Étude du transport des pollens en France avec le modèle de chimie-transport atmosphérique *CHIMERE*

Dmitry Khvorostyanov, Aurélie Potier, Laurent Menut
Laboratoire de Météorologie Dynamique IPSL

Mikhail Sofiev, Marje Prank, Pilvi Siljamo
Finnish Meteorological Institute

Michel Thibaudon
Réseau National de Surveillance Aérobiologique

Nicolas Viovy, Robert Vautard
Laboratoire des Sciences du Climat et l'Environnement IPSL

XVII^èmes JOURNEES D'ETUDES SCIENTIFIQUES
Metz, 30/11/2012

cnrs dépasser les frontières

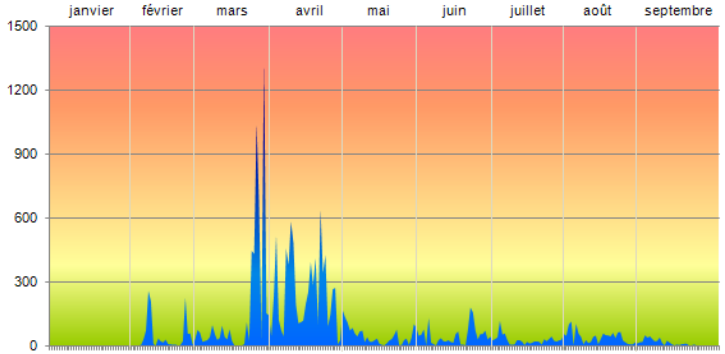
LMD

atopica atopic diseases in changing climate, land use & air quality

Institut Pierre Simon Laplace Sciences de l'environnement

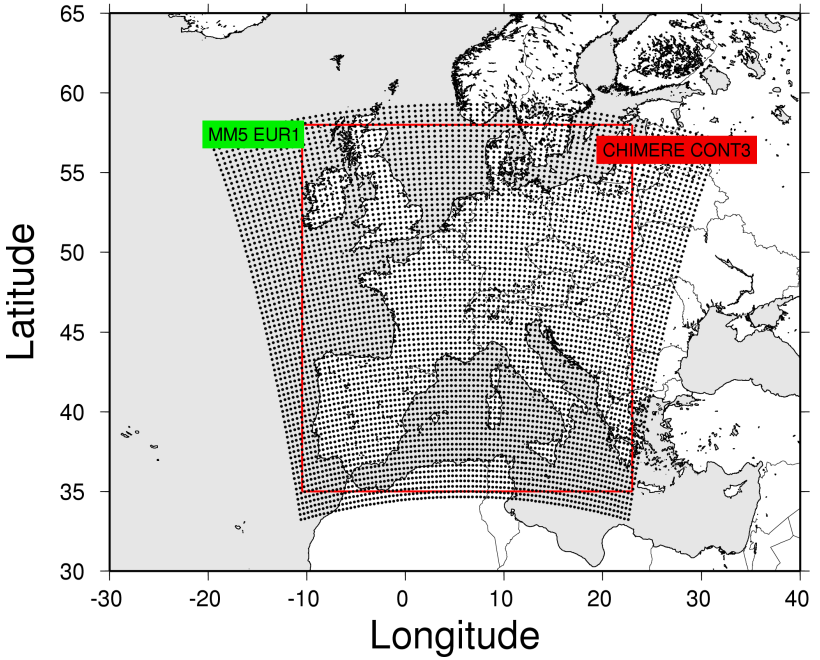
Modélisation de dispersion atmosphérique vs Observation

Le R.N.S.A.: observation et des services depuis 1996 ...



Que peut apporter la modélisation de dispersion atmosphérique?

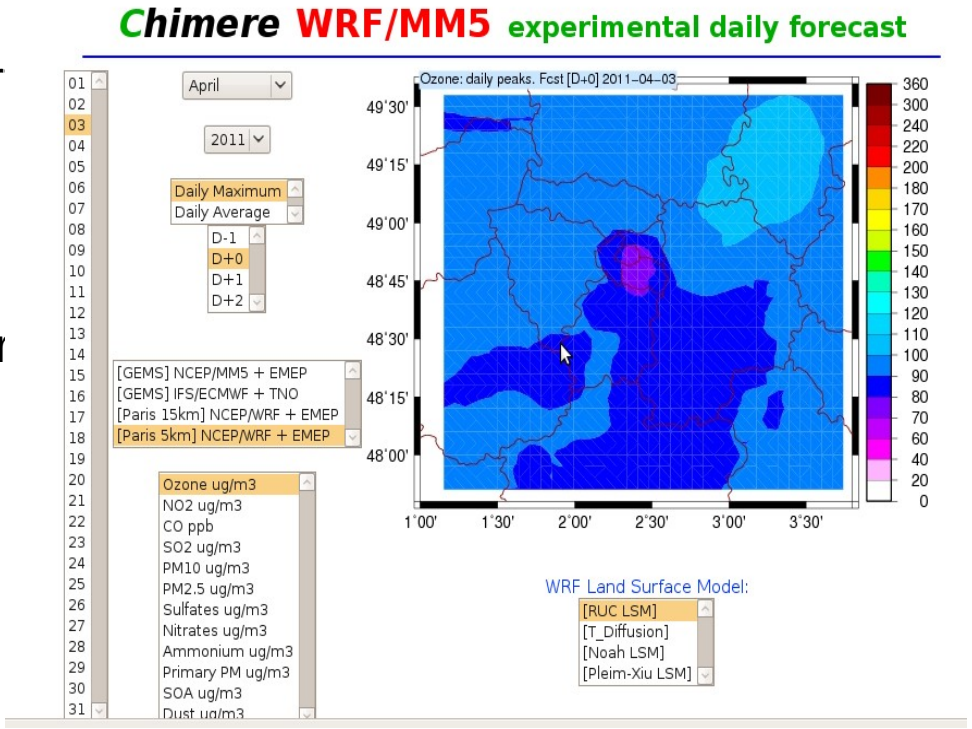
- Prévision de pollinisation de sources éloignées
- Contexte régionale d'événements de pollution
- Estimation des impacts de mesures de prévention



CHIMERE Chemistry-Transport Model

CHIMERE is an off-line chemistry-transpor model, a French CNRS national tool:
http://www.lmd.polytechnique.fr/chimere
Developed by IPSL/LMD and INERIS

·Used by more than 160 users for research or forecast
·Involved in projects such as GEMS, AMMA, GEOMON, CIRCE, MACC, ATOPICA, *etc*.

