Validation of aerosols dry deposition velocity models with new experimental data

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Aerosol pollution in the atmosphere → impact on the health

impact on the ecosystem if deposition

The impact of the aerosol pollution on ecosystem must be evaluated

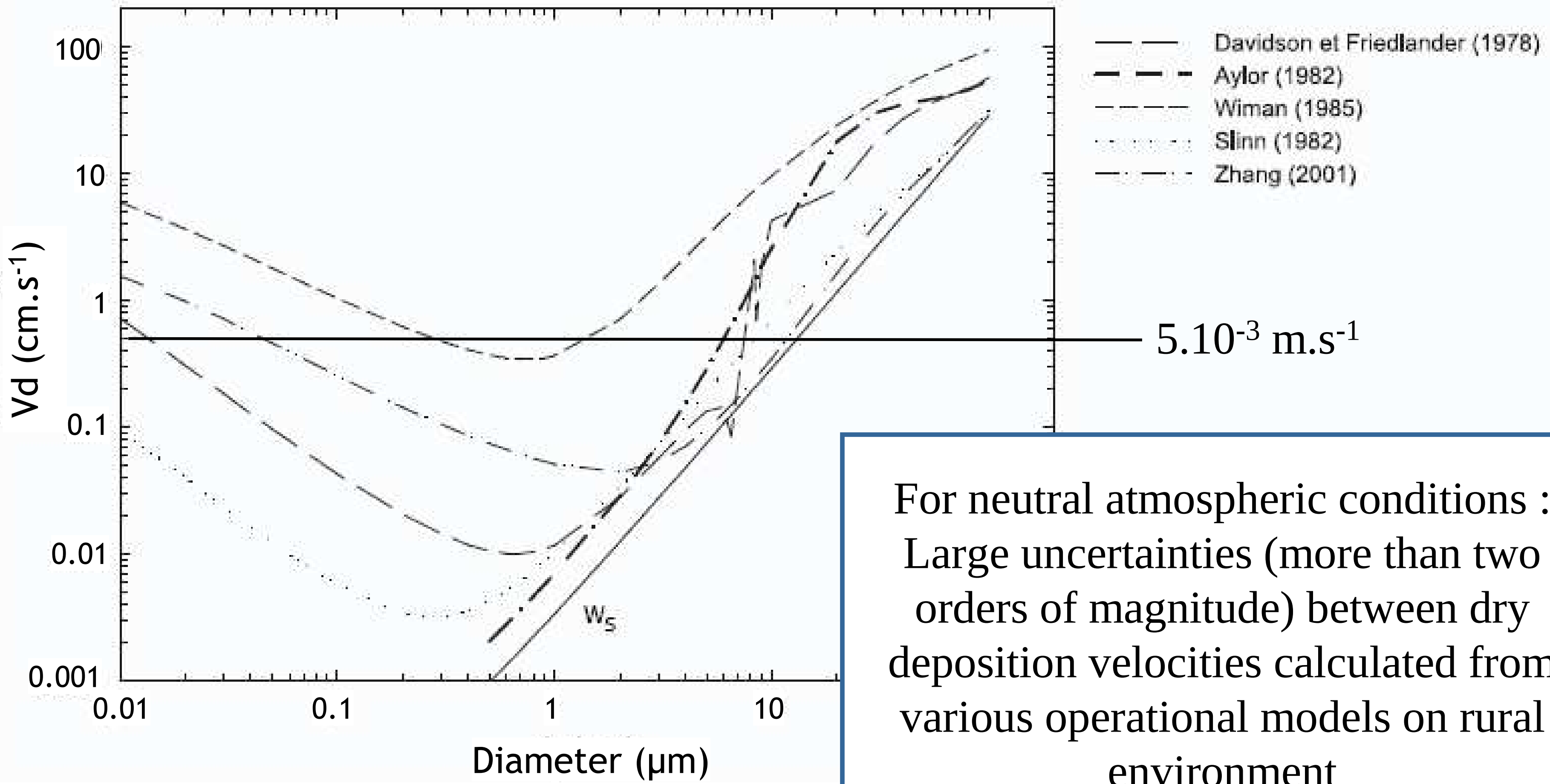
➡ We have to study some transfer functions of particles on vegetated canopies :

➡ ***the dry aerosol deposition velocity, Vd***

- Air quality prediction and accidental release need to know this parameter
- There are several models of aerosol dry deposition which take into account turbulence and particle size for a large range of sizes

But ……

Evolution of Vd in function of the aerosol size for different models



Alexandre Petroff (thesis, 2005)

For neutral atmospheric conditions : Large uncertainties (more than two orders of magnitude) between dry deposition velocities calculated from various operational models on rural environment

…..and for nanoparticles (<100nm), there is not enough reliable experimental data

→ ***Needing of experimental data on Vd***
- ***onto rural aeras***
- ***for different submicronic aerosol sizes***

Objectives of the work

→
- ***To develop a method to quantify dry deposition for submicronic aerosol : the Eddy Covariance method***
- ***To provide experimental data of the dry deposition velocity in a rural environment***
- ***To study the effect of micro-meteorology and aerosol size***
- ***To make comparison with 2 models : Slinn and Zhang et al.***

$$Vd = \frac{-F}{\overline{C}}$$

$$Vd = \frac{-\overline{W'C'}}{\overline{C}}$$

Choice of the experimental site:

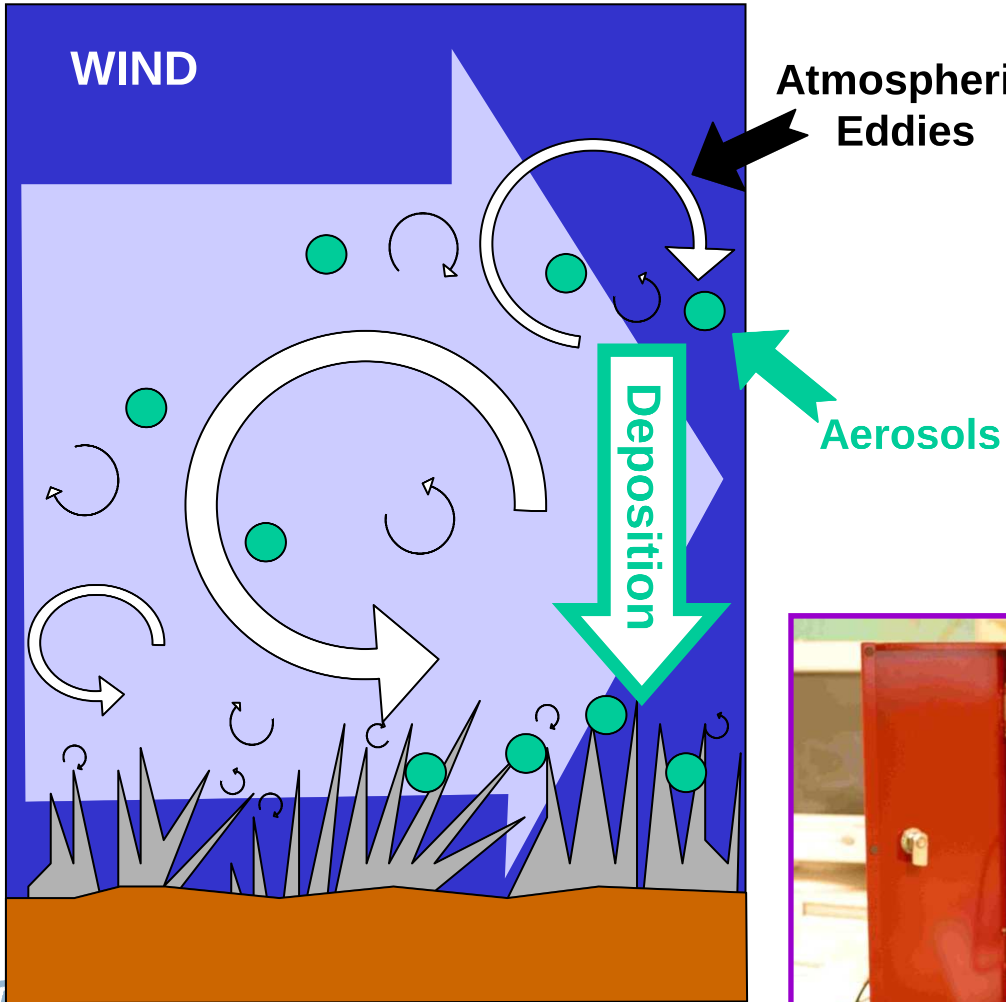
- Over a maize field
- Strong atmospheric stability variability between night and day

Main hypothesis for using EC:

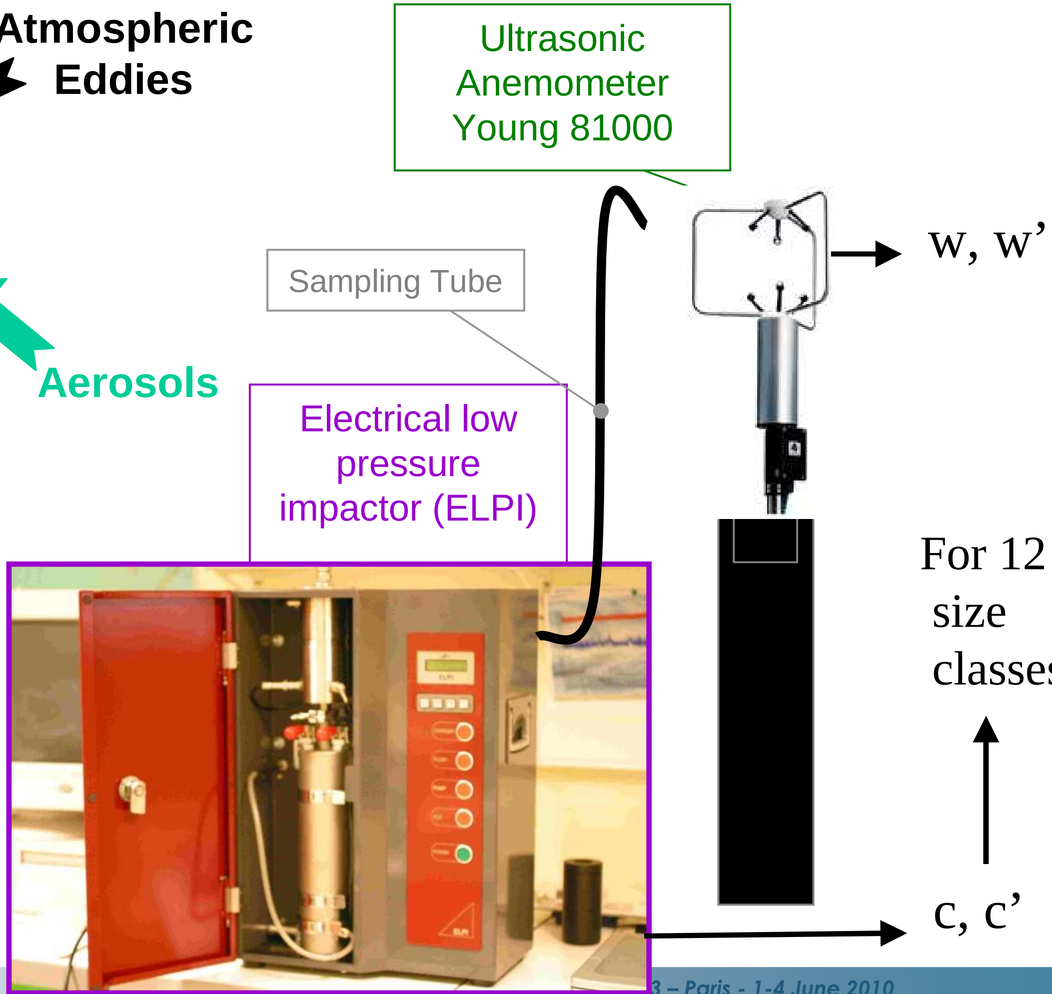
- Aerosol concentration stable for 30 min (no manmade sources)
- Horizontal homogeneity (fetch, footprint)
- Measurements in the constant fluxes layer

