# Desert dust modeling in AROME : Contribution of physical parametrization at convective scale.

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**ABSTRACT**

***This study is dedicated to the modeling of desert dust in the convective scale model AROME (Application of Research to Operations at MEsoéchelle) coupled with the ALADIN model (Aire Limitée Adaptation dynamique Development InterNational) operational at Algerian meteorological office. For this purpose, we carried out simulations with AROME_Dust model (resolution of 3km and 60 level) in order to investigate the contribution of the physical parameterizations of this model to the quality of desert dust cycle prediction. The selected dust event corresponds to the one which occurred on 1st April 2017. It was marked by a sandstorm of an exceptional intensity which affected several localities in the Southern Algeria, sweeping in particular the departements of Ouargla, Ghardaïa and Tamanrasset. North-South traffic and vice versa were paralyzed due to sand deposition over the roadway at several locations.***

## 1. Desert dust prediction in Algeria

The interest of modeling the cycle of desert aerosols in Algeria is important because the Sahara covers more than 75% of the country's surface area. This interest is reinforced by the fact that desert dust has a direct impact on the economy, the environment and public health.

Since February 2014, the prediction of atmospheric cycle of desert dust at the ONM (Office National de Météorologie-ALGERIA) is based on the operational model ALADIN_Dust with 14 km of horizontal resolution (Mokhtari et al., 2012). An AROME_Dust configuration based on cycle 40 was updated (M.Mokhtari and A.Ambar, 2016) in order to investigate the contribution of physical scheme implanted in the convective-scale model AROME. We carried out meteorological simulations of a particular event (sandstorm in southern Algeria, 1st April 2016). AROME_Dust outputs are compared with those of ALADIN_Dust (operational) and with observations.

## 2. AROME model and dust Modules

The AROME convective scale model (Seity et al., 2011) is operational at the National Center of Meteorological Forecasts (Algeria) since April 2014, covering the northern part of the country (Latitude: 28°N-40°N, Longitude: 3°W-9°E). An AROME covering all the country was configured basing on cycle 40 in order to simulate dust aerosol cycle (Tab 1).

Physical parameterizations of the model are inherited from the Meso-NH search model whereas the dynamic part is an adaptation for the fine scale of the ALADIN dynamic. Desert dusts emission processes are managed by the DEAD model which is integrated into coupled system AROME-SURFEX (Grini et al., 2006). The transport, deposition and leaching processes are managed by the ORILAM log-normal aerosol scheme (ORganic Inorganic Log-normal Aerosol Model, Tulet et al., 2005).

Initially, desert dust modules was activated in the ALADIN configuration (cycle 36 and 38) (Mokhtari et al., 2012, Mokhtari et al., 2015) and AROME (cycle 33) (Kocha, 2011) in order to provide predictions of dust events during the FENNEC measurement campaign (Chaboureau et al., 2016). For more technical details about the activation of dust modules in AROME, see the following link: http://www.umrcnrm.fr/aladin/IMG/pdf/stay_report_mokhtari_ambar_2016.pdf.

***Tab. 1:*** *Characteristics and computational costs of AROME-Algeria*

| | | |
|---|---|---|
| Model | | AROME |
| Cycle | | 40 |
| Resolution | | 3 km |
| Levels | | 60 |
| Grid | | 1024 x 972 |
| Area | Latitude | 18°N – 42°N |
| | Longitude | 10°W– 13°E |
| Initial conditions | | ALADIN (8km) |
| Starting time | | 00h |
| Cycle interval | | 01h |
| Verification times | | 09h, 12h, 15h, 18h |
| Number of processors (NPROC) | | 16 x 16 |
| Computational costs (IBM-ONM) | Dust on | 7260 sec |
| | Dust off | 4740 sec |

The activation of dust modules in AROME costs about 40% increase in CPU.

