



Observed and expected impact of climate change on a defoliator insect species, the pine processionnary moth, in France and Europe

Christelle Robinet, Jérôme Rousselet, Francis Goussard, Jacques Garcia & Alain Roques

Forest Zoology Research Unit, INRA Orléans, France

Tackling climate change: the contribution of forest scientific knowledge

Tours (France), 21-24 May 2012

OUTLINE

(1) Observations

- Role of climate warming in the range expansion
- Effects of climatic anomalies
- Role of human-mediated dispersal

(2) Predictions

- Description of the model
- Validation
- Predictions

(3) Conclusion and perspectives

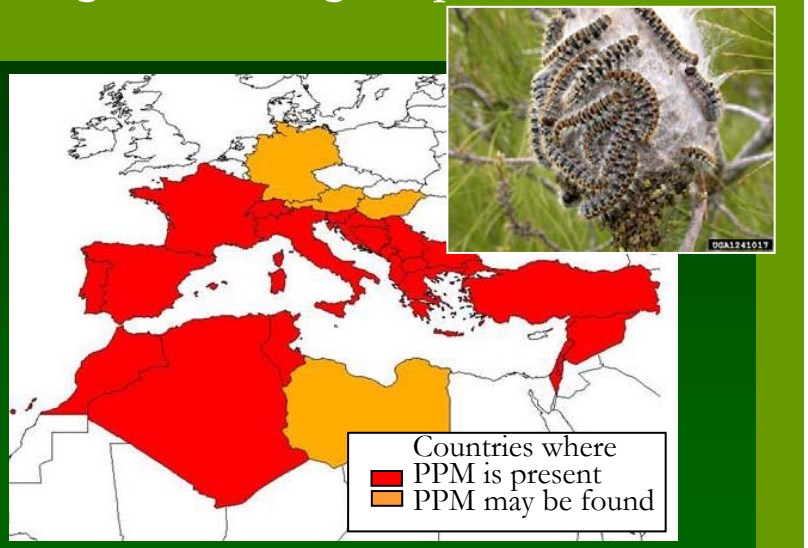
(1) Observations

Role of climate warming in the range expansion

(1) Observations

Role of climate warming in the range expansion

PPM is largely distributed over Mediterranean countries



PPM makes its larval development in winter
=> very sensitive to winter temperatures

PPM causes sanitary problems :
- larvae can release urticating hairs
- they can affect human and animal health

PPM causes phytosanitary problems :
- larvae feed on pine needles
- they reduce the tree growth

PPM causes aesthetic problems :
- pines can be severely defoliated
- larvae build white silk nests

(1) Observations

Role of climate warming in the range expansion

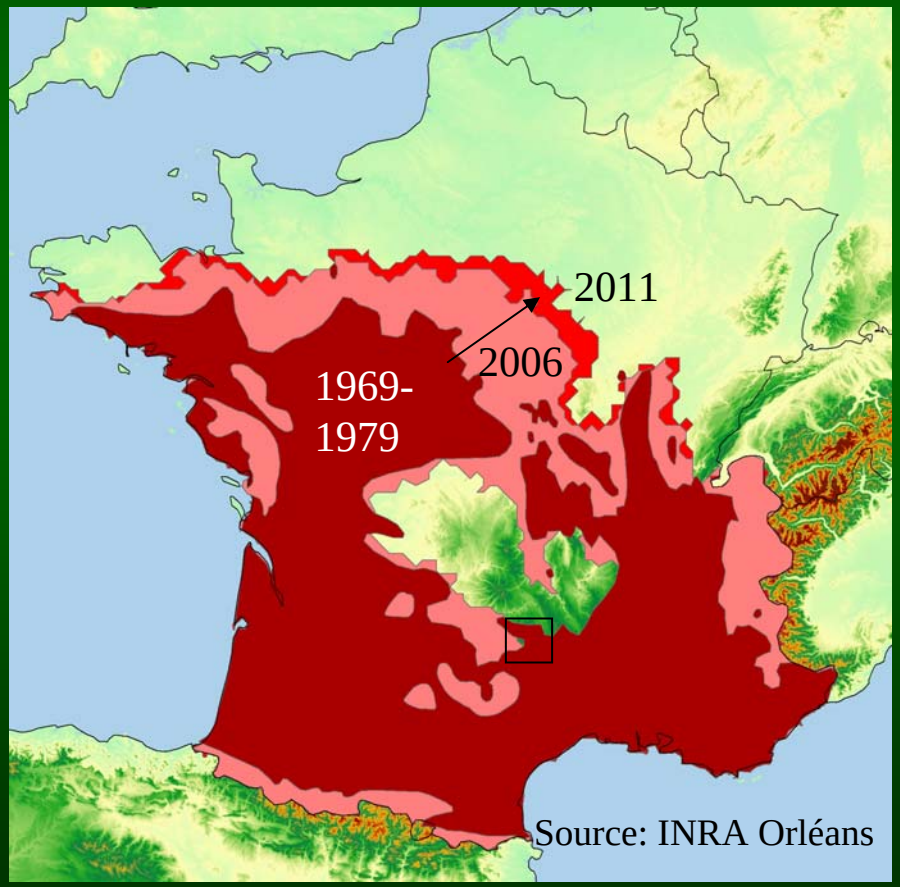
PPM range is spreading northwards and in higher elevations

- north-eastern direction:
  5 - 6 km/yr since the early 1990s

- altitudinal gradient:

South Massif Central
+ 106 m between 2006-2007

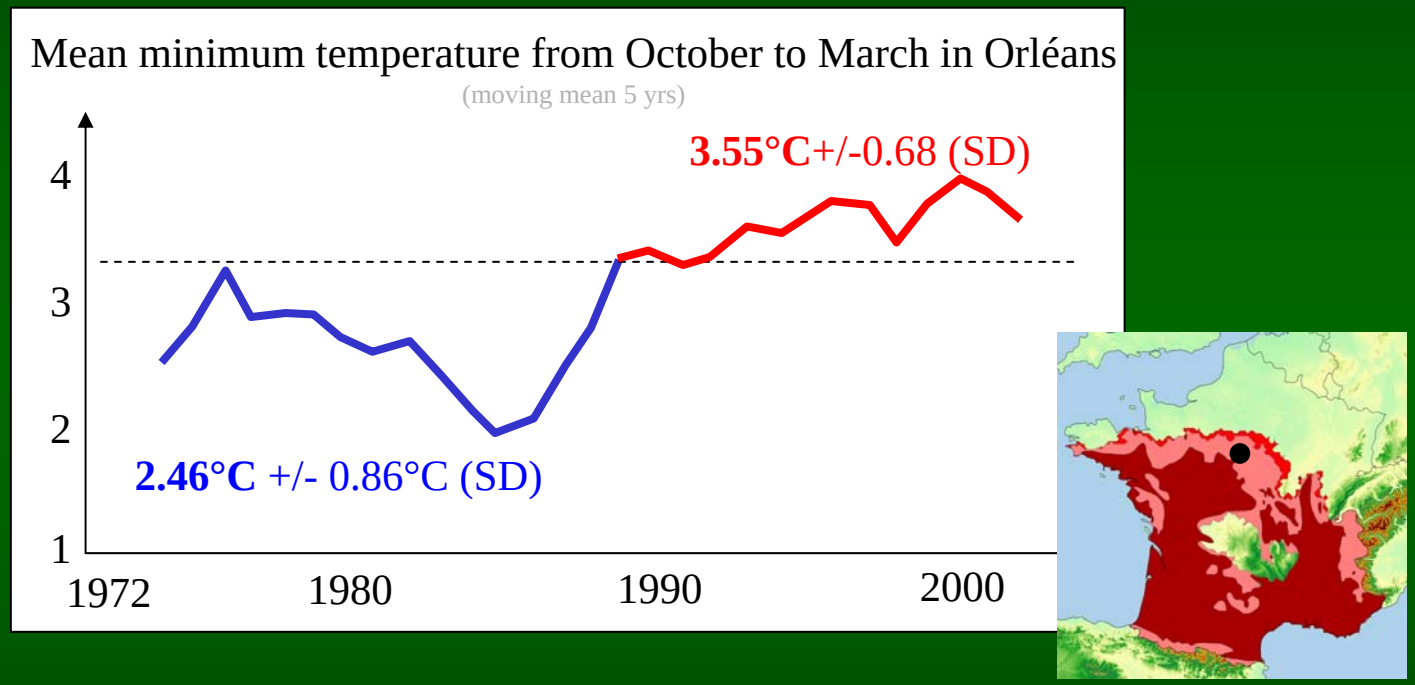
Italian Alps (Battisti et al. 2005, 2006):
+ 7 m/yr on South slope (1975-2004)
+ 3 m/yr on North slope (1975-2004)
+ 99 m between 2003-2004



(1) Observations

Role of climate warming in the range expansion

Winter temperature increased by 1°C in the early 1990s

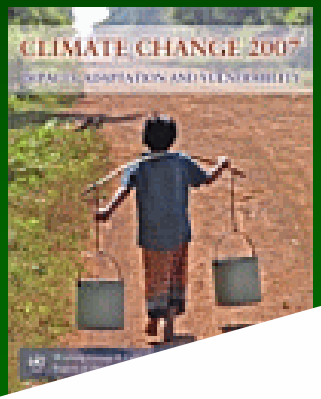


A simple correlation between range expansion and warming is not enough to prove the cause and effect relationship.

