Radiative and climatic effects of ammonium-nitrate aerosols over the Euro-Mediterranean region

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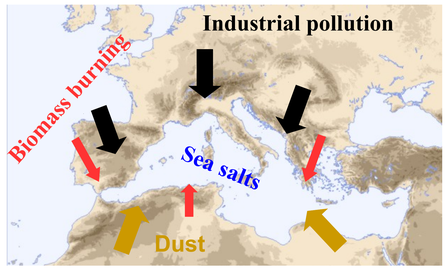
1 | Aerosols over the Mediterranean region



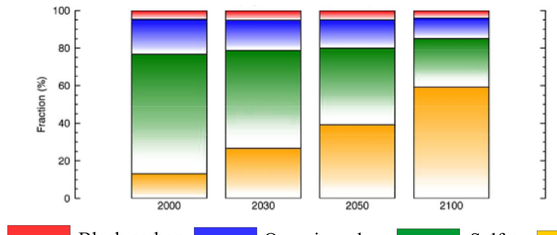
– > Crossroads of air masses bringing aerosols from different sources (Lelieveld et al., 2002),

– > High spatio-temporal variability,

– > Important impact on radiative budget and climate,

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

Average contribution of different aerosols to the anthropogenic AOD (Aerosol Optical Depth) at global scale for the RCP 2.6 (Hauglustaine et al., 2014)



– > Increase of the nitrate contribution: 15% in 2000 vs 60% in 2100.

2 | Methodology

The ALADIN-Climat Model

ALADIN-Climate configuration:

- Atmospheric model
- Horizontal resolution : 50 km
- Number of vertical level : 91

CNRM RCSM

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 ammonium-nitrate (AN) 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 (ECMWF)

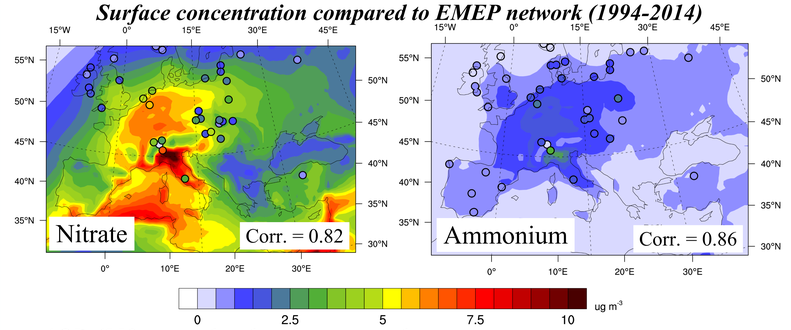
NH_3: CMIP6 Emissions

Two ALADIN-Climat simulations have been realised over the 1979-2016 period:
NIT (with AN) / REF (without AN).

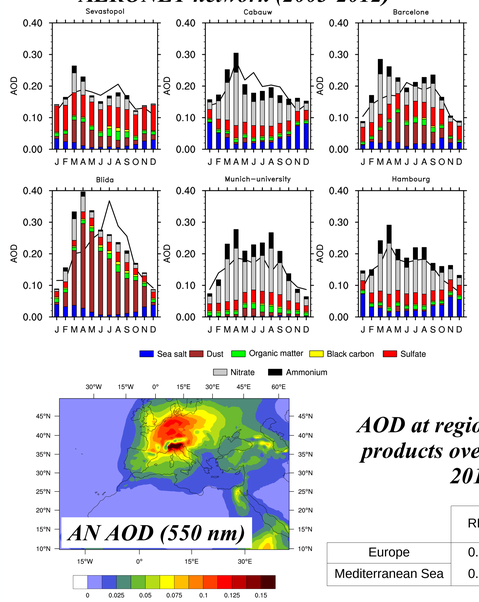
- CMIP6 emissions: anthropogenic (Hoesly et al. 2018) and biomass burning (Van Marle et al. 2017)
- LBC : ERA-Interim
- No « chemical » LBC

3 | Model evaluation

Surface concentration compared to EMEP network (1994-2014)



AOD (550 nm) at local scale compared to AERONET network (2003-2012)



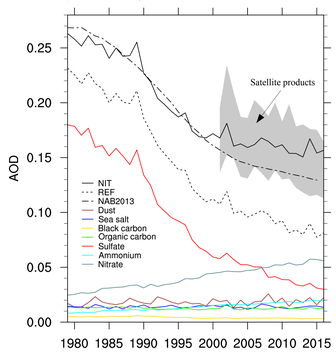
- Surface concentration: good correlation but overestimation of nitrate concentration,
- AOD at local scale: improvement of the average AOD seasonal cycle with AN aerosols,
- AOD at regional scale: imporvement of the total AOD with AN aerosols especially over Europe (0.16 instead of 0.09 with AN aerosols).

