Modélisation couplée de la dispersion et des échanges de polluants
Le model FIDES

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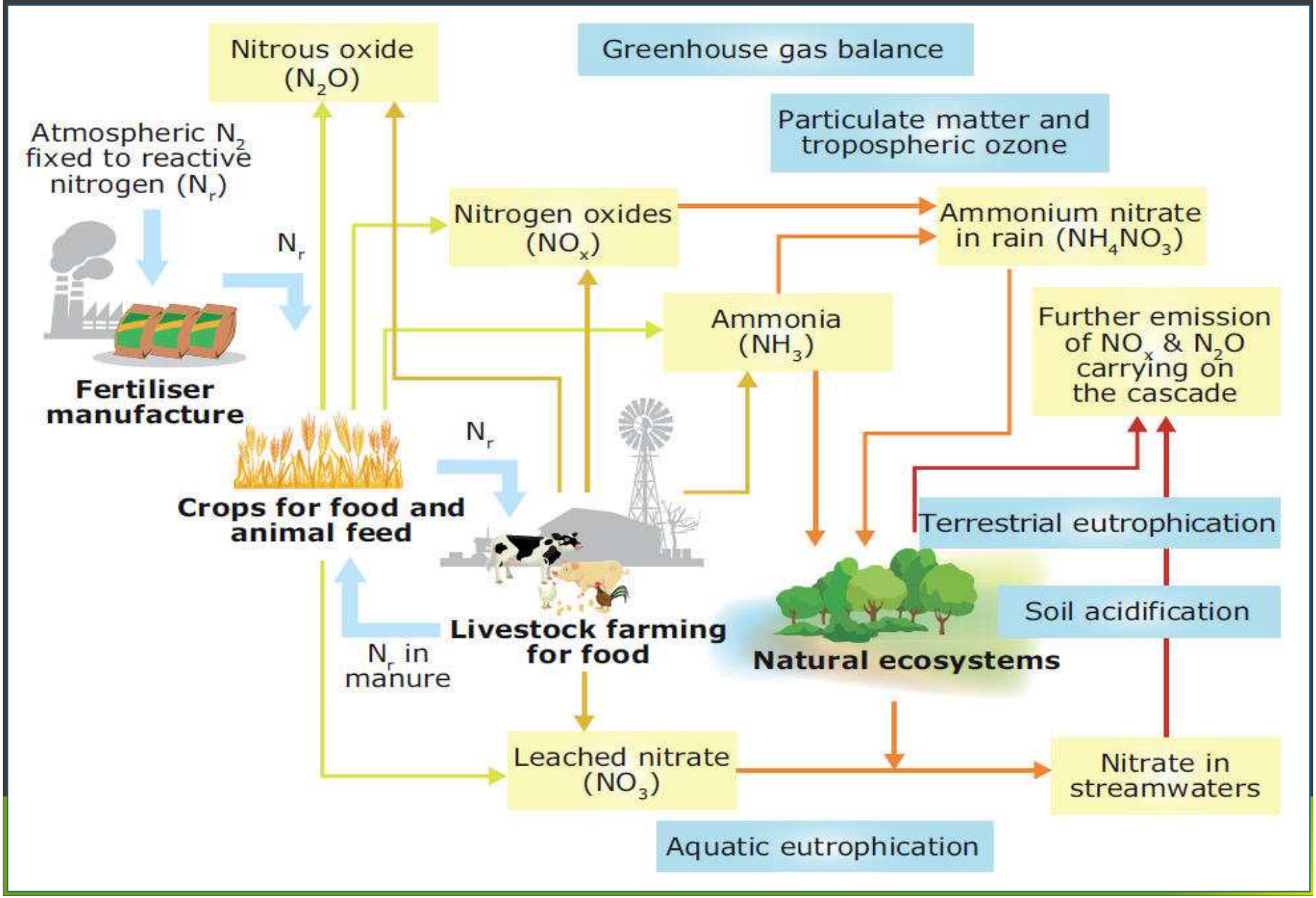
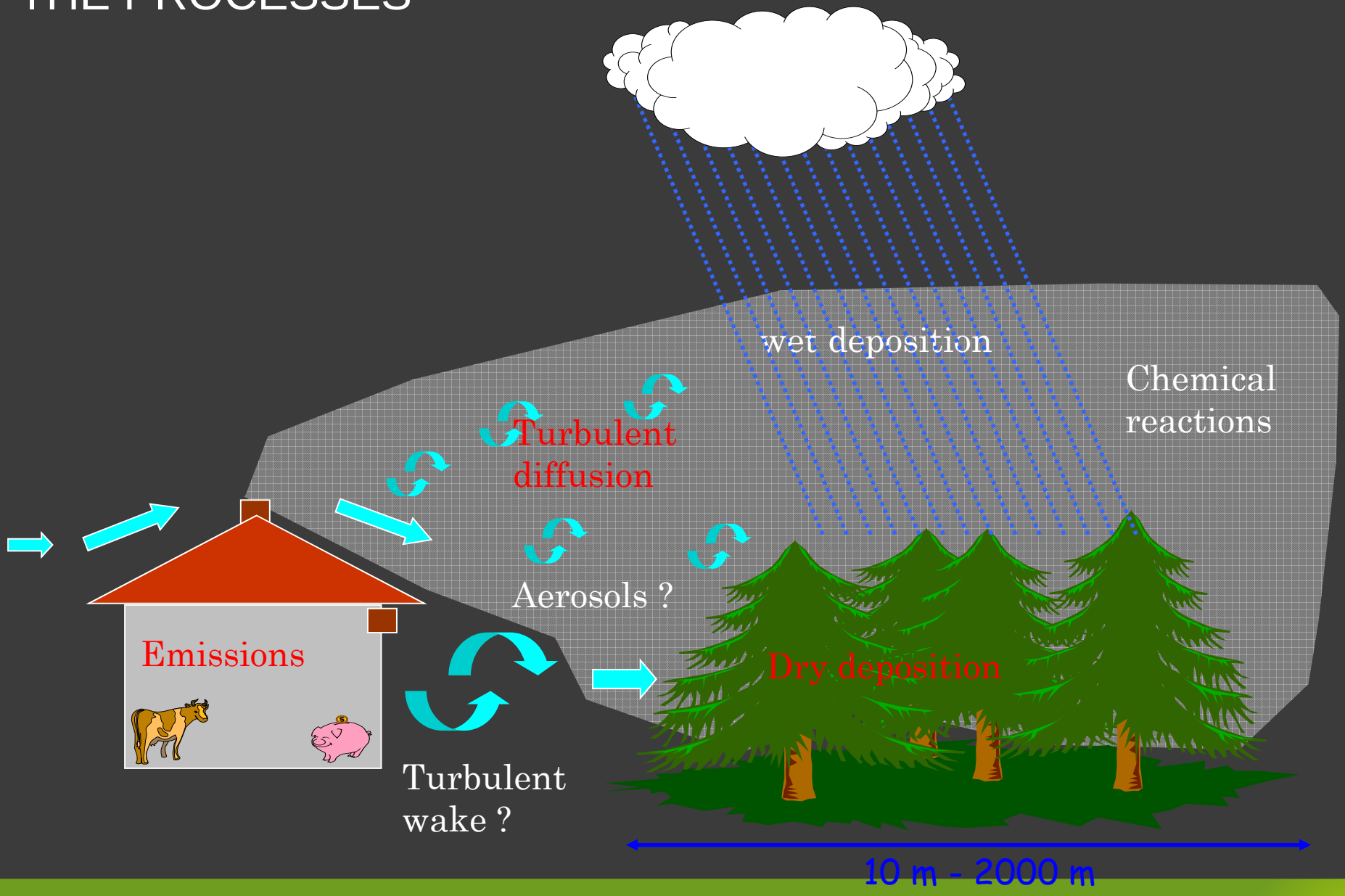
Context

