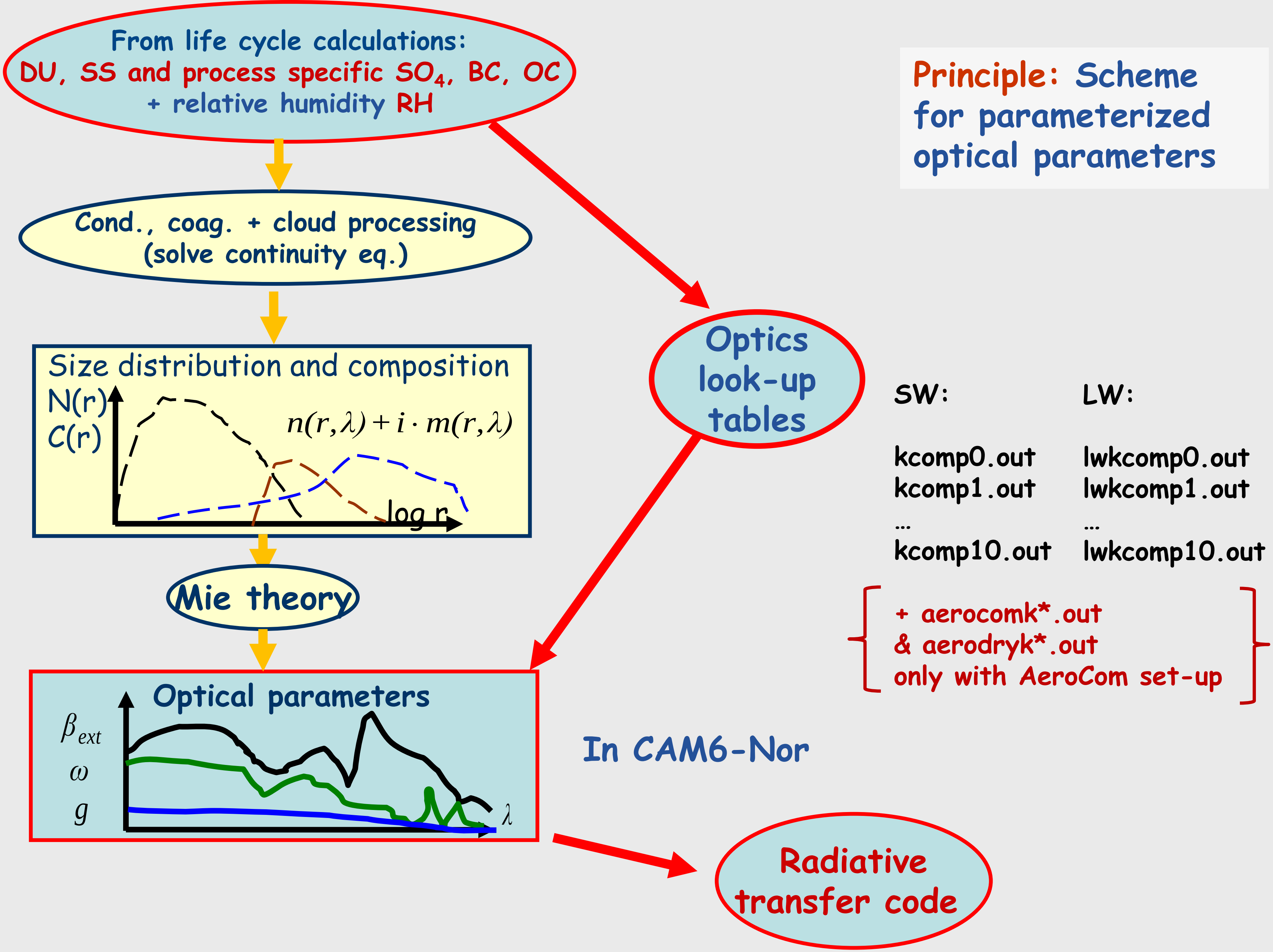
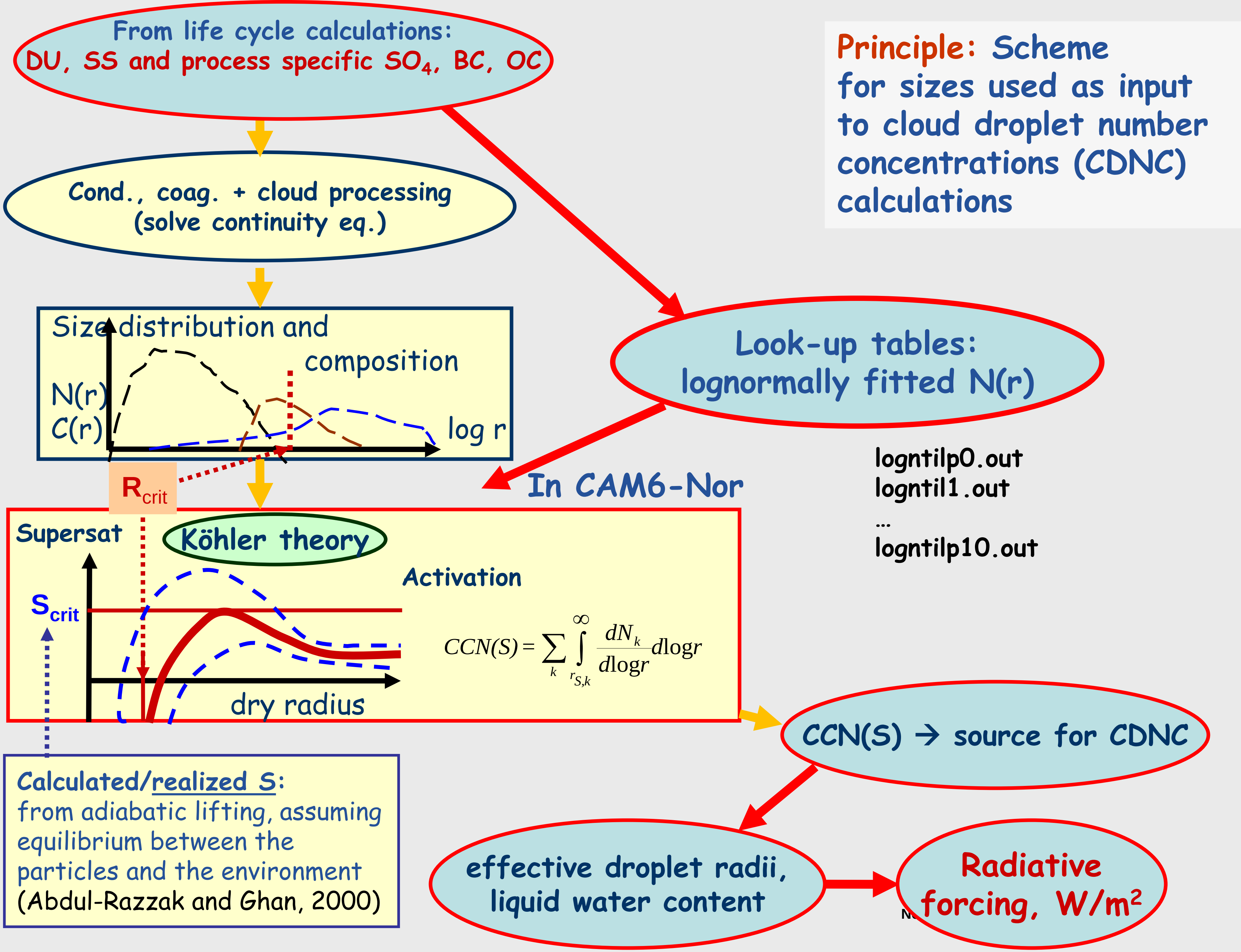
Norwegian Meteorological Institute

# AeroTab (NorESM2) :
## look-up table code for aerosol optics and size-info, e.g. for CCN activation

Alf Kirkevåg


From life cycle calculations:
DU, SS and process specific $SO_4$, BC, OC
+ relative humidity RH
Cond., coag. + cloud processing
(solve continuity eq.)
Size distribution and composition
N(r)
C(r)
$n(r,\lambda) + i \cdot m(r,\lambda)$
log r
Mie theory
Optical parameters
$\beta_{ext}$
$\omega$
$g$
$\lambda$
Principle: Scheme for parameterized optical parameters
Optics look-up tables
SW:
kcomp0.out
kcomp1.out
…
kcomp10.out
LW:
lwkcomp0.out
lwkcomp1.out
…
lwkcomp10.out
+ aerocomk*.out
& aerodryk*.out
only with AeroCom set-up
In CAM6-Nor
Radiative transfer code