## 3. Results and discussion

| *April, 1st , 2016* | 9h | 12h | 15h | 18h |
|---|---|---|---|---|

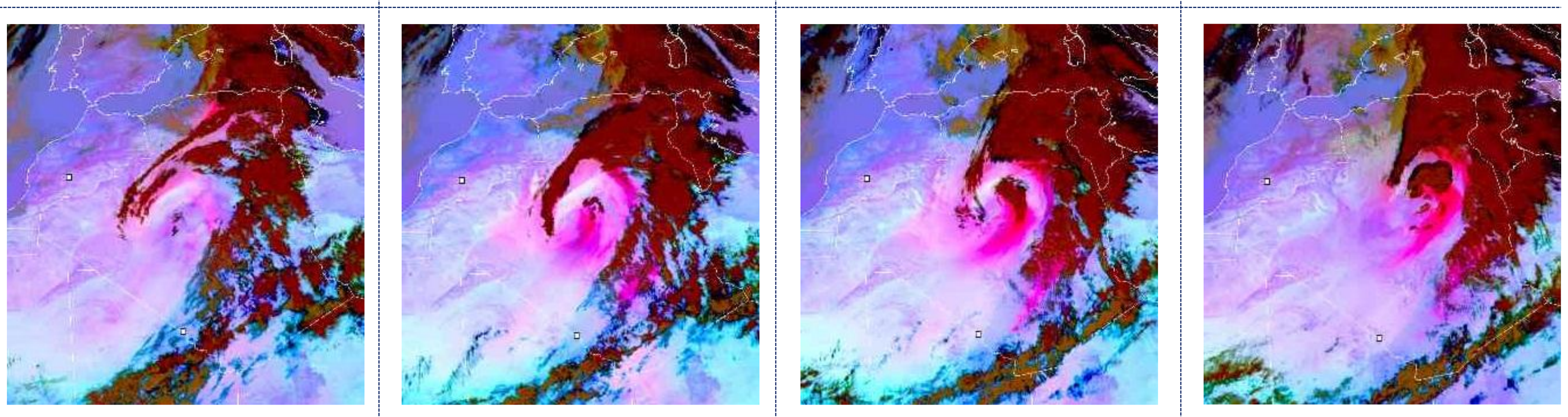

*Fig 1: MSG-SEVIRI satellite image over Algeria.*

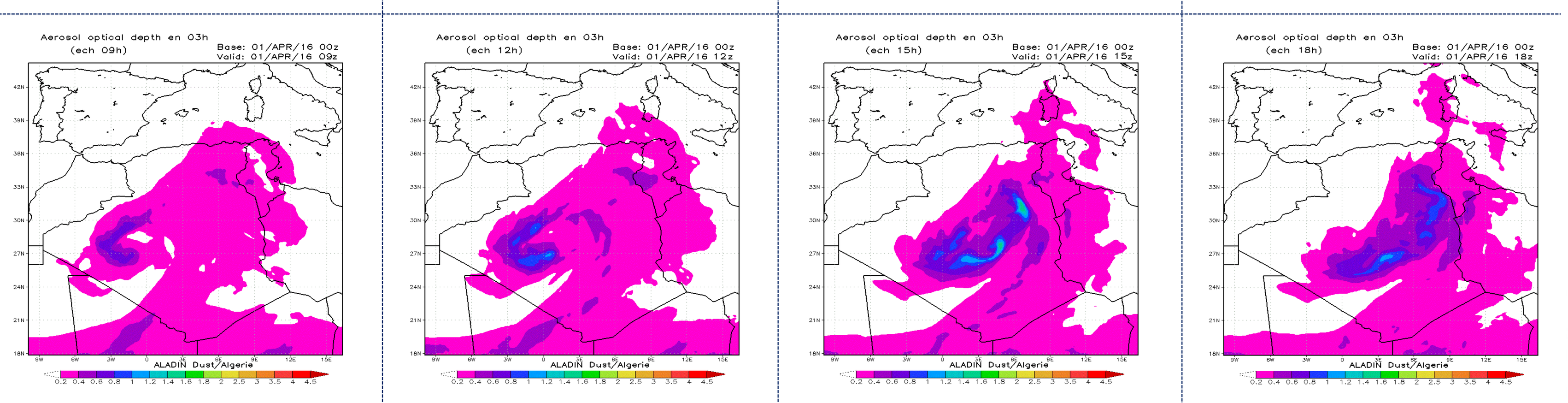

