Wet Deposition in SILAM

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Outline:

- SILAM briefly
- WD in SILAM old vs. new
- Mechanistic WD
- Special case: SO2
- Improvements due to new scheme
- Conclusions

SILAM v.5: outlook

Modules

8 chemical and physical transformation modules (6 open for operational use),

6 source terms (all open),

2 aerosol dynamics (one open)

3D- and 4D- Var

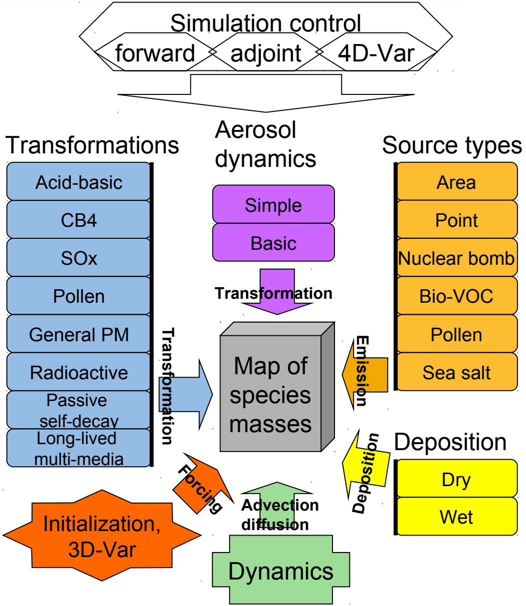
Domains: from global to beta-meso scale (~1km resolution)

Meteo input:

ECMWF

HIRLAM, AROME, HIRHAM, ECHAM, and any other who can write GRIB-1 or GRIB-2

WRF



Wet deposition

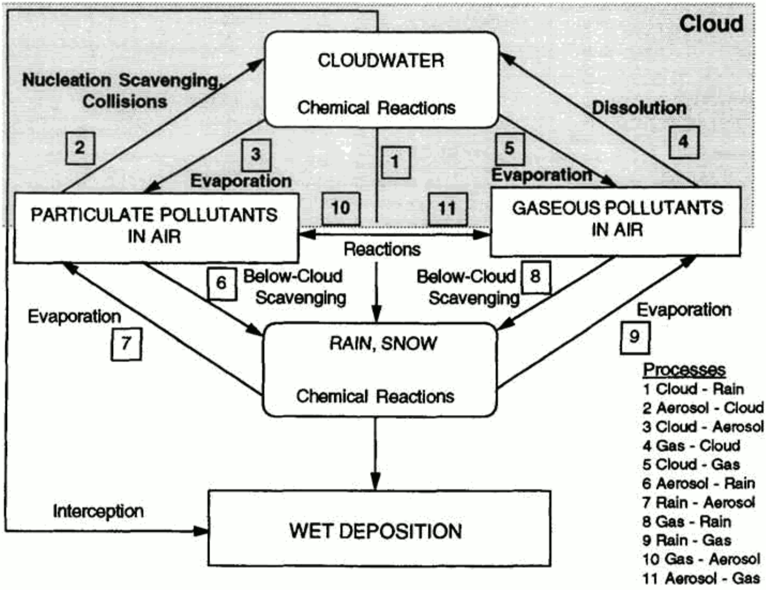


FIGURE 20.1 Conceptual framework of wet deposition processes.

Seinfeld & Pandis (2006)

Wet deposition in SILAM

Operational SILAM:

- Precipitation rate from meteo
- Prescribed cloud height
- Constant precip. below cloud
- Prescribed scavenging coefficients (in- or below-cloud, rain or snow)
- Species-dependent scaling
- Saturation of SO_2

New scheme:

- Meteo input for rain/snow profiles:
  - Precipitation rates
  - Cloud water content
  - Cloud fraction
- Equilibrium in clouds
- Fraction of cloud precipitating
- Solubilities
- Simple dissociation chemistry (SO_2)

Basic concepts

For *most* chemicals in-water equilibrium CNC is proportional to in-air concentration

- can define "Equivalent volume" of water: in-water-mass / in-air-CNC in equilibrium
- flux $\propto$ conc. difference
- resistance: $R = \Delta \mathrm{CNC}/F$
- exchange is a relaxation process

