Dusty gust fronts at synoptic scale, initiated and maintained by moist convection over the Sahara desert

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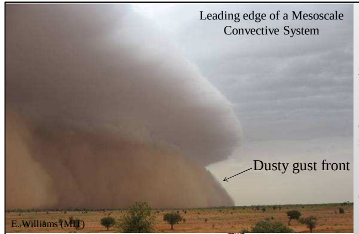
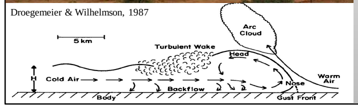
African gust fronts: Major mechanism for dust emission during the wet season



E. Williams (MIT)



Droegemeier & Wilhelmson, 1987

The gust fronts

➢ Origin: Cold downdrafts from moist convection.

➢ Occurrence: Over the **Sahel** and the **Sahara** during the wet season (May-October),

➢ Frequency (associated with deep convection): < 5/day

➢ Main characteristics:
- ✓ Mean lifetime: 25h
- ✓ Mean span : 1000 km
- ✓ Propagation speed: 10-15 m s^{-1}
- ✓ Depth: 2-4 km in altitude

Laing et al., (2008)

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➢ Typical meteorological conditions associated with dusty gust fronts:
- ✓ Wind speed: 5-15 m s^{-1}
- ✓ Visibility conditions: 0-1 km.
- ✓ Surface temperature drop: 0-20°C
- ✓ Surface pressure increase: ~ 9 hPa.

Focus of this study ➔ Dusty cold pools over the Sahara desert

Aspects of interest:

➢ What are the forcing mechanisms for gust front long-distance propagation (up to ~1000 km from the initial location at generation)?

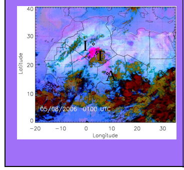
➢ What are the synoptic conditions that favor the propagation of gust fronts into the Sahara desert?

➢ What are the impacts of the dusty cold pools on the atmospheric conditions over the Sahara desert?

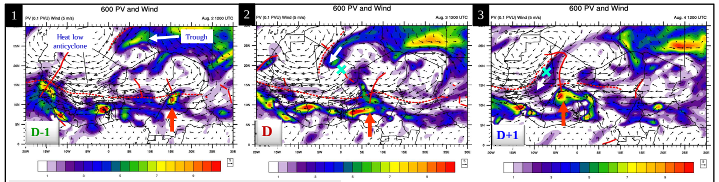
➢ What quantity of dust is lofted by the cold pool during a given MCS event?

The August 3-8th 2006 case

Data sources

Observations		Analysis
Ground based	**Spaceborne**	
Surface temperature (2m agl), visibility and surface wind speed (10m agl) at: ▪ Agadez (A) => Initiation phase. ▪ Tamanrasset (T) => Propagation phase. ▪ In Salah (I) => Last phase. 	➢ CALIPSO ➔ Vertical structure of the dusty cold pool. ➢ CloudSat ➔ Vertical structure of clouds. ➢ MSG-SEVIRI ➔ False color images for dust and clouds monitoring with 15 minutes of temporal resolution. ➢ MODIS Deep Blue ➔ AODs associated with the dust cloud + estimation of the dust load. ➢ TRMM ➔ Precipitation rates	0.5° AMMA Re-analysis & CMORPH (NOAA)

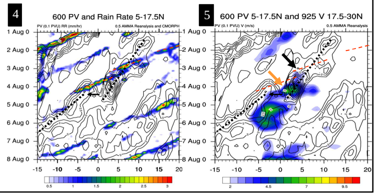
Synoptic Situation



➢ D-1: Intrusion of an extratropical trough associated with high PV (Fig.1).

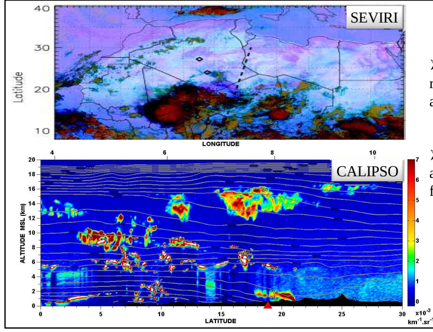
➢ D-1 to D: Intensification of low level vorticity along the ITD ➔ Surge of the southerly monsoon flow ➔ Transport of moisture at high latitude (i.e. 17°N) + Topography effect ➔ MCS genesis southwest of the Aïr Mountain.

➢D to D+1: Significant PV production ➔ Intensification of the AEW + Merging of the extratropical streamer with the AEW (Fig. 3) ➔ Intense AEW (Fig.4) ➔ Strong southerlies that favored the northward transport of dust (Fig. 5).



The vertical distribution of dust and clouds

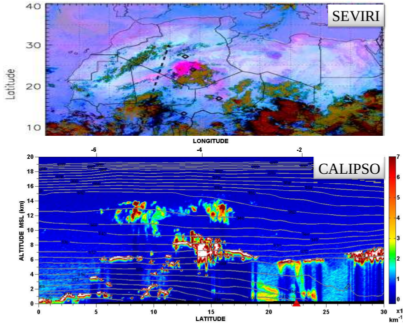
On 4 August 2006 at 0100 UTC



➢ Sharp dust front reaching 2 km in altitude.

➢ Lidar reflectivity associated with the dust front > 7 $x10^{-3}$/km/Sr

On 5 August 2006 at 0200 UTC

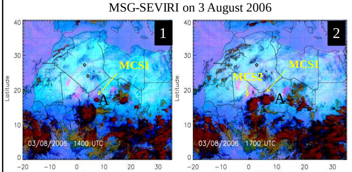


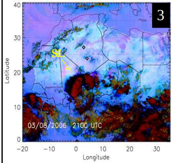
➢ Dust cloud mixed over 3 km in altitude.

