Aerosol module of CAM4-Oslo linked with Mozart

D. Olivié, M. Sand, T. Berntsen, Ø. Seland, A. Kirkevåg and T. Iversen

dirk.olivie@geo.uio.no

March 1, 2012

Overview

- CAM-Oslo aerosol scheme
- Comparison with other aerosol schemes
- Coupling CAM-Oslo with Mozart gas-phase chemistry
- Results
- Conclusions - final remarks

CAM-Oslo / NorESM

CAM2, CAM3, CAM4, ...

- Microphysics
- Aerosols

NorESM: based on CCSM-4

- atmosphere: CAM4-Oslo (Oslo) (1.9° x 2.6°, 26 levels)
- land model : CLM
- sea ice: CICE
- land ice:
- ocean model: MICOM (Bergen) (1° x 1°, 53 levels)

UiO, UiB, Met.no

Contribution to CMIP5

Aerosols in CAM-Oslo

Aerosol modes

		radius [μm]			
1	SO4(n)	0.0118			
2	BC(n)	0.0118			
3	BC/OC(ni)	0.04			
4	BC(ax)	0.1			
			SO4(a1)		
5	SO4(na)	0.04	SO4		
6	BC(a)	0.04	SO4		
7	BC/OC(ai)	0.04	SO4		
8	SO4(pr)	0.075	SO4		
			SO4(ac)	BC(ac)	OC(ac)
9	DU	0.22	SO4	BC	OC
10	DU	0.63	SO4	BC	OC
11	SS	0.022	SO4	BC	OC
12	SS	0.13	SO4	BC	OC
13	SS	0.74	SO4	BC	OC

Remarks

- 13 log-normal modes, with fixed dry median radius; 20 aerosol tracers
- SO4 (aq)
- Number concentrations is a diagnostic based on mass
- An extension of CAM

Aerosols in Mozart

Aerosol modes

SO4			
BC1	BC2		
OC1	OC2	SOA	
DU1	DU2	DU3	DU4
SS1	SS2	SS3	SS4
NH4	(NH4)NO3		

Remarks

- 16 aerosol tracers
- Aging of hydrophobic OC1 and BC1 to hydrophylic BC2 and OC2

HAM-M7

Stier et al. (2005), Pozzoli et al. (2008)

- HAM-M7

Aerosol types

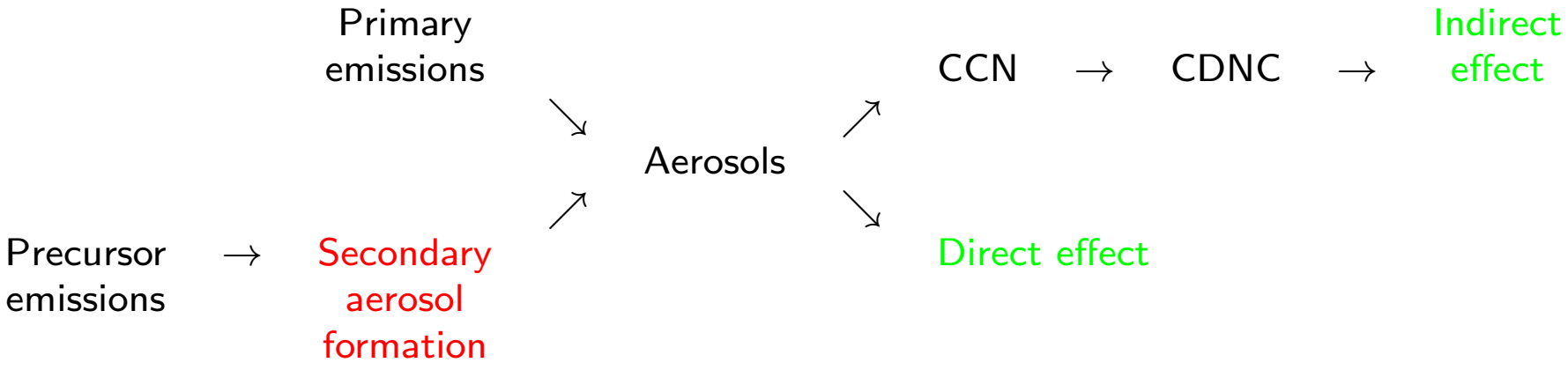
Radius [μm]	SO4	BC	OC	DU	SS	#	$\bar{r}$
			Insoluble				
$0.005 \leq r \leq 0.05$		BC	OC			n	r
$0.05 \leq r \leq 0.5$				DU		n	r
$r > 0.5$				DU		n	r
			Soluble				
$r \leq 0.005$	SO4					n	r
$0.005 \leq r \leq 0.05$	SO4	BC	OC			n	r
$0.05 \leq r \leq 0.5$	SO4	BC	OC	DU	SS	n	r
$r > 0.5$	SO4	BC	OC	DU	SS	n	r