Eddy Covariance Method using atmospheric aerosols

Deposition mechanism

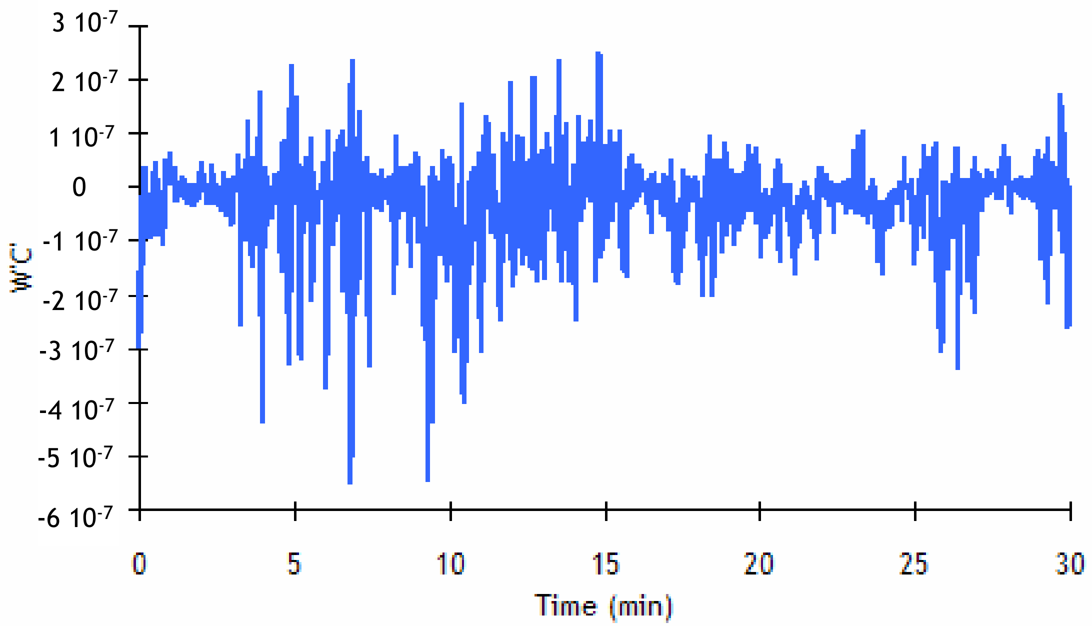


Turbulent fluctuation measurements



- w
- C

→ W'C' →



Vertical aerosol flux

$$Vd = \frac{-F}{\overline{C}} = \frac{-\overline{W'C'}}{\overline{C}}$$

For each 30 min period

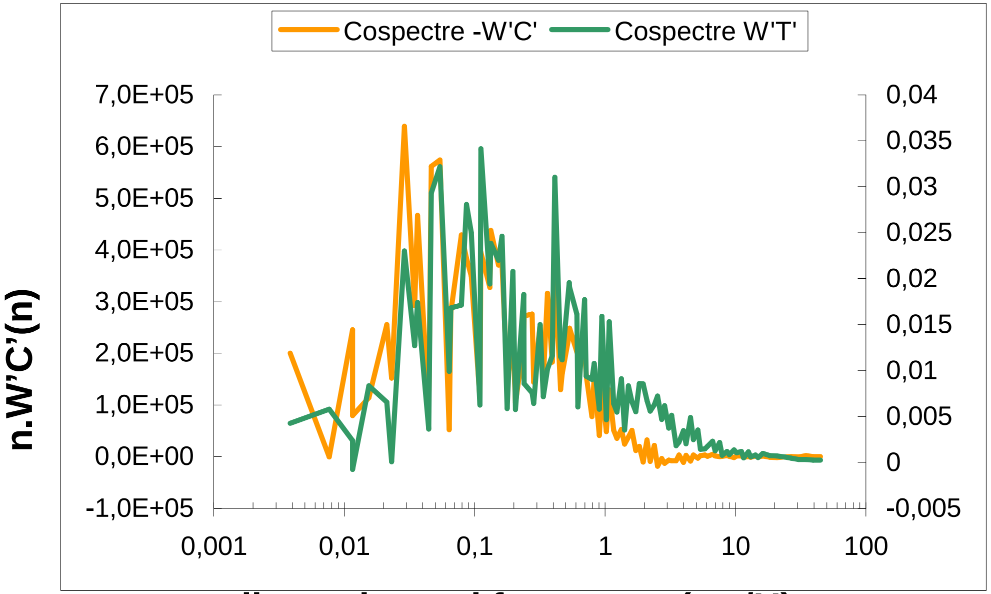
$\overline{w'c'} > 0$ for emission flux
$\overline{w'c'} < 0$ for deposition flux

Important data processing

See publication in *Journal of Aerosol Science* , ***40***, *1050-1058, 2009 :*
P. Damay, D. Maro, A. Coppalle, E. Lamaud, O. Connan, D. Hebert, M. Talbaut, M. Irvine
" Size resolved eddy covariance measurements of fine particle vertical fluxes",

- Data processing :
  - –Verticality correction (w=0)
  - –Filtration (to avoid the linearity between C and T)
  - –Quality tests : - Stationnarity (variation of the flux < 30%)
    - Constant flux layer (Turbulent characteristic integral < 30 %)

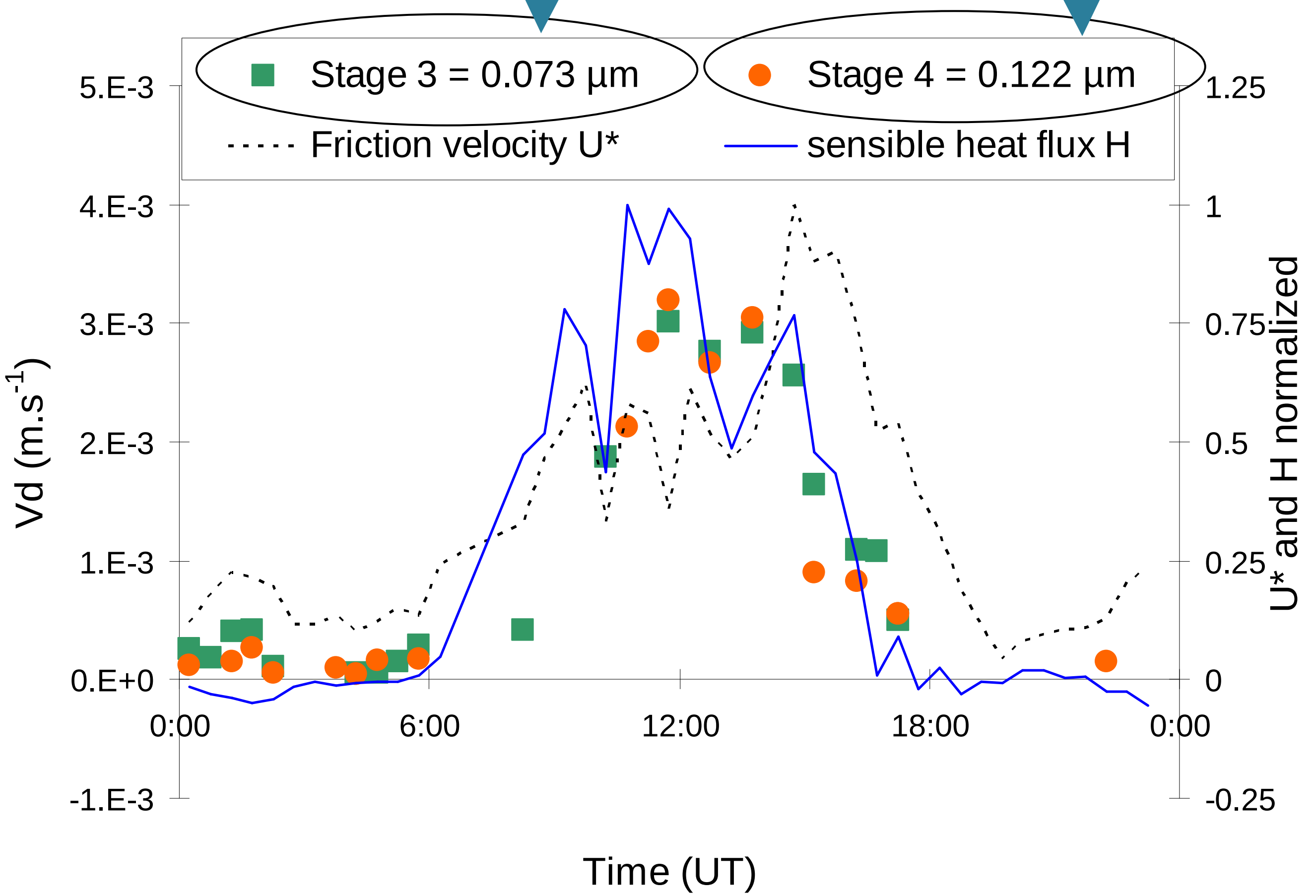
- Spectral analysis
  - – Spectral loss due to the low response time of the devices (ELPI)
  - – Spectral correction based on the similarity between the cospectra of the heat flux (w'T') and the cospectra of the vertical particule flux (w'C')