Principle: Scheme for sizes used as input to cloud droplet number concentrations (CDNC) calculations
From life cycle calculations:
DU, SS and process specific $SO_4$, BC, OC
Cond., coag. + cloud processing (solve continuity eq.)
Size distribution and composition
N(r)
C(r)
log r
$R_{crit}$
Look-up tables: lognormally fitted N(r)
In CAM6-Nor
logntilp0.out
logntil1.out
…
logntilp10.out
Supersat
Köhler theory
Activation
$S_{crit}$
dry radius
$$CCN(S) = \sum_k \int_{r_{S,k}}^{\infty} \frac{dN_k}{d\log r} d\log r$$
CCN(S) → source for CDNC
Calculated/realized S: from adiabatic lifting, assuming equilibrium between the particles and the environment (Abdul-Razzak and Ghan, 2000)
effective droplet radii, liquid water content
Radiative forcing, $W/m^2$

## Aerosol growth by:

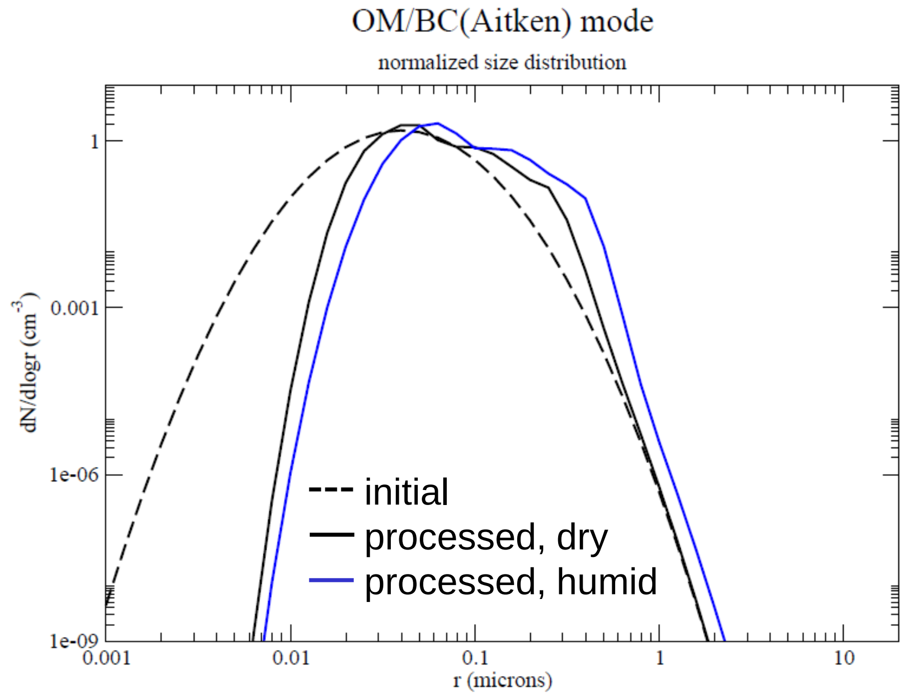
- condensation of $H_2SO_4$ or SOA

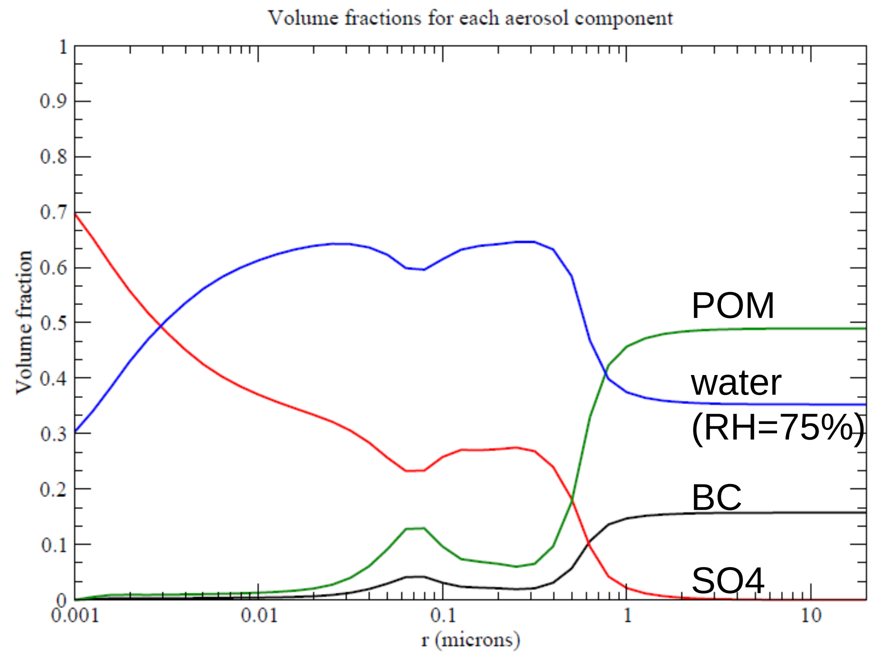
- coagulation of Aitken particles onto larger pre-existing particles

- cloud-processing/wet phase chemistry

- hygroscopic growth

$$\ln\left(\frac{e_r}{e_{s,w}}\right) = \frac{2M_w\sigma_{s/r}}{RT\rho_w r} - \frac{M_w}{\rho_w}\frac{1}{\left[\left(\frac{r}{r_0}\right)^3 - 1\right]}\sum_{\kappa}\nu_\kappa\Phi_\kappa\frac{\rho_\kappa v_{\kappa,k}(r_0)}{M_\kappa}$$




Ex. from old version without SOA

[20] We describe the size distribution with 44 size-bins along a logarithmic r-axis, with a bin-width of $\Delta\log(r/\mu m) = 0.1$. A discrete form of the continuity equation for $N_k(r,t)$;

$$\frac{\partial}{\partial t}\left[\frac{\partial N_k(r,t)}{\partial \log r}\right] + \frac{\partial}{\partial \log r}\left[\frac{D\log r}{Dt}\frac{\partial N_k(r,t)}{\partial \log r}\right] = 0, \qquad (2)$$

Continuity equations for particle number concentrations (see Kirkevåg and Iversen, 2002)

and similar equations for constituent mass concentrations are solved using a positive definite (anti-diffusive up-wind) advection scheme by Smolarkiewicz (1983) *(Mon. Wea. Rev. 111, 479-486.)*

[22] Following *Chuang and Penner* [1995],

$$\delta V_{aq}(r) = \frac{\Delta V_{aq}}{I_{max}}\theta(r - r_c)\left(\int \frac{dN(r)}{d\log r}\theta(r - r_c)d\log r\right)^{-1}$$

$$\delta V_{con}(r) = \frac{\Delta V_{con}}{I_{max}}rD'(r)\left(\int \frac{dN(r)}{d\log r}rD'(r)d\log r\right)^{-1}$$

and assuming coagulation of small particles onto larger size-modes:

$$\delta V_{coag}(r) = \frac{\Delta V_{coag}}{I_{max}}K_{1,2}(r,r_2)\left(\int \frac{dN(r)}{d\log r}K_{1,2}(r,r_2)d\log r\right)^{-1}$$

Hygroscopic growth of size distributions is also solved with the Smolarkiewicz scheme, but here with known growth factors, f(r) (from Köhler Eq.), instead of known process mass (e.g. condensate, from CAM-Oslo life-cycle scheme).

**Not a part of AeroTab,**
**but related assumptions which are needed in CAM-Oslo, in the subroutine modalapp:**

(from Kirkevåg and Iversen, 2002):

[26] Let $\Delta V_{k,aq}$, $\Delta V_{k,con}$, and $\Delta V_{k,coag}$ denote the integrated added volumes per volume of dry air for mode $k$. Integrating equations (6–8) multiplied with the total size distribution or only mode $k$, yields the apportionment between the modes:

$$\Delta V_{k,con} = \Delta V_{con}\left[\int rD'(r)\frac{dN_k(r)}{d\log r}d\log r\right] \cdot \left[\int rD'(r)\frac{dN(r)}{d\log r}d\log r\right]^{-1}, \qquad (9)$$

$$\Delta V_{k,coag} = \Delta V_{coag}\left[\int K_{1,2}(r,r_2)\frac{dN_k(r)}{d\log r}d\log r\right] \cdot \left[\int K_{1,2}(r,r_2)\frac{dN(r)}{d\log r}d\log r\right]^{-1}, \qquad (10)$$

$$\Delta V_{k,aq} = \Delta V_{aq}\left[\int \theta(r-r_c)\frac{dN_k(r)}{d\log r}d\log r\right] \cdot \left[\int \theta(r-r_c)\frac{dN(r)}{d\log r}d\log r\right]^{-1}. \qquad (11)$$

To reduce computational costs by table look-up and interpolation, we approximate equations (9–11) by using the initial size distribution in the integrands. We therefore only need to evaluate the modal apportionments for the first iteration. This approximation may displace the size-distributions, the effect of which is examined more closely in section 4, but is necessary in order to avoid solving equation (2) for the whole size distribution $N(r)$. Figure 1 shows an example of the effect of this approximation on a contaminated marine aerosol. The differences are negligible except for the smallest particles. For continental aerosol modes, the differences are even smaller.