(1) Observations

Role of climate warming in the range expansion

PPM : a unique example to demonstrate the underlying mechanism



IPCC
2007, WG II

1

Assessment of observed changes and responses in natural and managed systems

Climate warming can also change the disturbance regime of forests by extending the range of some damaging insects, as observed during the last 20 years for bark beetles in the USA (Williams and Liebhold, 2002) or pine processionary moth in Europe (Battisti et al., 2005). The latter has displayed a northward shift of 27 km/decade near Paris, a 70 m/decade upward shift in altitude for southern slopes, and 30 m/decade for northern slopes in Italian mountains.

French national observatory on the effects of climate warming

ONERC
Observatoire National sur les Effets du Réchauffement Climatique

Shift of the northern edge of the PPM distribution

=

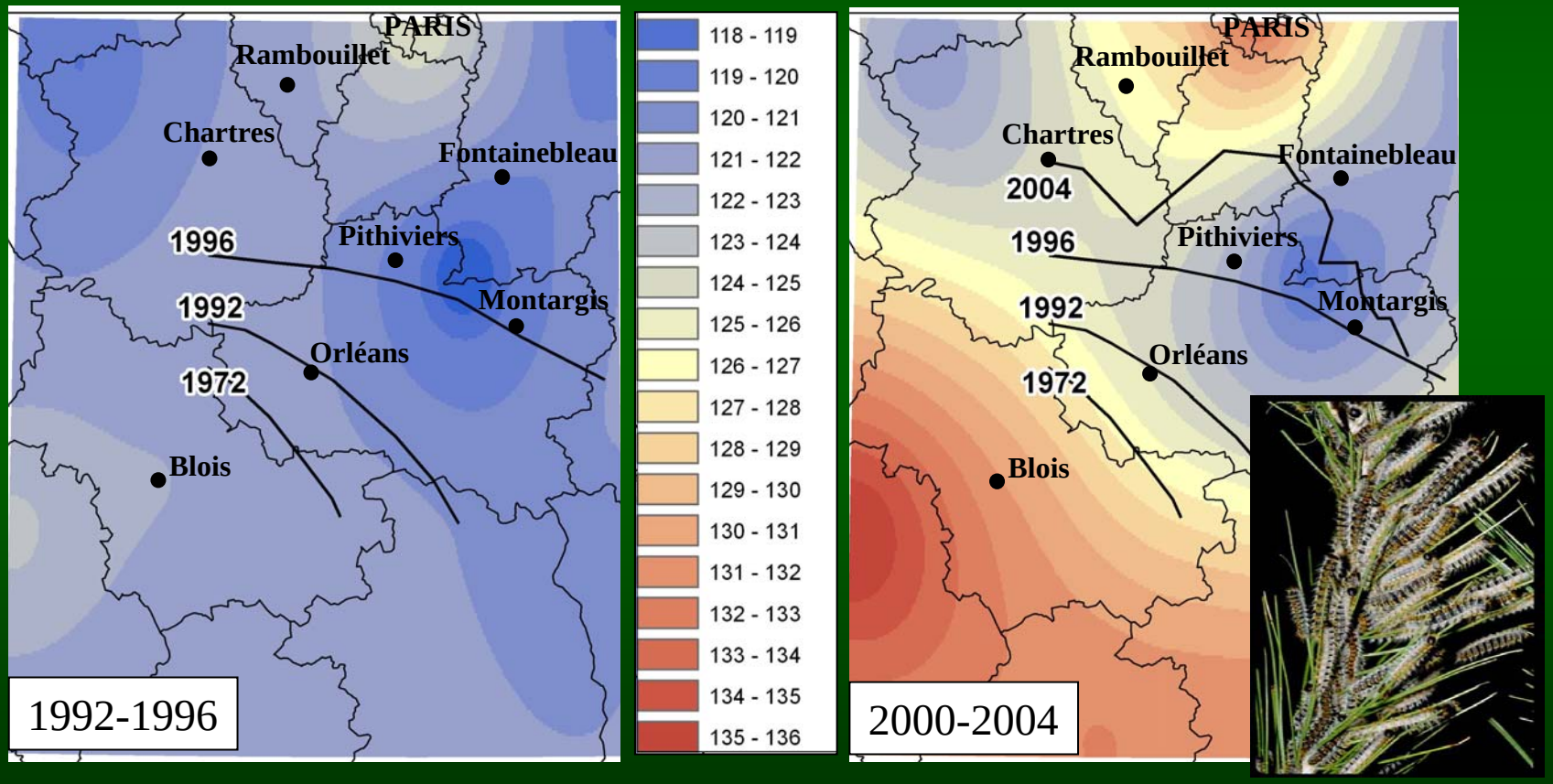
a bio-indicator of climate warming in France

(1) Observations

Role of climate warming in the range expansion

Winter warming increases larval feeding activity and colony survival
(Battisti et al. 2005)

T nest > 9°C (day) and T air > 0°C (following night)



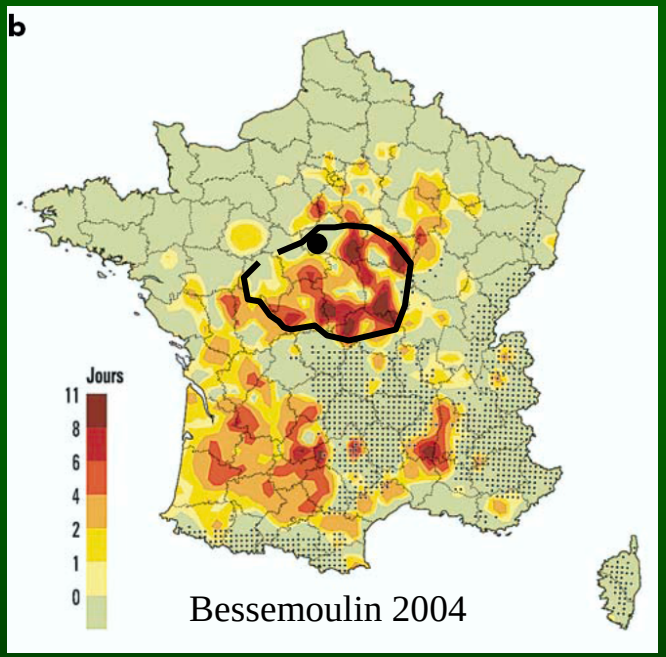
Number of days with suitable conditions for feeding during the cold season (Robinet et al. 2007)

(1) Observations

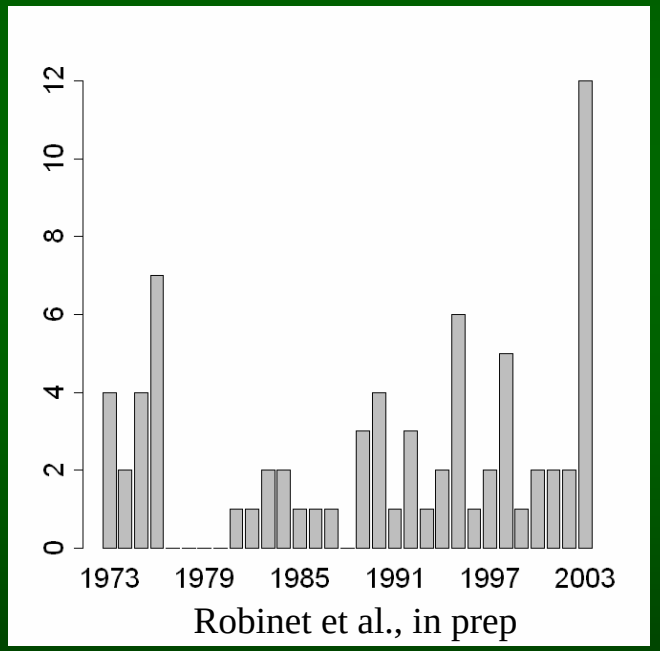
Effects of climatic anomalies

Climate change: warming trend + increase of the frequency of climatic anomalies

Heat-wave in 2003



Number of days with Tmax > 40°C
(Aug 1-18, 2003)



Number of consecutive days where the daily maximum temperature was above 32°C in Orléans.

