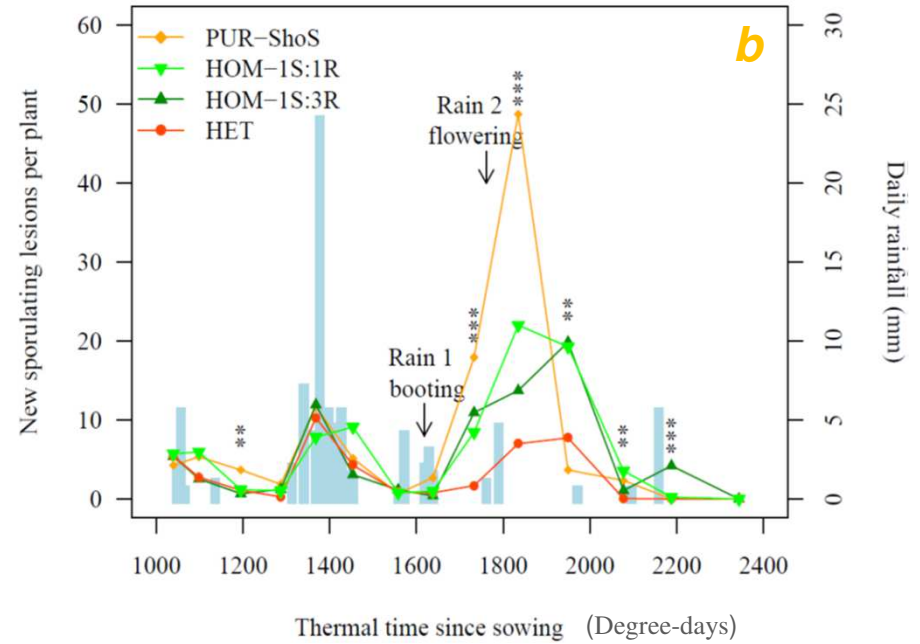
WP3

Manipulating the microclimate using cultivar mixtures

Crop heterogeneity as a lever to lower infection (a) and limit splash-dispersal (b)



PUR-Sho : short pure stand
Resistant (R) or Susceptible (S)



HOM : homogeneous mixture = Short S + Short R
HET : heterogeneous mixture = Short S + Tall R

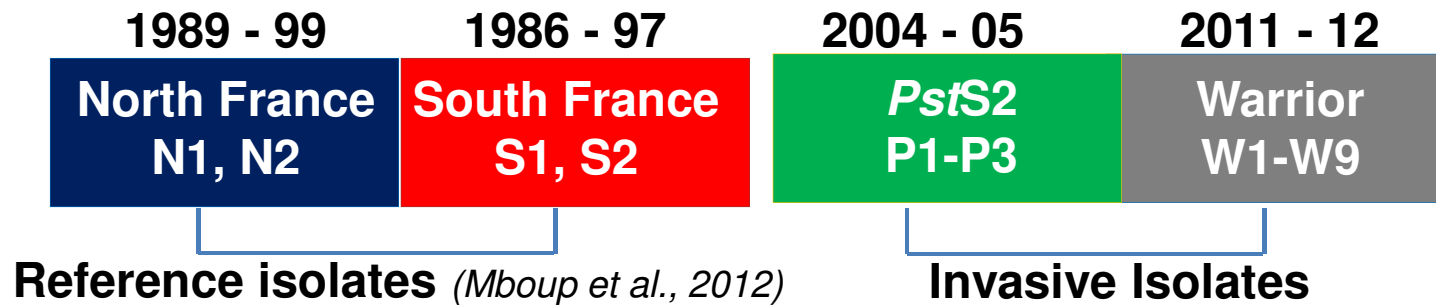
In the HET mixture, upper leaves of tall R cultivar protect bottom leaves of short S cultivar from :

- radiative loss and dew deposits (a)
- incident rainfall drops and splash dispersal (b)

Thermal impact on Infection Efficiency (IE) & Latent Period (LP)

(Vallavieille-Pope et al, Plant Pathology, 2018)

Controlled-conditions experiments on 16 *Puccinia striiformis* isolates



2 susceptible wheat varieties: cv-Cartago, cv-Victo

2 thermal regimes for LP

Cold
10/15°C

Warm
16/25°C

5 temperatures for IE

5°C

10°C

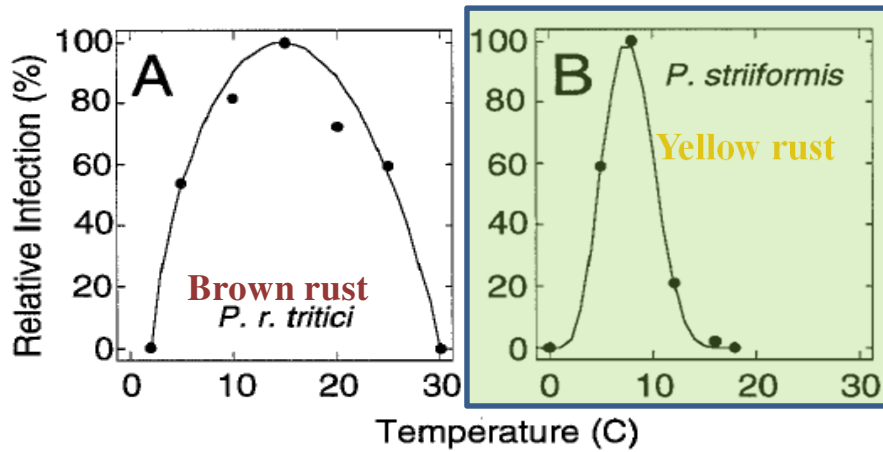
15°C

20°C

23°C

40 leaves per experiment, 2 biological replicates

Combining isolate-response of infection efficiency and temperature scenario in the near and far future

