Norwegian
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AeroTab:
look-up table code for aerosol optics and size-info (e.g. cloud drop activation)

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Main subroutines of AeroTab.f, and their main purposes:

specbands	Define spectral bands, and sub-bands for Chandrasekhar averaging
constsize	Define constants and necessary aerosol parameters
openfiles	Open files for output (to use as input in CAM-Oslo)
modepar	Define log-normal size parameters and grids for use in the look-up tables
drydist	Define (calculate) dry modal background size distributions
condsub	Calculate diffusion coefficients (both done in coagsub in CMIP5 version)
coagsub	Calculate coagulation coefficients (both done in coagsub in CMIP5 version)
tabrefind	Read in and interpolate refractive indices for the used spectral bands
conteq -> smolar	Find process-modified size distributions of number and constituent mass by use of the Smolarkiewicz advection scheme
rhsub -> koehler -> mixsub -> smolar	Calulate hygroscopic growth by numerically solving the Köhler equation for all externally and internally mixed components, and using the Smolarkiewicz advection scheme
sizemie	Calculate gross optical properties (integrated over all or some sizes)
-> refind	Calculate refractive indices for internal mixtures (volume / Maxwell Garnett)
-> miev0	Mie-calculations: qext, qsca, gqsc, sback
-> chandrav	Calculate chandrasekhar averaged optical properties for spectral bands consisting of several sub-bands
modetilp	Find log-normal fits to the process-modified number size distributions

Setting up AeroTab to produce the needed lookup-tables, in AeroTab.f:

```
c     Adjustable input parameters to the look-up table calculations:
c     Calculations for background aerosol modes 1 to 10 or mode 11 to 14
c     (itot=0), or total aerosol, mode 1-10 only (itot=1):
      itot=1
c     Let iccn=0 for optics tables, iccn=1 for CCN (CAM-Oslo with DIAGNCDNC)
c     --> ccnk*.out, or size distribution calculations (CAM4-Oslo and CAM5-Oslo
c     with the prognostic CDNC scheme):
      iccn=0
c     Lognormal mode fitting (itilp=1) or not (itilp=0) (requires iccn=1)
c     --> logntilp*.out (and nkcomp.out for dry size distributions):
      itilp=1
c     We only do the lognormal fitting only if iccn=1 (and for dry aerosols):
      if(iccn.eq.0) itilp=0
c     Options for iccn=0 --> 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 31 (ave.=>14) (RRTMG);
c     LW: ib=19 (ave.=>16) (RRTMG) (Added November 2013):
      ib=31
cSOA  Added December 2013
c     SOA may be internally mixed with the SO4(ait) mode (1) or not (0).
c     iSOA=0 in CAM4-Oslo/NorESM1 (e.g., KirkevÃ¥g et al., 2013)
      iSOA=0
cSOA
```

Let ib=31 only for CAM5-Oslo optics and for the CAM4-Oslo AeroCom look-up tables aerodryk*.out aerocomk*.out.

…Loop over all modes:

```
do kcomp=1,10   ! for look-up tables, kcomp=1,10 and 13 (with 13 "renamed" to 0)
```

Aerosol growth by:

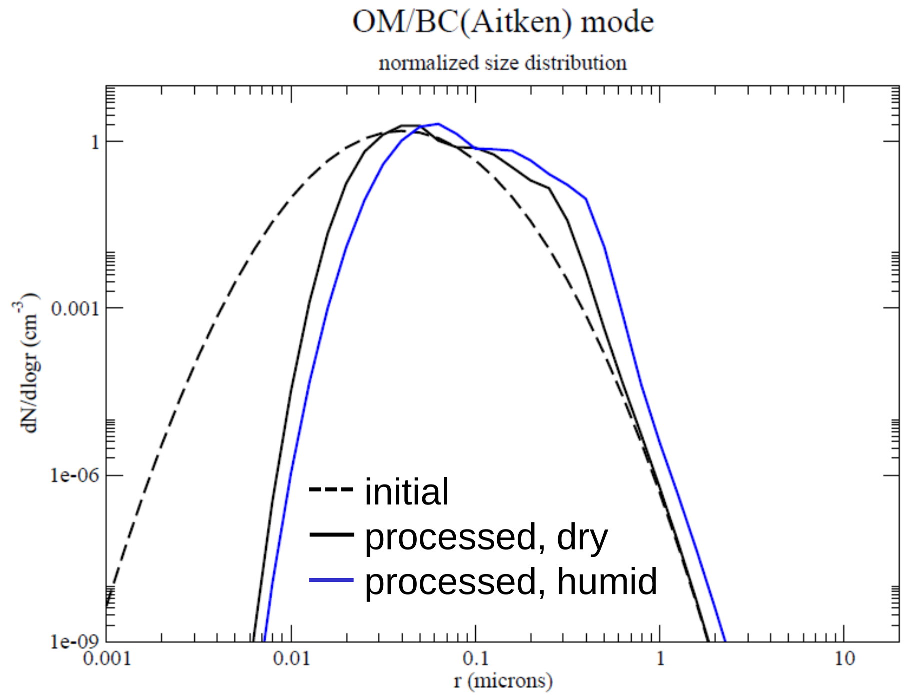
- condensation of H_2SO_4

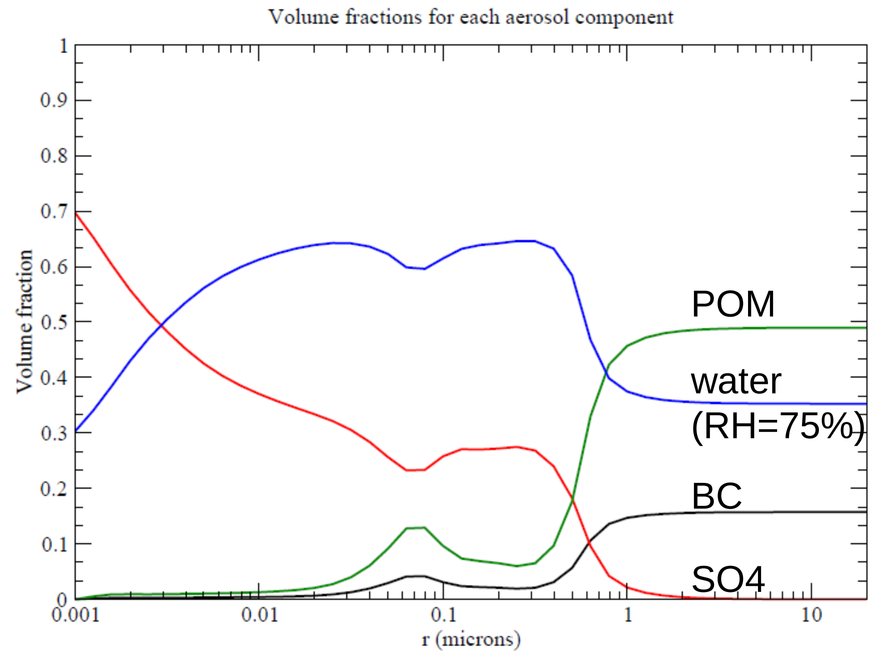
- coagulation of Aitken particles onto larger pre-existing particles

- cloud-processing/wet phase chemistry

- hygroscopic growth

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





[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:

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

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

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

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.

