Saharan dust lofting by Haramattan and monsoon flows convergence: Numerical Modelling and Lidar observations

D. Boukaram [1], C. Flamant [1], J.-P. Chaboureau [2], P. Tulet [3], J. Cuesta [4], L. Descroix [5]

[1] Service d'Aéronomie/IPSL, CNRS-UPMC-UVSQ, Paris, France, [2] Laboratoire d'Aérologie, CNRS-UPS, Toulouse, France, [3] Météo France, CNRM/GMEI, Toulouse, France, [4]Laboratoire de Météorologie Dynamique/IPSL, Palaiseau, France, [5] Laboratoire des Transferts en Hydrologie et Environnement, Grenoble, France

Contact: diana@aero.jussieu.fr

RATIONALE AND BJECTIVES

The ITD (defined as the interface between the monsoon and harmattan flows near the surface) is a key feature of the West African monsoon (WAM) system. Its position over Sahel is highly variable on daily-to-seasonal timescales, but its somewhat abrupt northward shift occuring around the end of June (as determined from OLR or rainfall data) marks the beiginning of the rainy season in Sahel.

Dust production in the Sahel and Sahara regions are known to be connected with the occurence of large wind speeds at the surface. Winds associated with the WAM are also known for exhibiting a strong diurnal cycle (e.g. Parker et al., 2005). However, the maximum in wind speed is generally observed to be during the nighttime (0000-0600~UTC).

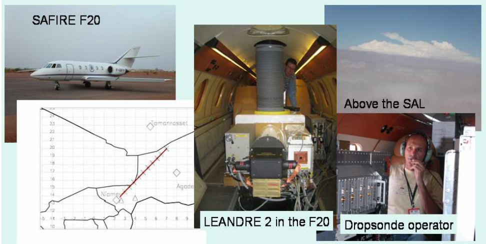
The ITD region, at the interface between the monsoon and harmattan flows is a convergence zone which intensity is particularly strong during the nighttime. Therefore, provided that it is located over or in the vicinity of dust sources, the dynamical system associated with the ITD should be prone to aerosol lofting.

In this presentation, the mechanims associated with the **Saharan dust lofting** and transport in connection with the inter-tropical discontinuity (ITD) dynamics and structure are analysed by means of **airborne lidar and dropsonde observations** acquired during the field phase of the AMMA (African Monsoon Multidisciplinary analysis) which was held in the summer of 2006, as well as numerical modelling.

MEANS AND STRATEGIES

Experimental strategy and operations during AMMA SOP 2a1

The PBL thermodynamic and aerosol spatial distribution was documented in the ITD region over Niger by the SAFIRE (Service des Avions Français Instrumentés pour la Recherche en Environnement) Falcon 20 (F/F20) equipped with the airborne lidar LEANDRE 2 and AVAPS 4-channel dropsonde system during the AMMA SOP 2a1 "ITD and SHL surveys" mission performed on 3, 7 and 10 July 2006.



Numerical modeling strategy

Models

- The Non Hydrostatic Mesoscale model **MesoNH** includes a prognostic **dust scheme** allowing feedback studies between dynamics and radiations. Mesonh simulations are driven by **ECMWF** analysis.
- Dust emission: The Dust Entrainment And Deposition module **DEAD** embedded in MesoNH.
- Surface scheme: **ISBA** initialized by ECOCLIMAP, FAO and GTOPO30.

Strategy

- One domain centered at 20°N and 7°E
- 20-km horizontal resolution, 100 x 100 points
- 62 levels used on the vertical resolution starting at 30 m above the ground.
- Simulation over ten days between 2 and 12 of July 2006.

