Alternative interpretation of combined backscatter and humidity measurements of stratospheric particles during the SCOUT-AMMA balloon campaign

J. K. Nielsen <jkn@dmi.dk>, N. Larsen, T. Christensen, S. Khaykin , J.-P. Pommereau

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Outline

- Background: Backscatter soundings
  - Bauru Feb. 2004
  - Niamey Aug. 2006
- Interpretation
  - Possible explanations
- New theory
  - Charge
- Conclusions/perspectives

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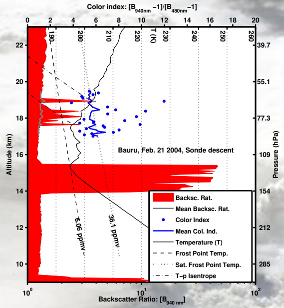
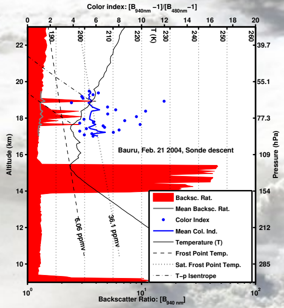
Backscatter Sonde Bauru 2004



Nielsen et al. ACP 2007

- “clouds” above TTL

Backscatter Sonde Bauru 2004



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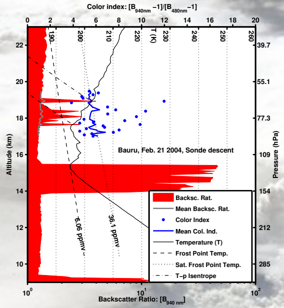
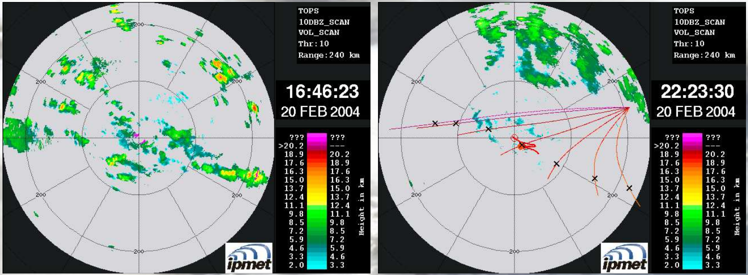


