Aerosol forcing for CORDEX

15 February 2021, Version 1.0

provided by the Med-CORDEX Flagship Pilot Study on Aerosol

Contact : fabien.solmon@aero.obs-mip.fr, marc.mallet@meteo.fr

https://tinyurl.com/aerosol4cordex

1. Background

Some regions have experienced or will experience significant aerosol concentration trends linked to societal and technical evolutions.

While the majority of Global Climate Models (GCMs) account for these trends, most Regional Climate Models (RCMs) have not considered interannual variations of aerosol and their effect on the radiative budget in the CORDEX downscaling of CMIP5 (see Annex of Gutierrez et al. 2020 for a description of the aerosol representation in CORDEX RCMs to date). This can partly explain difficulties to represent past climate trends in RCM evaluation runs (Nabat et al. 2014) and climate change signal discrepancy between GCMs and RCMs (Boé et al. 2020) over specific domains (for example over Europe where a drastic decrease of aerosol and precursor emissions has been taking place since the early 90's). Due to their limited lifetime, aerosol particles are typically regional-scale forcing agents that must be somehow represented within RCM domains.

Explicit on-line aerosol and atmospheric chemistry modelling can be an option for some RCMs, but at the price of higher numerical costs and additional constraints on the domain's geographical boundaries (which must include relevant sources).

An alternative solution is to use prescribed monthly datasets of aerosol optical properties as input to the RCM radiation scheme. Most RCMs include at least a basic representation of aerosol optical properties. However, in many cases the datasets should be updated for integrating interannual variations as well as past and projected trends. We propose hereafter some recommendations to insure a consistent treatment of aerosol effects in RCMs for CORDEX downscaling of CMIP6 and the associated evaluation runs.

2. Evaluation experiment (hindcast simulations)

Ideally, a dataset including aerosol seasonal cycle, interannual variability and trends should be used for the evaluation experiment. We recommend primarily the MERRA-2 reanalysis (monthly

means) which provides aerosol optical properties for the period 1980-present (Randles et al., 2017). This reanalysis product was chosen over the CAMS reanalysis (covering 2002-onward) essentially because it covers a longer time period. An intercomparison of CAMS and MERRA-2 can be found in Geymard and Yang, 2020. The MERRA2 period does not cover 1979 - the first year for downscaling of ERA5. It is recommended to replicate the MERRA-2 aerosol data for 1980 to simulate 1979 in the evaluation experiment. MERRA-2 data can be accessed e.g. via the GIOVANNI data portal https://giovanni.gsfc.nasa.gov/giovanni/

Relevant aerosol representation in model shall include:

Specific Aerosol Optical Depth (AOD): Global monthly time series of Dust, Sea Salt, Black Carbon, Particulate Organic Matter and Sulfate AOD centered on the visible spectral band.

Species single scattering albedo and asymmetry parameter: Three possibilities are envisioned by order of priority :

- Use of properties that are considered in the MERRA-2 reanalysis such as the scattering AOD.
- Use of the existing optical properties for RCMs that already have species-based aerosol representation.
- Use of properties derived from the MACV2-SP plume model parameterisation (see Stevens et al., 2017 for info and database access).

Spectral interpolation: Aerosol optical properties should be ideally interpolated on every spectral band of the radiative scheme. Angstrom exponent will be provided for each aerosol species based on pre-cited data sources.

Vertical distribution: The vertical distribution of AOD (or the extinction profile if AOD is normalized by atmospheric layer thickness) will be provided considering lat-lon gridded typical aerosol species vertical distributions retrieved from :

- MERRA-2 vertical distributions based on extinction profiles considered in reanalysis
- Vertical distribution information already present in RCM
- MACV2-SP generated vertical distributions.

Remarks: The possibility of quickly gathering all relevant data in a dedicated CORDEX repository is discussed within the Med-CORDEX FPS-aerosol. A reasonable horizon for that could be spring 2021.

3. Historical and Scenario experiments

Preferred strategy: As much as possible, RCMs should use the aerosol monthly (or higher frequency) aerosol optical data produced by the driving CMIP6 GCMs. A potential problem here is that available output in terms of aerosol data is quite different across the CMIP6 GCMs. By order of priority we suggest to use:

- Minimum requirement : AOD at 550 nm (od550aer)
- Strongly advised: 550 nm AOD by species (od550bb, od550bc, od550dust, od550no3, od550oa, od550so4, od550ss and od550so4so)
- If possible: wavelength dependant and vertically resolved optical properties (aerasymbnd, aeroptbnd and aerssabnd)

The Med-CORDEX FPS-aerosol will eventually provide guidelines to derive missing information (e.g. species level AOD, vertical profiles) using reasonable approximations. If a GCM does not provide the required aerosol data, an alternative can be using the MACV2-SP approach (addressing only the anthropogenic component), which includes simplified representations of aerosol evolution for historical and future periods (based on different SSPs, Fiedler et al., 2019). Other alternatives can be envisioned as building a default climatology from available GCM outputs for different emission scenarios (obviously this will require a bit of time).

References

Boé J., S. Somot, L. Corre and P. Nabat: Large discrepancies in summer climate change over Europe as projected by global and regional climate models: causes and consequences. *Climate Dynamics*, **54**, 2981–3002, 2020, https://doi.org/10.1007/s00382-020-05153-1

Fiedler, S., Stevens, B., Gidden, M., Smith, S. J., Riahi, K., and van Vuuren, D.: First forcing estimates from the future CMIP6 scenarios of anthropogenic aerosol optical properties and an associated Twomey effect, Geosci. Model Dev., 12, 989–1007, 2019, https://doi.org/10.5194/gmd-12-989-2019

Gutiérrez, C., Somot, S., Nabat, P., Mallet, M., Corre, L., van Meijgaard, E., ... & Gaertner, M. Á. (2020). Future evolution of surface solar radiation and photovoltaic potential in Europe: investigating the role of aerosols. Environmental Research Letters, 15(3), 034035, https://doi.org/10.1088/1748-9326/ab6666

Nabat, P., Somot, S., Mallet, M., Sanchez-Lorenzo, A., & Wild, M. (2014). Contribution of anthropogenic sulfate aerosols to the changing Euro-Mediterranean climate since 1980. Geophysical Research Letters, 41(15), 5605-5611, https://doi.org/10.1002/2014GL060798

Randles, C.A., Da Silva, A.M., Buchard, V., Colarco, P.R., Darmenov, A., Govindaraju, R., Smirnov, A., Holben, B., Ferrare, R., Hair, J. and Shinozuka, Y., 2017. The MERRA-2 aerosol

reanalysis, 1980 onward. Part I: System description and data assimilation evaluation. Journal of Climate, 30(17), pp.6823-6850, https://doi.org/10.1175/JCLI-D-16-0609.1

Stevens, B., Fiedler, S., Kinne, S., Peters, K., Rast, S., Müsse, J., Smith, S. J., and Mauritsen, T.: MACv2-SP: a parameterization of anthropogenic aerosol optical properties and an associated Twomey effect for use in CMIP6, Geosci. Model Dev., 10, 433–452, 2017, https://doi.org/10.5194/gmd-10-433-2017