Interfacing near real-time aerosols with radiation schemes, 2022

- **Time:** 26/09/2022 - 21/10/2022
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1 Introduction

This stay was a continuation of the work from my last stay in Prague in 2021. As described in the report from that stay [3], the final goal is implementing near real-time aerosol concentrations from the CAMS (Copernicus Atmosphere Monitoring Service) model in the radiation schemes. The outcome of the previous stay was design of dataflow of aerosol optical properties and the draft version of the new subroutine. During this stay, the main focus was on finishing the code, debugging and technical testing.

2 Code design

For activating the new procedure, logical switch LAERONRT has been added to NAMPHY. The whole new procedure includes new subroutine RAD_AER_MMR, new triplet SUAERO/YOMAERO/NAMAERO, and corresponding structures:

```
arpifs/module/type_aero.F90
arpifs/module/yomaero.F90
arpifs/namelist/namaero.nam.h
arpifs/phys_radi/acraneb_aer_550.F90
arpifs/phys_radi/rad_aer_mmr.F90
arpifs/setup/suaero.F90
```

The new setup routine SUAERO performs actions not needed to be done in every time step:

- reading the NetCDF file with aerosol inherent optical properties (IOPs),
- reading the new namelist NAMAERO,
- spectral averaging.

Through the namelist, it is possible to define:

- the location and name of the NetCDF file,
- mapping (which aerosols from the NetCDF file to use in radiation and which GFL fields contain their MMRs),
- spectral weights and masks.

Subroutine RAD_AER_MMR for averaging over aerosol types has been drafted.

More details can be found in [3] and here only the new and changed parts will be described.

2.1 Subroutine RAD_AER_MMR

In RAD_AER_MMR there are performed two actions:

- binning for hydrophilic aerosols according to actual relative humidity and
- averaging over aerosol types.

Averaging over aerosol types is described in [3].
Subroutine RAD_AER_MMR is called every timestep and it gets information about relative humidity.
Calculating relative humidity bin (IRH) is designed as follows. For each gridpoint and each vertical level, there is a loop going through the lower boundaries of 12 possible bins. Starting value of the relative humidity bin IRH is set to maximal value 12 and every time relative humidity is lower than some of the lower boundary values, the value of IRH is decreased by one. The resulting value corresponds to the number of relative humidity bin.

2.2 TYPE_AERO structure

Structure TYPE_AERO described in [3] has been changed since. The new structure contains three main subtypes:

- TYPE_FILE (Table 1) contains inherent optical properties of individual aerosol types from the NetCDF file,
- TYPE_AVG (Table 2) contains individual aerosol optical properties averaged to target spectral resolution, and
- TYPE_MIX (Table 3) contains optical properties of the resulting aerosol mixture.

Dataflow of aerosol optical properties is as follows:

$$\text{NetCDF file} \xrightarrow{\text{TYPE\_FILE}} \text{SUAERO} \xrightarrow{\text{TYPE\_AVG}} \text{RAD\_AER\_MMR} \xrightarrow{\text{TYPE\_MIX}} \text{RADIATION\_SCHEME}$$

The architecture of these types is shown in Tables 1, 2 and 3. Subtypes in TYPE_AERO are marked in bold; scalars and arrays are in normal font.
Please note that ordering of indices of arrays REXT, RSSA and RASM in Fortran is opposite than in NetCDF file, which uses C convention.

Table 1: TYPE **TAERO_FILE**

NAERO		
SW	NBAND RWEIGHT (:) RMASK (:,:) (input_band, output_band)	
	PHOBIC	REXT(:,:) RSSA(:,:) RASM(:,:) (spectral_band, aerosol_type)
	PHILIC	REXT(:,:,:) RSSA(:,:,:) RASM(:,:,:) (spectral_band, relative_humidity, aerosol_type)
LW	NBAND RWEIGHT (:) RMASK (:,:) (input_band, output_band)	
	PHOBIC	REXT(:,:) RSSA(:,:) RASM(:,:) (spectral_band, aerosol_type)
	PHILIC	REXT(:,:,:) RSSA(:,:,:) RASM(:,:,:) (spectral_band, relative_humidity, aerosol_type)