Nielsen et al. ACP 2007

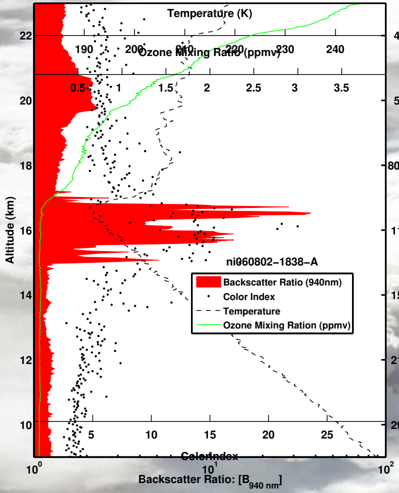
- “clouds” above TTL

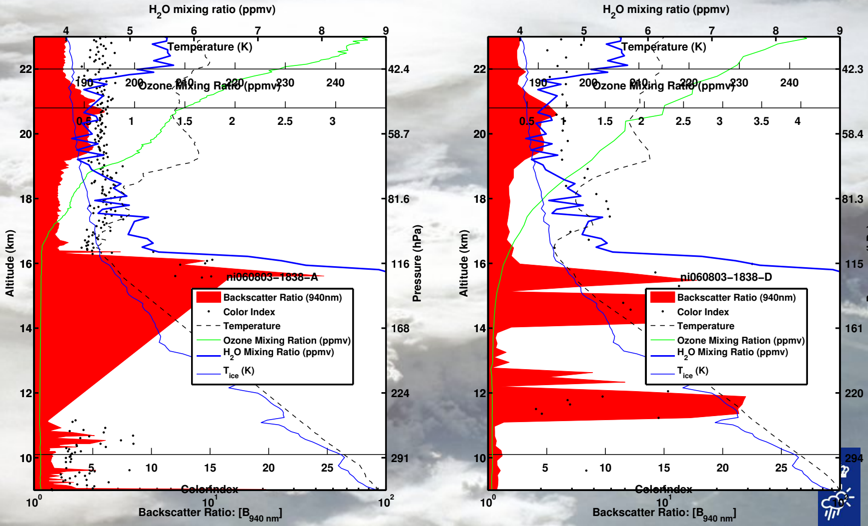
Meteorological conditions

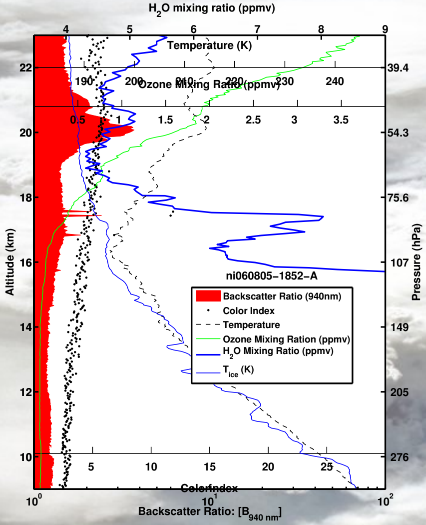


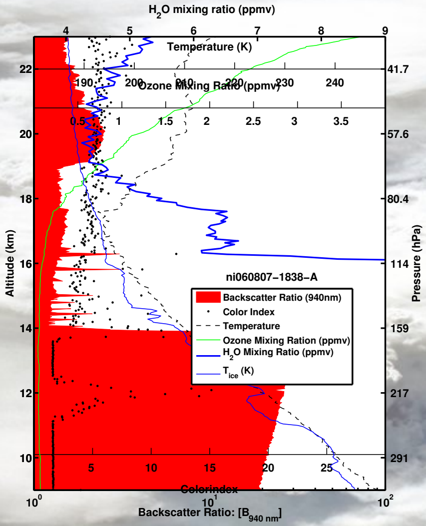
- Observation matches specific convection cell.

Another continent


Temperature (K)
190 200 210 220 230 240
Ozone Mixing Ratio (ppmv)
0.5 1 1.5 2 2.5 3 3.5
Altitude (km)
10 12 14 16 18 20 22
Pressure (hPa)
42 58 80.7 114 159 217 291
ni060802–1838–A
Backscatter Ratio (940nm)
Color Index
Temperature
Ozone Mixing Ration (ppmv)
5 10 15 20 25
Colorindex
10^0 10^1 10^2
Backscatter Ratio: [$B_{940\ nm}$]
Temperature (K)
190 200 210 220 230 240
Ozone Mixing Ratio (ppmv)
0.5 1 1.5 2 2.5 3 3.5
Altitude (km)
10 12 14 16 18 20 22
42 58 80.9 114 160 219 293
ni060802–1838–D
Backscatter Ratio (940nm)
Color Index
Temperature
Ozone Mixing Ration (ppmv)
5 10 15 20 25
Colorindex
10^0 10^1 10^2
Backscatter Ratio: [$B_{940\ nm}$]


H2O mixing ratio (ppmv)
Temperature (K)
Ozone Mixing Ratio (ppmv)
Altitude (km)
Pressure (hPa)
ni060803−1838−A
Backscatter Ratio (940nm)
Color Index
Temperature
Ozone Mixing Ration (ppmv)
H2O Mixing Ratio (ppmv)
Tice (K)
Colorindex
Backscatter Ratio: [B940 nm]
ni060803−1838−D

