



HAL
open science

Previsibility of Saharan dust events using the CHIMERE-DUST transport model

L. Menut, I. Chiapello, C. Moulin

► **To cite this version:**

L. Menut, I. Chiapello, C. Moulin. Previsibility of Saharan dust events using the CHIMERE-DUST transport model. IOP Conference Series: Earth and Environmental Science, 2009, à renseigner, Unknown Region. pp.012009, 10.1088/1755-1307/7/1/012009 . hal-04113779

HAL Id: hal-04113779

<https://hal.science/hal-04113779>

Submitted on 2 Jun 2023

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons Attribution 4.0 International License

OPEN ACCESS

Previsibility of Saharan dust events using the CHIMERE-DUST transport model

To cite this article: L Menut *et al* 2009 *IOP Conf. Ser.: Earth Environ. Sci.* **7** 012009

View the [article online](#) for updates and enhancements.

You may also like

- [Video analysis of dust events in full-tungsten ASDEX Upgrade](#)
F. Brochard, A. Shalpegin, S. Bardin et al.
- [Successes of soil conservation in the Canadian Prairies highlighted by a historical decline in blowing dust](#)
Thomas A Fox, Thomas E Barchyn and Chris H Hugenholtz
- [Impact of drought on dust storms: case study over Southwest Iran](#)
Mostafa Javadian, Ali Behrangi and Armin Sorooshian



245th ECS Meeting
San Francisco, CA
May 26–30, 2024

PRiME 2024
Honolulu, Hawaii
October 6–11, 2024

Bringing together industry, researchers, and government across 50 symposia in electrochemistry and solid state science and technology

Learn more about ECS Meetings at
<http://www.electrochem.org/upcoming-meetings>

 **Save the Dates for future ECS Meetings!**

Previsibility of Saharan dust events using the CHIMERE-DUST transport model

L Menut¹, I Chiapello² and C Moulin³

¹Laboratoire de Météorologie Dynamique, Palaiseau, France

²Laboratoire d'Optique Atmosphérique, CNRS/Université des Sciences et Technologies de Lille, Villeneuve d'Ascq cedex, France

³Institut Pierre-Simon Laplace, Laboratoire des Sciences du Climat et de l'Environnement, CEA Orme des Merisiers, Gif sur Yvette, France

E-mail: menut@lmd.polytechnique.fr

Abstract. The previsibility of Northern Africa dust events is quantified using daily numerical forecast simulations for the next three days. The dust concentrations fields, modeled by CHIMERE-DUST, are first evaluate by comparisons to AERONET surface data, OMI and MSG Seviri satellite measurements. The accuracy and spread between measurements and model are discussed focussing on the first short observation period of the AMMA experiment in western Africa, with a simulation period ranging from January to March 2006. Second, the previsibility of dust is estimated by comparing model results for different leads in a forecasts mode. The model skill is evaluate in term of capability to forecast (i) the surface wind speed (the key process for dust emissions), (ii) the dust emissions (depending on the wind speed as well as numerous others uncertain parameters, including threshold values on the friction velocity) and (iii) the transport of aerosols from source to remote areas (depending of horizontal transport, convection etc.). It is shown that emissions forecast can vary up to 80% (close to the sources) and that final forecasted dust concentrations and relative optical thickness do not exceed 40% and 20% in forecast variability.

1. The CHIMERE-DUST model

1.1. Scientific objectives

The main goals of the CHIMERE-DUST model are a better understanding and representation of emissions and long-range transport of thin dust layers. In this way, and due to the specific trends of mineral dust, it is important to validate the model with hourly simulations (to account for the small scales processes) but for long-term simulations (climatological studies). This is also a tool dedicated to quantify the amount of mineral dust transported from Africa to Western Europe for a better aerosol forecast at regional scale in the framework of European air quality analysis and forecast, such as with the PREVAIR french national forecast system [1]. In this way, the forecast is necessary and may also be considered as a good tool for research.