Table 2: TYPE **TAERO_AVG**

<table>
<tr><td>NHUM
RHUM (:)</td><td></td><td></td></tr>
<tr><td rowspan="3">SW</td><td>NBAND</td><td></td></tr>
<tr><td>PHOBIC</td><td>REXT(:,:)
RSSA(:,:)
RASM(:,:)
(spectral_band, aerosol_type)</td></tr>
<tr><td>PHILIC</td><td>REXT(:,:,:)
RSSA(:,:,:)
RASM(:,:,:)
(spectral_band, relative_humidity, aerosol_type)</td></tr>
<tr><td rowspan="3">LW</td><td>NBAND</td><td></td></tr>
<tr><td>PHOBIC</td><td>REXT(:,:)
RSSA(:,:)
RASM(:,:)
(spectral_band, aerosol_type)</td></tr>
<tr><td>PHILIC</td><td>REXT(:,:,:)
RSSA(:,:,:)
RASM(:,:,:)
(spectral_band, relative_humidity, aerosol_type)</td></tr>
</table>

Table 3: TYPE **TAERO_MIX**

SW	RDEL (:,:,:) RSSA(:,:,:) RASM(:,:,:) (jlon, jlev, band_sw)
LW	RDEL(:,:,:) RSSA(:,:,:) RASM(:,:,:) (jlon, jlev, band_lw)

NAERO - number of aerosol types
NHUM - number of relative humidity bins
RHUM - lower bounds of relative humidity bins
NBAND - number of input bands (NetCDF file) in TYPE_FILE and number of output bands (radiation scheme) in TYPE_AVG
RWEIGHT - spectral weights for input bands
RMASK - masks defining output bands
REXT - mass extinction coefficient; [m^2/kg] in file and [1/Pa] in model
RSSA - single scattering albedo [1]
RASM - asymmetry factor [1]
RDEL - layer optical depth [1]

3 Technical testing

After finalizing the code and its successful compilation, technical tests were made to check the basic functionality of the new procedure. All changes were made on the cy46t1_bf.06 as the reference.
The model used was ALARO-1 version B with a horizontal resolution of 2.325 km, timestep of 90 s and 87 vertical levels. The radiation scheme used was ACRANEB2. Domain size is shown in Figure 1.

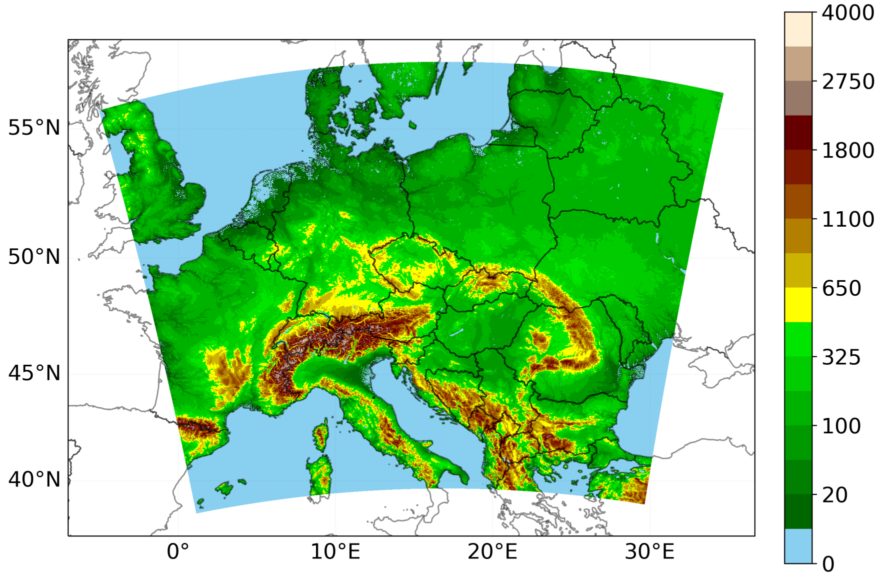


Figure 1: Orography of the domain area in [m]

The model was run for the case of the desert dust intrusion on the 20^{th} of February, 2021. Saharan dust has spread over central Europe reaching even Scandinavia. More about the event can be found in [1].

Since GFL fields containing CAMS MMRs are not interfaced with the code yet, three exponentially decaying artificial profiles of MMRs are constructed:

$$MMR = e^{-\frac{\Phi}{gd}} \cdot 10^{-6},$$

where MMR is mass mixing ratio in [1], Φ is geopotential in [m^2/s^2], g gravity acceleration and d characteristic depth. Characteristic depths of the three profiles were 1, 2 and 3 km.

Altogether four experiments have been run, one reference and three with included code modifications. In the namelist NAMAERO, variable MAP_AERO_GFL2NC has been set to:

- MAP_AERO_GFL2NC=0,0,0,1, - no aerosols are used since the three non-trivial profiles are referring to 0 aerosols,
- MAP_AERO_GFL2NC=3,2,1, - hydrophobic aerosols are used (three desert dust bins),
- MAP_AERO_GFL2NC=-3,-2,-1, - hydrophilic aerosols are used (three sea salt bins).

