Echanges biosphère-atmosphère : flux de matière et transport turbulent

Yves Brunet

MicrobAERO 2009

Narbonne, 6-8 octobre 2009

Echanges biosphère-atmosphère :
flux de matière et transport turbulent

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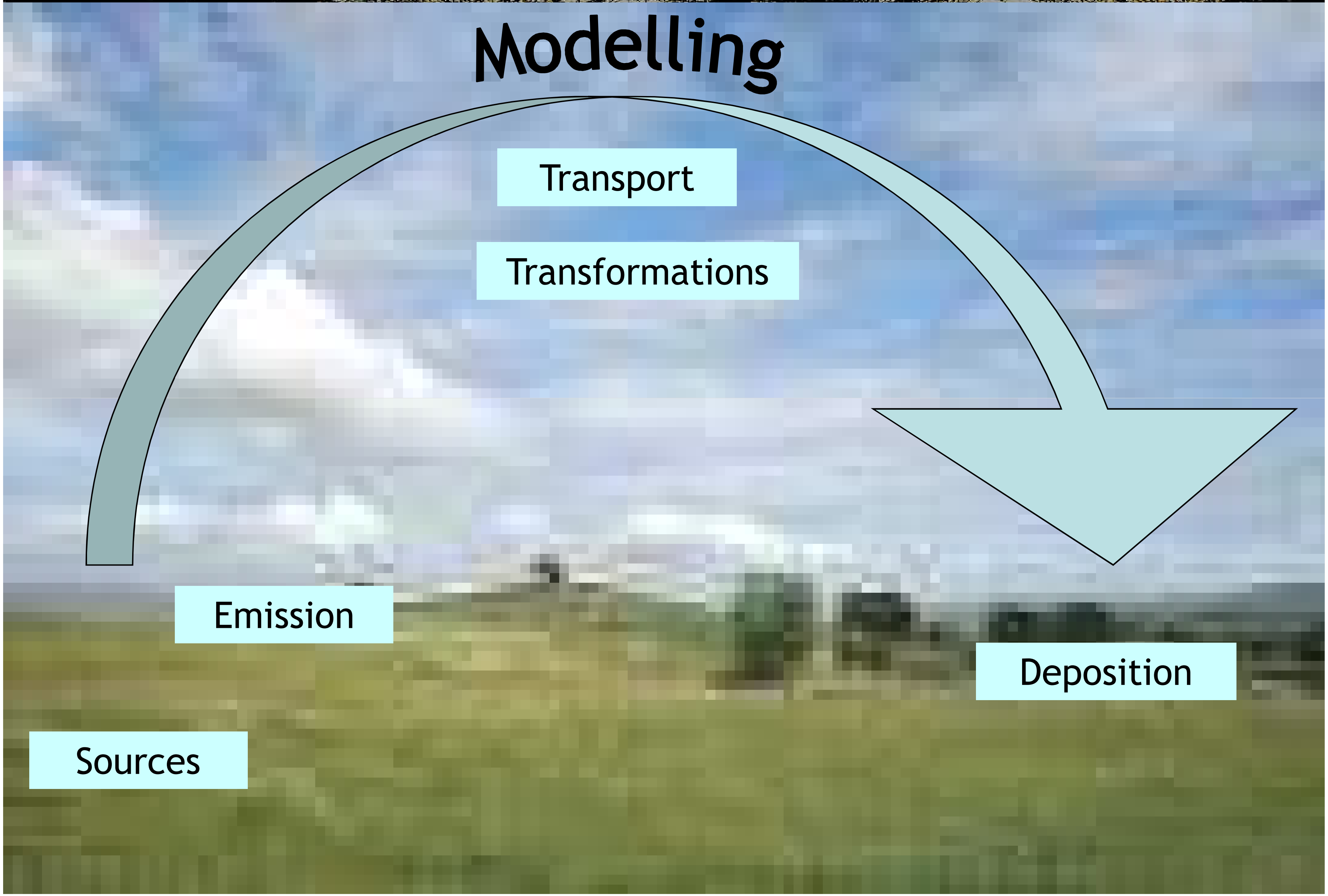
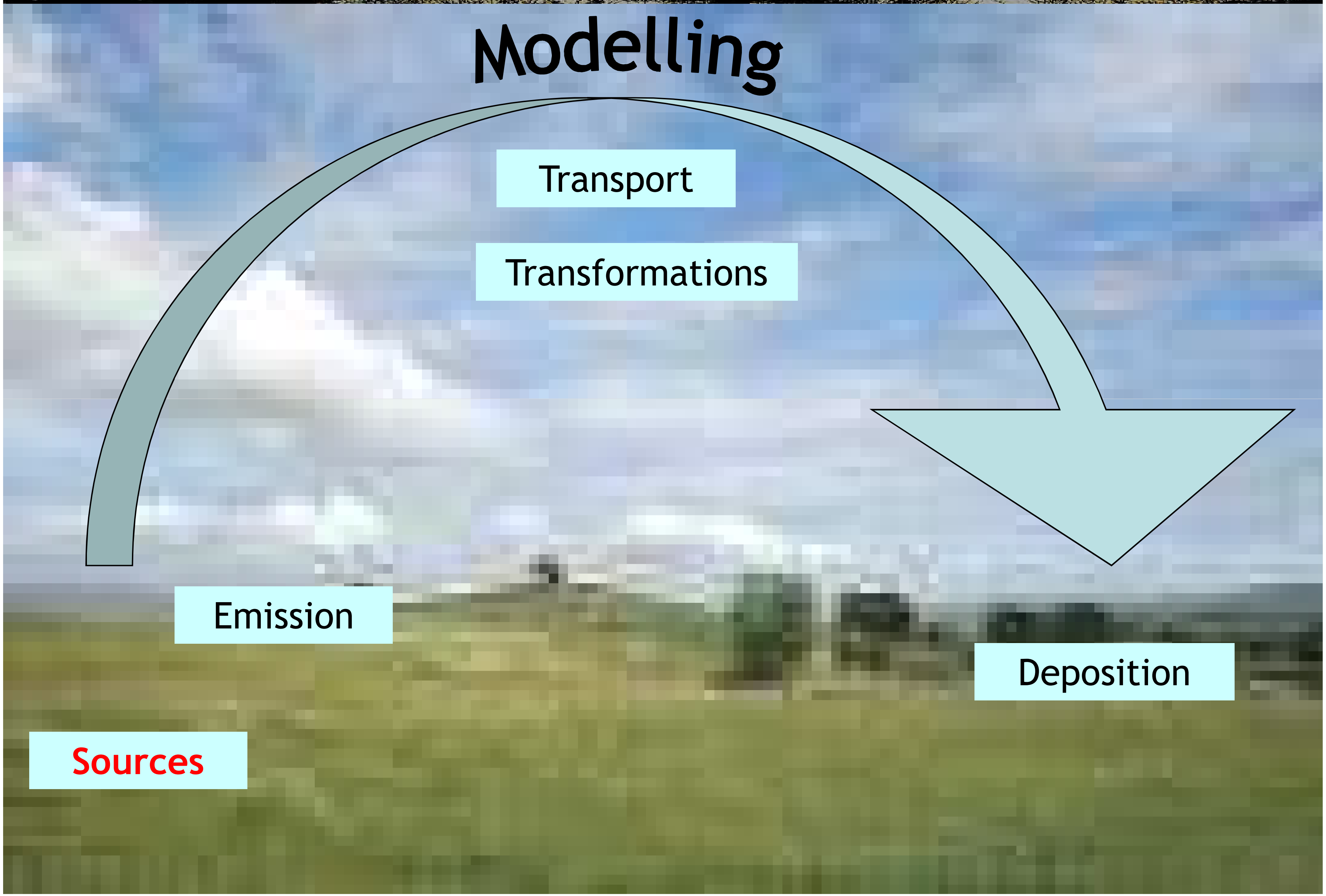
Inra, Ephyse, Bordeaux