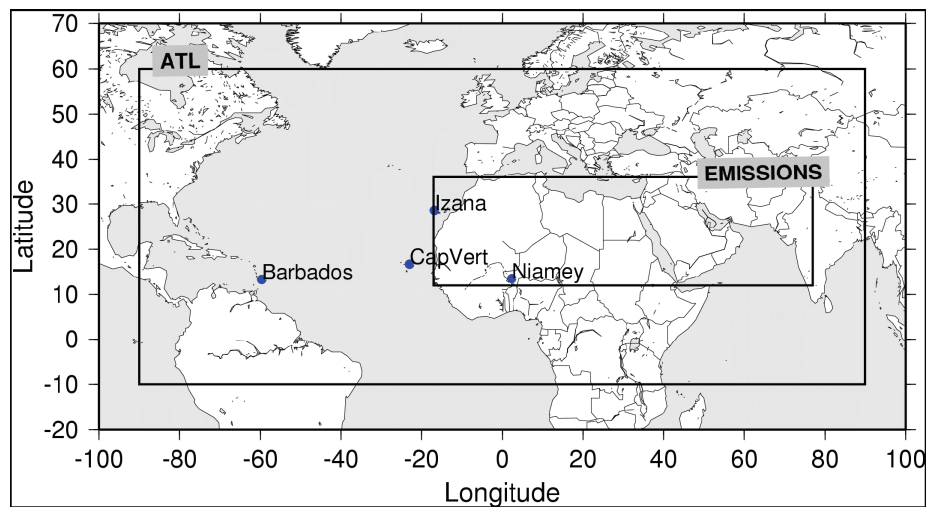


Figure 1. The model domain (ATL), with the emissions area (EMISSIONS). For the two, the horizontal resolution is $1^\circ \times 1^\circ$.

1.2. Model characteristics

The model consists of three elements: (i) the meteorological platform with the MM5 model forced by the NCEP global meteorological fields, (ii) the dust emissions model and (iii) the CHIMERE-DUST transport model. These elements are used together and in the same manner both in analysis or forecast mode. CHIMERE-DUST is a specific version of CHIMERE and exists since 2005. The model was developed using modules from B.Marticorena, G.Bergametti and S.Alfaro (LISA), R.Vautard (LMD), among others.

The horizontal analysis data of NCEP [2] are provided on a regular $1.125^\circ \times 1.125^\circ$. These fields are used as boundary conditions and nudging for the MM5 model [3]. The dust emissions scheme used in the model is the [4] scheme. It computes horizontal fluxes from wind velocities and surface features for the emissions area (the 'EMISSIONS' area in the figure 1).

The dust vertical fluxes are computed by using the [5] parameterization, numerically optimized following [6]. The vertical fluxes are calculated corresponding to three dust size modes, then redistributed into the model size bins using a mass partition scheme. The wet deposition scheme is that described in [7]. The dry deposition velocity is parameterized following [8]. The transport model CHIMERE-DUST was developed on the basis of the chemistry-transport model CHIMERE [9,10]. The horizontal domain has an horizontal resolution of $1^\circ \times 1^\circ$ and is displayed as the "ATL" frame in figure 1. Vertically, 15 levels are defined from the surface to 200hPa. Turbulent parameters as u^* , the friction velocity and h the boundary layer depth are estimated from the mean meteorological parameters. The horizontal transport is performed using the Van Leer scheme [11] and the vertical mixing is estimated from the calculation of the bulk Richardson number as extensively described in [12]. The dust simulations are performed with a time-step of 7'30". A sectional aerosol size distribution was chosen with 12 bins after [13] and [14].

2. Model "validation"

In order to validate the accuracy of the modelled dust concentrations, numerous periods were modelled and output concentrations were compared to available data such as AERONET network and SEVIRI/METEOSAT and MODIS satellite data. An example of comparisons between model and measurements is displayed in the figure 2 for the case of the 6 March 2004. The maps show comparisons of modelled dust load (g/m^2) for the dust plumes patterns validation. An example of

AERONET site comparison with the model for the validation of the hourly variability of surface dust concentrations is presented in terms of Aerosol Optical Thickness (AOT) for the Capo verde site.

