Sensitivity of desert dust modeling to spatial scales: a numerical study

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1. Scientific context

Atmospheric aerosols are known to play an important role in the Earth's climate system. In many regions, like in desert regions, dust is the biggest contribution to aerosol optical thickness [*Tegen et al.*, 1997]. *Washington et al.* [2005] found that the Bodélé depression is the most important limited source of mineral dust in the Sahara. Low level winds are channelled between the Tibesti (~3000 m) and the Ennedi (~1000 m) Mountains. The Bodélé source lies roughly at the exit of the "defile", which explains the frequent dust plumes.

Dust emission is a threshold phenomenon driven by the intensity of horizontal wind. Recently, *Koren and Kaufman* [2004] revealed that the reanalysis data (NCEP) that can be used as an input data in numerical model underestimates wind speeds in the Bodélé region.

2. Objectives

Using the mineral dust source established by *Laurent* [2005] for Northern Africa coupled with a mesoscale model, we underline the importance of the scale at which horizontal winds are computed in order not to underestimate dust emissions from the Bodélé depression.

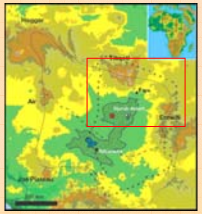
The results are validated using the data of BoDEx 2005 Experiment [*Washington et al.*, 2006].

3. Model and conditions of simulation

3.1 Numerical tool

We use the Regional Atmospheric Modeling System (RAMS, *Pielke et al.*, 1992) coupled with the Dust Production Model (DPM) developed by *Marticorena et al.* [1995] and updated by *Laurent* [2005].
The mesoscale model is initialized and nudged by the ECMWF fields.

3.2 Simulated domain



The simulated domain is a grid centered 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.
There are 30 vertical levels from ground to 22 km agl, with 10 levels between 0 and 1.2 km.

3.3 Conditions of simulation

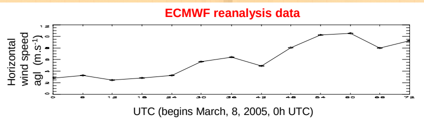
The simulation is done for 2 periods:
- the period of BoDEx 2005 Experiment [*Washington et al.*, 2006], which took place in the Bodélé region during February-March 2005. The simulation begins on March, 5 at 0h UTC and ends on March, 13 at 0h UTC.
- July, 25 and 26 1996, when a squall line was passing 200 km south of the modeled area.

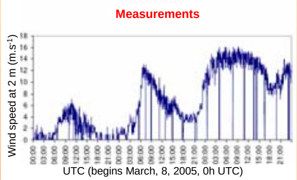
We examine 3 grid resolutions: $\Delta x = \Delta y = 50$ km,
$\Delta x = \Delta y = 10$ km,
and $\Delta x = \Delta y = 5$km.

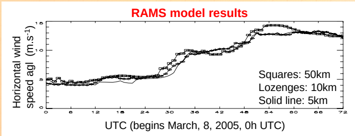
4. Results

4.1 BoDEx 2005

At (17°N,18.5°E)

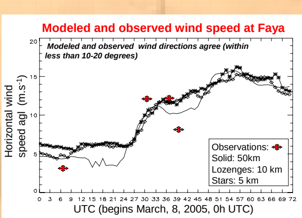






Dust mass budget for the 3 days:
35.1 Mt for 10 and 50 km, 36.6 Mt for 5 km

At (18°N,19°E)



ECMWF data exhibit a good phase agreement with observations with an obvious underestimation. On the other hand, model data are in good agreement with observed speed at both measurement sites; the phase agreement is less satisfactory.
In this case, the role of horizontal resolution does not look crucial: surface winds and mass budget are somewhat insensitive to this parameter. The average wind speed is higher than in the next case.