ALIMENTATION
AGRICULTURE
ENVIRONNEMENT

Modelling transport processes

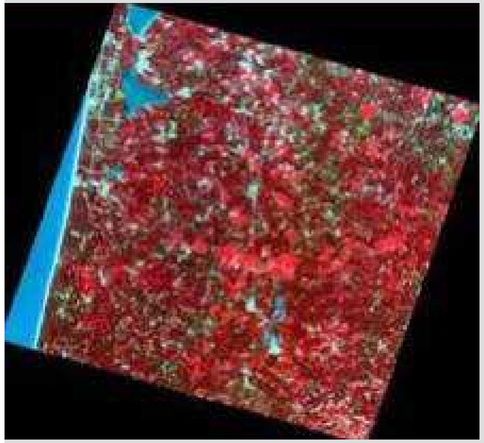


Sources

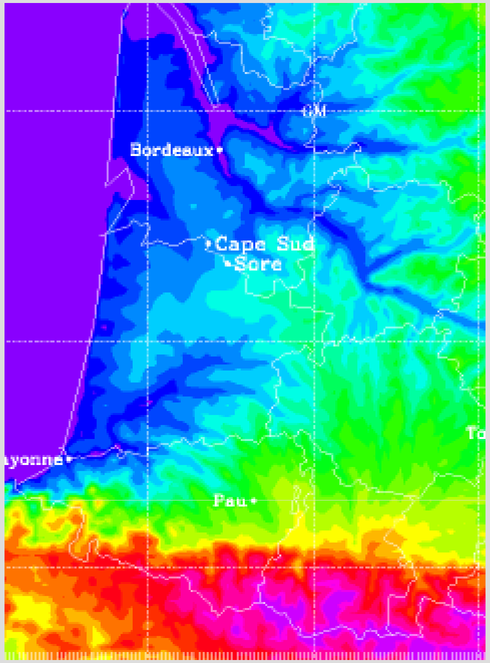

Modelling
Transport
Transformations
Emission
Deposition
Sources

Source distribution: landuse classes

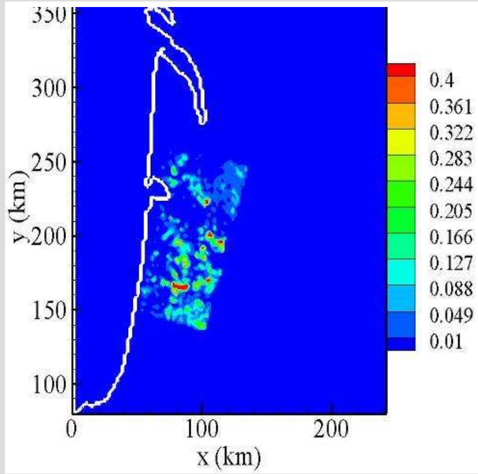
SPOT images



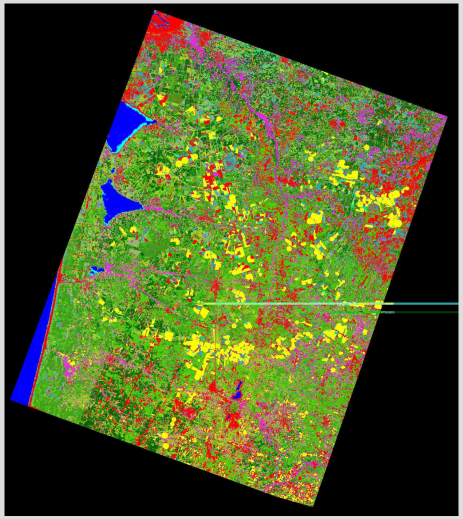
South-West France



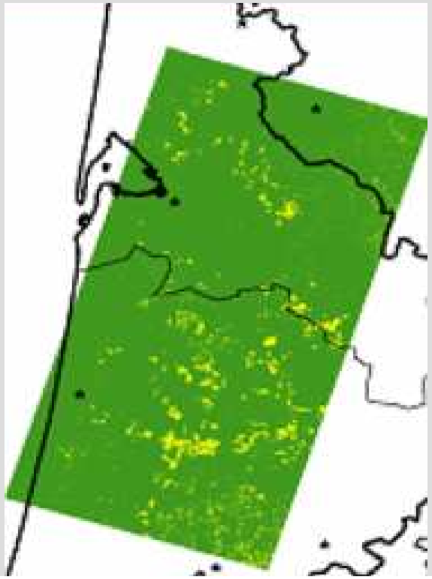
% Maize area



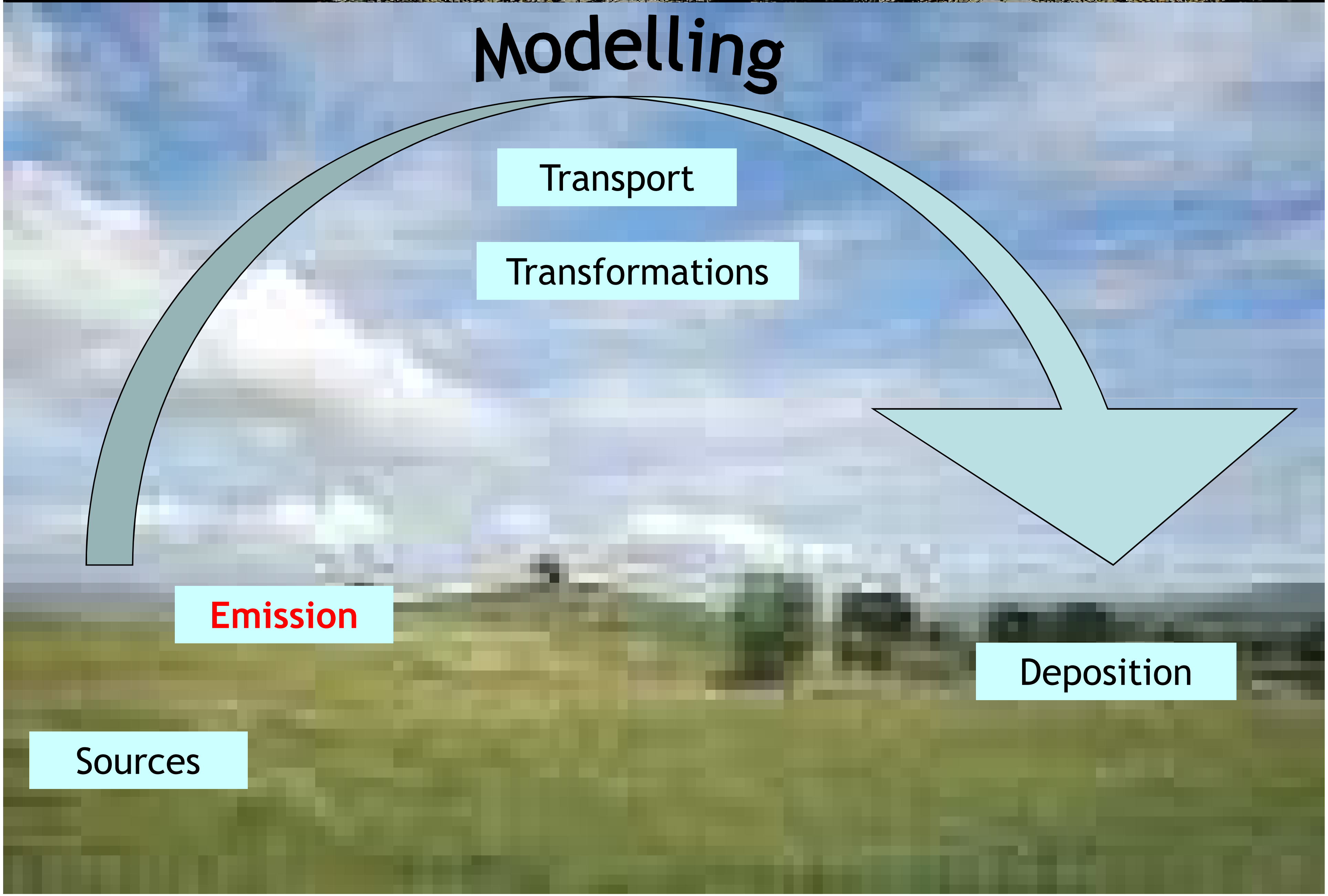
Landuse classes



Map of maize fields



Emission



Modelling
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Sources

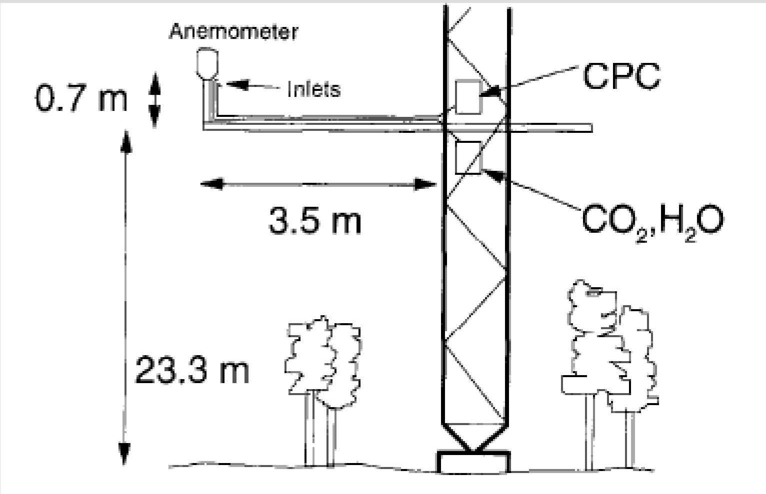
Source intensity: measurements

Chamber or bag

Air concentration

(2 levels, see C. Leyronas)

Source intensity: measurements



Eddy-correlation $F \propto \overline{w'C'}$

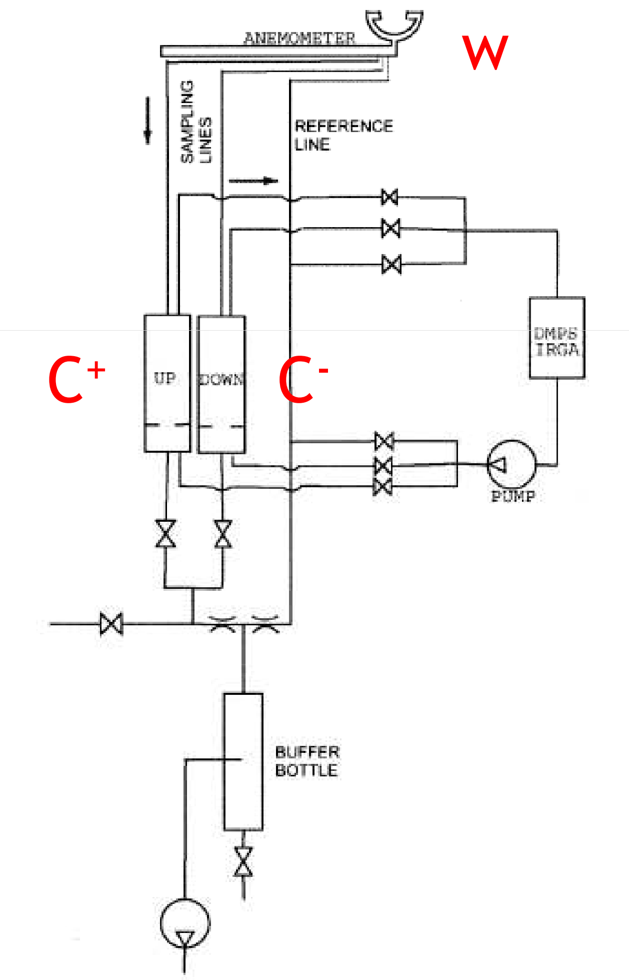


FIG. 1. REA system for aerosol particles: DMPS and IRGA. One of the concentration measurement devices can be used at a time.

$F \propto (C^+ - C^-)$

Relaxed-eddy accumulation

(development planned in 2010 for microbial flux)

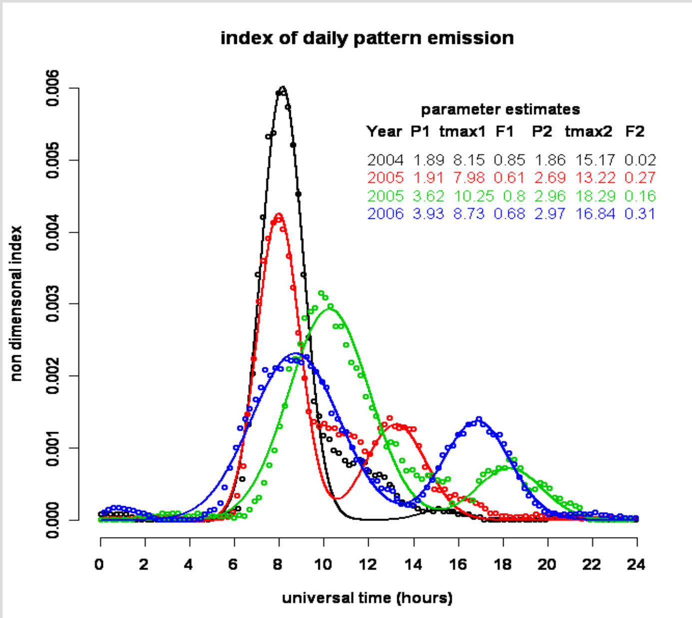
Source intensity: modelling the emission

Ex.: aerosol suspension

F = F (u(t), u_*, stab…)

Ex.: pollen emission

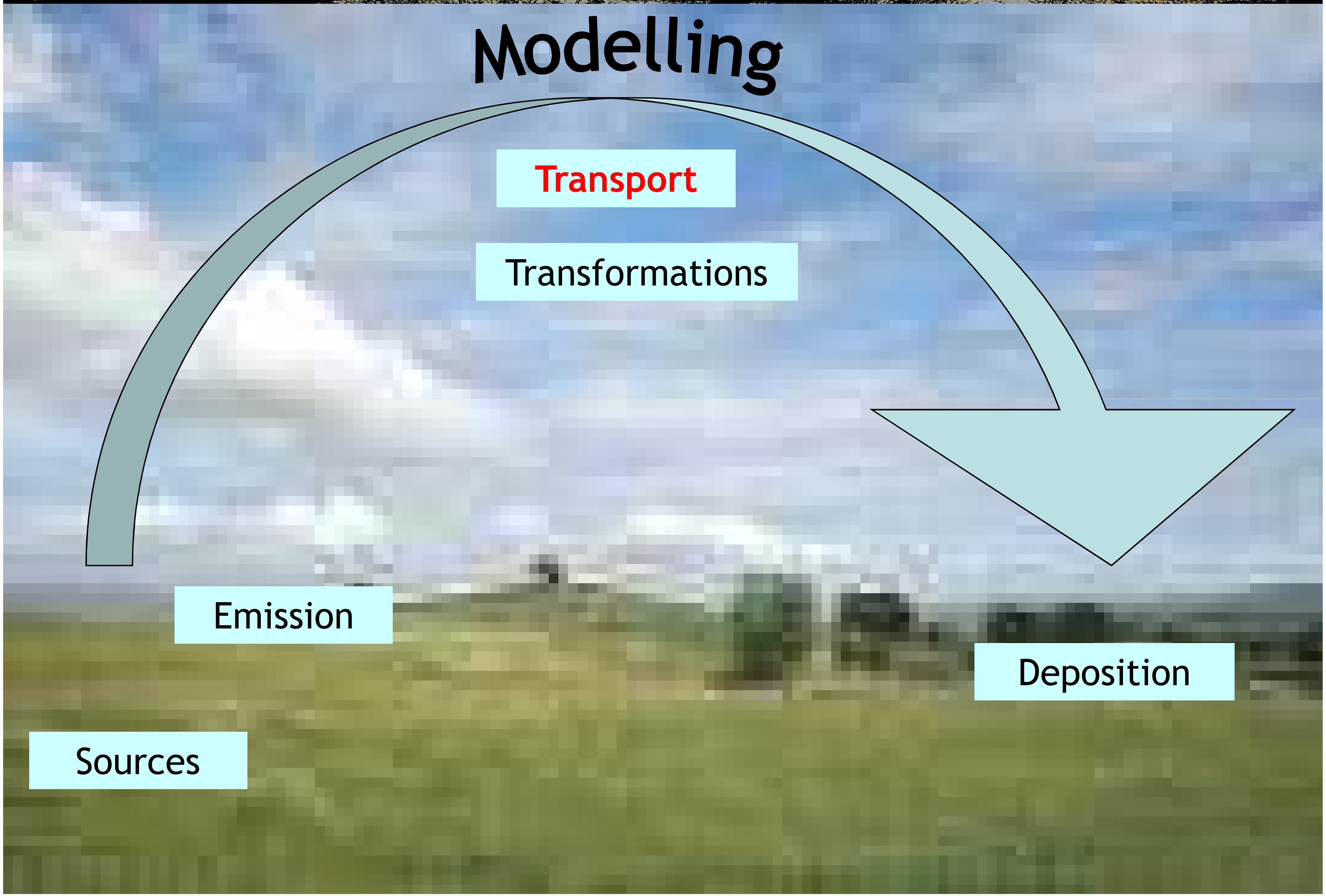
Marceau and Huber (2007)



$$I_B(t)_d = \frac{Q_d(t)}{Q_d^{tot}} = \frac{F1_d}{P1_d \times \sqrt{\pi/2}} \times \exp\left(-2\left(\frac{t - t\max1_d}{P1_d}\right)^2\right) + \frac{F2_d}{P2_d \times \sqrt{\pi/2}} \times \exp\left(-2\left(\frac{t - t\max2_d}{P2_d}\right)^2\right)$$

Model parameters depend on microclimatic factors

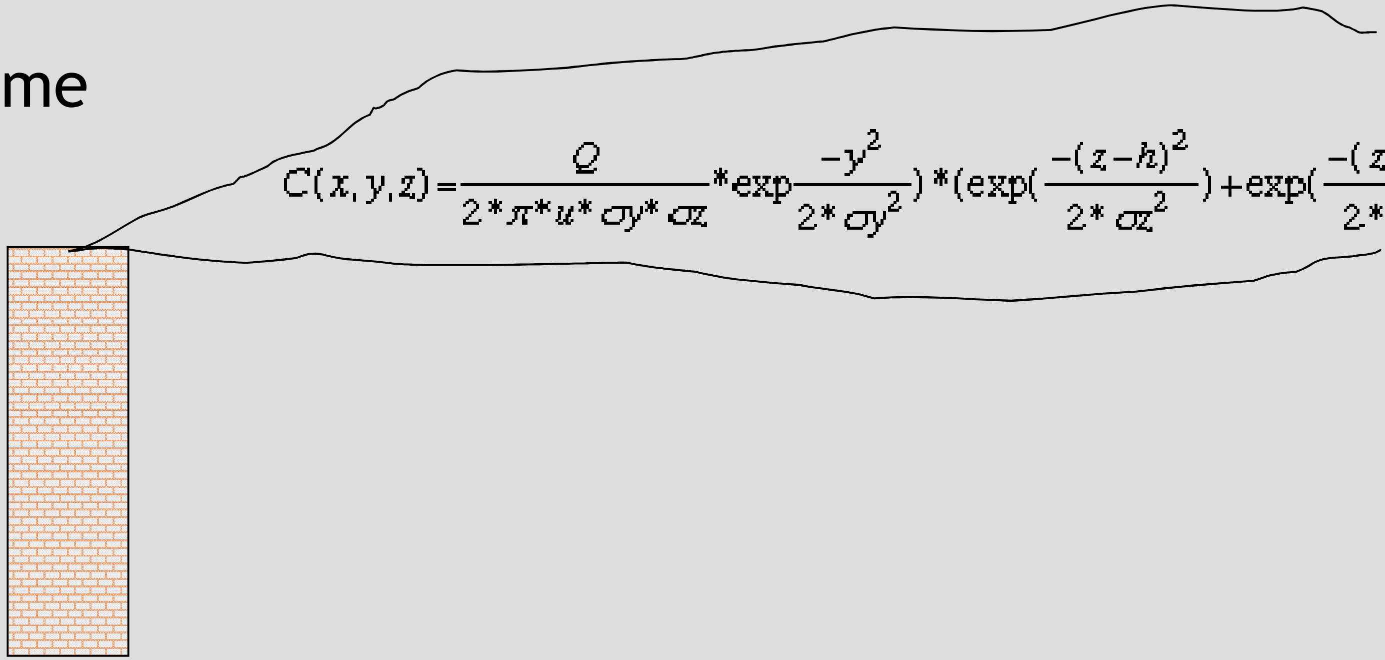
Turbulent transport



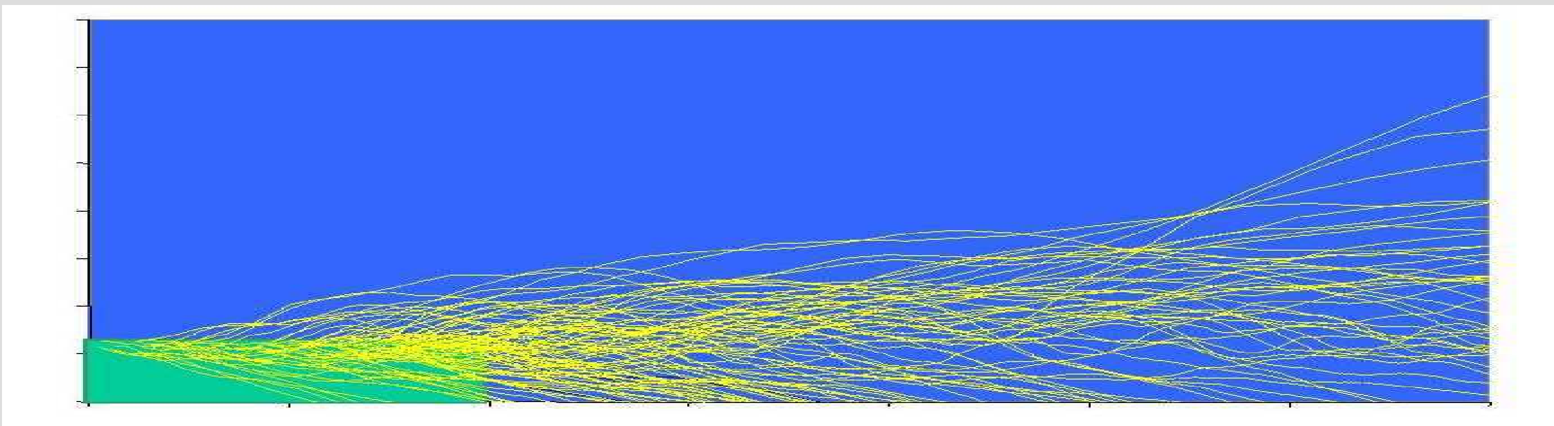
Turbulent transport

Gaussian plume

$$C(x,y,z)=\frac{Q}{2*\pi*u*\sigma y*\sigma z}*\exp\frac{-y^2}{2*\sigma y^2})*(\exp(\frac{-(z-h)^2}{2*\sigma z^2})+\exp(\frac{-(z+h)^2}{2*\sigma z^2}))$$