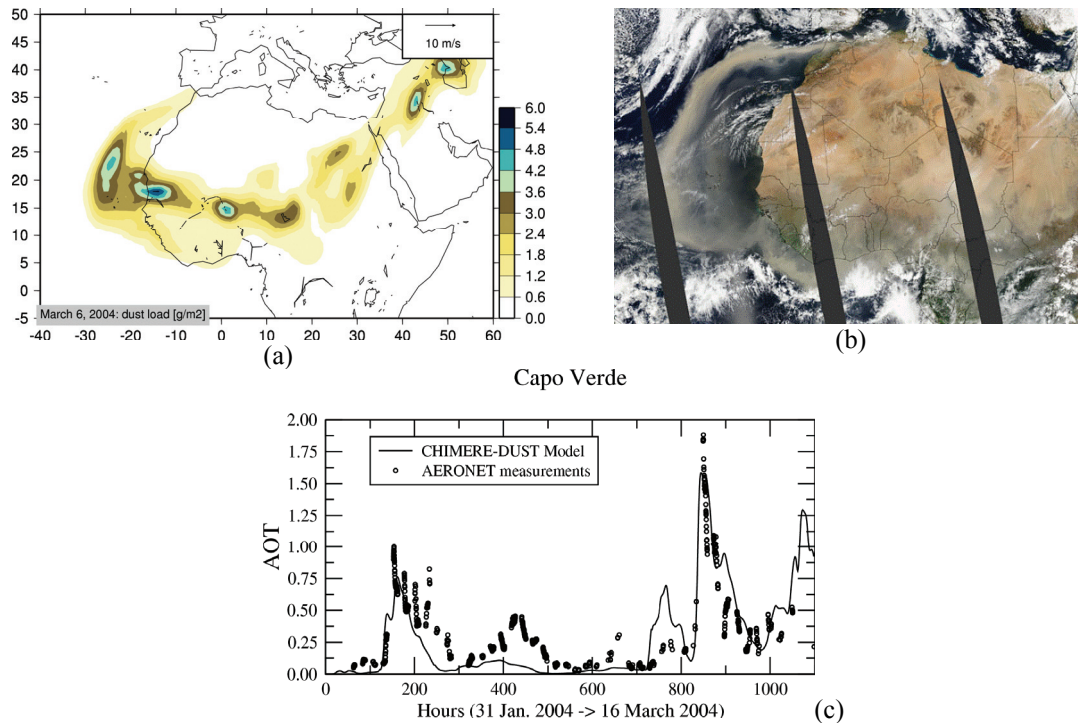


Figure 2. Dust load for the 6 March 2004 (a) CHIMERE-DUST model and (b) SEAWIFS; and (c) comparison of CHIMERE-DUST versus AERONET at Capo Verde site

3. The CHIMERE-DUST forecast

The forecast is done every day at the Laboratoire de Météorologie Dynamique in an experimental context since September 2005 and all output results are downloadable in free access via ftp. The model used for forecast is strictly the same than the version used for analysis or sensitivity studies [6,14]. The only difference is the meteorological forcing. In place of reanalysis fields, the NCEP forecast fields are downloaded every midnight and mesoscale MM5 runs are performed during the following night. After the meteorological runs, the CHIMERE-DUST used these fields to estimate dust emissions and transport. Forecasts fields are provided on a web site every morning for the next three days. The simulation is initialized the day before using the analysis meteorology and dust boundary conditions issued from the CHIMERE-DUST forecast done 24h before.

The home page of the experimental CHIMERE-DUST forecast is presented in the figure 3 (left). In parallel, output results are formatted to be directly compared to other available products on the web and for specific needs (such as during the AMMA experiment). Systematic comparisons are done with AERONET aerosol optical thicknesses (see for example figure 3 (right)) and with NAAPS model maps.

