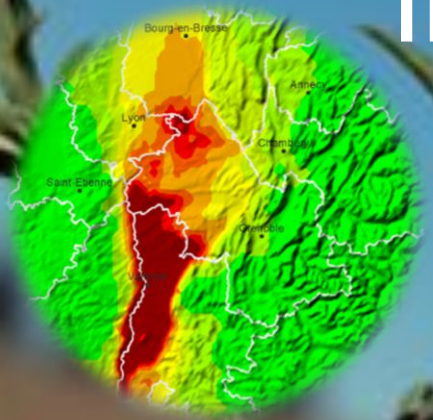
Modelling ragweed pollen in Rhône-Alpes (France)



IRC Conference, Lyon, March 28th 2012

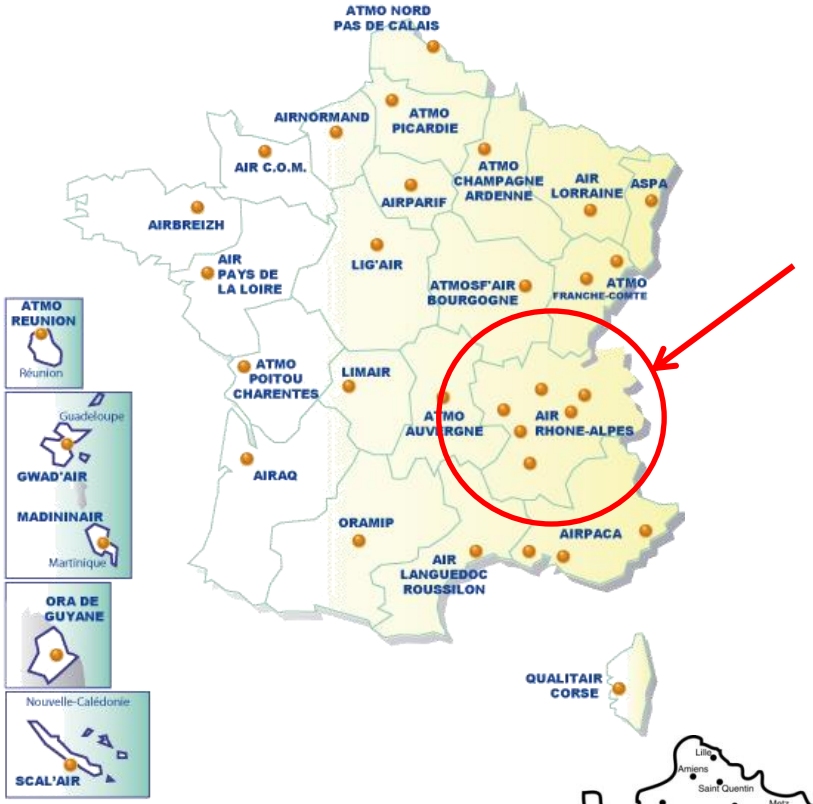
Project funded by:

E. Chaxel[1], C. Rieux[1], I. Rios[1], M. Thibaudon[2], G. Oliver[2]

[1] Air Rhône-Alpes, Bron (France)

[2] RNSA, Brussieu (France)

Monitoring air quality and pollen in France and in Rhône-Alpes region



Air Rhône-Alpes is member of

RÉSEAU NATIONAL DE SURVEILLANCE AÉROBIOLOGIQUE **RNSA**

Air Rhône-Alpes is an *Association Agréée pour la Surveillance de la Qualité de l'Air (AASQAs)* in Federation ATMO France

AASQAs main objectives are **monitoring** air quality and **informing** at regional scale: individuals, industries and local authorities

Airborne pollutants :

O_3, NO_2, SO_2, PM, HAP, VOC…

Activities in the framework of RNSA

- 2 pollen monitoring stations in Grenoble and Roussillon
- Pollen modelling project since 2007

Modelling ragweed is still challenging…

Modelling pollen grains (emission and transport) is extensively applied for other species like trees (birch) but modelling these processes for ragweed is still challenging…

Modelling ragweed in Rhône-Alpes: a short story

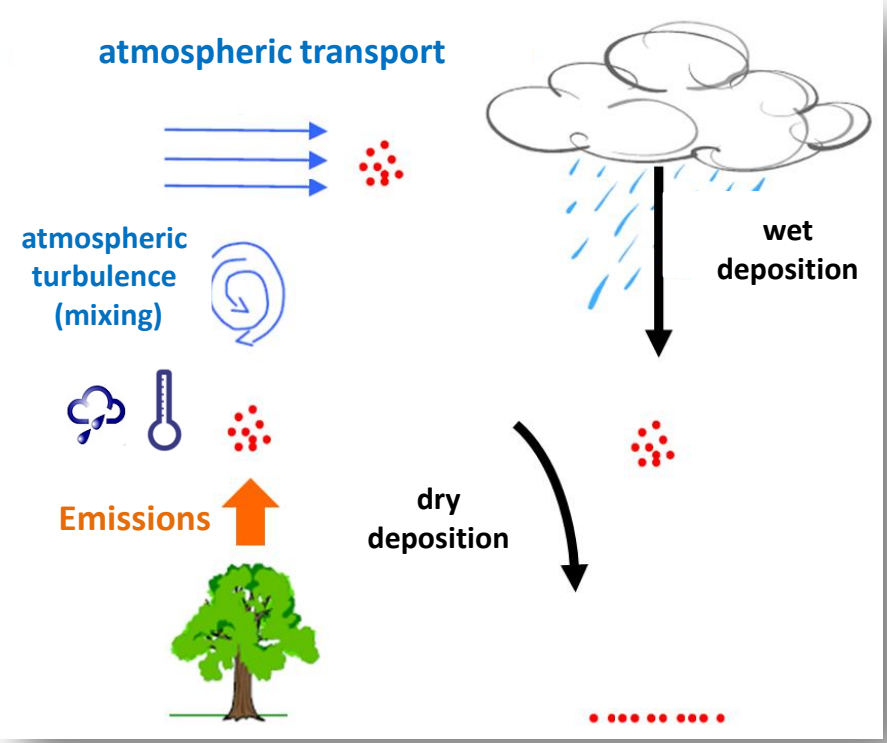
- 2007-2008: spatial inventory of ragweed presence (Camille Rieux)[1]
- 2010-2012:
  - update of the inventory for 2009
  - Summer 2011: forecast of pollen concentration and an associated "*allergenic risk*"
  - Running : impacts of ragweed struggle actions on atmospheric pollen concentrations

[1] Rieux, C. & al. Cartographie de l'ambroisie : première étape de la modélisation pollinique. http://www.ambroisie.info/docs/colloque-2008/2-Rieux.pdf

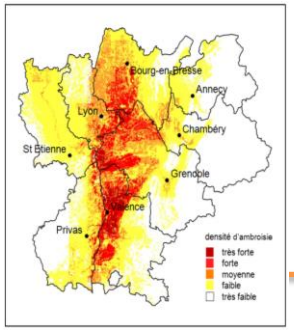
Modelling pollen in atmosphere

Different mechanisms control airborne pollen concentrations

- **Localization of sources**
  - Human activities (dispersion of seeds/control)
  - Climate change
- **Emissions to atmosphere**
  - Meteorology: temperature, humidity, precipitation
  - Climate change
- **Atmospheric transport, mixing & deposition**
  - Meteorology: wind, turbulence, precipitation

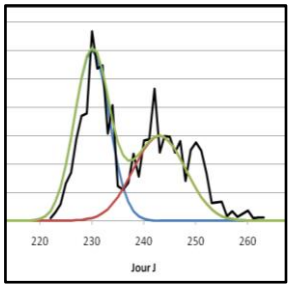


Modelling system overview



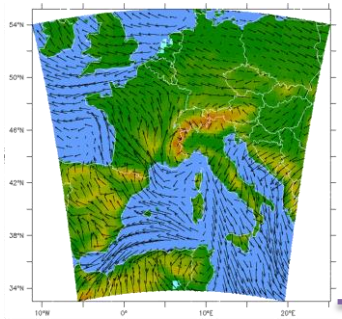
Localization of sources

Plants inventory



Emissions

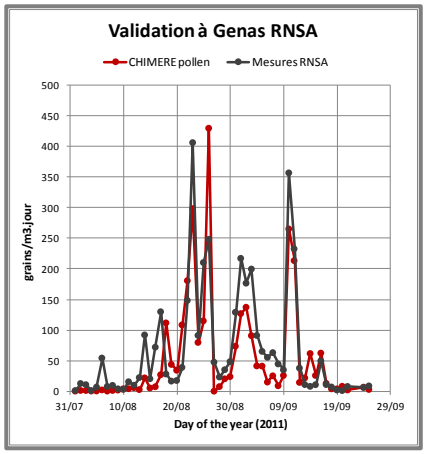
1. Phenological model
2. Liberation model