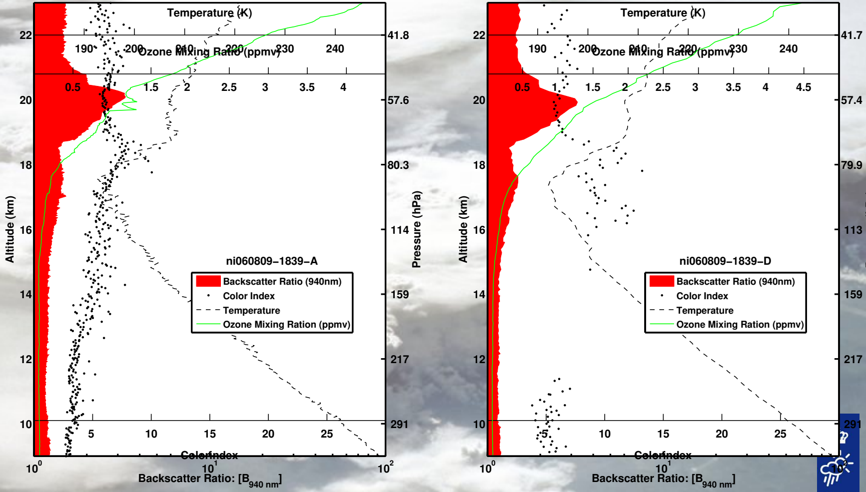

H2O mixing ratio (ppmv)
4 5 6 7 8 9
Temperature (K)
190 200 210 220 230 240
Ozone Mixing Ratio (ppmv)
0.5 1 1.5 2 2.5 3 3.5
Altitude (km)
22 20 18 16 14 12 10
Pressure (hPa)
39.4 54.3 75.6 107 149 205 276
ni060805−1852−A
Backscatter Ratio (940nm)
Color Index
Temperature
Ozone Mixing Ration (ppmv)
H2O Mixing Ratio (ppmv)
Tice (K)
5 10 15 20 25
ColorIndex
10^0 10^1 10^2
Backscatter Ratio: [B940 nm]

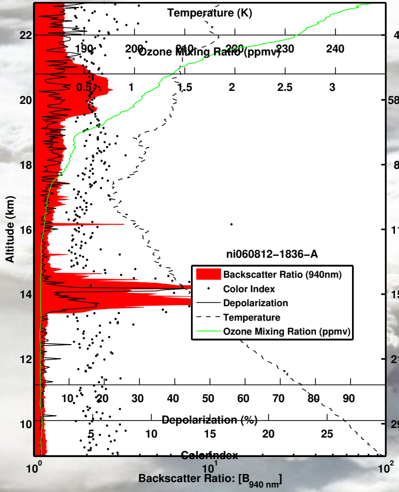

H2O mixing ratio (ppmv)
4 5 6 7 8 9
Temperature (K)
190 200 210 220 230 240
Ozone Mixing Ratio (ppmv)
0.5 1 1.5 2 2.5 3 3.5
Altitude (km)
22 20 18 16 14 12 10
Pressure (hPa)
41.7 57.6 80.4 114 159 217 291
ni060807–1838–A
Backscatter Ratio (940nm)
Color Index
Temperature
Ozone Mixing Ration (ppmv)
H2O Mixing Ratio (ppmv)
Tice (K)
5 10 15 20 25
Colorindex
10^0 10^1 10^2
Backscatter Ratio: [B940 nm]