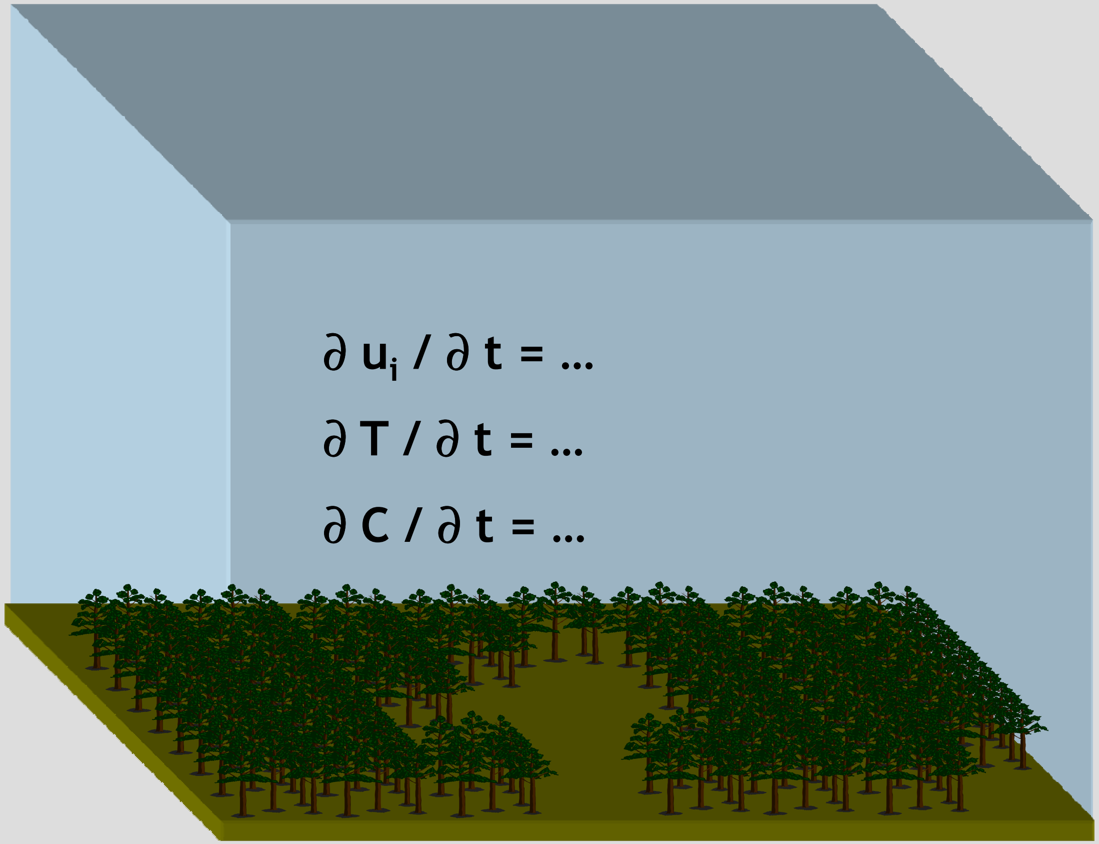


Lagrangian model



Turbulent transport

Eulerian modelling

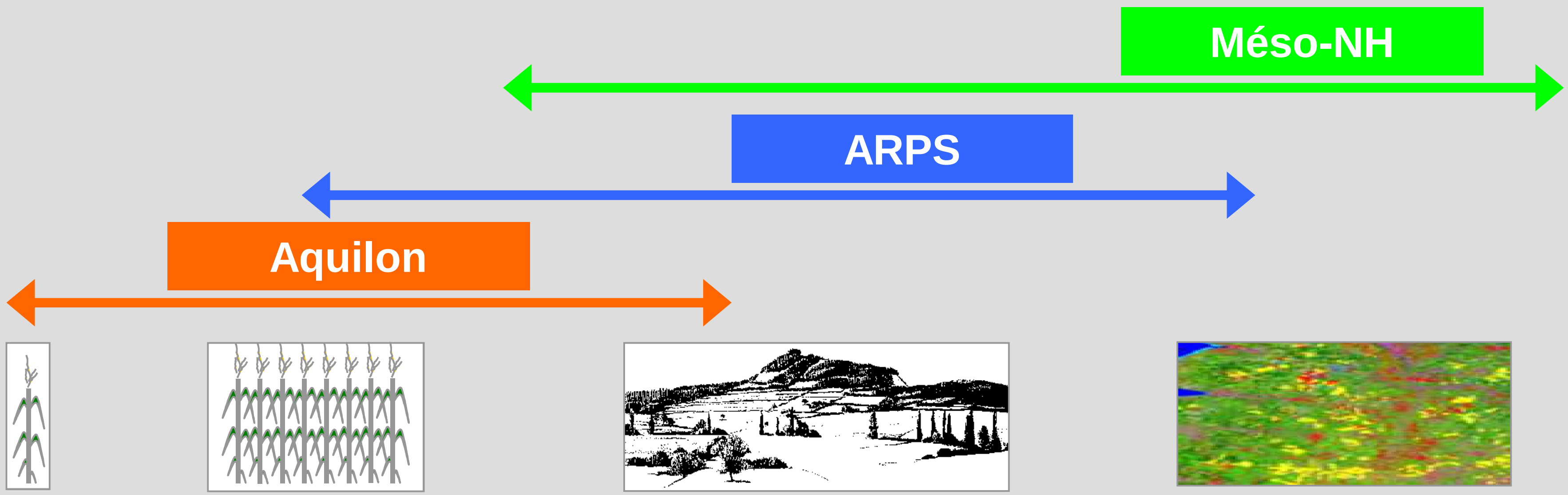


Turbulent transport

Model type

CFD

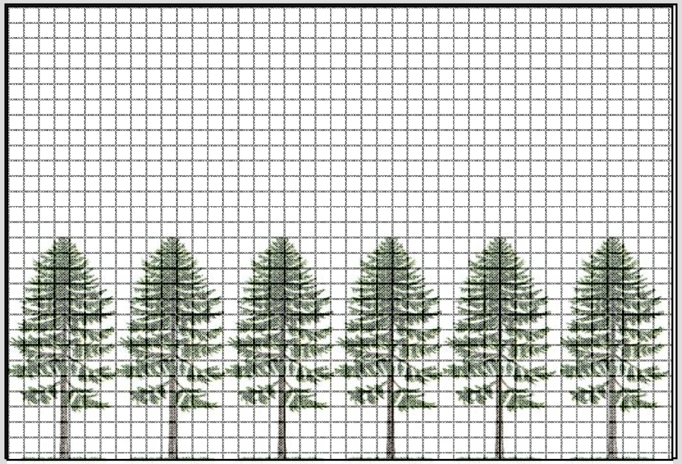
Atmospheric models



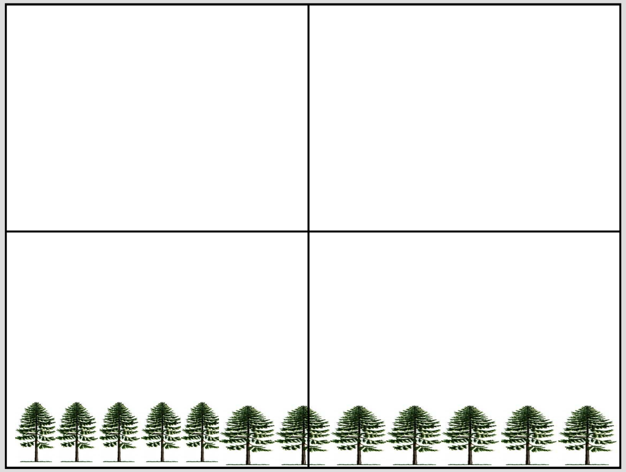
Turbulent transport

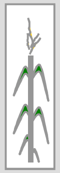
Surface modelling

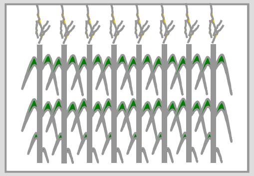
Drag force, several sources

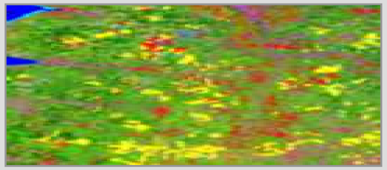


Roughness, one source







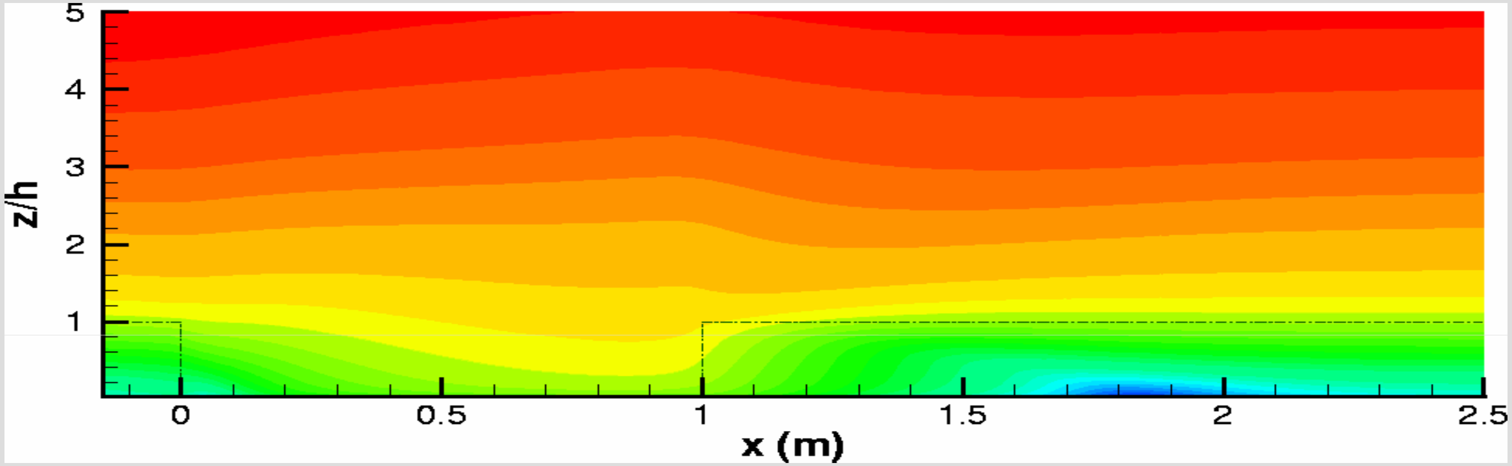


Turbulent transport

Turbulence modelling

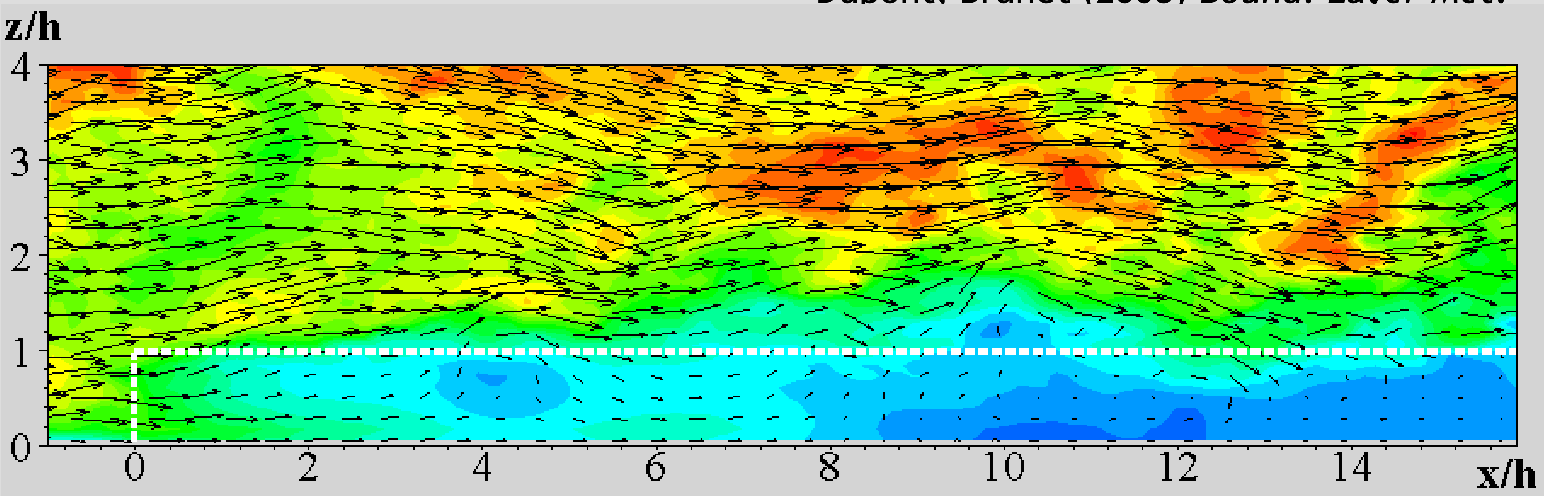
Foudhil, Brunet, Caltagirone (2005) *Env. Flu. Mech.*

