Initiation of deep convection during the early-monsoon sahelian convective boundary layer: an observational study

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METEO FRANCE
Toujours un temps d'avance

Objective

This study aims at analyzing the initiation factors of local deep convection to better understand the transition from dry convection to shallow convection and from shallow to local deep convection.

Based on the AMMA (African Monsoon Multidisciplinary Analysis) dataset, the characterization of the atmospheric convection which occurred over Niamey (Niger) during the early African monsoon (26 days in July 2006) was made.

Data and Methods

⊕ MIT (Massachusetts Institute of Technology) C-band Doppler radar
- 3D interpolation of reflectivity ⇒ horizontal and vertical cross sections
- VVP (Volume velocity processing) ⇒ vertical profile of divergence

⊕ Atmospheric Radiation Measurement (ARM) mobile facility:
- ⇒ Radiosoundings **(CAPE, CIN, CTP, HI_{low}, and θ)**
- ⇒ UHF wind profiler **(diurnal cycle of Convective boundary-layer (CBL))**
- ⇒ Surface turbulent fluxes ⇒ 95 GHz cloud-radar

⊕ Satellite data (MSG)

The classification of convection day is based on the PPI and horizontal cross sections of reflectivity MIT radar

- Deep convection: reflectivity > 30 dBz and vertical extension > 7 km, T_b < 233 k (Mathon et al 2001)
- Shallow convection: reflectivity < 30 dBz and vertical extension < 7 km
- Dry convection: fair weather
- Propagating convection: deep convection formed outside and moved in the scope of the MIT radar.

Classification

Local deep convection (LC)	9 cases
Propagating deep convection (PC)	9 cases
Shallow convection (SH)	4 cases
Dry convection (FW)	4 cases

Local deep convection is common during this period

↪ All cases of class LC, SH, and FW except one in class LC start with organization in rolls in the CBL

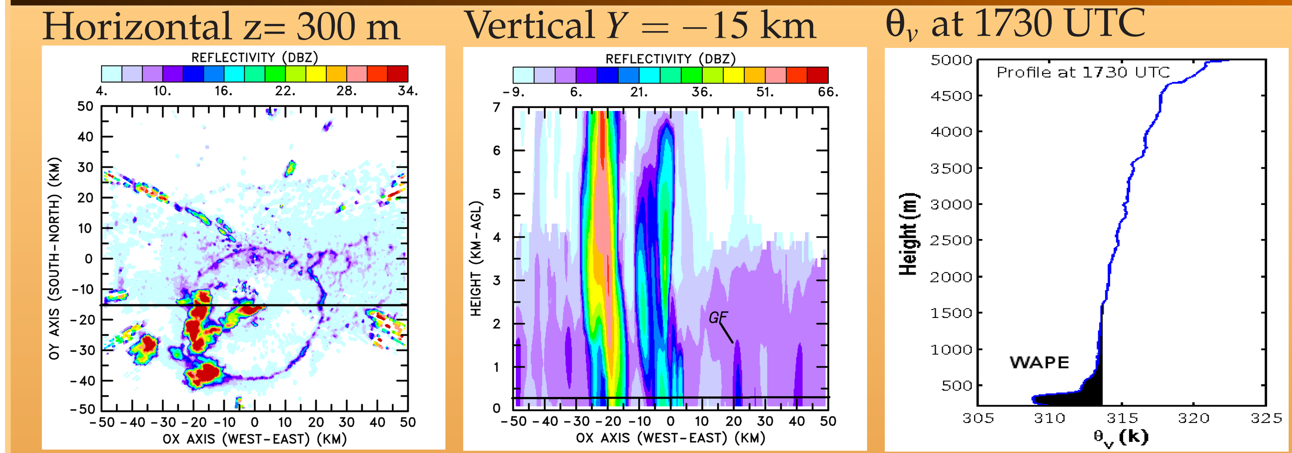
↪ 7 cases of local deep convection are associated with gust fronts

↪ All gust fronts except one triggered new deep convective cells

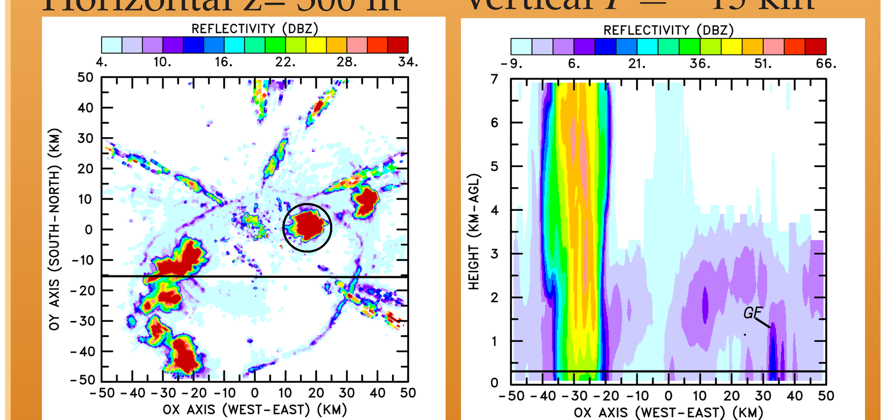
↪ 3 cases of local convection are triggered on a convection line

