



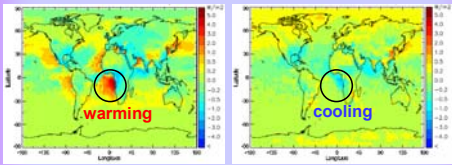
The vertical distribution of biomass burning aerosols from Southern Africa

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S. Kinne (MPIIM) & AeroCom modelers



Motivation: Large uncertainty of aerosol radiative forcing due to biomass burning aerosols west of southern Africa

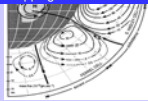
Direct aerosol forcing in cloudy regions from two different models annual mean 2000



- Black smoke
- above clouds: warming (positive forcing)
- below clouds: cooling (negative forcing)
- importance of vertical distribution of aerosols

Conditions in Southern Africa

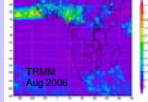
Stable meteorological situation: capping inversion at ~5km



Nearly cloud-free over land, low stratocumulus clouds over ocean



Very little precipitation



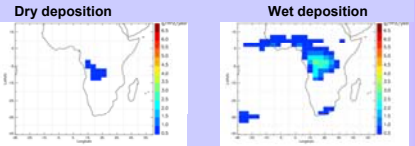
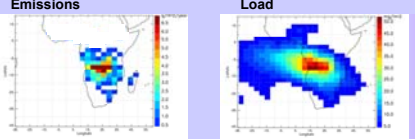
Intensive burning in dry season



- Aerosol is dominated by carbonaceous particles from fires
- Dry season of August 2006: CALIOP data available

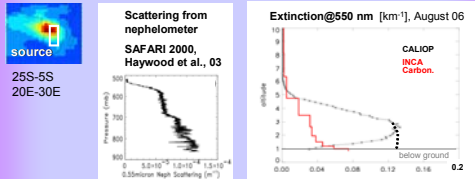
Carbonaceous aerosols as simulated by INCA

~20% dry, 80% wet dep. residence time ~ 9 days in region



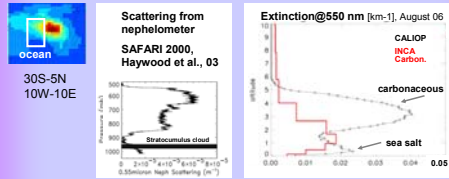
Africa August 2006

Vertical extinction profiles over source region



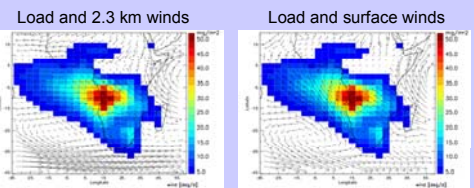
- Observations from previous studies**
- Aerosol mixed in the PBL up to ~5km, almost no aerosol above.
 - CALIOP (level 2, all data in August averaged, if number of obs per level >1000)
 - Profiles show unrealistic minimum extinction in lower levels
 - Saturation of detector leads to bias in less polluted situations
- Model**
- Amplitude too small (factor of ~3): emissions underestimated, mass extinction coefficients, POM/OC ratio?
 - Not well mixed in the PBL, but decreasing too fast with height

Vertical extinction profiles over the ocean

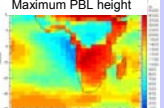


- Observations from previous studies**
- Distinct smoke layer at about 3 km, above MBL and low clouds.
- CALIOP (level 2, #obs/level >1000)**
- Consistent with previous studies
- Model**
- Amplitude too small (factor of ~2)
 - Layered structure matched, but at too low altitude

Distinct Aerosol layer above MBL: Transport



- Aerosols are vertically well mixed in the PBL over land and in a layer at 2-3 km, above the MBL over the ocean
- Winds at 2-3 km transport aerosol from land to ocean
- Low-level winds transport clean air towards land
- Wind directions explain vertical aerosol distribution



Sensitivity studies: More realistic parameterization of fire emissions

Reference Experiment LMD - INCA

- Fire emissions from GFEDv2, monthly August 2006
- Meteorology nudged to ECMWF August 2006
- All emissions into lowest model level, no daily variation

Sensitivity studies:

- Fire injection height
 - Injection homogeneously distributed into PBL (from GCM), or PBL+1
 - Injection into the 2nd model layer
- Daily cycle of emissions (Gaussian distribution, max at 2pm)
- Meteorology and emission data set (2000 vs 2006)

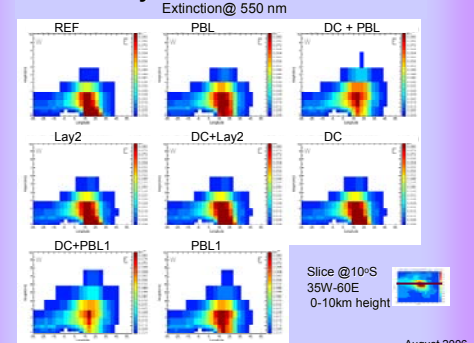
Sensitivity studies on fire emissions

Reference Experiment LMD - INCA:

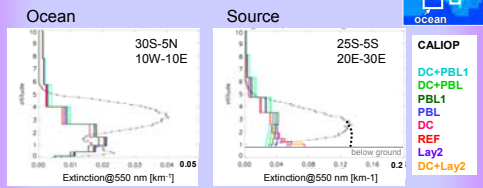
- Fire emissions from GFEDv2, monthly August 2006
- Meteorology nudged to ECMWF August 2006
- All emissions into lowest model level, no daily variation

Test	Daily Cycle	PBL	PBL+1	Lay2	Year	FireEmi
REF						
PBL		X				
DC + PBL	X	X				
Lay2				X		
DC & Lay2	X			X		
DC	X					
DC & PBL+1	X		X			
PBL+1			X			
DC & PBL & Meteo	X	X			2000	
DC & PBL & Meteo & Emi	X	X			2000	AeroCom
Meteo					2000	
Meteo & Emi					2000	AeroCom

Sensitivity studies with LMD INCA



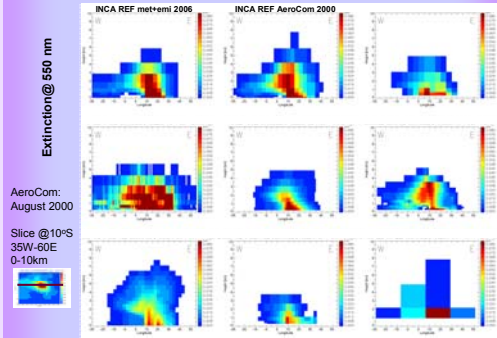
Summary sensitivity studies



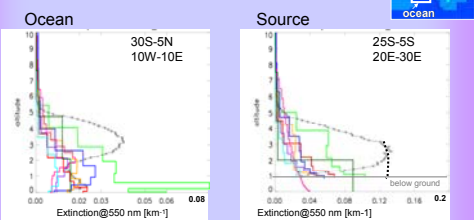
- The model is not very sensitive to the modifications.
- Injection into whole PBL gives more realistic profile over source region, but does not improve profiles down-wind.
- Daily cycle of fire activity alone has no significant effect, but enhances vertical mixing if injection into PBL is considered.

August 2006

INCA and 7 AeroCom models with the same fire emissions



Vertical extinction profiles: AeroCom 2000 vs CALIOP 2006



- Significant differences among models despite unified emissions.
- None of the model reproduces observed profiles.
- Insufficient vertical mixing over land in PBL.
- Aerosol layer over ocean at too low altitude → forcing!

Comparison AOD/ region

Region	CALIOP	MODIS	MODMEDIAN AeroCom	
			AER	BCPOM
SOURCE	>0.36	0.3	0.18 + 0.05	0.13 + 0.06
OCEAN	0.13	0.38 ?	0.16 + 0.04	0.06 + 0.04
Region	CALIOP	MODIS	MODMEDIAN LMD INCA	
			AER	BCPOM
SOURCE	>0.22 + 0.01	0.13 + 0.008		
OCEAN	0.25 + 0.01	0.08 + 0.014		

- Models underestimate AOD seen by CALIOP and MODIS, especially over the source region
- Diversity of LMD INCA model studies is by about one order of magnitude smaller than AeroCom model diversity

Conclusions

- Intensive biomass burning in southern Africa during the dry season.
- Aerosol over source regions well mixed in the PBL up to ~5km.
- Aerosol transported off-shore to the N-W in a distinct layer above MBL.
- CALIOP level 2 data might not be correct over regions of high pollution.
- Modeling shows large differences from observations:
 - Underestimation of smoke aerosol, especially over source regions: Emission data set, mass extinction coefficients, POM/OC ratio
 - Vertical mixing in PBL over source regions insufficient: Transport (dry convective mixing)
 - Aerosol layer over the ocean at too low altitude: Transport (initial height too low, large scale subsidence)
- Modification of emission parameterizations or meteorology in one model does not considerably improve the results.
- AeroCom model diversity is by about one order of magnitude larger than INCA studies' diversity for different fire emission & mixing assumptions.
- Results are dominated by model architecture.
- Aerosol radiative forcing uncertainty can only be reduced through a joint effort of observationalists, dynamics modelers and aerosol modelers.

Acknowledgements

- Model data: The modelers and their teams for their contributions to AeroCom.
- Emission data: GFED v1 and v2 : Randerson et al., VdWerff et al.
- Observations:
 - CALIOP data: CALIPSO Science team at NASA.
 - AERONET data: PI investigators and their staff for establishing and maintaining the Southern African sites used in this investigation, and the AERONET Science team.
 - MODIS data: Science team at NASA Goddard Space Flight Center's Earth Sciences Distributed Active Archive Center (GES DAAC).
 - TRMM data: TRMM Science Team, the TRMM Science Data and Information System, and the TRMM Office.
 - GIOVANNI web site: NASA's Goddard Earth Sciences (GES) Data and Information Services Center (DISC).
 - ICARE thematic center for the provision of the analysis tools.
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