

Technical document:
Use of CAMS atmospheric aerosols in AROME/HARMONIE-AROME/ALARO
RC-LACE scientific stay
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20-Dec-2024

1. Introduction:

In the ACCORD system, in cycle 50t1 the reading of CAMS aerosol fields (climatological and n.r.t.) is introduced. The user can define which source of data they want to use:

1. 2D CAMS climatological aerosols (maximum number of species 11),
2. 3D n.r.t. CAMS aerosols (maximum number of species 42),
3. combination of 2D CAMS climatological aerosols and 3D n.r.t. CAMS aerosols (maximum number of species 42).

2. Technical details:

Below are listed main points:

- The Tegen and CAMS aerosol species cannot be used together.
- Two logical keys are defined in namelist block **&NAMPHY** for using CAMS aerosols.
- In the proposed approach, CAMS aerosols (2D climatological and 3D n.r.t.) during the integration are stored in 3D GFL array which is described by the user in the namelist block **&NAMGFL**.
- Total number of used aerosol types is given by **&NAMGFL** variable **NAERO**.
- The CAMS 2D climatological aerosols are read from initial file in fixed order (see Table 1). Then they are mapped to the GFL array. The user can define which of them will be used in the namelist block **&NAMAERO**, array **MAP_AERO_CMS2GFL**.
- In the case of 2D climatological aerosols the user can define vertical distribution of individual species in the namelist **[2]**. The vertical redistribution is done by a new subroutine RADECMR which takes care also about tropospheric/stratospheric backgrounds and stratospheric volcanic aerosols.
- The aerosol inherent optical properties (IOPs) used in radiation are read from the NetCDF file (file: aerosol_ifs_rrtm_46R1_with_NI_AM.nc available at belenos supercomputer) [1]. The name of the NetCDF file can be defined in namelist block **&NAMAERO**, variable **CFAERO** (default value 'aerosol_optics.nc'). Description of the netCDF file is included in the Appendix A.

- The aerosol optical properties must be assigned properly to each aerosol field stored in the GFL array. The user defines mapping of aerosol properties in the namelist block **&NAMAERO**, variable **MAP_AERO_GFL2NC**.
- In the case of using CAMS aerosols, the user must define the location of hydrophobic organic matter in GFL structure to determine tropospheric and stratospheric background, namelist block **&NAMAERO**, variable **NUMGFL_AERO_OM2**. If background values should not be used, the variables **RBGST_MMR_OM2** and **RBGTR_MMR_OM2** must be set to 0.
- There is a possibility to prescribe stratospheric volcanic forcing via field **SURFAEROS.VOLCAN** in the initial file. It contains total AOD at 550nm, and its reading is activated by setting variable **LAEROVOL=.TRUE.** in the namelist block **&NAMPHY**. The user has to specify which GFL field contains sulfate via variable **NUMGFL_AERO_SU** in namelist block **&NAMAERO**. Conversion from aerosol optical depth to mass is done using sulphate extinction coefficient at 550nm. Its default value was tuned so that the new treatment using CAMS aerosol optical properties gives the same stratospheric response as the old Tegen treatment.

Table 1: List of 2D CAMS climatological aerosol types and their IOPs mapping from NetCDF file. First column contains index of array **MAP_AERO_GFL2NC**.

No.	Field name	Description	MAP_AERO_GFL2NC value
1	SURFAEROCMS.SS1	sea salt, small	-1
2	SURFAEROCMS.SS2	sea salt, medium	-2
3	SURFAEROCMS.SS3	sea salt, large	-3
4	SURFAEROCMS.DD1	desert dust, small	1
5	SURFAEROCMS.DD2	desert dust, medium	2
6	SURFAEROCMS.DD3	desert dust, large	3
7	SURFAEROCMS.OM1	organic matter, hydrophilic	-4
8	SURFAEROCMS.OM2	organic matter, hydrophobic	10
9	SURFAEROCMS.BC1	black carbon, hydrophilic	11
10	SURFAEROCMS.BC2	black carbon, hydrophobic	11
11	SURFAEROCMS.SU	sulfates	-5

In Appendix B and C are presented examples of namelist for the preparation of initial conditions and forecast using CAMS climatological or near-real time aerosols.

3. Namelist variables description:

Below are described two logic keys defined for using CAMS aerosols database.

