Renewal of aerosol climatology for HARMONIE-AROME radiation parametrizations

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Alessio Bozzo ECMWF

Finnish Meteorological Institute

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Spanish Meteorological Institute

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The ALADIN-HIRLAM numerical weather prediction (NWP) system is used for operational weather forecasting by 26 national meteorological services in Europe and North Africa which form the HIRLAM (http://hirlam.org) and ALADIN (http://www.cnrm-game-meteo.fr/aladin/) consortia. The acronym HARMONIE (HIRLAM ALADIN Regional Mesoscale Operational NWP in Europe) denotes the specific configuration of the ALADIN-HIRLAM system maintained by the HIRLAM consortium. The dynamical core and physical parametrizations of HARMONIE-AROME (Bengtsson et al. 2017) are based on AROME, the high-resolution limited area model developed at Meteo-France (Seity et al. 2011).

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Parametrization of the radiative transfer

Solar (SW) radiation: scattering and absorption
Terrestrial (LW) radiation: emission and absorption

In the air:
Gas molecules
Cloud droplets and crystals
Aerosol particles

Physico-chemical properties:
Mass concentration
Size
Shape
Composition

Grid-scale variables:
T, qv, qi, ql (qg, qs, qr)
Aerosol (concentration)
Radiative fluxes

Optical properties:
Optical depth
Single scattering albedo
Asymmetry factor

Surface-atmosphere radiative interactions

Surface albedo and emissivity
Orographic radiation effects

Characteristics of surface types
Surface elevation

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Aerosol forecasts

https://atmosphere.copernicus.eu/charts/cams/aerosol-forecasts

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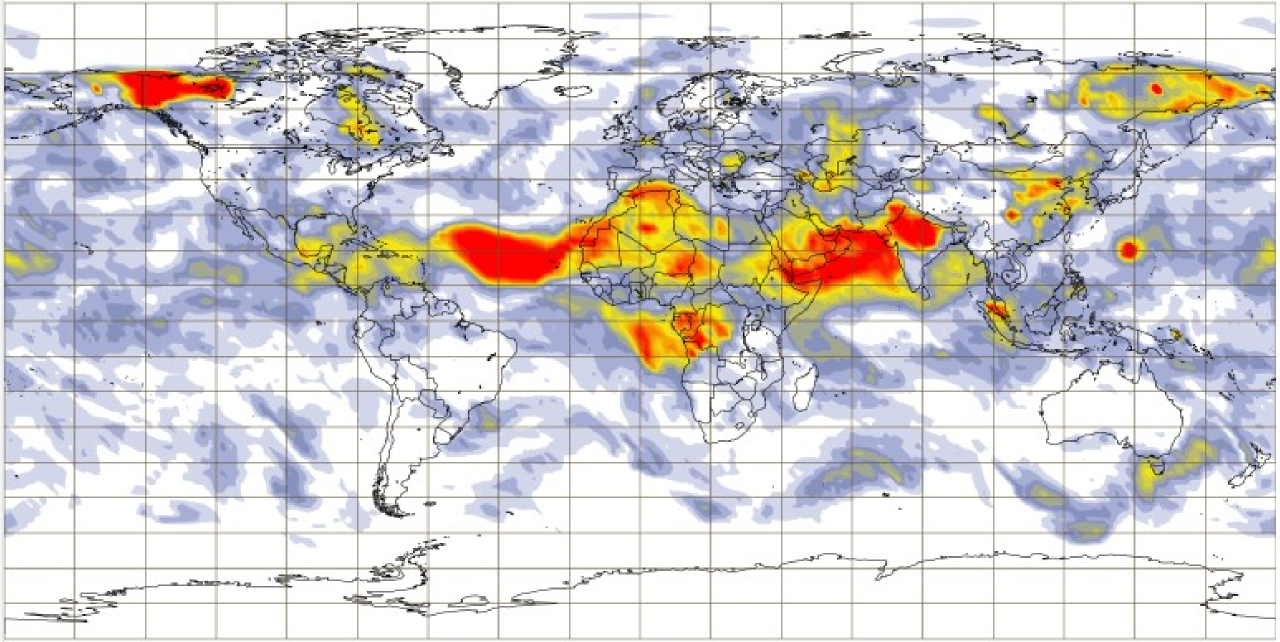
Aerosol optical depth at 550 nm (provided by CAMS, the Copernicus Atmosphere Monitoring Service)
Sunday 8 Jul, 00 UTC T+3 Valid: Sunday 8 Jul, 03 UTC



Climatological or real-time 2D/3D mass mixing ratio of 11 aerosol categories

```
!SS1,SS2,SS3,DD1,DD2,DD3,OM1,OM2,BC1,SU
!CLSUF(1)='AEROMMR.SS1   ' Sea salt (RH, wavelength) size bin 1
!CLSUF(2)='AEROMMR.SS2   '  (hydrophilic)            size bin 2
!CLSUF(3)='AEROMMR.SS3   '                           size bin 3
!CLSUF(4)='AEROMMR.DD1  ' Desert dust (two flavours, wavelength) size bin 1
!CLSUF(5)='AEROMMR.DD2  '  (hydrophobic)             size bin 2
!CLSUF(5)='AEROMMR.DD3  '                            size bin 3
!CLSUF(7)='AEROMMR.OM1  ' Organic matter hydrophilic (RH, wavelength)
!CLSUF(8)='AEROMMR.OM2  '                hydrophobic (wavelenght)
!CLSUF(9)= 'AEROMMR.BC1  ' Black Carbon hydrophilic (RH,wavelength)
!CLSUF(10)='AEROMMR.BC2 '              hydrophobic (wavelenght)
!CLSUF(11)='AEROMMR.SUL ' Tropospheric sulphates (RH, wavelenght)
                           (hydrophilic)
```

ALSO AVAILABLE:

SO2 precursor mixing ratio	aermr12
Volcanic ash aerosol mixing ratio	aermr13
Volcanic sulphate aerosol mixing ratio	aermr14
Volcanic SO2 precursor mixing ratio	aermr15

Aerosol optics

Aerosol IOP* data available

SW [nm]	LW [µm]
3846 – 12195	28.57 – 1000.00
3077 - 3846	20.00 - 28.57
2500 - 3077	15.87 - 20.00
2151 - 2500	14.29 - 15.87
1942 - 2151	12.20 - 14.29
1626 - 1942	10.20 - 12.20
1299 - 1626	9.26 - 10.20
1242 - 1299	8.47 - 9.26
778 - 1242	7.19 - 8.47
625 - 778	6.76 - 7.19
442 - 625	5.56 - 6.76
345 - 442	4.81 - 5.56
263 - 345	4.44 - 4.81
200 - 263	4.20 - 4.44
	3.85 - 4.20
	3.08 - 3.85

Default radiation parametrizations in HARMONIE-AROME:

Solar radiation flux at 6 spectral intervals of IFS scheme

0.185 – 0.25 – 0.44 – 0.69 – 1.19 – 2.38 – 4.00 µm

0 % 11 % 38 % 35 % 15 % 0.4 %

Terrestrial radiation flux is calculated at 16 spectral intervals of the RRTM (IFS) scheme
- but presently only AOD of 6 LW bands is used

Broadband IOP's needed for ACRANEB, HLRADIA

* IOP = inherent optical properties:

mass extinction, asymmetry, single-scattering albedo

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The vertically integrated AOD550nm climatology was renewed:

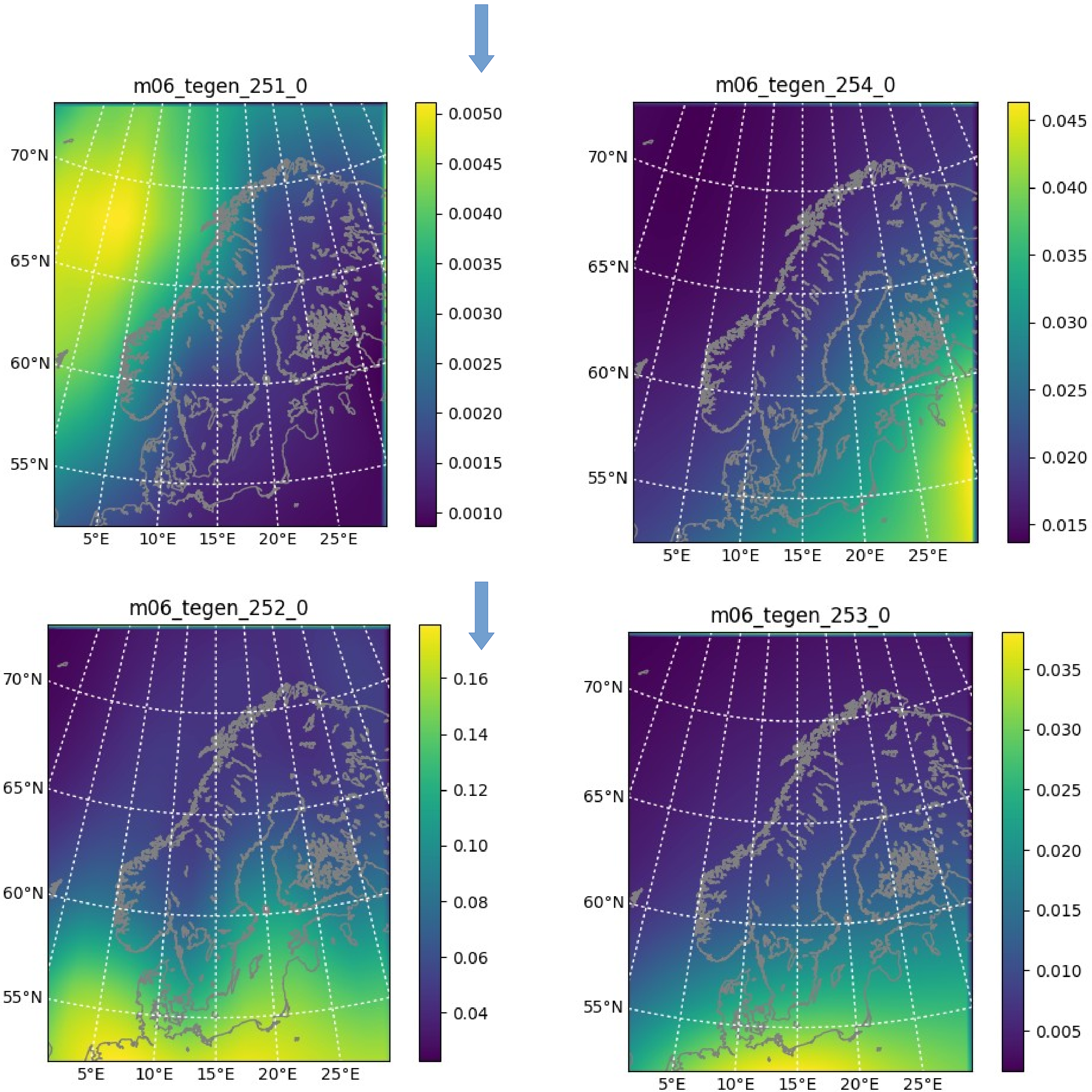
11 classes of climatological AOD of CAMS aerosols
were converted to 4 old ones: sea, land, urban, desert

- Size bins combined
- Sulphates divided between land and soot

Vertical distribution and background assumptions
were retained in the troposphere and stratosphere

Prescribed optical properties of 6 species
in 6 SW and 6 LW intervals retained

Humidity dependencies of IOPs ignored

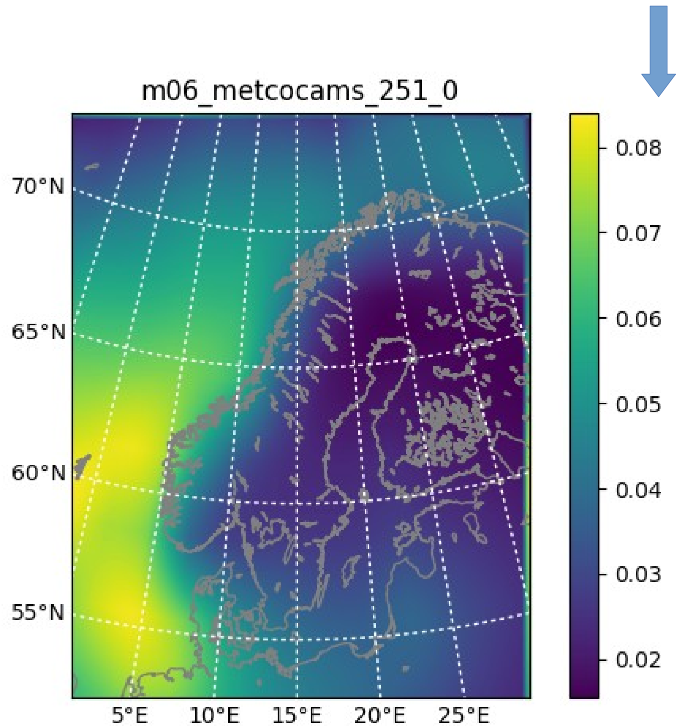


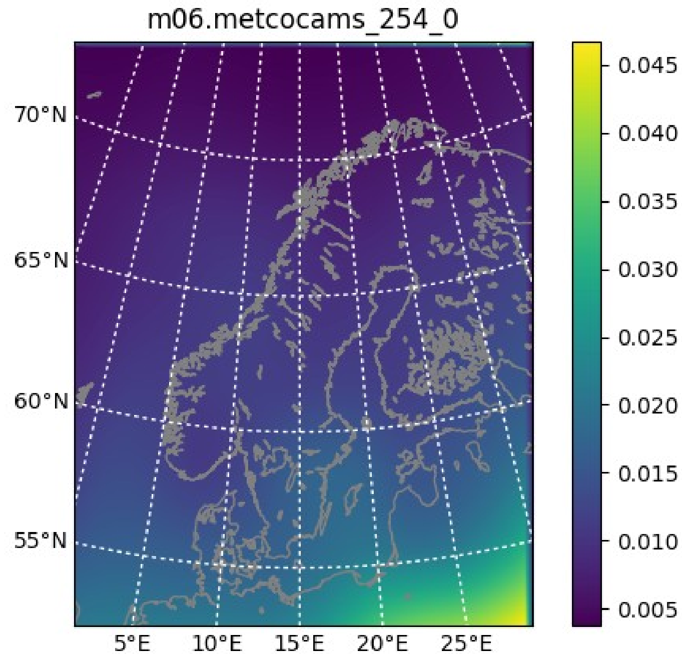
Default Tegen AOD550

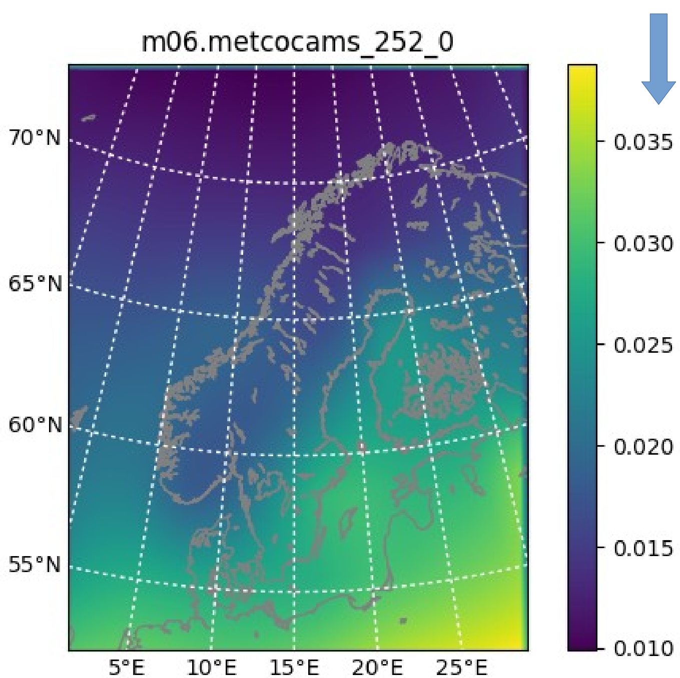
sea salt * desert dust

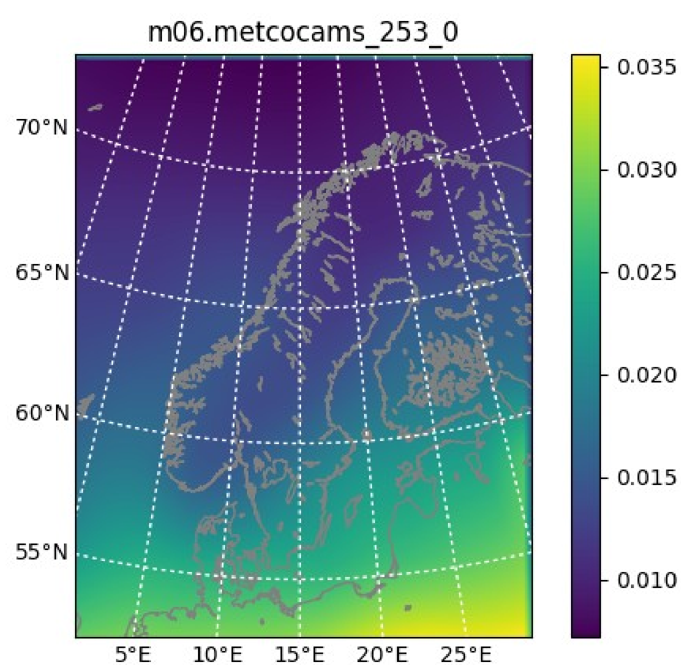
land * urban

in June HARMONIE









Remapped CAMS AOD550

sea salt * desert dust

land * urban

in June HARMONIE

Half of the sulphates went to LAND (OR), half to URBAN (BC)