Meteorology

WRF Model

(wind, temperature, turbulence, humidity, precipitation, soil parameters)

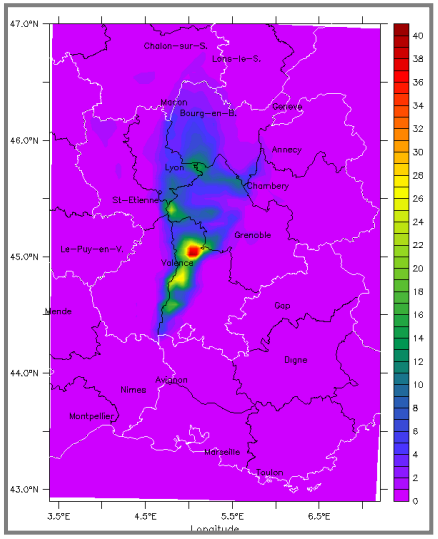


Time period:

- hourly
- 2-hourly
- daily

time series at stations (validation)

maps of concentration of pollen grains



Applications:

time

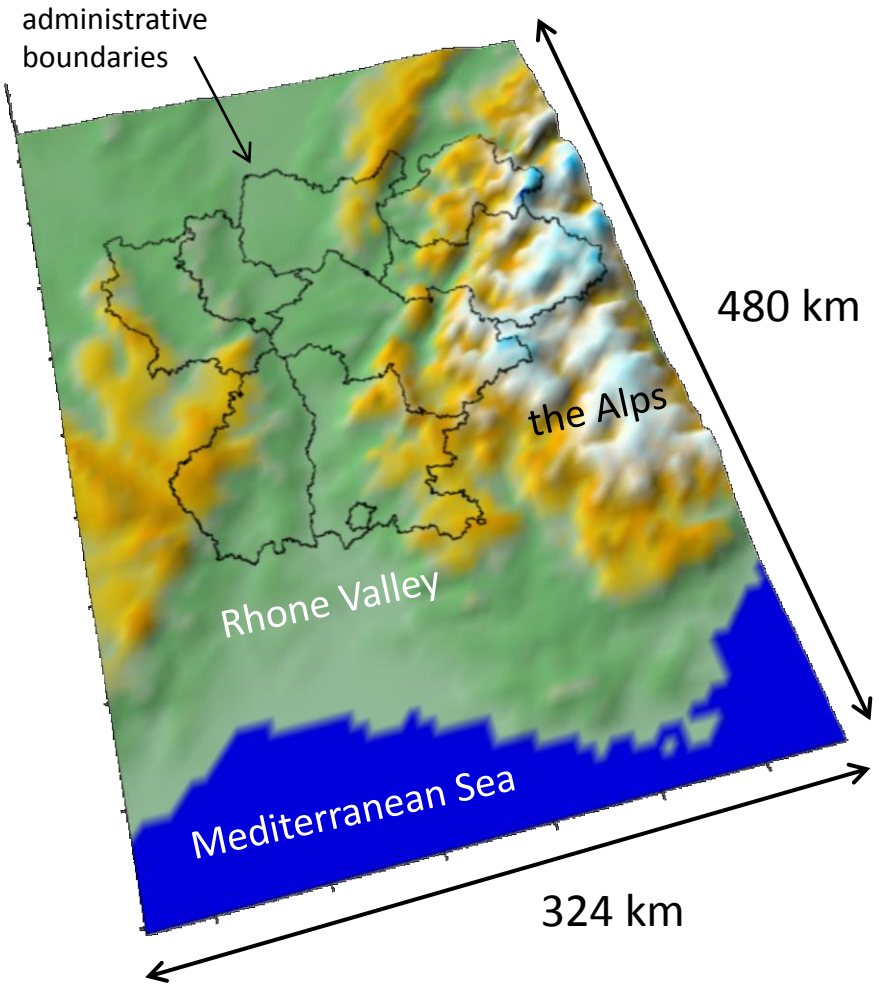
Analysis
Past

Forecast
Next few days

Scenario
Next years

Modelling ragweed pollen project: MODPOL program

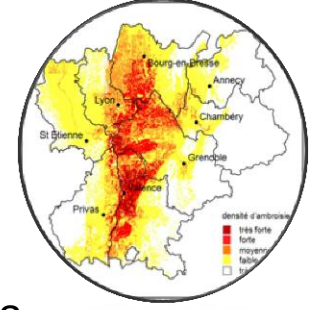
Partners: Air Rhône-Alpes, RNSA, ARS Rhône-Alpes & Région Rhône-Alpes



Domain for modelling :

- **Horizontal resolution**: 3 km
- **Vertical resolution:** 40 m – 1000 m
- **Reference year for meteorology**: 2011

Ambrosia artemisiifolia L. inventory
spatial probability of presence Φ



The first part of the modelling chain is based on work of Rieux et al., 2008.

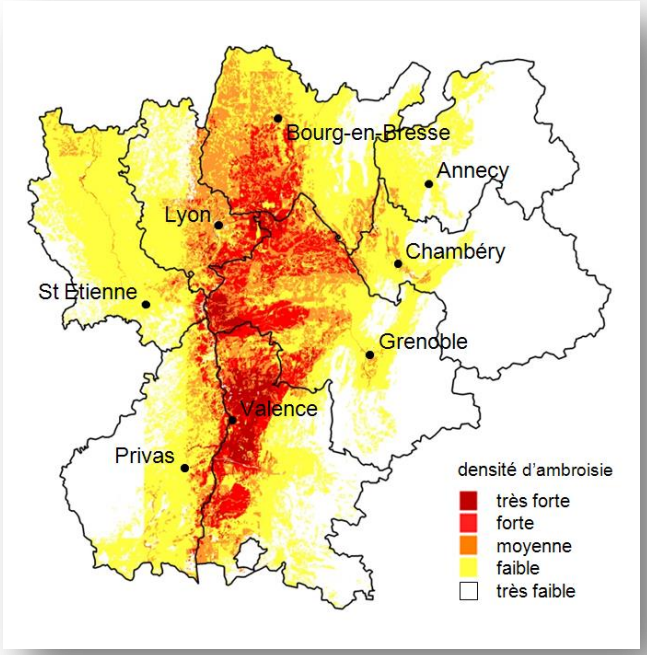
Methodology: geostatistical exploitation of botanical inventories data (reports > 4500 ; 2003-2007) , topography and land use data (Corine Land Cover 2000)

Result:
map of probability Φ of ragweed presence

Resolution: 1 x 1 km^2

Probability range: 0-100%

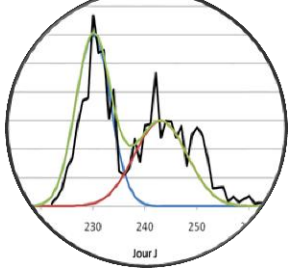
Maximum surface emission:
1.5×10^{14} $grains.km^{-2}.day^{-1}$



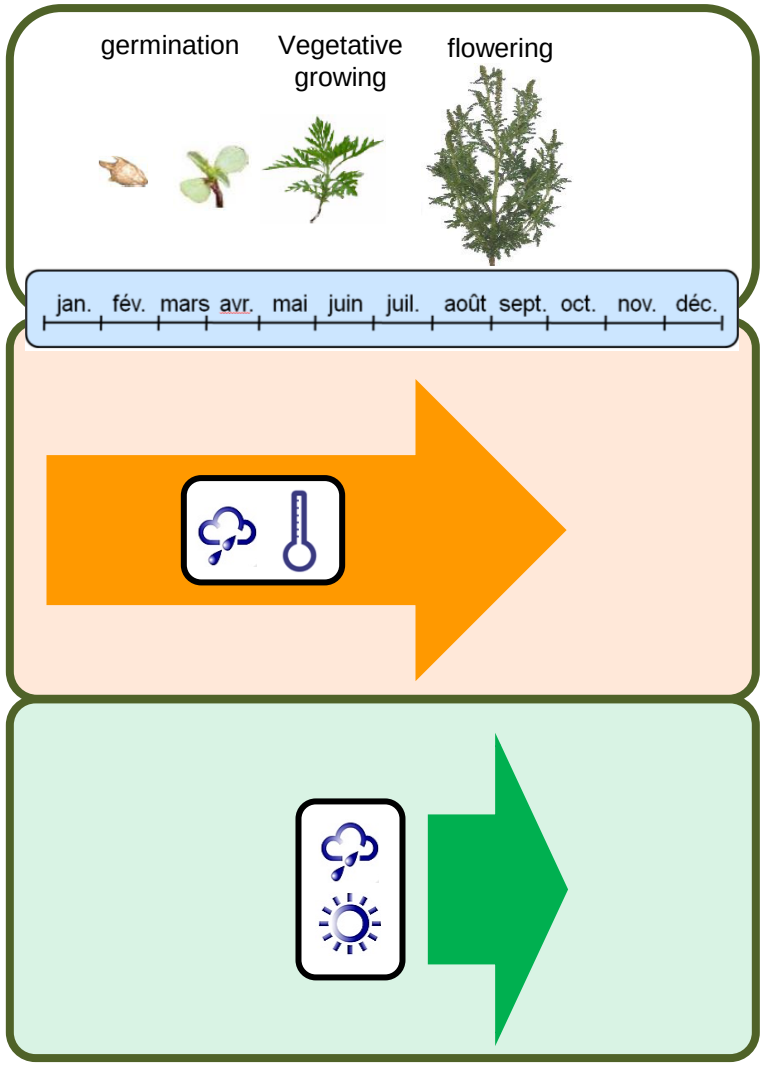
Rieux et al., 2008 – Colloque ambroisie 2008

First spatial inventory available for 2003-2007. Additional data used for 2009 map.

