Modification of cloud condensation nuclei in HARMONIE-AROME microphysical parametrization using CAMS outputs

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Modification of cloud condensation nuclei in HARMONIE-AROME microphysical parametrization using CAMS outputs.

Outline:

- Use of condensation nuclei in microphysical parameterizations.
- Obtaining aerosol fields from CAMS (Copernicus Atmosphere Monitoring Service).
- Aerosol fields inside the HARMONIE-AROME:
  - Advection of aerosol fields
  - Calculation of number of condensation nuclei
  - Number of activated condensation nuclei
- Case study.
- Summarize.

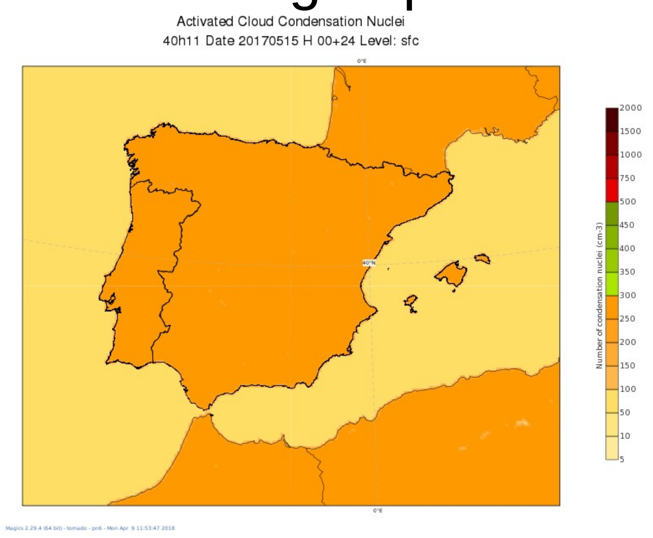
Use of cloud condensation nuclei in the HARMONIE-AROME model

Cycle used: 40h1.1. at the ECMWF

The number of cloud condensation nuclei is used in some microphysical parameterizations (LOCND2 active):

- Autoconversion (cloud droplets → rain droplets)
- Cloud droplet sedimentation.
- Collision of cloud liquid.

Currently the number of cloud condensation nuclei is fixed for every level and depends on whether the grid point is over land (300/cm3) or over sea (100/cm3)



Aerosol fields from CAMS

“The atmospheric composition outputs from the IFS are released as CAMS Global near-real-time data.

As of May 2017 the horizontal resolution of the CAMS Global data is ~40 km (T511L60). Output data is available at a 3-hour intervals.”

Number of levels in the vertical: 60

“The CAMS global forecasting system produces two 5-day forecasts per day, starting from 00 UTC and 12 UTC, respectively”.

- In this table, in red, the aerosol types considered as CCN:
  - 3 sea salt types: Sea salt mixing ratio (aermr01, aermr02, aermr03)
  - sulphate mixing ratio (aermr11)

https://software.ecmwf.int/wiki/display/CKB/What+is+the+IFS

Name	Short Name	Units	Parameter ID
Sea Salt Aerosol (0.03 - 0.5 um) Mixing Ratio	**aermr01**	kg kg-1	210001
Sea Salt Aerosol (0.5 - 5 um) Mixing Ratio	**aermr02**	kg kg-1	210002
Sea Salt Aerosol (5 - 20 um) Mixing Ratio	**aermr03**	kg kg-1	210003
Dust Aerosol (0.03 - 0.55 um) Mixing Ratio	aermr04	kg kg-1	210004
Dust Aerosol (0.55 - 0.9 um) Mixing Ratio	aermr05	kg kg-1	210005
Dust Aerosol (0.9 - 20 um) Mixing Ratio	aermr06	kg kg-1	210006
Hydrophobic Organic Matter Aerosol Mixing Ratio	aermr07	kg kg-1	210007
Hydrophilic Organic Matter Aerosol Mixing Ratio	aermr08	kg kg-1	210008
Hydrophobic Black Carbon Aerosol Mixing Ratio	aermr09	kg kg-1	210009
Hydrophilic Black Carbon Aerosol Mixing Ratio	aermr10	kg kg-1	210010
Sulphate Aerosol Mixing Ratio	**aermr11**	kg kg-1	210011
SO2 precursor mixing ratio	aermr12	kg kg-1	210012
Volcanic ash aerosol mixing ratio	aermr13	kg kg-1	210013
Volcanic sulphate aerosol mixing ratio	aermr14	kg kg-1	210014
Volcanic SO2 precursor mixing ratio	aermr15	kg kg-1	210015

Strategies to obtain Boundary conditions containing aerosol fields

- CAMS
  - Atmospheric, surface and aerosol from CAMS data.
  - Minor modifications of the scripts and code.
  - Less number of vertical levels.
  - Lower horizontal resolution.

- CAMS + HRES IFS
  - Atmospheric and surface paremeters from HRES IFS.

    +

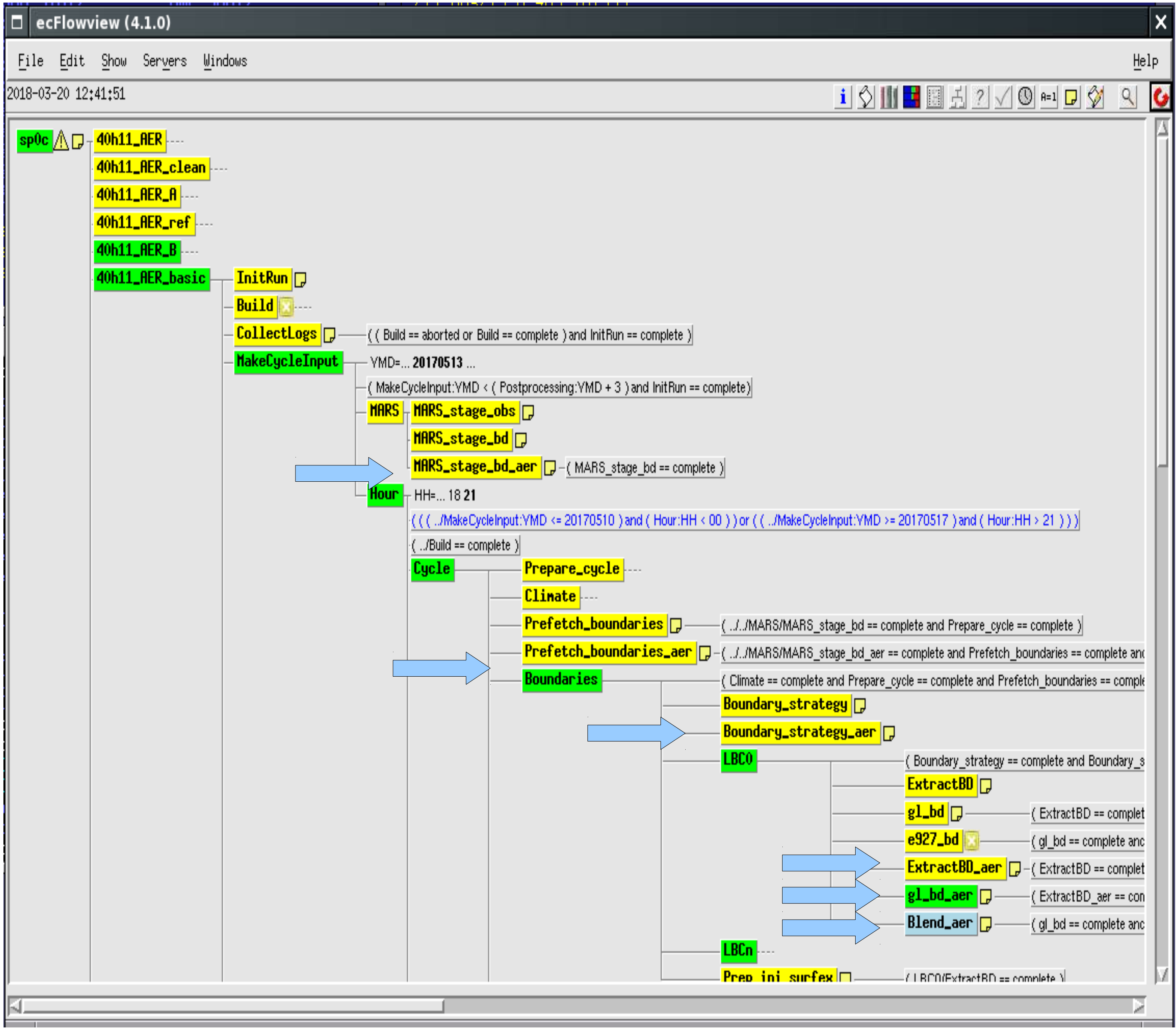
  - Aerosol parameters from CAMS.
  - It is needed to do a blending of fields.