*Fig 2: Aerosols optical depths (AOD) simulated by ALADIN_Dust.*

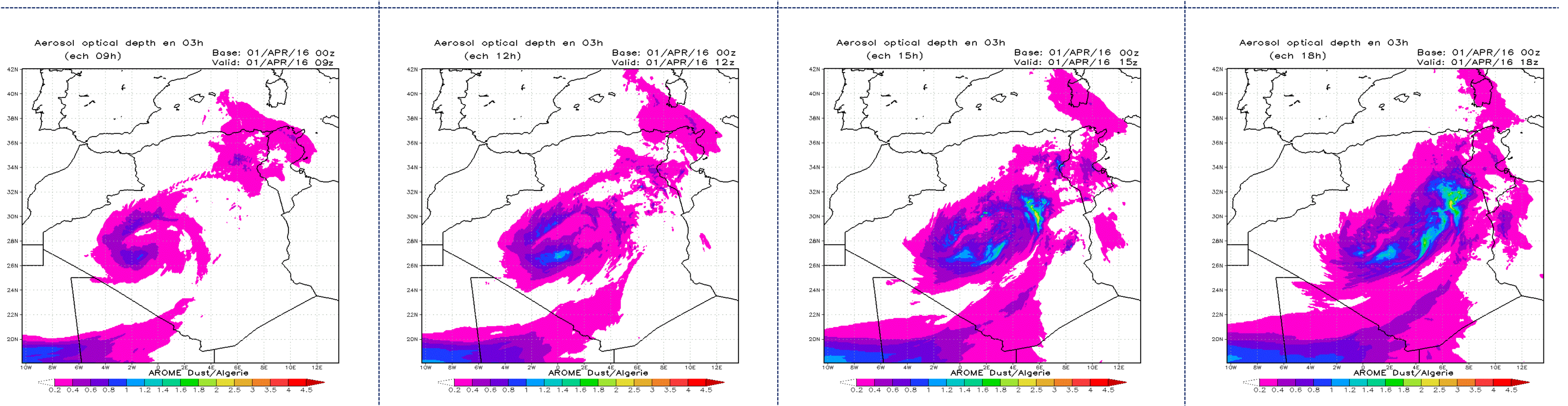

*Fig 3: Aerosols optical depths (AOD) simulated by AROME_Dust.*

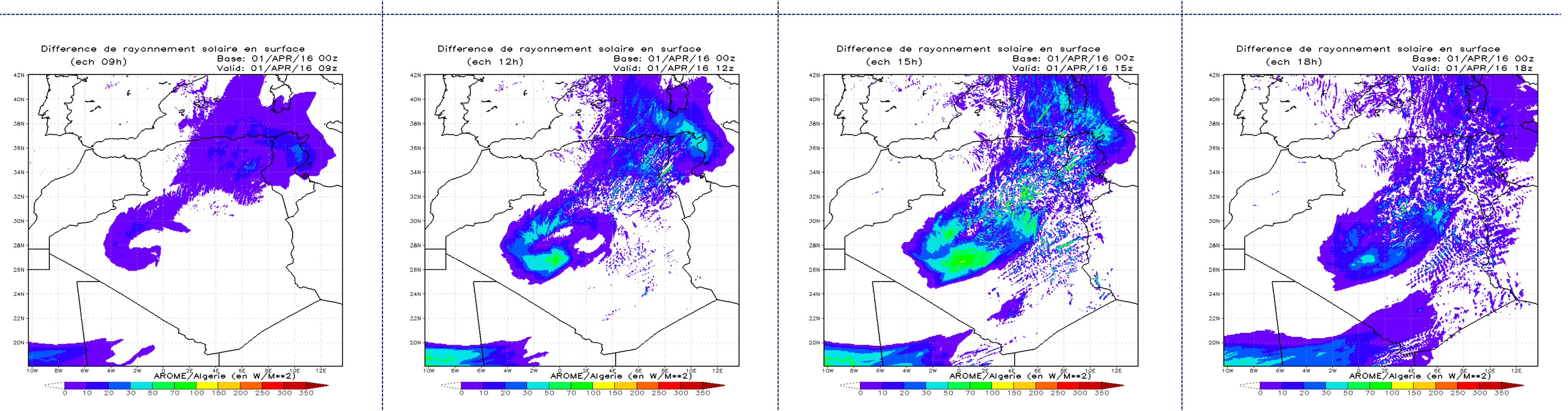

*Fig 4: Net solar radiation differences between AROME (dust off) and AROME-Dust.*