Circular gust fonts

Horizontal z= 300 m | Vertical $Y = -15$ km | θ_v at 1730 UTC



Horizontal z= 300 m | Vertical $Y = -15$ km



WAPE Available Potential Energy is calculated by integrating over the virtual potential temperature difference between the cool pold and its environment

$$WAPE = -g\int_0^{hw} \frac{\delta\theta_v(z)}{\overline{\theta_v}}\,dz$$

$\delta\theta_v(z) = \theta_{vw} - \overline{\theta_v}$

$C_* = k * \sqrt{2WAPE}$, $C_* = 0.67 * U$

U: velocity of the DC

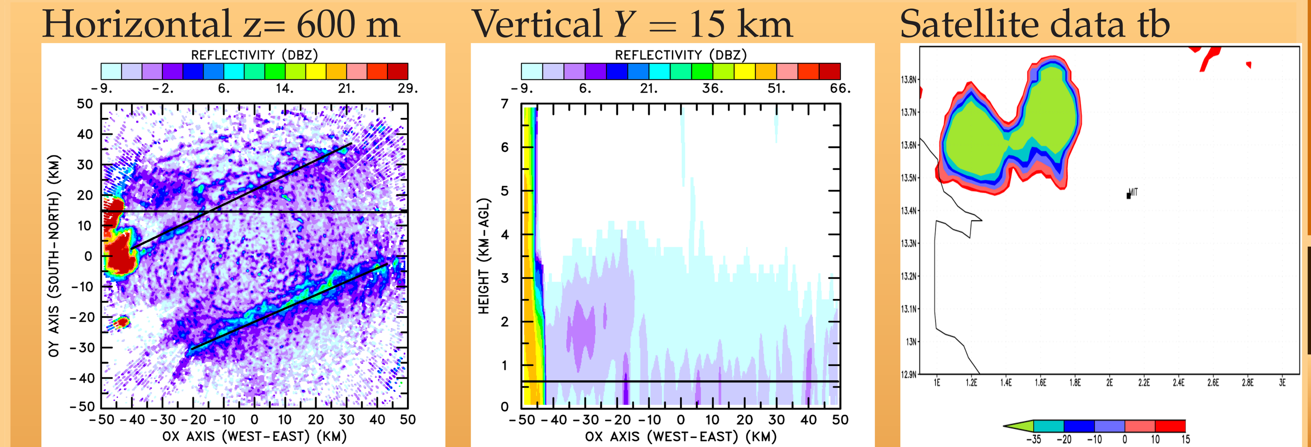
Deep convection associated with gust front observed on 11 July 2006: horizontal and vertical cross sections at 1610 and 1640 UTC and vertical profile of θ_v at 1730 UTC

For this day we estimate the Wape using the radiosoundings at 1730 UTC. The Gust front deph is h_w=1620 m
$\overline{\theta_v} = 313.6\ k$, U= 6 m s−1
C_*=4 m s−1 at this time
$WAPE = 38.5\ J\ kg^{-1}$
k*= 0.45

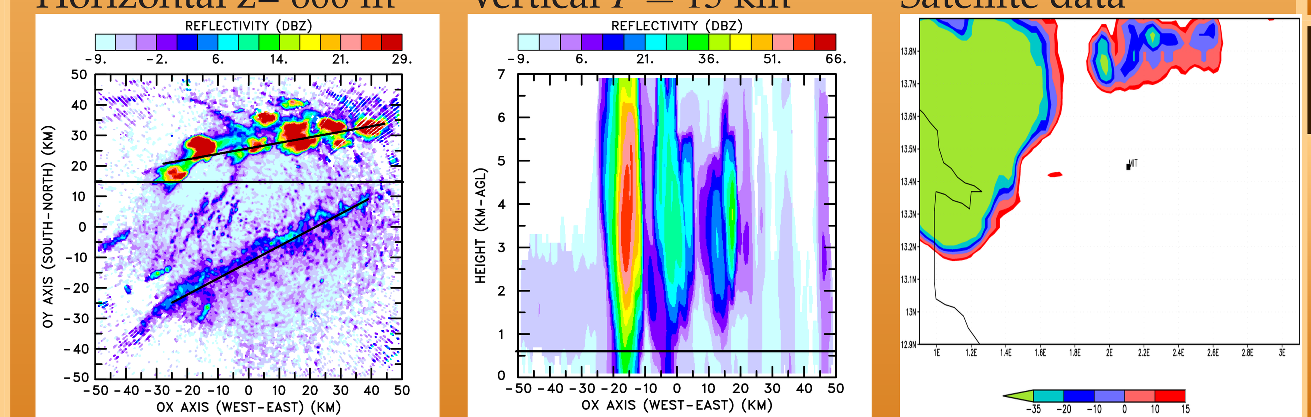
We found k* between 0.3 and 0.7 favorable for the triggering of news deep convection by the density current (Grandpeix and Lafore (2010))
Lothon et al, (2011) found k*=0.52 for one other case (included in this study)