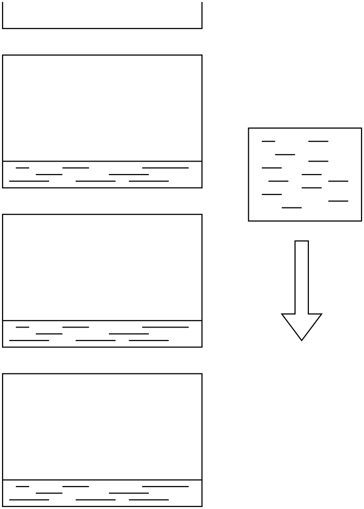
Exchange is driven by:

- equilibrium mass fractioning
- exchange time scales

Mechanistic Wet Deposition

Air-water relaxation

- In-cloud equilibrium
- Rainout $\tau = \mathrm{CWC}/R$
- Washout – relaxations:
  - droplet CNC to air
  - in-air to incoming rain



Sub-cloud scavenging efficiency

- Diffusion D
- Interception d_p
- Impaction τ_p

Accumulation around 1 μm

Diffusion for gases

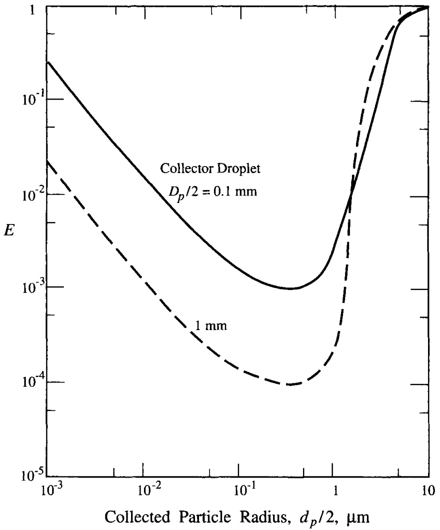


FIGURE 20.6 Semiempirical correlation for the collection efficiency E of two drops (Slinn 1983) as a function of the collected particle size. The collected particle is assumed to have unit density.

Seinfeld & Pandis (2006)

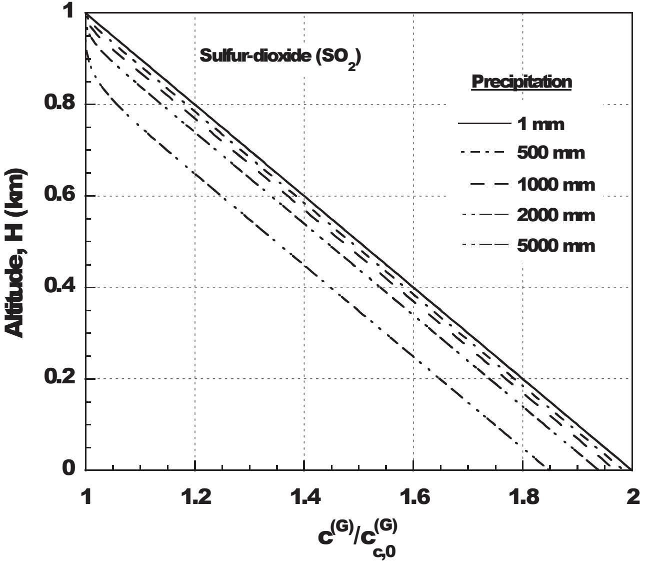
Gas solubility

- Henry factor – mole/(l Pa) says how much of dissolved gas is in equilibrium with 1 Pa of partial pressure
- Temperature-dependent
- Henry factor does not say "how much stuff can get into droplet at given in-air concentration"
- Reason: dissociation
- Effective Henry coefficient helps helps sometimes

For $\mathrm{SO_2}$ situation even worse...

SO_2: how NOT to

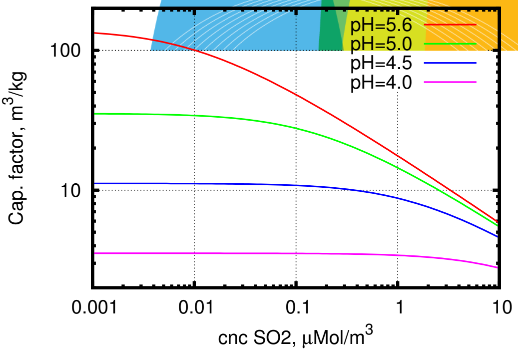
Blind use of Henry constant from manuals.