THE NITROGEN CASCADE

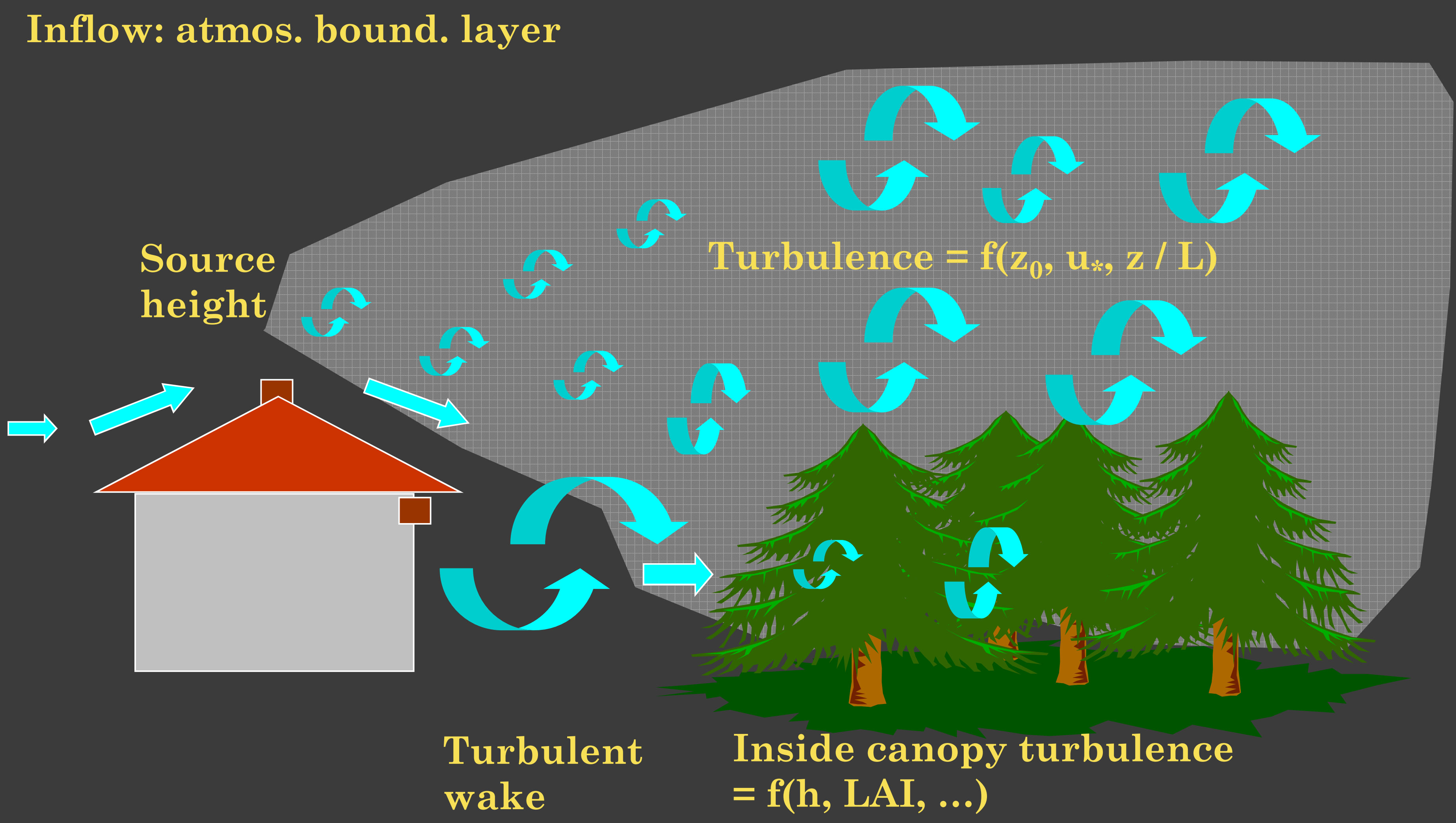


THE PROCESSES



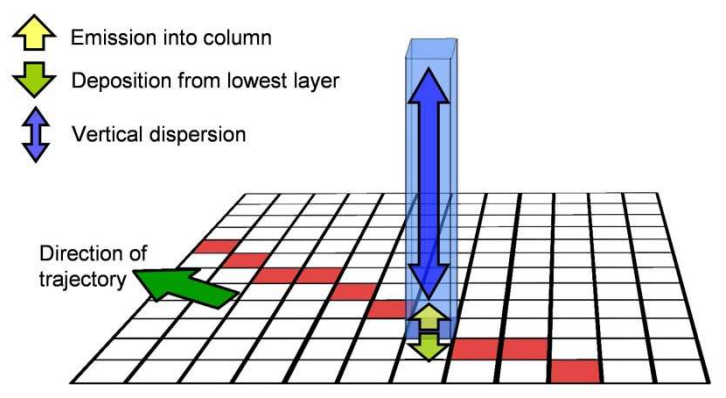
Dispersion modelling

ATMOSPHERIC DISPERSION IS KEY

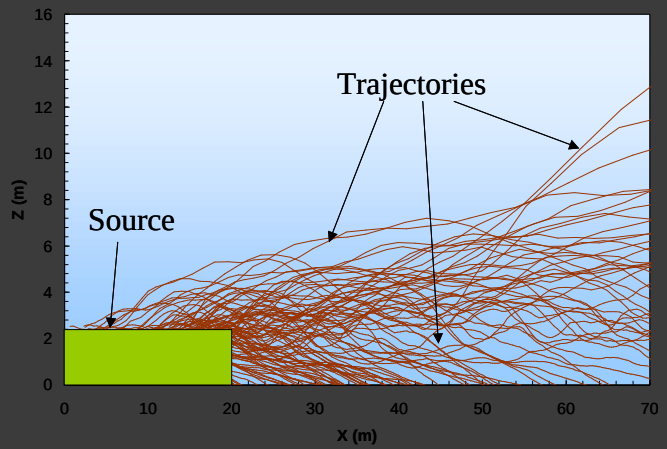


THE EXISTING DISPERSION APPROACHES

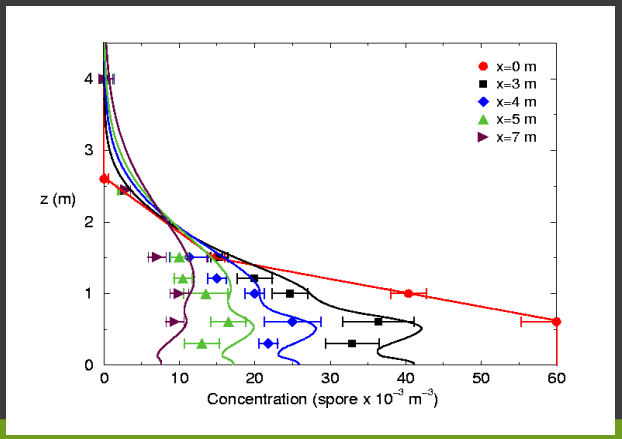
Air column + diffusion



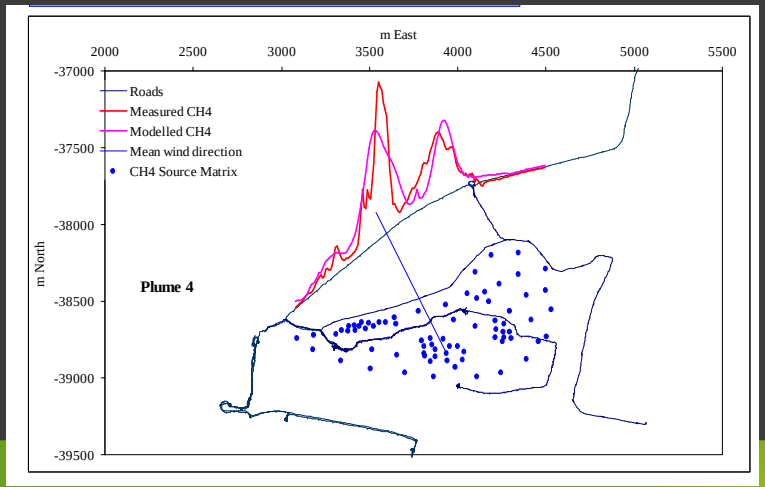
Lagrangian Stochastic and Randomn walk



High order Eulerian



Gaussian



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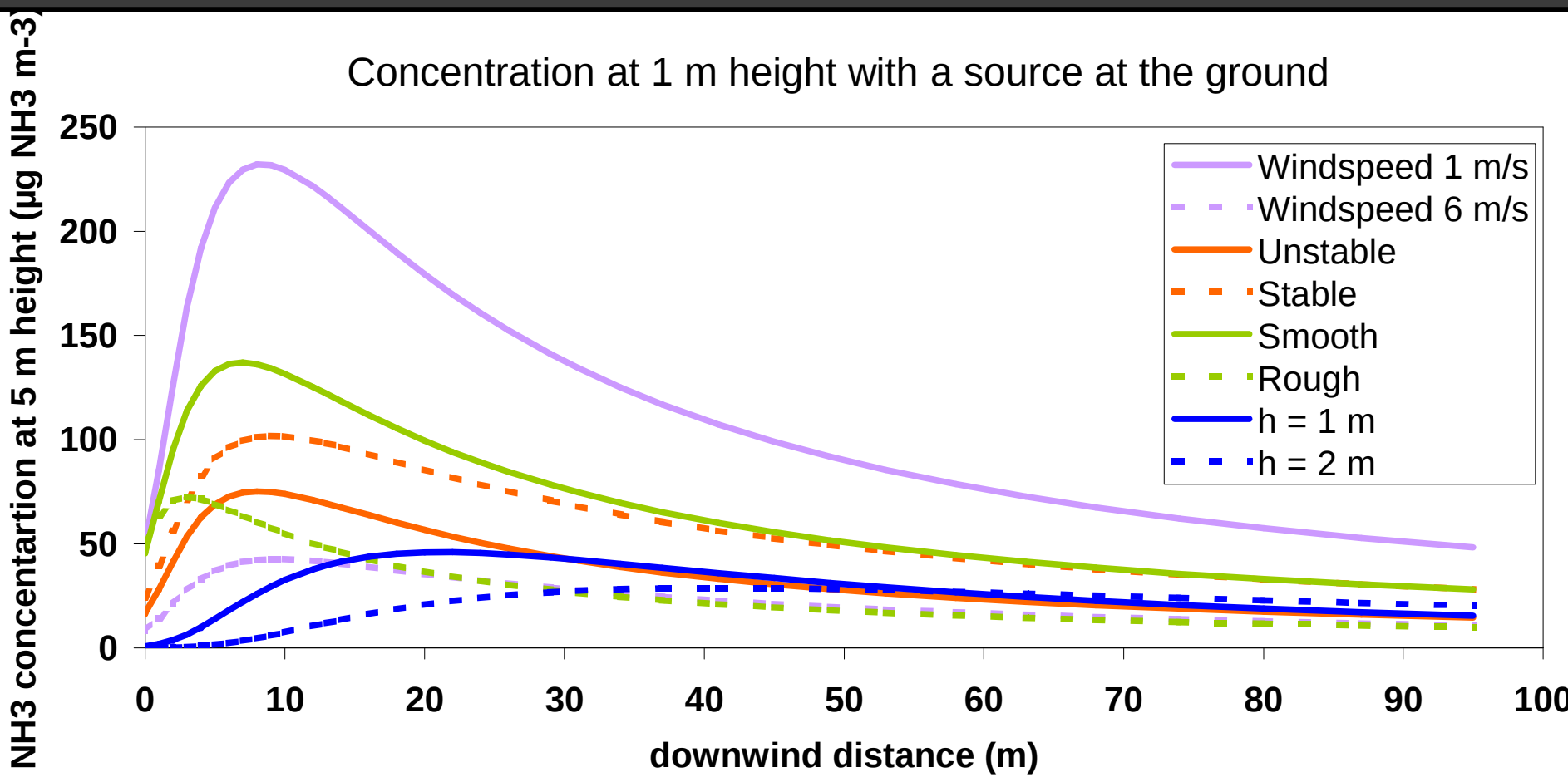
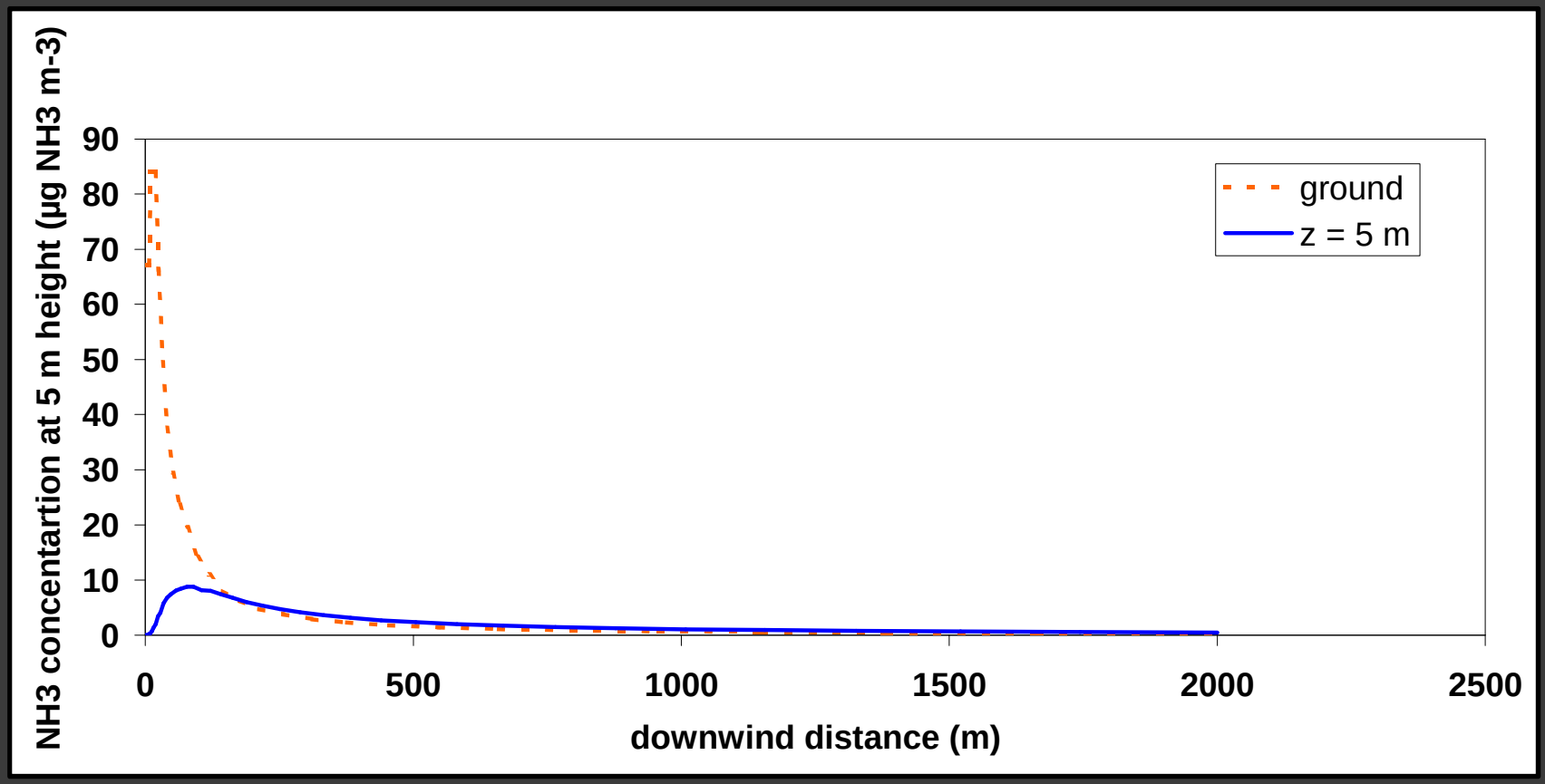
MAJOR PARAMETERS INFLUENCING LOCAL DISPERSION