[1] Rieux, C. & al. Cartographie de l'ambroisie : première étape de la modélisation pollinique.
http://www.ambroisie.info/docs/colloque-2008/2-Rieux.pdf



Emissions: biological and meteorological processes

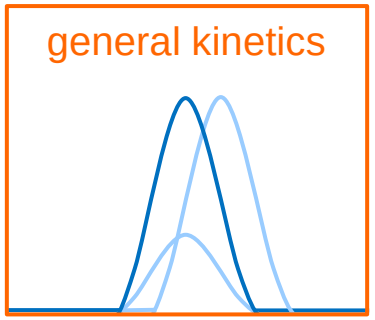


Emission of pollen (in grains/h/m^2) for an hour *h* of a given day *J*:

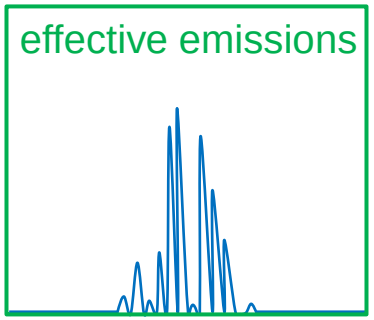
(1) $E(J,h) = \Phi \times f_{pheno}(J) \times f_{liberation}(h) \times E_{total}$

(2) $f_{liberation}(h) = f_{bio}(h) \times f_{meteo}(u^*, w)$

atmospheric turbulence (u^*) and soil moisture (w)

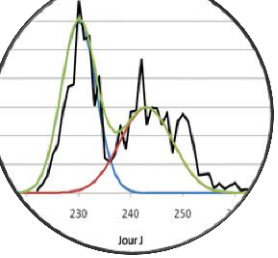


Static model (Gauss function)
Empirical formulation

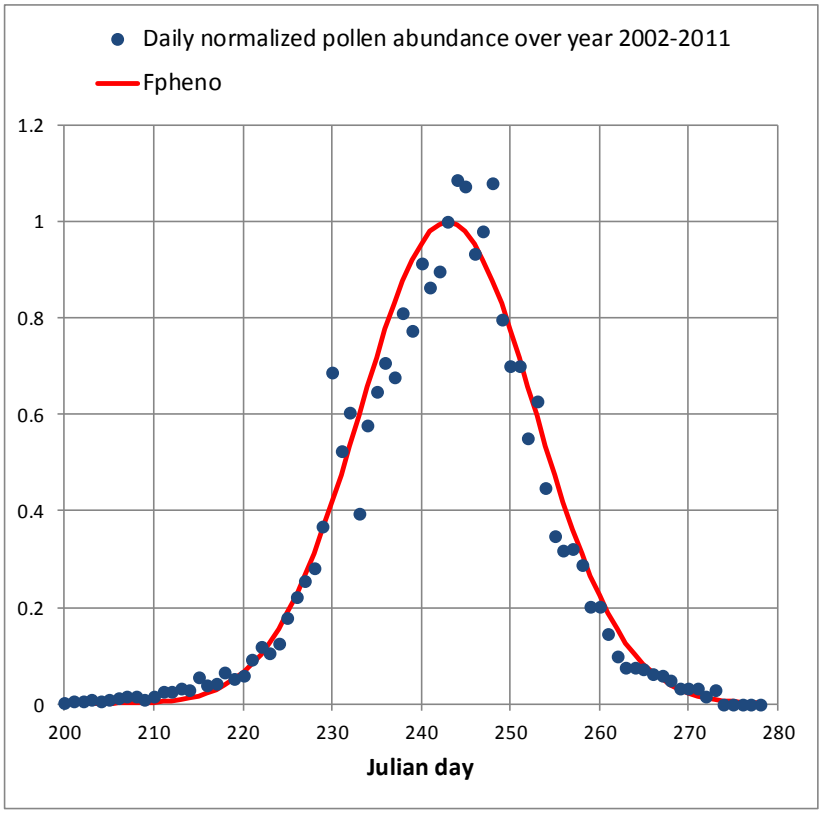


Biological model (empirical)

Meteorological emissive model



Empirical phenological model



Fitting of Gauss model (1) in Roussillon for years 2002-2011:
each point is the 2002-2011 mean concentration for a given Julian day.
Fitted parameters: J_{half} = 243 (August 31st), J_{start}-J_{end} = 59, α = 20

Despite some efforts, no mechanistic model was able to reproduce day D emissions.

An empirical formulation based on historical data for years 2002-2011 at RNSA station Roussillon is used.

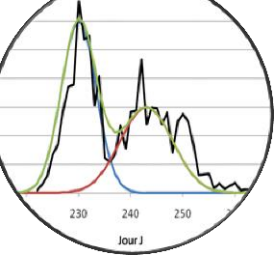
Emission factor f_{pheno} defined by Gauss function:

$$(1)\quad f_{pheno}(J) = e^{-\alpha x^2}$$

$$(2)\quad x = \frac{J - J_{half}}{J_{end} - J_{start}}$$

$$(3)\quad J_{half} = \frac{J_{start} + J_{end}}{2}$$

Same model is applied for the entire model domain
→ hypothesis: meteorology/climate change do not impact phenology

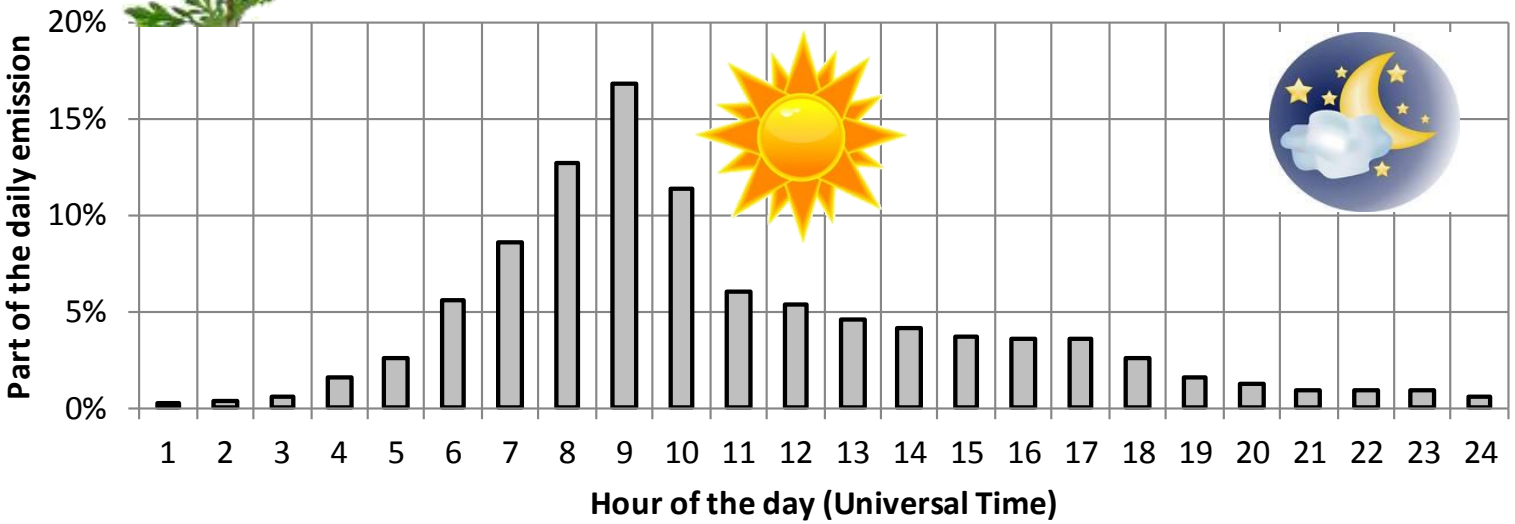


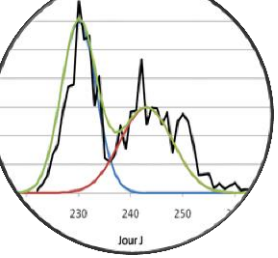
Empirical liberation model: biological part