Obtaining aerosol mixing ratio fields from MARS

New scripts have been added to include the aerosol in the boundary files:

- MARS_stage_bd_aer
- Prefetch_boundaries_aer
- Boundary_strategy_aer
- ExtractBD_aer
- gl_bd_aer
- Blend_aer

The last one is in charge of blending the aerosol fields from CAMS with the atmospheric fields from HRES IFS to get the definitive BC files.



Obtaining aerosol mixing ratio fields from MARS

Routines and namelists modified in HARMONIE-AROME

mf_phys.F90

```
   CALL APL_AROME( KBL, KGPCOMP, KST  , KEND   , NPROMA ,&
...
    & PGFL(1,1,YAERO(1)%MP), &
...
```

apl_arome.F90

```
SUBROUTINE APL_AROME ( KBL, KGPCOMP, KIDIA , KFDIA , KLON ,&
...
 & PTKEM   , PAEROM, PEFB1   ,PEFB2  , PEFB3,&
 ...
REAL(KIND=JPRB)   ,INTENT(INOUT) :: PAEROM(KLON,KLEV,NAERO)
...
```

harmonie_namelists.pm

```
NAMGFL=>{
...
  'NAERO' => '4,',
  'YAERO_NL(1)%CNAME' => '\'SEA.SALT1\',',
  'YAERO_NL(1)%IGRBCODE'   => '210001',
  'YAERO_NL(1)%LADV'   => '.TRUE.',
  'YAERO_NL(1)%LGP'   => '.TRUE.',
  'YAERO_NL(1)%LREQOUT' => '.TRUE.',
  'YAERO_NL(1)%LSP'   => '.FALSE.',
  'YAERO_NL(1)%NREQIN'=> '1,',
  'YAERO_NL(2)%CNAME' => '\'SEA.SALT2\',',
  'YAERO_NL(2)%IGRBCODE'   => '210002',
  'YAERO_NL(2)%LADV'   => '.TRUE.',
  'YAERO_NL(2)%LGP'   => '.TRUE.',
  'YAERO_NL(2)%LREQOUT' => '.TRUE.',
  'YAERO_NL(2)%LSP'   => '.FALSE.',
  'YAERO_NL(2)%NREQIN'=> '1,',
  'YAERO_NL(3)%CNAME' => '\'SEA.SALT3\',',
  'YAERO_NL(3)%IGRBCODE'   => '210003',
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  'YAERO_NL(3)%LGP'   => '.TRUE.',
  'YAERO_NL(3)%LREQOUT' => '.TRUE.',
  'YAERO_NL(3)%LSP'   => '.FALSE.',
  'YAERO_NL(3)%NREQIN'=> '1,',
  'YAERO_NL(4)%CNAME' => '\'SULPHATE\',',
  'YAERO_NL(4)%IGRBCODE'   => '210011',
  'YAERO_NL(4)%LADV'   => '.TRUE.',
  'YAERO_NL(4)%LGP'   => '.TRUE.',
  'YAERO_NL(4)%LREQOUT' => '.TRUE.',
  'YAERO_NL(4)%LSP'   => '.FALSE.',
  'YAERO_NL(4)%NREQIN'=> '1,',
 },
```

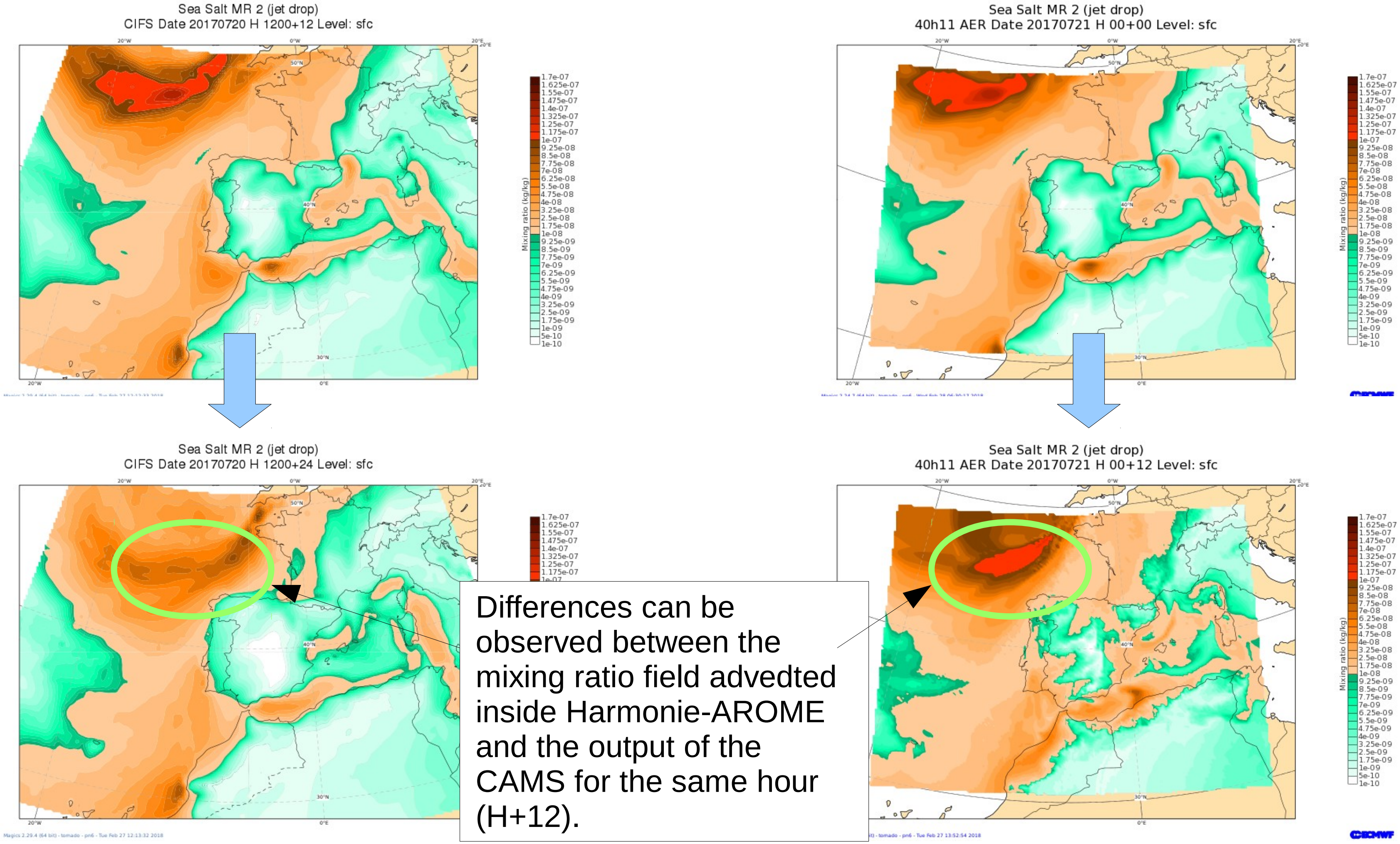
Advection of mixing ratio fields in HARMONIE-AROME