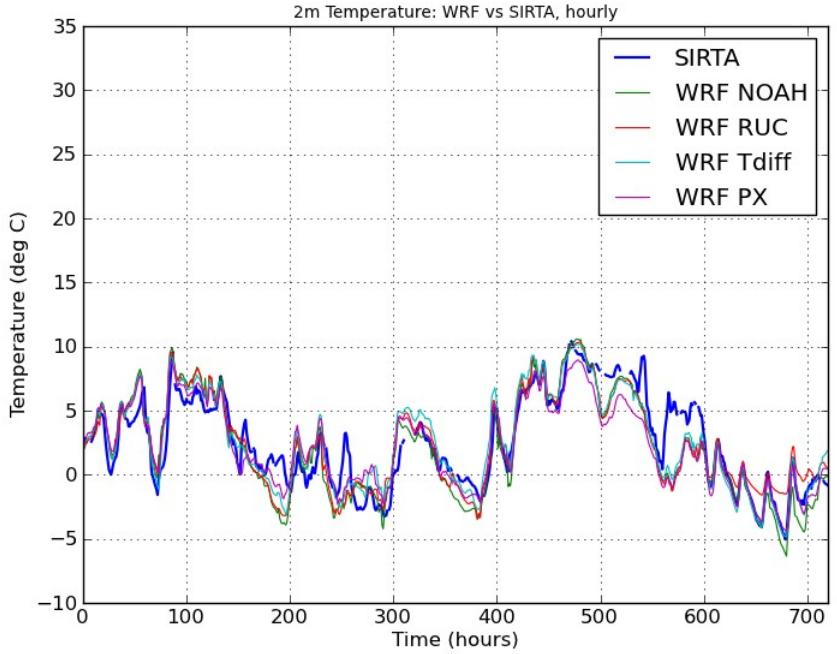


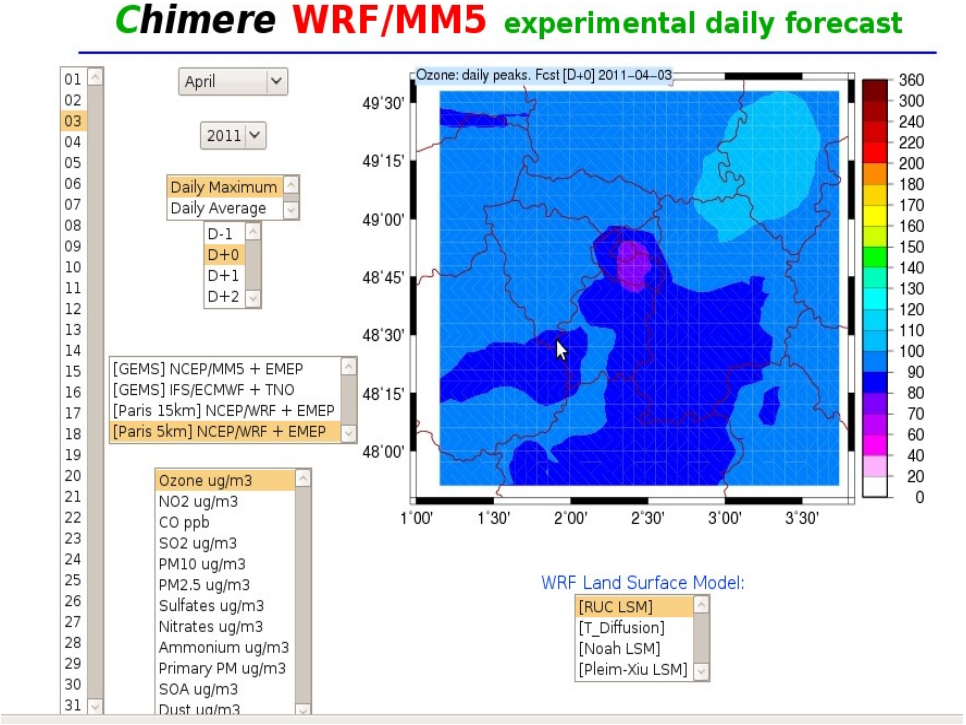
WRF and CHIMERE are used every day in experimental forecast for the COSY project: http://www.lmd.polytechnique.fr/cosy

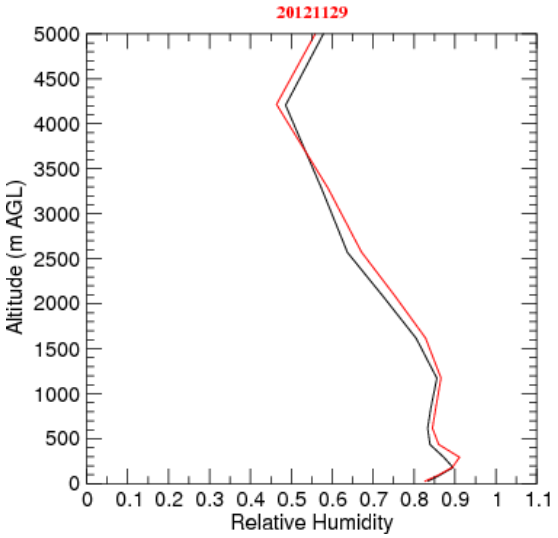
<u>Pollen transport processes:</u>

- Horizontal transport using the Van Leer or PPM scheme
- Turbulent vertical mixing using a non-local plume scheme (Troen & Mahrt, 1986; Cheinet 2002)
- Convection (Tiedke, 1989)
- Gravitational settlement
- Wet deposition (wash out)
- Resuspension (Helbig et al, 2004)
- Viability (Schueler & Schlunzen, 2006)
- *Double heat-sum model emissions (Sofiev et al, 2012)*