adimensionned frequency (n.z/U)

- **Example of diurnal pattern evolution of the dry deposition velocity**

for 2 aerosol size



- Important variation between diurnal and nocturnal results for :

  -*Dry deposition velocity Vd*

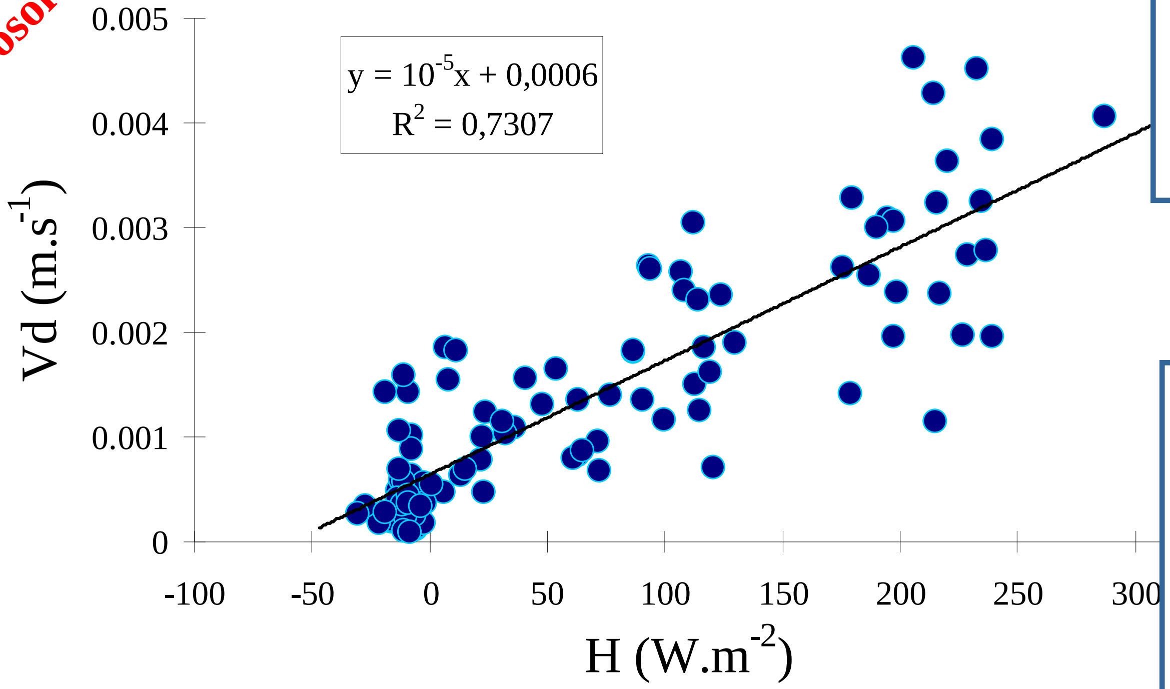
  - *Sensible heat flux H*

  - *Friction velocity U**

- max value of 3.10^{-3}m.s^{-1}
- Similar shape for other size classes

- **Impact of micrometeorological parameters : Sensible heat flux H**

Aerosol size of 33nm



■ Vd increases with H

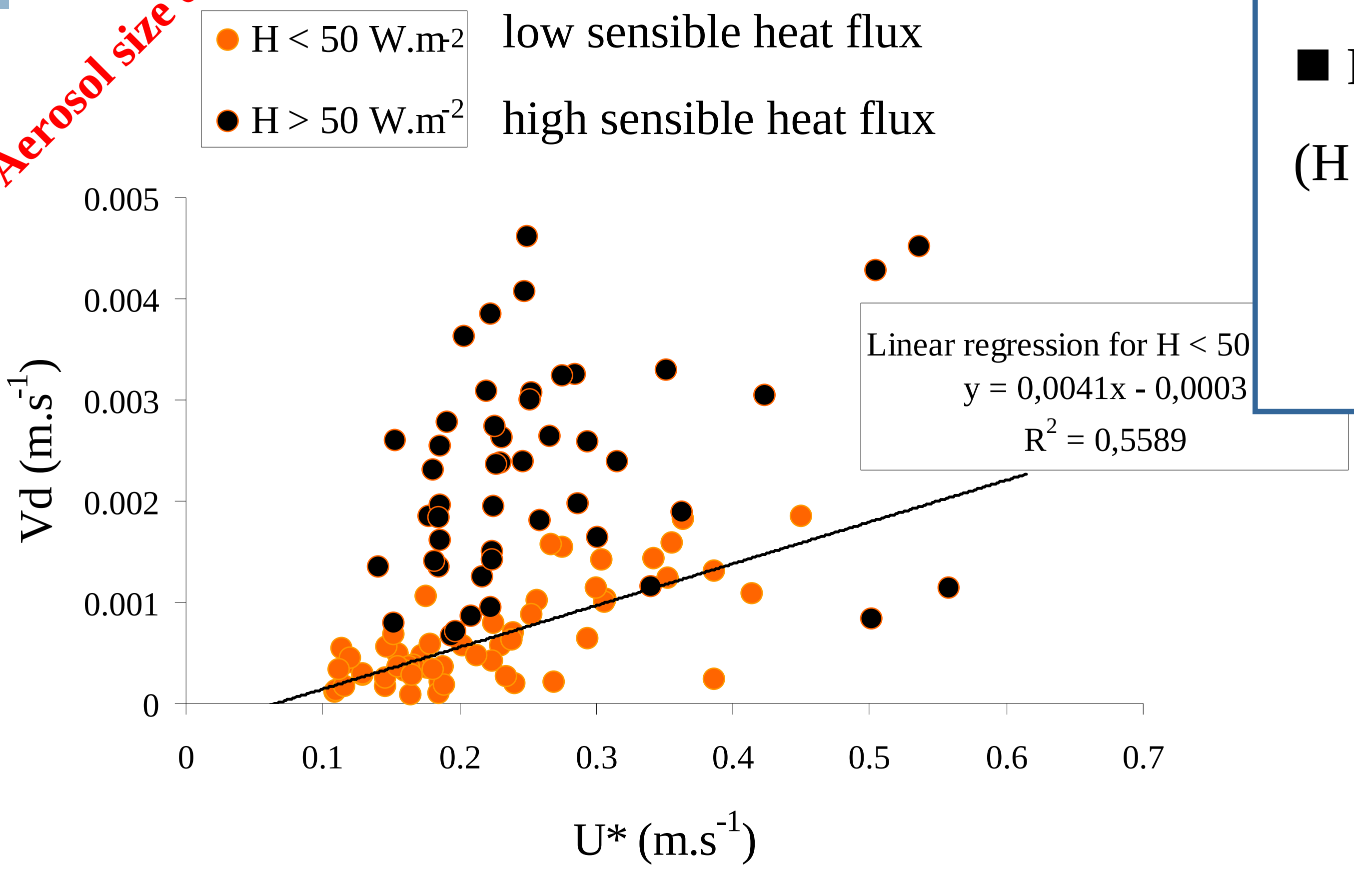
■ But don't forget the influence of the mechanical turbulence