Convection Lines

Horizontal z= 600 m | Vertical $Y = 15$ km | Satellite data tb



Horizontal z= 600 m | Vertical $Y = 15$ km | Satellite data

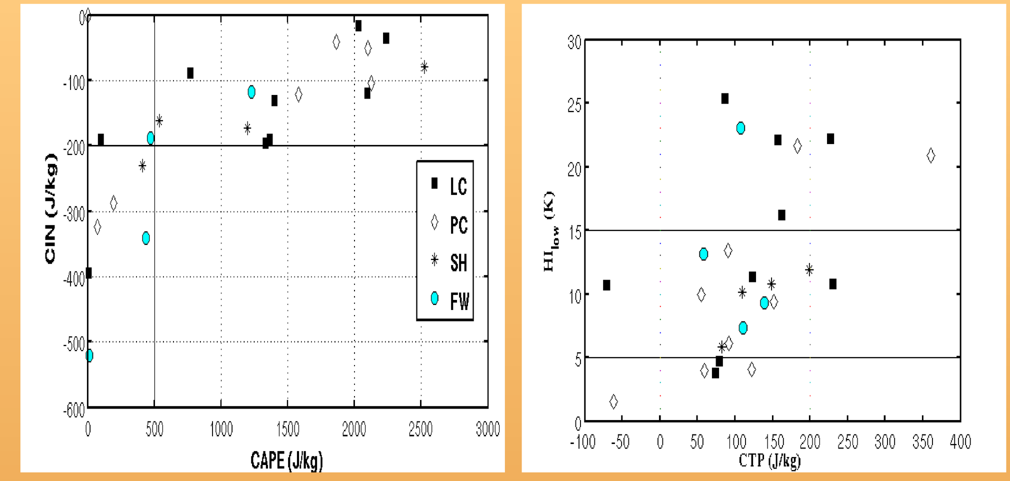


Horizontal and vertical cross sections of reflectivity radar respectively (first and second row) and brightness temperature (thirst row) at 1550 UTC (first panel) and 1640 UTC (second panel).

Typical deep convection triggering on a convection line in the North of the MIT radar. Two other cases of convection lines triggering deep convection are found in the exploration volume of the radar.

The convection lines are identified to be precursors of deep convection in the Sahel in the early monsoon.

Convection initiation factors



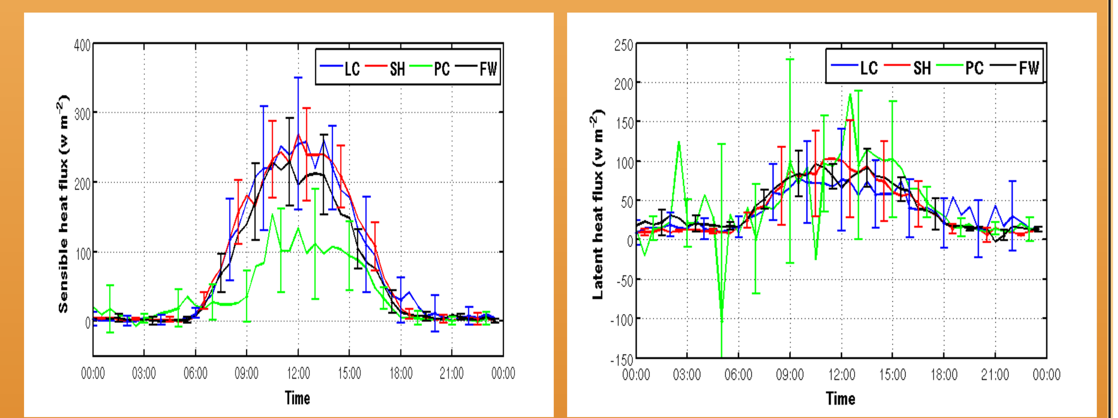
All cases are represented here at 0530 :(first) CIN versus CAPE and (second) HI_{low} versus CTP. "◇": propagating convection cases, "■": local deep convection,"•": fair weather , and "∗": shallow convection.