Sea salt mixing ratio (jet drop) Maximum mixing ratio in the column over every grid point.

Left: Boundary condition from **CAMS**

Right: Analysis for **HARMONIE-AROME**

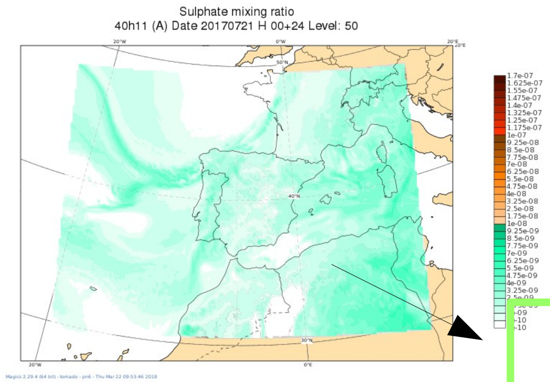
(no sources or sinks, ONLY ADVECTION)



Differences can be observed between the mixing ratio field advedted inside Harmonie-AROME and the output of the CAMS for the same hour (H+12).

Number of condensation nuclei

Mixing ratio of aerosol type

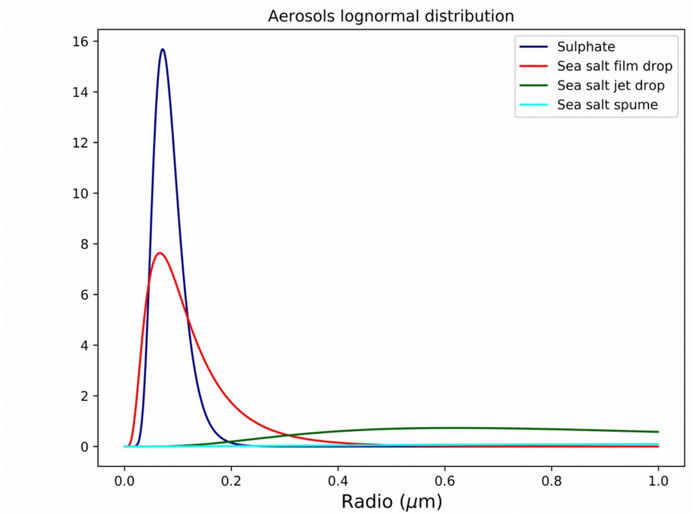


* Density of aerosol particle
* Mean cubic radius of aerosol paricle.

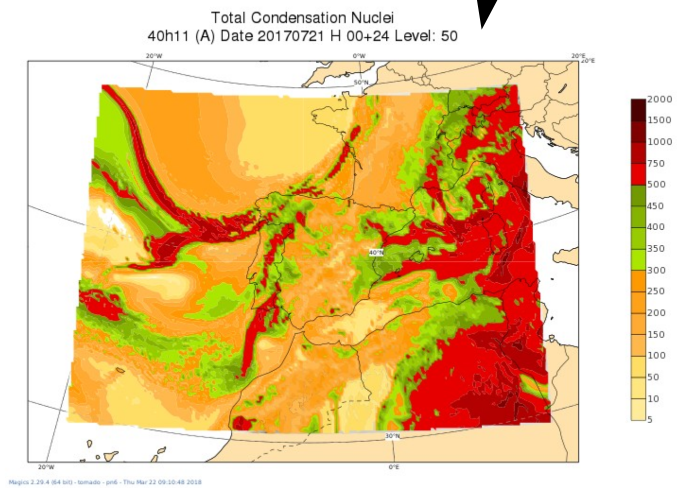
Log-normal size distribution.

Mixing ratio formula

$$Q_s = \frac{\rho_s}{\rho_{air}} = \frac{N_s}{V} \frac{4\pi}{3} \mu_s \langle r_s^3 \rangle \frac{1}{\rho_{air}}$$



Number of condensation nuclei per volume



	Density (kg m-3)	Rg (µm)	Sigma,σ	Mean cubic r. (m-3)
Sea salt 1	1182	0,1	1,9	6,39E-021
Sea salt 2	1182	1	2	8,69E-018
Sea salt 3	1182	6	3	4,93E-014
Sulphate	1600	0,08	1,4	8,52E-022

Ghan et al., 1998 & Mocrette et al., 2009

Number of activated condensation nuclei. Sea Salt

- With the parameters used for the size distribution, the sea salt concentration number seems to be too low.

  https://software.ecmwf.int/wiki/display/CKB/CAMS+global+sea+salt+aerosol+mixing+ratios

  - *"Prognostic aerosols of sea salt are described using three size bins. For sea-salt, radius bin limits are at 0.03, 0.5, 5 and 20 microns.."*
  - *"..., that the reported sea salt mixing ratios are for 80% relative humidity. To transform the provided values back to dry matter a reduction factor of 4.3 is needed for the mass mixing ratios and a reduction factor of 1.99 for the radii of the sea salt bin limits."*

- The density used in the production of sea salt is calculated asuming a 80% relative humidity and it's equal to 1182 Kg m-3 (Mocrette et al., 2009) While the density used for the sea salt for the dry particles is 2160 Kg m-3.