Remarks

- 7 log-normal modes
- tracers: 18 for mass, 7 for number or radius

Role of aerosols in CAM-Oslo

Role



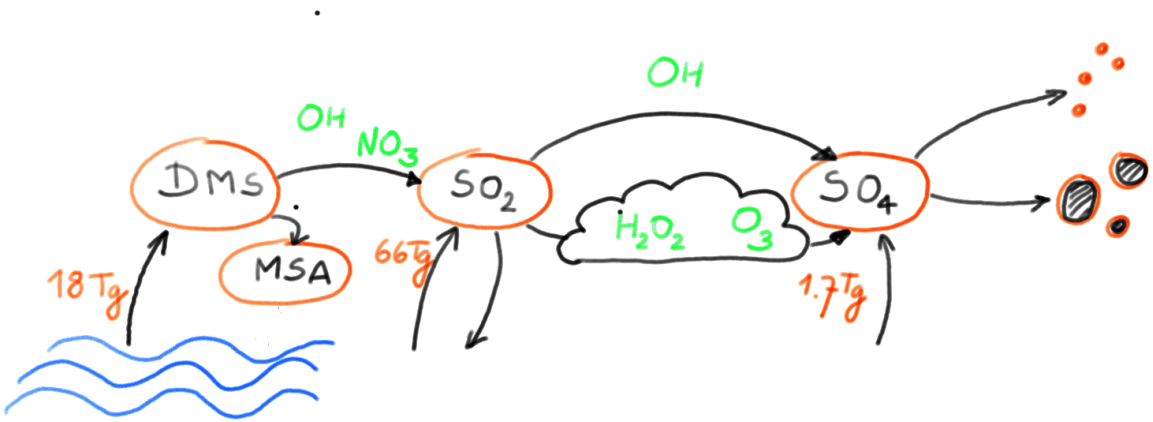
Physical transformations of the aerosols

- Nucleation of SO4 aerosol
- Aging through condensation of H2SO4 on existing aerosols
- Coagulation
- Wet and dry deposition

Secondary aerosol formation in CAM-Oslo (1)