FIDES model. Loubet et al., 2001

LARGE VERTICAL GRADIENTS LOCALLY!



Surface Exchange modeling

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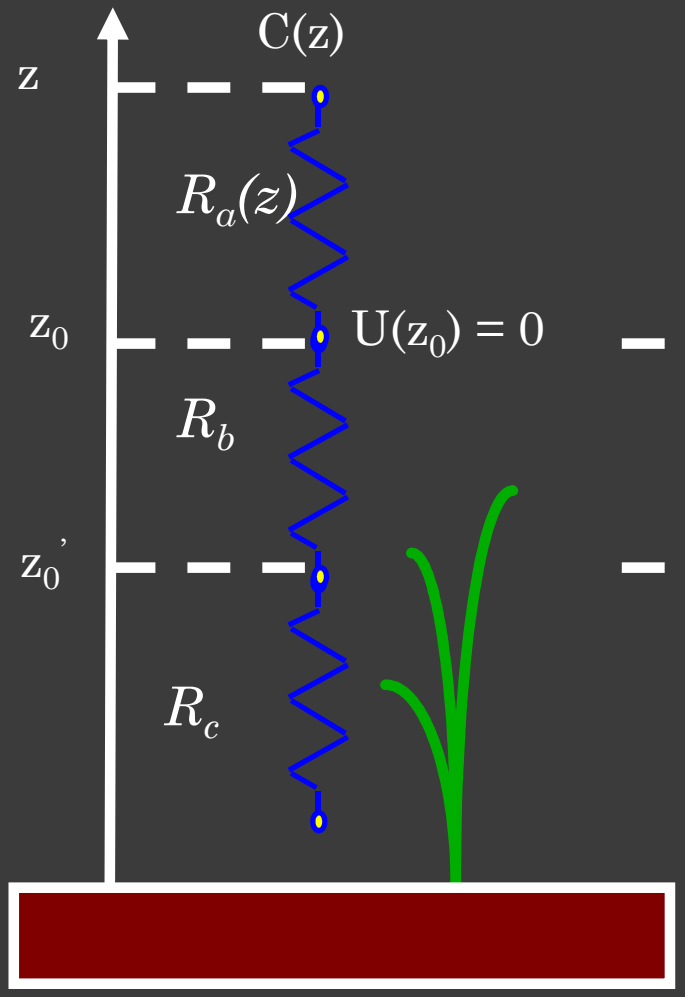
THE RESISTANCE APPROACH: BASICS



Subject to advection

$$R_a(z) = \frac{u(z)}{u_*^2}$$

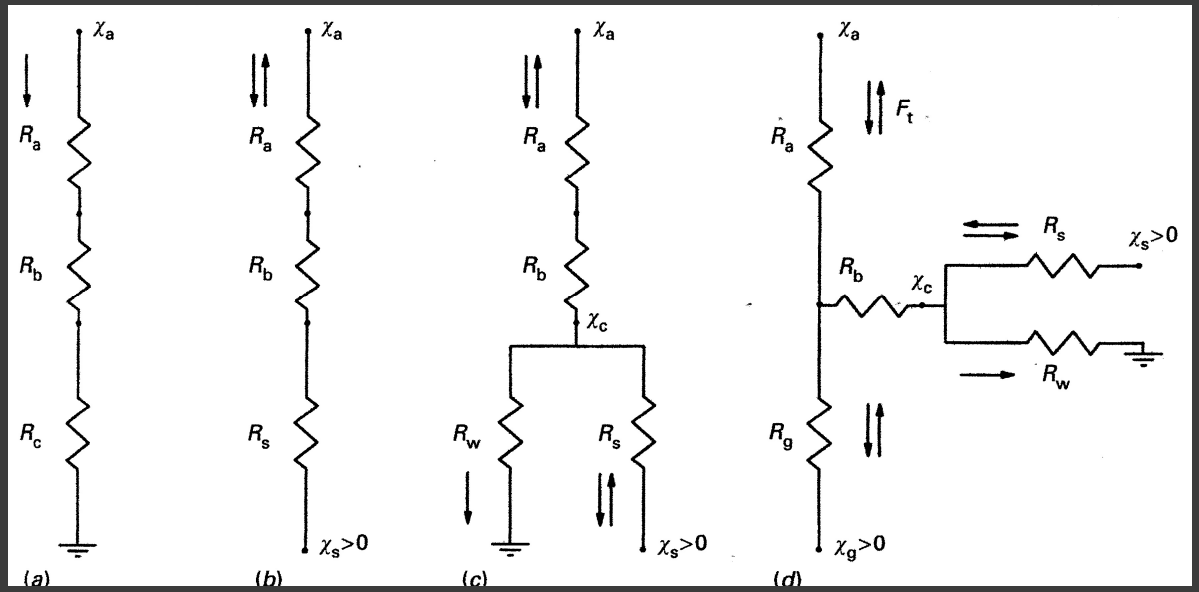
Not subject to advection

$$R_b = \frac{2(Sc/Pr)^{\frac{2}{3}}}{\kappa u_*}$$

Canopy resistance

THE RESISTANCE APPROACH: VERSATILE

Depending on the processes accounted for, several resistance-analog models:



V_d

Stomatal exchange

Cuticular & stomatal exchange

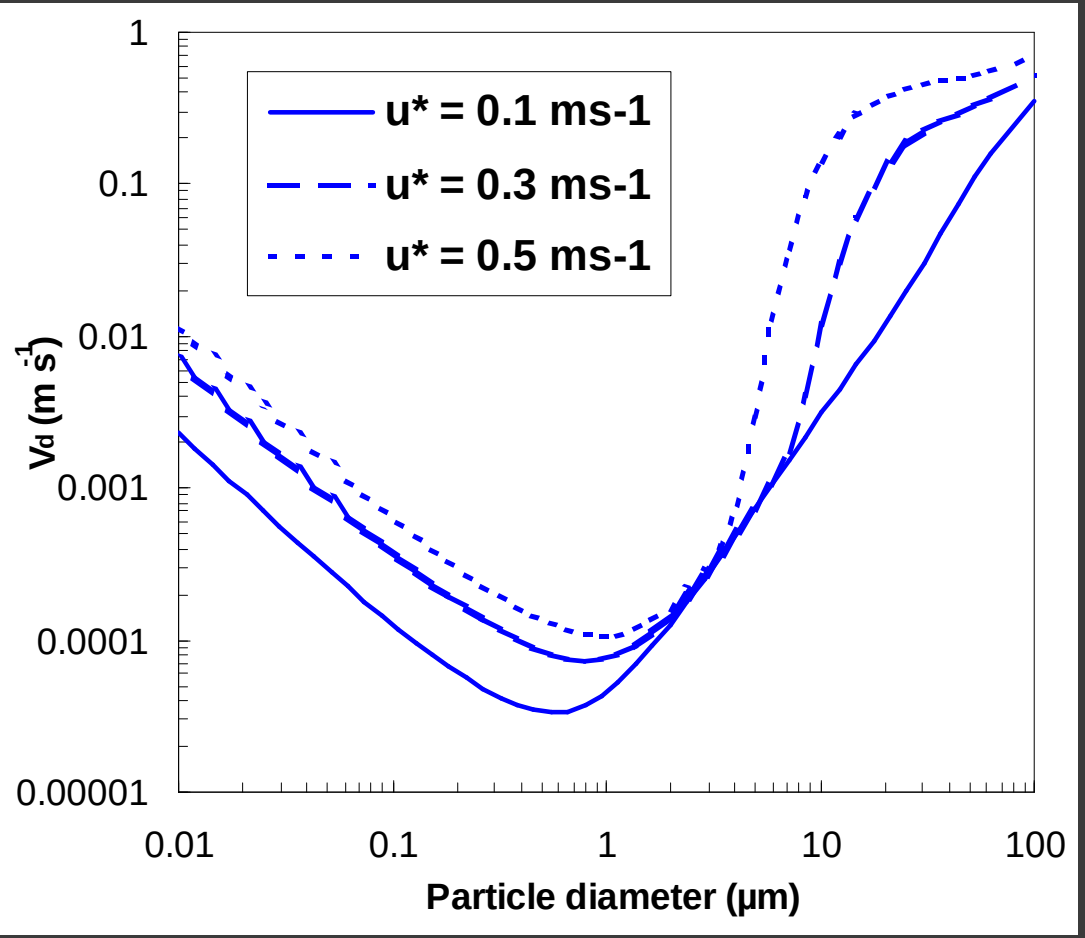
Two-layer Cuticular & stomatal exchange

THE RESISTANCE APPROACH: AEROSOLS

$$V_d = V_s + \frac{1}{R_a(z_{ref}) + R_{bpart}}$$

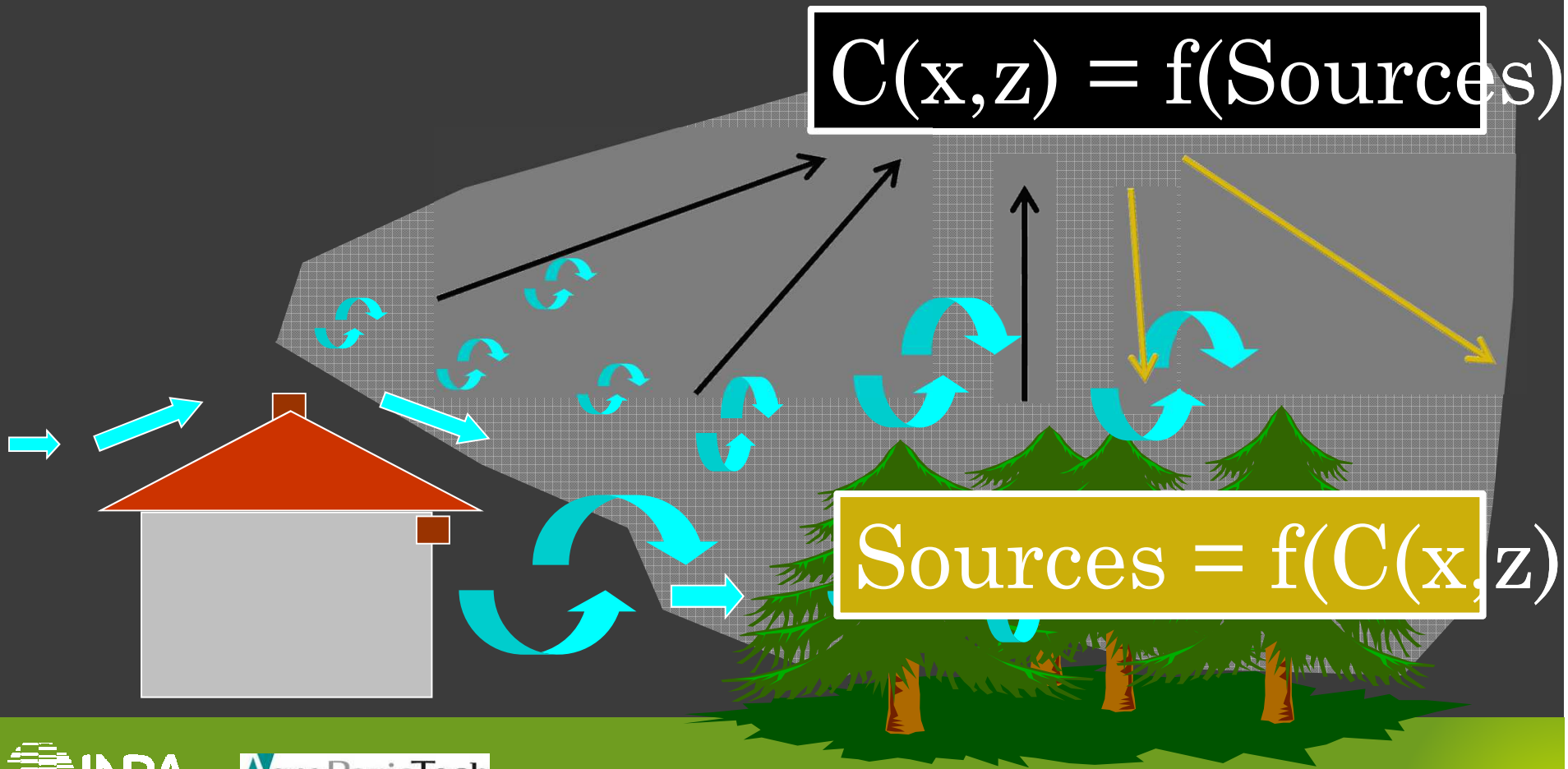
Also an effect
on the diffusivity !

$$K_z^P = \frac{K_z}{\sqrt{1+\left(\frac{\beta \cdot V_s}{\sigma_w}\right)^2}}$$



Coupling dispersion and exchange

HOW TO COUPLE DISPERSION AND DEPOSITION



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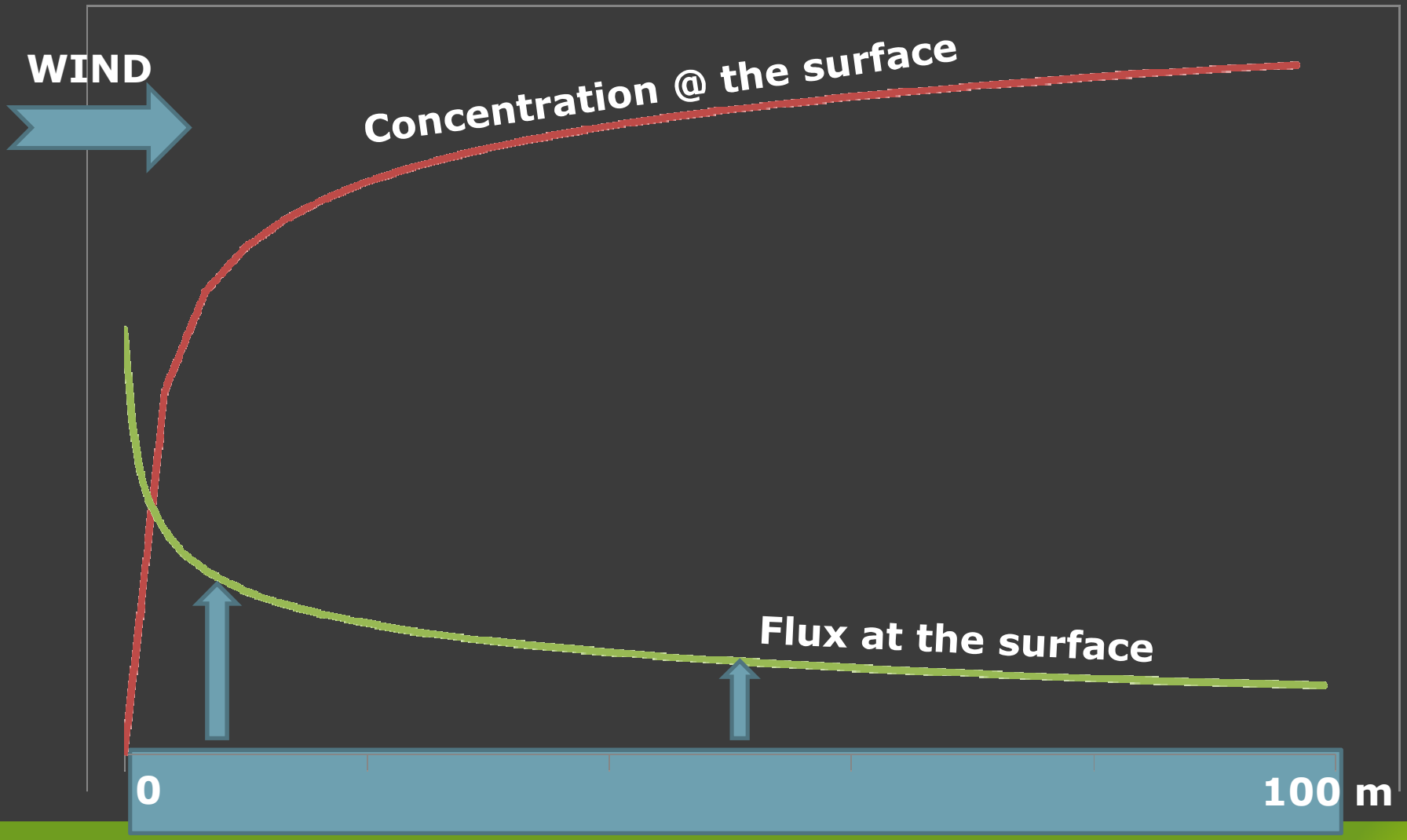
AN EXAMPLE: THE OASIS EFFECT



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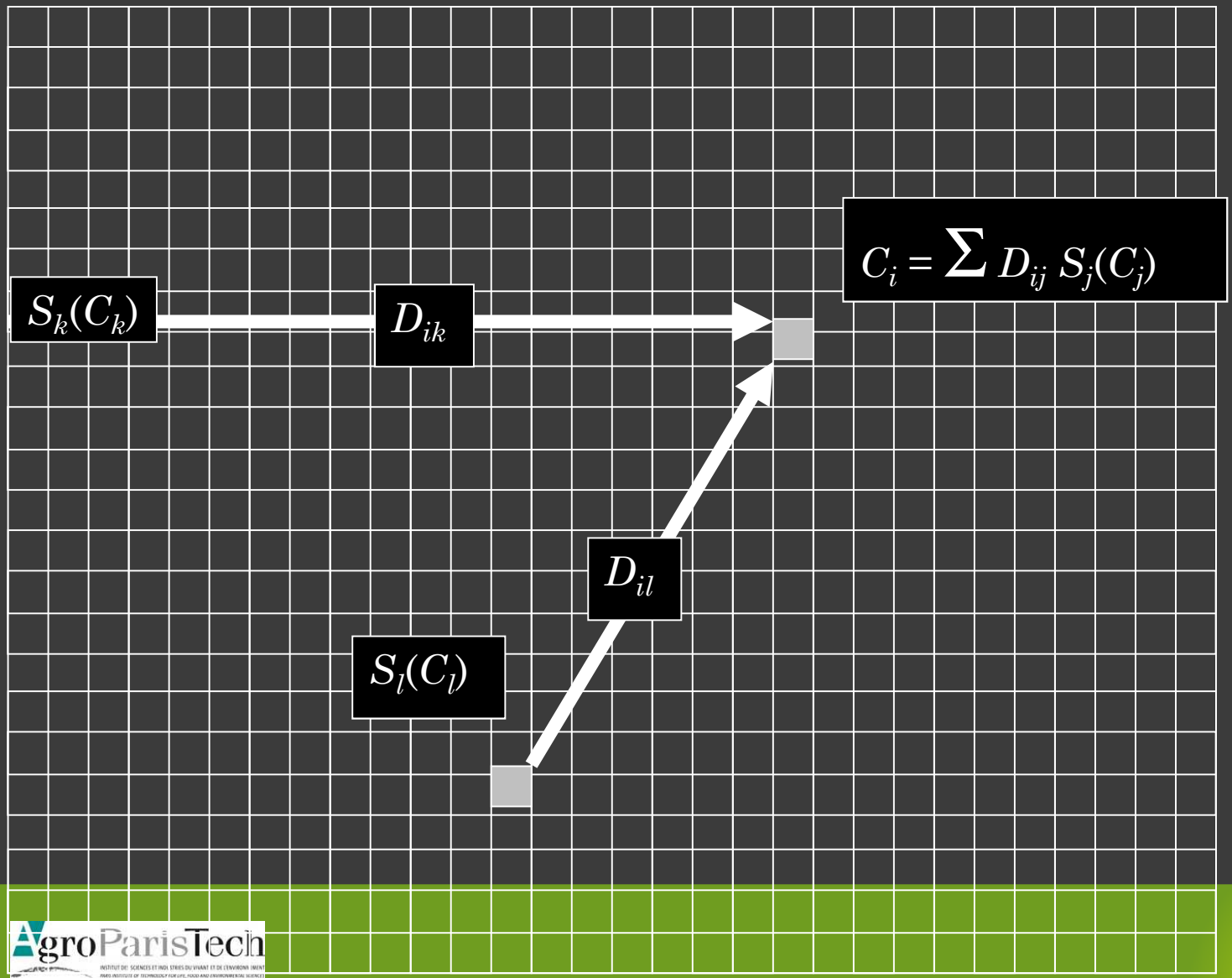
THE CONCEPT USED IN THE FIDES MODEL