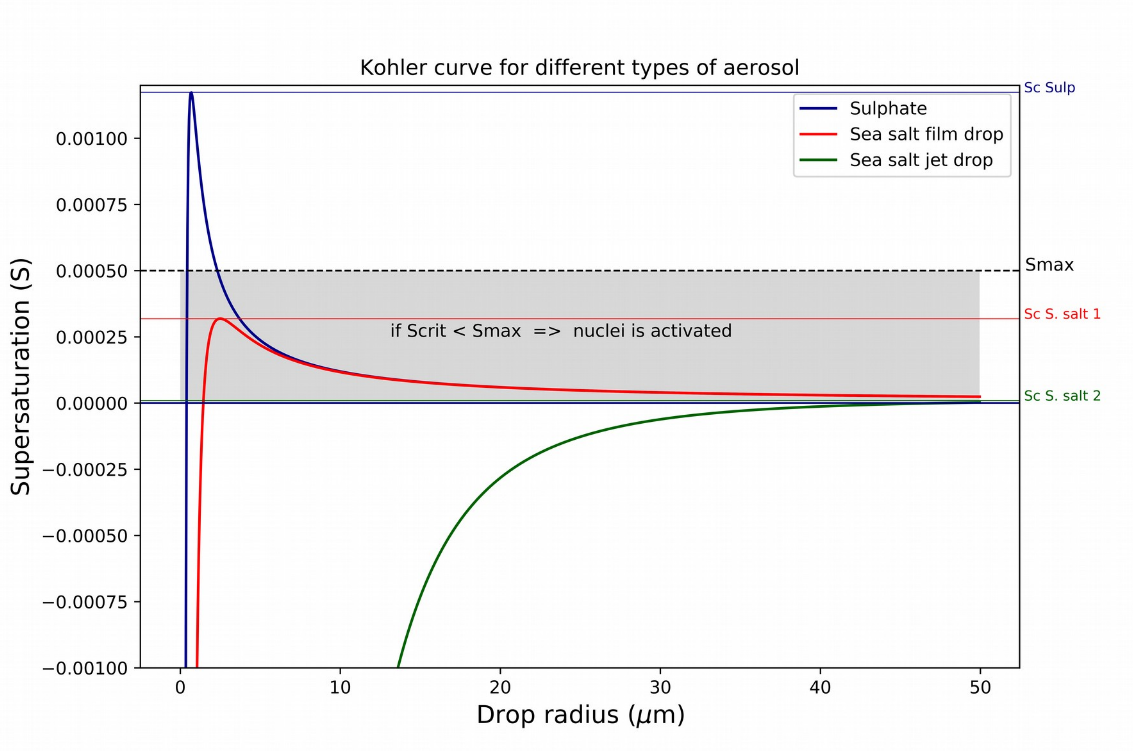
- Which are the correct parameters for the log-normal size distribution?

When is a condensation nuclei activated

We need to know the activated nuclei.

In order to obtain the CCN activation, for simplicity, an alternative to the Twomey approximation is going to be used.

The kohler curve gives a relationship between the supersaturation and the size of the drop depending on the characteristics of the aerosol.

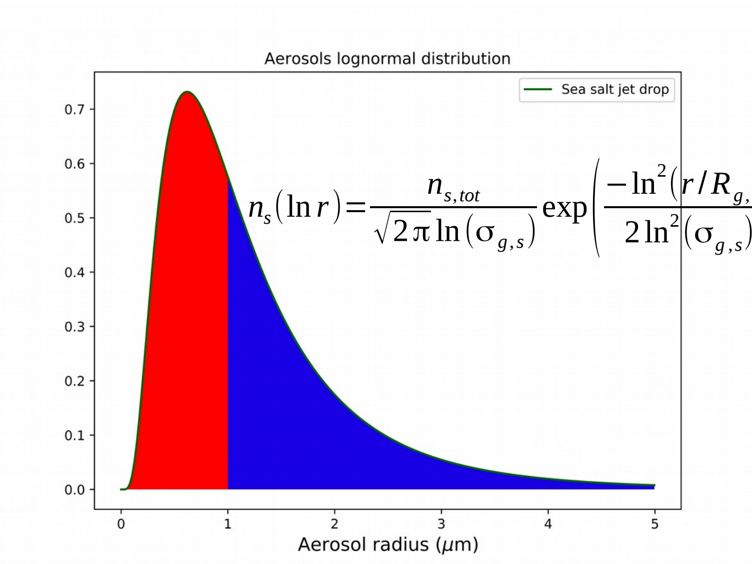


The maximum supersaturation is going to give us a limit to determine the activated condensation nuclei

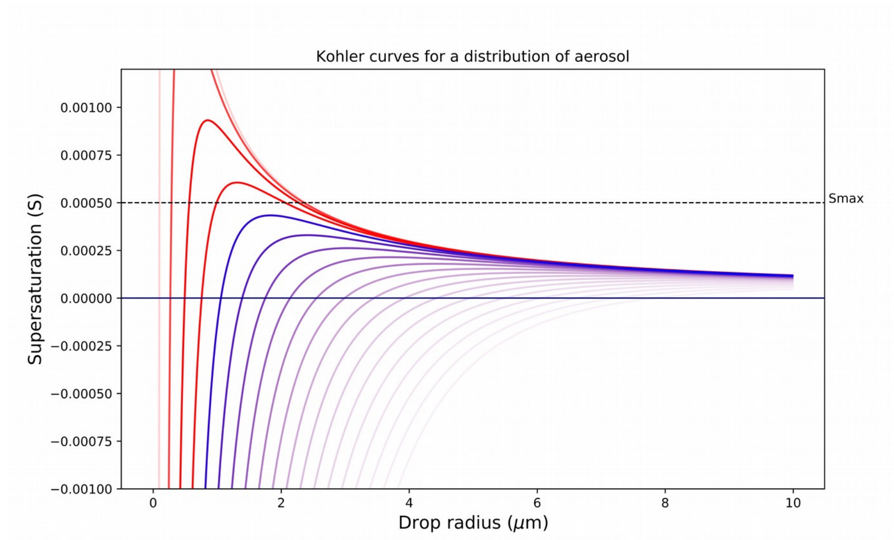
Those aerosol whose critical supersaturation is lower than the supersaturation maximun are considered activated.

"*Sea salt particles are typically larger than sulfate particles and hence are activated as CCN at lower supersaturations*". (Ghan et al., 1998)

Number of Activated condensation nuclei.



$$n_s(\ln r)=\frac{n_{s,tot}}{\sqrt{2\pi}\ln(\sigma_{g,s})}\exp\left(\frac{-\ln^2(r/R_{g,s})}{2\ln^2(\sigma_{g,s})}\right)$$



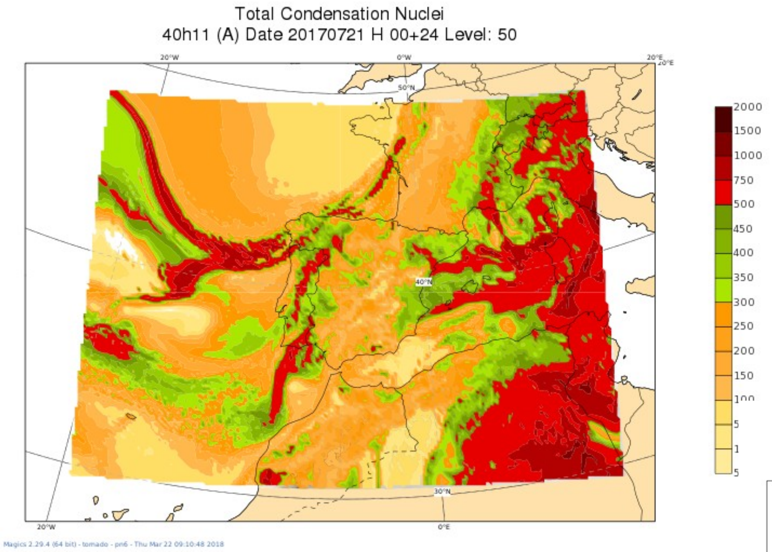
$$n_{s,act}=\int_{r_{s,Smax}}^{\infty} n_s(\ln r)\frac{dr}{r}=\frac{n_{s,tot}}{2}[1-erf\left(\frac{\ln(r_{s,Smax}/R_{g,s})}{\sqrt{2}\ln(\sigma_{g,s})}\right)]$$