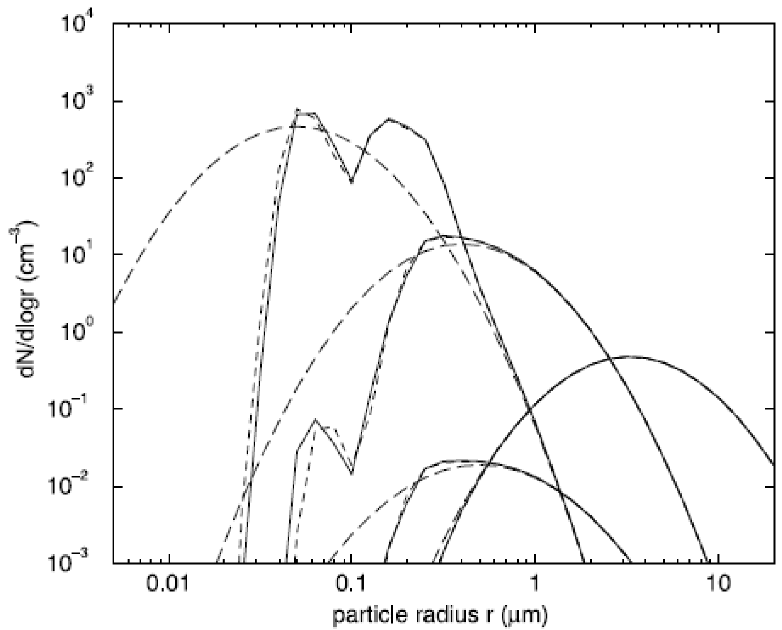
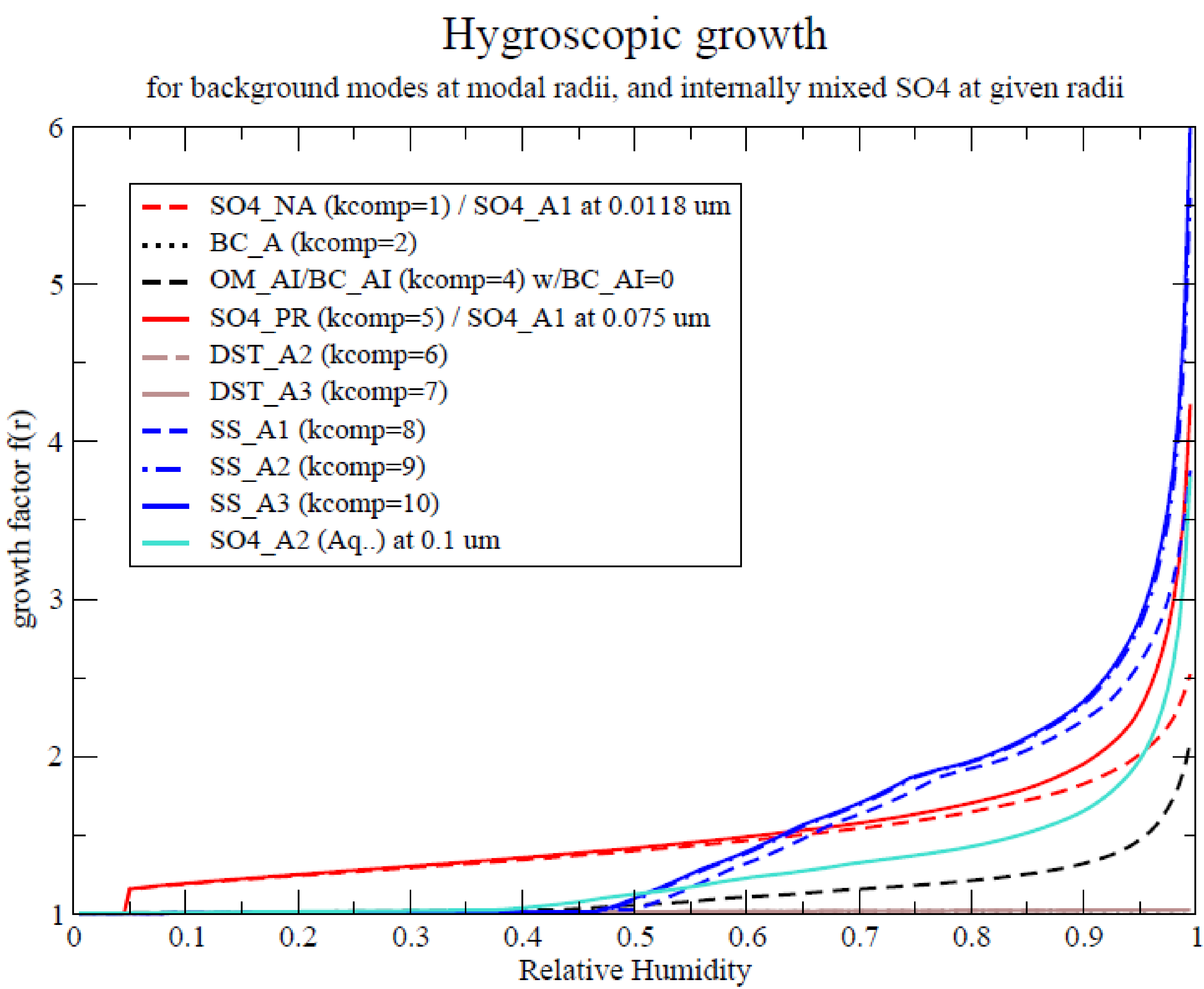


Figure 1. Example of the effects of condensation, coagulation and cloud processing on 4 modes of a marine size distribution, where $C^a = 10\,\mu g\,cm^{-3}$, $f_{bc} = 0.1$, and $f_{aq} = 0.75$. The long-dashed curves are pure background size distributions, while the dashed and solid curves are parameterized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


Hygroscopic growth
for background modes at modal radii, and internally mixed SO4 at given radii
SO4_NA (kcomp=1) / SO4_A1 at 0.0118 um
BC_A (kcomp=2)
OM_AI/BC_AI (kcomp=4) w/BC_AI=0
SO4_PR (kcomp=5) / SO4_A1 at 0.075 um
DST_A2 (kcomp=6)
DST_A3 (kcomp=7)
SS_A1 (kcomp=8)
SS_A2 (kcomp=9)
SS_A3 (kcomp=10)
SO4_A2 (Aq..) at 0.1 um
growth factor f(r)
Relative Humidity
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
2
3
4
5
6

