Aerosol processing in Stratocumulus clouds

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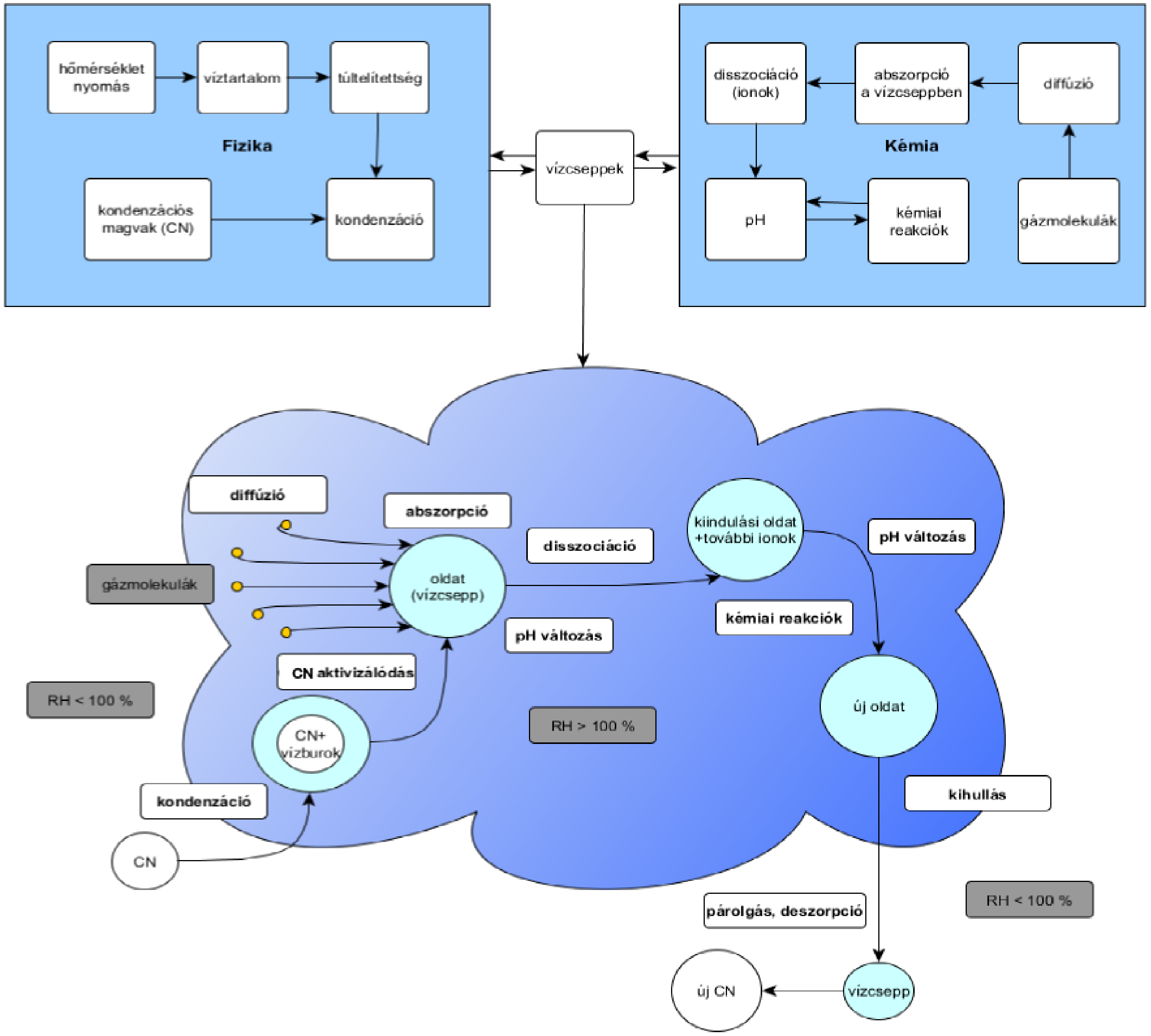
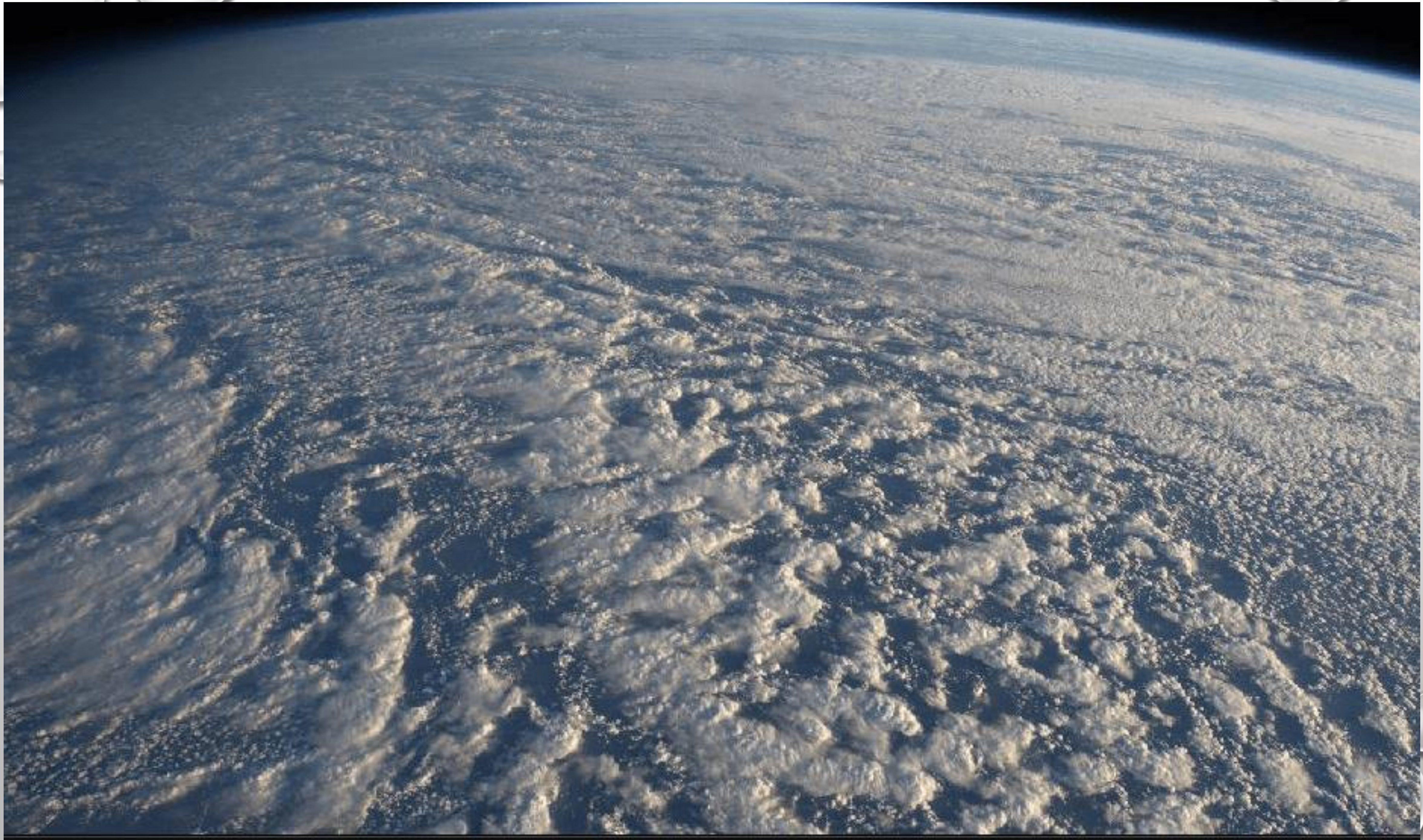
Friday **A**fternoon **C**loud Physics **T**alk