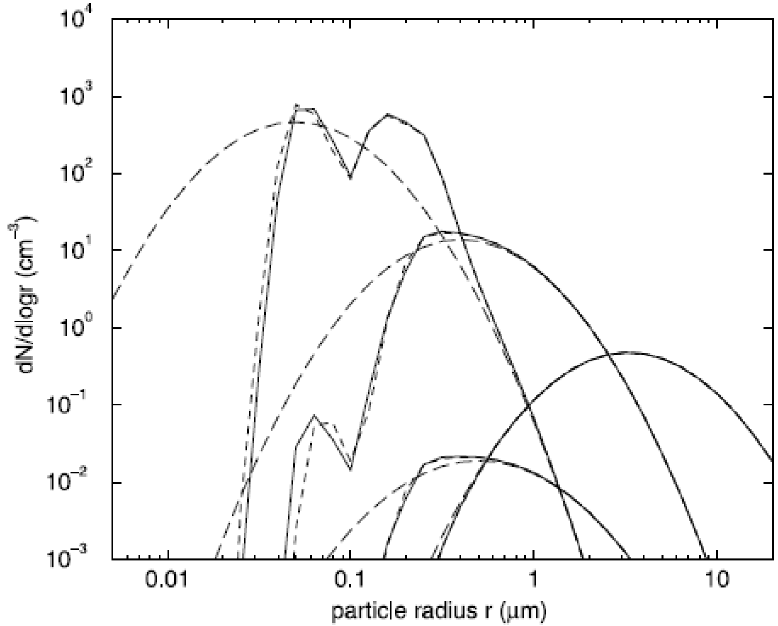
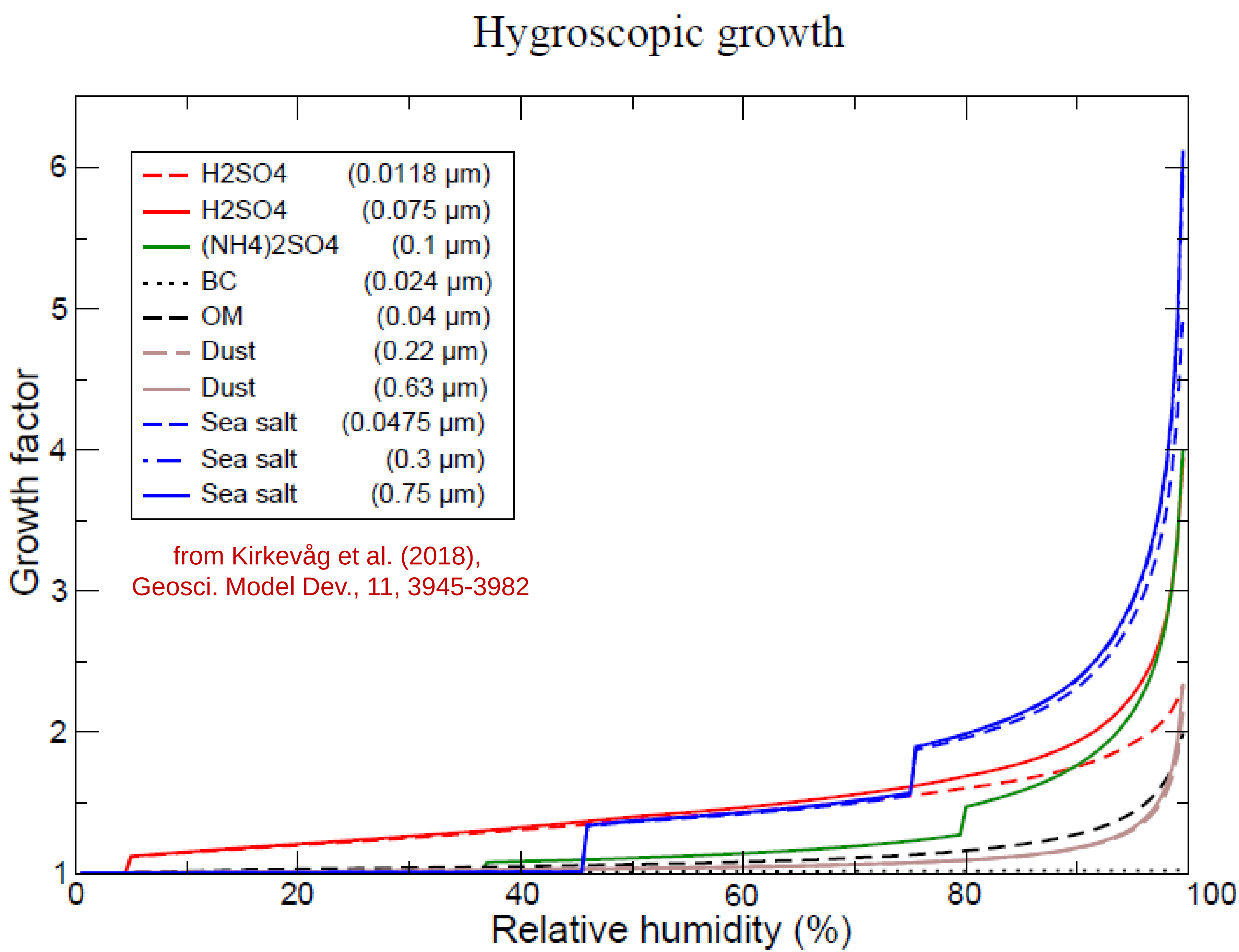



**Figure 1.** Example of the effects of condensation, coagulation and cloud processing on 4 modes of a marine size distribution, where $C^a = 10\ \mu g\ cm^{-3}$, $f_{bc} = 0.1$, and $f_{aq} = 0.75$. The long-dashed curves are pure background size distributions, while the dashed and solid curves are parameterized and nonparameterized internally mixed modes.



Hygroscopic growth
H2SO4 (0.0118 µm)
H2SO4 (0.075 µm)
(NH4)2SO4 (0.1 µm)
BC (0.024 µm)
OM (0.04 µm)
Dust (0.22 µm)
Dust (0.63 µm)
Sea salt (0.0475 µm)
Sea salt (0.3 µm)
Sea salt (0.75 µm)
from Kirkevåg et al. (2018),
Geosci. Model Dev., 11, 3945-3982
Growth factor
1
2
3
4
5
6
0
20
40
60
80
100
Relative humidity (%)

# The AeroTab code for producing look-up tables (LUT) (on NorESM git)

| | |
|---|---|
| AeroTab | Main program, loops over a predefined input parameter space to make LUT |
| specbands | Define spectral bands, and sub-bands for Chandrasekhar averaging |
| constsize | Define physical constants and necessary aerosol parameters |
| modepar | Define log-normal size parameters and grids for use in the LUT |
| drydist | Calculate dry log-normal background number size distributions |
| condsub | Calculate diffusion coefficients |
| coagsub | Calculate coagulation coefficients |
| tabrefind | Read in and interpolate refractive indices for the used spectral bands |
| openfiles | Open files for output (LUT for use in CAM6-Nor) |
| tableinfo | Add relevant header info to the LUT (mode/mixture dependent) |
| hygro | Calculate hygroscopicity for each pure component (not always a constant) |
| conteq<br>-> smolar | Find process-modified size distributions of number and constituent mass<br>by use of the Smolarkiewicz advection scheme |
| rhsub<br>-> koehler -> mixsub<br>-> smolar | Calulate hygroscopic growth by numerically solving the<br>Köhler equation for all externally and internally mixed components,<br>and find new size distributions after hygroscopic swelling |
| sizemie<br>-> refind<br>-> miev0<br>-> chandrav | Calculate gross optical properties (integrated over all or some sizes)<br>Calculate refractive indices for internal mixtures (volume / Maxwell-Garnett)<br>Mie-calculations: qext, qsca, gqsc, sback<br>Calculate chandrasekhar averaged optical properties sub-bands -> bands |
| modetilp | Find log-normal fits to the process-modified number size distributions |