H2SO4 formation

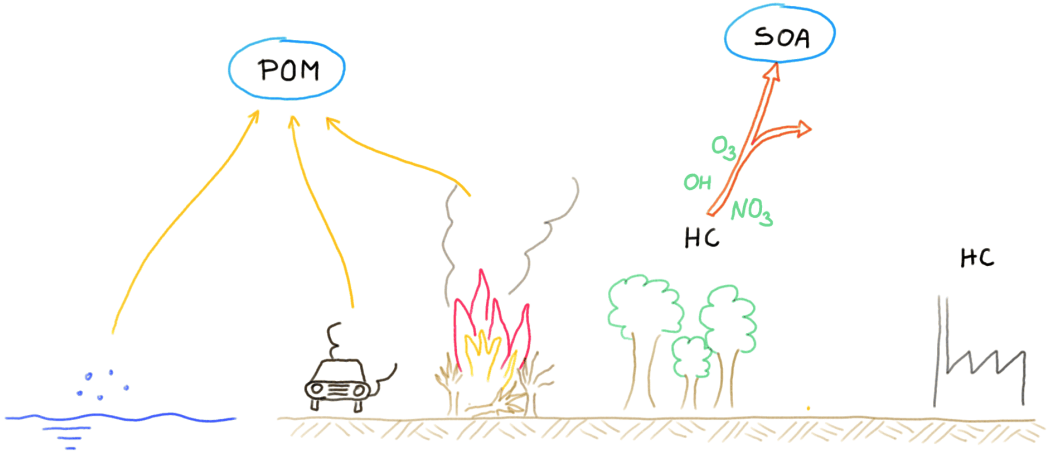
- Model only 2 gas-phase species: DMS and SO2 (emissions, transport, chemistry with oxidants, deposition, ...)
- Prescribed oxidants as monthly mean 3D climatologies
  - O3
  - H2O2 (take into account replenishment)
  - OH (imposed daily cycle)
  - NO3



Secondary aerosol formation in CAM-Oslo (2)

Secondary organic aerosol (SOA) formation

- DMS $\rightarrow$ MSA $\rightarrow$ OC
- All other SOA emitted as primary organic carbon (POA)



Consequences

- No short time-scale variability of oxidants
- Same 3D oxdidant climatologies in changing climate
- Same SOA-emission data set in changing climate

Modifications

Mozart → CAM-Oslo

- Include MSA and MSA-formation in Mozart and use this production in CAM-Oslo
- Use gas-phase H2SO4 and aqueous phase SO4 production from Mozart in CAM-Oslo
- Use SOA-formation from Mozart as source of OC in CAM-Oslo

CAM-Oslo → Mozart

- Use CAM-Oslo SO4 in NH4/NH4(NO3)/HNO3/NH3/SO4 equilibrium
- Use CAM-Oslo aerosol surfaces for heterogeneous reactions in Mozart

Results

Comparison

- Mozart
- CAM-Oslo
- CAM-Oslo coupled to Mozart gas-phase

Period

- 1990's
- Only results for July

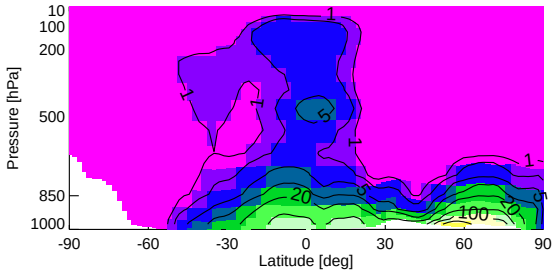
Emissions

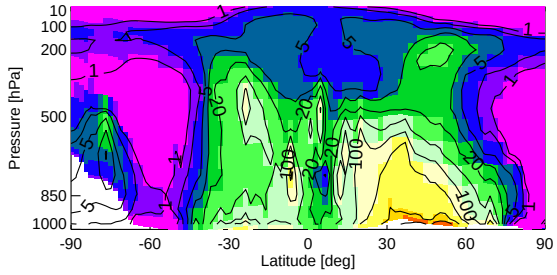
- Differences between Mozart and CAM-Oslo

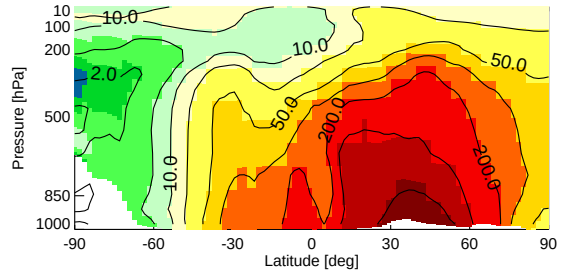
Sulphur cycle

DMS [ppt] SO2 [ppt] SO4 [ppt]

