Effect of Terrain Relief on Dust Transport over Complex Terrains in West Asia

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Keywords— **Mineral dust, dust transport, NMMB/BSC-Dust, dust modelling, horizontal resolution and topography**

EXTENDED ABSTRACT

This work investigates the impact of orography on dust transport using the multi-scale NMMB/BSC-Dust model. For this purpose, two model simulations at horizontal resolutions of 0.03º x 0.03º (Low-resolution; LR) and 0.3º x 0.3º (High-resolution; HR) are performed and analysed covering two intense dust storms that occurred in West Asia in March 2012. Differences between both simulations emerge when the dust storms reach the south and west Arabian Peninsula where its complex topography affected meteorology and dust fields in many ways. The HR simulation is better than the LR simulation at reproducing the topography and its topographic effects on meteorology, such as developing orographic clouds, wind speed bias reduction under the dust flows (larger than 5 m/s) and more accurate wind directions, as well as on dust fields, such as a more realistic representation of dust channeling/blocking. Consequently, it improves dust forecasts in the vicinity of complex terrains.

I. *Introduction*

Mineral dust is one of the most abundant atmospheric aerosols. Dust particles uplifted by strong winds from arid or semiarid regions can be injected into the atmosphere and, under favourable conditions, transported over thousands of kilometres away. Mineral dust plays an important role in the Earth system due to its impacts on radiation, clouds, precipitation, atmospheric chemistry, ecosystems, biogeochemical cycles and human health (e.g. respiratory and cardiovascular diseases). Dust storms can reduce visibility to a few meters and negatively impact goods and human activities by causing serious hazards in road and air transportation, reducing commercial solar energy production, and damaging crops and livestock [1].

In this framework, dust models have many applications on the Earth system because they are a powerful tool for predicting and simulating the dust cycle and its interaction in the climate-weather system, estimating the global or regional dust budgets, as well as complementing observations and improving our knowledge about dust processes.

The present work investigates the NMMB/BSC-Dust model's ability to reproduce dust transport in the vicinity of complex terrains. In order to do that, we perform two NMMB/BSC-Dust simulations at different horizontal resolutions covering two intense dust storms that occurred on 17-20 March 2012 and spanned over thousands of kilometres in West Asia where its topography affected dust propagation in many ways. Based on the literature, this dust event is considered among the most powerful ones [2]. The model results will be compared against ground-based (AERONET and weather) observations and satellite aerosol products (Aqua/MODIS and MSG/SEVIRI).

II. *The NMMB/BSC-Dust model and model setup*

The NMMB/BSC-Dust model [3]–[5] is one of the dust models in the Earth Sciences Department of the Barcelona Supercomputing Center (ES-BSC). This dust model is composed by the online coupling of the non-hydrostatic multiscale atmospheric NMMB model and the BSC-Dust dust module, which provides a unique framework to simulate and/or predict dust and meteorological fields at a wide range of spatio-temporal scales. The model provides daily operational dust forecasts over North Africa, the Middle East and Europe (NAMEE) at the Barcelona Dust Forecast Center (http://dust.aemet.es/), the first regional specialized meteorological center with activity specialization on atmospheric sand and dust forecast.

In this study, two NMMB/BSC-Dust configurations as LR and HR are performed; their main differences are shown in Table 1 and their main common features are explained below.

Table 1 The NMMB/BSC-Dust model configurations and their main features used in the present study

Features	**Model configurations**	
	LR (Low-resolution)	**HR (High-resolution)**
Grid Spacing	0.33ºx0.33º (~33km^2 in the equator)	0.03ºx0.03º (~3km^2 in the equator)
Grid Points	211x307	1001x1001
Box Domain (Lat, Lon)	0º – 70ºN 31ºW – 71ºE	10ºN – 40ºN 35ºE – 65ºE
Timestep (s)	40	25
NetCDF (Gb/day of simulation)	~1.5	~15

The simulation period is 10 – 21 March 2012, and consists of daily forecasts (initialized at 0 UTC) with model outputs saved every 3 h. The initial meteorological state is supplied by the NCEP/Final Analyses (FNL; at 1º×1º horizontal resolution) and boundary conditions are updated every 6 h. The vertical resolution for both simulations is 40 σ-hybrid layers with the top of the atmosphere at 50 hPa. Dust concentration at 0 UTC is defined by the value at hour 24 of the previous day's dust forecast, except at 0 UTC 10 March when dust concentration is set to zero (cold start). The first six days are discarded and are only used as a warm up of the simulation.