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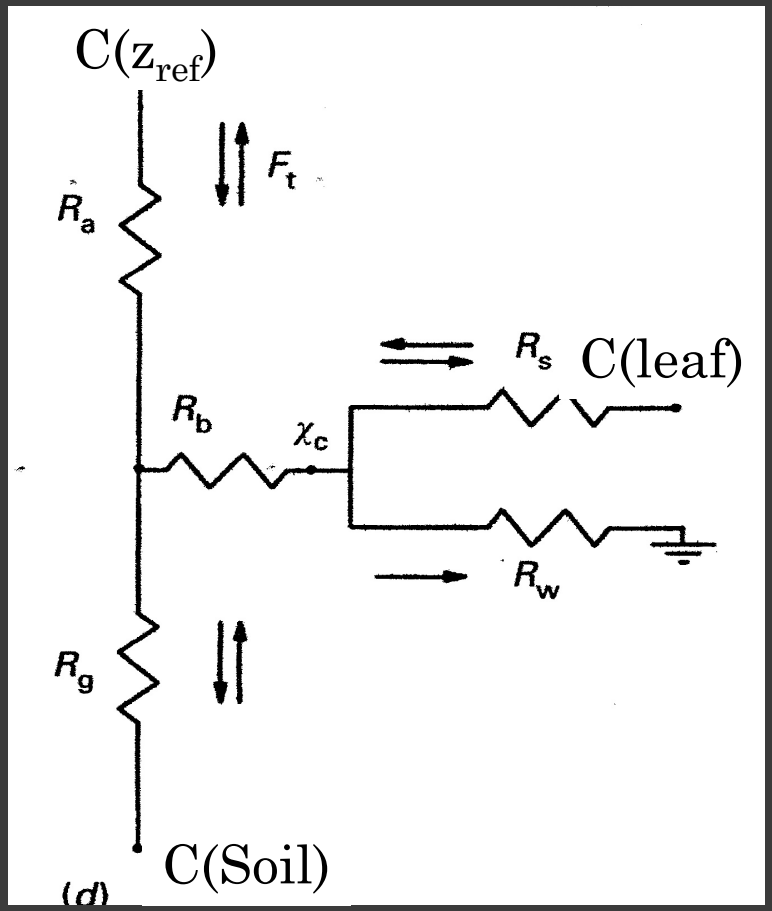
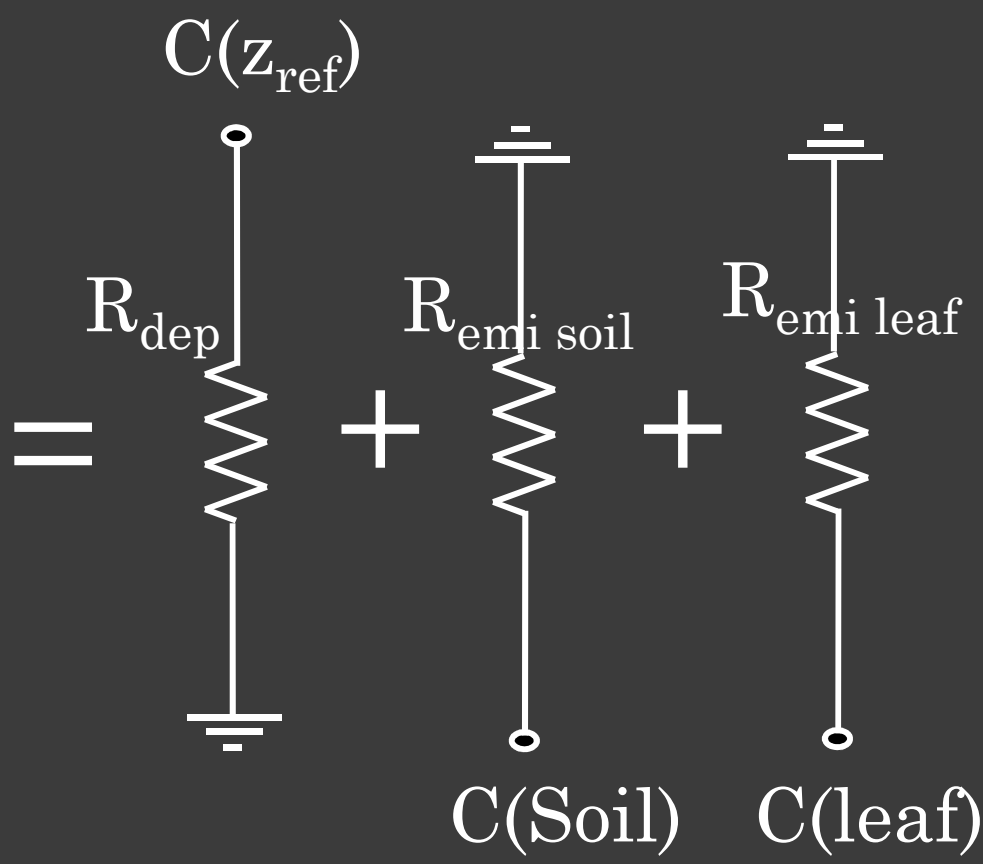
THE KEY: DECOUPLING EMISSION AND DEPOSITION





THE DISPERSION EQUATIONS IN FIDES

a) Advection-diffusion equation

$$U(z)\frac{dC(x,z)}{dx} = -\frac{d}{dz}\left[-K_z(z)\frac{dC(x,z)}{dz}\right] + S(z)$$

b) Assumption of power-law profiles for U(z) and K(z)

$$U(z) = a(z - d - z_o)^p$$

$$K_z(z) = b(z - d - z_o)^n$$

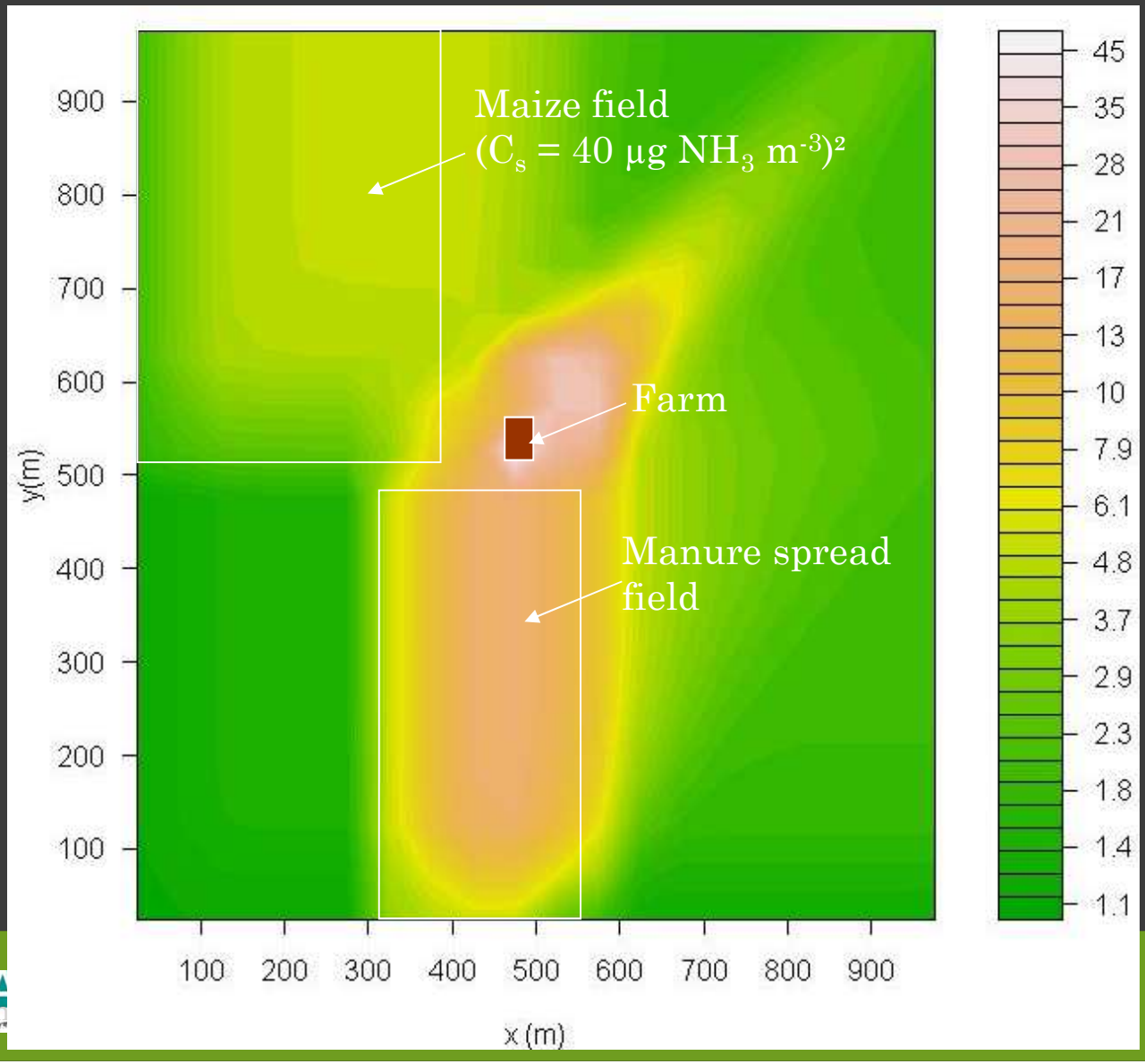
c) Analytical solution (see e.g. Huang, 1979)

$$C(x,z) = \frac{Q \cdot A}{x^{\beta}} exp\left[-\frac{Z^{\alpha} + Z_s{}^{\alpha}}{c \cdot x}\right]$$