# Setting up AeroTab.f to produce the required choice of lookup-tables

```
c     Modify the following input to create different sets of look-up tables:
c     Let iopt=1 for optics tables (CCN look-up tables for CAM-Oslo with diagnostic
c     CDNC is no longer available), or iopt=0 for size distribution calculations
c     (used in CCN activation in CAM4/5-Oslo and CAM6-Nor with prognostic CDNC):
      iopt=1
c     Lognormal mode fitting (itilp=1, iopt=0) --> logntilp*.out (and nkcomp.out
c     for dry, modified size distributions).
      itilp=1-iopt
c     Output for iopt=1 --> lwkcomp*.out or kcomp*.out, aerodryk*.out,
c     aerocomk*.out, and nkcomp*.out (for size distributions for all RH).
c     SW: ib=29 (ave.=>12) SW "bands" (CAMRT), or
c     SW: ib=31 (ave.=>14) (RRTMG) (Added November 2013), or
c     LW: ib=19 (ave.=>16) (RRTMG) (Added November 2013):
      ib=31
```

Let ib=31 for SW optics, and ib=19 for LW optics

## …Loop over all modes/mixtures:

```
do kcomp=0,10 ! for look-up tables, kcomp=0,10 (only kcomp=1-10 needed for logntilp*.out)

(… calculation for each mixture kcomp)

end do
```

# Aerosol tracers and mixtures

some tracers are lumped in the look-up tables (LUT)

| MODE/MIXTURE INDEX | Tracer 1 | Tracer 2 | Tracer 3 | Tracer 4 | Tracer5 | Tracer 6 | Tracer 7 | |
|---|---|---|---|---|---|---|---|---|
| 0 (BC_AX) | BC_AX | | | | | | | these need LUT |
| 1 (SO4 COAT) | SO4_NA | SOA_NA | SO4_A1 | SOA_A1 | | | | |
| 2 (BC COAT) | BC_A | SO4_A1 | SOA_A1 | | | | | |
| 3 (NO LONGER USED) | | | | | | | | |
| 4 (OM/BC COAT) | OM_AI | BC_AI | SO4_A1 | SO4_A2 | SOA_A1 | | | |
| 5 (SO4 PRIMARY) | SO4_PR | BC_AC | OM_AC | SO4_A1 | SO4_AC | SO4_A2 | SOA_A1 | |
| 6 (DST A2) | DST_A2 | BC_AC | OM_AC | SO4_A1 | SO4_AC | SO4_A2 | SOA_A1 | |
| 7 (DST A3) | DST_A3 | BC_AC | OM_AC | SO4_A1 | SO4_AC | SO4_A2 | SOA_A1 | |
| 8 (SALT A1) | SS_A1 | BC_AC | OM_AC | SO4_A1 | SO4_AC | SO4_A2 | SOA_A1 | |
| 9 (SALT A2) | SS_A2 | BC_AC | OM_AC | SO4_A1 | SO4_AC | SO4_A2 | SOA_A1 | |
| 10 (SALT A3) | SS_A3 | BC_AC | OM_AC | SO4_A1 | SO4_AC | SO4_A2 | SOA_A1 | |
| 11 (NO LONGER USED) | | | | | | | | |
| 12 (BC NUCL) | BC_N | | | | | | | = clean 2 |
| 13 (NO LONGER USED) | | | | | | | | |
| 14 (BC NUCL) | OM_NI | BC_NI | | | | | | = clean 4 |

*Tracers contributing to number concentration in green.*

*New tracers since CAM4-Oslo in red.*

_AC = coagulation
_A1 = condensation
_A2 = cloud processing

| Do Loop: | The Index represents: |
|---|---|
| do kcomp = 0, 10 | mode/mixture **kcomp** |
| do 540 irelh = irelh1, irelh2 | ambient relative humidity **relh** |
| do 540 ifombg = ifombg1, ifombg2 | mass fraction of OM (as SOA) in the OM & SO4 backgr. of mixture 1, **fombg** |
| do 540 ifbcbg = ifbcbg1, ifbcbg2 | mass fraction of BC in the OM & BC backgr. of mixture 4, **fbcbg** |
| do 540 ictot = ictot1, ictot2 | total added mass (µg/m3 per particle per cm3) from cond.& coag., and wet phase chemistry/cloud processing for kcomp = 5-10, **ctot** |
| do 540 ictote = ictote1, ictote2 | total added mass (µg/m3 per particle per cm3) from cond.& coag., and wet phase chemistry/cloud processing, for kcomp = 1-2, **ctote** |
| do 540 ifac = ifac1, ifac2 | OM+BC mass fraction of total added process mass, **fac** |
| do 540 ifbc = ifbc1, ifbc2 | BC fraction of added OM and BC, **fbc** |
| do 540 ifaq = ifaq1, ifaq2 | wet phase SO4 to total SO4 added, **faq** |

*(…. code …)*

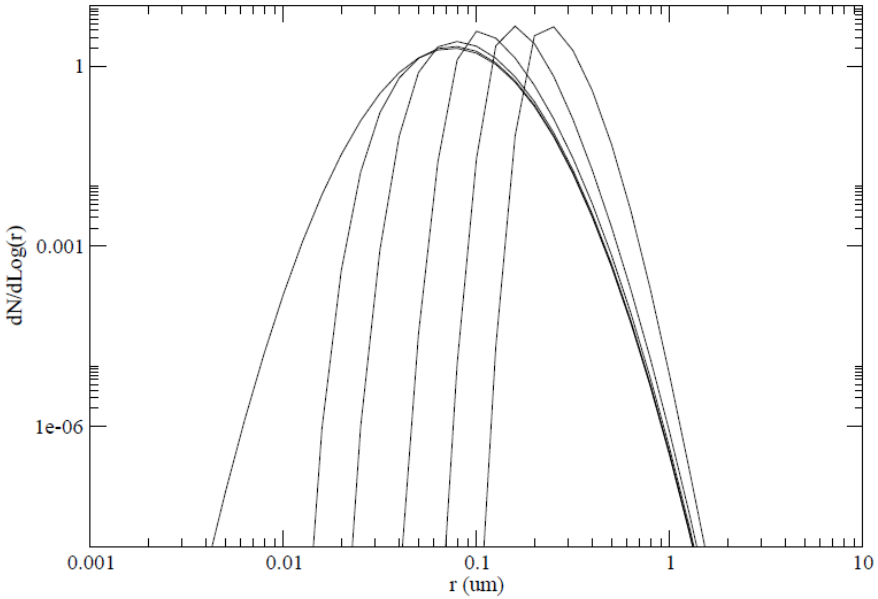
```
540  continue        ! ifaq, ifbc, ifac, ictot/ictote, ifombg, ifbcbg, irelh

     enddo  ! kcomp
```

Note: «added» here means added onto an originally «log-normal background», i.e. addition of process-specific mass which causes changes in the size distributions.