Because biological processes, ragweed pollen is mainly emitted by the plant during the morning. Processes are complex:
a simple liberation model is calculated using statistical data at a single station : Roussillon

Data for model calibration :

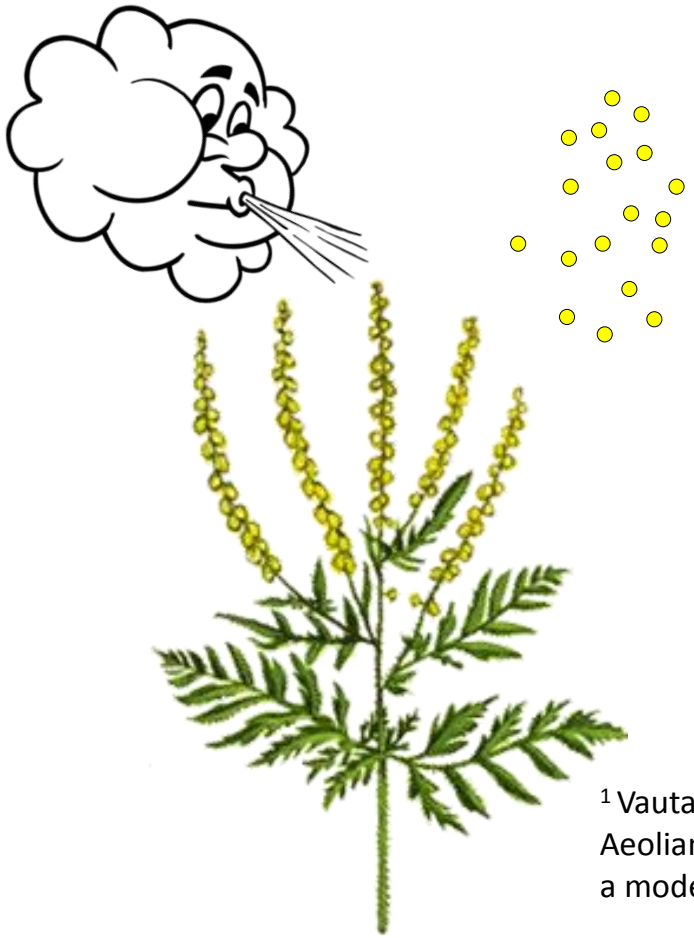
- 2-hour concentrations of pollen grains in 2007
- Height of boundary layer calculated by meteorological model (WRF) for Roussillon station





Empirical liberation model: meteorological part

Atmospheric turbulence and canopy moisture control emission of available pollen grains by a plant. This mechanism is called entrainment.



The model developed for dust in CHIMERE (Vautard et al., 2005)[1] is adapted for pollen grains.

This model is based on atmospheric turbulence (u^*) and soil moisture (w).

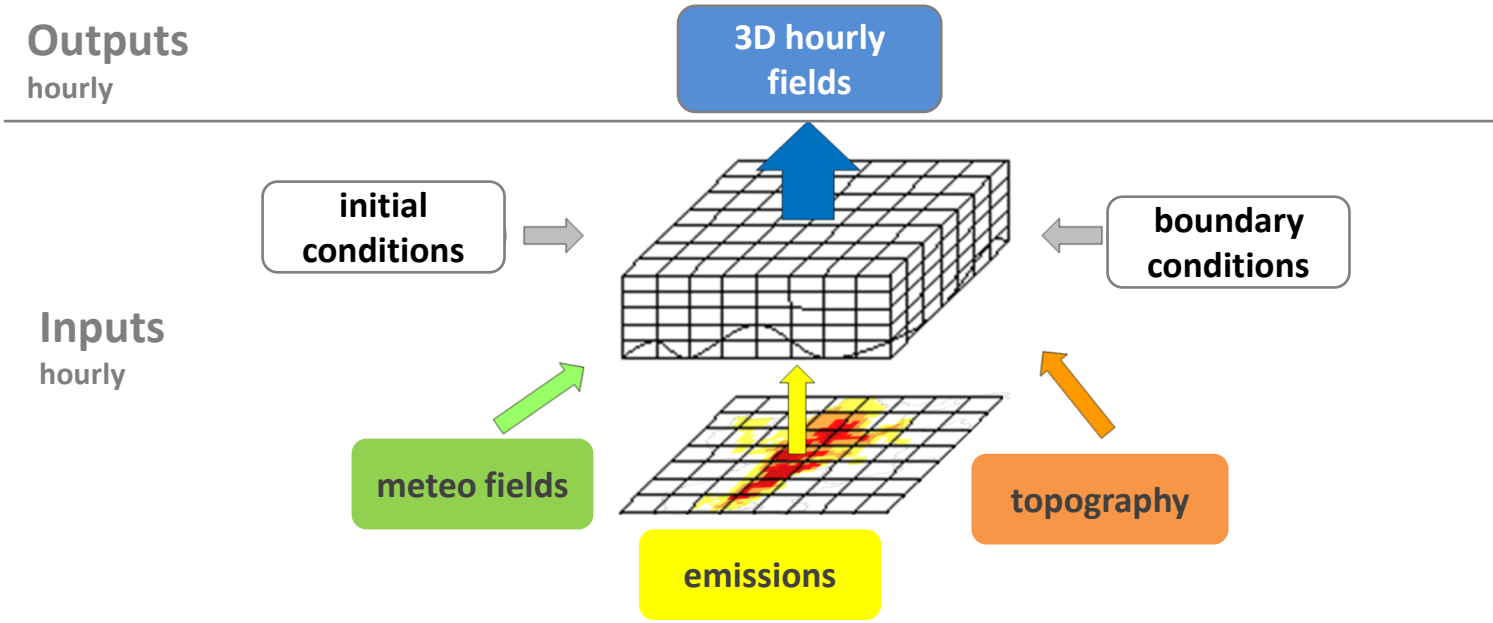
[1] Vautard, R., Bessagnet, B., Chin, M., & Menut, L. (2005). On the contribution of natural Aeolian sources to particulate matter concentrations in Europe: testing hypotheses with a modelling approach. *Atmospheric Environment , 39* (18), 3291-3303.

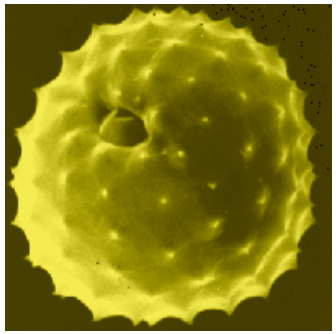
Chemistry Transport Model CHIMERE

The Chemistry Transport Model (CTM) CHIMERE is developed at IPSL (Paris, France).

Model solves finite difference equations for transport and dispersion on 3D mesh with hourly inputs/outputs. Aerosols and chemical transformation are modeled.

CHIMERE is operationally used by Air Rhône-Alpes (ozone, aerosols species, etc.).





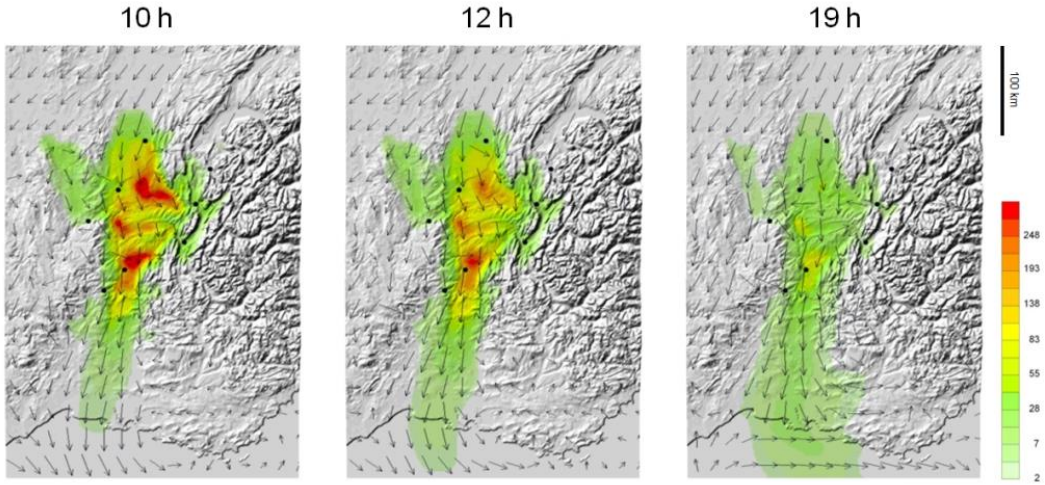
CHIMERE is modified to take into account ragweed pollen:
a species “pollen grains” (diameter 20 µm) is created, emissions implemented