RANS

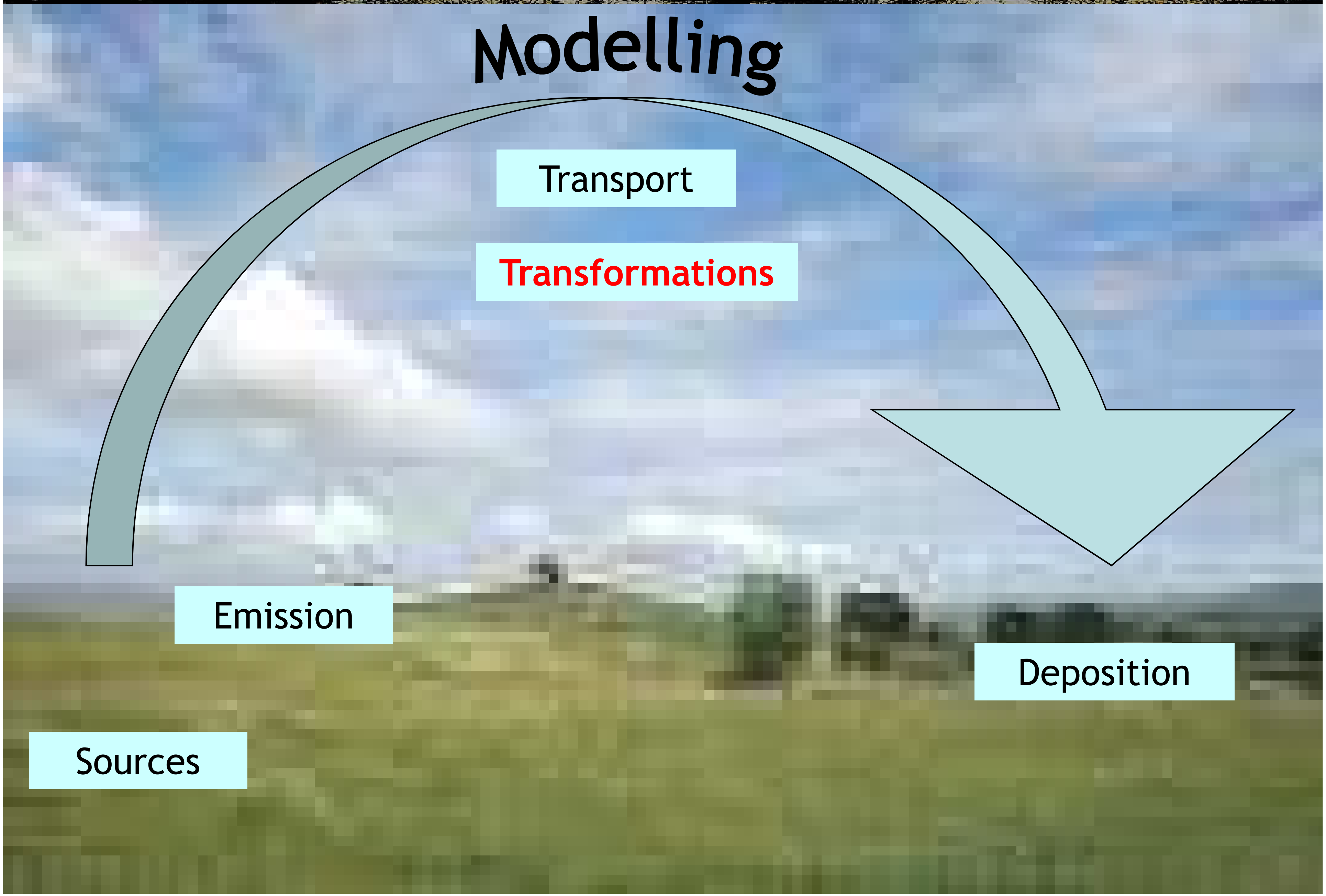


Dupont, Brunet (2008) *Bound. Layer Met.*

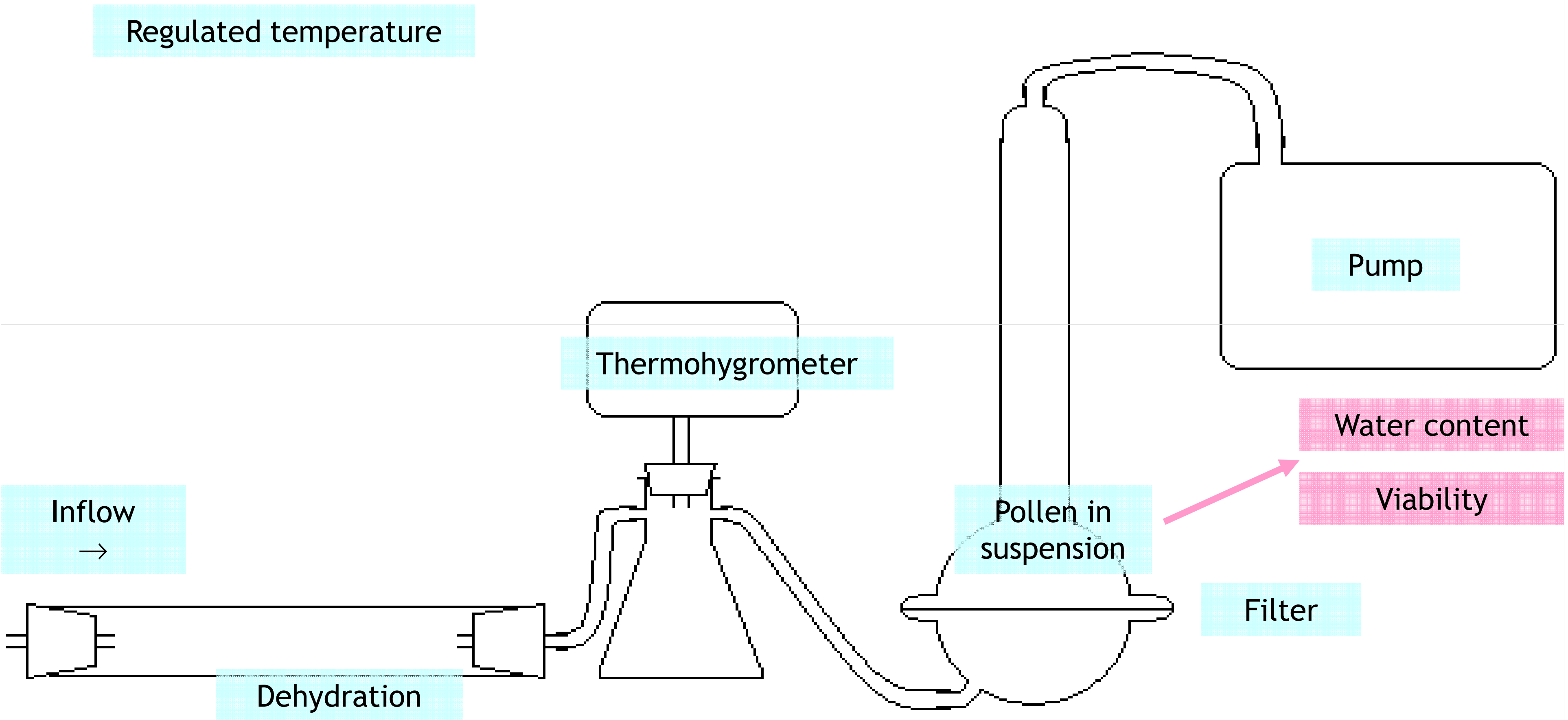
LES



Transformations

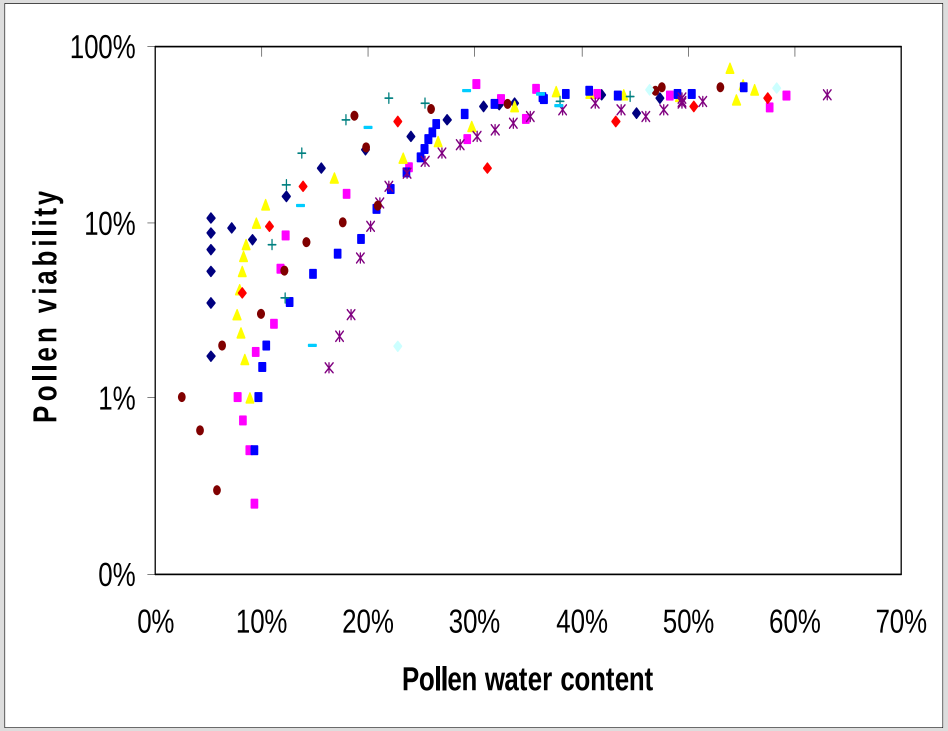


Transformation



Transformation

Viability depends on water content



A model for pollen dessication

- $V_p \, d\theta/dt = - E$
- $E = A_{eff} \, g_{eff} \, \delta$

$$A_{eff} = A_p \, \theta$$

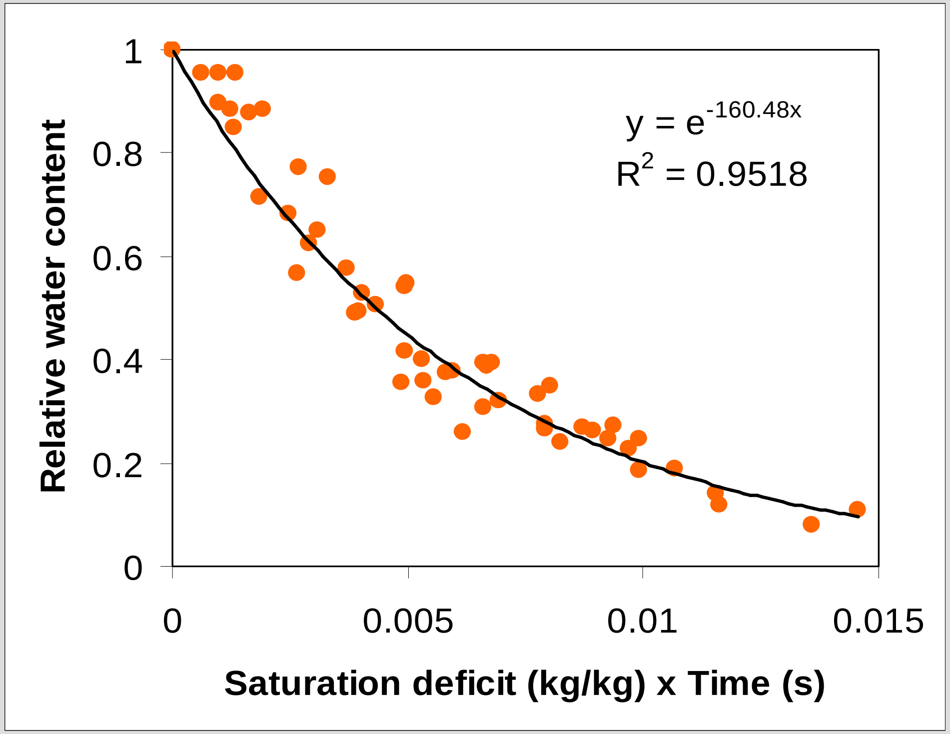
$$g_{eff} = g_a \, g_s \, / \, (g_a + g_s)$$

δ = *saturation deficit*

- $d\theta/dt = - (A_p/V_p) \, \theta \, g_{eff} \, \delta$
- $\theta(t) = \exp[- (A_p/V_p) \, g_{eff} \, \delta \, t]$

Transformation

Good prediction of pollen dessication



A model for pollen dessication

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- $\theta (t) = \exp [- (A_p/V_p) \, g_{eff} \, \delta \, t]$

Transformation

Inclusion of Eulerian pollen transport

For alive and dead pollen, add conservation equations

- for pollen concentration

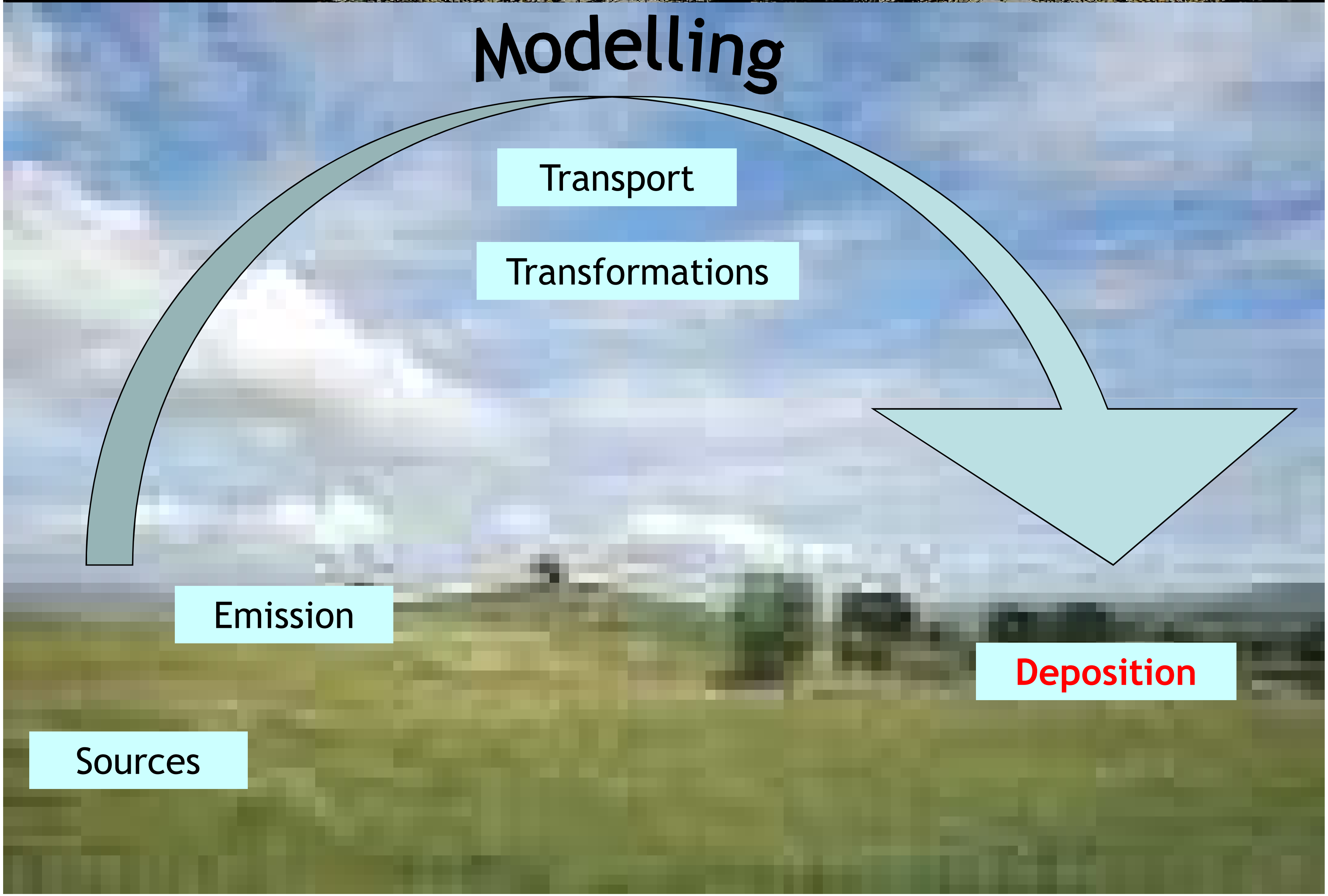
$$\delta C_{al} / \delta t = adv + turb + gravity - T_{a \rightarrow d} \qquad (N\ gr\ m^{-3})$$