The first step

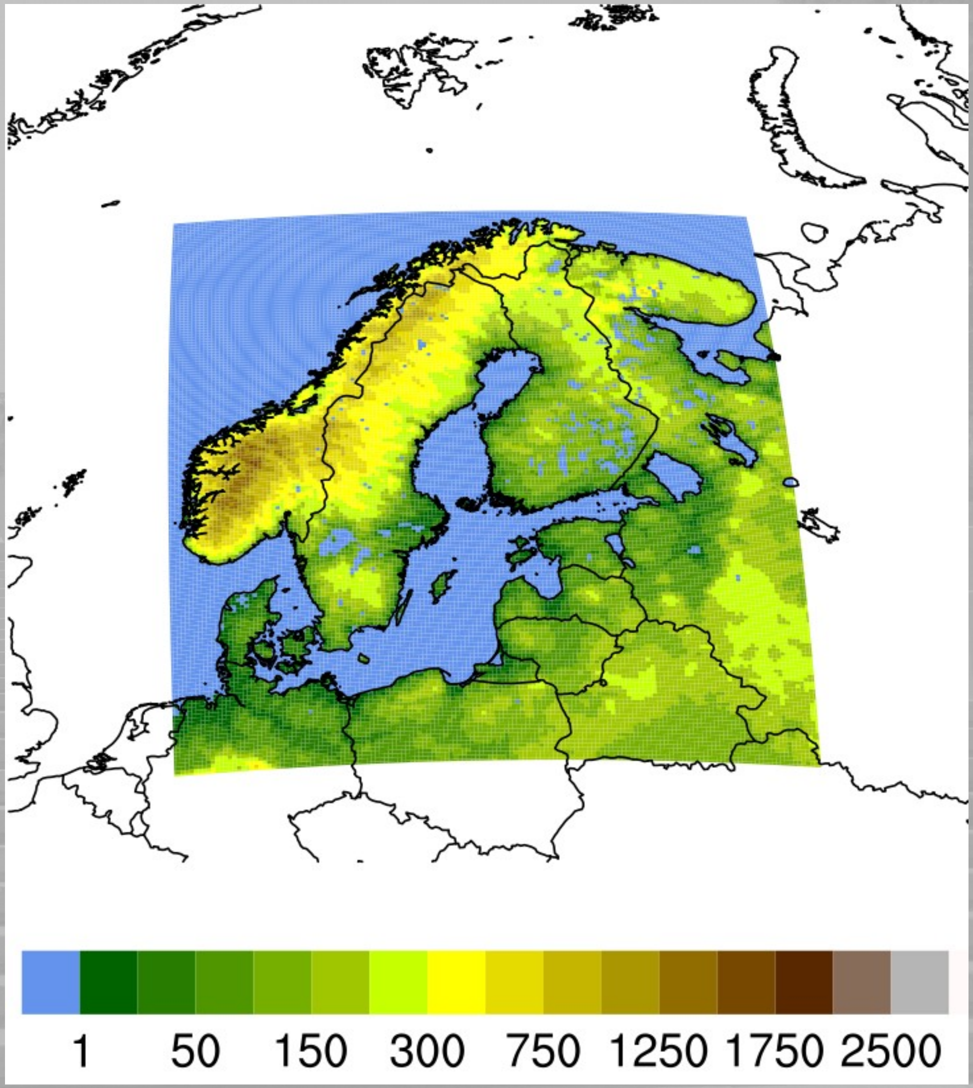
Updated climatology was tested within a HARMONIE-climate (HCLIM v. 38h1) experiment