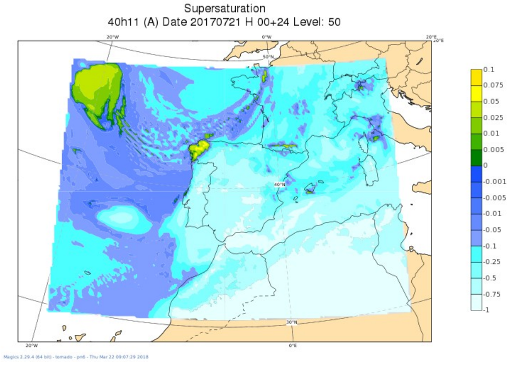
$$r^3_{s,Smax}=\frac{4a^3}{27(S_{max}-1)^2}\frac{\rho_w}{M_w}\frac{M_s}{\nu_s\rho_s}$$

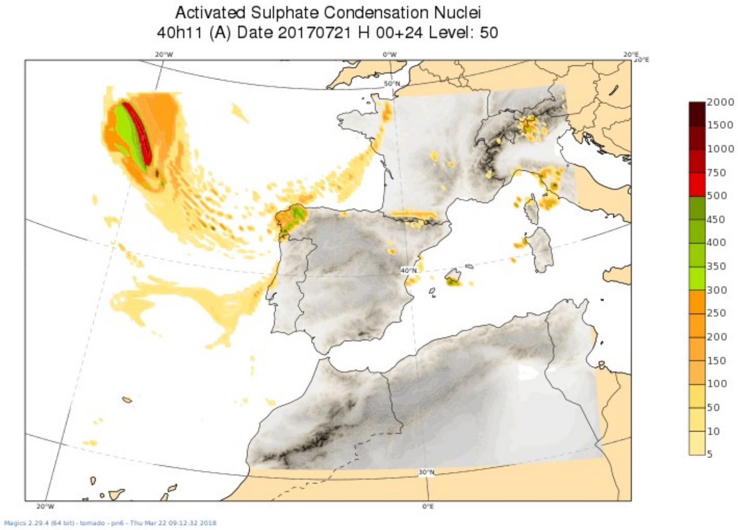
$$a=\frac{2M_w\sigma_{w/a}}{RT\rho_w}\approx\frac{3.3\times10^{-5}}{T}$$

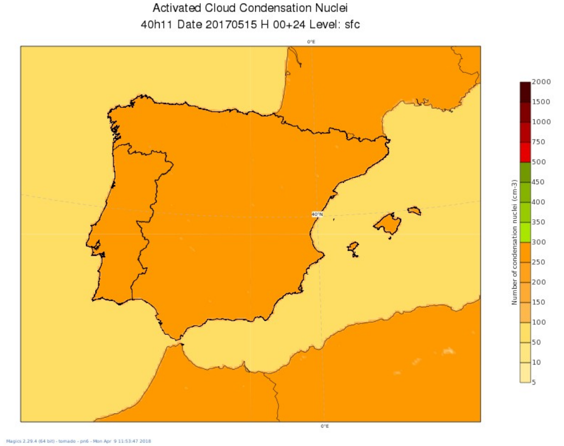
The number of activated condensation nuclei will be given by integrating of the aerosol size distribution for particles with radius bigger than the one whose critical saturation is equal to the saturation maximum.

Number of Activated condensation nuclei







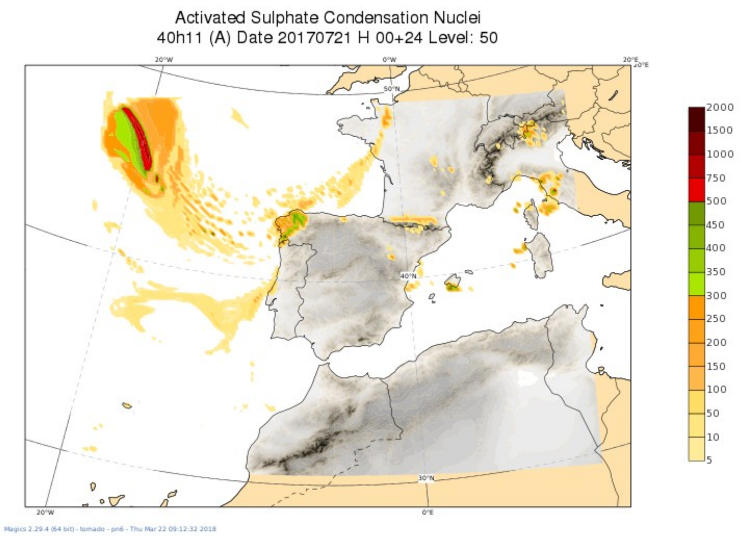


Supersaturation parameter obtain from the model variables

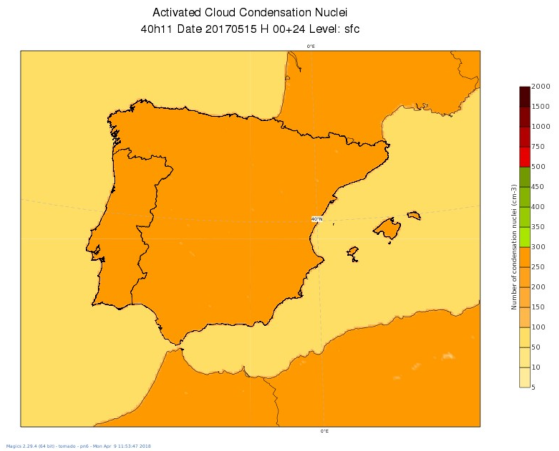
$$S_{max} = \frac{(r_v + r_c / clf) * P}{\varepsilon e_s}$$

Number of Activated condensation nuclei

Concentration number of activated condensation nuclei from sulphate for level 50 when the aerosol mixing ratio is taken from CAMS outputs.



Total concentration number of activated condensation nuclei for every level considered originally in the microphysical parametrizations in HARMONIE-AROME



Number of activated condensation nuclei

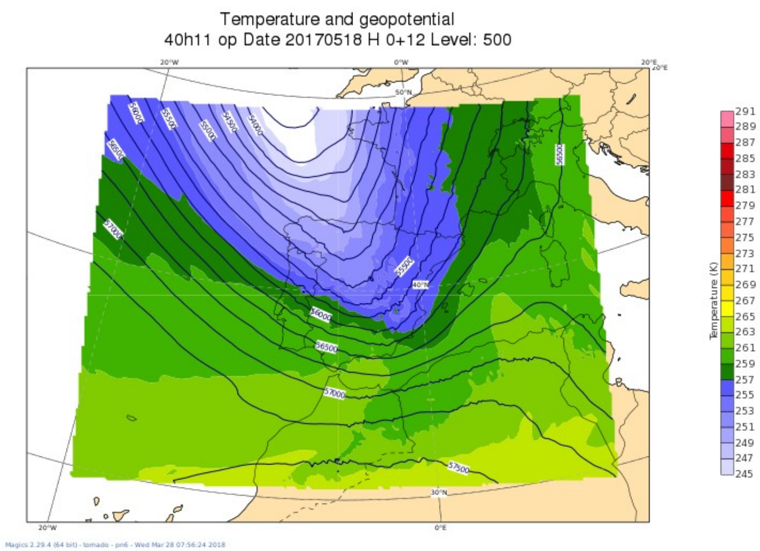
The modifications involved in the calculation of the concentration number of activated nuclei had been include in the routine rain_ice.F90.