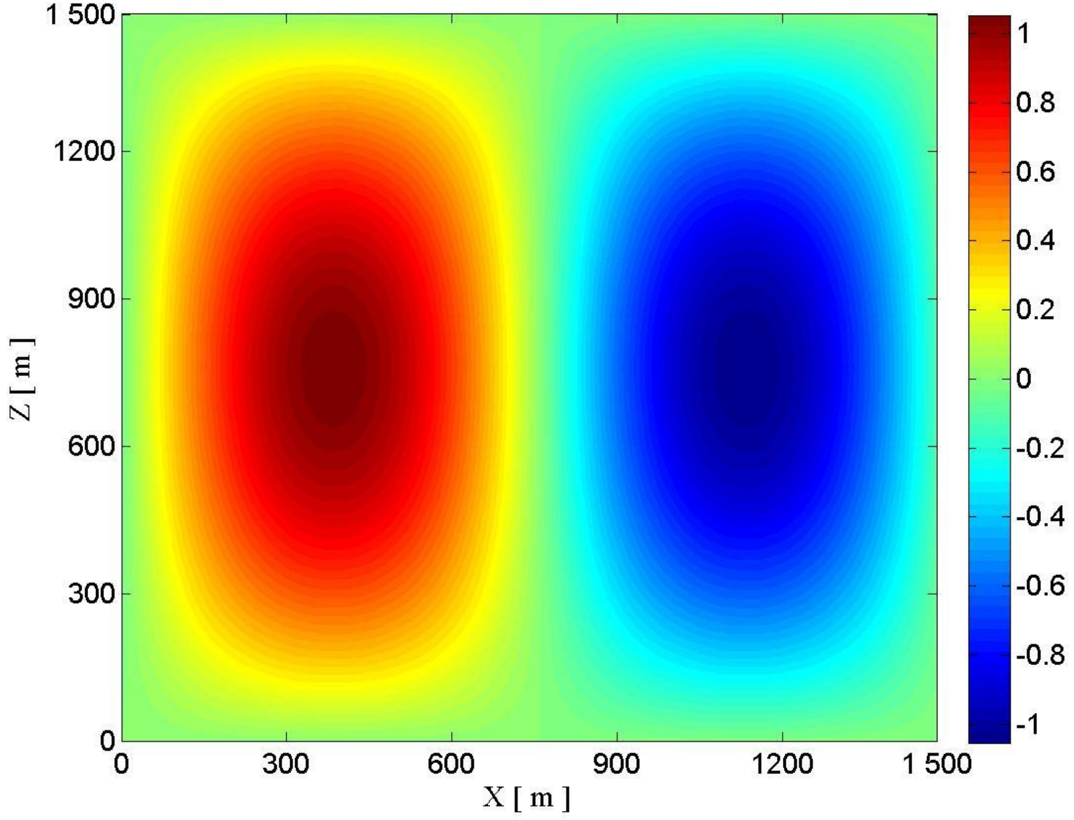
hőmérséklet nyomás
víztartalom
túltelítettség
Fizika
kondenzációs magvak (CN)
kondenzáció
vízcseppek
disszociáció (ionok)
abszorpció a vízcseppben
diffúzió
Kémia
pH
kémiai reakciók
gázmolekulák
diffúzió
abszorpció
disszociáció
kiindulási oldat +további ionok
pH változás
gázmolekulák
oldat (vízcsepp)
kémiai reakciók
pH változás
CN aktivizálódás
RH < 100 %
CN+ vízburok
RH > 100 %
új oldat
kondenzáció
kihullás
CN
párolgás, deszorpció
RH < 100 %
új CN
vízcsepp

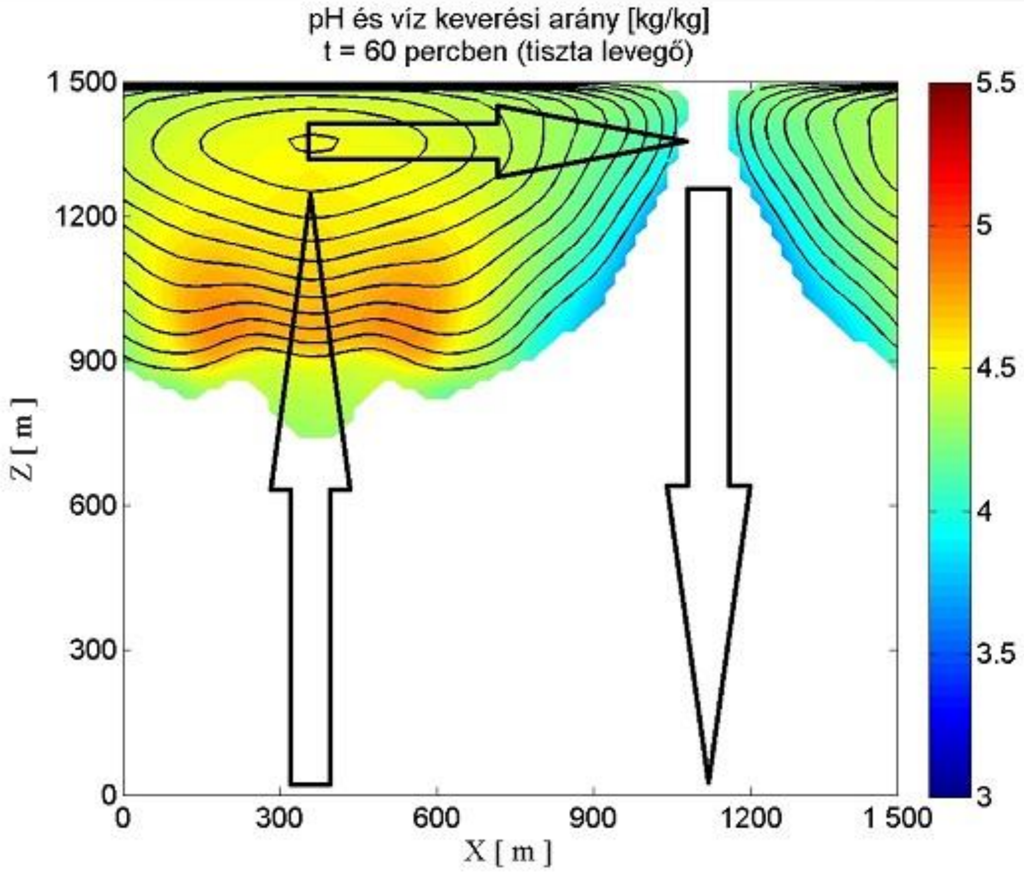


Model

- 2D kinematic framework (Grabowski, 1998; Smolarkievicz, 1984), typical parameters for Stratocumulus clouds
    - most common cloud type globally
    - approx. thickness of 300-500
    - precipitation: drizzle
  - Size of the domain: 1.5 km vertically, 1.5 km horizontally (spatial resolution in both directions 20 m)
  - Steady – state flow field, max. 1 m s^{-1} wind speed in the updraft and -1 m s^{-1} in the downdraft region
  - Physical processes involved: diffusional growth of water drops, collision- coalescence and evaporation of water drops

