The Impact of Saharan Air Layer on Tropical Cyclone Genesis and Intensification

> S.-H. Chen UC Davis

Thanks to C.-T. Cheng, S.-H. Wang, S.-C. Tsai, M.-D. Jou, and J.-P. Chen

Outline



Intro

Saharan Air Layer Conceptual Model

An extended warm, dry, and potentially dusty air from the Saharan Desert to the Atlantic Ocean

Influence on easterly wave disturbances and Tropical Cyclone (TC) activities



Karyampudi et al. 1999 BAMS

Intro

SAL & Hurricanes/TCs



Dunion and Velden 2004, BAMS

Impact of SAL on TC Activities

Through dynamical and thermodynamical processes

- The entrainment of dry, stable air into storms, promoting evaporatively driven downdrafts in TCs
- > Vertical shear MLEJ due to warm SAL air
- > Trade wind inversions, stabilizing the atmosphere
- Dust-cloud-radiation interaction, modifying TC development

1.5-km T, 4km Winds, Dust, 2.8 km-P (MM5)

Chantal (2001) Integrated dust

1.5 km T





CONTOURS:	UNITS=h	Pa 10W= 729	00 HIGH=	739.00	INTERVAL=	1.0000
Model info: V3.6.1	KF-2	MRF PBL	Simple ice	30 km,	37 levels,	30 sec

	C	ONTOURS:	UNITS	=hPa MAXIMU	LOW= 729 M VECTOR:	00.0 9.0S	m s ⁻¹	739.00		ERVAL=	1.0000		
280	282	284	588	885	290	292	294	296	298	300	302	304	K
М	odel inf	o: V3.6.1	KF-2		MRF PBL	Sir	mple ice	30 k	m. 37	levels.	30 sec		

To study the influence of SAL on TC genesis and intensification in terms of its warm and dry air, vertical shear induced by MLEJ, and Saharan dust. The role of environmental stability and moisture in TC genesis will also be investigated.

Approaches

Study dust characteristics & improve dust mobilization parameterization using observations

- > Develop and evaluate an on-line dust model
- Evaluate the impact of assimilating observations on TC simulations
- Study the impact of SAL on TC genesis and intensification
 - SAL structure and intensity
 - Wave's/TC's environment, e.g., shear, instability, etc.
 - Intrusion of SAL into TSs and its consequence
 - Dust-cloud-radiation effects

Dust model

Development of WRF Dust Model



Dust continuity equation

$$\begin{aligned} \frac{\partial C}{\partial t} &= -\nabla \bullet \vec{V}C + c_{pbl} + c_{cov} + S_c + E_c \\ C &= \mu c \\ \mu &= p_{hs} - p_{ht} \\ c : dust \\ S_c : se \ dim \ entation \\ E_c : Source \ / \ Sink \end{aligned}$$

NAMMA, 2006

DC-8 aircraft flew 13 missions from 19 Aug to 12 Sep 2006, and seven AEWs were identified

Wave #	Observed date	Development
1	August 19 and 20	Pre-Ernesto
2	August 23	Debby (TS)
3	August 25 and 26	Non-developing
4	September 1	Non-developing
5	September 3 and 4	Pre-Gordon
6	September 8 and 9	Non-developing
7	September 12	Helene

Observations that Will Help

To study dust characteristics & improve dust mobilization parameterization

- surface winds, dust concentration, size distribution, etc.
- To improve initial conditions for numerical simulations
 winds, T, moisture, pressure, etc.
- > To evaluate model performance
 - winds, T, moisture, dust concentration, microphysics, rainfall, etc.

Satellite Observations

instruments	Observations
MODIS	Total precipitable water (TPW) or soundings
QuikSCAT	Surface wind vectors
AIRS	TPW or soundings
SSM/I	Surface wind speed and TPW
AMSU	Temperature profiles

NAMMA Observations

Instruments	Observations
Dropsondes	Pressure, wind, temperature, mixing ratio
Lidar (Atmos. Sensing Experiment)	Mixing ratio
Meteoro. Measurement Sys.	Pressure, temperature, wind
Radiosondes	Pressure, wind, temperature,
(Praia, Cape Verde)	mixing ratio
Radiosondes	Pressure, wind, temperature,
(Kawsara, Senegal)	relative humidity

NAMMA (2006)



MODIS/Terra on Sep 11, 2006 Saharan dust outbreak passing over Cape Verde

Sep 05-14 averaged, 2006 aerosol optical thickness (MODIS/Deep-Blue algorithm)

(Courtesy S.-C. Tsai, NASA)

Hurricane Florence (Sep 3-12, 2006)









NIVR-FMI-NASA-KNMI

2.0 2.5 3.0 3.5 4.0 4.5> Aerosol Index

1.5

1.0



96h Simulation Results (every 6h)



Model Info: V3.0.1.1 KF MRF PBL Noah LSM 30 km, 30 levels, 120 sec LW: RRTM SW: Goddard DIFF: simple KM: 2D Smagor

Integrated dust & hydrometeors

3km T and winds

10



Surface Net Downward Heat Flux (84h)







Surface T & Integrated DUST

DR - NDR





co	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$														
-9	-8	-7	-6	-5	$^{-4}$	-3 -	2 -1	0	1	2	3	4	K		
Model	Info:	V3.0.1	1 KF	MRF	'PBL I	Lin et a	l Noah	LSM	30 km,	30 le	vels,	120 sec			
			LW: 1	RRTM SW	: Godda	ard DIFF	: simple	KM: 2	D Smago	r					