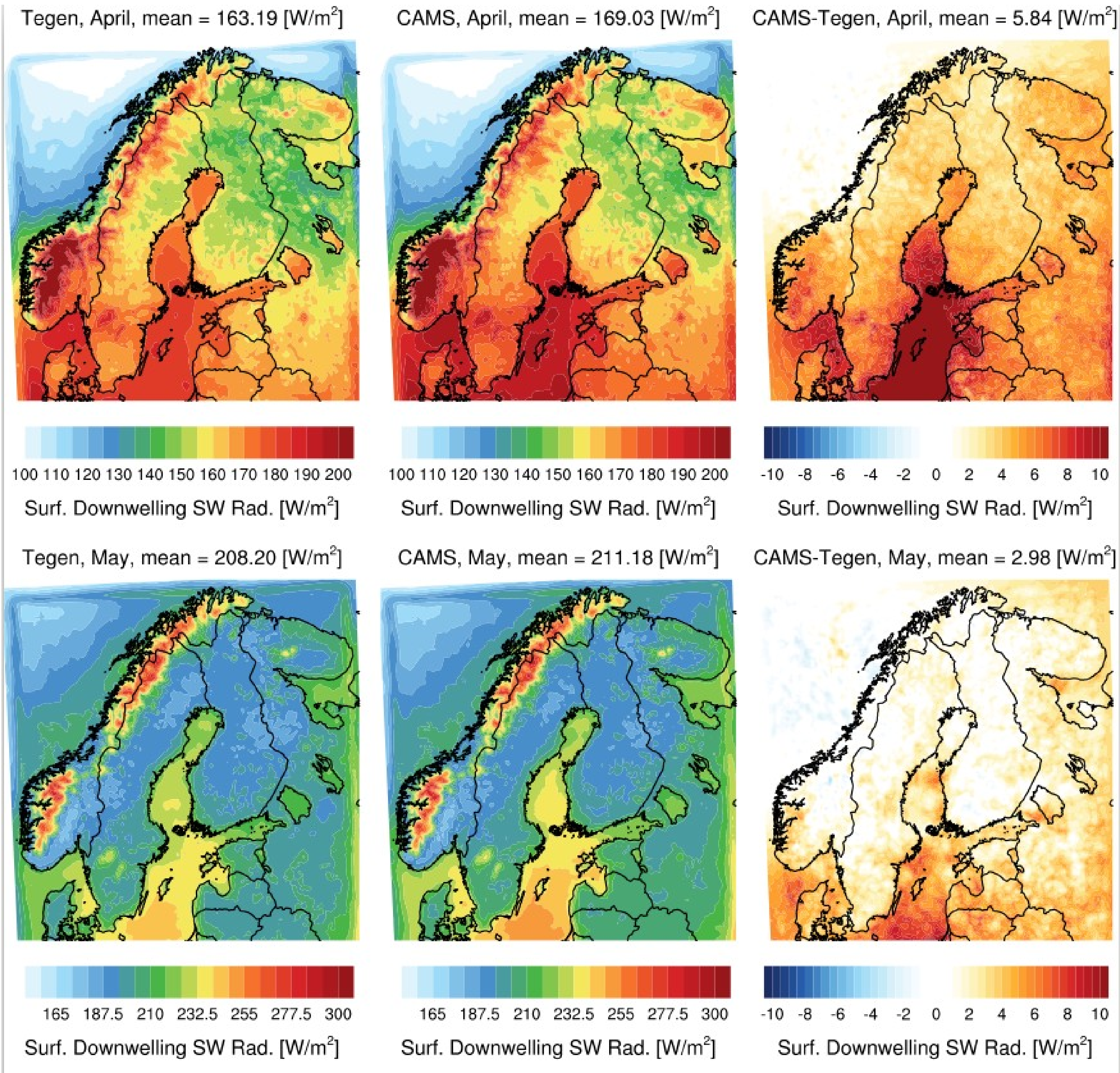
5 (3.5) years of simulation 2011-2015

Hydrostatic ALARO physics

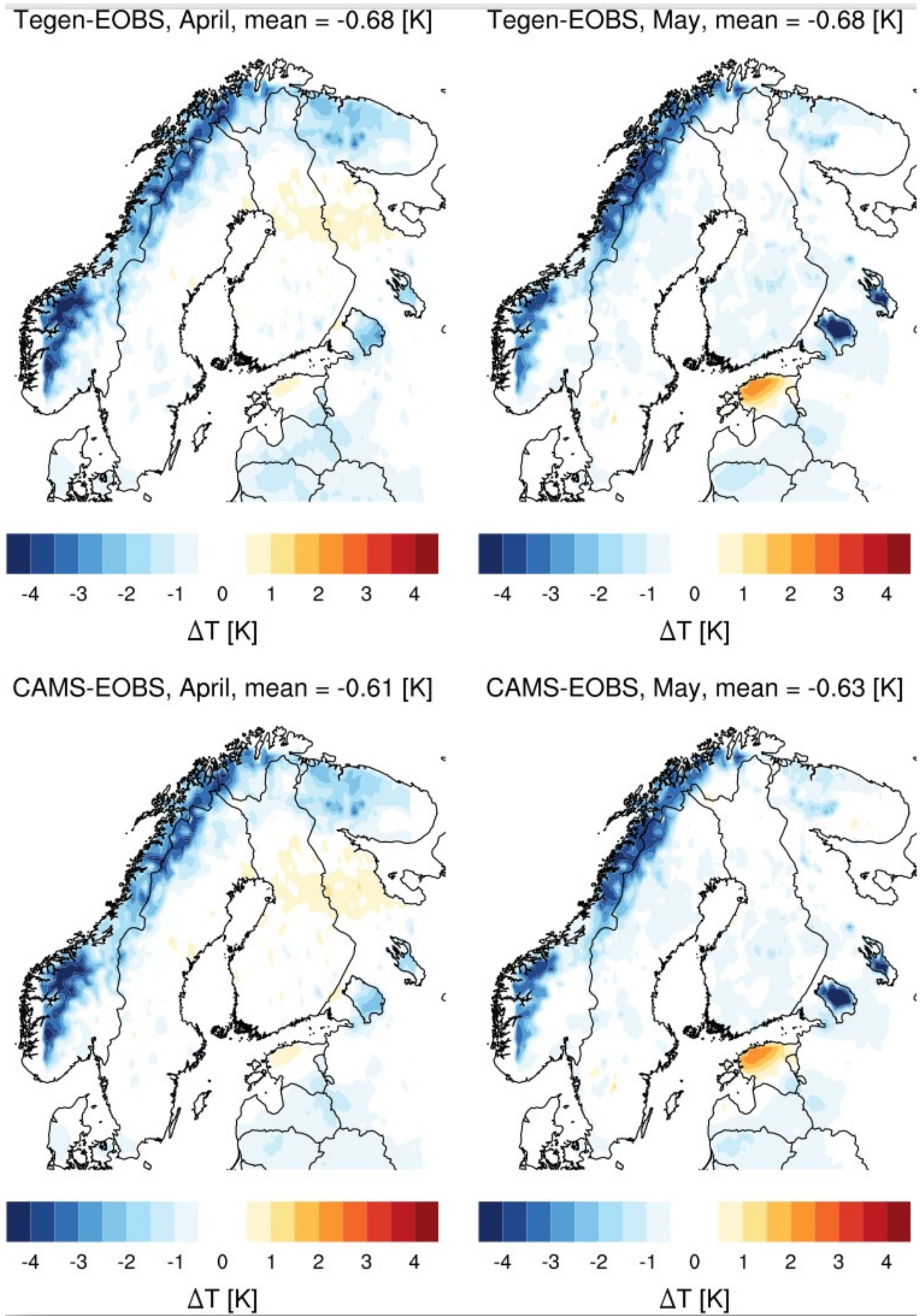
Nordic domain

> Monthly mean results: SWDS, T2m, precipitation





Tegen, April, mean = 163.19 [W/m2]
CAMS, April, mean = 169.03 [W/m2]
CAMS-Tegen, April, mean = 5.84 [W/m2]
100 110 120 130 140 150 160 170 180 190 200
Surf. Downwelling SW Rad. [W/m2]
100 110 120 130 140 150 160 170 180 190 200
Surf. Downwelling SW Rad. [W/m2]
-10 -8 -6 -4 -2 0 2 4 6 8 10
Surf. Downwelling SW Rad. [W/m2]
Tegen, May, mean = 208.20 [W/m2]
CAMS, May, mean = 211.18 [W/m2]
CAMS-Tegen, May, mean = 2.98 [W/m2]
165 187.5 210 232.5 255 277.5 300
Surf. Downwelling SW Rad. [W/m2]
165 187.5 210 232.5 255 277.5 300
Surf. Downwelling SW Rad. [W/m2]
-10 -8 -6 -4 -2 0 2 4 6 8 10
Surf. Downwelling SW Rad. [W/m2]



Summary of the HCLIM test

- Maximum differences of monthly mean SWDS due to different aerosol were ca. 10 Wm-2 over the Baltic Sea in spring
- When compared to observations, T2m and precipitation showed almost no difference between the experiments

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The second step:
update the IOPs and 2D MMR climatology

Read the climatological IOPs and vertically integrated mass mixing ratios for 11 aerosol species

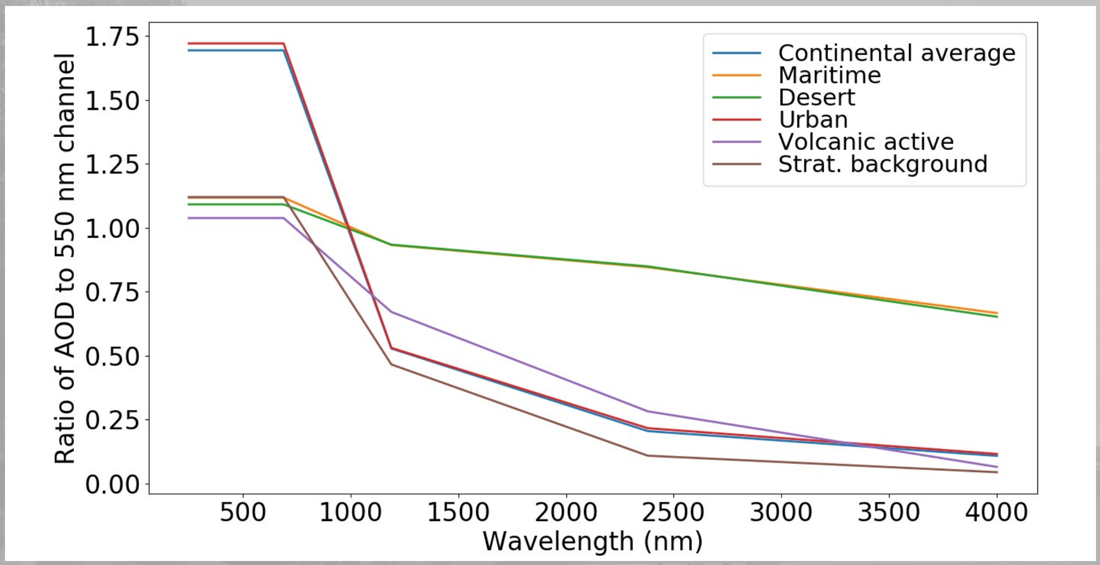
Still use the prescribed vertical distributions

Combine 3D MMR and prognostic humidity fields with prescribed IOPs to obtain AOD, SSA and asymmetry factors of the aerosol mixture as functions of wavelength for each time step