III. *Results and discussion*

On 17 March, a dust storm originated in Iraq as a result of strong north-westerly Shamal winds and rapidly extended towards the Arabian Gulf, uplifting and transporting a dust cloud that dropped visibility below 500 m in its path. The dust storm then moved to the mountain ranges in the south and west Arabian Peninsula where it was initially blocked on 18 March, and between 18 and 19 March, satellite images observed dust plumes channeling through valleys between the

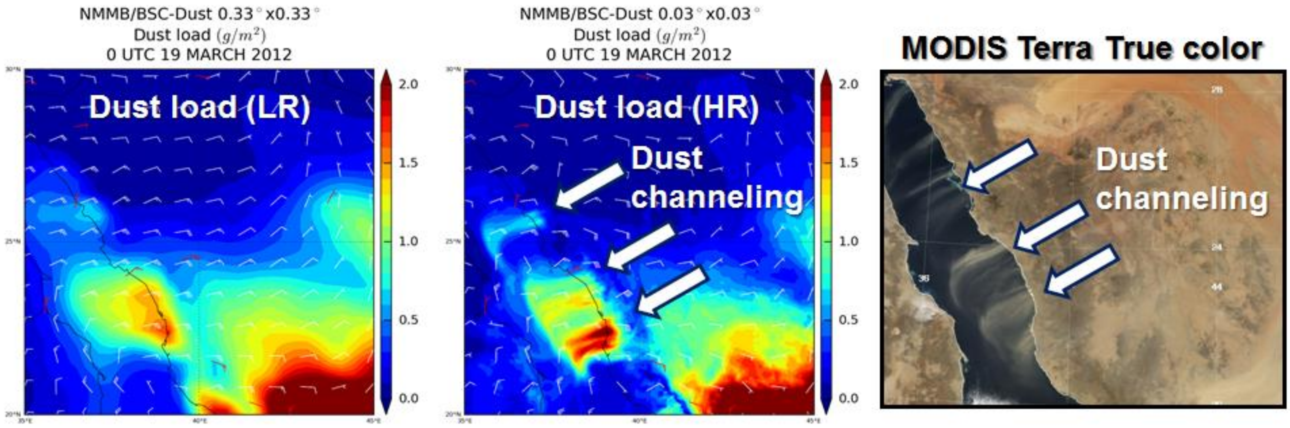

Fig. 1 The simulated dust load (g/m^2) for both NMMB/BSC-Dust configurations as LR (left panel) and HR (middle panel) at 0 UTC on 19 March 2012 and satellite MODIS Terra True Color snapshot (right panel) over the western Arabian peninsula and the Red Sea.

near-coast mountain ranges towards the Red Sea (Fig. 1) and the Arabian Sea. Both configurations reproduce the emission and transport of dust from Iraq to the mountain ranges in the south and west Arabian Peninsula, although overestimations in dust fields are found in comparison with observations (i.e. AERONET sun-photometers and Aqua/MODIS AOD) in the eastern Arabian Peninsula associated with a wind speed overestimation. Furthermore, both present a delay in the arrival of the dust front to those mountain ranges of about 8 h due to a wind speed underestimation in the inner Arabian Peninsula. Both presented wind speed biases are partly caused by the NCEP/FNL initial conditions. When the dust front reached the west and south Arabian Peninsula, both configurations represent the initial dust blocking by the topography, although the HR, in comparison with the LR, more realistically reproduces the steep mountains along the region (e.g. height and valleys). Compared to the satellite, the HR allows for a better representation of orographic clouds, dust blocking and dust channeling trough valleys (Fig. 1), and when compared to weather sites, the HR shows wind speed bias reduction under the dust flows (larger than 5 m/s) and more accurate wind directions.

IV. Conclusion

This work demonstrates how increasing horizontal resolution in dust simulations improves dust forecasts in the vicinity of mountains. This is an important result because most of the current operational dust models work at lower horizontal resolutions than the HR, due to its lower computational cost, and it consequently leads those models to regionally decrease their performance over complex topographies.

ACKNOWLEDGEMENT

The authors of this study acknowledge the contributions of the "Supercomputación and e-ciencia" project (CSD2007-0050) from the Consolider-Ingenio 2010 program, the CICYT project (CGL2013-46736) and Severo Ochoa (SEV-2011-00067) program of the Spanish Government. We would like to thank K. Serradell and F. Benincasa for their technical support, H. Becker for their comments on this work. The model simulations were performed on the MareNostrum supercomputer hosted by BSC.

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Author biography

Lluís Vendrell (LV'85) was born in Barcelona, Spain, in 1985. He received a Bachelor's Degree in Physics (2010) and a Master's Degree in Meteorology (2011) both at the University of Barcelona. He received the Obra Social Fundación la Caixa – Severo Ochoa fellowship (2013) to do a PhD at the ES-BSC. Since then, he has been working in modelling the dust cycle, with a special focus on high-resolution models. His current research interests include dust modelling, high-resolution modelling, and meteorological processes that cause dust emissions. He was awarded as the best poster presentation in the 8th International Workshop on Sand/Duststorms and Associated Dustfall (2016), Lisbon, Portugal.