Based on 0530 UTC CTP/HI_{low}/CAPE/CIN, it is difficult to predict that the deep convection will occur in the afternoon

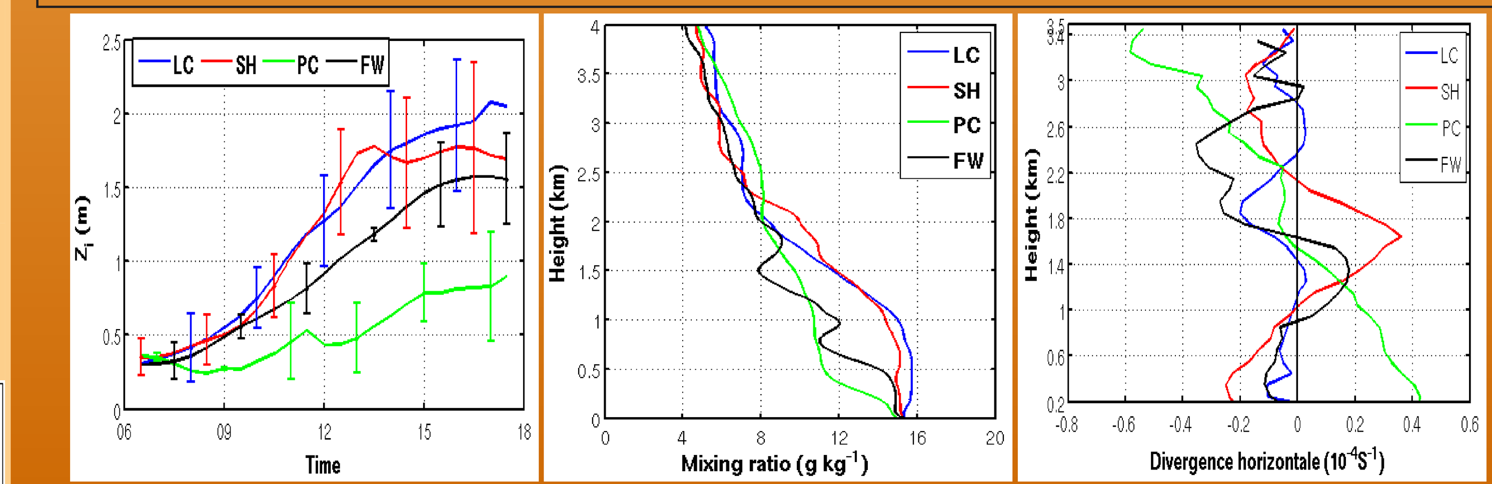
3 LC, 2 SH, 3 FW and 2 PC: $CAPE < 1000$, $|CIN| < 100\ J\ kg^{-1}$
4 LC, 1 FW,1 SH, and 2 PC: Larger CAPE, $100 < |CIN| < 200\ J\ kg^{-1}$
2 LC and 2 PC: favorable conditions
CTP and HI_{low} (Findell and Eltahir (2003)) not distinguished convection class
No clear regimes of CTP and HI_{low}

Large surface Fluxes are necessary for deep convection (Couvreux et al, 2012)

Low sensible heat flux and significant latent heat flux for PC
Large sensible heat flux for LC, SH than FW
Increasing latent heat flux for LC in afternoon by convection
LC and SH are similar on diurnal cycle of turbulence heat fluxes



Composite of diurnal cycle: (first) sensible heat flux and (second) latent heat flux, from the surface fluxes data at Niamey Airport: (blue line) afternoon local deep convection days, (red line) shallow convection days, (green line) propagating deep convection days and (black line) dry convection all days. Error bars represent the standard deviation over, the cases of a given class.



Composite diurnal cycle: CBL height, vertical profile of θ at 1130 UTC and vertical profile of the horizontal divergence average between 1100 and 1500 UTC

Slight convergence is observed for class LC from surface to 3 km above. Classes LC and SH have higher CBL than classes FW and PC. Class LC have mixed layer wetter than SH.

Low convective boundary-layer top for class FW and PC
Divergence in the low-level for class PC
Divergence at the top of the CBL top for classes FW and **SH specially**

Futur works

We will consider the same set of cases to further analyze the role of the **surface temperature and moisture heterogeneity** ***LES (Large Eddy-Simulations) studies*** to further understand the triggering factors of afternoon deep convection.

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