Organization of Mesoscale Convective Systems over Northern Africa: Radiative Impact of Dust

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MOTIVATION

- **What controls the distribution of precipitation over northern Africa?**
  
  Over West Africa: Mesoscale Convective Systems (MCSs). 90% over Sahel (Mathon et al., 2002), 50% over Benin (Fink et al., 2006) and 20% over the Guinean Coast (Omotosho, 1985).

  What is the contribution of the MCSs to the diurnal variability of precipitation?

- **Can Convection-Permitting Models (CPMs) simulate precipitation and MCSs in a realistic manner?**

  Added-value of CPMs on means and variability, e.g. contribution of MCSs to precipitation, diurnal cycle, ...?

- **What is the radiative impact of dust on the atmosphere?**

  African Easterly Jet (AEJ) is modulated by the temperature variations induced by dust (Tompkins et al., 2005)

  What is the effect on the organization of the MCSs?
Méso-NH model & tracking of MCSs

Three simulations of dust outbreak 9-14 June 2006.
Init. cond. 00 UTC 9 June from ECMWF analysis. Outputs 3h.

- **HiRes** $\Delta x = 2.5$ km, 3072 x 1536 x 72, 1/3 billion gdpts, 7 TB
- **LowRes** $\Delta x = 20$ km with KFB convective parameterization
- **HiNod** $\Delta x = 2.5$ km, no radiative effect of dust

Standard param: ICE3 bulk $\mu \phi$, 1D turb, RRTM radiation

**Assessment of simulations** (MSG BT; TRMM3B42 rain; MODIS Deep Blue AOD; CALIOP backscatter coeff)

**Identification of clouds**
- Deep convective clouds (DCCs): BT<230K
- Cirrus anvil clouds (CACs): 230K<BT<260K

**Dust:**
- emission: DEAD (Zender et al., 2003)
- transport: ORILAM (Tulet et al., 2005)

**Assign 3-h accumulated precip**

**Tracking of MCSs** (DCCs $D_{eff} > 120$ km, overlap method)

**Properties of long-lived MCSs** (lifetime>6h) in sub-regions: **SWA, CAF, ETH**
Long-lived MCSs are the main contributors to precipitation (55%)

**HiRes** captures very well the observed distribution!

Most of precip south of 15ºN

**LowRes**: low values too frequent
Diurnal cycle of precipitation

**OBS**: maximum of precipitation at 21 LST

**HiRes**: good agreement in amplitude and phase.

**Lack of nocturnal precipitation (mostly from long-lived MCSs)**

**LowRes**: peak too early (15 LST)

1st contributor: long-lived MCSs
Long-lived MCSs trajectories

Propagation mainly to the west

The number of trajectories differs
Characteristics of long-lived MCSs

a) Number of long-lived MCSs

HiRes: agreement with OBS except in SWA (too small, short-lived and slow, small northward meridional component)

OBS: most organized long-lived MCSs in SWA

LowRes: drawbacks more pronounced
Environmental conditions for long-lived MCSs (6 h before detection)

OBS
Over SWA near-surface is moister, with larger *conditional instability* and larger *wind shear* than over CAF and ETH.
Environmental conditions for long-lived MCSs (6 h before detection)

HiRes wet bias at 2-3 km altitude
Assessment of dust

Mean AOD 9-14 June 2006

AOD larger in SWA than in other sub-regions

Vertical stratification captured: plume at altitude of AEJ

14 June 2006 0000 UTC

Vertical stratification captured: plume at altitude of AEJ
Impact on temperature and the AEJ...

ECMWF
AEJ core (> 16 m/s)
strongest over SWA

HiRes

HiNod

Thermal wind equilibrium

At y = y_0 
\[ \frac{d\theta}{dy} = 0 \]
Impact on temperature and the AEJ...

ECMWF

AEJ core (> 16 m/s) strongest over SWA

HiRes

HiNod

At \( y = y_0 \)

\[ \frac{d \theta}{dy} = 0 \]

Thermal wind equilibrium

HiRes: AEJ core more intense and located higher than in HiNod in response to changes in \( \theta \)
... and on precipitation

**HiRes**: warming at 3 to 5-km altitude (1.3 K) and cooling in the near-surface (0.3 to 0.9 K) with respect to **HiNod** → stability increases

**HiRes**: precipitation decrease with respect to **HiNod**
Precipitation and long-lived MCSs

HiRes: rainfall drop in SWA mainly due to long-lived MCSs
Impact on the number and organization of long-lived MCSs

Over SWA
HiRes:
long-lived MCSs less numerous than HiNod

HiRes:
• longer-lived (2 h)
• precipitate more (50 mm/h)
• faster (3 m/s) than in HiNod
HiRes
Change in the stability

AEJ located higher

wind speed

wind direct
CONCLUSIONS

The long-lived MCSs are the first contributor to precipitation (55%)
- Also to the diurnal cycle of precipitation
- Well reproduced by HiRes

The long-lived MCSs are the most organized over southern West Africa
- Due to the largest wind shear and conditional instability

*Reinares Martínez and Chaboureau, 2018*

The radiative effect of dust is a mid-level warming and a surface cooling
- More pronounced over southern West Africa than further east
- Intensification of the AEJ & stabilization of the low-level atmosphere

The radiative effect of dust acts enhancing the organization of convection
- Although suppressing total precipitation