Examples from old version without SOA

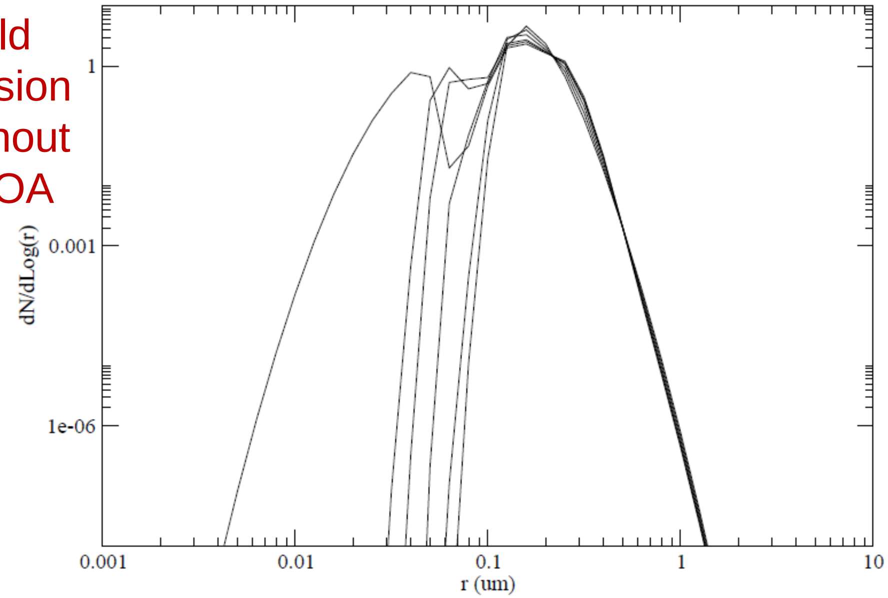
modified SO4(a) mode

with varying cat



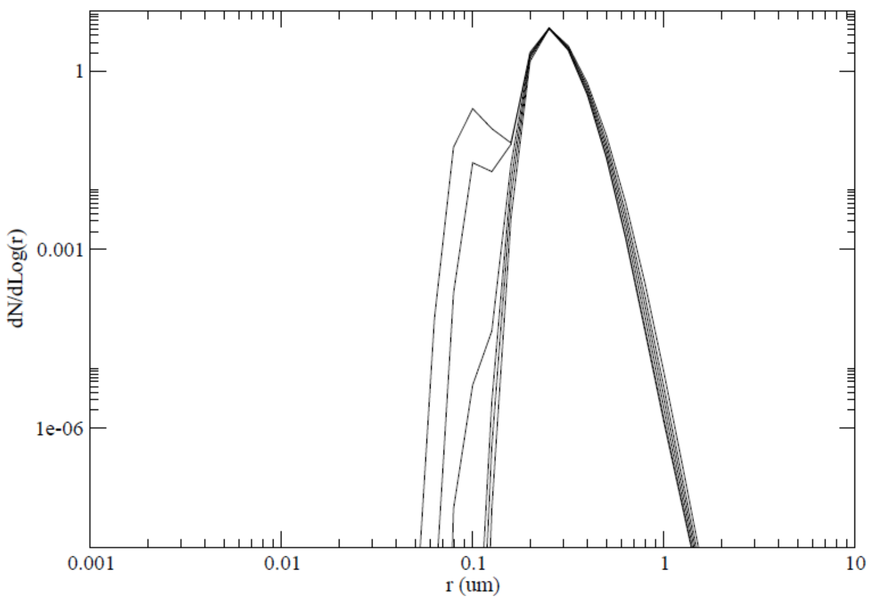

modified SO4(a) mode

with varying faq



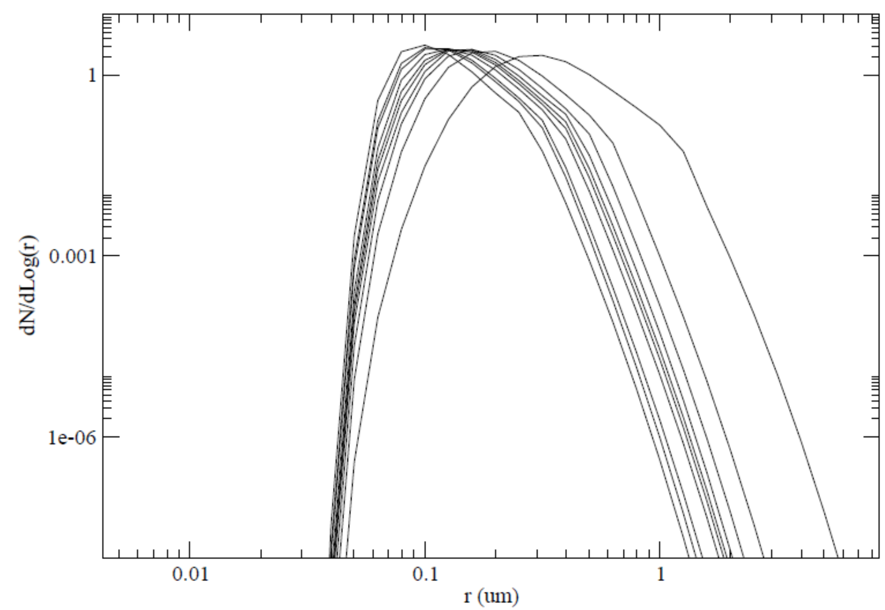

modified SO4(a) mode

with varying fac




modified SO4(a) mode

with varying RH



# Ex. optics look-up tables for normalized size-distribution (1 $cm^{-3}$): SO4_NA / SO4_A1 mode (without SOA), kcomp1.out

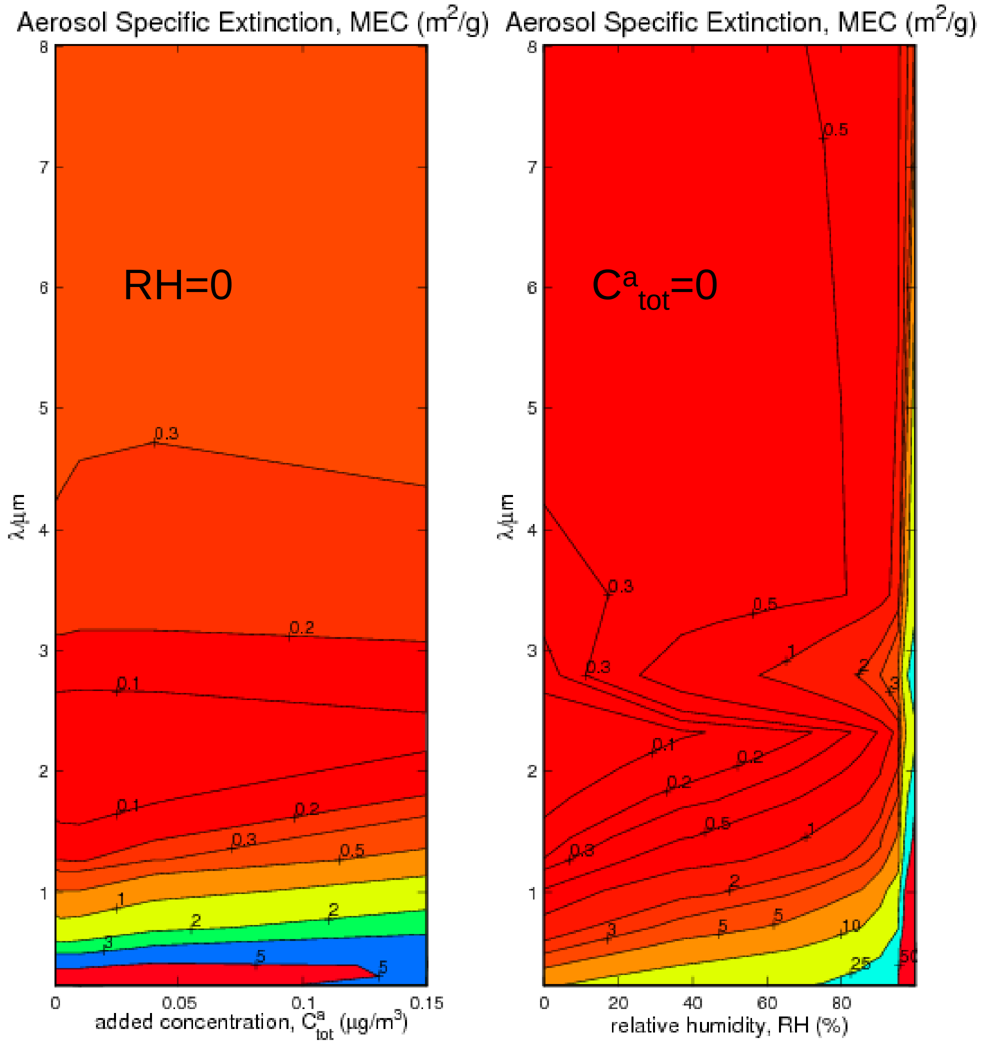
(+ fac, fbc, faq for full mixtures, i.e. for kcomp5-10.out)

| kcomp | λ- band | RH | catot (μg/m³) | ω (SSA) | g (ASS) | $\beta_{ext}$ ($km^{-1}$) | $k_{ext}$ ($m^2/g$) |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 0.000 | 0.100E-09 | 0.10000E+01 | 0.47359E+00 | 0.16628E-06 | 0.27715E+01 |
| 1 | 2 | 0.000 | 0.100E-09 | 0.10000E+01 | 0.39279E+00 | 0.71593E-07 | 0.11932E+01 |
| 1 | 3 | 0.000 | 0.100E-09 | 0.10000E+01 | 0.32032E+00 | 0.31281E-07 | 0.52137E+00 |
| 1 | 4 | 0.000 | 0.100E-09 | 0.10000E+01 | 0.23817E+00 | 0.11838E-07 | 0.19731E+00 |
| 1 | 5 | 0.000 | 0.100E-09 | 0.10000E+01 | 0.16972E+00 | 0.42962E-08 | 0.71605E-01 |
| 1 | 6 | 0.000 | 0.100E-09 | 0.99925E+00 | 0.10729E+00 | 0.13311E-08 | 0.22185E-01 |
| 1 | 7 | 0.000 | 0.100E-09 | 0.98957E+00 | 0.68222E-01 | 0.40892E-09 | 0.68156E-02 |
| 1 | 8 | 0.000 | 0.100E-09 | 0.89741E+00 | 0.54710E-01 | 0.26690E-09 | 0.44485E-02 |
| 1 | 9 | 0.000 | 0.100E-09 | 0.51139E+00 | 0.37973E-01 | 0.20475E-09 | 0.34126E-02 |
| 1 | 10 | 0.000 | 0.100E-09 | 0.17958E+00 | 0.28885E-01 | 0.29873E-09 | 0.49789E-02 |
| 1 | 11 | 0.000 | 0.100E-09 | 0.63999E-01 | 0.22469E-01 | 0.45194E-09 | 0.75325E-02 |
| 1 | 12 | 0.000 | 0.100E-09 | 0.16020E-02 | 0.15484E-01 | 0.71279E-08 | 0.11880E+00 |
| 1 | 13 | 0.000 | 0.100E-09 | 0.47779E-03 | 0.10429E-01 | 0.15419E-07 | 0.25700E+00 |
| 1 | 14 | 0.000 | 0.100E-09 | 0.23886E-04 | 0.17066E-02 | 0.26914E-07 | 0.44857E+00 |
| 1 | 1 | 0.000 | 0.100E-04 | 0.10000E+01 | 0.46974E+00 | 0.18902E-06 | 0.26923E+01 |
| 1 | 2 | 0.000 | 0.100E-04 | 0.10000E+01 | 0.38826E+00 | 0.81015E-07 | 0.11539E+01 |