COSY Project: Model/Mesurement Comparison



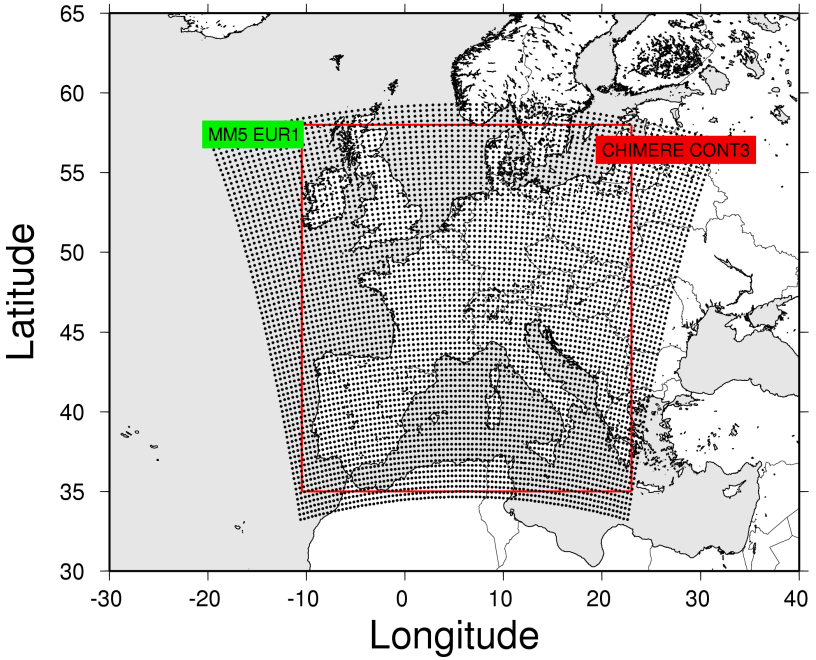


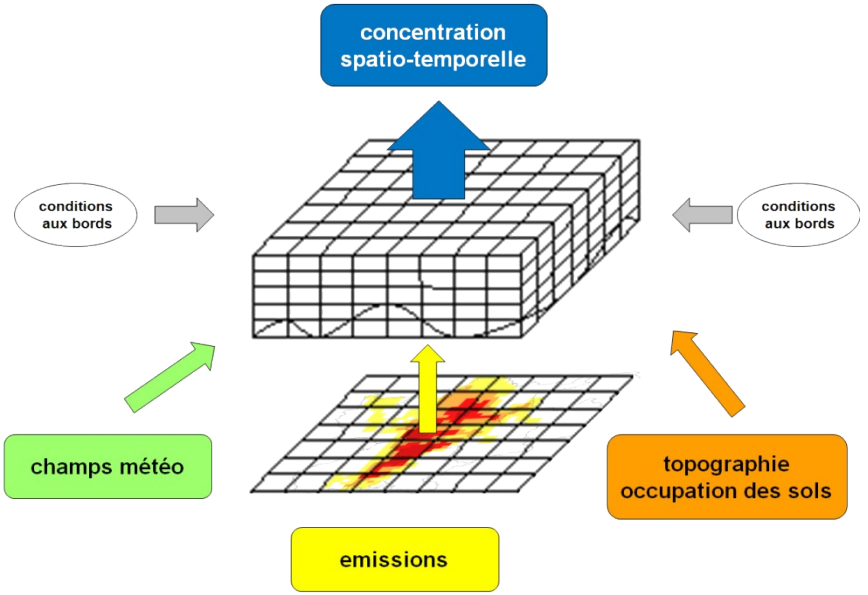


WRF and CHIMERE are used every day in experimental forecast for the COSY project: http://www.lmd.polytechnique.fr/cosy

CHIMERE: Offline Atmospheric Dispersion Model

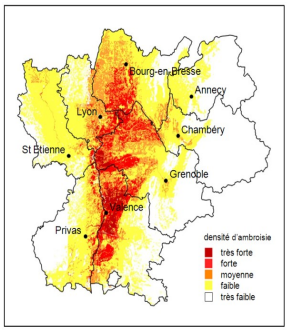
$$\frac{\partial c_i}{\partial t} + \mathbf{u}\nabla c_i = \nabla(K\nabla c_i) + P - L$$

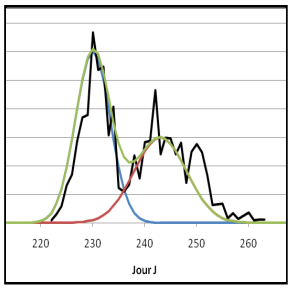




Pollen modeling with CHIMERE

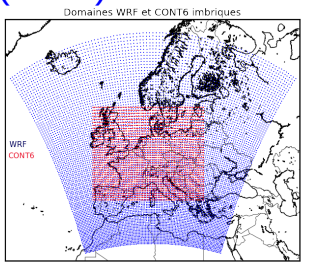
Plants inventory



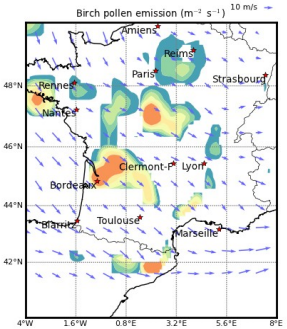


Emission Model :
Phenology
+
Liberation

Meteorology model (WRF)