Tracers

SO4_N, SO4_NA, SO4_A1, SO4_A2, SO4_AC, SO4_PR,
BC_N, BC_AX, BC_NI, BC_A, BC_AI, BC_AC
OM_NI, OM_AI, OM_AC (OM_N not used any more)
DST_A2, DST_A3
SS_A1, SS_A2, SS_A3

MIXTURES

kcomp CAM-Oslo	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
	BC ax	SO4 na	**BC a**		**OM ai**	SO4 pr	**DST a2**	**DST a3**	**SS a1**	**SS a2**	**SS a3**	SO4 n	**BC n**	OM n	**OM ni**
		SO4 a1	SO4 a1		BC ai	**BC ac**	**BC ac**	**BC ac**	**BC ac**	**BC ac**	**BC ac**				BC ni
					SO4 a1	OM ac	OM ac	OM ac	OM ac	OM ac	OM ac				
					SO4 a2	SO4 a1	SO4 a1	SO4 a1	SO4 a1	SO4 a1	SO4 a1				
						SO4 ac	SO4 ac	SO4 ac	SO4 ac	SO4 ac	SO4 ac				
						SO4 a2	SO4 a2	SO4 a2	SO4 a2	SO4 a2	SO4 a2				
kcomp AeroTab	13	1	2	3	4	5	6	7	8	9	10	11, 12, 14 not used			

(3 = OM_A = OM_N + condensate in older code versions)

(use1, 2, 4 with nothing added)

Internal mixtures of process-tagged mass

cate: total added mass (μg/m^3 per particle per cm^3) from condensation and wet phase chemistry/cloud processing, for kcomp = 1-2.

cat: total added mass (μg/m^3 per particle per cm^{-3}) from coagulation, condensation and wet phase chemistry/cloud processing, for kcomp = 5-10.

Cat and cate should be scaled up/down whenever the modal parameters (modal radius and width) are increased/decreased a lot.

fac: mass fraction of cat or cate from coagulating carbonaceous aerosols (BC+OM). The remaining mass cate*(1-fac) or cat*(1-fac) is SO4.

fbc: mass fraction of BC from coagulating carbonaceous aerosols, BC/(BC+OM).

faq: mass fraction of sulfate which is produced in wet-phase, $SO4_{aq}$/SO4. The remaining SO4 mass, SO4*(1-faq), is from condensation.

Exception, for kcomp=4:

Both OM and BC exist in the background size-mode (co-emitted with same modal parameters but varying BC/OC ratio), so that only condensate or wet-phase SO4 is added with varying size-dependence. To avoid making a new programming structure for this special case, we may pretend that only OM is in the background, and then add BC in a radius-independent way, before adding sufate. New meaning of fac:

fac: BC mass fraction of background carbonaceous aerosols, BC/(BC+OM)

(**fbc not used:** no BC or OM coagulate on this size-mode)

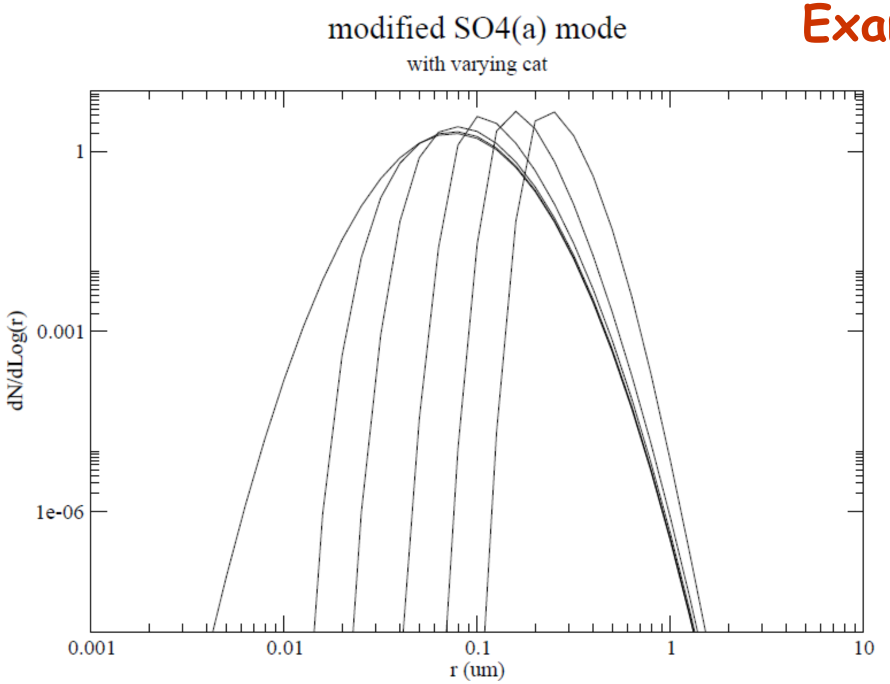
cate: BC in the background mode + total added mass (µg/m^3 per particle per cm^3) from condensation and wet phase chemistry/cloud processing