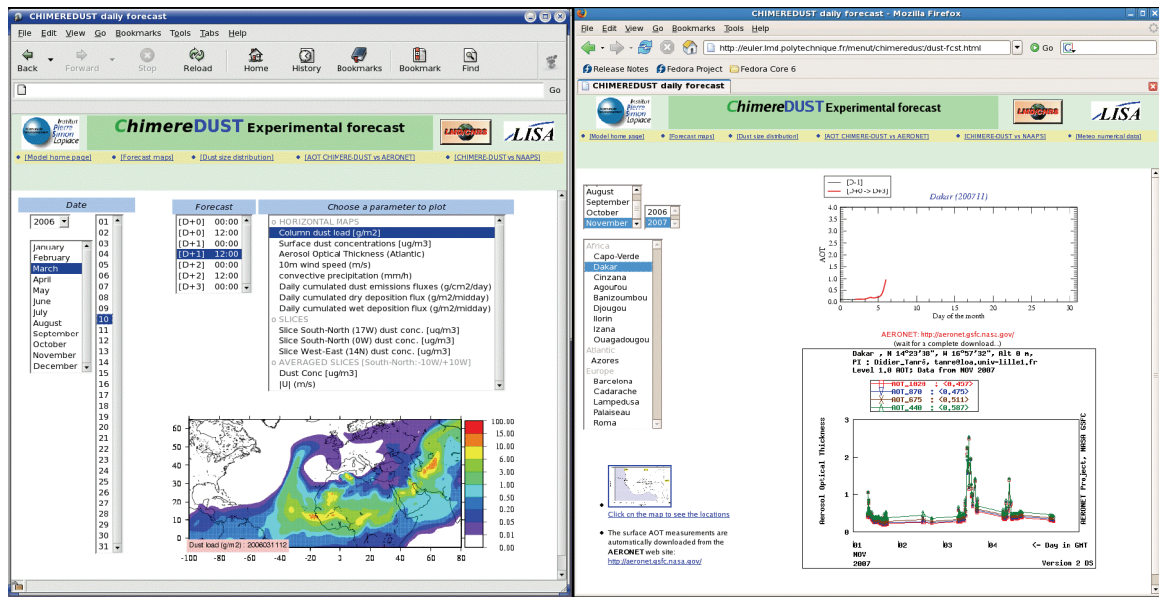


Figure 3. <http://euler.lmd.polytechnique.fr/menut/chimeredust/dust-fcst.html>. Daily comparison to AERONET level 1 AOT data (+ NAAPS model)

4. A specific test-case : The AMMA experiment

To illustrate the variability of the dust forecast, we present meteorological and dust concentrations fields estimated day after day and for different periods. The time period of interest correspond to the first three months of 2006 i.e the period of the First Short Observation Period of the African Monsoon Multidisciplinary Analyses (AMMA) experiment (SOP0). The modelled results (MM5) are presented for the wind speed in the Figure 4 for two specific sites (Djougou and Dakar) and for the period from the 1st to the 10th March 2006. Each hour, one can see one value for [D-1], [D+0], [D+1] and [D+2], where [D-1] is the "analysis" and the others days are forecast.