- for pollen water concentration

$$\delta W_{al} / \delta t = adv + turb + gravity - T_{a \rightarrow d} - evap \qquad (kg\ m^{-3})$$

gravity	α	$V_s(\theta)$	*(Aylor, 2002)*
$T_{a \rightarrow d}$	α	$dG(\theta) / dt$	*(Aylor, 2003)*
evap	α	$A_p\ \theta\ g_{eff}\ \delta$	*(present model)*

Deposition


Modelling
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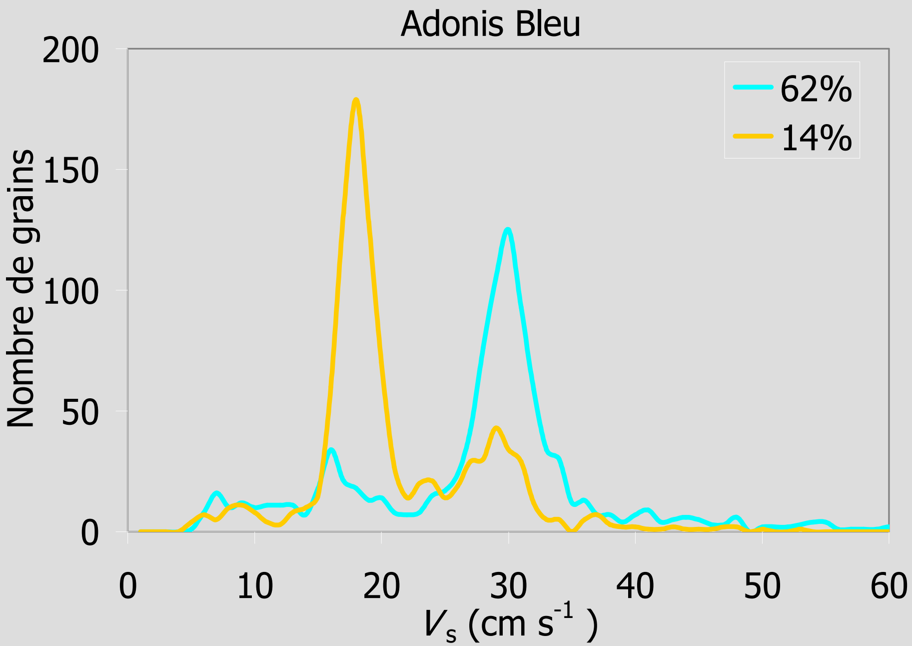
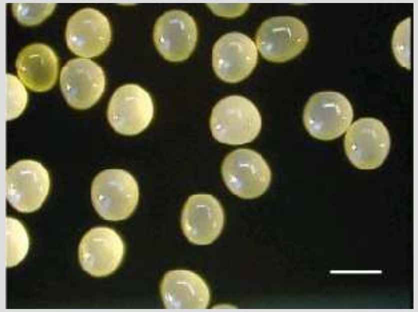
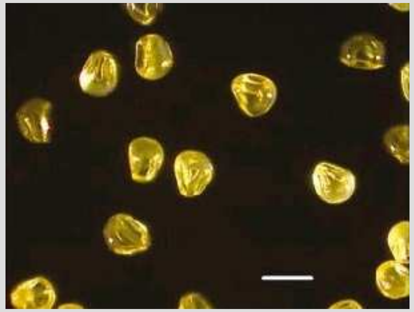
Particle deposition

$v_d = v_s + v_t$







Canopy structure	$v_d = v_s(1 + LAI)$	*(Yao, 1997)*
Turbulence	$v_d = v_s + 0.1u_*$	*(Callender et al., 1983)*
Particle size and shape	$v_d = 2 \times v_s$	*(McCartney, 1991)*

Particle deposition

$$\langle \overline{S} \rangle = \langle \overline{S_s} \rangle + \langle \overline{S_i} \rangle$$

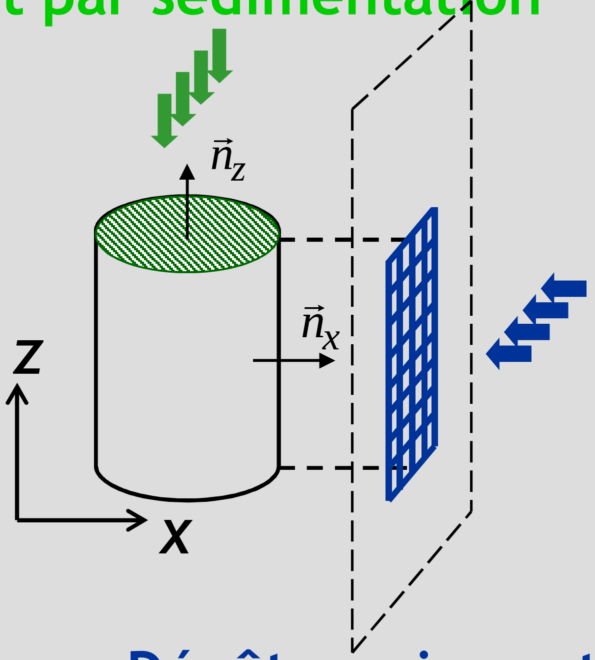
$$\langle \overline{S_s} \rangle = \langle \overline{C} \rangle f_z \mathrm{A} \mathrm{v}_s E_s$$

- Efficacité de sédimentation $E_s = 1$

$$\langle \overline{S_i} \rangle = \langle \overline{C} \rangle E_i \langle u \rangle \left(f_{xt} \mathrm{A}_t + f_{xf} \mathrm{A}_f + \ldots \right)$$

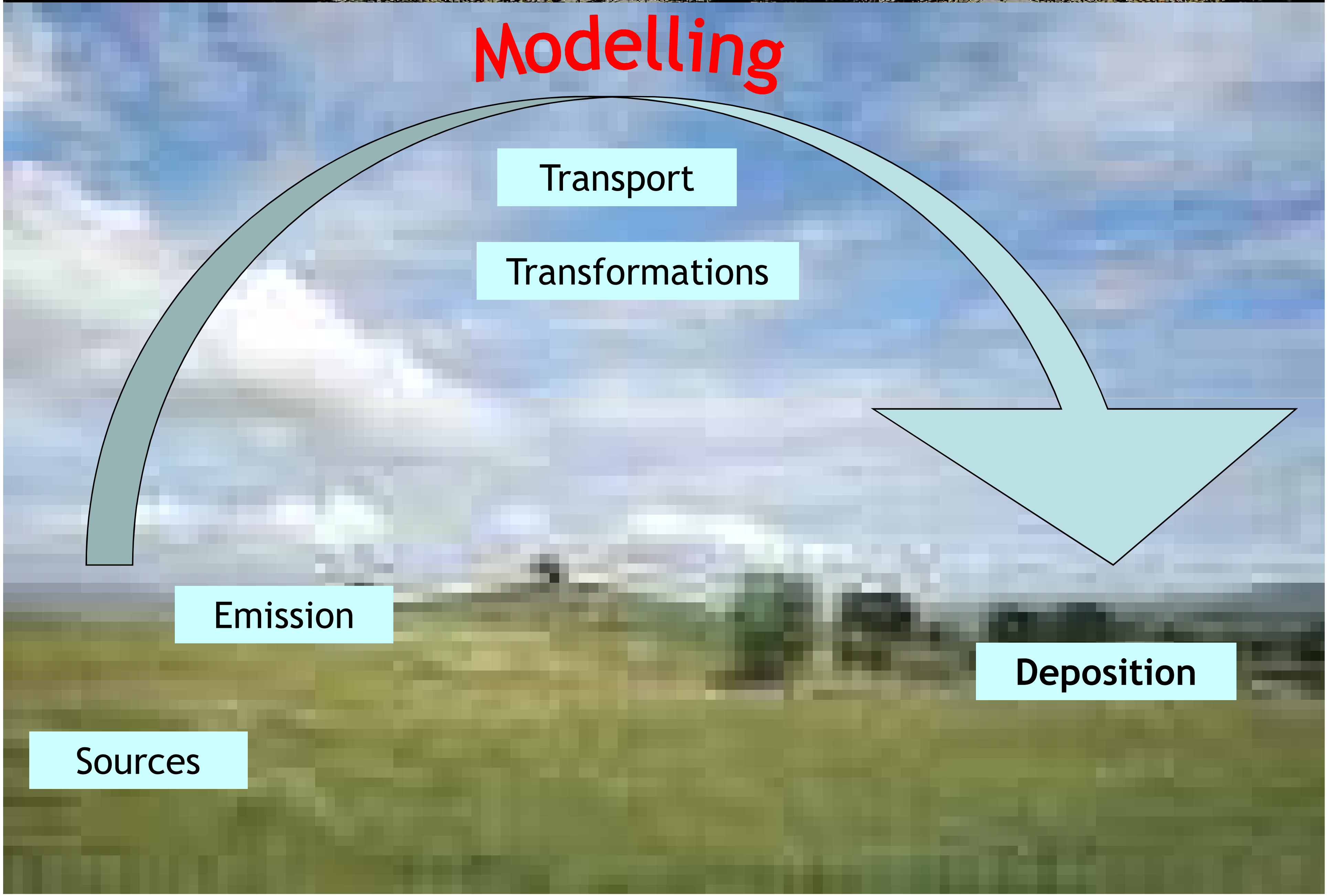
- Efficacité d'impact $E_i = \dfrac{0.86}{1 + 0.442\, St^{-1.967}}$