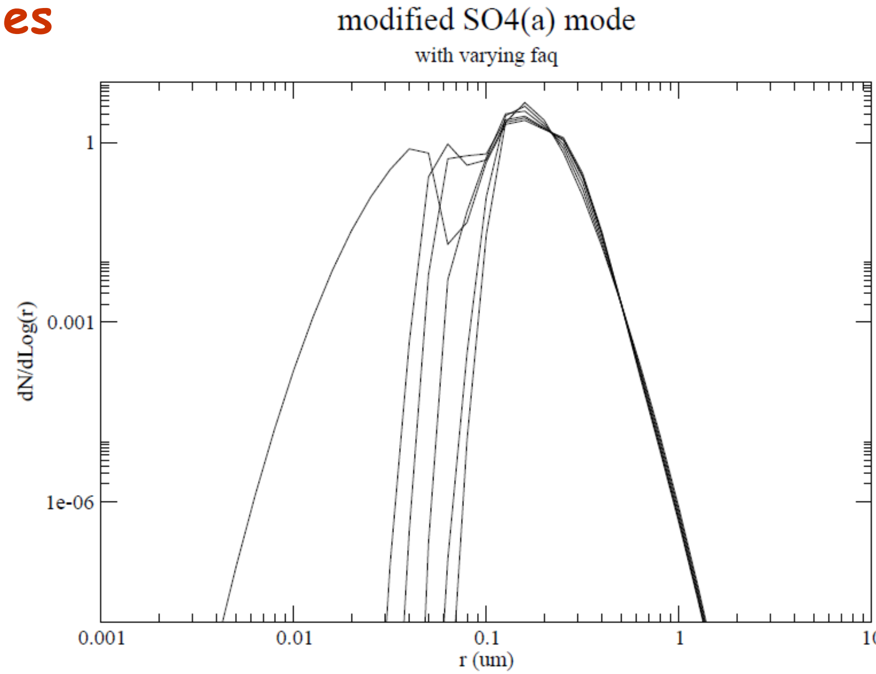
```
real(r8), public, dimension(6) :: fac = (/ 0.0_r8, 0.1_r8,  0.3_r8, 0.5_r8, 0.7_r8, 0.999_r8    /)
real(r8), public, dimension(6) :: fbc = (/ 0.0_r8, 0.01_r8, 0.1_r8, 0.3_r8, 0.7_r8, 0.999_r8    /)
real(r8), public, dimension(6) :: faq = (/ 0.0_r8, 0.25_r8, 0.5_r8, 0.75_r8,0.85_r8,1.0_r8      /)
real(r8), public, dimension(10) :: rh = (/ 0.0_r8, 0.37_r8, 0.47_r8,0.65_r8,0.75_r8,            &
                                           0.8_r8, 0.85_r8, 0.9_r8, 0.95_r8,0.995_r8             /)

real(r8), public, dimension(5:10,6) :: cat = reshape ( (/ &
  1.e-10_r8, 1.e-10_r8, 1.e-10_r8, 1.e-10_r8, 1.e-10_r8, 1.e-10_r8, &
  5.e-4_r8 , 0.01_r8  ,   0.02_r8  ,  1.e-4_r8 ,  0.005_r8 , 0.02_r8  , &
  2.e-3_r8 , 0.05_r8  ,   0.1_r8   ,  6.e-4_r8 ,  0.025_r8 , 0.1_r8   , &
  0.01_r8  , 0.2_r8   ,   0.5_r8   ,  2.5e-3_r8, 0.1_r8    ,   0.5_r8   , &
  0.04_r8  , 0.8_r8   ,   2.0_r8   ,  1.e-2_r8 , 0.4_r8    ,   2.0_r8   , &
  0.15_r8  , 4.0_r8   ,   8.0_r8   ,  3.5e-2_r8, 2.0_r8    ,   8.0_r8   /), (/6,6/) )

 real(r8), public, dimension(4,16) :: cate = reshape ( (/ &
  1.e-10_r8, 1.e-10_r8, 1.e-10_r8,  1.e-10_r8*1.904e-3_r8, &
  1.e-5_r8 ,  1.e-5_r8 ,   1.e-4_r8 ,  0.01_r8*1.904e-3_r8  , &
  2.e-5_r8 ,  2.e-5_r8 ,   2.e-4_r8 ,  0.05_r8*1.904e-3_r8  , &
  4.e-5_r8 ,  4.e-5_r8 ,   4.e-4_r8 ,  0.1_r8*1.904e-3_r8   , &
  8.e-5_r8 ,   8.e-5_r8 ,  8.e-4_r8 ,  0.2_r8*1.904e-3_r8   , &
  1.5e-4_r8, 1.5e-4_r8,  1.5e-3_r8, 0.4_r8*1.904e-3_r8   , &
  3.e-4_r8 ,   3.e-4_r8 ,  3.e-3_r8 ,  0.7_r8*1.904e-3_r8   , &
  6.e-4_r8 ,   6.e-4_r8 ,  6.e-3_r8 , 1.0_r8*1.904e-3_r8   , &
  1.2e-3_r8, 1.2e-3_r8,  1.2e-2_r8, 1.5_r8*1.904e-3_r8   , &
  2.5e-3_r8,  2.5e-3_r8, 2.5e-2_r8, 2.5_r8*1.904e-3_r8   , &
  5.e-3_r8 ,   5.e-3_r8 ,  5.e-2_r8 ,  5.0_r8*1.904e-3_r8   , &
  1.e-2_r8 ,   1.e-2_r8 ,  0.1_r8   ,   10.0_r8*1.904e-3_r8  , &
  2.e-2_r8 ,   2.e-2_r8 ,  0.2_r8   ,   25.0_r8*1.904e-3_r8  , &
  4.e-2_r8 ,   4.e-2_r8 ,  0.4_r8   ,   50.0_r8*1.904e-3_r8  , &
  8.e-2_r8 ,   8.e-2_r8 ,  0.8_r8   ,  100.0_r8*1.904e-3_r8 , &
  0.15_r8  ,   0.15_r8  ,  1.5_r8   ,   500.0_r8*1.904e-3_r8 /), (/4,16/) )
```