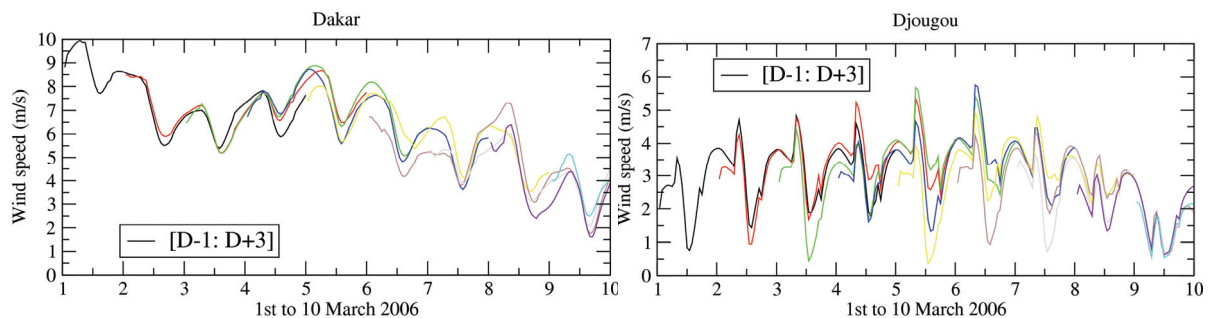


Figure 4. Time series of forecasted wind speed (m/s) for Djougou and Dakar, from the 1st to the 10th March 2006. For each hour, the several leads are superimposed.

As presented in the figure 4, the day to day wind speed variability may be important as ± 2 m/s. For low values, typically less than 7 m/s when dust are never emitted, this variability is not an important factor of uncertainty for dust forecast: in this case, the error is only linked to a change in the plume transportation and potentially its direction. Around the saltation friction velocity threshold (the fraction velocity used to estimate dust emission or not), this variability may be very important: as a function of the forecast wind speed value, the dust emission model may diagnose dust fluxes or not at all. Thus, a real uncertainty exists around this threshold and the next point to study is to evaluate if this has an impact on dust emission over the whole domain.

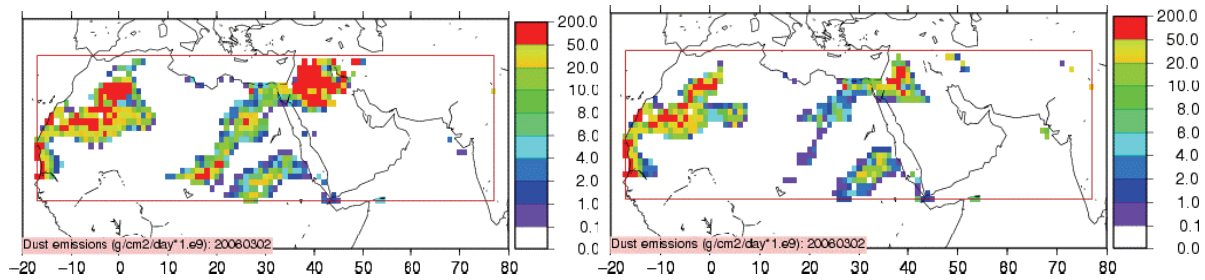


Figure 5. Surface dust emissions fluxes maps. The red frame represents the whole emissions domain. Dust fluxes are summed up over the day and presented in $\text{g}/\text{cm}^2/\text{day}$.

Figure 5 presents dust emissions fluxes calculated for the same time (1st march 2006, 12:00 UTC) but with two different meteorological forcings: the analysis (i.e the more accurate fields) and the forecast for two days later (i.e computed on 3 March 2006). The impact of a small error on wind speed clearly may induce a large error on emitted dust: at the center of the domain, important fluxes are diagnosed two days in advance. Using the analyzed wind field, these fluxes are removed. This is a case where non existing dust plume may be forecast.

Using these dust emissions fluxes, the CHIMERE-DUST model runs in forecast mode and estimates the transport and deposition of dust concentrations. Vertically integrating the whole atmospheric column of dust concentrations, the dust load may be estimated as well as the aerosol optical thickness. These two quantities are directly compared to the OMI aerosol index and the SEVIRI AOT, as presented in the figure 6. With OMI, there is no direct estimation of AOT but the signal may be use over ocean and over land. Comparing the plumes horizontal structures between OMI and CHIMERE-DUST, we can see a very good representation of the dust plume by the model. On the other hand, SEVIRI is able to estimate an accurate AOT but only over the ocean. The comparison with the model also shows that the magnitude of the modelled AOT is of the same order of magnitude than the satellite retrieval. With these two types of information, we can conclude than the model is able to reproduce both intensities and patterns of dust plumes.