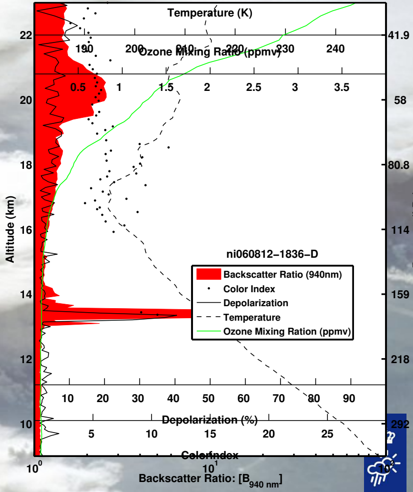
Stratospheric particles

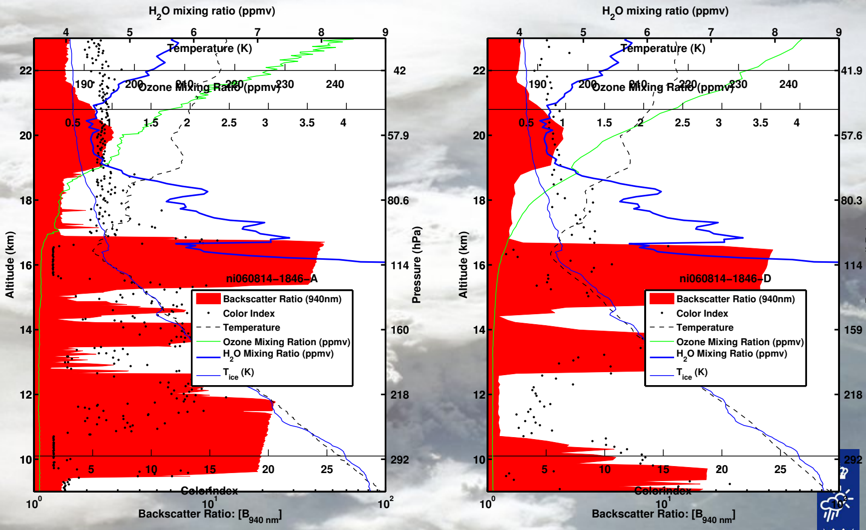
Background: Backscatter soundings

Niamey Aug. 2006




Temperature (K)
190
200
210
220
230
240
Ozone Mixing Ratio (ppmv)
0.5
1
1.5
2
2.5
3
Altitude (km)
Pressure (hPa)
42
58.1
81
114
159
217
290
ni060812–1836–A
Backscatter Ratio (940nm)
Color Index
Depolarization
Temperature
Ozone Mixing Ration (ppmv)
Depolarization (%)
Colorindex
Backscatter Ratio: [B940 nm]


Temperature (K)
Ozone Mixing Ratio (ppmv)
Altitude (km)
41.9
58
80.8
114
159
218
292
ni060812–1836–D
Backscatter Ratio (940nm)
Color Index
Depolarization
Temperature
Ozone Mixing Ration (ppmv)
Depolarization (%)
Colorindex
Backscatter Ratio: [B940 nm]


H2O mixing ratio (ppmv)
Temperature (K)
Ozone Mixing Ratio (ppmv)
Altitude (km)
Pressure (hPa)
Color Index
Backscatter Ratio: [B940 nm]
ni060814–1846–A
ni060814–1846–D
Backscatter Ratio (940nm)
Color Index
Temperature
Ozone Mixing Ration (ppmv)
H2O Mixing Ratio (ppmv)
Tice (K)

Stratospheric particles

Background: Backscatter soundings

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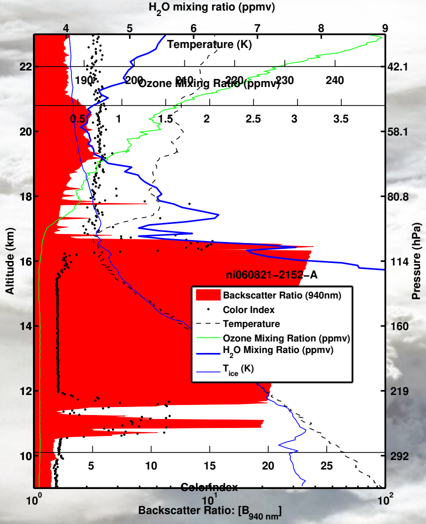
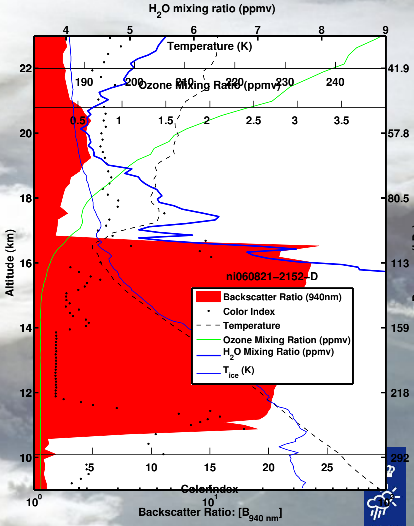
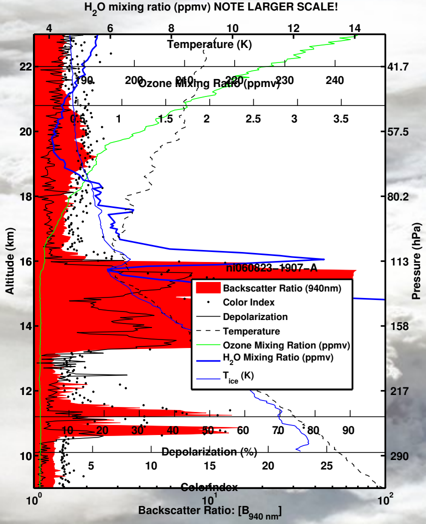
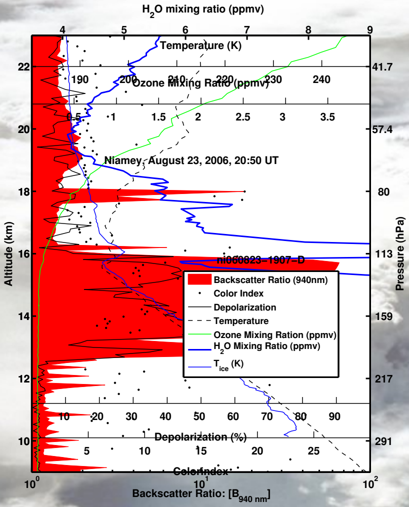