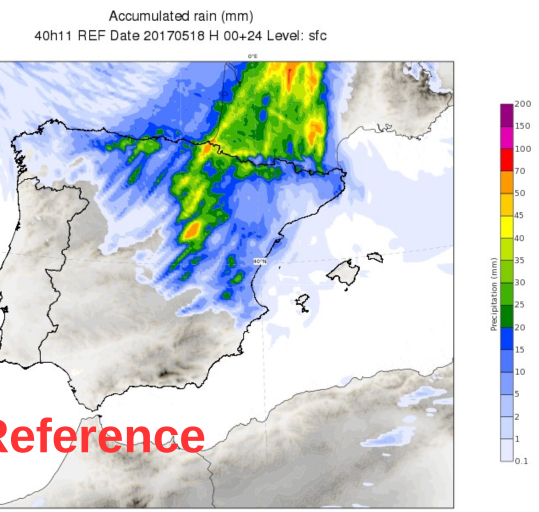
The parametrizations afected are: Autoconversion (cloud droplets → rain droplets), Cloud droplet sedimentation and Collision of cloud liquid, so there won't be siginificant changes in the forecast.

The cloud droplet sedimentation distinguish between sea and land giving a different size distribution to the droplets depending on whether the grid point is over sea or ever land for the droplet velocity. This distintion has been kept.

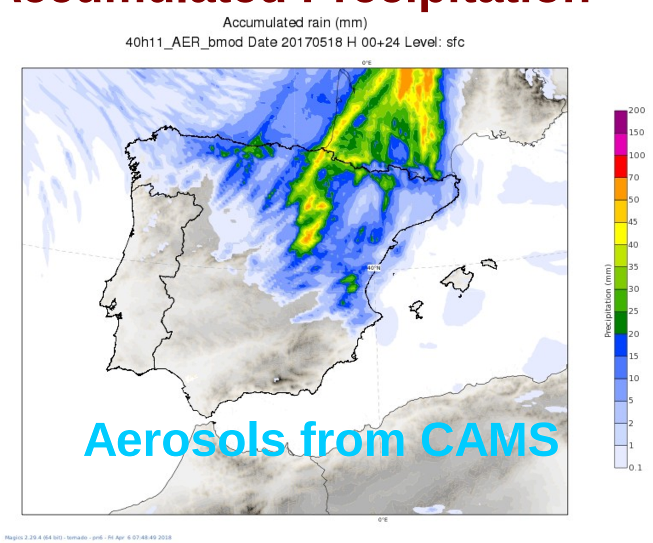
Case study. 20170518.

- The Iberian peninsula is under the influence of a through.
- Precipitation in the north east of the peninsula.
- Two HARMONIE-AROME Experiments:
  - **REF.** (not modified) & **Aerosol from CAMS**





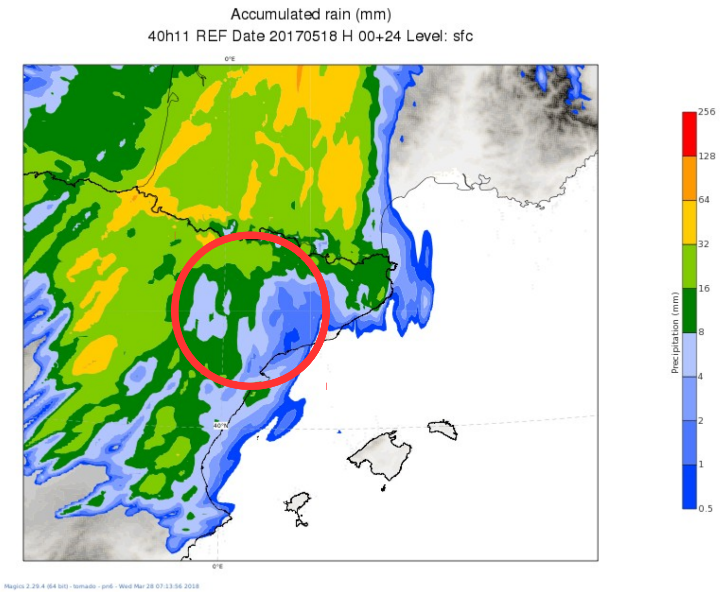
24h Accumulated Precipitation



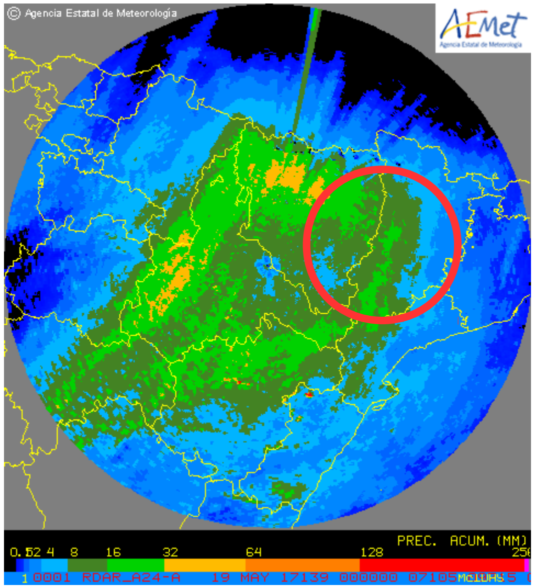
24h accumulated precipitation:

- the light precipitation over the Mediterranean sea is reduced when the aerosols from CAMS are introduced.
- There are some differences in the features of the precipitation and the intensity of the maxima seems to decrease, although not everywhere.

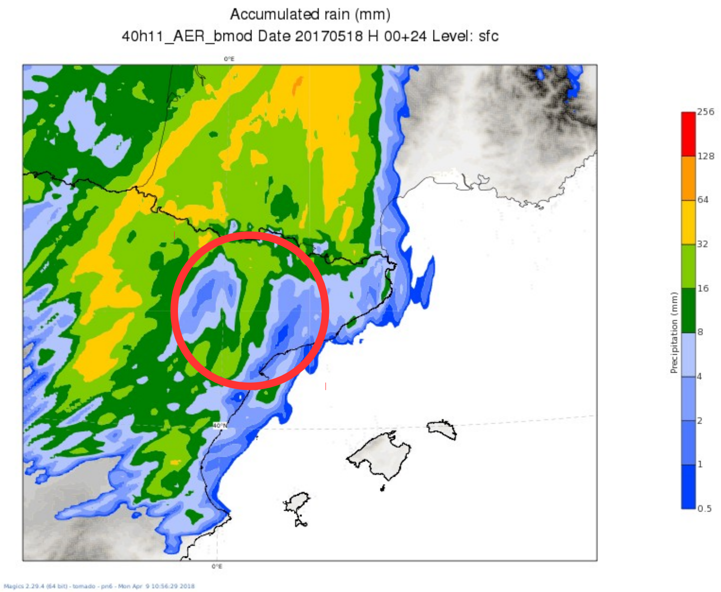
Case study. 20170518.