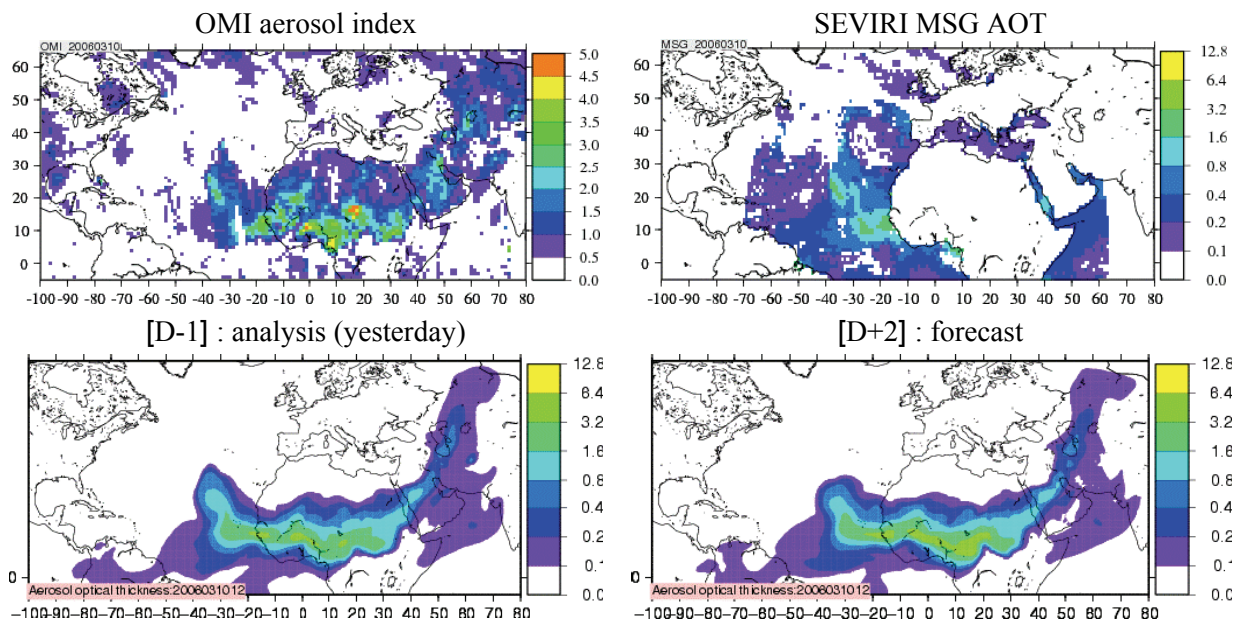


Figure 6. Comparison of satellite data with OMI for aerosol index over land and ocean (figure prepared by Isabelle CHIAPELLO) and SEVIRI for aerosol optical thickness (figure prepared by Cyril MOULIN) and modelled aerosols optical thickness for the 10 March 2006, 12:00 UTC.

To go further in the comparison, we can directly analyze dust surface concentrations. This quantity is of great interest in the framework of air quality studies and an accurate forecast would be of great importance for the global particulate matter forecast over urbanized areas for example. In the figure 7, we compare the modelled surface concentrations for several sites and several leads. The comparison to data is not presented here because data are a global budget of many particulate matter origins (dust, biomass burning, resuspension of locally produced matter etc.) and thus the comparison modelled dust to observed particulate matter has no sense.

The results are presented in the figure 7 for the 10 March 2006 and for the sites of Banizoumbou and Djougou in Africa (near the sources), Roma and Barcelona (in Italy and Spain, respectively and acting as remote sites). The [D-1] time series may be considered as the 'reference' case since this is the simulation with the 'best' (i.e analyzed) meteorology. Near the sources, in Banizoumbou and Djougou, the modelled concentrations are huge (several hundred $\mu\text{g}/\text{m}^3$). The temporal variability is the same between every leads but the magnitude of the concentrations varies a lot. It is not possible to estimate a systematic bias or a systematic tendency correlated to the lead: depending on site and period, the modelled concentrations may be under- or over-estimated compared to the reference. But a more general result may be expressed: a variability up to 50% is observed between the [D-1] and the [D+1] simulations. Over Europe, the concentrations are really lower and in accordance with usually recorded values in these regions. The variability is in general of the same order of magnitude than over the near sources sites and may reach $\pm 50\%$. This variability is important to quantify for the uncertainty estimation of air quality forecast in Europe.