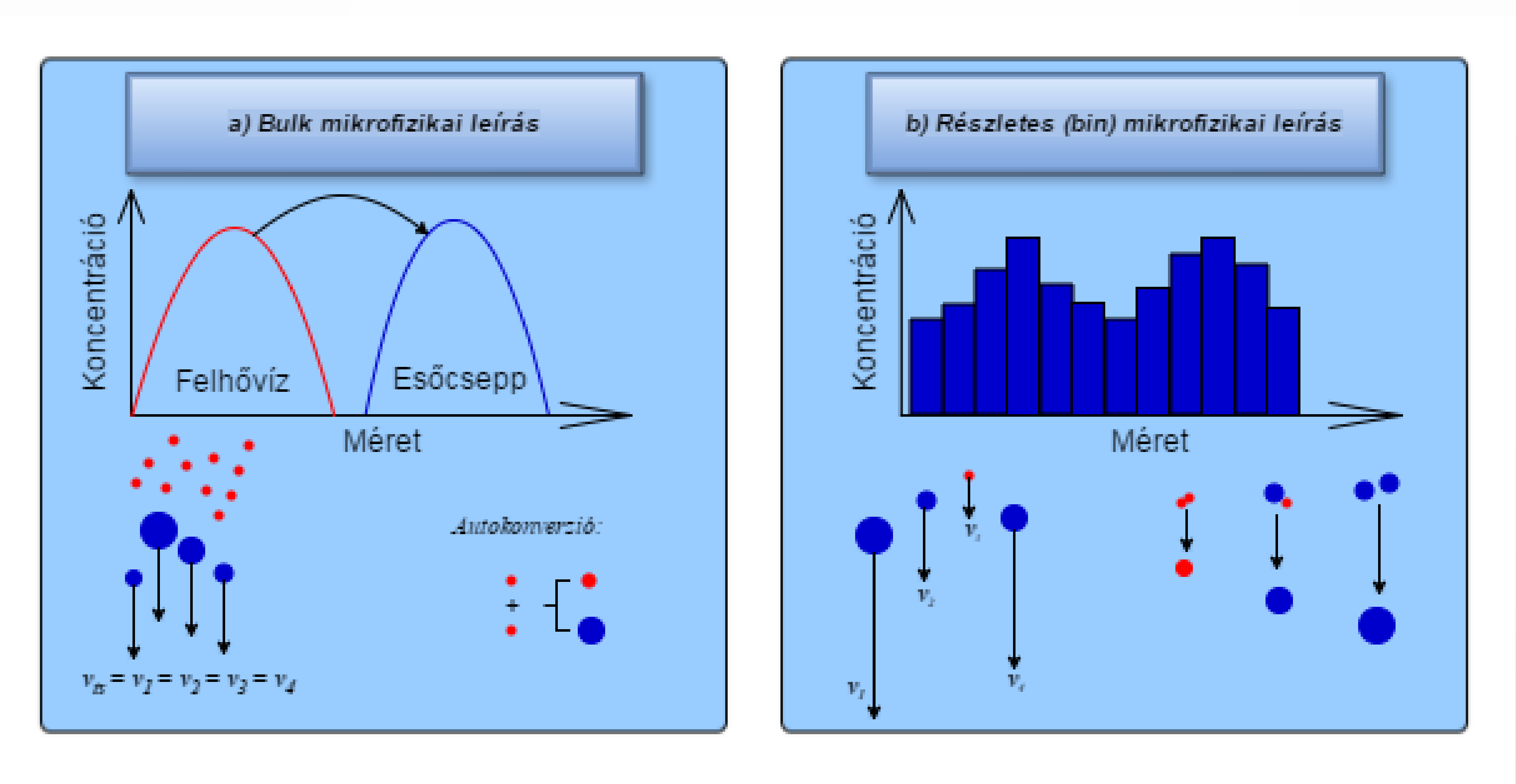
Up- and downdraft regions



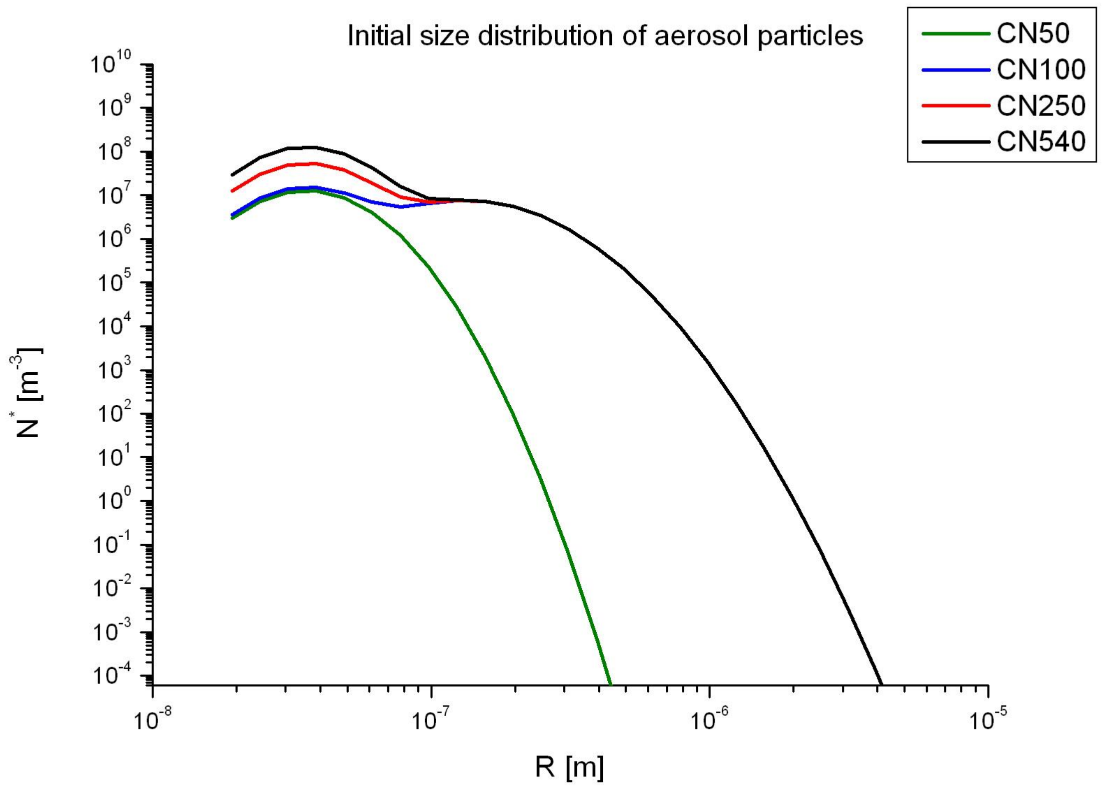


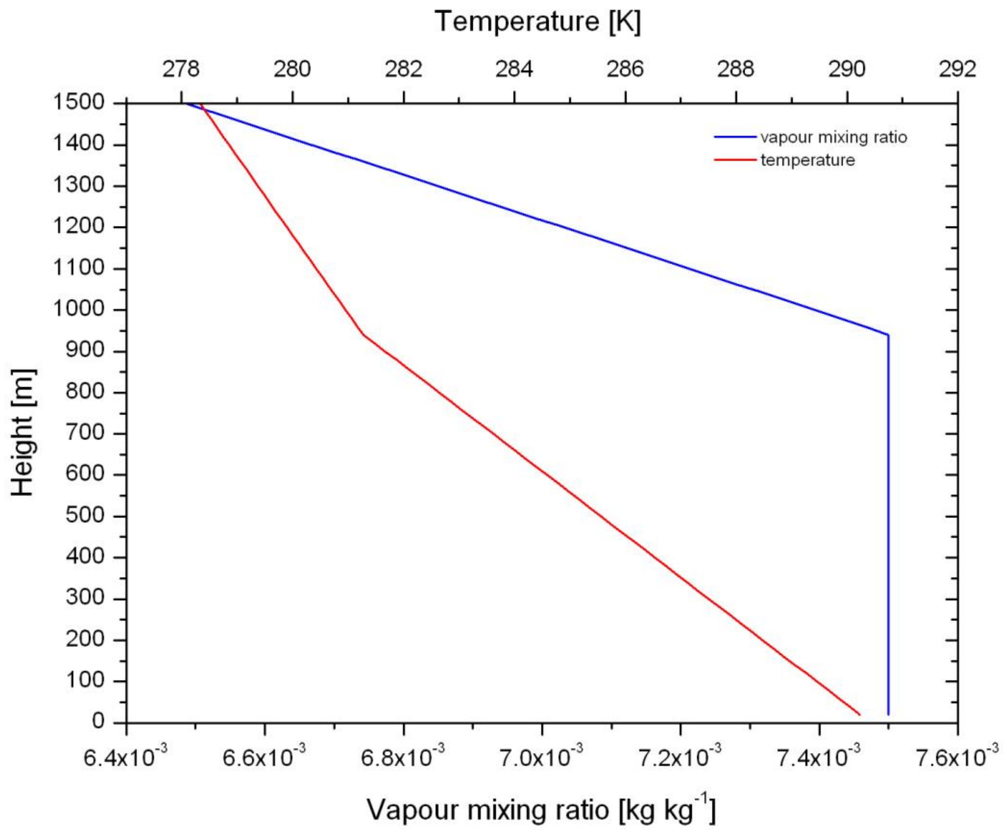
Initial values

- Chemical composition of aerosol particles: ammonium-sulfate
- Use of bin scheme (Geresdi & Rasmussen, 2005)
- Two types of particles, size range (in radius):
  - Dry aerosol, from 0.01μm to 10 μm, divided into 36 bins
  - Water drops/haze particles: from 0.01 μm to 5 mm, divided into 55 bins
  - Computation of chemical reactions and collision-coalescence only for droplets greater than 1.5 μm in radius
  - Formation of droplets in aerosol particles: at 90 % relative humidity or more



Ed.: Dr. Noémi Sarkadi


Initial size distribution of aerosol particles
CN50
CN100
CN250
CN540
N* [m-3]
R [m]