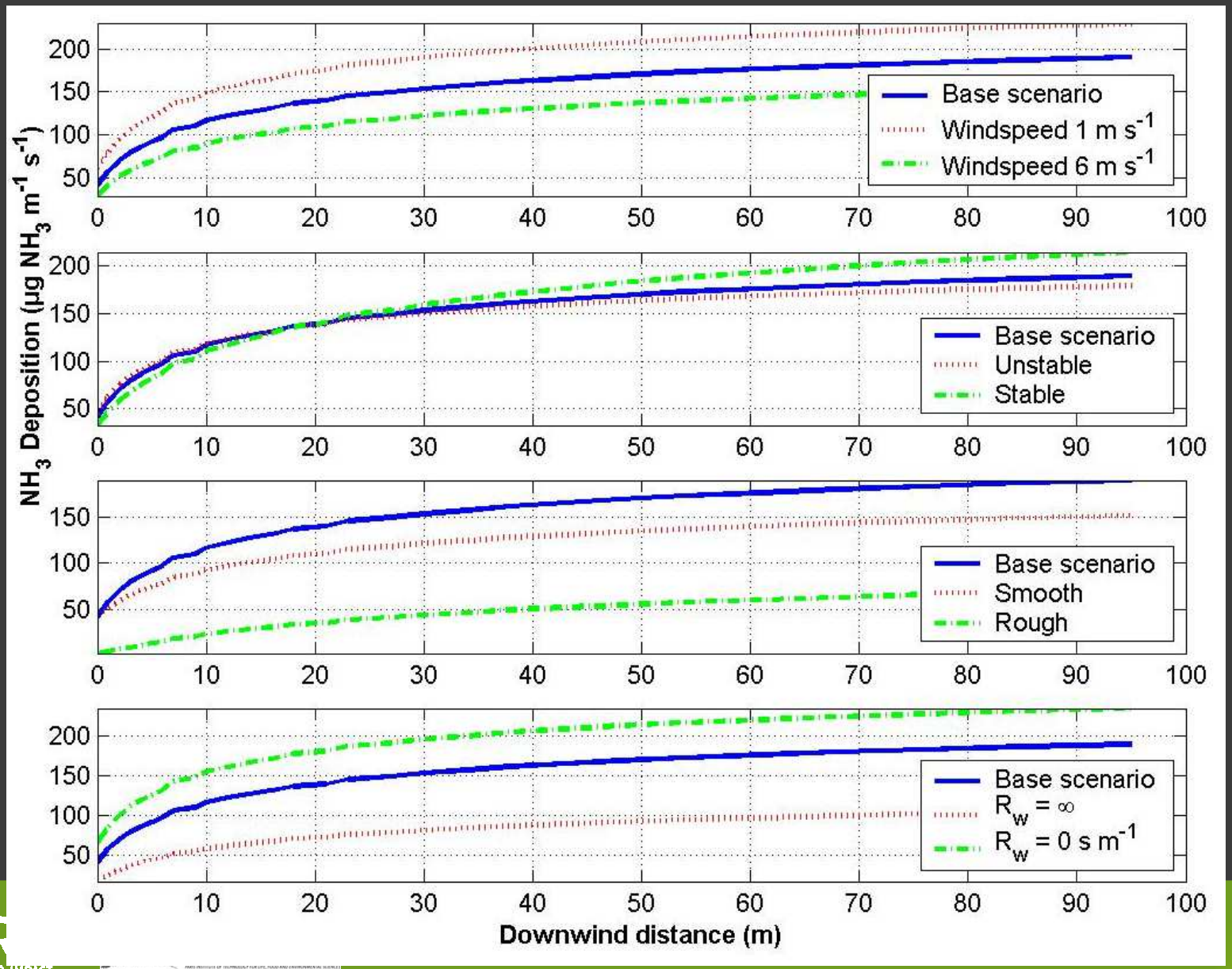
Q is the source term

EXAMPLE OUTPUT

NH_3 concentration arround a farm and its and its vicinity ($\mu g\ NH_3\ m^{-3}$)



EFFECT OF ENVIRONMENT AL PARAMETERS ON LOCAL DEPOSITION



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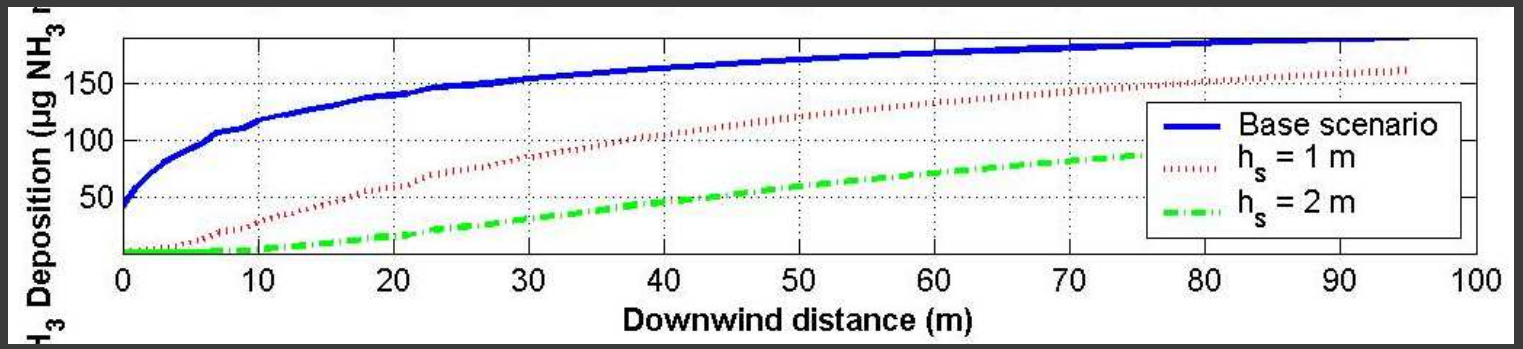
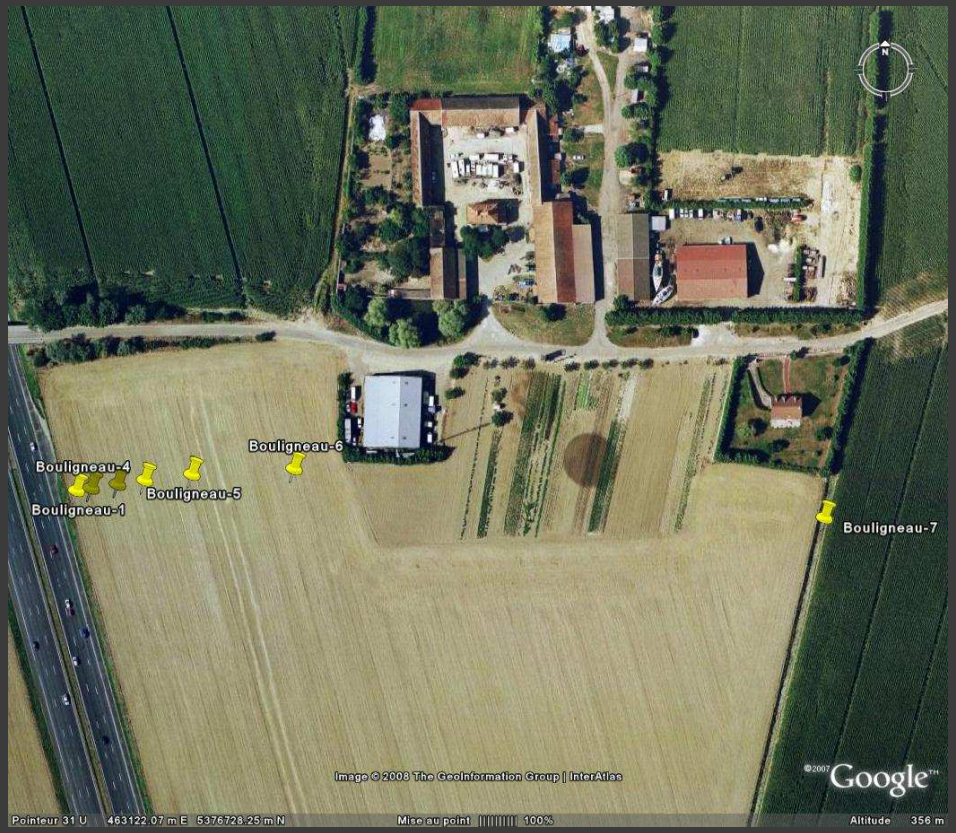


Example use of FIDES

DRY DEPOSITION NEAR A HIGH TRAFFIC ROAD



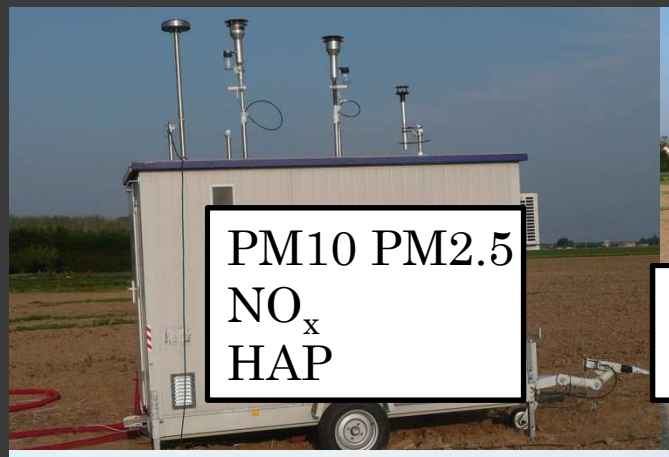
A6 highway
15 September and 13 October 2008.
73200 vehicles per day (**10300 trucks)**

$$v_d = \frac{1}{R_a + R_b + R_c}$$

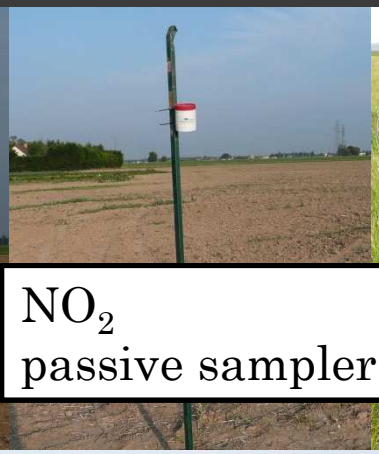
$$v_d = \frac{1}{R_a + R_b + R_a R_b v_g} + v_g$$