etc…

Example from old version without SOA

# Example use of output from look-up tables for SO4(a) mode using MATLAB




Examples from old version without SOA

Mass specific extinction coefficient:

$$MEC = \beta_{ext} / C_{tot\ (without\ water)}$$

MEC's dependence on 2 of 5 input parameters (pluss λ): total internally mixed mass, and RH

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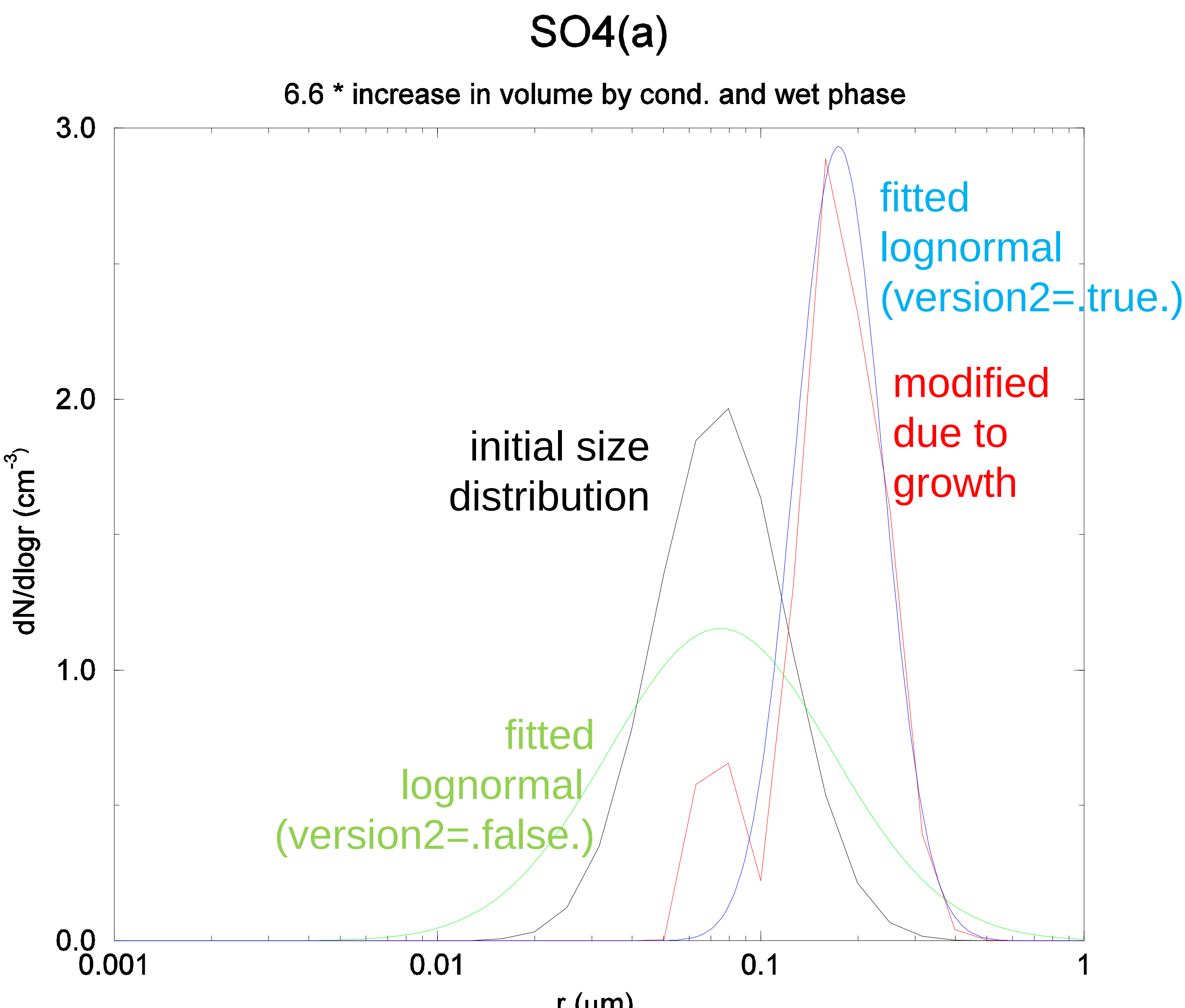
# Ex. look-up tables for log-normal size parameters (dry aerosol): SO4(a) mode, logntilp5.out

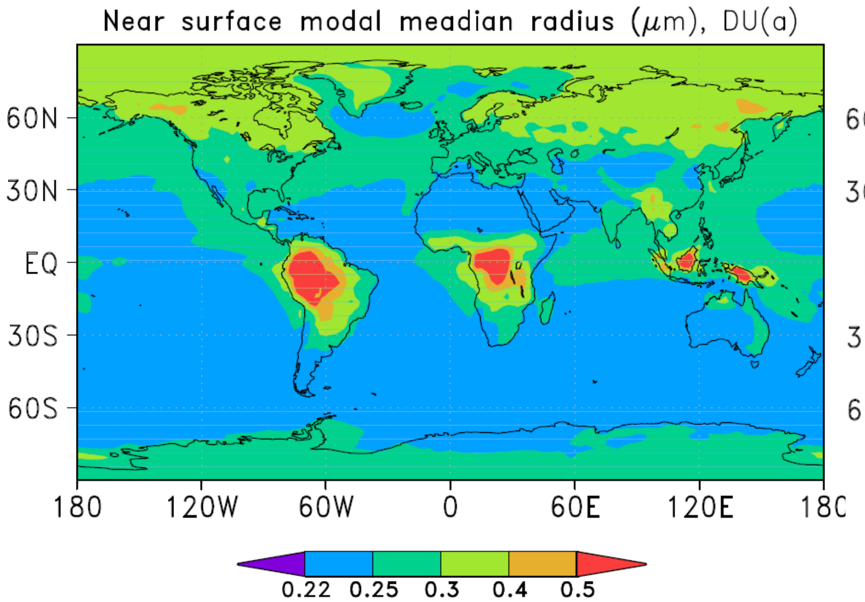
| catot (µg/m$^3$) | fac | fbc | faq | R (m) | $\log_{10}(\sigma)$ | kcomp |
|---|---|---|---|---|---|---|
| 0.10000E-09 | 0.00000E+00 | 0.00000E+00 | 0.00000E+00 | 0.75000E-01 | 0.20140E+00 | 5 |
| 0.10000E-09 | 0.00000E+00 | 0.00000E+00 | 0.25000E+00 | 0.75000E-01 | 0.20140E+00 | 5 |
| 0.10000E-09 | 0.00000E+00 | 0.00000E+00 | 0.50000E+00 | 0.75000E-01 | 0.20140E+00 | 5 |
| 0.10000E-09 | 0.00000E+00 | 0.00000E+00 | 0.75000E+00 | 0.75000E-01 | 0.20140E+00 | 5 |
| 0.10000E-09 | 0.00000E+00 | 0.00000E+00 | 0.85000E+00 | 0.75000E-01 | 0.20140E+00 | 5 |
| 0.10000E-09 | 0.00000E+00 | 0.00000E+00 | 0.10000E+01 | 0.75000E-01 | 0.20140E+00 | 5 |
| 0.10000E-09 | 0.00000E+00 | 0.10000E-01 | 0.00000E+00 | 0.75000E-01 | 0.20140E+00 | 5 |
| 0.10000E-09 | 0.00000E+00 | 0.10000E-01 | 0.25000E+00 | 0.75000E-01 | 0.20140E+00 | 5 |
| etc… | | | | | | |
| … | | | | | | |
| 0.15000E+00 | 0.99900E+00 | 0.70000E+00 | 0.50000E+00 | 0.23800E+00 | 0.11835E+00 | 5 |
| 0.15000E+00 | 0.99900E+00 | 0.70000E+00 | 0.75000E+00 | 0.23800E+00 | 0.11835E+00 | 5 |
| 0.15000E+00 | 0.99900E+00 | 0.70000E+00 | 0.85000E+00 | 0.23800E+00 | 0.11831E+00 | 5 |
| 0.15000E+00 | 0.99900E+00 | 0.70000E+00 | 0.10000E+01 | 0.23900E+00 | 0.11621E+00 | 5 |
| 0.15000E+00 | 0.99900E+00 | 0.99900E+00 | 0.00000E+00 | 0.23100E+00 | 0.11803E+00 | 5 |
| 0.15000E+00 | 0.99900E+00 | 0.99900E+00 | 0.25000E+00 | 0.23100E+00 | 0.11803E+00 | 5 |
| 0.15000E+00 | 0.99900E+00 | 0.99900E+00 | 0.50000E+00 | 0.23100E+00 | 0.11803E+00 | 5 |
| 0.15000E+00 | 0.99900E+00 | 0.99900E+00 | 0.75000E+00 | 0.23100E+00 | 0.11803E+00 | 5 |
| 0.15000E+00 | 0.99900E+00 | 0.99900E+00 | 0.85000E+00 | 0.23100E+00 | 0.11803E+00 | 5 |
| 0.15000E+00 | 0.99900E+00 | 0.99900E+00 | 0.10000E+01 | 0.23100E+00 | 0.11800E+00 | 5 |