First test: Episode of long-range transport in 2007

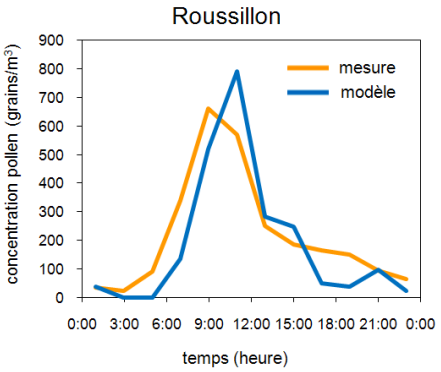
Simulation of several days for season 2007 of Ambroisia

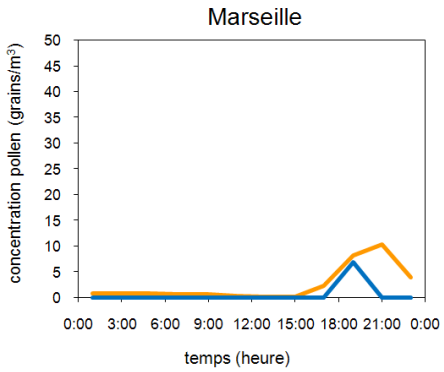
Highlighting long-range transport

Simulation :
Concentrations at ground level
September 8th

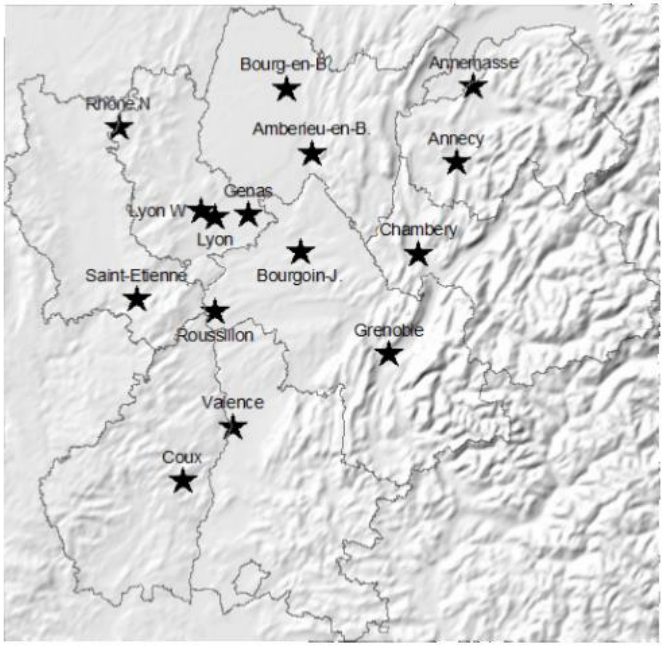


Model + measurements timeseries
September 8th





Model validation for year 2011

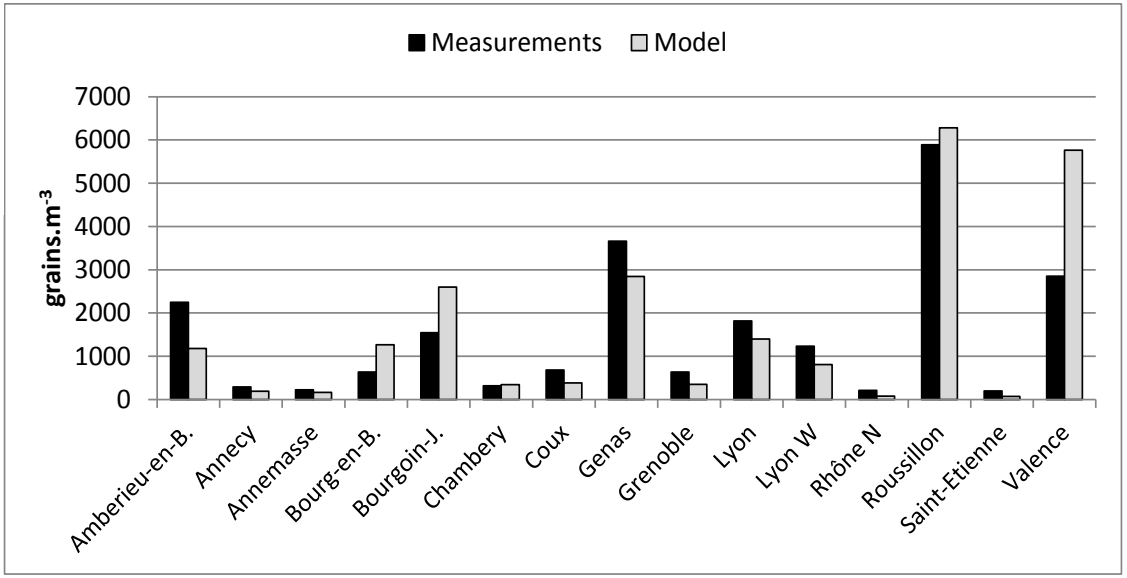


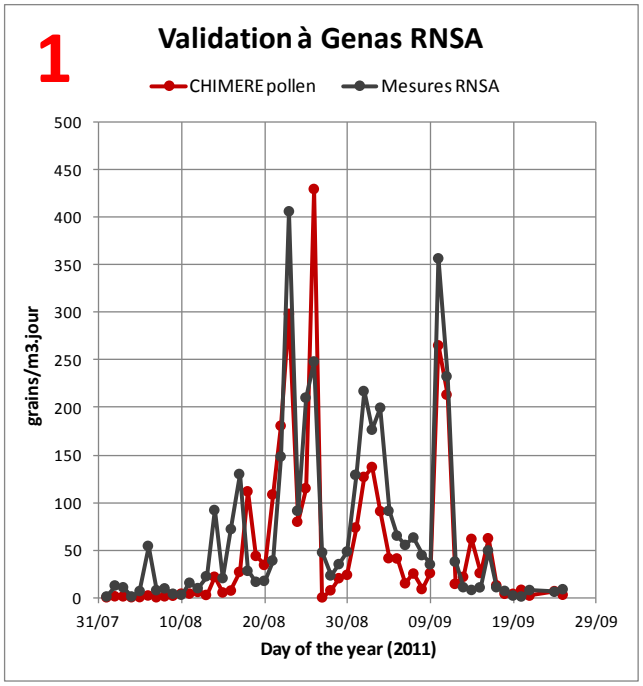
Concentrations from model are validated using measurements at 15 sites of Rhône-Alpes

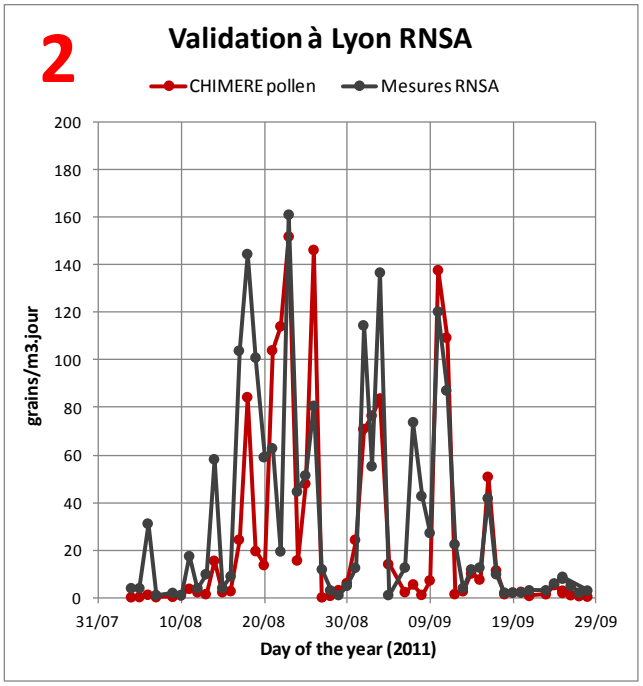
CHIMERE model performs well except in Valence