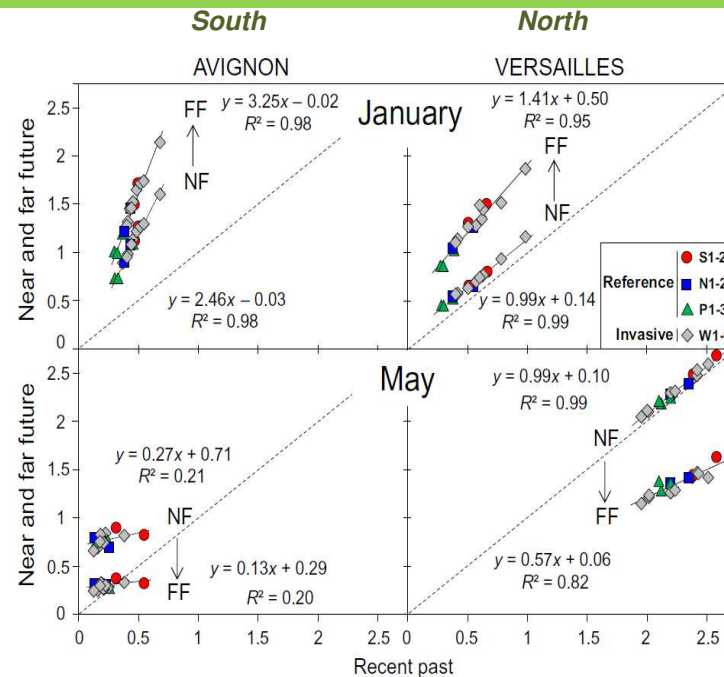
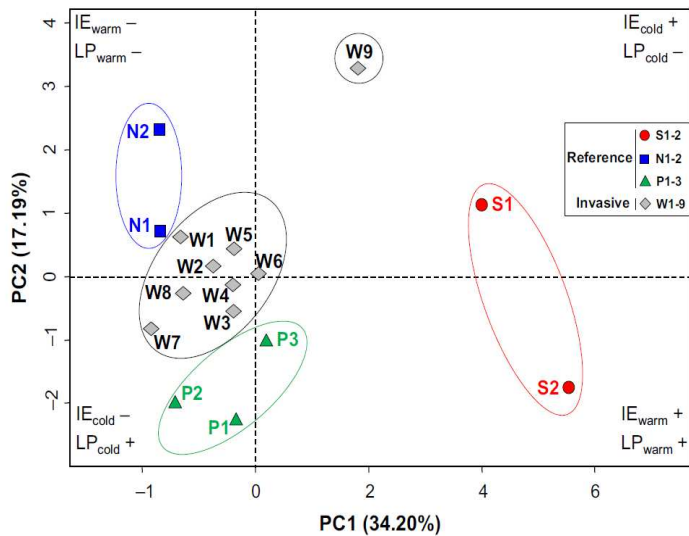


Comparing Northern (N) and Southern (S) reference isolates to invasive PstS and W in terms of response to temperature assessed using 2 major epidemiological processes : Infection Efficiency (IE) and Latent Period (LP)

Does the response to temperature provide an advantage to S or W isolates ?

Vallavieille-Pope et al, 2002, 2018

Approach including both experiments and thermal response models



Mean monthly infection efficiencies in January and May for two French sites

January : IE(FF) > IE(NF)
May : IE(FF) < IE(NF)

Conclusions and perspectives

❖ Pathogens are sensitive to climate, likely more than their host plants, and particularly to persistence and motion of liquid water in the canopy

- modelling intermittent variables such as leaf Wetness duration
- simulating diseases in relation to climate scenarios and knowledge gaps
- controlled conditions experiments to anticipate climate-disease relationships
- field experiments to increase disease prevention and ecosystem resilience

⇒ methods to assess the CC effects on native diseases of existing crops

❖ What about disease emergence risks ? primarily linked to crop area expansion, pathogen introduction, technological tools, globalized trade, human migrations, ... rather than direct CC effects (von Tiedemann et al., 2017)

❖ What could be our contribution to the understanding of disease emergence ?

- incorporating the human behaviour : sensitivity analysis to modifications of agricultural practices, use of technological innovation
- assessing the impact of CC adaptation to abiotic stresses on plant disease risks
- applying system dynamics in a wider approach to emerging risks