Transport of dust particles from the Bodele region to the monsoon layer: Case study of the 9-14 june 2006 period.

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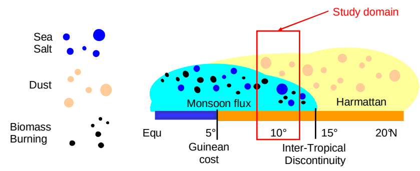
Introduction

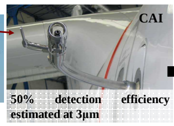
In Africa, the air mass circulation is formed by south and north trade winds converging toward the Inter Tropical Discontinuity (ITD). The continental north easterly trade is called Harmattan and the south westerly trade is called monsoon flux. These two major fluxes create two distinct layers characterized by different aerosol properties: the monsoon layer (ML) and the Saharan Air Layer (SAL) (Carlson and Prospero, 1972; Pirletta et al., 1972). In the ML, the monsoon flux transports marine air masses over the continent where they are mixed with anthropogenic, biogenic and other sources of aerosols. North of the ITD and above the ML is the SAL, which can be characterized by high dust content, consistent with low visibility (Karyampudi et al., 1999). The SAL is decoupled from the surface below and is more closely linked to the desert regions (Parker et al., 2005).

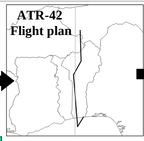
The presence of aerosol in the SAL is connected to long range transport from Sahelian and Saharan regions. However the presence of desert dusts is not limited to the Saharan Air layer. Indeed, the local lifting of desert dust due to the MCS passage or high wind speed and the particle sedimentation from the SAL are processes that lead to the presence of desert dust in the monsoon flux.

The goal of the present study is 1. to improve the aerosol size distribution 2. to quantify the sedimentation process that involve the presence of dust particles in the monsoon layer by comparing aerosol airborne measurements along a meridian between Niamey (Niger) and Cotonou (Benin) and two meso-scale simulations (one with sedimentation process [SED] and another one without sedimentation process [NOSED] using an explicit representation of aerosol processes.



Experimental and Numerical Strategy





SMPS (0.02 to 0.3µm)

Grimm (0.3 to 2 µm)

Complete size distribution

Size distribution input

Description of the Model (MESO-NH, Lafore et al. 1998)

- Cloud Resolving Model (Two way nesting).
- ECMWF Re-Analysis nudging.
- Dust emission : The Dust Entrainment And Deposition module (DEAD) (*Grini et al., 2005*)
- Dust transport and sedimentation scheme : ORILAM (*Tulet et al. 2005*)
- Dust/Solar radiation/dynamics interactions.

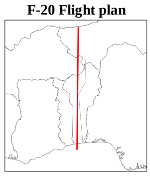
Used Strategy

- Two domains : 1) Over the whole AMMA Domain centered at 15°N and 5°E 2) One over the Benin and Niger centered at 11° N and 4°E
- Resolution : 1) 36km 2) 5km
- Simulation over 8 days between 9 and 15 of June 2006
- Nudging every 6 hours

Model validation

Falcon - 20

F-20 Flight plan



RESULTS

The new dust size distribution

Alfaro and Gomes 2001(**AG 2001**) size distribution :
- ➔ Two coarse mode of particles
- ➔ No fine mode of particles

The size distribution measured with the **ATR-42**
- ➔ No coarse mode of particles (because of instrumental limit)
- ➔ One fine mode of particles

Based on the Alfaro and Gomes 2001 (AG01) parameterisation and on ATR-42 measurements, a new scheme of dust size distribution has been constructed by summing 3 modes (a coarse mode derived from AG01, a finer mode derived from observations and a mode in-between common to observations and AG01). This multimodal log-normal distribution has been developed and implemented to modelize an intense African dust event that has been observed over Niger from 9 to14 June 2006.