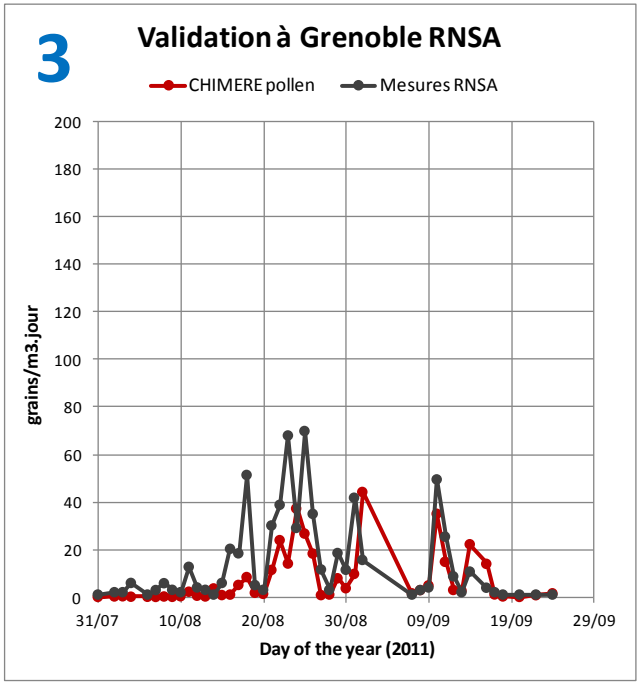
Total ragweed pollen abundance for the whole season 2011 at 15 sites of region Rhône-Alpes

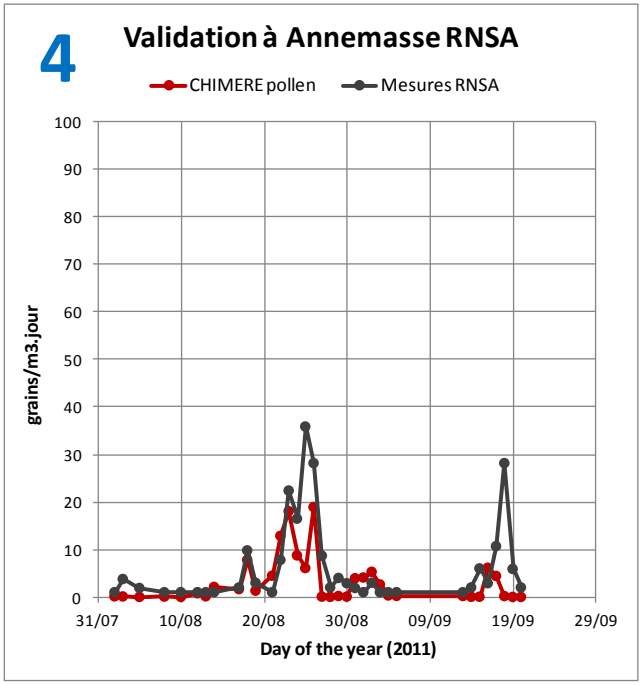
Period of data in 2011:
07/30 - 09/26 (59 days)
Model: CHIMERE CTM
Measurements: RNSA data







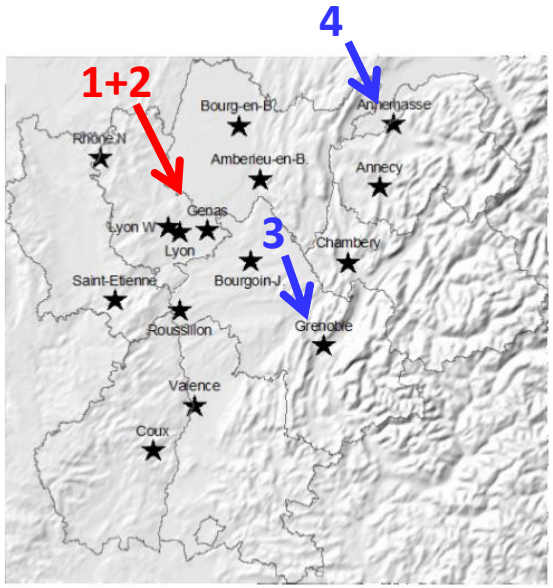




Time series of daily abundances of ragweed pollen

grey: measured at RNSA sites
red: modeled with CHIMERE

Sites on figures:
1, 2 : ragweed-infested zones
3, 4 : poor-ragweed zones



Validation statistics for 15 RNSA stations

Basic statistics are calculated with daily pollen abundance for each site where data are available for a given day of the period 07/30 - 09/26 (59 days) in 2011.

Summary of statistics is given in table:

Site	Data available	Annual observed abundance	Annual modelled abundance	Mean Normalized Bias	Mean Bias	Mean Error	Linear Reg. A	Linear Reg. B	Correlation (r2)	RMSE
Amberieu-en-B.	54	2250	1123	-1.01	-20.86	26.59	0.58	-3.34	0.55	34.63
Annecy	33	291	163	-0.81	-3.87	6.42	0.37	1.66	0.4	11.05
Annemasse	35	223	111	-0.86	-3.2	4.46	0.32	1.11	0.35	7.84
Bourg-en-B.	47	634	1195	0.04	11.94	21.38	0.57	17.73	0.13	40.77
Bourgoin-J.	41	1546	1572	-0.45	0.65	29.39	0.75	10.22	0.3	52.55
Chambery	36	316	309	-0.51	-0.22	6.1	0.59	3.39	0.45	9.41
Coux	47	686	358	-0.59	-6.97	10.35	0.2	4.78	0.17	15.57
Genas	**54**	**3659**	**2830**	**-0.52**	**-15.34**	**34.47**	**0.79**	**-1.37**	**0.72**	**50.86**
Grenoble	46	638	329	-0.89	-6.71	9.47	0.38	1.91	0.39	15.53
Lyon	53	1816	1395	-0.65	-7.94	19.32	0.74	0.92	0.56	31.2
Lyon W	47	1233	658	-0.8	-12.24	16.55	0.49	1.1	0.55	25
Rhône N	34	213	72	-1.35	-4.14	4.99	0.31	0.18	0.27	8.38
Roussillon	**54**	**5890**	**6242**	**-0.27**	**6.53**	**82.17**	**0.81**	**27.6**	**0.23**	**132.32**
Saint-Etienne	48	202	72	-1.15	-2.71	3.58	0.06	1.23	0.01	5.33
Valence	**58**	**2853**	**5741**	**0.4**	**49.79**	**64.89**	**1.02**	**49**	**0.33**	**99.2**

Some results…

- Regarding total annual abundance, CHIMERE model performs well at sites with high annual abundance (> 1000 grains.m^{-3}.year^{-1}) except in Valence site.
- The bias of the model is negative: CHIMERE model underestimates pollen abundance
- Regarding temporal correlation, some sites show disagreement (ex: Valence and Roussillon).
- Results of CHIMERE model at site Genas are very encouraging since Genas site recorded highest daily abundance in 2011.

Calculating a « potential allergenic risk »

Pollen concentration is not easily understandable by population.

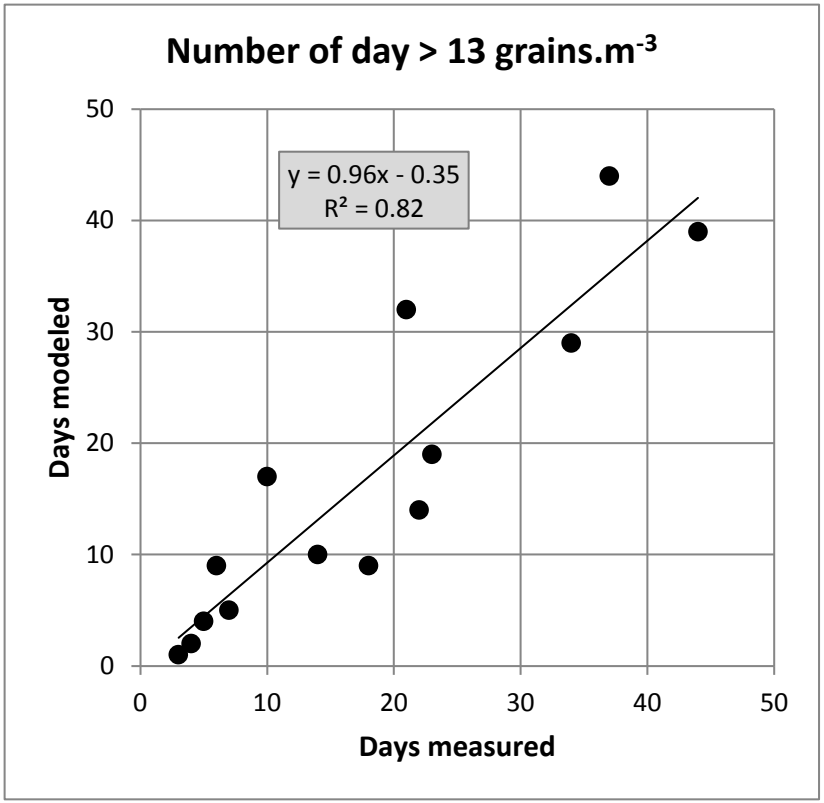
The calculation of an allergenic risk from concentrations of pollen is necessary but is delicate: a “potential allergenic risk” is proposed.

Atmospheric concentration (daily abundance) of pollen are converted into a risk from 0 (none) to 5 (very high).