NOx and PM measurements
plants and inert plates receptors 9-m to 284-m

DRY DEPOSITION NEAR A HIGH TRAFFIC ROAD

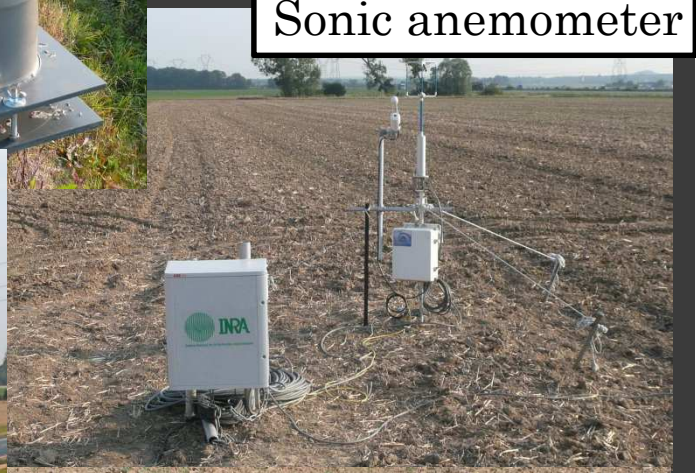


PM10 PM2.5
NO_x
HAP



NO_2
passive sampler

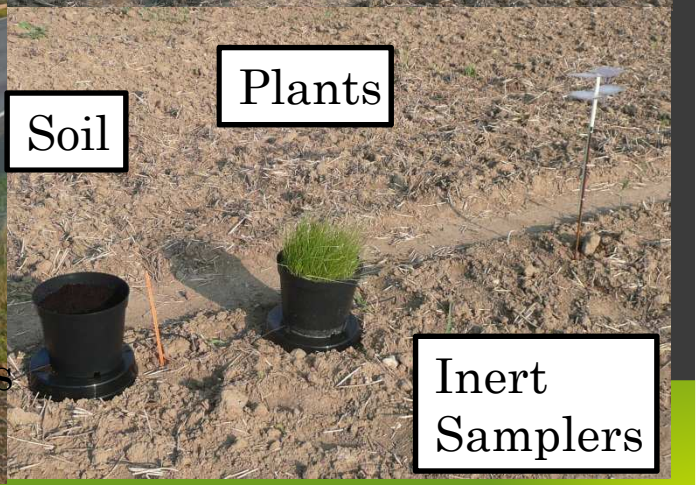
Wet deposition



Sonic anemometer

Site

A6 highway : 73200 vehicles per day. 10300 trucks



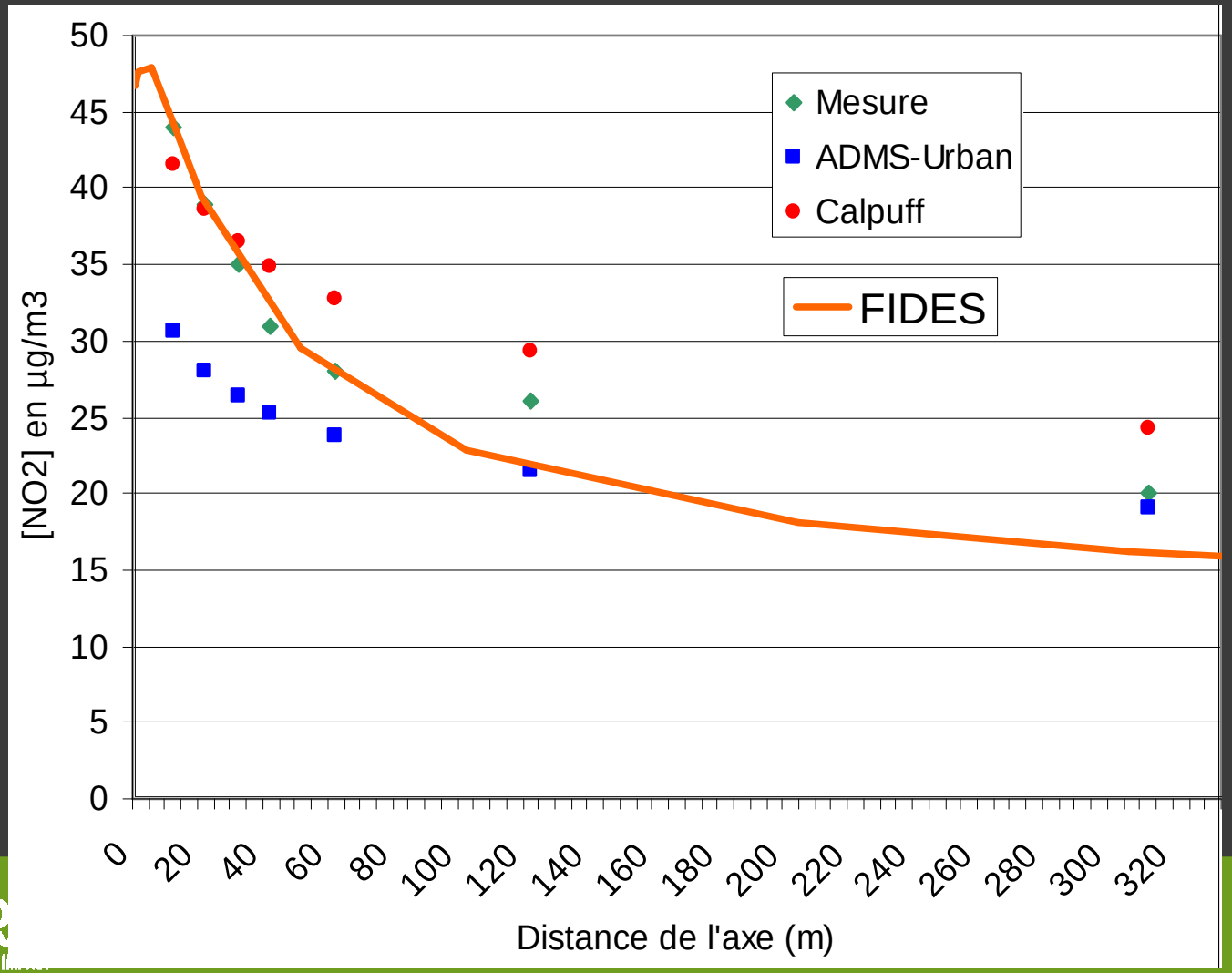
Soil

Plants

Inert Samplers

DRY DEPOSITION NEAR A HIGH TRAFFIC ROAD

modelled and measured NO_2



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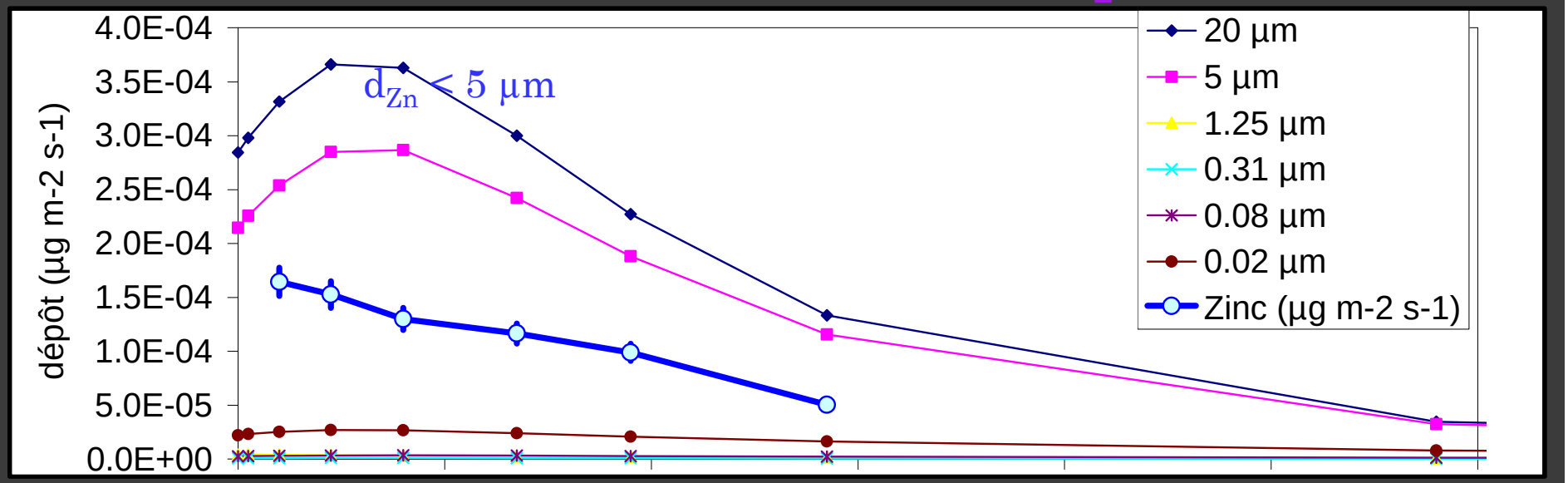
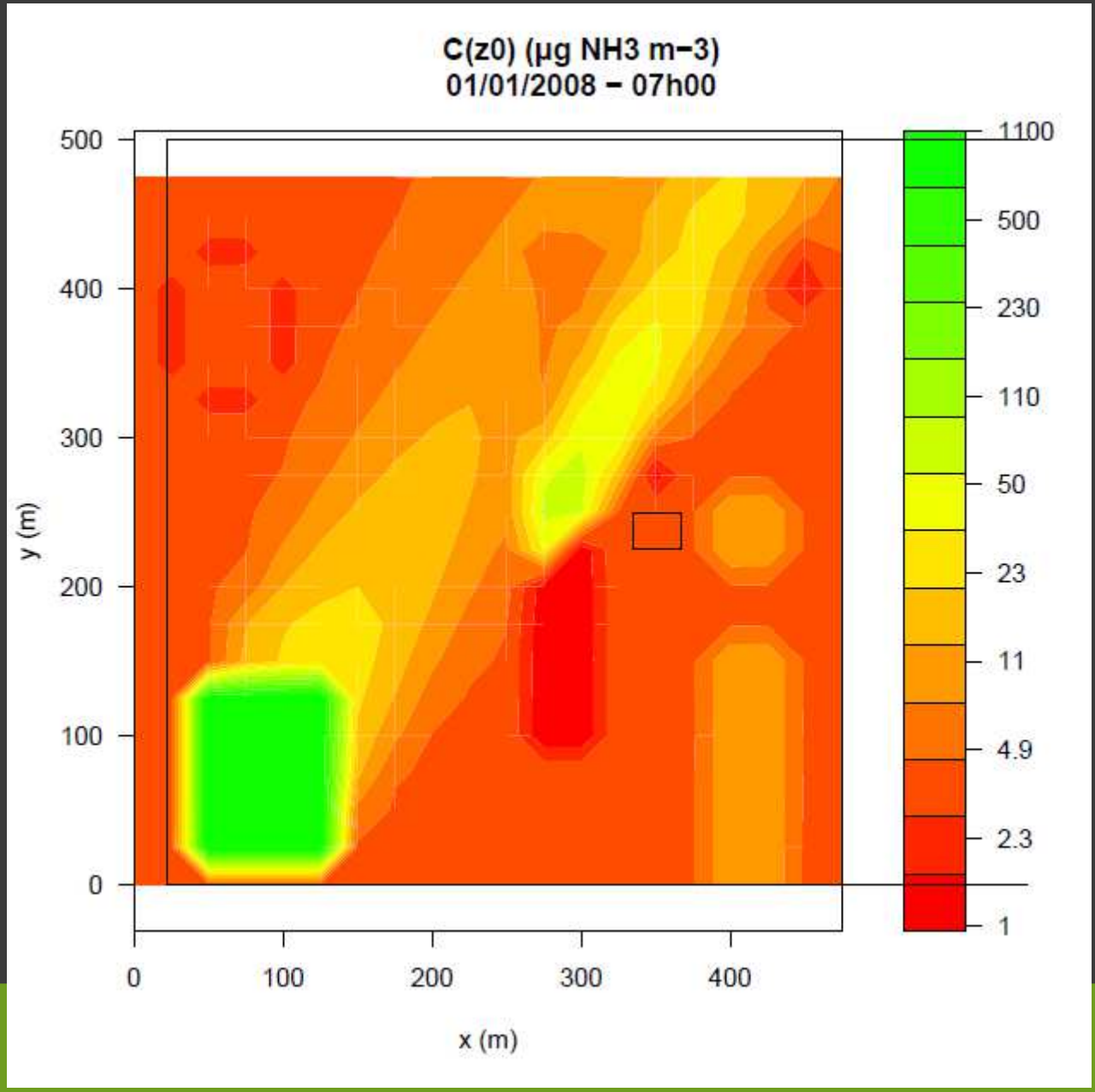
DRY DEPOSITION NEAR A HIGH TRAFFIC ROAD

modelled and measured metal deposition



Pb, Cr and Cd → dominated by **re-suspended matter** rather than emissions from vehicles