&NAMPHY

Variable name	Default value	Meaning
LAEROMMR3D	.FALSE.	Main key activating use of aerosol MMRs in the model physics, implemented via GFL fields. These can be filled by climatological aerosols, n.r.t. aerosols (CAM5, MOCAGE), or their combination.
LAEROMASS2D	.FALSE.	Complementary key activating reading of vertically integrated mass of 11 climatological aerosols from initial file; some or all of them can be used by model.

Definition of GFL aerosol array

The user must define GFL fields in the namelist, number and their names of individual aerosol species, determine if aerosols will be advected, read from initial file, and coupled from LBC files, and if they should be written to the output files.

In the case of 2D CAMS climatological aerosols, reading, coupling and advection of corresponding aerosol GFL fields must be switched off. Vertically integrated aerosol mass is then read from initial file together with other surface fields. In APLPAR/APL_ALARO it is redistributed

Below is presented part of the namelist which defines the number of aerosols, and sets the first aerosol type to be used for climatological aerosol.

&NAMGFL

NAERO=11,	Number of GFL aerosol fields; this variable must be consistent with variable MAP_AERO_GFL2NC in &NAMERO
YAERO_NL(1)%LADV=.F.,	Advection off
YAERO_NL(1)%LGP=.T.,	Determines if field is defined in grid point space
YAERO_NL(1)%LSP=.F.,	Determines if field is defined in spectral space. LSP and LGP cannot be both TRUE!
YAERO_NL(1)%LPC=.T.,	Attribute for predictor-corrector scheme
YAERO_NL(1)%LREQOUT=.T.,	Save field to the output file
YAERO_NL(1)%NCOUPLING=0,	Coupling off
YAERO_NL(1)%NREQIN=0,	Initialize field to zero

In case of n.r.t. aerosol, setting of the following GFL attributes would differ:

YAERO_NL(1)%CNAME='SEA.SALT1',	Name of field in the init FA file
YAERO_NL(1)%LADV=.T.,	Advection on
YAERO_NL(1)%LINTLIN=.T.,	Use linear interpolator (non-overshooting, cheaper)
YAERO_NL(1)%NCOUPLING=1,	Coupling on
YAERO_NL(1)%NREQIN=1,	Read field from init file

In the model namelist the new block **&NAMAERO** was introduced, dedicated to CAMS aerosol treatment. Below are included all possible variables with their default values. Not all of them are necessary to run the experiment.

&NAMAERO

Variable name	Default value	Meaning
CFAERO	'aerosol_optics.nc'	The name of the NetCDF file which contains aerosol optical properties, necessary to use CAMS aerosols. More details are included in the Appendix A
MAP_AERO_GFL2NC	0,0,0,...,0	REQUIRED: Define IOPs for each aerosol type (used in radiation). The size of the array must be consistent with NAERO variable. The index is order in GFL array, the value order in the NetCDF file (positive for hydrophobic, negative for hydrophilic aerosols, zero – aerosol is not used). Routine which describes maximum number of aerosols (variable JPAERO): arpifs/module/par_gfl.F90
MAP_AERO_CMS2GFL	0,0,0,...,0	REQUIRED: 2D CAMS aerosol mapping to 3D GFL array, maximum number of elements is equal to 11 (number of 2D CAMS climate aerosol species). The index specifies the number of 2D aerosol type. If 0 or negative aerosol not used, if positive copy element to specific GFL field. For case only with climatological aerosols,

		MAP_AERO_CMS2GFL=1,2,3,4,5,6,7,8,9,10,11
NUMGFL_AERO_OM2	0	REQUIRED: Position of hydrophobic organic matter in the GFL array when using CAMS aerosols. Not needed when RBGST_MMR_OM2 and RBGTR_MMR_OM2 to 0. For using only CAMS climatological aerosols NUMGFL_AERO_OM2 is equal to 8 .
RBGST_MMR_OM2	4.50E-10	Unit: kg/kg, equivalent of Tegen #5 background stratospheric AOD@550=0.007
RBGTR_MMR_OM2	1.65E-09	Unit: kg/kg, equivalent of Tegen #1 background tropospheric AOD@550=0.0534
REXT550_SU	6000.	Unit: m ² /kg, tuned mass extinction coefficient at 550nm of stratospheric volcanic aerosols
NUMGFL_AERO_SU	0	GFL position of sulfate; required when LAEROVOL=.TRUE. and Tegen field SURFAEROS.VOLCAN in the initial file.
RAERO_HEIGHT_SCALE	1000.0, 1000.0, 1000.0, 3000.0, 3000.0, 3000.0, 2000.0, 2000.0, 1000.0, 1000.0, 4000.0	Specific aerosol heights in meters, maximum elements of the array are equal to 11. Used only for 2D climatological aerosols species Defined in routine: arpifs/setup/suaero.F90 Default values: <ul style="list-style-type: none"> • 1000m for sea salt and black carbon • 2000m for organic matter • 3000m for dust (can be seasonally dependent for LDUSEASON=T) • 4000m for sulfate
RAERO_GAMMA_EXP	1,1,1,...,1	Beta exponent for gamma distribution of aerosol species.