■ The dispersion of the points can be due to :

- experimental uncertainties
- the mechanical effect of U*

- **Impact of micrometeorological parameters : the friction velocity U***

Aerosol size of 33nm



- Dispersion of the points
- For low thermal turbulence, (H small) : Vd is linear with U*

↓

Vd/U* constant

- similar shapes for the other aerosol sizes

(but only for the days where the values of H are contrasted between day and night)

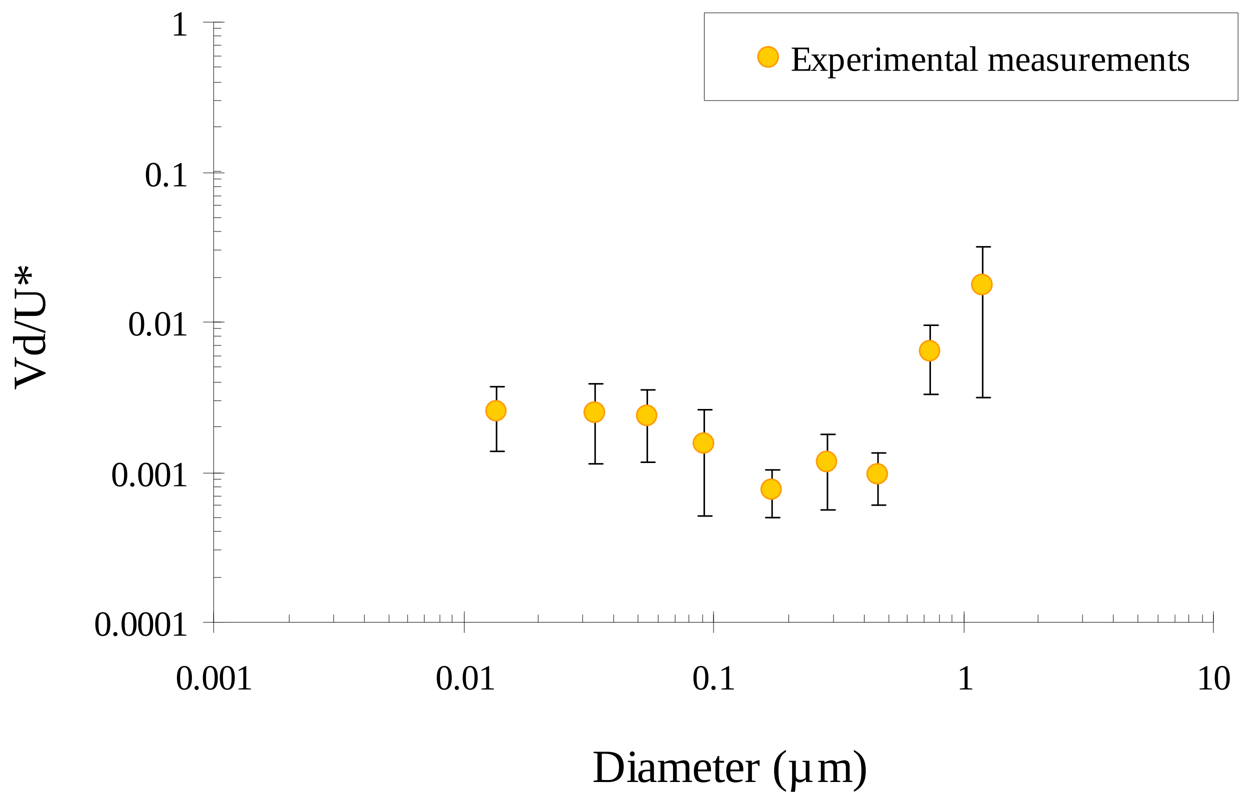
- Low values of H -> low thermal turbulence
  - ➡ For neutral and stables conditions: Vd/U*=constant
  - ➡ The average of Vd/U* can be plotted in function of the size