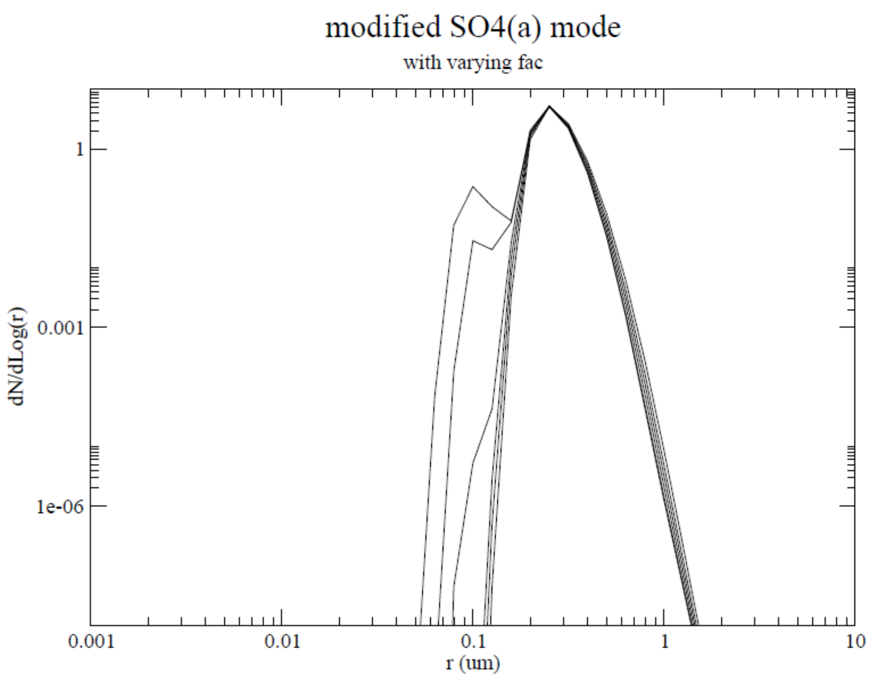
Discrete look-up table grid values

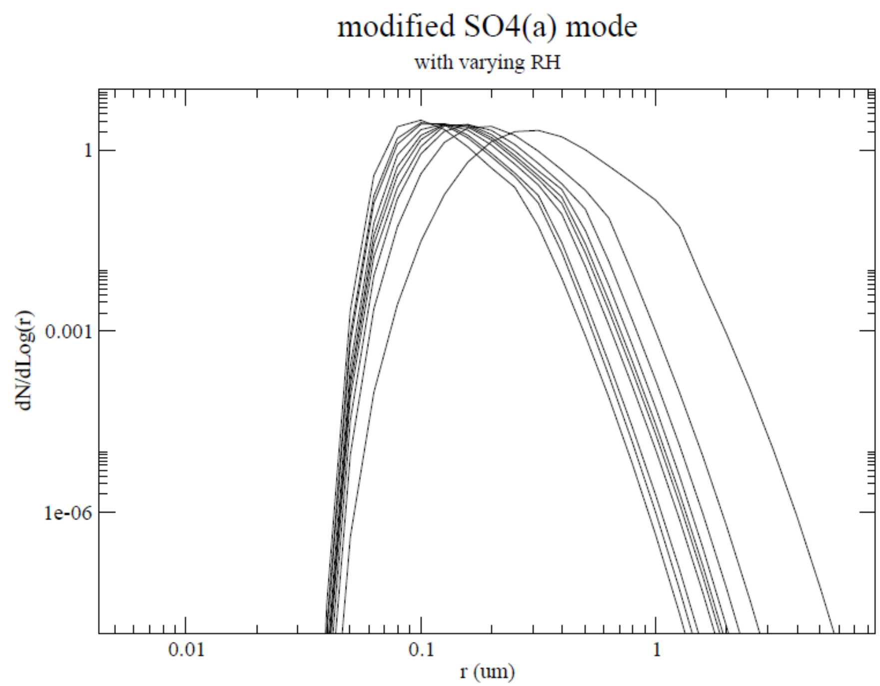
(code from opttab.F90 in CAM4-Oslo. Same as in modepar.f in AeroTab)

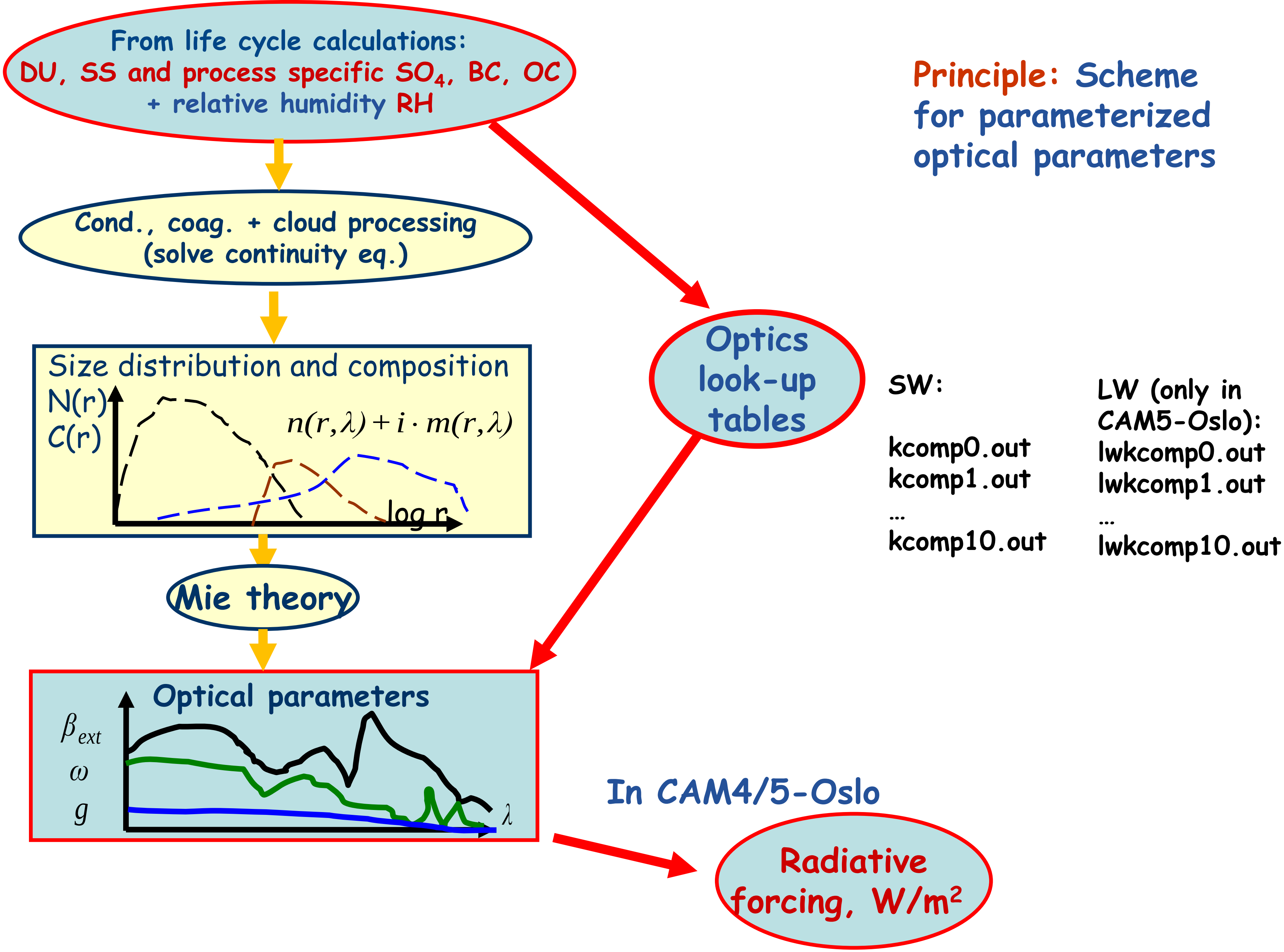
Examples


modified SO4(a) mode
with varying cat
dN/dLog(r)
1
0.001
1e-06
0.001
0.01
0.1
1
10
r (um)


modified SO4(a) mode
with varying faq
dN/dLog(r)
1
0.001
1e-06
0.001
0.01
0.1
1
10
r (um)


modified SO4(a) mode
with varying fac
dN/dLog(r)
1
0.001
1e-06
0.001
0.01
0.1
1
10
r (um)


modified SO4(a) mode
with varying RH
dN/dLog(r)
1
0.001
1e-06
0.01
0.1
1
r (um)


From life cycle calculations:
DU, SS and process specific SO_4, BC, OC
+ relative humidity RH
Principle: Scheme for parameterized optical parameters
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
β_{ext}
ω
g
λ
Optics look-up tables
SW:
kcomp0.out
kcomp1.out
…
kcomp10.out
LW (only in CAM5-Oslo):
lwkcomp0.out
lwkcomp1.out
…
lwkcomp10.out
In CAM4/5-Oslo
Radiative forcing, W/m^2