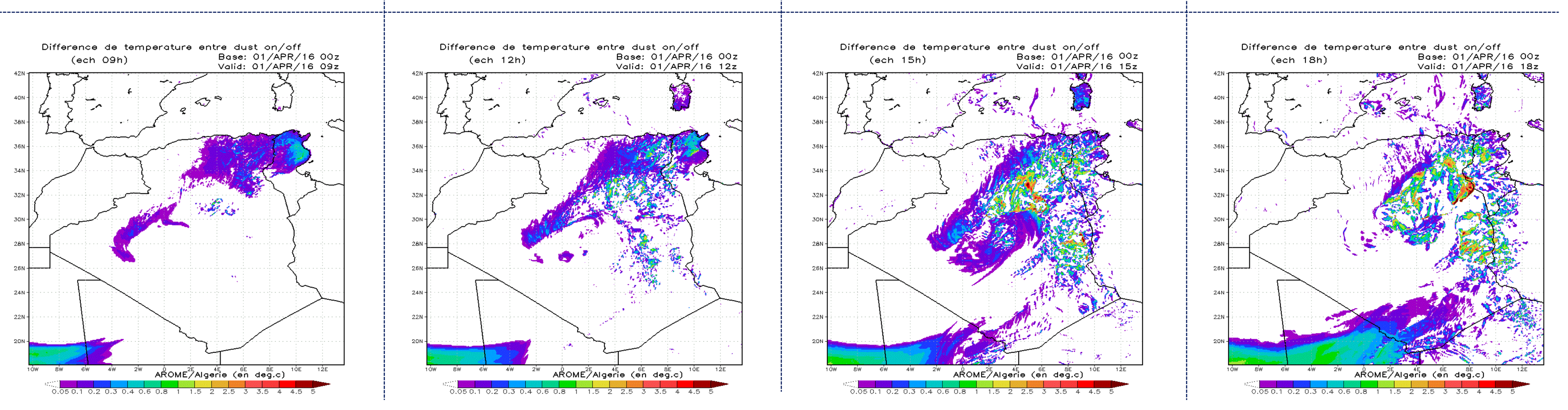

*Fig 5: Temperature (at 2meters) differences between AROME (dust off) and AROME-Dust.*

Since we don't have measurements of dust concentrations, we applied an empirical equation (1) relating desert dust concentrations and horizontal visibility (Bertrand, 1976). We can then use observations of the visibility available on various meteorological stations in Algerian Sahara and compare it to the model outputs.

$$VV = \left(\frac{1897}{C}\right)^{1/0.91} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ (1)$$

- ➢ VV : visibility in meters.
- ➢ C : Concentration in mg*m-3.