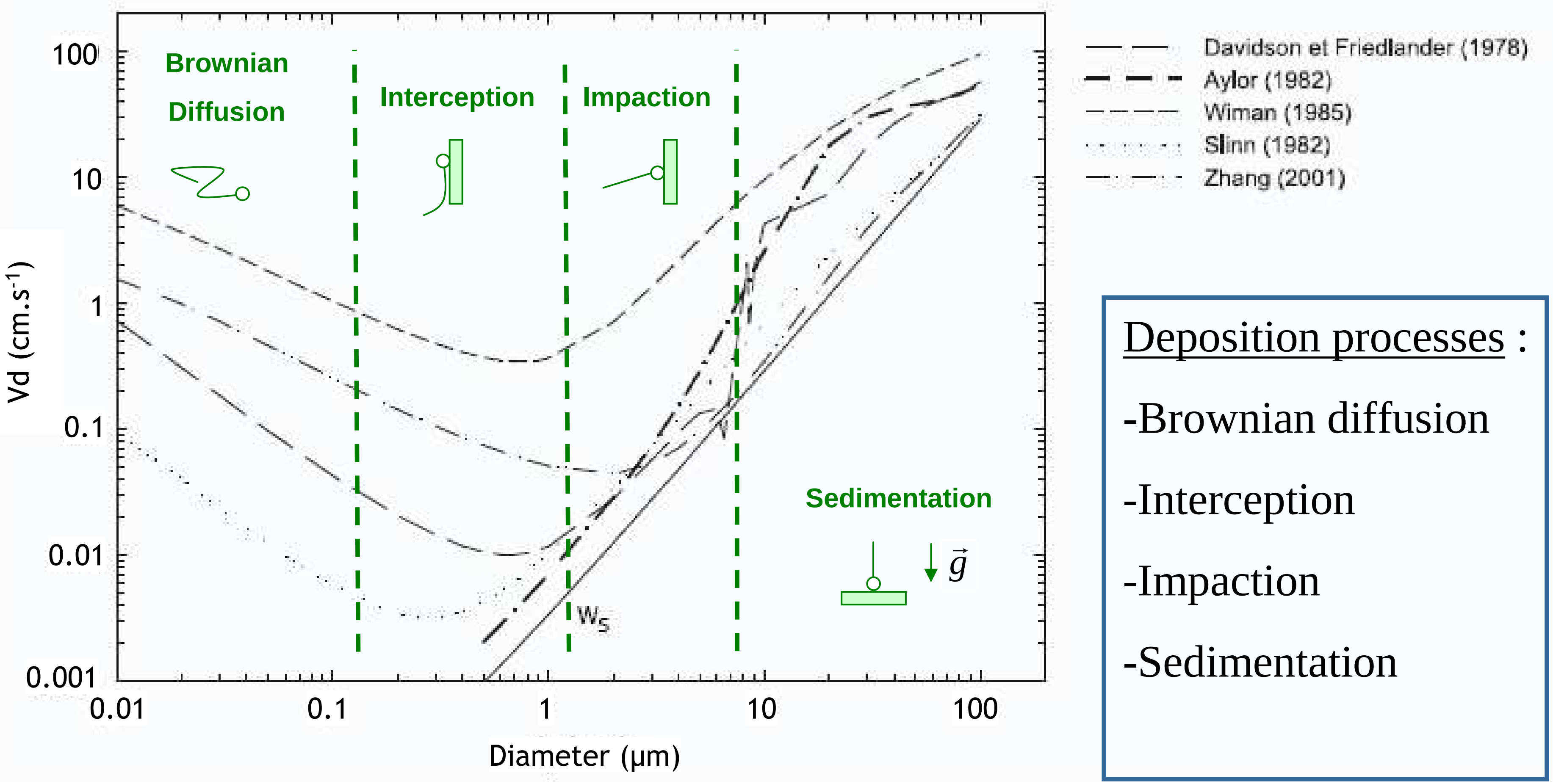
•<u>Impact of aerosol size</u>

-Constant for little sizes

-Low decrease

-Strong increase for the biggest sizes





<u>Deposition processes</u> :