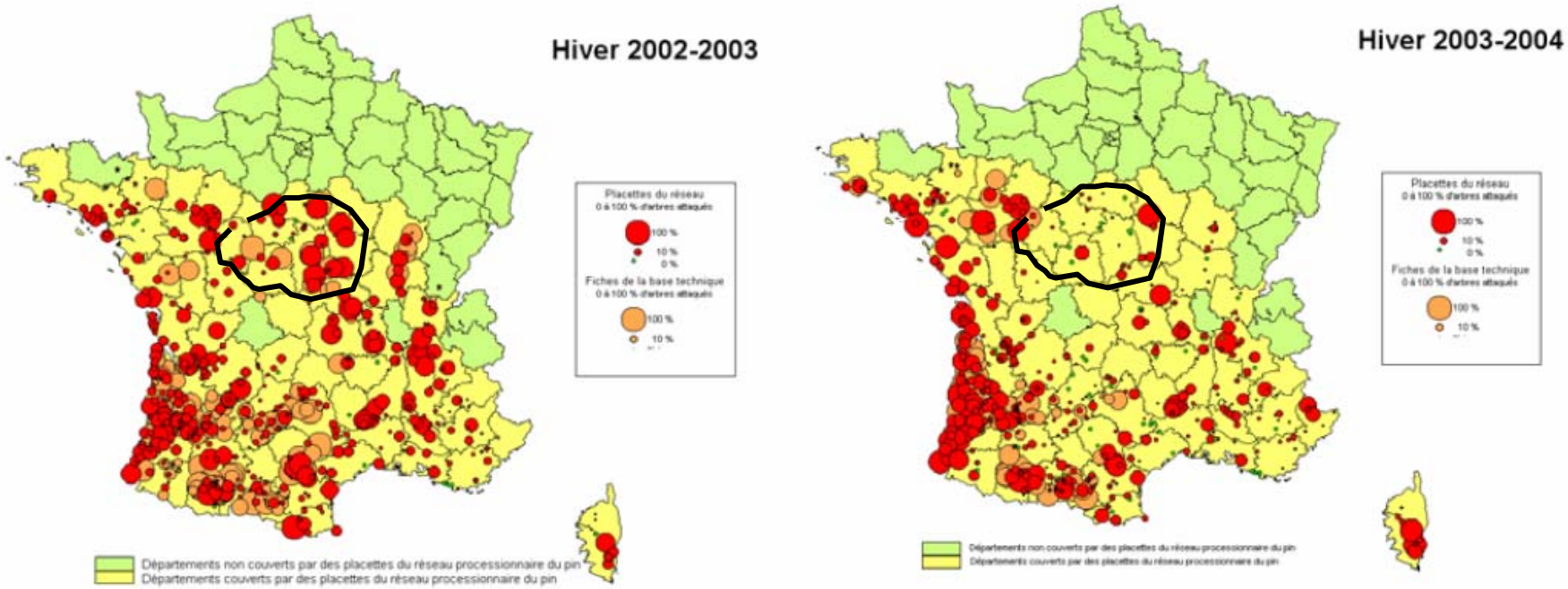
(1) Observations

Effects of climatic anomalies

PPM abundance decreased simultaneously in this region where extremely high temperatures were recorded over a long period (Bouhot-Delduc 2005).

This heat wave probably affected directly or indirectly young larvae (Robinet et al, in prep)

a large proportion of them died



Bouhot-Delduc 2005

Fig. 2 : Observation des attaques de la processionnaire du pin lors des hivers 2002–03 et 2003–04
Pine processionary caterpillar attacks during the winters of 2002–03 and 2003–04

(1) Observations

Effects of climatic anomalies

New challenge: to disentangle the effects of the warming trend
from the effects of climatic anomalies

Difficulties:

- heatwave: stochastic process
  intensity not homogeneous over space

- PPM phenology: not synchronous over space
  - population collapse in Paris Basin (Bouhot-Delduc 2005)
  - activation of adult flight in Italian Alps (Battisti et al. 2006)

Needs further studies to quantify their effects and predict their impact

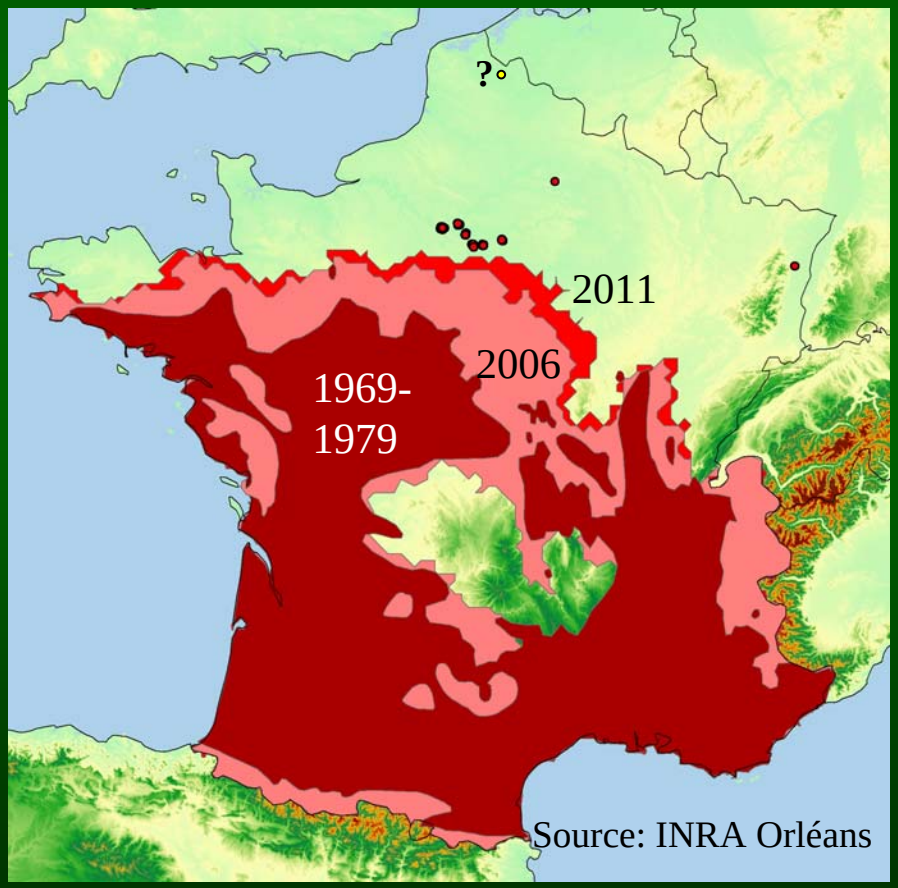
(1) Observations

Role of human-mediated dispersal

(1) Observations

Role of human-mediated dispersal

Pioneer colonies have been recently discovered far from the main distribution

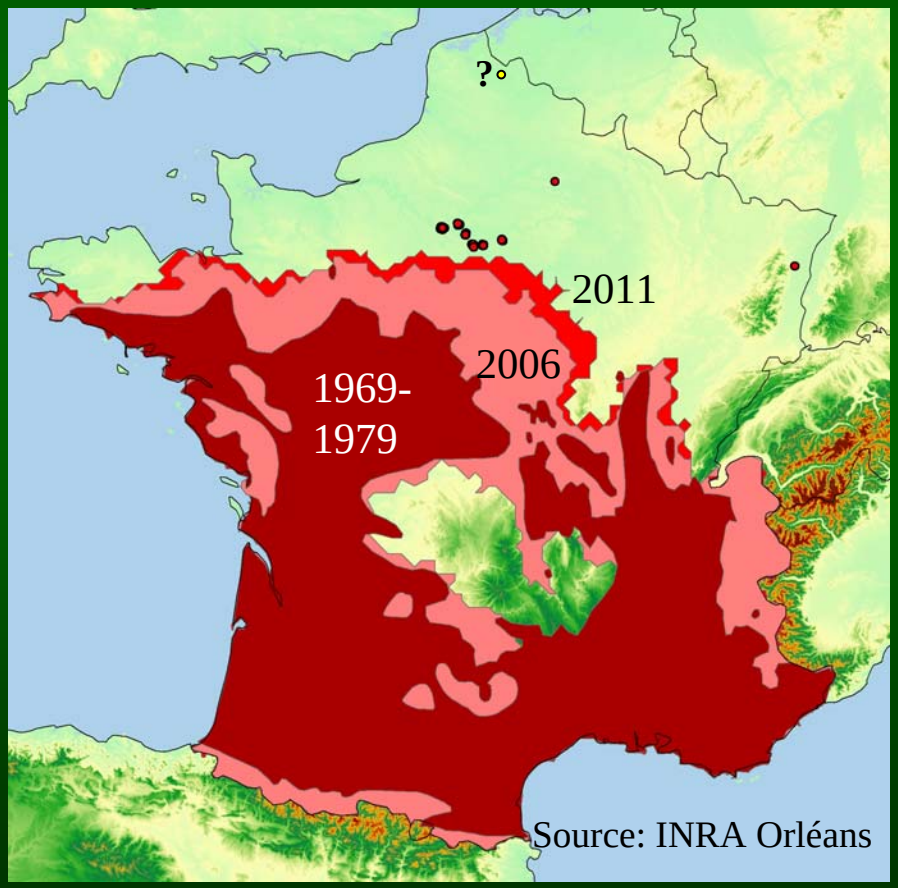


(1) Observations

Role of human-mediated dispersal

Pioneer colonies have been recently discovered far from the main distribution

PPM was probably accidentally transported as pupae in the soil of large potted trees (Robinet et al. 2012)