Pollen emission flux

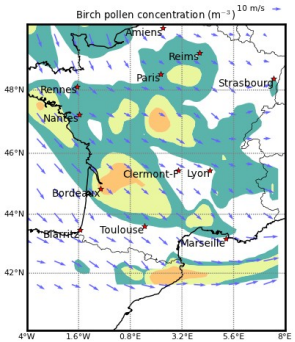


CHIMERE

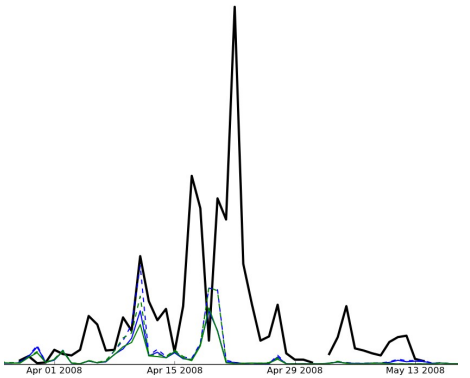
Transport Deposition Wash out

Viability/allerginicity Resuspension

Pollen Concentrations



- Post-processing, analysis
- Comparaison with observations

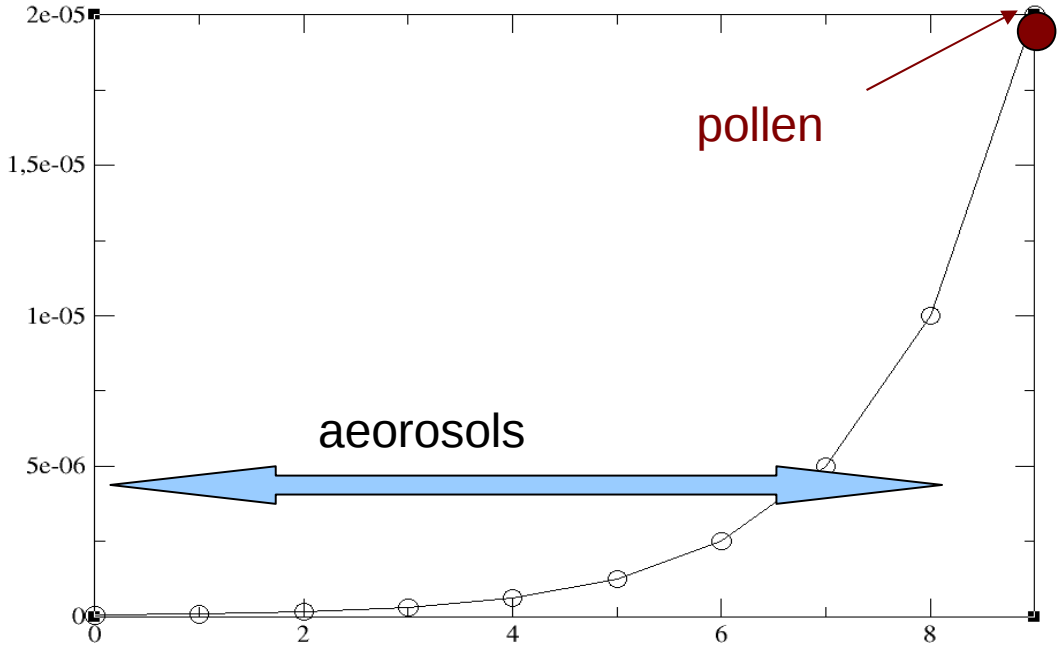


Pollen Aerosol in CHIMERE

- Biogenic aerosol (density/diameter changes due to moisture, viability, allergenicity)
- Pollen ~ large-size aerosol with a single bin

- Birch and ragweed pollen:

diameter	20-22µm
density	800-1050 kg/m3
shape	spherical
emission height	a few tens cm to 15 m
settling velocity	1.2-1.3 cm s^{-1}



Distribution en taille des aérosols dans CHIMERE

Pollen grains follow the airflow

Key assumption in the dispersion models: *pollutant follows the airflow, including small turbulent eddies => its inertia is negligible* (Sofiev, 2006)

$$m\frac{dv}{dt} = -F_{Strokes} = -3\pi\, d\, \eta u$$

$$\tau = \frac{d^2 \rho_{part}}{18\eta} \sim 10^{-3}\ \text{sec}$$

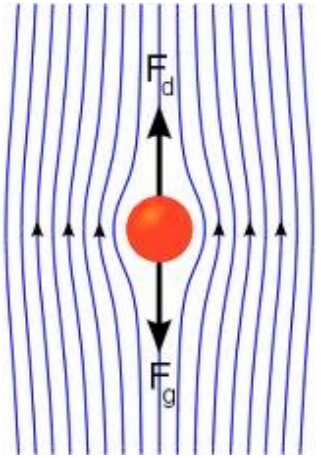
$$R_{grav} = 1/u \sim 85\ s\ m^{-1}$$

$$R_A \sim \quad 1\text{–}100\ s\ cm^{-1}$$

$$R_B = \frac{2}{\kappa u*}\left(\frac{Sc}{\text{Pr}}\right)^{2/3} \sim 3.5\ 10^5\ s\ m^{-1}$$

Stokes Law for spherical particles:

$$u = \frac{g\rho_{part} d^2}{18\eta} \qquad u \sim 1.2\ cm/s$$



Half-lifetime of ~1 day due to dry deposition

=> Half of the emitted mass will be transported over a distance >10^3 km

Turbulent vertical mixing opposes the downward motion =>part of the grains can stay in the atmosphere considerably longer

Pollen emissions 1: A double-threshold T sum model for birch

(Linkosalo et al, 2011) =>Sofiev et al (2012)

$$S(t) = \int_{t_0}^{t} r(i)di \cong \sum_{i=t_0}^{t} (r(i) \cdot \Delta t),$$

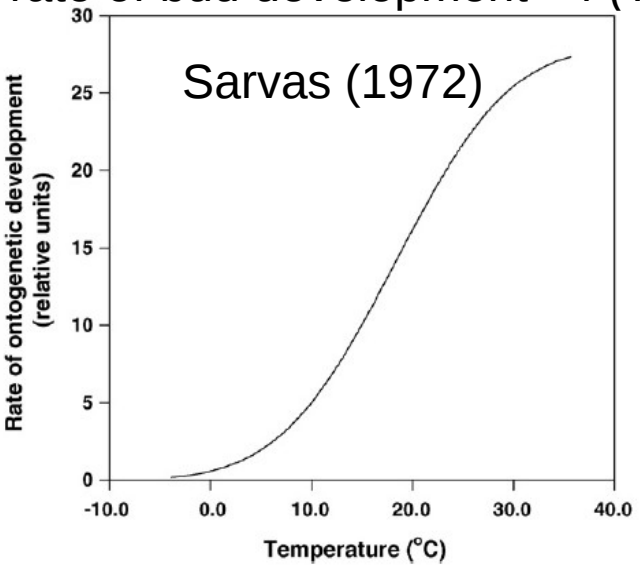
r – *rate* of ontogenetic development
S – *stage* of development or *T* sum