AOD at regional scale compared to satellite products over the period 2001-2016 (2003-2016 for MODIS Aqua)

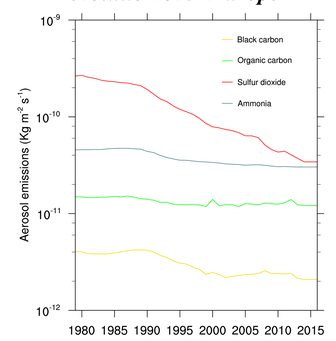
	REF	NIT	MISR	MODIS Aqua	MODIS Terra
Europe	0.09	0.16	0.13	0.16	0.19
Mediterranean Sea	0.19	0.22	0.20	0.20	0.22

4 | AOD trend

AOD (550 nm) evolution over Europe



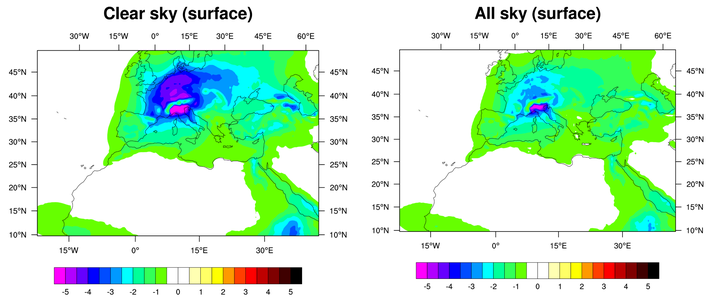
Anthropogenic aerosol sources evolution over Europe



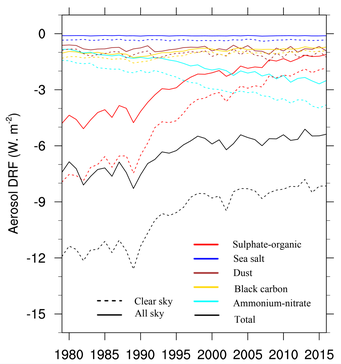
- Strong decrease of the total AOD from 1979 to 2016: - 0.047 per decade for REF and - 0.035 per decade for NIT,
- Decrease due to the decline of sulfate emissions,
- Continuous increase of AN aerosols due to the decrease of sulfate (more free ammonia in the atmosphere).

5 | AN impacts on the regional radiative budget and surface temperature

AN SW DRF (Direct Radiative Forcing, W.m^{-2}) over the period 1979-2016

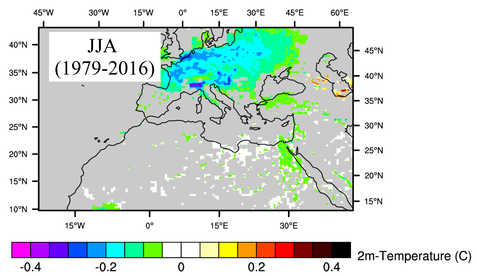


Aerosol SW DRF evolution over Europe at the surface



- Moderate effect of AN over Europe: -2.6 W.m^{-2} in clear sky conditions and -1.7 W.m^{-2} in all sky conditions (26 % of the total aerosol DRF),
- Local maxima in the Po Valley and the Benelux (up to -5 W.m^{-2}),
- From 2005, over Europe, AN aerosols become the species with the highest DRF (stronger than sulphate and organic).

AN aerosols impact on the near-surface air temperature at 2m



- Moderate temperature decrease over Europe (-0.2°C) during summer,
- Larger decline (-0.4°C) in regions with a strong AN AOD (Benelux, Po valley).

6 | Conclusion

We have developed a new configuration of the aerosol scheme TACTIC in ALADIN-Climate with the addition of ammonium-nitrate (AN) aerosols. Results indicate, over the period 1979-2016:

- **Continuous increase of AN AOD** due to the decrease of sulphates,
- **Moderate DRF** of AN over Europe (26 % of the total aerosol DRF) with local maxima (Po Valley and Benelux),
- AN aerosols become, from 2005, the species with the **highest DRF** (over Europe),
- AN aerosols cause a **moderate temperature decrease** over Europe (-0.2°C) during summer.

Future work: 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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