		Used only for 2D climatological aerosols species (11 types) Defined in routine: arpifs/setup/suaero.F90
RAERO_WEIGHT_SW	default set in SUAERO (no need to modify)	SW spectral weights for 14 input RRTM bands.
RAERO_WEIGHT_LW	default set in SUAERO (no need to modify)	LW spectral weights for 16 input RRTM bands.
RAERO_MASK_SW	default set in SUAERO (no need to modify)	Masks defining portions of input RRTM bands falling to output SW bands.
RAERO_MASK_LW	default set in SUAERO (no need to modify)	Masks defining portions of input RRTM bands falling to output LW bands.

References:

[1] A. Bozzo et al. "An aerosol climatology for global models based on the tropospheric aerosol scheme in the Integrated Forecasting System of ECMWF". In: *Geoscientific Model Development* 13.3 (2020), pp. 1007–1034. doi: 10.5194/gmd-13-1007-2020. url: <https://gmd.copernicus.org/articles/13/1007/2020/>.

[2] Ana Šljivić and Ján Mašek, [Vertical distribution of climatological aerosols](#), CHMI research note, Prague 2024

APPENDIX A

Description of netCDF file containing aerosol physical properties

(file: aerosol_ifs_rrtm_46R1_with_NI_AM.nc available at belenos supercomputer)

Instruction how to get the file:

```
/home/mf/dp/marp/gco/apps/gco_toolbox/default/bin/gget rrtm.const.04.tgz  
tar xvfz rrtm.const.04.tgz aerosol_ifs_rrtm_46R1_with_NI_AM.nc
```

NETCDF FILE

Description hydrophobic

- 1: Desert dust, bin 1, 0.03-0.55 micron, (SW) Dubovik et al. 2002 (LW) Fouquart et al. 1987,
- 2: Desert dust, bin 2, 0.55-0.90 micron, (SW) Dubovik et al. 2002 (LW) Fouquart et al. 1987,
- 3: Desert dust, bin 3, 0.90-20.0 micron, (SW) Dubovik et al. 2002 (LW) Fouquart et al. 1987,
- 4: Desert dust, bin 1, 0.03-0.55 micron, Fouquart et al 1987,
- 5: Desert dust, bin 2, 0.55-0.90 micron, Fouquart et al 1987,
- 6: Desert dust, bin 3, 0.90-20.0 micron, Fouquart et al 1987,
- 7: Desert dust, bin 1, 0.03-0.55 micron, Woodward 2001, Table 2,
- 8: Desert dust, bin 2, 0.55-0.90 micron, Woodward 2001, Table 2,
- 9: Desert dust, bin 3, 0.90-20.0 micron, Woodward 2001, Table 2,
- 10: Hydrophobic organic matter, OPAC (hydrophilic at RH=20%),
- 11: Black carbon, OPAC,
- 12: Black carbon, Bond and Bergstrom 2006,
- 13: Black carbon, Stier et al 2007,
- 14: Stratospheric sulfate (hydrophilic ammonium sulfate at RH 20%-30%),

Description hydrophilic

- 1: Sea salt, bin 1, 0.03-0.5 micron, OPAC,
- 2: Sea salt, bin 2, 0.50-5.0 micron, OPAC,
- 3: Sea salt, bin 3, 5.0-20.0 micron, OPAC,
- 4: Hydrophilic organic matter, OPAC,
- 5: Ammonium sulfate (for sulfate), GACP Lacis et al https://gacp.giss.nasa.gov/data_sets/ ,
- 6: Secondary organic aerosol - biogenic, Moise et al 2015,
- 7: Secondary organic aerosol - anthropogenic, Moise et al 2015,
- 8: Fine mode Ammonium sulfate (for ammonia), GACP Lacis et al
- 9: Fine mode Nitrate, GLOMAP,
- 10: Coarse mode Nitrate, GLOMAP,

APPENDIX B

Preparation of initial file with CAMS climatological aerosols

When initial/boundary conditions are prepared via configuration (e)e927, aerosols are not interpolated but taken from target climate file (options NFPCLI=2,3).