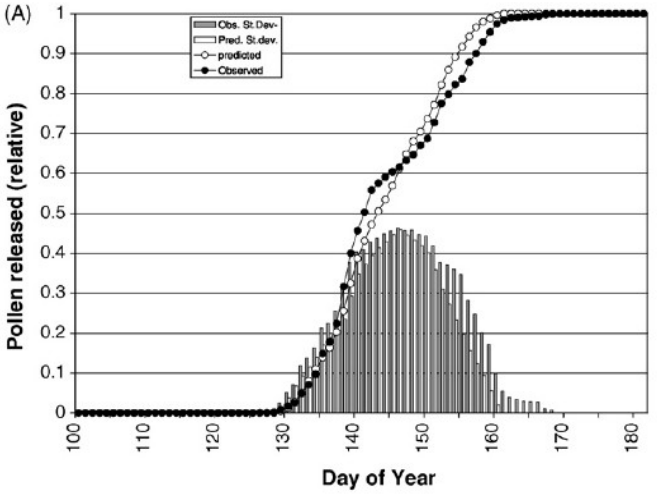
$$R(t) = \begin{cases} 0, & S(t) < S_1 \\ \dfrac{S(t) - S_1}{S_2 - S_1}, & S_1 \le S(t) \le S_2 \\ 1, & S(t) > S_2 \end{cases}$$

S_1, S_2, t_0 :
fitted with measured concentration or phenological data:

$$\mathrm{RMSE} = \sqrt{\frac{1}{N}\sum_{1}^{N}(O(i,j) - R(i,j))^2}$$

Phenological measurements:
r – rate of bud development = *f (T)*





Emission model requires...

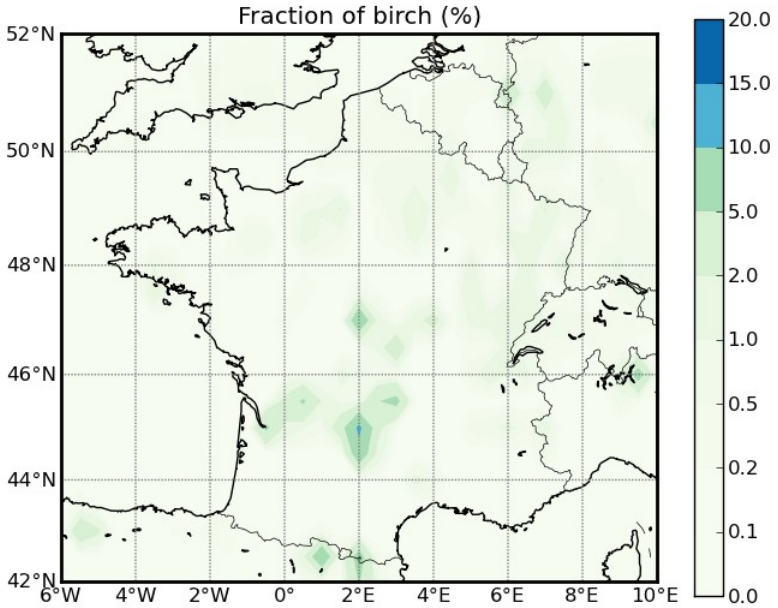
Birch map:
- Forest inventories
- Satellite images

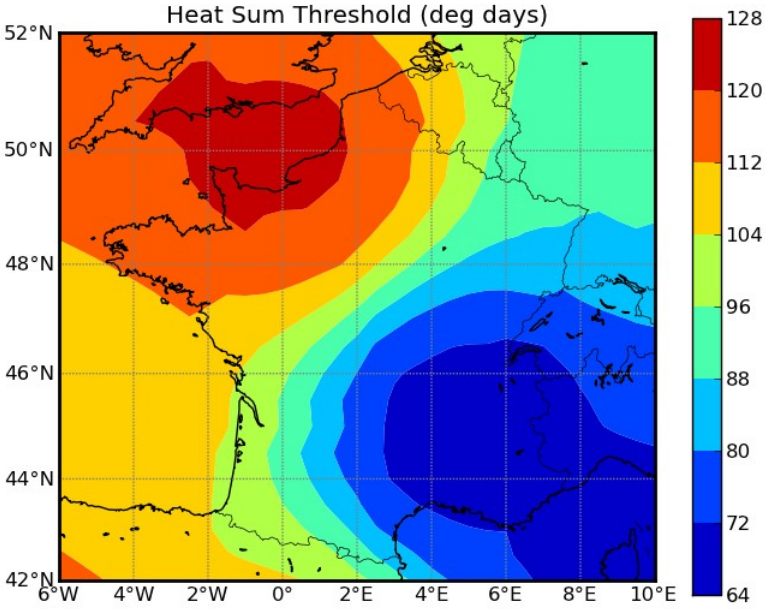
France :
0 to 11% birch forest
Mean : 0,9%