REFERENCE



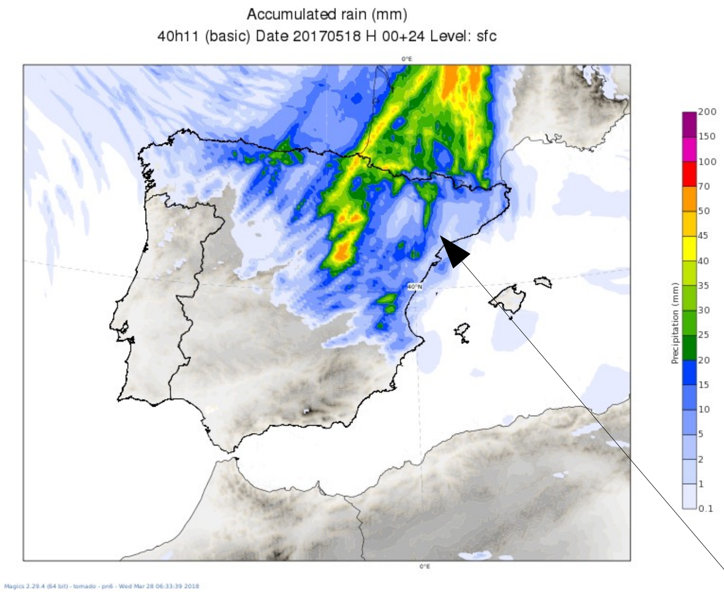
RADAR. ZARAGOZA



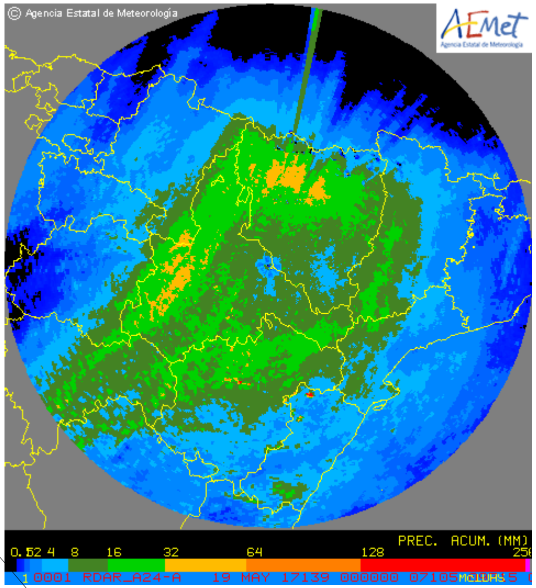
Condensation Nuclei

- 24 H accumulated rain compared with that from RADAR observation.
- In the north east. Radar of Zaragoza.
- There is a band of precipitation that is higher when the condensation nuclei are modified with CAMS data and agrees better with Radar.

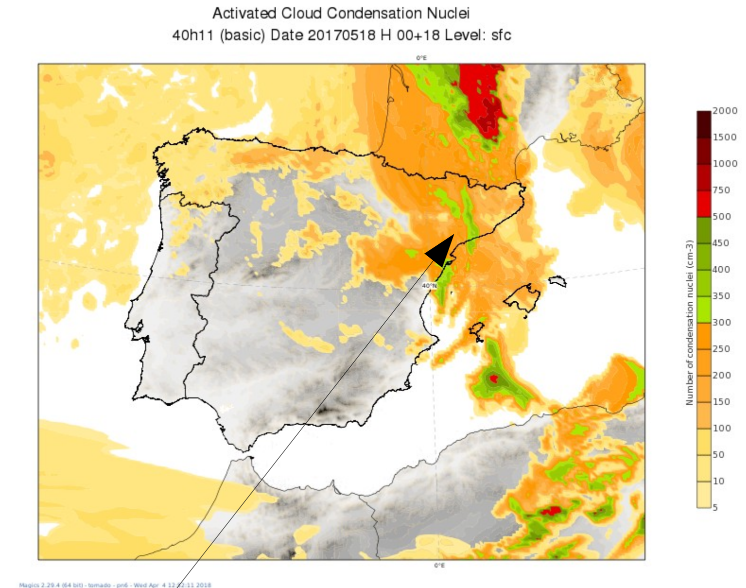
Case study. 20170518.



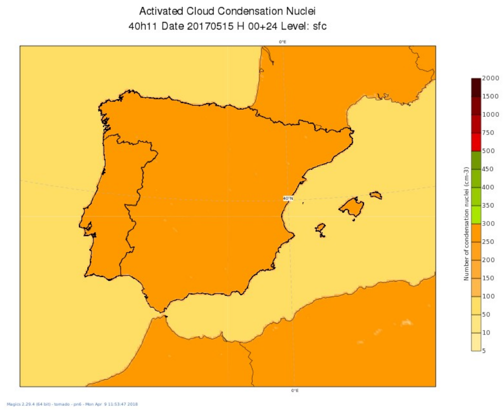
Aerosol from CAMS



RADAR. ZARAGOZA

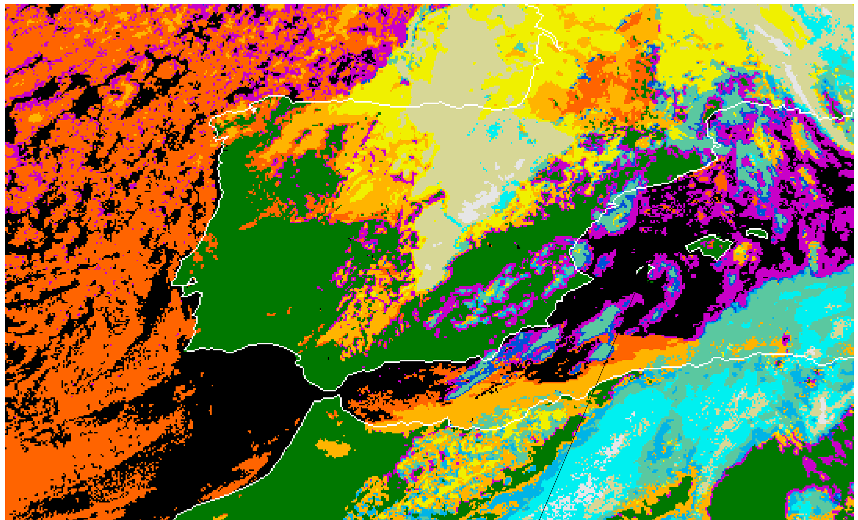


Activated Condensation Nuclei

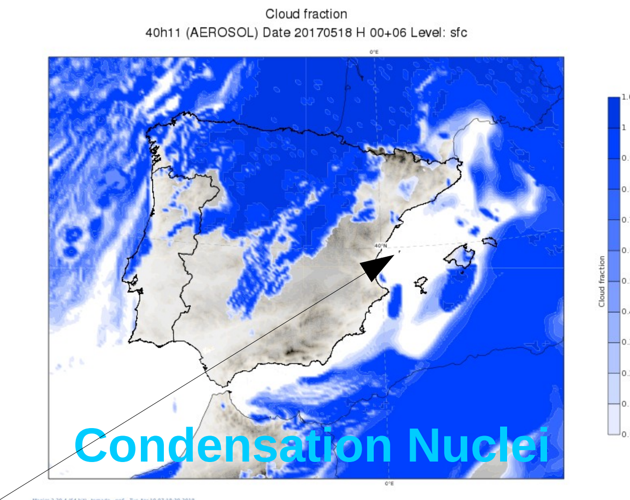


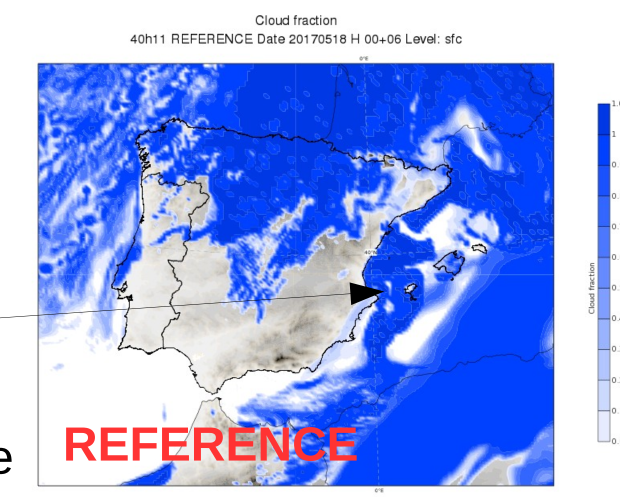
- On the right hand size the maximum number of activated condensation nuclei in the vertical.
- Around H+18, the hour when the maximum of precipitation occured it can be distinguish a band of higher concentration number of activated nuclei (in green) Is it the cause of the differences in the accumulated precipitation?