➢ Lidar reflectivity associated with the dust cloud > 3 $x10^{-3}$/km/Sr

Spatio-temporal evolution of the August 3-8th 2006 dusty cold pool

Initiation phase


MSG-SEVIRI on 3 August 2006



Meteorological conditions in Agadez at 1400 UTC:

➢ Drop in surface temperature (2 m agl): 13°C
➢ Visibility = 1 km
➢ Wind speed increased by 5 m/s.

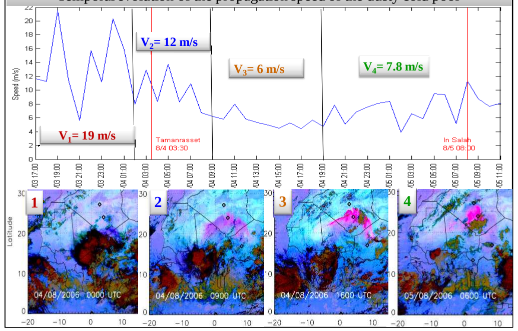
1) At 1300 UTC, isolated moist convection over the Aïr Mountain grew into a MCS (MSC1) over Agadez (8°E, 17°N).

2) At 1500 UTC, a second MCS (MCS2) was generated over northeastern Mali.

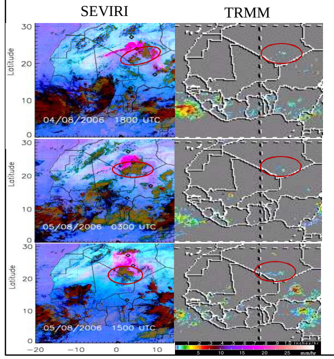
3) At 2100 UTC, MCS1 and MCS2 have merged and formed a large Squall Line (SL).

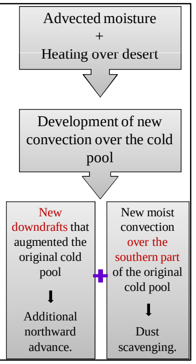
Propagation phase

Temporal evolution of the propagation speed of the dusty cold pool



New convection over the cold pool





Advected moisture
+
Heating over desert

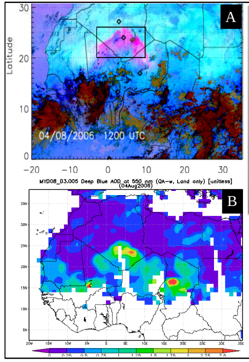
Development of new convection over the cold pool

New downdrafts that augmented the original cold pool
⬇
Additional northward advance.

+

New moist convection over the southern part of the original cold pool
⬇
Dust scavenging.

Dust load in the cold pool



Dust Load (Tg)= 1.9 x S x AOD

(Koren et al., 2006 & Todd et al., 2007)

- ▪ S = Surface covered by dust.
- ▪ AOD = Mean Aerosol Optical Depth over the area (derived from MODIS deep blue).

A ➔ S = 520 000 km^2
B ➔ AOD =1.75

Dust Load = ~ 1.5 Tg

!!! The Bodélé emits 0.7 Tg/day on 40% of the winter days *(Koren et al., 2006).*

Discussion & Conclusions

A dusty cold pool of synoptic scale over the Sahara desert was documented using a combination of satellite observations, ground based measurements and reanalysis.

➢ Origin of the cold pool: The cold pool was originated from isolated convection over the Aïr Mountains, that subsequently expanded into a squall line MCS over Mali and Niger on 3 August 2006.

➢ Origin of the relatively high-latitude MCS: The intensification of the ITD disturbance, caused by the intrusion of an extratropical trough, resulted in strong southerlies one day before the development of the MCS. The northward transport of moisture by the southerlies together with topographic lifting favored the development of the MCS at 17°N.

➢ The northward propagation of the dusty cold pool: The dusty cold pool that emanated from the squall line at 18°N propagated northward over 1000 km in latitude during 3 days. This pronounced northward transport resulted from the combination of local and synoptical conditions:
- ✓ New convection developed over the cold pool (behind the gust front) due to the presence of moisture and sensible heat flux over the desert. The outflows generated by the new convection provided additional northward extension for the northern part of the cold pool.
- ✓ The significant PV production associated with the squall line caused the intensification of the AEW which in turn and after the merging with the extratropical trough, enhanced the southerlies north of 20°N for 5 days.
- ✓ The gust front propagated northward with 22 m/s speed during the first 7 hours, then slowed to 12 m/s during the following 7 hours. The propagation speed of the cold pool was strongly attenuated by the diurnal heating over the desert (6 m/s during the whole day of 4 August 2006) that diluted the density contrast driving the gust front. During nighttime, the synoptic scale forcing induced an increase on the mean propagation speed (8 m/s) in addition to the localized accelerations from new convective downdrafts.

➢ The characteristics of the dusty cold pool:
- ✓ The dust load associated with the cold pool was estimated to be as large as 1.5 Tg.
- ✓ The dust cold pool reached 2.5 km in altitude according to CALIPSO observations and was associated with strong lidar reflectivity (> $7x10^{-3}$/km/Sr).

➢ The upwelling of dusty air associated with new moist convection that occurred over the southern part of the cold pool scavenged a large part of the uplifted dust.

Bou Karam et al., *In preparation*

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