(1) Observations

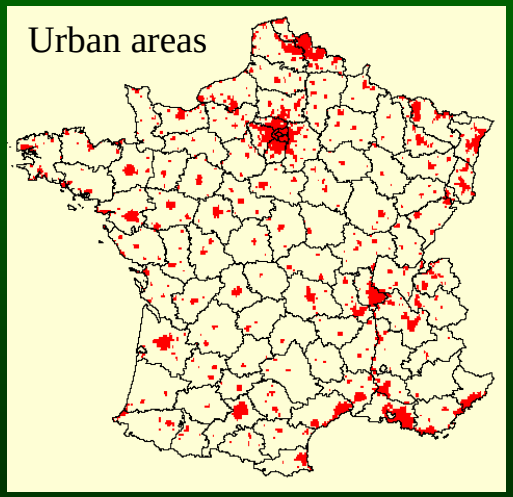
Role of human-mediated dispersal

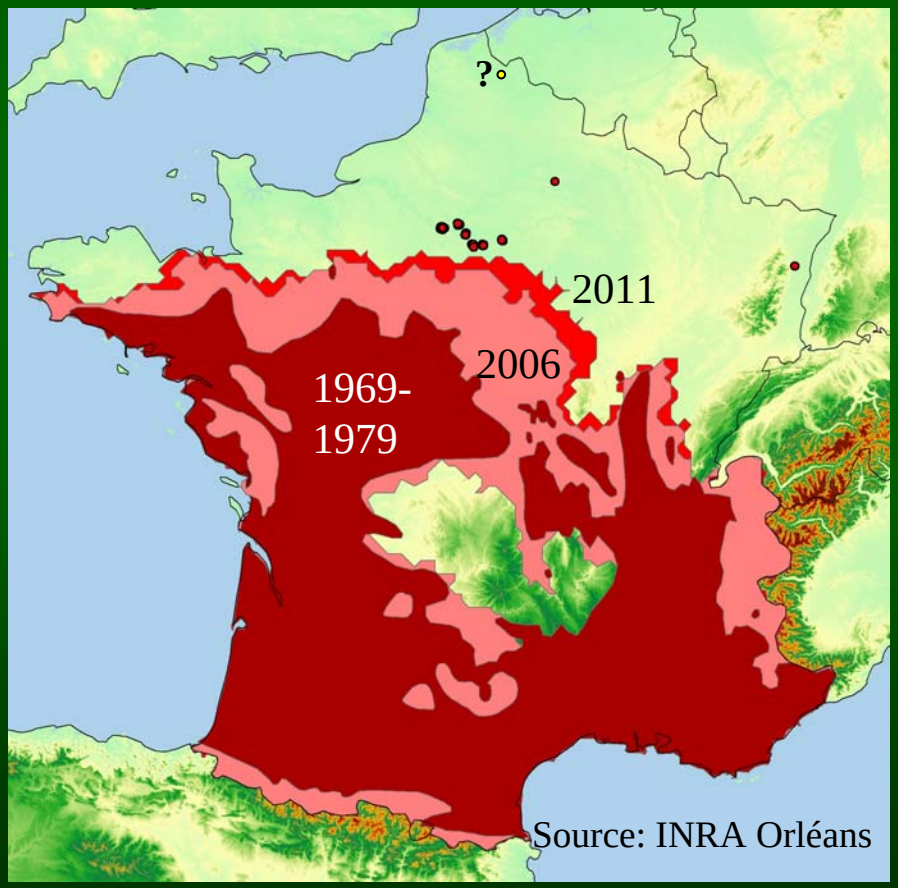
Pioneer colonies have been recently discovered far from the main distribution

PPM was probably accidentally transported as pupae in the soil of large potted trees (Robinet et al. 2012)

These colonies are mostly located in urban areas (host tree density very low).

The probability to move PPM is higher in areas where human density is higher.





(1) Observations

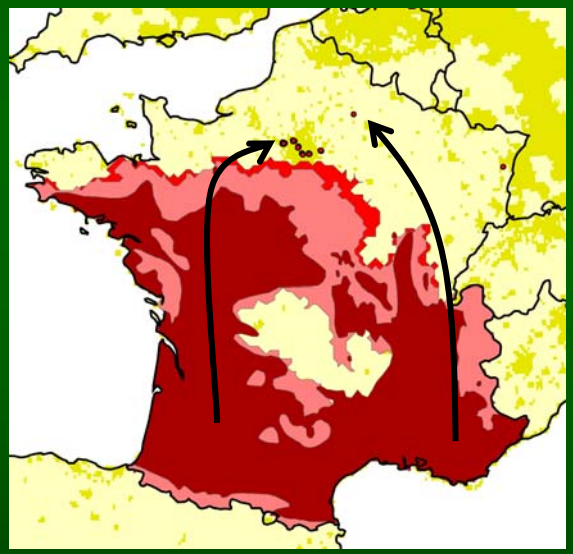
Role of human-mediated dispersal

New challenge: to identify the factors explaining accidental transportation of PPM

Difficulties:

- this pathway is a stochastic process

- impossible to validate this pathway directly



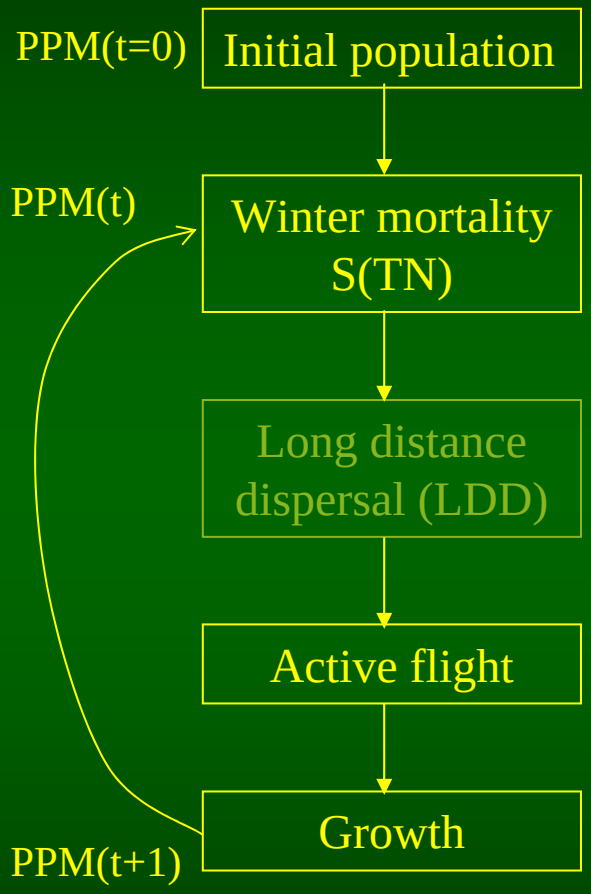
Tentative spread model possible but lack of information to validate this model

(2) Predictions

Description of the model

(2) Predictions

Description of the model



Impact of winter temperatures on larval survival

$$S(TN) = \frac{1}{1 + \exp(s(T_c - TN))}$$

Number of translocations

nbtransp ~ Binom(n=1,size=1000,p=0.001)

Location at random in urban areas

ninv = sample(potcell,size=nbtransp,replace=F)

Diffusion model

$$\frac{\partial E}{\partial \tau}(X,\tau) = D.\Delta E(X,\tau),\ \tau = 0..1$$

Delayed Ricker model (depends on host tree density)

$$\tilde{N}_{t+1}(X) = N_t(X).\exp\left[r.\left(1 - \frac{\overline{N}_{t-1}(X)}{K(X)}\right)\right]$$

Hyp: 20 nests / pine max

Parameters were estimated based on independent experiments or observed datasets

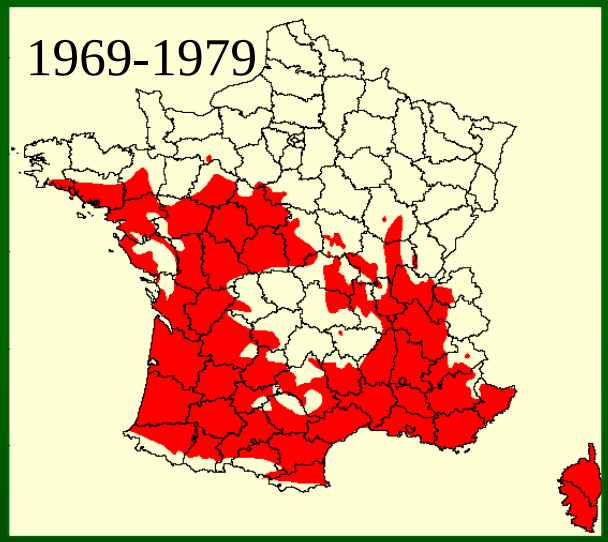
(2) Predictions

Validation of the model – without LDD

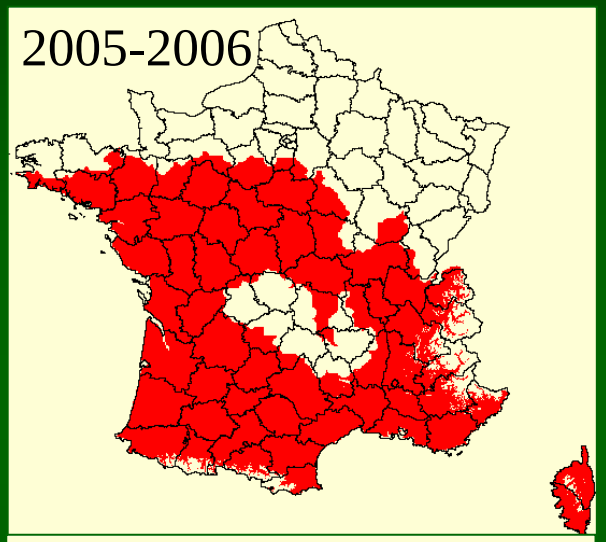
(2) Predictions

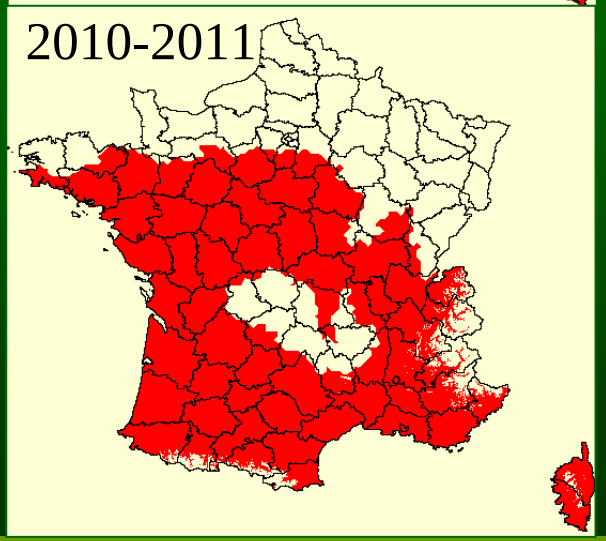
Validation of the model – without LDD

Initial population distribution:



Population distribution for validation:
(without pioneer colonies)

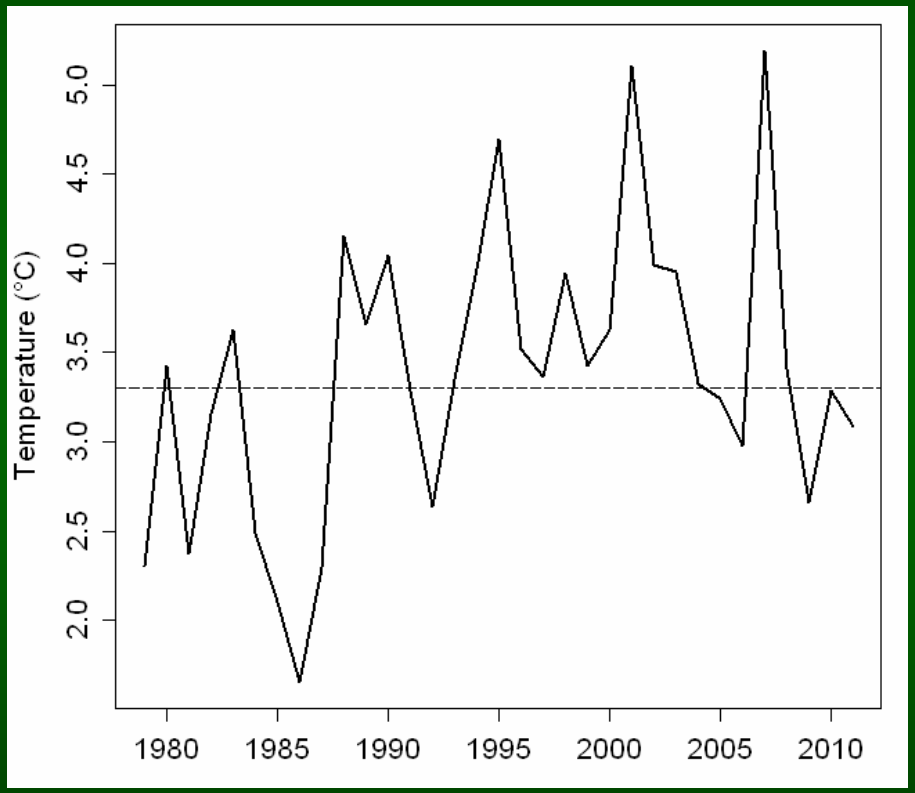




(2) Predictions

Validation of the model – without LDD

Temperature in the past for validation:
(baseline 2000 temperature + observed fluctuation)