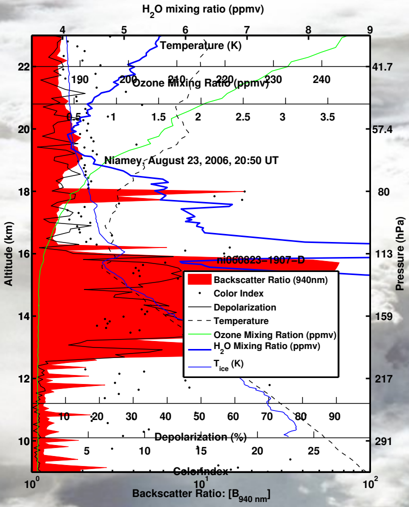

H2O mixing ratio (ppmv) NOTE LARGER SCALE!
4 6 8 10 12 14
Temperature (K)
190 200 210 220 230 240
Ozone Mixing Ratio (ppmv)
0.5 1 1.5 2 2.5 3 3.5
nl060823-1907-A
Backscatter Ratio (940nm)
Color Index
Depolarization
Temperature
Ozone Mixing Ration (ppmv)
H2O Mixing Ratio (ppmv)
Tice (K)
10 20 30 40 50 60 70 80 90
Depolarization (%)
5 10 15 20 25
ColorIndex
10^0 10^1 10^2
Backscatter Ratio: [B940 nm]
Altitude (km)
22 20 18 16 14 12 10
Pressure (hPa)
41.7 57.5 80.2 113 158 217 290

Niamey (13° North)



- Also in Africa.
- Now with water measurement.

Niamey (13° North)



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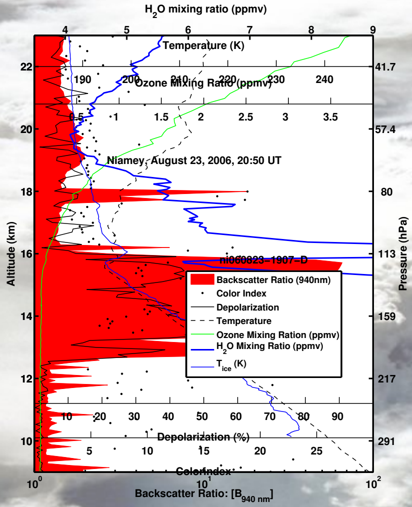