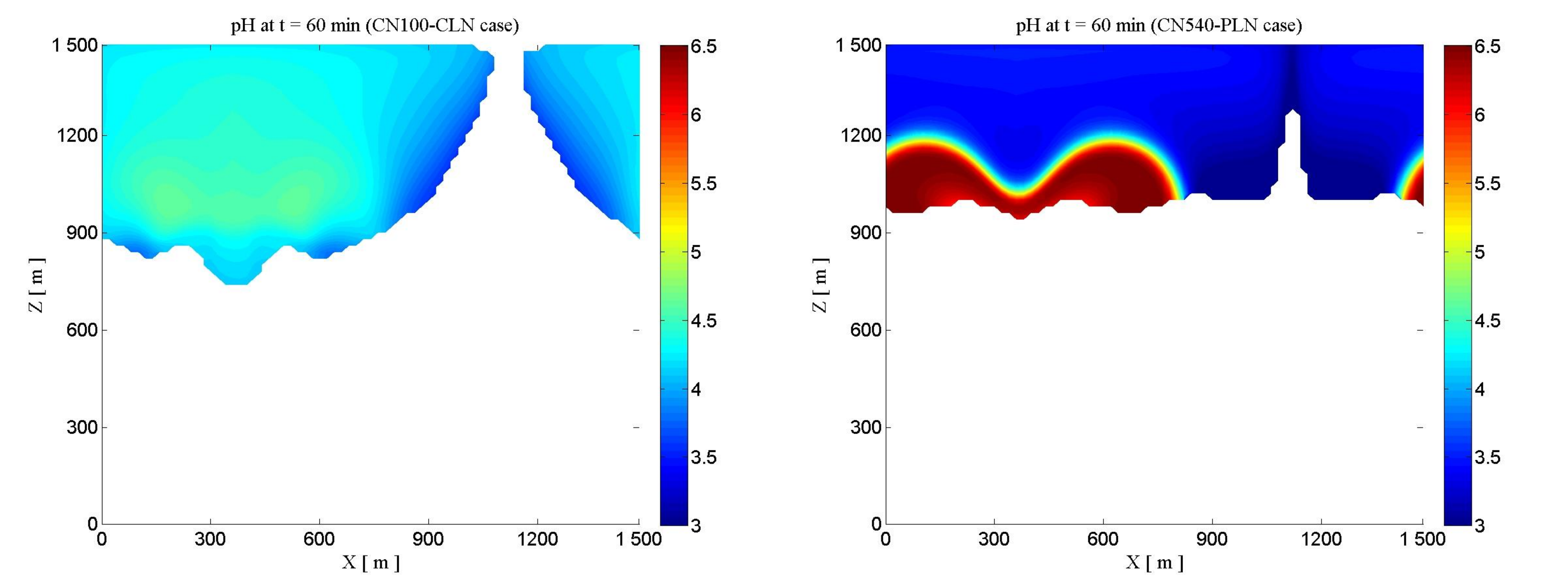

Temperature [K]
vapour mixing ratio
temperature
Height [m]
Vapour mixing ratio [kg kg-1]

- Absorbed gases by droplets: SO_2, NH_3, O_3, H_2O_2, CO_2
- Processes involved:
  - Absorption/desorption
  - Oxidation of SO_2 by H_2O_2 and O_3, production of sulfate ions
  - Change of pH
  - Aerosol mass increase after the evaporation of droplets

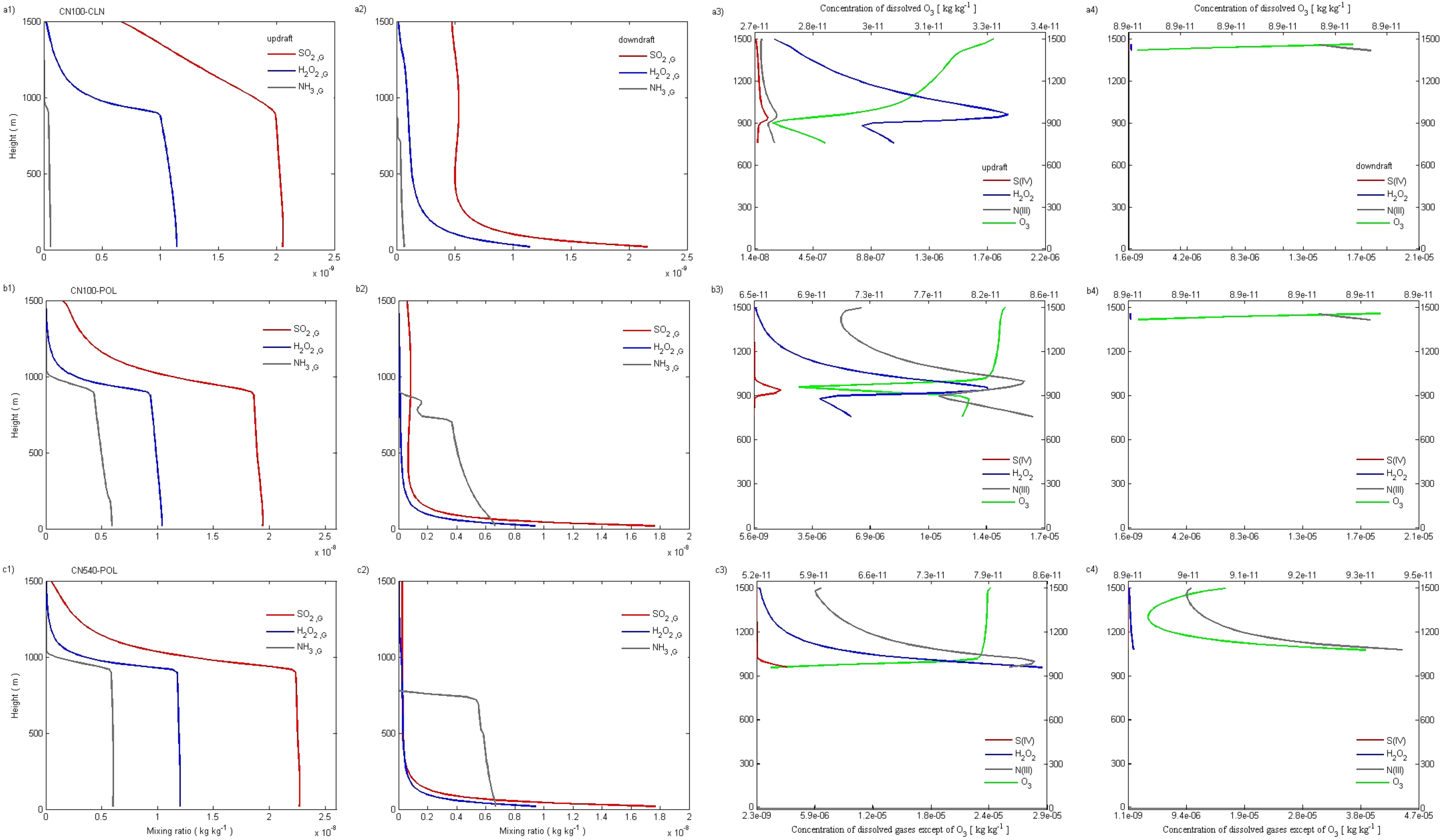
Concentration of the dry sulfate particles (cm^{-3})	Concentration of the trace gases in the atmosphere (ppbv)	name of the case
50	SO_2 = 0.1 H_2O_2 = 0.1 O_3 = 4.0 NH_3 = 0.1	CN50_CLN
100	SO_2 = 1.0 H_2O_2 = 1.0 O_3 = 40 NH_3 = 0.1	CN100_CLN
100	SO_2 = 10 H_2O_2 = 10 O_3 = 100 NH_3 = 10	CN100_POL*
250	SO_2 = 10 H_2O_2 = 10 O_3 = 100 NH_3 = 10	CN250_POL
540	SO_2 = 10 H_2O_2 = 10 O_3 = 100 NH_3 = 10	CN540_POL*