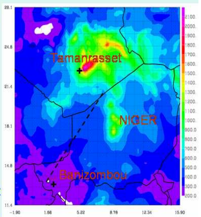
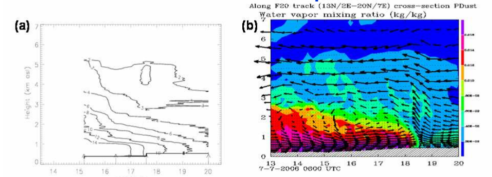


Figure 1: Meso-NH simulation domain

RESULTS

Position and structure of the intertropical front over Niger from dropsondes measurements and numerical simulations



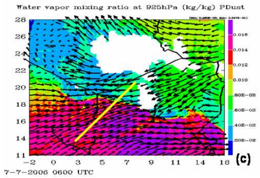
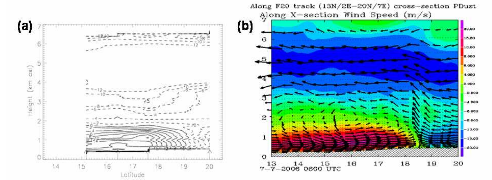


Figure 2: **(a)** Water Vapor mixing ratio (g/kg) measured by dropsondes during the July 7, 2006 F20 mission. Water Vapor mixing ratio (kg/kg) simulated by Meso-NH on July 7, 2006 at 0600 UTC: along the Falcon 20 track cross-section **(b)** and horizontal field at 925hPa **(C)**. The yellow line presents the Falcon 20 track (13°N/2°E -20°N/7°E)



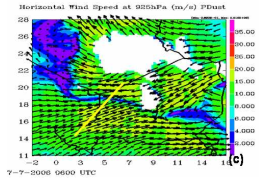
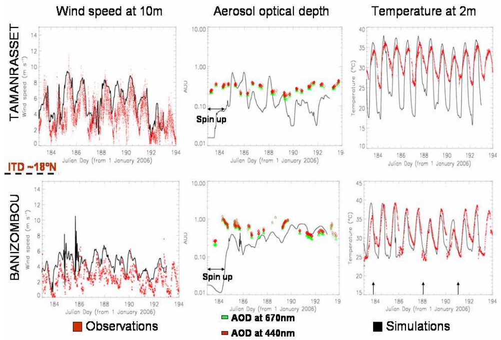
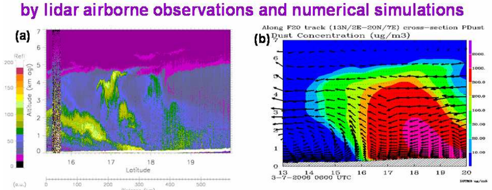


Figure 3: **(a)** Magnitude of the wind transverse to the F20 cross-section measured by dropsondes during the 7 July 2006 misison. Solid (dahed) lines represent westerly (easterly) winds. **(b)** Same as **(a)** but simulated by Meso-NH at 0600 UTC. **(c)** Horizontal wind field simulated at 925hPa on 7 Juy at 0600 UTC**(C)**.

Ground measurements to the south and to the north of the ITD



Dust uptake and transport on the 3, 7 and 10 of July 2006 by lidar airborne observations and numerical simulations



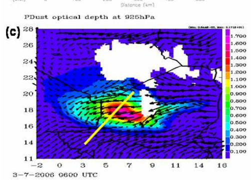
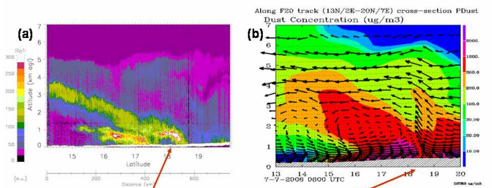


Figure 4: **(a)** Atmospheric reflectivity at 730 nm obtained by lidar LEANDRE 2 along the F20 track during the mission on 3 July 2006 between 0600 and 0730 UTC. Dust concentration (μg/m3) from MesoNH simulation on 3 July 2006 at 0600 UTC along the Falcon 20 track cross-section **(b)**, and horizontal field at 925hPa of dust optical depth **(c)**. Yellow line presents the F20 track (13°N/2°E - 20°N/7°E)



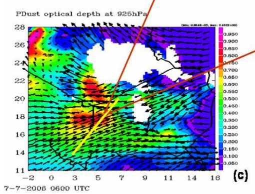
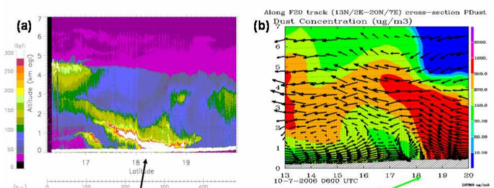


Figure 5: Same as Fig. 4 but on 7 July 2006.