Phenology:

cumulated heat ($T>T_{thresh}$ = 3.5°C) from March 1

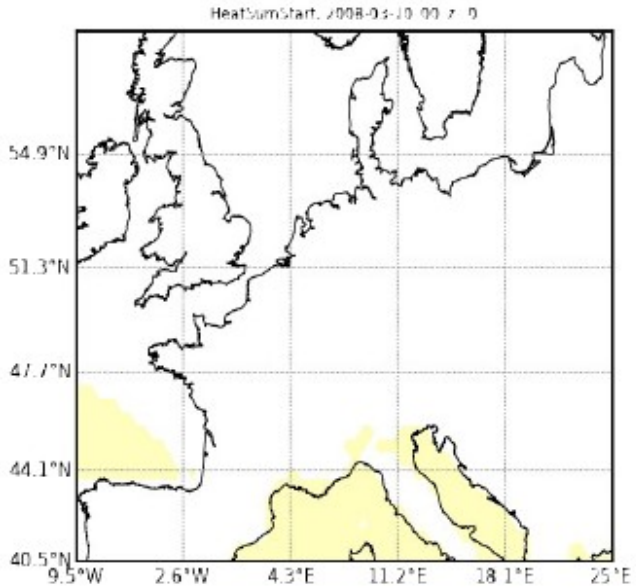
until H_{thresh} is reached



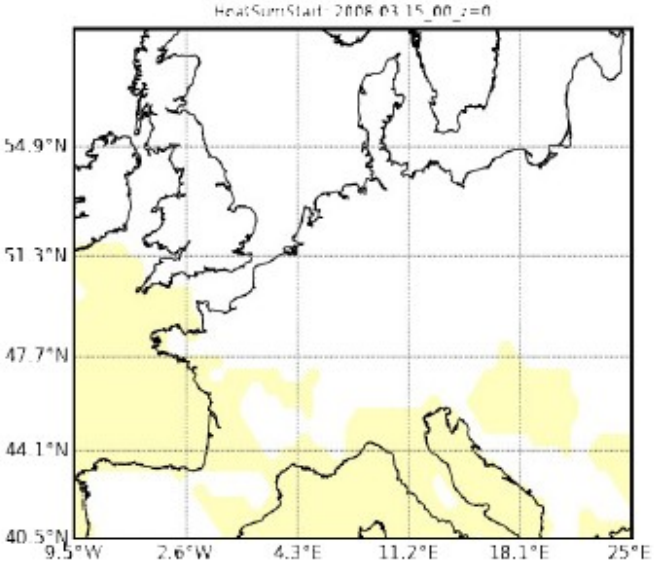


Pollination season start: heat sum threshold reached

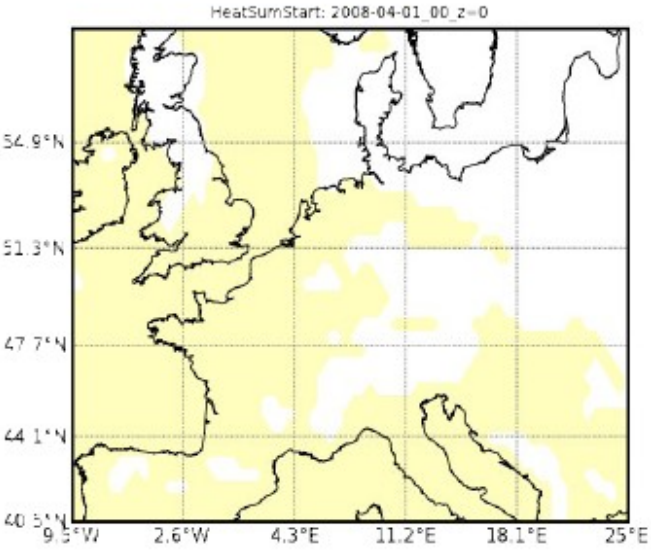
March 10



March 15



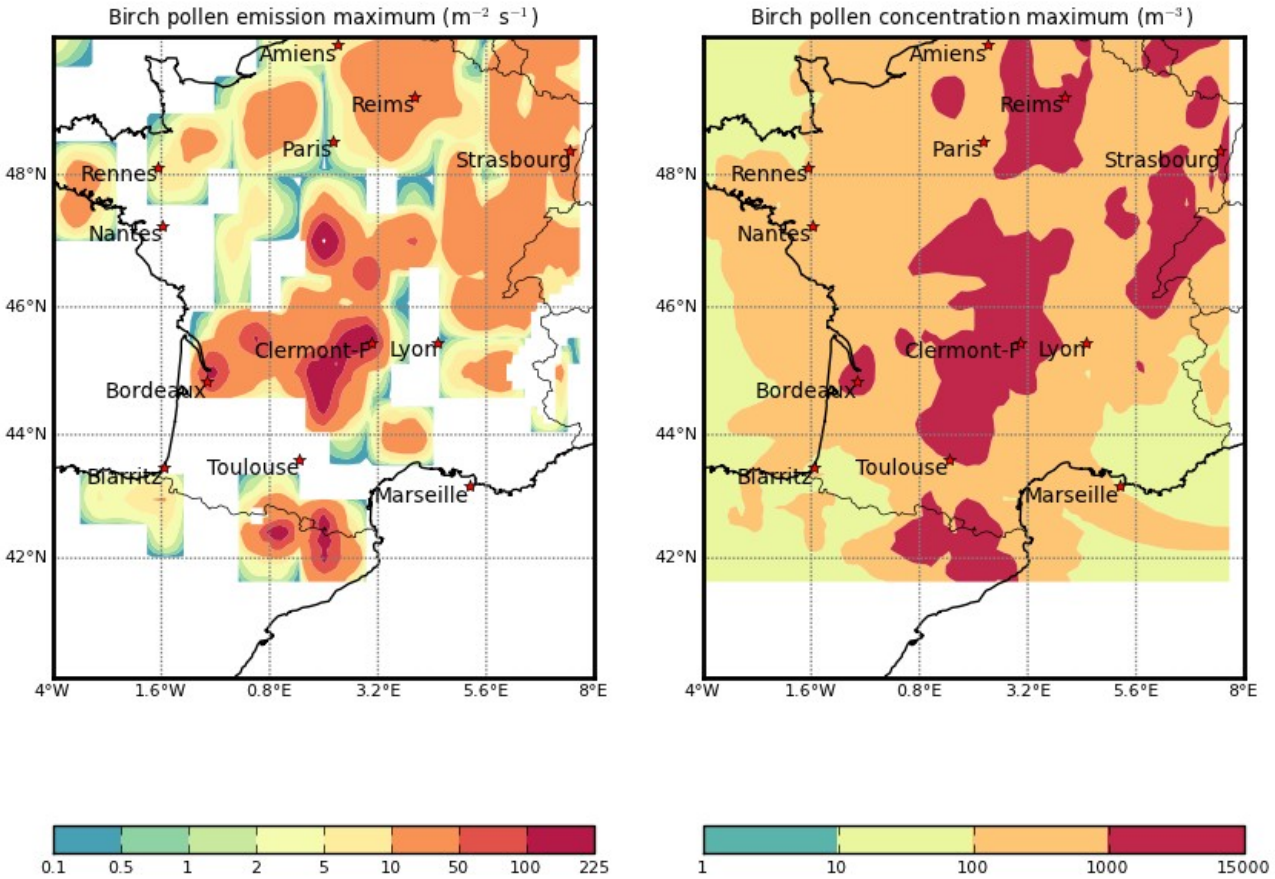
April 1



Pollination pattern propagates from south-west to north-east

Birch pollen animation here...

