Climate-aerosol interactions over the Mediterranean region : focus on the ammonium-nitrate aerosols

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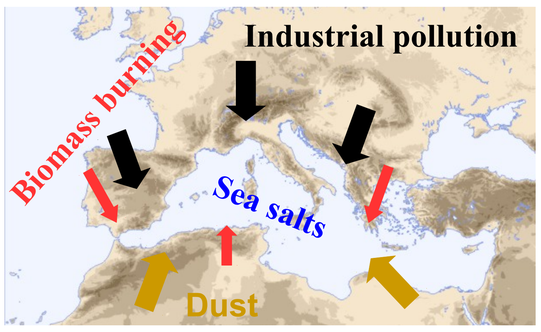
1 | Why study aerosols over the Mediterranean region ?



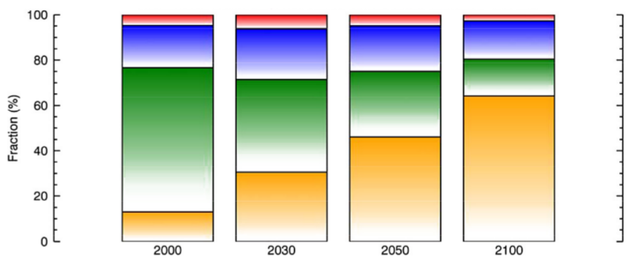
– > Crossroads of air masses bringing aerosols from different sources (Lelieveld et al., 2002)

– > High spatio-temporal variability

– > Important impact on radiative budget and climate

– > Very sensitive region to climate change (Giorgi, 2006)

Evolution of the contribution (%) of nitrates (yellow), sulfates (green), organic carbon (blue), and black carbon (red) to the total aerosol anthropogenic optical depth at 550 nm for the RCP 2.6 scenarios (Hauglustaine et al., 2014)



Currently, sulfates have the largest contribution of 64 %. Organic carbon and BC contribute 19 % and 5 % to the anthropogenic optical depth. Nitrates have a contribution of 13 %.

In all scenarios, there is an increasing contribution of nitrates to the anthropogenic aerosol optical depth, and in 2100, nitrates become the dominant contributors.

2 | Methodology

The ALADIN-Climat Model

ALADIN-Climate configuration:

- Atmospheric model
- Horizontal resolution : 50 km
- Number of vertical level : 91
- CMIP5 anthropogenic emissions
- LBC : ERA-Interim
- No « chemical » LBC
- Period of simulation : 1979-2014

Aerosols are represented with a prognostic aerosol scheme: TACTIC (**T**ropospheric **A**erosols fot **C**lima**T**e **I**n **C**NRM-CM)

The TACTIC aerosol scheme

Adapted from the GEMS/MACC scheme (Morcrette, 2009), 16 variables:

- 3 bins for dust aerosols (0.01-1.0 / 1.0-2.5 / 2.5-20.0 µm)
- 3 bins for sea-salt aerosols (0.03-0.5 / 0.5-5.0 / 5.0-20.0 µm)
- 2 bins for black carbon (BC) aerosols (hydrophilic / hydrophobic)
- 2 bins for organic carbon (OC) aerosols (hydrophilic / hydrophobic)
- 1 bin for sulphate aerosols and 1 bin for sulphate precursors

<u>And implementation of nitrate-ammonium module:</u>

- 2 bins for nitrate aerosols, 1 bin for ammonium aerosols and 1 variable for NH_3
- Ammonium-nitrate aerosols are considered as purely scattering species in the shortwave

Ammonium and nitrate formation:

- by reaction: $HNO_3 + NH_3 \longleftrightarrow NH_4NO_3$
- by absorption: $HNO_3 + NaCl \rightarrow NaNO_3 + HCl$

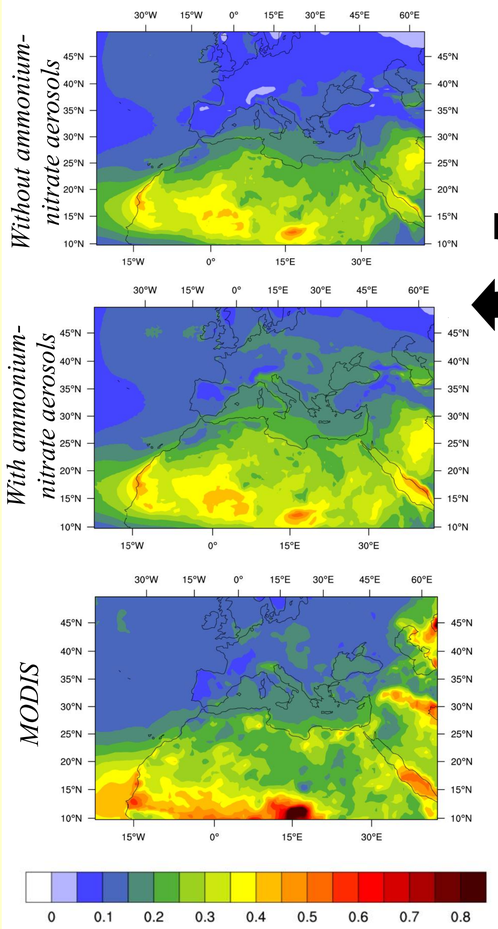
$2HNO_3 + CaCO_3 \rightarrow Ca(NO_3)_2 + H_2CO_3$