Control cases:
Oxidation processes are not involved

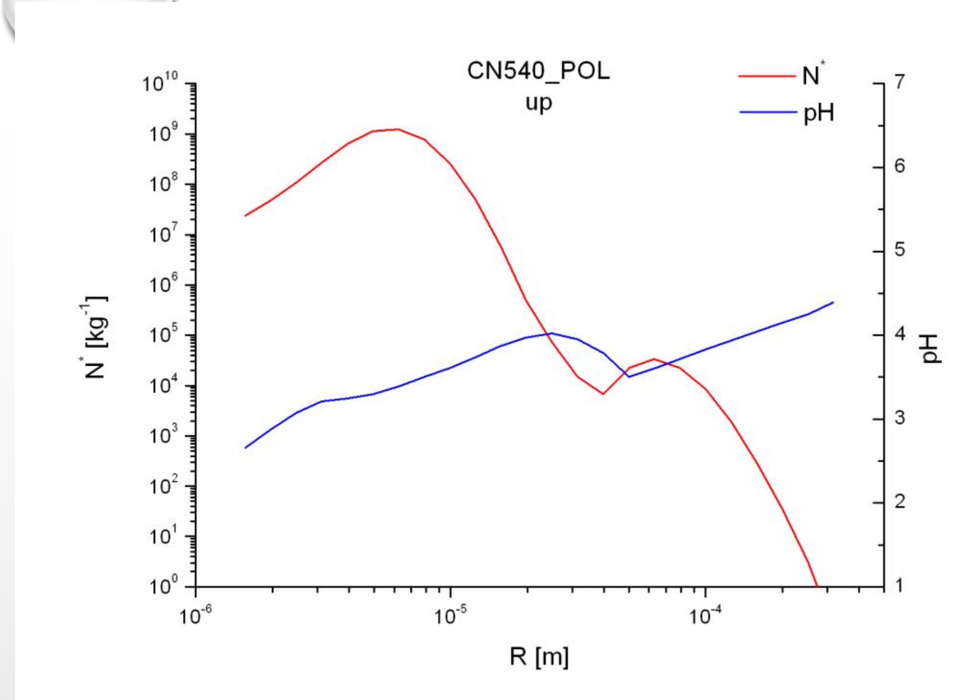
Change of pH

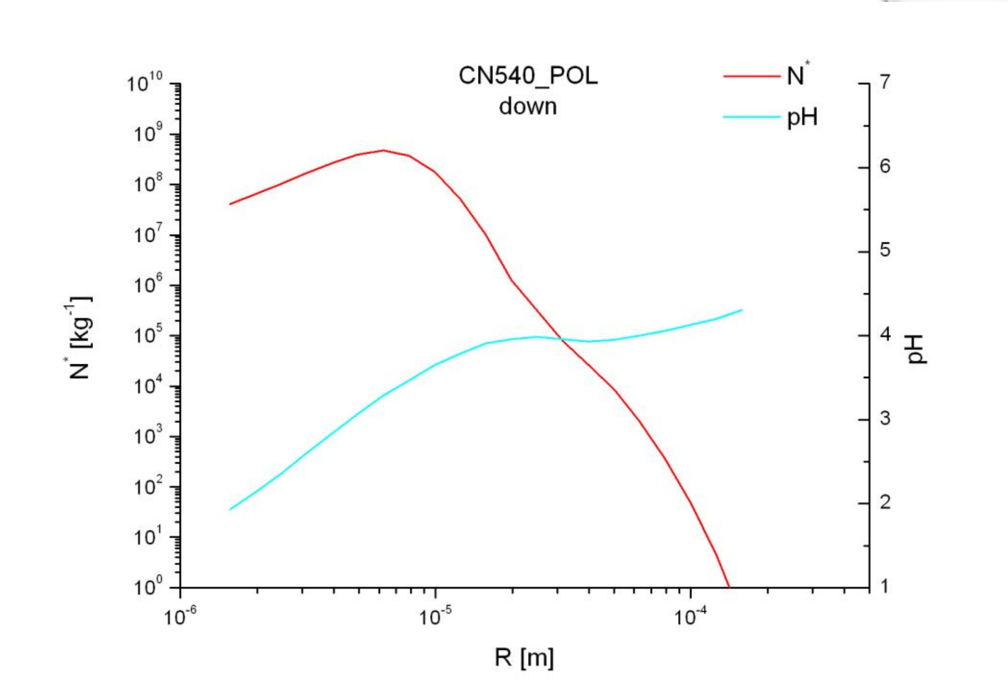


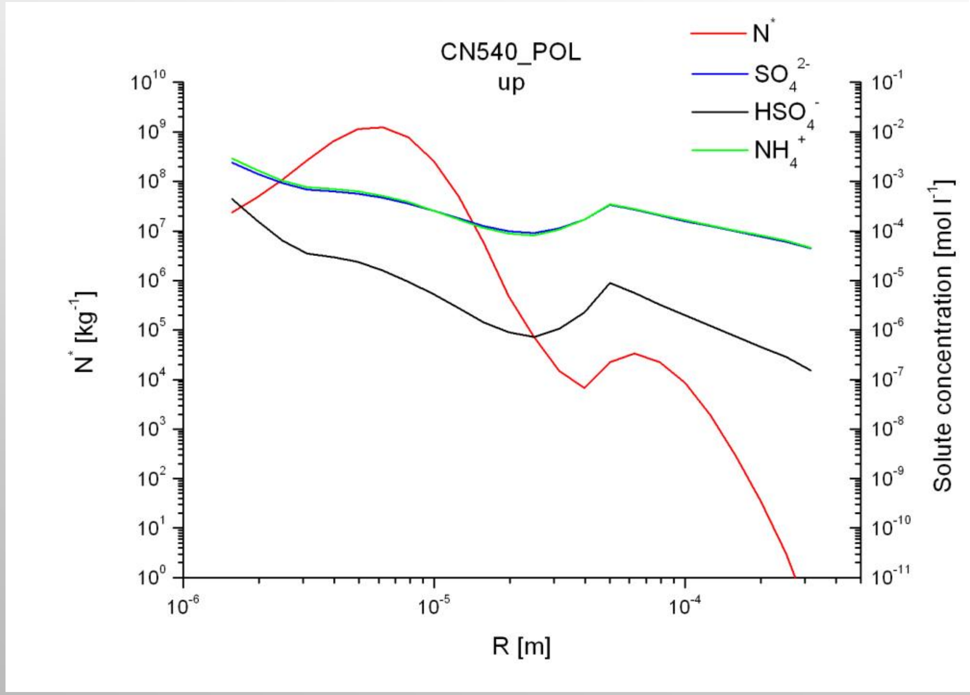
pH at t = 60 min (CN100-CLN case)
pH at t = 60 min (CN540-PLN case)
Z [m]
X [m]
1 500
1200
900
600
300
0
6.5
6
5.5
5
4.5
4
3.5
3