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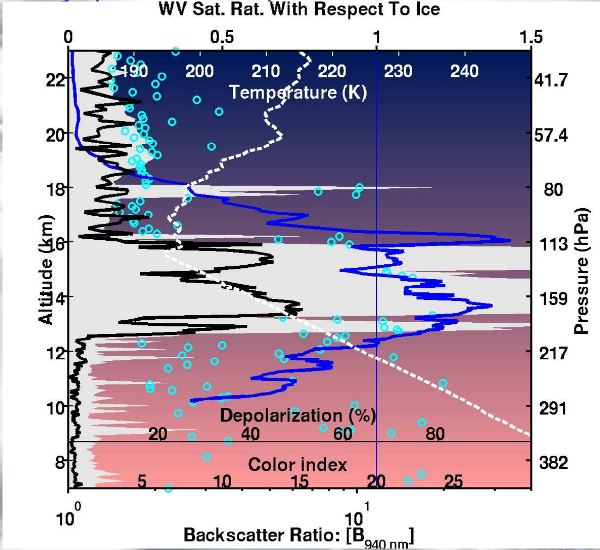
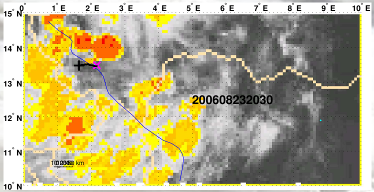
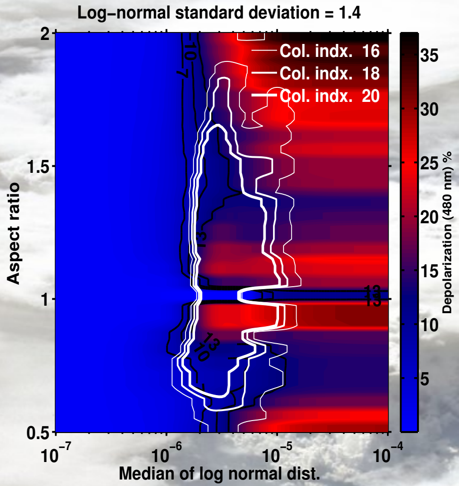


MCS tracking extract

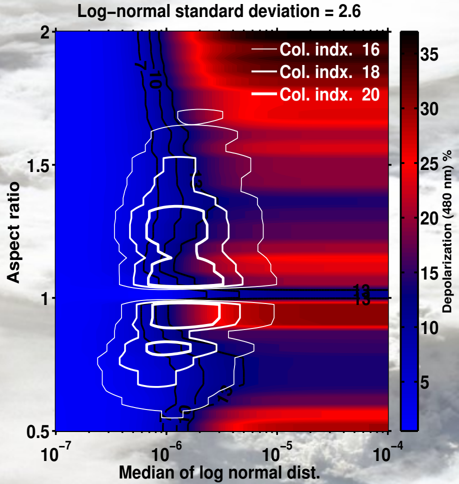


Back trajectories from ECMWF.
Circles: Uncertainty on trajectories.

Outline



Volume depolarization at 480 nm. Lognormal size distribution of stdev. 1.4. Color index $= B^A_{940}/B^A_{480}$.



Volume depolarization at 480 nm Lognormal size distribution with stdev. 2.6.

So:

- Larger than background aerosol
- Therefore probably solid
- Size [0.5-10]μm - otherwise spheric
- Sphericity would require special explanation
- Number density approximately $0.3 - 3 \times 10^6$/kg ($0.04 - 0.4$/cm^3)
- Solid phase water content < 1 ppmv

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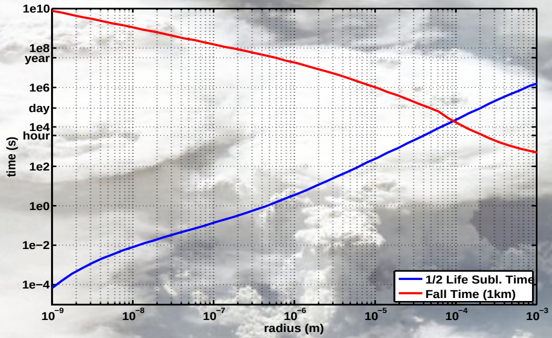
Timescales.



Quite unlikely observation. $[0.5 \times 10^{-6} - 10^{-5}]\mu$m - or $\tilde{[}1 - 300]$s

Several possibilities

- Dust?
- Smoke?
- NAT/NAT-Coating?
- Or...

Outline

Chemical potential

$$\mu_{\text{gas}}(r) = -\frac{q\mathbf{r}\cdot\mathbf{p}}{4\pi\epsilon_0 r^3} + \mu_0(T) + k_B T \log(e(r)) \qquad (1)$$

$q = ze$: electric charge
$\mathbf{p}$: water dipole moment
ϵ_0: the vacuum permitivity
In equilibrium $\frac{\partial \mu_{\text{gas}}}{dr} = 0$.