84h

MAXIMUM VECTOR: $1.9 \text{ m s} - 1 \longrightarrow$																										
	CONT	rou	RS:	UN	IITS-	=X	1000	ug-	2	LOW=	- 5	0.00	00		HIGH	I=	400	.00		INTE	RVAL	=X	2.00	00		
-	-2.5	-	2	-1.	.5	-1		.5	0		5	1	L	1.	.5	2	2	.5	3	3.	5	4	4.	5	5	K
Mo	del I	nfo	: V3	3.0.	1.1	KF	•	MR	\mathbf{F}]	PBL	Lin	ı et	al		Noah	L	SM	30	km,	30) lev	zels,	12	:0 s	ec	
					I	W:	RRT	MS	W:	Godd	lard	1 D	IFF:	si	imple	ŧΚ	M: 2	2D S	mae	or						

3km T & Integrated DUST

DR - NDR

10 E 50 W 40 W 30 W 20 W 10 W 0 20 E 30 E 50 W 220 _____ 200 180 160 140 120 100 80 60 40 midamaalai Binn warmun un un in 160 180 200 220 240 260 280 300 320 340 360 380 400 420 440 460 160 180

84h

10 W 10 E 20 E 30 E 40 W 30 W 20 W 0 40 N 30 N 20 N 10 N huunin 200 220 240 260 280 300 320 340 360 380 400 420 440 460

96h

	CONT	OURS:	UN	IITS=X	MAXIMUM 1000 ug-	VECTOR 2 LOW=	2: 2 = 50	2.3 m s 0.000	-1 – HIGH	→ = 40	00.00	INTER	VAL=X	2.0000	
		<u>^</u>			2	4	6	0			1.0	1 4	1.6	1	9 V
Мо	 Ullah	∽ nfo∙V	0 30	 11 KF	с МБ	F PRI	.u Lin	0. [e to	Noah	ISM	1.& 30 km	1.4	1.0 lovels	120 s	
MO	uci ii		0.0.	LW:	RRTMS	W: Godo	lard	DIFF:	simple	KM:	2D Smag	or	10 0 013,	150 2	,cc

			MAXIMUM	VECTOR:	2.1 m s	$^{-1} \longrightarrow$					
	CONTOURS:	UNITS=X	1000 ug-2	LOW= 5	60.000	HIGH = 40	00.00	INTER	VAL=X 2	0000.	
1	2	0	.2 .4	.6	.8	1	1.2	1.4	1.6	1.8	K
	Model Info: V	3.0.1.1 KH	r MRF	PBL Lii	n et al	Noah LSM	30 km,	30	levels,	120 sec	
		LW	RRTM SW	: Goddar	d DIFF:	simple KM:	2D Smag	or			

Integrated Cloud+Ice & DUST

DM - NDM

10 W 10 E 20 E 30 E 50 W 10 W 0 10 E 20 E 30 E 50 W 40 W 20 W 0 30 W 20 W 30 W 40 W 200 150 100 50 muuuli Fa. ສຸ່ດແມ່ນແບບບານເຫຼົ່າແມ່ນແຫ່ນແບບບານແບບບານປະກາ 350 450 350 150 200 250 300 400 150 200 250 300 400

	CO	NTOURS:	UNITS=	=X 1000	ug-2	LOW= 5	0.000	HIGH	= 400.0	00 I	NTERVAL=	=X 2.00	00	
	46	38	3	22	14	06	.02	.1	.18	.26	.34	.42	.5	mm
Mc	del	Info: V	3.0.1.1	KF	MRF 1	PBL		Noah	LSM 3	0 km,	30 lev	els, 12	0 sec	
			I	W: RRT	M SW:	Goddard	I DIFF:	simple	KM: 21) Smag	or			

84h

		coi	NTO	OURS	UN	IITS:	=X	1000	ug-	2 L	-wo	50	.000)	HIG	H=	40	0.00		INTER	VAL=	K 2.0	000		
	ľ	46	-	.42 –	.38	34	-	.3 -	.26	22	18	8 –	14	1	06	0)2	.02	.06	.1	.14	.18	.22	.26	mm
М	oć	lel	In	fo: \	/3.0.	1.1	KF	יקק	MR	F P	BL	ard	DIF	ידי.	Noal	1 LS	SM M·	30 2D 4	km,	30 	leve	ls, 1	20 s	ec	

96h

40 N

30 N

20 N

10 N

450

Integrated Precipitation & DUST

DM - NDM

50 W 40 W 30 W 20 W 10 W 0 10 E 20 E 30 E 50 W 40 W 30 W 20 W 10 W 0 10 E 20 E 30 E 40 N 200 00 1 30 N 150 50 20 N 100 00 10 N 50 50 ատենաստուստուներու աստաստանությո աստենուսուսուսո 200 250 300 350 400 450 150 200 250 300 350 400 450 150

CON	TOURS: UN	VITS=X 1	000 ug-2	LOW = 50	.000	HIGH= 40	00.00	INTERVAL=X	2.0000	
19	15	11	07	03	.01	.05	.09	.13	.17	m
Model I	nfo: V3.0.	1.1 KF	MRF	PBL		Noah LSM	30 km,	30 level	s, 120 sec	
		LW: H	RRTM SW:	Goddard	DIFF: s	simple KM:	2D Smag	gor		

84h

CC	NTOUR	S: UI	NITS=X	1000 ug-2	LOW = 50	.000	HIGH = 40	00.00	INTERVAL=	X 2.0000	
19	_	.15	11	07	03	.01	.05	.09	.13	.17	mm
Mode	Info:	V3.0	.1.1 KF	' MRF	PBL		Noah LSM	30 km,	30 leve	els, 120 sec	
			L.W.	RRTM SW	Goddard	DIFF	simple KM.	2D Smar	or		

96h