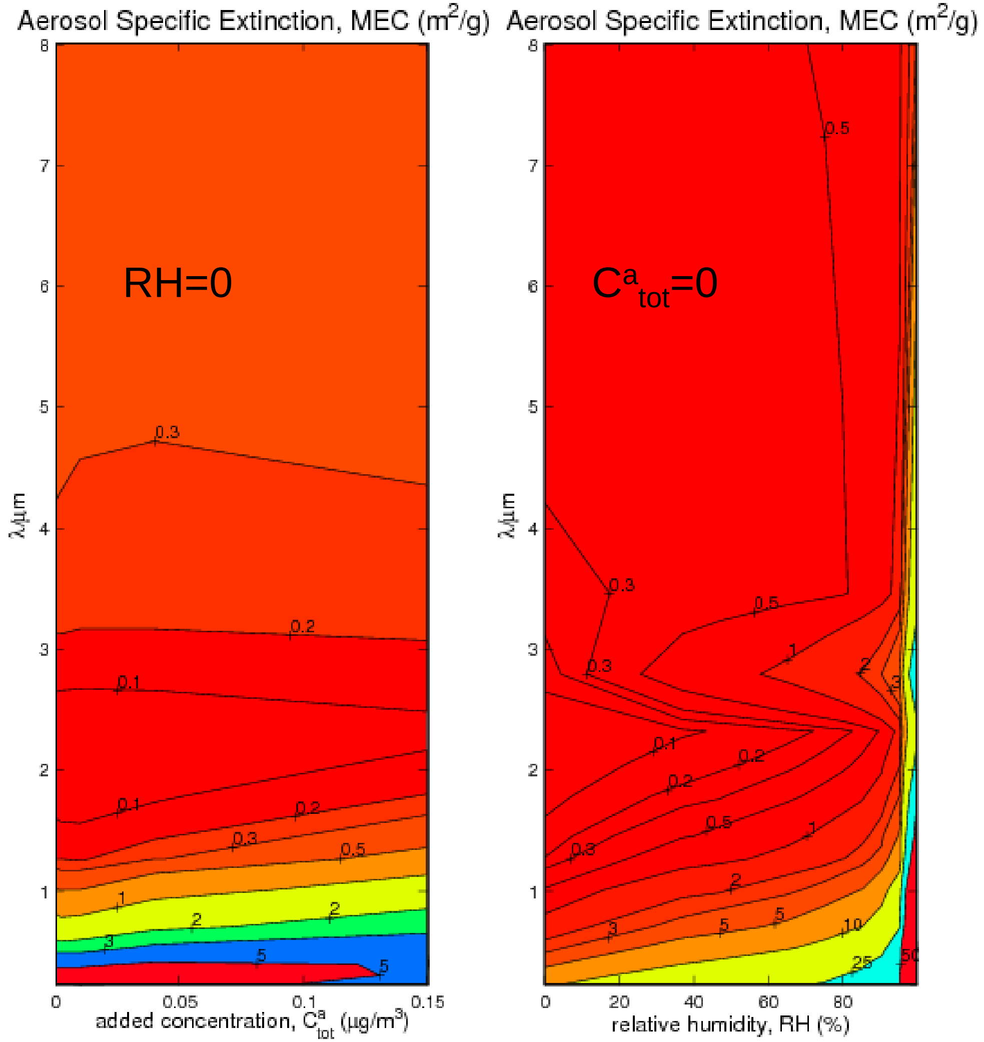
Ex. optics look-up tables for normalized size-distribution (1 cm^{-3}): SO4_NA / SO4_A1 mode (without SOA), kcomp1.out

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

kcomp	λ- band	RH	catot (μg/m^3)	ω (SSA)	g (ASS)	β_{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 use of output from look-up tables for SO4(a) mode using MATLAB