Below are two examples, showing how to force reading of Tegen or CAMS climate aerosols from climate file:

Tegen climate aerosols	CAMS climate aerosols
<pre>&NAMPHY LAERODES=.T., LAEROLAN=.T., LAEROSEA=.T., LAEROSOO=.T., &NAMFPC NFPCLI=3, CFPPHY= 'SURFAEROS.SEA ', 'SURFAEROS.LAND ', 'SURFAEROS.SOOT ', 'SURFAEROS.DESERT',</pre>	<pre>&NAMPHY LAERODES=.F., LAEROLAN=.F., LAEROSEA=.F., LAEROSOO=.F., &NAMFPC NFPCLI=3, LCLIMAEROCMS=.T., LCLIMAEROSOL=.F., CFPPHY= 'SURFAEROCMS.DD1', 'SURFAEROCMS.DD2', 'SURFAEROCMS.DD3', 'SURFAEROCMS.SS1', 'SURFAEROCMS.SS2', 'SURFAEROCMS.SS3', 'SURFAEROCMS.OM1', 'SURFAEROCMS.OM2', 'SURFAEROCMS.BC1', 'SURFAEROCMS.BC2', 'SURFAEROCMS.SU',</pre>

LCLIMAEROSOL: Read Tegen climate aerosols from climate file - default value is .TRUE.

LCLIMAEROCMS: Read 2D CAMS climate aerosols from climate file - default value is .FALSE.

NFPCLI: Options 2 and 3 mean that you copy climatological fields from a target climate file without interpolation.

User can keep both Tegen and CAMS climate aerosols in the initial file, and specify in integration namelist which one should be used.

APPENDIX C

Namelist for the integration with CAMS aerosols

2D CAMS climatological fields	3D n.r.t CAMS aerosol fields
&NAMAERO MAP_AERO_GFL2NC=-1,-2,-3,1,2,3,-4,10,11,11,-5, MAP_AERO_CMS2GFL=1,2,3,4,5,6,7,8,9,10,11, NUMGFL_AERO_OM2=8, /	&NAMAERO MAP_AERO_GFL2NC=-1,-2,-3,1,2,3,-4,10,11,11,-5,-9,-10,-8, NUMGFL_AERO_OM2=8, /
&NAMPHY LAEROMASS2D=.T., LAEROMMR3D=.T., LAERODES=.F., LAEROLAN=.F., LAEROSEA=.F., LAEROSOO=.F., /	&NAMPHY LAEROMASS2D=.F., LAEROMMR3D=.T., LAERODES=.F., LAEROLAN=.F., LAEROSEA=.F., LAEROSOO=.F., /
&NAMGFL NAERO=11, YAERO_NL(1)%CNAME='SEA.SALT1', YAERO_NL(1)%LADV=.F., YAERO_NL(1)%LGP=.T., YAERO_NL(1)%LINTLIN=.T., YAERO_NL(1)%LPC=.T., YAERO_NL(1)%LREQOUT=.T., YAERO_NL(1)%LSP=.F., YAERO_NL(1)%NCOUPLING=0, YAERO_NL(1)%NREQIN=0, ... YAERO_NL(11)%CNAME='SULPHATE', YAERO_NL(11)%LADV=.F., YAERO_NL(11)%LGP=.T., YAERO_NL(11)%LINTLIN=.T., YAERO_NL(11)%LPC=.T., YAERO_NL(11)%LREQOUT=.T., YAERO_NL(11)%LSP=.F., YAERO_NL(11)%NCOUPLING=0, YAERO_NL(11)%NREQIN=0, /	&NAMGFL NAERO=14, YAERO_NL(1)%CNAME='SEA.SALT1', YAERO_NL(1)%LADV=.T., YAERO_NL(1)%LGP=.T., YAERO_NL(1)%LINTLIN=.T., YAERO_NL(1)%LPC=.T., YAERO_NL(1)%LREQOUT=.T., YAERO_NL(1)%LSP=.F., YAERO_NL(1)%NCOUPLING=1, YAERO_NL(1)%NREQIN=1, ... YAERO_NL(14)%CNAME='AMMONIUM', YAERO_NL(14)%LADV=.T., YAERO_NL(14)%LGP=.T., YAERO_NL(14)%LINTLIN=.T., YAERO_NL(14)%LPC=.T., YAERO_NL(14)%LREQOUT=.T., YAERO_NL(14)%LSP=.F., YAERO_NL(14)%NCOUPLING=1, YAERO_NL(14)%NREQIN=1, /