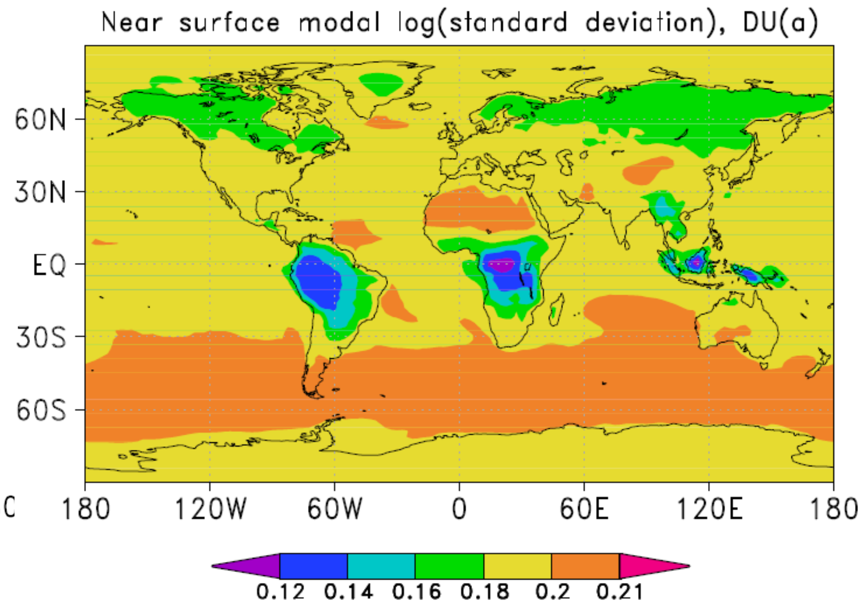
Example from old version without SOA

# Example of lognormal fitting (LUT for r and σ) for use in the activation code



# Example output from a 1 year PD simulation, CAM4-Oslo




Example from old version without SOA

Before growth: r=0.22 log(sigma)=0.2014

(Growth *in this case* also includes hygroscopic swelling)

**Extra output (LUT), e.g. for use in AeroCom / RFMIP / AerChemMIP**

used by CAM6-Nor only when set up with «#define AEROCOM»

aerodryk*.out — Parameters for calculation of effective radii in CAM-Nor, and dry mass concentrations for r < 0.5 µm and r > 1.25 µm

aerocomk*.out — Total and component specific optical parameters at wavelengths 440, 500, 550, 670 and 870 nm (not used for radiative transfer).
And, only at 550 nm:
backscattering coefficient
optical parameters for size ranges r < 0.5 µm and r > 0.5 µm.

and, not used in CAM6-Nor, but useful for control purposes:

nkcomp*.out — Modified aerosol number size distributions (sectional, 44 bins).

where * = 0, 1, 2,…,10

## In a new test version (under construction):

### Added mass from

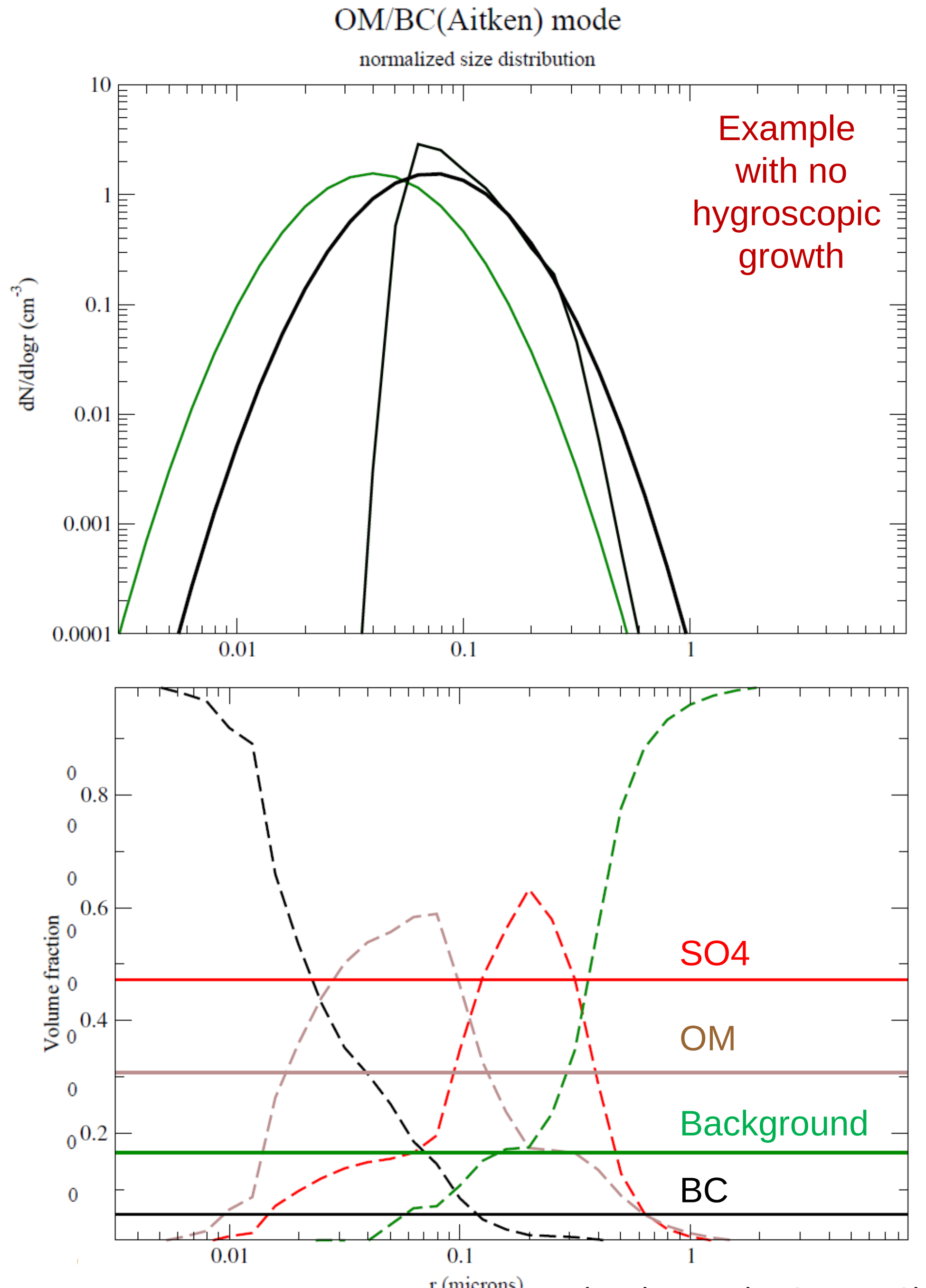
- condensation of $H_2SO_4$ or SOA
- coagulation of Aitken particles onto larger pre-existing particles
- cloud-processing/wet phase chemistry
- hygroscopic growth

$$\ln\left(\frac{e_r}{e_{s,w}}\right) = \frac{2M_w\sigma_{s/r}}{RT\rho_w r} - \frac{M_w}{\rho_w}\frac{1}{\left[\left(\frac{r}{r_0}\right)^3 - 1\right]}\sum_\kappa \nu_\kappa \Phi_\kappa \frac{\rho_\kappa v_{\kappa,k}(r_0)}{M_\kappa}$$

will here be mixed homogeneously, preserving log-normal number size distributions (similar to MAM)

→ check effects of complexity on optics, size and CCN activation !