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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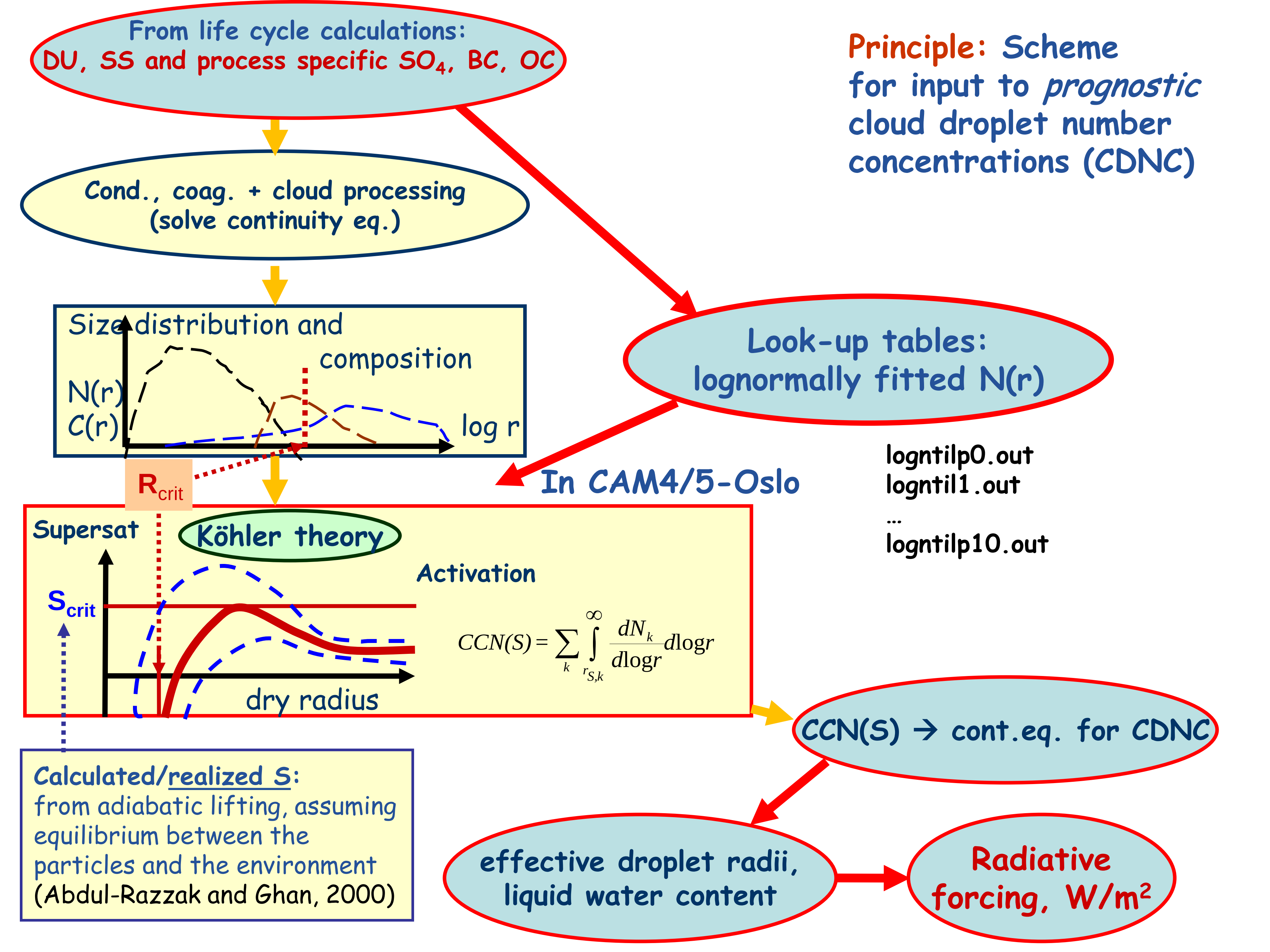
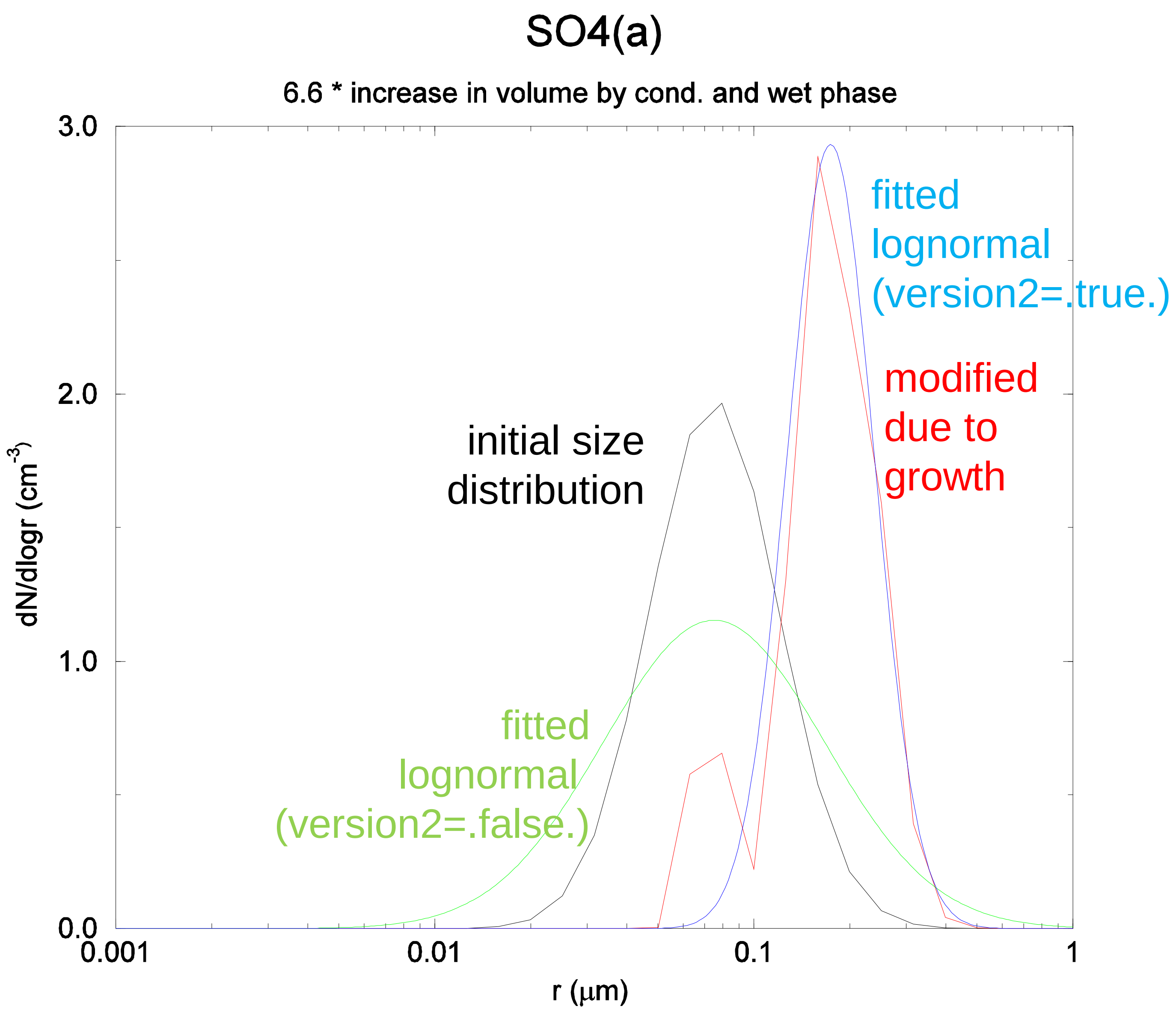


Principle: Scheme for input to prognostic cloud droplet number concentrations (CDNC)
From life cycle calculations:
DU, SS and process specific SO_4, BC, OC
Cond., coag. + cloud processing
(solve continuity eq.)
Size distribution and composition
N(r)
C(r)
log r
R_{crit}
Look-up tables:
lognormally fitted N(r)
logntilp0.out
logntil1.out
…
logntilp10.out
In CAM4/5-Oslo
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
CCN(S) → cont.eq. 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

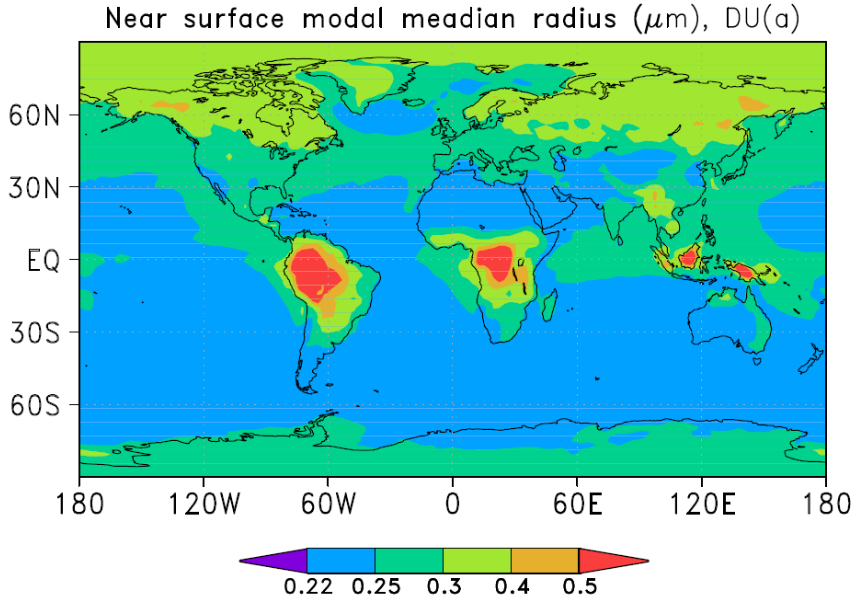
Example of lognormal fitting (LUT for r and σ) for use in the activation code