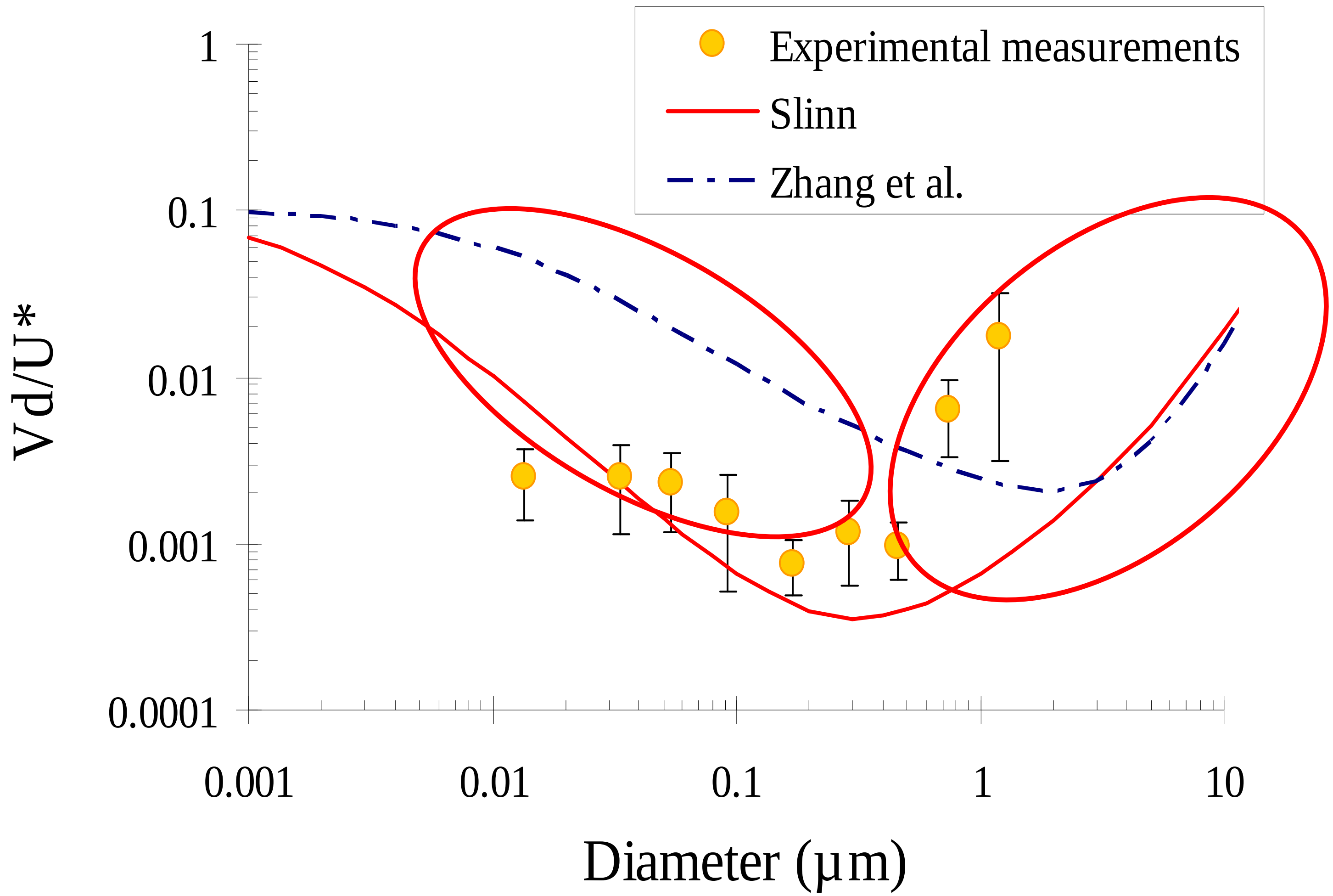
-Brownian diffusion

-Interception

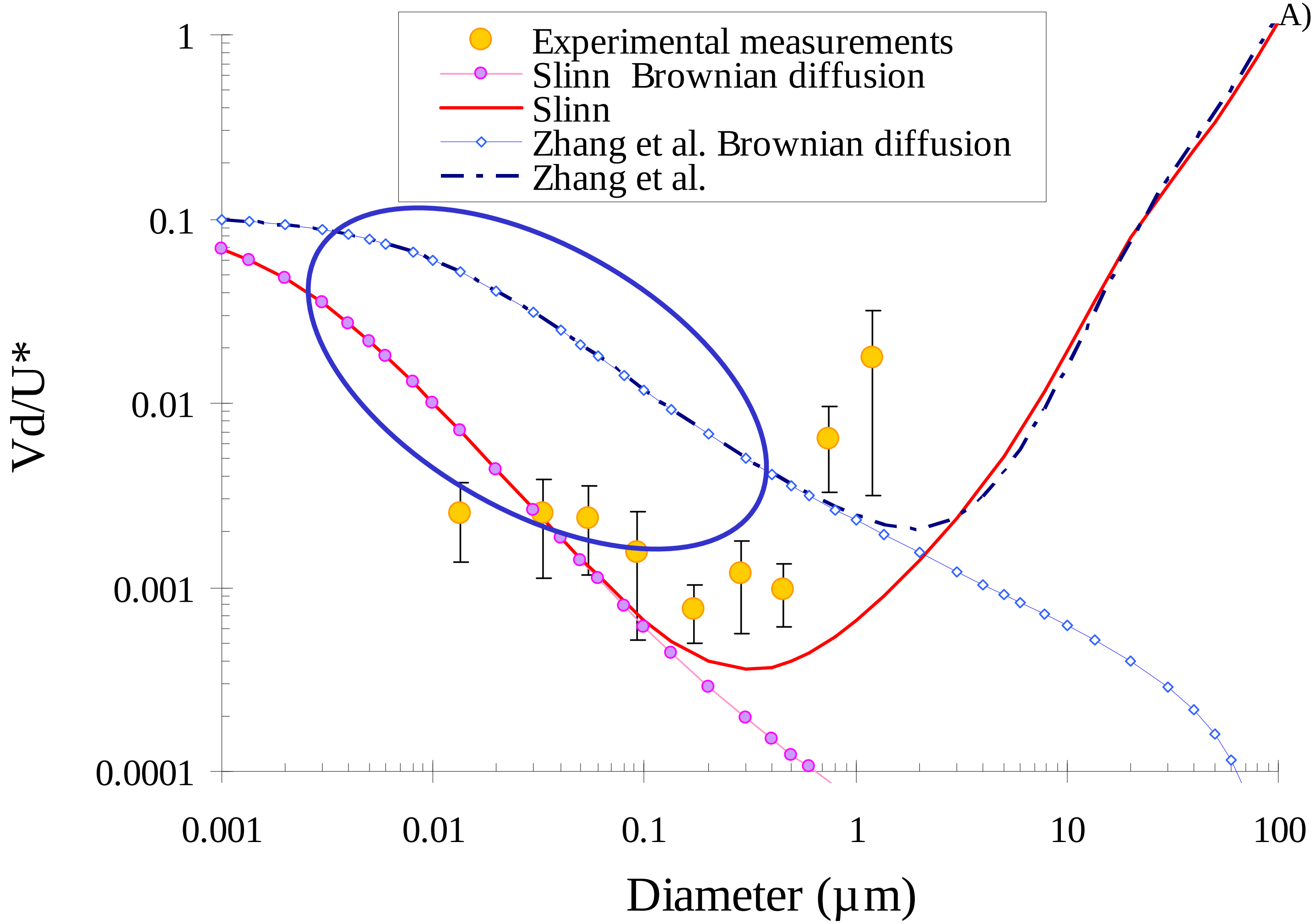
-Impaction

-Sedimentation

- **Comparison with Slinn et Zhang analytic models**

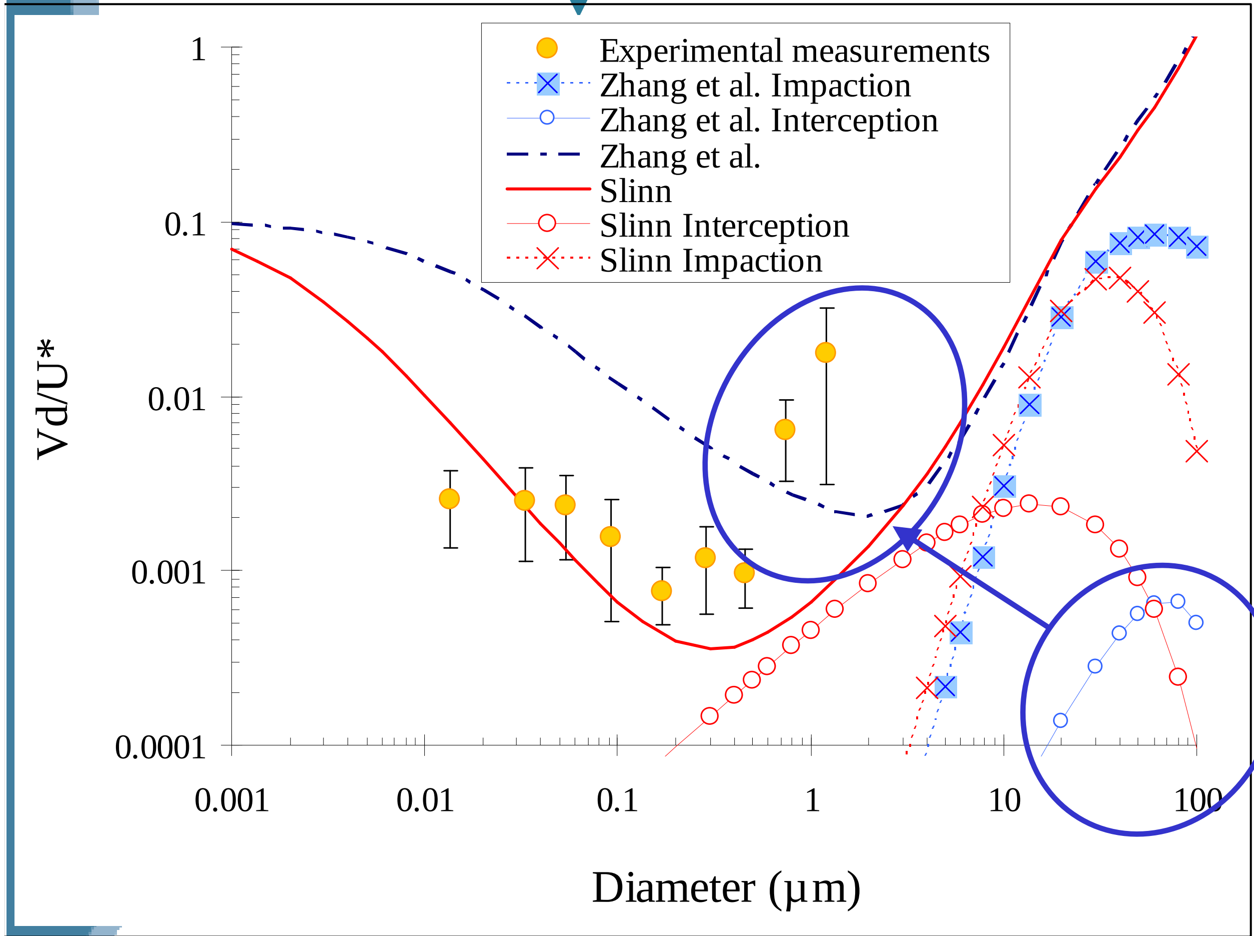


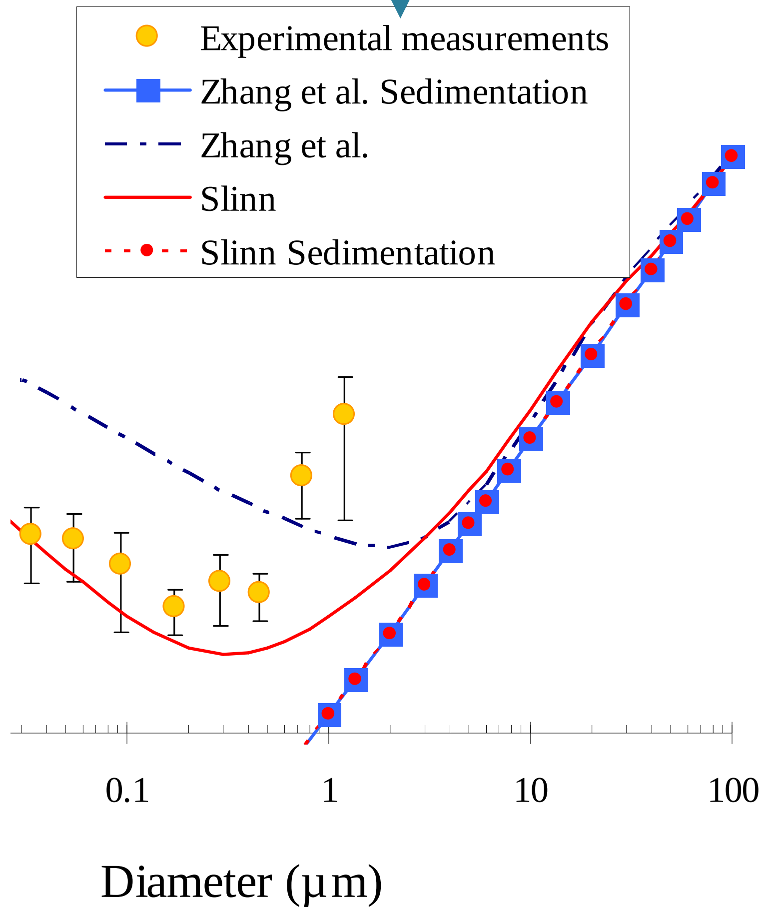
- **Brownian diffusion**



- Interception-Impaction

•Sedimentation





Conclusion

- Development a new method based on Eddy covariance
- Data of dry deposition velocity on maize
- Effect of the micrometeorological parameters H and U* on Vd
- Mean Values of Vd/U* (in stable and neutral conditions) for different sizes : between 7 nm and 2 μm

  → Effect of the aerosol size on the dry deposition
- Comparison with Zhang and Slinn models of deposition

Future

- Measurements on other substrates (grass, soil) have to be performed to study the effect of the substrate on the deposition
- A sensibility study could be realized to see the effect of each parameter used in the model because these parameters are often linked to measurements realized in wind tunnel and not in situ atmospheric conditions

Thanks for your attention

Collaborations :

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- IRSN/DSU/SERAC : Jacques Vendel, François Gensdarmes and Guillaume Basso
- IRSN/DEI/SECRE/LRC : Denis Maro, Pierre Damay, Olivier Connan and Didier Hébert

Article :