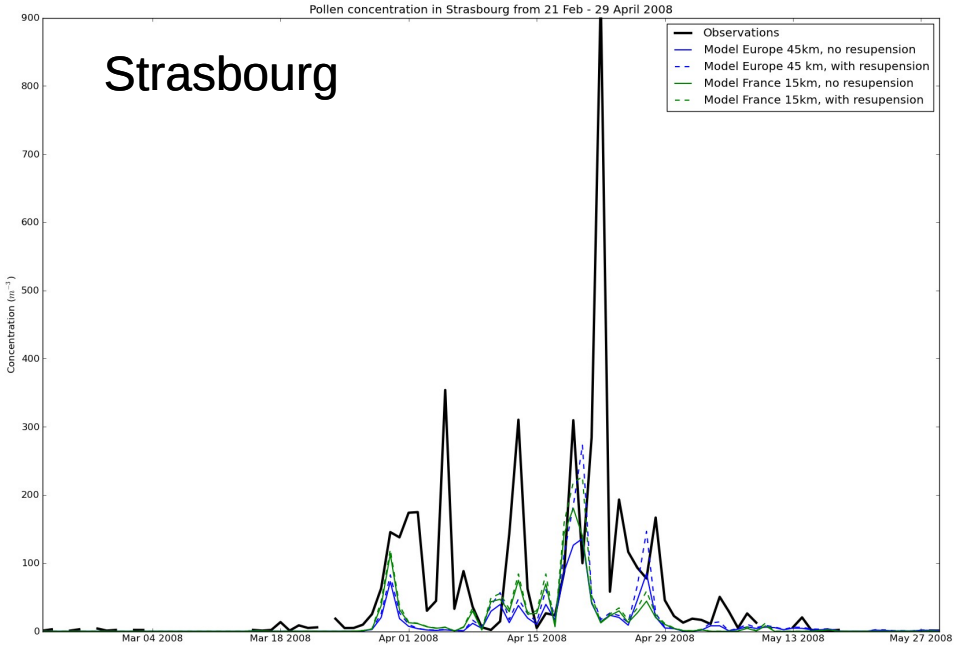
Birch pollen emission and concentration maximum
2008 flowering season

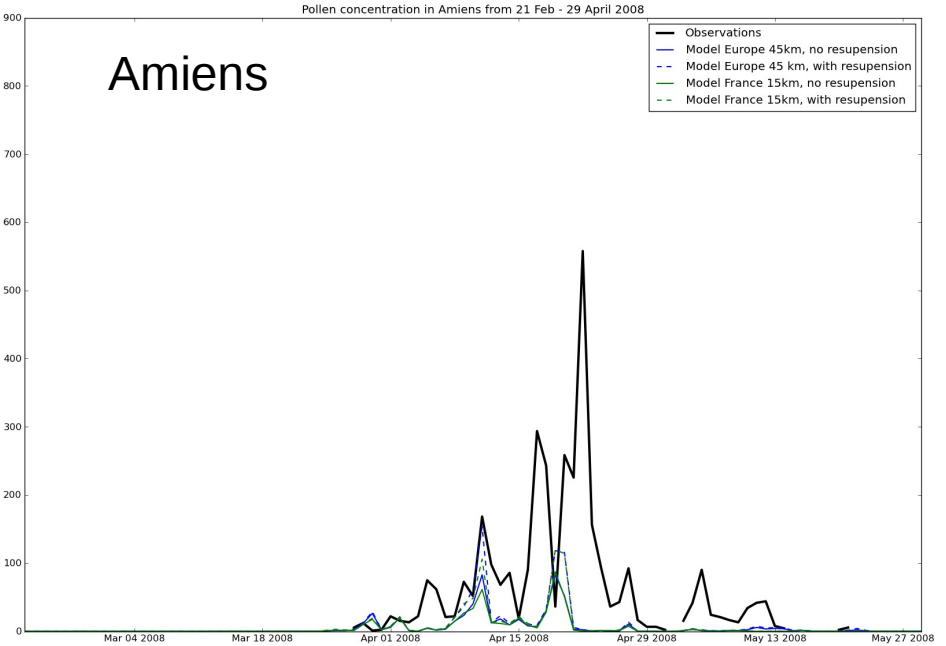


Simulated emisson maximum:
April 30, to the west of Bourges
(47.01N, 1.99E)