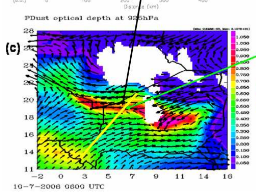


Figure 6: Same as Fig. 4 but on 10 July 2006.

DISCUSSION

		ITF Position	Harmattan characteristics	Monsoon Characteristics	SAL at	African Easterly Jet	Dust uptakes are caused by
July 3	Obs	17°N	Wvmr: 2-3 g/kg Θ: 316-322 K	Wvmr: 8-10 g/kg Θ: 306-312 K	5km	6-12 m/s	Harmattan flow
	Model	16°N	Wvmr: 2-4 g/kg Θ: 315-325 K	Wvmr:8-14 g/kg Θ: 306-310 K	5km	7-15 m/s	
July 7	Obs	19°N	Wvmr:2-3 g/kg Θ: 316-324 K	Wvmr:10-14g/kg Θ: 308-310 K	5km	8-12 m/s	Harmattan and monsoon flows
	Model	18,5°N	Wvmr: 2-4 g/kg Θ: 315-325 K	Wvmr:10-15 g/kg Θ: 302-310 K	7km	8-16 m/s	
July 10	Obs	18,3°N	Wvmr: 2-4 g/kg Θ: 314-322 K	Wvmr: 10-14g/kg Θ: 306-312K	4,8km	8-10 m/s	Harmattan flow
	Model	18°N	Wvmr: 2-5 g/kg Θ: 314-325 K	Wvmr: 10-14 g/kg Θ: 302-310 K	8km	8-12 m/s	

The position of the wind reversal region associated with the ITD derived from the simulation was found in agreement with that derived observations. The position of the ITD was observed to evolved during the period under scrutiny: 16°N on 3 July (Fig.4b), 19°N on 7 July (Fig.5b) and 18°N on 10 July (Fig.6b).

➔ Role of the AEJ and position of the Lybian high?

Lidar measurements show that the SAL reached 5 km on all 3 days, with a capping inversion limiting the mixture of dust aerosol in the free troposphere above (Fig4a, 5a and 6a). This inversion is well reproduced in the simulations on July 3 (Fig.4b), which is not the case on 7 and 10 July when aerosols are seen to reach 7-8km, (Fig.5b and 6b).

➔ Role of Numerical diffusion?

Lidar observations show the dust lofting to be related on the harmattan days 3 and 10 (Fig.4a and 6a), but also to the monsoon flow on 7 July (Fig.5a).

The shape and the vertical structure of the dust plumes are rather well reproduced by simulations on 7 and 10 July, and not so well on 3 July, possibly because the observed plume was not as intense as on the other two day.

These aerosols lofted in close to the ITD are observed to be transported towards the south above the monsoon layer. This is also seen in the simulation.

CONCLUSION AND PERSPECTIVES

The comparison of the MesoNH wind, temperature and humidity fields along the F-F20 flight track with their dropsonde-derived counterparts has been undertaken which shows good agreement at the time of the airborne operations.

The model is also able to reproduce the transport of dust above the monsoon flow seen in the observations even if the thickness of the dust plumes is over-estimated which might be due to a numerical diffusion of the model.

Always by using a synergy between observations and numerical simulations, we would like to:
1- Study the position and the structure of the African Easterly Jet (AEJ),
2- Understand the origin of the ITF fluctuations; role of the AEJ, the Lybian high and the dust,
3- Study the diurnal cycle of the ITD and its impact on the dust lofting,
4- Improve the representation of the SAL and the dust plumes by the model.