Damay, P. E., Maro. D., Coppalle, A., Lamaud. E., Connan, O., Hébert. D., Talbaut, M. et Irvine. M. (2009) Size resolved eddy covariance measurements of fine particle vertical fulxes. *Journal of Aerosol Science* 40, 1050-1058.

Congress :

Damay, P. E., Maro. D., Coppalle, A., Lamaud. E., Connan, O., Hébert. D., Talbaut, M. et Irvine. M. (2008) Contribution à l'étude des vitesses de dépôt sec des aérosols submicroniques dans un écosystème prairial. *23ième Congrès Français sur les aérosols*. Paris. (Talk)

Damay, P. E., Maro. D., Coppalle, A., Lamaud. E., Connan, O., Hébert. D., Talbaut, M. et Irvine. M. (2008) Measuring dry deposition velocity of submicronic aerosols in a prairie by eddy correlation using an electrical low pressure impactor. *European Aerosol Conference*. Thessaloniki (poster and back-up talk)

Damay, P. E., Maro. D., Coppalle, A., Lamaud. E., Connan, O., Hébert. D., Talbaut, M. et Irvine. M. (2009) Mesure par corrélation turbulente de la vitesse de dépôt sec des aérosols submicroniques sur différents couverts naturels. *24ième Congrès Français sur les aérosols*. Paris. (Talk)

Damay, P. E., Maro. D., Coppalle, A., Lamaud. E., Connan, O., Hébert. D., Talbaut, M. et Irvine. M. (2008). New data of dry deposition velocity of sub-micron aerosol on several rural substrates and comparison with models. *European Aerosol Conference*. Karlsruhe (Talk)