Chemical potential

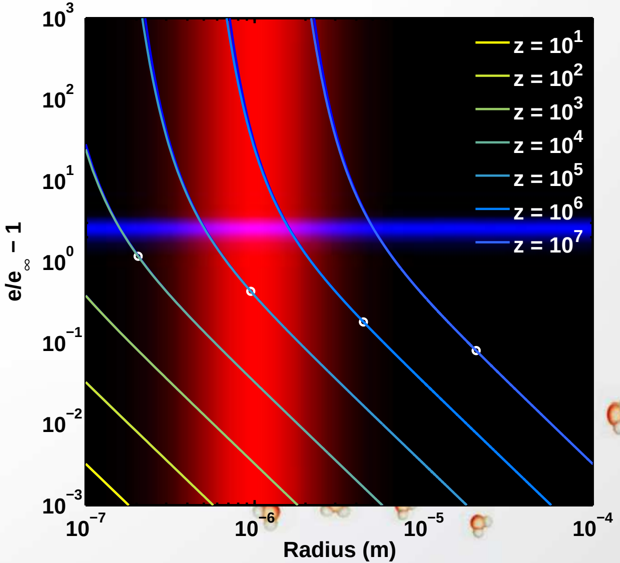
$$\mu_{\mathrm{gas}}(r) = -\frac{q\mathbf{r}\cdot\mathbf{p}}{4\pi\epsilon_0 r^3} + \mu_0(T) + k_B T \log(\mathrm{e}(r)) \tag{1}$$

$q = ze$: electric charge
$\mathbf{p}$: water dipole moment
ϵ_0: the vacuum permitivity
In equilibrium $\frac{d\mu_{\mathrm{gas}}}{dr} = 0$.

Increase in partial pressure of water:

$$e(r) = e_\infty \exp\left(\frac{q|\mathbf{p}|}{4\pi\epsilon_0 k_B T r^2}\right) \tag{2}$$

e_∞: ambient partial pressure


z = 10^1
z = 10^2
z = 10^3
z = 10^4
z = 10^5
z = 10^6
z = 10^7
e/e∞ − 1
Radius (m)
10^-7
10^-6
10^-5
10^-4
10^3
10^2
10^1
10^0
10^-1
10^-2
10^-3

Outline

Conclusions/Perspectives

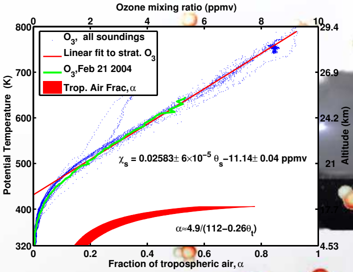
- The repeated observations of particles above the TTL close to tropical thunderstorms calls for an explanation.
- Solid particles, radius 0.5 -10 μm. They occur in connection to tropical thunderstorms, and they remain stable for longer time than expected in sub-saturated environment.
- “Stabilization by charge” should be considered along with the other possible explanations (NAT, dust, smoke ...).
- Presence of charged particles could change the microphysics of ice clouds in the TTL (deposition, sedimentation, aggregation).
- Particles and enhanced water vapor above TTL are indicating hydration through convective overshooting
- Quantification of hydration potential still missing.
- Can someone measure this?

Next Niamey 2008

- ˜10 flights
- New Backscatter-sondes (COBALT)
- Old Backscatter-sondes+Ozone
- FLASH Lyman α hygrometer.

- ASIM - Ground-based support, Danske følge forskningsmidler.
- ETH samarbejde.
- FP7 - Indtil nu kun nationale penge til feltarbejde.
- FNU ansøgning i samarbejde med Rumforskningsinst.

Mixing



- calculation of tropo-spheric/stratospheric air mixing ratio α
- $$\chi_{tro}\alpha + \chi_{str}(1-\alpha) = \chi_{mix}$$
  $$\theta_{tro}\alpha + \theta_{str}(1-\alpha) = \theta_{mix},$$
- water mixing ratio at time when air was crossing the tropopause: 160 ppmv

Summary

- Particles and enhanged water vapor above TTL are indicating hydration through convective overshooting
- Quantification of hydration potential still missing.