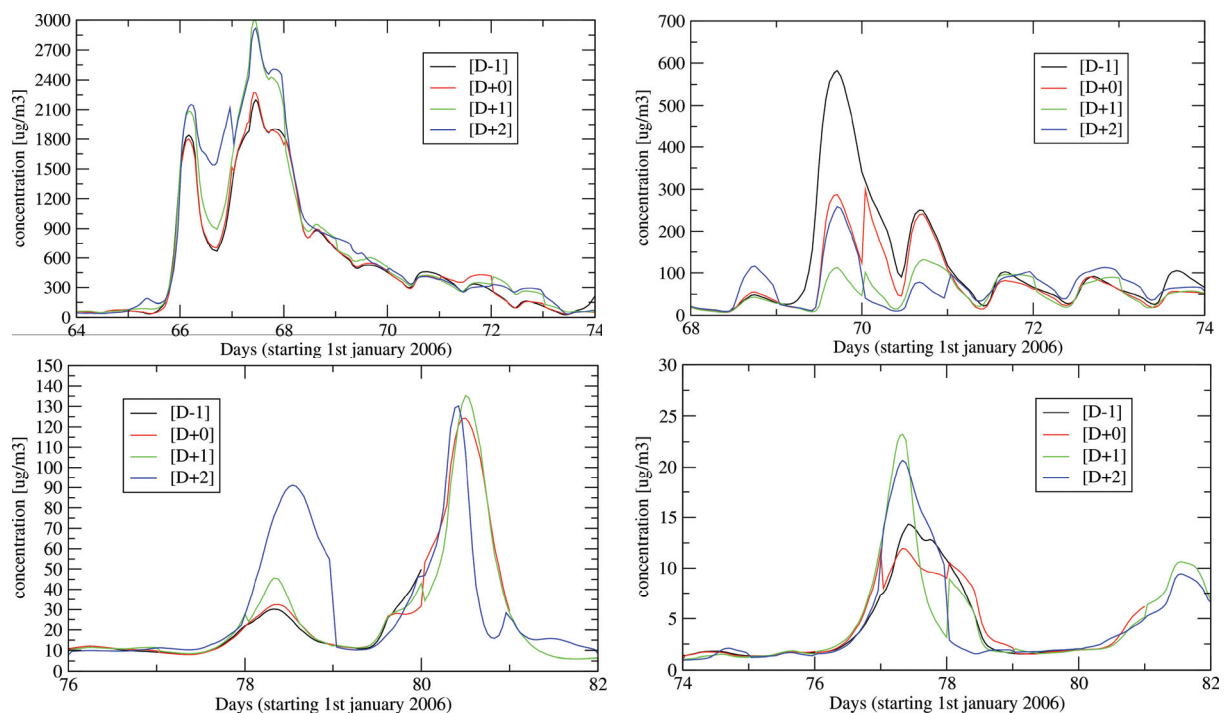


Figure 7. Dust concentrations time series for several sites in Africa (Banizoumbou and Djougou) and western Europe (Roma and Barcelona). For each time, all forecast leads are reported.

5. Conclusion

Every day, the CHIMERE-DUST model forecasts four days of mineral dust emissions and transport since 2005. The results are displayed every day on a dedicated web plat-form, including maps, time series, comparisons to observations and to other models. The output data are also provided on the web site for researchers interested to work with.