Mean of minimum temperature from
October to March in Orléans

Baseline 2000: http://www.ccafs-climate.org/ ; fluctuation: http://eca.knmi.nl/

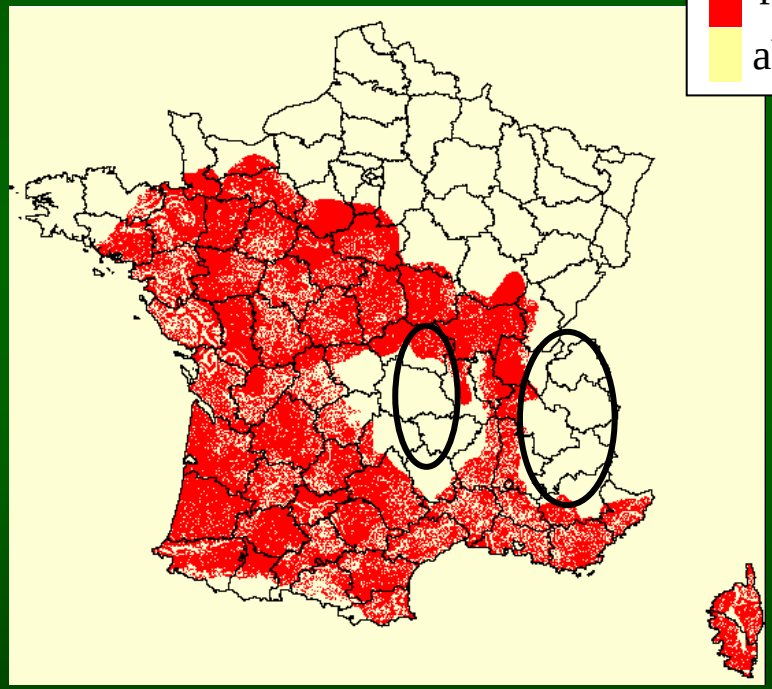
(2) Predictions

Validation of the model – without LDD

Simulation without LDD with historical temperature fluctuation

Correct classification rate = 77%

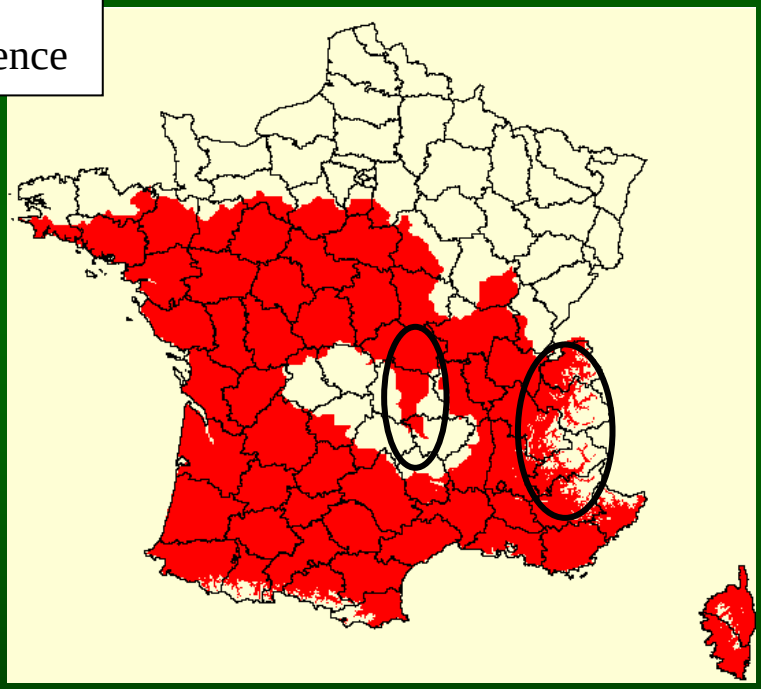
Simulation 2006



presence

absence

Observation 2006



Most of the errors are located in mountainous areas

Hyp: presence if the number of nests per pine ≥ 0.01

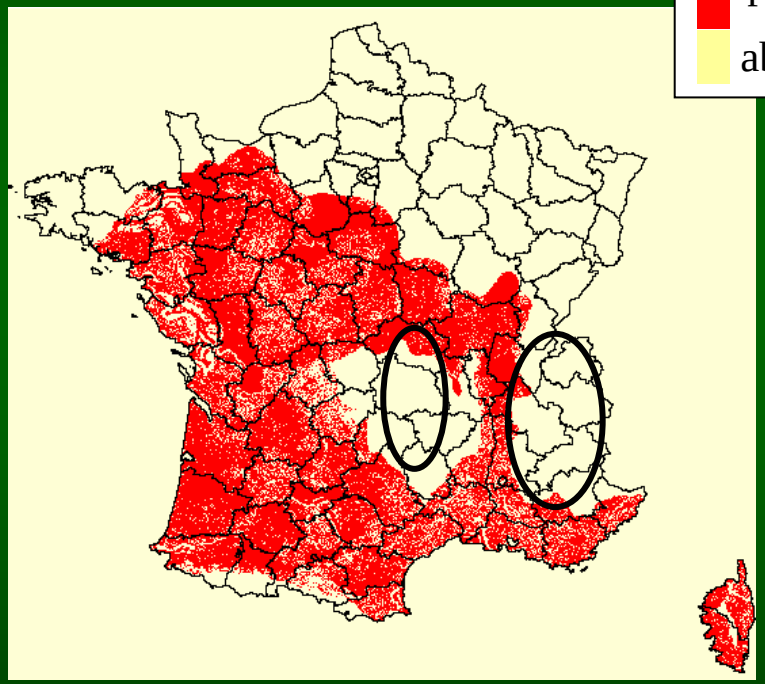
(2) Predictions

Validation of the model – without LDD

Simulation without LDD with historical temperature fluctuation

Correct classification rate = 77%

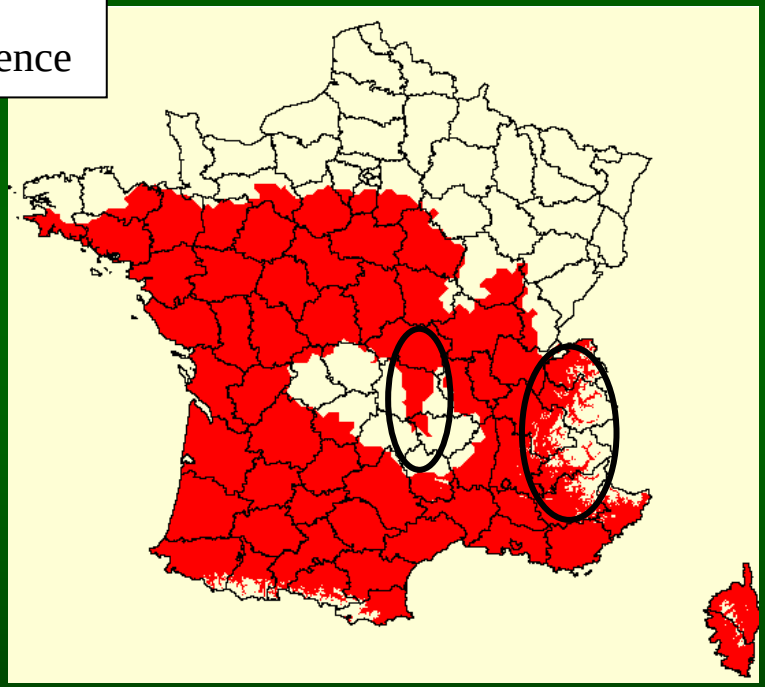
Simulation 2011



presence

absence

Observation 2011



Most of the errors are located in mountainous areas

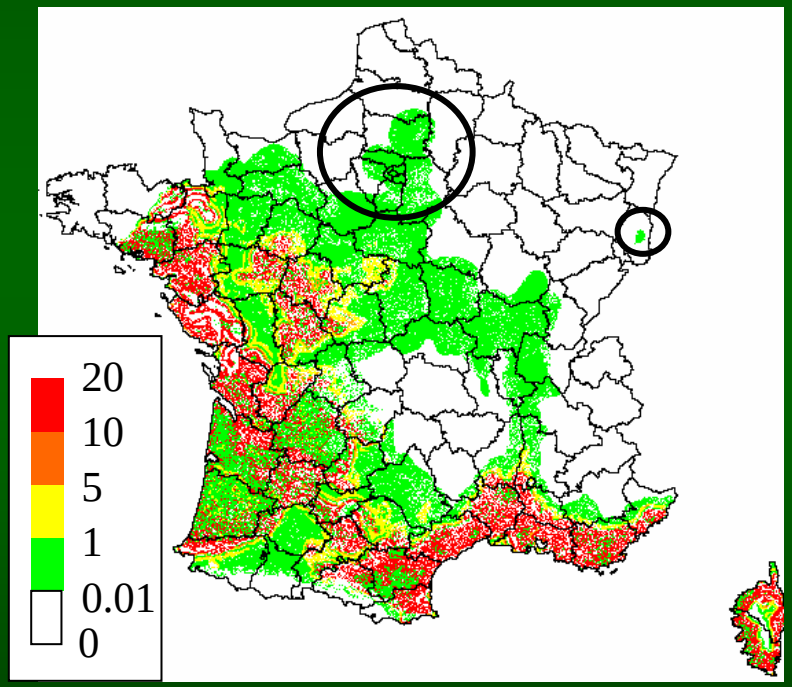
Hyp: presence if the number of nests per pine ≥ 0.01