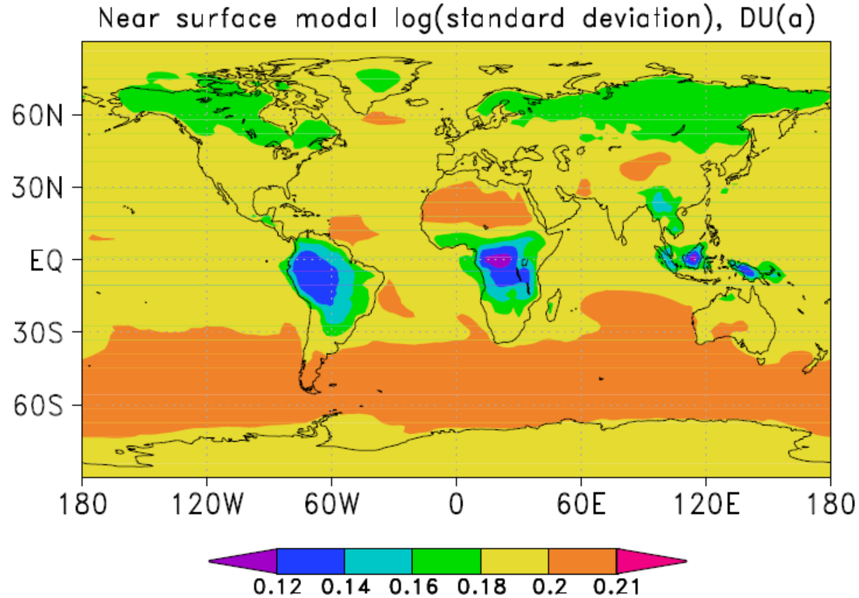


Ex. look-up tables for log-normal size parameters (dry aerosol): SO4(a) mode, logntilp5.out

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 output from a 1 year PD simulation, CAM4-Oslo





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

(Growth here also includes hygroscopic swelling)

Extra output tables, e.g. for use in AeroCom
(with #define AEROCOM in CAM-Oslo)

aerodryk*.out	Info for calculation of effective radii, and dry mass concentrations for r < 0.5 μm and r > 1.25 μm
aerocomk*.out	Species specific optical parameters for specific wavelengths (440, 500, 550, 670, 870 nm, not used in standard CAM-Oslo) and for r < 0.5 μm and r > 0.5 μm (at 550 nm). And for each size-mode (kcomp), backscattering coefficient (at 550 nm).

and (not used in CAM-Oslo)

nkcomp*.out	Modified aerosol number size distributions, never used
ccnk*.out	CCN(S) for various S (no longer used)

where * = 0, 1, 2,…,10

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 (NH4)2SO4:

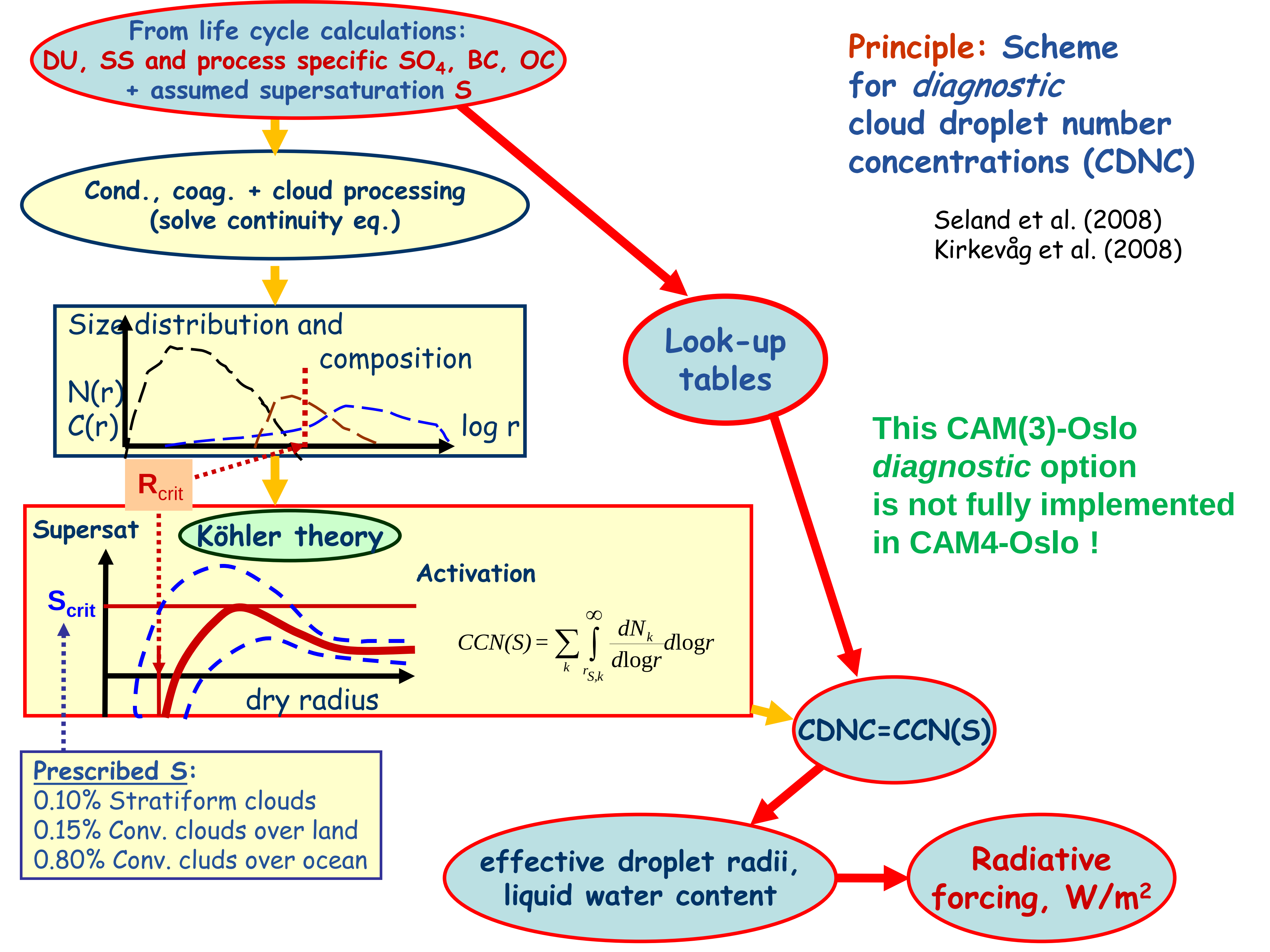
```
c     ammonium sulphate:
      Ms=1.3214e2
      rhosl=1.769e3
      if(frr0.le.1.02) then
        ai=-23.7649*frr0+24.4955
      elseif(frr0.gt.1.02.and.frr0.le.1.05) then
        ai=10.6373*frr0-10.5947
      elseif(frr0.gt.1.05.and.frr0.le.1.11) then
        ai=9.3474*frr0-9.2404
      elseif(frr0.gt.1.11.and.frr0.le.1.22) 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}
dry radius
$$CCN(S) = \sum_k \int_{r_{S,k}}^{\infty} \frac{dN_k}{d\log r} d\log r$$
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