In this paper, the variability of the dust forecast was extensively studied by comparing model and measurements during the first three months of 2006 and not only for the most important dust events: they correspond to the most easy periods to model with a dust model since the potential error on wind speed becomes negligible compared to the threshold friction velocity. The model was used for all days of the periods including non dusty days: with winds close to the estimated threshold, these days are the more difficult to model and the model has to be enough accurate to avoid false dust emissions and thus false forecasts of dust plume transport. The model was systematically compared to available observations (AERONET stations, satellites) and some comparisons were presented. For each studied period, the variability of the forecast was shown and the comparisons shows good results for the large scale patterns. The AOT are close and the dust plumes leaving the western Africa and transport towards Europe are well forecast in size and intensity. Thus we can conclude that the forecast is relatively stable at the continental scale. Far from the sources and in Europe, the forecast shows its sensitivity to all model errors made from the emissions to the transport. Between the analyzed day and the forecast for two days later, the dust concentrations differences ranged from 0 to 50%. This shows that, for an operational use for air quality forecast over Europe, a non negligible uncertainty remain in the modelling of Saharan dust emission and transport.

References

- [1] Honoré, C. et al., 2008 Predictability of european air quality: The assessment of three years of operational forecasts and analyses by the prev'air system, *J. Geophys. Atmos.*, in press.
- [2] Kalnay, E., et al. 1996 The ncep/ncar 40-year reanalysis project, *Bull. Amer. Meteorol. Soc.*, pp. 437-471.
- [3] Dudhia, J. 1993 A nonhydrostatic version of the penn state/ncar mesoscale model : validation tests and simulation of an atlantic cyclone and cold front., *Mon. Wea. Rev.*, 121, 1493-1513.
- [4] Marticorena, B., and G. Bergametti 1995 Modeling the atmospheric dust cycle: 1 Design of a soil derived dust production scheme, *J. Geophys. Res.*, 100, 16,415-16,430.
- [5] Alfaro, S. C., and L. Gomes 2001 Modeling mineral aerosol production by wind erosion: Emission intensities and aerosol size distribution in source areas, *J. Geophys. Res.*, 106, 18,075-18,084.
- [6] Menut, L., C. Schmechtig, and B. Marticorena 2005 Sensitivity of the sandblasting fluxes calculations to the soil size distribution accuracy, *J. Atmos. Ocean. Tech.*, 22, No. 12, 1875-1884.
- [7] Loosmore, G., and R. Cederwall 2004 Precipitation scavenging of atmospheric aerosols for emergency response applications: testing an updated model with new real-time data, *Atmos. Env.*, 38, 993-1003.
- [8] Venkatram, A., and J. Pleim 1999 The electrical analogy does not apply to modeling dry deposition of particles, *Atmos. Env.*, 33, 3075-3076.
- [9] Vautard, R., M. Beekmann, J. Roux, and D. Gombert 2001 Validation of a hybrid forecasting system for the ozone concentrations over the Paris area, *Atm. Env.*, 35, 2449-2461.
- [10] Bessagnet, B., A. Hodzic, R. Vautard, M. Beekmann, S. Cheinet, C. Honoré, C. Liousse, and L. Rouil 2004 Aerosol modeling with chimere : preliminary evaluation at the continental scale, *Atm. Env.*, 38, 2803-2817.
- [11] Van Leer, B. 1979 Towards the ultimate conservative difference scheme. V A second order sequel to Godunov's method, *J. Computational Phys.*, 32,101-136.
- [12] Menut, L. 2003 Adjoint modelling for atmospheric pollution processes sensitivity at regional scale during the ESQUIF IOP2, *J. Geophys. Res.*, 108 (D17), 8562, doi :10.1029/2002JD002549.
- [13] Forêt, G., G. Bergametti, F. Dulac, and L. Menut 2006 An optimized particle size bin scheme for modeling mineral dust aerosols, *J. Geophys. Res.*, 111, D17310, doi:10.1029/2005JD006797.

- [14] Menut, L., G. Forêt, and G. Bergametti 2007 Sensitivity of mineral dust concentrations to the model size distribution accuracy, *J. Geophys. Res.*, 112, D10210, doi:10.1029/2006JD007766.