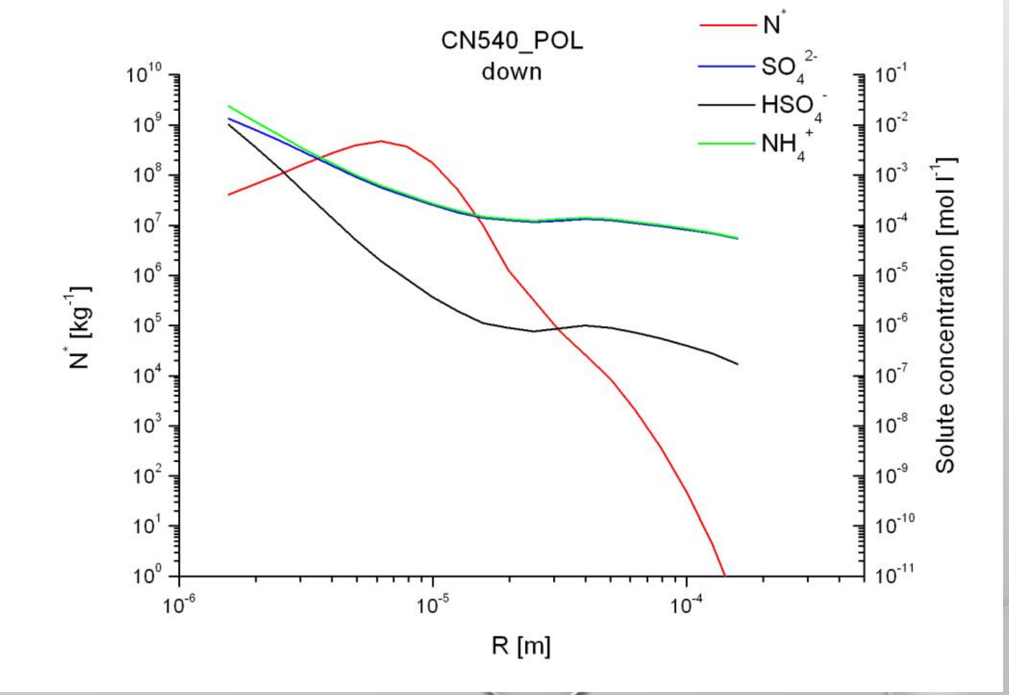


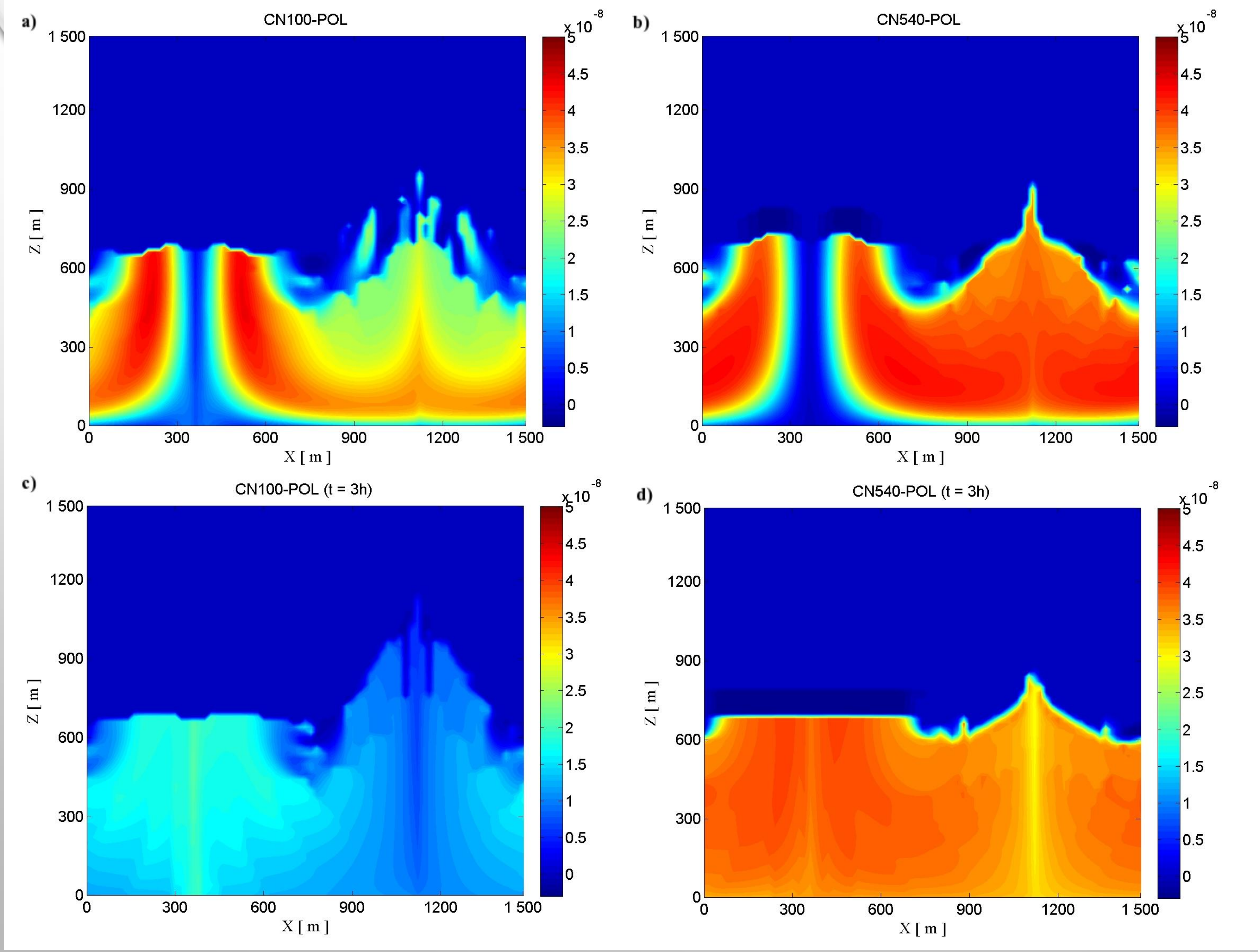
a1) CN100-CLN
updraft
SO2,G
H2O2,G
NH3,G
Height (m)
x 10-9
a2)
downdraft
a3)
Concentration of dissolved O3 [kg kg-1]
updraft
S(IV)
H2O2
N(III)
O3
a4)
downdraft
b1) CN100-POL
x 10-8
b2)
b3)
b4)
c1) CN540-POL
Mixing ratio (kg kg-1)
c2)
c3)
Concentration of dissolved gases except of O3 [kg kg-1]
c4)


CN540_POL
up
N*
pH
N* [kg-1]
pH
R [m]


CN540_POL
down
N*
pH
N* [kg-1]
pH
R [m]


CN540_POL
up
N*
SO4 2-
HSO4 -
NH4 +
N* [kg-1]
Solute concentration [mol l-1]
R [m]


CN540_POL
down
N*
SO4 2-
HSO4 -
NH4 +
N* [kg-1]
Solute concentration [mol l-1]
R [m]