COMPLEX LANDSCAPE



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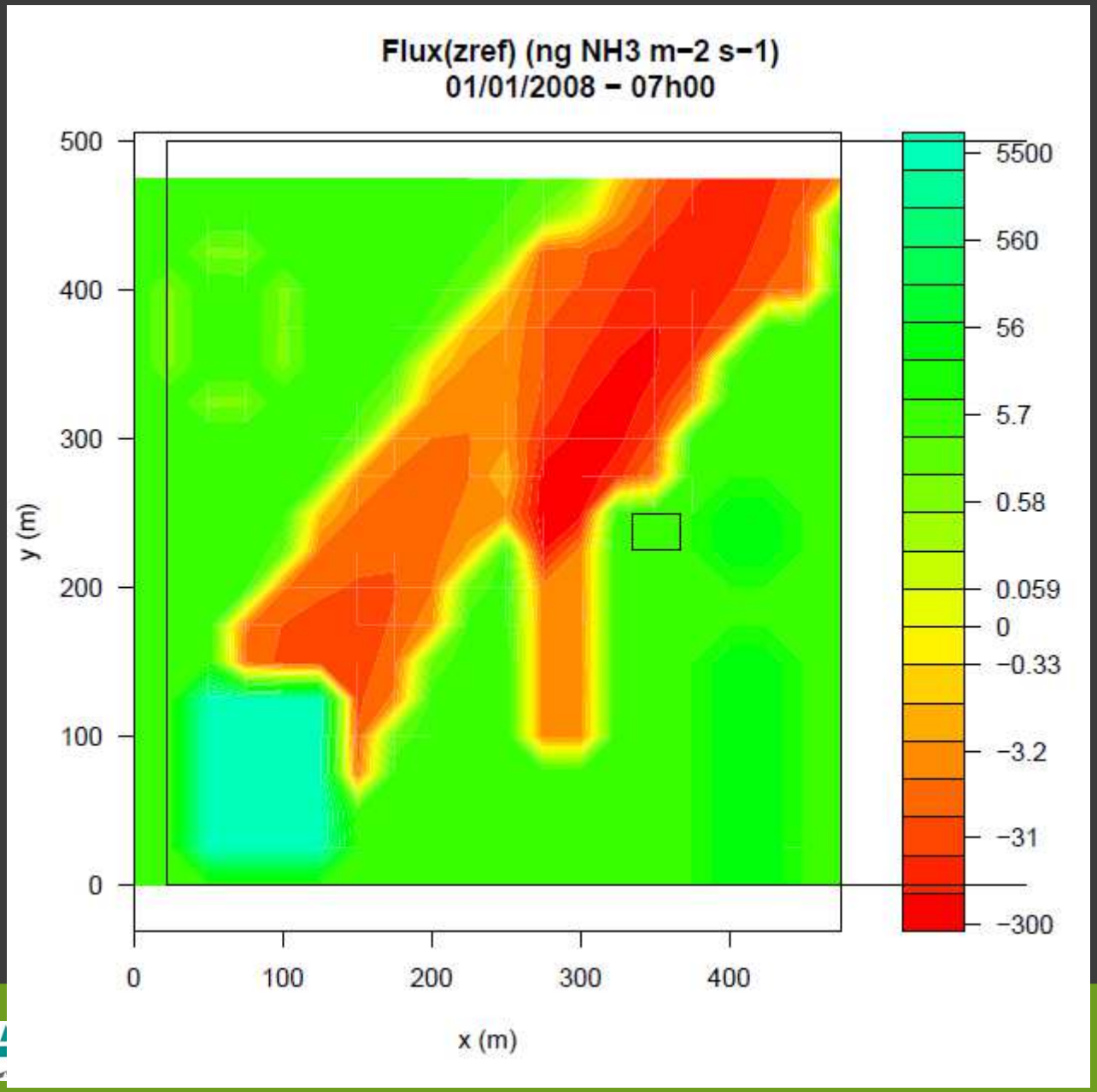
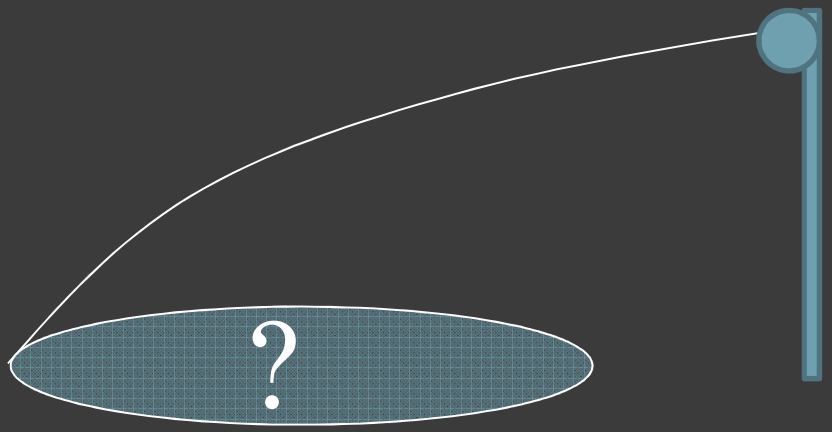
COMPLEX LANDSCAPE

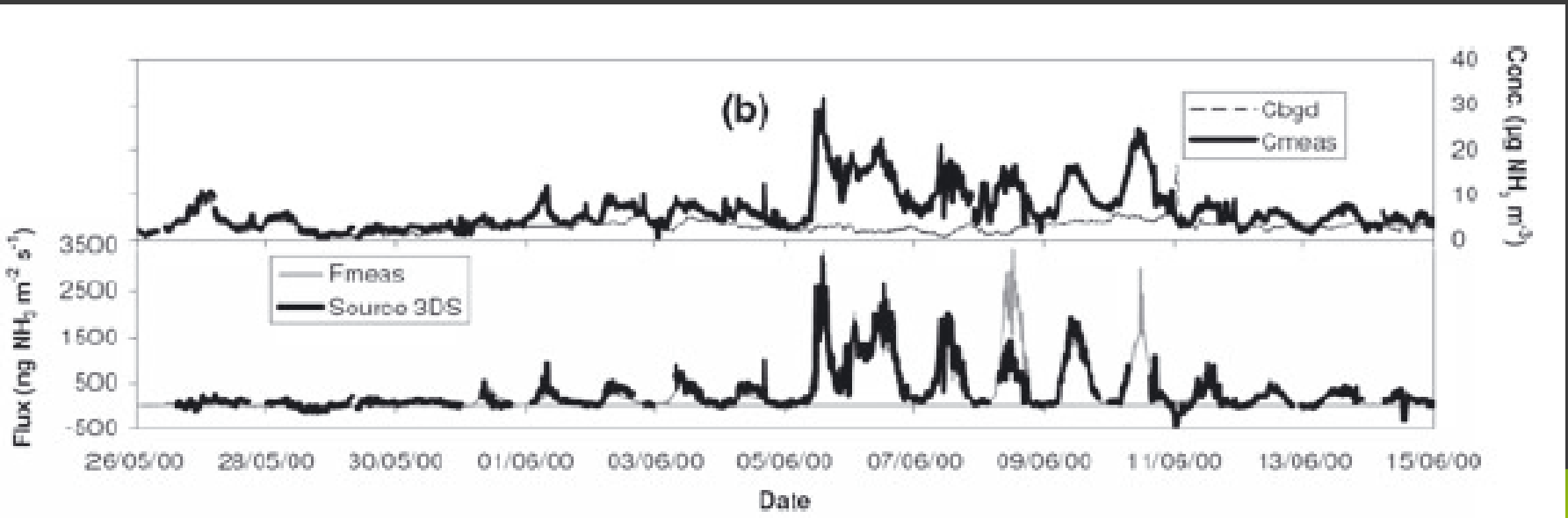


INVERSE DISPERSION MODELLING



Concentration Measured

Emission inferred



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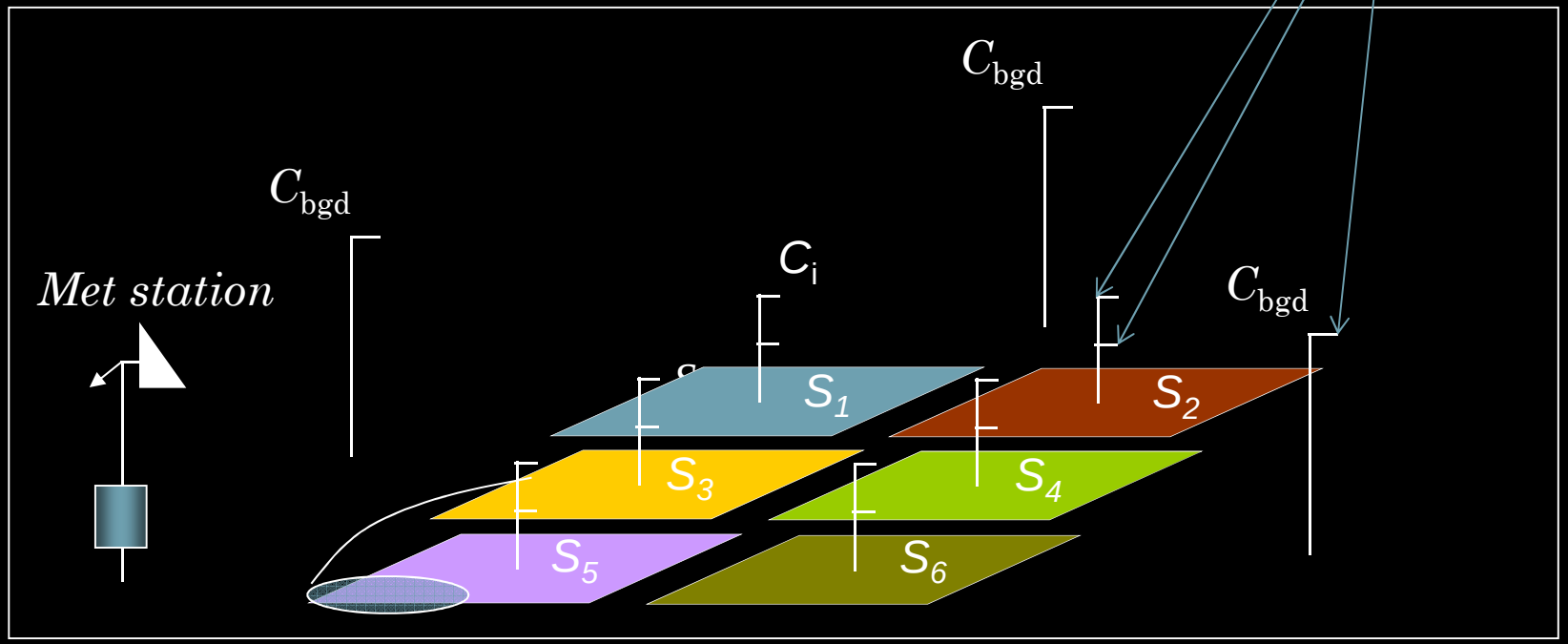
INVERSE DISPERSION MODELLING

Inversion with multiple sources

Loubet et al. 2001, 2009, 2010. Carozzi et al. 2012



Conclusions

- Important de considérer le couplage dispersion/dépôt
- Composés ayant des flux bi-directionnels (NH_3)
- Différents projets en cours:
  - NITROSCAPE, OPEN-FLUID, NH_3, Pesticides

- Limites :
  - Hypothèses du modèle : Zo, U*, L constants
  - Mémoire et temps de calcul pour des domaines larges

- Approches de découplage des dépôts et émissions
  - Prise en compte des échanges bi-directionnels dans une approche type big-leaf

  - Applicables à des échelles plus larges

MERCI

FIDES disponible

- 2D : sous excel / VB pour des cours
- 3D : Matlab / R / C++

Google : INRA ECOYS
Google : LOUBET INRA