(2) Predictions

Simulation in 2011 with LDD

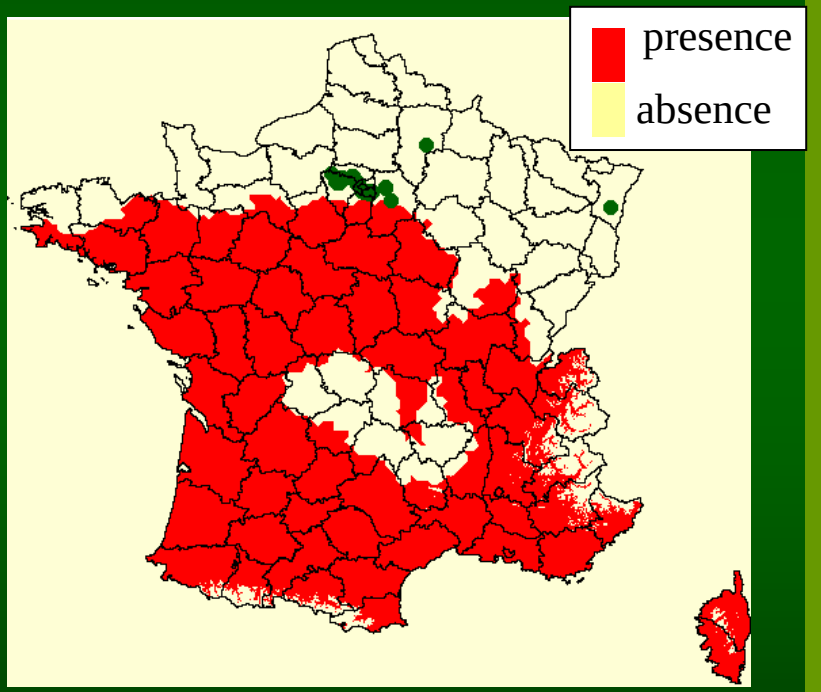
Simulation with LDD

Simulation 2011



Predicted number of nests per pine

Observation 2011



Distribution

Good prediction: most of pioneer colonies are located near Paris

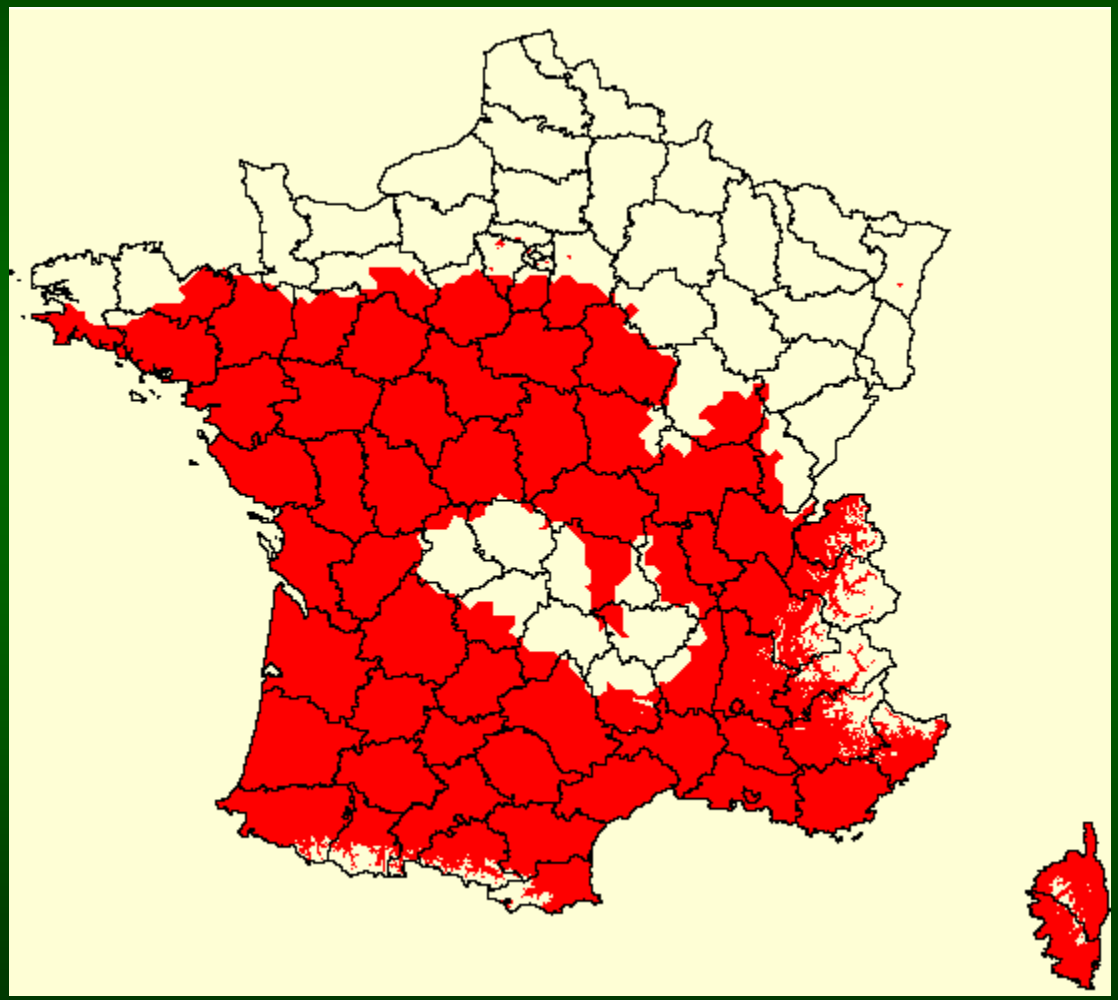
(2) Predictions

Simulations in 2030

(2) Predictions

Simulations in 2030 – initial population distribution

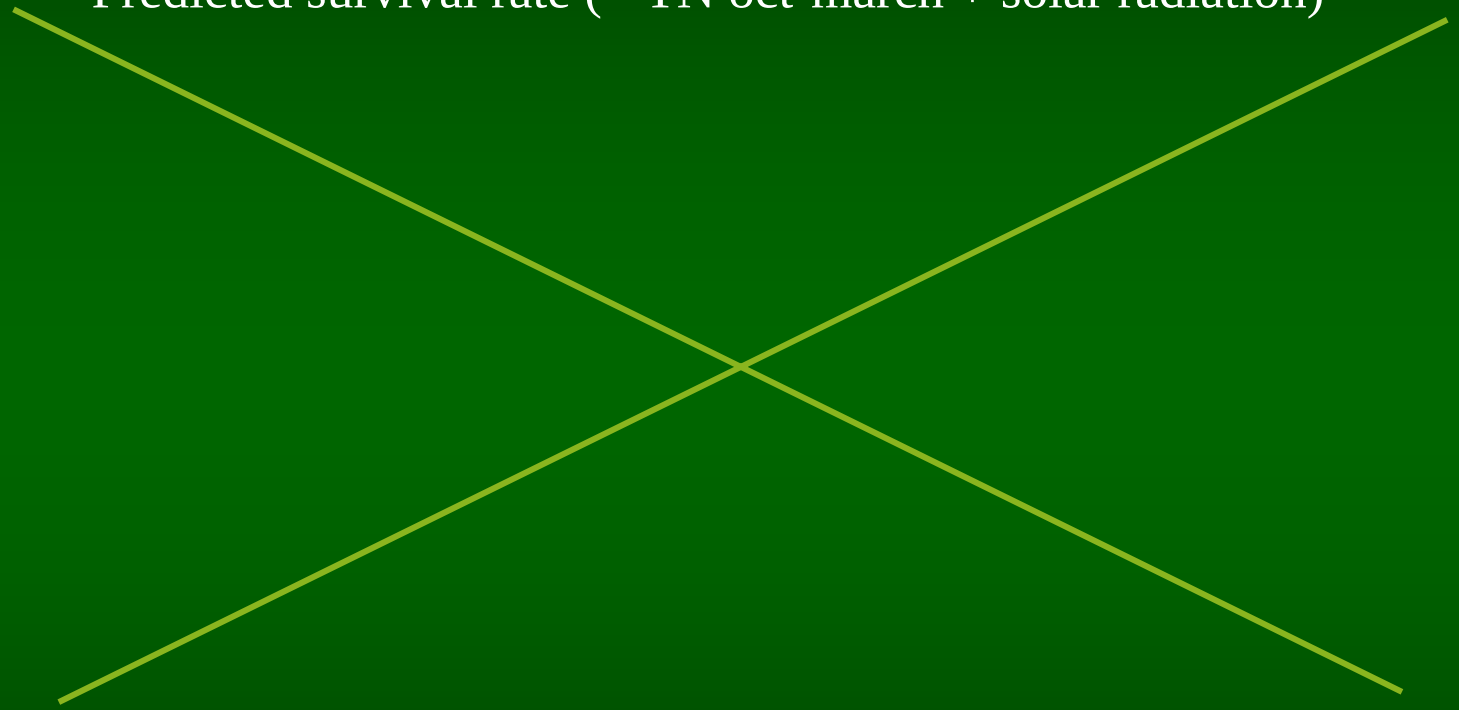
Distribution in 2010-2011 with pioneer colonies



(2) Predictions

Simulations in 2030 – scenario: *1- Constant climate*

Predicted survival rate (~ TN oct-march + solar radiation)

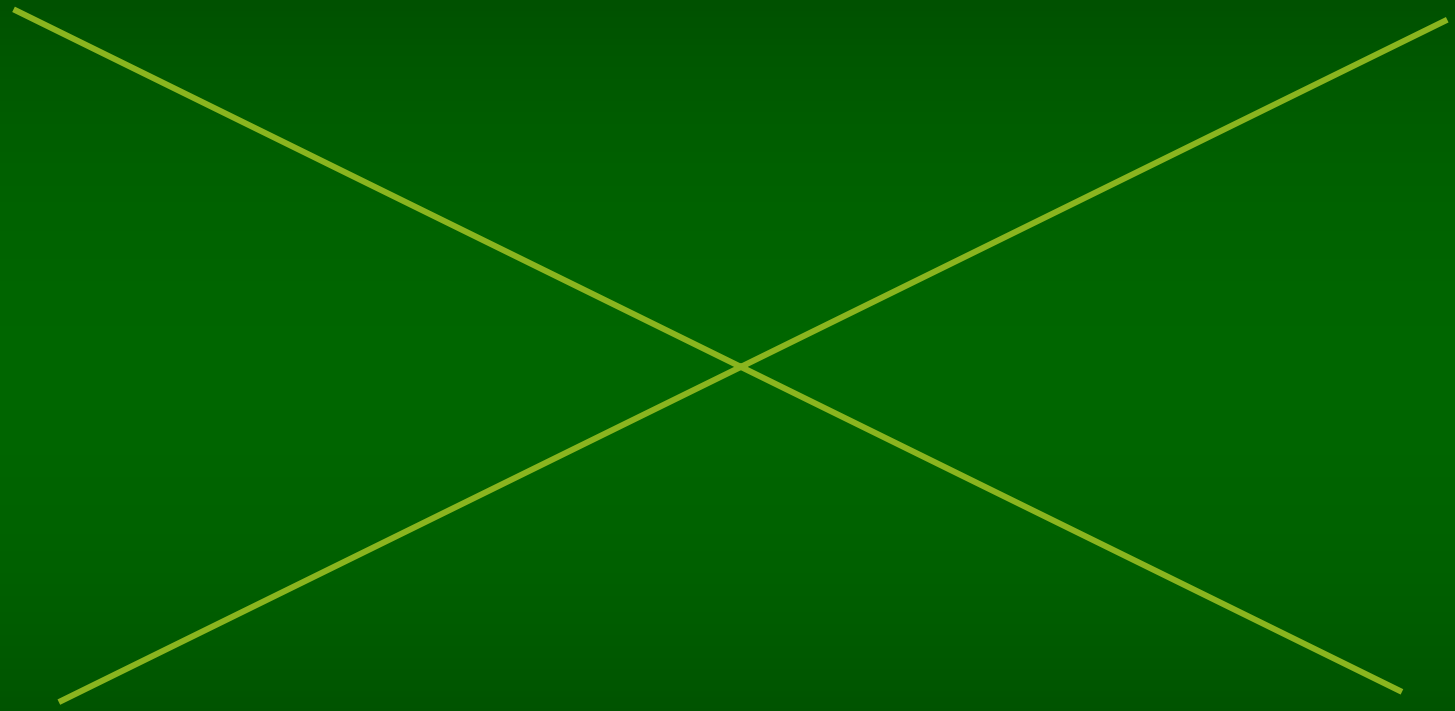


Based on the mean of minimum temperature from October to March (°C) over 1979-2011

(2) Predictions

Simulations in 2030 – scenario: *1- Constant climate*

Potential spread in 2030



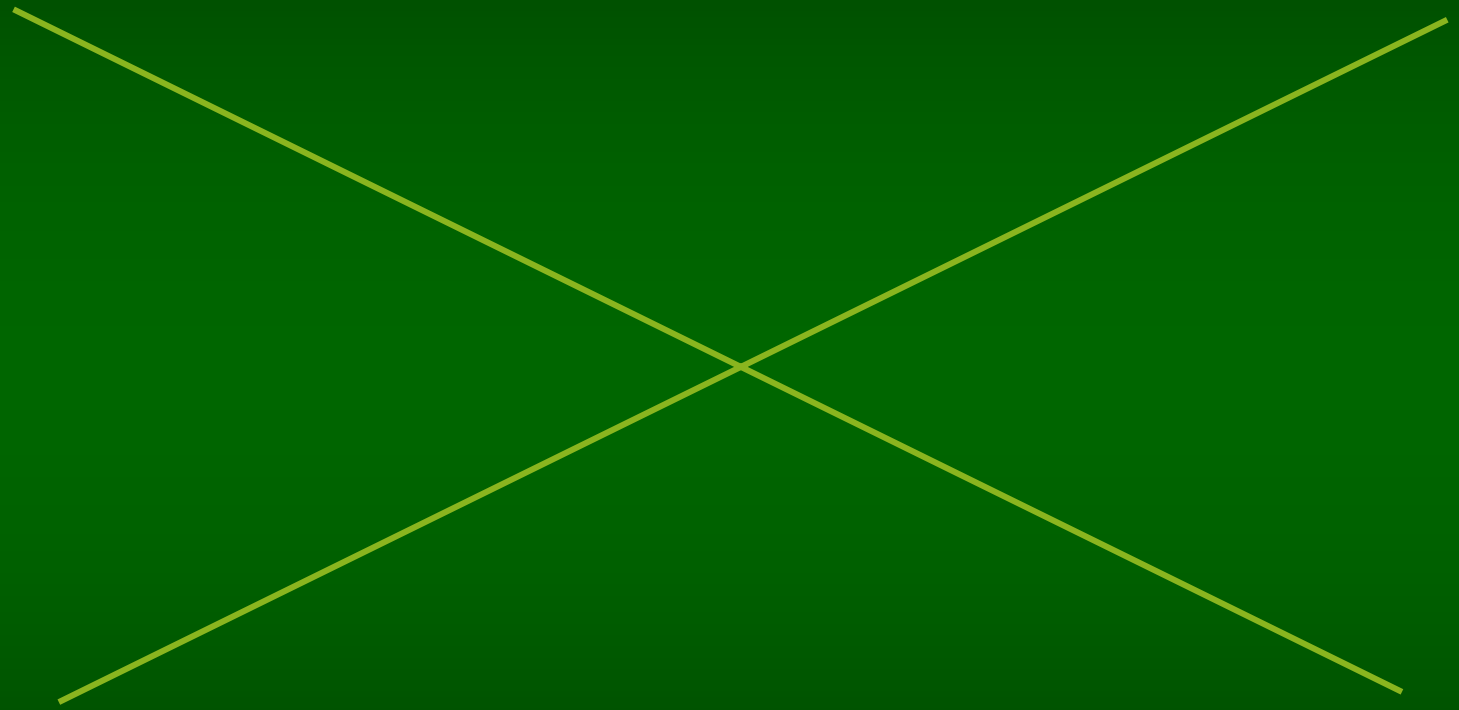
Predicted number of nests per pine

Without any additional temperature increase,
PPM could continue spreading, especially in the Paris region