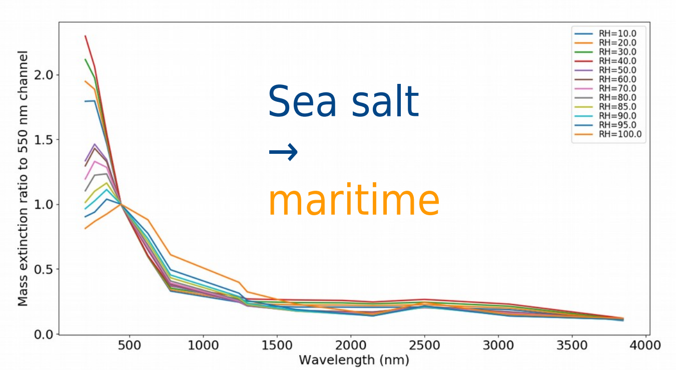
Renew the radiation schemes to use these fields to calculate aerosol transmission at each gridpoint and level

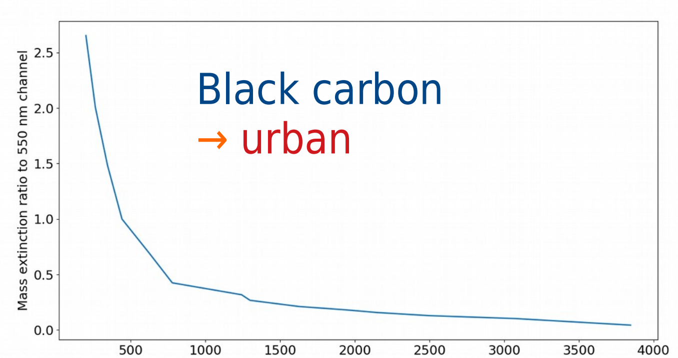
Update the IOPs and 2D MMR climatology

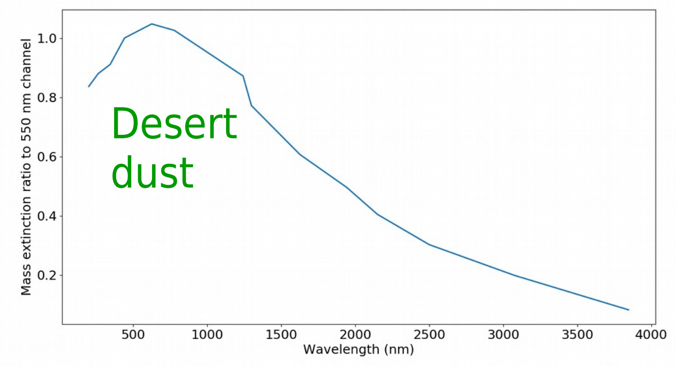
Present predefined AOD / AOD@550

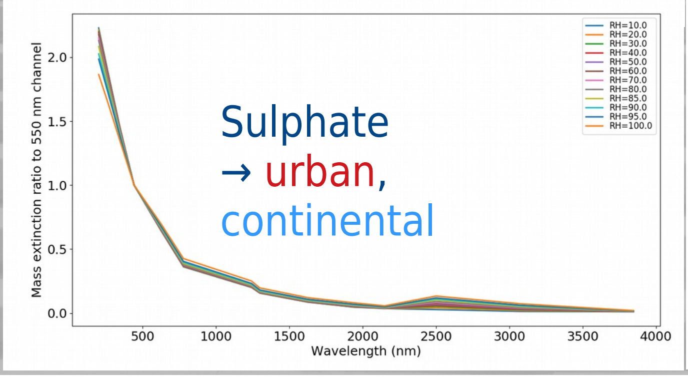


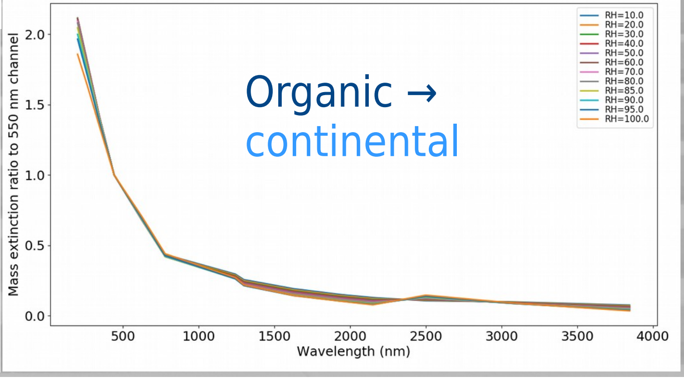
CAMS ME/ME@550









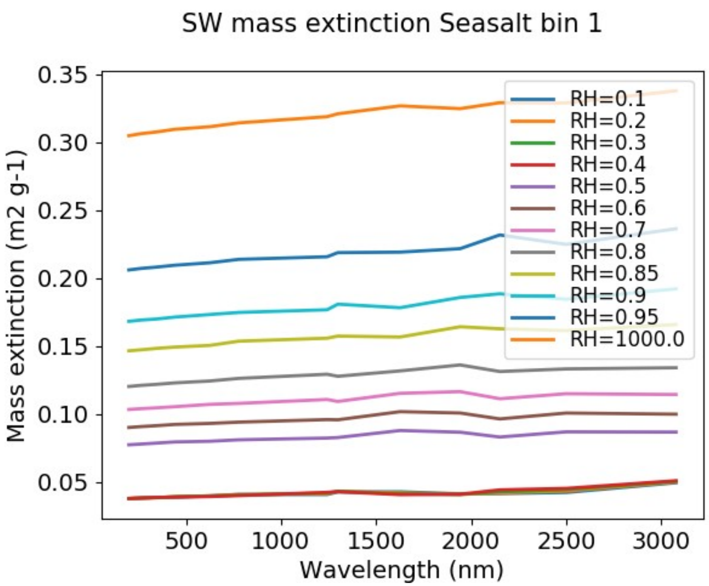


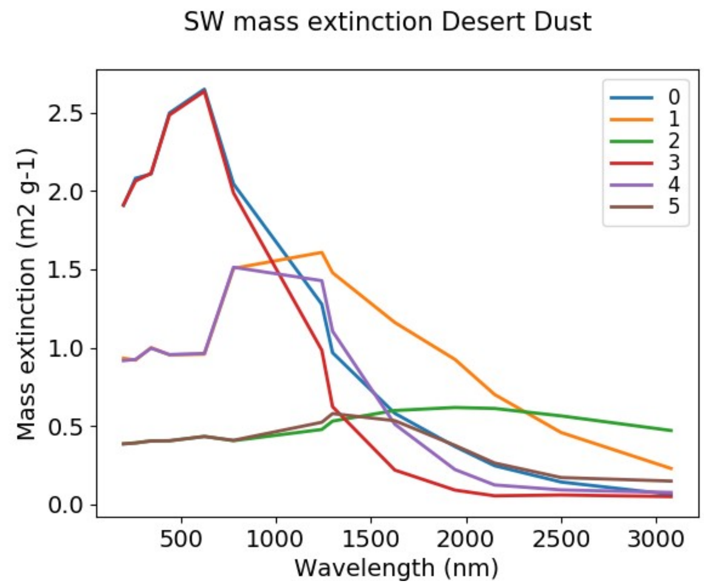
ME=mass extinction,
AOD = ME * MMR

A short-wave example

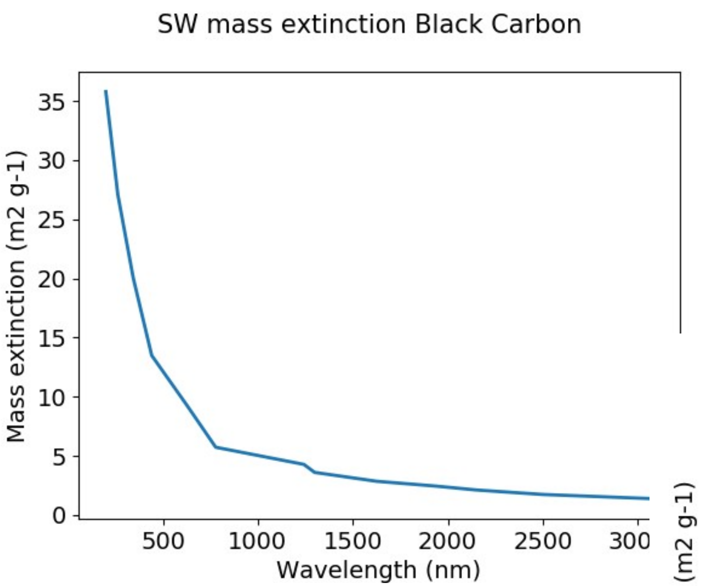
where sea salt and desert dust behave quite differently