Dépôt par sédimentation

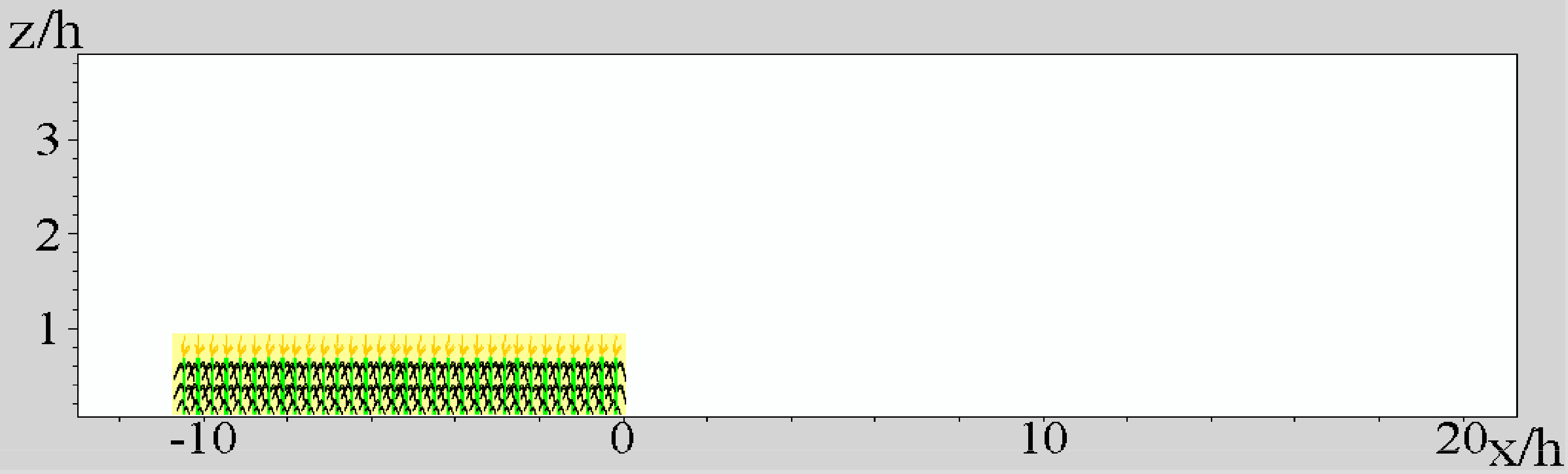


Dépôt par impact

A few modelling examples

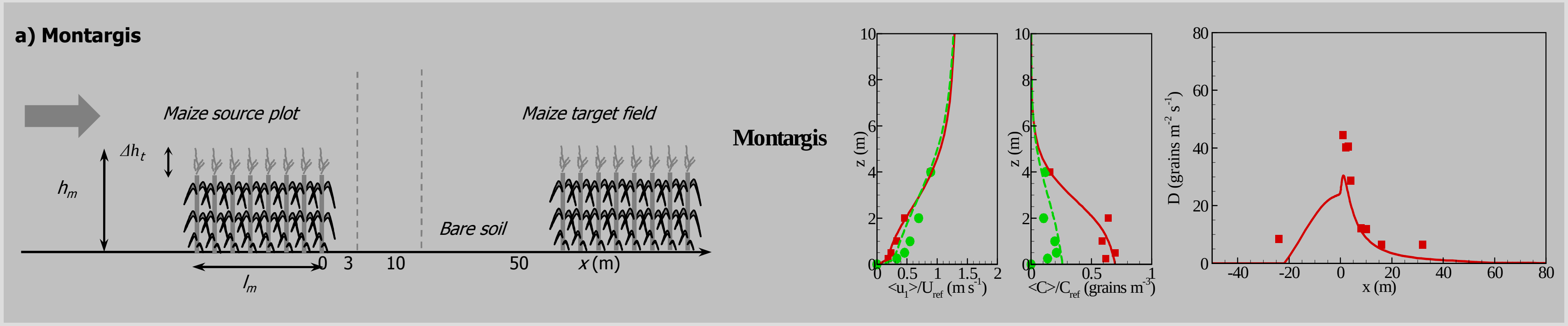


The plant canopy scale



Model evaluation

Dupont, Brunet, Jarosz (2006), *Ag. For. Met.*

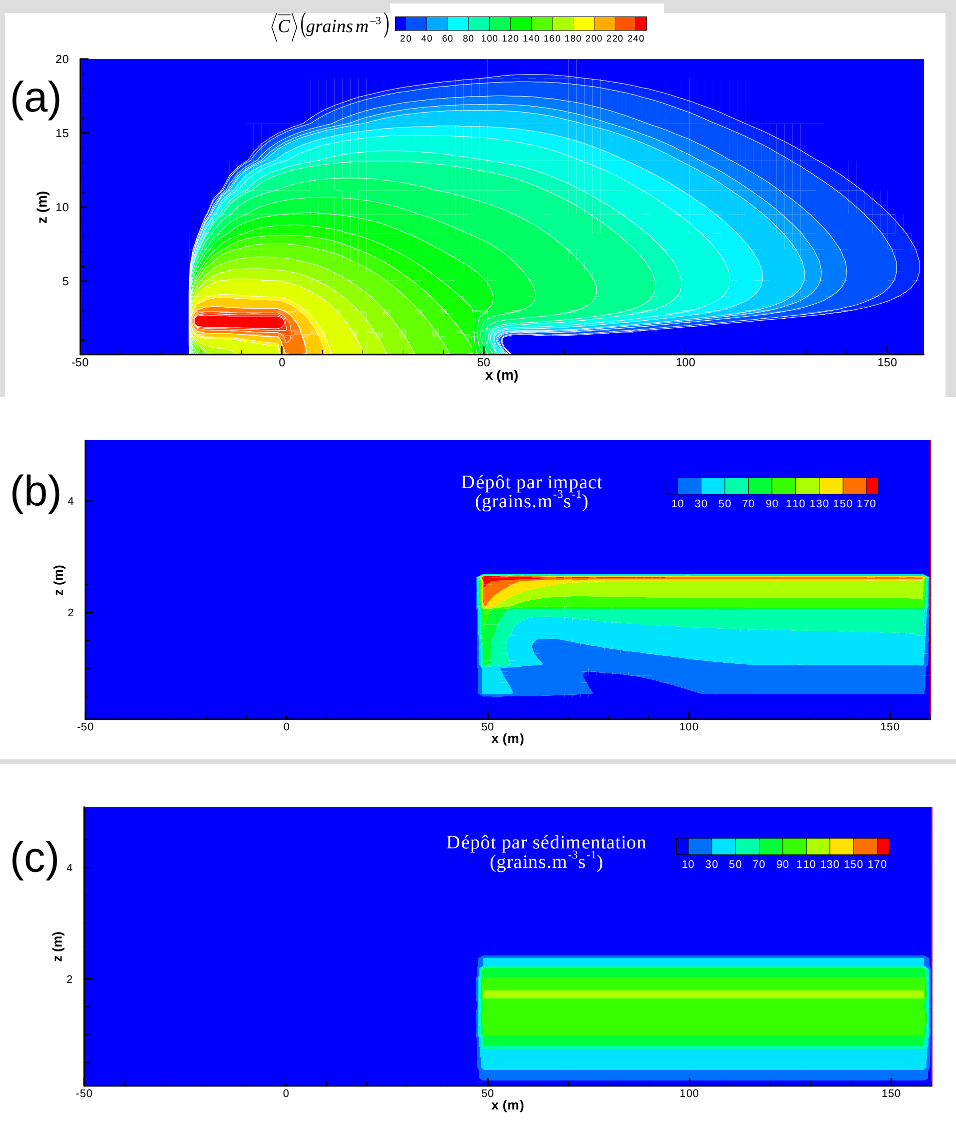


The plant canopy scale

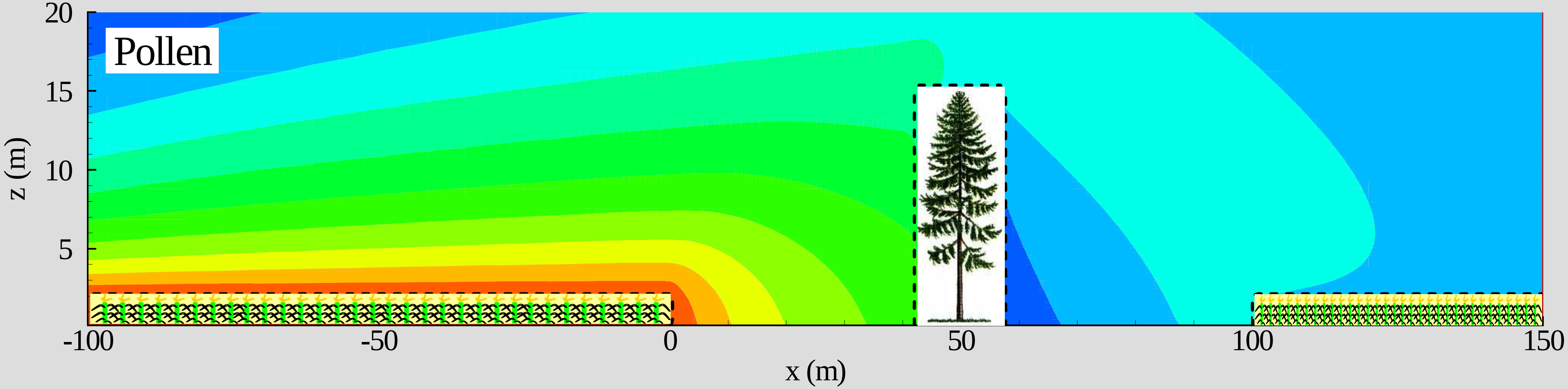
Concentration

Impaction

Sedimentation



Single obstacles



Single obstacles

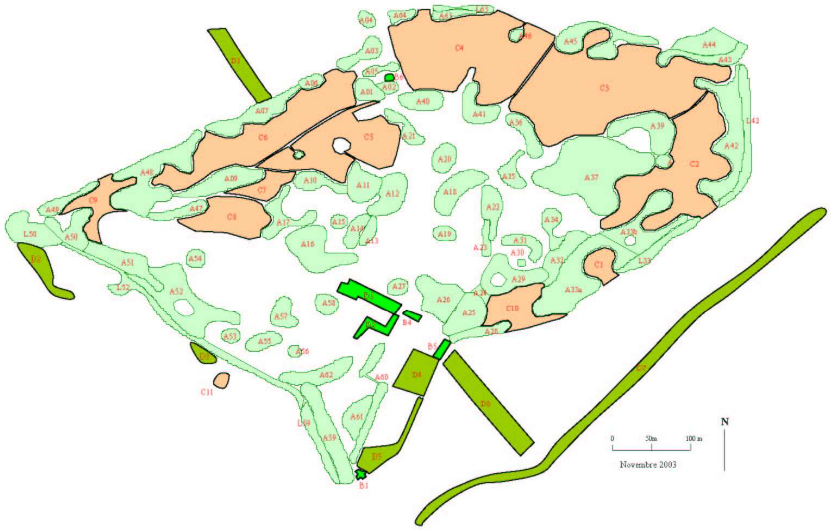
Fence height

Impossible d'afficher l'image. Votre ordinateur manqu

Fence
width
+
position

Heterogeneous landscapes

Dupont, Brunet (2006) *Bound. Layer Met.*



Zones boisées

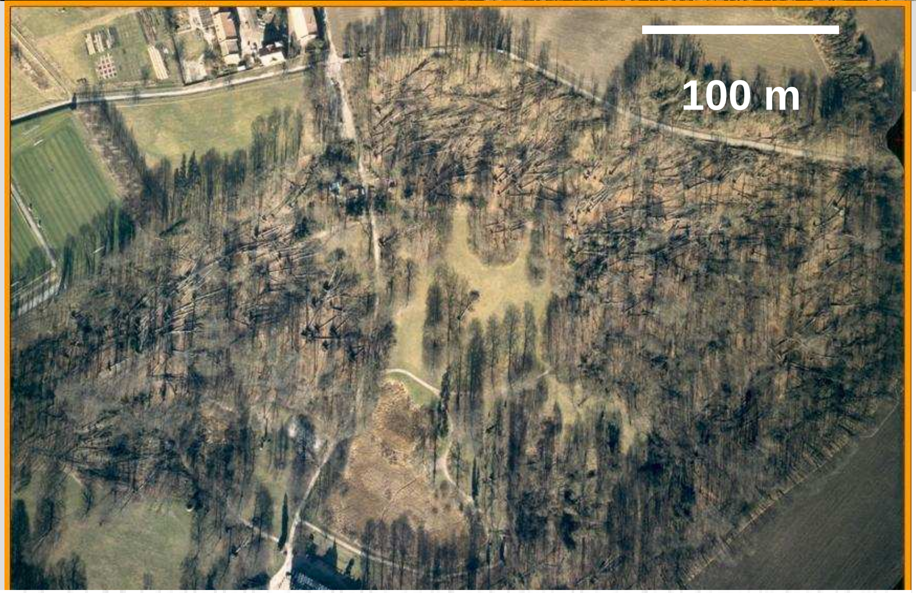
Zones boisées extérieures

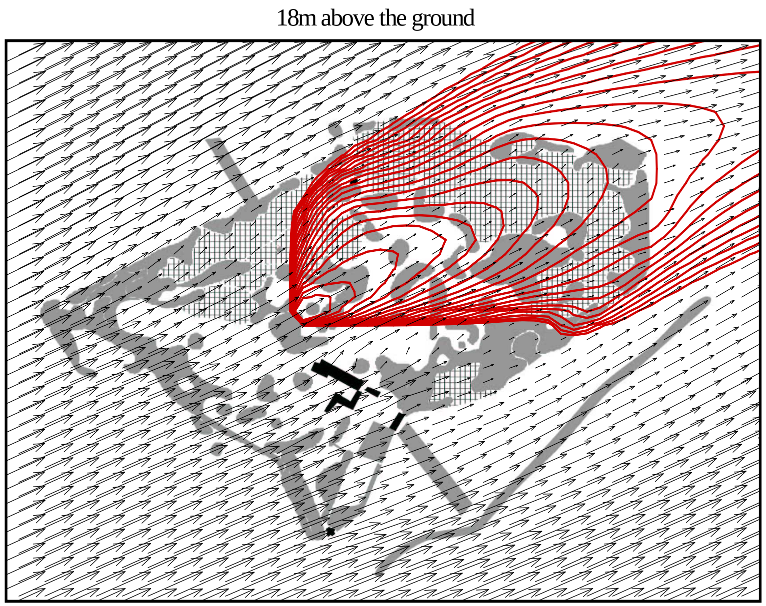