Satellite validation of dust uptake and transport during BoDEx 2005

Witness (dust free) image of the Bodélé depression (March, 2, 2005, MODIS Terra)

Acknowledgements:
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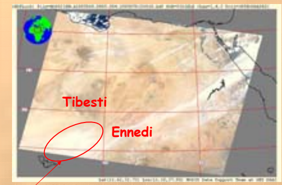
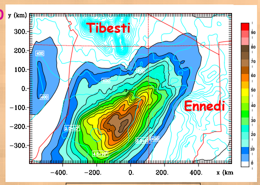
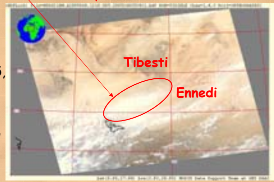


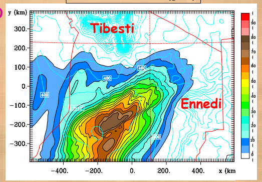
March, 10
9 h UTC



Columnar dust load (gm⁻²)



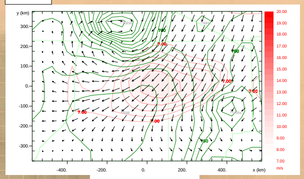
March, 10
12 h UTC



4.2 July, 25 and 26 1996

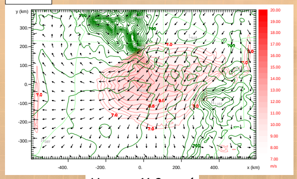
We now present a simulation of a case with lower velocity in the same area, but on July, 26 1996 at 12 h UTC.

50 km



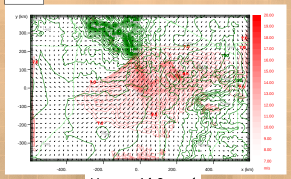
Vmax = 9.4 m.s^{-1}

10 km

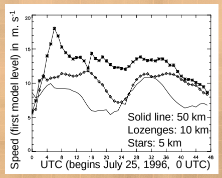


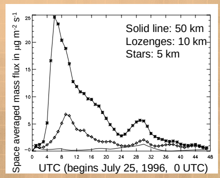
Vmax = 11.9 m.s^{-1}

5 km



Vmax = 14.0 m.s^{-1}





Contrary to the previous case, the grid resolution looks crucial.
With 50 km, we find a mass budget of 0.06 Mt and a maximum speed of 9.4 m.s^{-1} whereas for 10 km and 5 km, we respectively have for the mass budget 0.30 Mt and 1.00 Mt and for maximum speed 11.9 m.s^{-1} and 14.0 m.s^{-1}.

5. Conclusions and Perspectives

The present results show that the RAMS model coupled with the LISA DPM is able to retrieve the dynamical features of the Bodélé region, and the aeolian dust uptake as well. This represents a critical improvement when compared to a simple used of the ECMWF surface winds as input of the DPM. In our case, ECMWF data are used for initialization and nudging of the model.
The two examples displayed here show that the choice of the model resolution is not straightforward. It is possible that the choice is critical when wind speeds are weak and close to the threshold for dust uptake (about 7 m.s^{-1}).
In order to thoroughly depict this point, we have undertaken a intensive numerical experiment that covers a large part of Northern Africa for 2001 year.

References

Koren, I., and Y. J. Kaufman (2004), Direct wind measurements of Saharan dust events from Terra and Aqua satellites, *Geophys. Res. Lett.*, *31*, L06122, doi:10.1029/2003GL019338.
B. Laurent. *Thèse : Simulation des émissions d'aérosols désertiques à l'échelle continentale : Analyse climatologique des émissions du nord-est de l'Asie et du nord de l'Afrique*. Université de Paris 12, 2005.
R. A. Pielke, W. R. Cotton, R. L. Walko, C. J. Tremback, W. A. Lyons, L. D. Grasso, M. E. Nicholls, M. D. Moran, D. A. Wesley, T. J. Leel, and J. H. Copeland (1992), A comprehensive meteorological modeling system rams, *Meteorol. Atmos. Phys.*, *49*, 69–91.
Washington, R., M. C. Todd, S. Engelstaedter, S. Mbainayel, and F. Mitchell (2006), Dust and the low-level circulation over the Bodélé Depression, Chad: Observations from BoDEx 2005, *J. Geophys. Res.*, *111*(D3), D03201, doi:10.1029/2005JD006502.