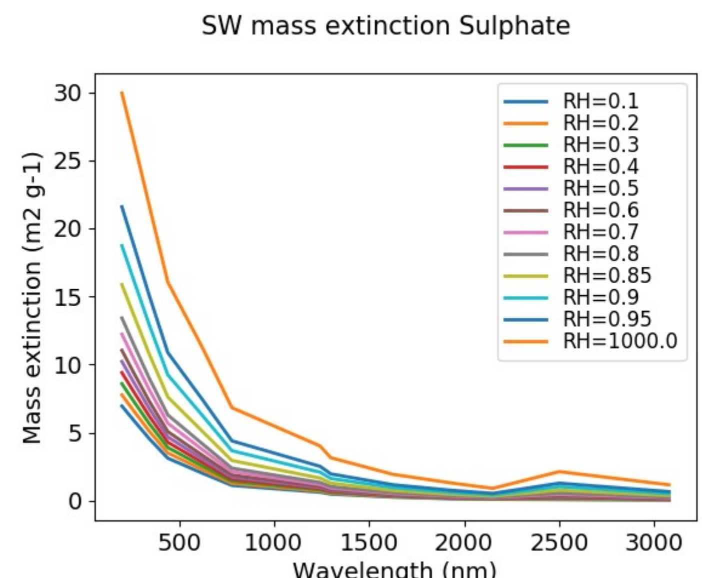
Note the different scales of the y-axis!

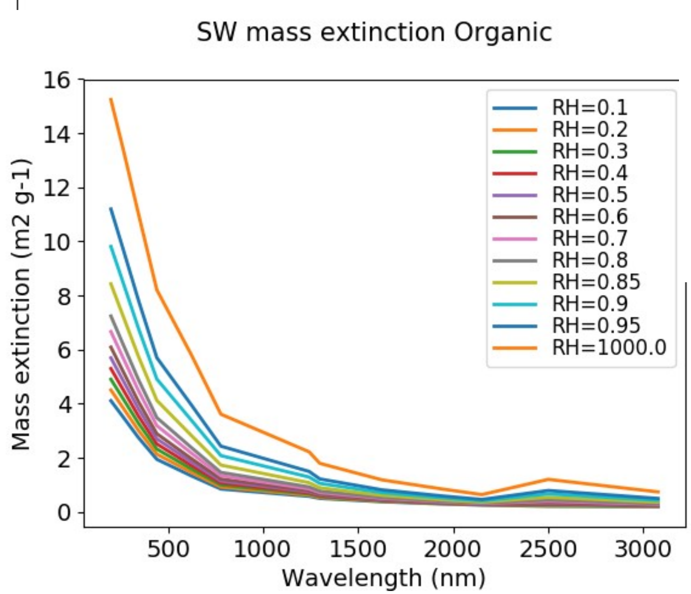




Examples of SW mass extinction coefficients

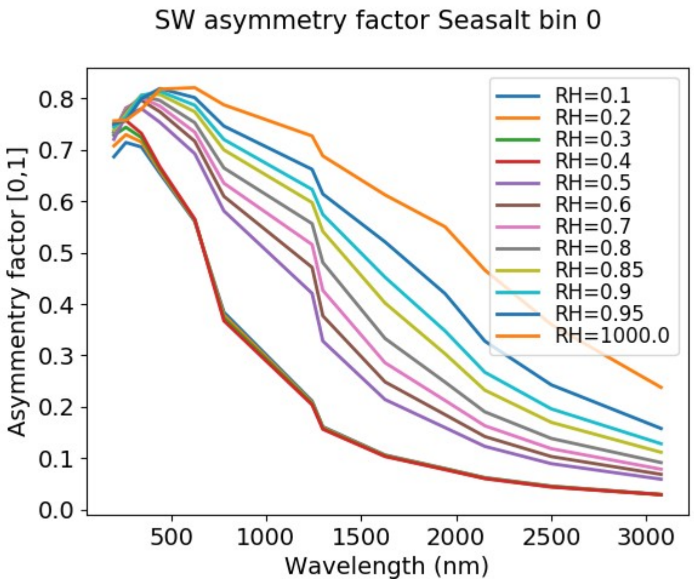


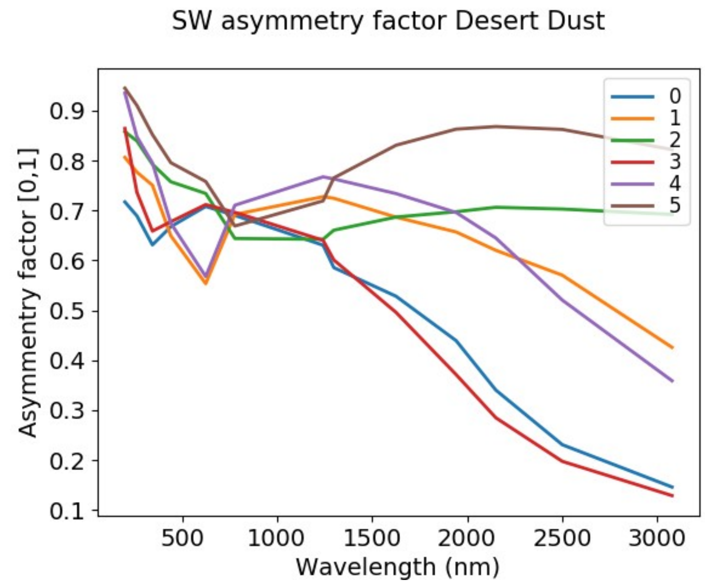


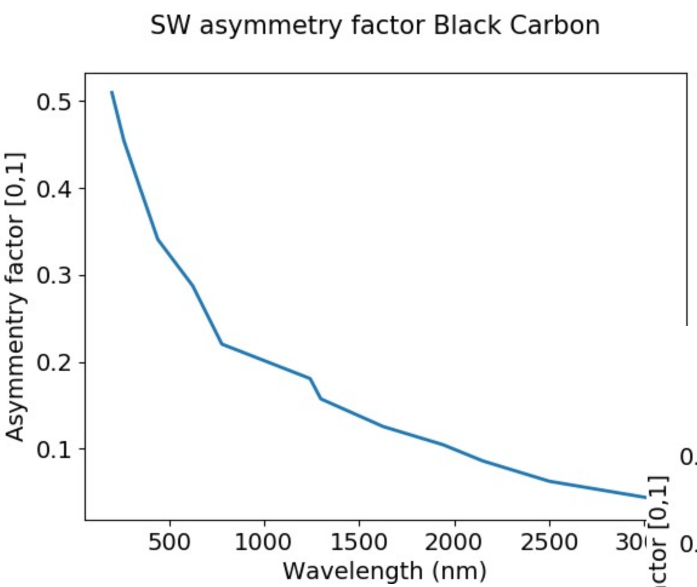


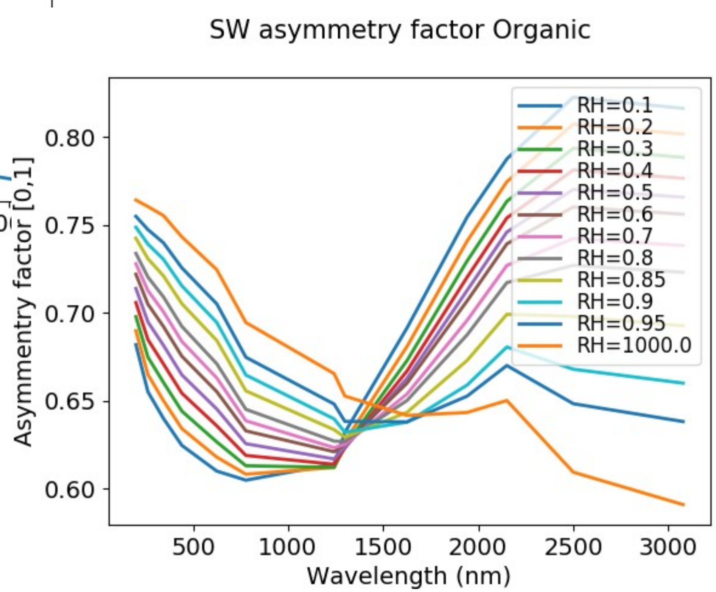
Note the humidity dependencies!