Table: correspondence between a daily abundances and a daily potential allergenic risk

Allergenic risk	Color	Daily abundance (grains.m^{-3})
None	0	0
Very low	1	1 à 2
Low	2	3 à 6
Middle	3	6 à 12
High	4	13 à 30
Very High	5	≥ 30

Model is validated regarding the risk (scatter plot).

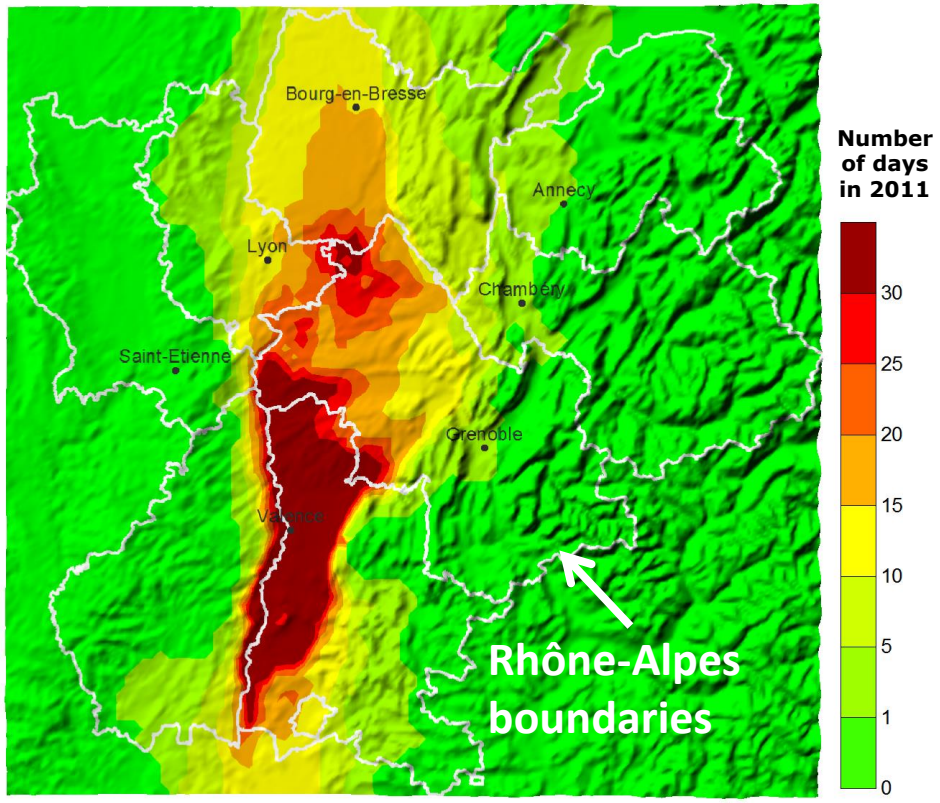


Scatterplot:
Number of days in 2011 with risks 4 or 5 at RNSA stations versus number of days calculated with CHIMERE model

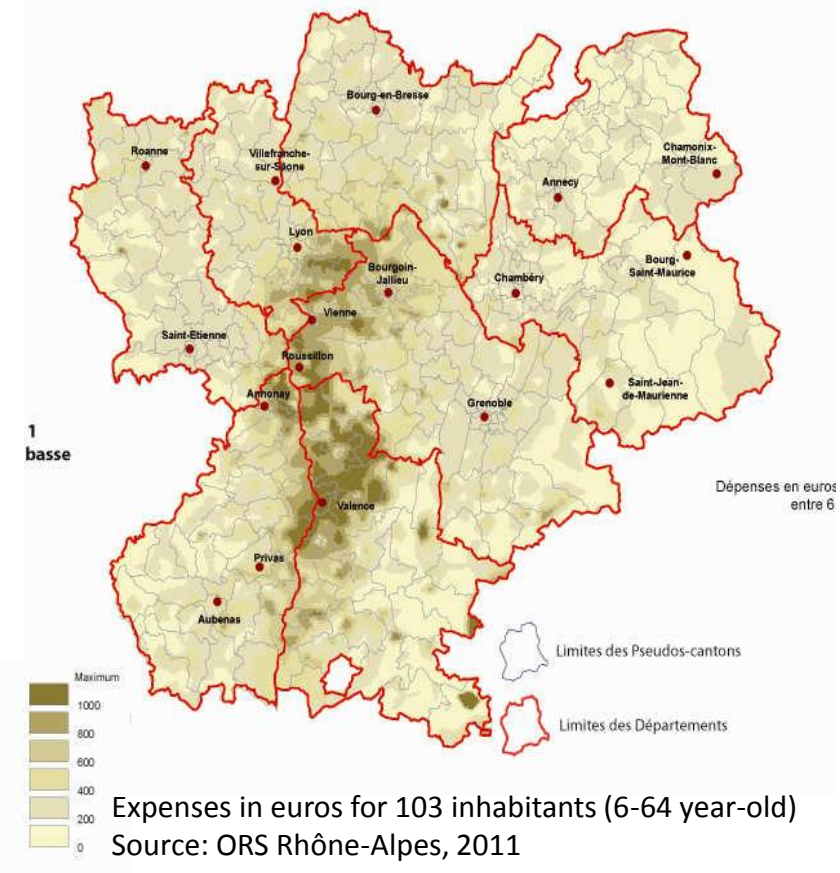
Validation of potential allergenic risk using anti-allergy treatments

Maps of number of days with a “very high” allergenic risk and map of communal expenditure for treating ragweed-allergy in 2009 (ORS, 2011)

CHIMERE results: map of number of days in 2011 with a « very high » potential allergenic risk (daily pollen abundance ≥ 30 grains.m^{-3})



Correlation between risk and expenses: $r^2 = 0.56$ for communes > 2000 inhab



Expenses in euros for 103 inhabitants (6-64 year-old)
Source: ORS Rhône-Alpes, 2011

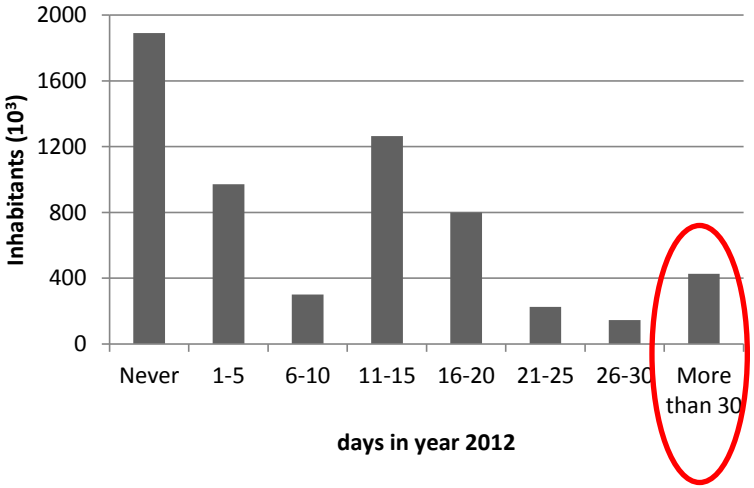
Population exposure to allergenic risk due to ragweed pollen in region Rhône-Alpes in 2011

In Rhône-Alpes, 400 000 people breathe more than 30 grains.m^{-3} more than 30 days a year

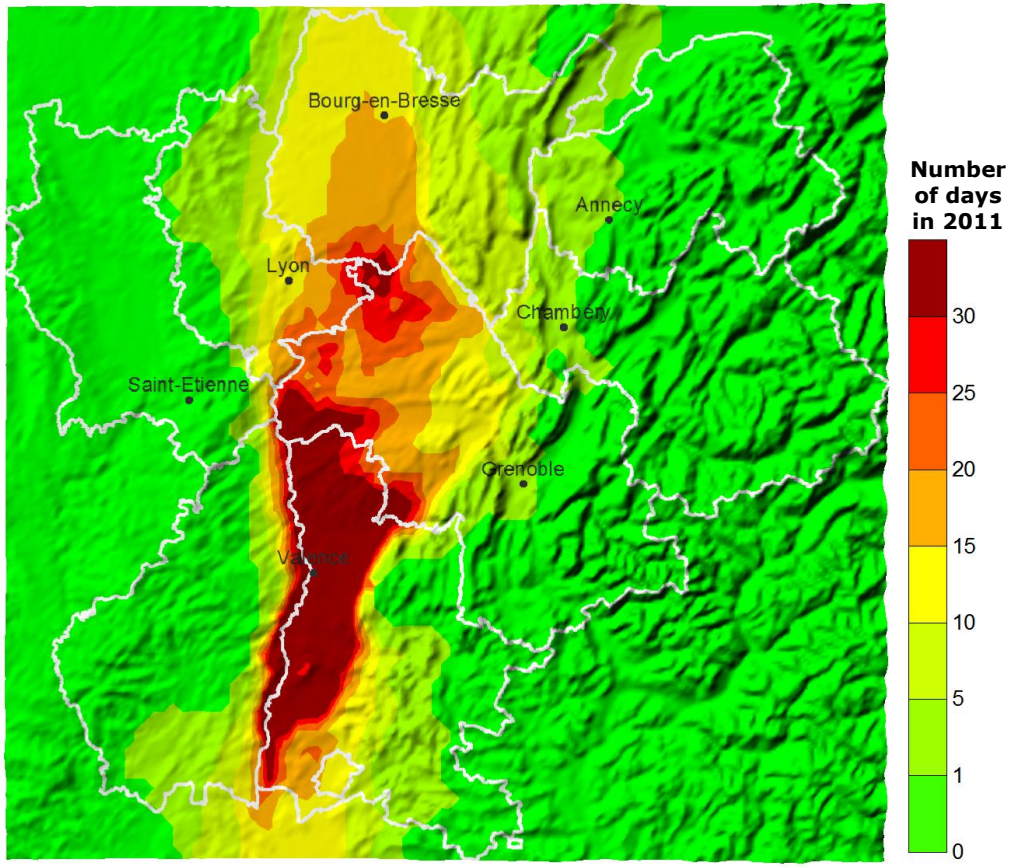
Correspondence between daily abundances and potential allergenic risk