Zones détruites en 99

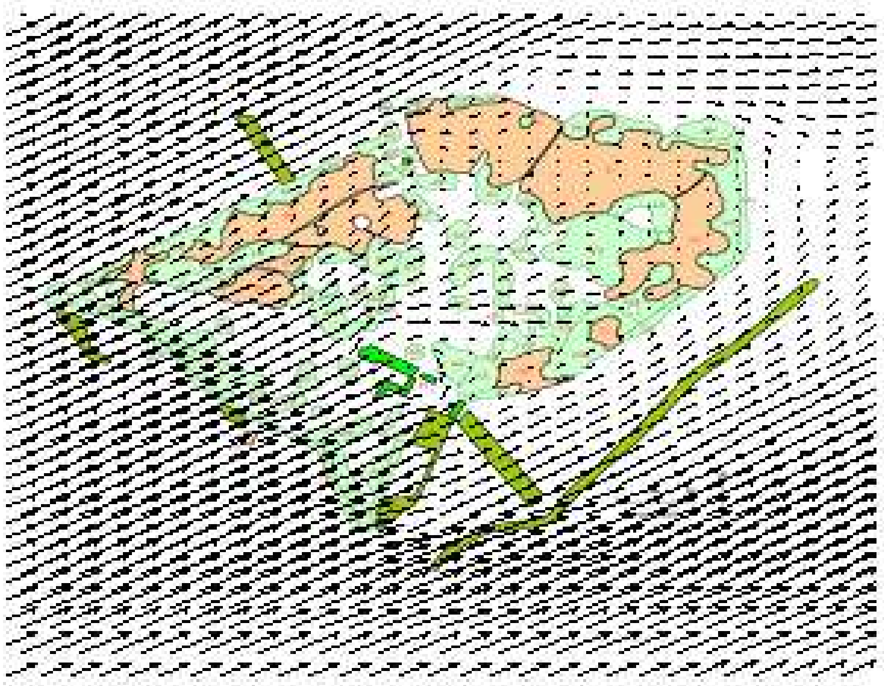
Bâtiments

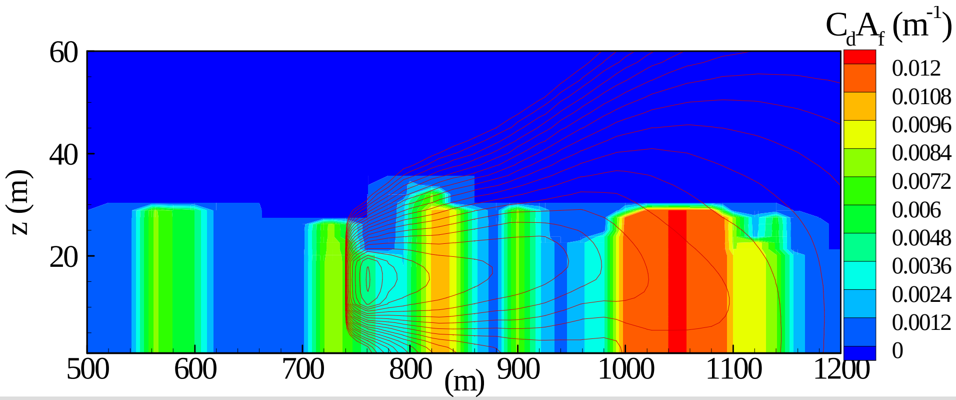
Heterogeneous landscapes

Dupont, Brunet (2006) *Bound. Layer Met.*

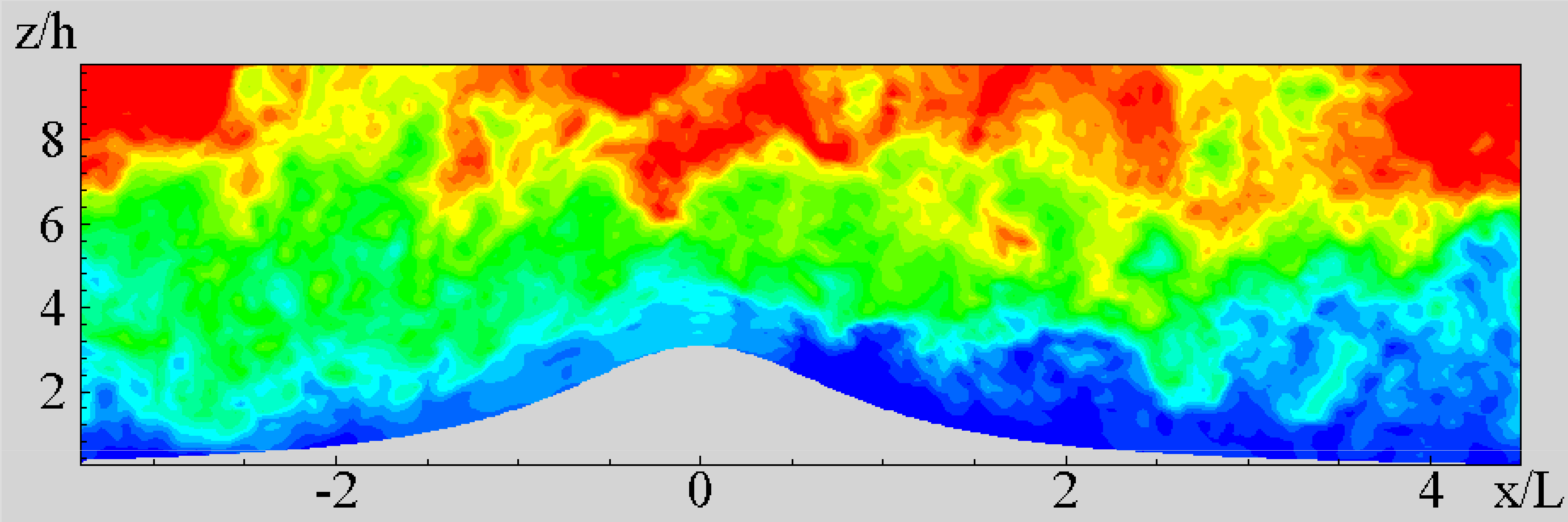


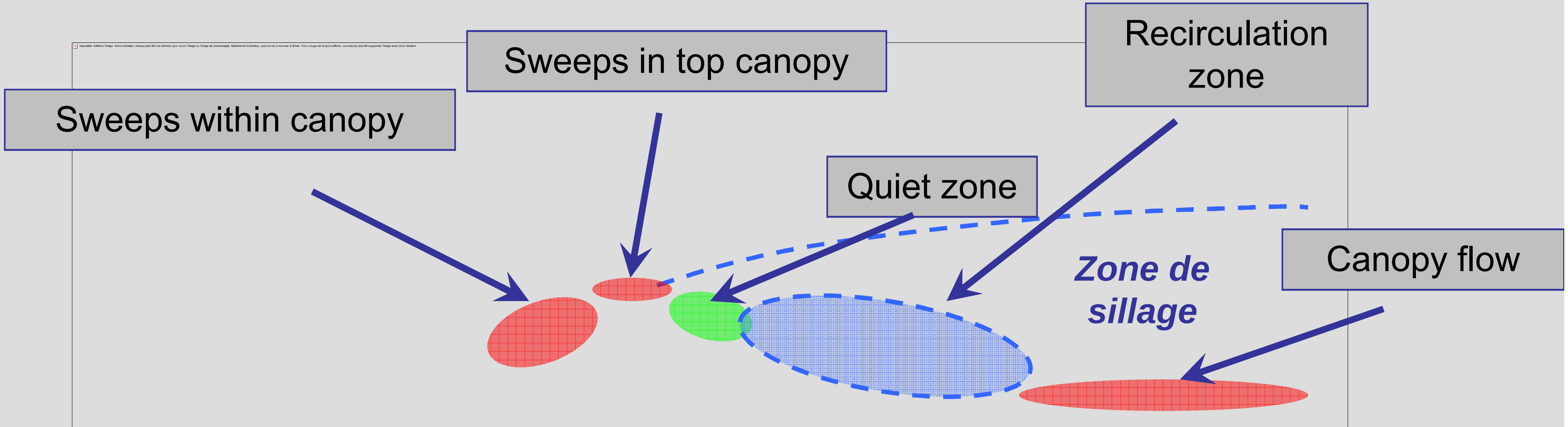






Topography



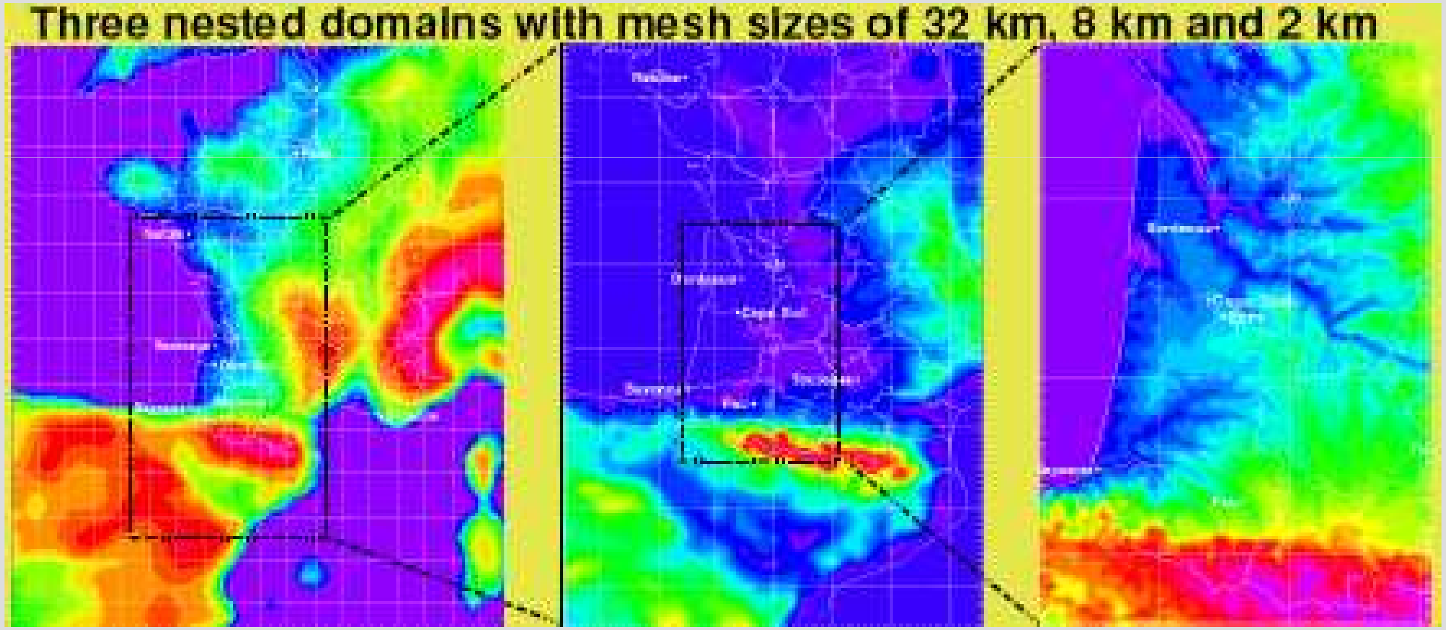


Dupont, Brunet, Finnigan (2008) *Q.J.R.M.S.*

Regional scale: long-distance dispersal

Simulation of regional transport with Meso-NH

(a 3D, non-hydrostatic mesoscale atmospheric model
developed by Météo-France and Laboratoire d'Aérologie)

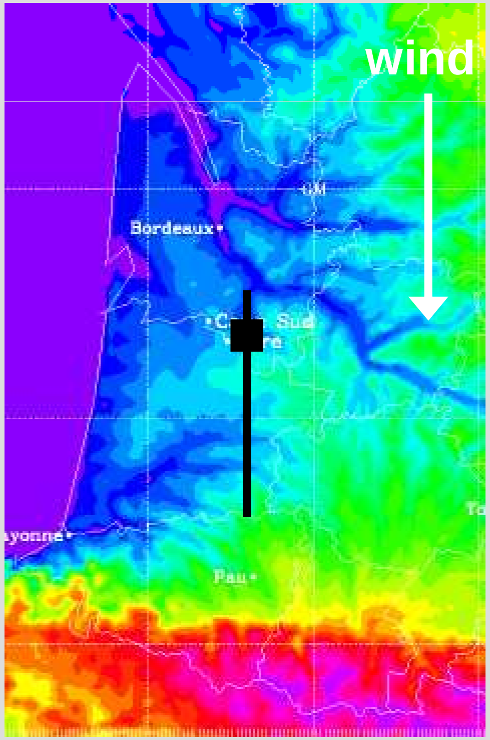


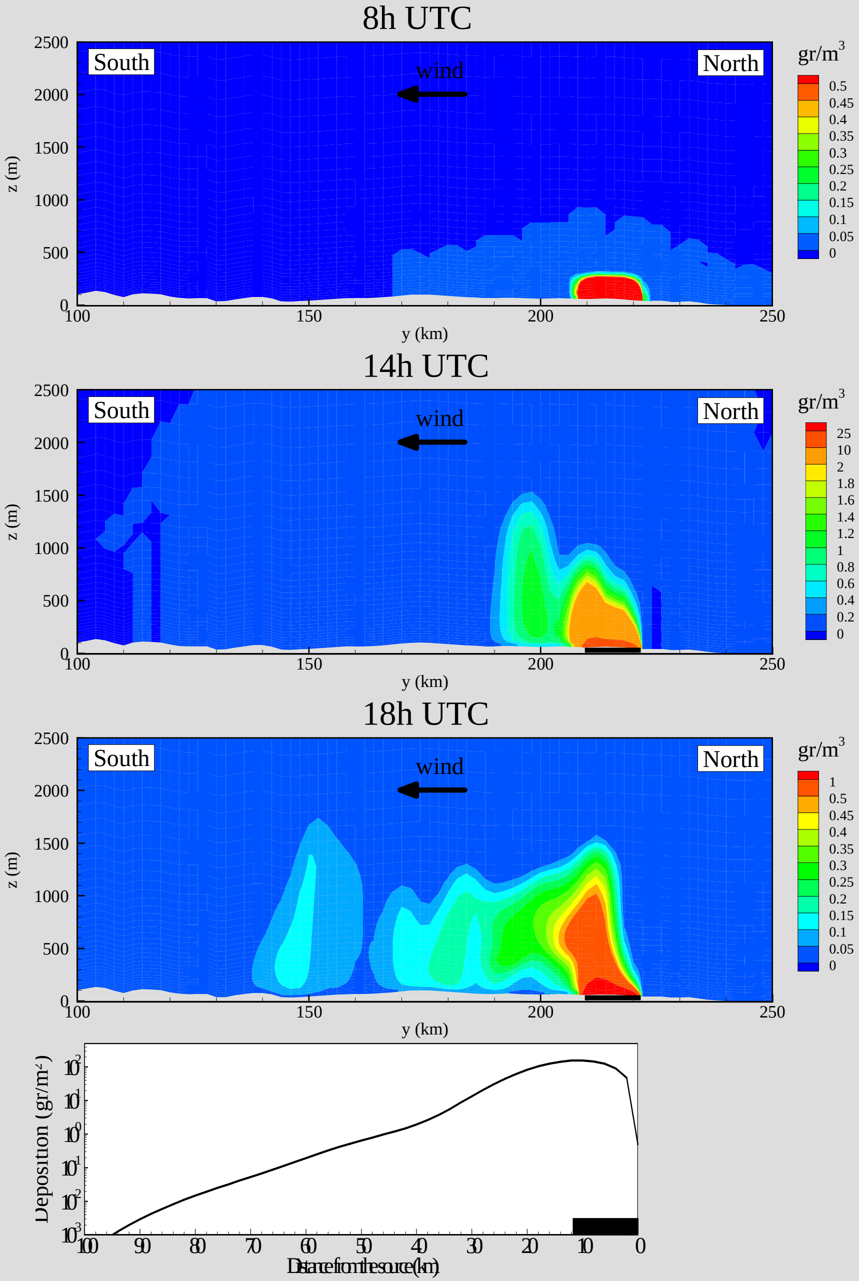
Long-distance deposition

A case study:

simulation of dispersal and deposition downwind from a single field (July 10, 2003)