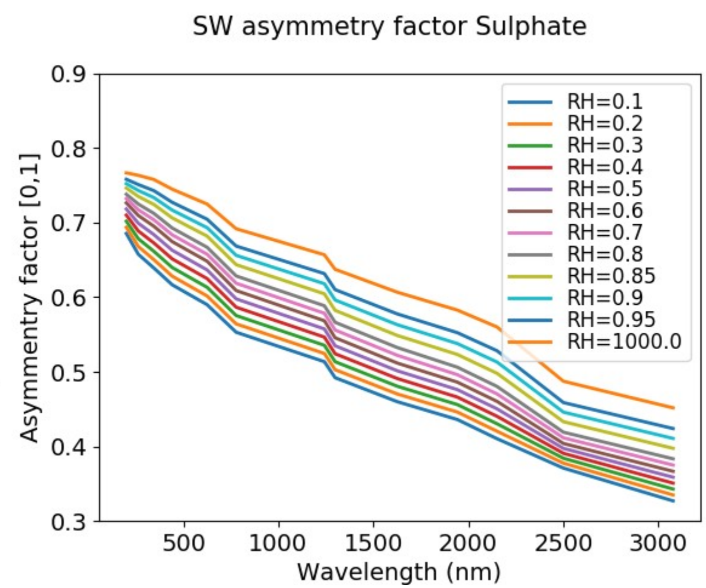
Examples of SW asymmetry factors





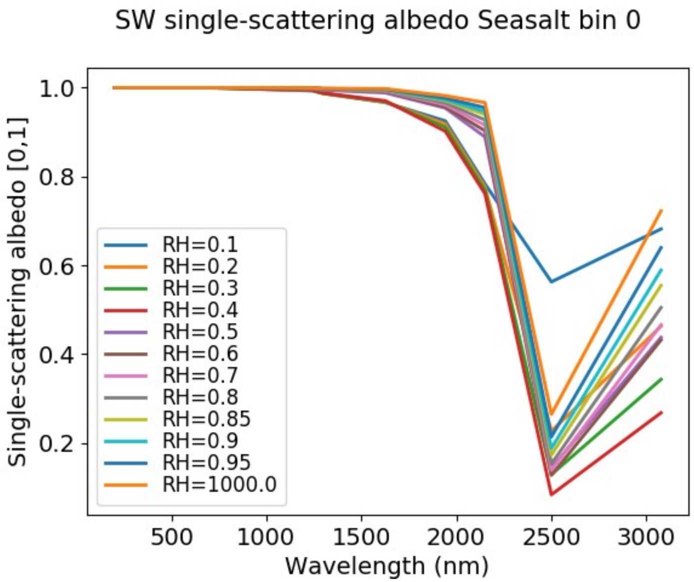


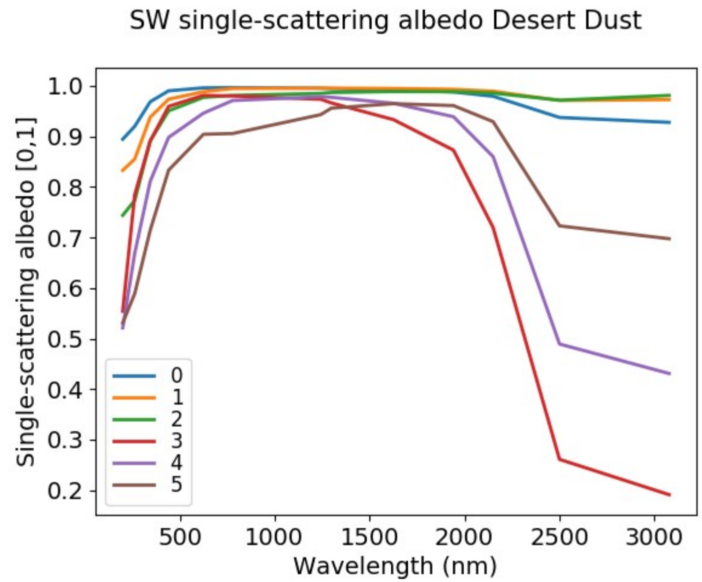


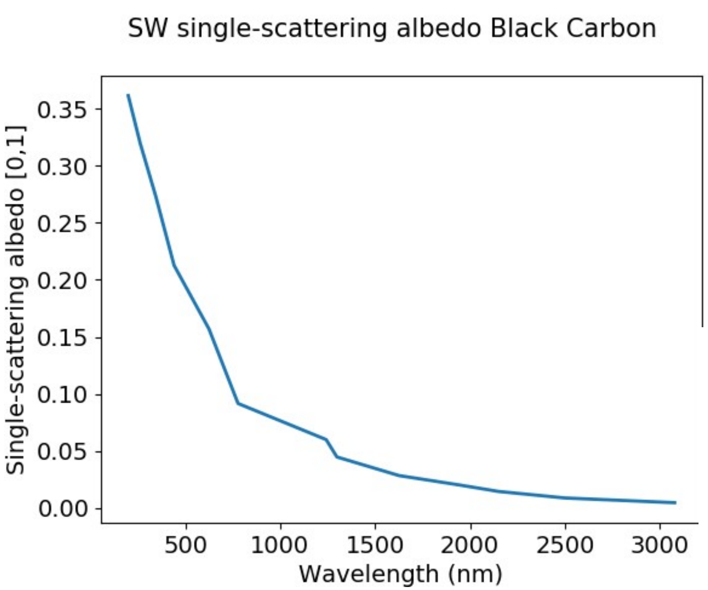


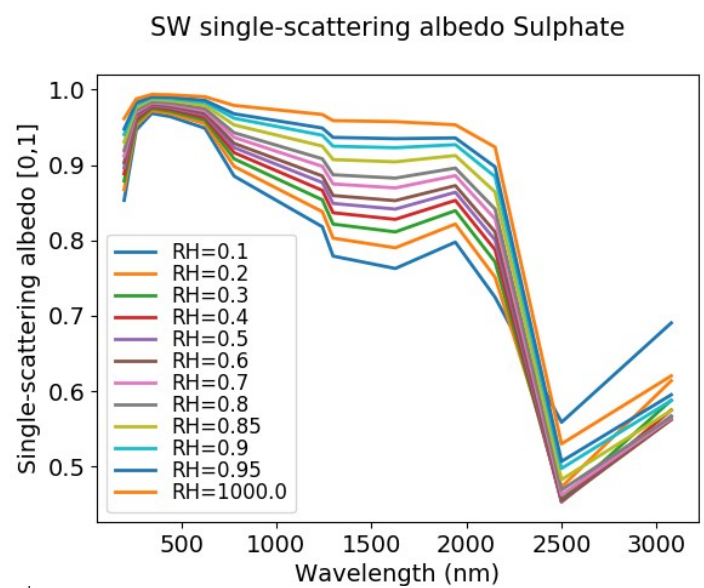
Note the humidity dependencies!

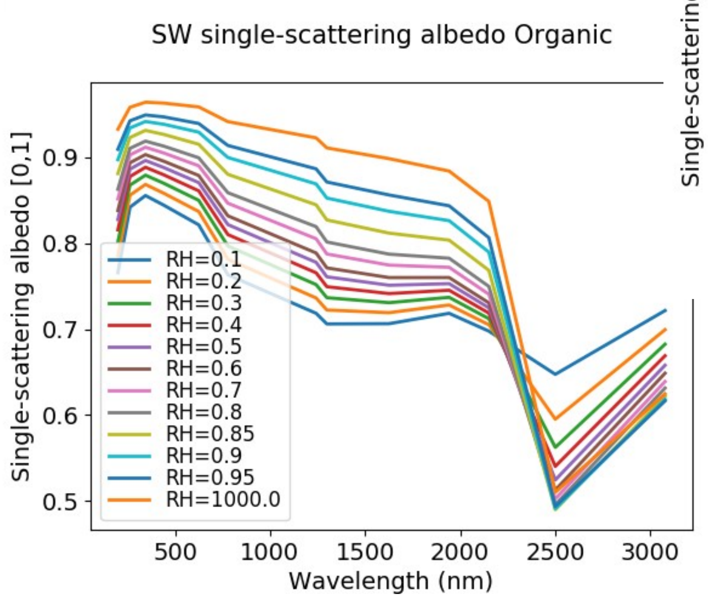
Examples of SW single scattering albedo











Note the humidity dependencies!