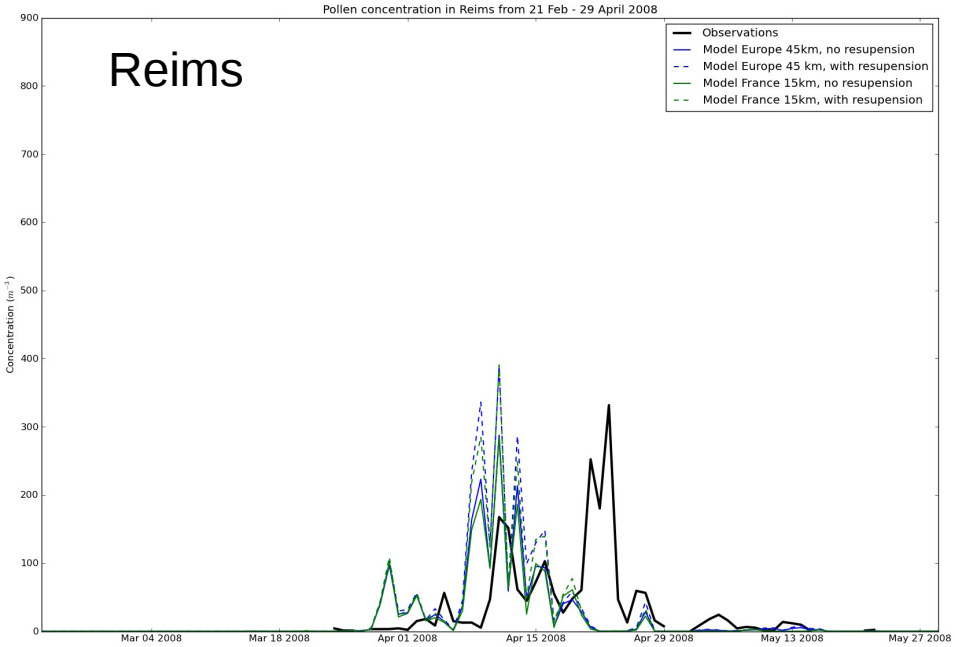
Max concentrations reach 12600 grains m^{-3} :
May 3 morning, south-west of Clermond-Ferand
(45.53N, 2.67E), i.e., 3 days after the emission max
and at about 175 km to the south-south-east

Birch pollen concentrations : Obs vs Model

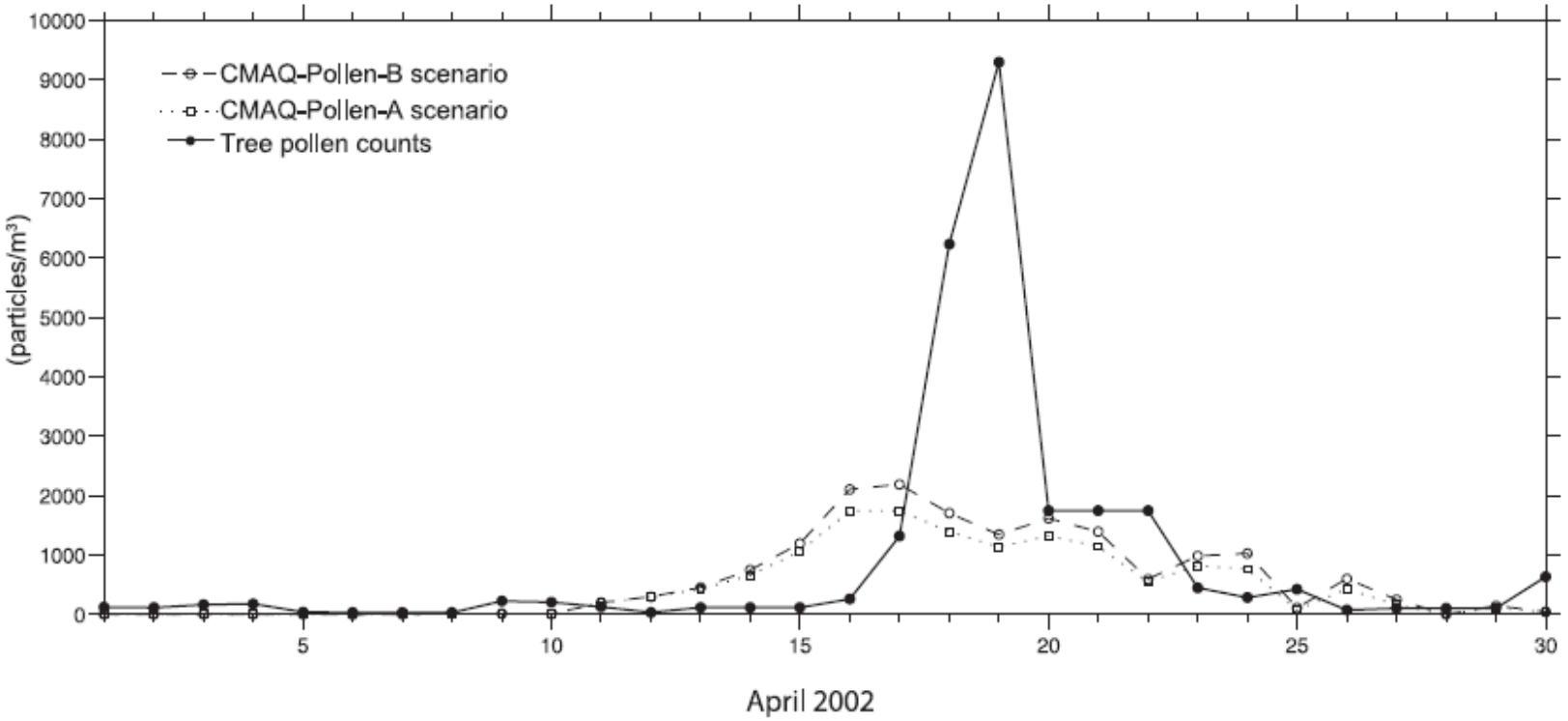




- General underestimation of *C*
- Resuspension can double *C* peaks
- Resolution and long-range transport contributions are of comparable magnitude



State of the art : CMAQ-Pollen
(Efstathiou et al, 2011)



Underestimation of pollen concentrations by the model

Some conclusions...

Although flowering season propagation follows southwest → northeast gradient, actual pollen emissions and concentrations show rather sporadic pattern

Simulated daily pollen concentrations vs observations are comparable to similar modeling studies (SILAM, MOCAGE, CMAQ). However a systematic statistical analysis of scores is needed

Long-range pollen transport, model resolution, and resuspension flux seem to be of comparable importance for the simulated peak concentrations

Further/current work

- Improve emissions ?
  - ➔ Comparison with CORINE/IFN-based birch forest map
  - ➔ Comparison with phenological model Chuine et al (2000)
- Evaluate the role of meteorological forcing
  - ➔ Sensitivity to meteorological forcing

➢ Inter-model comparison with the same meteorology and emission module (MACC 2 project)

➢ Ambrosia pollen modeling and climate change scenarios (ATOPICA project)