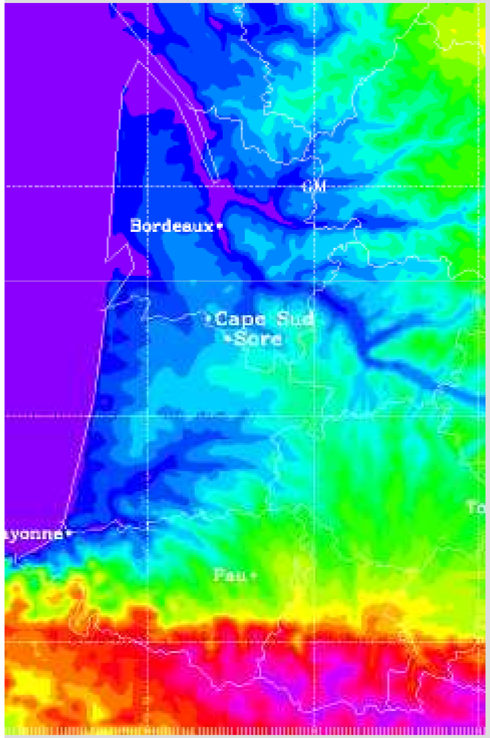
fictitious field, 12 x 12 km



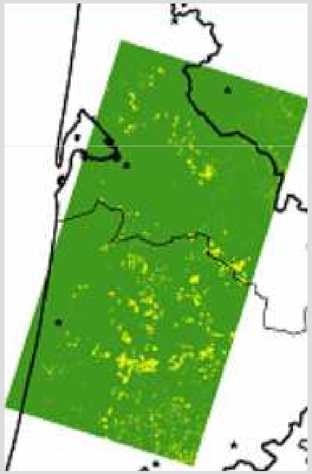


Regional scale: long-distance dispersal

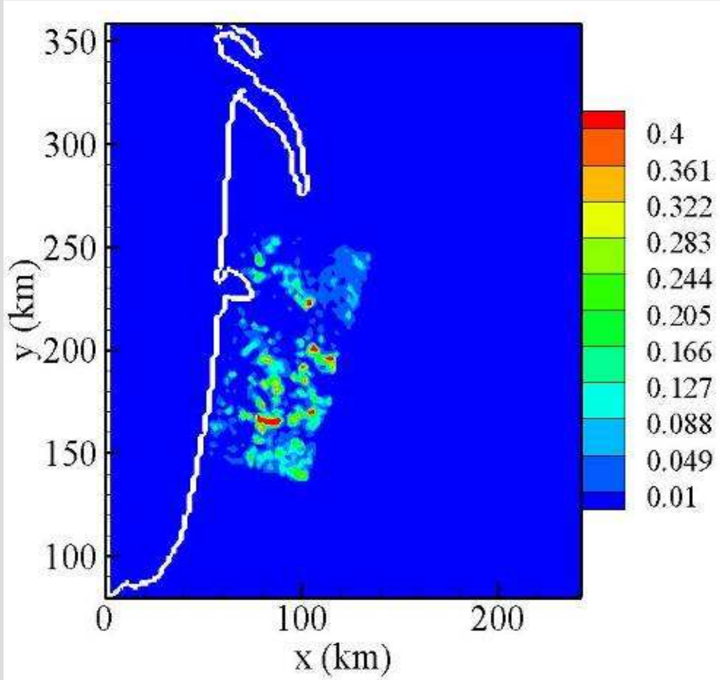
South-West France



Map of maize fields



% Maize area



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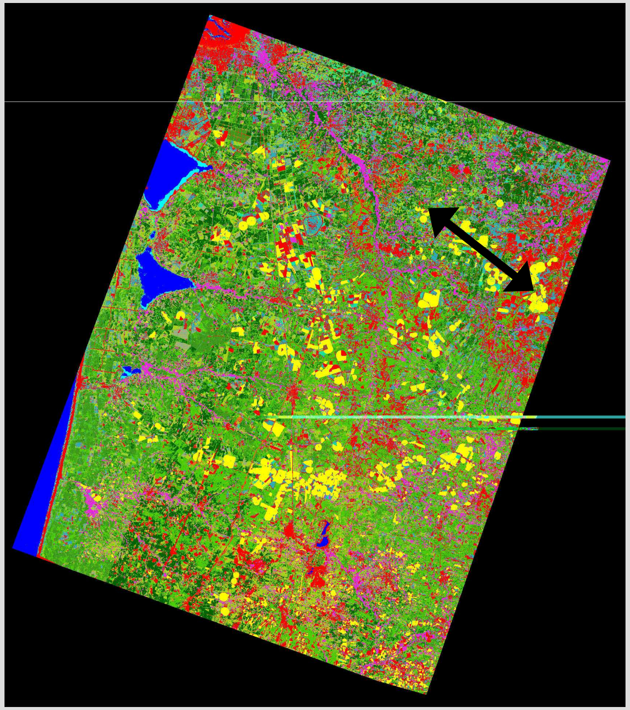
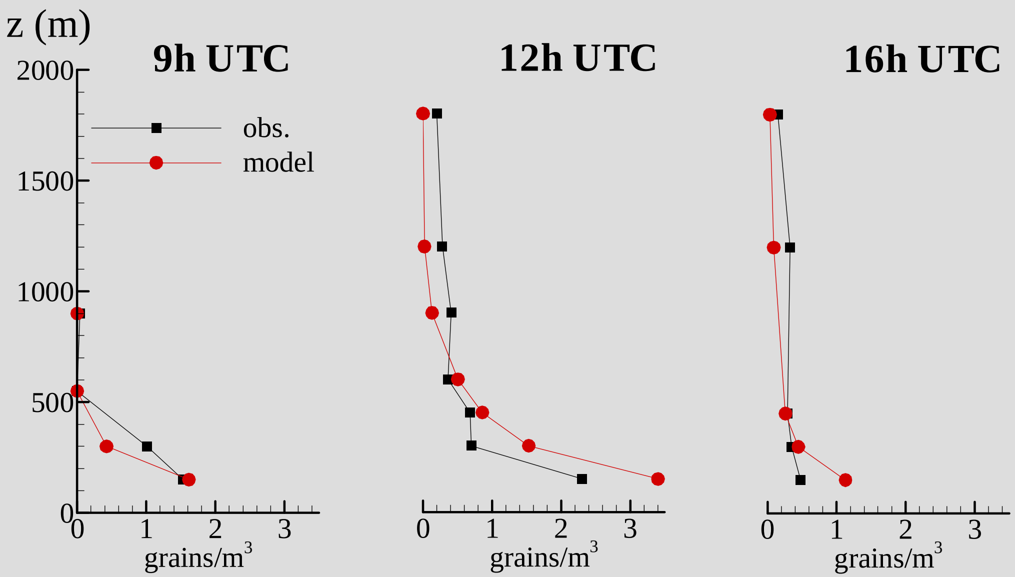


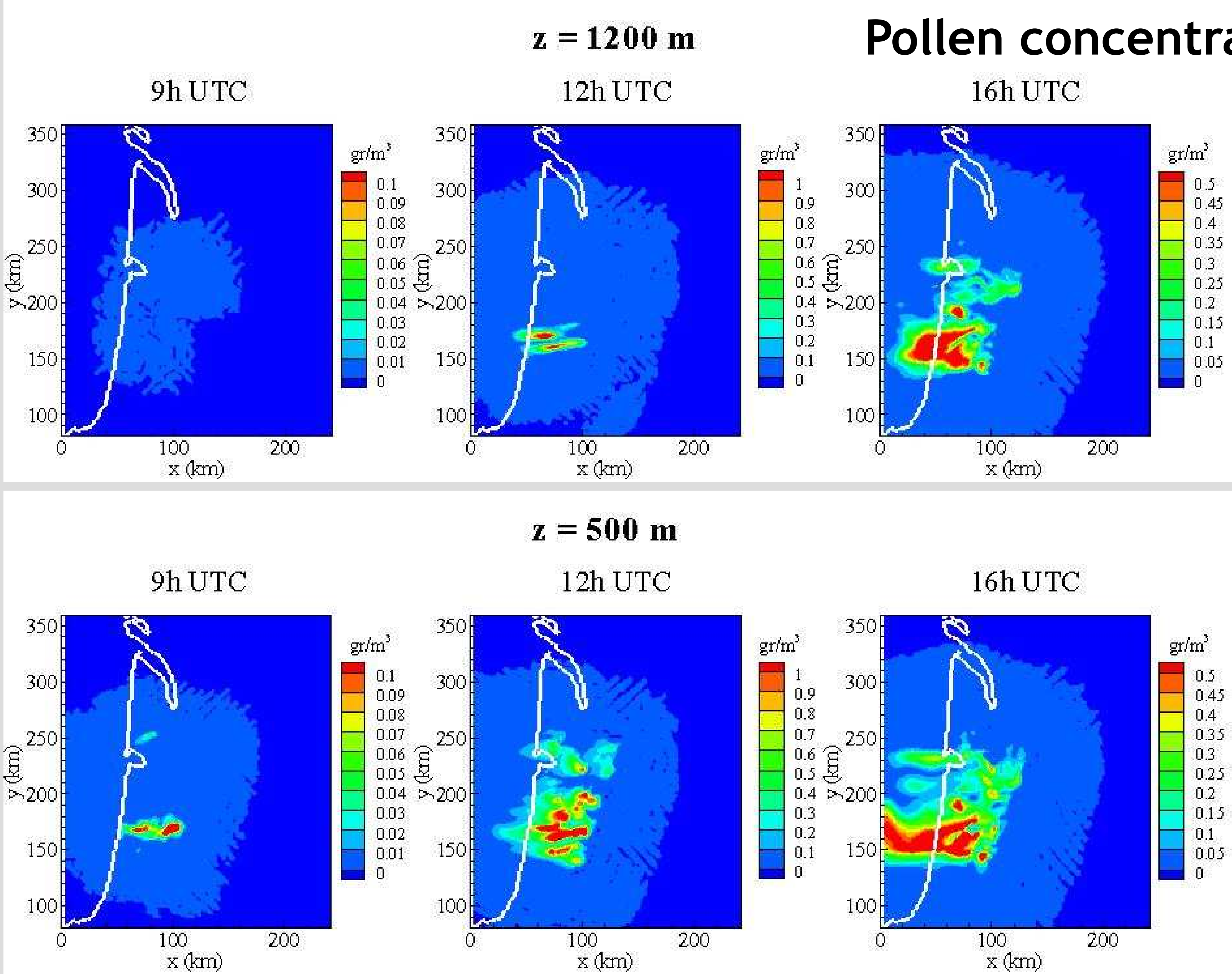
Model evaluation

Test model results over transects with aircraft measurements at various heights and times (e.g. 12 July 2003)



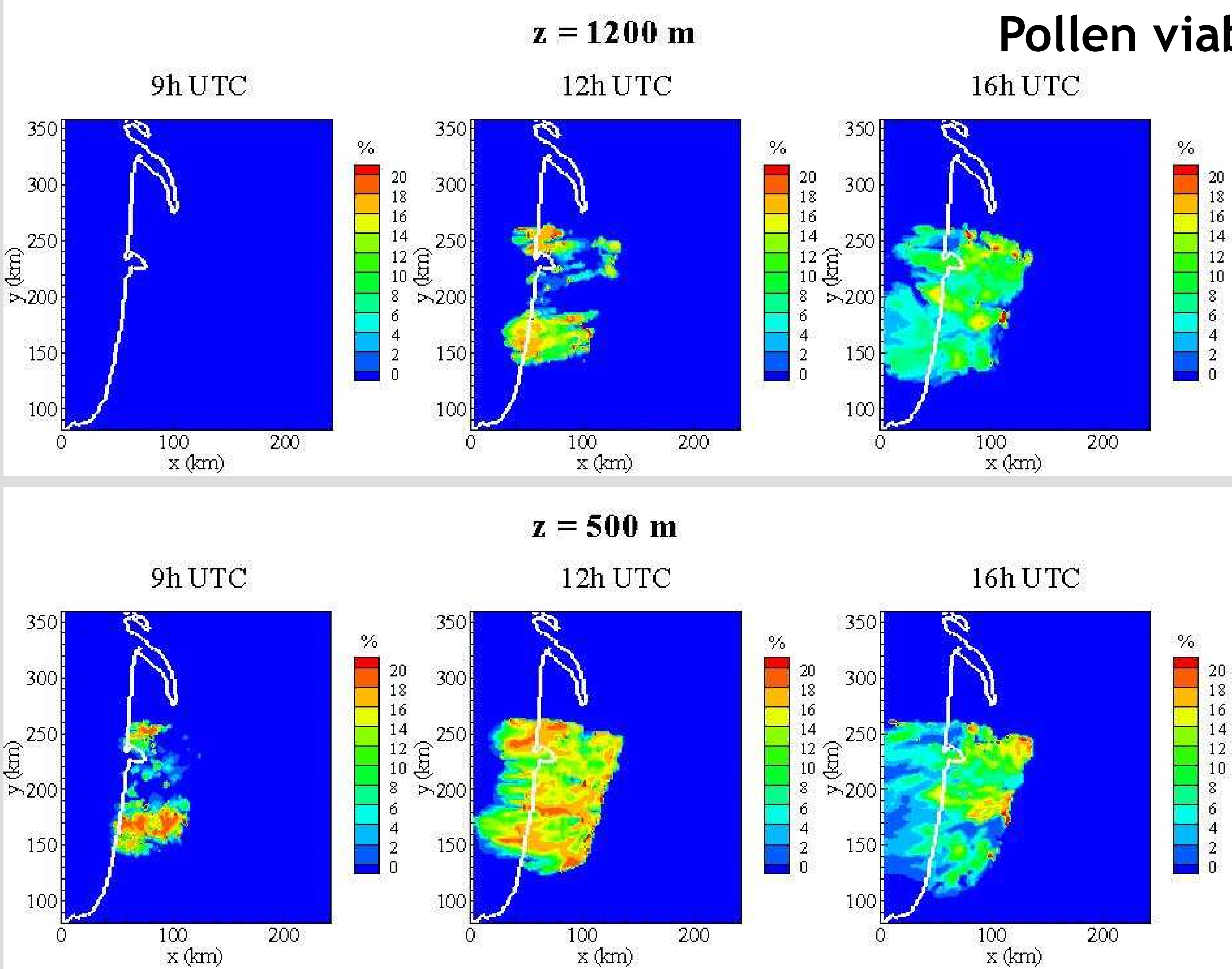
Regional scale: long-distance dispersal

Pollen concentration



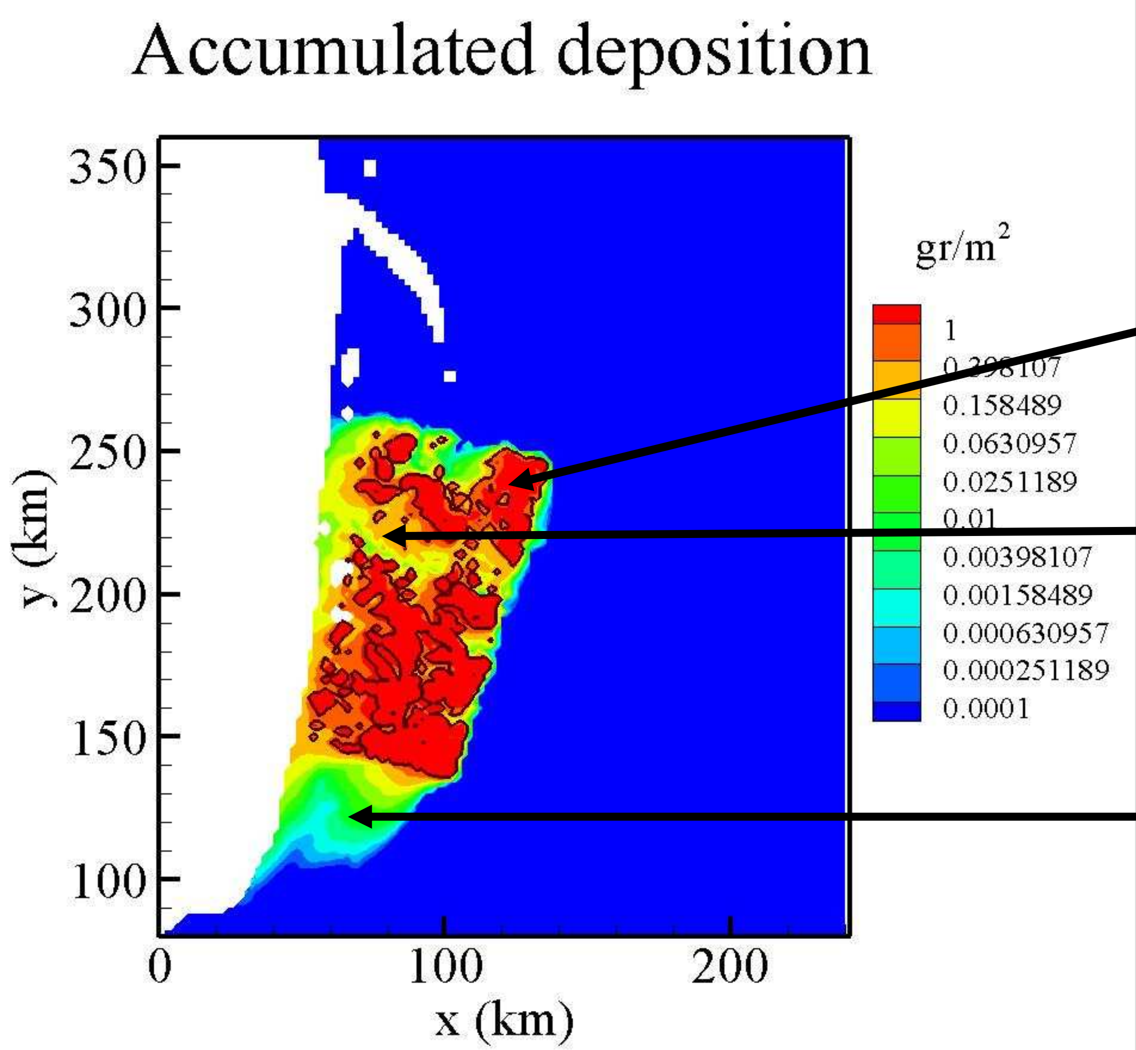
Regional scale: long-distance dispersal

Pollen viability



Regional scale: long-distance dispersal

Pollen deposition



large deposition over maize areas

"background levels" in enclosed regions

steady decrease outside of maize region

Conclusion

- A range of atmospheric models

- Inclusion of particle transport and transformation

- Possible use in all domains of Aerobiology:
  - pollen transport (GMO, biodiversity, allergies…)
  - pathogens (spores, fungi…)
  - dust, sand…
  - microbes

- Inclusion of microbial aerosols to be done

Merci