Allergenic risk	Color	Daily abundance (grains.m^{-3})
None	0	0
Very low	1	1 à 2
Low	2	3 à 6
Middle	3	6 à 12
High	4	13 à 30
Very High	5	≥ 30

Population exposed to a « very High » risk (demography: INSEE, 2006)



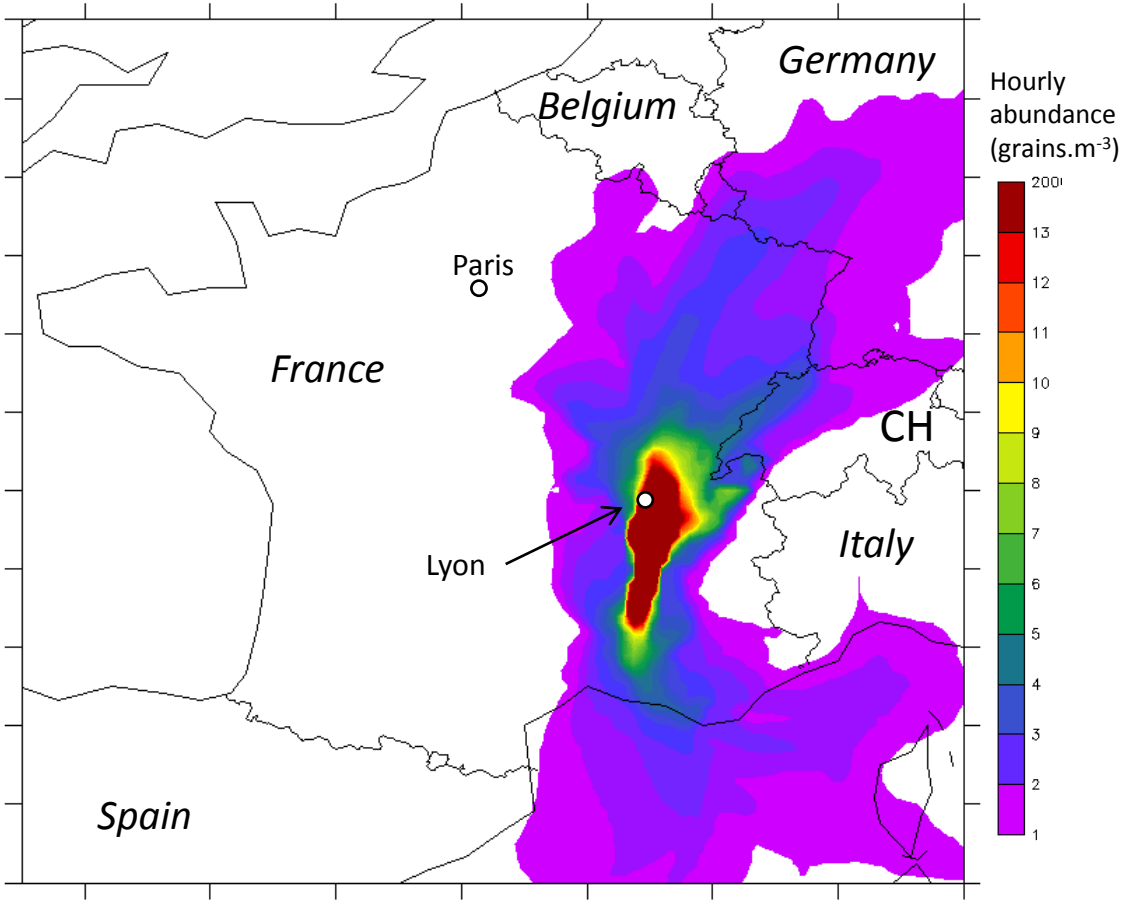
CHIMERE results: map of number of days in 2011 with a « very high » potential allergenic risk (daily pollen abundance ≥ 30 grains.m^{-3})



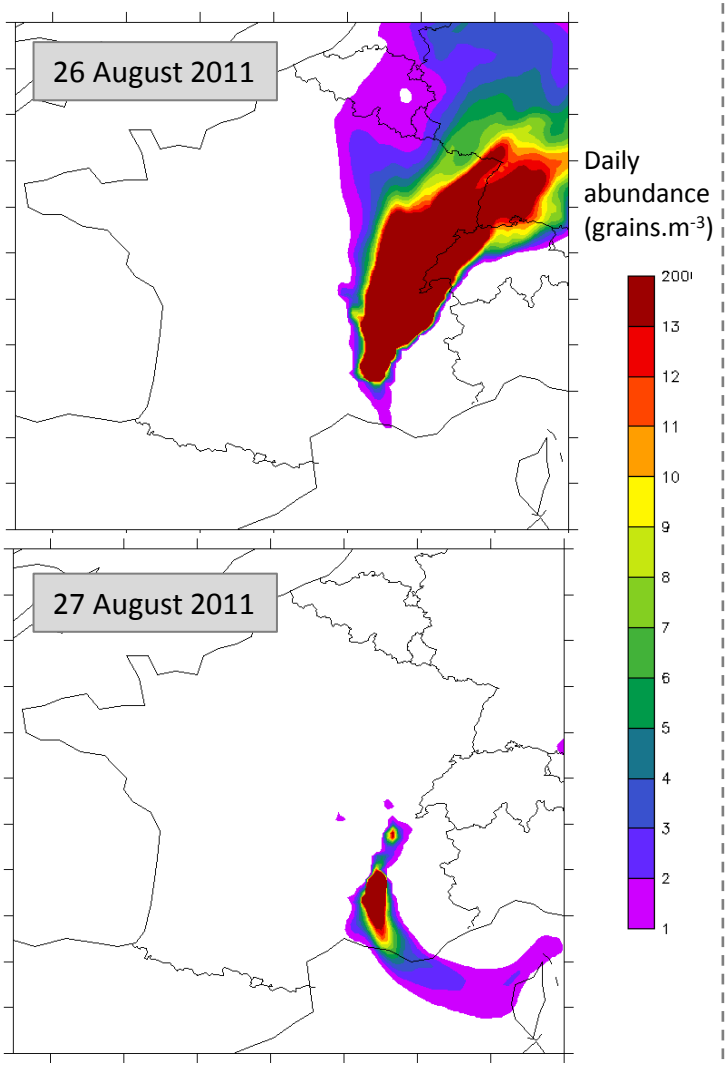
Continental transport of ragweed pollen

Atmosphere has no boundaries…

Max. hourly abundance of pollen grains emitted from Rhône-Alpes in 2011



Daily abundance of pollen grains emitted from Rhône-Alpes on 08/26 and 08/27



Conclusion & perspectives

Conclusion

- Air Rhône-Alpes developed a comprehensive methodology of pollen modelling which has been applied and validated for ragweed on year 2011.
- A mechanistic phenological model based on meteorology did not give good results for ragweed: a empirical model has been used. A liberation model taking into account turbulence and soil moisture is used.
- A 2011 map of "*potential allergenic risk*" caused by ragweed pollen is available for Rhône-Alpes region. Population exposure to frequent high concentrations is highlighted.

Perspectives

- Emission scenarios will be tested in 2012 to complete model development.
- Looking for an low-cost method for updating plant inventory every year: plant inventory is the key part for modelling airborne pollen.
- Transport of ragweed pollen at continental scale needs further investigation: publication in preparation in 2012.

Thank you for your attention

http://www.air-rhonealpes.fr