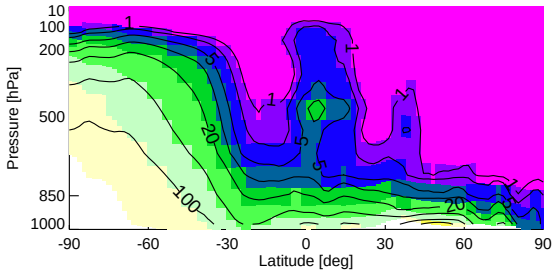
Mozart

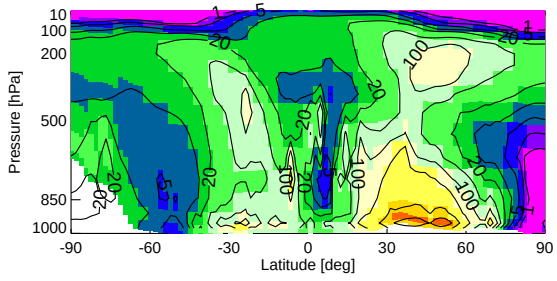


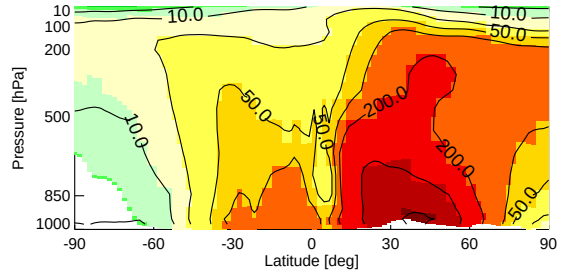




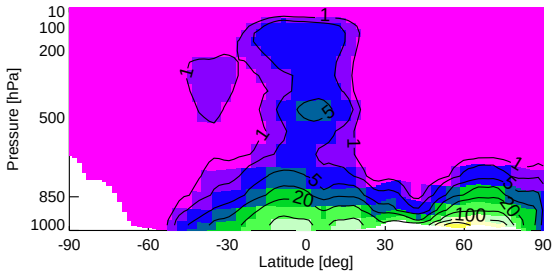
CAM-Oslo

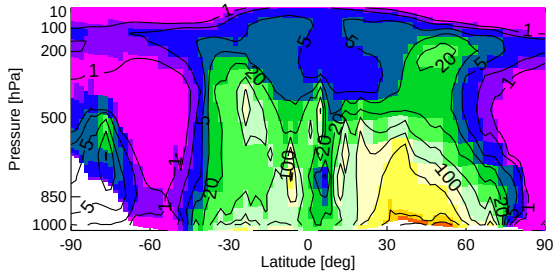


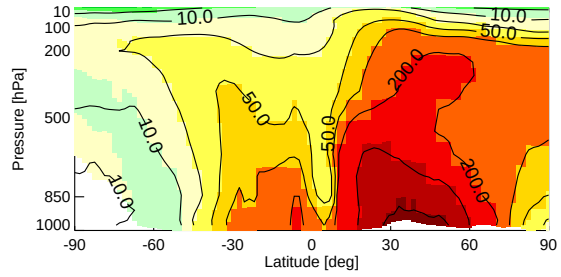




CAM-Oslo/Mozart

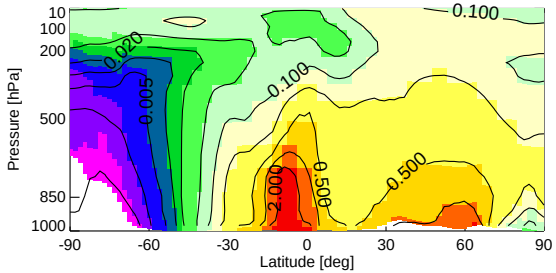




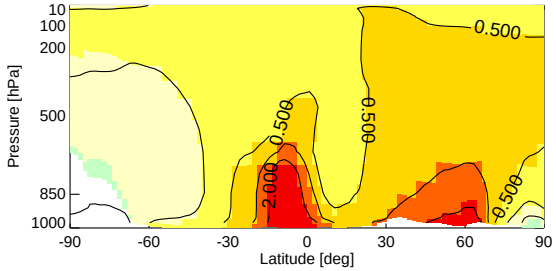


Organic matter

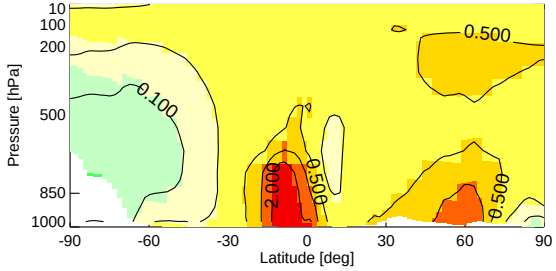
Mozart: 2×OC1 + 2×OC2 + SOA [ppb]



CAM-Oslo: POM [ppb]



CAM-Oslo/Mozart: POM [ppb]



Heterogeneous chemistry (1)

Surface area density

- No nitrate available in CAM-Oslo