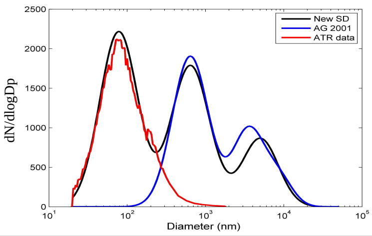


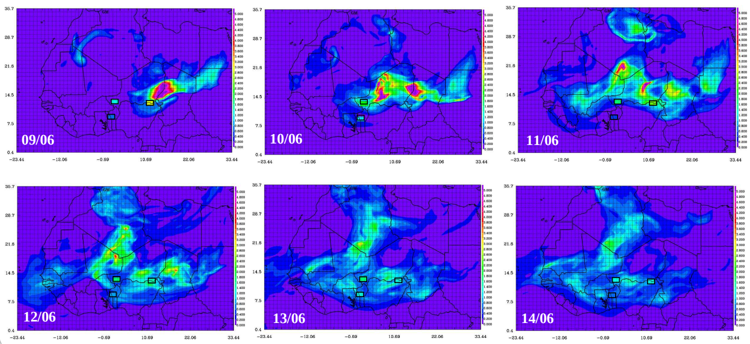
Table 1 : Log normal parameters of the number size distribution measured by the ATR-42, given by Alfaro and Gomes 2001 (AG01) and determined for this study (New SD).

	ATR-42		AG01		New SD	
	Dp	σ	Dp	σ	Dp	σ
Fine mode	87.9	2			78	1.75
Accumulation mode	645	1.8	640	1.7	641	1.76
Coarse mode	Cannot be observed in the ATR		3540	1.6	5000	1.70
			8660	1.5		

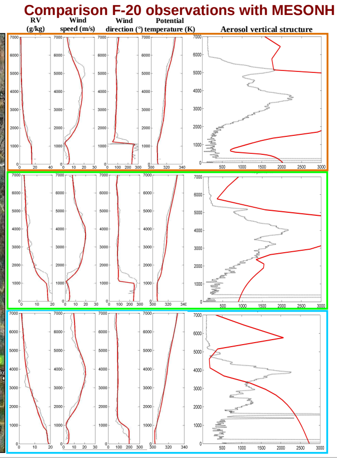
Model validation

AOD comparison during the dust event of the 9-14 June 2006

The Aerosol Optical Depth (AOD) modelised and observed (Aeronet data) at Djougou (Benin), Banizoumbou (Niger) and Maine-Soroa (Niger, closed to the Bodélé region) are represented during the 6 day of dust event in june 2006.



Comparison F-20 observations with MESONH



Dropsonde vs MESONH

The comparison of the dropsondes data (black dashed line) and the MESONH vertical cuts (red line) shows some differences between observation and simulation results, but the vertical structure is well represented 12°N and 10°N.

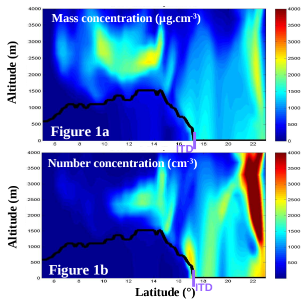
Souther 8.5°N, the wind direction and the wind speed observed are not well represented by the MESONH model.

LEANDRE 2 vs MESONH

The aerosol vertical structure is measured by the lidar LEANDRE 2 (black dashed line) and compared to the number concentration of particles (red line). When the dynamical features are well represented by the model, the modelised dust vertical structure is well represented.

Sedimentation quantification using two simulations (NOSED and SED)

SED simulation



Dust mass (**Figure 1a**) and number (**Figure 1b**) concentration for the SED simulation. The black line corresponds to the top of the monsoon flux calculated from wind directions in the simulation.

Difference of dust mass concentration (NOSED – SED)

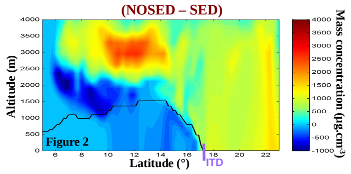


Figure 2 : Difference of dust mass concentration between NOSED and SED simulations, in which all dynamical and cloud microphysics are the same. The difference of concentration corresponds to the sedimented particle concentration. North of the ITD, the SAL is linked to the surface and one layer appear from the surface to 4000m. In this mixed layer the difference of concentration is positive because of high dust surface deposition by sedimentation. South of the ITD, the SAL is decoupled from the surface, thus the dry surface deposition process of dust is weak. The difference between NOSED and SED in the SAL is only due to long range transport and sedimentation. The red (blue) color represent a loss (gain) of dust particles. Between 5°N and 6°N, there is no dust in SED and in NOSED simulation, thus the difference is equal to 0.