(2) Predictions *Simulations in 2030 – scenario:*

2- IPCC scenarios

Predicted survival rate (~ TN oct-march + solar radiation)

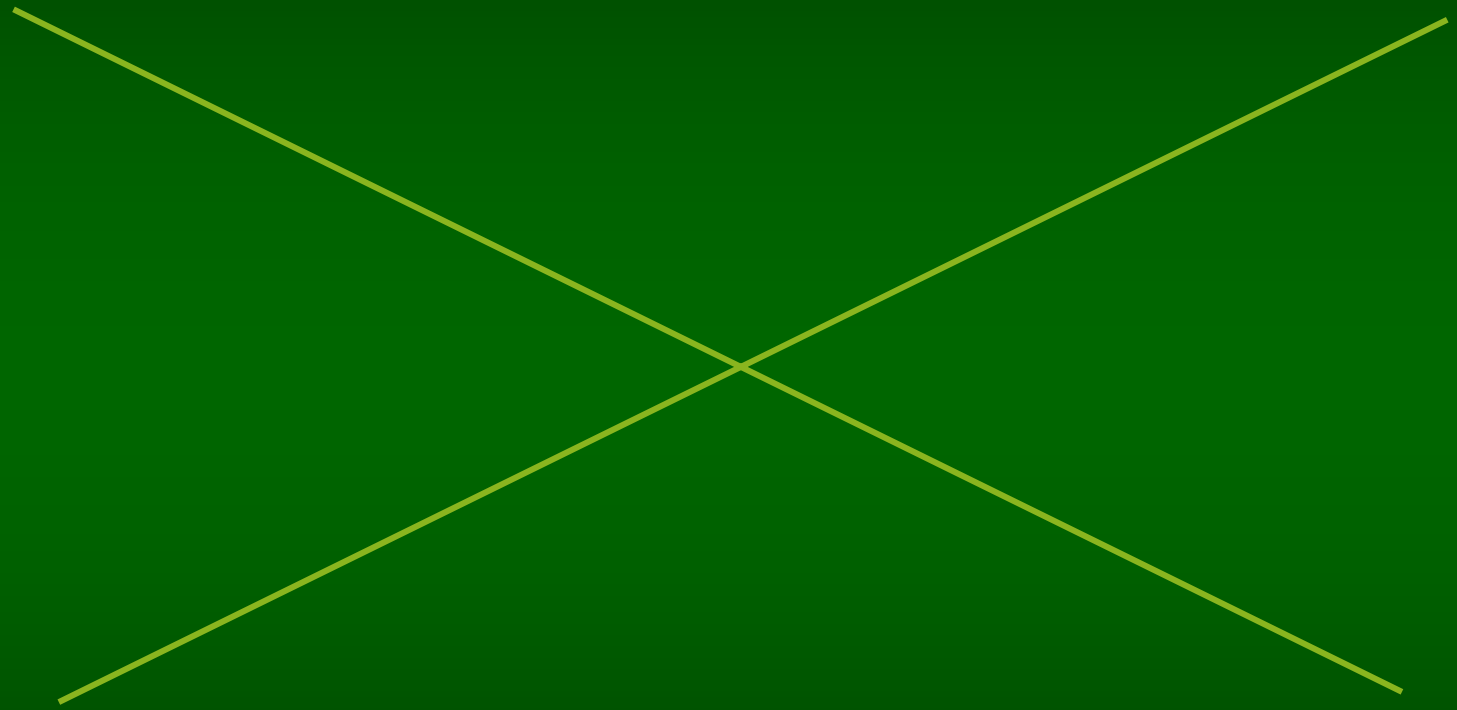


Based on climate change scenarios: A1, A2 and B2 for 2020s

(2) Predictions

Simulations in 2030 – scenario: *2- IPCC scenarios*

Potential spread in 2030



Predicted number of nests per pine

PPM could spread a little more

(3) Perspectives

Improvement of the model

(3) Perspectives

Improvement of the model

What do we need to improve the model?

- to account for the regional variability of the phenology

  => PHENOLOGY MODEL

  => to fit locally the survival function and consider climate variables over more appropriate periods in each region

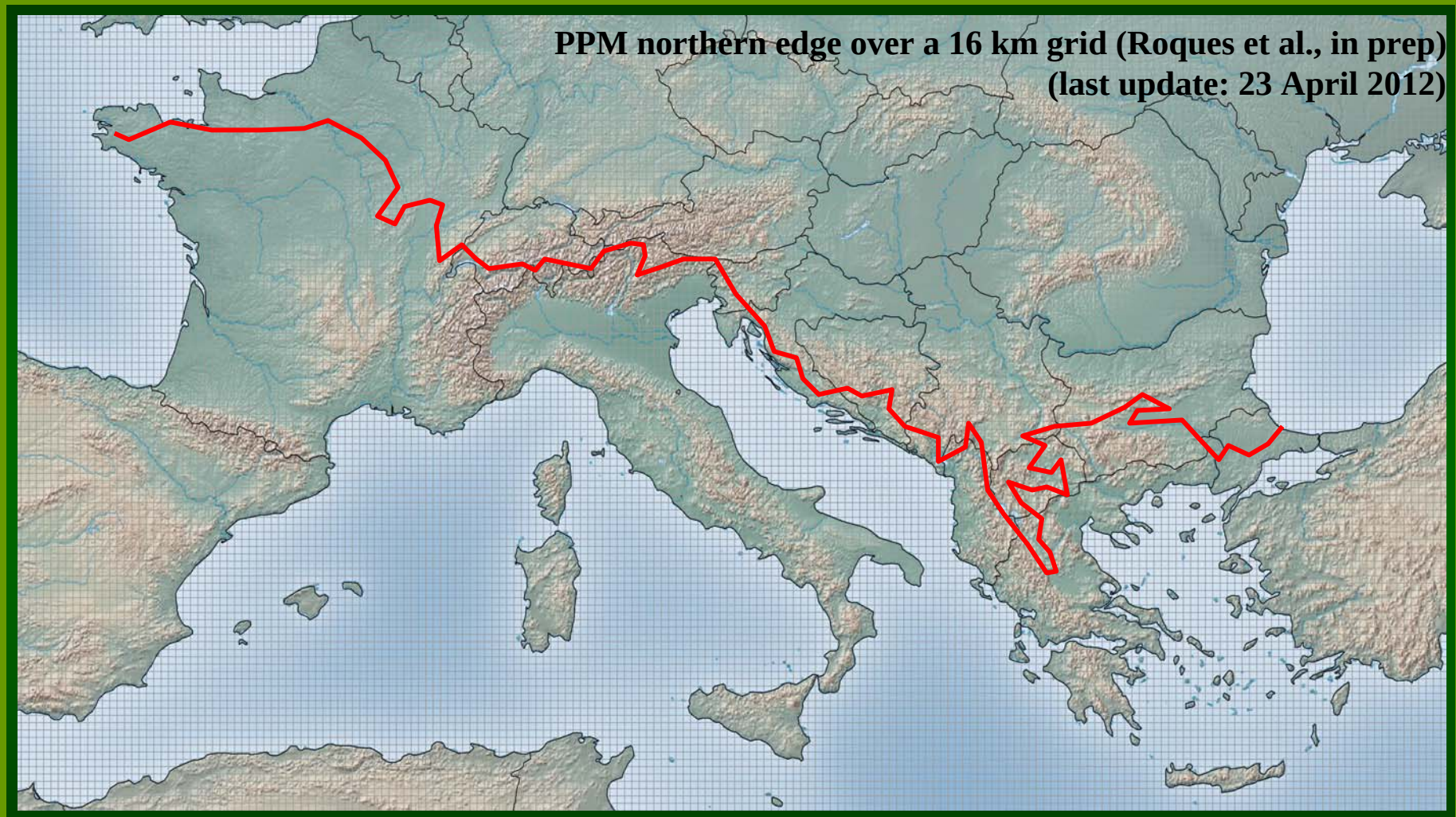
- to quantify the effects of climatic anomalies and to better determine the risk of accidental transportation (long distance jumps)

- to simulate more precisely the temporal dynamics (outbreak cycles)

- to explore Allee effects at low population density

(3) Perspectives

Potential range expansion in Europe



Northern shift of the northern edge at continental scale?
What about the southern edge (North Africa)?

(3) Perspectives

Still a good bio-indicator of climate warming?

- Even in case of warming stagnation, the PPM could continue extending its range and spreading in areas which turned favorable the years before
- Human mediated dispersal could affect the spread rate of the PPM

⇨ The PPM spread rate cannot be directly associated with warming velocity only

⇨ PPM range expansion is an integrated answer to: warming trend + more frequent climatic anomalies + human activity

PPM range expansion should be an indicator of a broader change: the combined effects of climate change and human disturbance

THANK YOU FOR YOUR ATTENTION

This study was supported by :

PCLIM (2011-2015)

URTICLIM (ANR 2008-2011)

ISEFOR (EU 2010-2013)

FAST (GICC 2010-2012)

ECONET Balkan (Egide 2009-2010)

BACCARA (EU 2009-2012)