Uptake coefficient γ: Liao and Seinfeld [2005], Pozzoli et al. [2008]

Reaction	Aerosol	γ
N2O5 $\rightarrow$ 2 HNO3	SO4	$f(RH, T)$
	BC	0.005
	OC	$f(RH)$
	mineral dust	$f(RH)$
	sea salt	$f(RH)$
NO3 $\rightarrow$ HNO3	wet aerosols	0.001
NO2 $\rightarrow$ 0.5 HNO3 + 0.5 HNO2	wet aerosols	0.0001
HO2 $\rightarrow$ 0.5 H2O2	wet aerosols	0.2

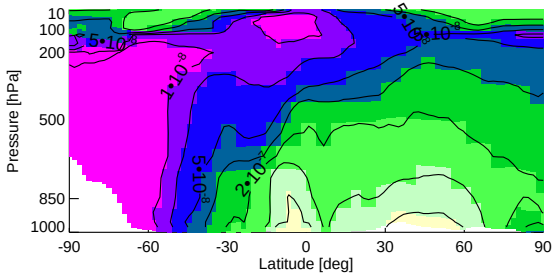
Further specifications

- Wet aerosols: if $RH > 50\,\%$
- Hygroscopic growth is taken into account
- Internally mixed aerosols: which fraction of surface is covered by which aerosol type

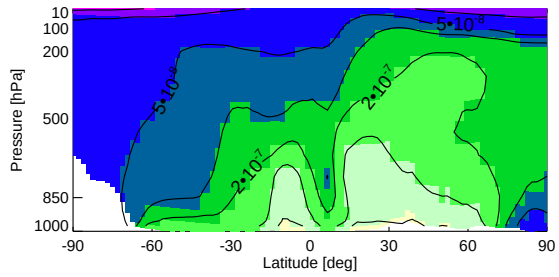
Heterogeneous chemistry (2)

Surface area density [cm2/cm3]