Case study. 20170518.



Cloud Types from NWC SAF:
2017051806

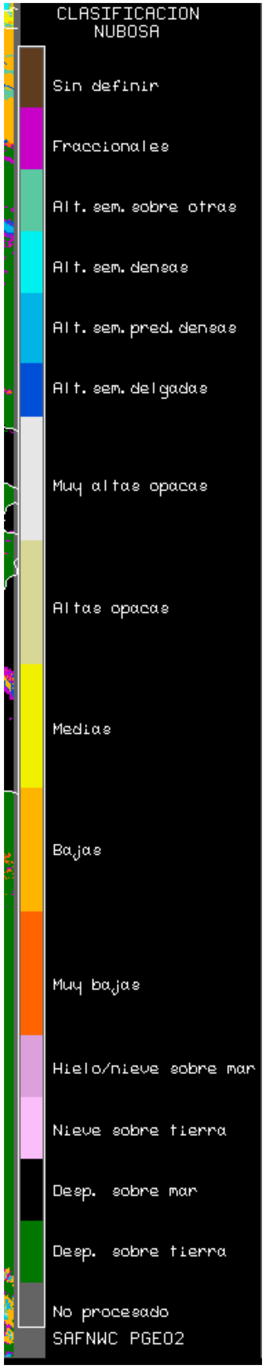


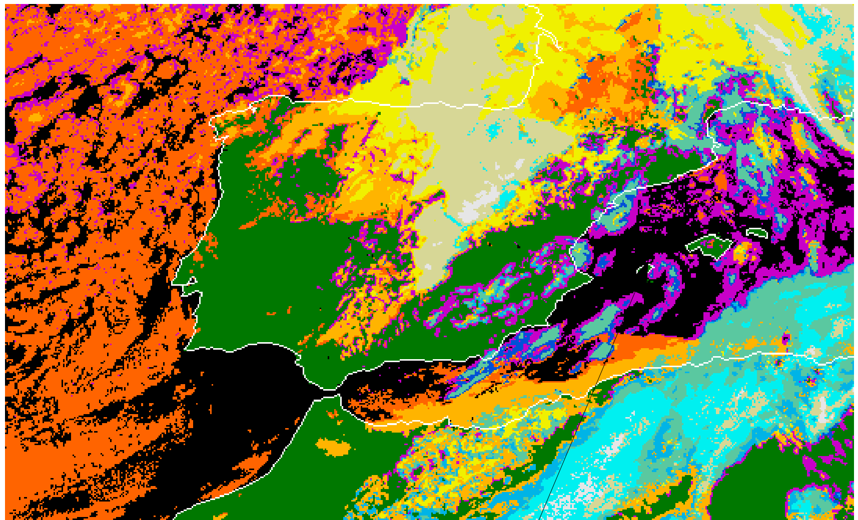


- Cloud fraction. Clouds over the mediterranean are not formed when the aerosol from CAMS are considered.
- In the satellite image only a few high clouds appear in that area (light blue).

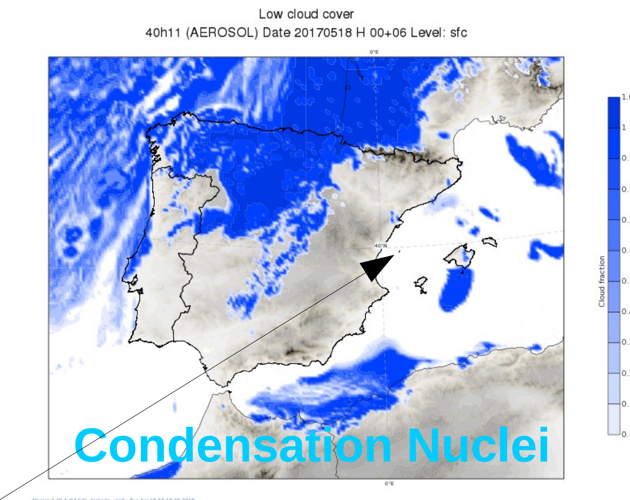
The EUMETSAT Network of Satellite Application Facilities
NWC SAF
Support to Nowcasting and Very Short Range Forecasting

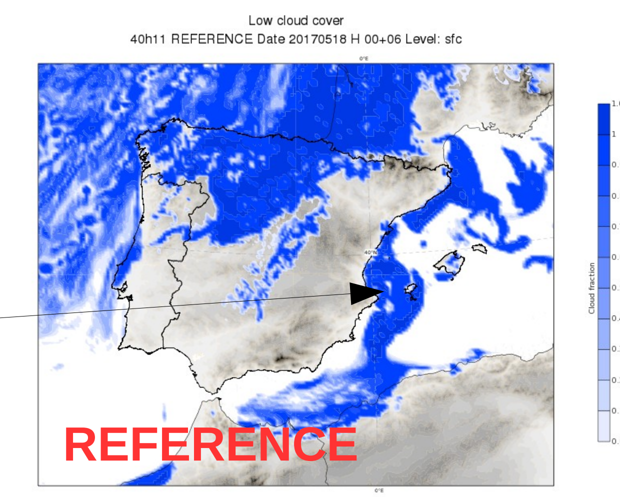
Case study. 20170518.





Cloud Types from NWC SAF: 2017051806





- Low cloud cover.
- Low clouds are formed in the REFERENCE model due to wrong values of cloud condensation nuclei.

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NWC SAF
Support to Nowcasting and Very Short Range Forecasting

Summary and Conclusions

- The concentration number of cloud condensation nuclei is obtained from the aerosol fields from the CAMS data and used in the microphysical parametrization schemes of HARMONIE-AROME.

  The mixing ratio fields are advedted in HARMONIE-AROME, thus, the lack of sources and sinks will make the fields unrealistic.

- **Precipitation**. In the case study, light precipitation over the mediterranean sea disappear. It seems that the intensity of the maximum of precipitation is reduced, but not by default. It is shown a positive

- **Improvement of low clouds over sea**. In the case stdy considered low clouds over the sea are not formed in the case study when the number of condensation nuclei. Better agreement with the observation.

- There's some margin to improve as:

  - The number of nuclei obtained from the mixing ratio depends on the election of parameters of the size distribution and density, which are the correct parameters?

  - The scheme used for the activation of the nuclei and the way the maximum saturation parameter is calculated, being very basic, should be improved.

  - The parameterization of the cloud droplet sedimentation still distinguish between land and sea instead of sea salt and sulphate particles.

- Next step: Inclusion of aerosol fields for the radiation scheme.

Bibliography

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AEMet Agencia Estatal de Meteorología

Thank you for your attention !!