Advantages of this approach

1) The same aerosol input for any radiation scheme

2) No need to know the optical properties for different aerosol species inside the radiation schemes

3) Aerosol MMRs might be used by the cloud-precipitation microphysics

4) The same approach is applicable for the use of real-time aerosol both for cloud microphysics and radiation

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Read and use the CAMS aerosol 3D MMR
– skip the prescribed vertical distribution functions

3D climatology of 11(15) species

3D real-time fields of 11(15) species

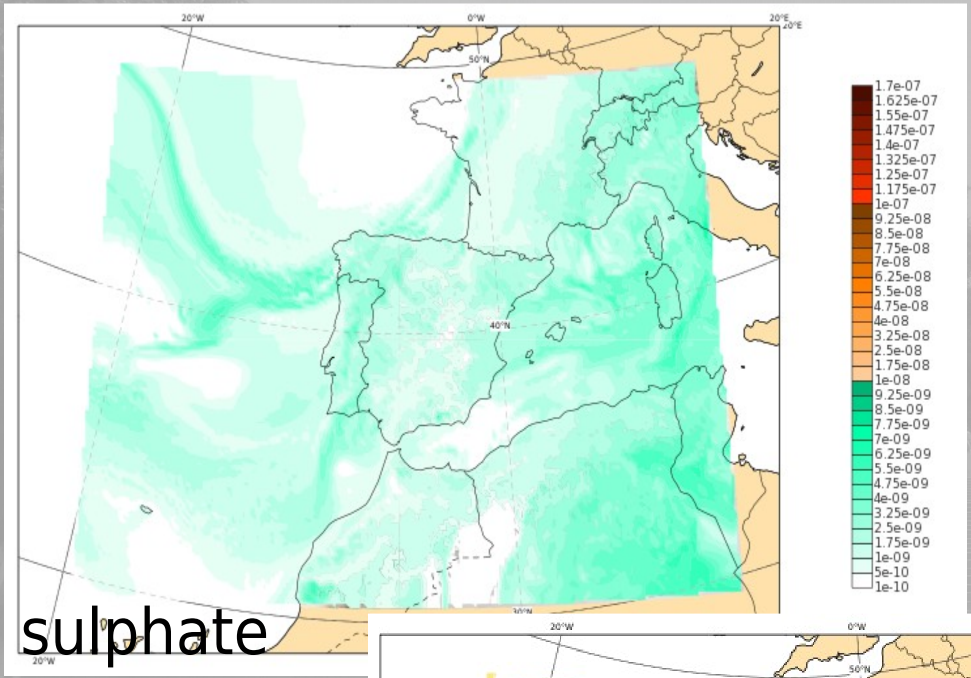
Combine with the optical properties as
with the 2D climatological aerosol MMRs

Real-time fields have been tried already
for the cloud microphysics:

Use of CAMS aerosol fields in near-real time in HARMONIE-AROME model

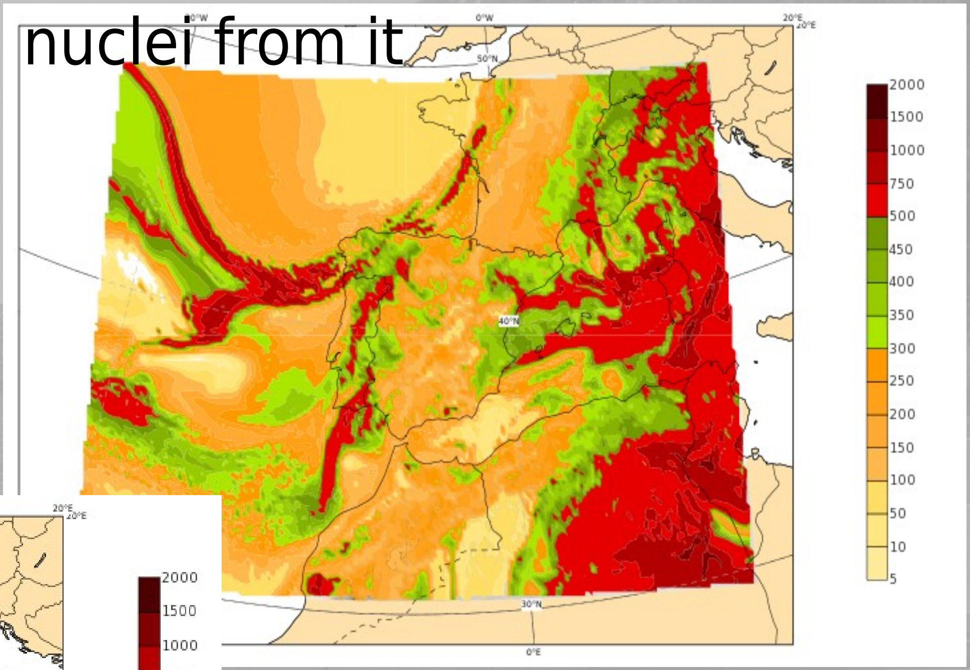
- CAMS sea salt and sulphate MMR have been used in near real time in HARMONIE-AROME to get the number of cloud condensation nuclei (CCN) for the microphysical parametrizations (in the reference version, constant values of the number of CCN are used for sea, land and urban).
- The MMR fields are included in the initial state and boundary conditions obtained from CAMS via IFS model. They are advected by the dynamics of the HARMONIE-AROME model.
- MMR fields are converted to the number of condensation nuclei and, after considering the supersaturation, the number of activated condensation nuclei is obtained.

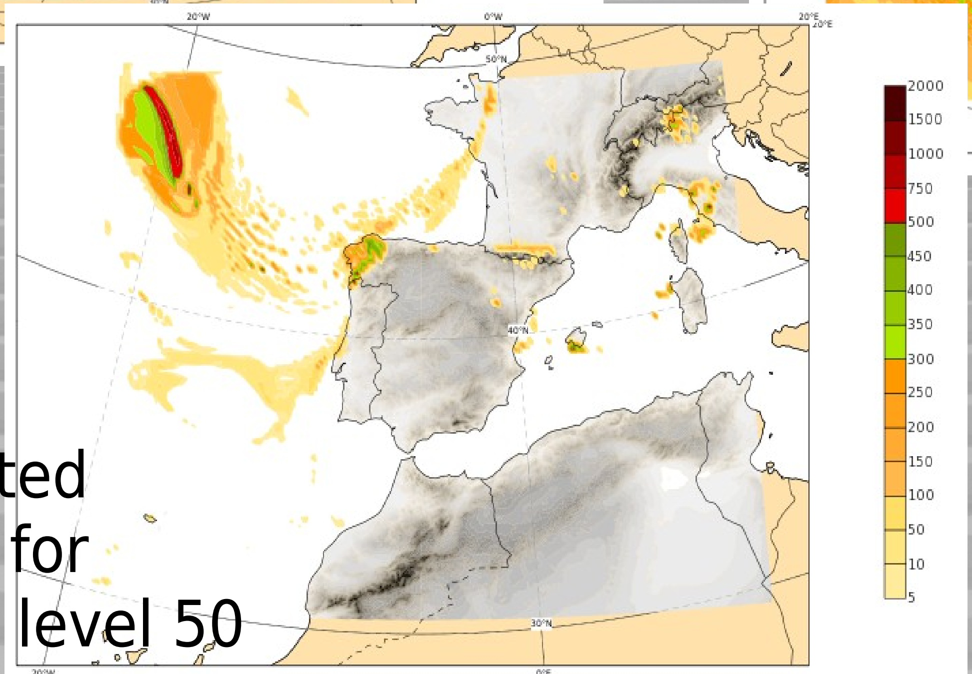
Use of CAMS aerosol fields in near real time in HARMONIE-AROME model



sulphate mixing ratio

condensation nuclei from it





activated nuclei for model level 50

Example of 20170721 HH+24 HARMONIE-AROME v.40h1.1.

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We replaced the old vertically integrated land, sea, desert and urban AOD@550nm by Tegen with CAMS and tried that in a short HARMONIE climate experiment: found a small effect in spring-time SW radiation

We are on the way of replacing the prescribed aerosol IOPs and combining them with the climatological 2D aerosol mass mixing ratio from CAMS, for any radiation scheme

We plan to use 3D climatological or real-time aerosol mixing ratio fields of 11(15) species, combined with the new IOPs. A method to introduce real-time CAMS data has been tried for cloud microphysics parametrizations.


THANK YOU FOR YOUR ATTENTION!