NOSED - SED

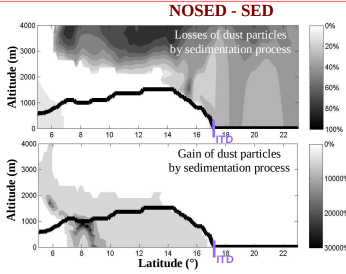


Figure 3 : Losses and gain of dust mass concentration. As the coarser mode contribution is the most important, the sedimentation process is controled by the coarse mode of particles. North of the ITD, the process of sedimentation implies a loss of particles of about 40%. In the monsoon flux, the gain of dust particles by sedimentation is maximum between 7°N and 10°N and can reach 30000%. That result supposes that the sedimentation of dust particles is a dominant process that implies the presence of dust particles in the monsoon flux.

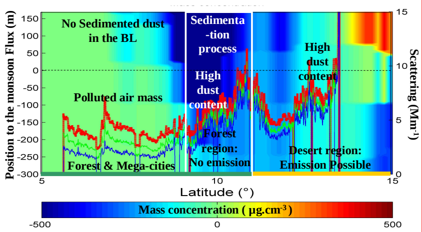


Figure 4 : Difference of dust mass concentration between NOSED and SED simulations in function of the position between the top of the monsoon flux (represented by the dotted line). The lines (red, green, blue) correspond to the scattering coefficient observed on-board the ATR-42 for 3 different wavelength (red, green, blue). On the X-axis the green and yellow lines correspond to the type of soil respectively cultivated/forest and desert area determined by MODIS. The ATR-42 measurements show the presence of a large quantity of dust particles between 8°N and 12°N. Indeed the scattering coefficient is not a function of the wavelength. In the same zone the MESONH results highlight that dust enter in the monsoon flux by sedimentation.

Conclusions

✓ The number size distributions measured during the AMMA experiment highlight the lack of parameterisation generally used in mesoscale simulation. Indeed, the dust size distribution proposed by Alfaro and Gomes (2001) does not represent the fine mode of particles. In order to improve the mesoscale simulation of dust particle behaviour, a new particle size distribution (NSD) has been proposed. Our results show that the number and the mass concentrations as well are better represented using the NSD.

✓ The scattering coefficients provided by a 3-l airborne nephelometer show a high dust content zone between 8° and 12,5°N. The soil of this region is covered by vegetation which implies that local emissions of soil dust is not possible. The comparison of both simulations, with sedimentation [SED] and without sedimentation [NOSED], illustrates the sedimentation process that involves the presence of dust particles from the Saharan Air Layer in the Monsoon Flux.

✓ North of the ITD where the SAL is linked with the surface, the sedimentation process involves dry deposition of dust particles to the surface (mainly coarse mode), decreasing their mass concentration (of 40%) in altitude. South of the ITD, the SAL is decoupled and thus, the sedimentation process implies the presence of two layers. One where dust particles accumulate (maximum gain: 30000%) and another one where the dust particle concentration decreases (maximum losses: 80%) .

Alfaro S. C. and L. Gomes. Modeling mineral aerosol production by wind erosion: Emission intensities and aerosol size distributions in source areas. *J. Geophys. Res.*, 106, D16, 18075-18084, 2001.

Carlson T.N. and J.M. Prospero. The large scale movements of Saharan air outbreaks over the northern equatorial atlantic, J. Appl. Meteorol., 11, 283-297, 1972.

Grini A., G. Myhre, C. S. Zender, and I. S. A. Isaksen. Model simulations of dust sources and transport in the global atmosphere: Effects of soil erodibility and wind speed variability, J. Geophys. Res., 110, D02205, 2005.

Karyampudi V.M., S.P. Palm J.A. Reagen, H. Fang, W.B. Grant, R.M. Hoff, C. Moulin, H.F. Pierce, O. Torres, E.V. Browell and S.H. Melfi. Validation of the Saharan dust plume conceptual model using lidar, Meteosat, and ECMWF data. Bull. Am. Meteorol. Soc., 80, 1045-1075, 1999.

Parker D.J., C.D. Thorncroft, R.R. Burton and A.Diongue-Niang. Analysis of the african easterly jet, using aircraft observations from the jet2000 experiment. Quart. J. Roy. Meteor. Soc., 131,1461-1482, 2005.

Pirletta et al. Vertical and area distributions of Saharan dust over the western equatorial North Atlantic Ocean. J. Geophys. Res. , 77, 5255-5265, 1972.

Tulet P., V. Crassier, F. Cousin, K. Shure, and R. Rosset. Orilam, a three moment lognormal aerosol scheme for mesoscale atmospheric model. on-line coupling into the mesonh-c model and validation on the escompte campaign. J. Geophys. Res., 110, doi:10.1029/2004JD005716, 2005.