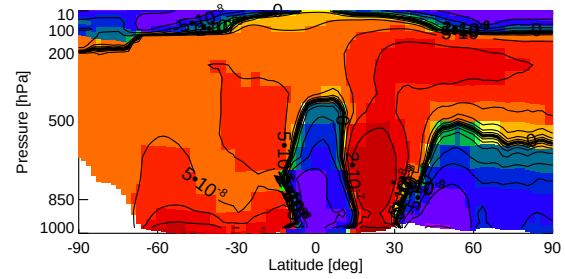
Mozart



CAM-Oslo

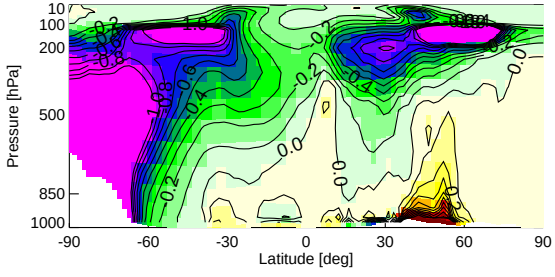


CAM-Oslo -Mozart

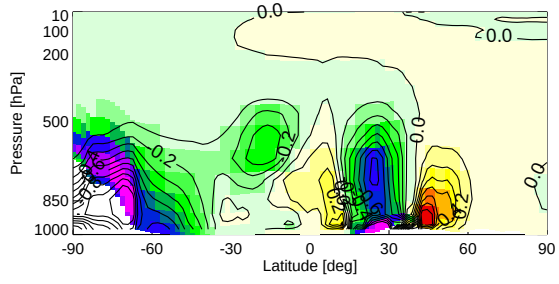


Impact on mixing ratios ($\gamma_{N2O5} = 0.1$)

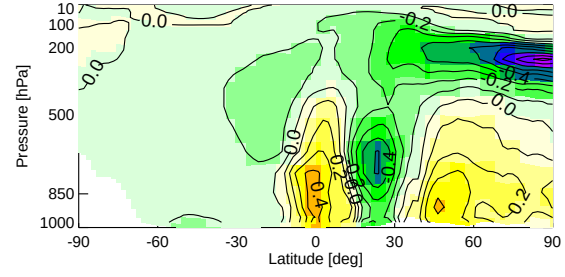
N205 [pptv]



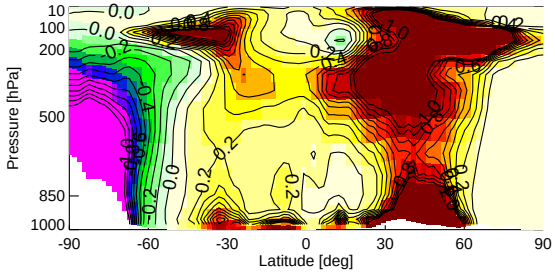
NO3 [pptv]

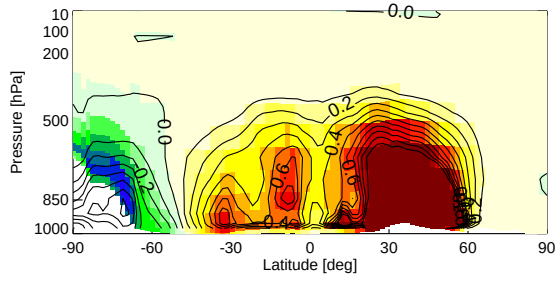


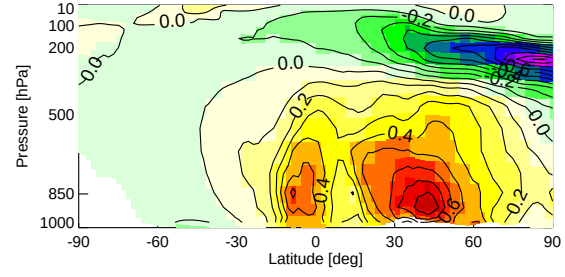
HO2 [pptv]



Impact on mixing ratios ($\gamma_{N2O5} = f(RH, T)$)



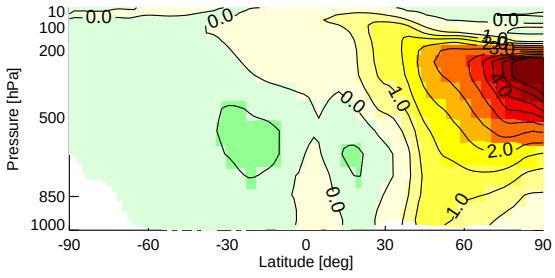




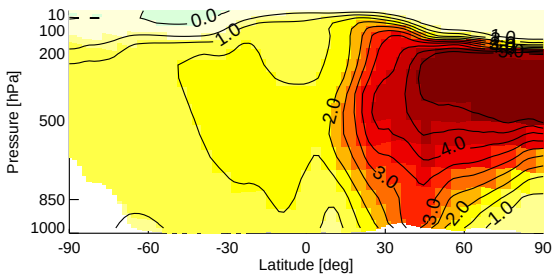
Heterogeneous chemistry (3)