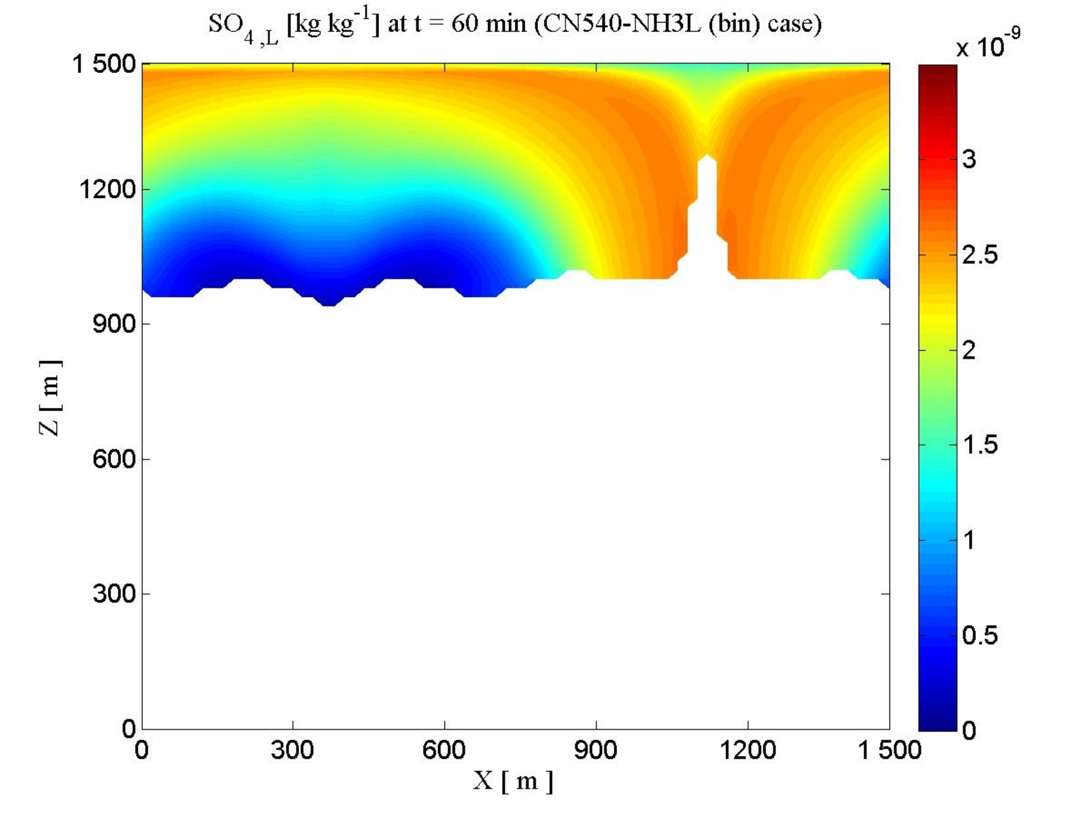


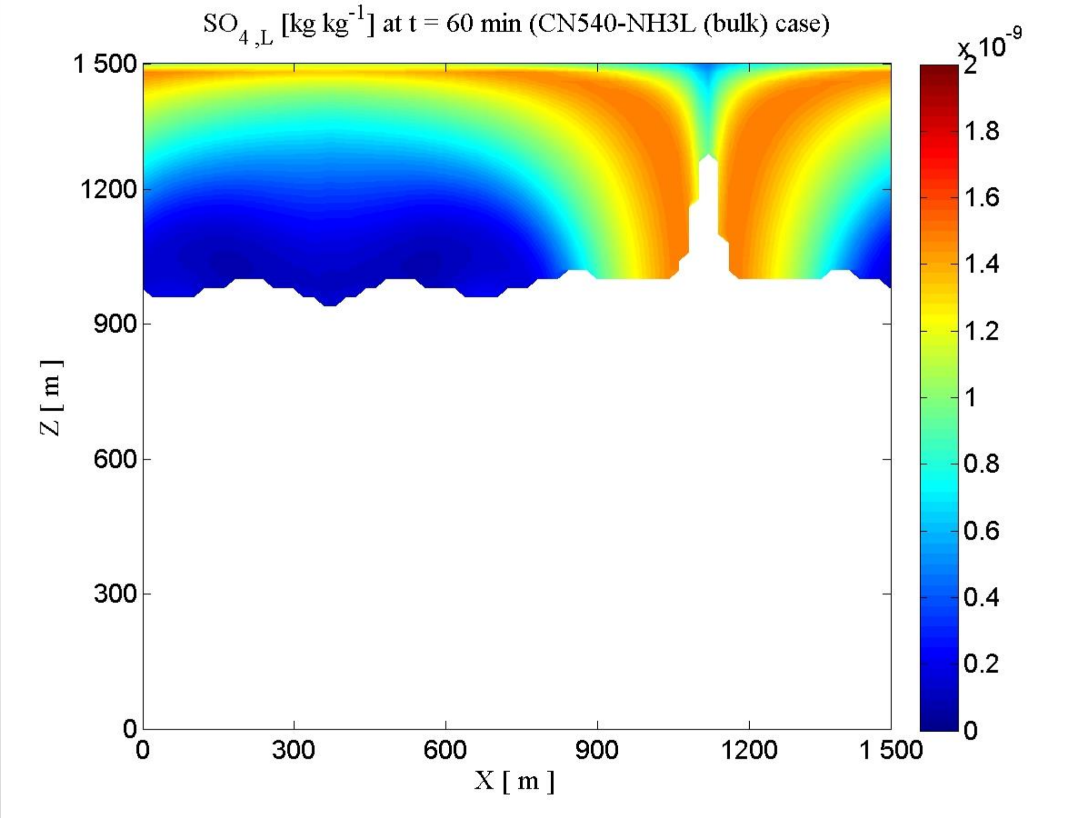
Production of dry aerosol

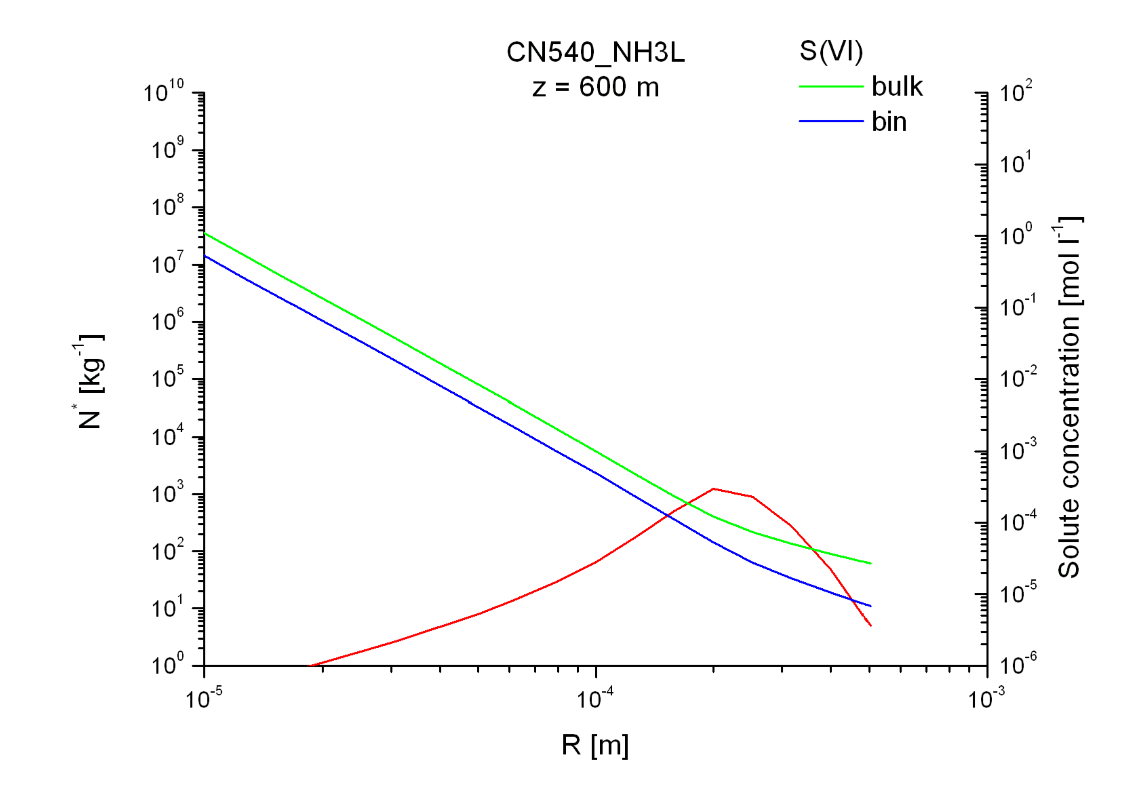
(cases – control cases)

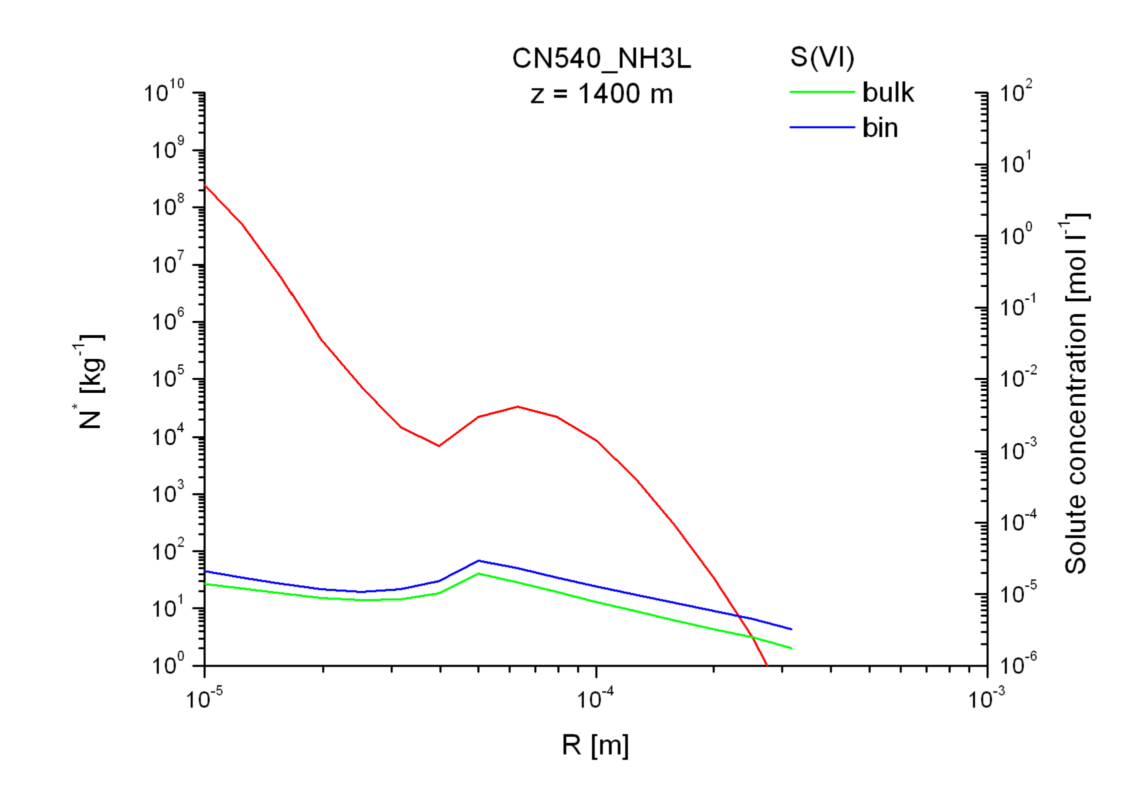
[kg kg^{-1}]

