How to model aeolian dust emission from hot spots for climate assessments: the example of the Bodélé depression (Chad)

C. Bouet[(1)], G. Cautenet[(1)], R. Washington[(2)], M. C. Todd[(3)], B. Laurent[(4)], B. Marticorena[(5)], and G. Bergametti[(5)]

(1) Laboratoire de Météorologie Physique, Aubière, France, Université Blaise Pascal, CNRS
(2) Climate Research Lab, Oxford, United Kingdom, Oxford University Center for the Environment
(3) Department of Geography, London, United Kingdom, University College London
(4) Leibnitz-Institute for Tropospheric Research, Leipzig, Germany
(5) Laboratoire Interuniversitaire des Systèmes Atmosphériques, Créteil, France, Universités Paris 7 et 12, CNRS

C.Bouet@opgc.univ-bpclermont.fr

1. Scientific context

Desert dust is one of the most important contributors to the atmospheric aerosol burden (some Gt/year). For long term climate investigations, it is particularly important to accurately model the global cycle of these aerosols.
The Bodélé depression (Northern Chad) is believed to be the single largest source for the Saharan dust transported over the Atlantic Ocean, especially that emerging in the Gulf of Guinea in boreal winter. The problem is that, when dealing with such sources (known as "hot spots"), Global Circulation Models (GCMs), the numerical tool dedicated to climatologic studies, are quite unable to correctly estimate emissions from these regions [*Koren and Kaufman*, 2004].

2. Objectives

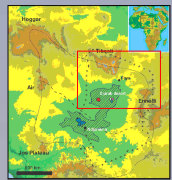
During the Bodélé Dust Experiment 2005 (BoDEx 2005 [*Washington et al.*, 2006; *Todd et al.*, 2007]), which was performed in February-March 2005 in the Bodélé region, a severe dust event was observed and some of its main features (surface wind, dust concentrations, radiation) were recorded.
The aim of this work is to test the capability of a mesoscale model coupled online with a Dust Production Model (DPM) to reproduce the small scale features associated to this dust event.
After the validation step, a modelling strategy is exposed so that hot spots can be better represented in GCMs.

3. Model and conditions of simulation

3.1. *Numerical tool*

We use the Regional Atmospheric Modeling System (RAMS, *Cotton et al.*, [2003]) coupled online with the Dust Production Model (DPM) developed by *Marticorena et al.* [1995] and upgraded by *Laurent* [2005]. The mesoscale model is initialized and nudged by the ECMWF fields.
The dust concentration field is not initialized.

3.2 *Simulated domain*



The simulated domain is a grid centred on Faya Largeau, i.e. on 18°N and 19°E.
The domain covers the region from 21.5°N to 14.4°N and from around 13°E to around 25°E, i.e. its horizontal extent is 1200 x 800 km².
Number of grid points: nx = 120; ny = 80; nz = 30 from ground to 22 km agl, with 10 levels between 0 and 1.2 km.
Horizontal resolution: $\Delta x = \Delta y = 10$ km

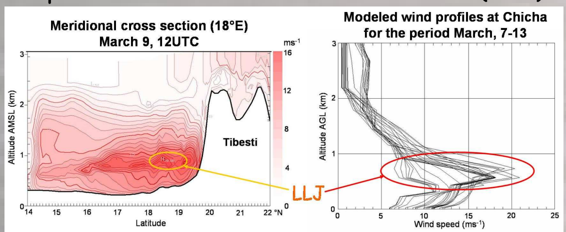
3.3. *Simulated period*

The simulation is done for the period of BoDEx 2005 Experiment [*Washington et al.*, 2006; *Todd et al.*, 2007].
The simulation begins on March, 5 at 0h UTC and ends on March, 13 at 0h UTC in order to simulate both clear and dusty conditions (from 10 to 12 March 2005, there was a major dust event over the region under study).

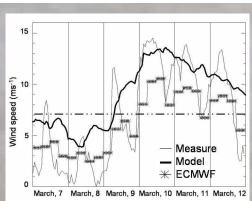
4. Results

4.1. *Wind field*

Representation of the Low Level Jet (LLJ)



Intensity and diurnal cycle

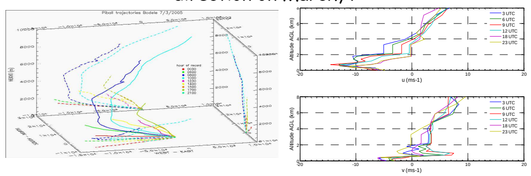


Intensity:
-well captured by the model
-underestimated by ECMWF

Diurnal cycle:
-not well reproduced by the model
-well reproduced by ECMWF

Wind direction

Comparison of PIBAL trajectories to simulated wind direction on March, 7



The simulated wind direction is also consistent with the PIBAL observations for March, 7

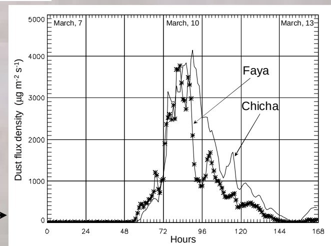
Highlight of the shear between Harmattan flux in altitude and LLJ near the surface

4.2. *Dust flux*

Daily flux estimates:
- *Todd et al.* [2007]: 1.2 Mt
- RAMS: 1 Mt
- ECMWF: 0.4 Mt

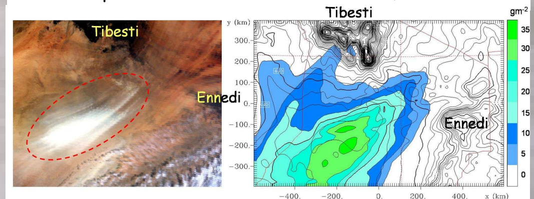
=> Clear underestimation by GCM

Modelled dust mass flux density as a function of surface wind speed →



4.3. *Dust field*

An example of dust field retrieval: March, 11 at 10UTC

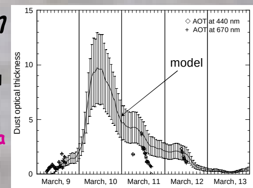


The simulations reproduce quite well the dust emission area including its extension and the location of the most emitting places

4.4. *Dust concentration*

The central curve is the DOT considering an extinction coefficient of 0.15 m²g⁻¹; the error bars are obtained using the minimal and maximal values of the interval suggested by *Foret et al.* [2006] (0.1-0.2 m²g⁻¹ at 550 nm)

Satisfactory agreement despite a slight overestimation of AOT by the model



5. Conclusion and perspectives

A regional model with a spatial resolution of 10 km×10 km is able to capture the dust emission pattern in source regions of complex topography such as the Bodélé depression. For the studied dust event, the total dust emissions computed with the RAMS model are 40% higher than the emissions computed from ECMWF surface wind fields with a spatial resolution of 0.5°×0.5°.
Such a tool could be used as a basis for the development of a correction of wind fields in regions like the Bodélé depression.

The following protocol is suggested:
-1st step: validate the tool for the region of interest
-2nd step: run the model on a climatologic period (1 year for instance) over the region of interest
-3rd step: derive a corrective factor for the studied region
-4th step: integrate the correction in GCMs

Acknowledgements:
Part of the data used in this study were acquired as part of the NASA's Earth Science Enterprise. The algorithms were developed by the MODIS Science Teams. The data were processed by the MODIS Adaptive Processing System (MODAPS) and Goddard Distributed Active Archive Center (DAAC), and are archived and distributed by the Goddard DAAC