HNO_3: Climatology

NH_3: CMIP6 Emissions

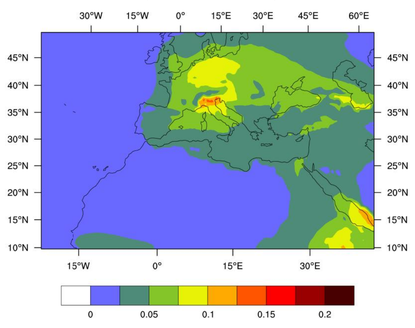
Two ALADIN-Climat simulations have been realised over the 1979-2014 period: NIT (with nitrates and ammonium) / REF (without nitrates and ammonium).

3 | Model evaluation (AOD and surface concentrations)

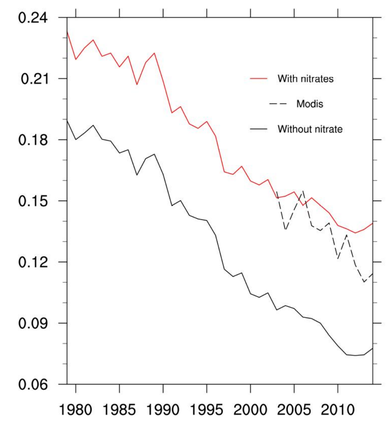


Comparison of the AOD simulated at 550 nm (with and without ammonium-nitrate aerosols) and the AOD measured by MODIS at 550 nm (2003-2014)

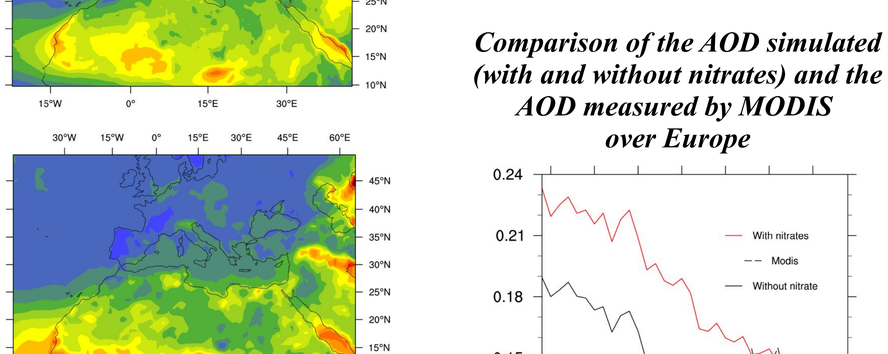
AOD of nitrates and ammonium (2003-2014)



Comparison of the AOD simulated (with and without nitrates) and the AOD measured by MODIS over Europe



Comparison of the surface concentration of nitrates and ammonium to the EMEP stations (1994-2014)