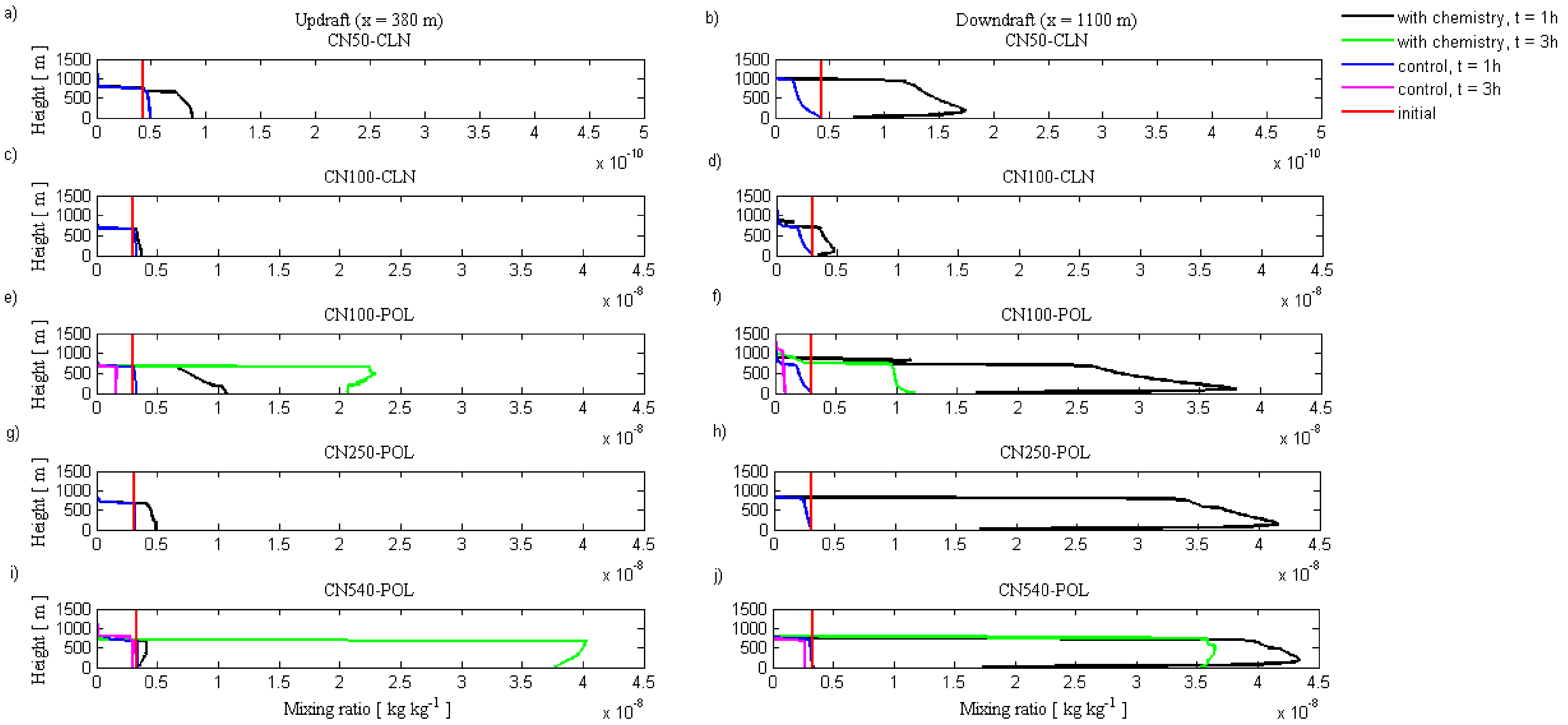
Comparison of the results of bin and bulk scheme



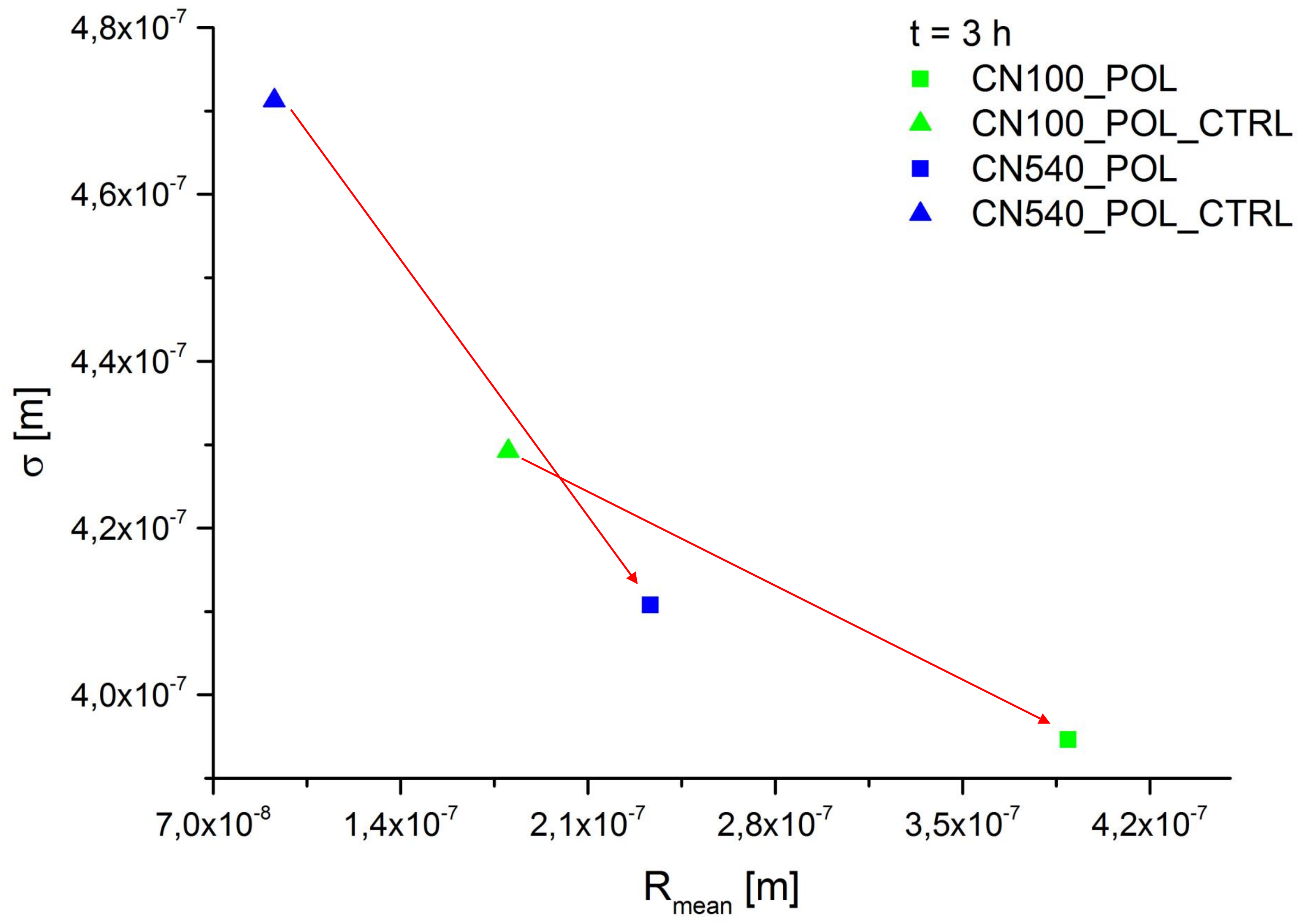



CN540_NH3L
z = 600 m
S(VI)
bulk
bin
N* [kg-1]
Solute concentration [mol l-1]
R [m]


CN540_NH3L
z = 1400 m
S(VI)
bulk
bin
N* [kg-1]
Solute concentration [mol l-1]
R [m]



a)
Updraft (x = 380 m)
CN50-CLN
b)
Downdraft (x = 1100 m)
CN50-CLN
with chemistry, t = 1h
with chemistry, t = 3h
control, t = 1h
control, t = 3h
initial
x 10^-10
c)
d)
CN100-CLN
x 10^-8
e)
f)
CN100-POL
g)
h)
CN250-POL
i)
j)
CN540-POL
Height [m]
Mixing ratio [kg kg^-1]



t = 3 h
CN100_POL
CN100_POL_CTRL
CN540_POL
CN540_POL_CTRL
σ [m]
4,8x10^-7
4,6x10^-7
4,4x10^-7
4,2x10^-7
4,0x10^-7
7,0x10^-8
1,4x10^-7
2,1x10^-7
2,8x10^-7
3,5x10^-7
4,2x10^-7
R_mean [m]

Summary

- Absorption and pH strongly depends on the size of droplets
- Significant amount of sulfate is produced in droplets due to the oxidation of SO_2
- The size distribution of aerosol particles changes after the evaporation of droplets, which is the consequence of sulfate ions produced due to oxidation and the formation of ammonium-sulfate after the evaporation of droplets
- The change of the aerosol size distribution decreases the amount of surface precipitation in the case of high initial aerosol concentration

Thank you for your attention!