Inspecting the horizontally averaged difference (using the DDH tool) in the temperature budget for the reference experiment without aerosols and experiment with a new code where aerosols are deactivated via mapping, we can conclude that the differences are on the level of noise (Figure 2).

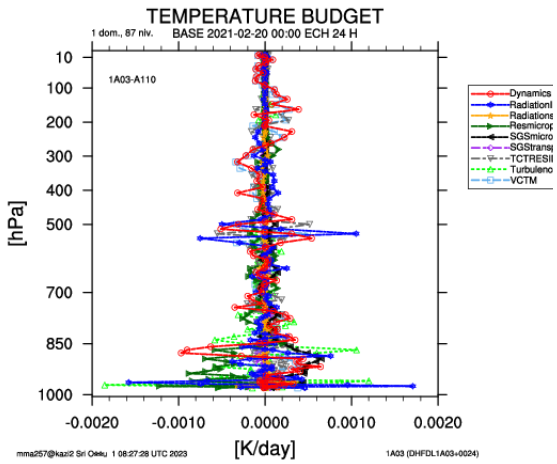
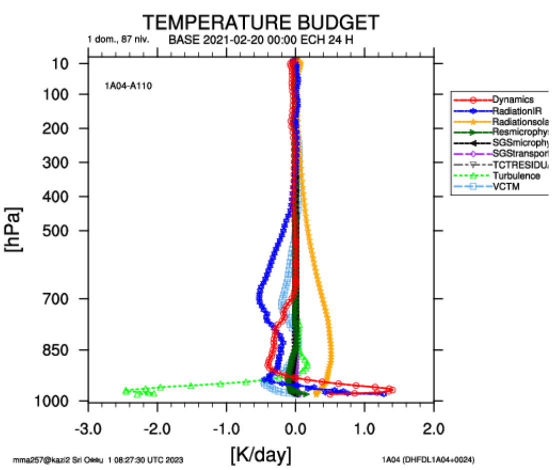
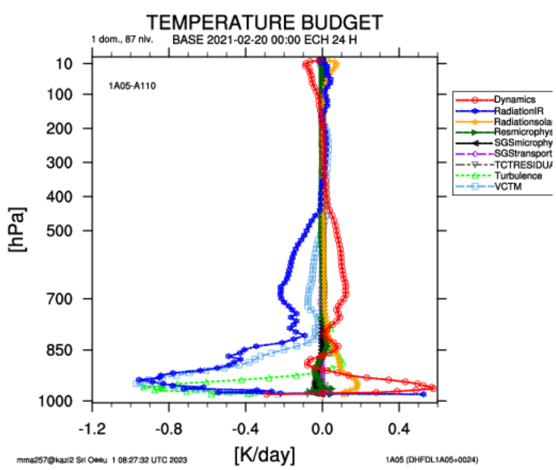


Figure 2: Differences in the temperature budget after 24 hour forecast between the modified code without using any aerosols and the reference run

DDH plots in Figure 3 are showing impact on the atmosphere temperature budget due to aerosol presence (only desert dust, Figure 3a and only sea salt, Figure 3b). Impact can be observed separately for shortwave (yellow) and longwave (dark blue) radiation. For both types of aerosols, temperature is increasing due to absorption of shortwave radiation. Similar results were obtained in [2] when comparing temperature profiles without and in the presence of aerosols. The longwave effect is mixed, dominated by cooling to space at higher levels.



(a) desert dust



(b) sea salt

Figure 3: Differences in the temperature budget after 24 hour forecast between the modified code using aerosols and the reference run

4 Conclusion and further work

The code for the new procedure of using near real-time aerosols in radiation has been finalized, compiled and performs as expected in the basic validation. The new modset should be interfaced with the GFL dataflow of aerosol MMRs and with the remaining radiation schemes (currently it is working only with ACRANEB2). After that, sensitivity to CAMS near real time aerosols can be evaluated and compared with other schemes. An important next step will be implementation of CAMS climatological aerosols.

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References

[1] https://www.severe-weather.eu/europe-weather/sahara-dust-storm-warm-wave-europe-mk/?fbclid=IwAR3DJD5bg7KCfLBBkEKLBTo6ghDOgw5OZcctwMsjmgHcOxsBbr9ueoenTz4. Accessed: 2023-03-02.

[2] J. Mašek et al. “Single interval shortwave radiation scheme with parameterized optical saturation and spectral overlaps”. In: *Q. J. R. Meteorol. Soc.* 142 (2016), pp. 304–326. DOI: 10.1002/qj.2653.

[3] A. Šljivić. *Interfacing near real-time aerosols with radiation schemes.* 2021.