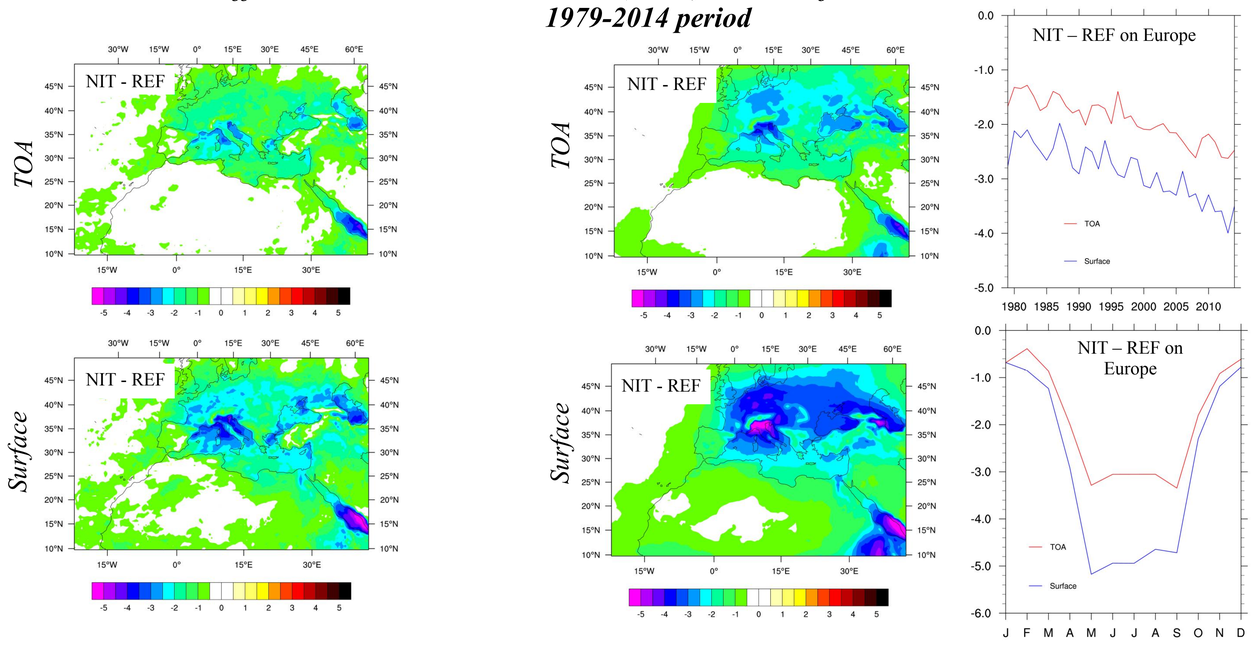
Nitrates *Ammonium*

– > Improvement of the AOD simulated thanks to nitrates especially over northern europe and on the Red Sea.

– > Comparisons with EMEP stations (with a minimum of five years of data per station) indicate that the nitrate and ammonium concentrations simulated at the surface by the ALADIN-Climat model are consistent with observations. On the other hand, there is potentially a bias on ocean surfaces caused by climatology of HNO_3.

4 | Impact of secondary ammonium-nitrate aerosols on the regional radiative budget and surface temperature

Difference in the net SW radiation (W/m²) at the surface and TOA over the 1979-2014 period



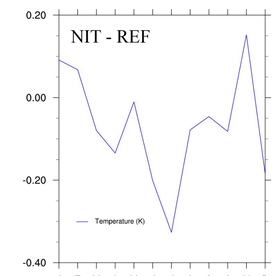
All sky conditions

Clear sky conditions

– > Mean SW radiation decreases (around -2 W/m² over the Europe) due to the extinction of incident radiation by nitrates. The maximums of the SW radiation decline are located, at the surface, over Western Europe (France and Po Valley in Italy) during summer.

		DRF (Wm^{-2}) (Simulation without ammonium-nitrates)	DRF (Wm^{-2}) (Simulation with ammonium-nitrates)	C-AER (Wm^{-2}) (Nabat et al., 2015)
Europe	Annual	- 1.3	- 2.8	- 6.5
	DJF	- 0.4	- 0.7	- 3.0
	MAM	- 1.0	- 2.5	- 8.2
	JJA	- 2.3	- 5.1	- 9.3
	SON	- 1.4	- 2.9	- 5.6
Mediterranean Sea	Annual	- 4.2	- 6.1	- 10.5
	DJF	- 2.3	- 2.9	- 6.2
	MAM	- 4.2	- 6.7	- 13.3
	JJA	- 6.4	- 9.1	- 13.5
	SON	- 3.9	- 5.5	- 9.3

Direct Radiative Forcing (DRF) with and without ammonium-nitrates compared with the values of C-AER (simulation that used the CNRM-RCSM4 model and all aerosols execpt nitrate and ammonium, Nabat et al. 2015)



Difference of 2-m temperature with and without ammonium-nitrate aerosols, over Europe, over the 1979-2014 period

– > Decrease of surface temperature (T2m), over Europe, by nitrates especially in summer (- 0.2°C on average) during the period 1979-2014.

5 | First conclusion

Thanks to the implementation of secondary ammonium-nitrate aerosols in the ALADIN-Climat model, impacts on the regional radiative budget and surface temperature have been studied over the Mediterranean region for the 1979-2014 period. Results indicate, over Europe, a negative radiative forcing (around -2 W/m²) at the surface and TOA causing cooling (- 0.2°C at the surface in summer).

Future work:

– > Additional evaluation analyses on different terms (vertical profiles, AERONET data, observations from experimental campaigns, deposition,...)

– > Study the role of anthropogenic/natural aerosols from now until 2100 on the climate change with a regional coupled modelling approach.

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