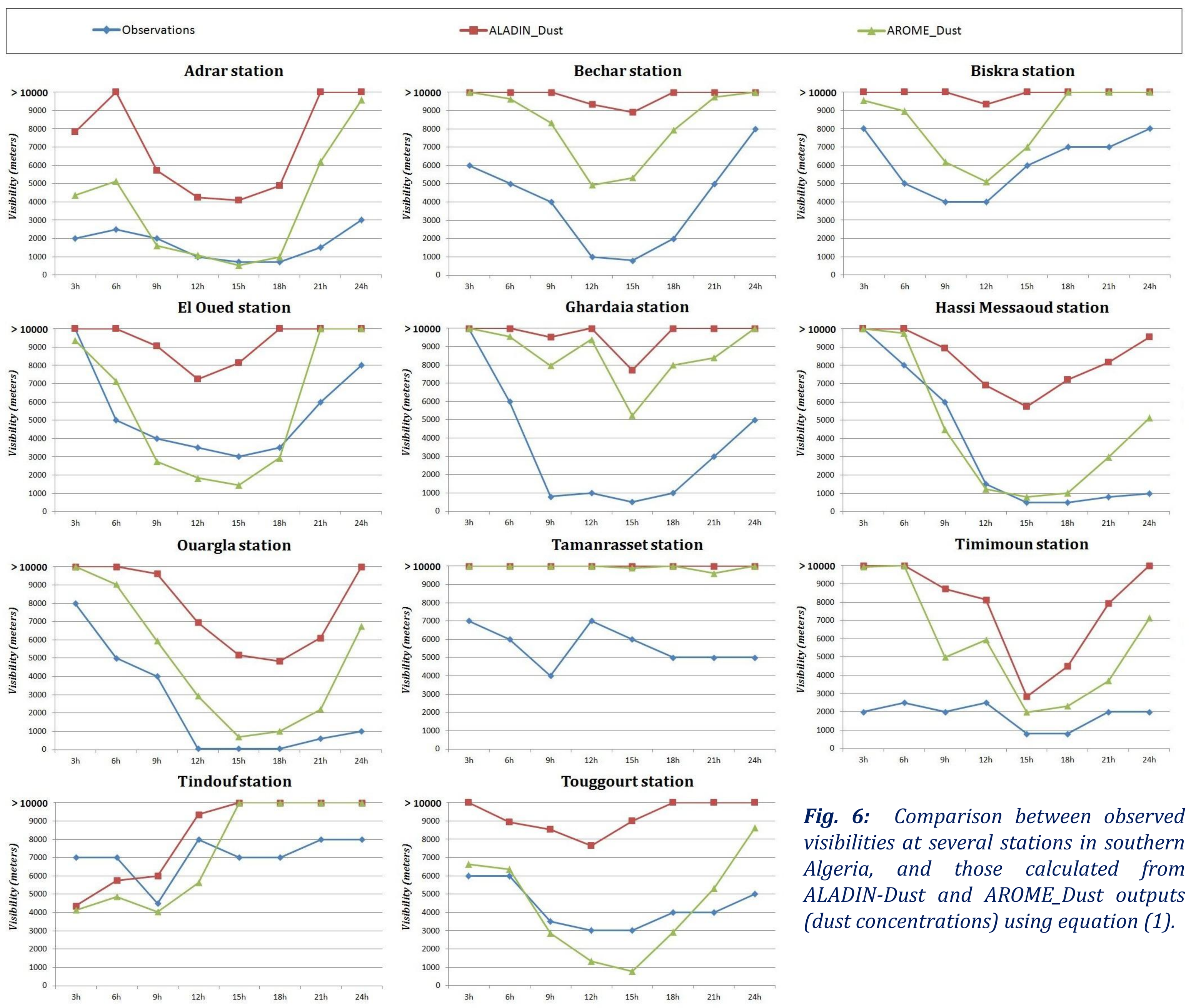


*Fig. 6: Comparison between observed visibilities at several stations in southern Algeria, and those calculated from ALADIN-Dust and AROME_Dust outputs (dust concentrations) using equation (1).*

▪Dust plume is well predicted by AROME_Dust (Fig 3) comparing to MSG-SEVIRI satellite images and to the operational model ALADIN_Dust, with a better consideration of extreme values.
▪The net solar radiation at surface (Fig 4) decreases significantly during sand-uprising episodes.
▪Temperature differences fields (at 2 meters) reveals that the presence of desert dust particles could reduce the temperature up to 5°c (Fig 5) during high sand-uprising events.
▪the calculated visibility based on AROME concentration outputs is nearest to the observation comparing to that calculated based on ALADIN concentration outputs, but it remains overestimated. Generally speaking, the visibility prediction is well because it had the same fluctuation as the observation, with an exception for Tamanrasset station. Indeed, the Tamanrasset region is a very rocky area, while in reality it contains important dust deposit areas surrounding mountains including the Hoggar and Tassili, which can be subsequently reactivated by the wind.

## 4. Conclusion

➢The physical scheme implanted in AROME showed an important contribution by improving the desert dust forecasting in term of vertical distribution (AOD) and horizontal visibility.
➢The convective scale of AROME_DUST (3km) compared to ALADIN_DUST (14km) allowed to better grasp the spatial extent of desert plumes and extreme values.
➢The presence of desert aerosols leads to a significant reduction in the Surface temperature (up to 5 ° c ), and a radiative forcing which can reach 150w / m2.

## Acknowledgments

*The visibility data comes from the observation network of ONM (Office National de la Météorologie – Algeria). MSG-SEVIRI satellite images are downloaded from the EUMETSAT web site. The authors wish to thank Yves BOUTELOUP and Claude FISCHER at Meteo-France for their help and advices.*

## References

**Bertrand, J.:** Visibilité et brume sèche en Afrique. La météorologie, VI, 6, 201-2011, 1976.
**Chaboureau, J.-P. et al.:** Fennec dust forecast intercomparison over the Sahara in June 2011, Atmos. Chem. Phys., 16, 6977-6995, doi:10.5194/acp-16-6977-2016, 2016.
**Grini, A., Tulet, P., and Gomes, L.:** Dusty weather forecasts using the MesoNH mesoscale atmospheric model, J. Geophys. Res., VOL. 111, D19205, doi:10.1029/2005JD007007, 2006.
**Kocha, C :** Interactions entre poussières désertiques et convection profonde en Afrique de l'Ouest: observation et modélisation à échelle convective, Thèse de Doctorat de l'Université de Toulouse 3. 2011.
**Mokhtari, M. et Ambar, A.:** Updating and validation of Arome_dust. Stay report, CNRM. 2016.
**Mokhtari et al.:** Importance of the surface size distribution of erodible material: an improvement on the Dust Entrainment And Deposition (DEAD) Model, Geosci. Model Dev., 5, 581–598, 2012, doi:10.5194/gmd-5-581-2012.
**Mokhtari et al.:** Three-dimensional dust aerosol distribution and extinction climatology over northern Africa simulated with the ALADIN numerical prediction model from 2006 to 2010, Atmos. Chem. Phys., 15, 1–20, 2015, doi:10.5194/acp-15-1-2015.
**Sity, Y. et al.:** The AROME-France Convective-Scale Operational Model. AMS. 2011.
**Tulet, P. et al.:** Mixing of dust aerosols into a mesosclae convective system: Generation, filtring and possible feedbacks on ice anvils. Atmos. Res. 2010.