(c) Respected authors, 2011
(c) Respected journal (IF=3.7), 2011

$\sim$10% reduction of SO_2 in air needs 5000 mm of rain.

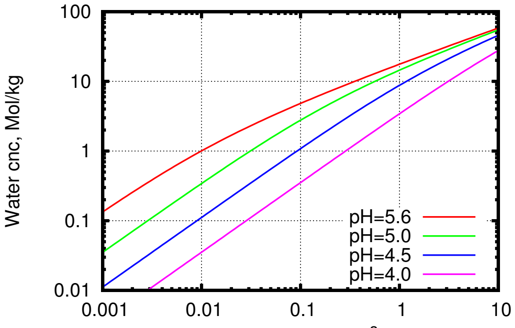
SO_2 solubility



Solubility depends on "background" pH of water and on SO_2 itself.

No linear models work!
(incl. scavenging coefficients)

In polluted regions
$\sim 1 \mu mol/m^3$



Gas solubility (cont.)

The effective Henry factor for $\mathrm{SO_2}$ depends on pH, in particular on the amount of dissolved $\mathrm{SO_2}$

$$[\mathrm{S(IV)}] = [\mathrm{SO_2}]\left(1 + \frac{K_{S1}}{[\mathrm{H^+}]}\right)$$

Result: Solubility concept does not apply.

Operational SILAM: Saturation of SO2 in rain water.

New scheme – approximate electro-neutrality:

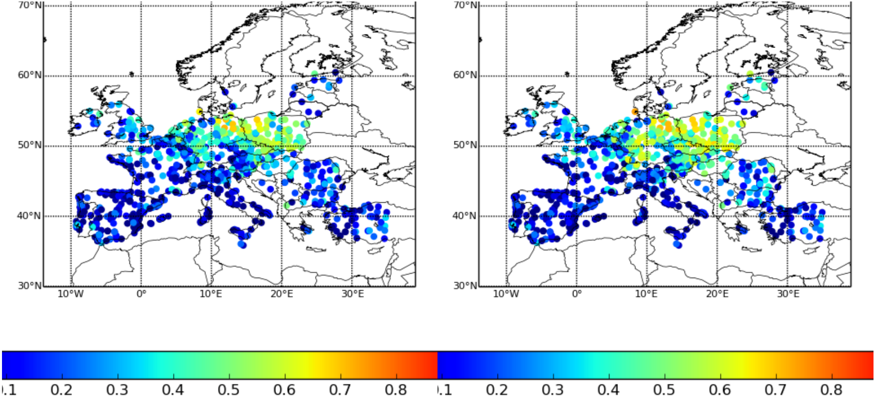
$$[\mathrm{H^+}] \simeq [\text{Strong Acids}] + [\mathrm{HSO_3^-}] - [\mathrm{NH_4^+}], \quad [\mathrm{HSO_3^-}] \simeq [\mathrm{S(IV)}].$$

Scavenging of SO2

- SO2 last species to scavenge
- In-water acids and ammonia are known
- Effective equilibrium solubility for given amount of water and SO2 in cell, and given acids in rain.
- Same linear algorithm is asymptotically right

Improvement

Correlation oldWD vs. newWD. 2010, $\sim$ 1000 sites



	OLD	RMS	Bias	Corr.	NEW	RMS	Bias	Corr.
95th		11.30	1.46	0.58		11.16	1.82	0.64
Mean		3.94	-1.23	0.26		3.84	-0.90	0.31
Median		2.97	-0.87	0.27		2.94	-0.59	0.32

Effect of resolution

Example:

- heavy rain in half of grid cell
- rain scavenges 99% per time step
- little wind

Question:

- How much stuff will be left in air after two time steps?

Summary

- WD scheme based on relaxation
- Incloud and subcloud
- Dissociation must be accounted for SO2
- Substantial improvement of SO2 concentrations
- Subgrid effects need to be accounted for