Impact on mixing ratios ($\gamma_{N2O5} = 0.1$)

O3 [ppbv]



Impact on mixing ratios ($\gamma_{N2O5} = f(RH, T)$)



SOA formation (1)

CAM-Oslo

- Standard emissions: 37.2 Tg/yr

Mozart

- Under 1850 conditions: 11.4 Tg/yr
- Under 1994-1998 conditions: 9.6 Tg/yr

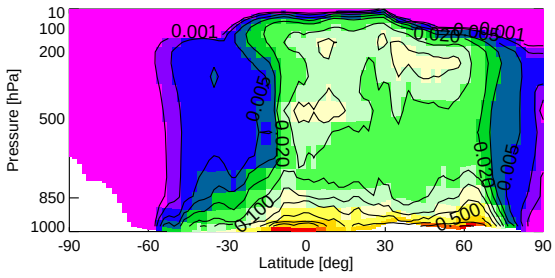
Comment

- No SOA formation from isoprene in Mozart

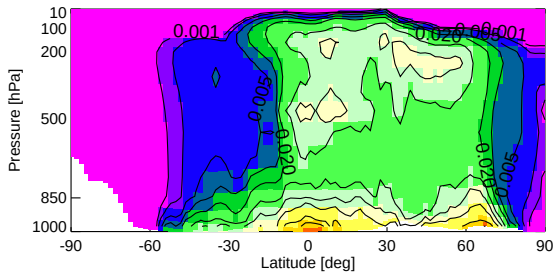
SOA formation (2)

Mozart (9.45 Tg/yr)

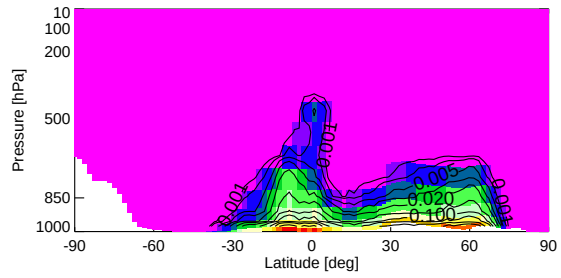
Total [kg/kg/s]



Low OM availability

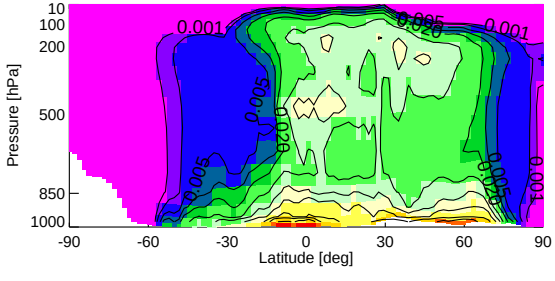


High OM availability

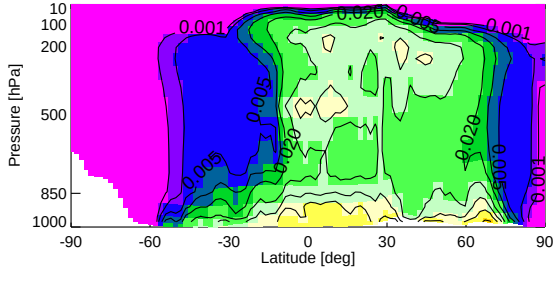


CAM-Oslo (8.21 Tg/yr)

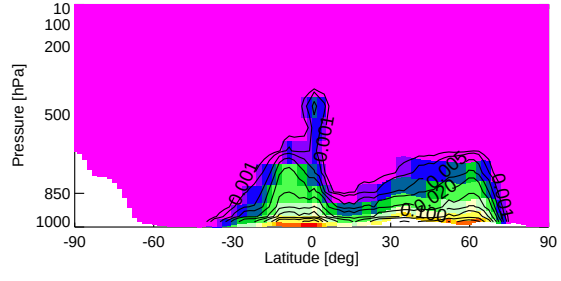
Total [kg/kg/s]