If results are acceptable, this can form the basis of a light version of AeroTab.




(Background = OM & BC)

# Extra slides

# Hygroscopic growth calculations, in koehler.f :

(… inside some do loops)

```
c           mixsub calculates hygroscopic properties (given by x)
c           for an internally mixed aerosol
            call mixsub (frr0, itot, faq, Mw, rhow,
     $        j, vsk, vbck, vock, x, rh, kcomp)
            rhumg=rhum
c           the Koehler equation
            rhum=e**(2e3*Mw*sigm/(Rg*T*rhow*rk(i))
     $        -x/((rk(i)/rk(j))**3-1.0))
```

x=x(r)

$$\ln\left(\frac{e_r}{e_{s,w}}\right) = \frac{2M_w\sigma_{s/r}}{RT\rho_w r} - \frac{M_w}{\rho_w}\frac{1}{\left[\left(\frac{r}{r_0}\right)^3 - 1\right]}\sum_{\kappa}\nu_\kappa\Phi_\kappa\frac{\rho_\kappa\nu_{\kappa,k}(r_0)}{M_\kappa}$$

## and calculating x in mixsub.f,
## e.g. for $(NH_4)_2SO_4$:

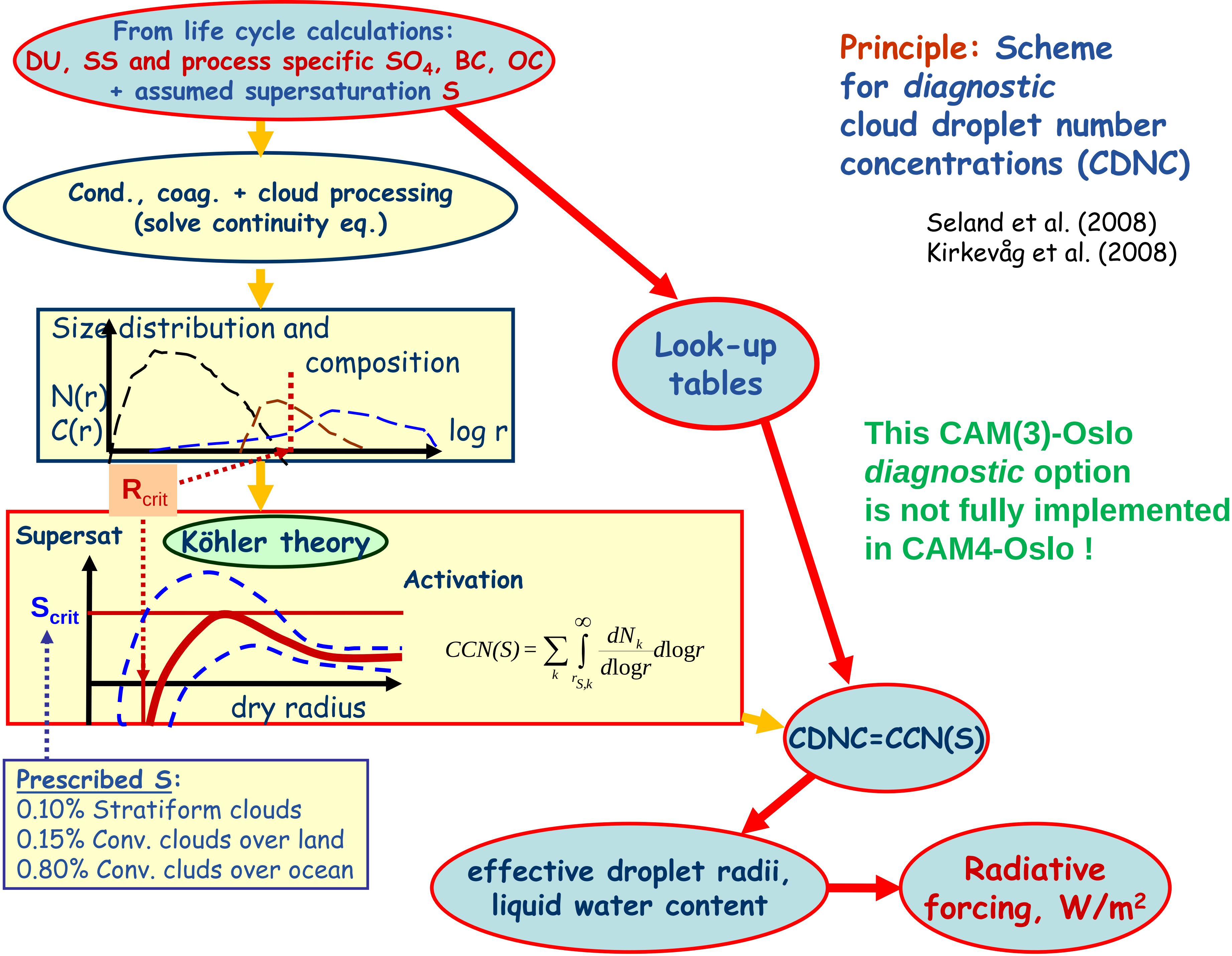
```
c     ammonium sulphate:
      Ms=1.3214e2
      rhosl=1.769e3
      if(frr0.le.1.02) then
        ai=-23.7649*frr0+24.4955
      elseif(frr0.gt.1.02.and.frr0.le.1.05) then
        ai=10.6373*frr0-10.5947
      elseif(frr0.gt.1.05.and.frr0.le.1.11) then
        ai=9.3474*frr0-9.2404
      elseif(frr0.gt.1.11.and.frr0.le.1.22) then
        ai=6.2080*frr0-5.7556
      elseif(frr0.gt.1.22.and.frr0.le.1.325) then
        ai=1.8385*frr0-0.4248
      elseif(frr0.gt.1.325.and.frr0.le.1.424) then
        ai=-2.0065*frr0+4.6699
      elseif(frr0.gt.1.424.and.frr0.le.1.65) then
        ai=-0.8021*frr0+2.9548
      elseif(frr0.gt.1.65.and.frr0.le.1.974) then
        ai=-0.1192*frr0+1.8279
      elseif(frr0.gt.1.974.and.frr0.le.2.593) then
        ai=0.1629*frr0+1.2712
      elseif(frr0.gt.2.593.and.frr0.le.3.185) then
        ai=0.1734*frr0+1.2437
      else
        ai=1.8
      endif
      xa=ai*(Mw/Ms)*(rhosl/rhow)
```

from offline parameterization:
x is a function of frr0 (=r/r0)

Simplify: **x = const.**

## e.g. internally mixed in mode 4, OC&BC(a):

```
      elseif(kcomp.eq.4) then                          ! BC or OC + H2SO4 + (NH4)2SO4
        if(itot.eq.0) then
          x=xbg
        else    ! internal mixture
          if(rh.lt.0.37) then
             x=(1.0-vsk(i)-vbck(i))*xbg+vsk(i)*(1.0-faq)*xs
          else
             x=(1.0-vsk(i)-vbck(i))*xbg+vsk(i)*(faq*xa+(1.0-faq)*xs)
          endif
        endif
```


Principle: Scheme for *diagnostic* cloud droplet number concentrations (CDNC)
Seland et al. (2008)
Kirkevåg et al. (2008)
From life cycle calculations:
DU, SS and process specific $SO_4$, BC, OC
+ assumed supersaturation S
Cond., coag. + cloud processing
(solve continuity eq.)
Size distribution and composition
N(r)
C(r)
log r
$R_{crit}$
Supersat
Köhler theory
Activation
$S_{crit}$
$$CCN(S) = \sum_k \int_{r_{S,k}}^{\infty} \frac{dN_k}{d\log r} d\log r$$
dry radius
Look-up tables
This CAM(3)-Oslo *diagnostic* option is not fully implemented in CAM4-Oslo !
CDNC=CCN(S)
Prescribed S:
0.10% Stratiform clouds
0.15% Conv. clouds over land
0.80% Conv. cluds over ocean
effective droplet radii, liquid water content
Radiative forcing, $W/m^2$