Low OM availability



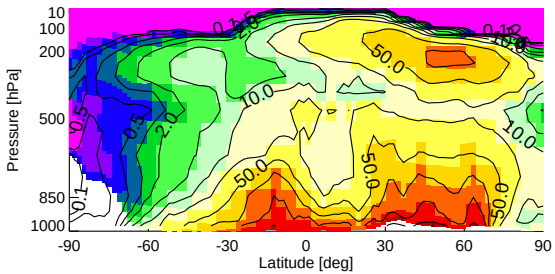
High OM availability



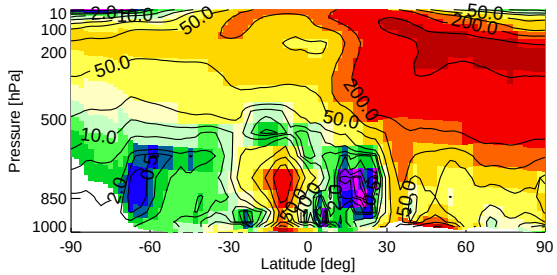
NH3/NH4/(NH4)NO3 equilibrium

Mozart

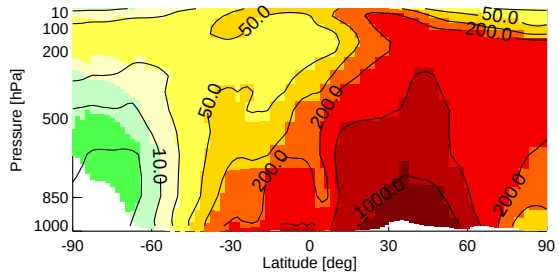
NH3 [ppt]



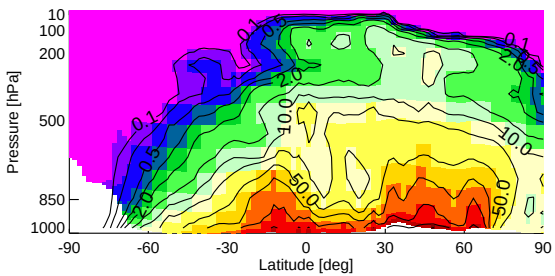
NH4NO3 [ppt]

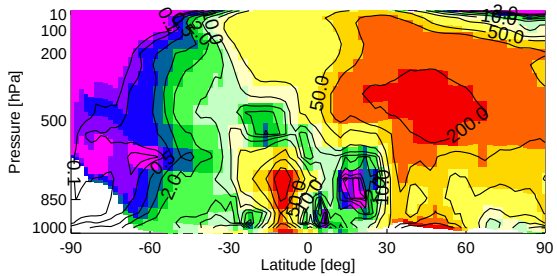


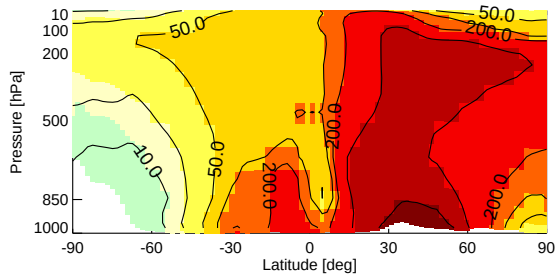
NH4 [ppt]



CAM-Oslo/Mozart







Conclusions - final remarks

Plans

- Longer simulations
- Quantify impact on AOD, indirect effect
- Move aerosols (processes) from CAM4-Oslo to Mozart

Other tests

- Taking into account aerosols in long-wave calculation
- $\gamma = f(RH, T)$ for heterogeneous reactions
- Using nitrate aerosol for heterogeneous reactions
- Conversion DMS $\rightarrow$ MSA, SO2
- Conversion MSA $\rightarrow$ H2SO4, OM

Questions?